

PDE6.3_sparse

April 9, 2024

This program simulates a magnetohydrodynamics system using the vorticity equation and flux equation. It uses a centered finite difference timestepping method.

```
[1]: import numpy as np
import matplotlib as mp
import matplotlib.pyplot as plt
import time
import cupy as cp
from scipy.sparse.linalg import LaplacianNd
import scipy as sp
```

```
[2]: ##initial values

#number of time steps
n_steps = 1800

#number of spacial grid cells
n_x = 128
n_y = 64

#plot frequency
pltfreq = 9

#constants
mu = 10**(-4)
eta = 10**(-4)
V_0 = 1.
B_0 = 0.6
mu_0 = np.pi * 4 * 10**(-7)
alfven_velocity = B_0

#epsilon
epsdiff = 0.2
epsadv = 0.8

#ends of spacial grid
x_min = 0.
x_max = 2.
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y_min = 0.
y_max = 1.

#Length of the spacial grid
Lx = x_max - x_min
Ly = y_max - y_min

#distance between grid cells and time steps
delta_x = Lx/n_x
delta_y = Ly/n_y

#change in time based on distance between cells and the wave propogation speed
delta = min(delta_x, delta_y)
delta_t = min(epsadv * delta / V_0, epsdiff * delta**2 / mu)

#last time step
t_max = n_steps * delta_t

#x and y values of each grid point
x = np.zeros(n_x)
for i in range(n_x):
    x[i]=delta_x*i

y = np.zeros(n_y)
for j in range(n_y):
    y[j]=delta_y*j

print(delta_t)
print(t_max)

```

0.0125

22.5

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[3]: xticklabels = [Lx/8, Lx/4, Lx*3/8, Lx/2, Lx*5/8, Lx*3/4, Lx*7/8, Lx]
      #xticklabels = [0, Lx/4, Lx/2, Lx*3/4, Lx]
      yticklabels = [0, Ly/8, Ly/4, Ly*3/8, Ly/2, Ly*5/8, Ly*3/4, Ly*7/8, Ly]
      xticks = [n_x * 1/8, n_x * 1/4, n_x * 3/8, n_x * 1/2, n_x * 5/8, n_x * 3/4, n_x *
        ↪ 7/8, n_x * 1]
      #xticks = [0, n_x * 1/4, n_x * 1/2, n_x * 3/4, n_x * 1]
      yticks = [0, n_y * 1/8, n_y * 1/4, n_y * 3/8, n_y * 1/2, n_y * 5/8, n_y * 3/4,
        ↪ n_y * 7/8, n_y * 1]

def plot(w, title, low, high, t, var):
    plt.plot(w[:, n_y/2].get())
    plt.title(title)
    plt.show()

```



```

w = cp.asnumpy(w)
plt.figure(figsize=(x_max*4.8, y_max*4.8))
fig = np.swapaxes(w, 0, 1)
plt.xlim([x_min, x_max])
plt.ylim([y_min, y_max])
plt.title(title)
plt.pcolormesh(fig, vmin = low, vmax = high, cmap = "bwr")
plt.xticks(xticks, xtickslabels)
plt.yticks(yticks, ytickslabels)
plt.grid()
plt.colorbar()
n = int(t/pltfreq)
frame = "{:04d}".format(n)
plt.savefig("images/wide/B=0.6/e-7/" + var + frame + ".png")
plt.show()

def do_plot(array, t):
    if array == 1:
        pass
        plot(w1, 'omega', -1., 1., t, 'w')
        plot(psi1, 'psi', -.125, .125, t, 'psi')
    else:
        pass
        plot(w2, 'omega', -1., 1., t, 'w')
        plot(psi2, 'psi', -.125, .125, t, 'psi')
        #plot(phi, 'phi', -.075, .075, t, 'phi')
        plot(bx, 'magnetic field in x', -.01, .01, t, 'bx')
        plot(by, 'magnetic field in y', -.5, .5, t, 'by')
        # plot(lapl_psiy, 'lapl psi in y', -.1, .1, t, 'lapl_psiy')
        # plot(lapl_psi_x, 'lapl psi in x', -1, 1, t, 'lapl_psi_x')
        plot(elec_j, 'electric current in z', -1., 1., t, 'j')
        plot(mag_erg, 'magnetic energy', 0, 30000, t, 'erg')
        # plot(mag, 'vorticity induced by magnetic field', -.01, .01, t, 'mag')
        # plot(magdiff, 'magnetic diffusion', -.001, .001, t, 'magdiff')
        # plot(magadv, 'magnetic advection', -.01, .01, t, 'magadv')

        #plot(phi, 'phi', -.001, .001, t, 'phi')
        #plot(vx, 'velocity in x', -.05, .05, t, 'vx')
        #plot(vy, 'velocity in y', -.1, .1, t, 'vy')
        # plot(lapl_wx, 'lapl_wx', -1, 1, t, 'lapl_wx')
        # plot(lapl_wy, 'lapl_wy', -1, 1, t, 'lapl_wy')

do_dump = True

def dump(var, title):
    myfile = open(title, "w")

```

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for i in range(n_x):
    for j in range(n_y):
        myfile.write('%s ' % var[i, j])

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[4]: #initial vorticity and flux function
w_init = cp.zeros([n_x, n_y])

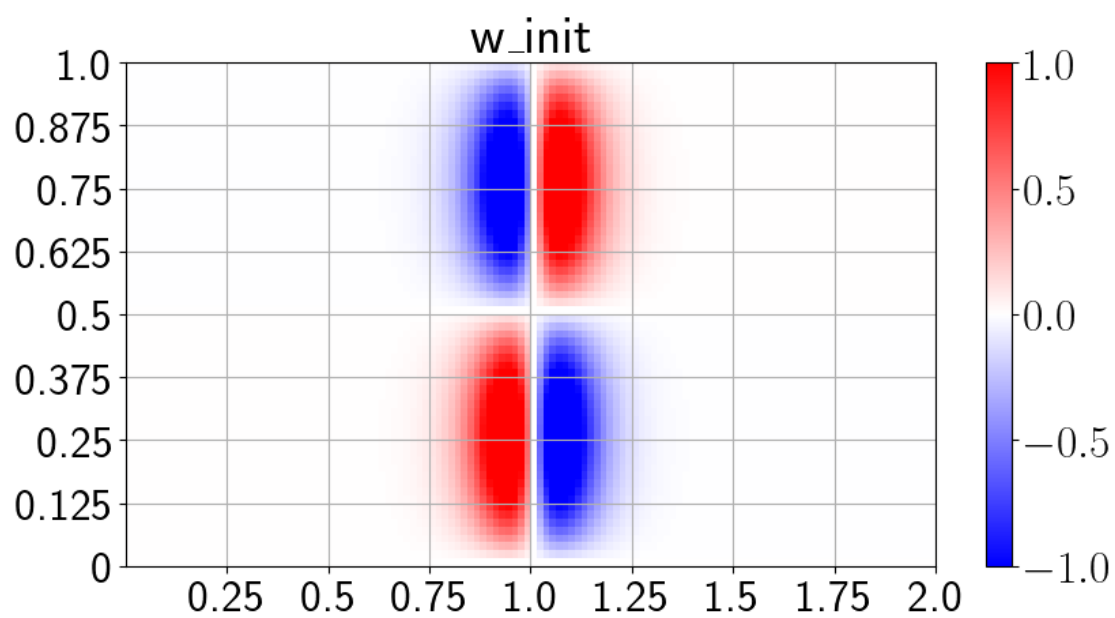
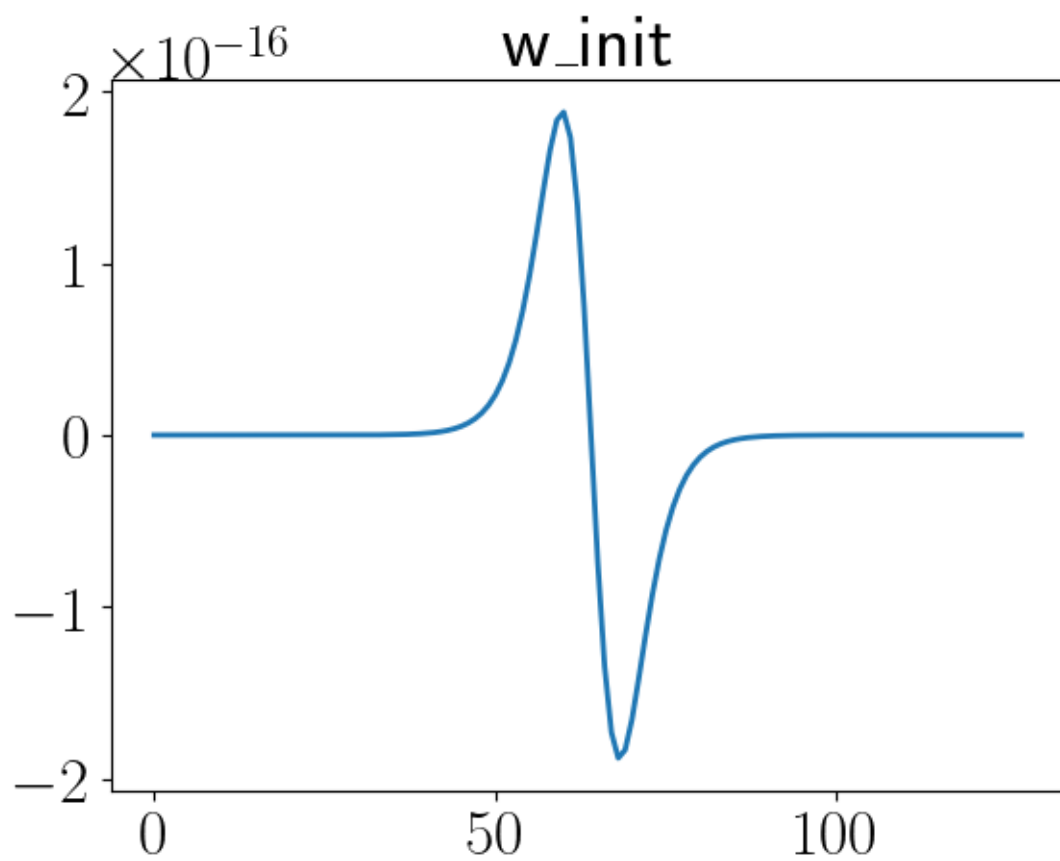
width = .1
x1 = Lx/2
amp = .2
m = 1.
k = m * 2. * np.pi / Ly
for j in range(n_y):
    for i in range(n_x):
        w_init[i, j] = -2./width * V_0 * np.tanh((x[i]-x1)/width) / np.
        ↪ cosh((x[i]-x1)/width)**2 * amp * np.sin(k*y[j])

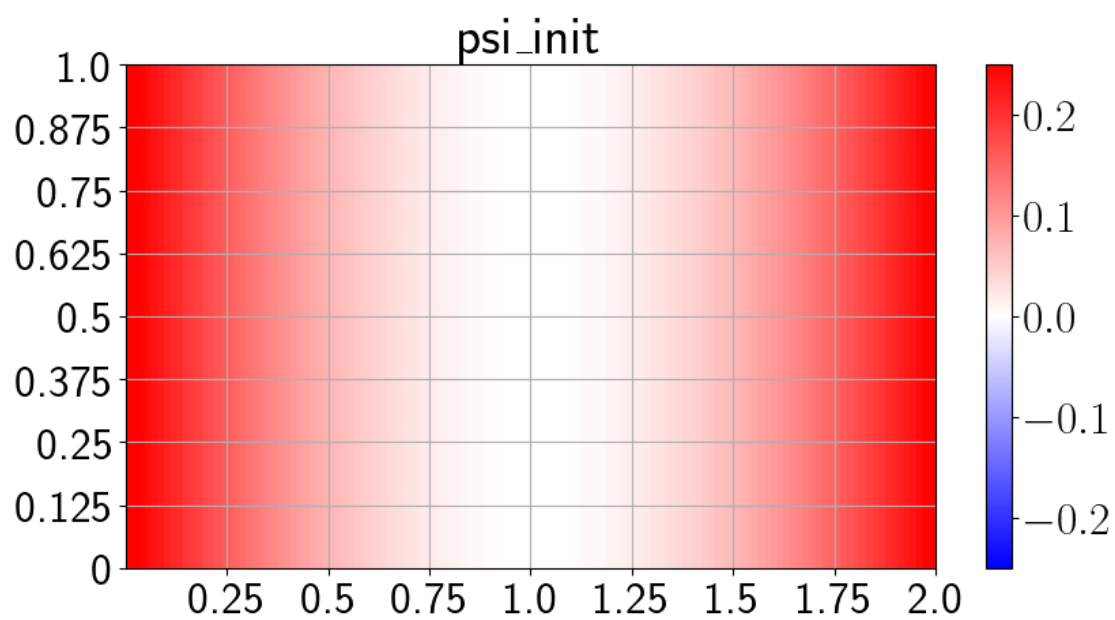
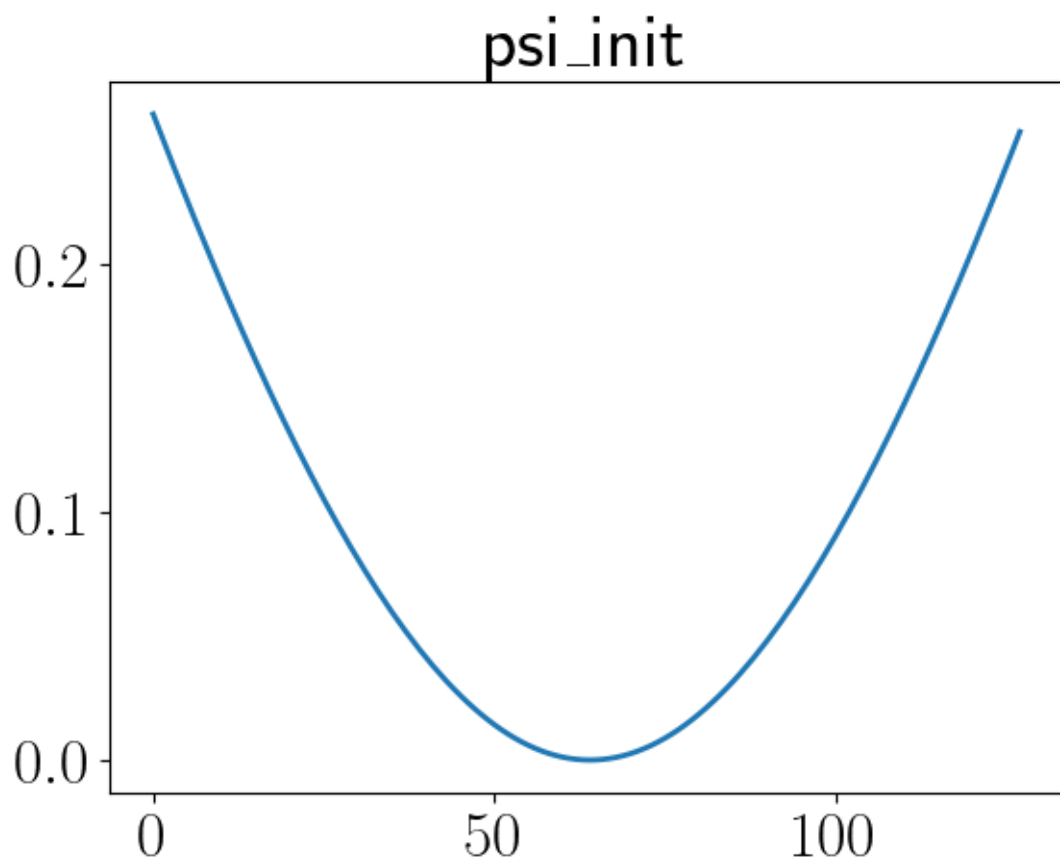
psi_init = cp.zeros([n_x, n_y])

for i in range(n_x):
    psi_init[i, :] = B_0 * np.log(np.cosh((x[i]-x1))#/width))

plot(w_init, 'w_init', -1, 1, 9, 'w')
plot(psi_init, 'psi_init', -.25, .25, 9, 'psi')

```





```
[5]: w1 = cp.zeros([n_x, n_y])
w2 = cp.zeros([n_x, n_y])

psi1 = cp.zeros([n_x, n_y])
psi2 = cp.zeros([n_x, n_y])

w1 = w_init
psi1 = psi_init
```

```
[6]: #fluid dynamics variables and terms
phi = cp.zeros([n_x, n_y])

vx = cp.zeros([n_x, n_y])
vy = cp.zeros([n_x, n_y])

dwdx = cp.zeros([n_x, n_y])
dwdy = cp.zeros([n_x, n_y])

lapl_wx = cp.zeros([n_x, n_y])
lapl_wy = cp.zeros([n_x, n_y])
lapl_w = cp.zeros([n_x, n_y])

adv = cp.zeros([n_x, n_y])
diff = cp.zeros([n_x, n_y])

#electromagnetic variables and terms
bx = cp.zeros([n_x, n_y])
by = cp.zeros([n_x, n_y])

djdx = cp.zeros([n_x, n_y])
djdy = cp.zeros([n_x, n_y])

lapl_psix = cp.zeros([n_x, n_y])
lapl_psiy = cp.zeros([n_x, n_y])
elec_j = cp.zeros([n_x, n_y])

mag = cp.zeros([n_x, n_y])
magdiff = cp.zeros([n_x, n_y])
magadv = cp.zeros([n_x, n_y])

mag_erg = cp.zeros([n_x, n_y])

psi_diff = cp.zeros(n_steps)

#discrete laplacian matrix used to solve laplacian equation
omega_vector = cp.zeros(n_x * n_y)
omega_mod = cp.zeros(n_x * n_y)
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phi_vector = cp.zeros(n_x * n_y)
phi_mod = cp.zeros(n_x * n_y)

a = LaplacianNd((n_x, n_y), boundary_conditions='periodic').tosparse()

```

[7]: *#repeats the advance function for n_steps*

```

def solve():
    for t in range(n_steps):
        advance(t)

```

[8]: *#timesteps the profile*

```

def advance(t):
    global w1, w2, phi, vx, vy, dwdx, dwdy, lapl_wx, lapl_wy, lapl_w, adv,
    ↪diff, omega_vector, omega_mod, phi_vector, phi_mod
    global psi1, psi2, bx, by, lapl_psix, lapl_psiy, elec_j, djdx, djdy, mag,
    ↪magdiff, magadv, mag_erg, psi_diff
    if t % 2 == 0:
        #solves laplacian equation to find phi from omega
        for j in range(n_y):
            for i in range(n_x):
                omega_vector[i+j*n_x] = w1[i, j]
            omega_mod = (omega_vector - cp.sum(omega_vector) / (n_x * n_y)).get()

        phi_vector = sp.sparse.linalg.spsolve(a, delta_x**2 * omega_mod)
        phi_mod = phi_vector - np.sum(phi_vector) / (n_x * n_y)
        for j in range(n_y):
            for i in range(n_x):
                phi[i, j] = phi_mod[i+j*n_x]

        for i in range(n_x):
            #velocity in x
            tmp = cp.diff(phi[i,:], prepend=phi[i, -1], append=phi[i, 0])/
            ↪delta_y
            vx[i,:] = -(tmp[1:] + tmp[:-1])/2

            #y derivative of vorticity
            tmp2 = cp.diff(w1[i,:], prepend=w1[i, -1], append=w1[i, 0])/delta_y
            dwdy[i,:] = (tmp2[1:] + tmp2[:-1])/2

            #magnetic field in x
            tmp3 = cp.diff(psi1[i, :], prepend=psi1[i, -1], append=psi1[i, 0])/
            ↪delta_y
            bx[i, :] = -(tmp3[1:] + tmp3[:-1])/2

            #laplacian of vorticity and psi (only y direction)
            lapl_wy[i, :] = cp.diff(tmp2)/delta_y
            lapl_psiy[i, :] = cp.diff(tmp3)/delta_y

```

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    for j in range(n_y):
        #velocity in y
        tmp = cp.diff(phi[:,j], prepend=phi[-1, j], append=phi[0, j])/
        delta_x
        vy[:,j] = (tmp[1:] + tmp[:-1])/2

        #x derivative of vorticity
        tmp2 = cp.diff(w1[:,j], prepend=w1[-1, j], append=w1[0, j])/delta_x
        dwdx[:,j] = (tmp2[1:] + tmp2[:-1])/2

        #magnetic field in y
        prepend = 2.*psi1[0, j] - psi1[1, j]
        append = 2.*psi1[-1, j] - psi1[-2, j]
        tmp3 = cp.diff(psi1[:, j], prepend=prepend, append=append)/delta_x
        by[:, j] = (tmp3[1:] + tmp3[:-1])/2

        #laplacian of vorticity and psi (only x direction)
        lapl_wx[:, j] = cp.diff(tmp2)/delta_x
        lapl_psix[:, j] = cp.diff(tmp3)/delta_x

        #fluid advection and diffusion terms
        lapl_w = lapl_wx + lapl_wy
        adv = vx * dwdx + vy * dwdy
        diff = mu * lapl_w

        #current
        elec_j = lapl_psiy + lapl_psix

        #derivative of the current in y and x
        for i in range(n_x):
            tmp = cp.diff(elec_j[i,:], prepend=elec_j[i,-1],
            append=elec_j[i,0])/delta_y
            djdy[i,:] = (tmp[1:] + tmp[:-1])/2

            for j in range(n_y):
                tmp = cp.diff(elec_j[:,j], prepend=elec_j[-1, j], append=elec_j[0,
                j])/delta_x
                djdx[:,j] = (tmp[1:] + tmp[:-1])/2

        #fluid magnetic term, magnetic field advection term, and magnetic field
        diffusion term
        mag = bx * djdx + by * djdy
        magadv = vx * by + vy * -bx
        magdiff = eta * elec_j

        w2 = w1 + delta_t * (-adv + diff + mag)

```

```

psi2 = psi1 + delta_t * (-magadv + magdiff)

mag_erg = (bx**2 + by**2)/(2 * mu_0)

psi_diff[t] = cp.max(psi1) - cp.min(psi1)
#psi_diff[t] = psi1[n_x/2, n_y/2] - psi1[n_x-1, n_y/2]
#print(psi_diff[t])
#diagnostic plotting
if t % pltfreq == 0:
    do_plot(1, t)
else:
    for j in range(n_y):
        for i in range(n_x):
            omega_vector[i+j*n_x] = w2[i, j]
        omega_mod = (omega_vector - cp.sum(omega_vector) / (n_x * n_y)).get()

    phi_vector = sp.sparse.linalg.spsolve(a, delta_x**2 * omega_mod)
    phi_mod = phi_vector - np.sum(phi_vector) / (n_x * n_y)
    for j in range(n_y):
        for i in range(n_x):
            phi[i, j] = phi_mod[i+j*n_x]

    for i in range(n_x):
        #velocity in x
        tmp = cp.diff(phi[i,:], prepend=phi[i, -1], append=phi[i, 0])/
↪delta_y
        vx[i,:] = -(tmp[1:] + tmp[:-1])/2

        #y derivative of vorticity
        tmp2 = cp.diff(w2[i,:], prepend=w2[i, -1], append=w2[i, 0])/delta_y
        dwdy[i,:] = (tmp2[1:] + tmp2[:-1])/2

        #magnetic field in x
        tmp3 = cp.diff(psi2[i, :], prepend=psi2[i, -1], append=psi2[i, 0])/
↪delta_y
        bx[i, :] = -(tmp3[1:] + tmp3[:-1])/2

        #laplacian of vorticity and psi (only y direction)
        lapl_wy[i, :] = cp.diff(tmp2)/delta_y
        lapl_psiy[i, :] = cp.diff(tmp3)/delta_y

    for j in range(n_y):
        #velocity in y
        tmp = cp.diff(phi[:,j], prepend=phi[-1, j], append=phi[0, j])/
↪delta_x
        vy[:,j] = (tmp[1:] + tmp[:-1])/2

```



```

    #x derivative of vorticity
    tmp2 = cp.diff(w2[:,j], prepend=w2[-1, j], append=w2[0, j])/delta_x
    dwdx[:,j] = (tmp2[1:] + tmp2[:-1])/2

    #magnetic field in y
    prepend = 2.*psi2[0, j] - psi2[1, j]
    append = 2.*psi2[-1, j] - psi2[-2, j]
    tmp3 = cp.diff(psi2[:, j], prepend=prepend, append=append)/delta_x
    by[:, j] = (tmp3[1:] + tmp3[:-1])/2

    #laplacian of vorticity and psi (only x direction)
    lapl_wx[:, j] = cp.diff(tmp2)/delta_x
    lapl_psix[:, j] = cp.diff(tmp3)/delta_x

    #fluid advection and diffusion terms
    lapl_w = lapl_wx + lapl_wy
    adv = vx * dwdx + vy * dwdy
    diff = mu * lapl_w

    #current
    elec_j = lapl_psiy + lapl_psix

    #derivative of the current in y and x
    for i in range(n_x):
        tmp = cp.diff(elec_j[i,:], prepend=elec_j[i,-1],
        ↪append=elec_j[i,0])/delta_y
        djdy[i,:] = (tmp[1:] + tmp[:-1])/2

    for j in range(n_y):
        tmp = cp.diff(elec_j[:,j], prepend=elec_j[-1, j], append=elec_j[0,
        ↪j])/delta_x
        djdx[:,j] = (tmp[1:] + tmp[:-1])/2

    #fluid magnetic term, magnetic field advection term, and magnetic field
    ↪diffusion term
    mag = bx * djdx + by * djdy
    magadv = vx * by + vy * -bx
    magdiff = eta * elec_j

    w1 = w2 + delta_t * (-adv + diff + mag)
    psi1 = psi2 + delta_t * (-magadv + magdiff)

    mag_erg = (bx**2 + by**2)/(2 * mu_0)

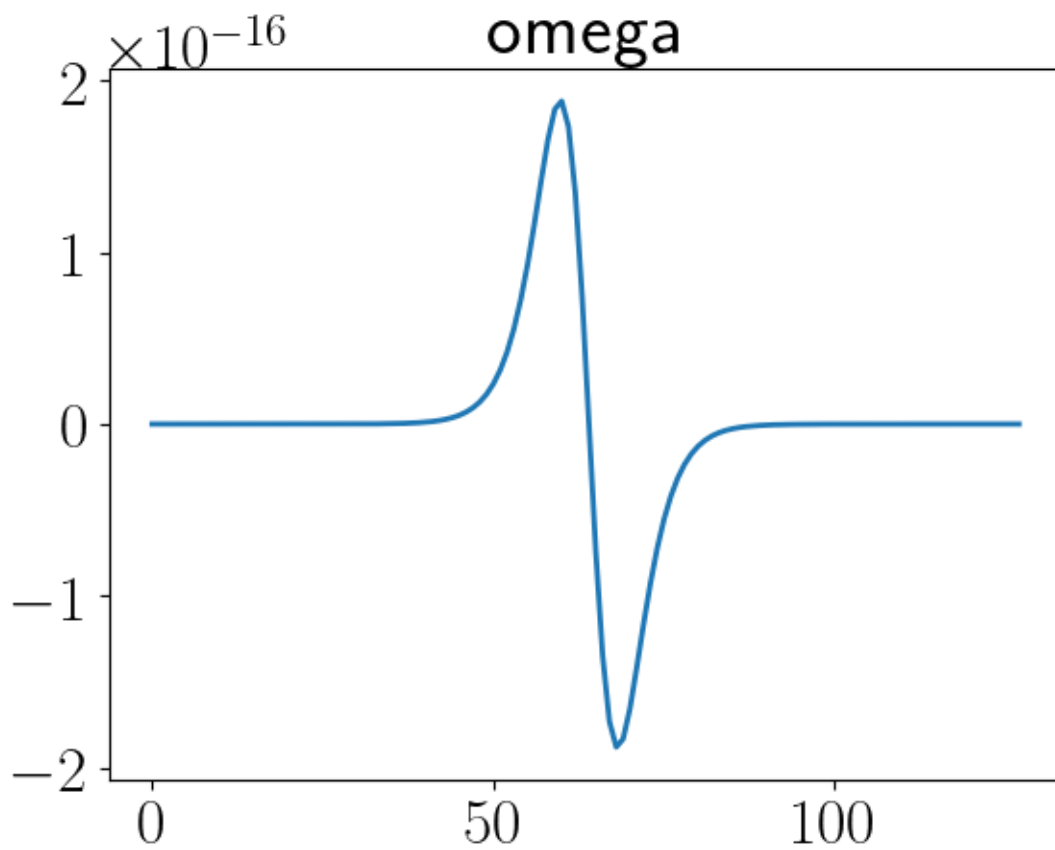
    #diagnostic plotting
    if t % pltfreq == 0:
        do_plot(2, t)

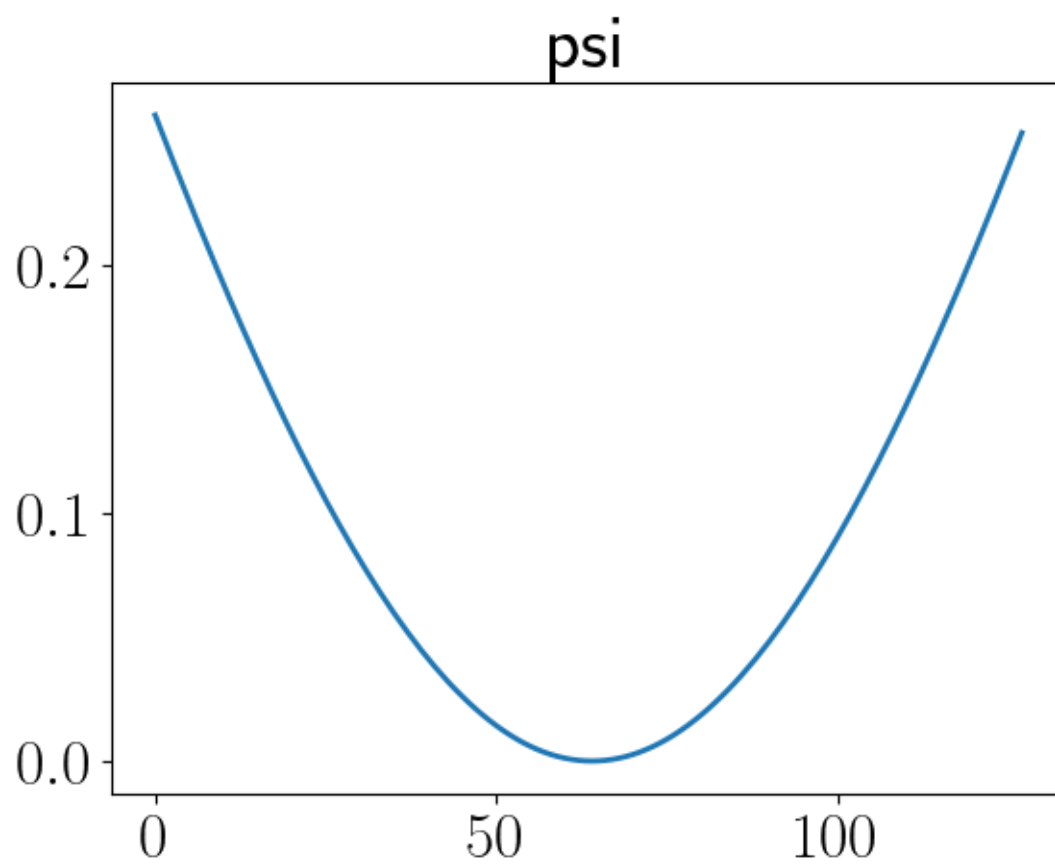
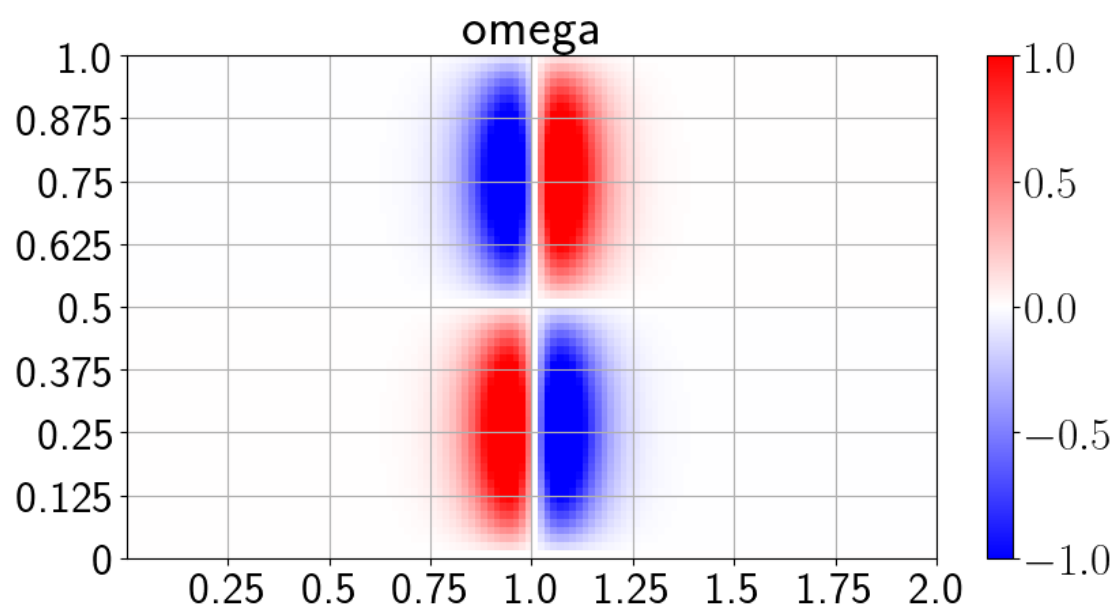
```

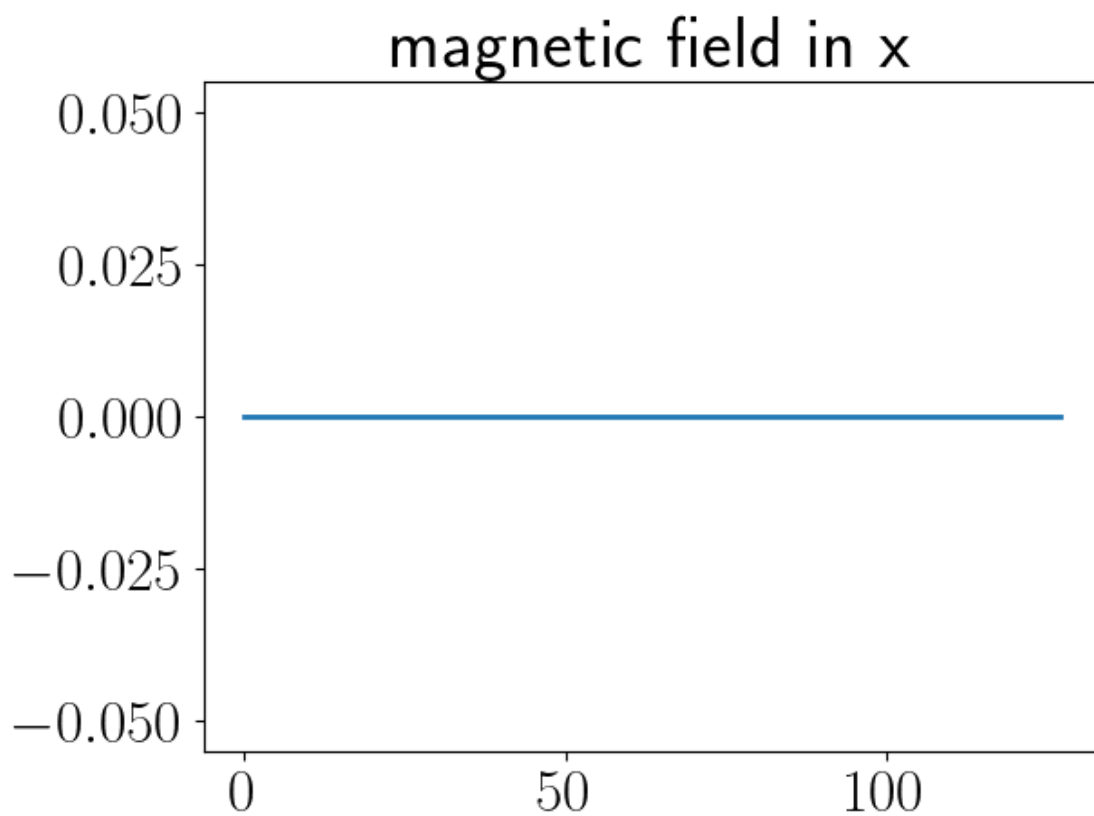
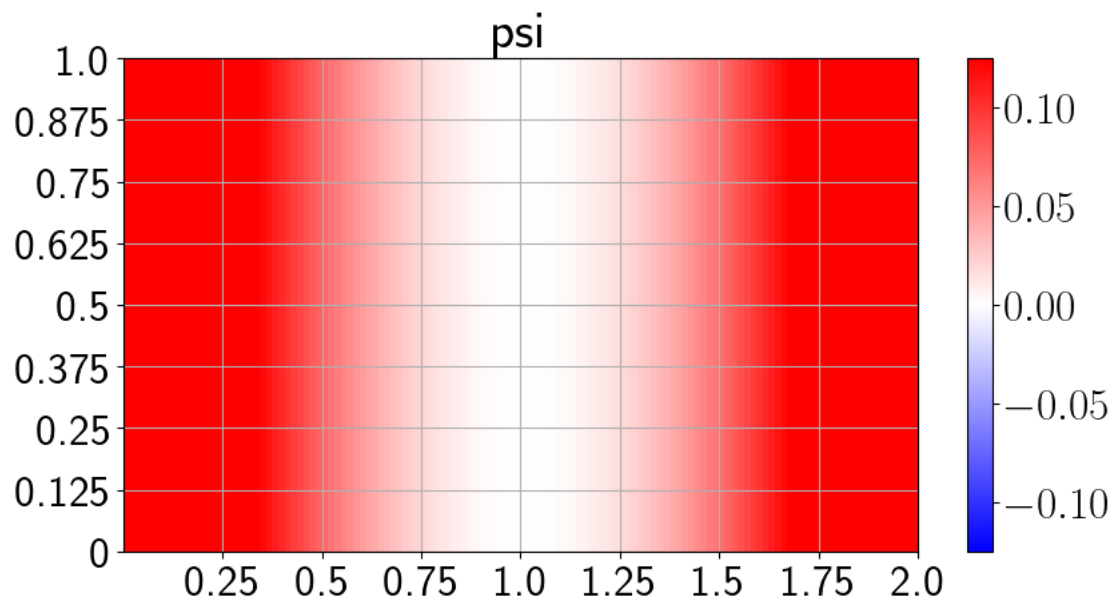
```
psi_diff[t] = cp.max(psi2) - cp.min(psi2)
#psi_diff[t] = psi2[n_x/2, n_y/2] - psi2[n_x-1, n_y/2]
#print(psi_diff[t])
```

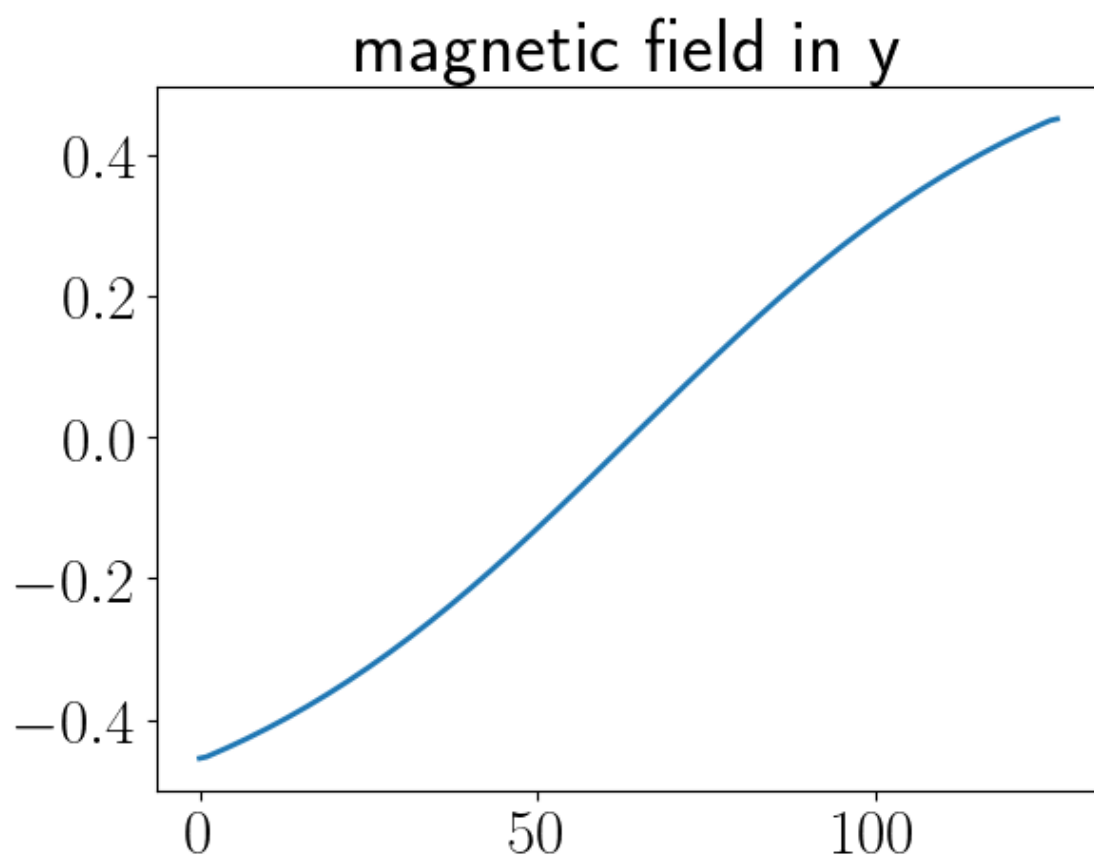
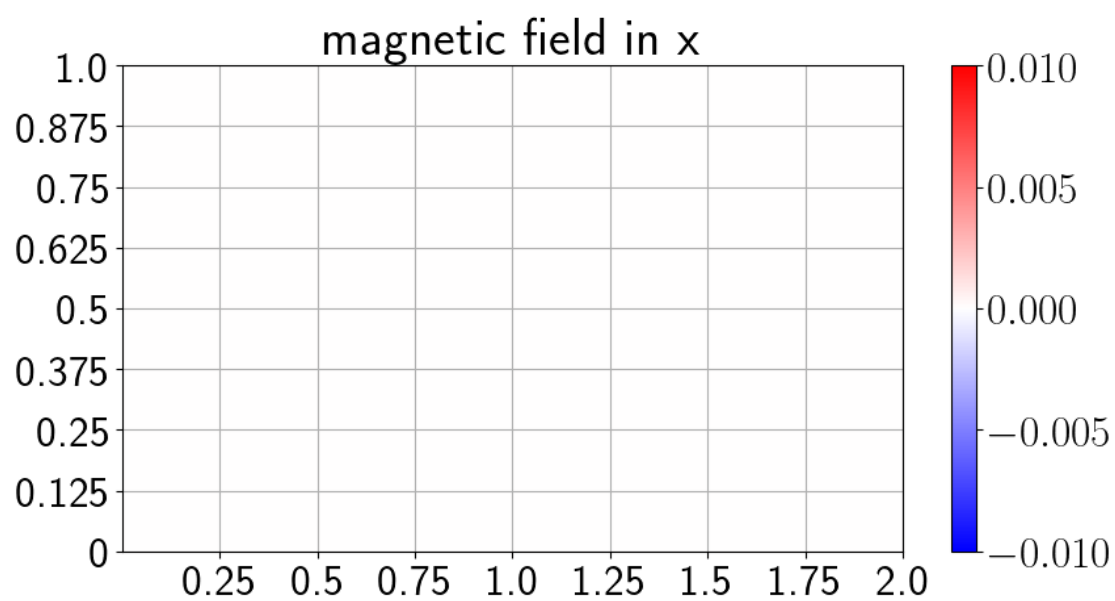
```
[9]: #runs simulation
      inittime = time.time()

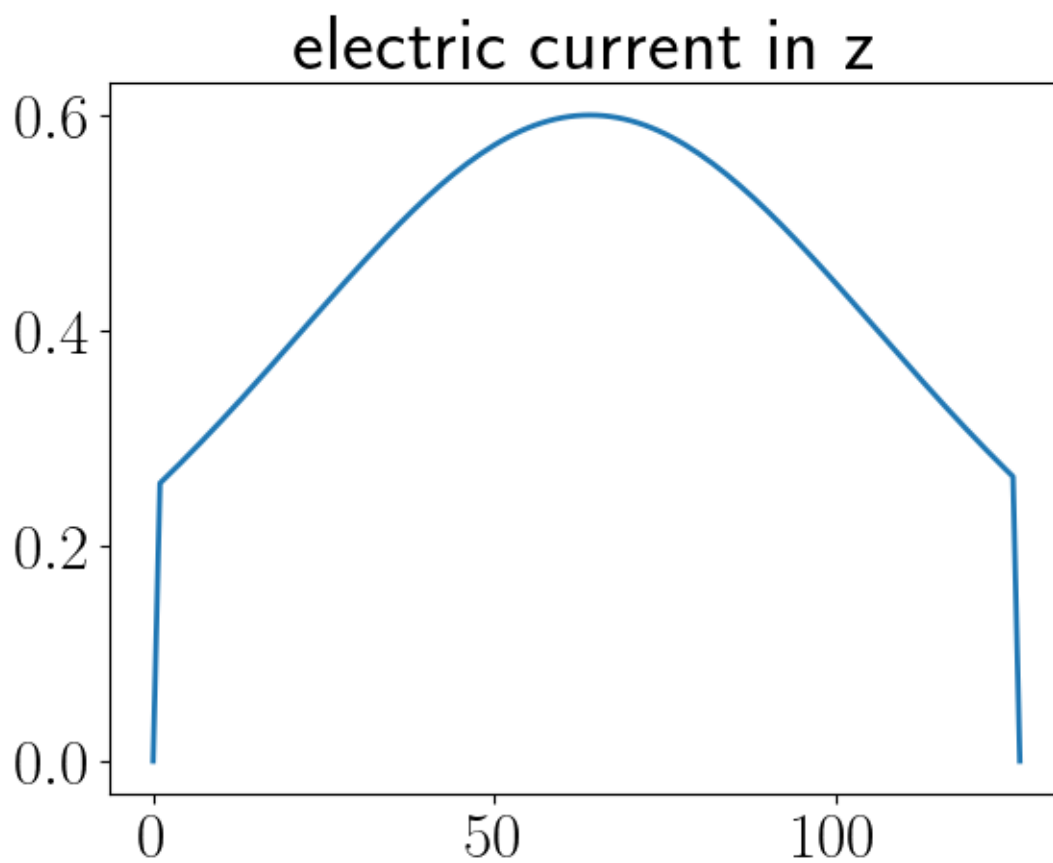
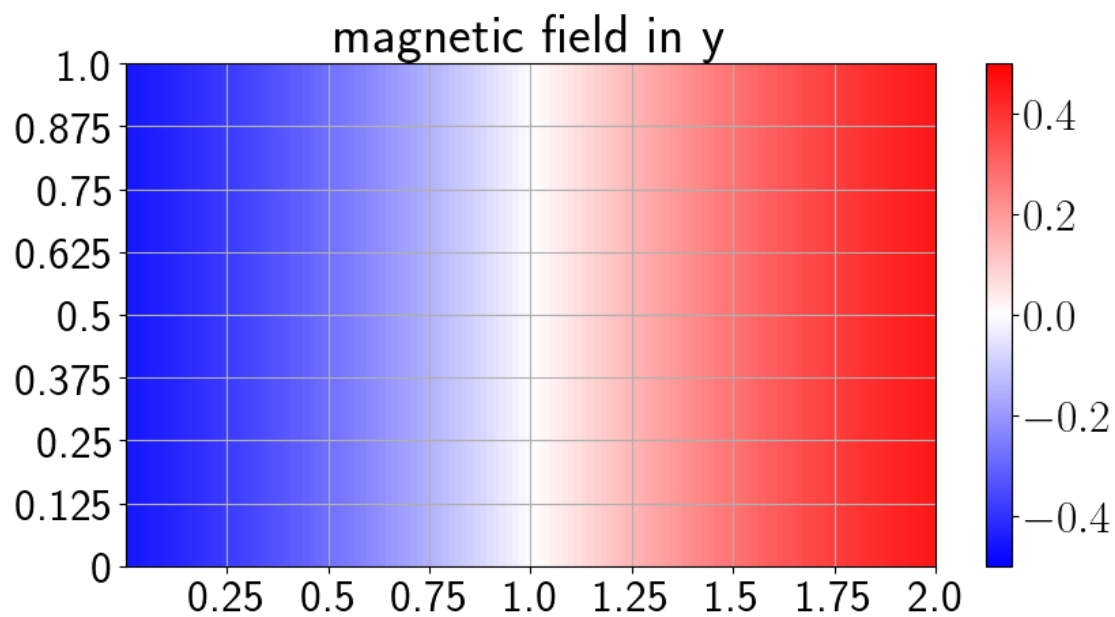
      solve()
```

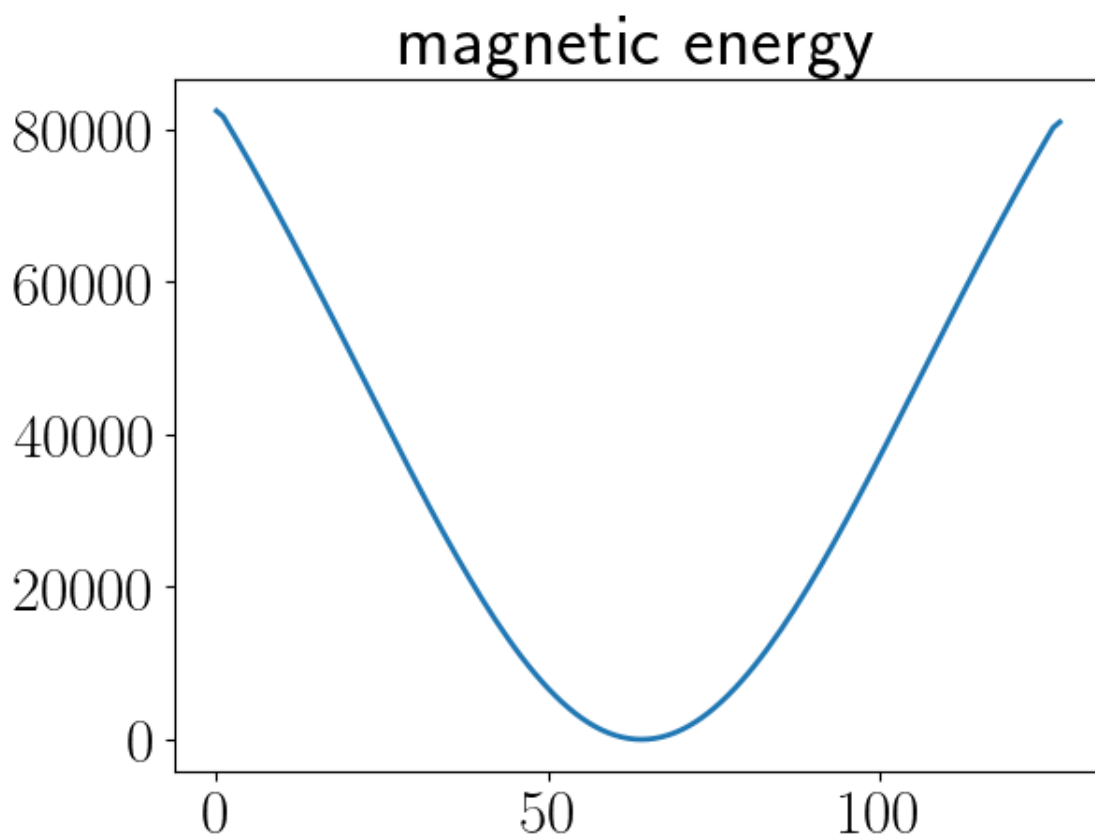
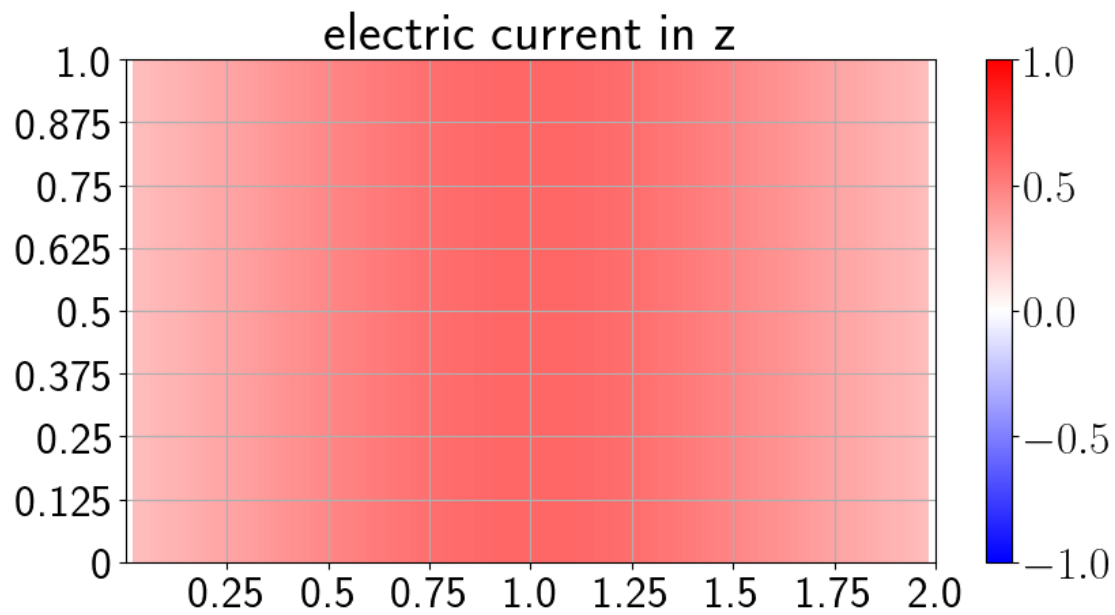


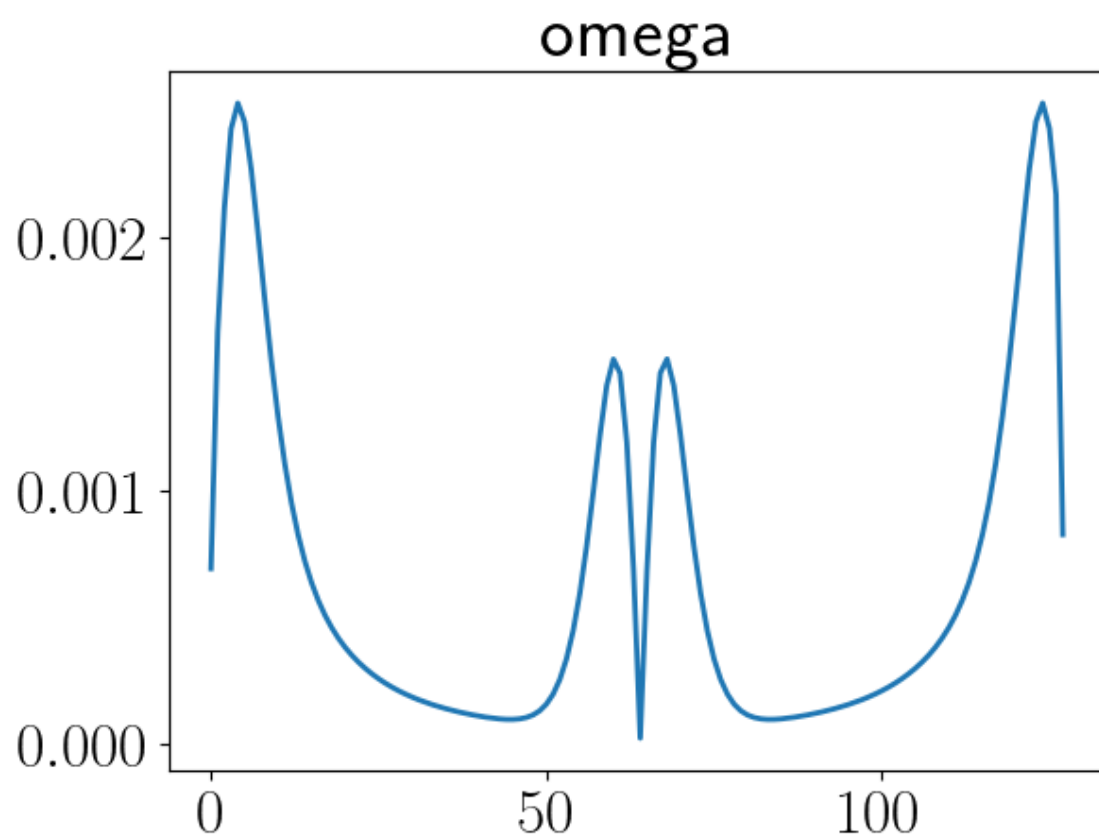
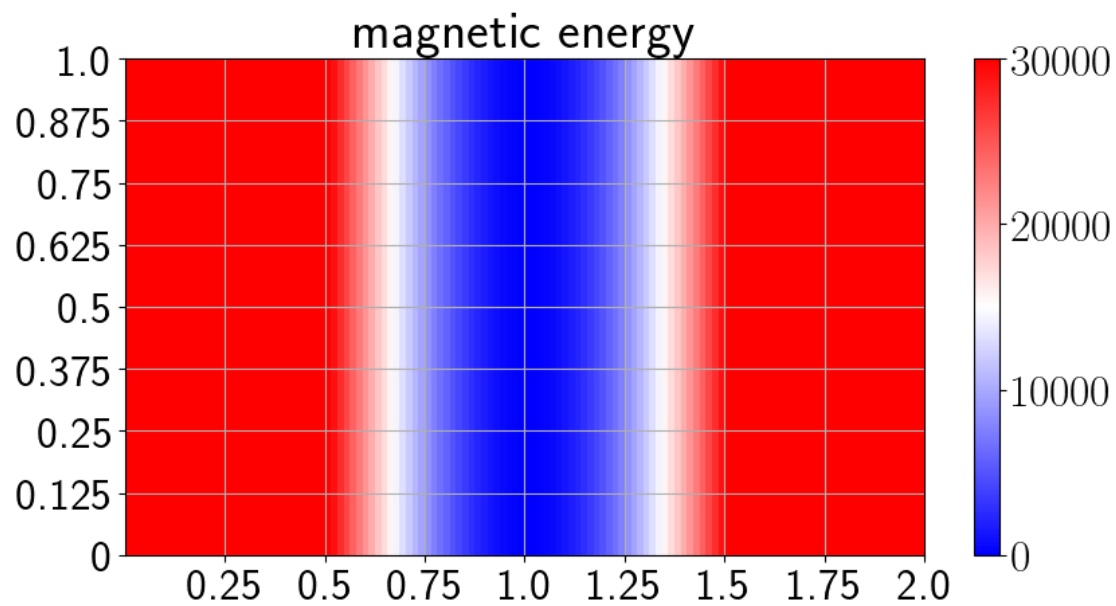


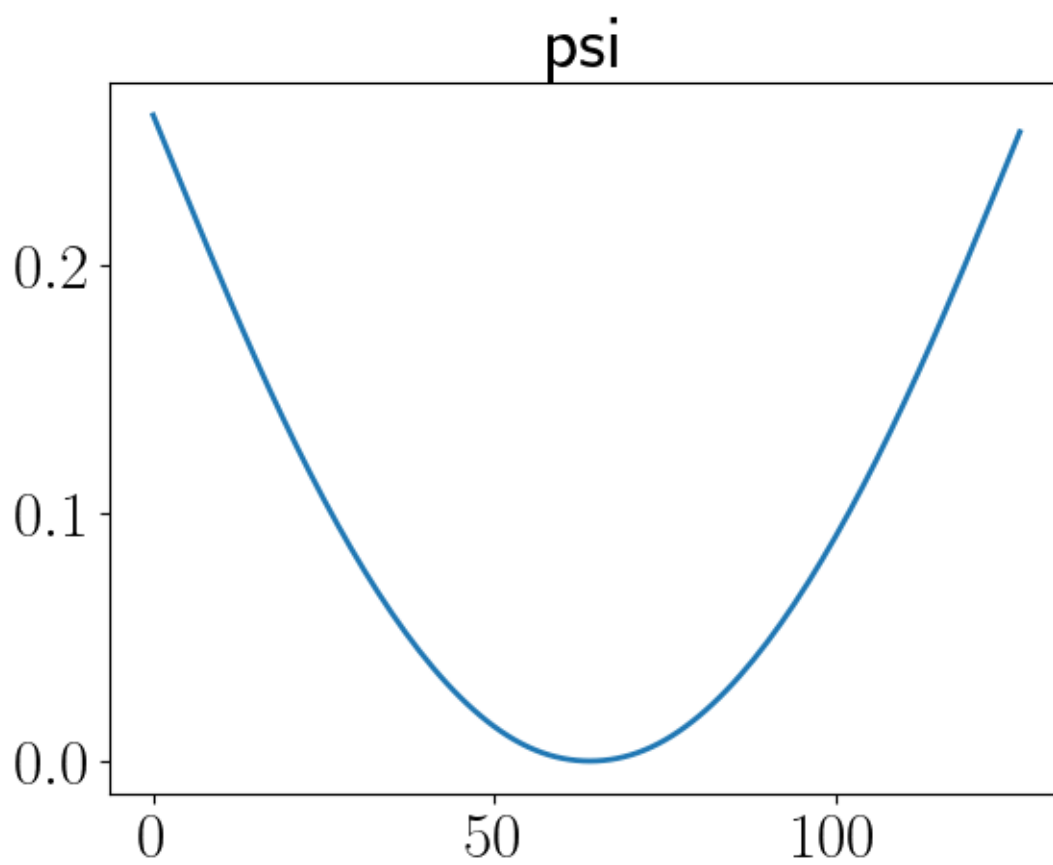
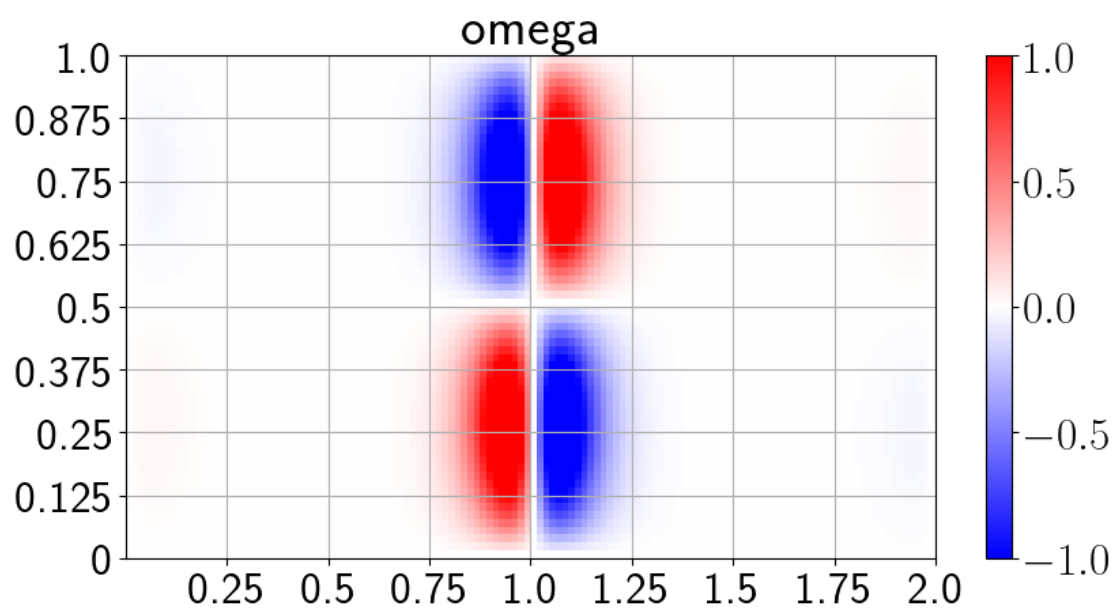


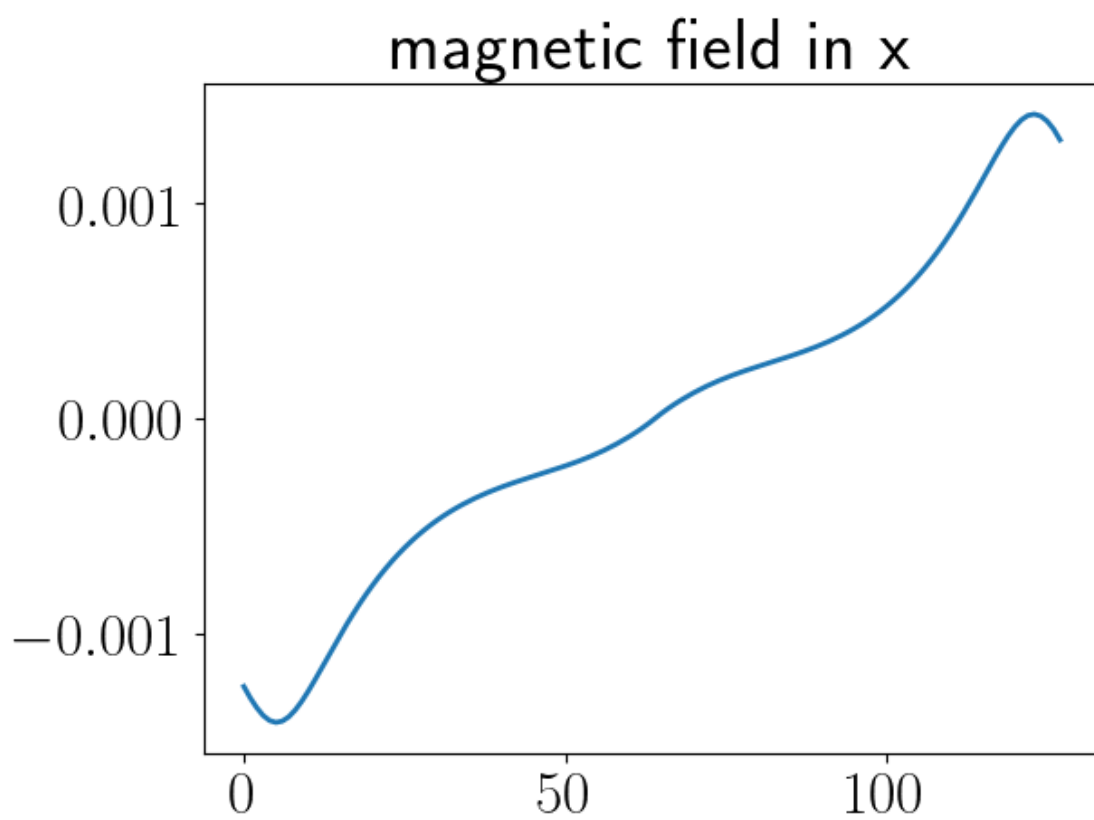
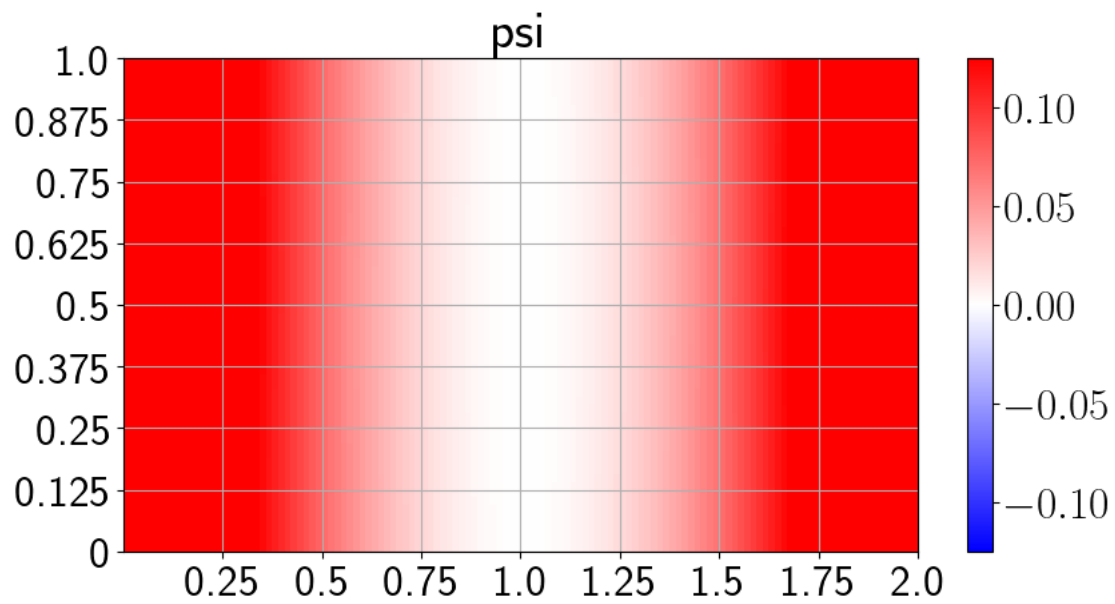


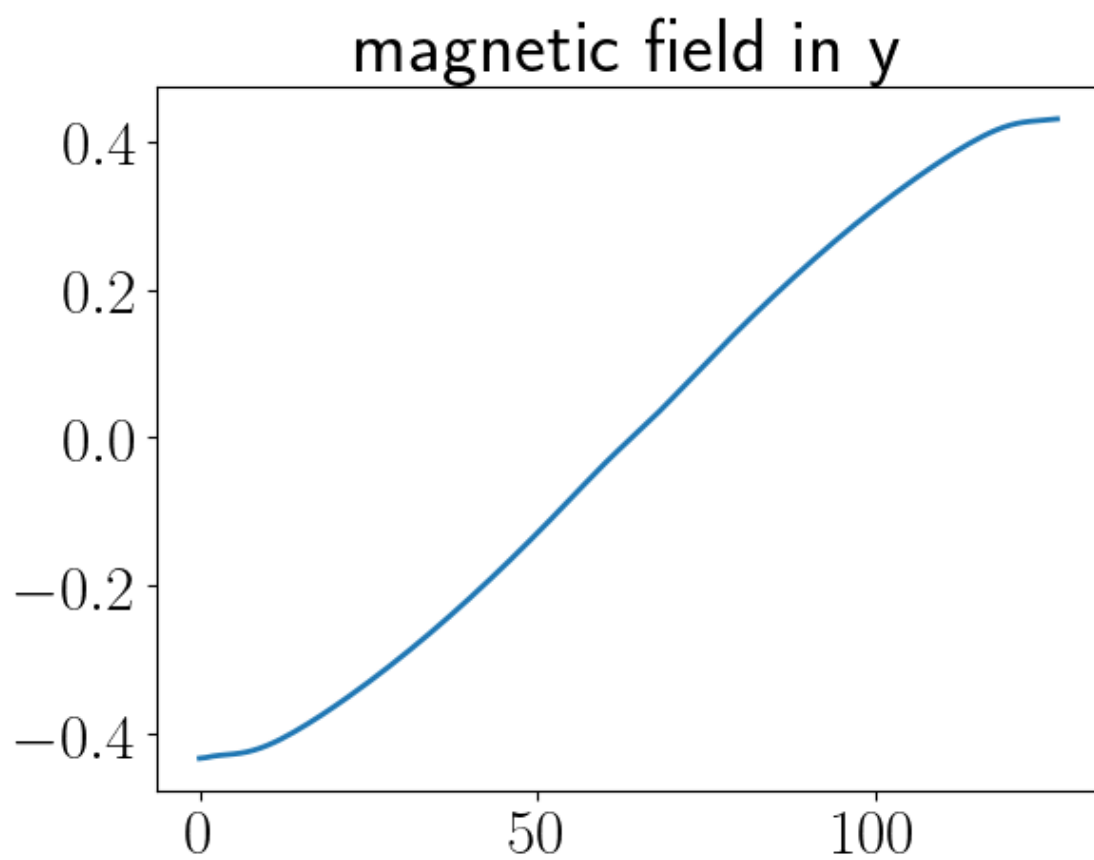
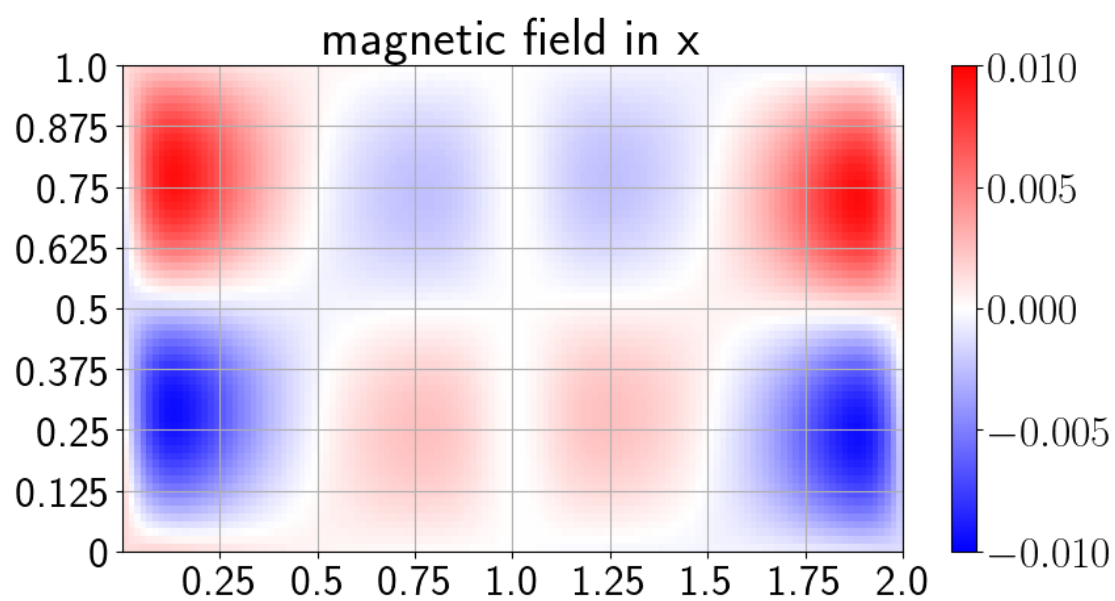


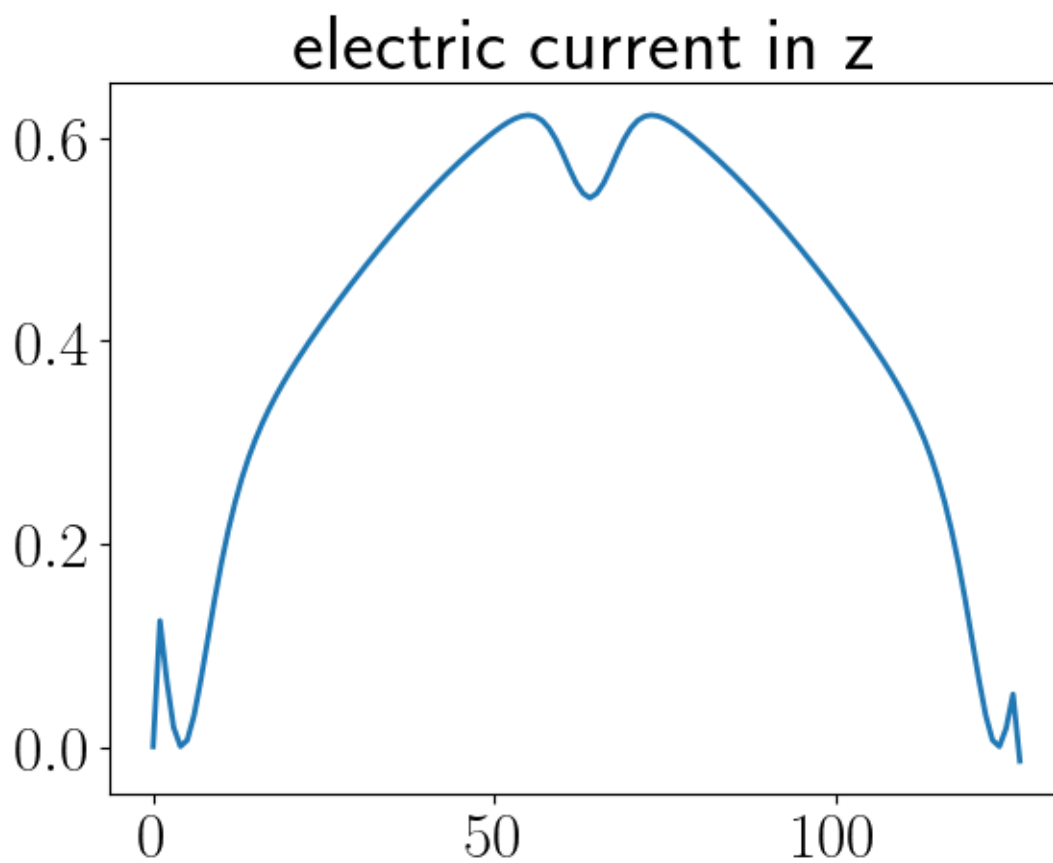
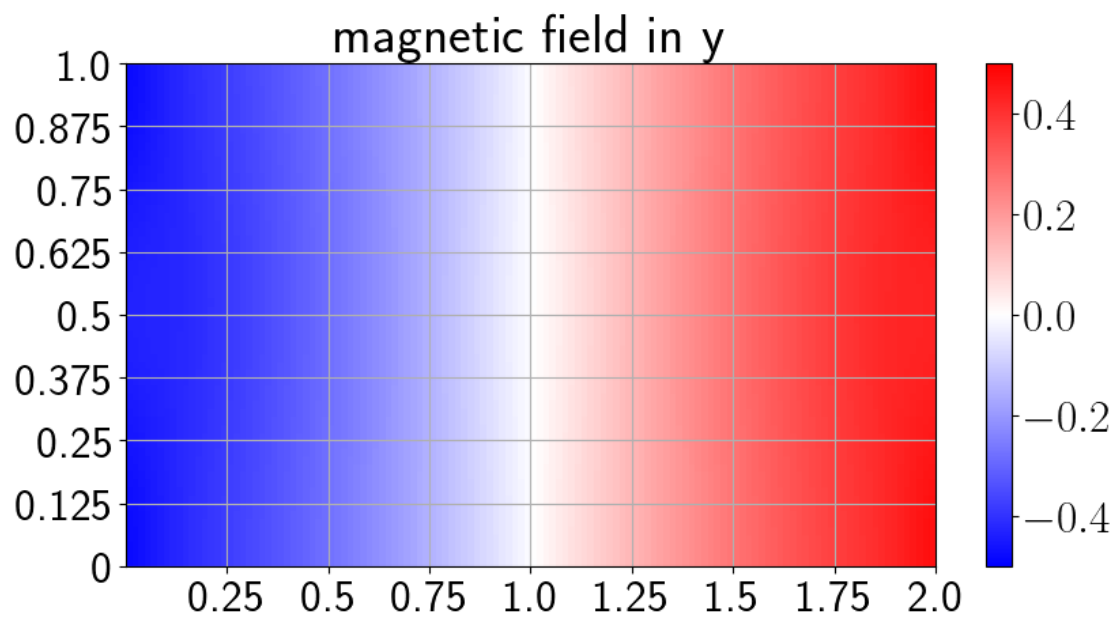


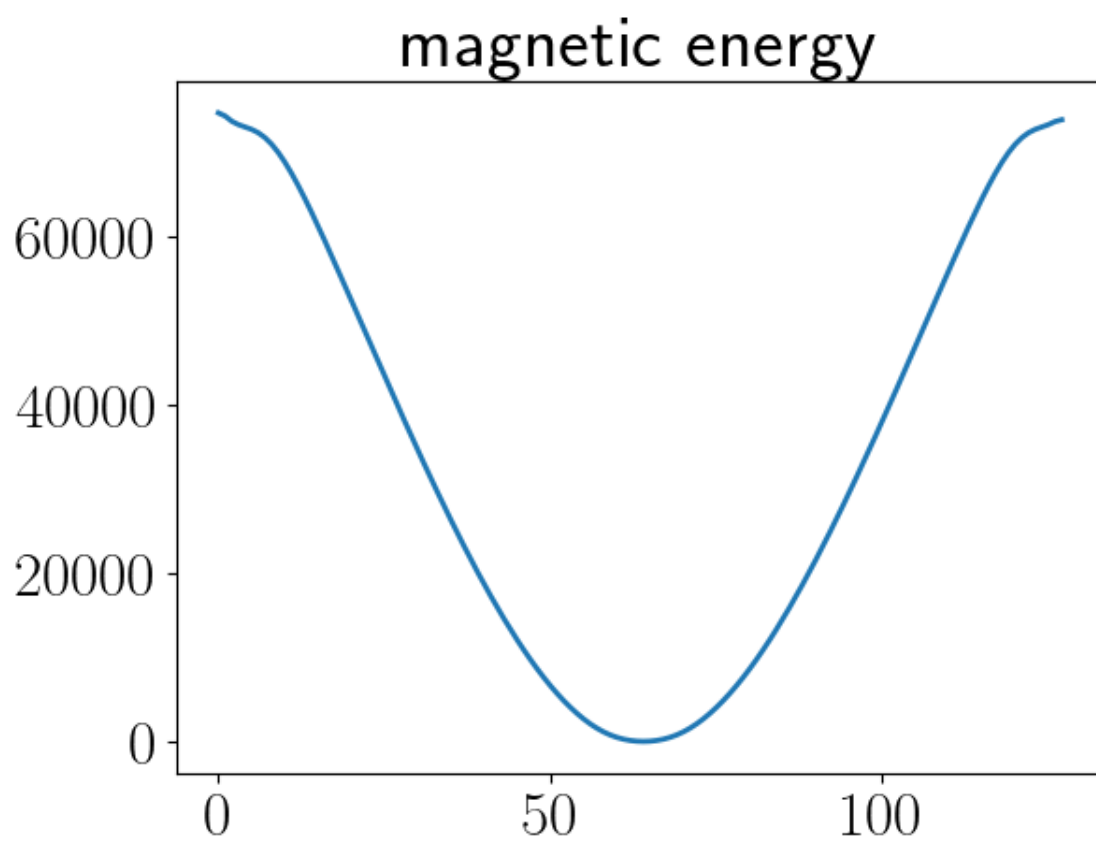
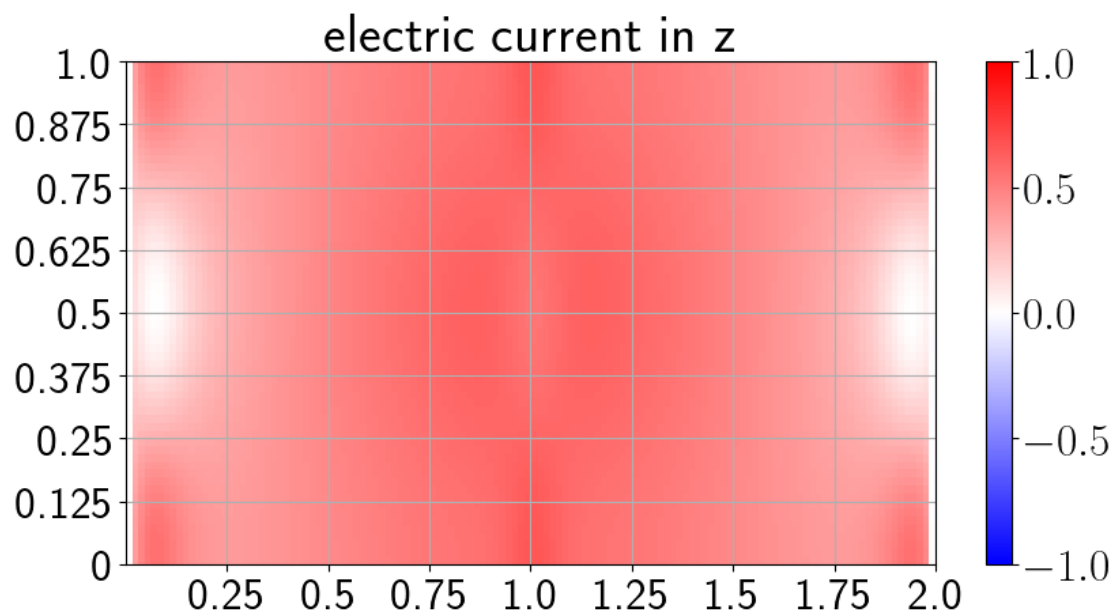


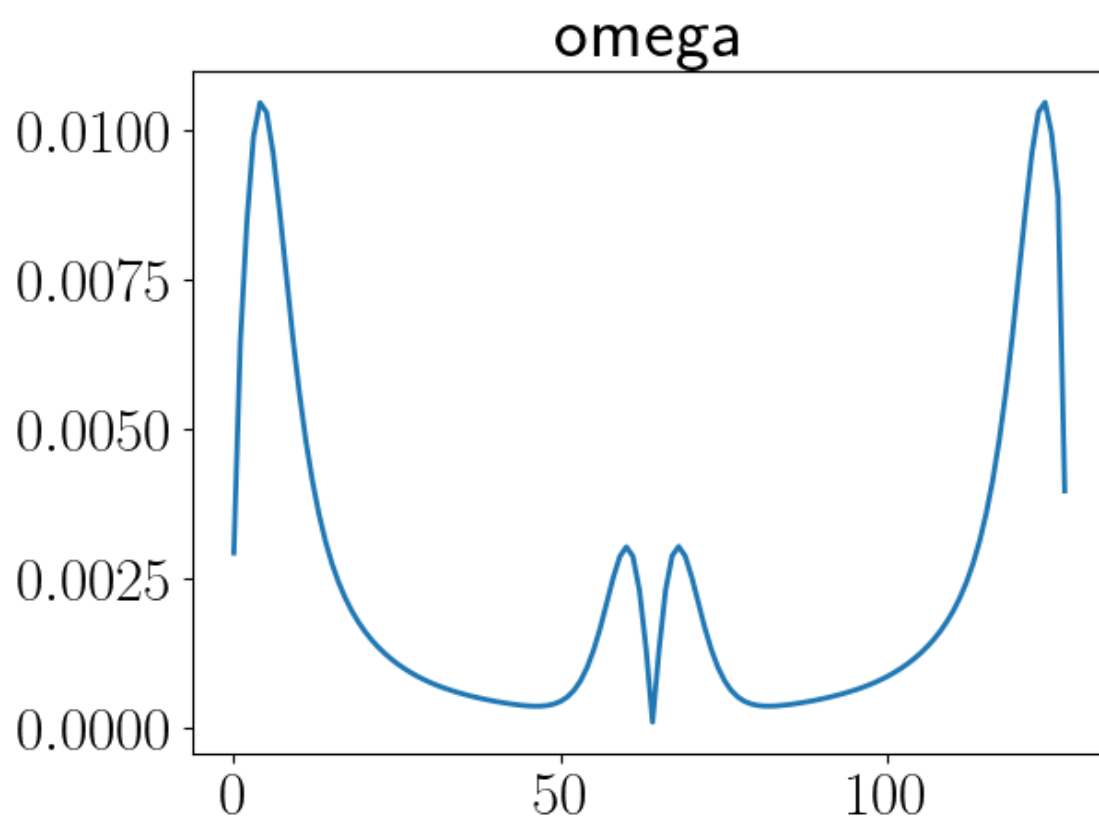
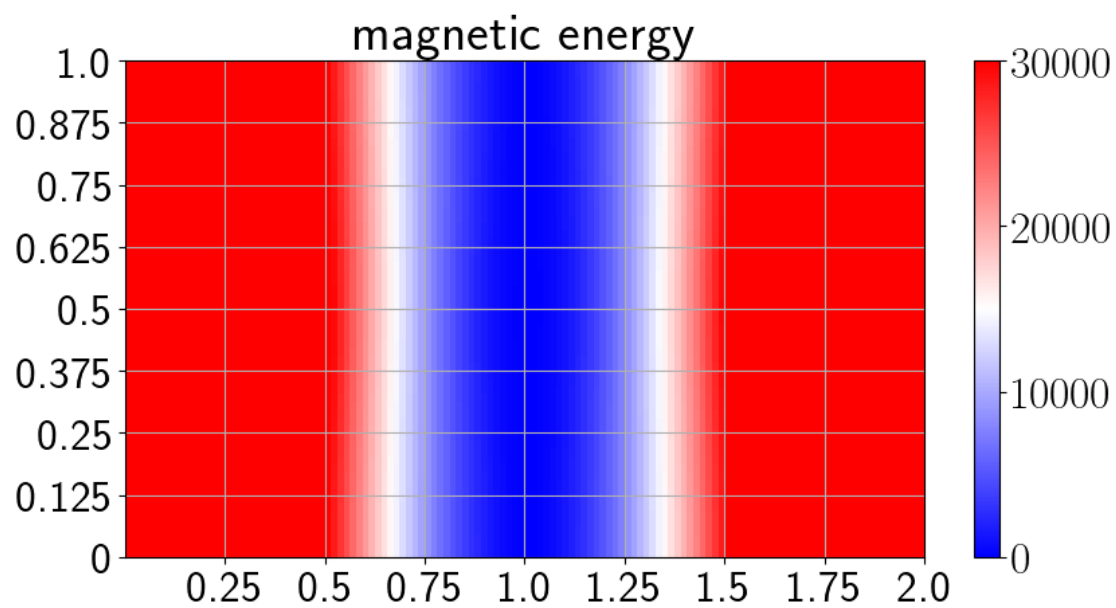


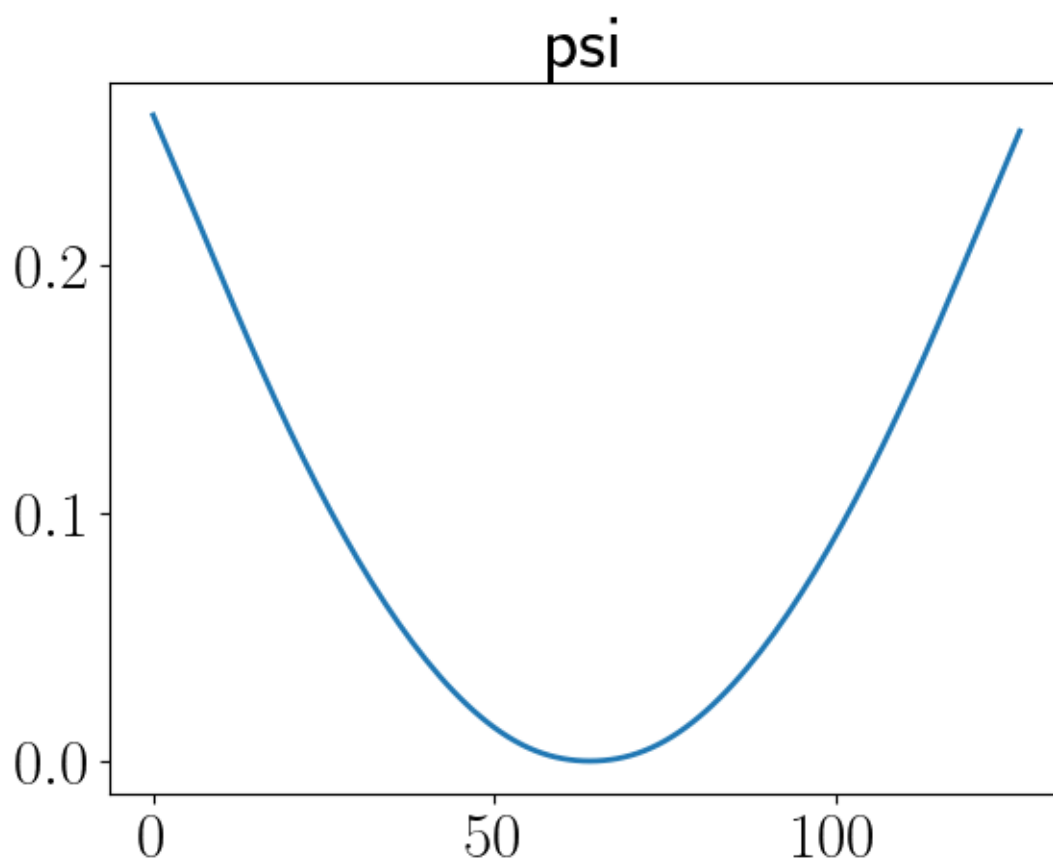
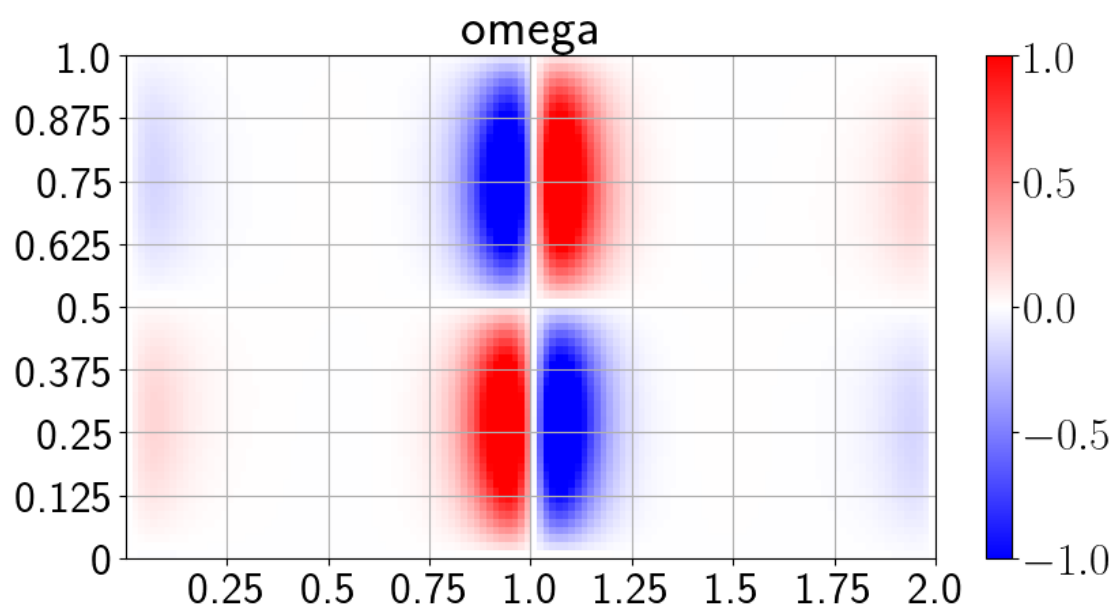


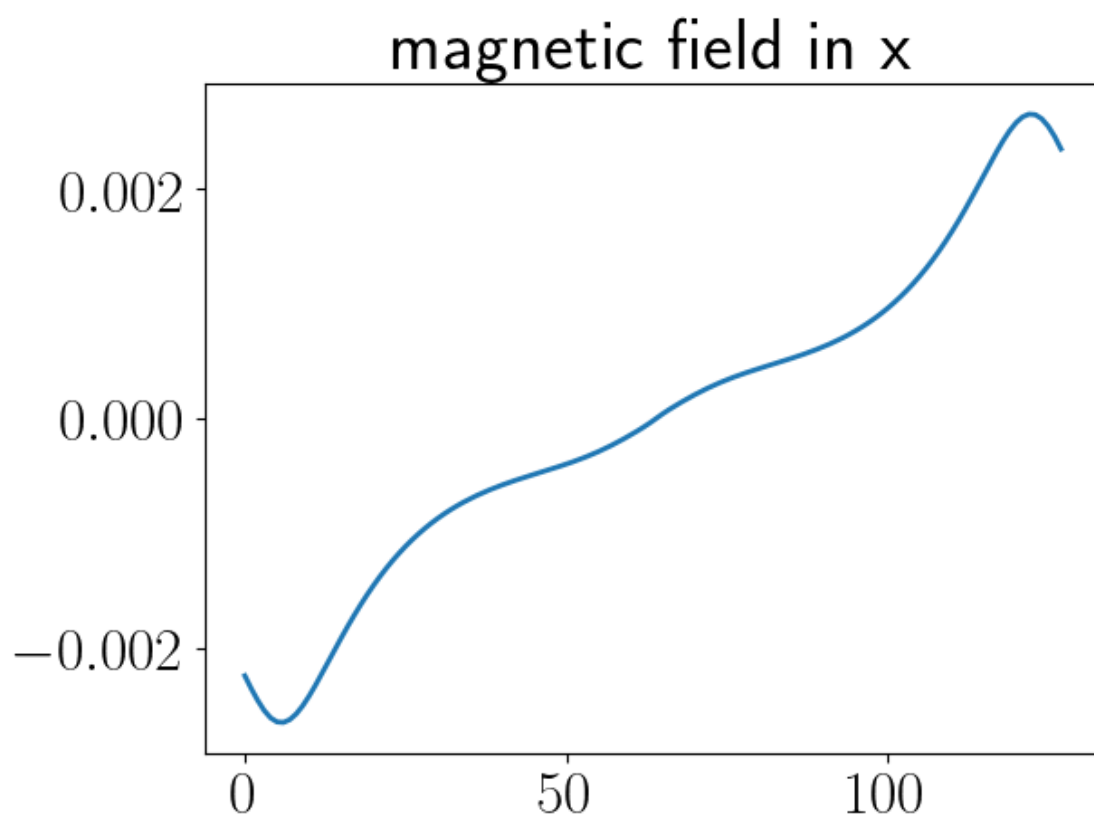
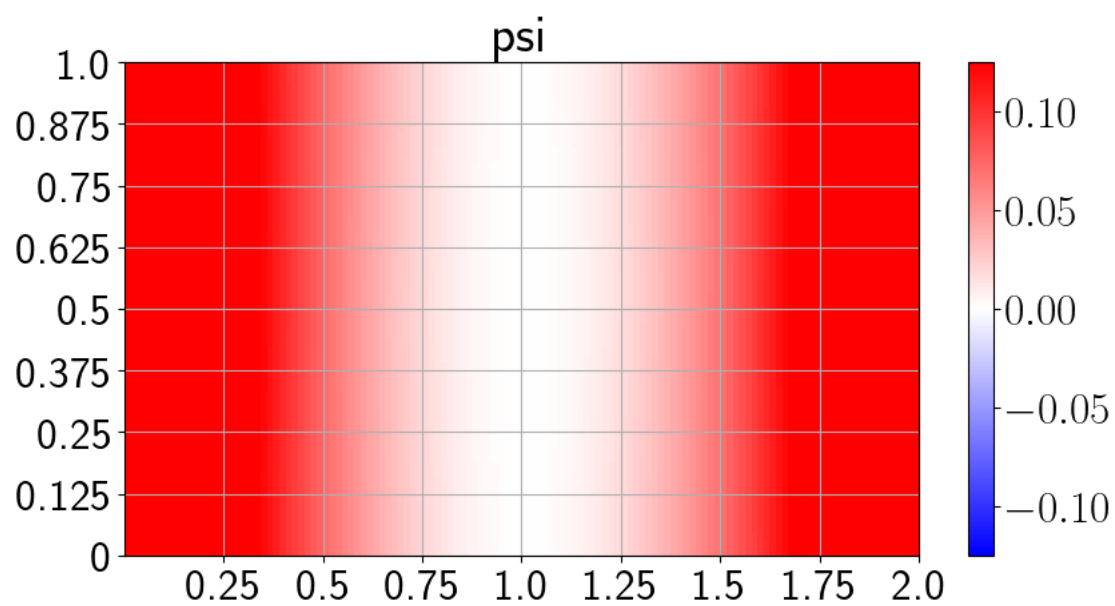


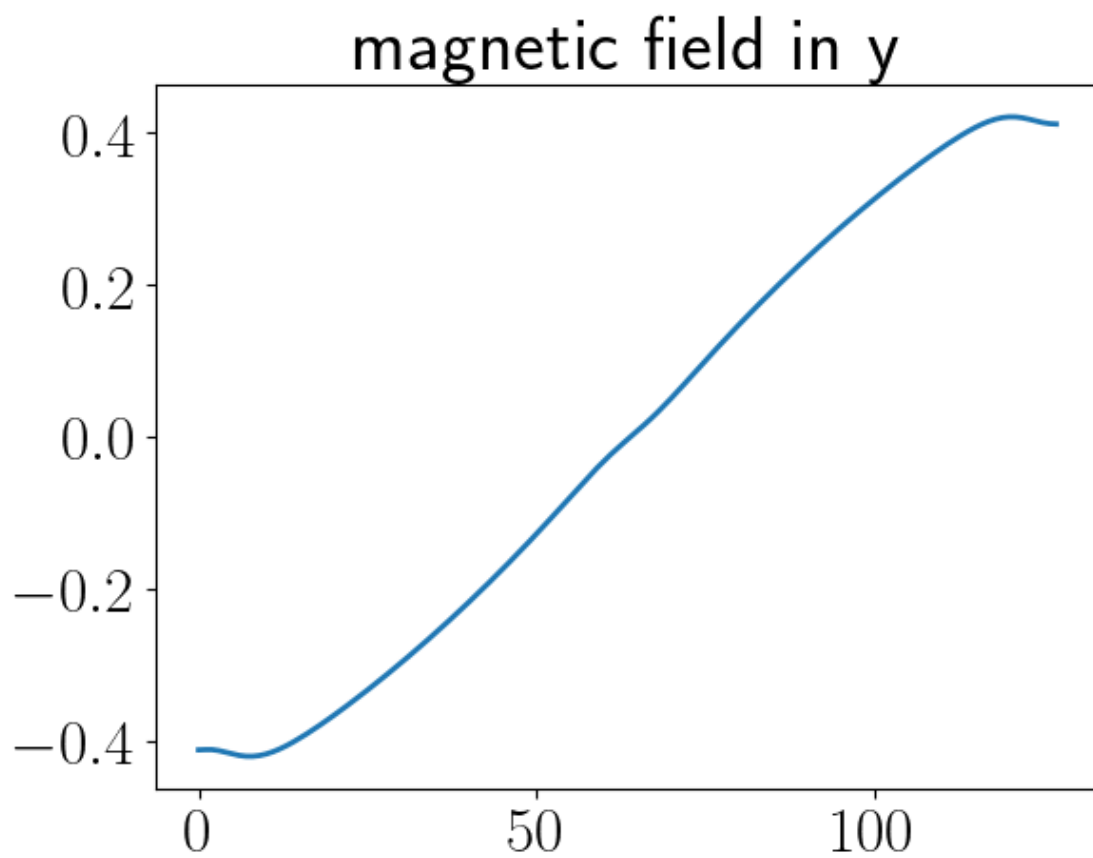
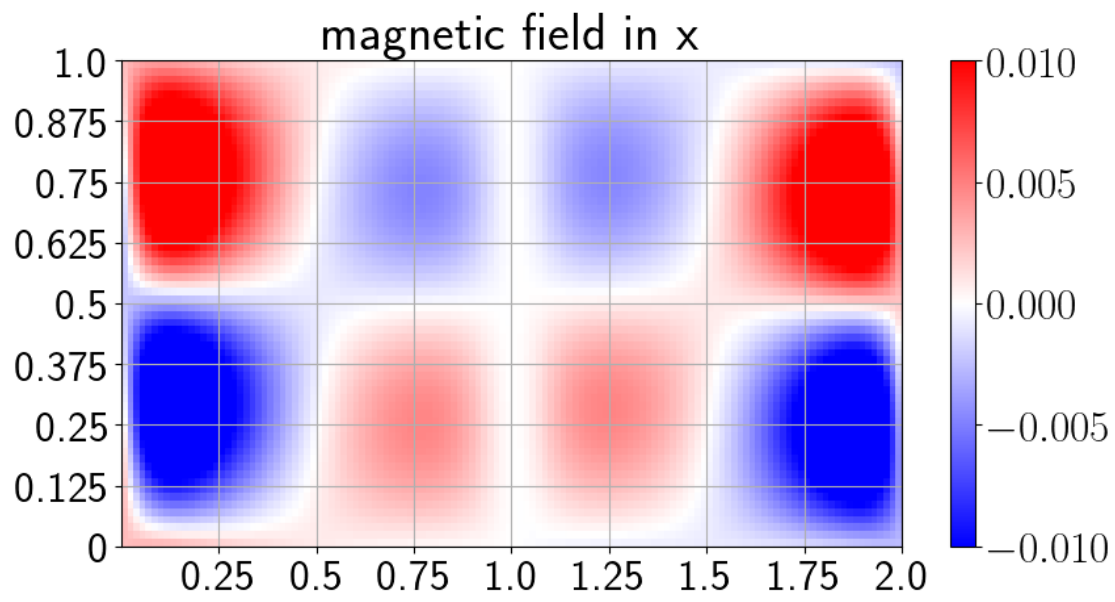


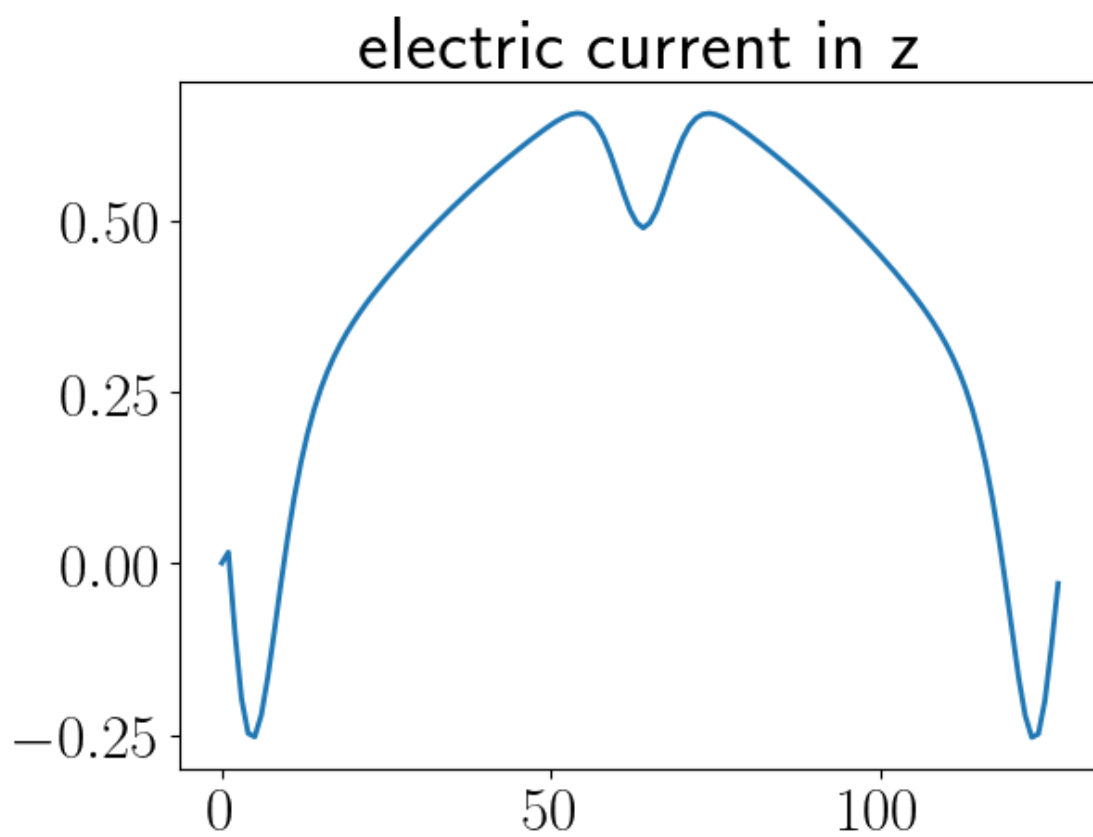
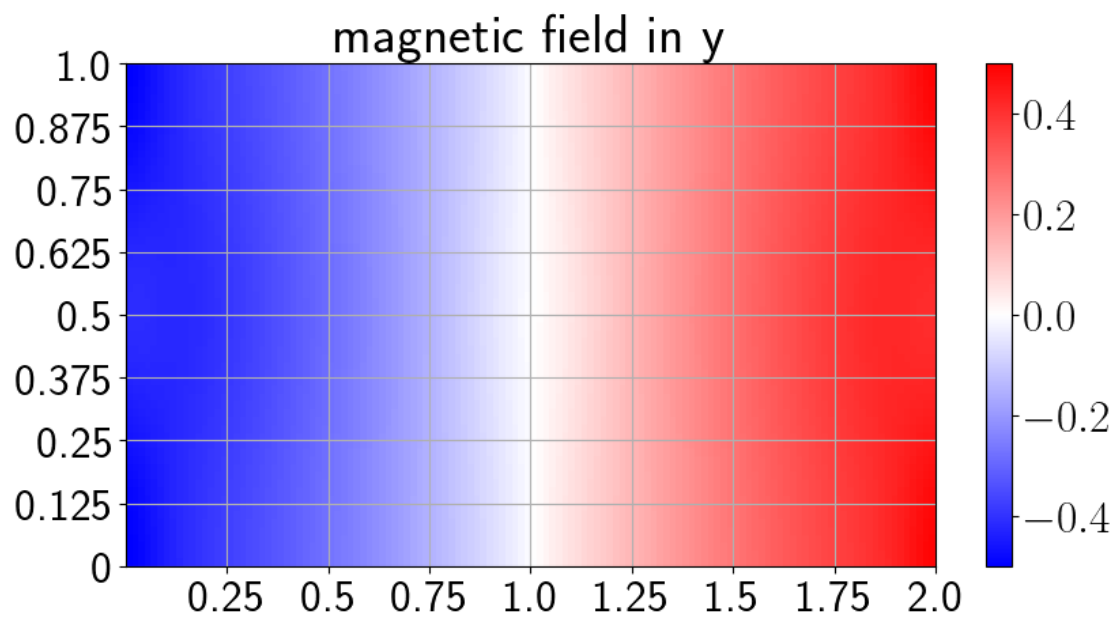


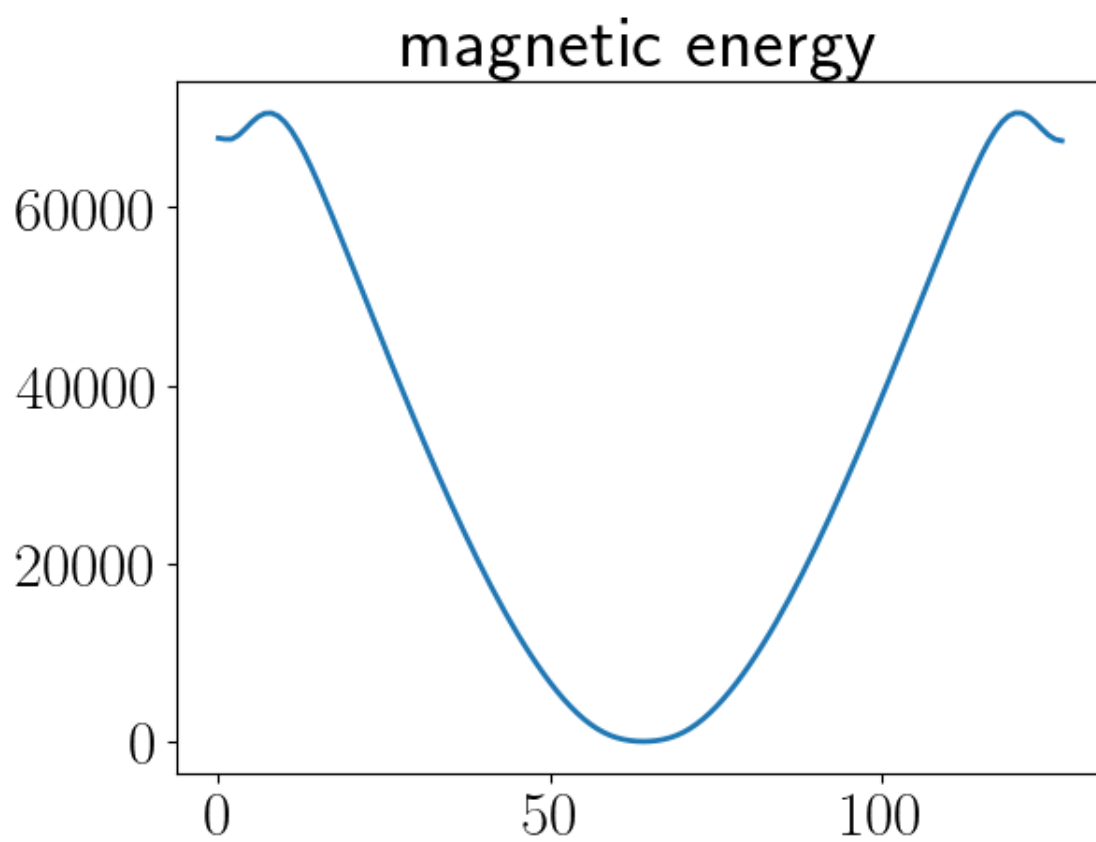
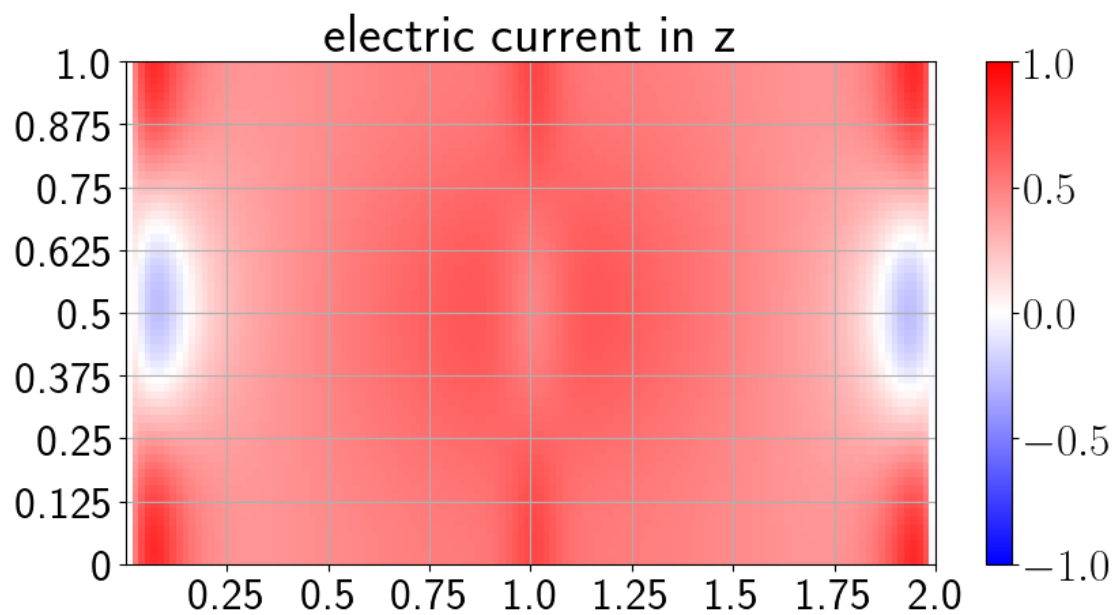


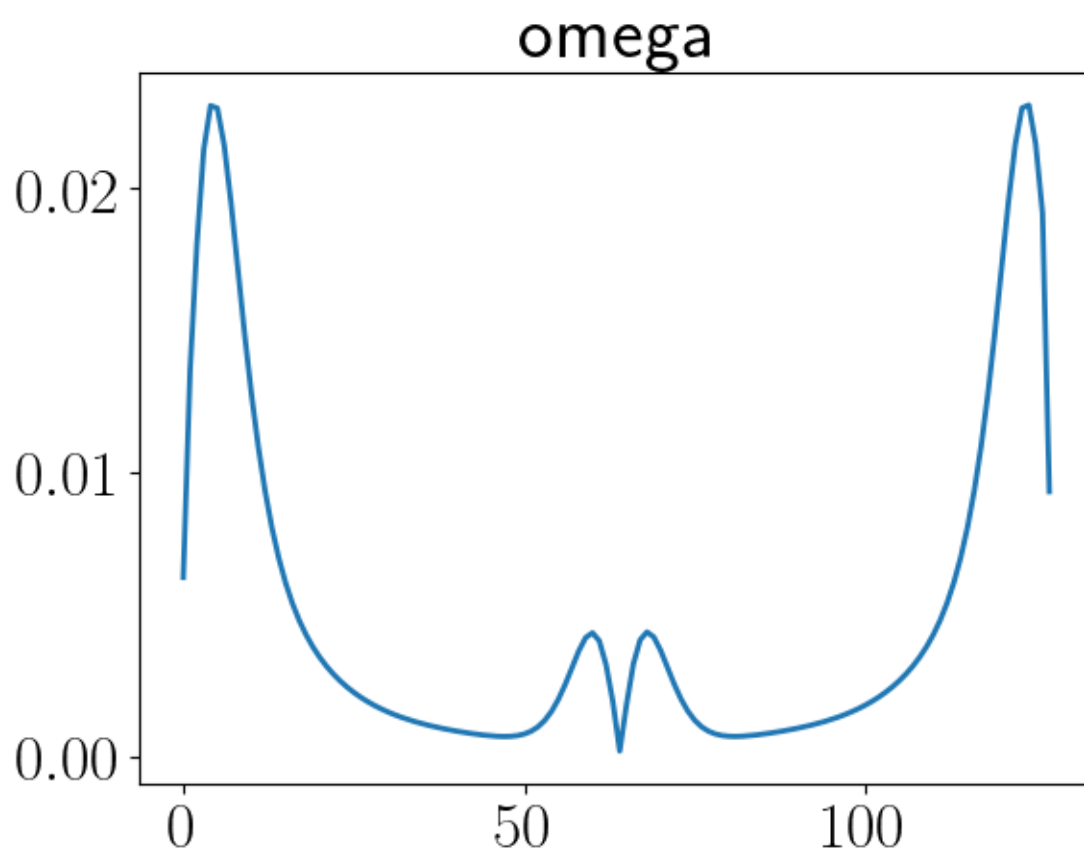
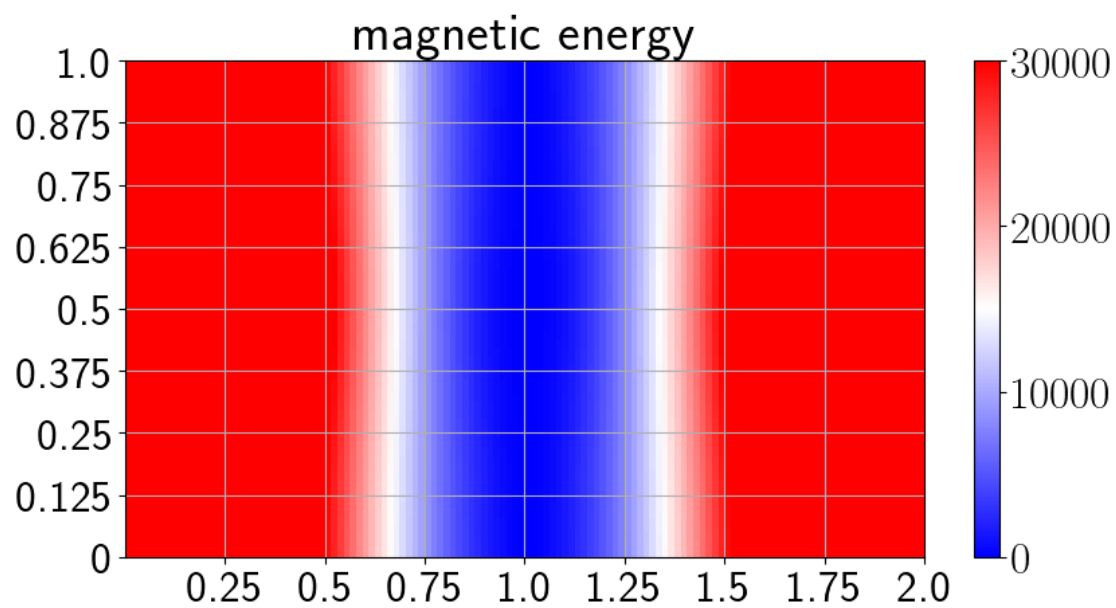


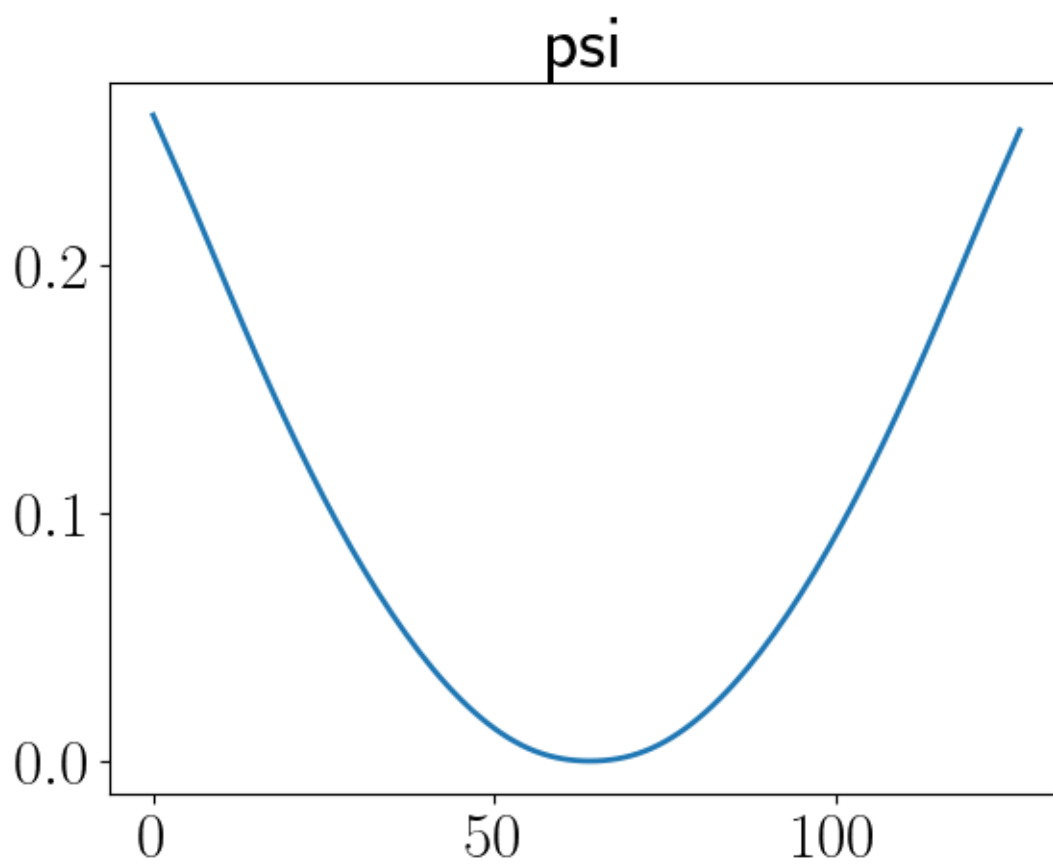
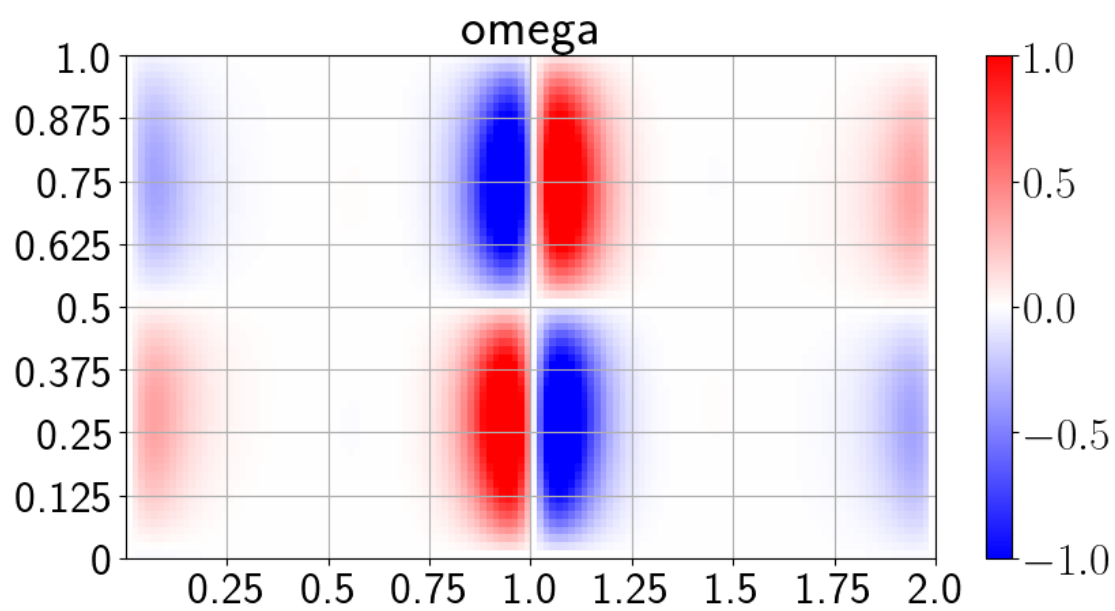


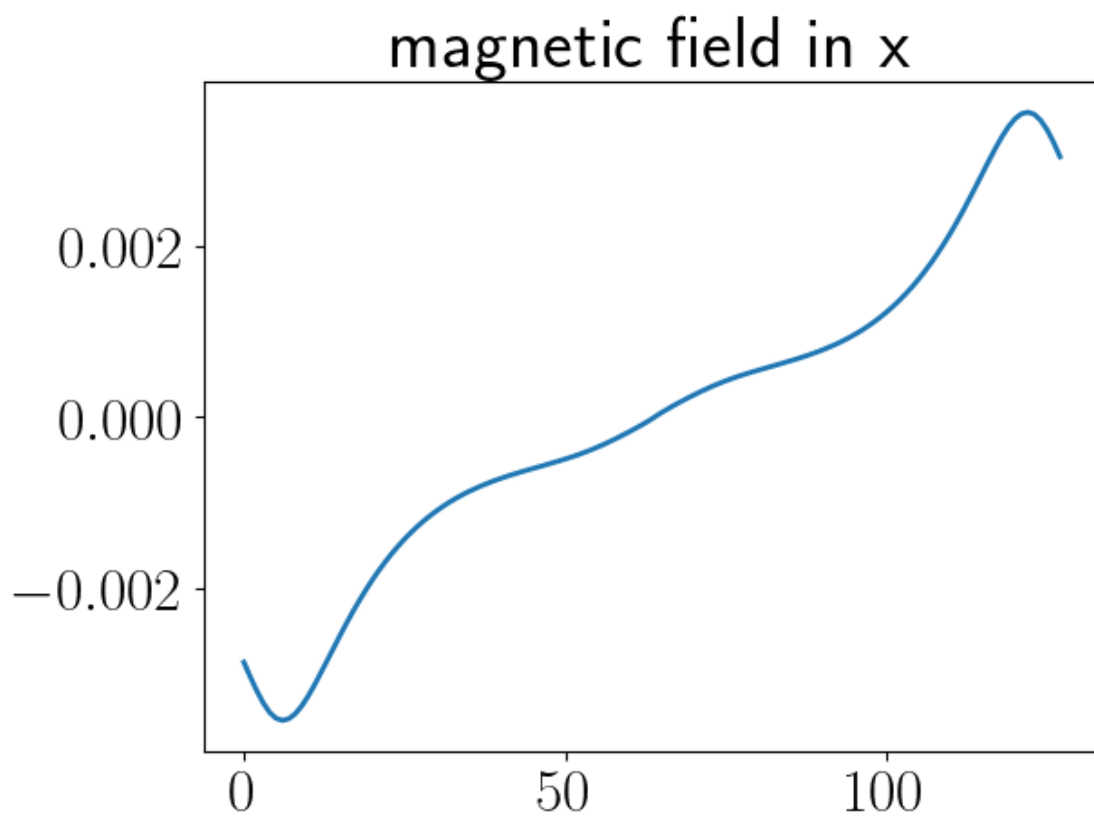
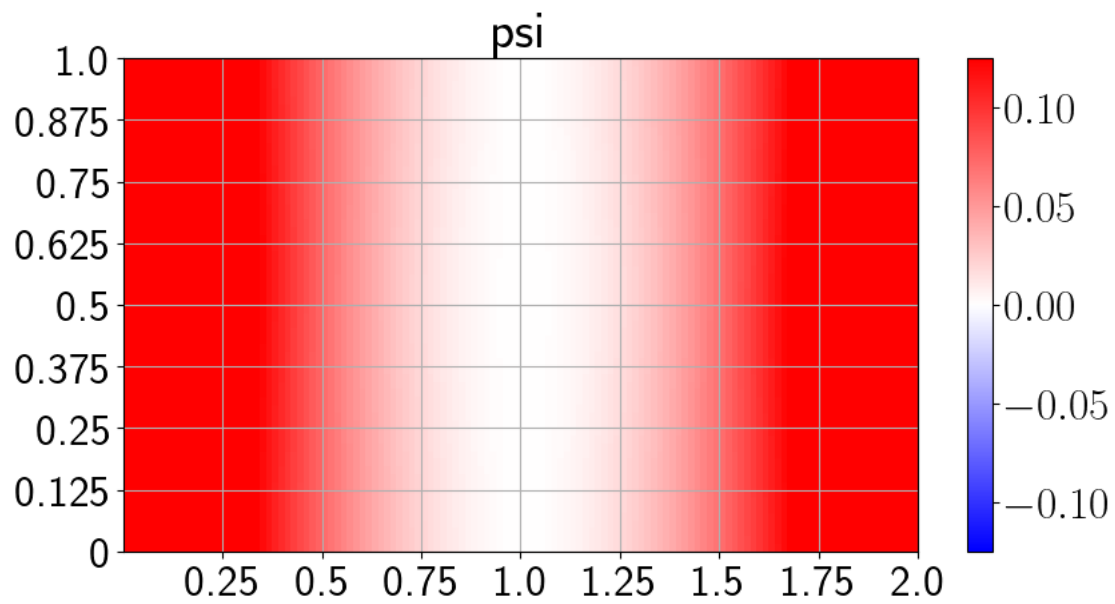


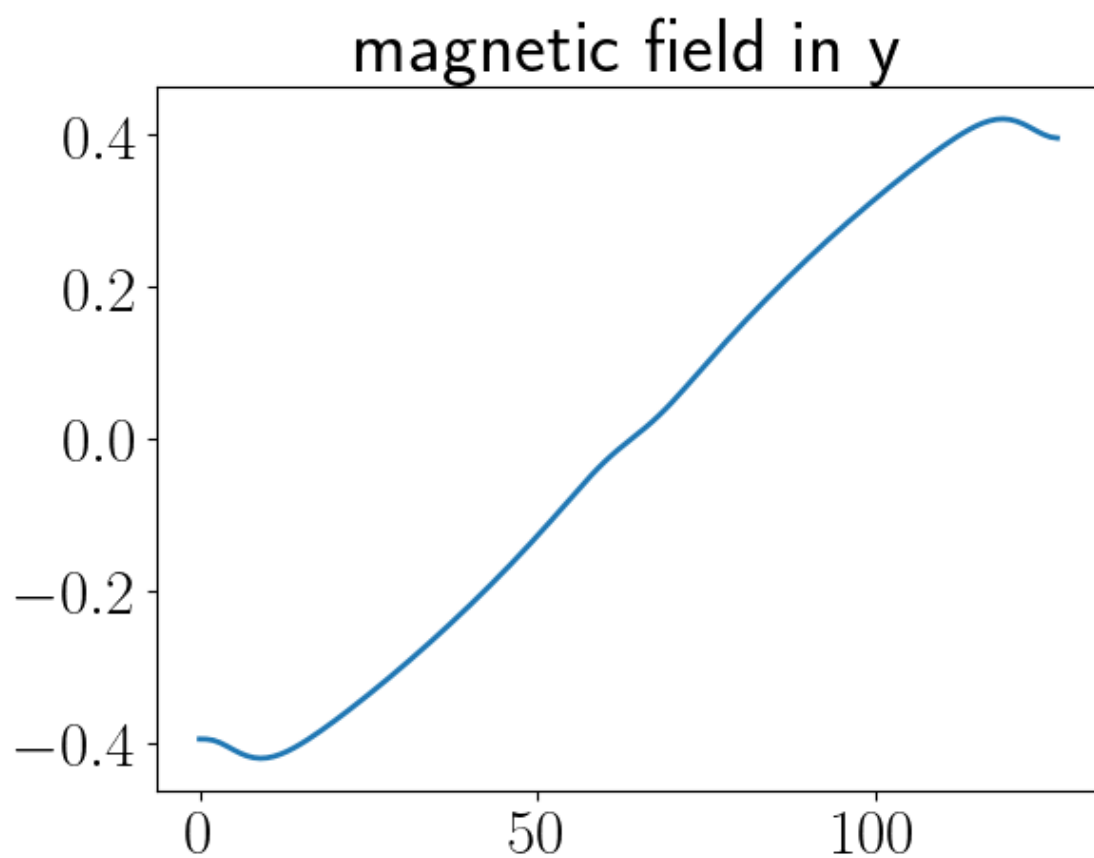
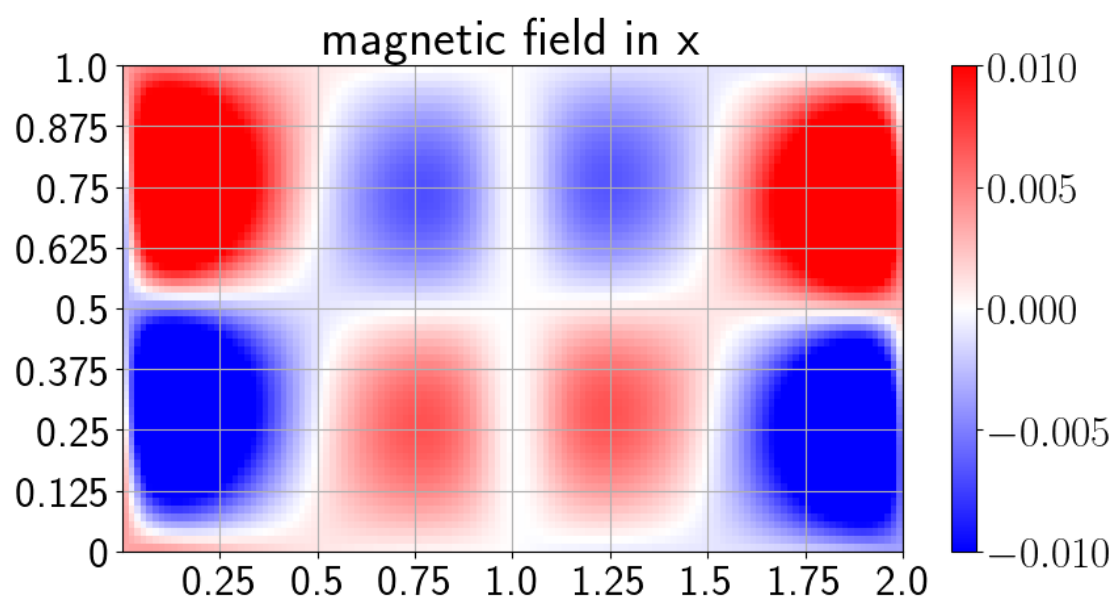


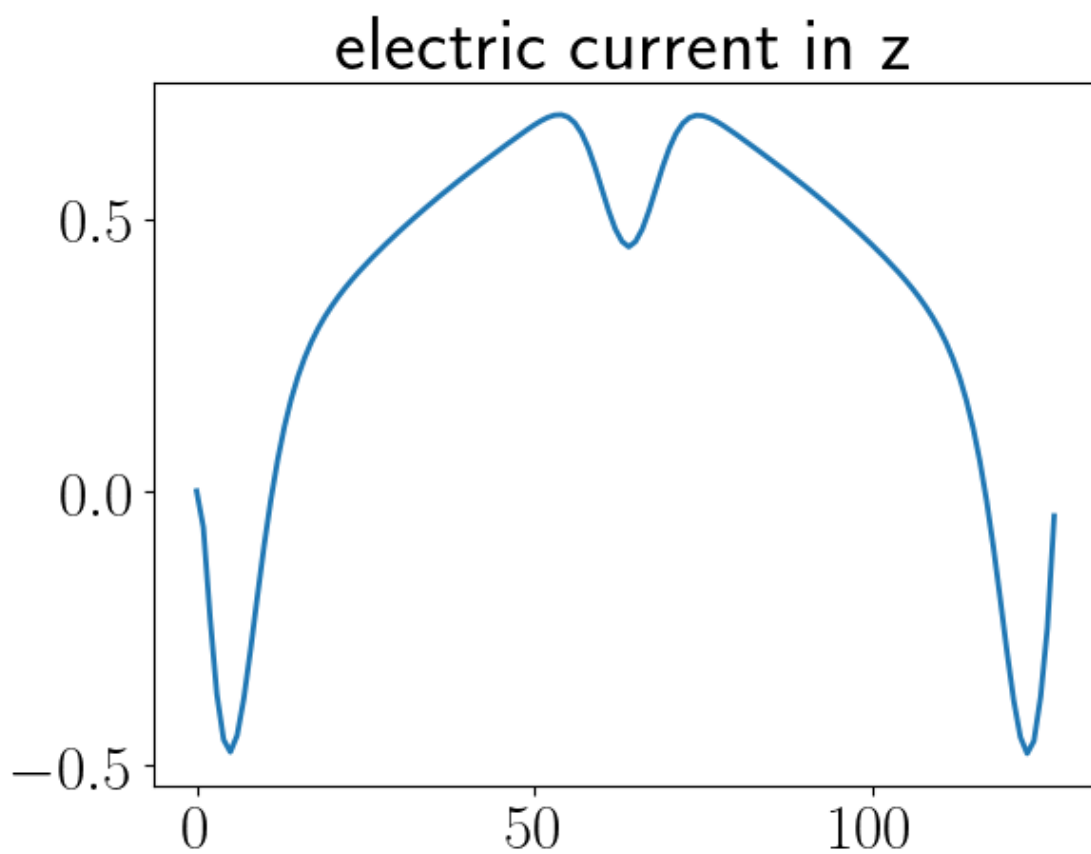
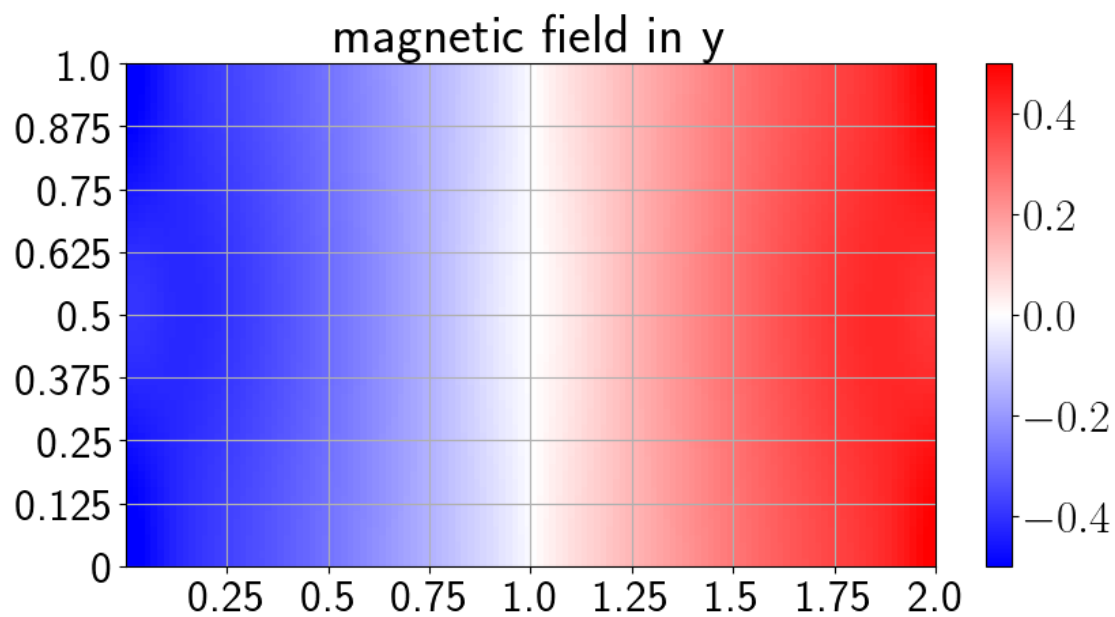


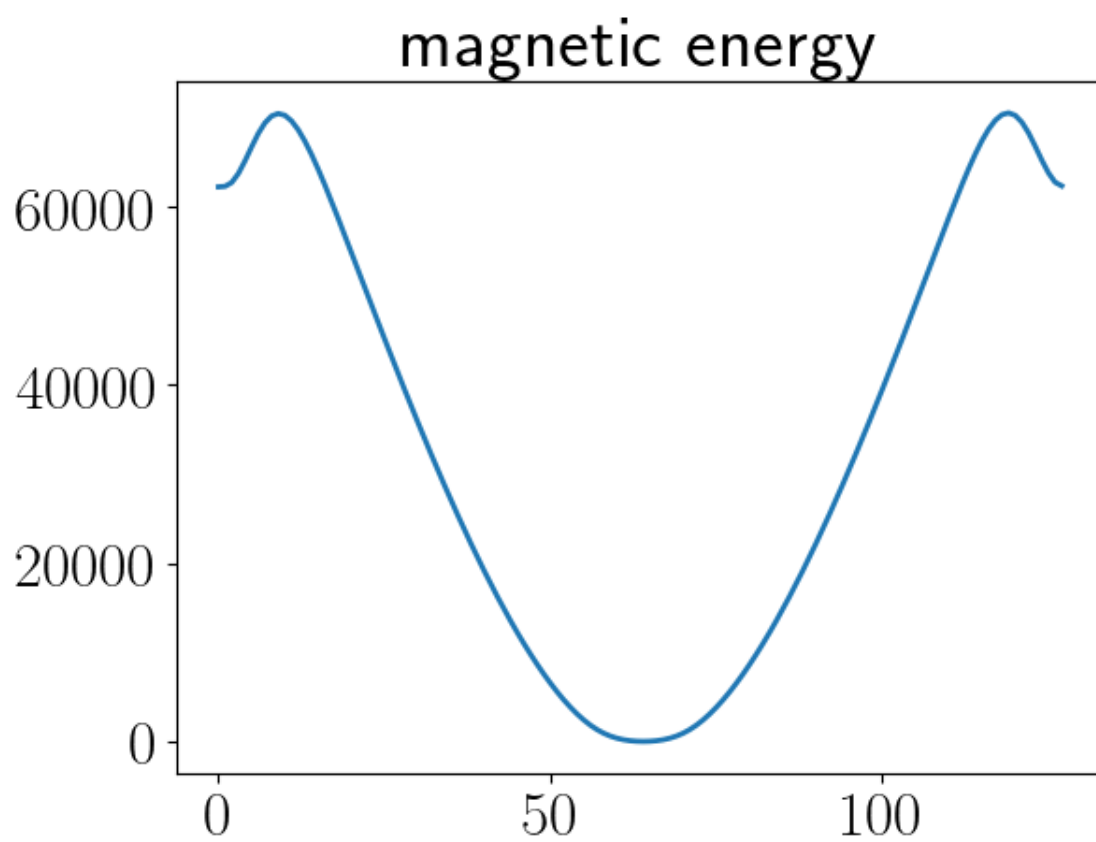
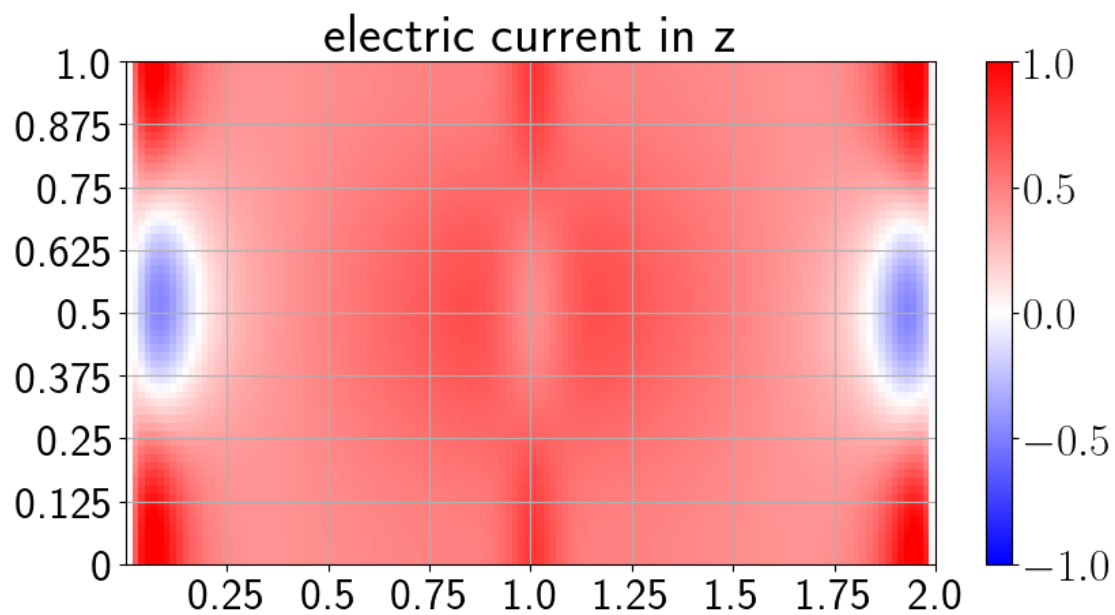


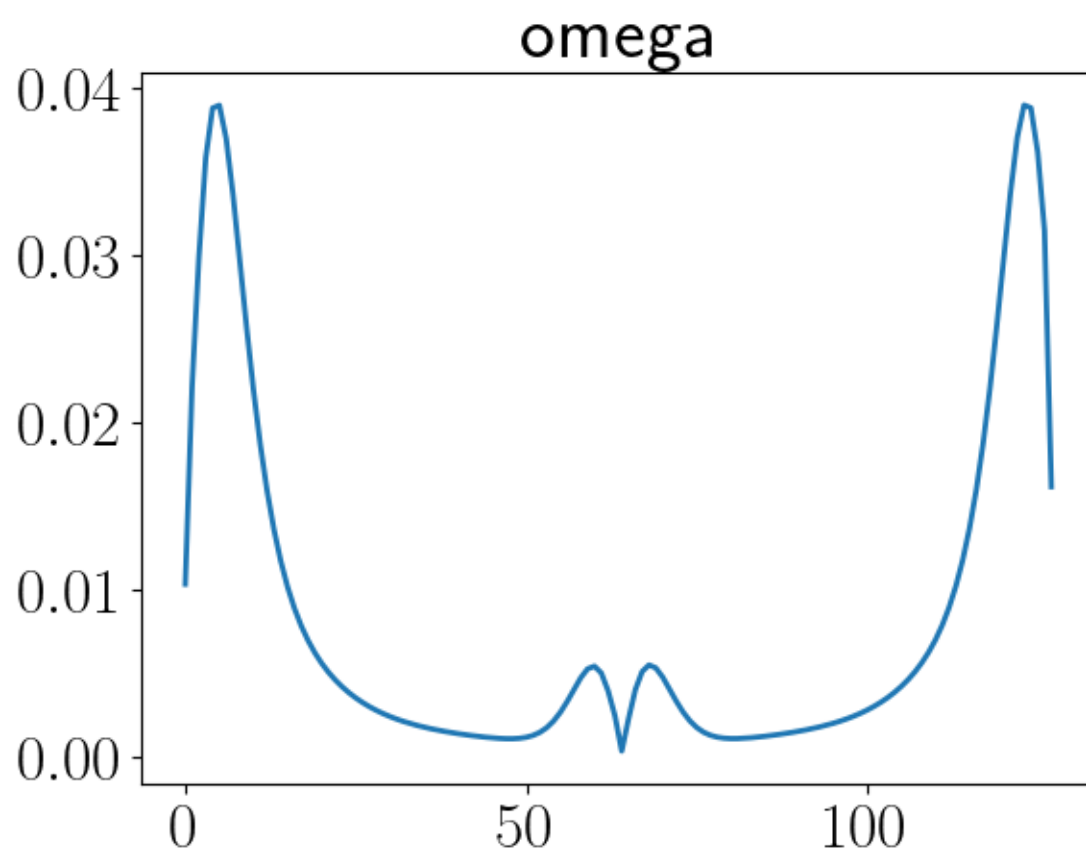
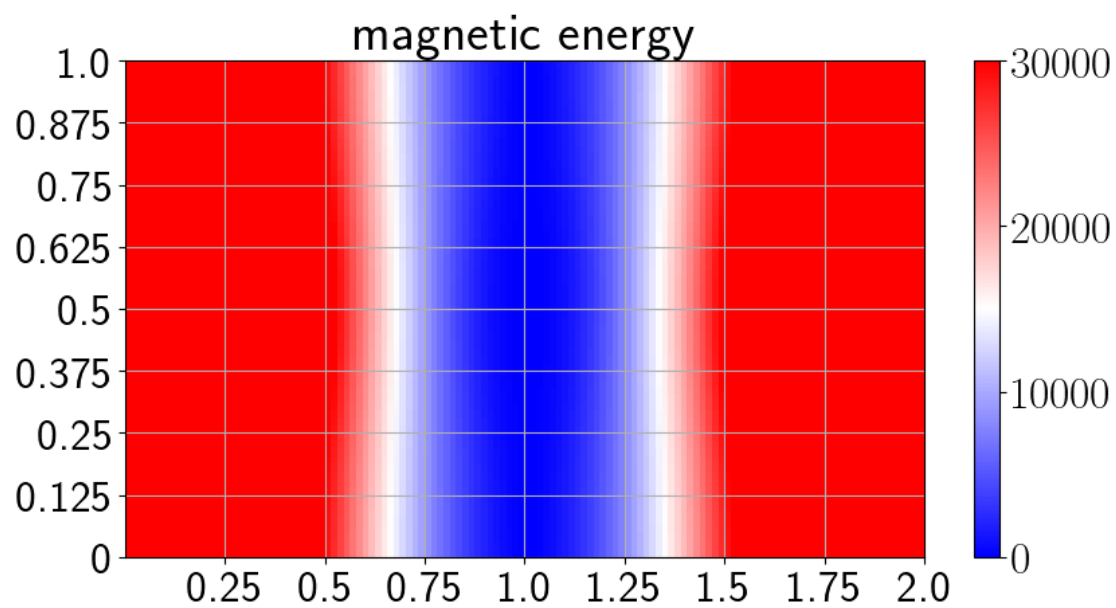


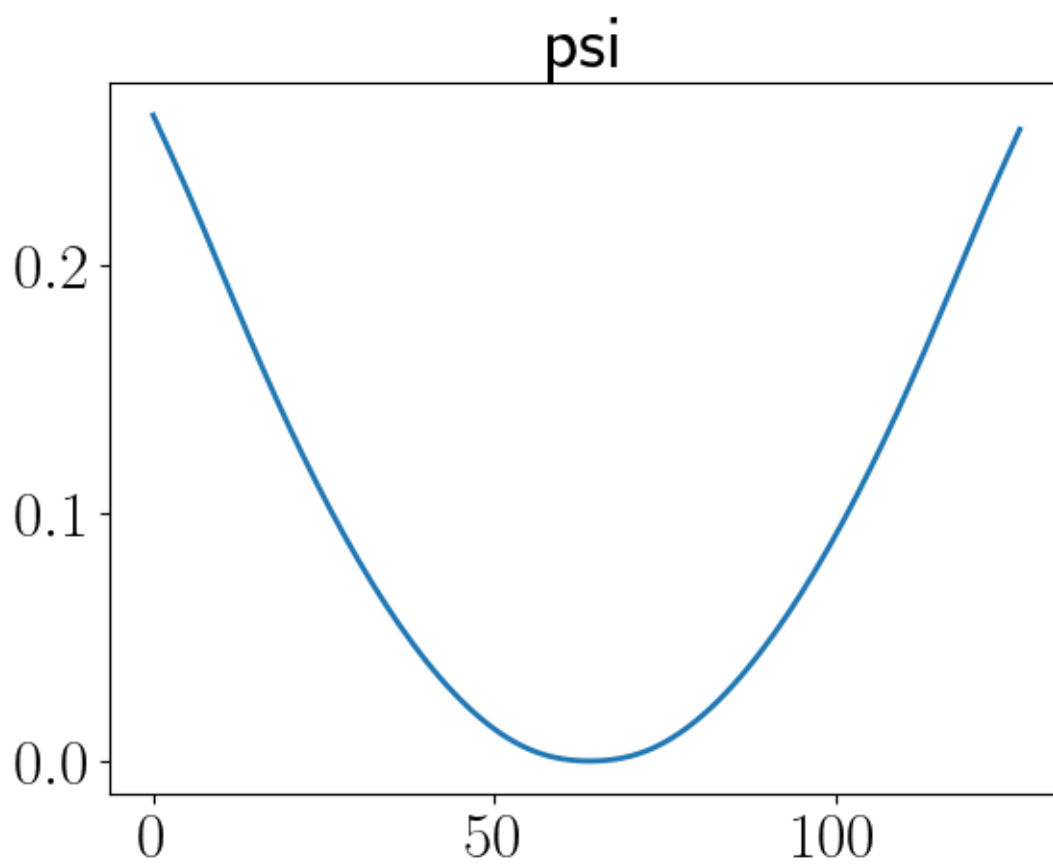
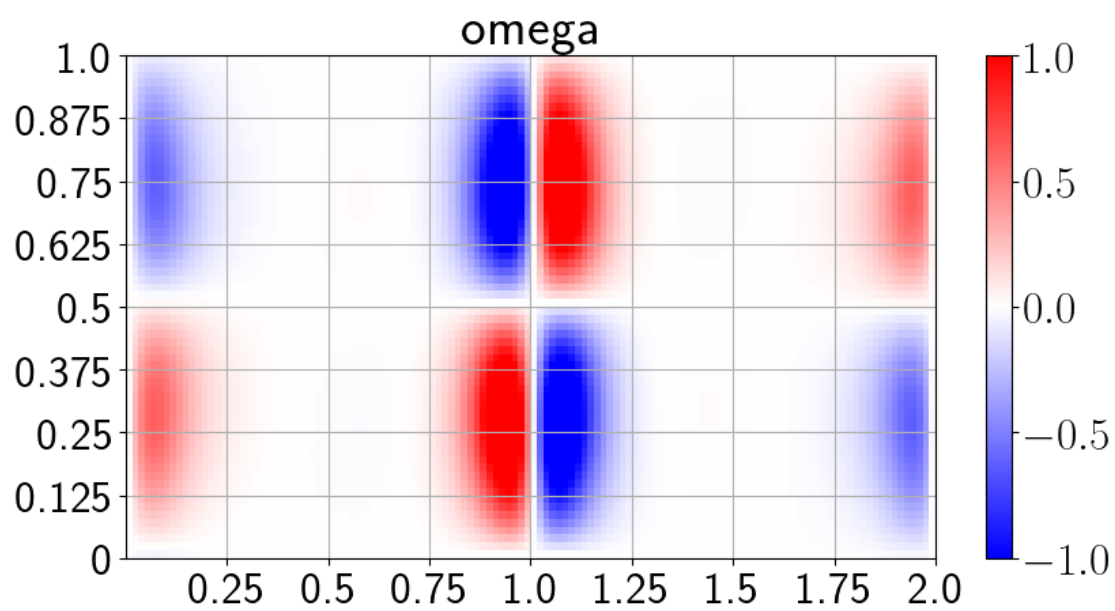


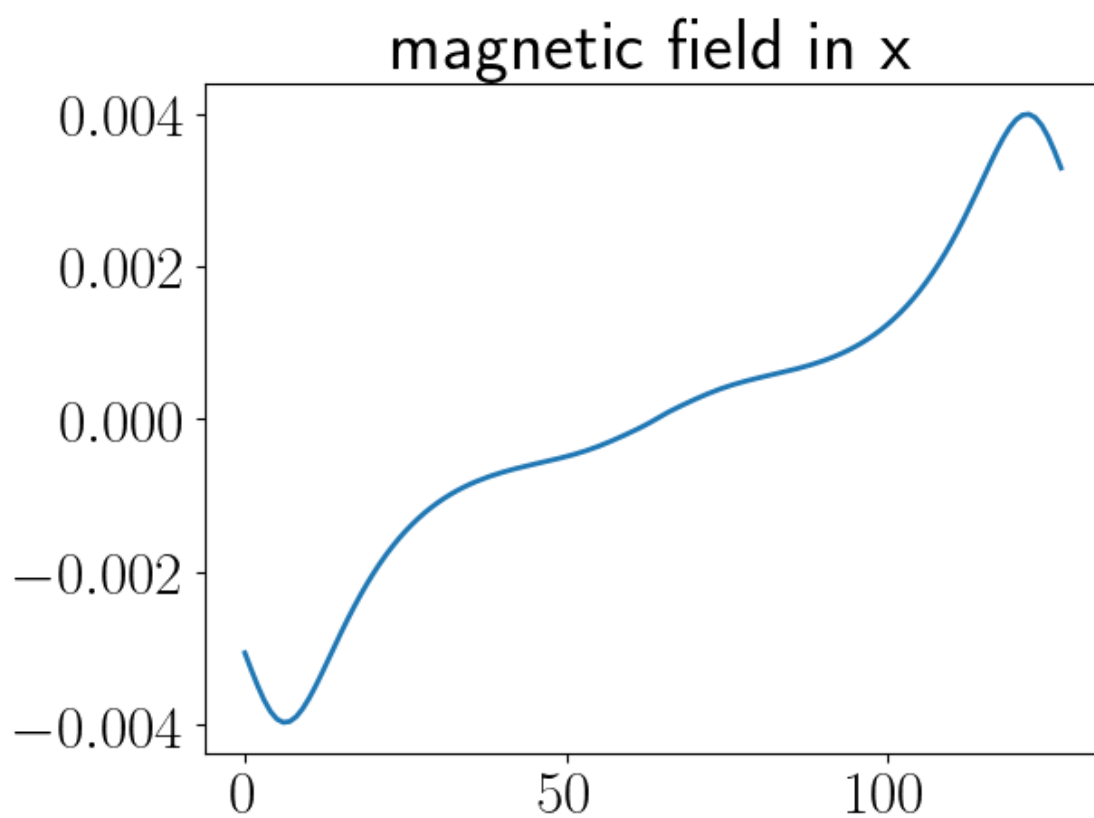
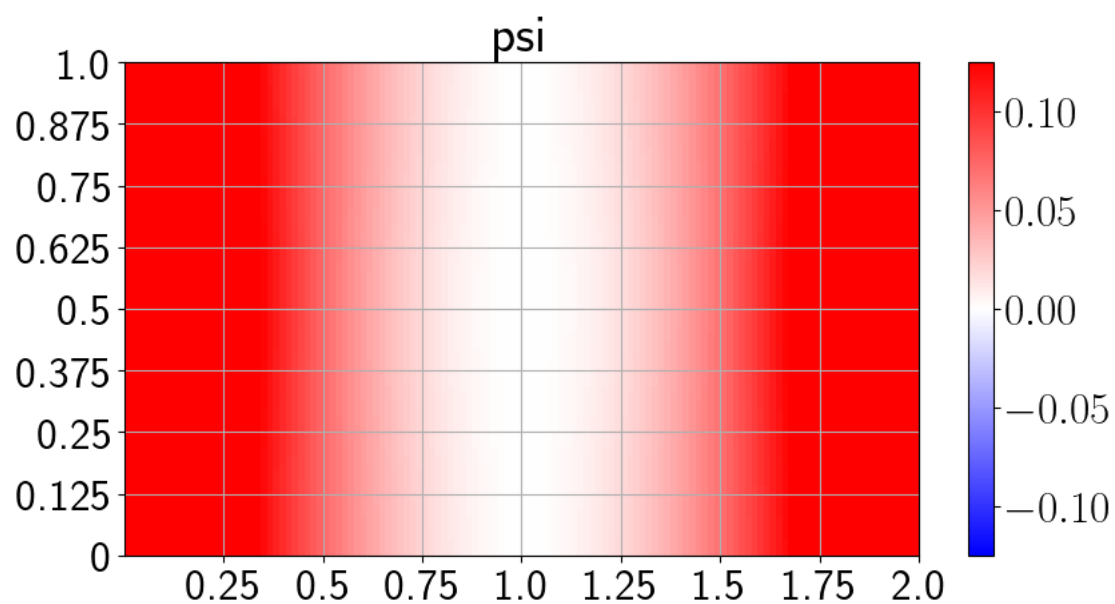


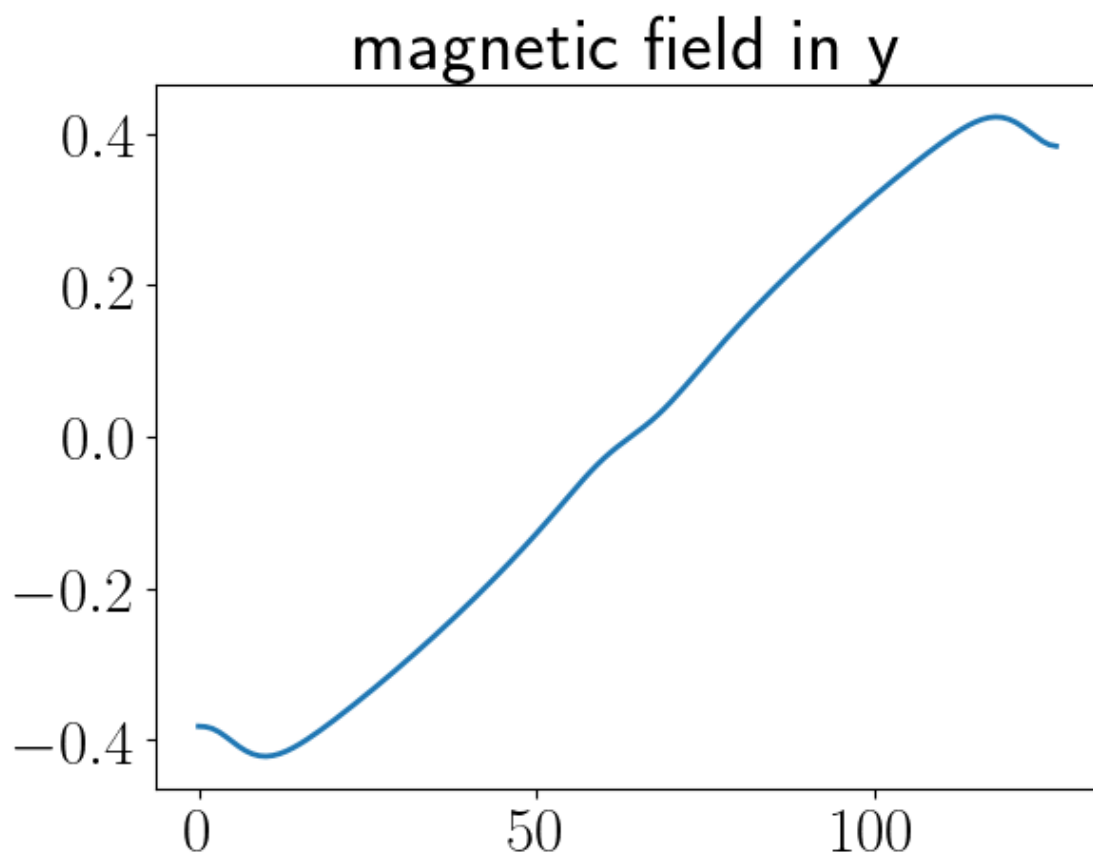
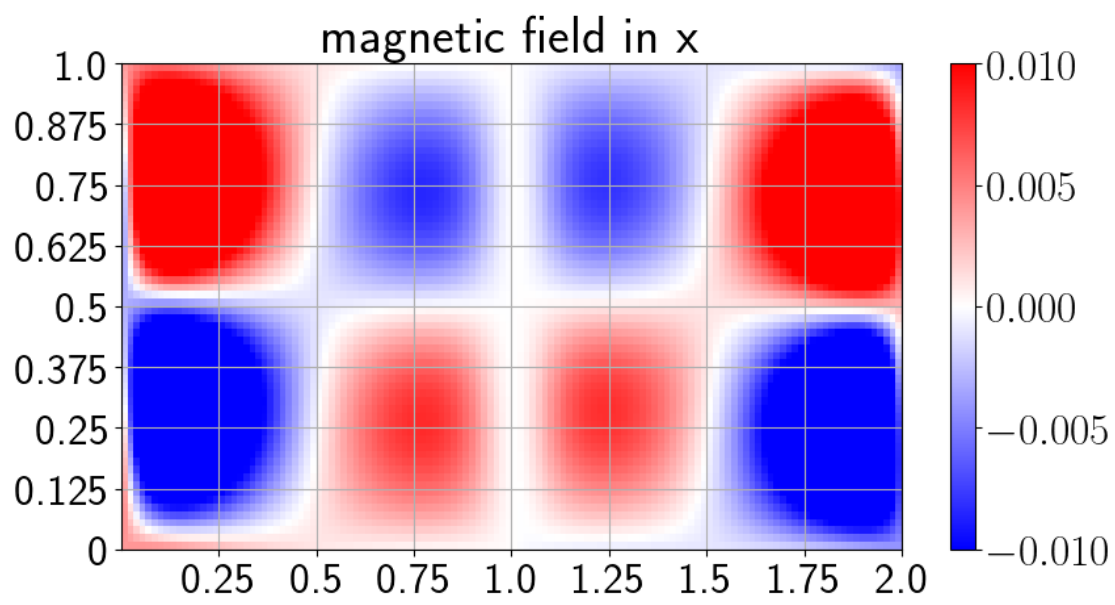


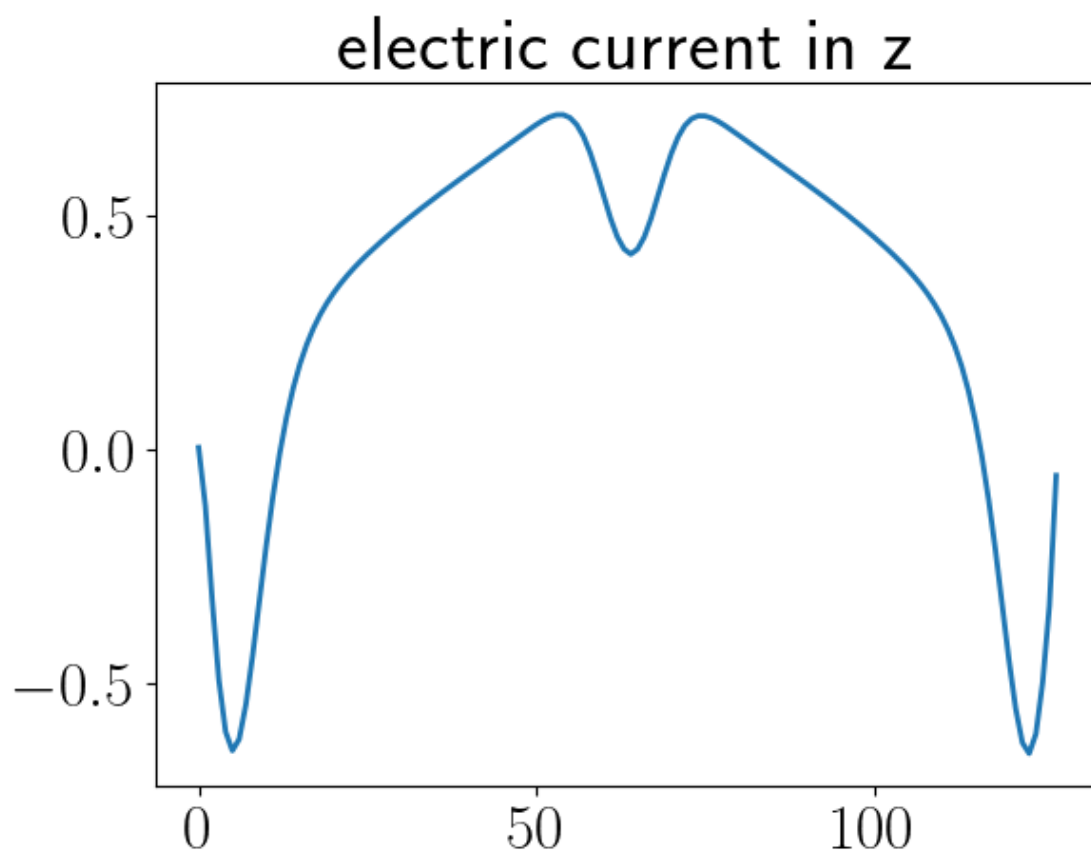
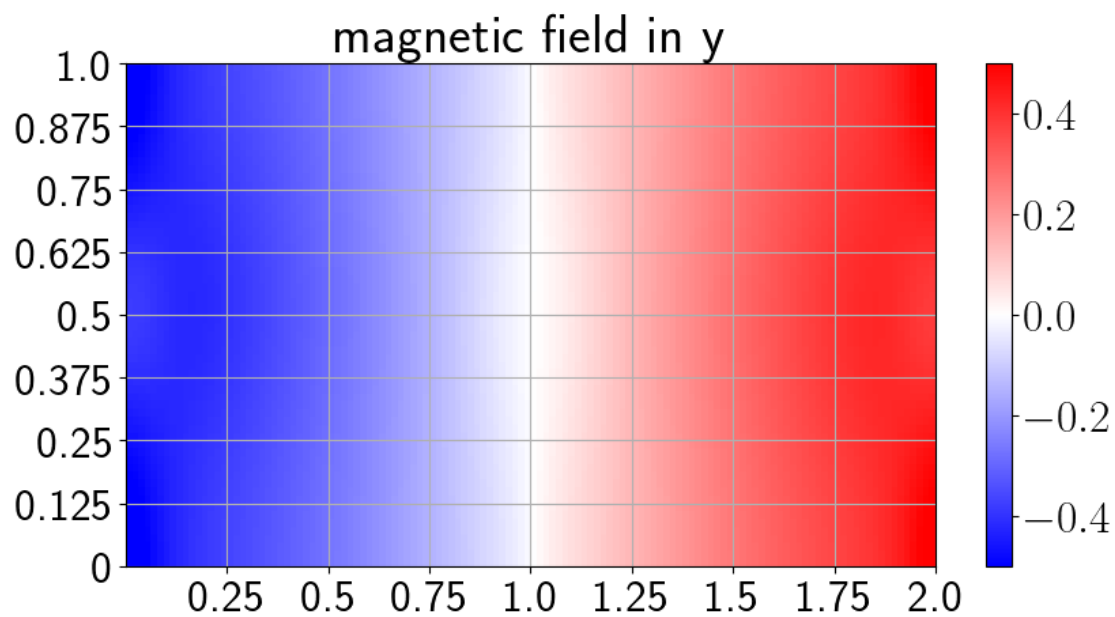


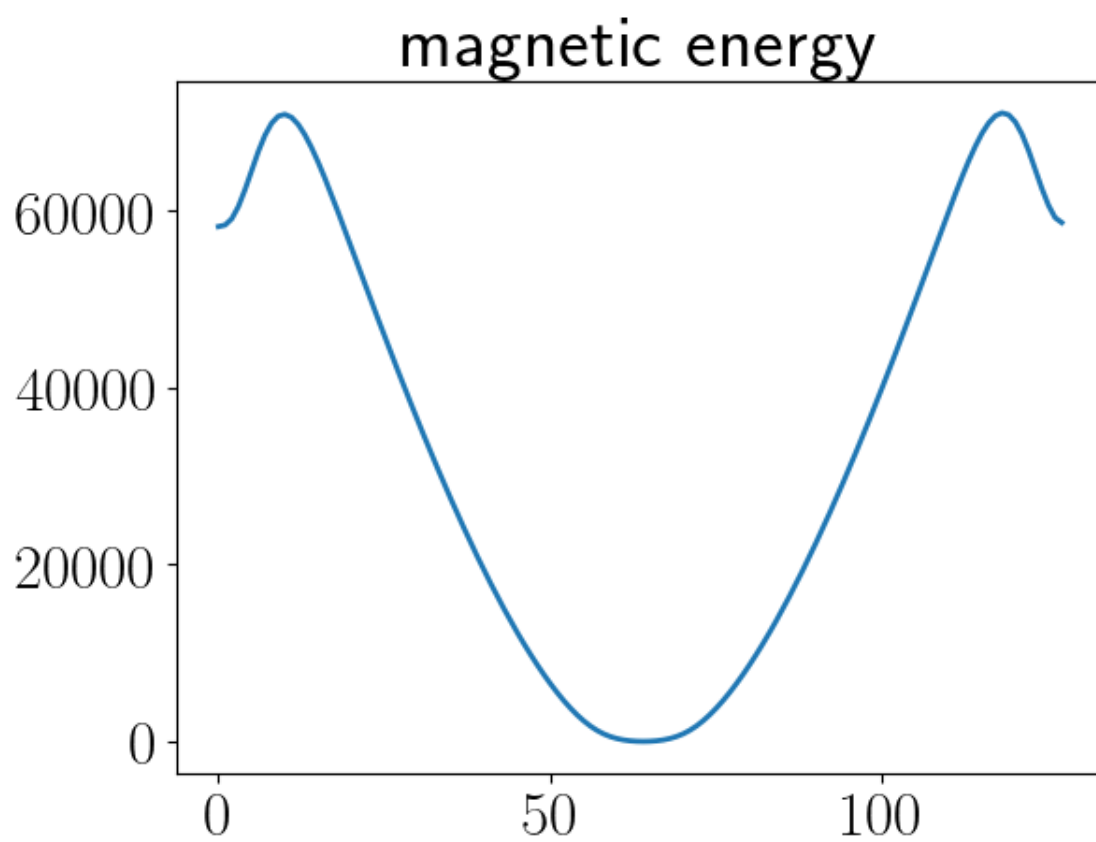
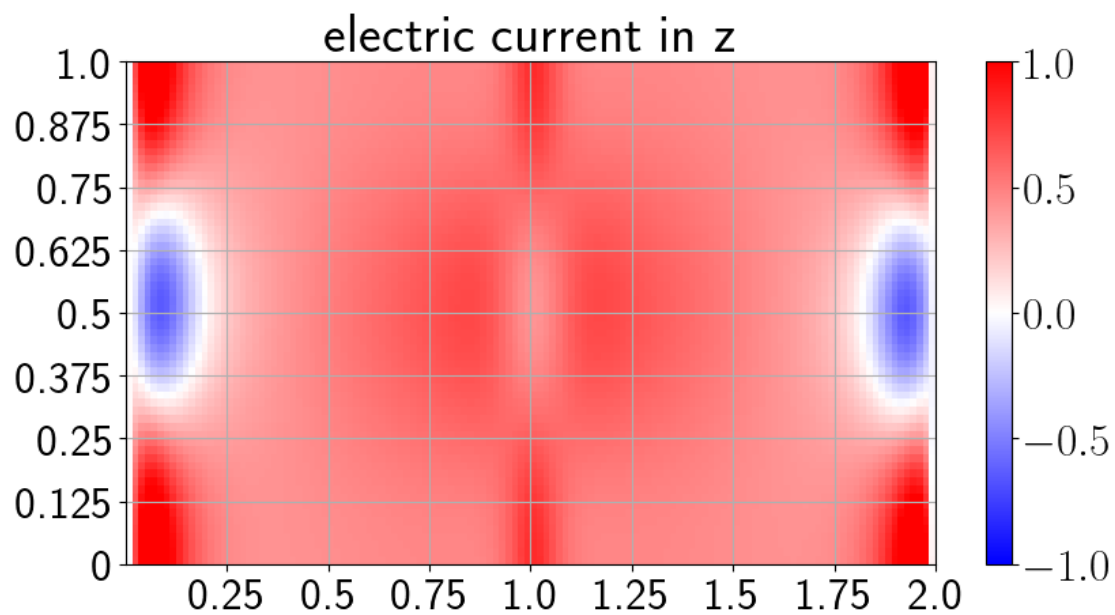


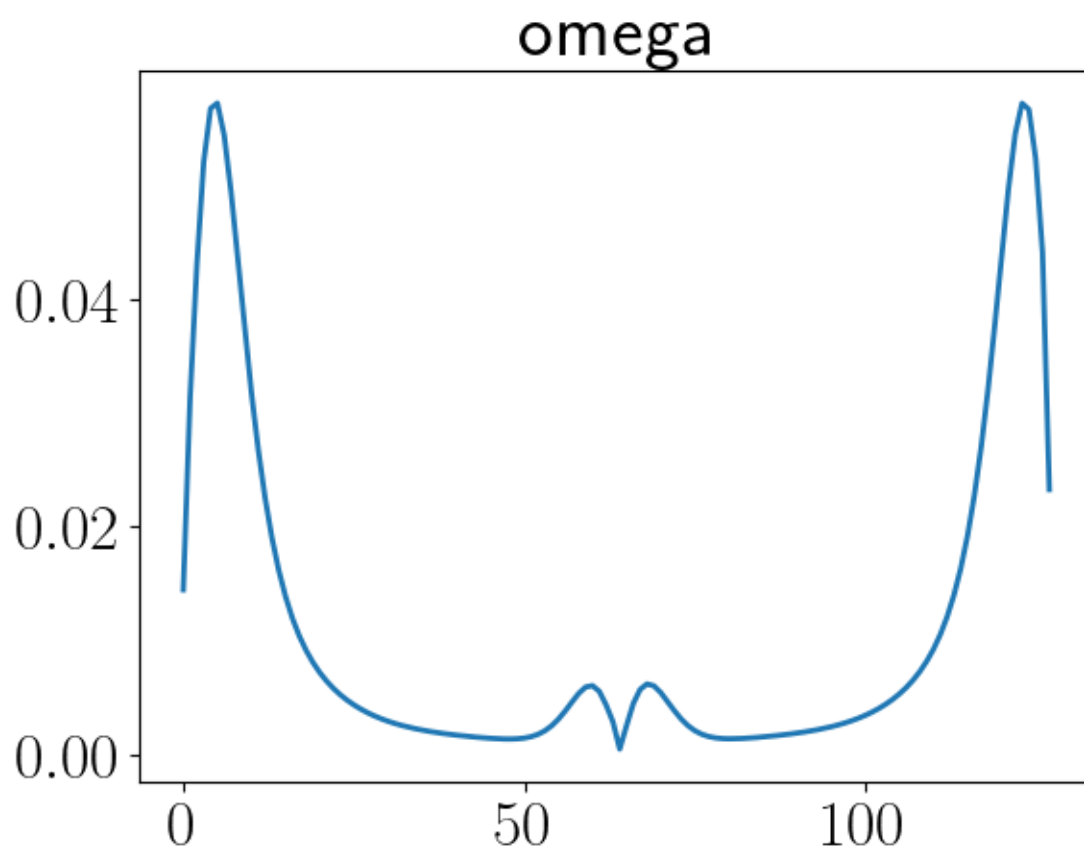
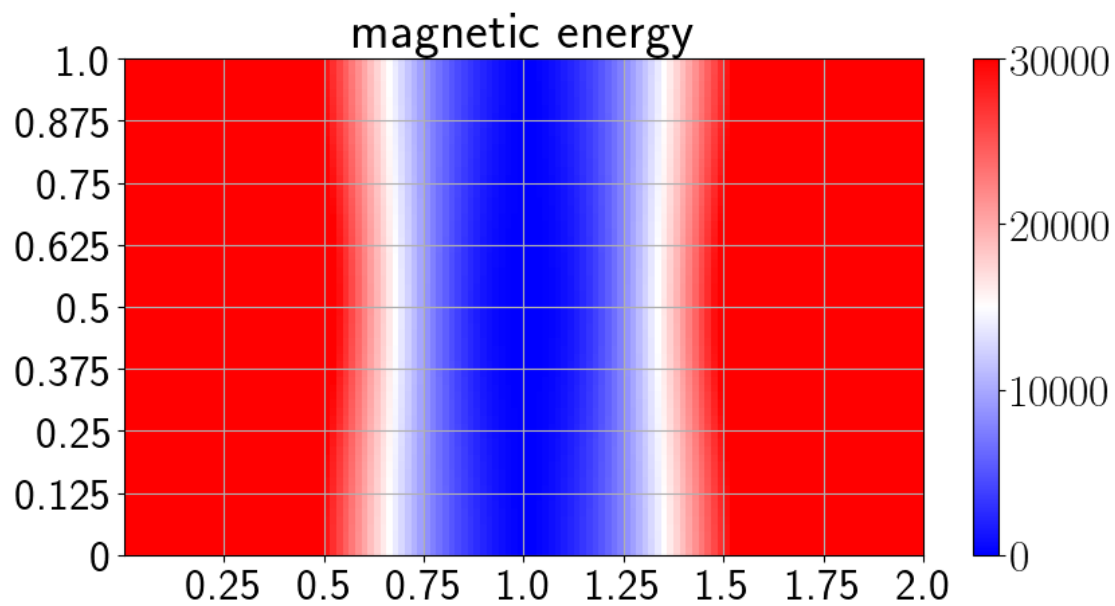


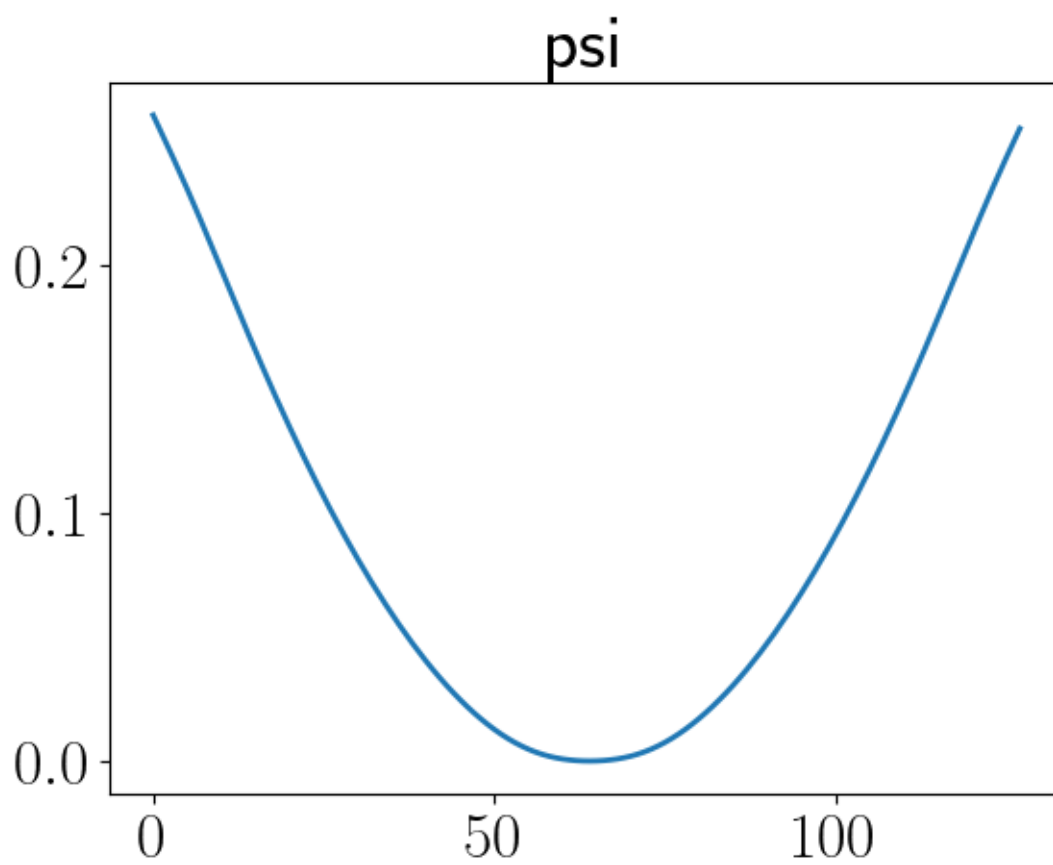
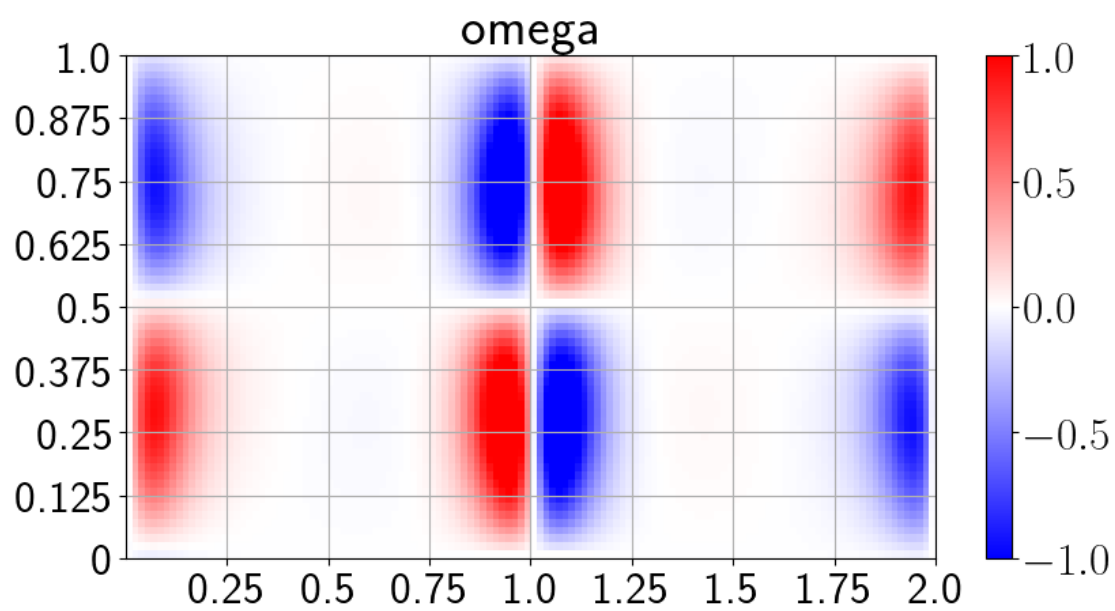


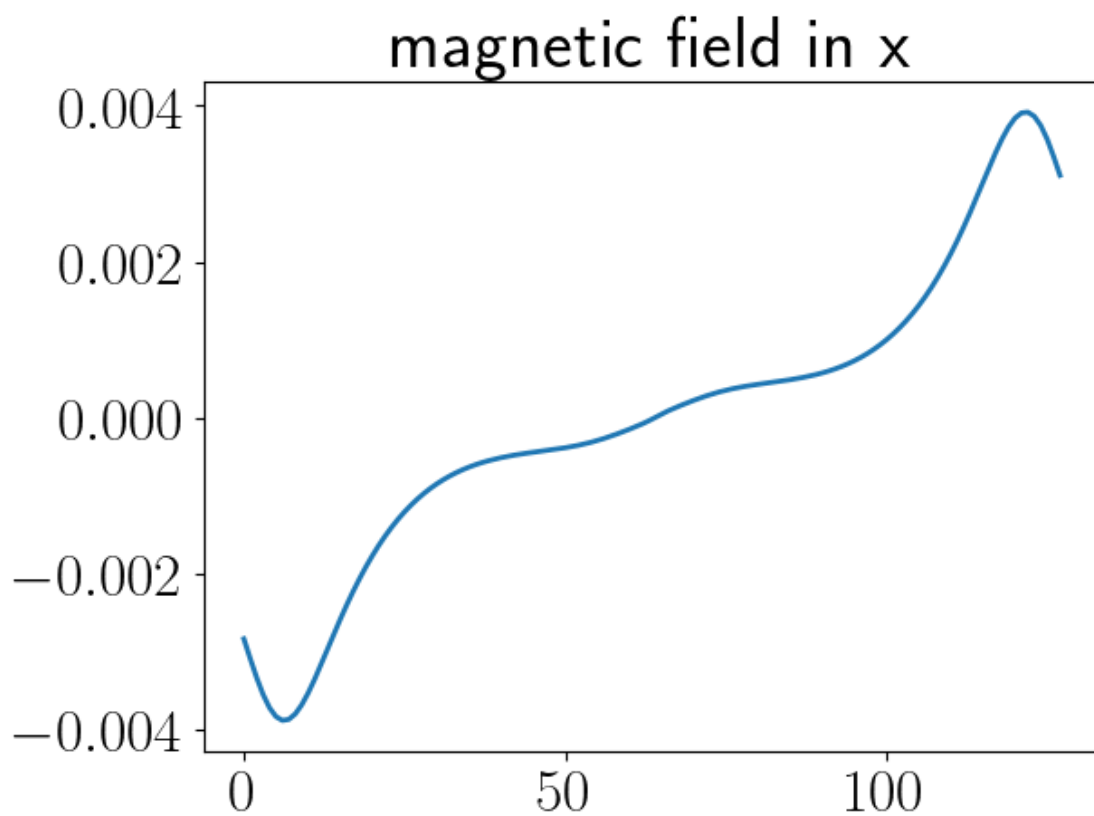
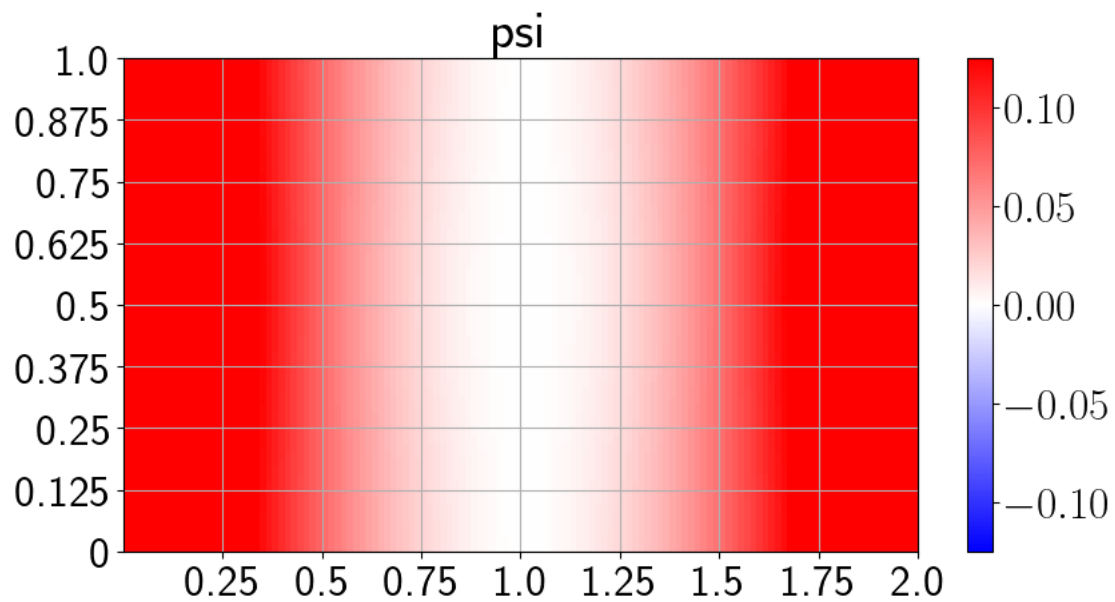


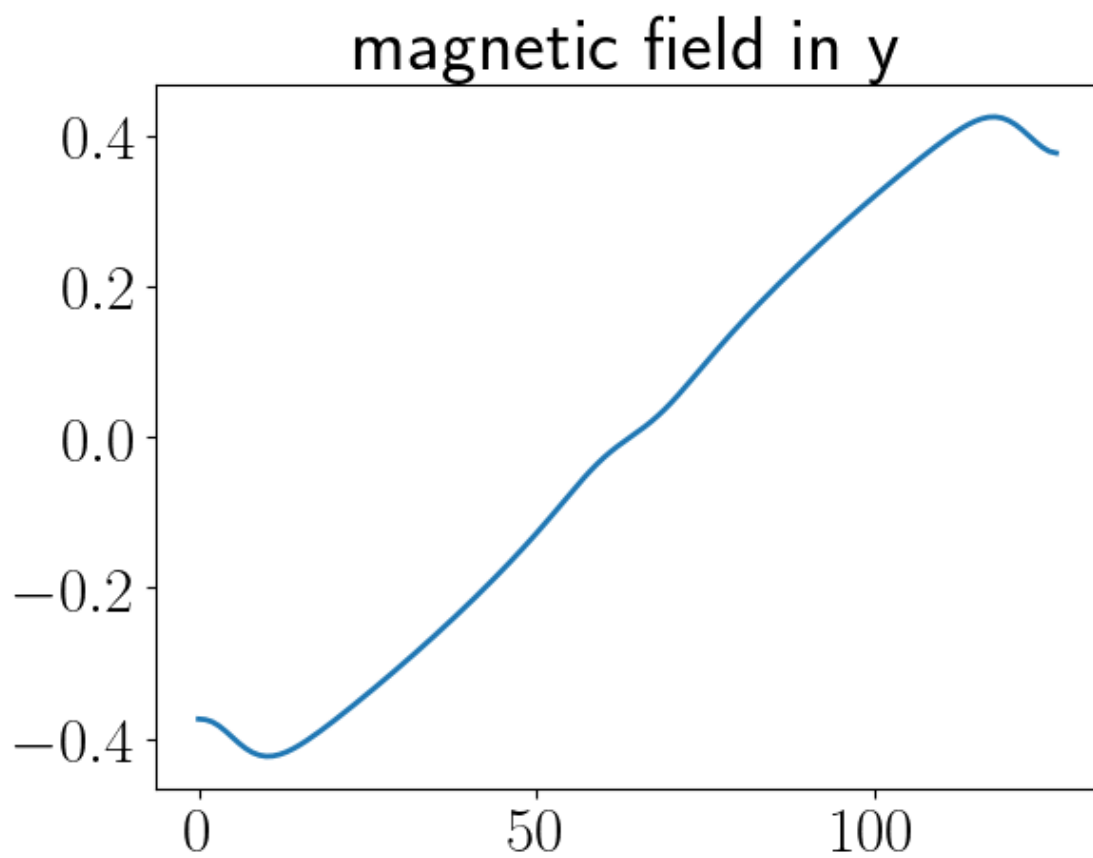
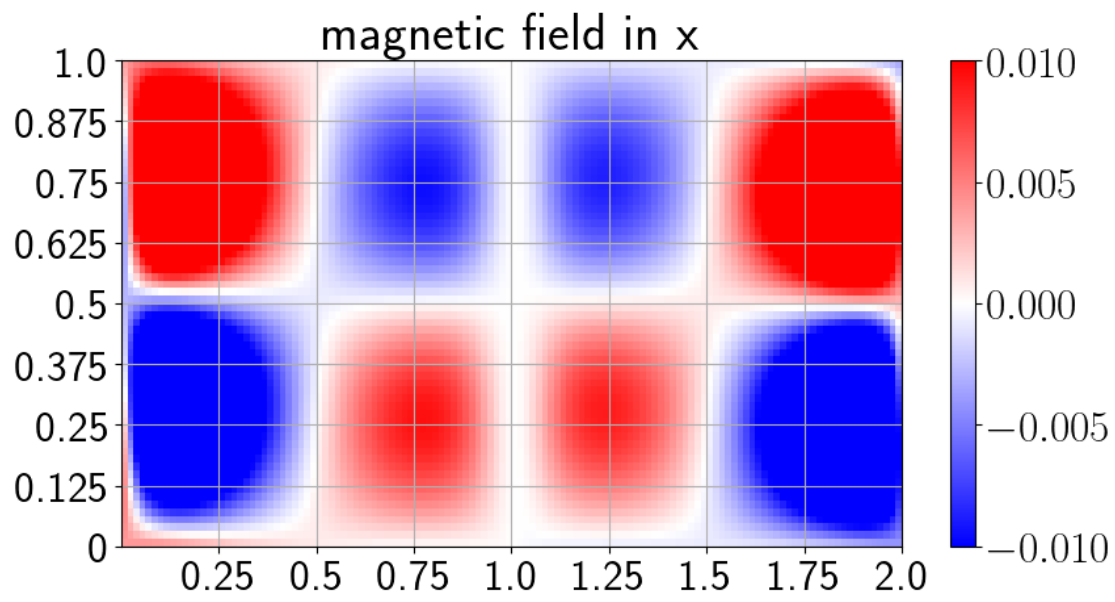


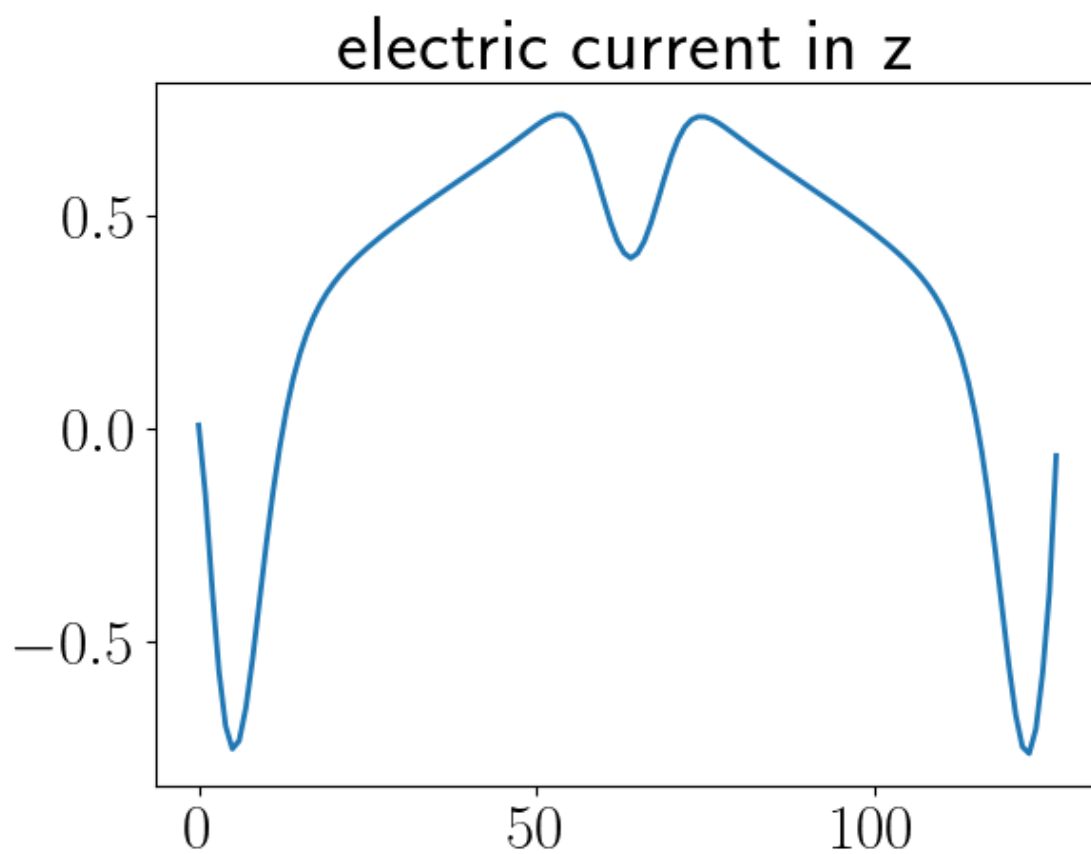
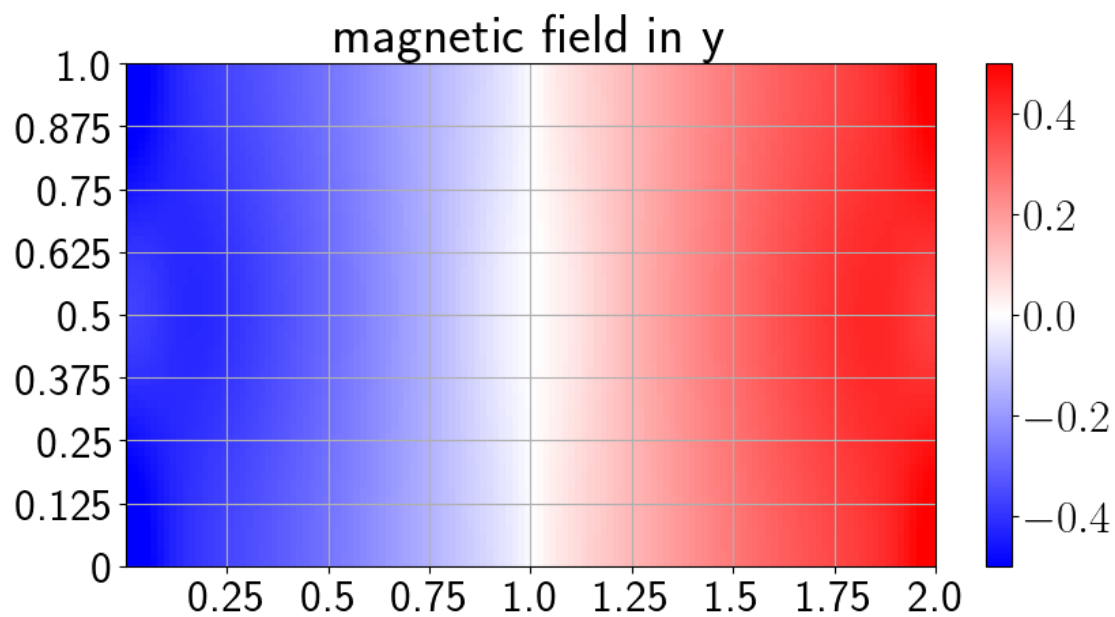


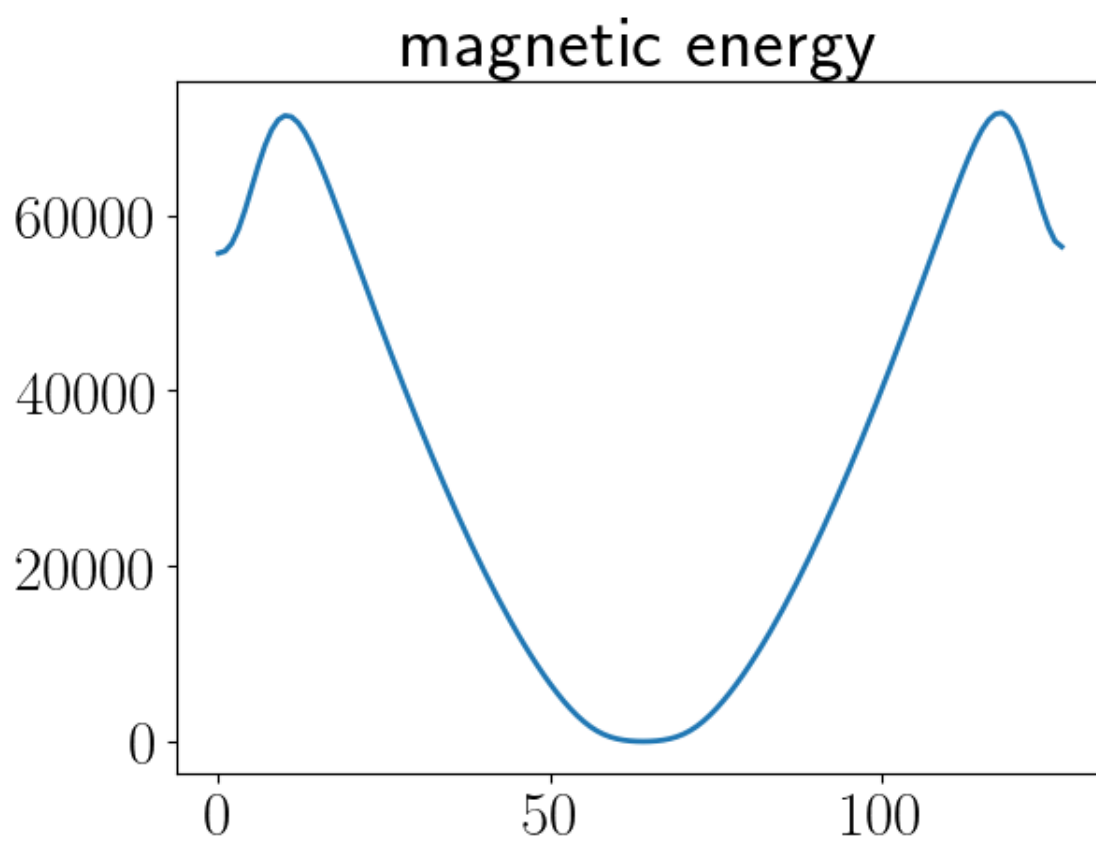
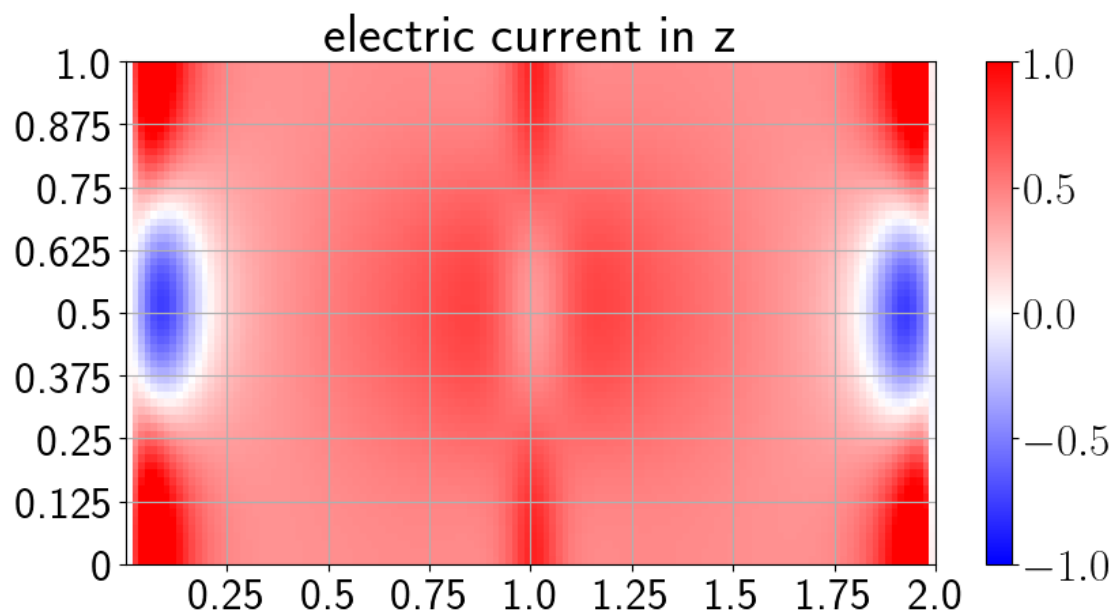


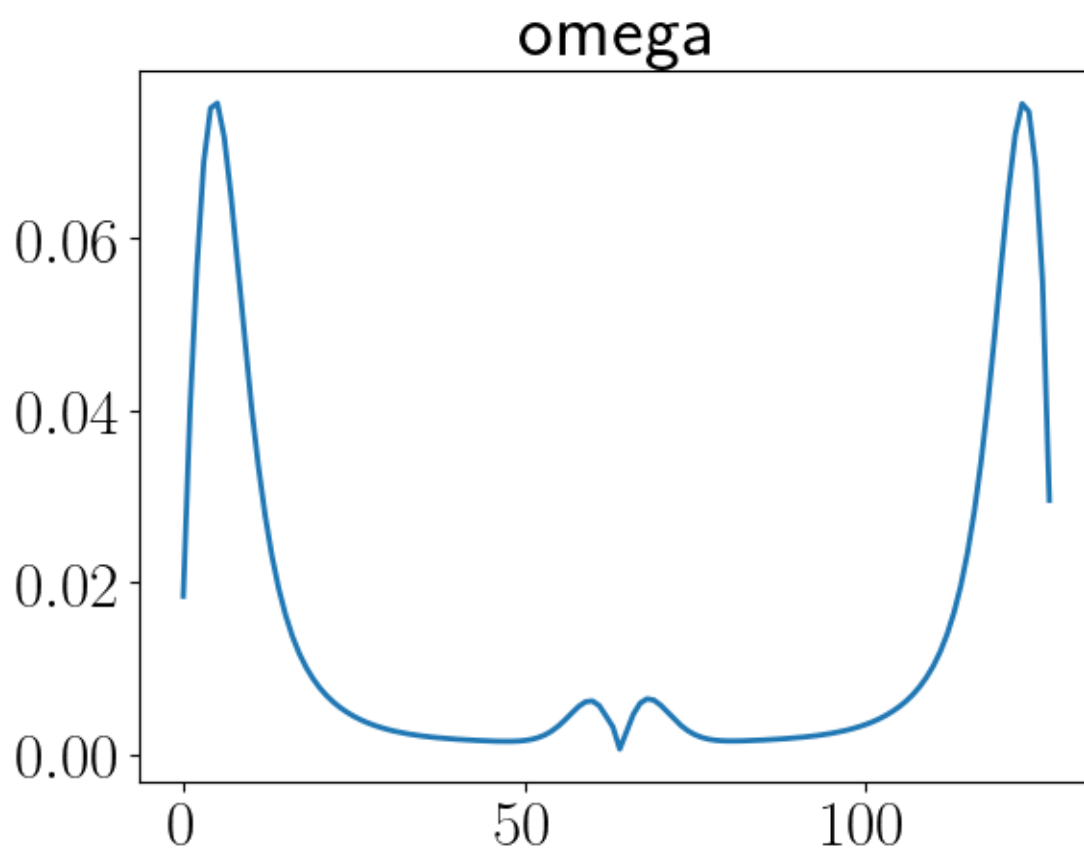
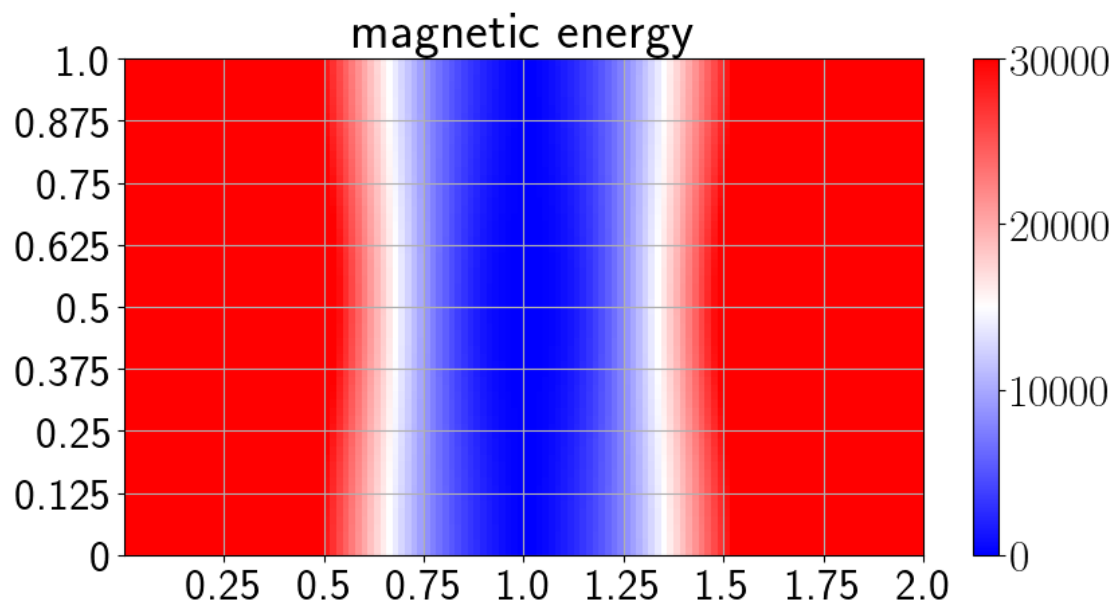


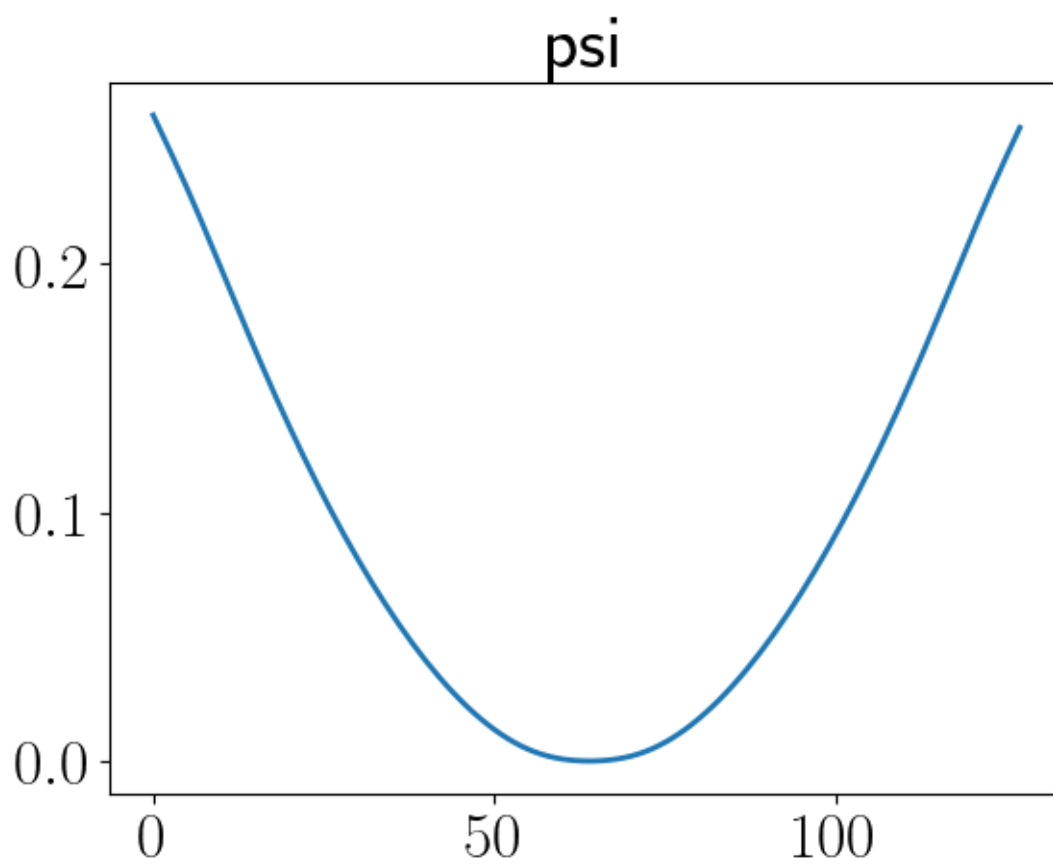
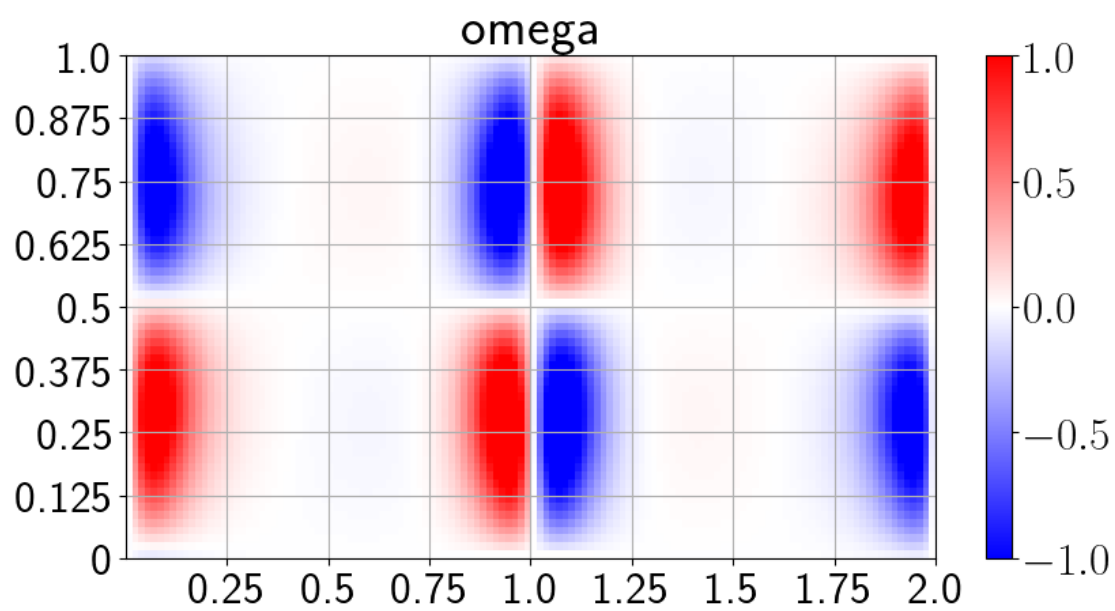


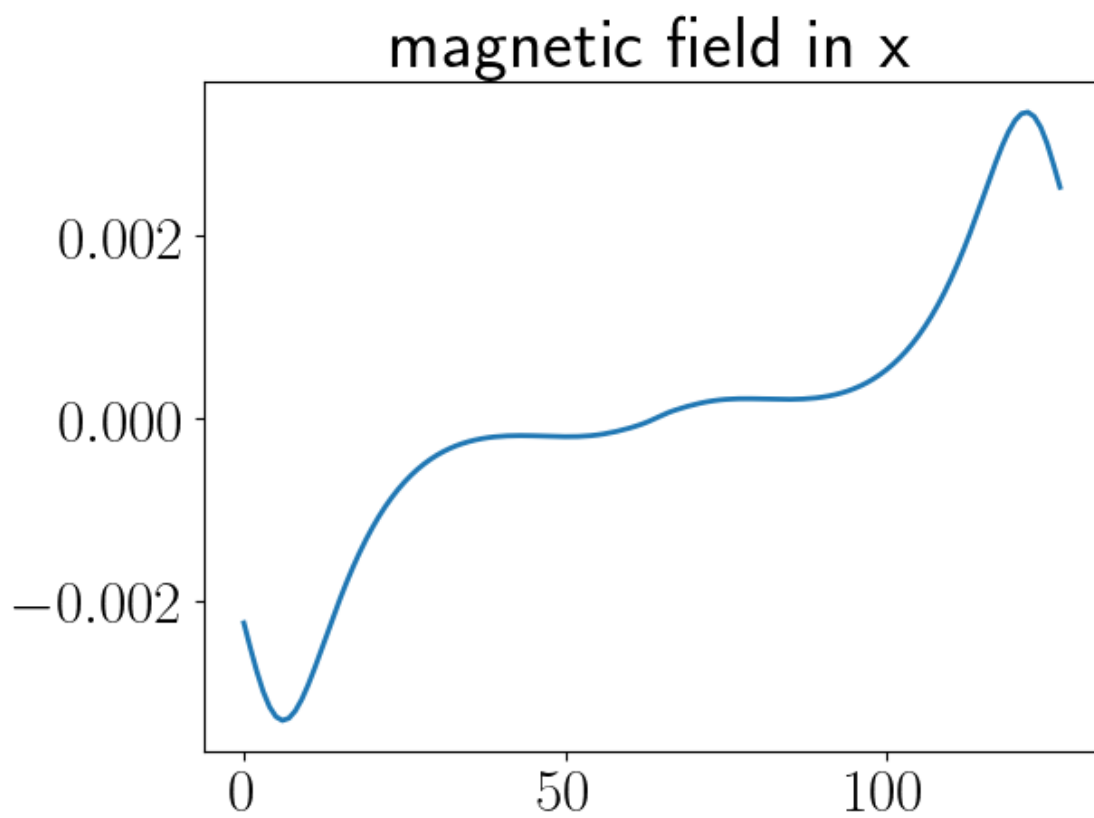
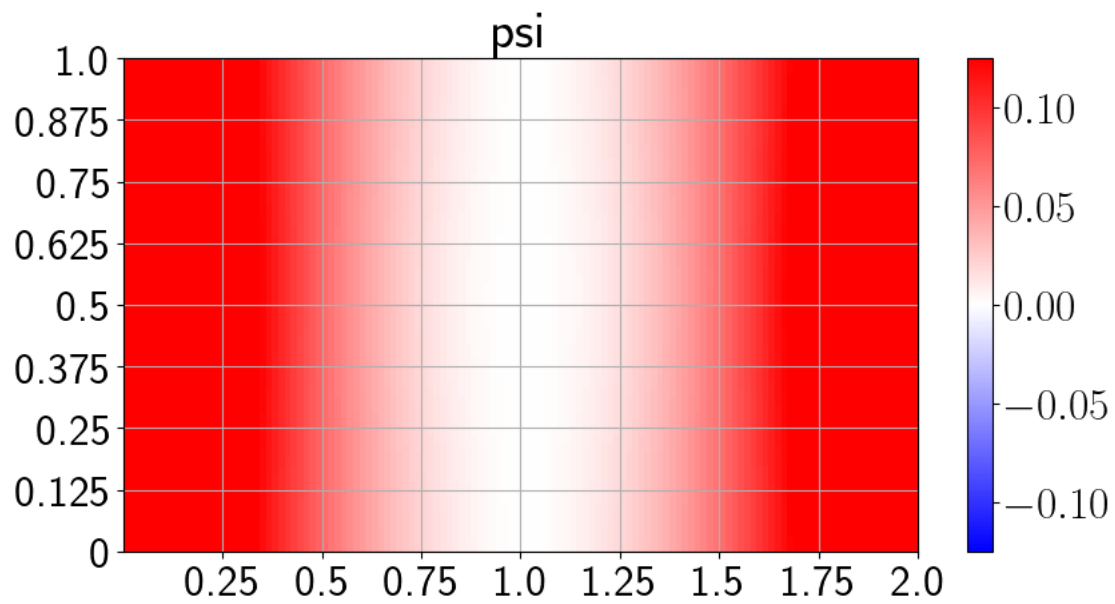


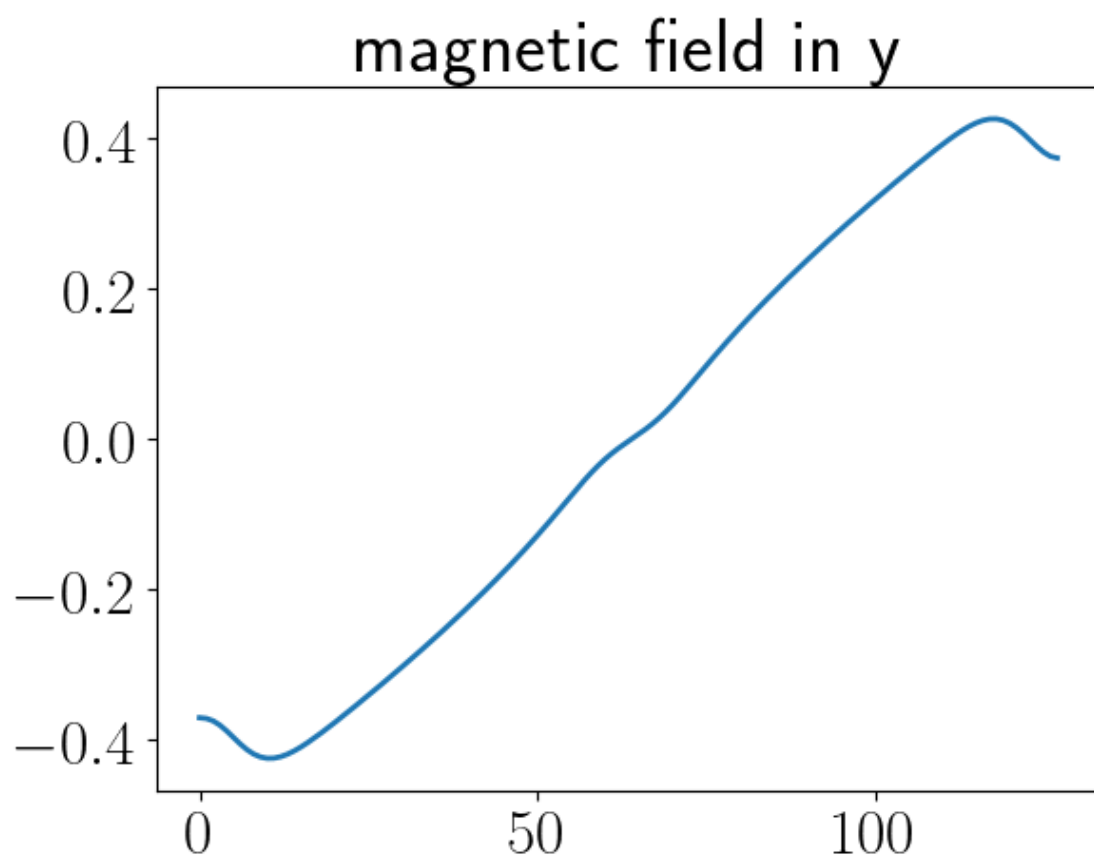
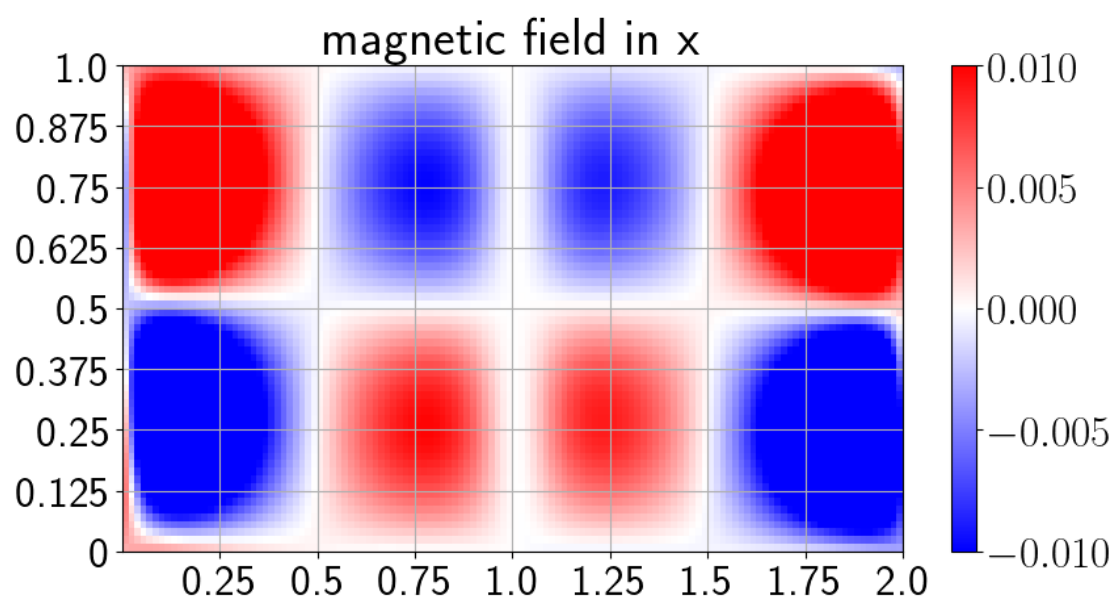


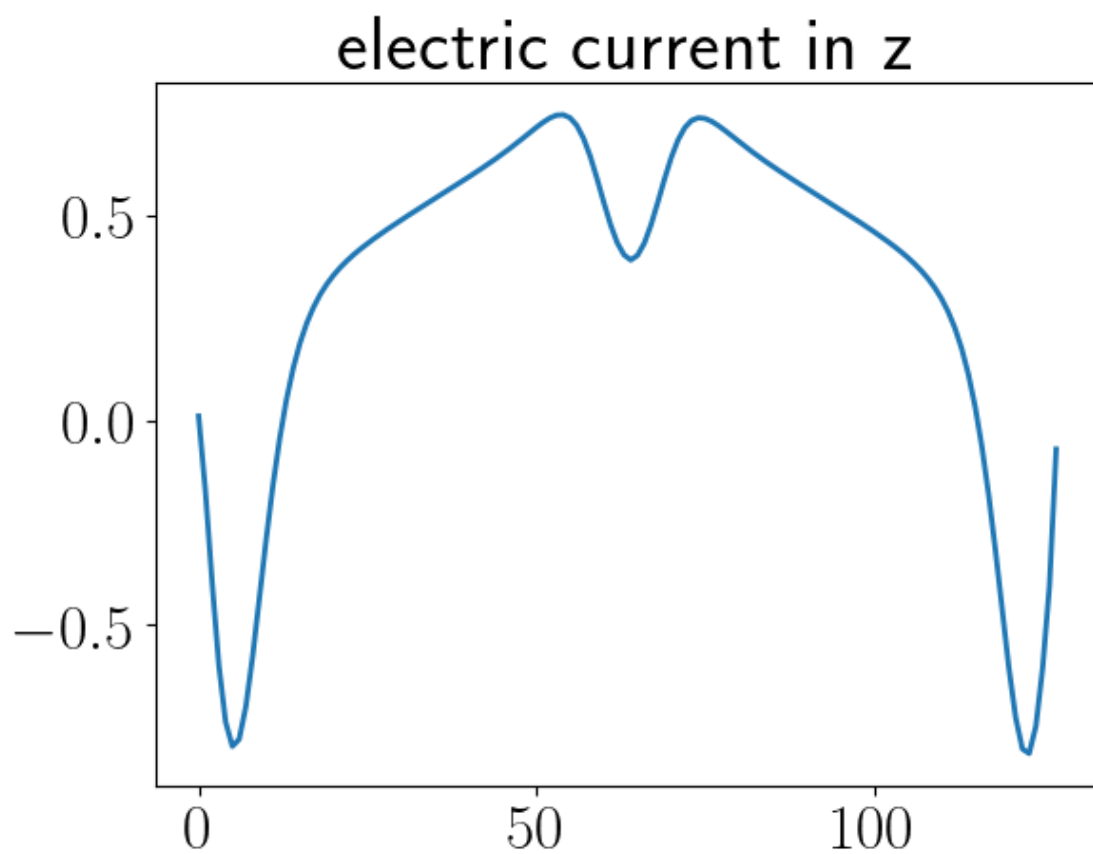
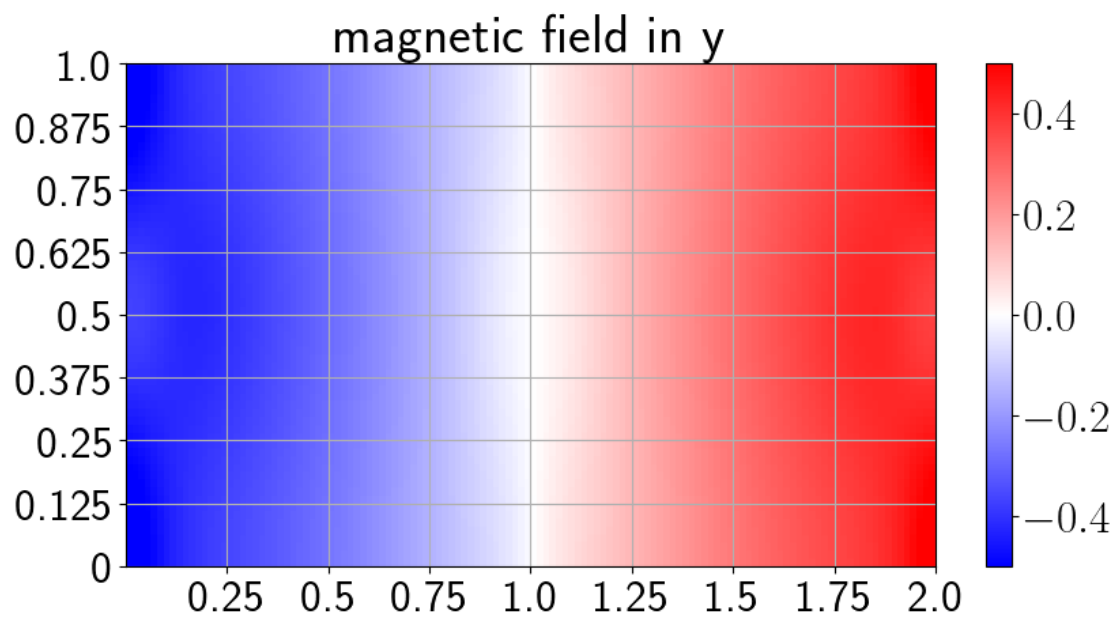


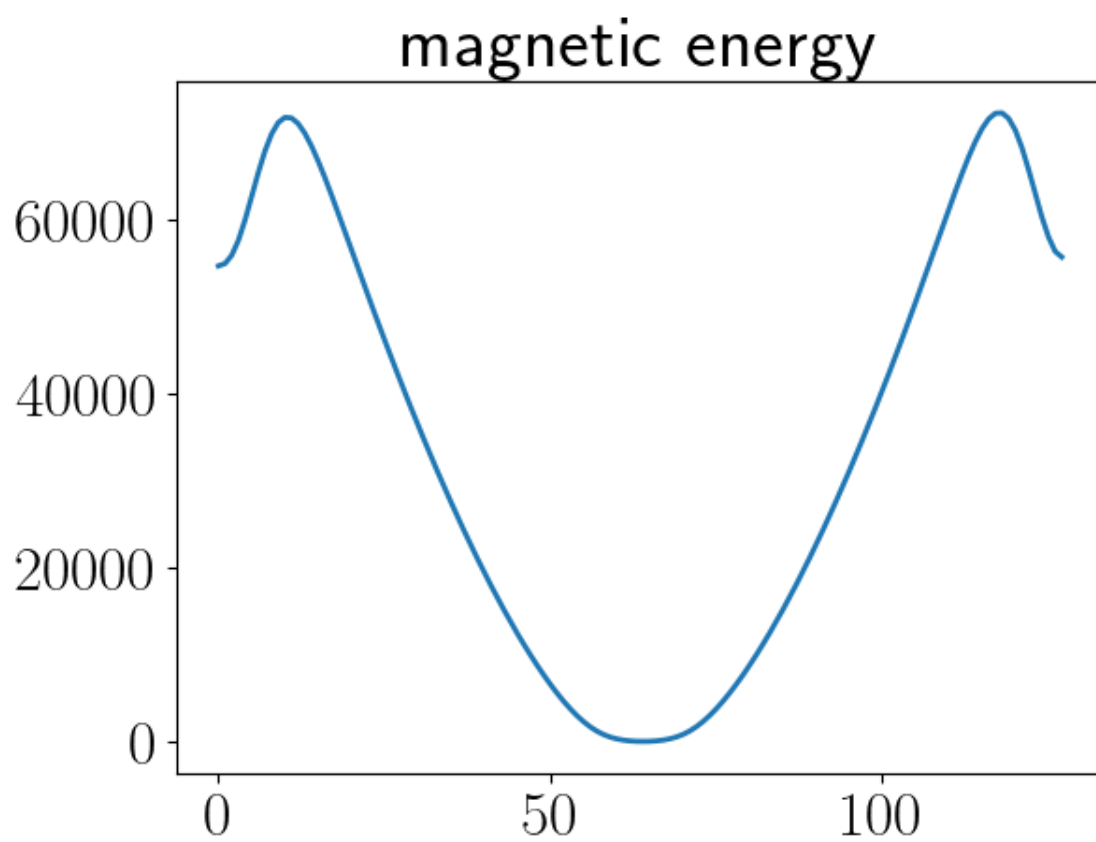
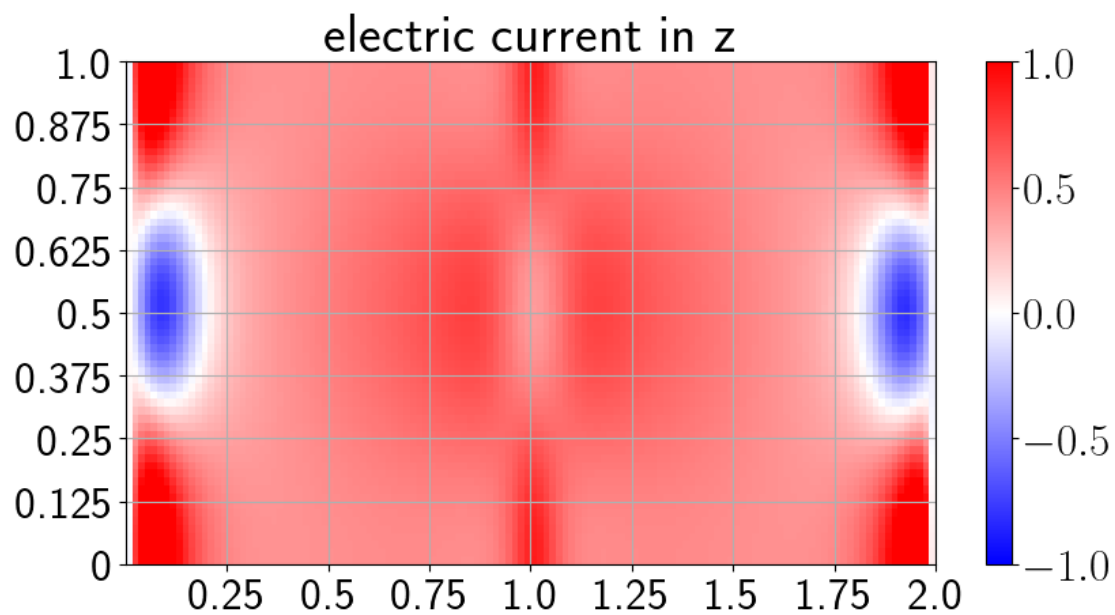


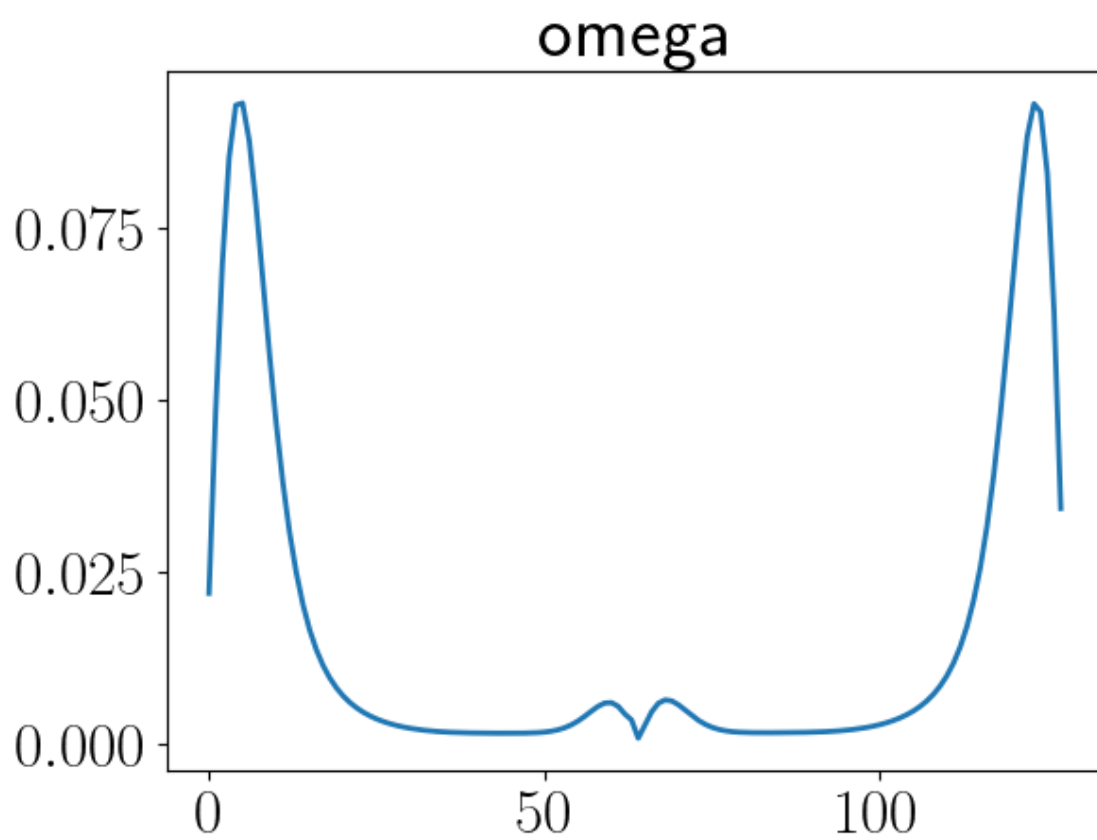
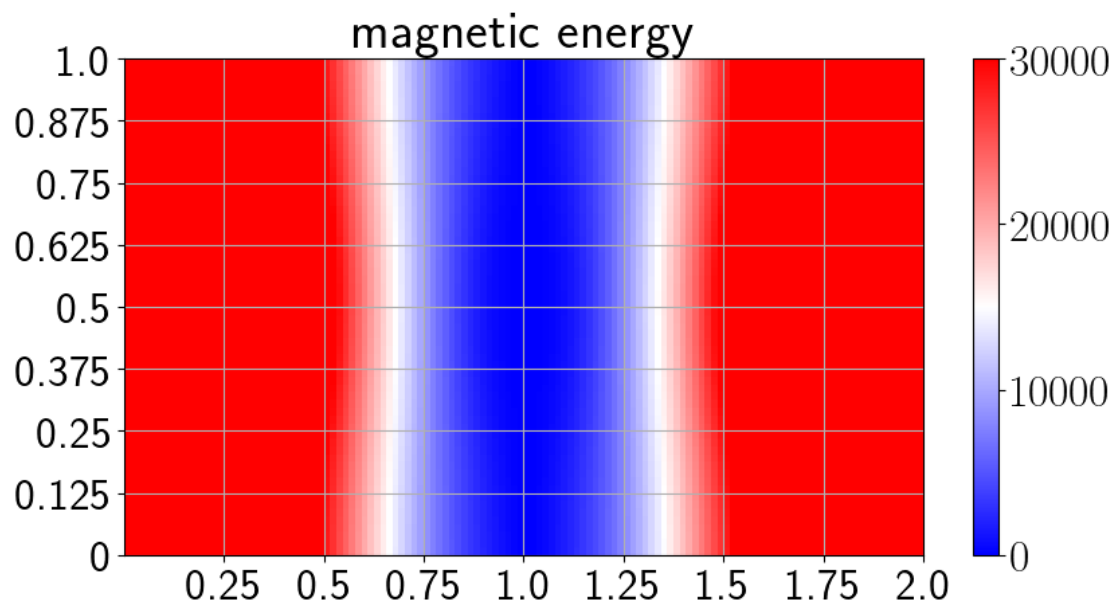


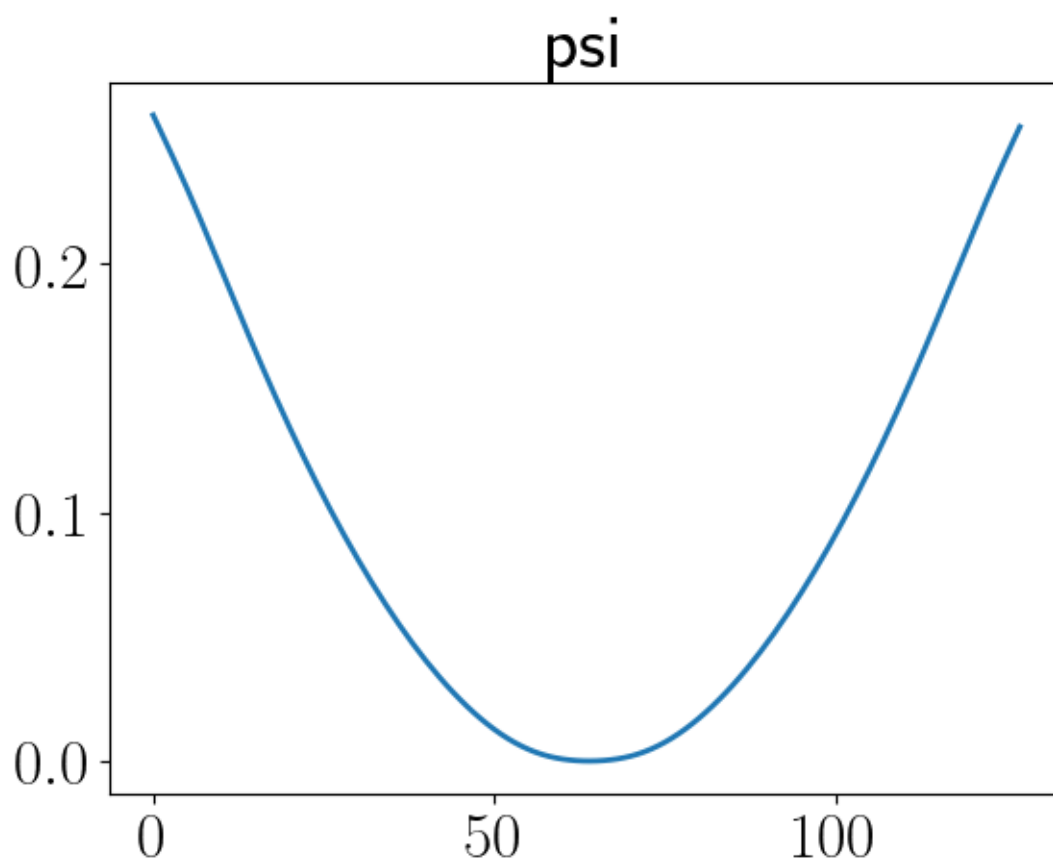
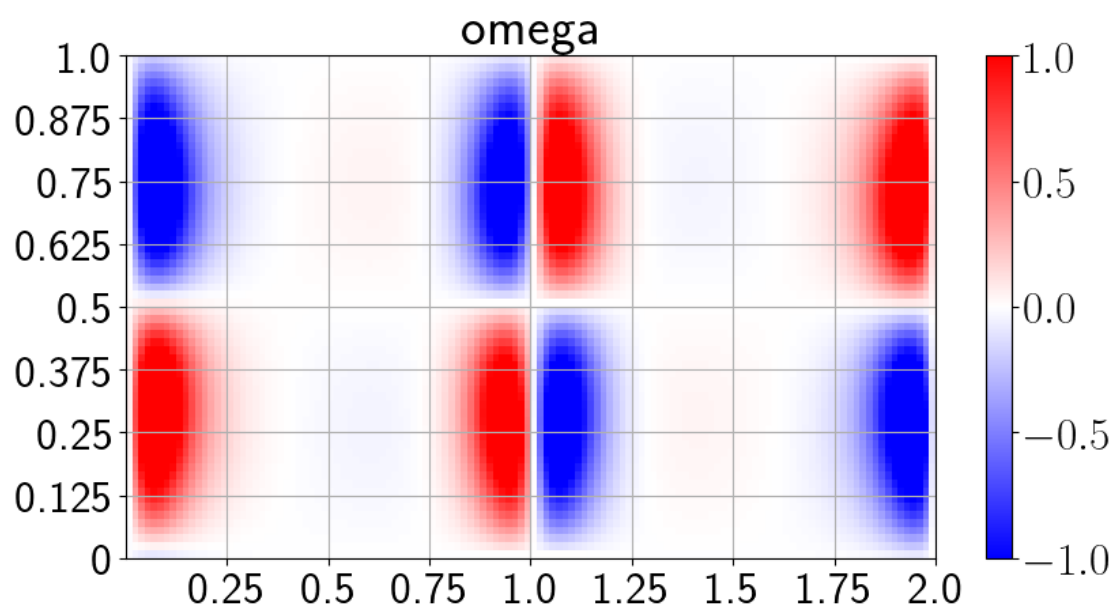


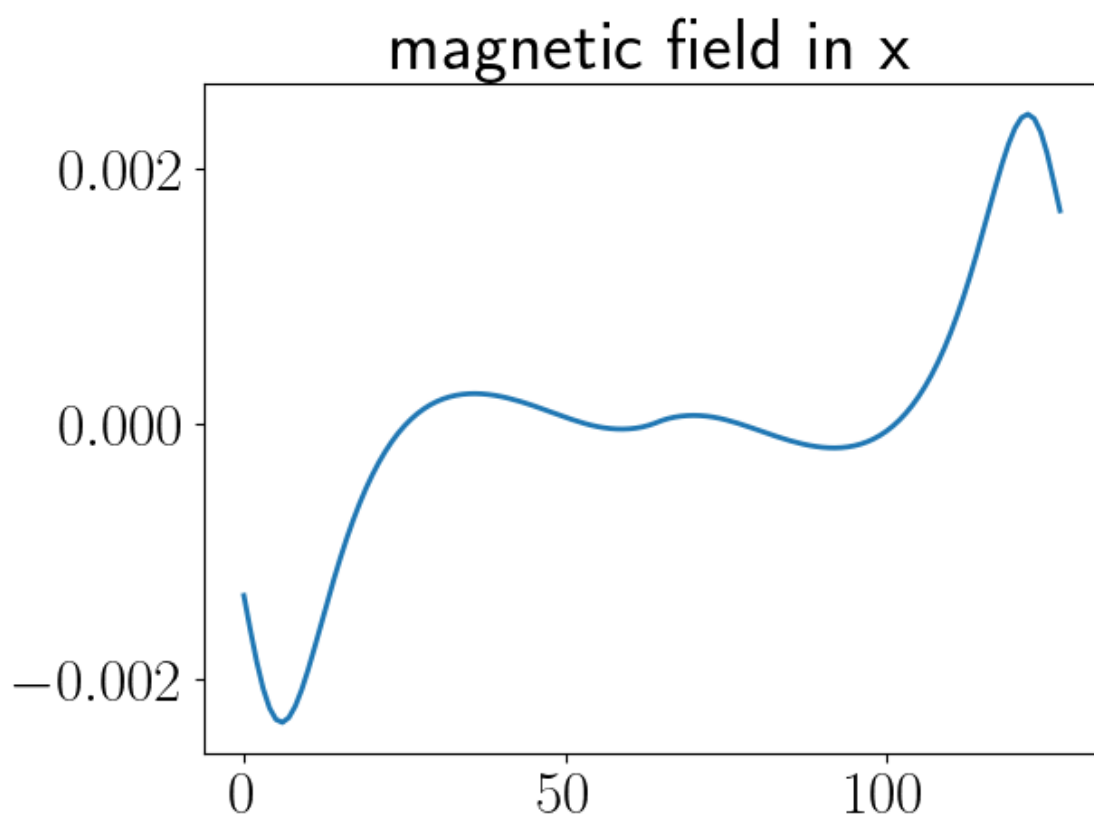
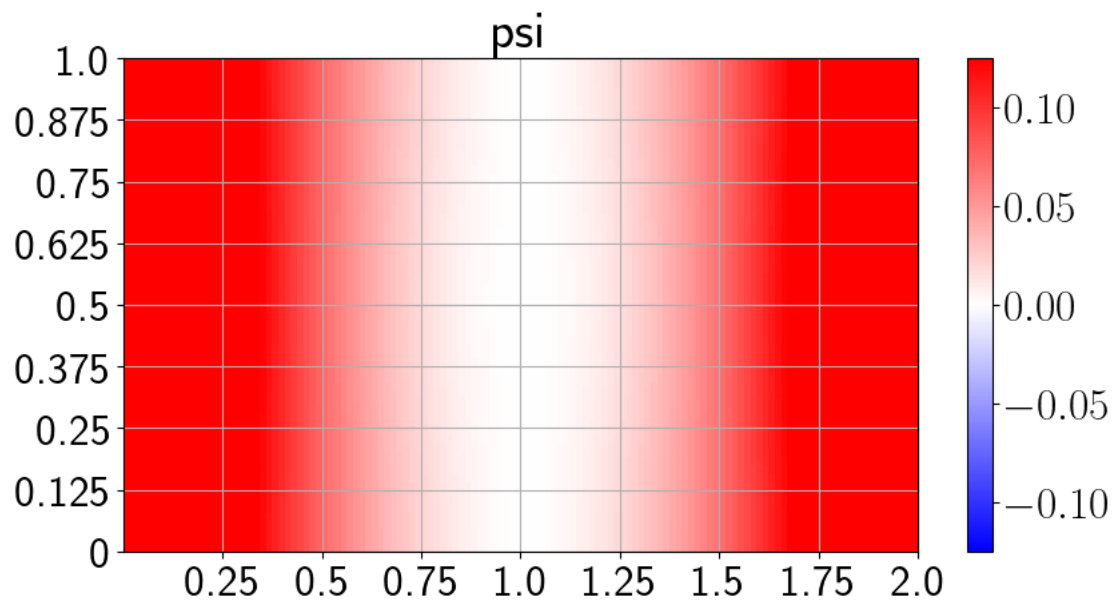


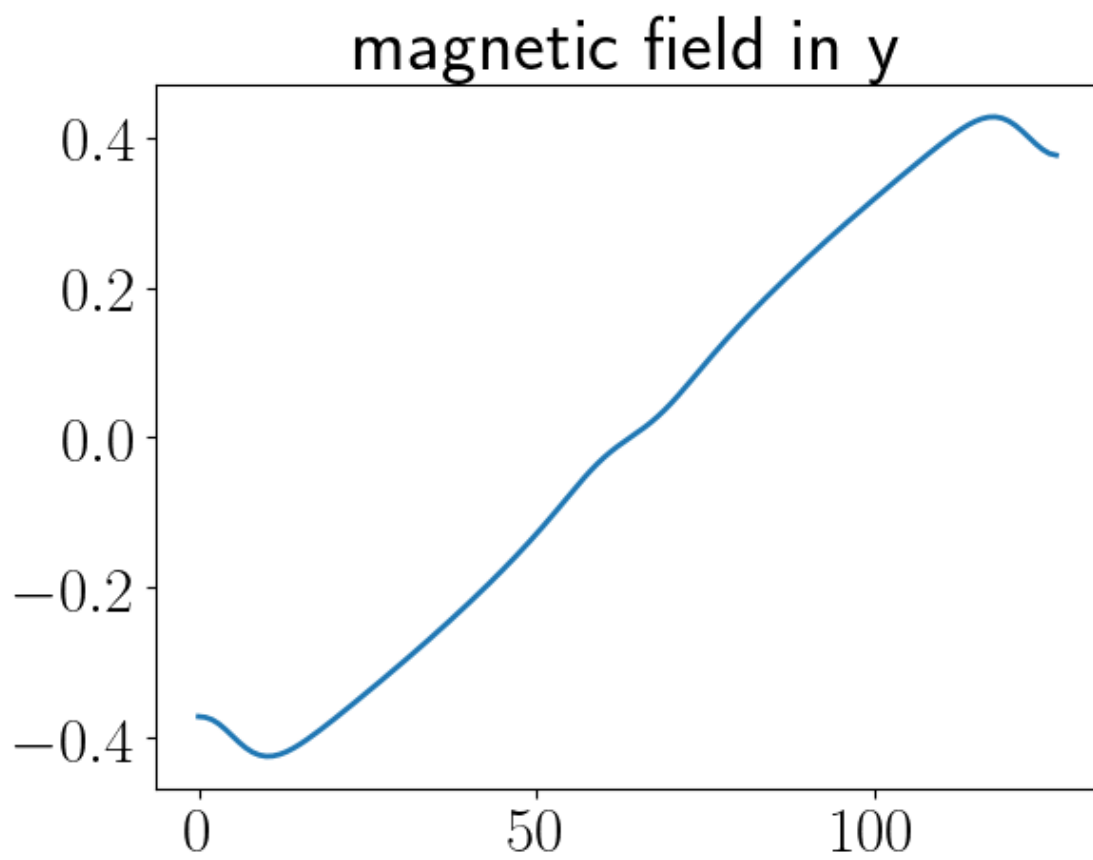
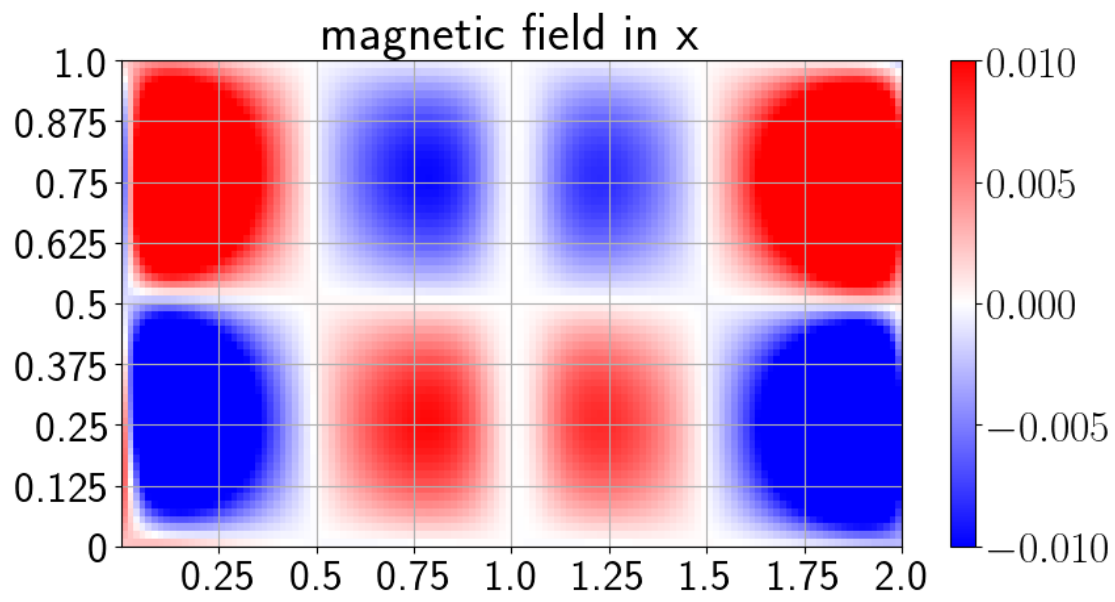


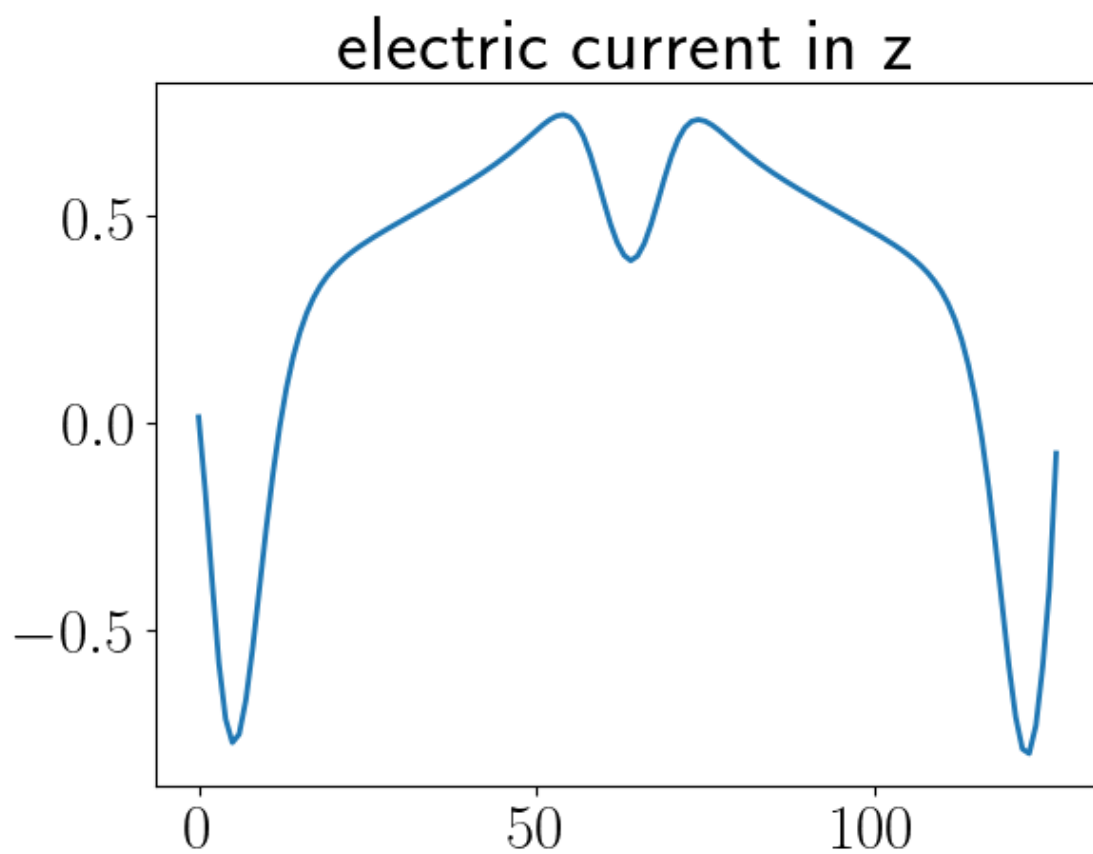
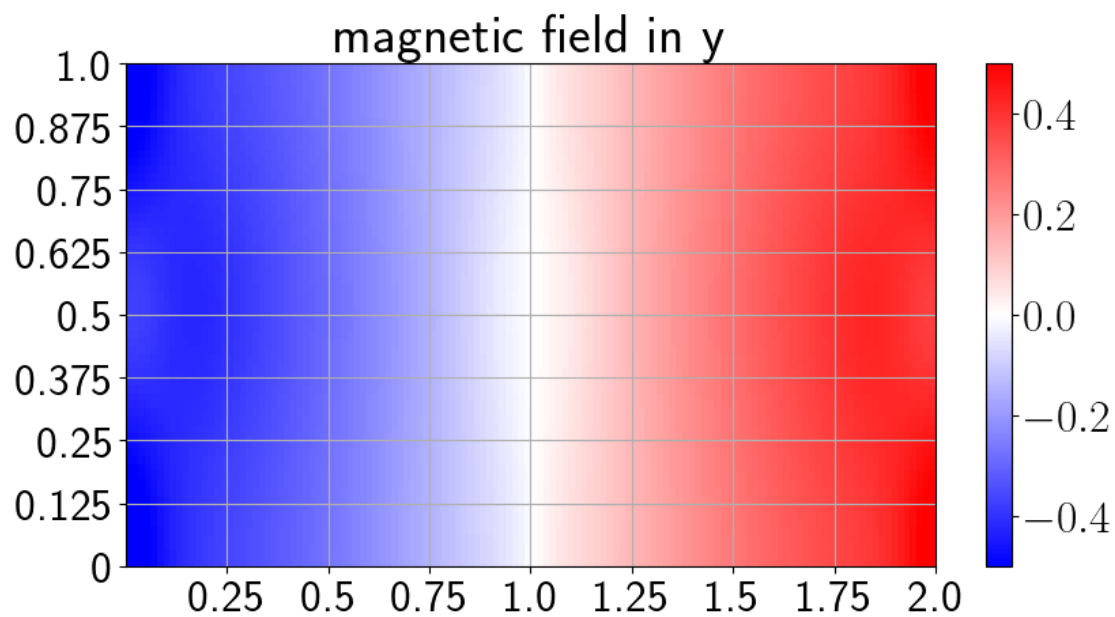


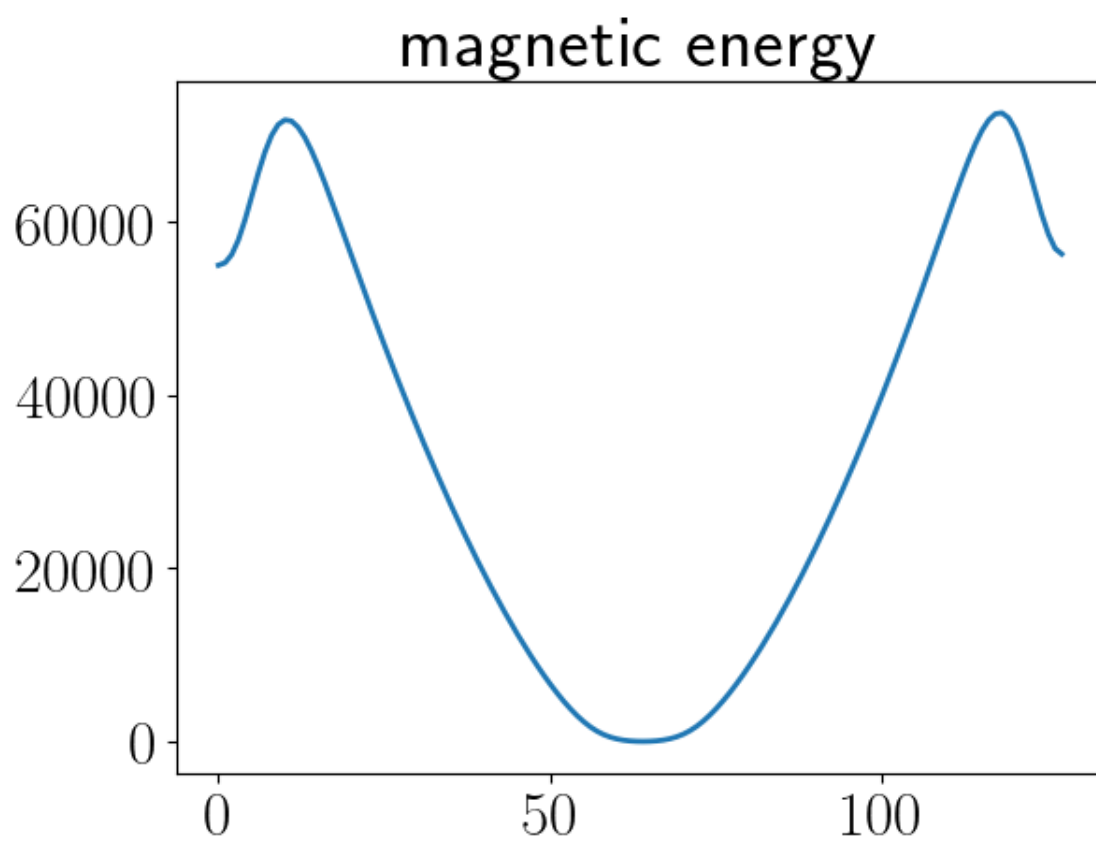
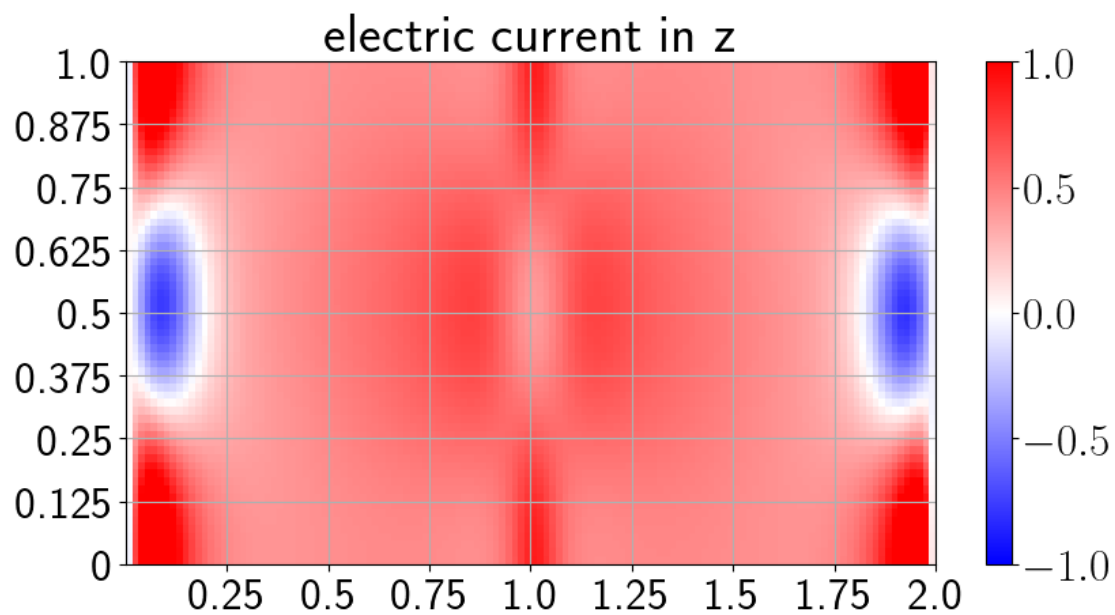


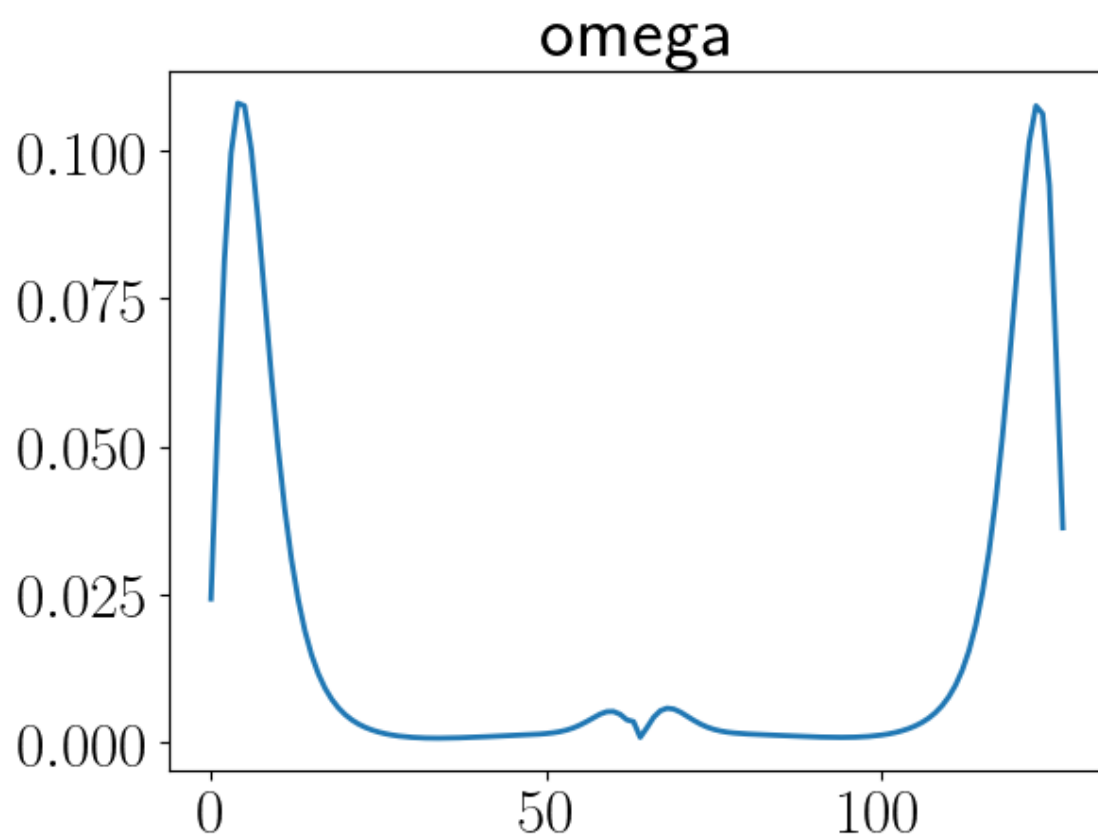
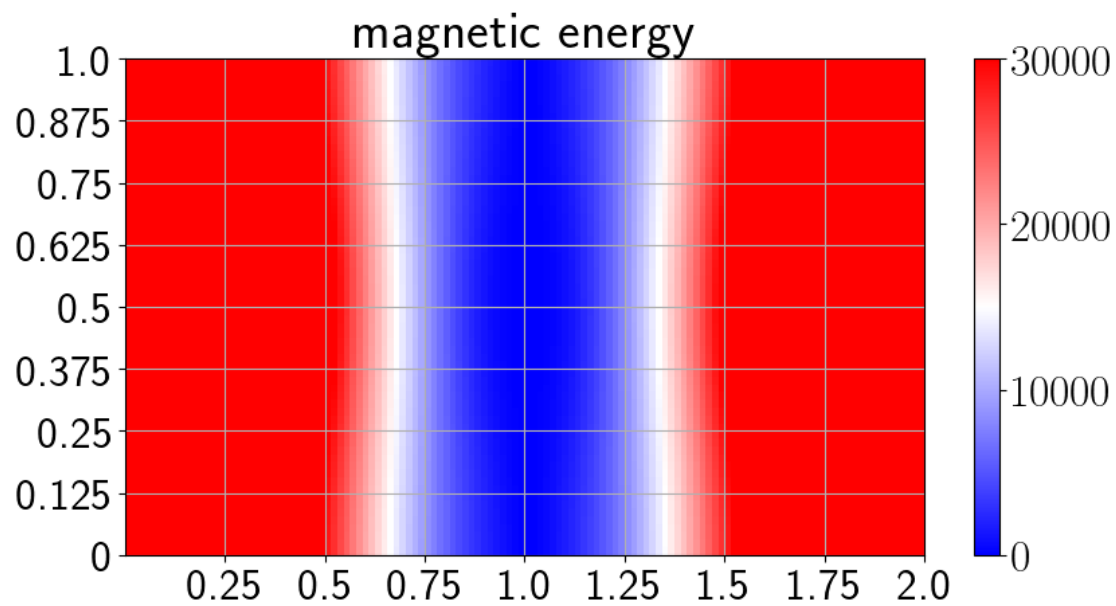


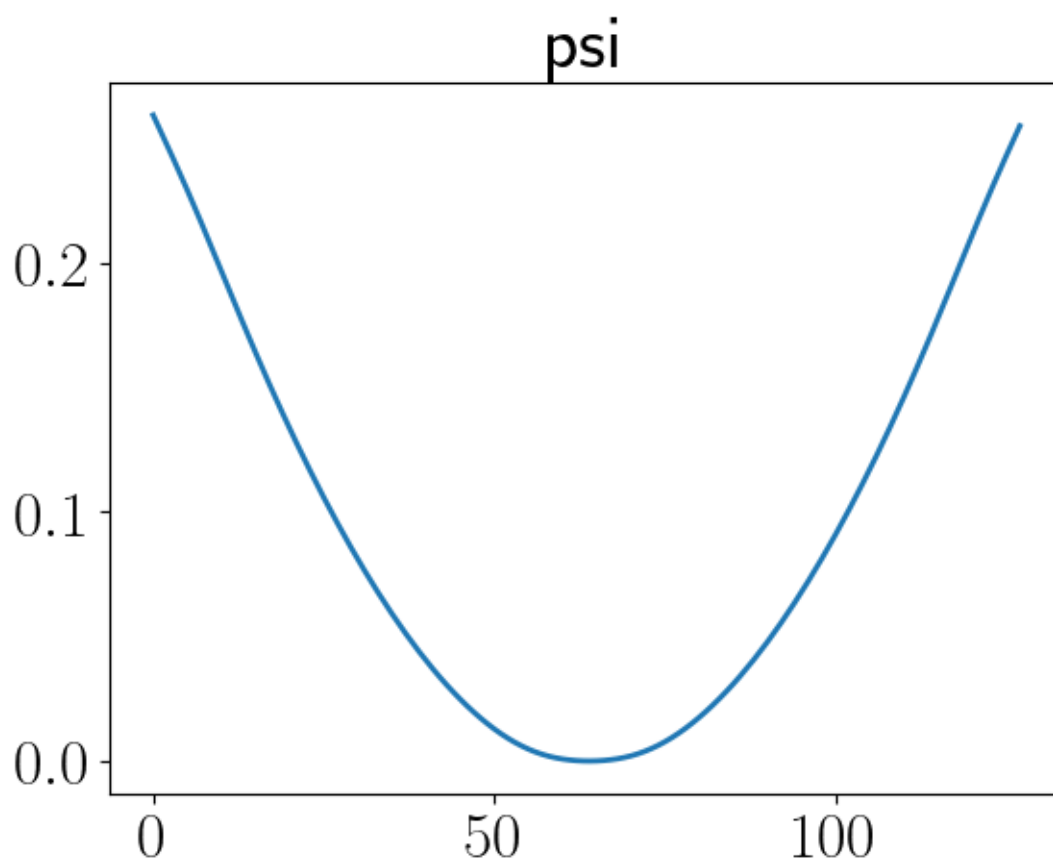
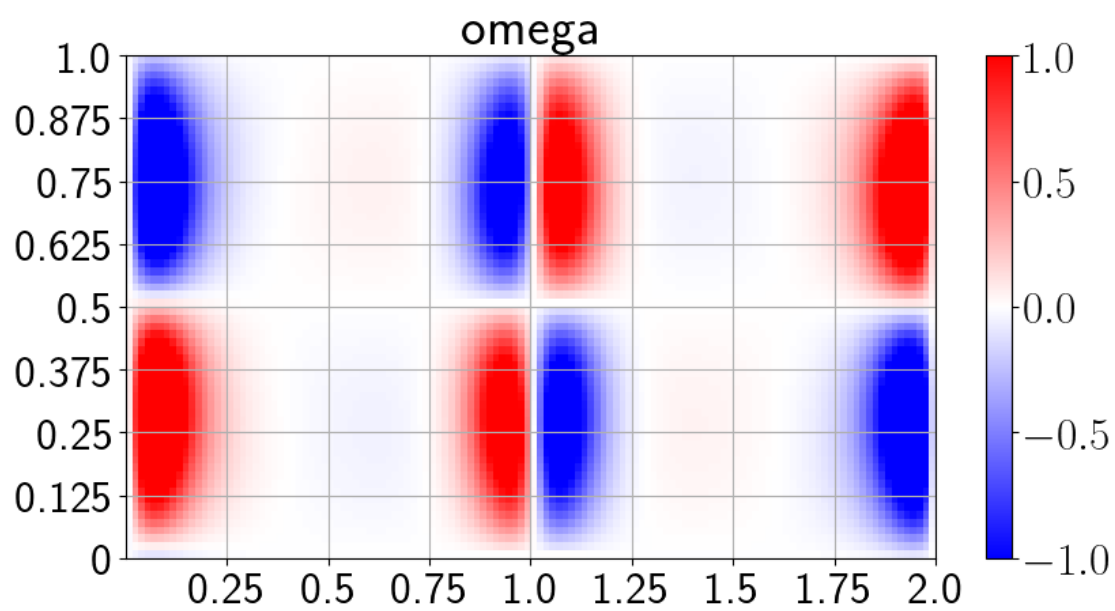


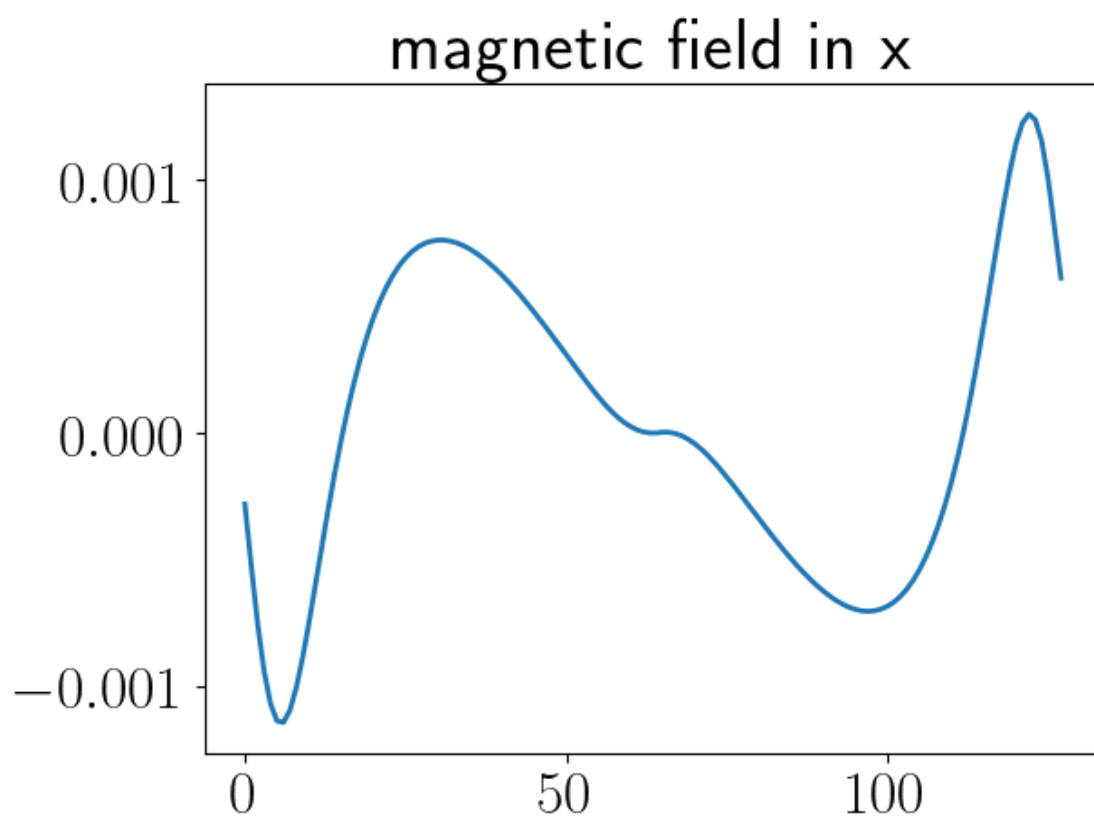
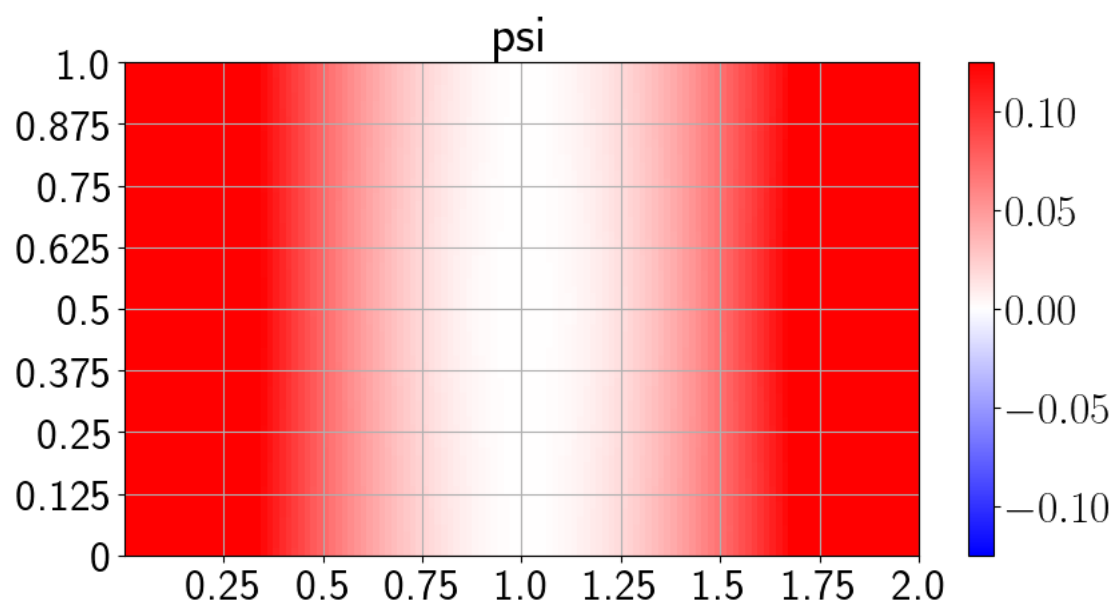


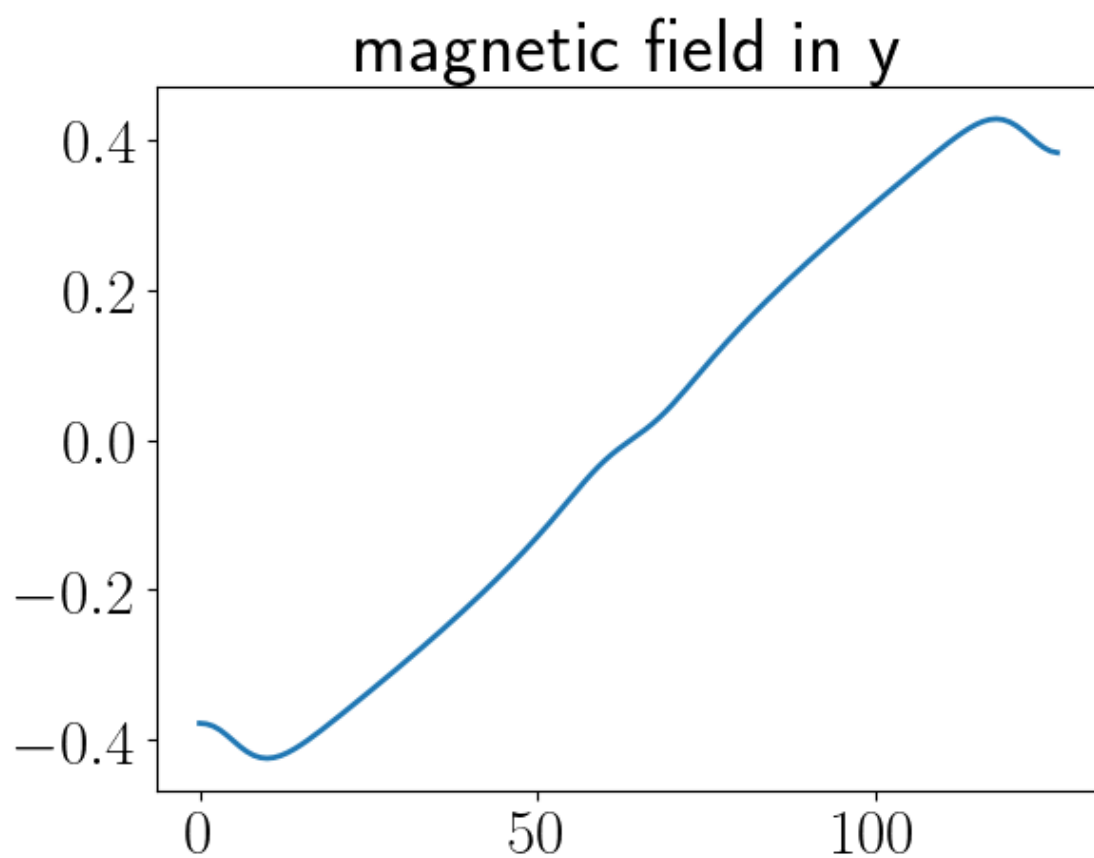
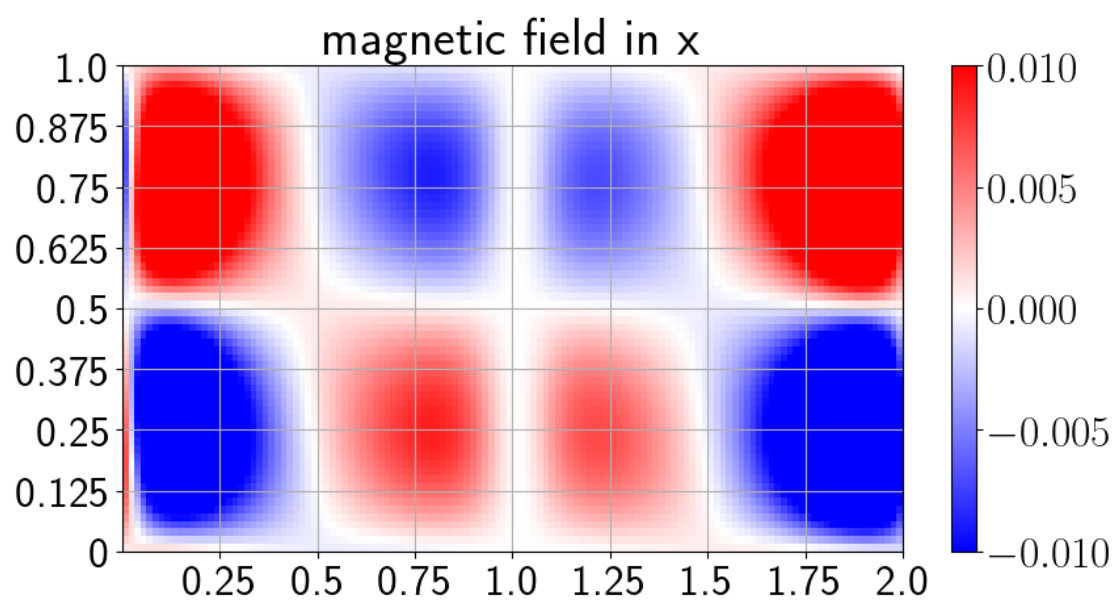


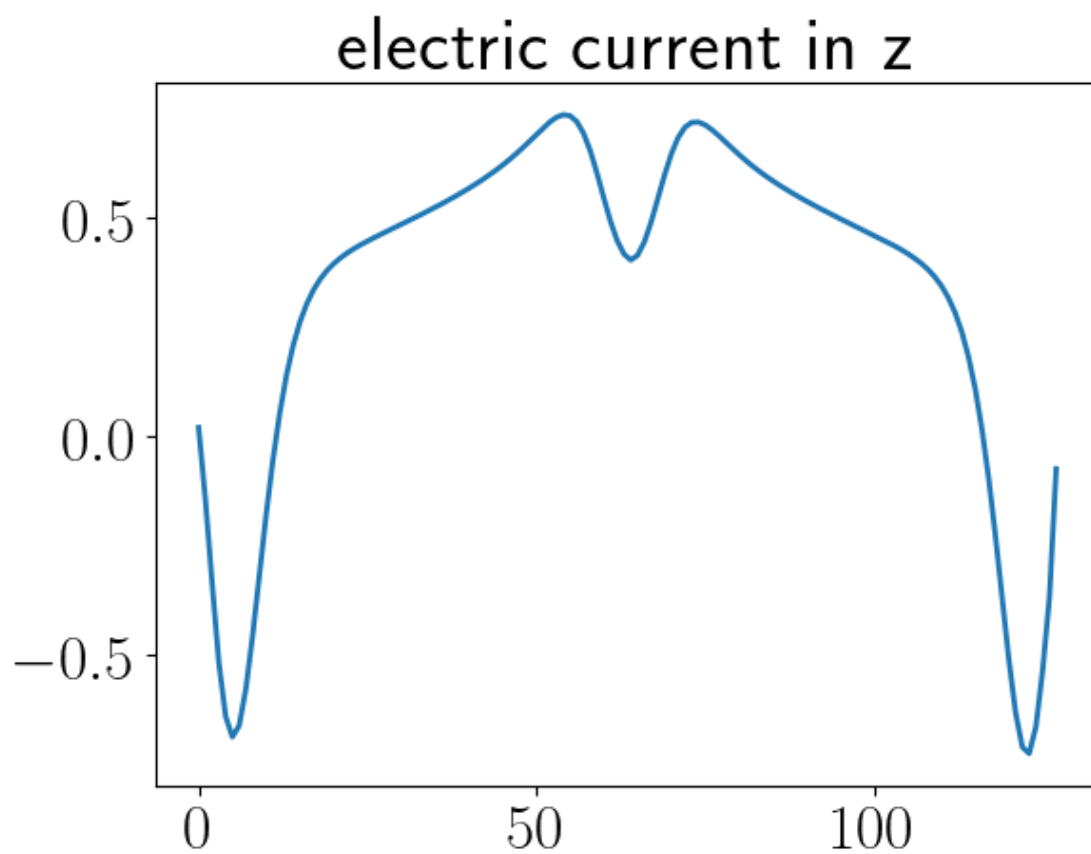
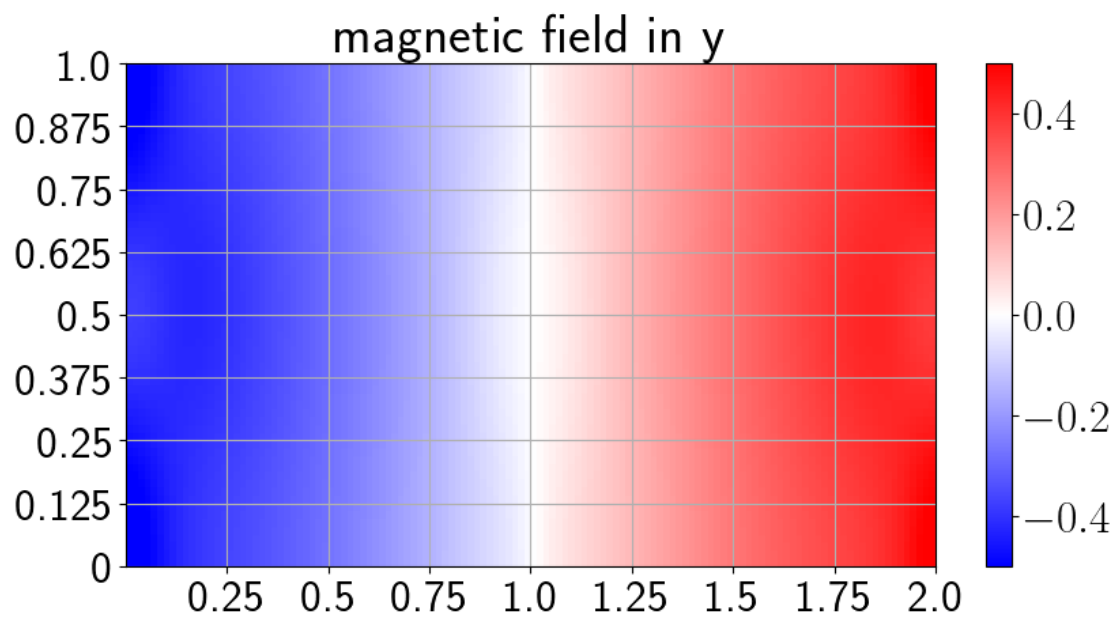


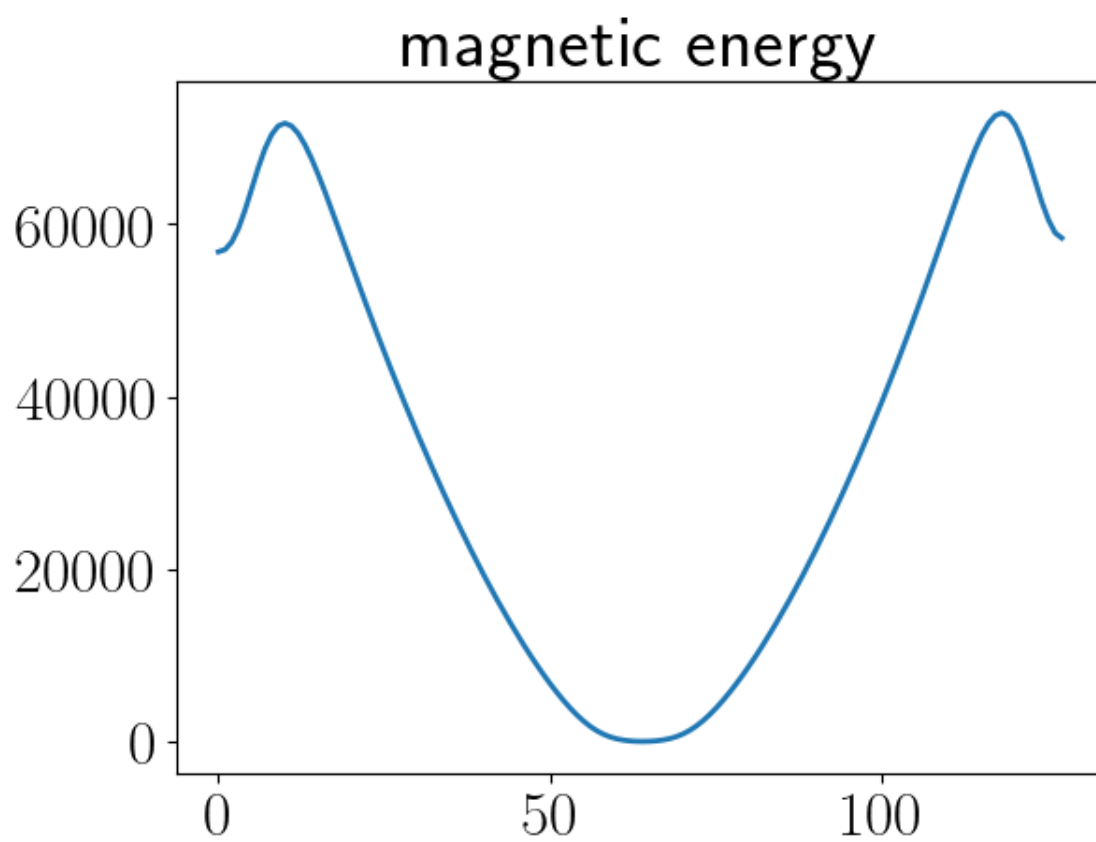
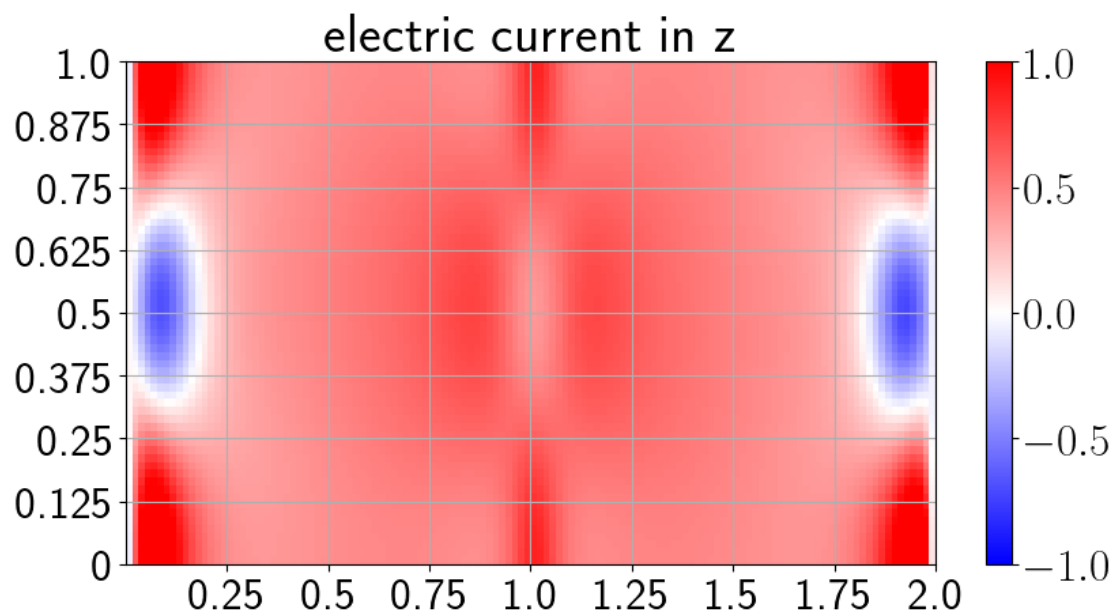


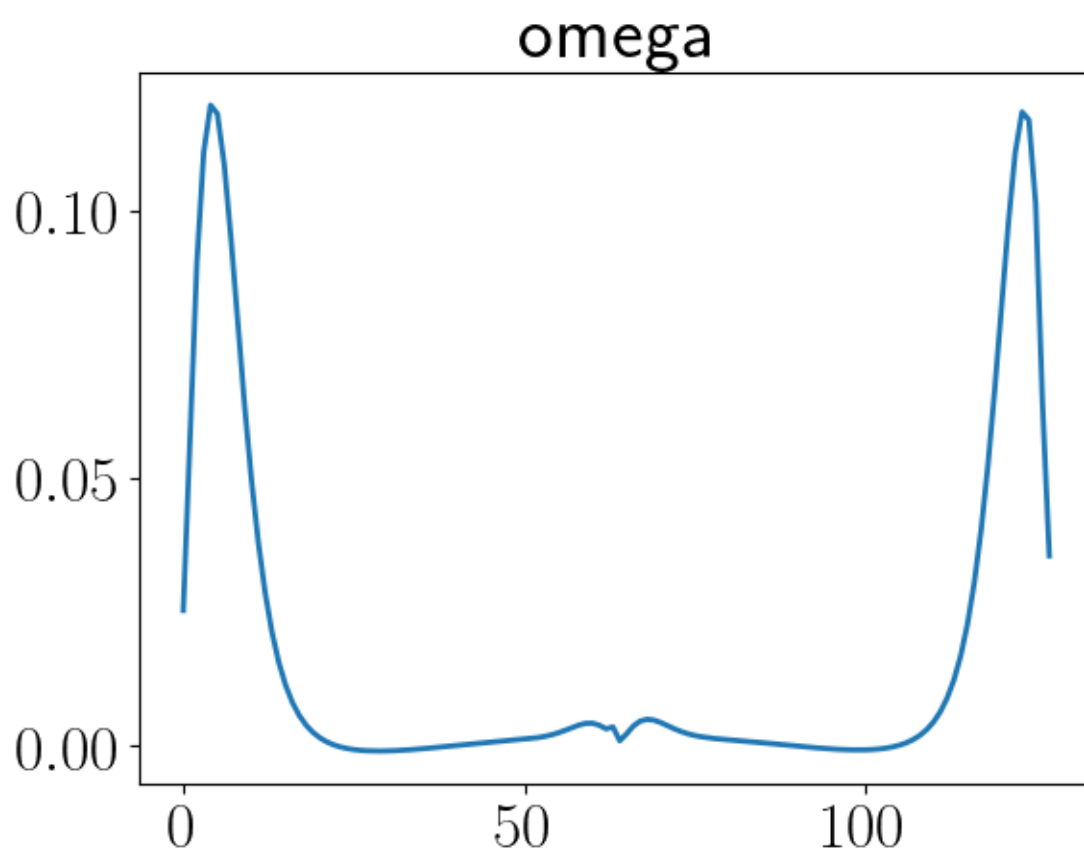
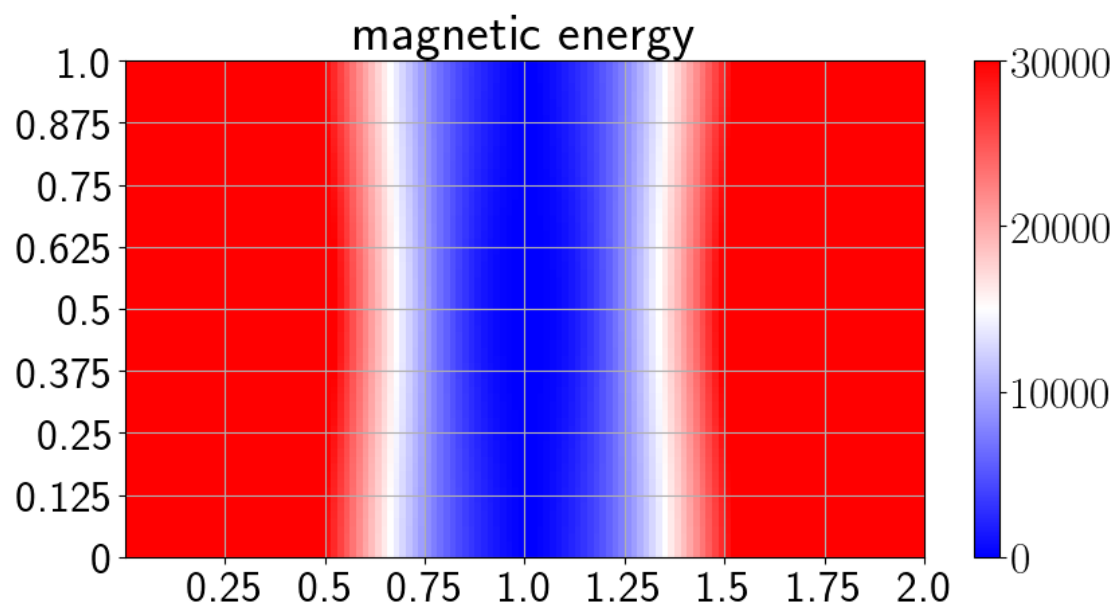


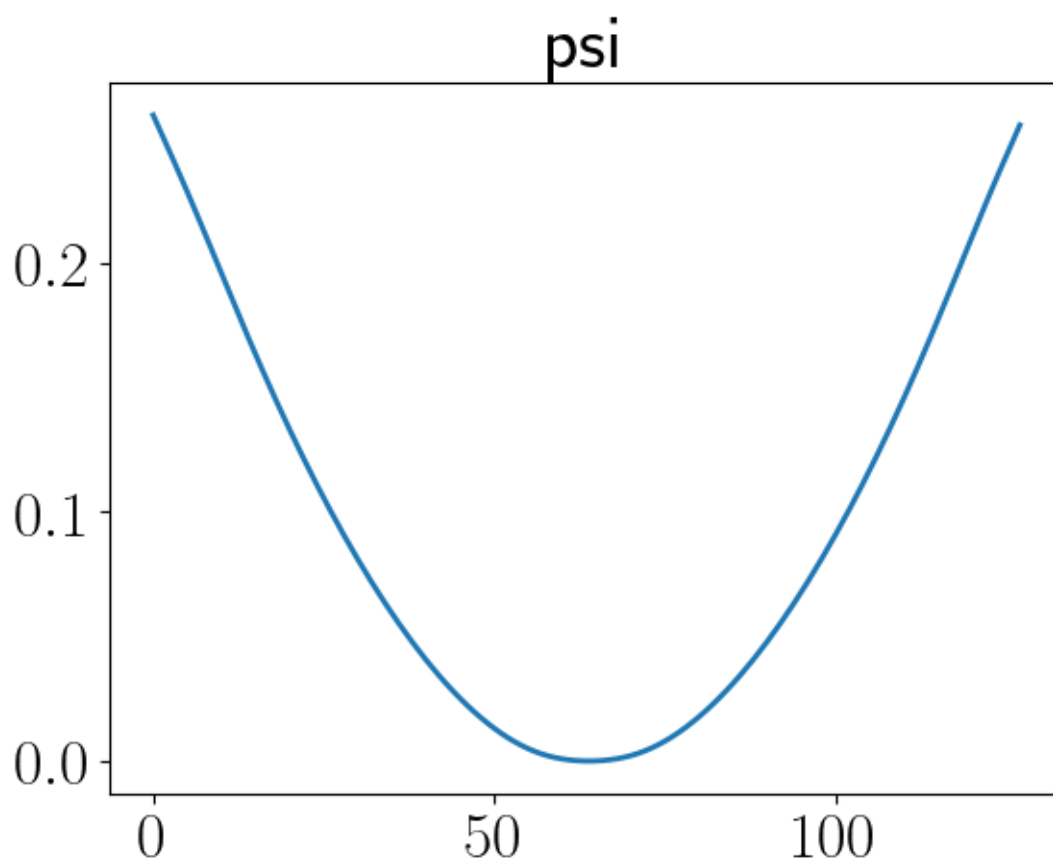
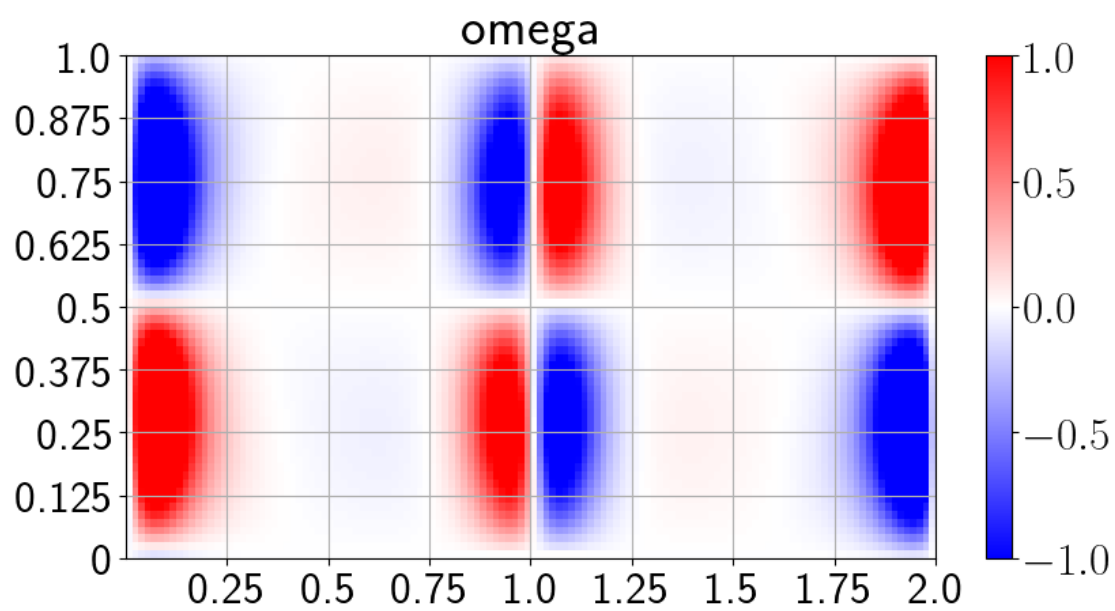


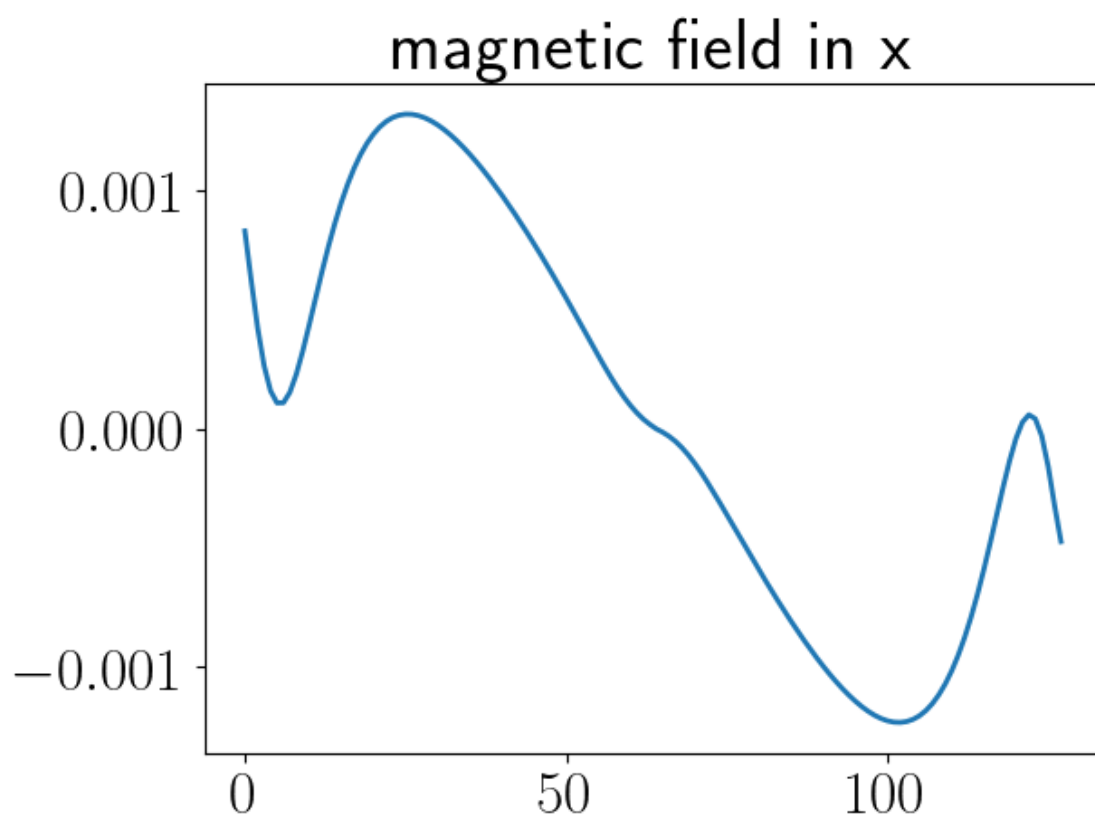
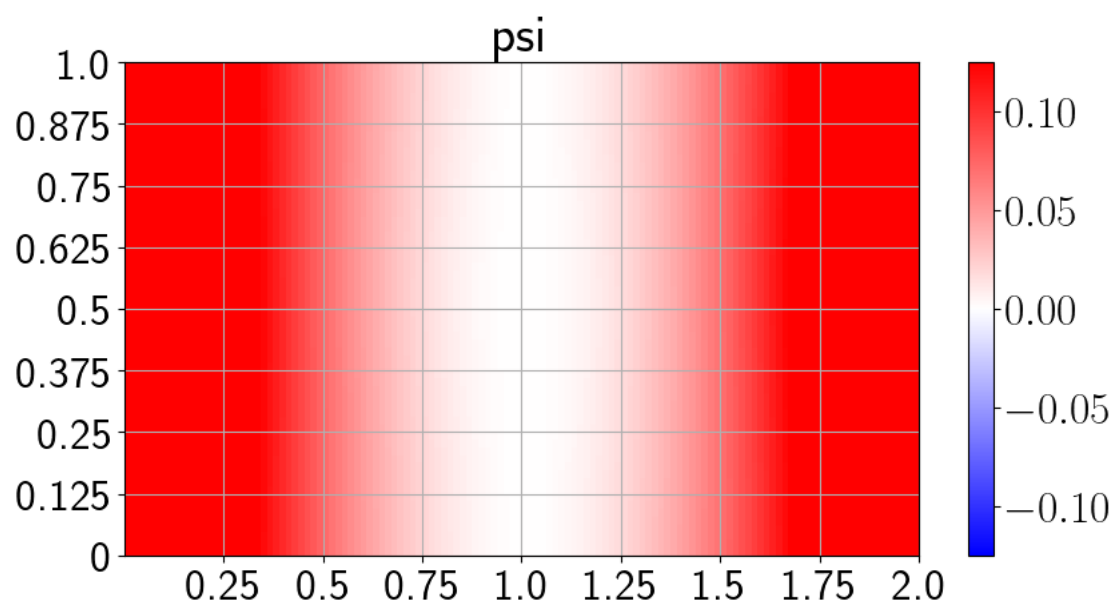


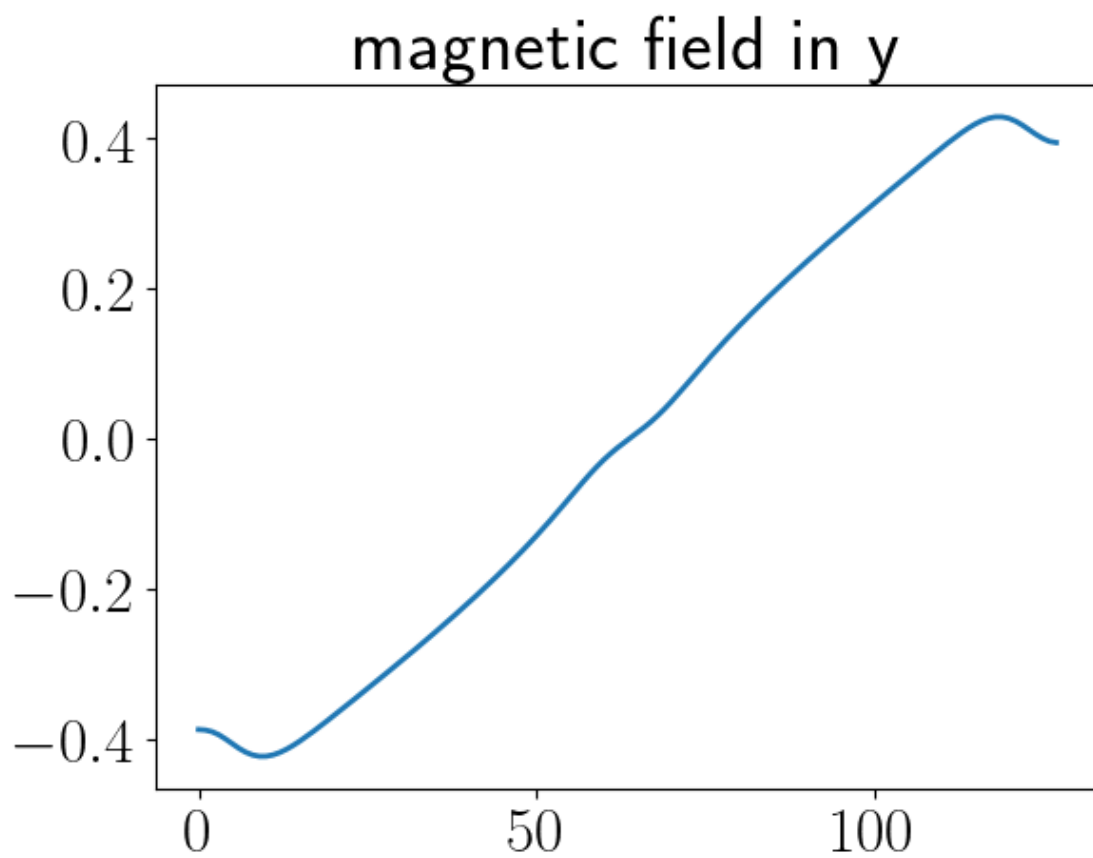
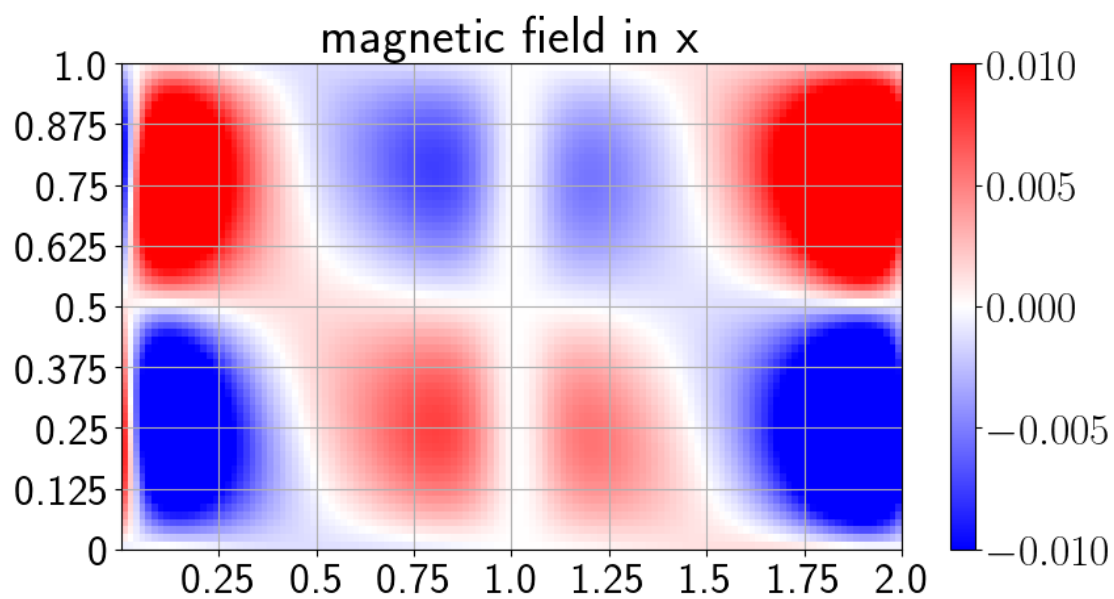


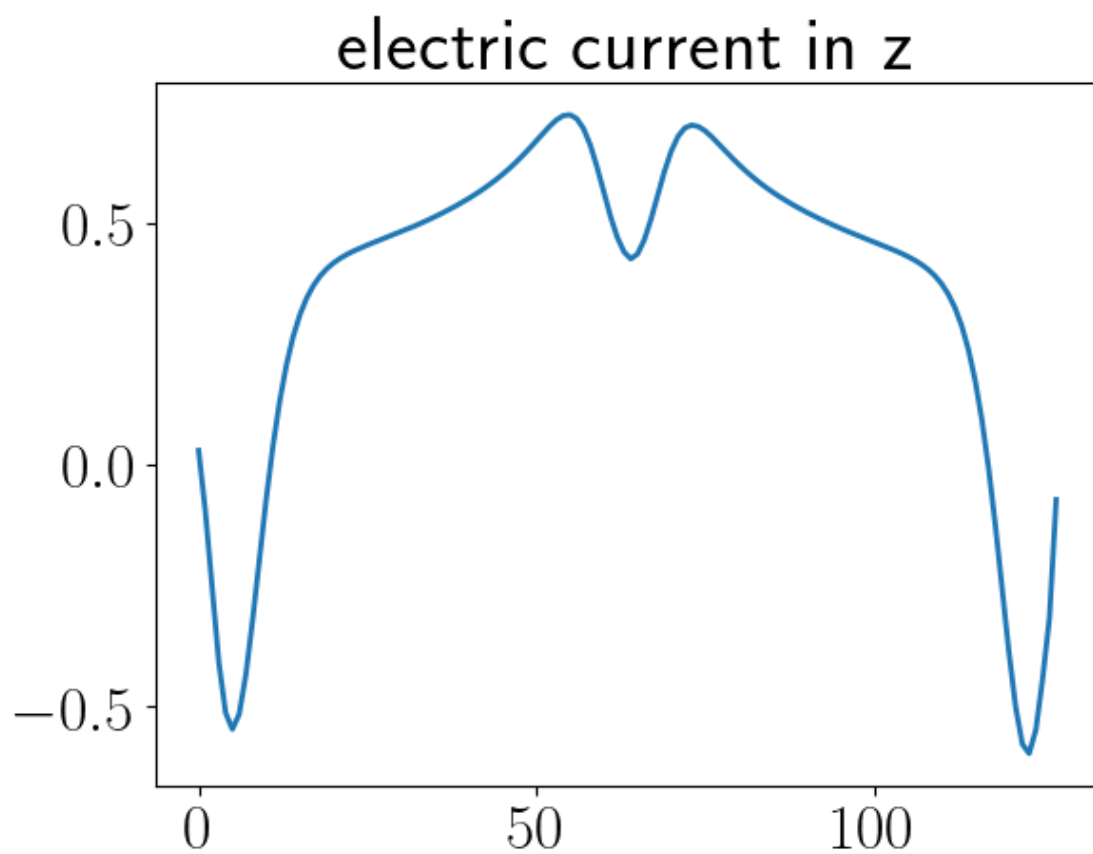
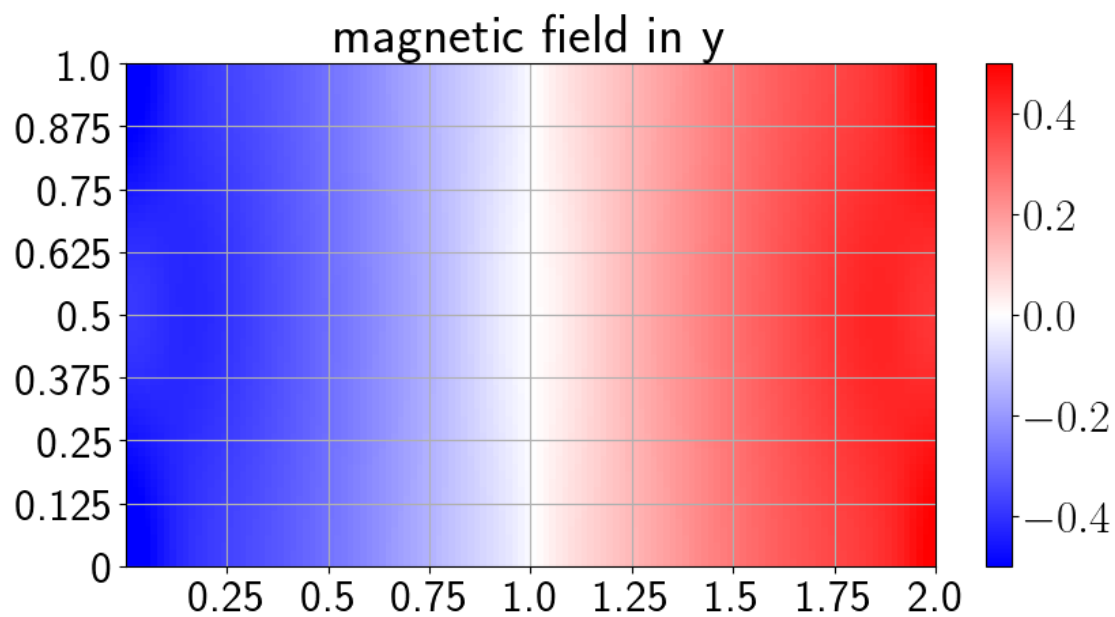


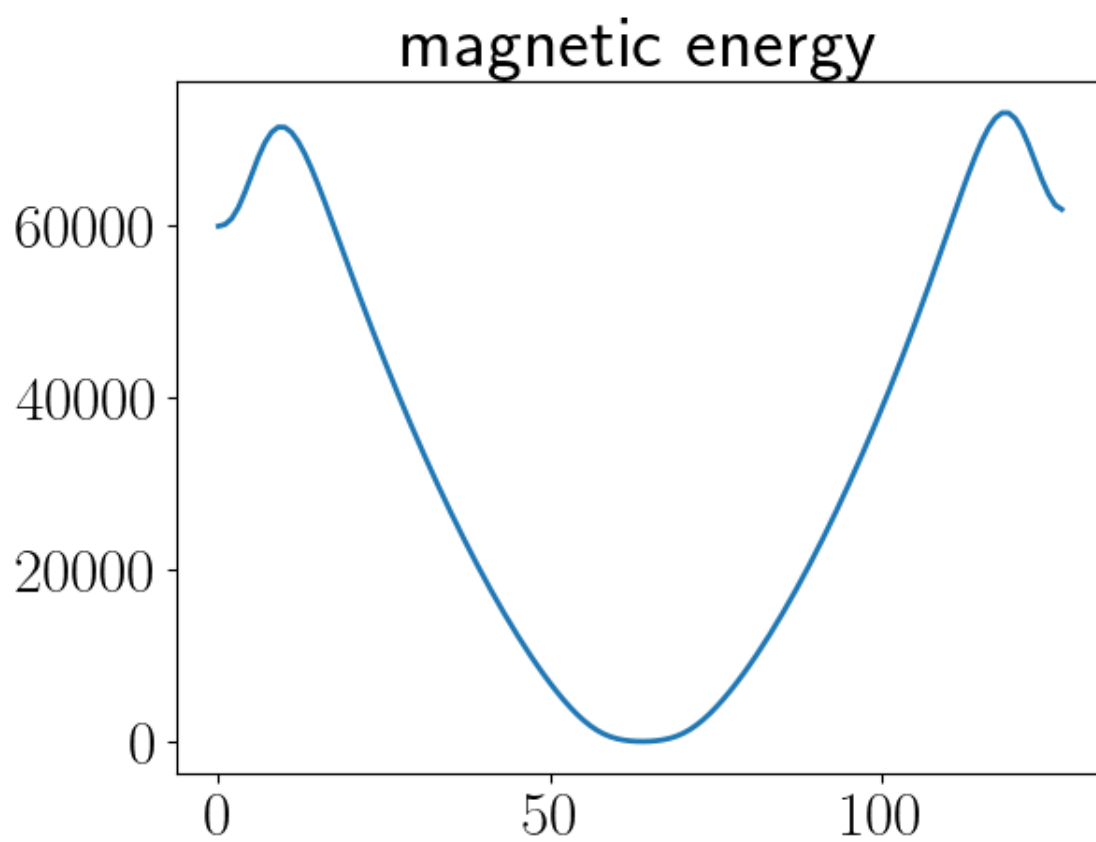
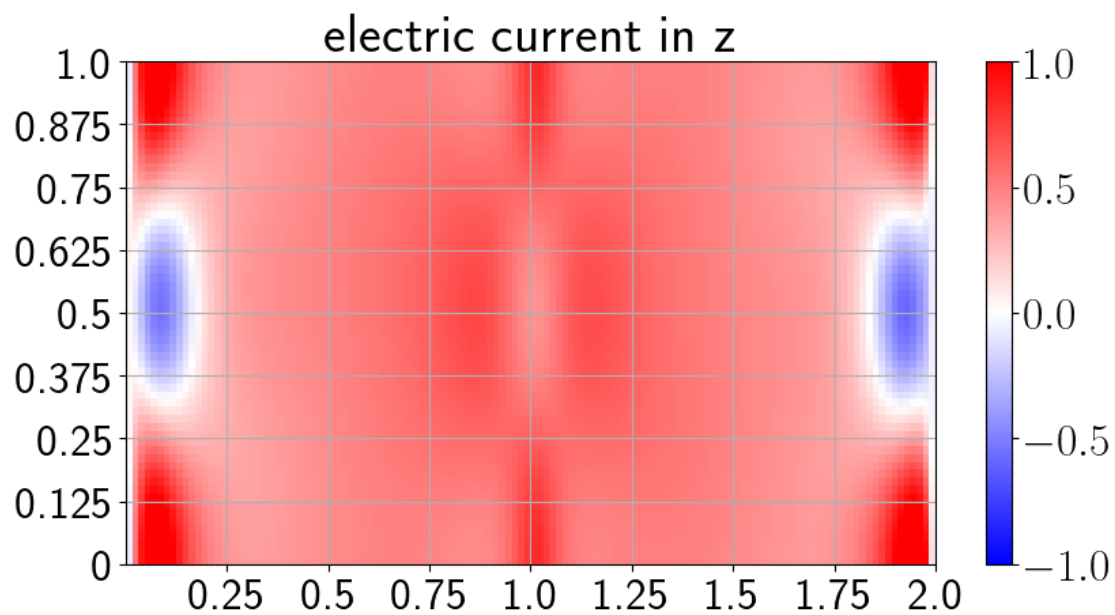


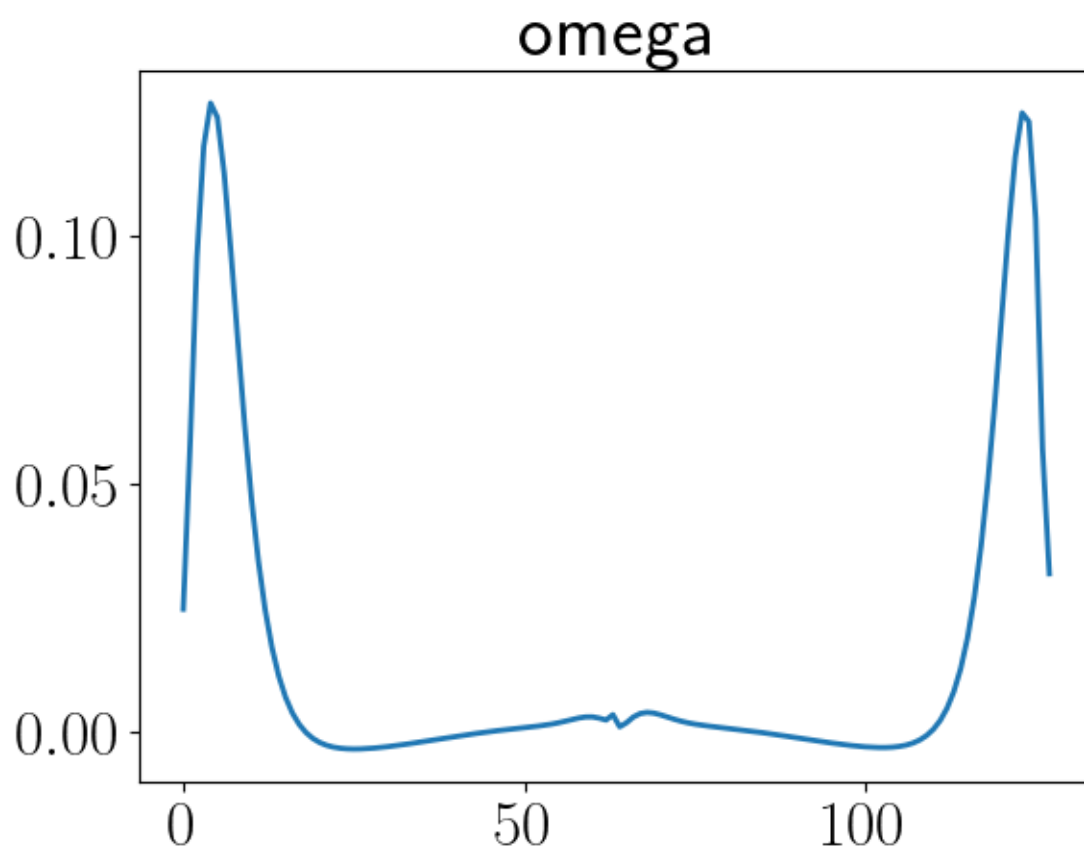
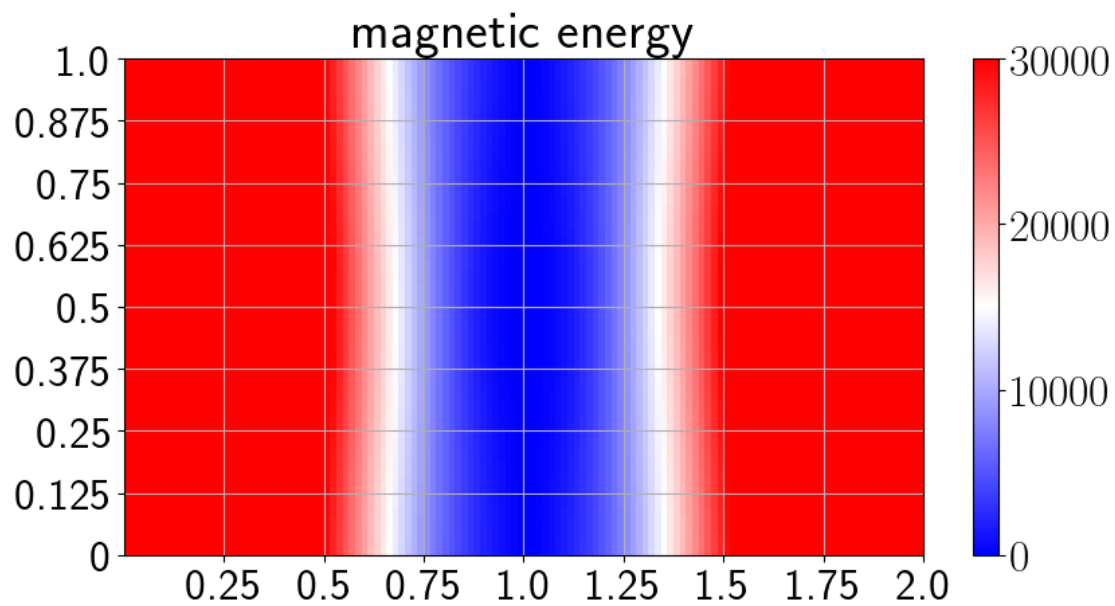


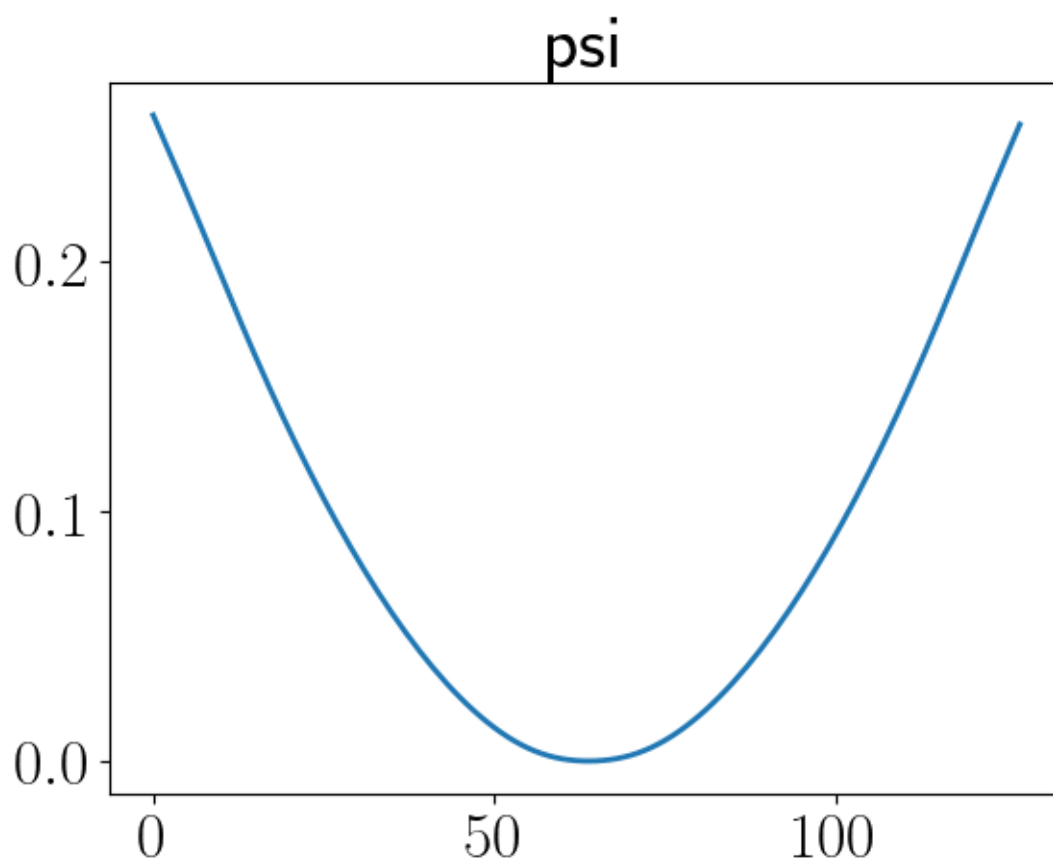
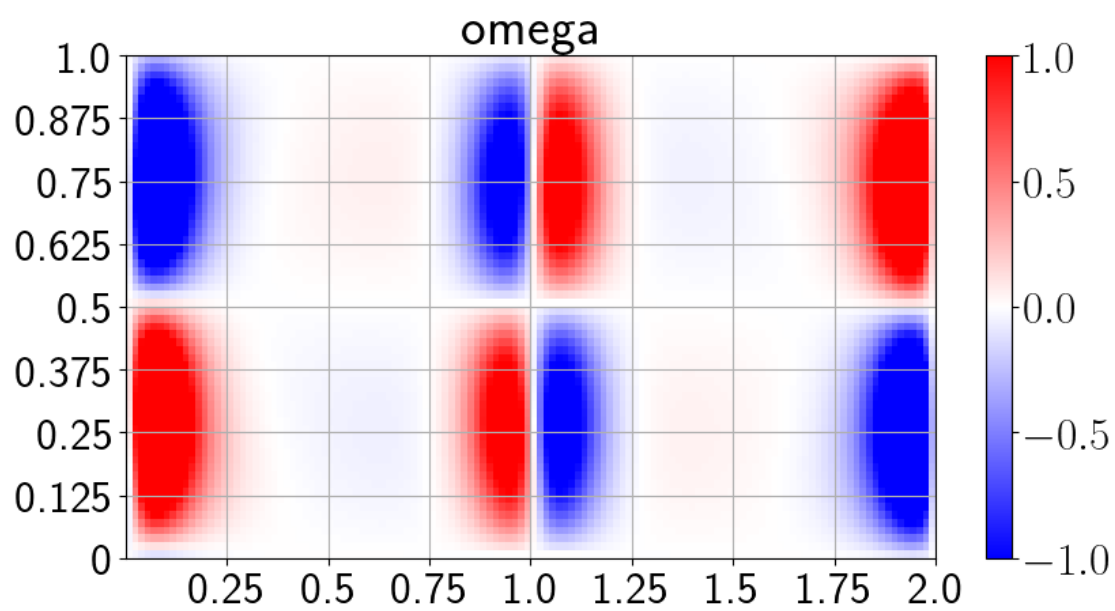


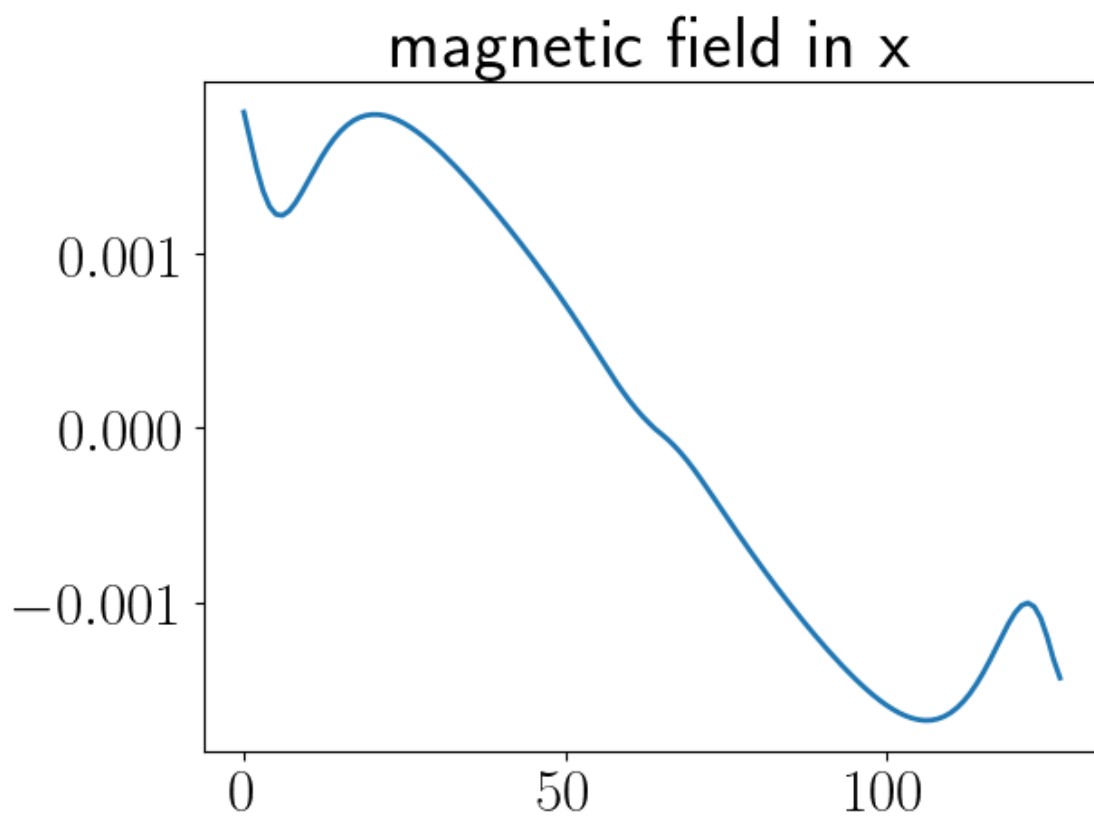
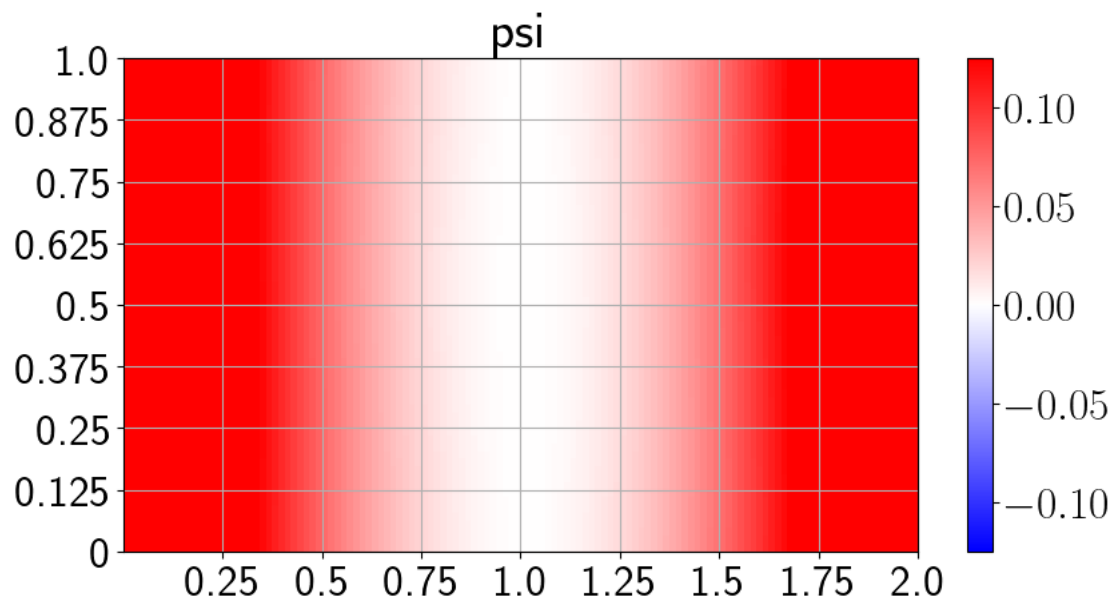


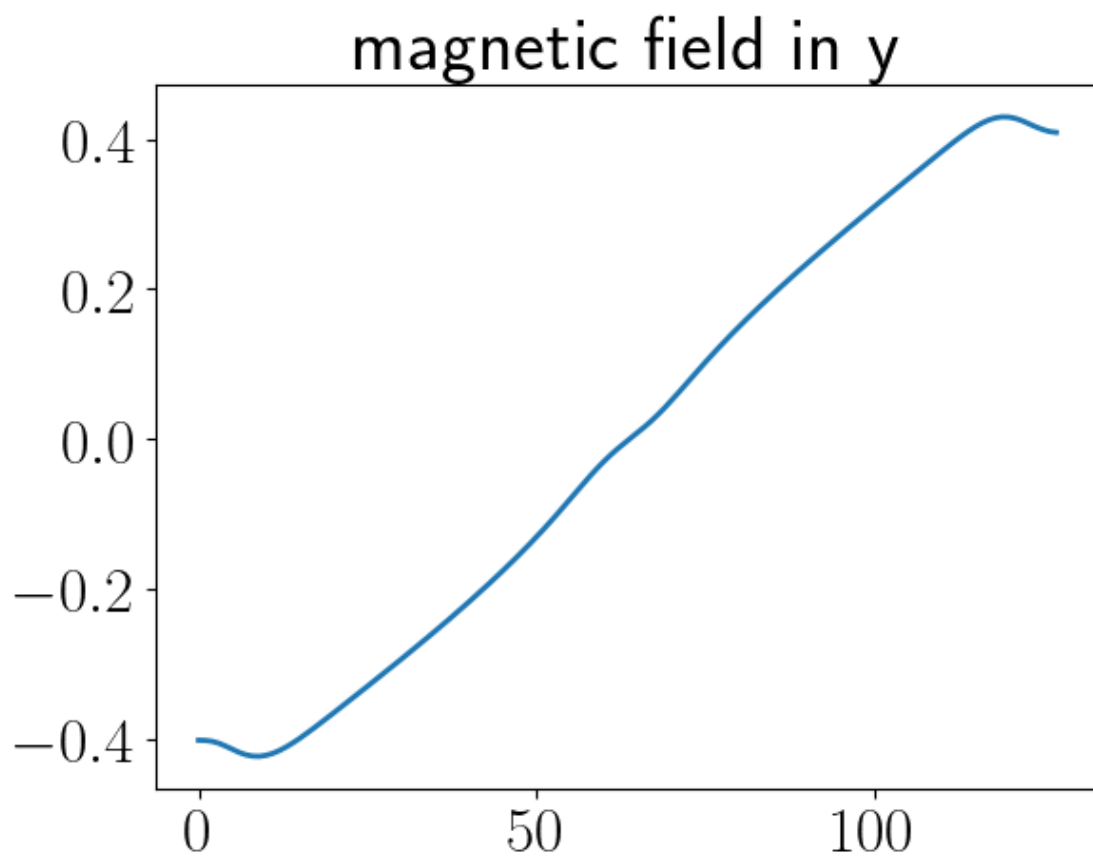
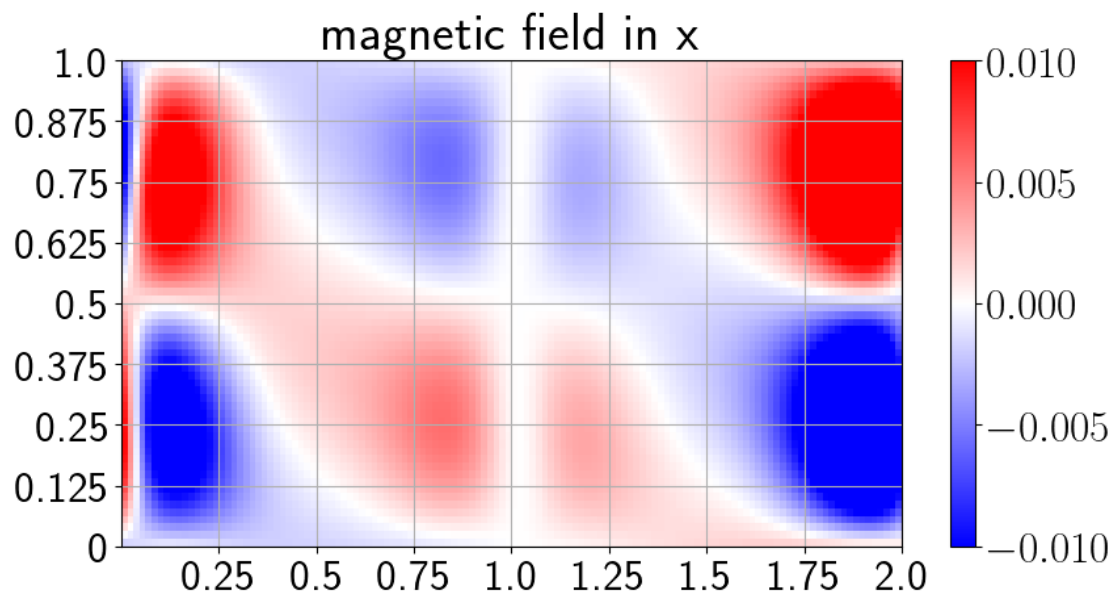


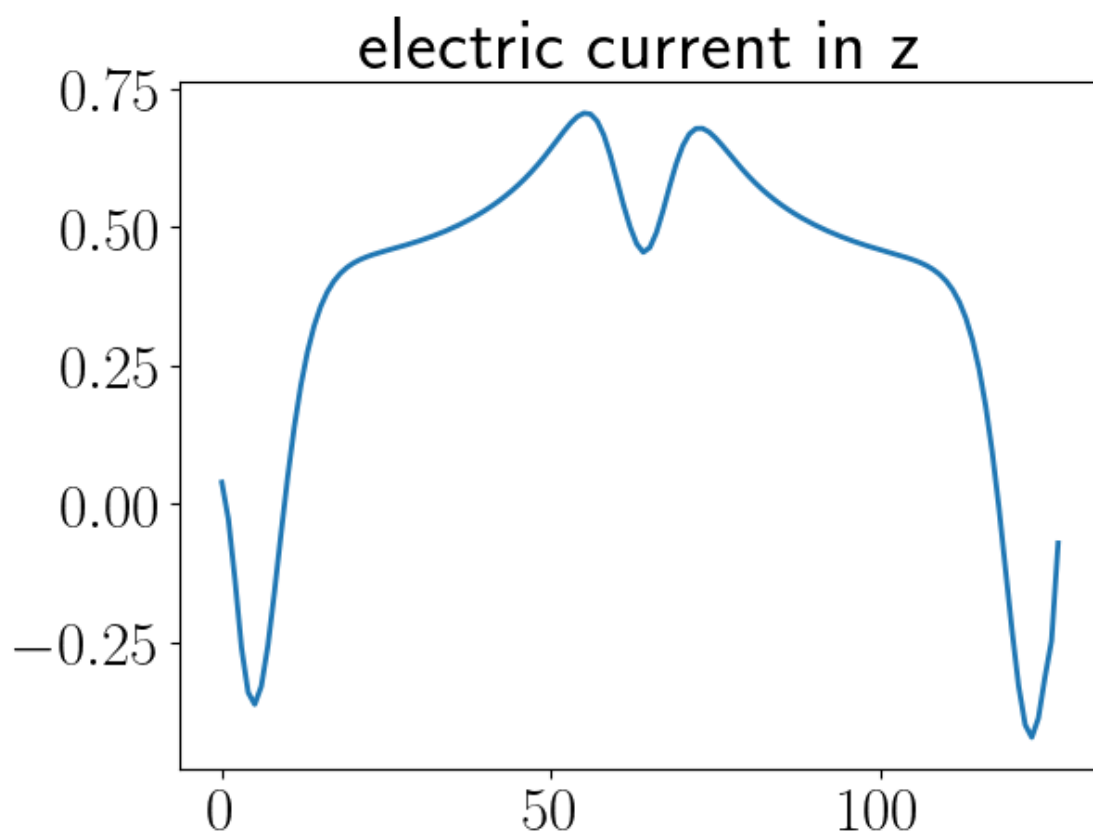
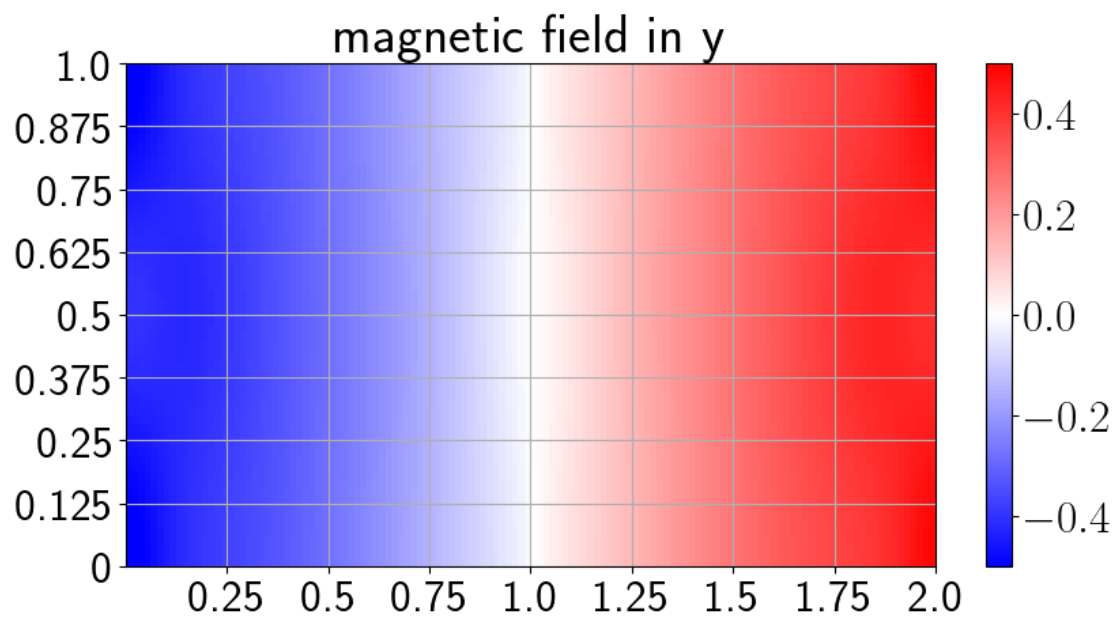


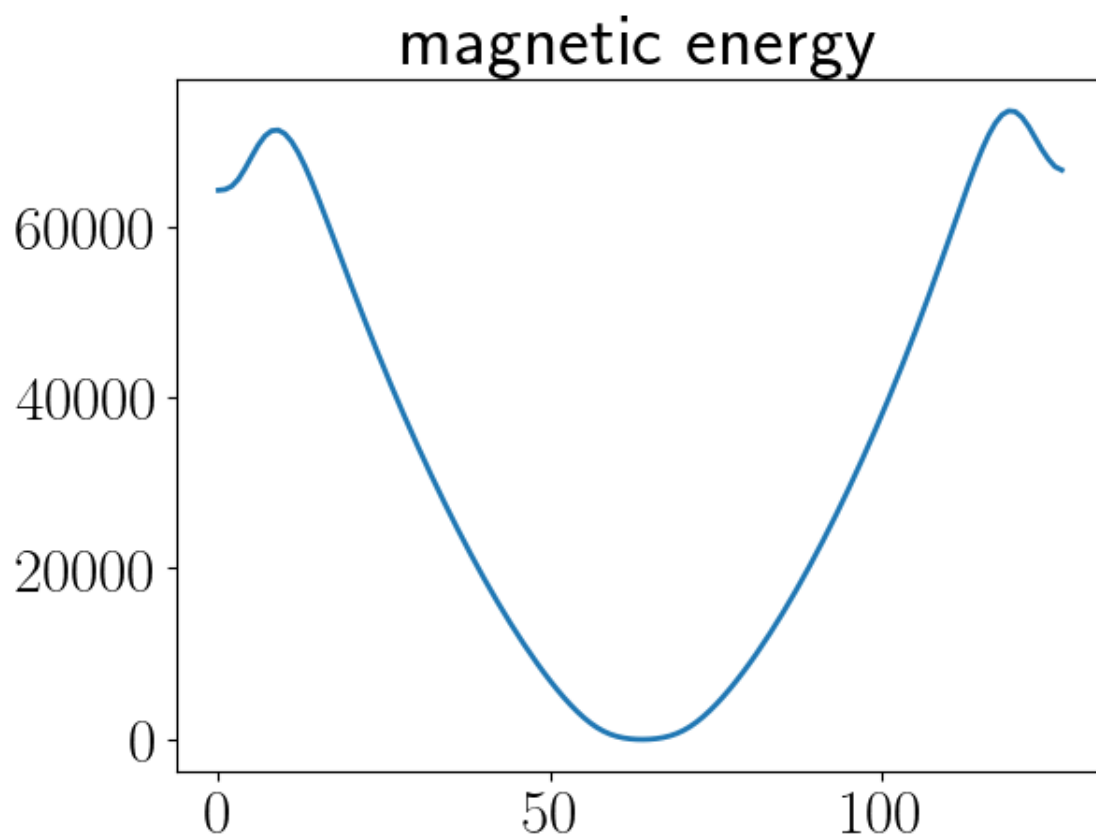
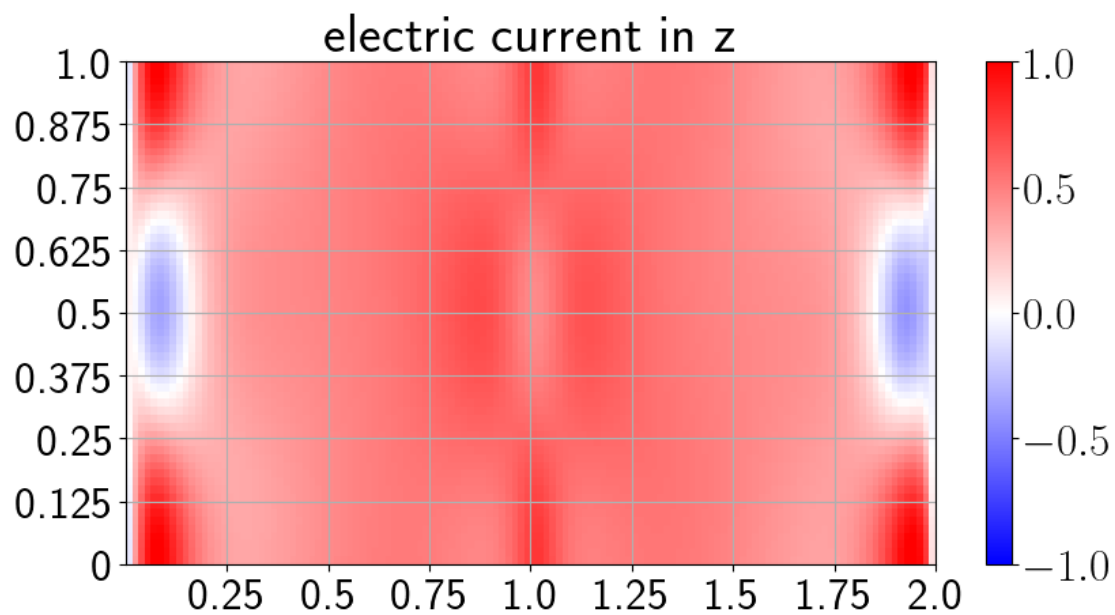


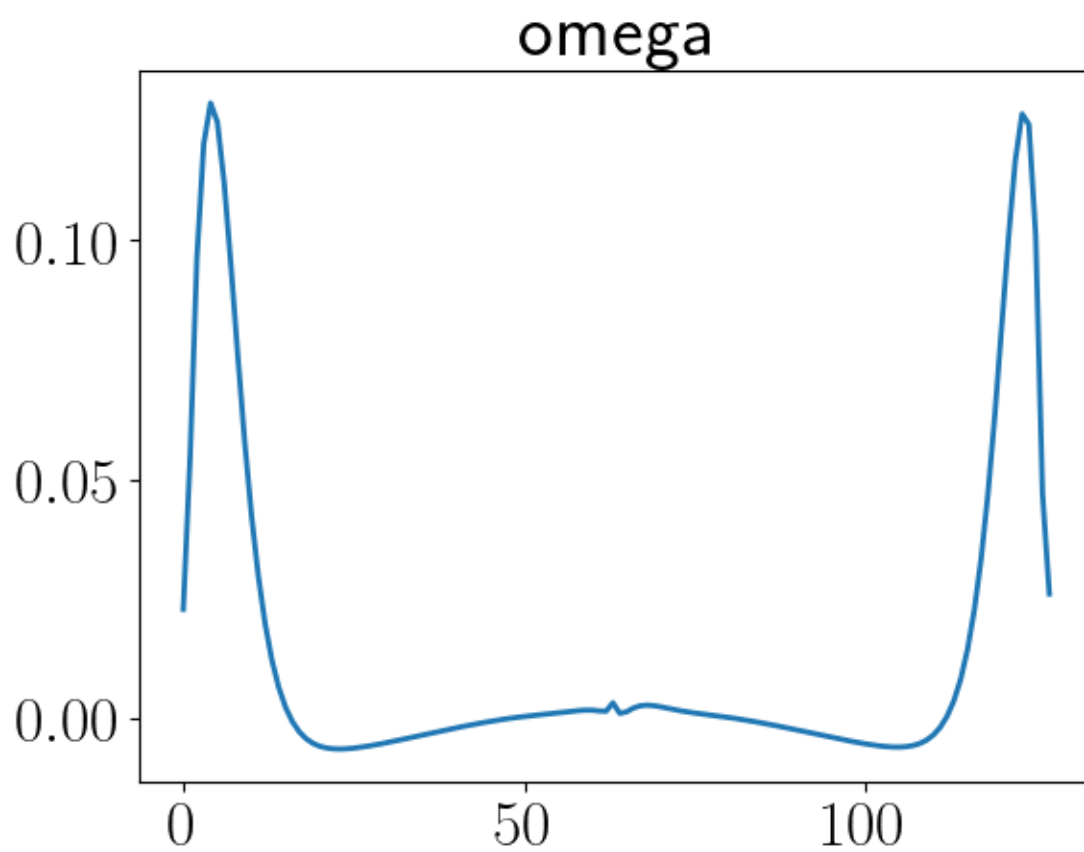
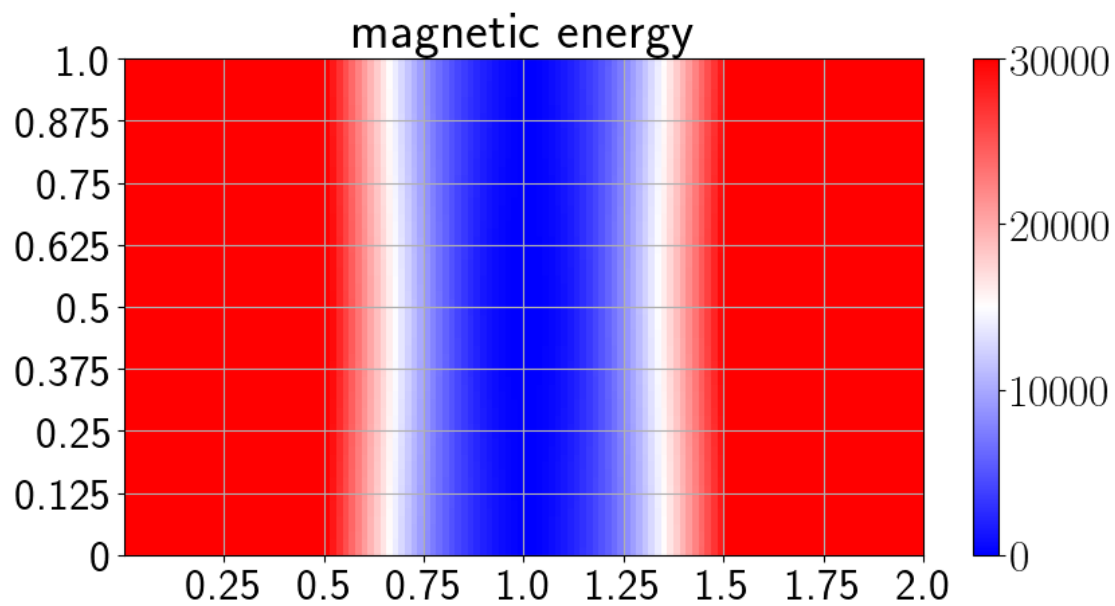


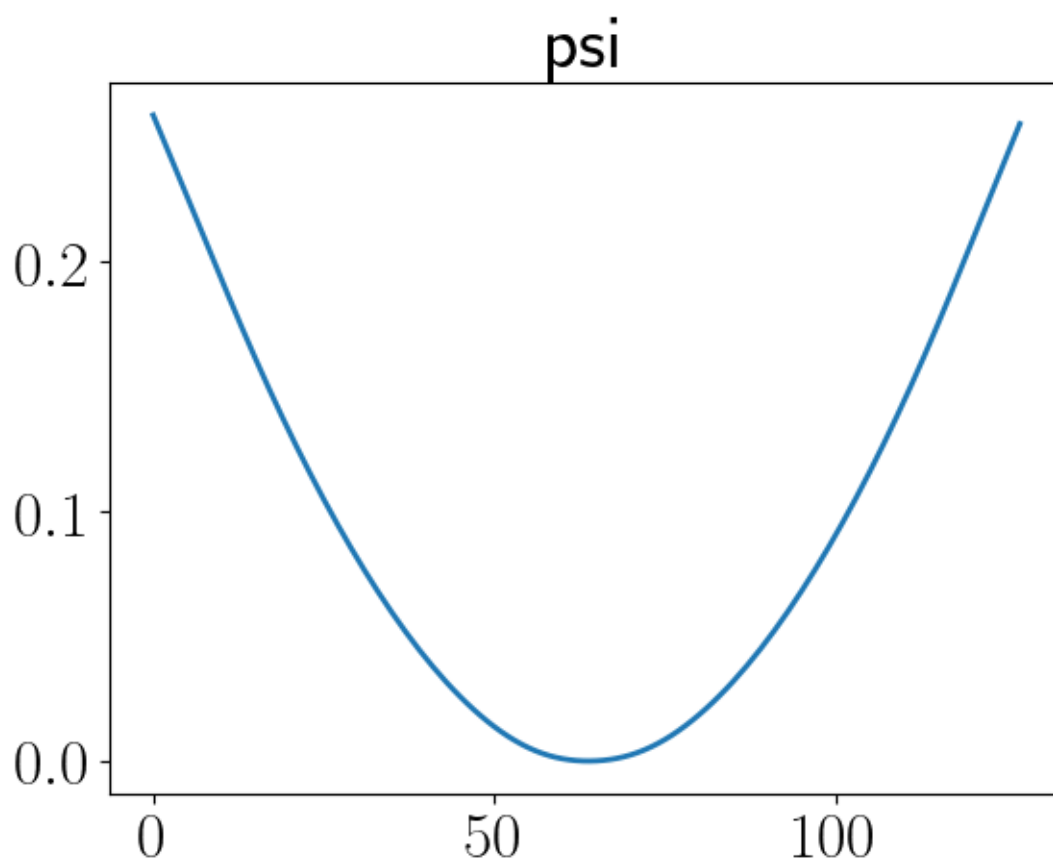
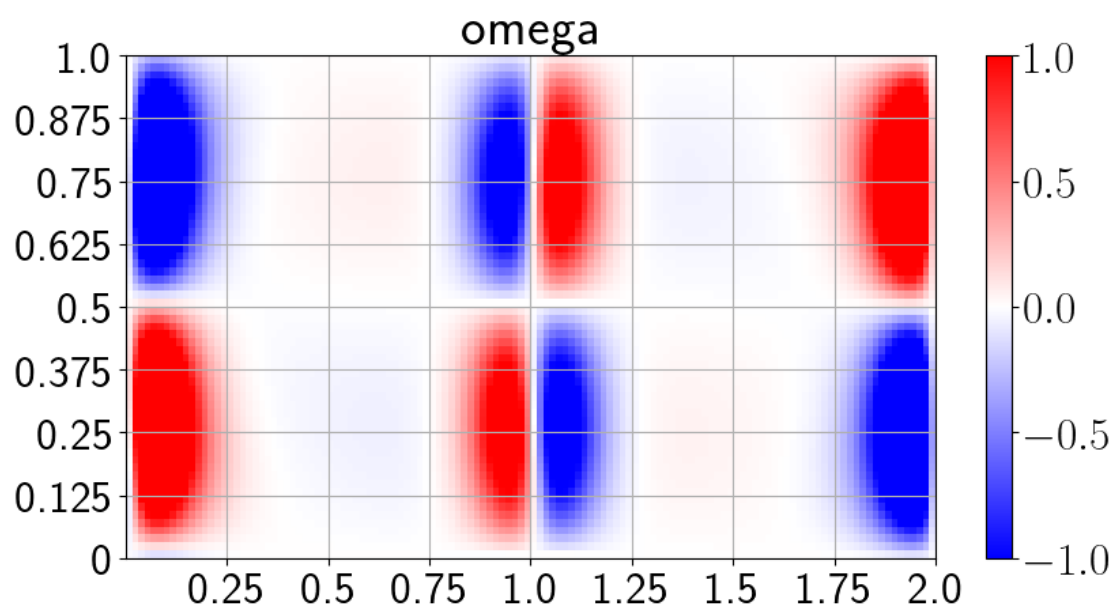


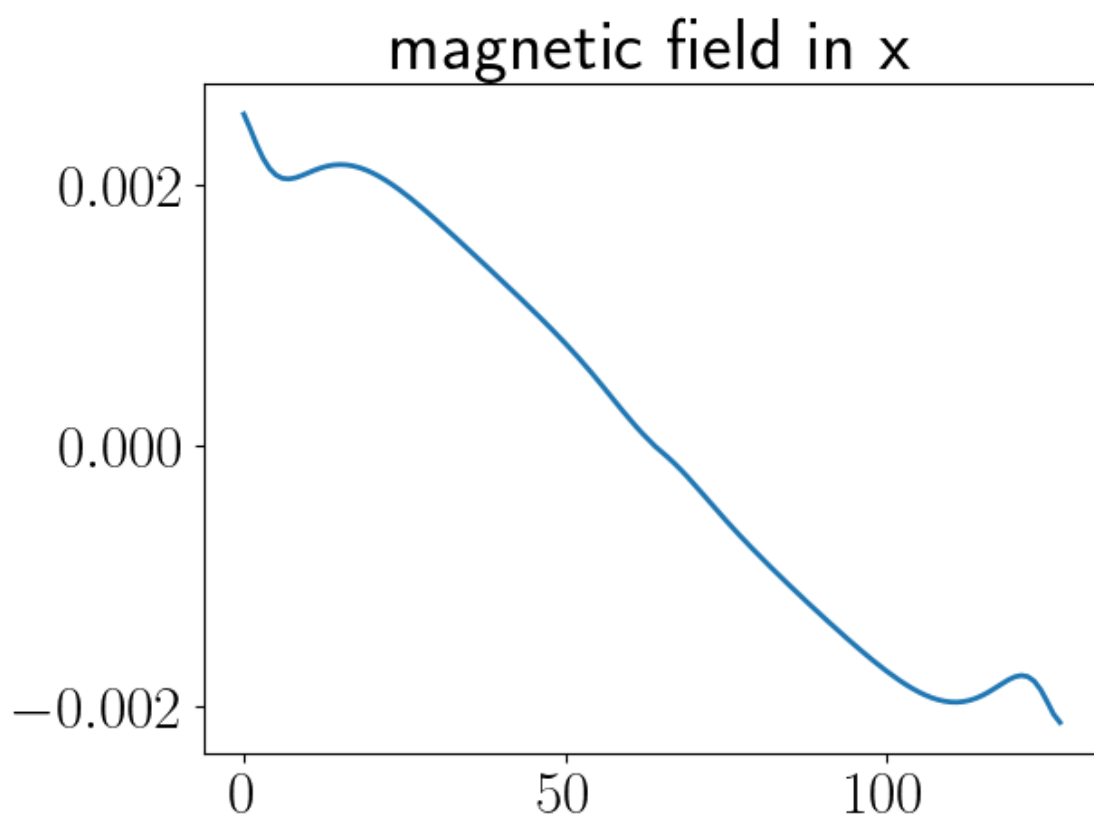
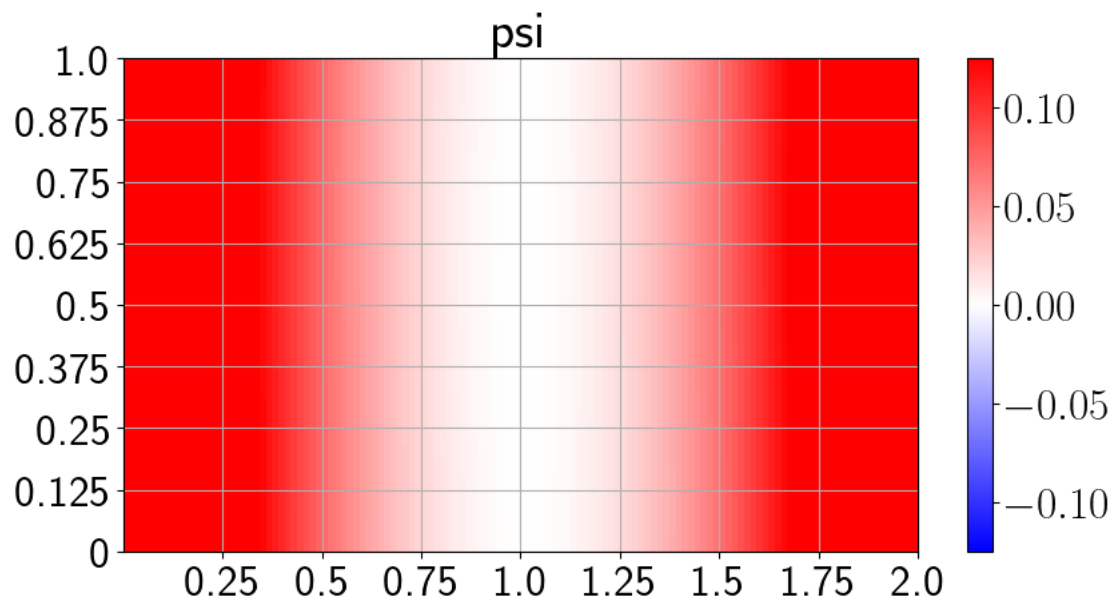


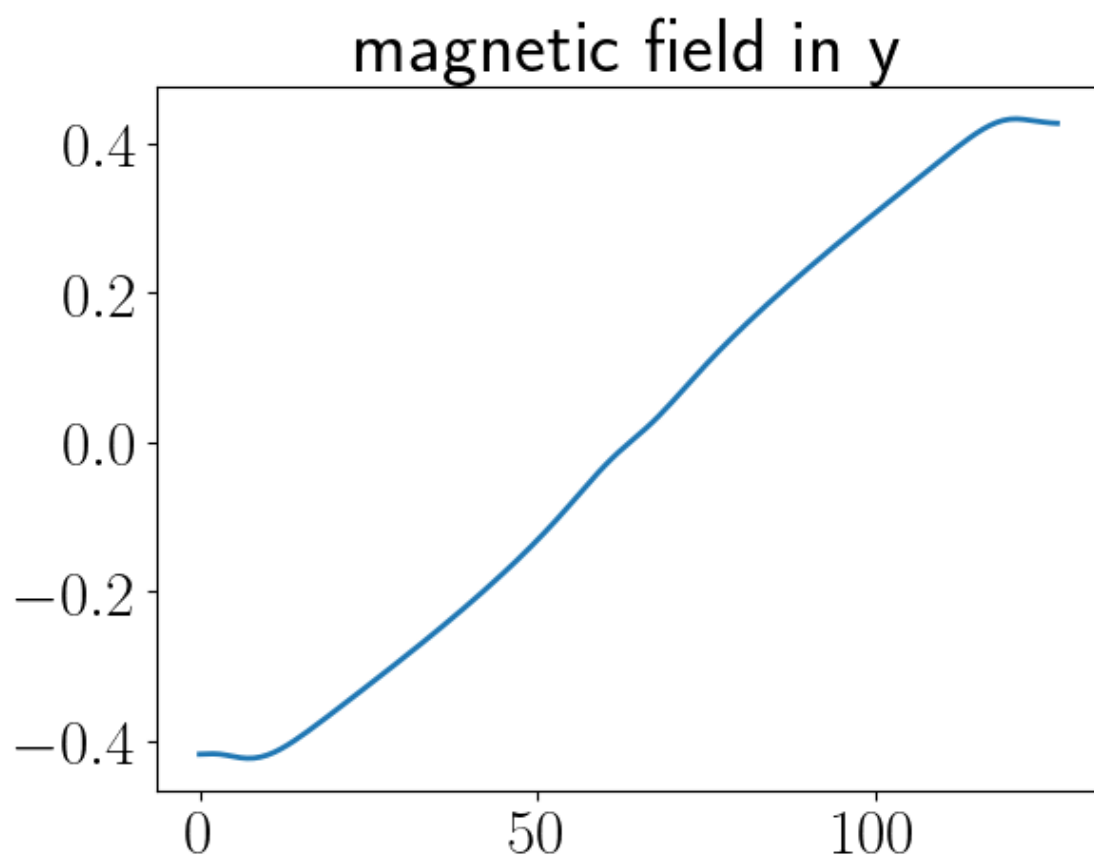
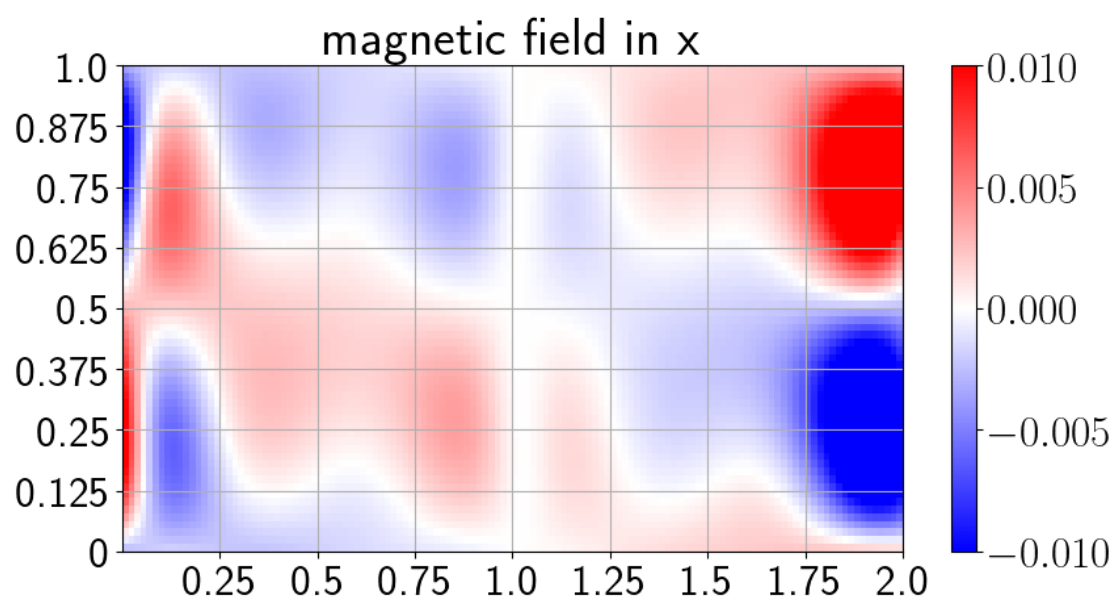


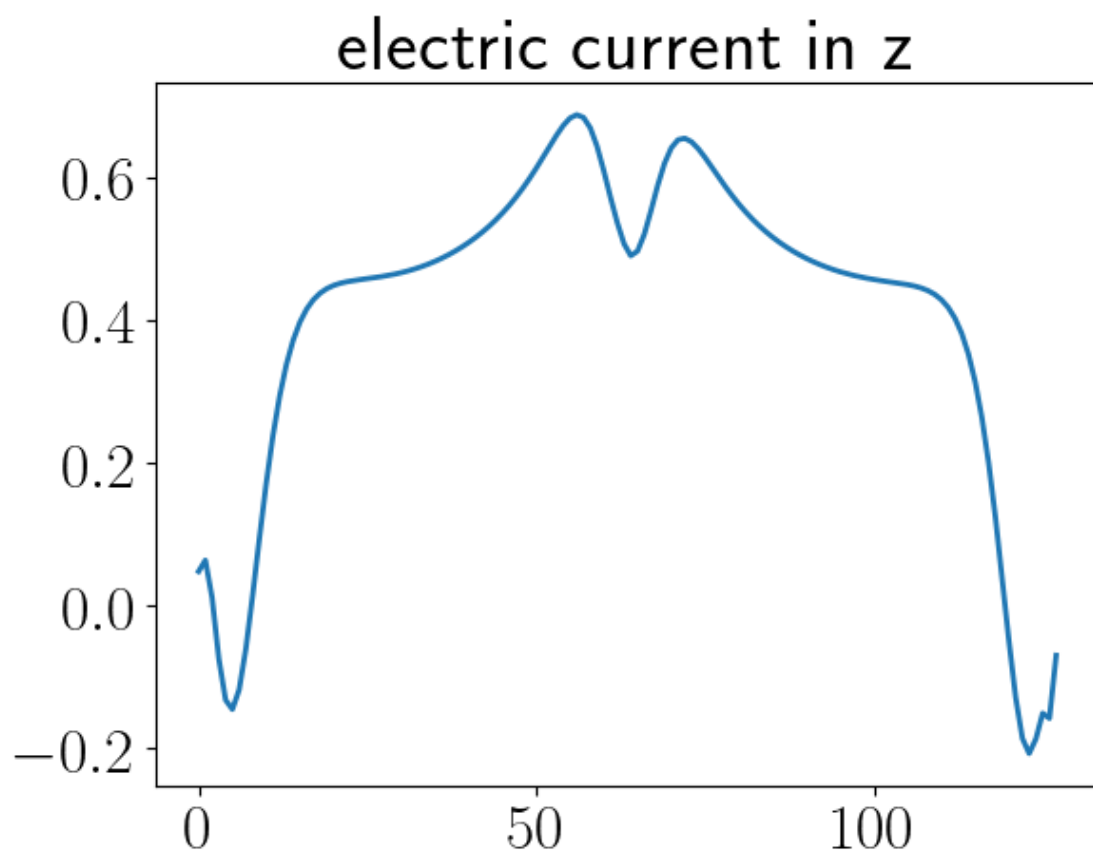
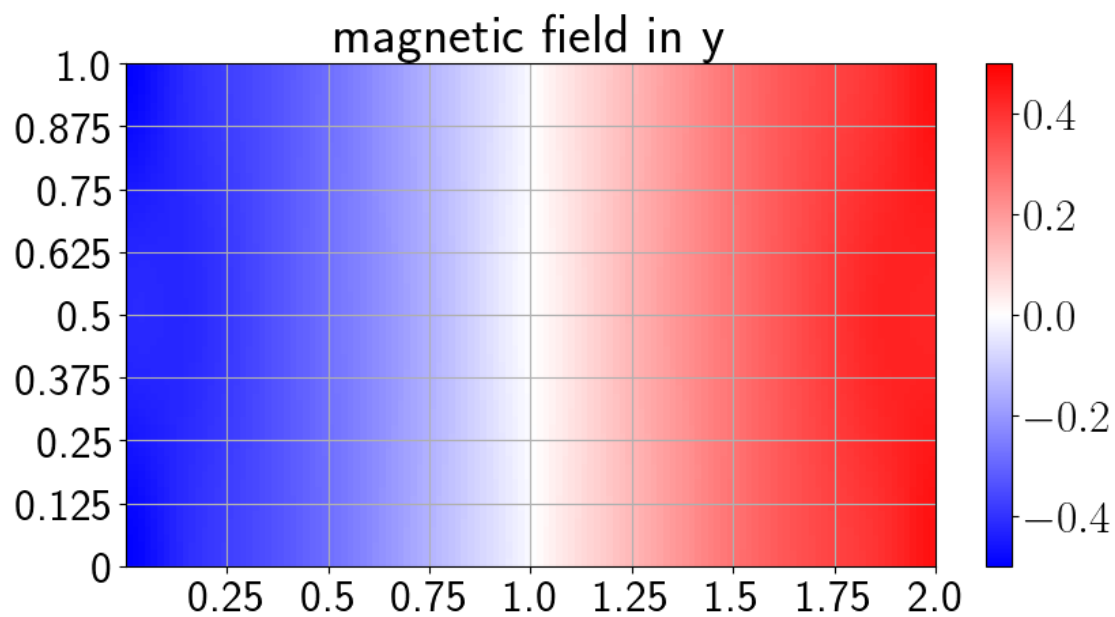


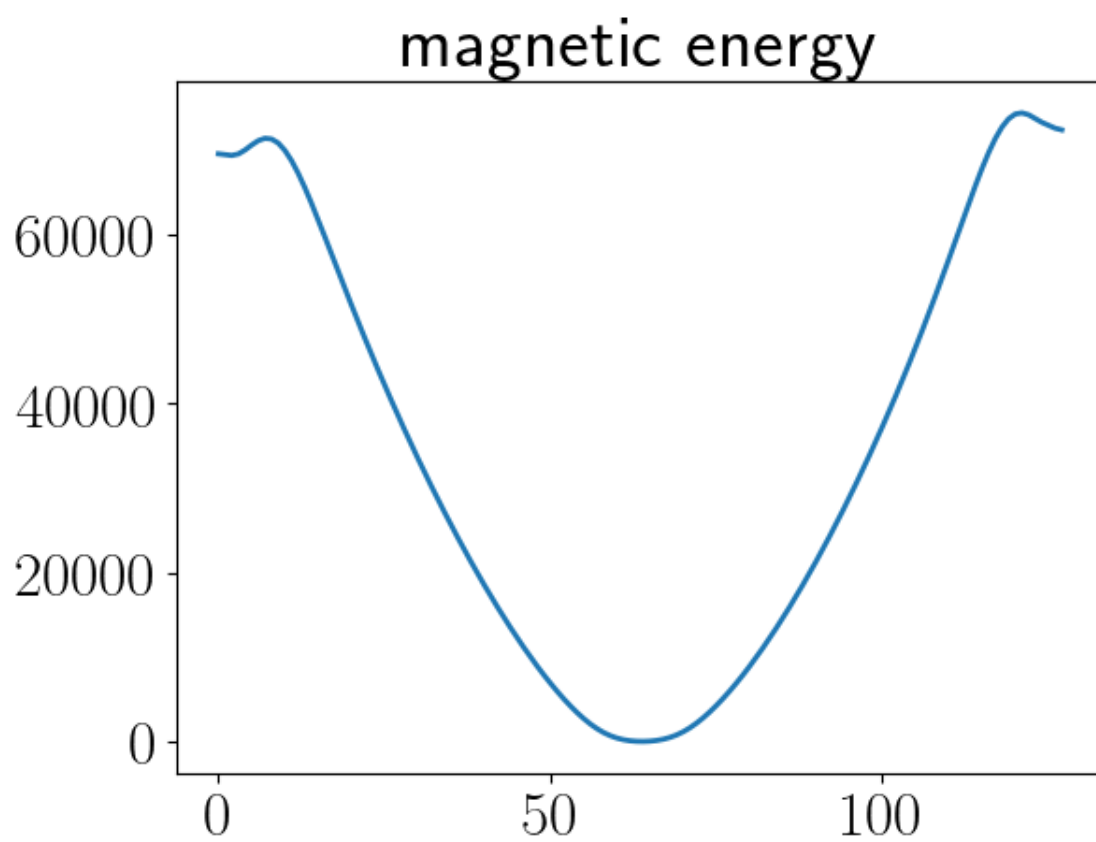
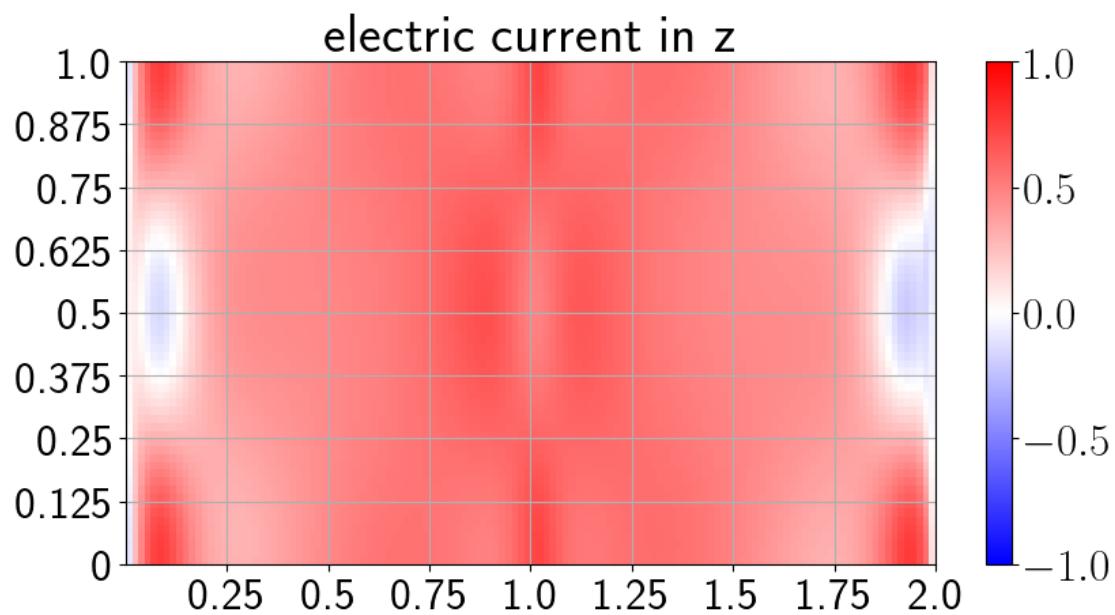


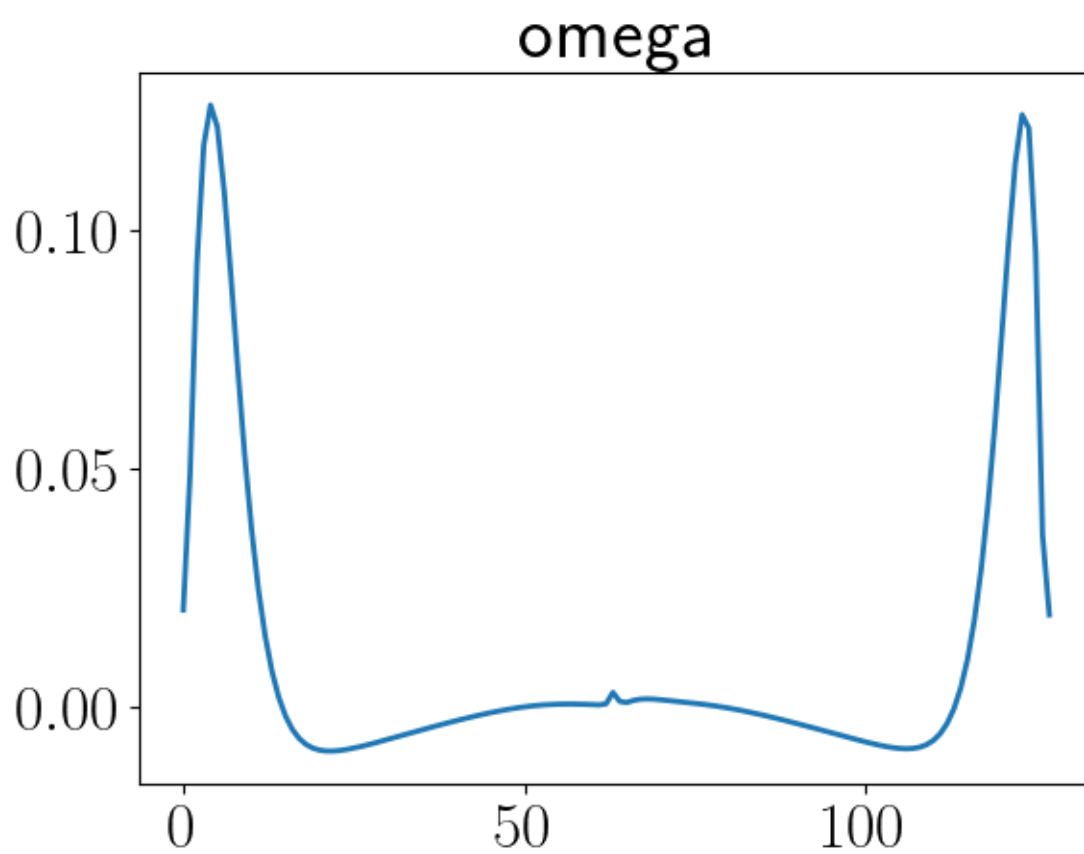
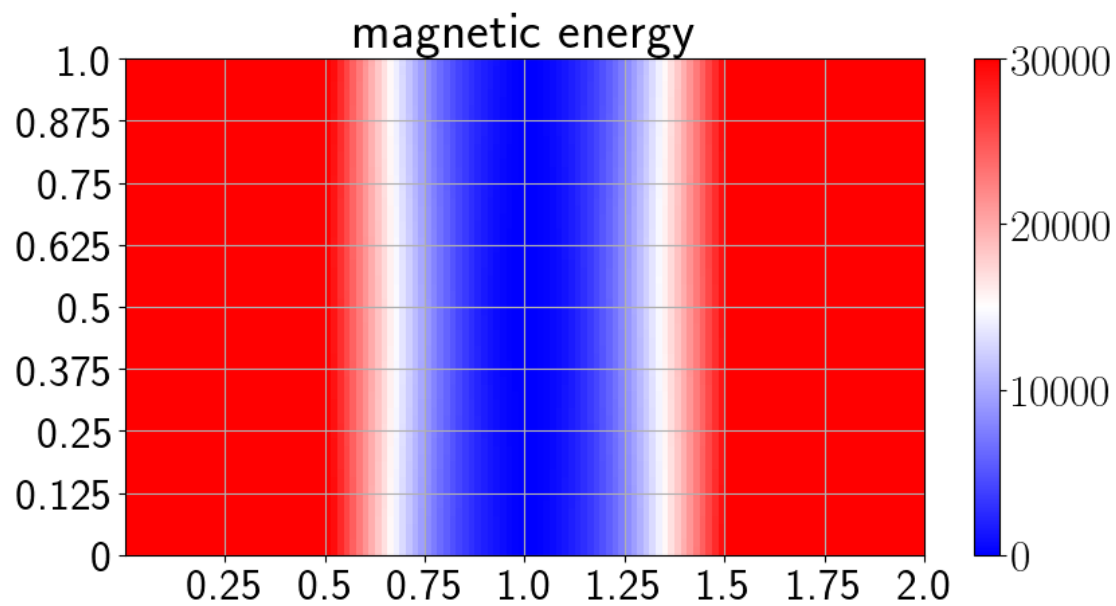


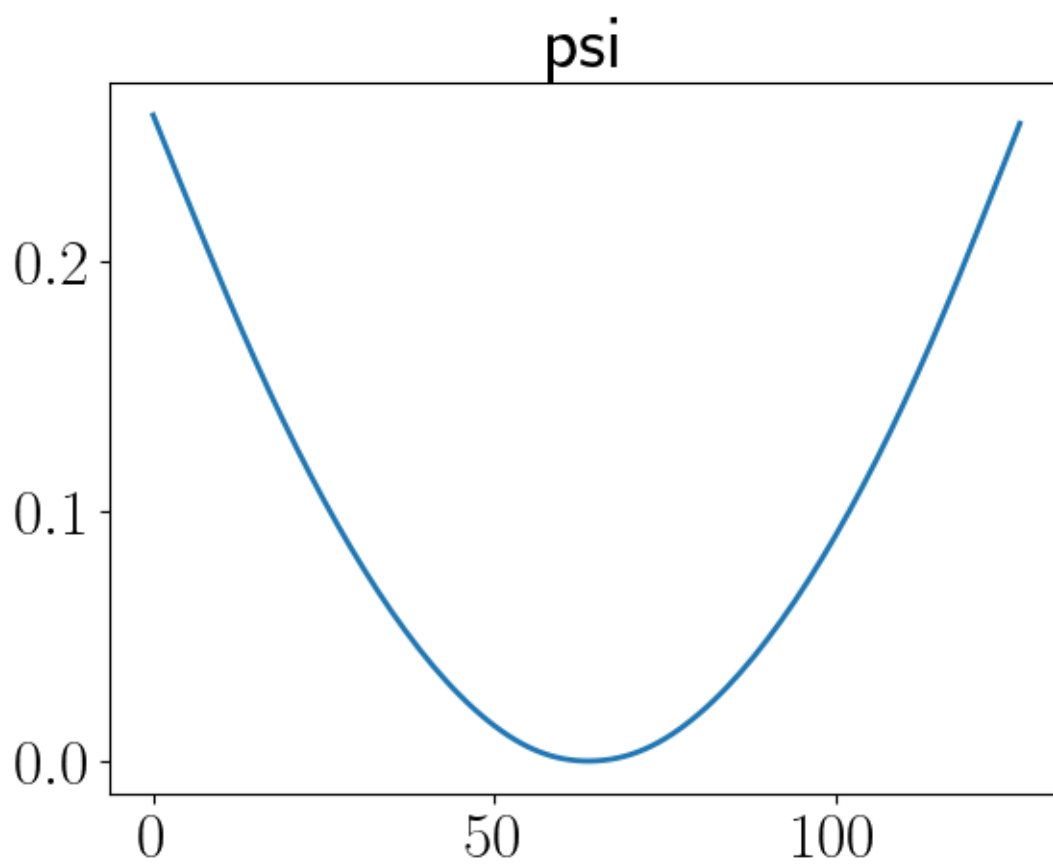
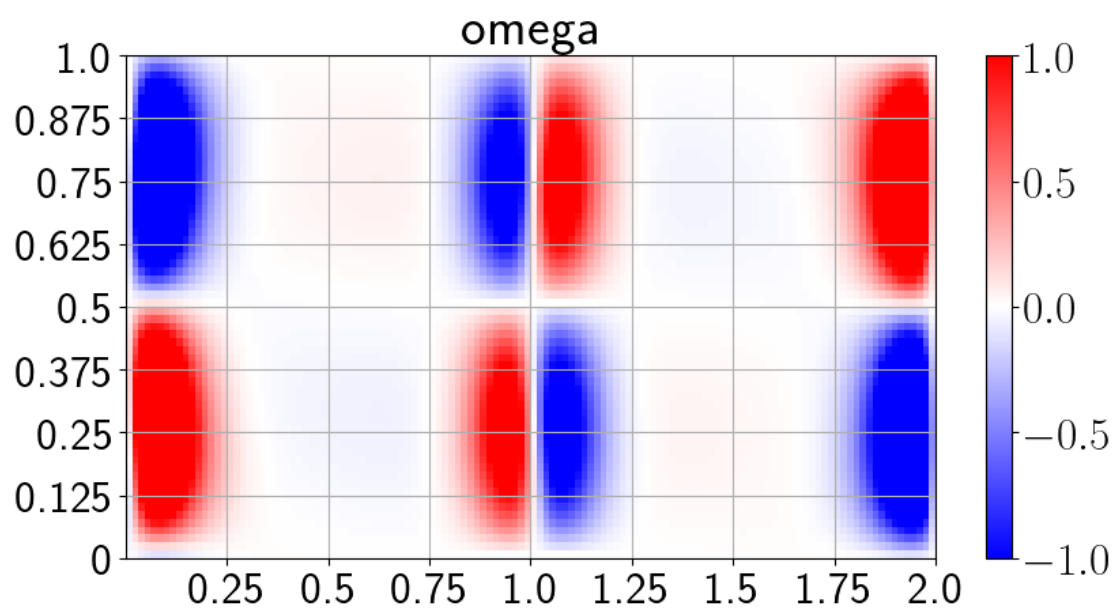


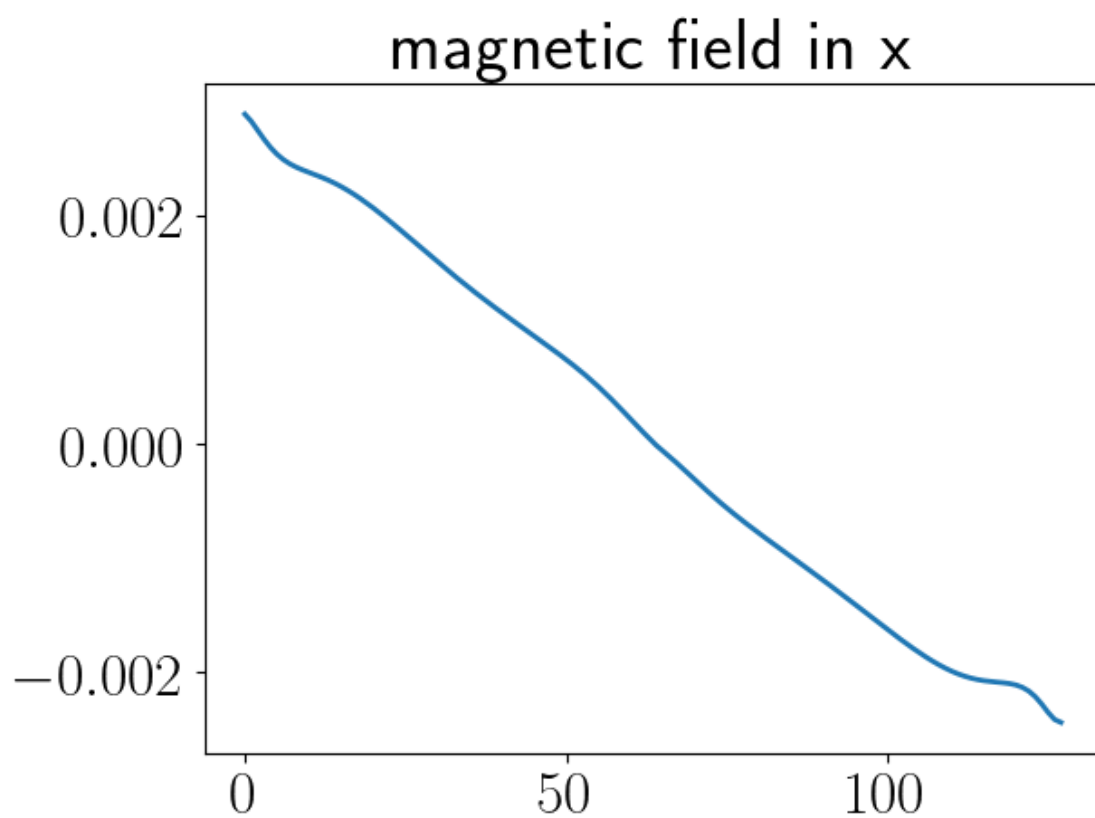
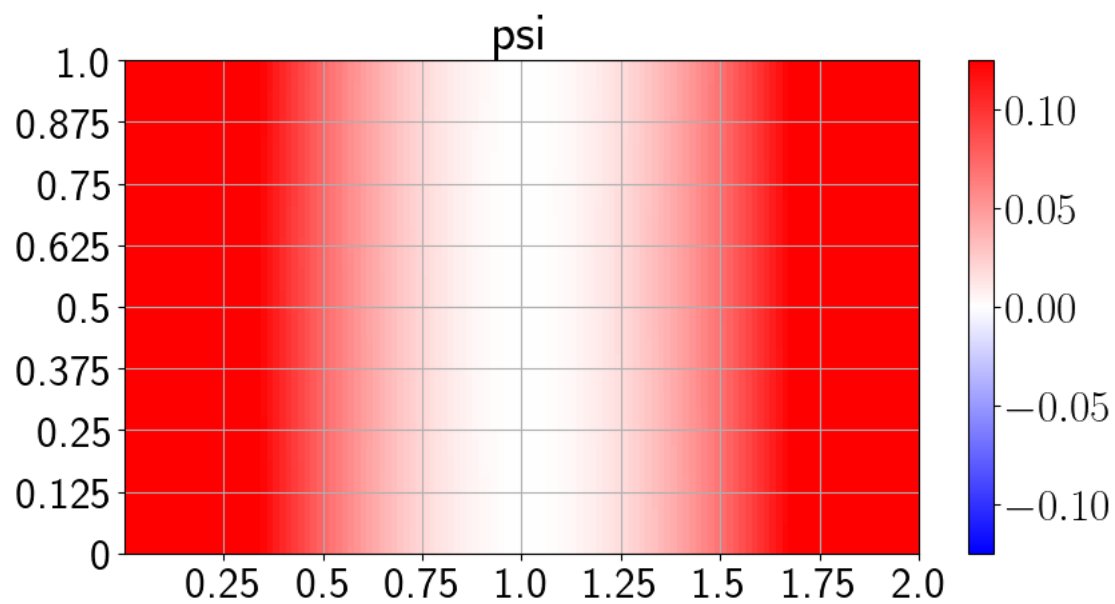


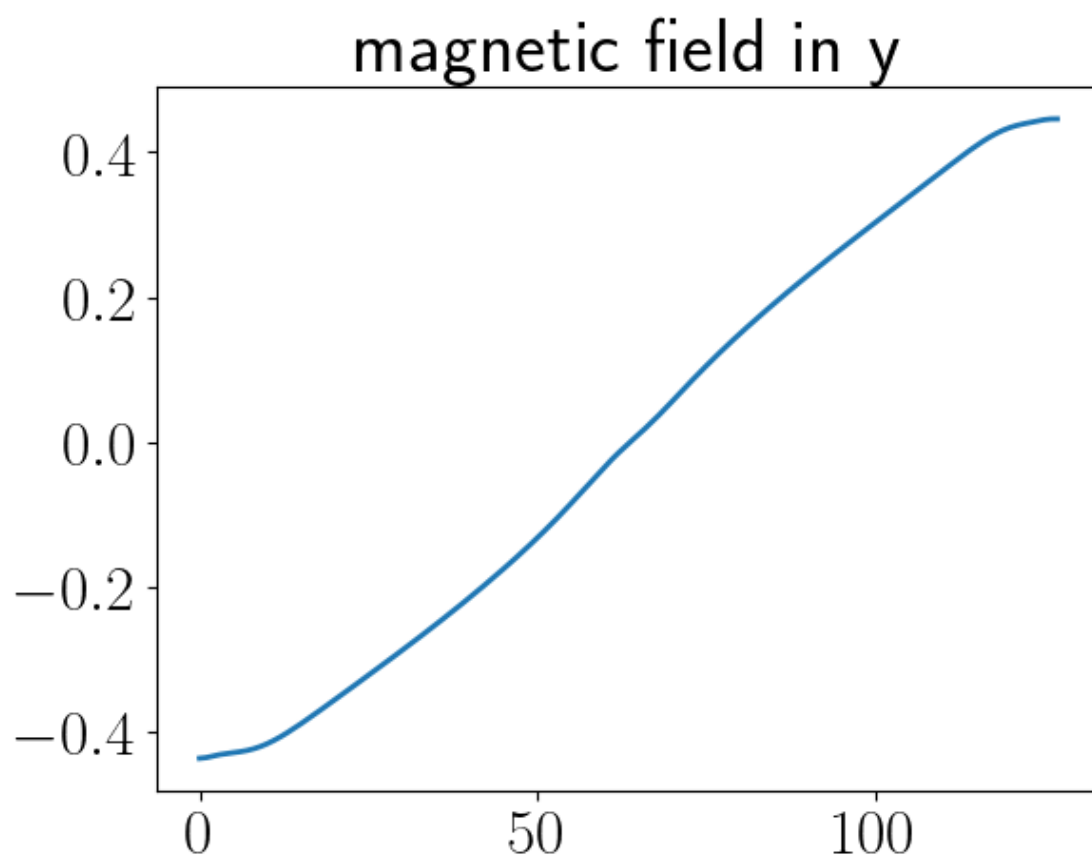
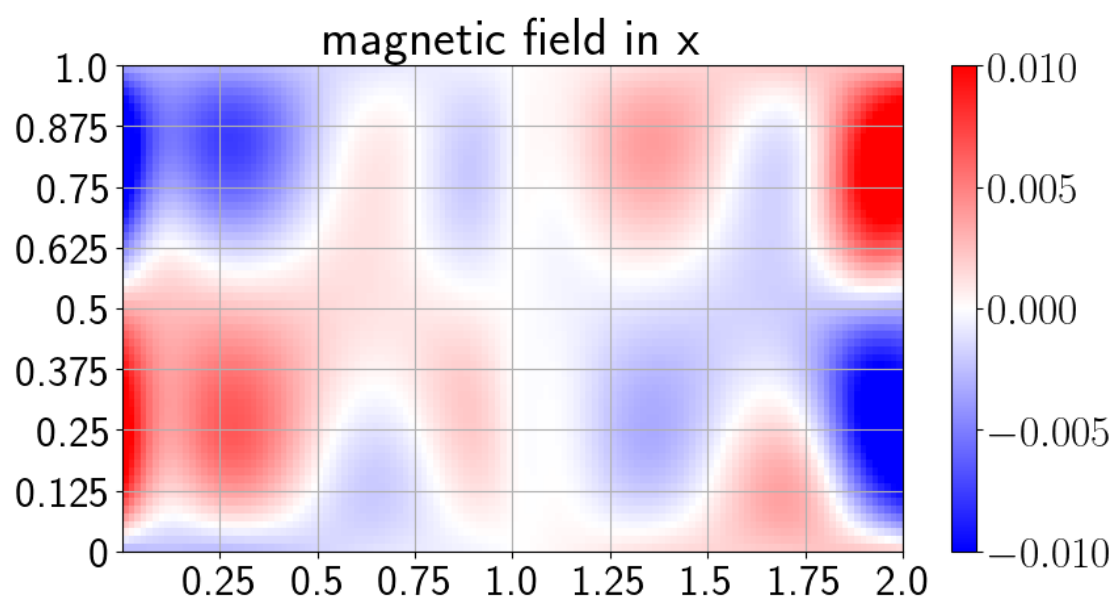


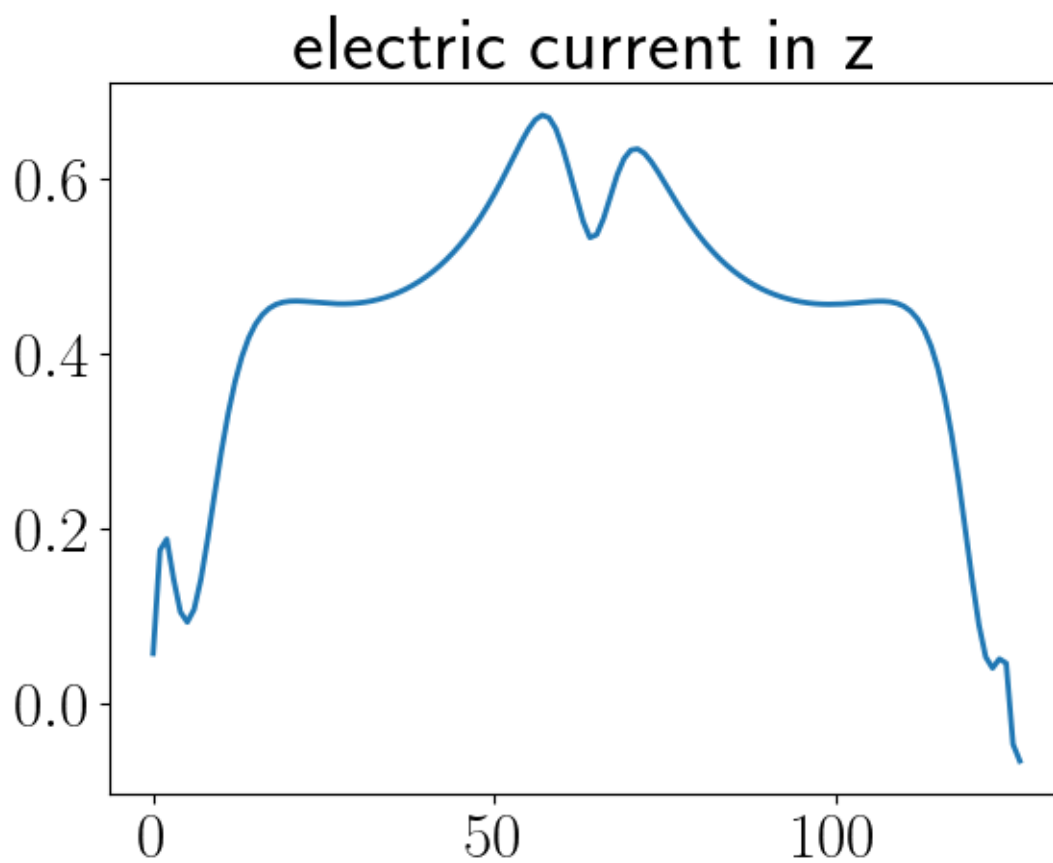
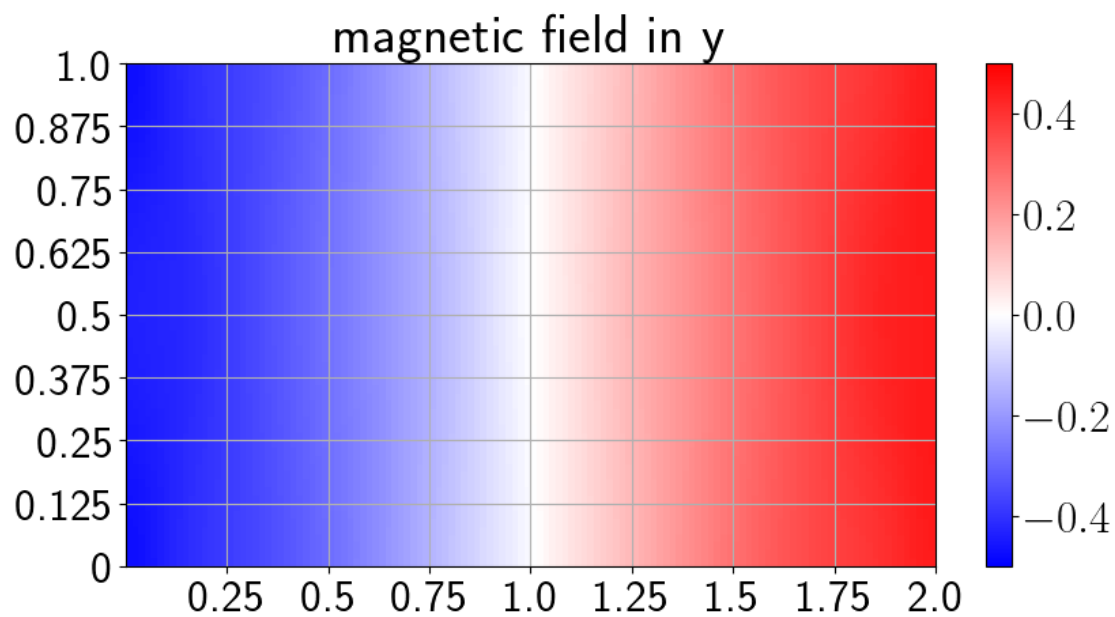


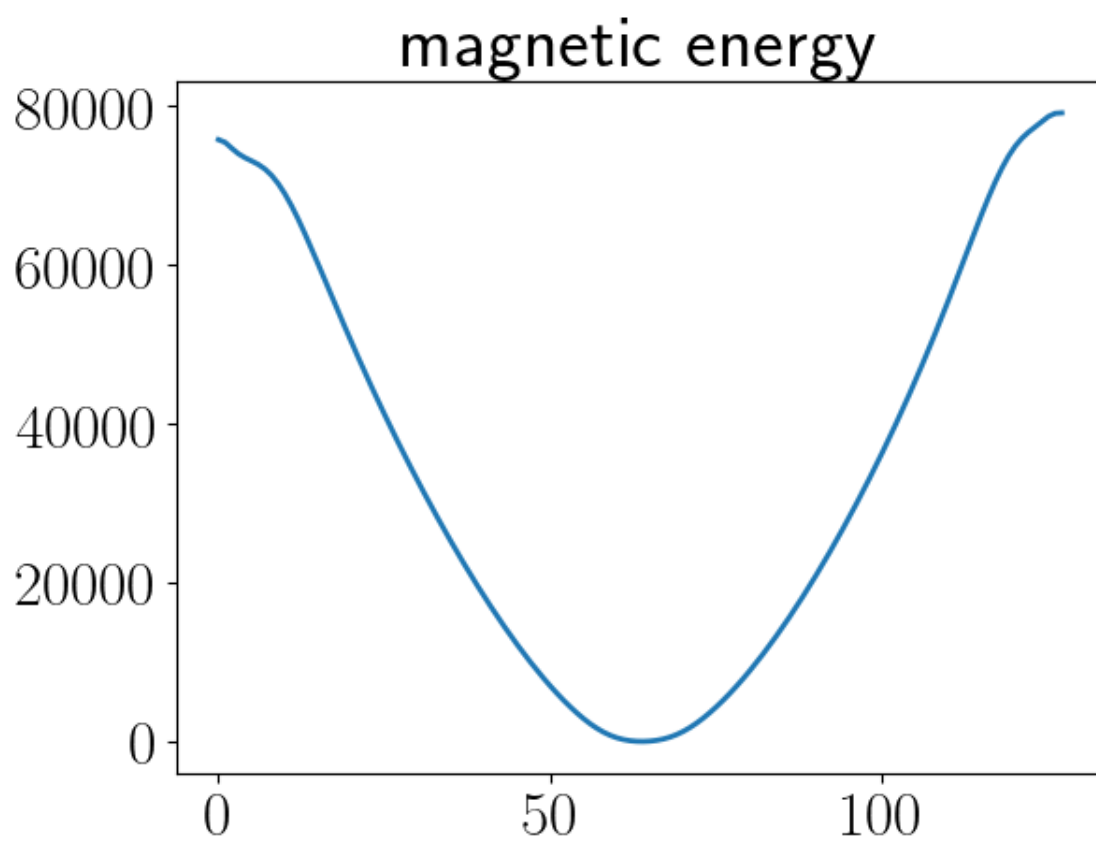
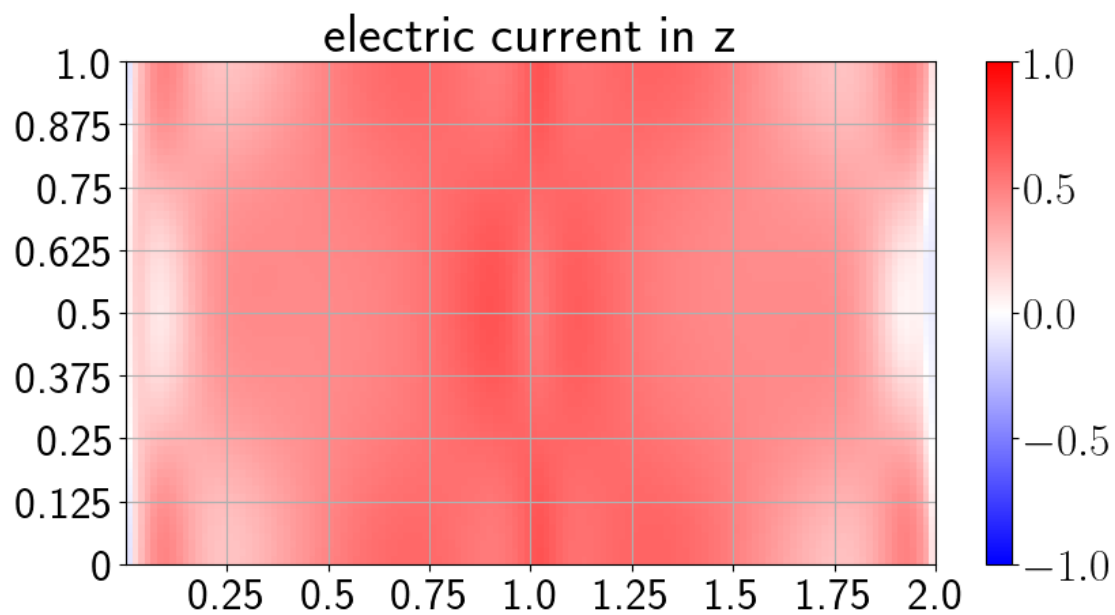


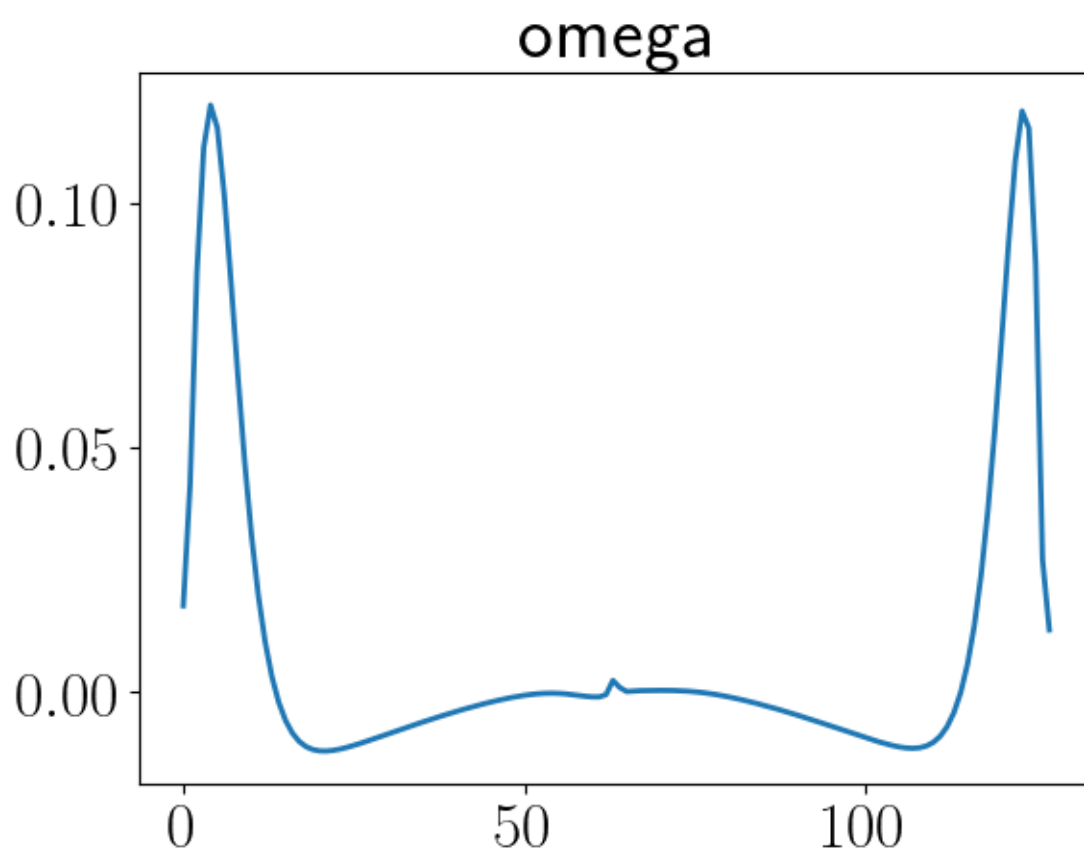
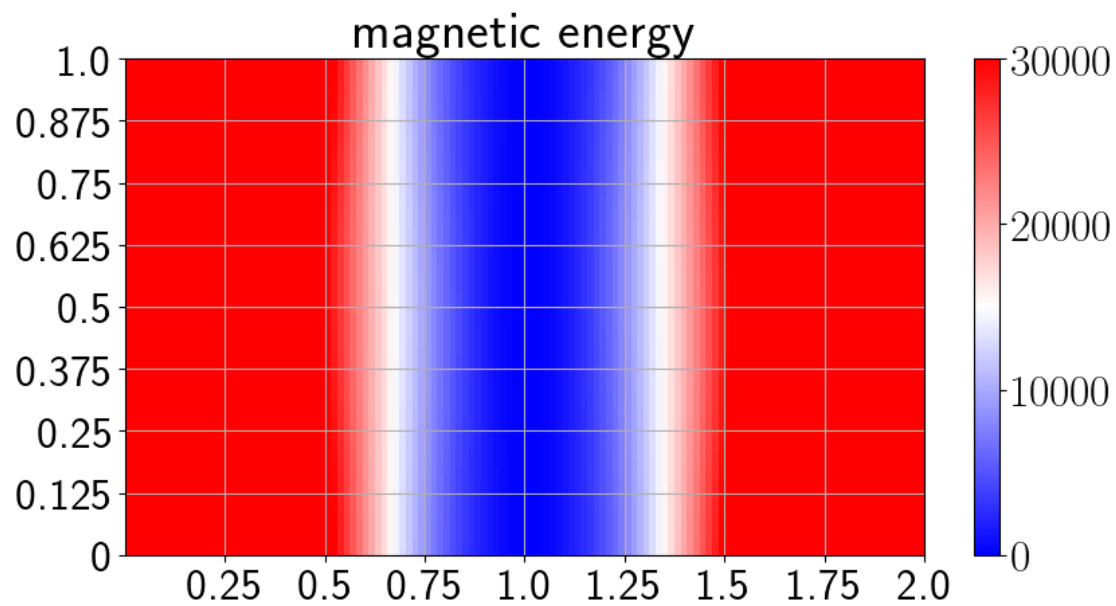


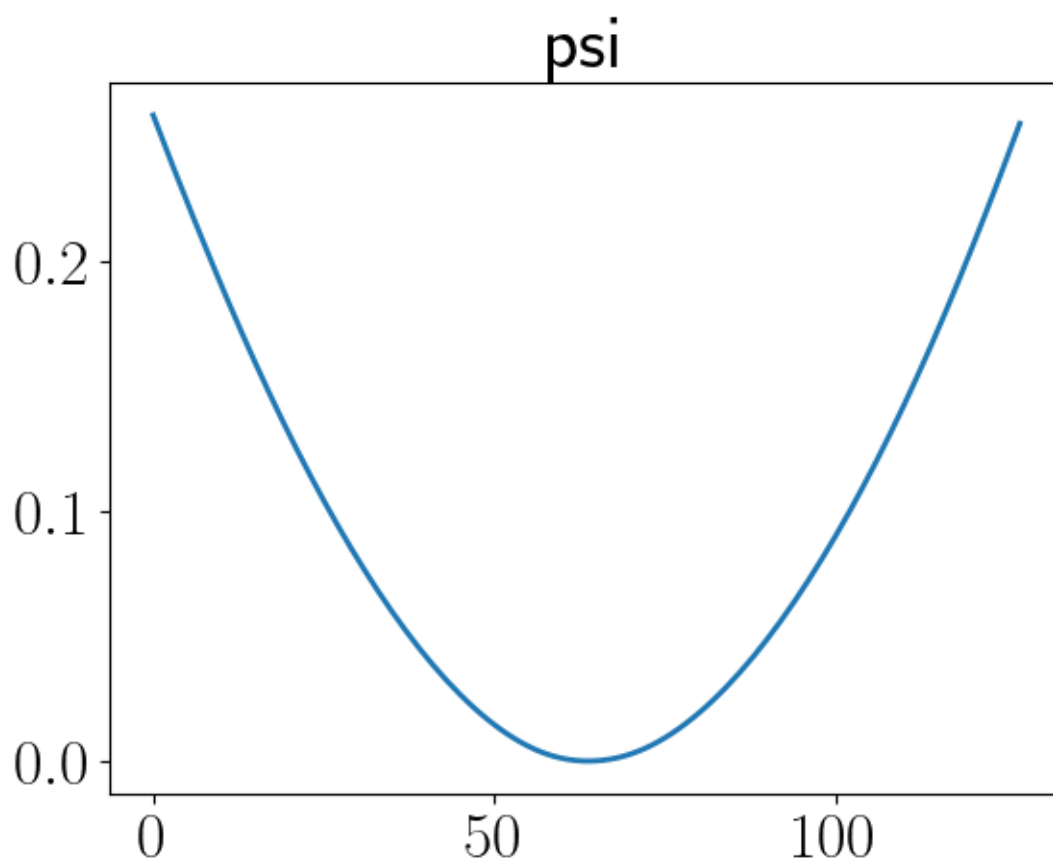
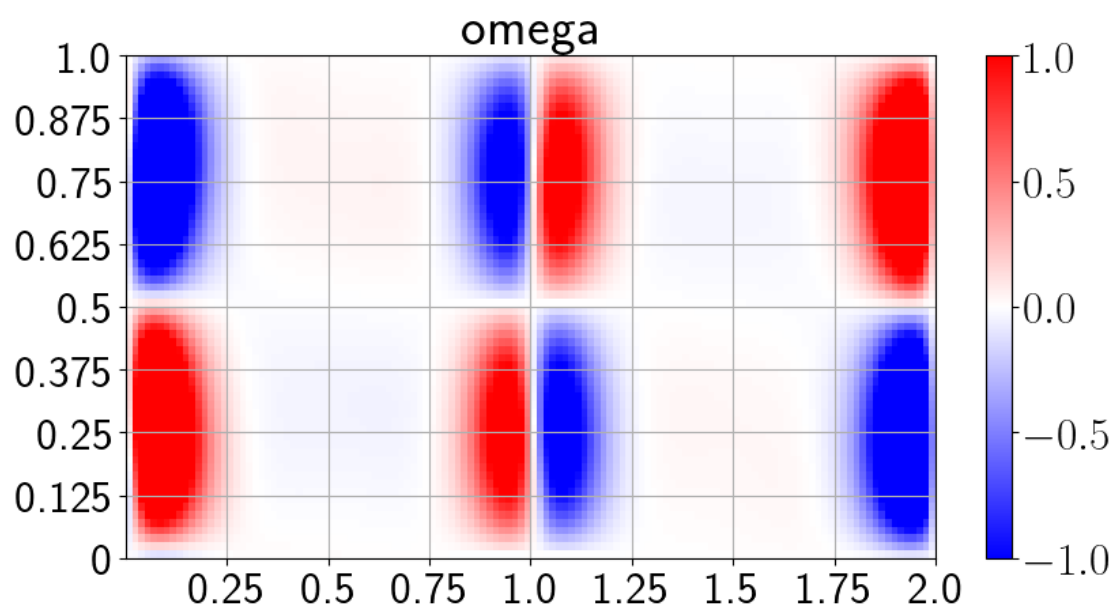


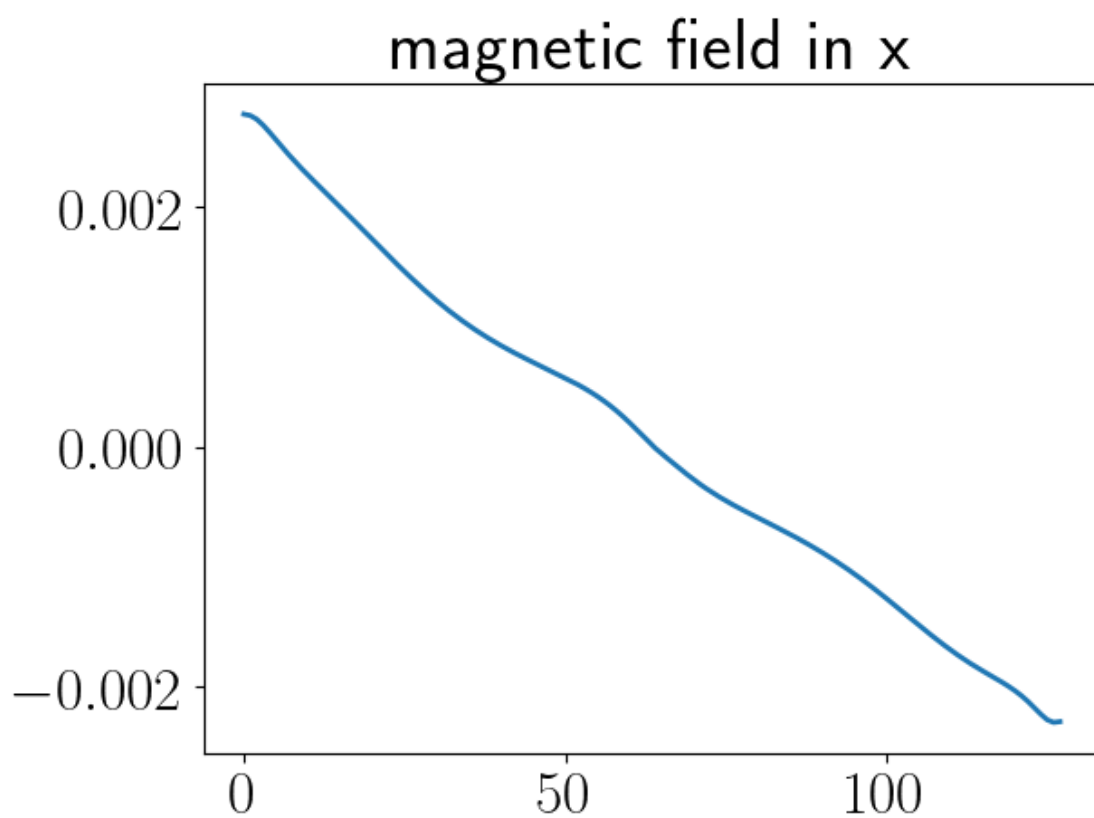
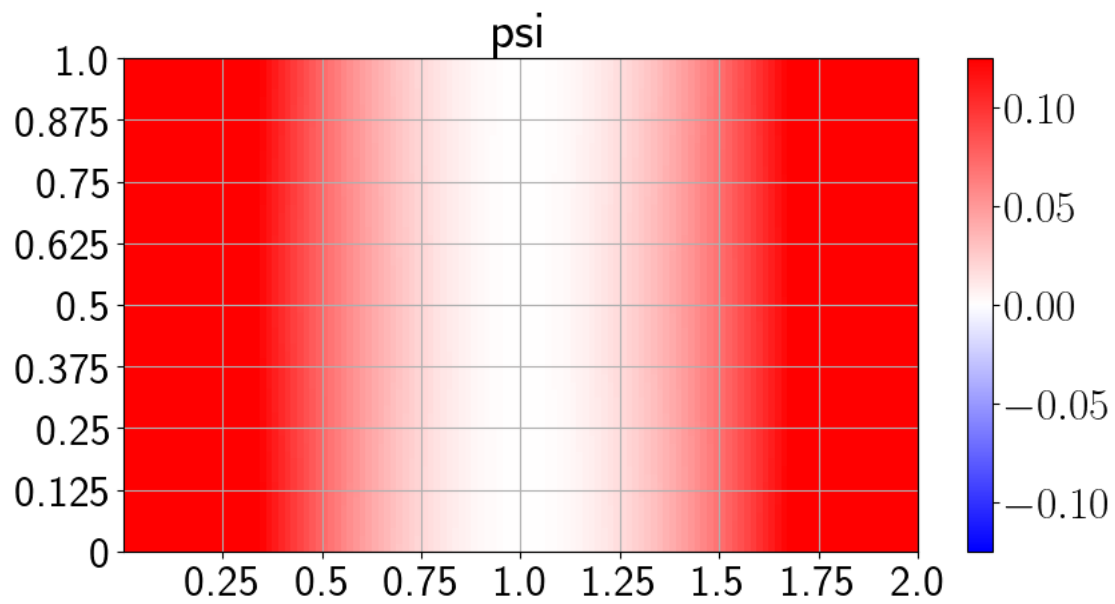


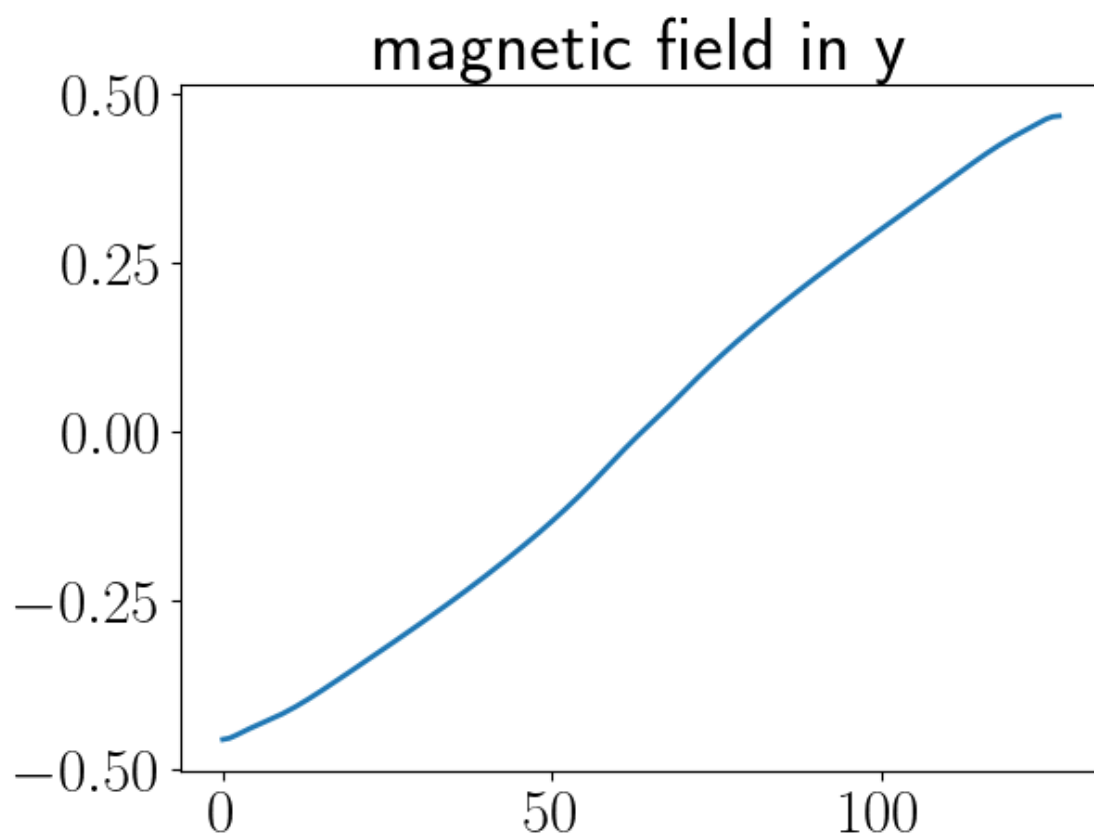
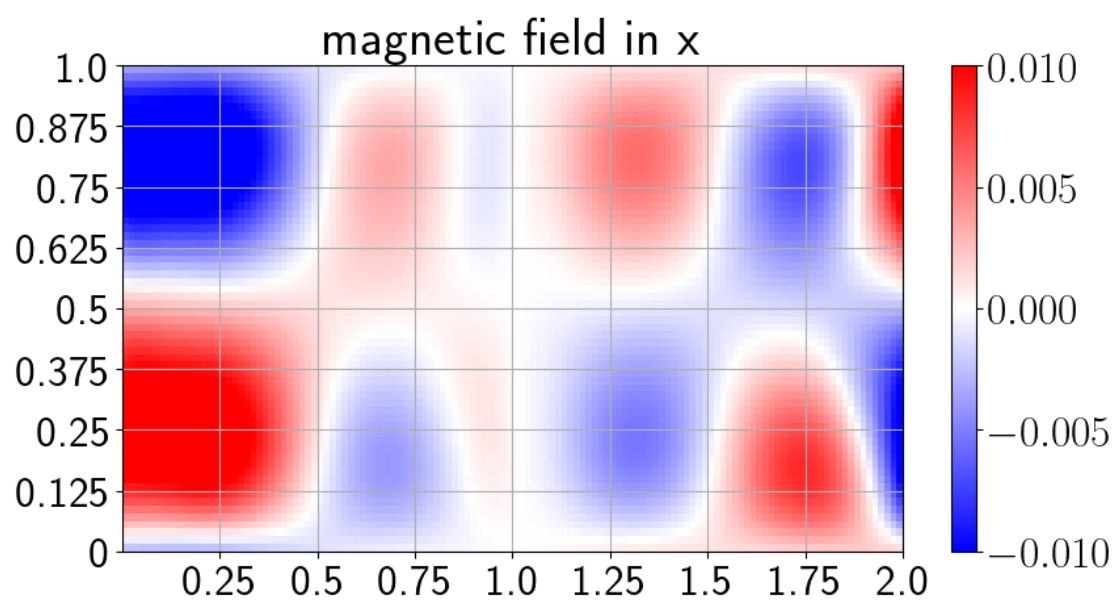


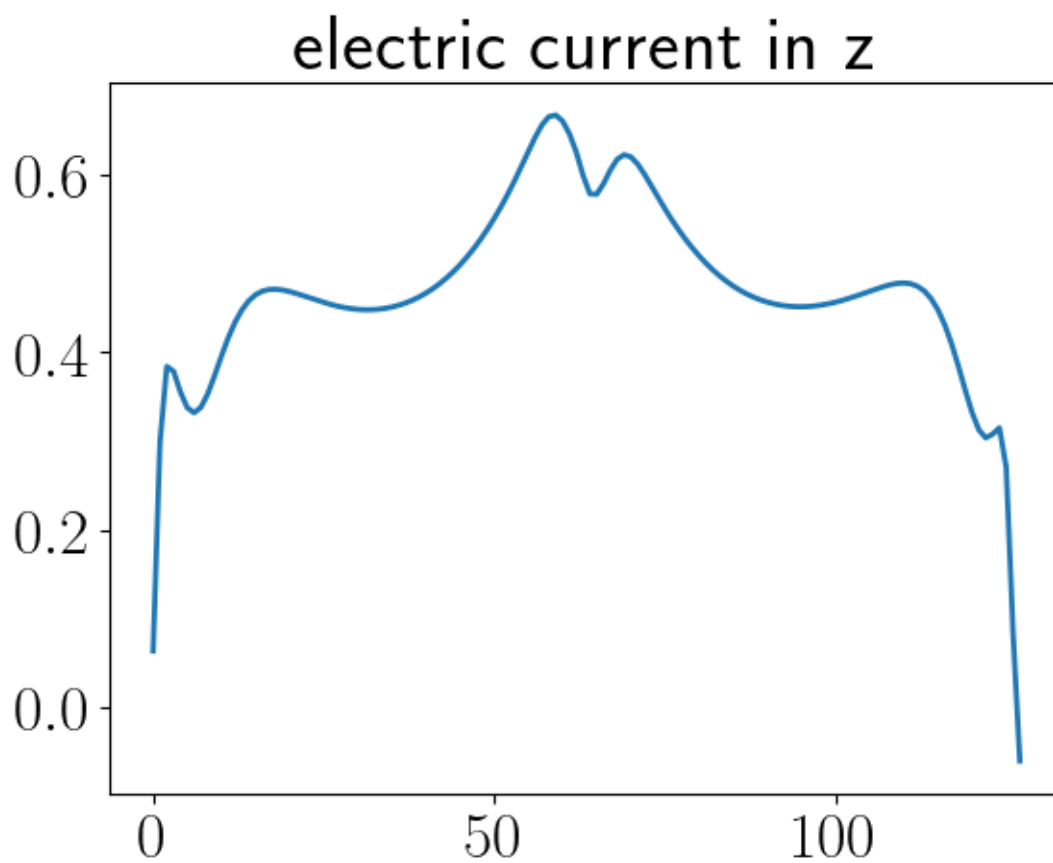
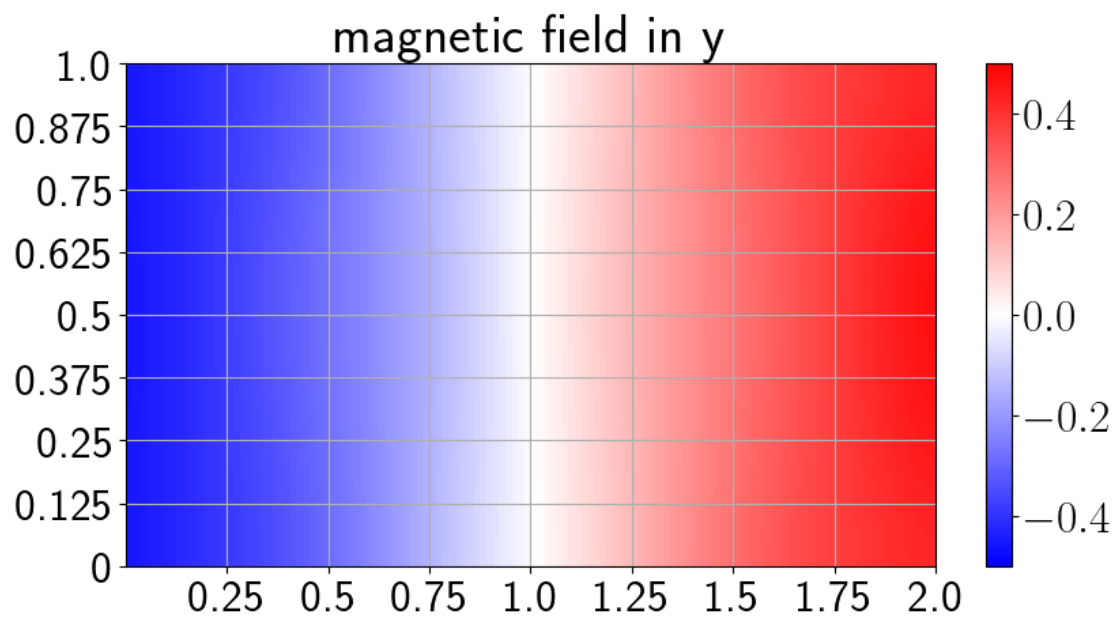


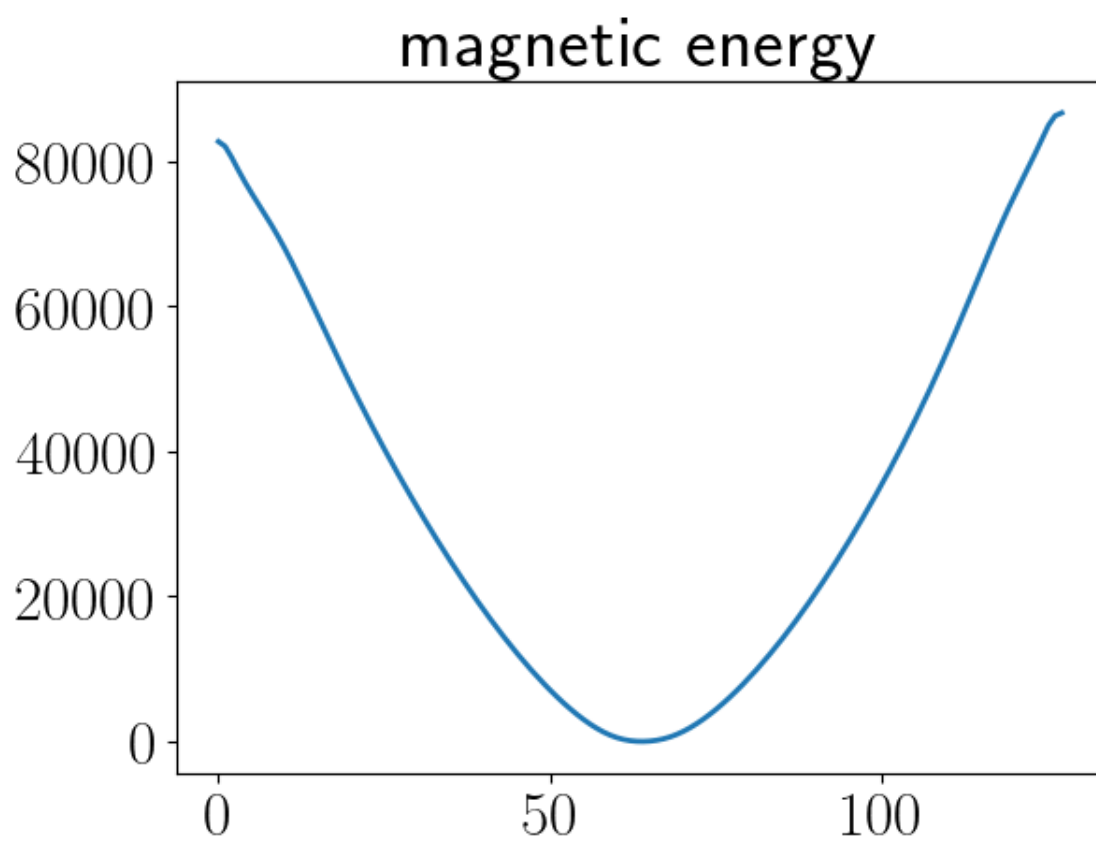
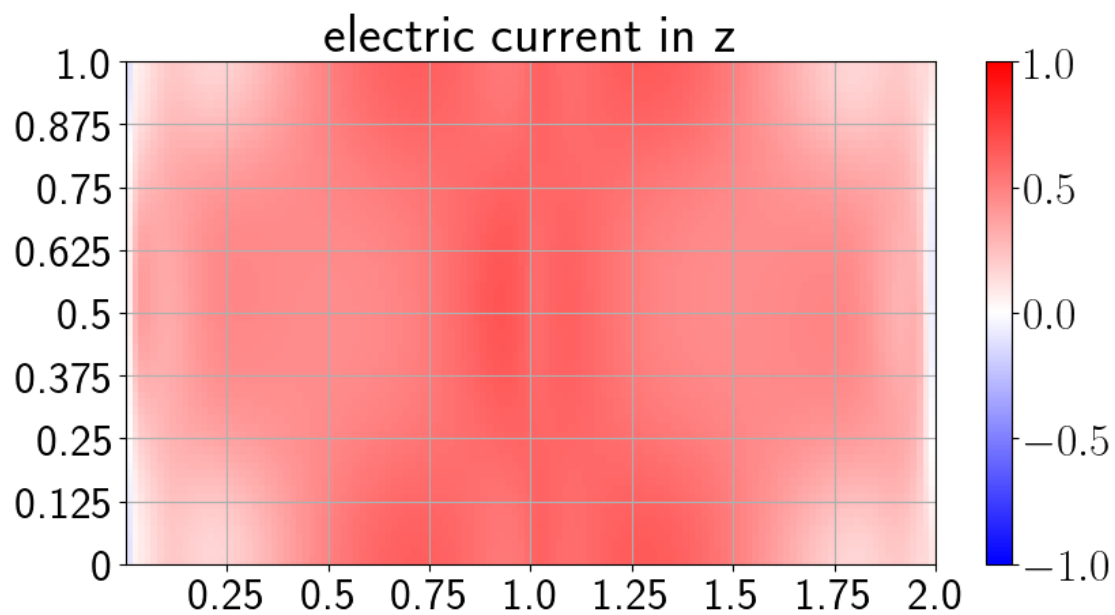


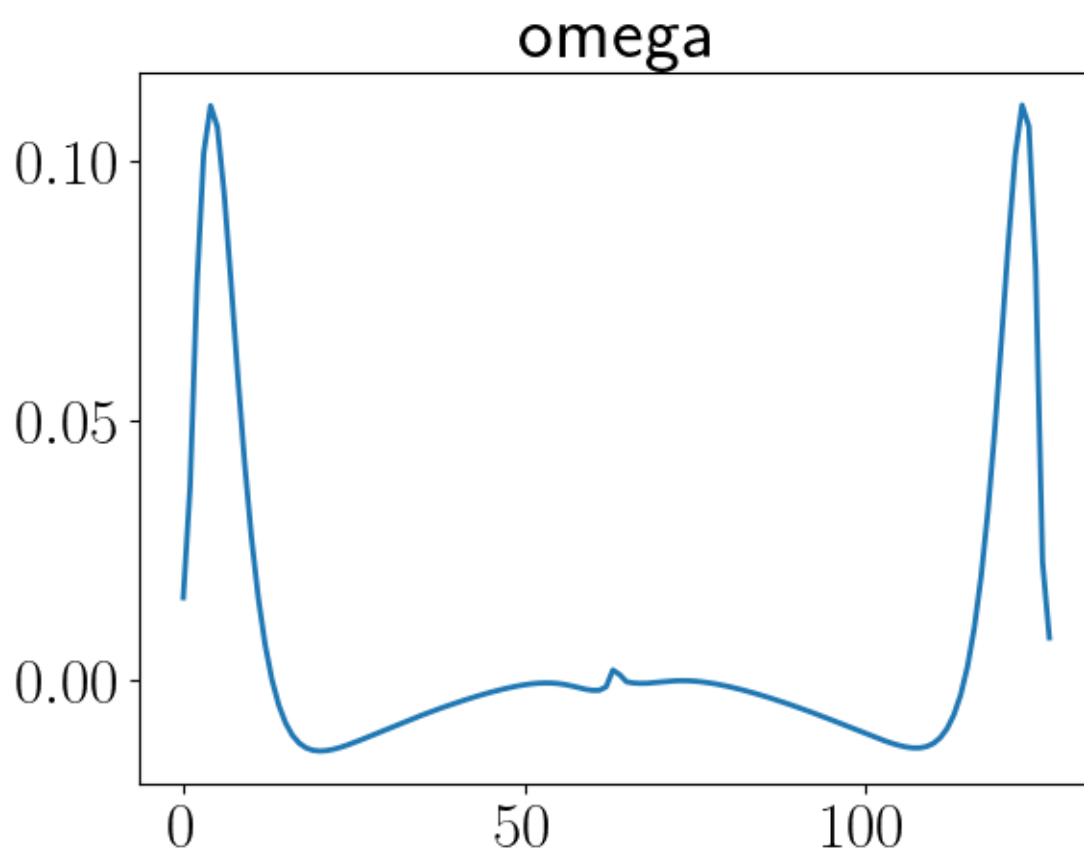
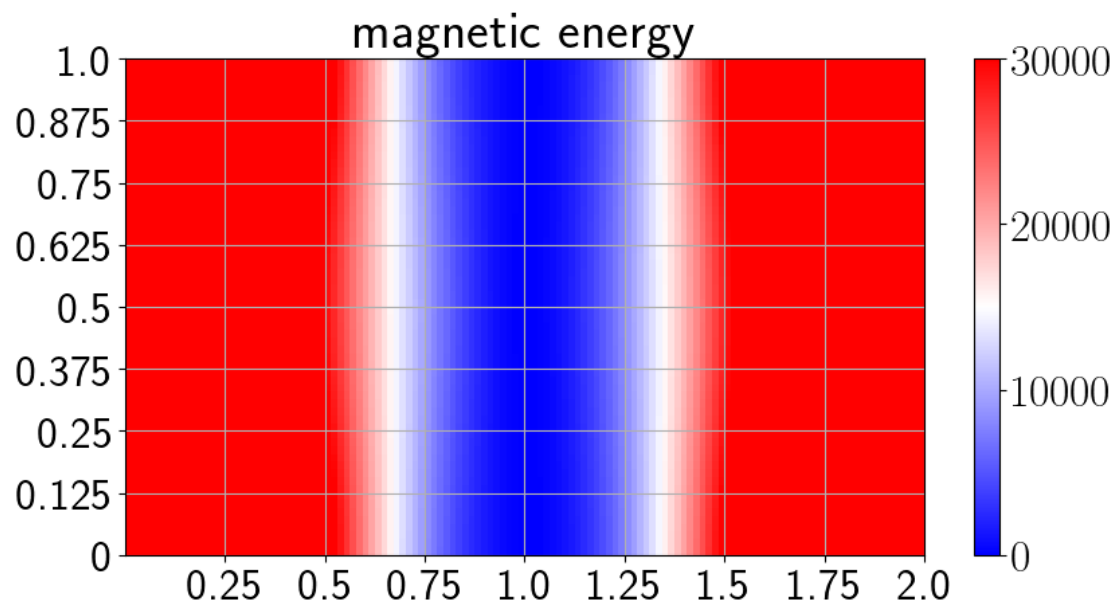


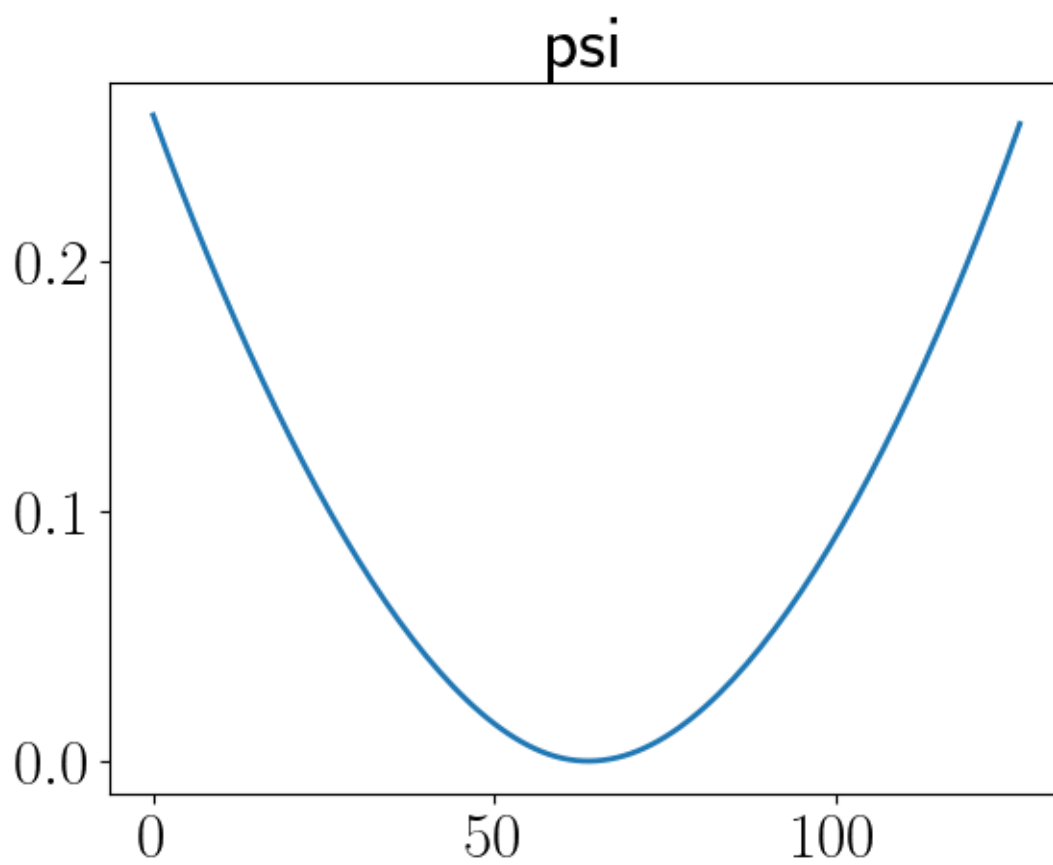
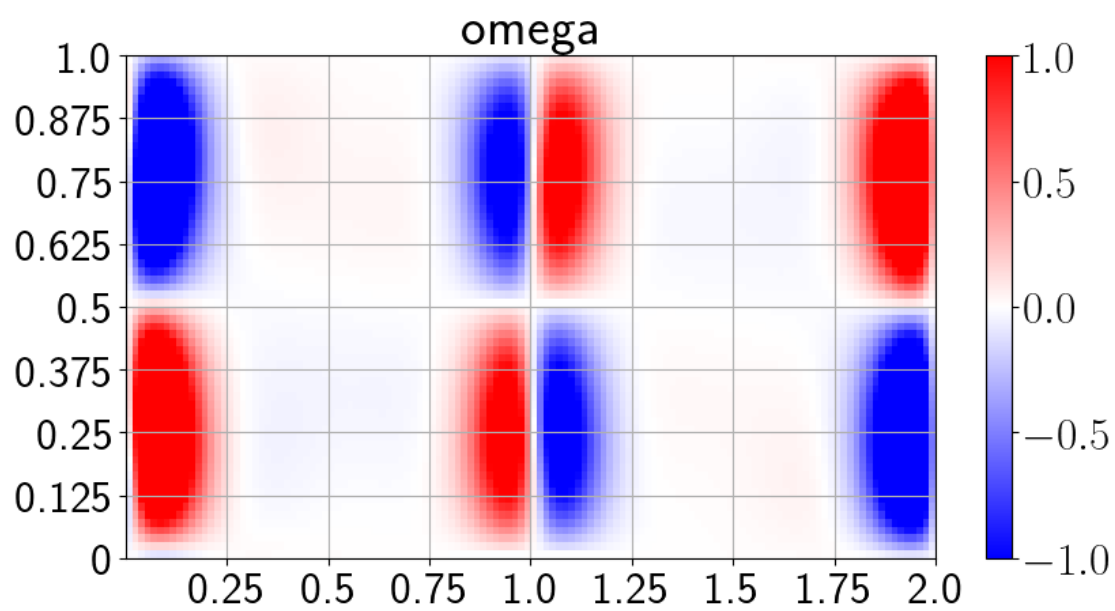


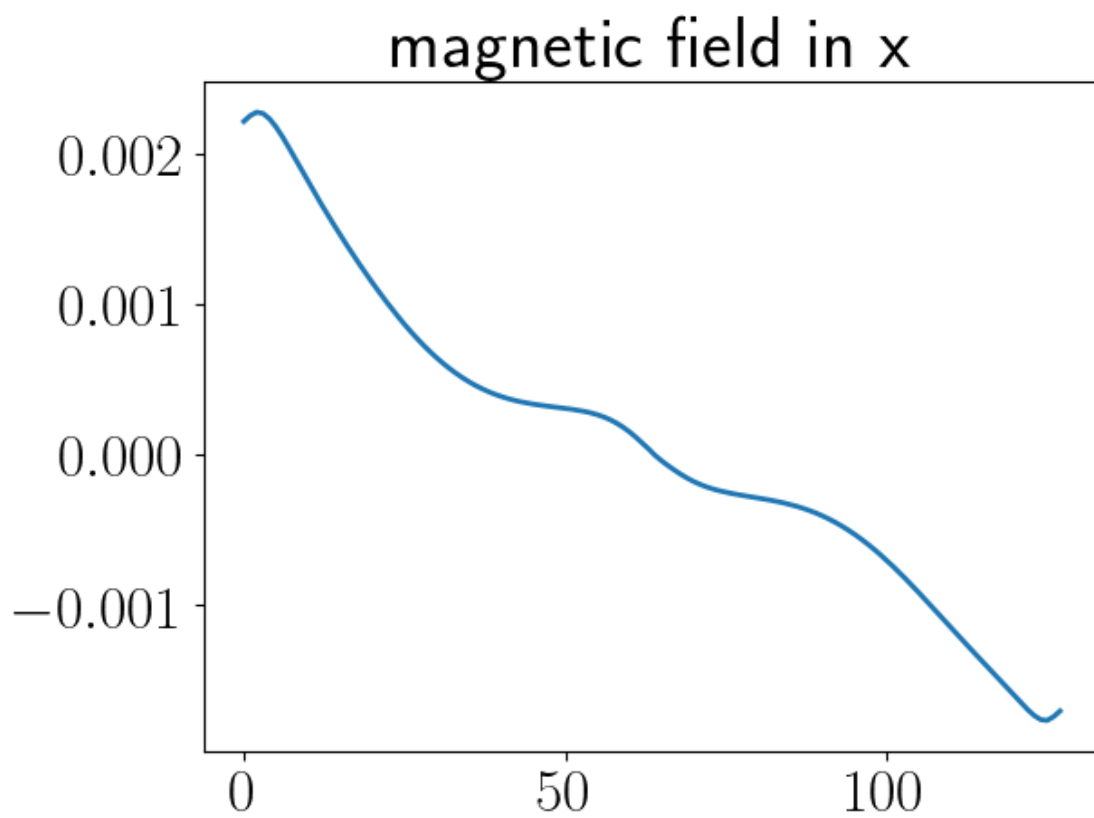
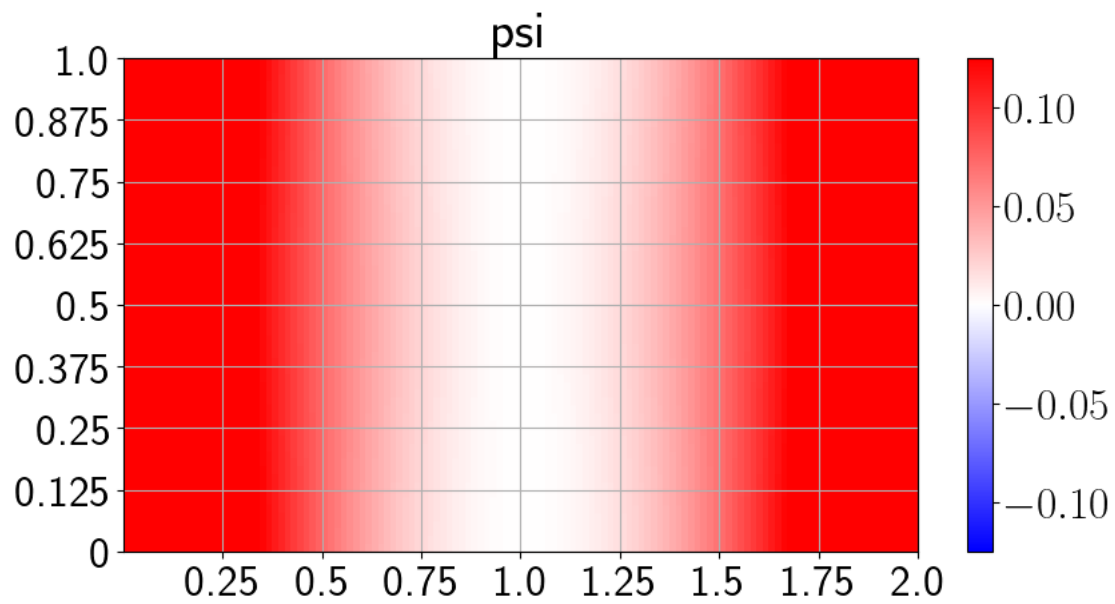


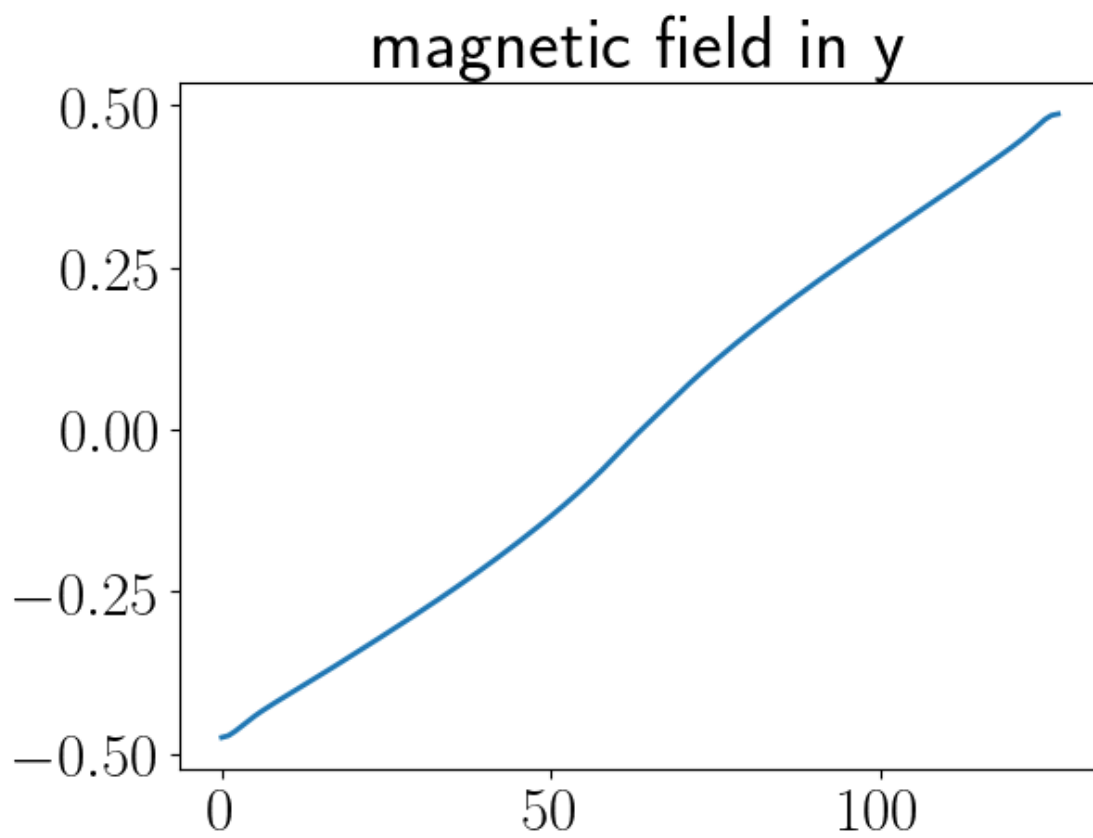
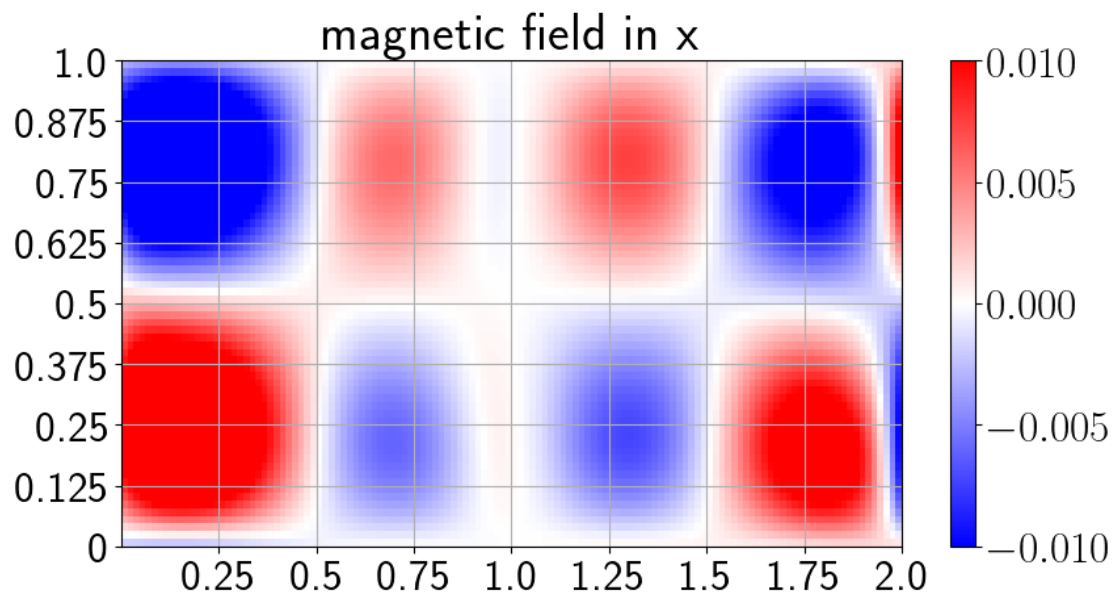


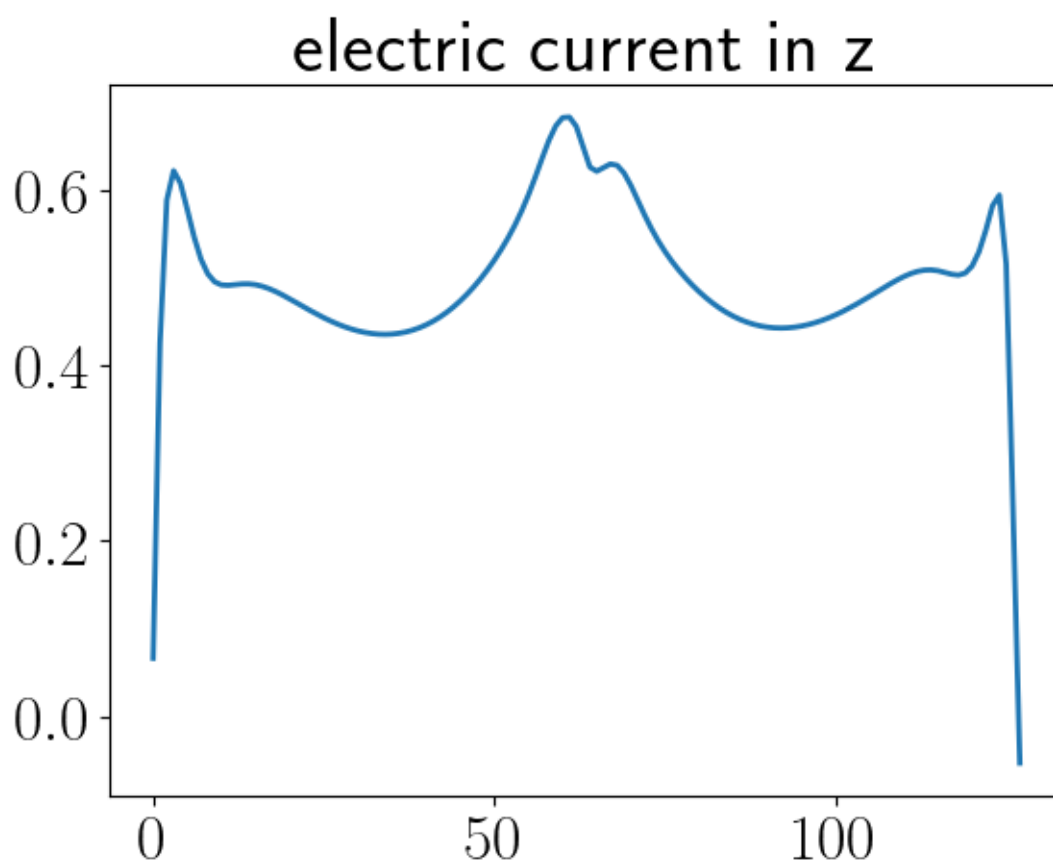
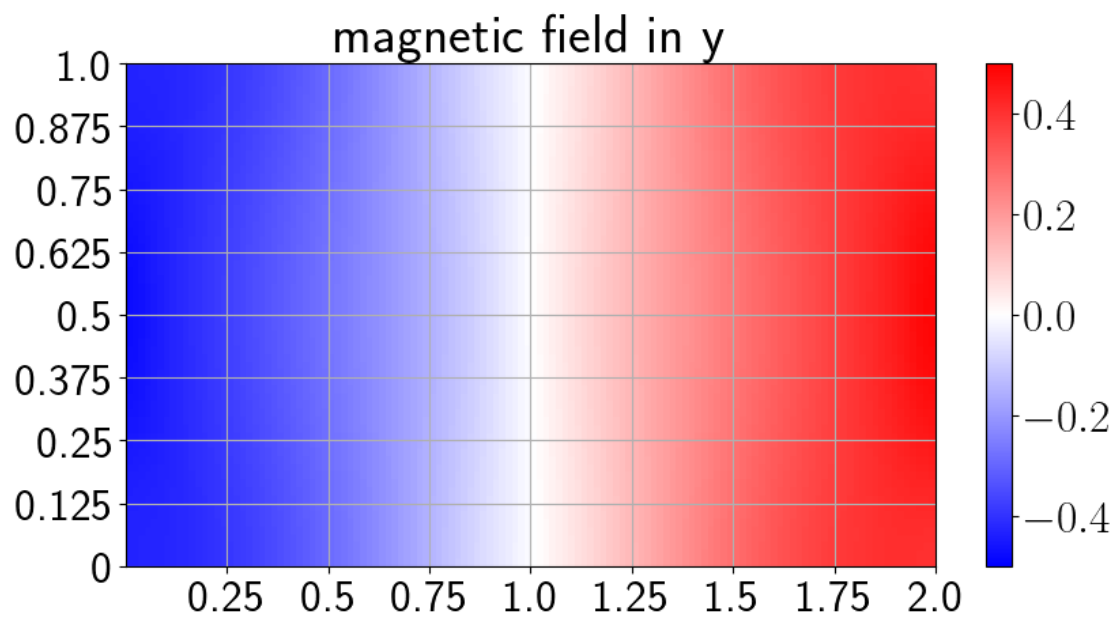


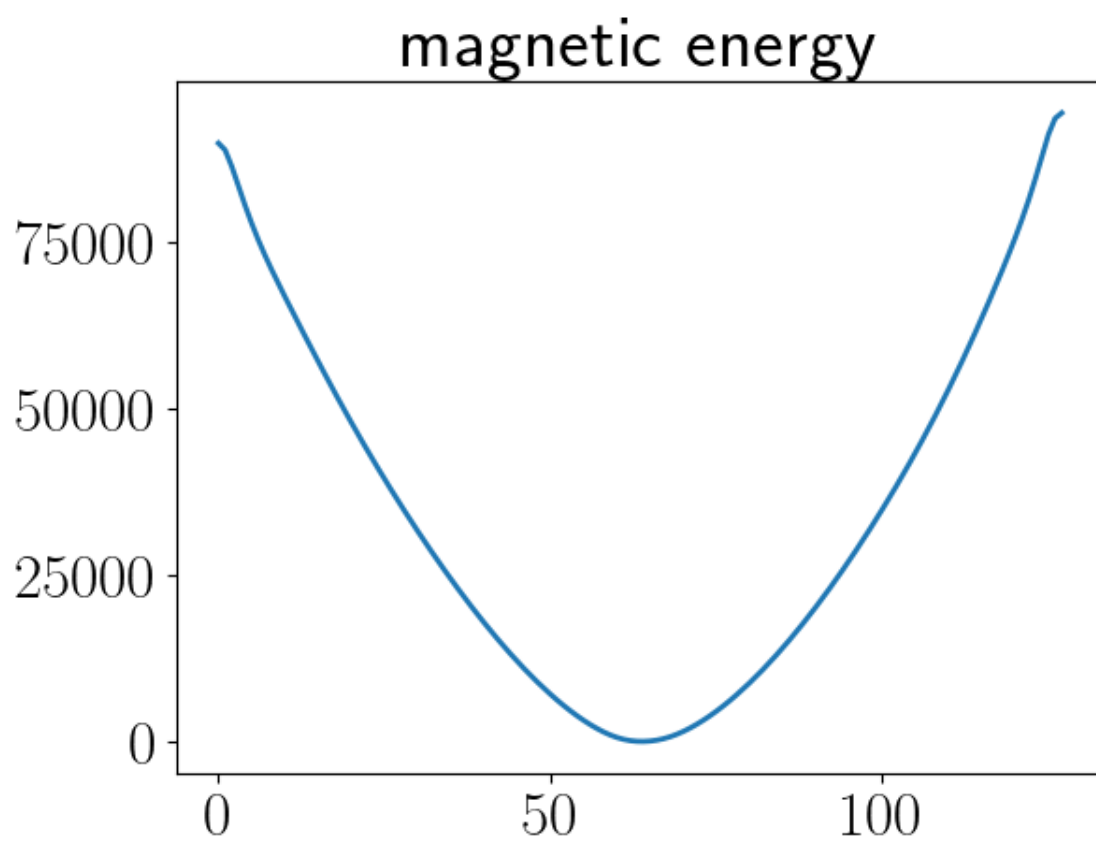
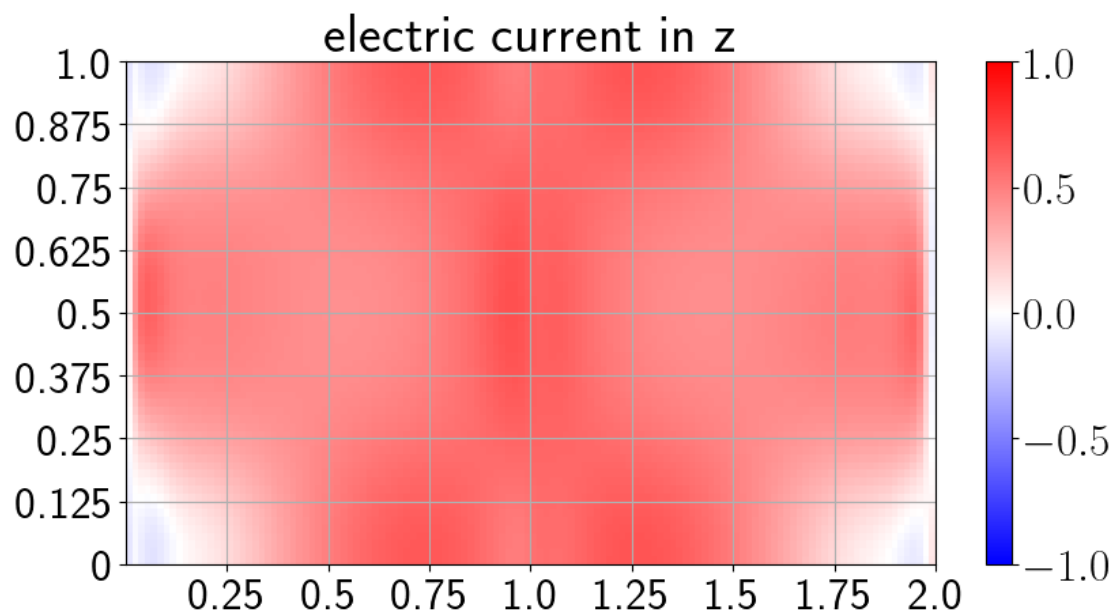


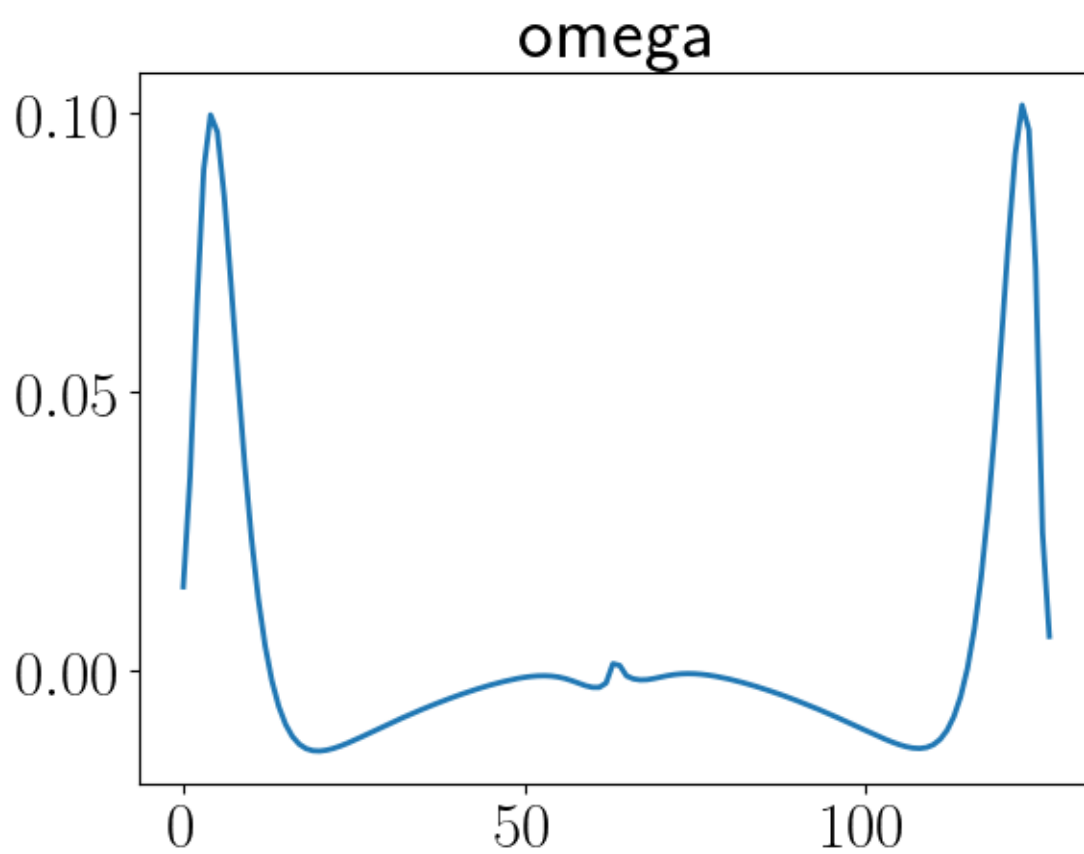
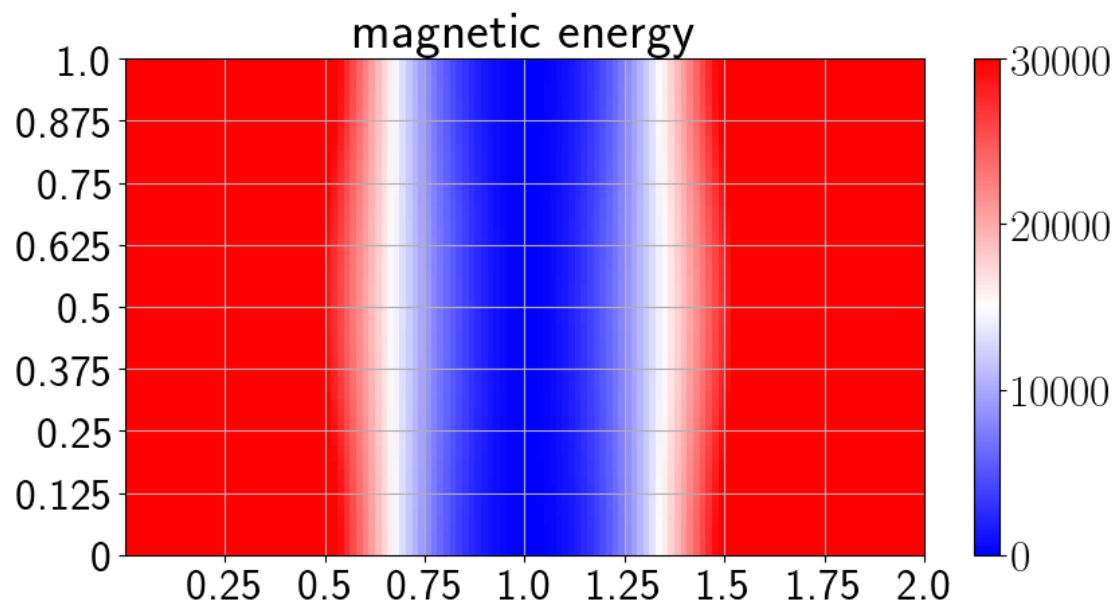


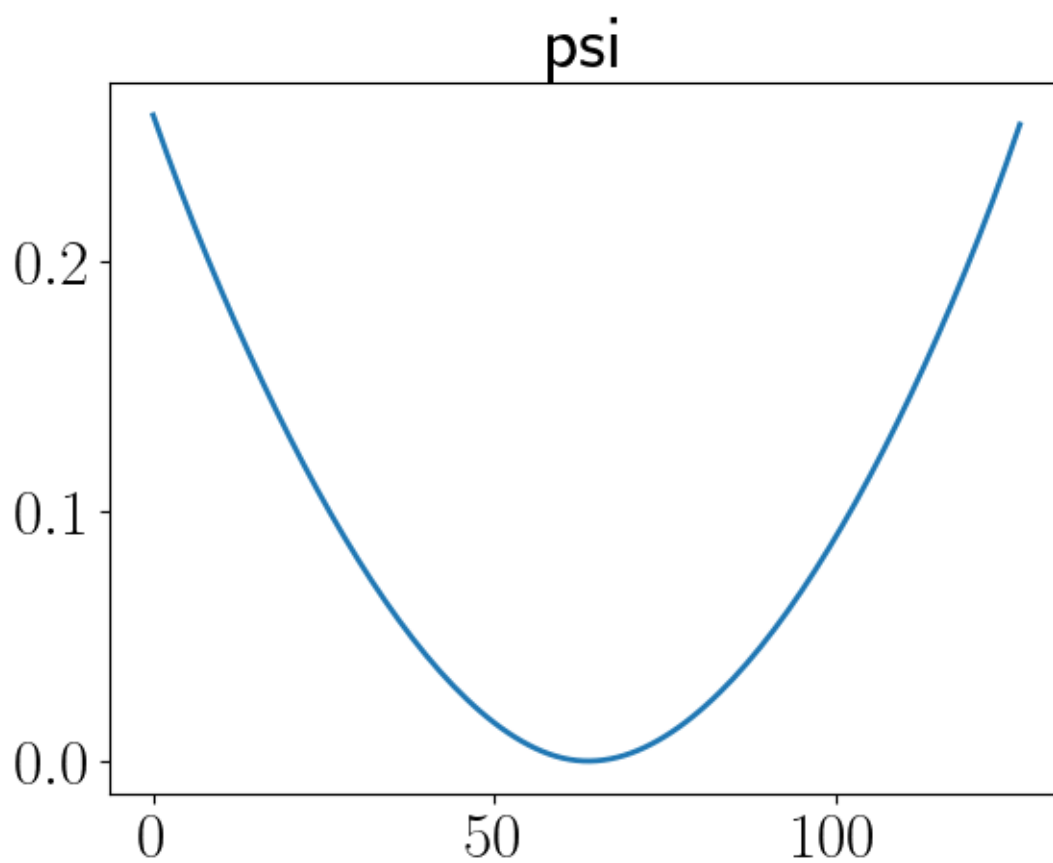
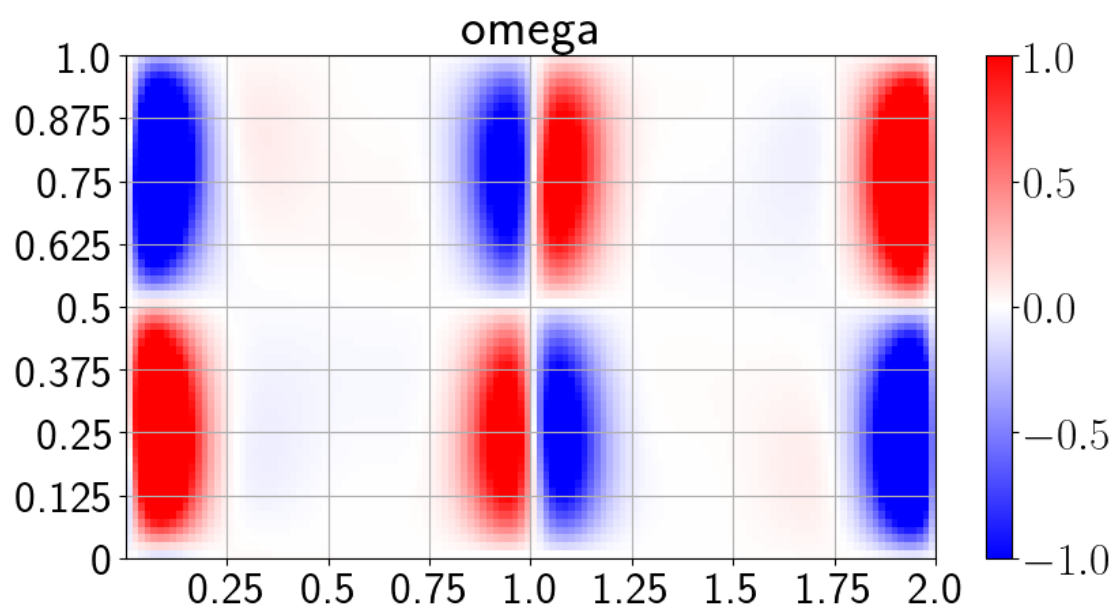


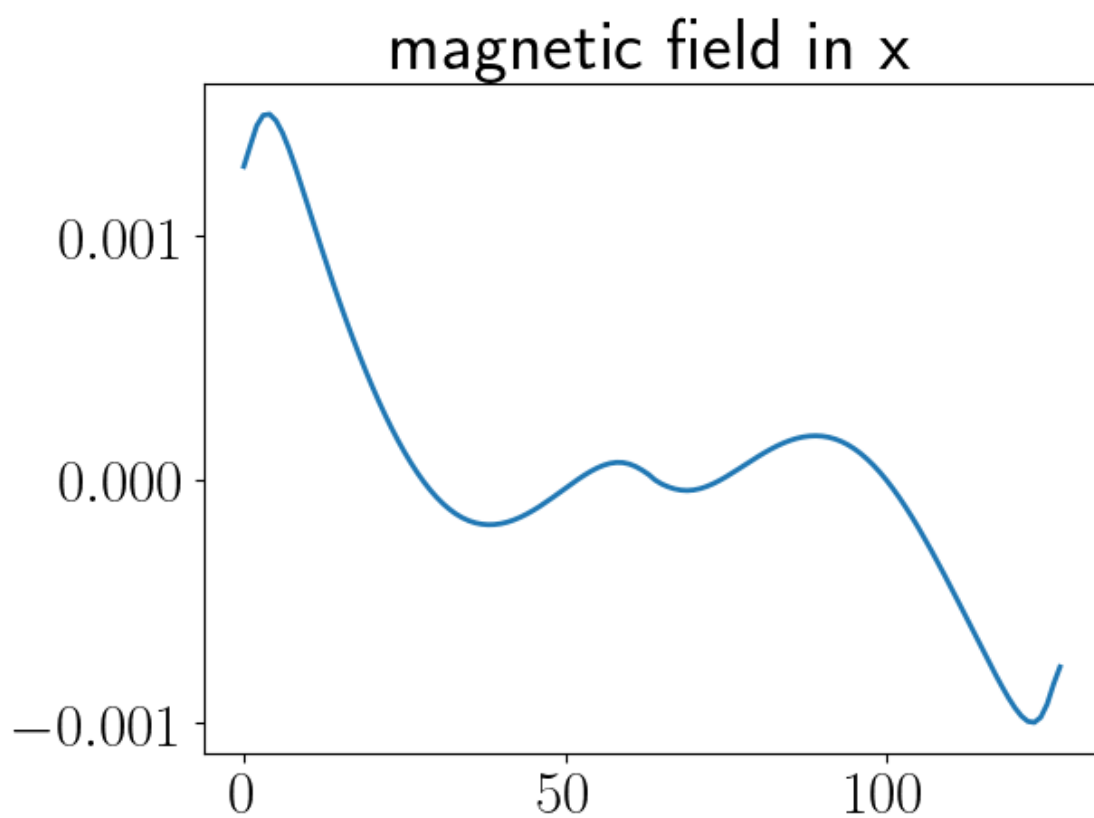
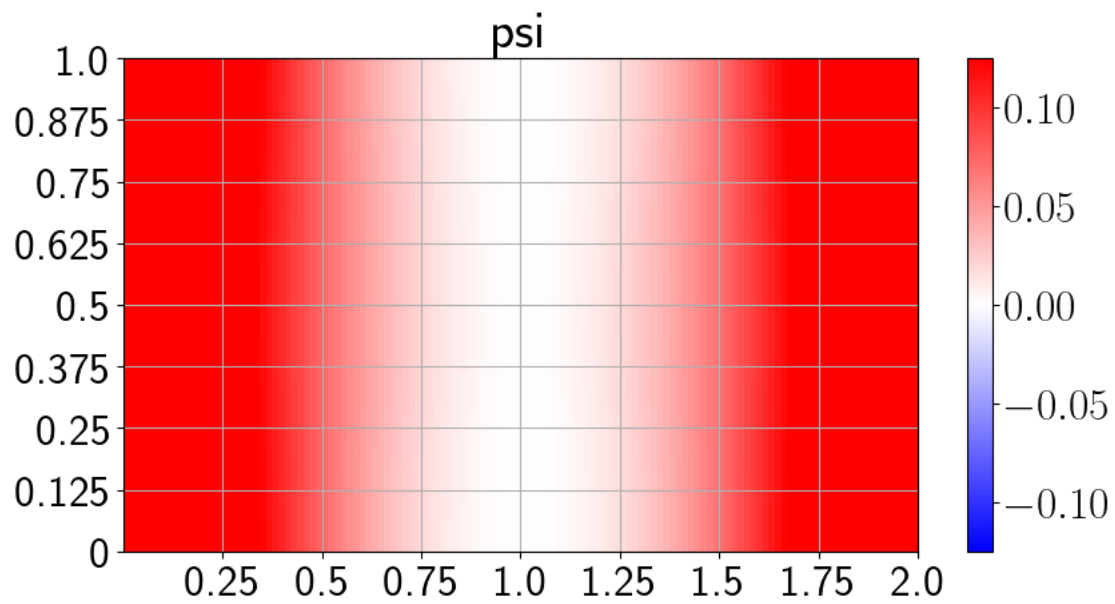


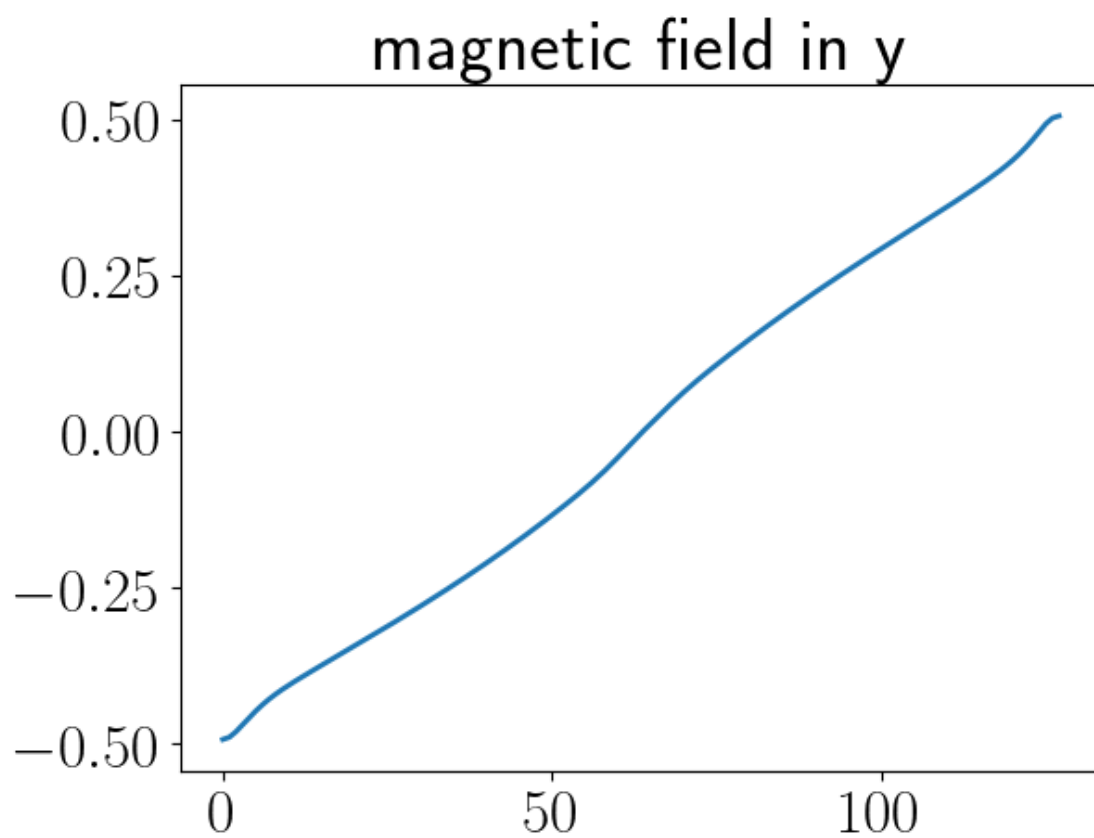
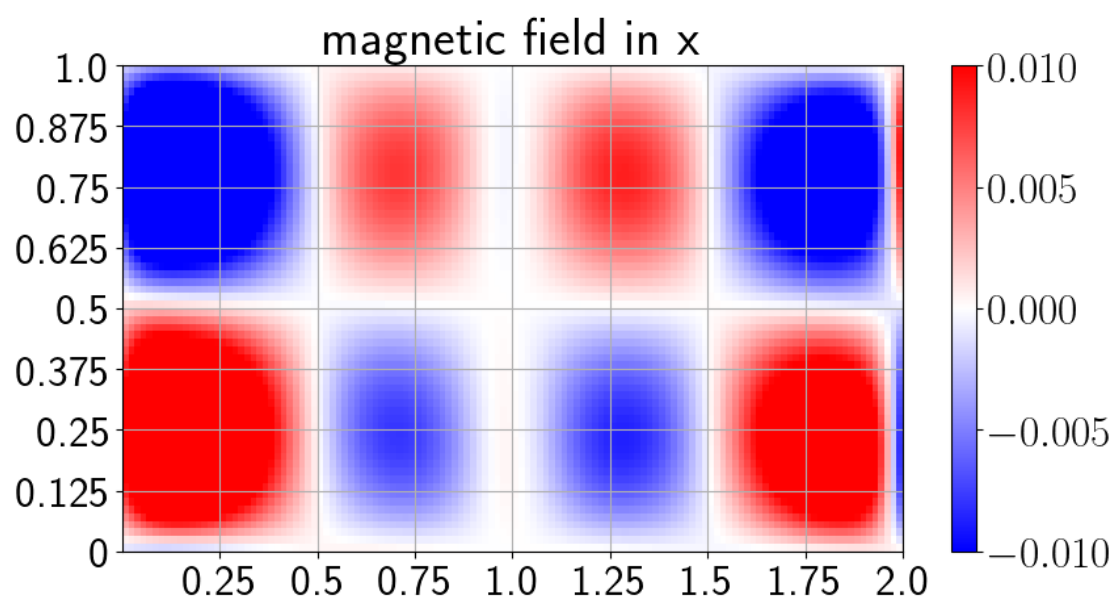


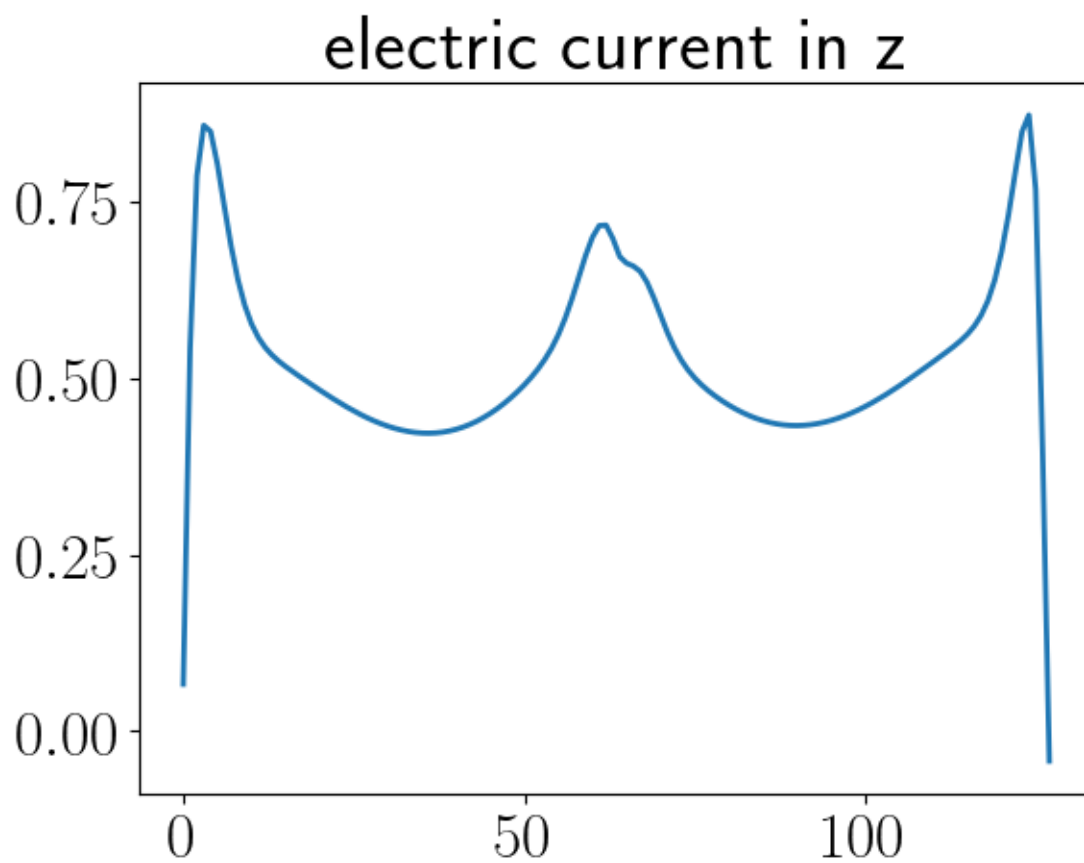
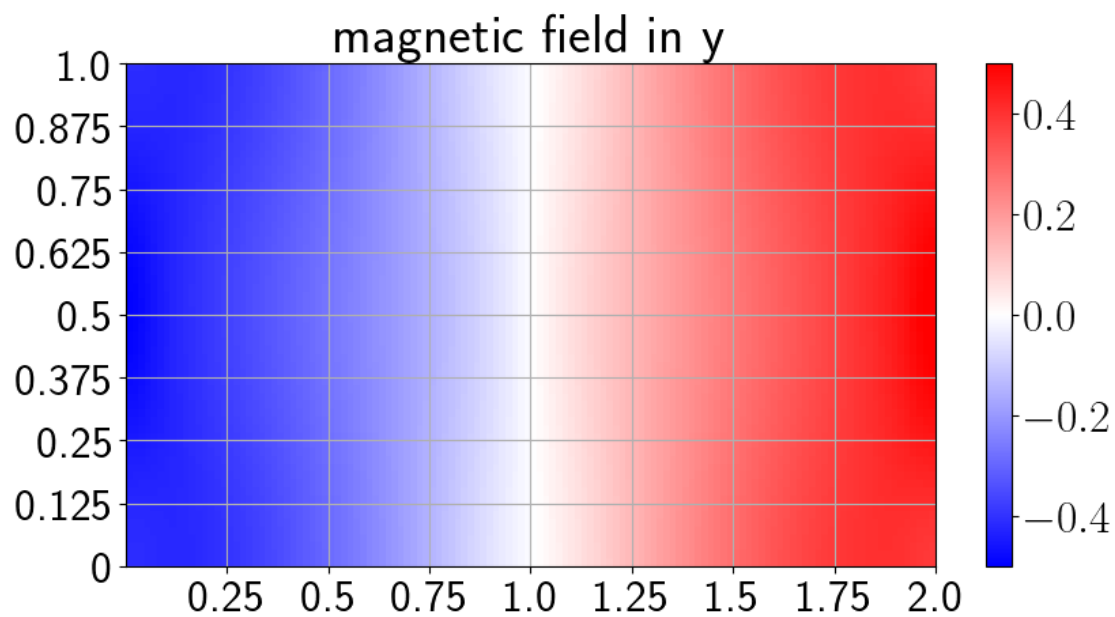


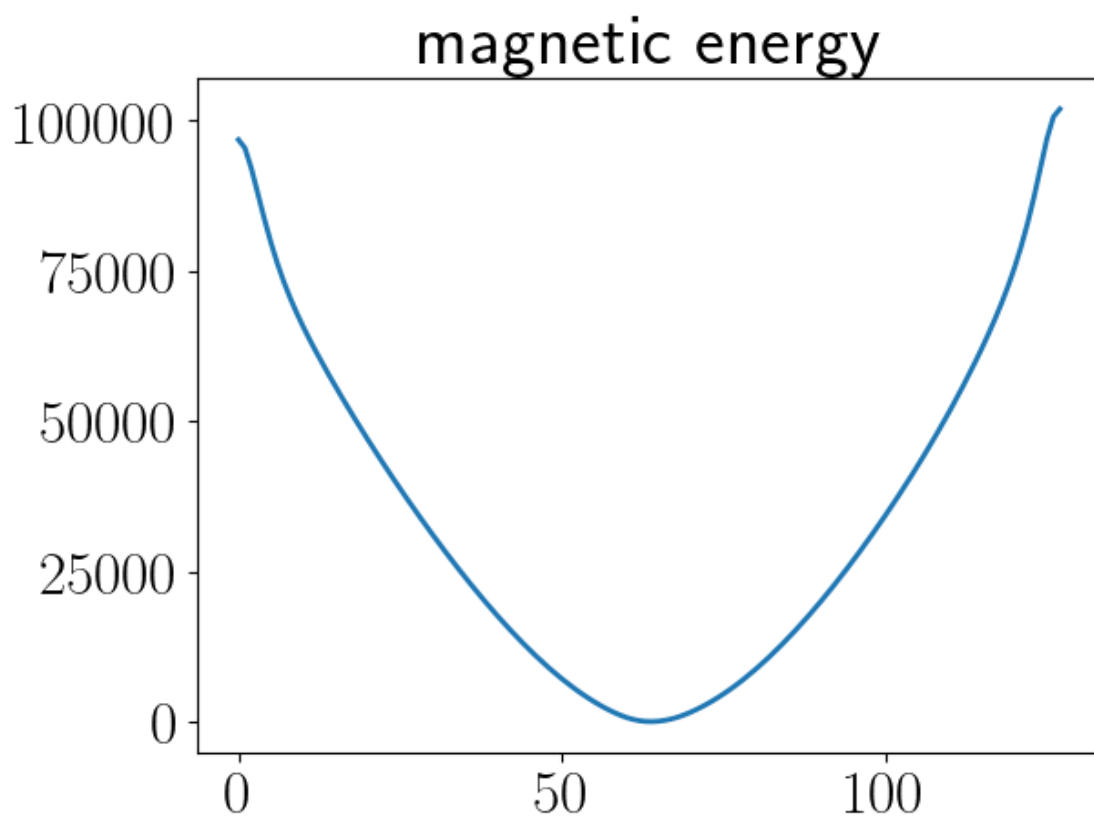
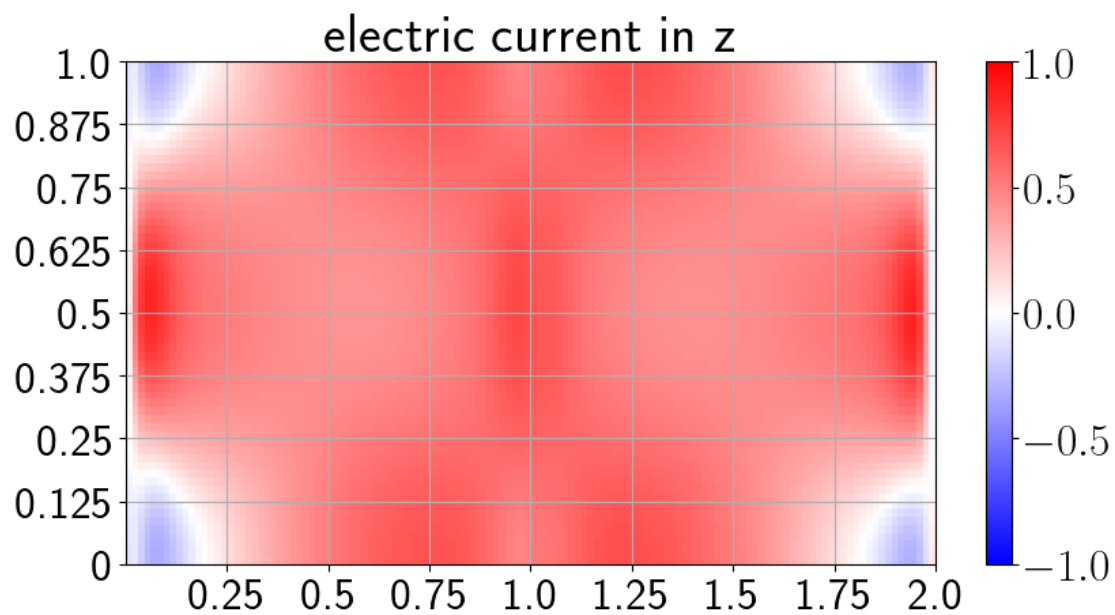


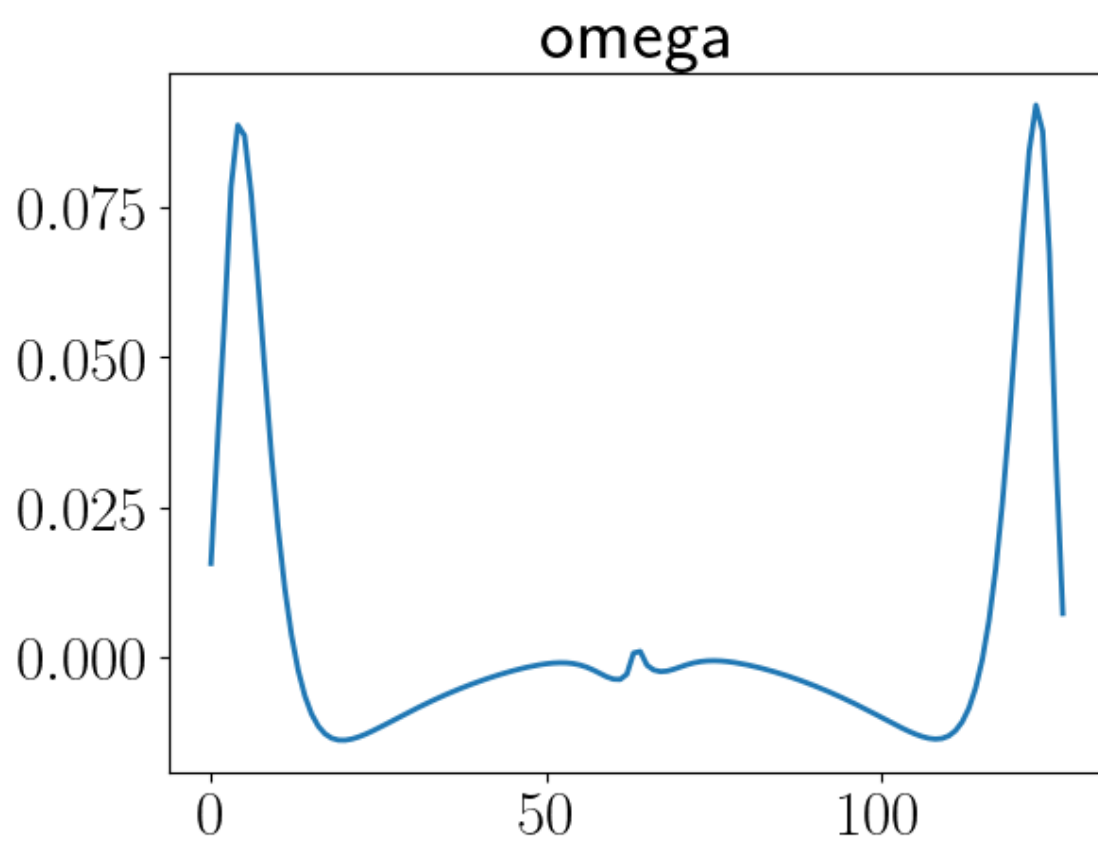
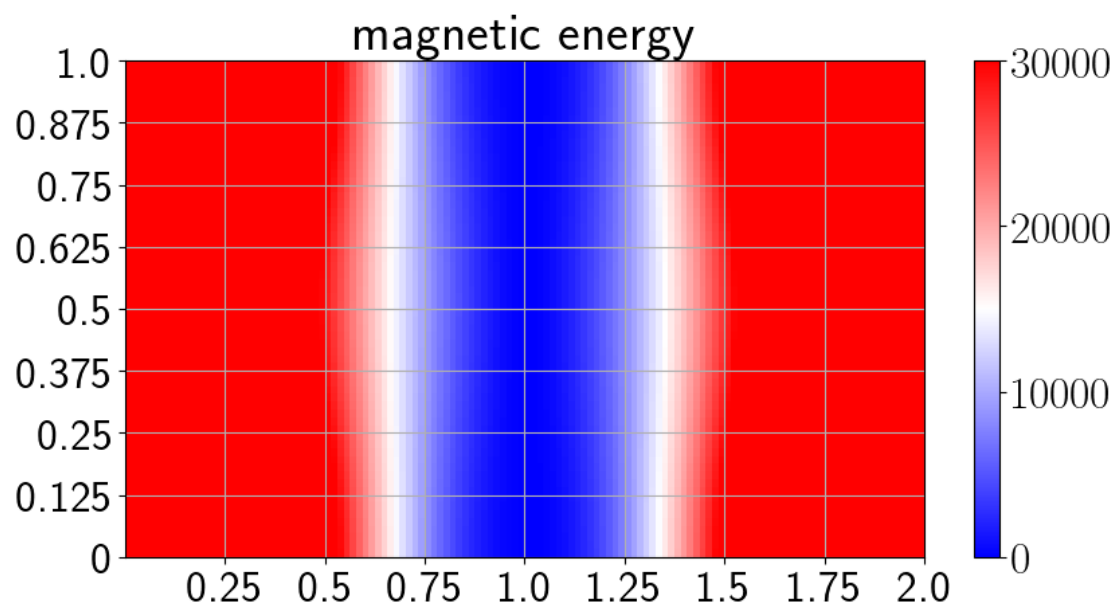


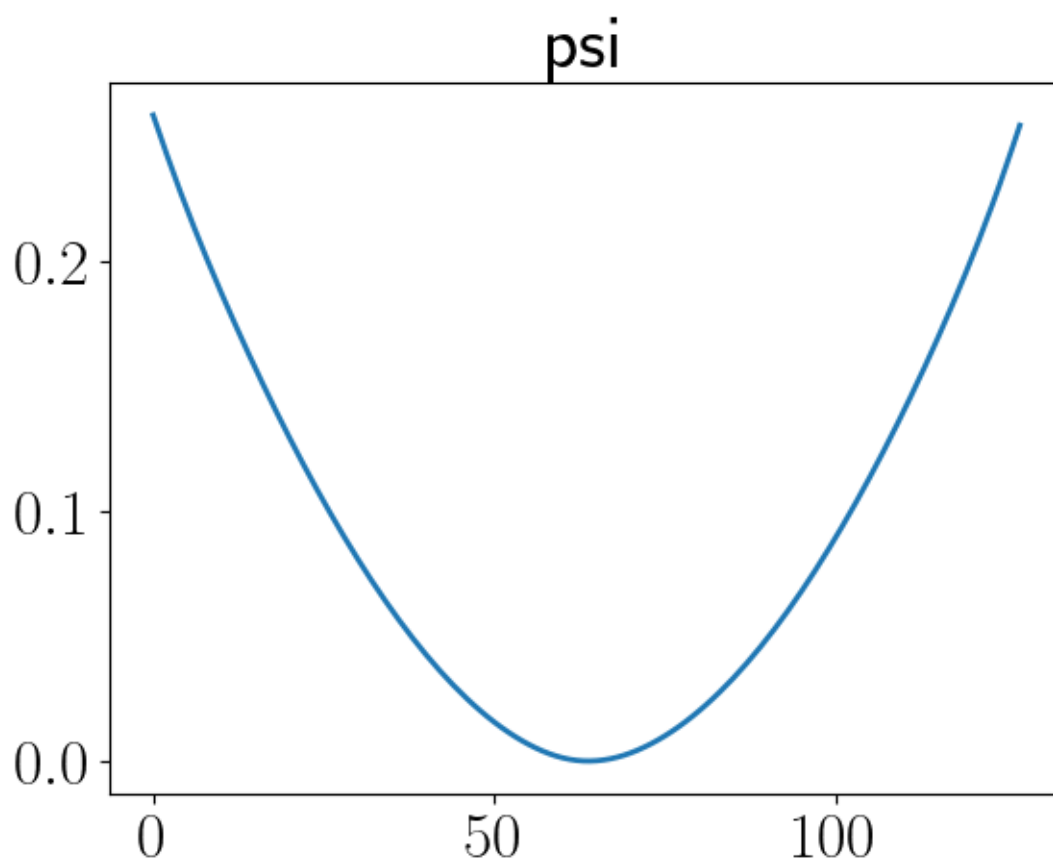
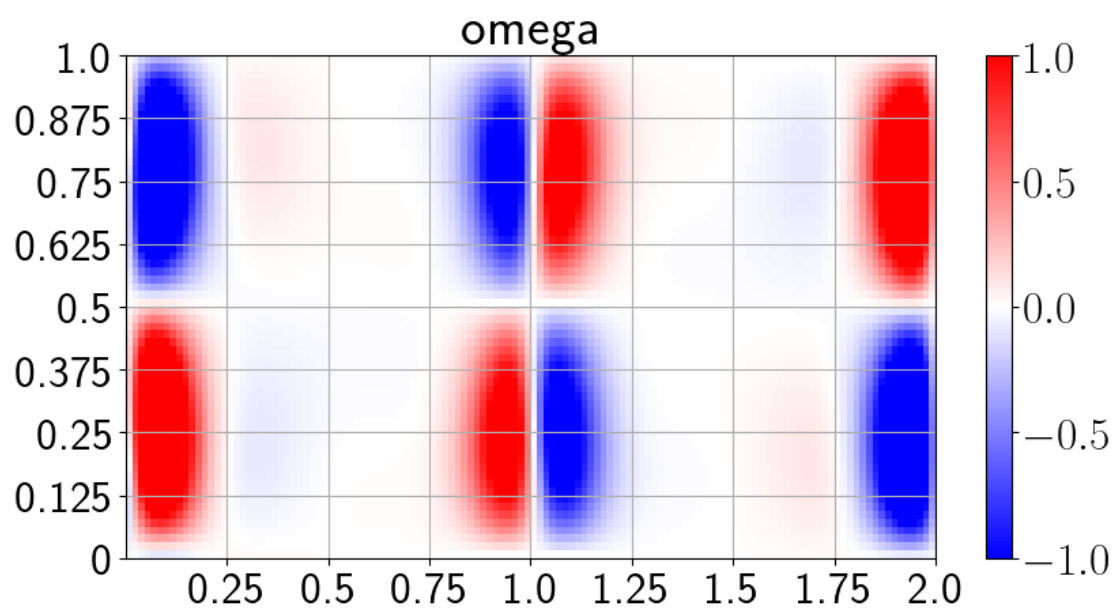


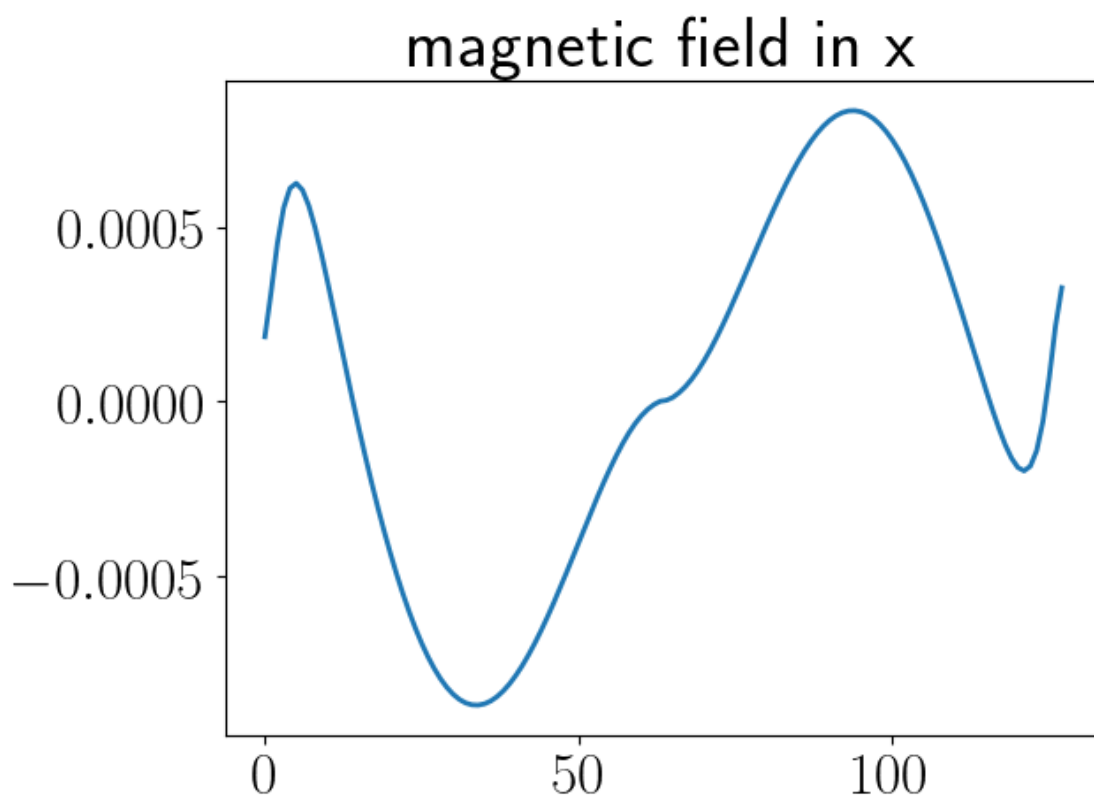
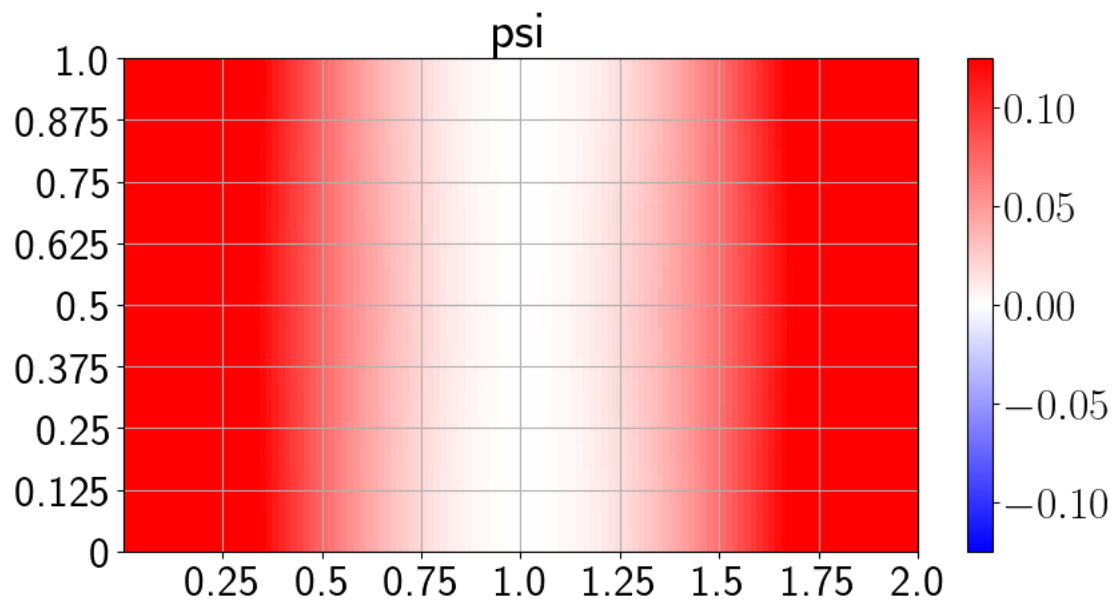


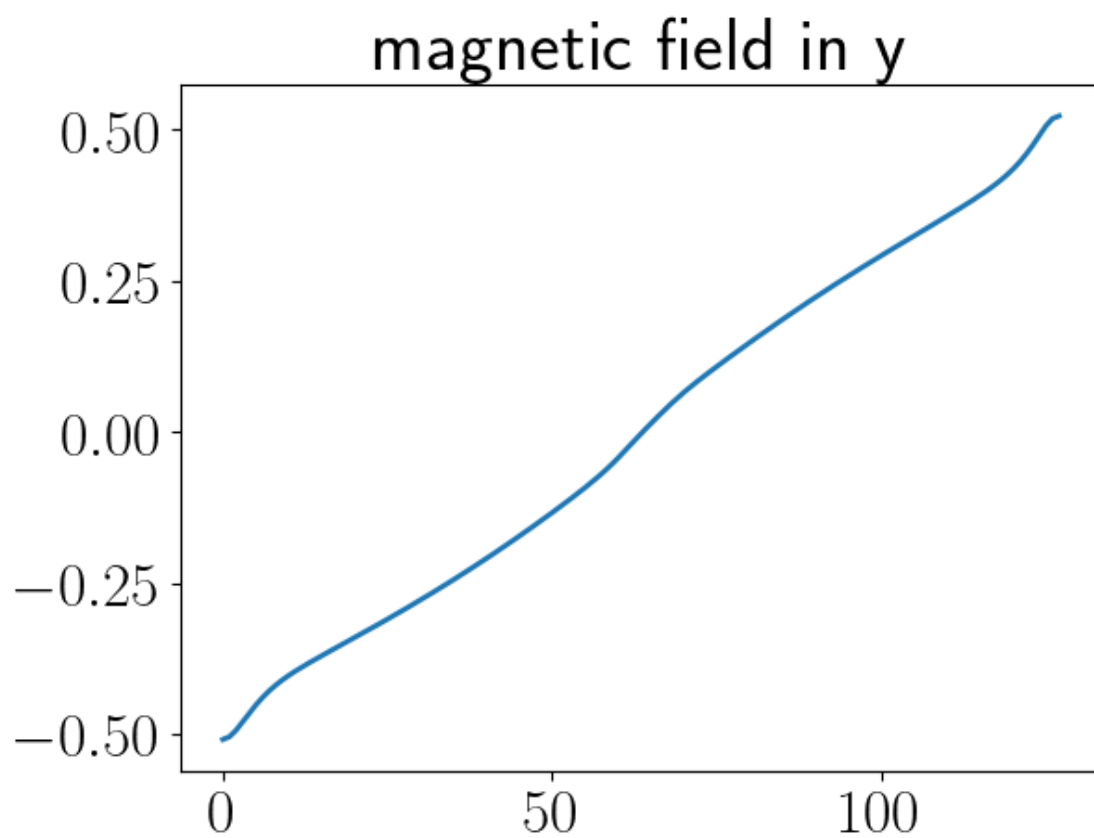
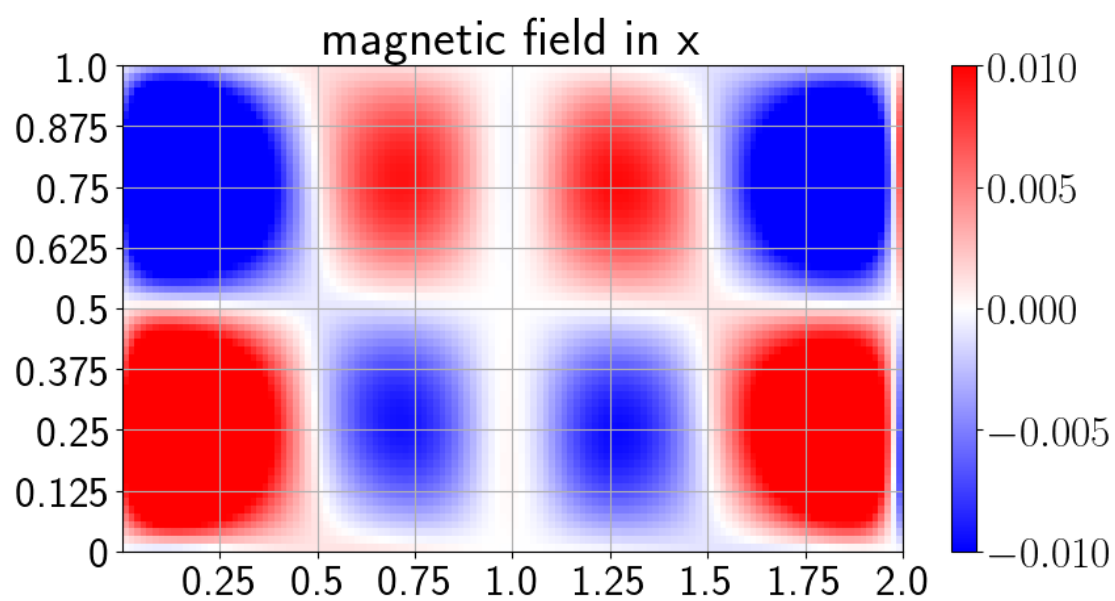


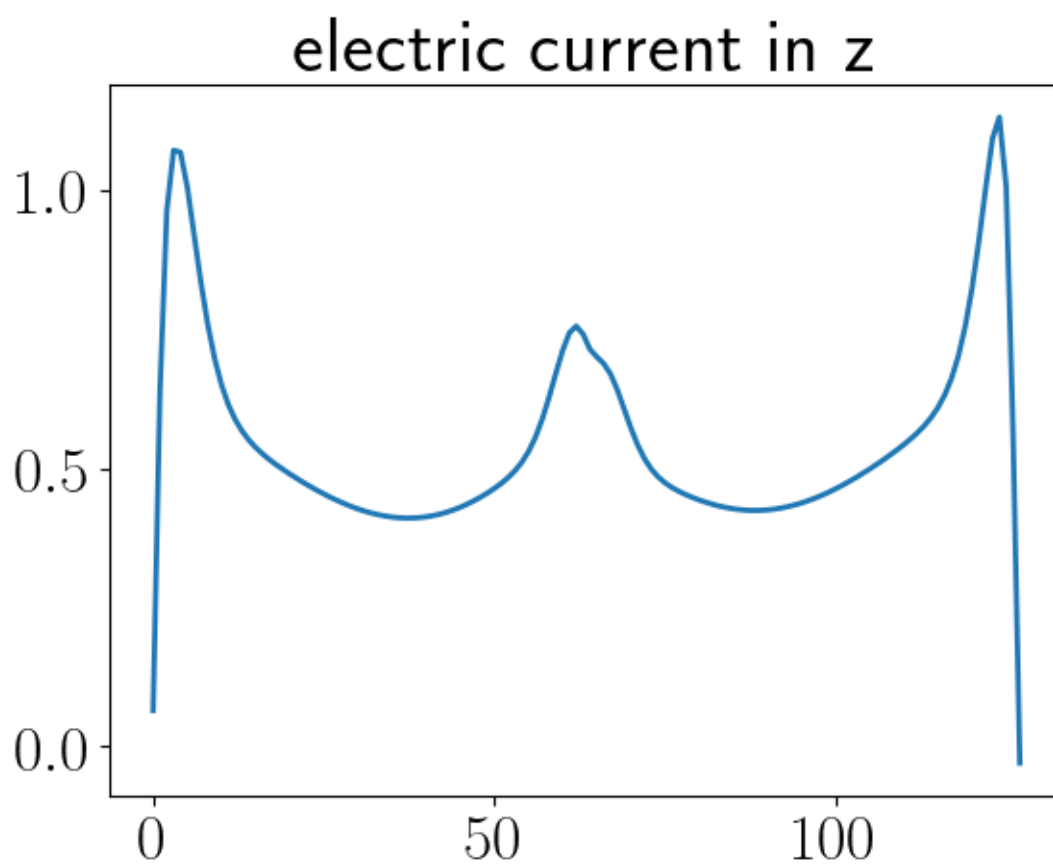
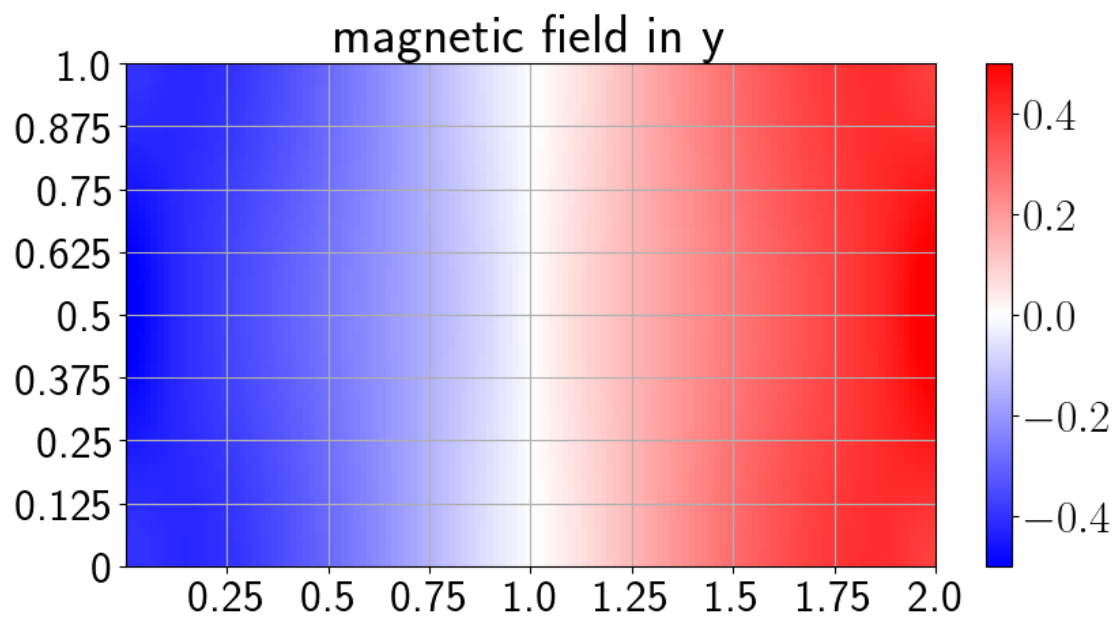


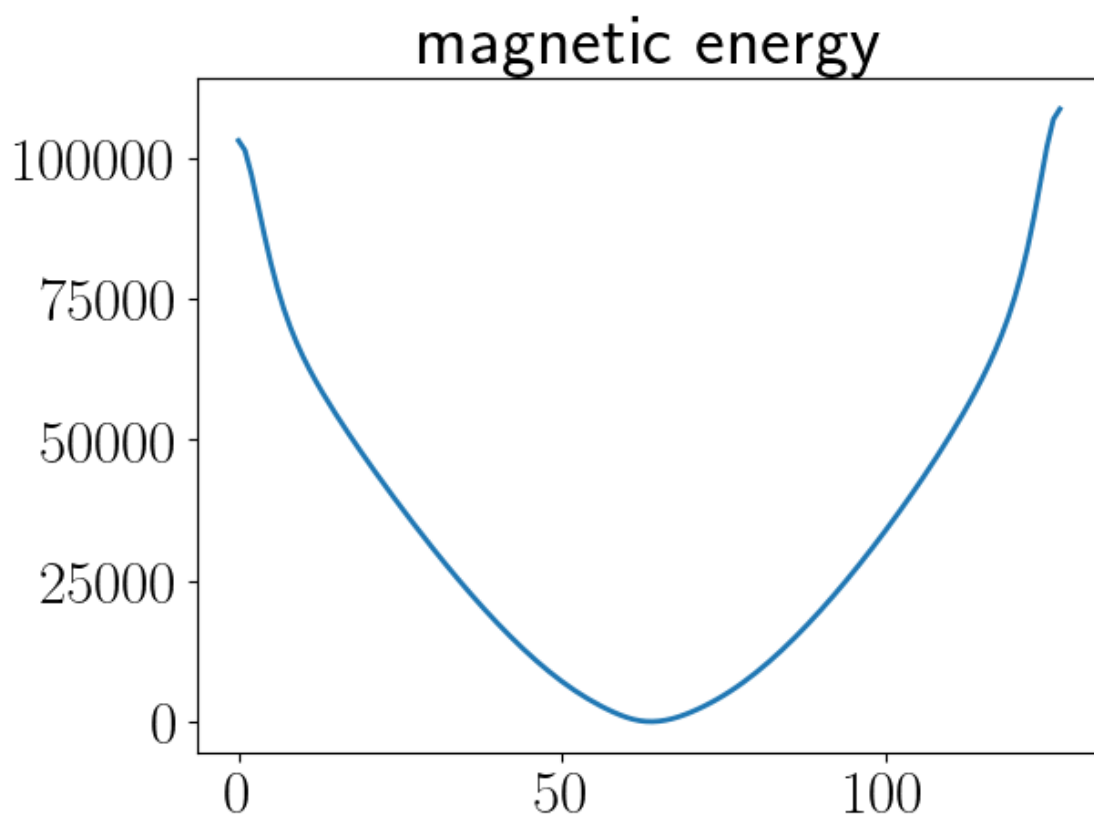
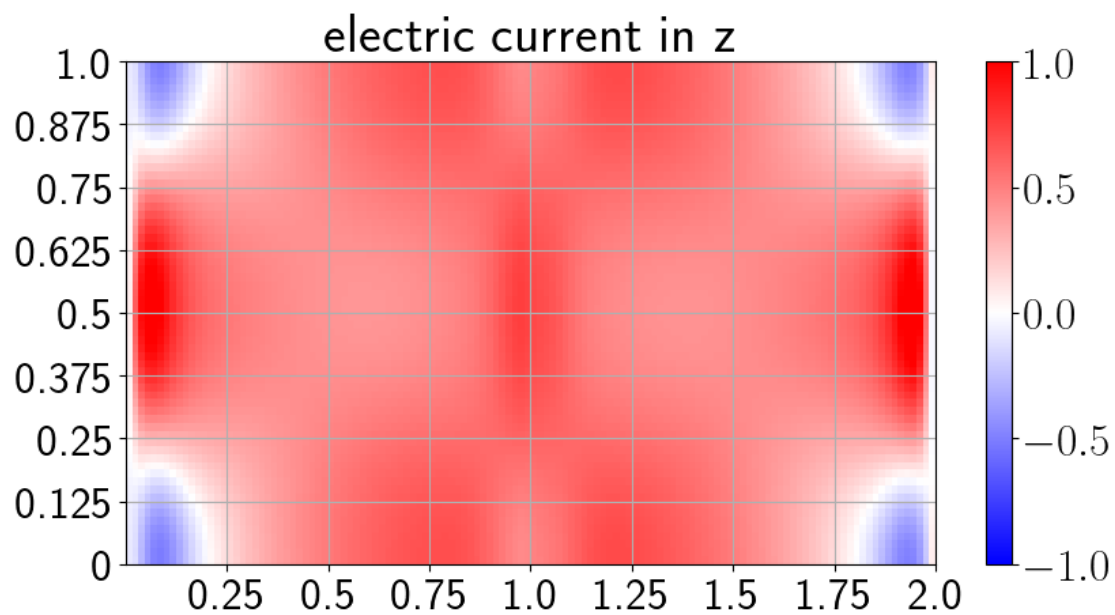


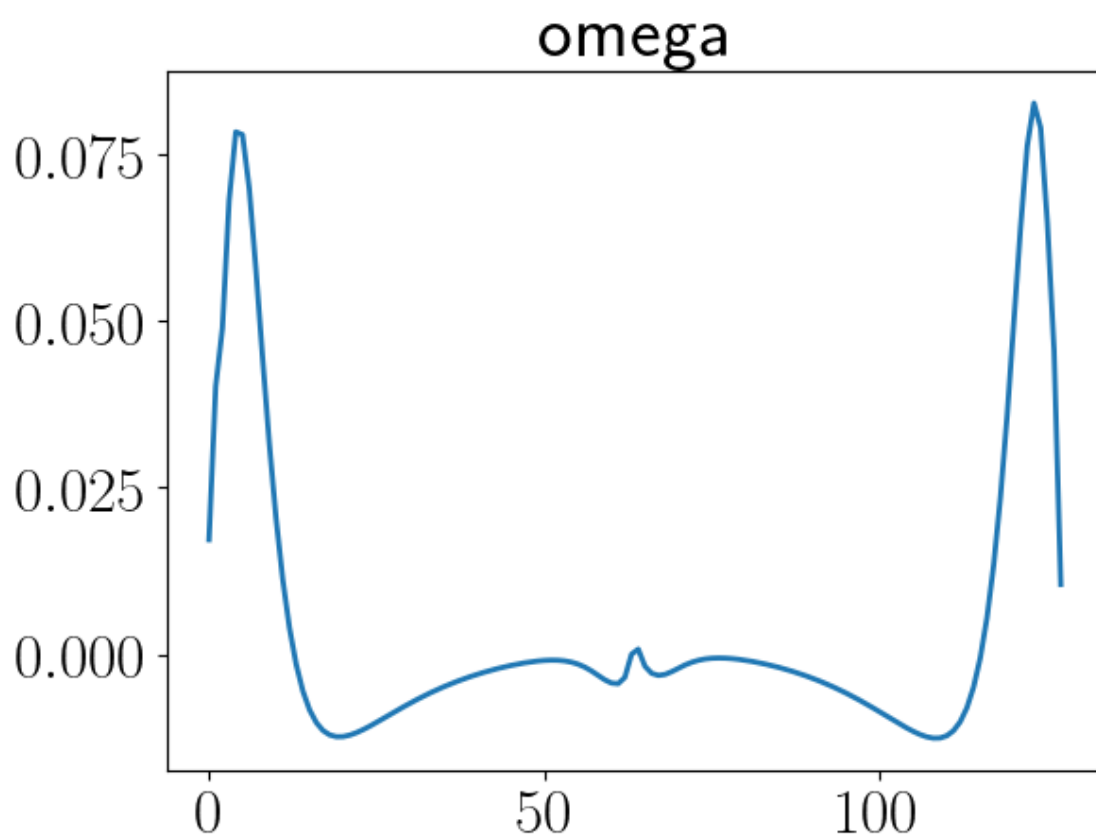
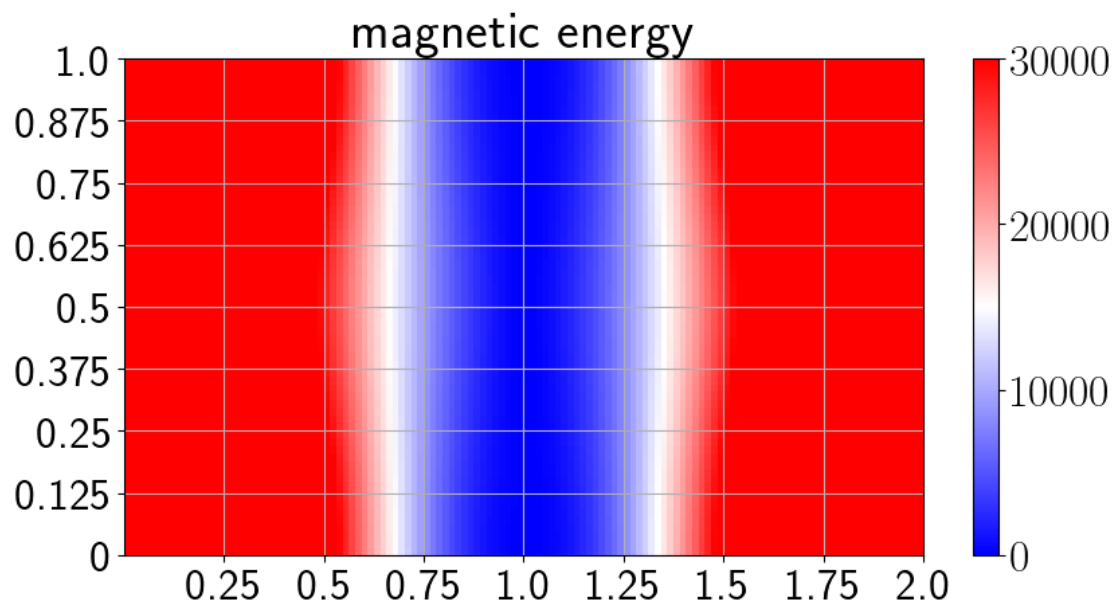


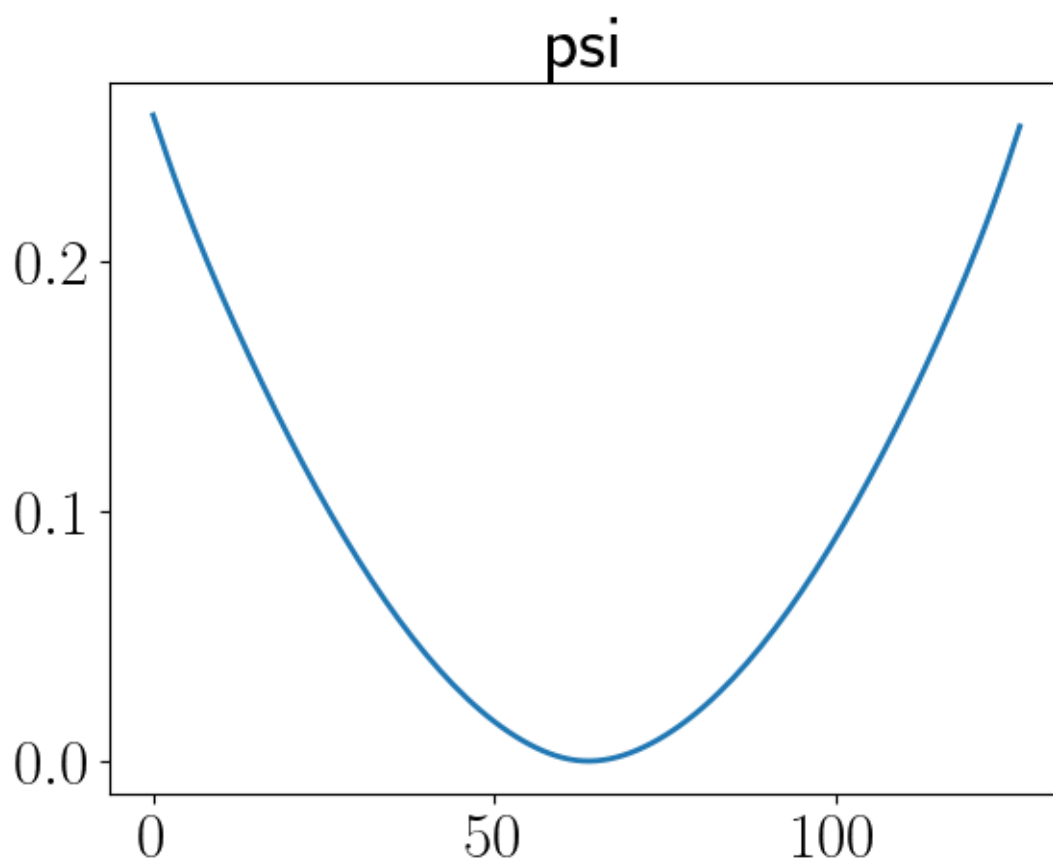
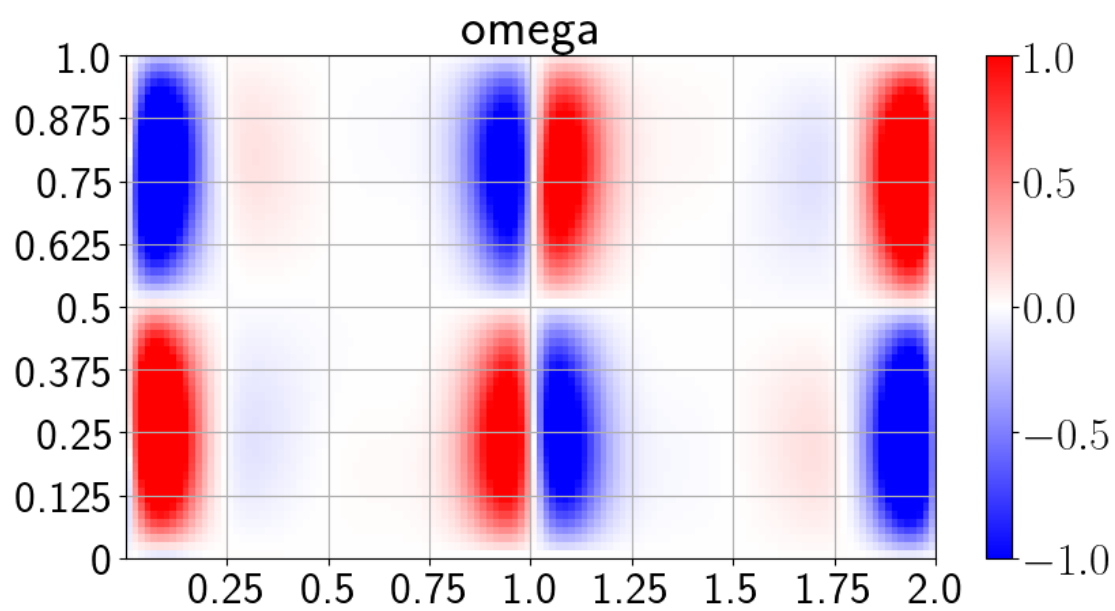


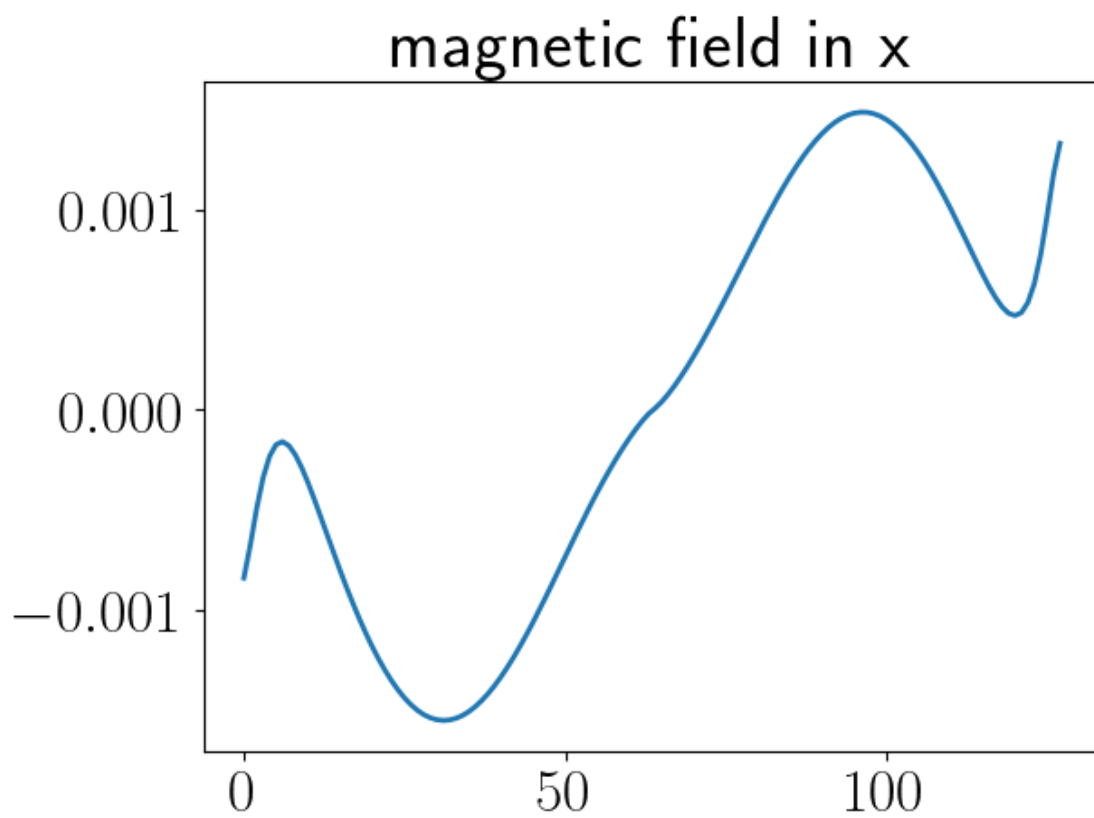
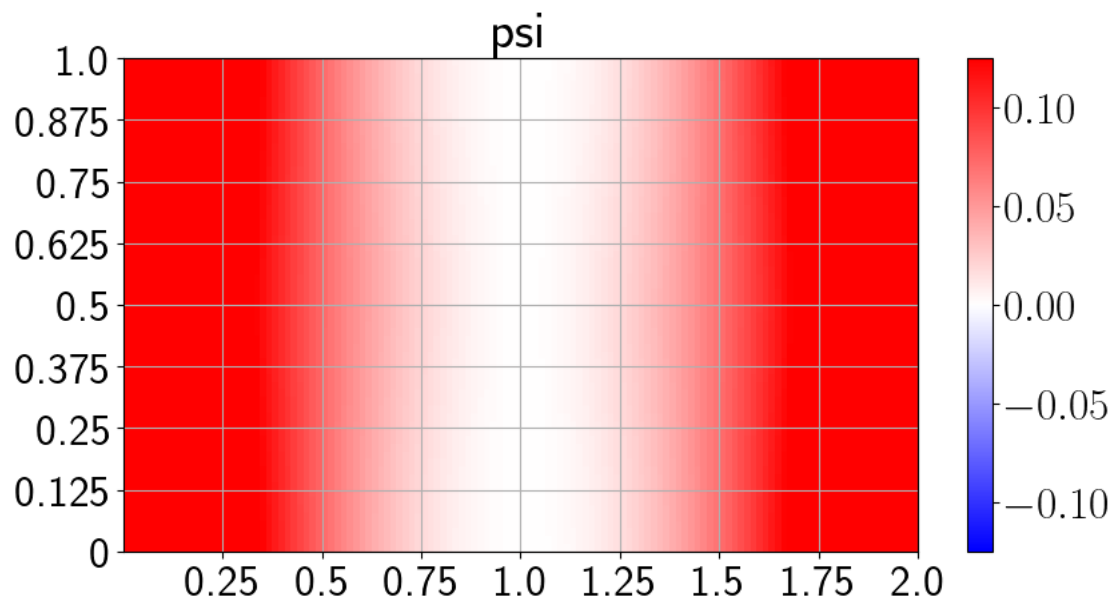


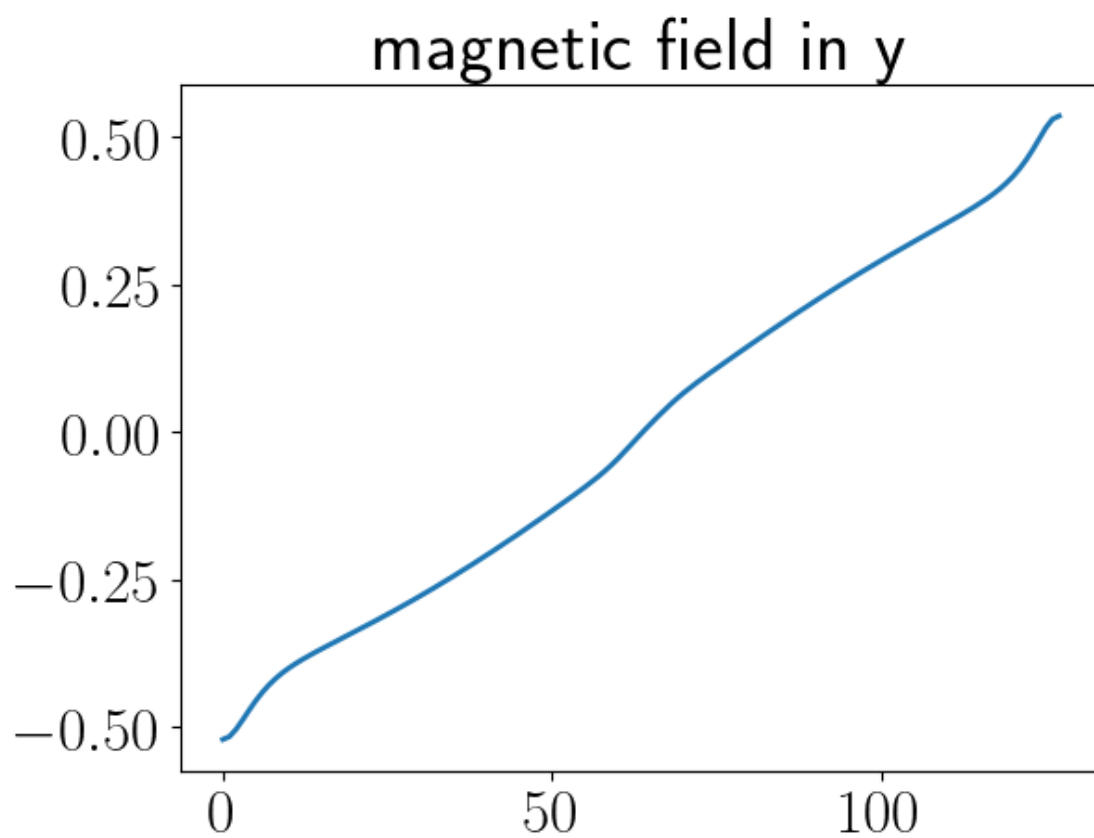
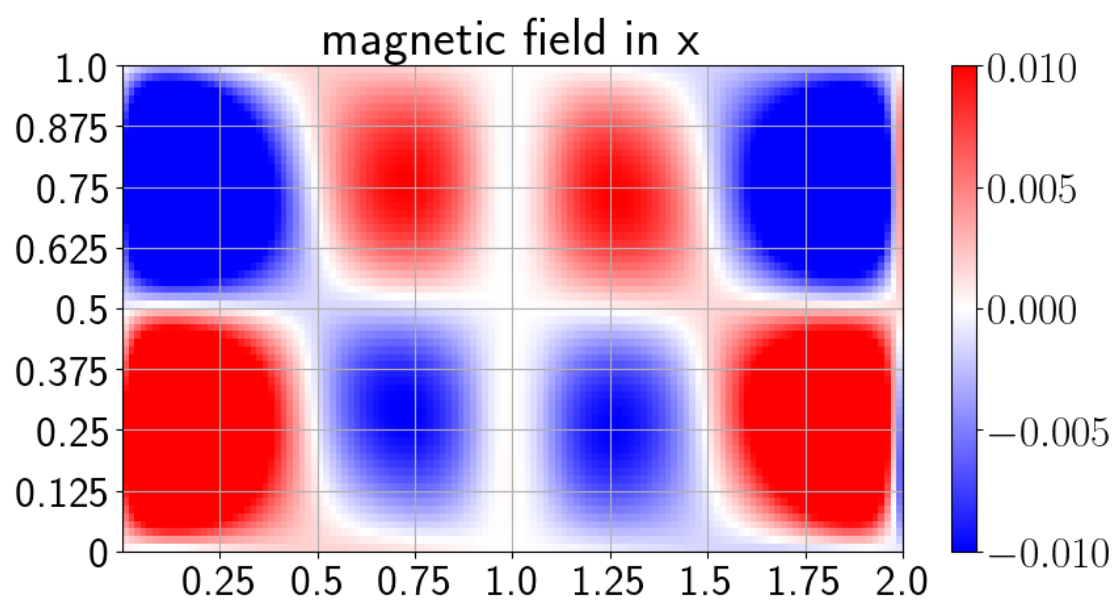


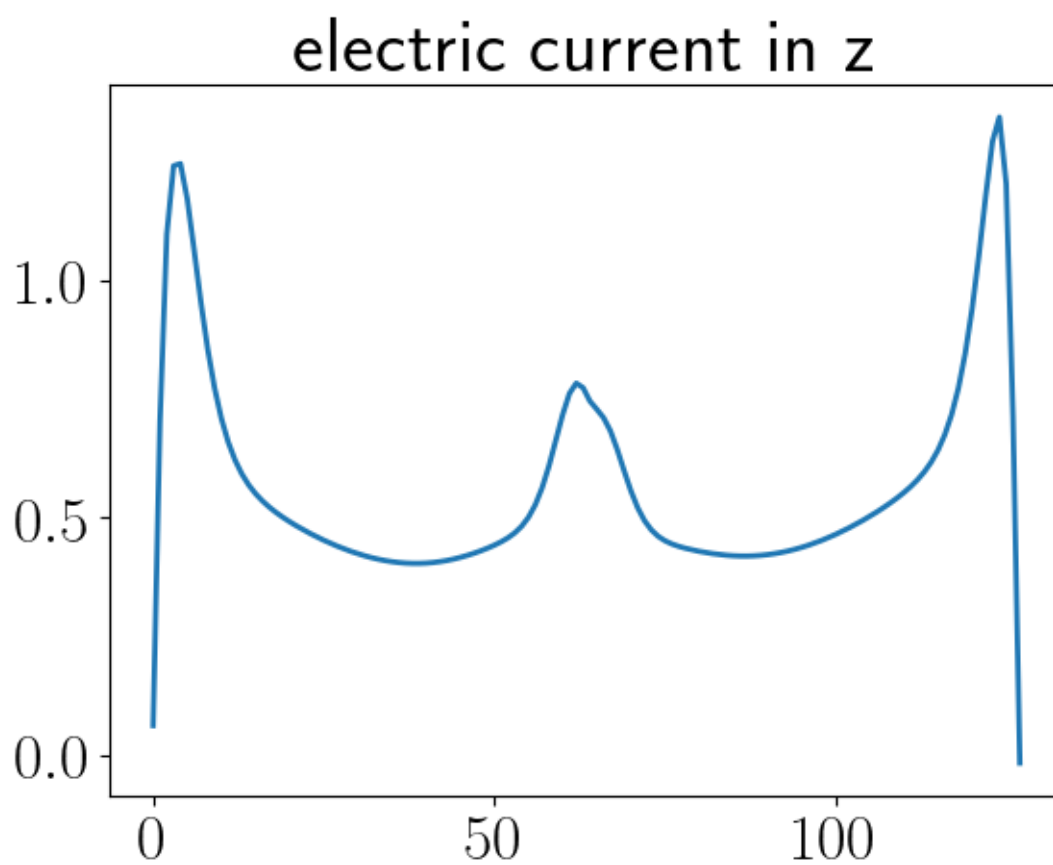
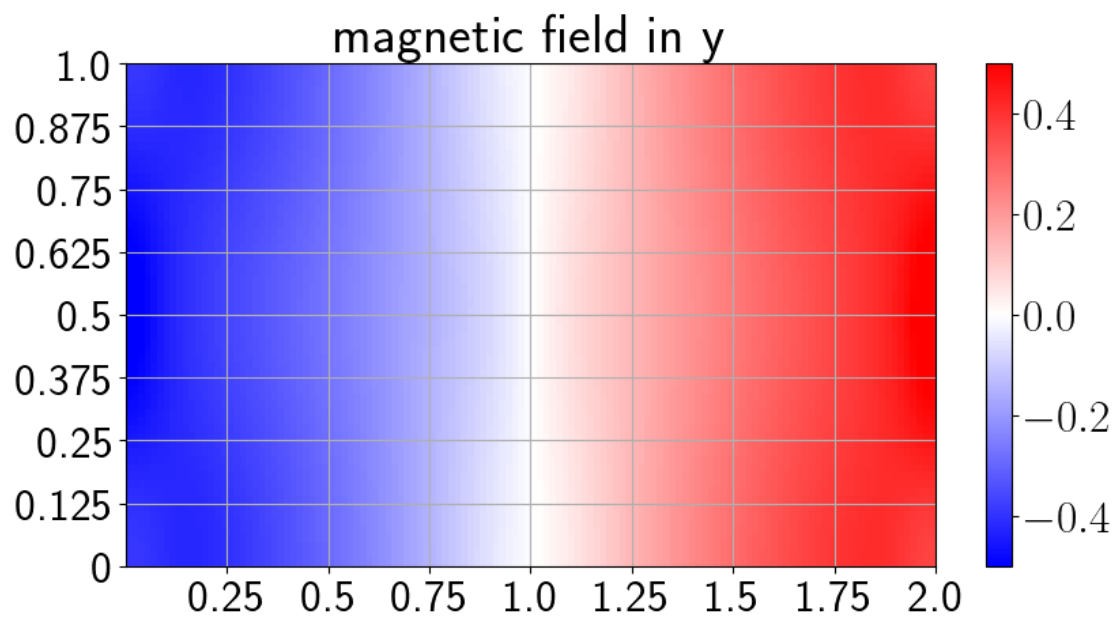


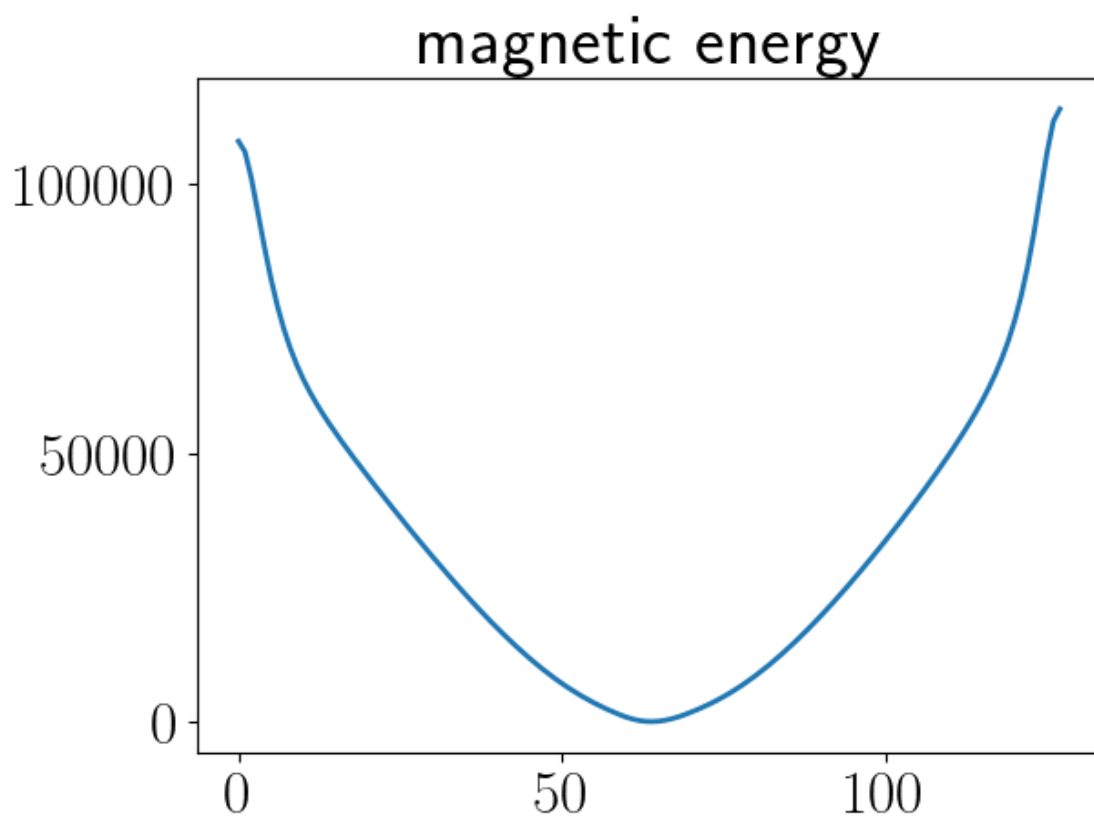
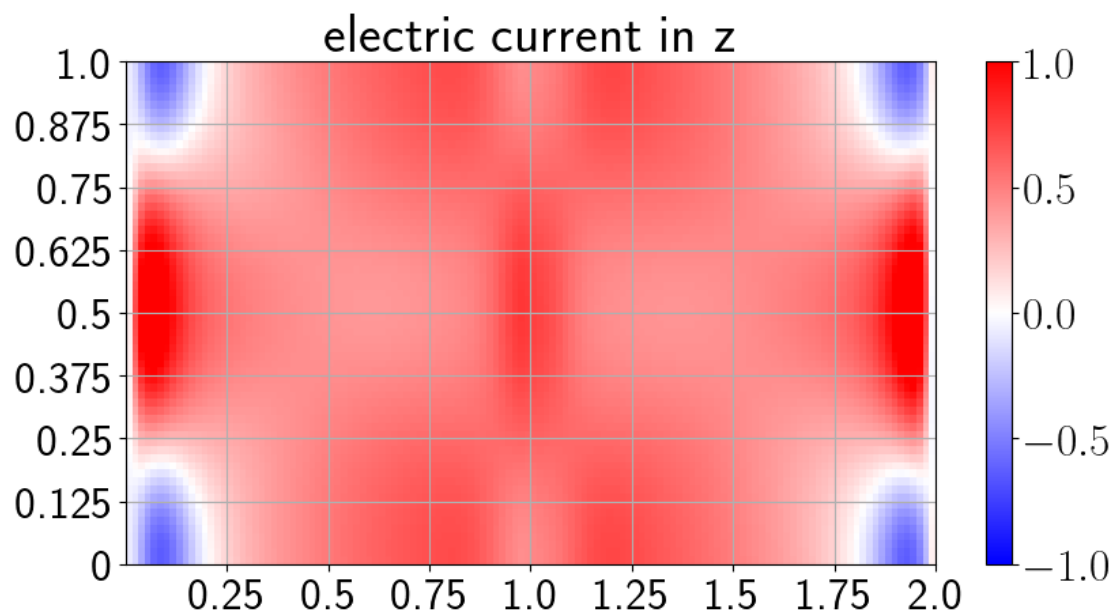


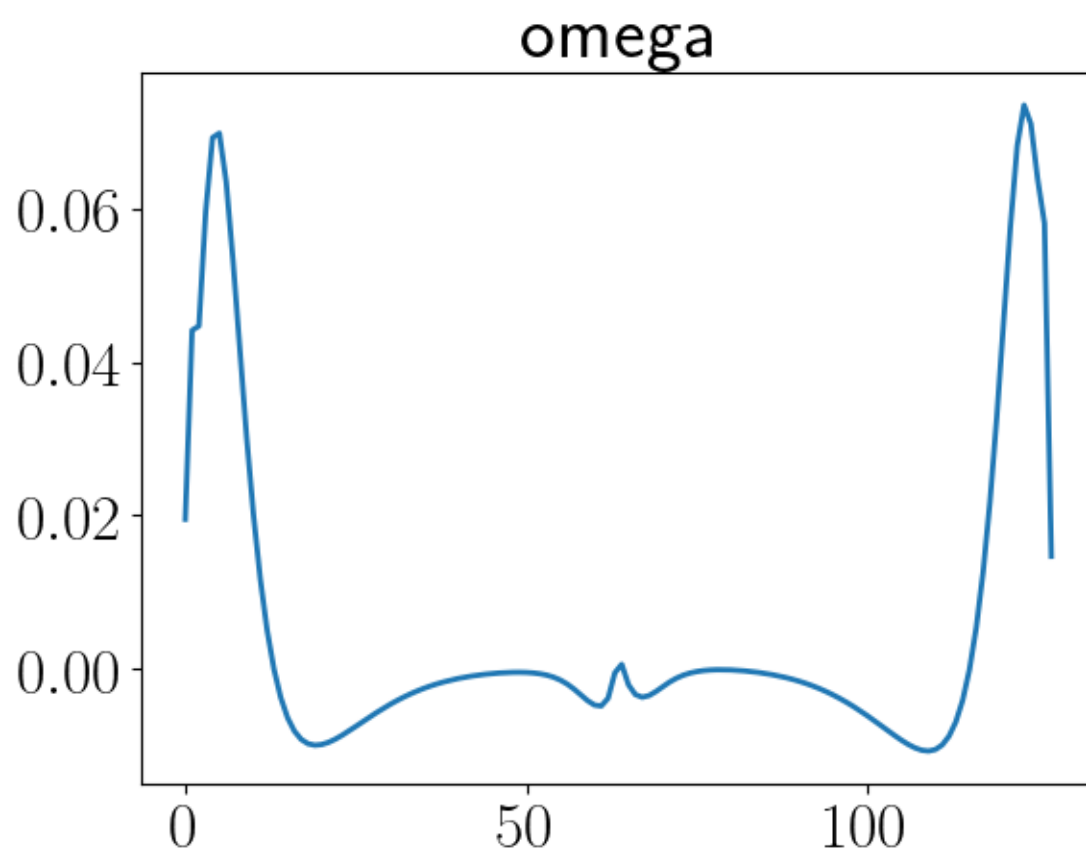
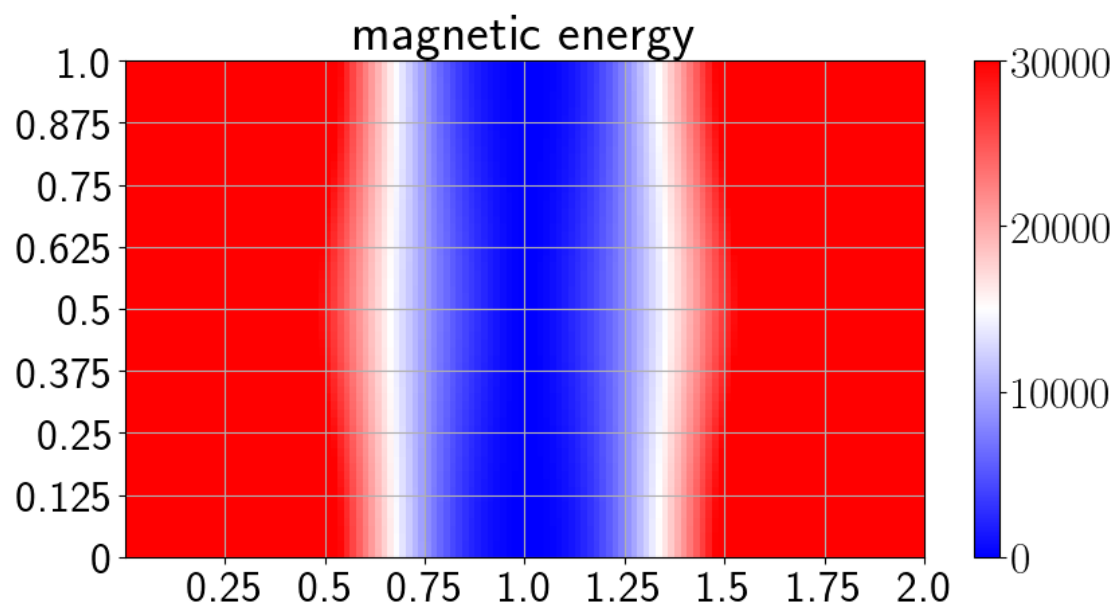


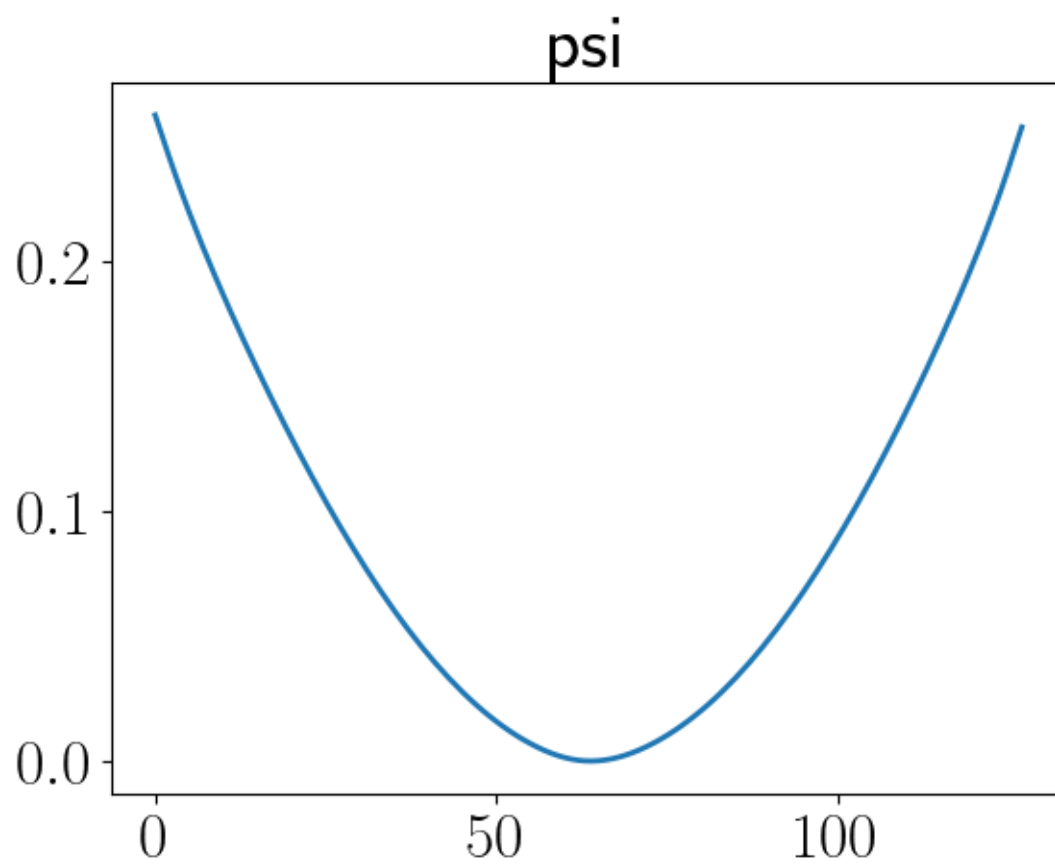
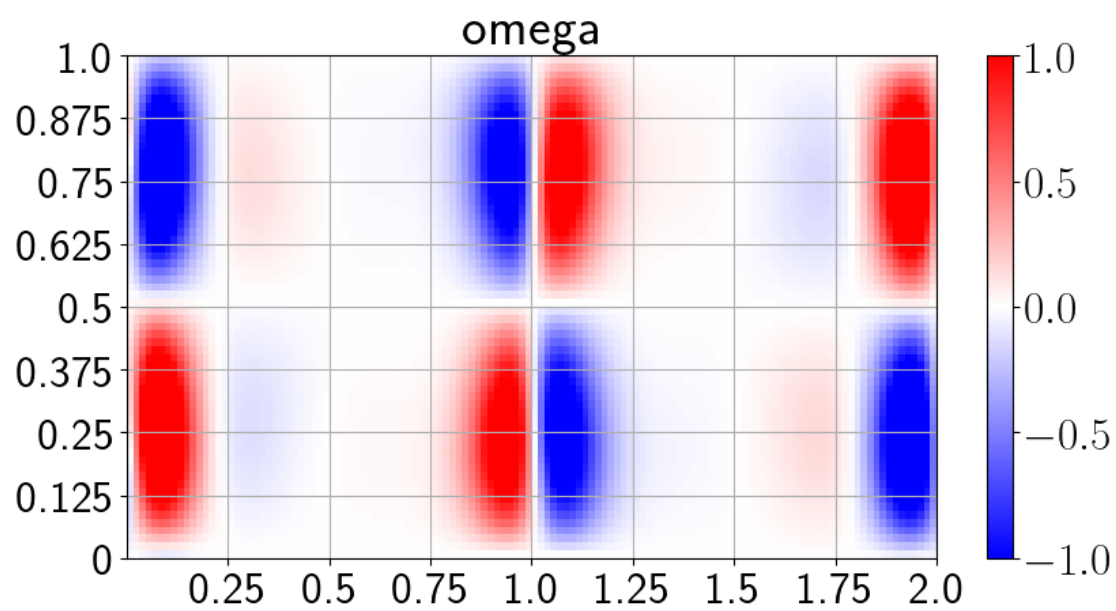


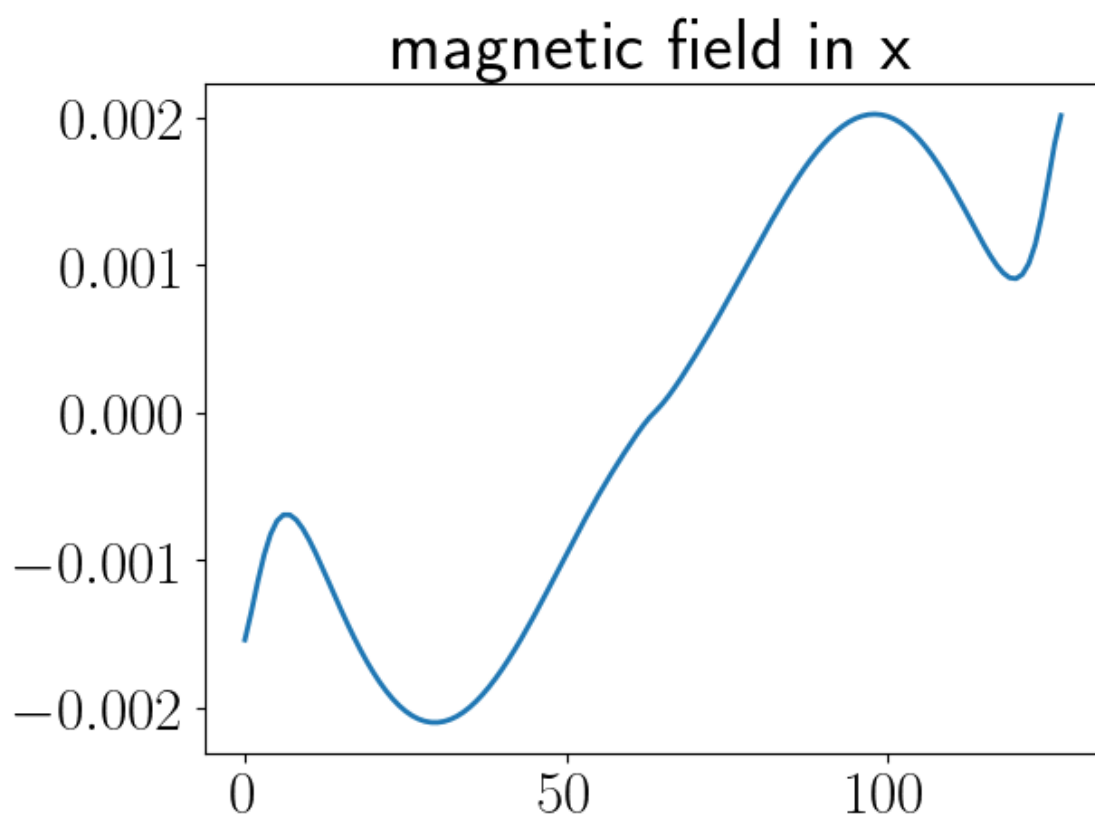
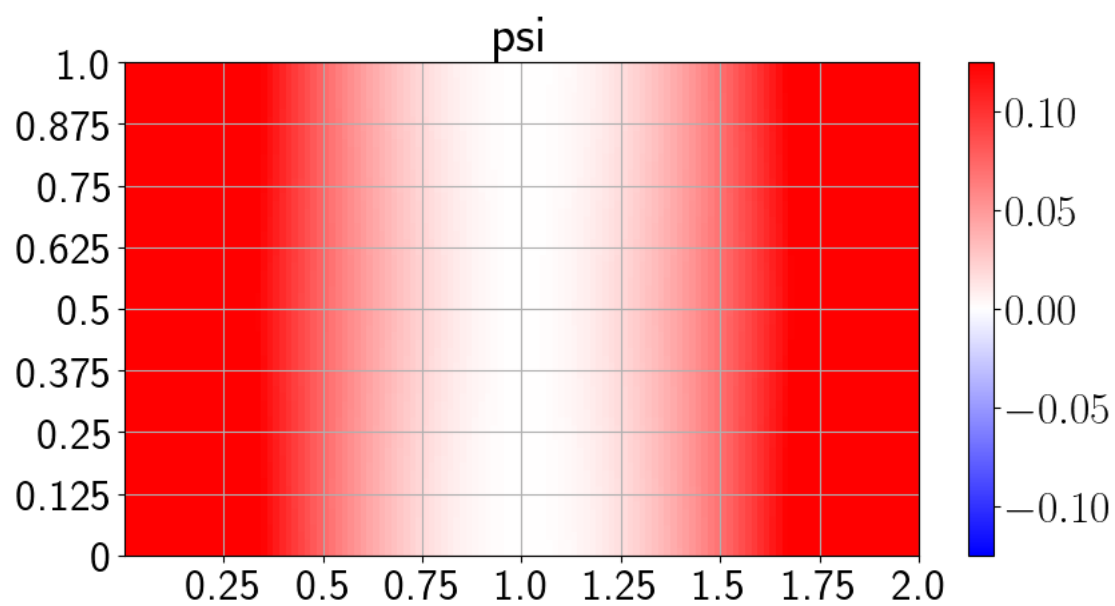


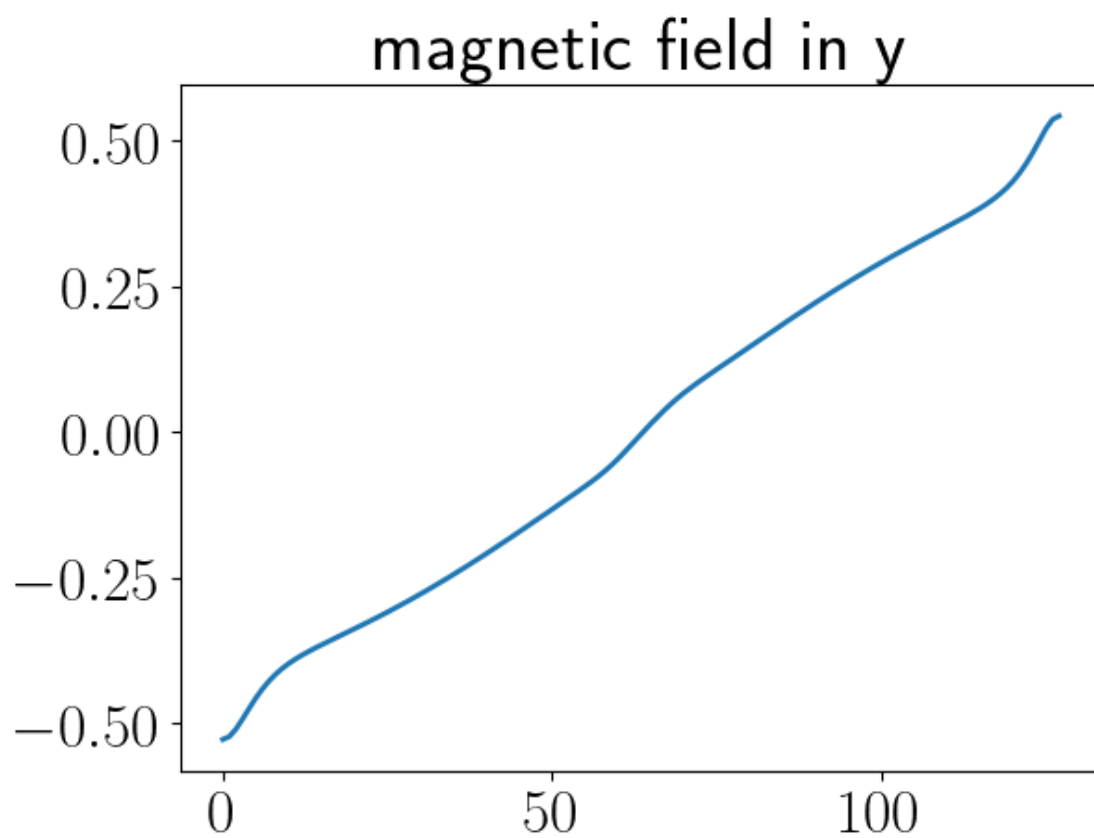
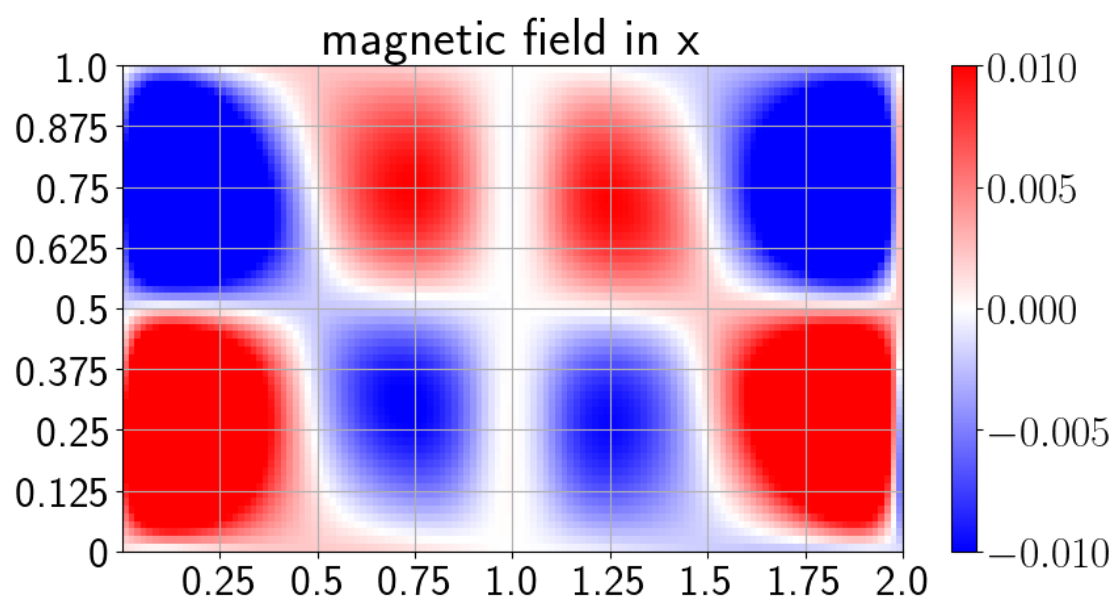


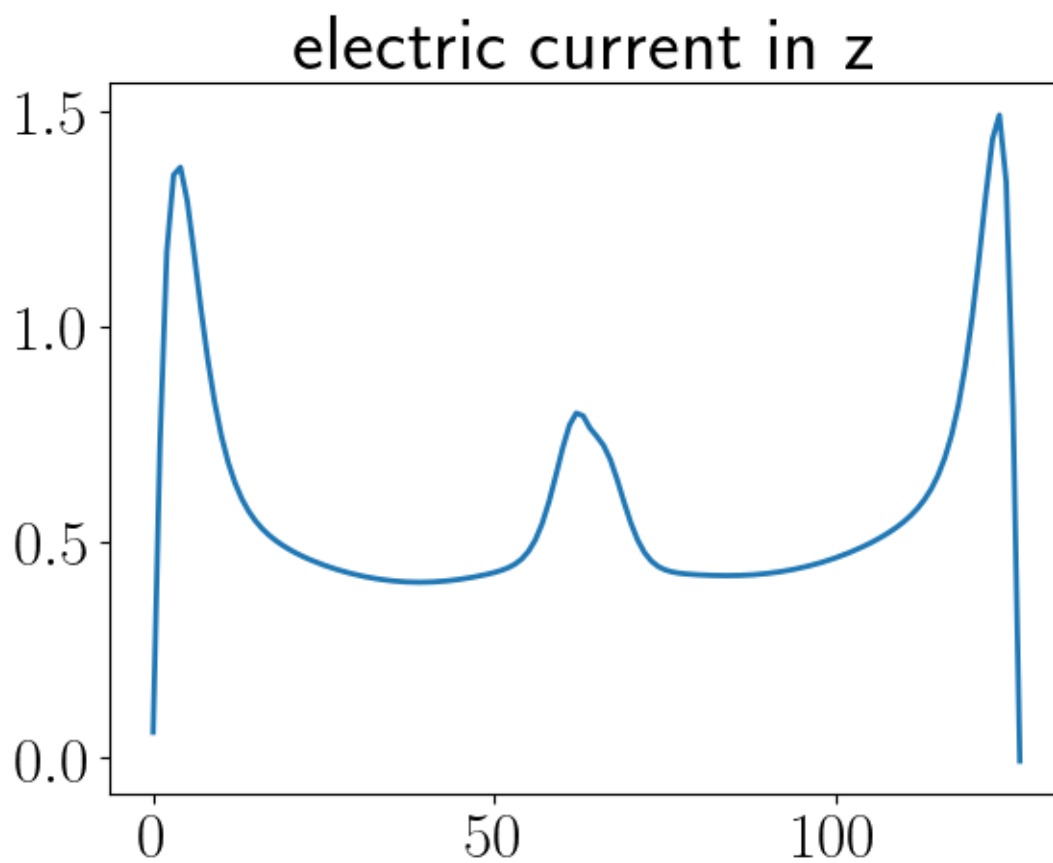
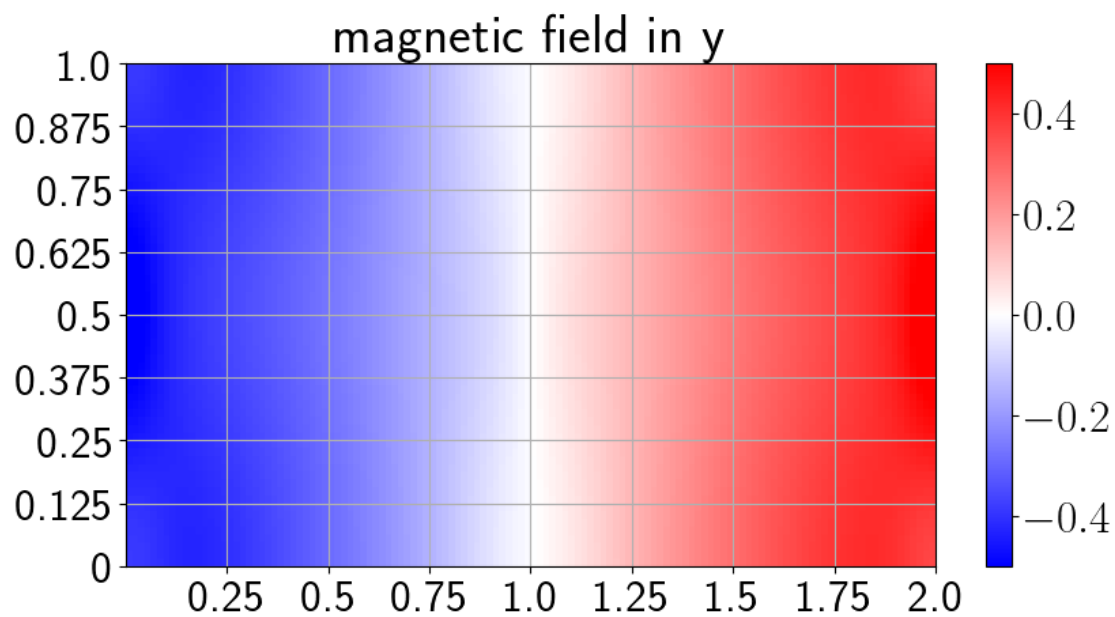


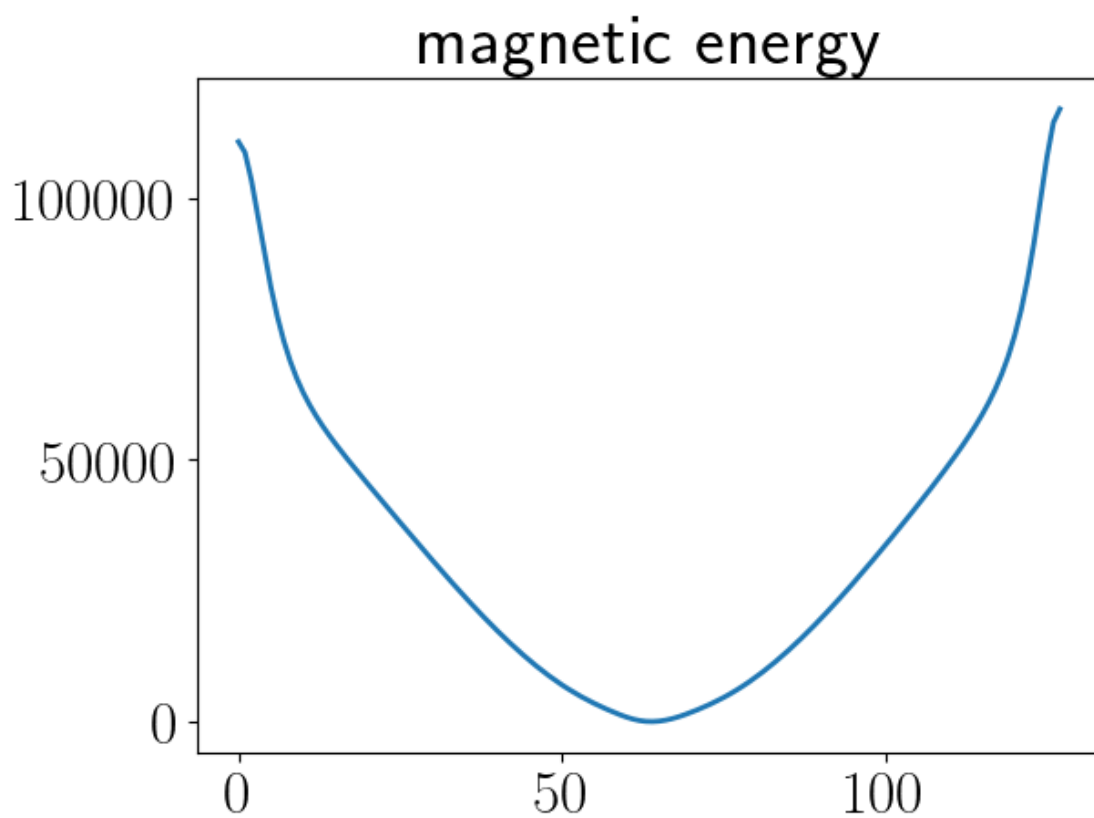
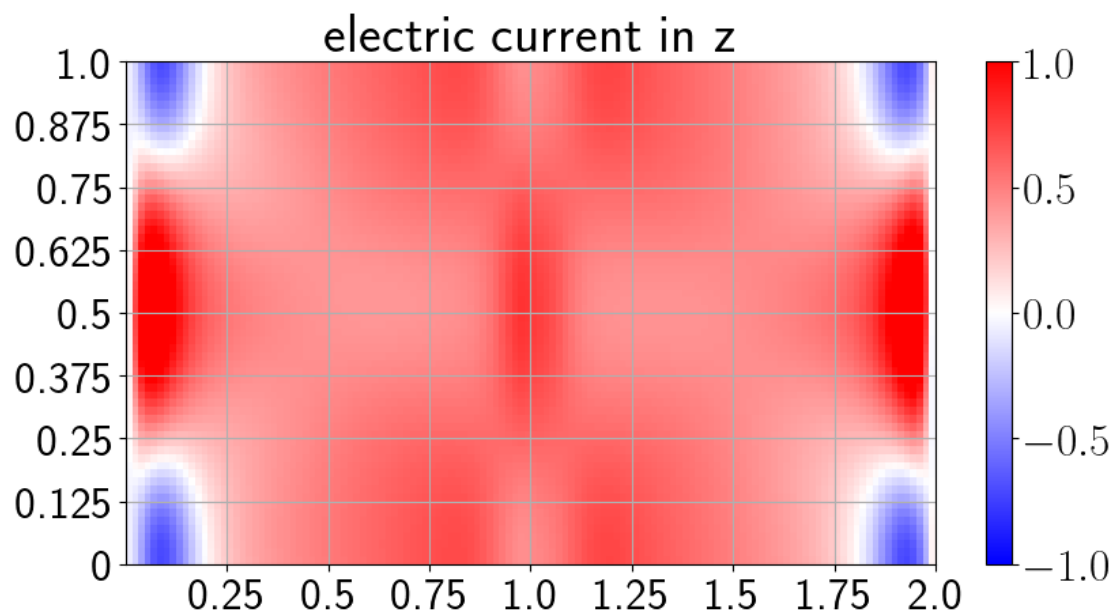


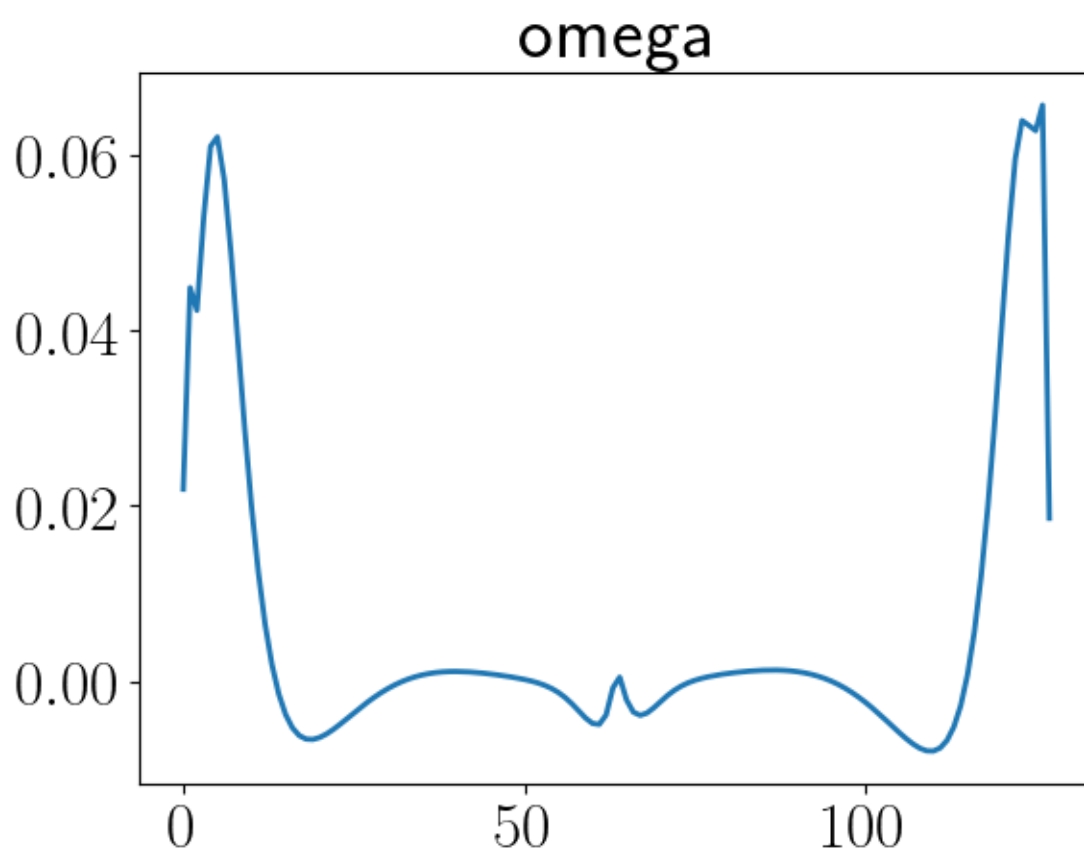
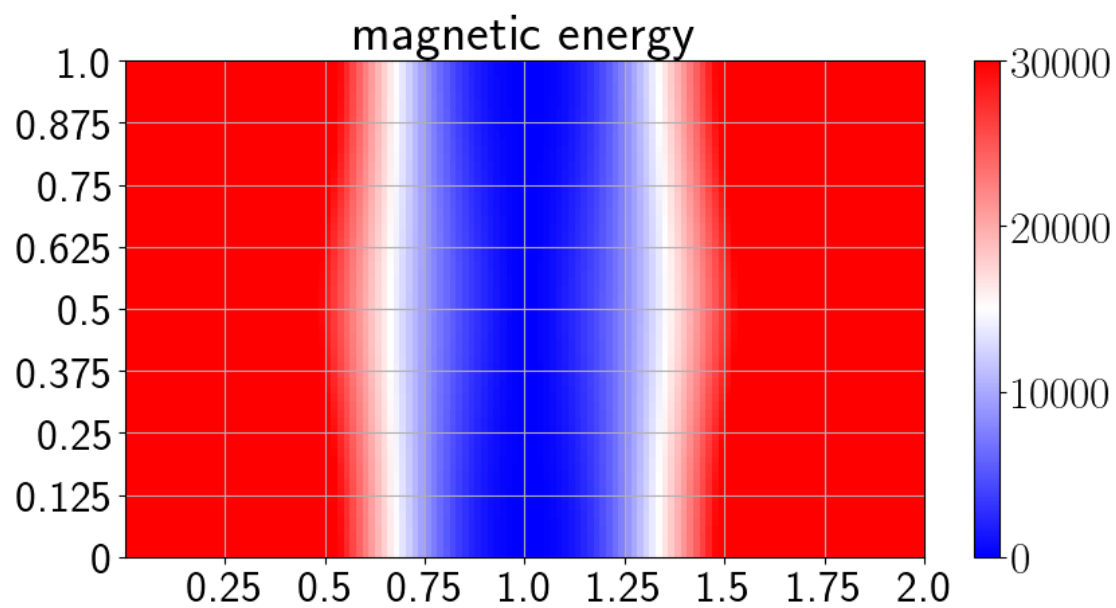


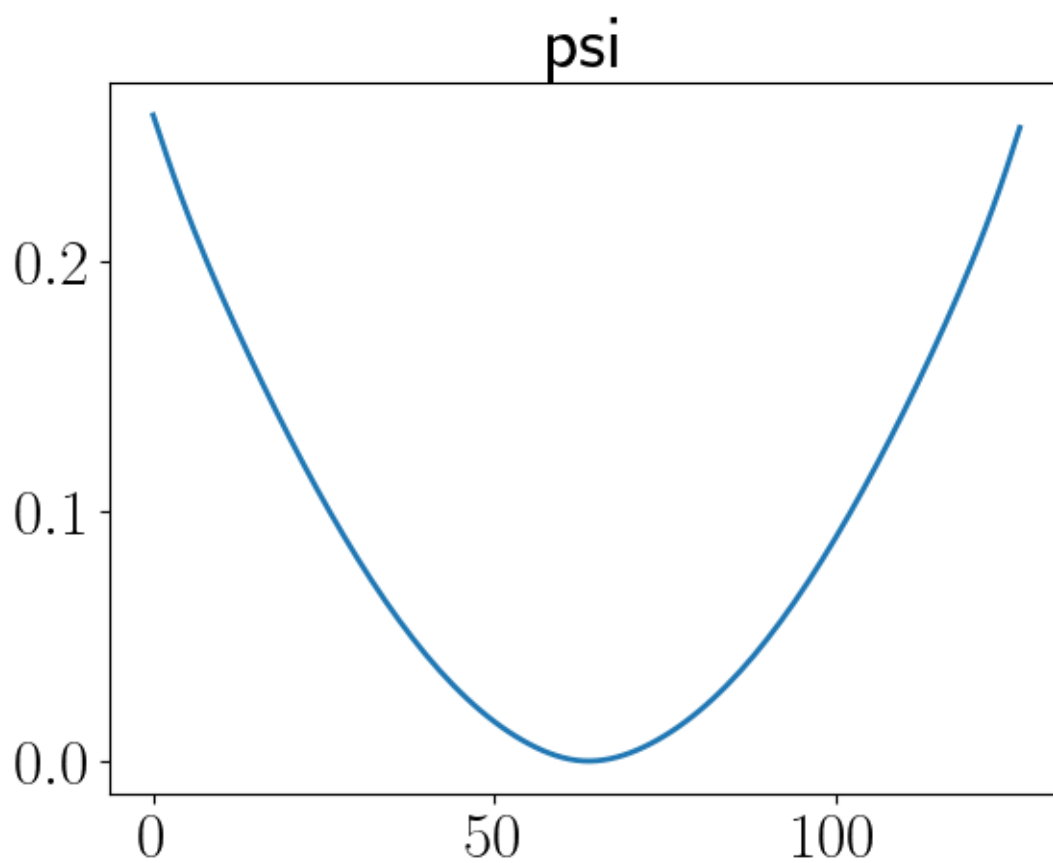
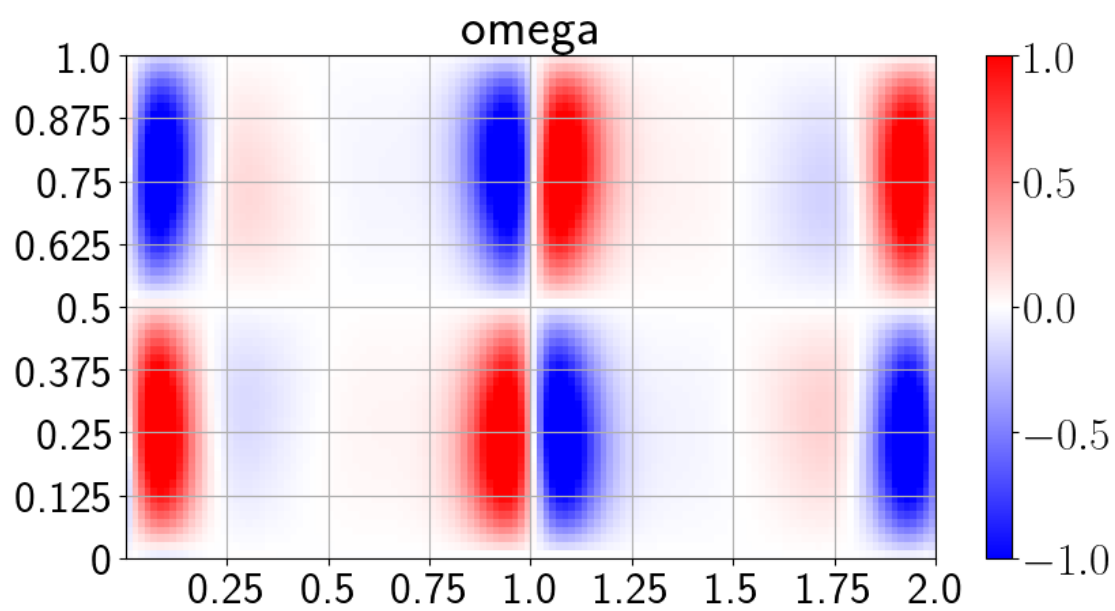


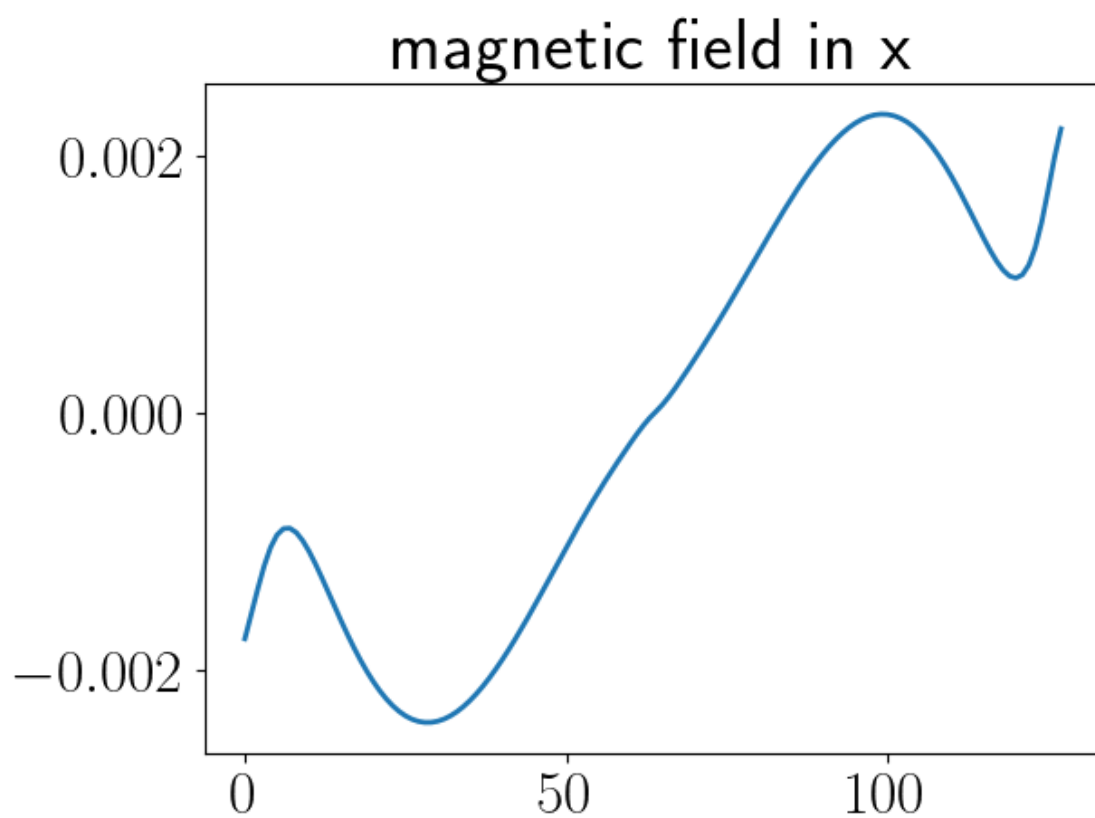
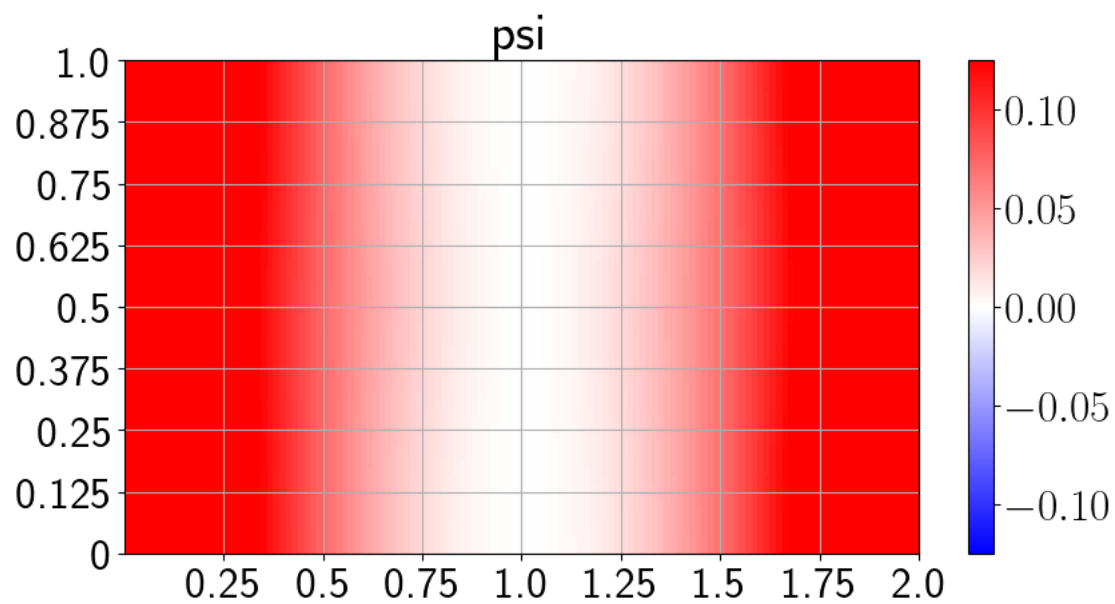


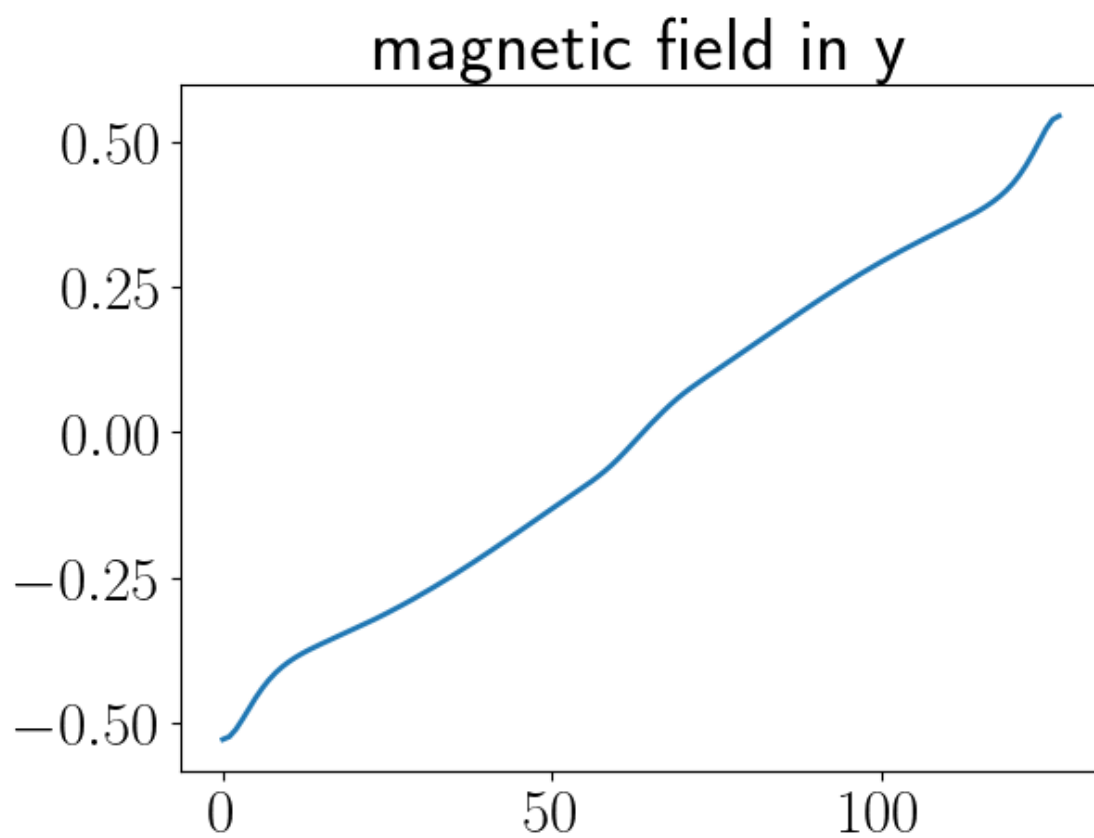
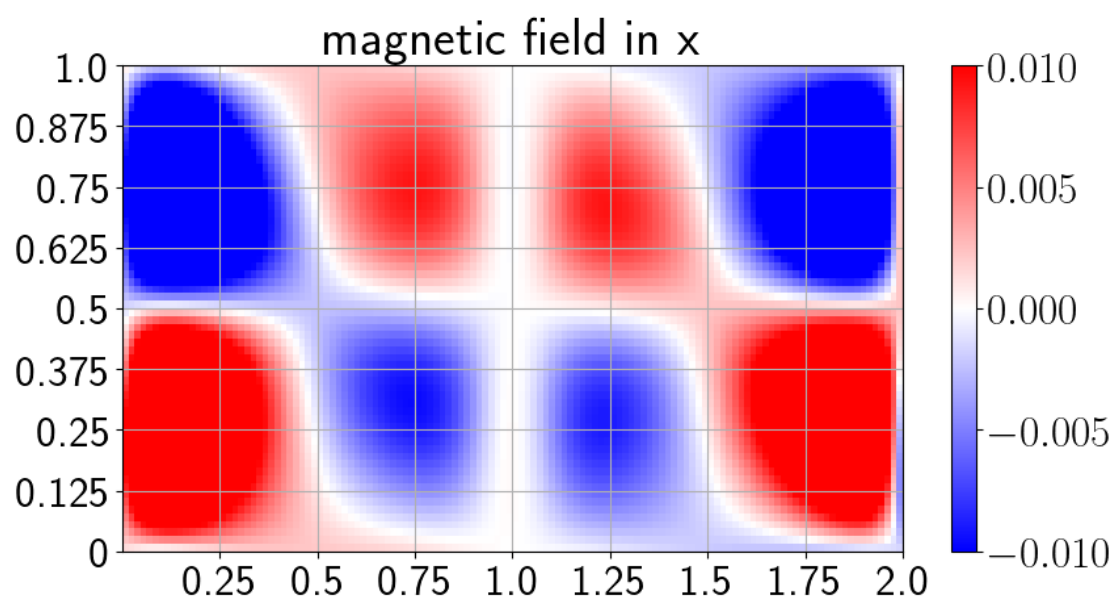


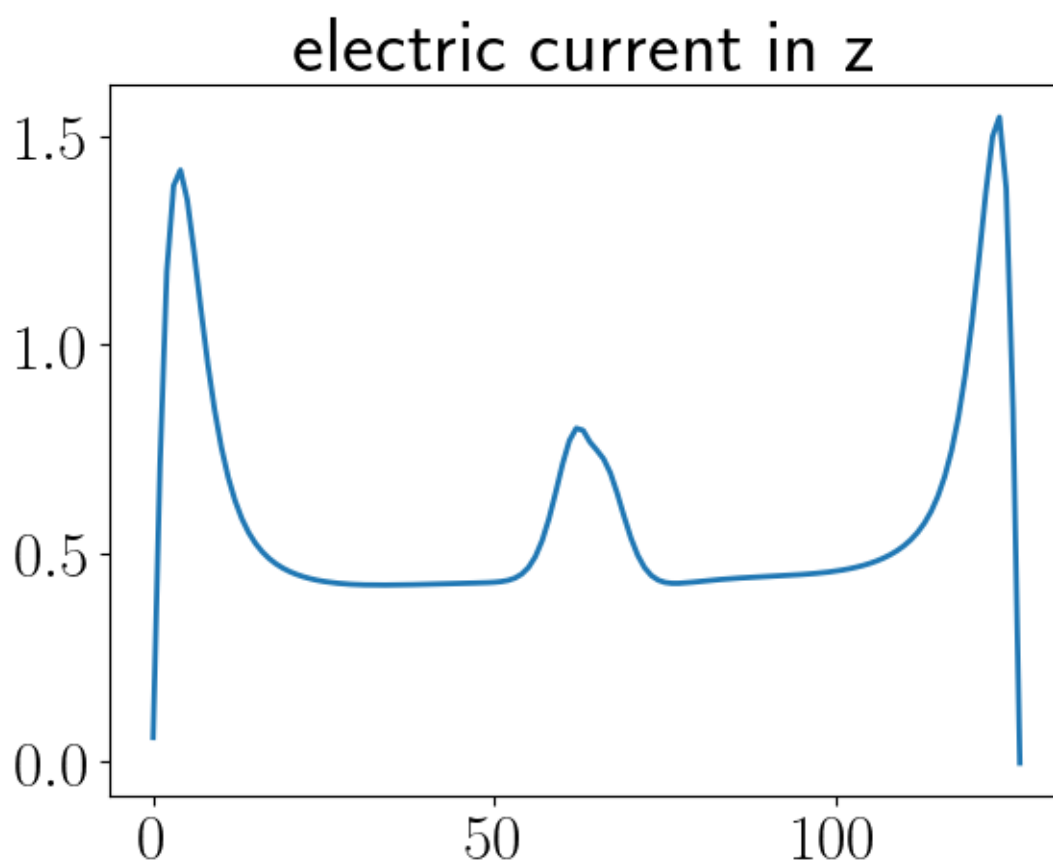
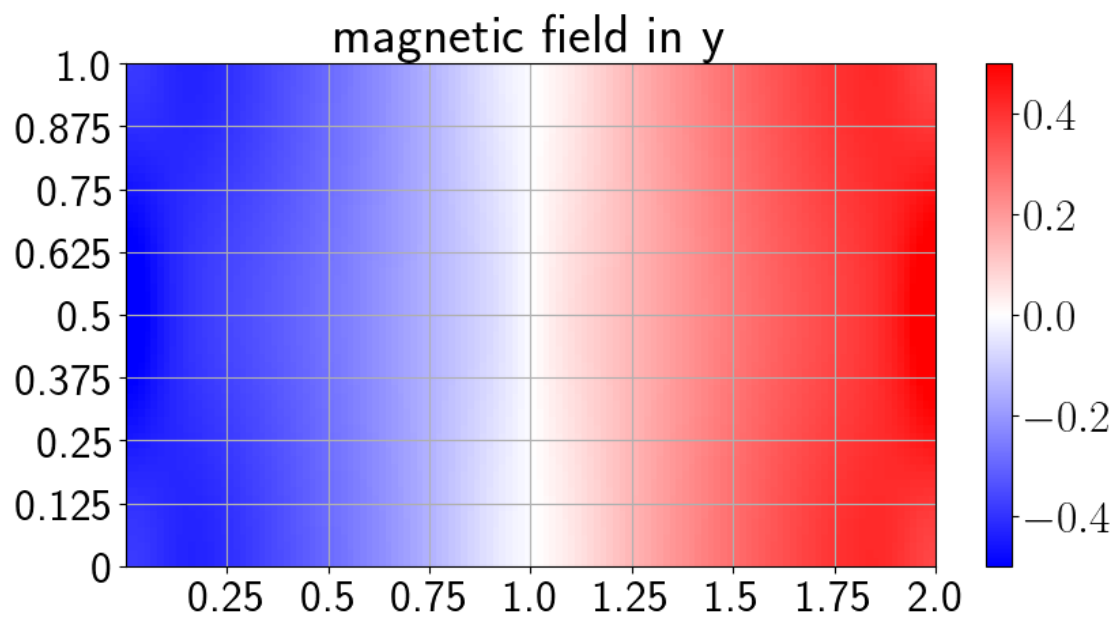


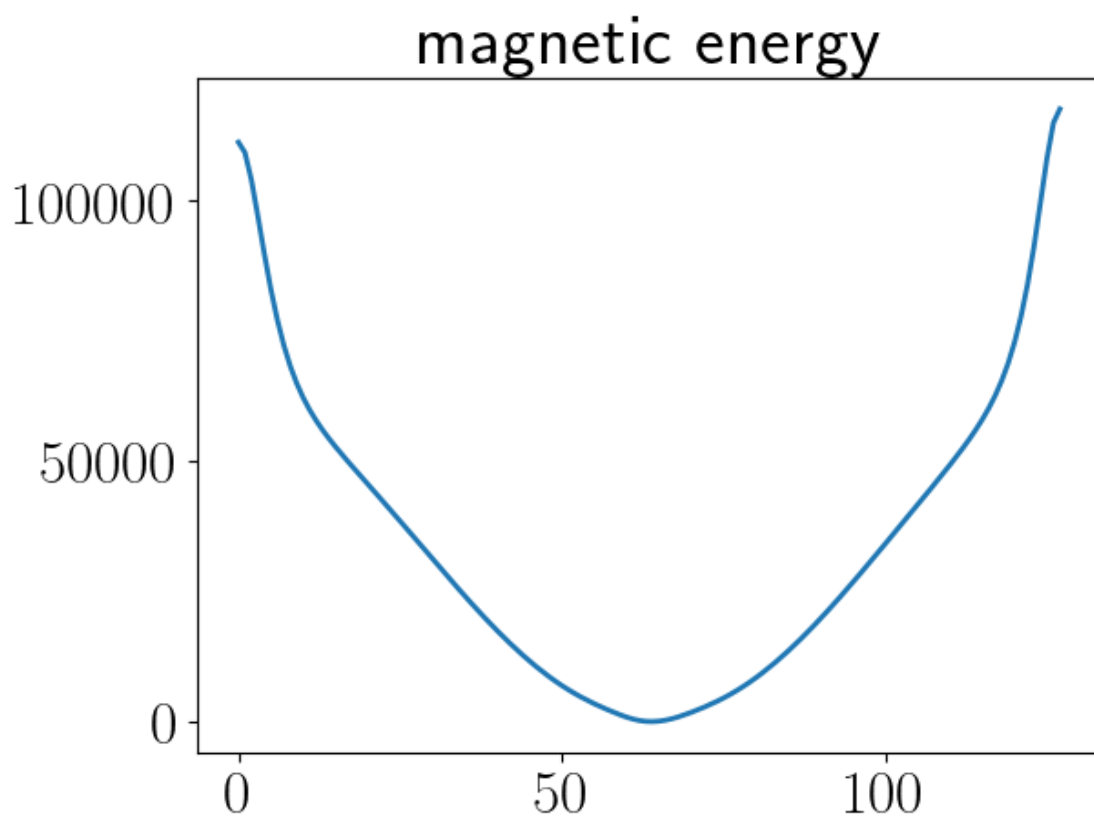
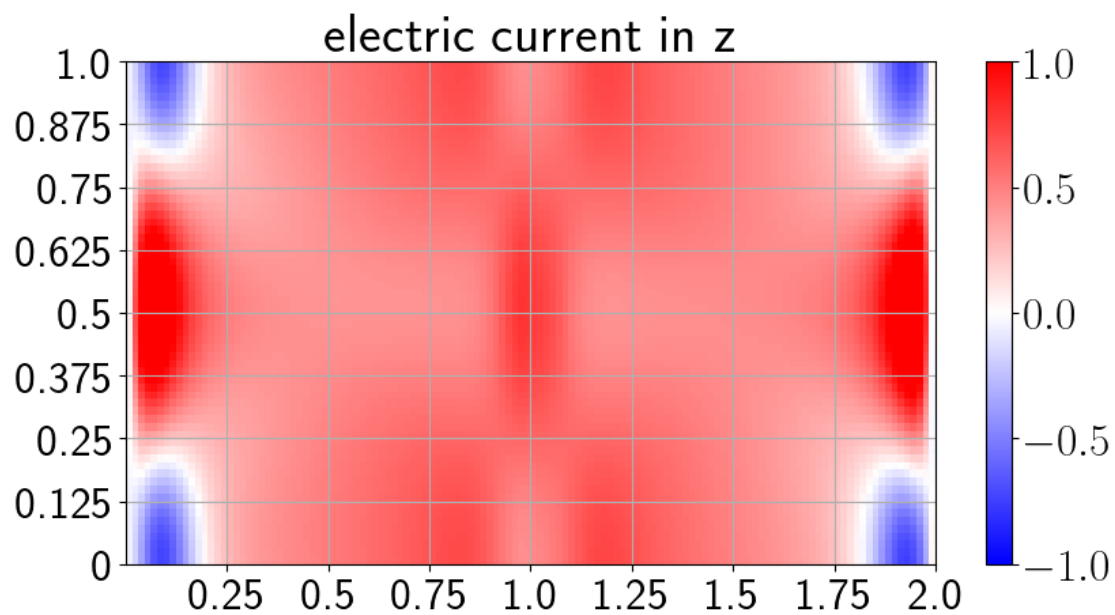


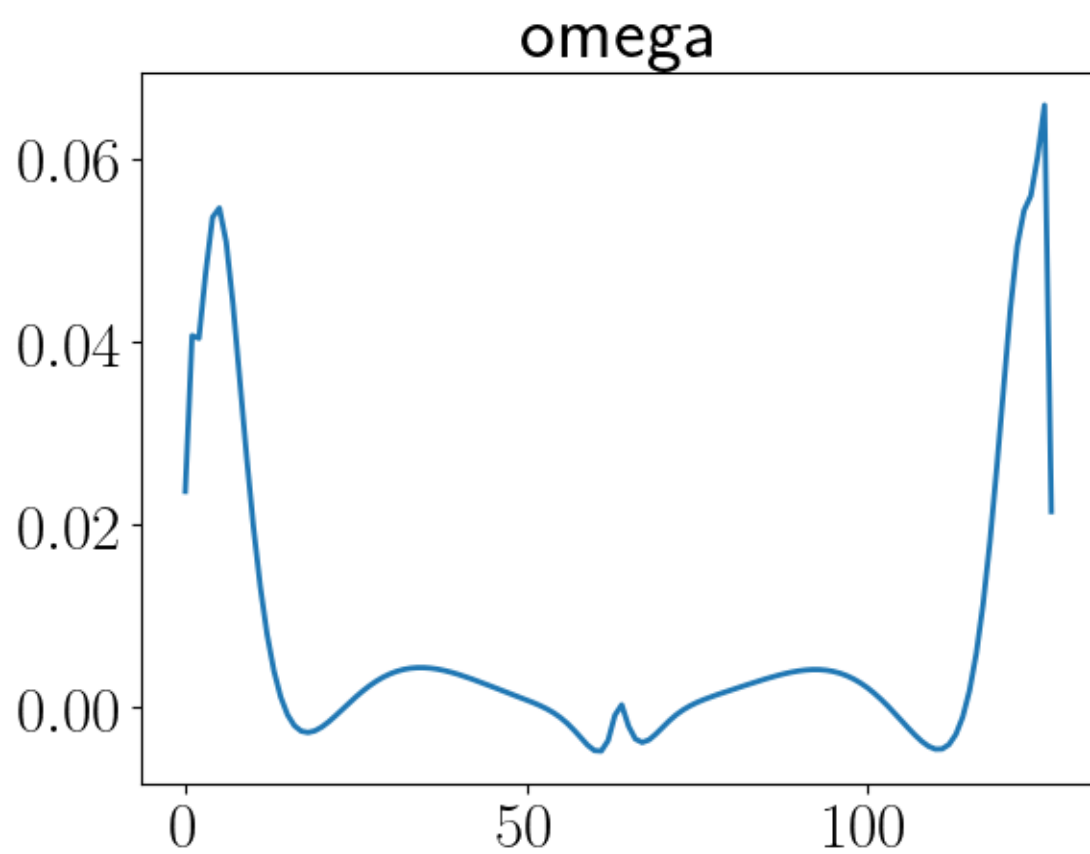
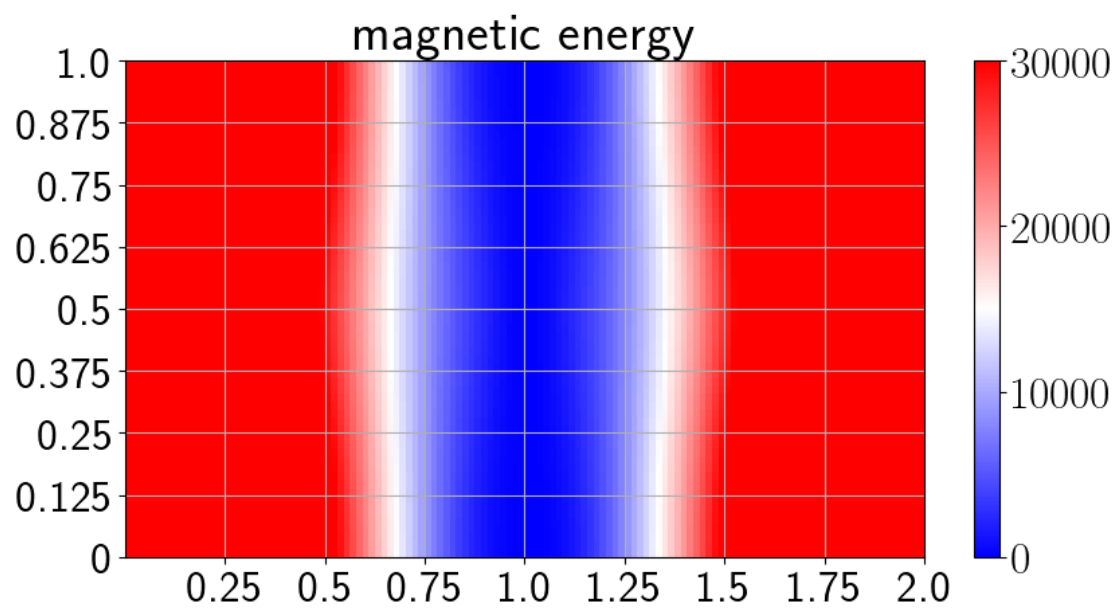


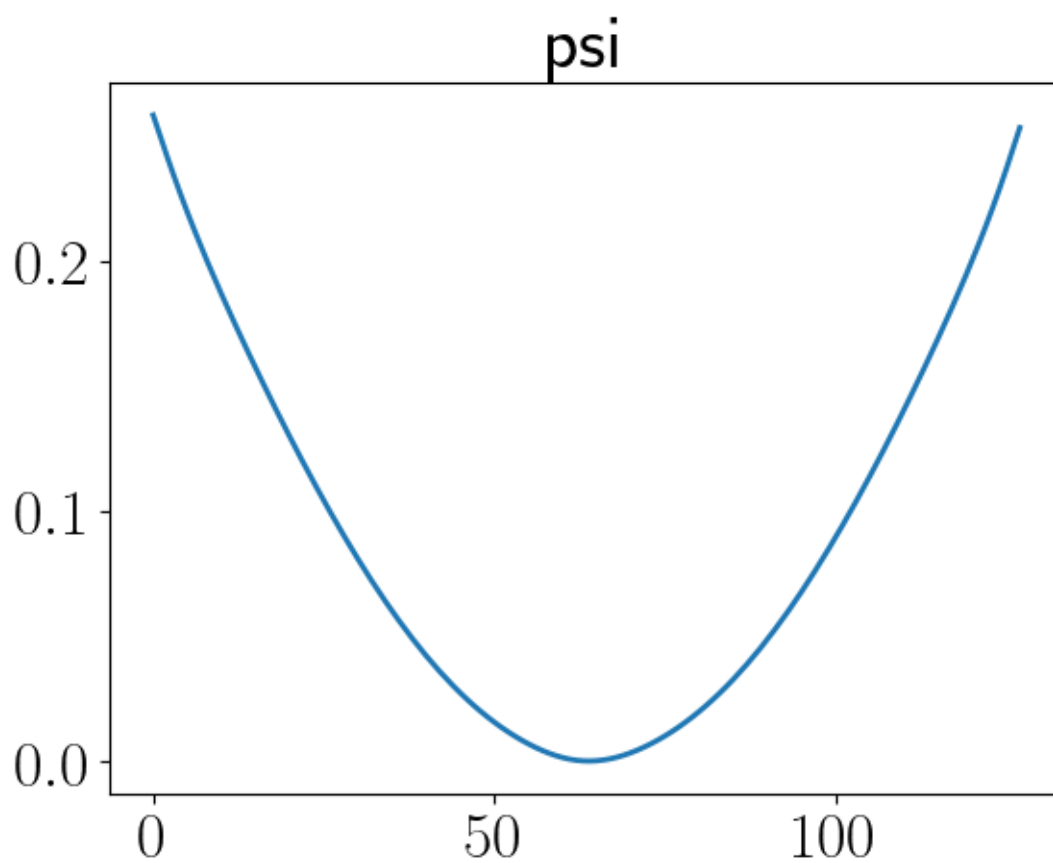
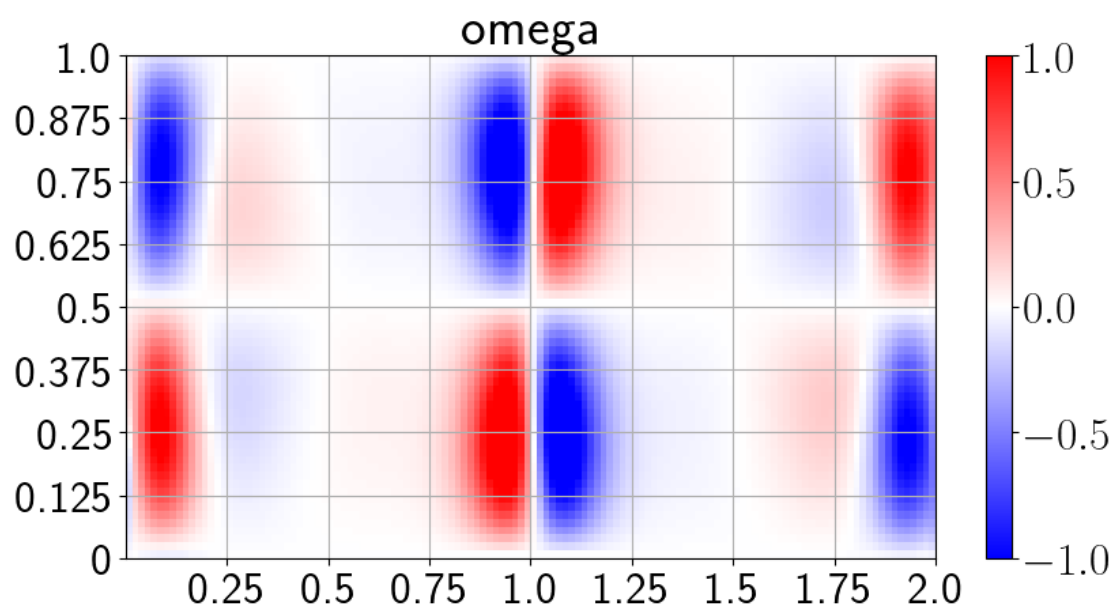


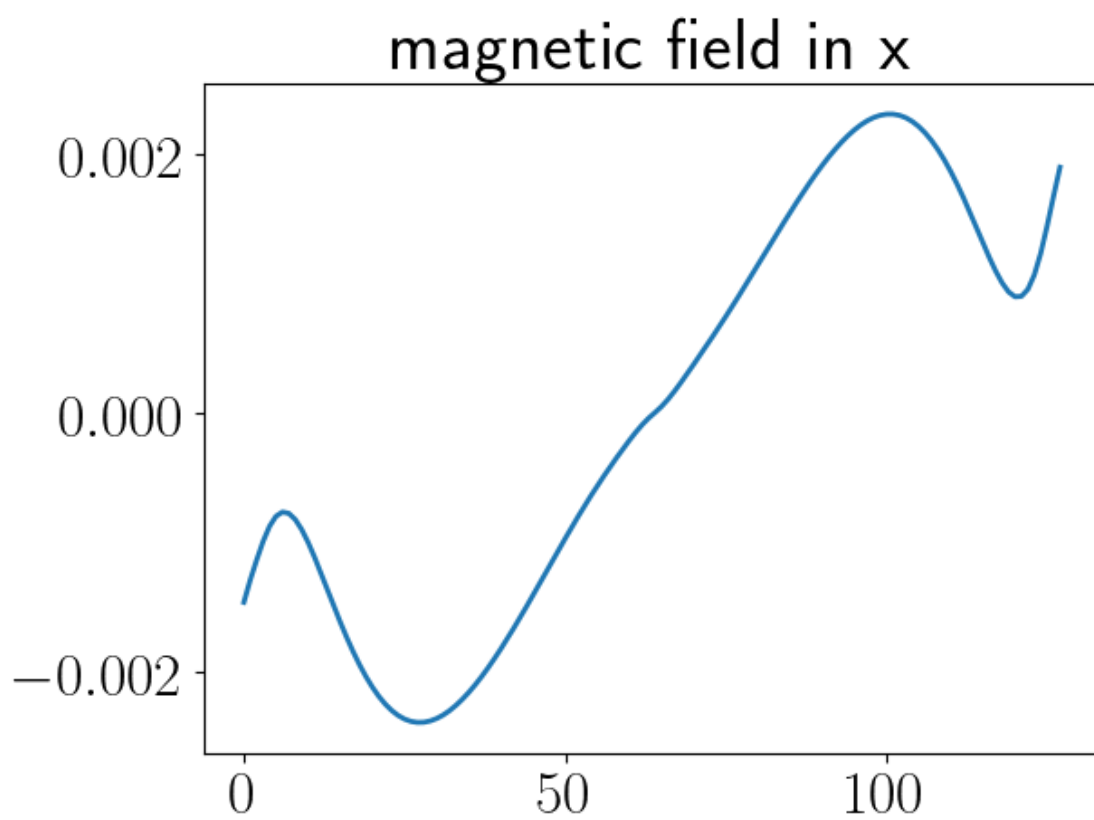
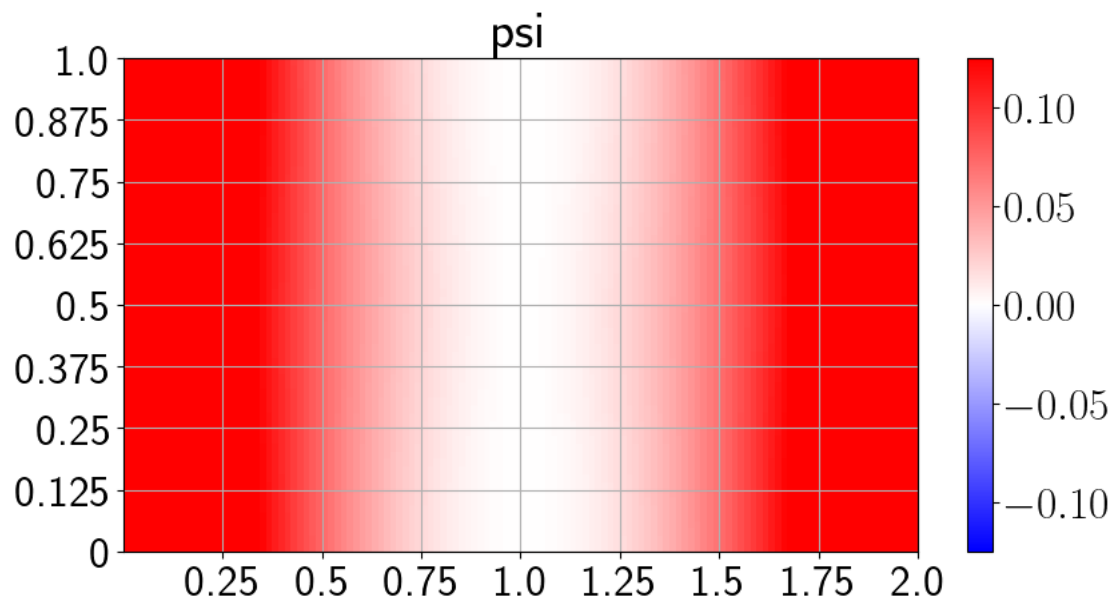


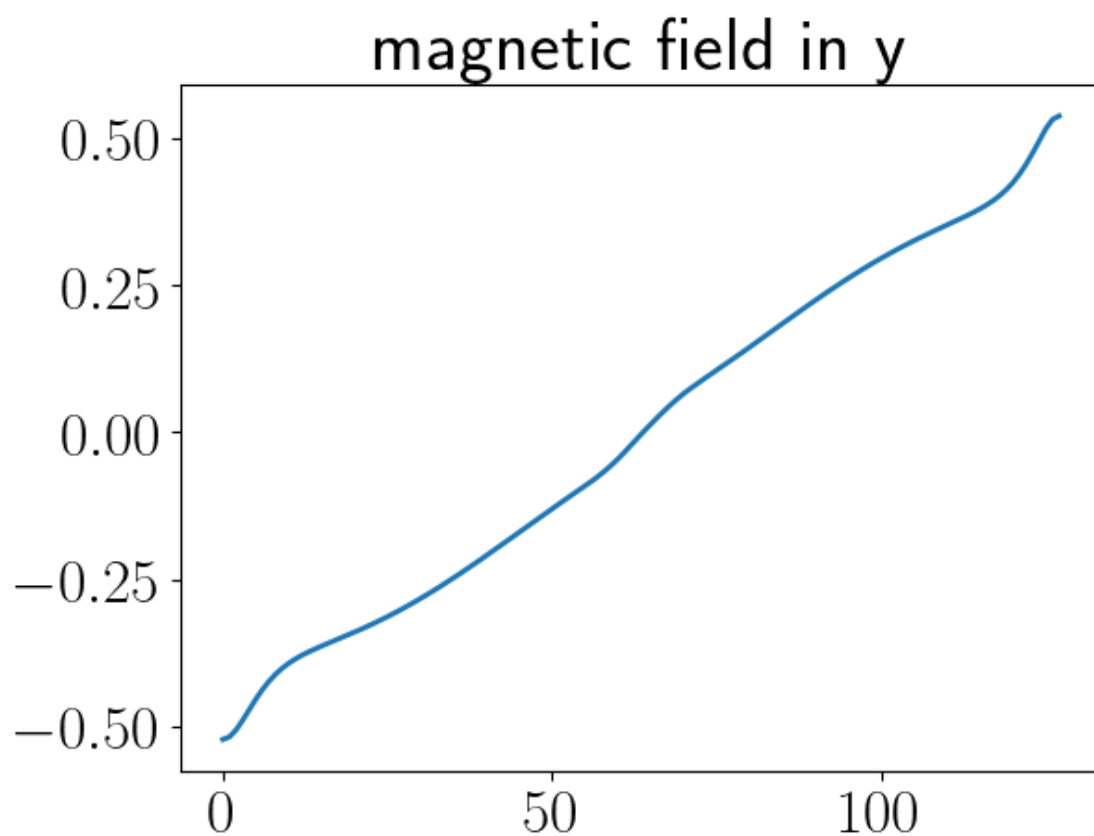
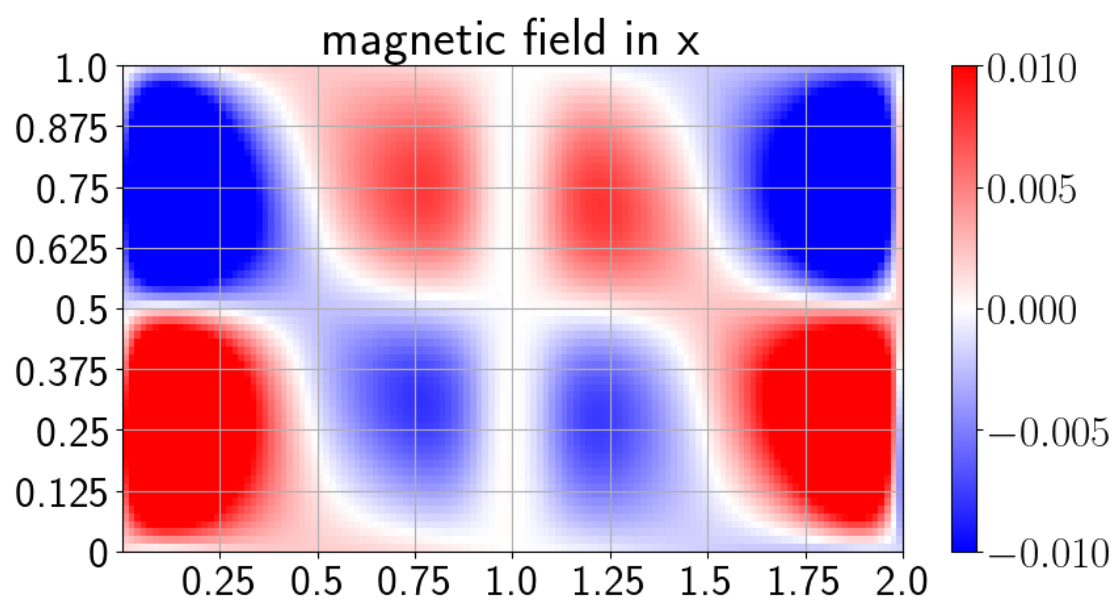


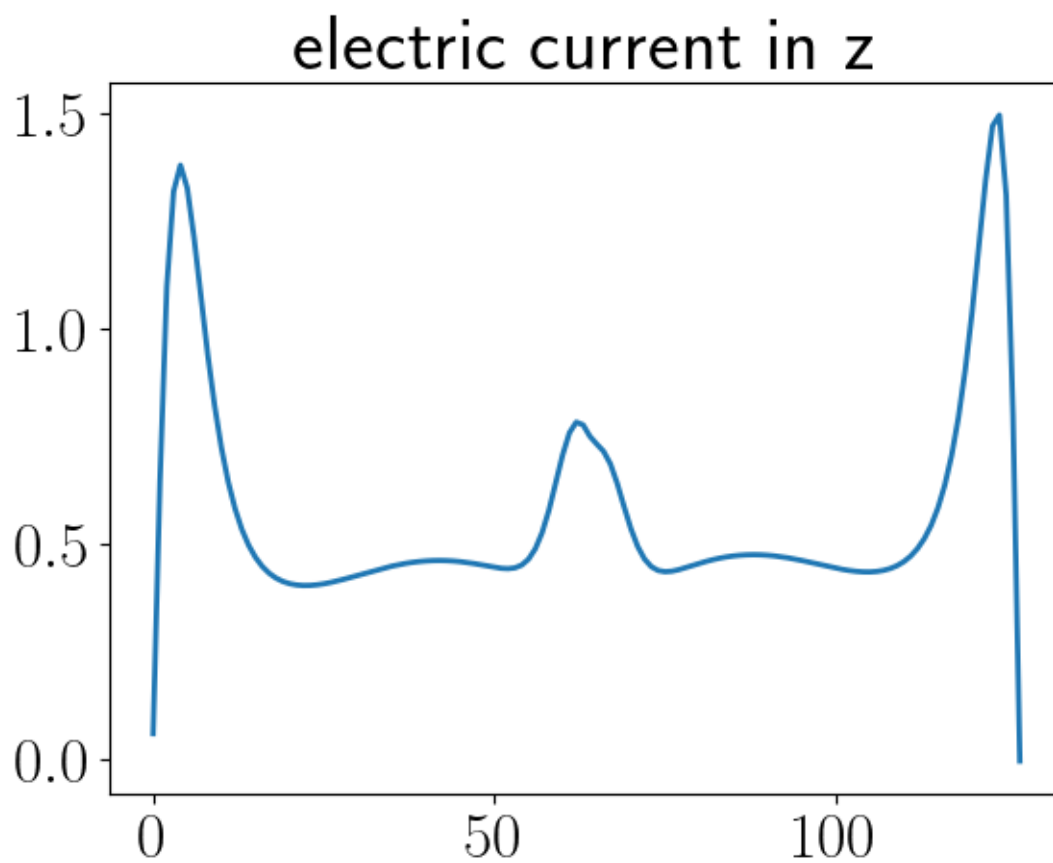
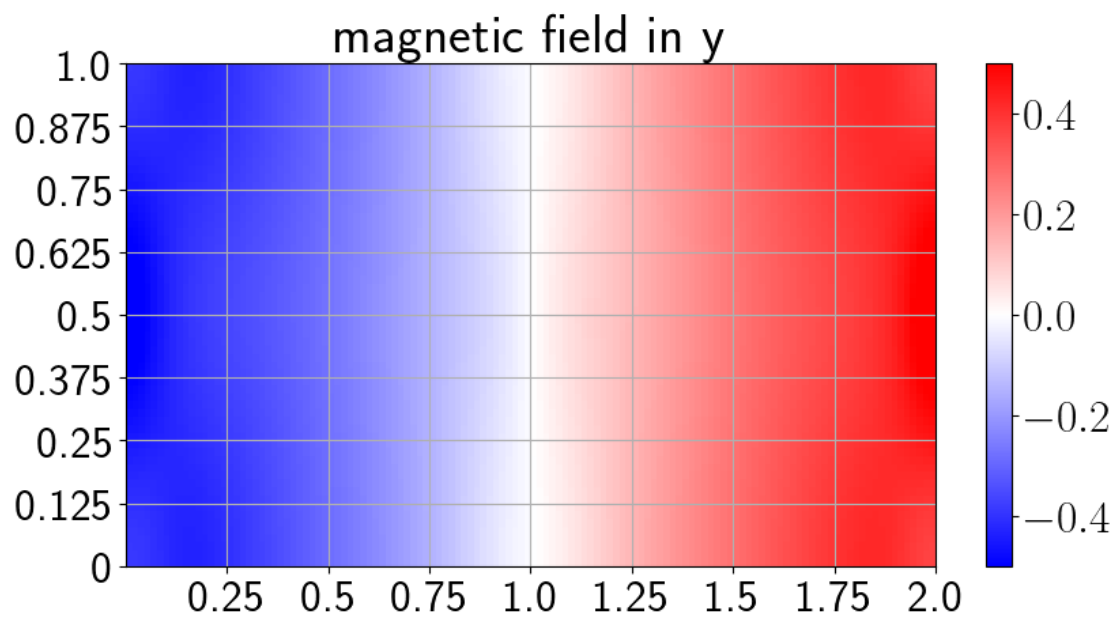


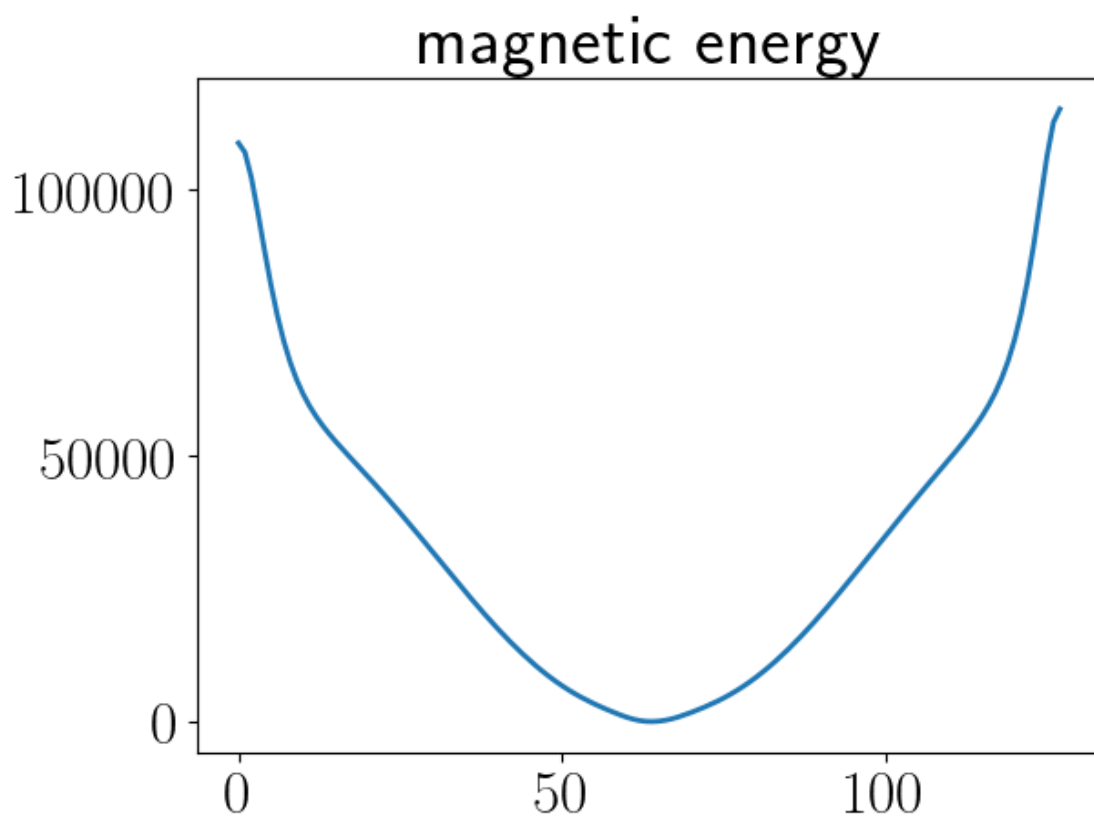
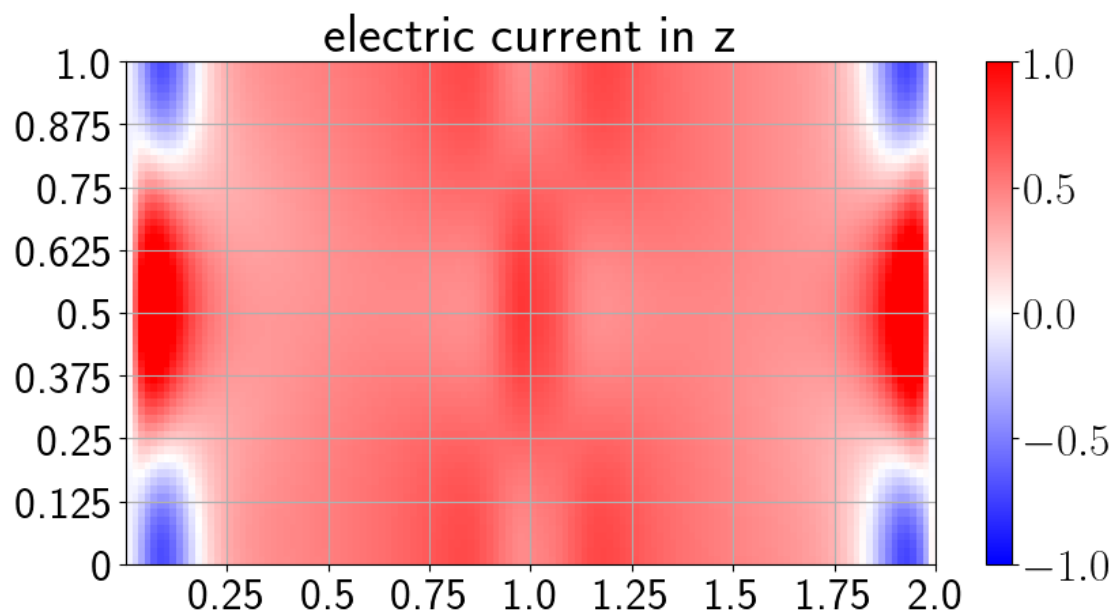


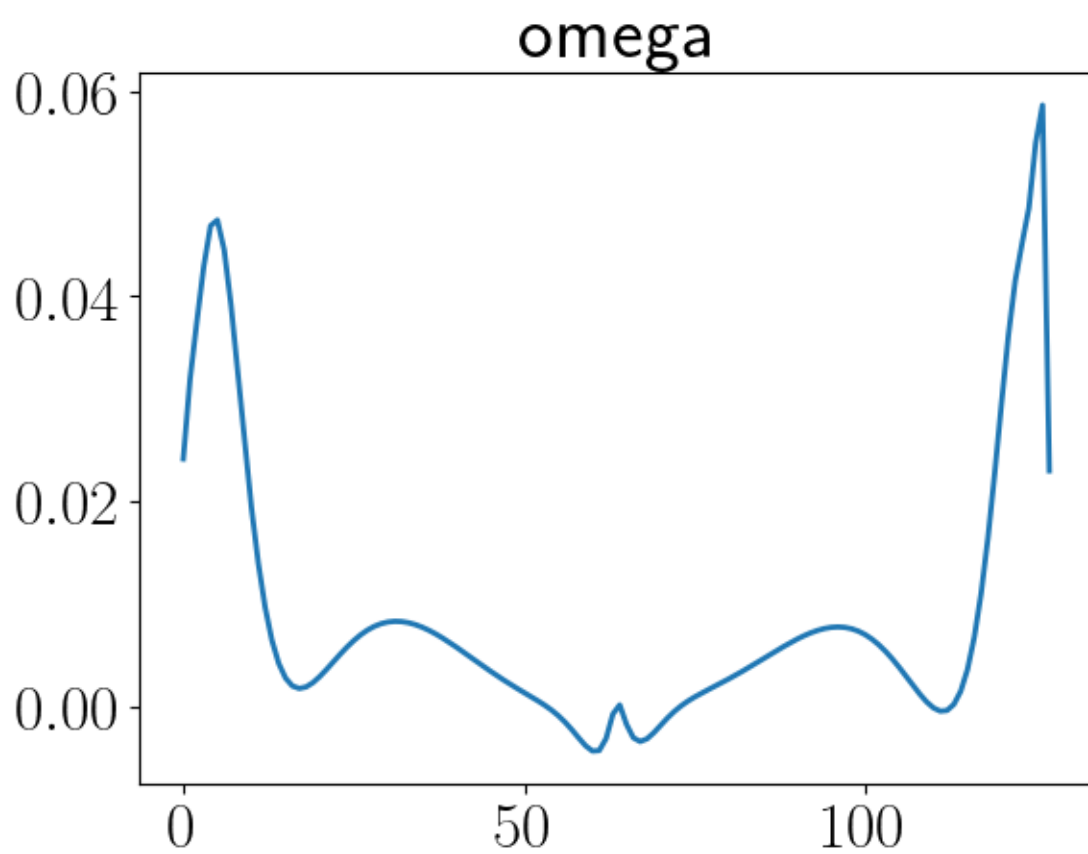
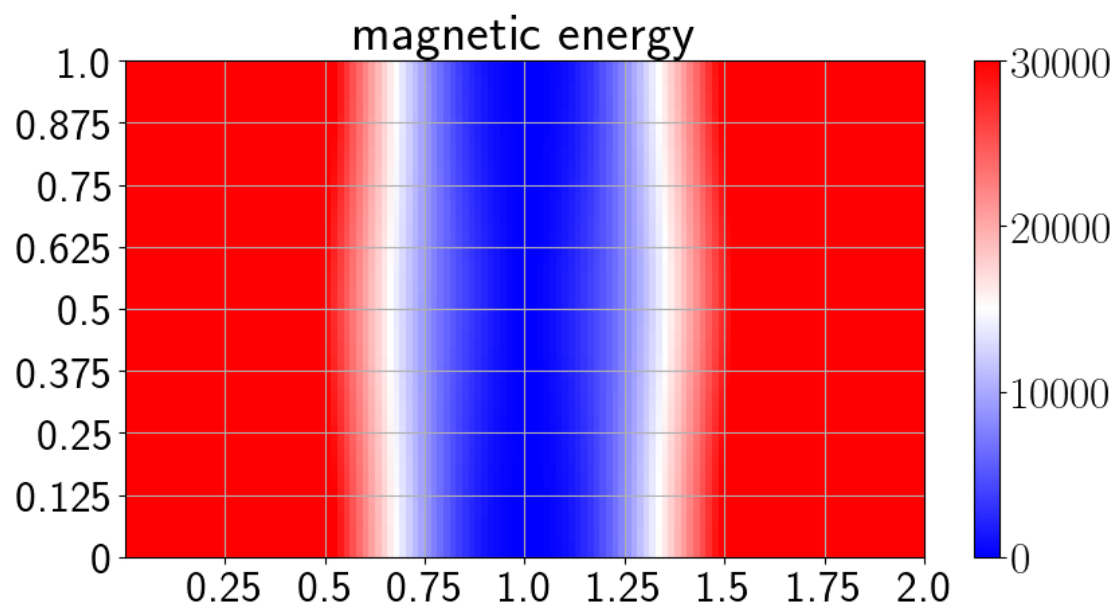


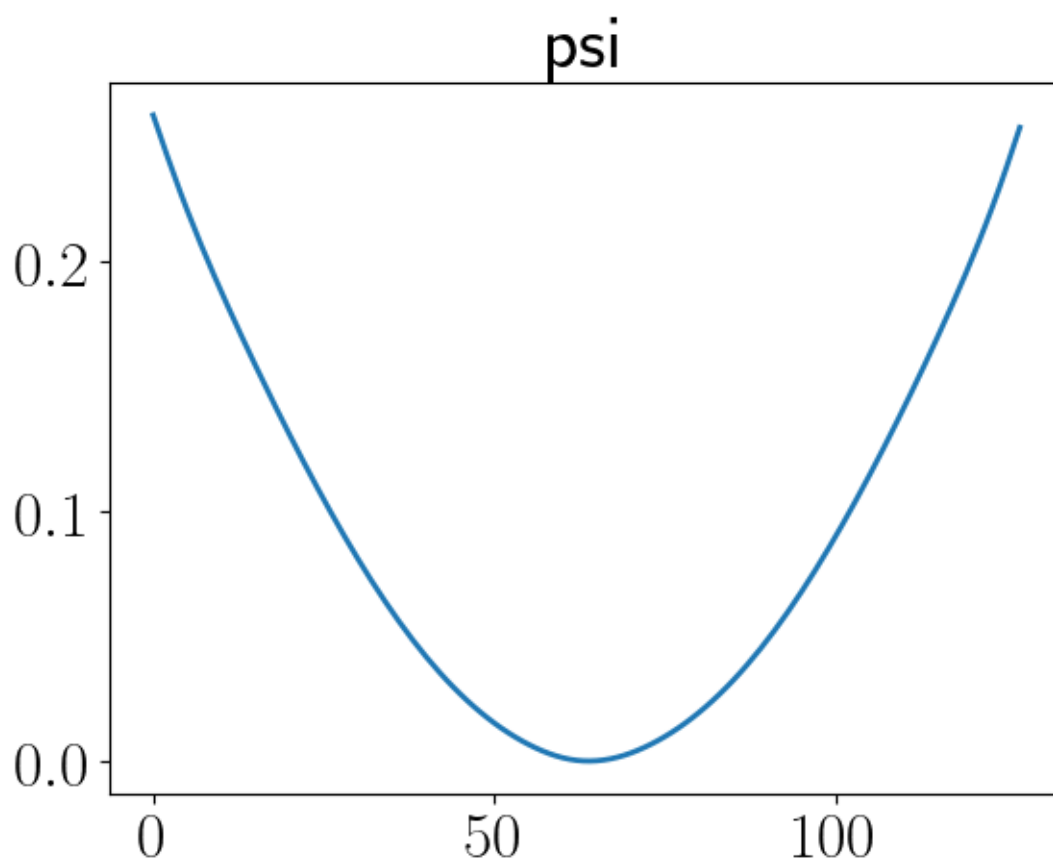
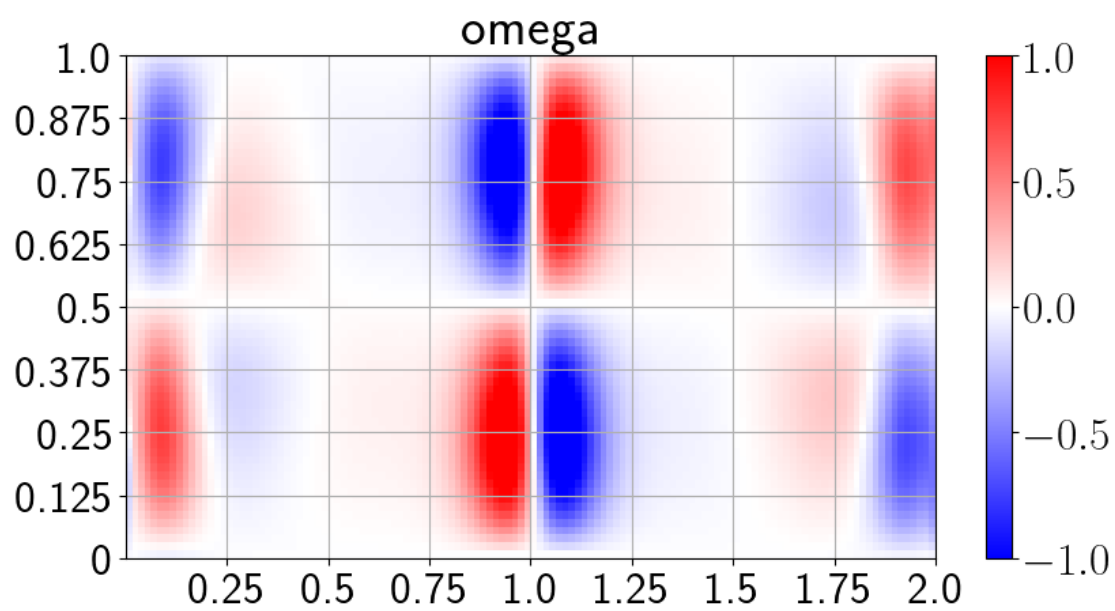


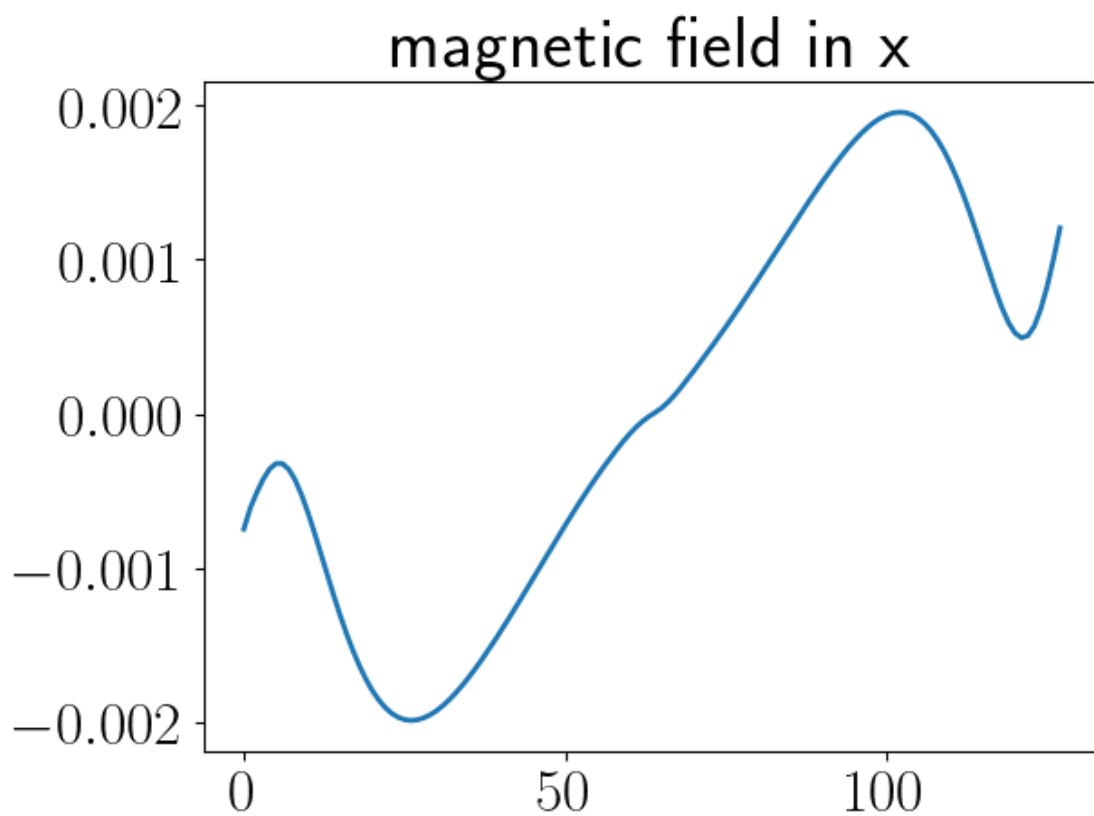
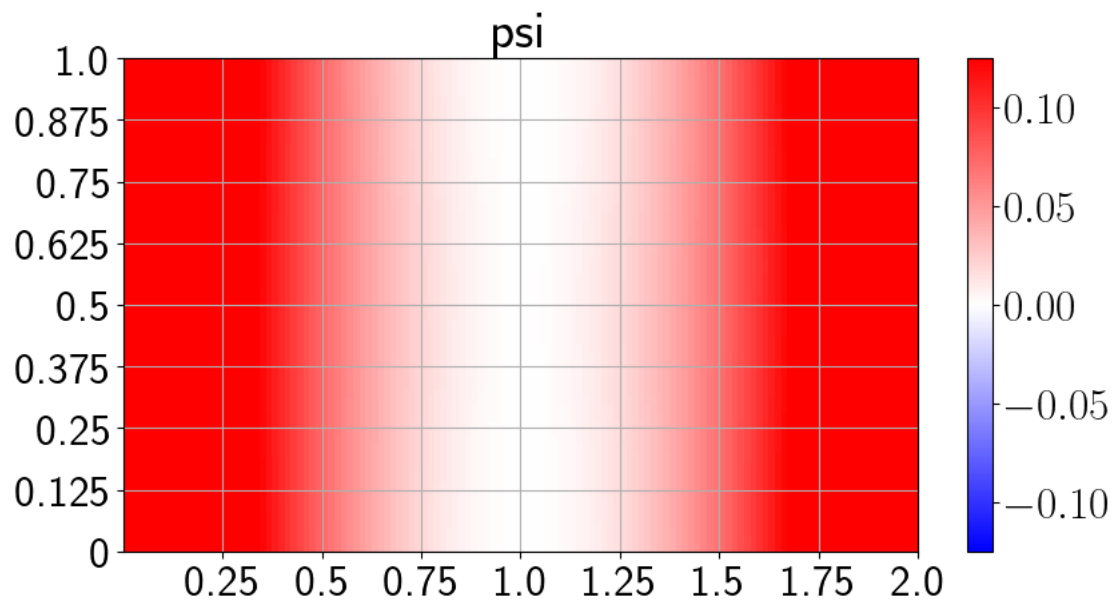


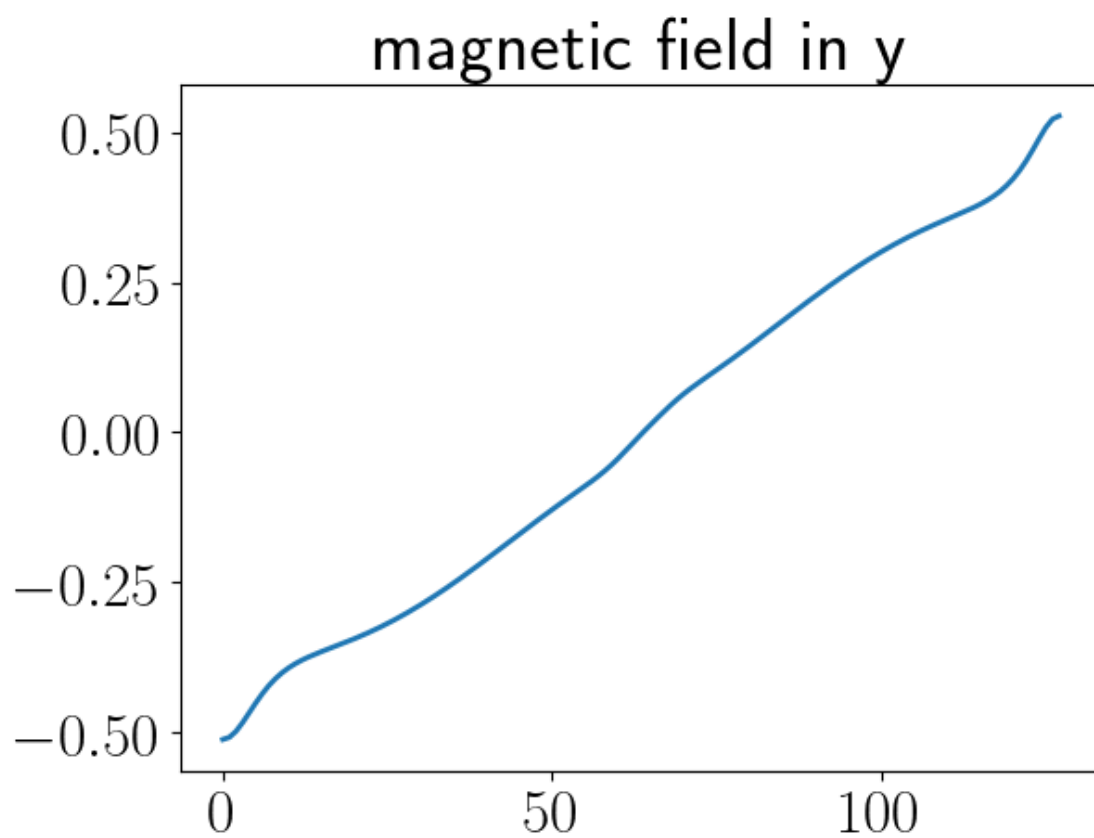
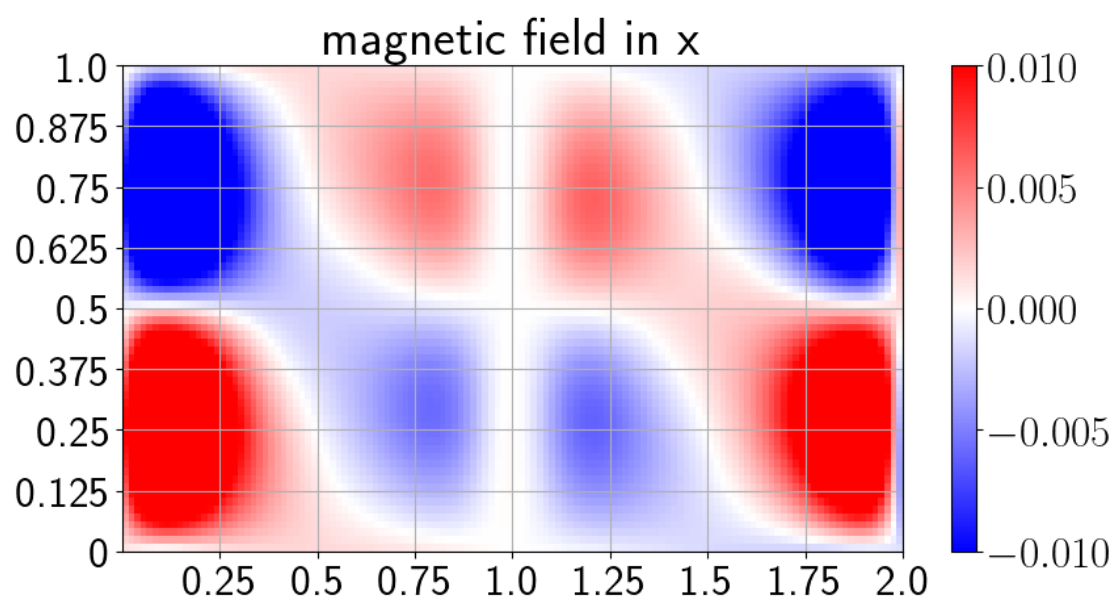


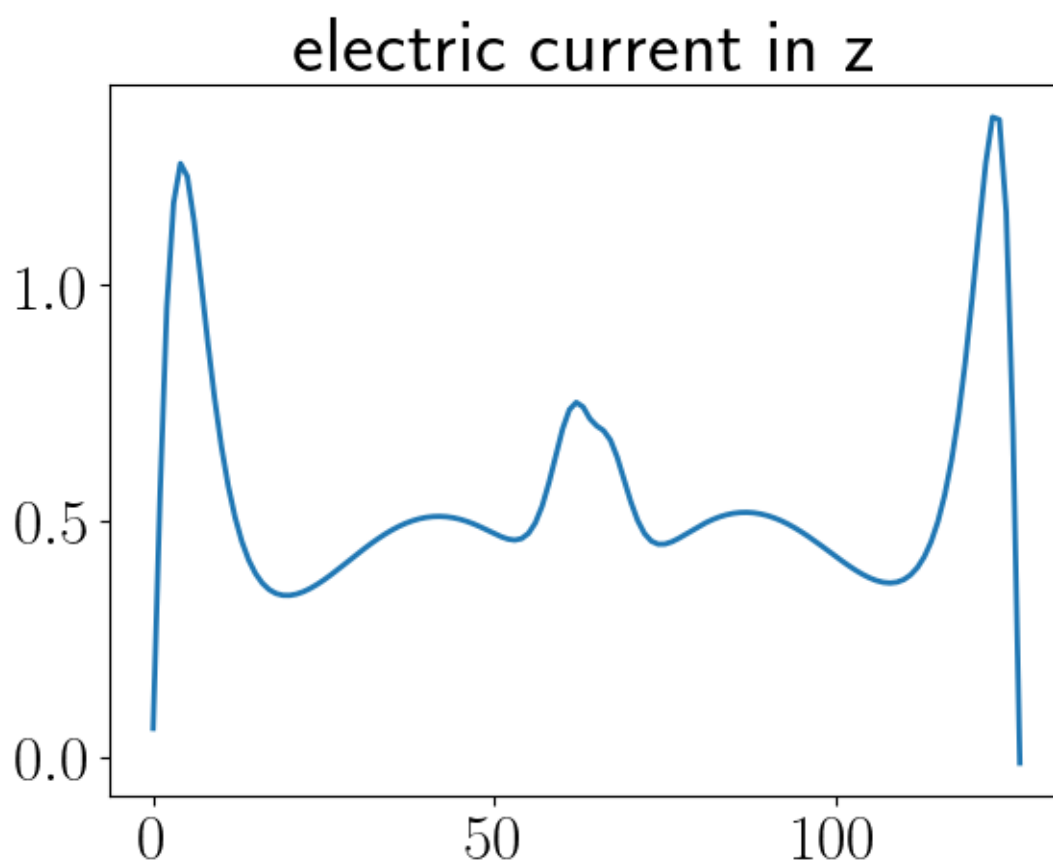
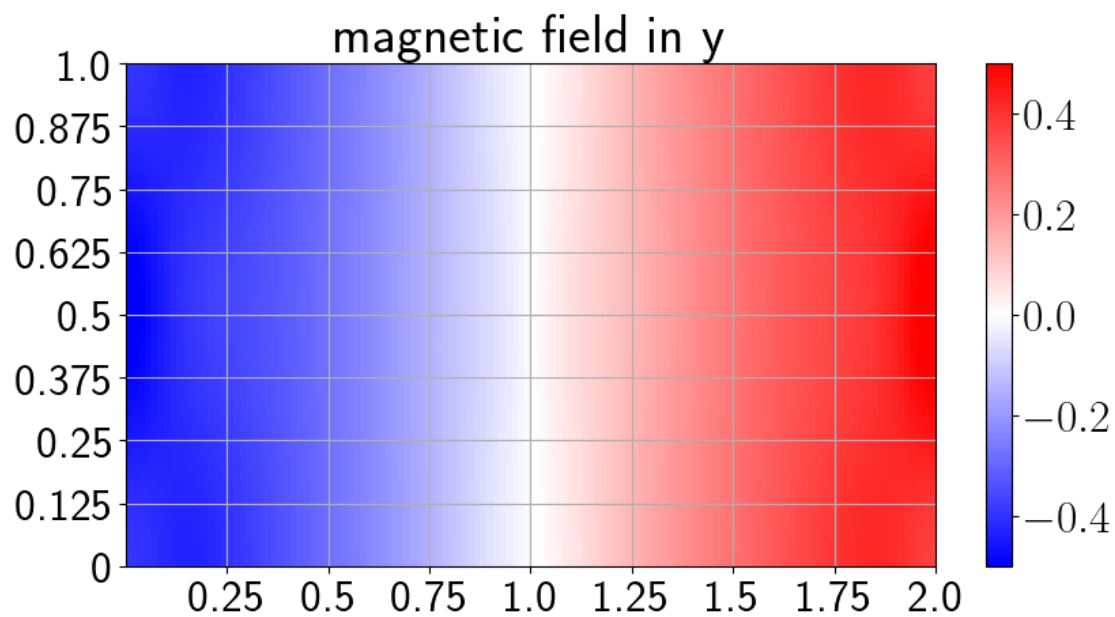


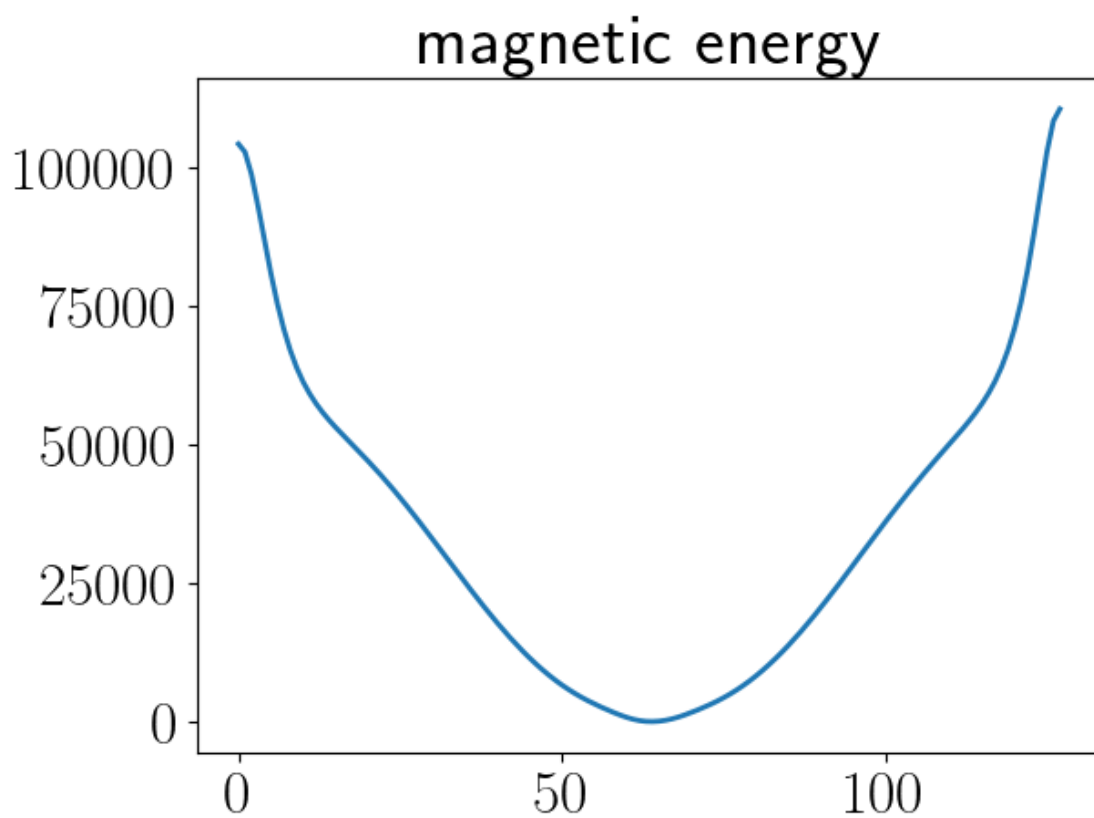
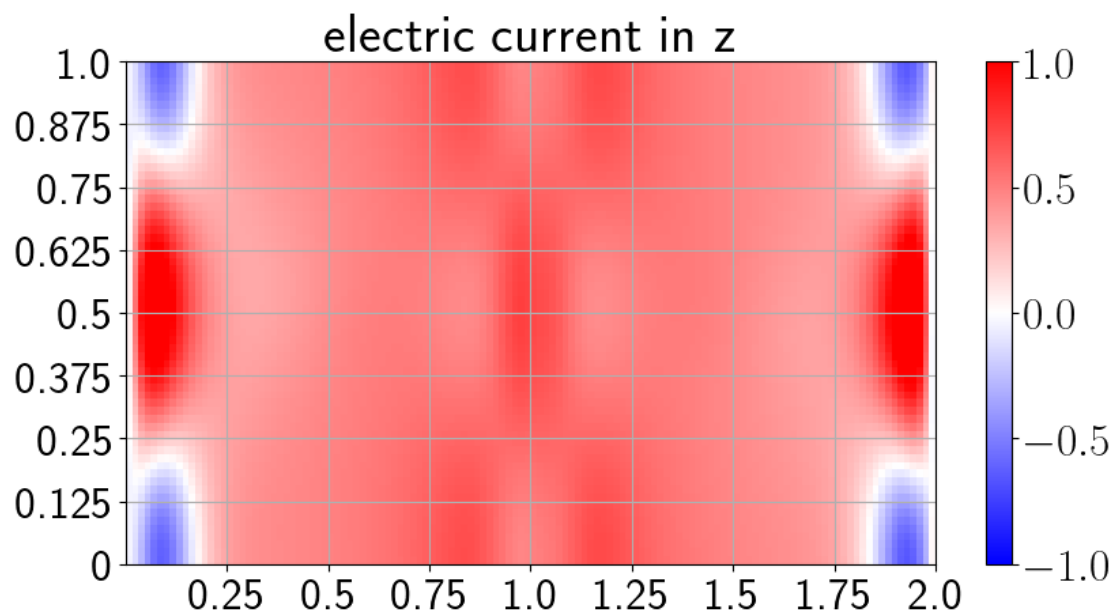


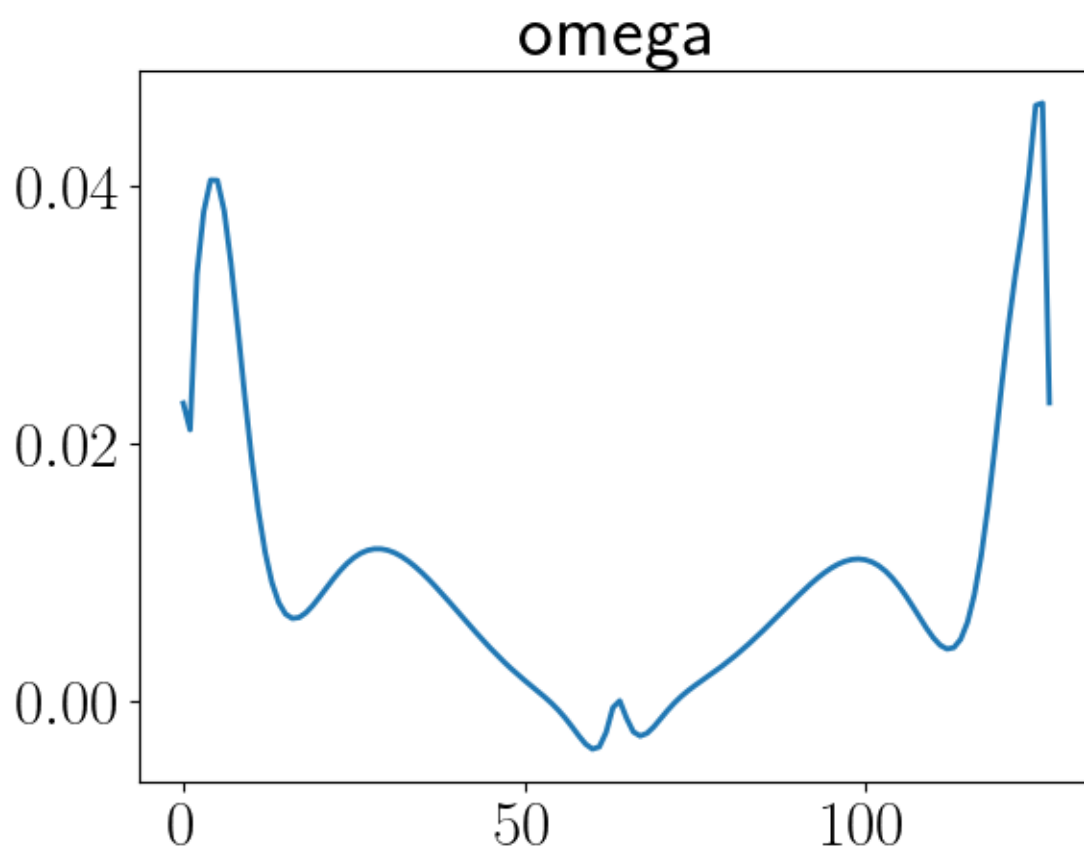
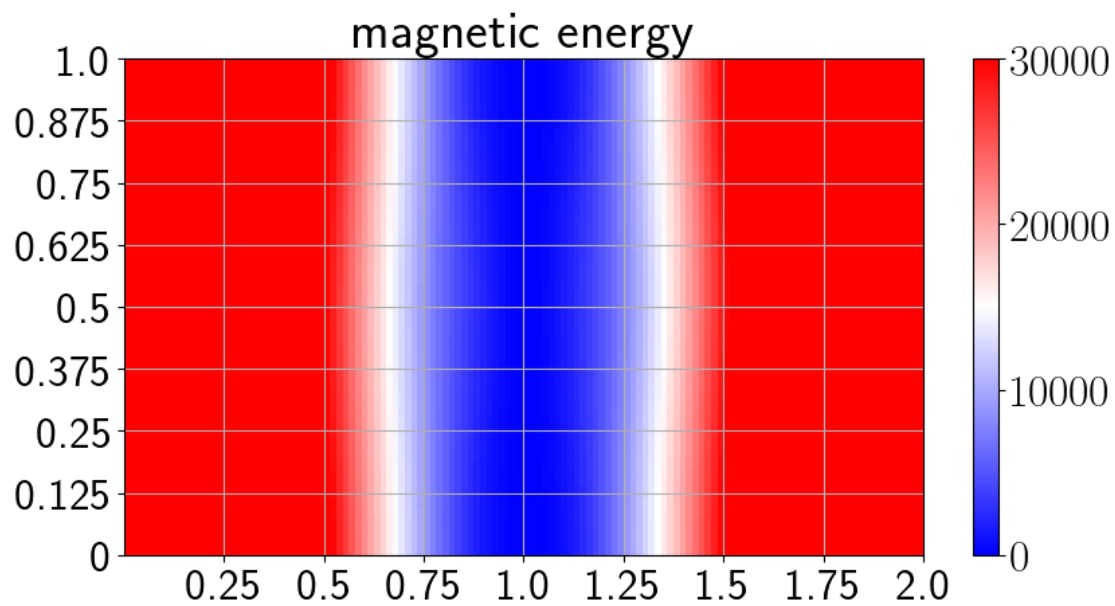


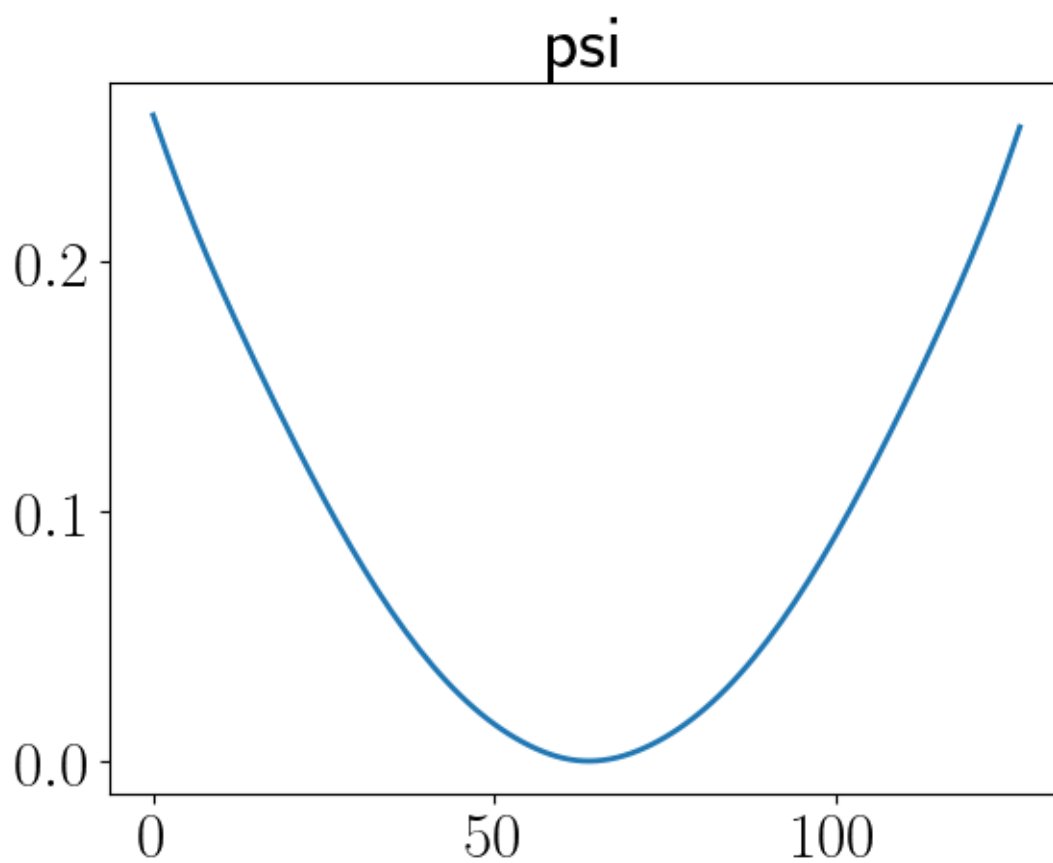
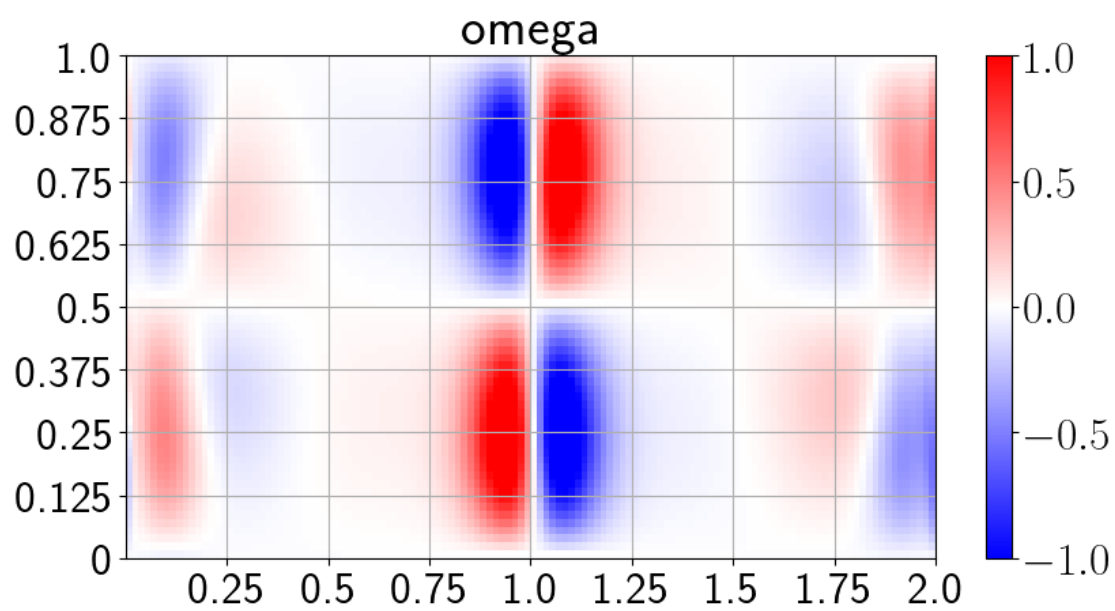


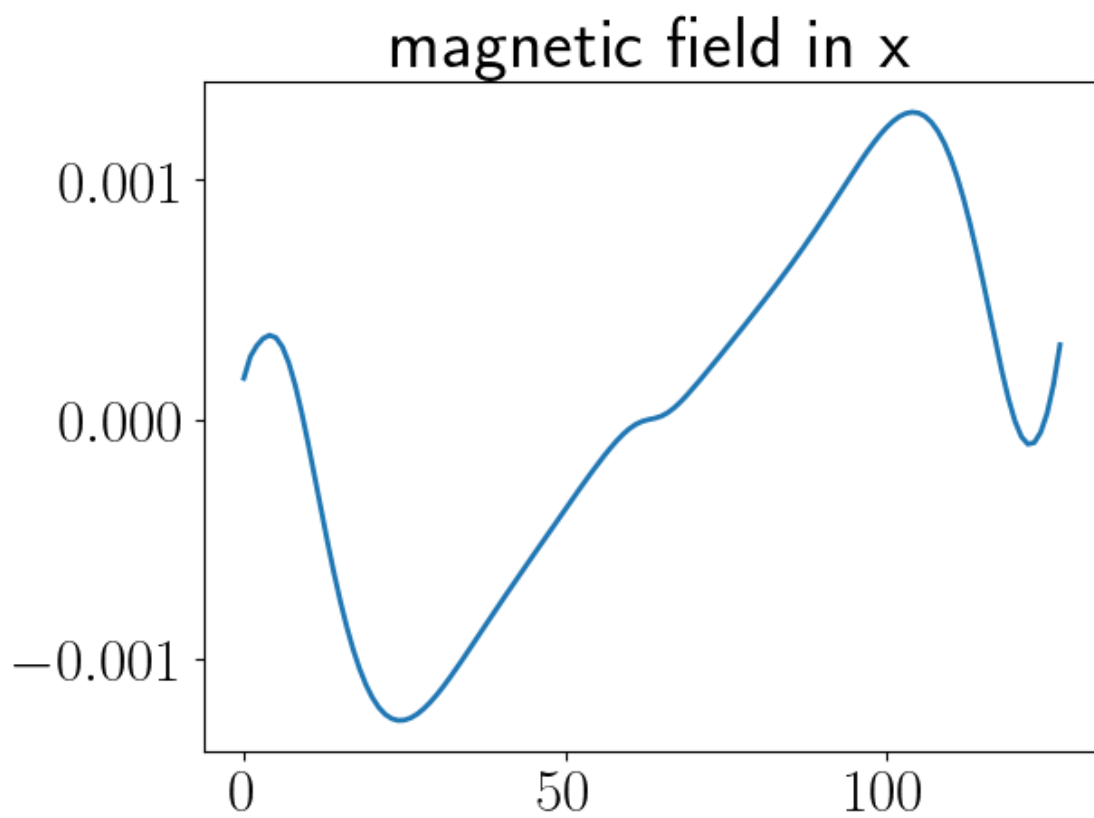
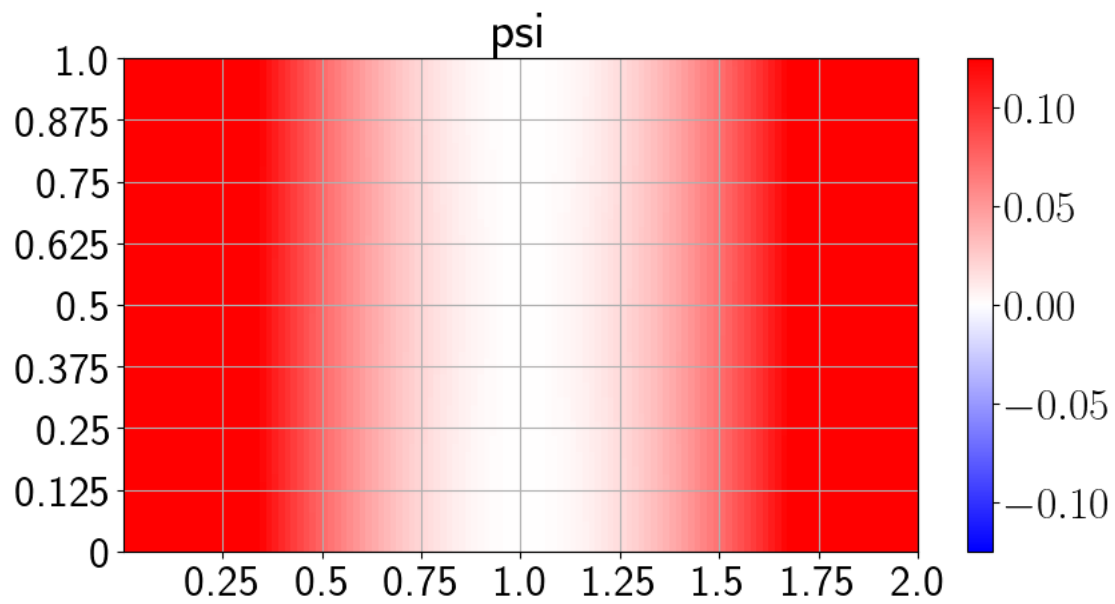


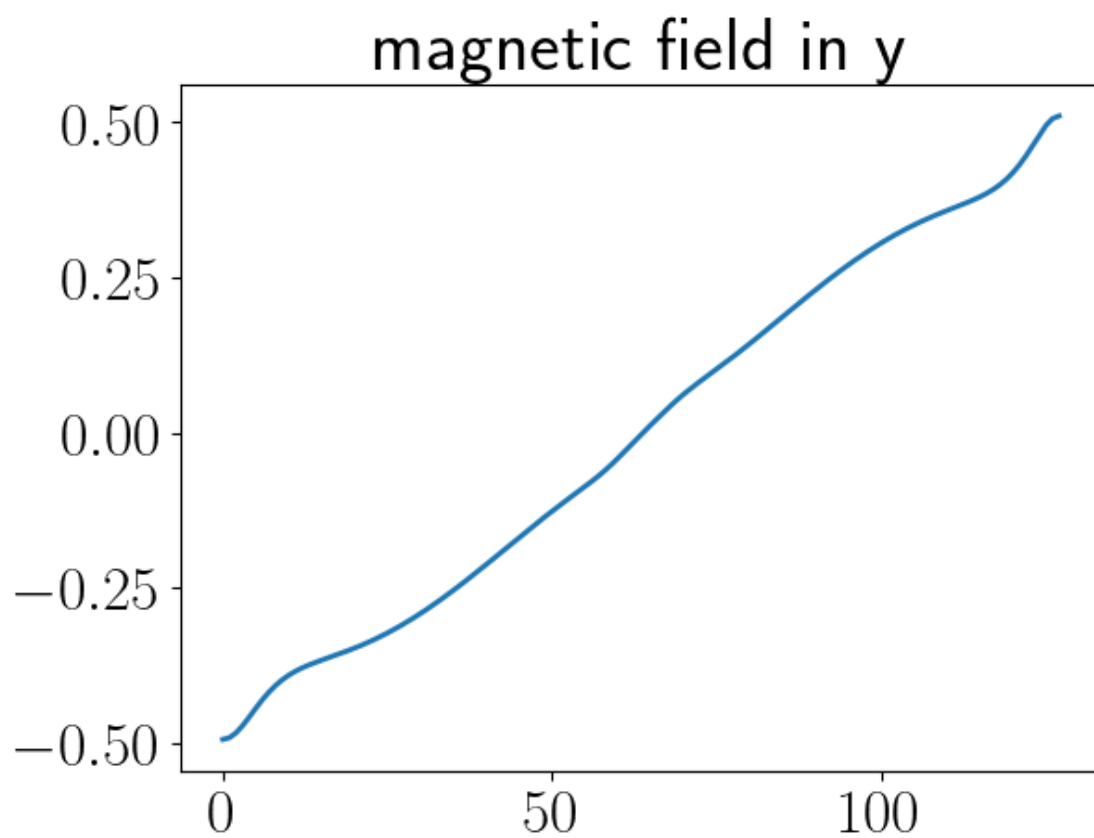
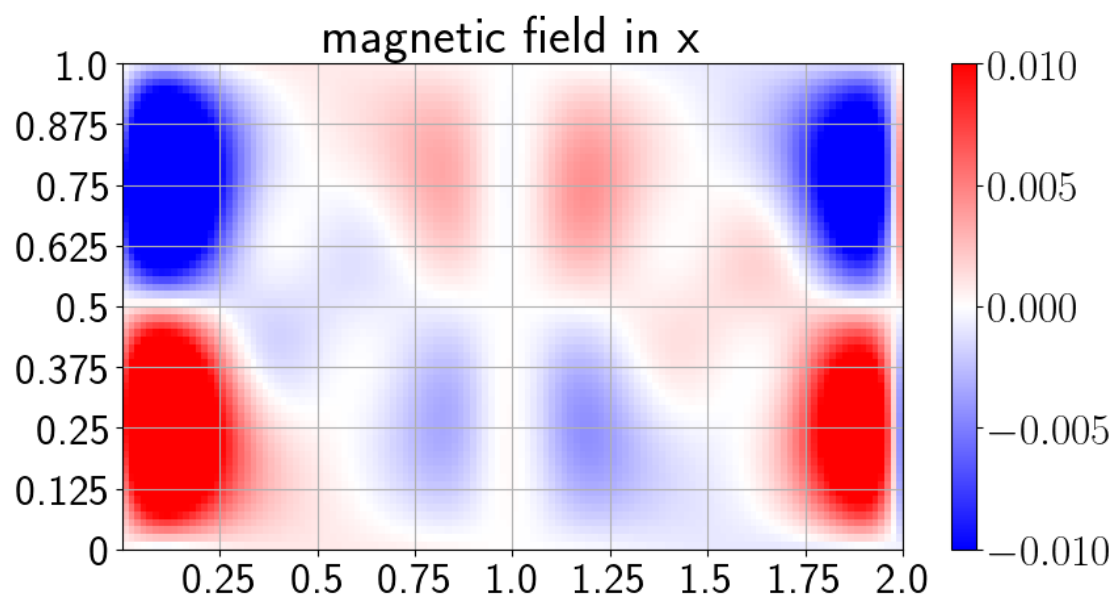


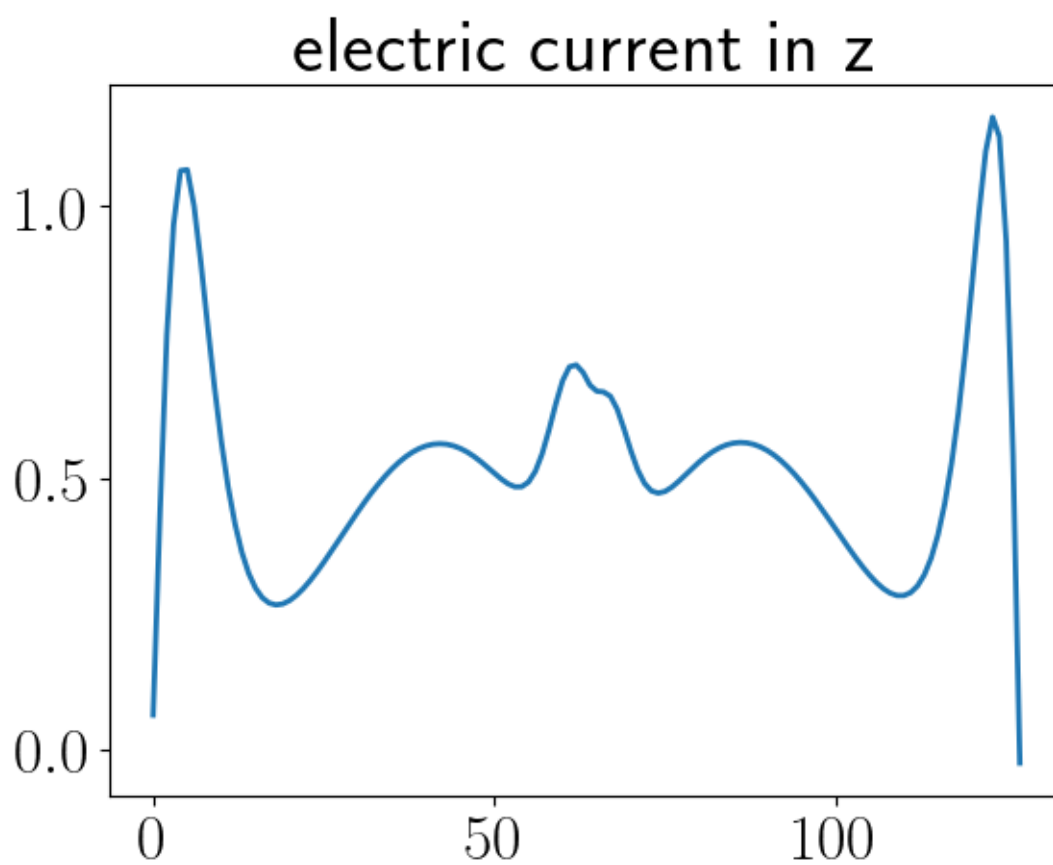
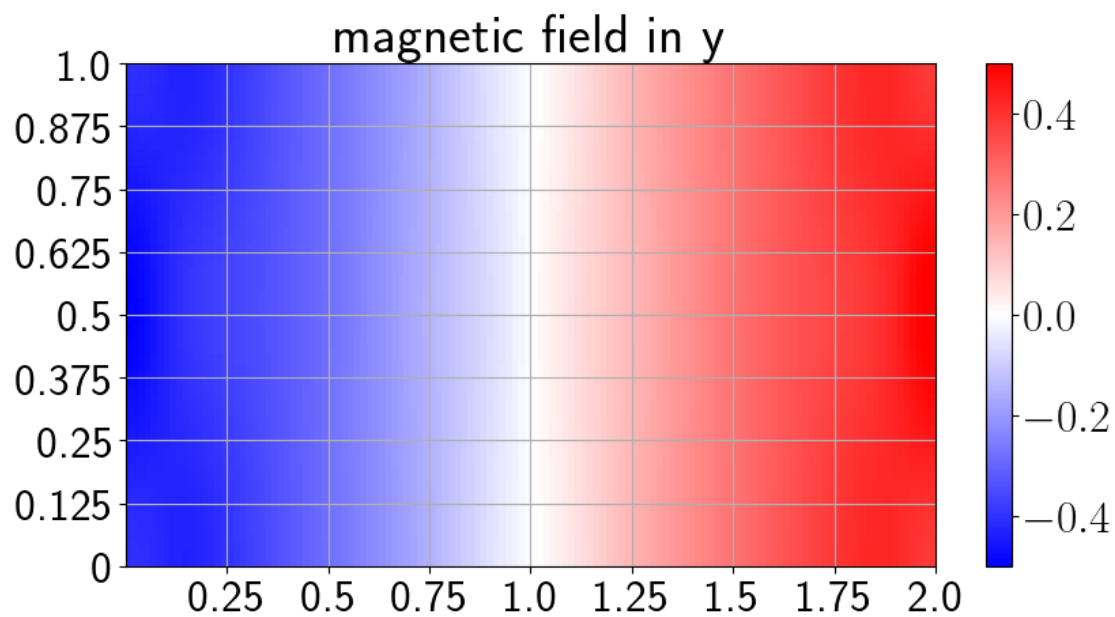


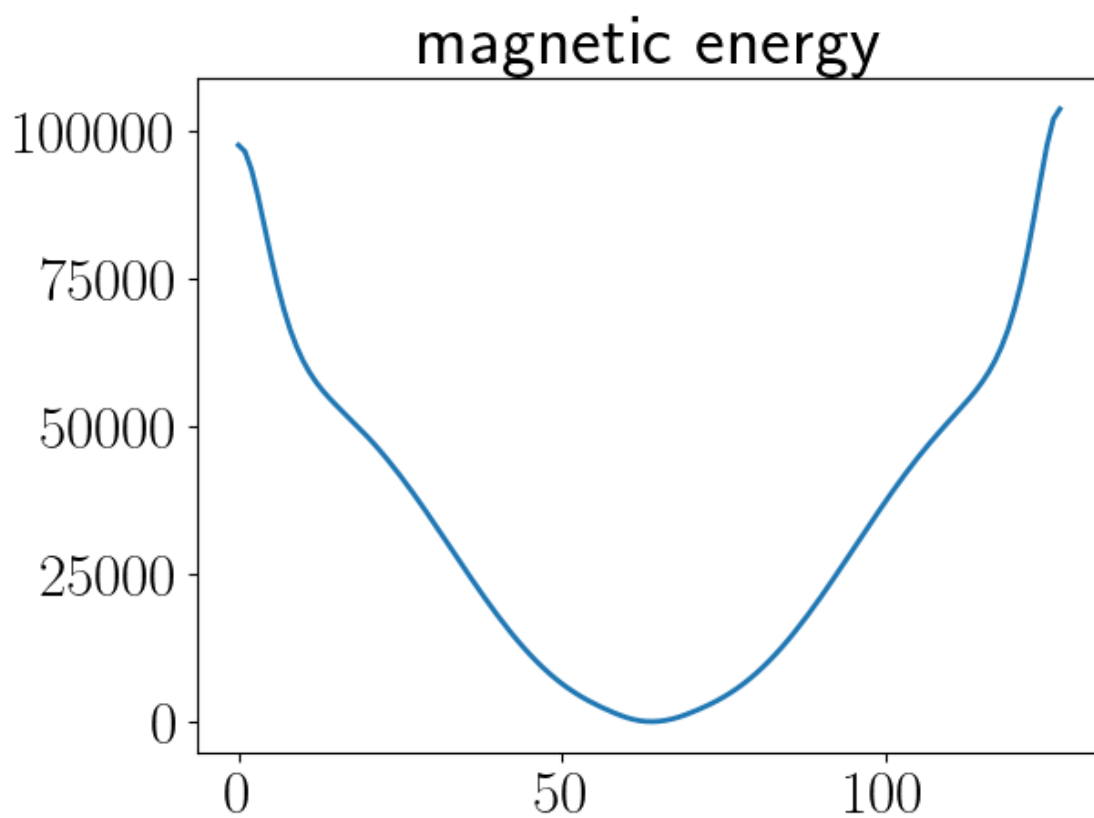
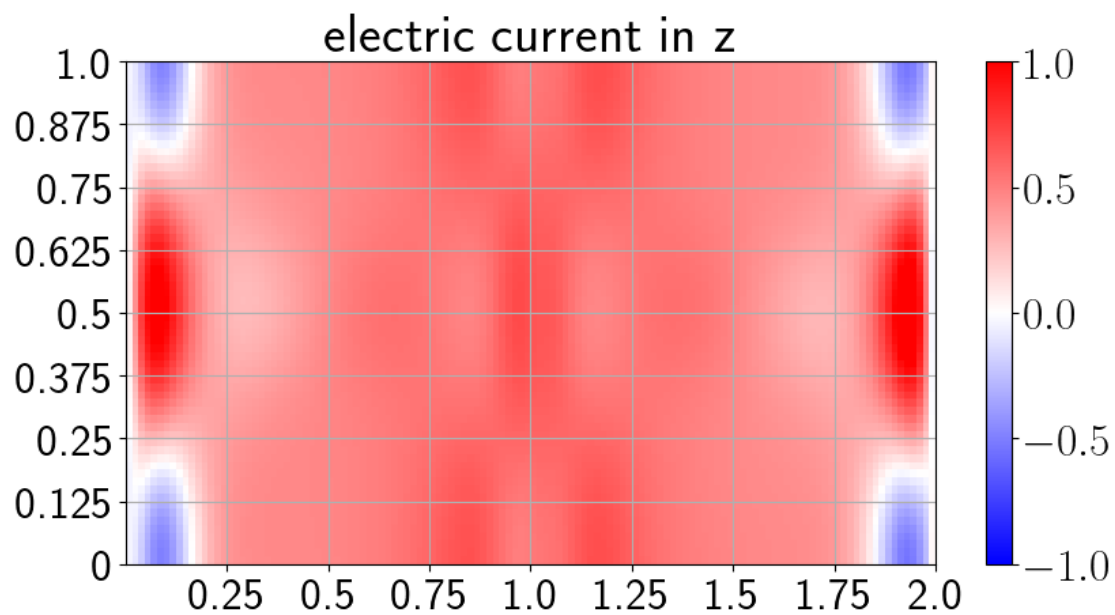


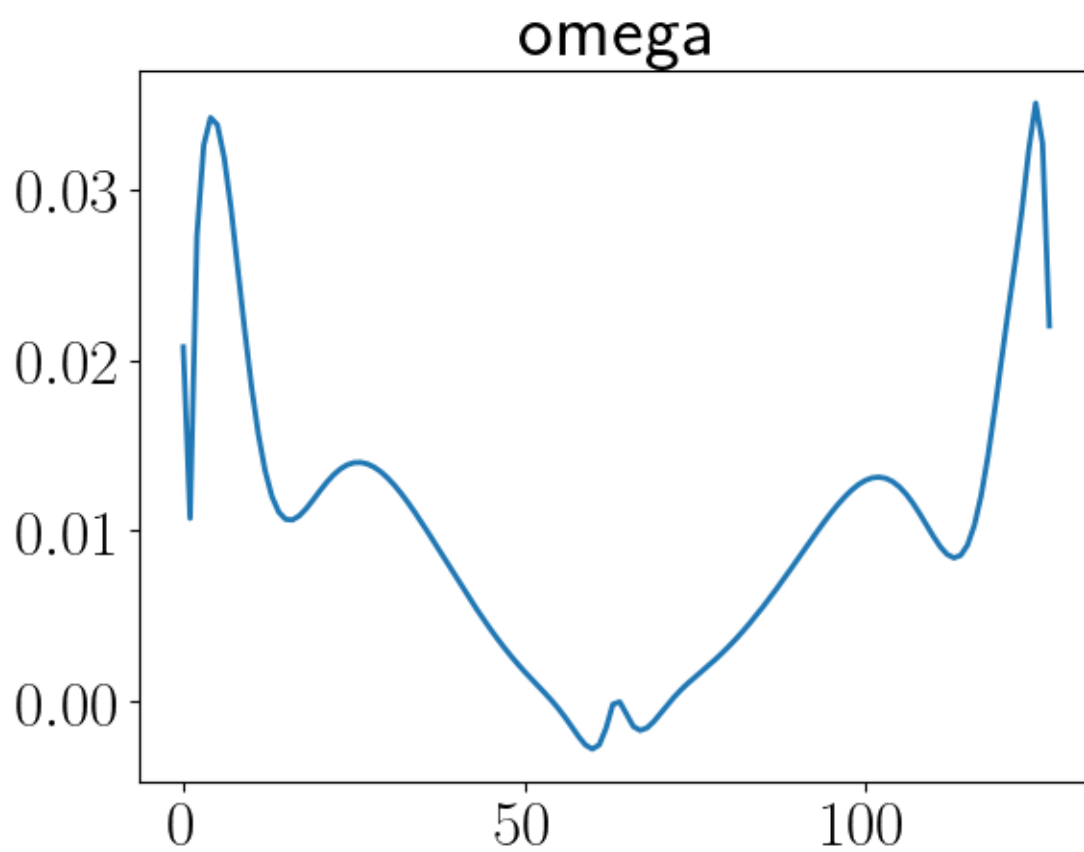
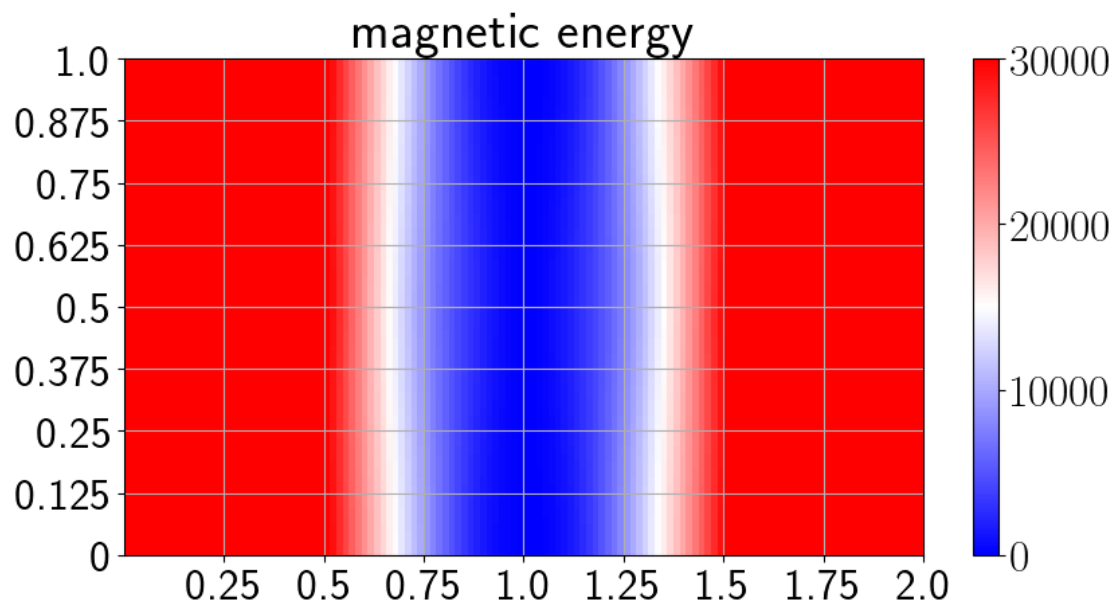


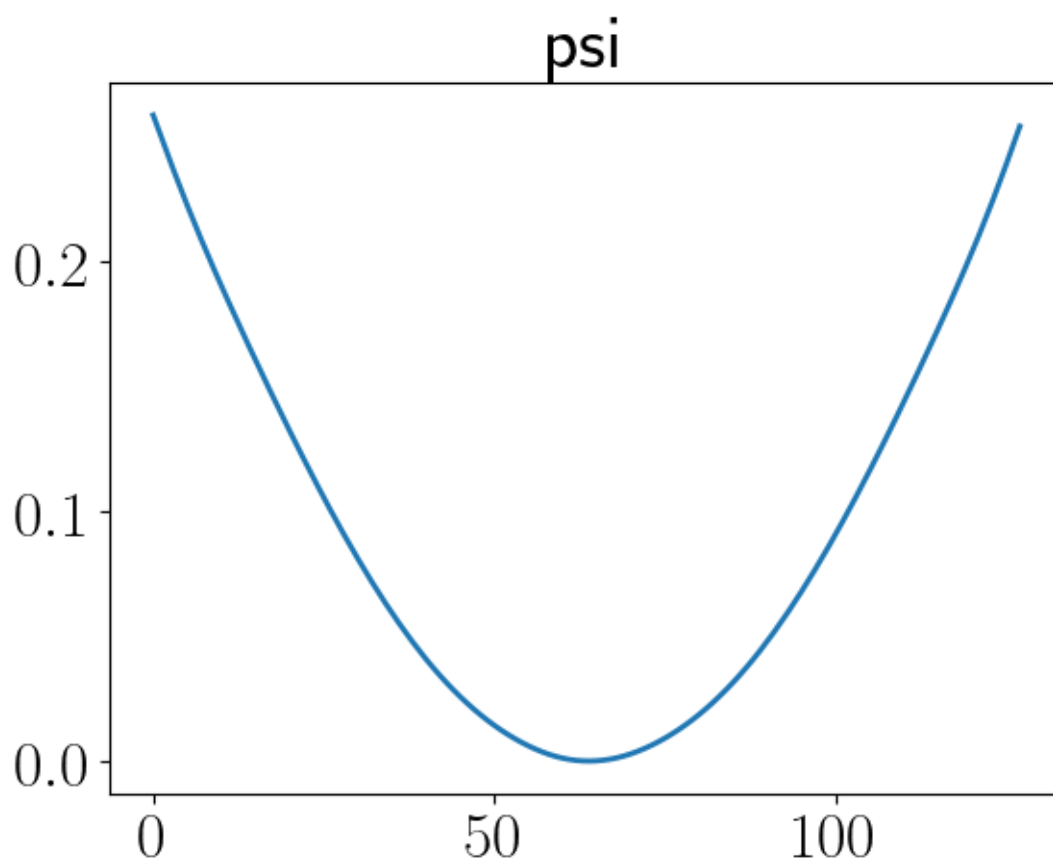
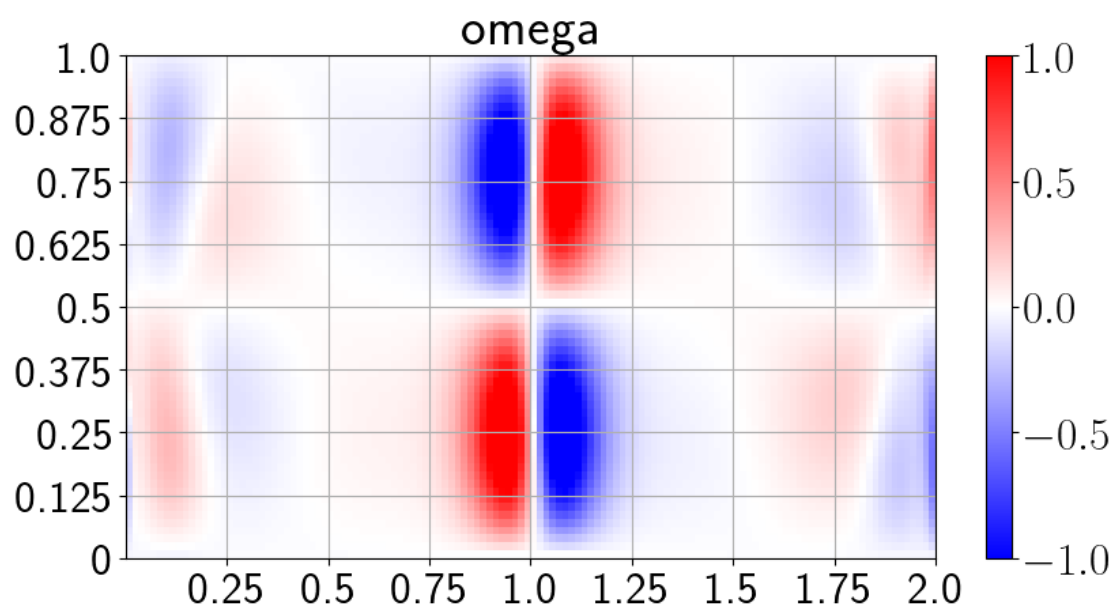


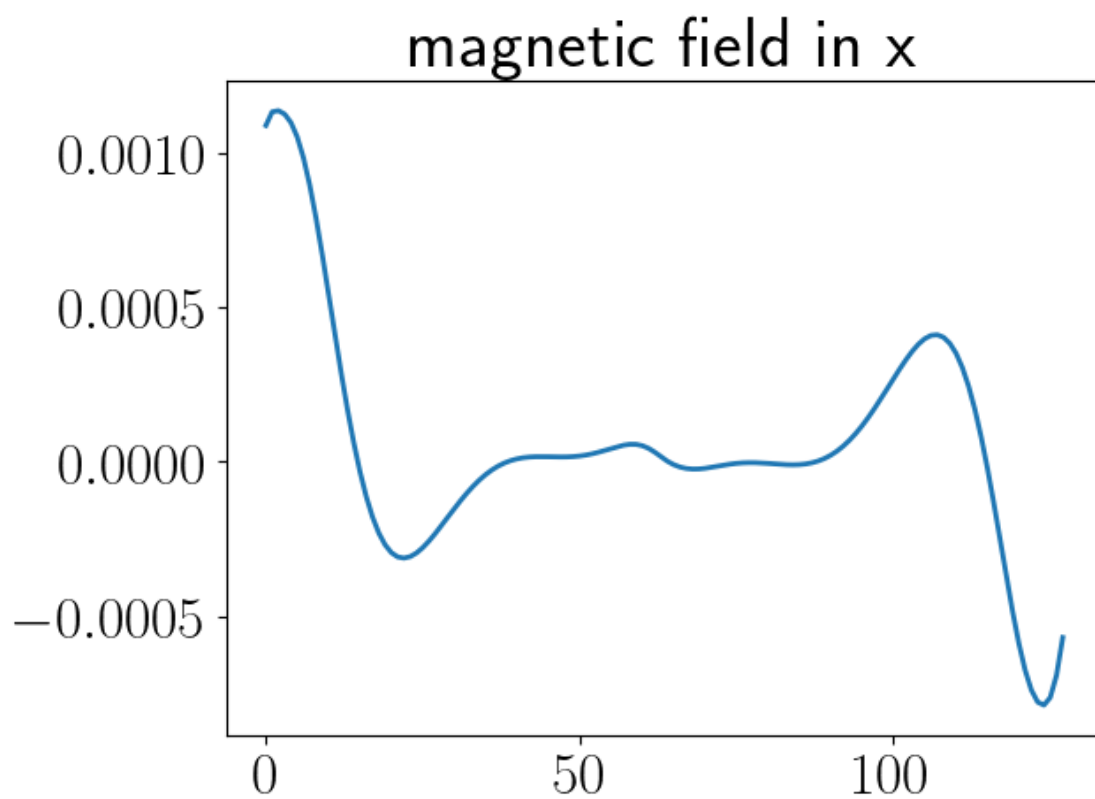
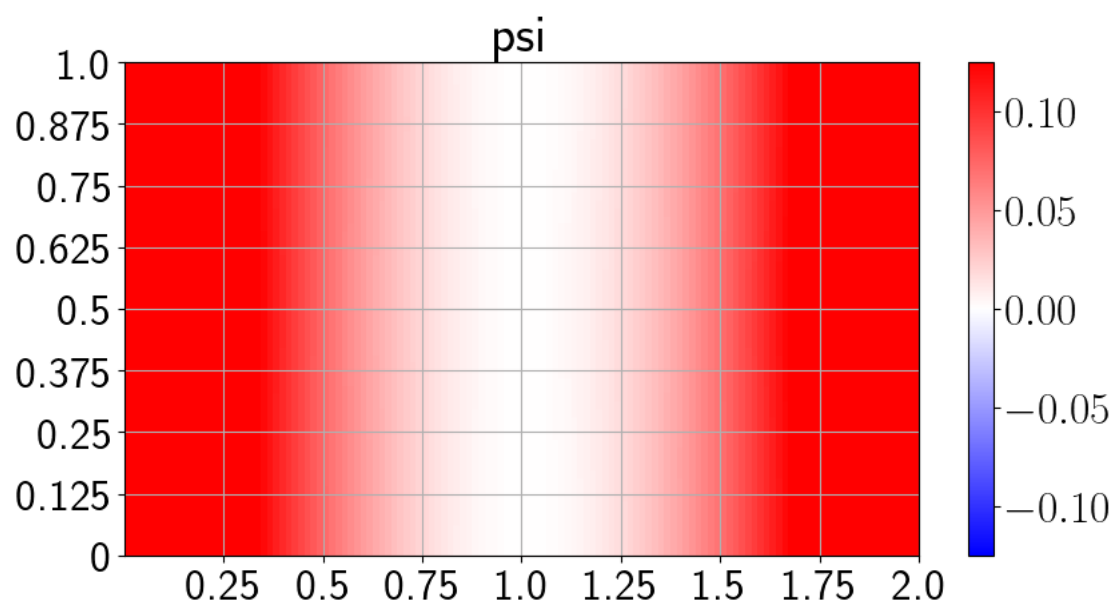


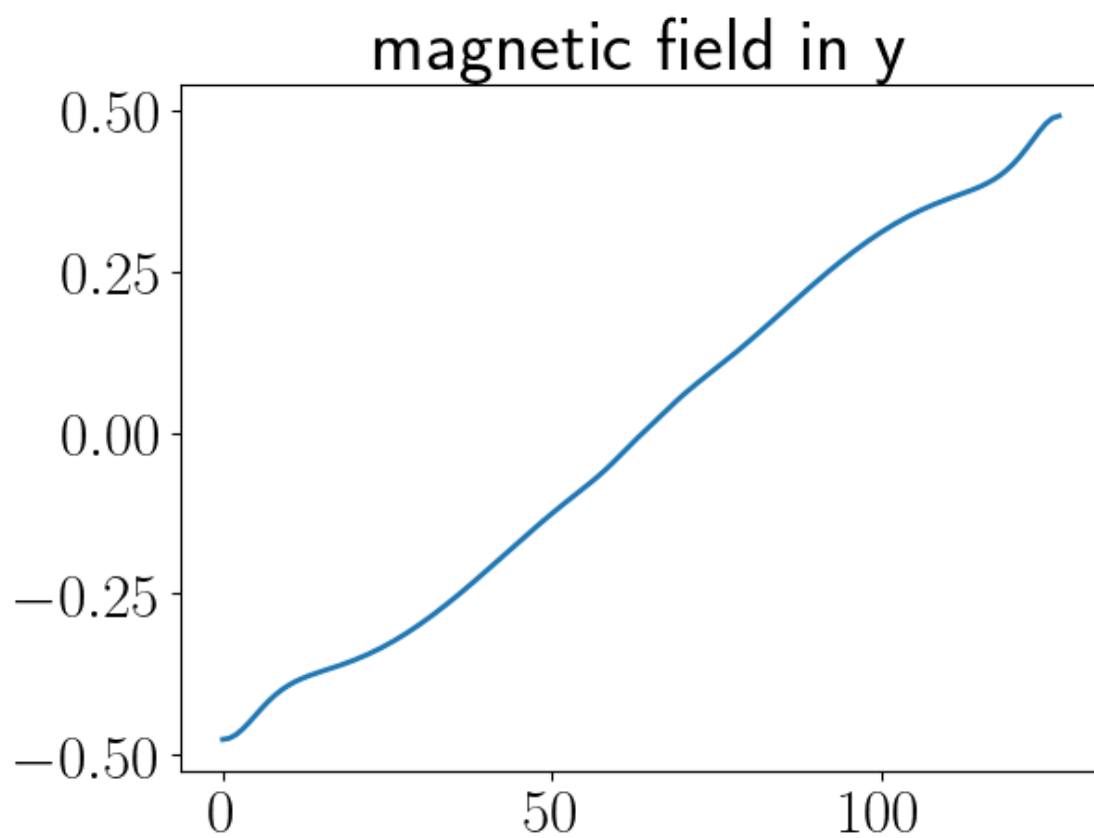
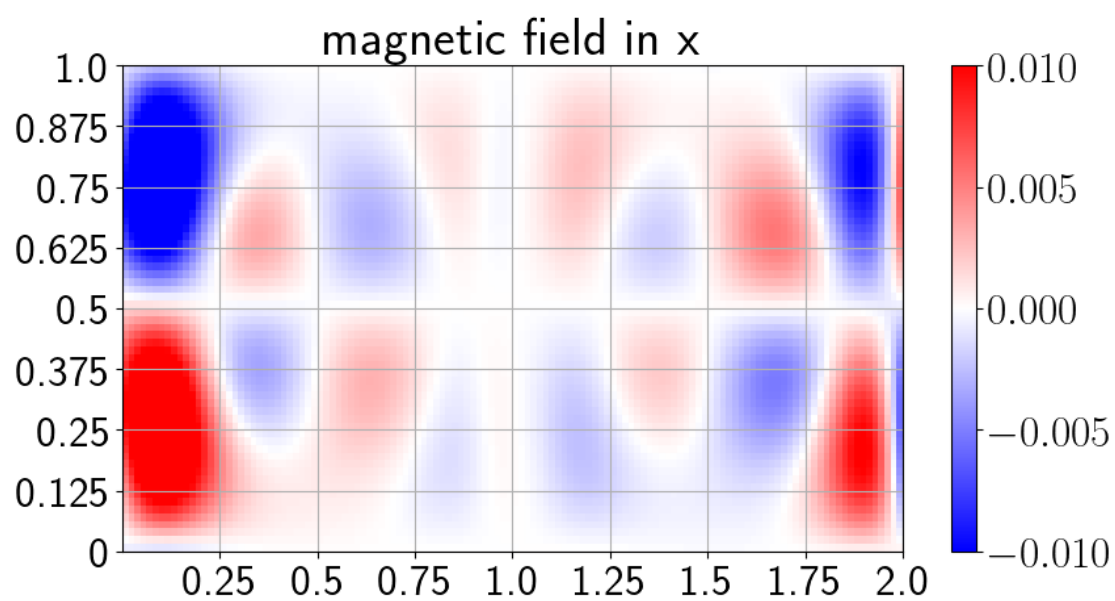


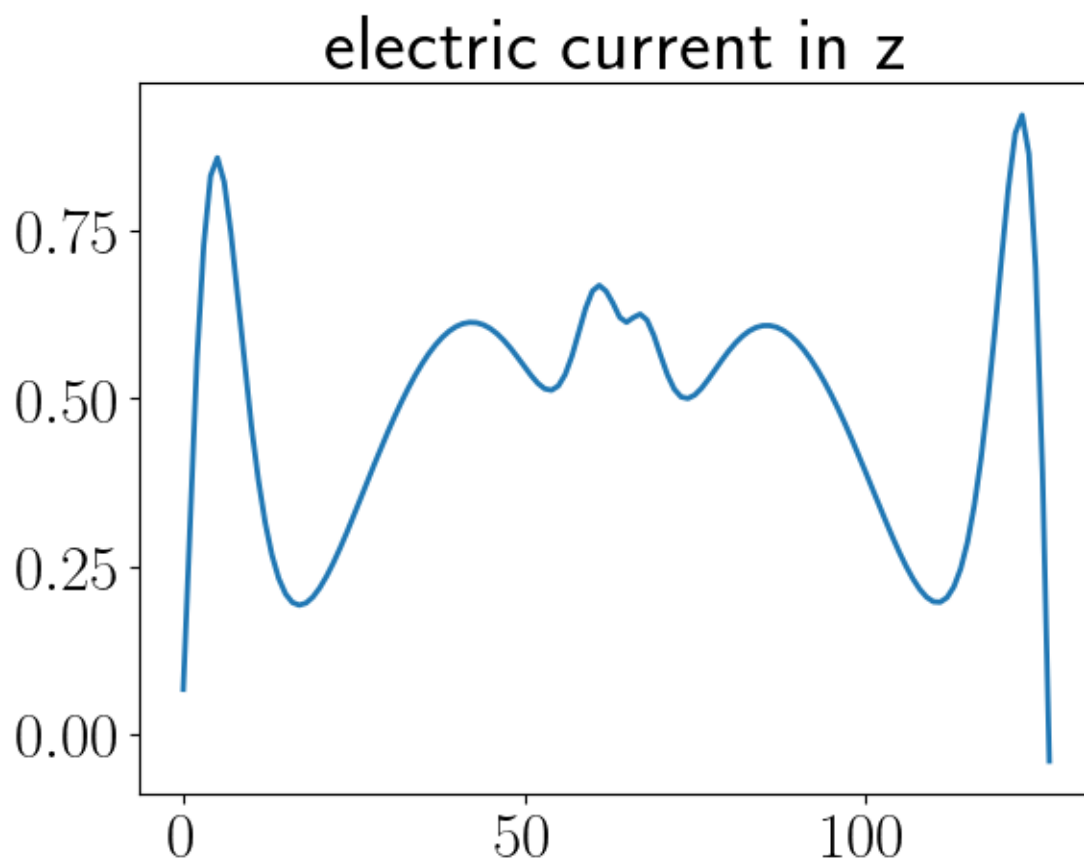
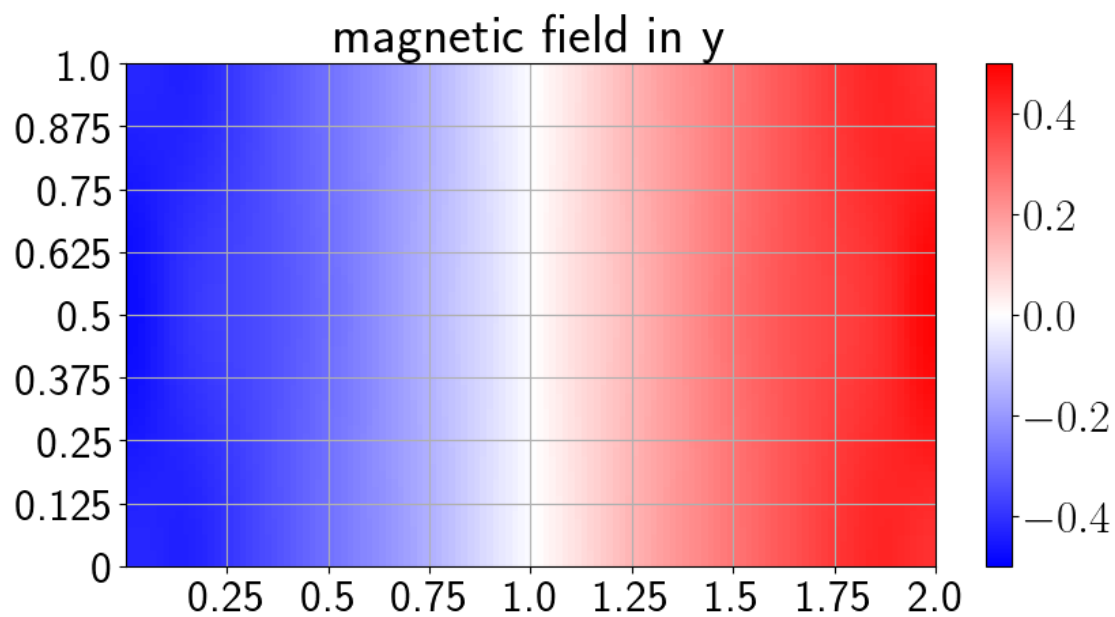


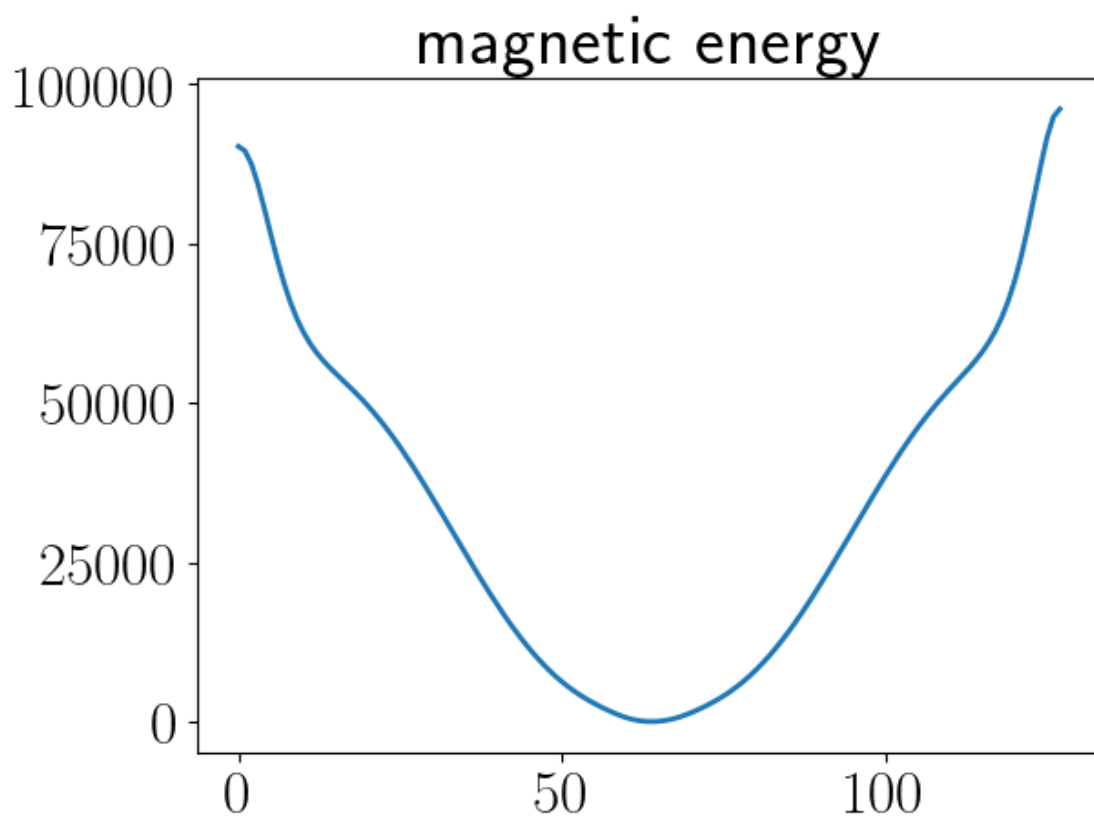
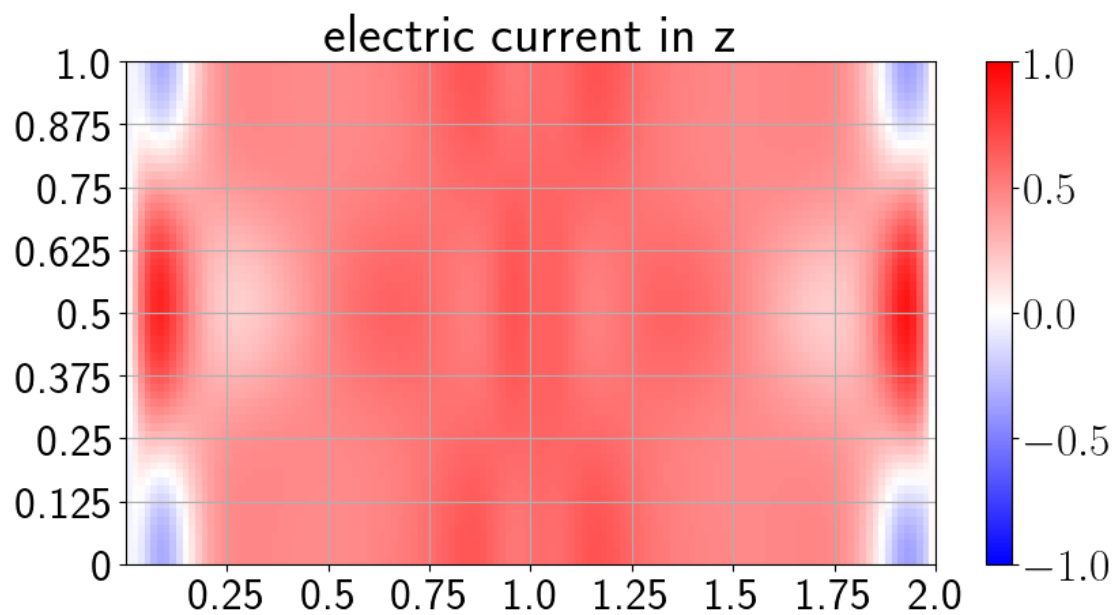


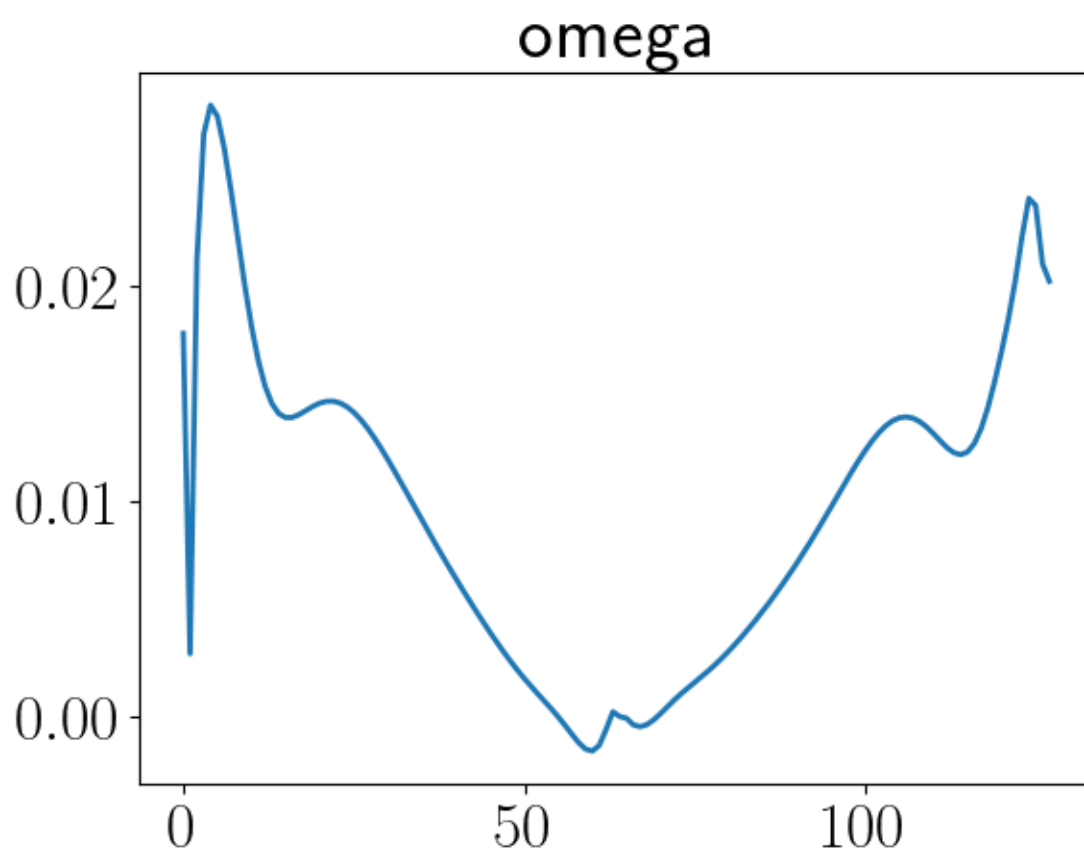
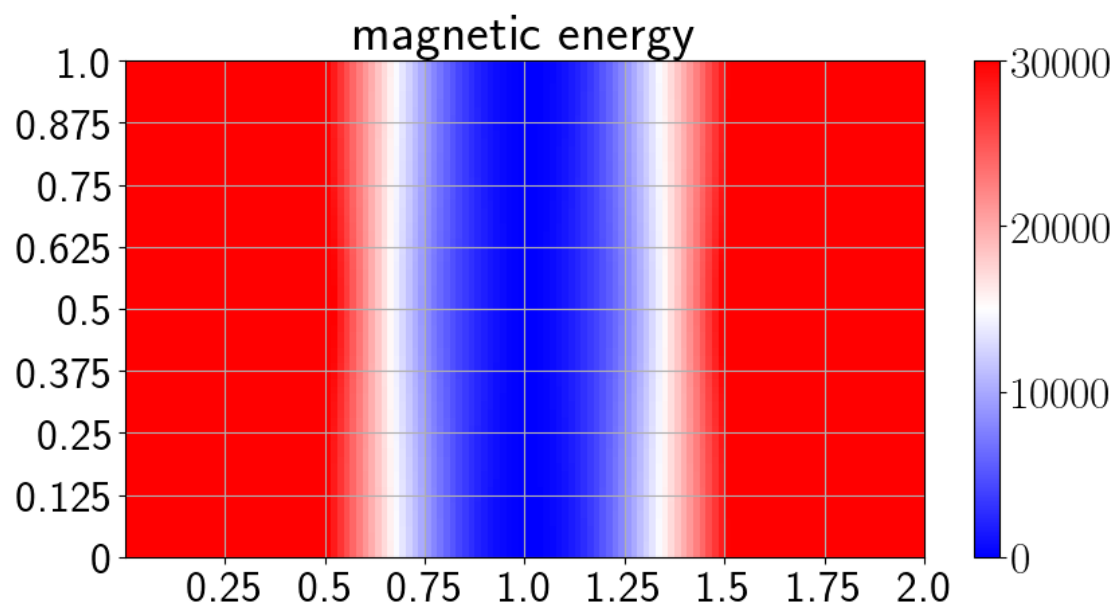


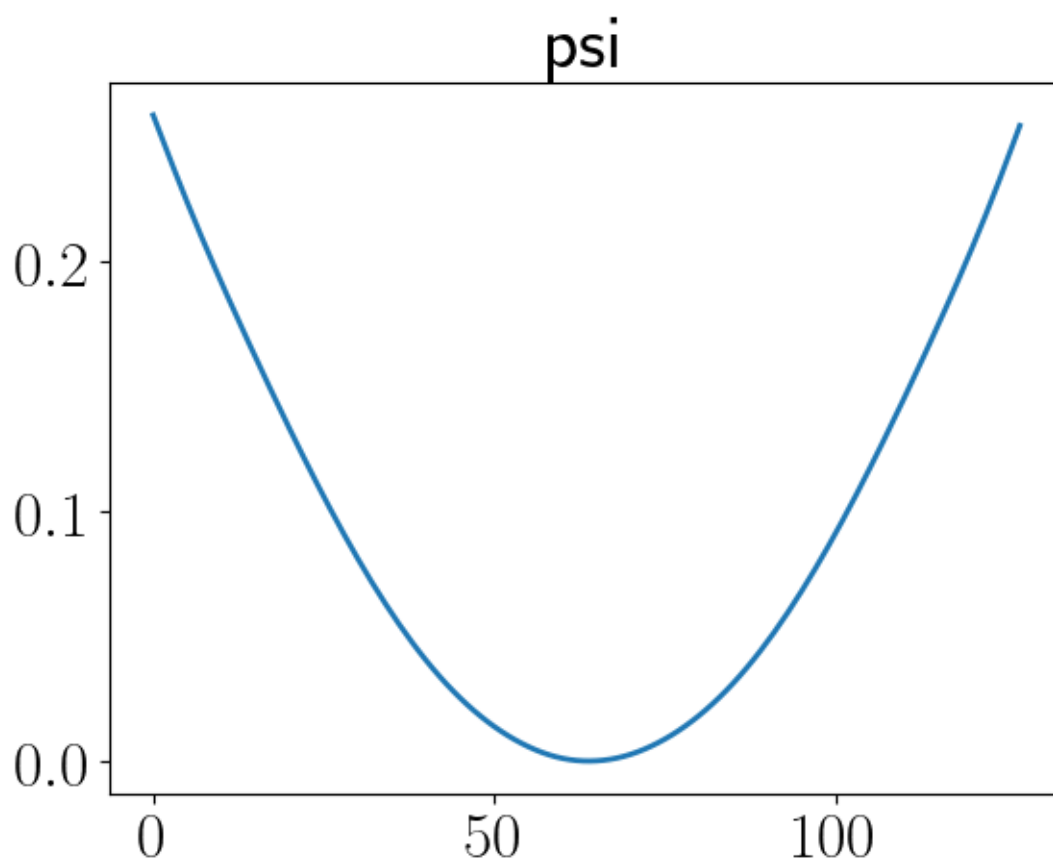
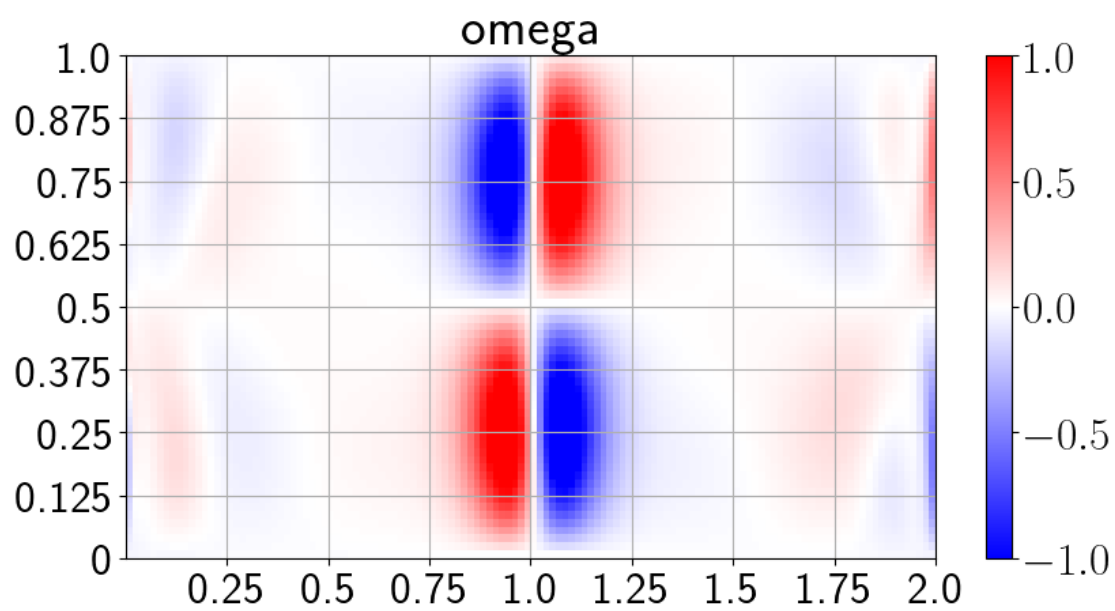


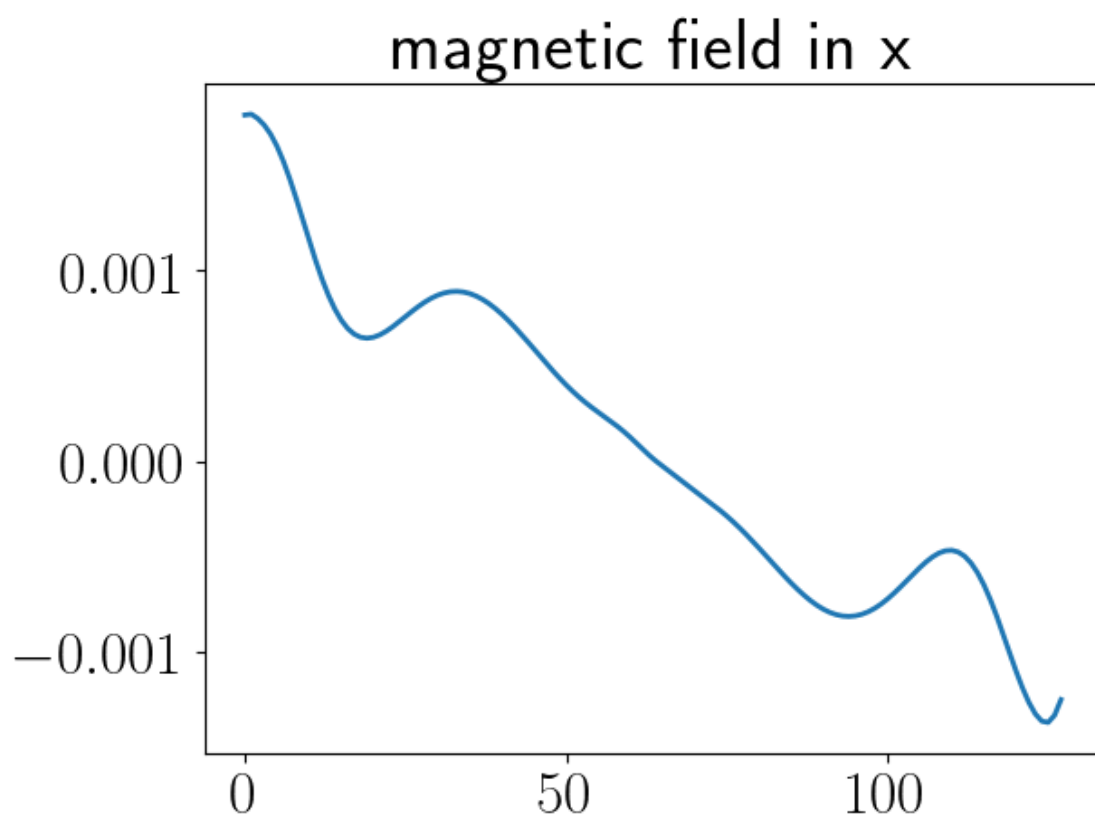
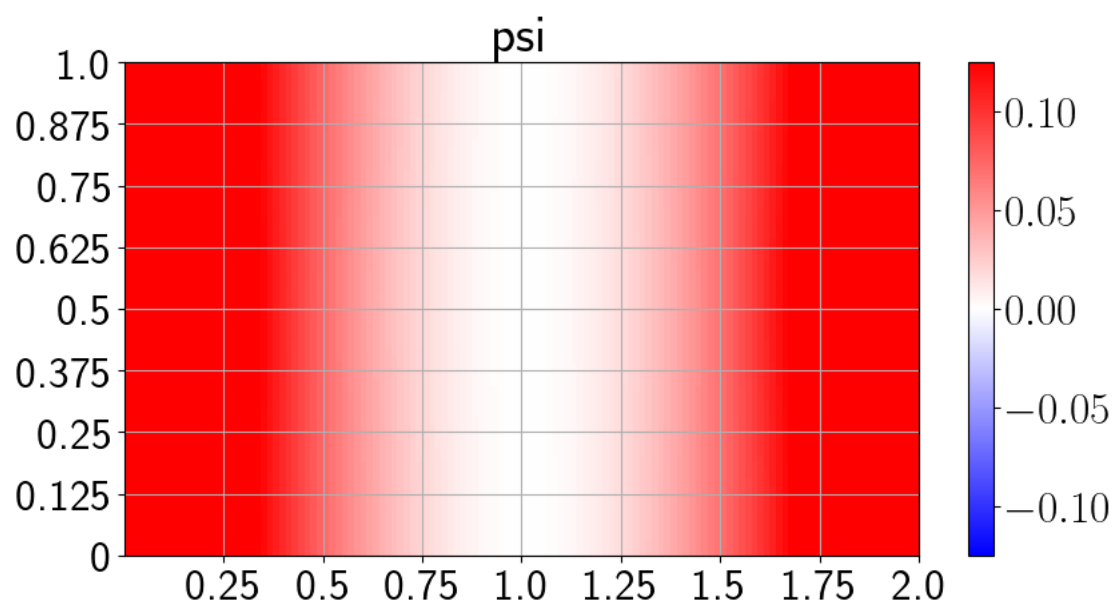


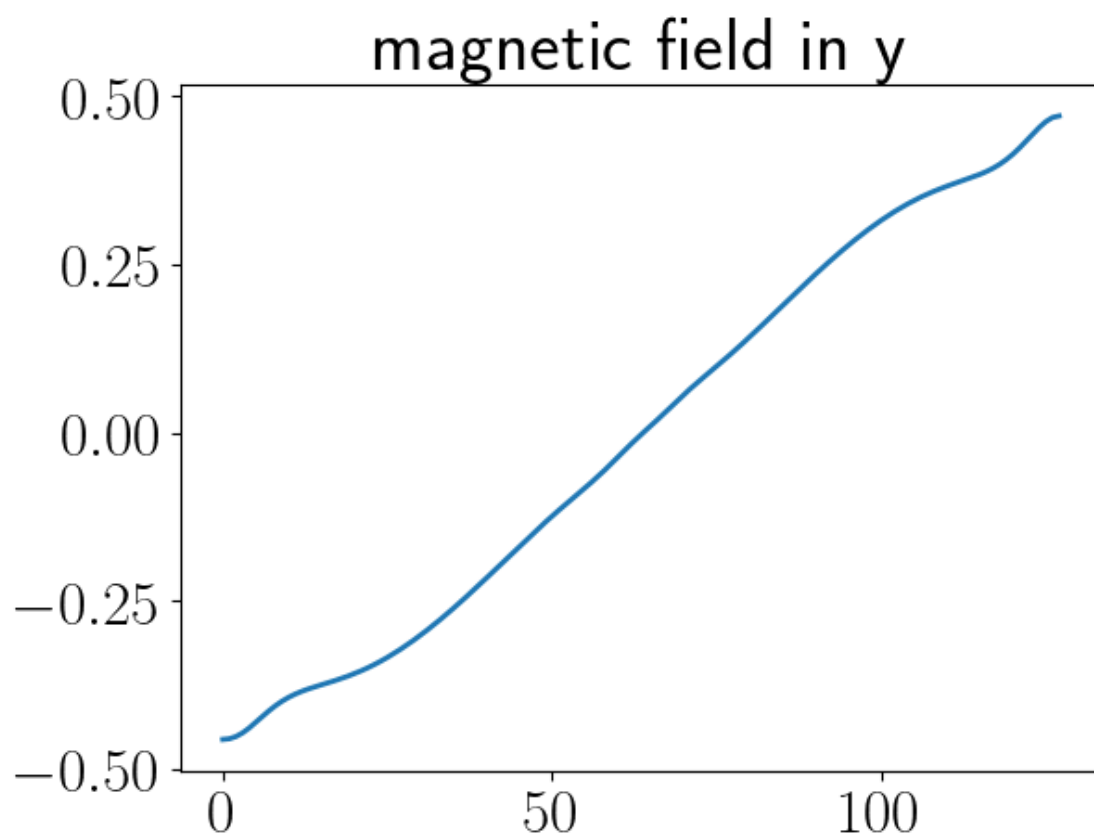
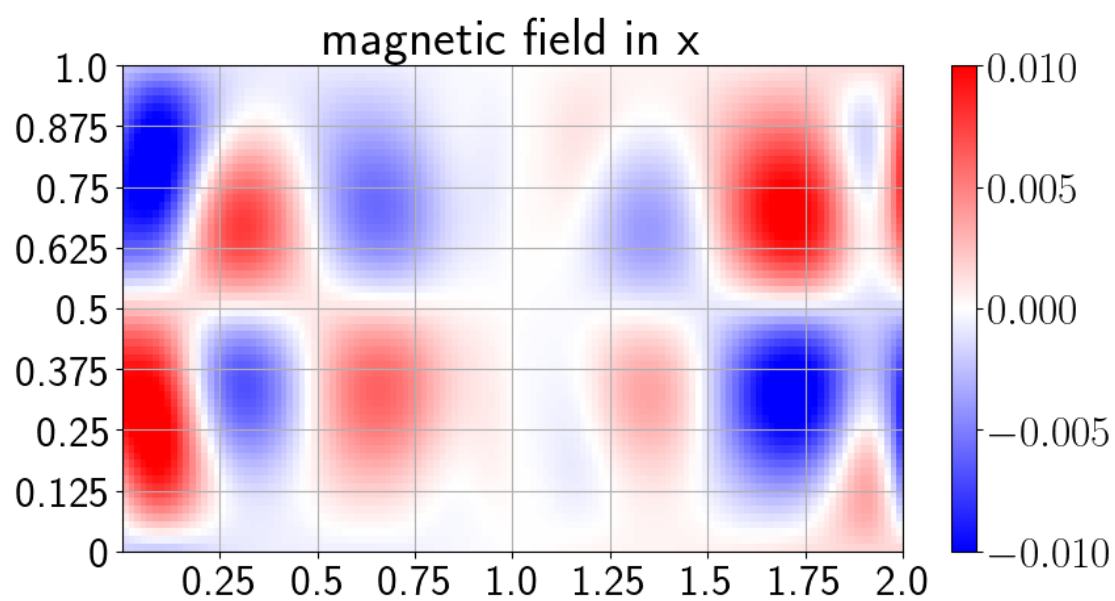


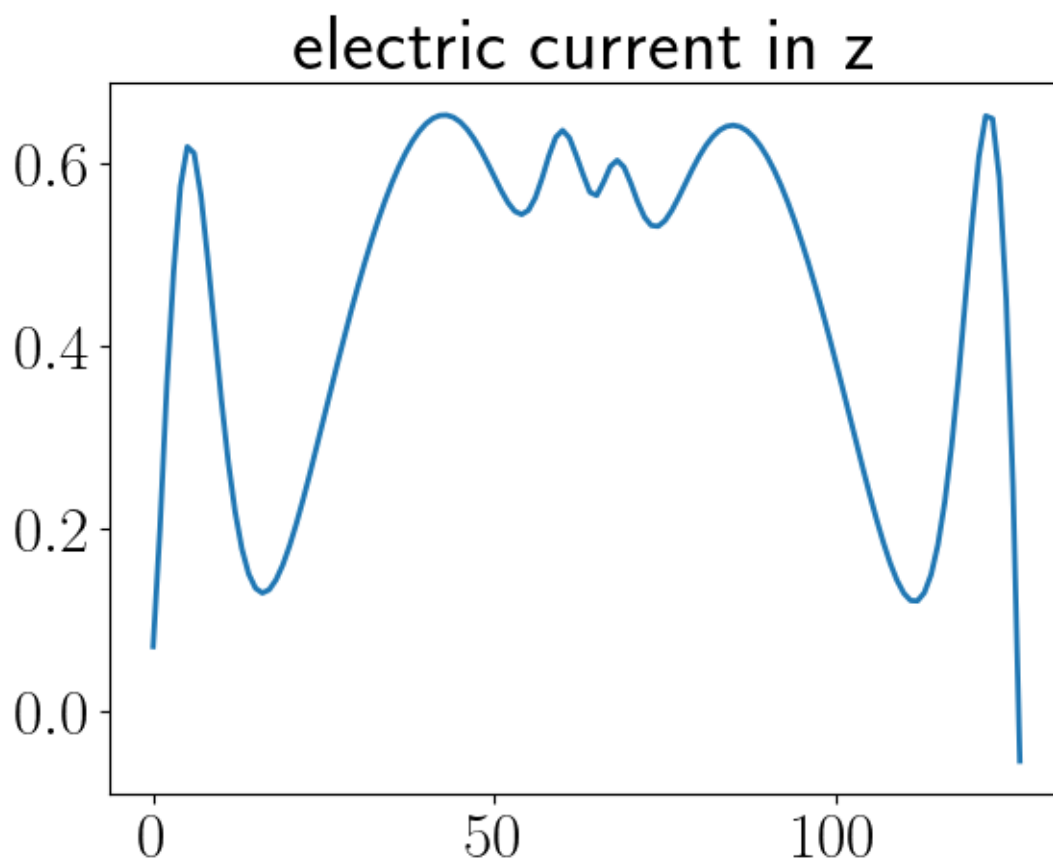
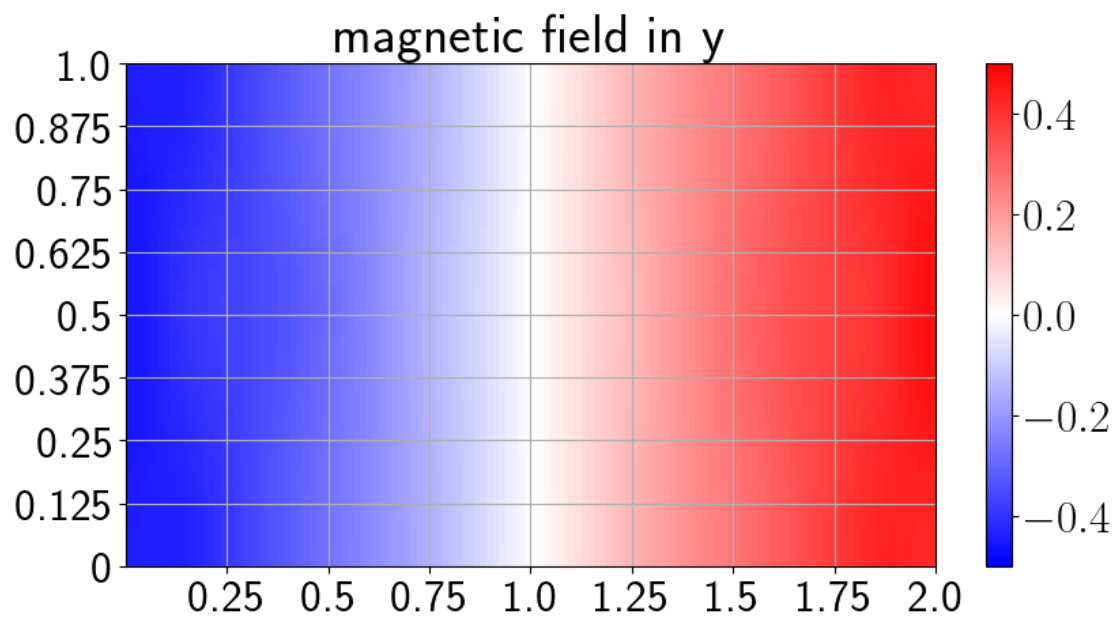


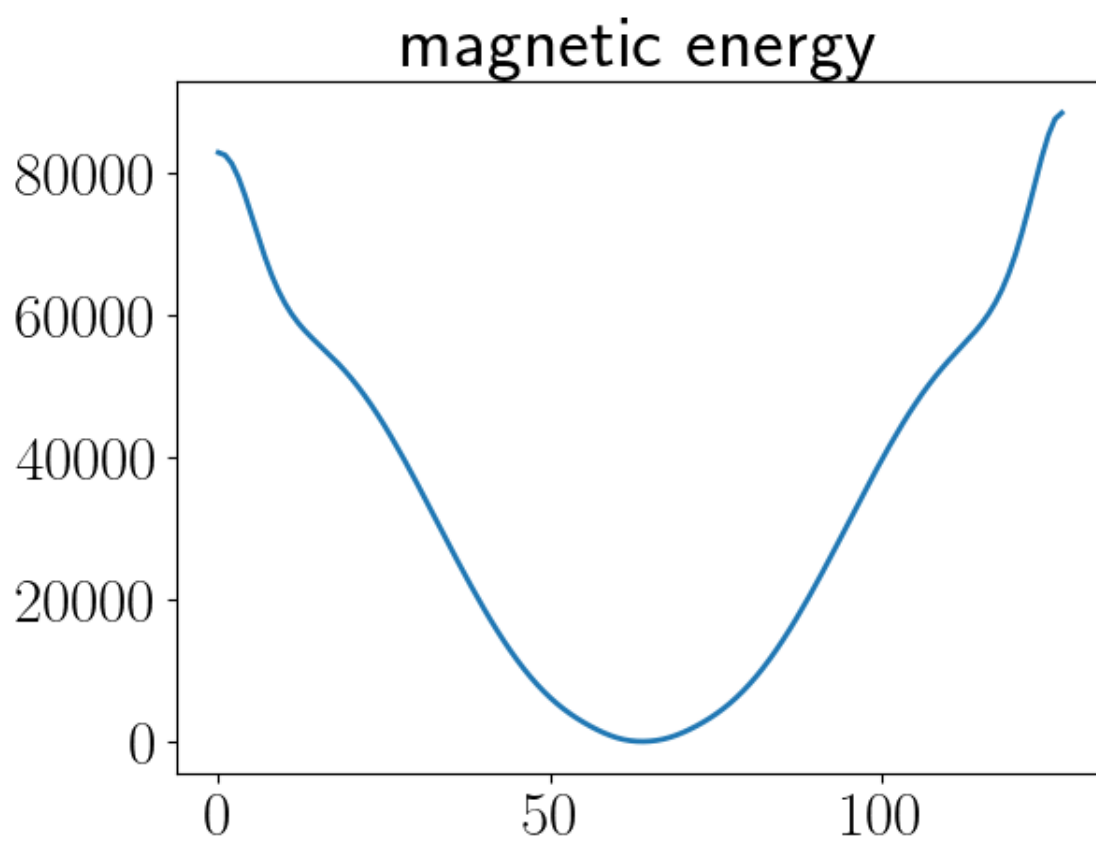
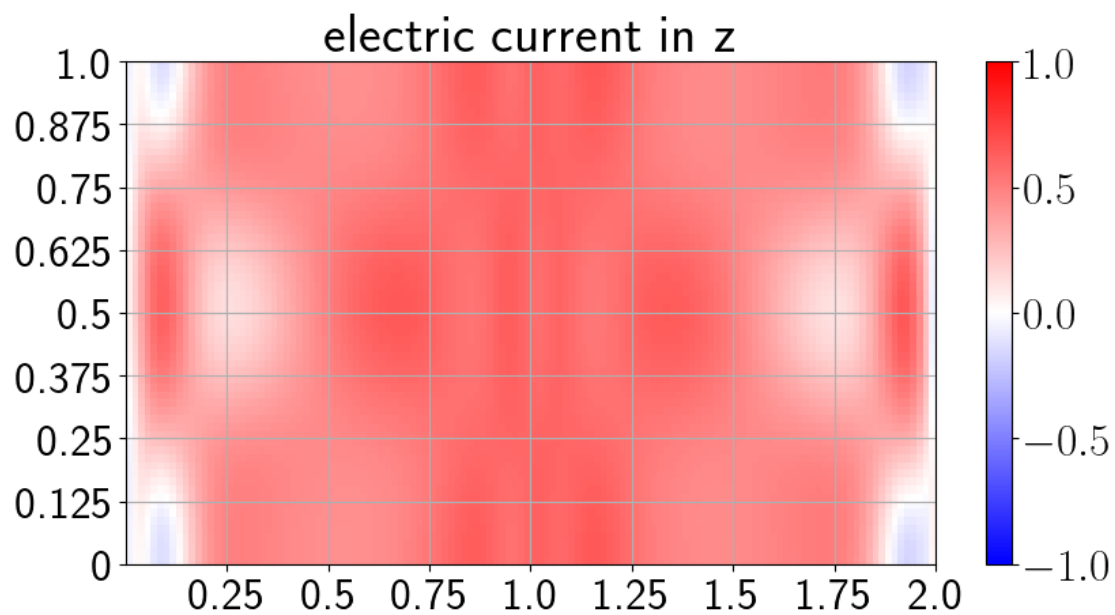


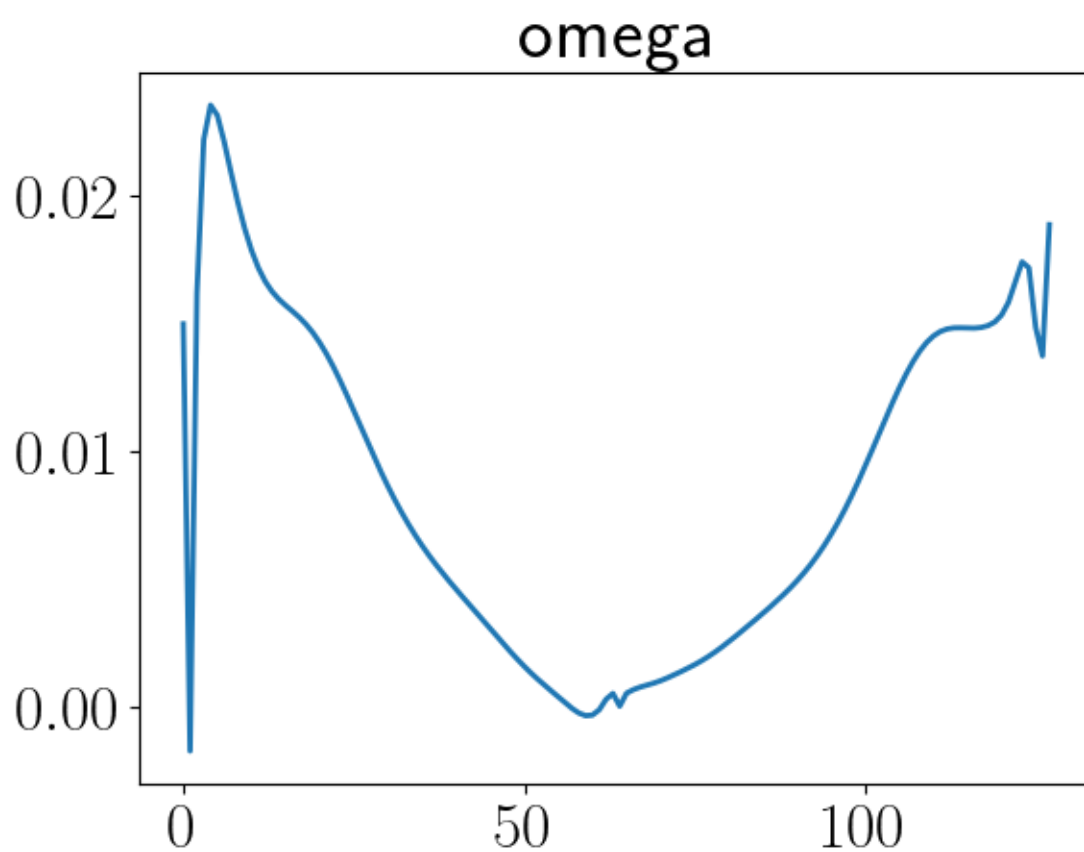
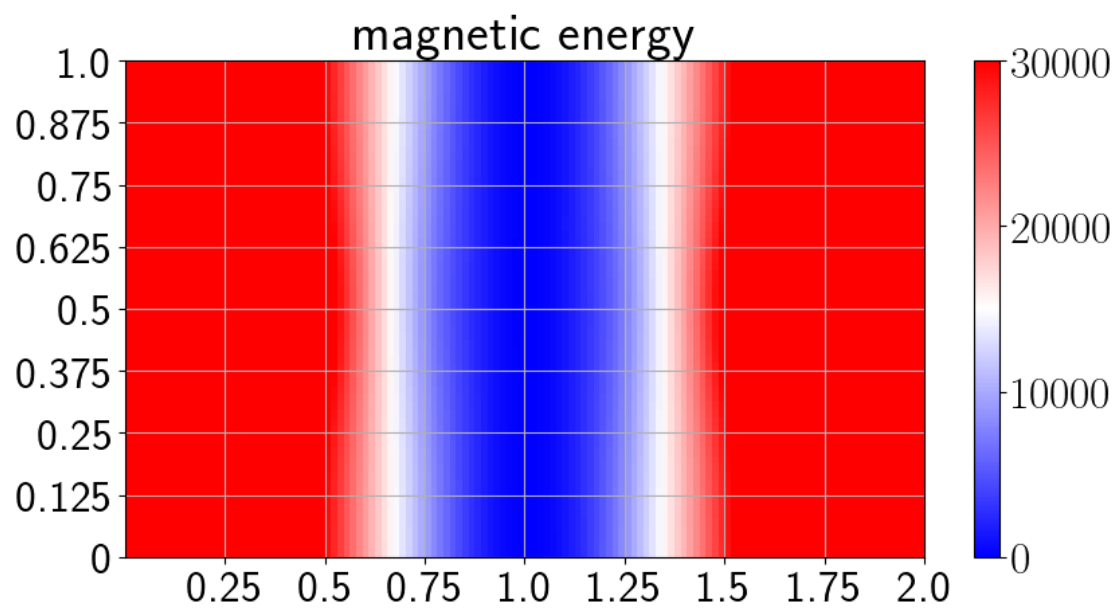


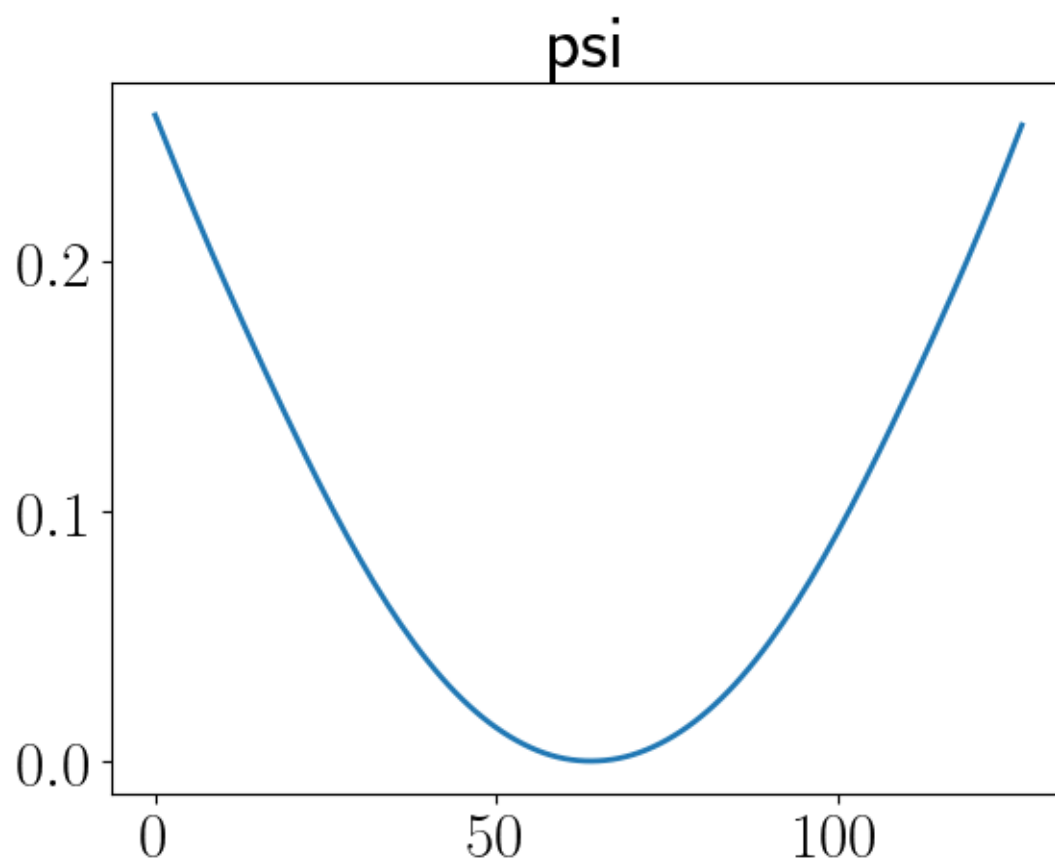
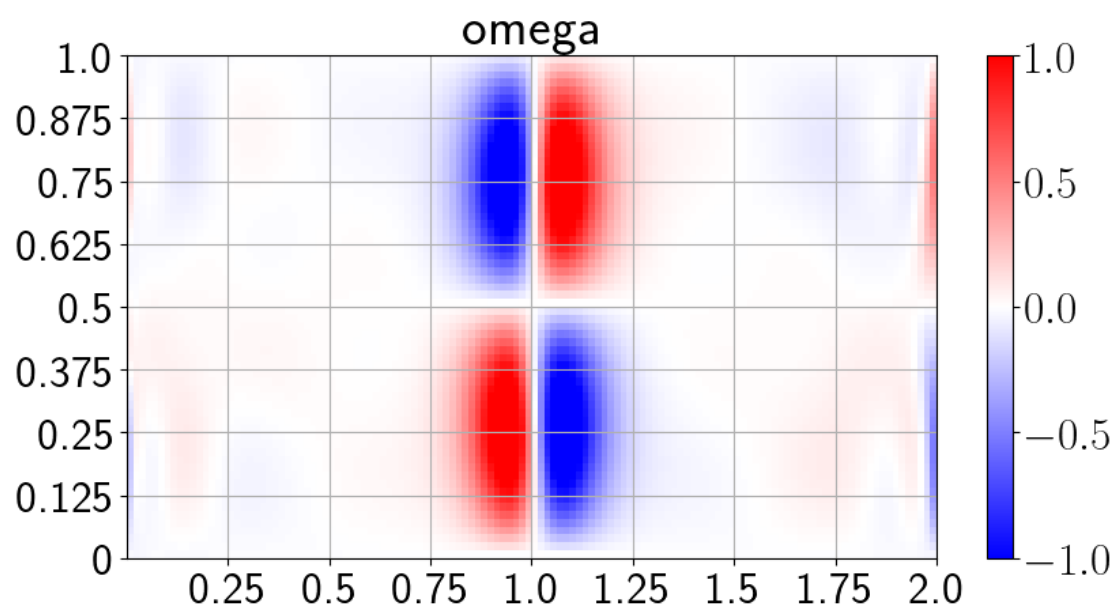


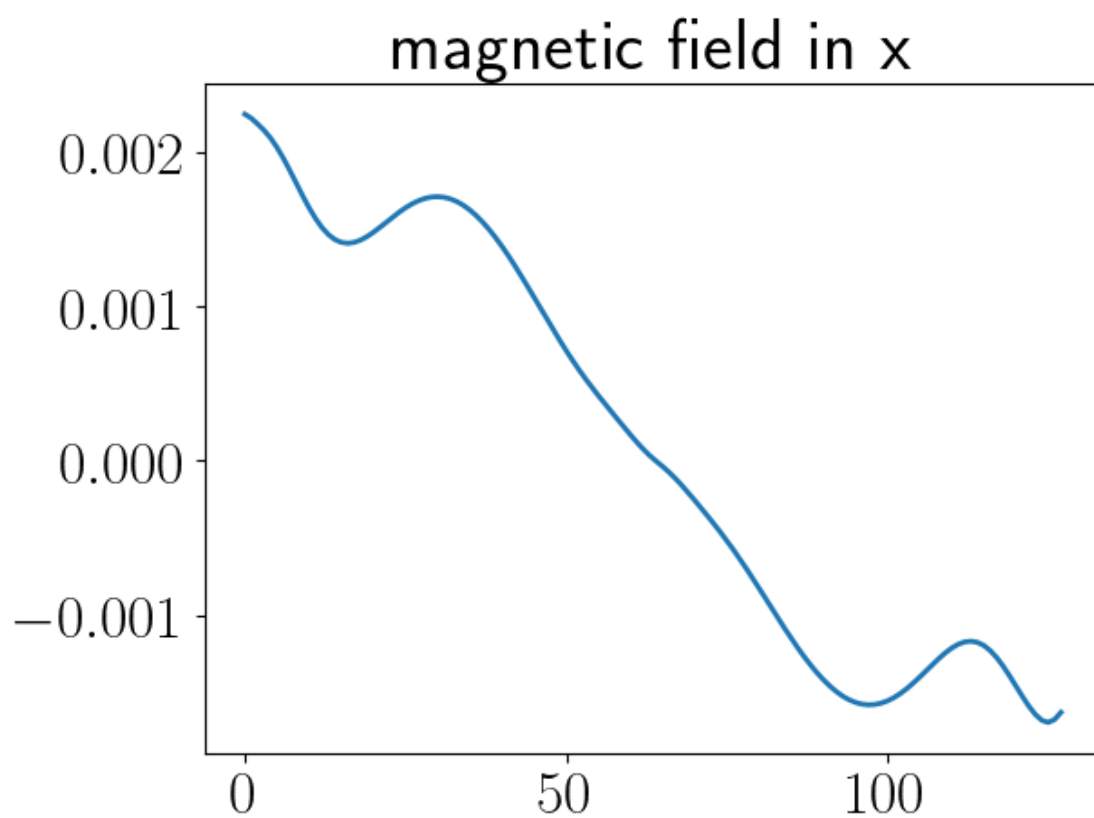
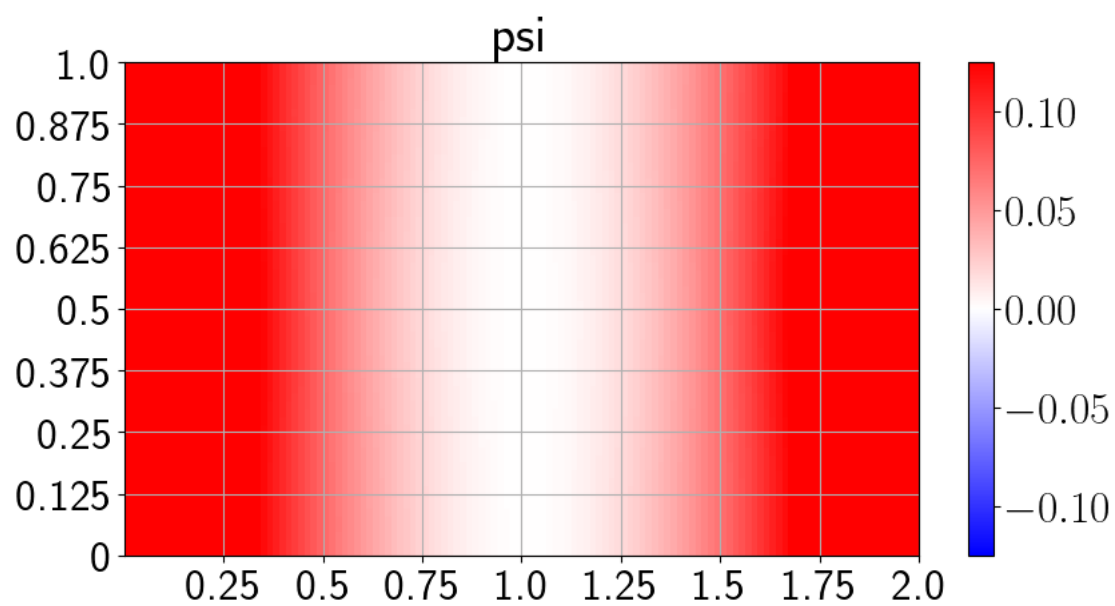


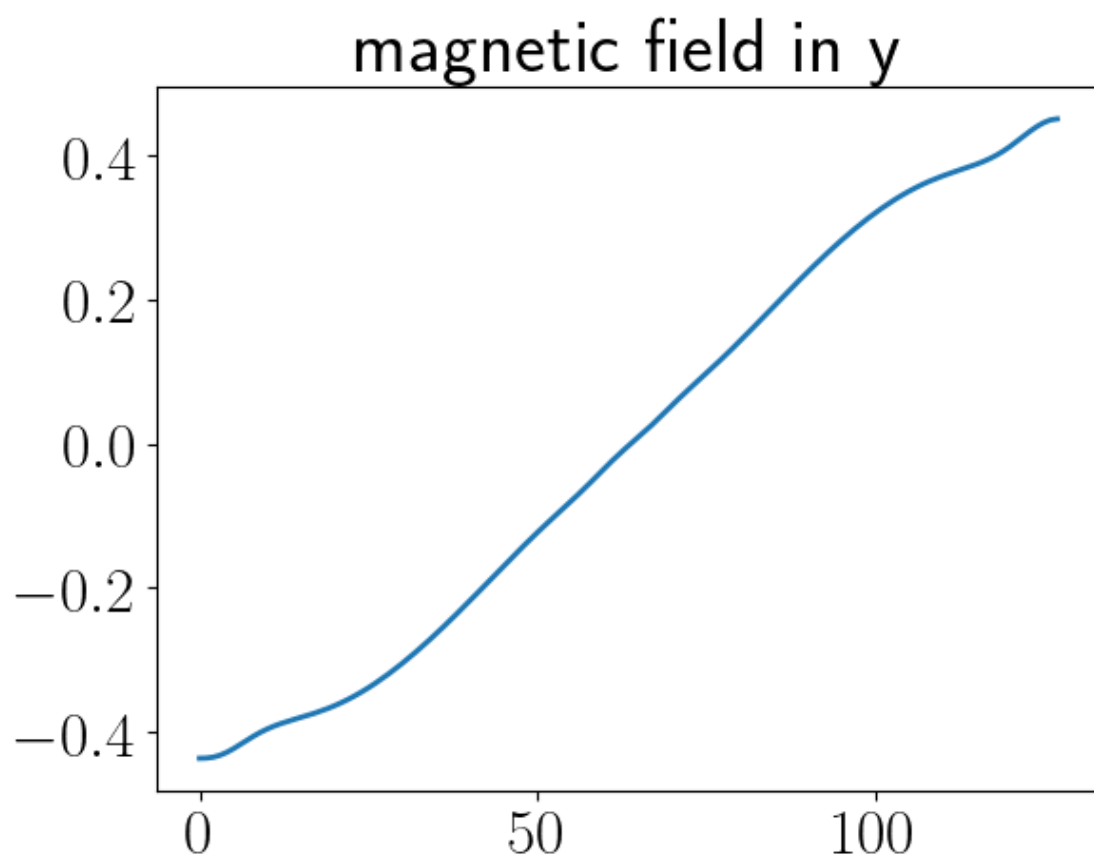
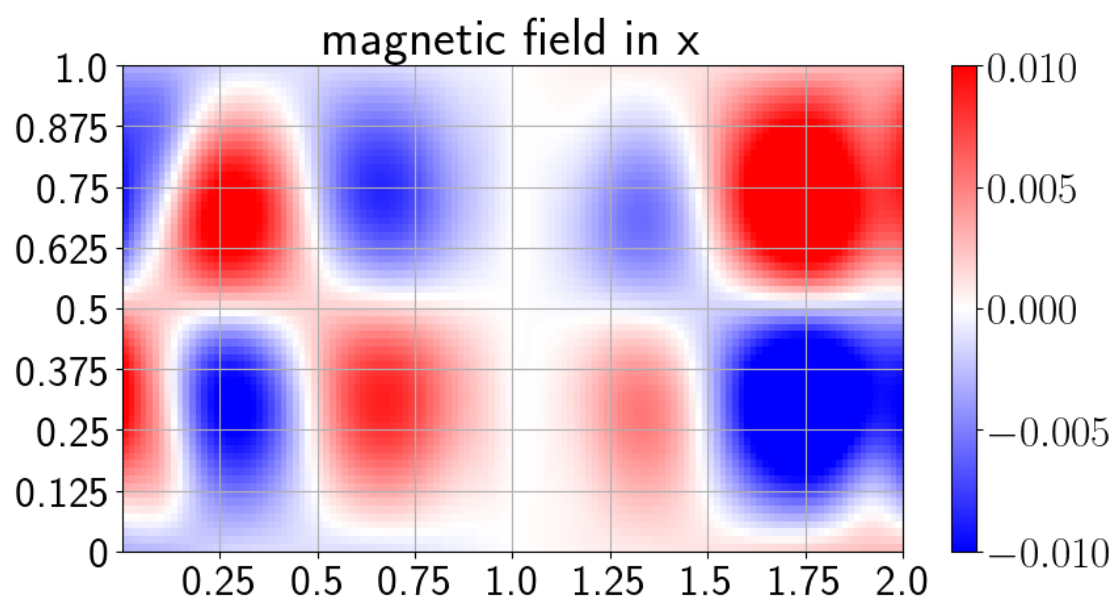


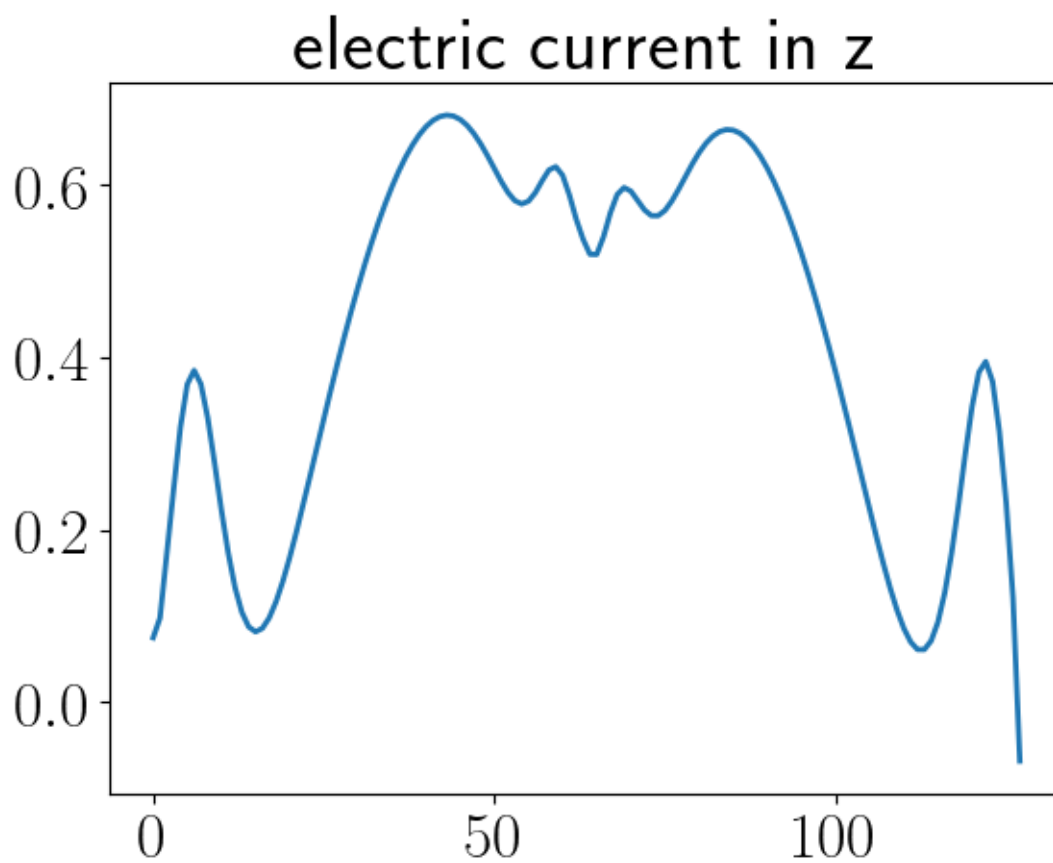
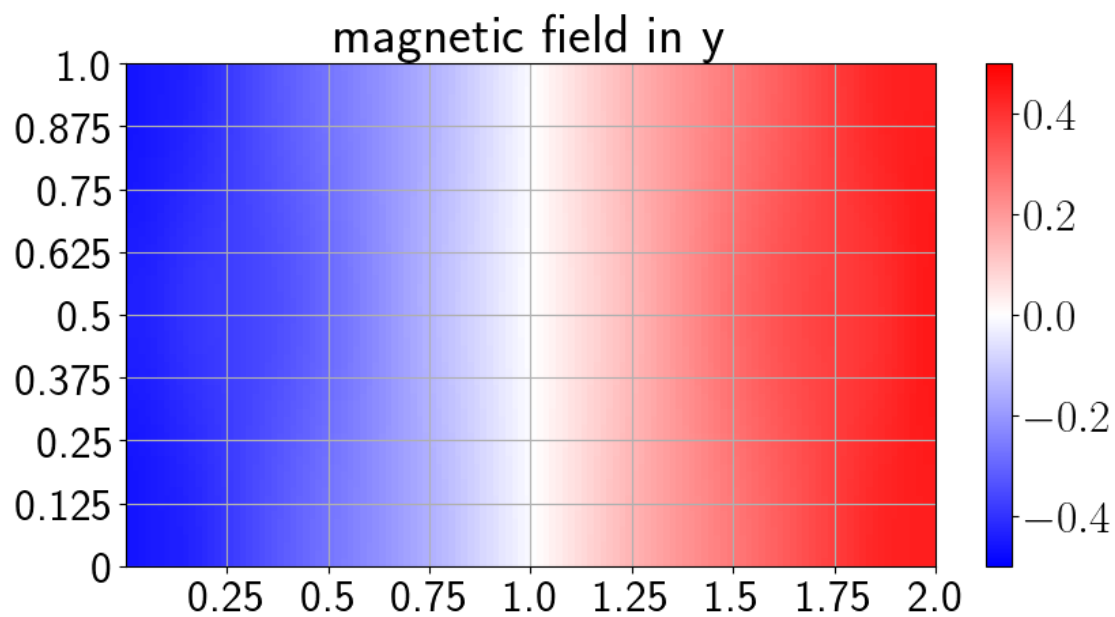


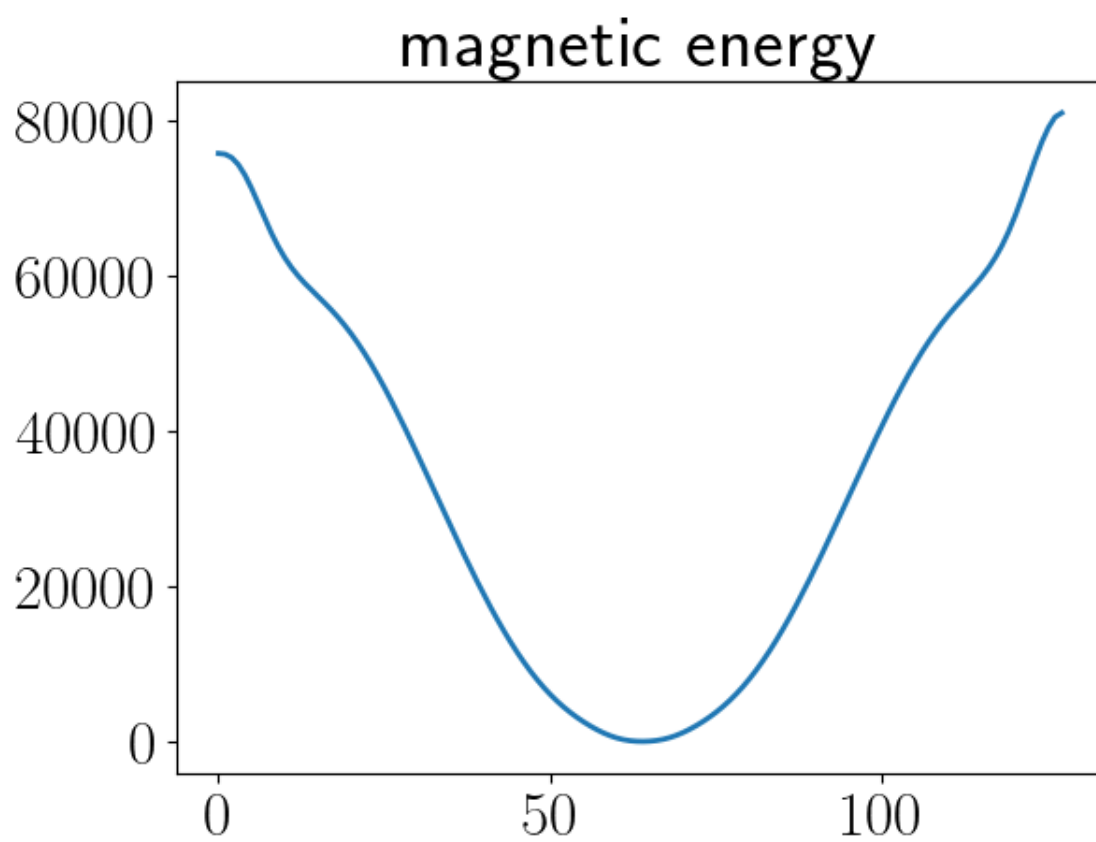
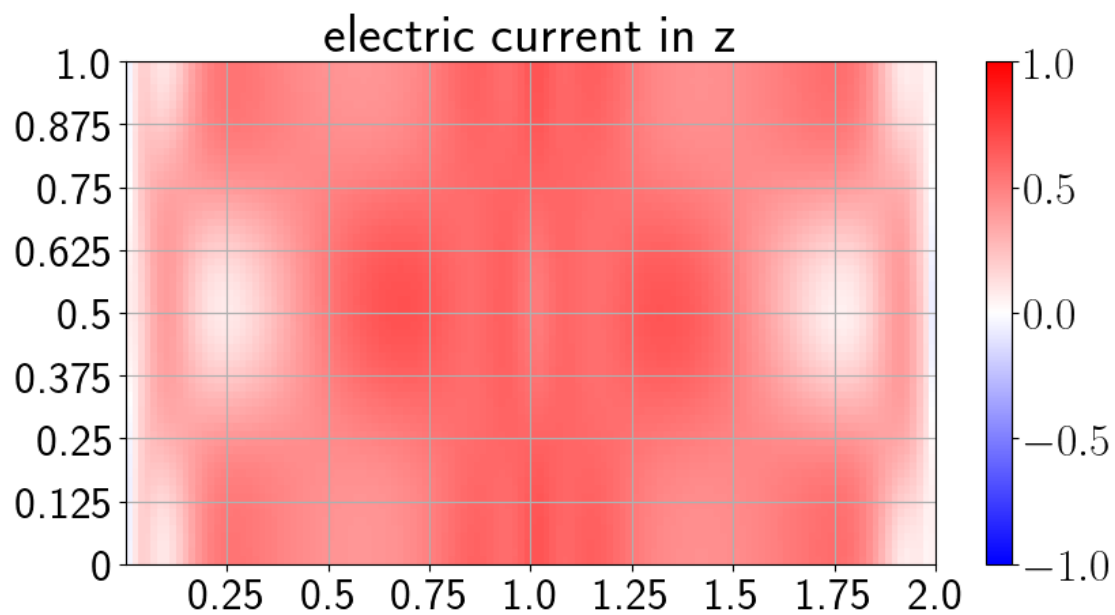


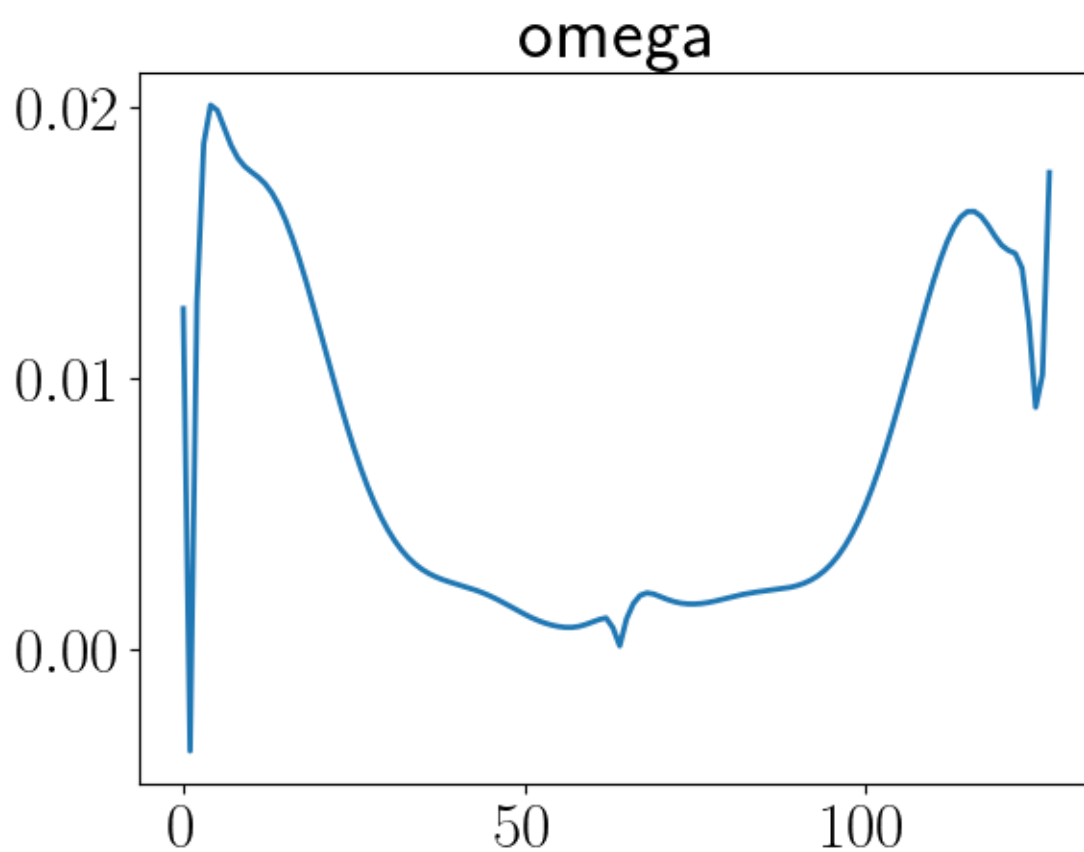
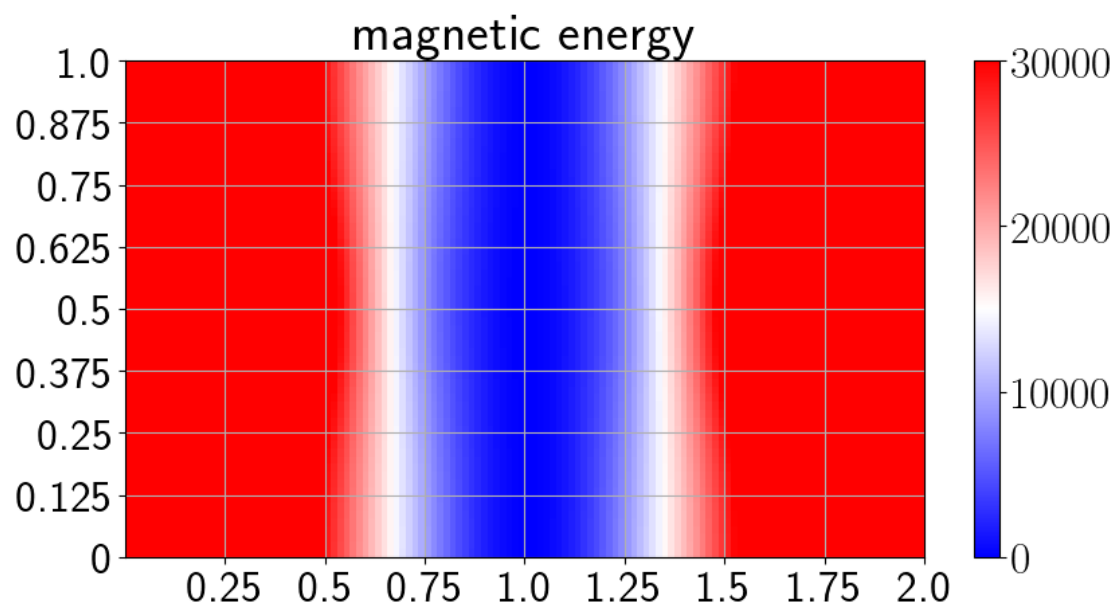


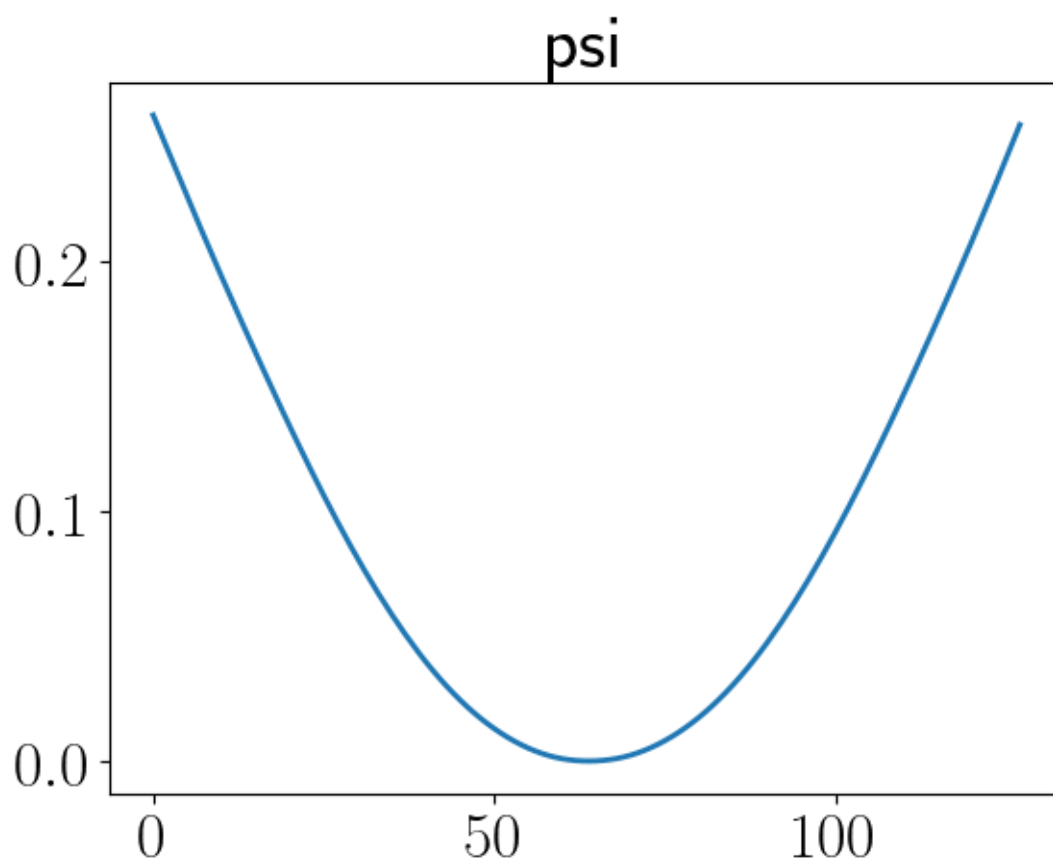
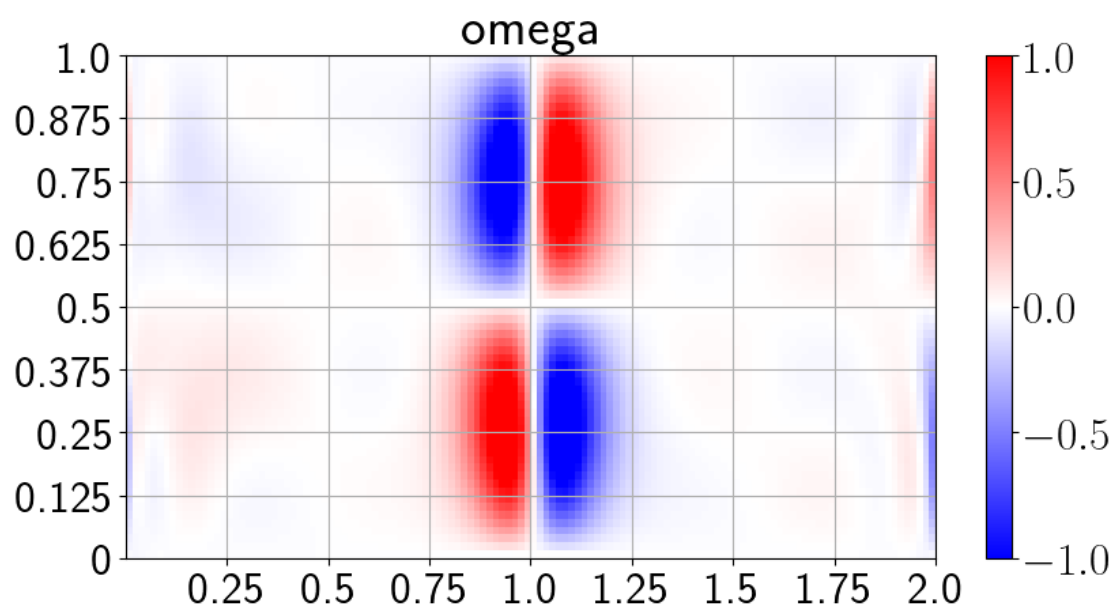


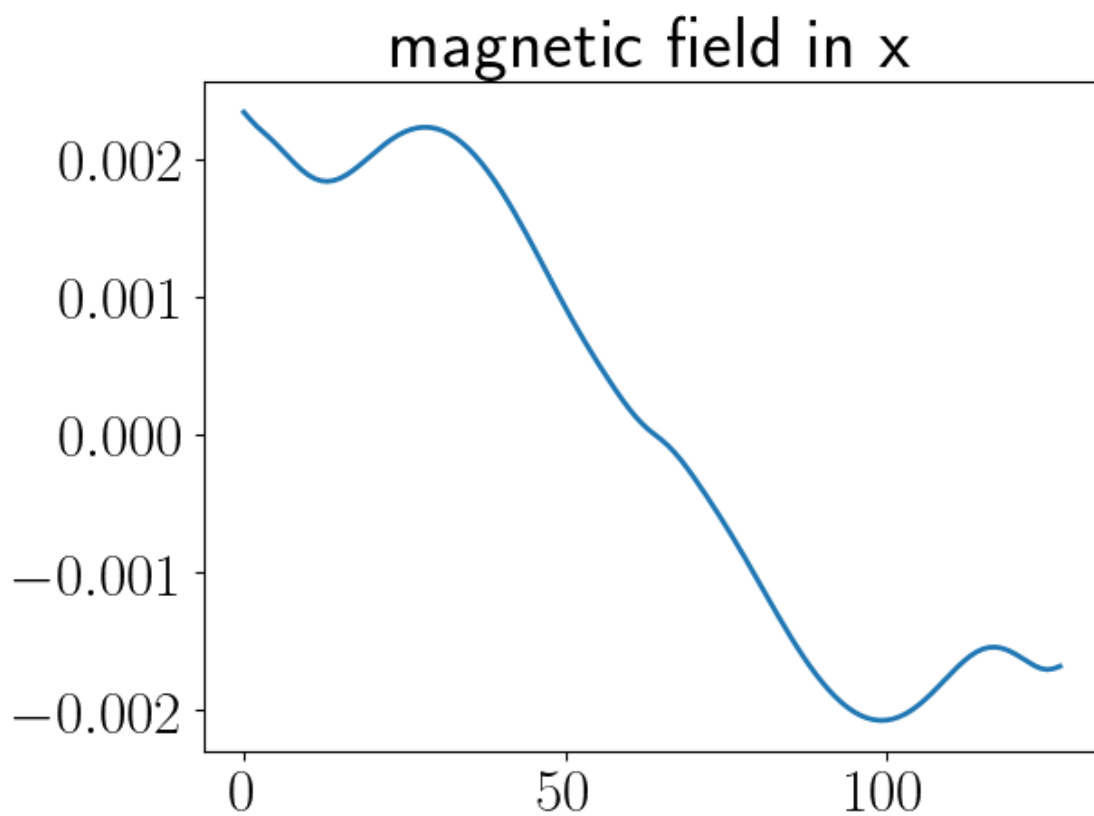
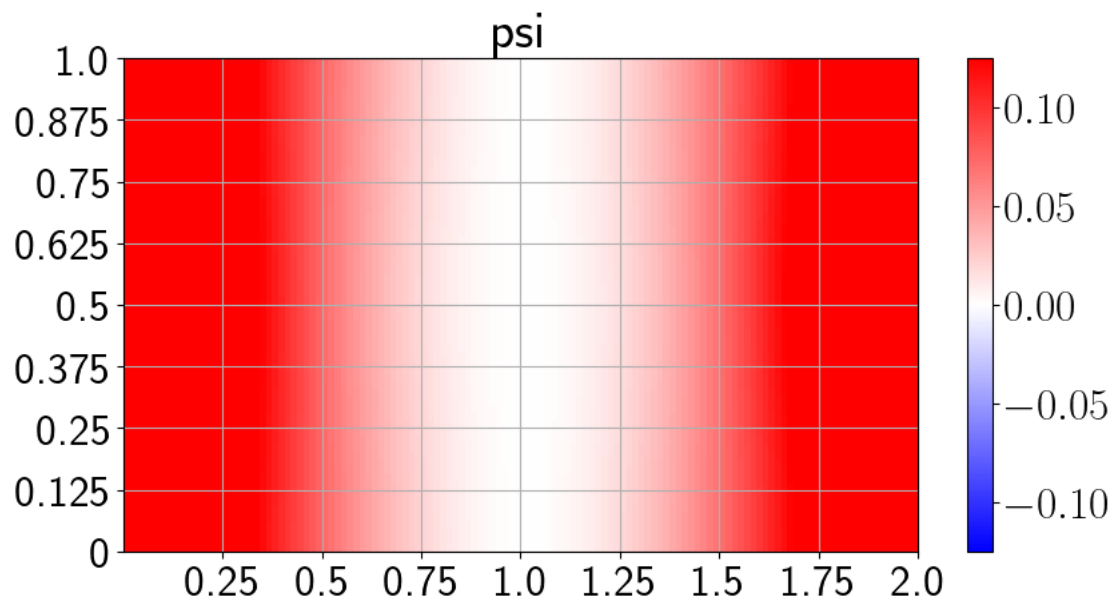


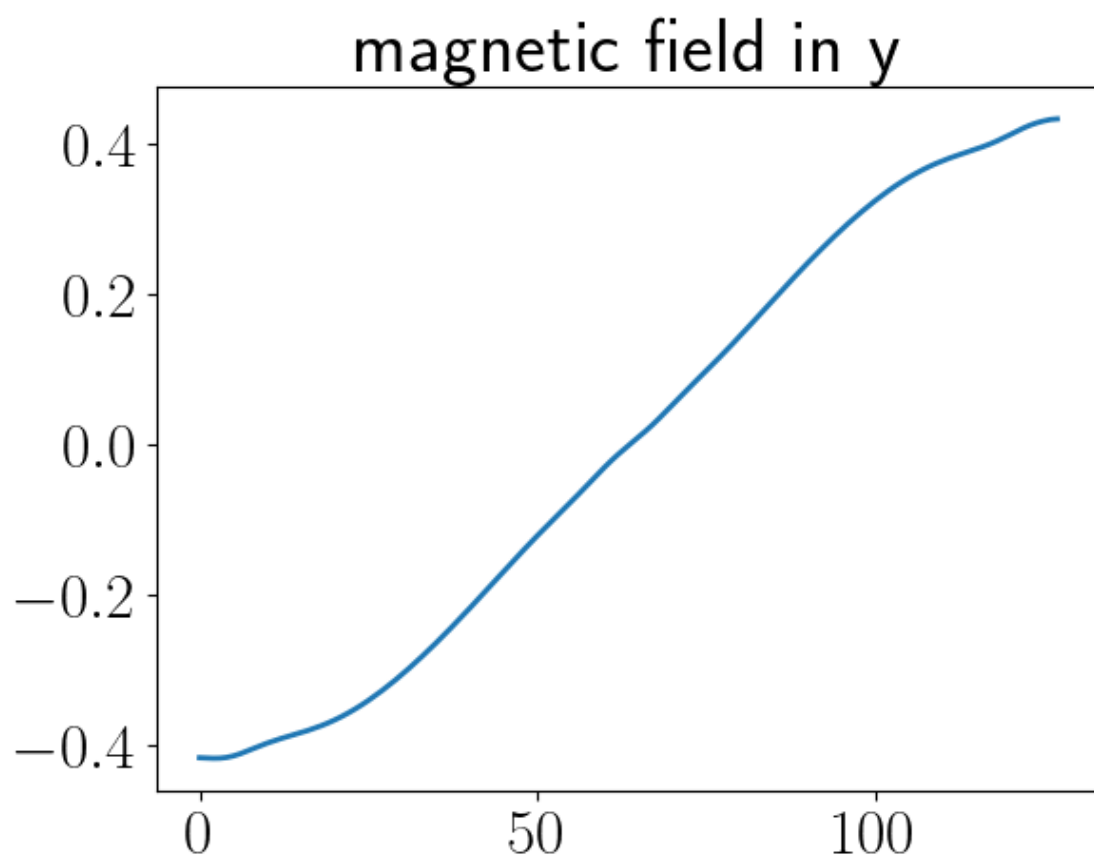
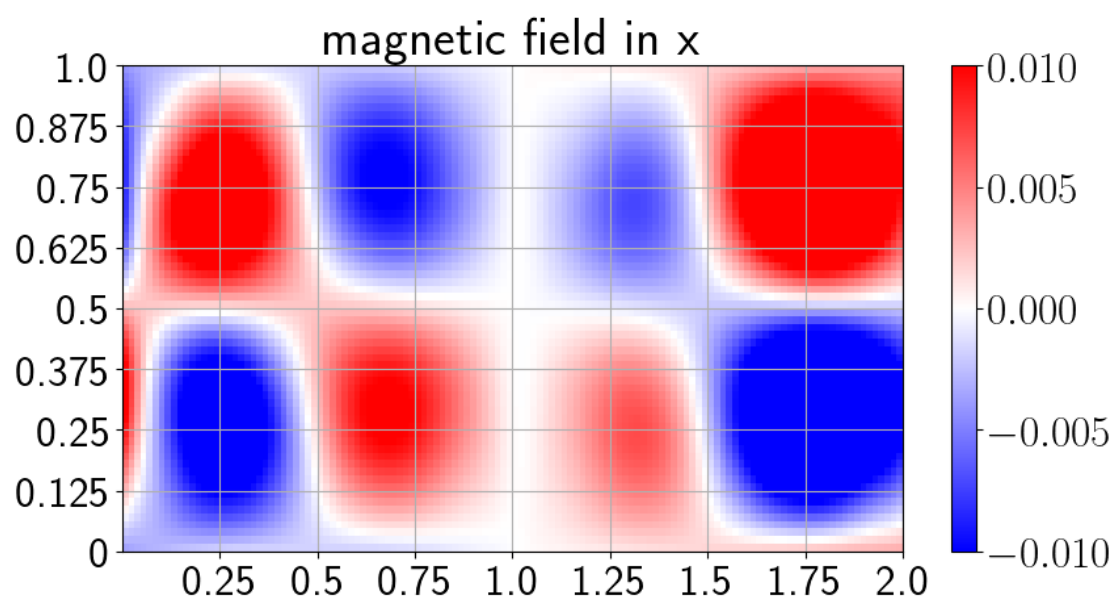


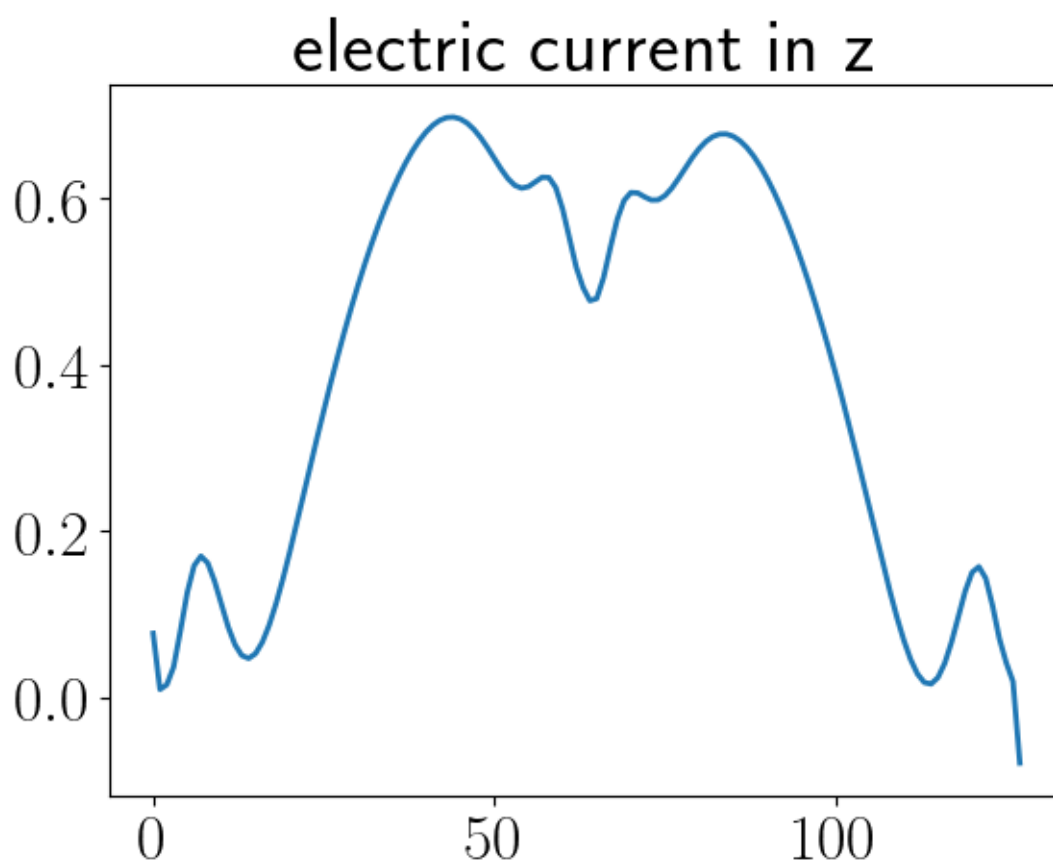
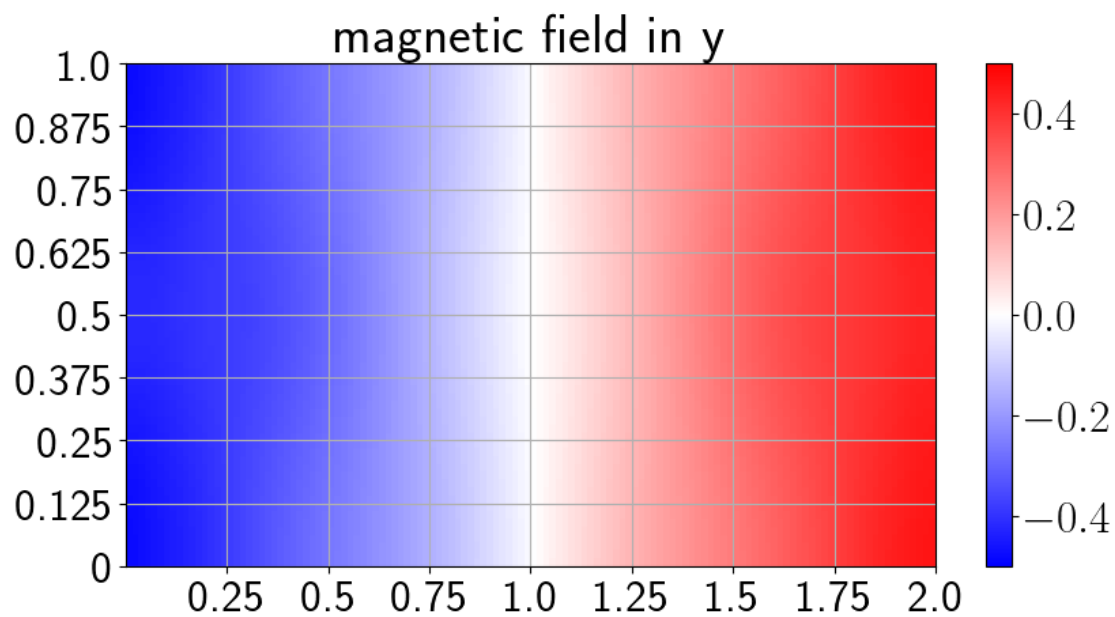


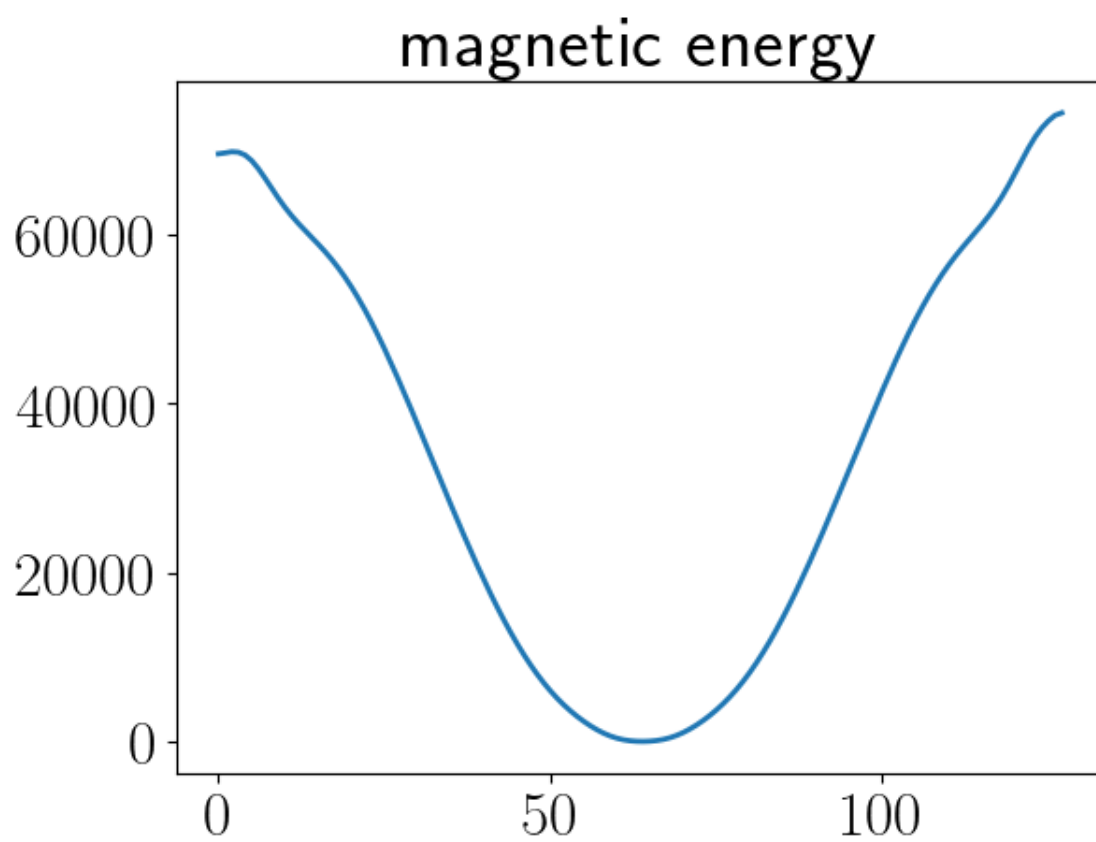
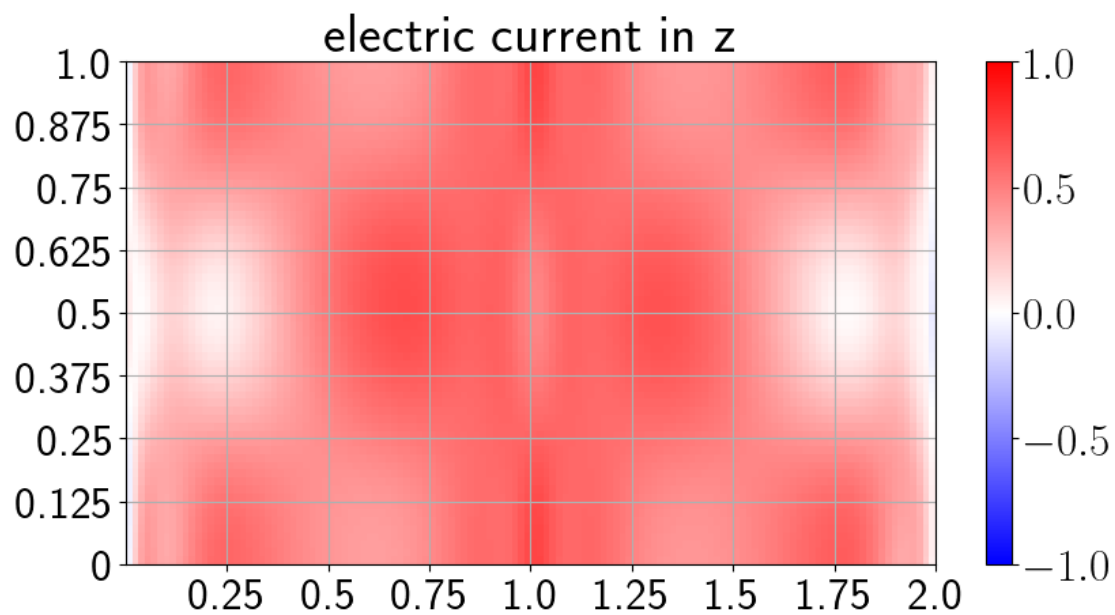


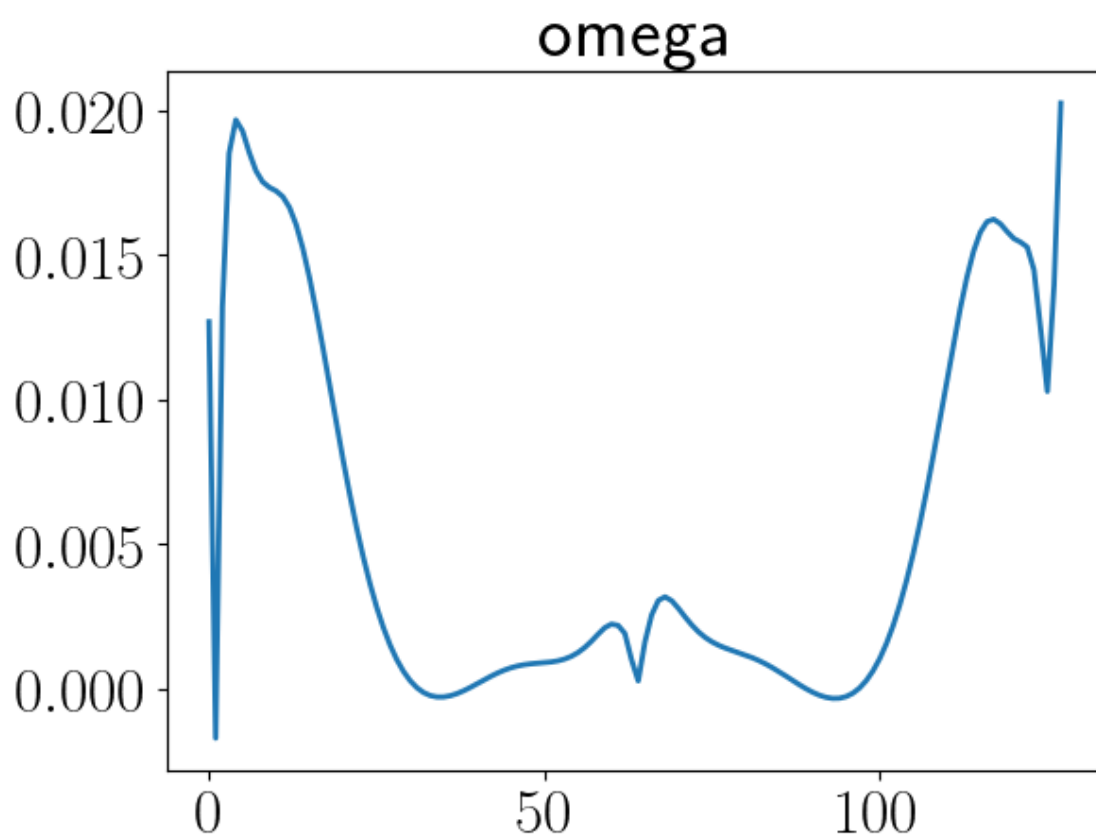
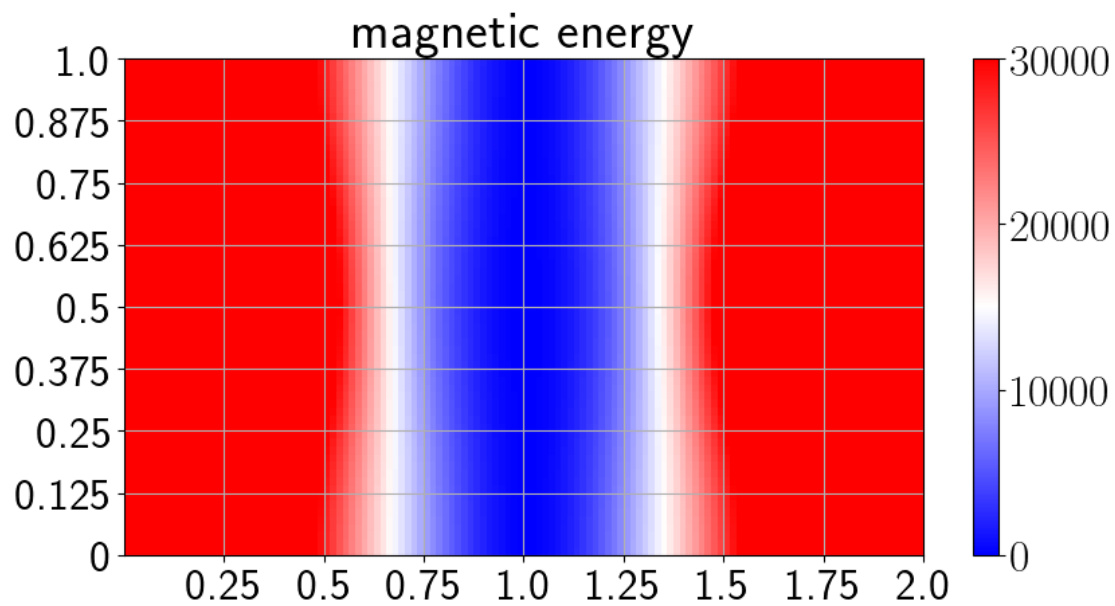


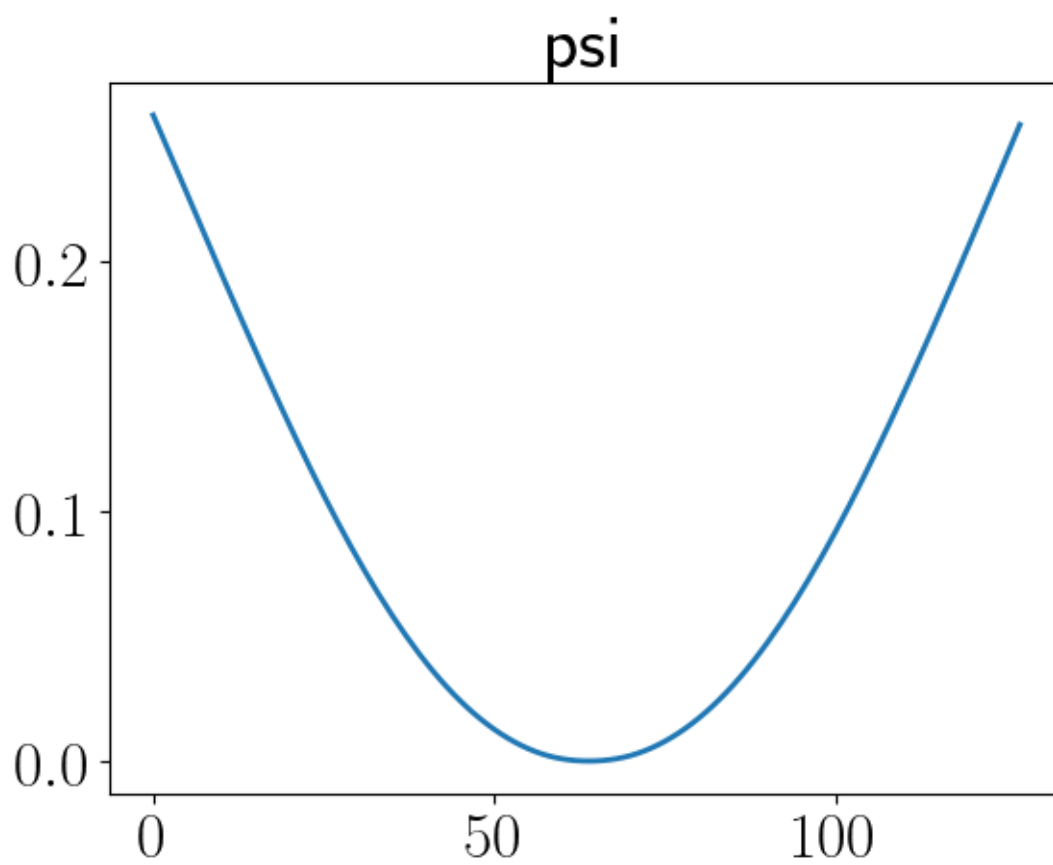
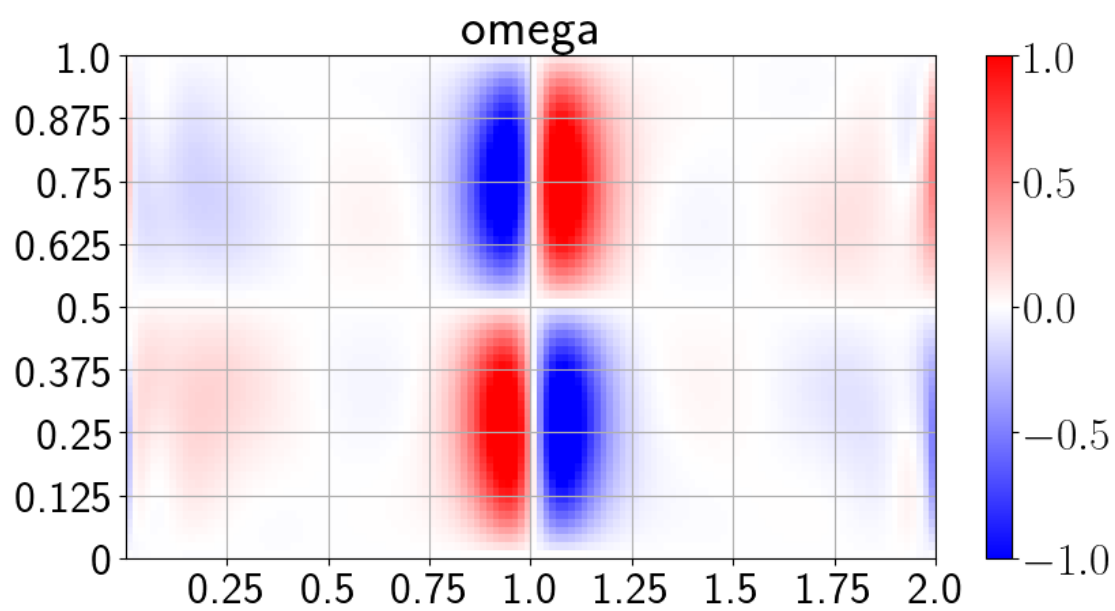


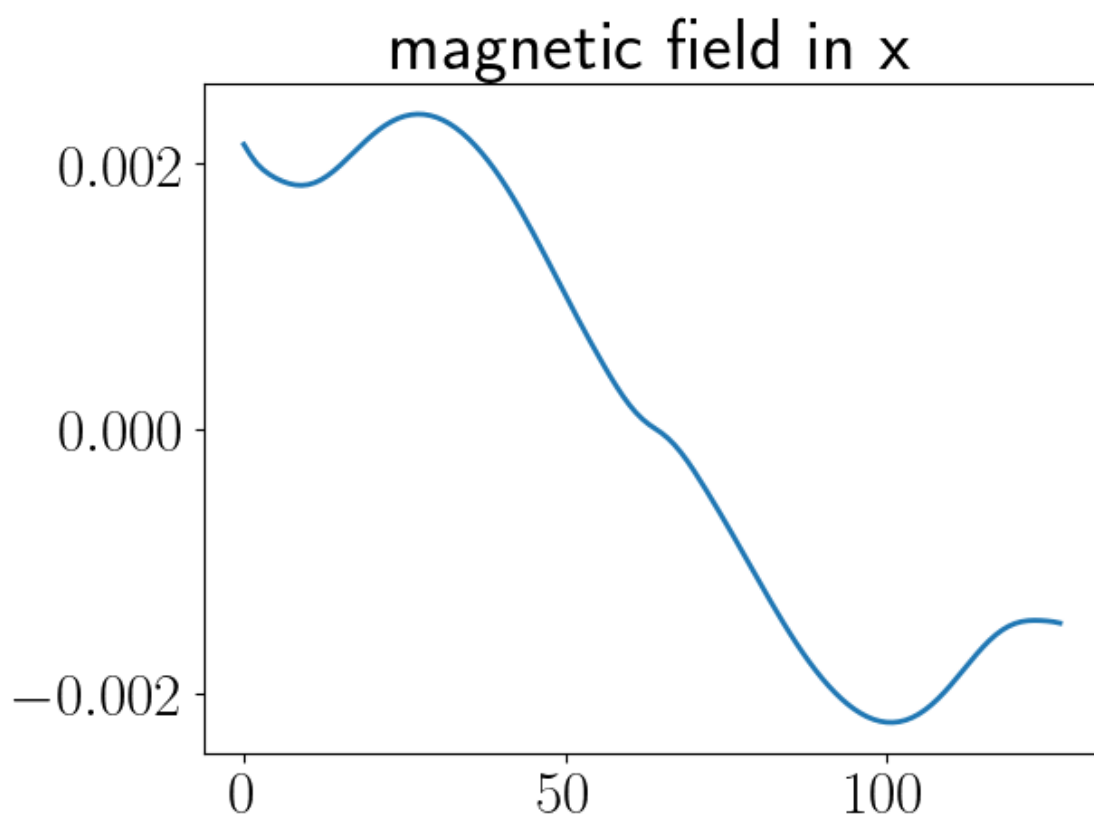
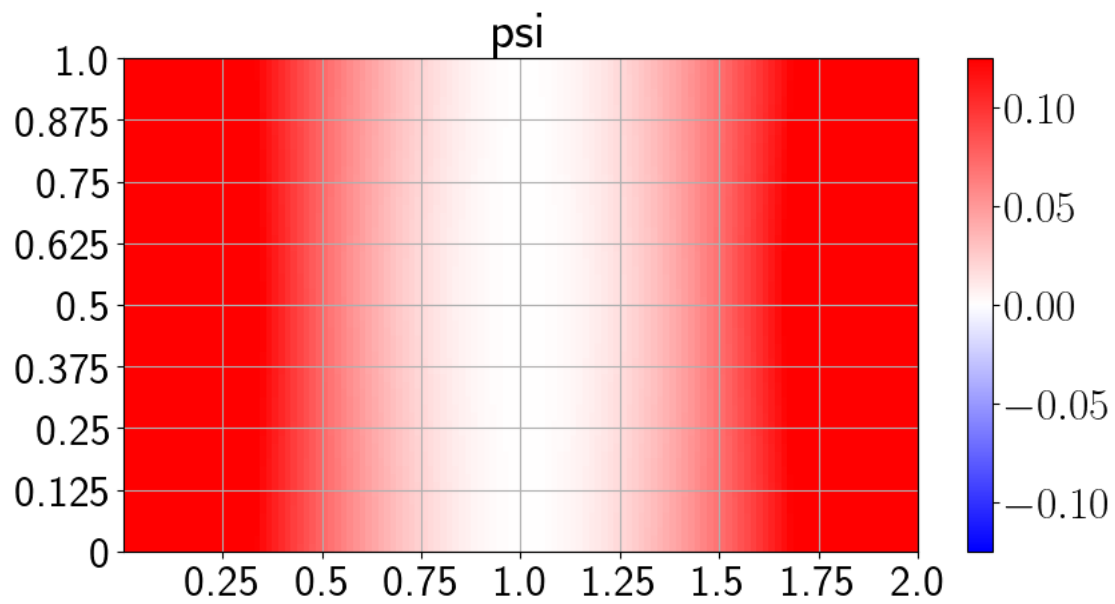


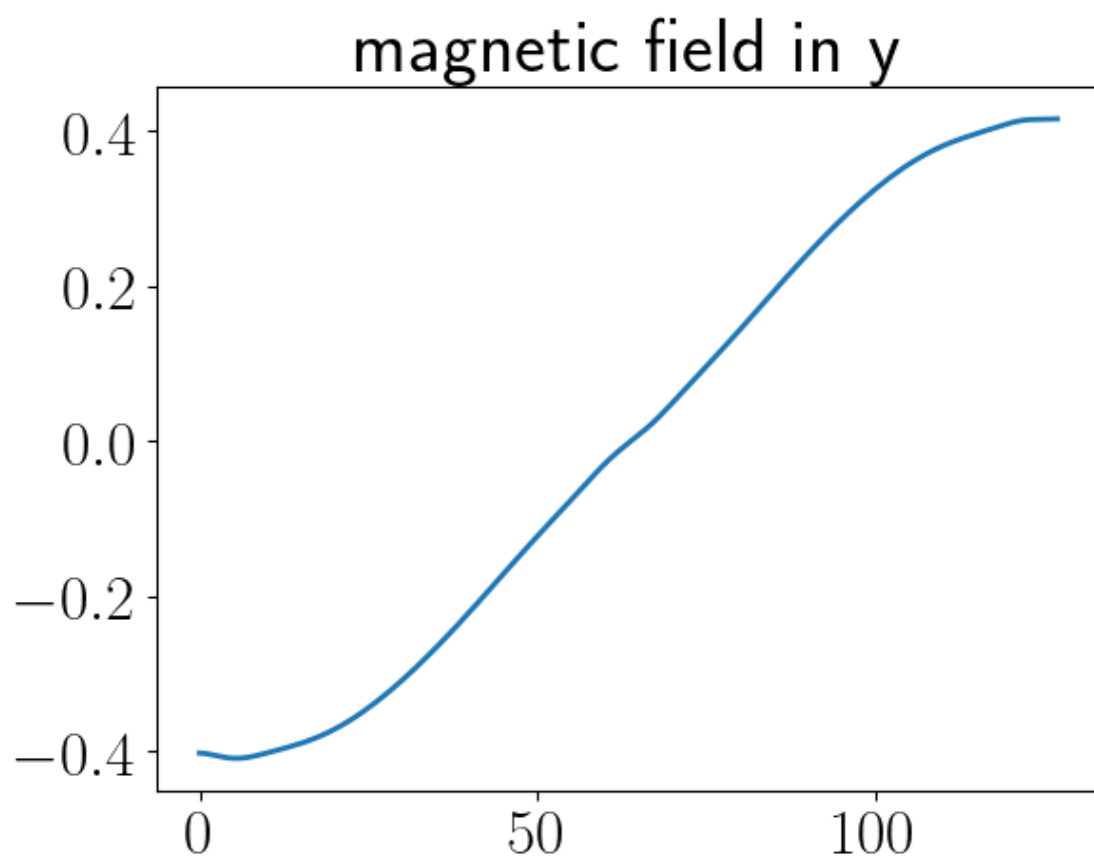
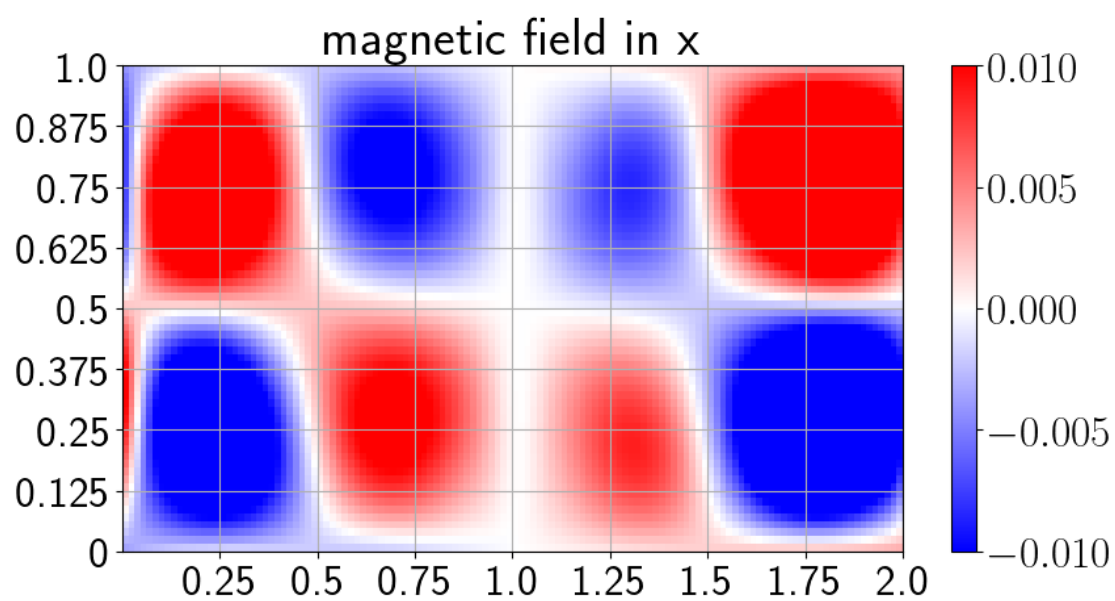


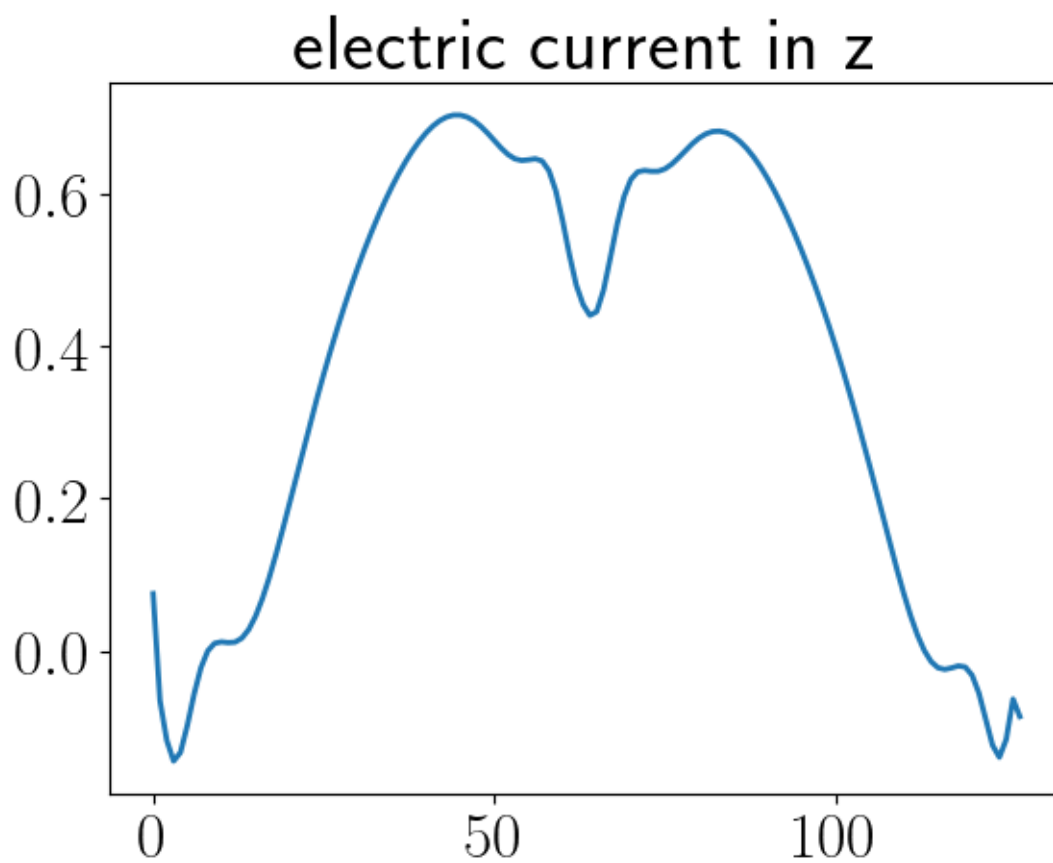
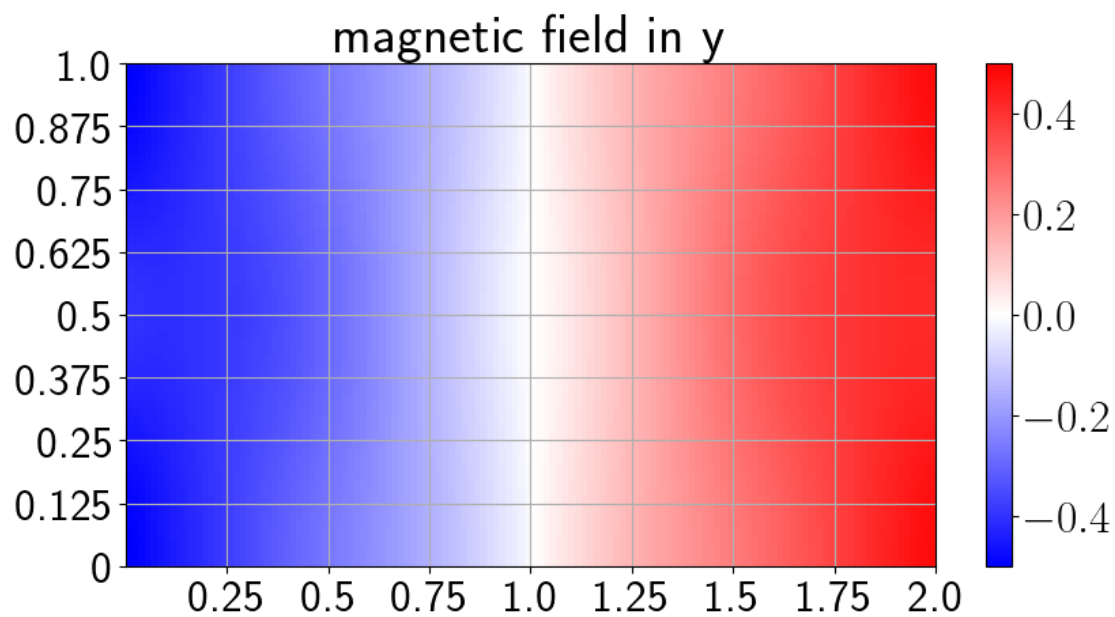


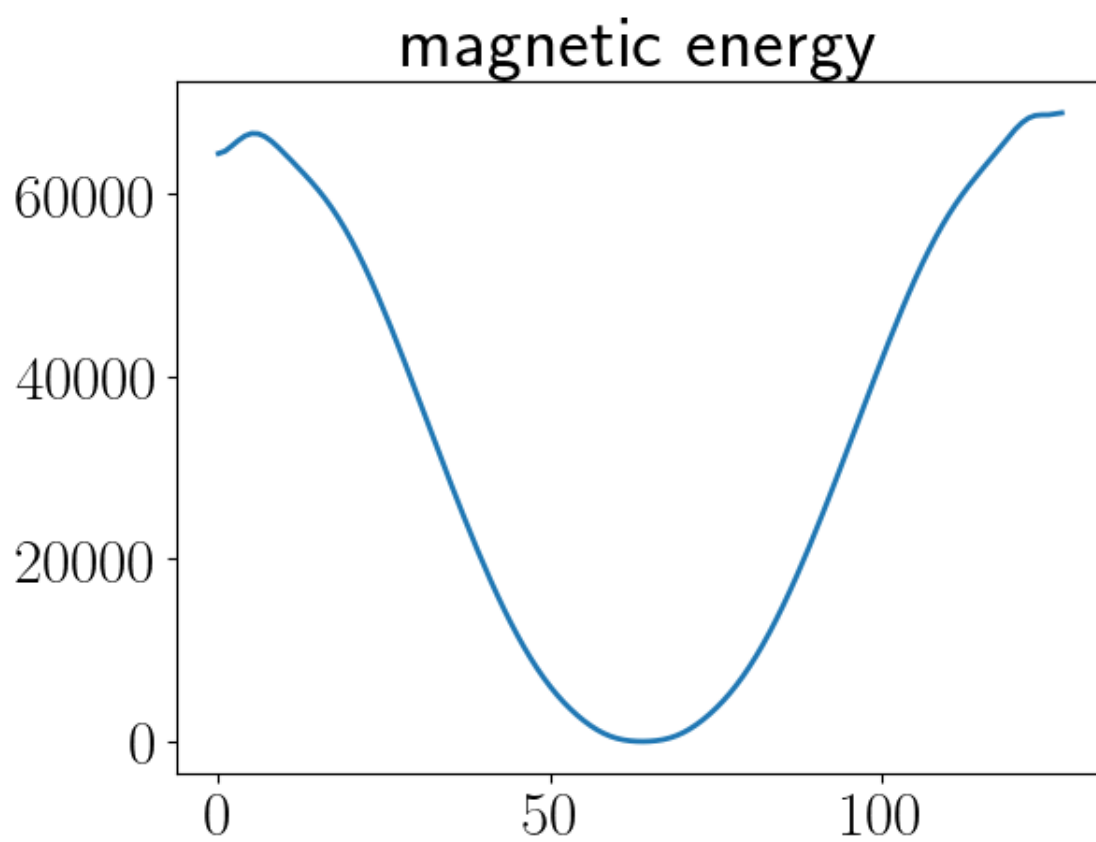
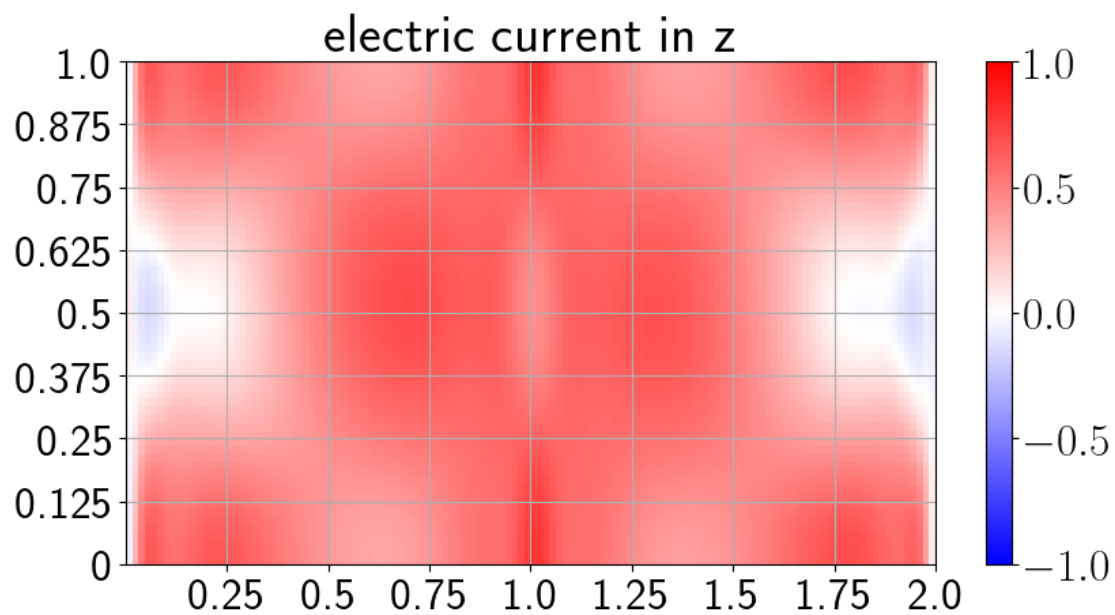


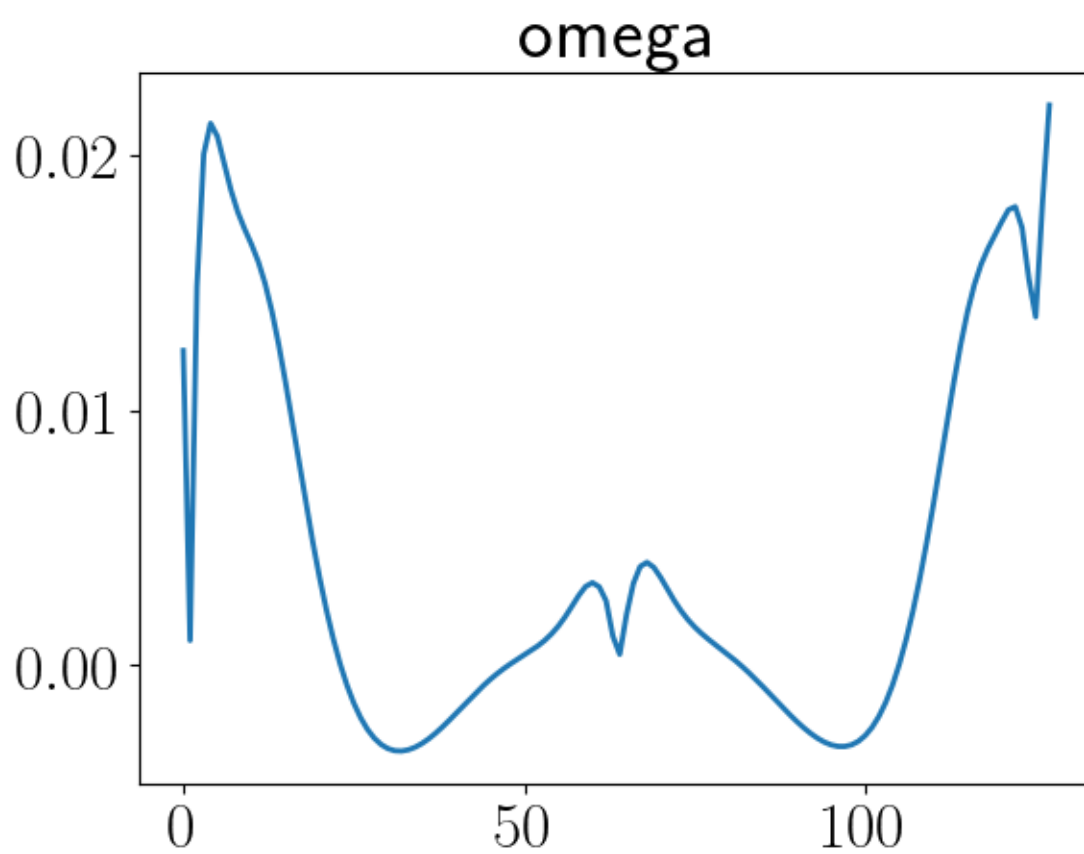
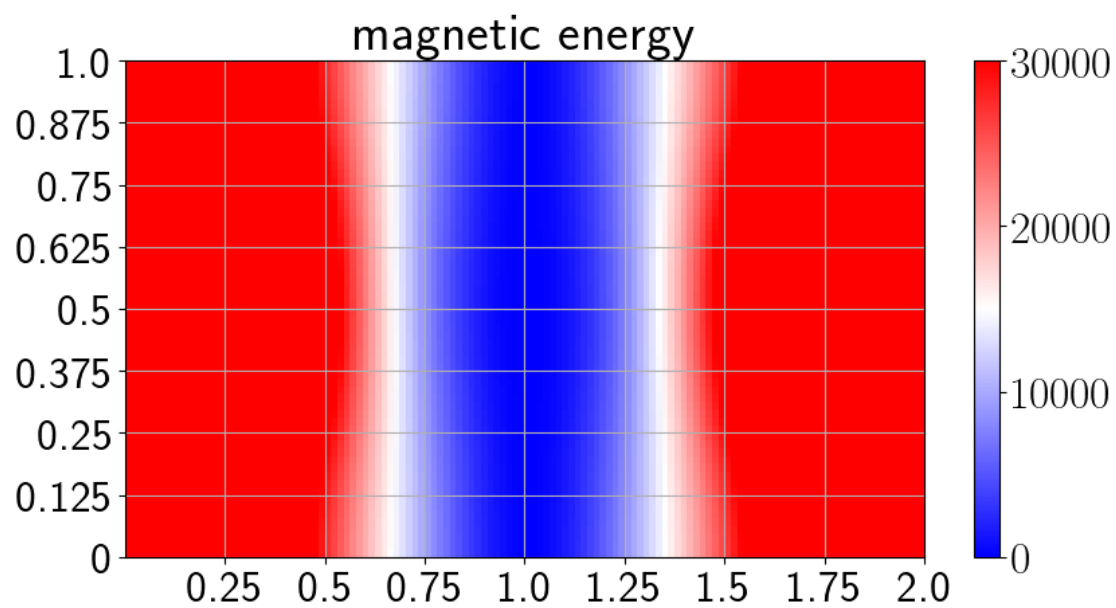


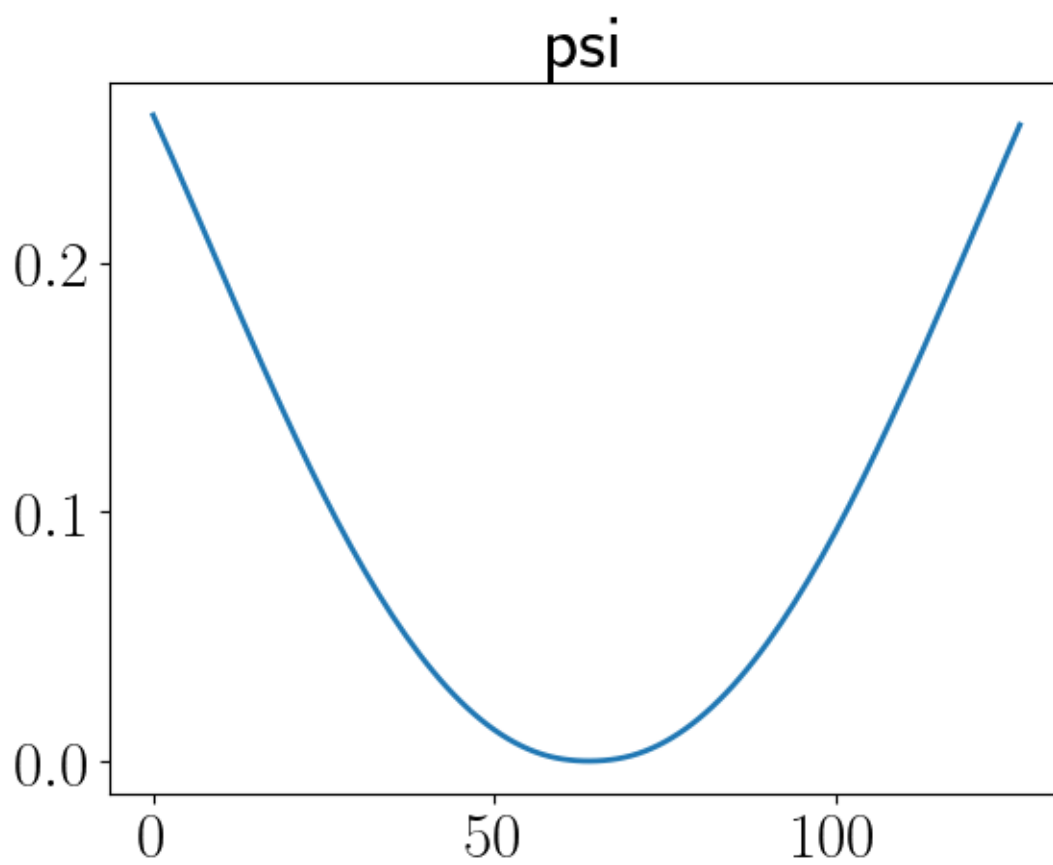
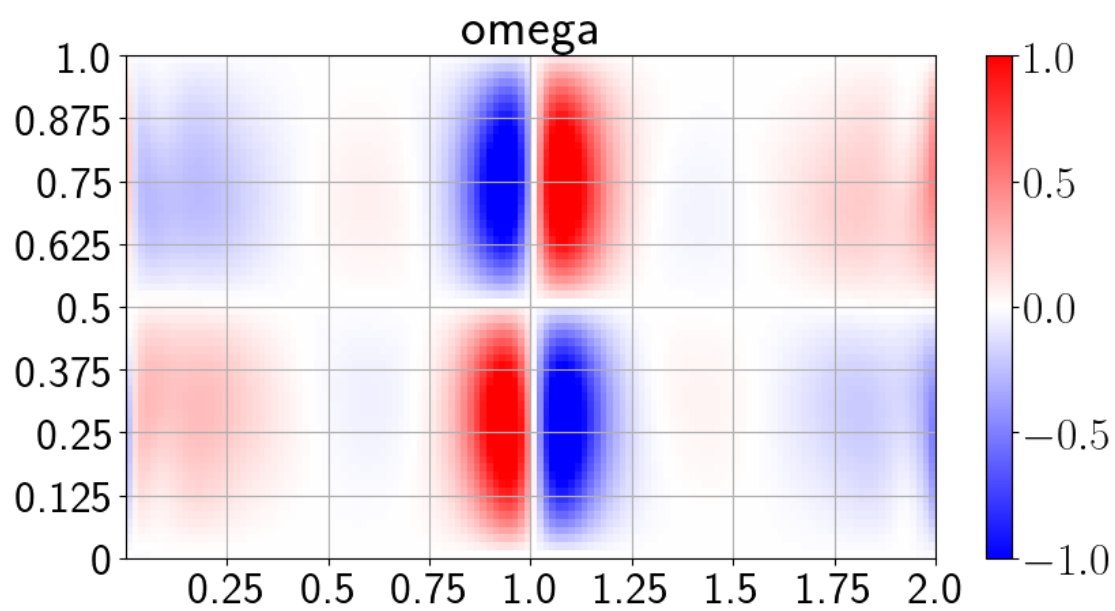


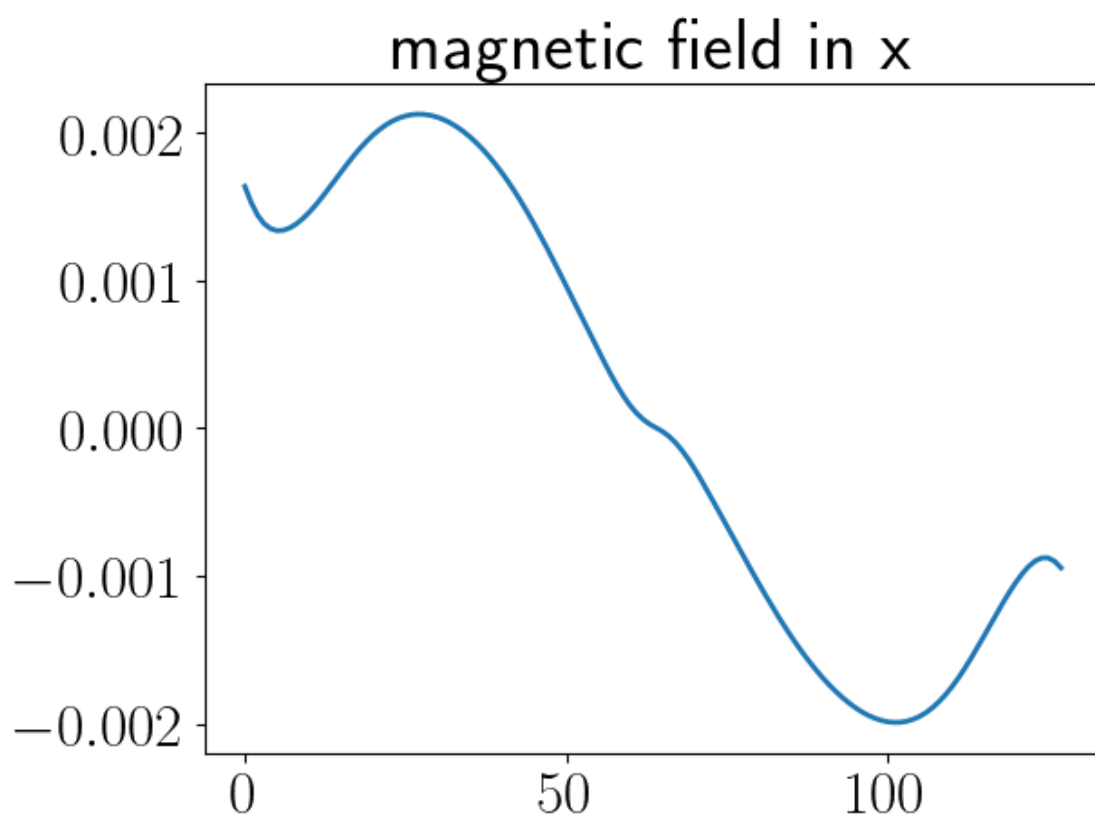
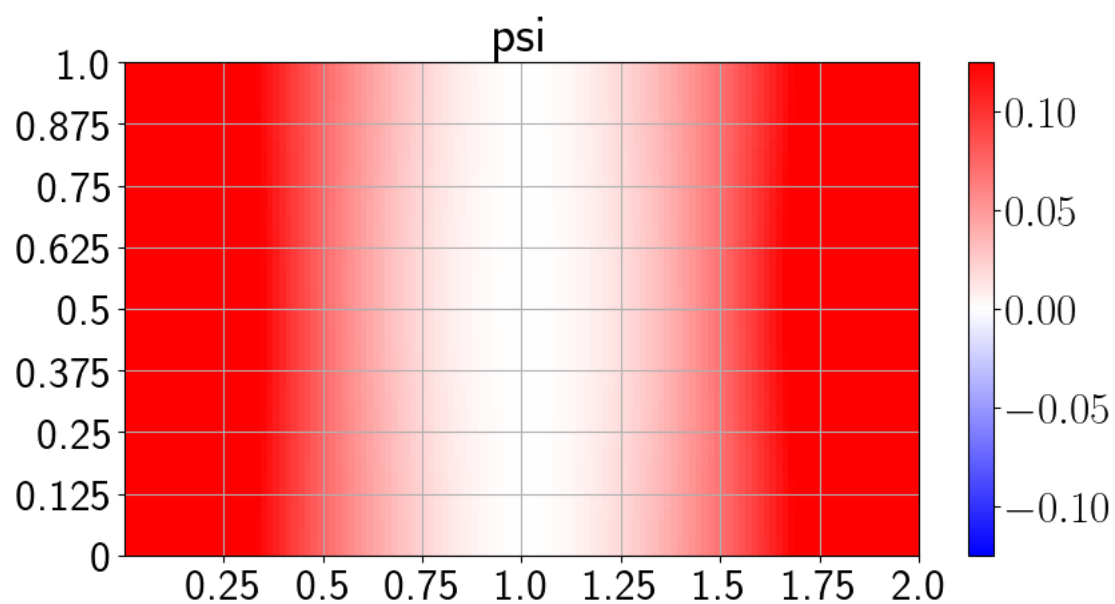


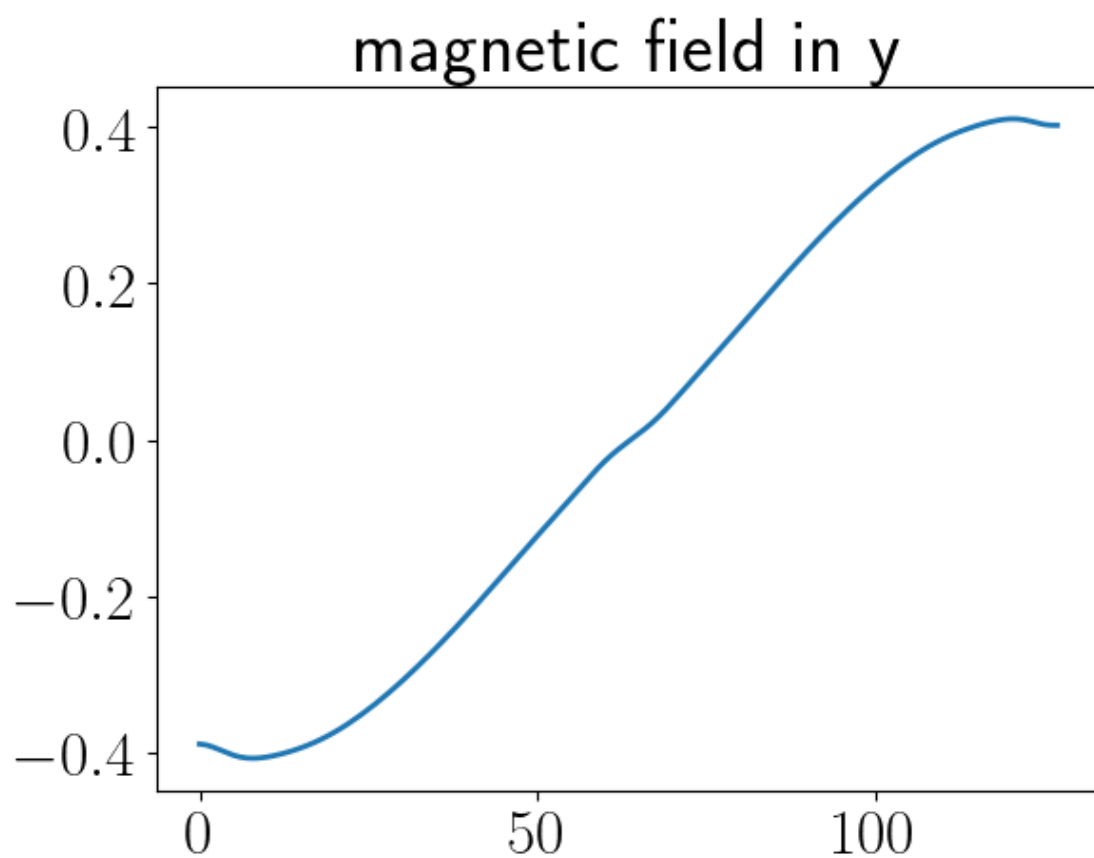
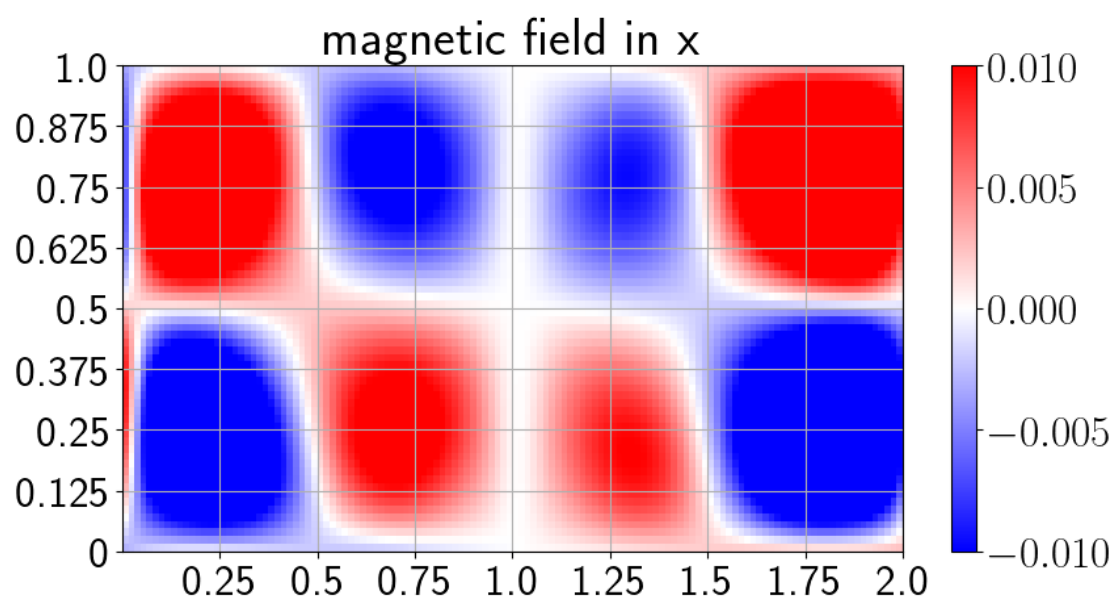


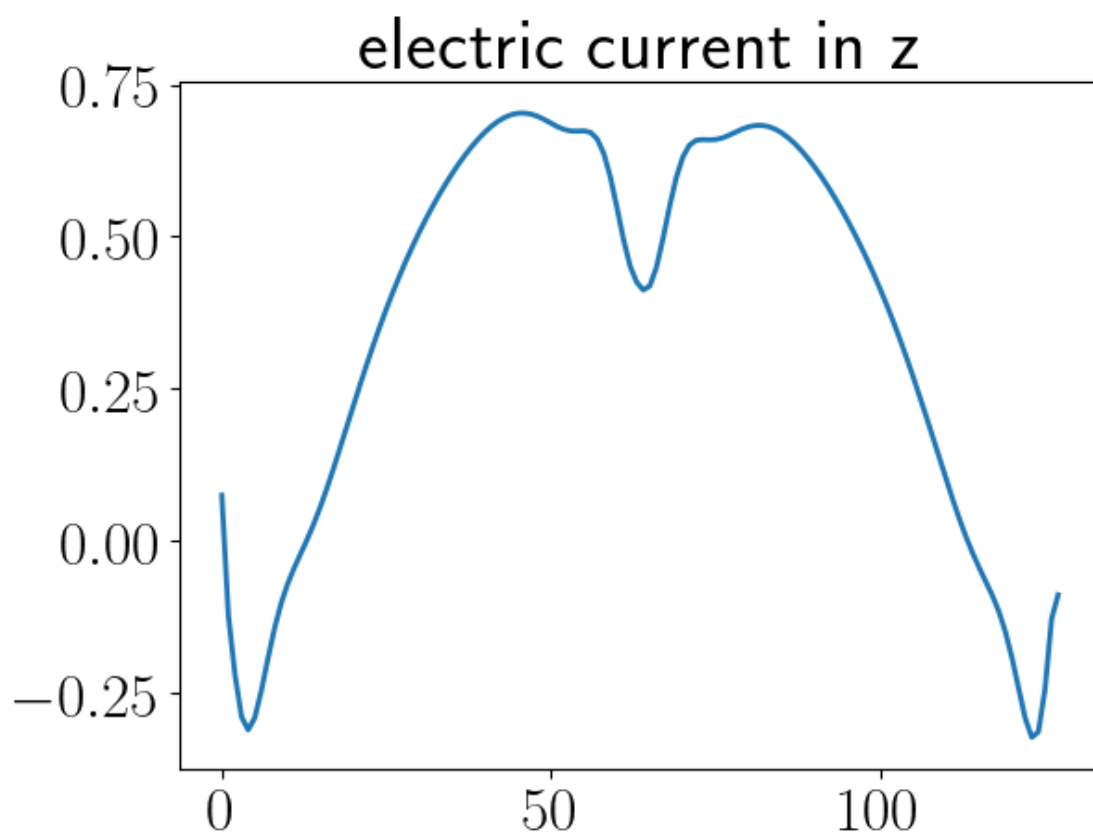
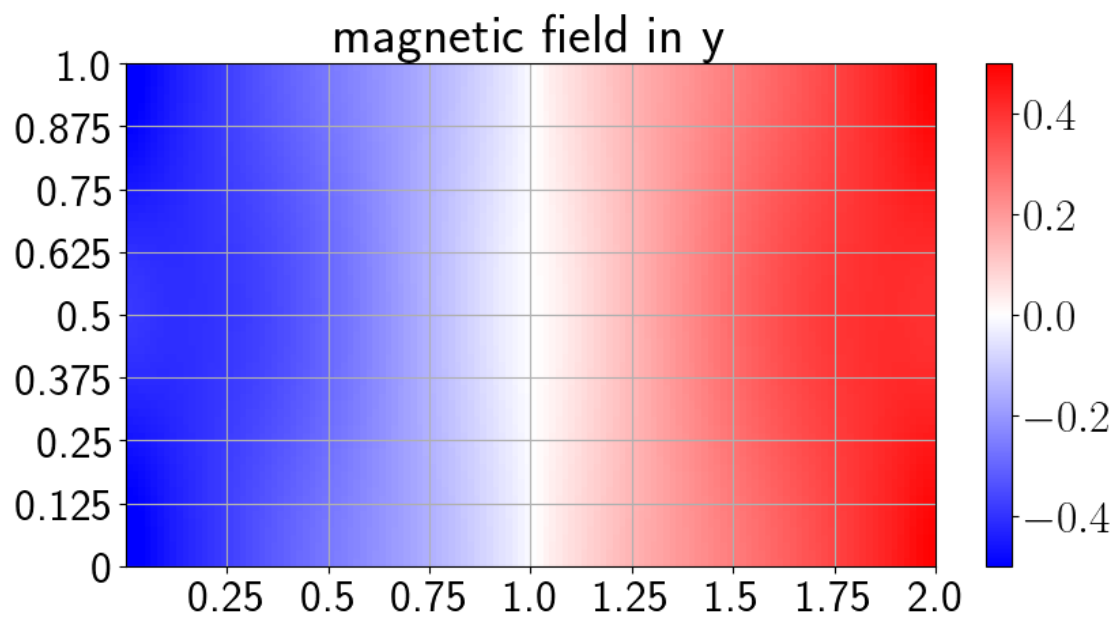


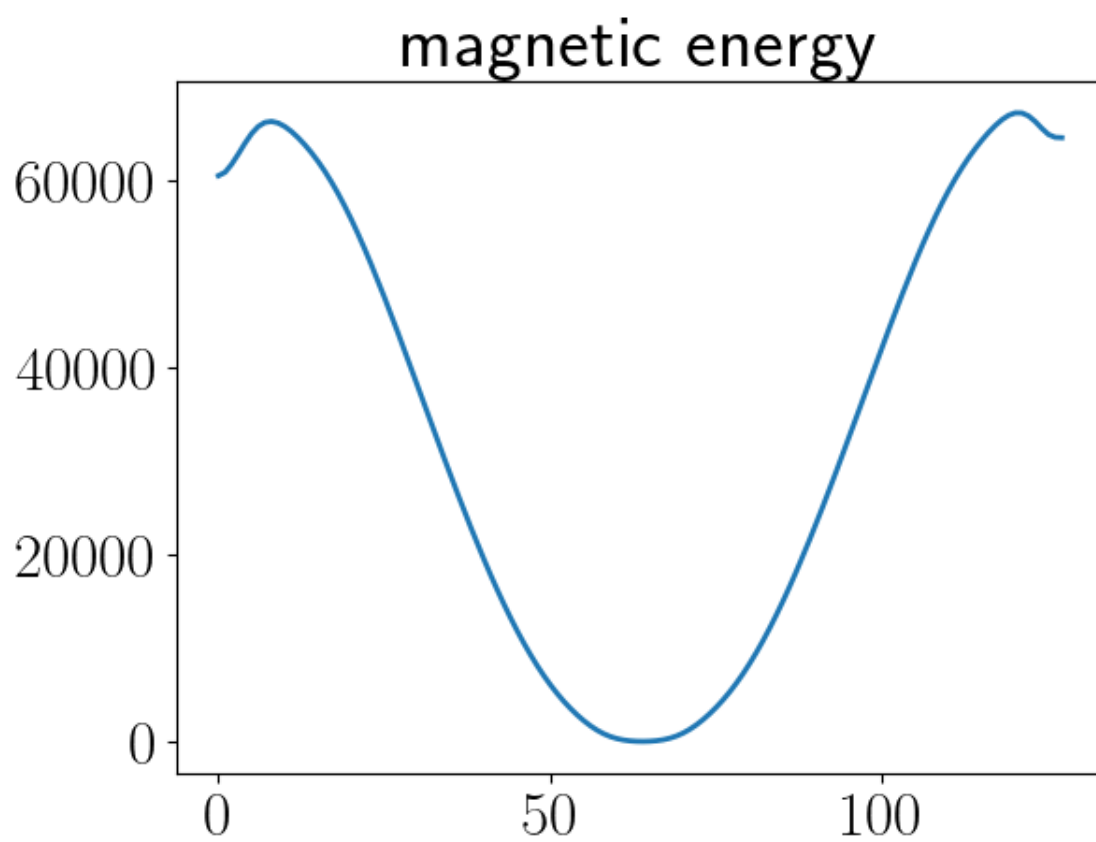
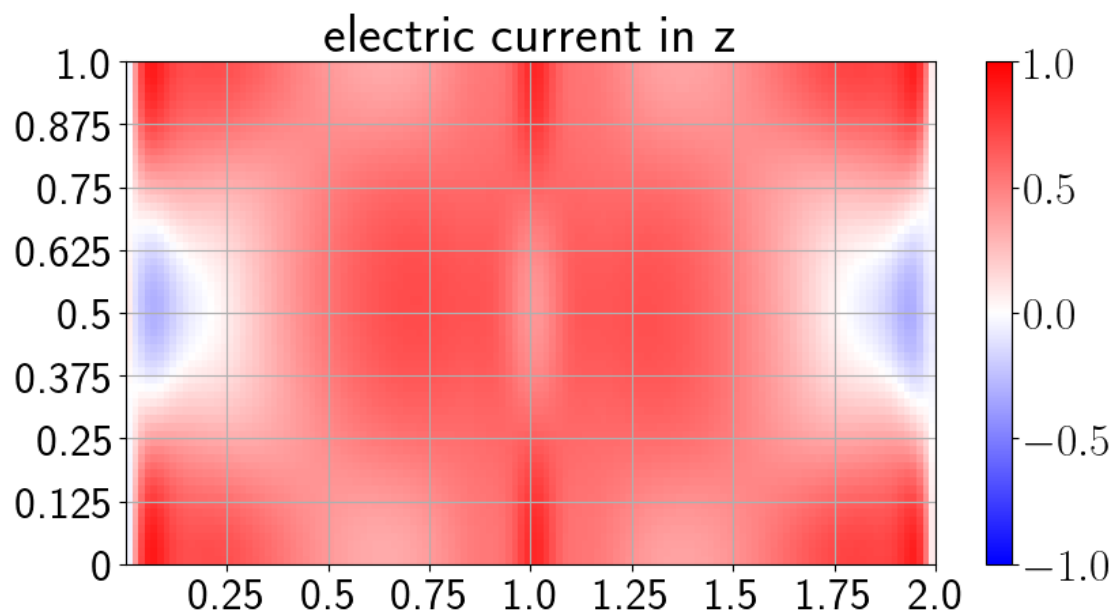


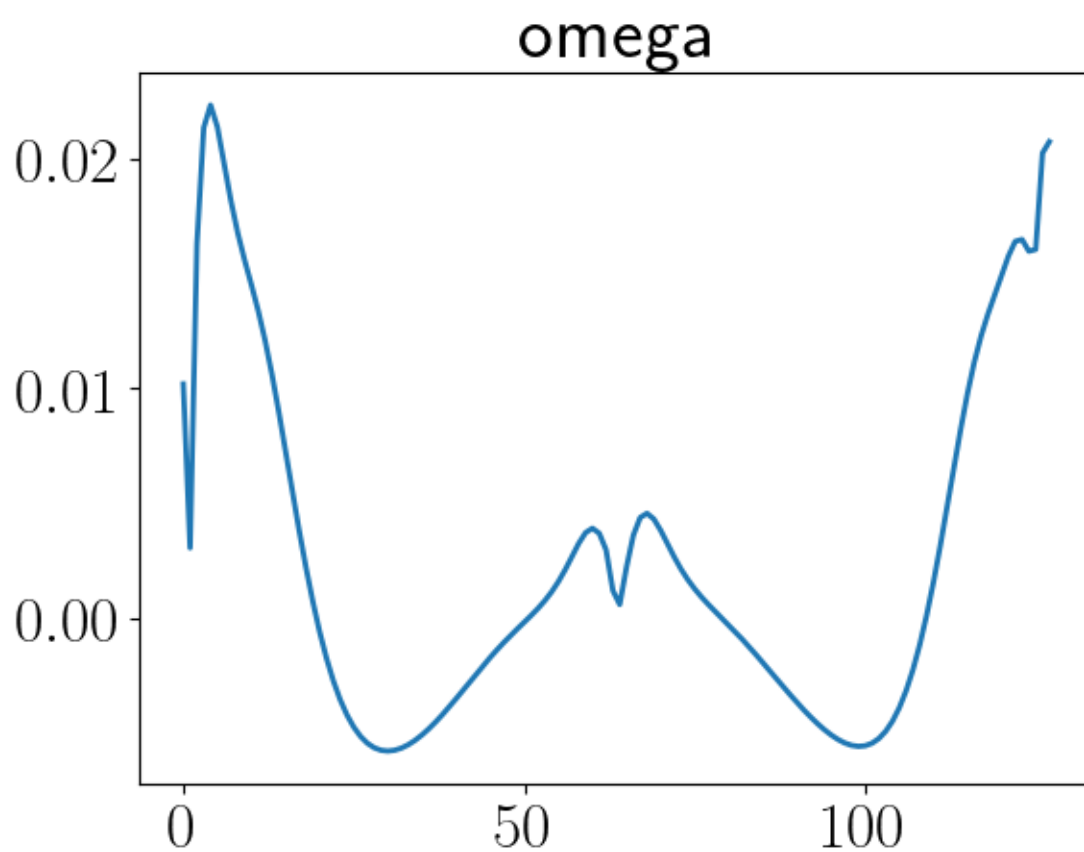
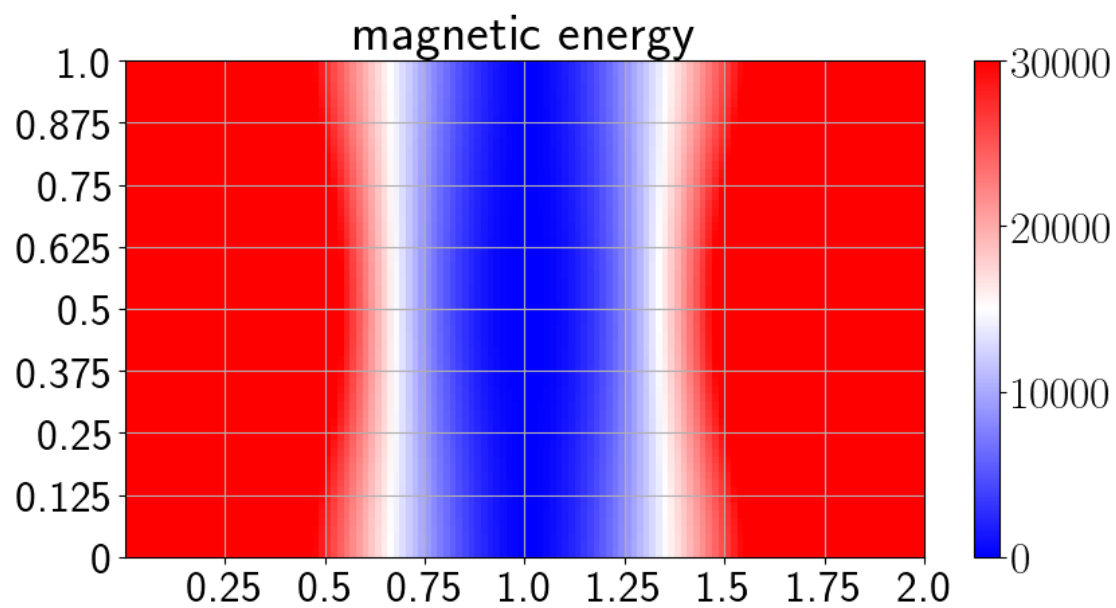


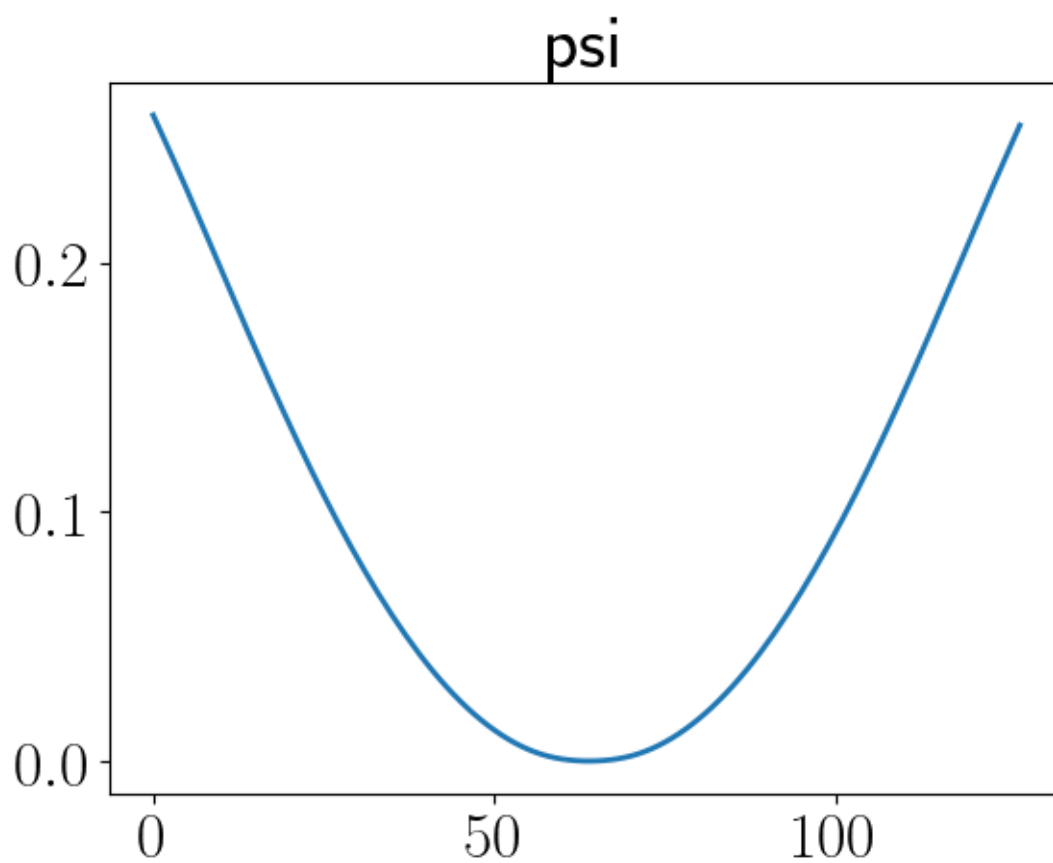
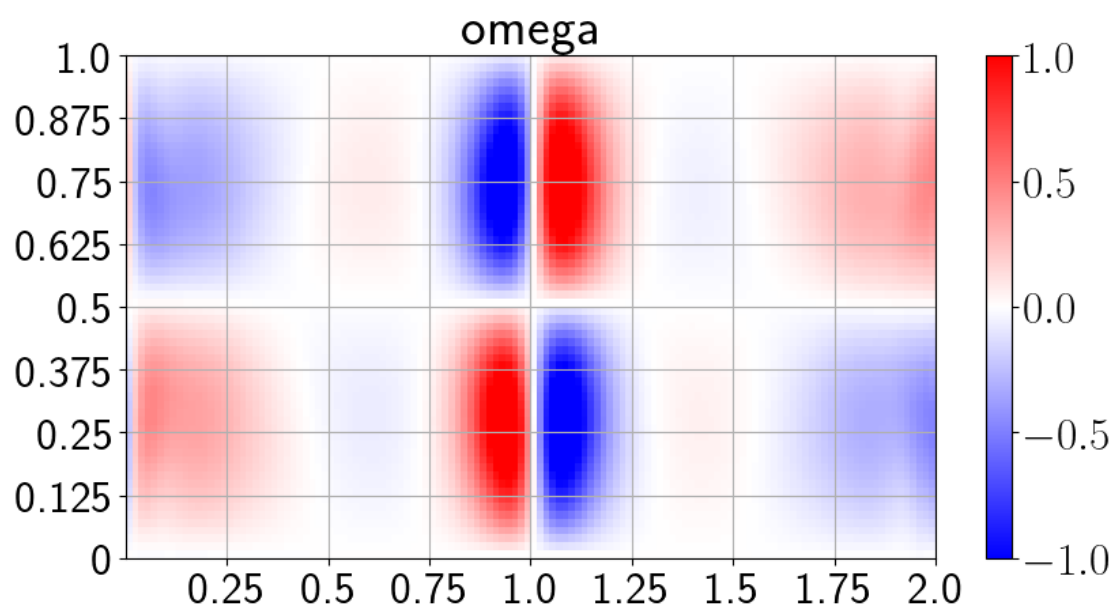


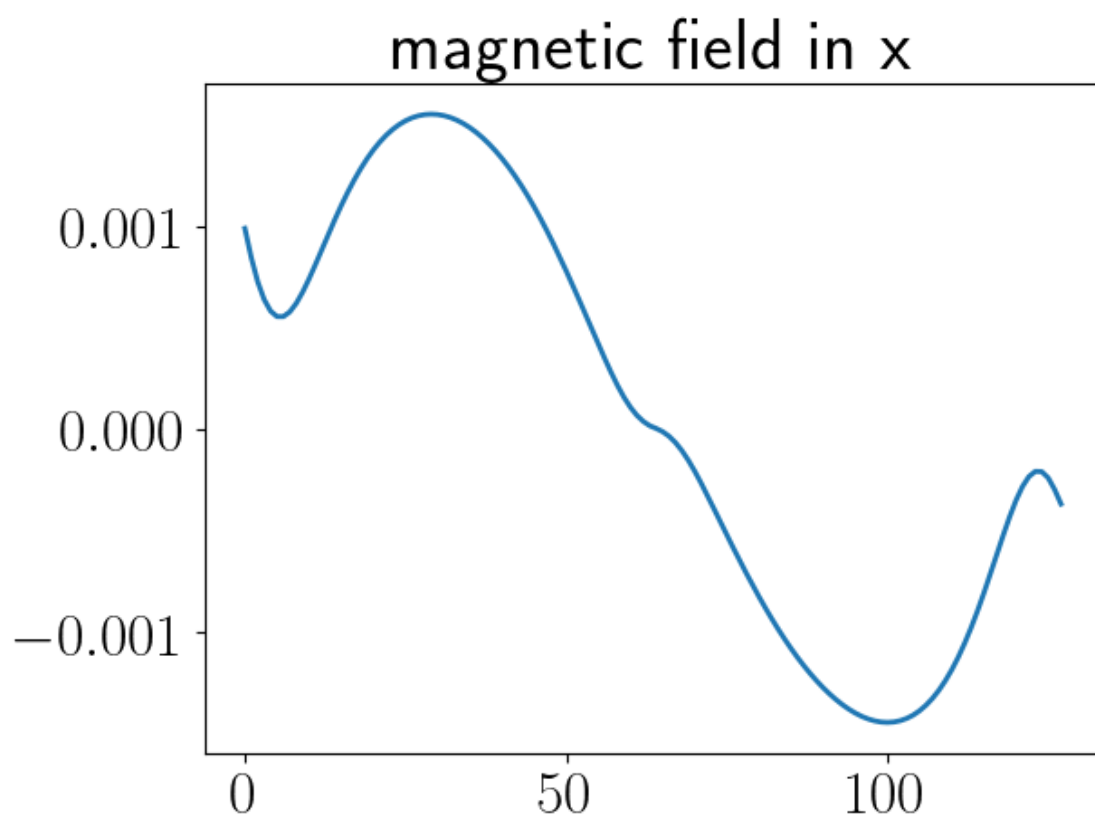
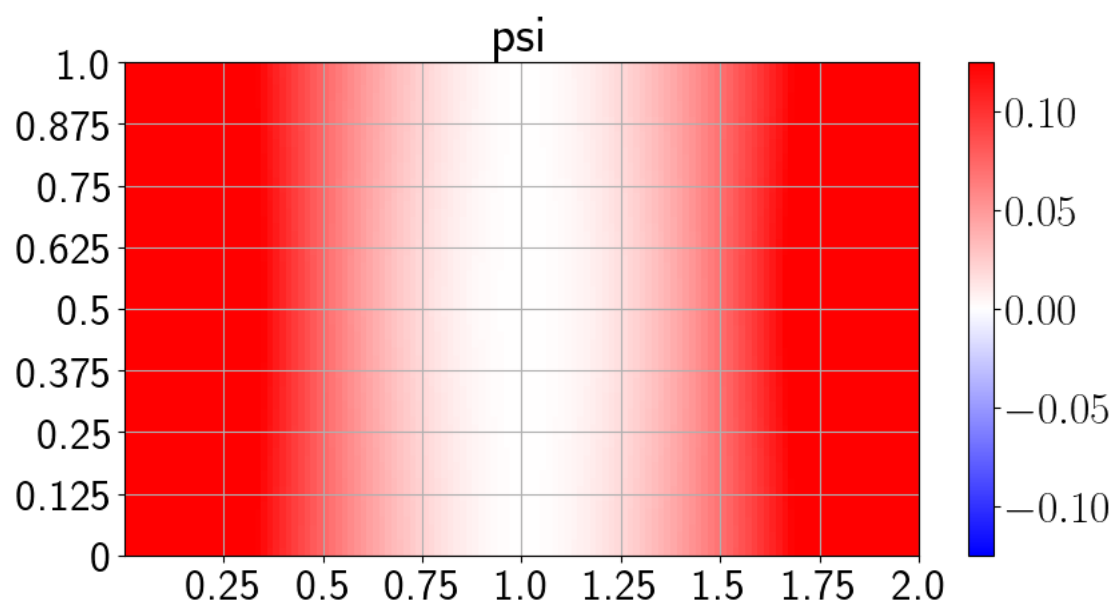


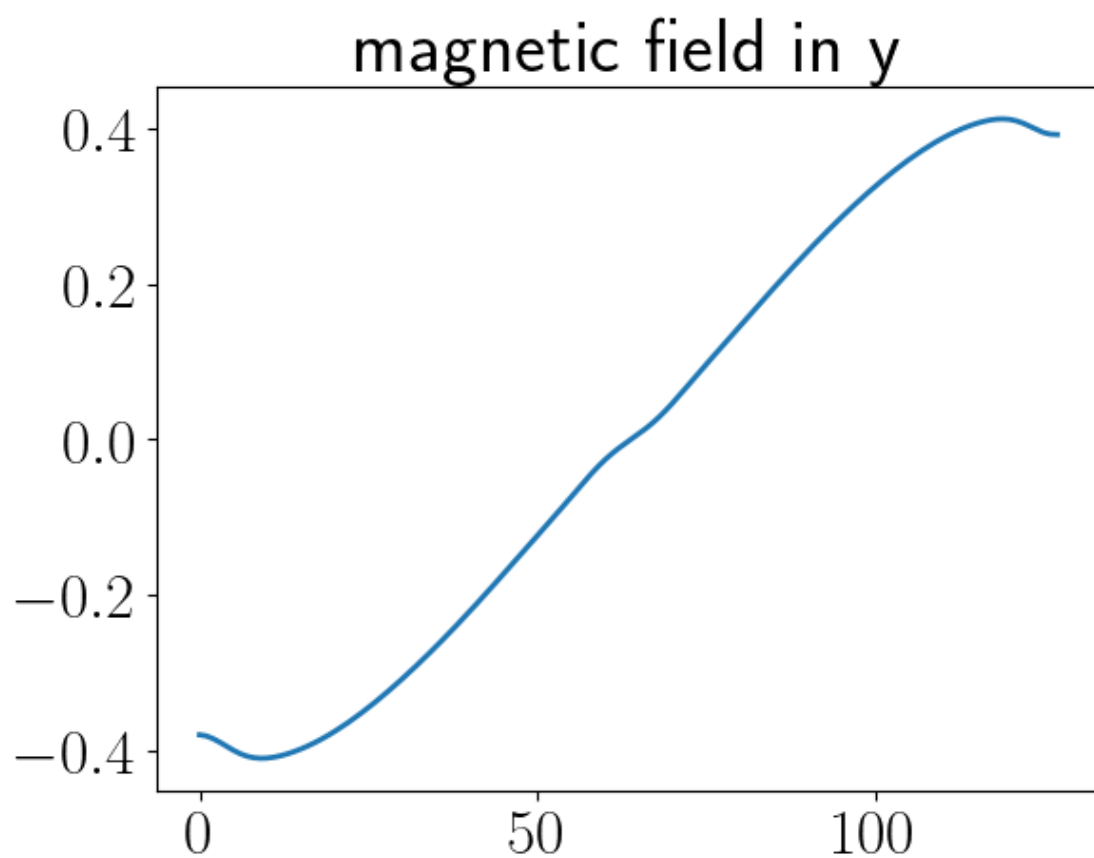
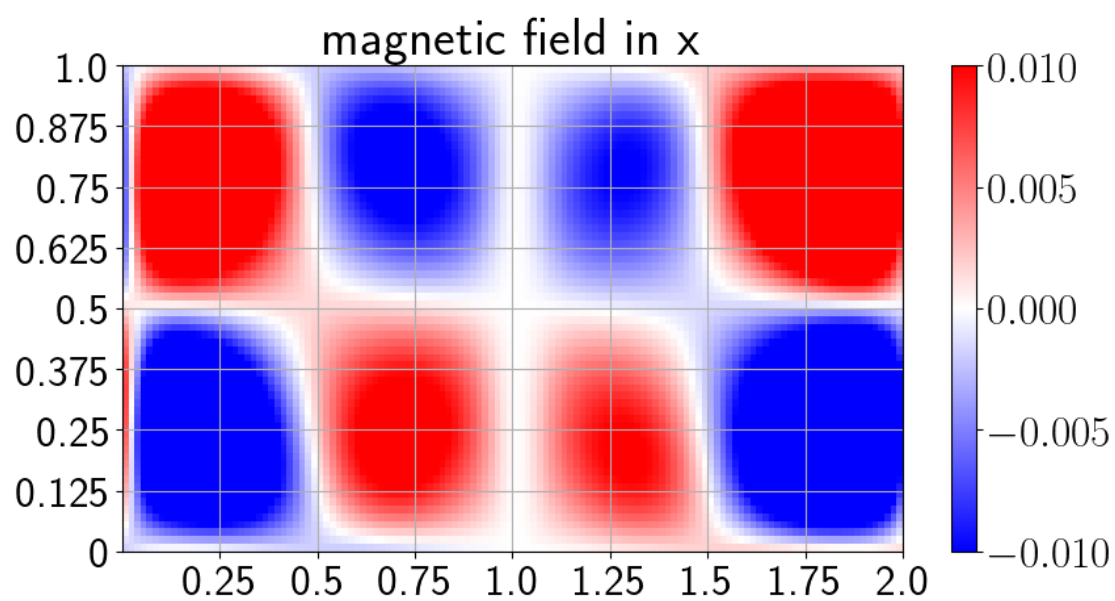


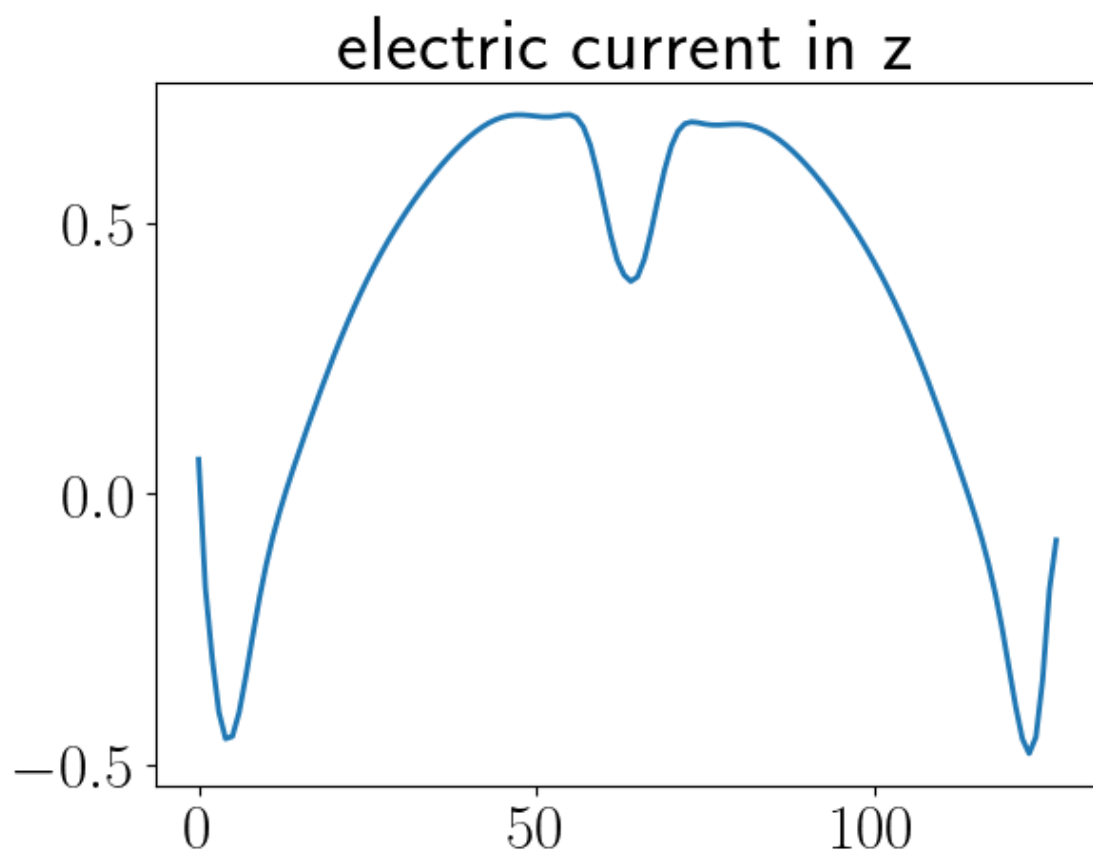
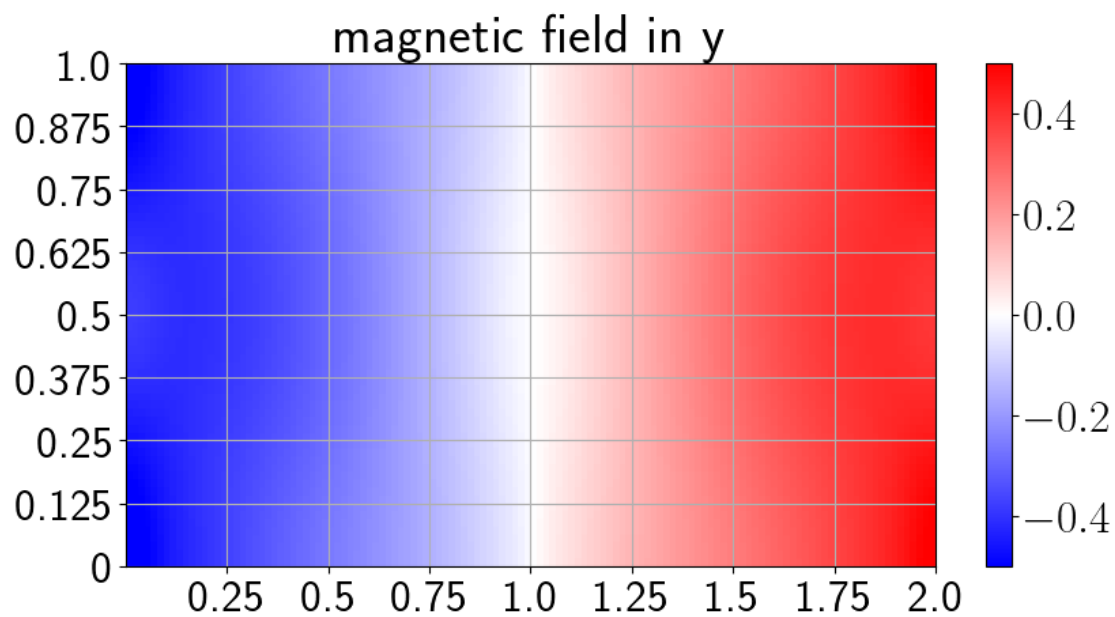


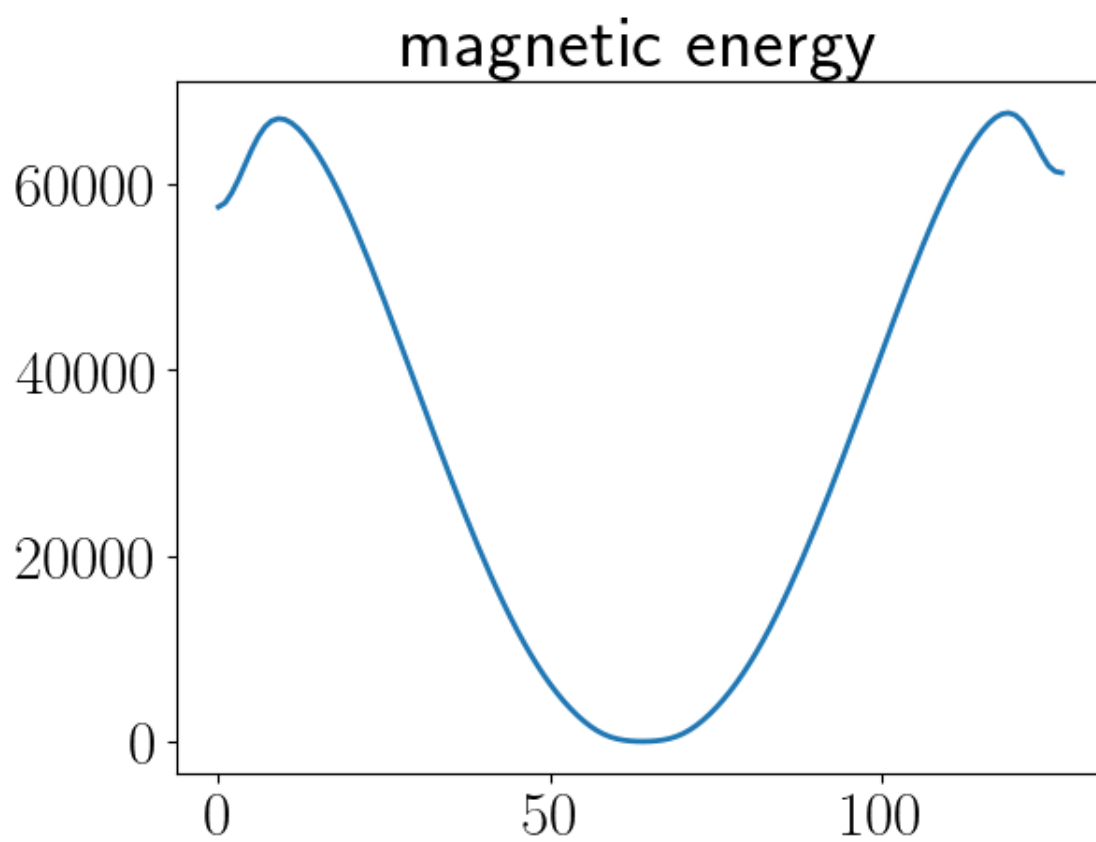
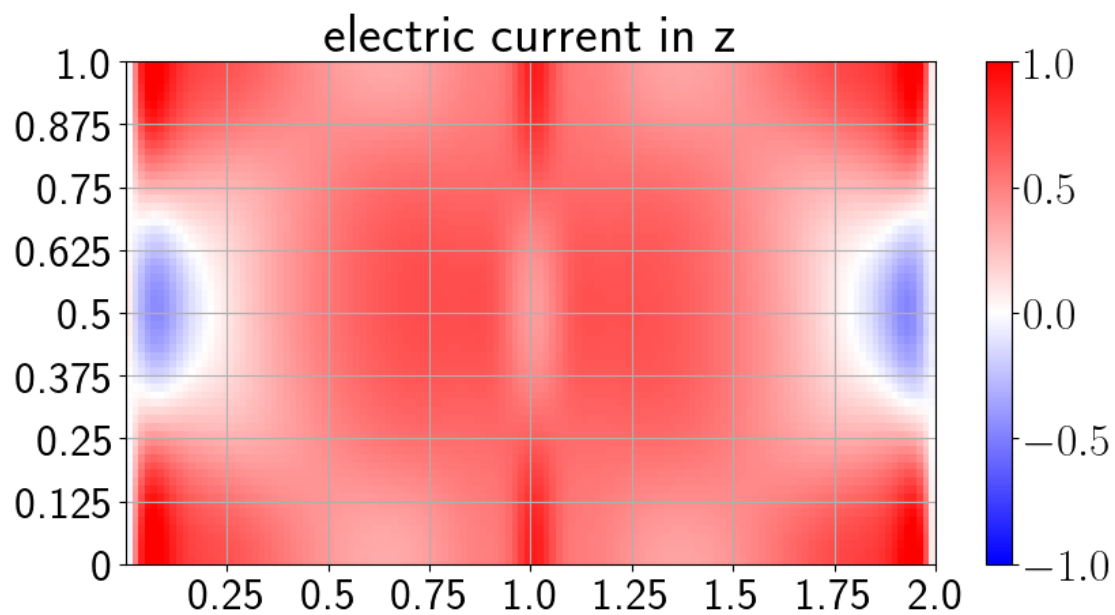


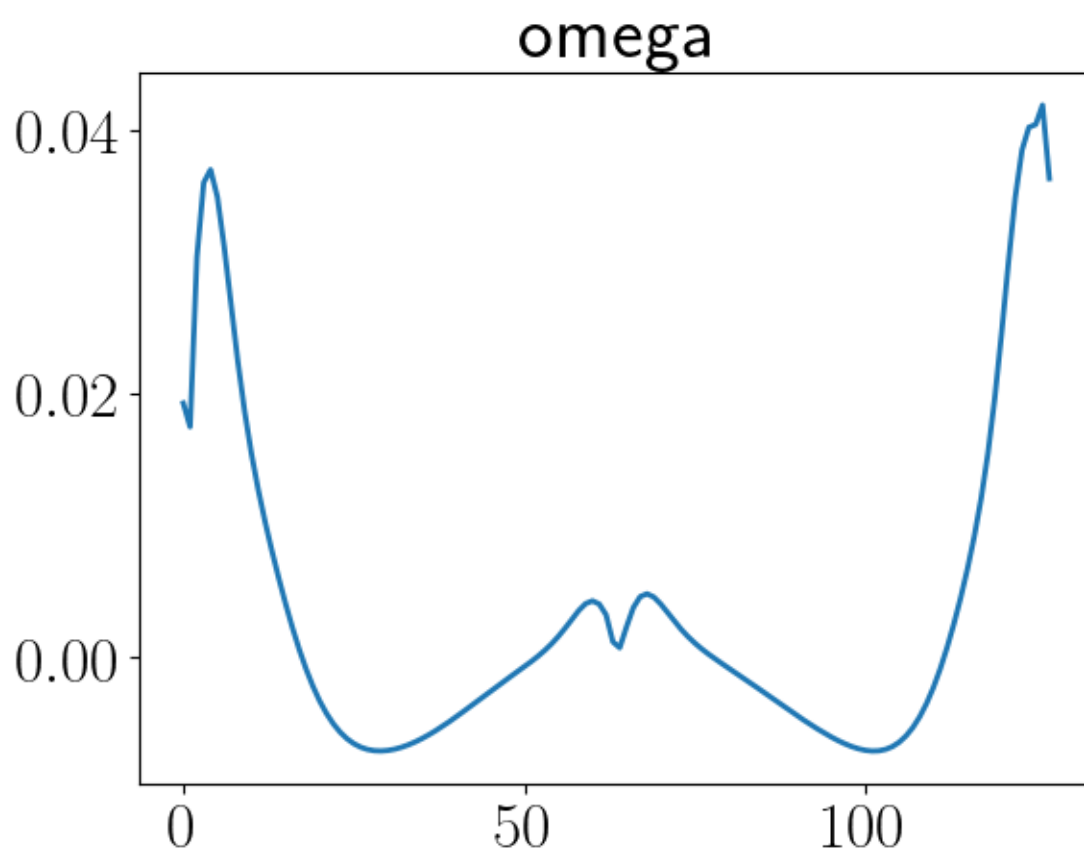
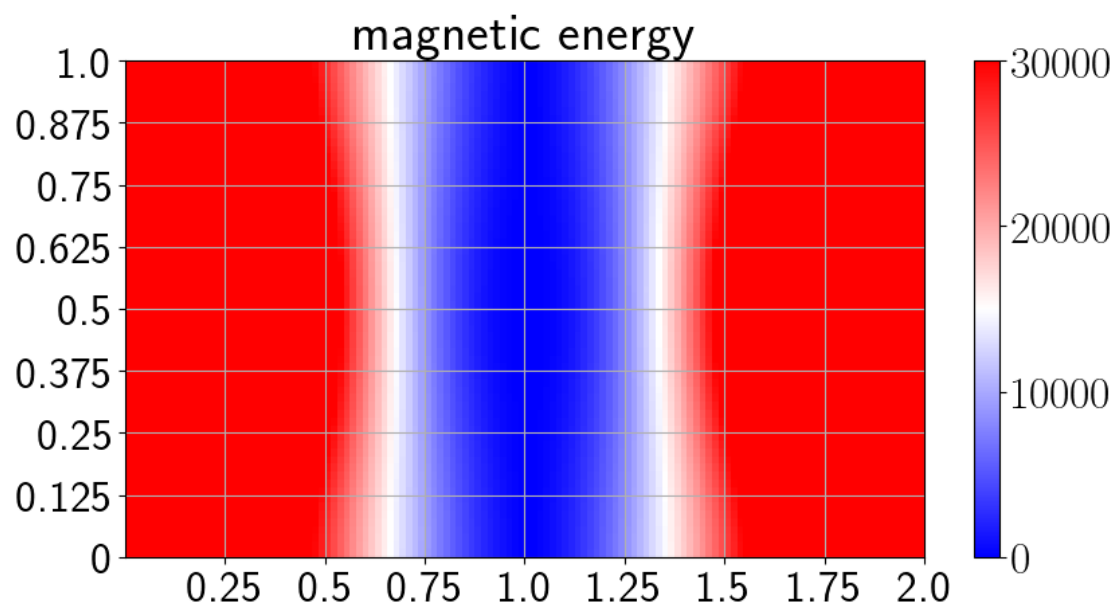


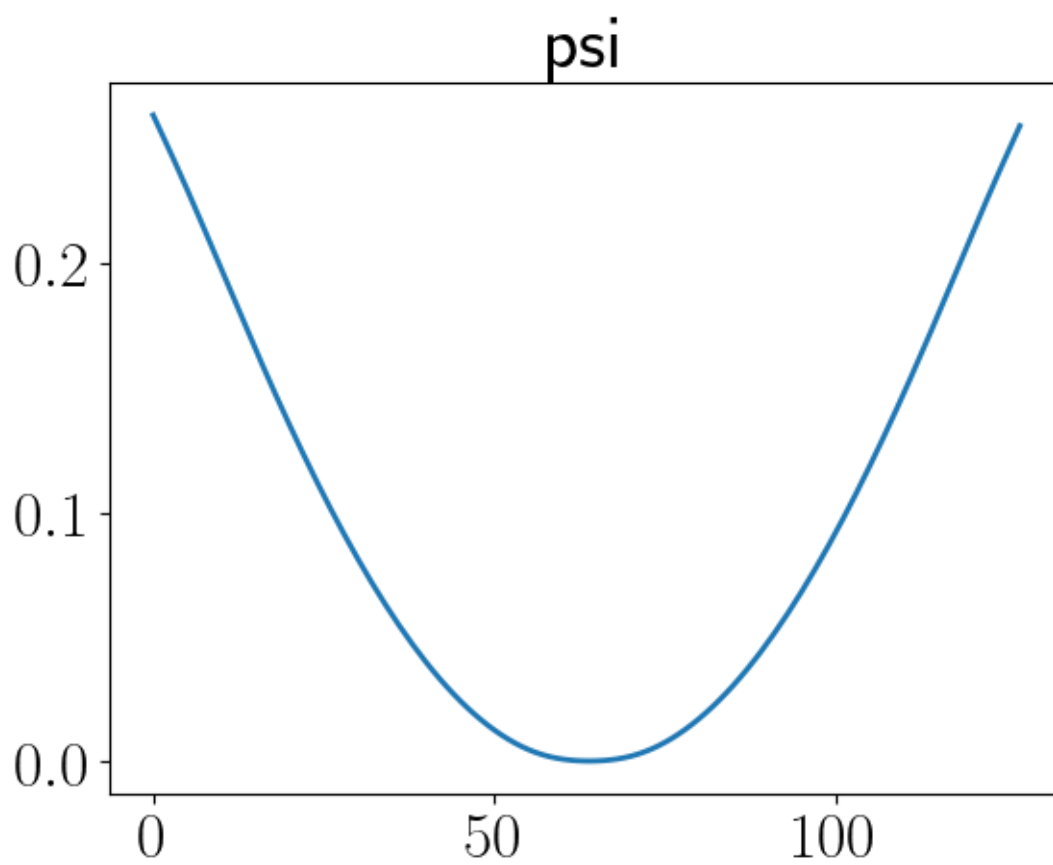
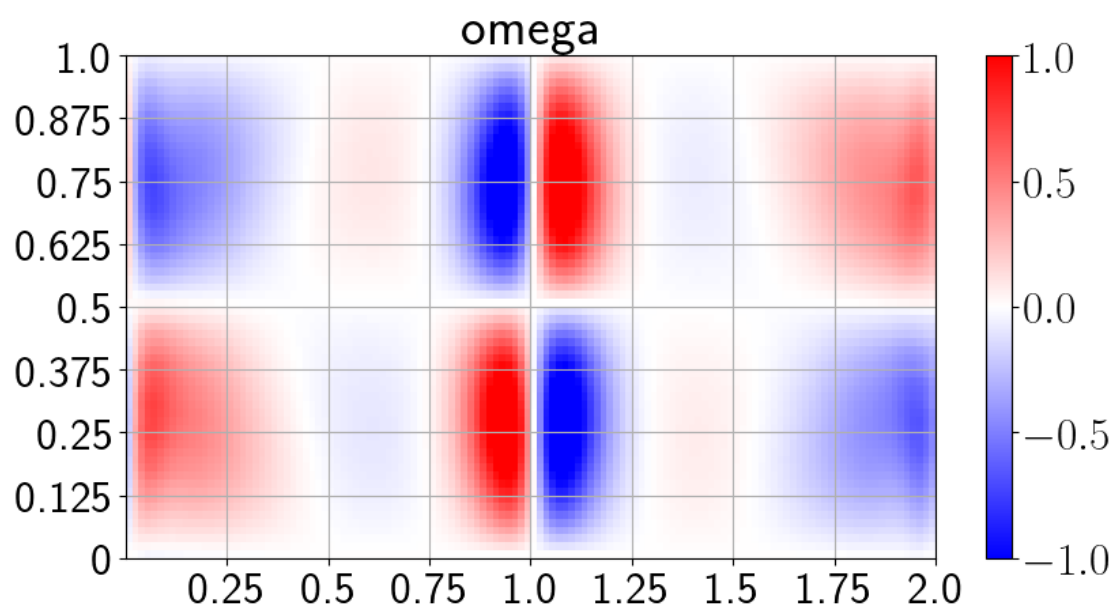


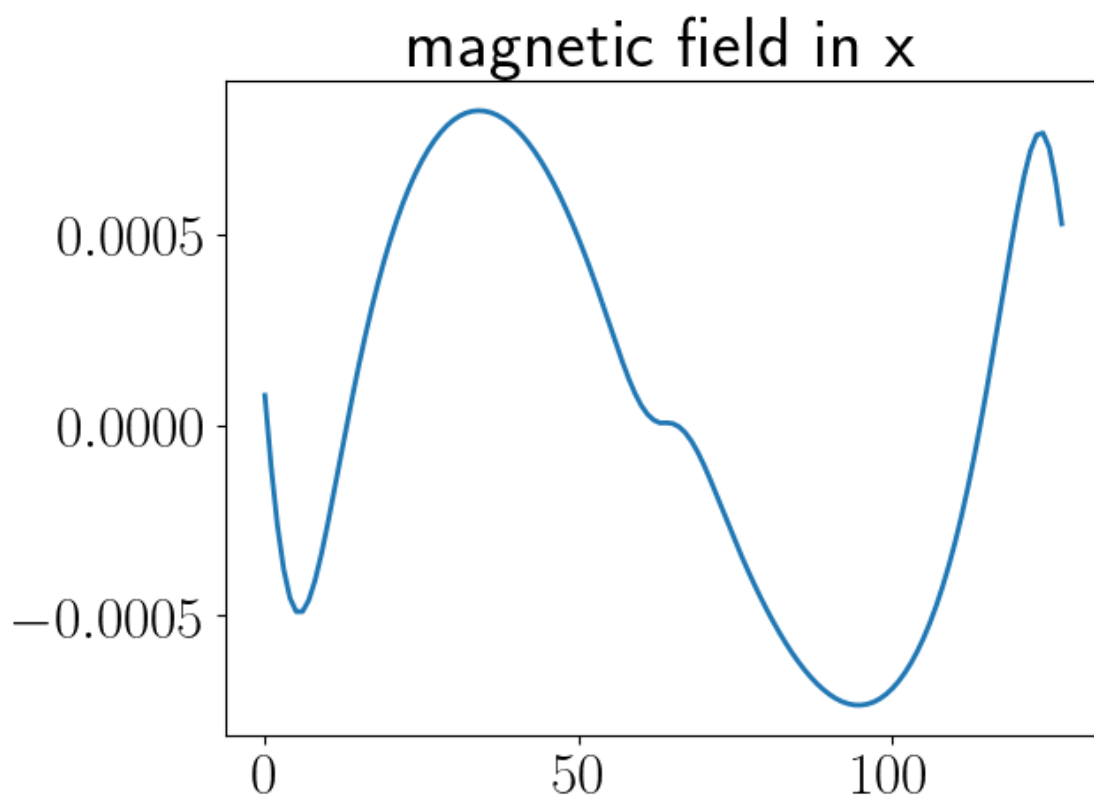
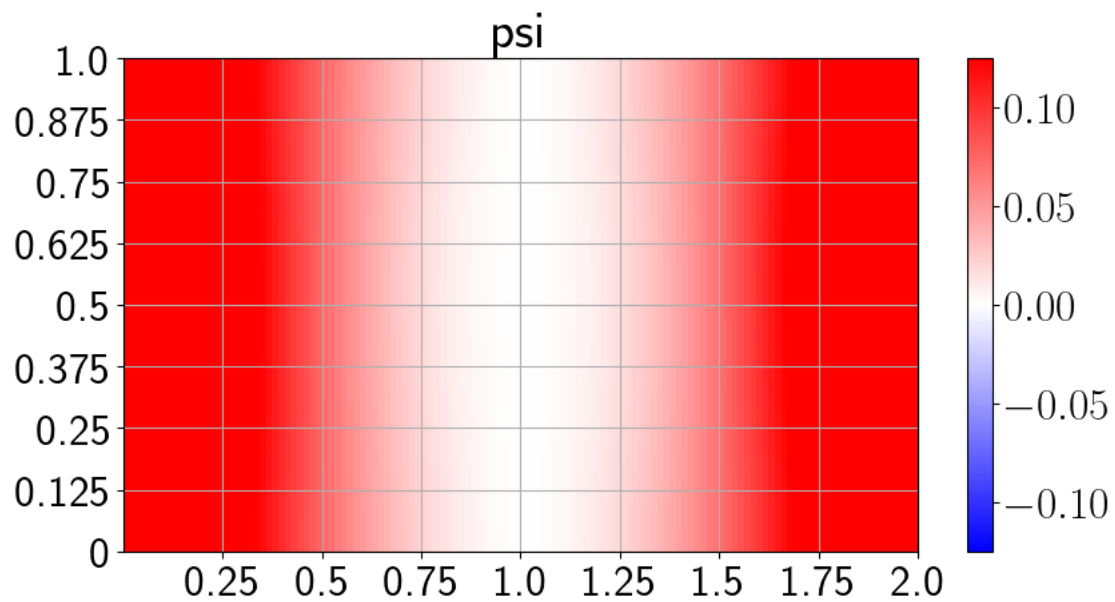


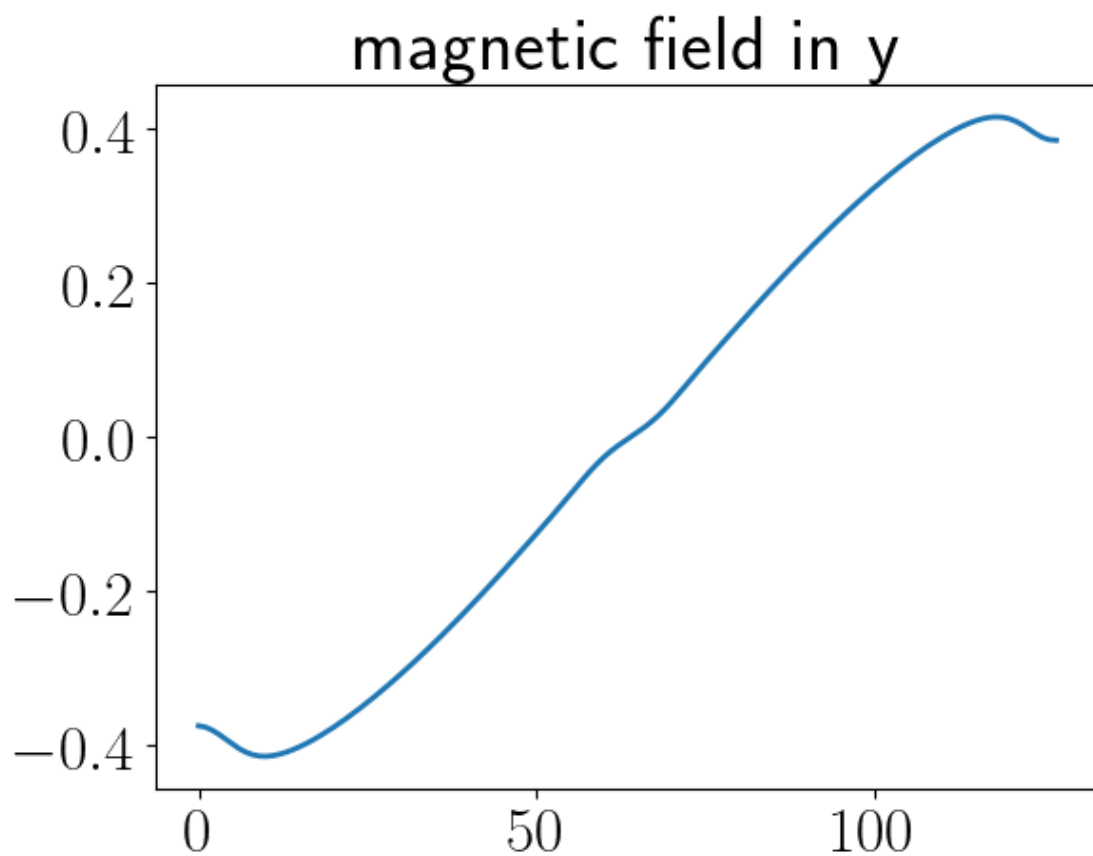
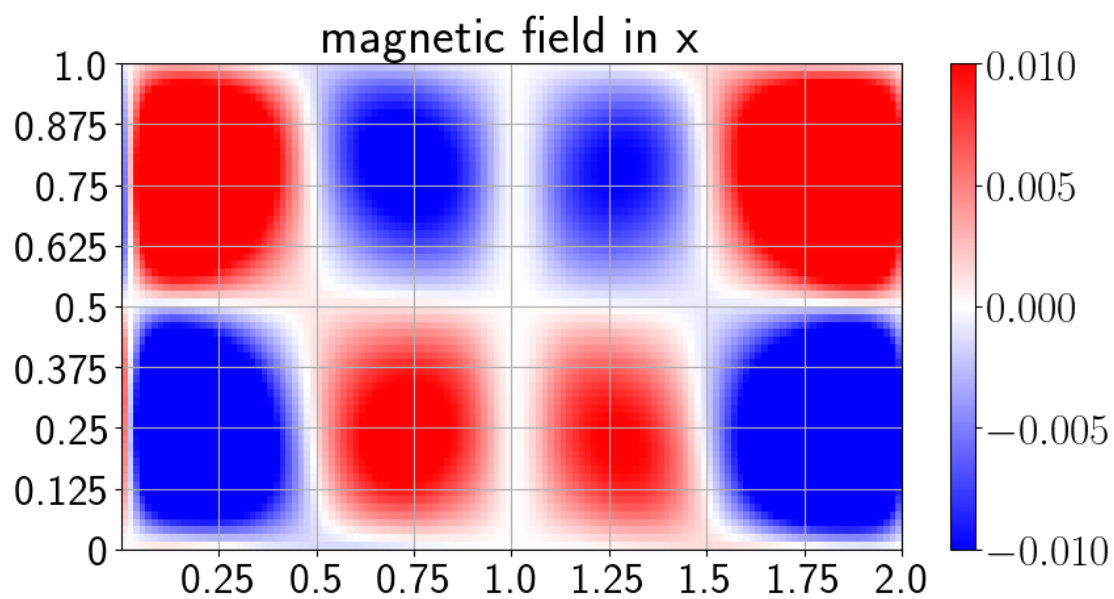


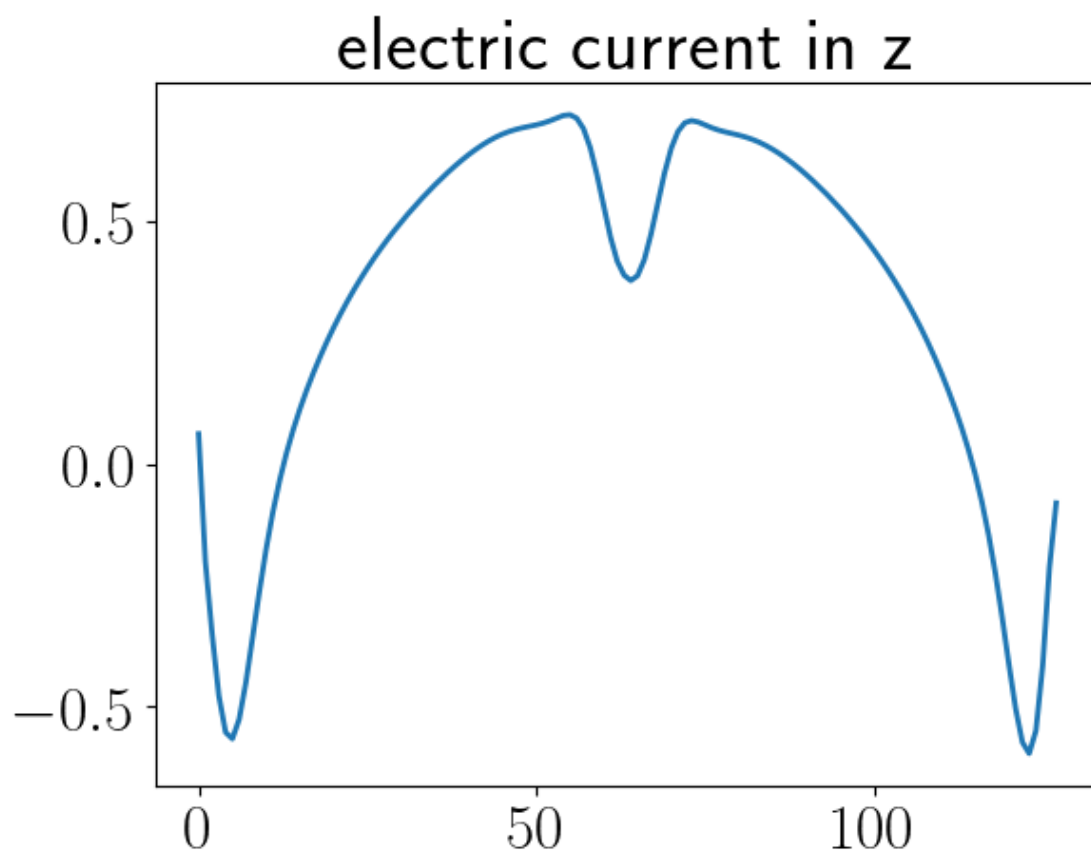
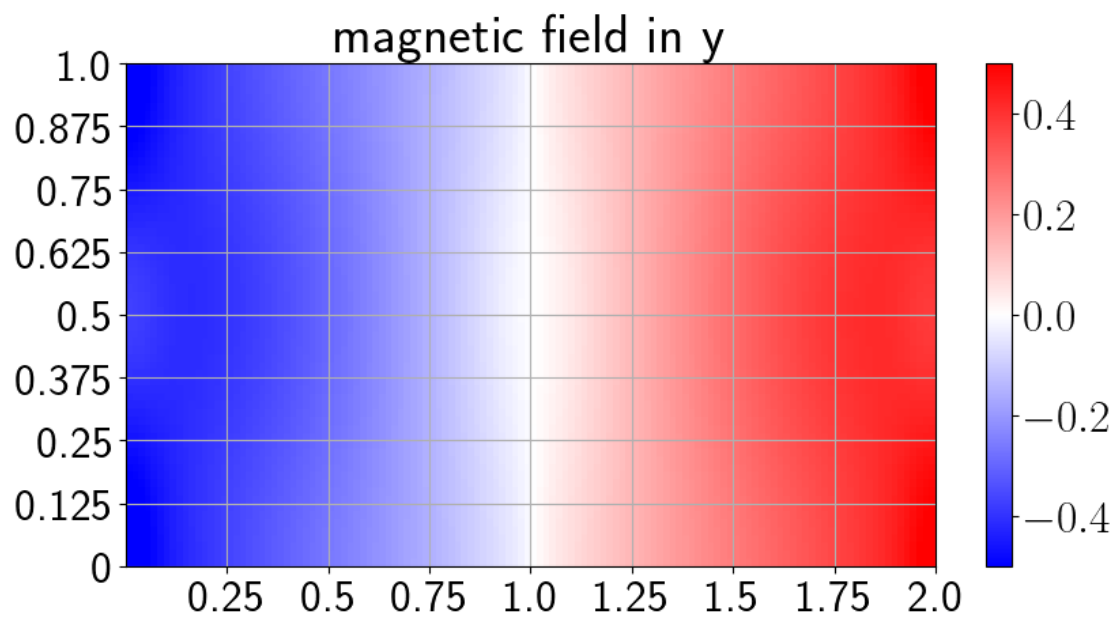


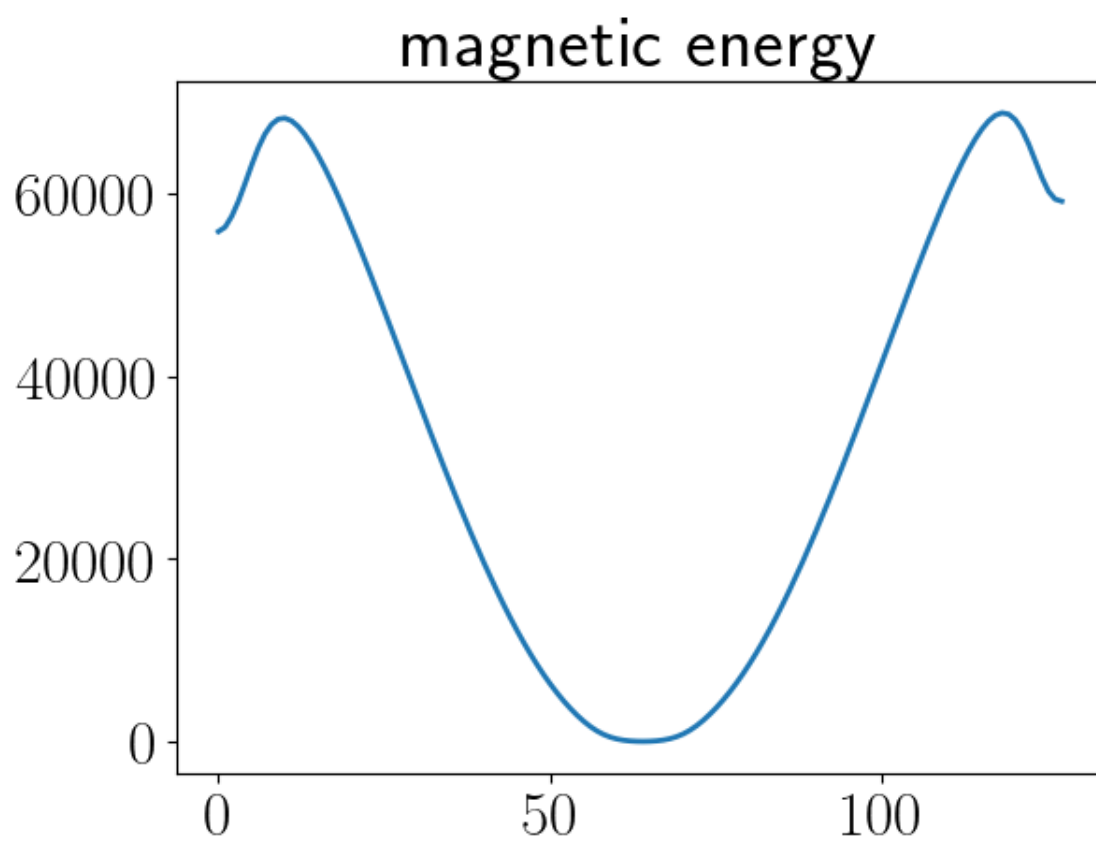
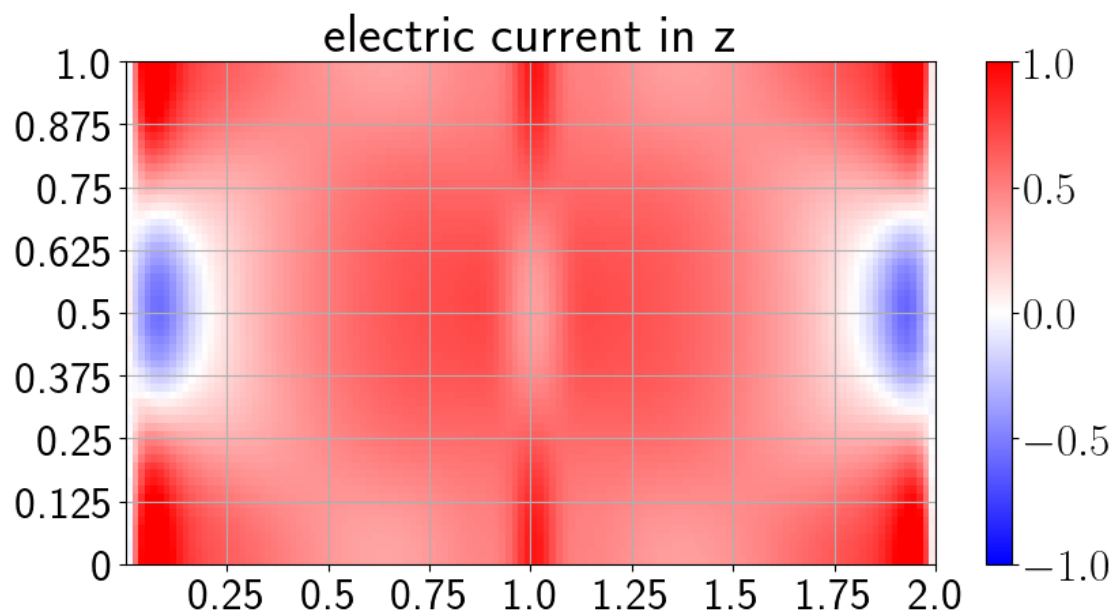


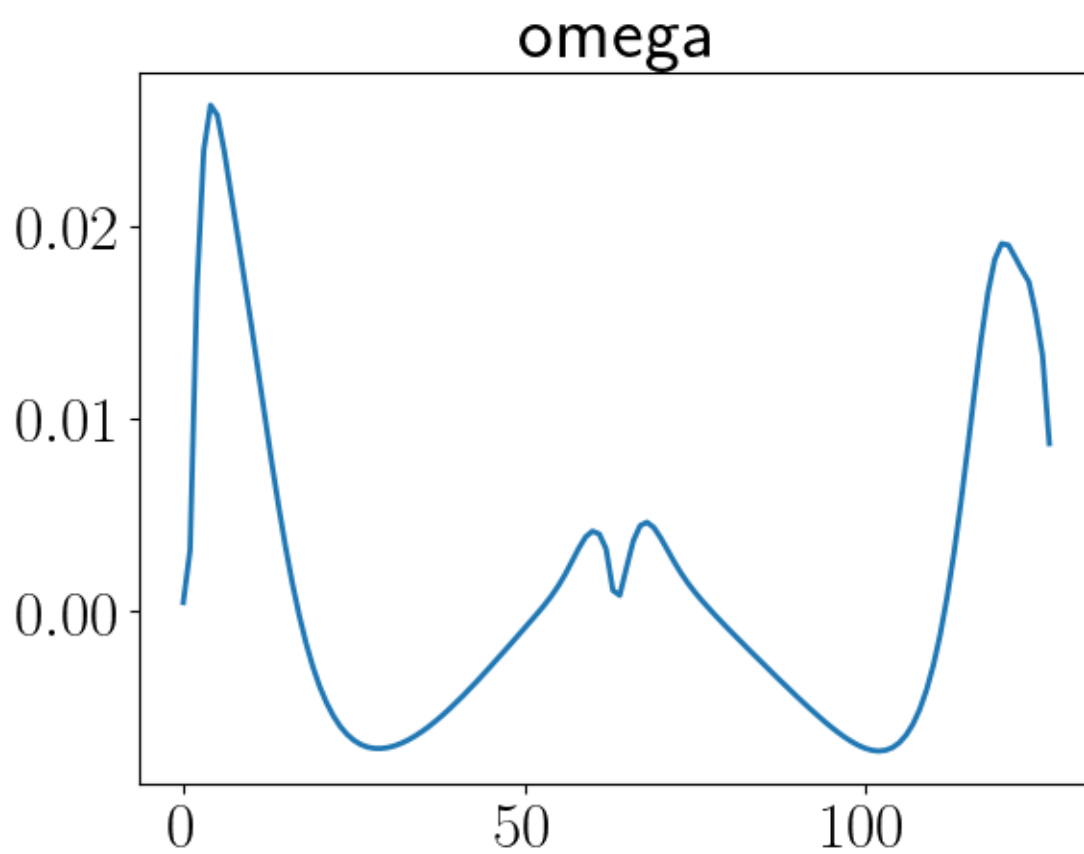
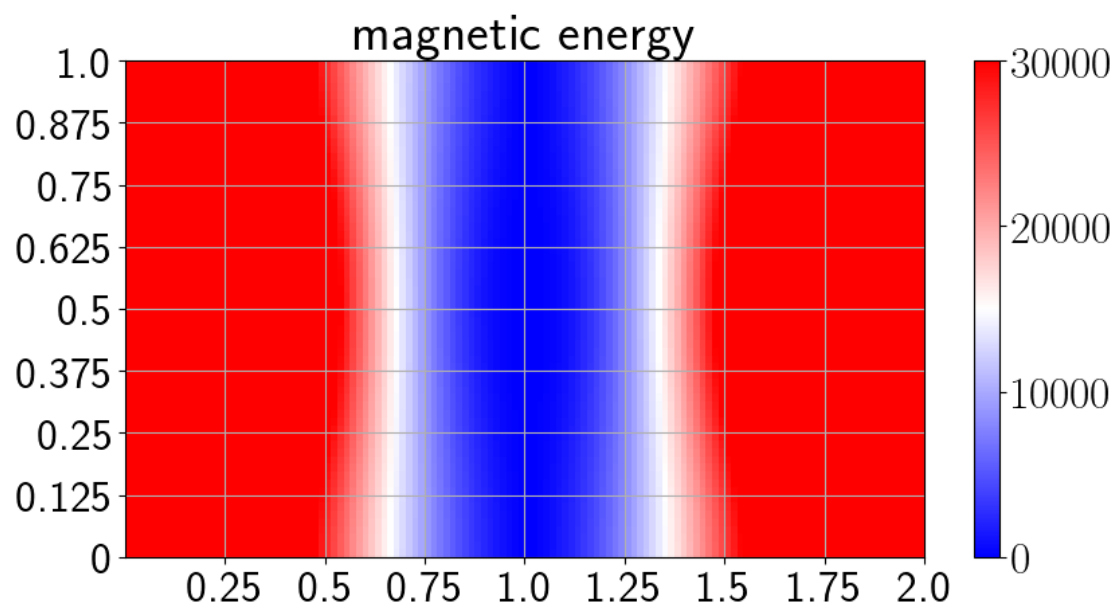


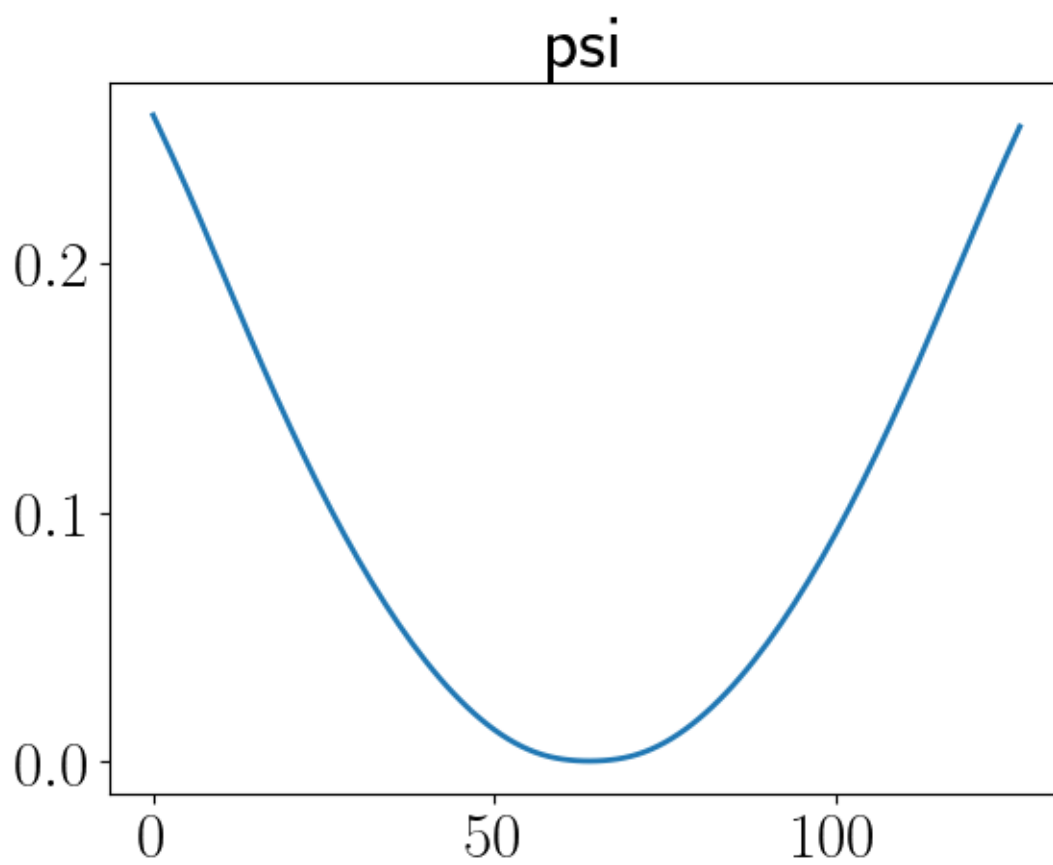
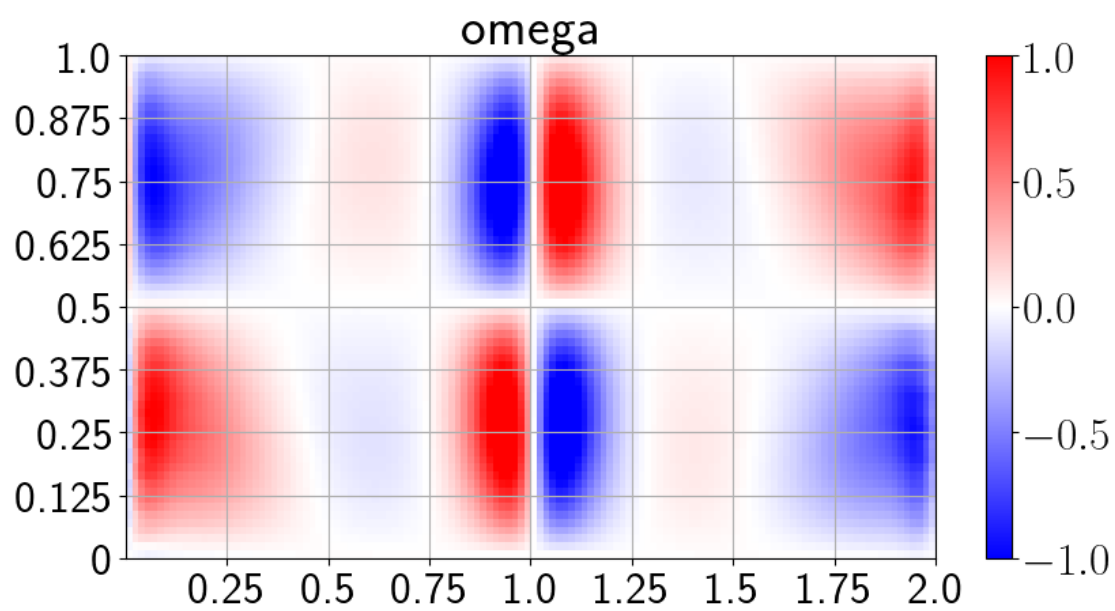


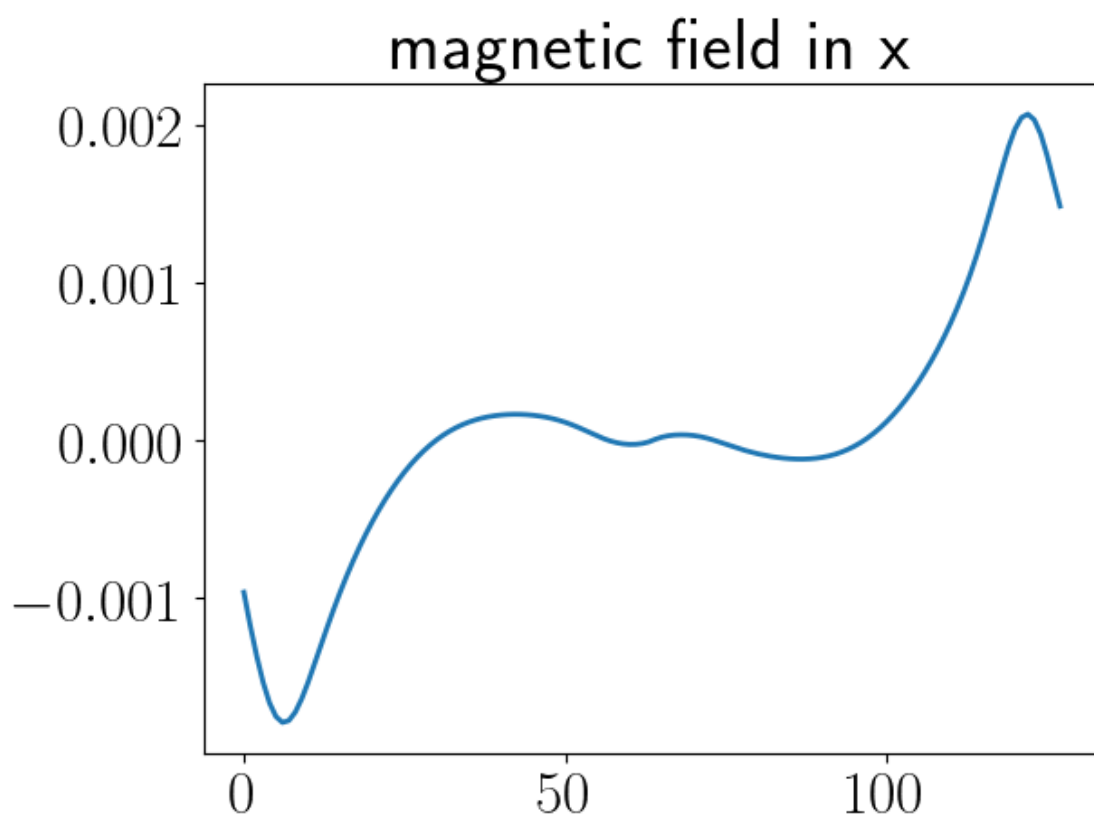
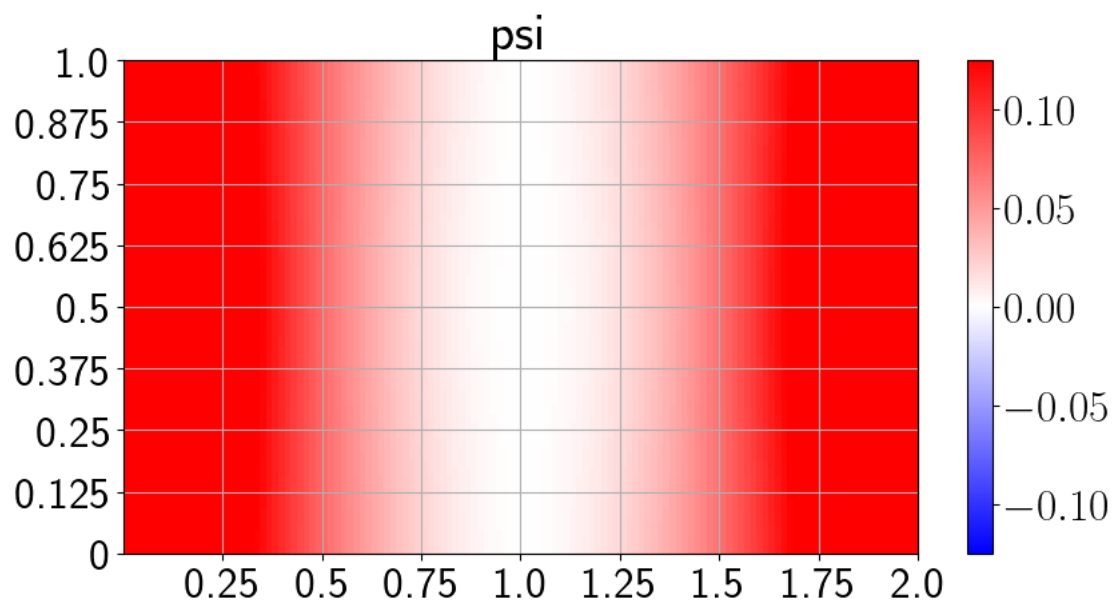


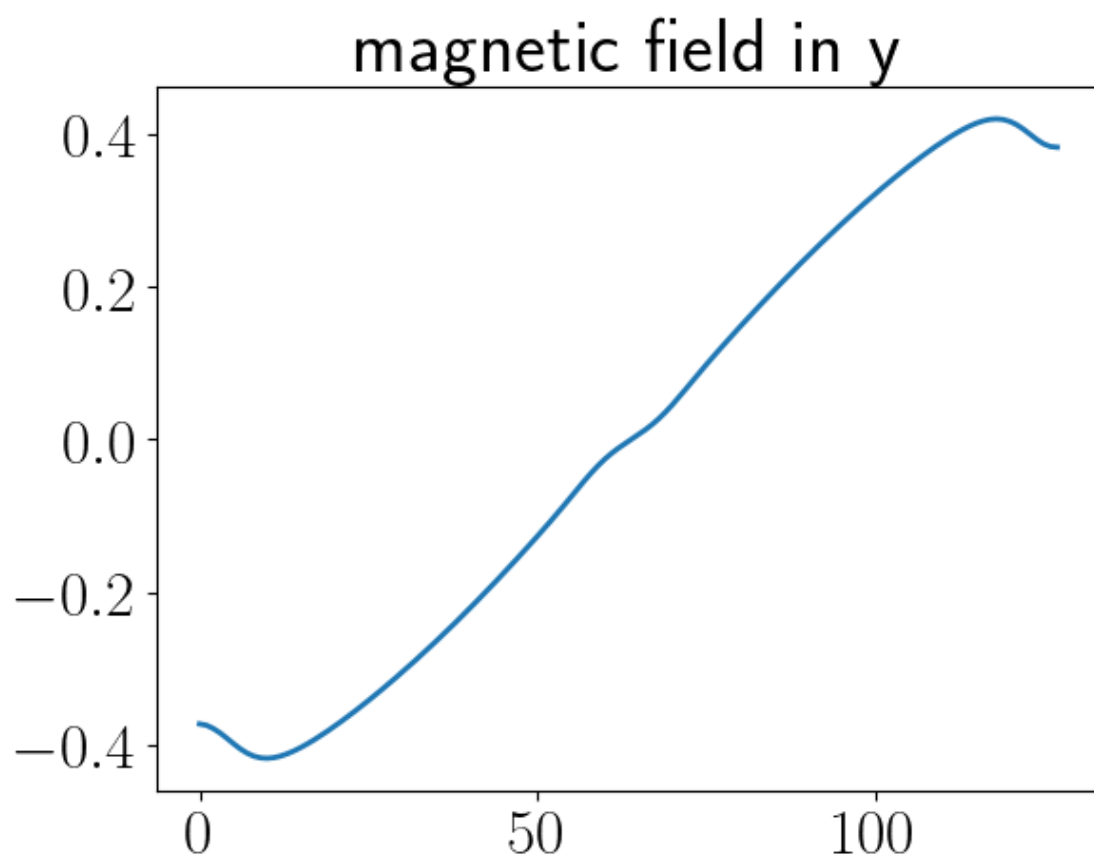
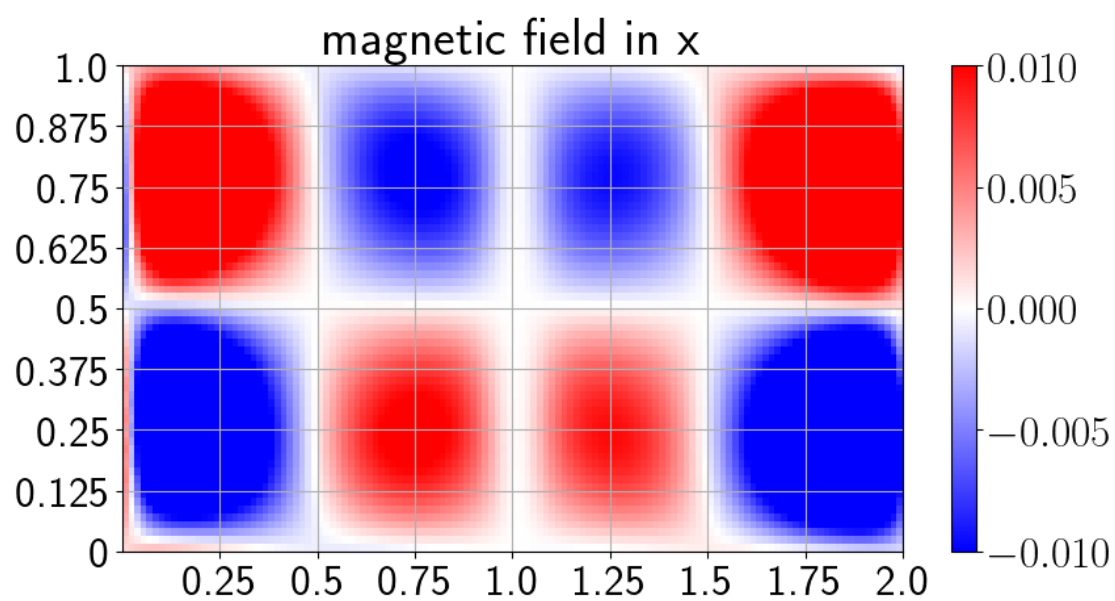


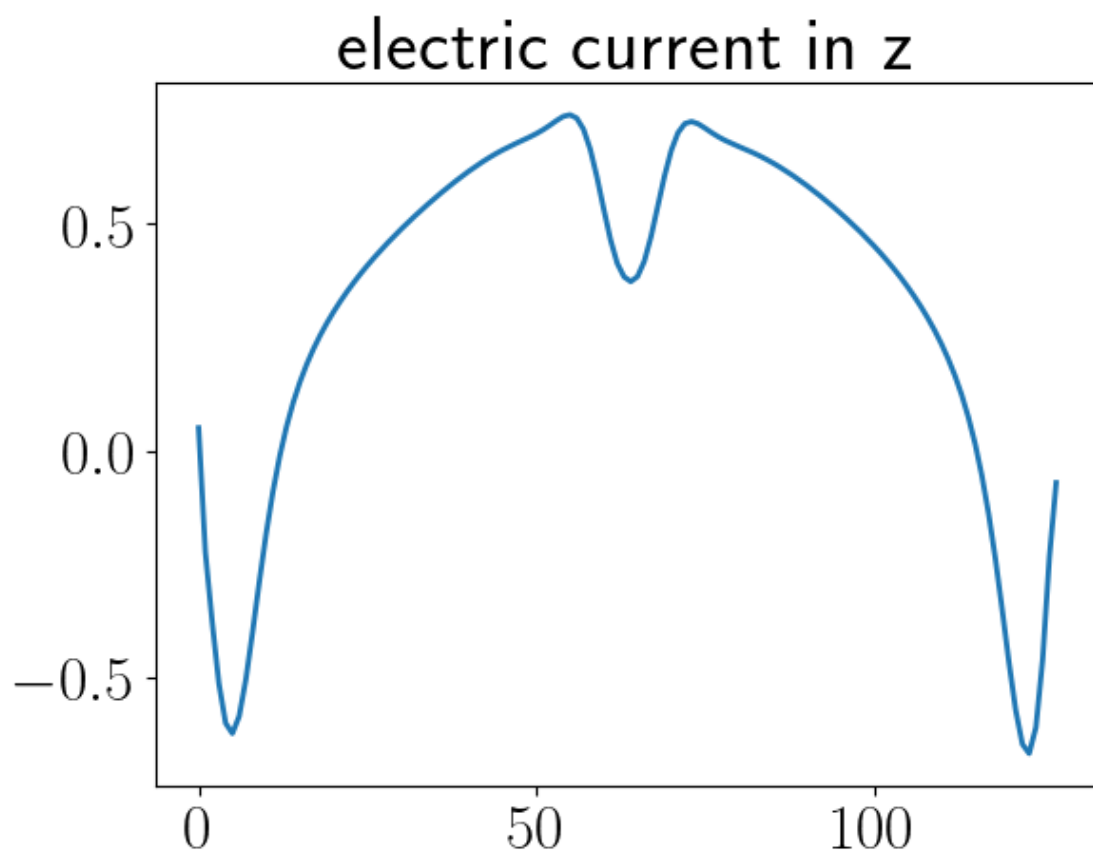
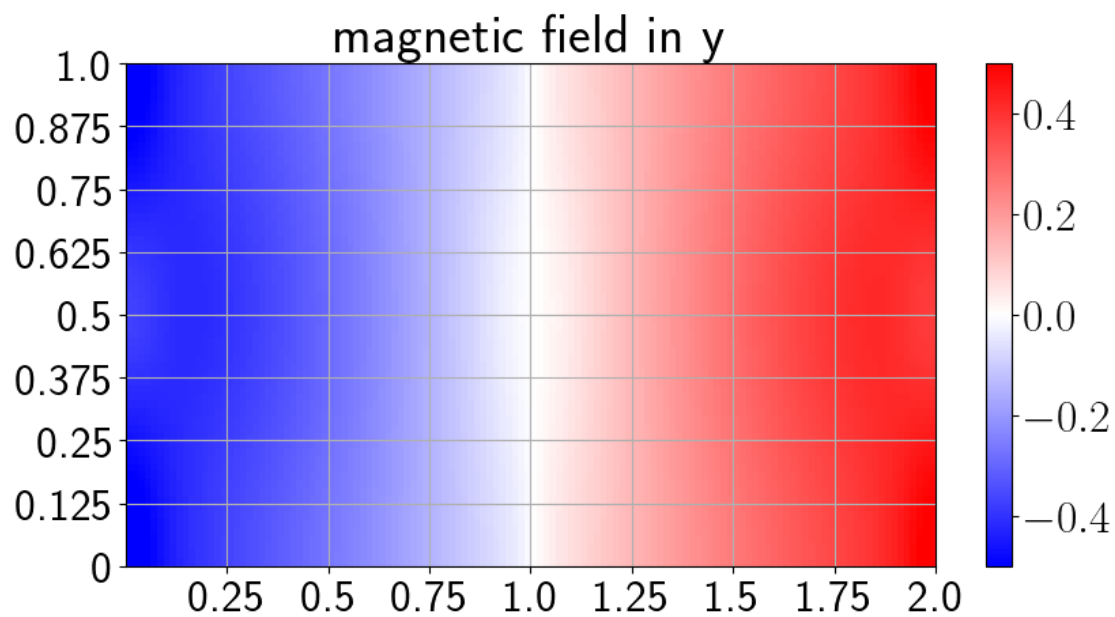


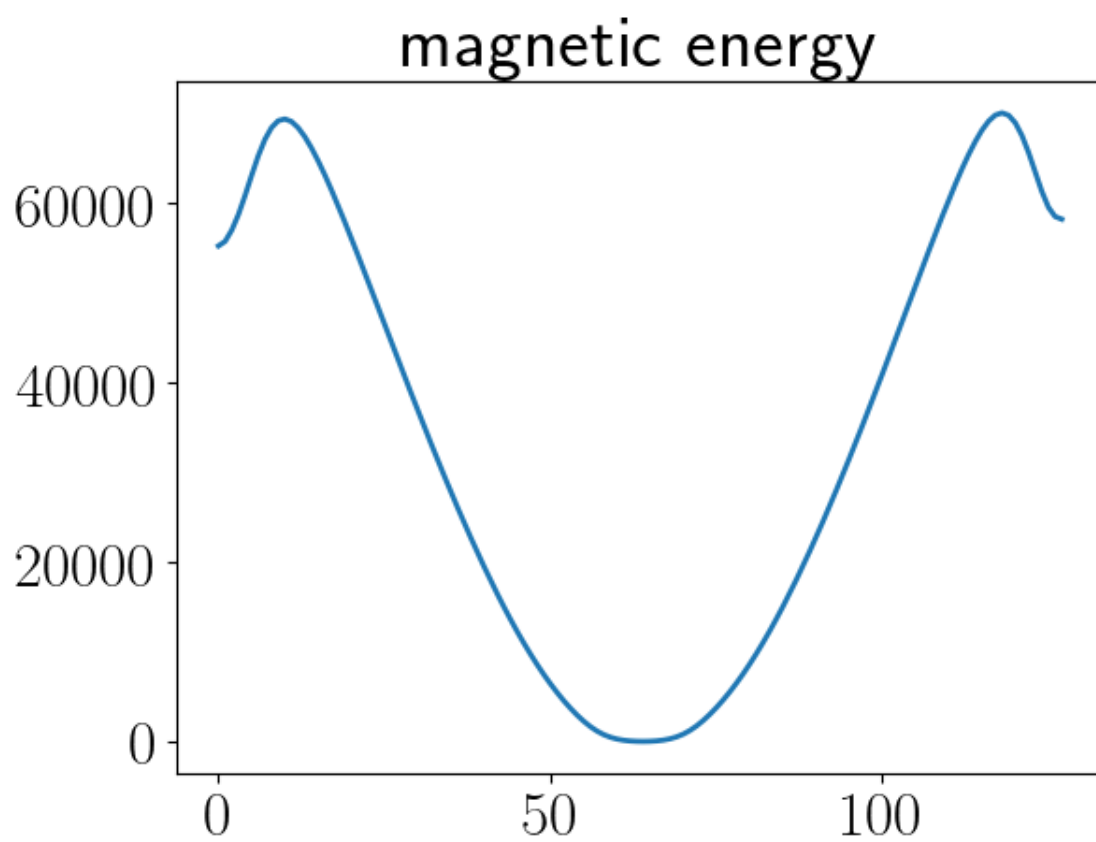
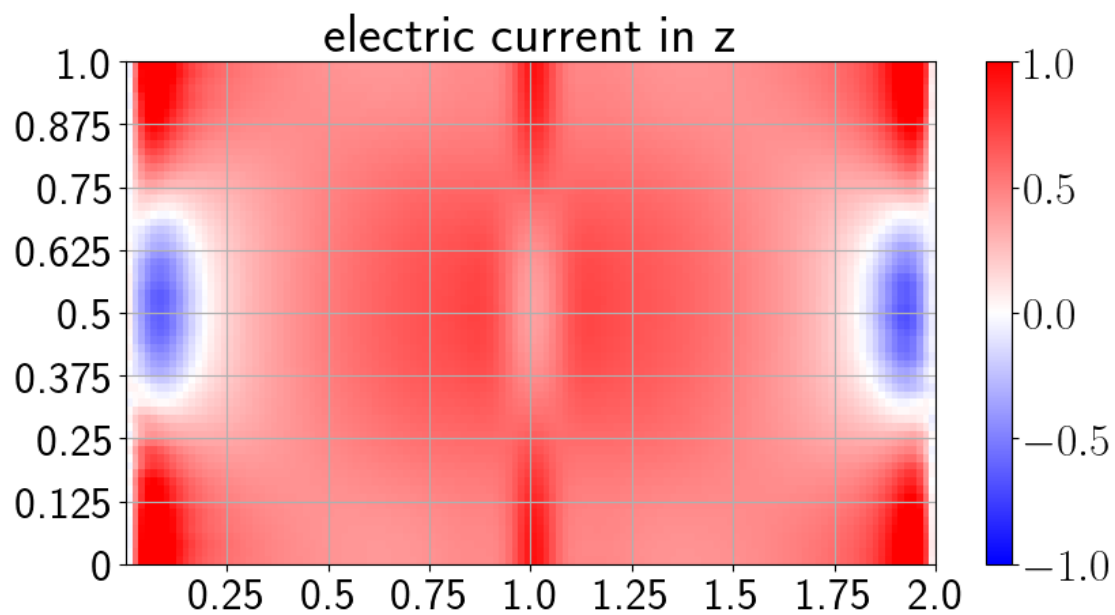


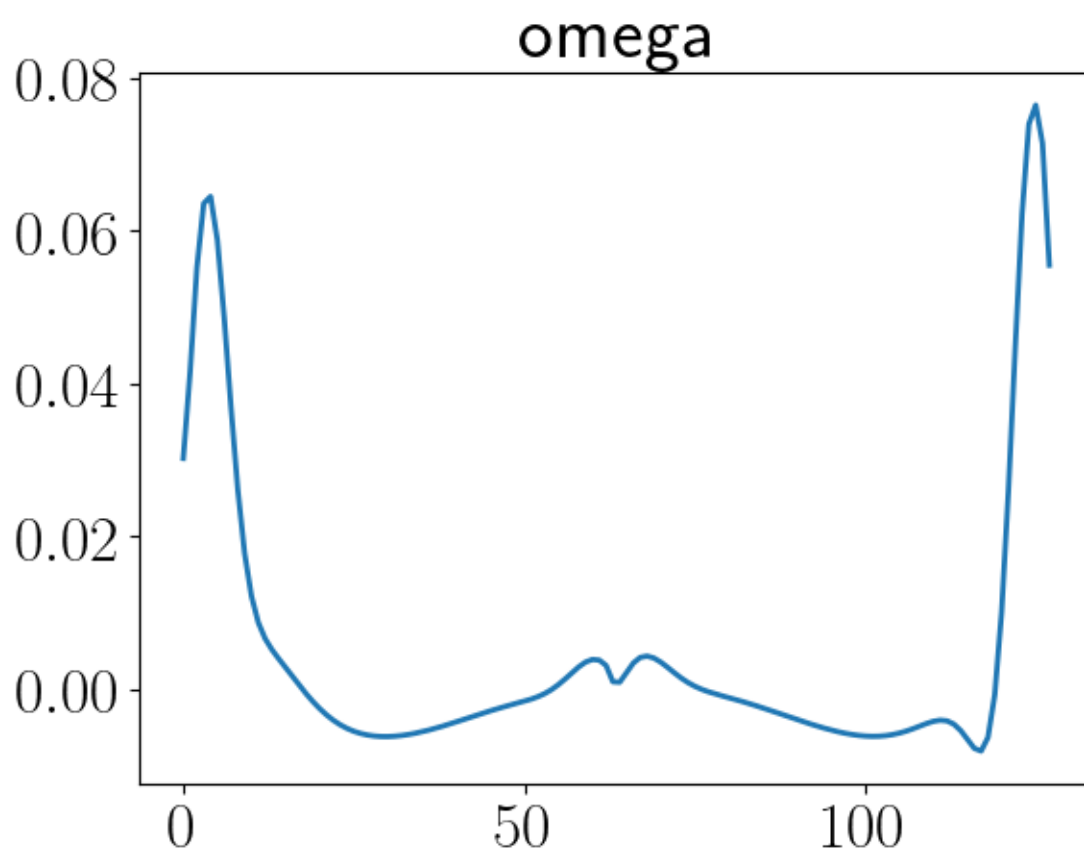
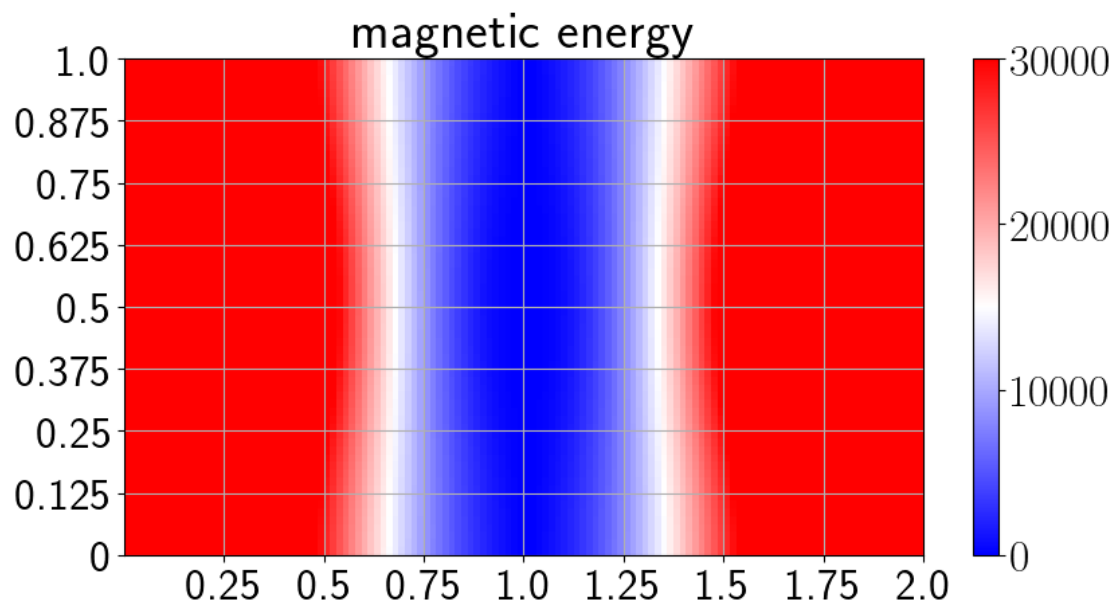


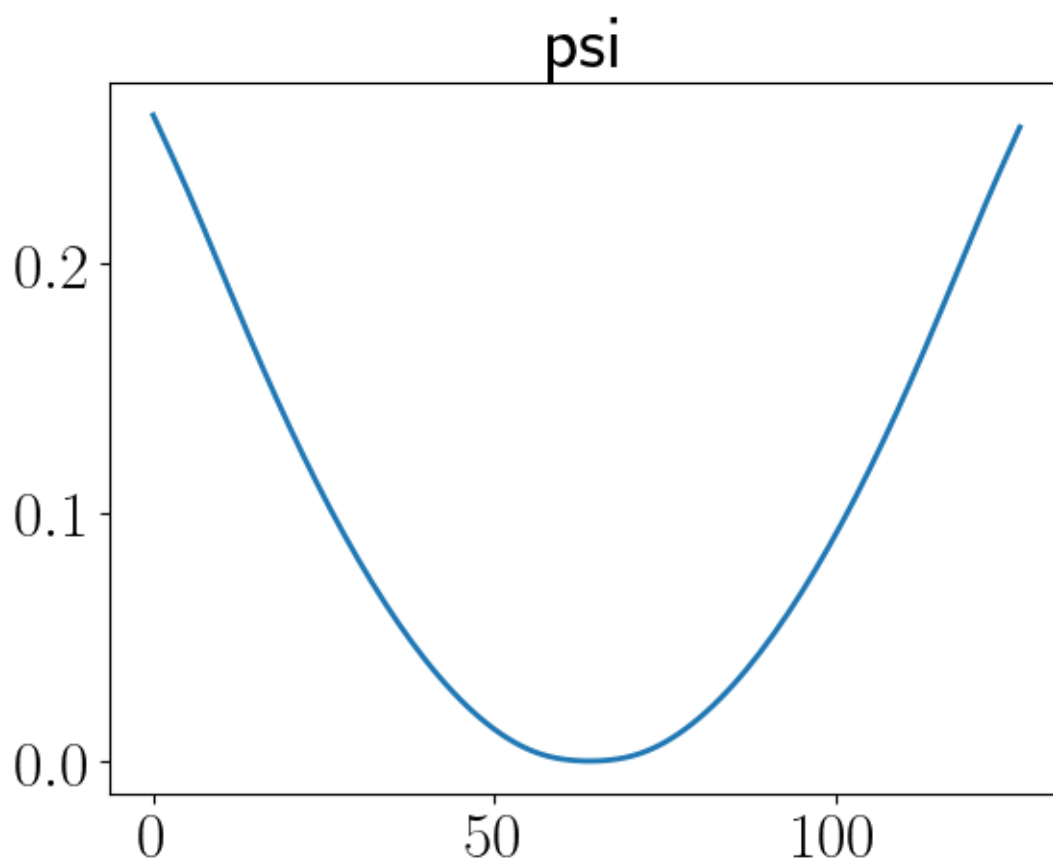
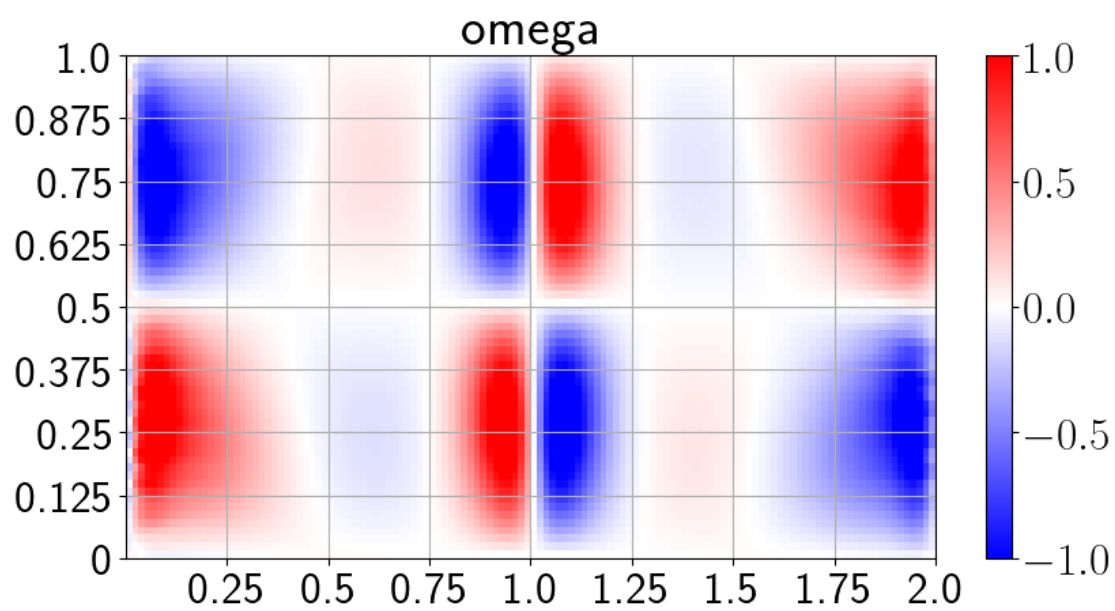


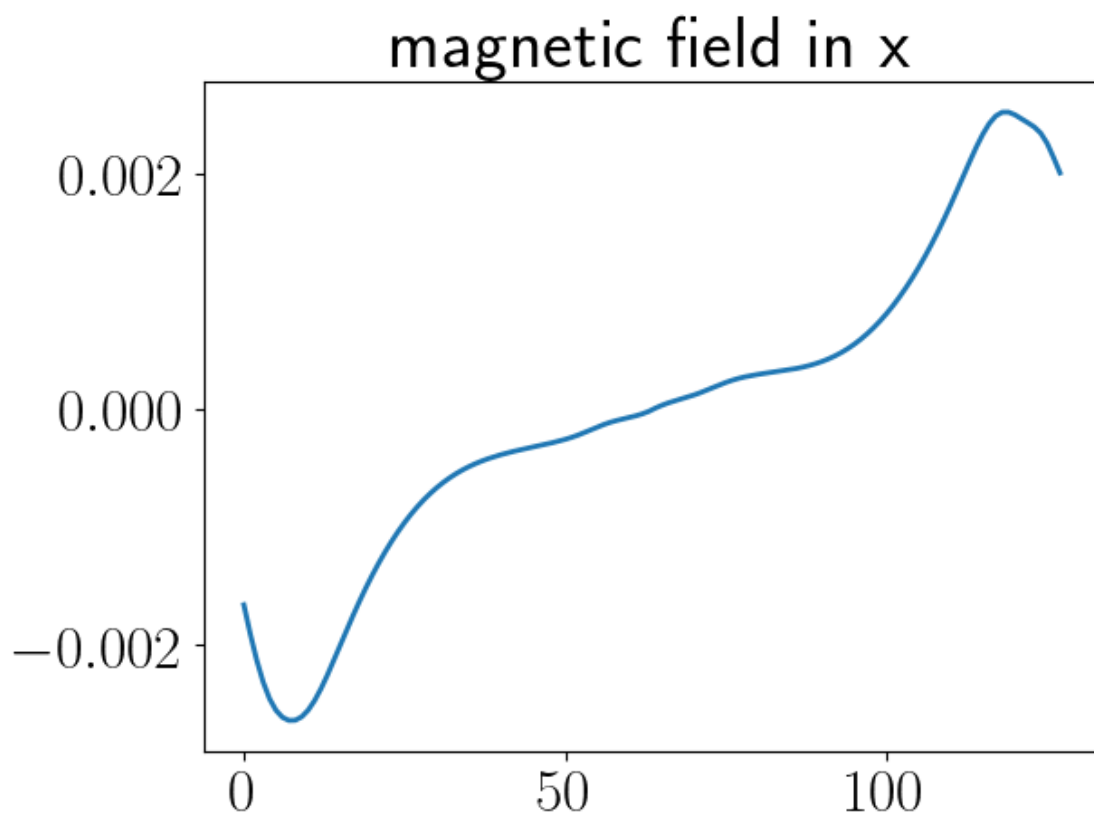
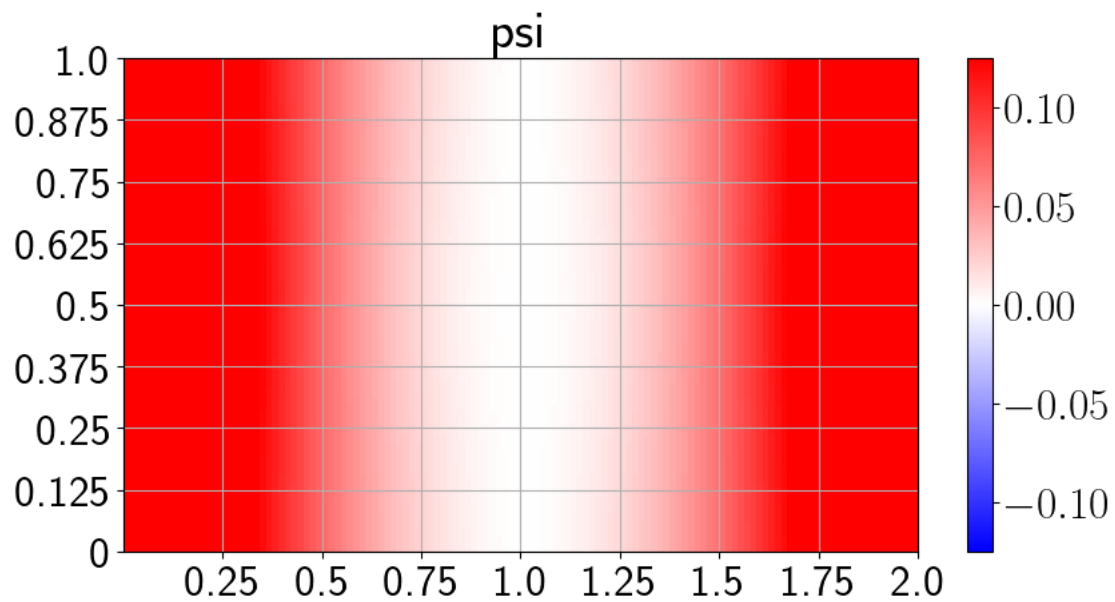


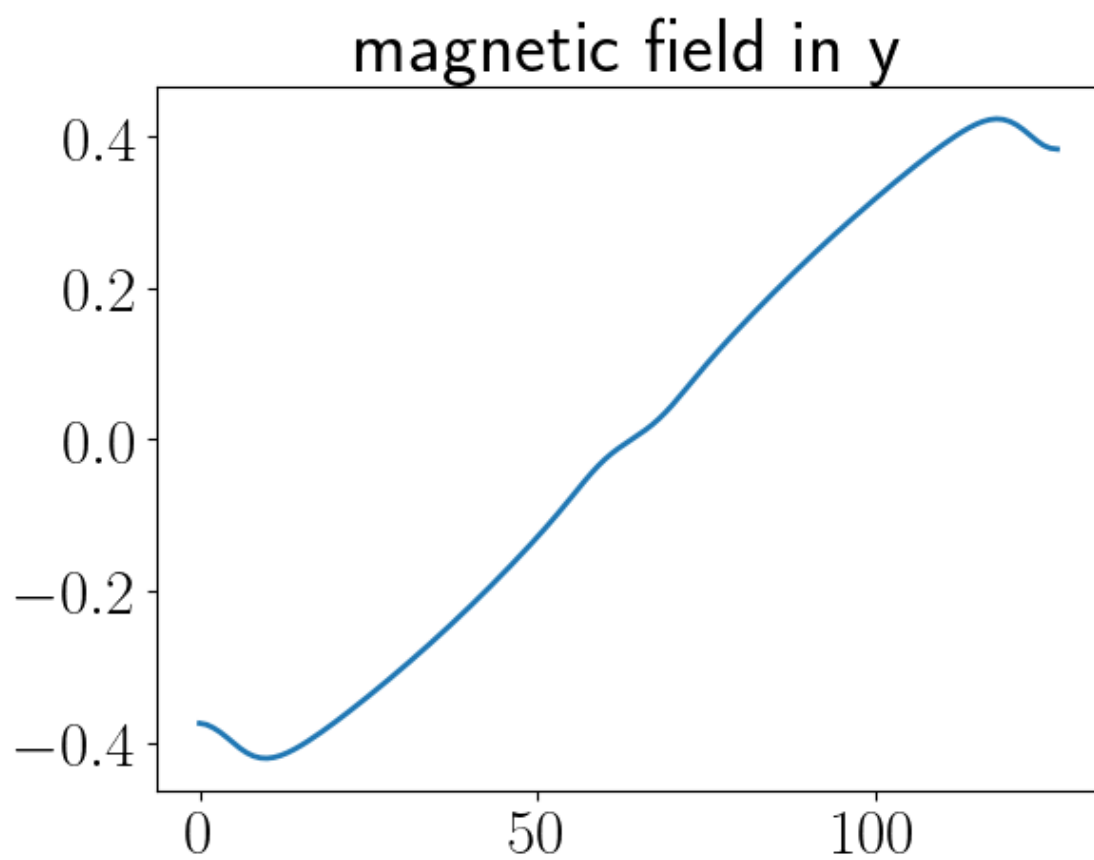
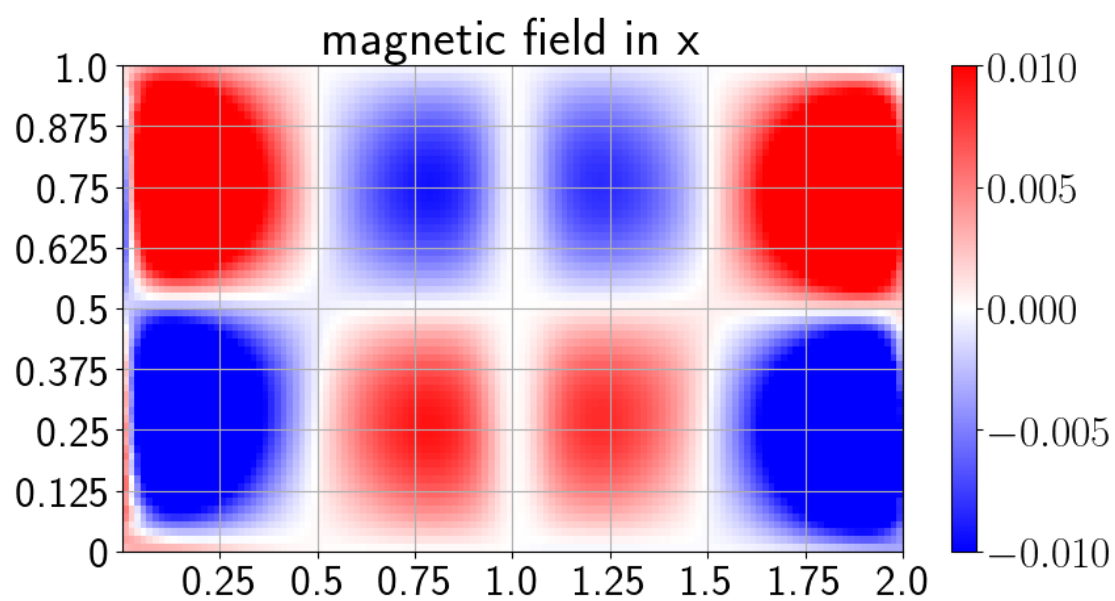


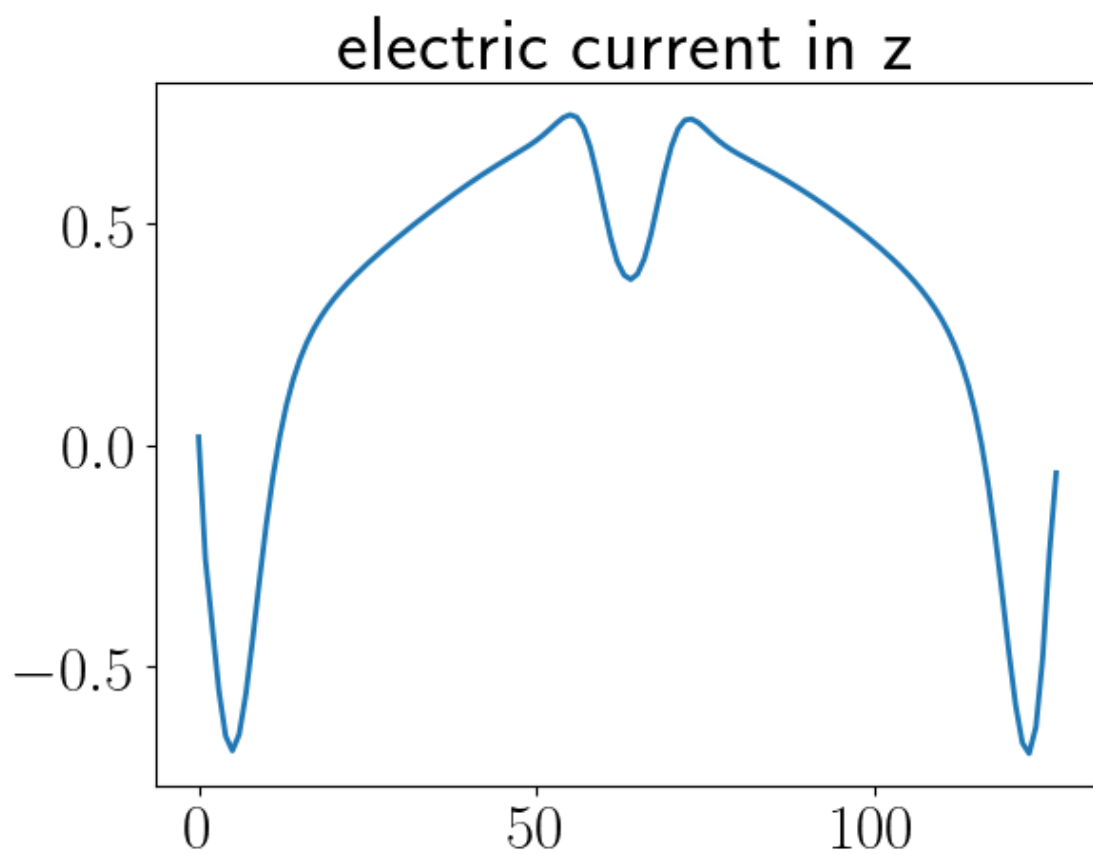
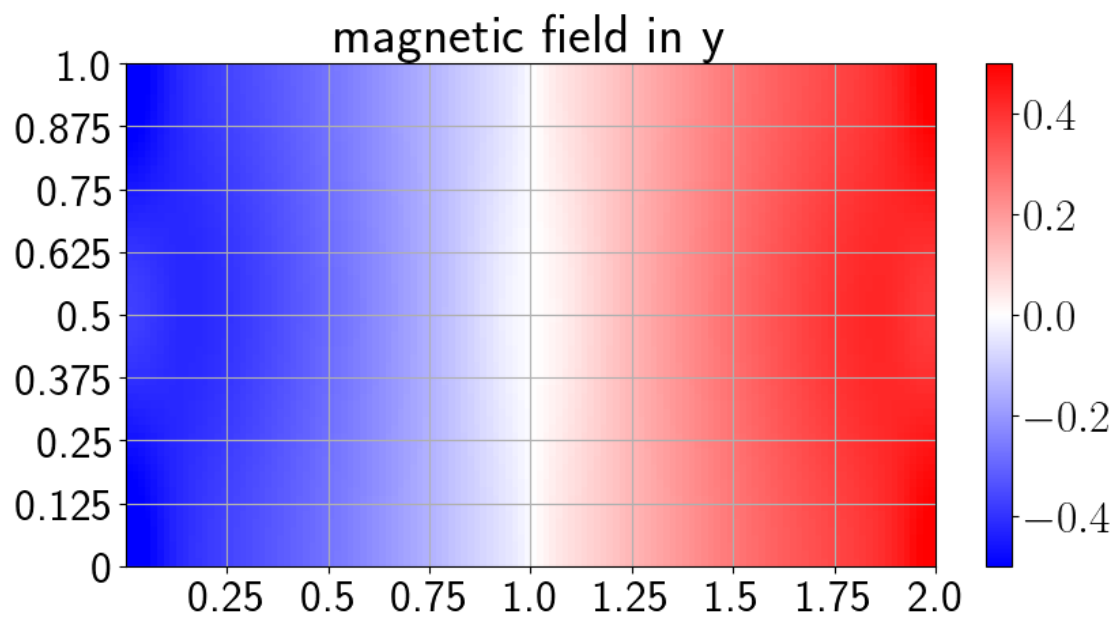


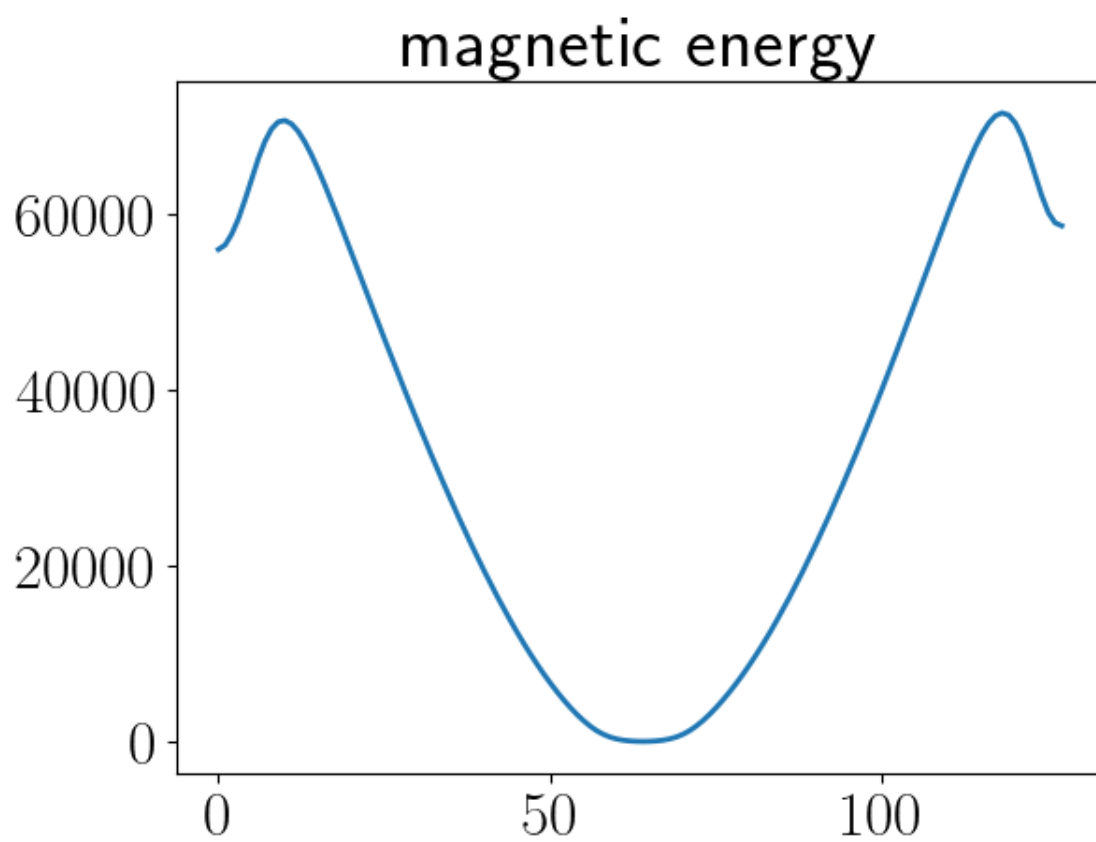
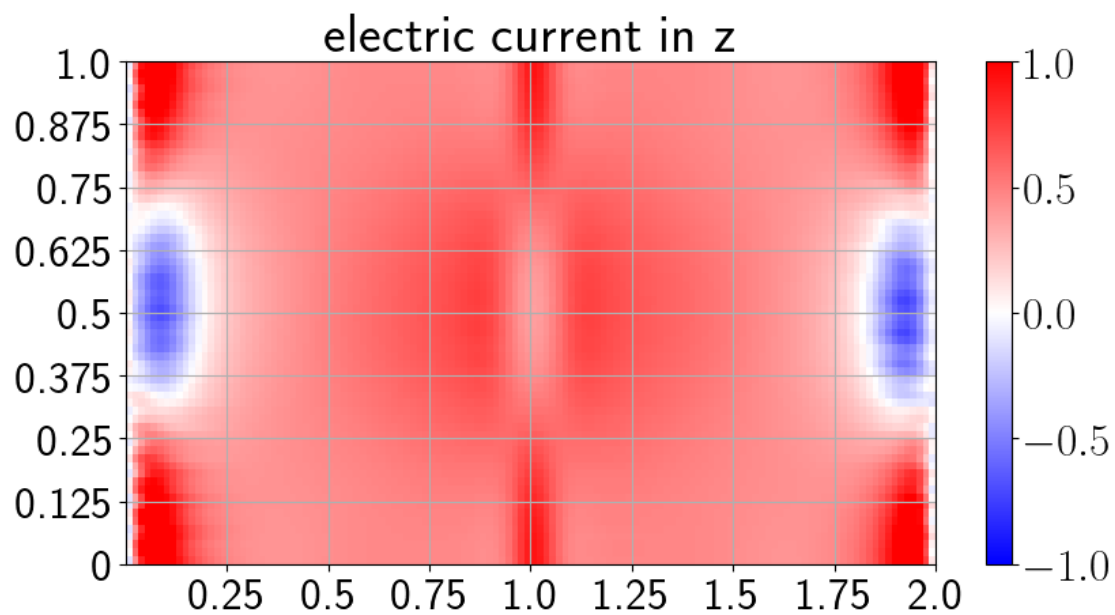


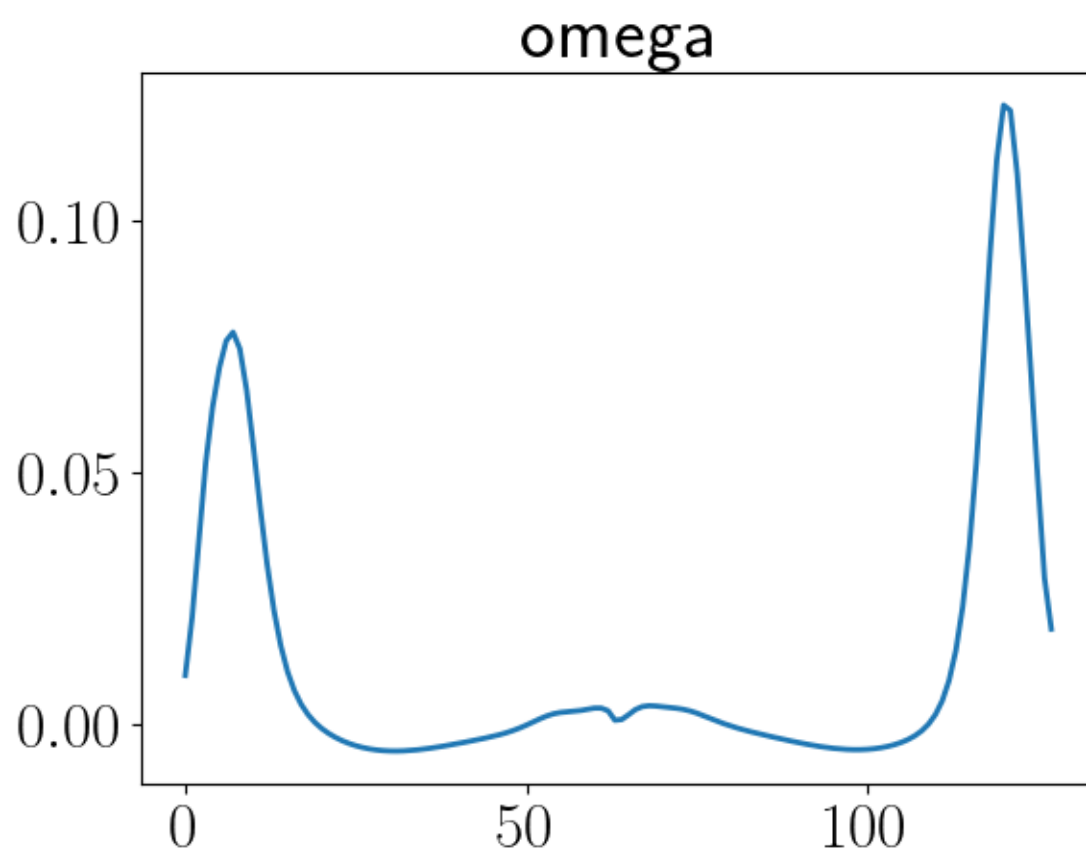
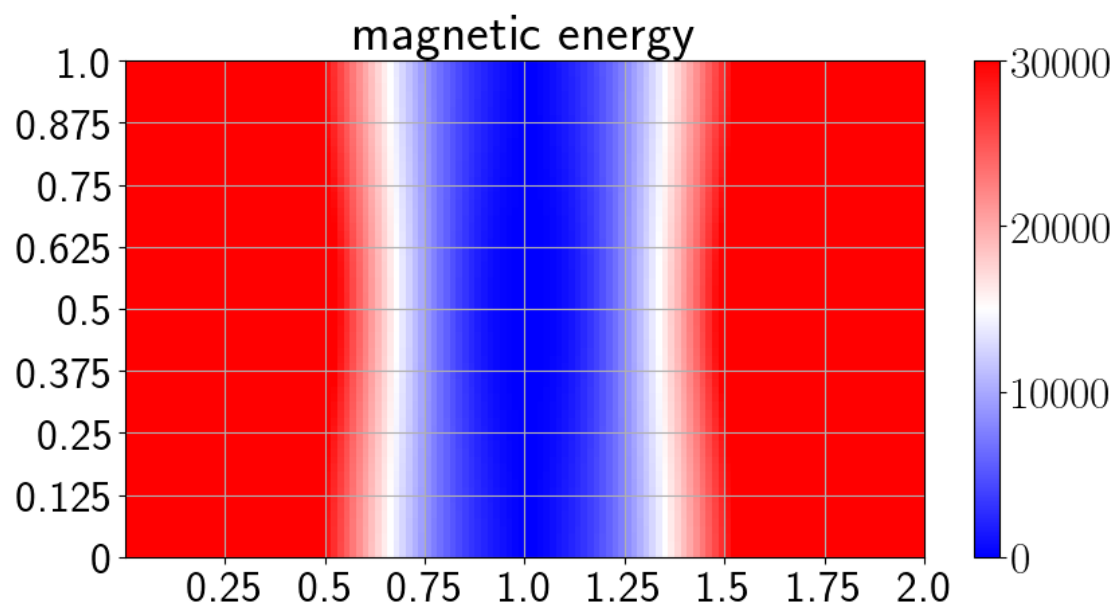


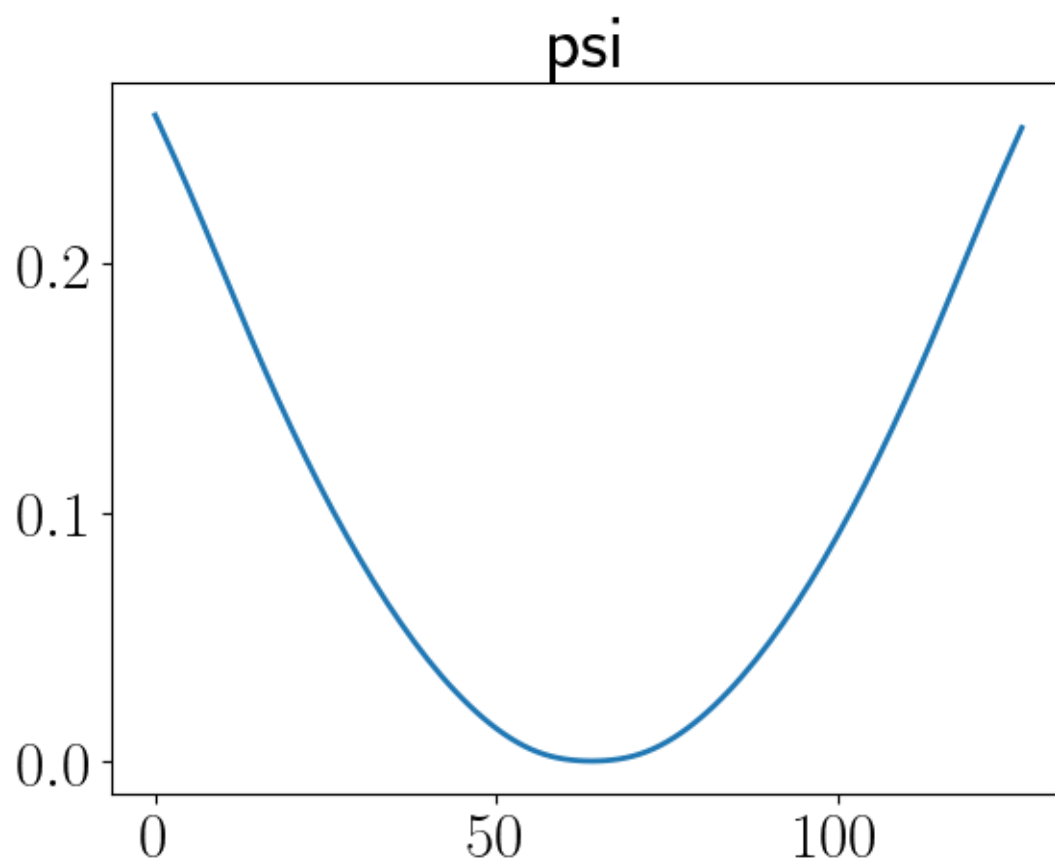
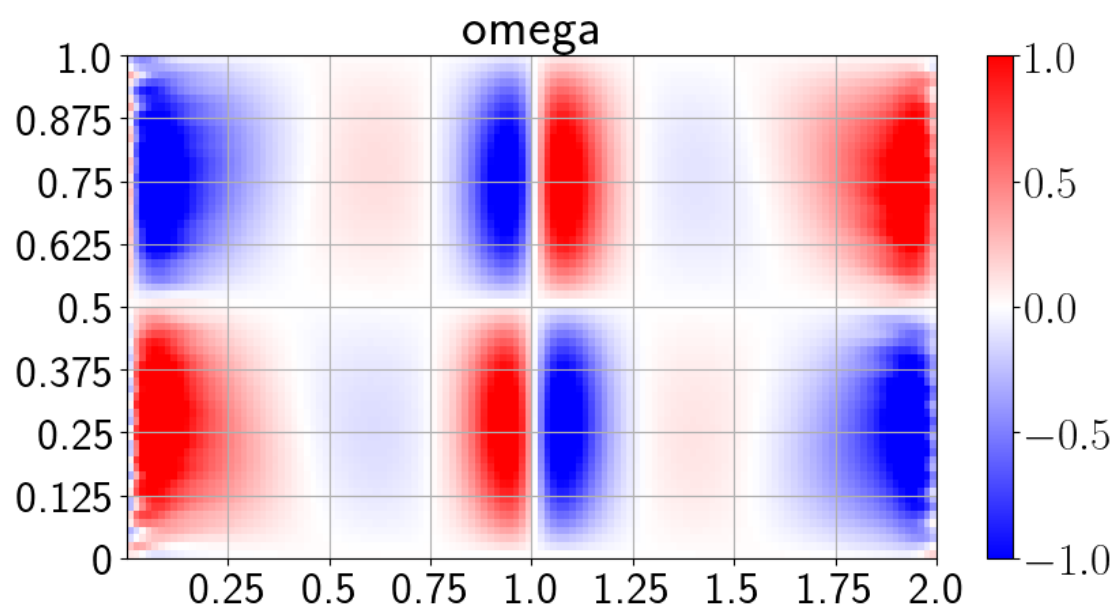


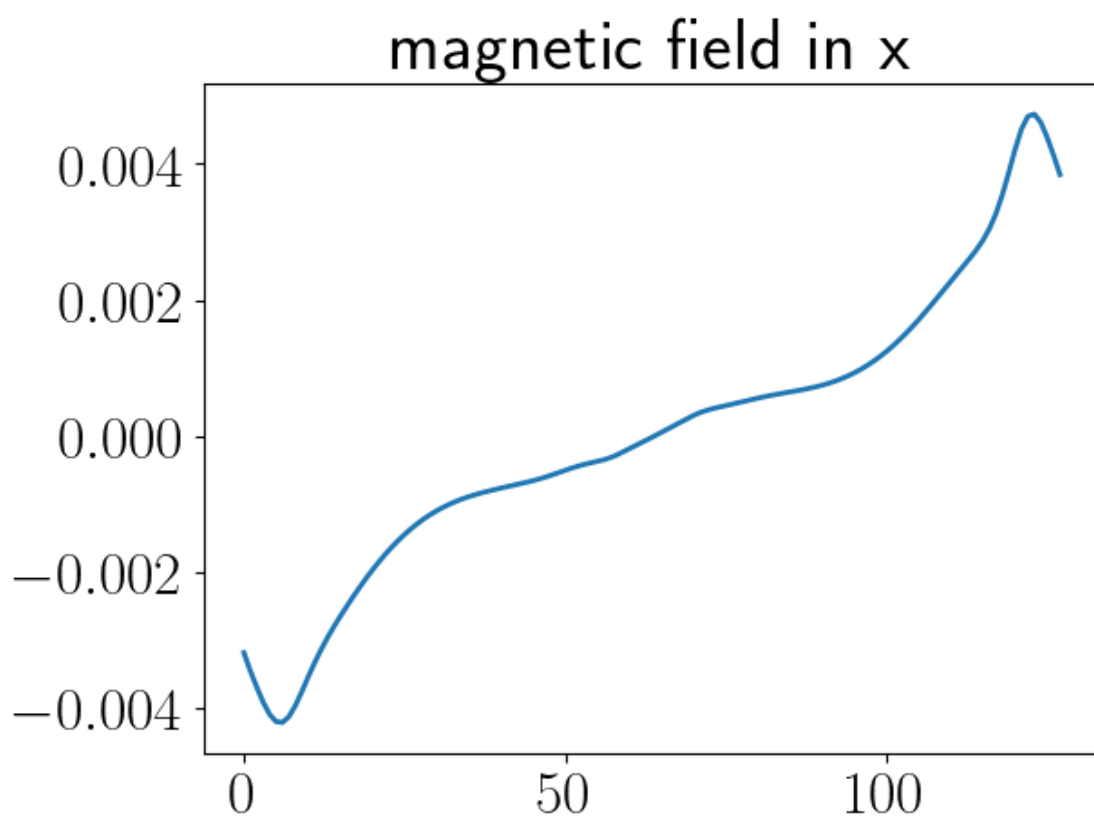
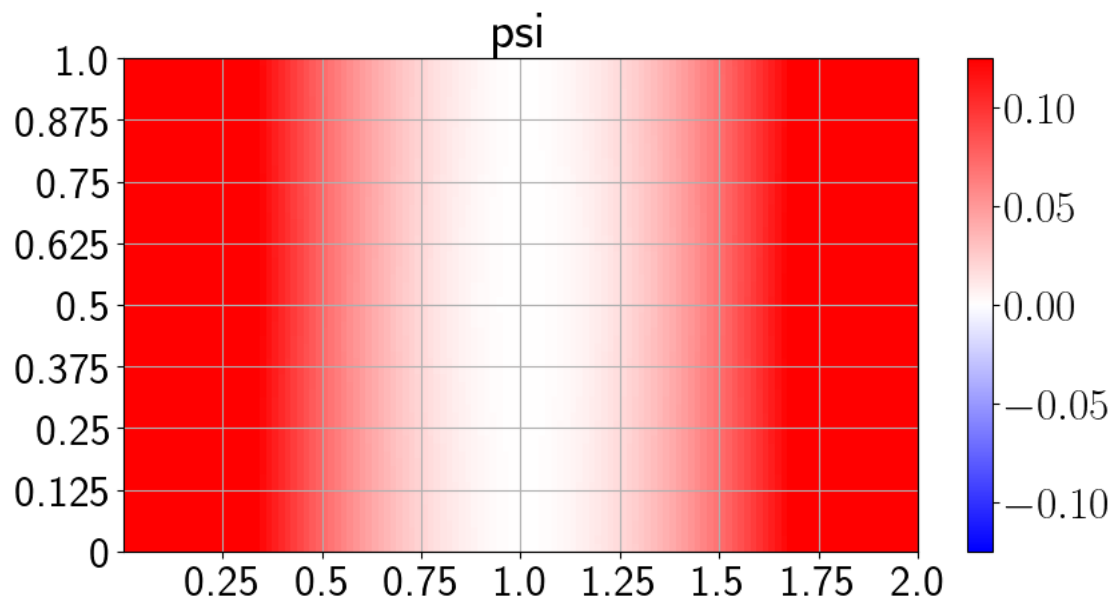


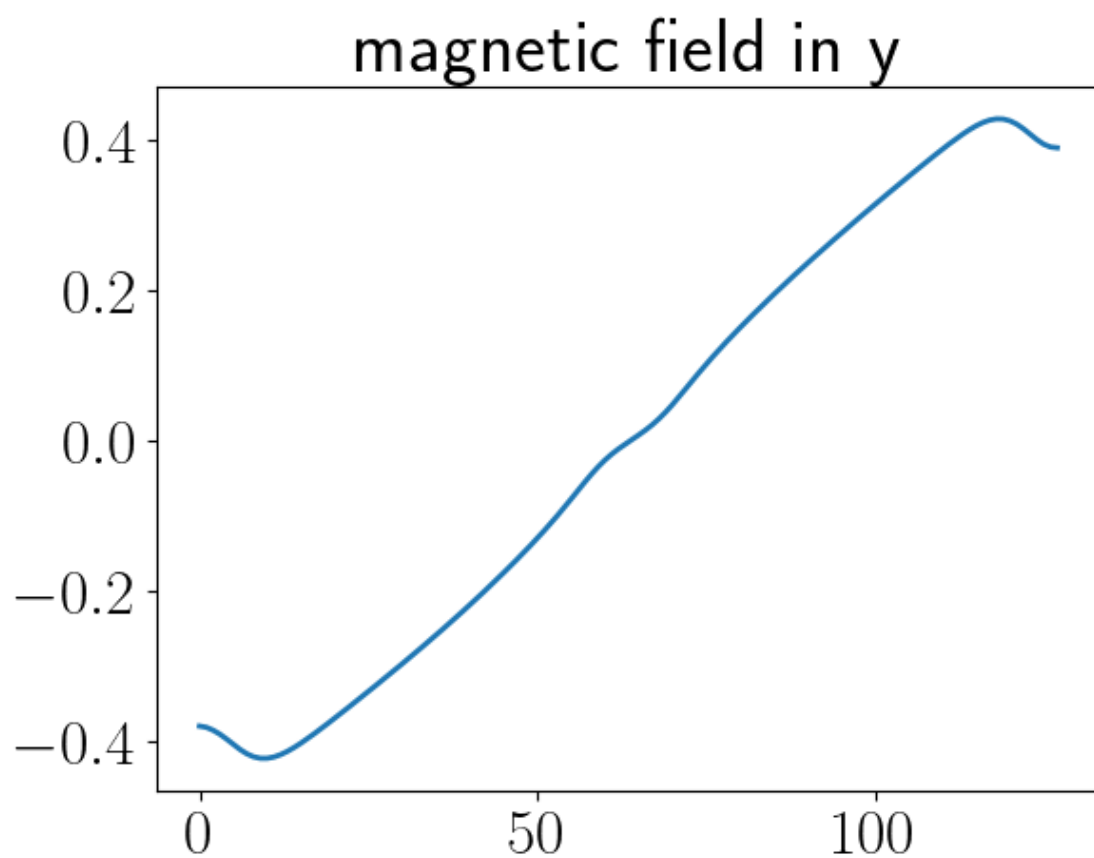
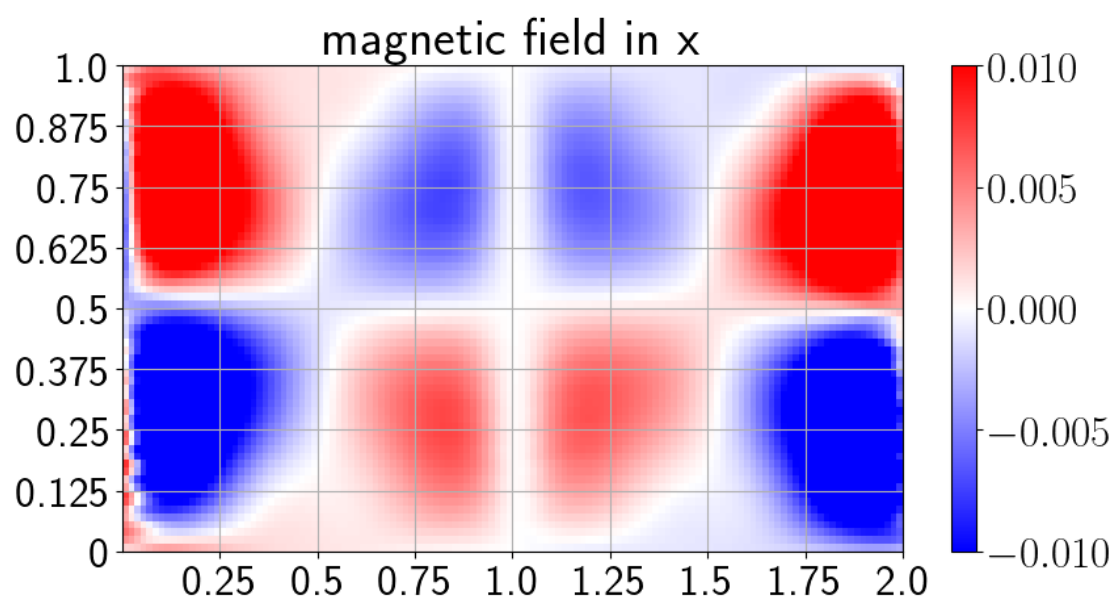


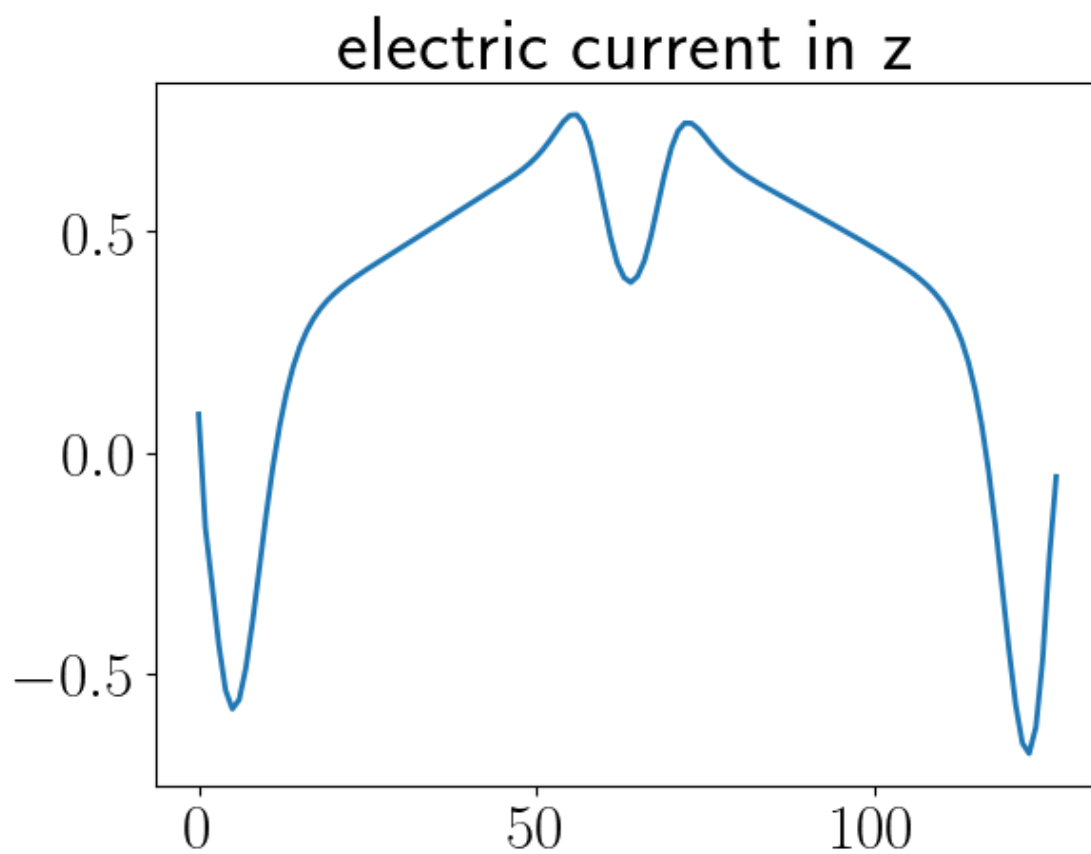
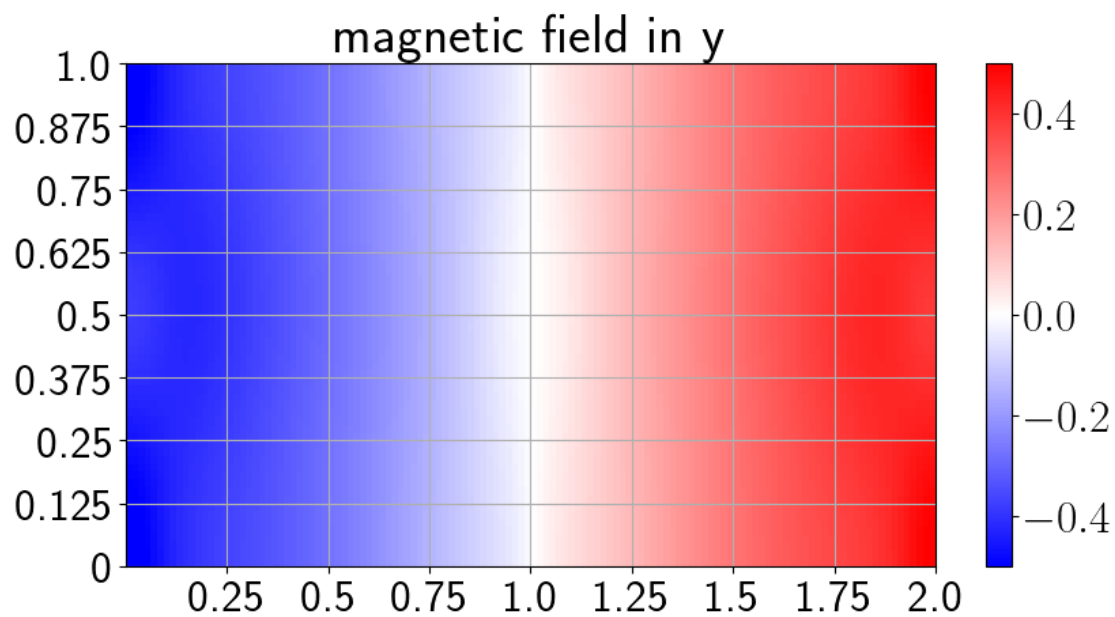


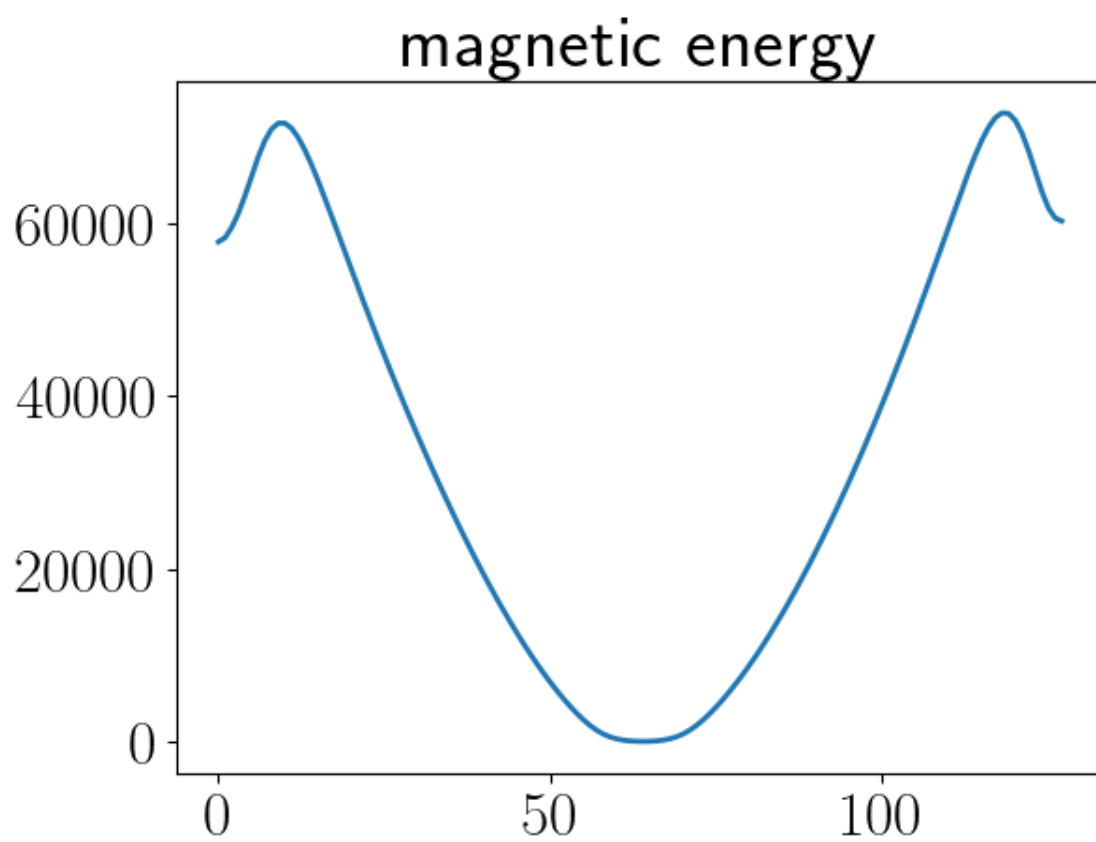
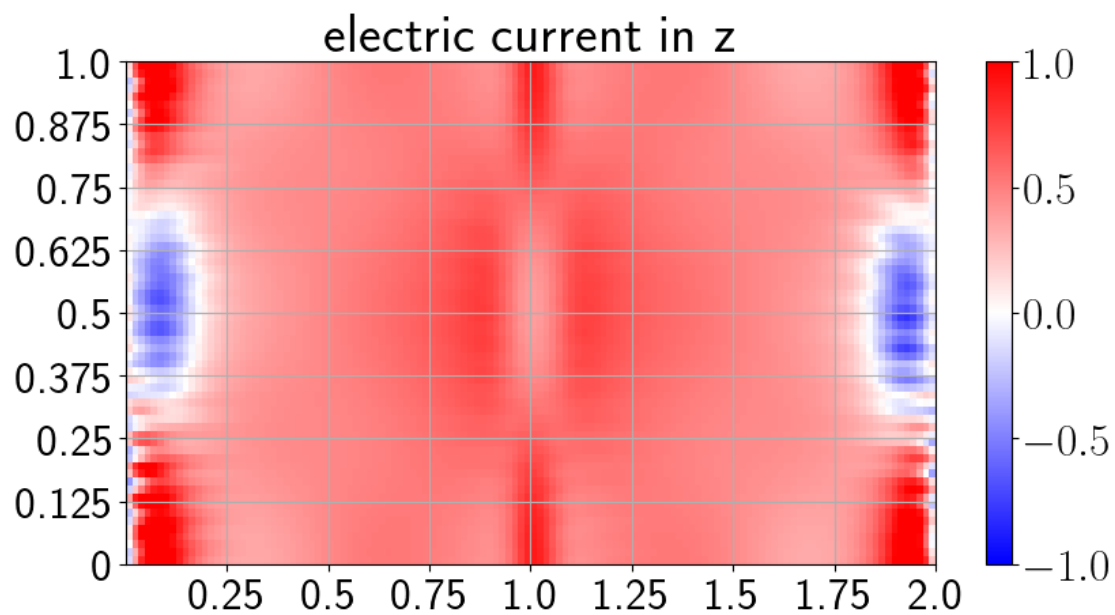


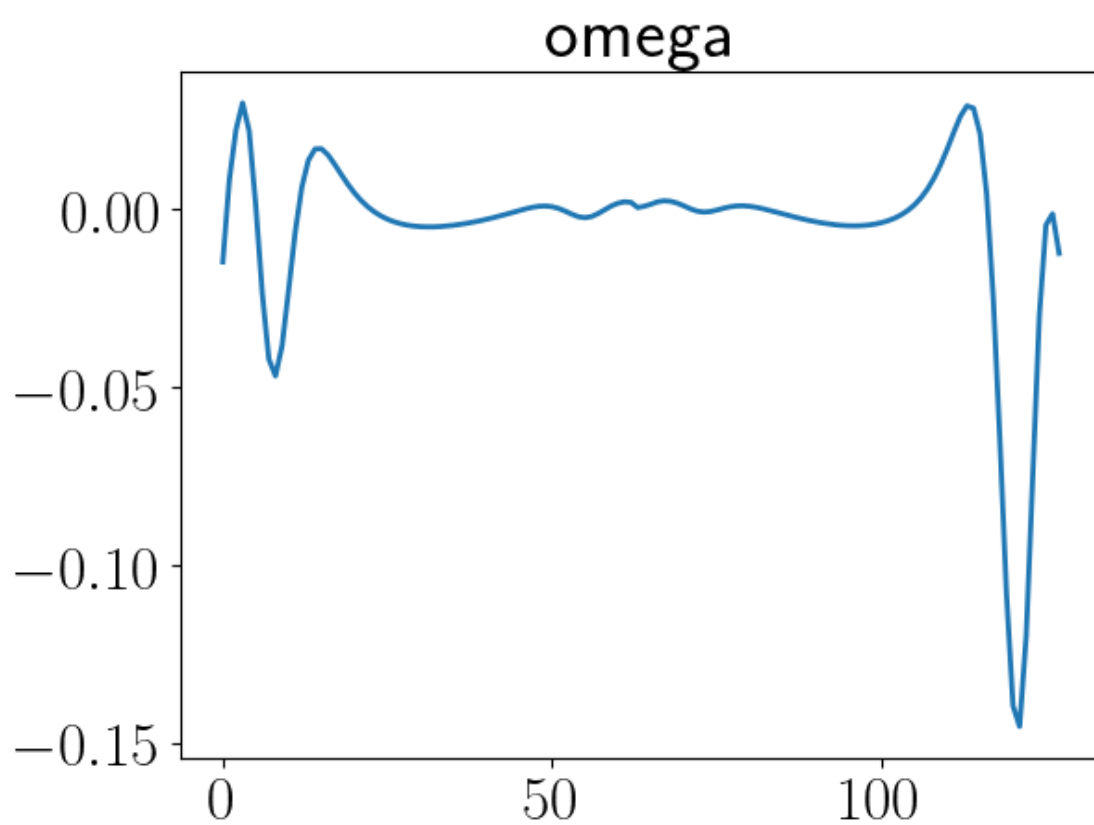
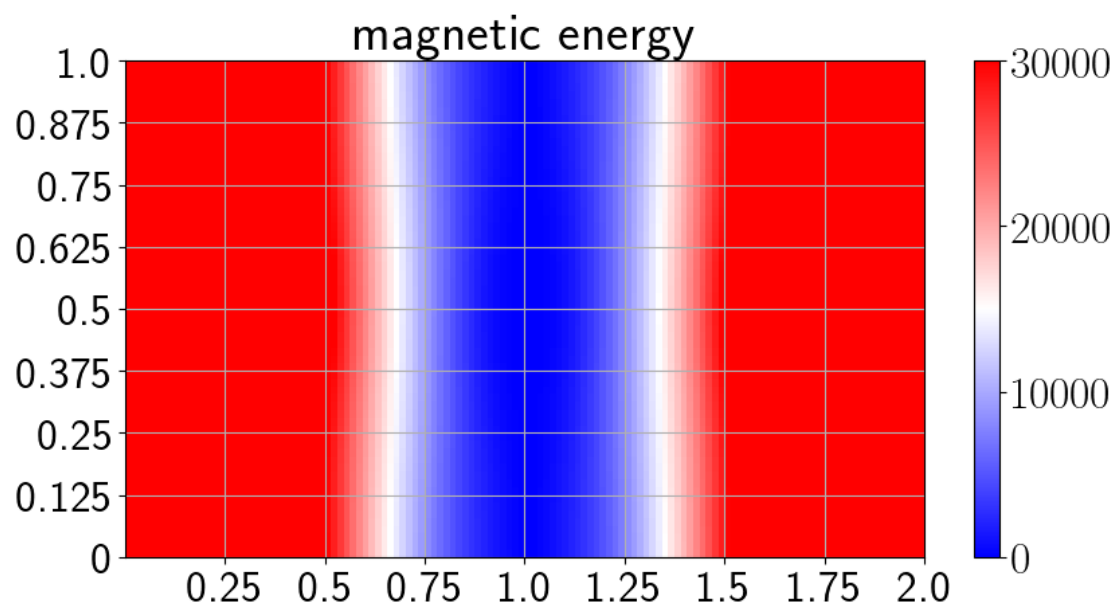


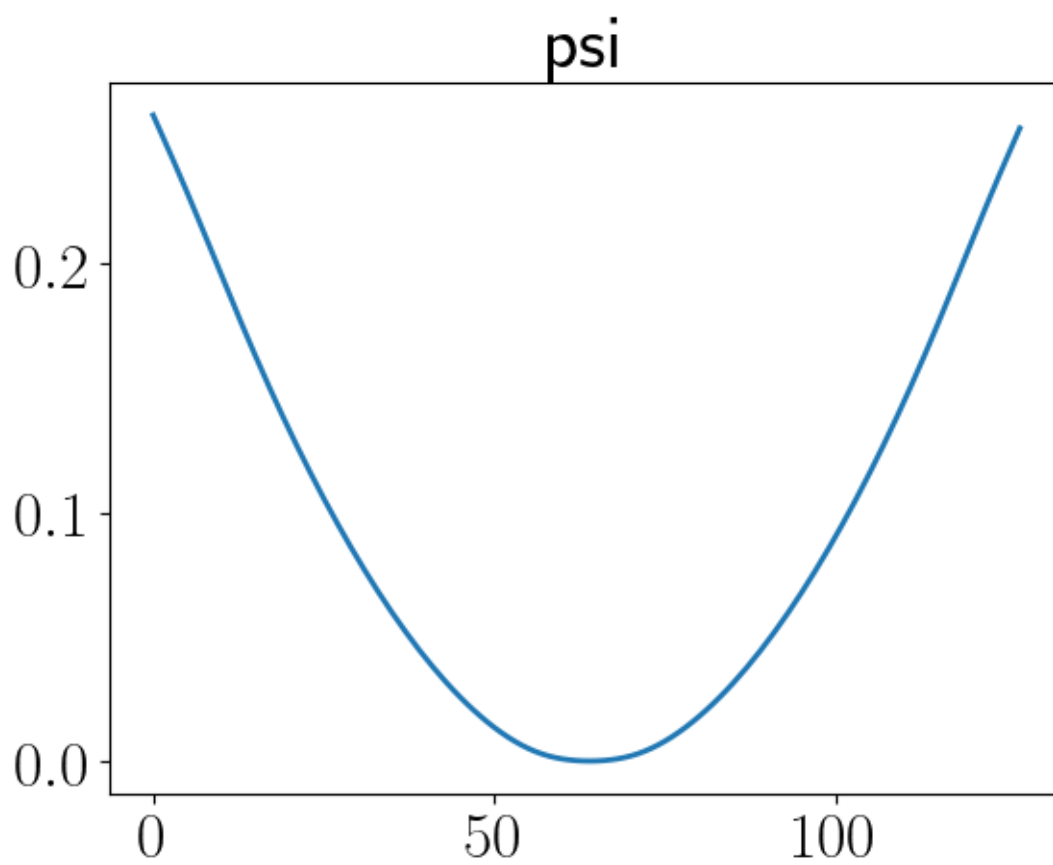
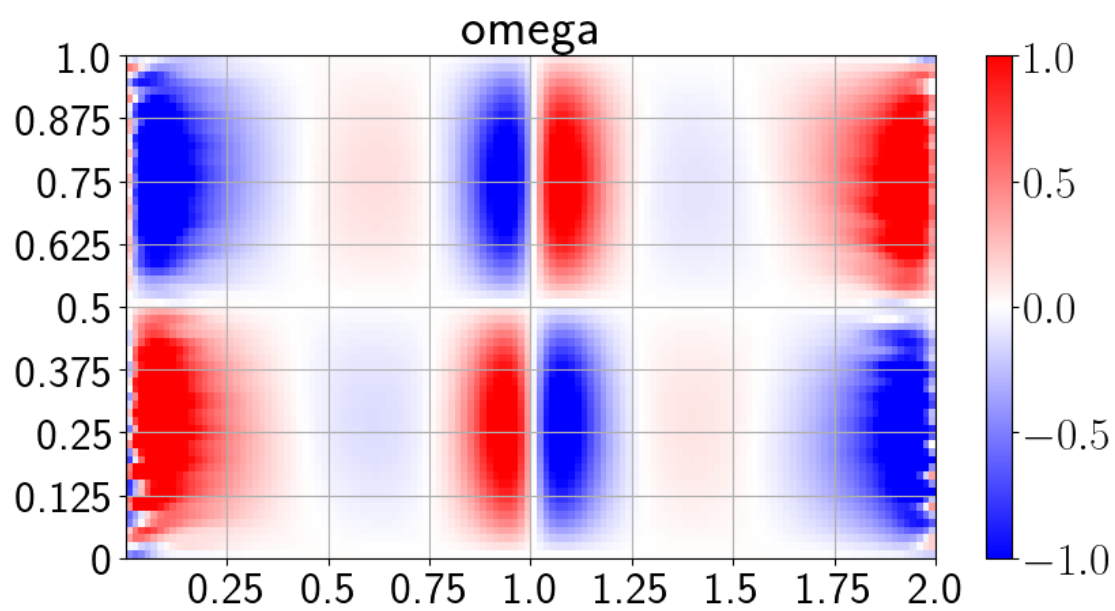


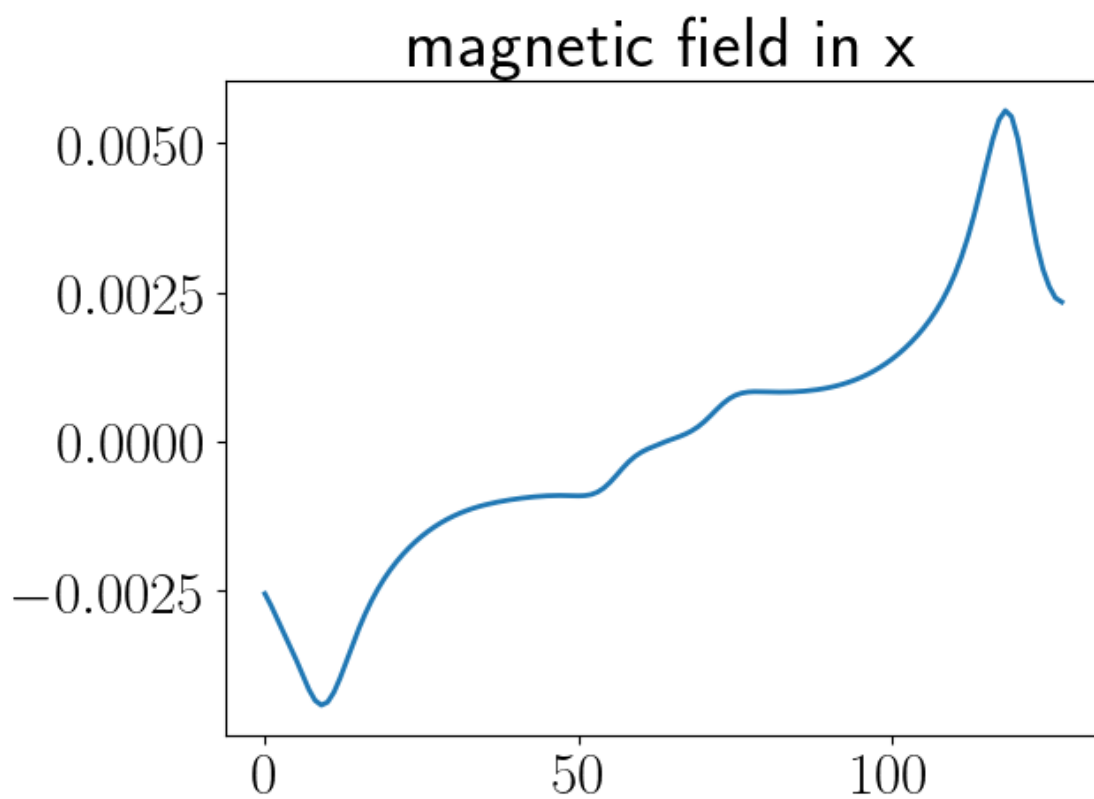
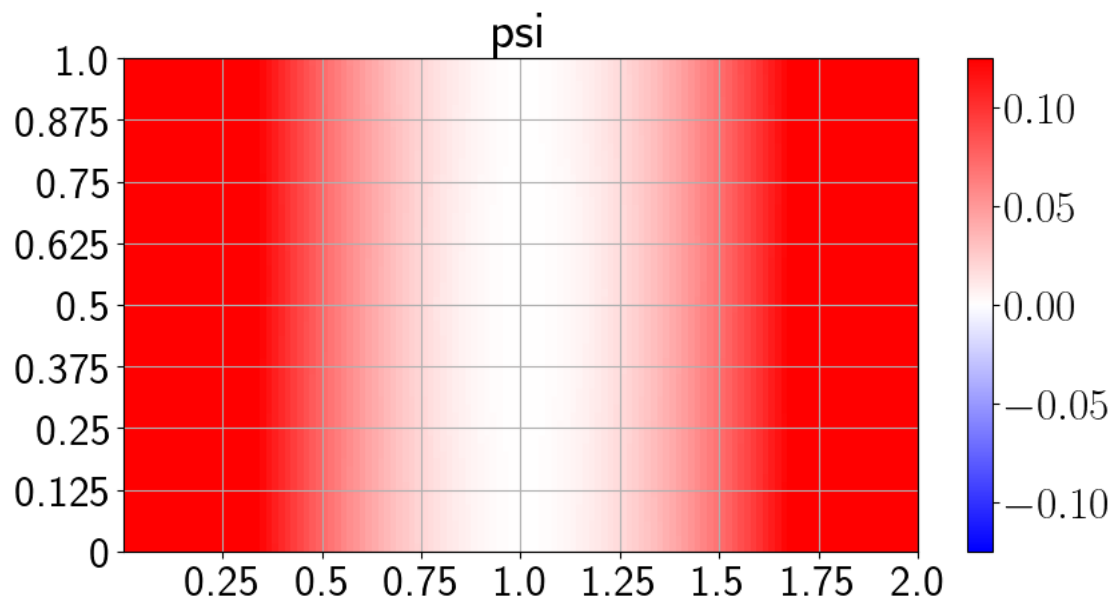


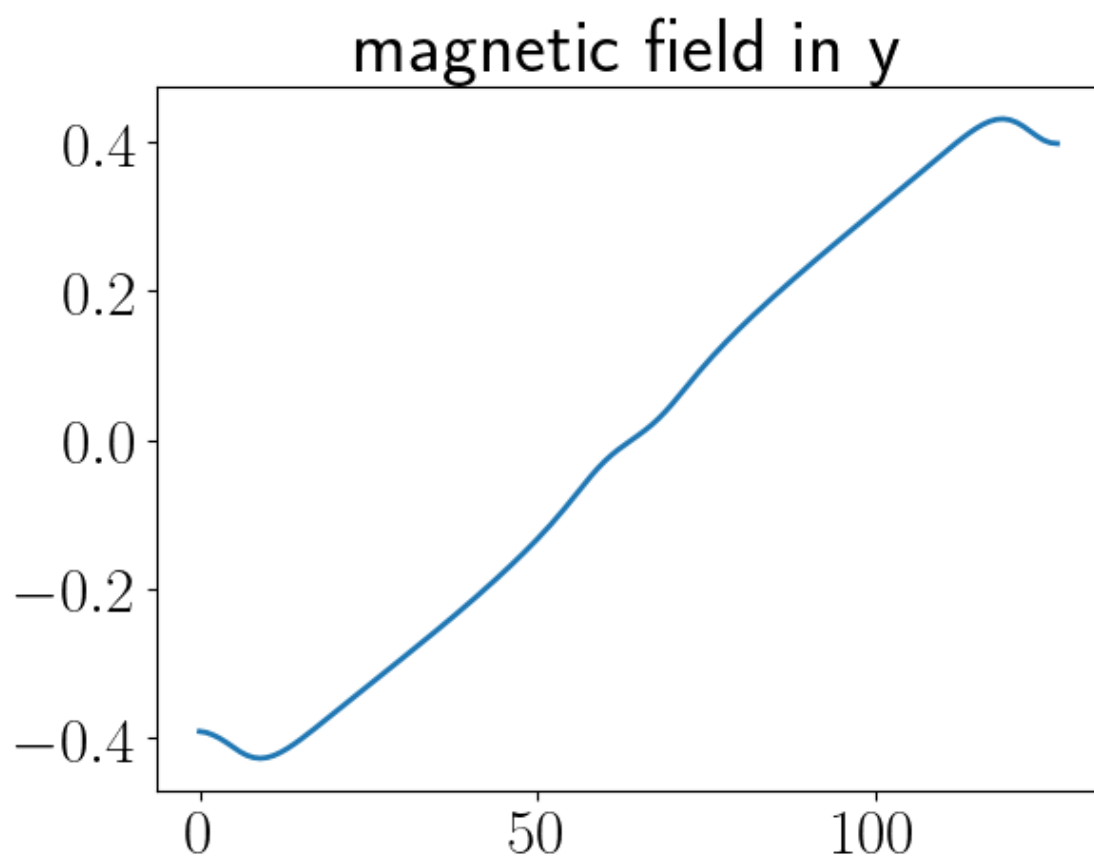
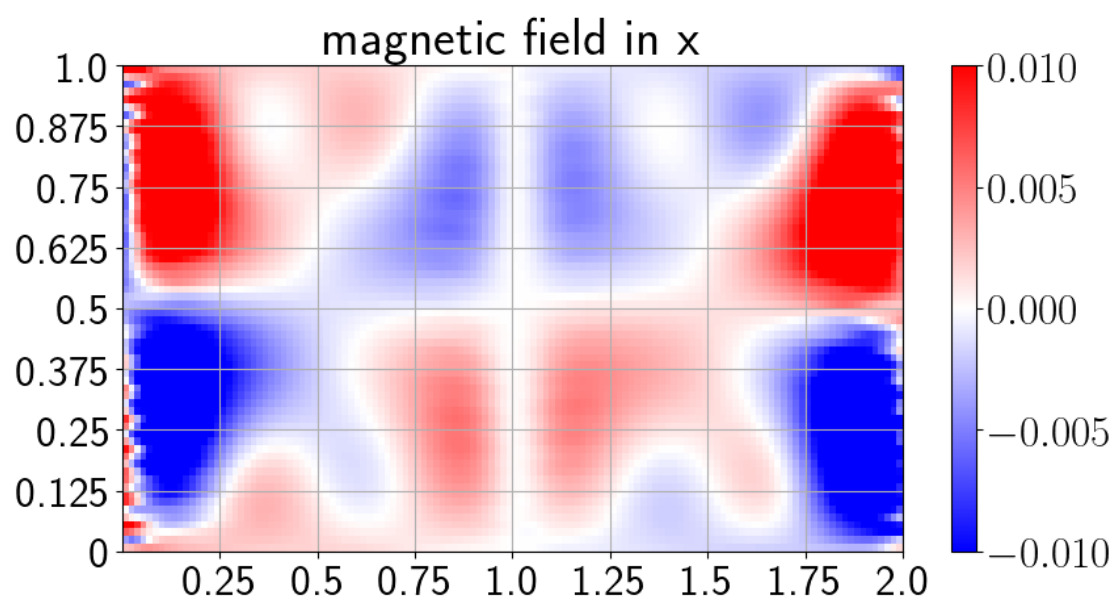


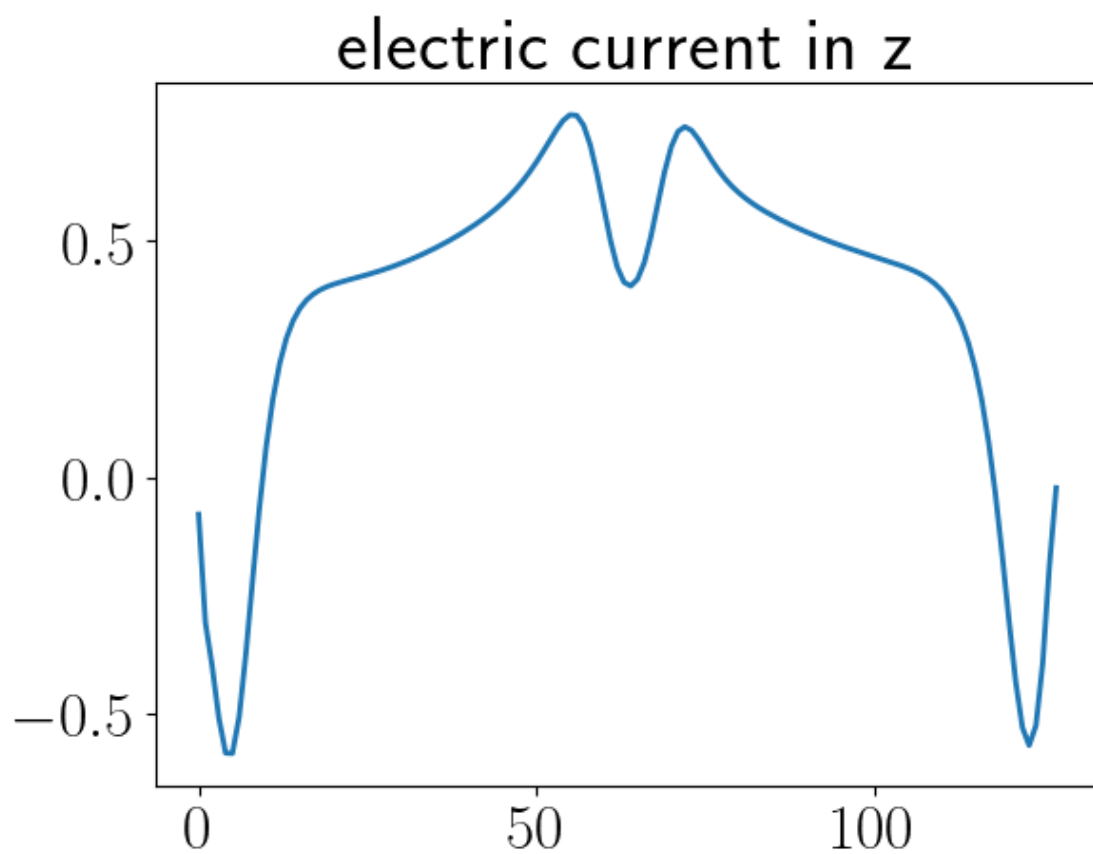
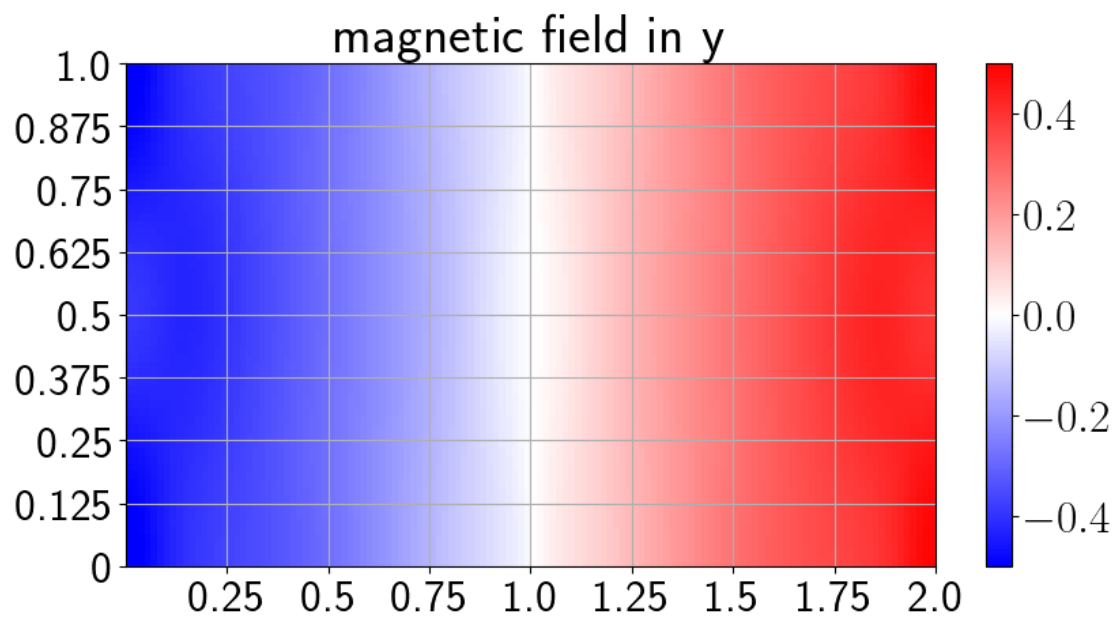


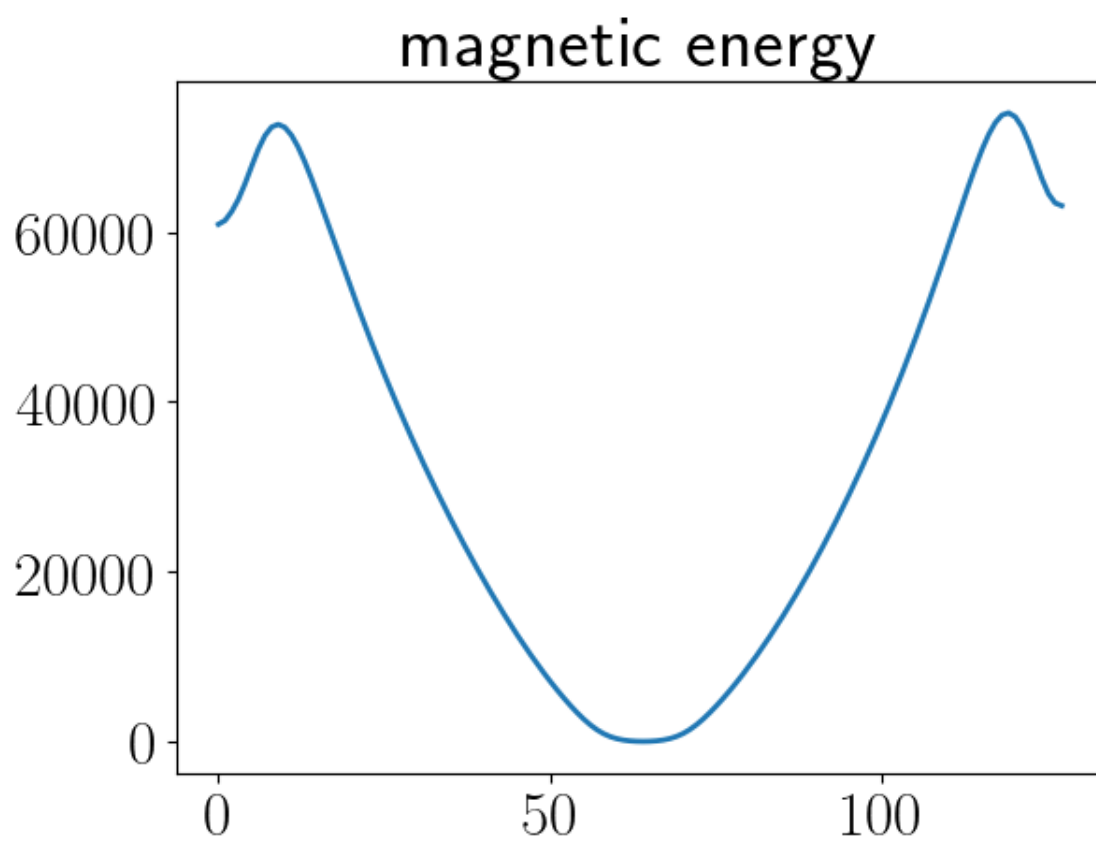
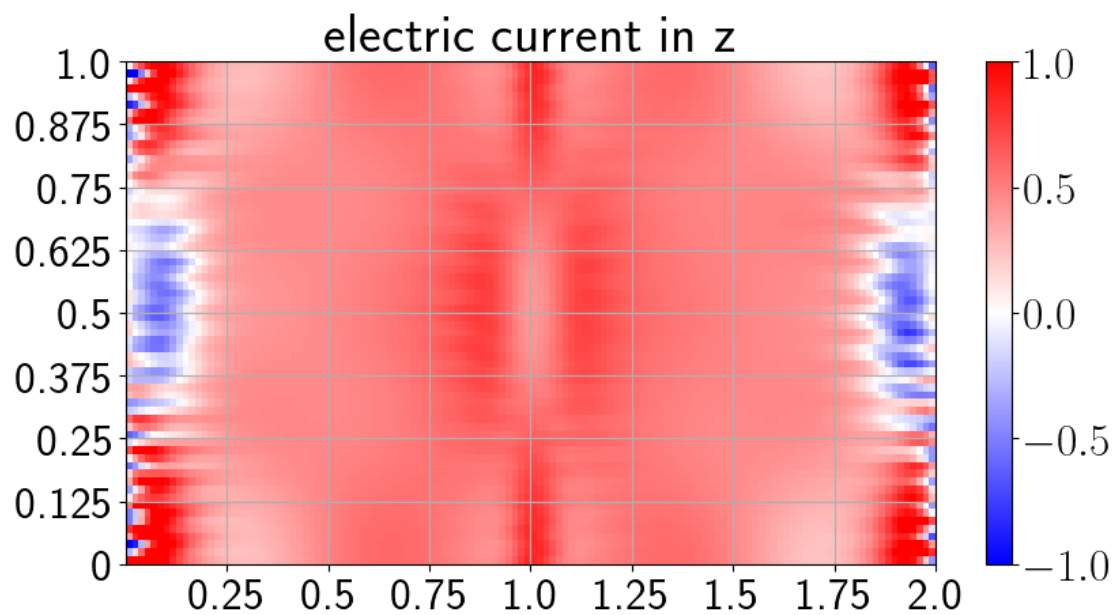


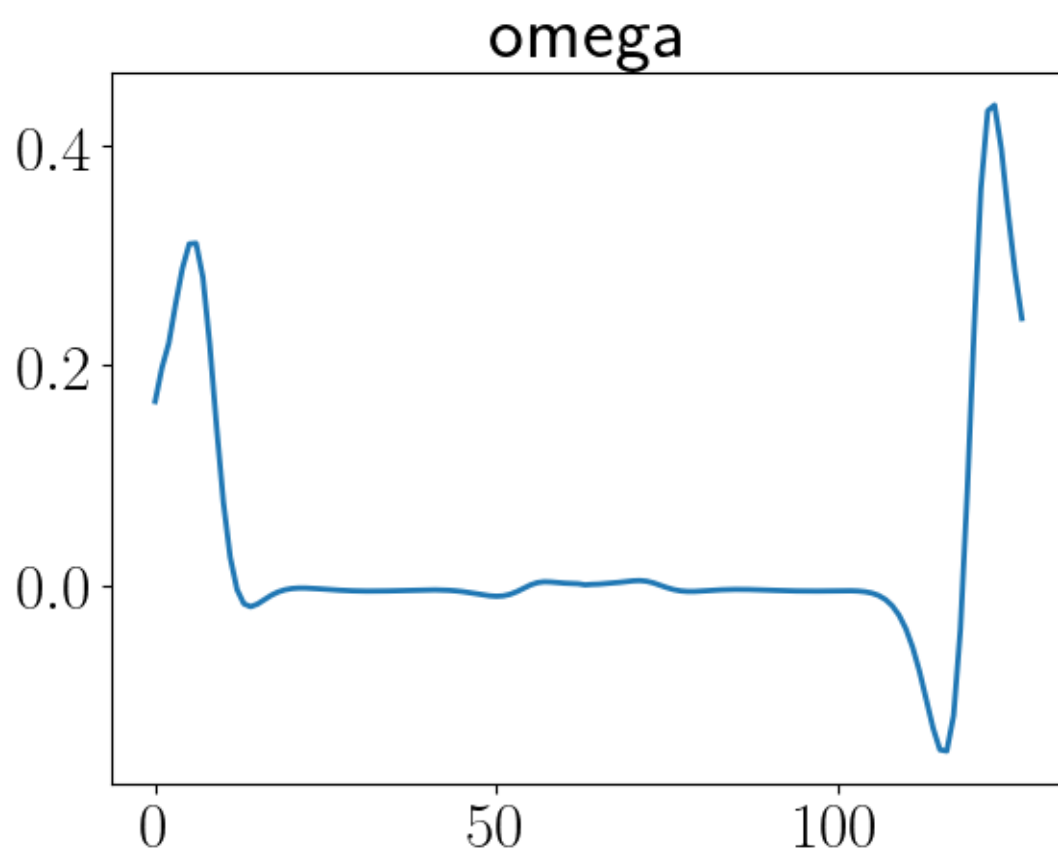
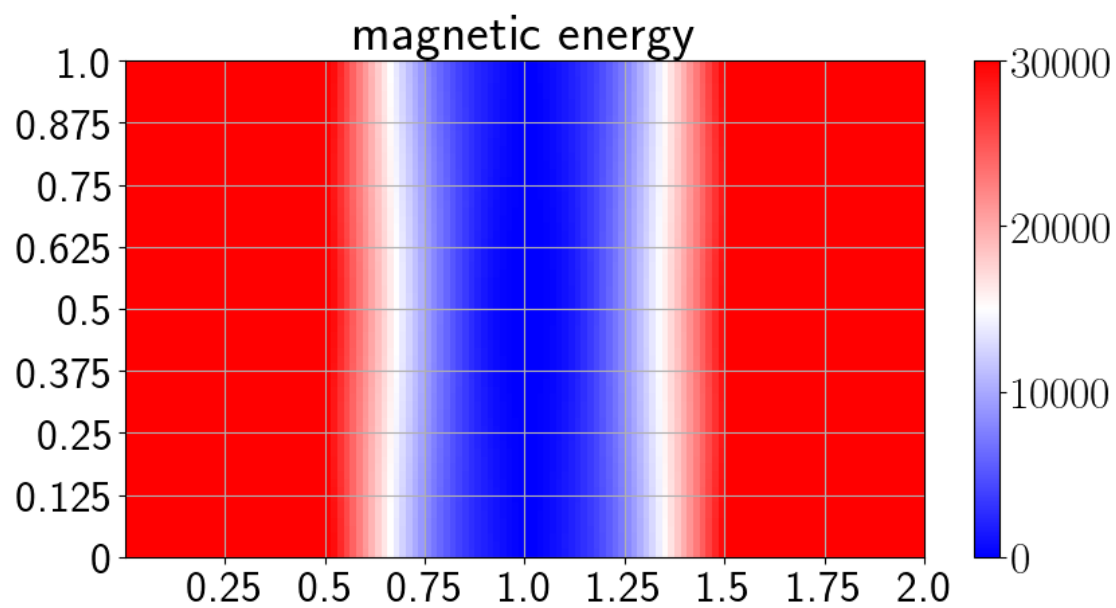


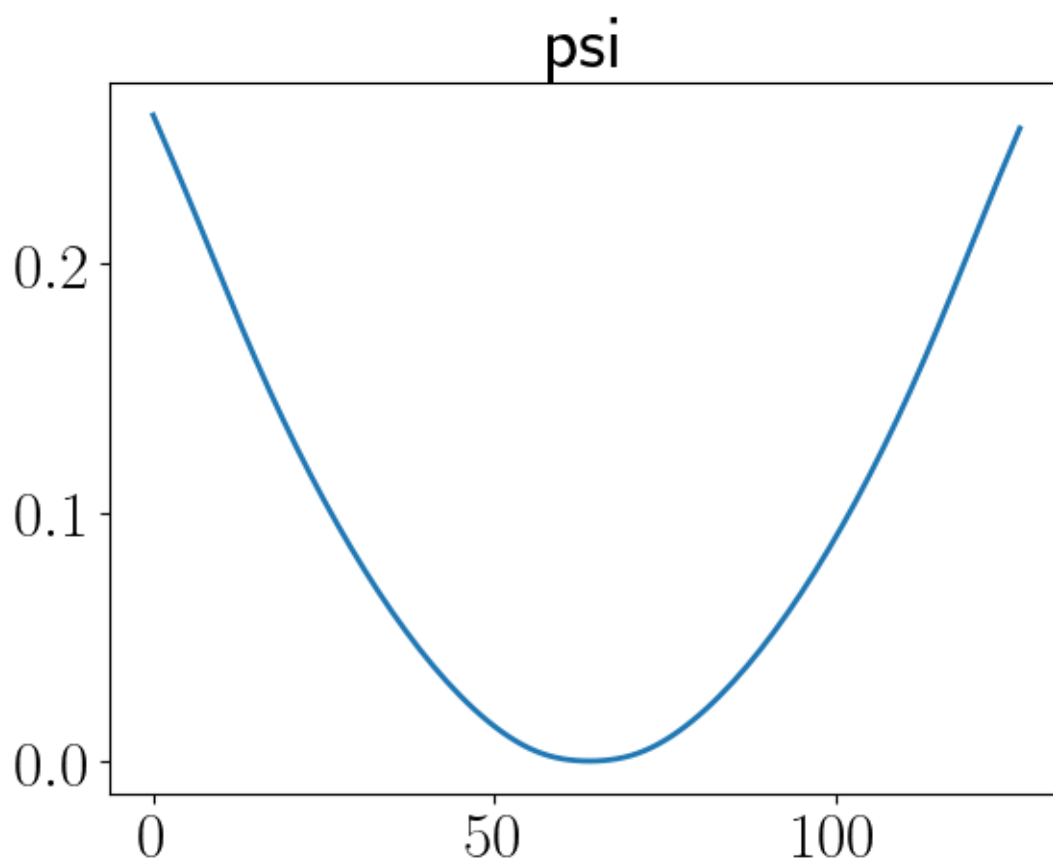
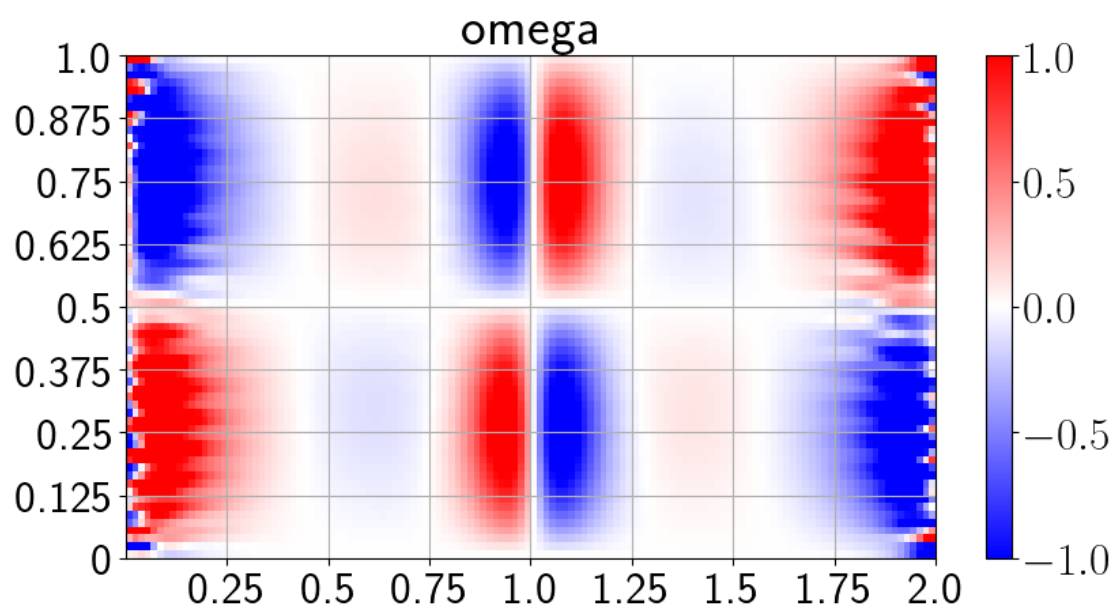


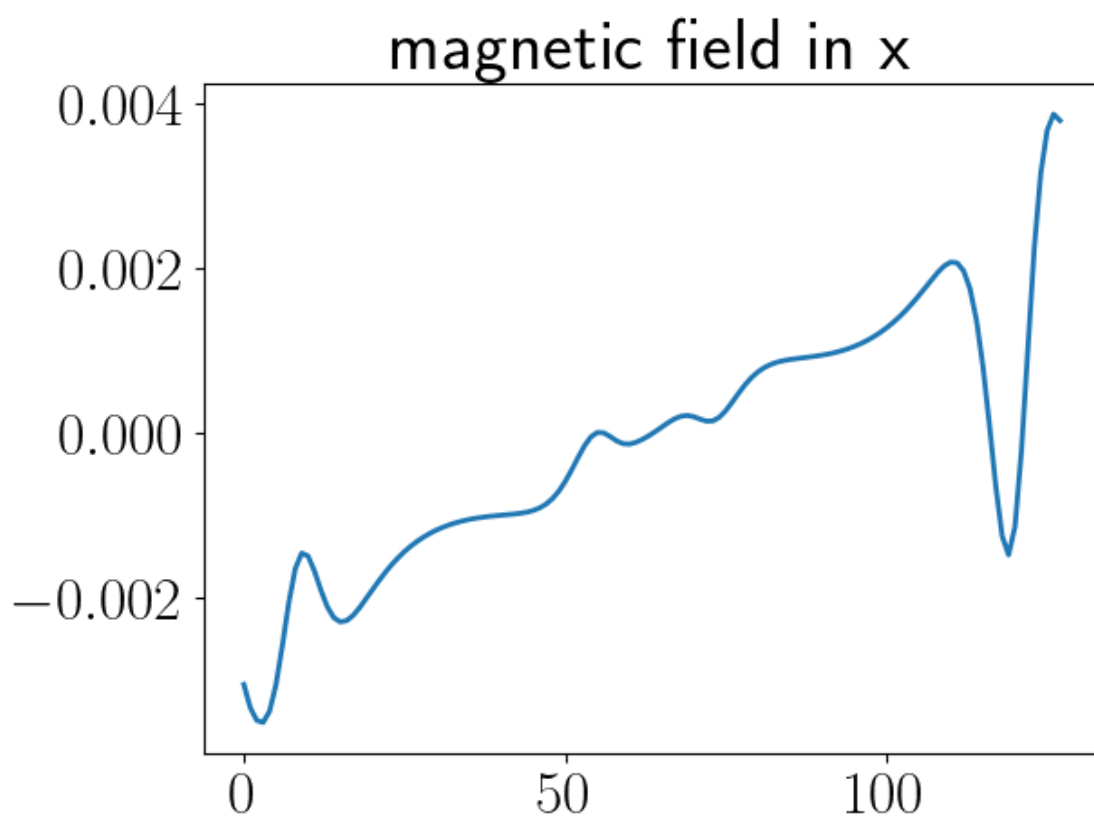
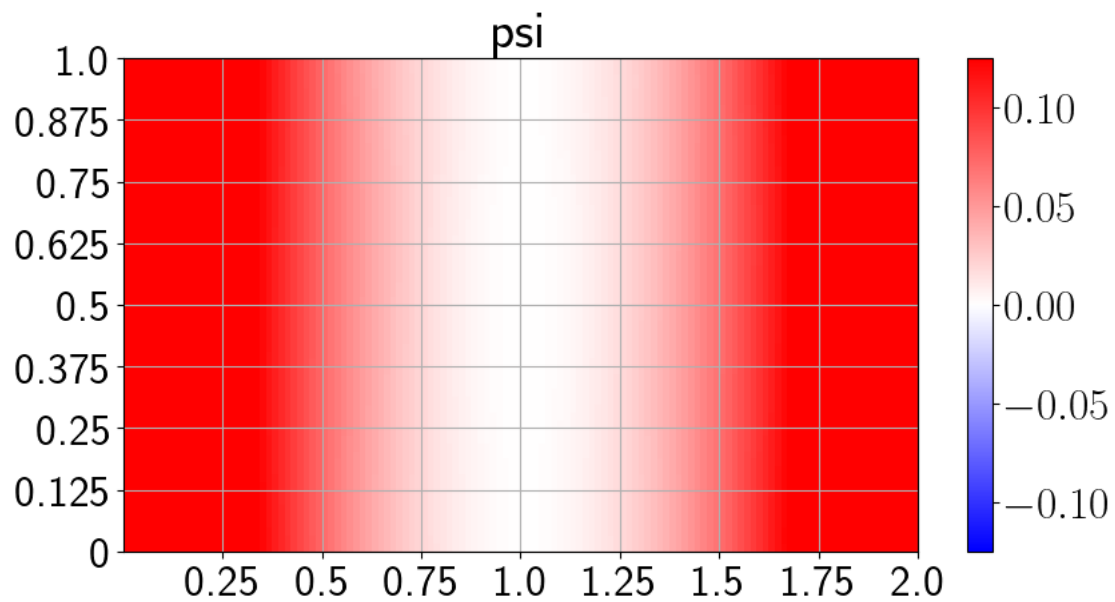


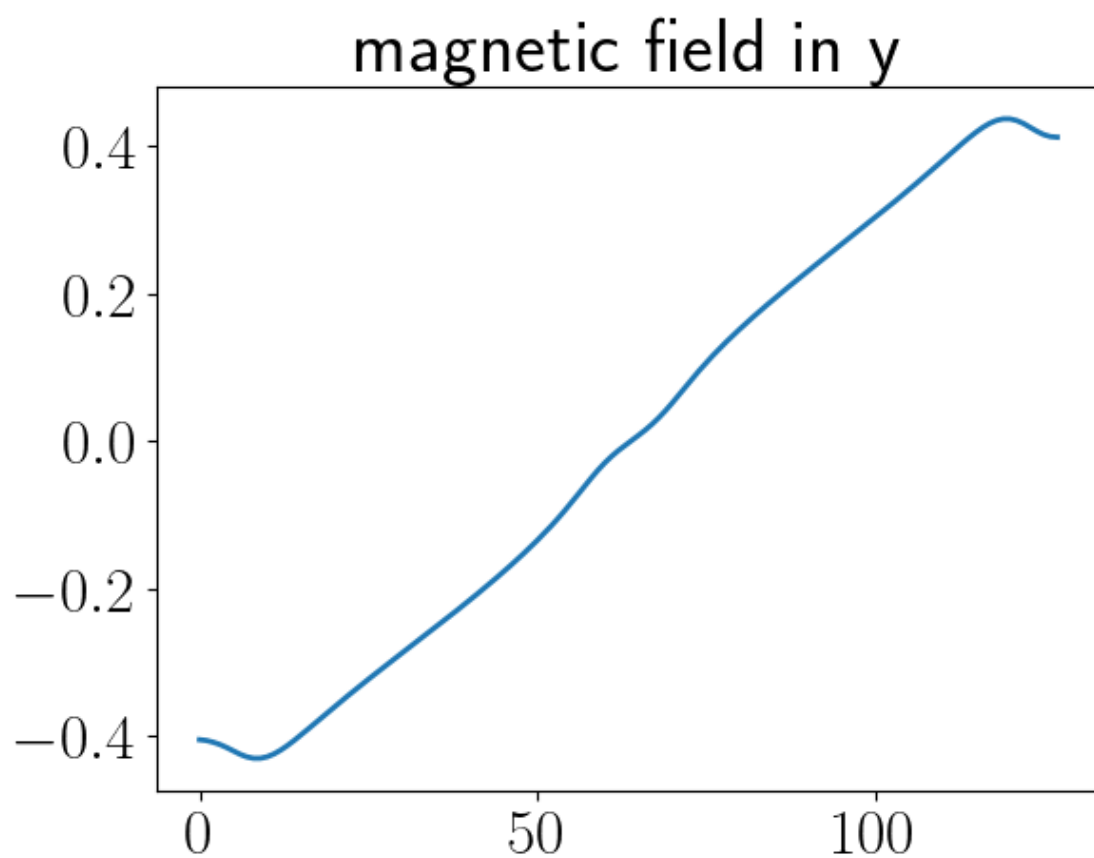
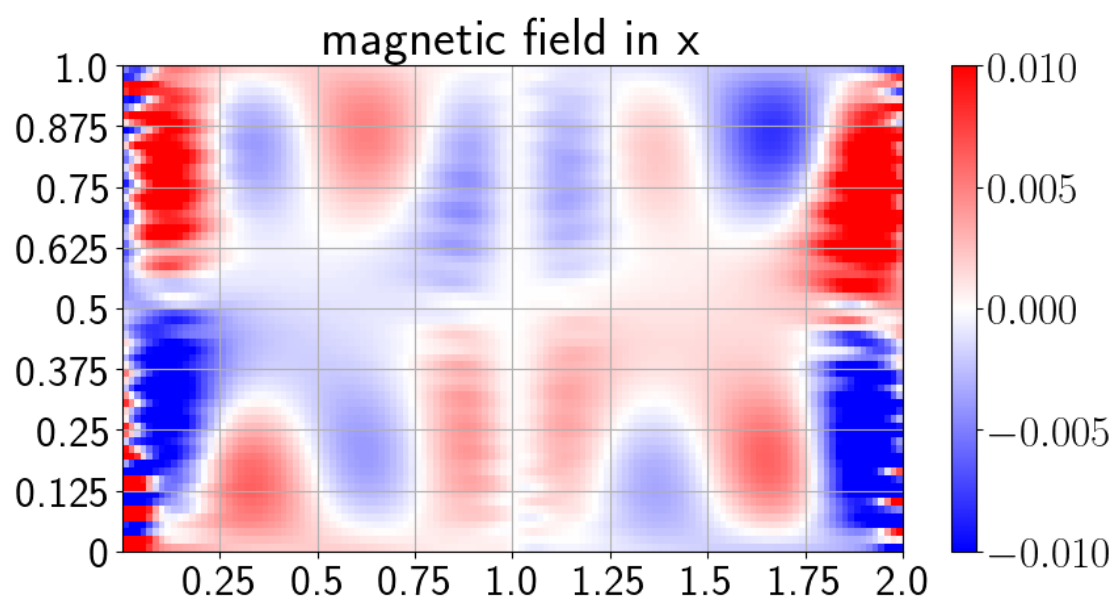


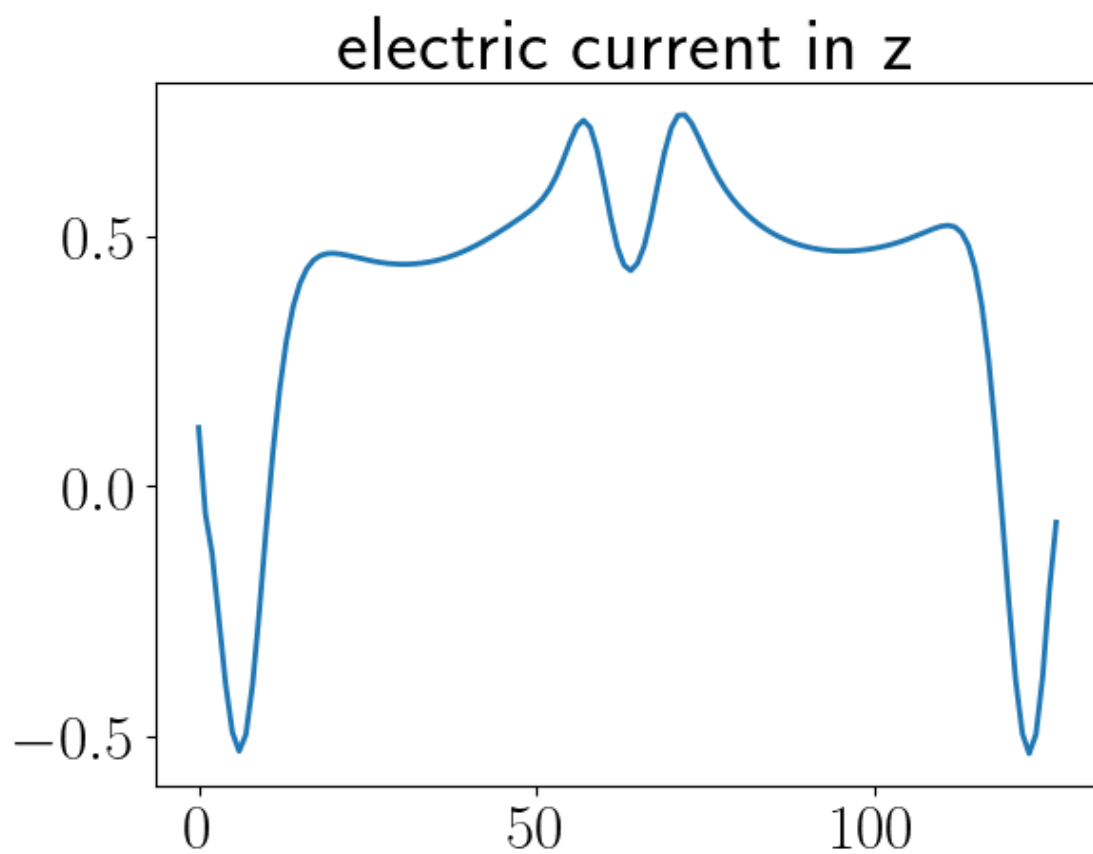
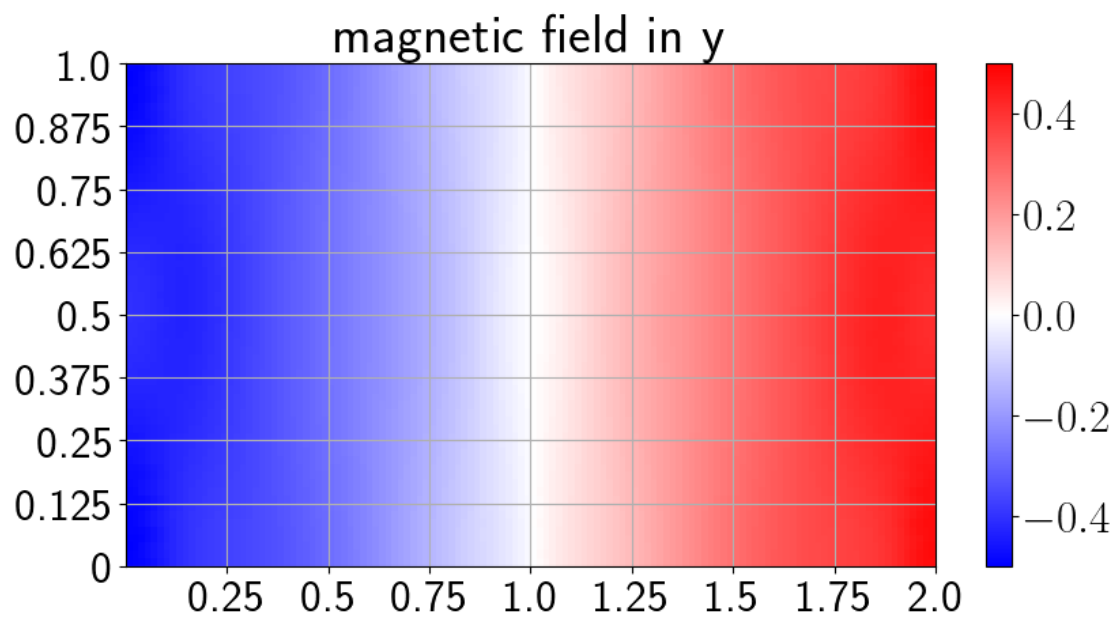


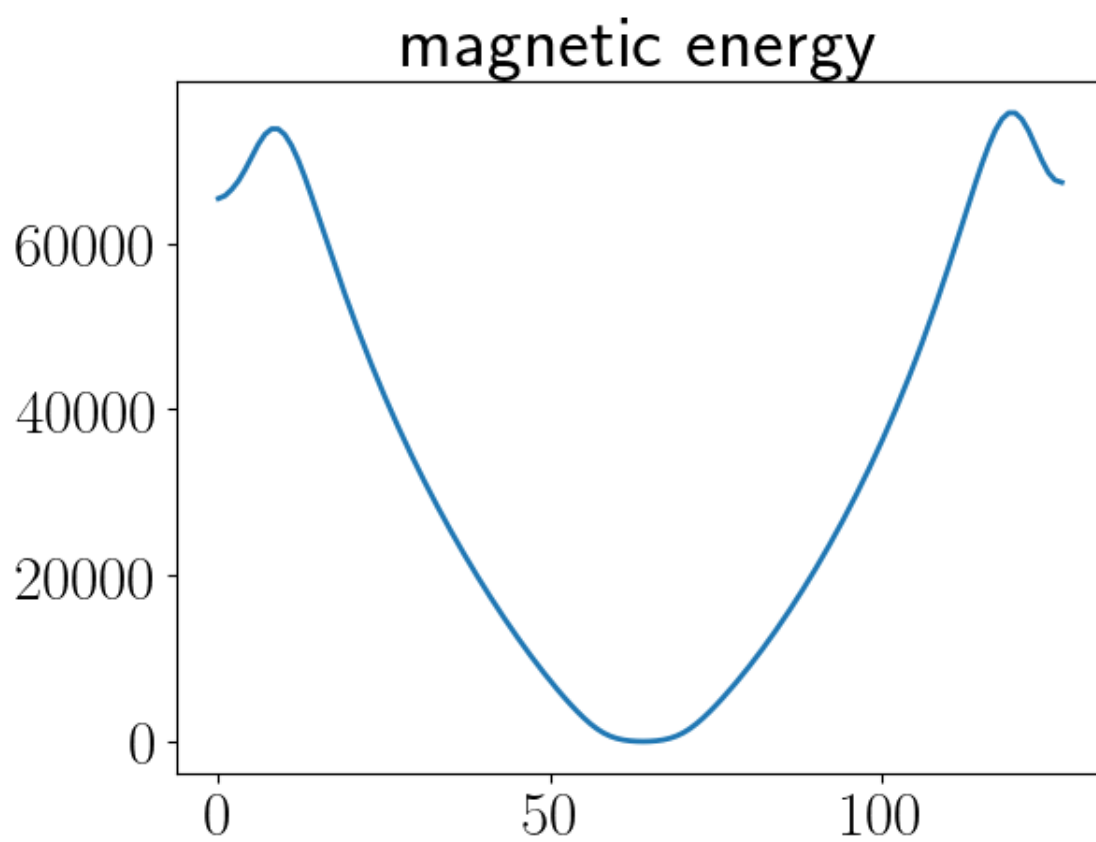
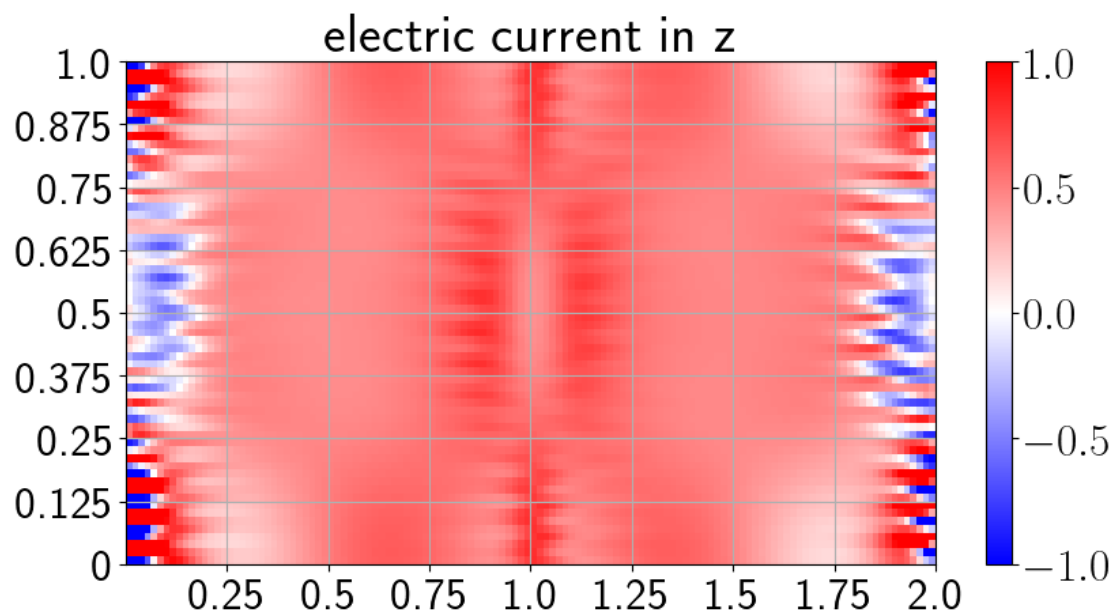


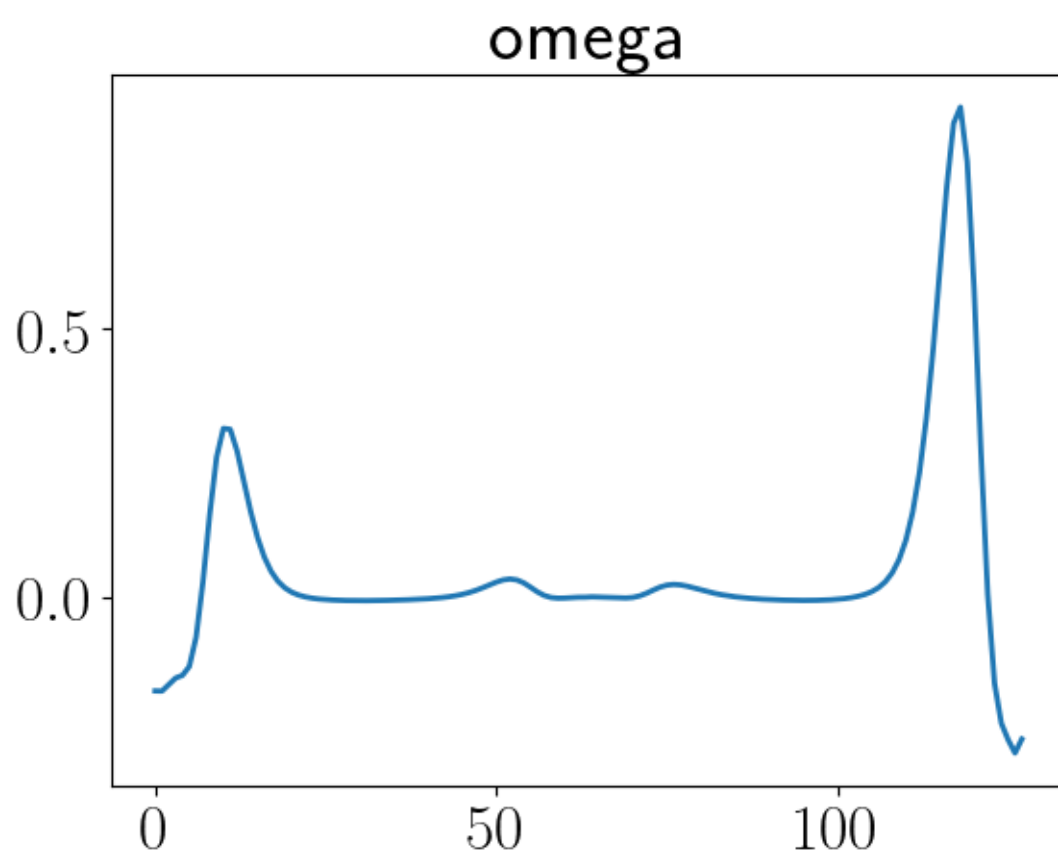
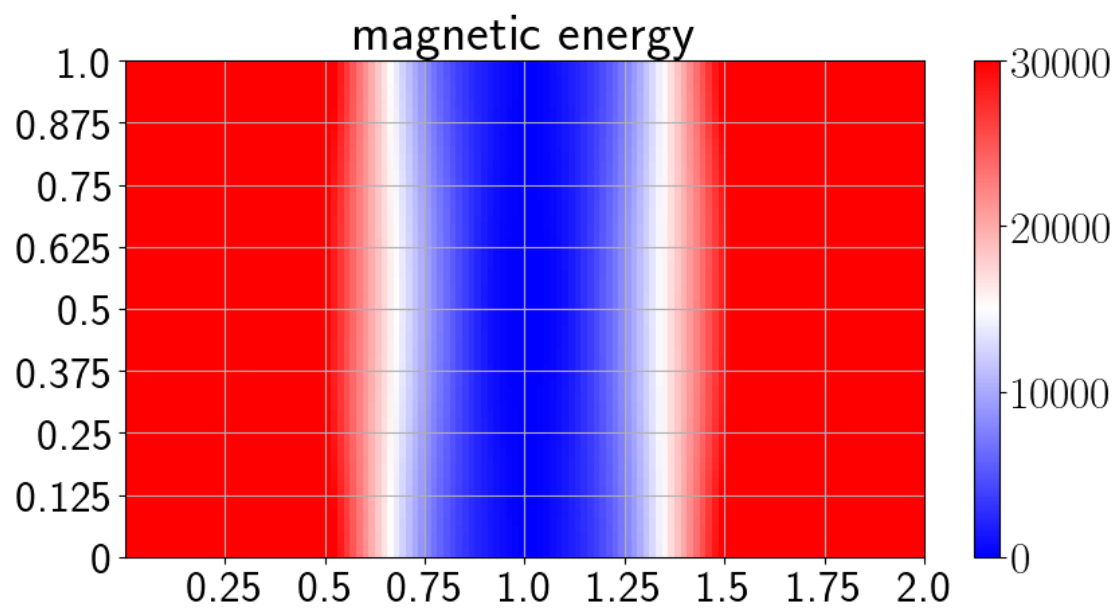


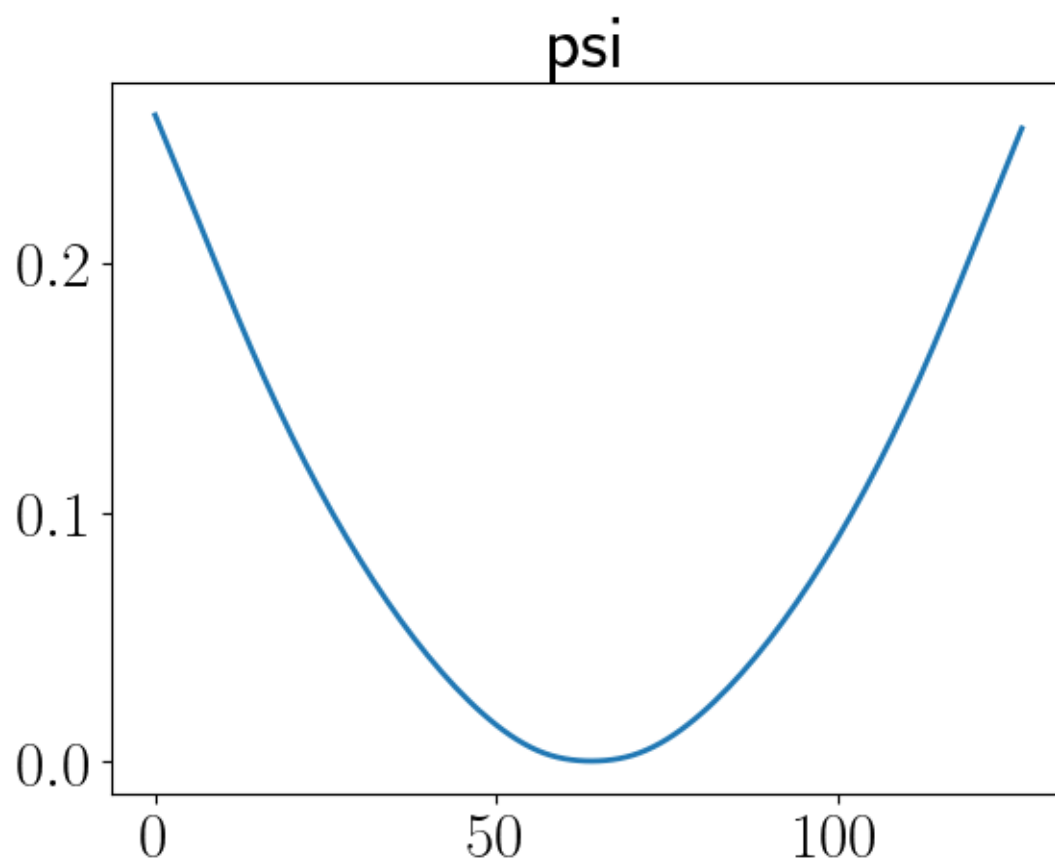
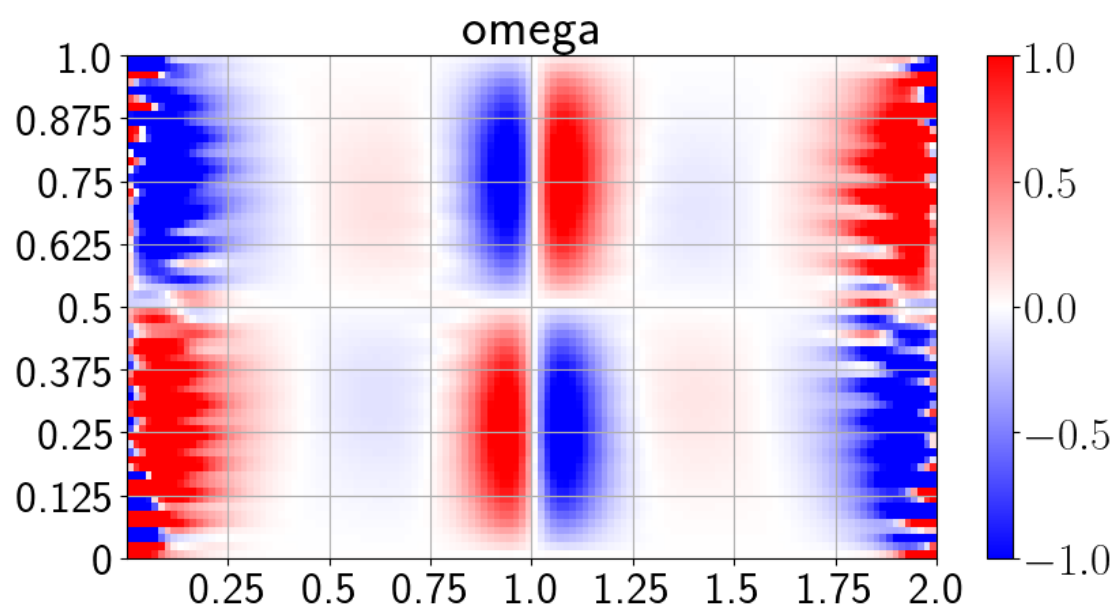


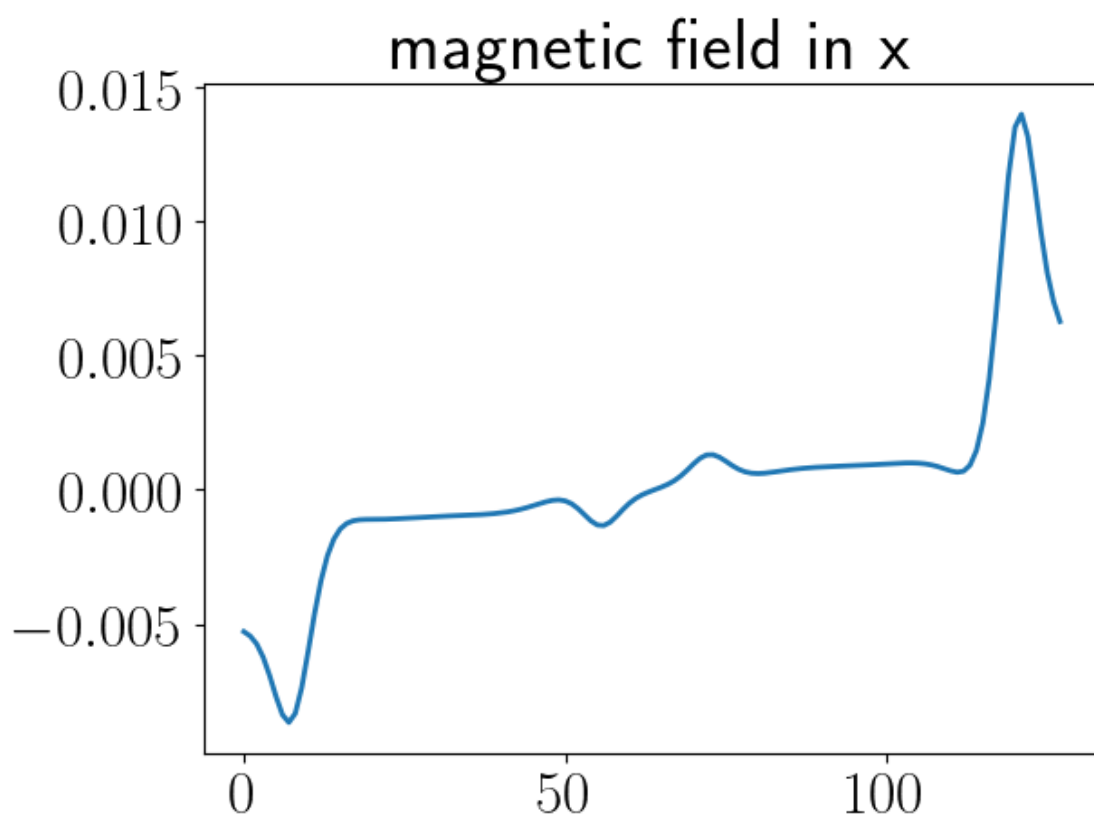
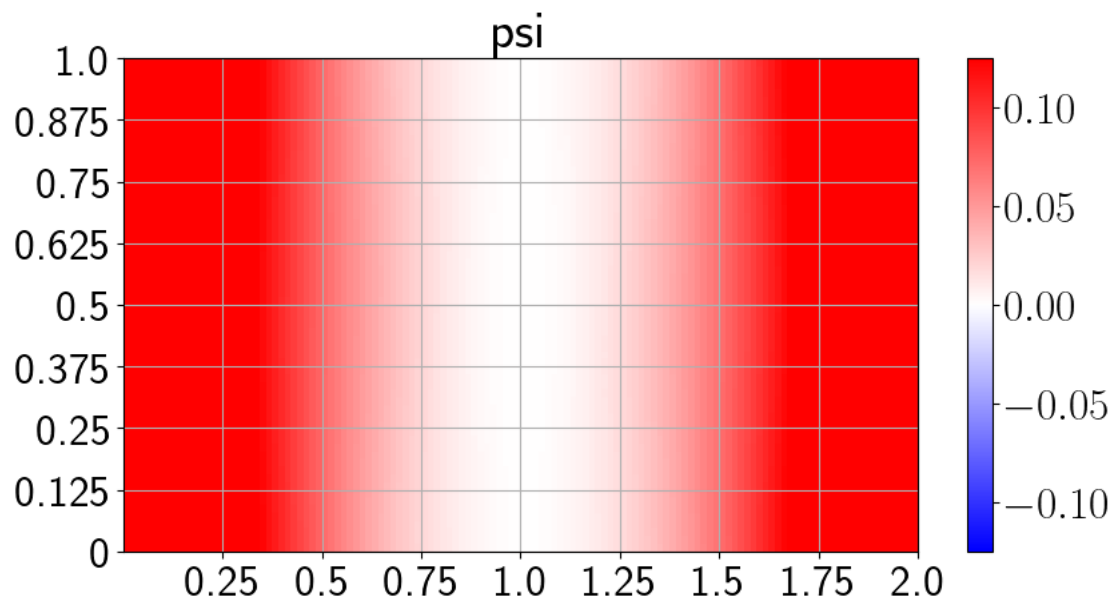


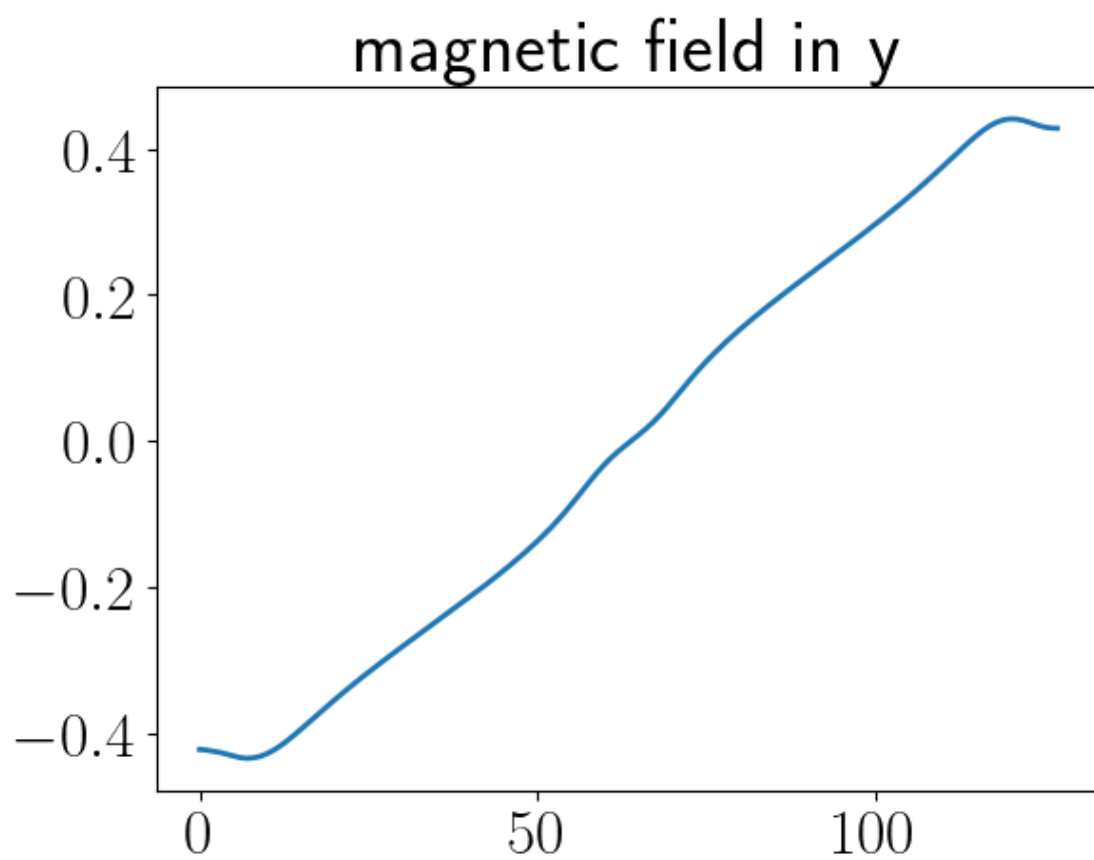
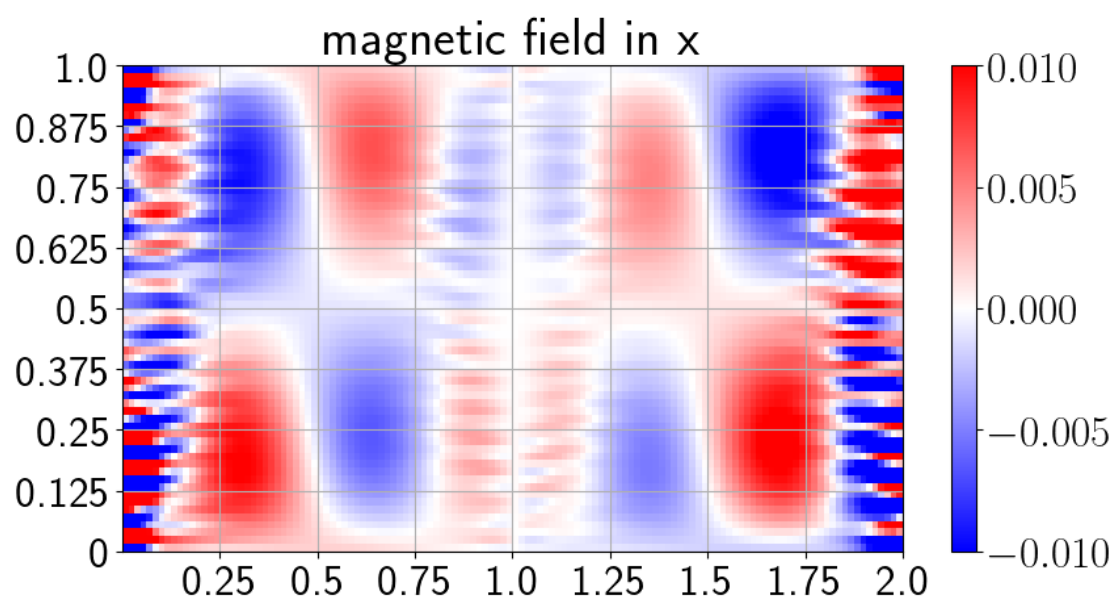


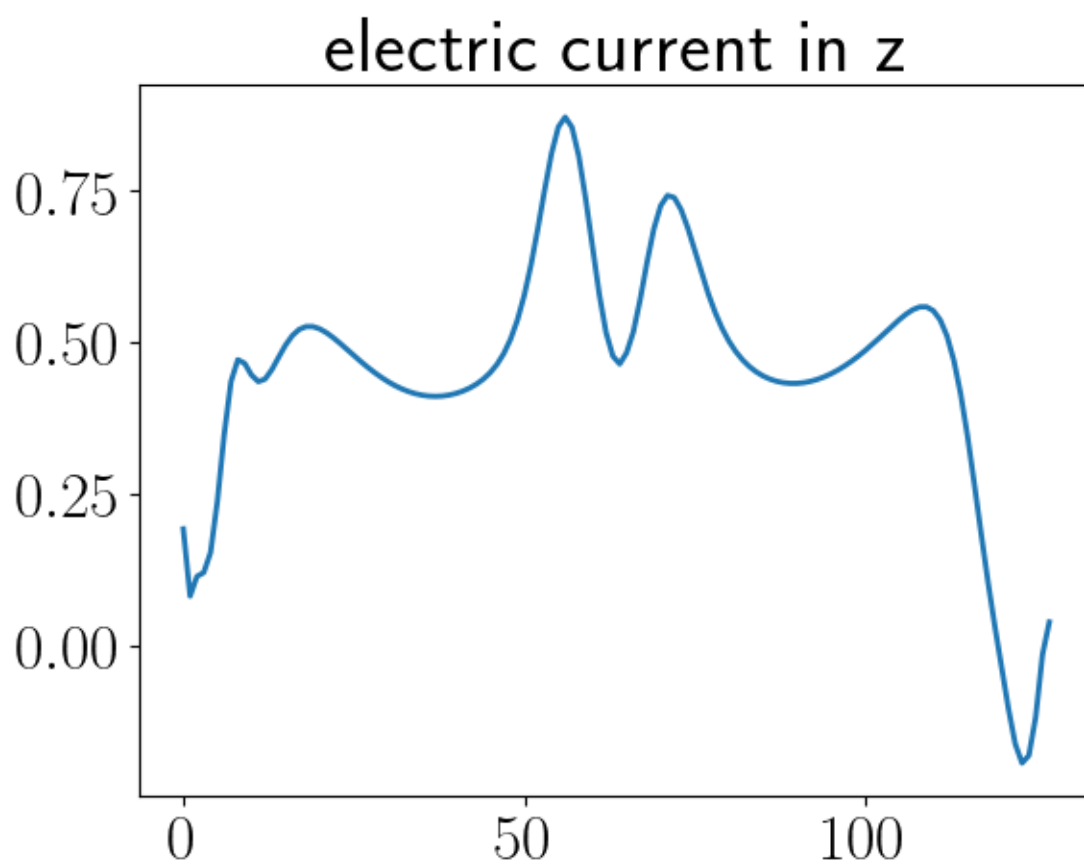
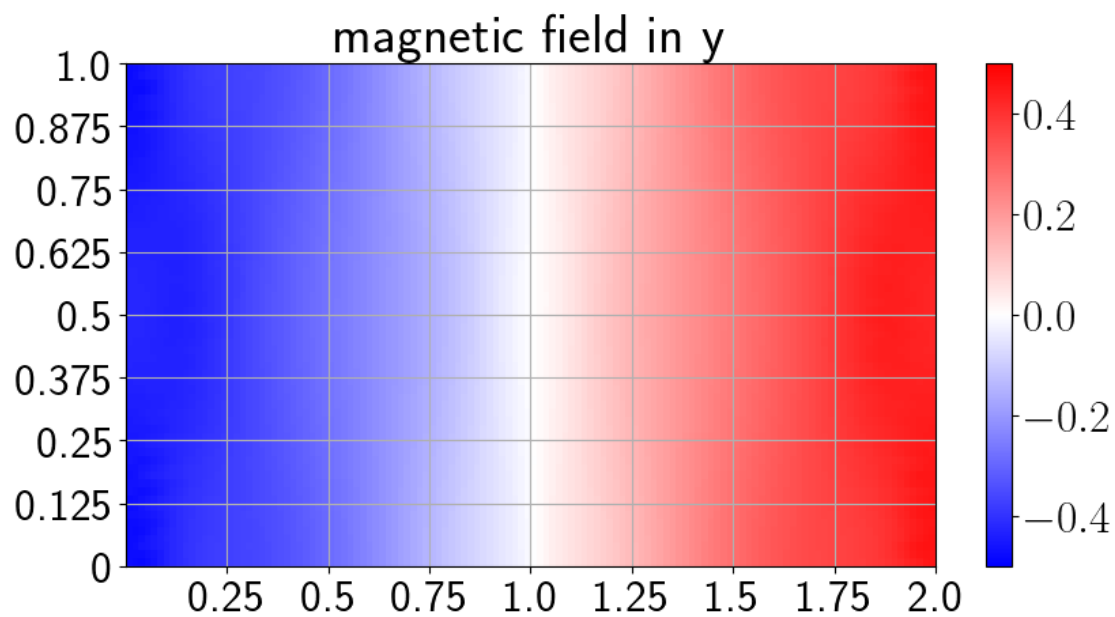


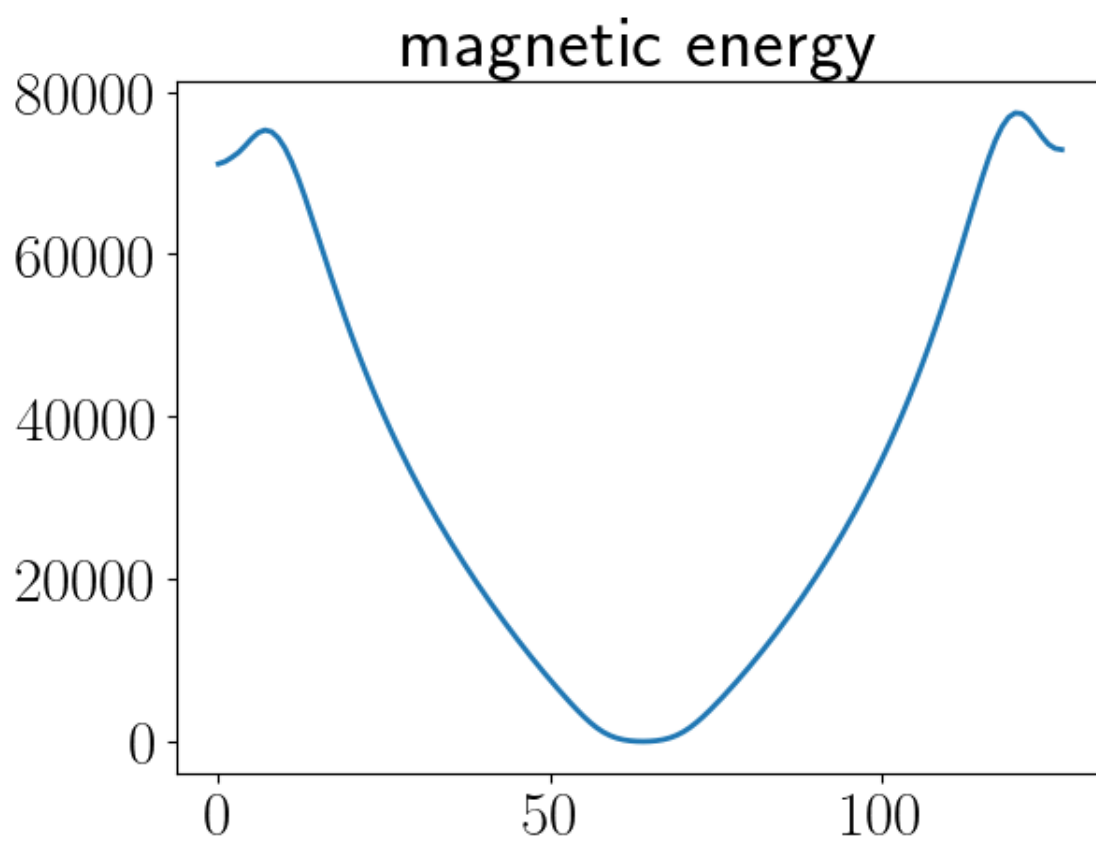
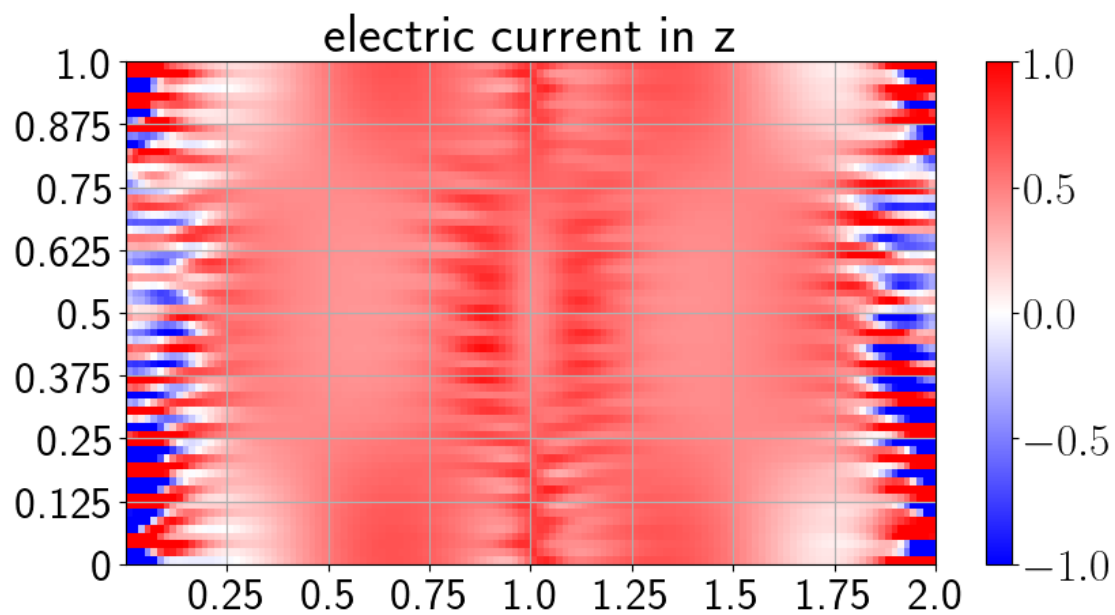


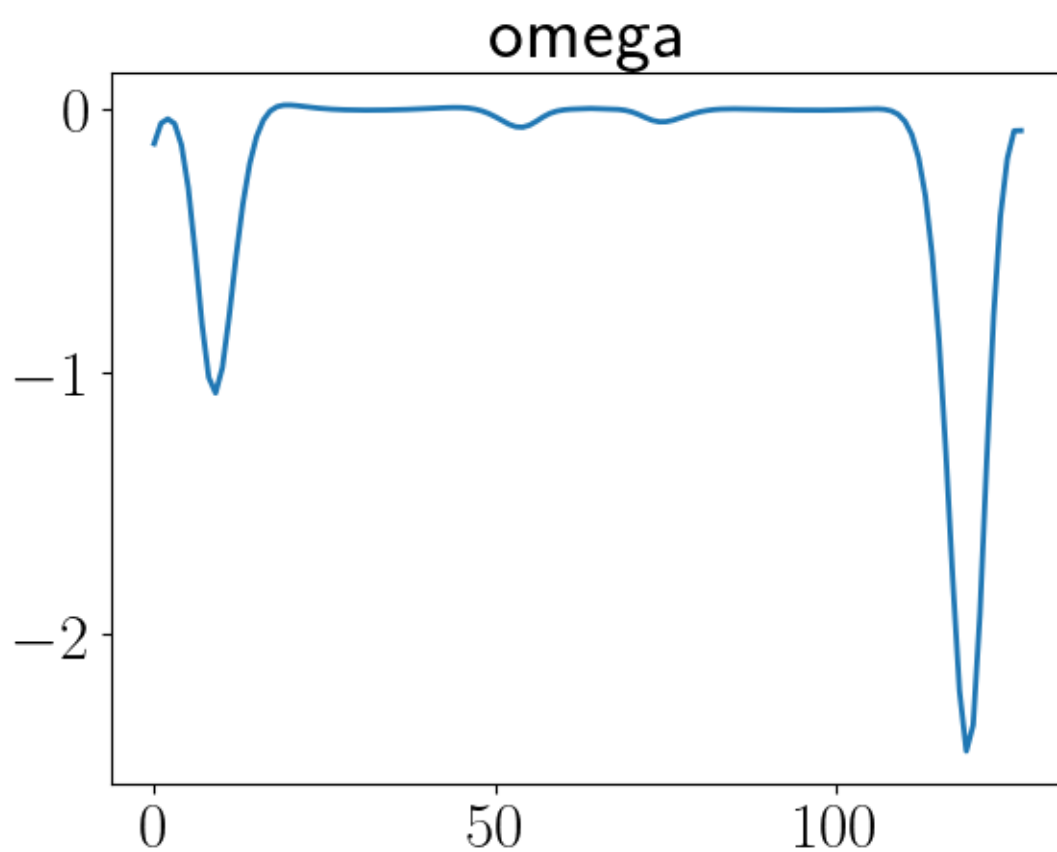
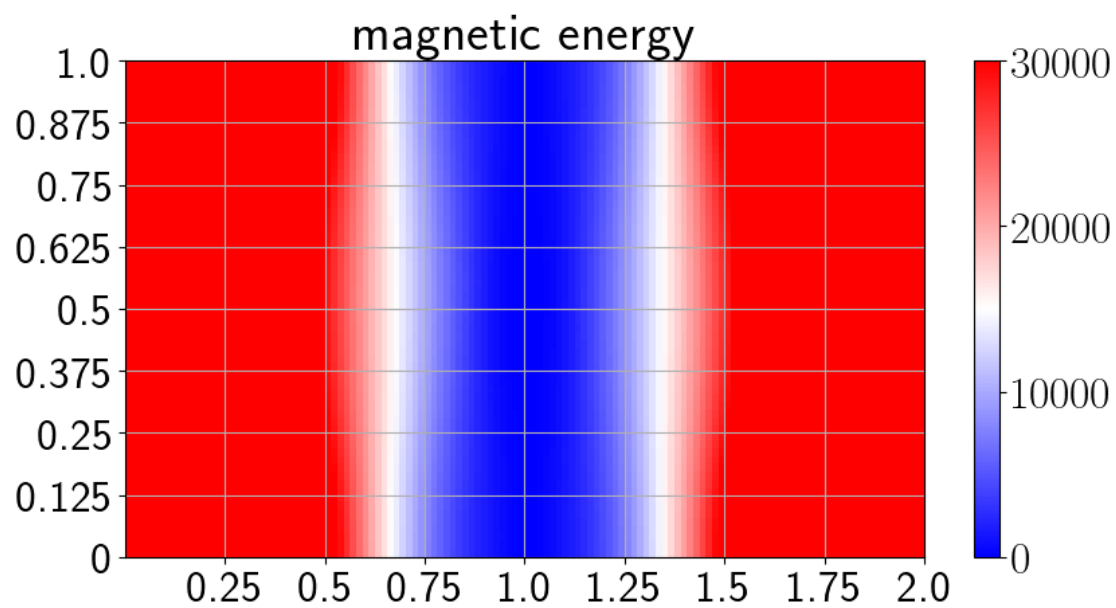


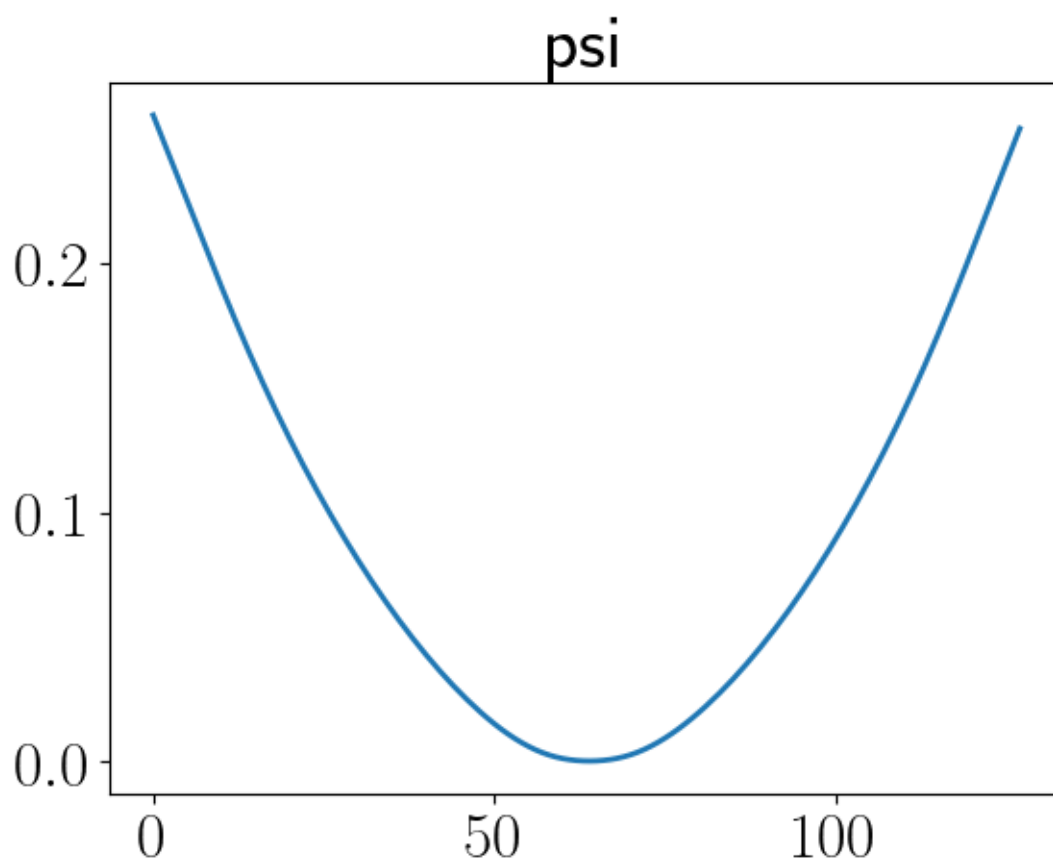
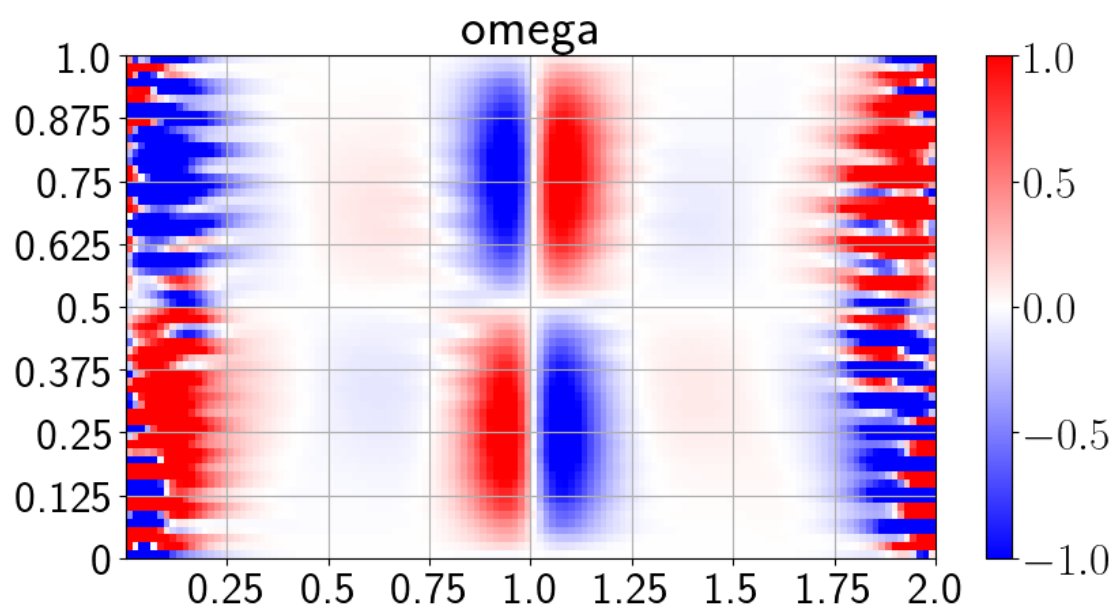


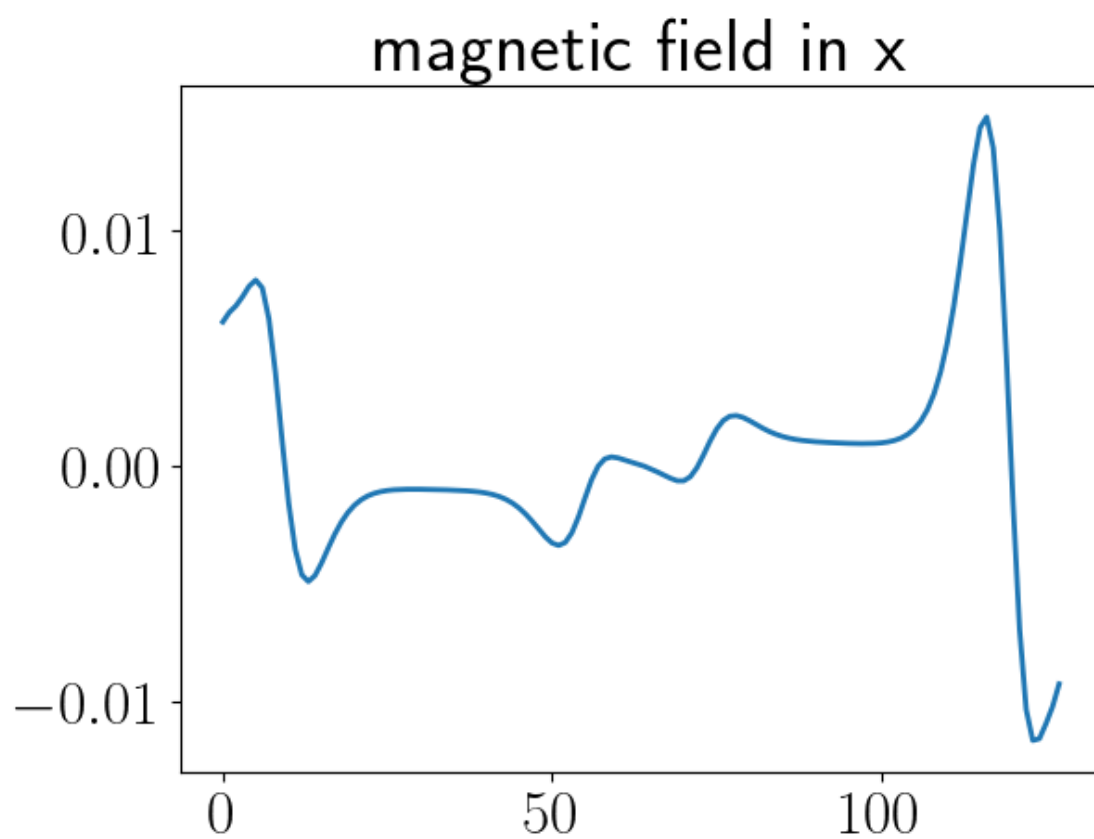
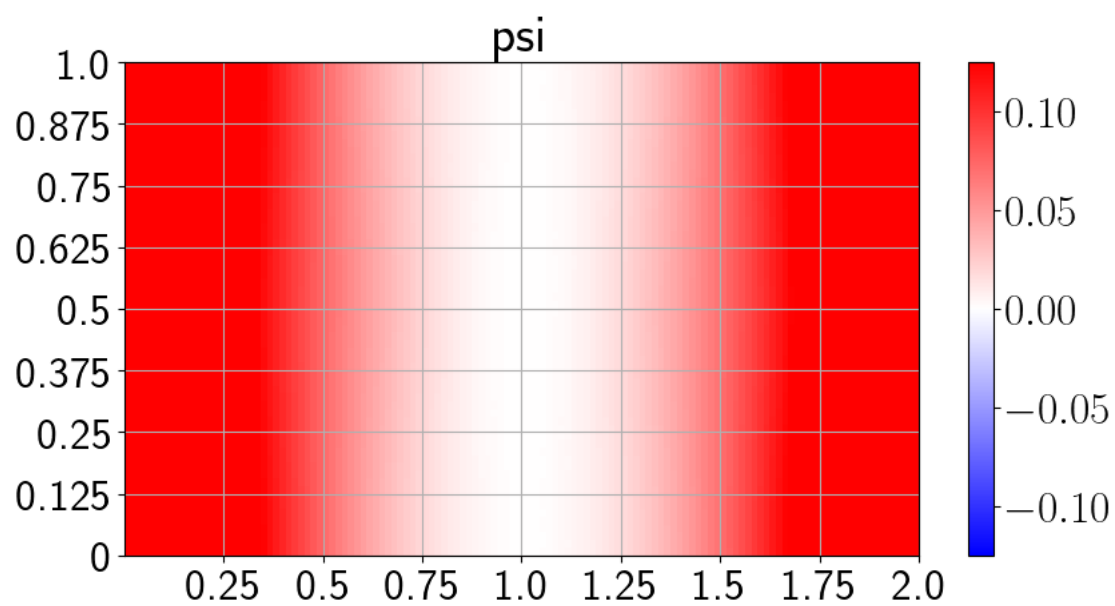


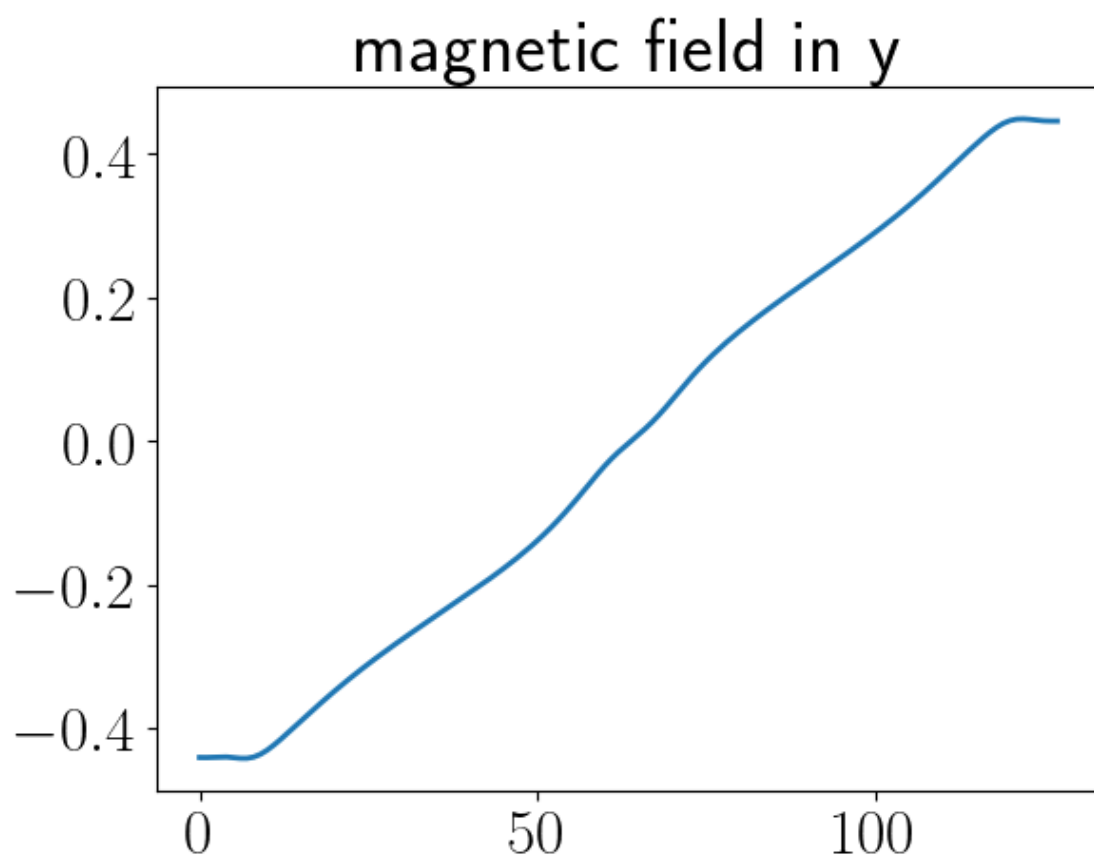
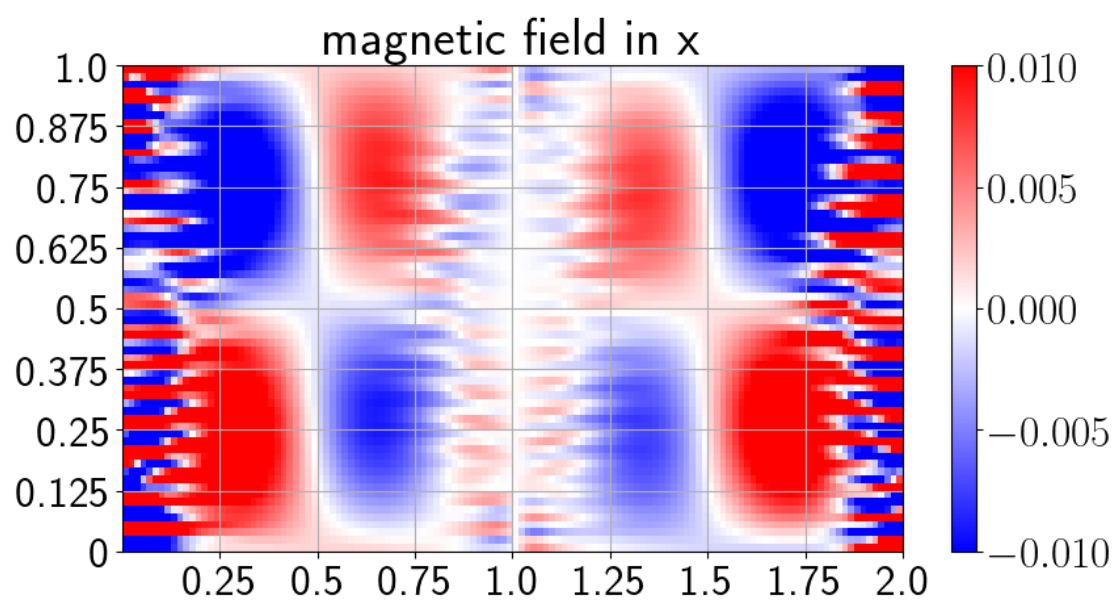


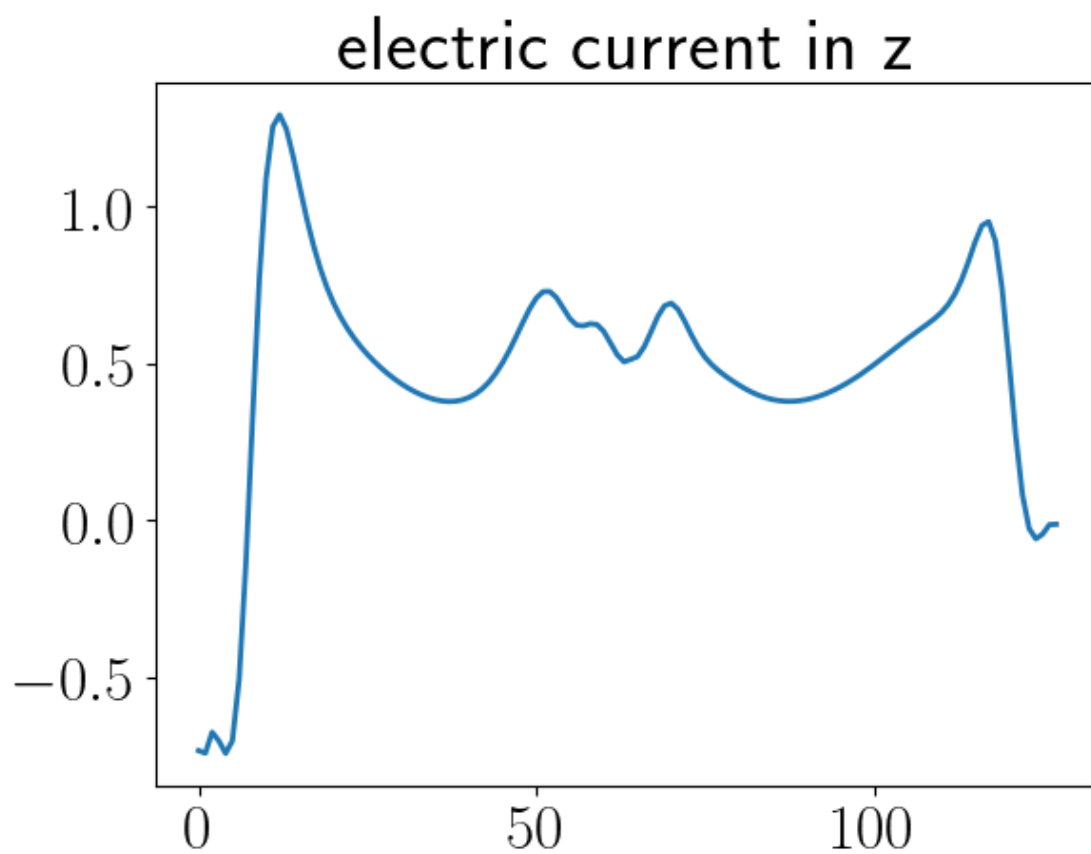
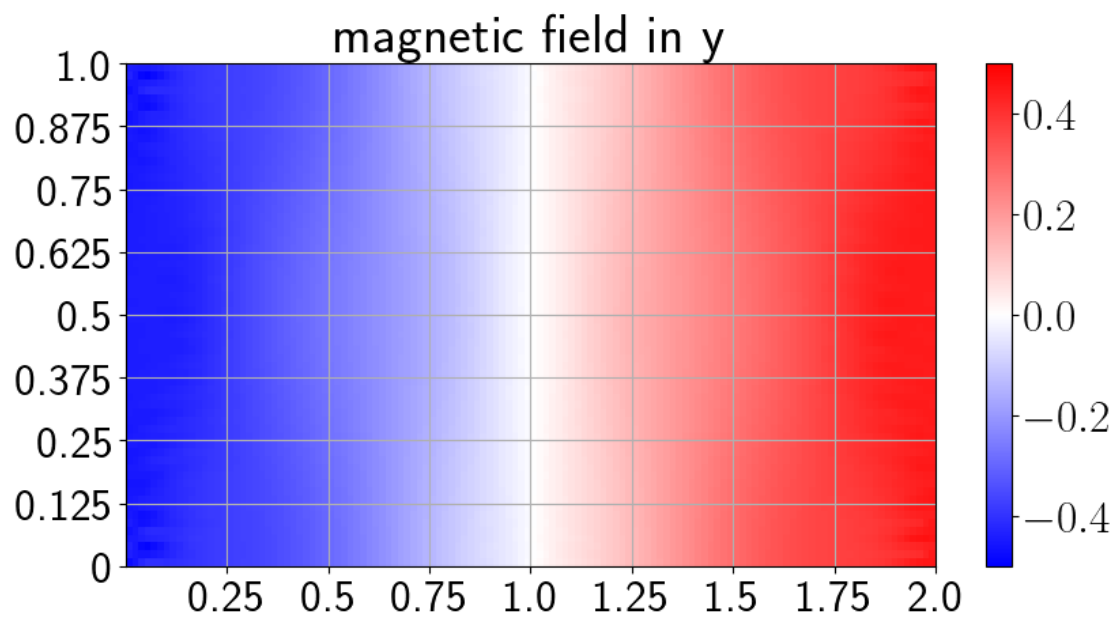


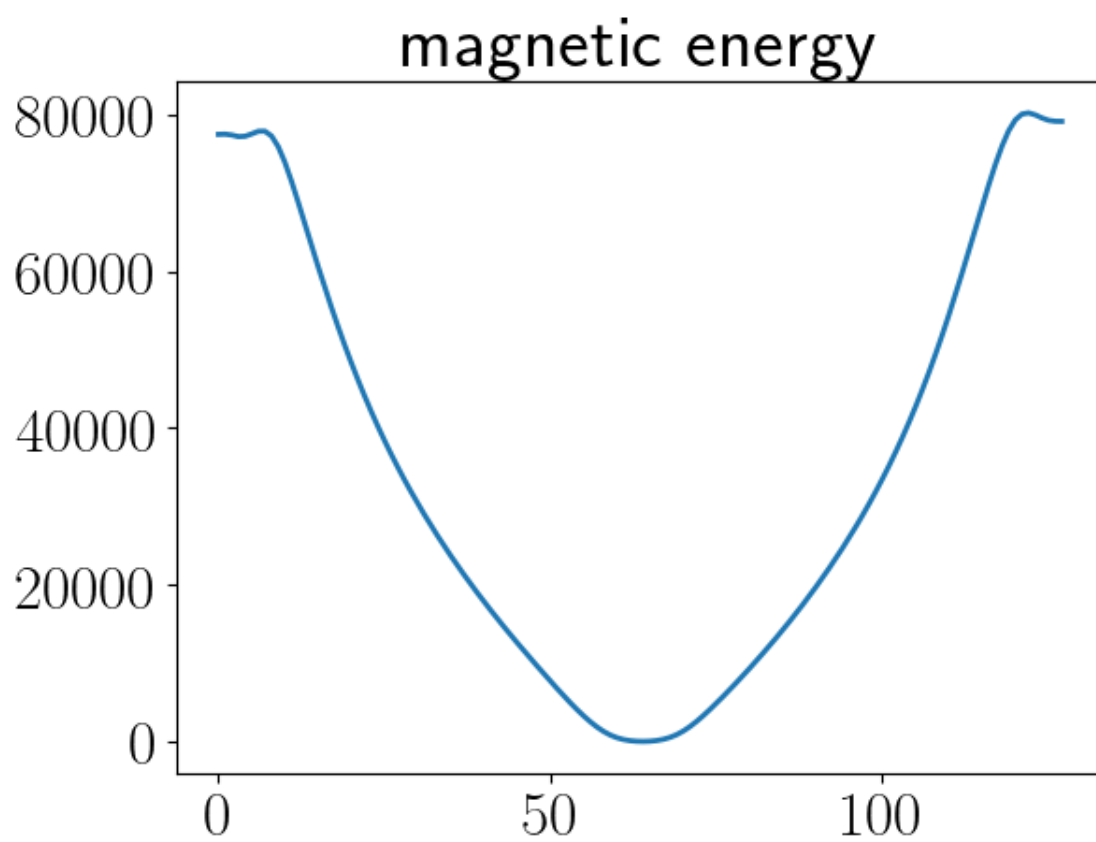
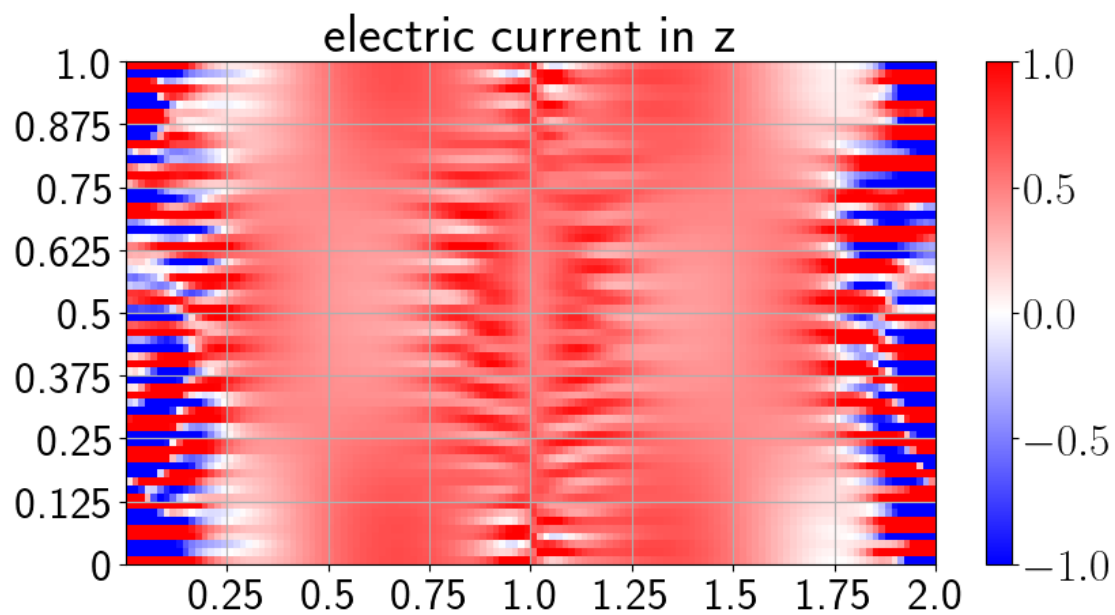


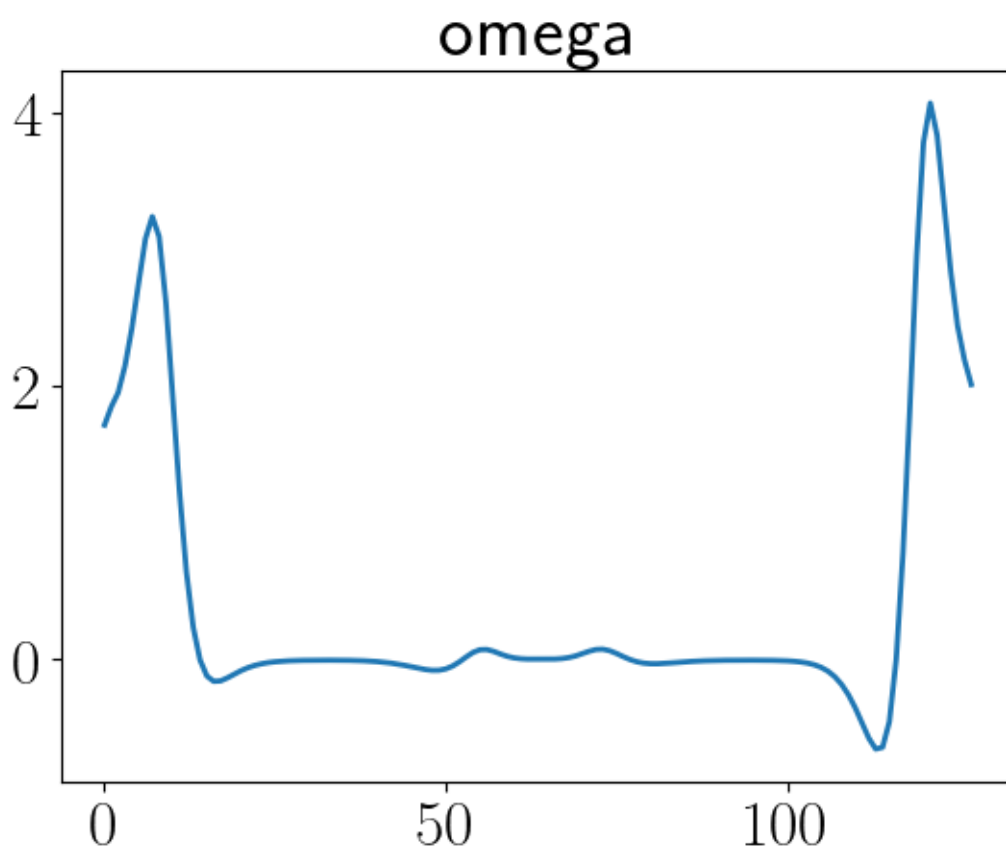
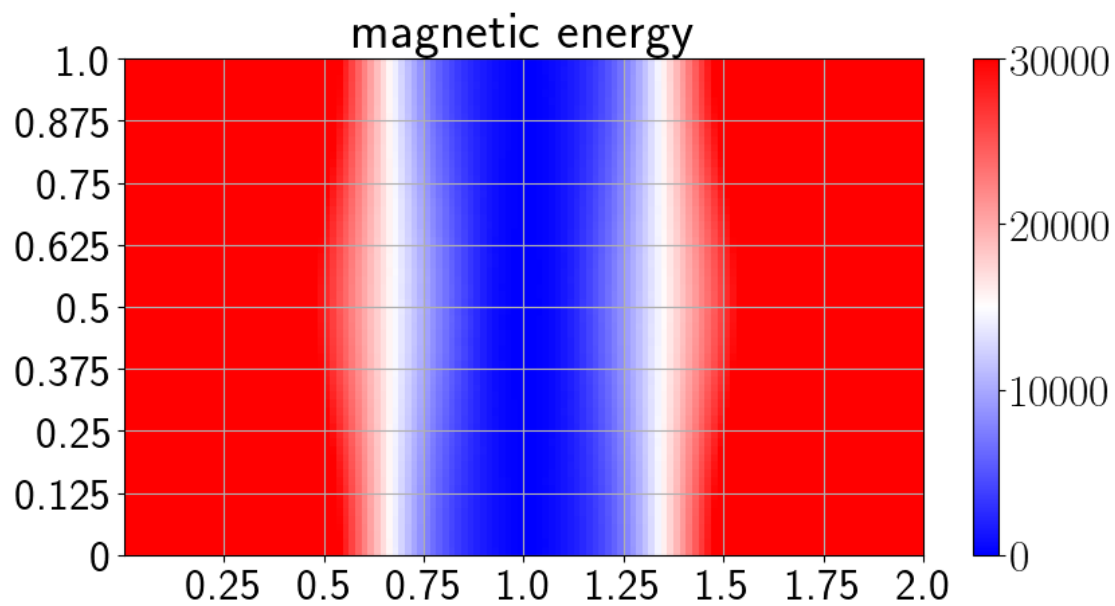


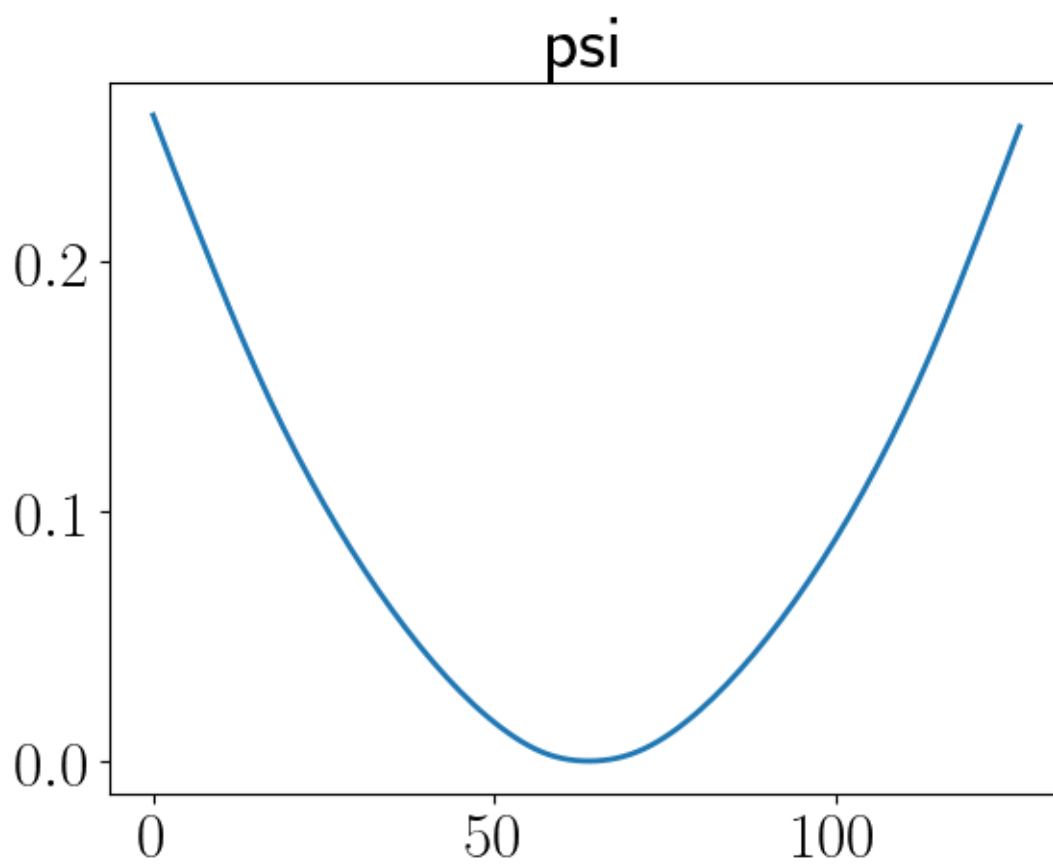
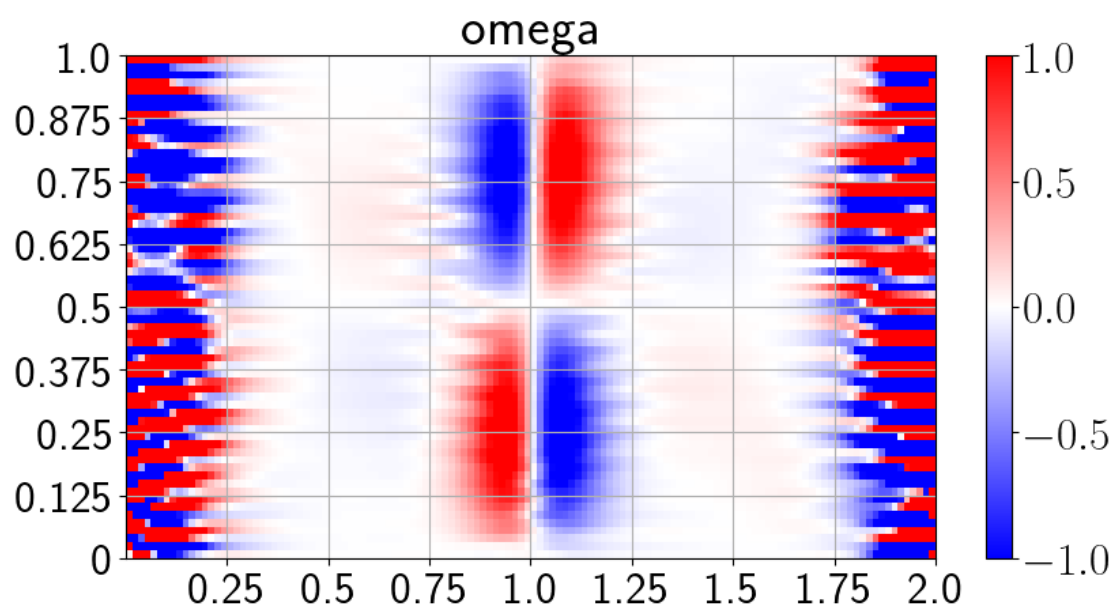


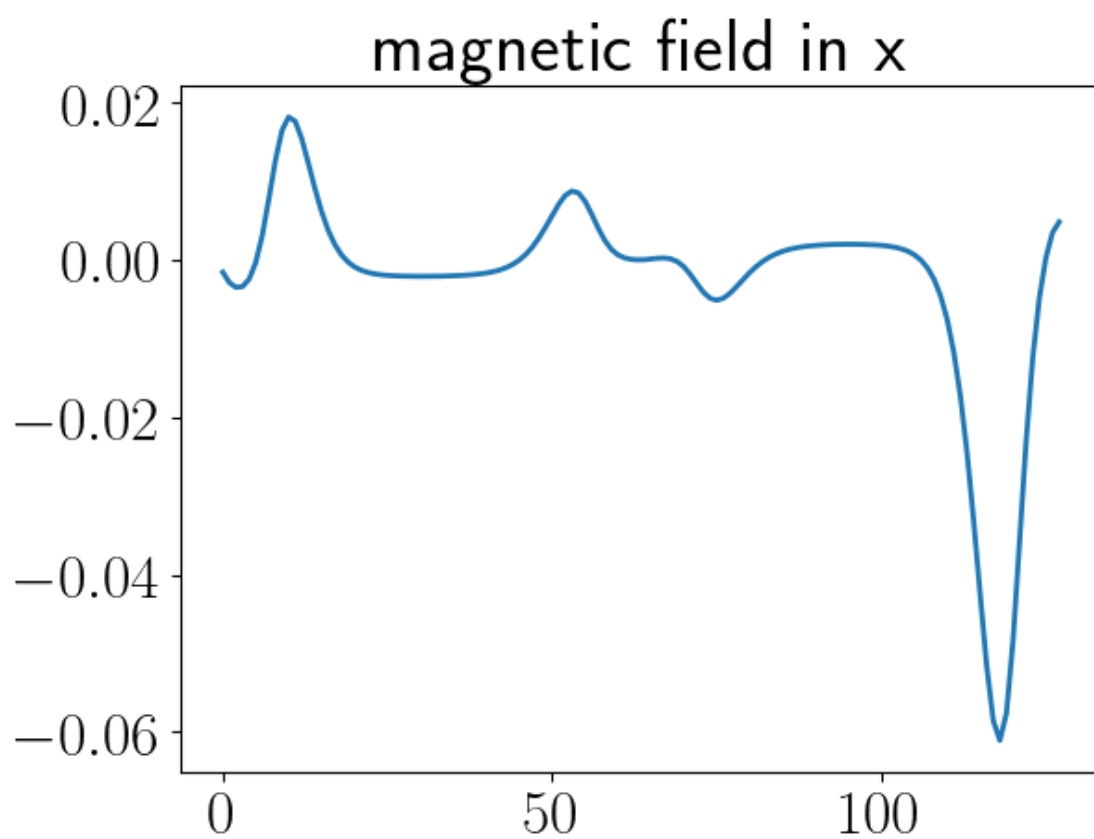
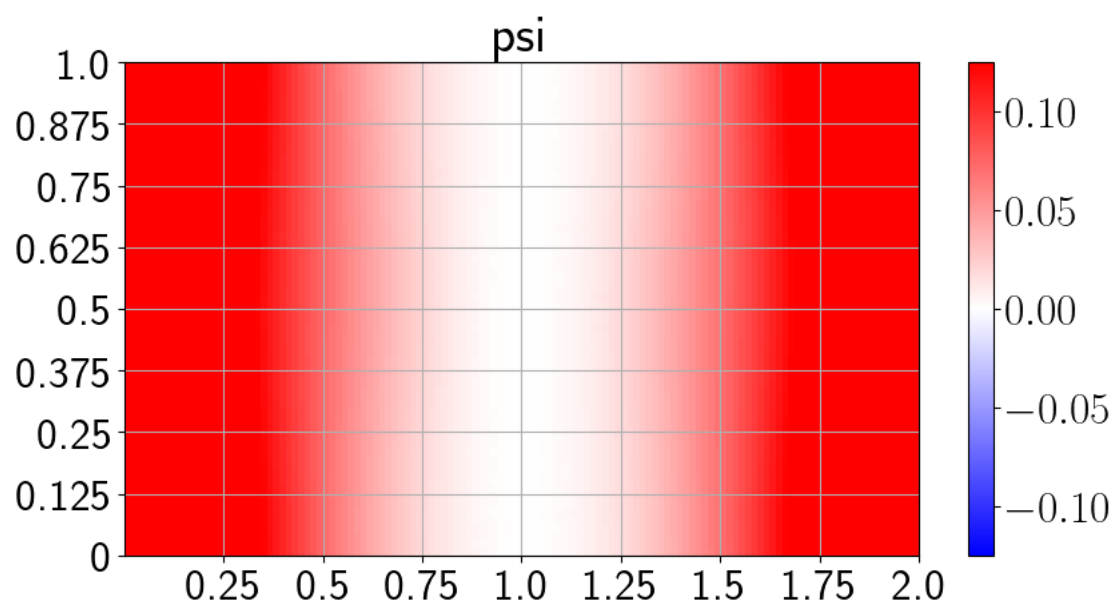


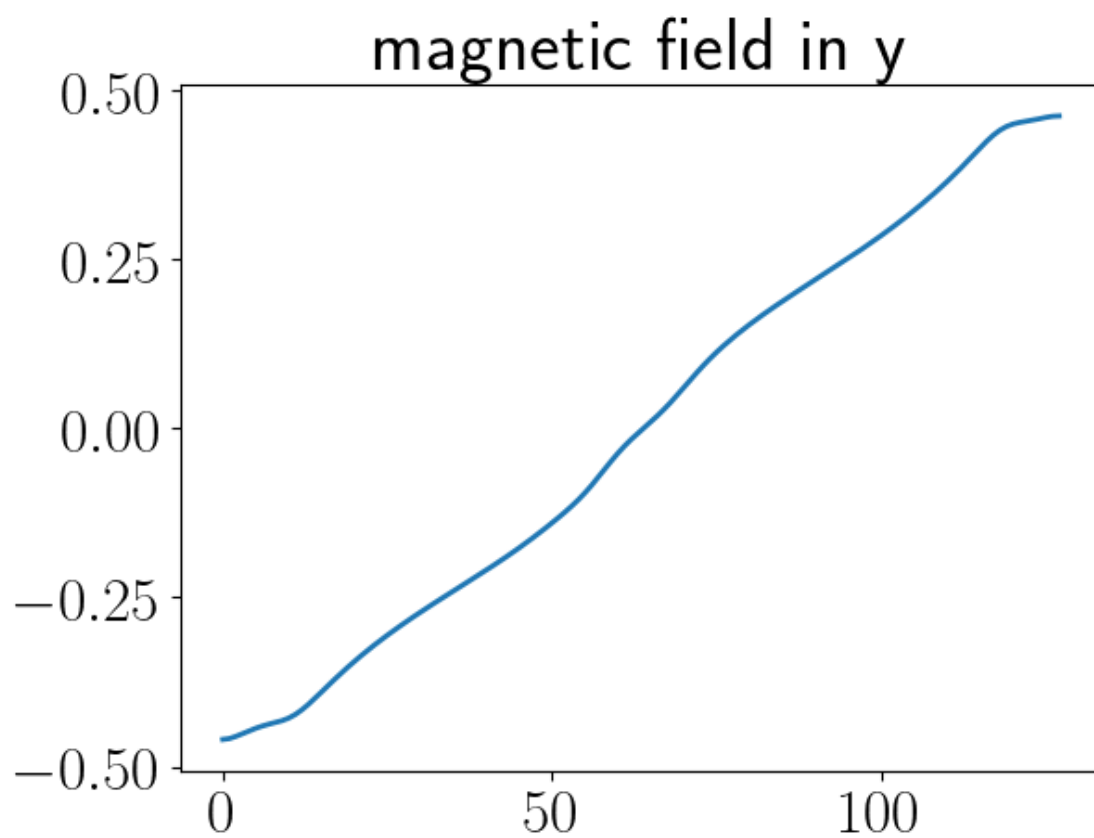
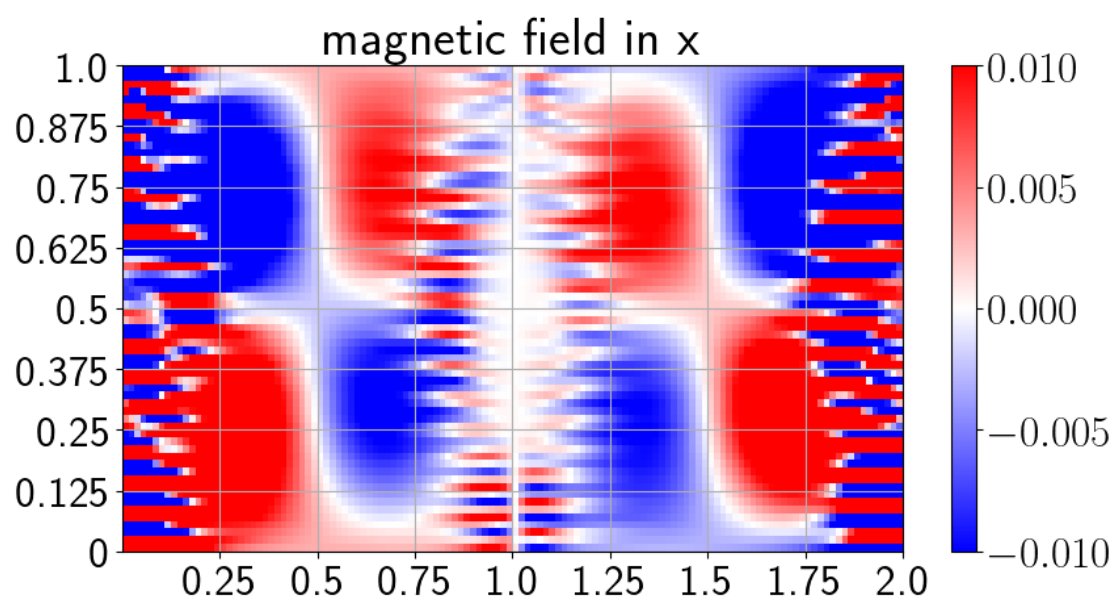


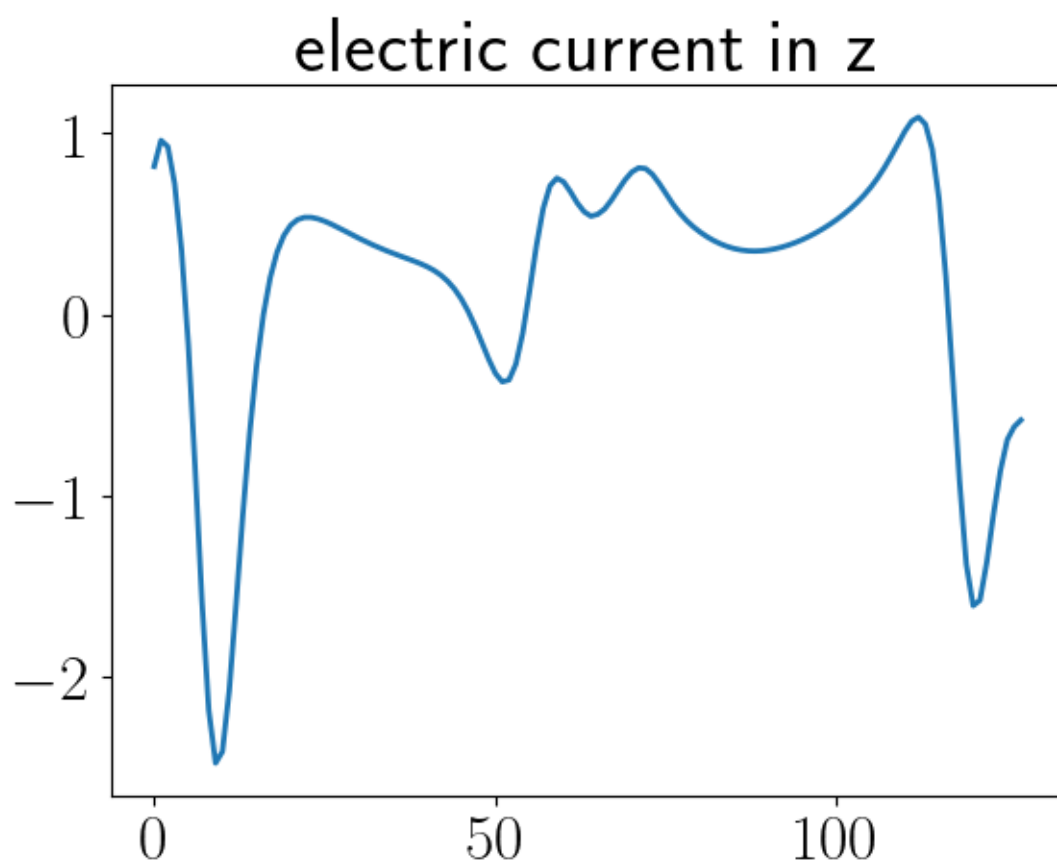
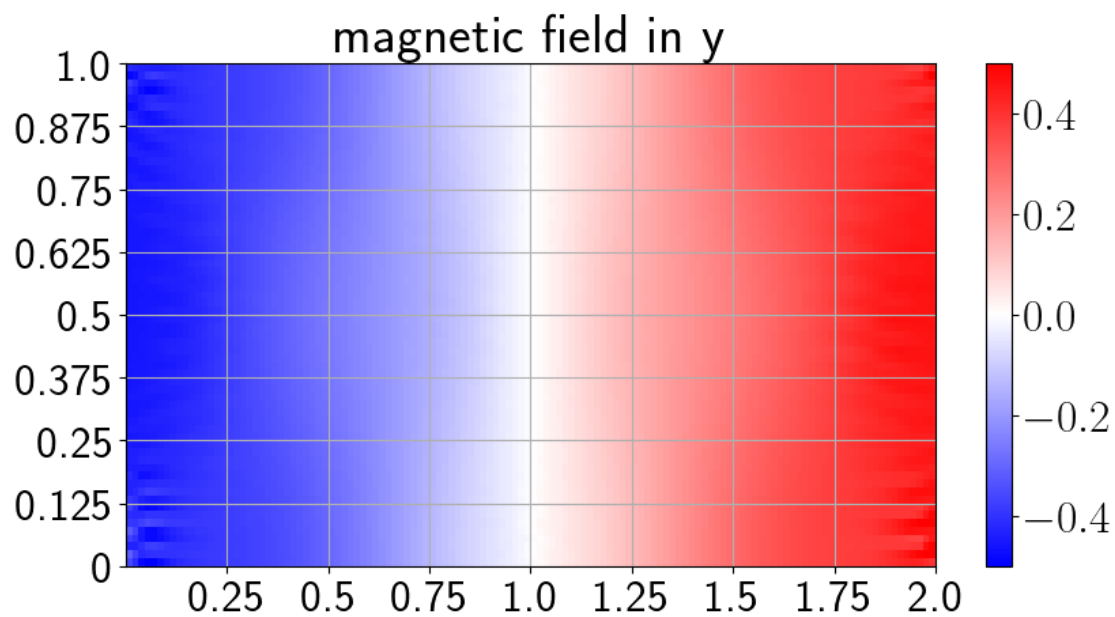


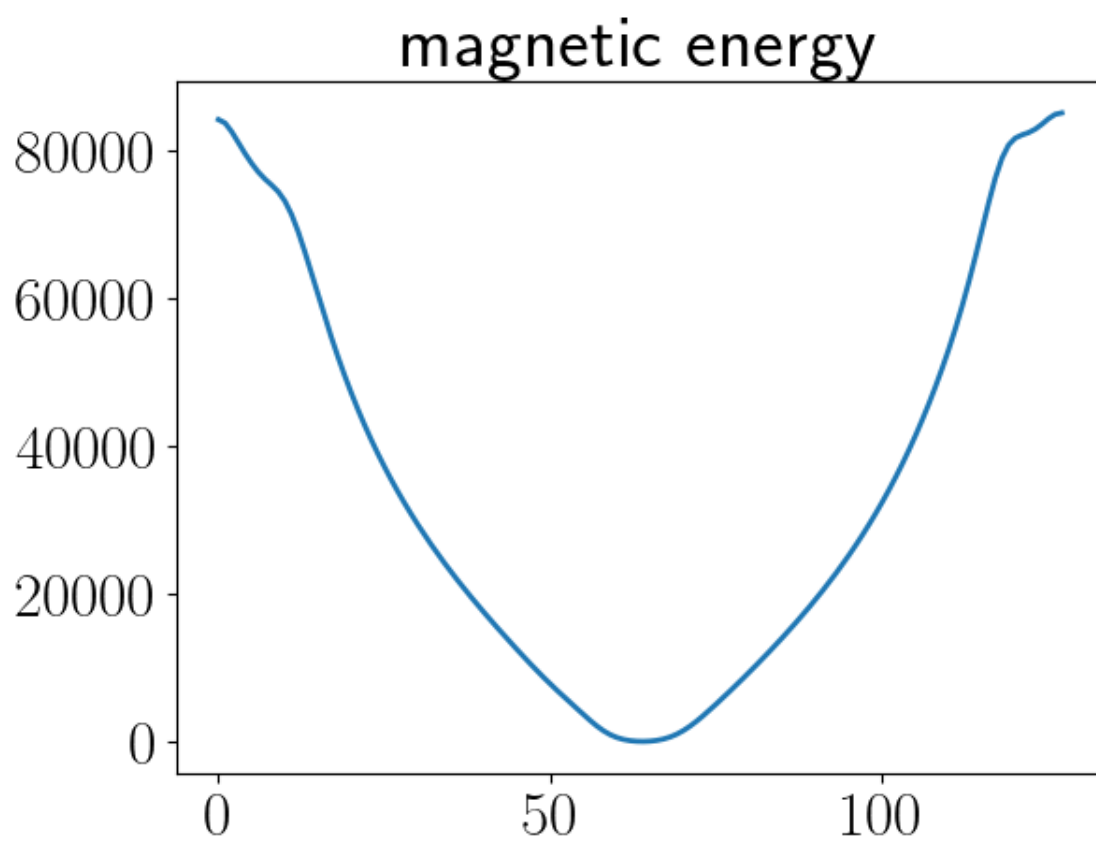
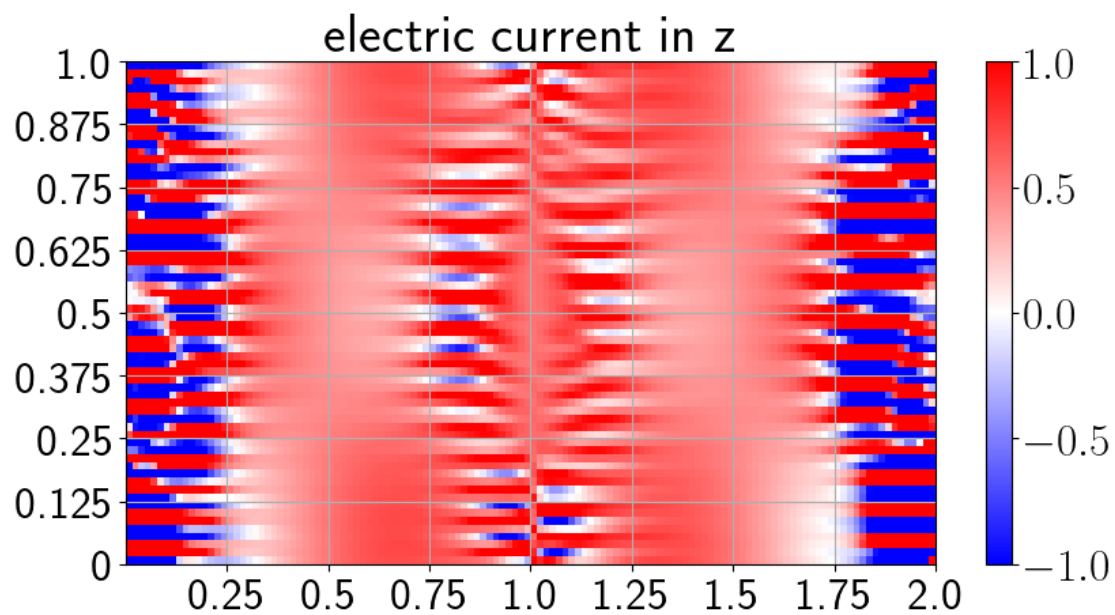


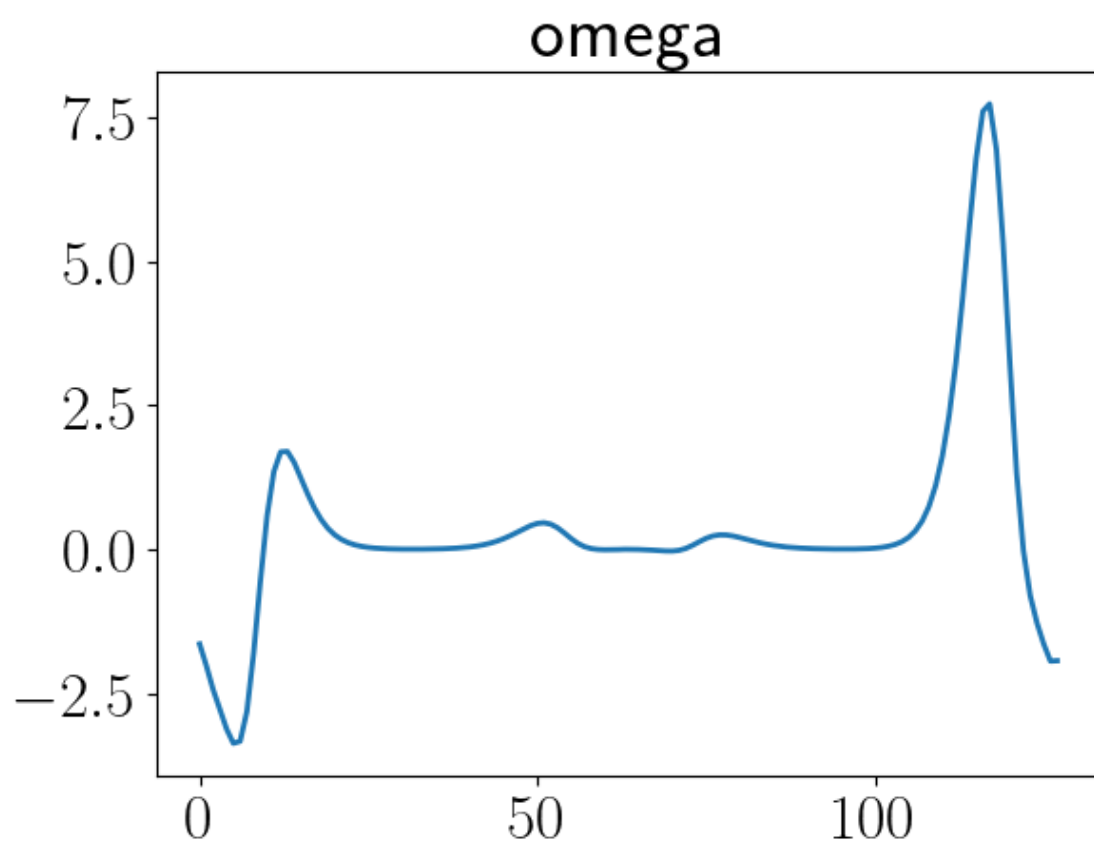
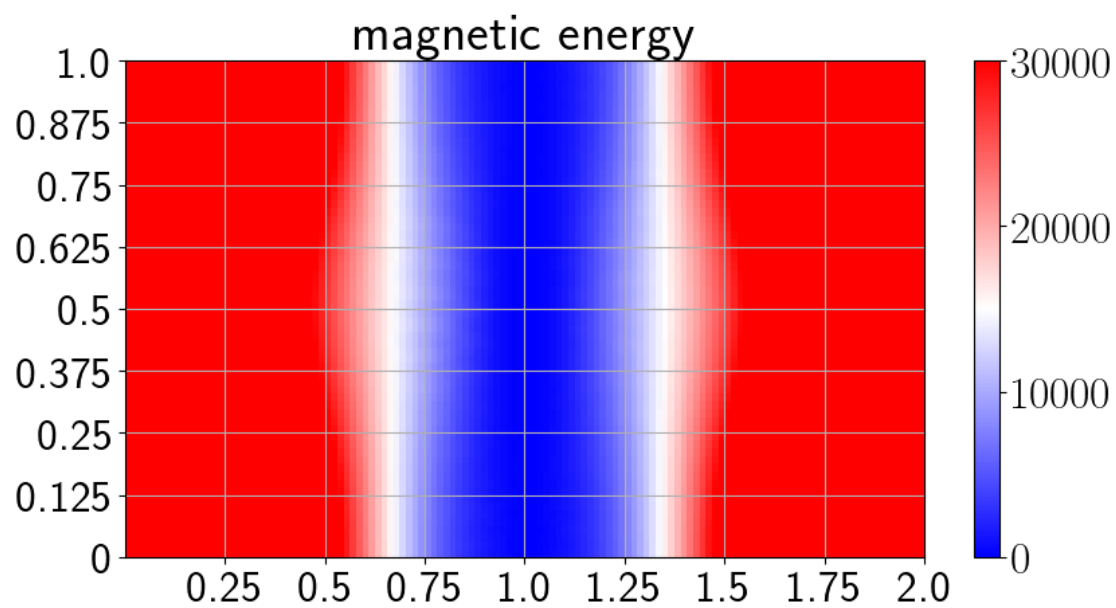


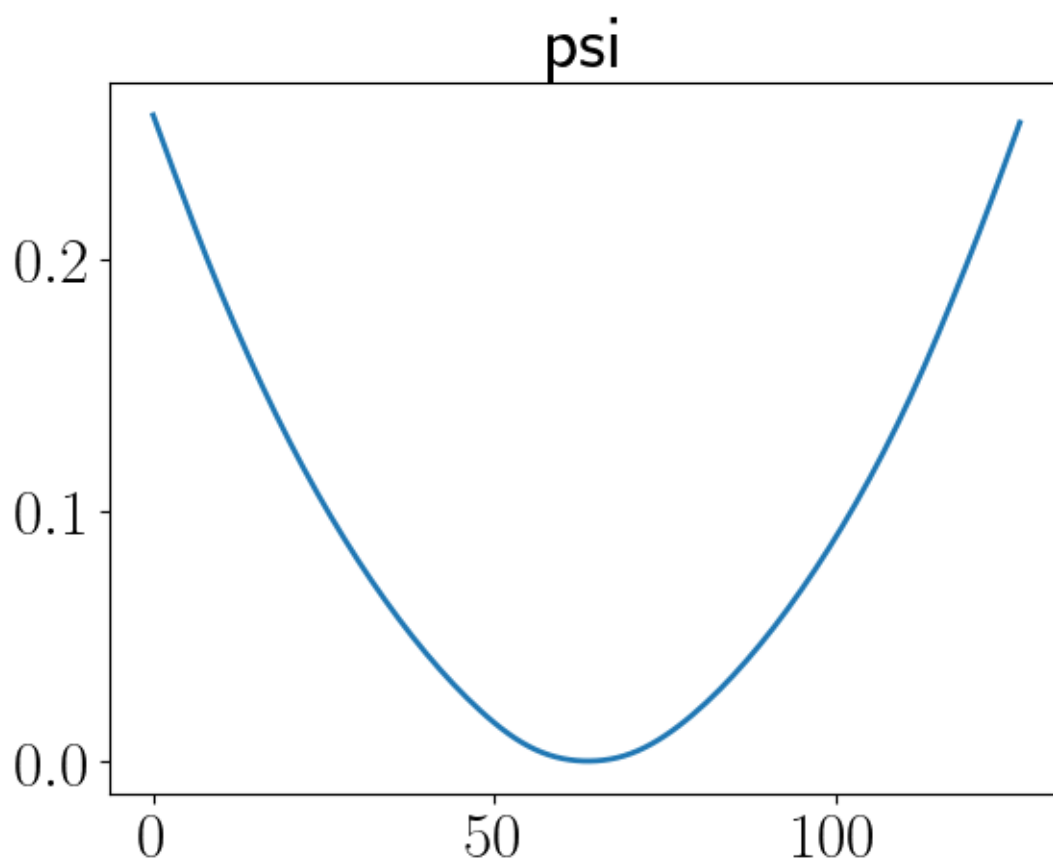
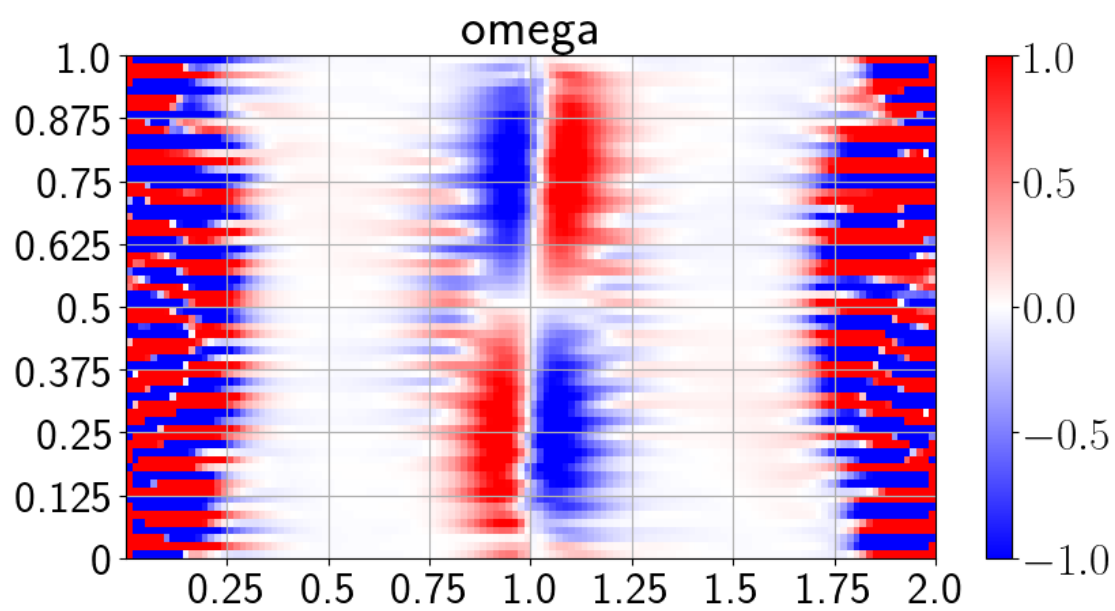


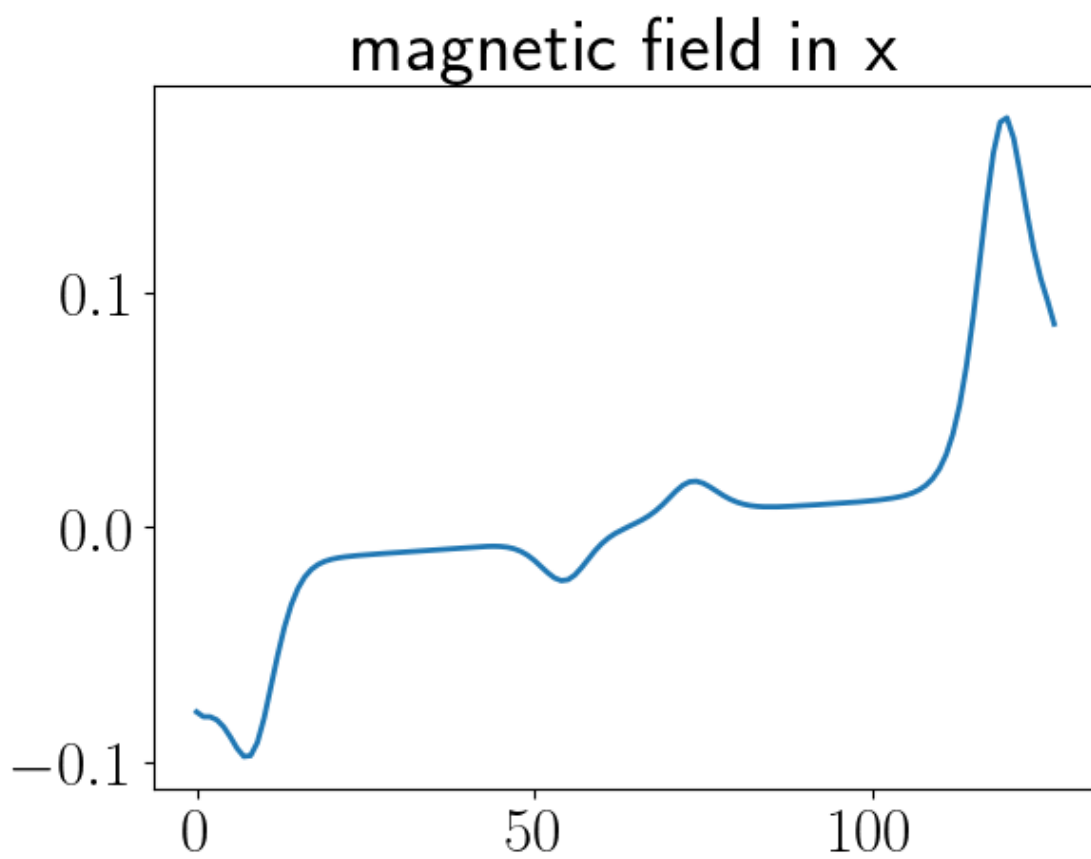
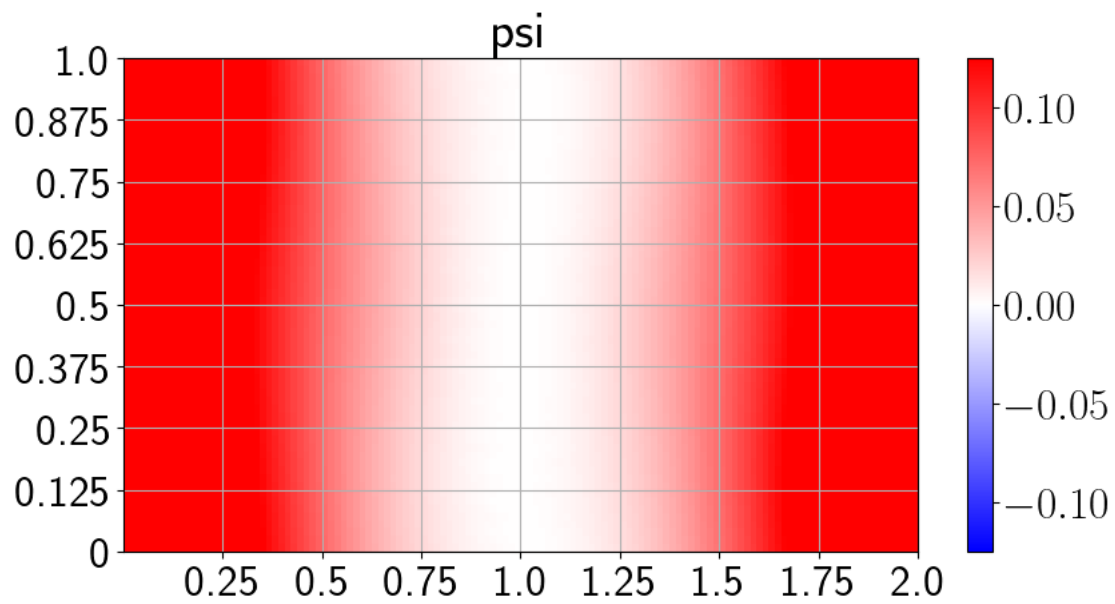


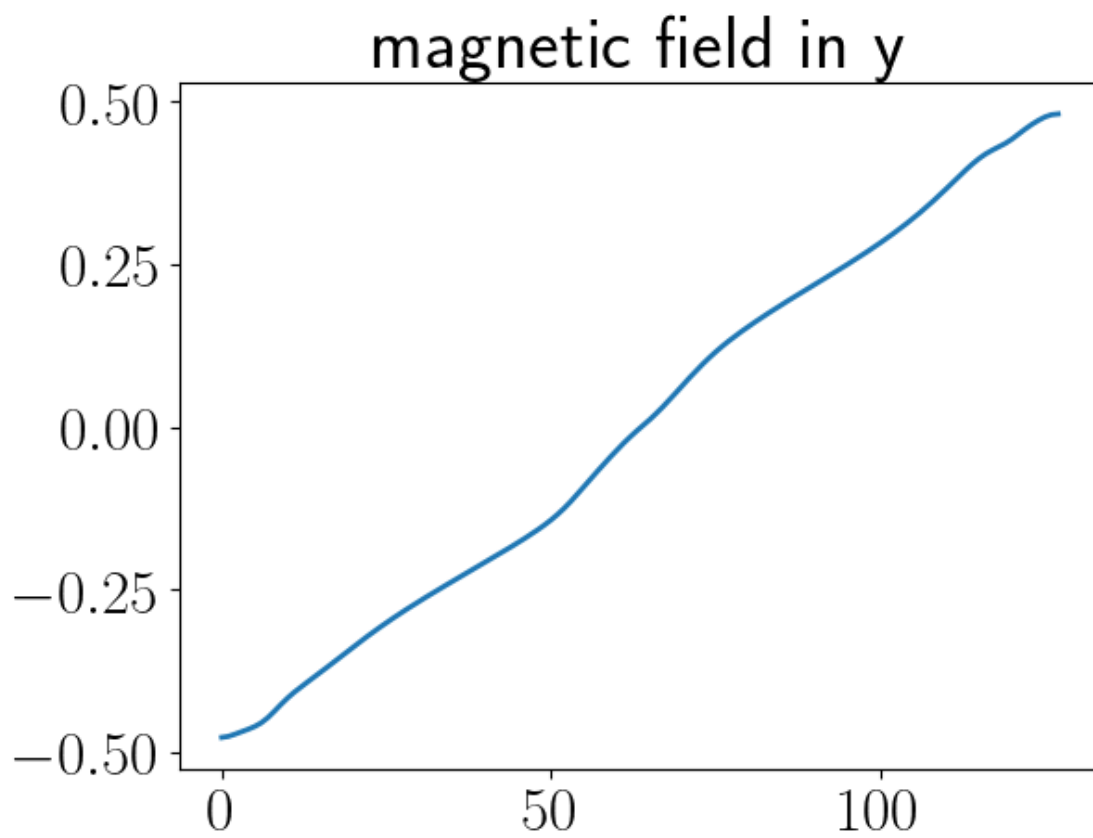
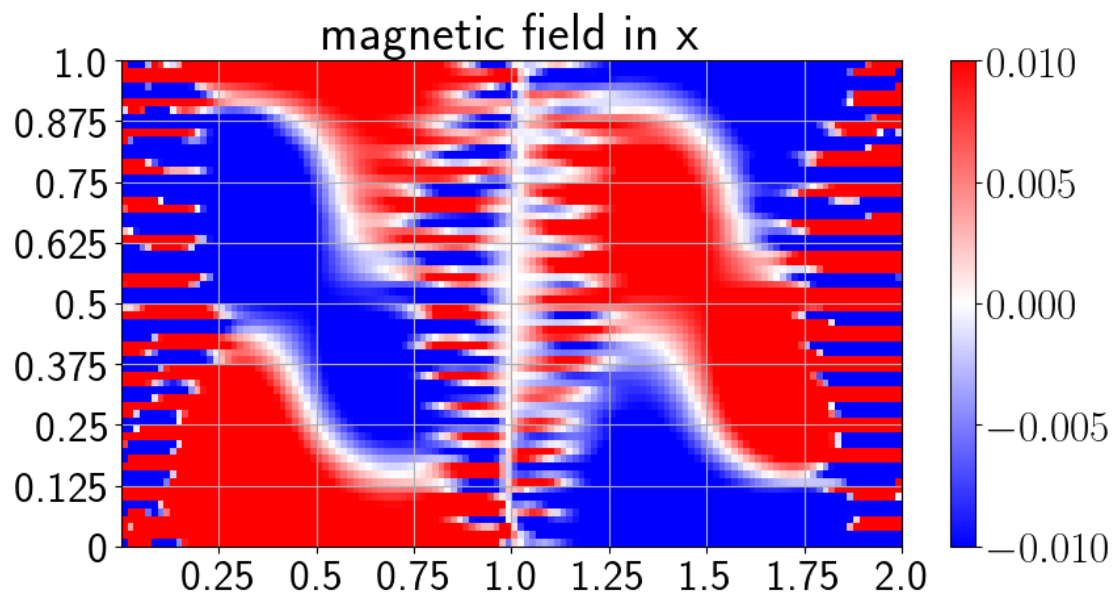


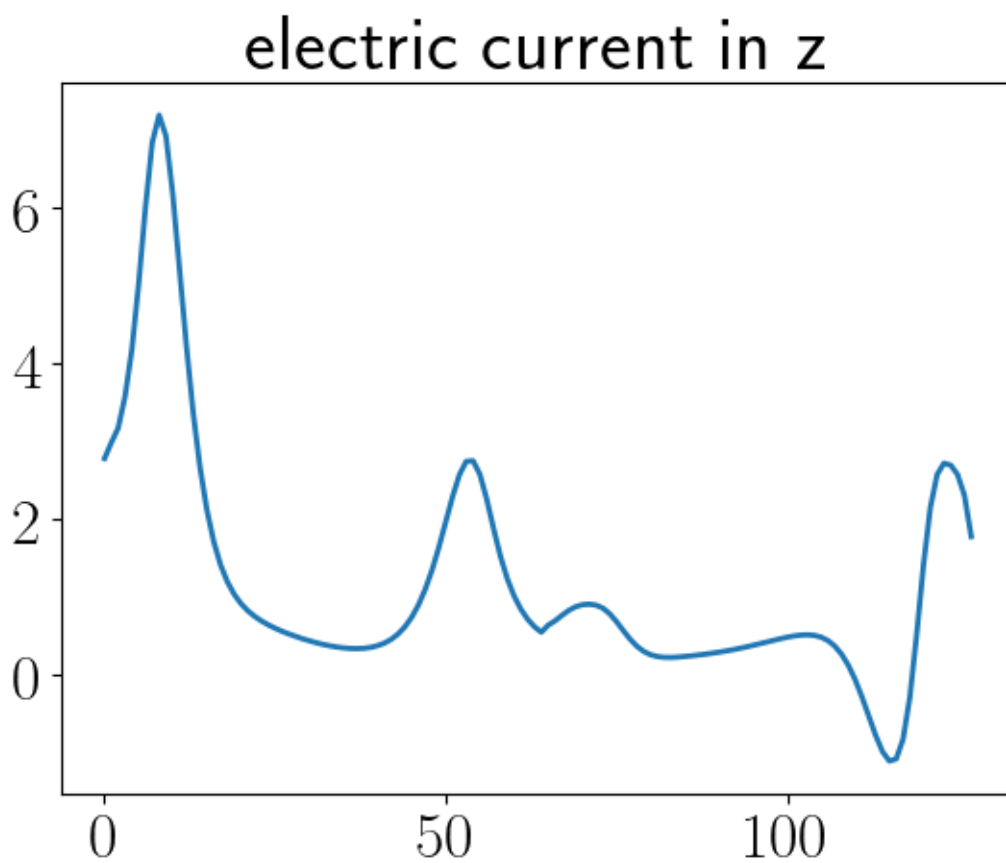
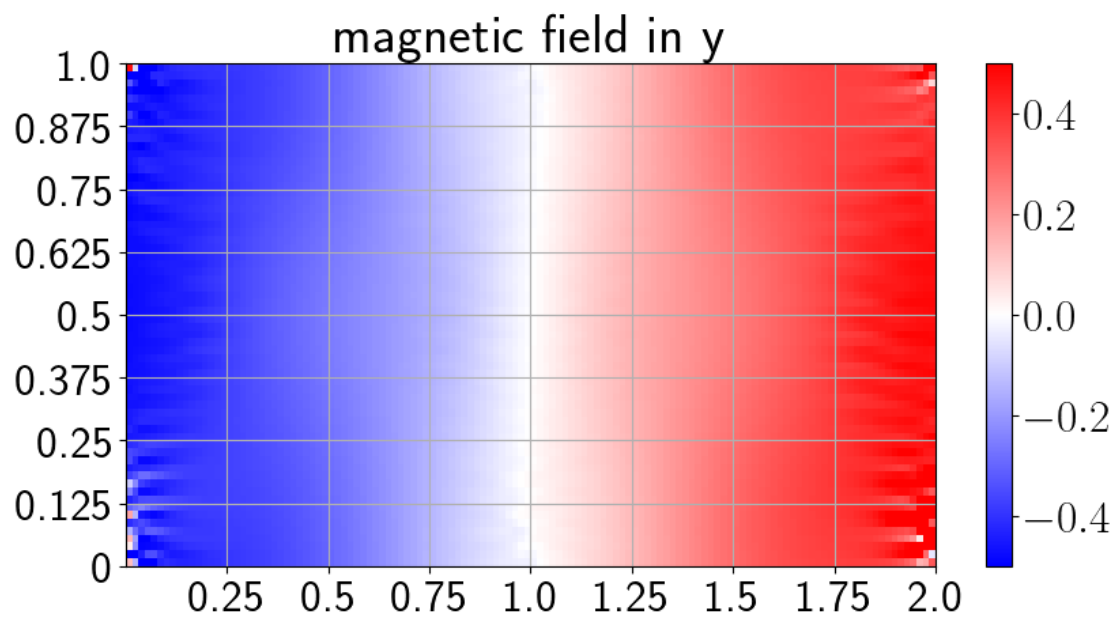


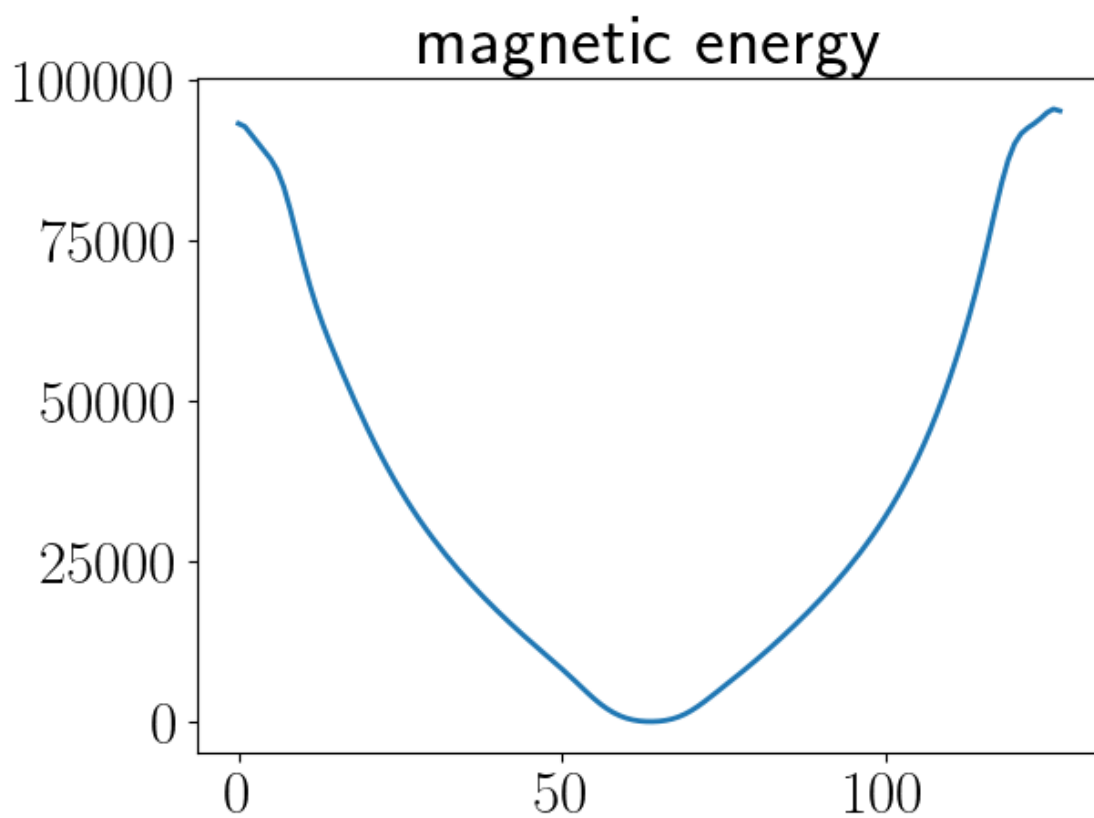
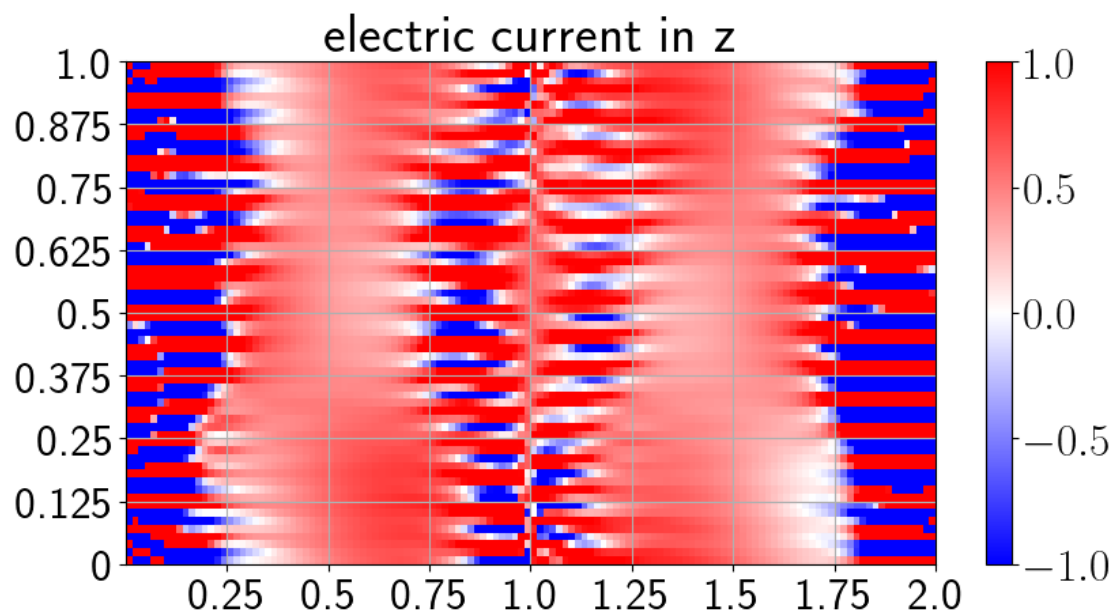


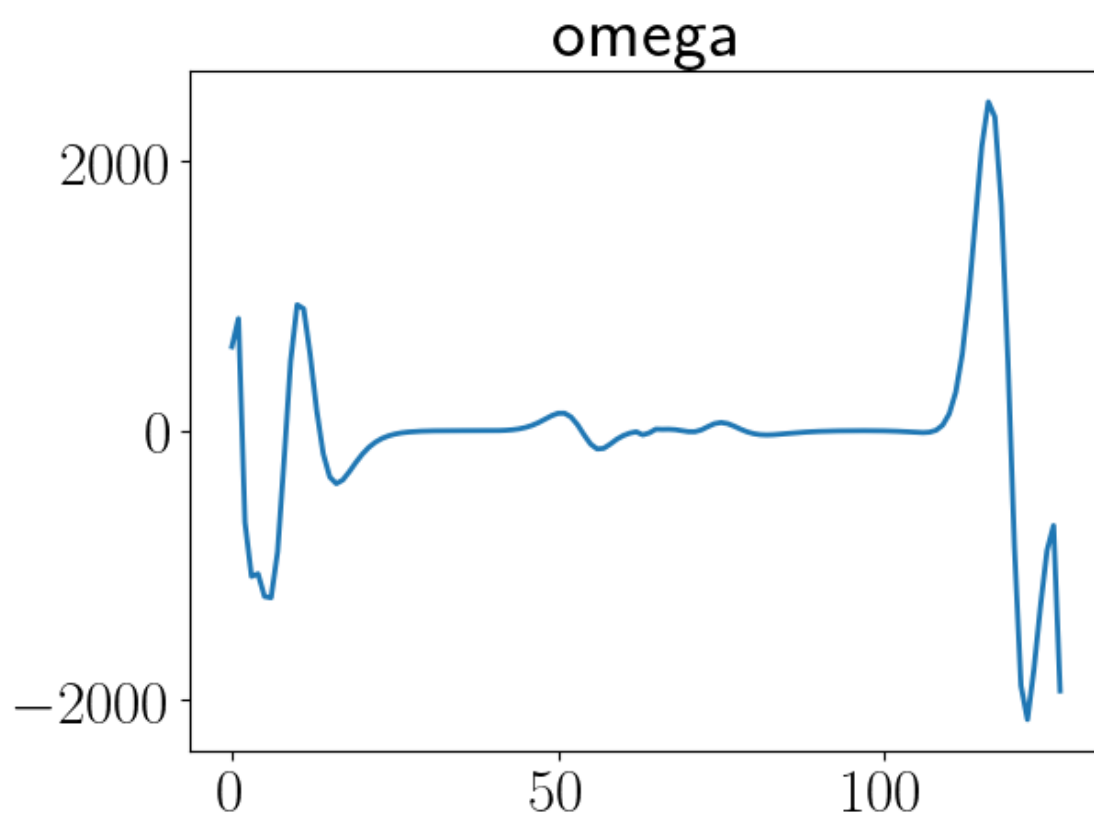
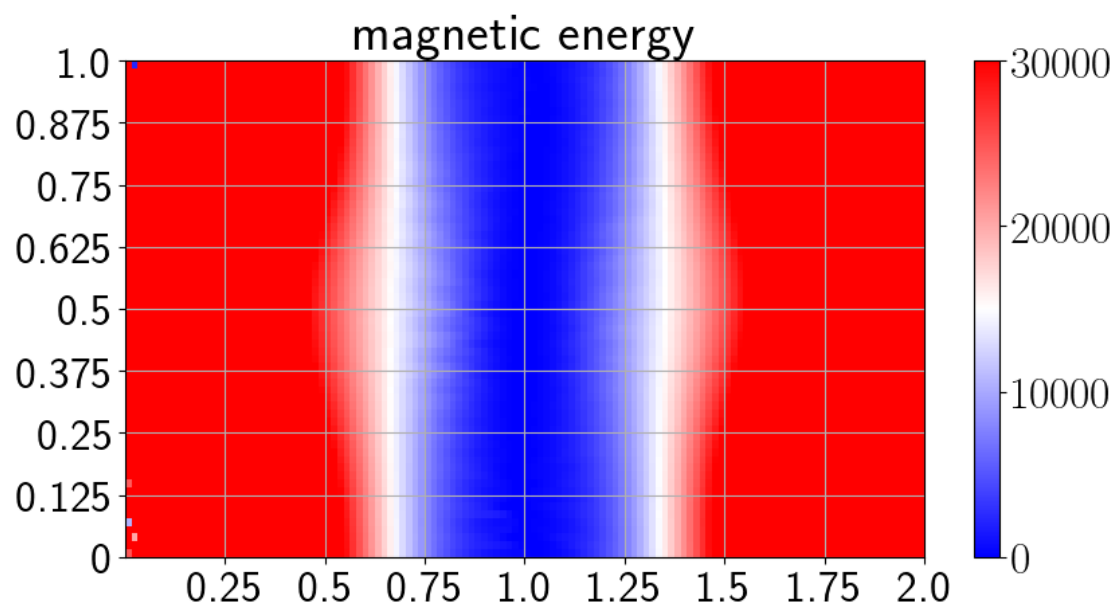


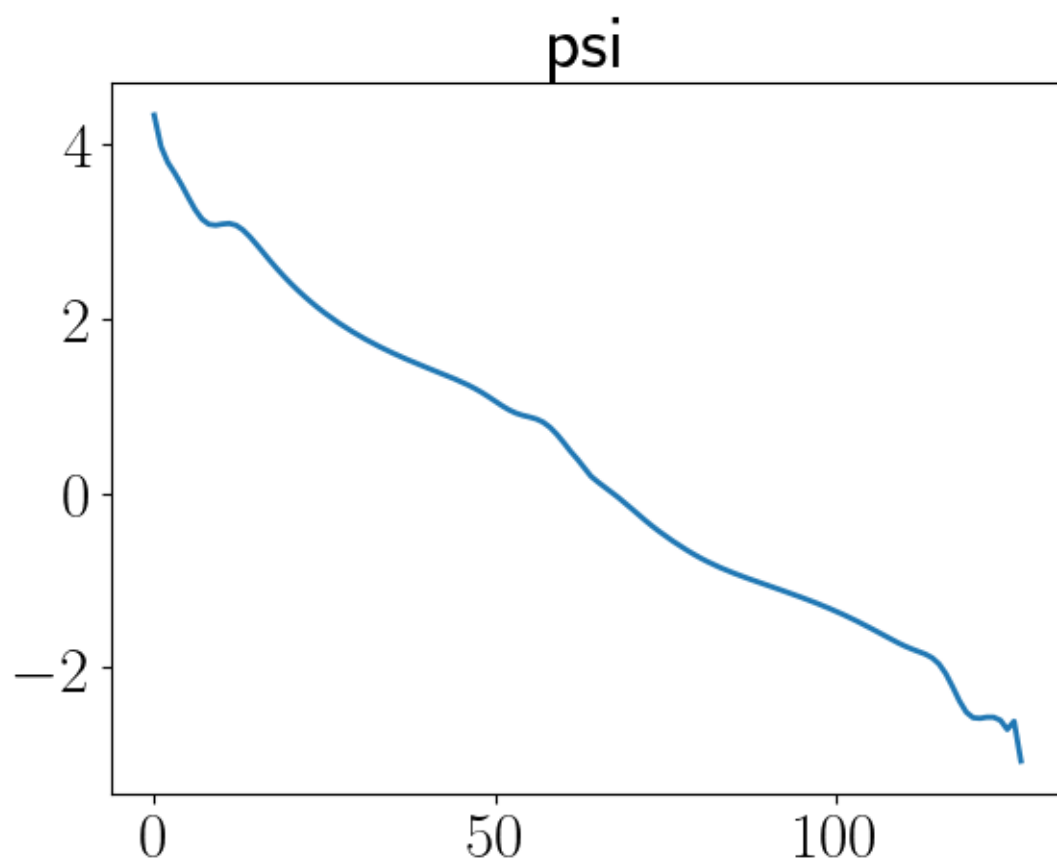
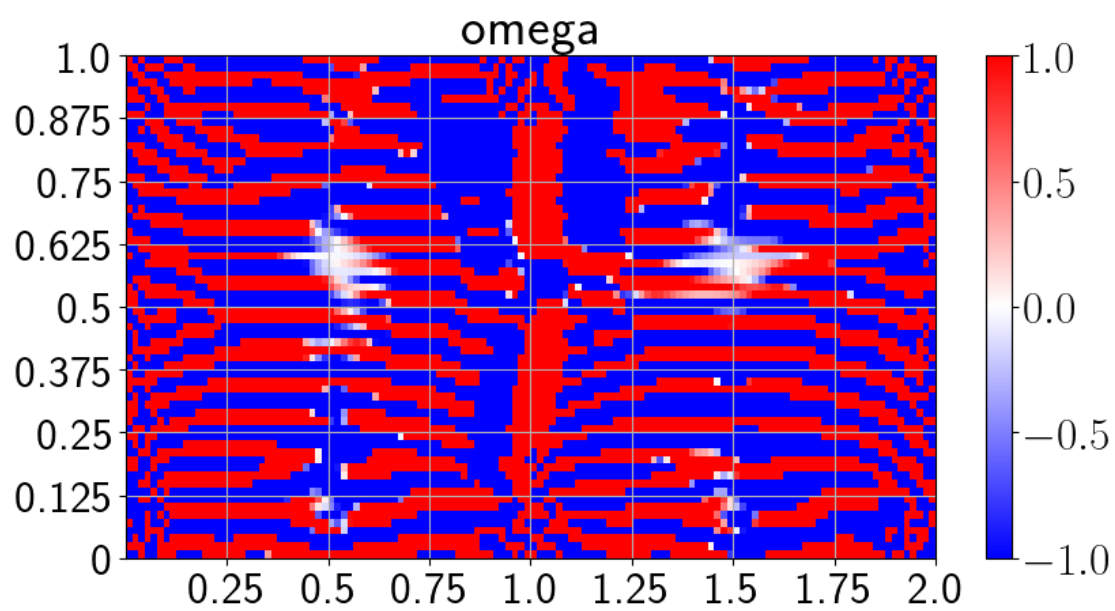


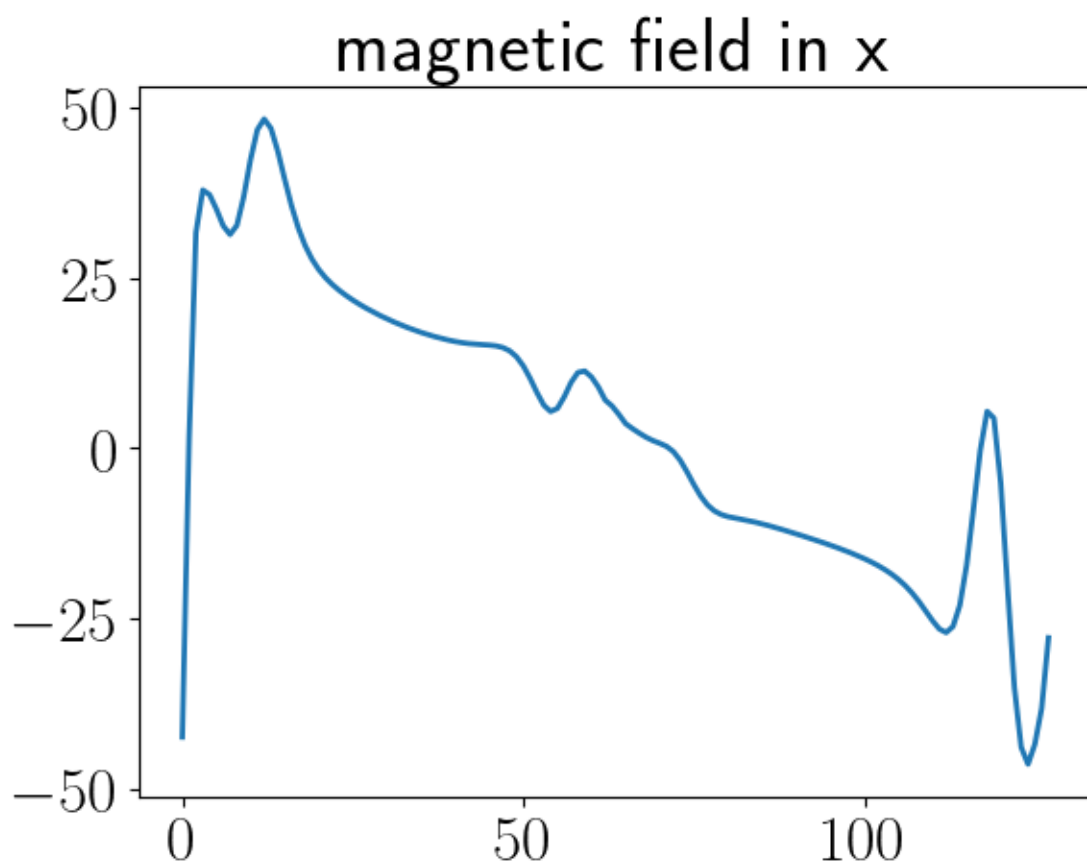
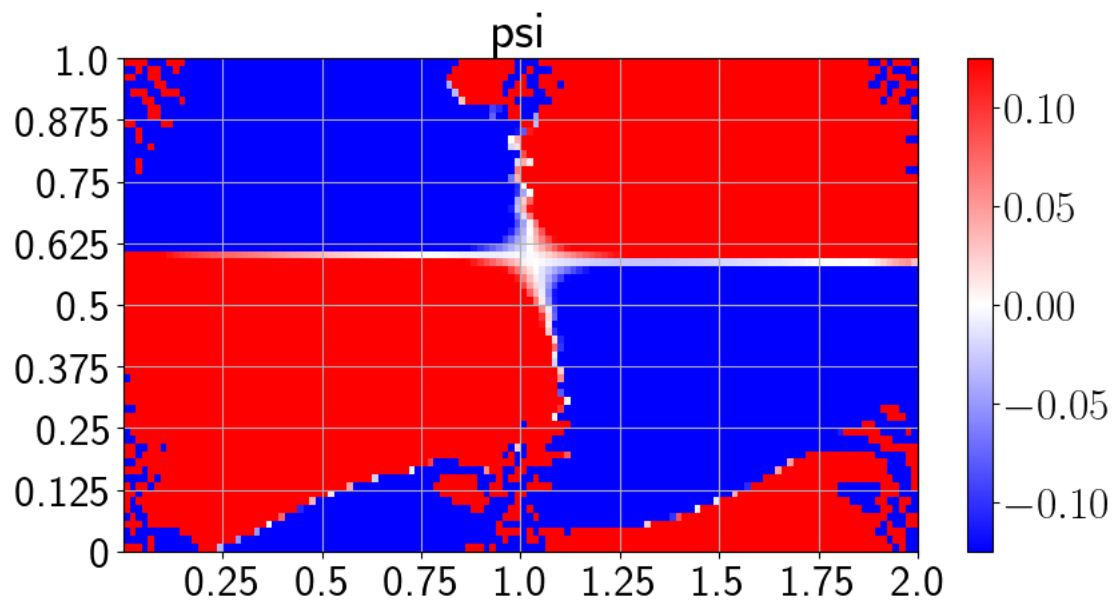


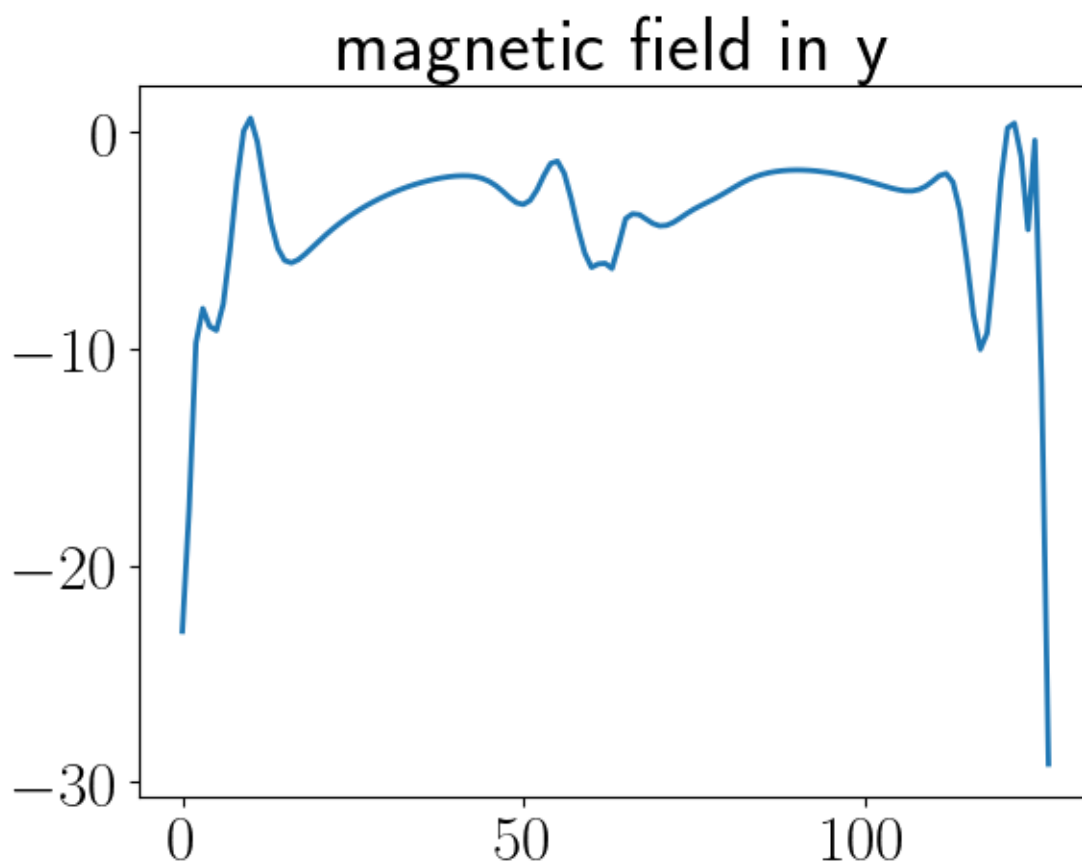
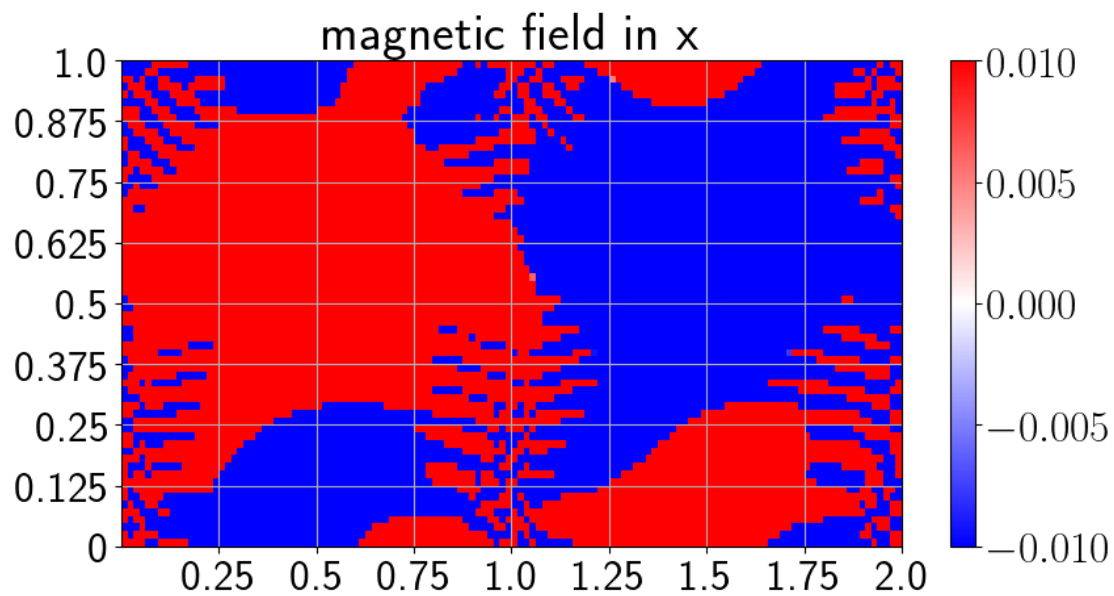


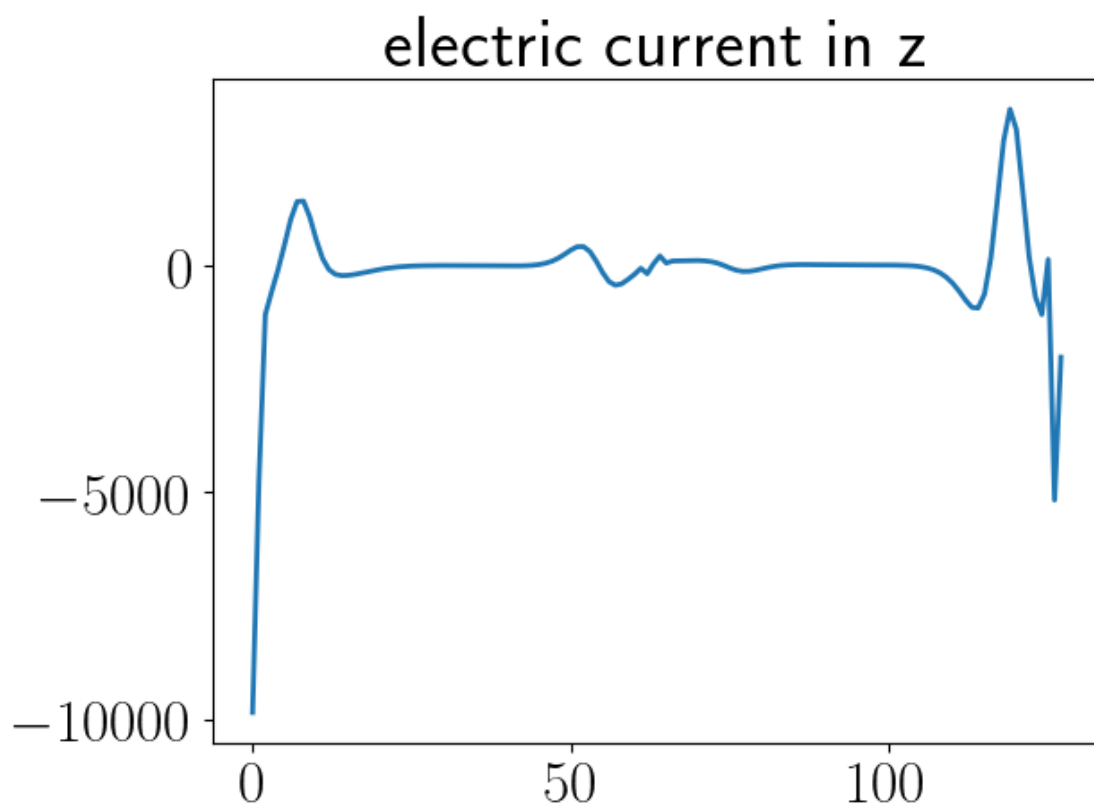
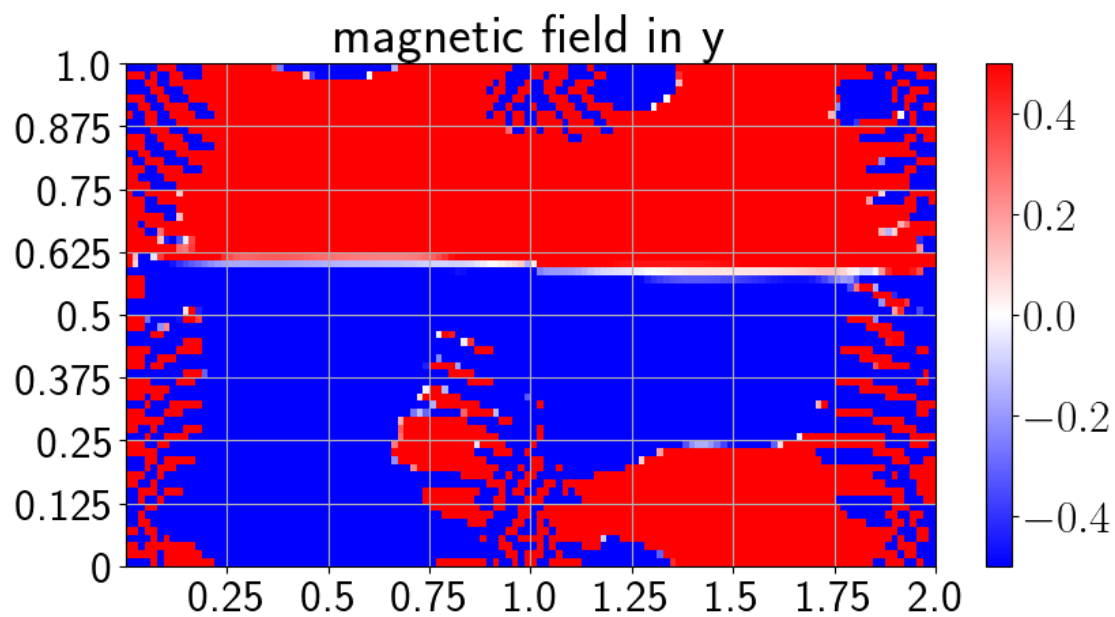


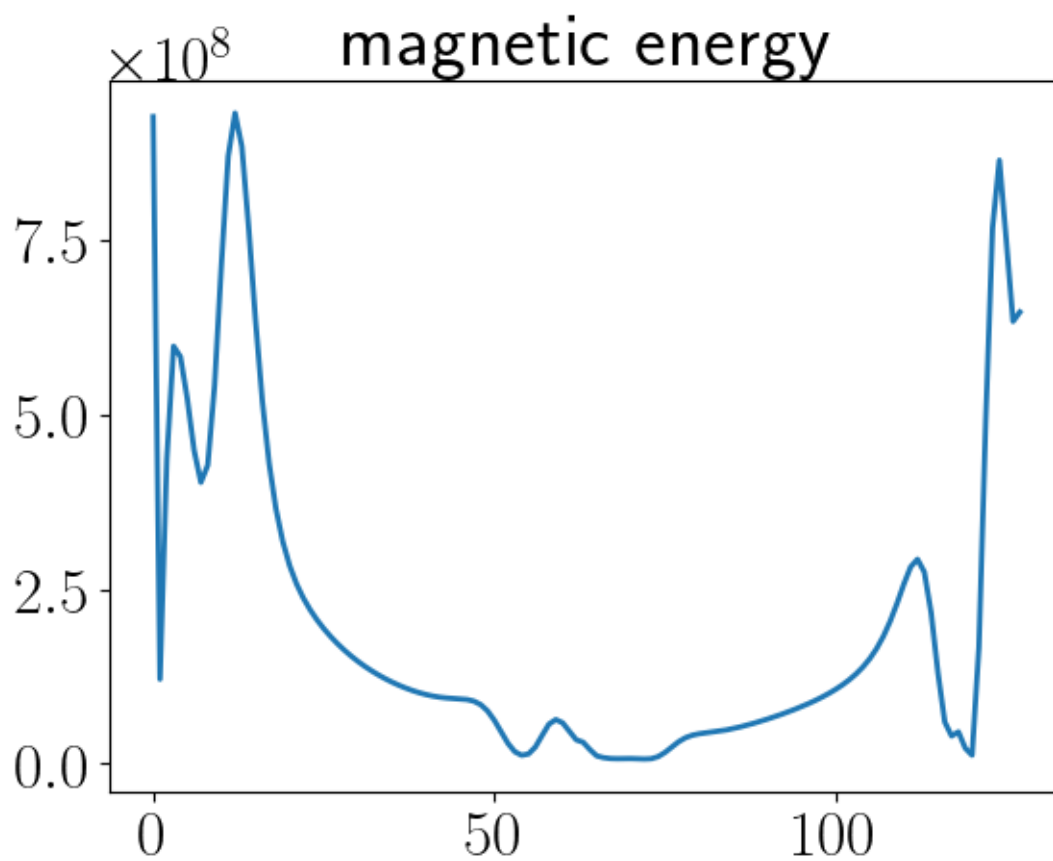
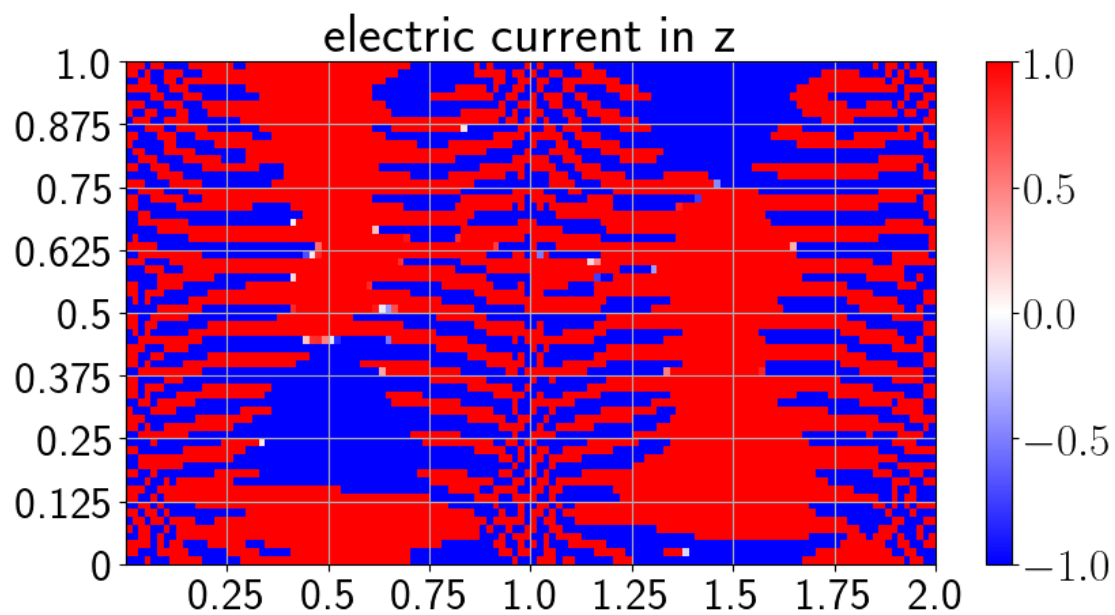


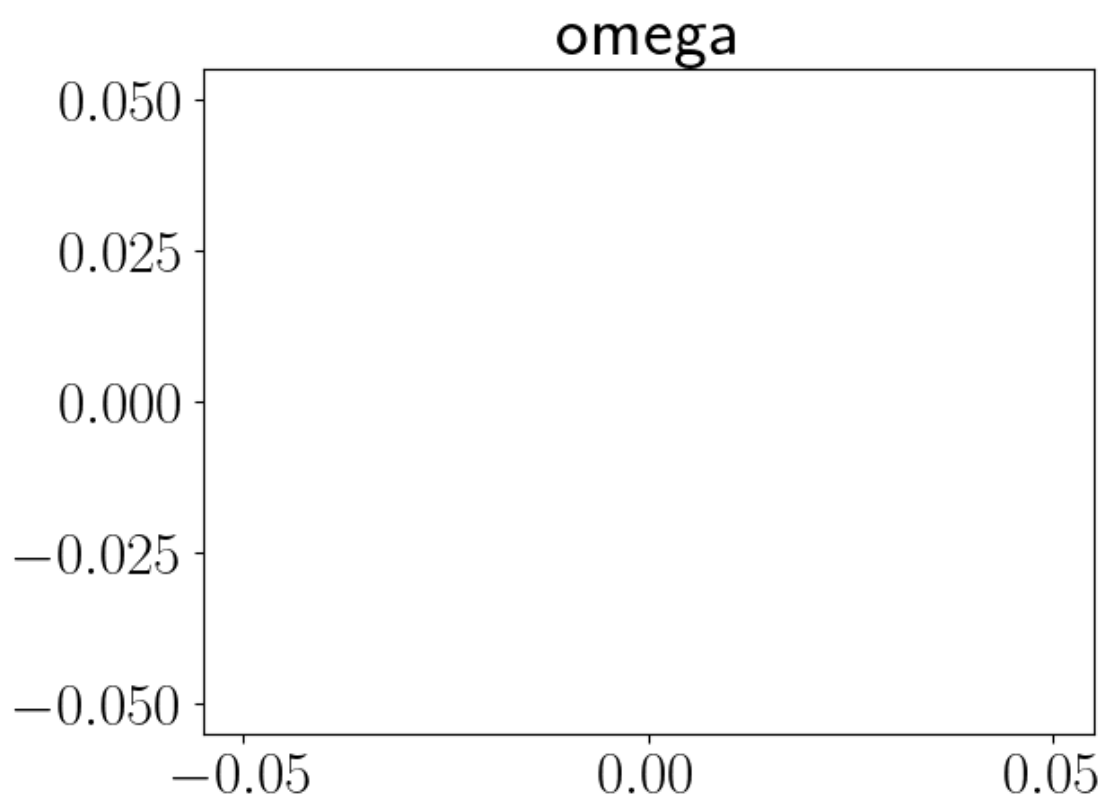
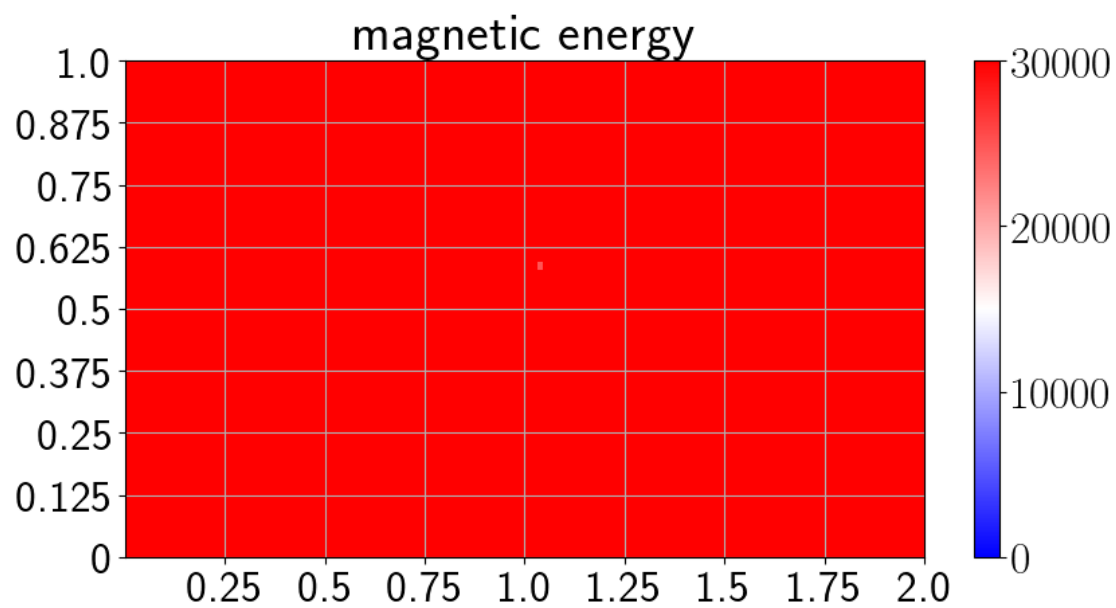


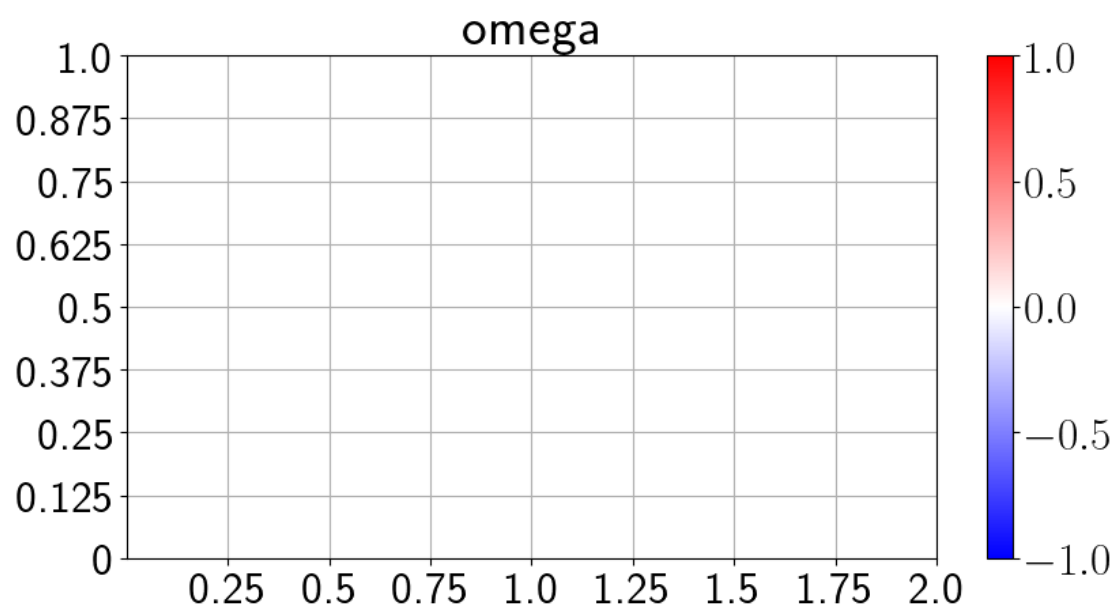


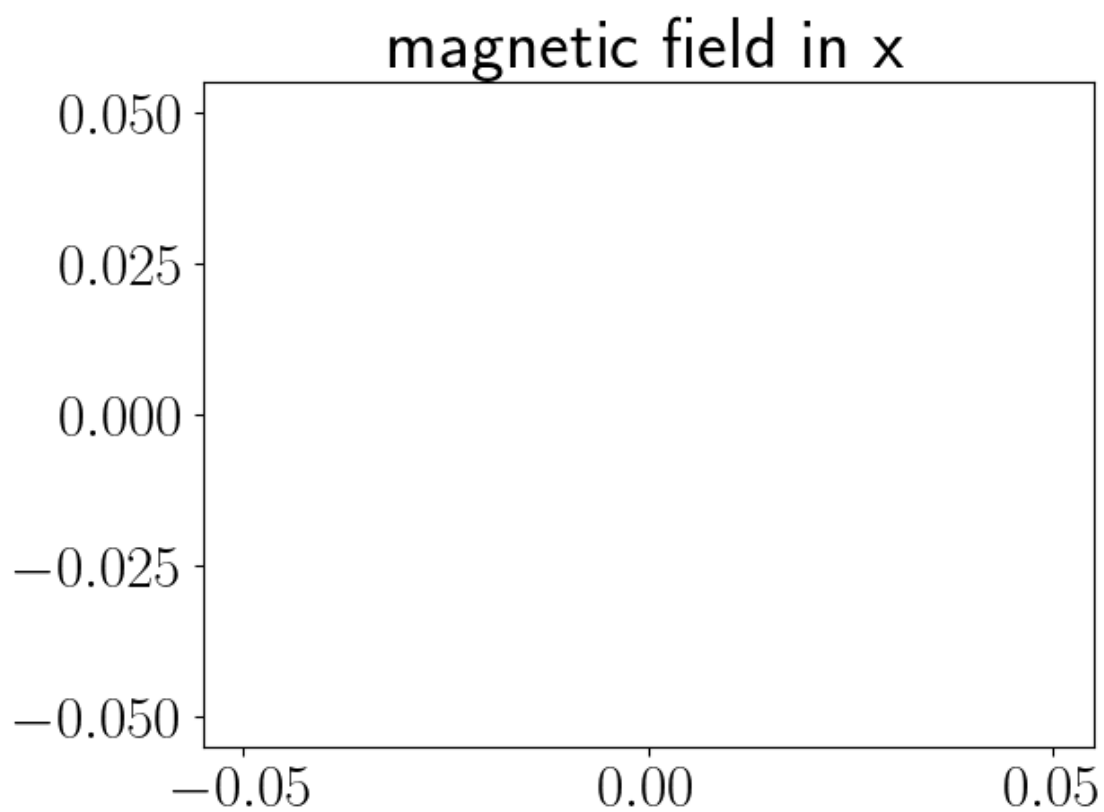
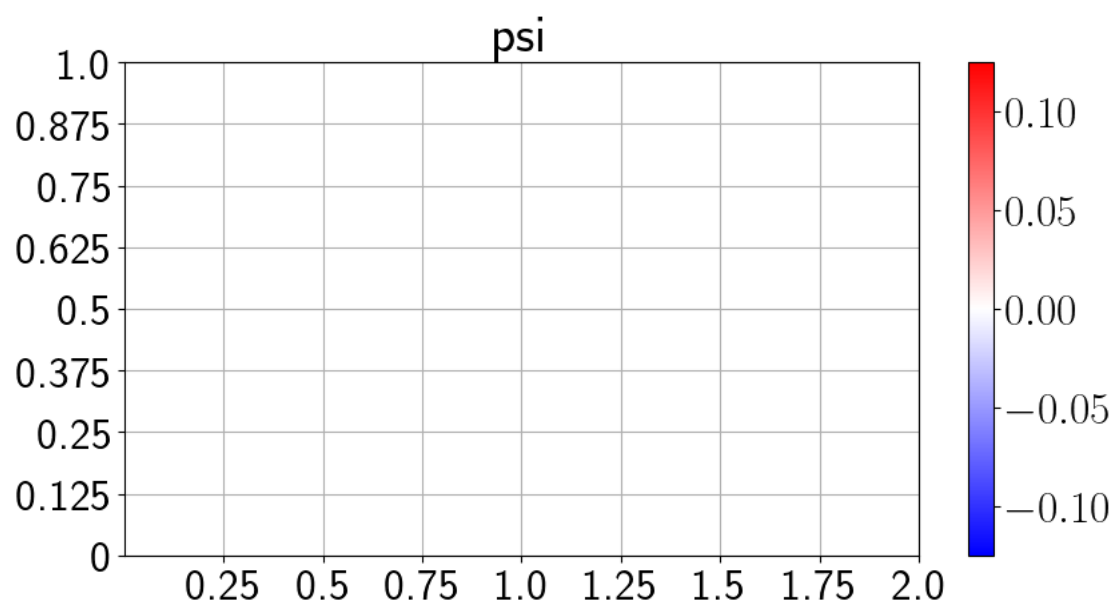


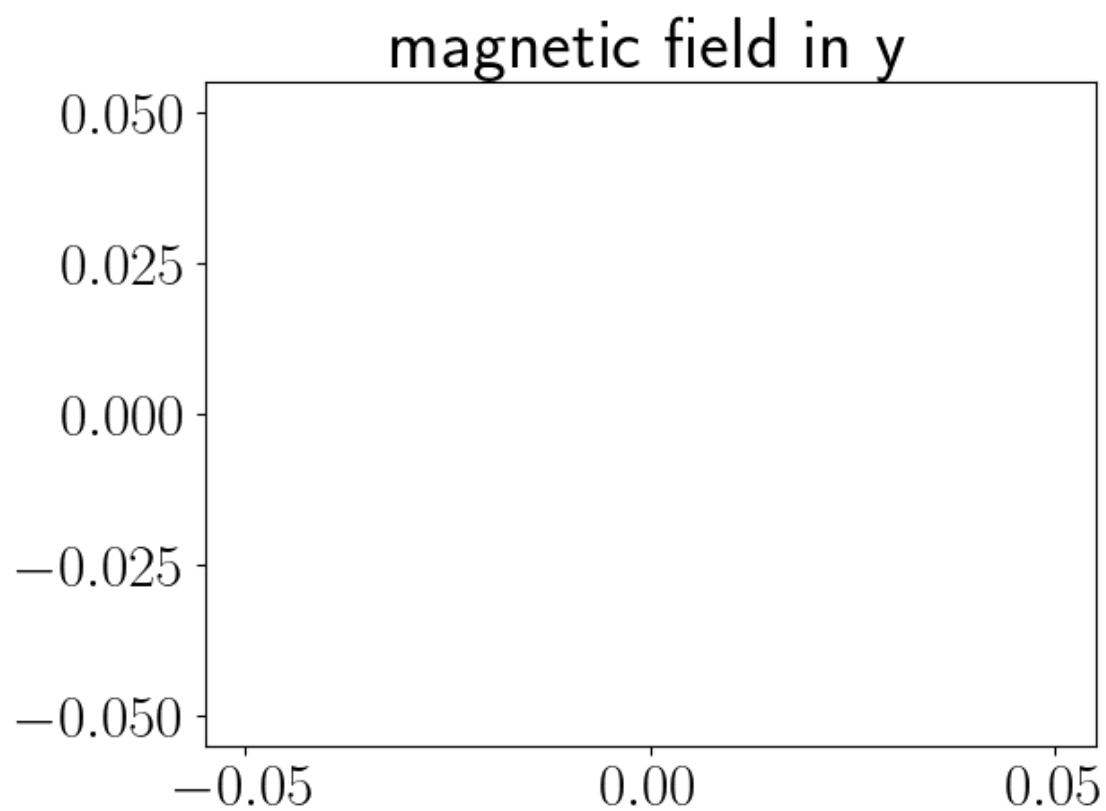
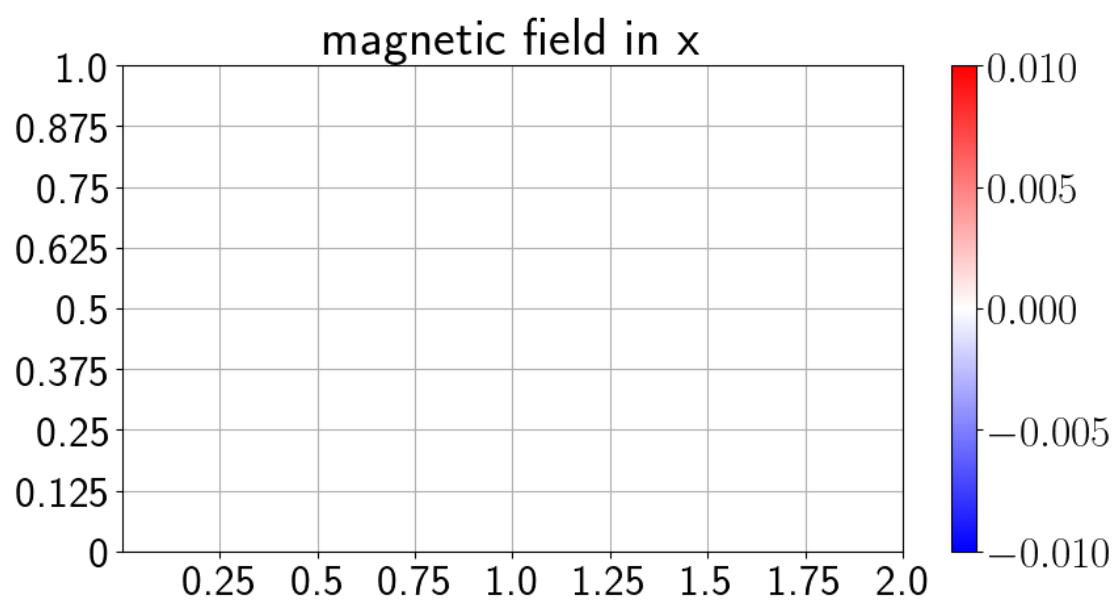


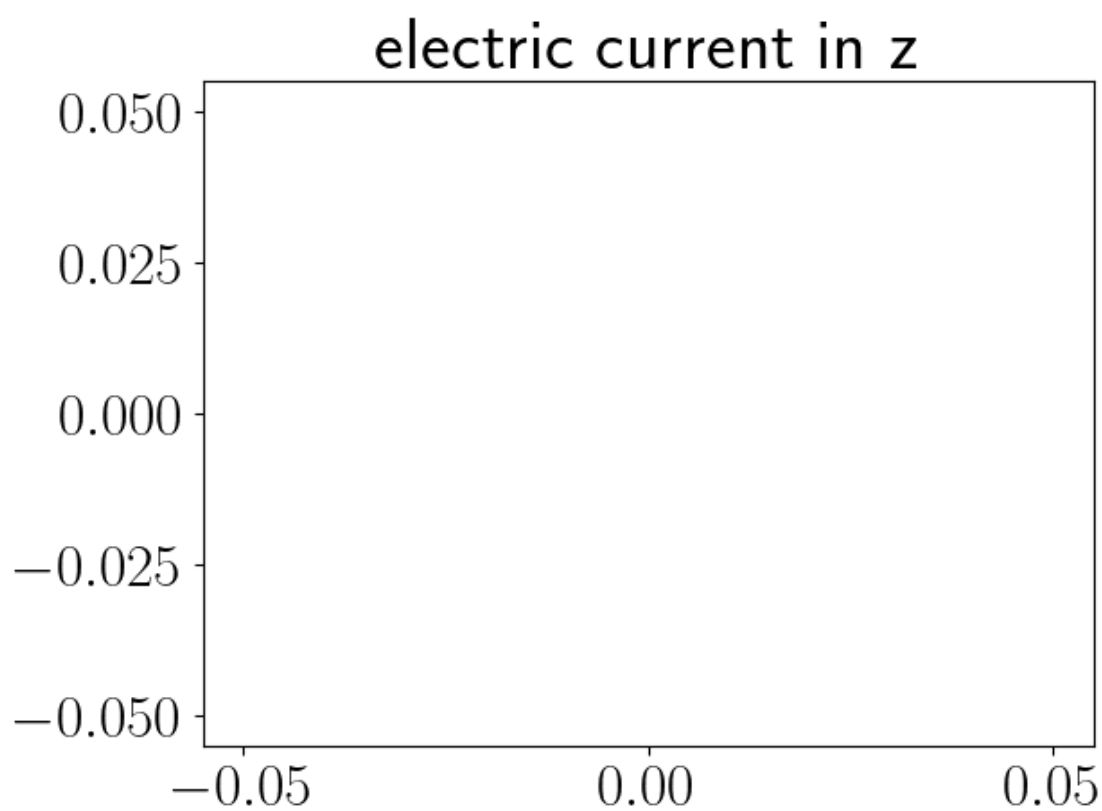
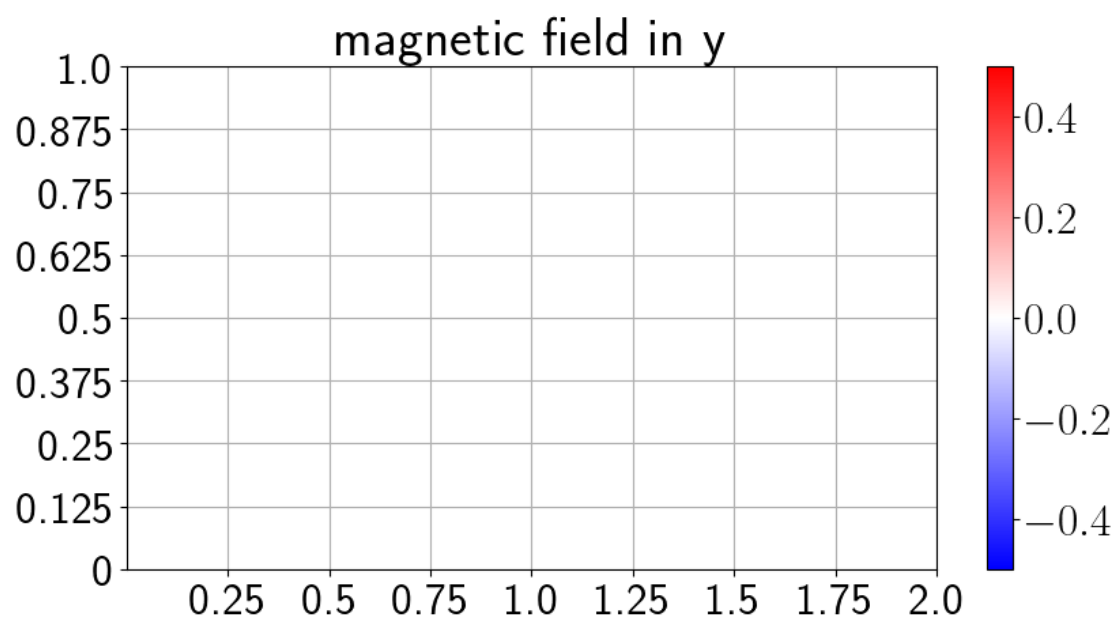




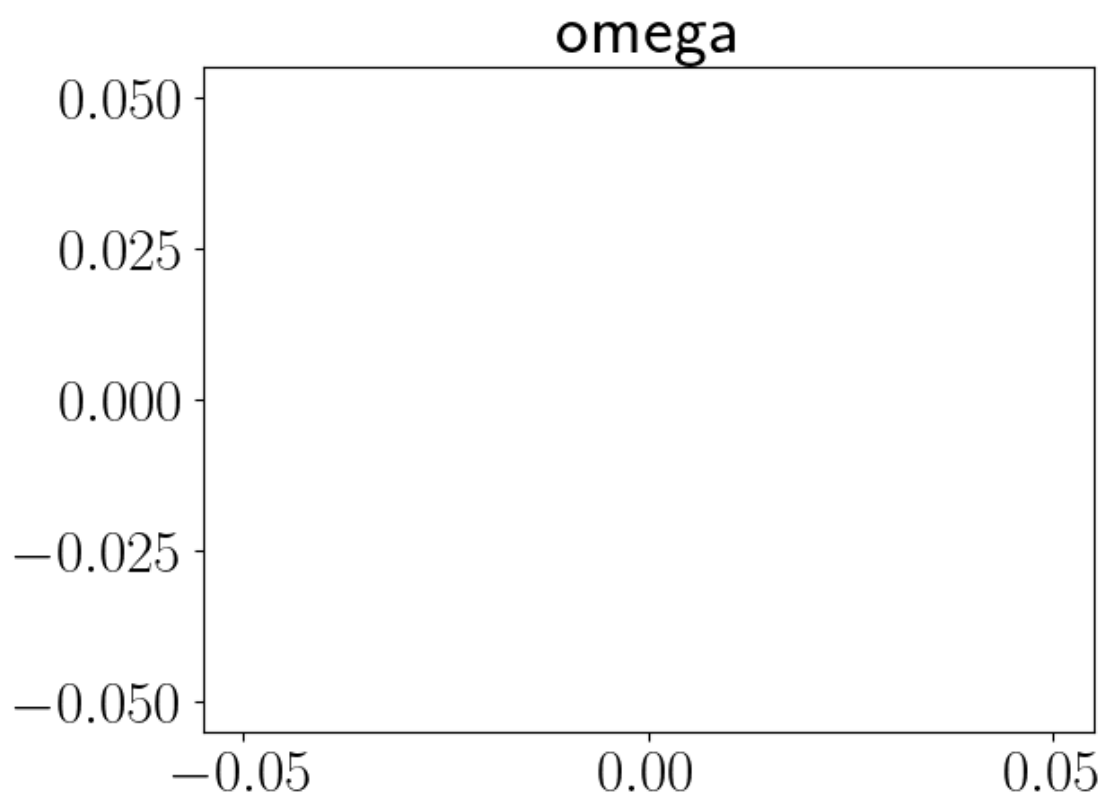
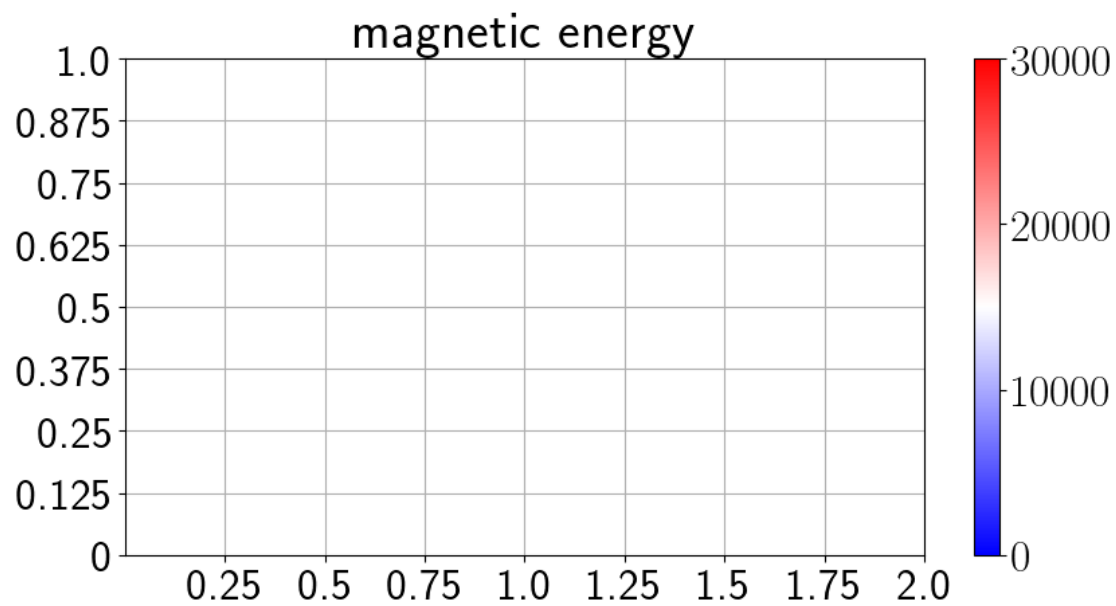


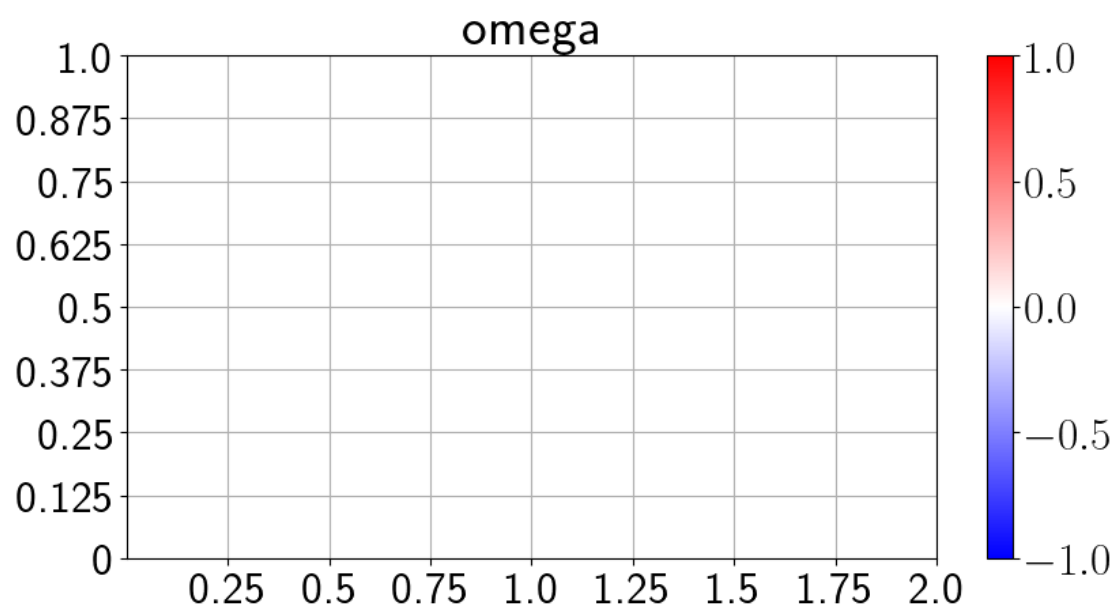


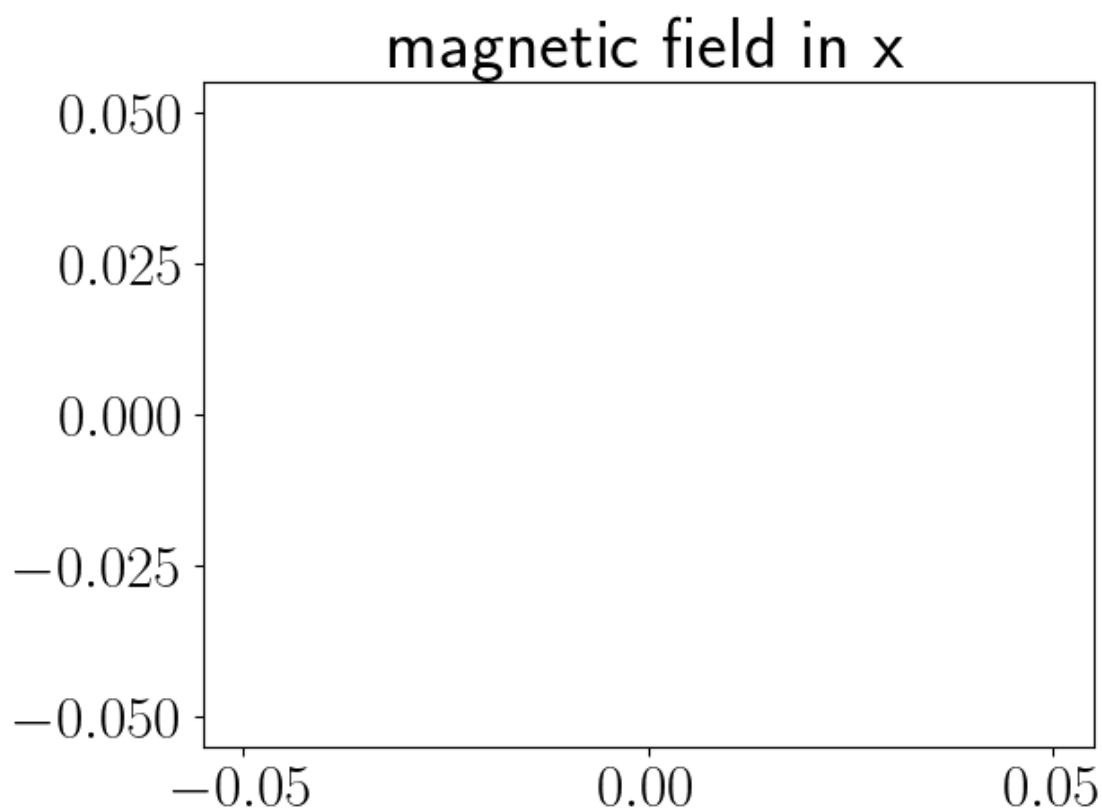
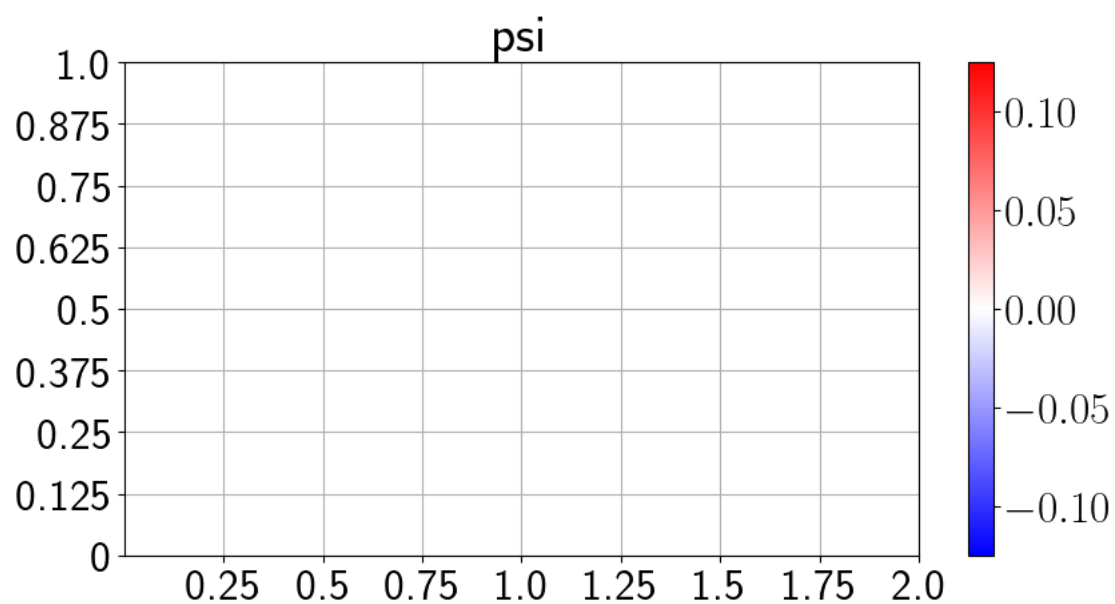


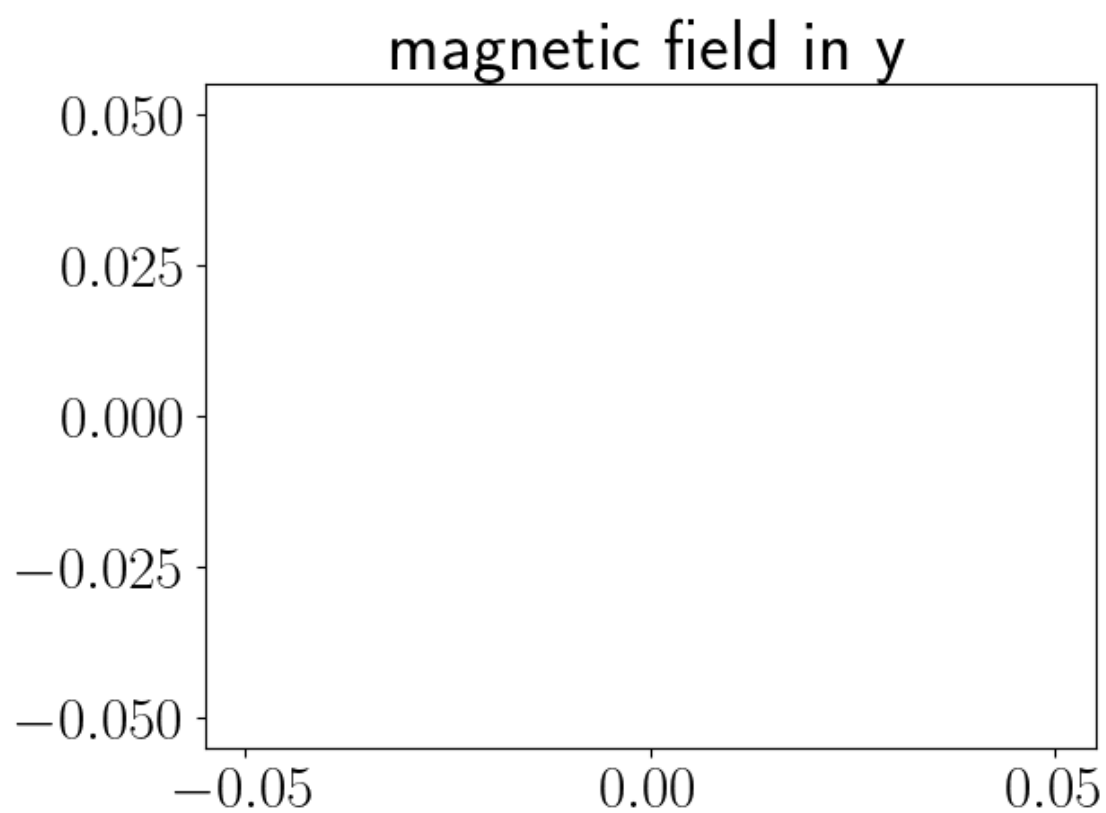
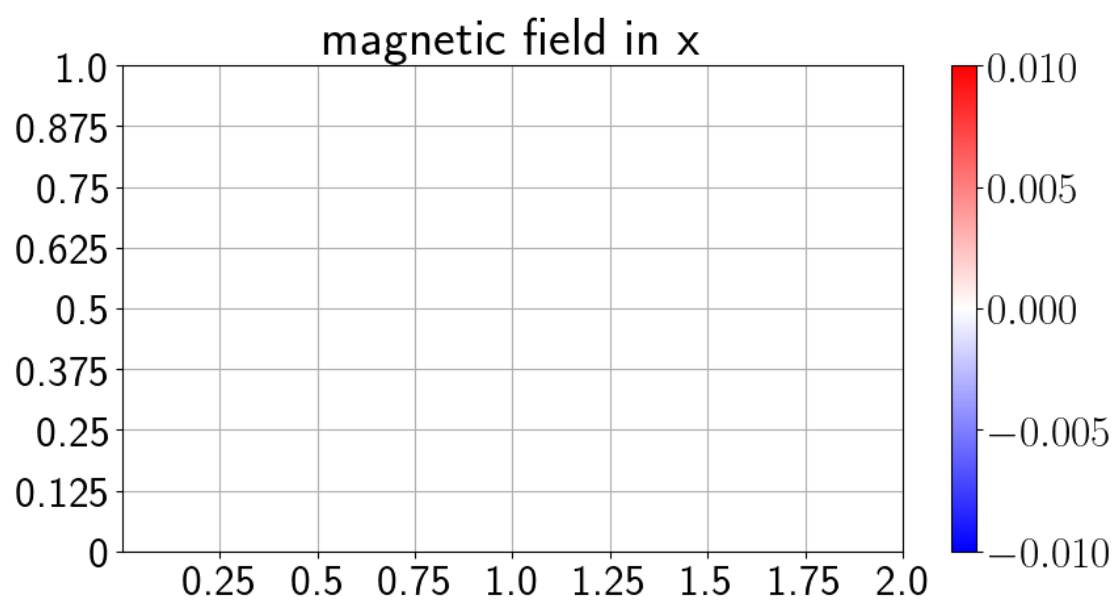


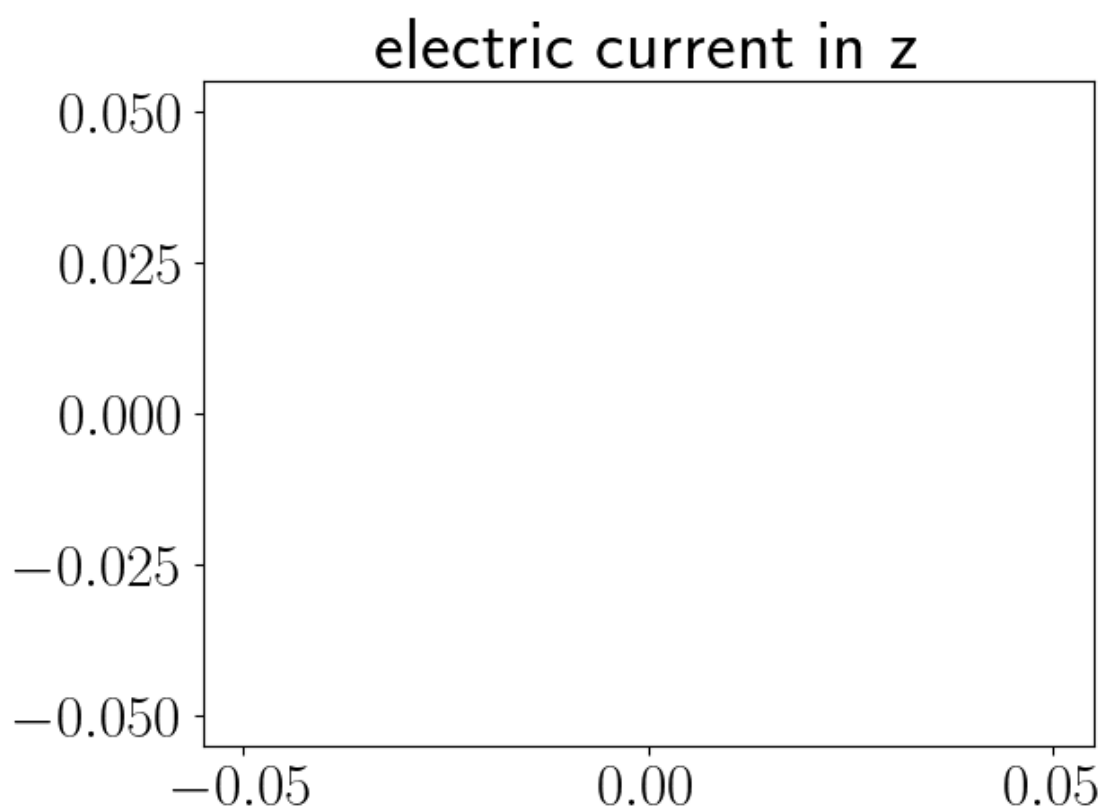
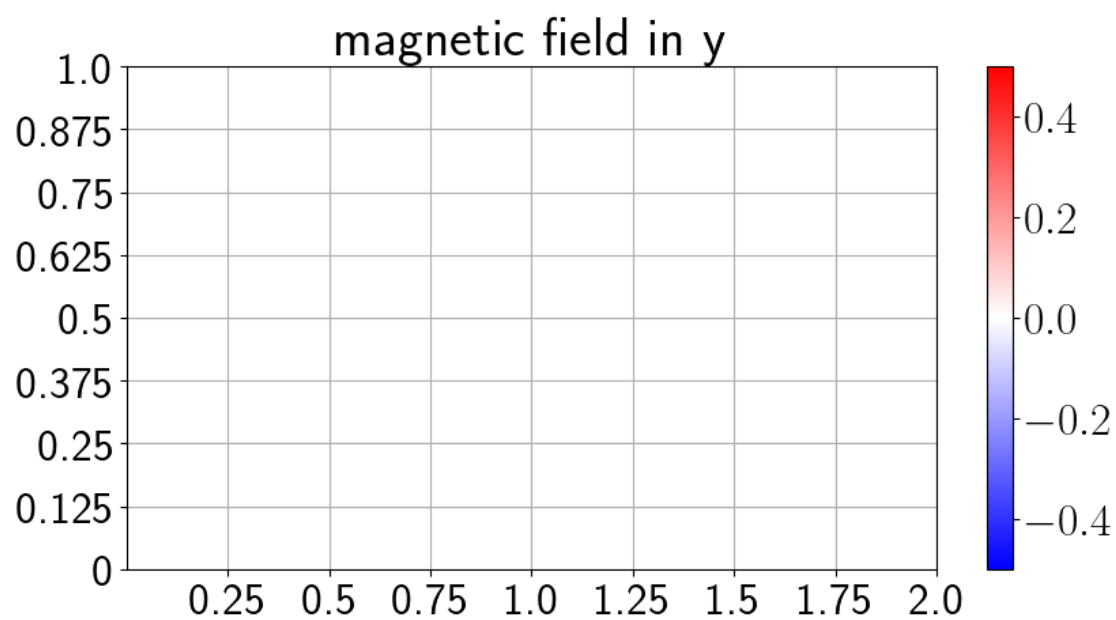




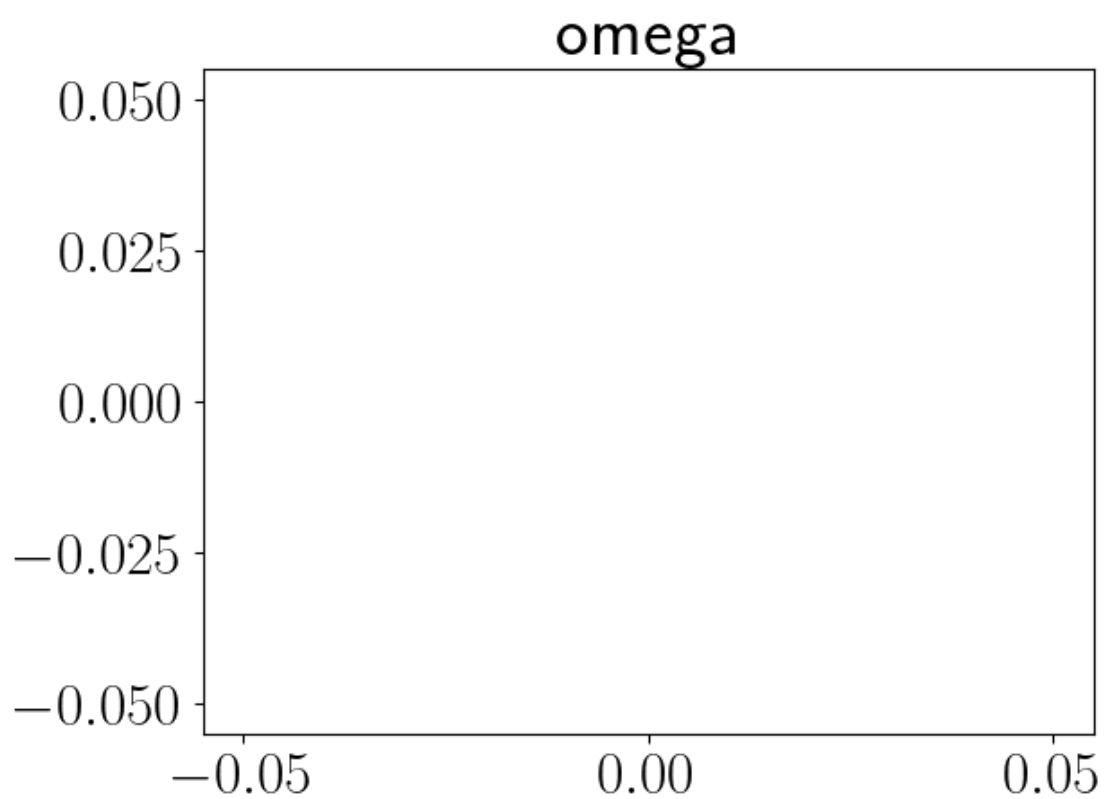
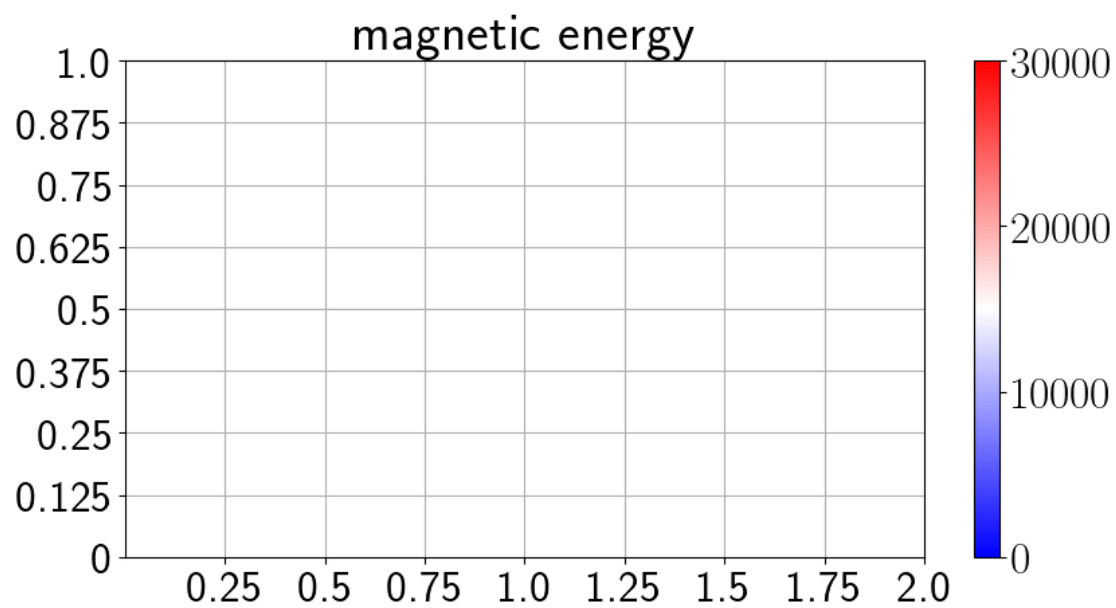


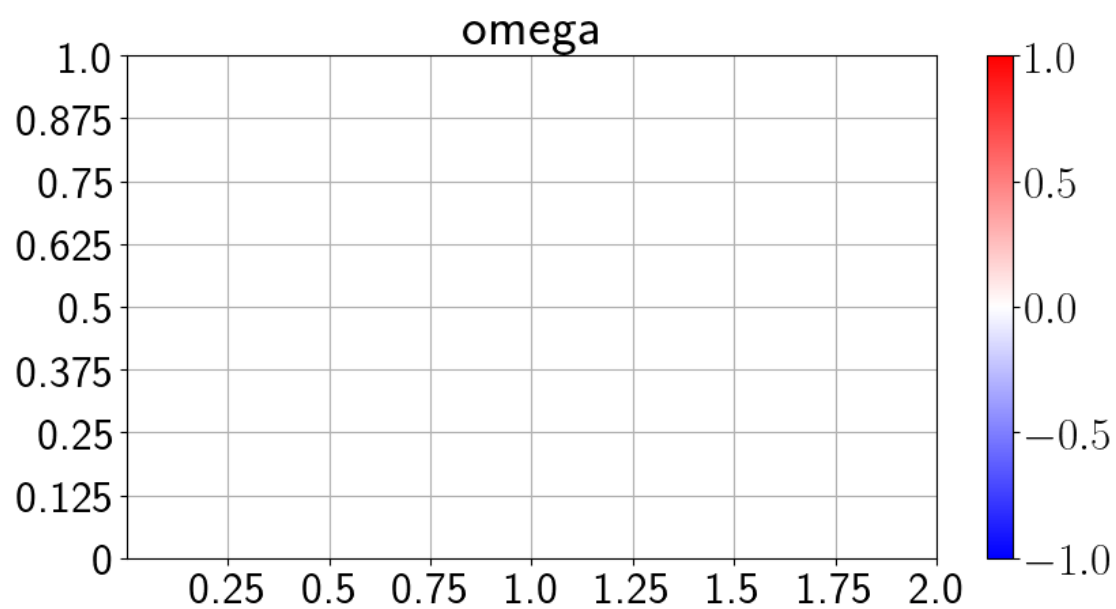


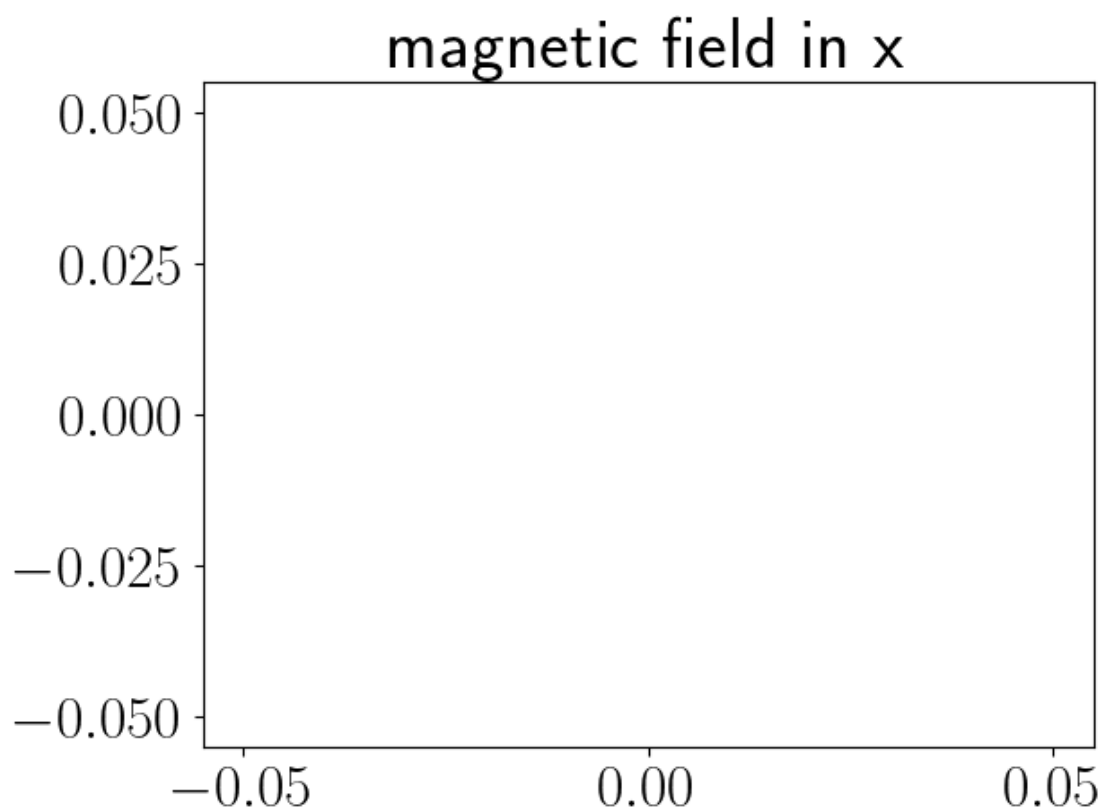


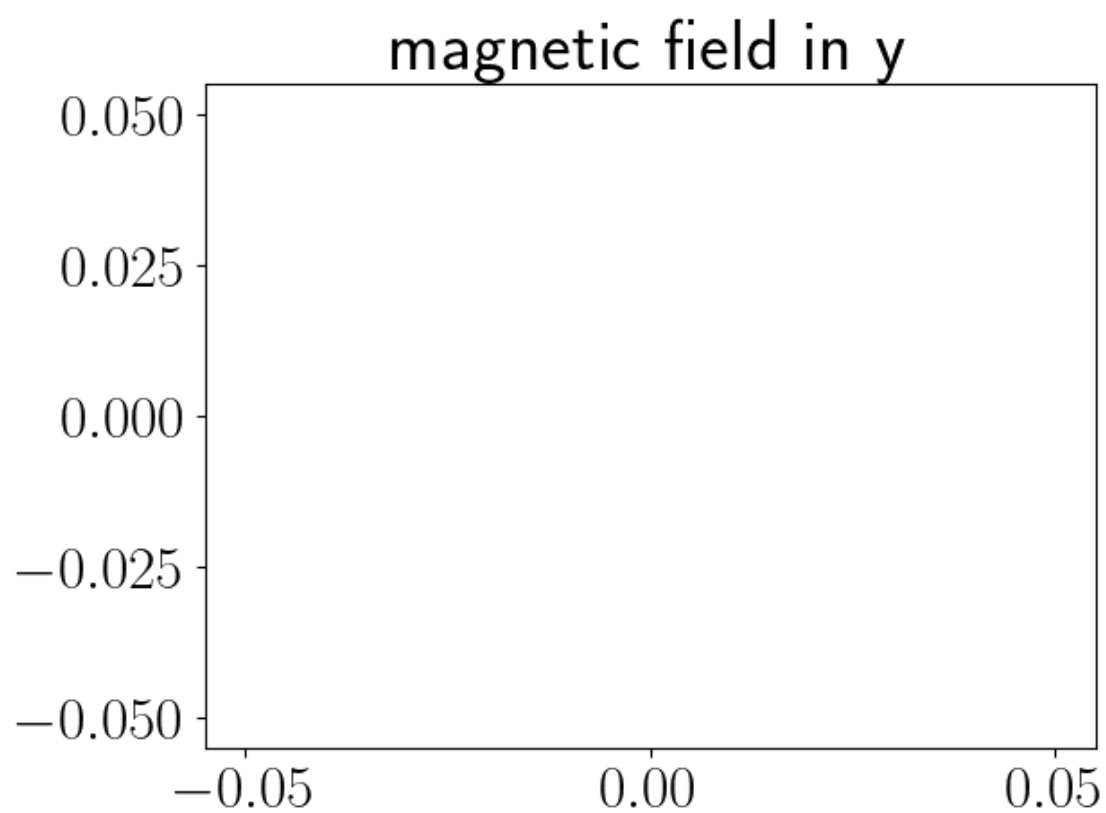
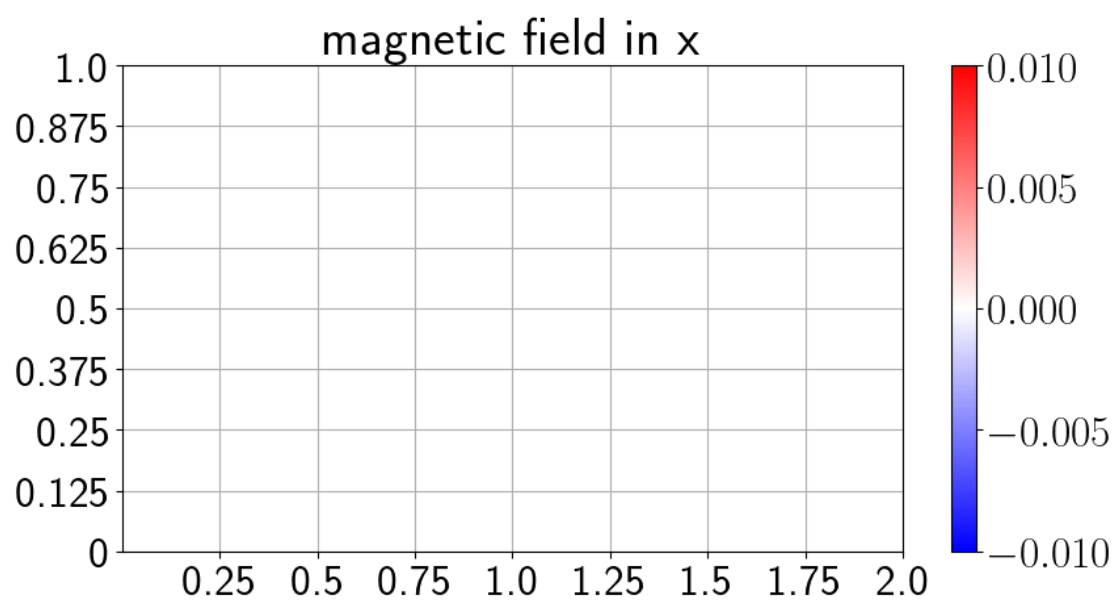






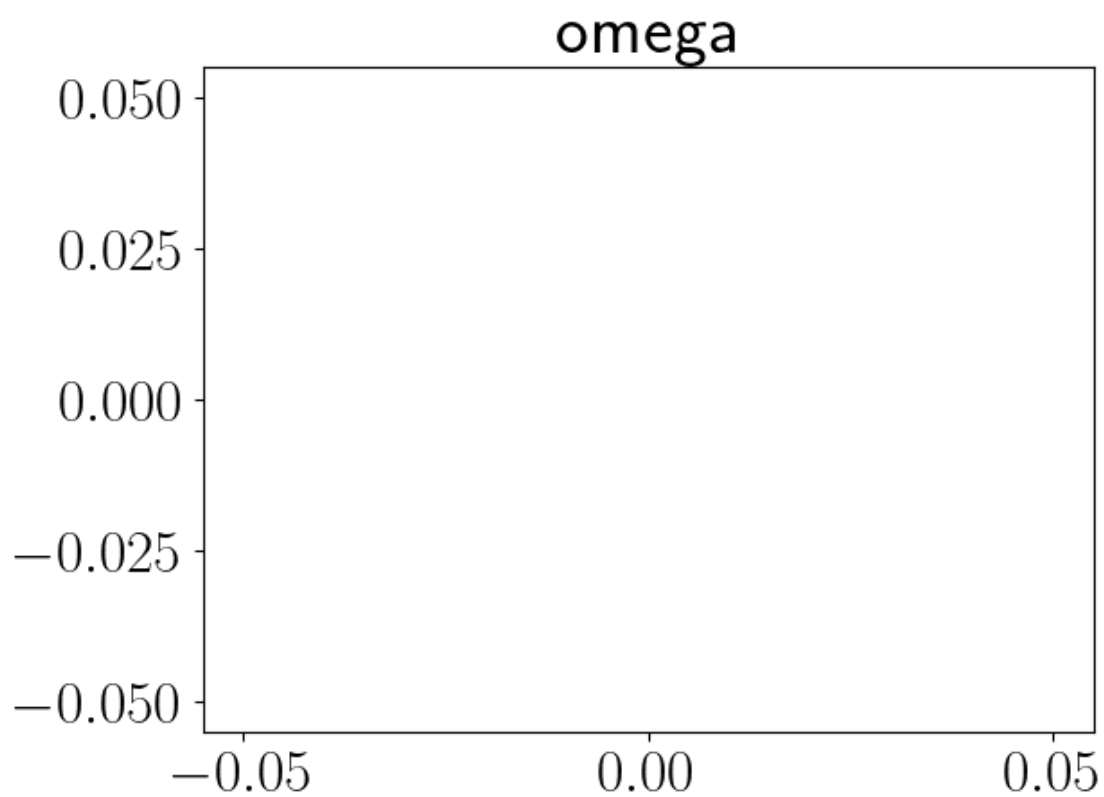
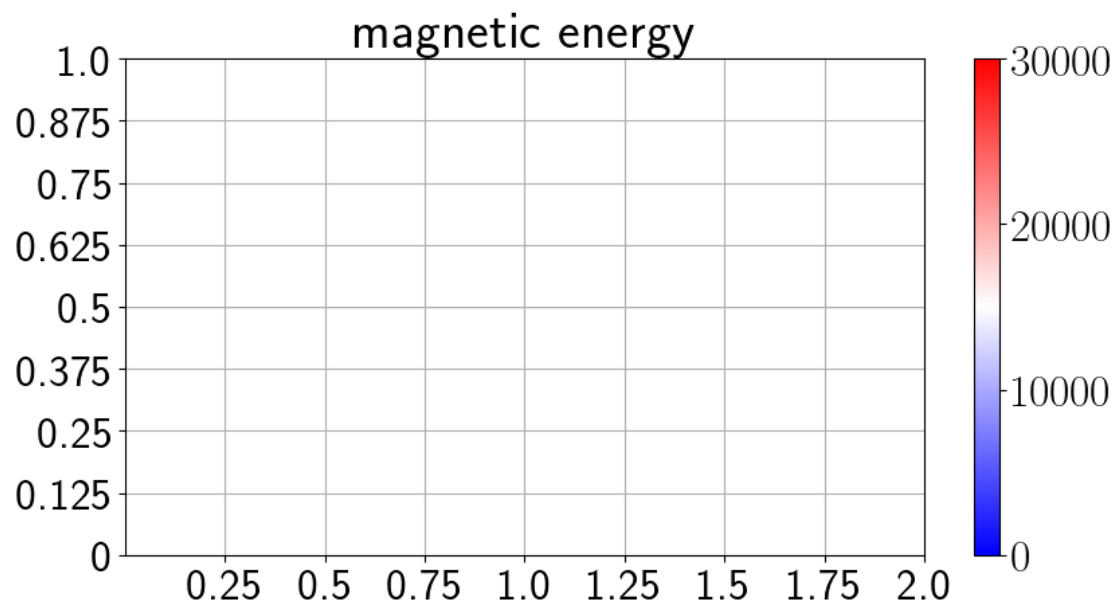


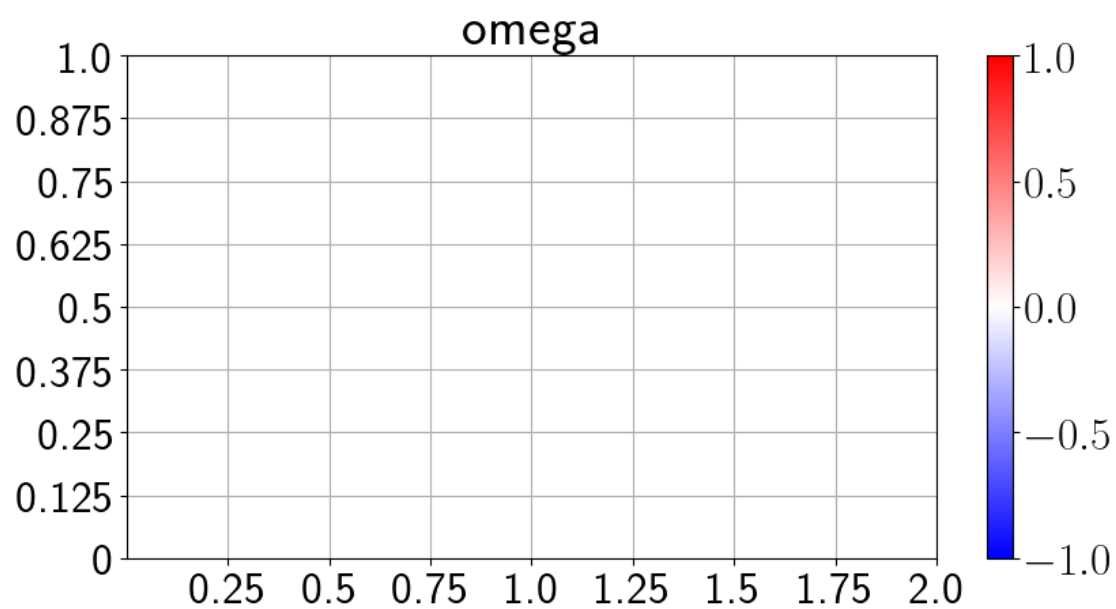


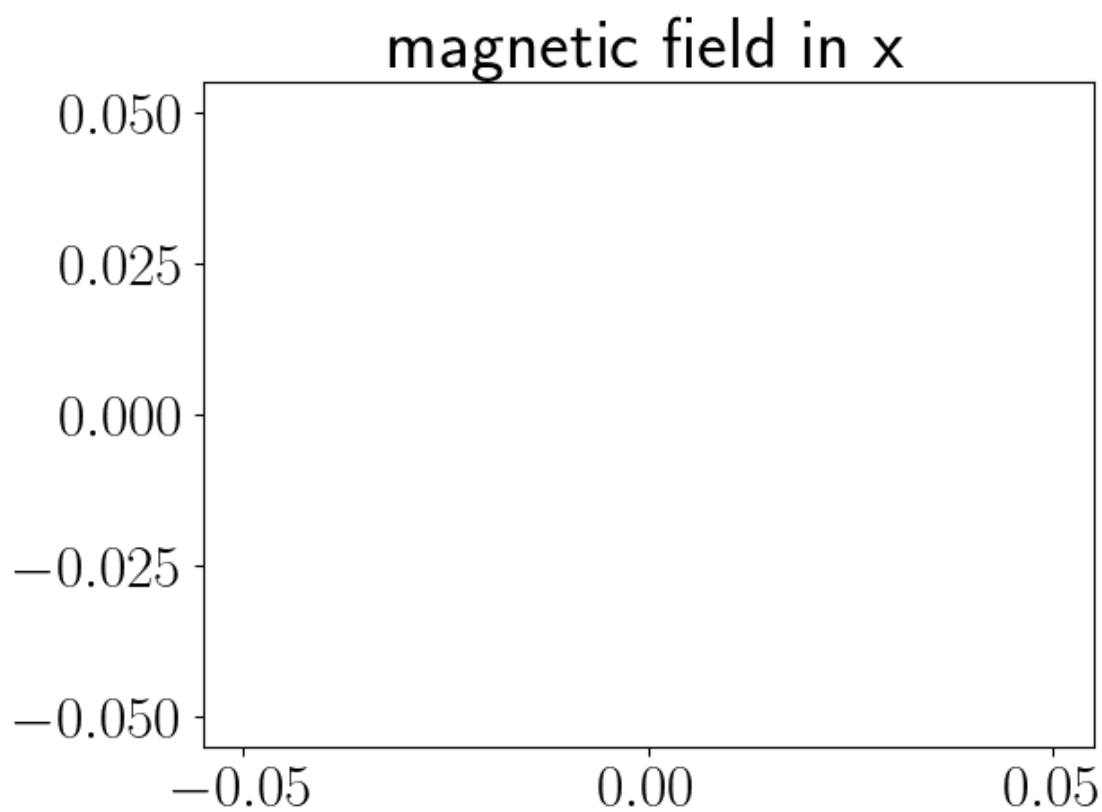
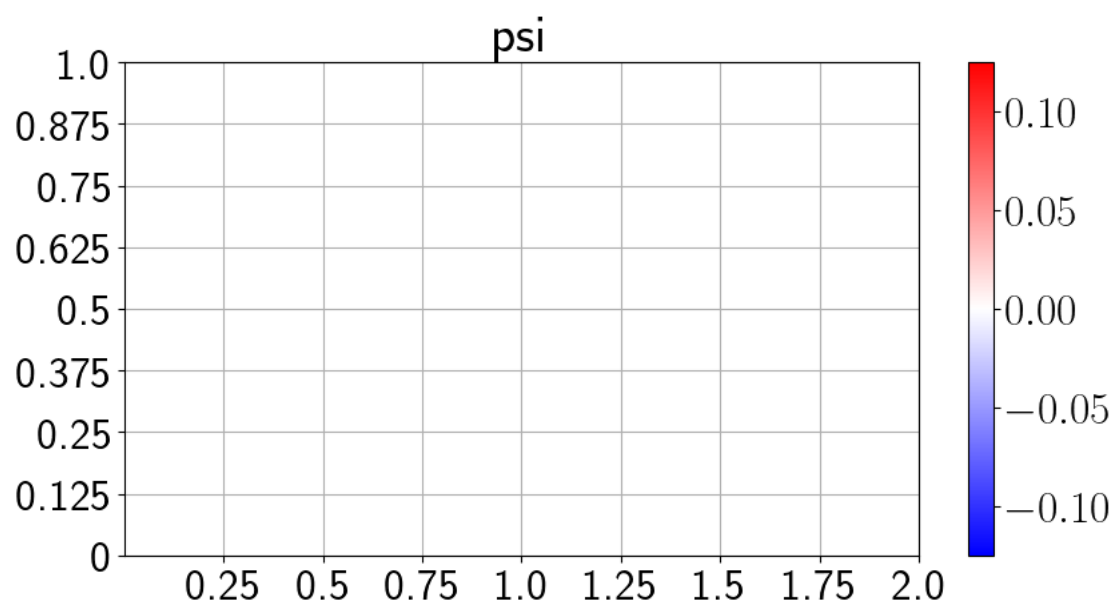


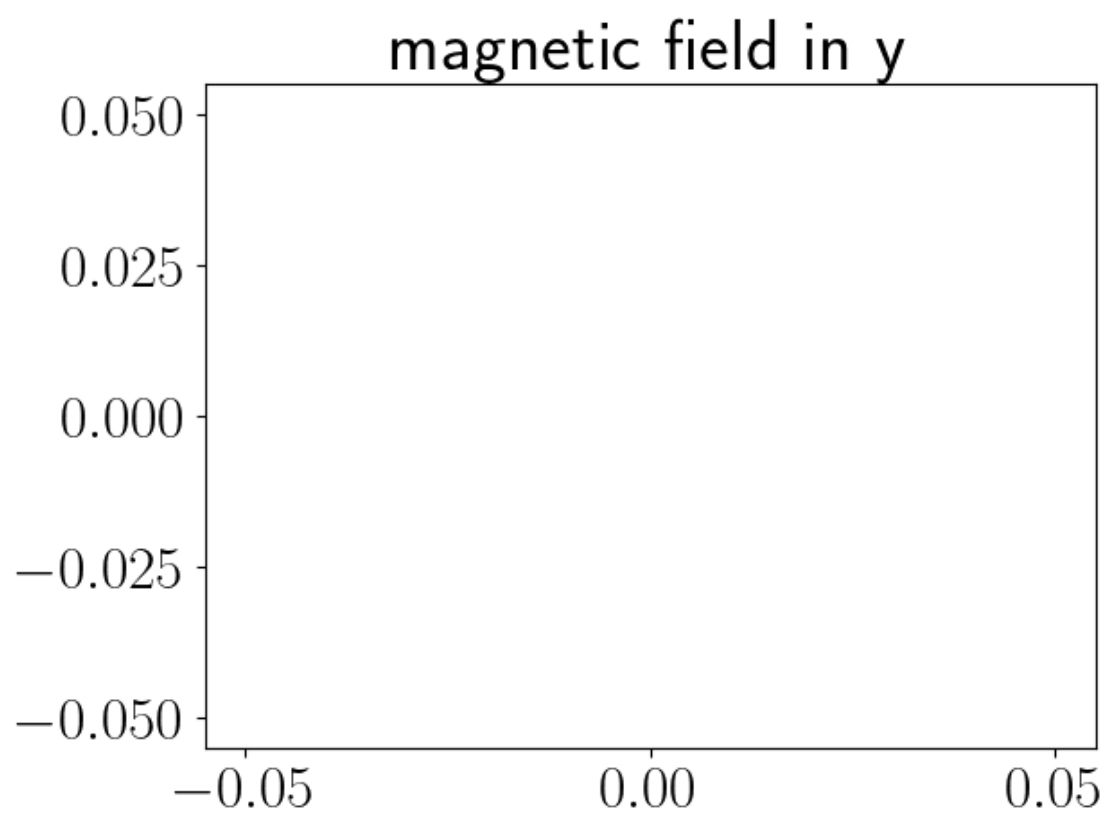
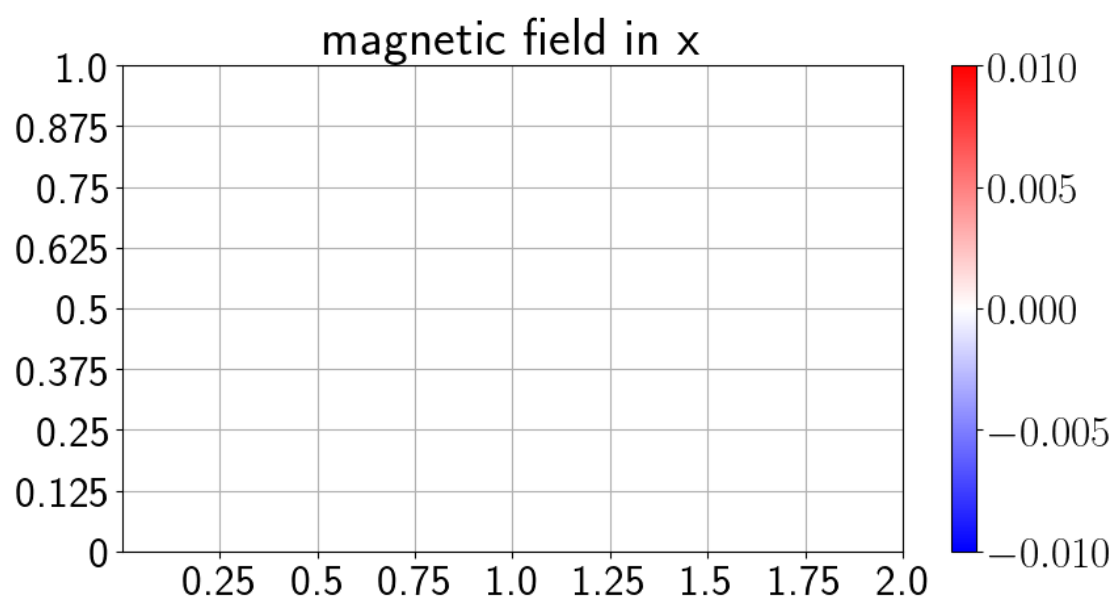


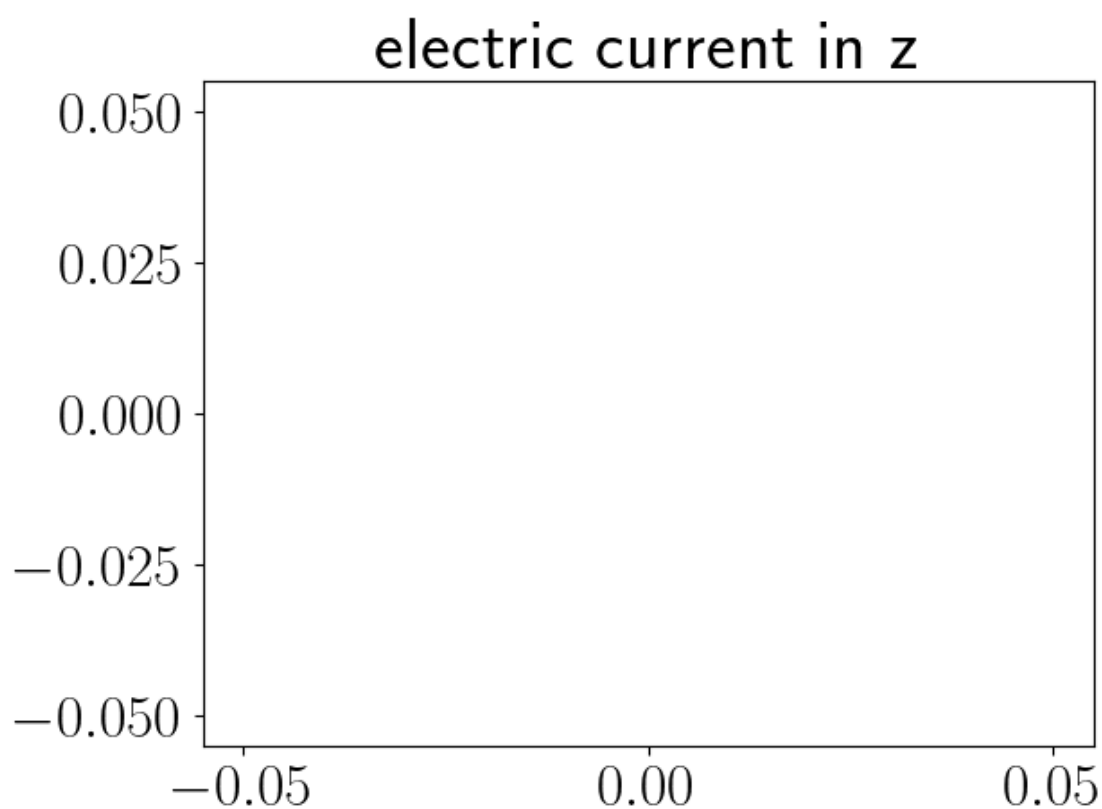
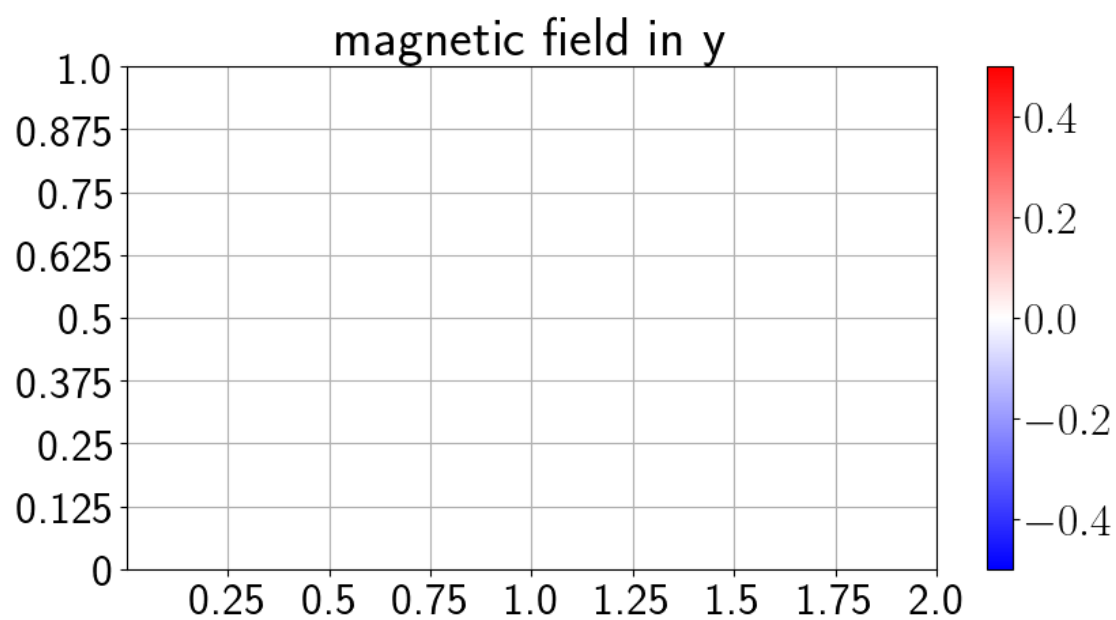


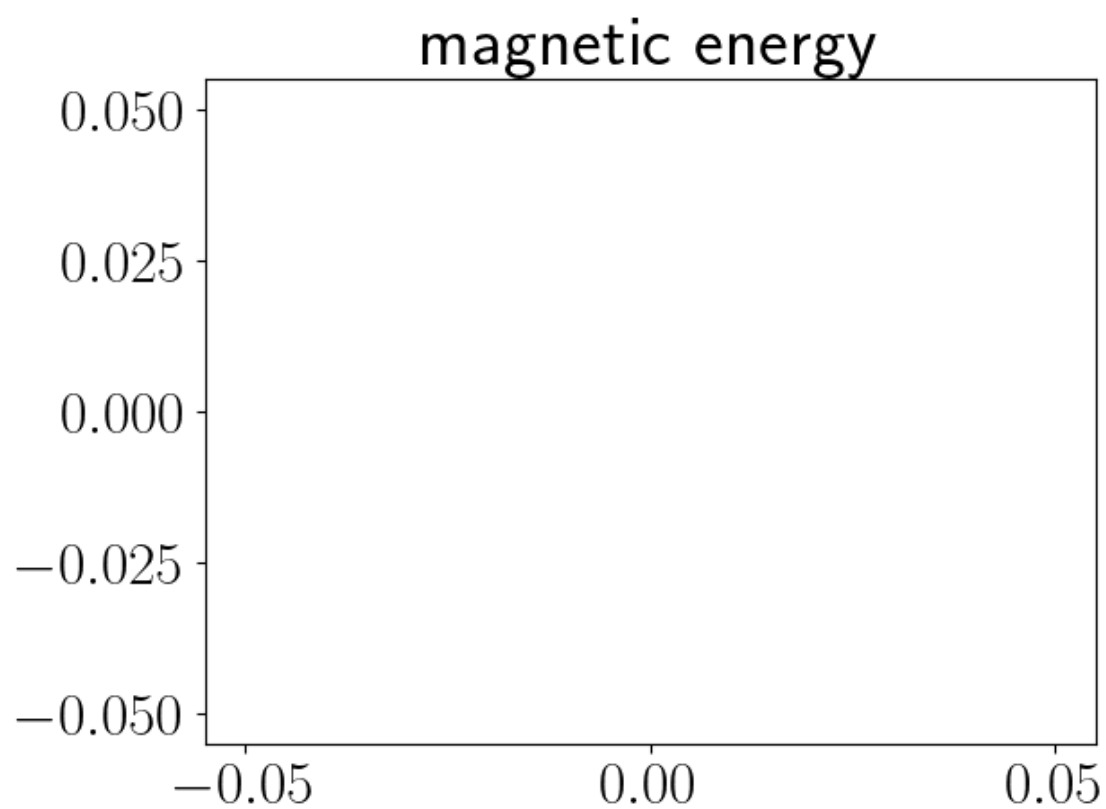
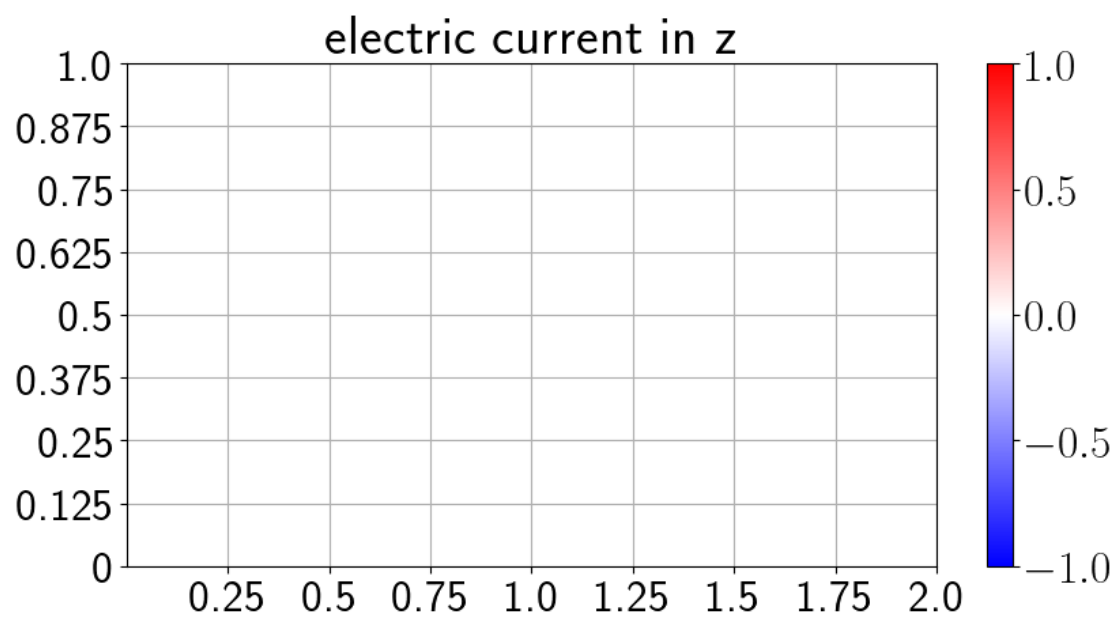


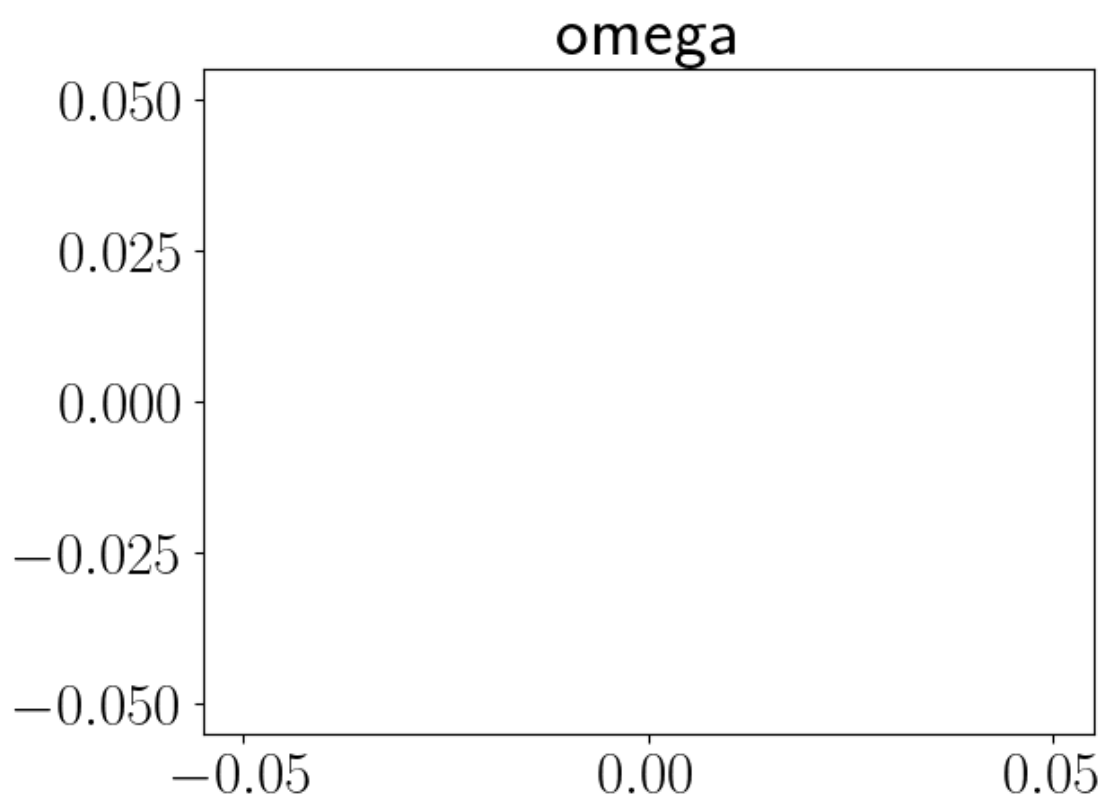
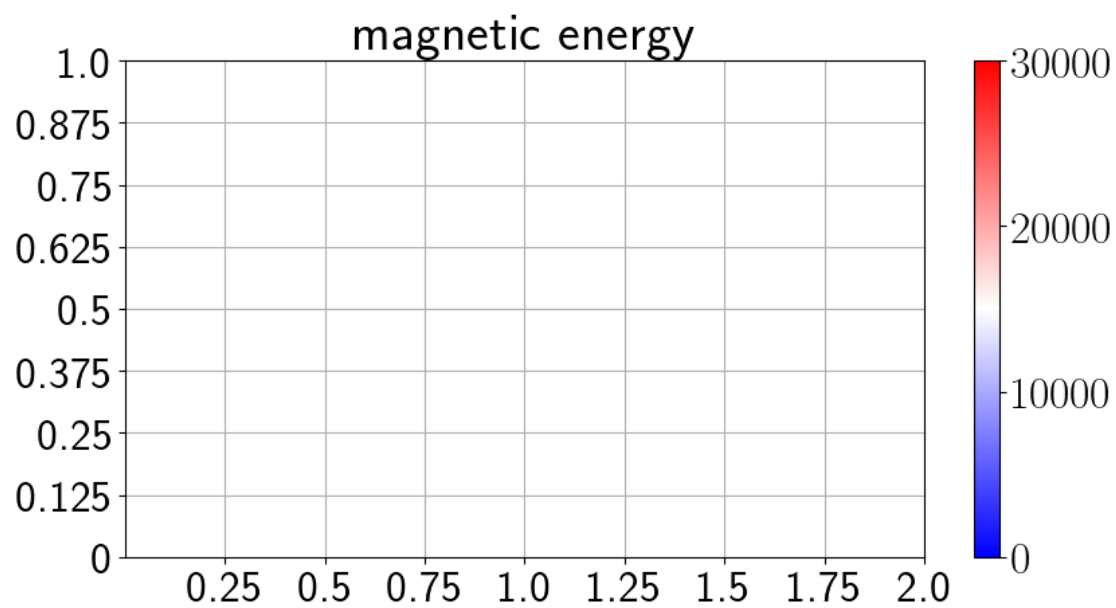


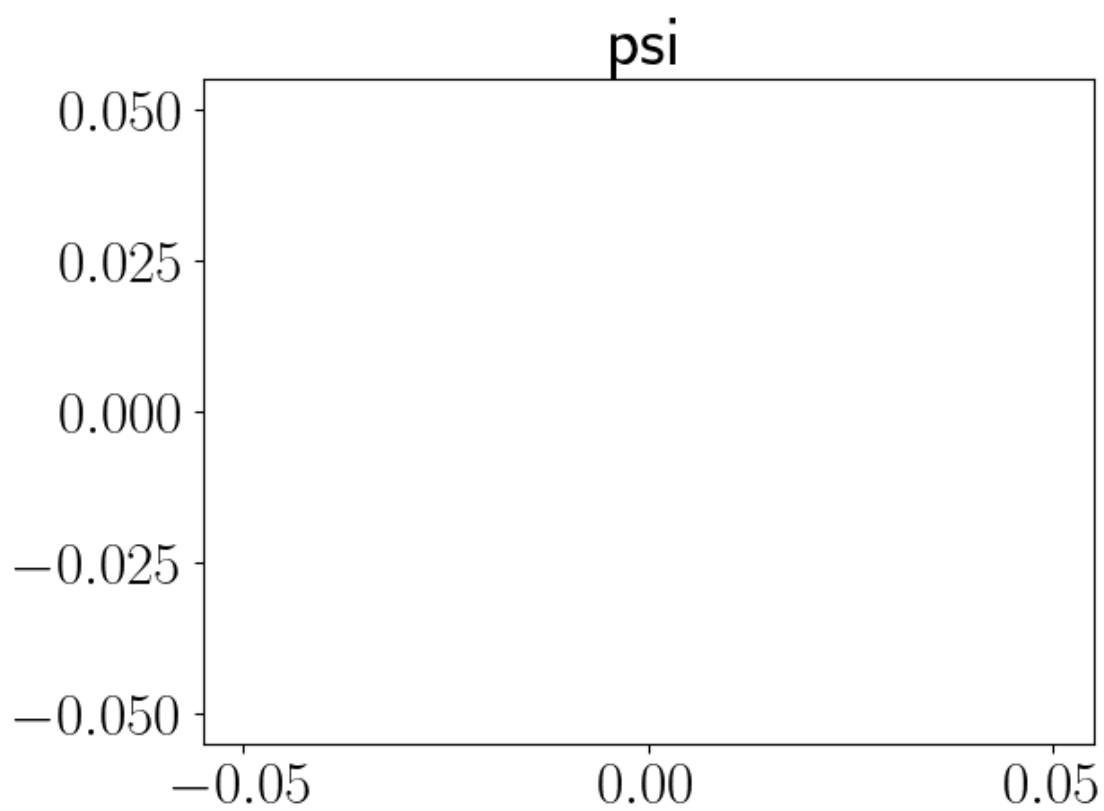
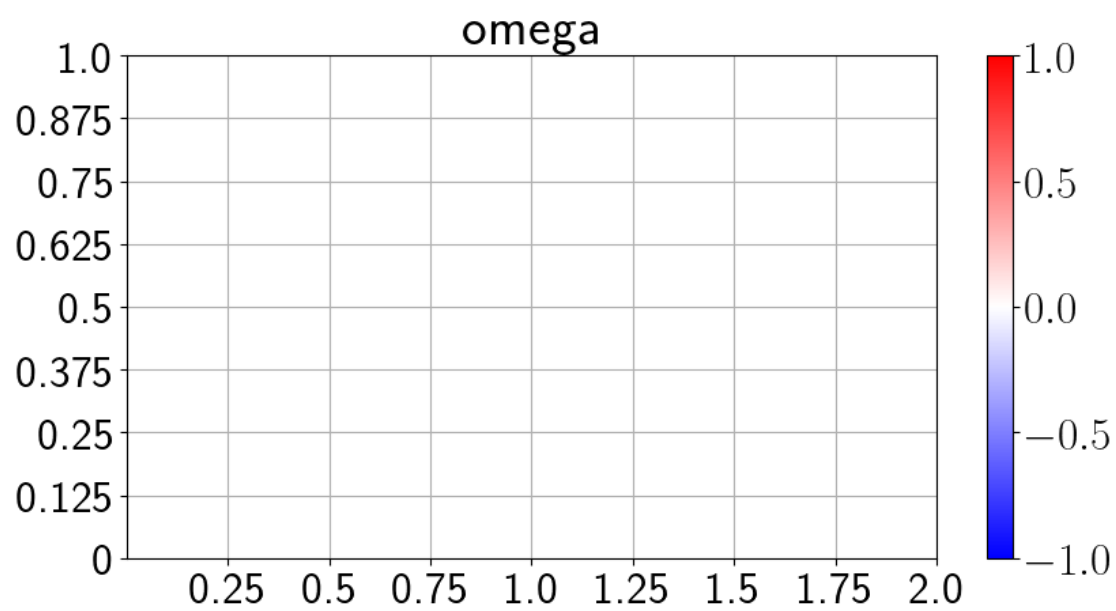


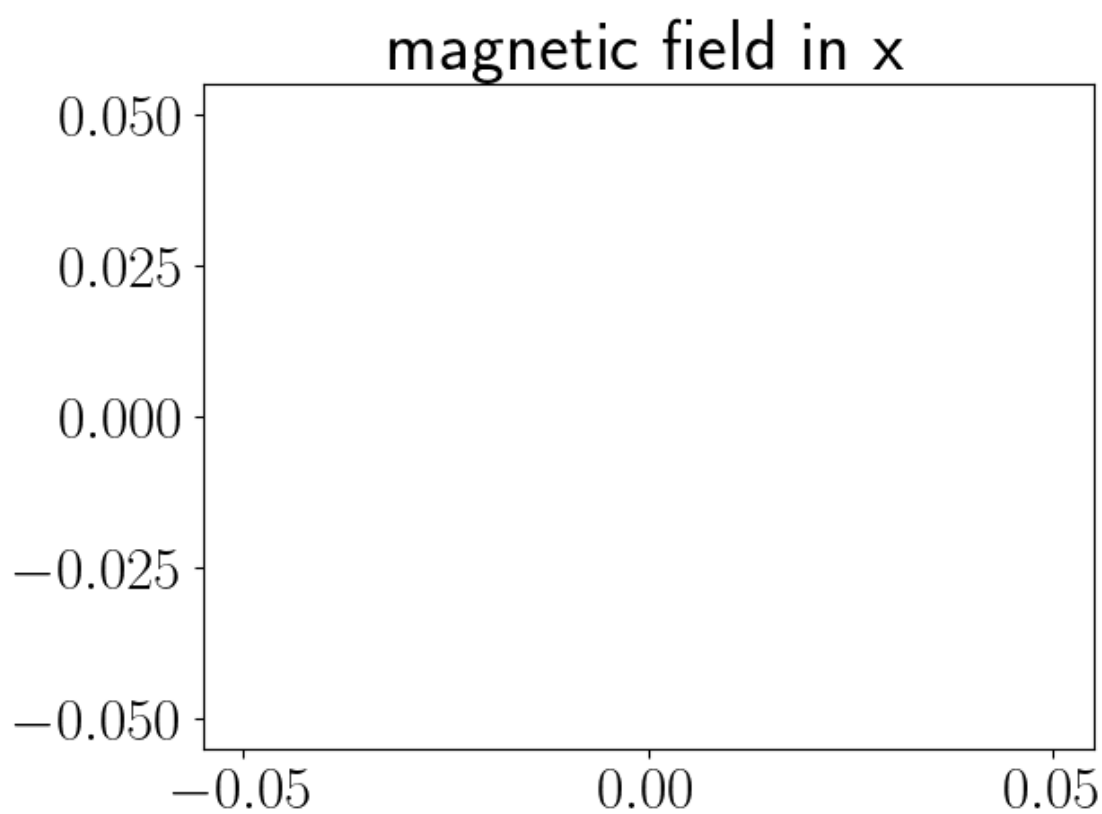
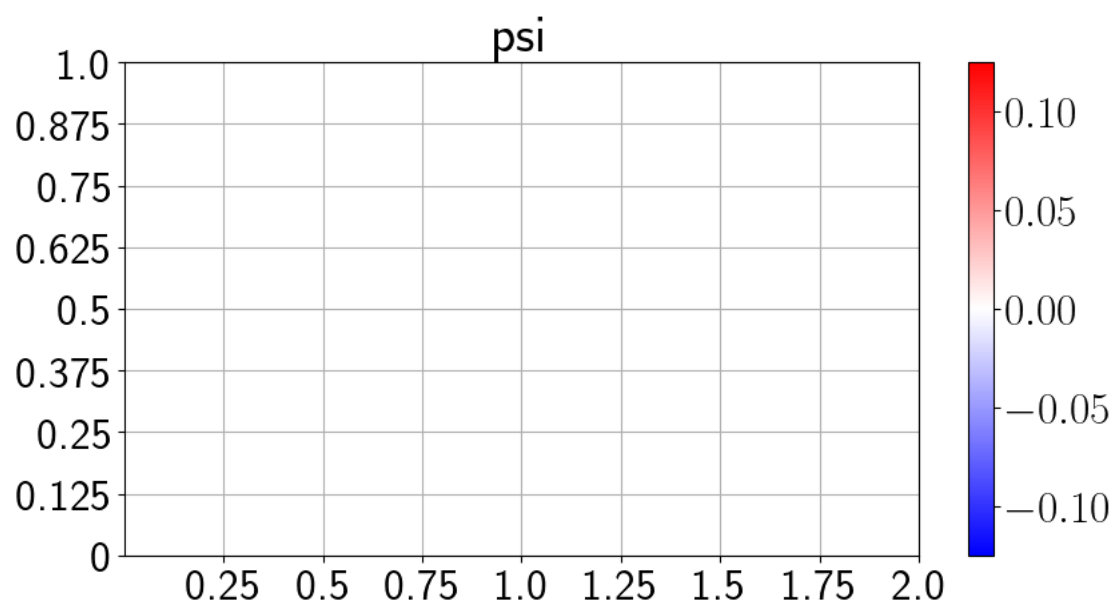


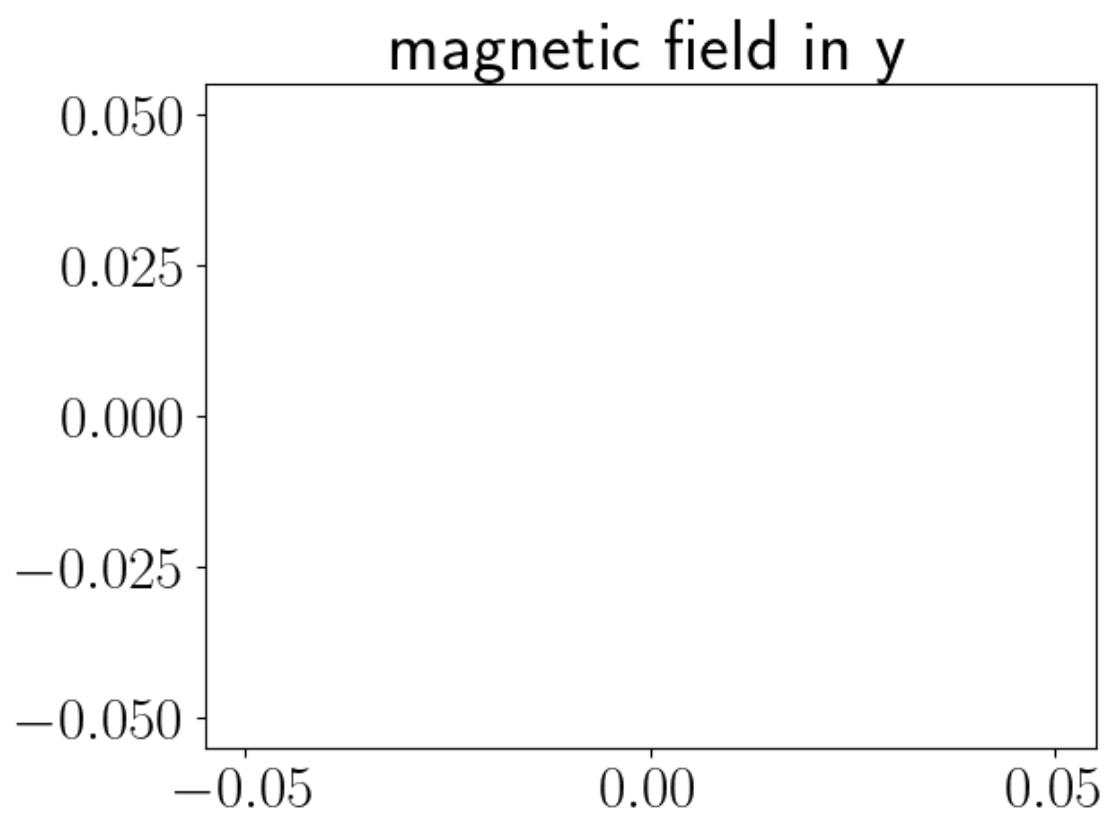
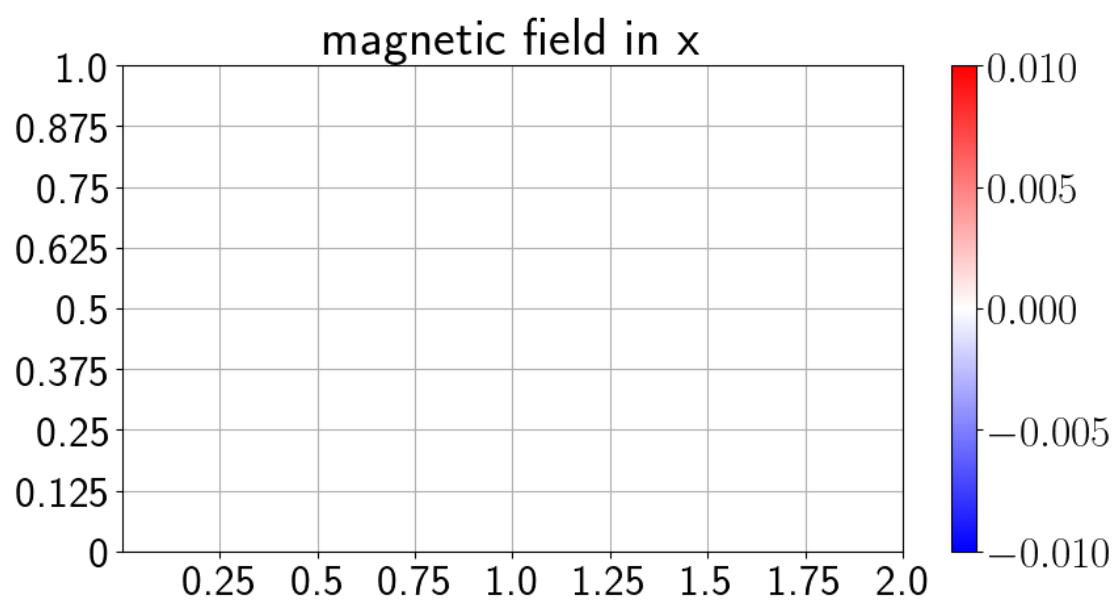


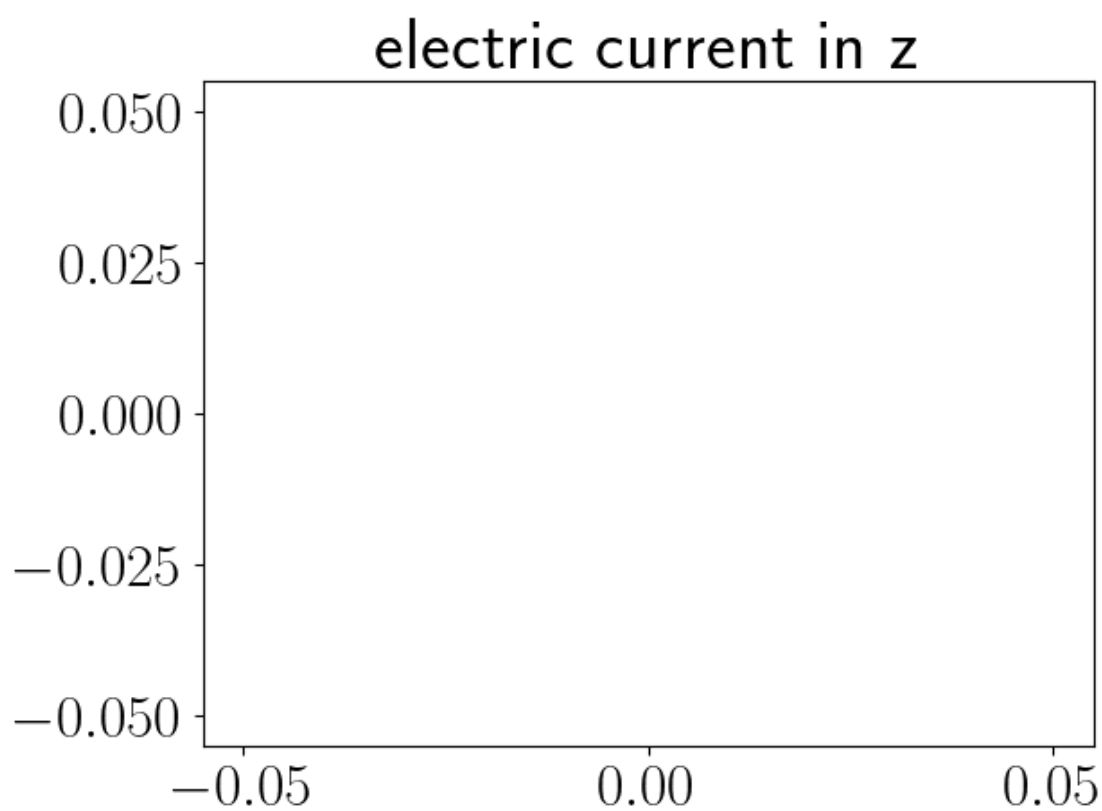
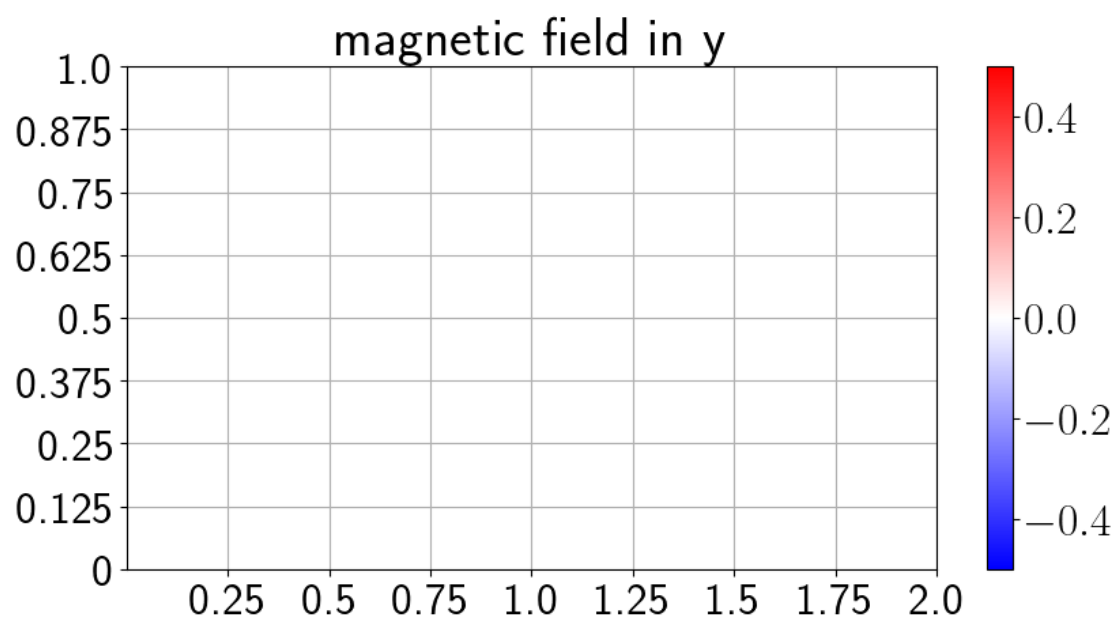


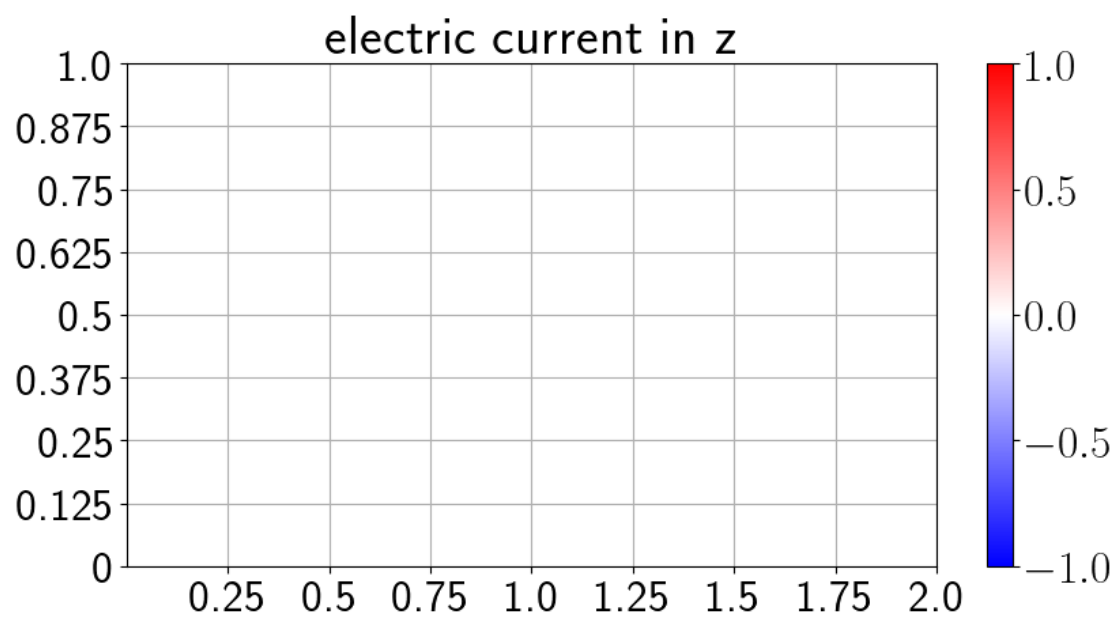


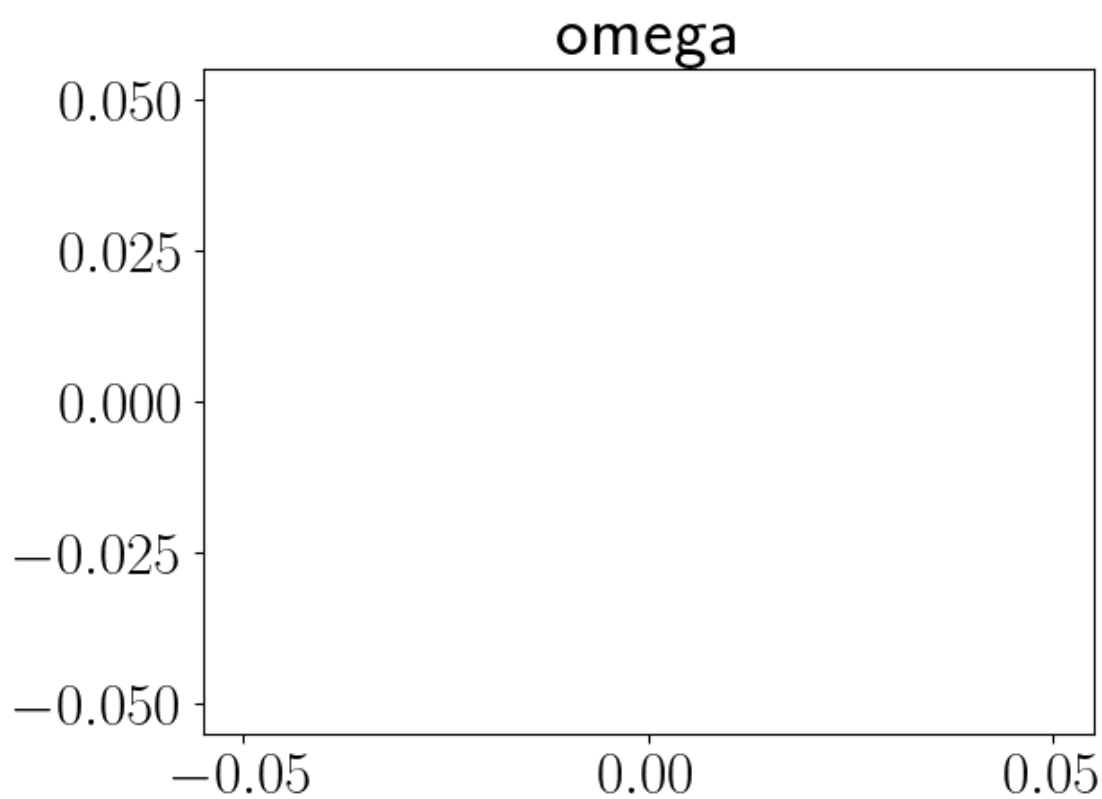
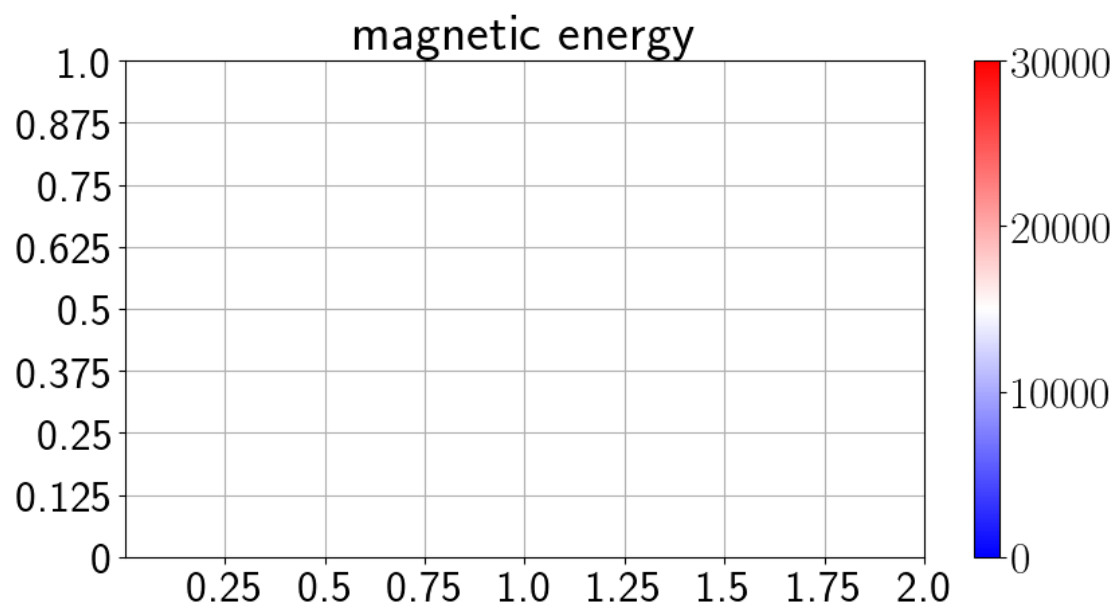


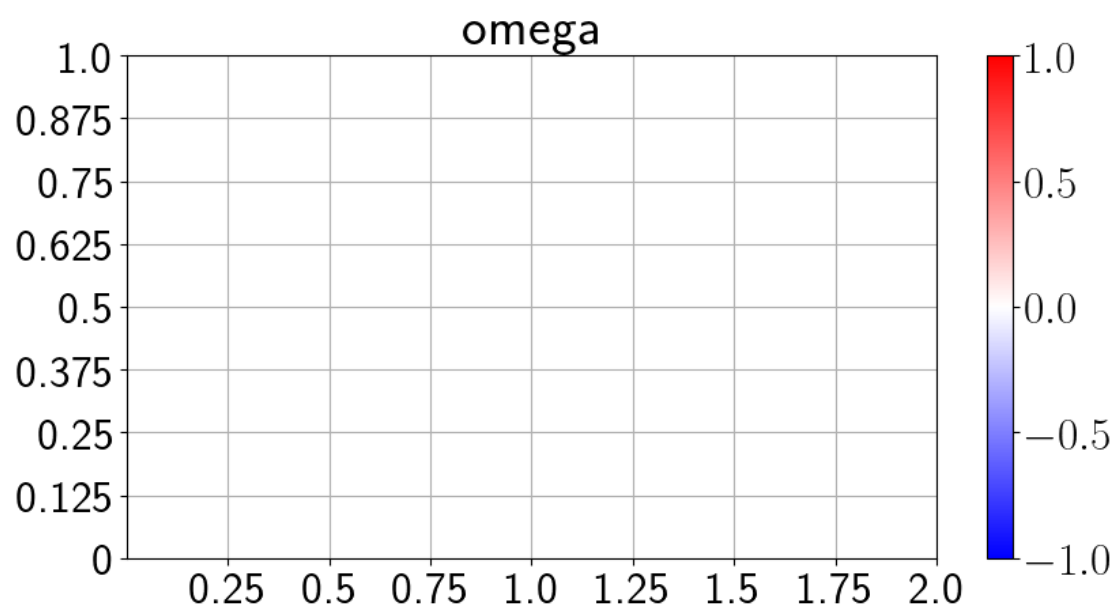


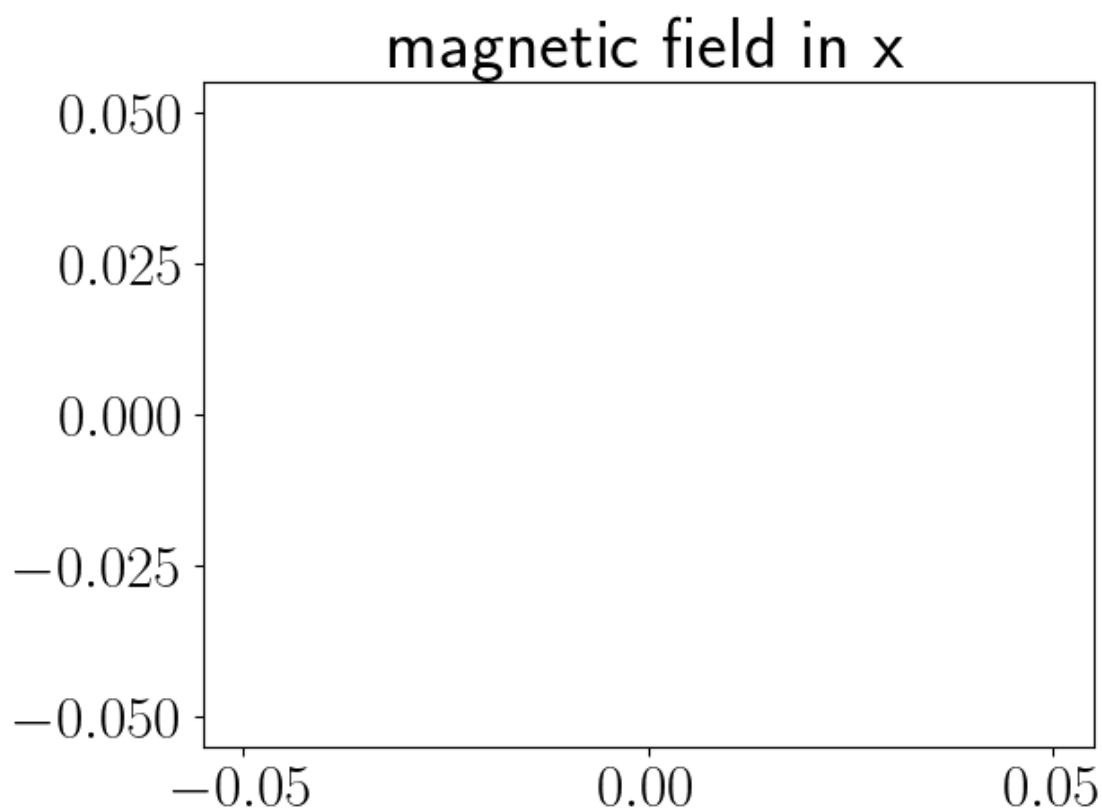
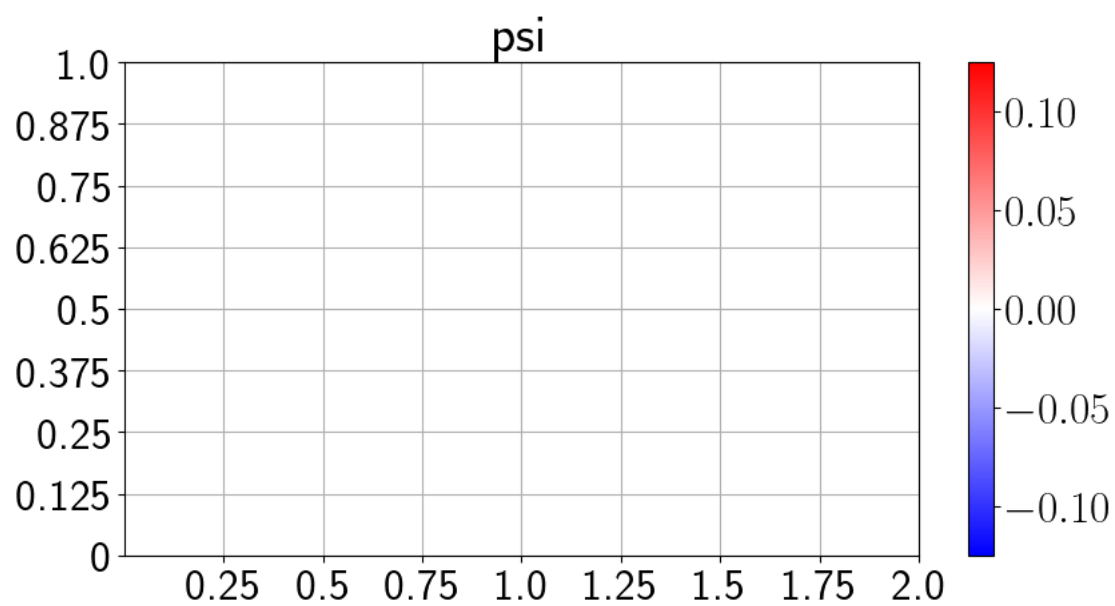


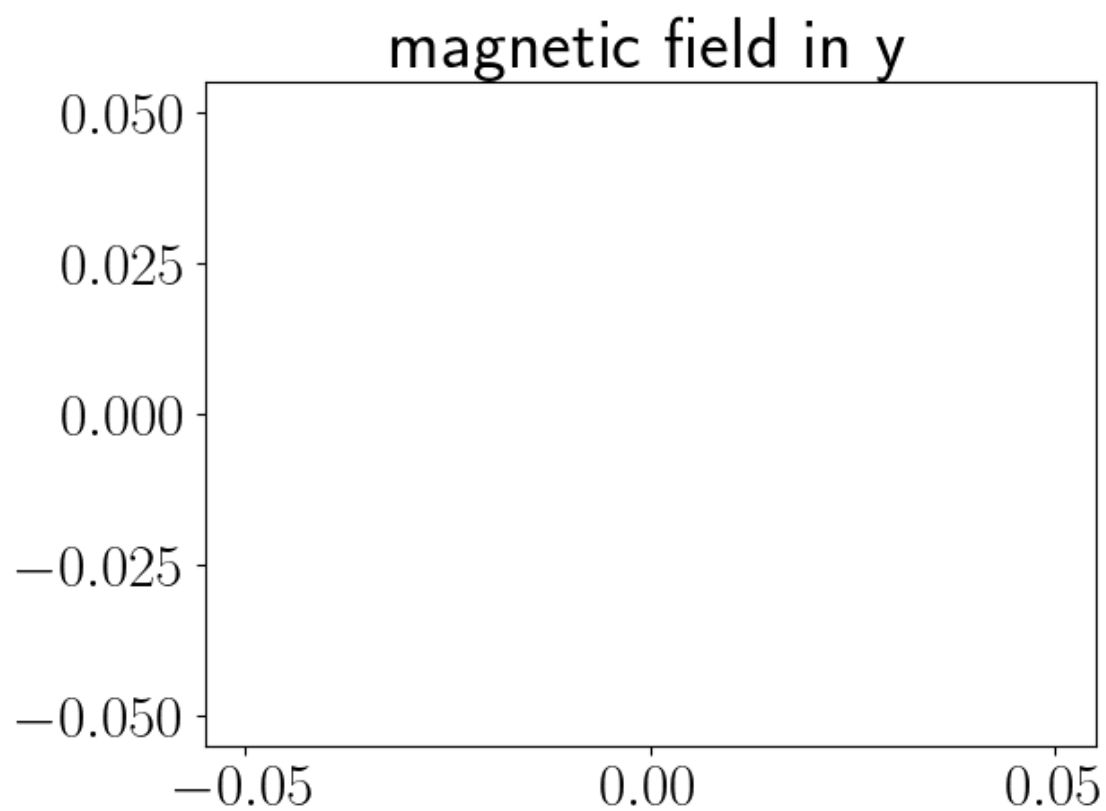
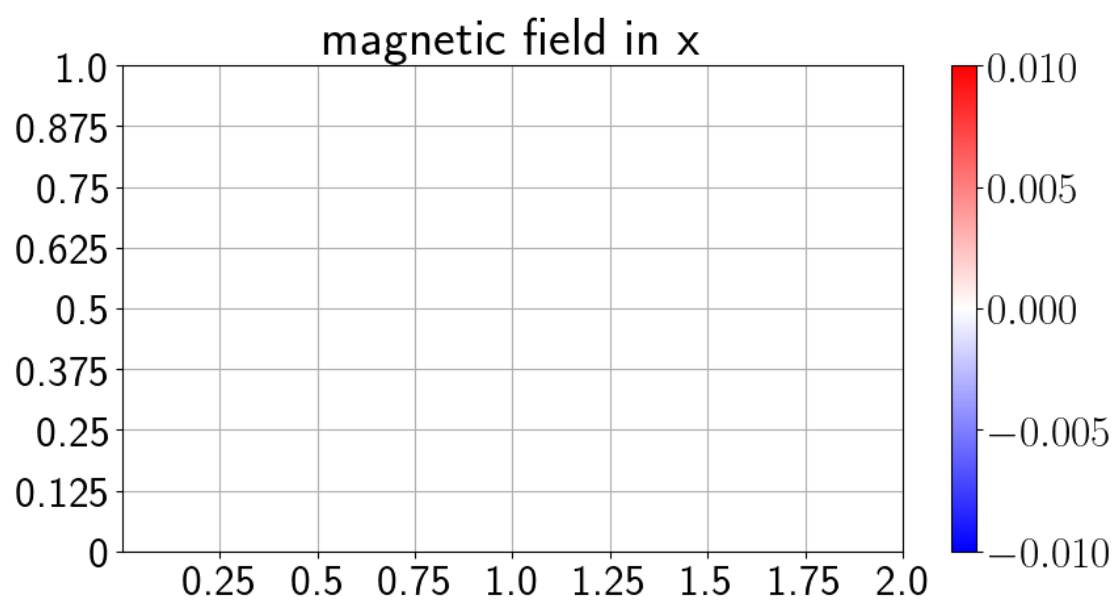


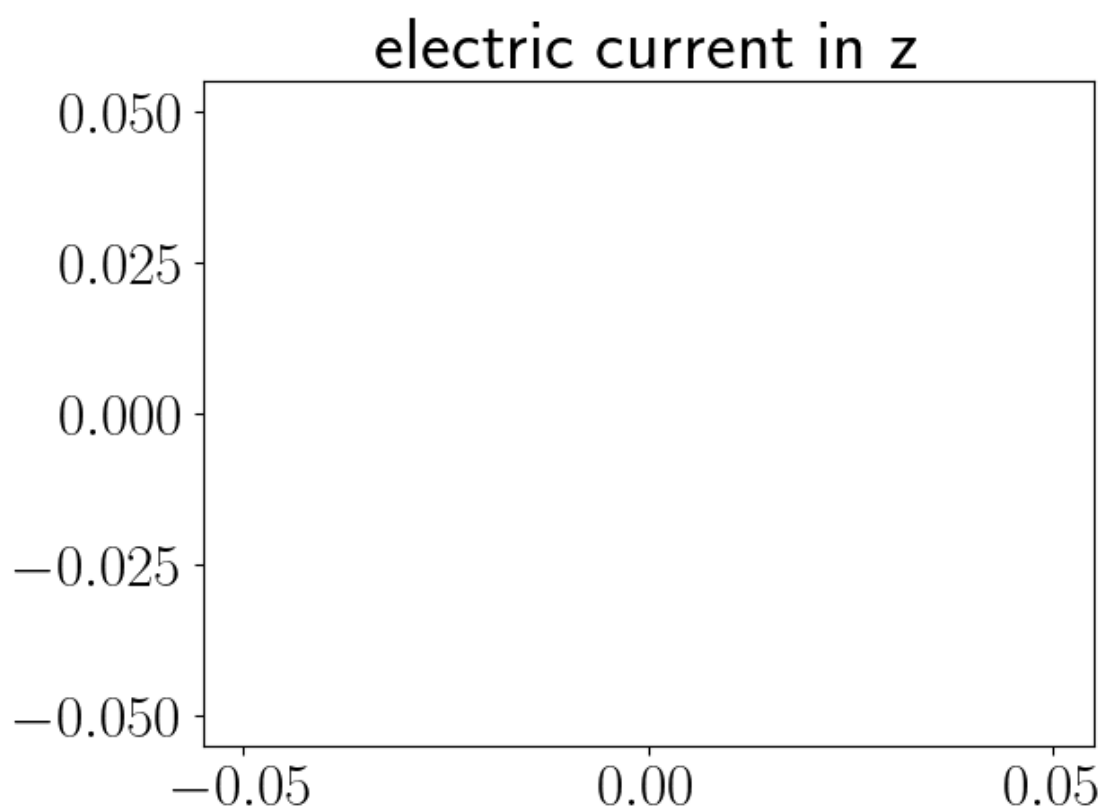
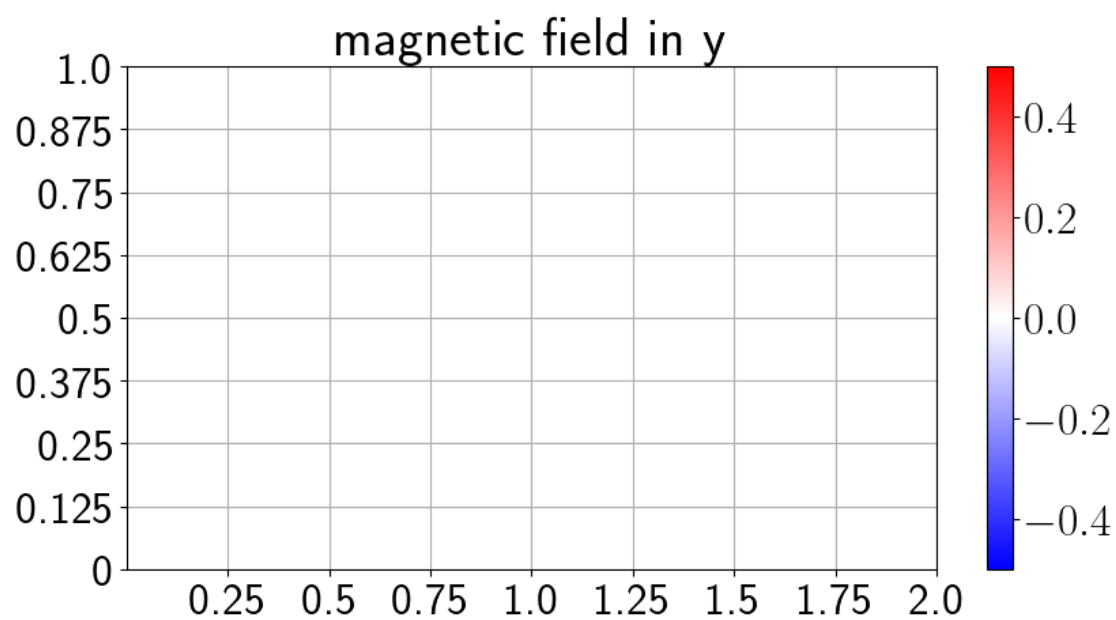


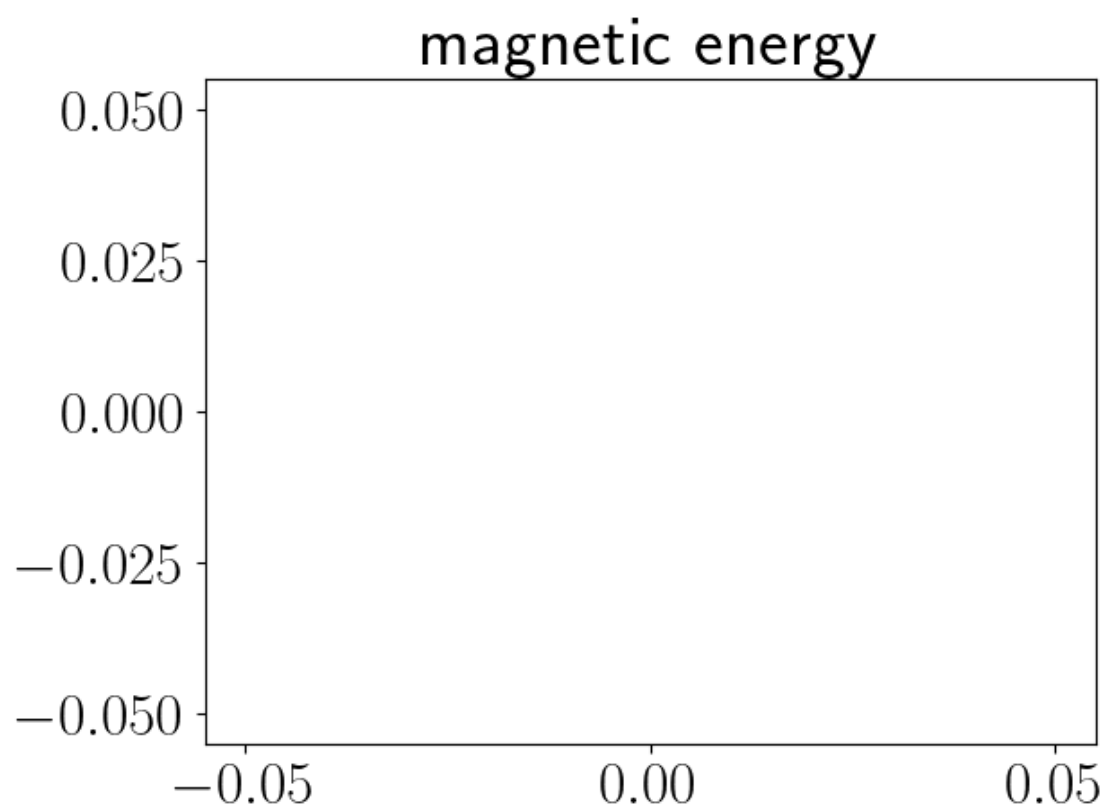
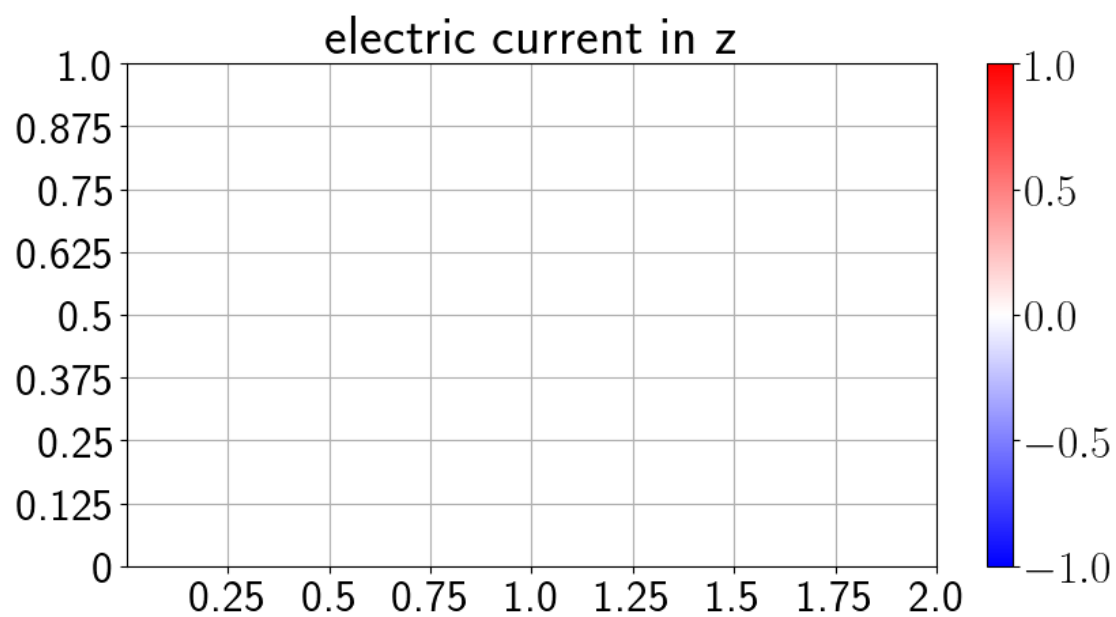


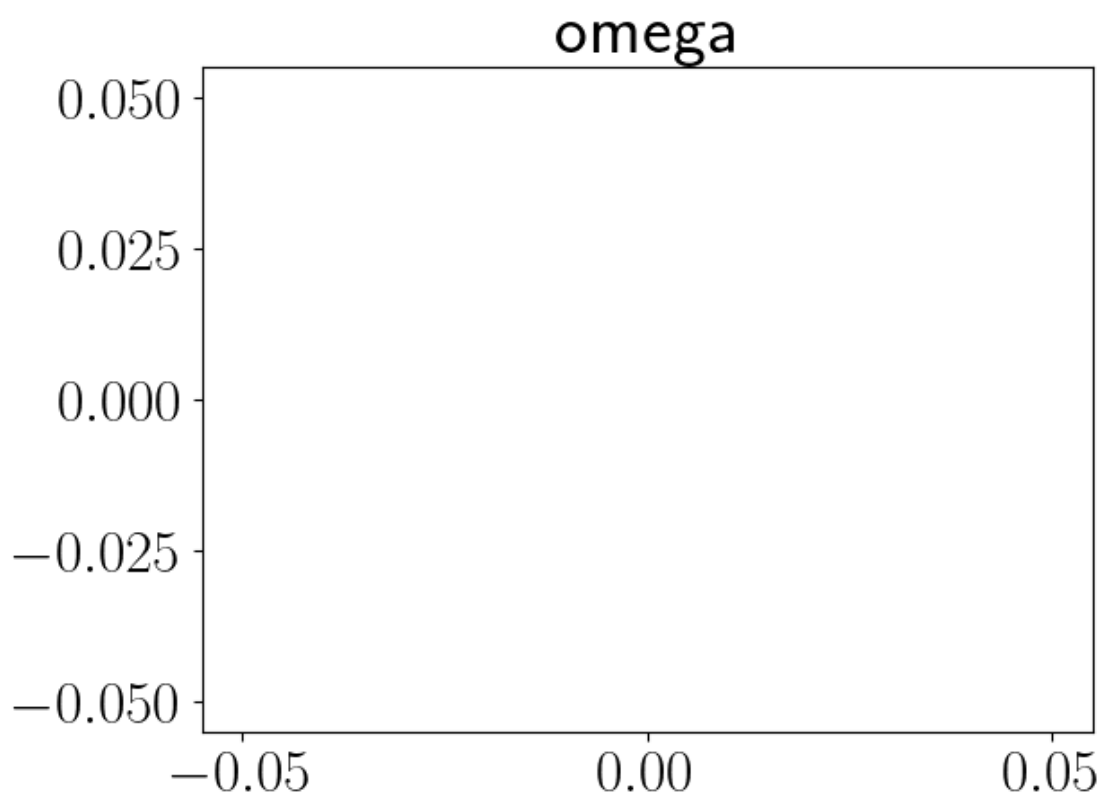
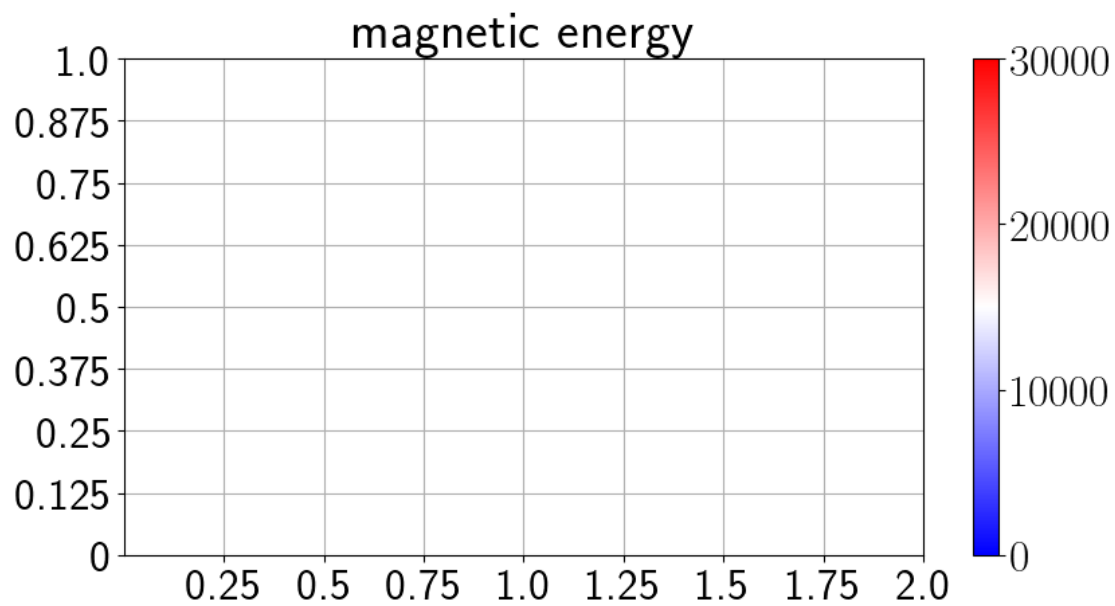


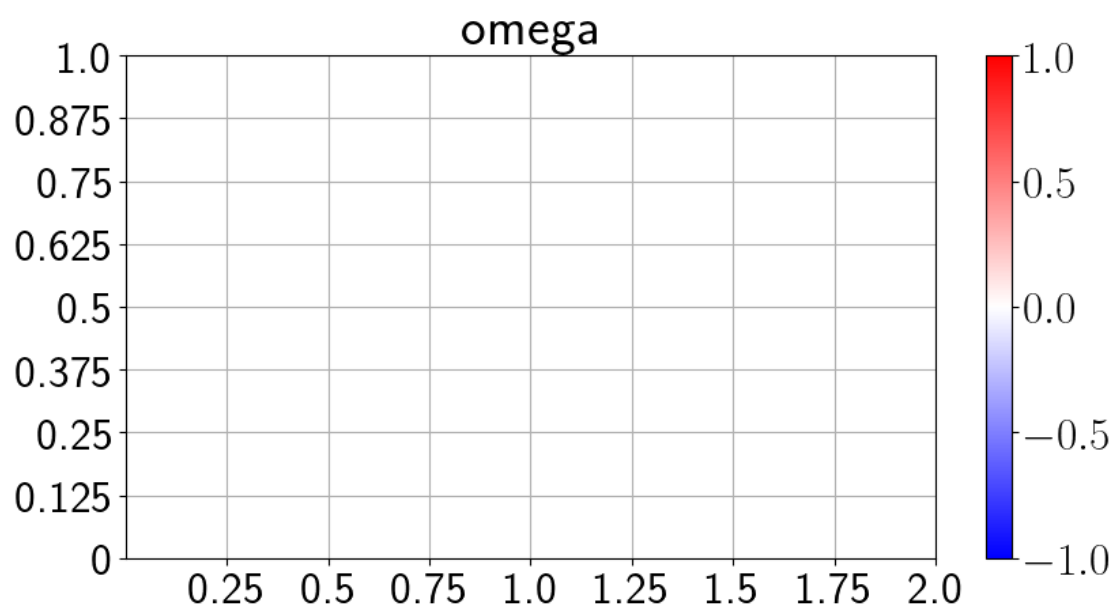


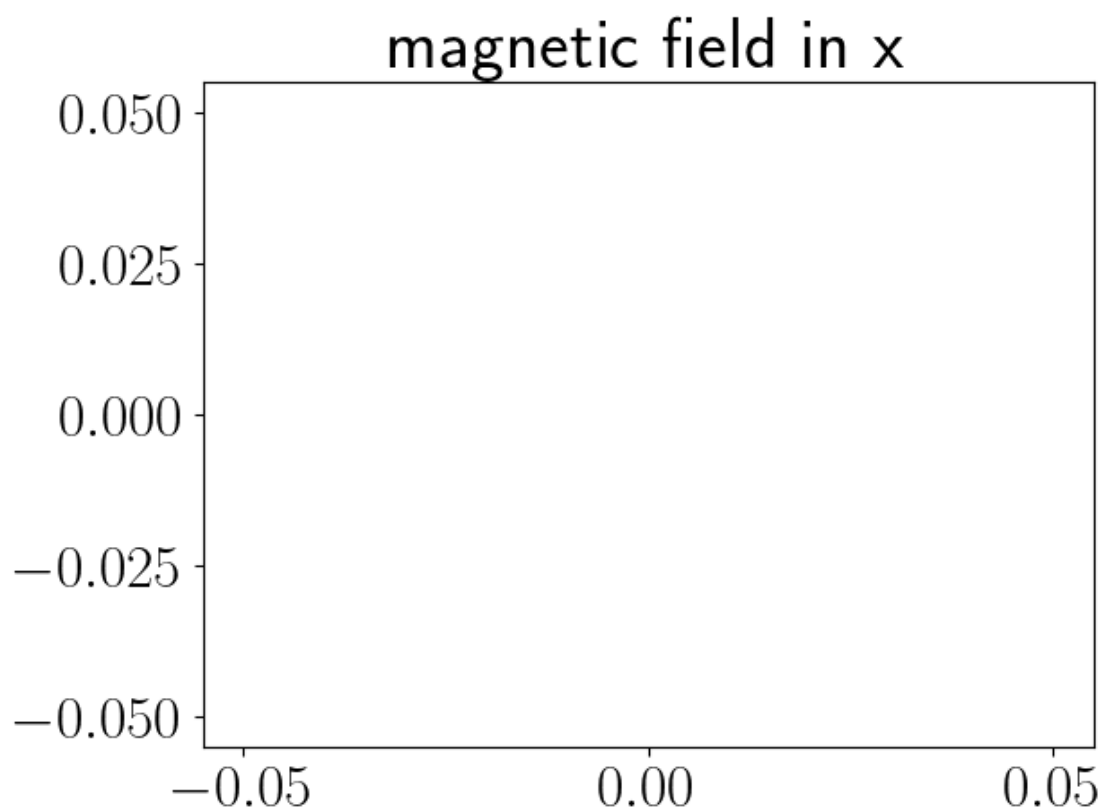




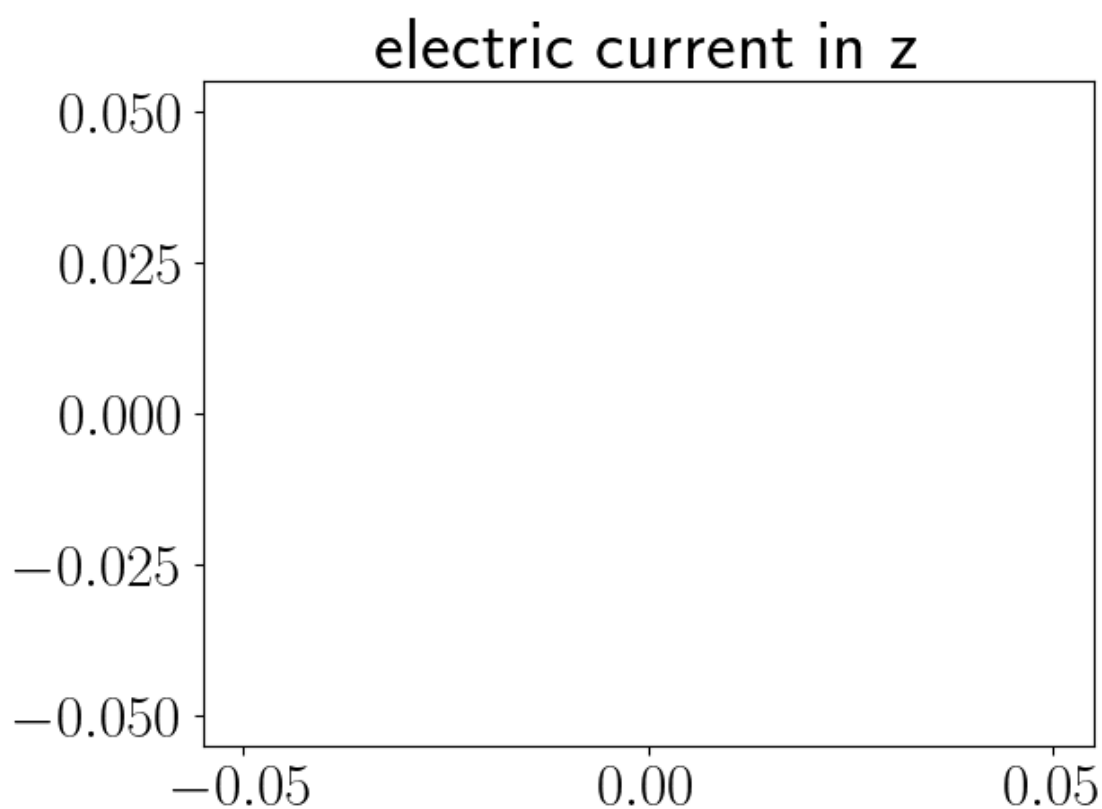
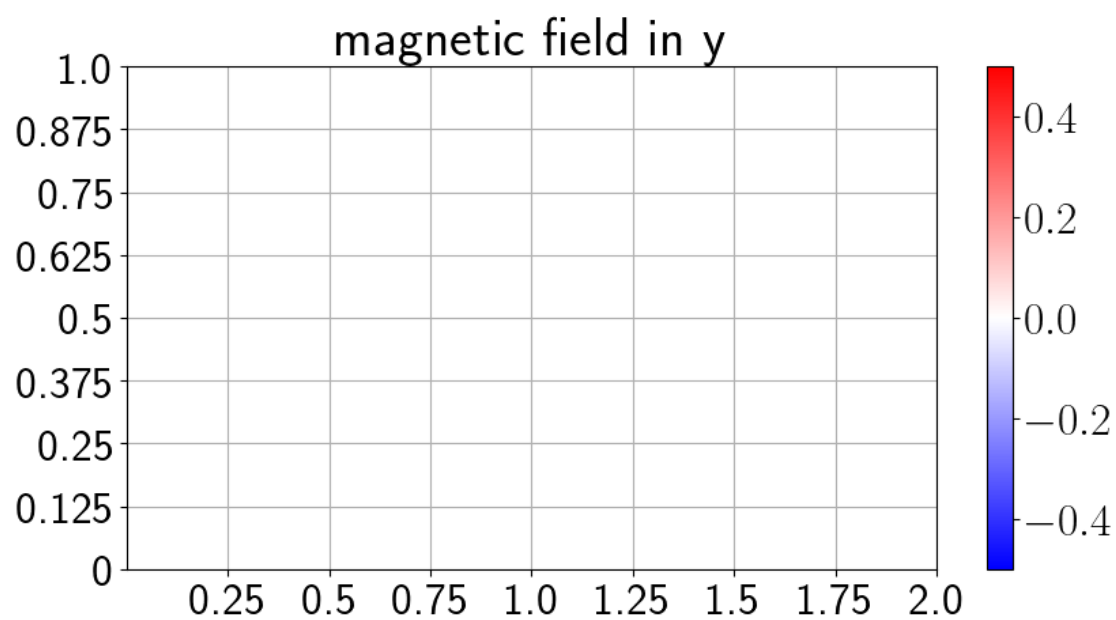


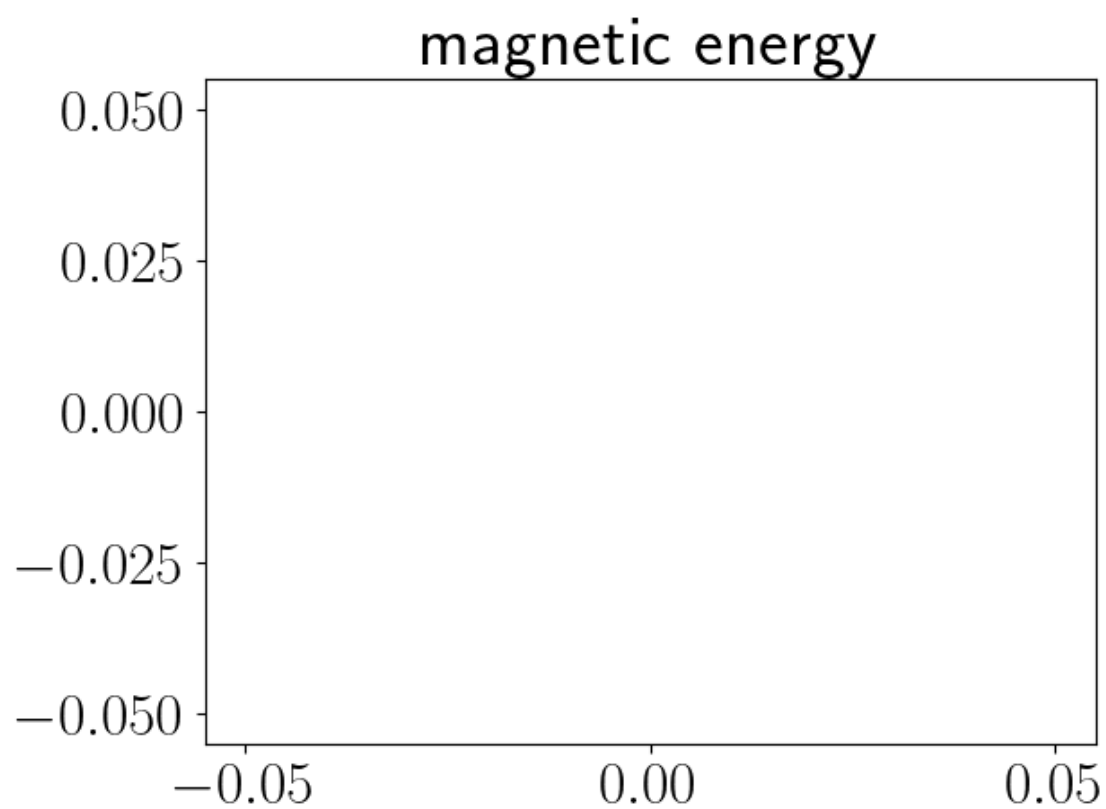
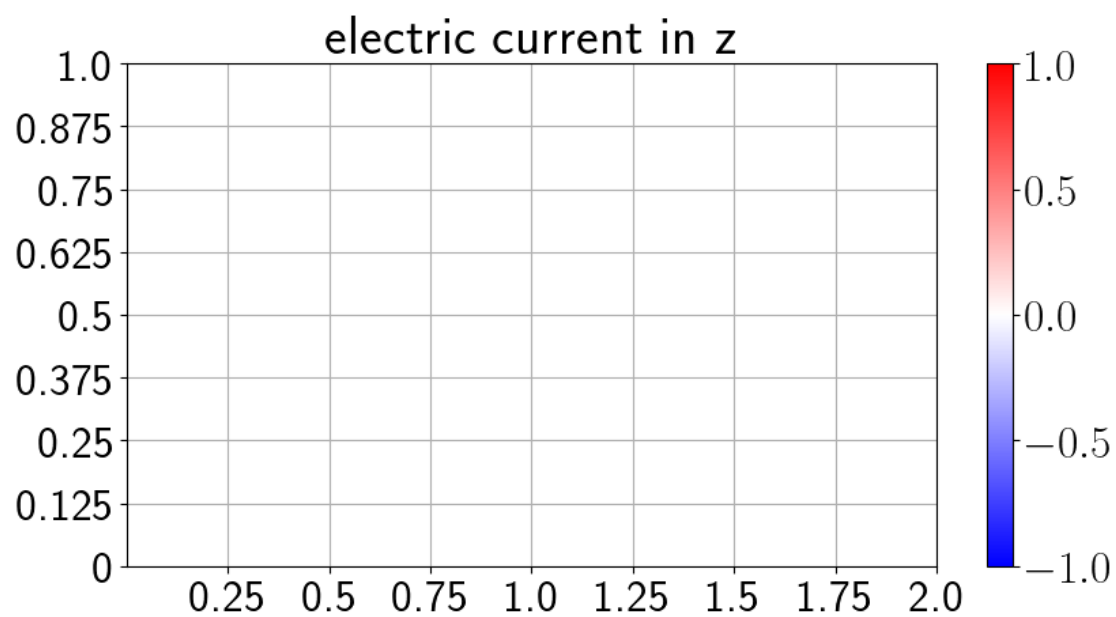


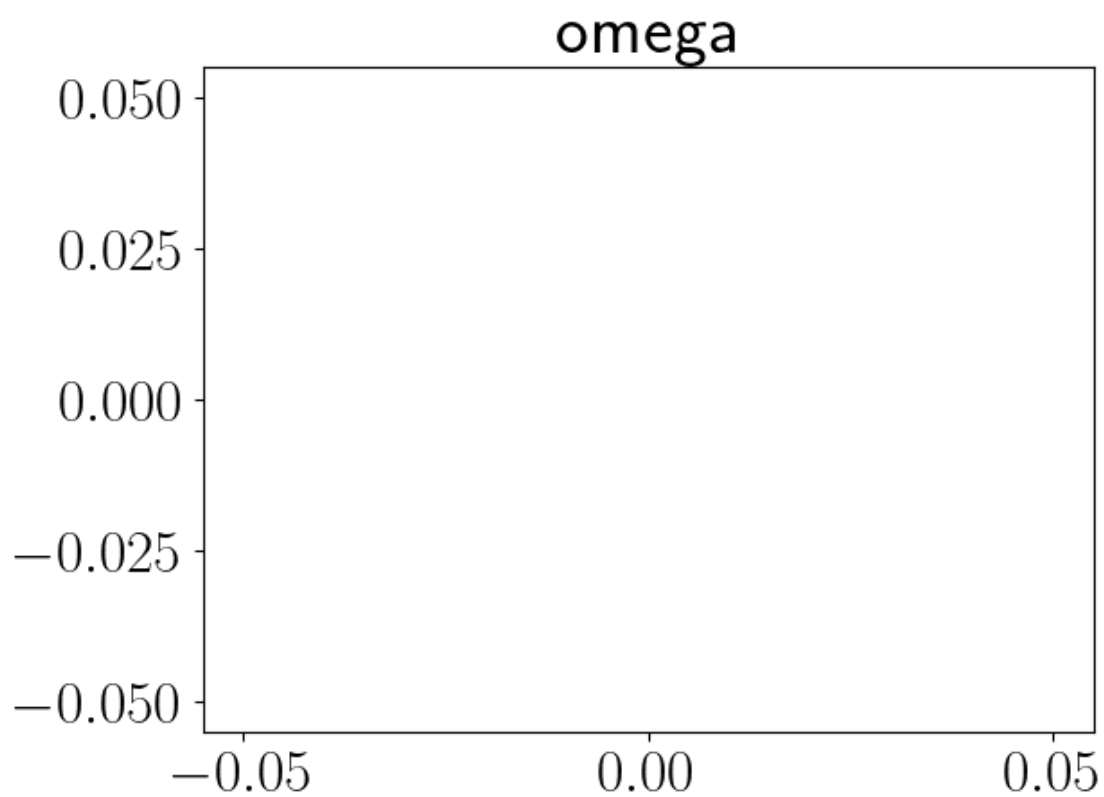


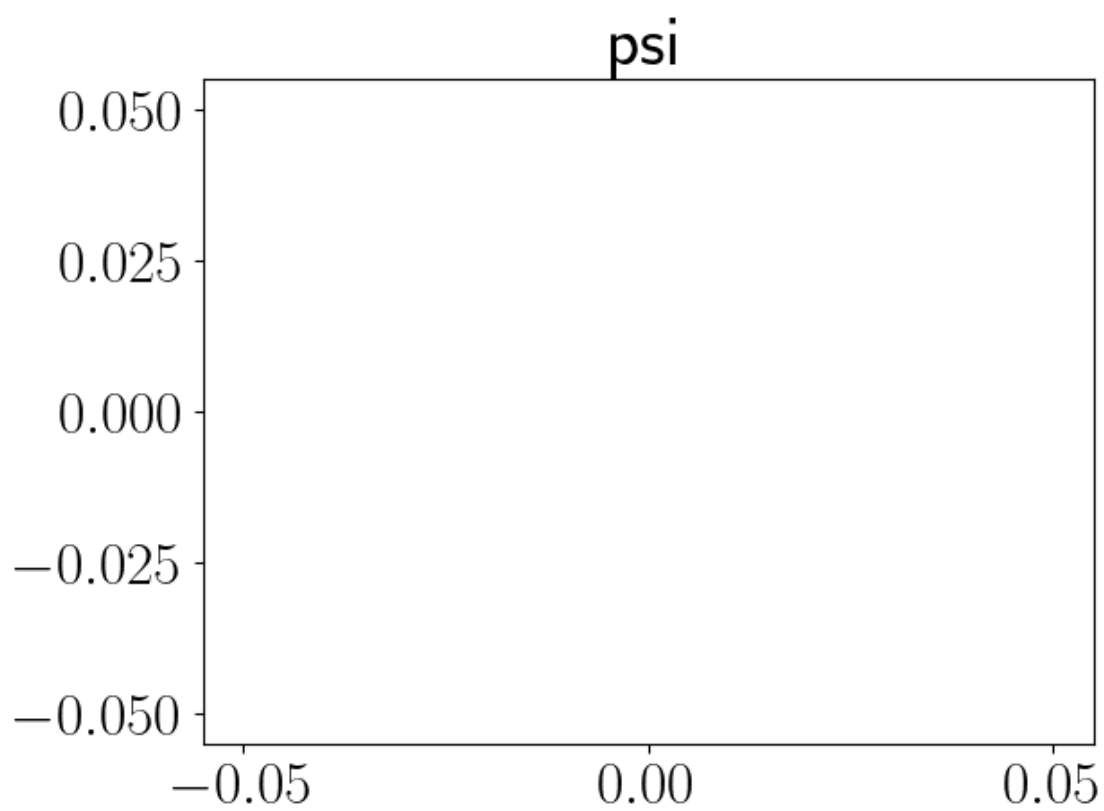
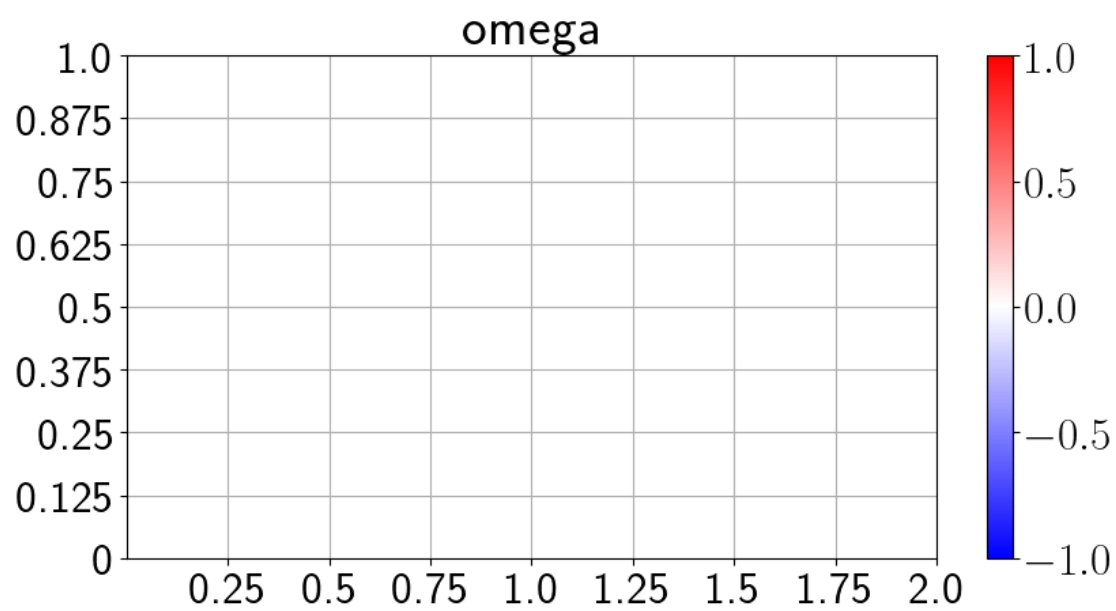


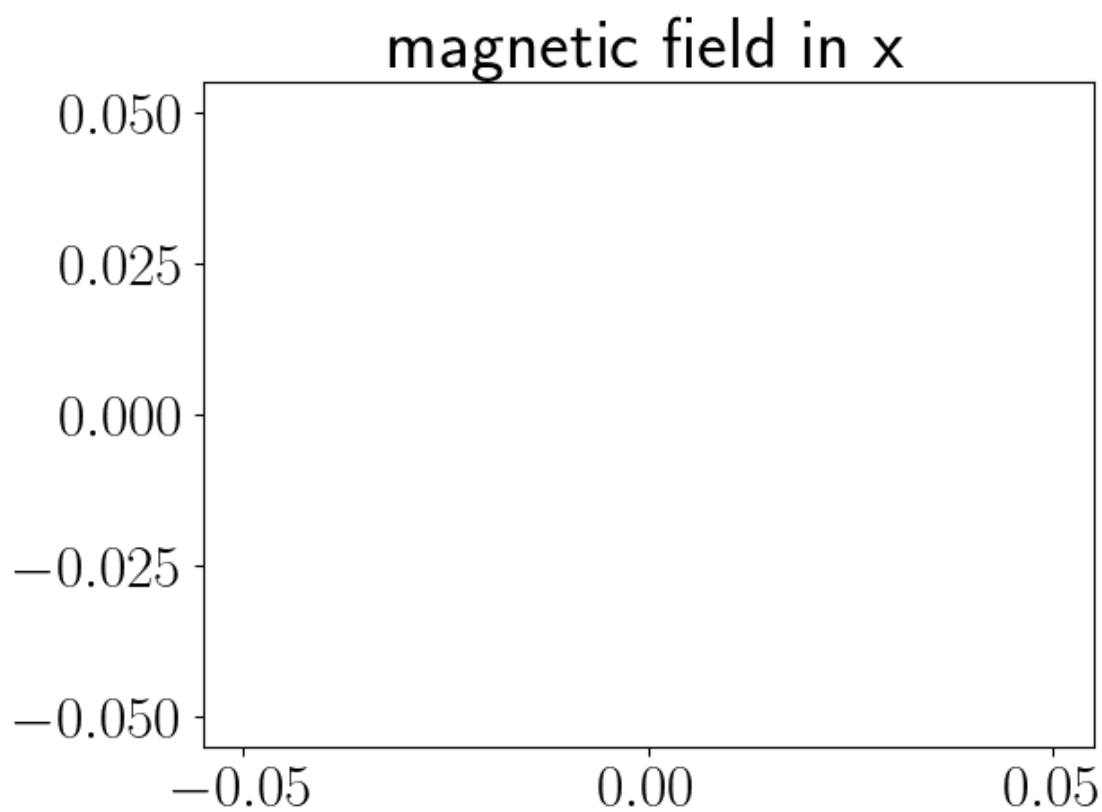
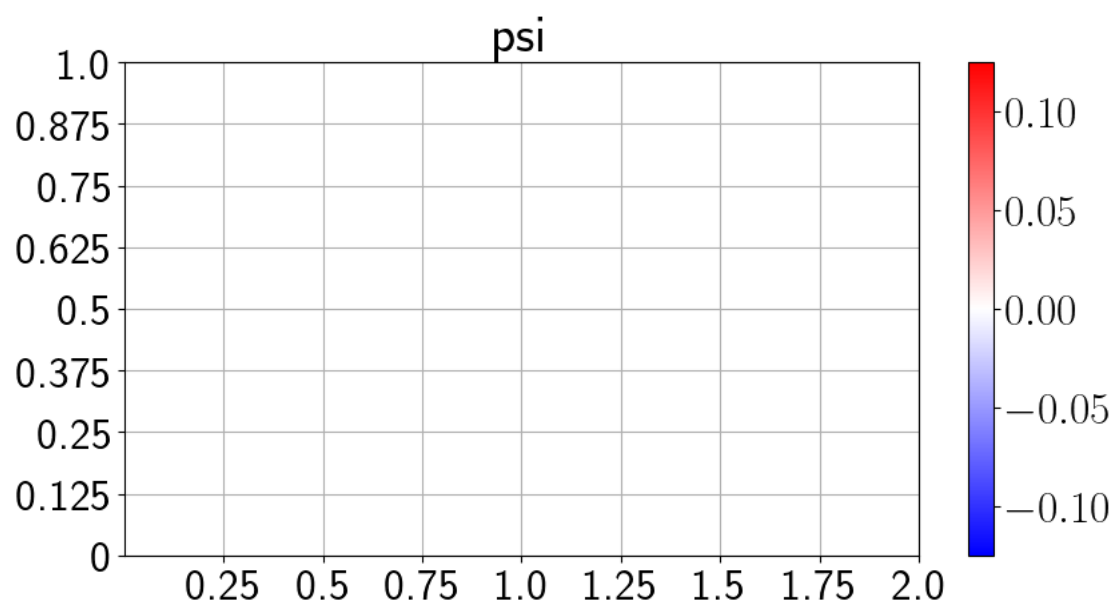


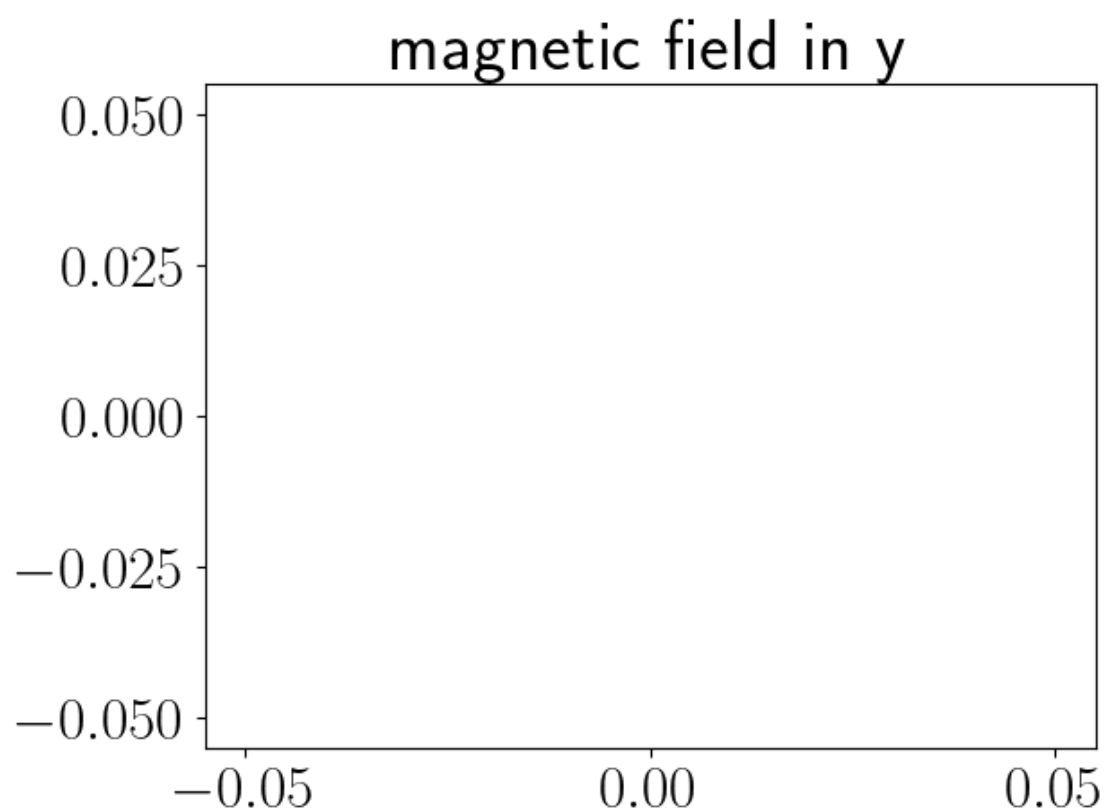
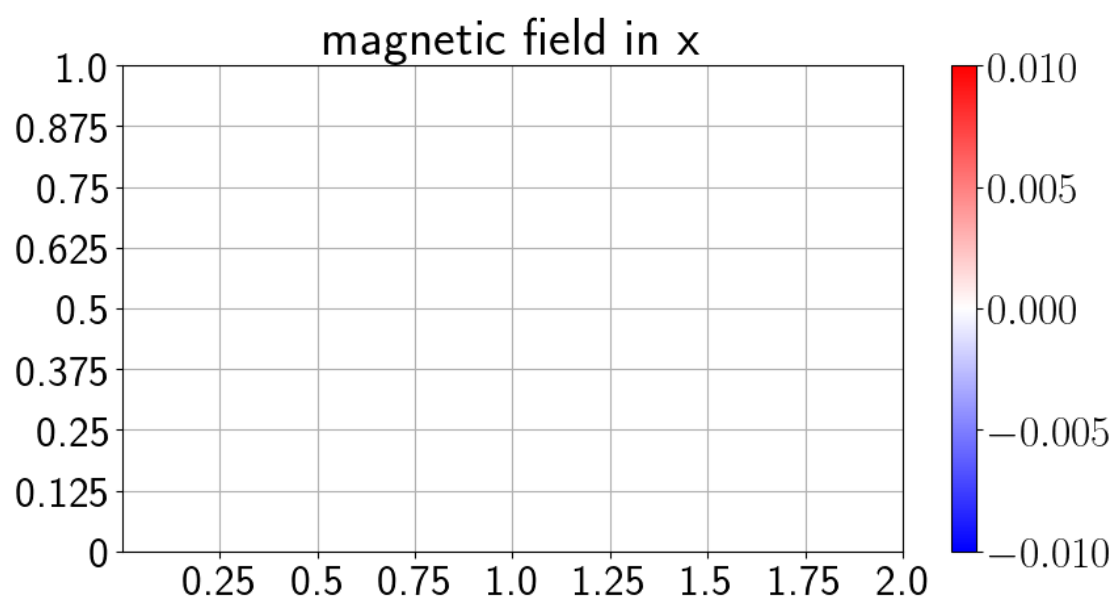






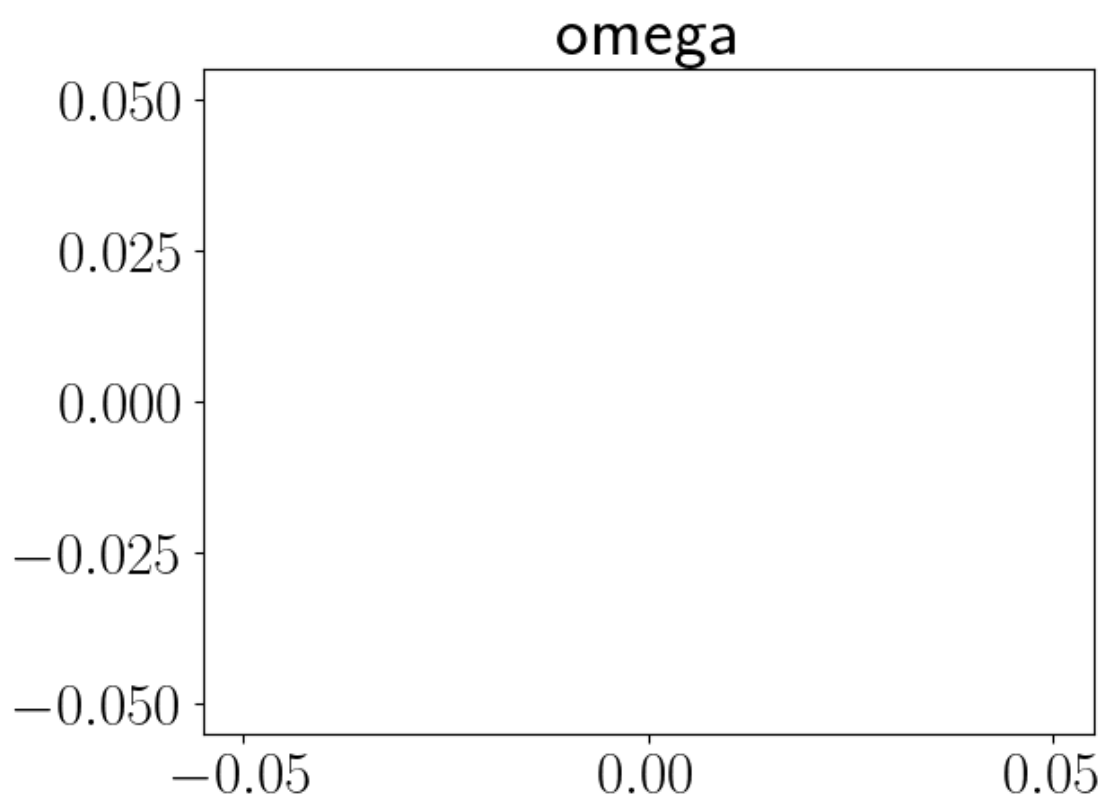
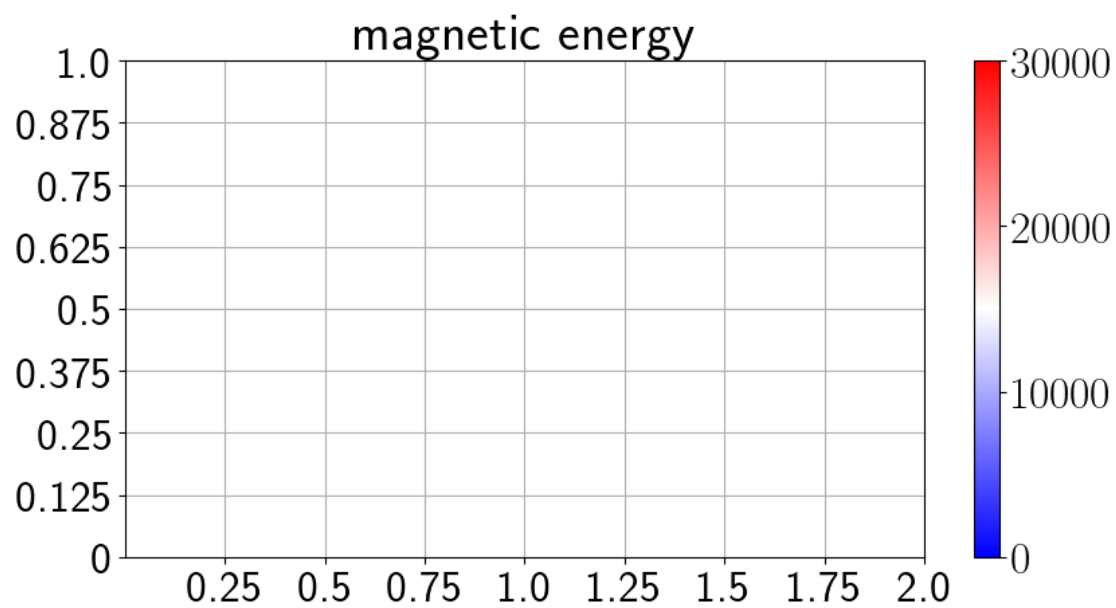


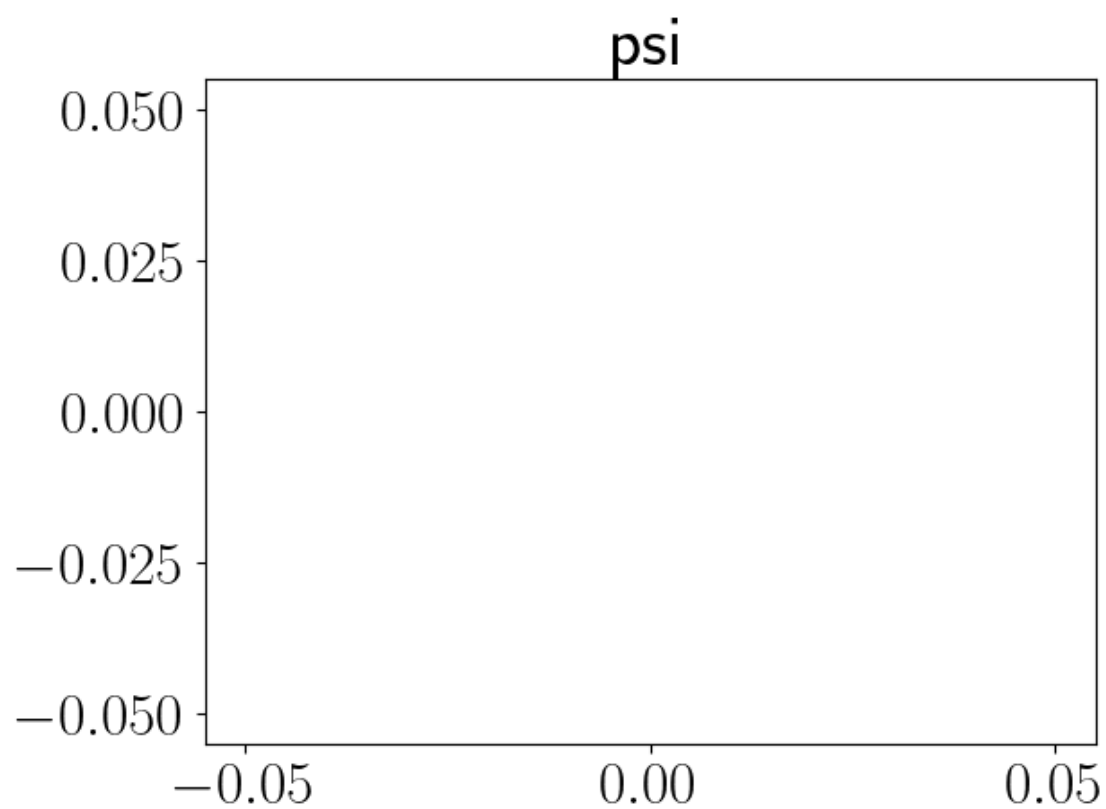
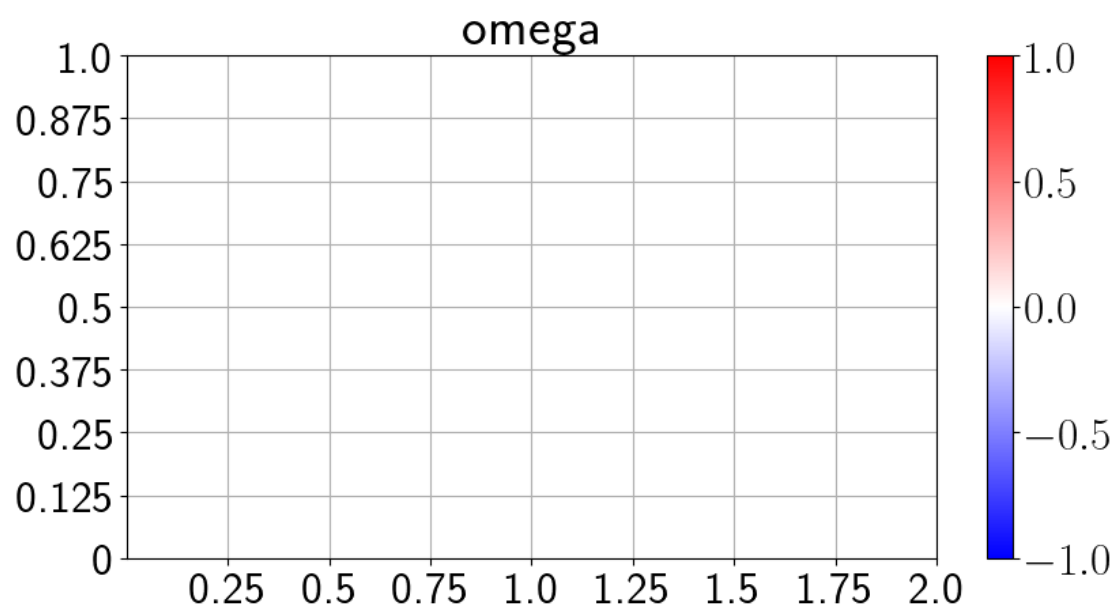


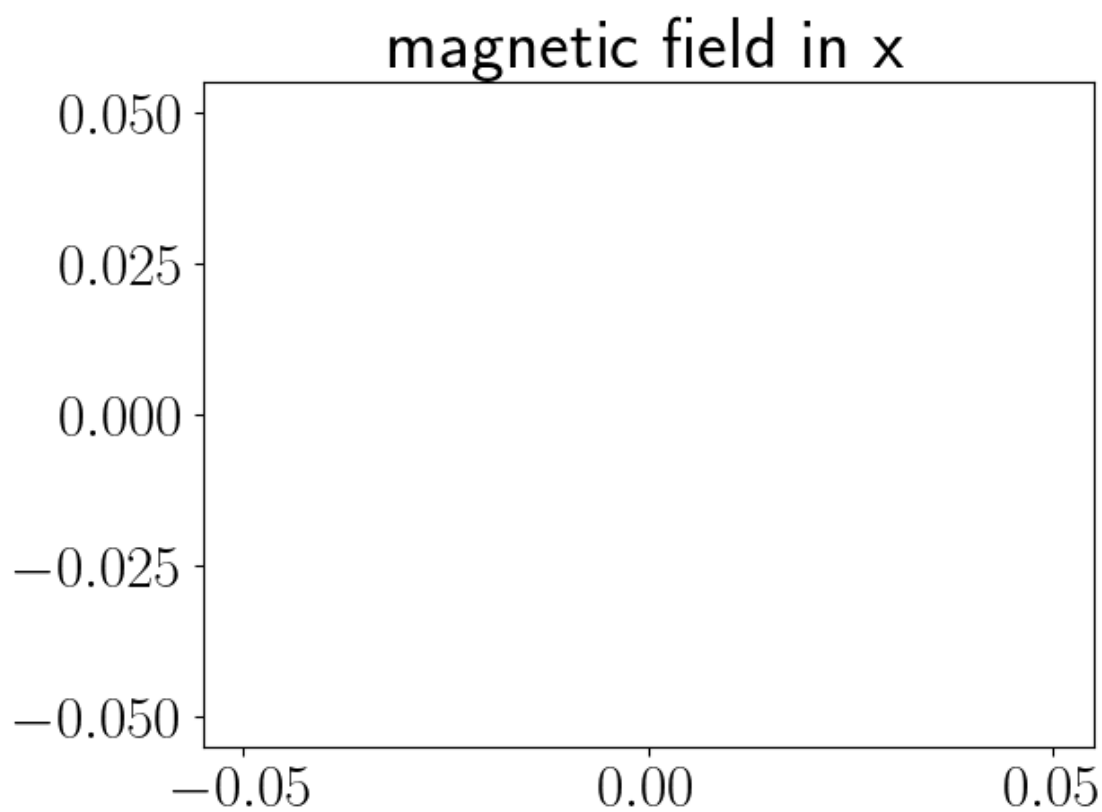
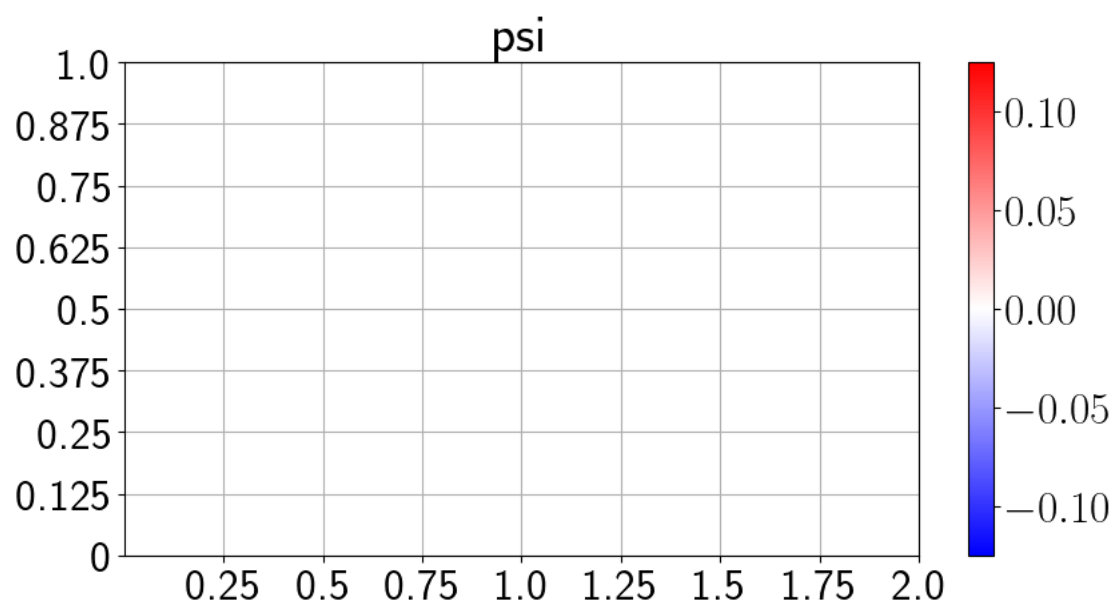


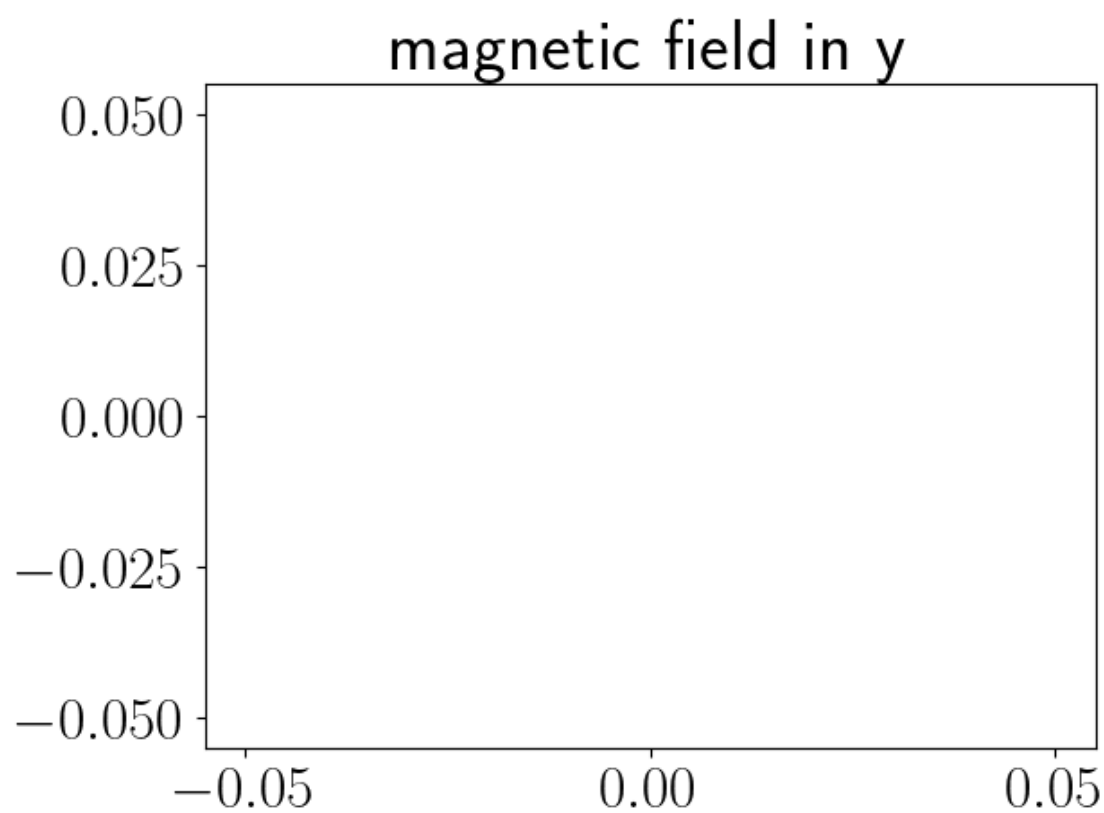
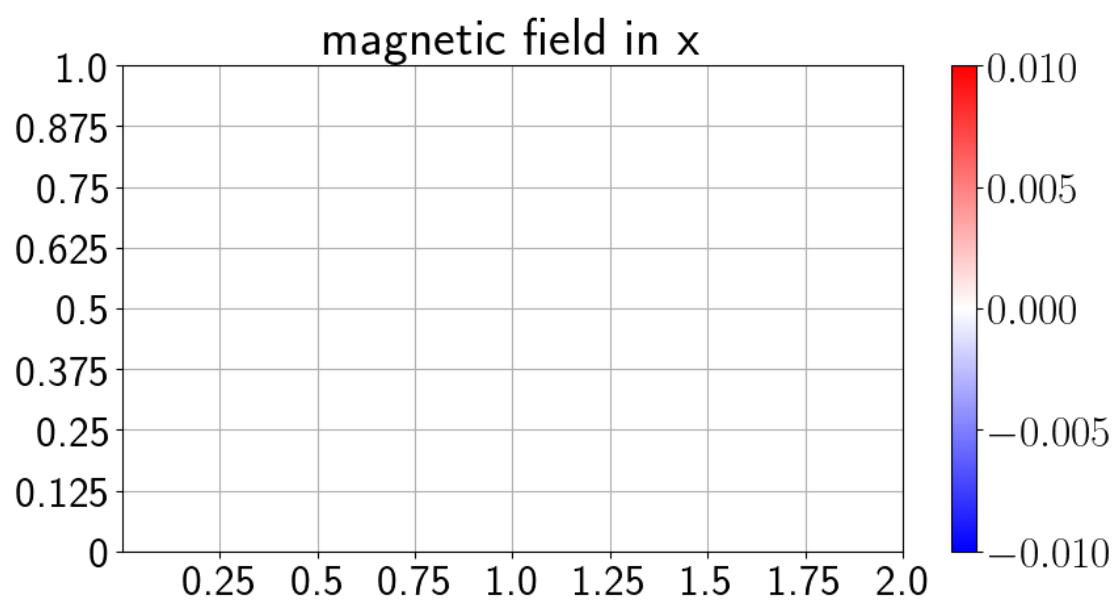


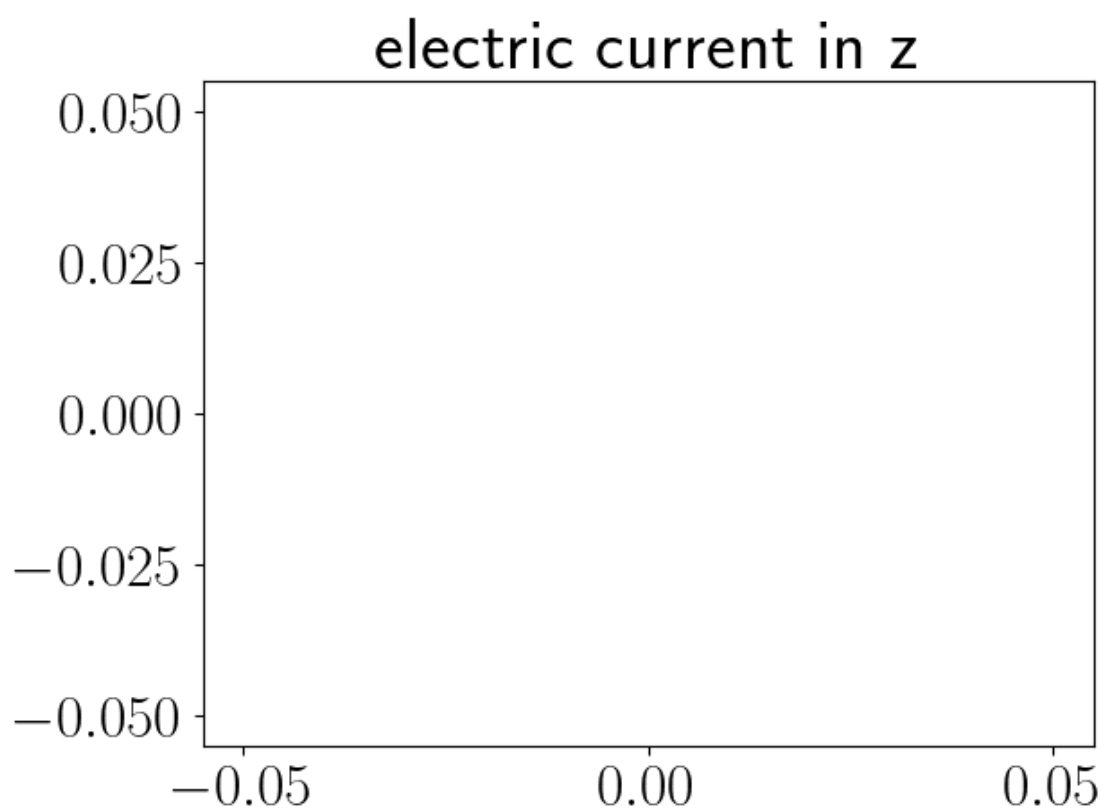
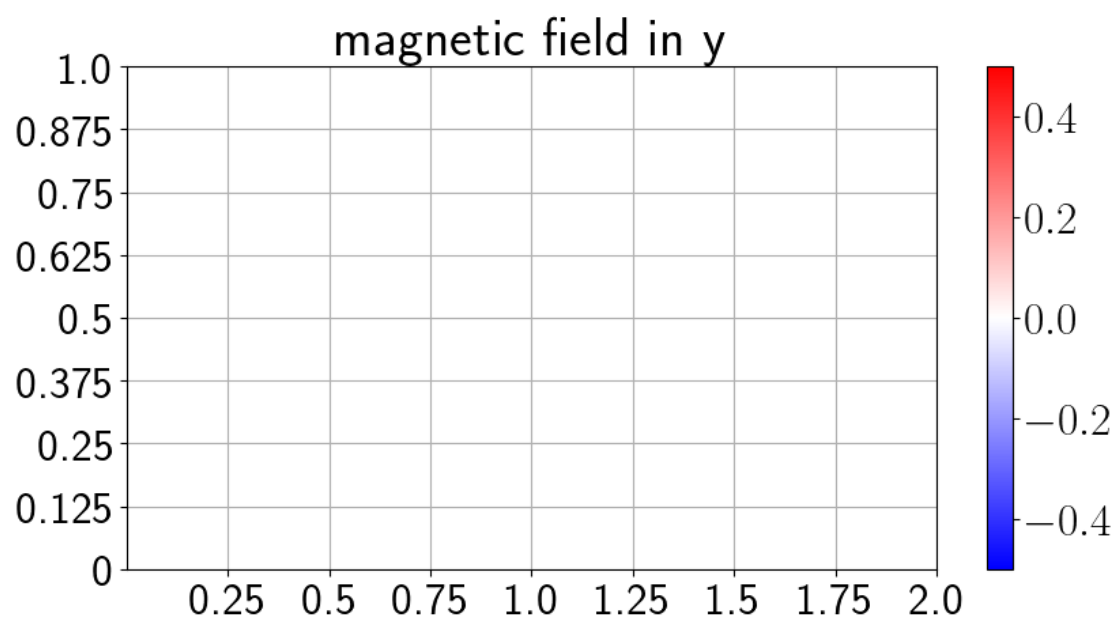


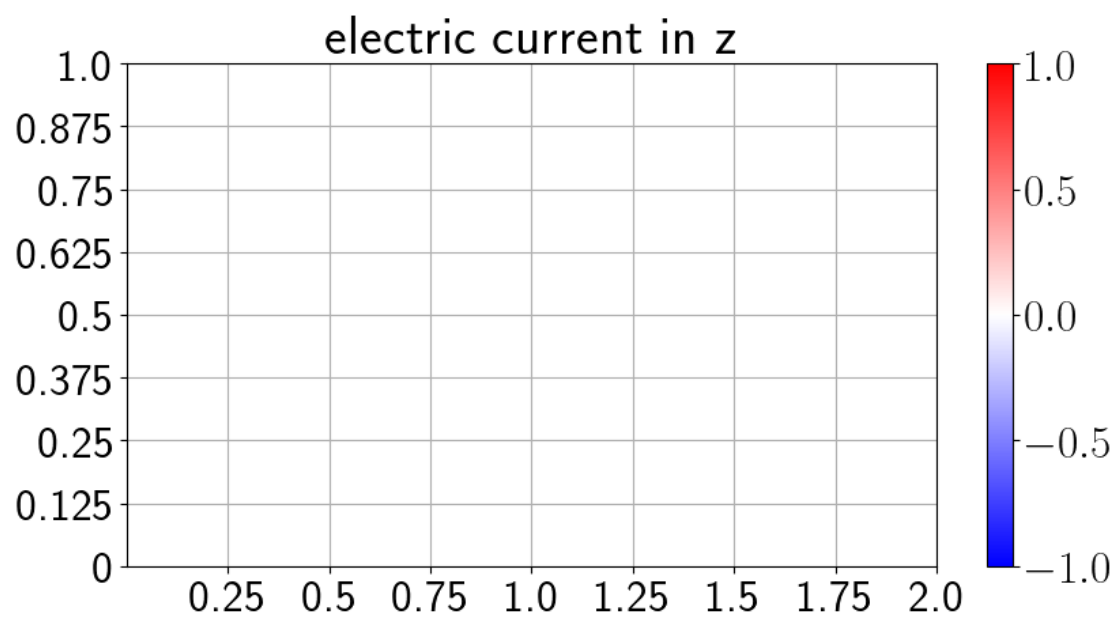


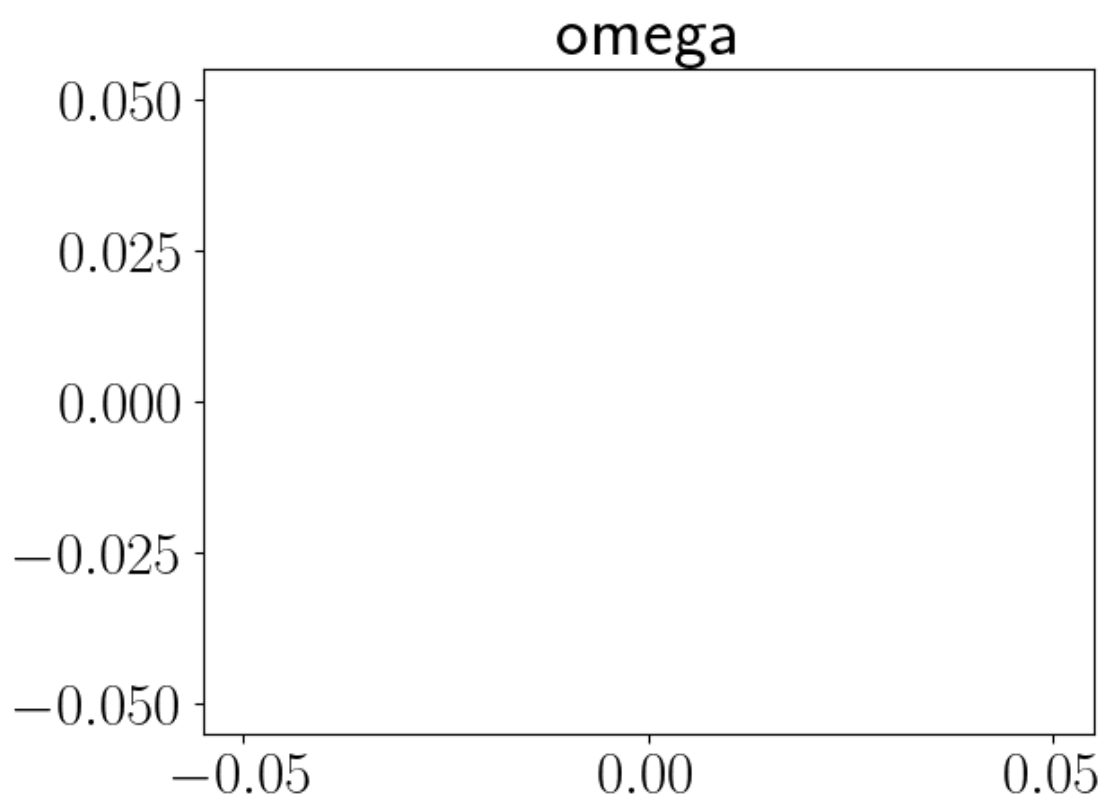
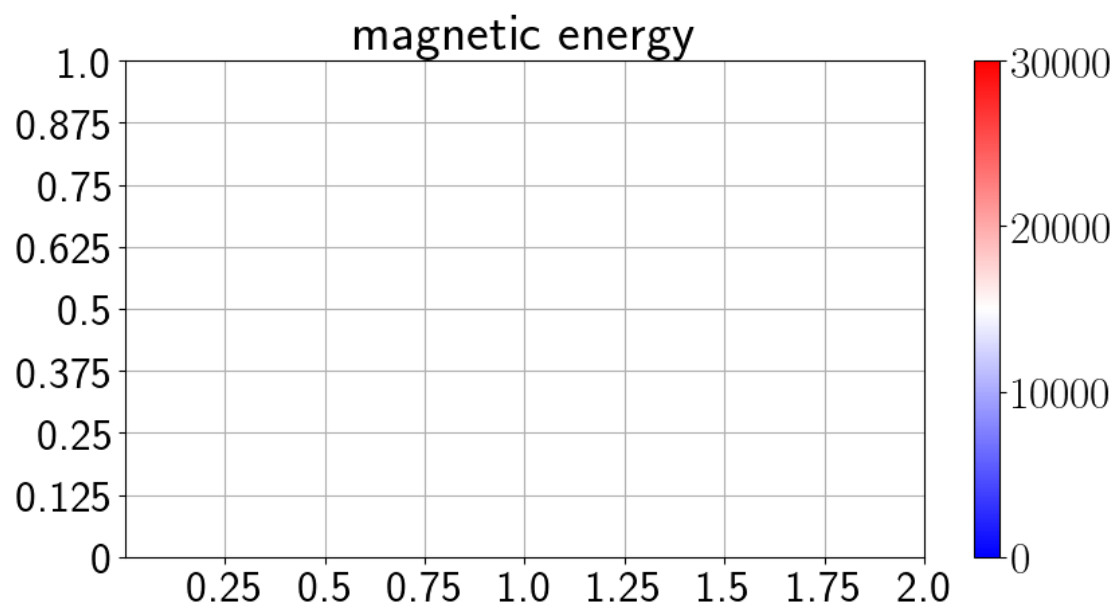


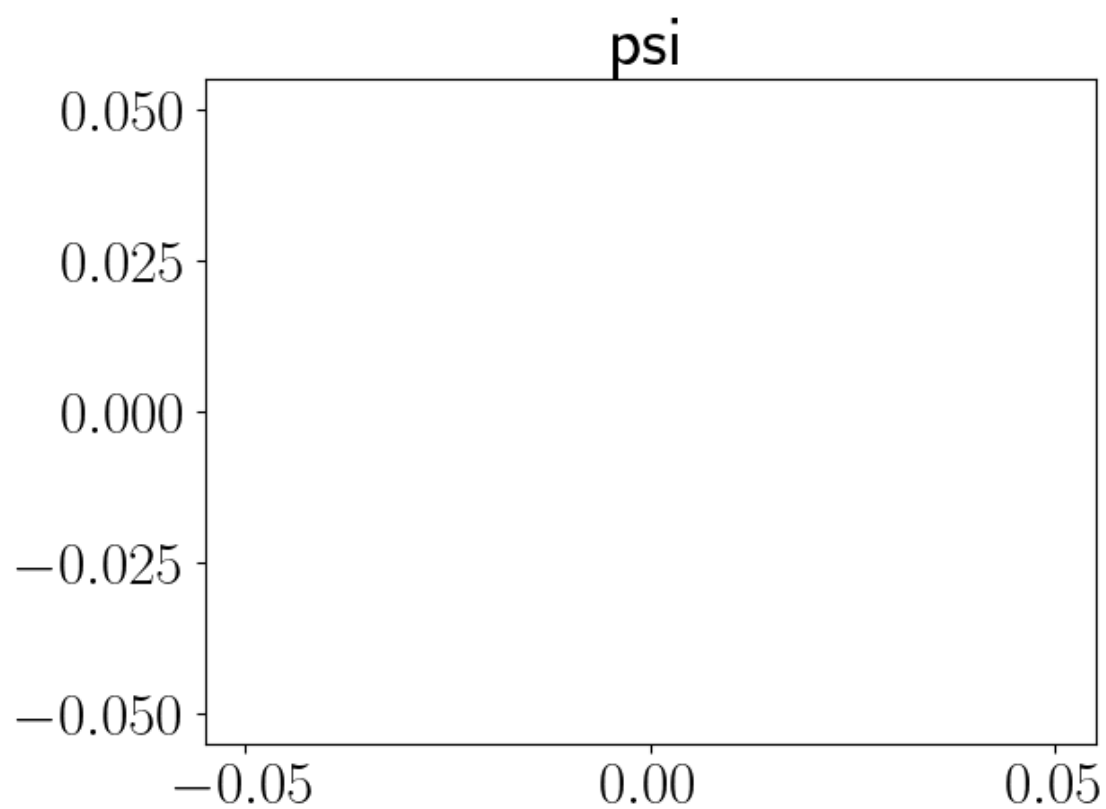
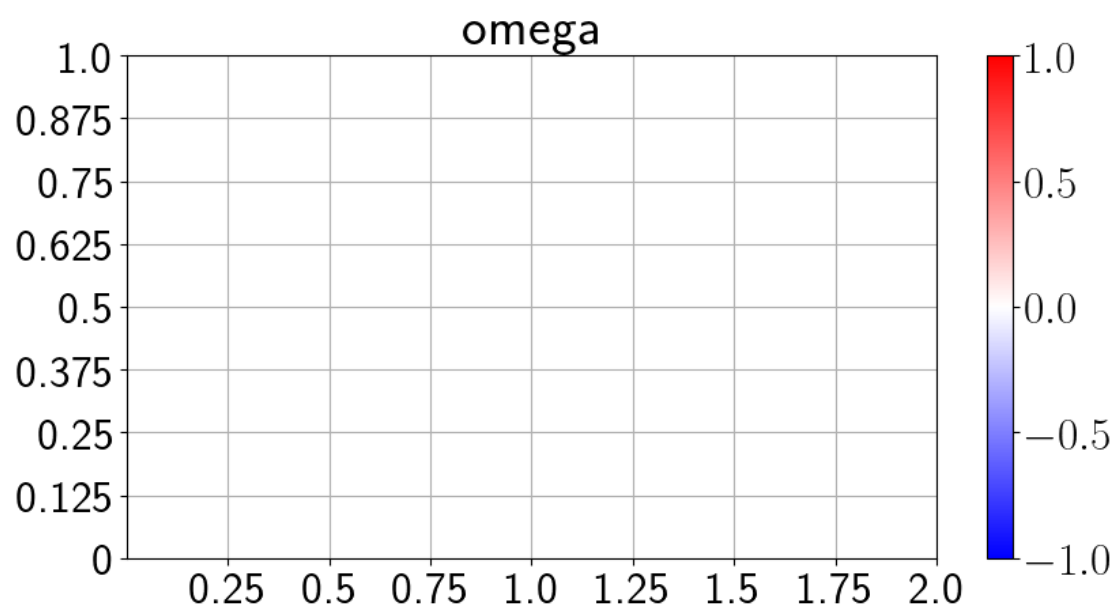


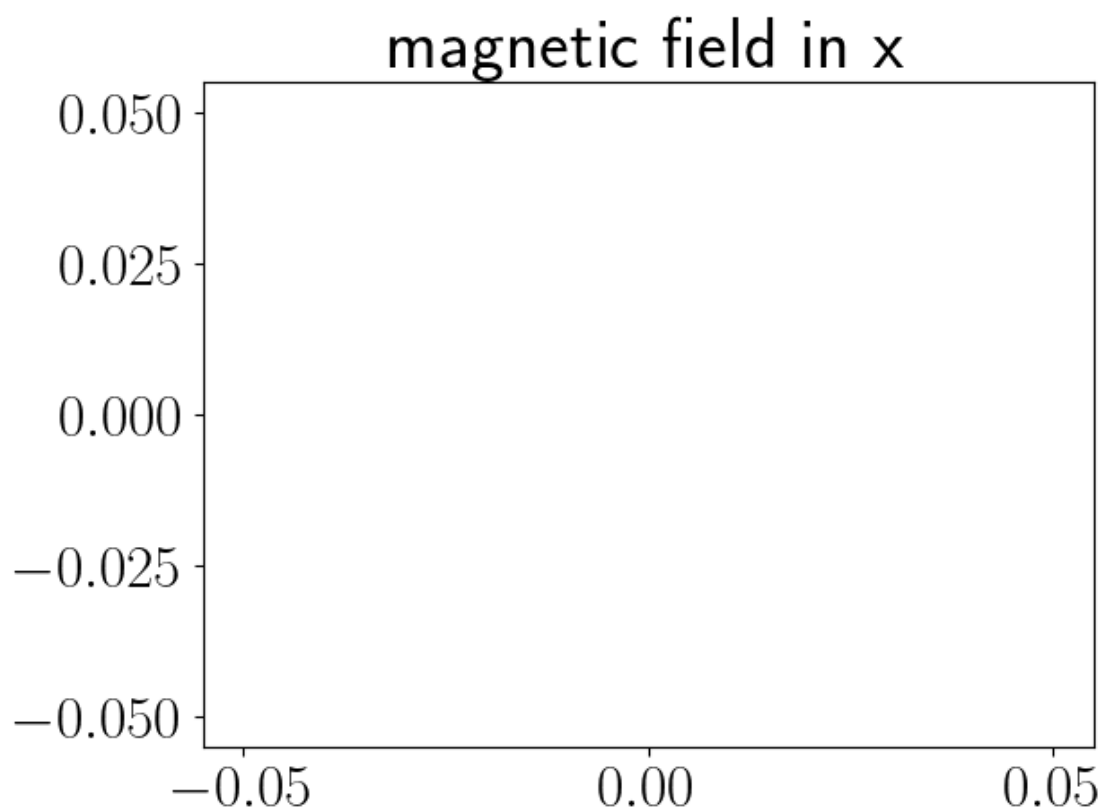
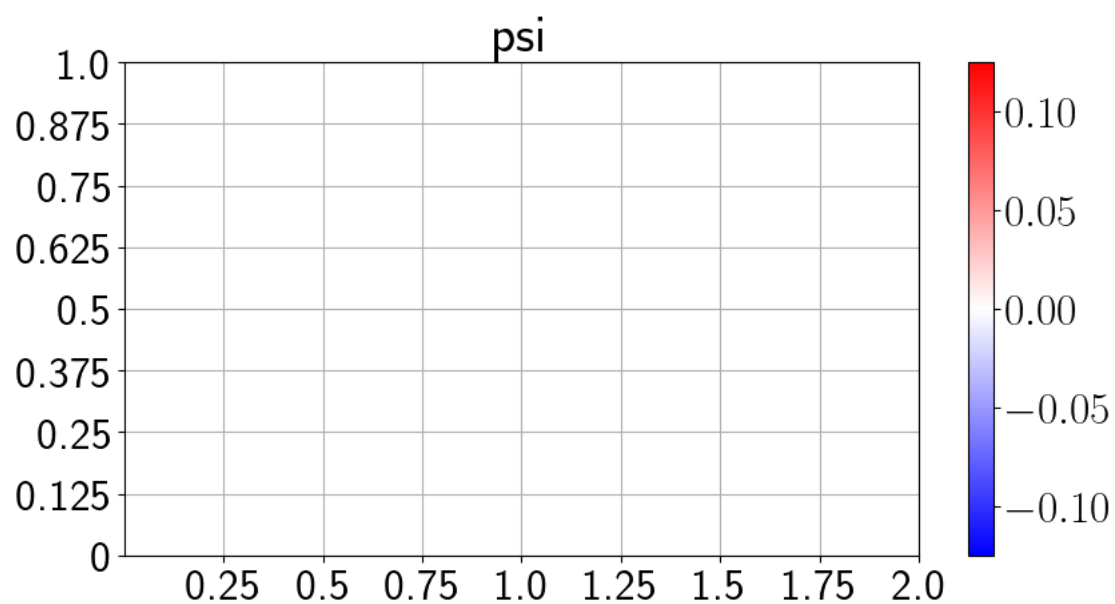


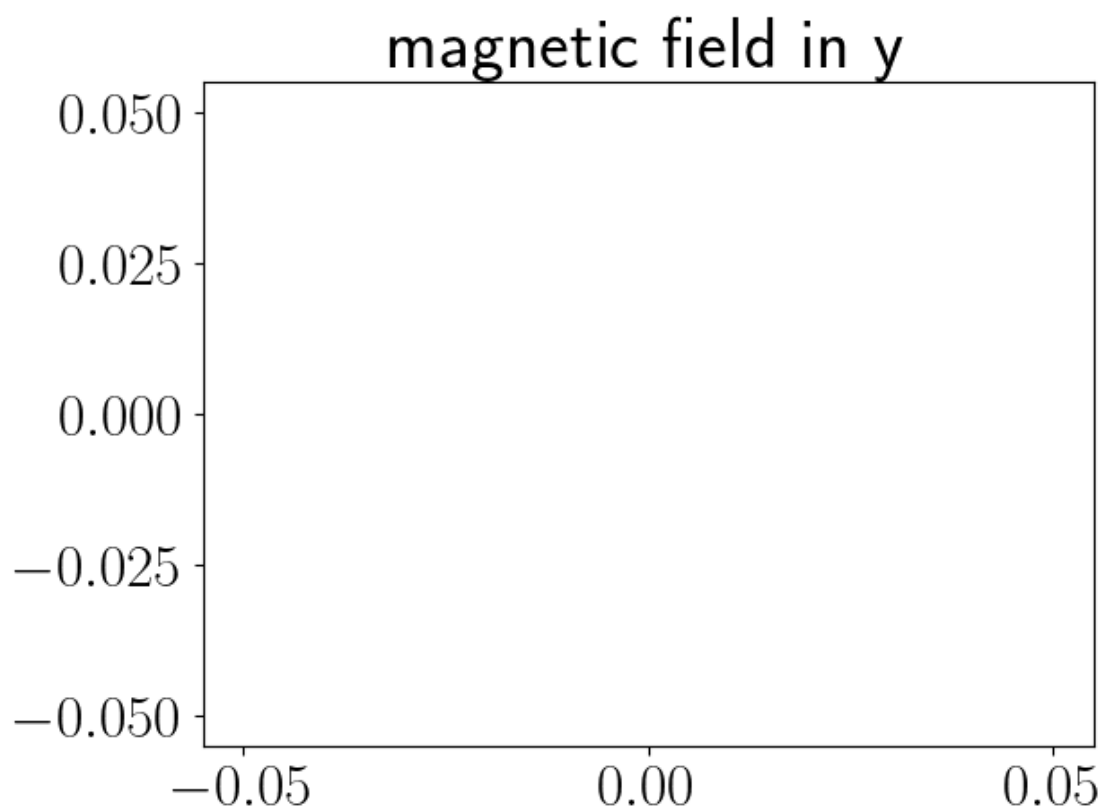
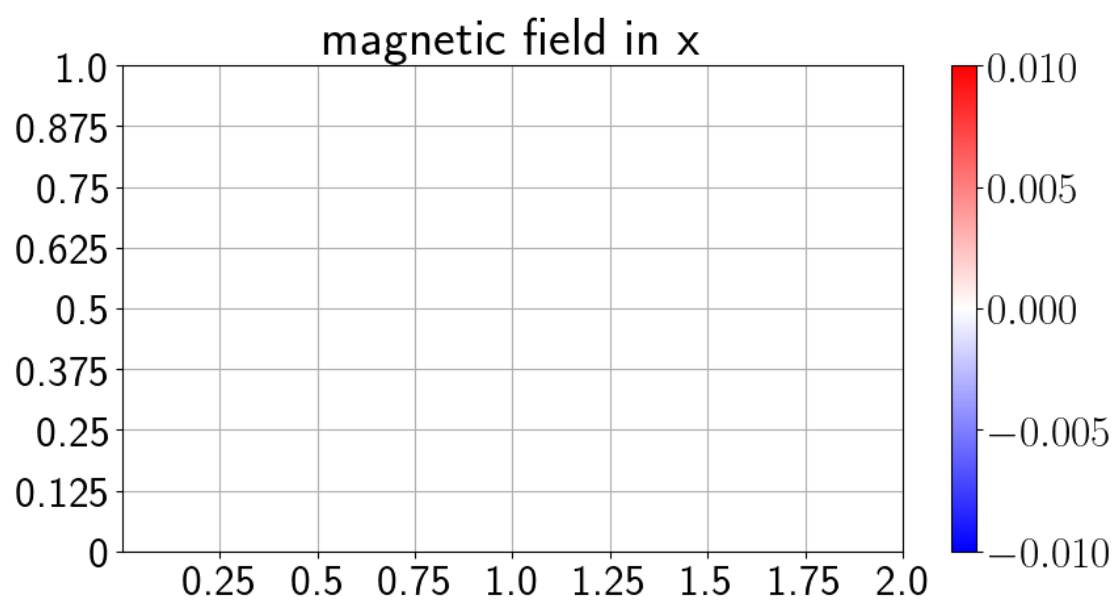






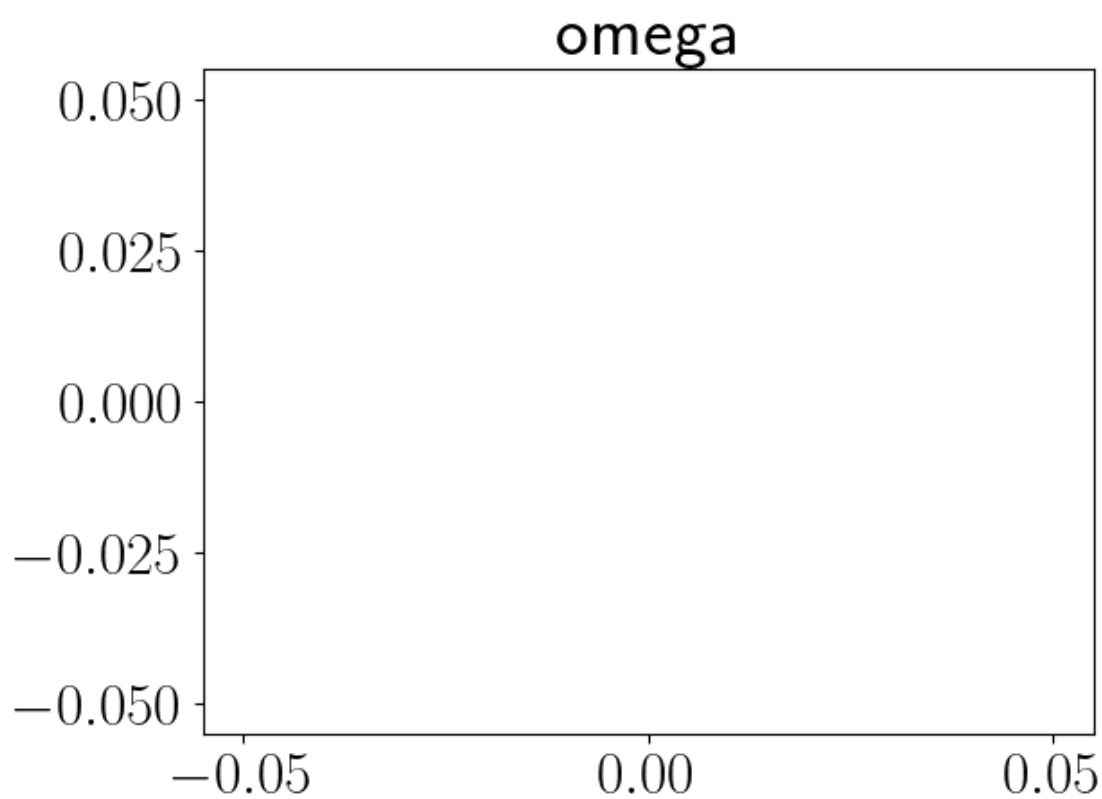
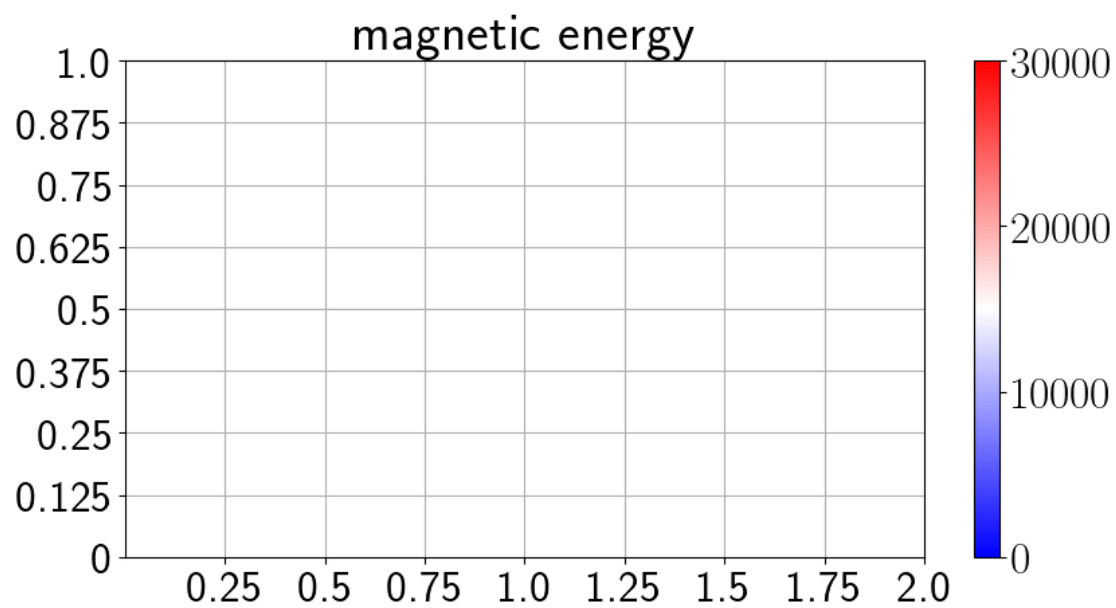


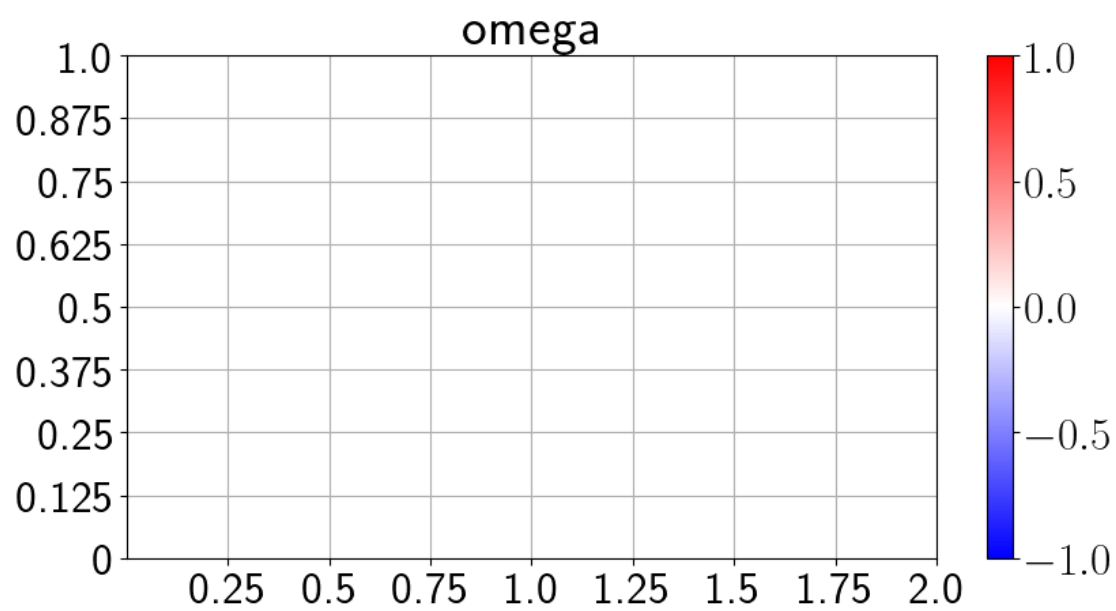


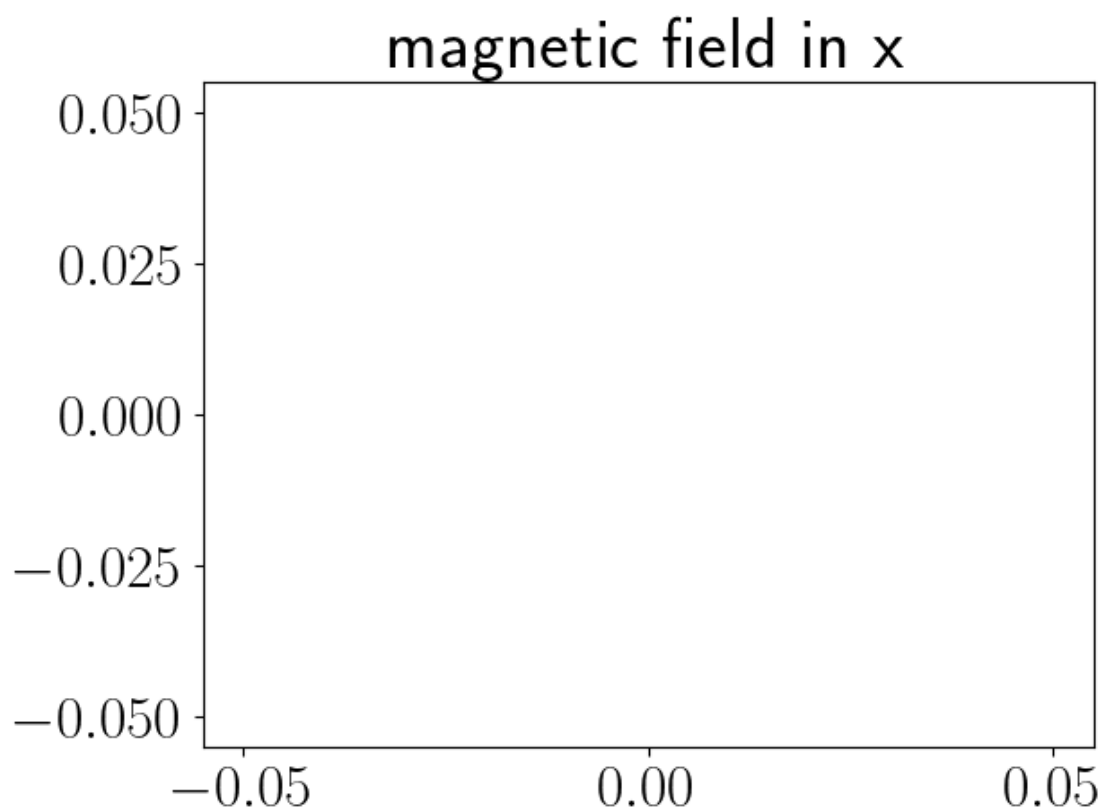


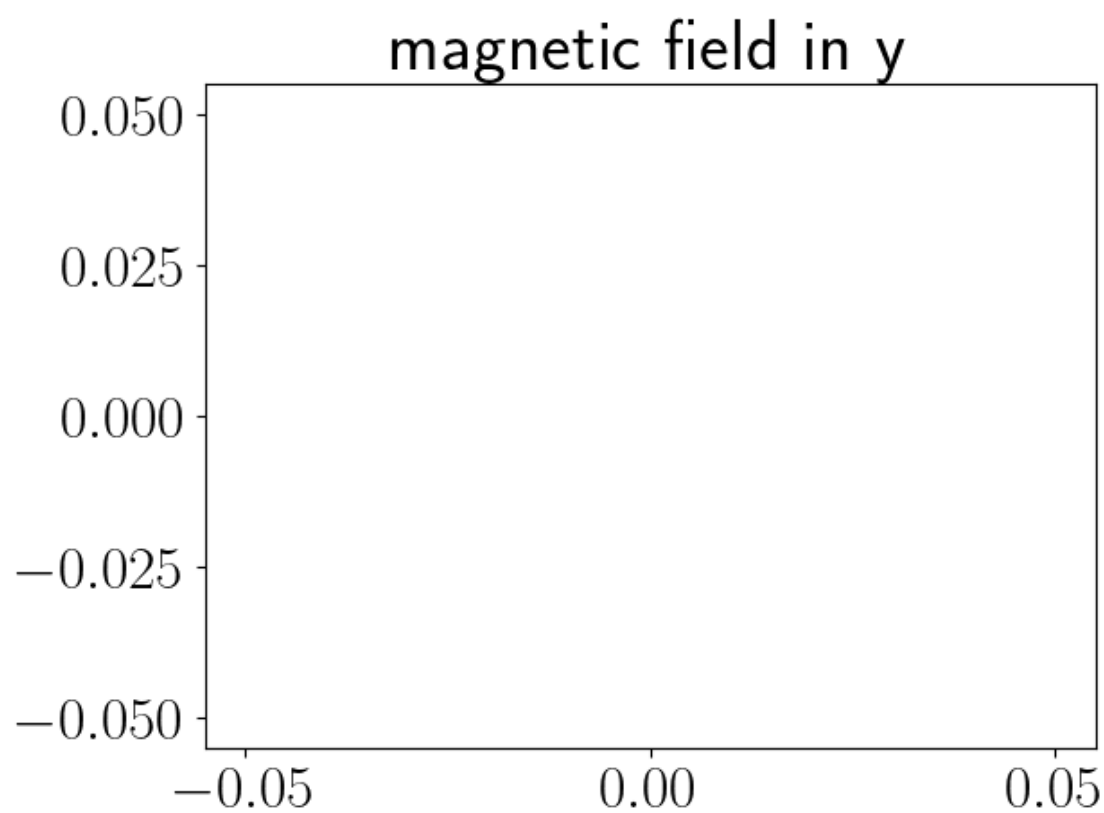
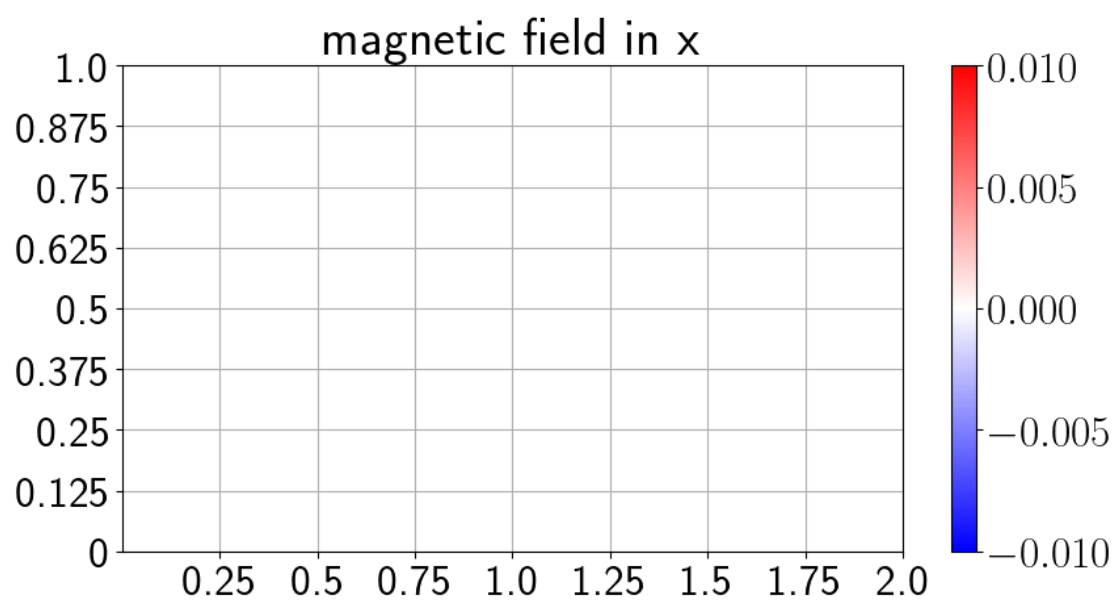


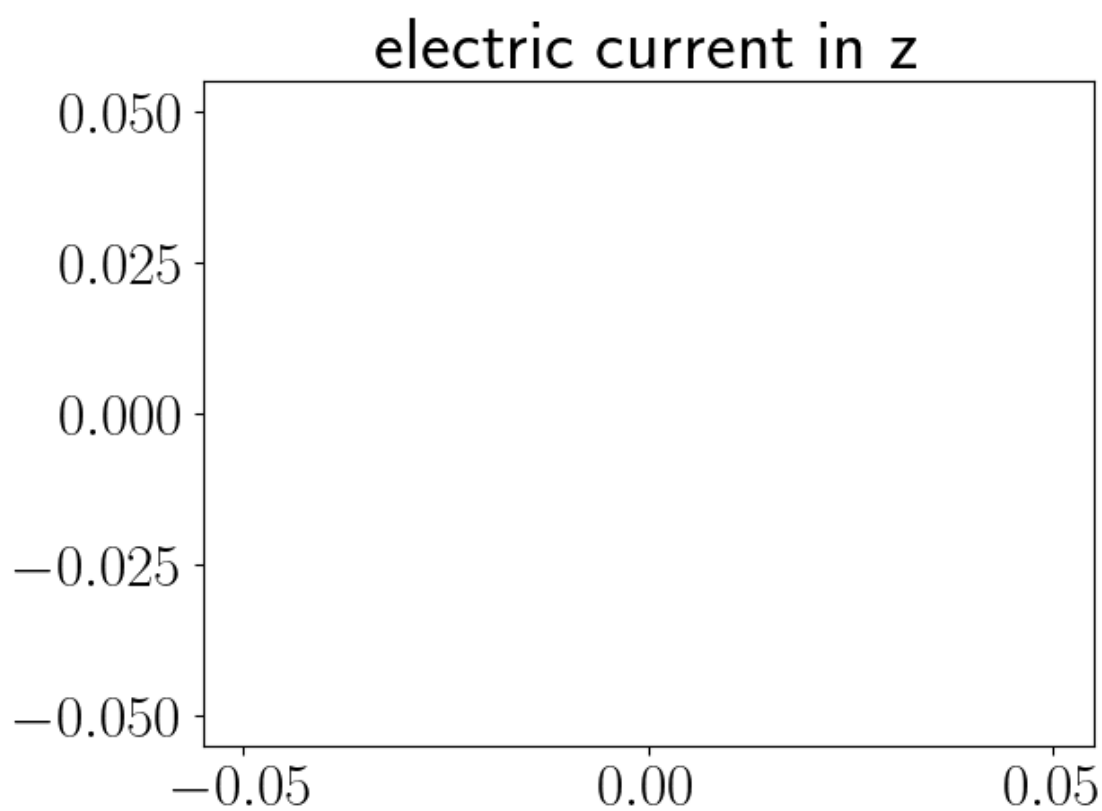
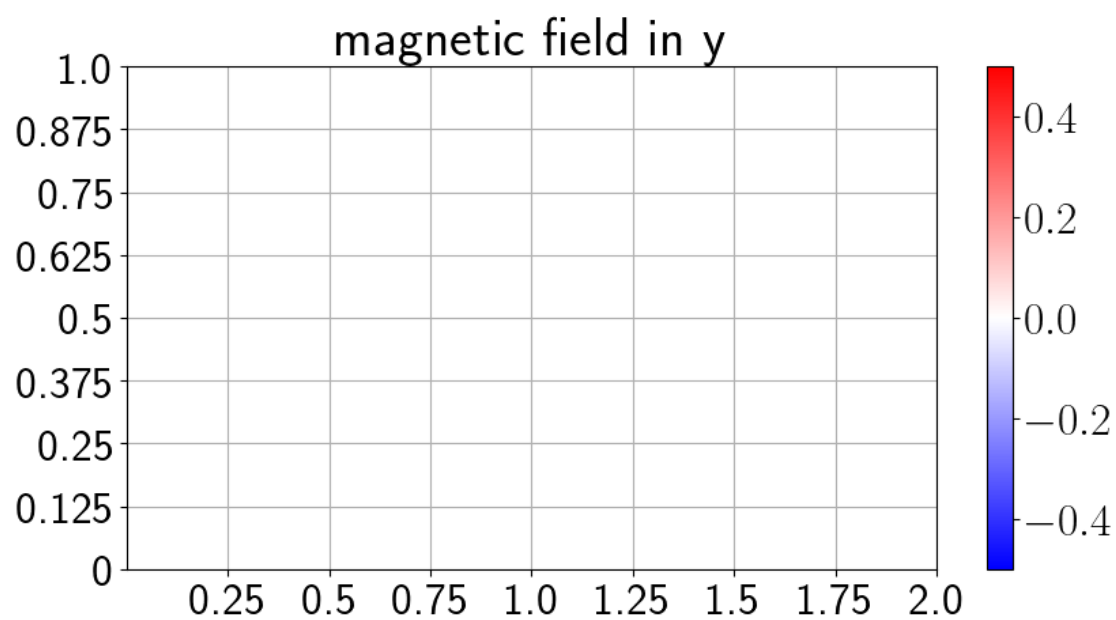


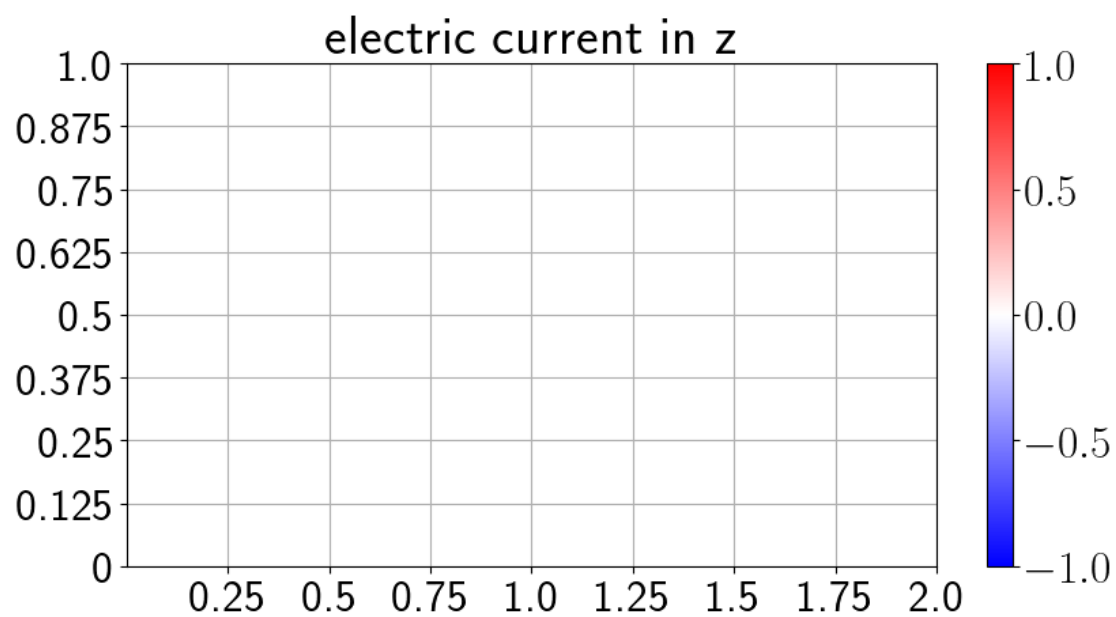


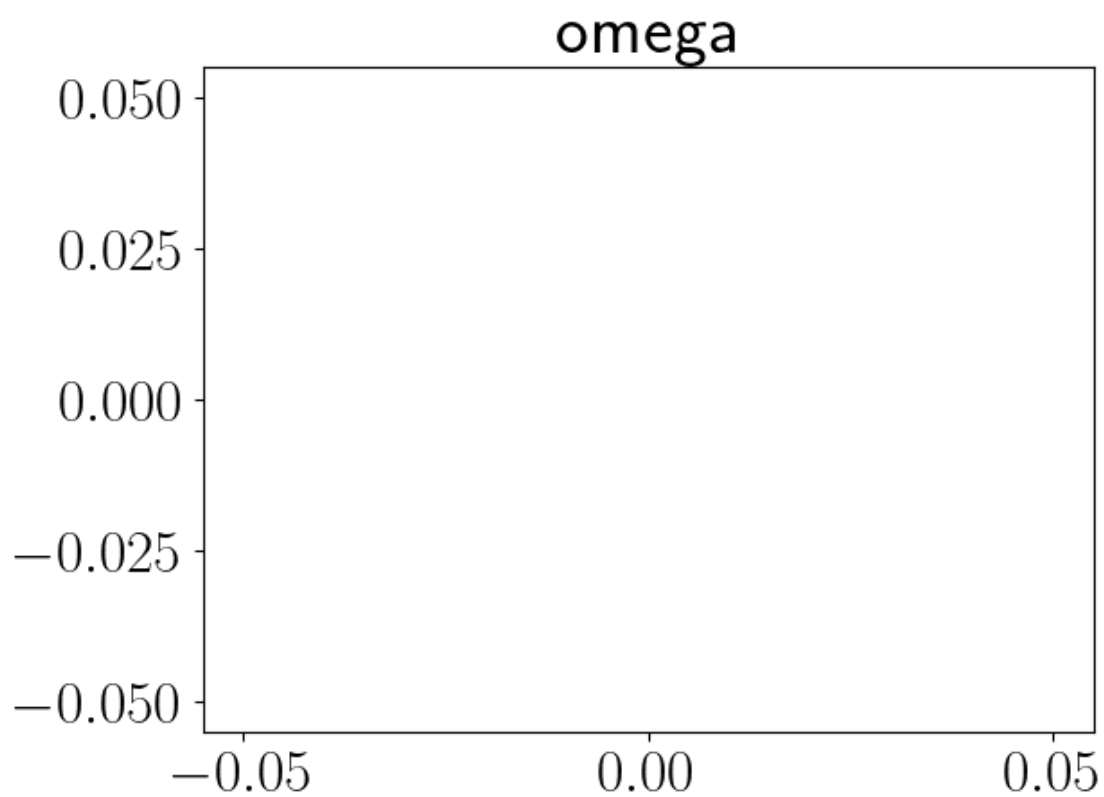
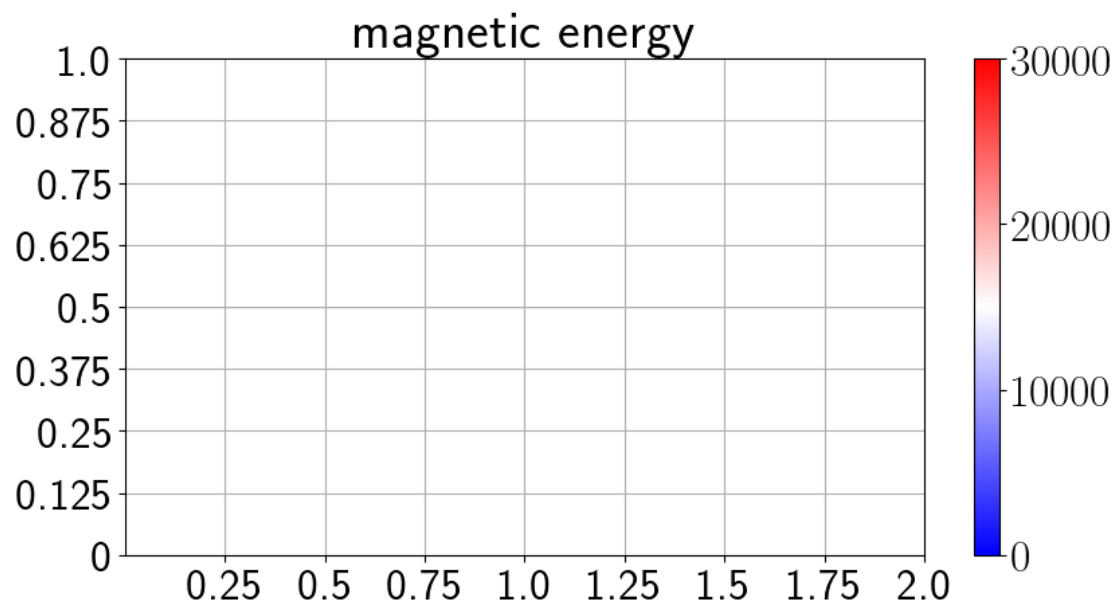


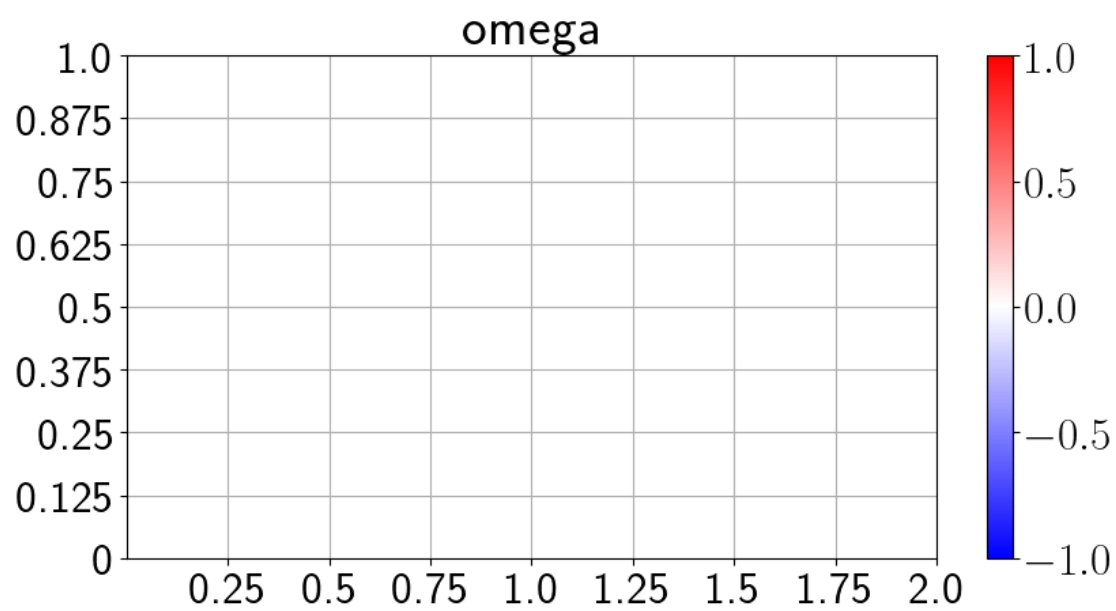


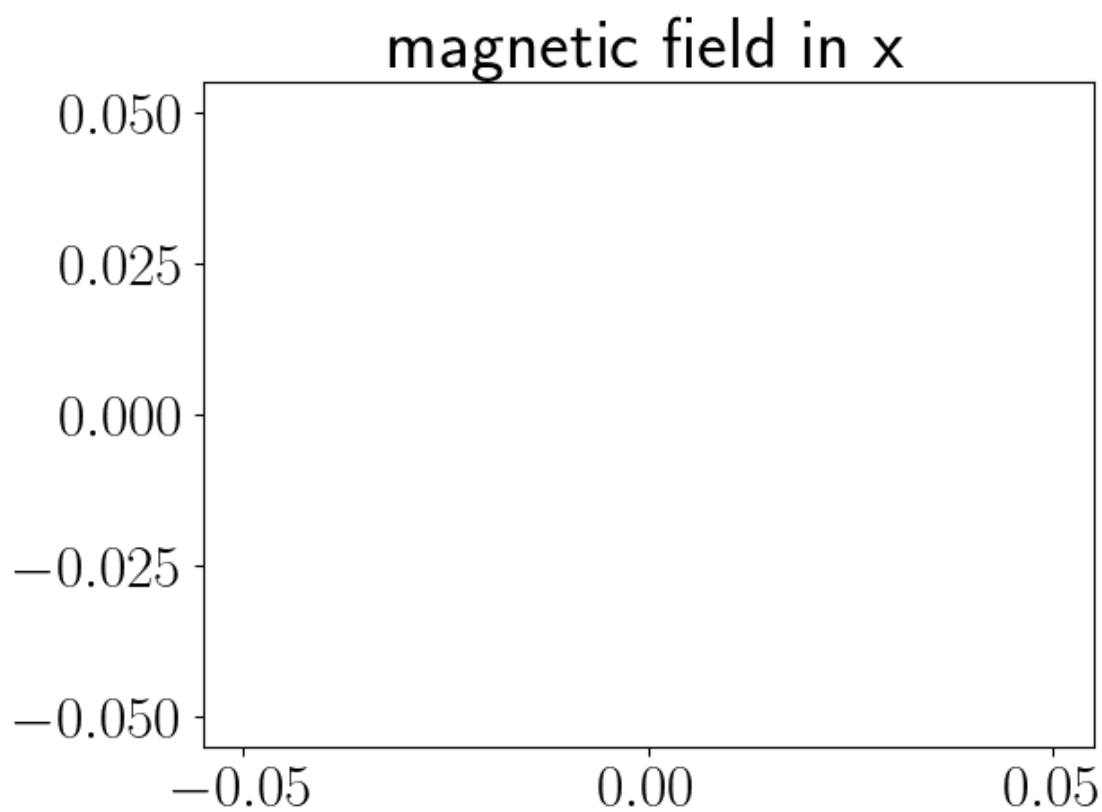
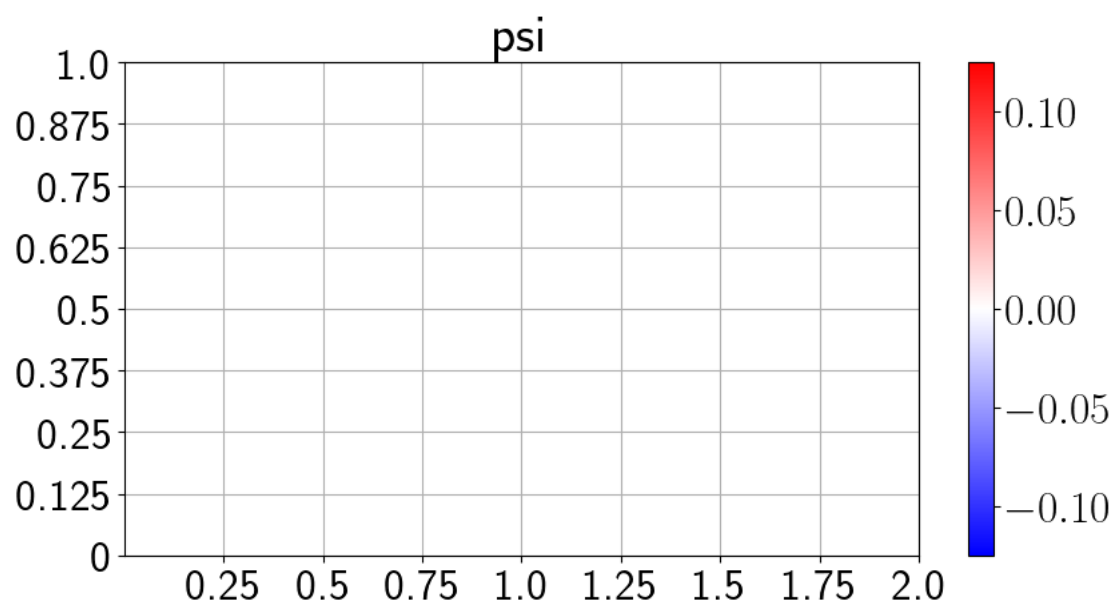


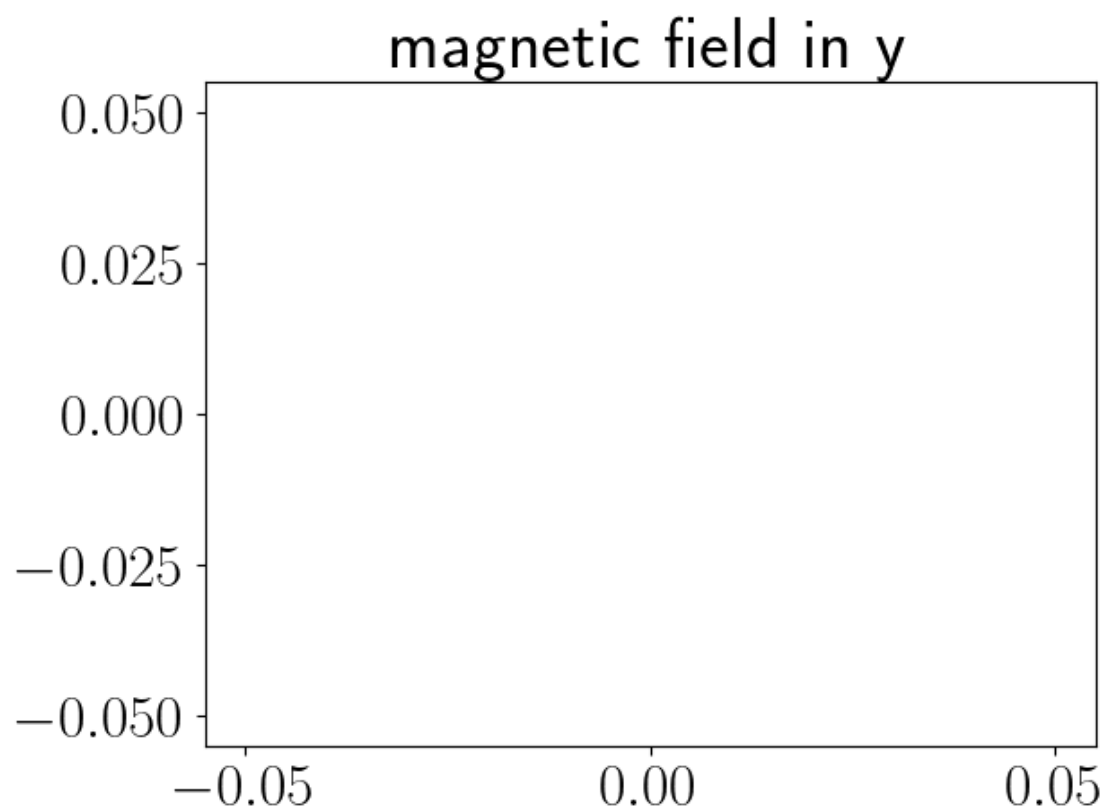
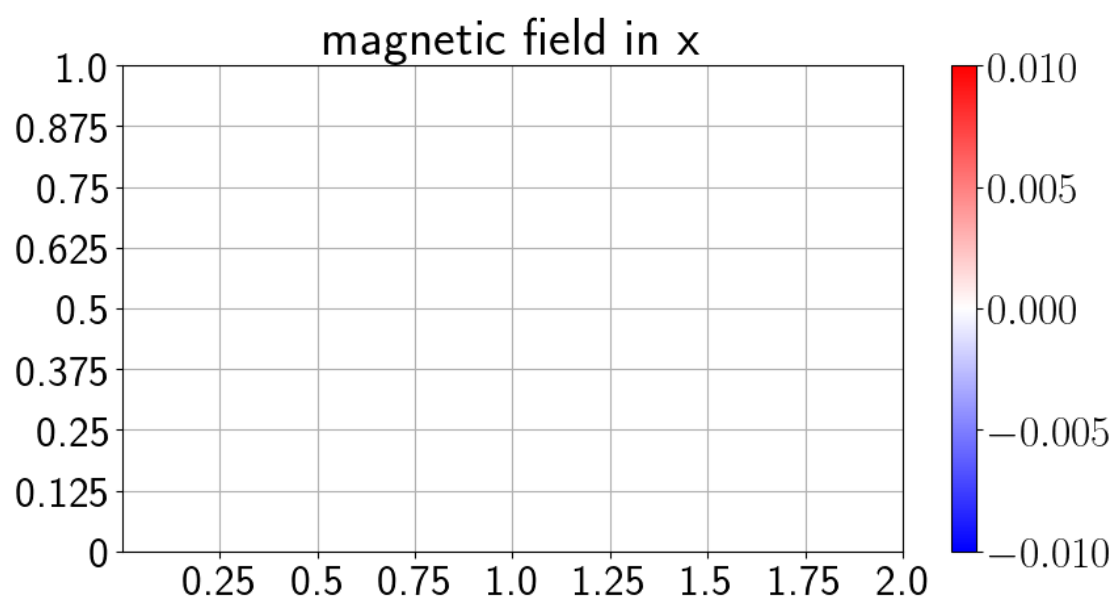


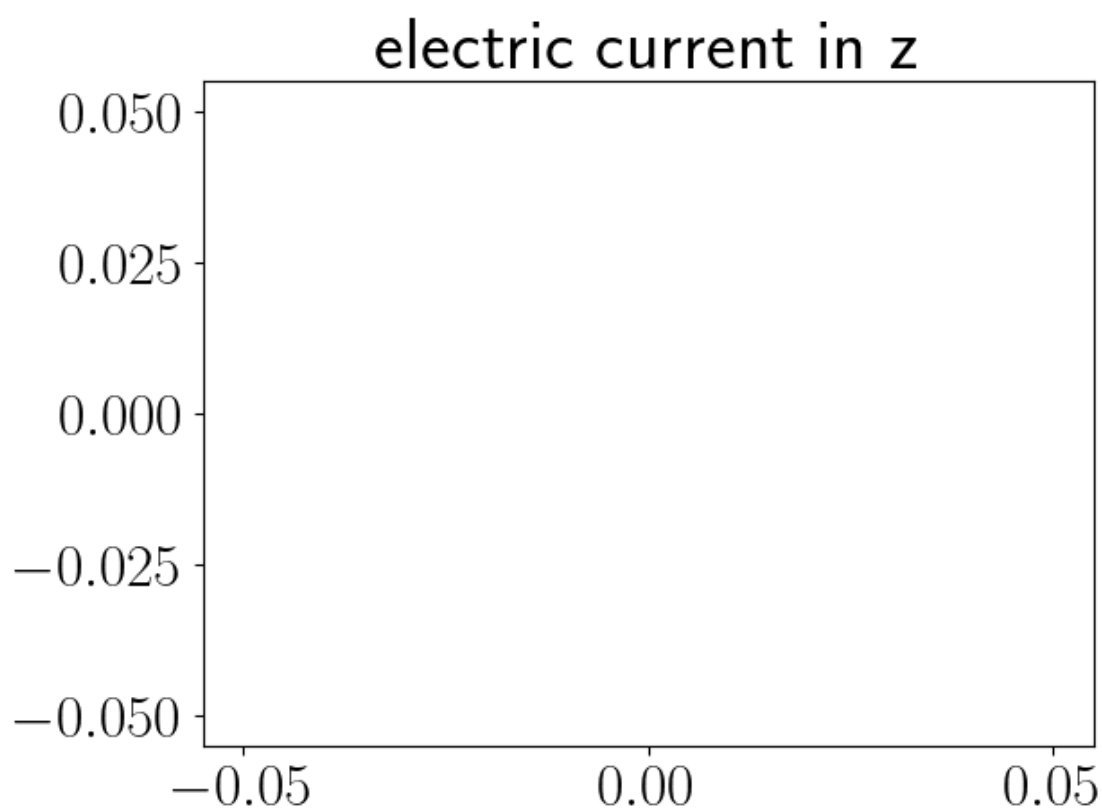
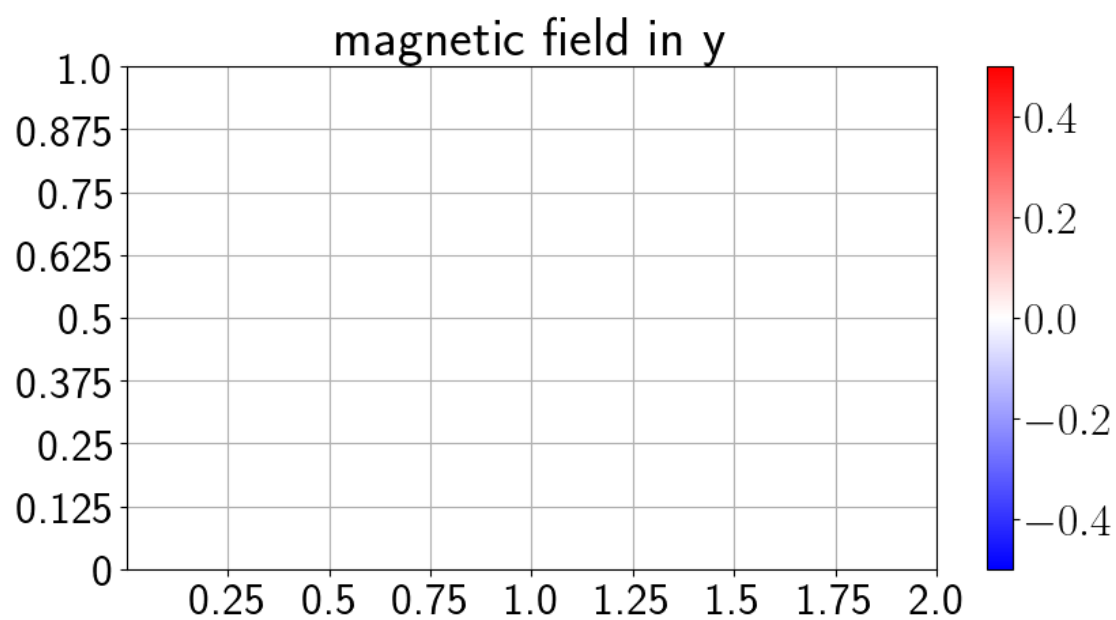


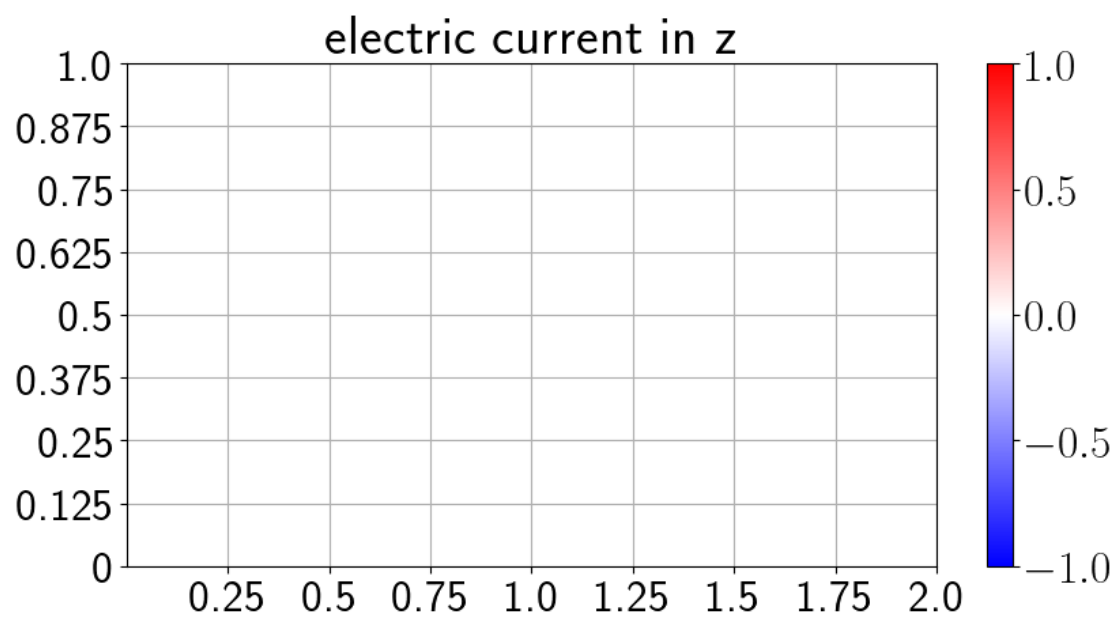


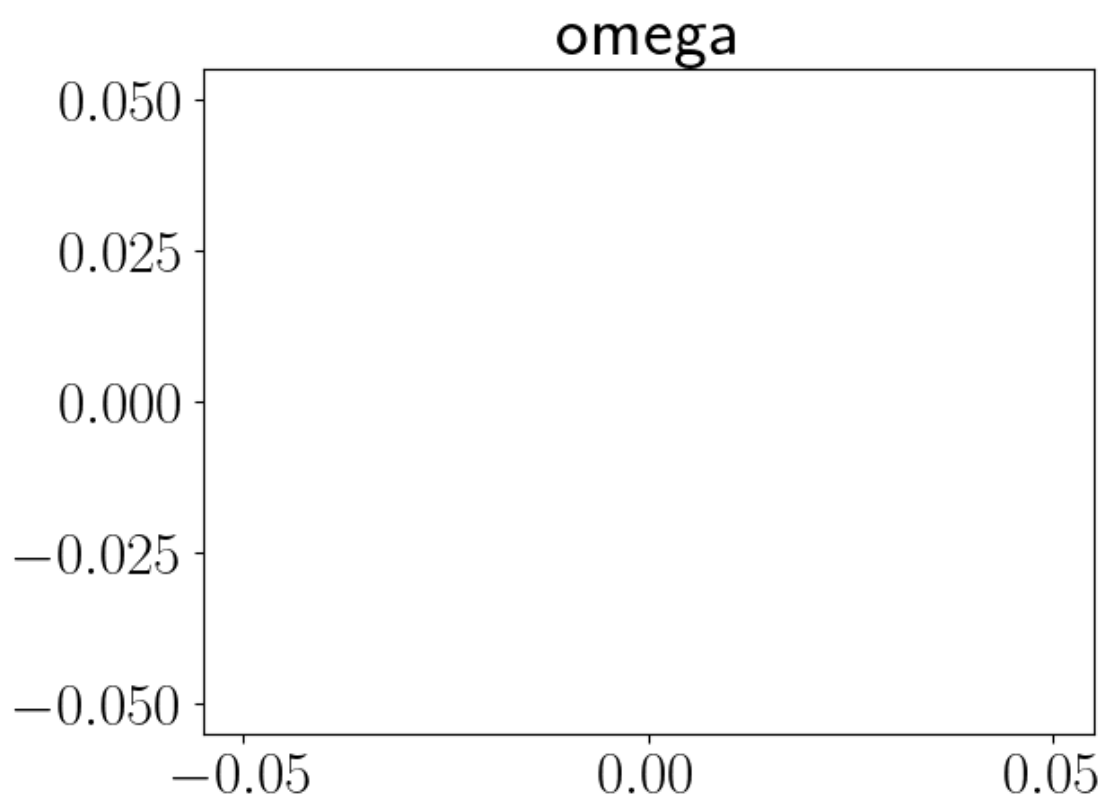
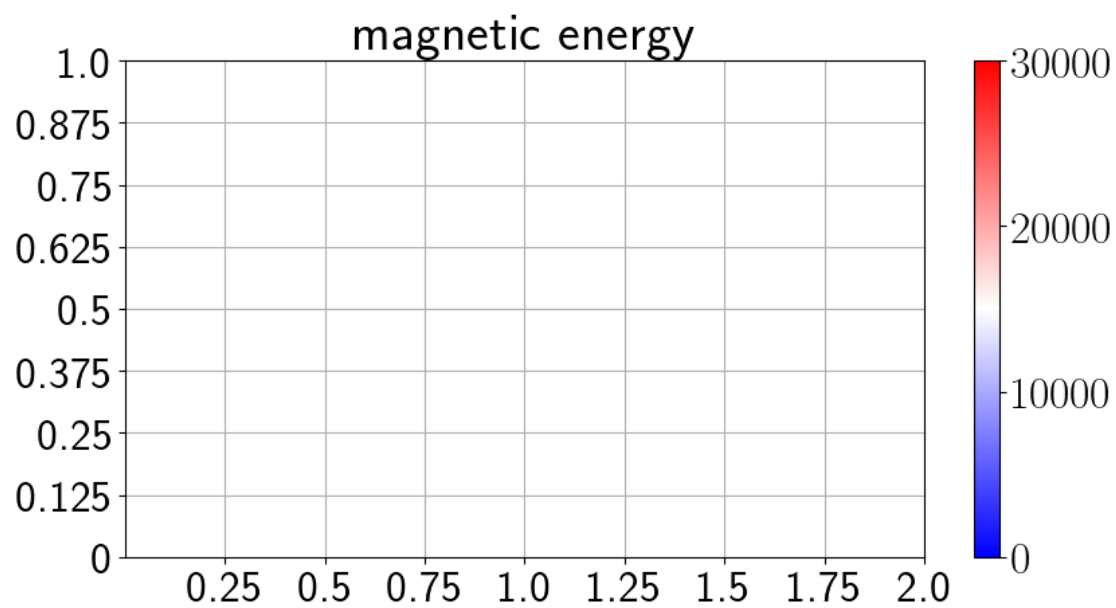


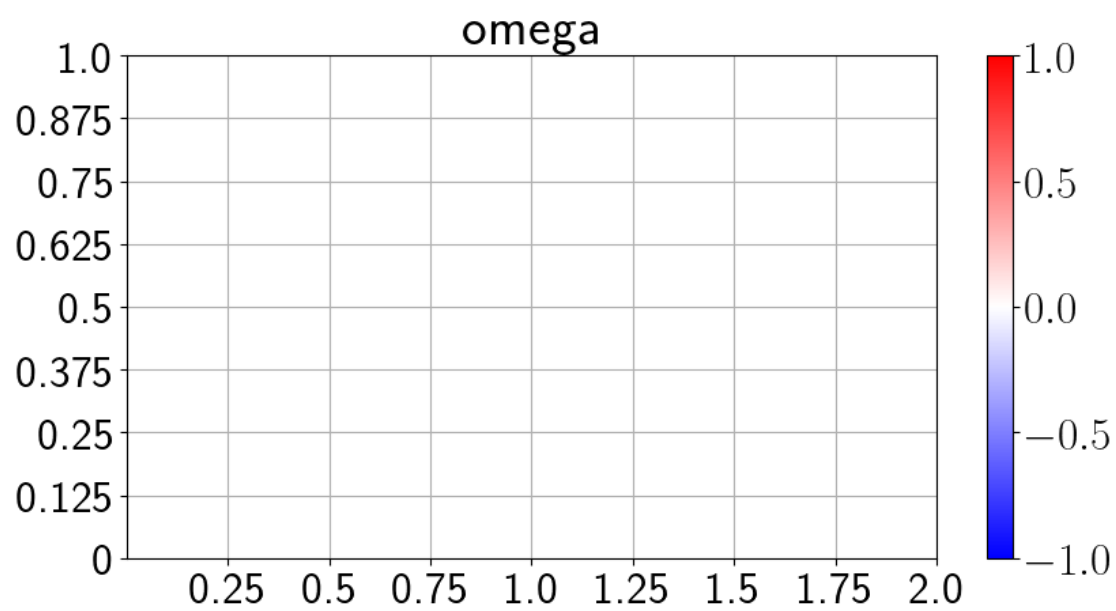


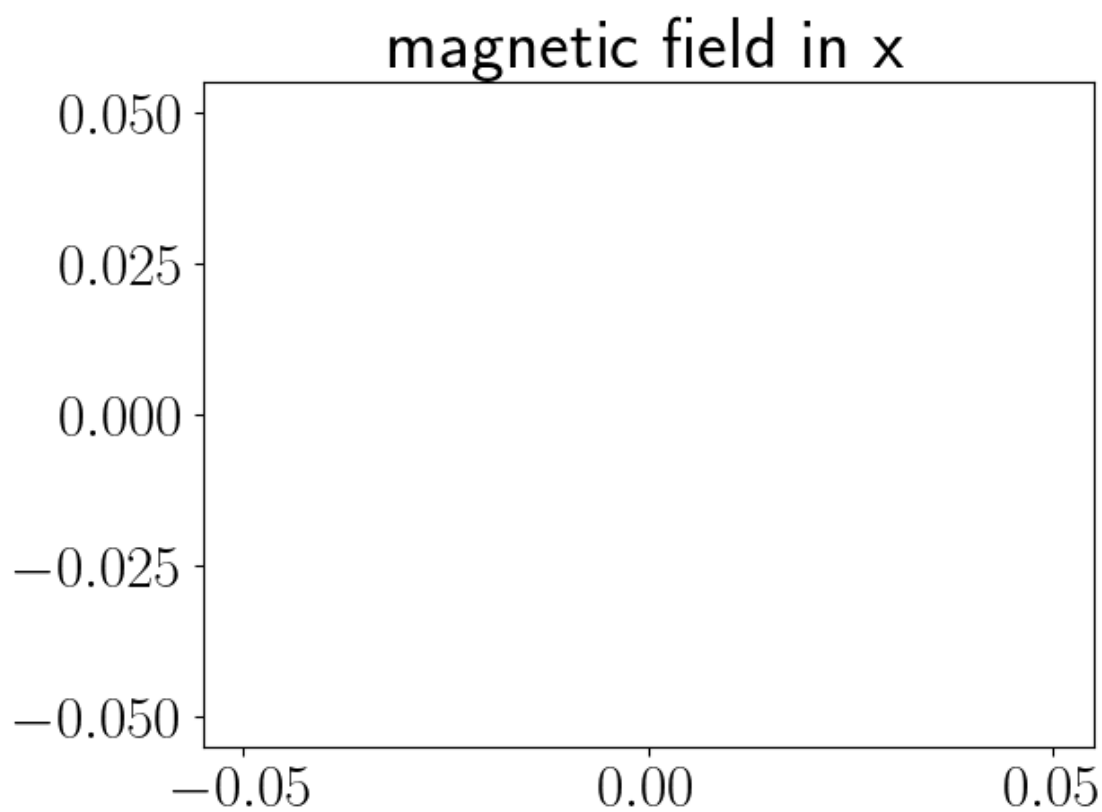
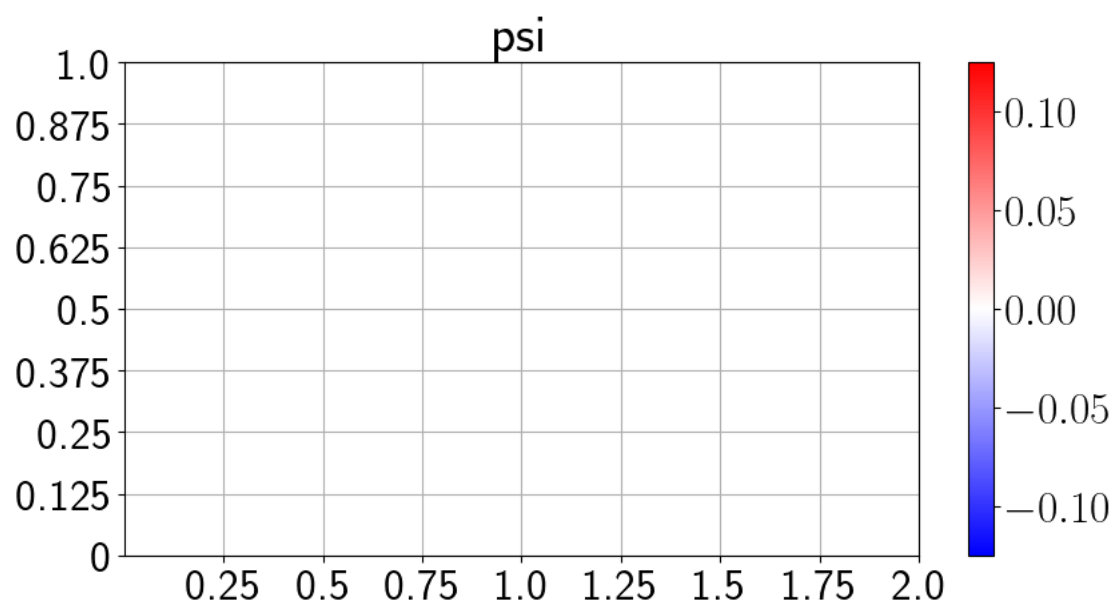


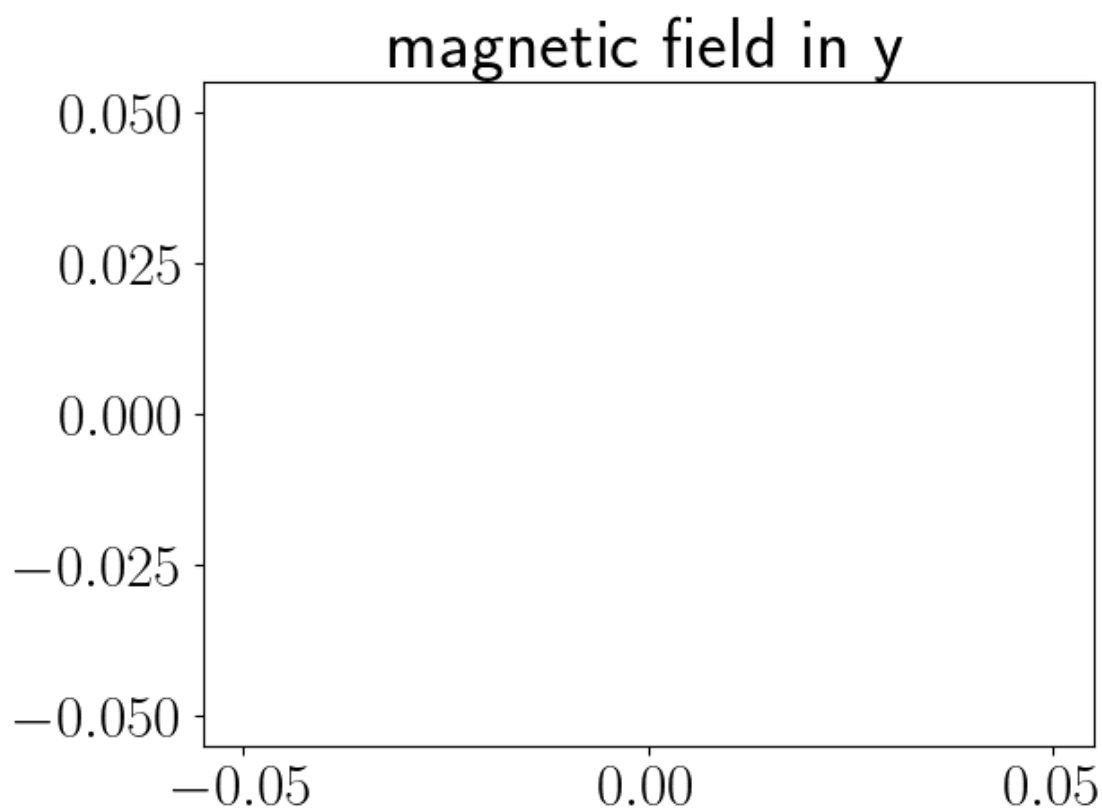
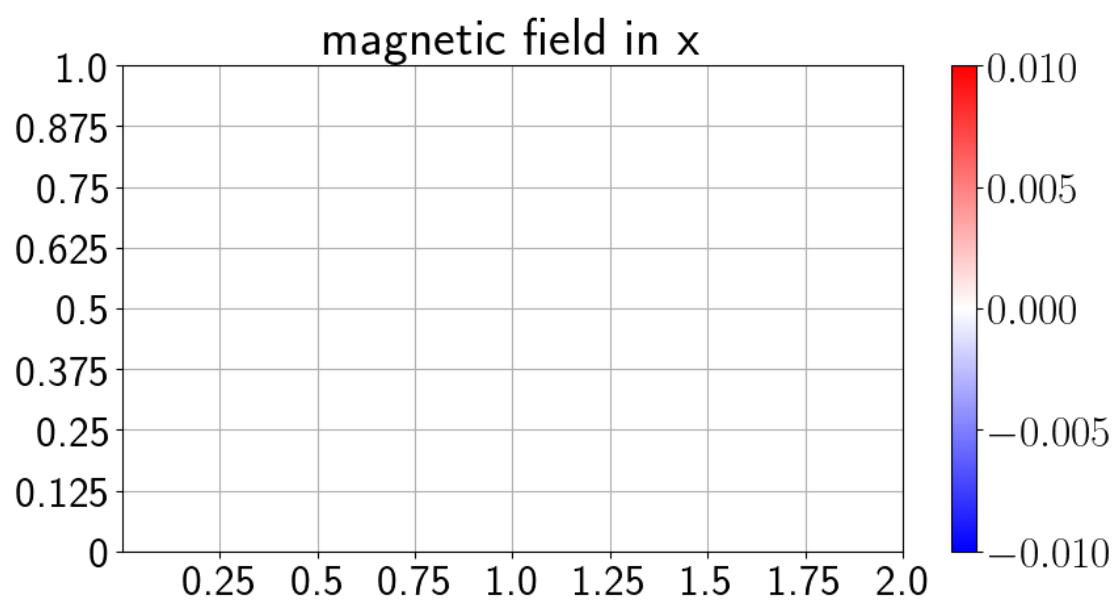


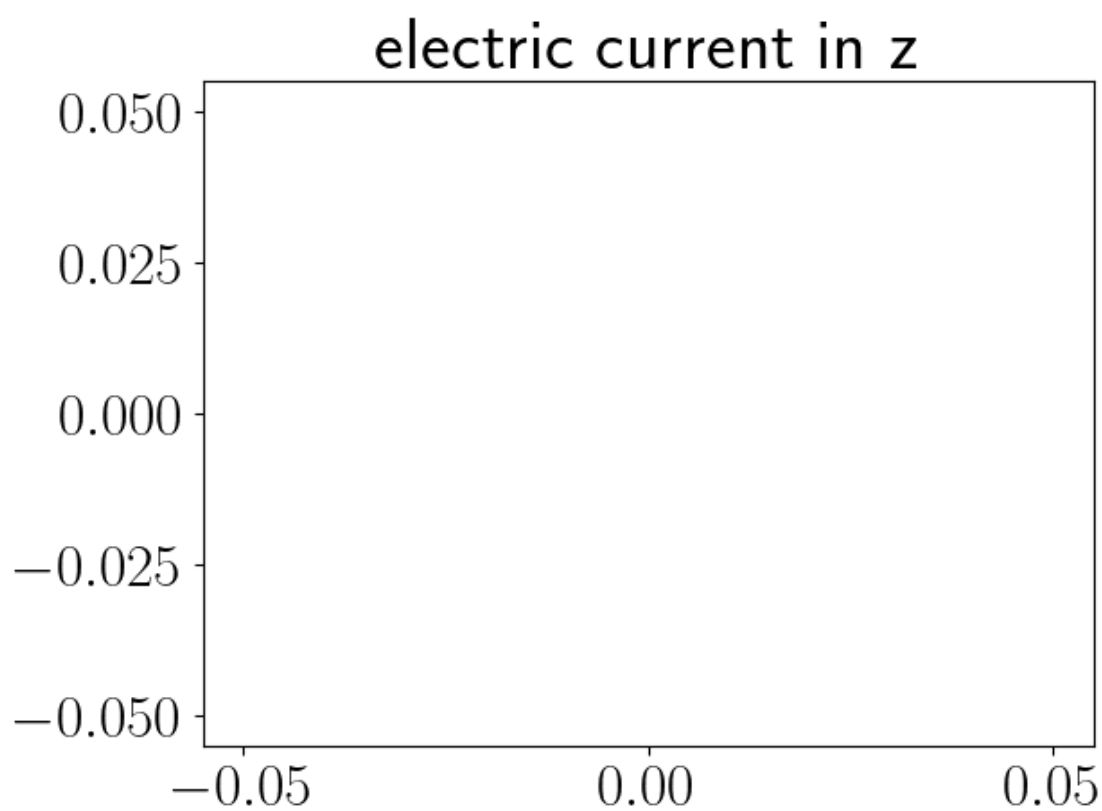
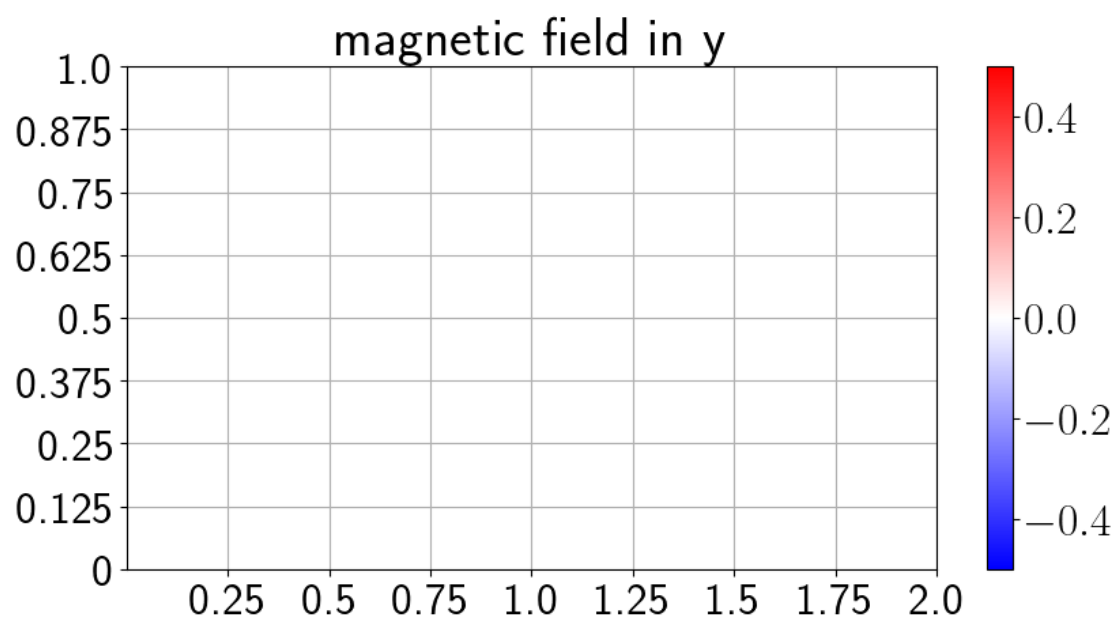


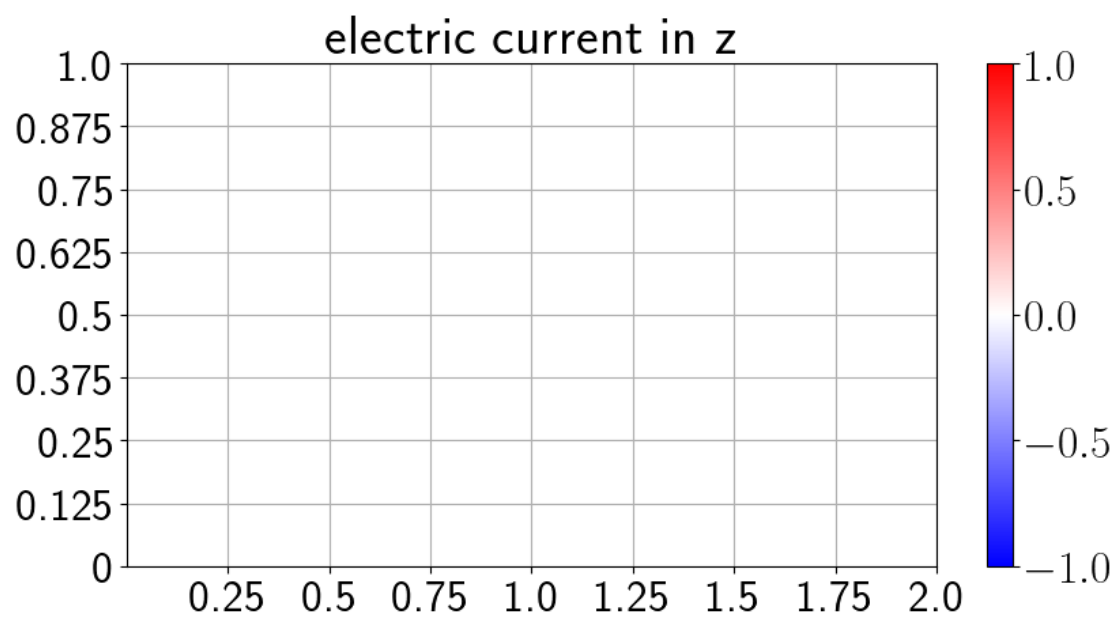


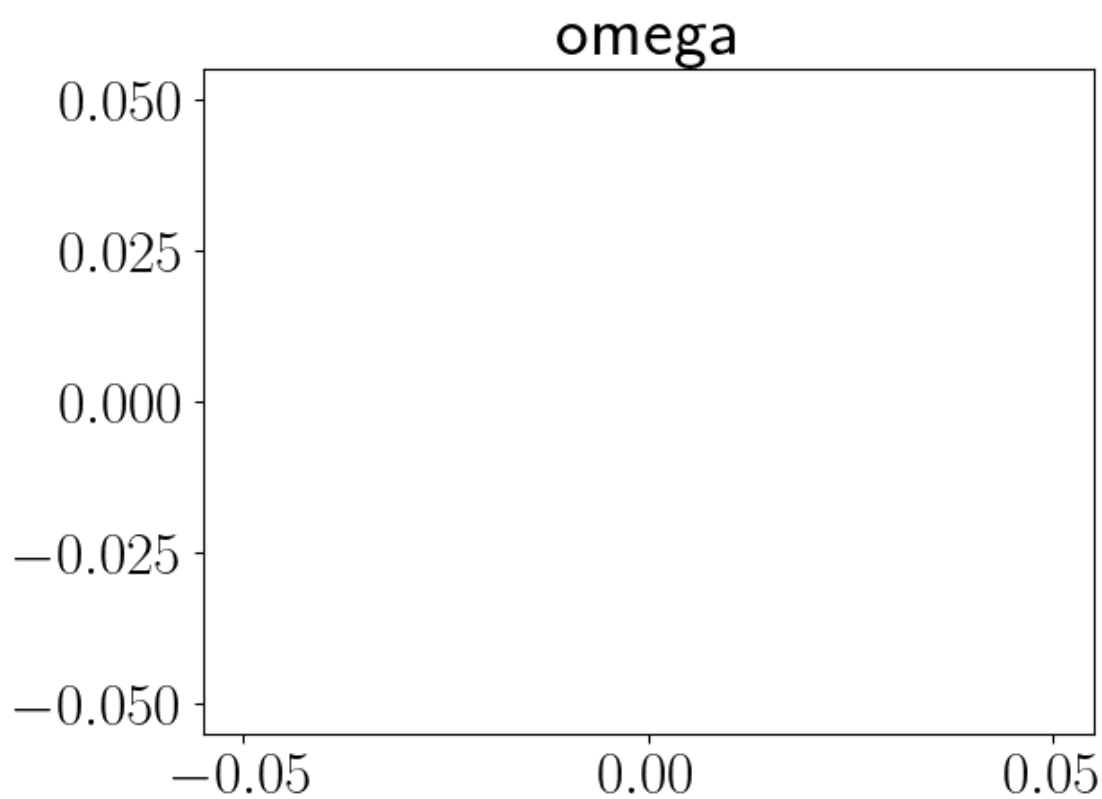
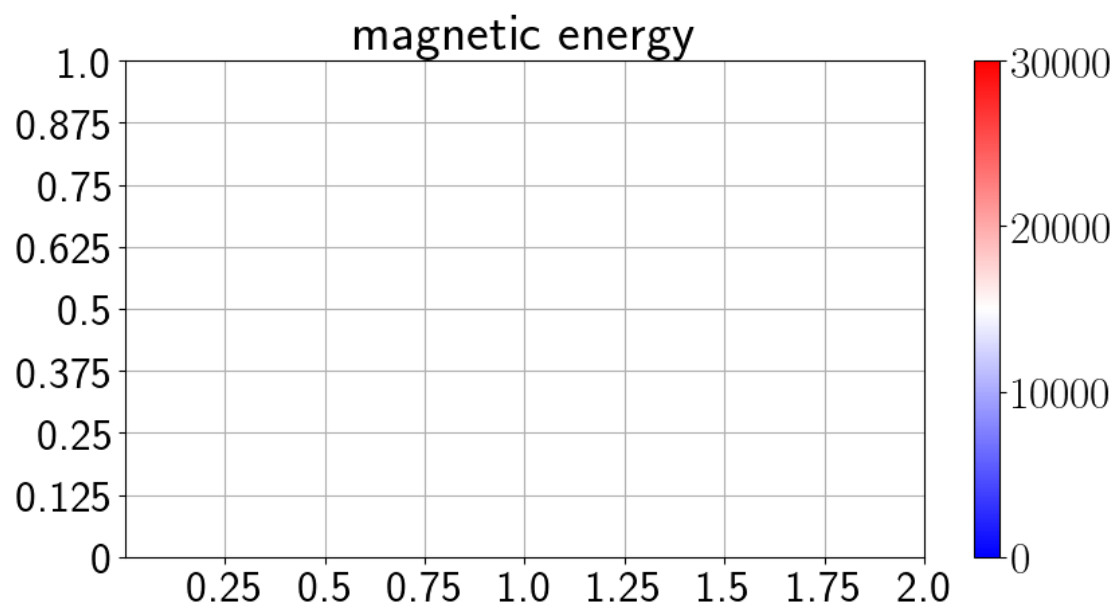


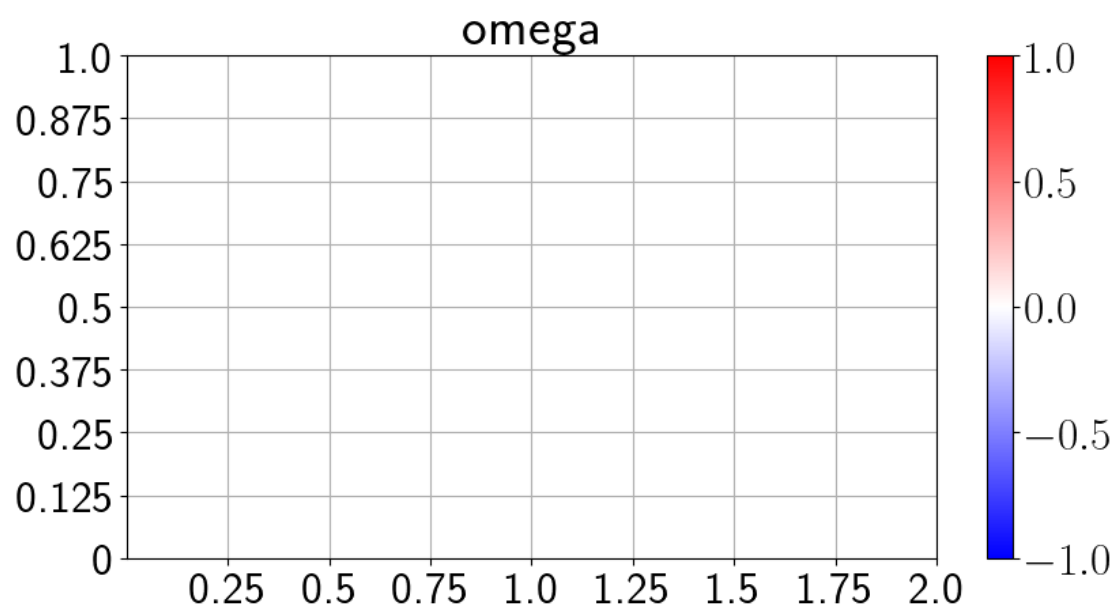


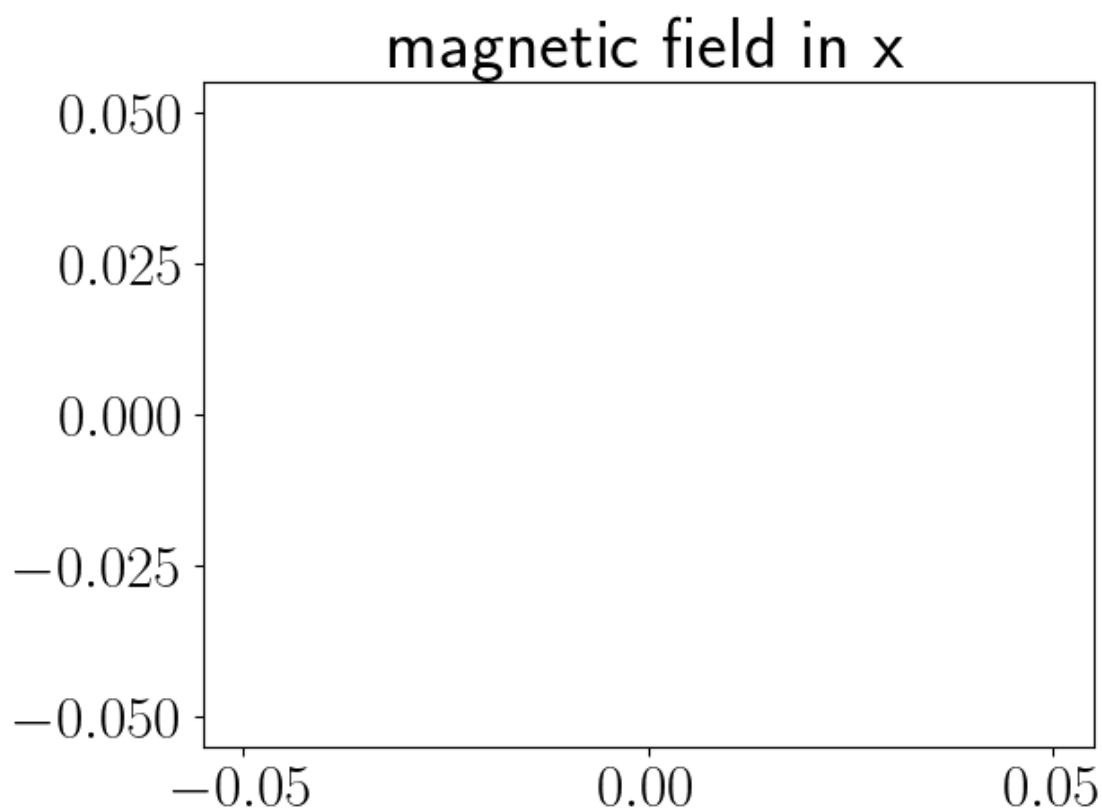
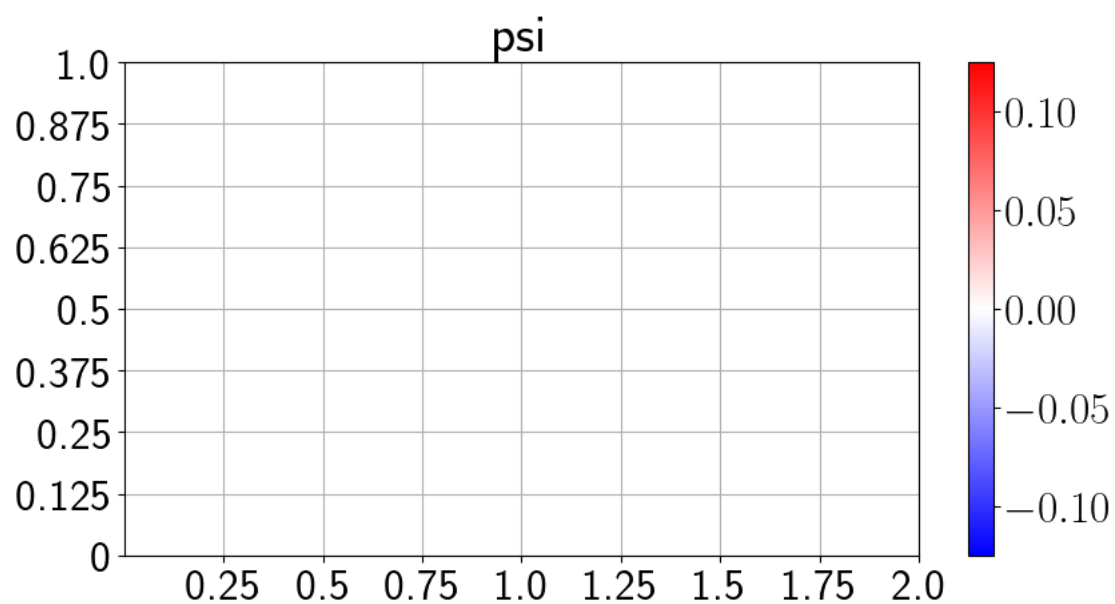


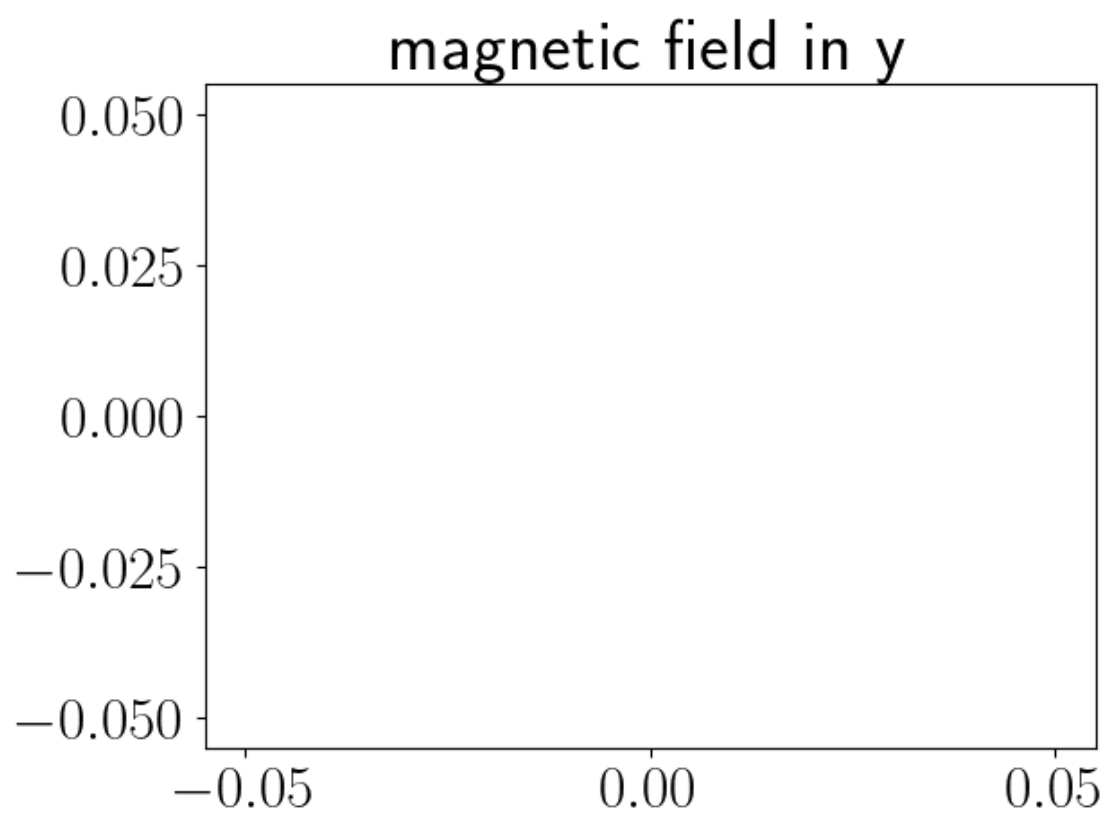
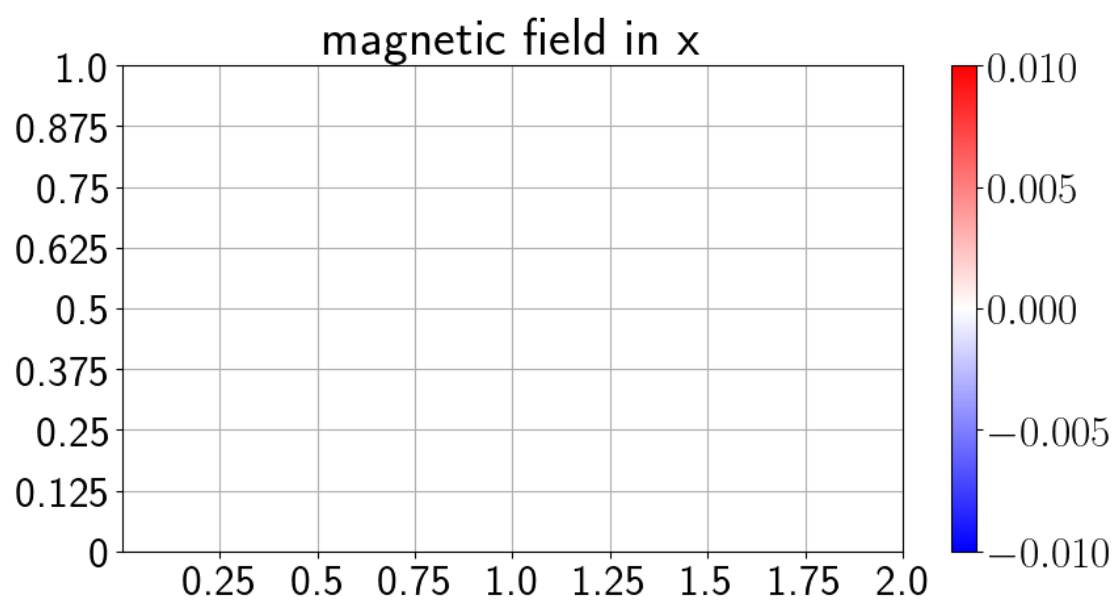


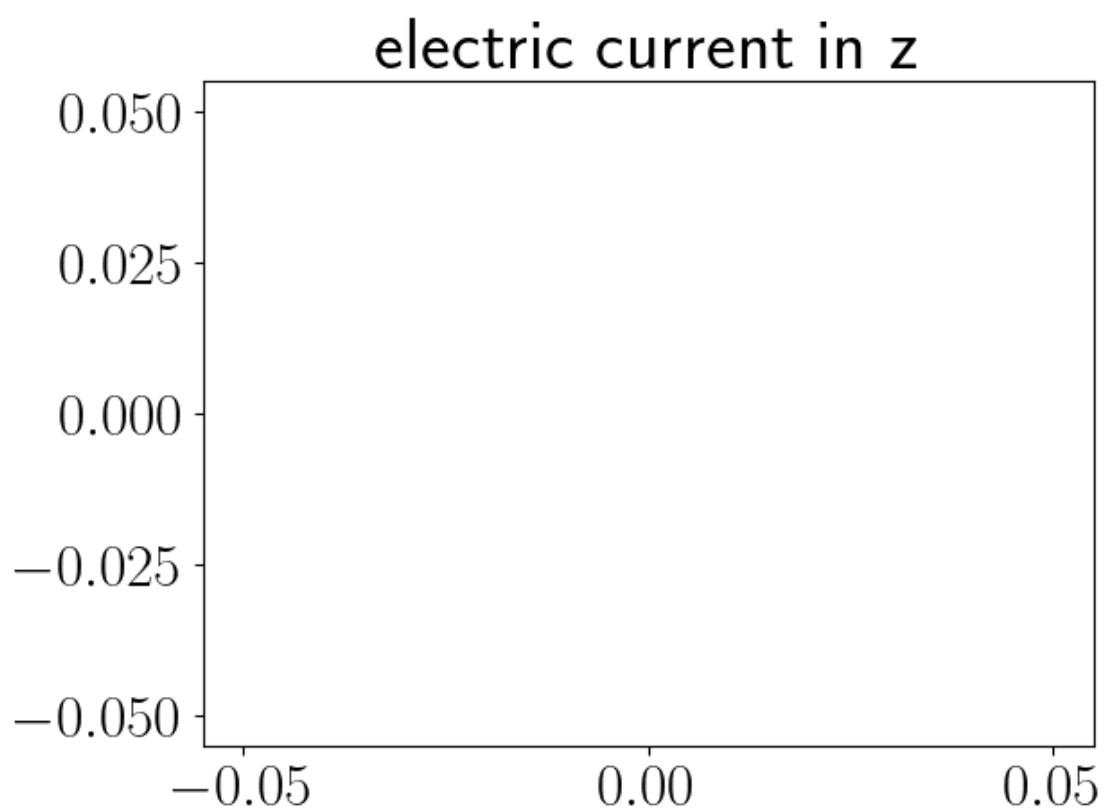
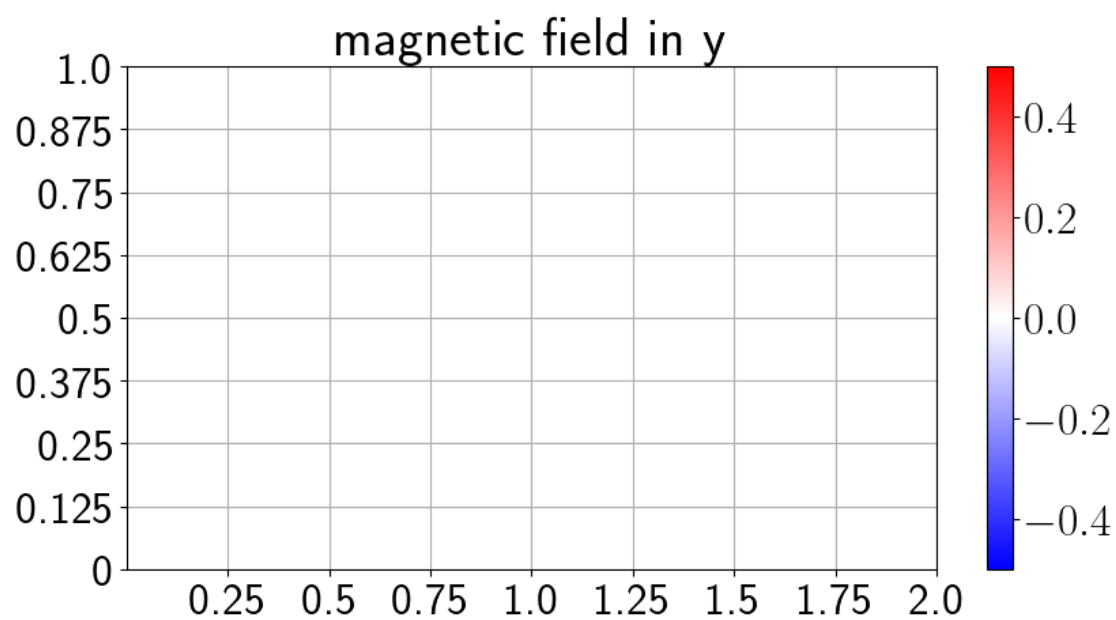


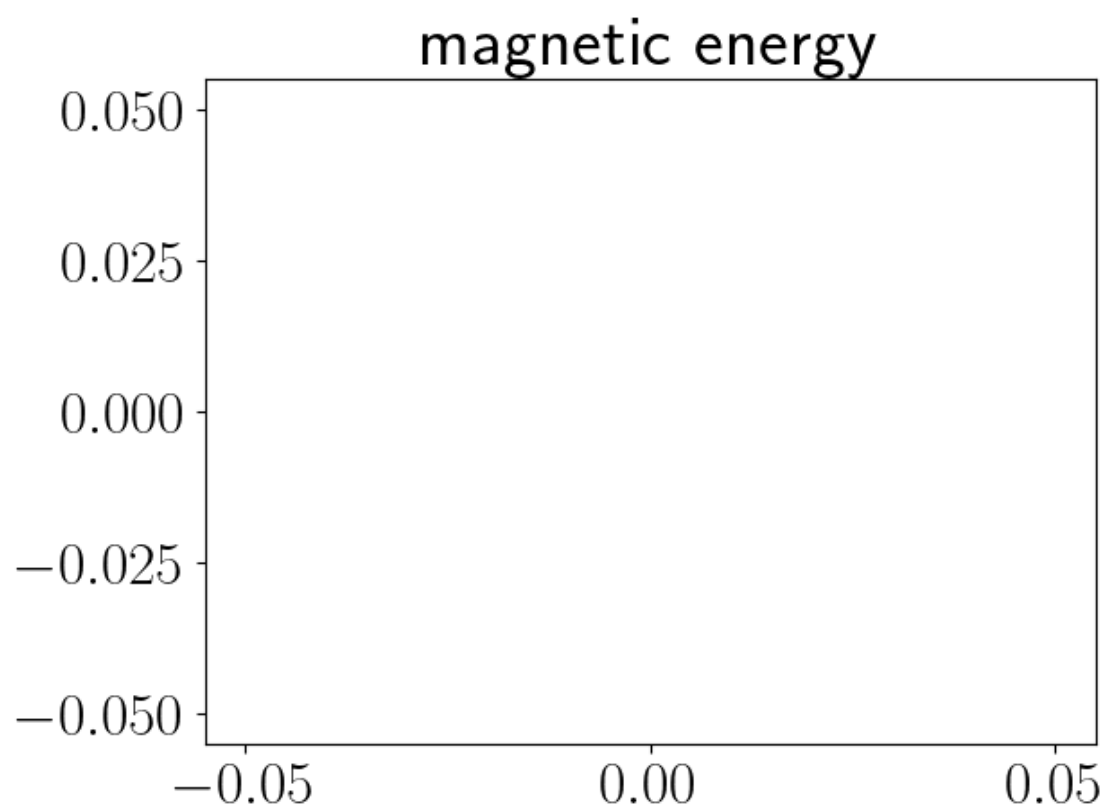
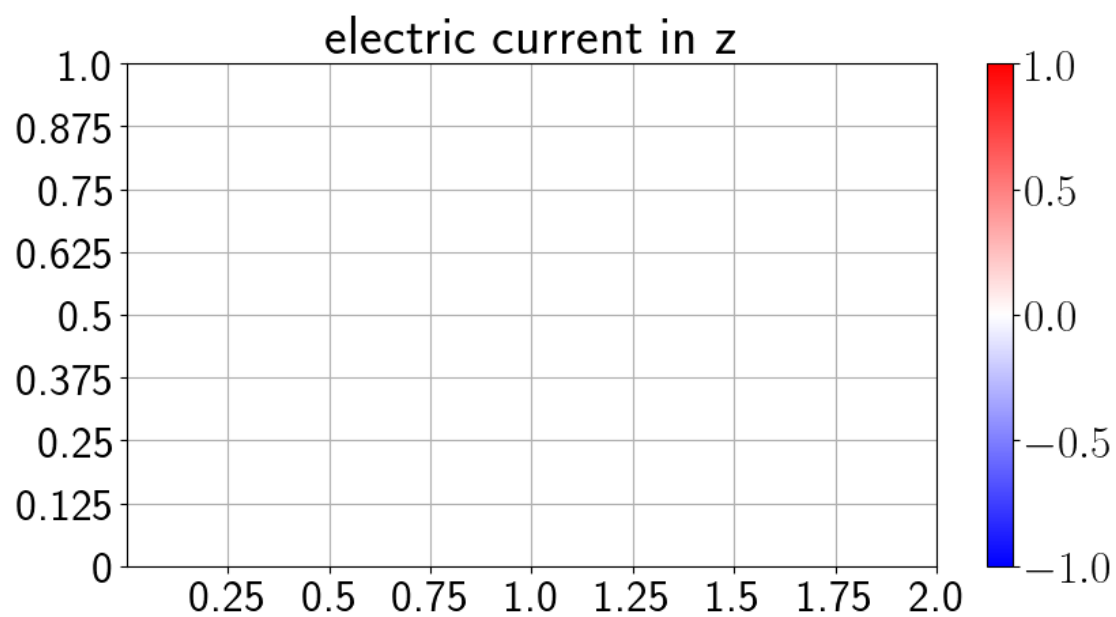


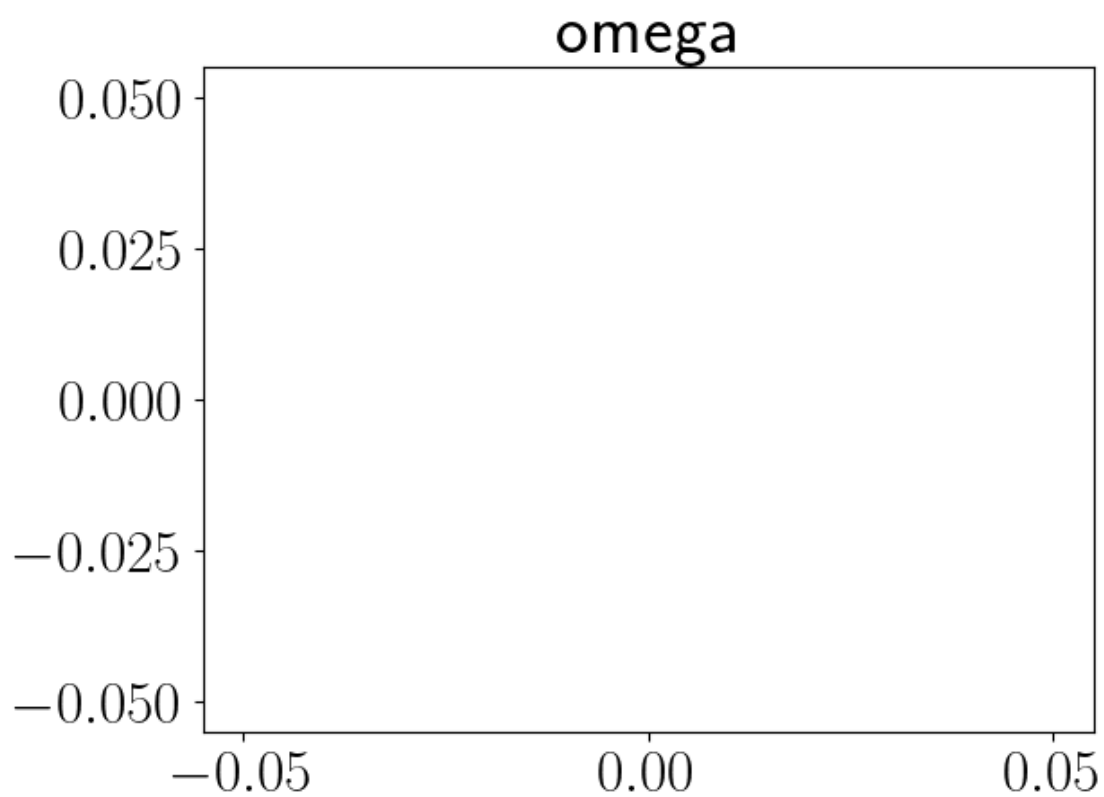
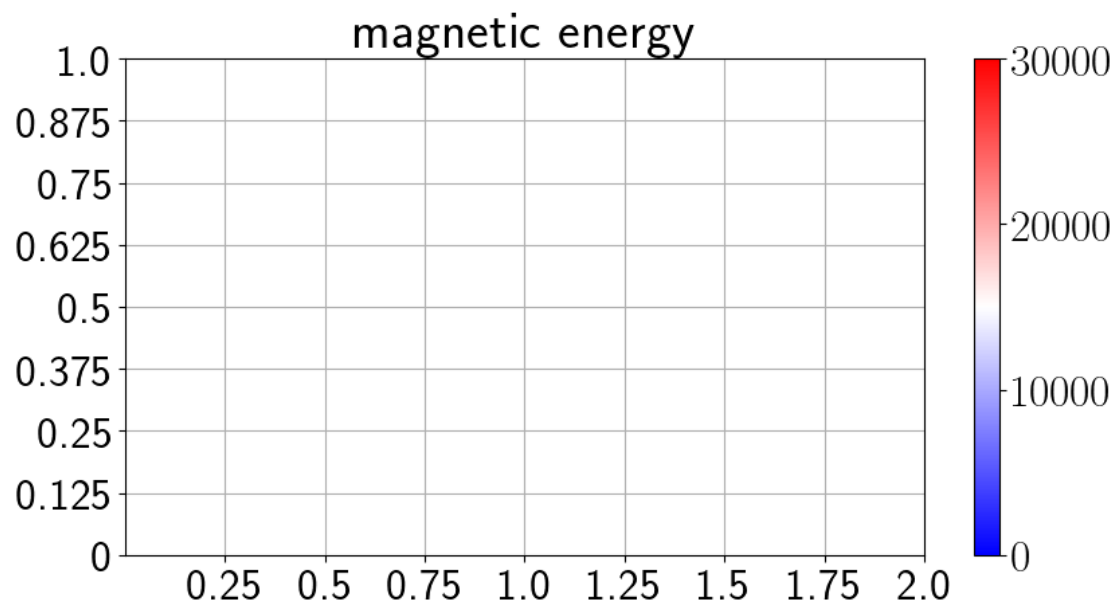


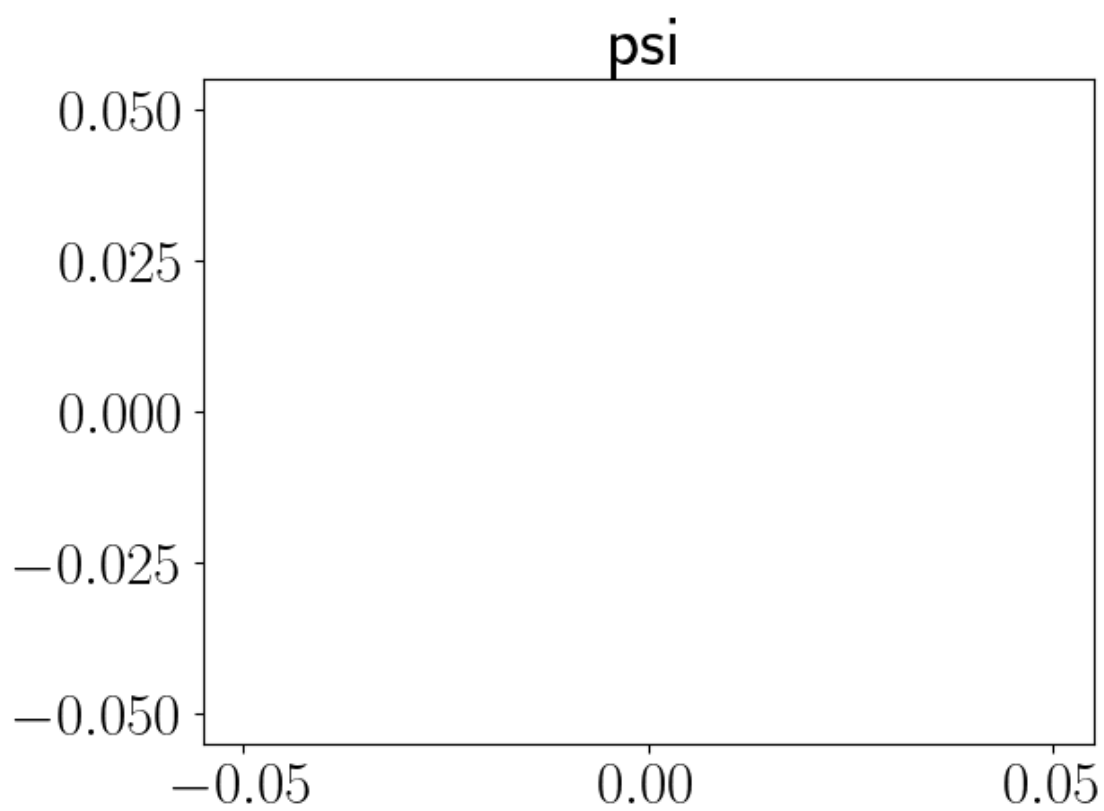
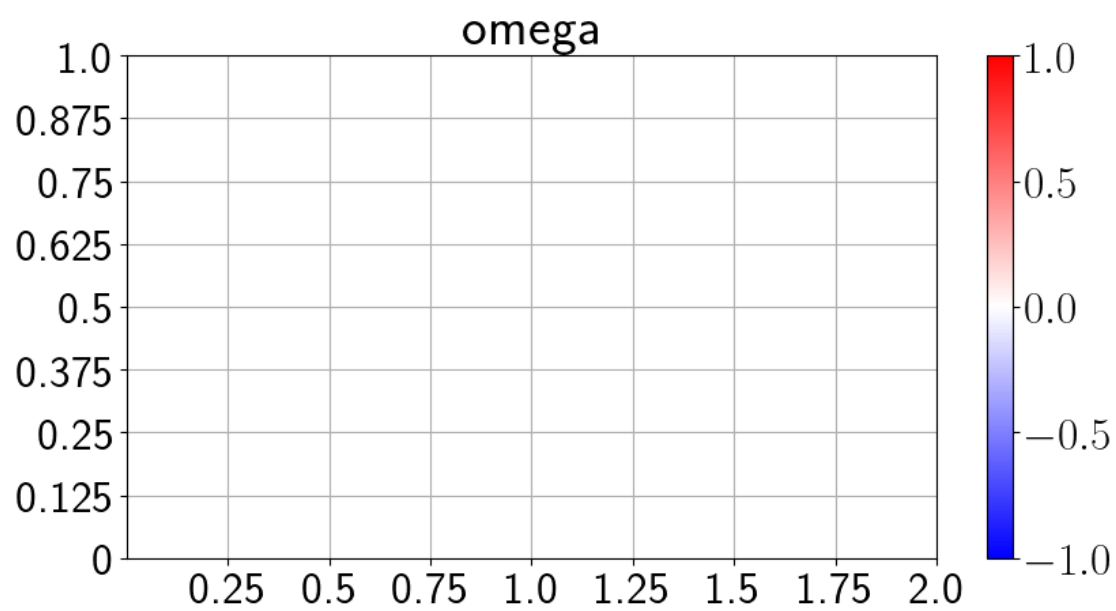


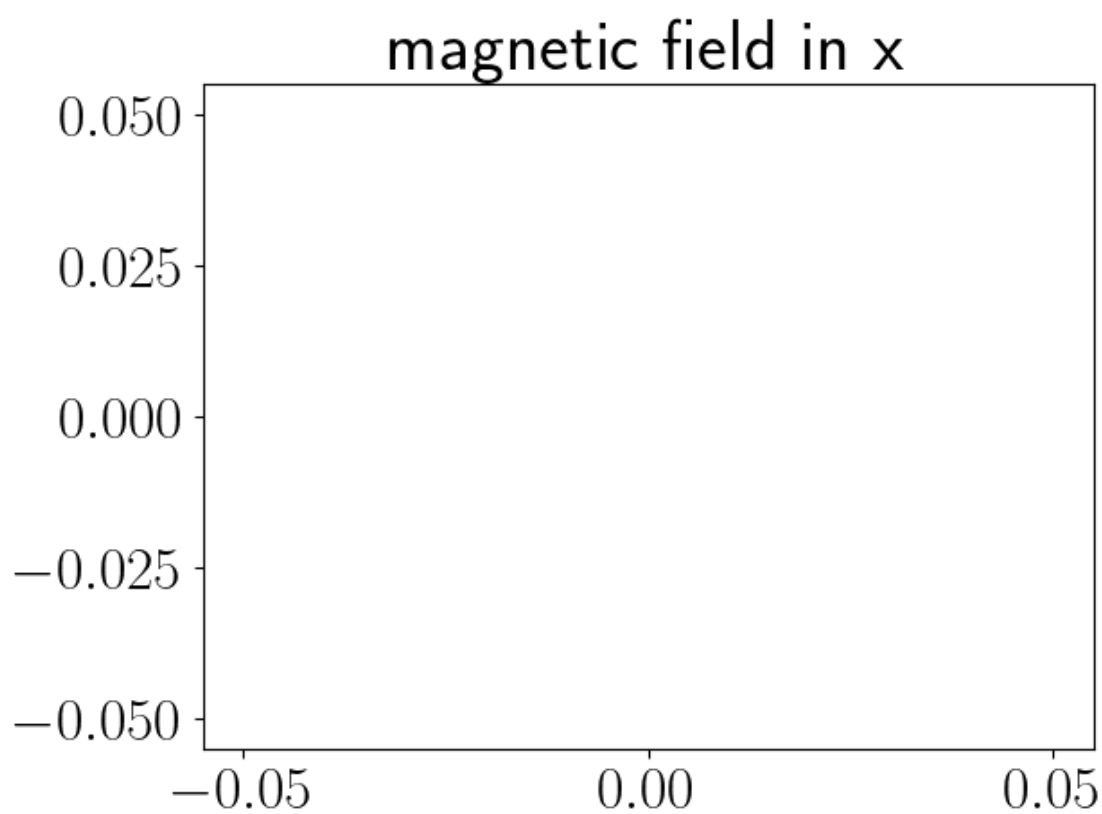


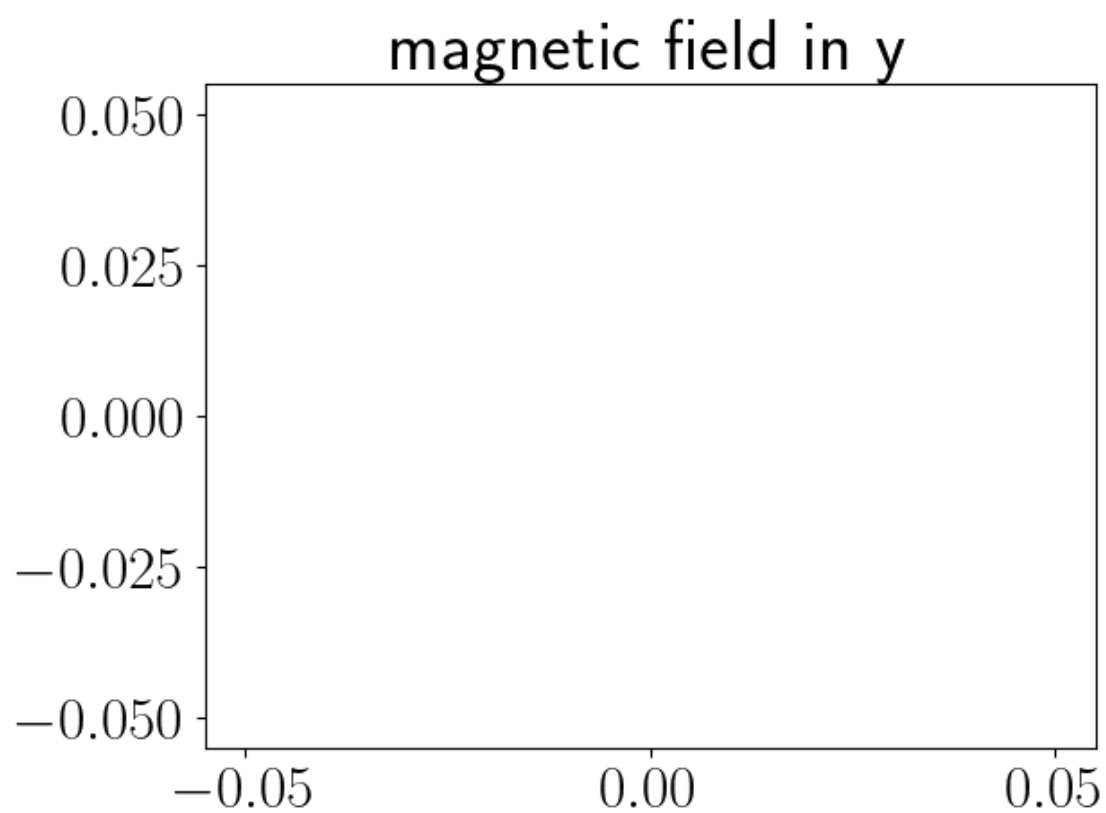
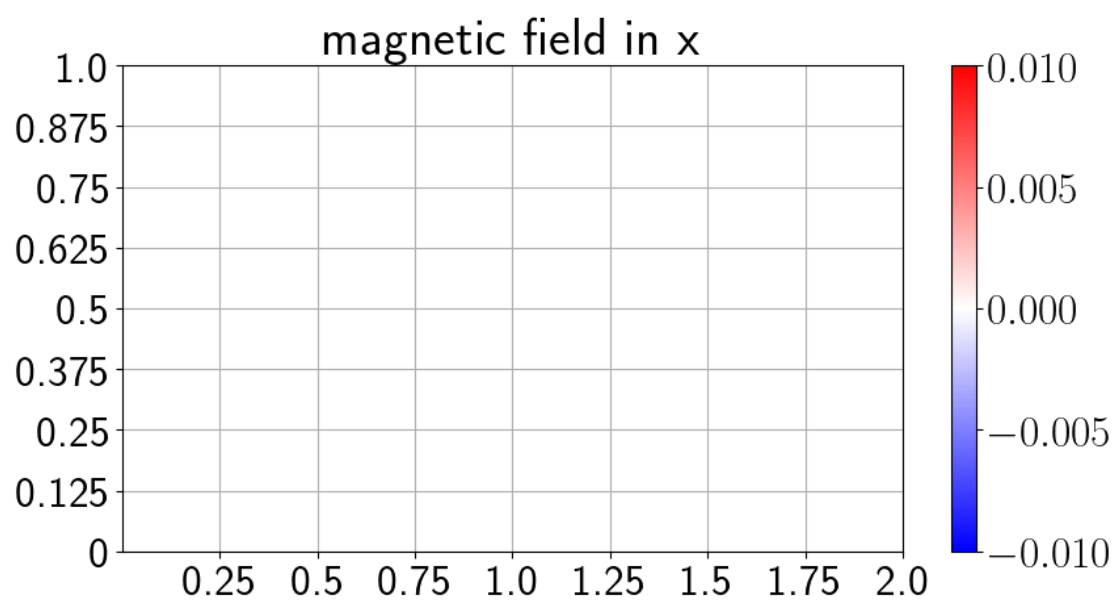


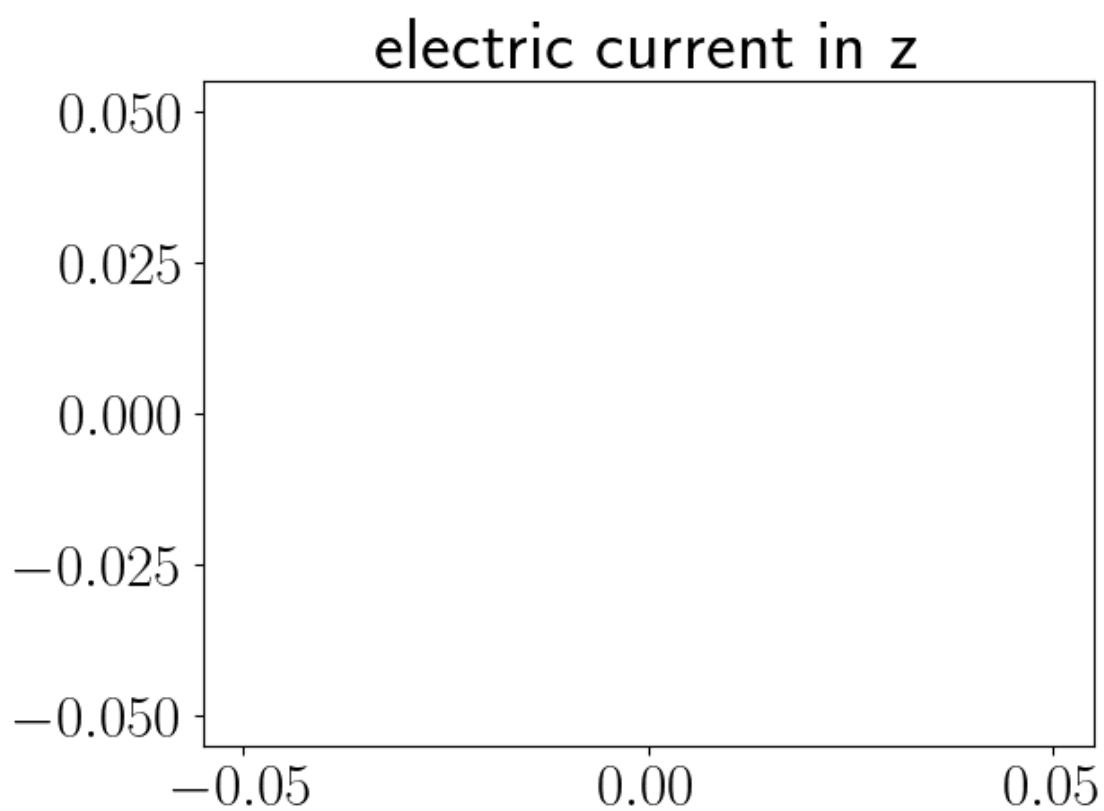
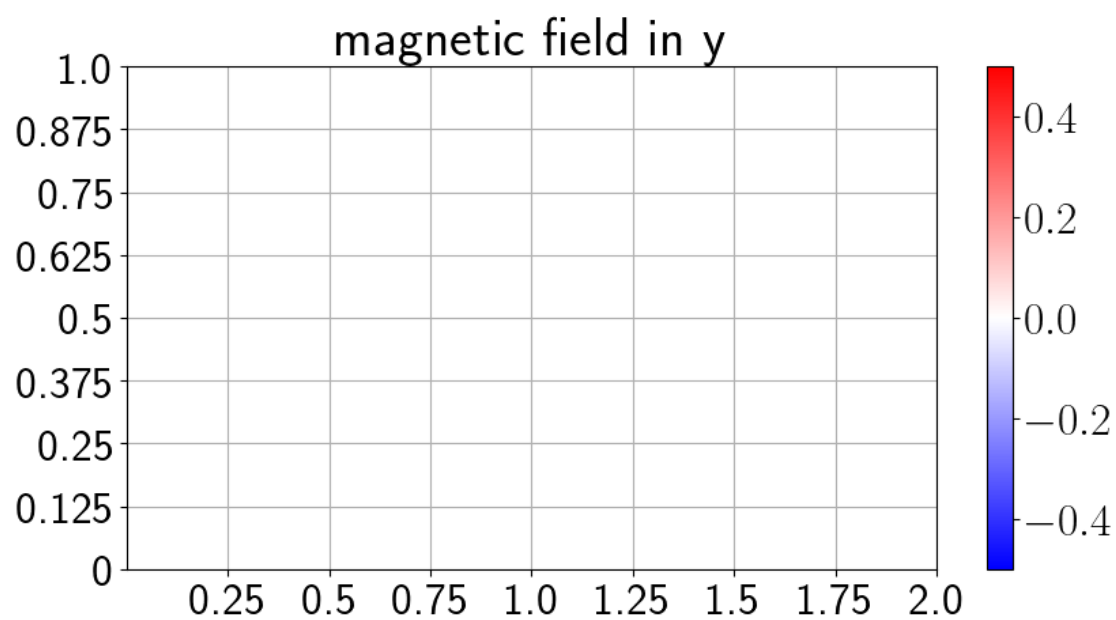


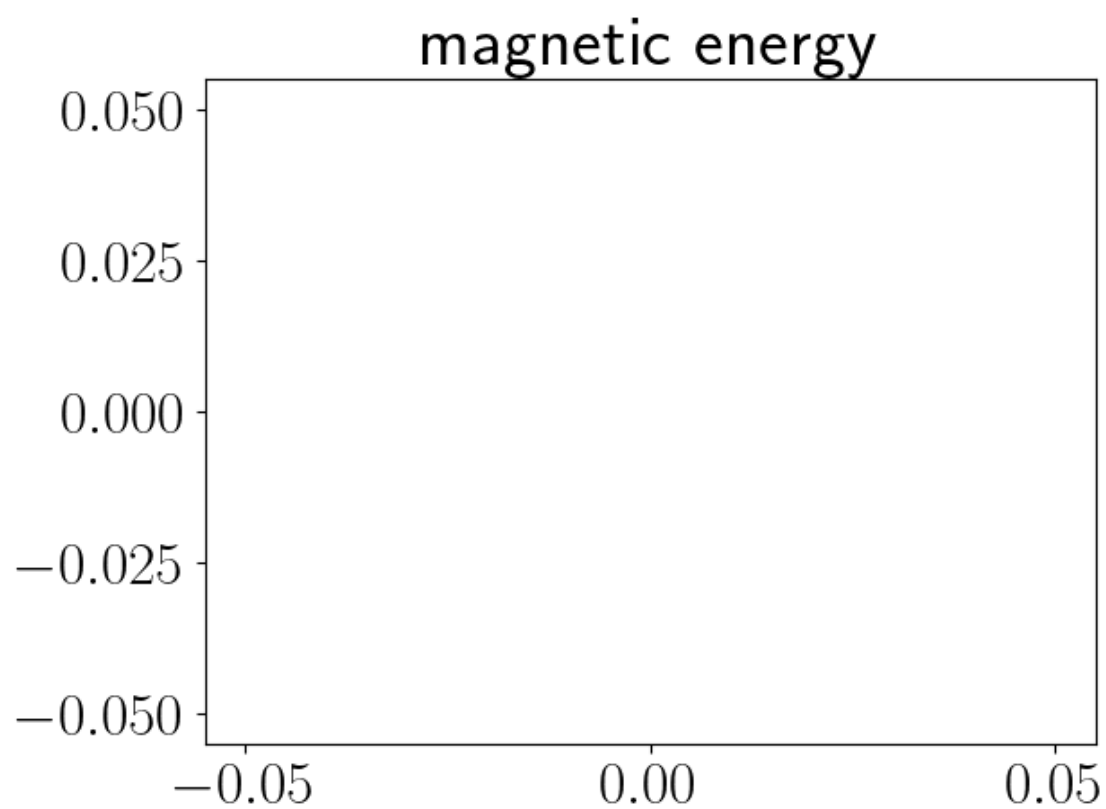
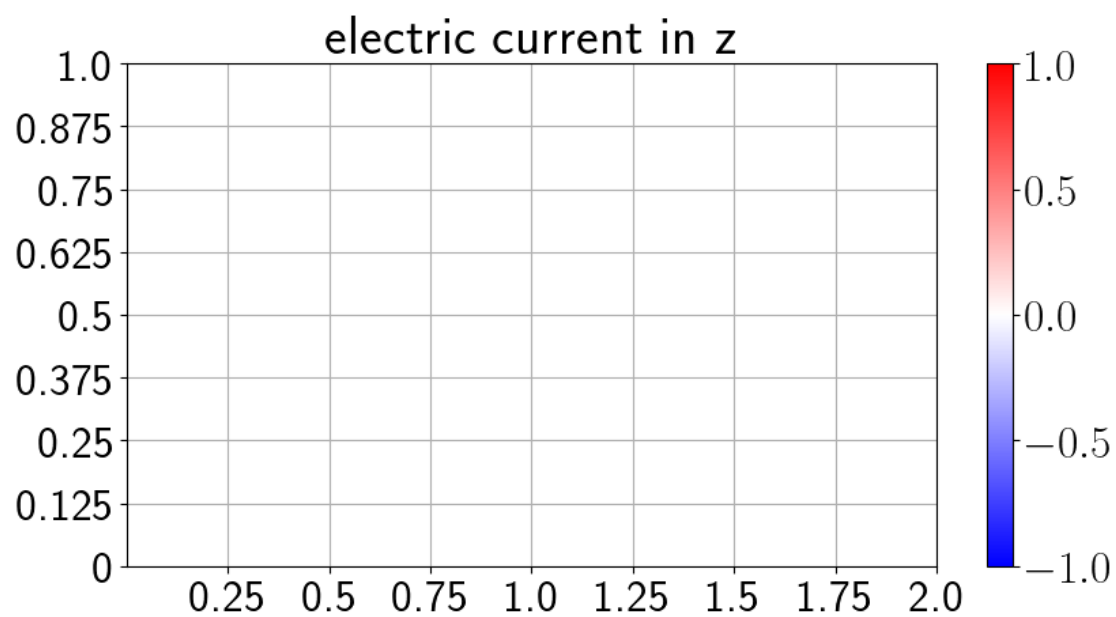


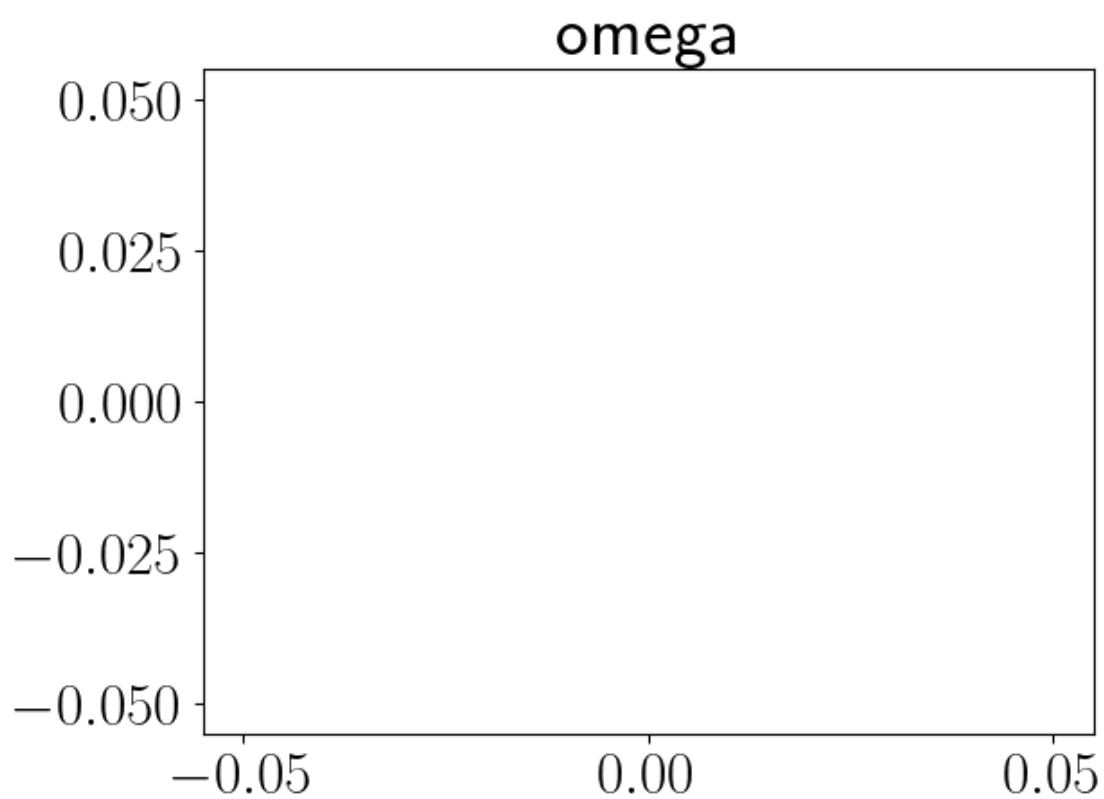
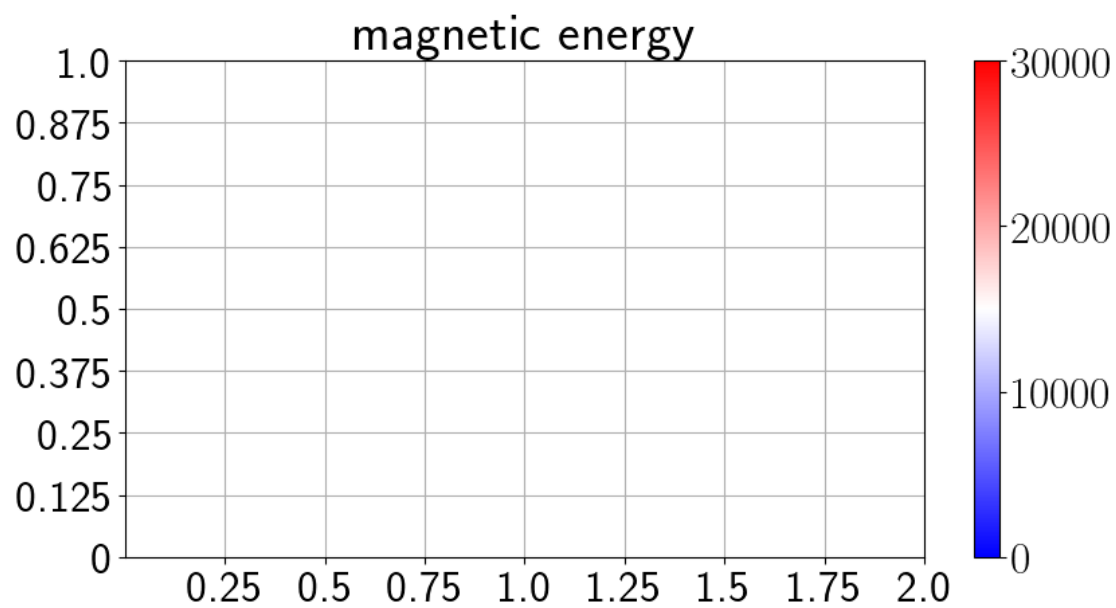


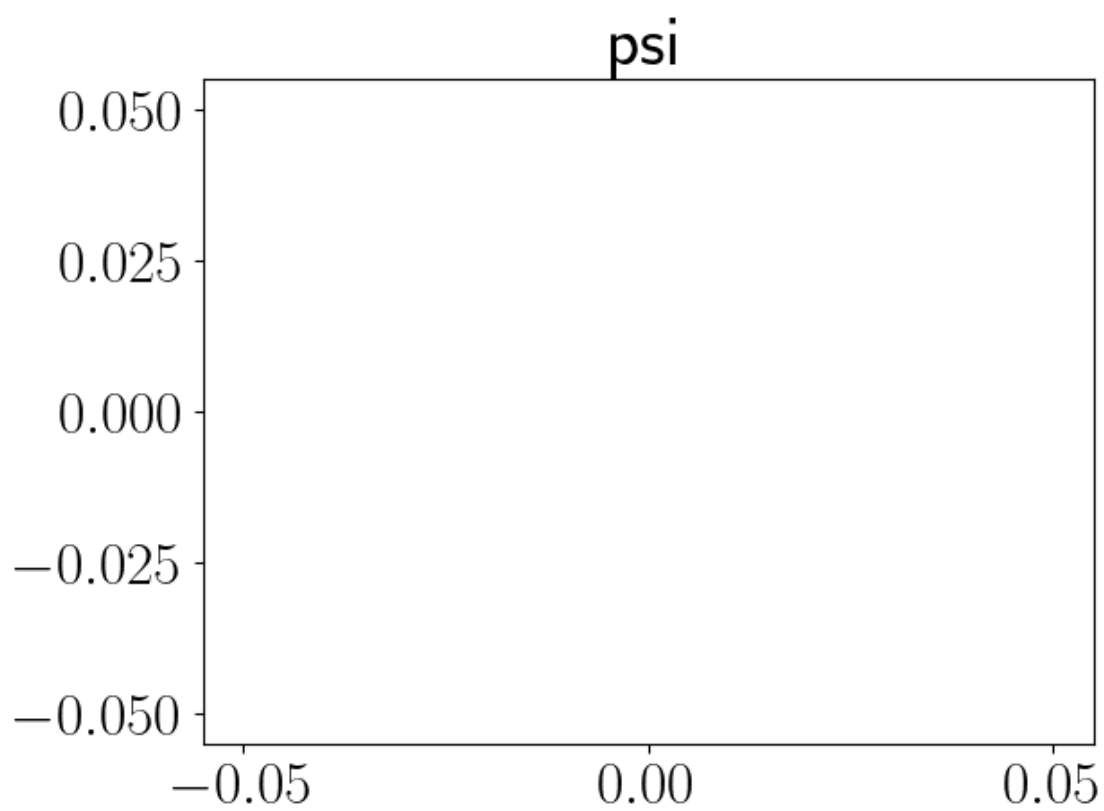
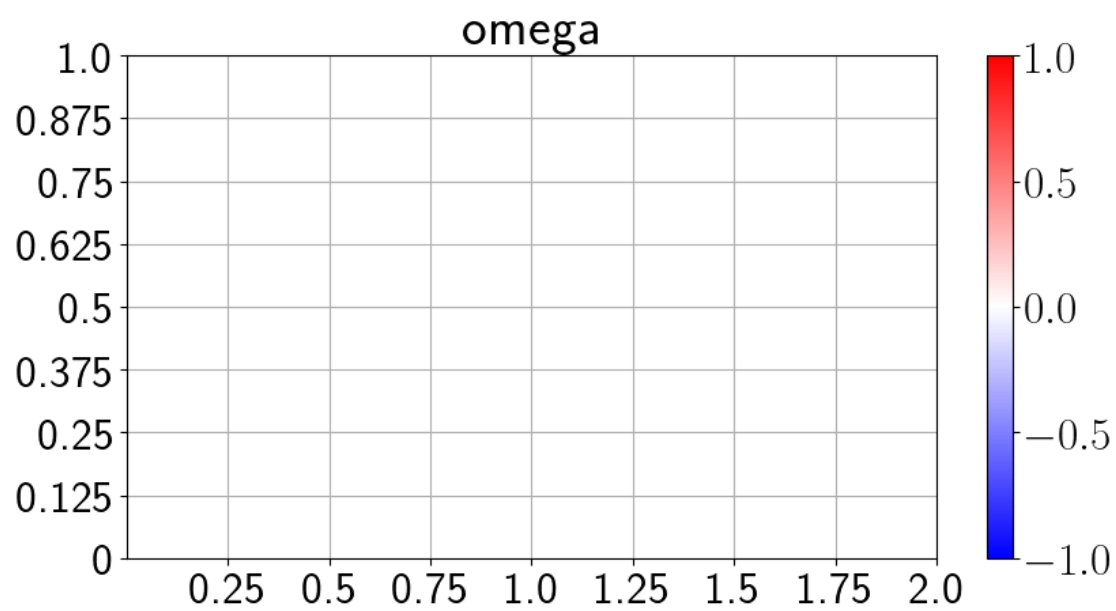


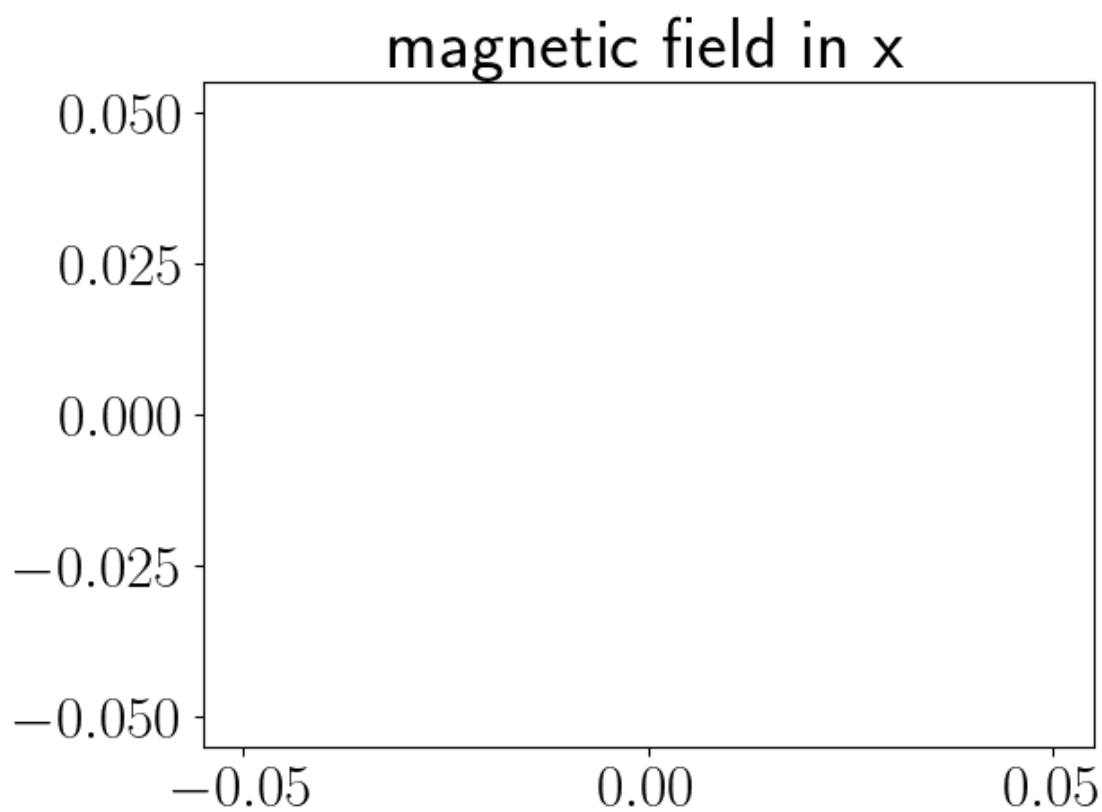
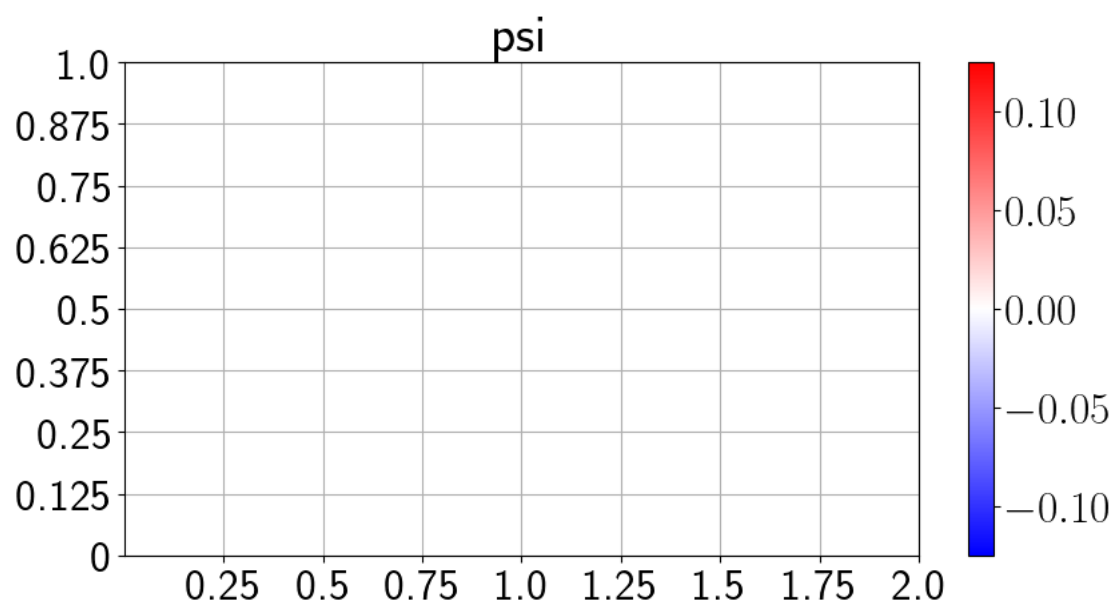


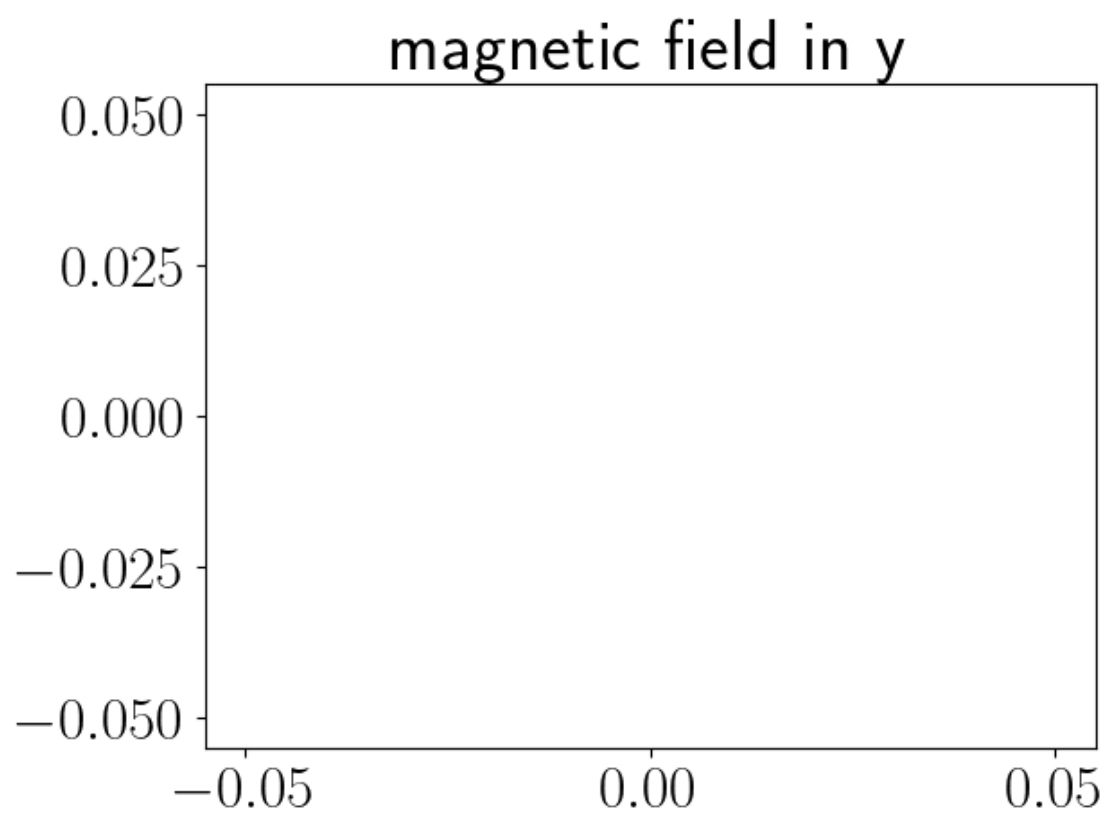
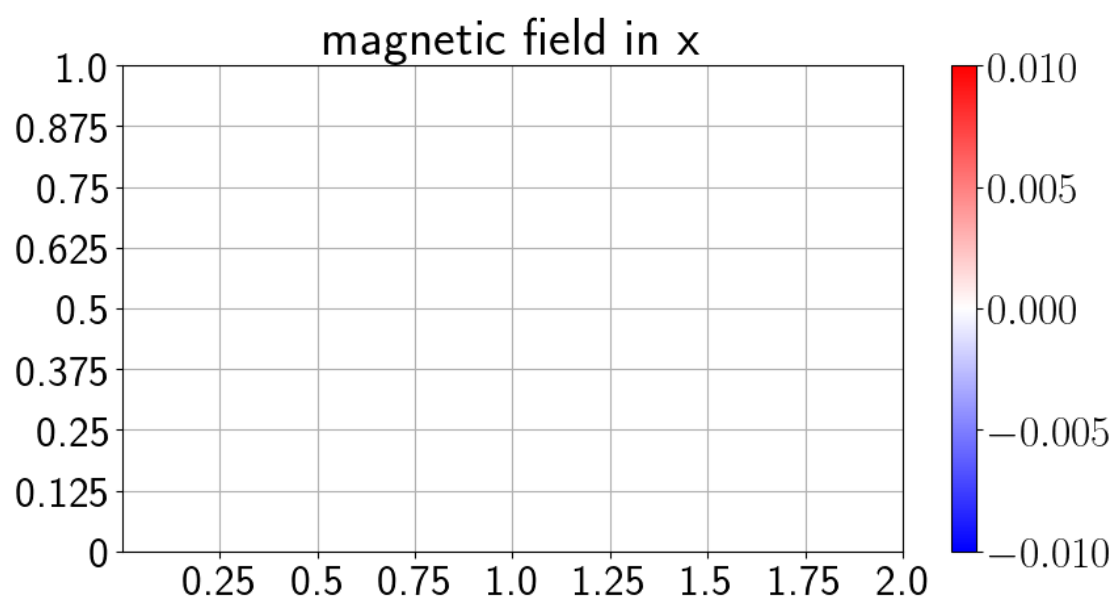


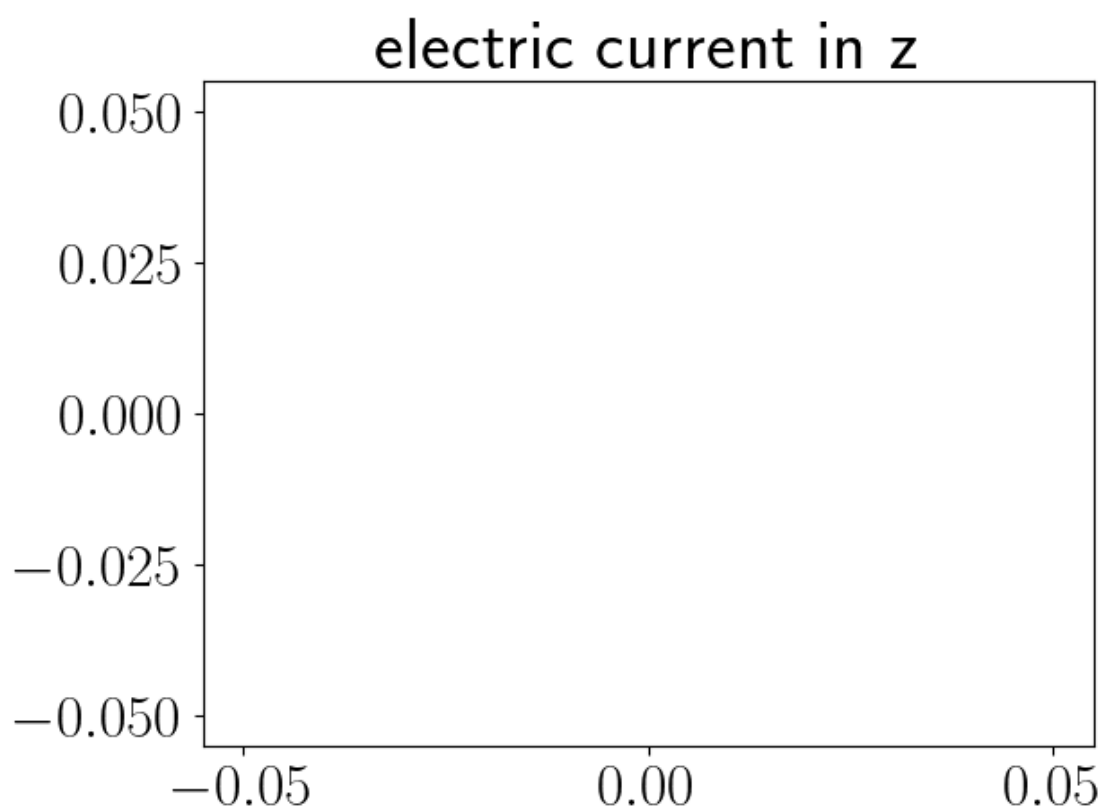
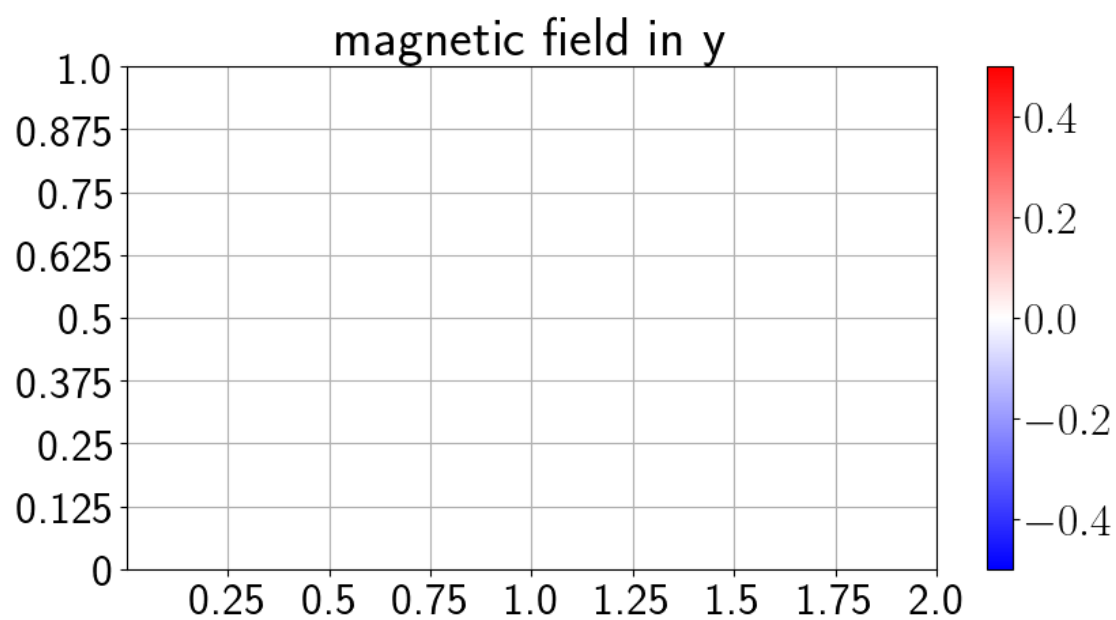


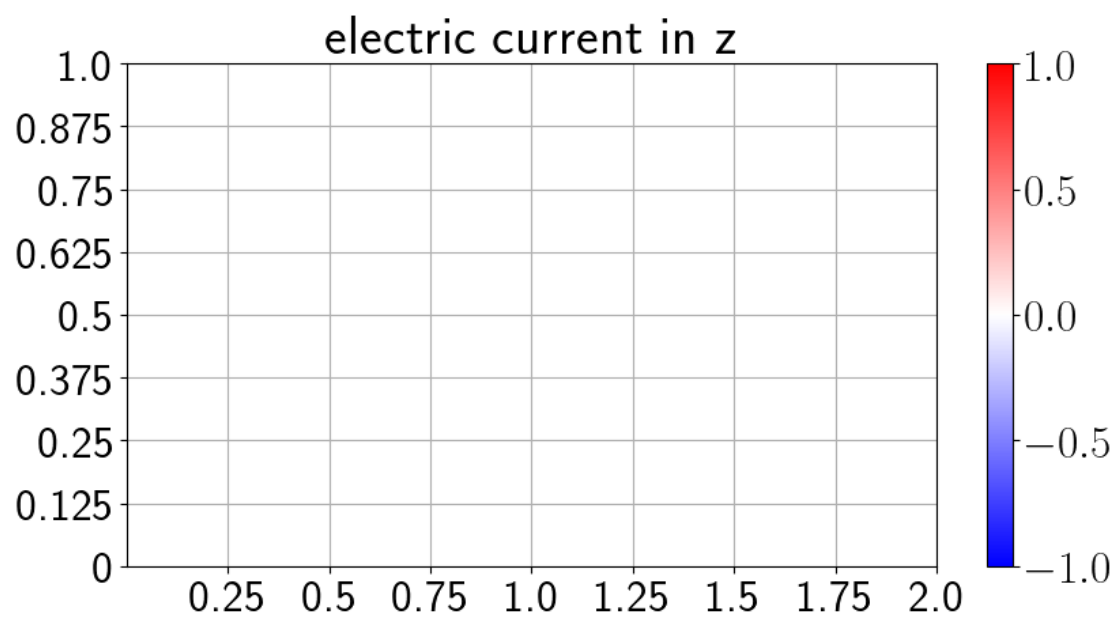


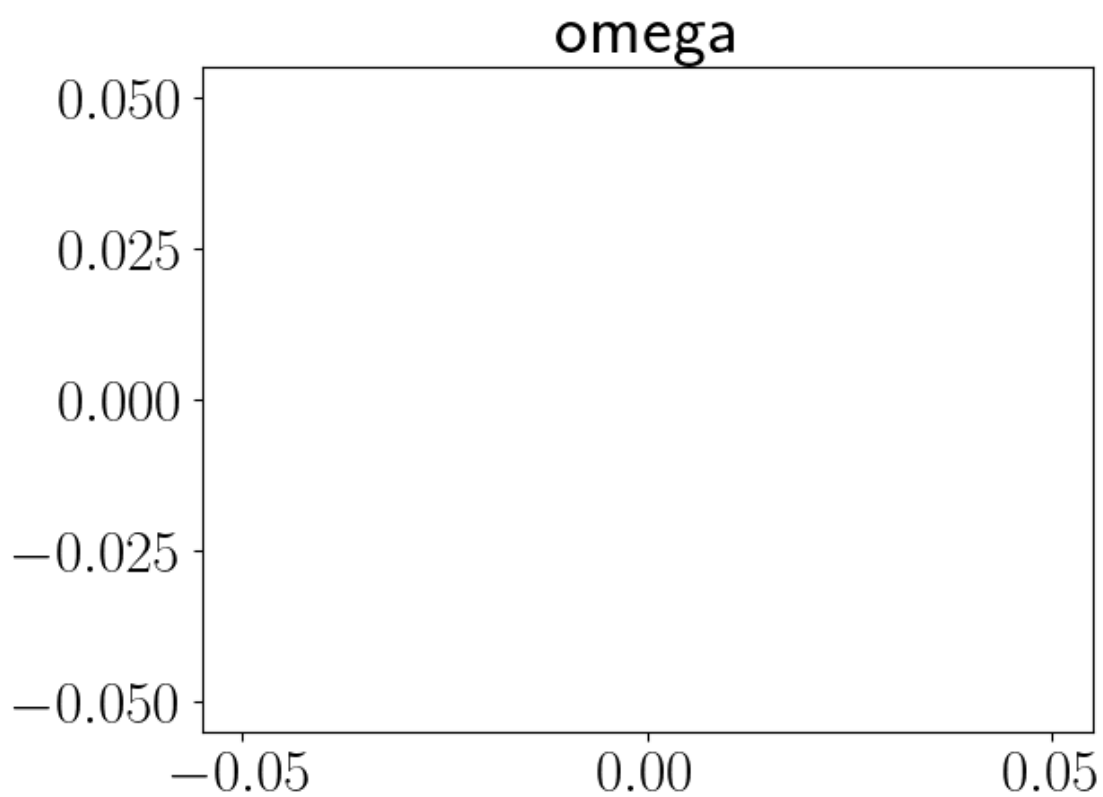


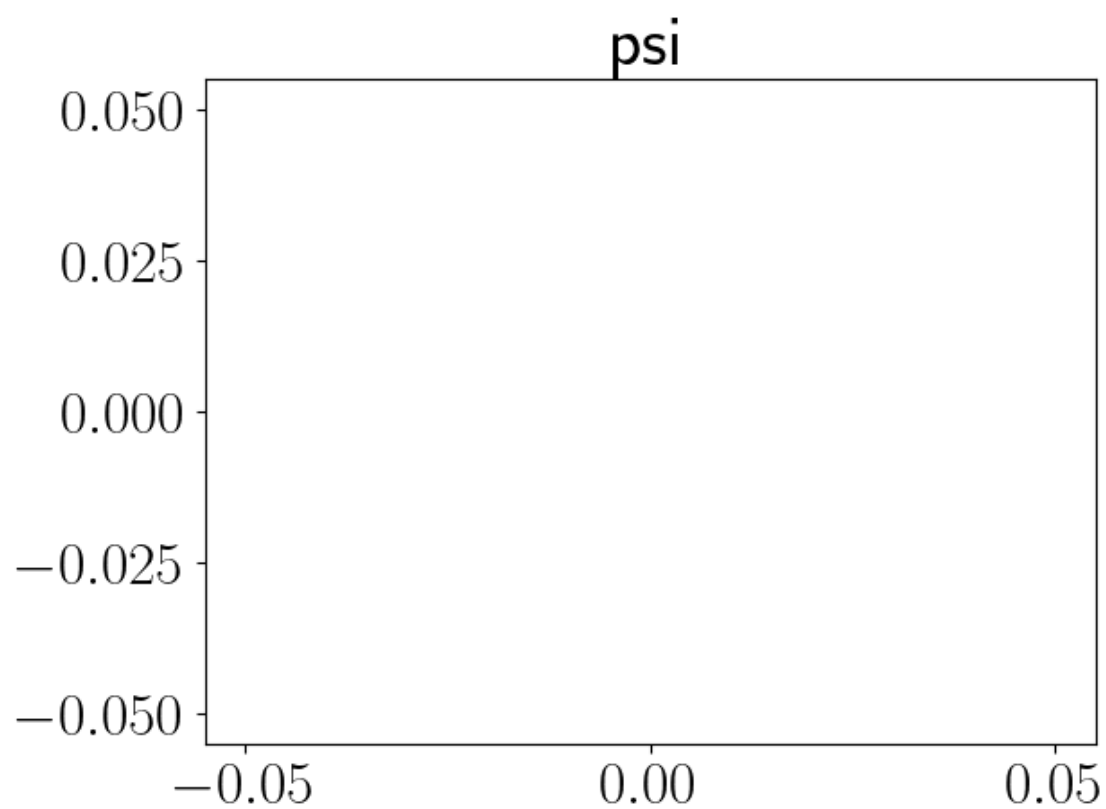
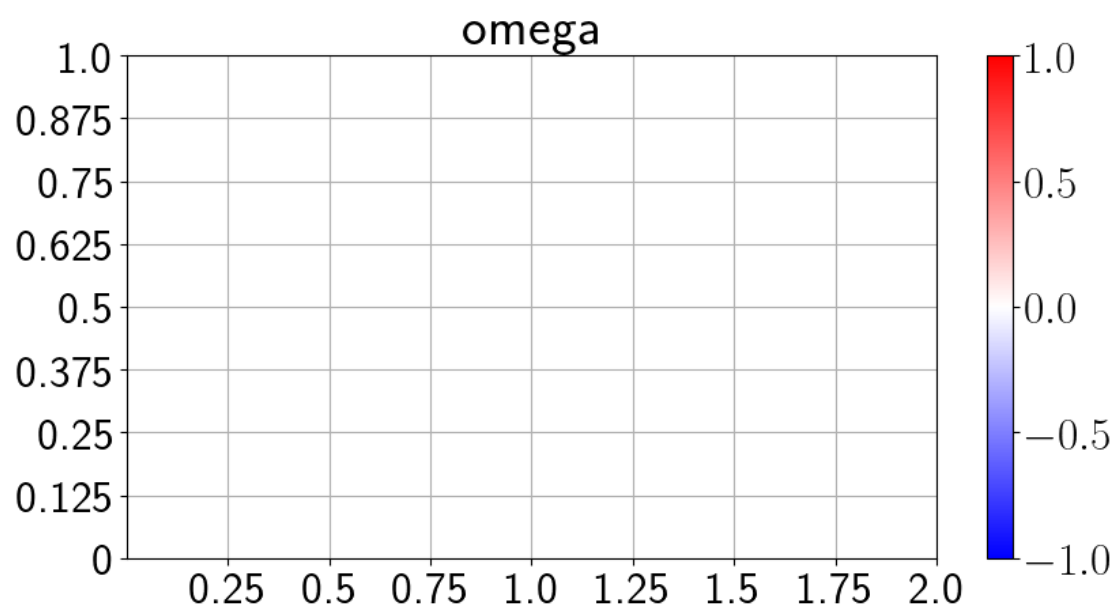


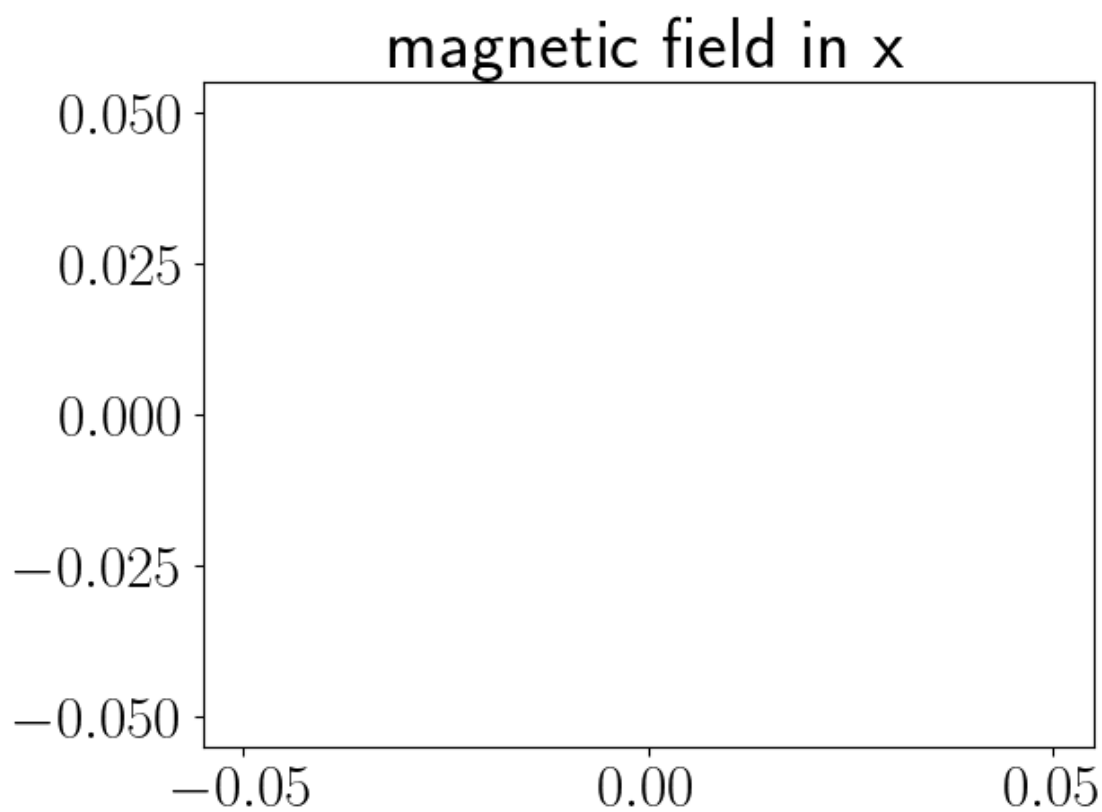
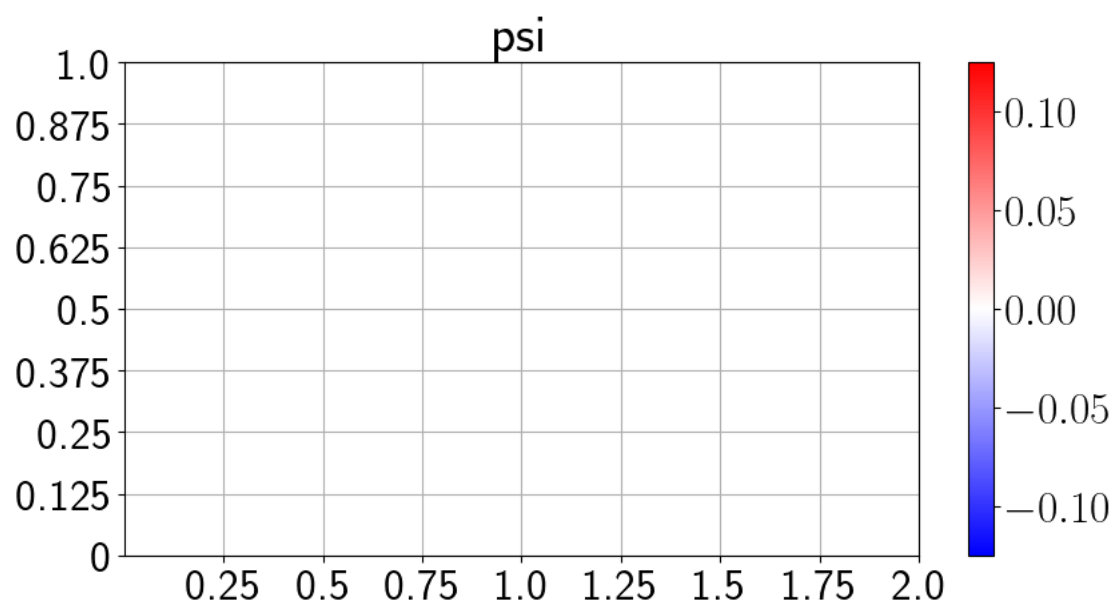


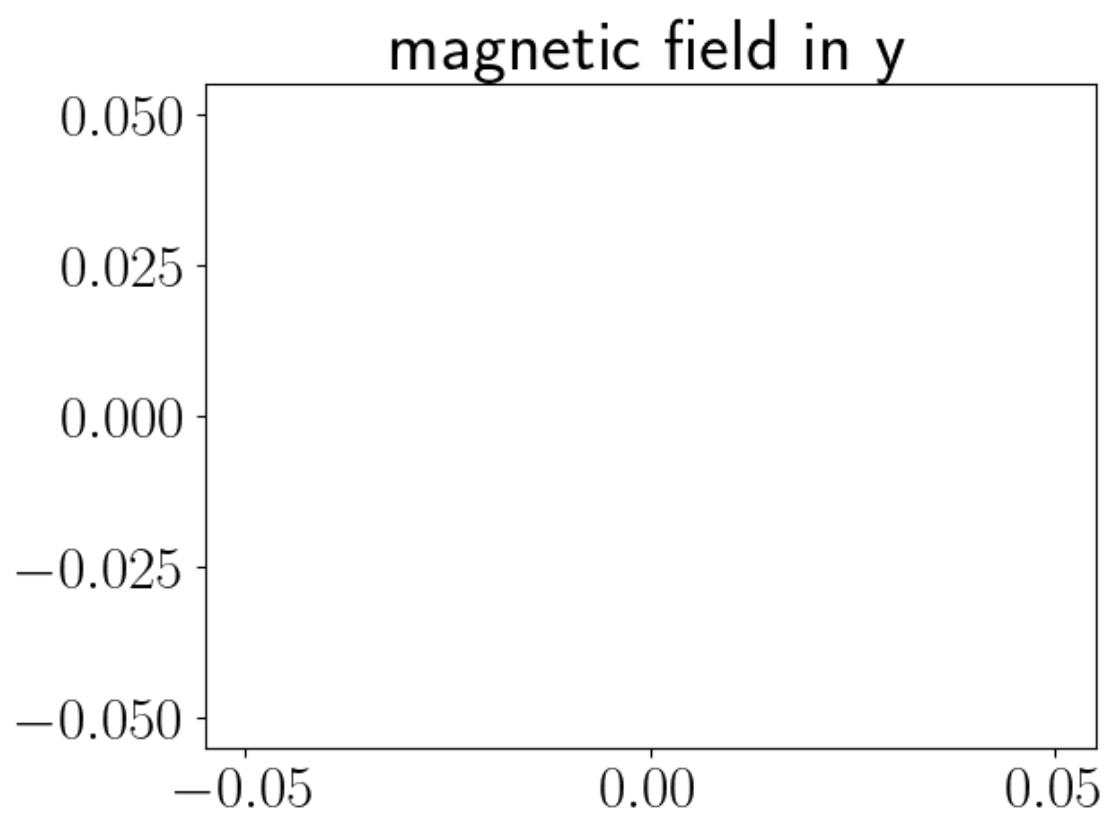
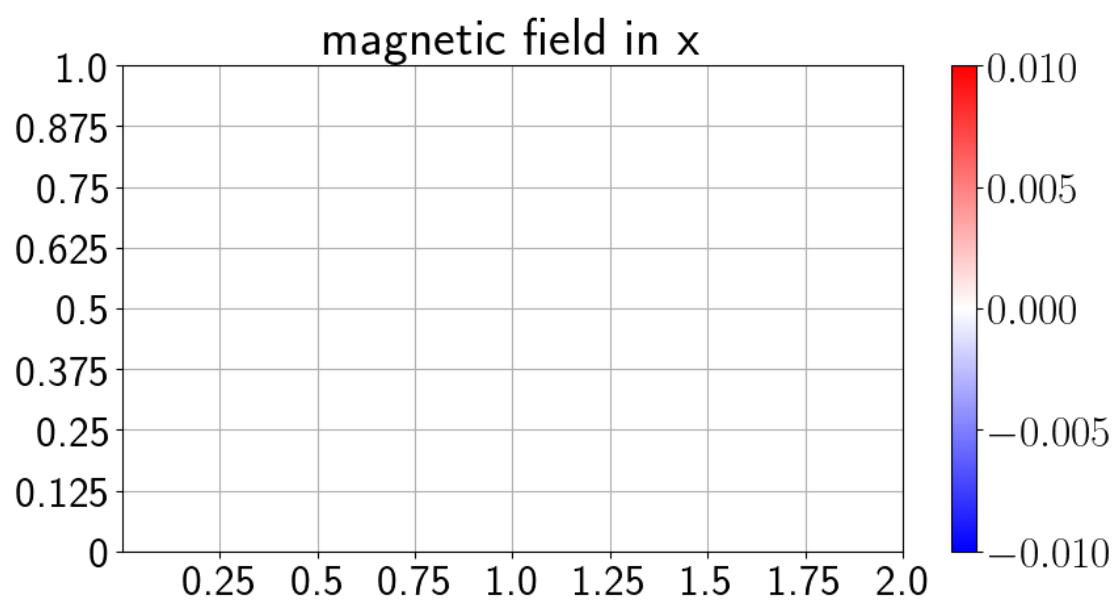


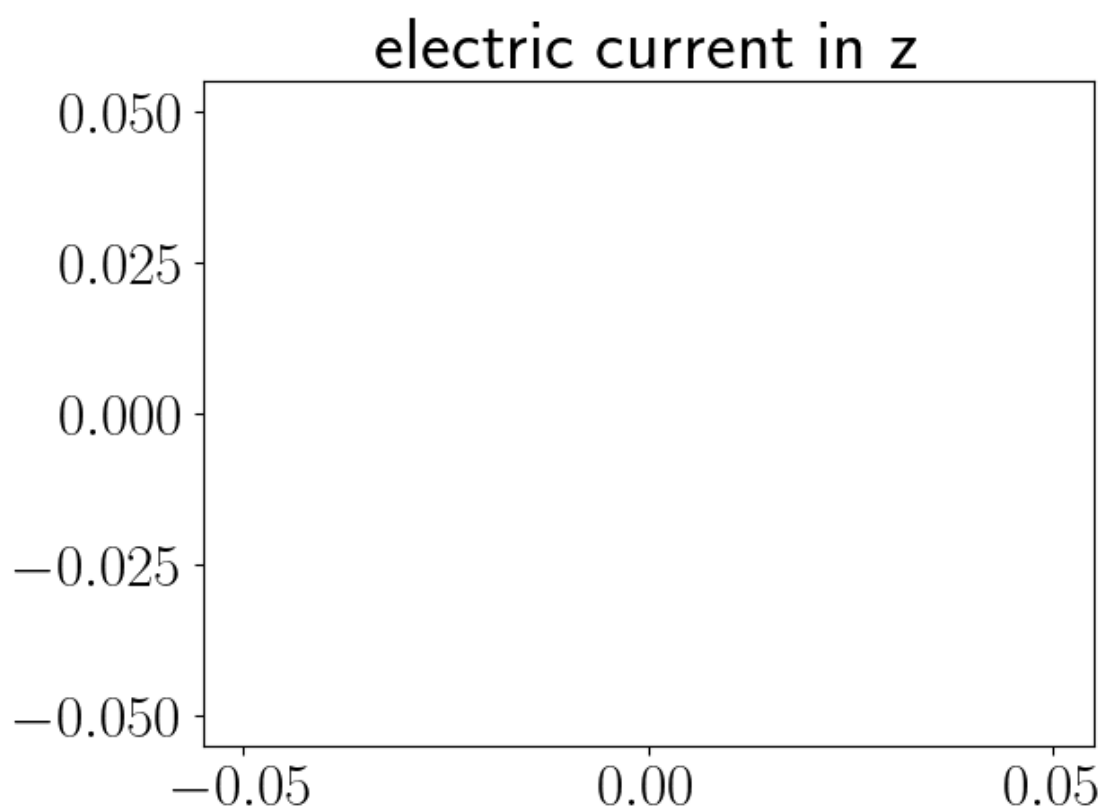
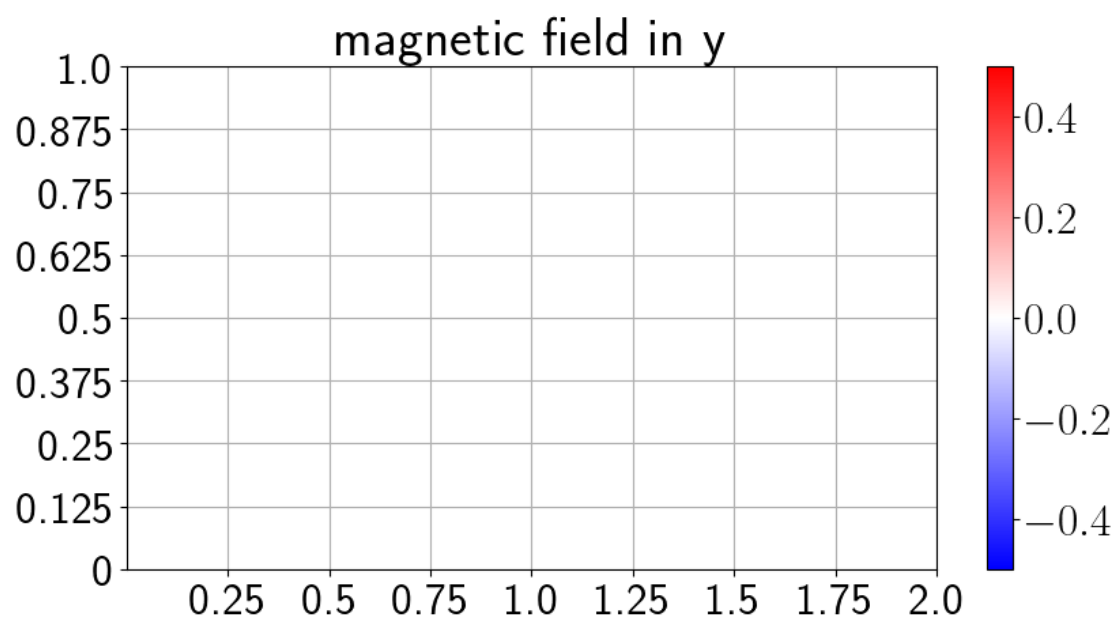


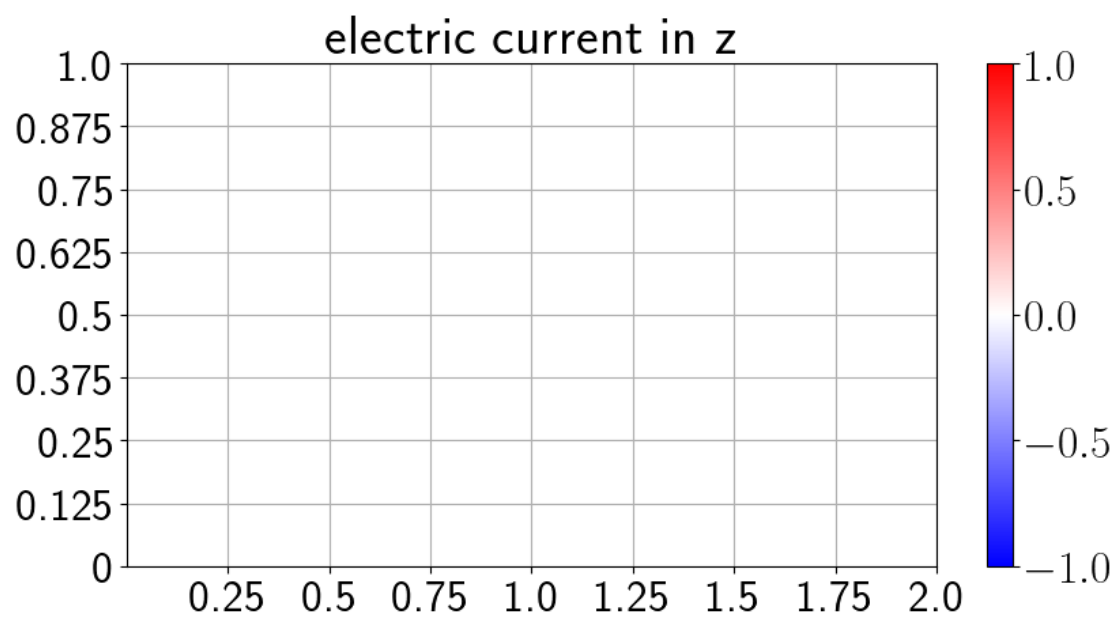


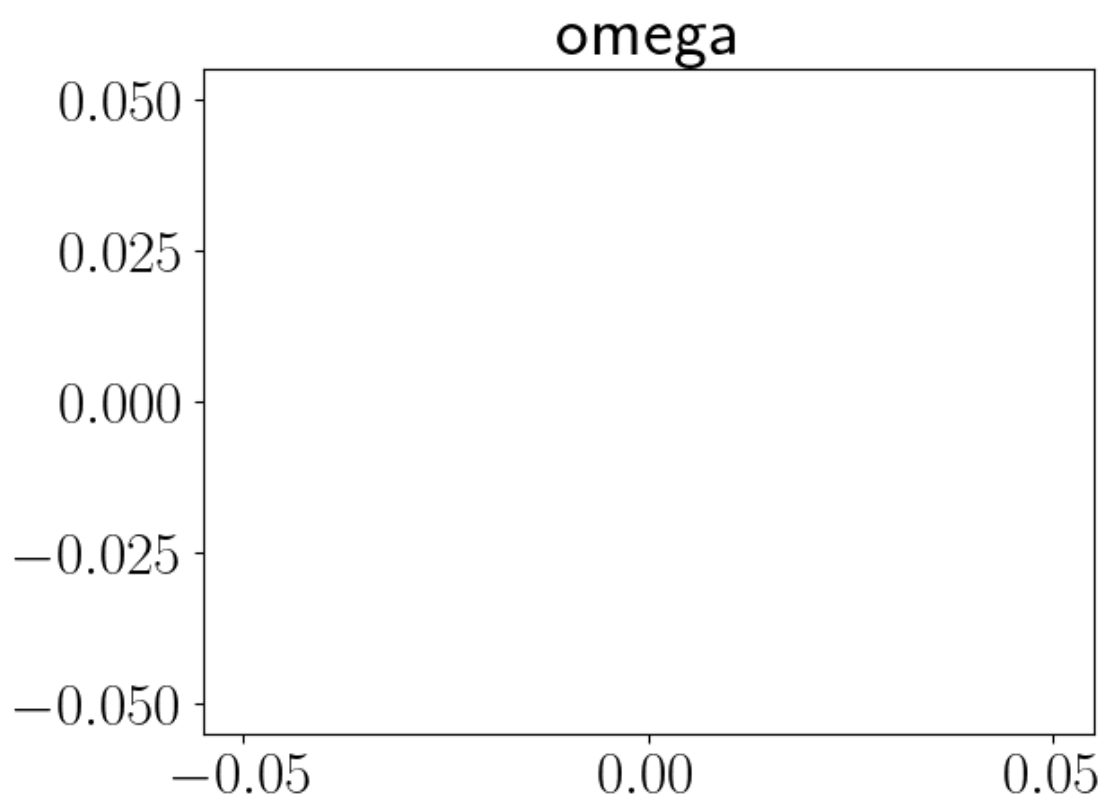
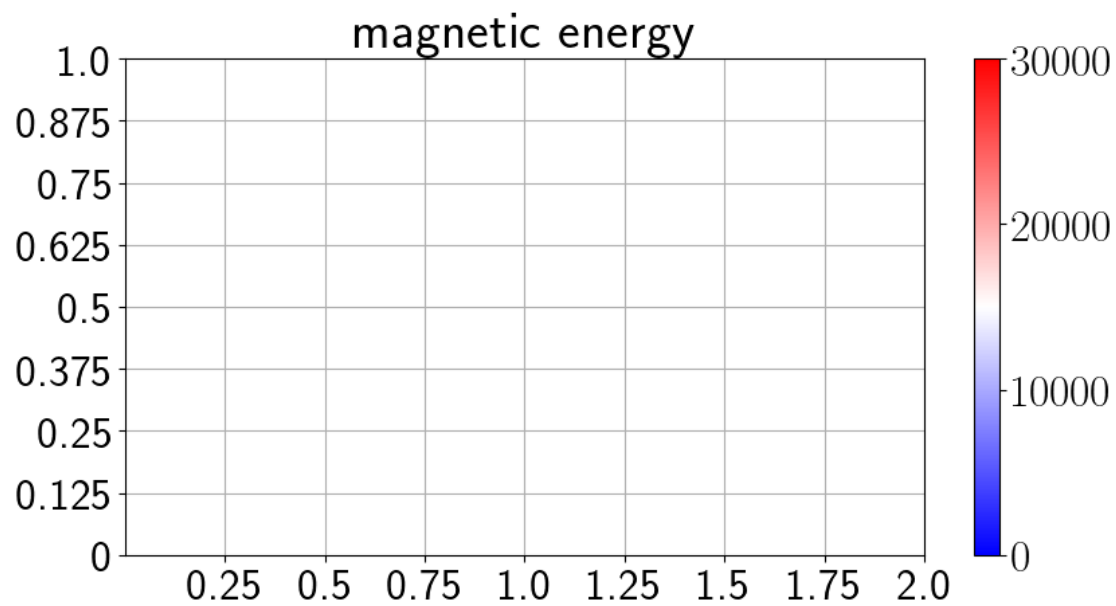


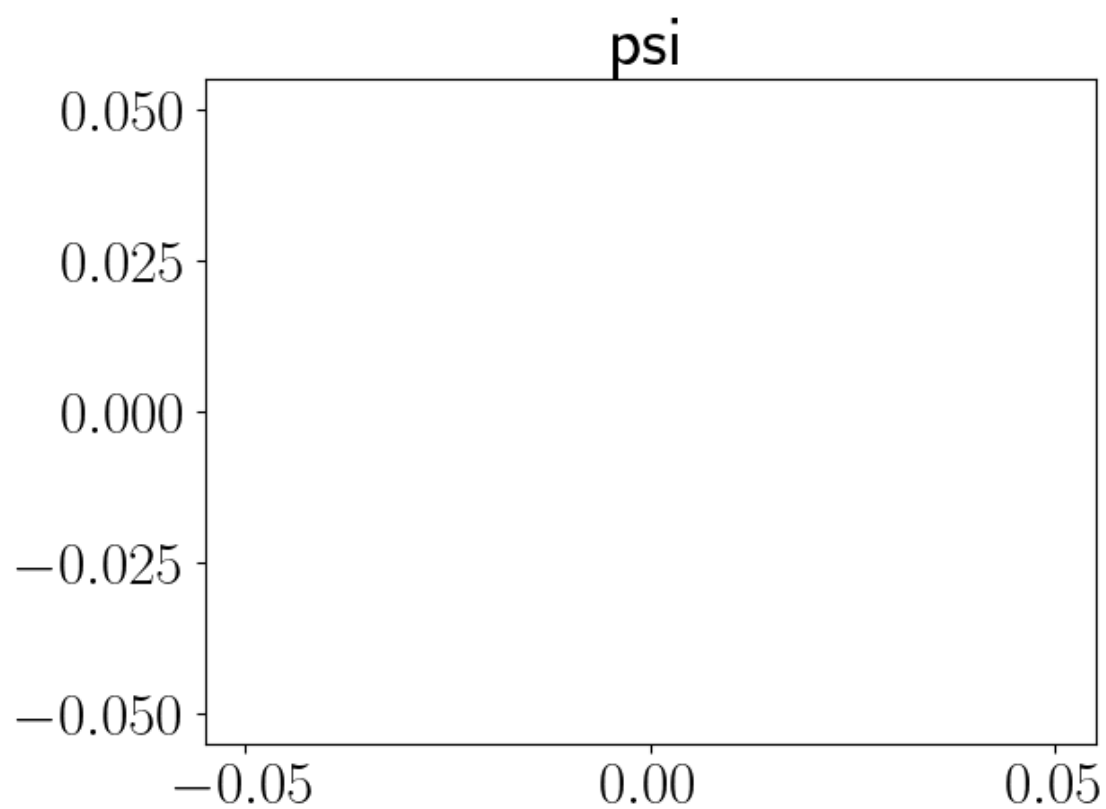
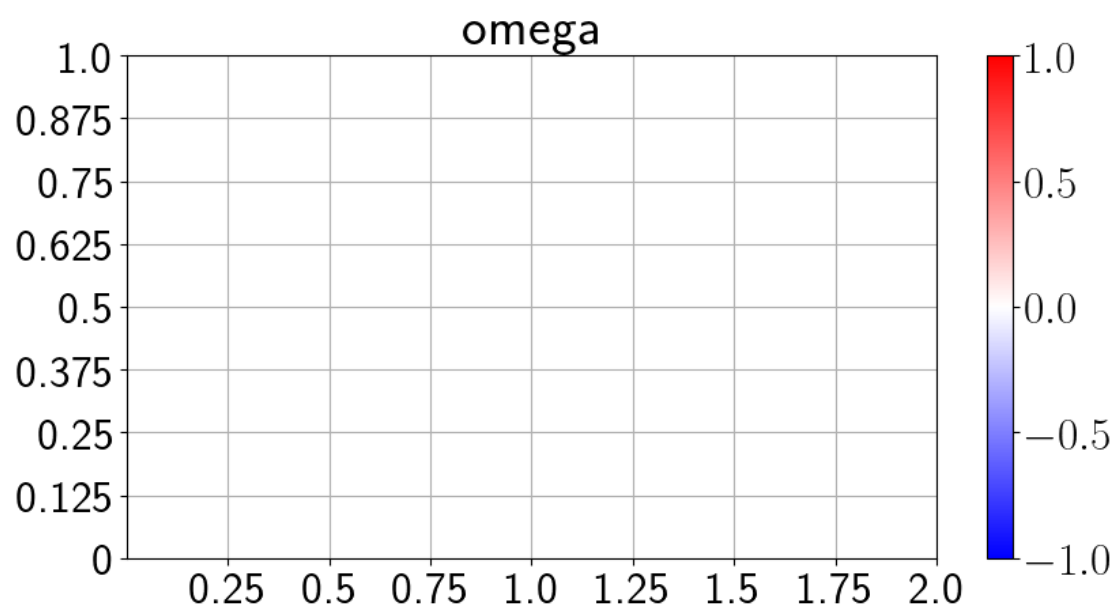


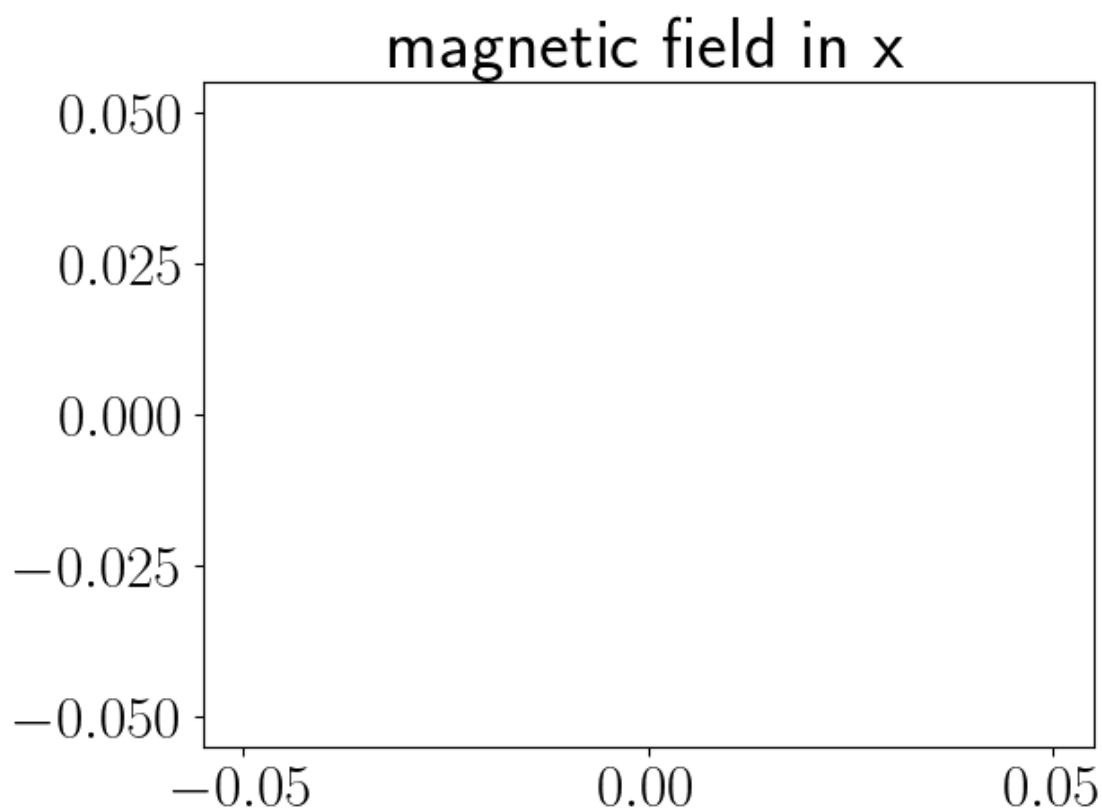
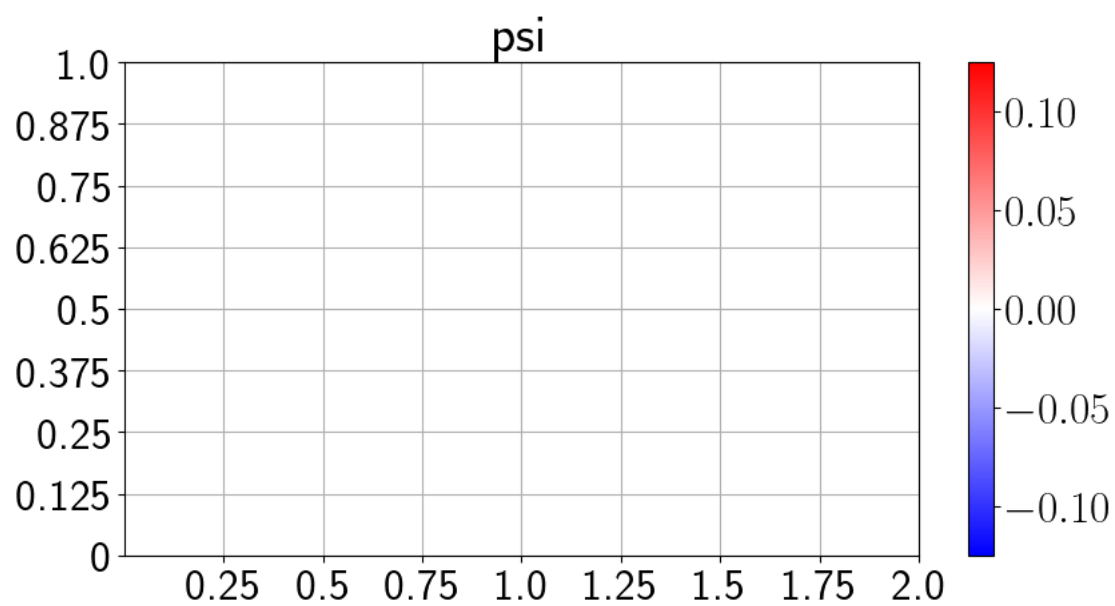


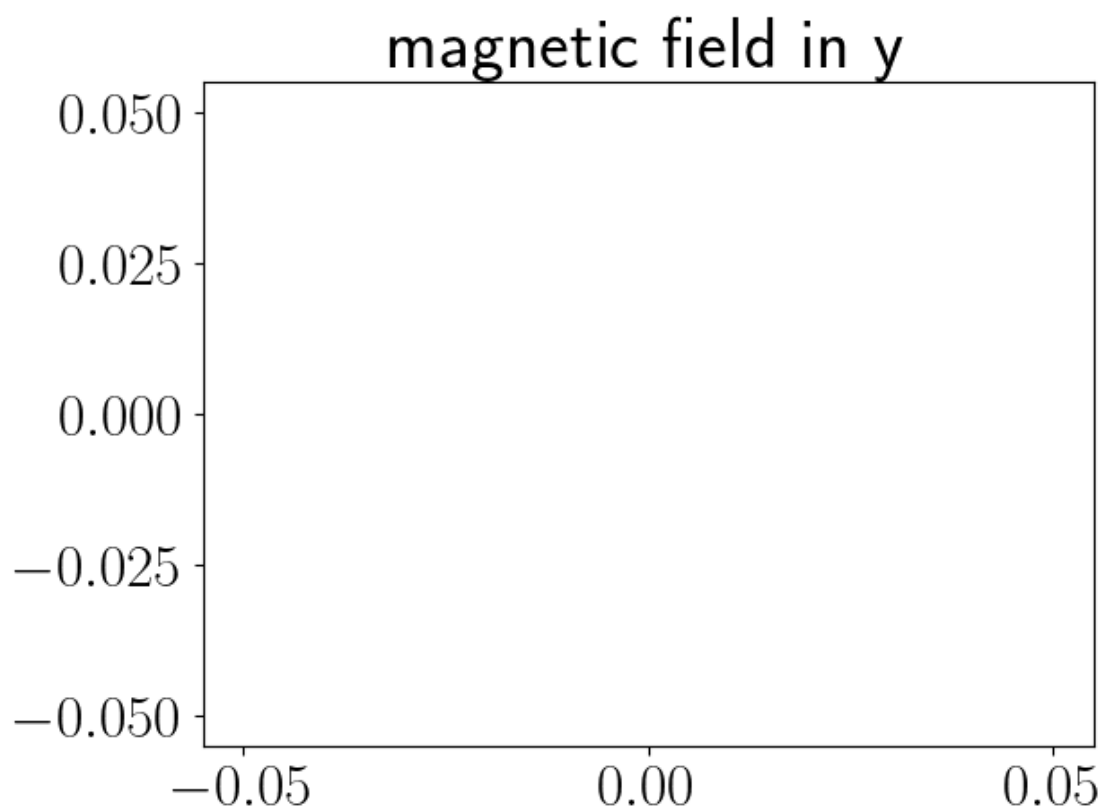
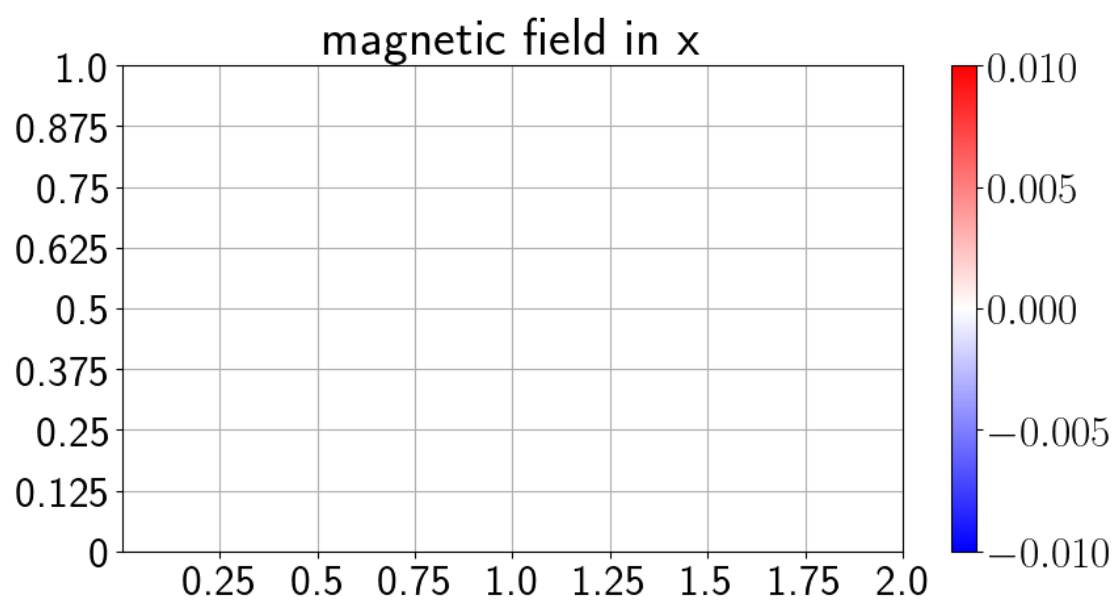






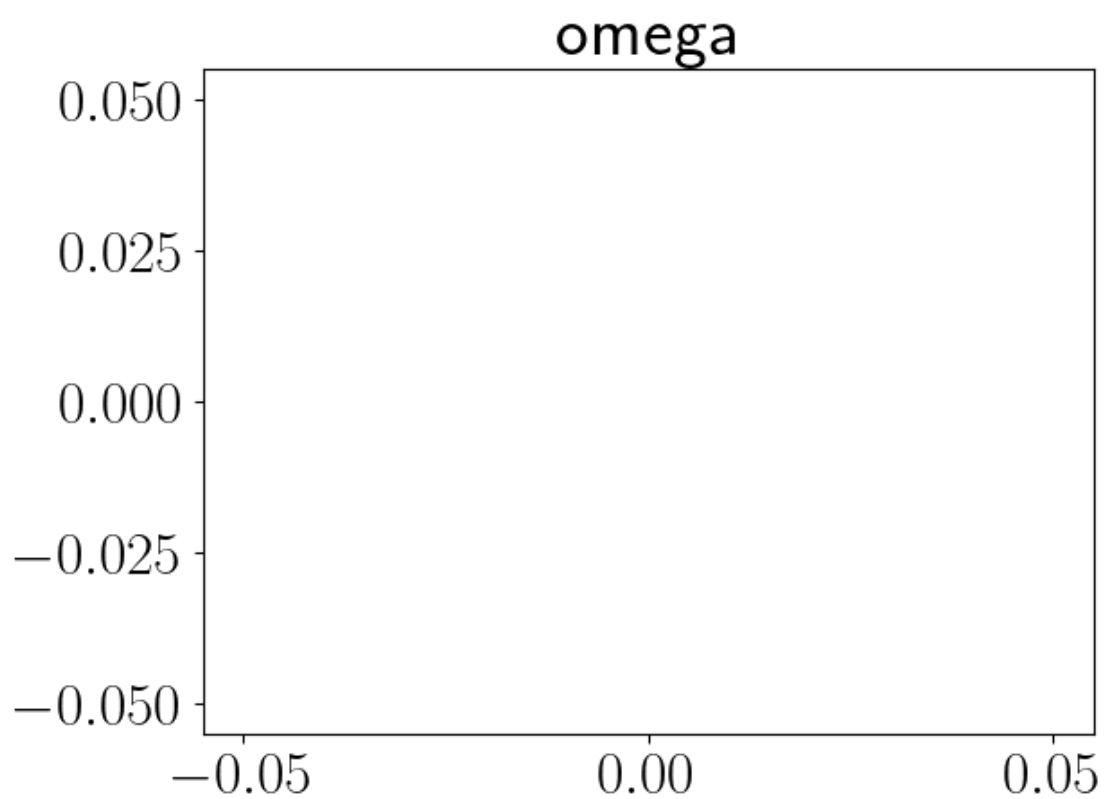
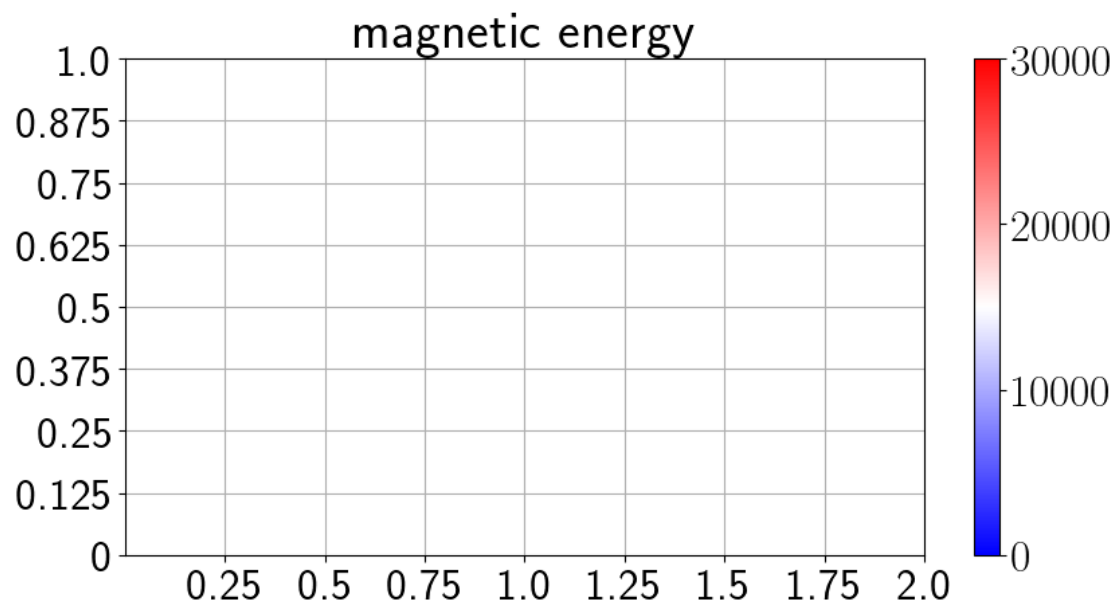


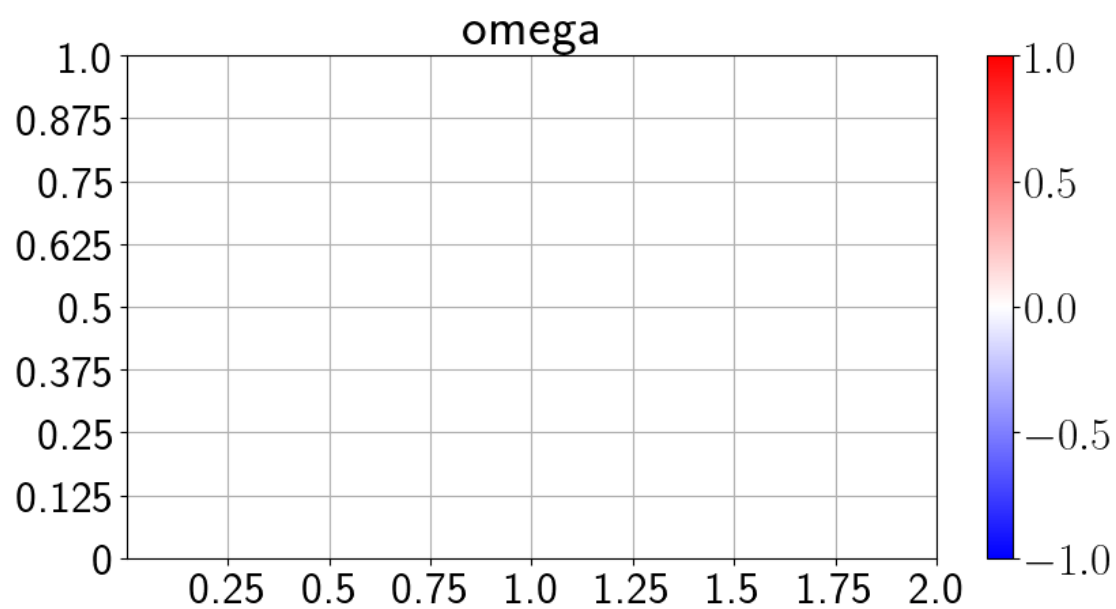


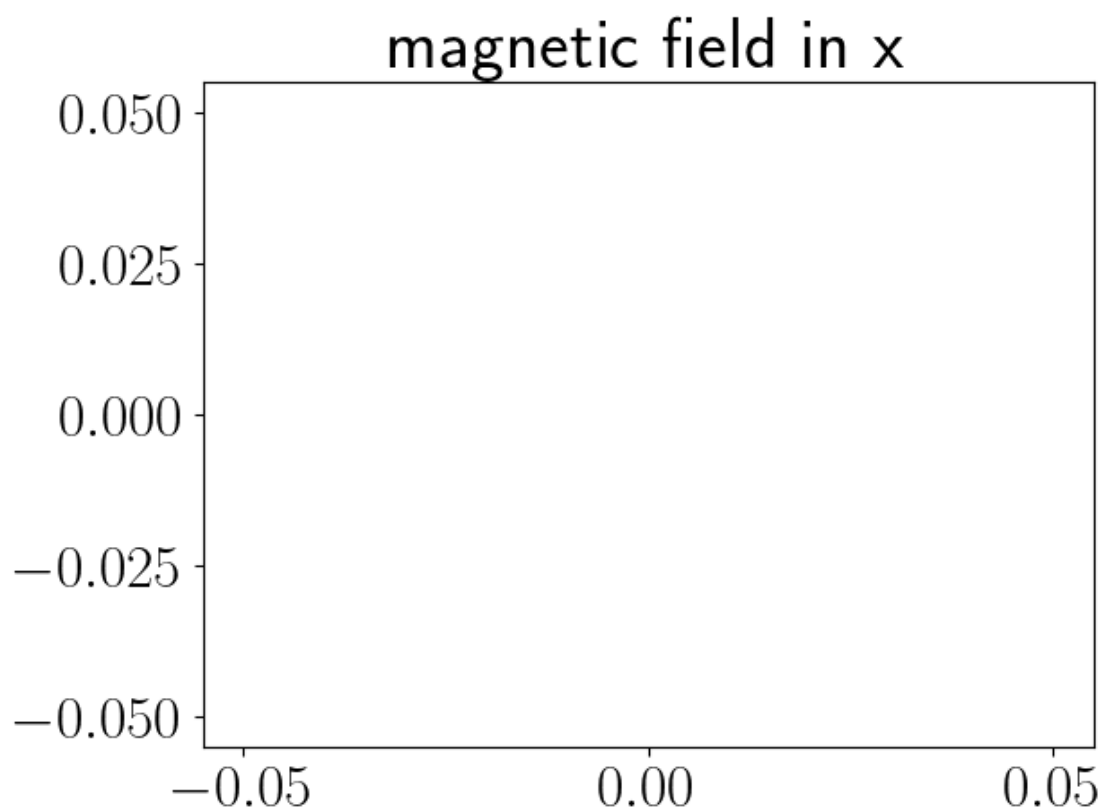


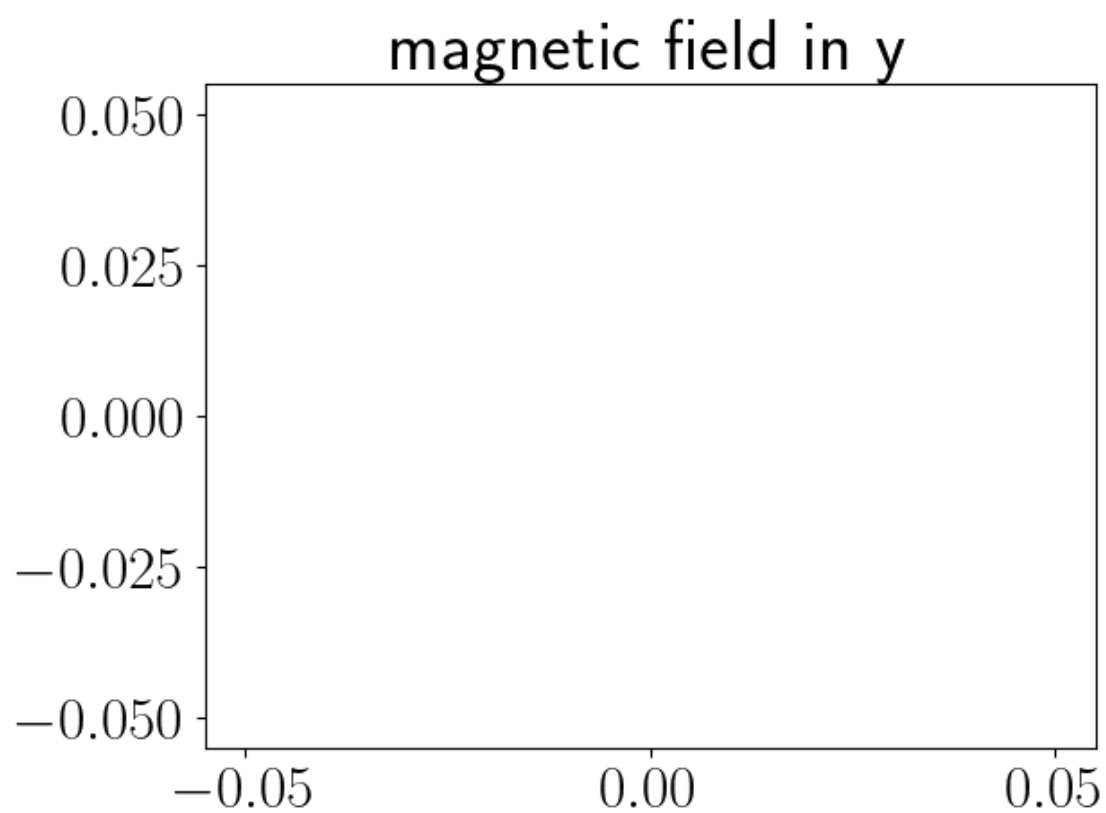
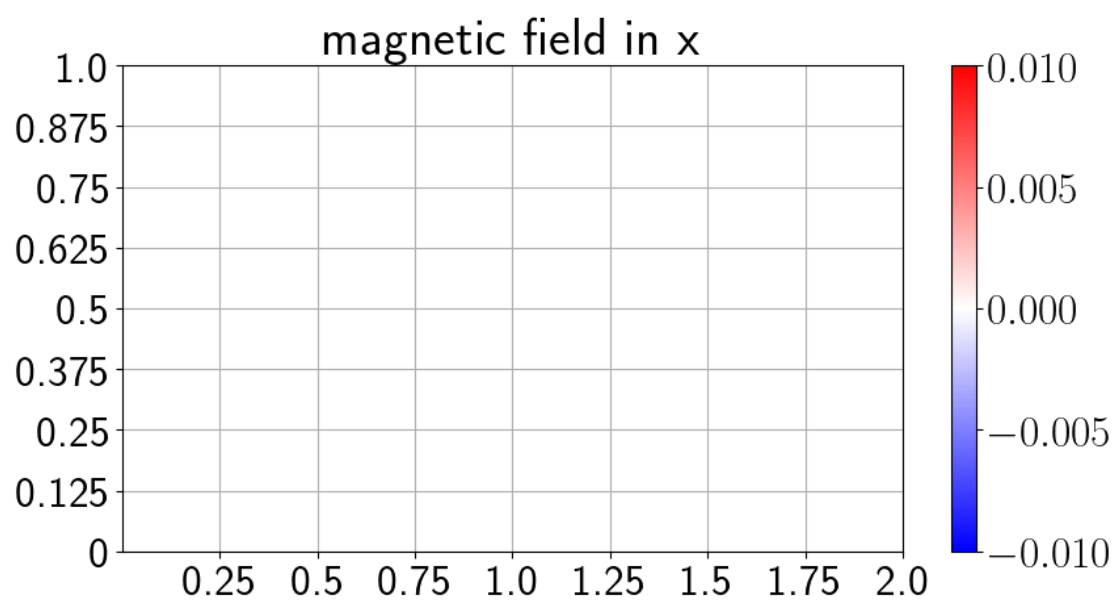




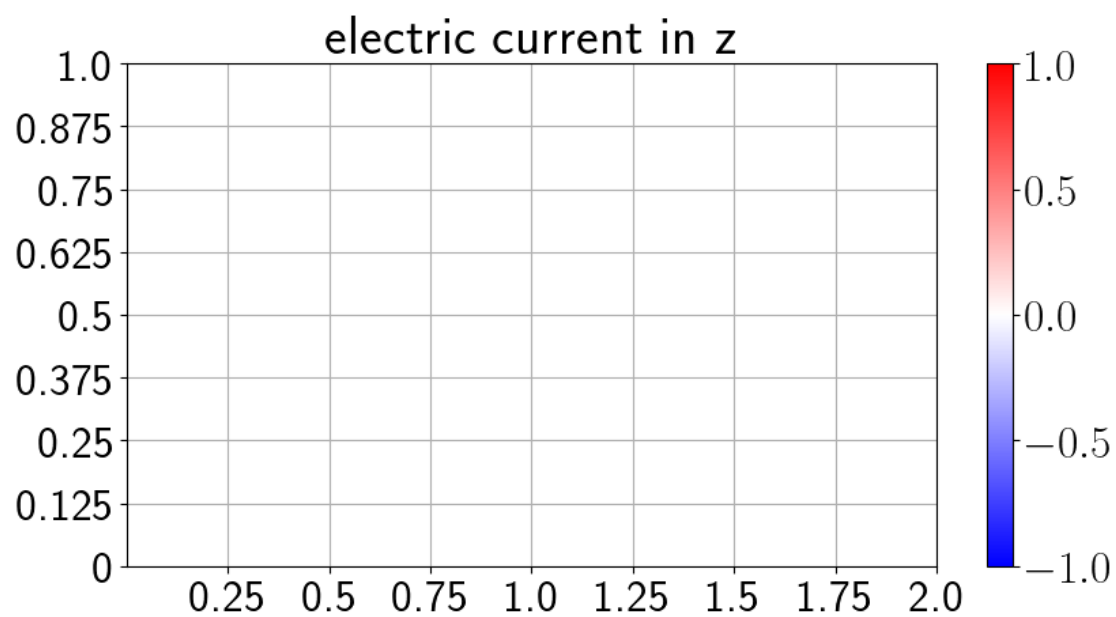


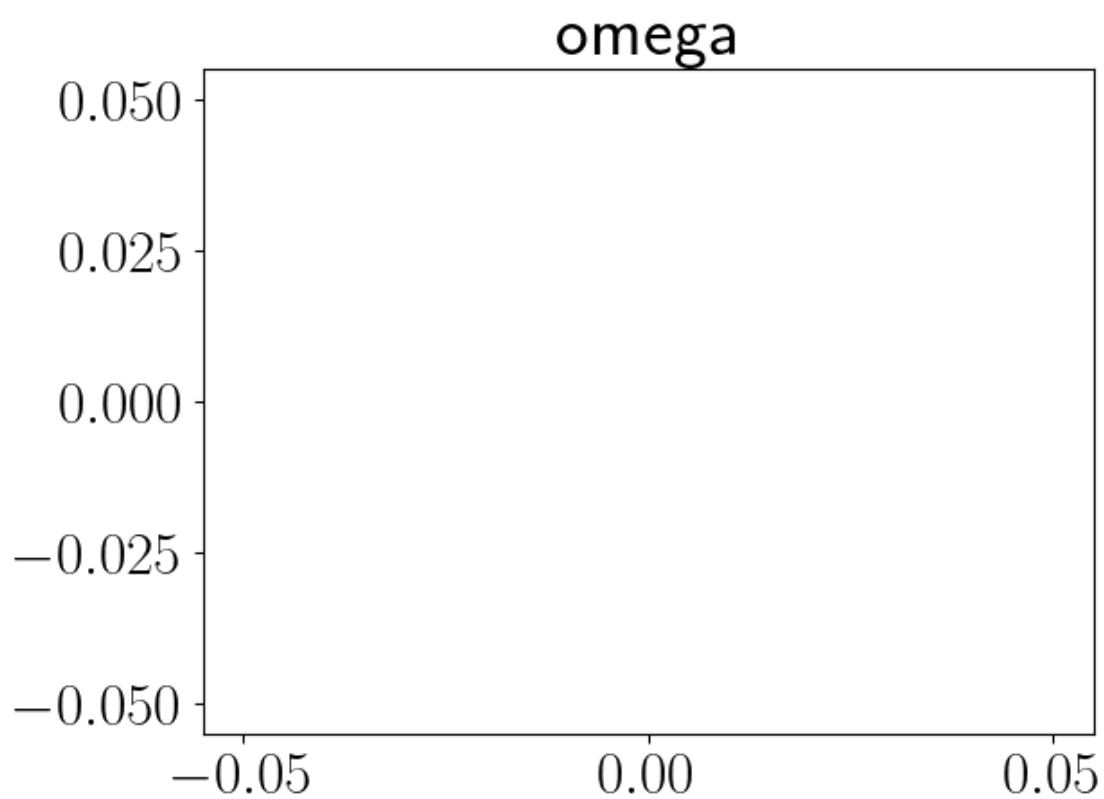
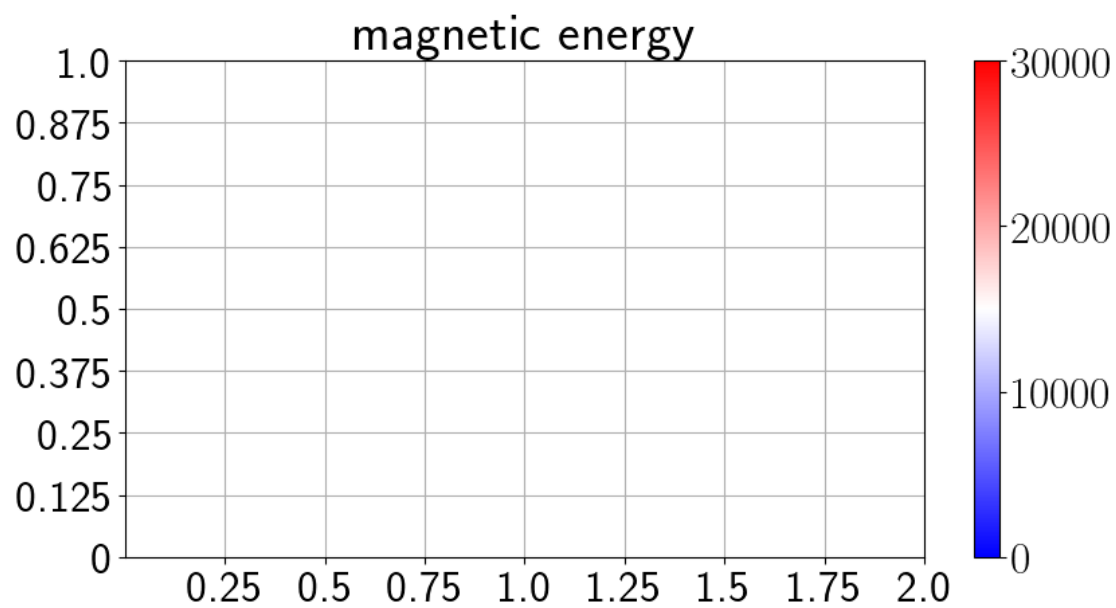


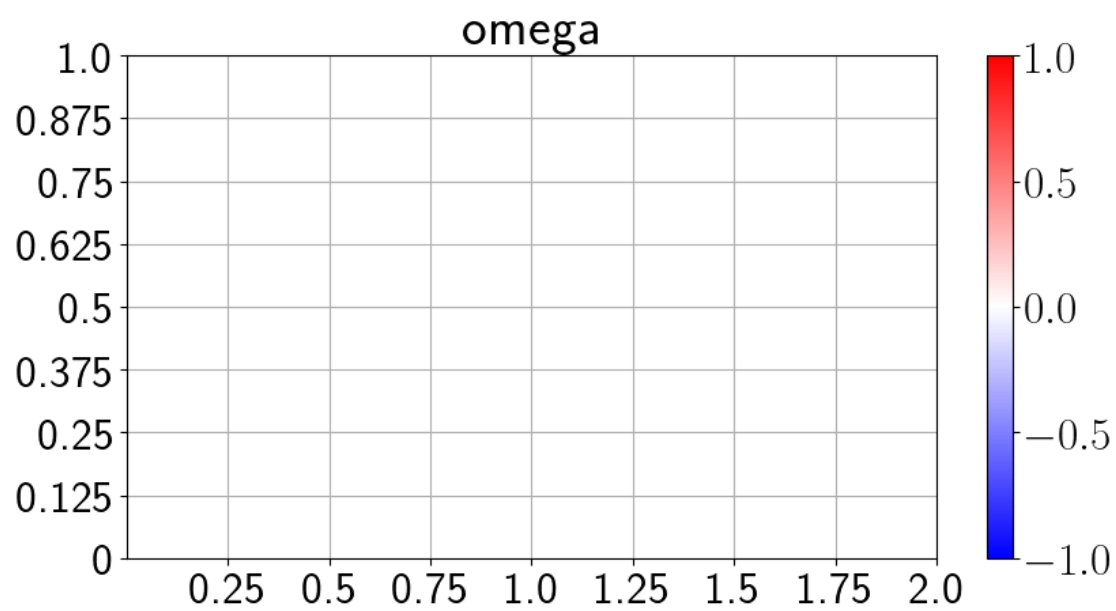


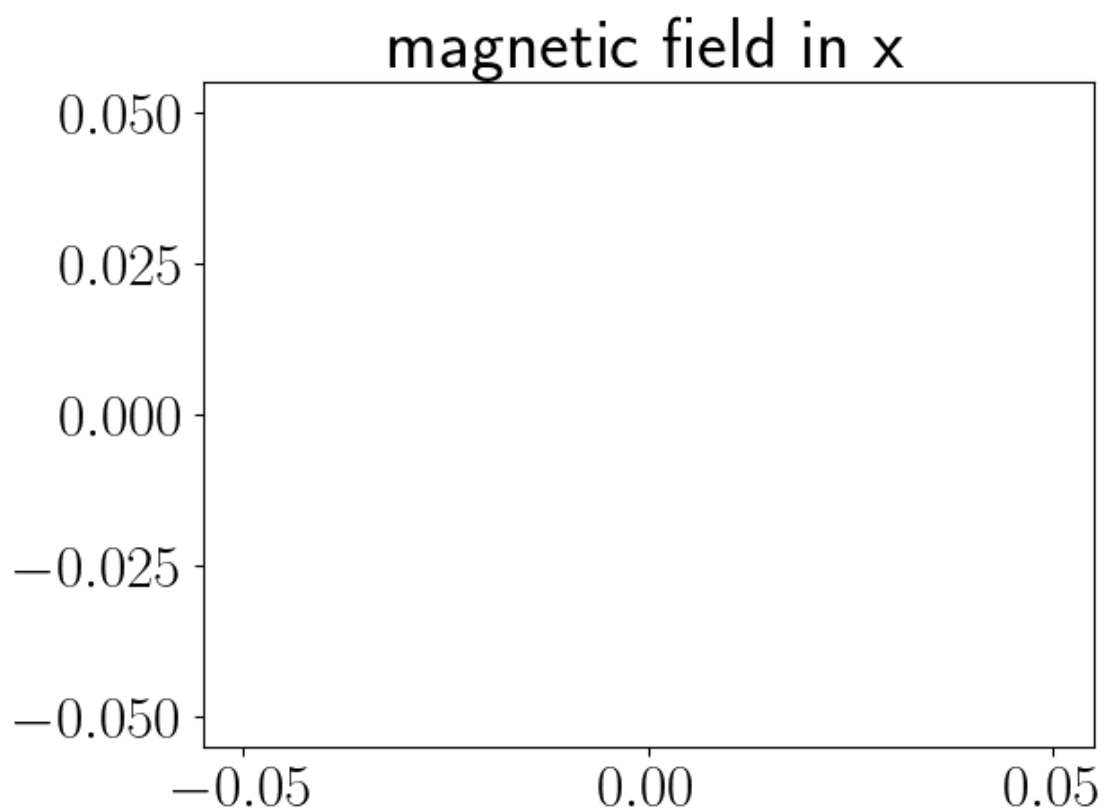
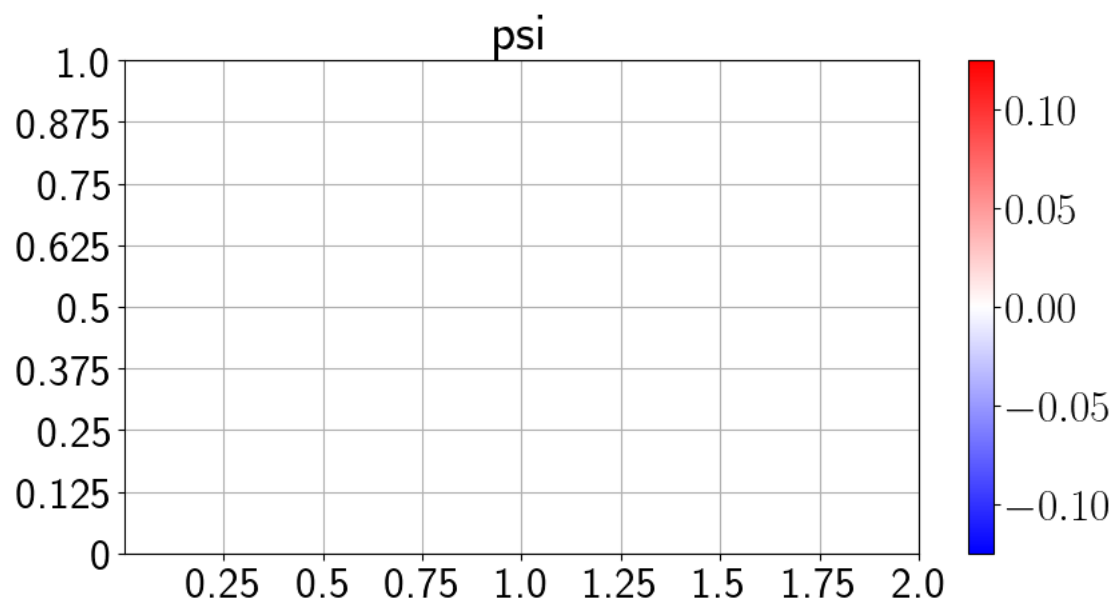


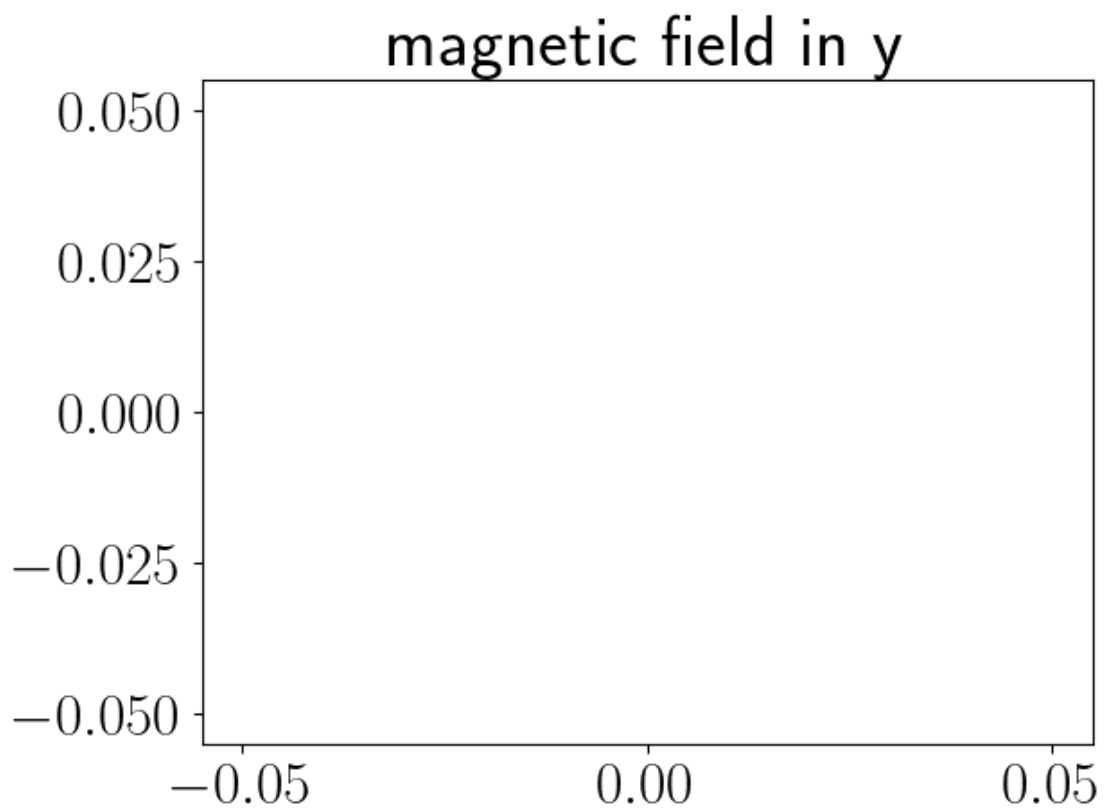




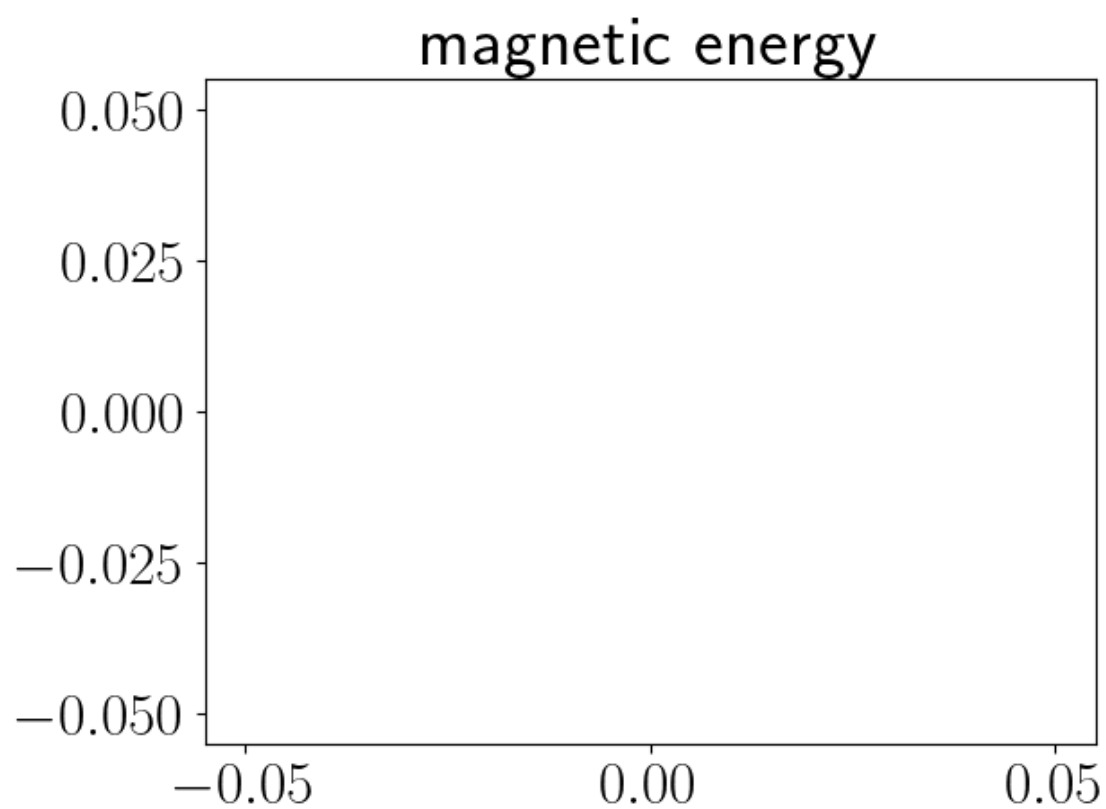
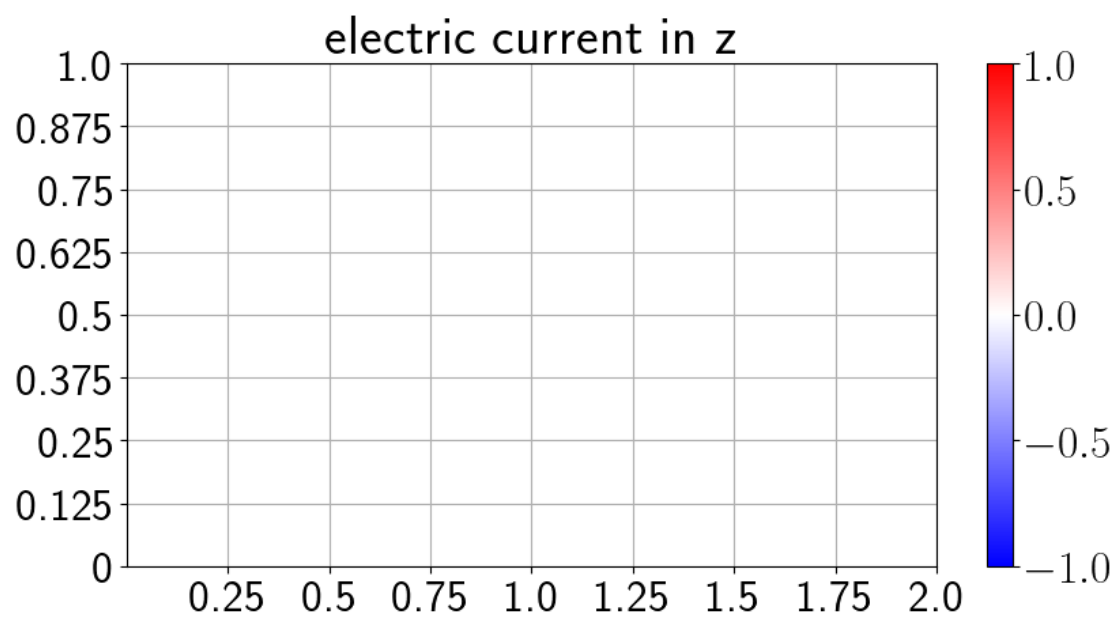


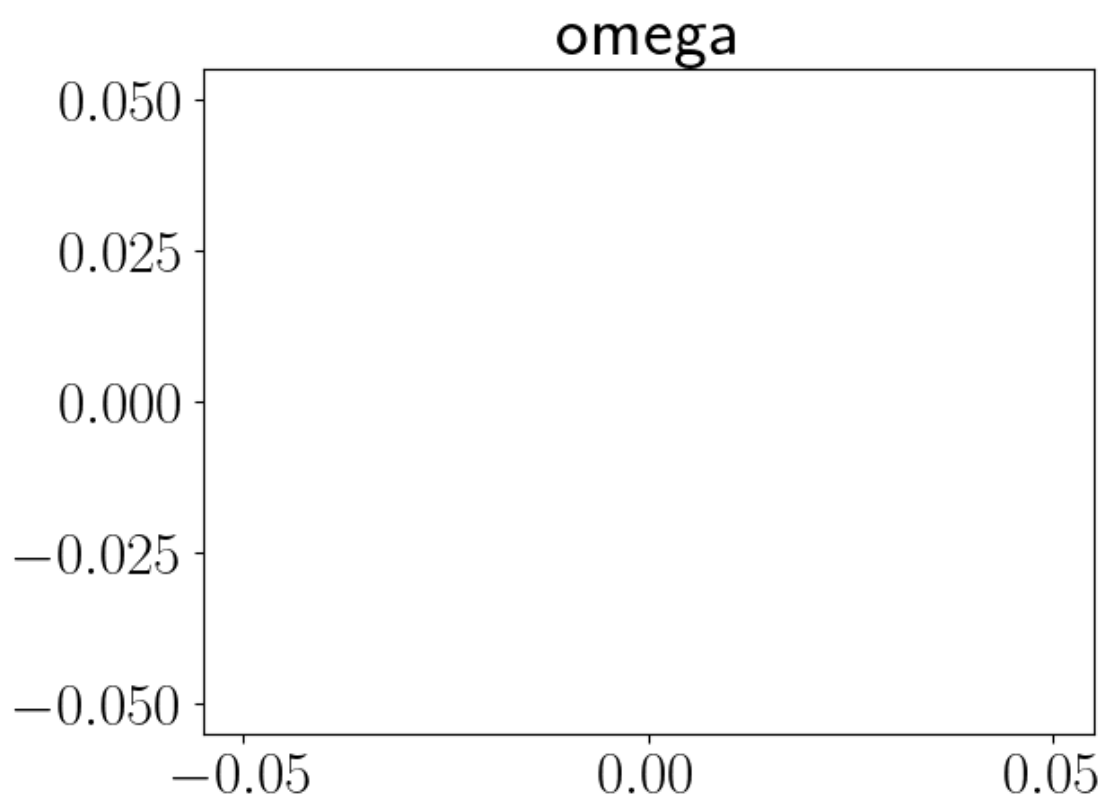
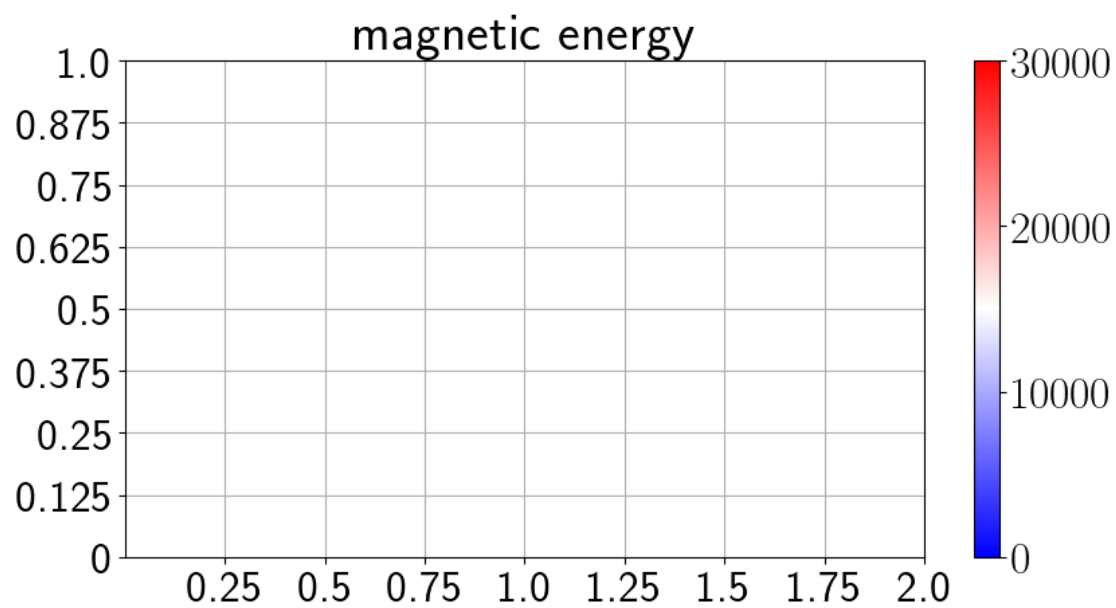


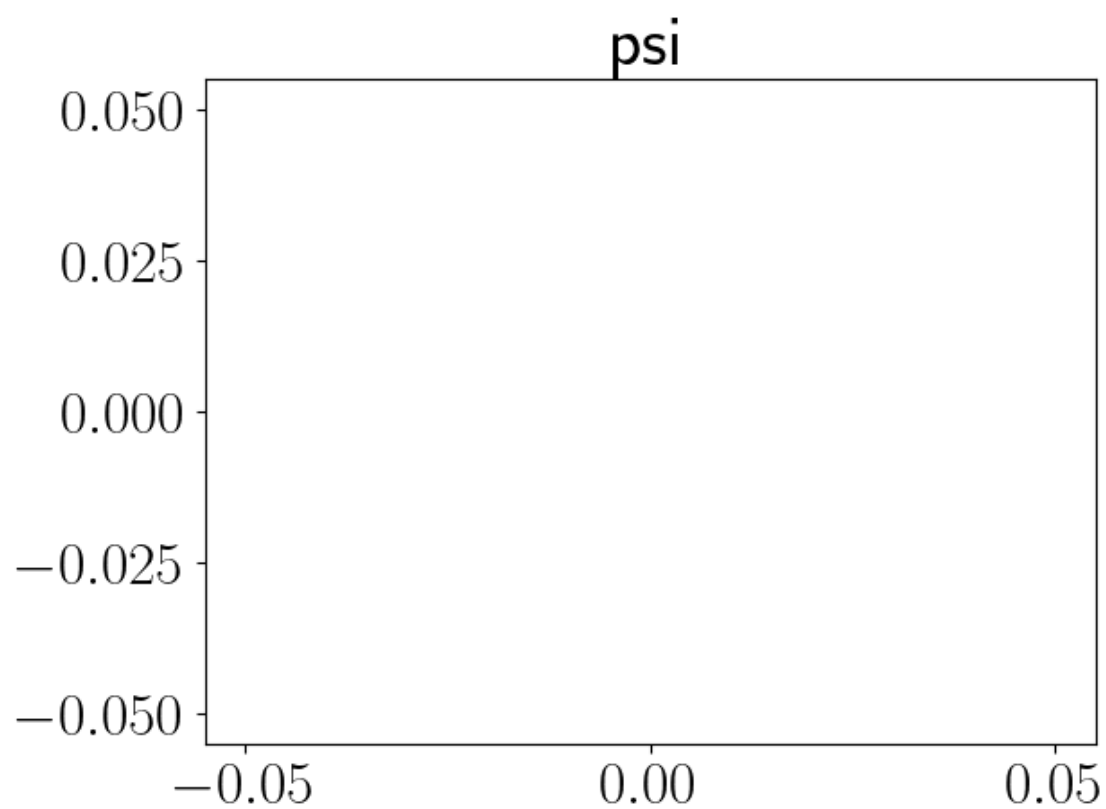
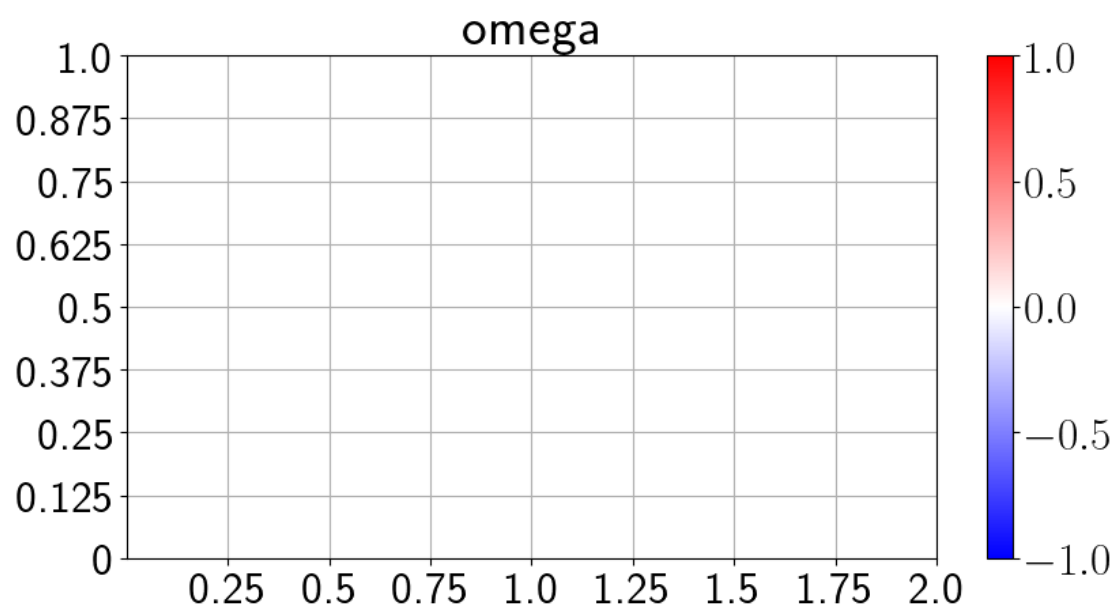


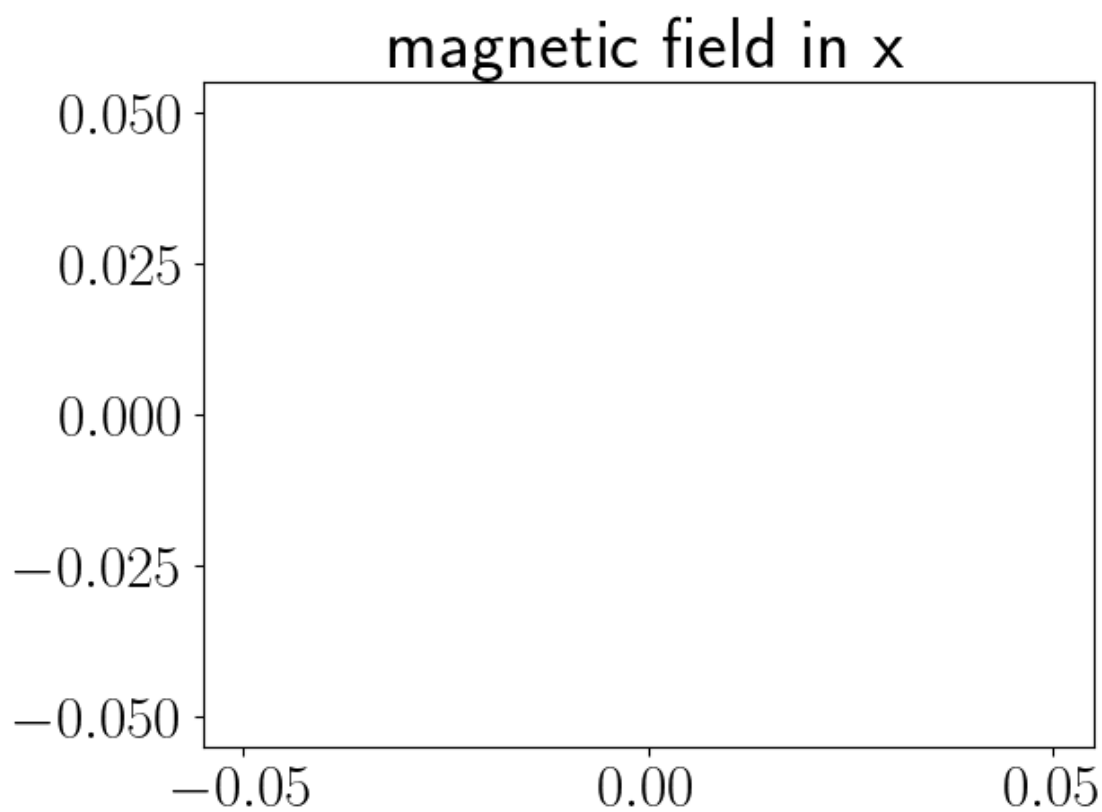
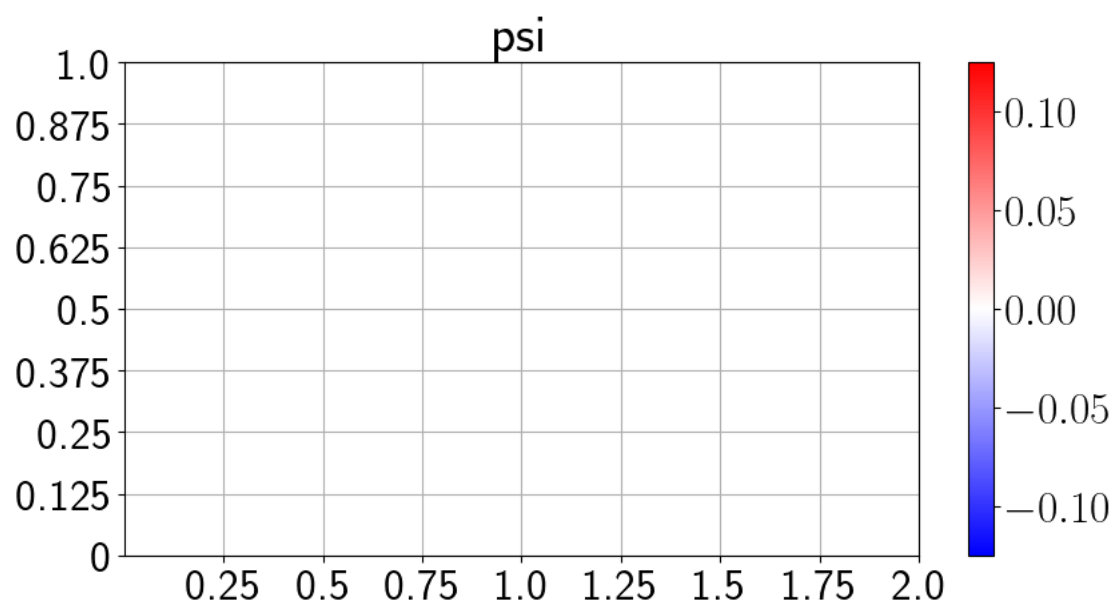


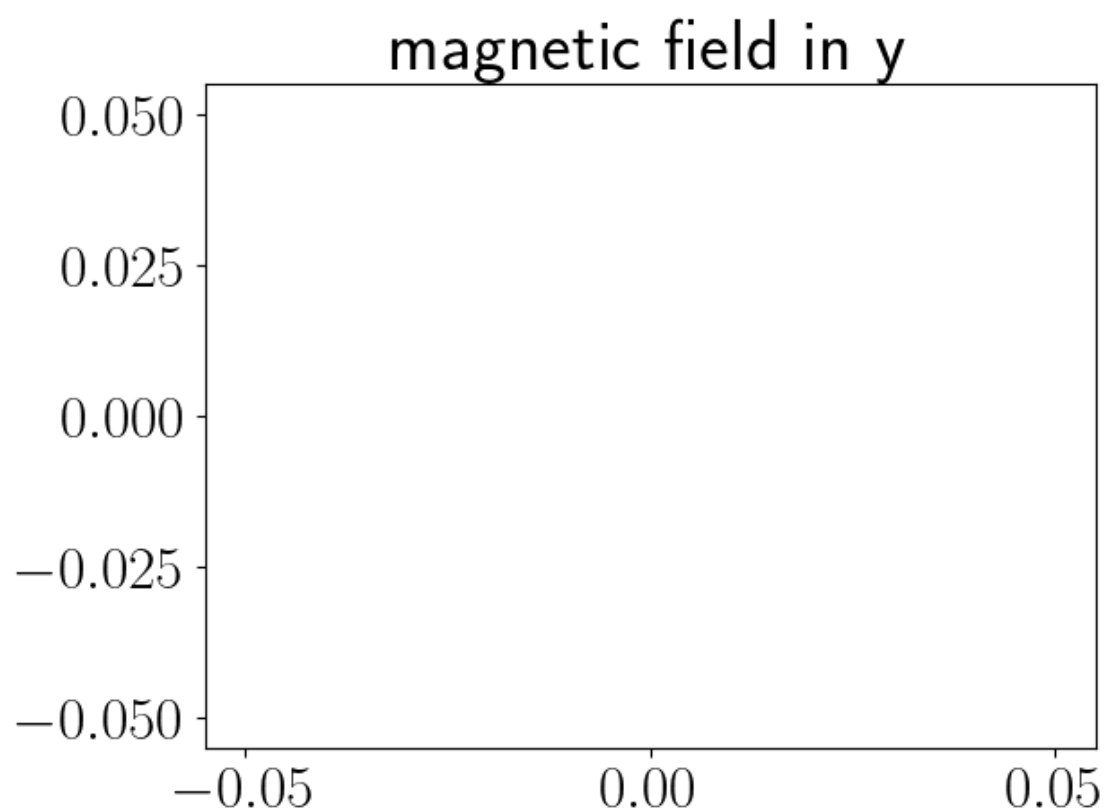
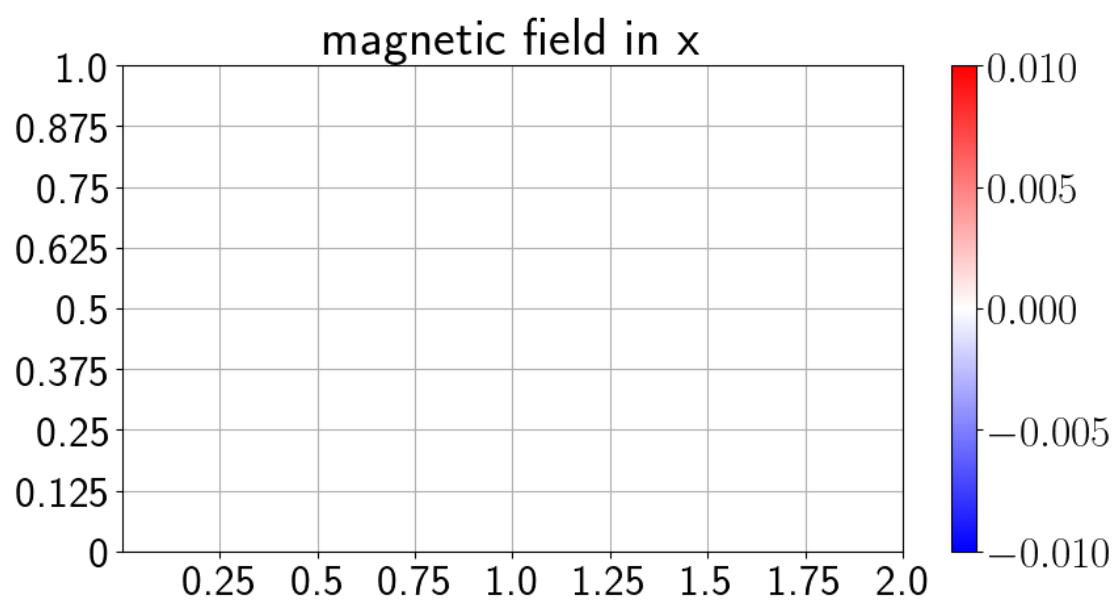


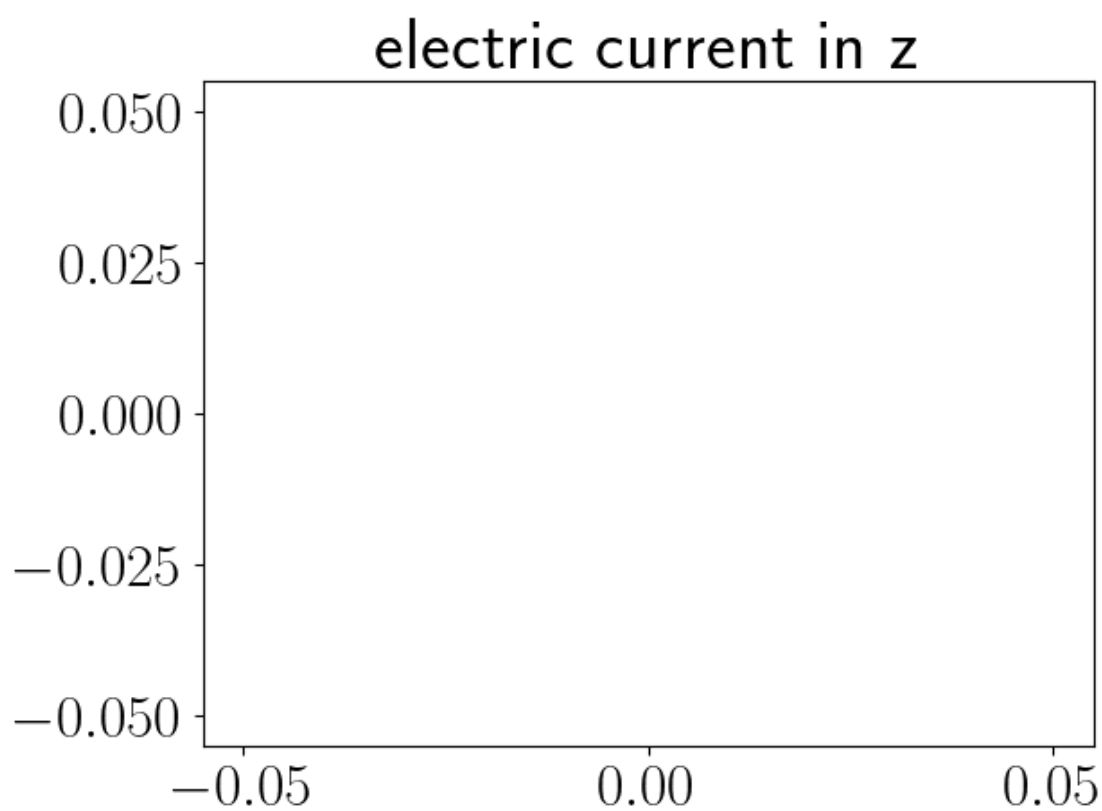
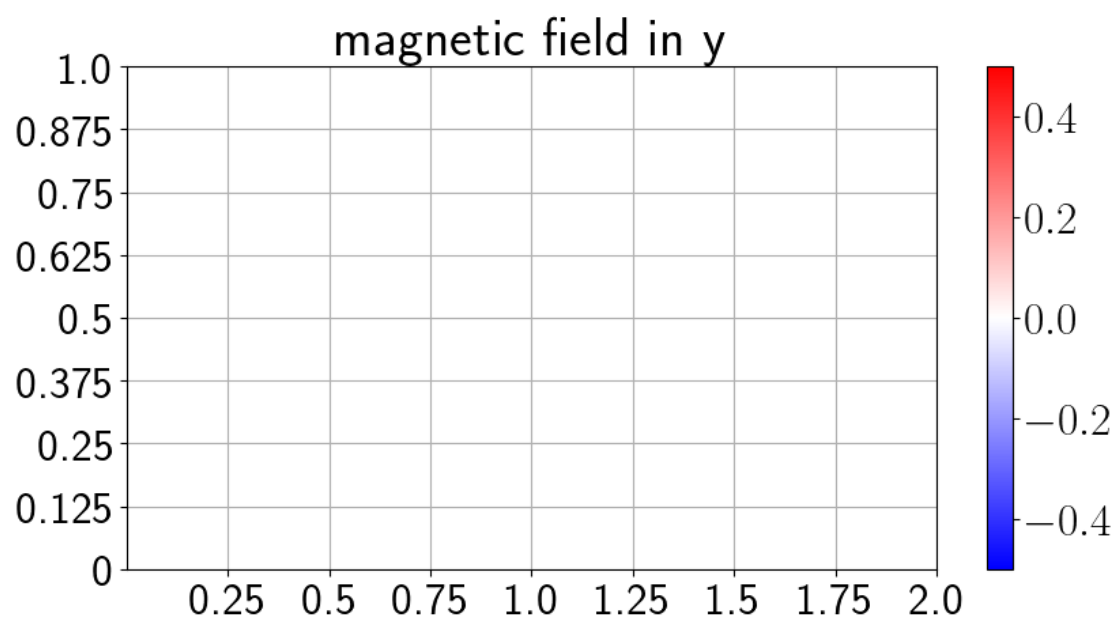


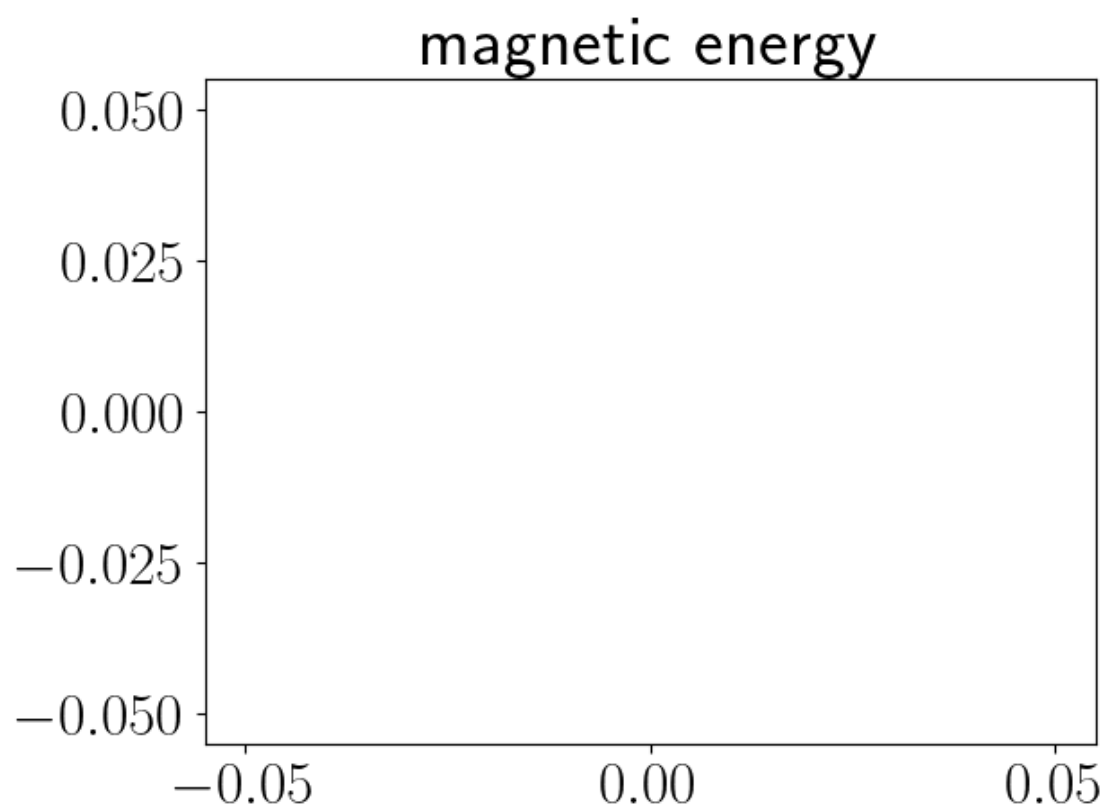
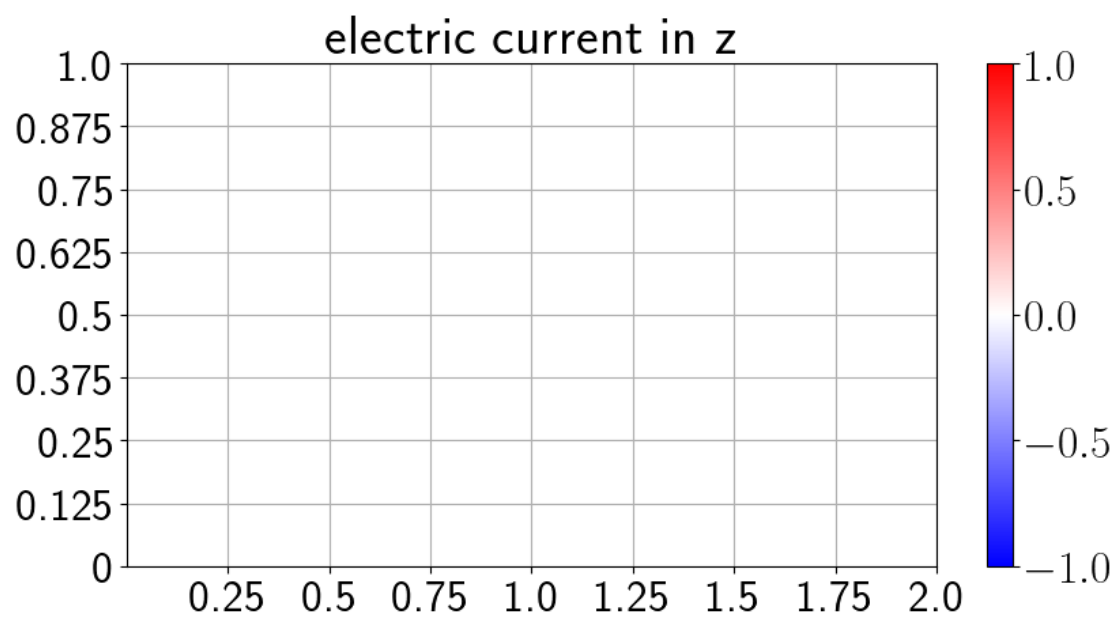


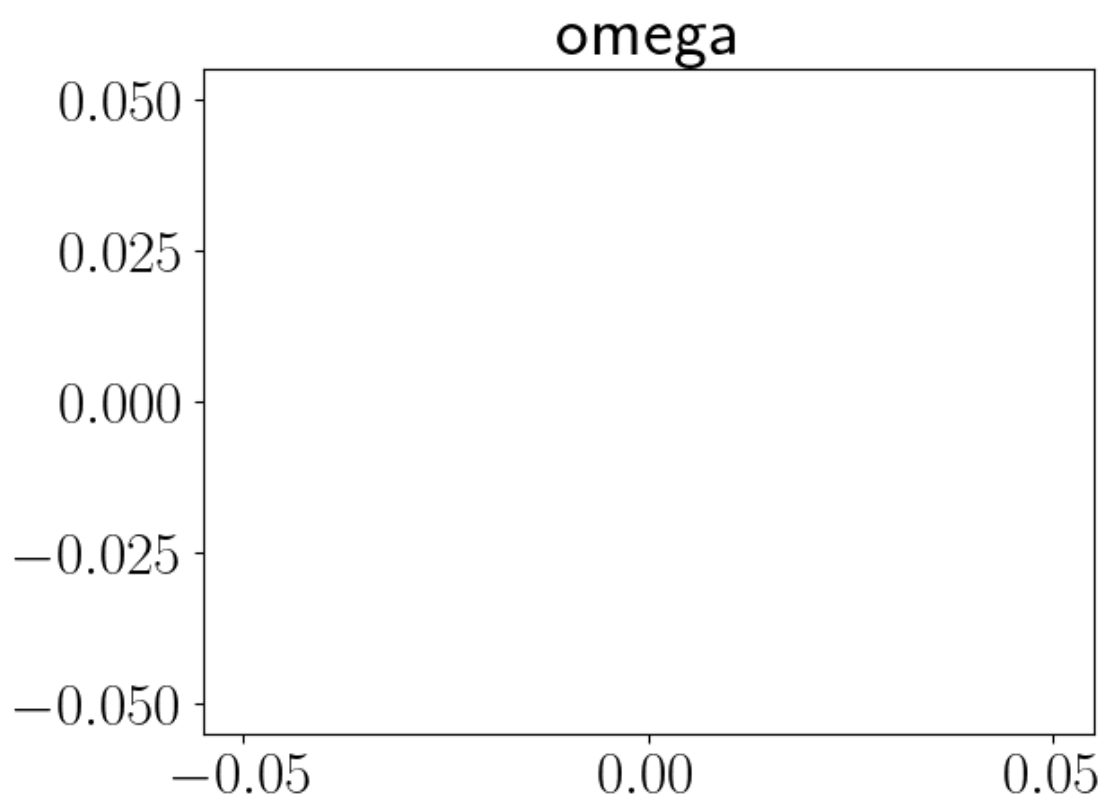
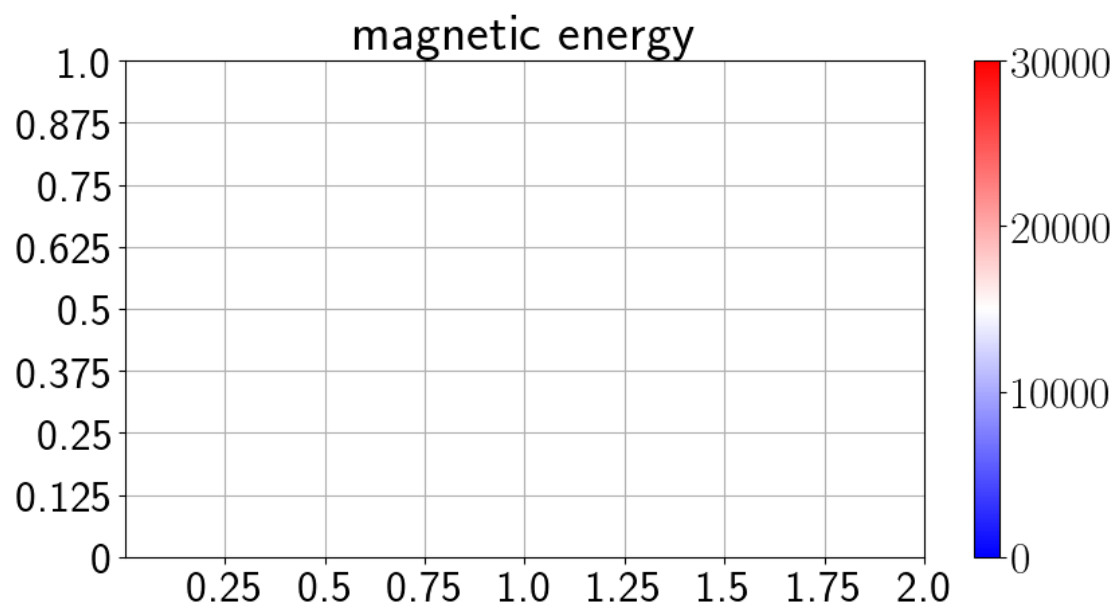


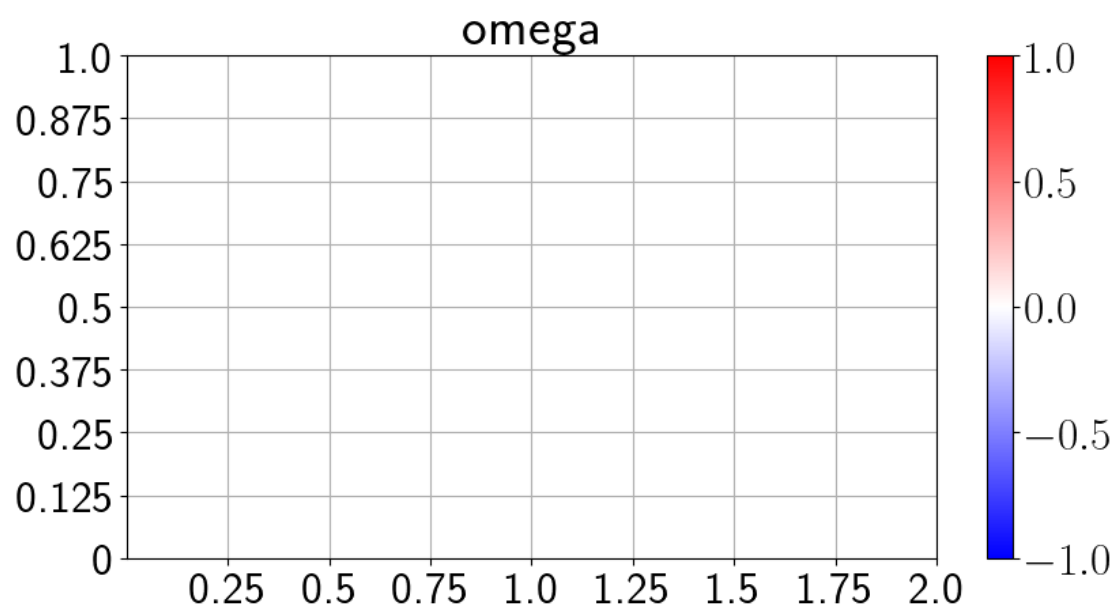


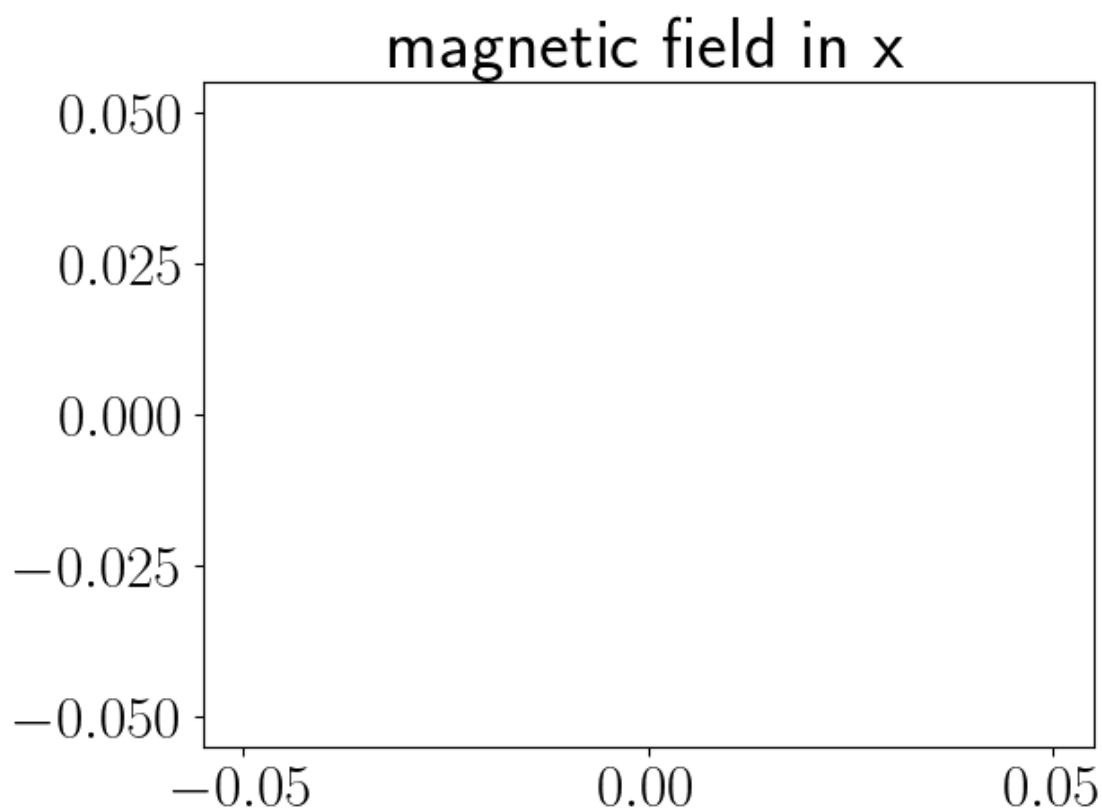
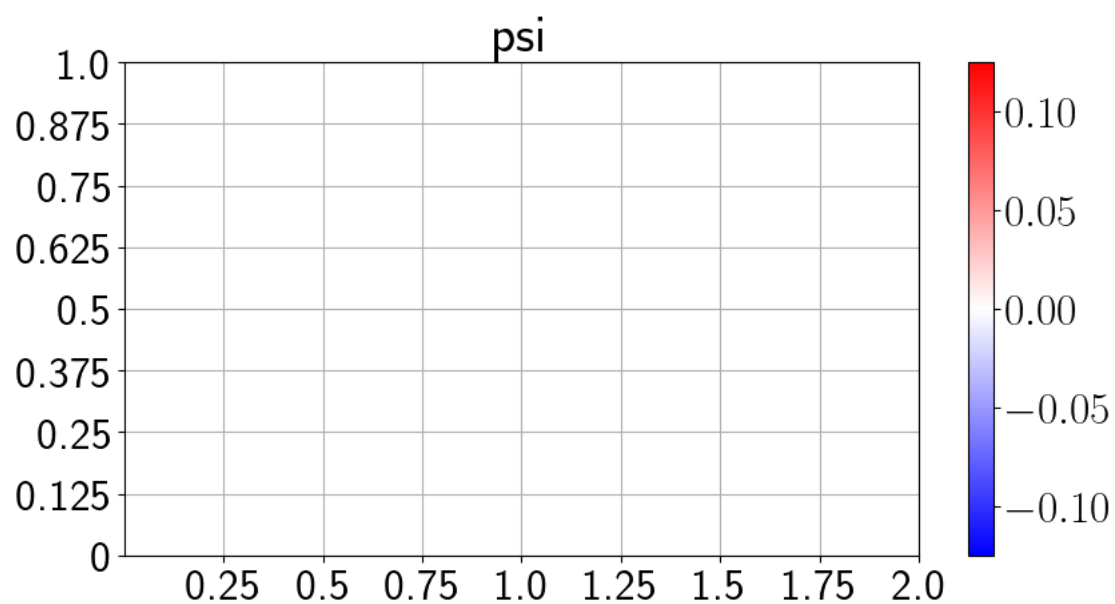


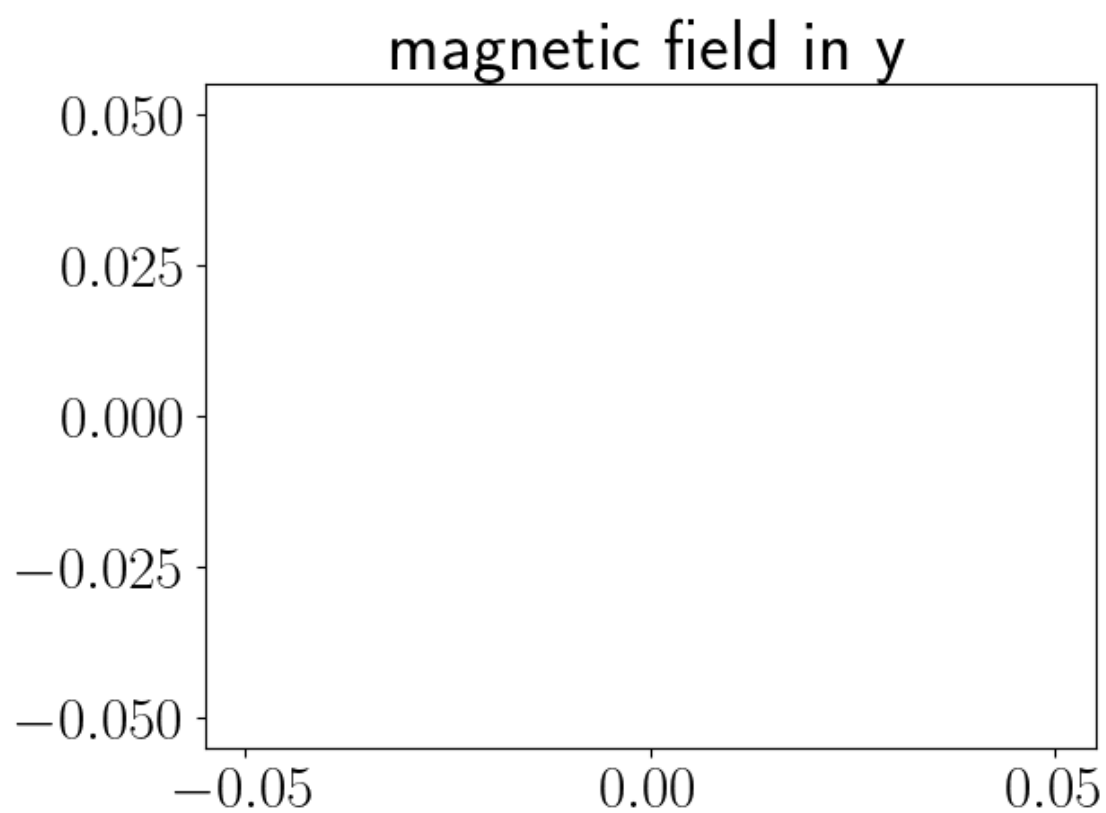
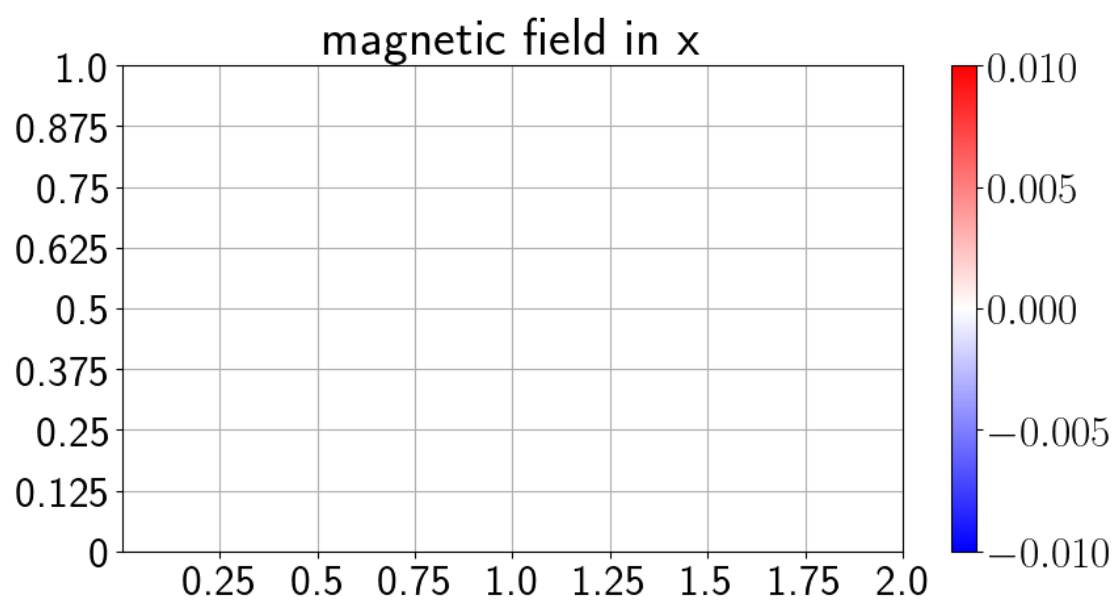


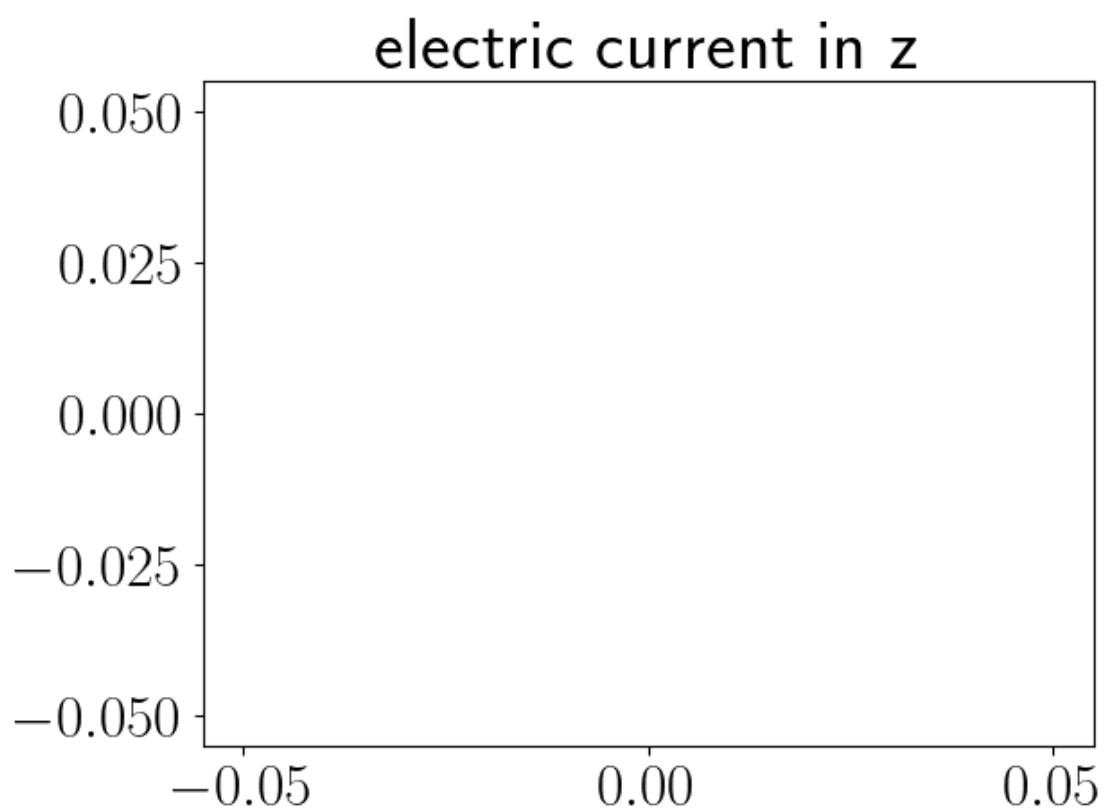
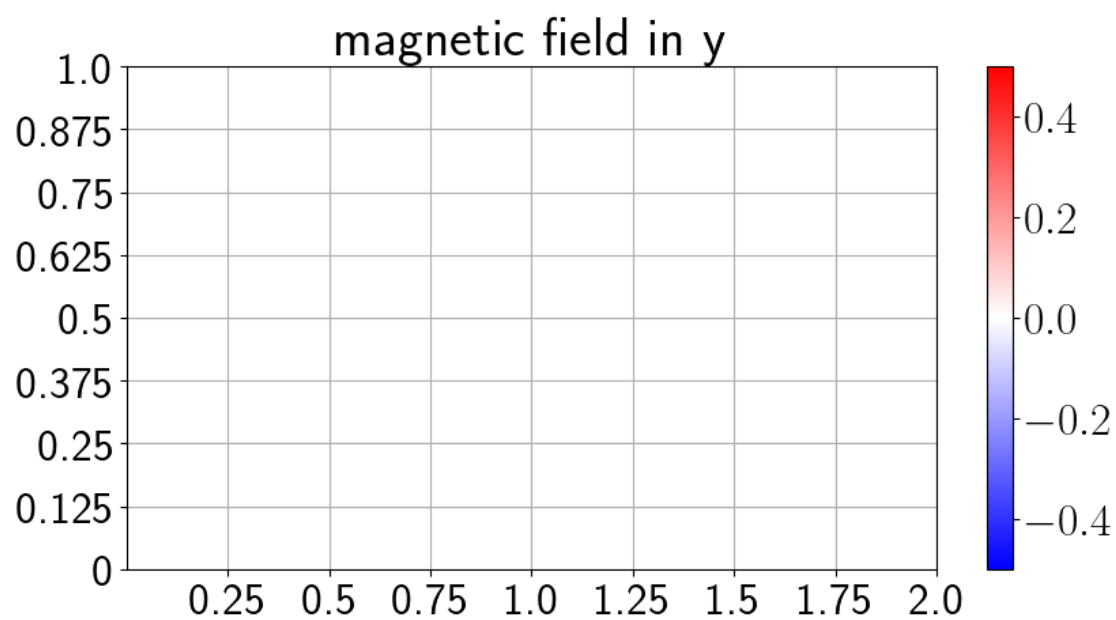


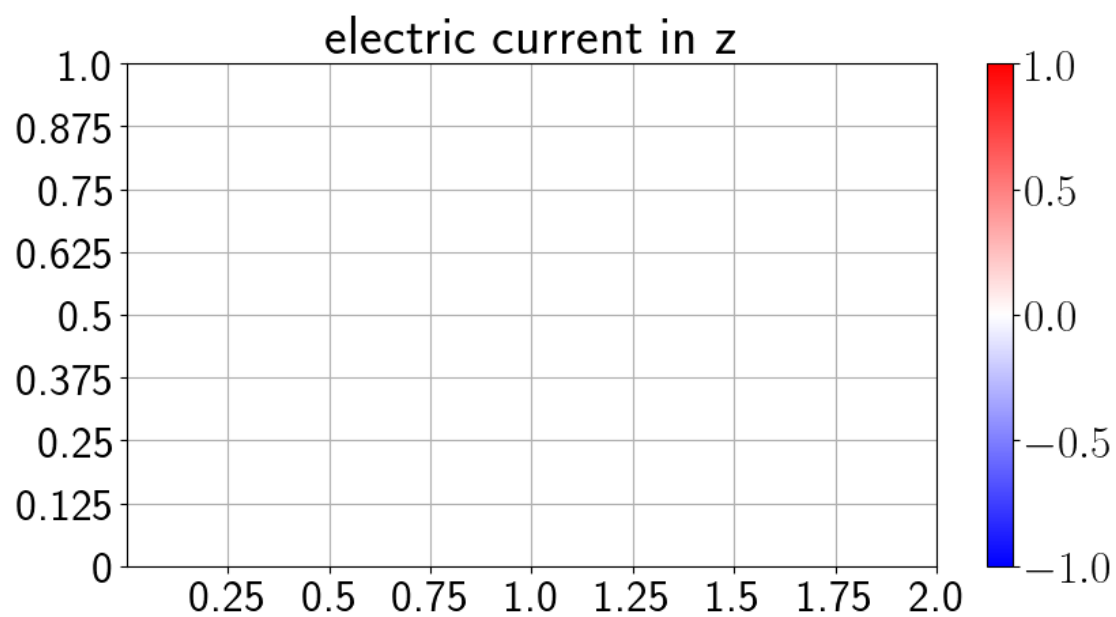


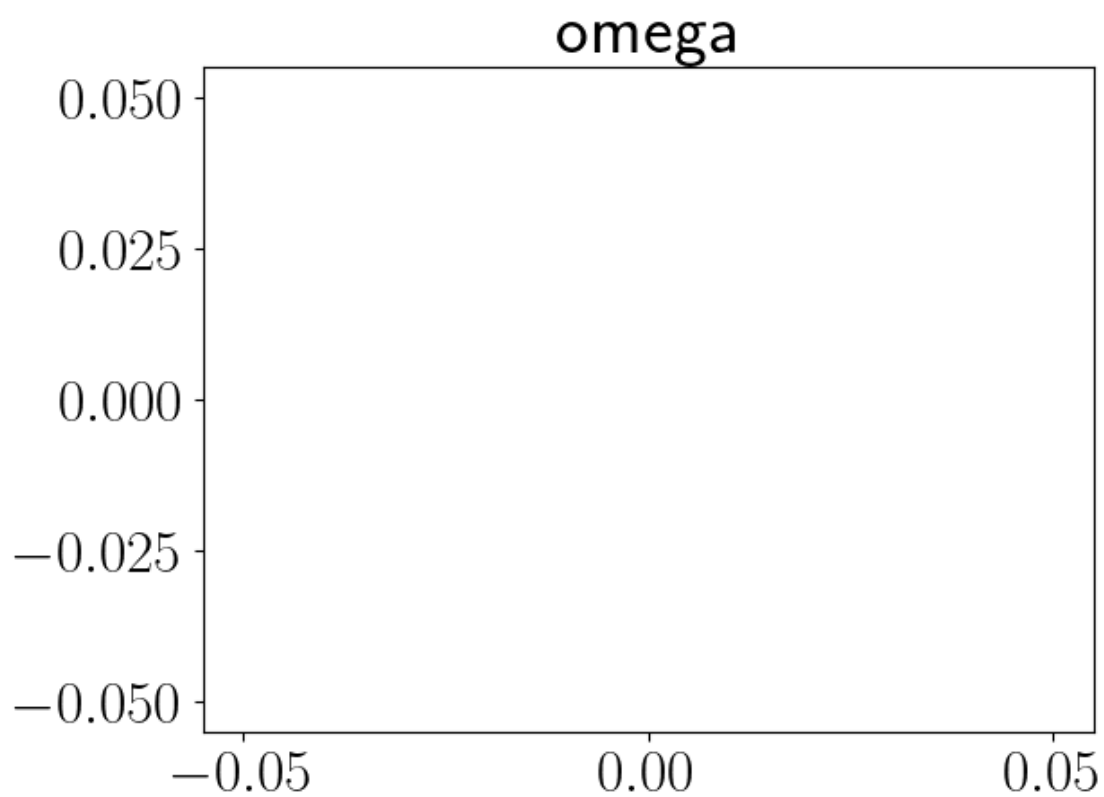
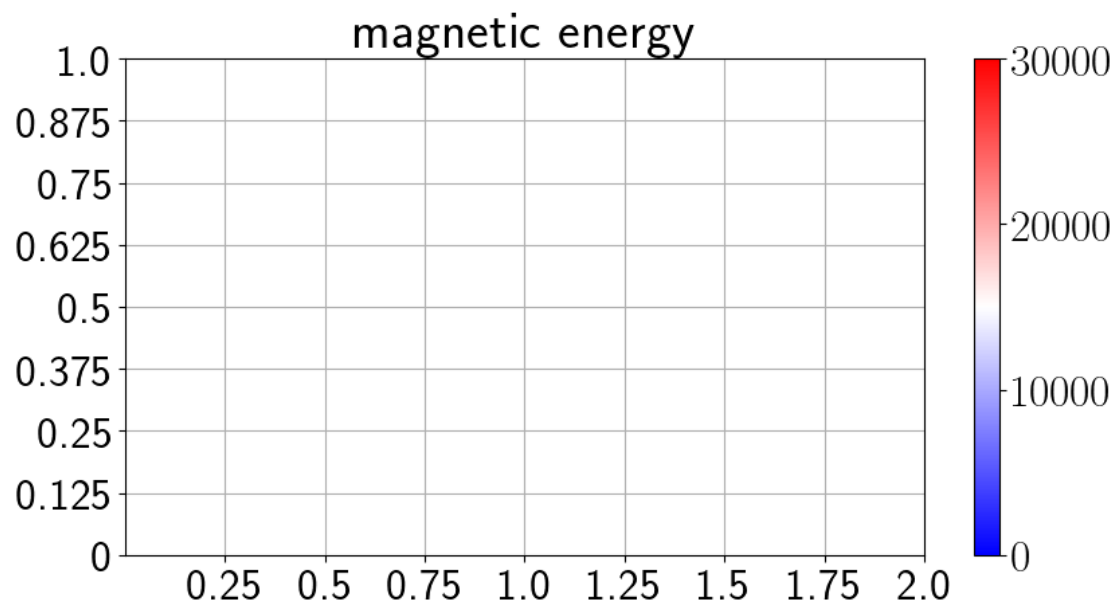


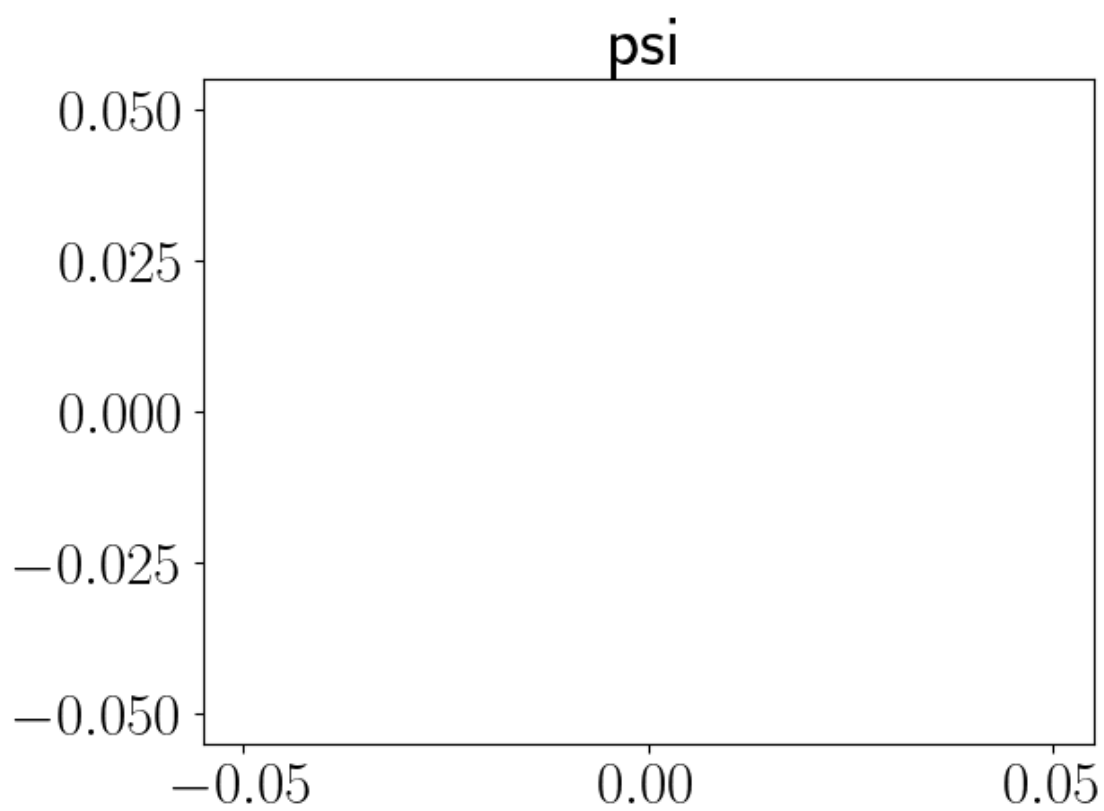
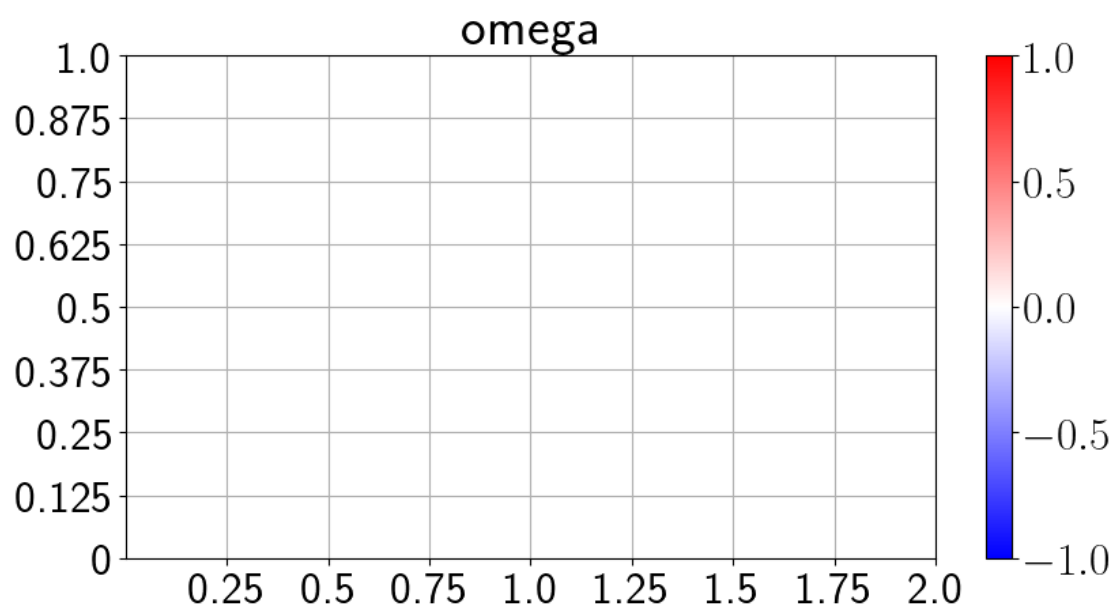


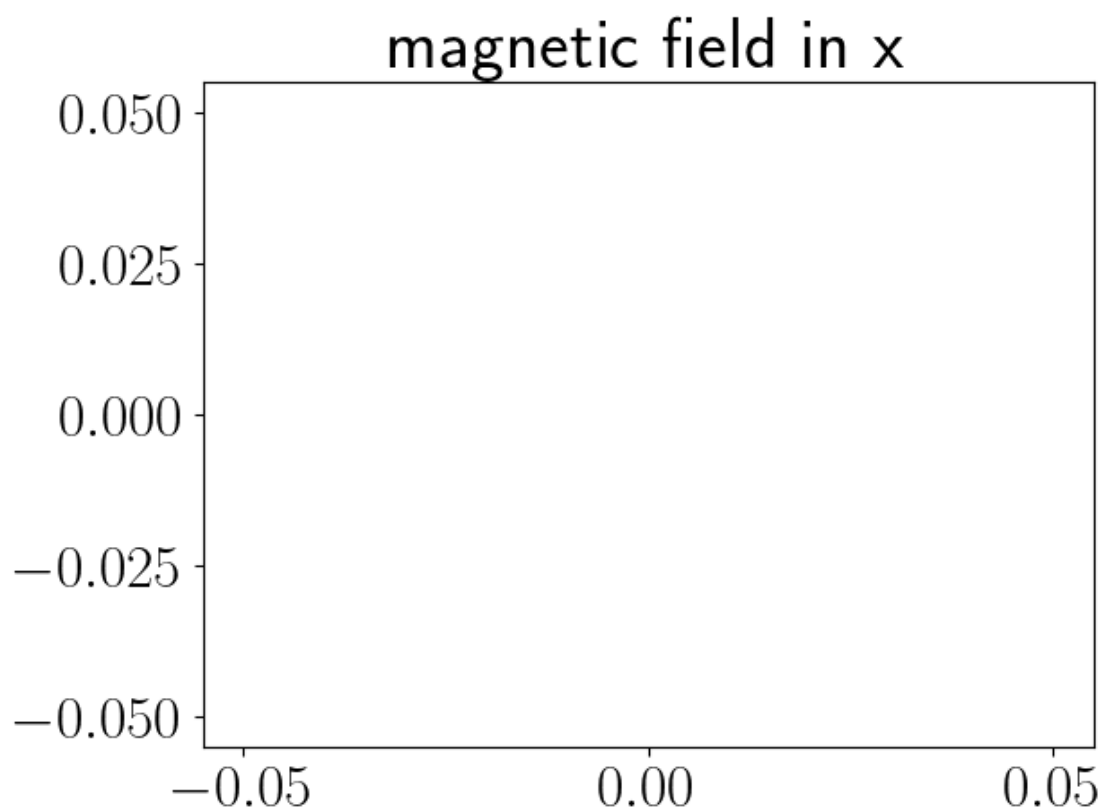


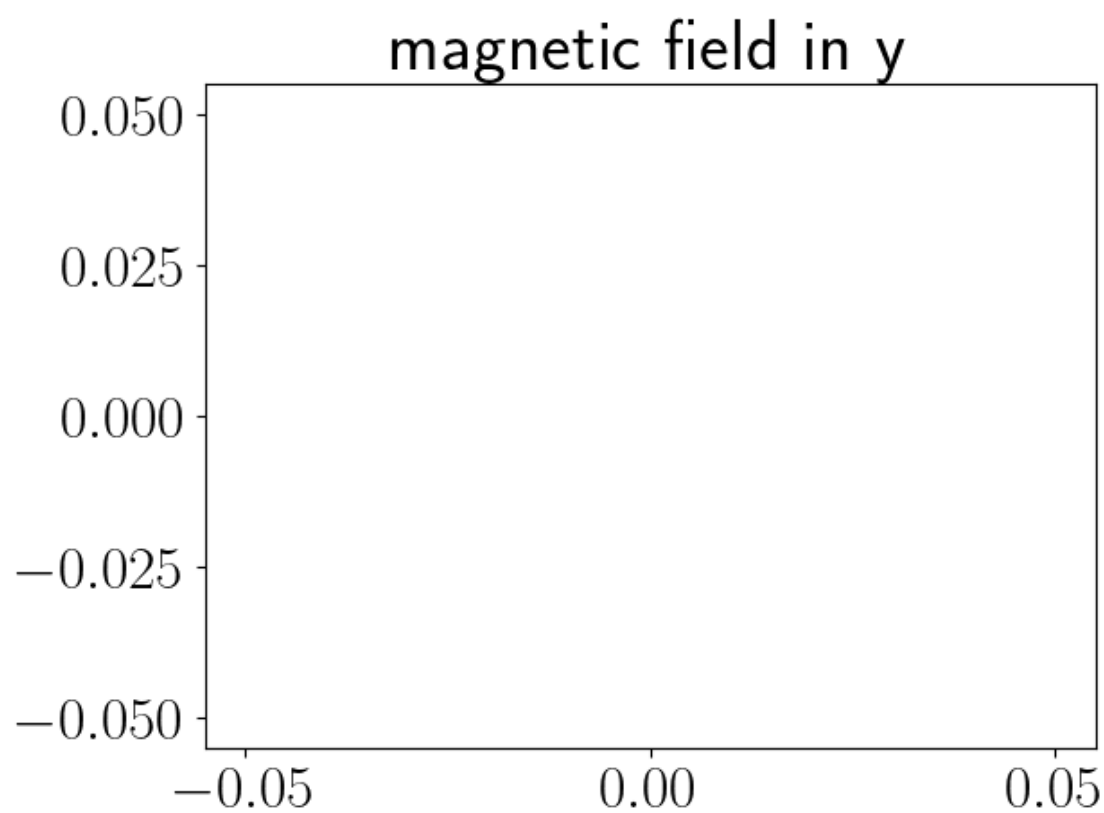
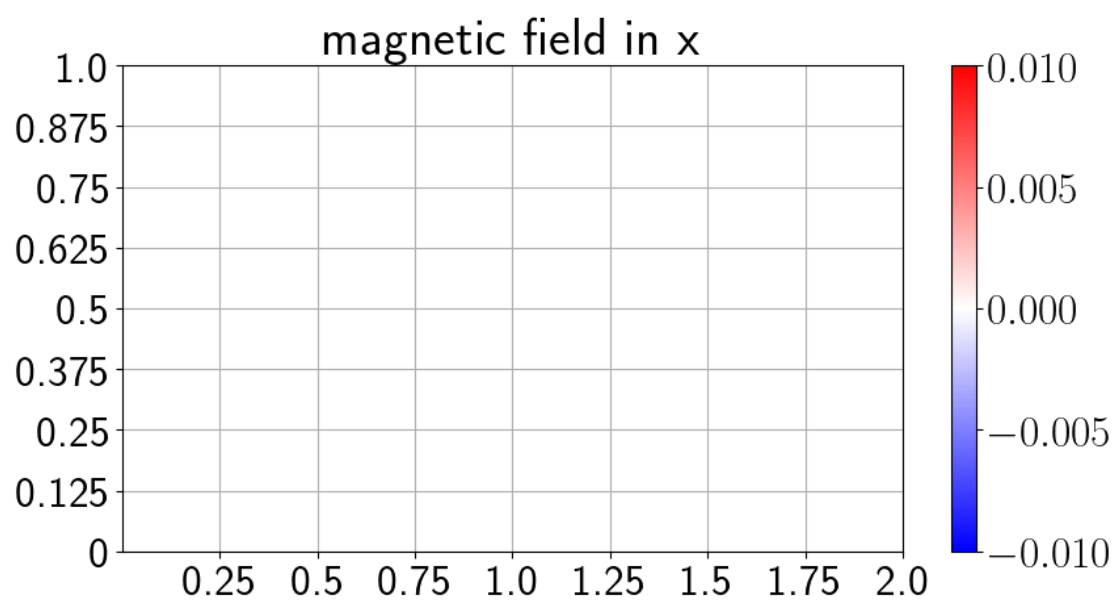






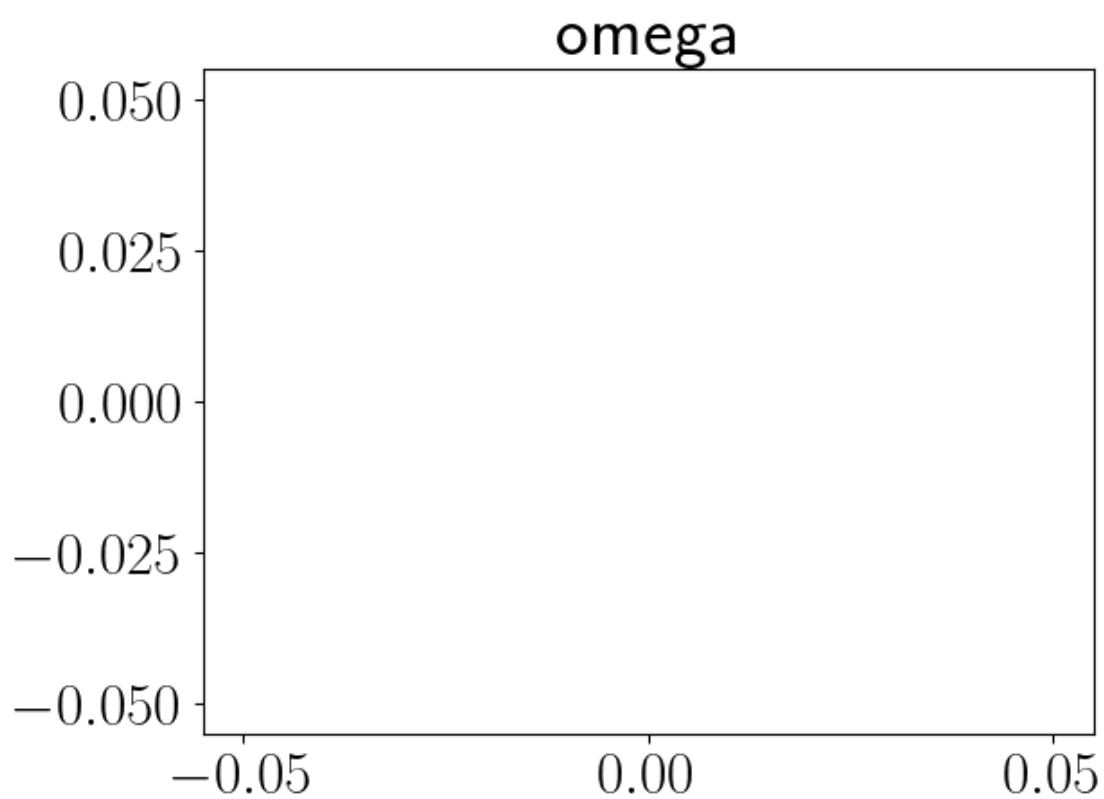
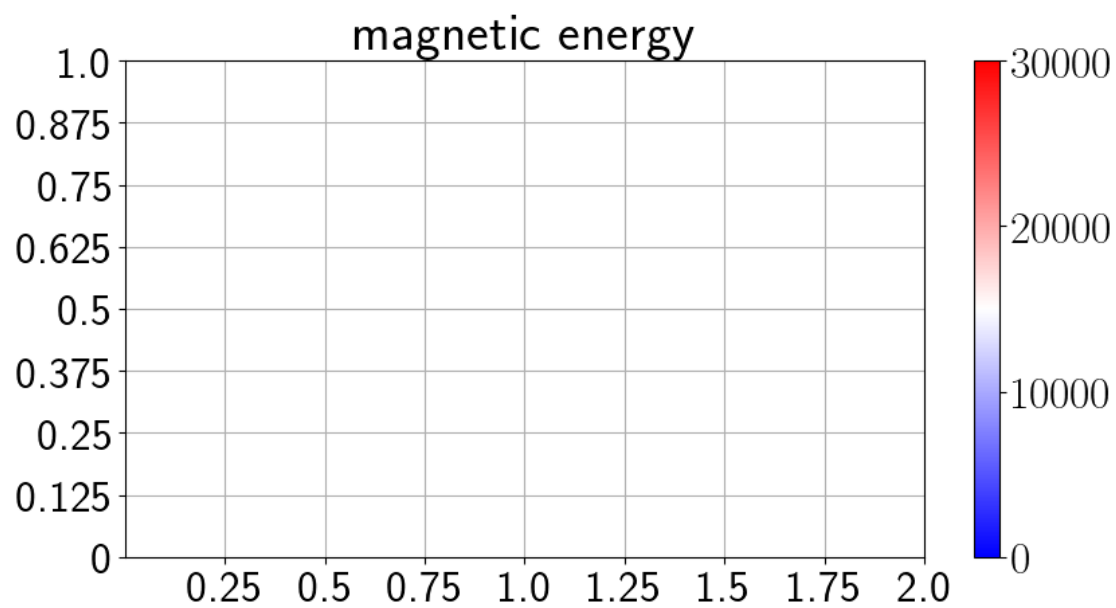




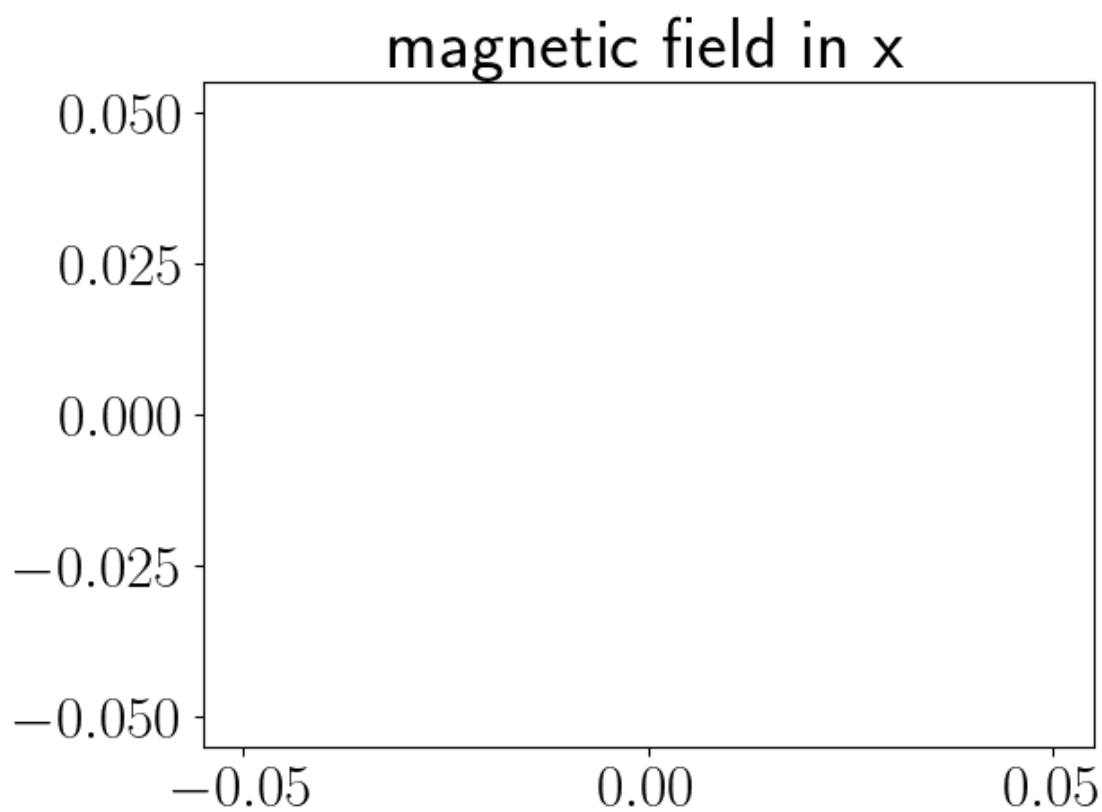
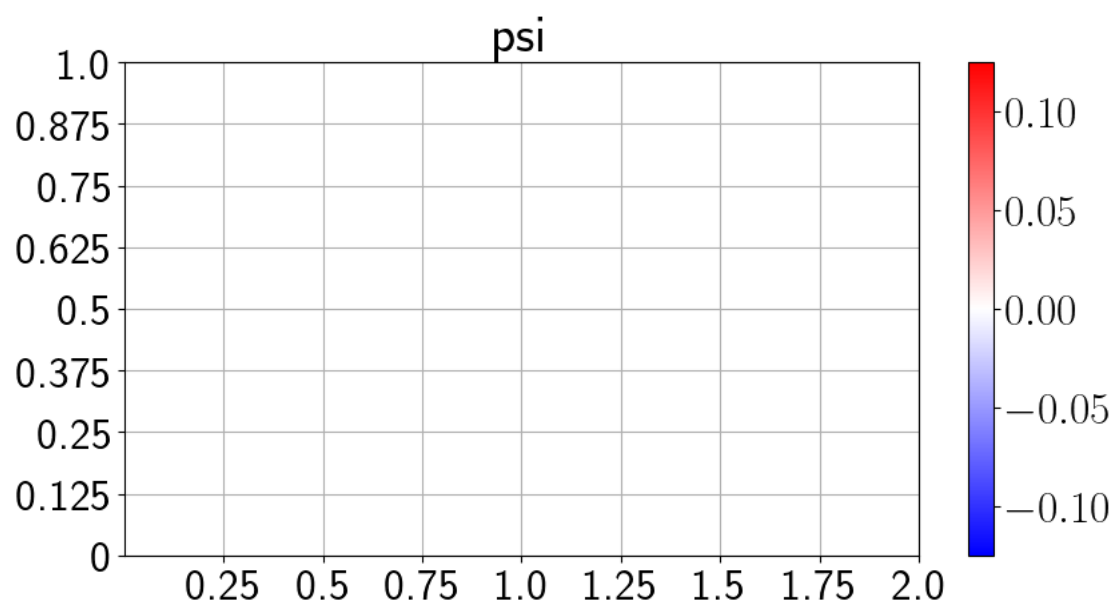


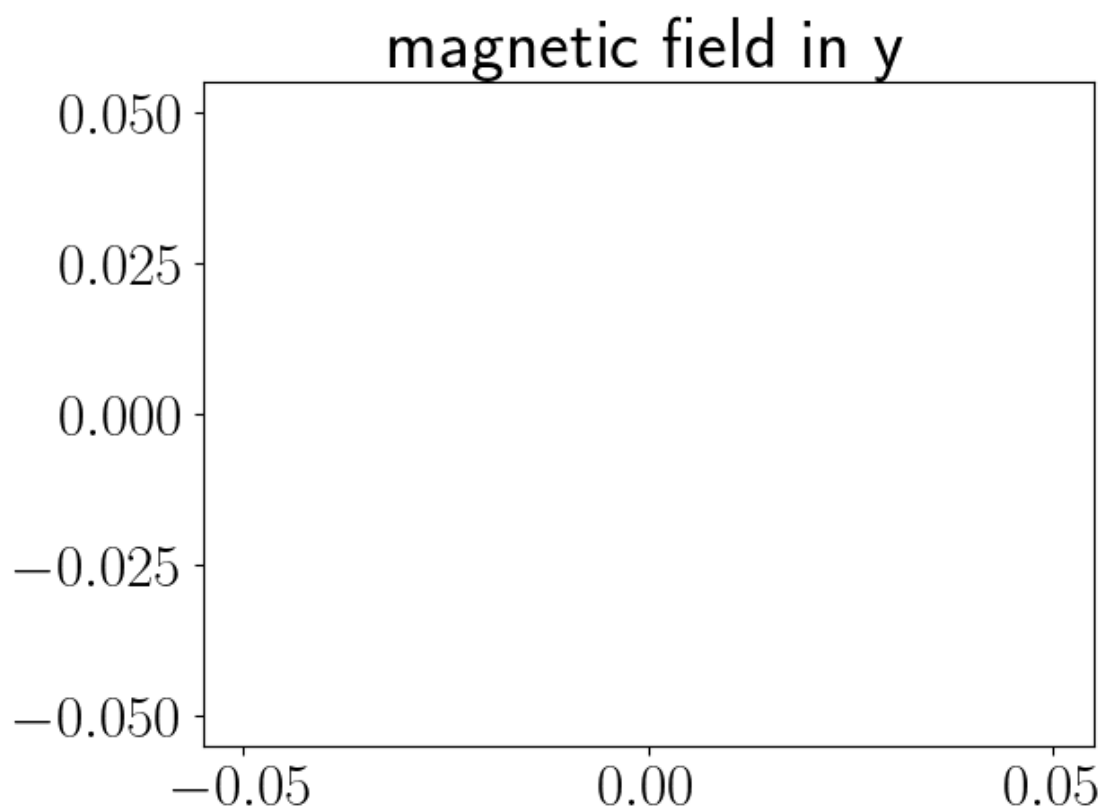
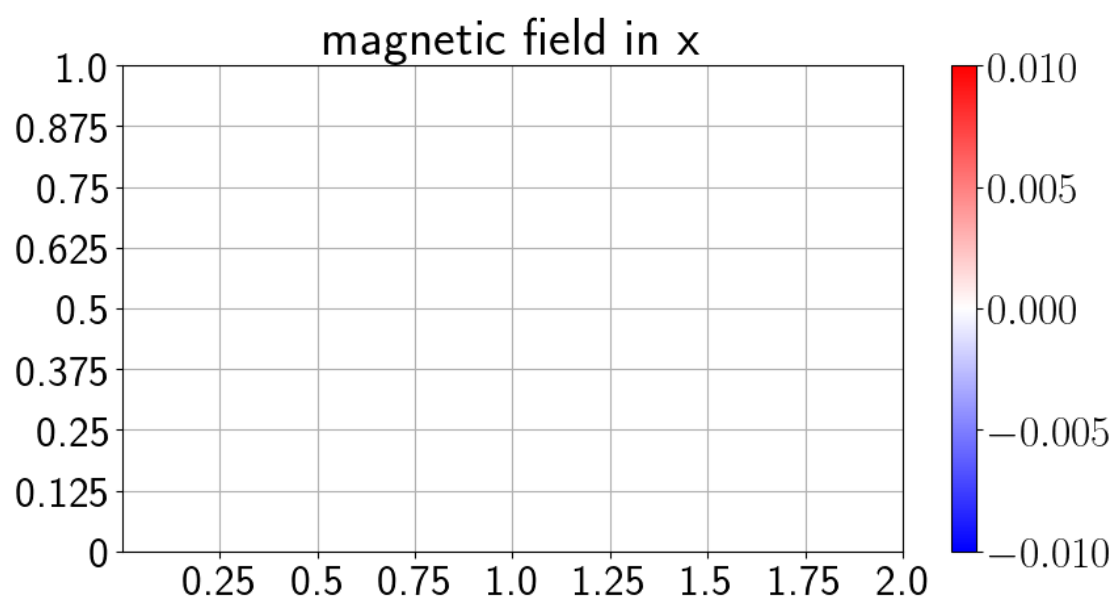






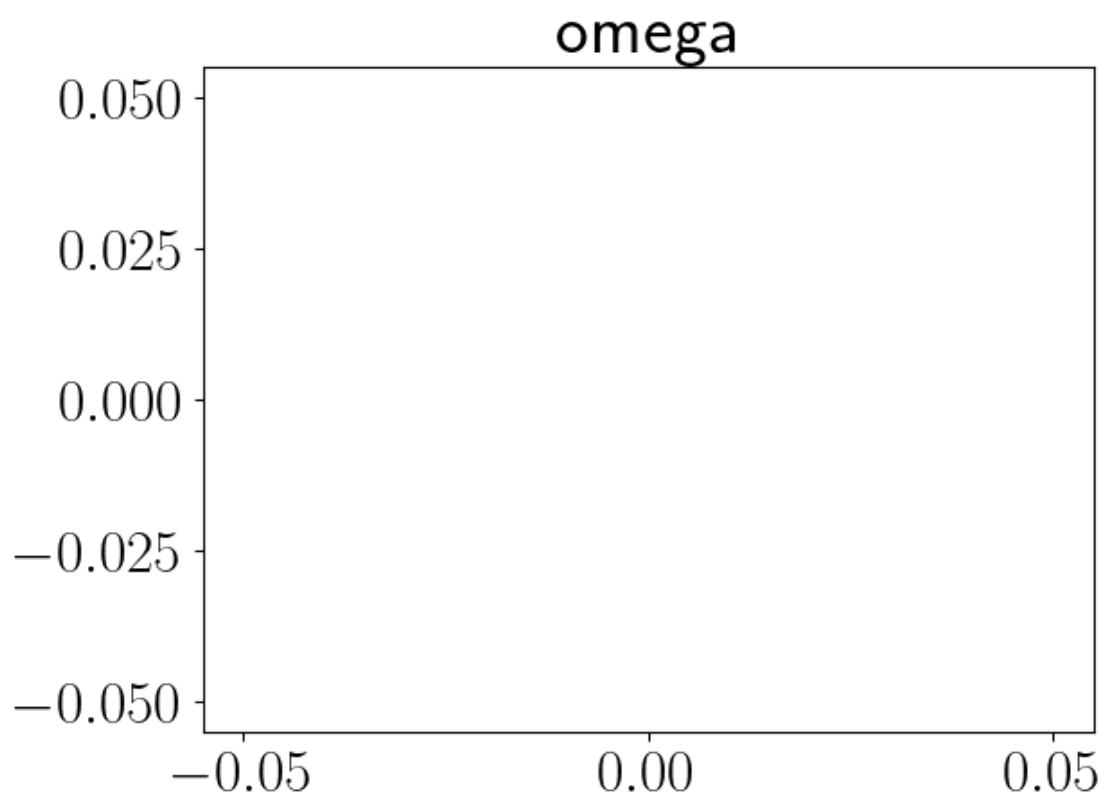




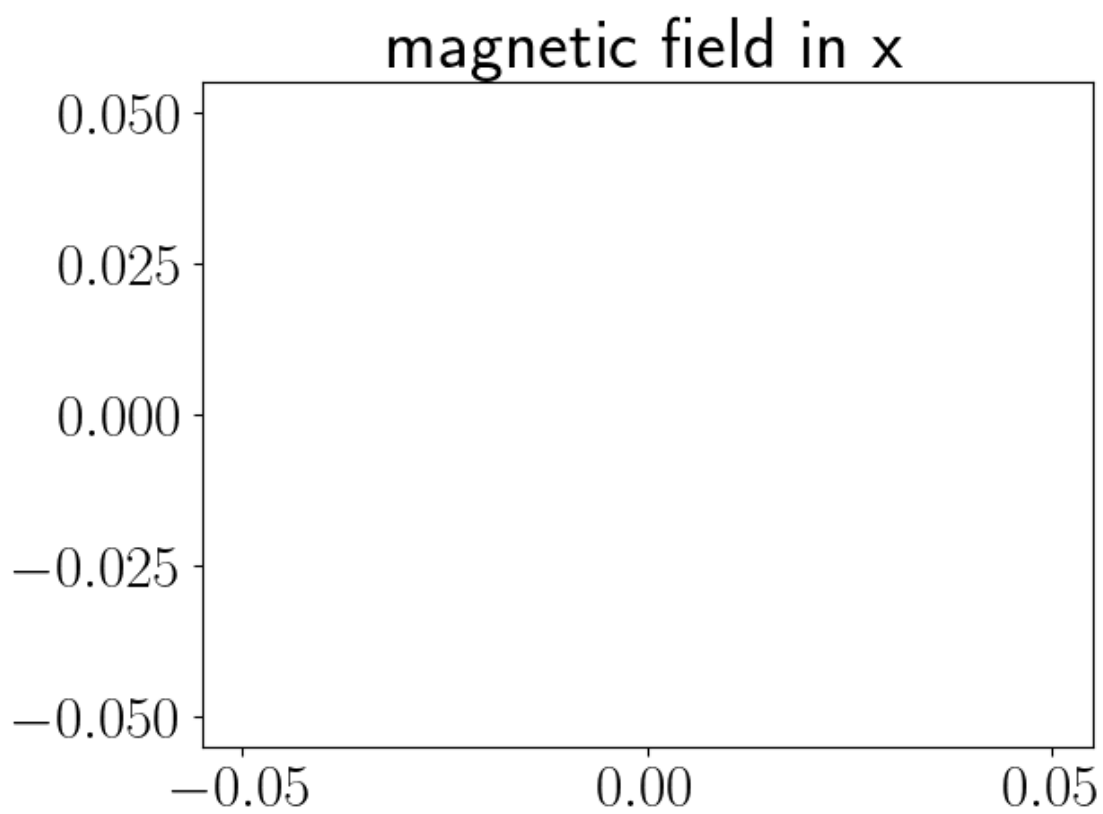
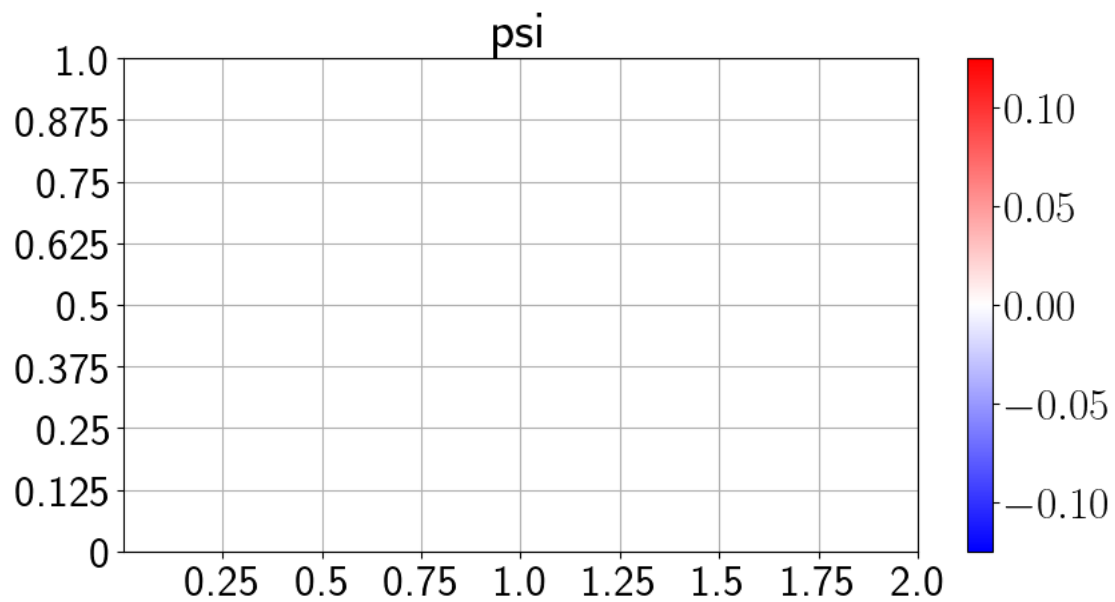


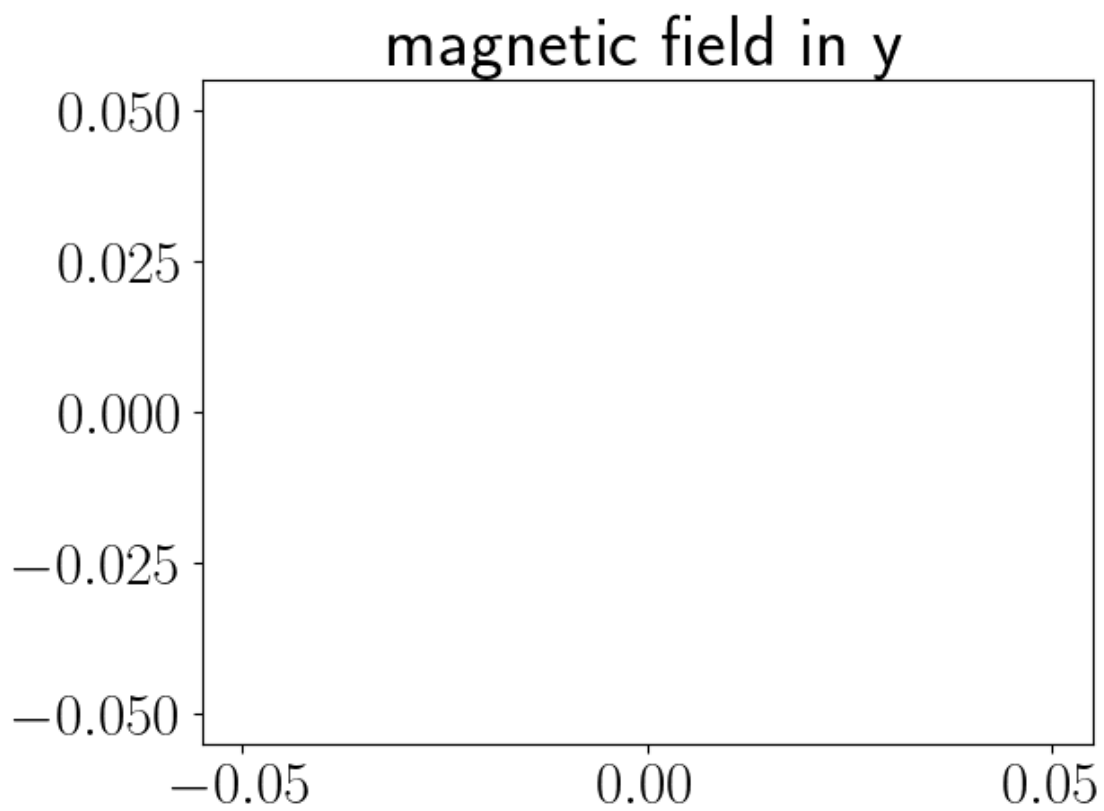






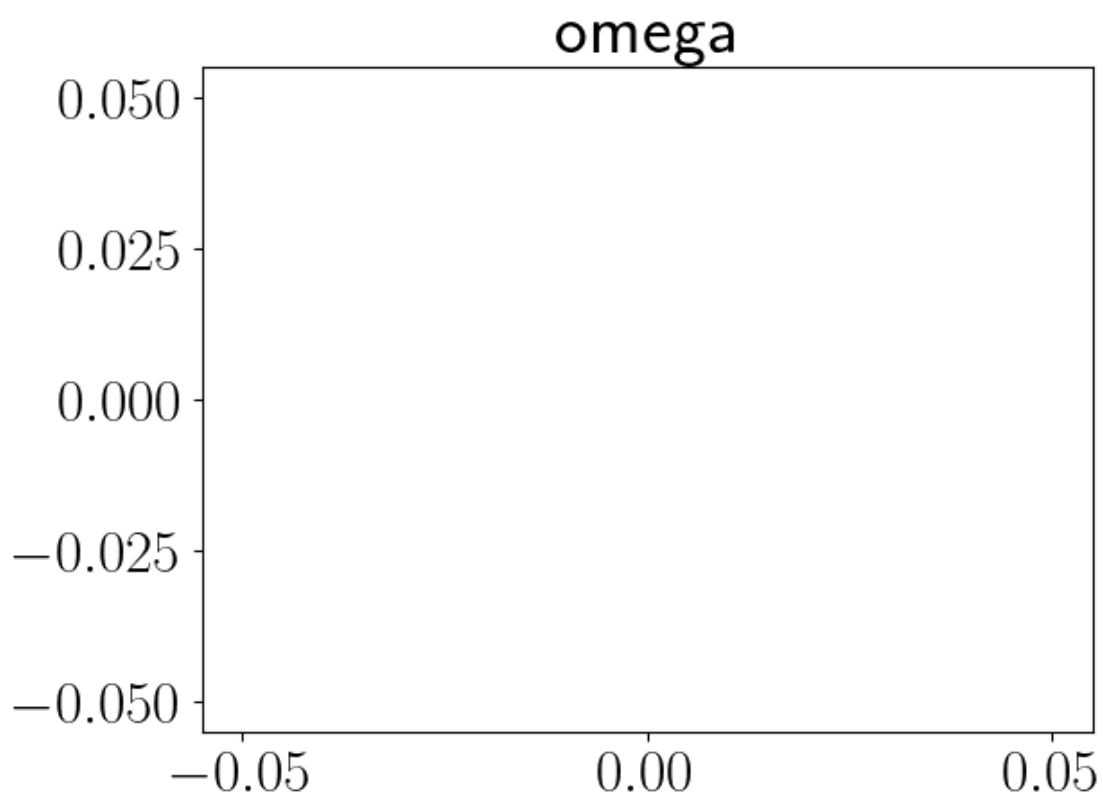




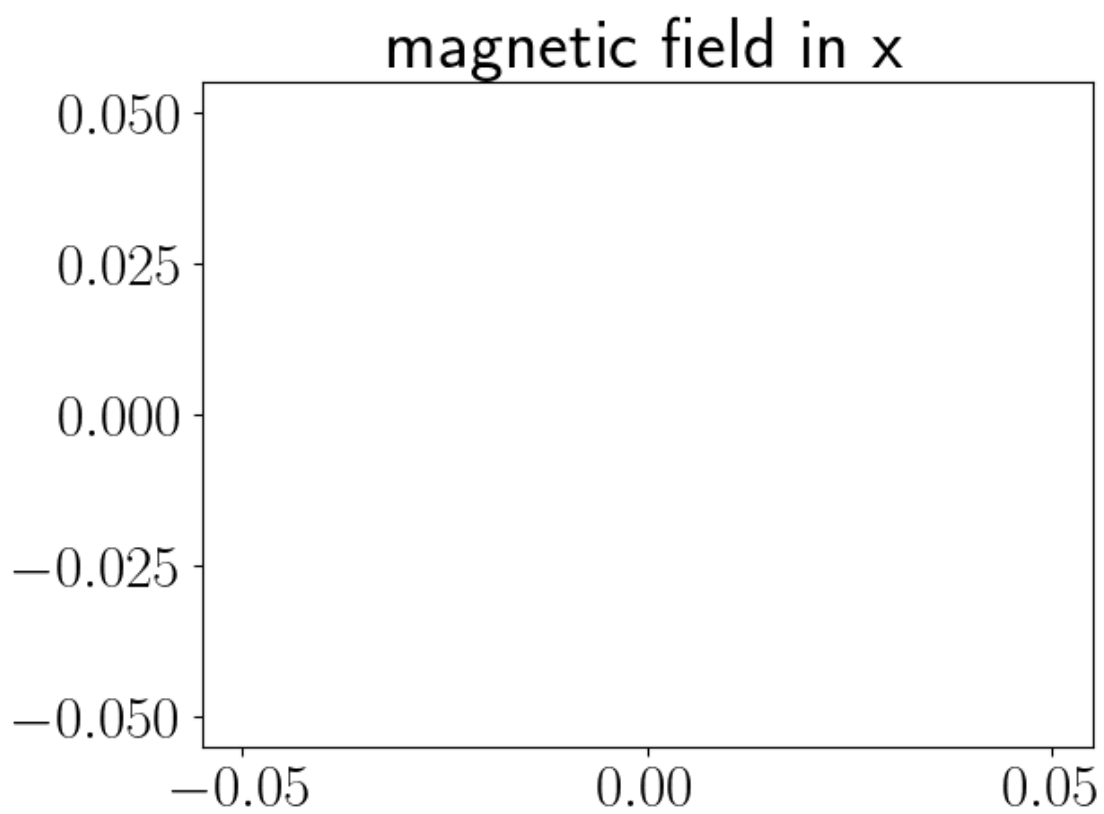
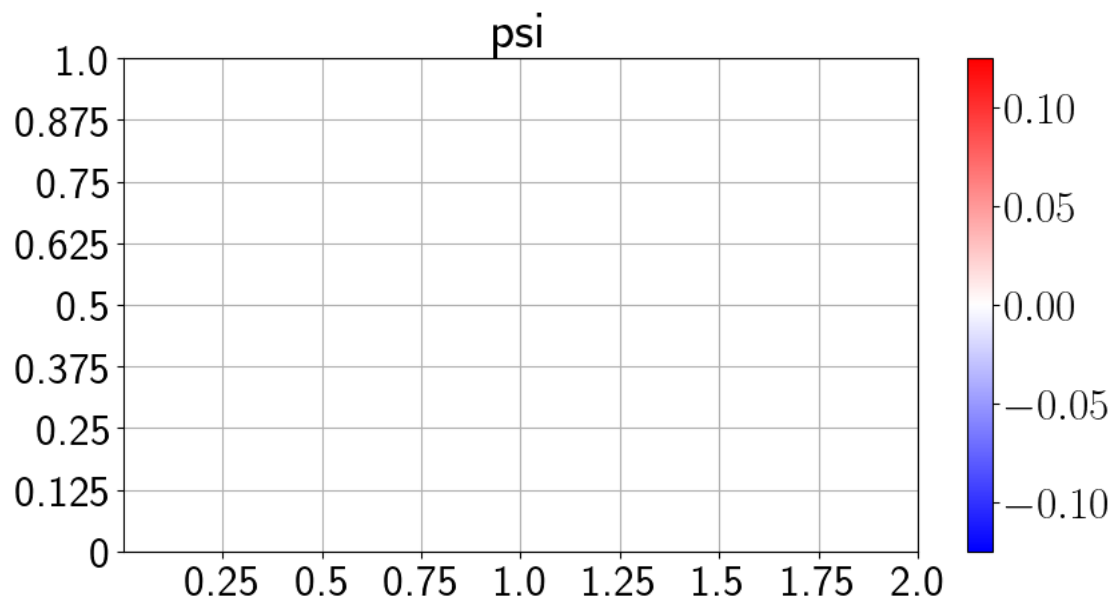


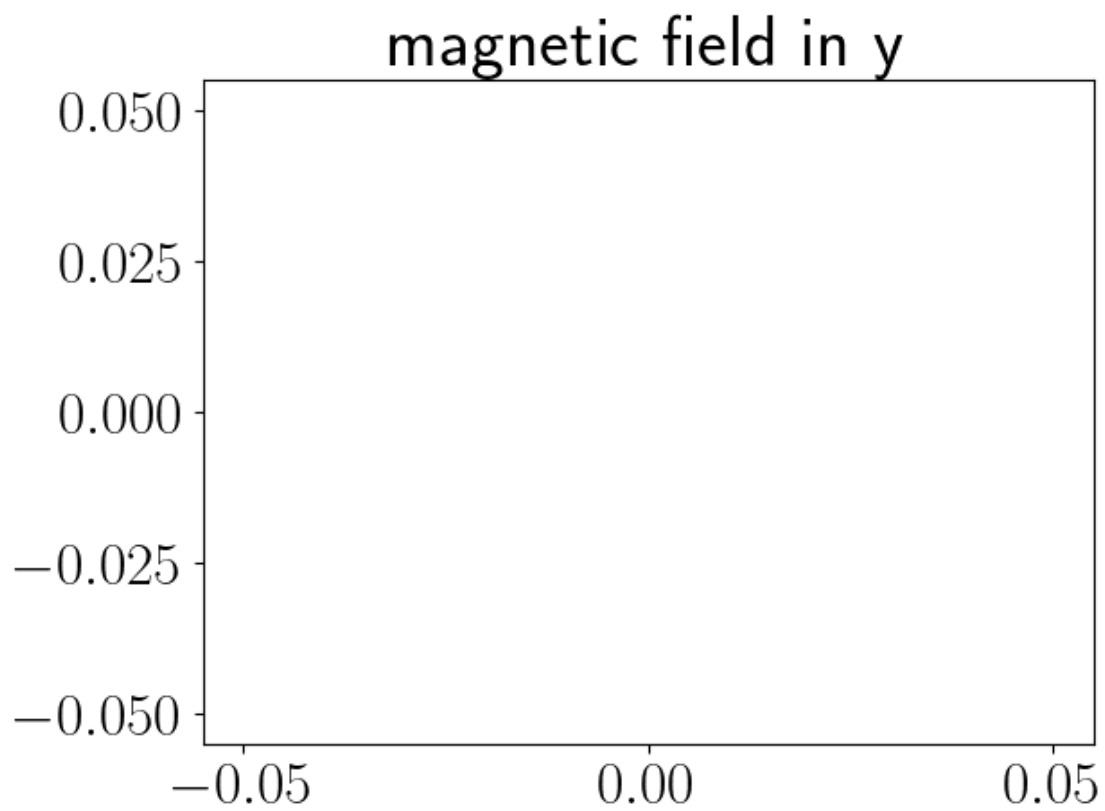






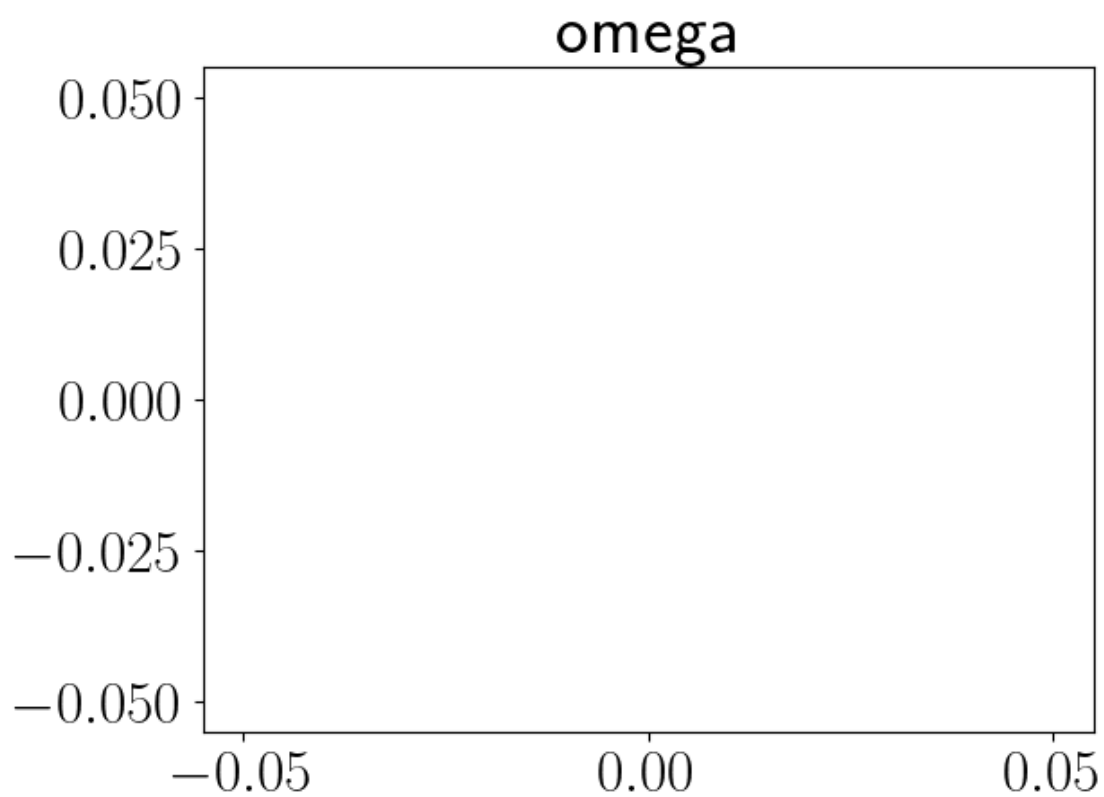
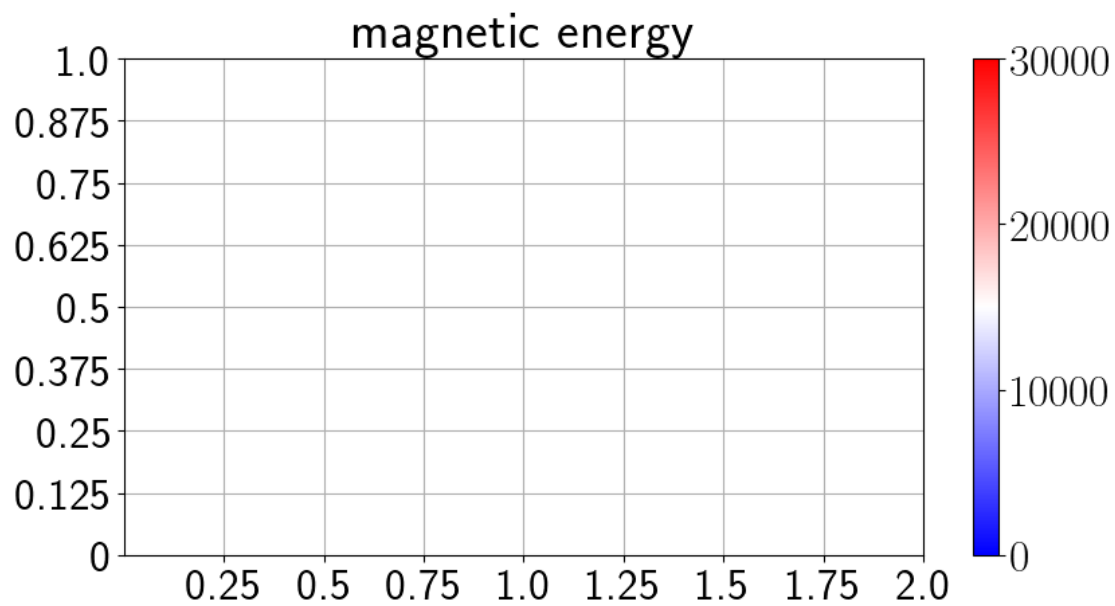


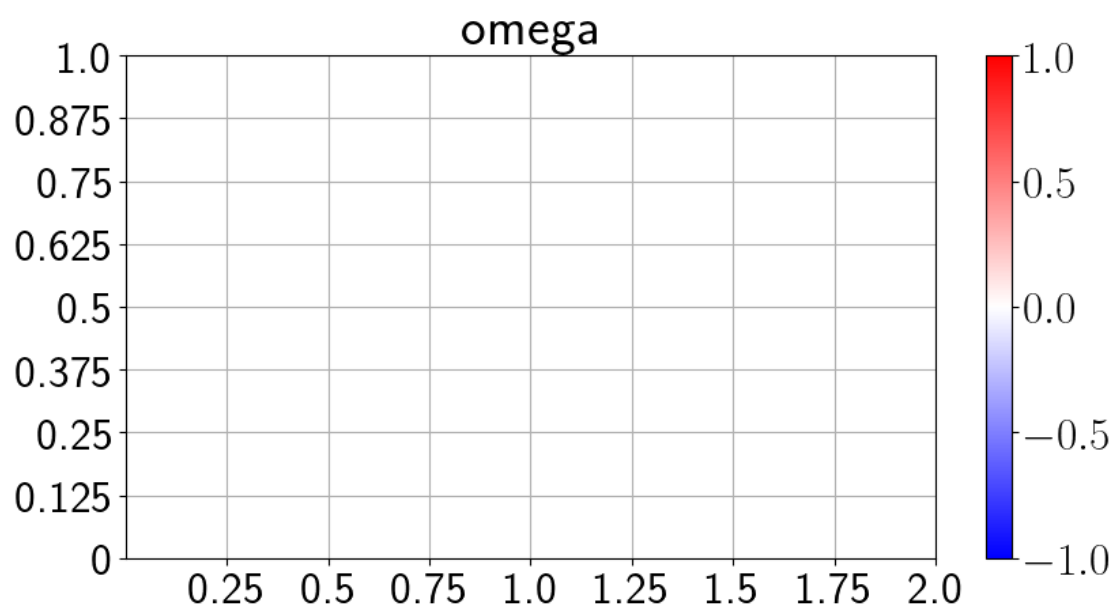


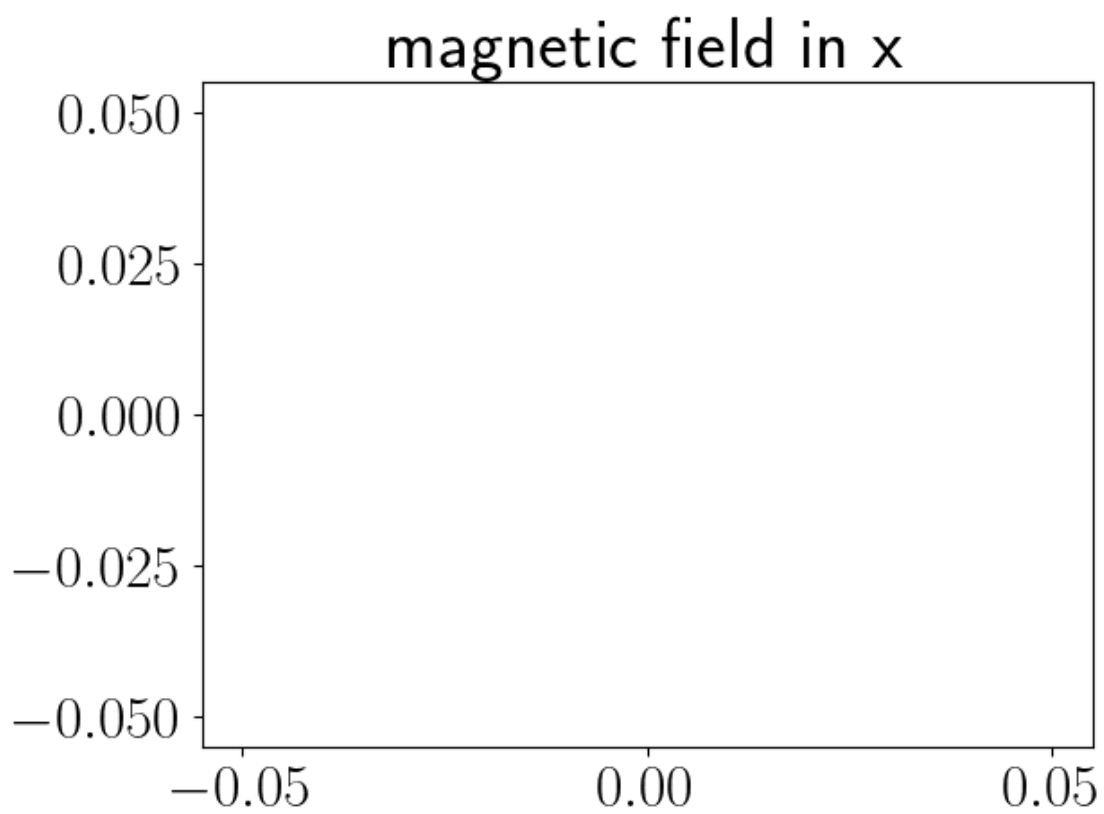
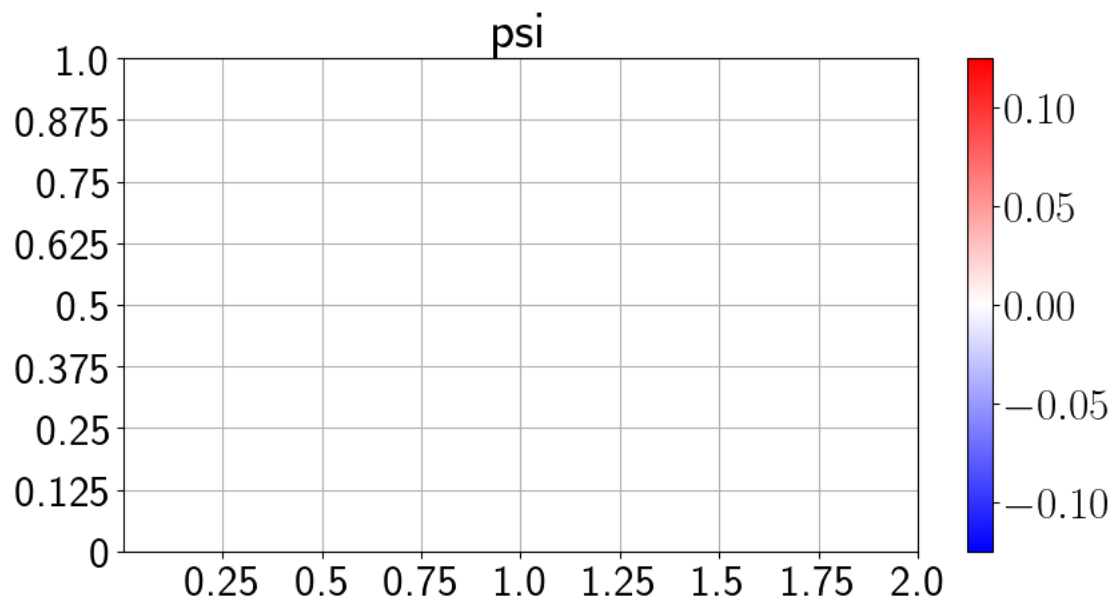








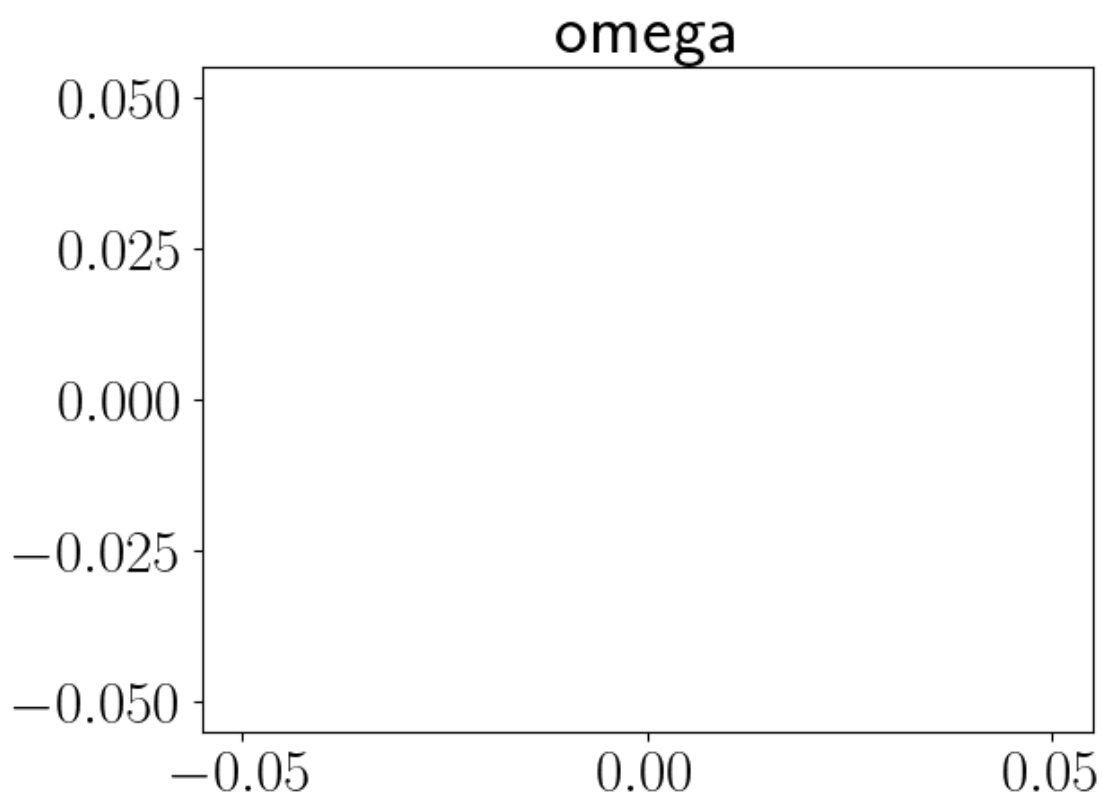




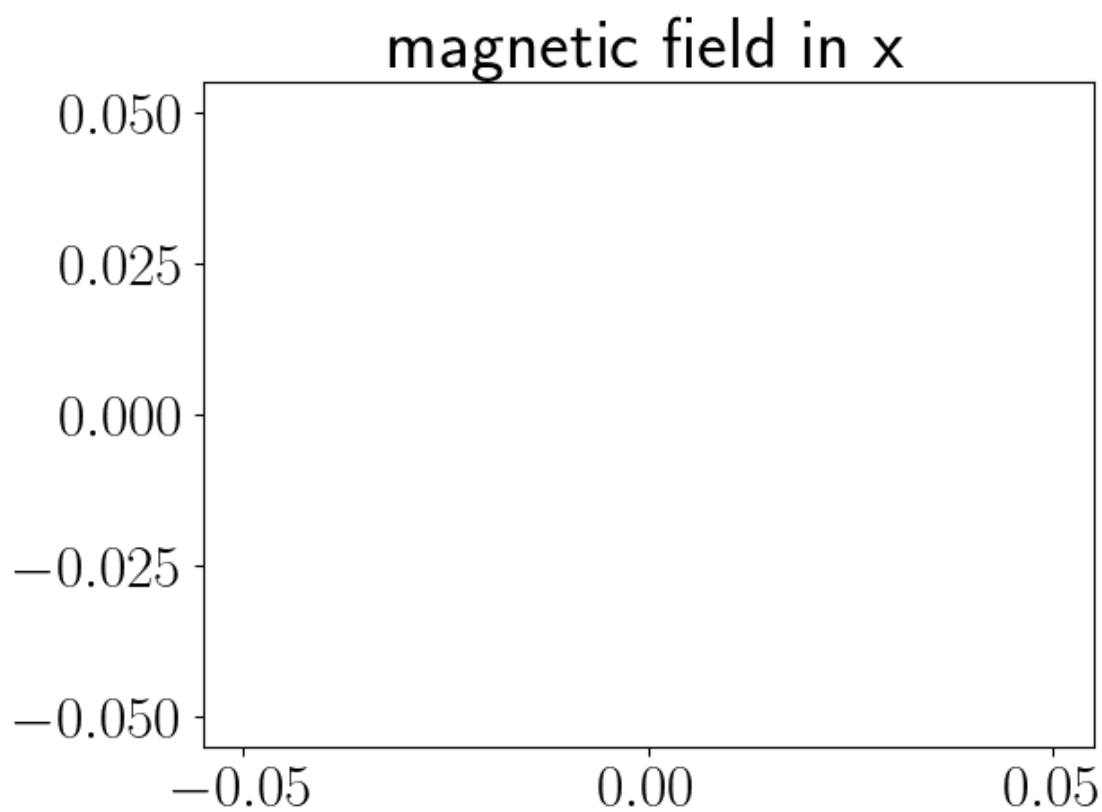
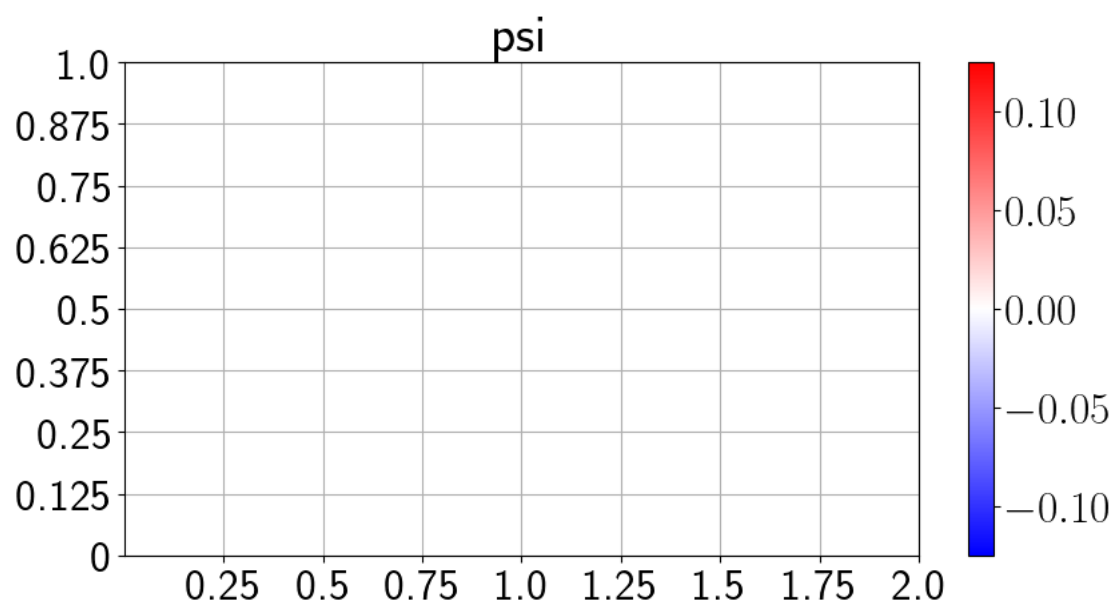


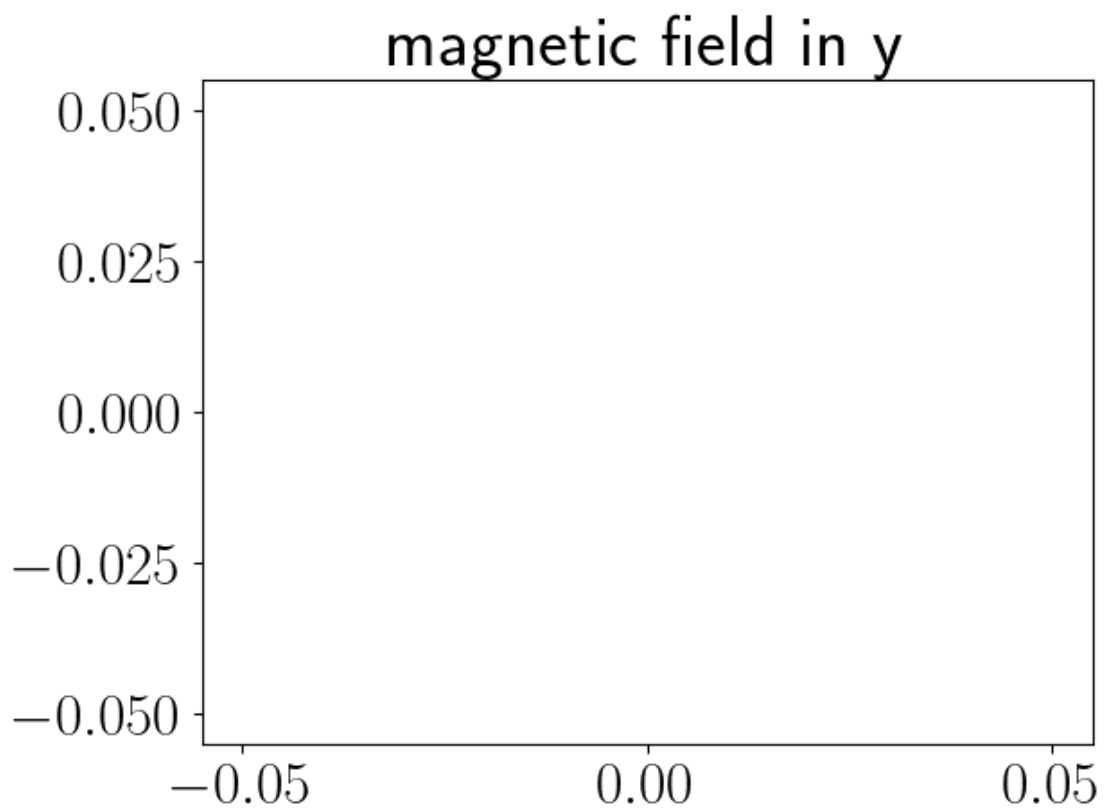






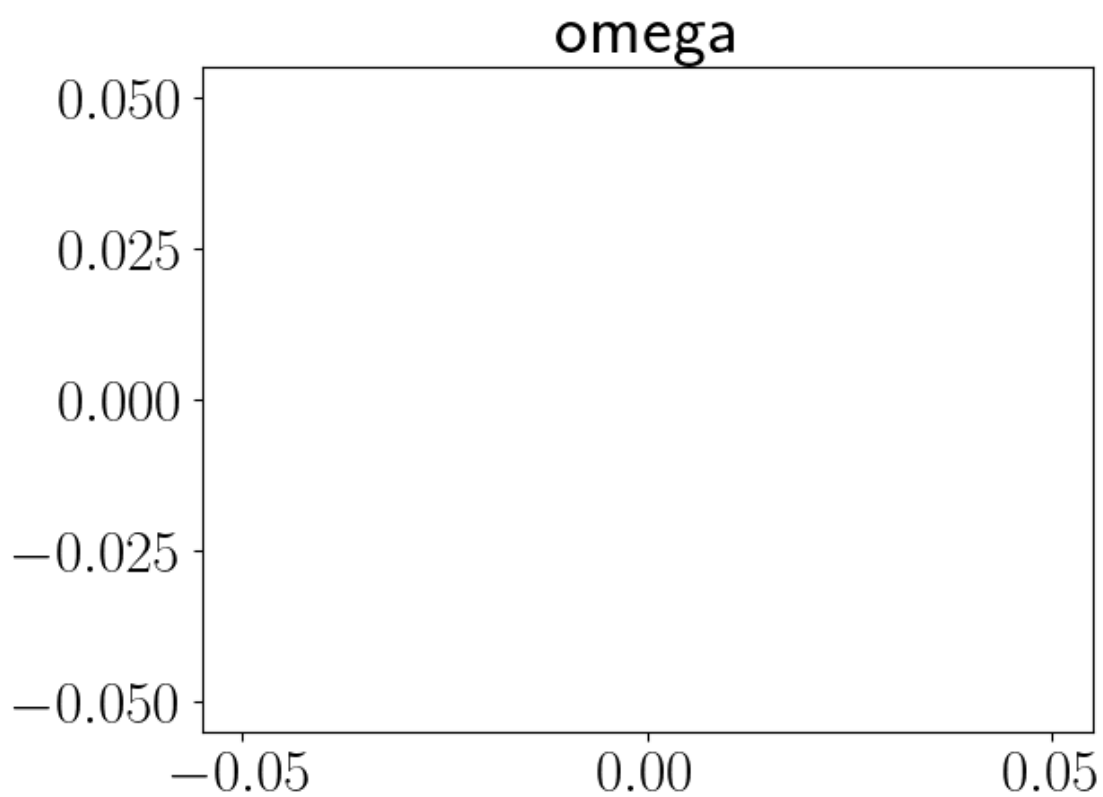


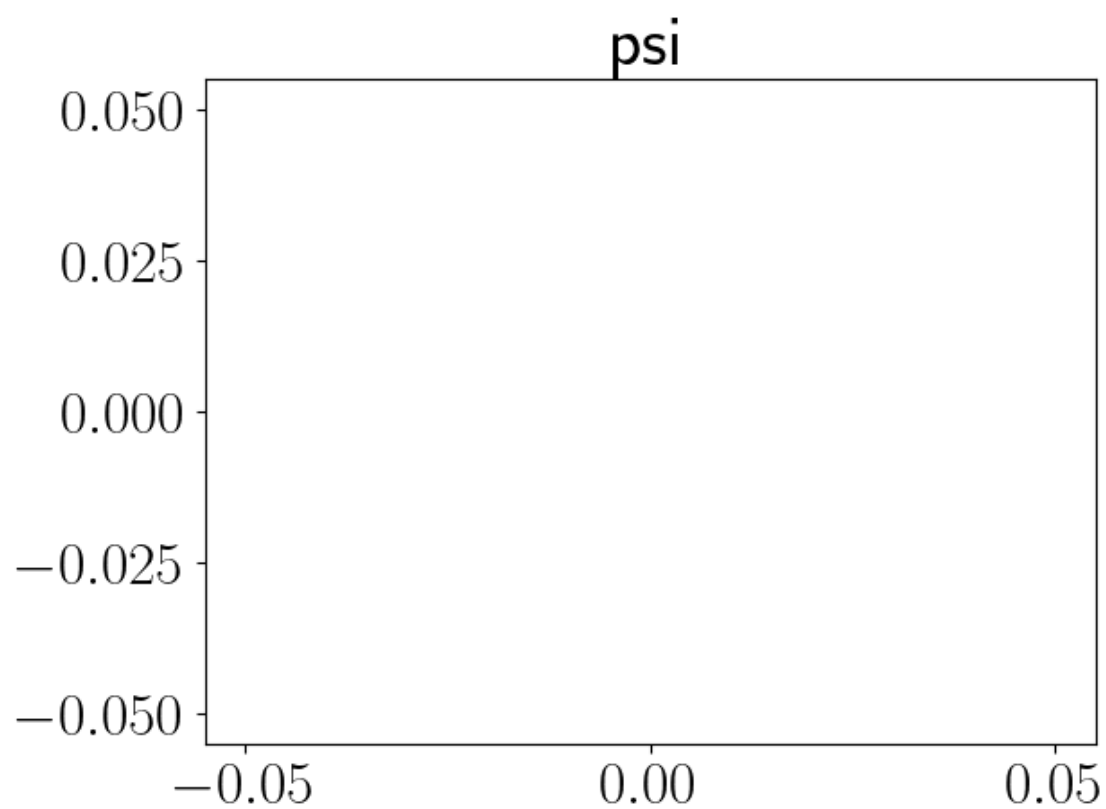
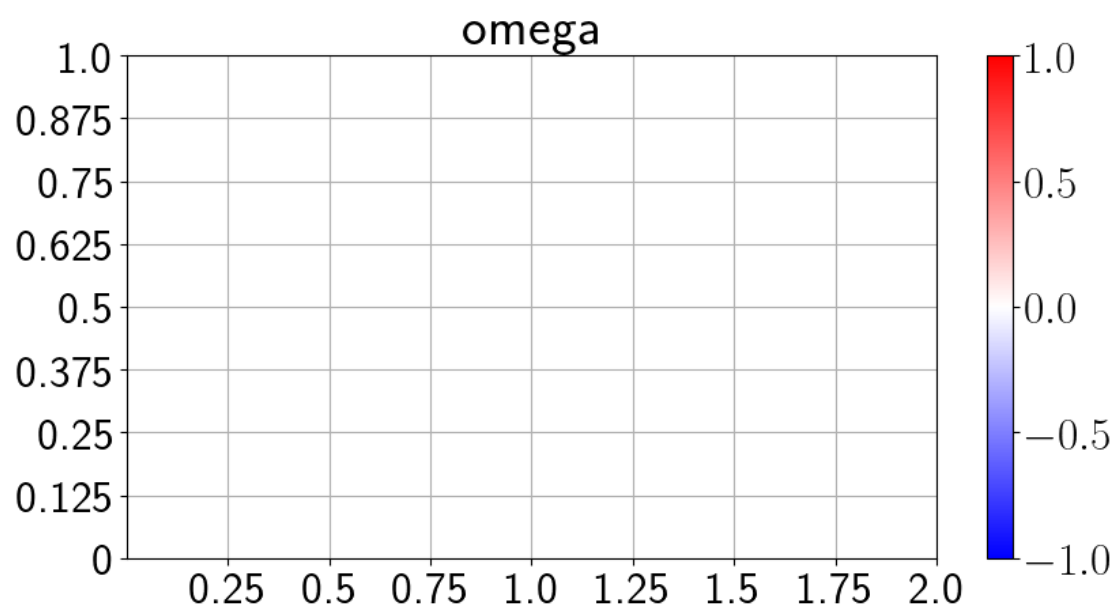


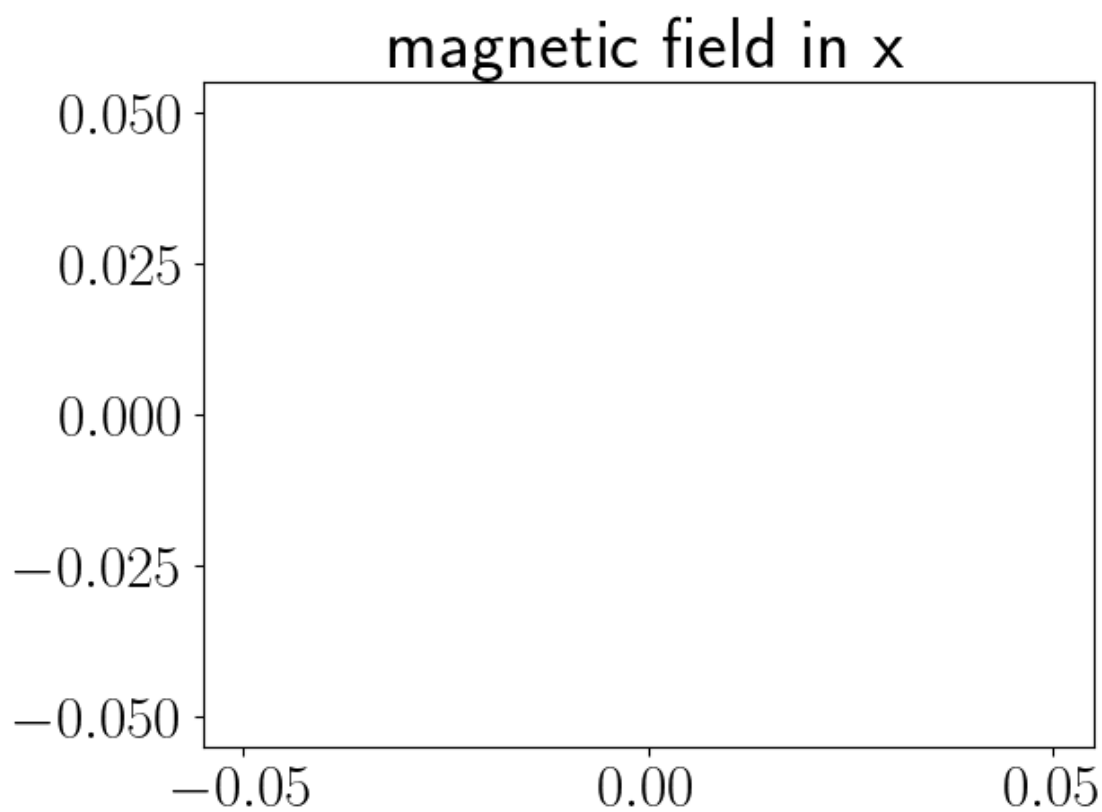
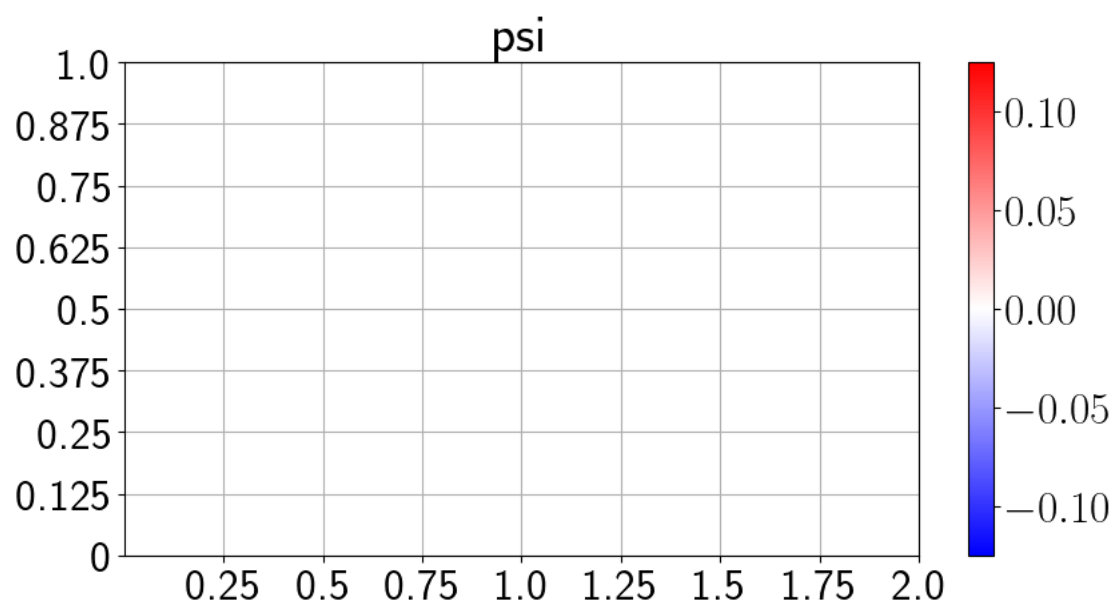


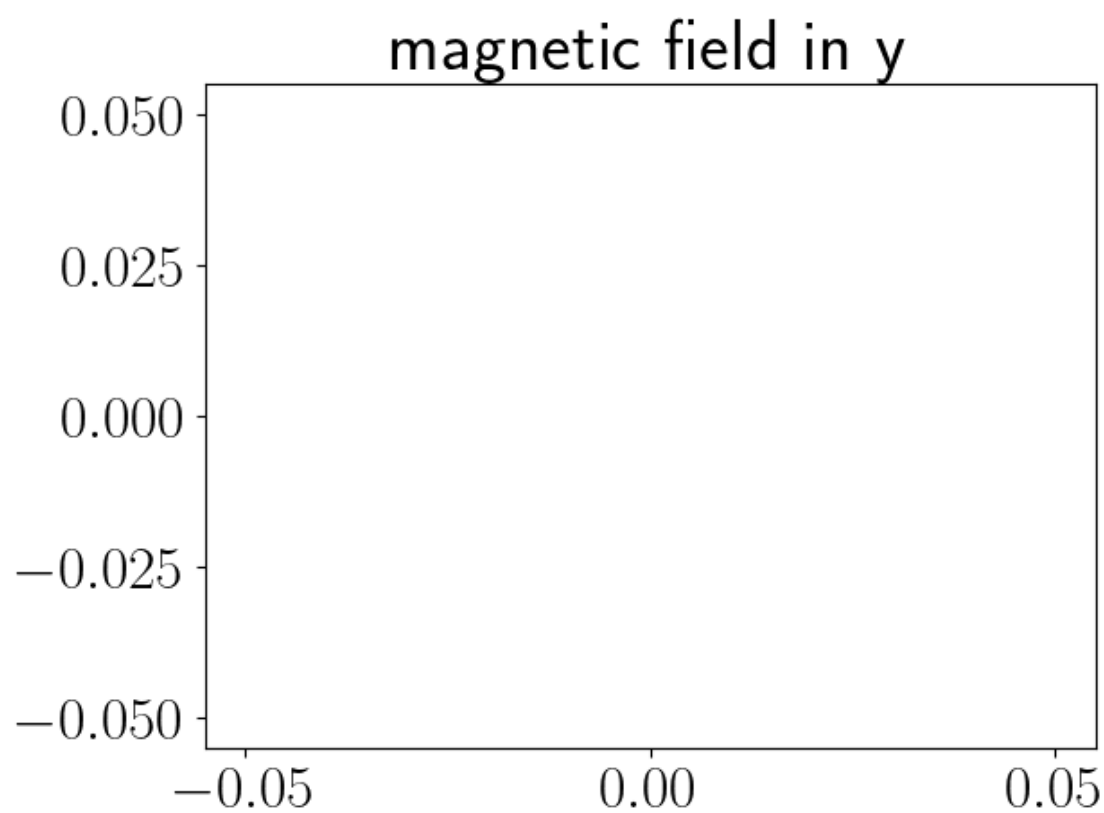
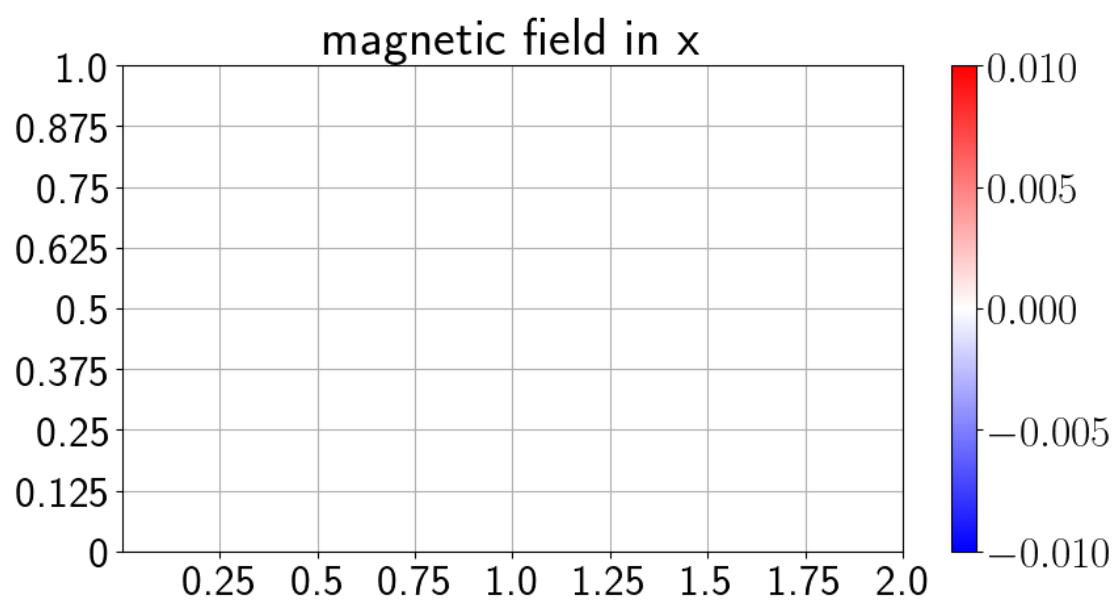






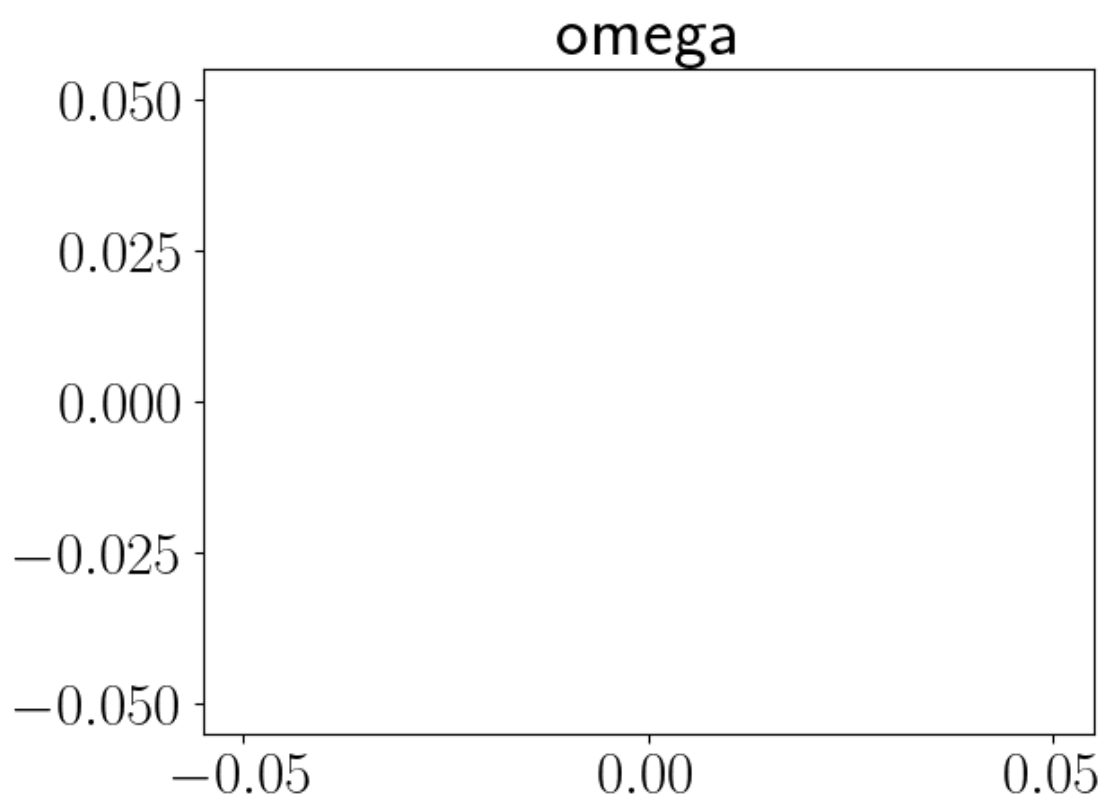
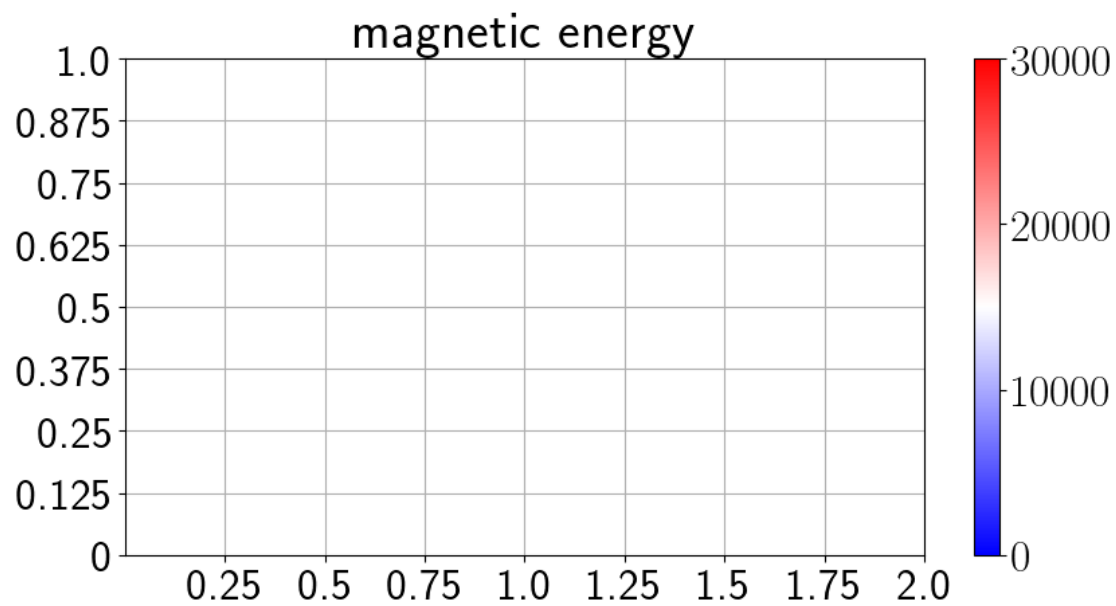


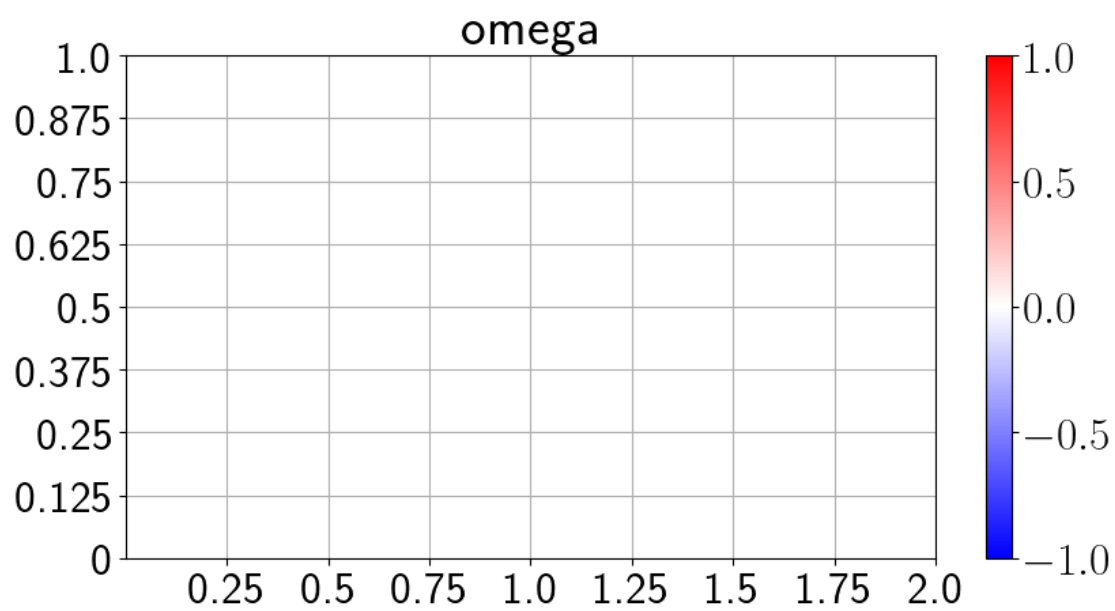


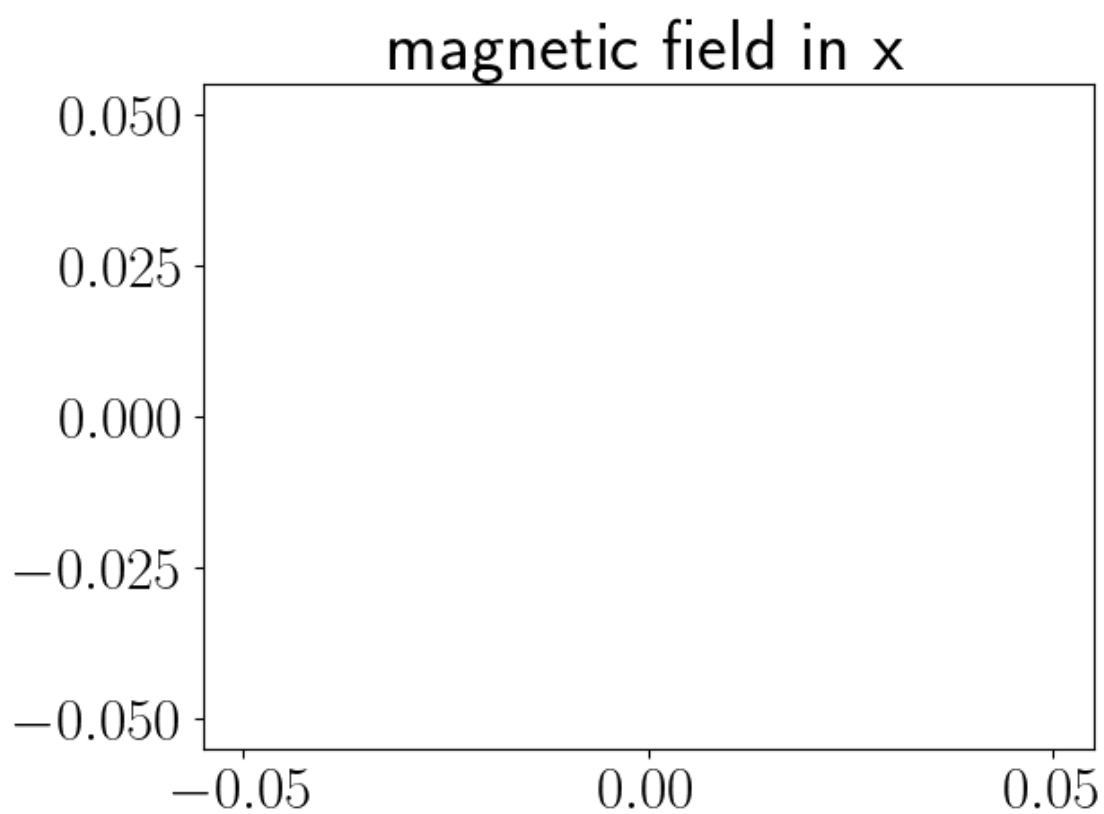
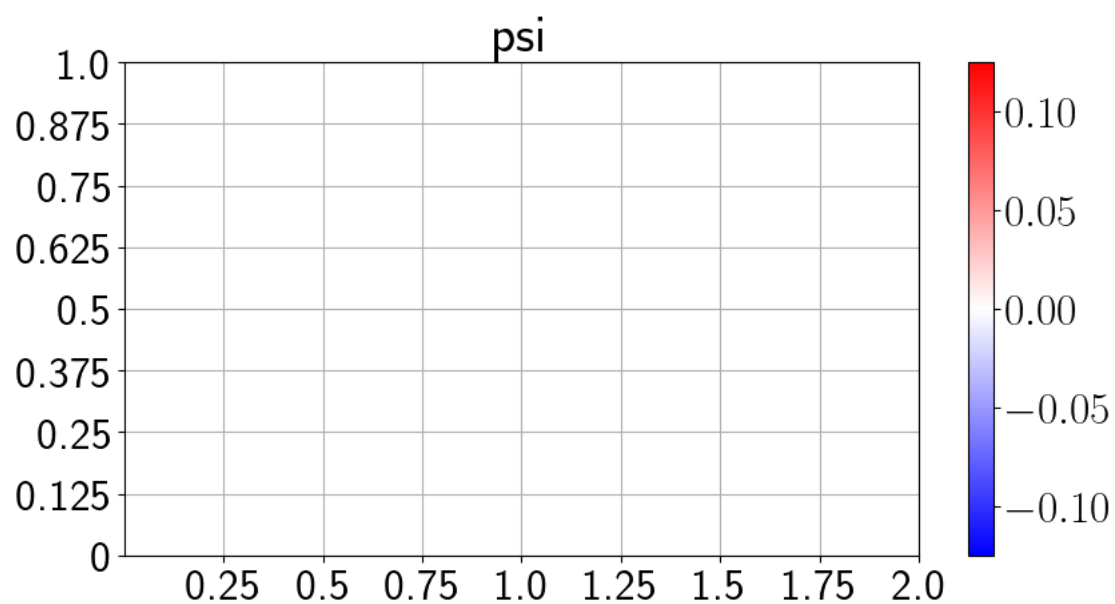


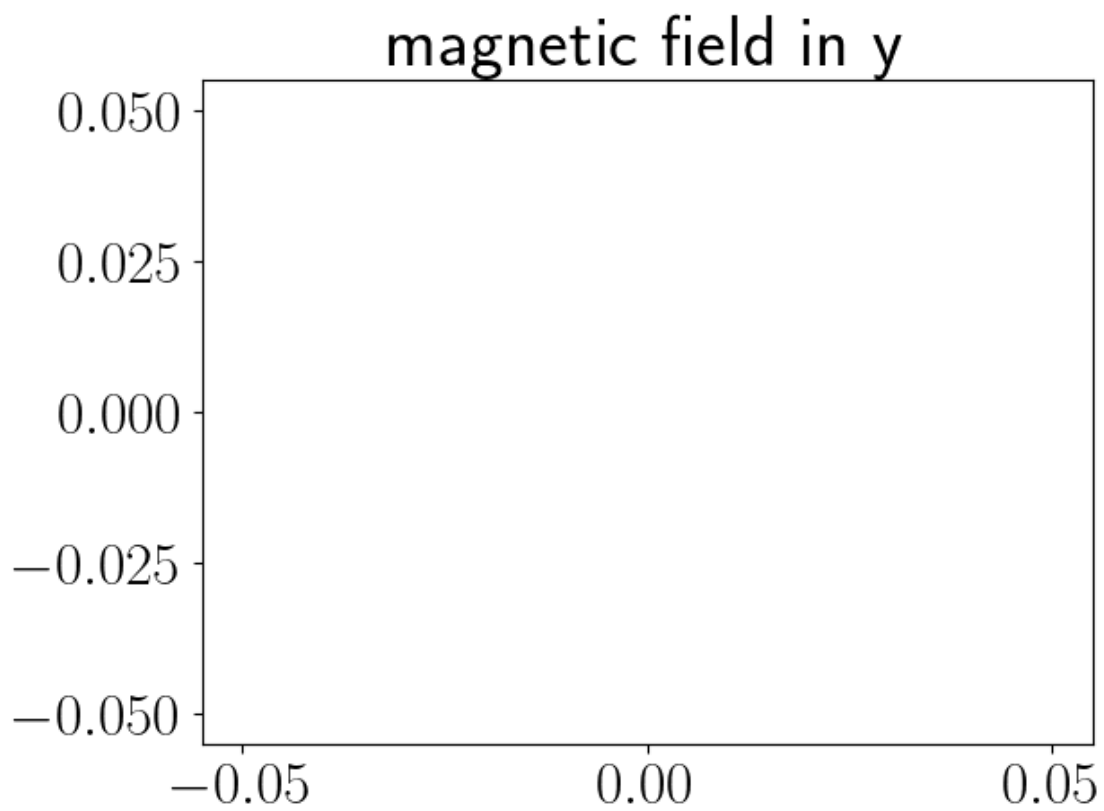






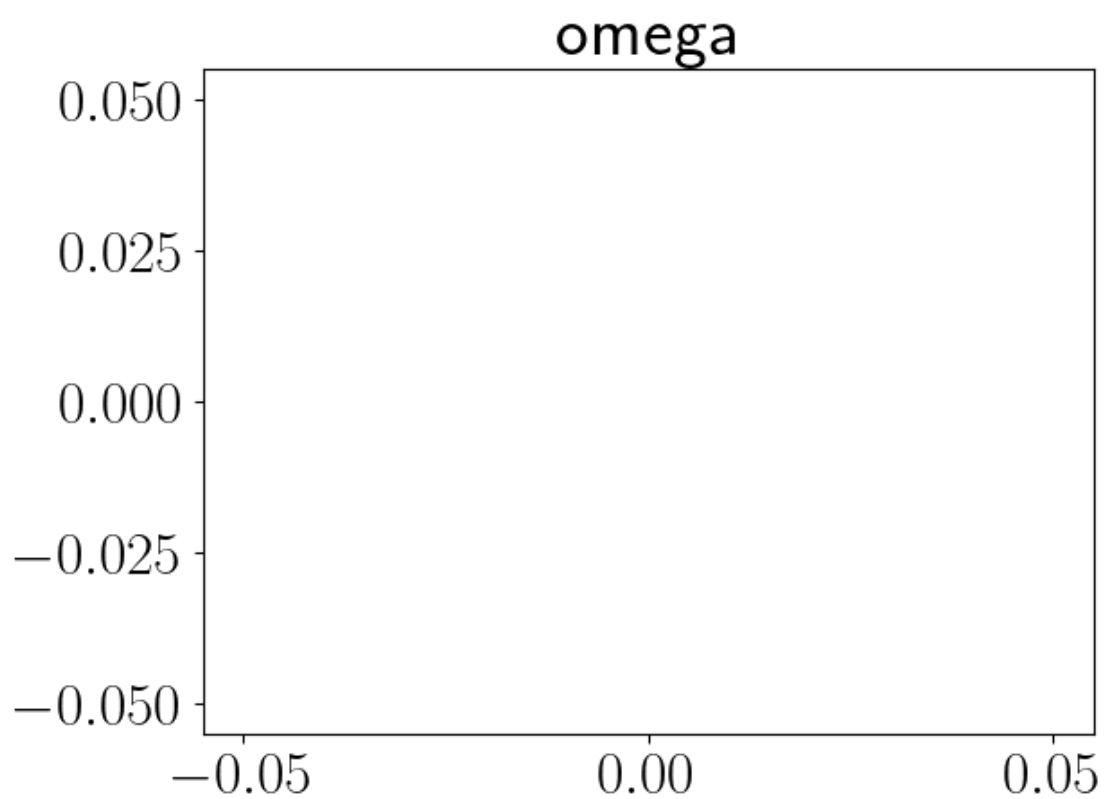
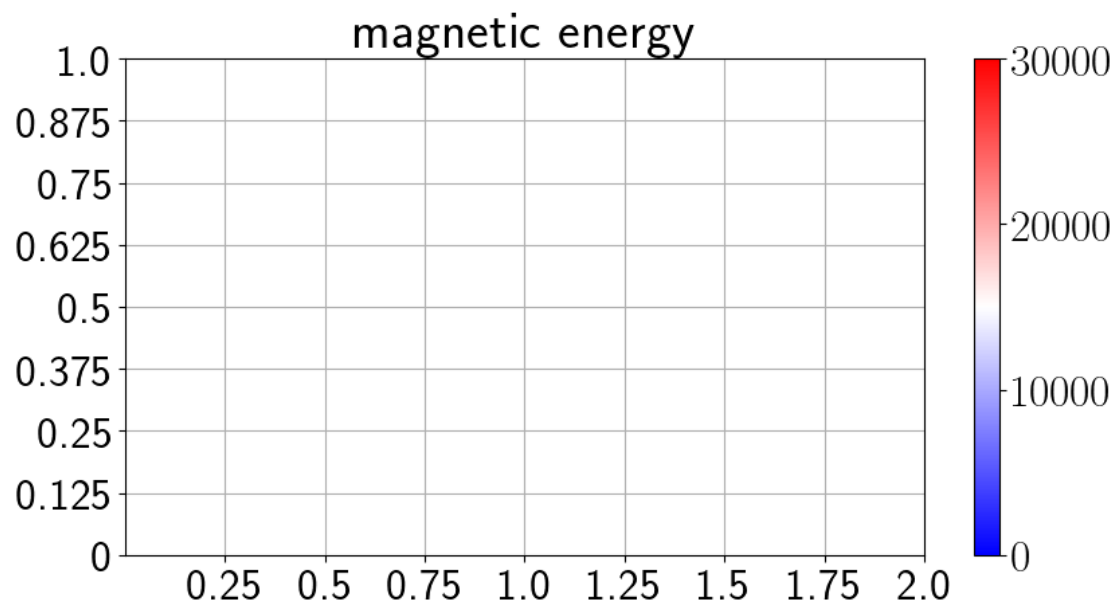


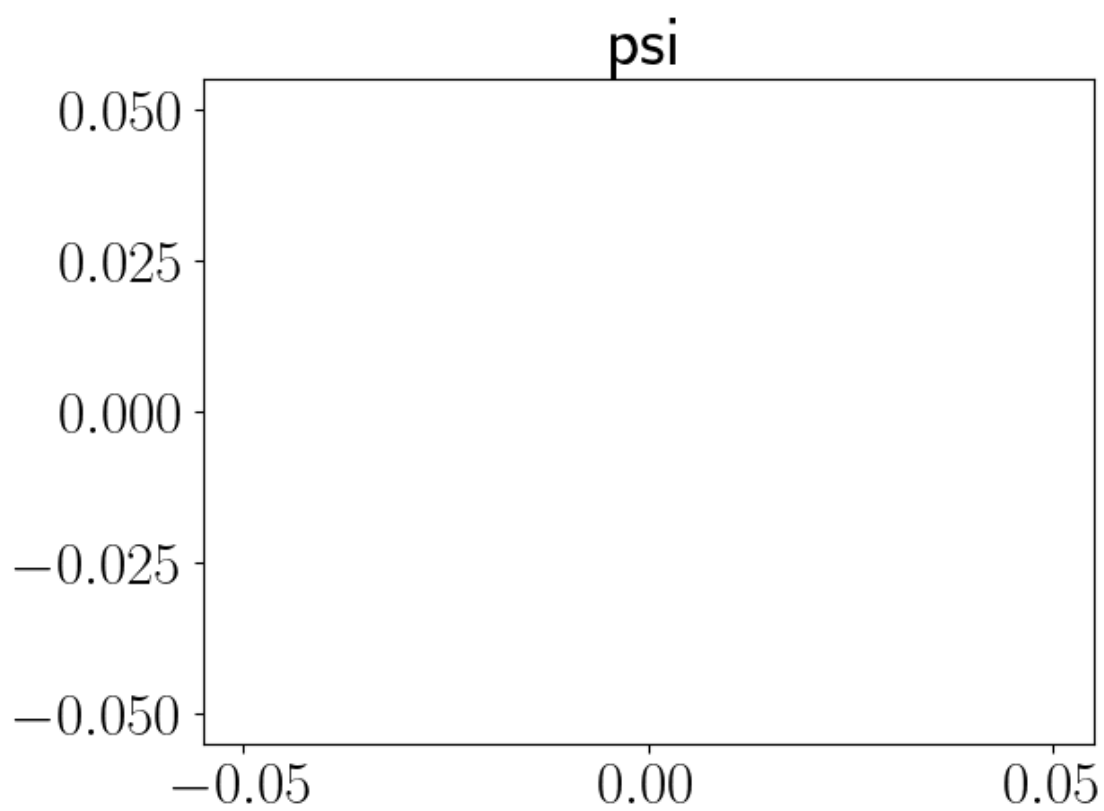
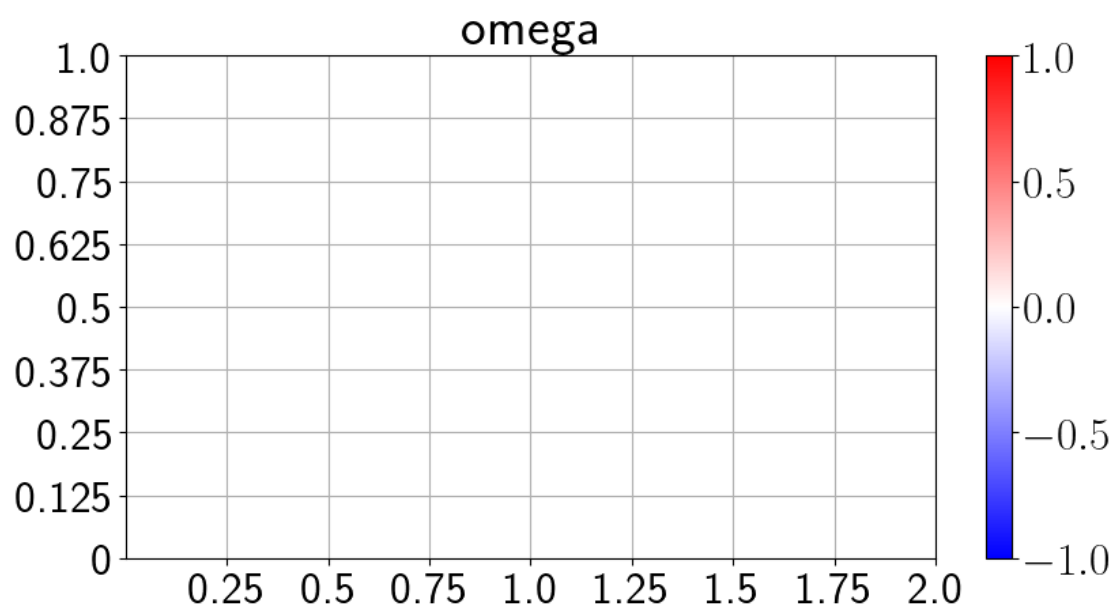


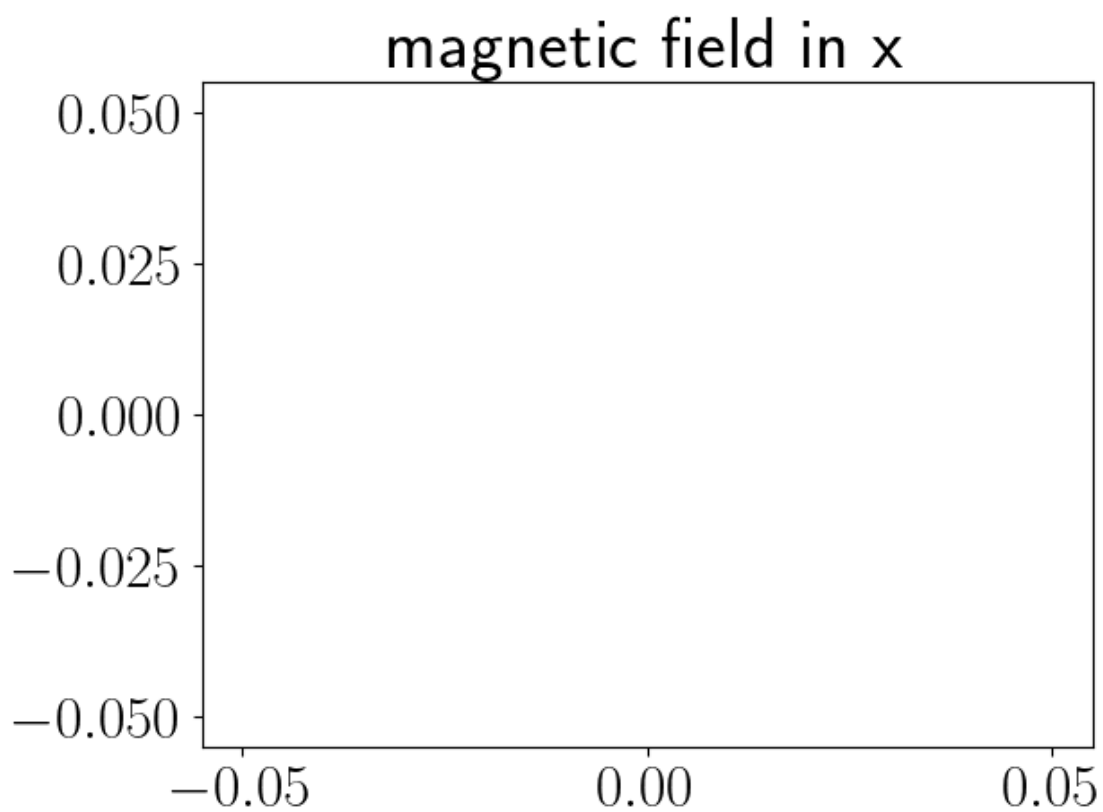
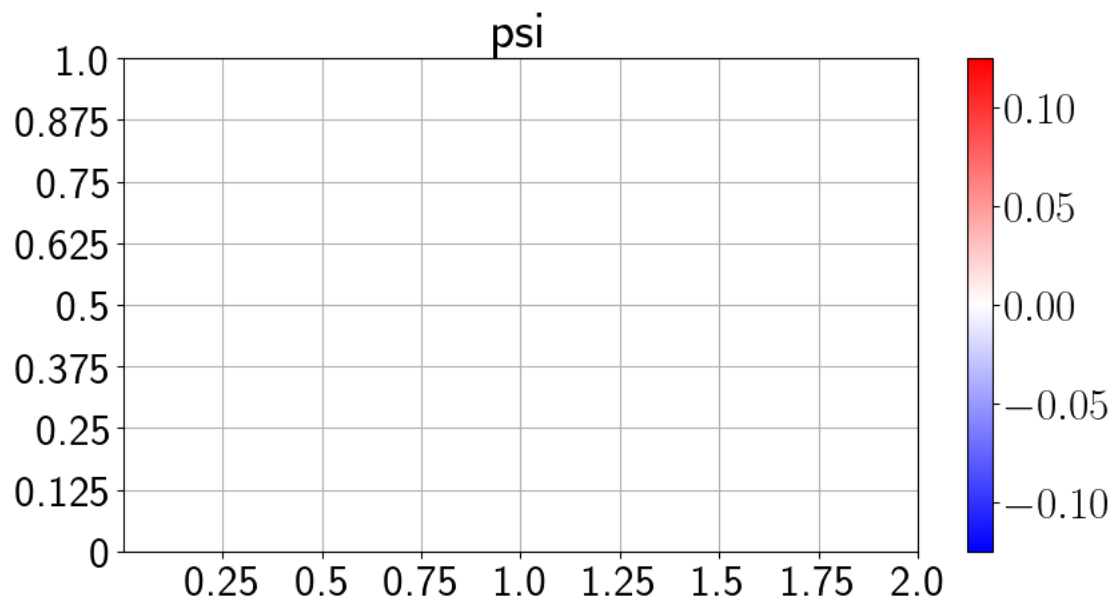








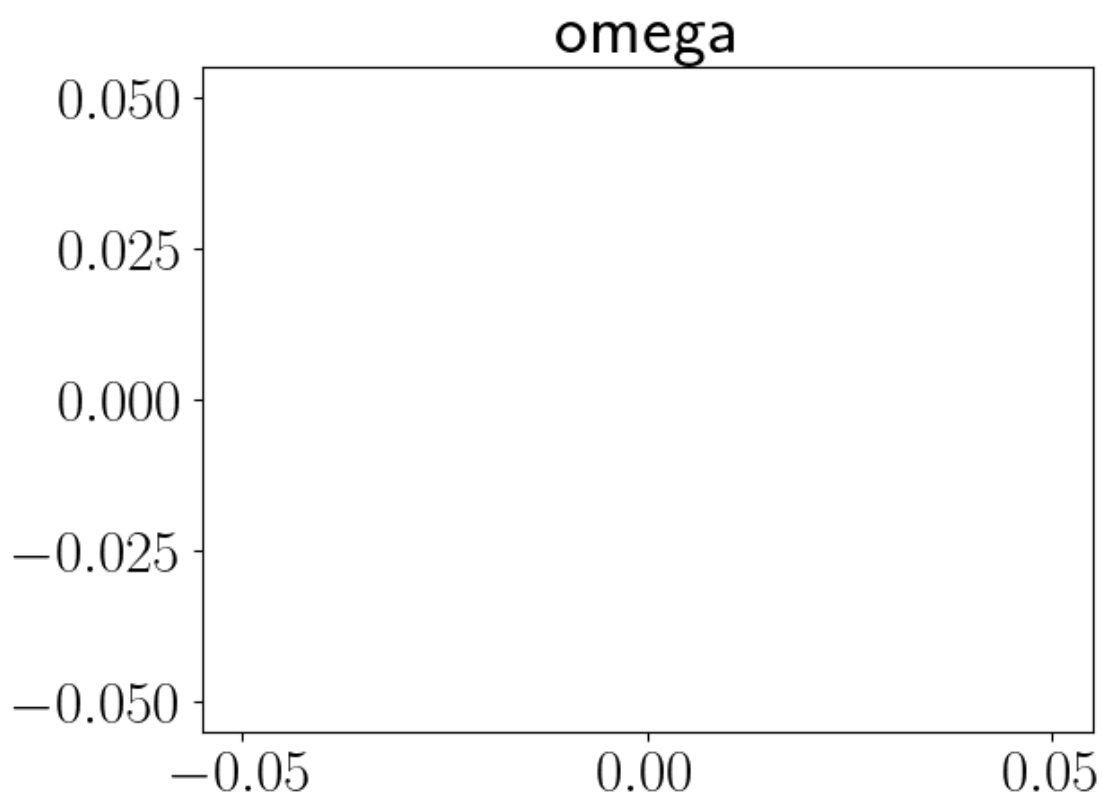




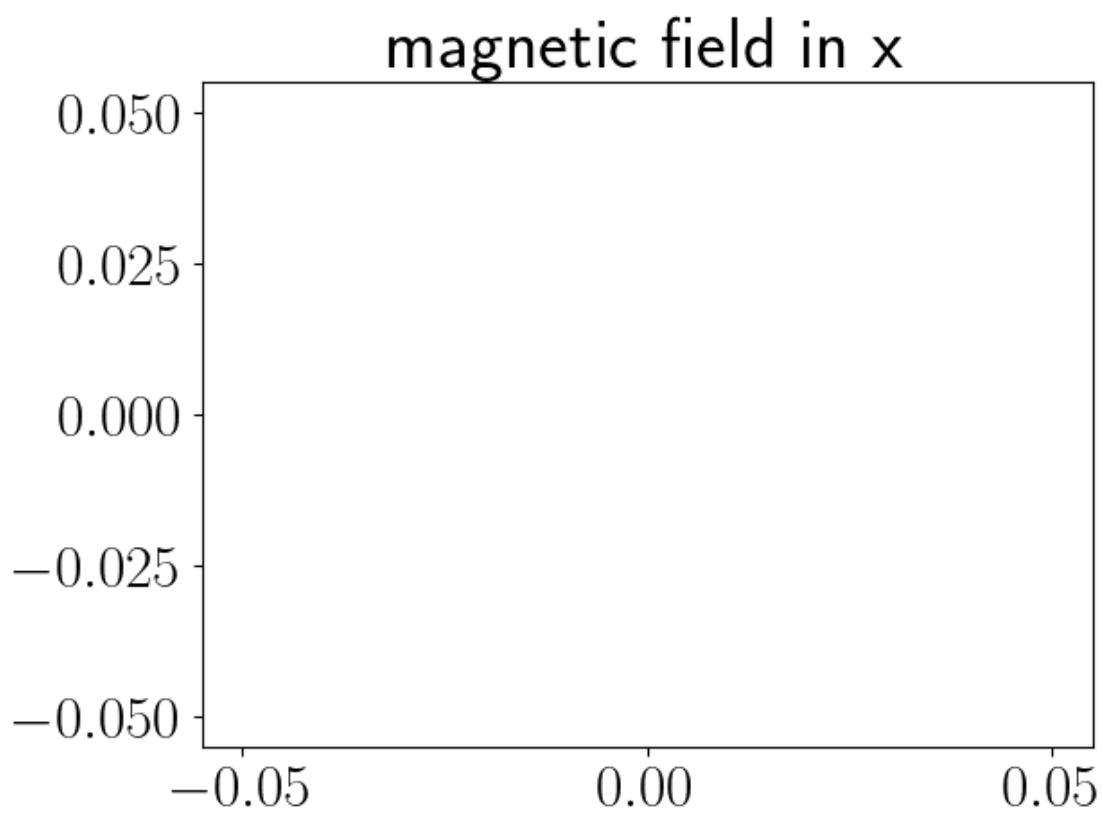
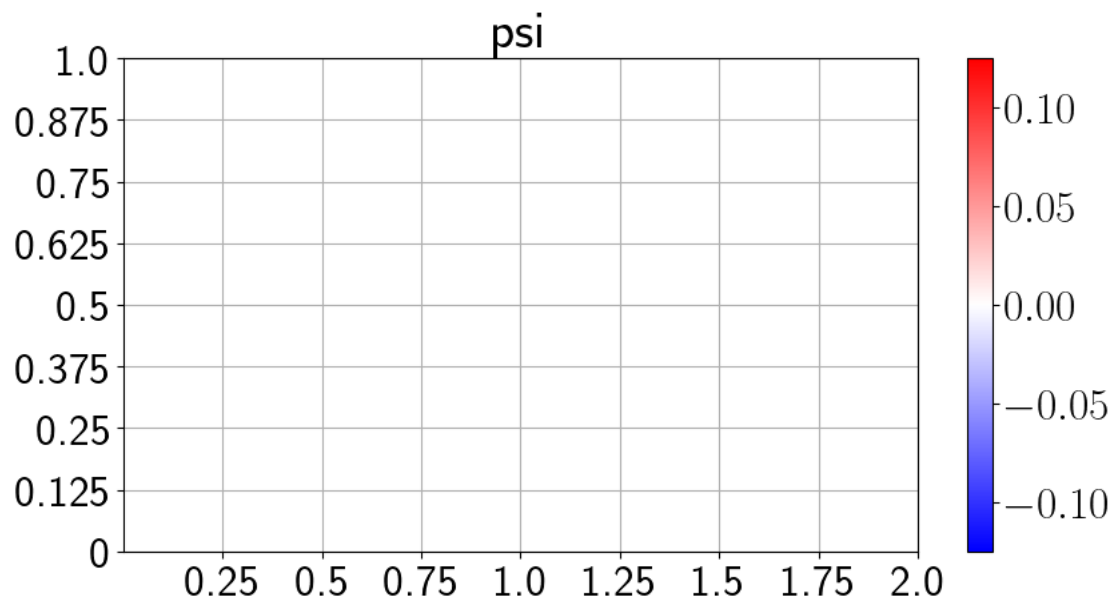


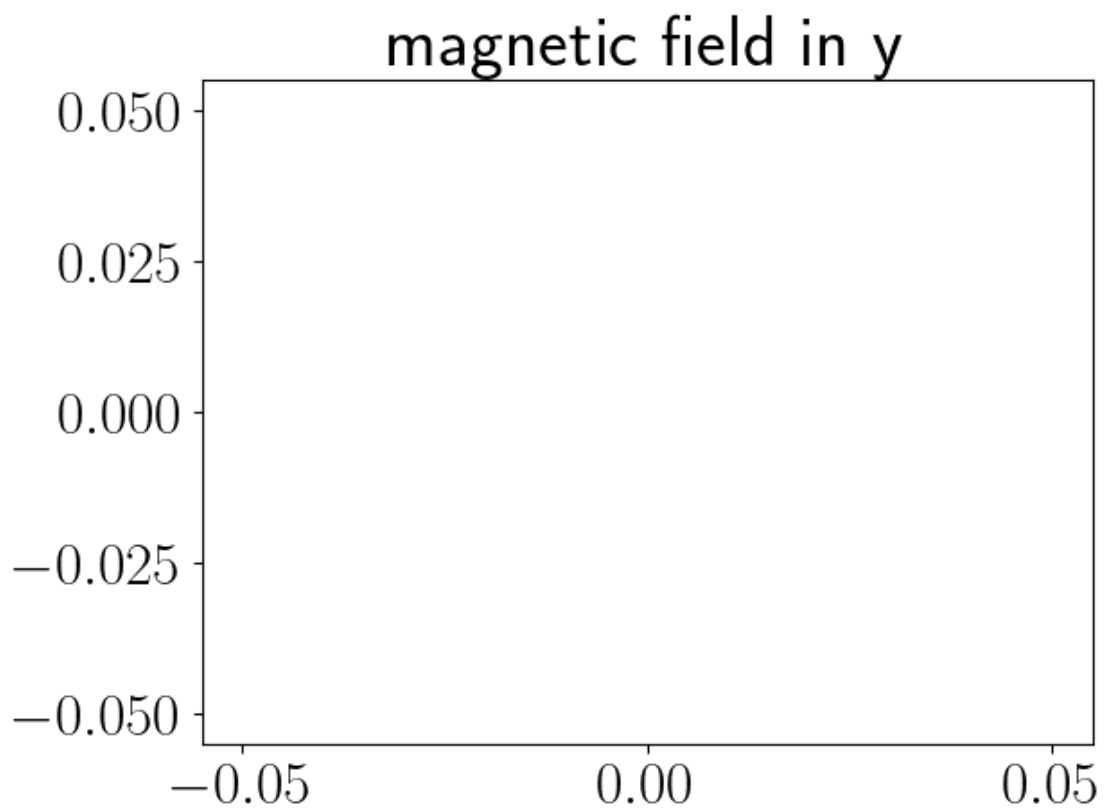






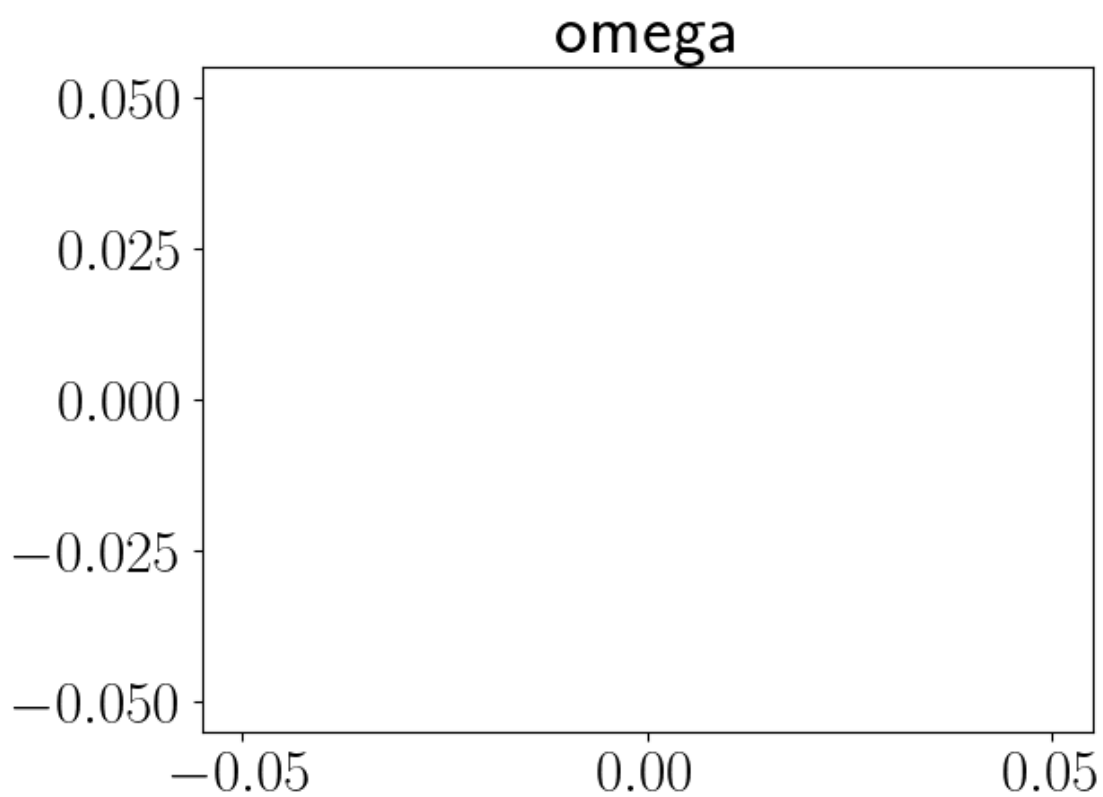




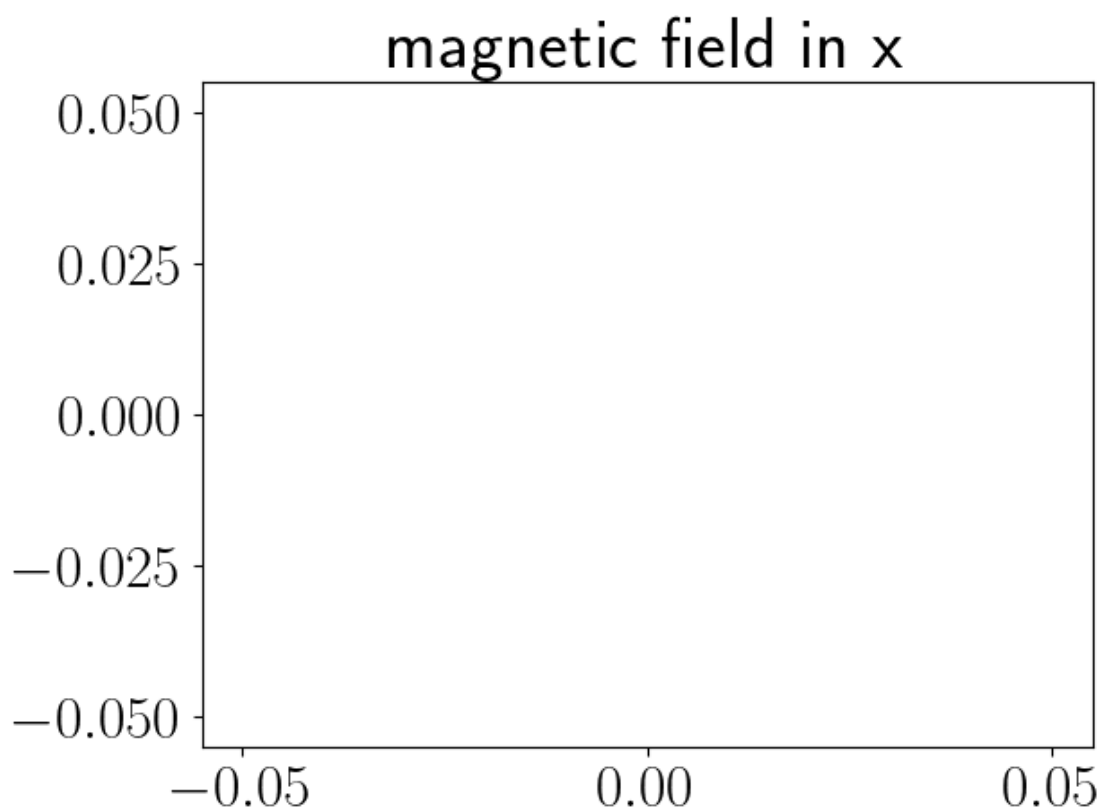
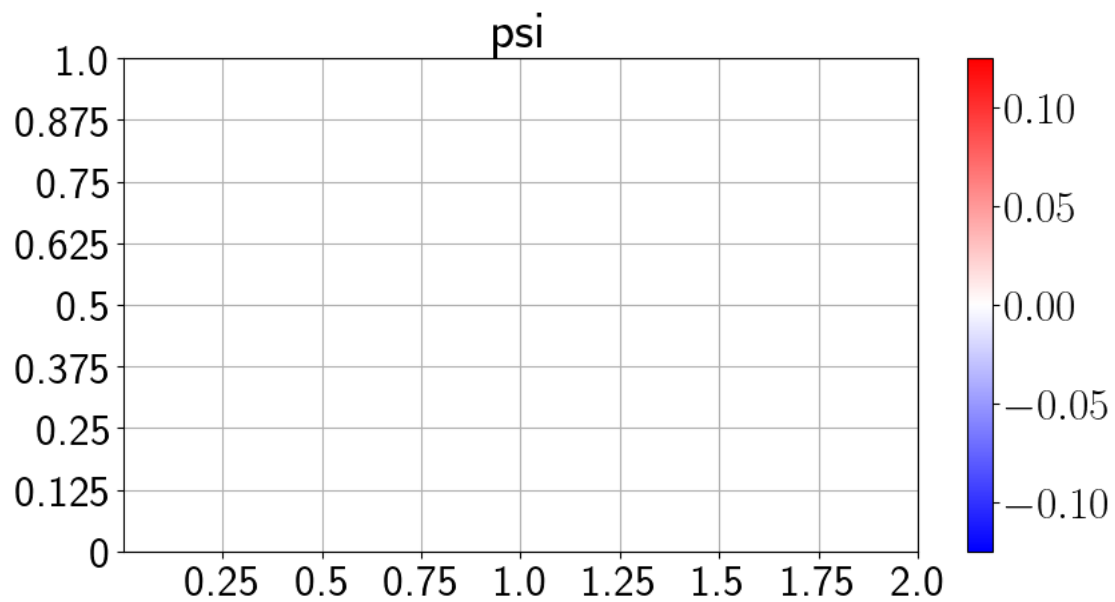


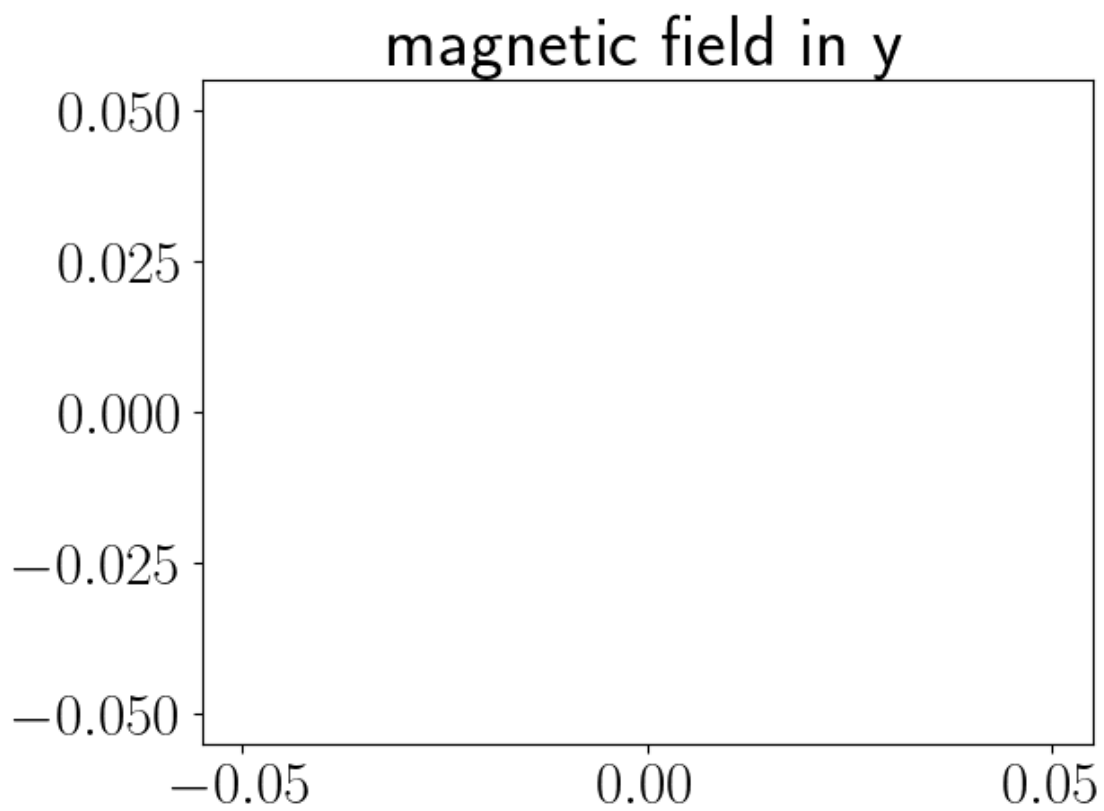






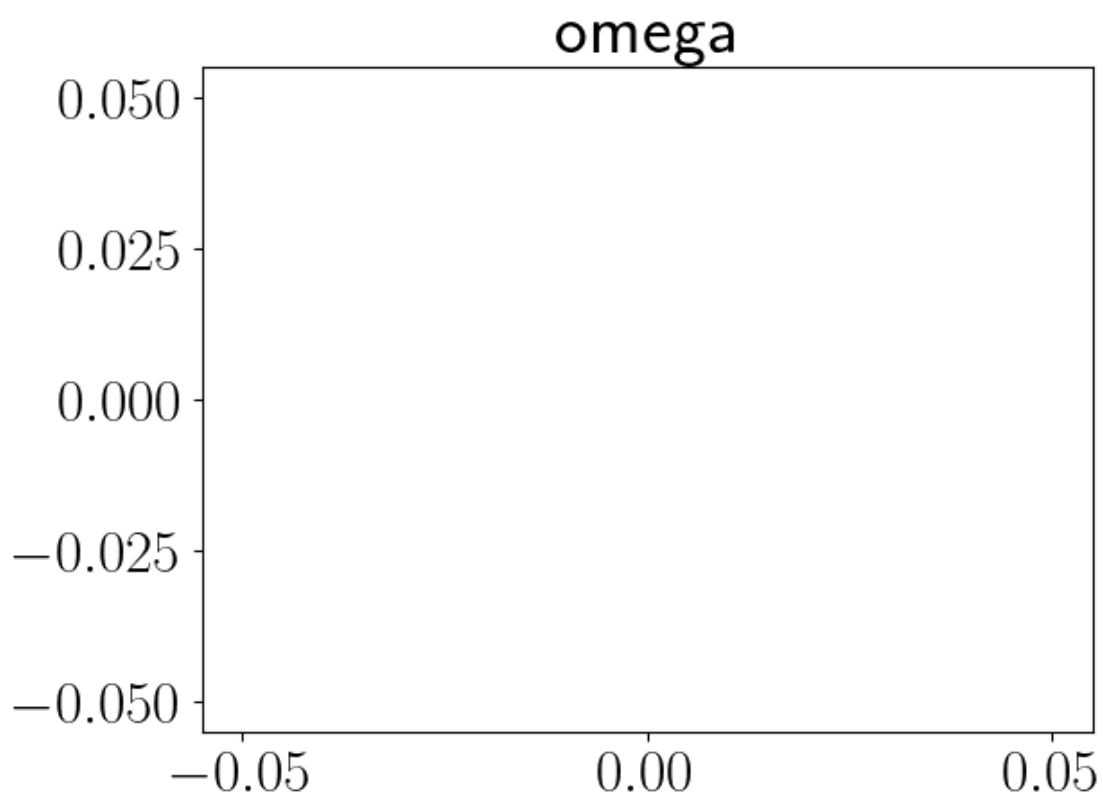




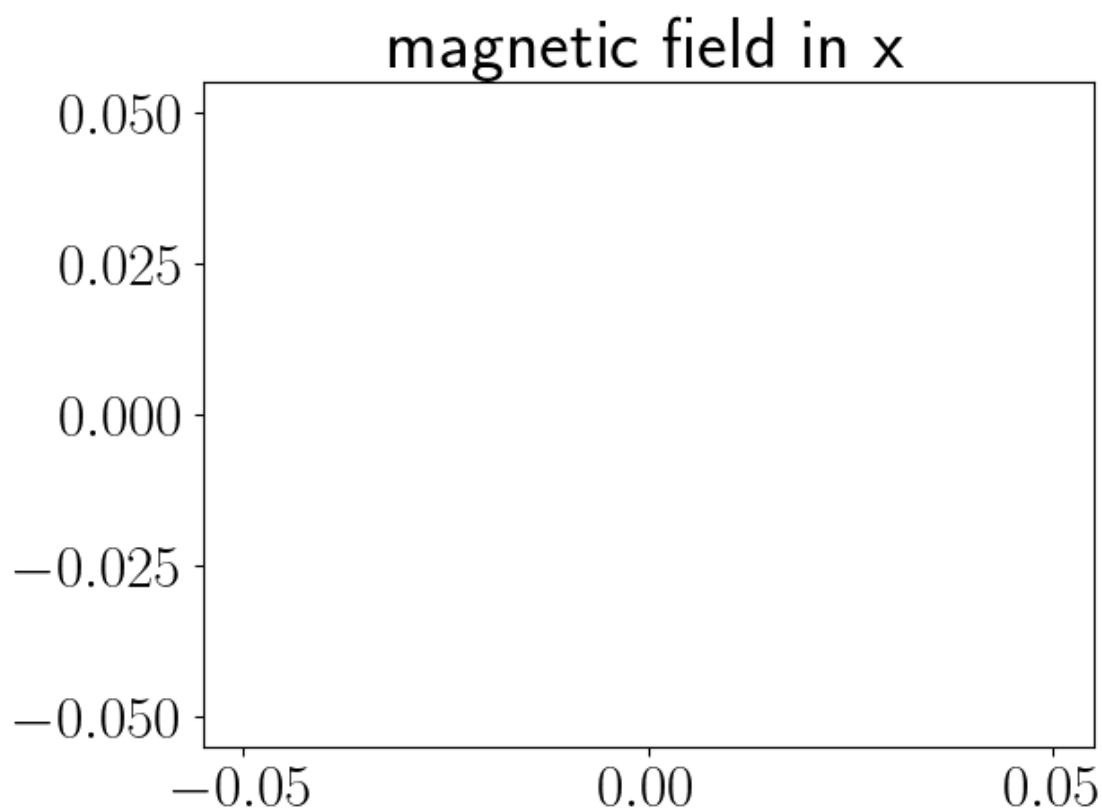
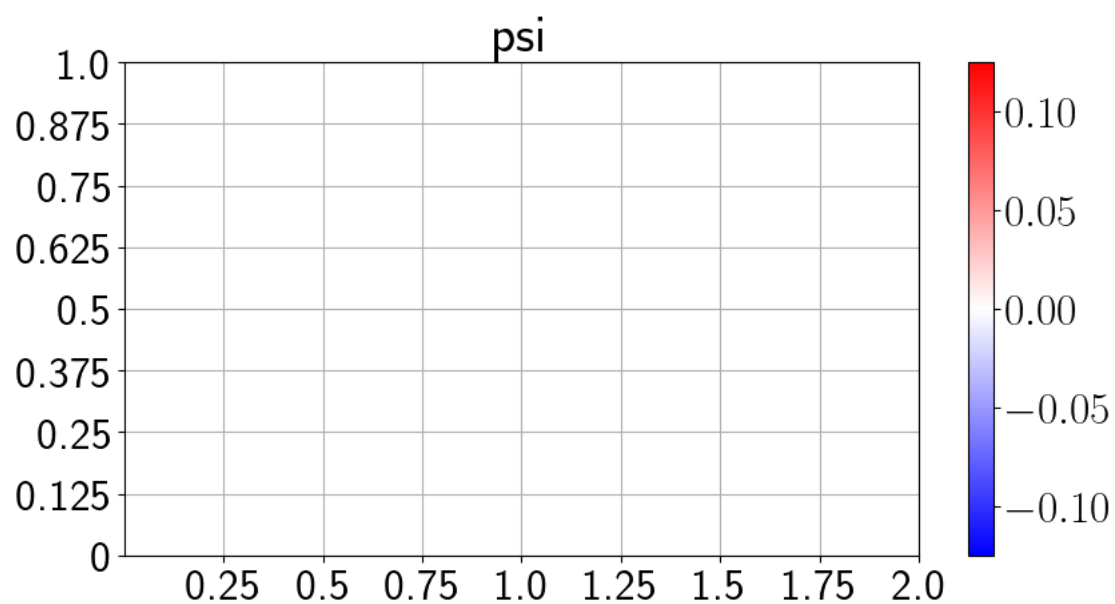


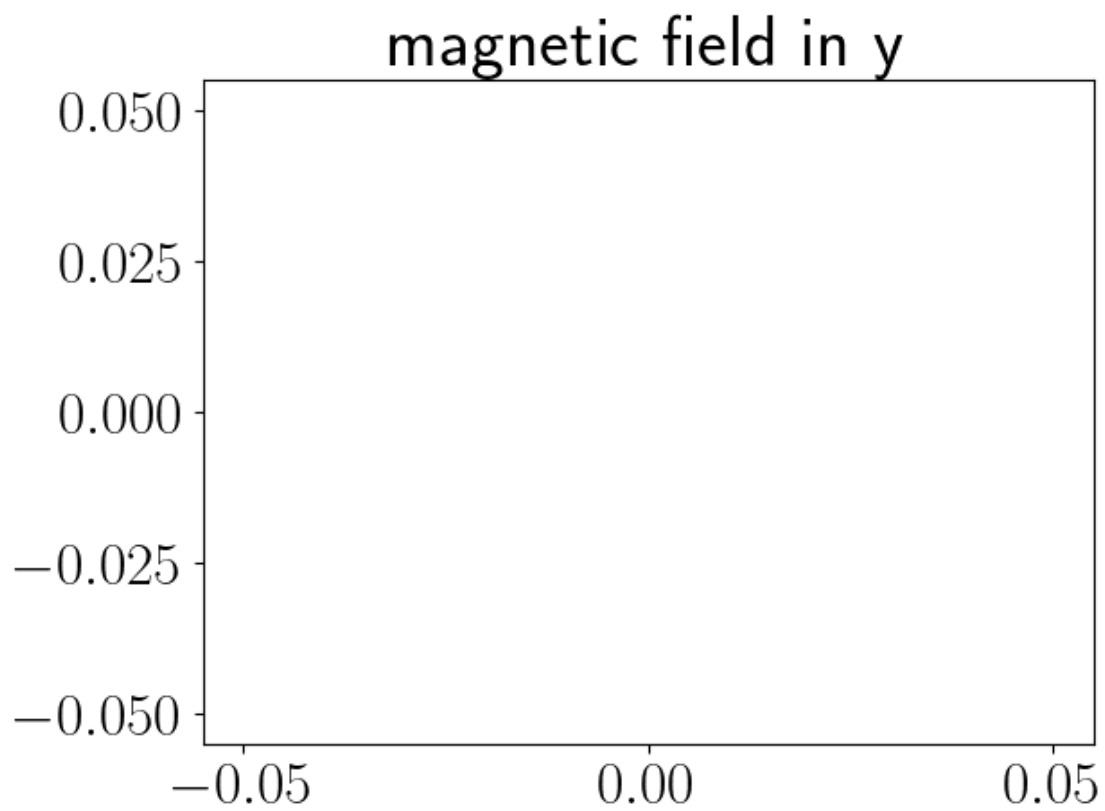






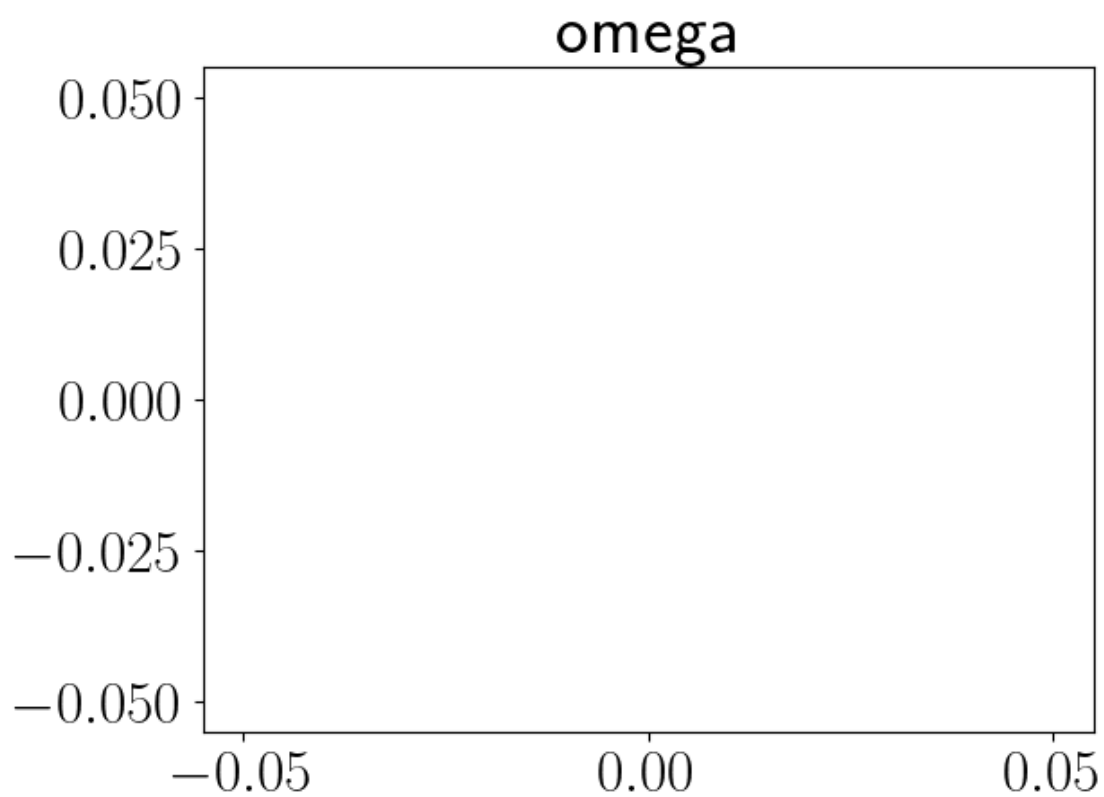
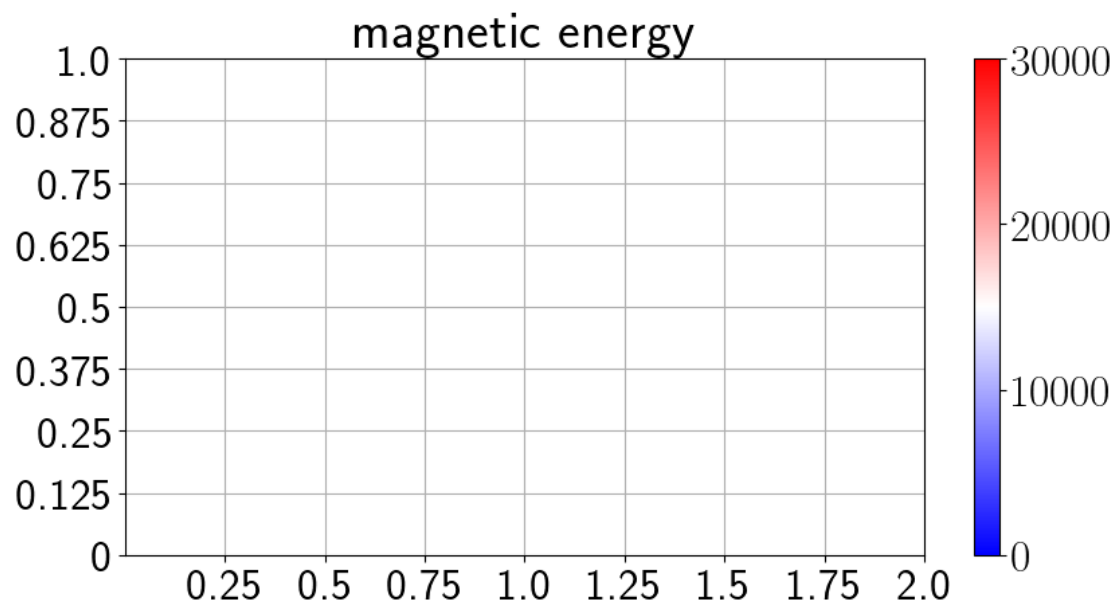


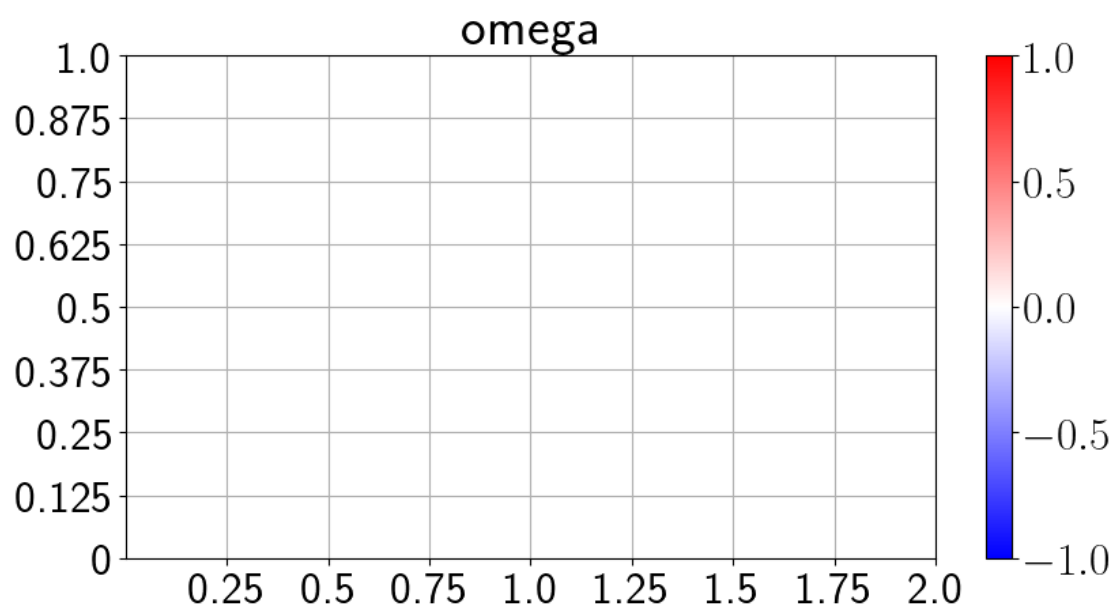


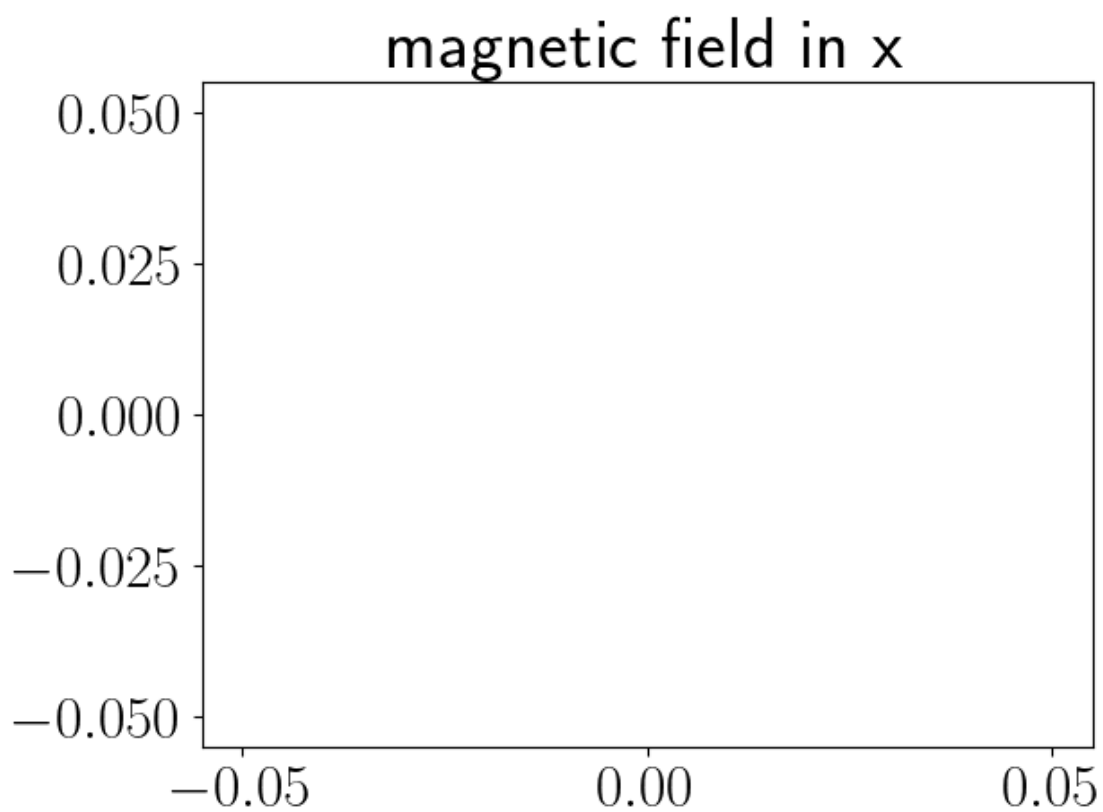
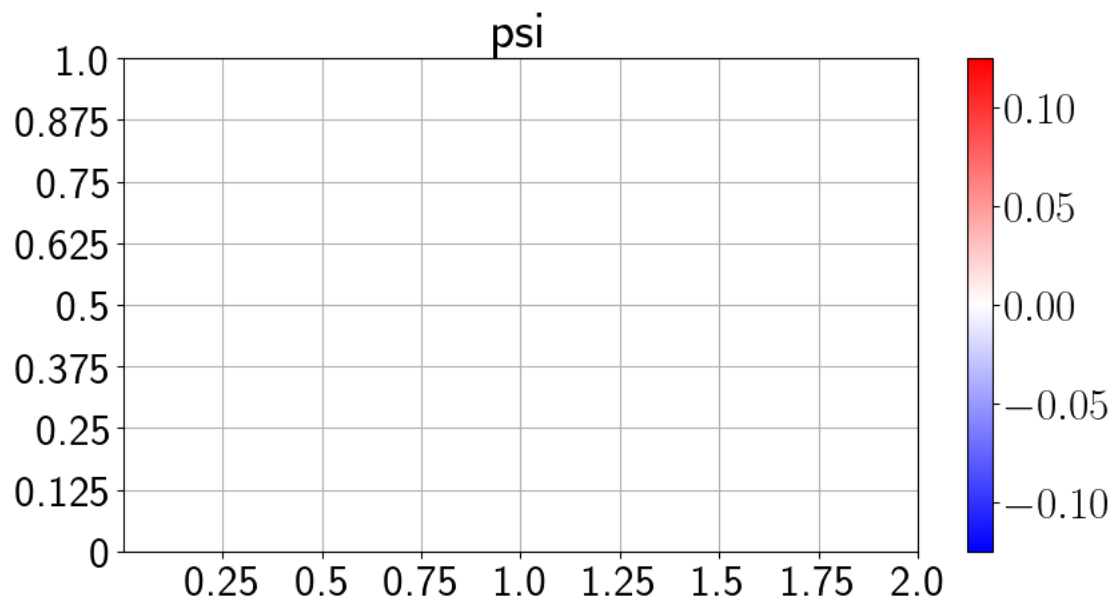








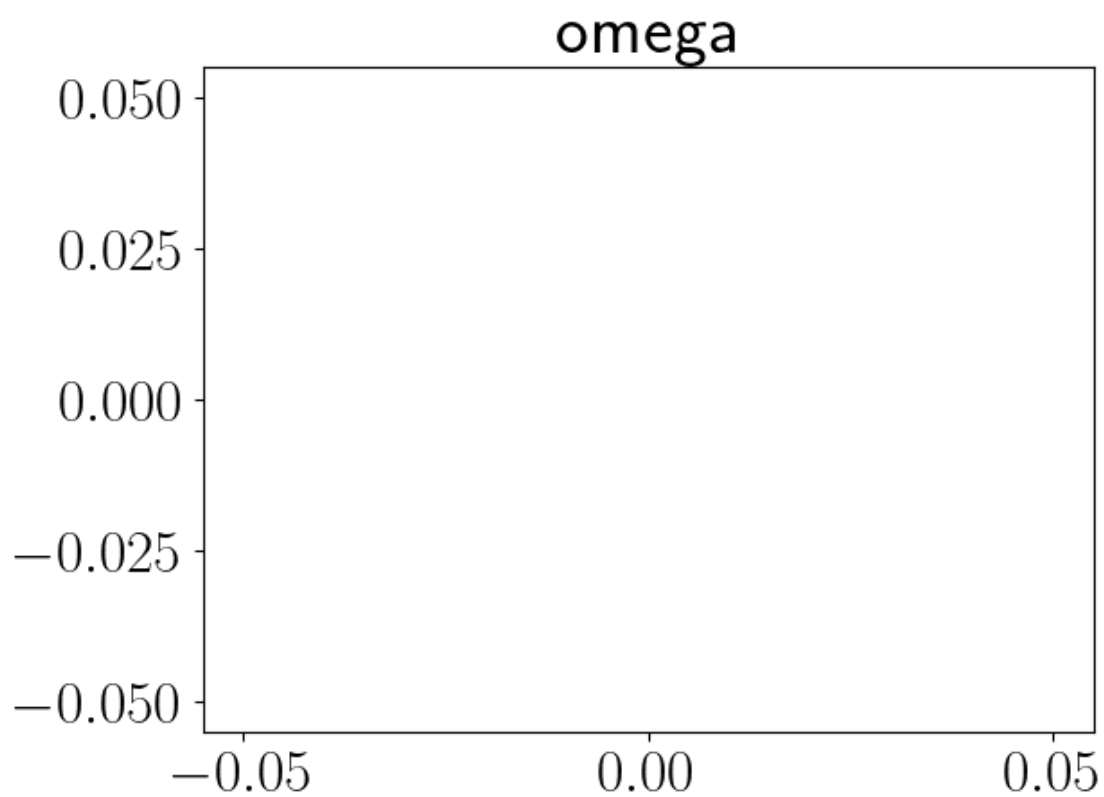
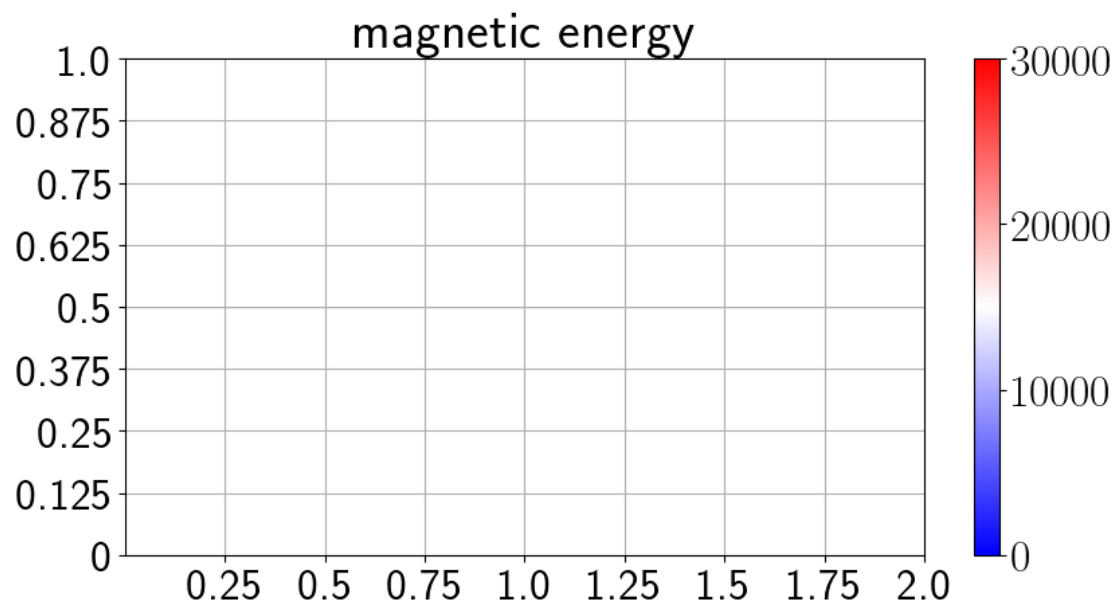




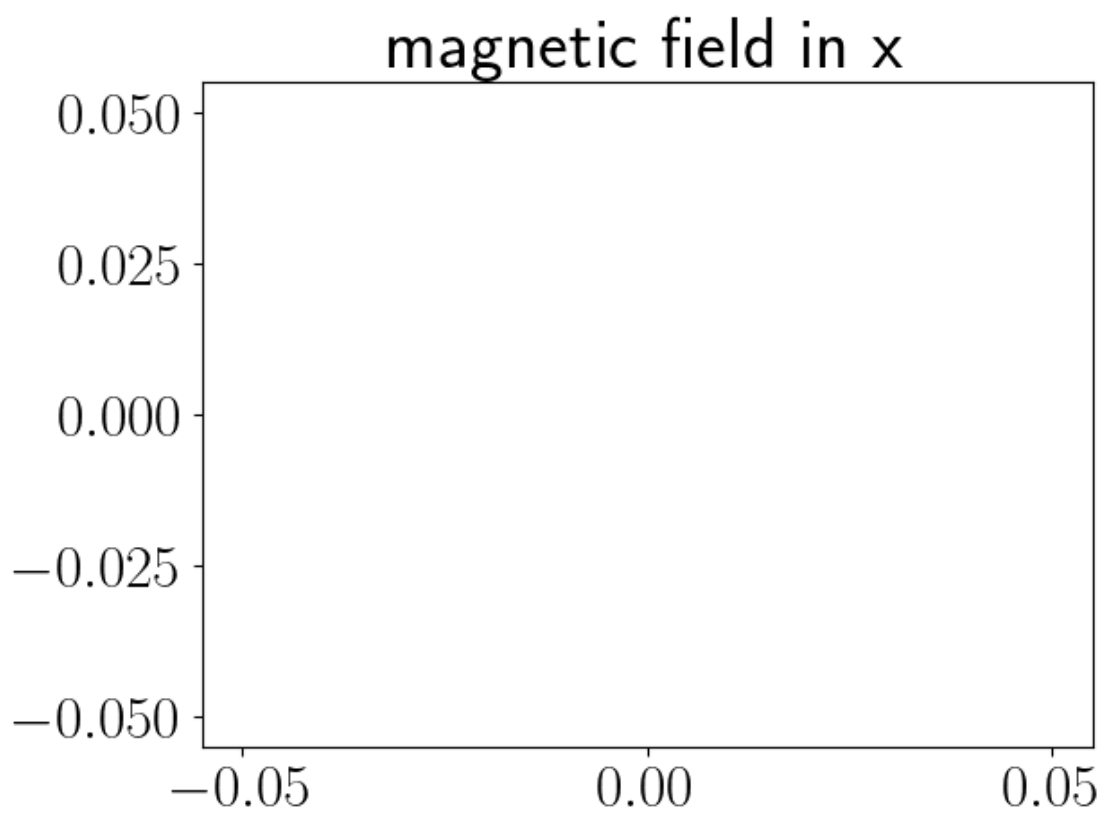
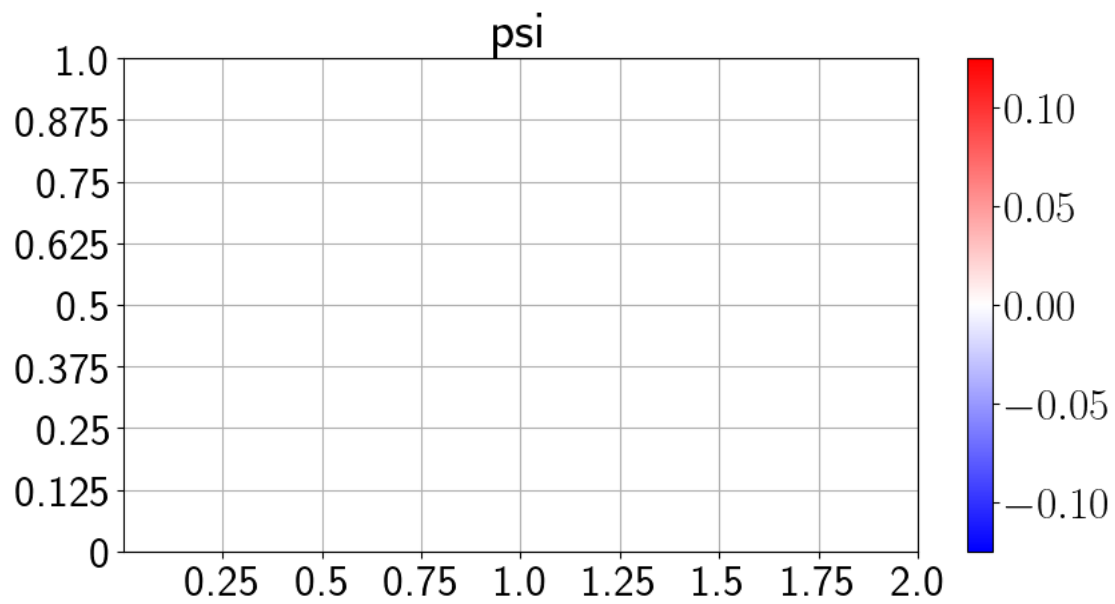


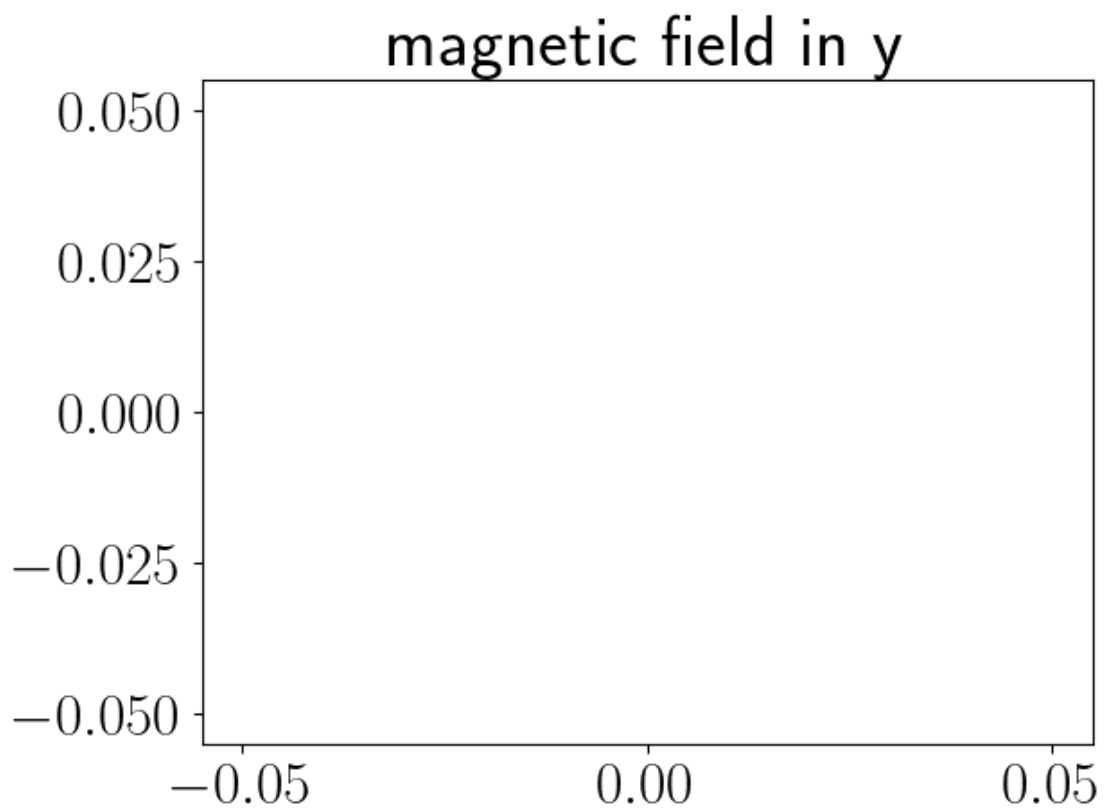






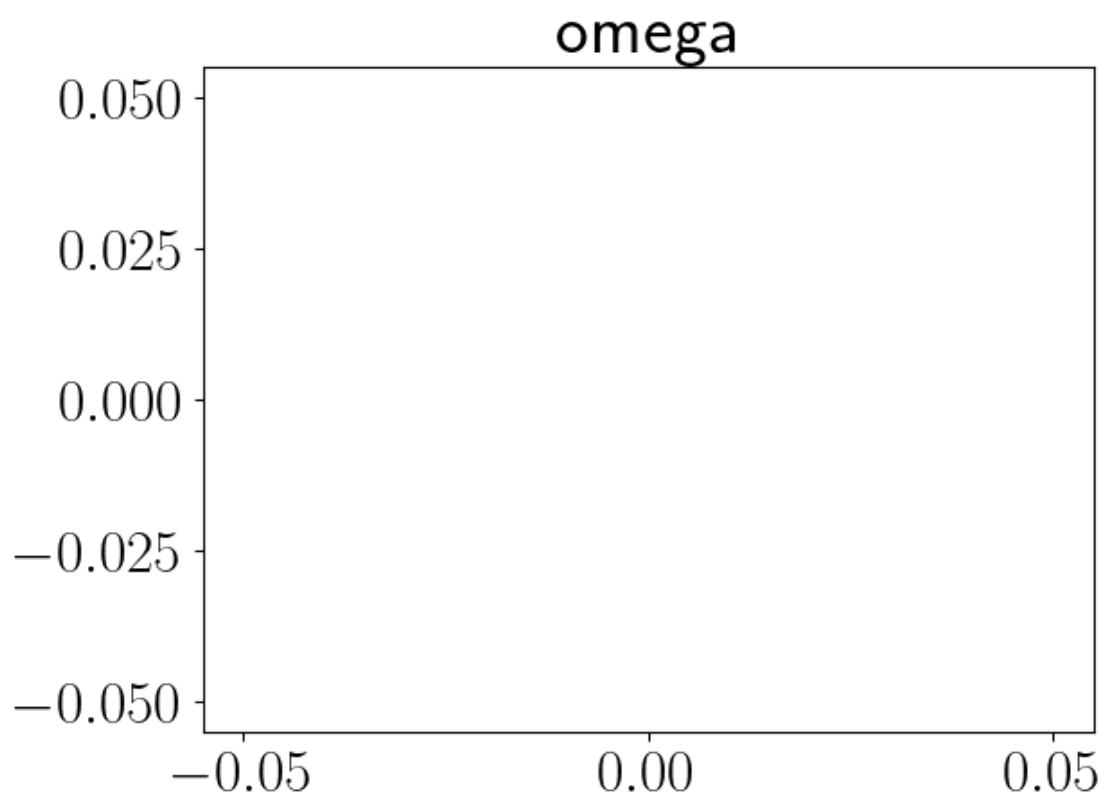




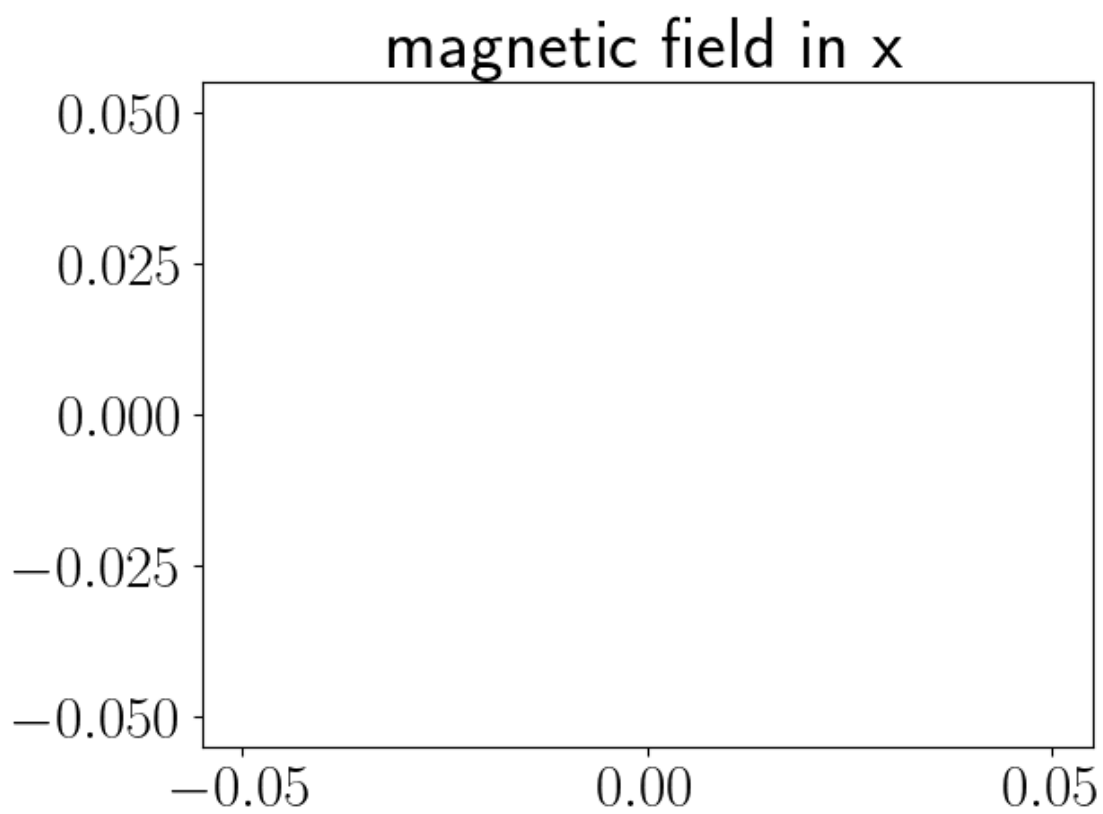
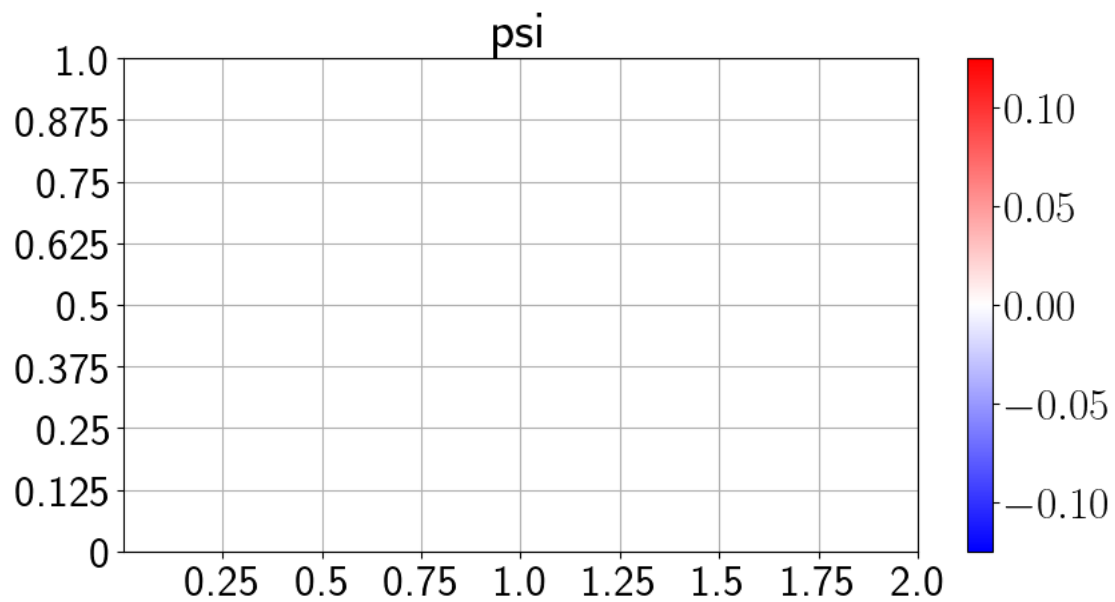


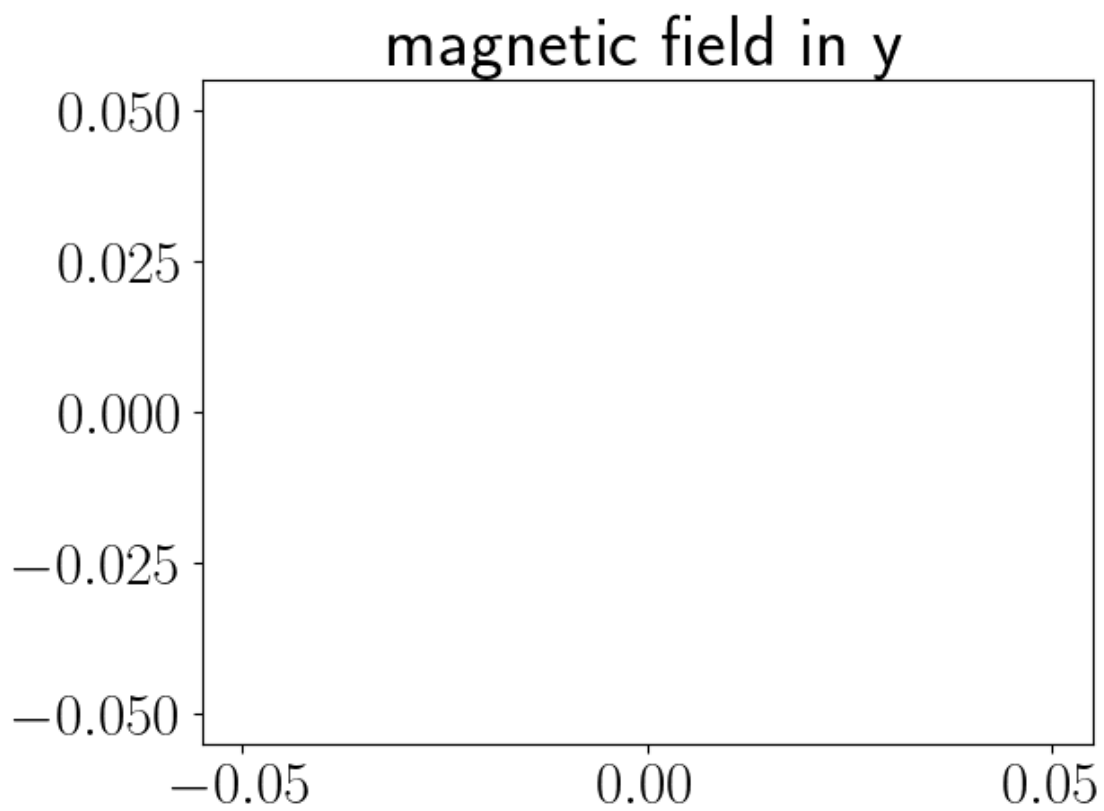


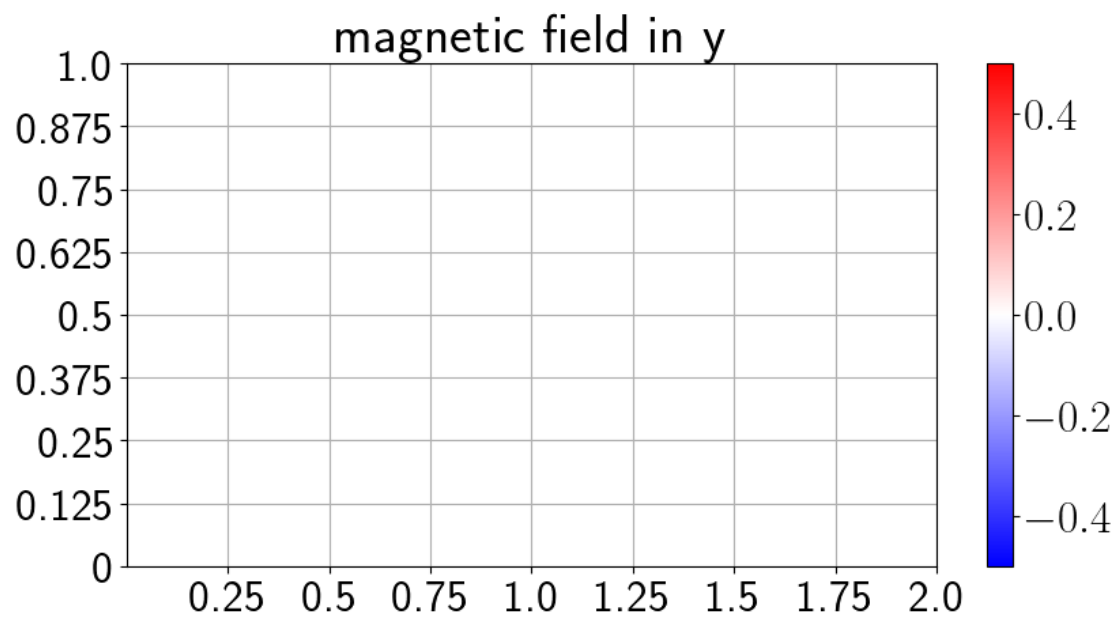




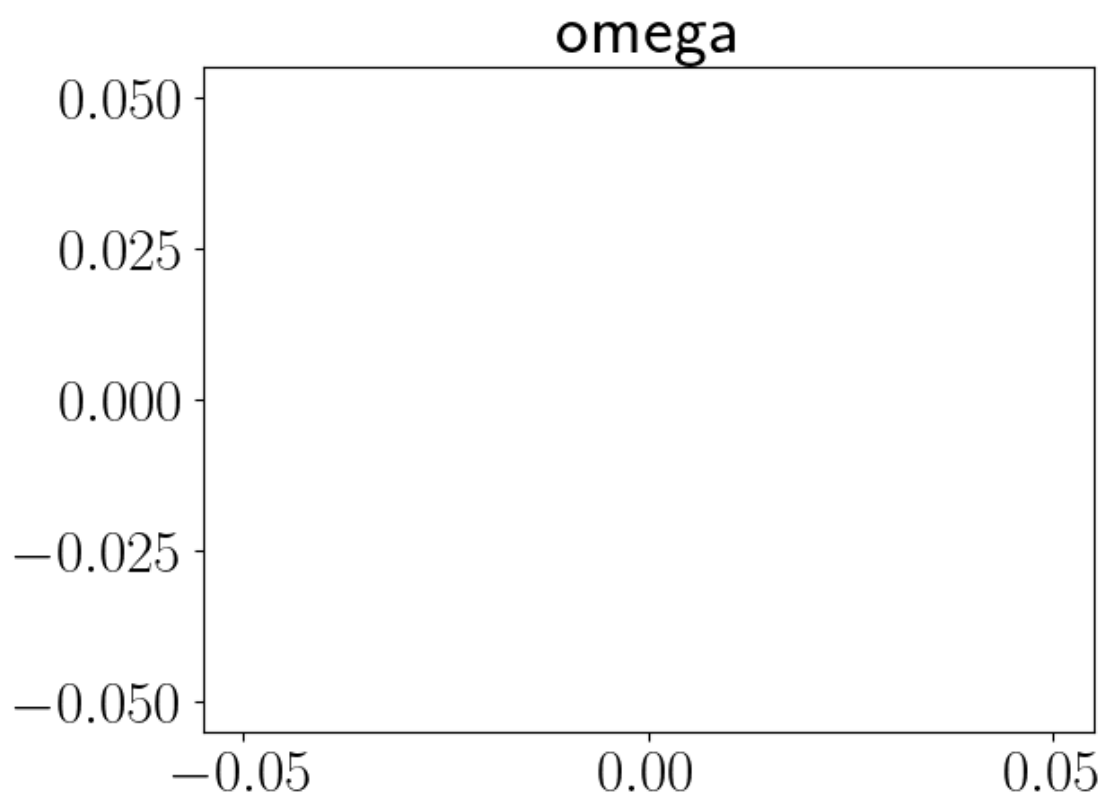




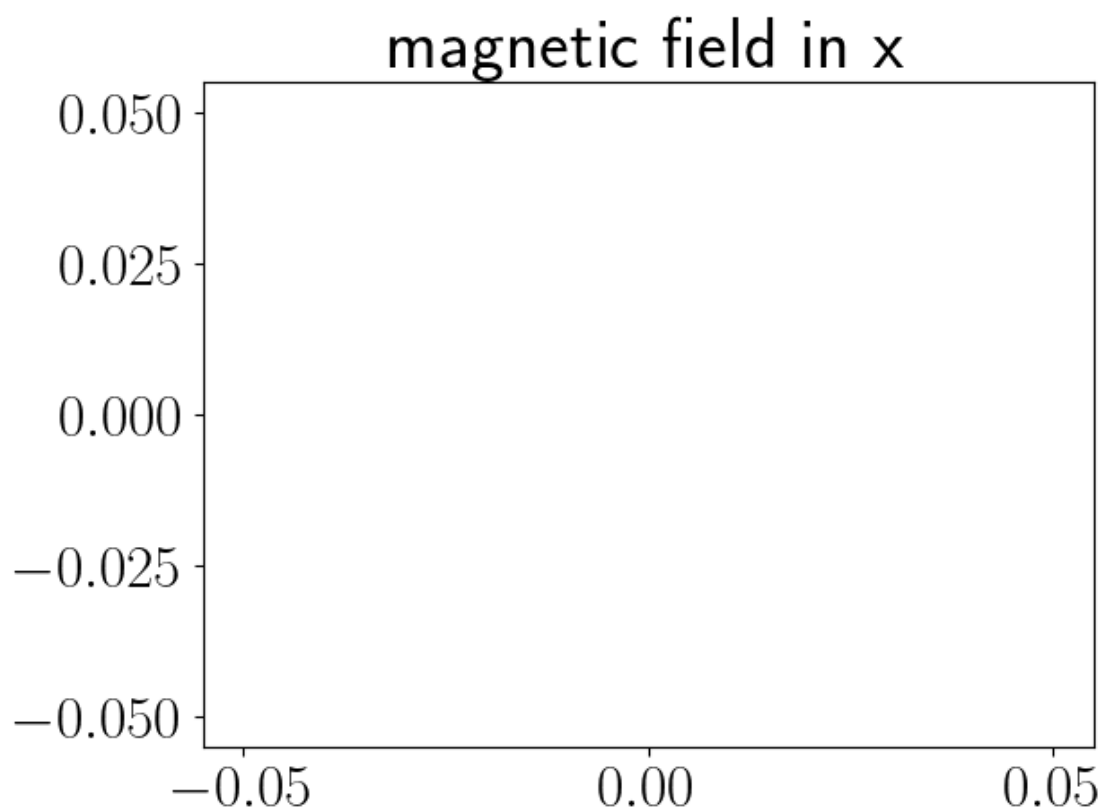
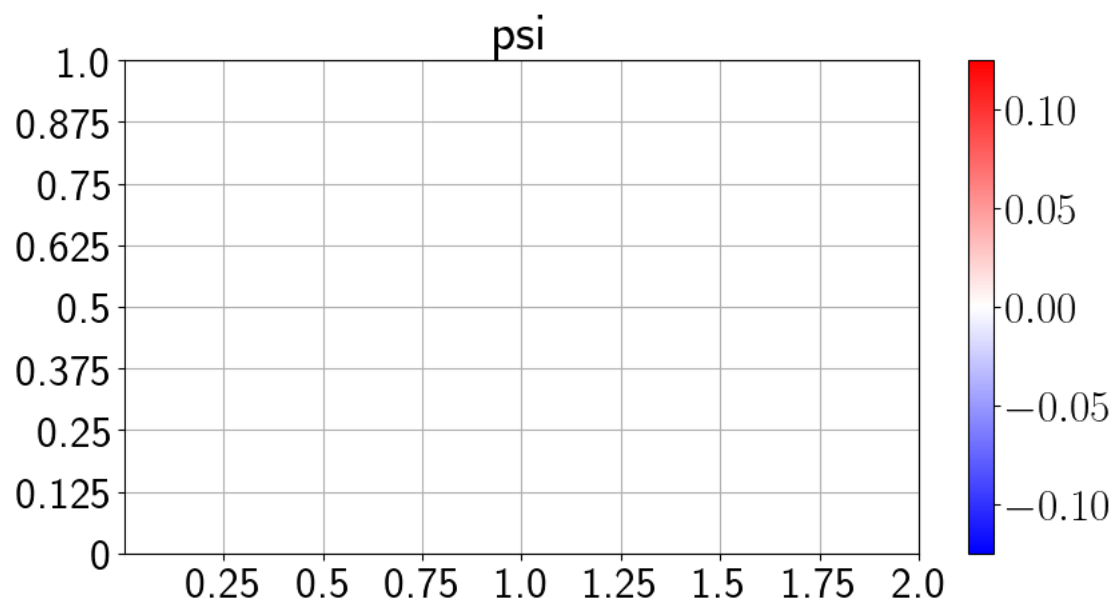


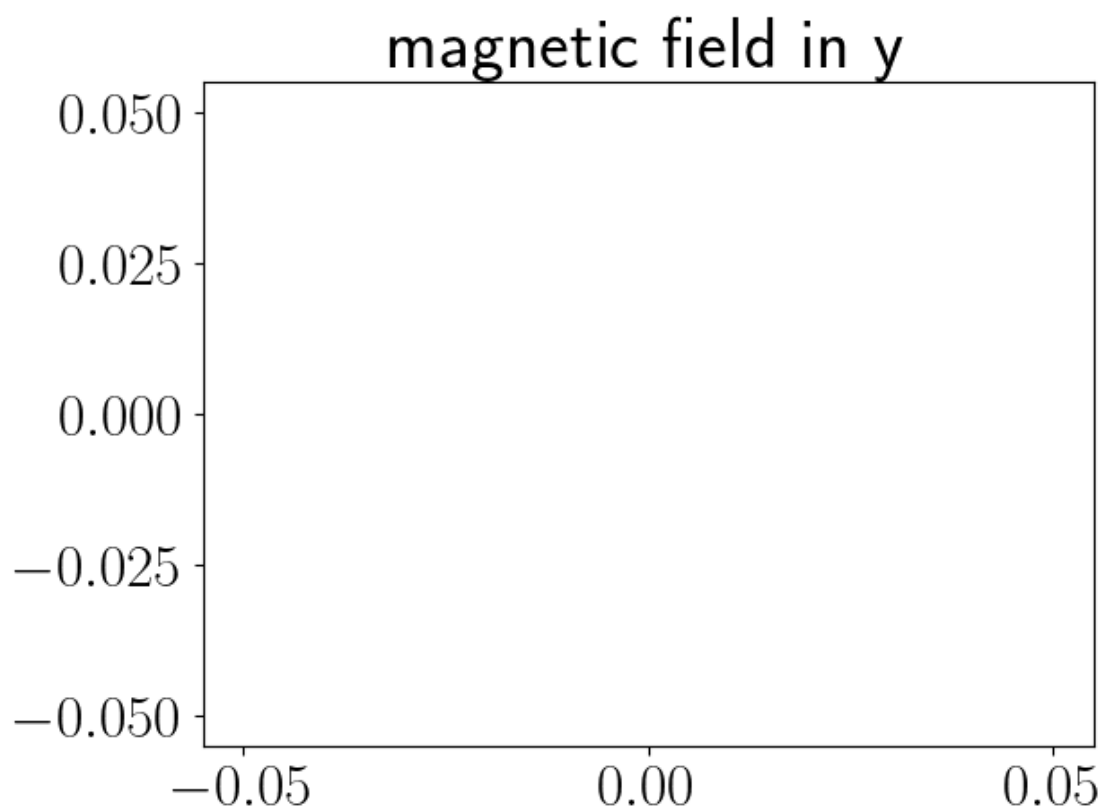
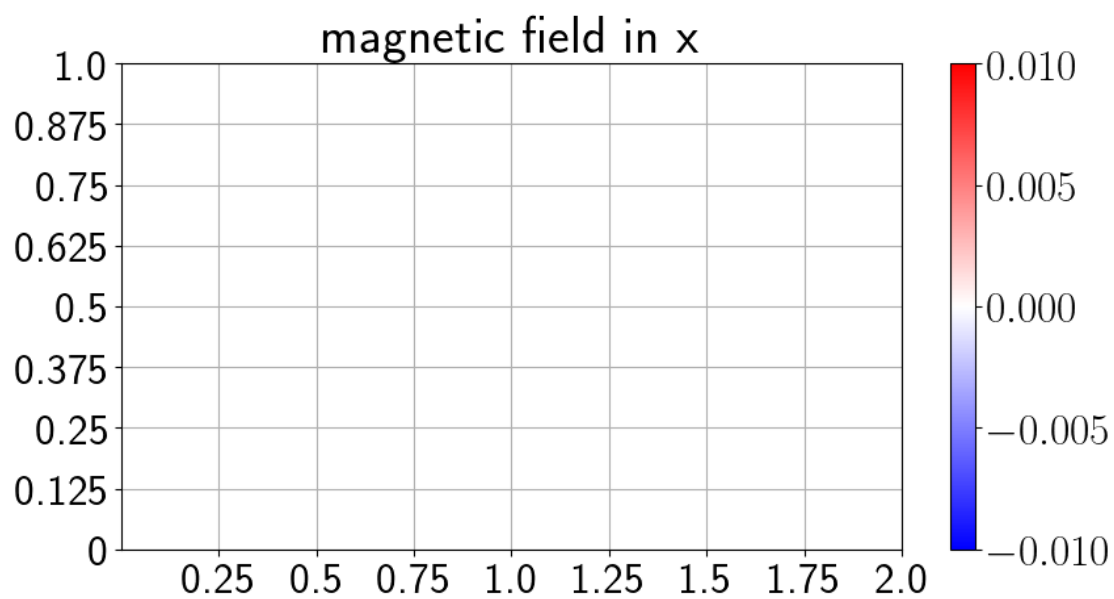






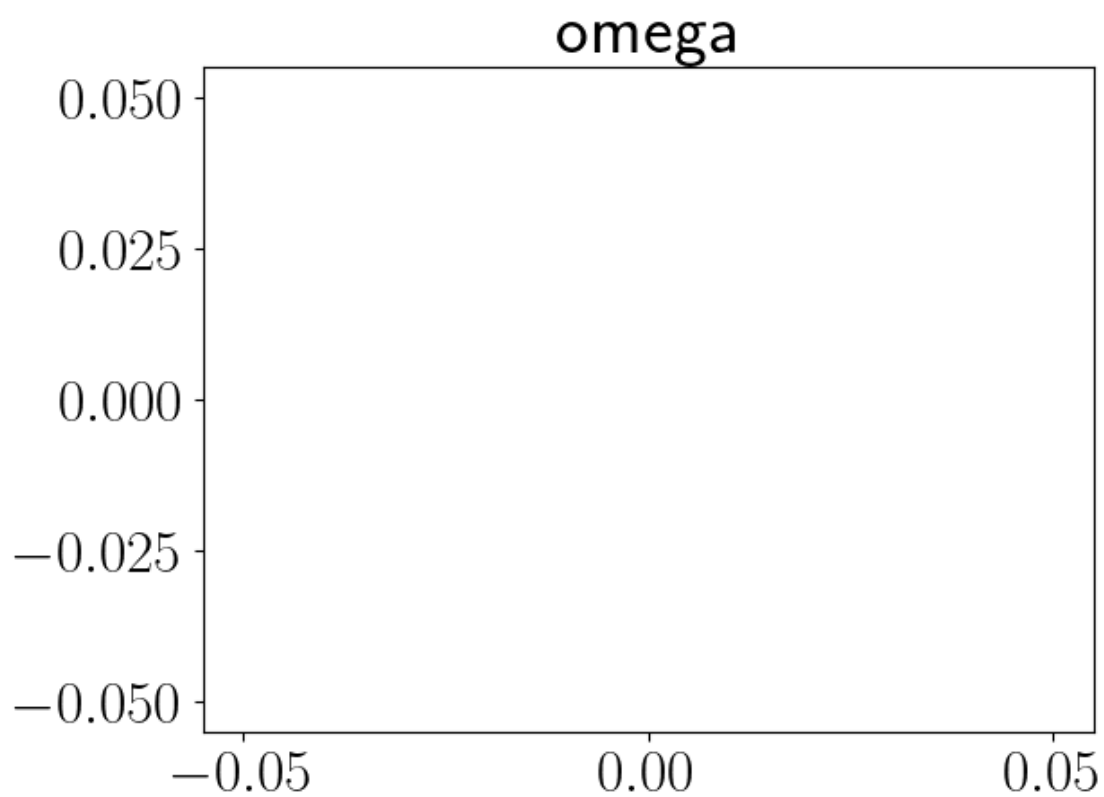
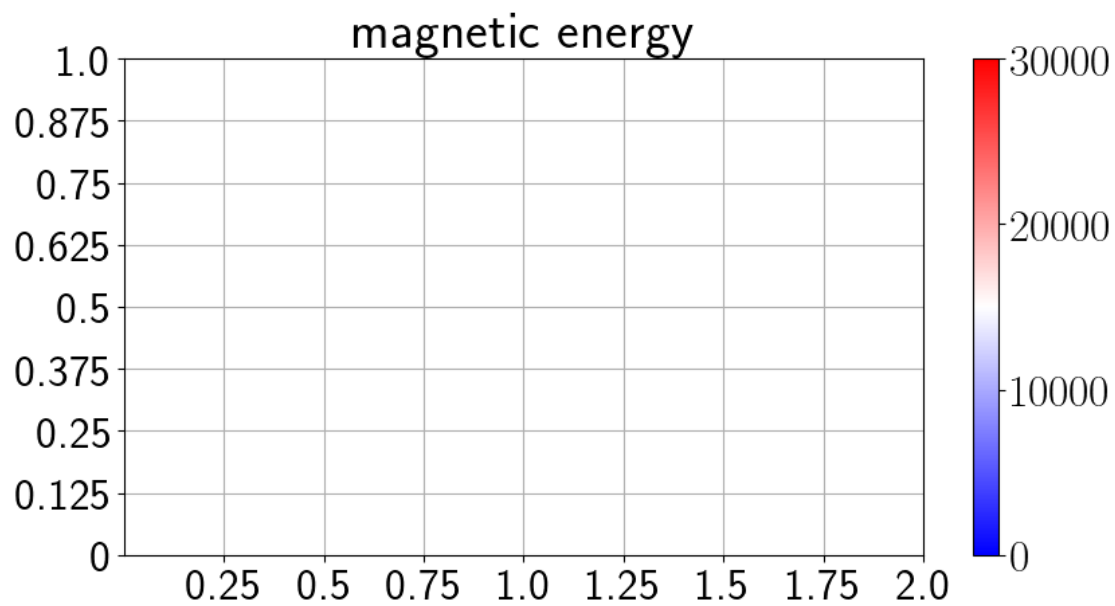


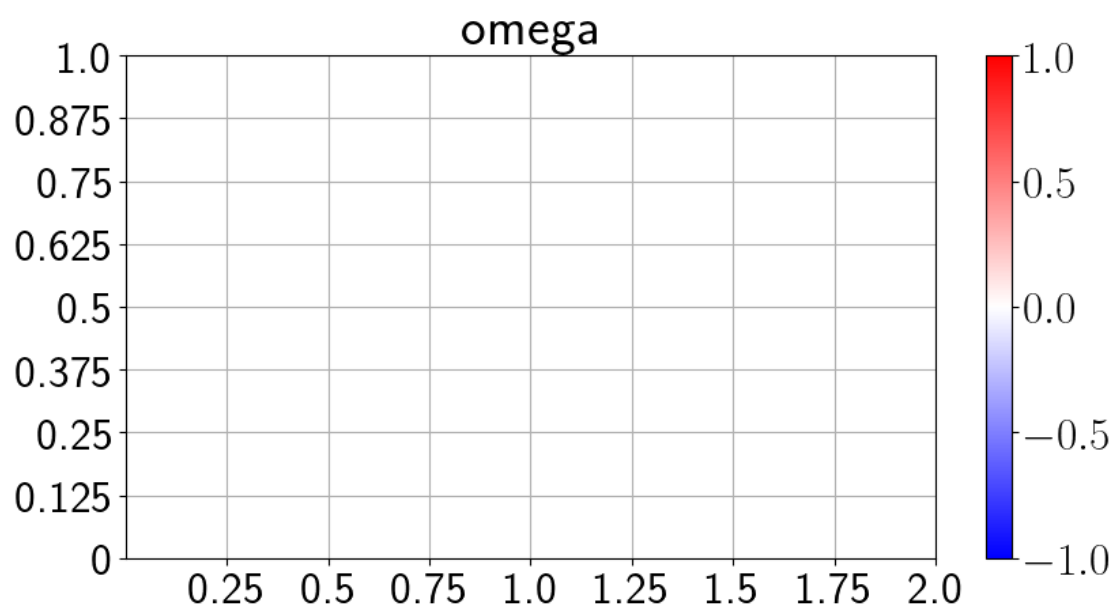


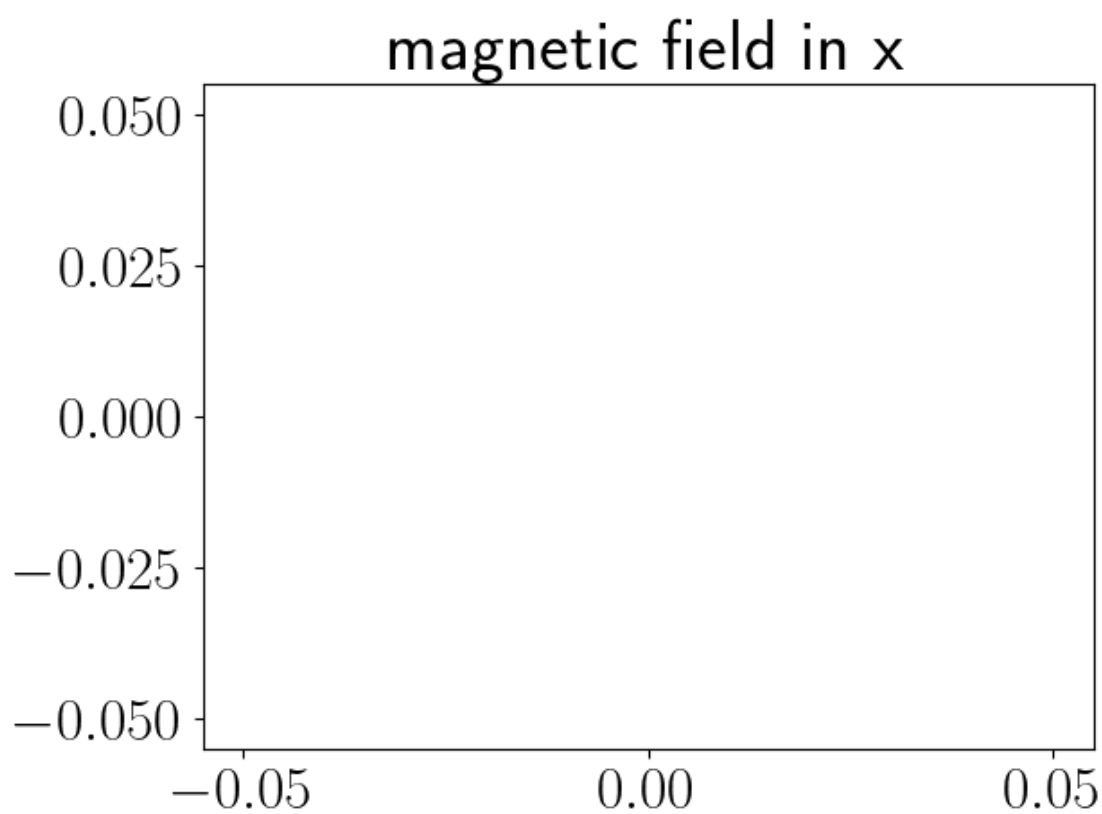






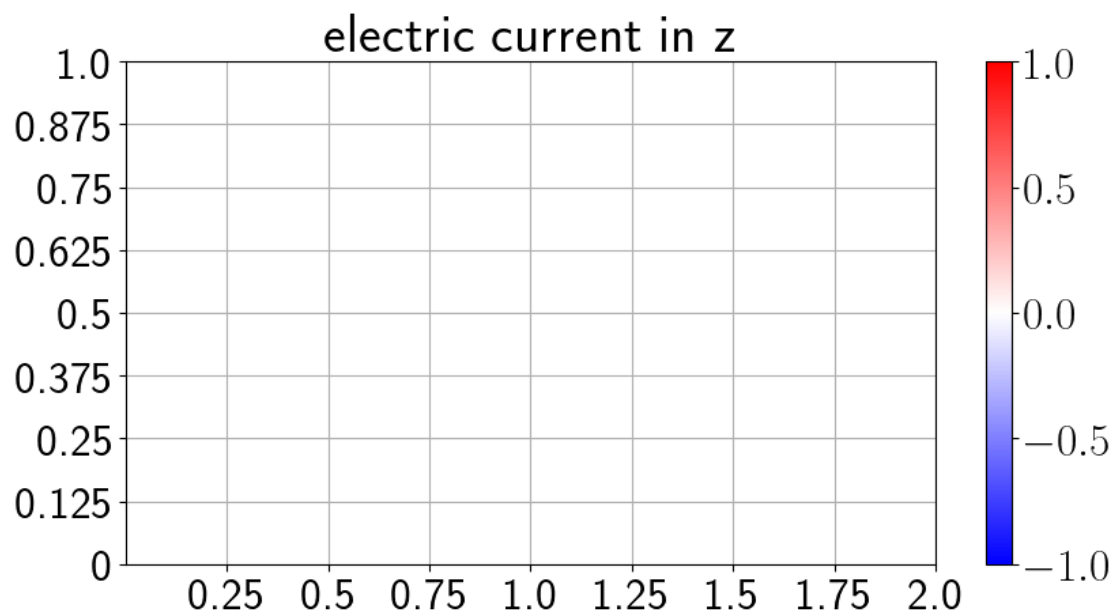


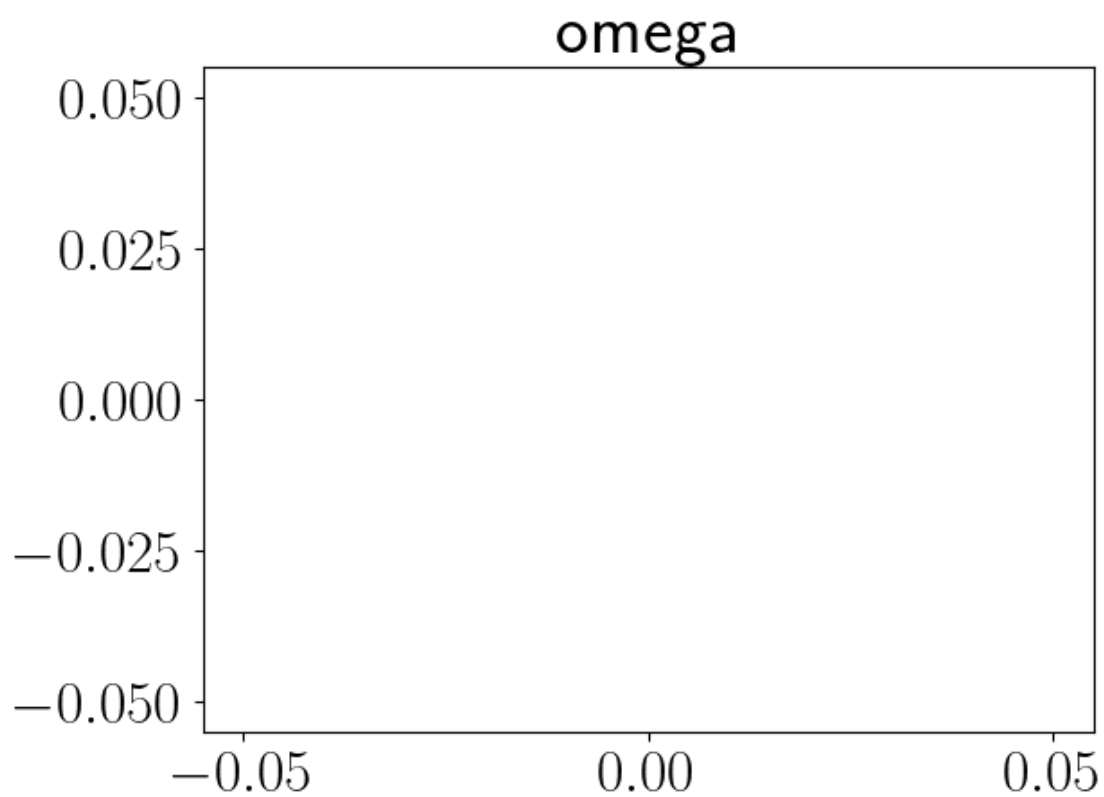




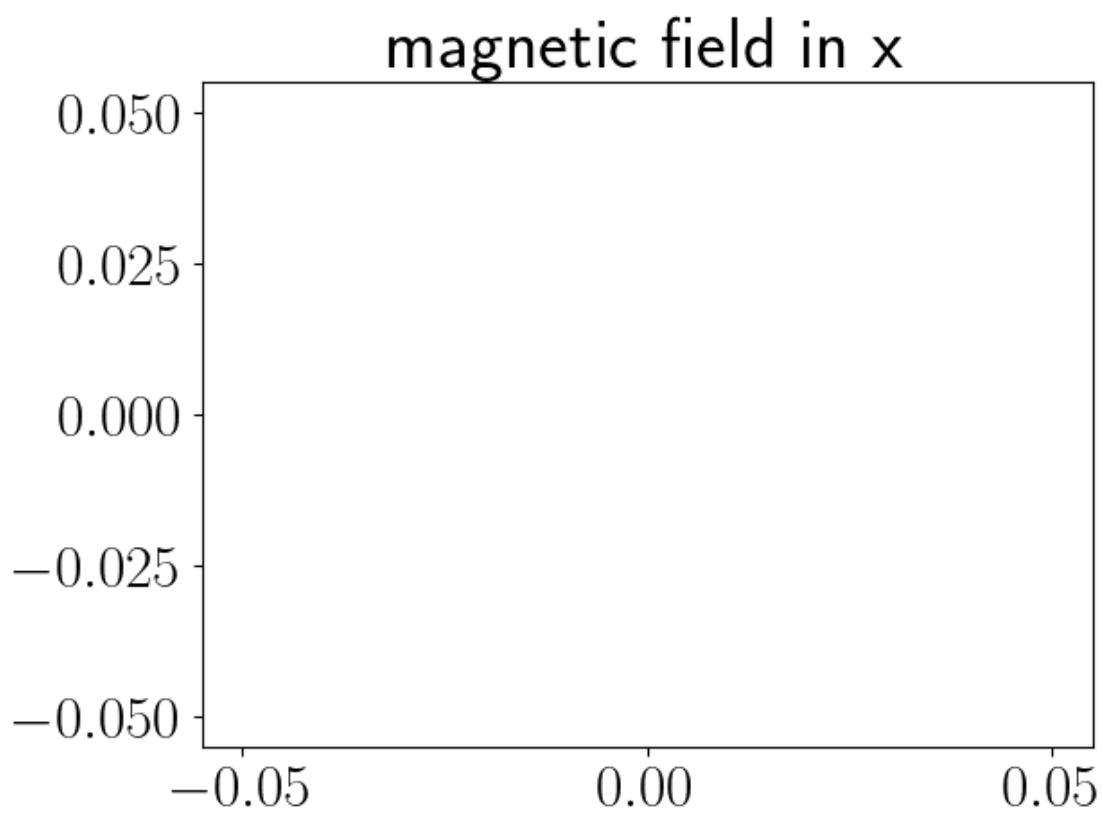
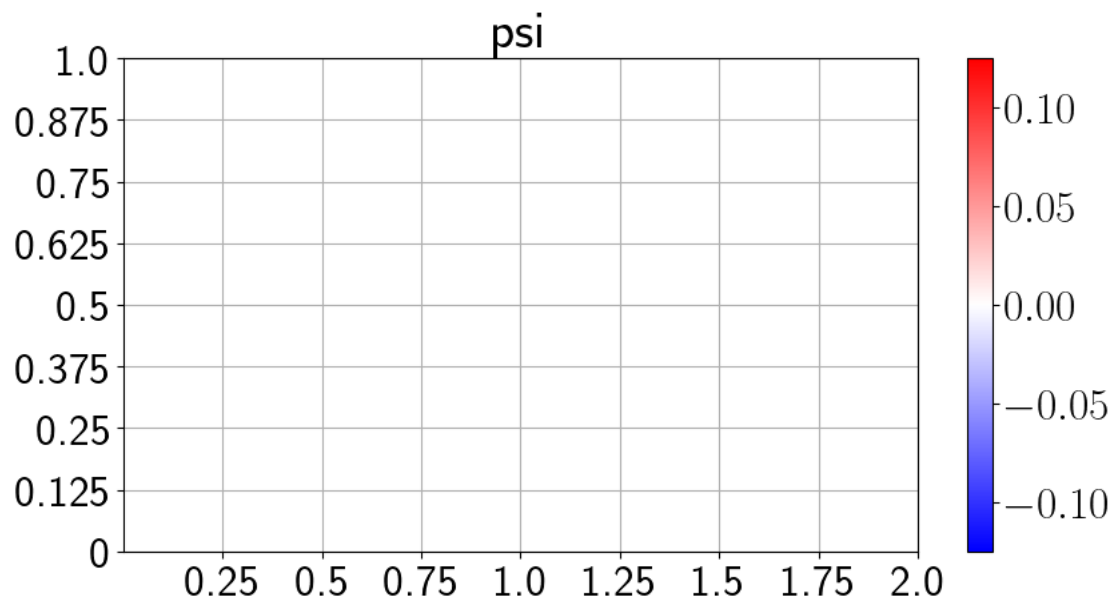


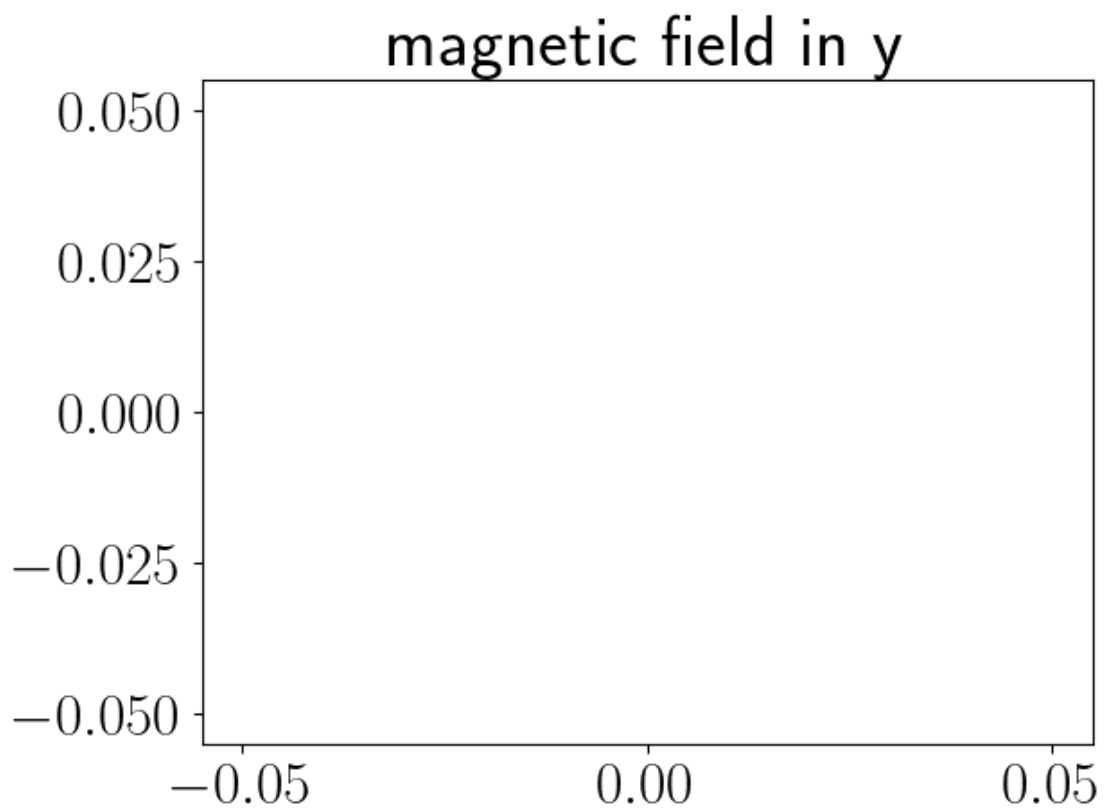






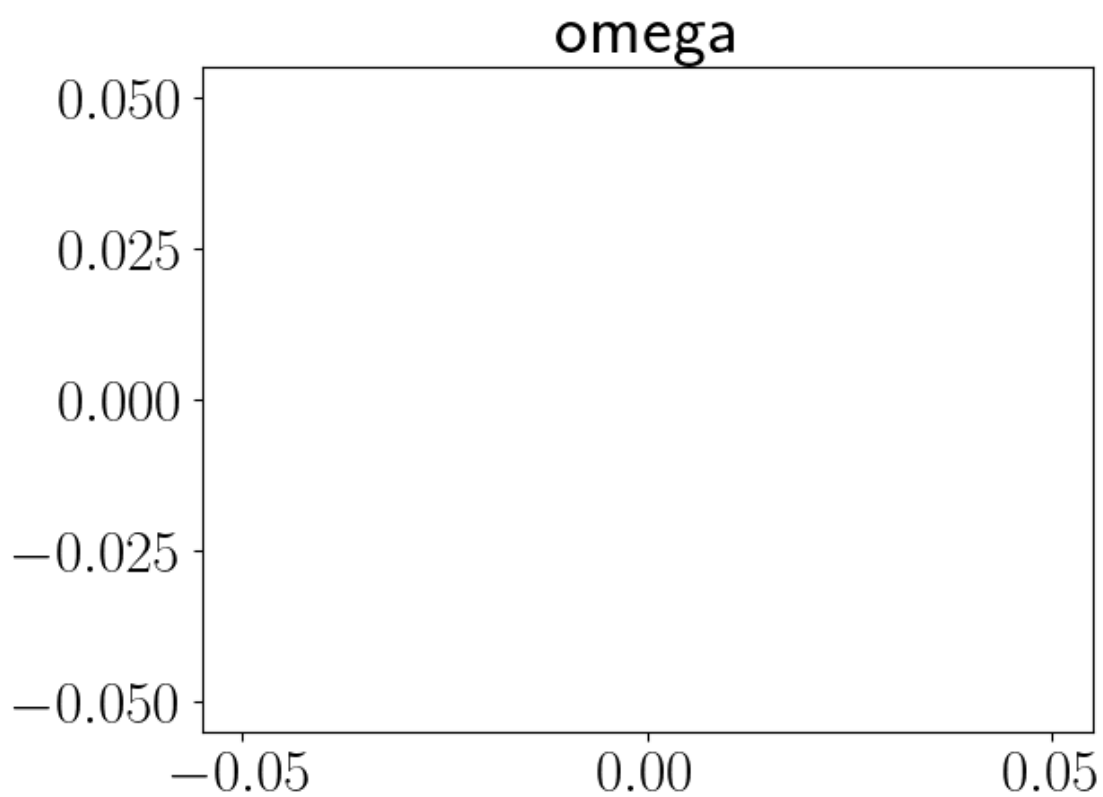




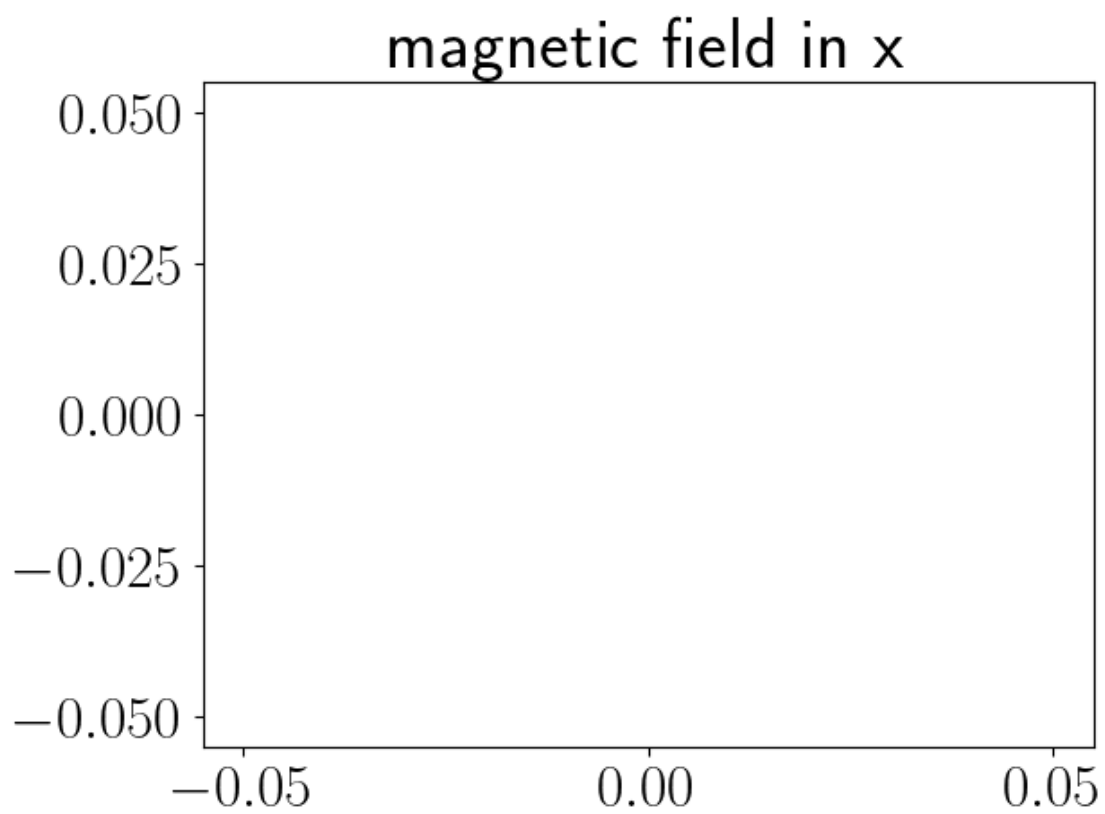
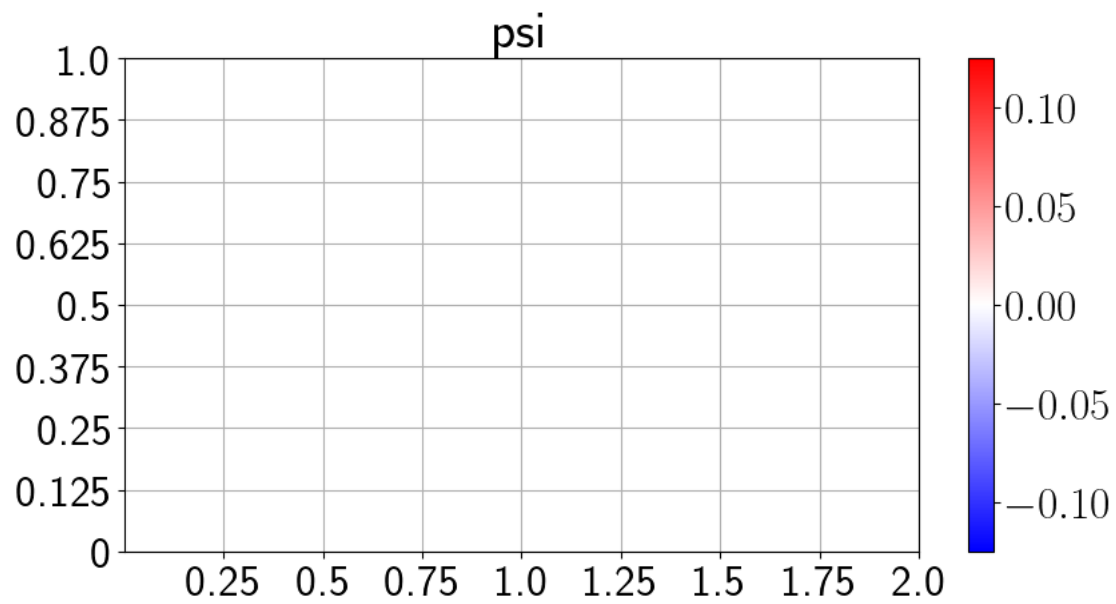


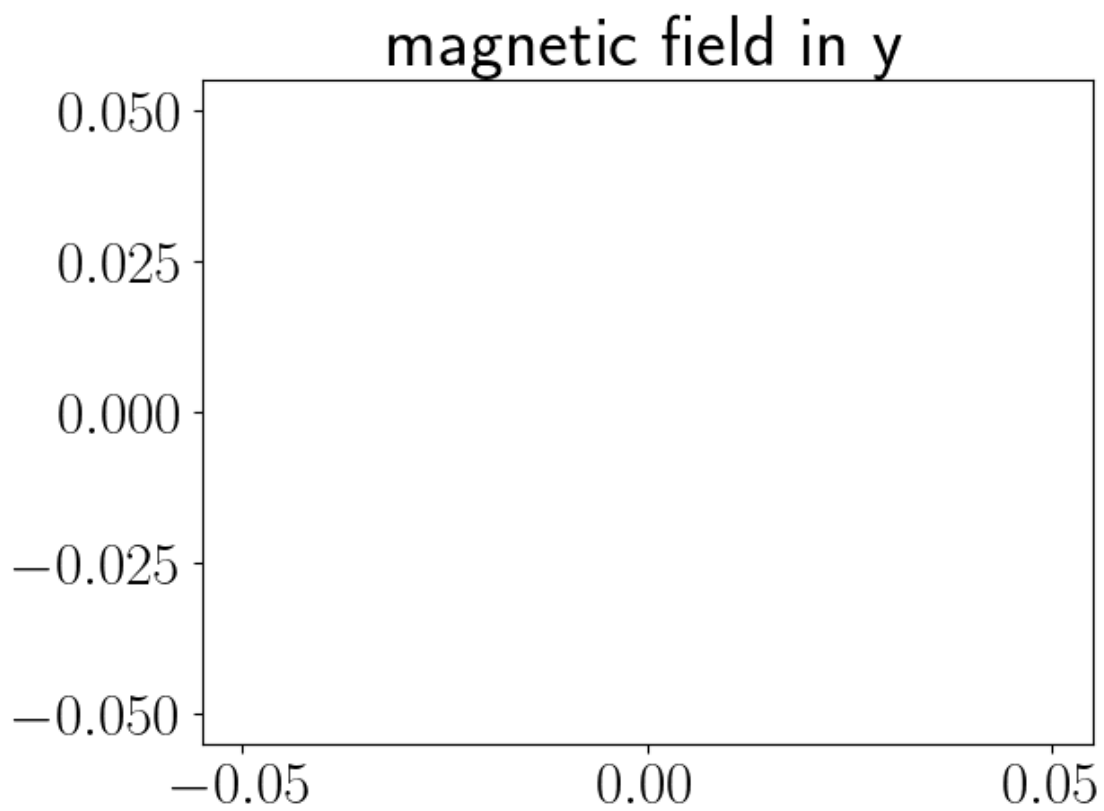




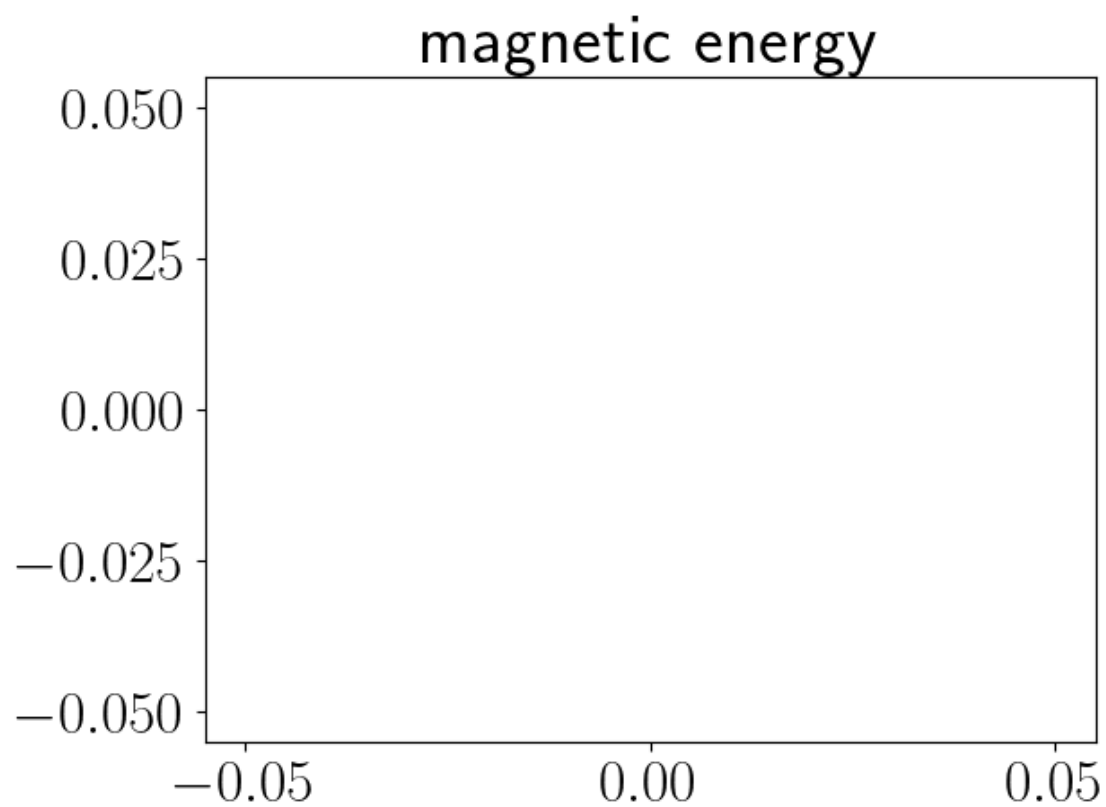
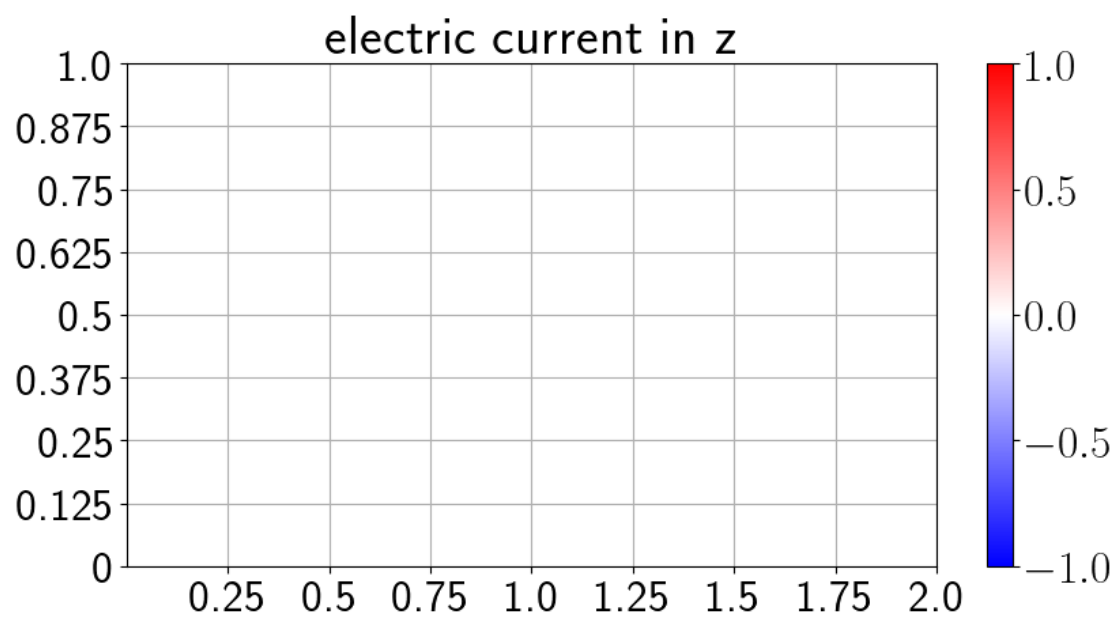


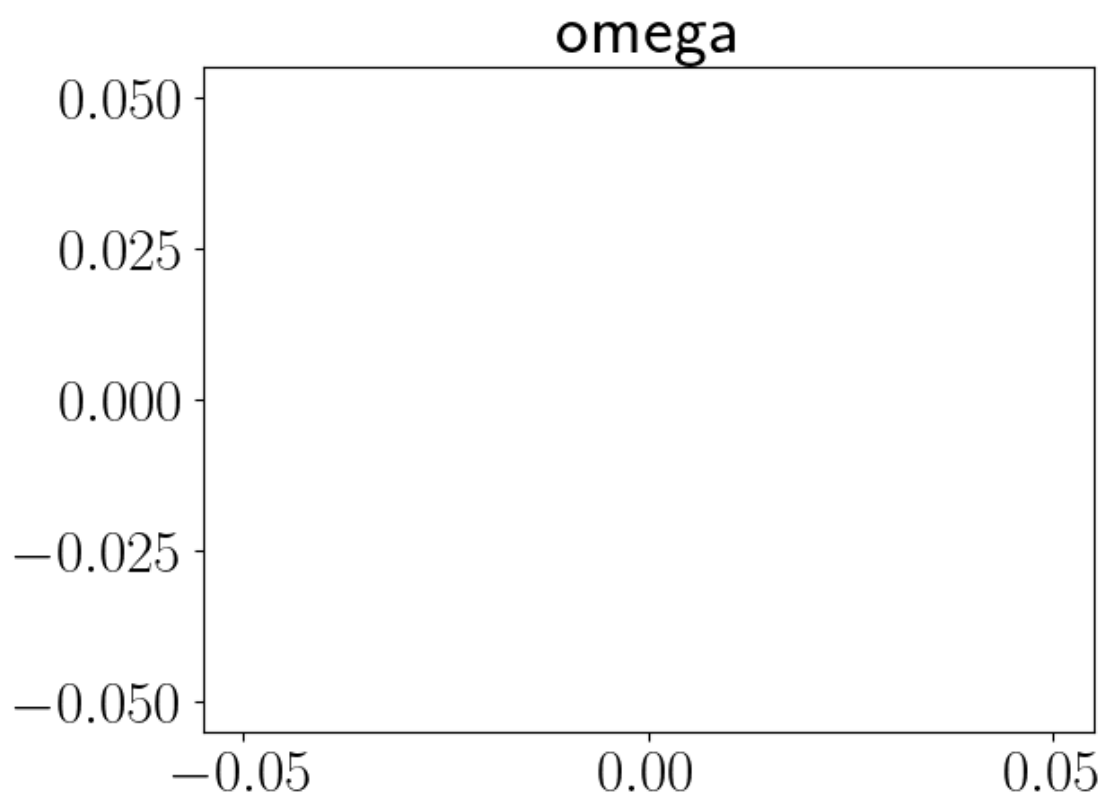




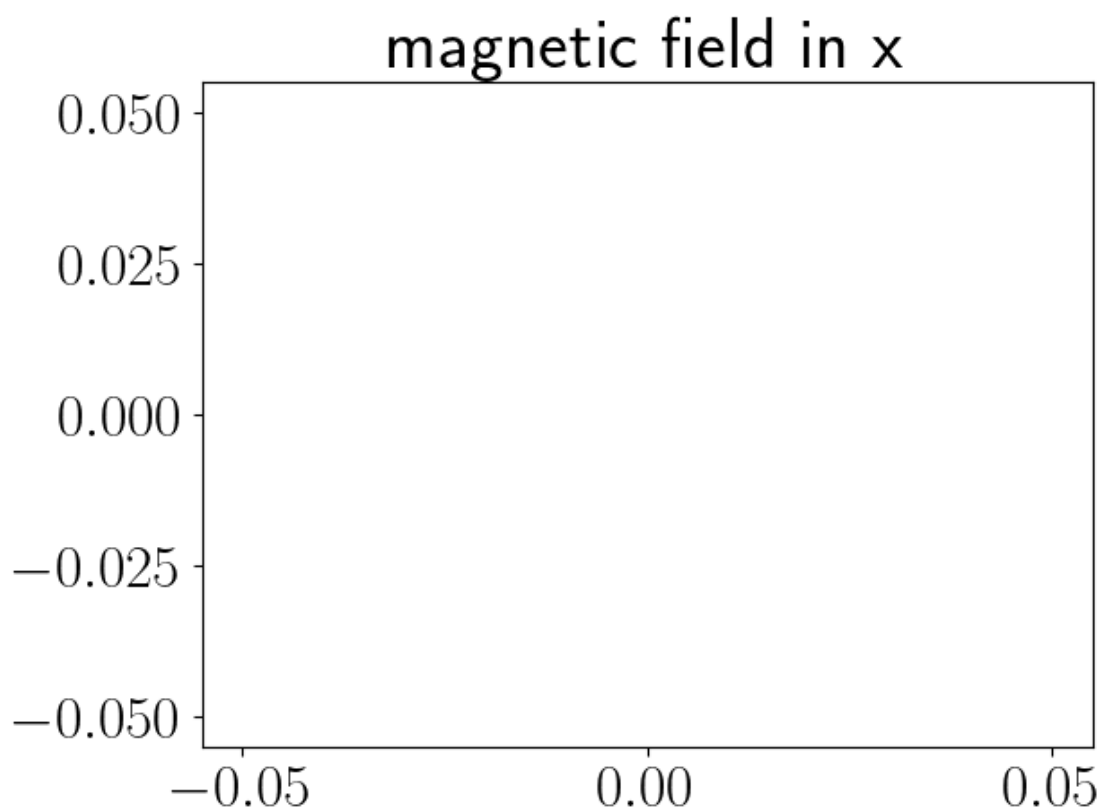
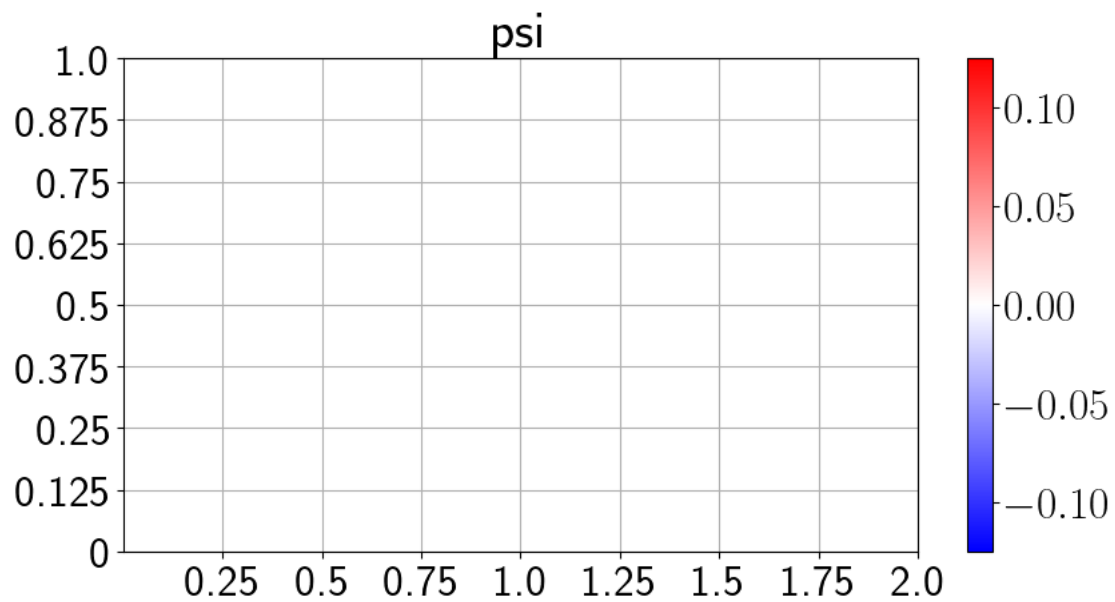


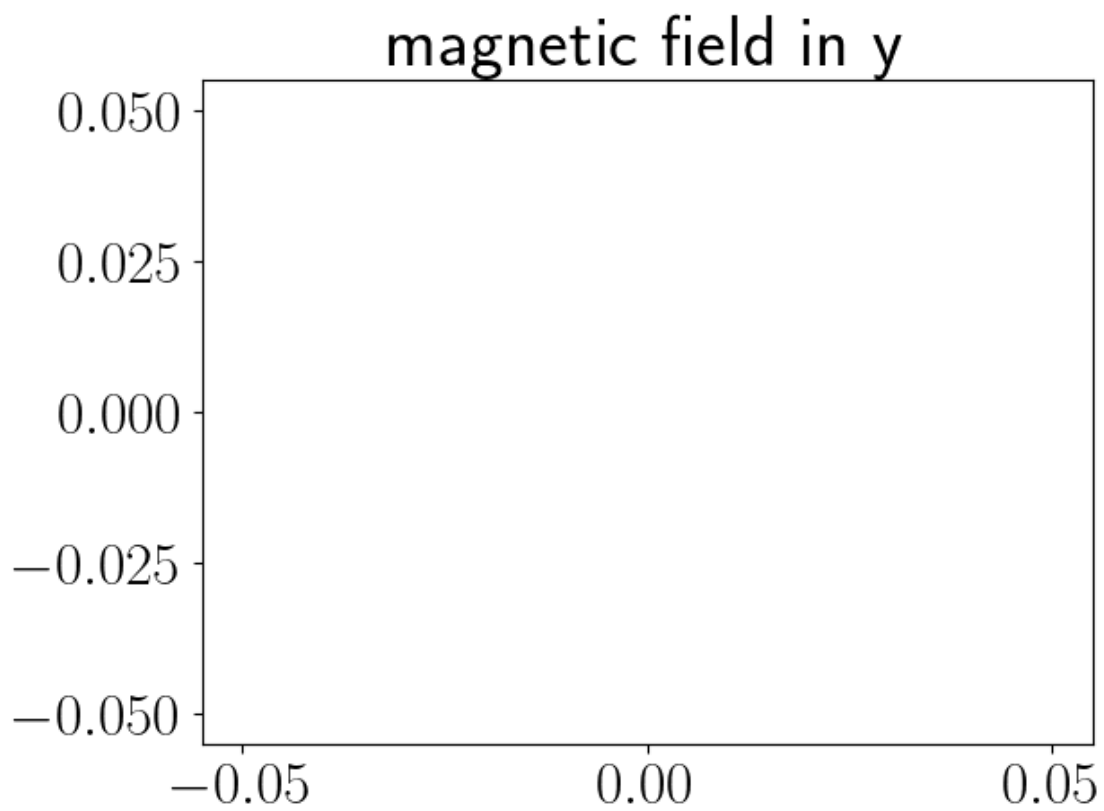


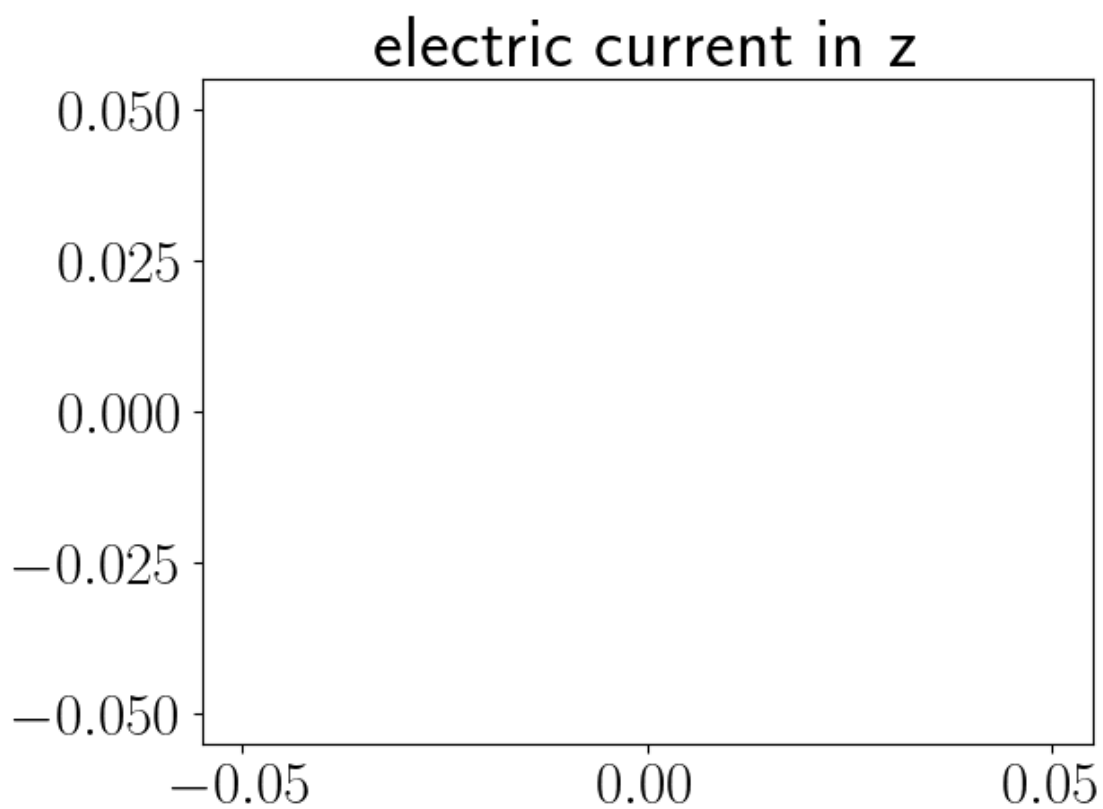




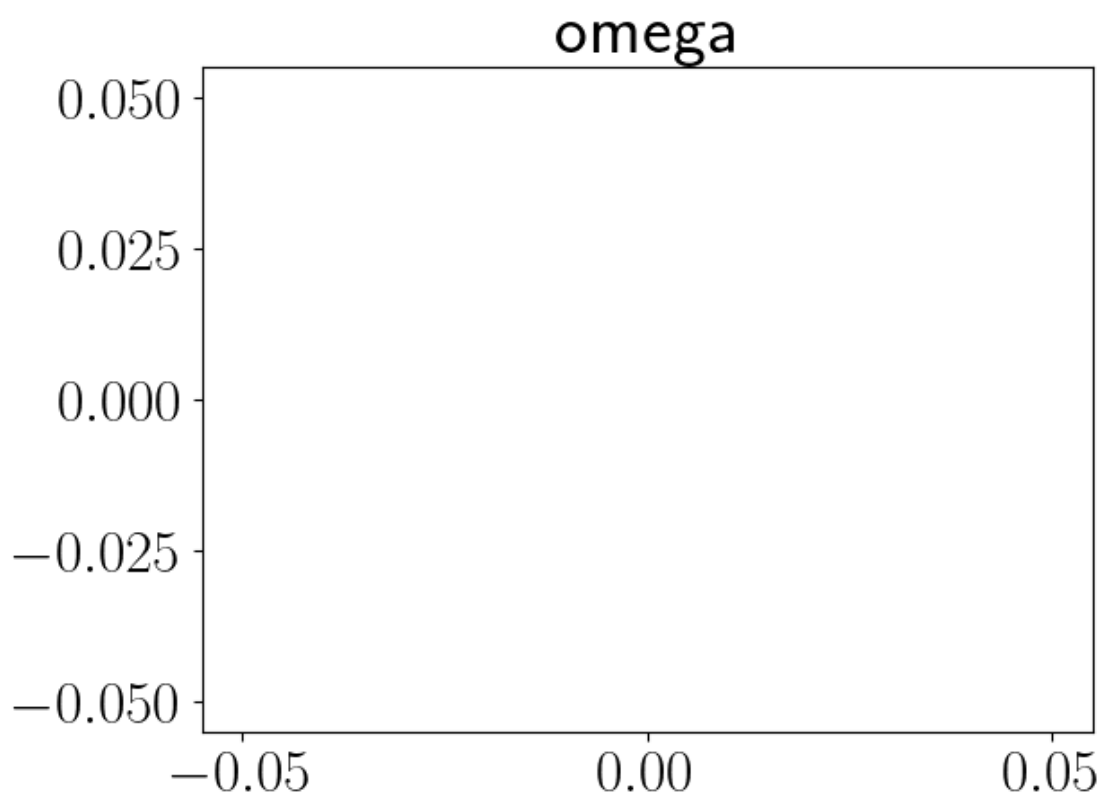
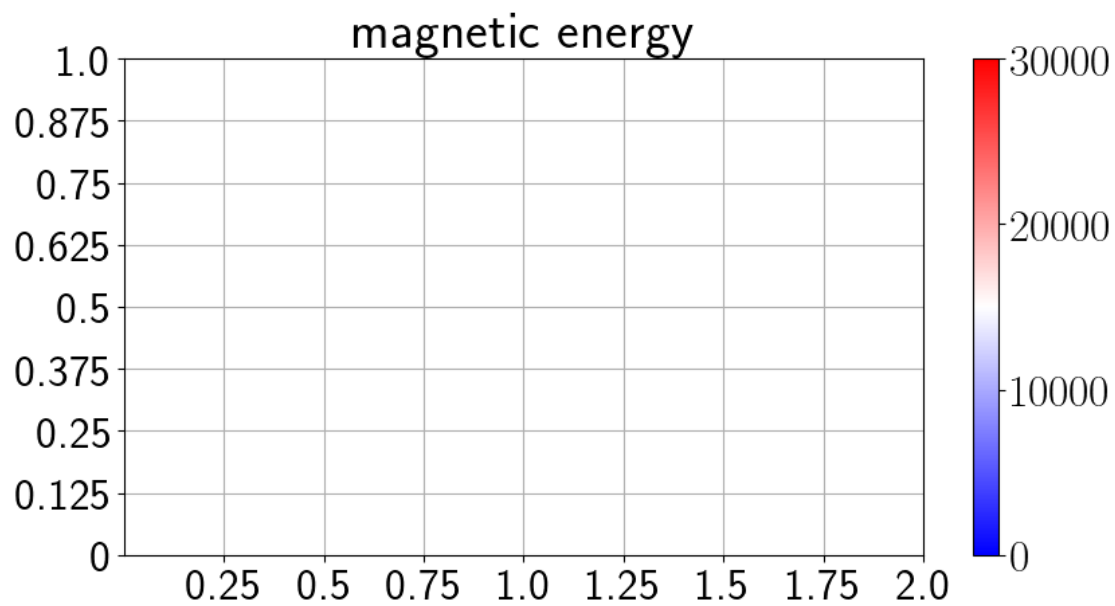


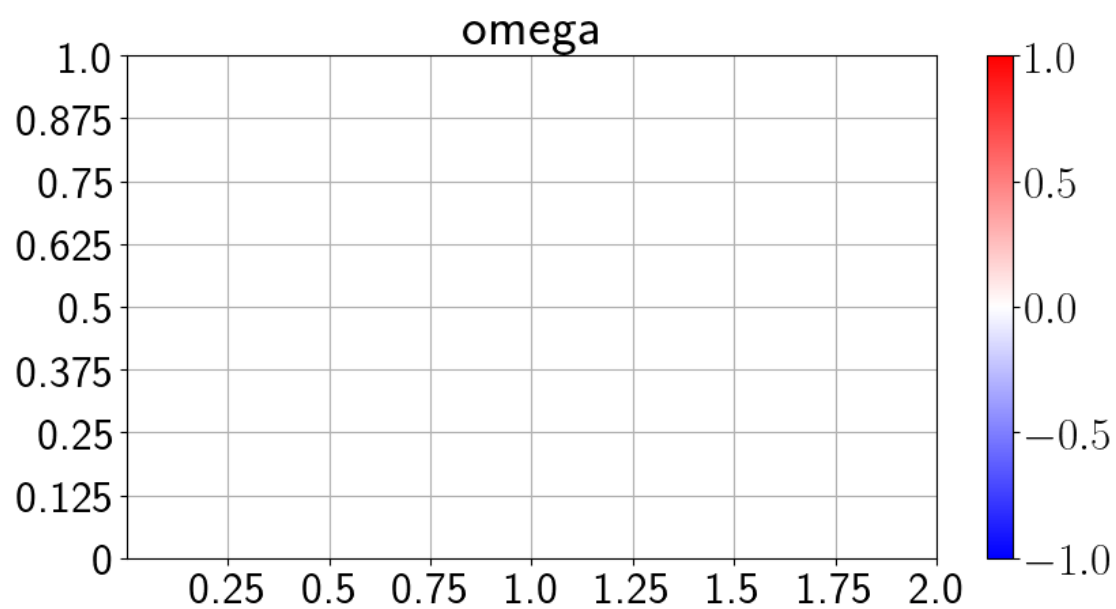


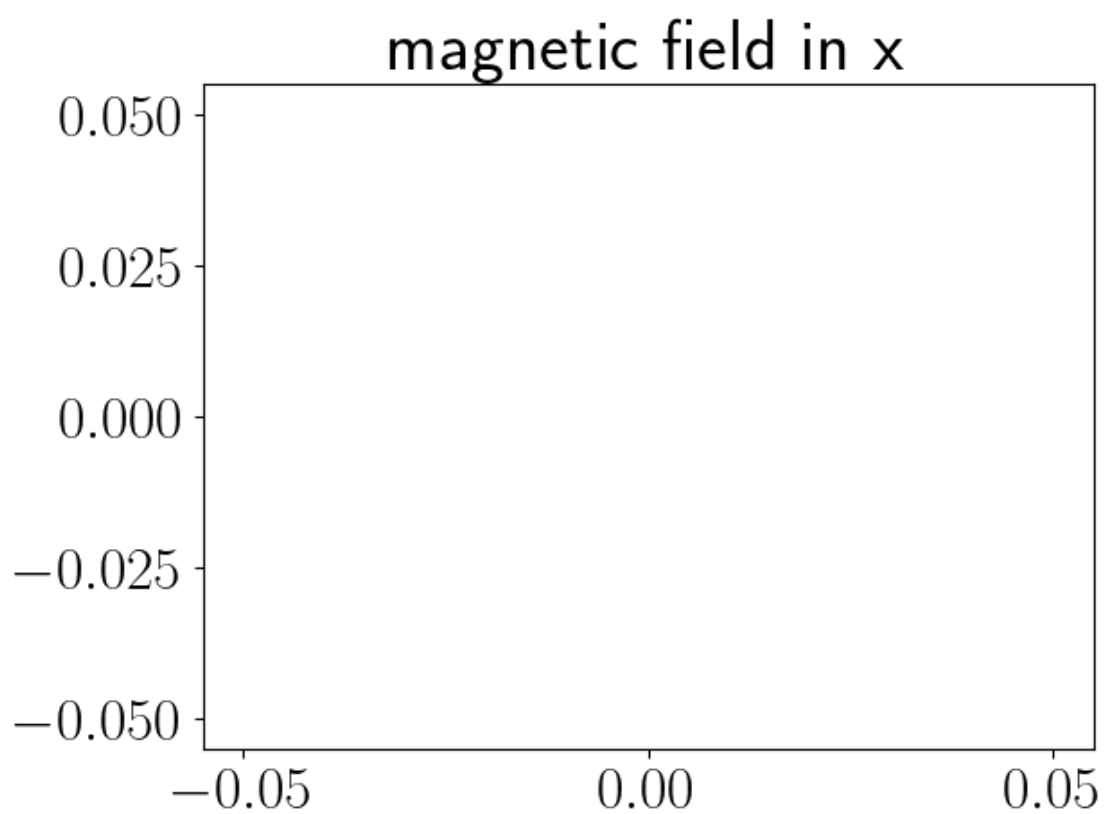


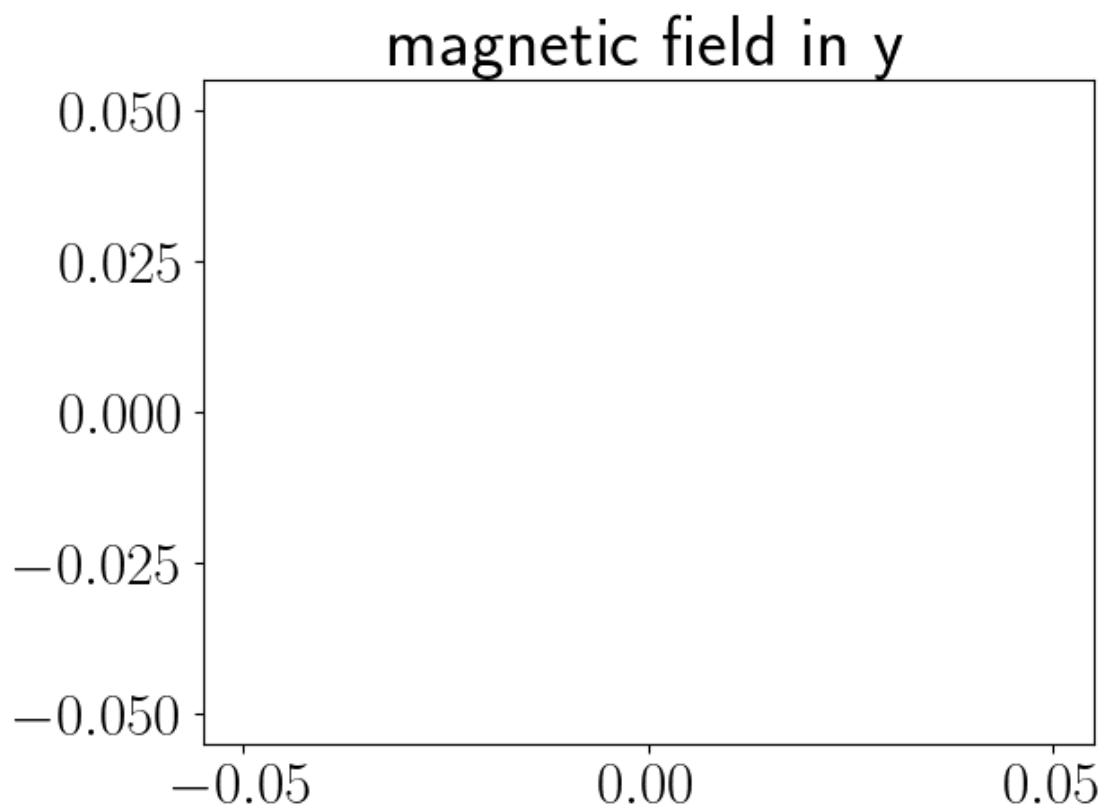






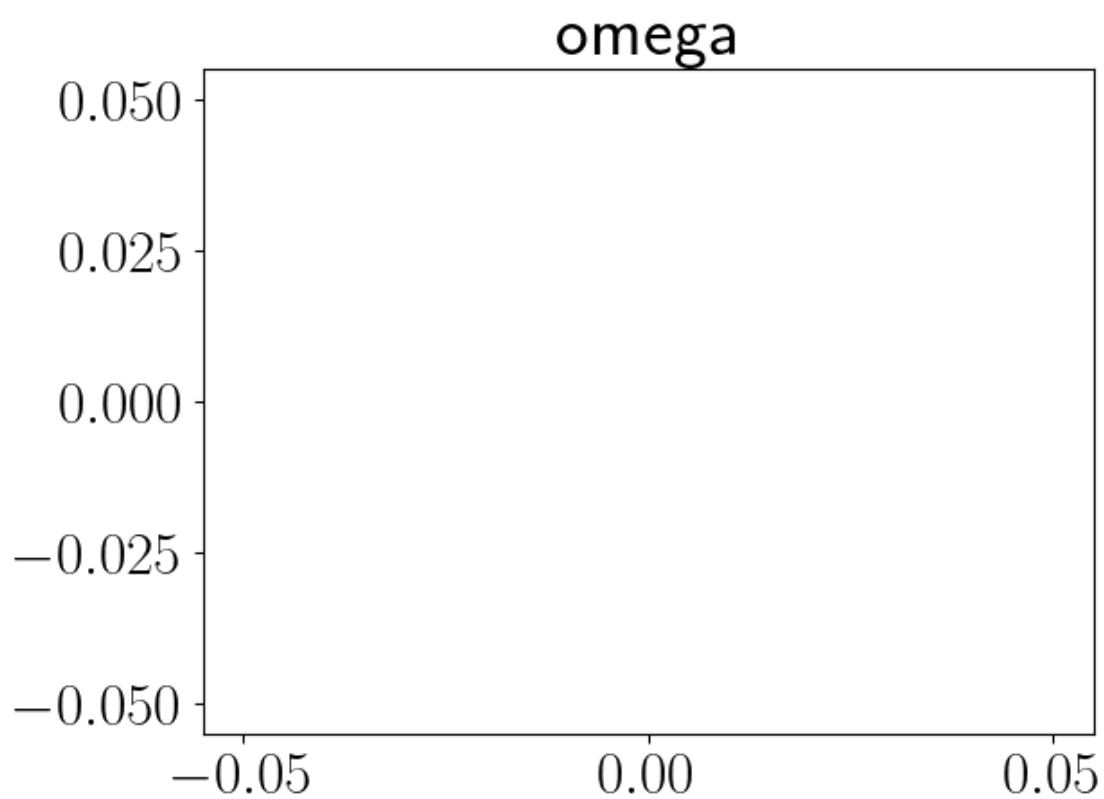
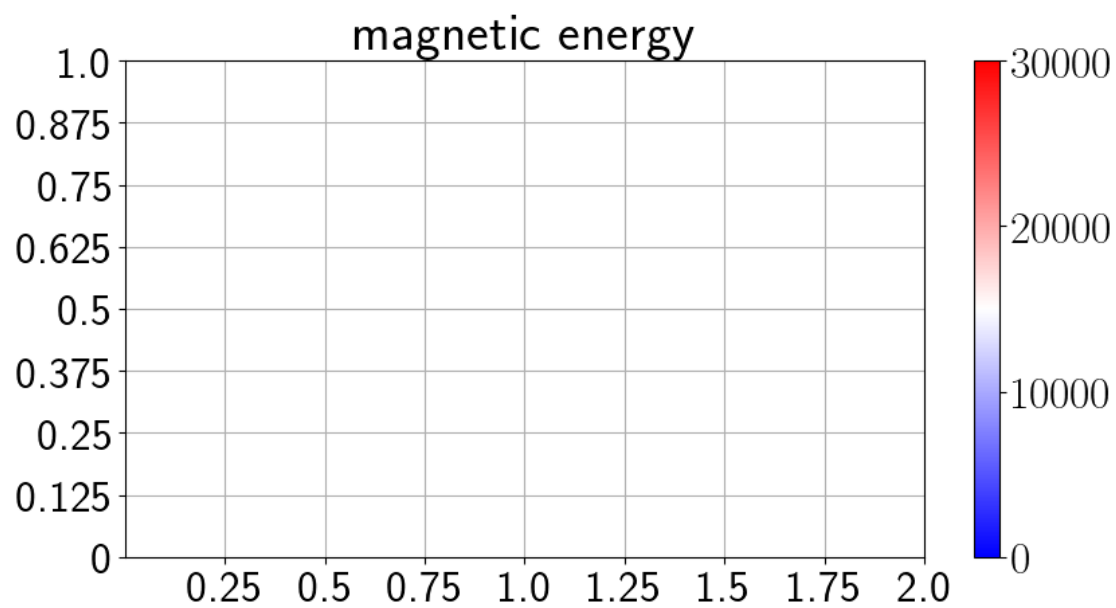




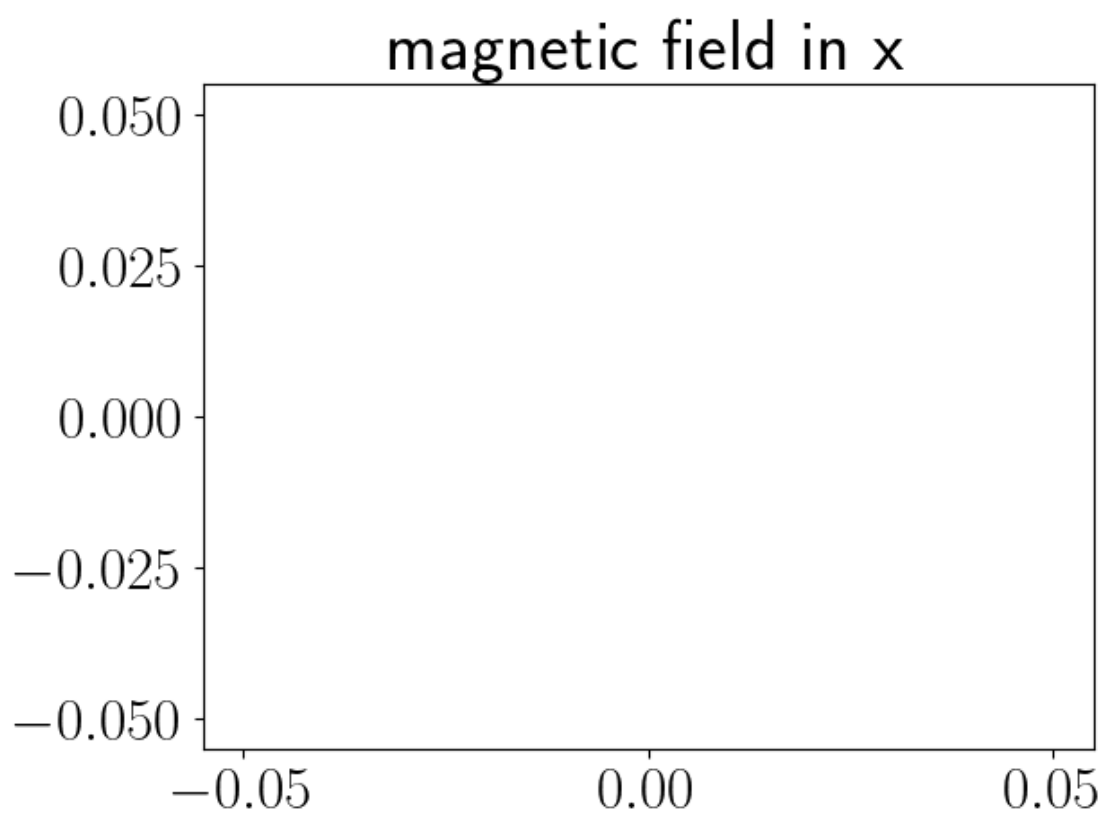
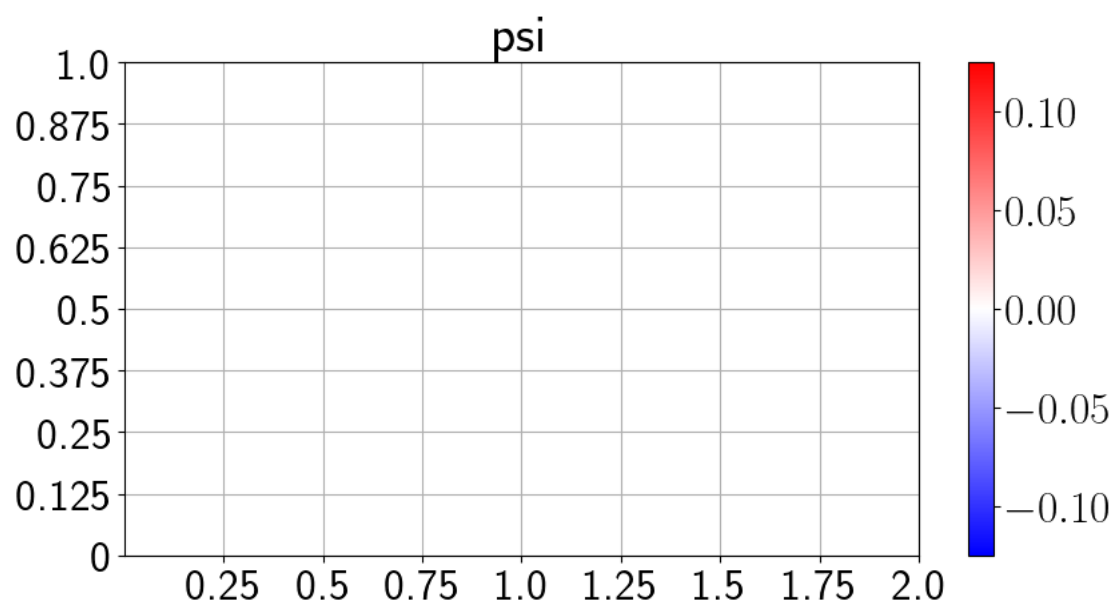


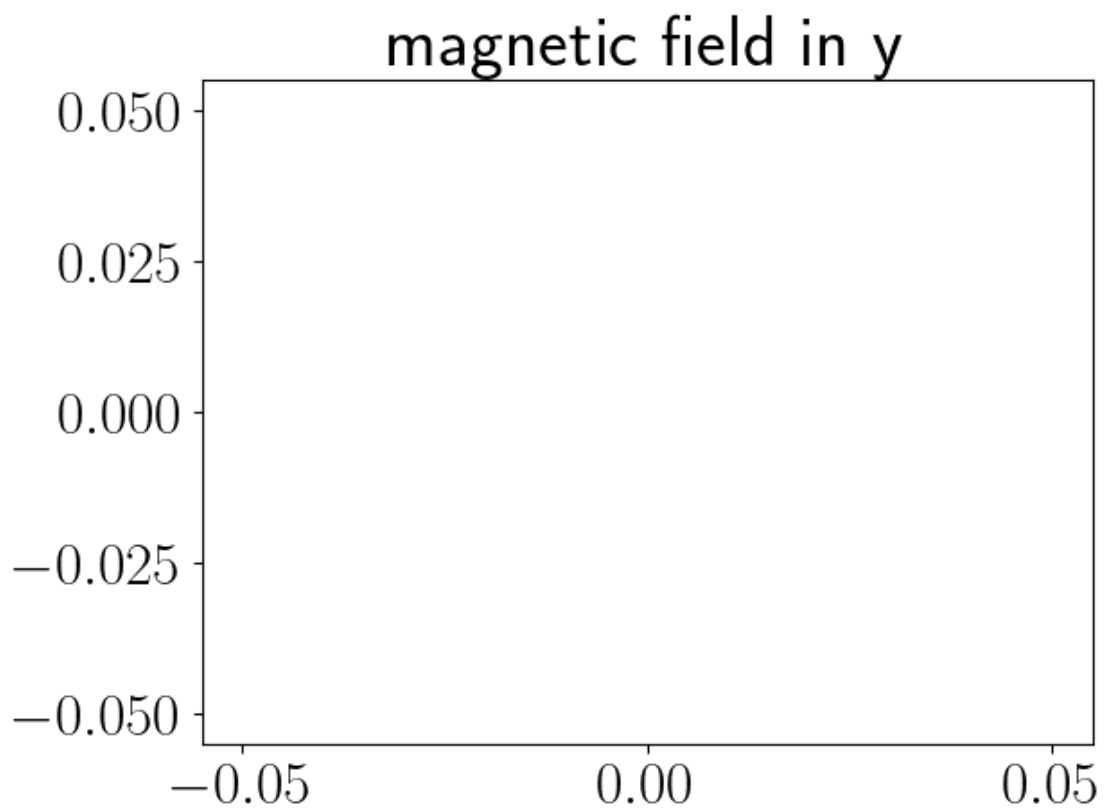




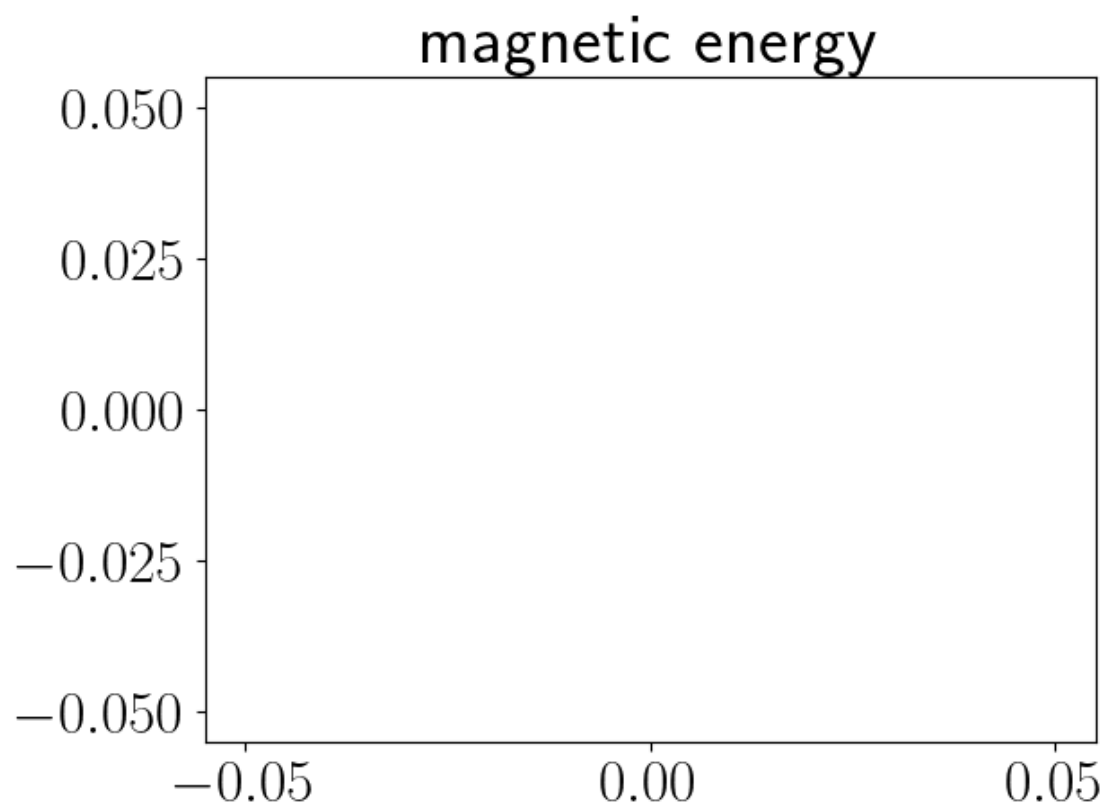
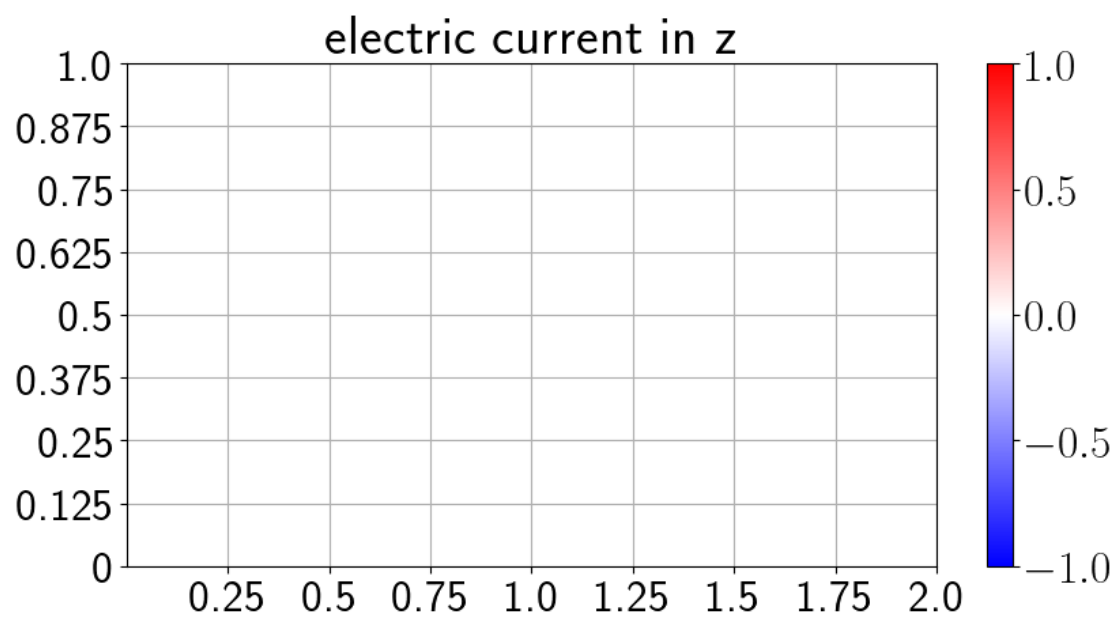


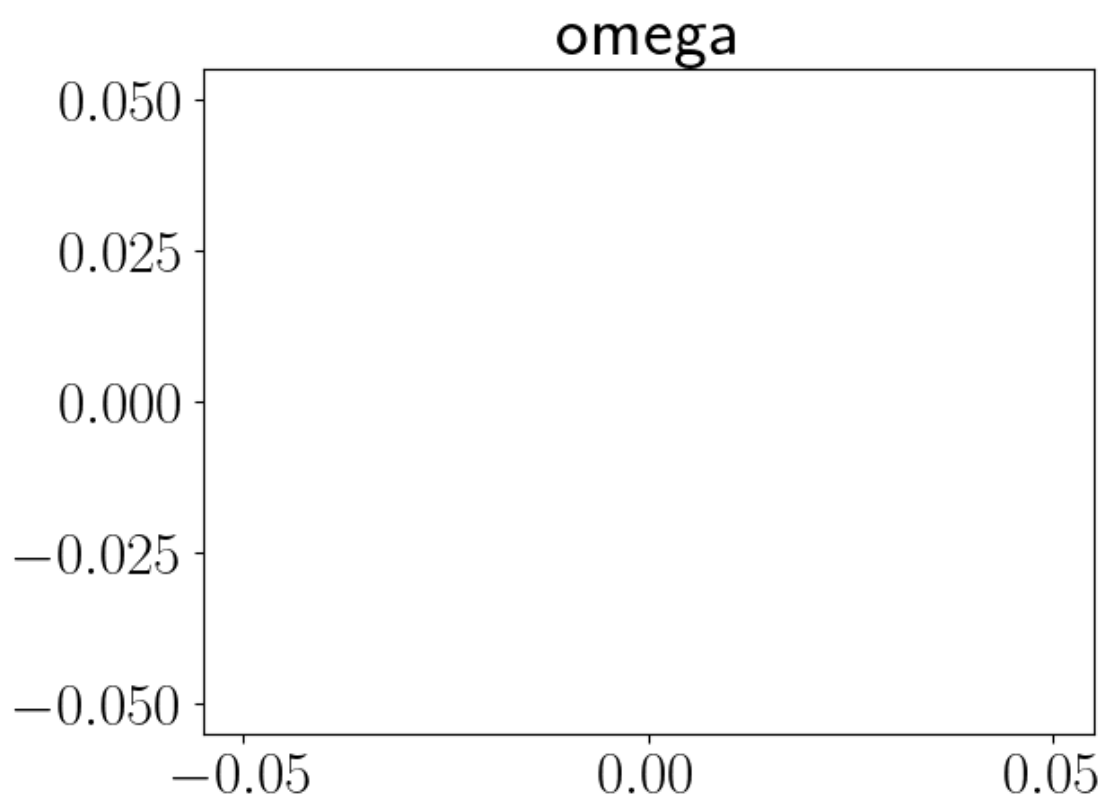
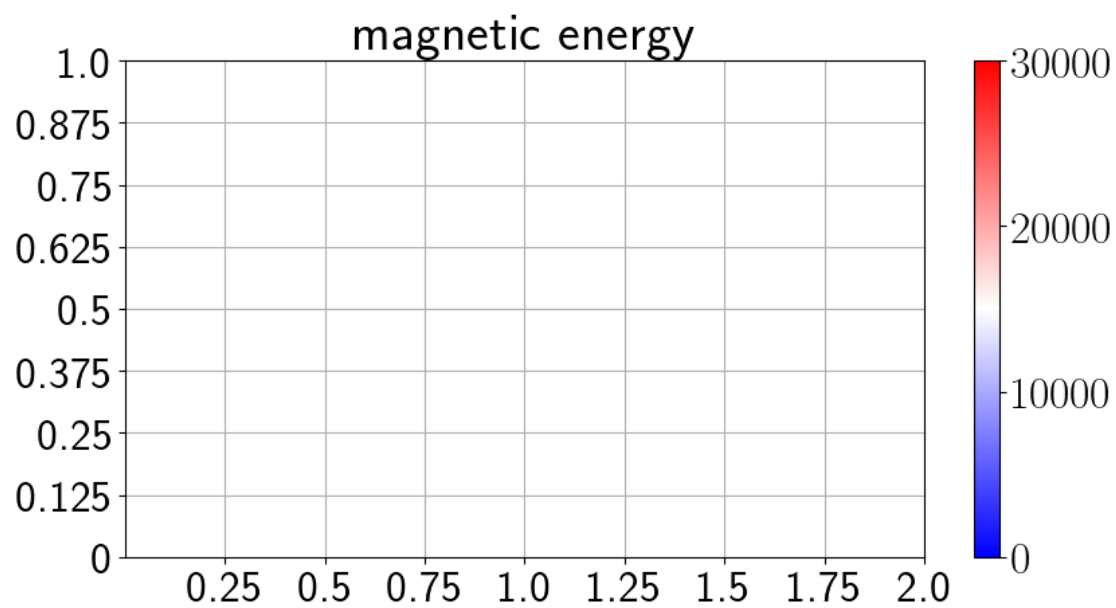


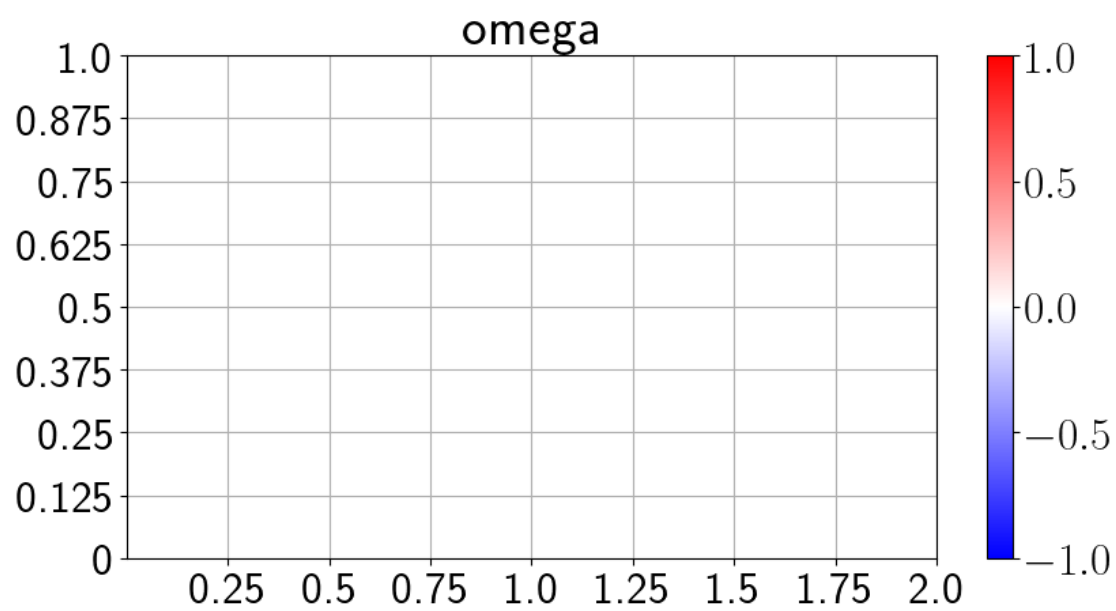


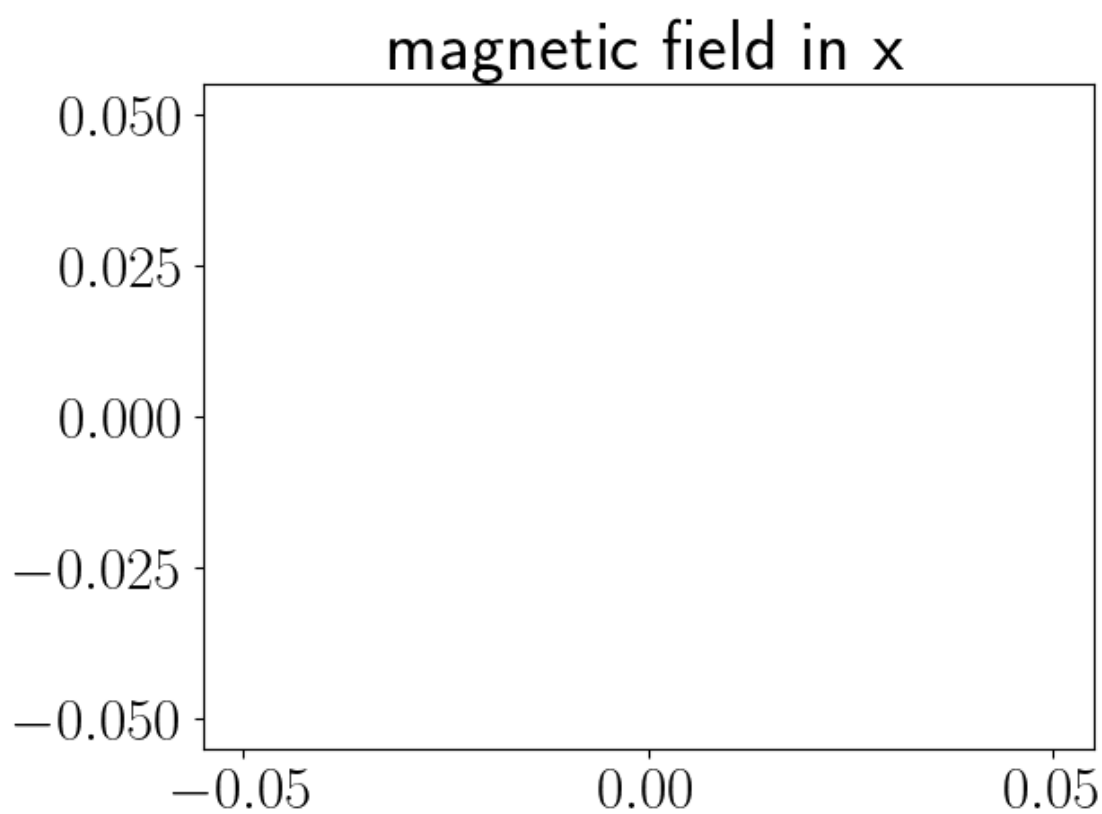
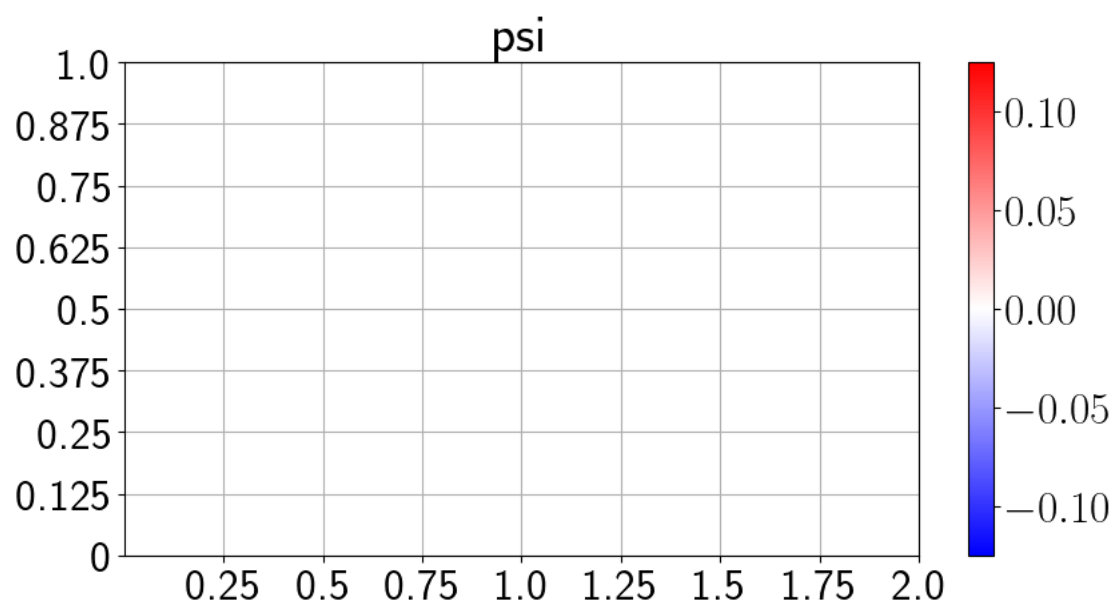


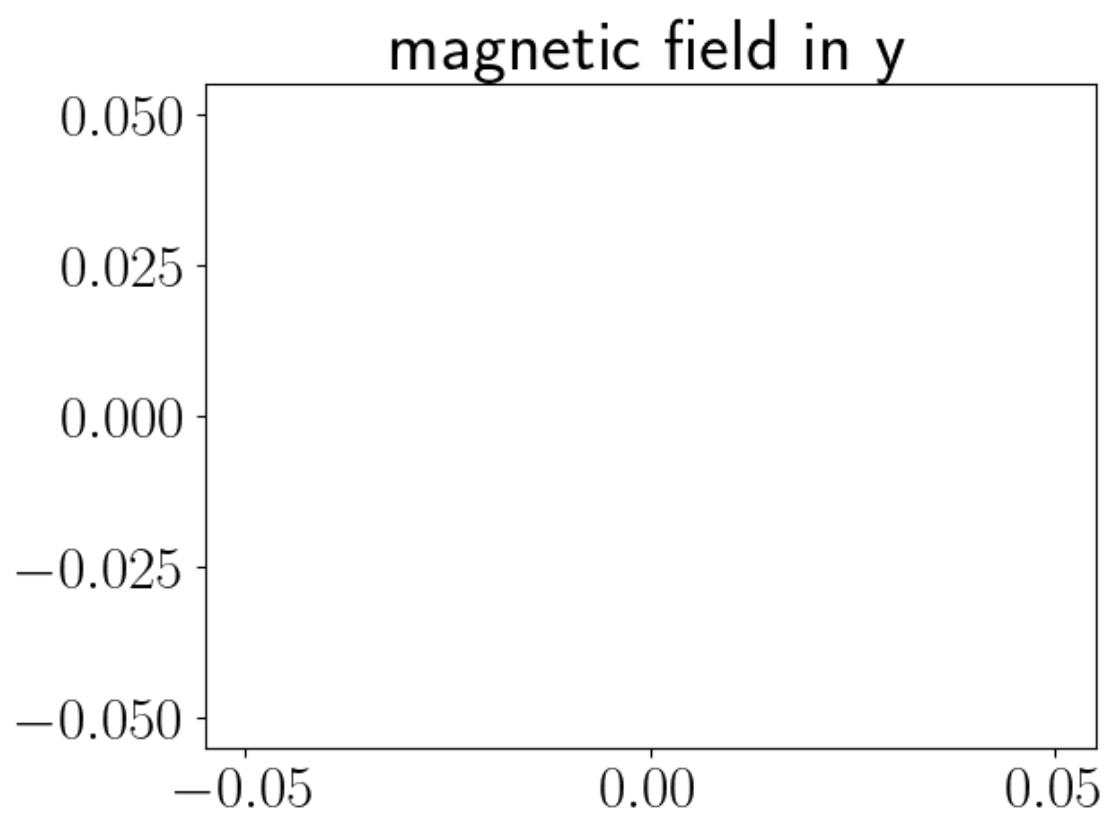
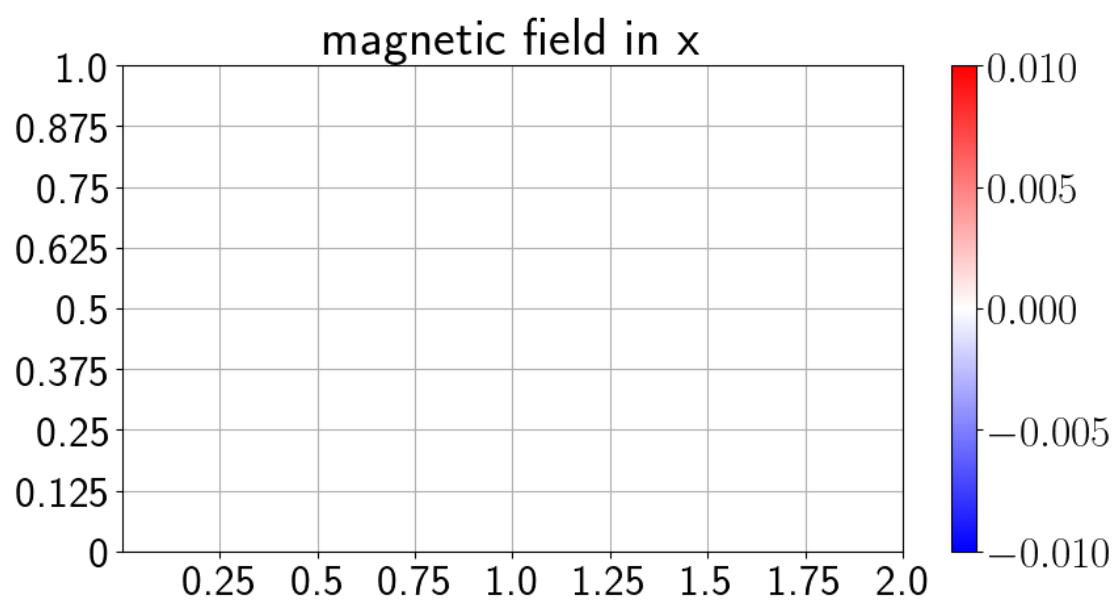


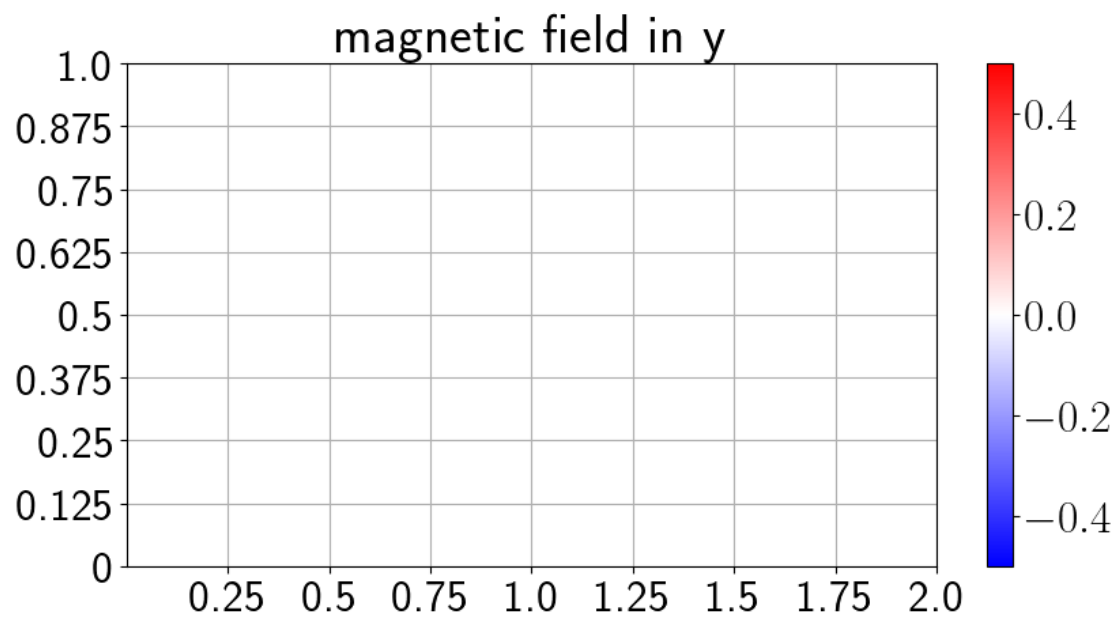


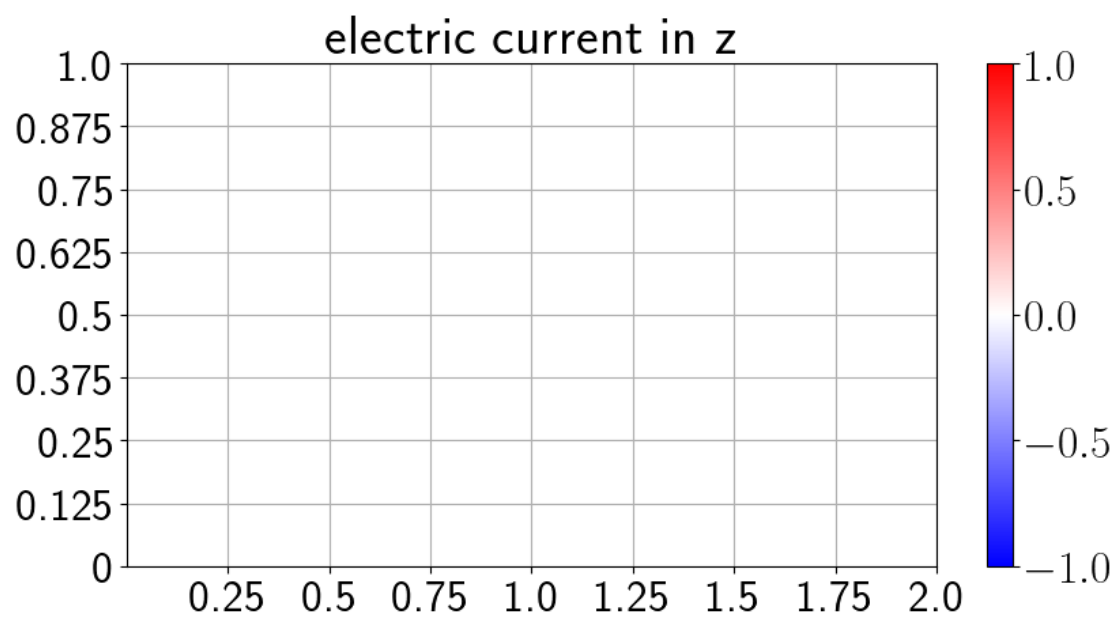


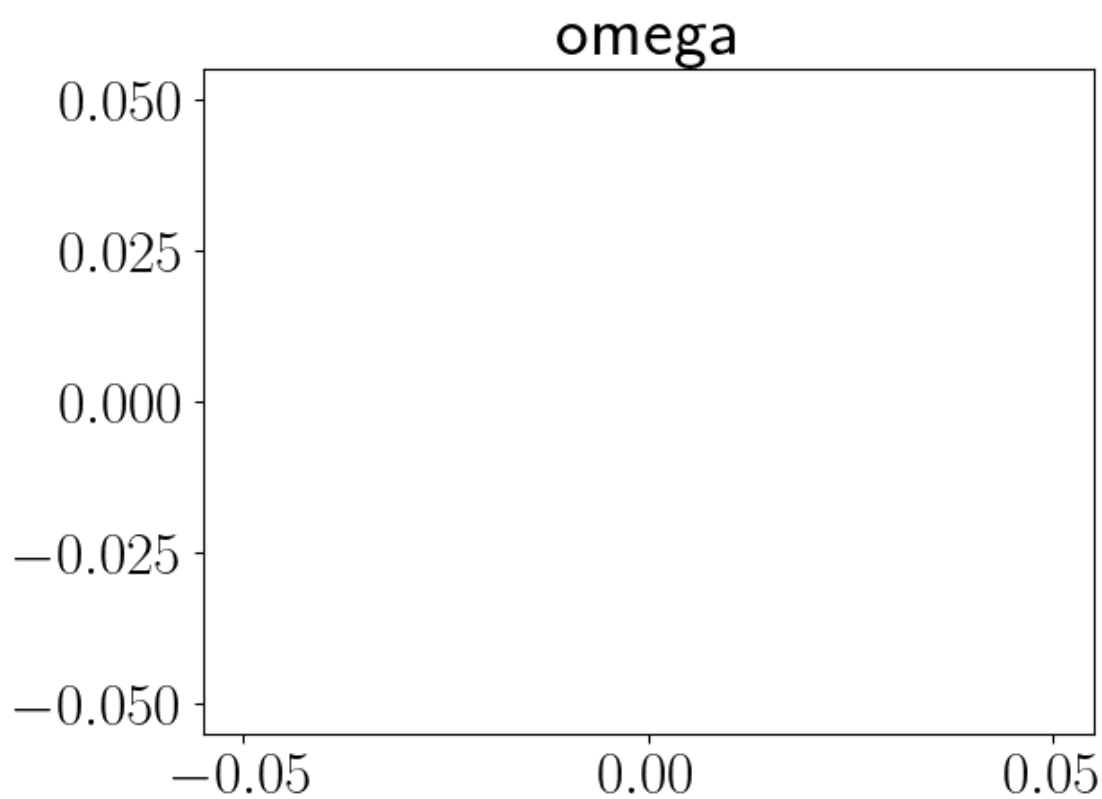
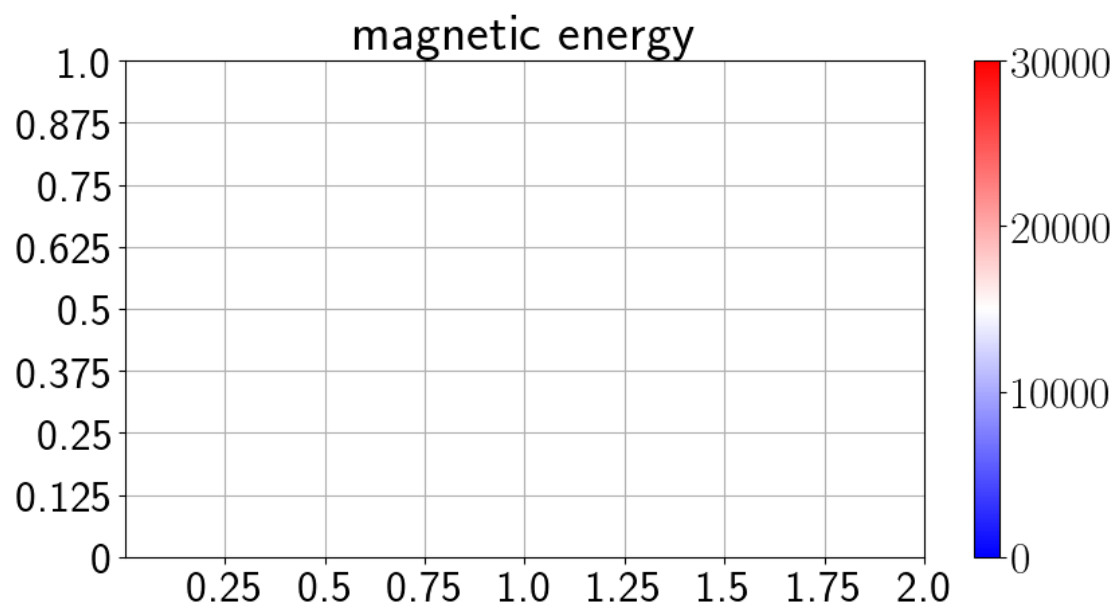


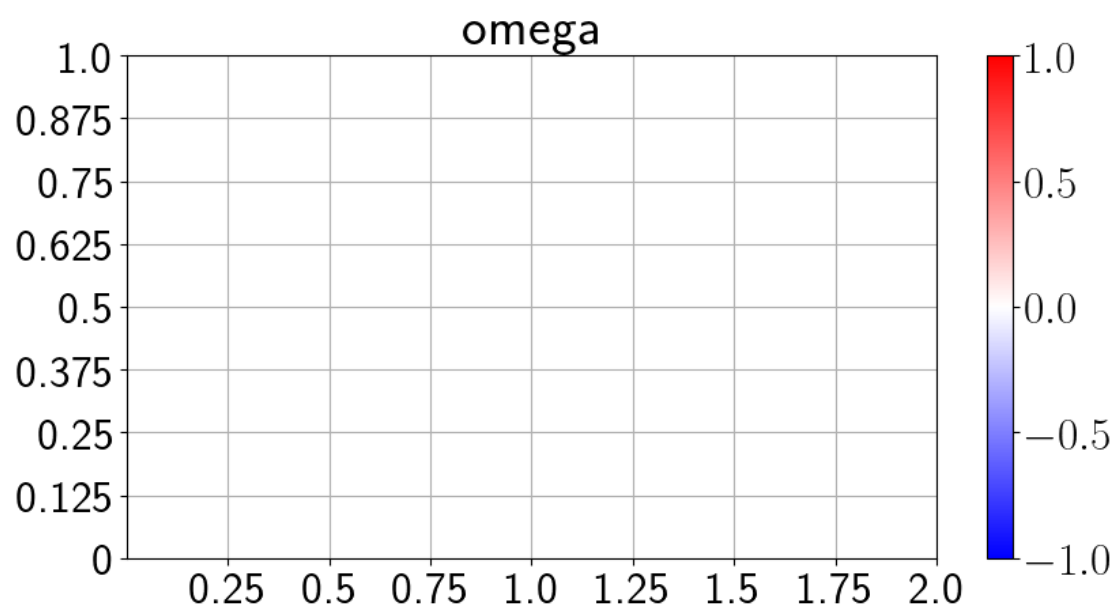


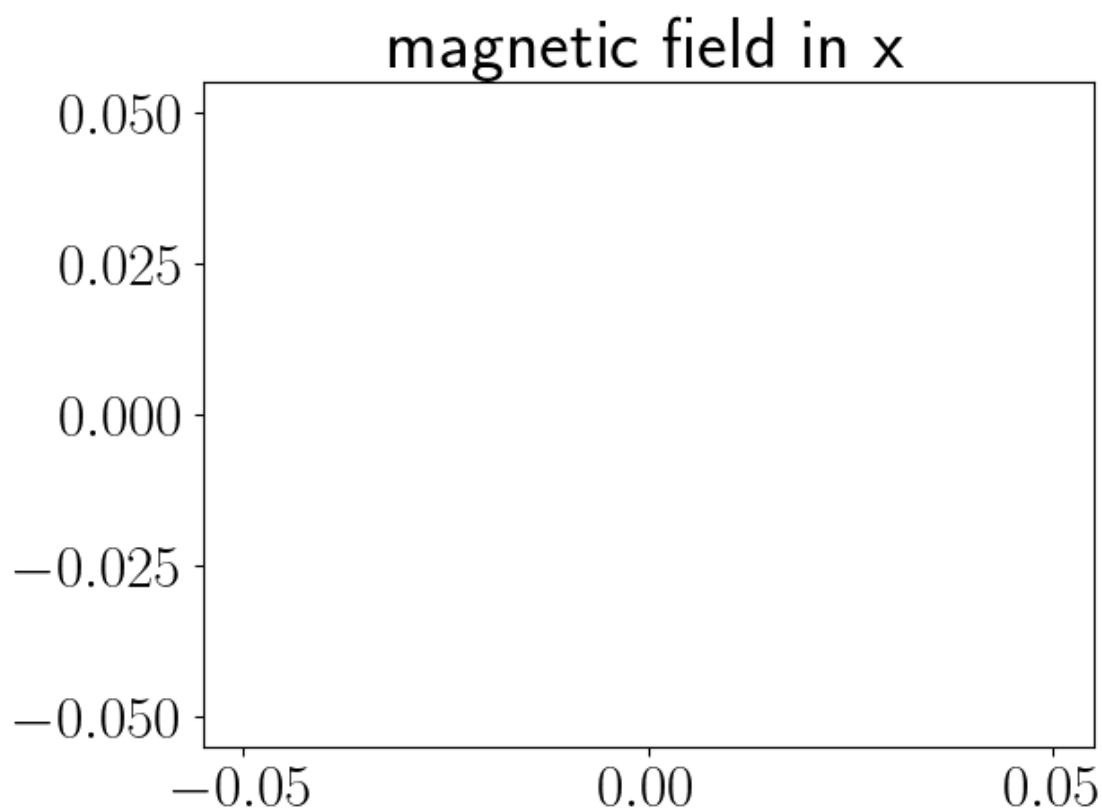
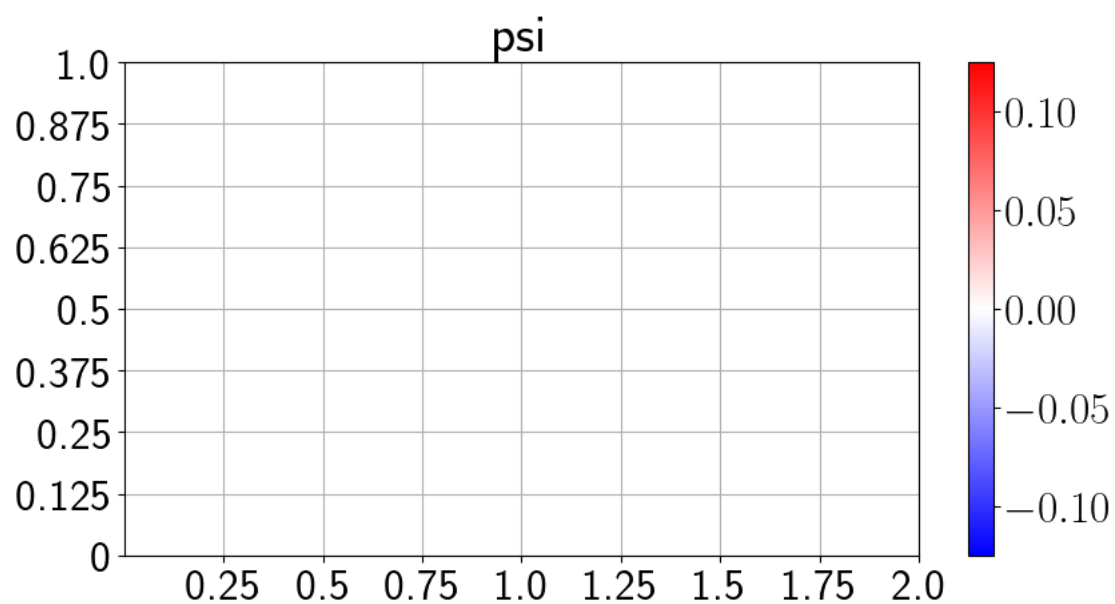


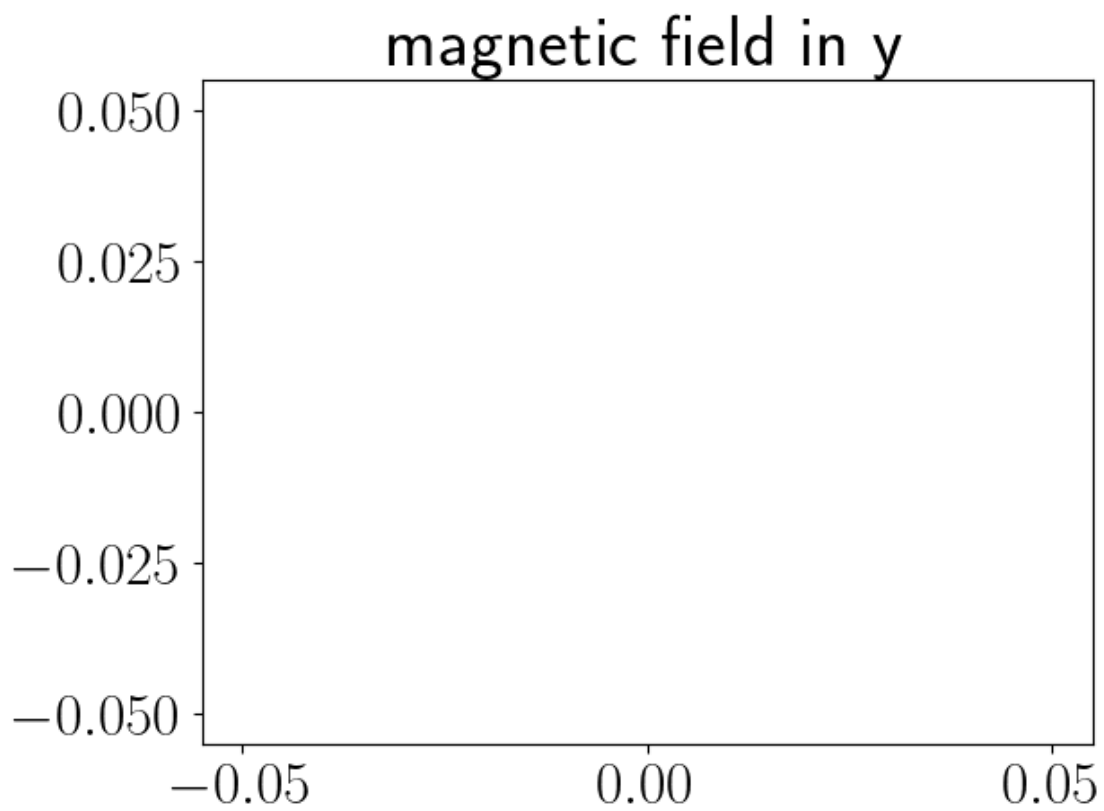




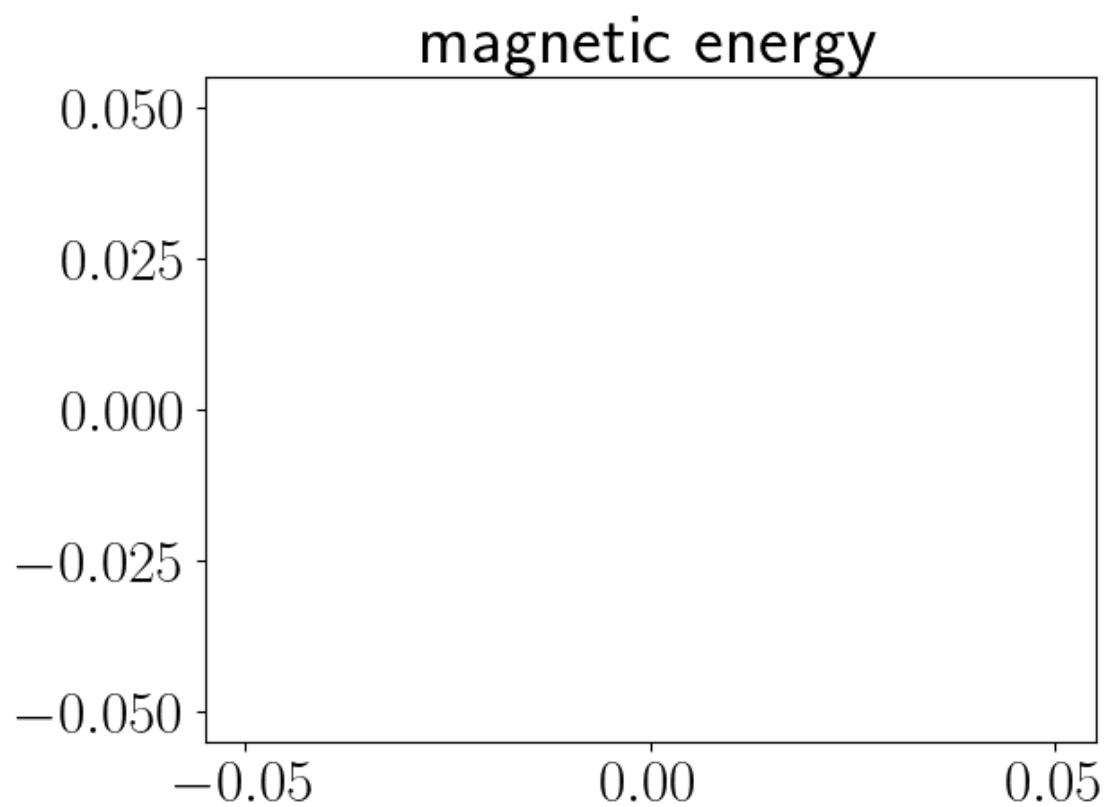
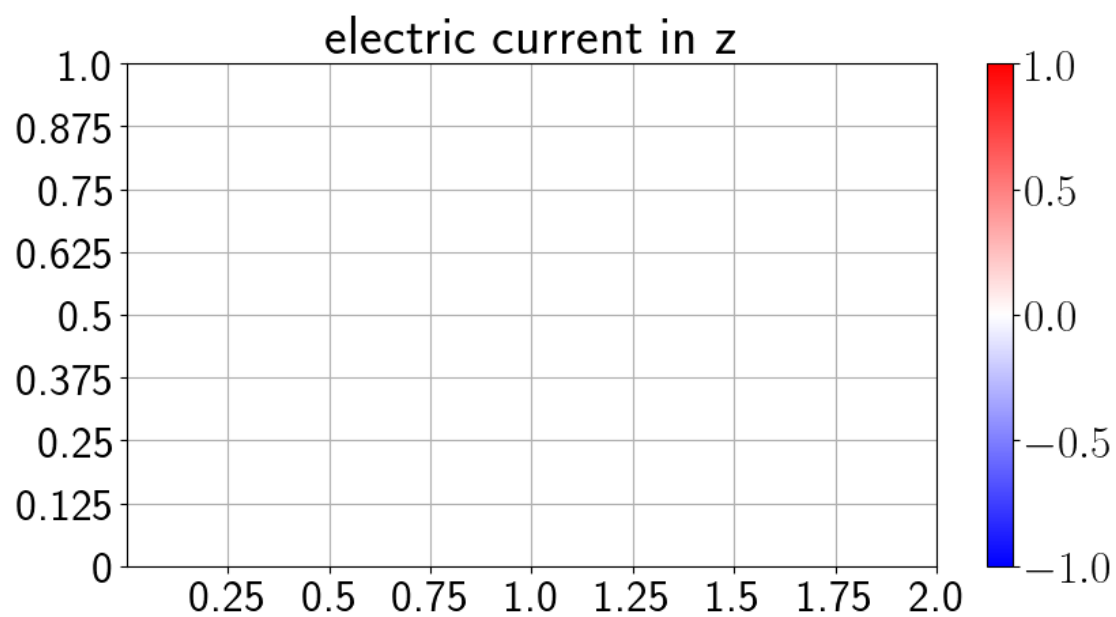


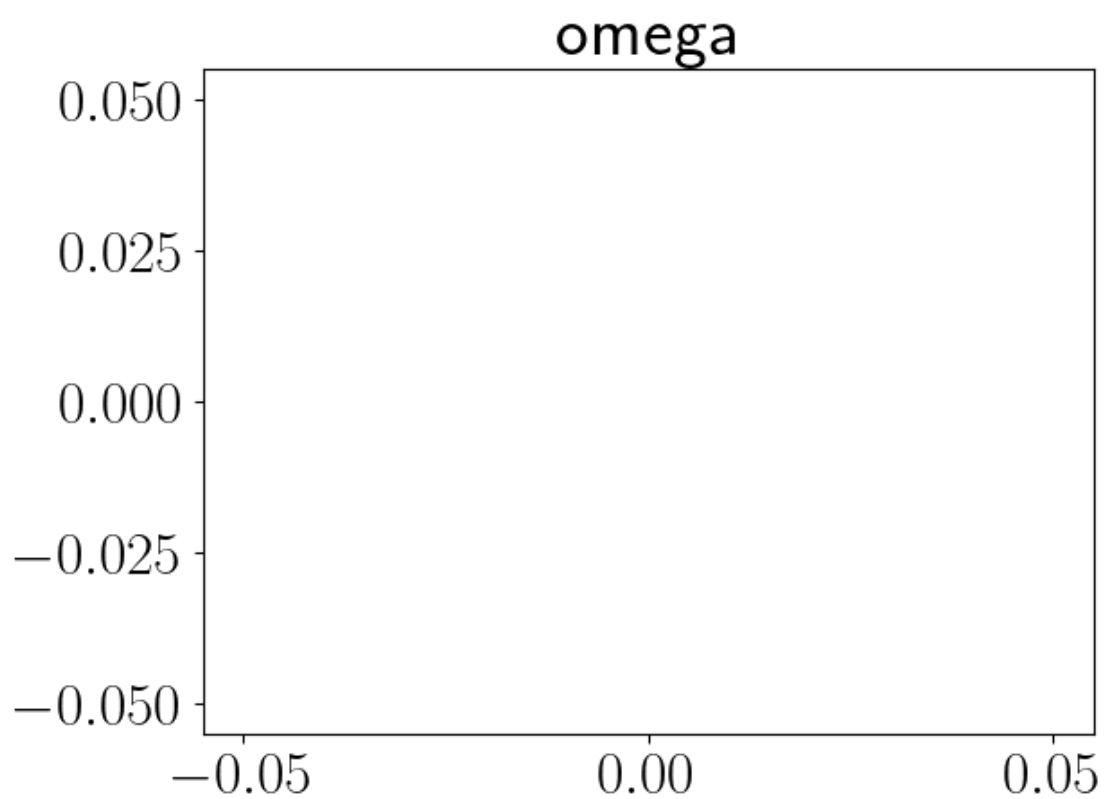
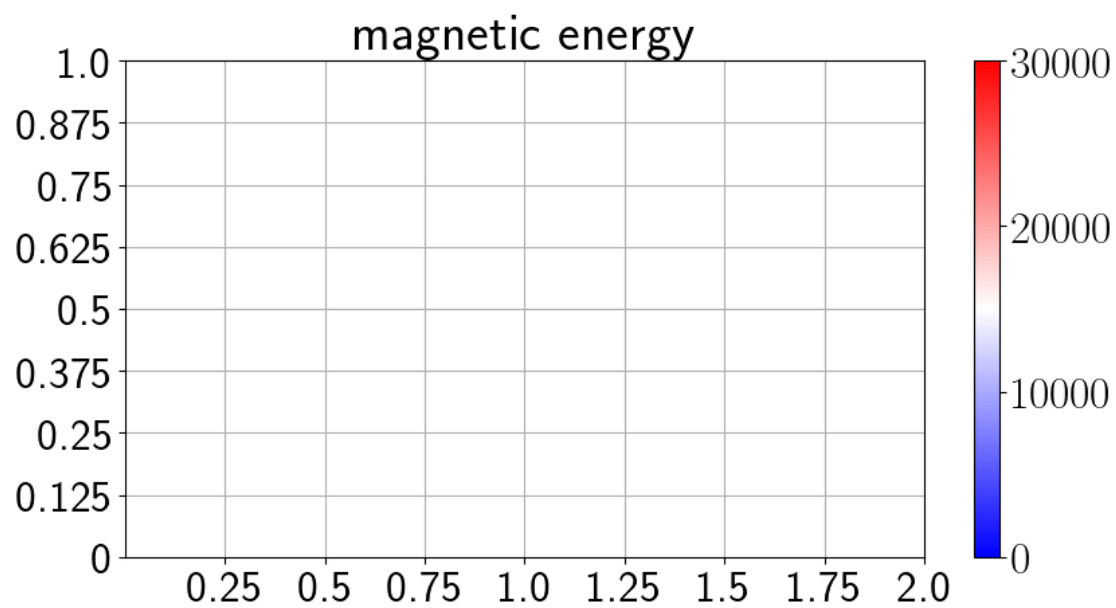


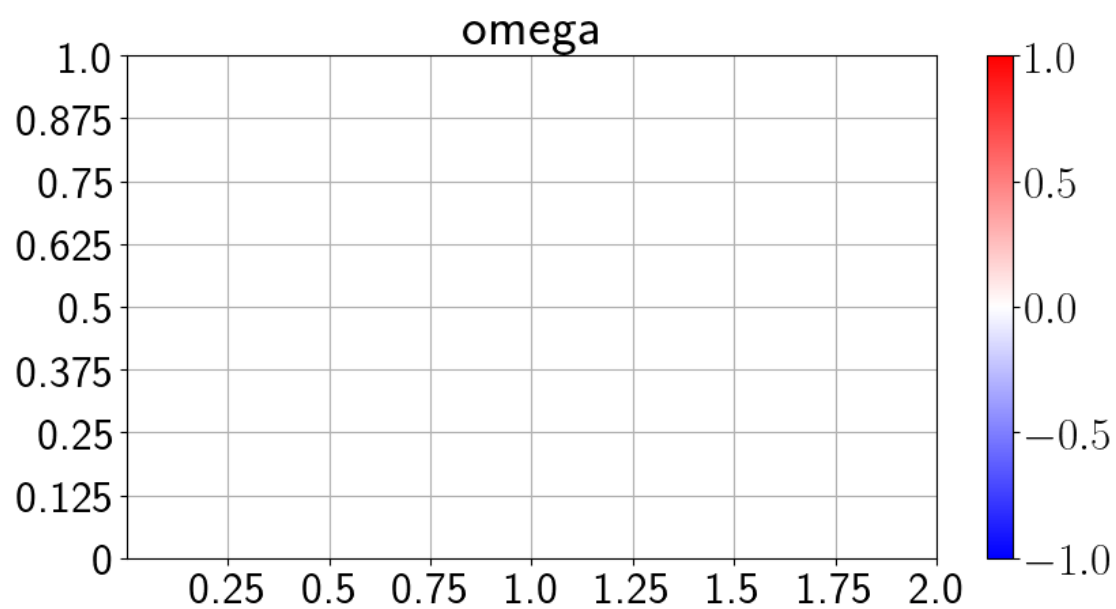


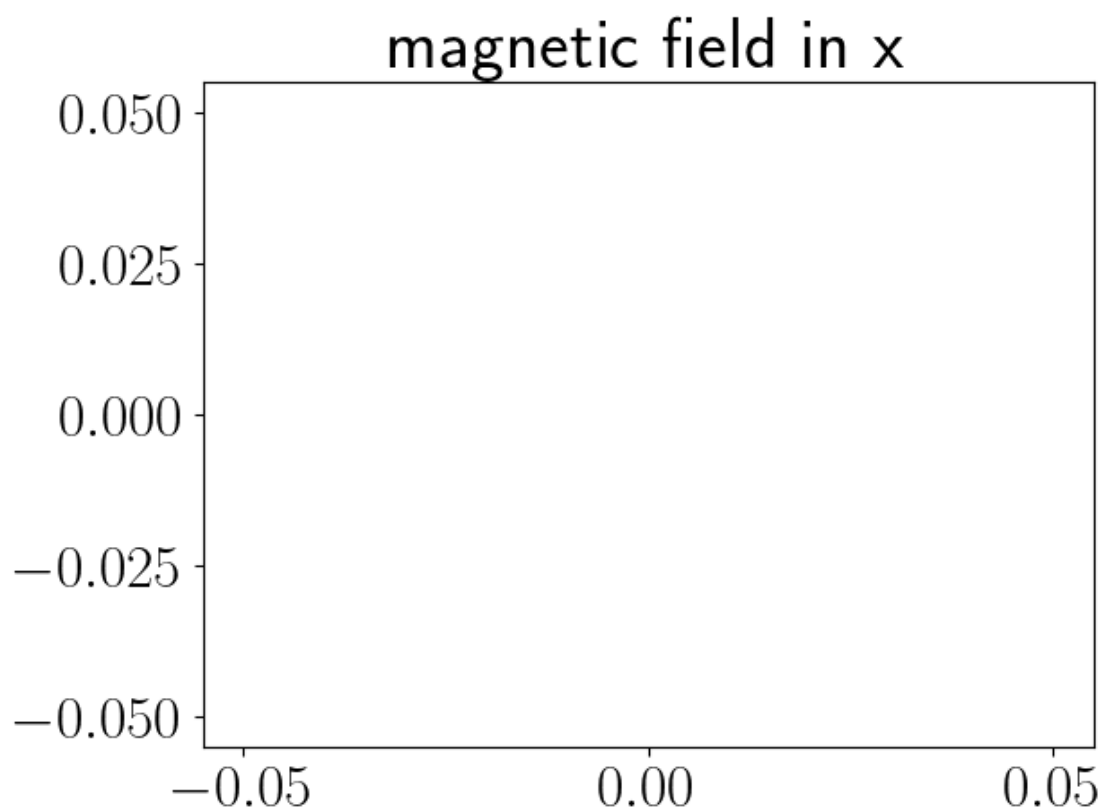




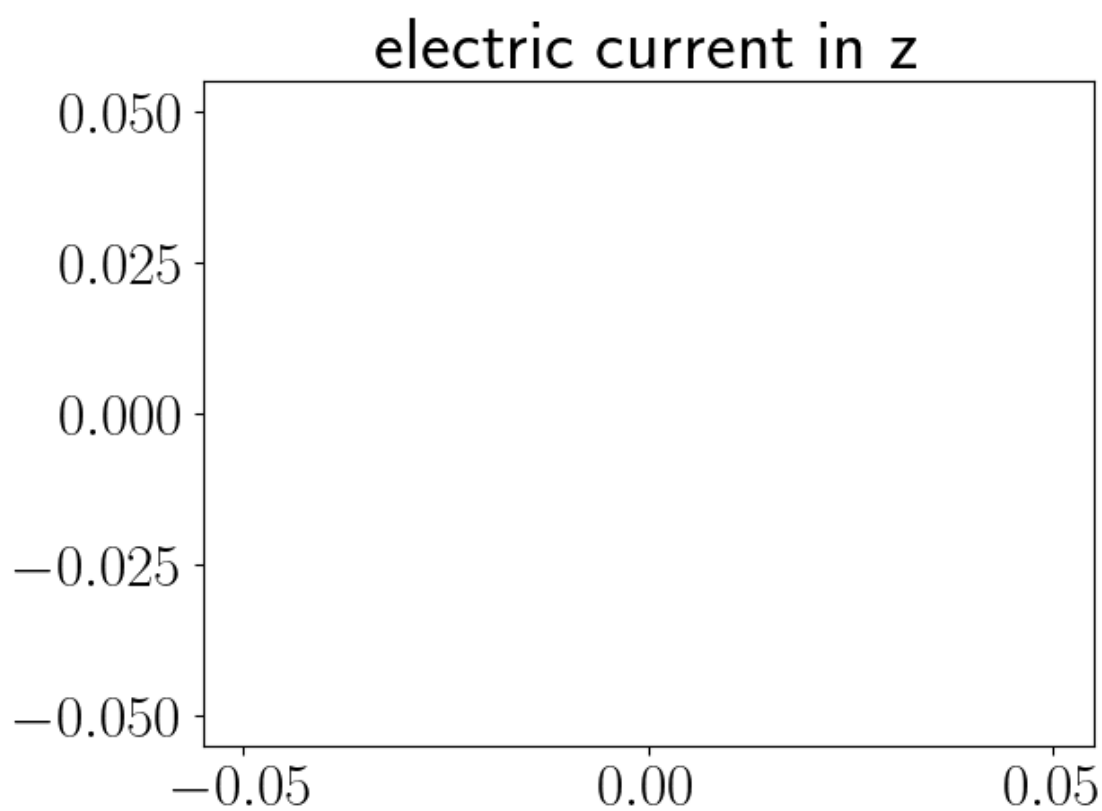
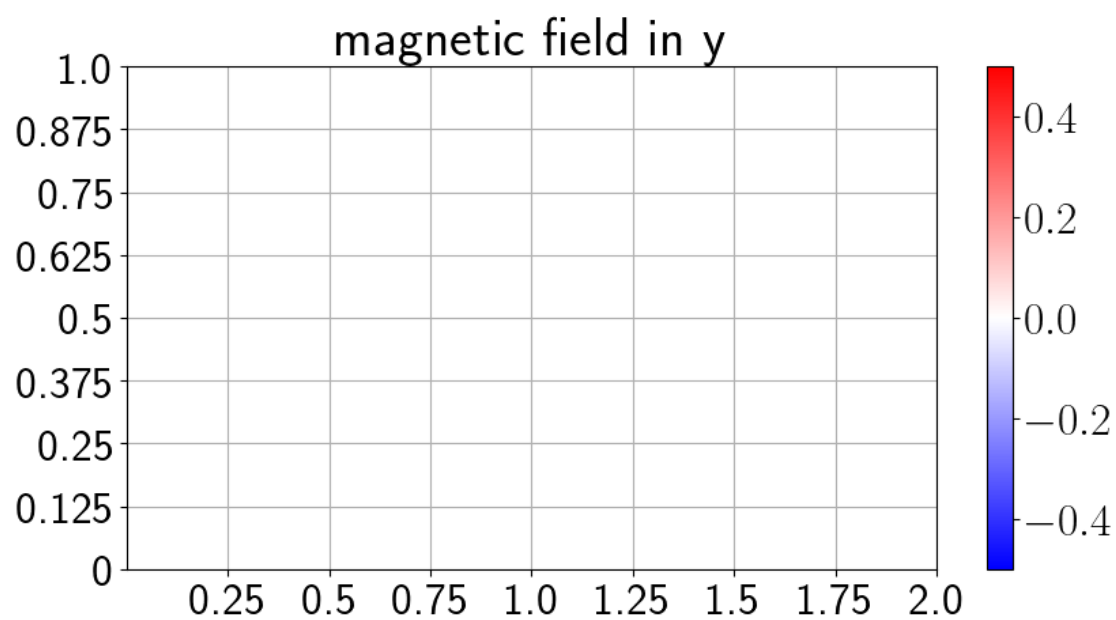


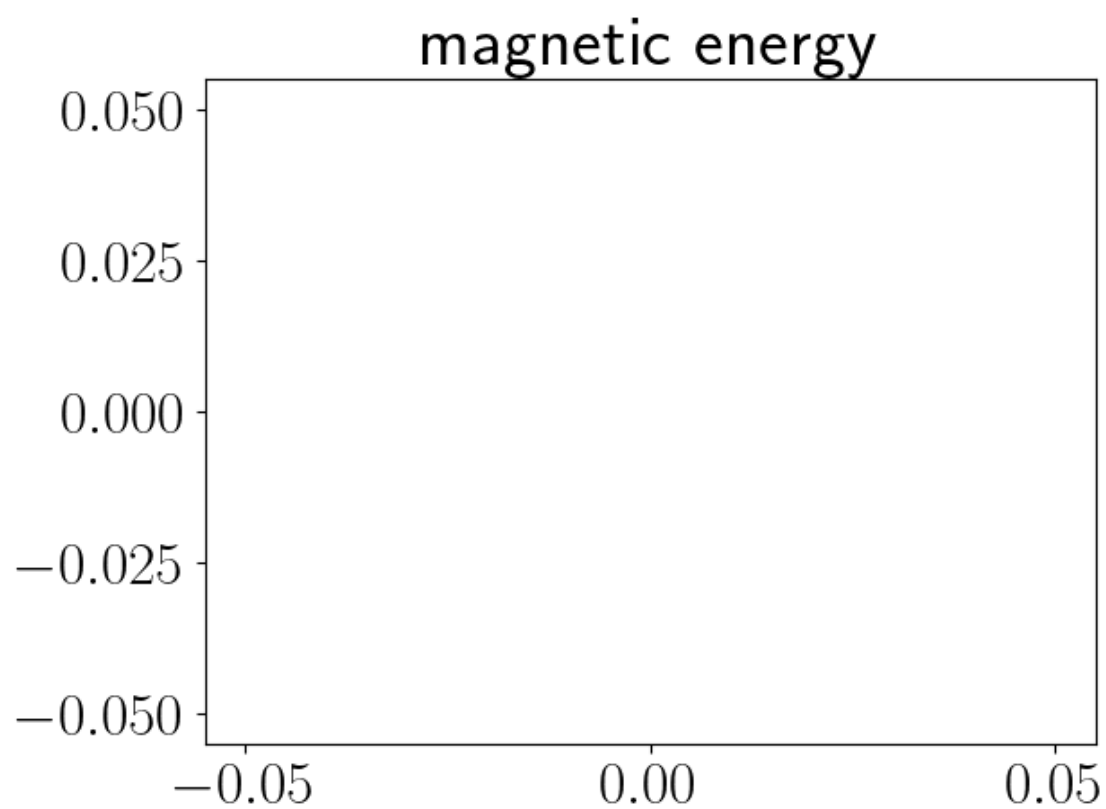
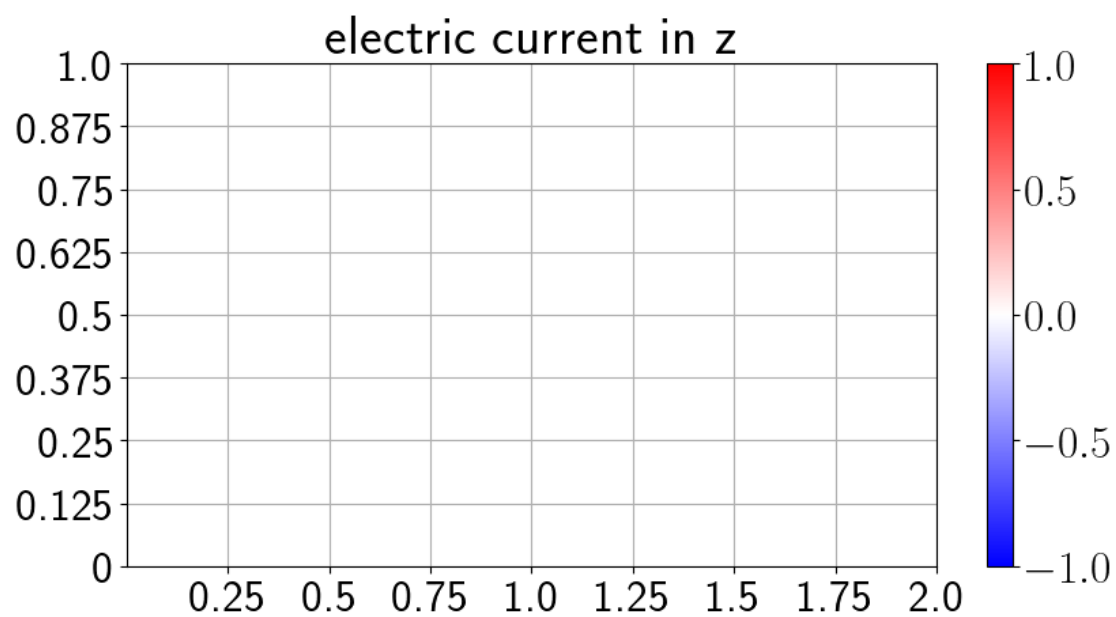


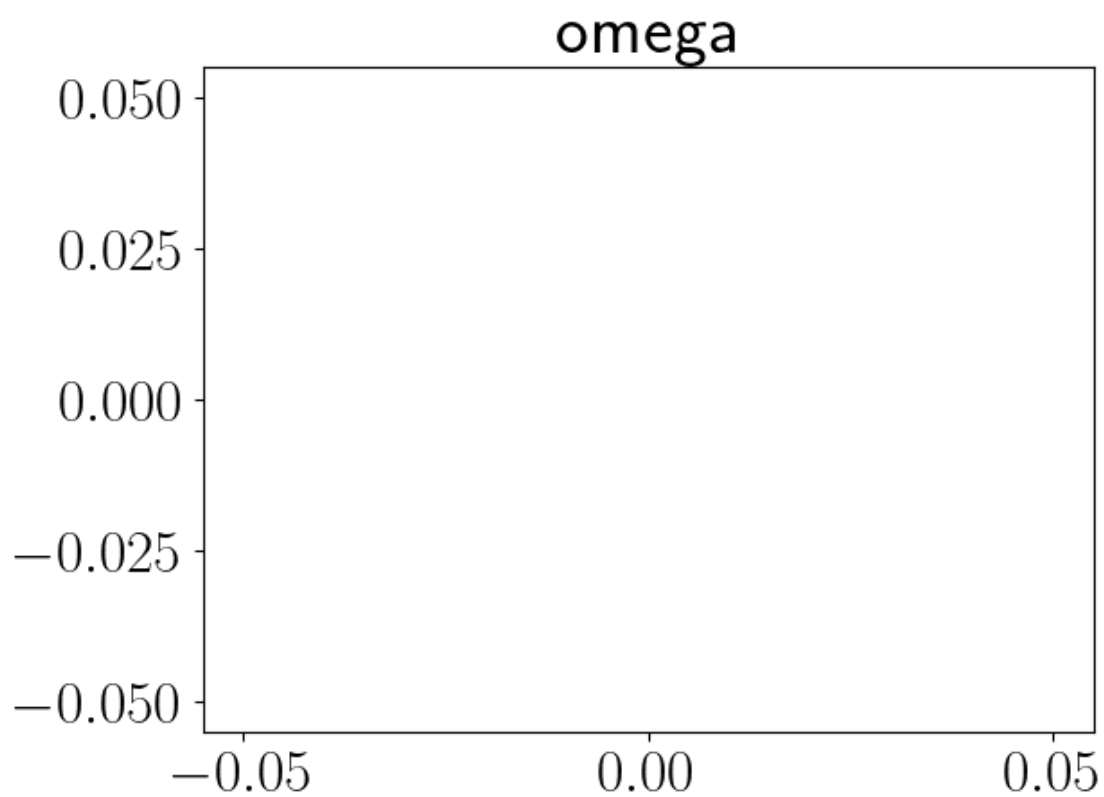




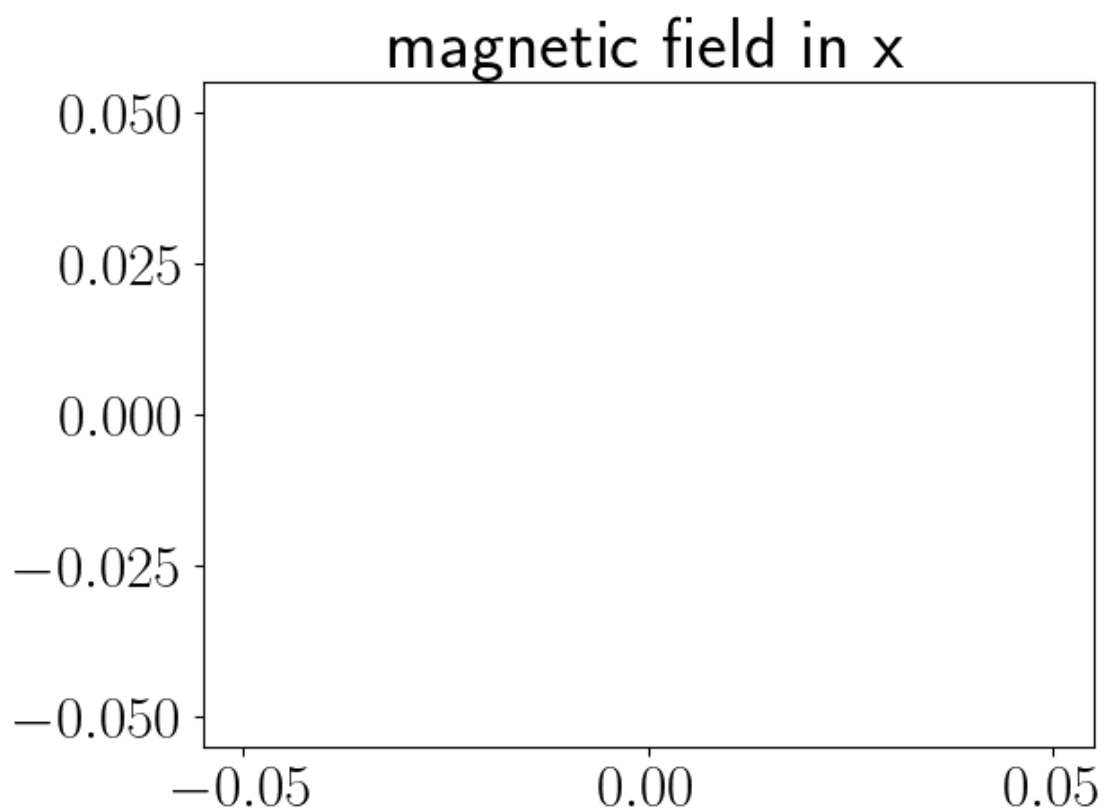
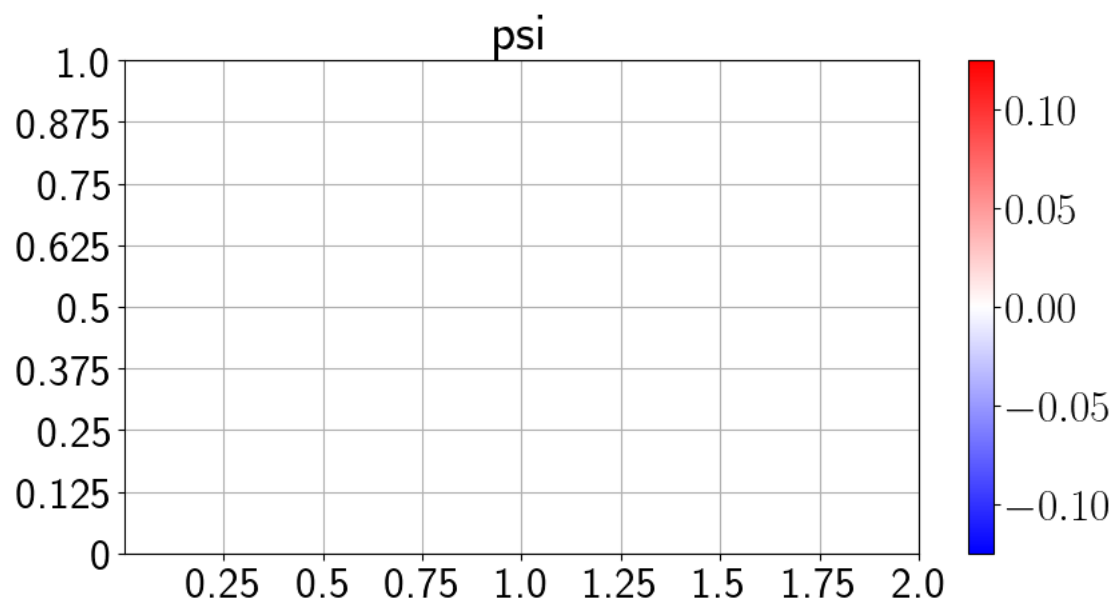


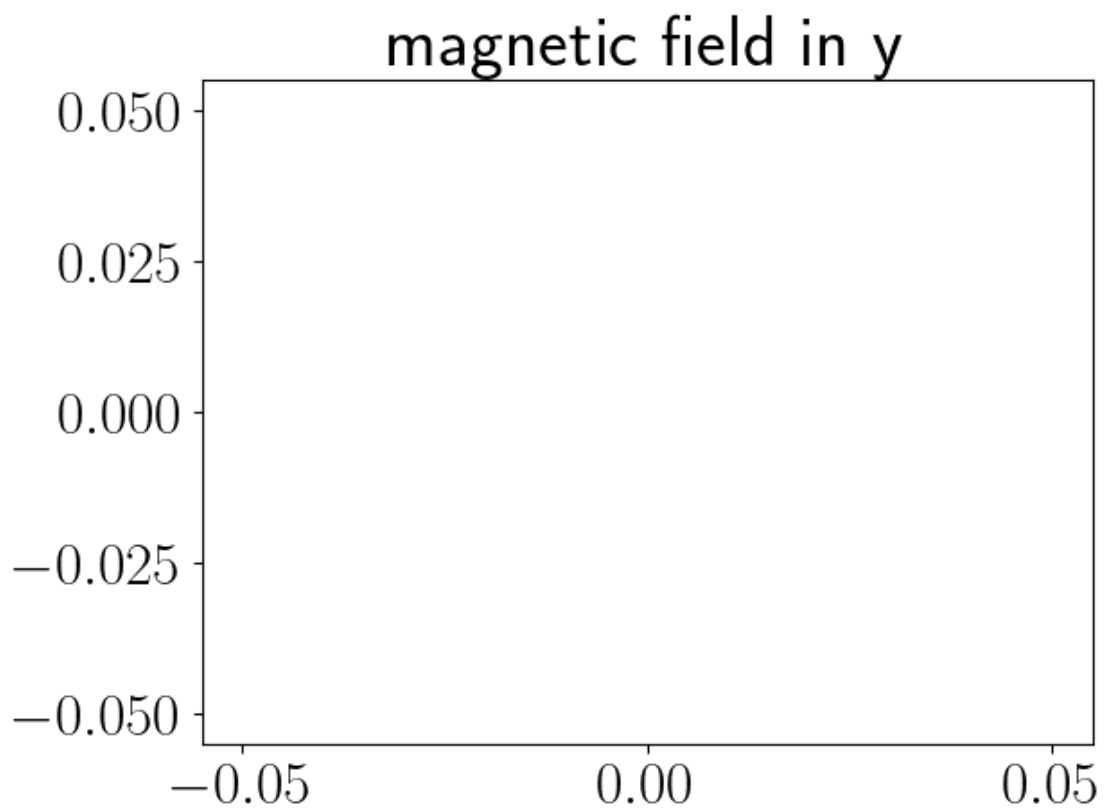






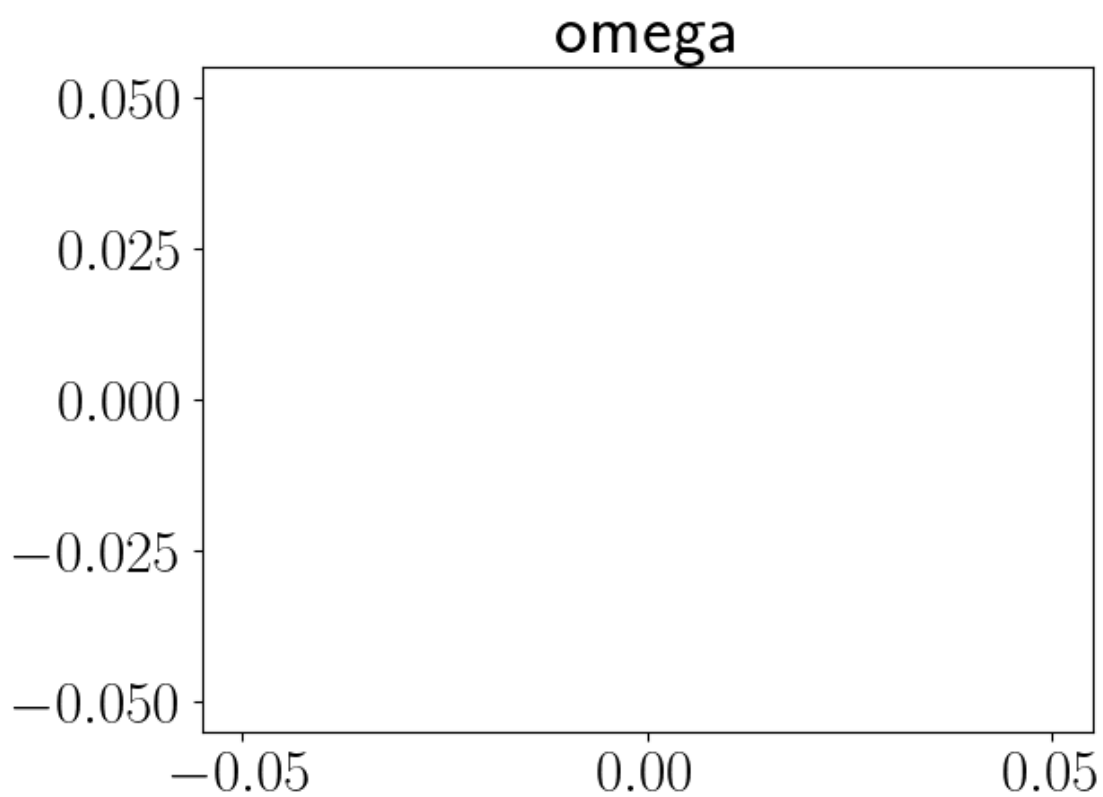




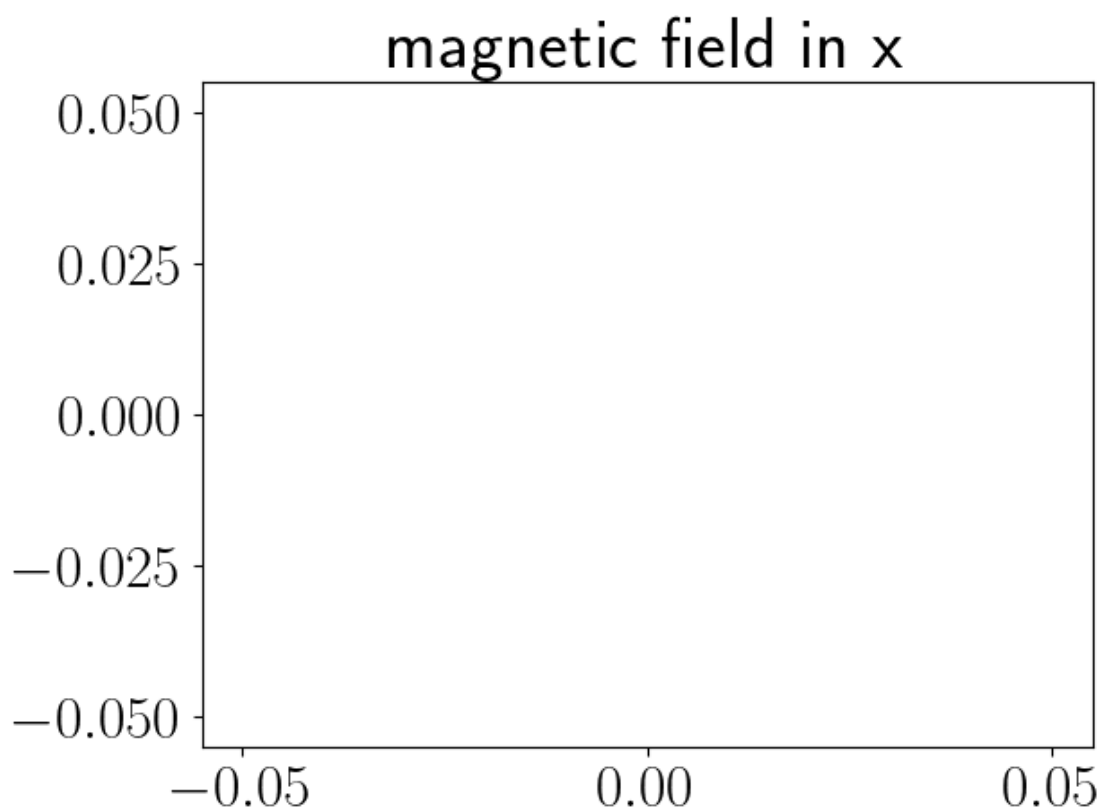
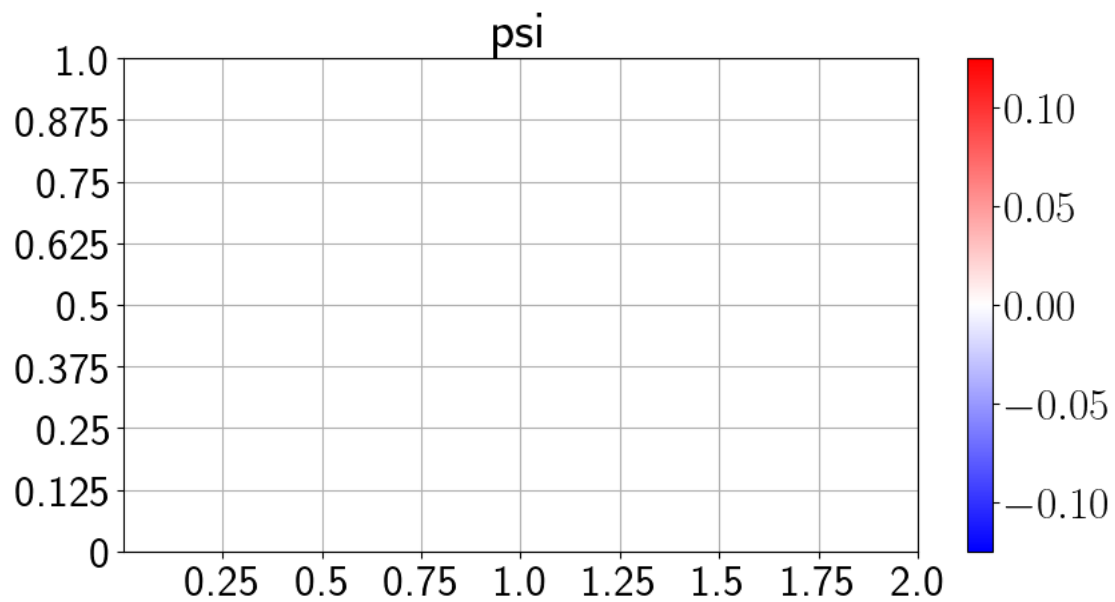


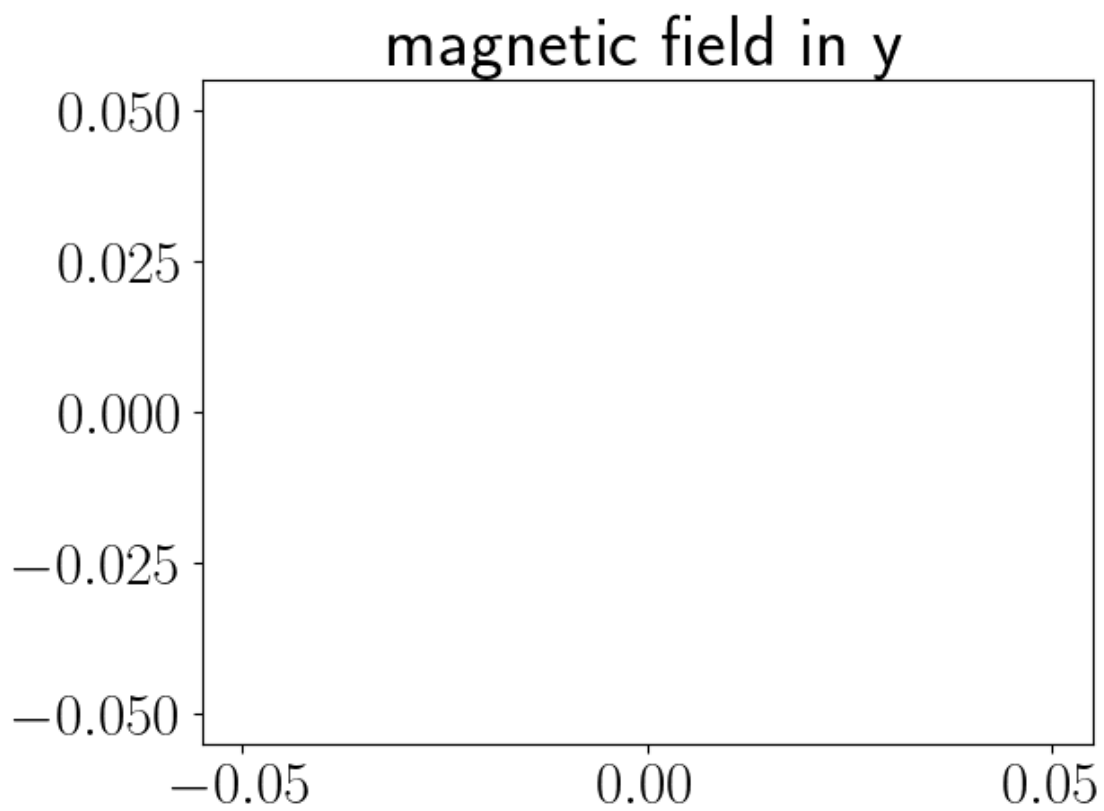






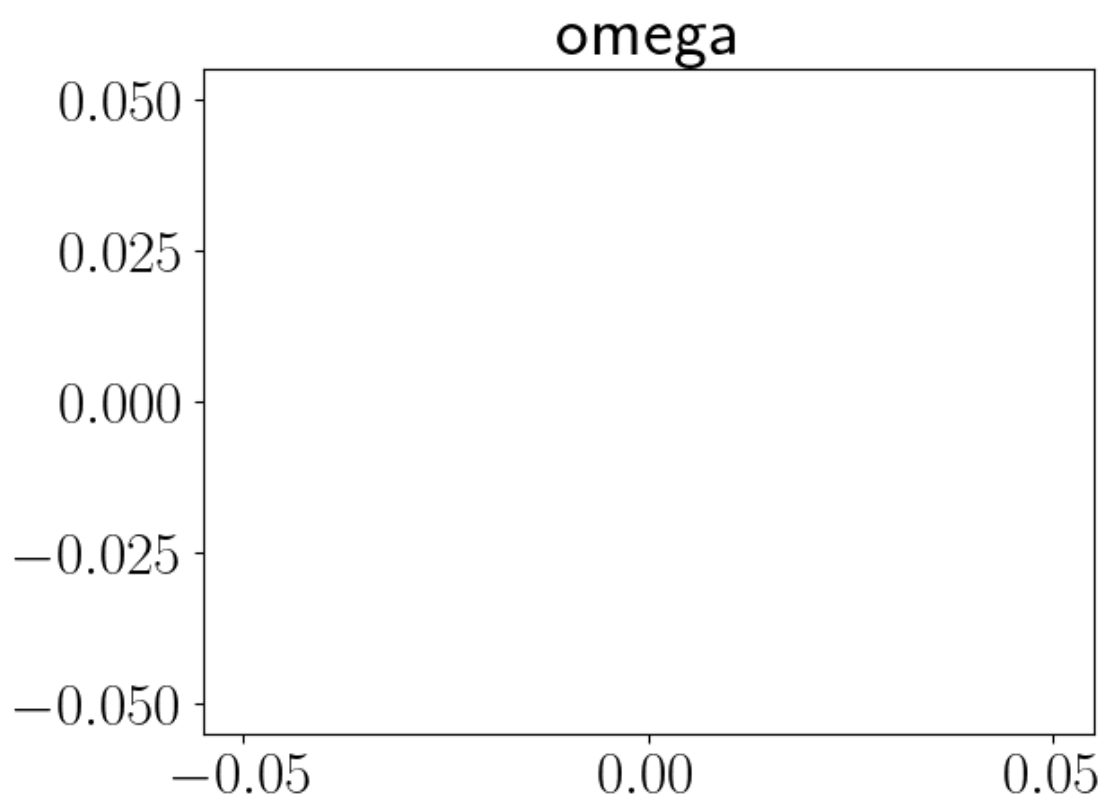
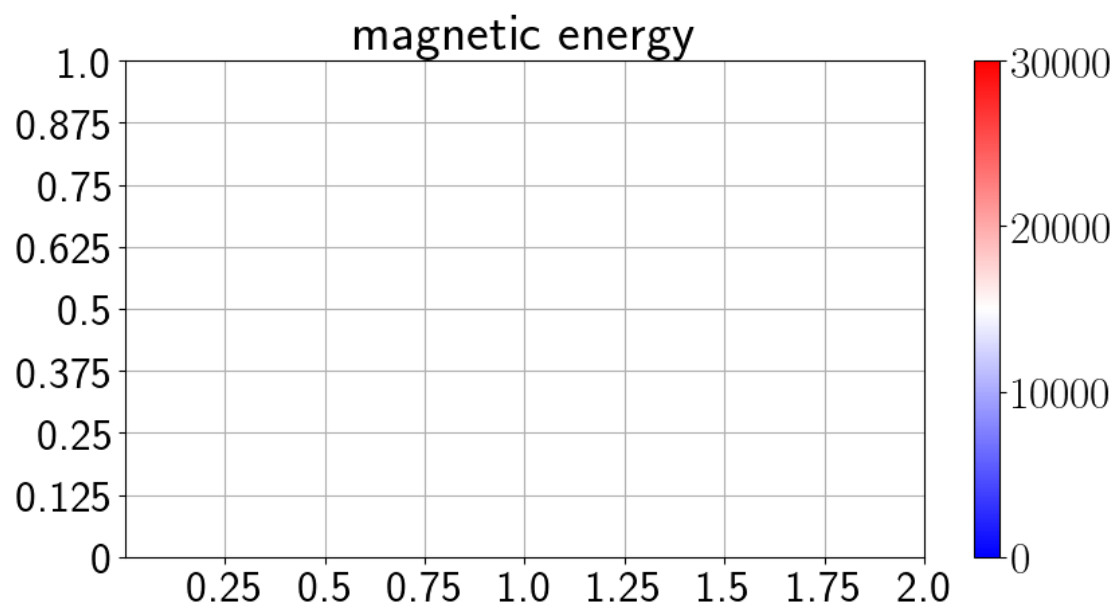


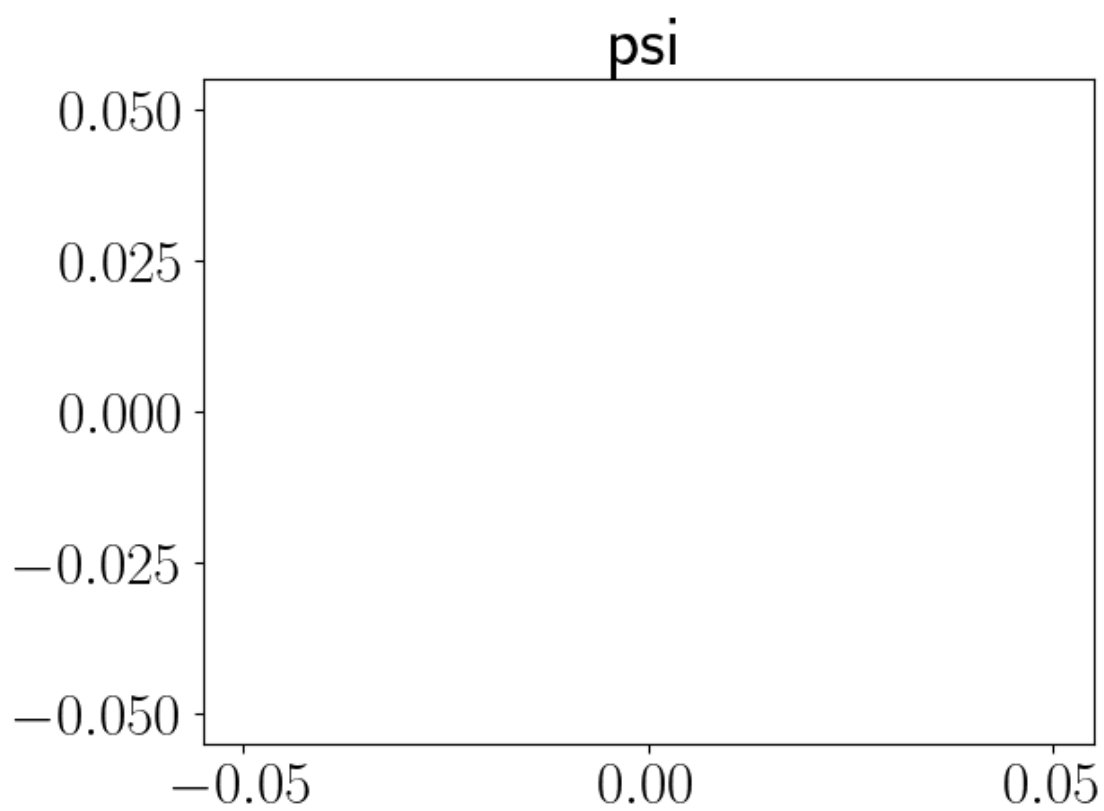
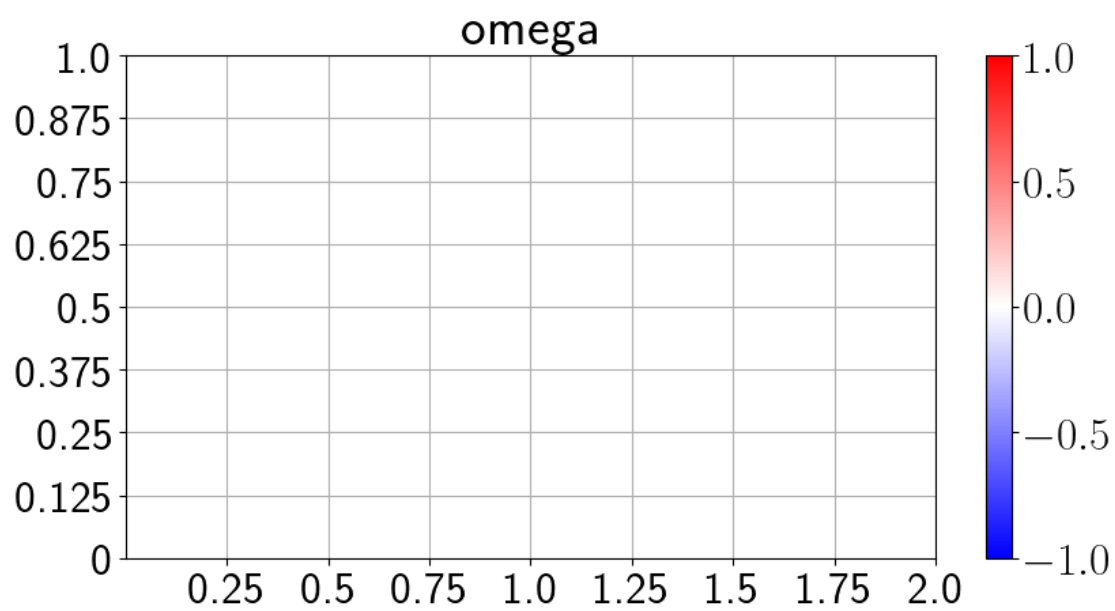


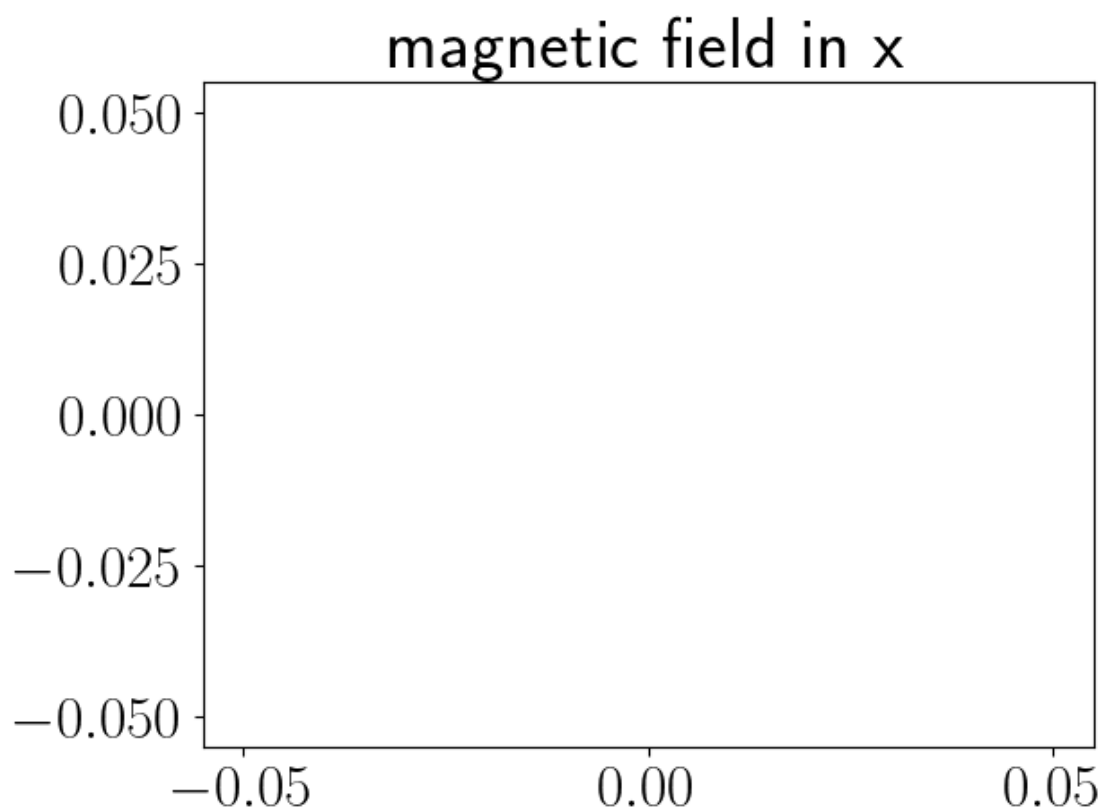
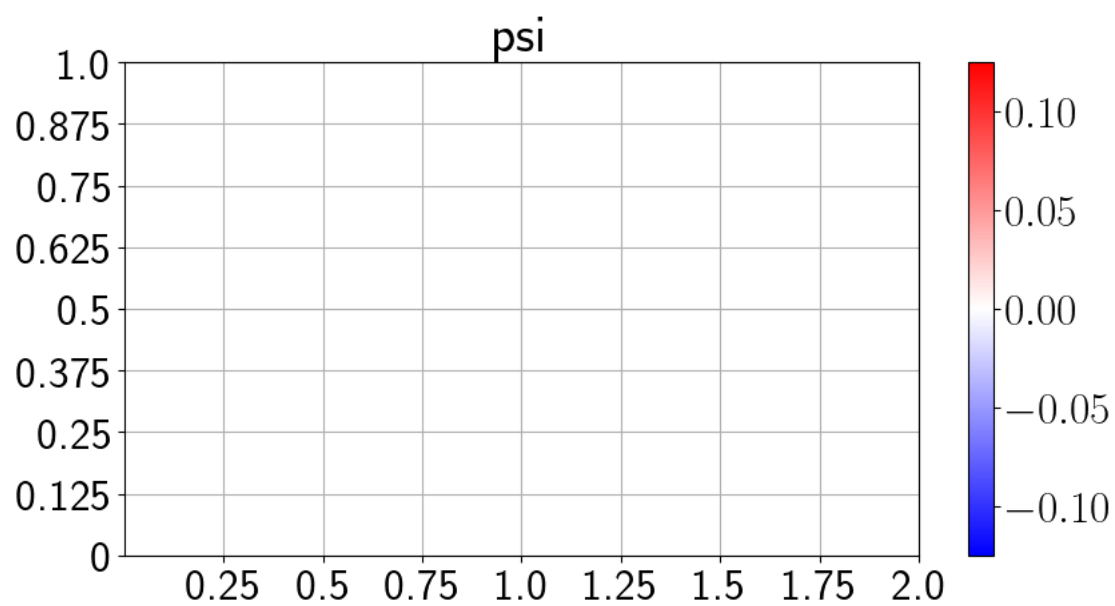


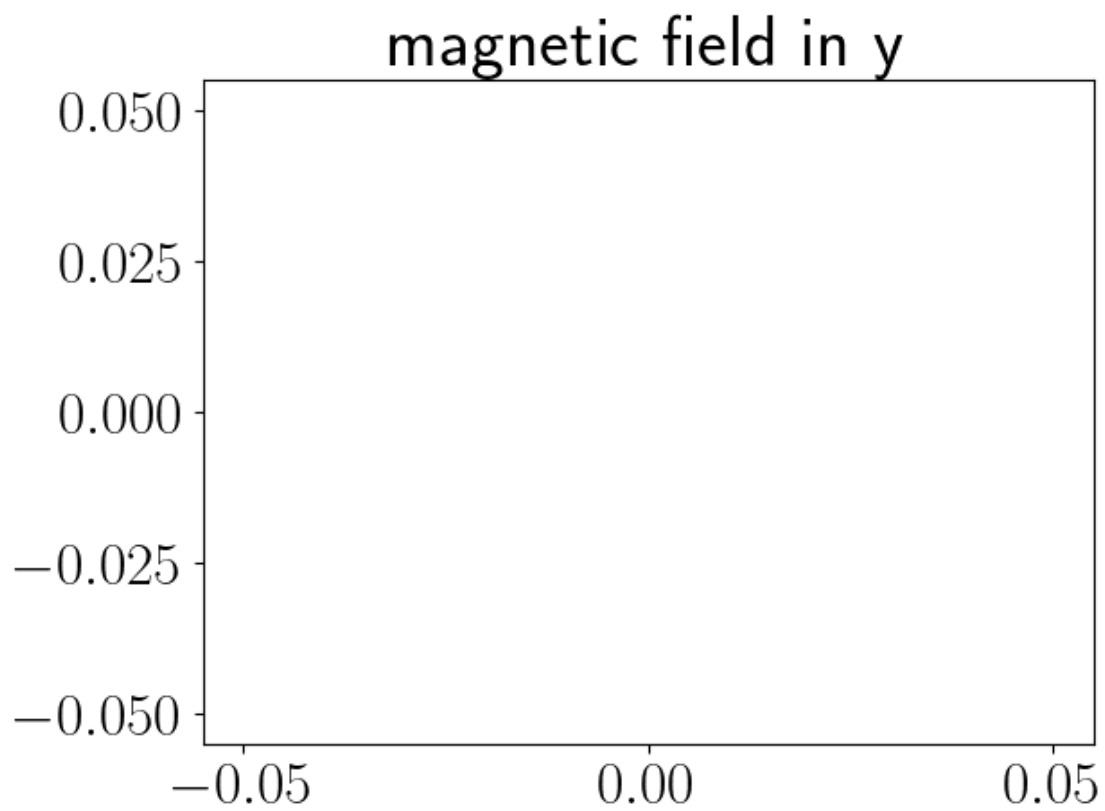




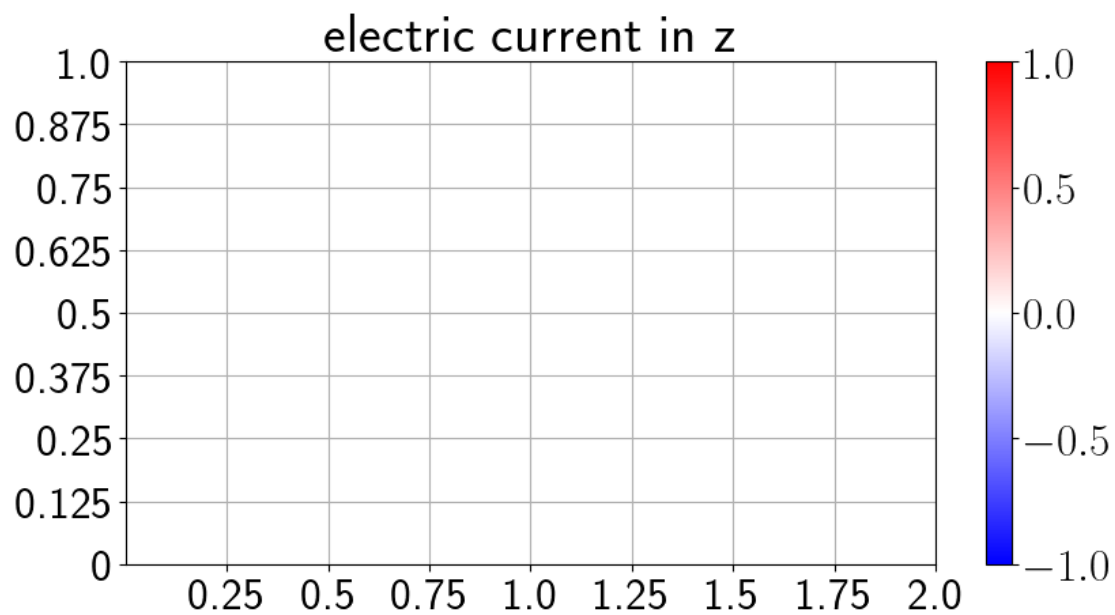


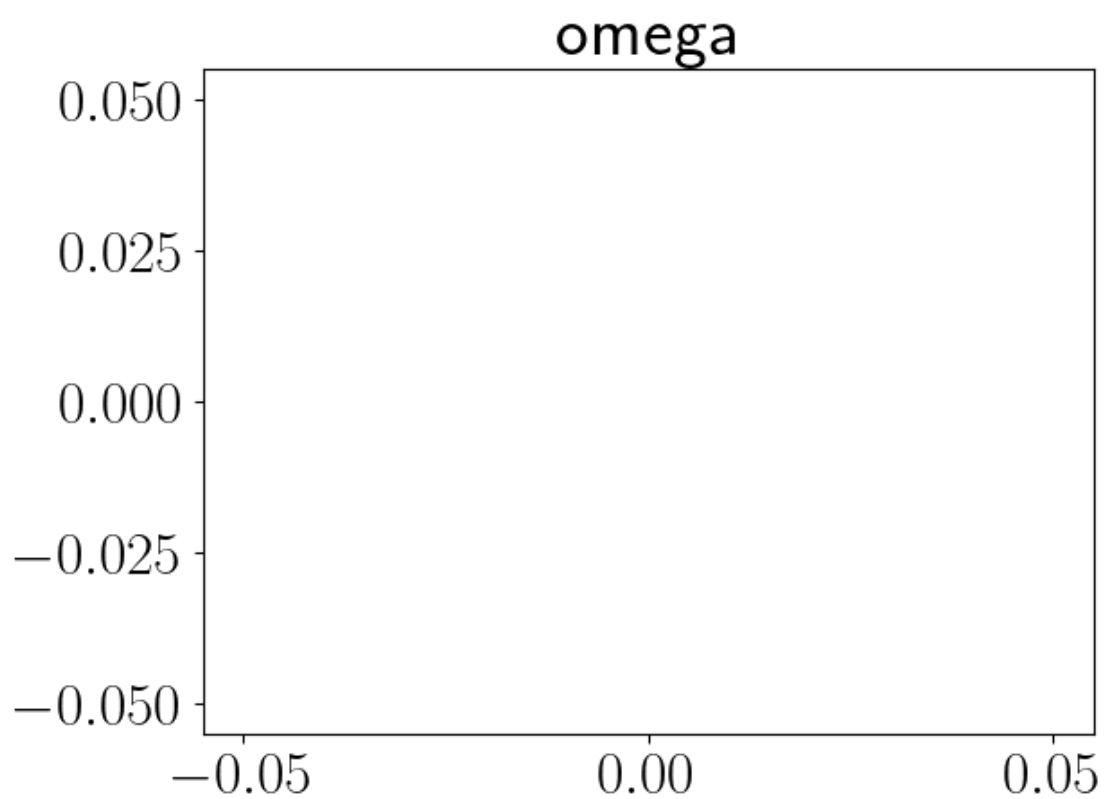
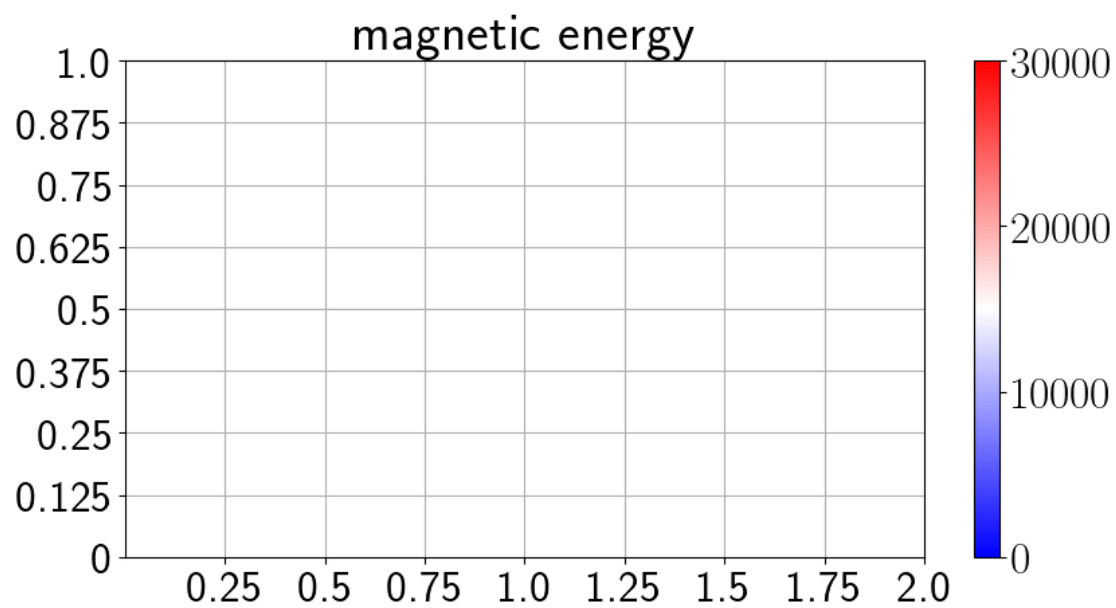


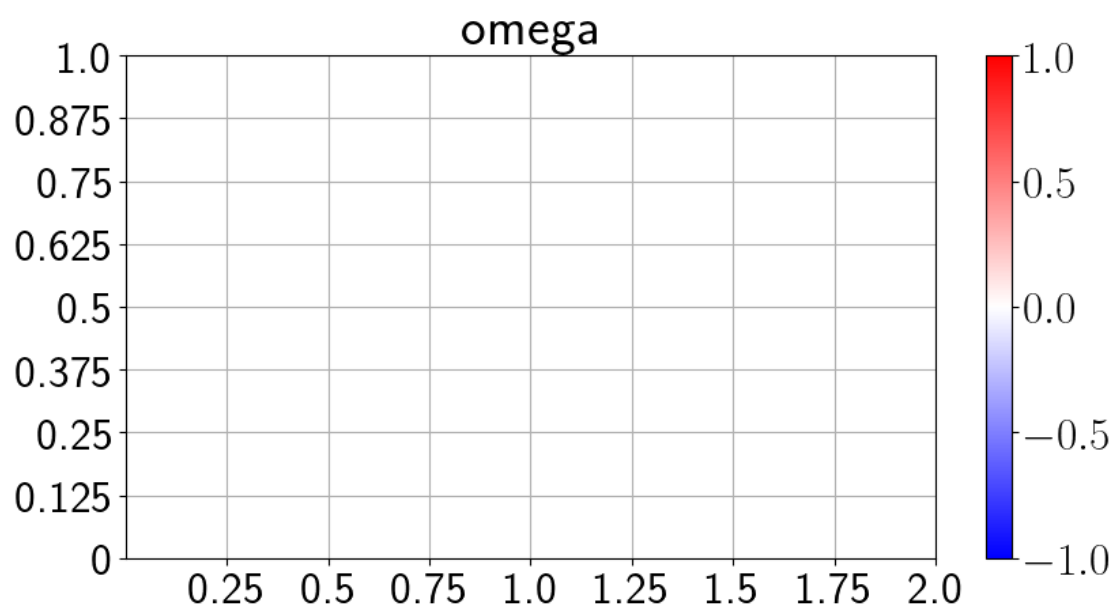


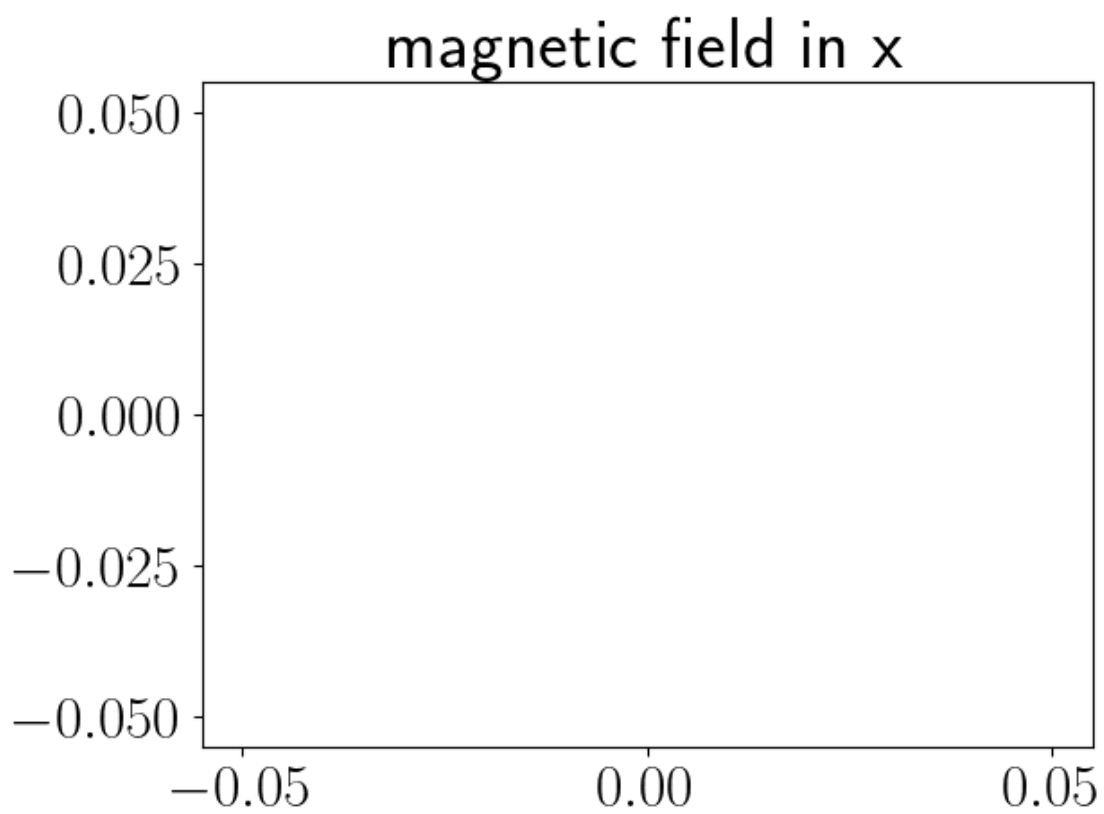
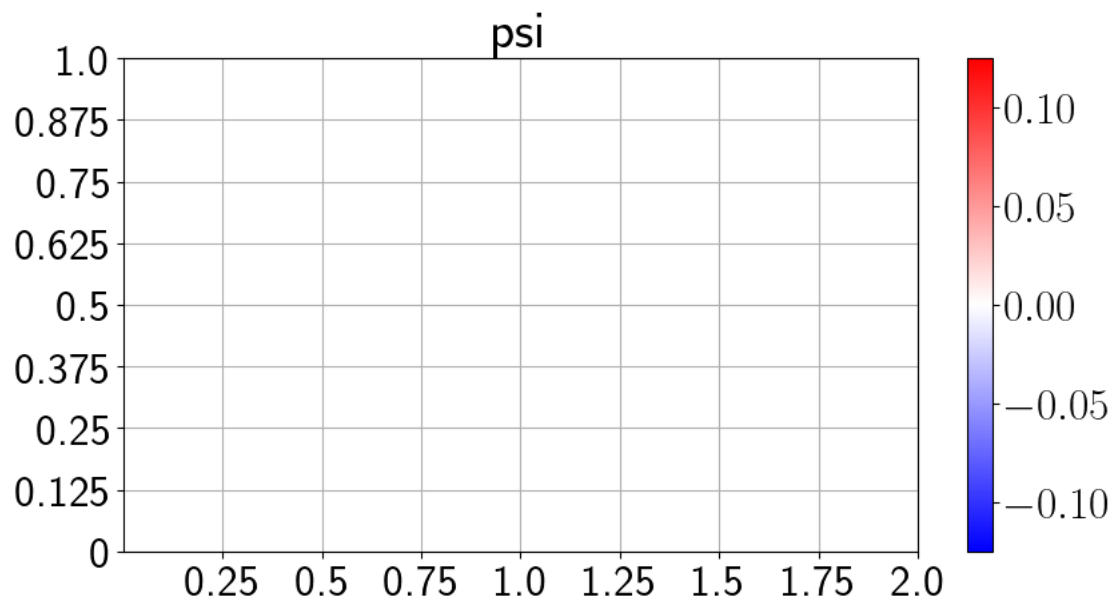






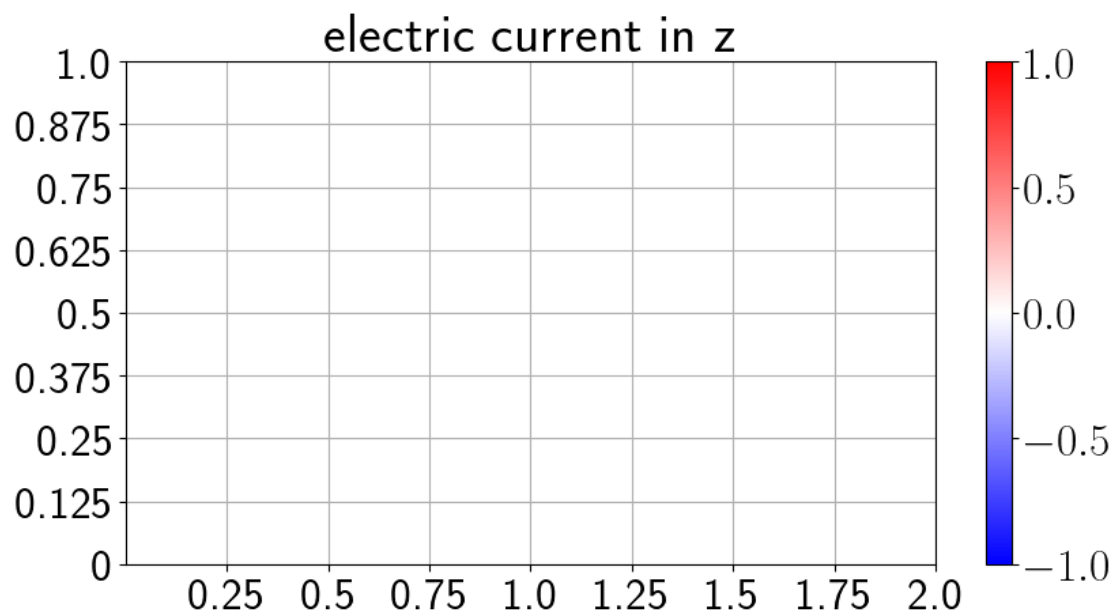


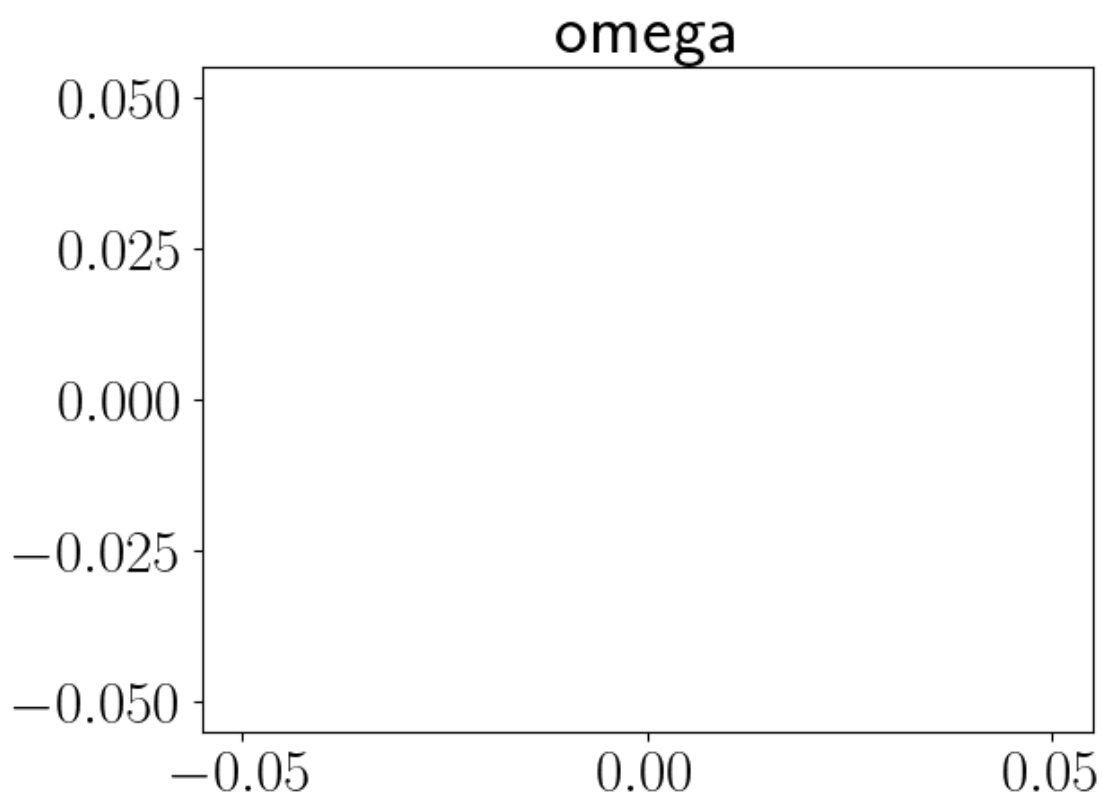




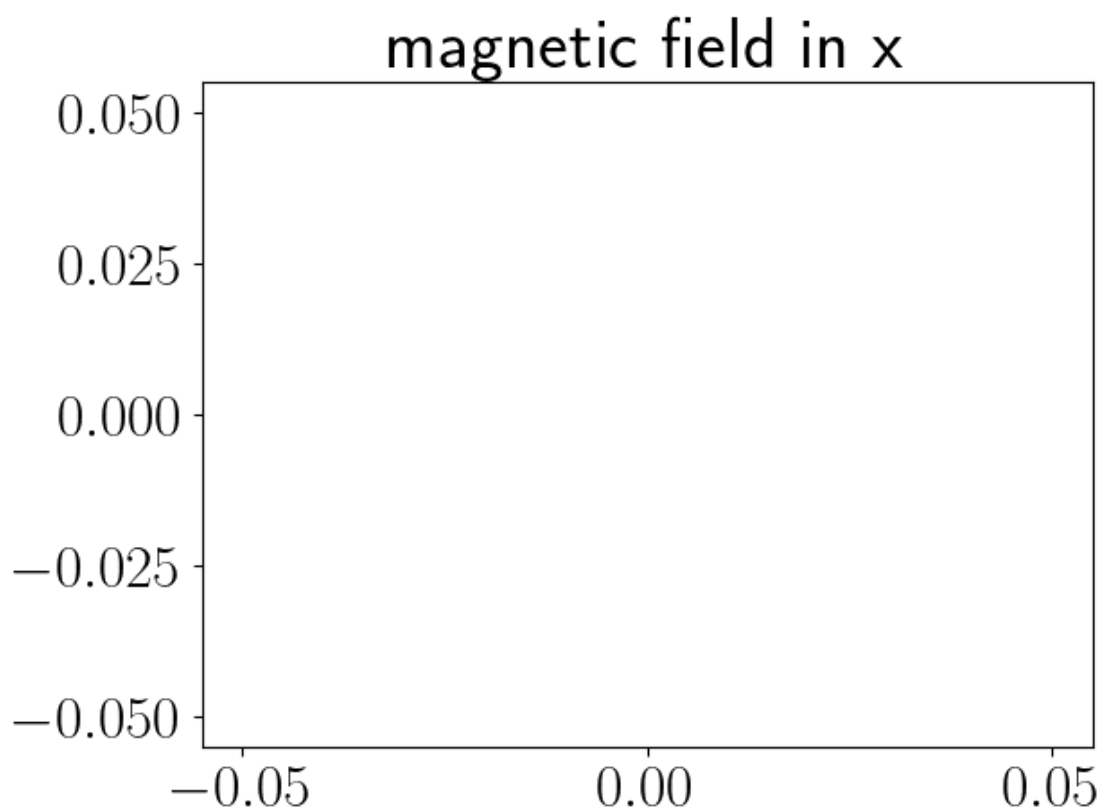
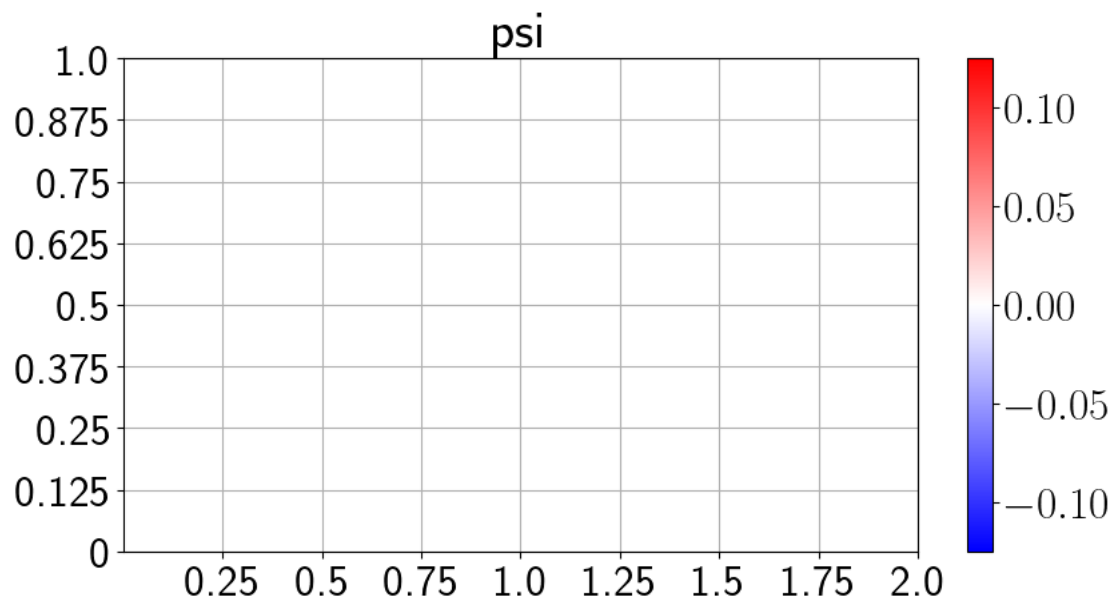


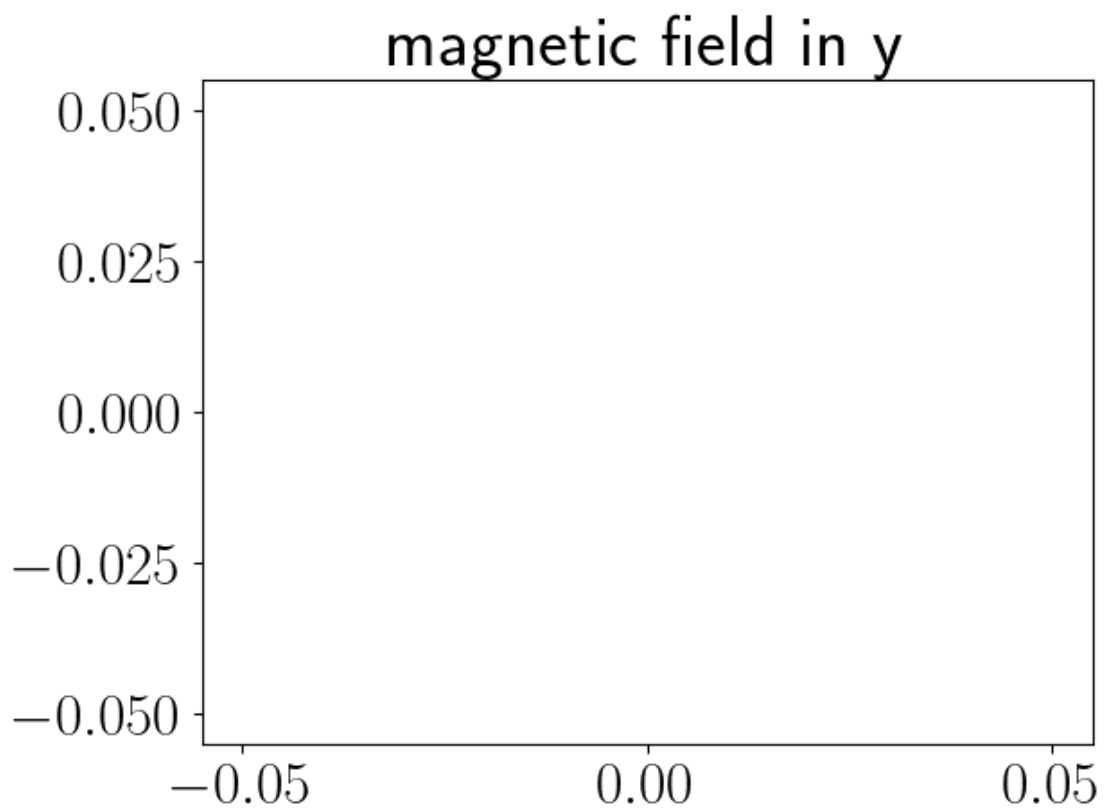






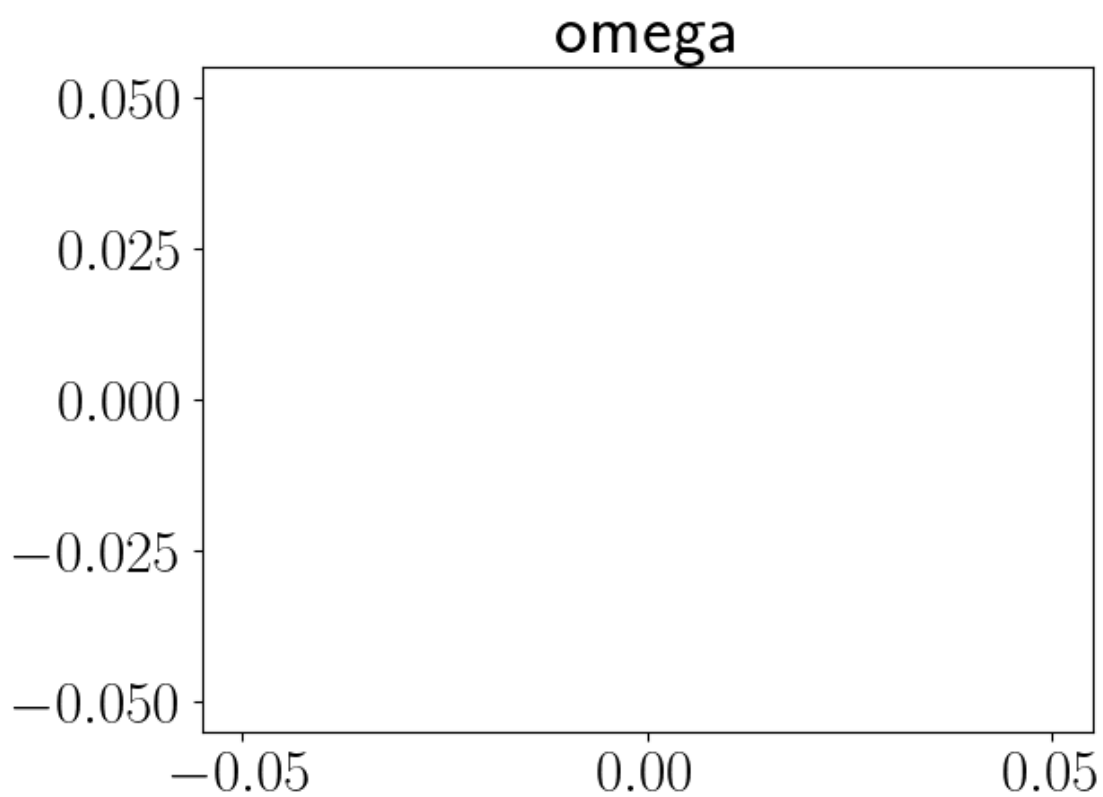




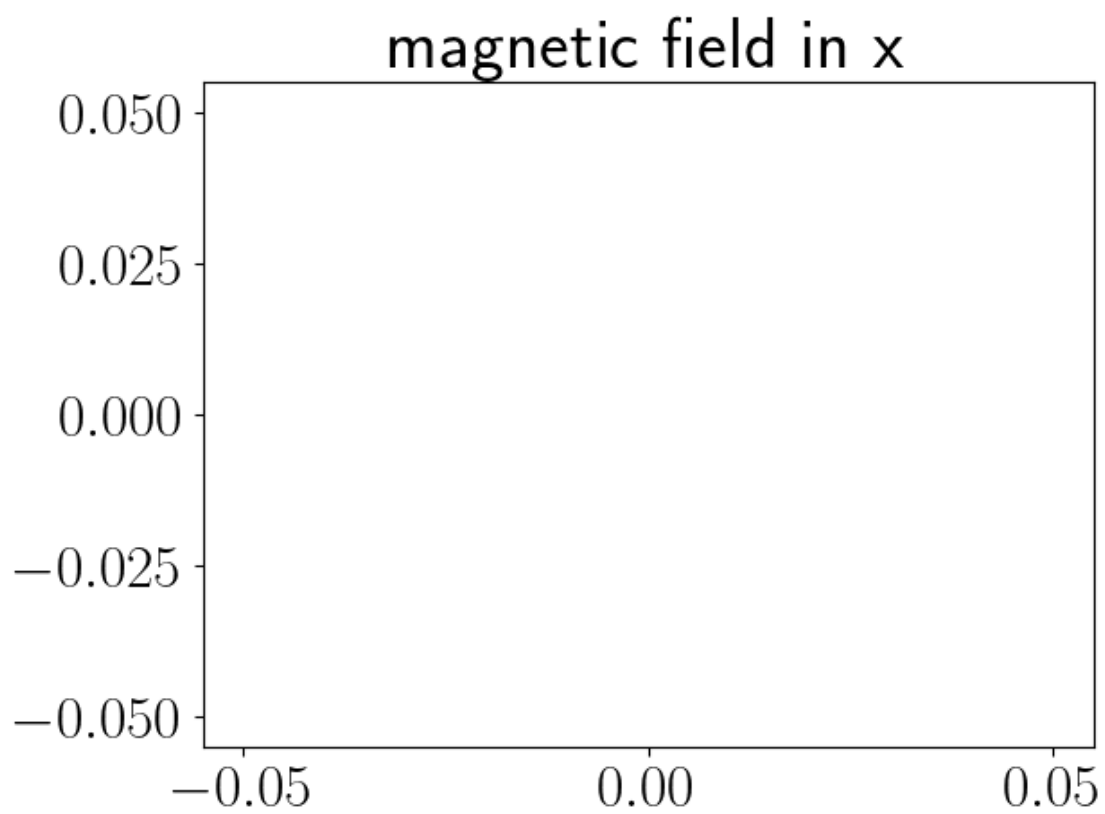
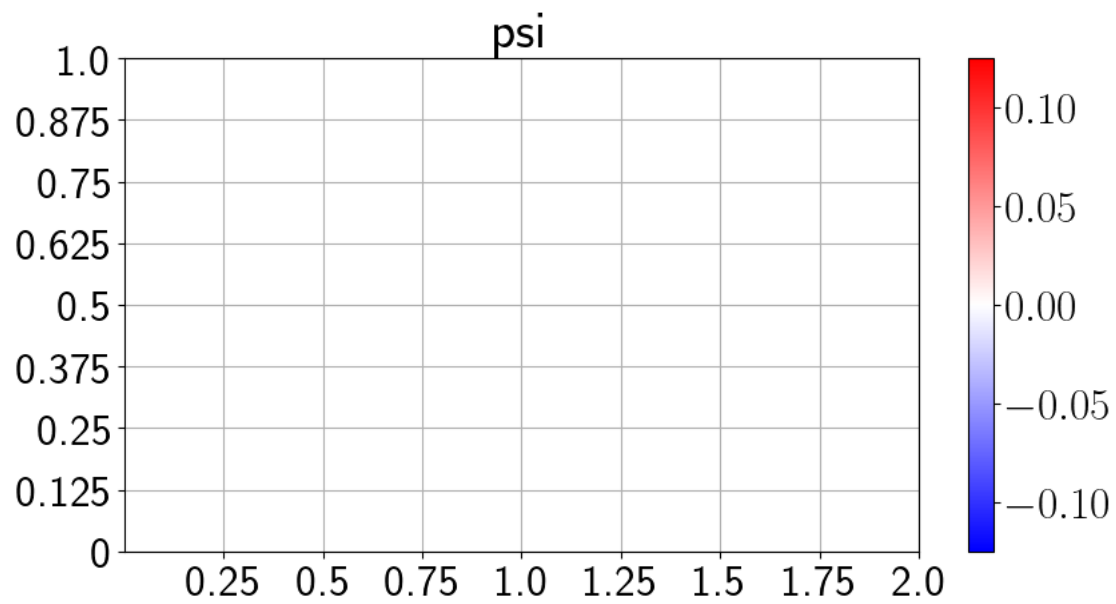


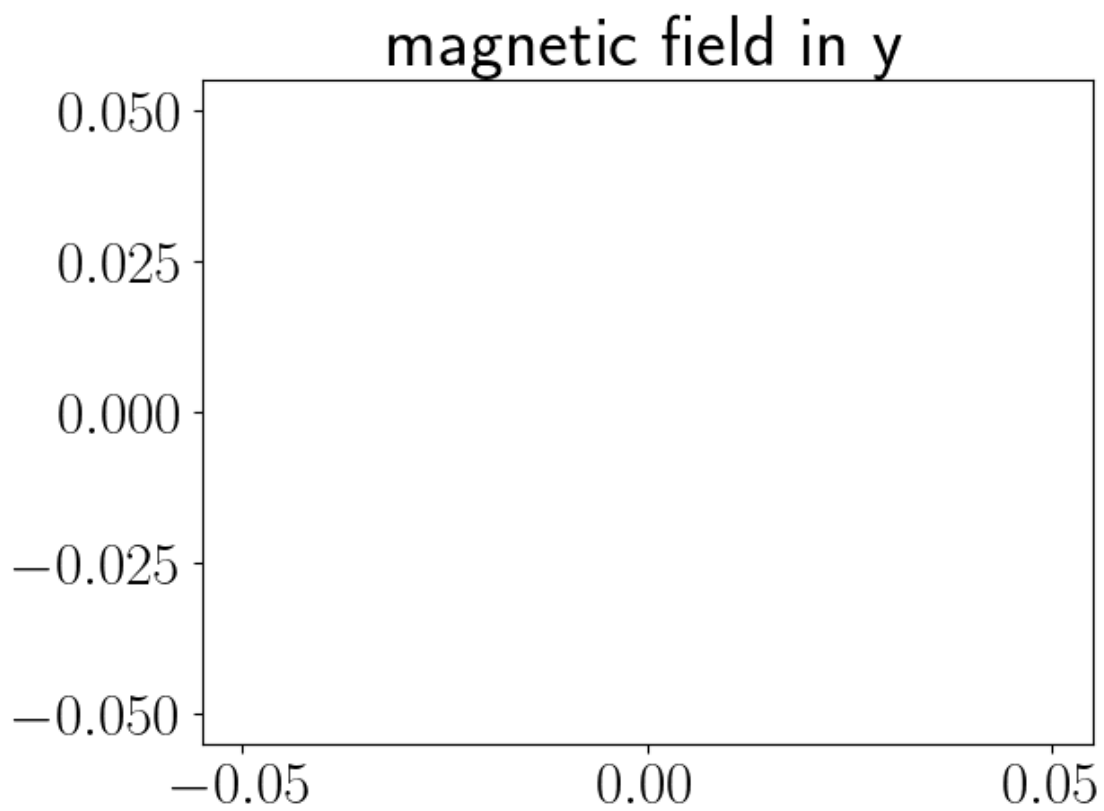






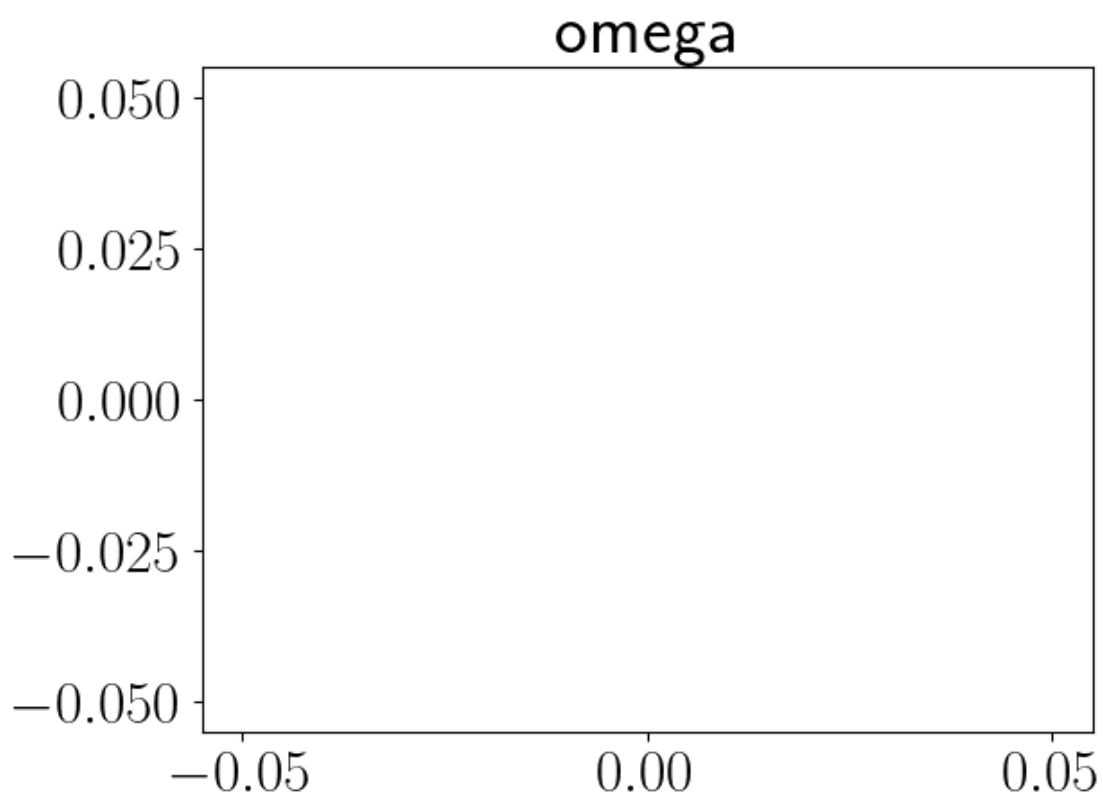




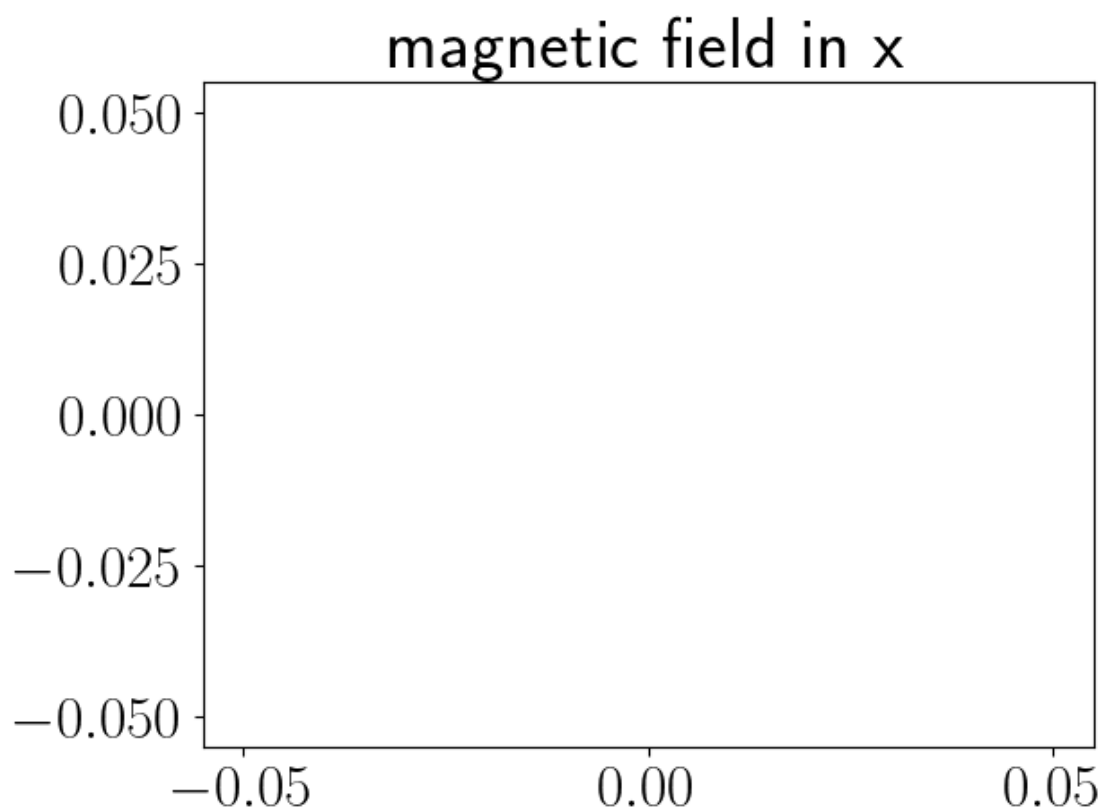
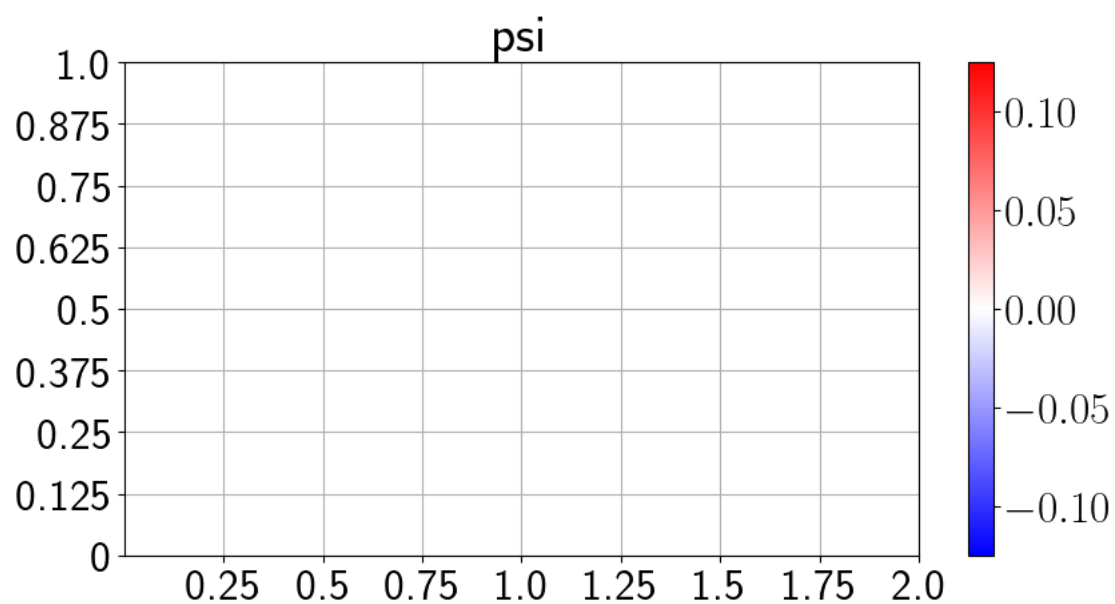


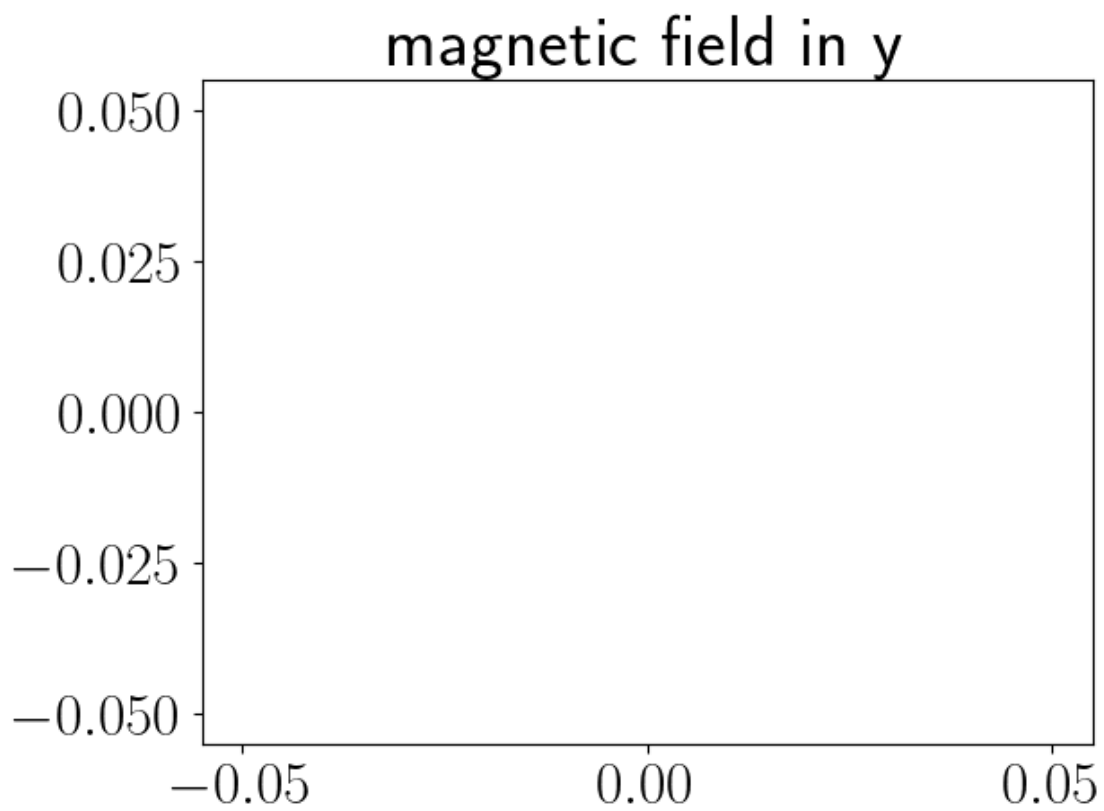






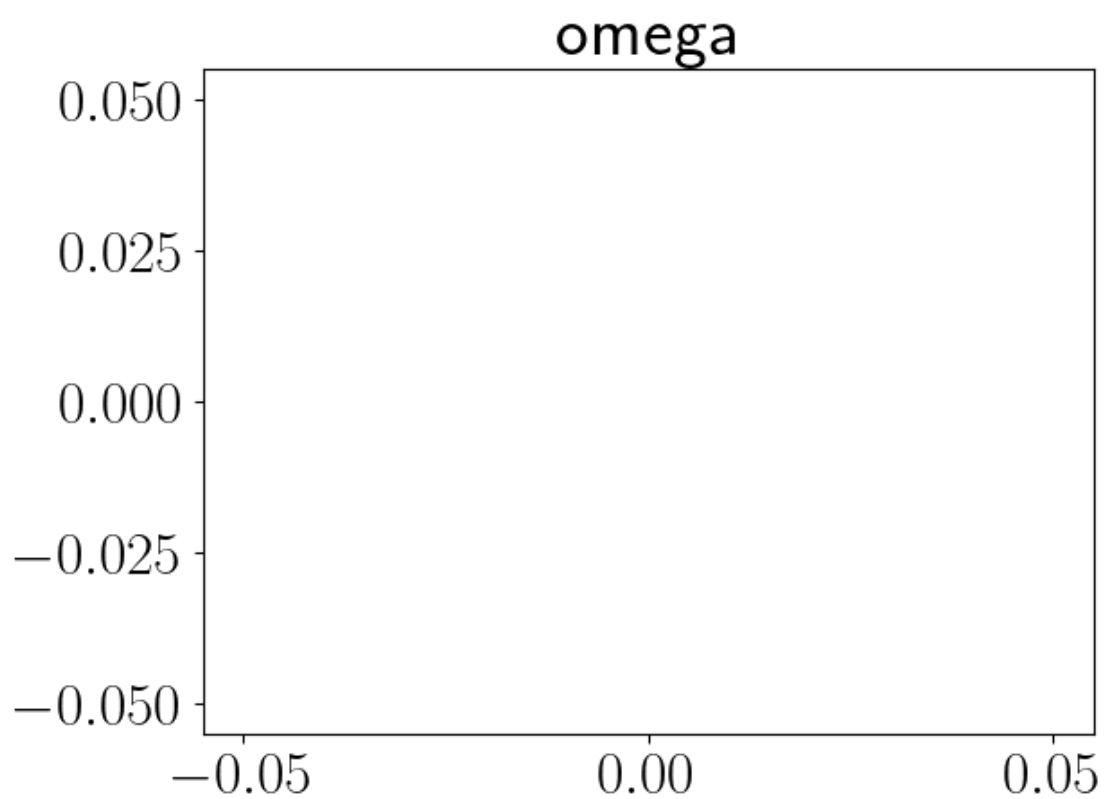
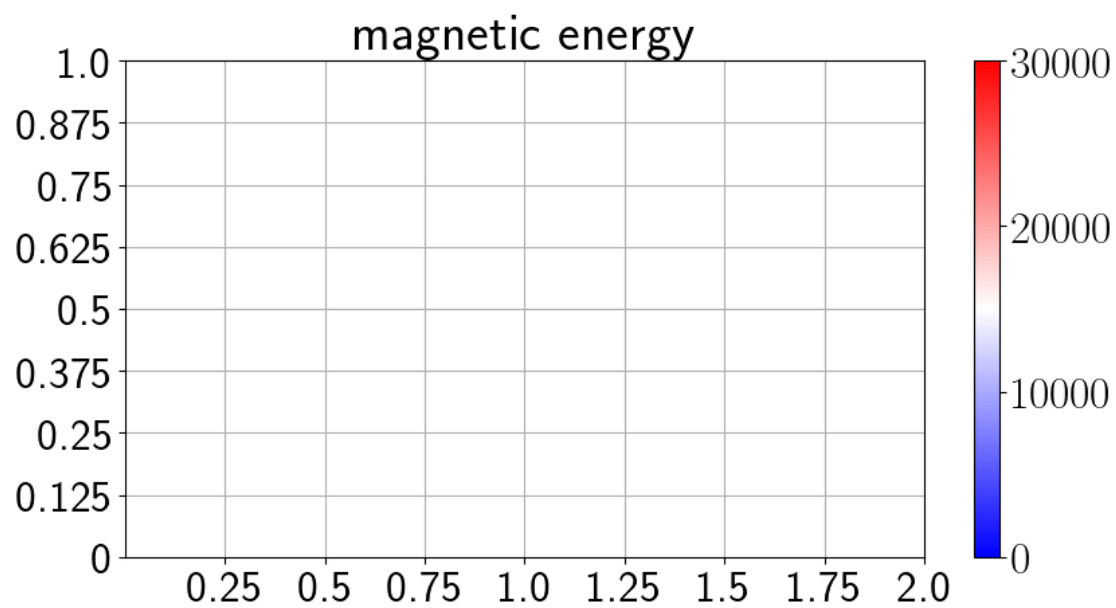


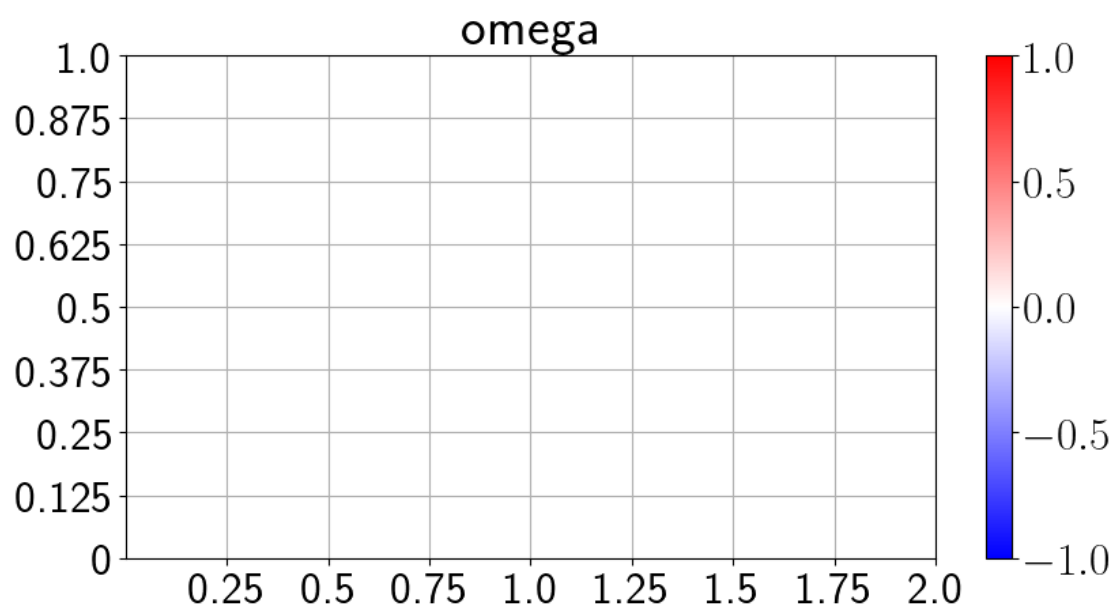


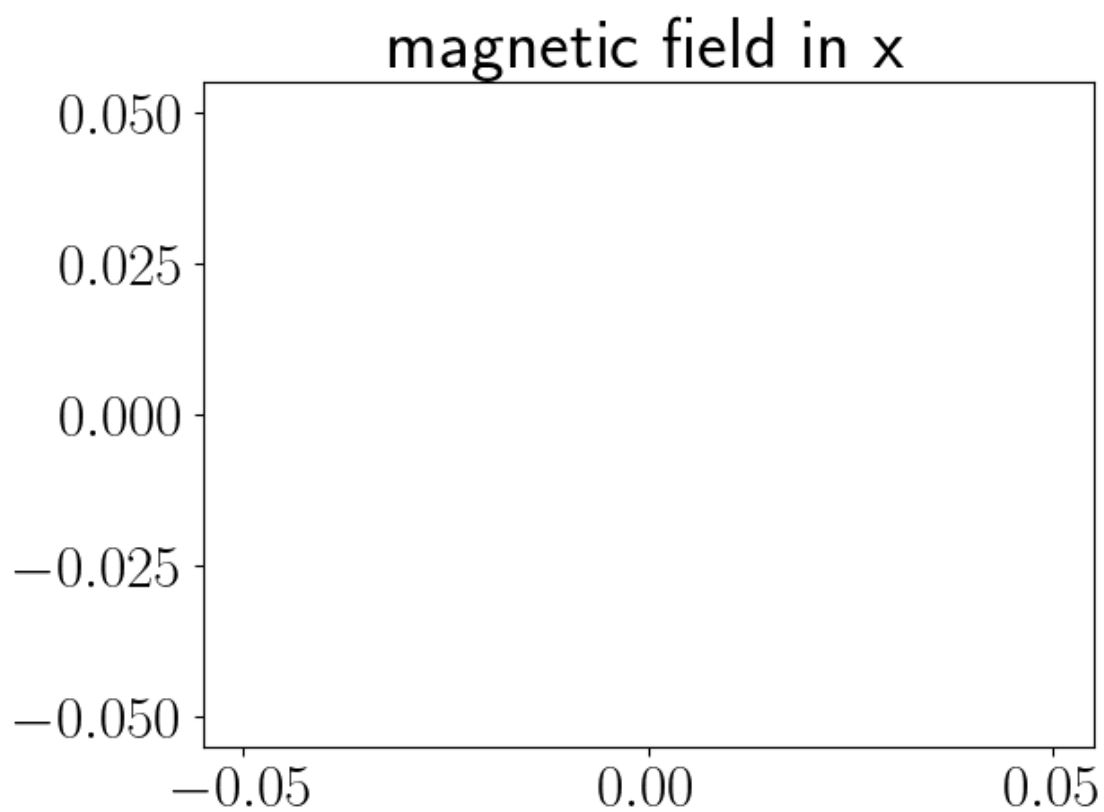
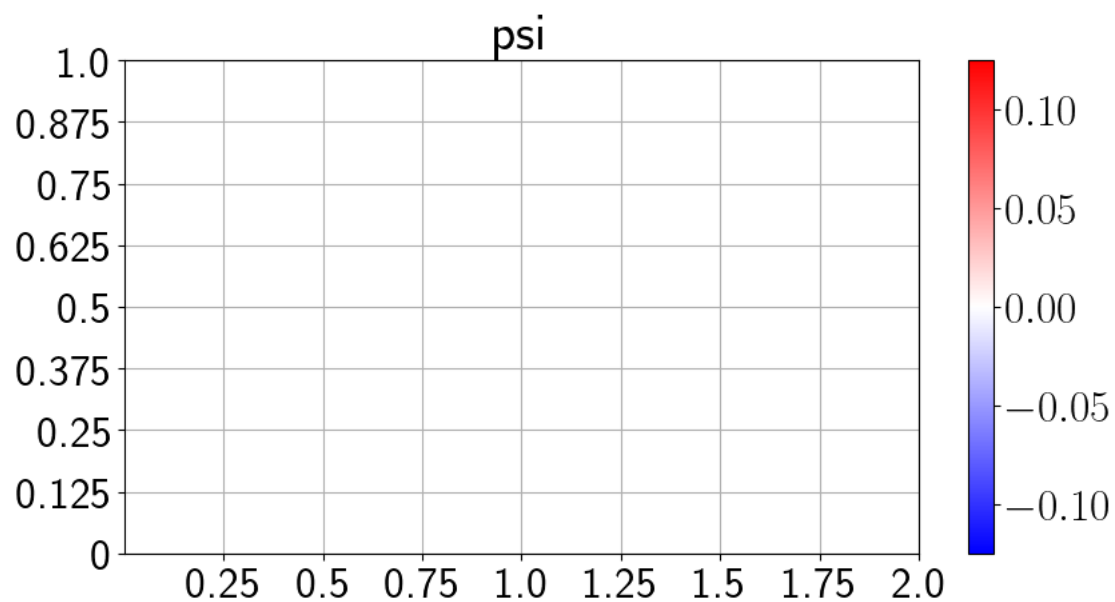


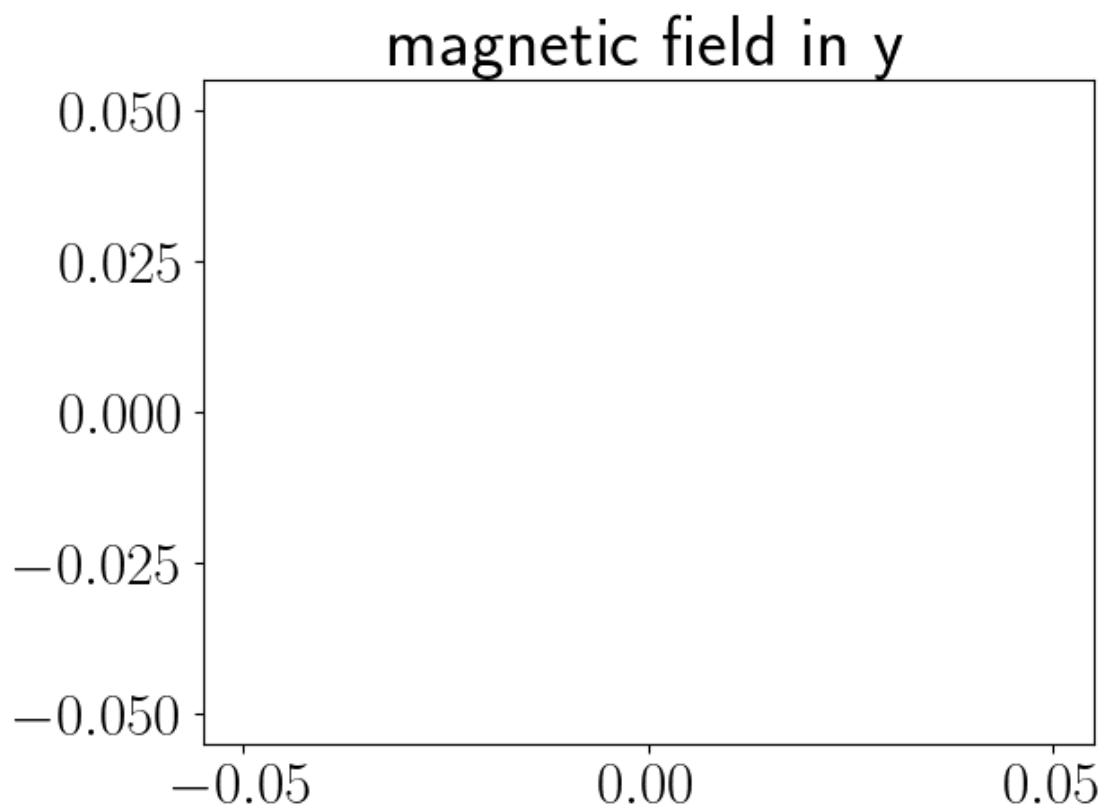






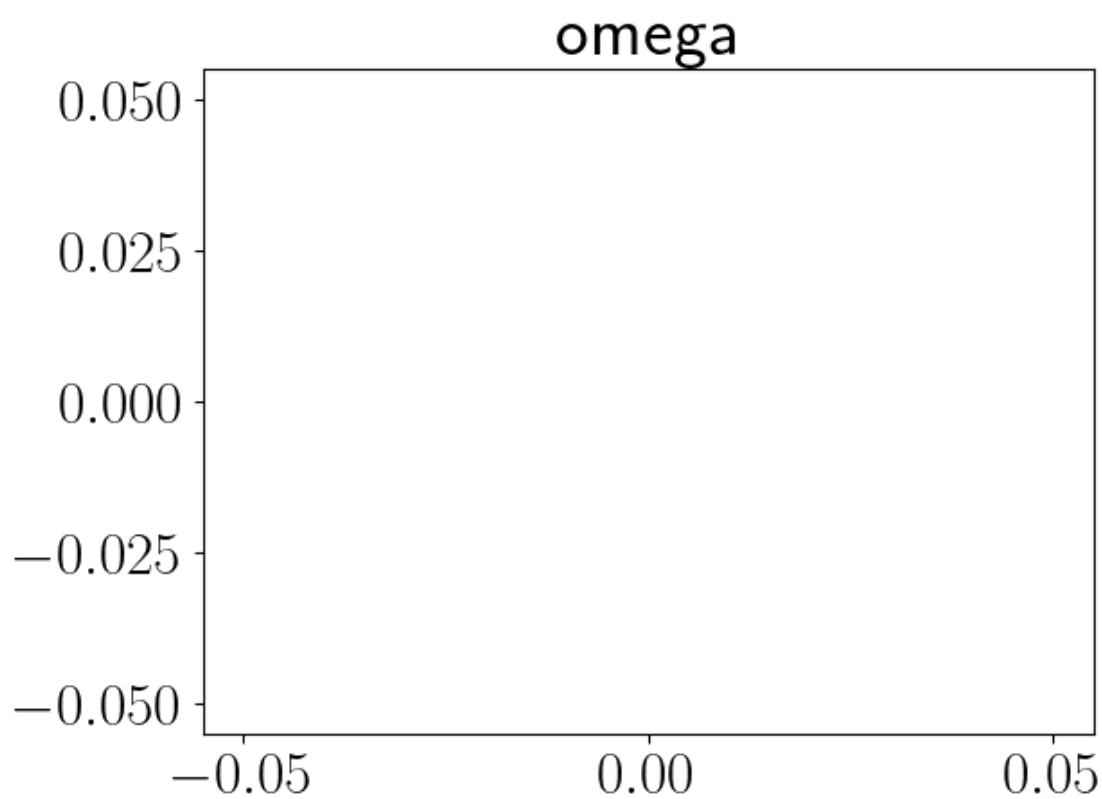
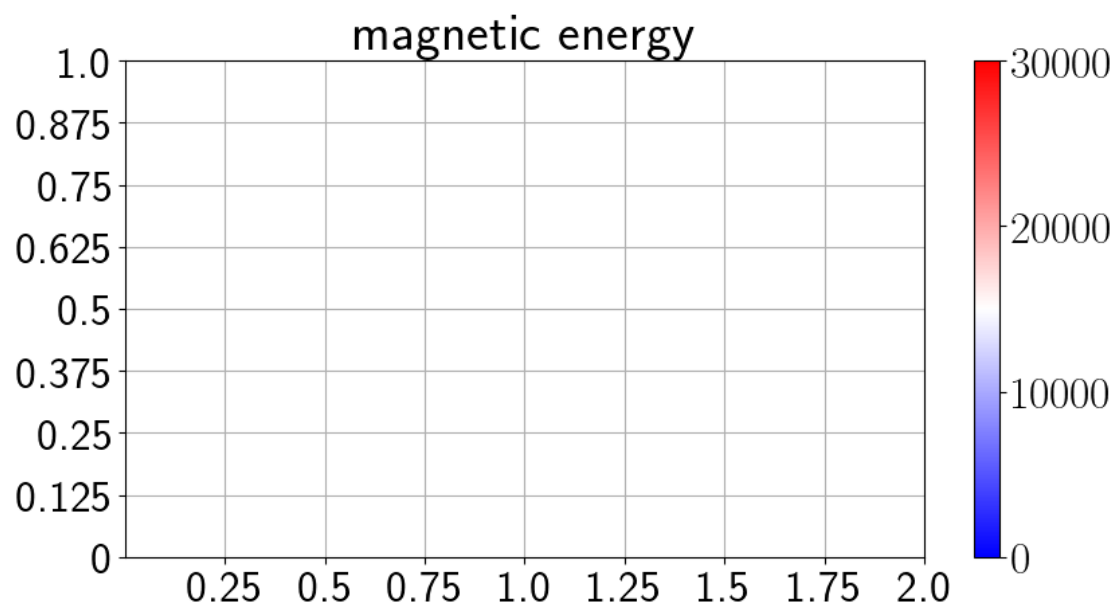




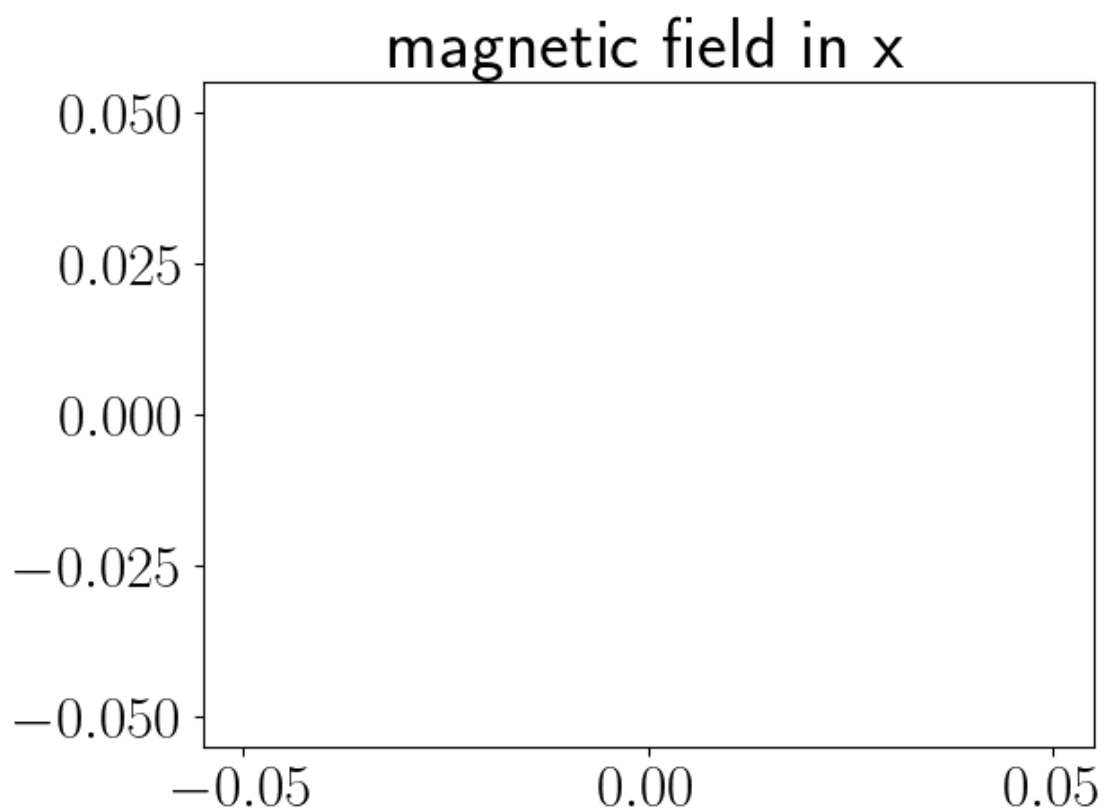
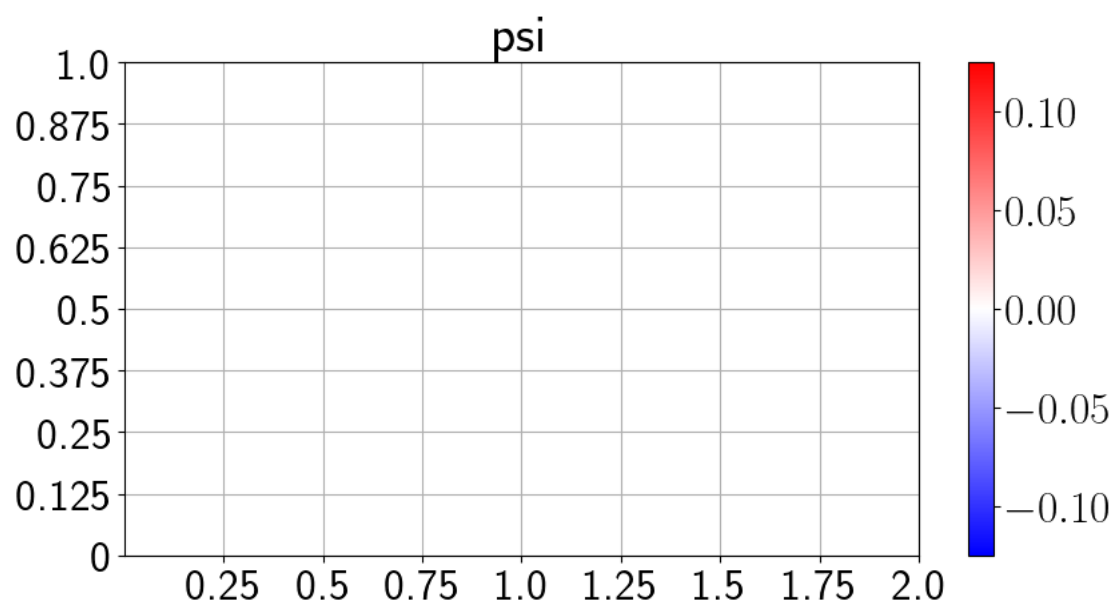


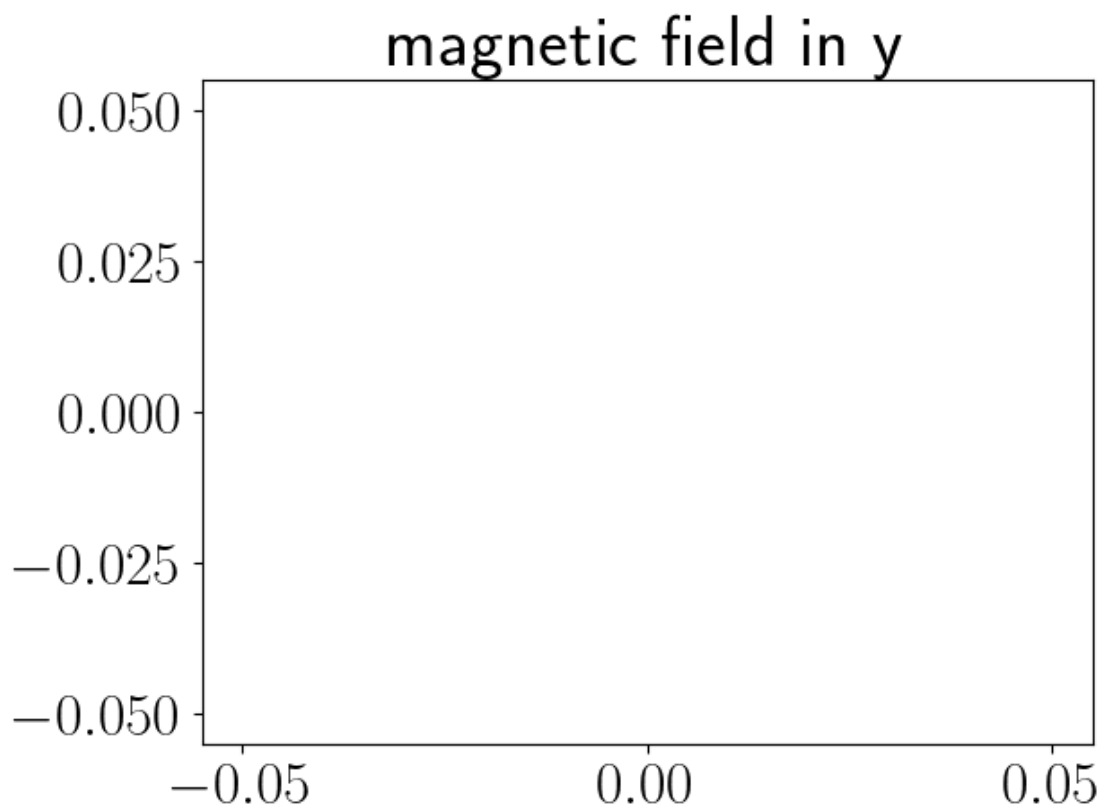






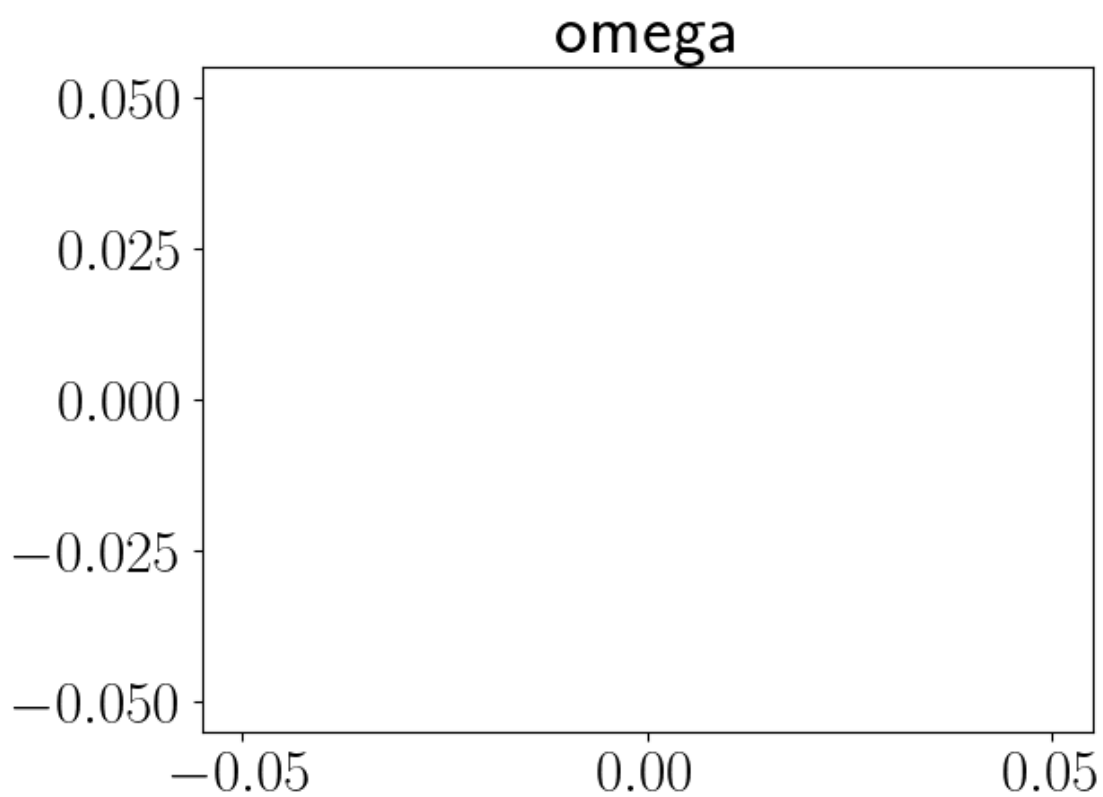




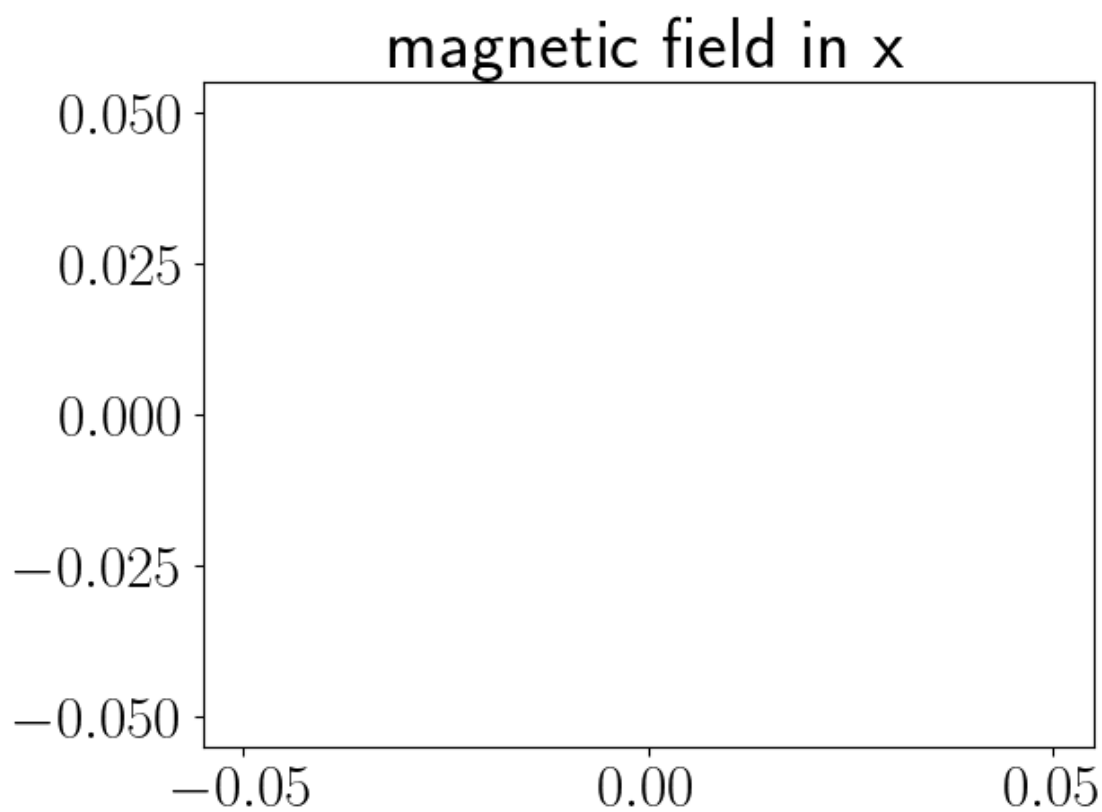
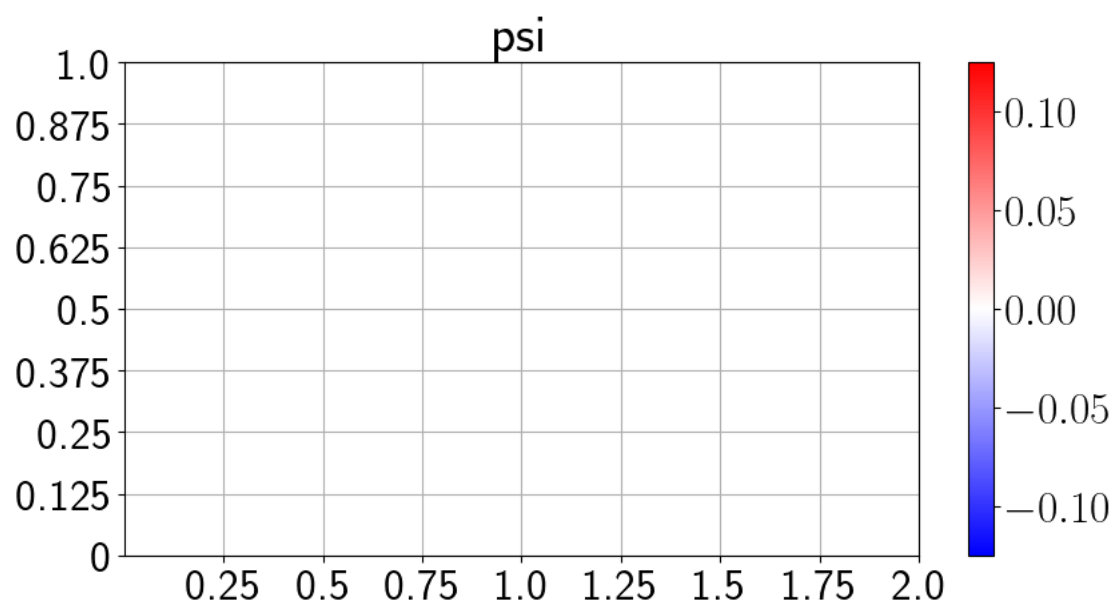


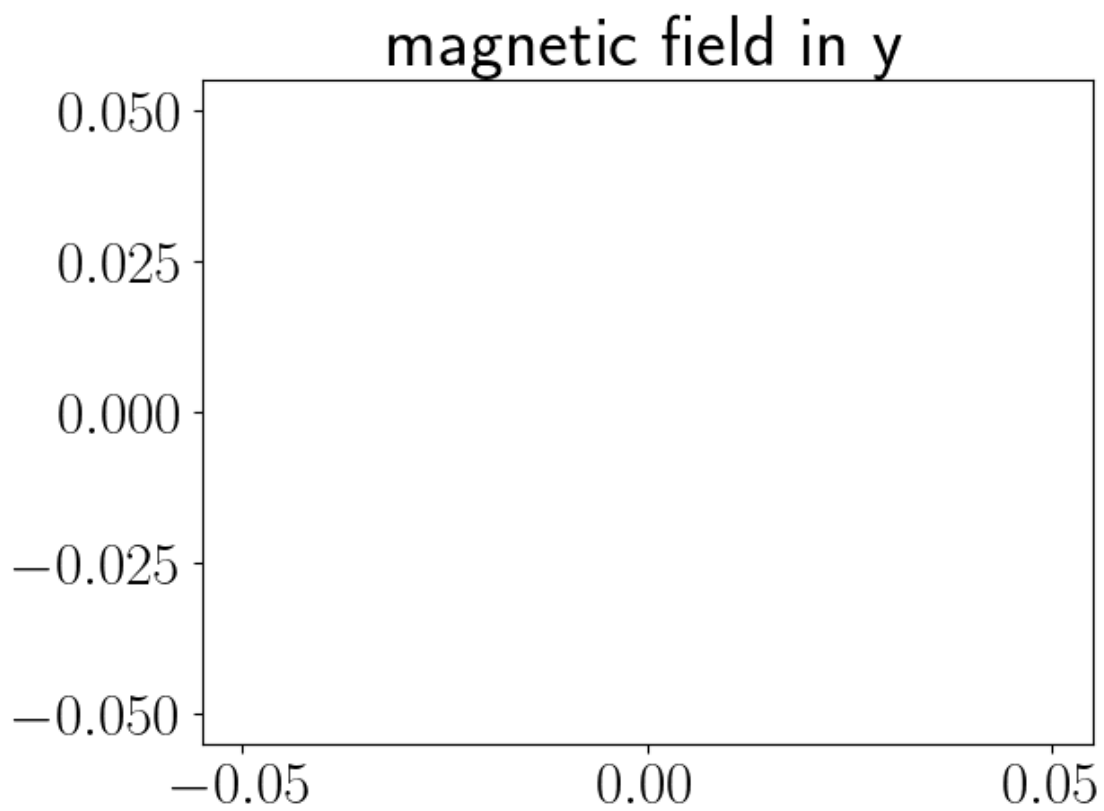




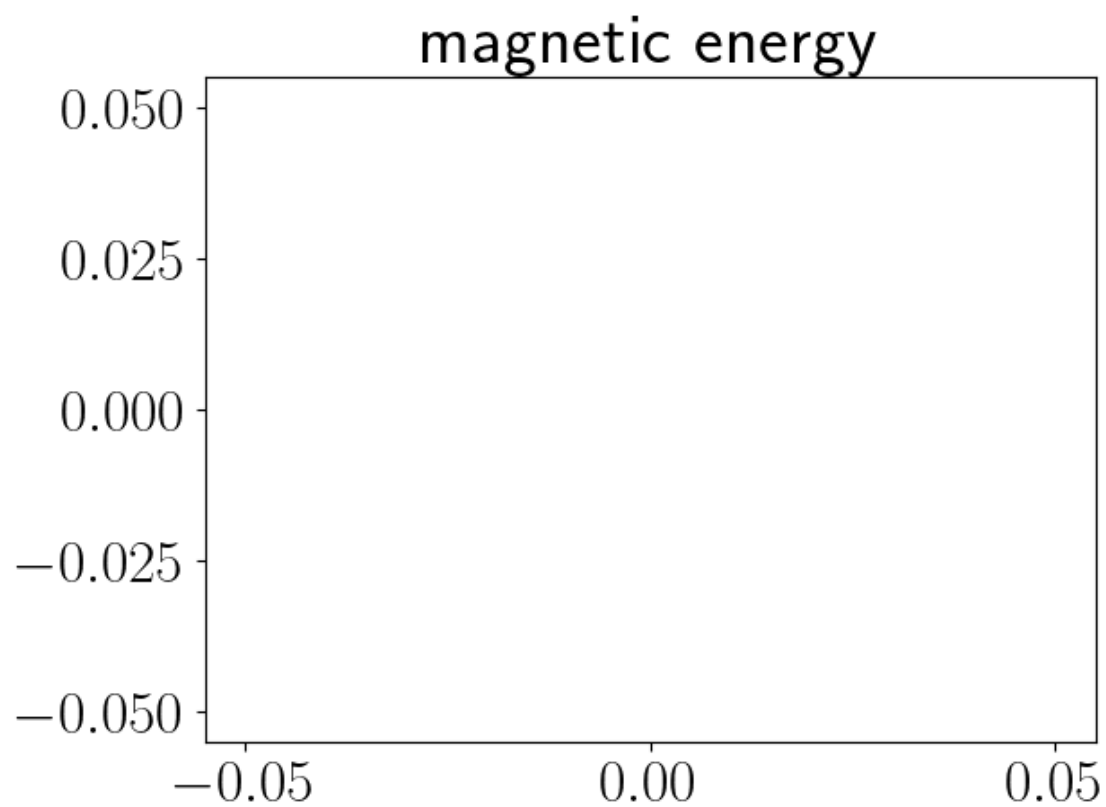
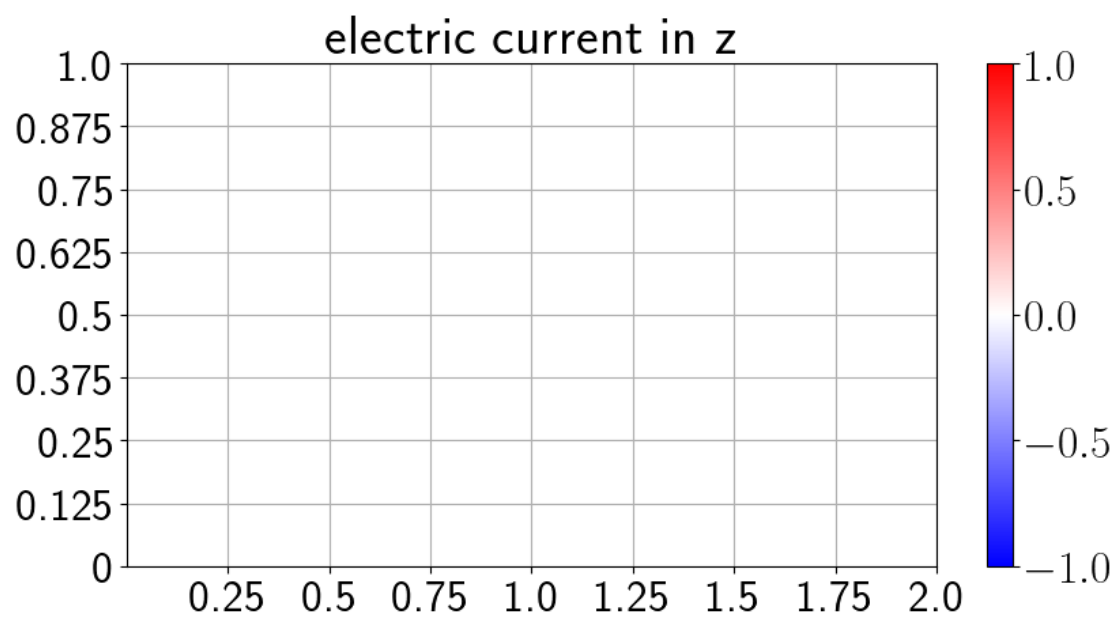


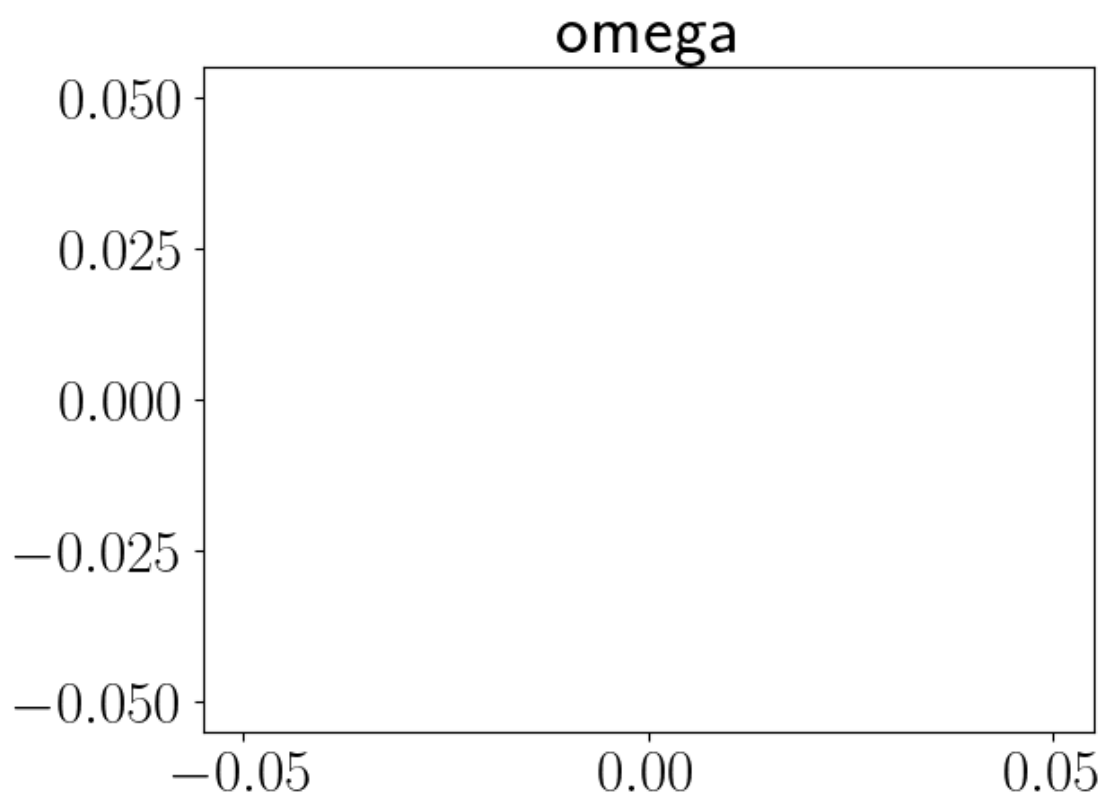




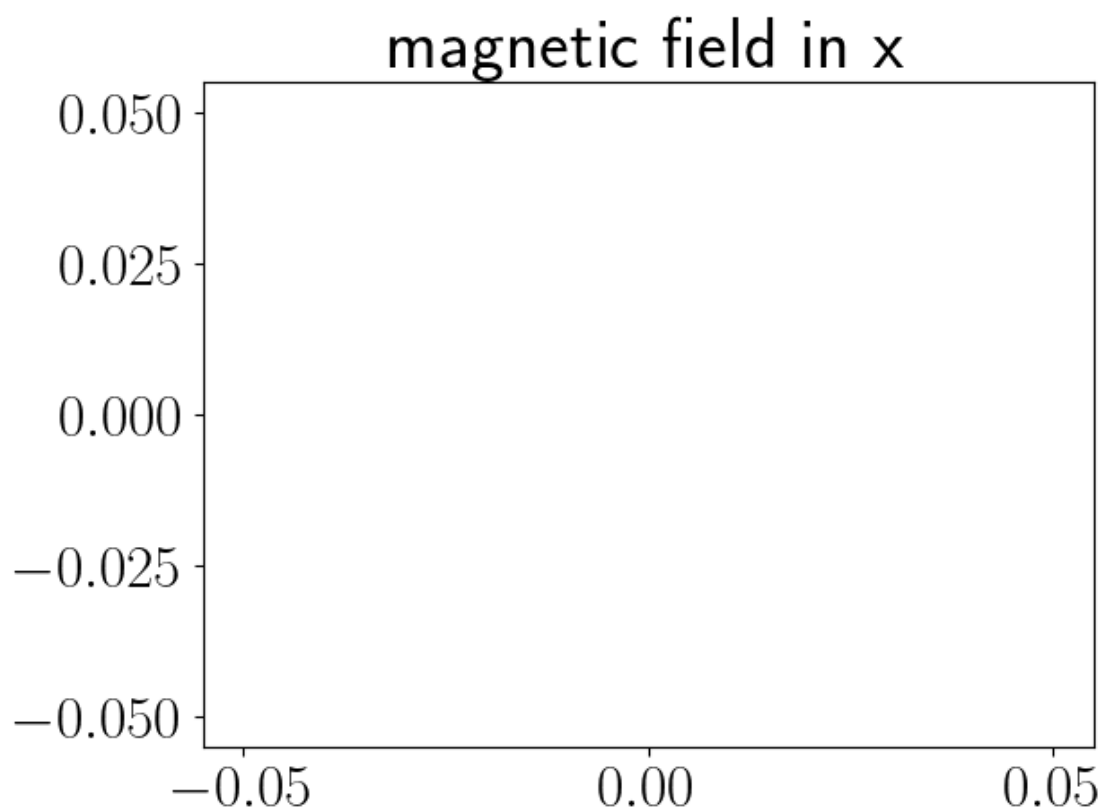
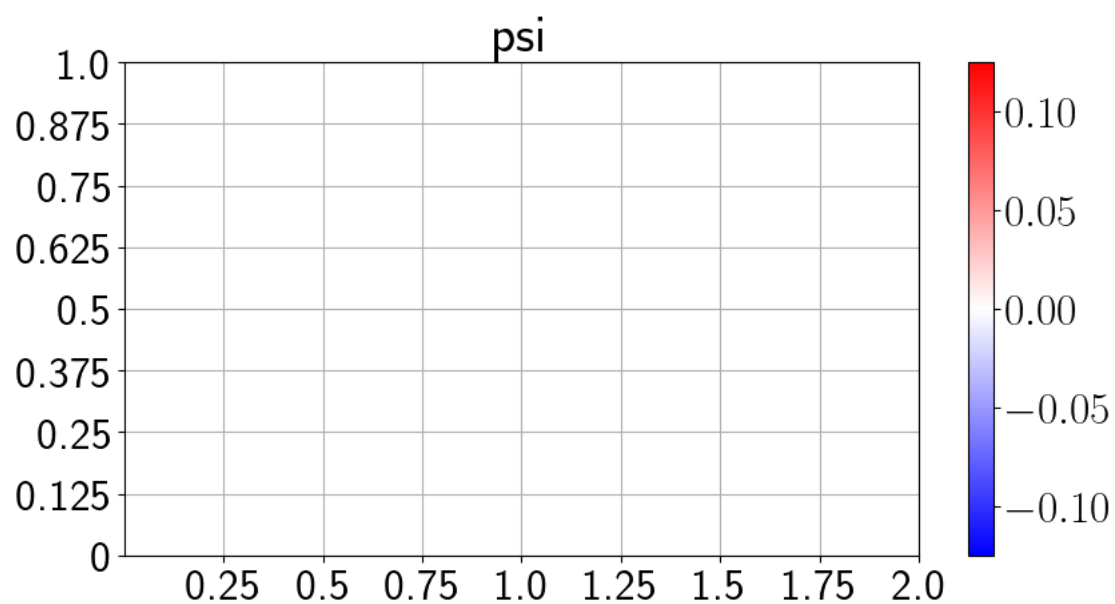


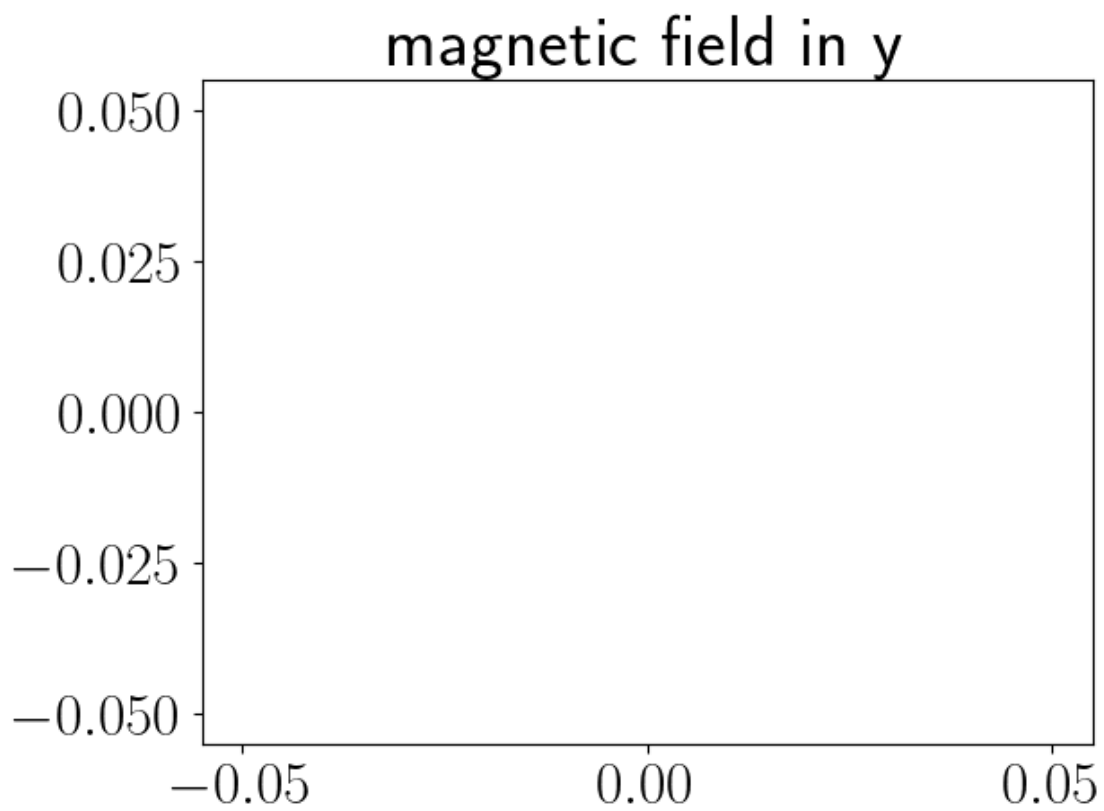






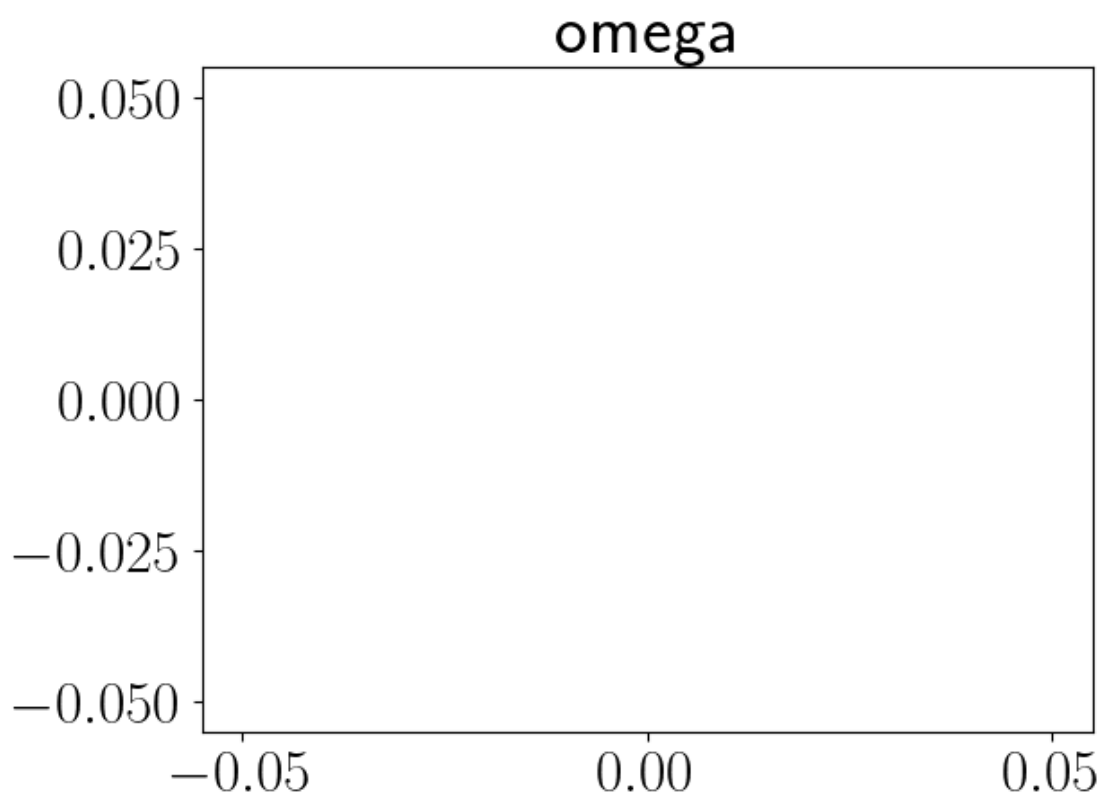
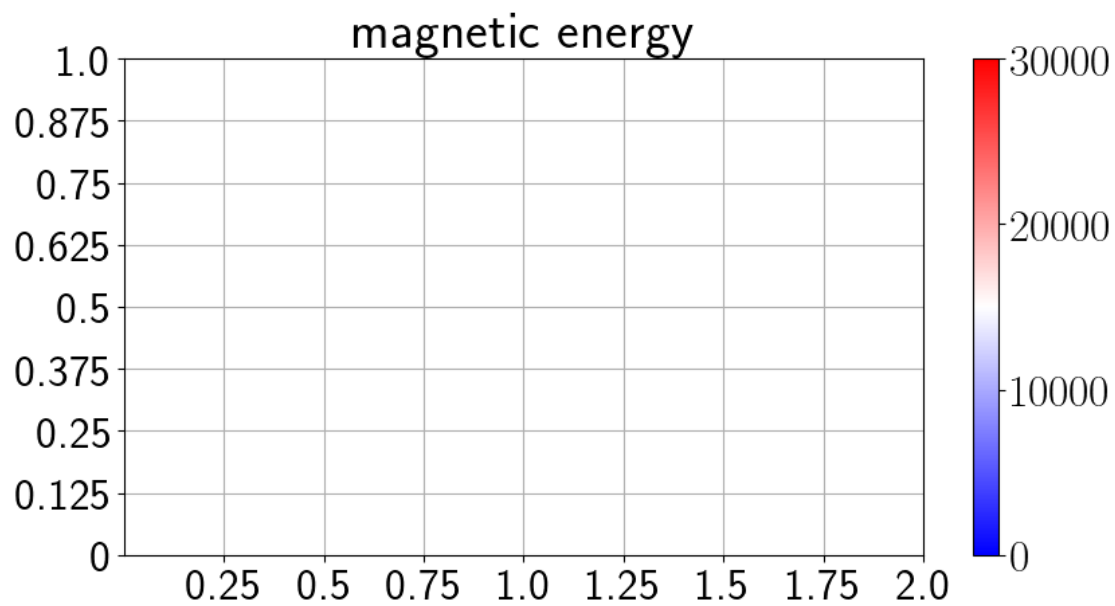


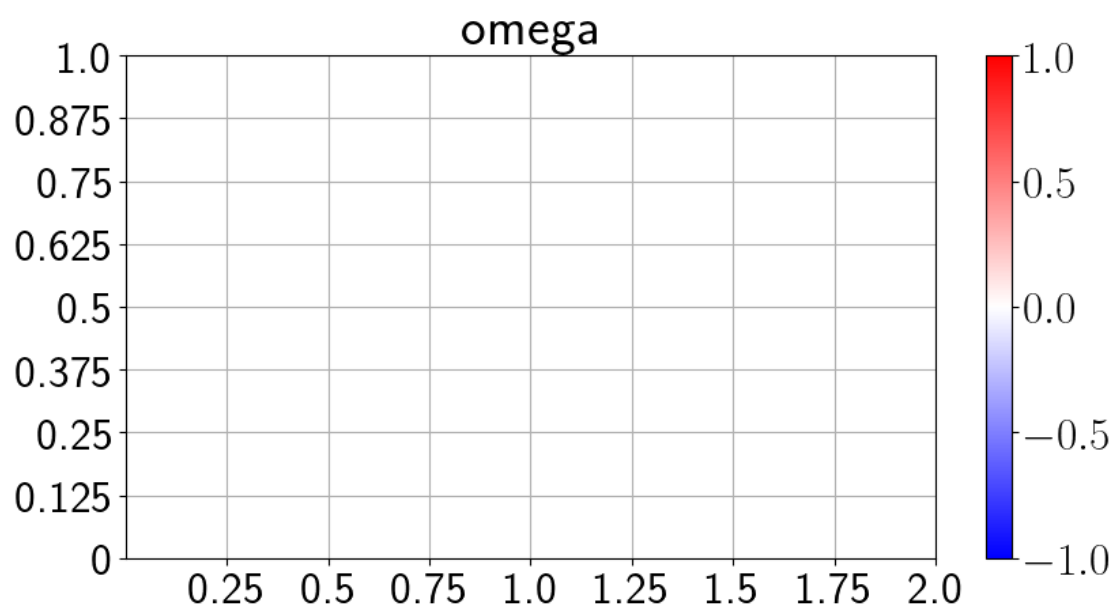


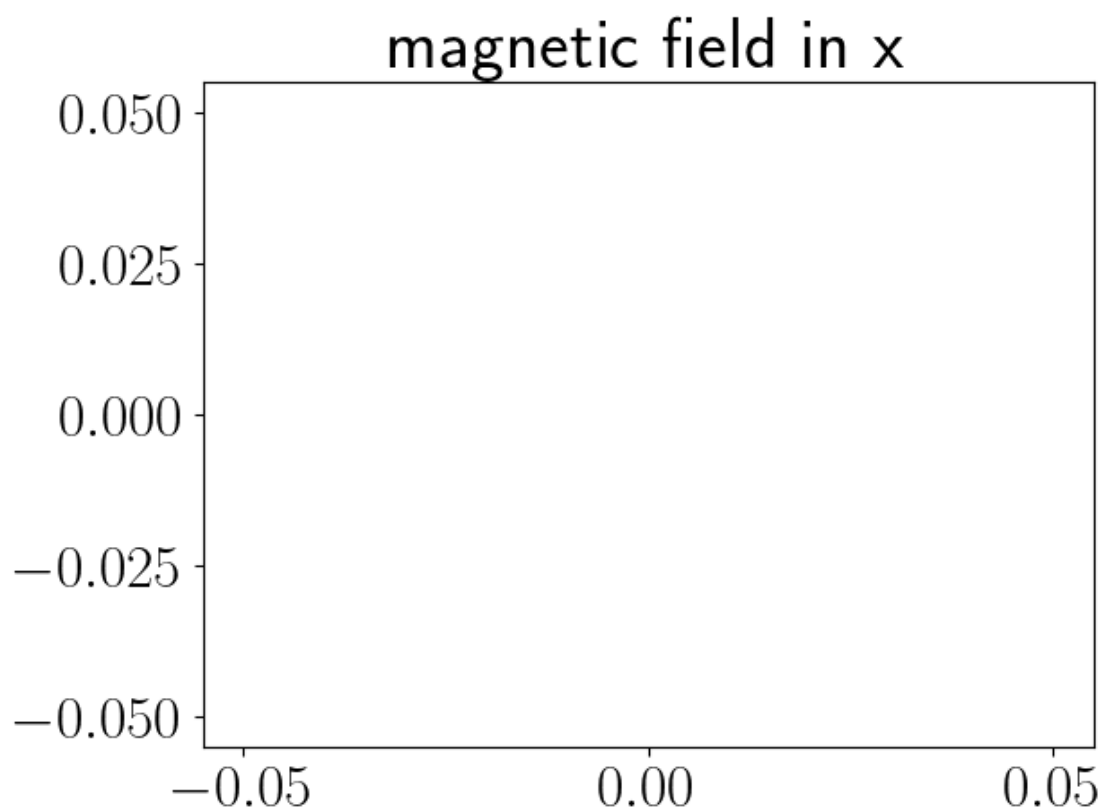








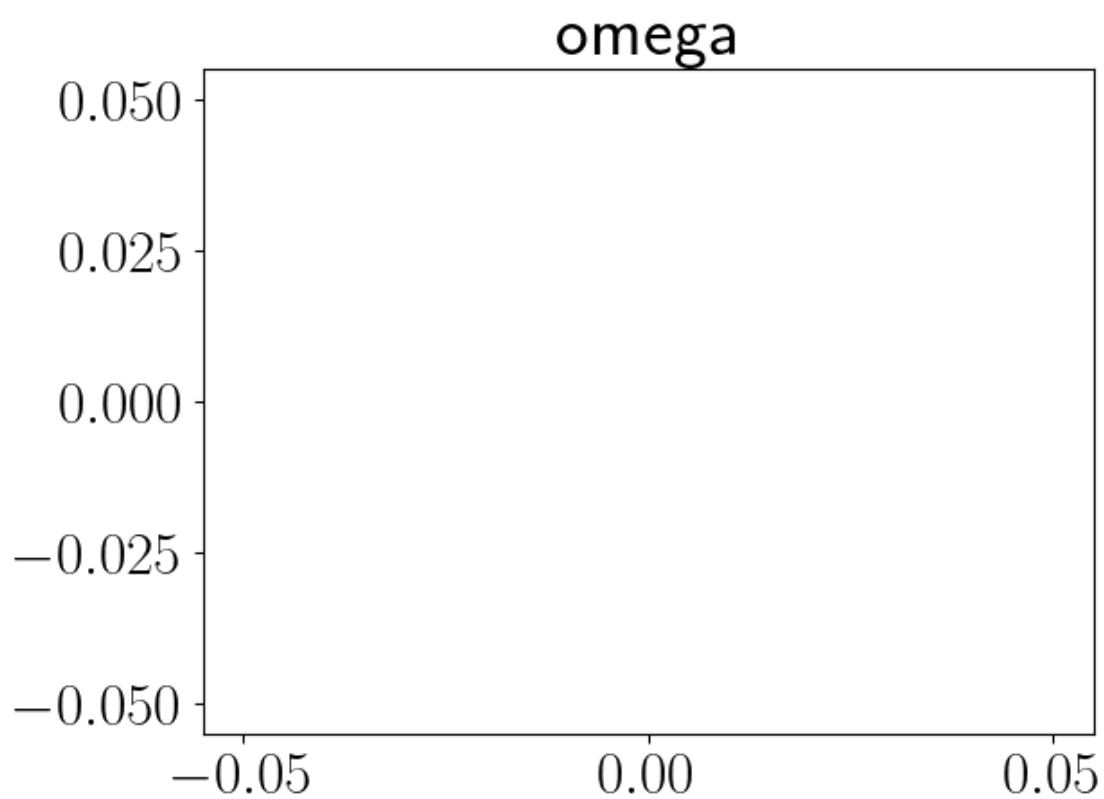
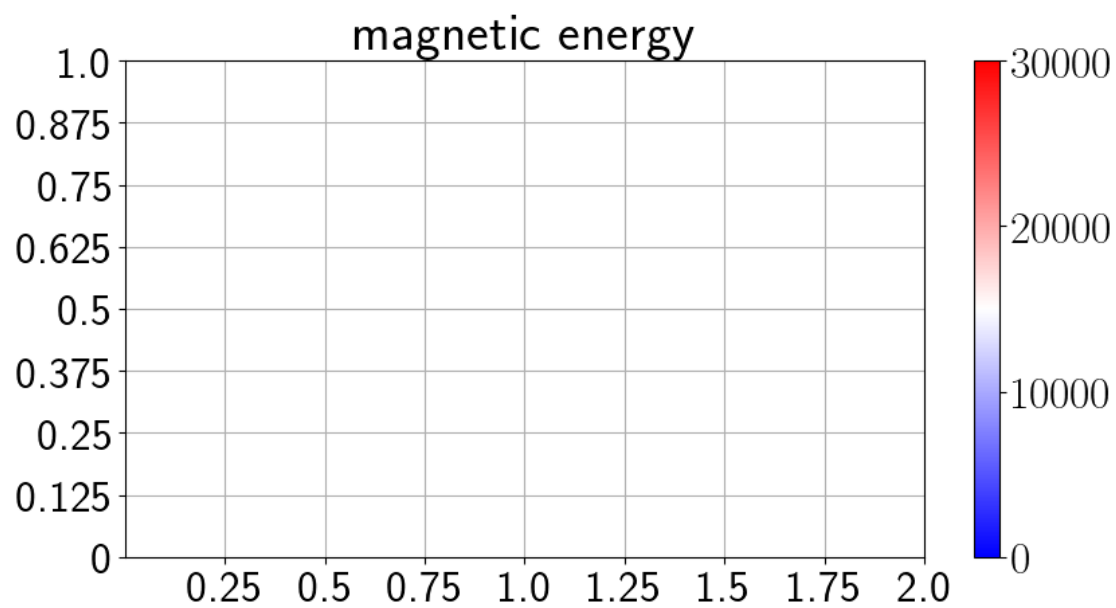


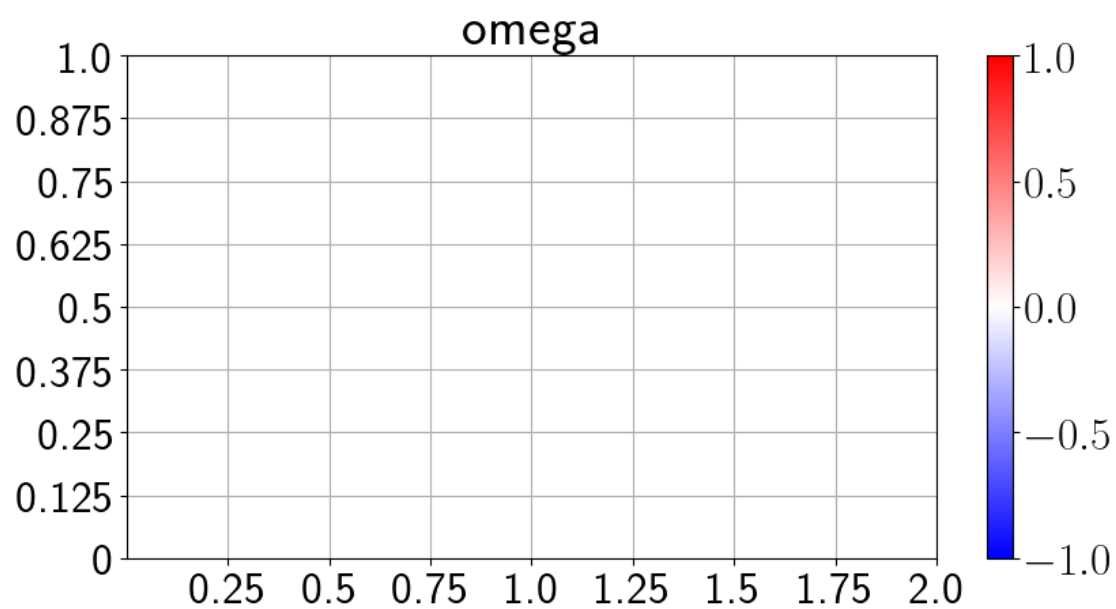


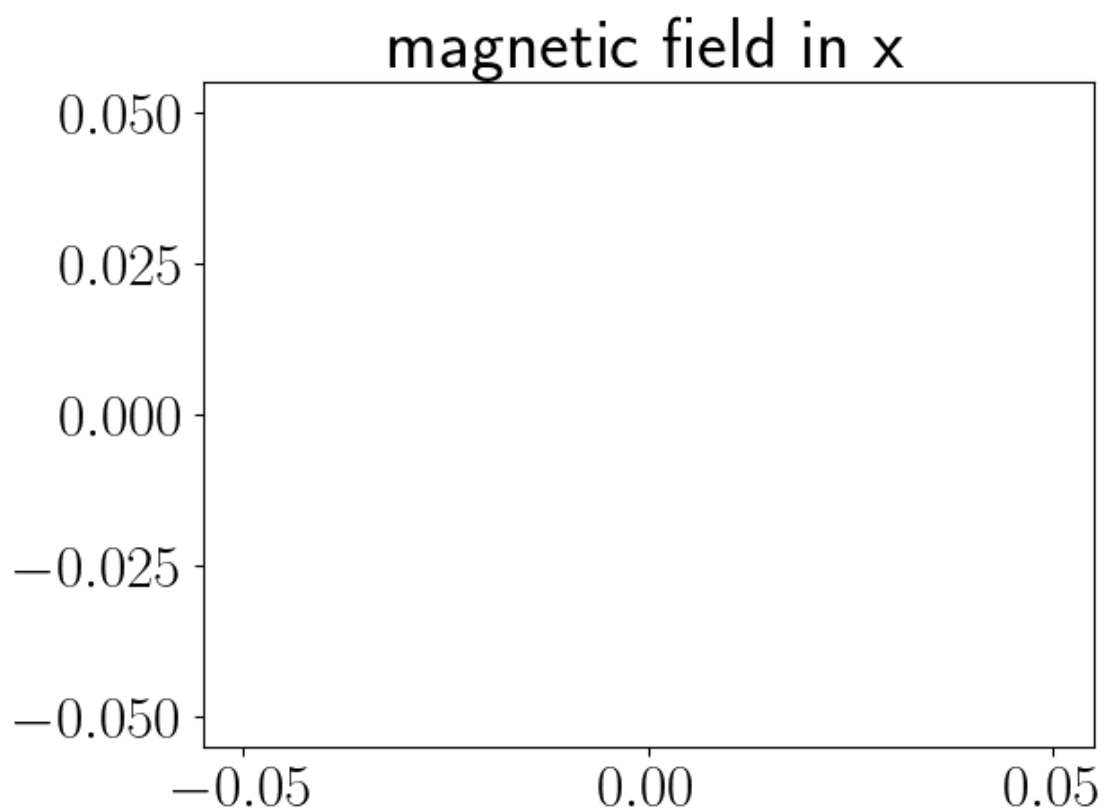
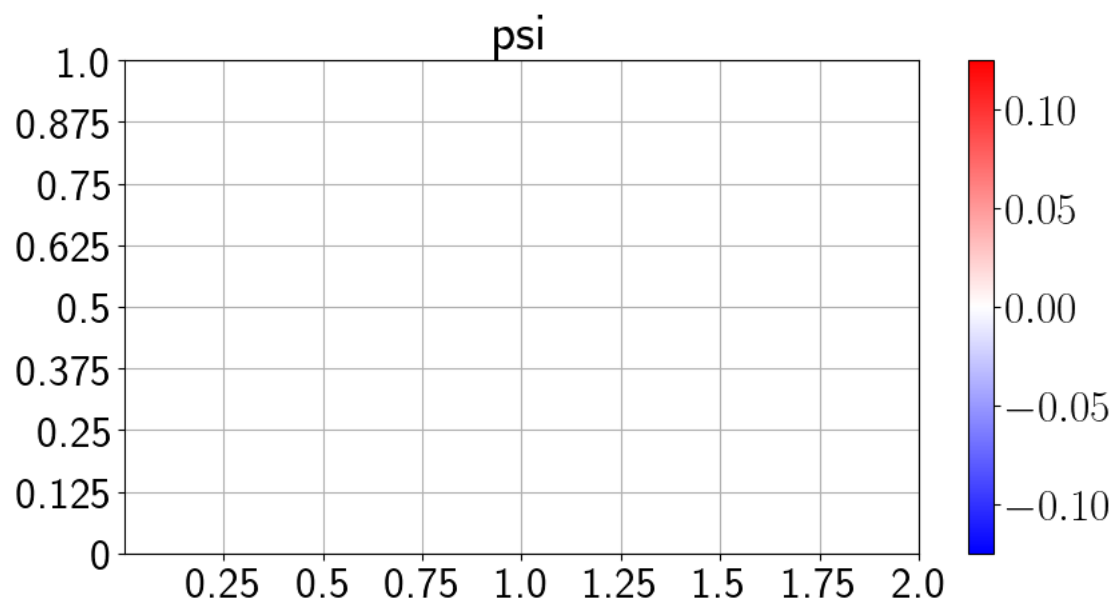


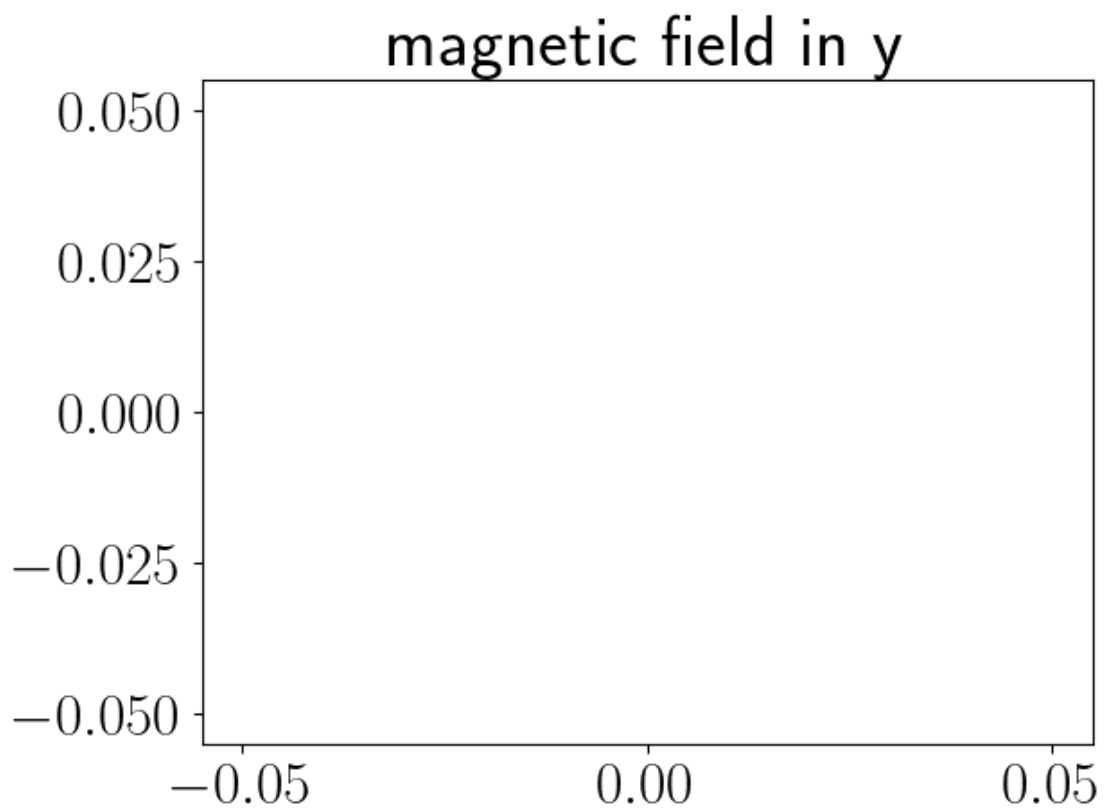






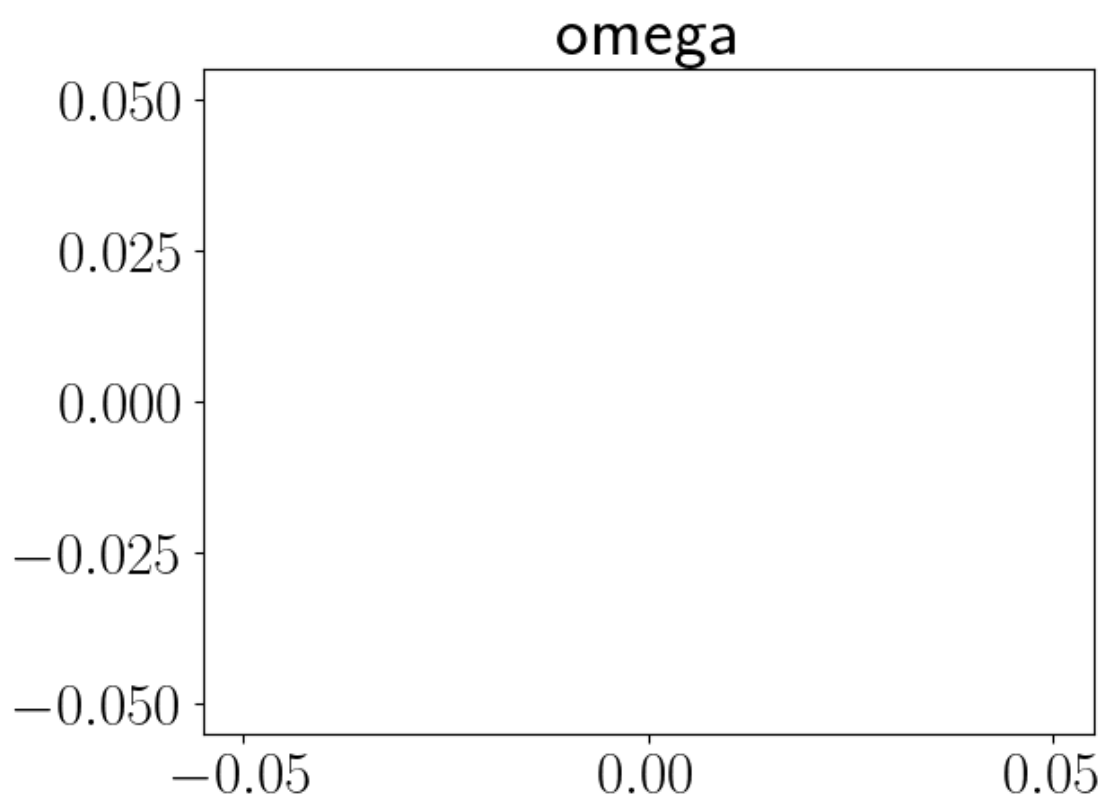
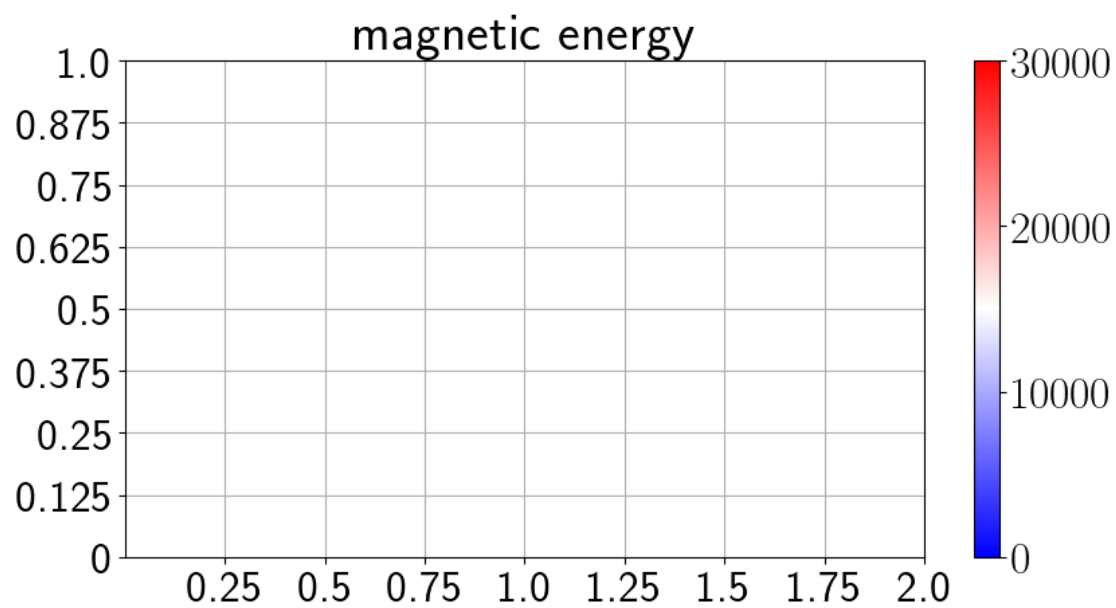


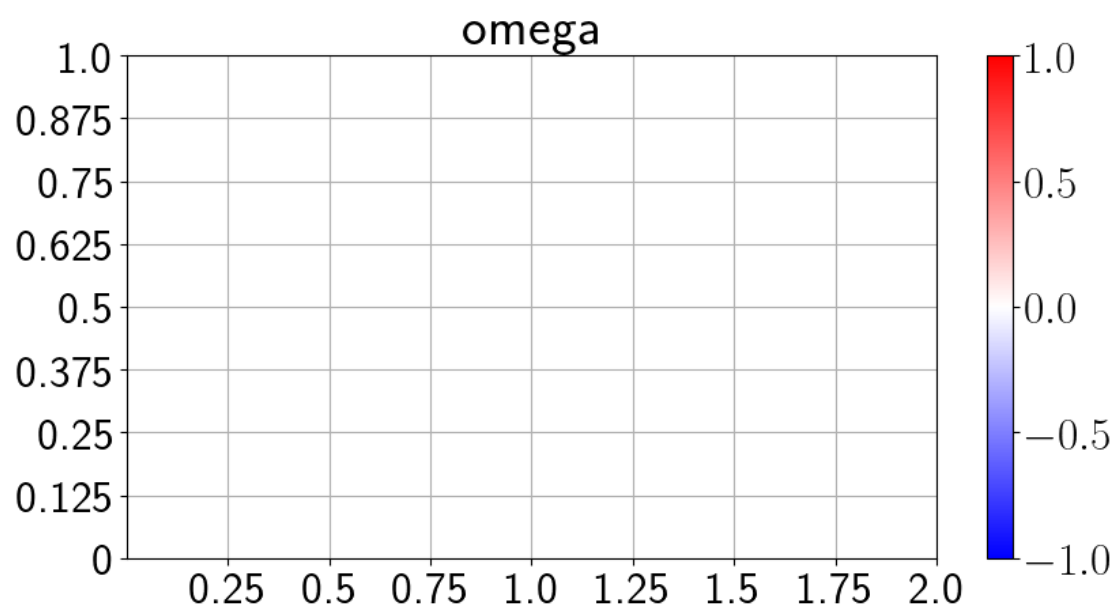


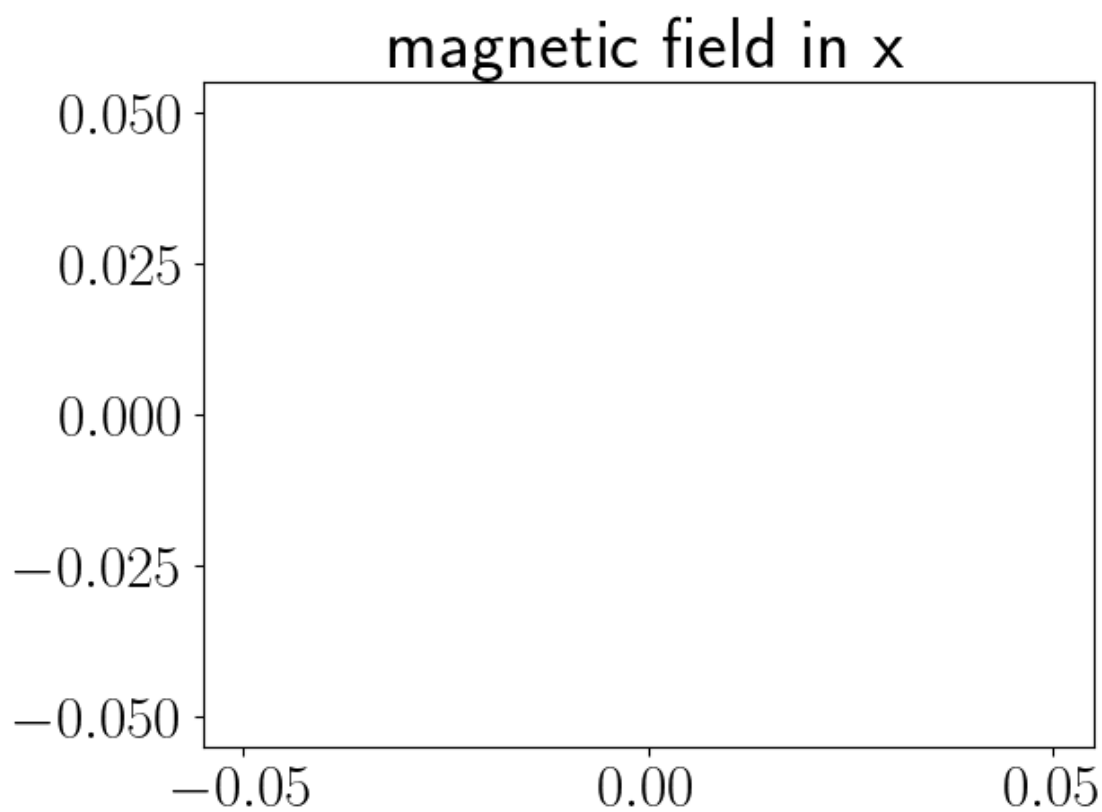
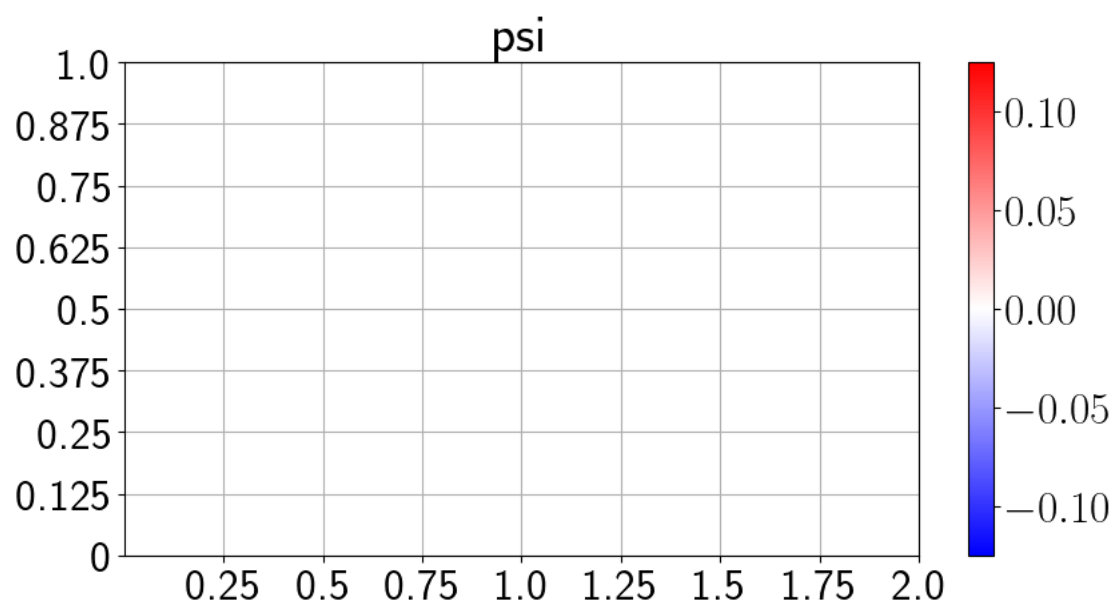


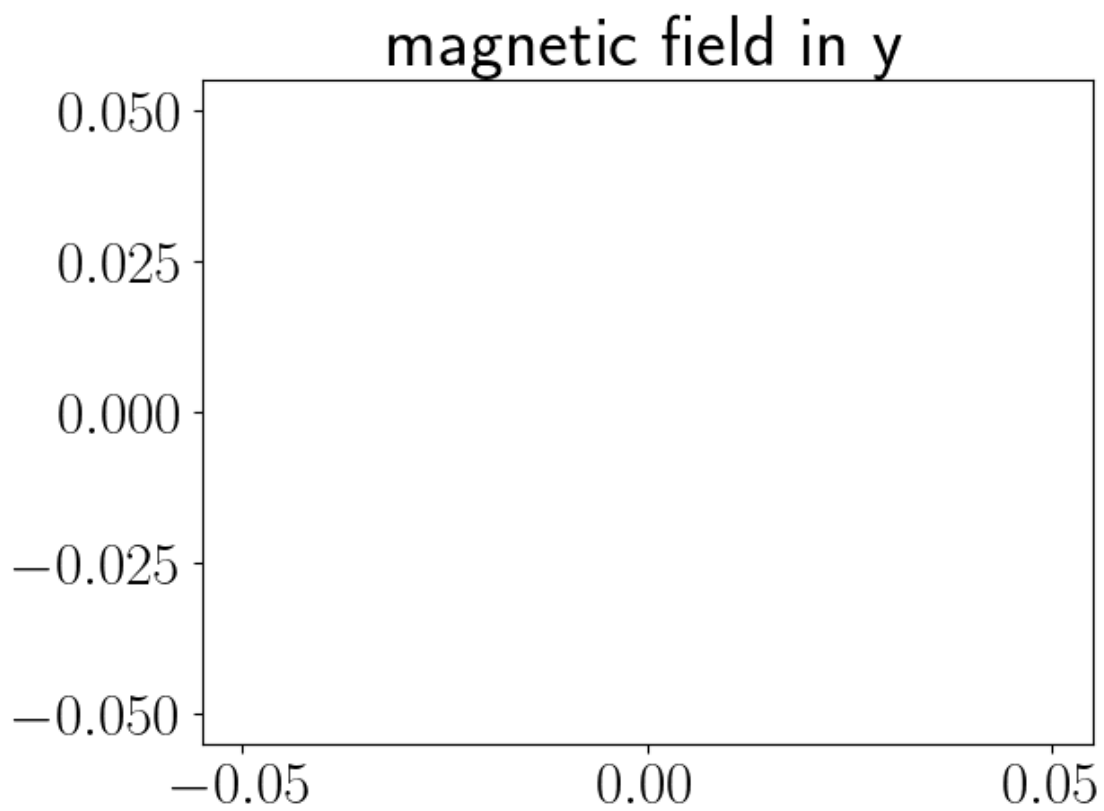


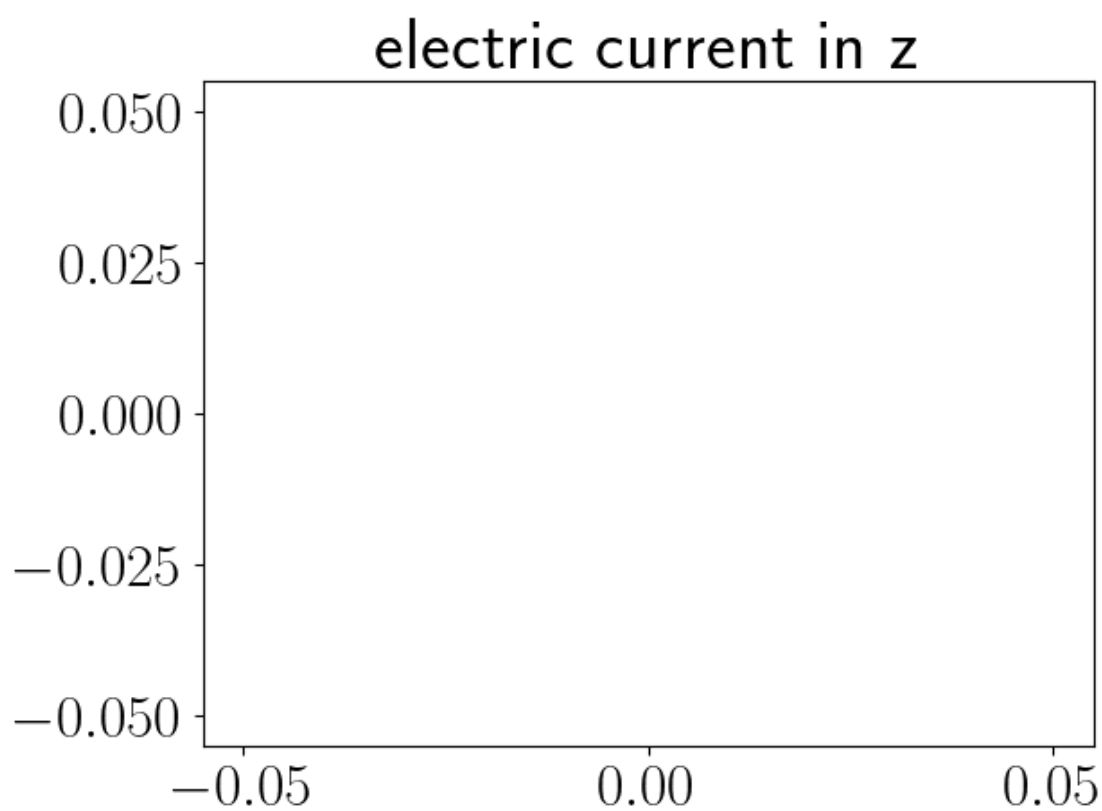
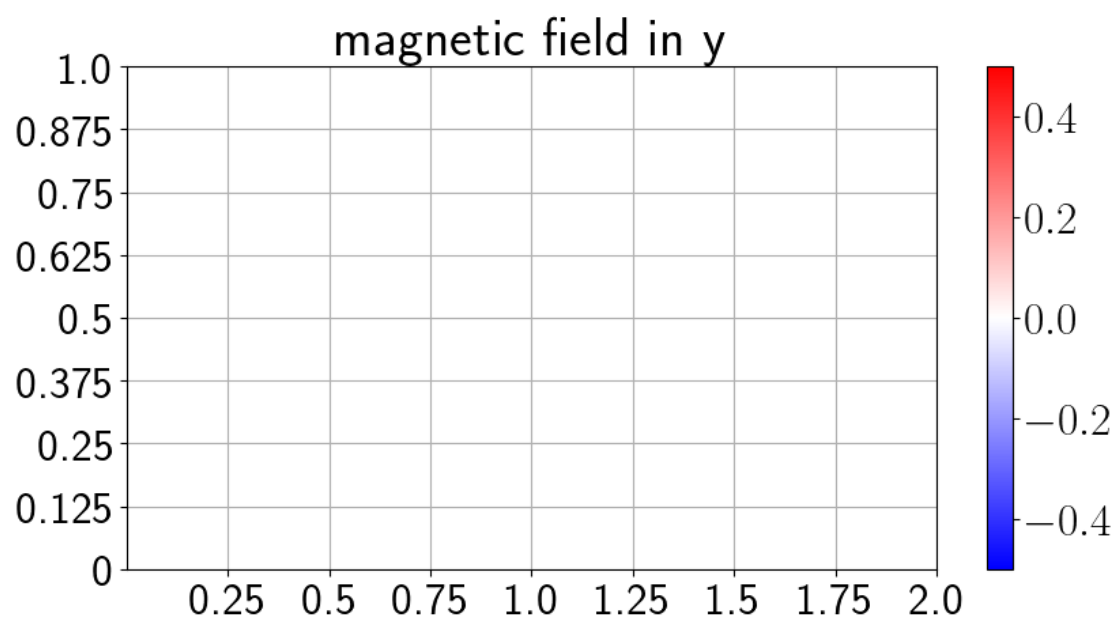


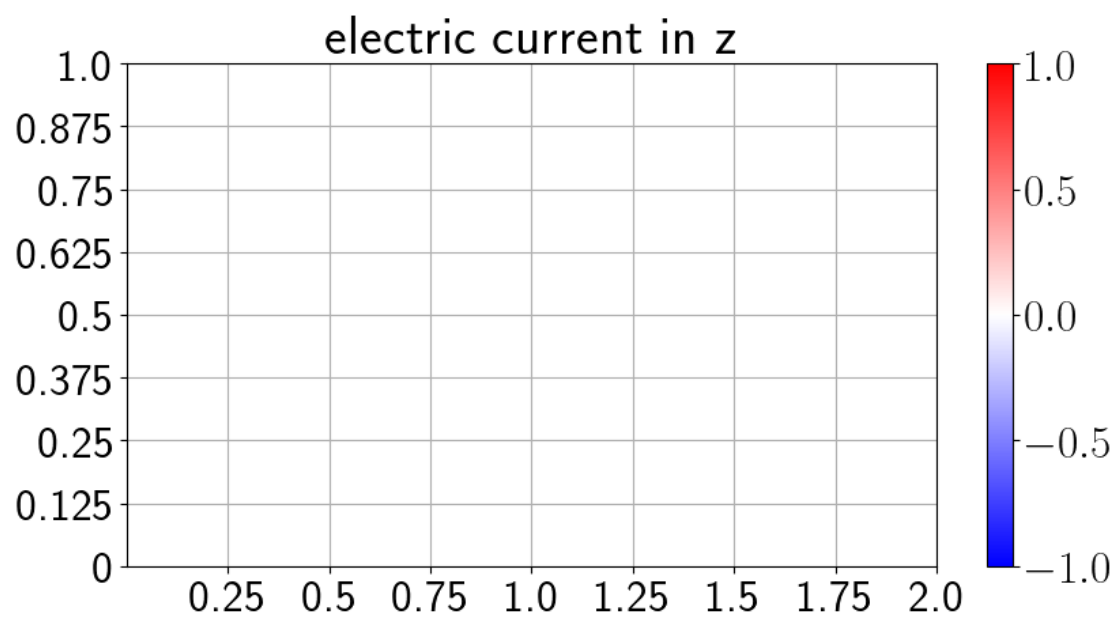


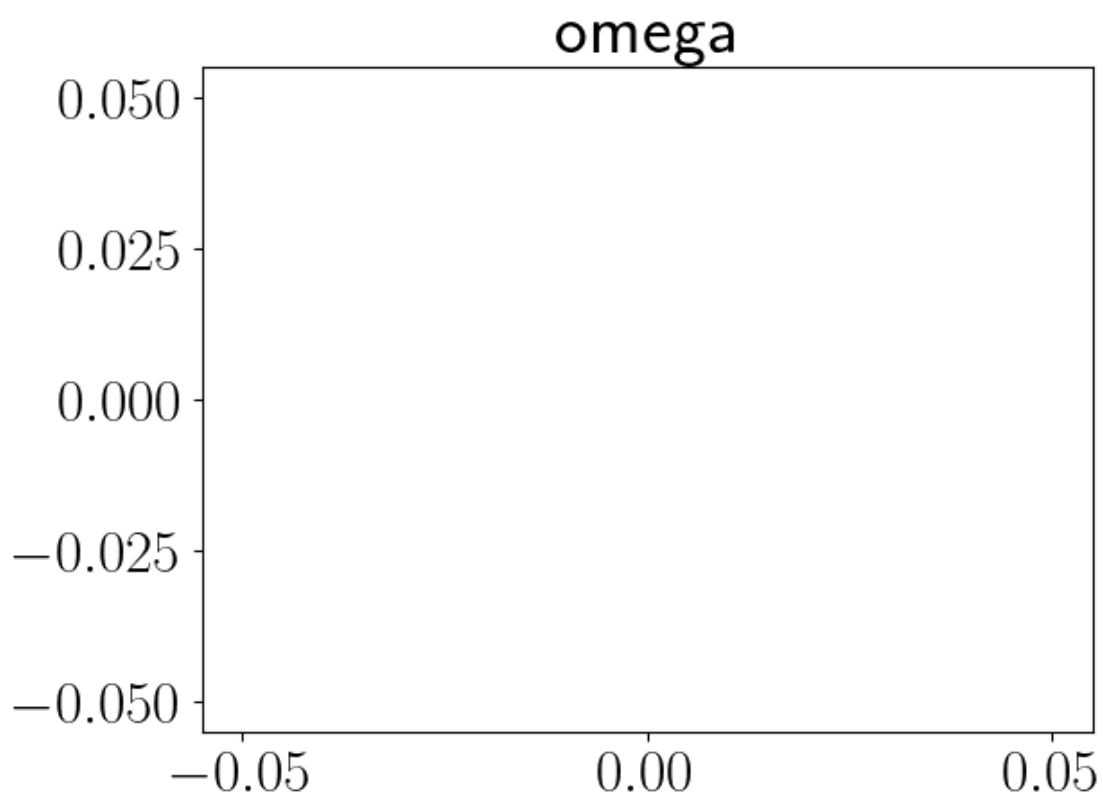


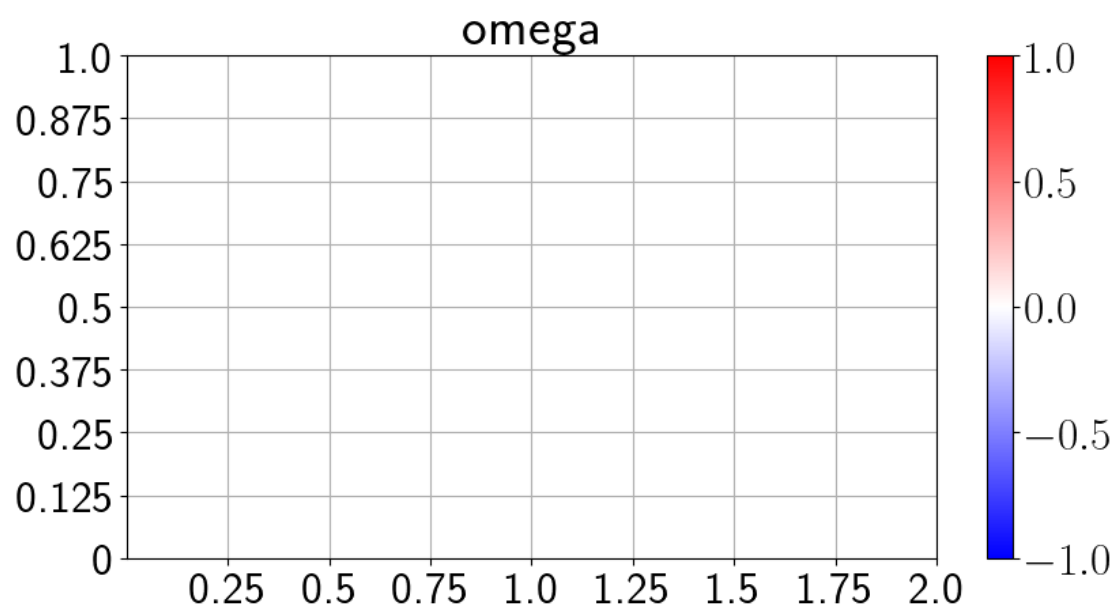


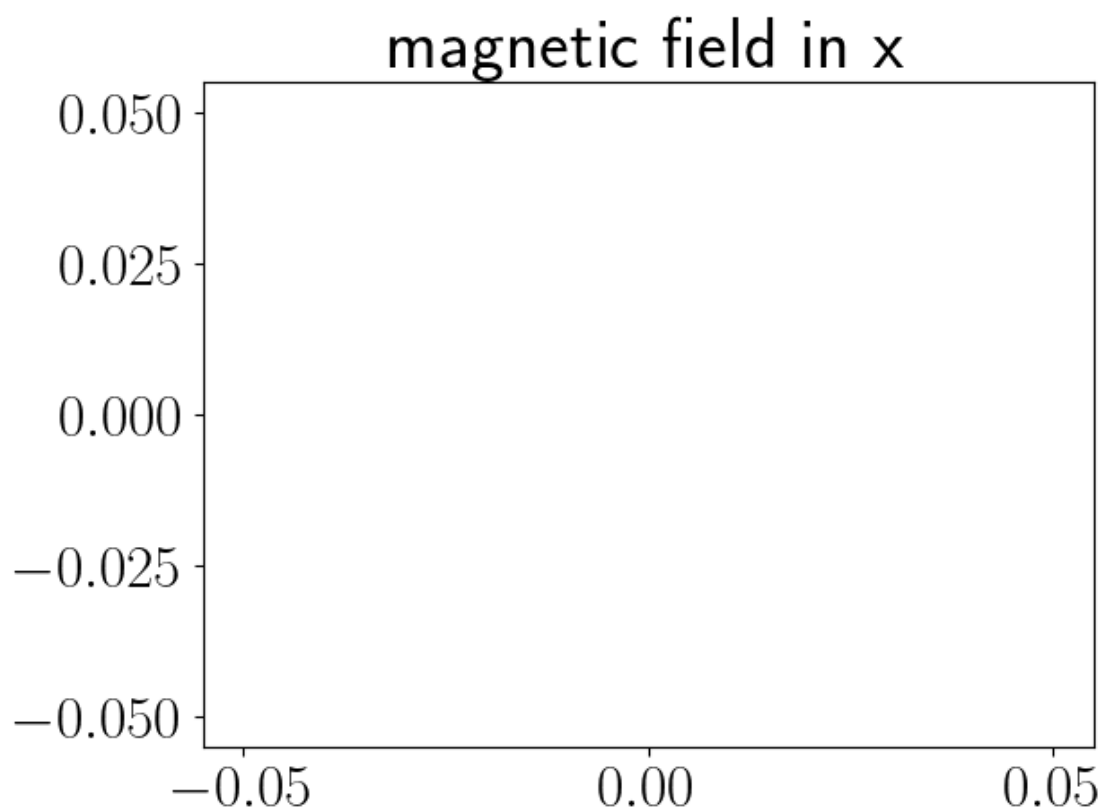
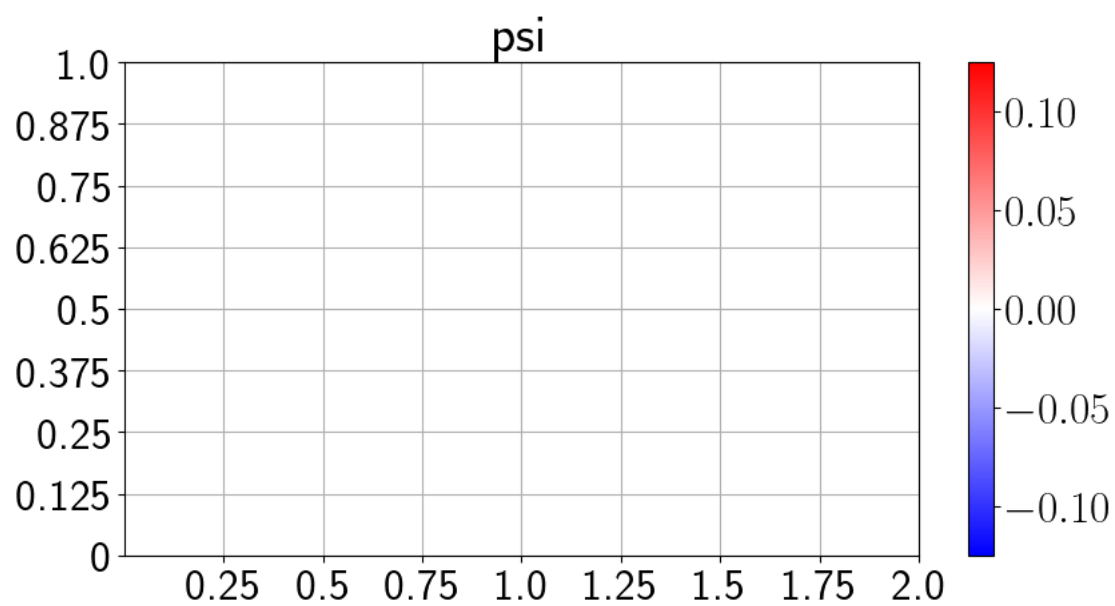


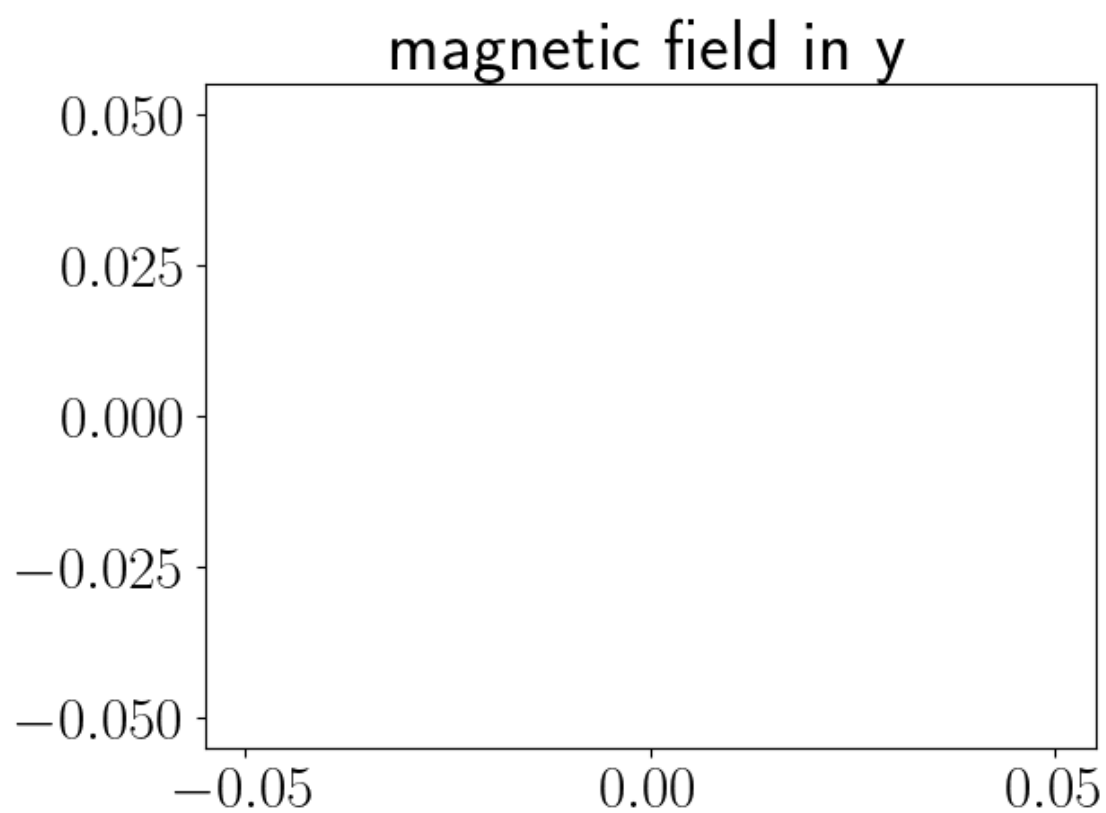
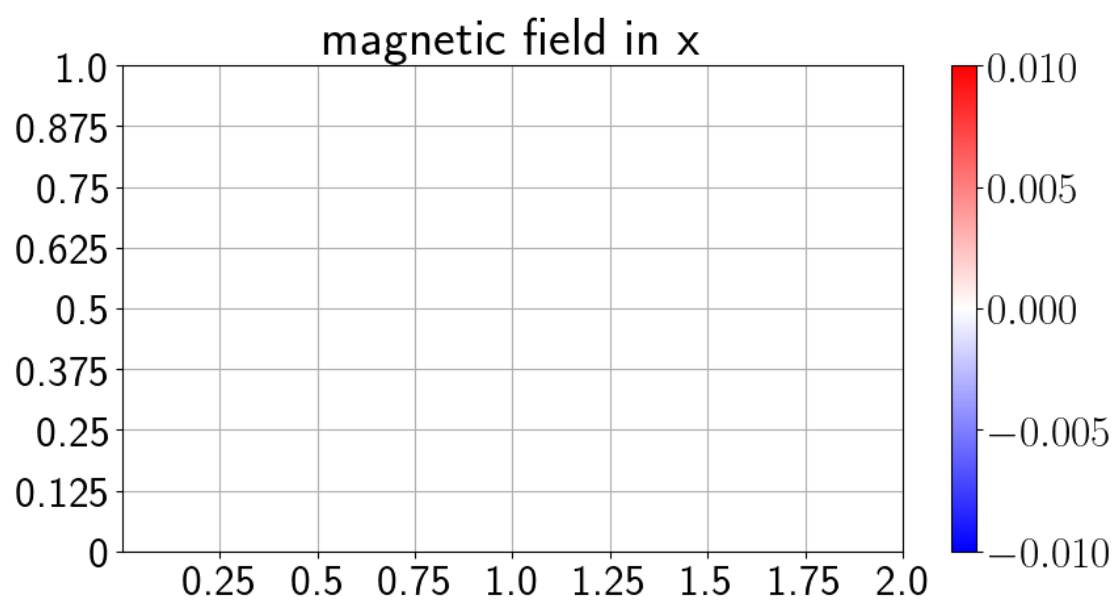


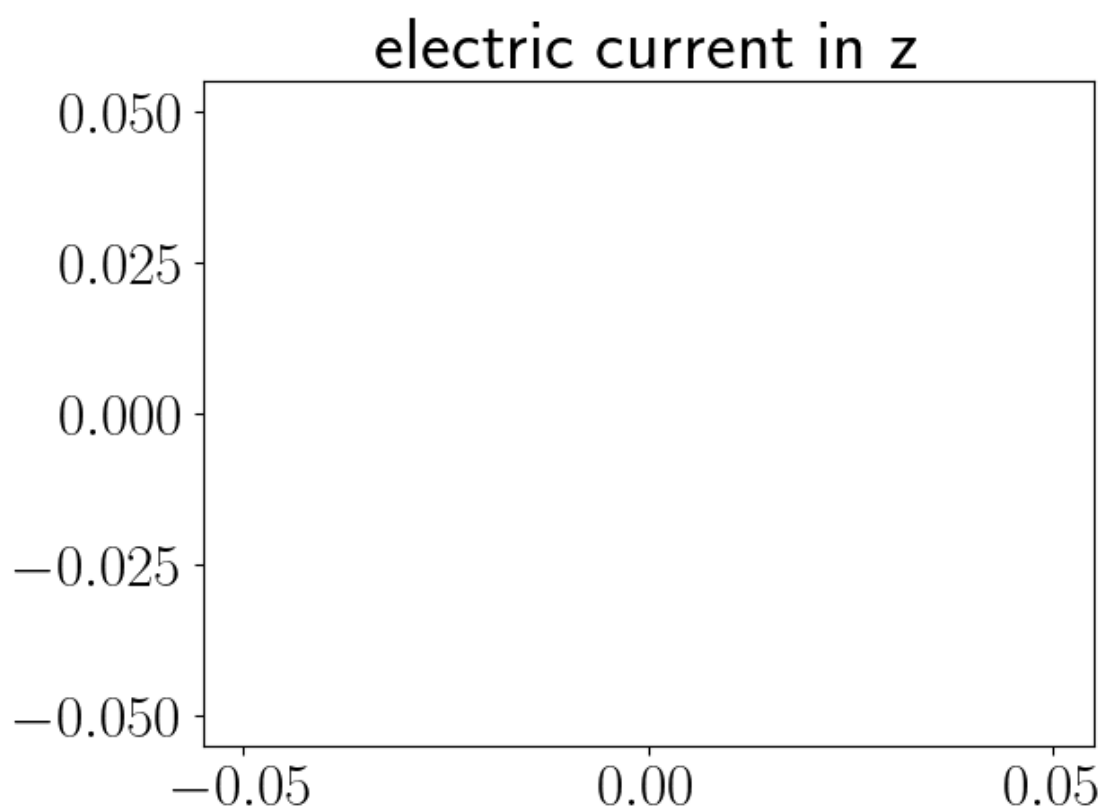
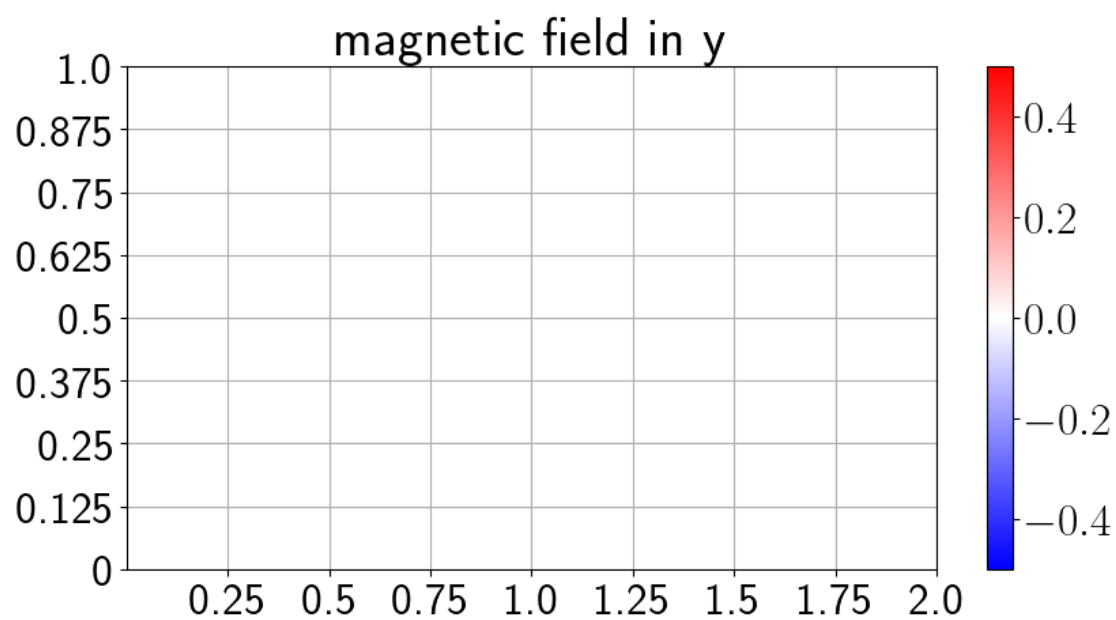


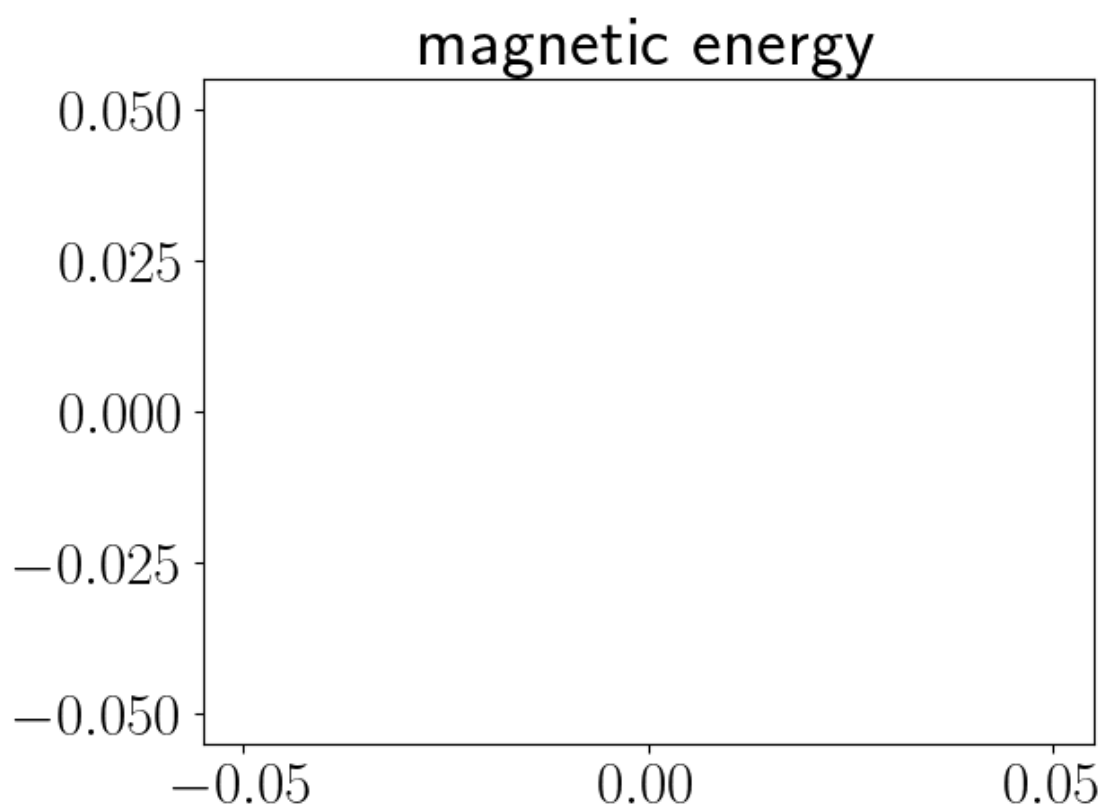
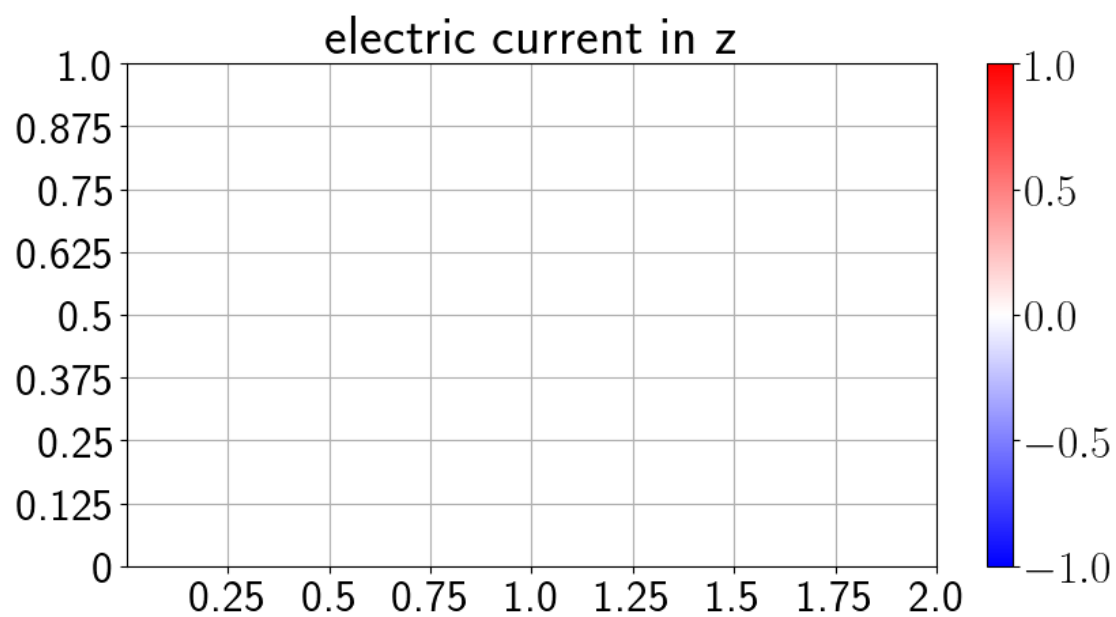


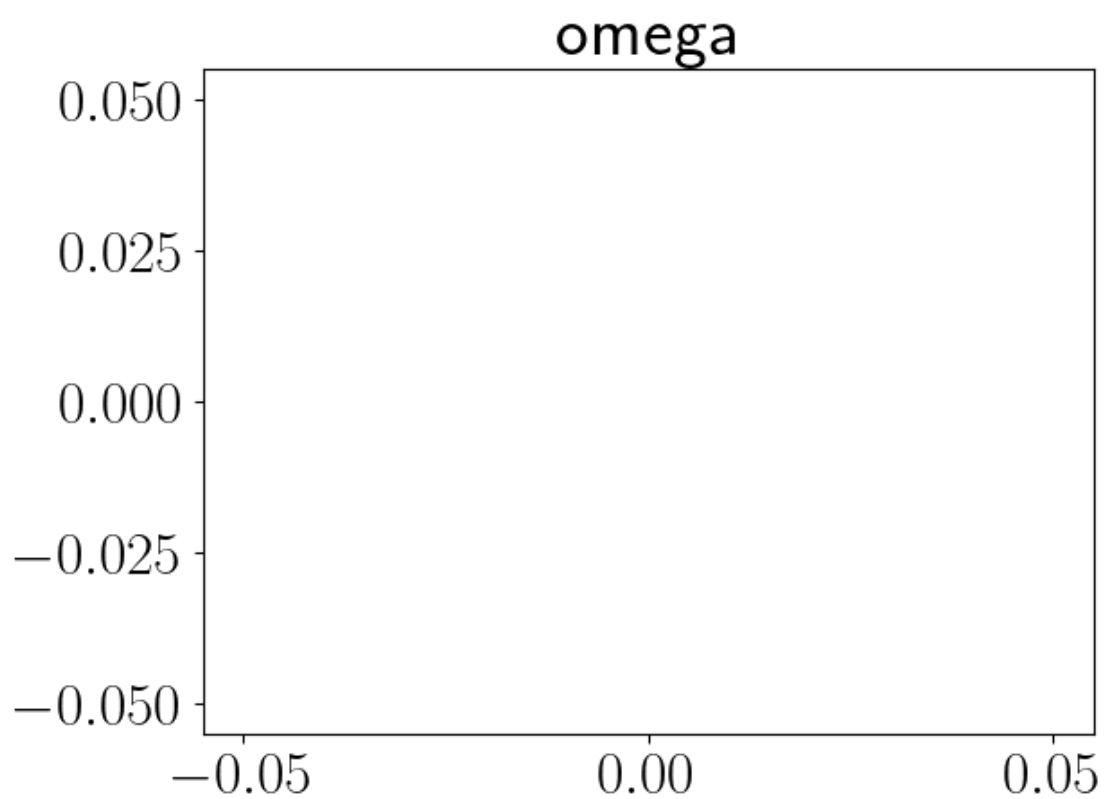
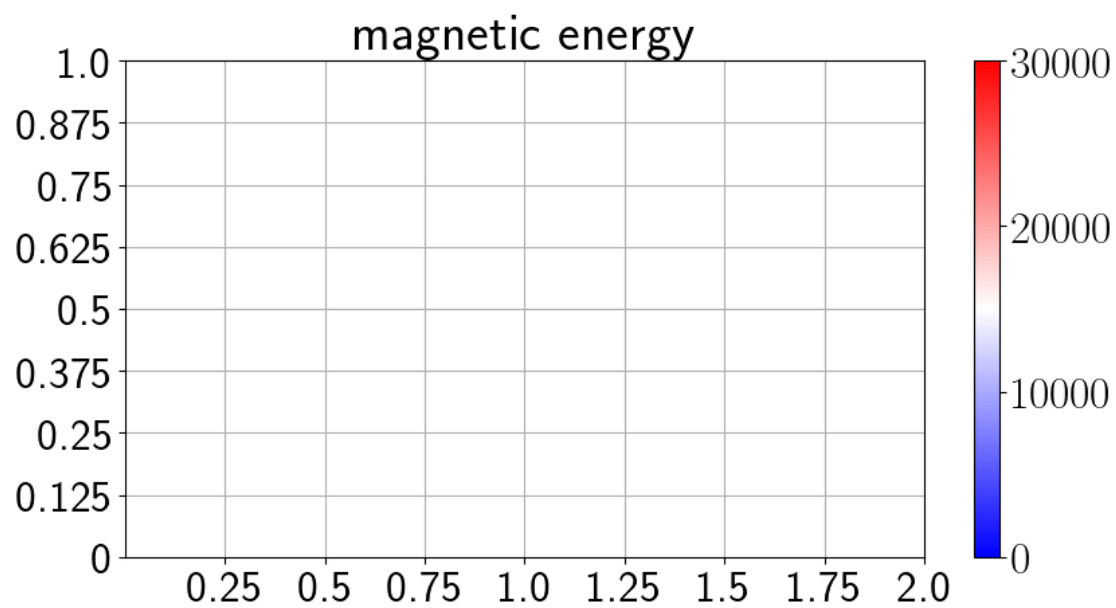


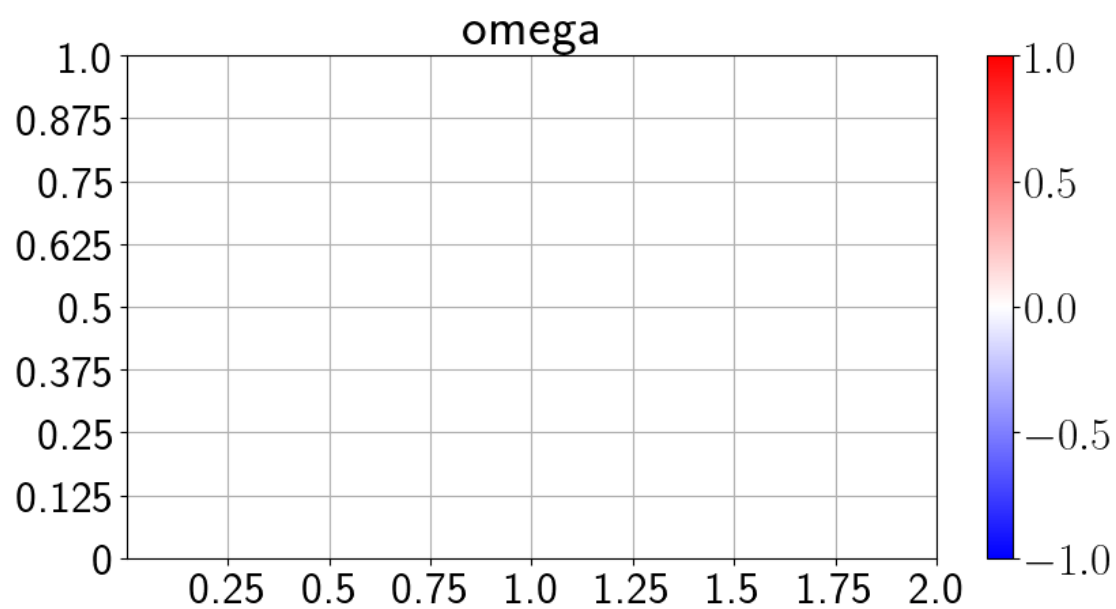


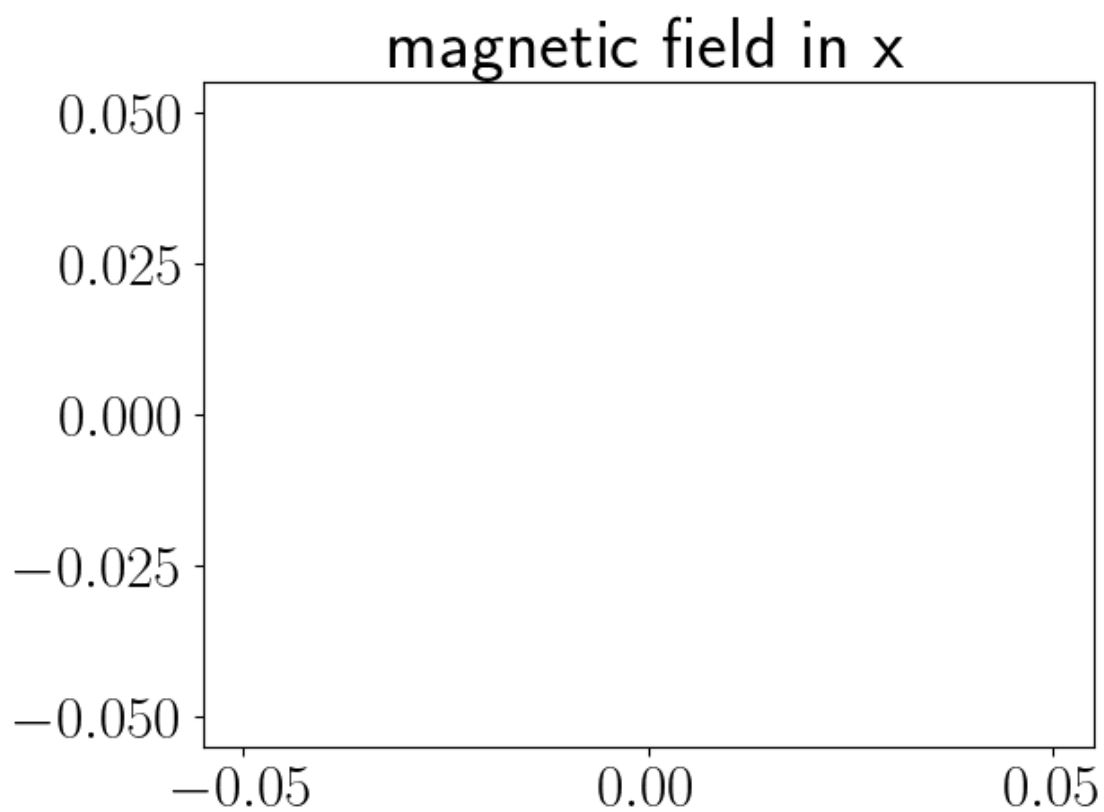
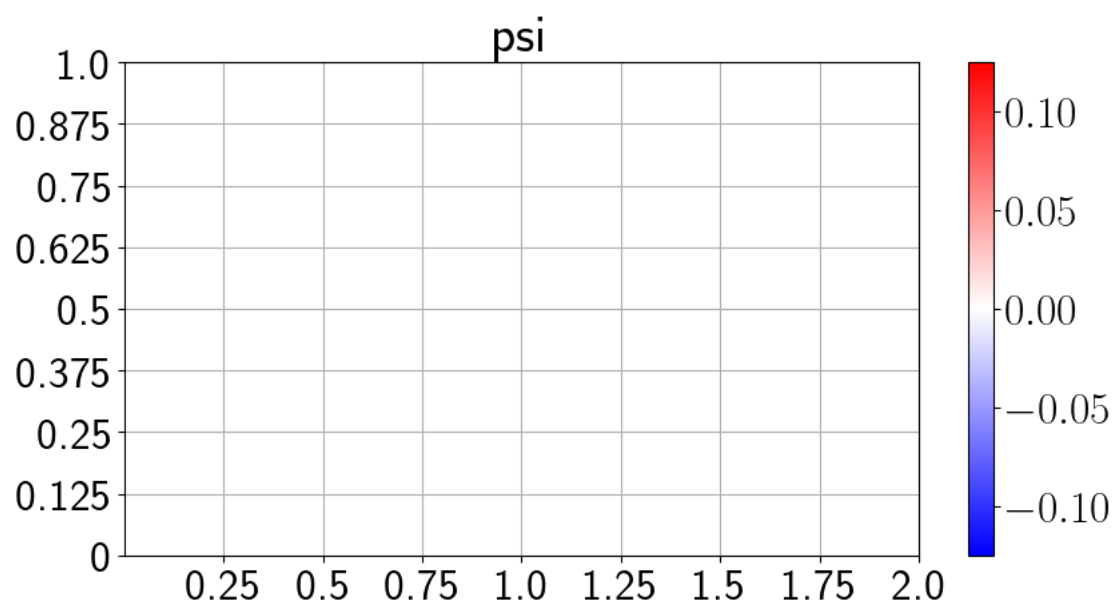


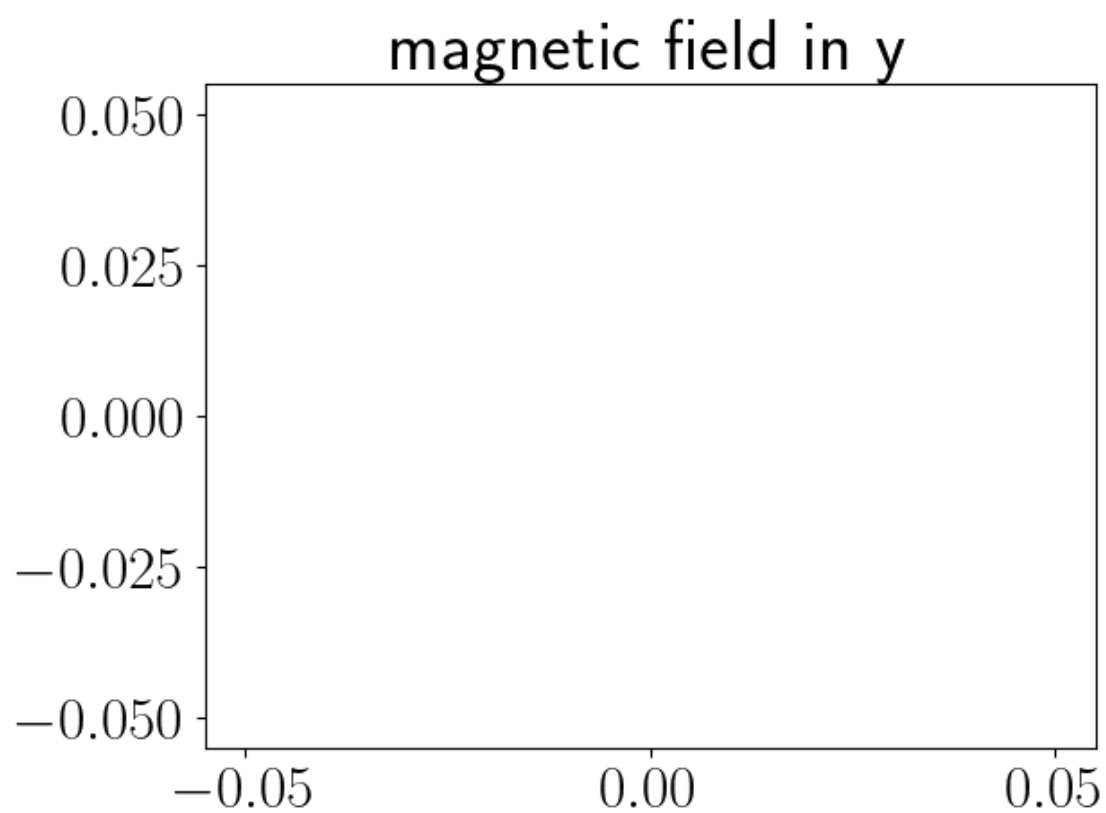
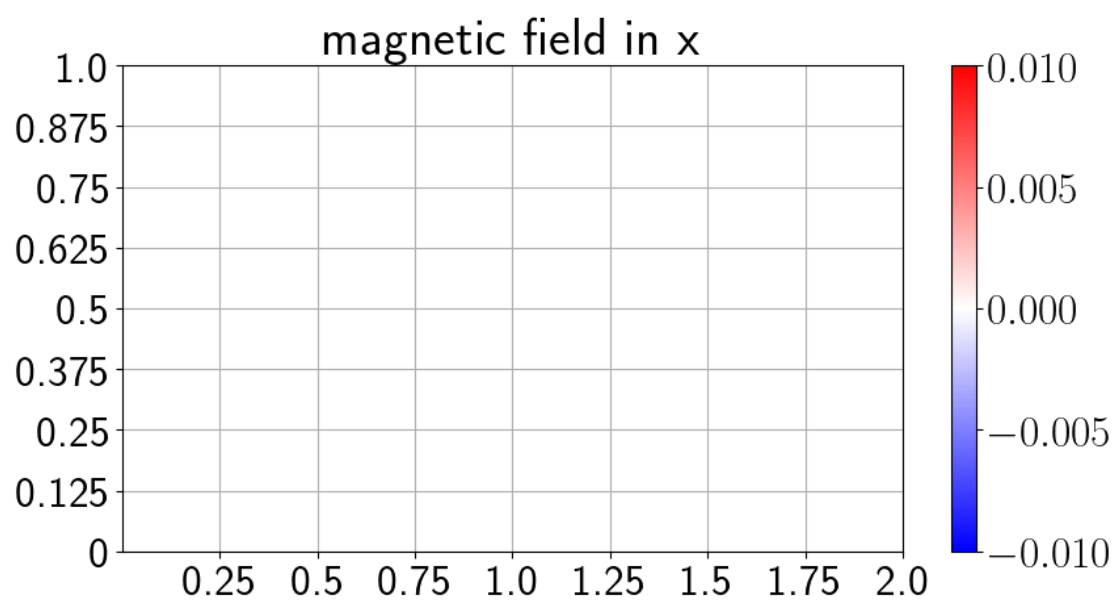






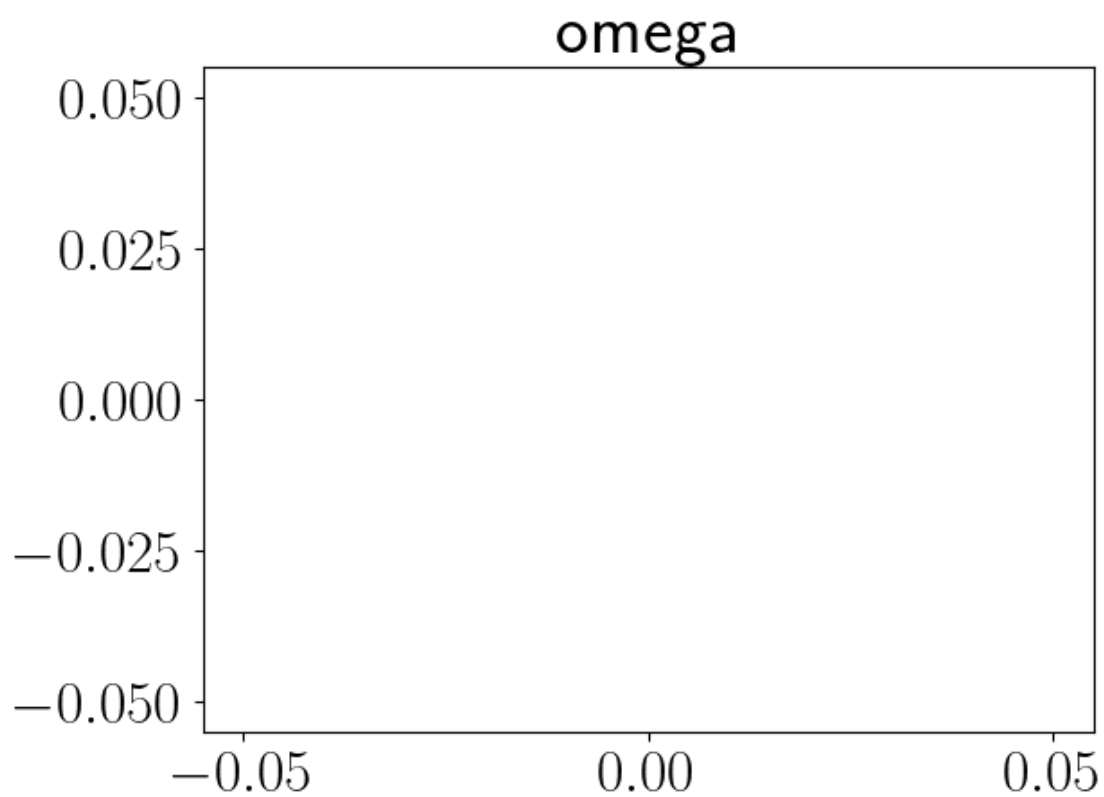
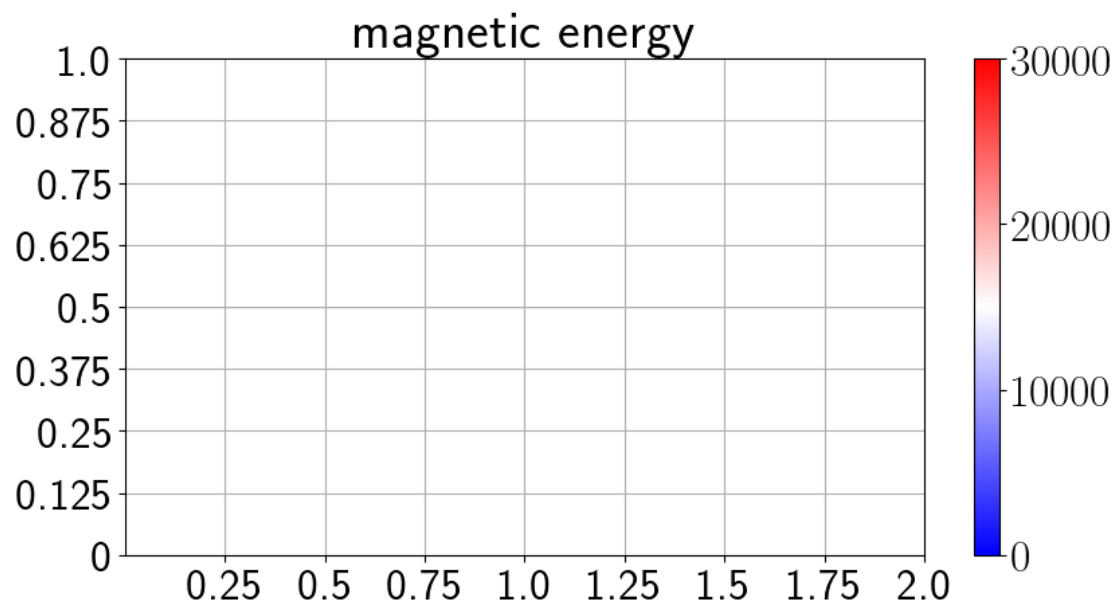




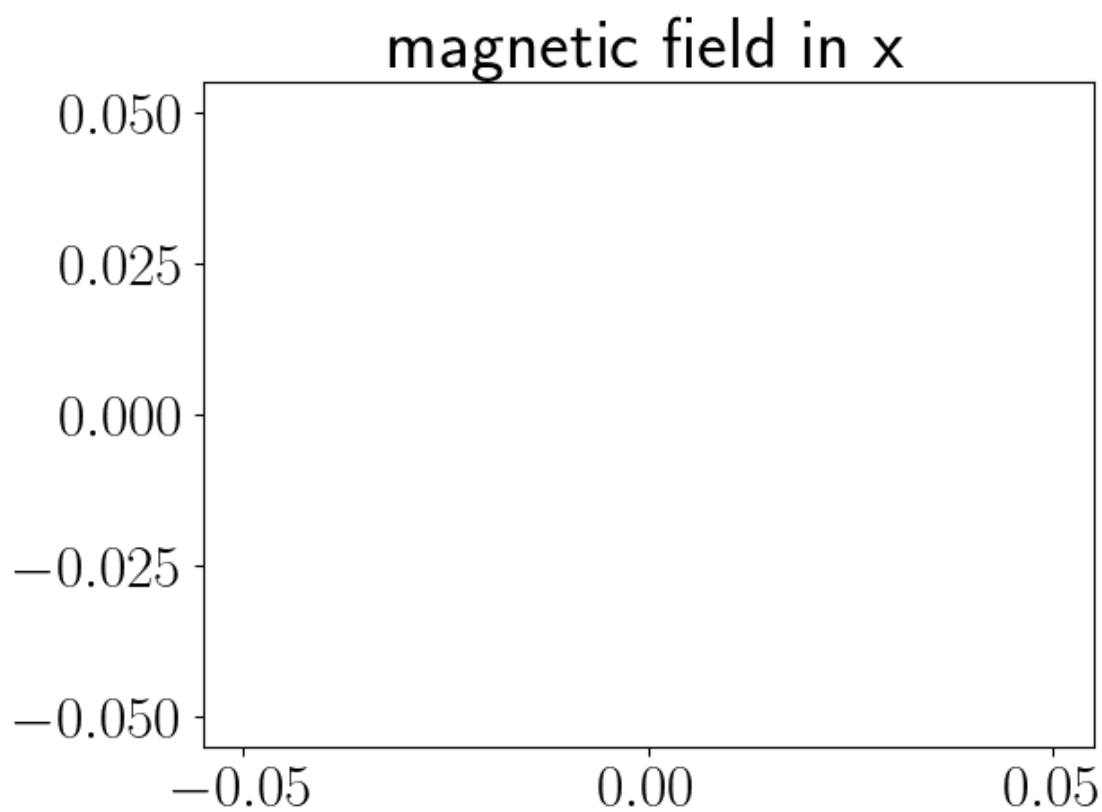
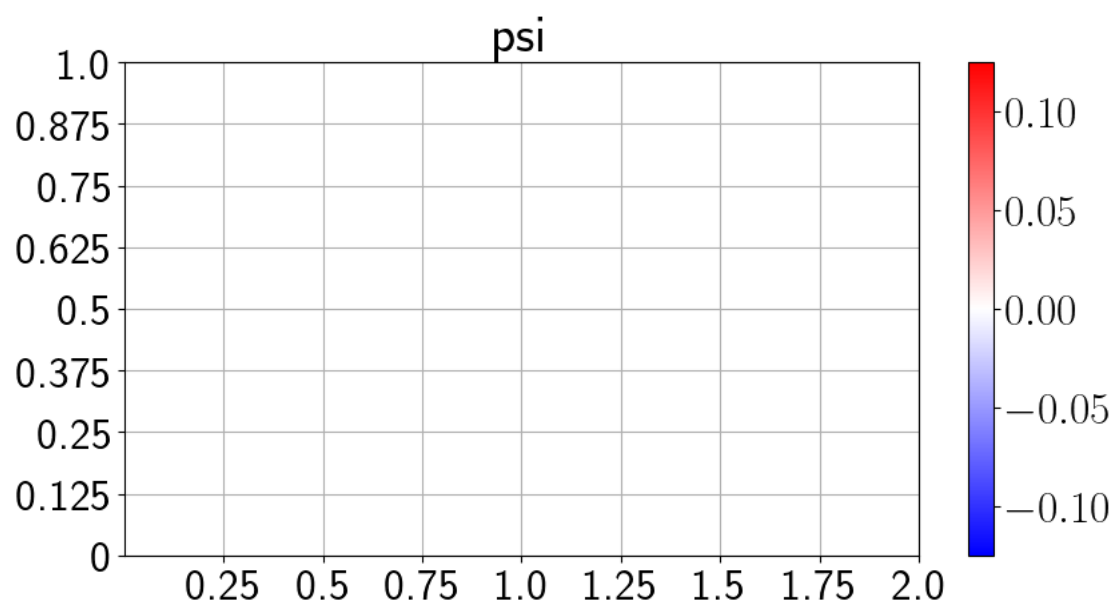


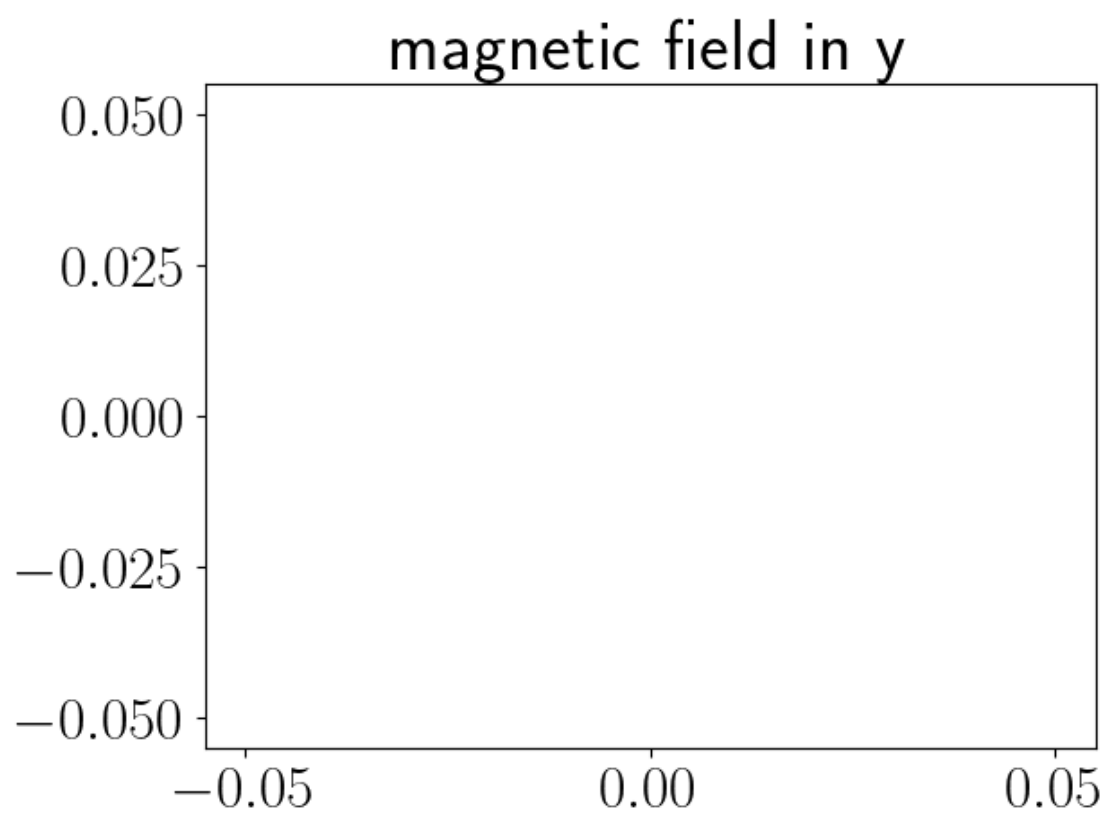
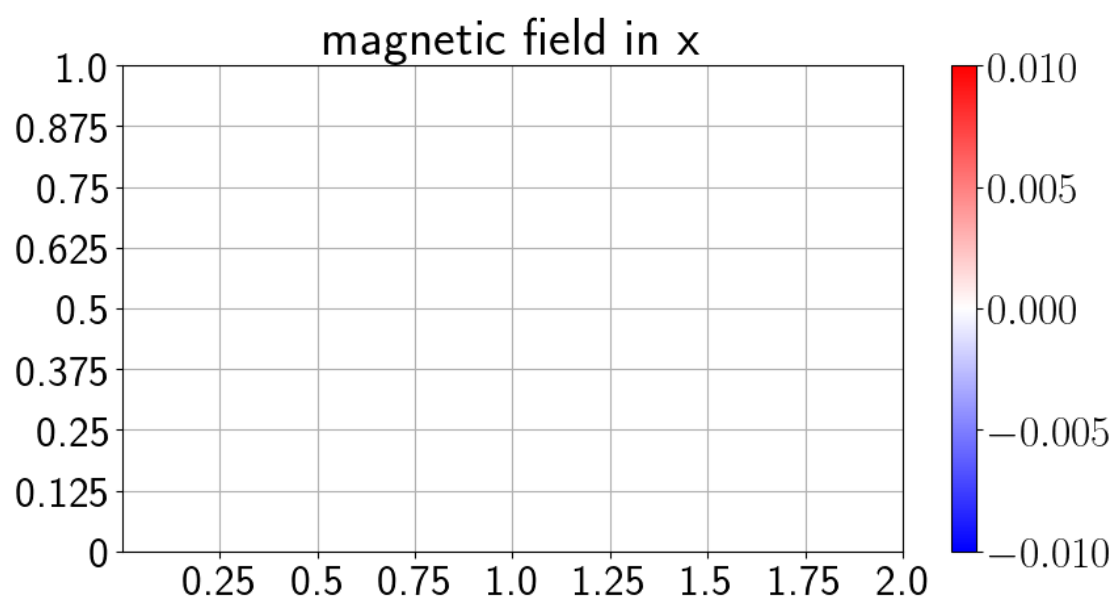






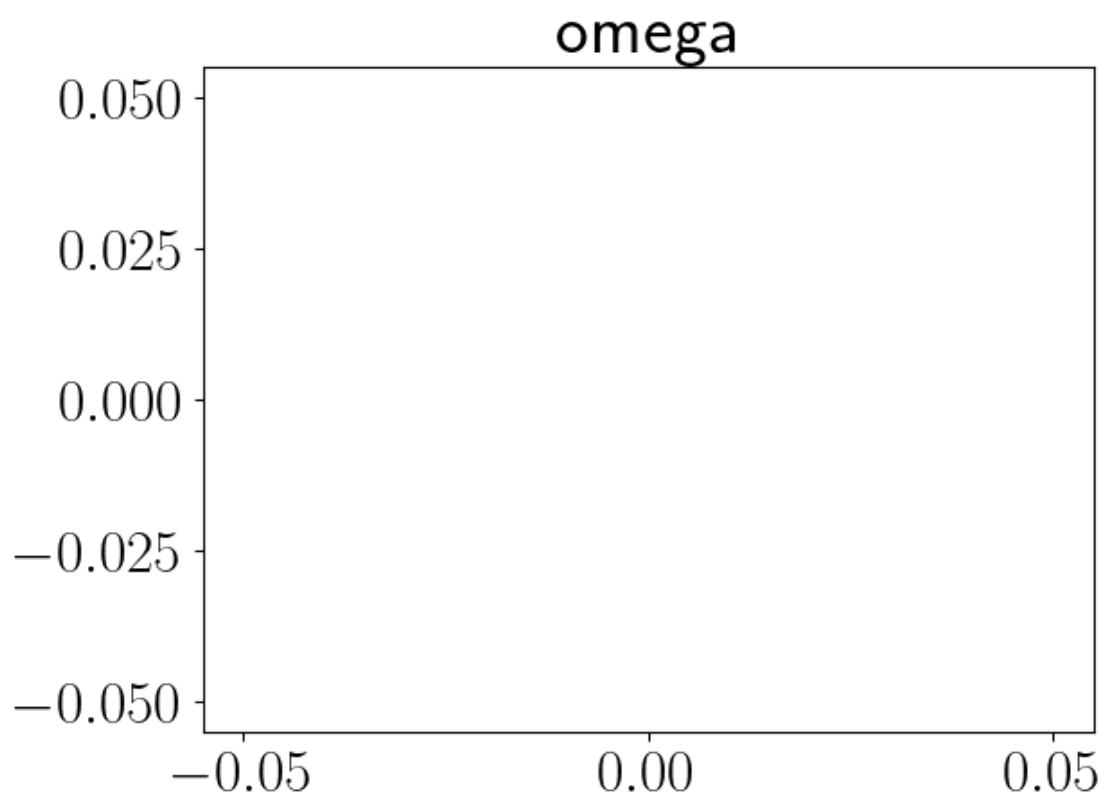




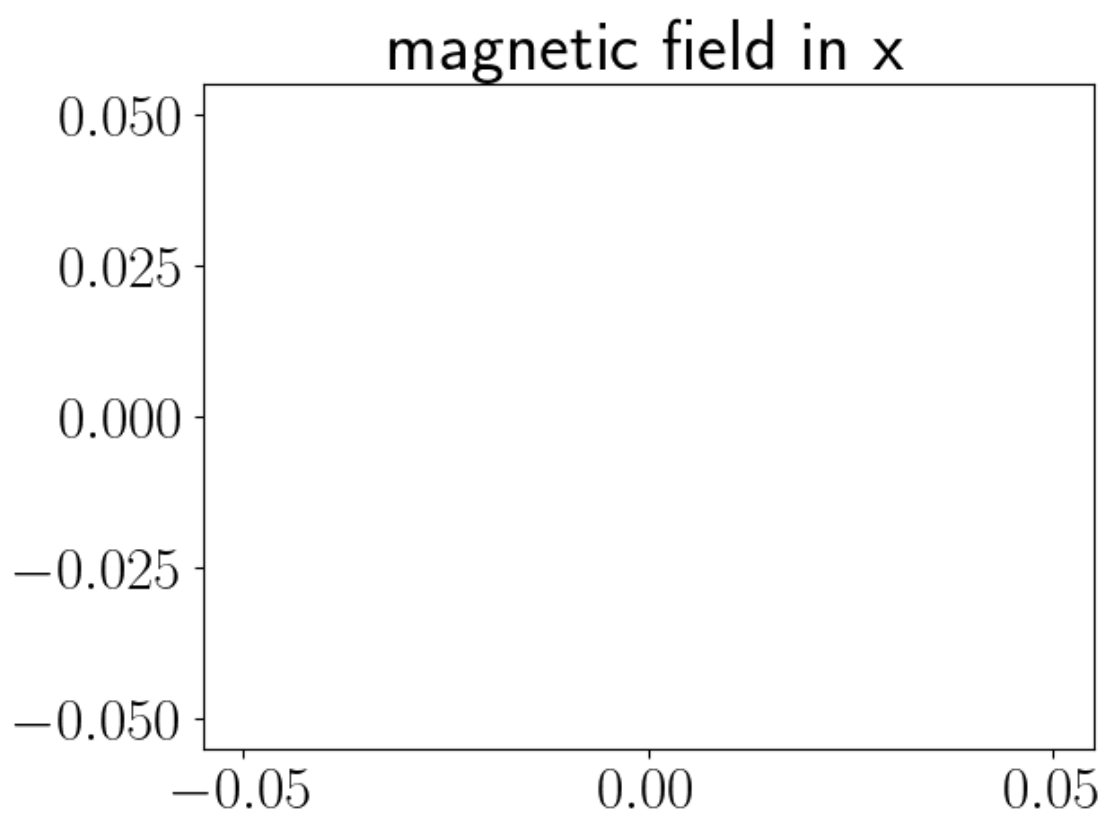
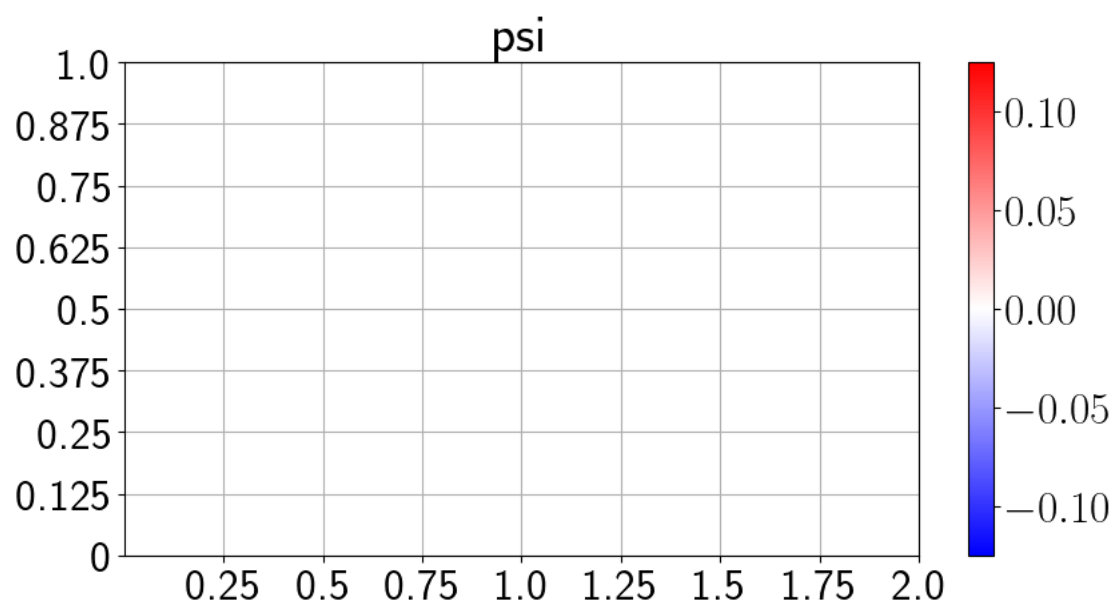


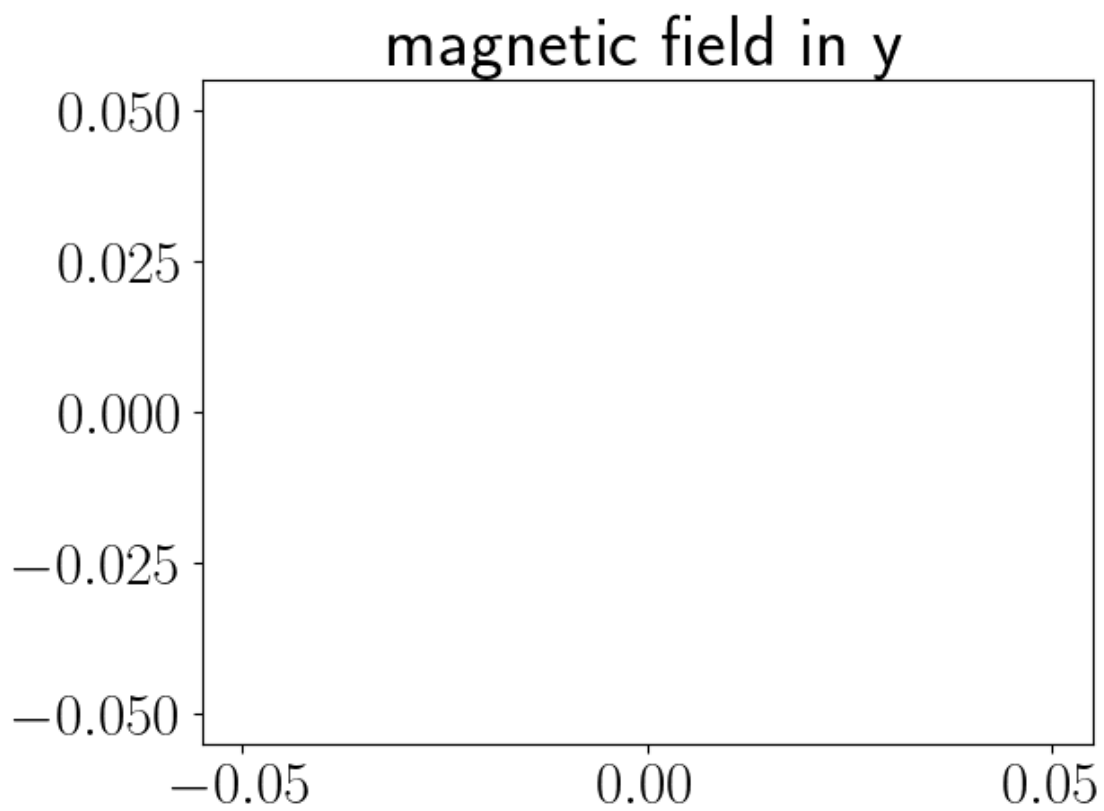






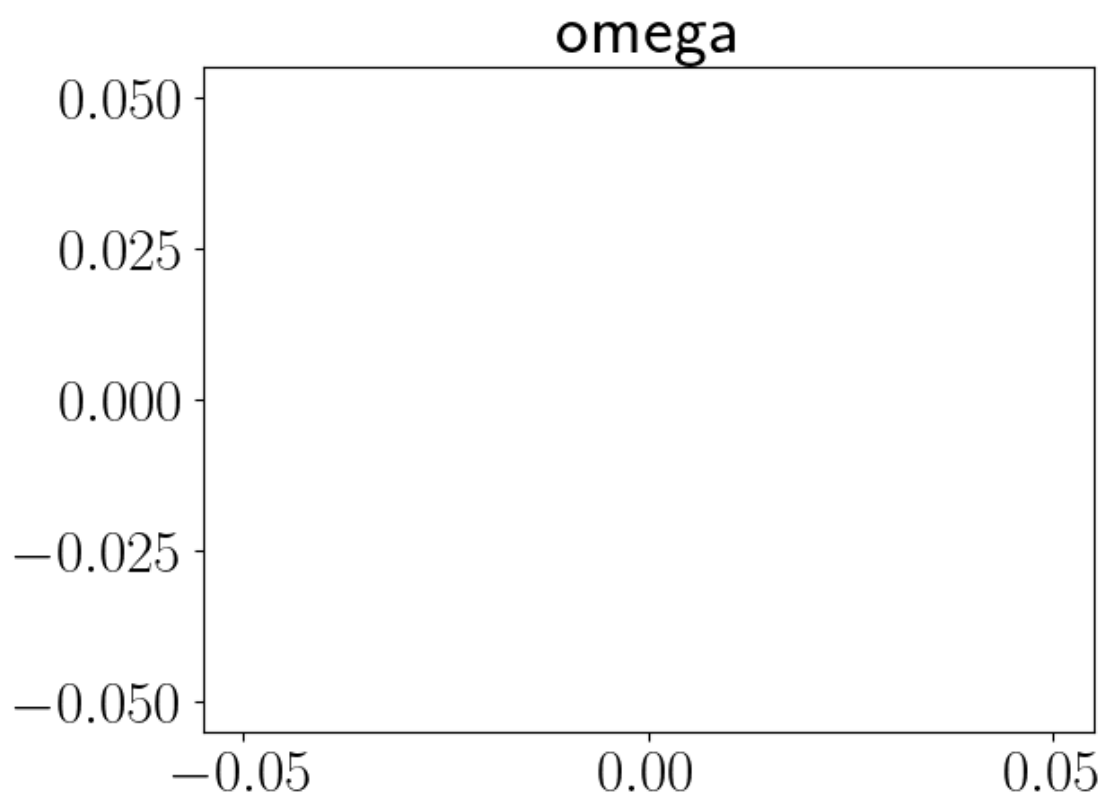




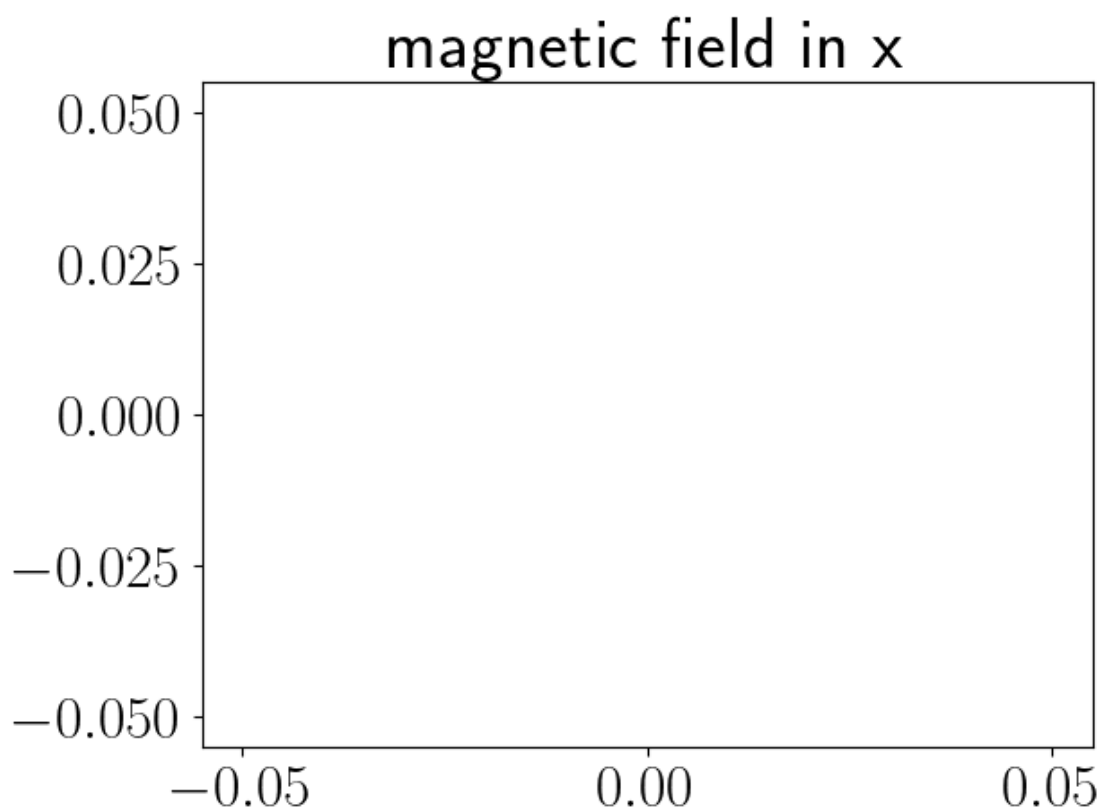
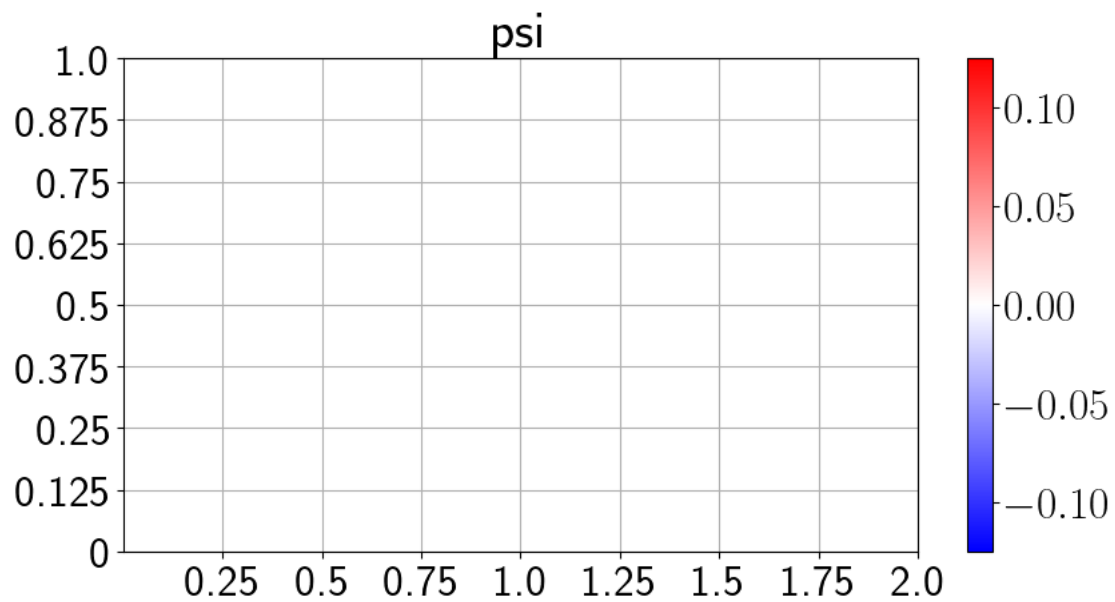


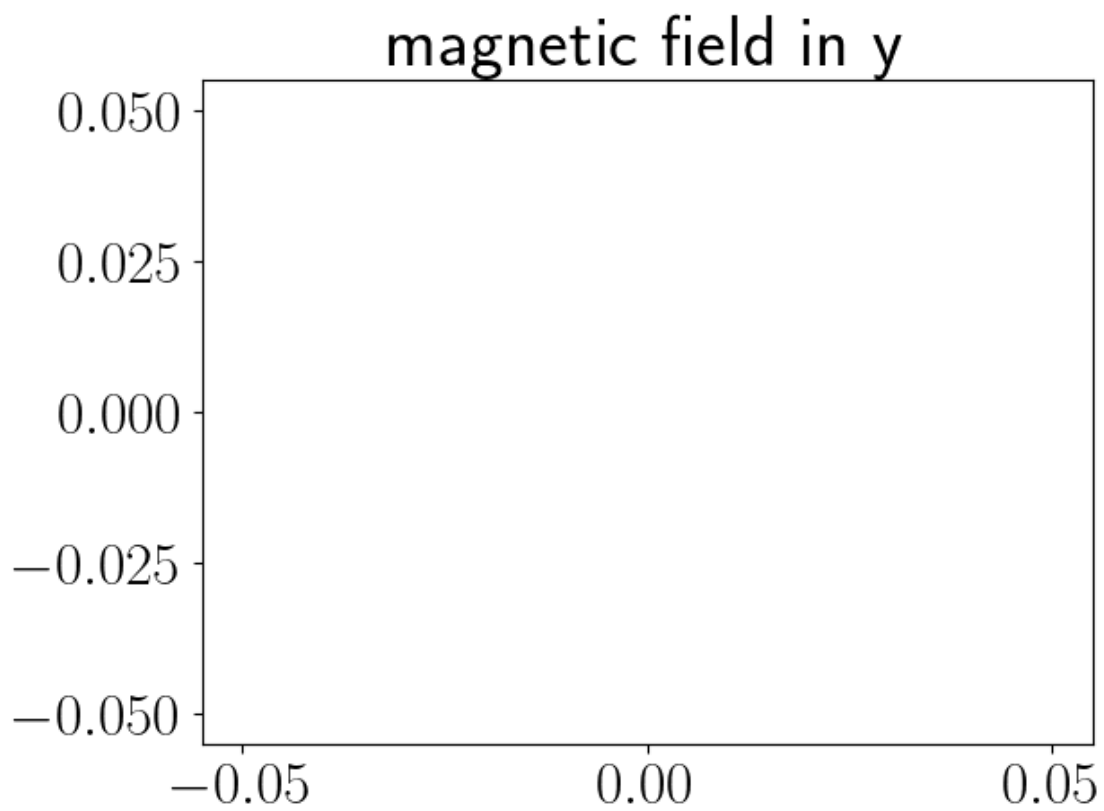






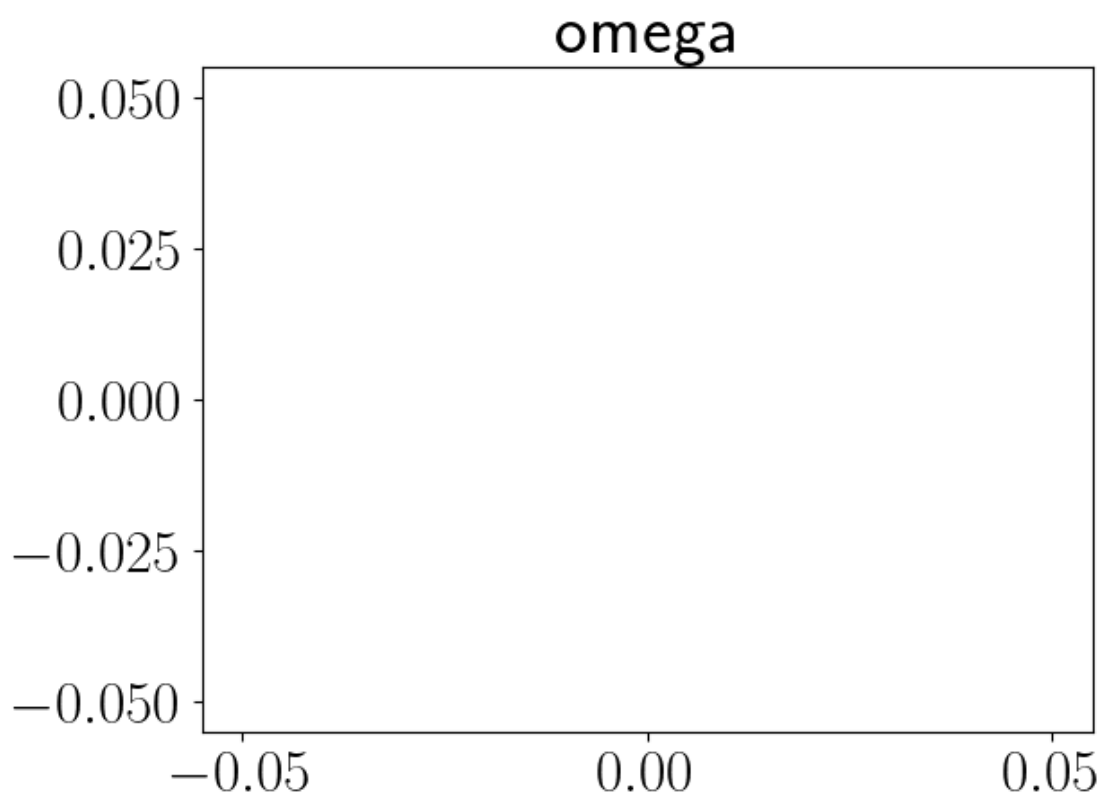
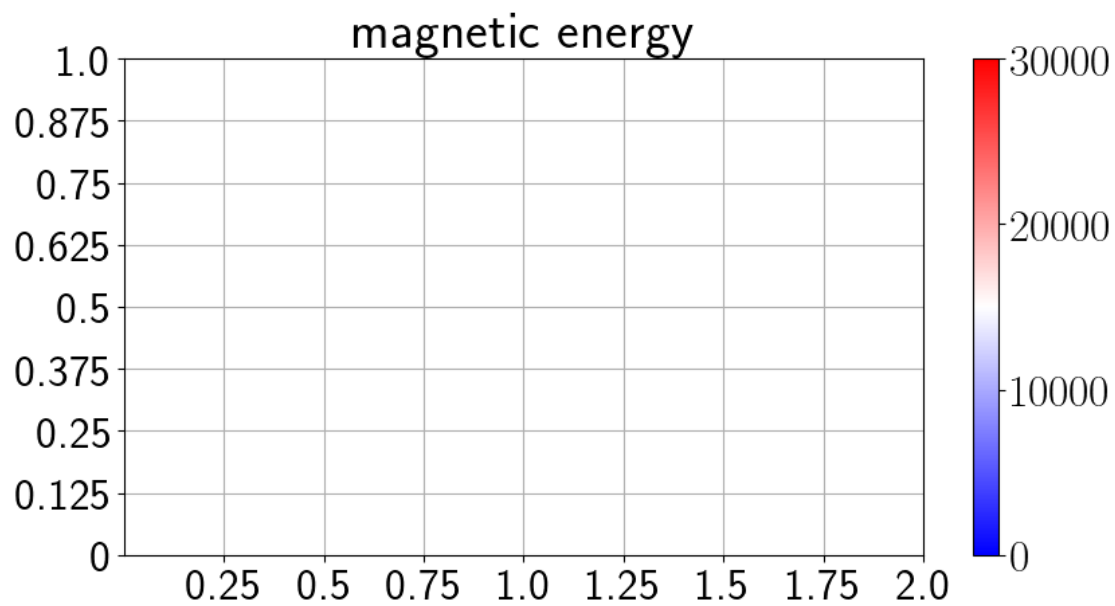


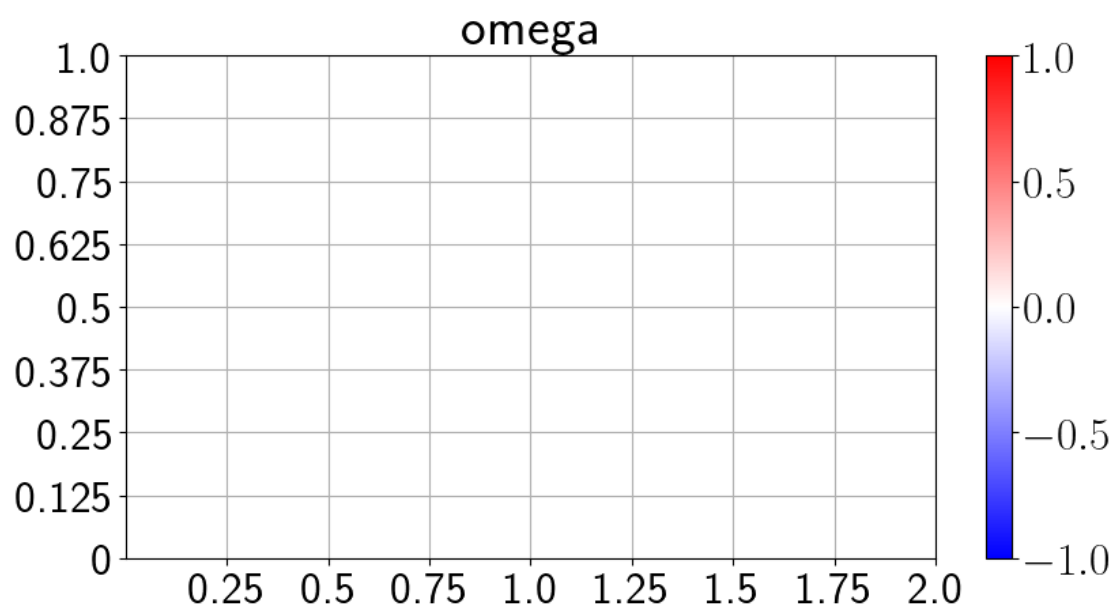


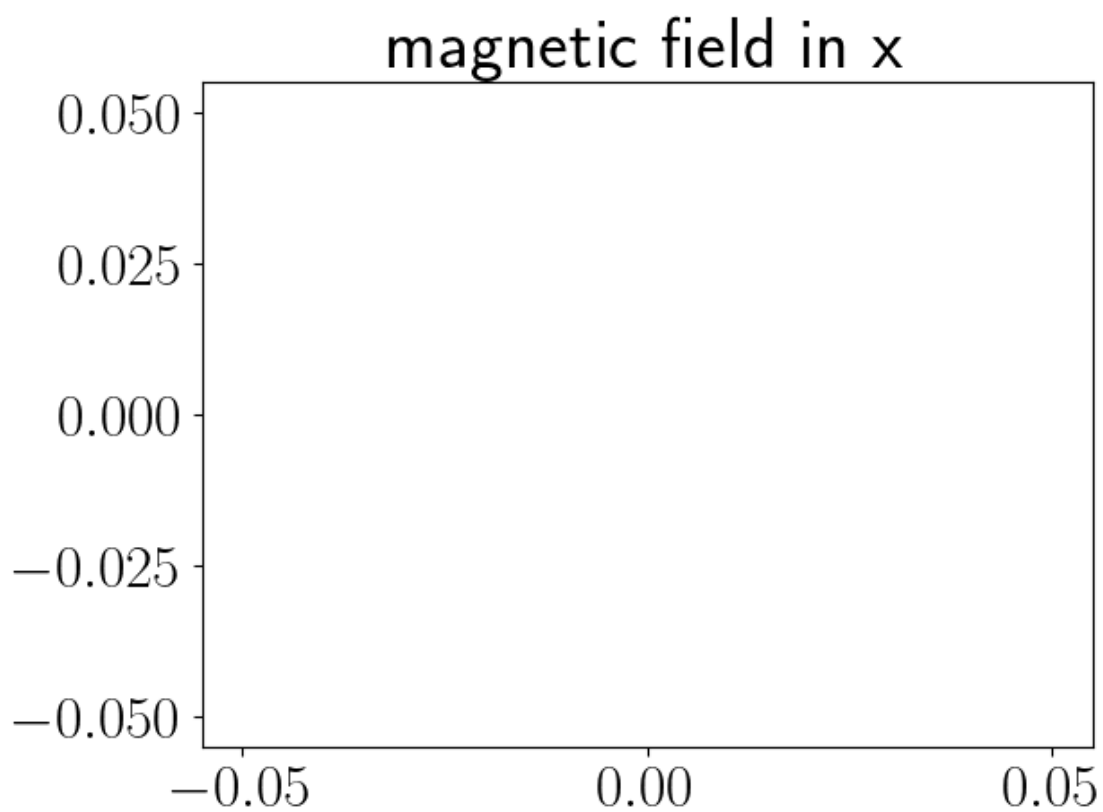
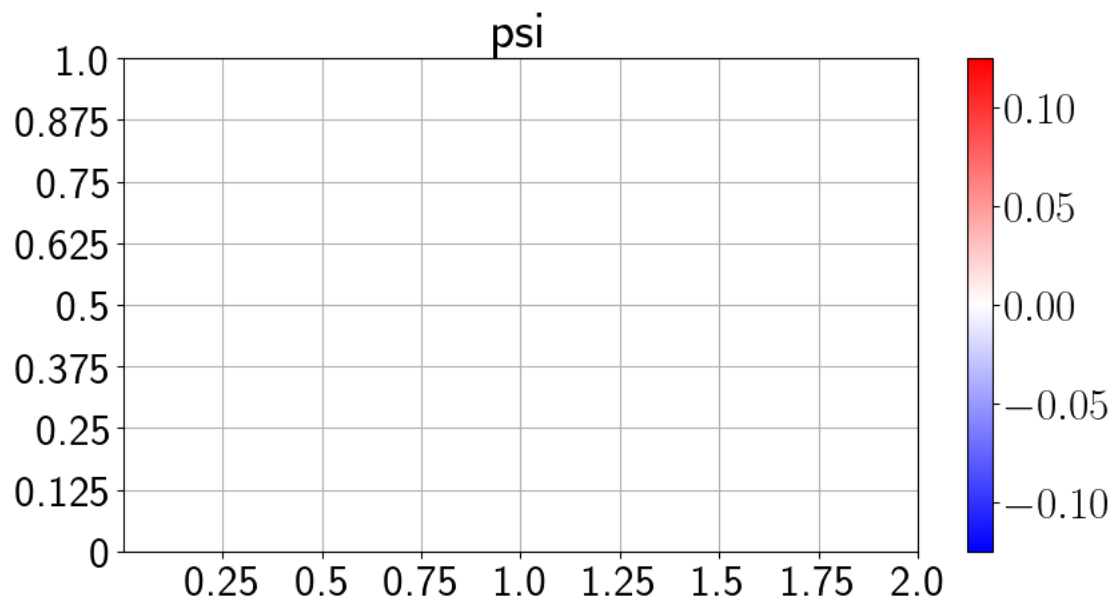








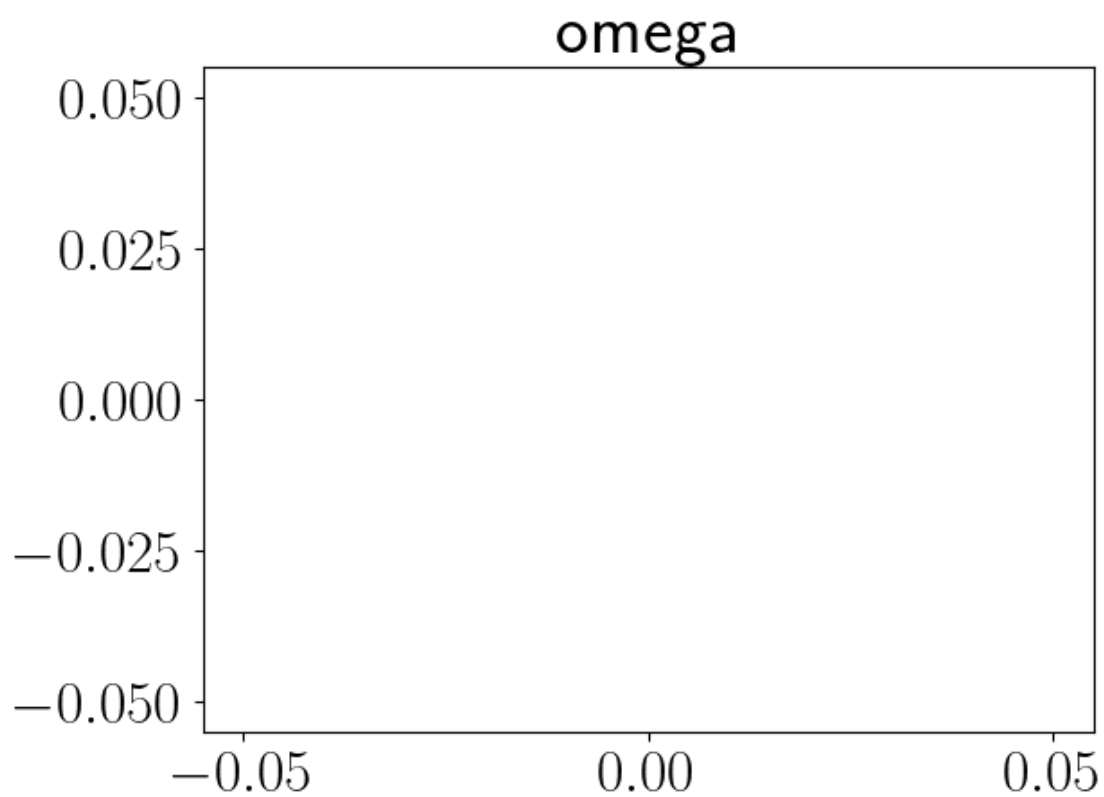




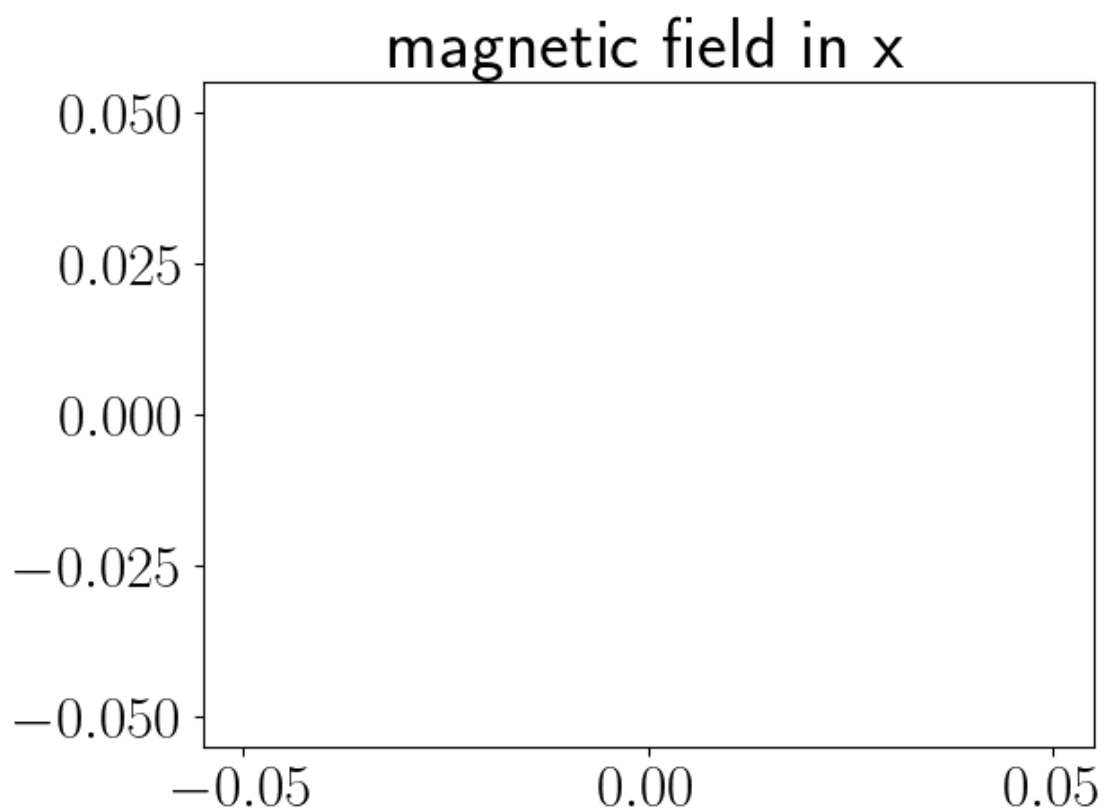
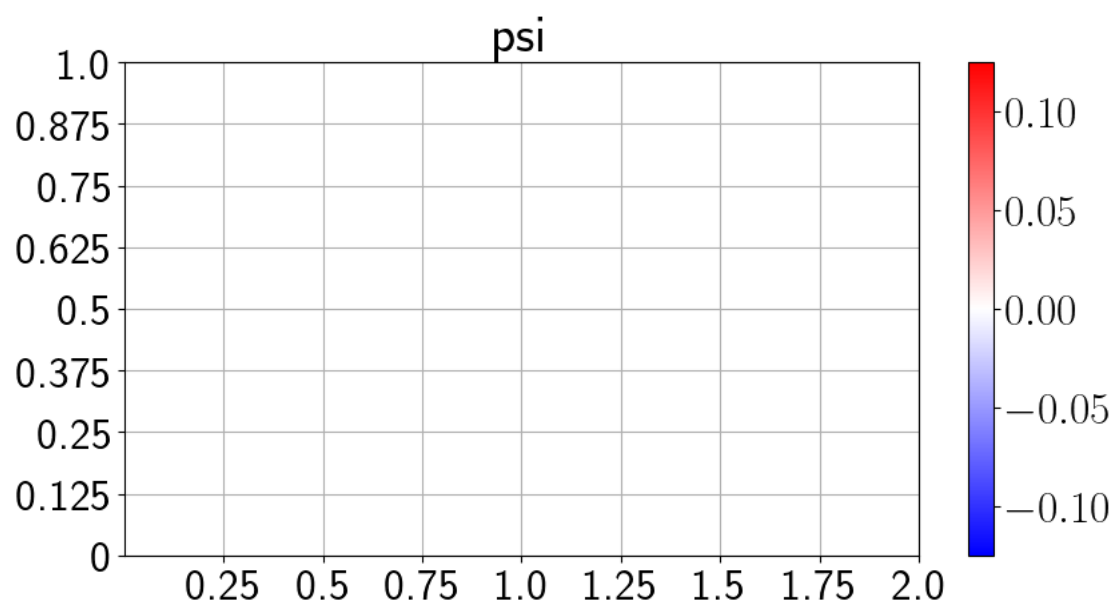


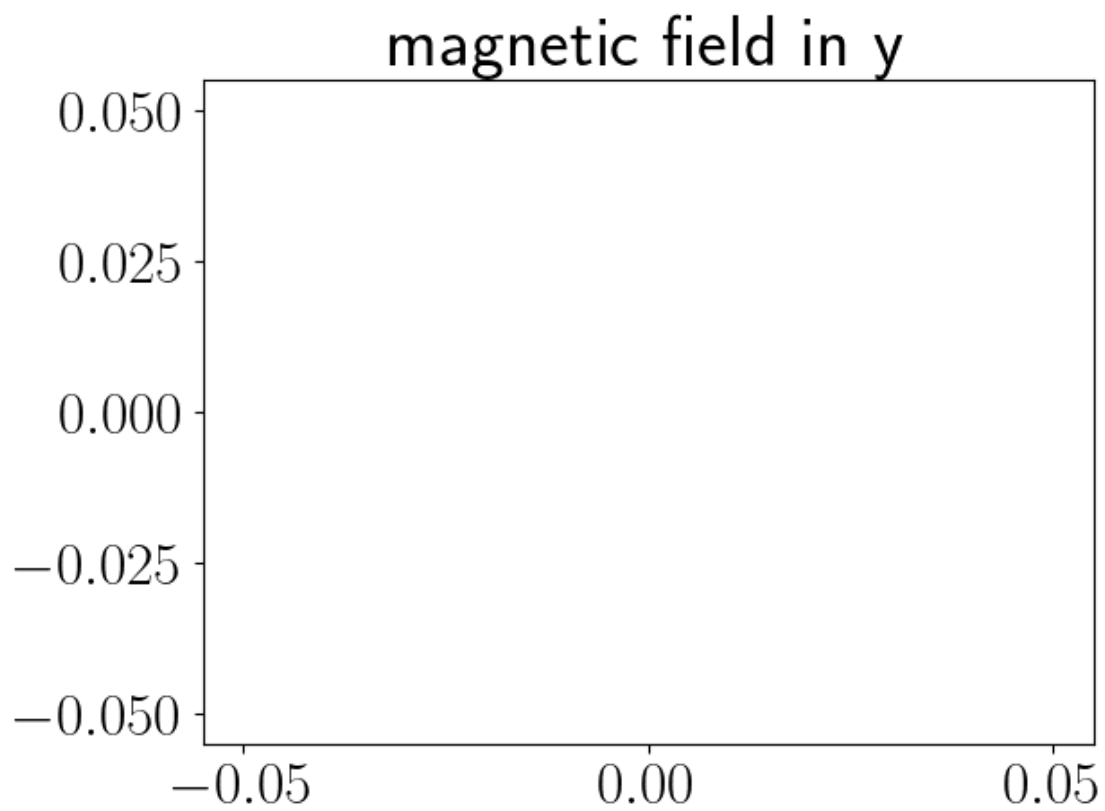






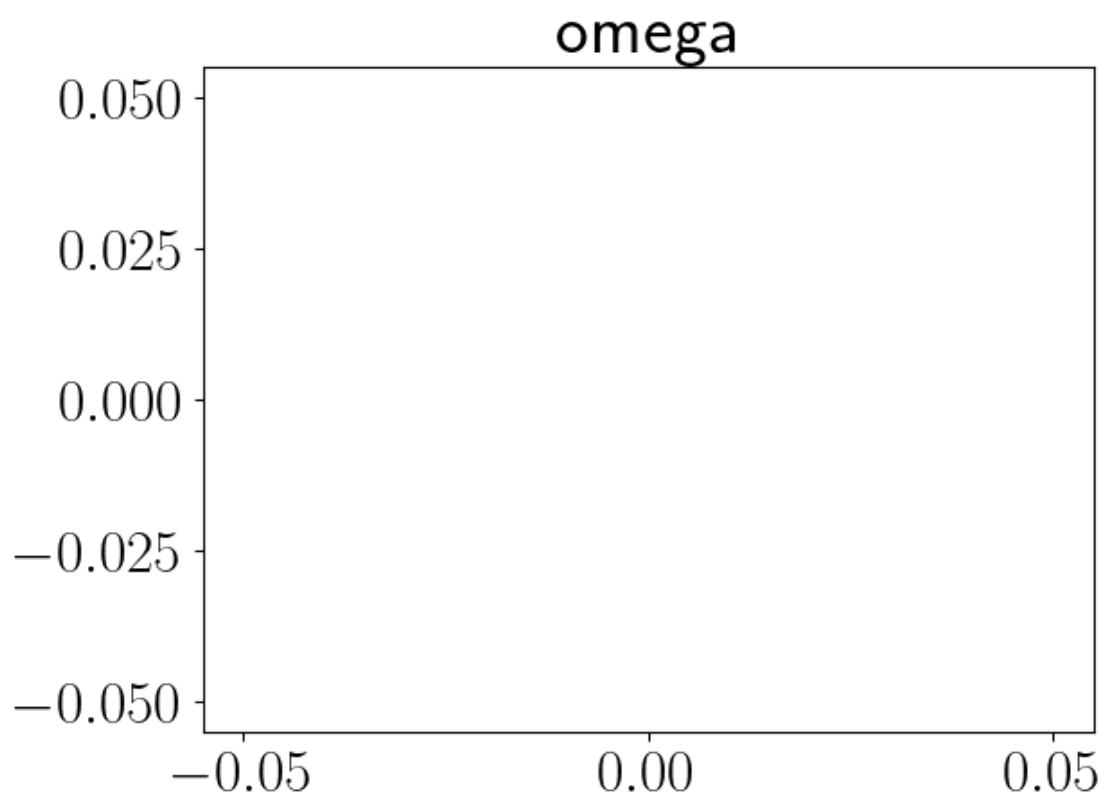
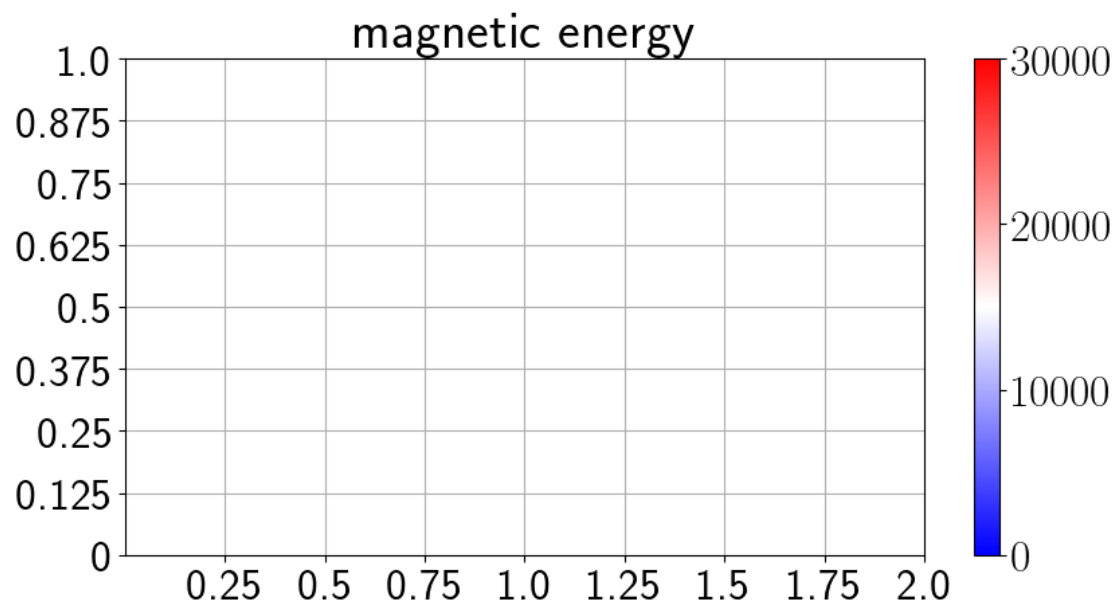




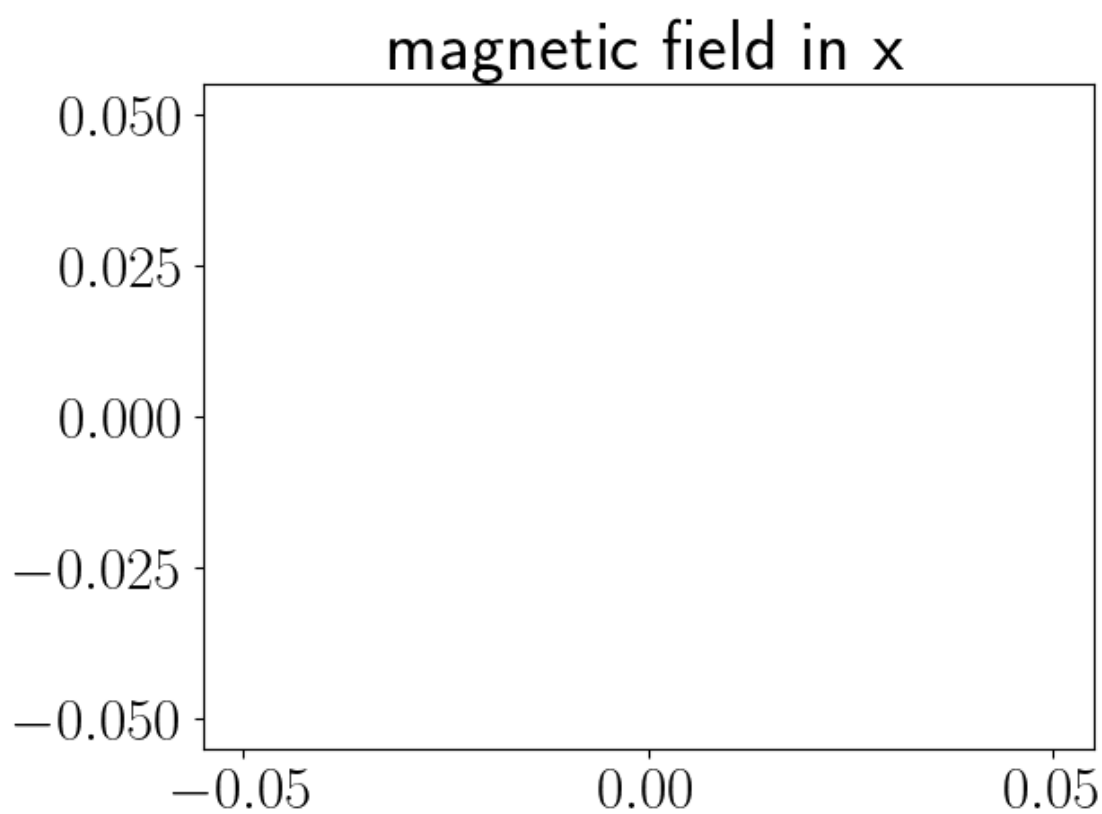
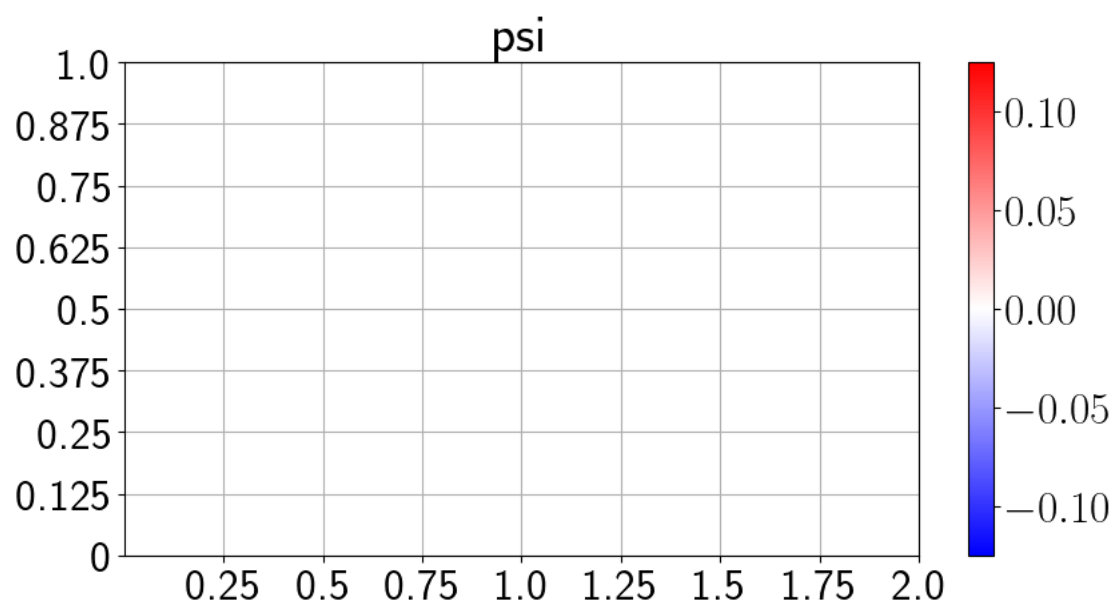


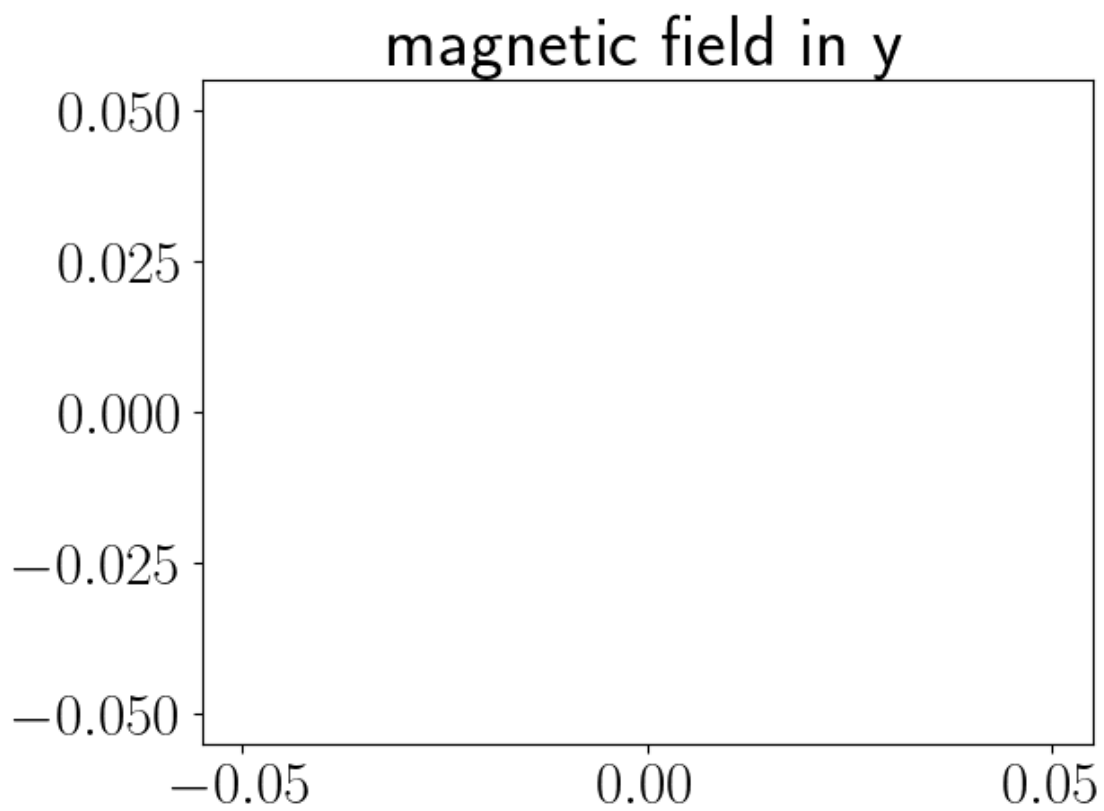




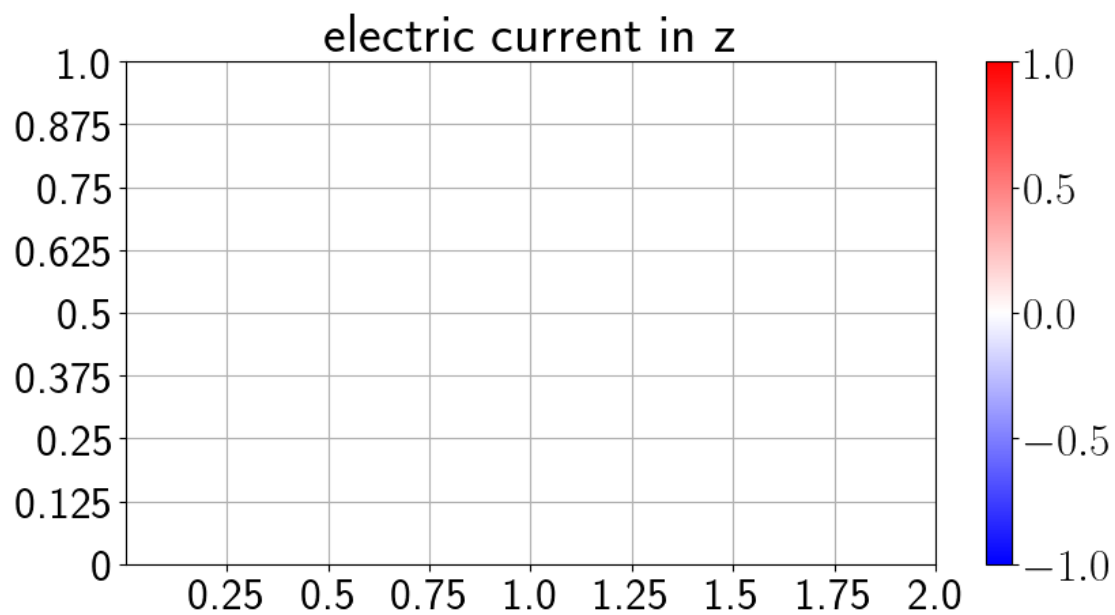


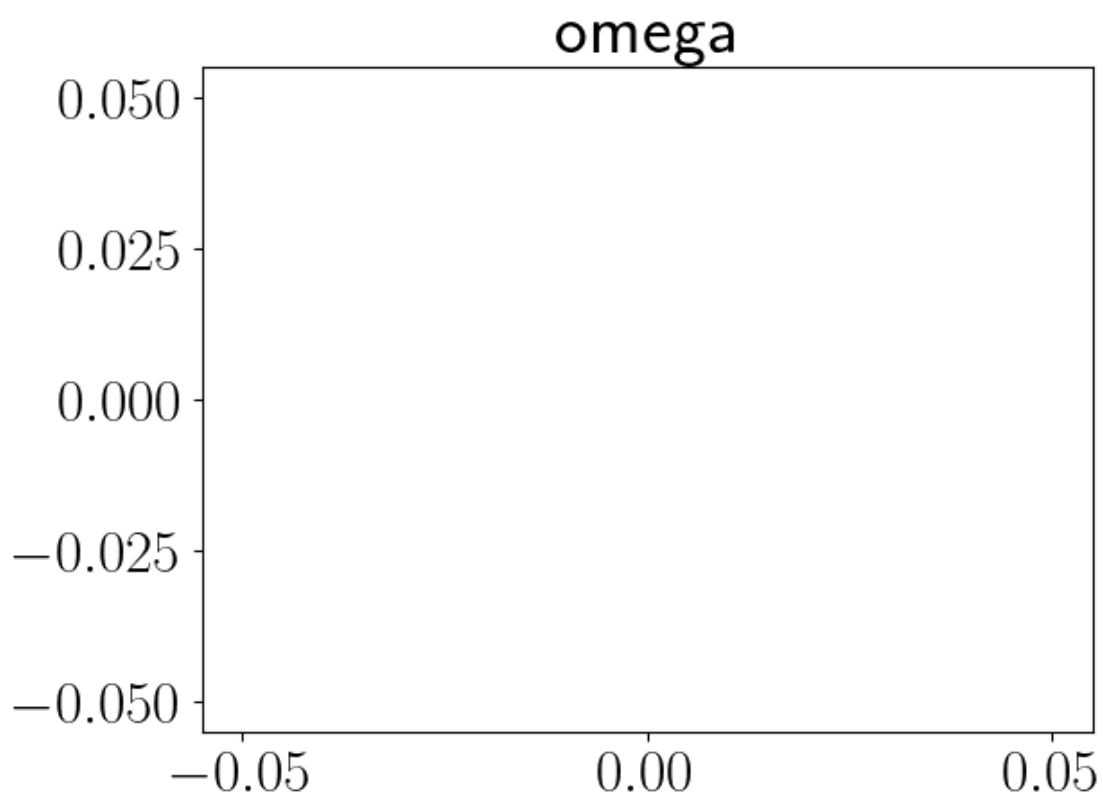




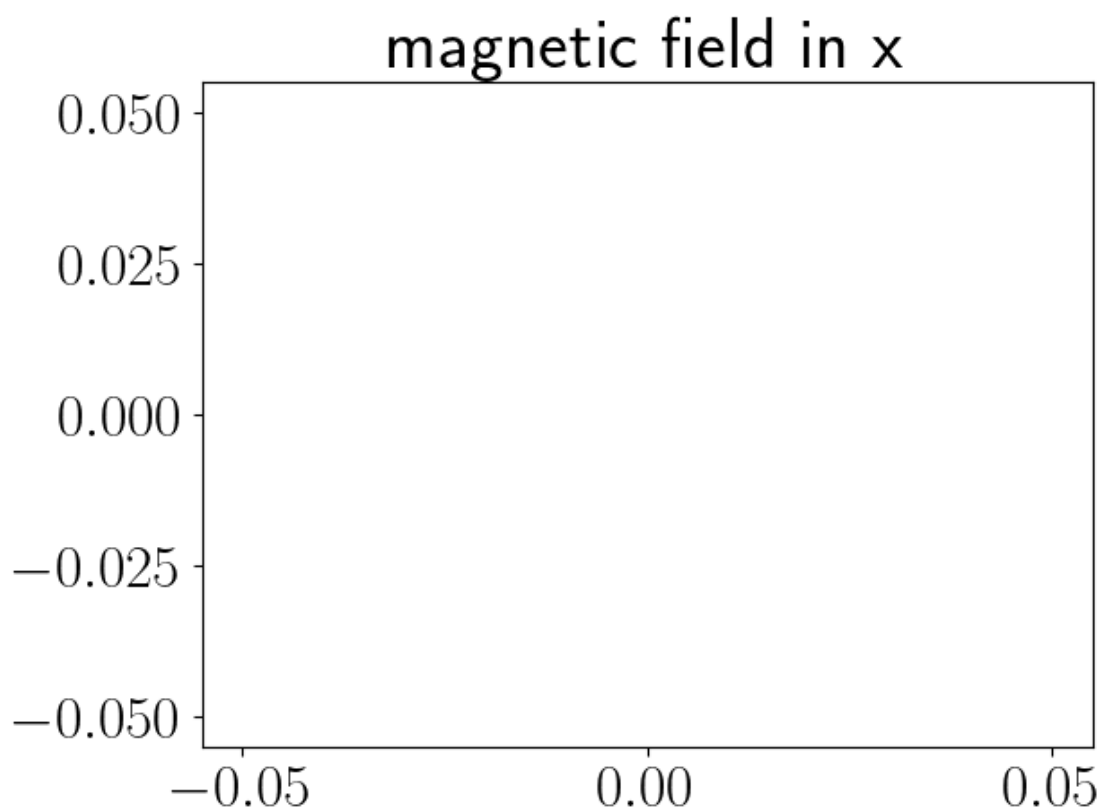
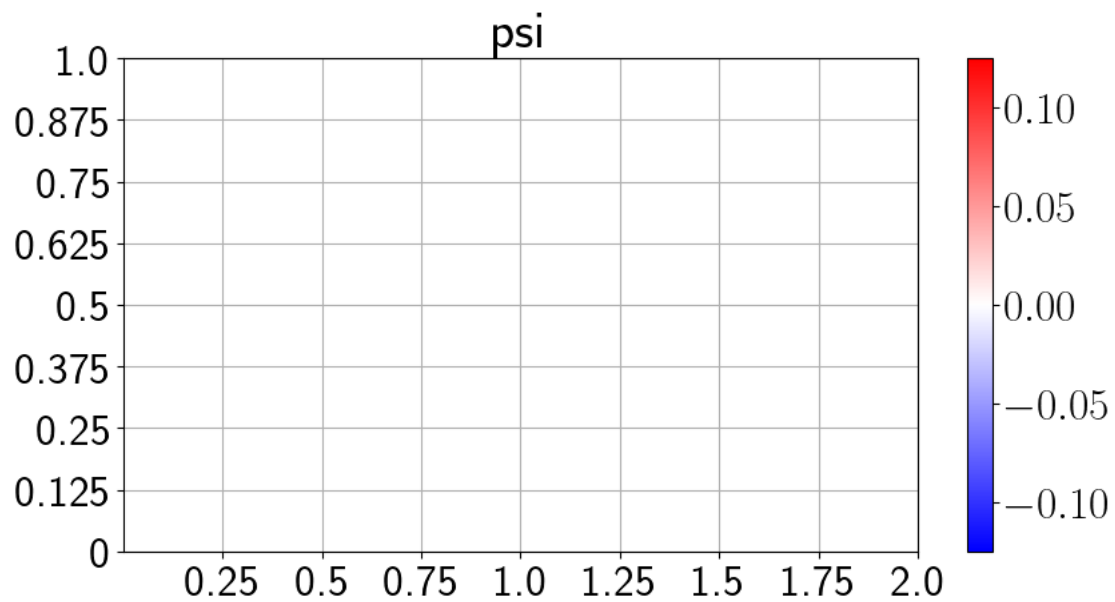


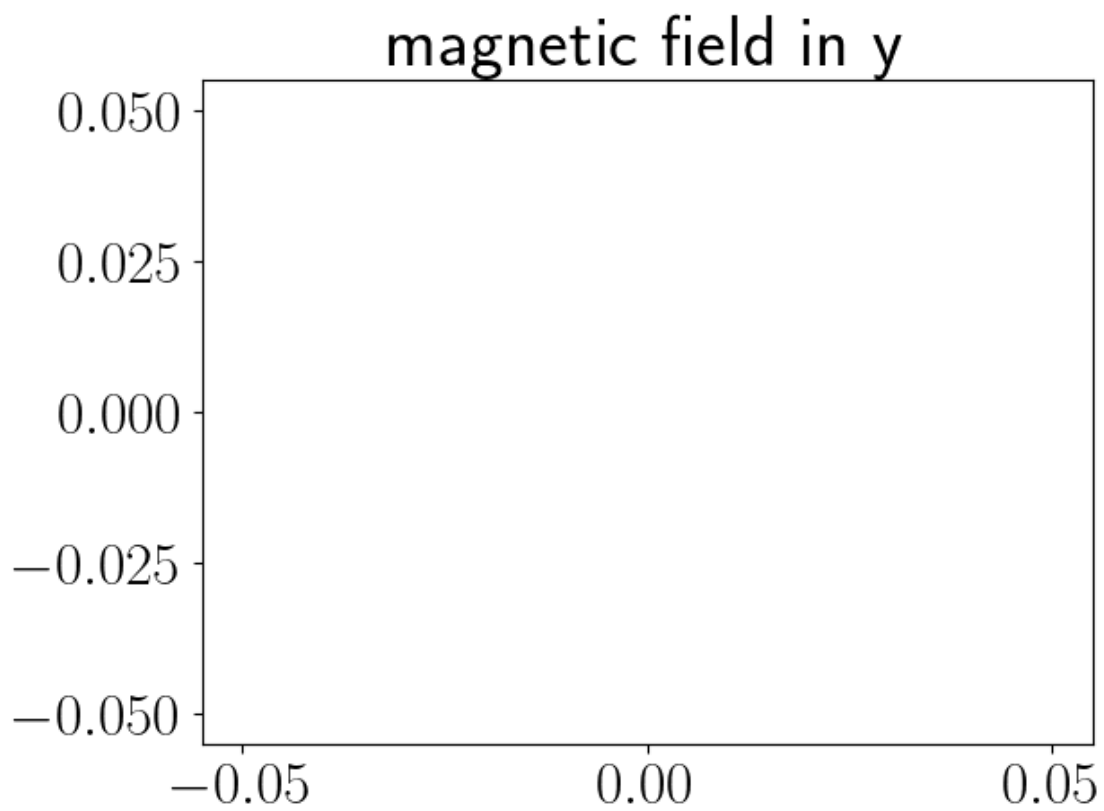






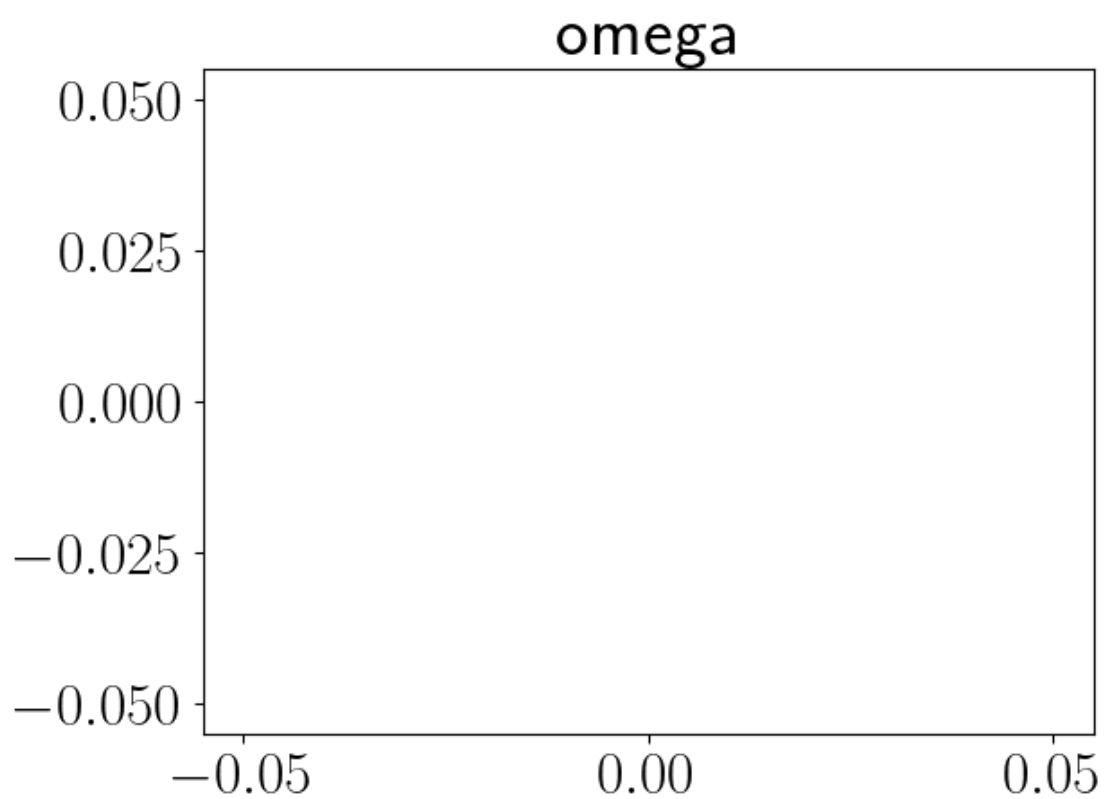
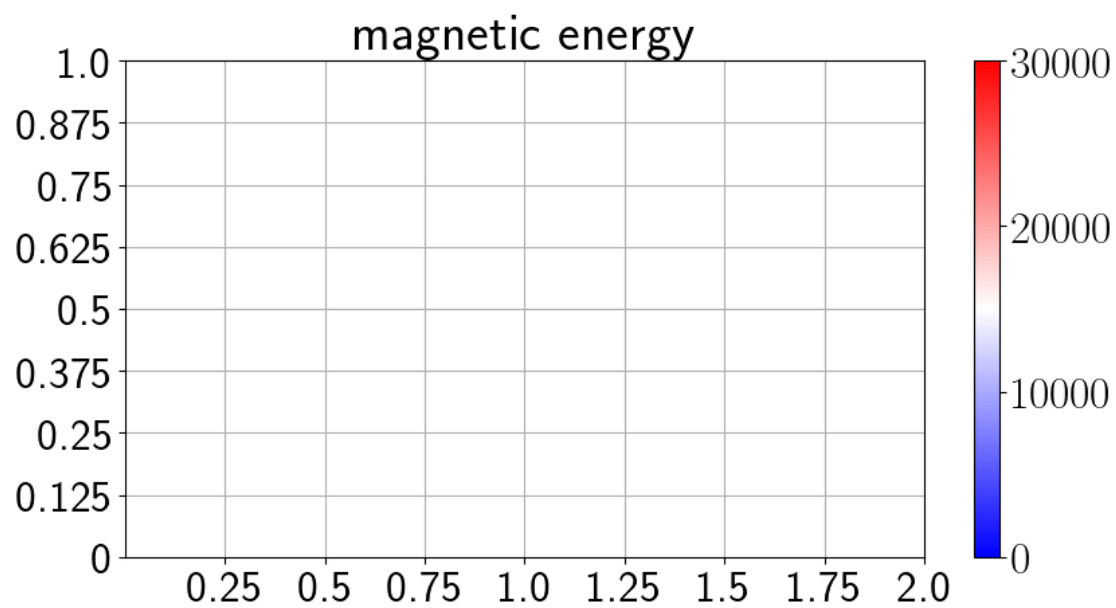


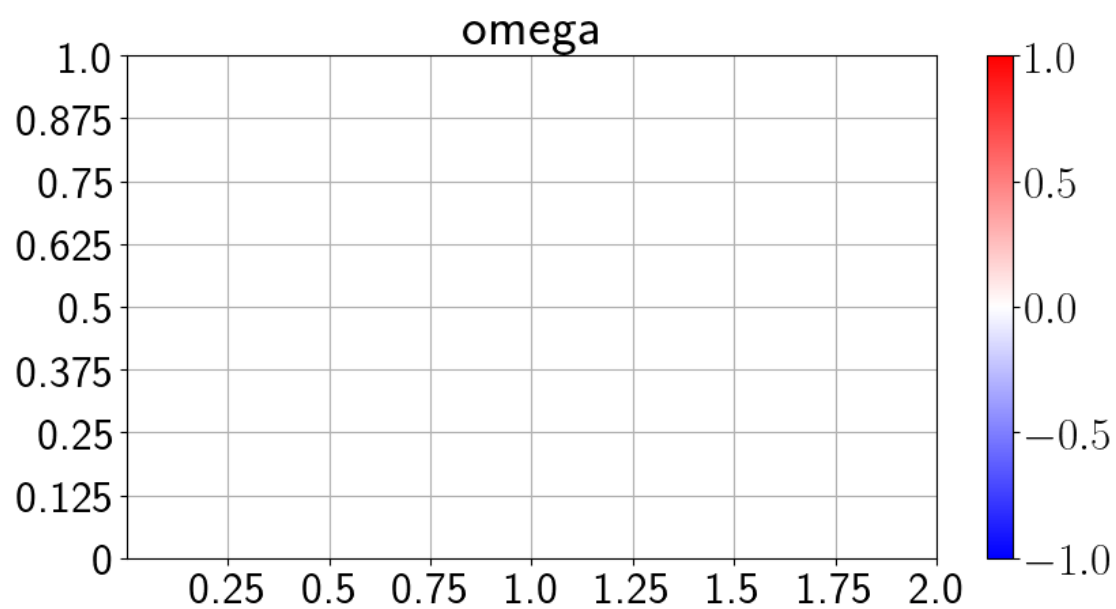


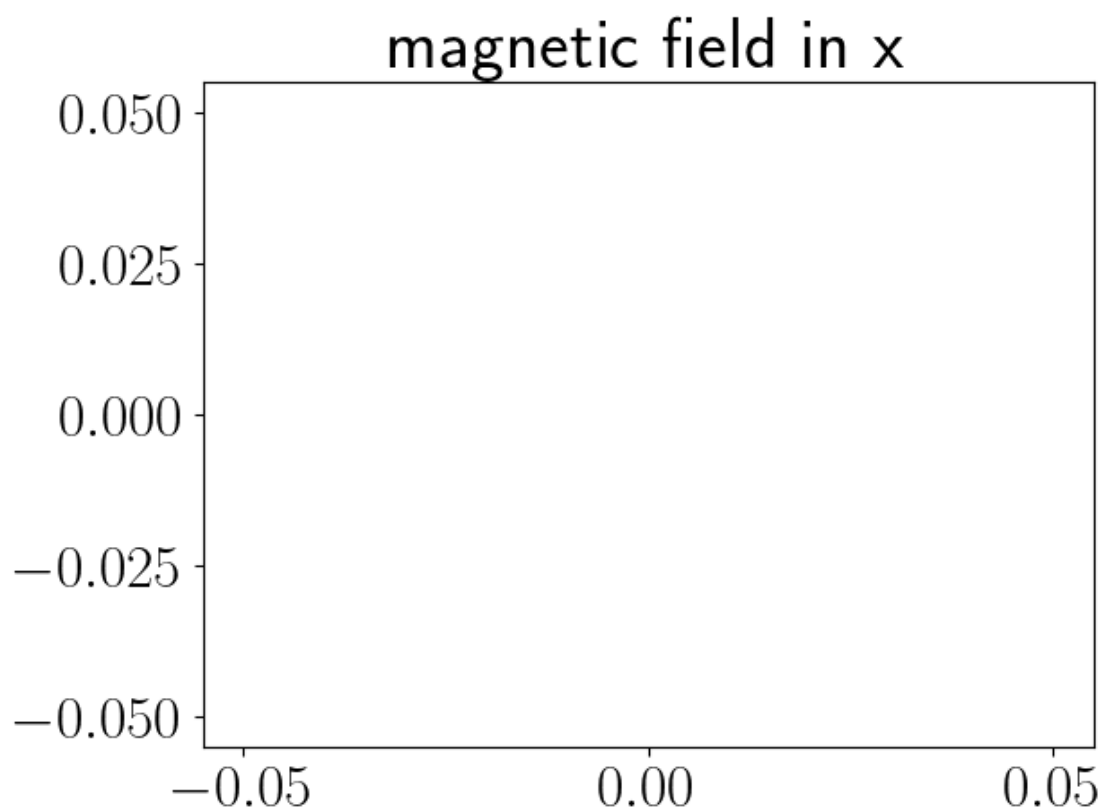


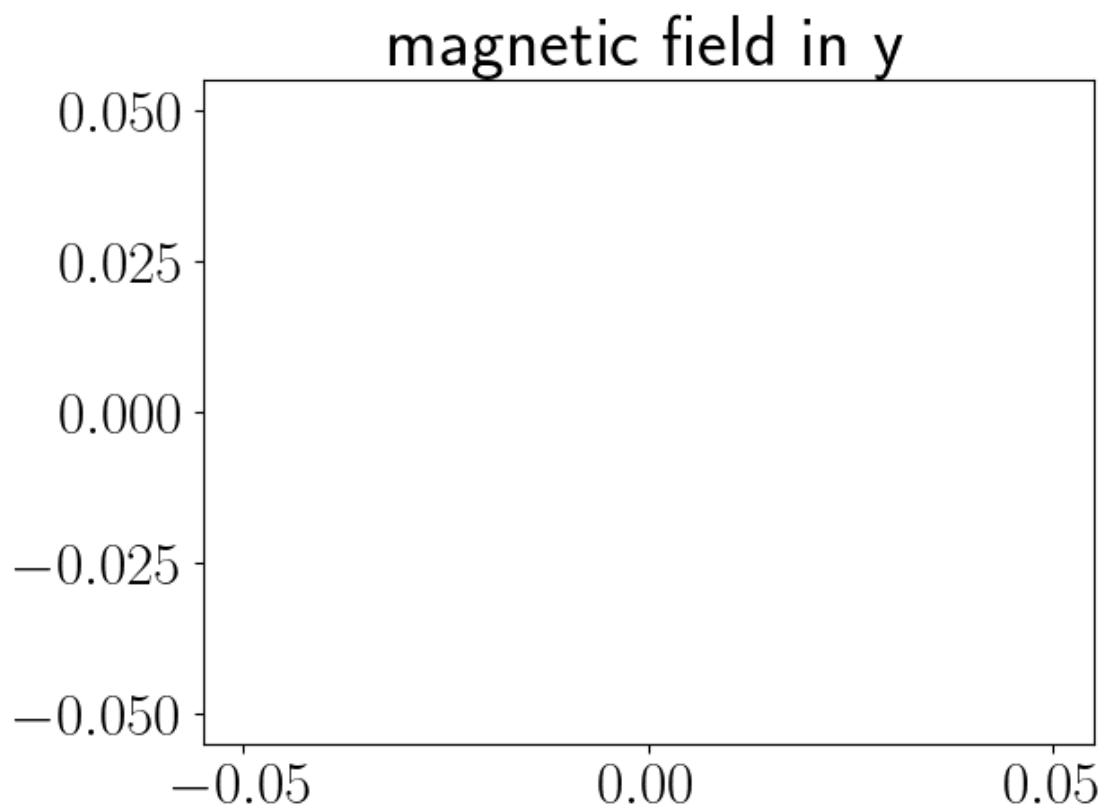
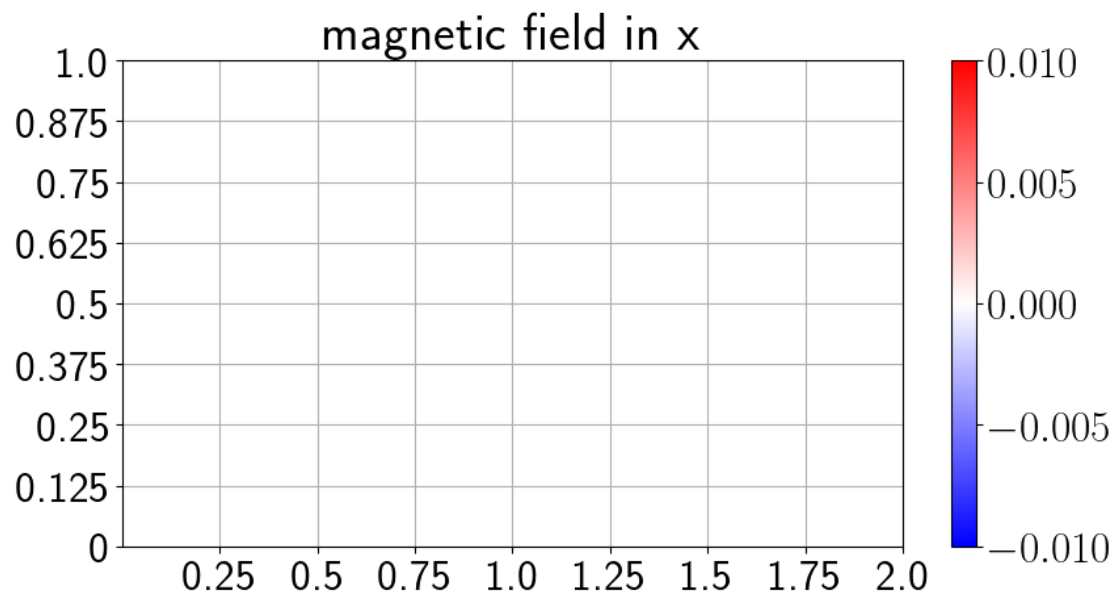






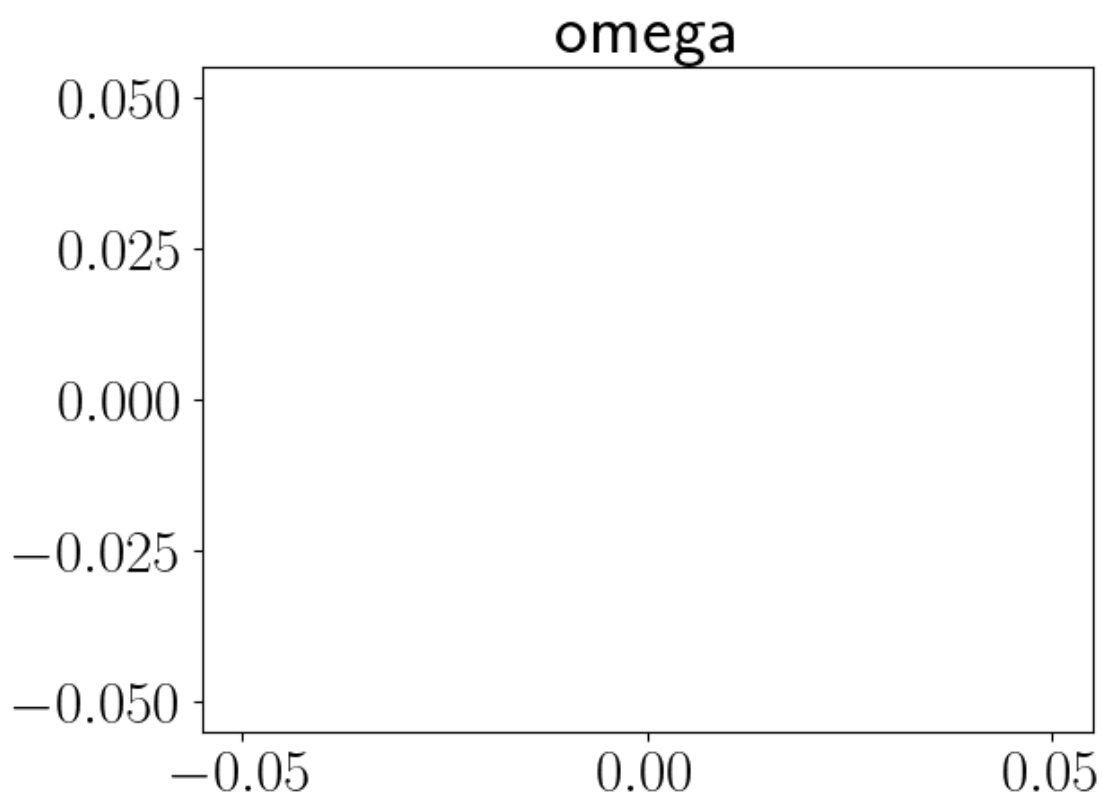




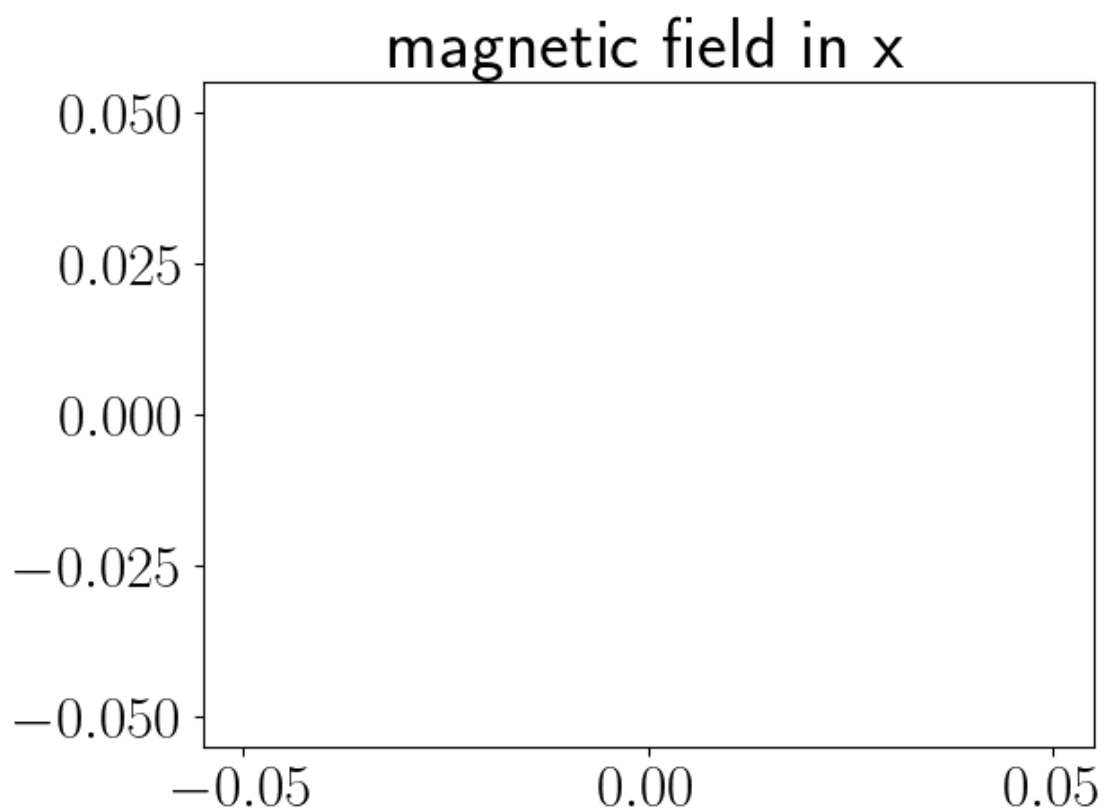
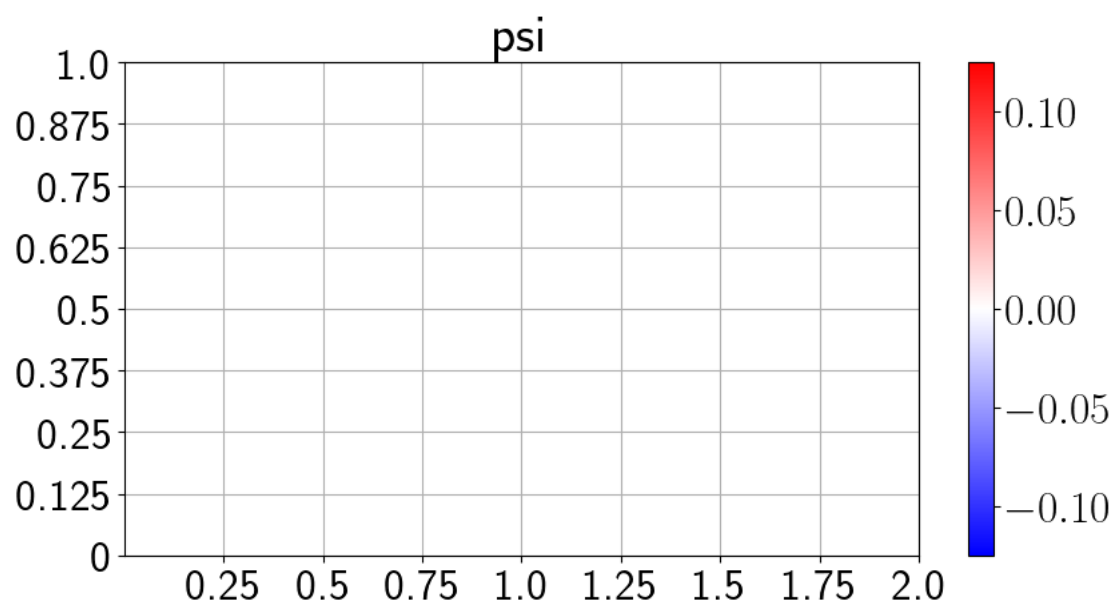


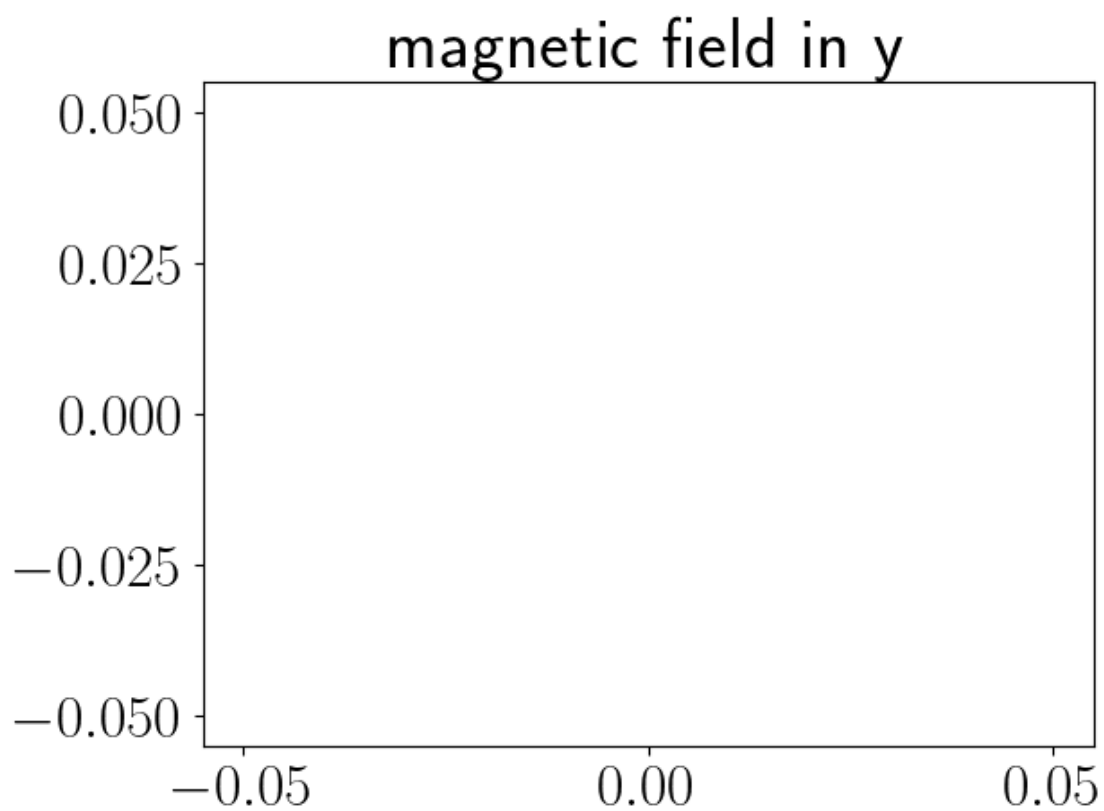
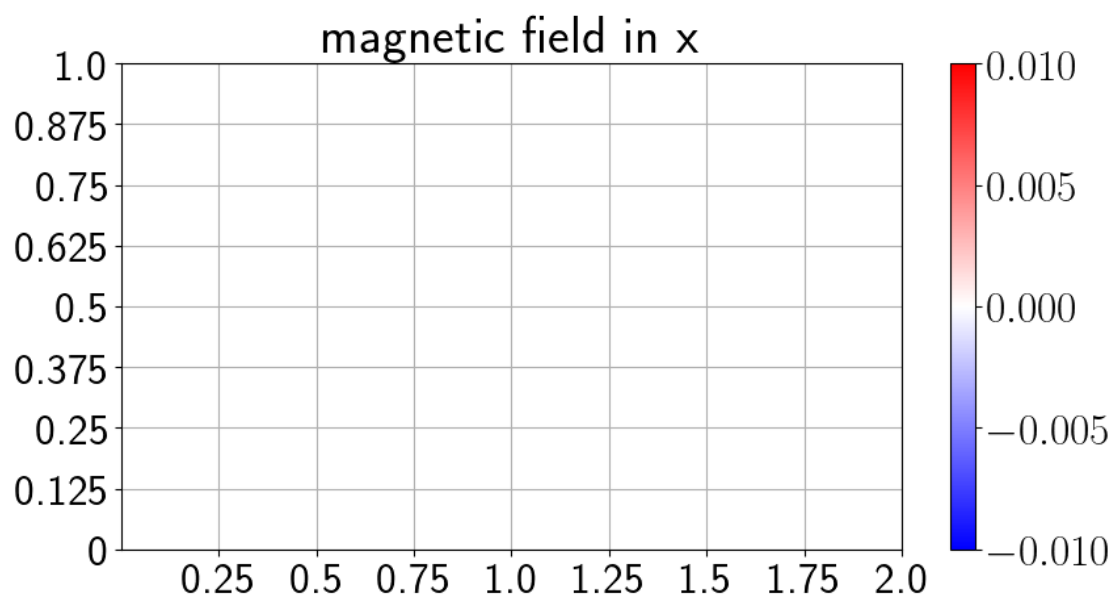


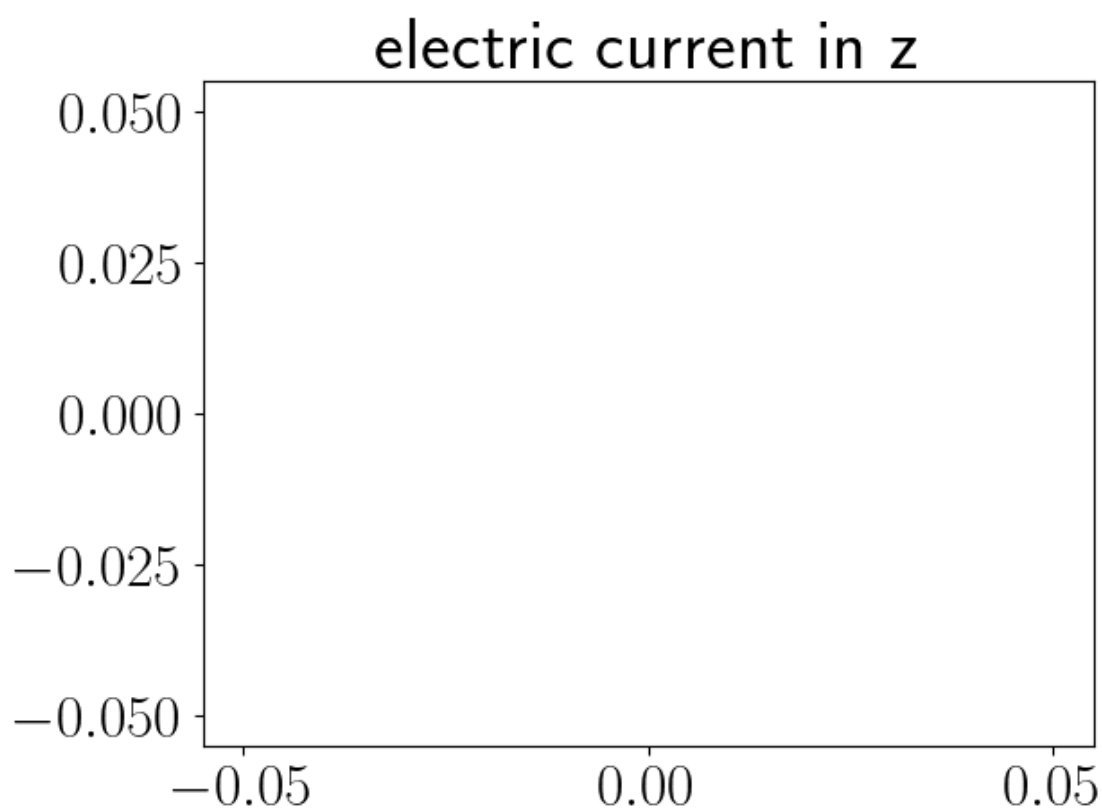
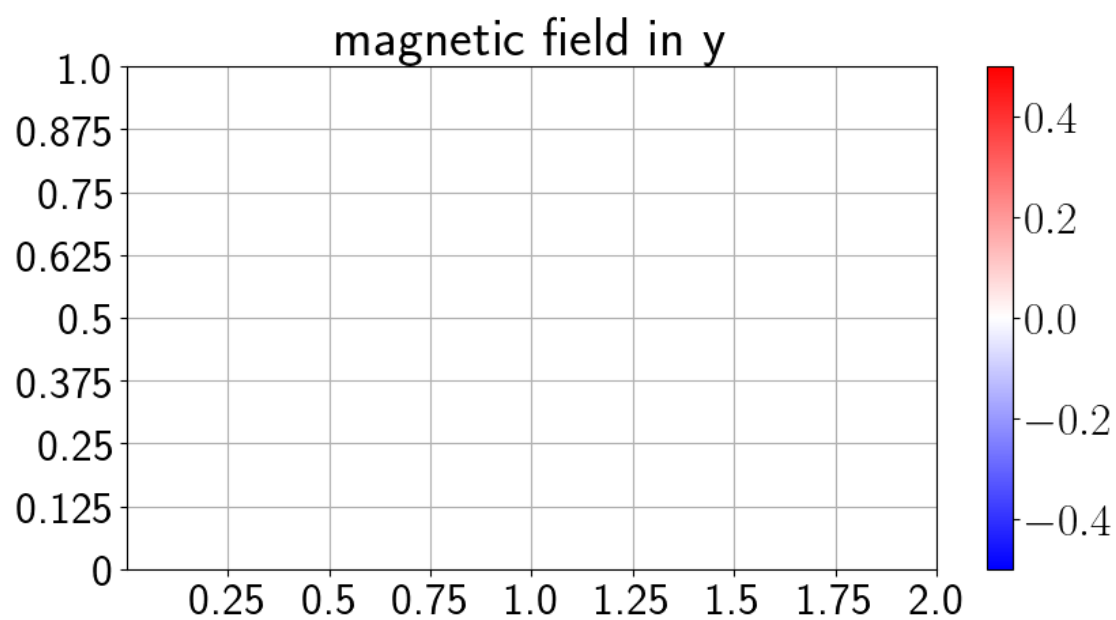


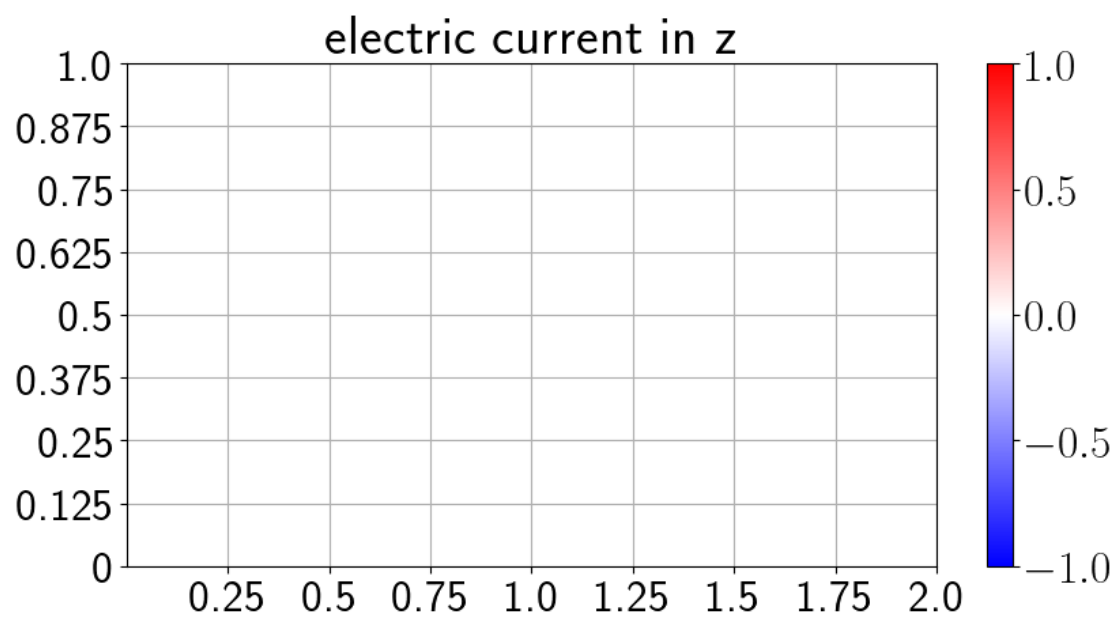


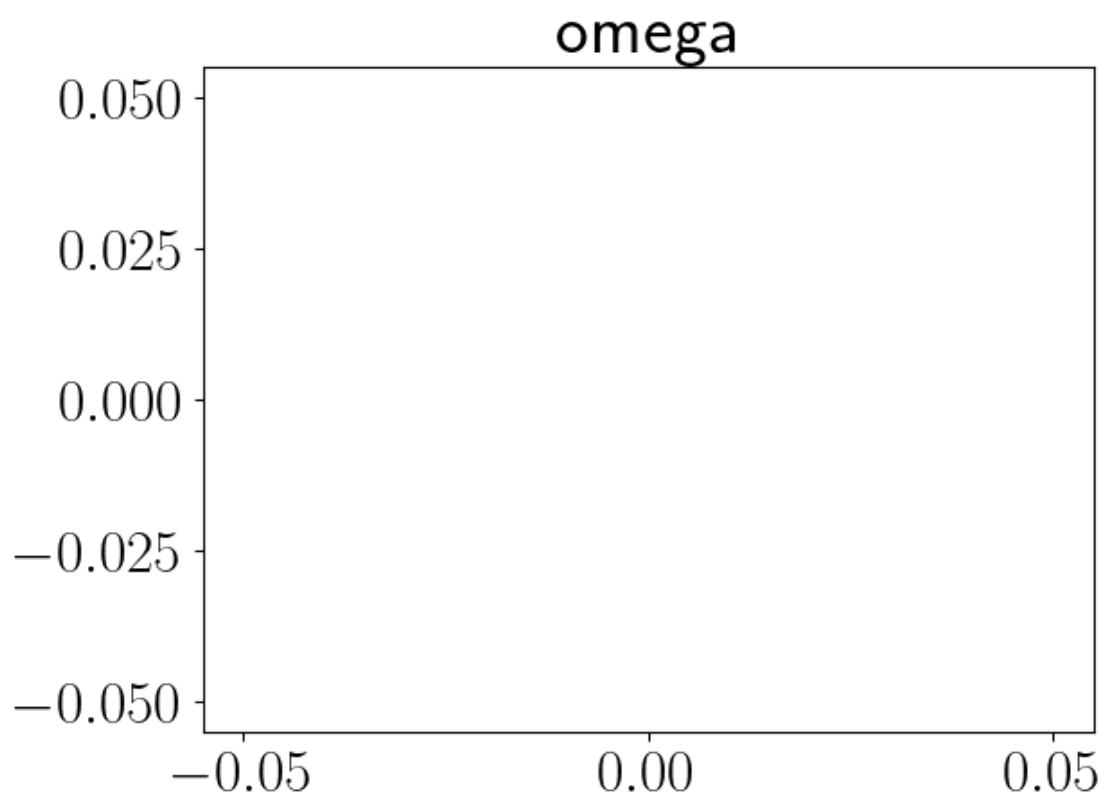




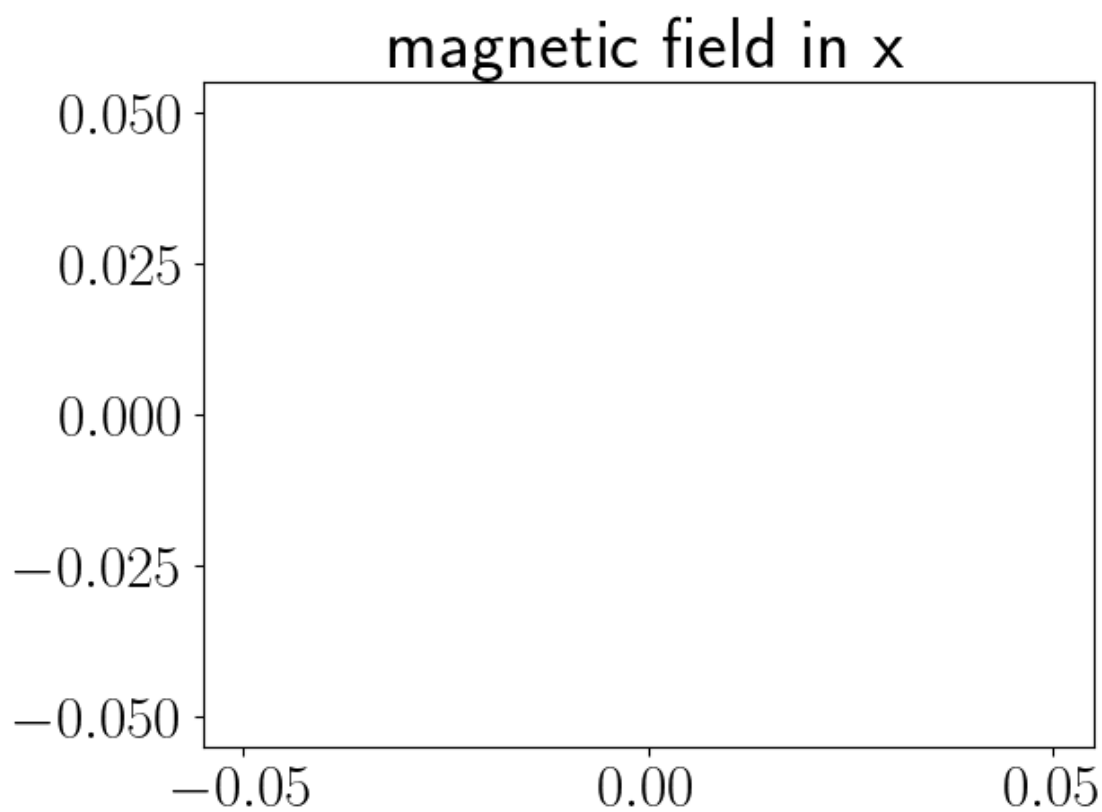
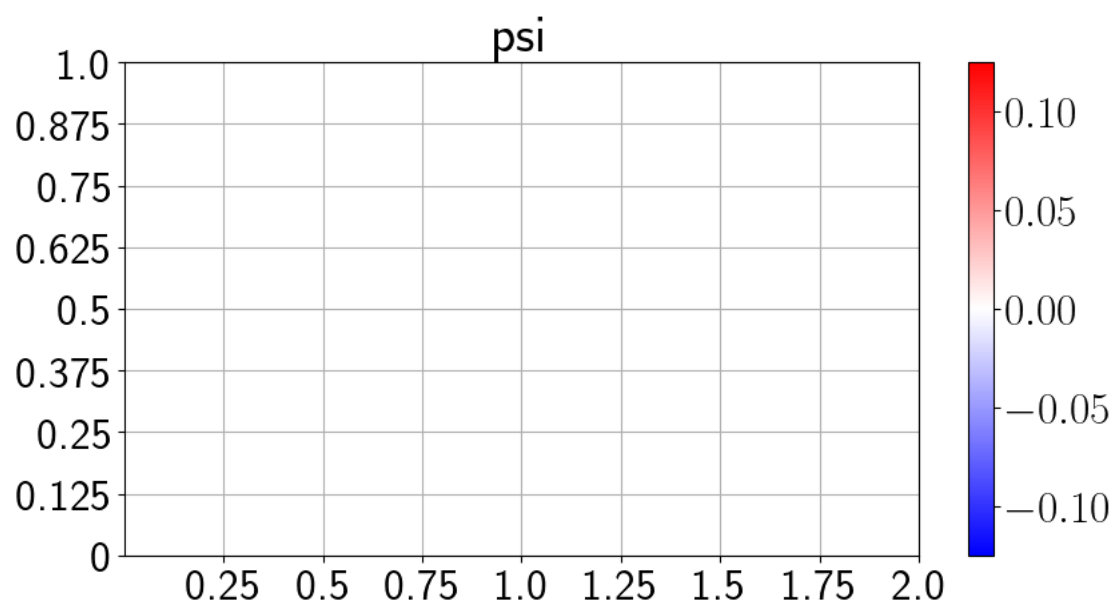


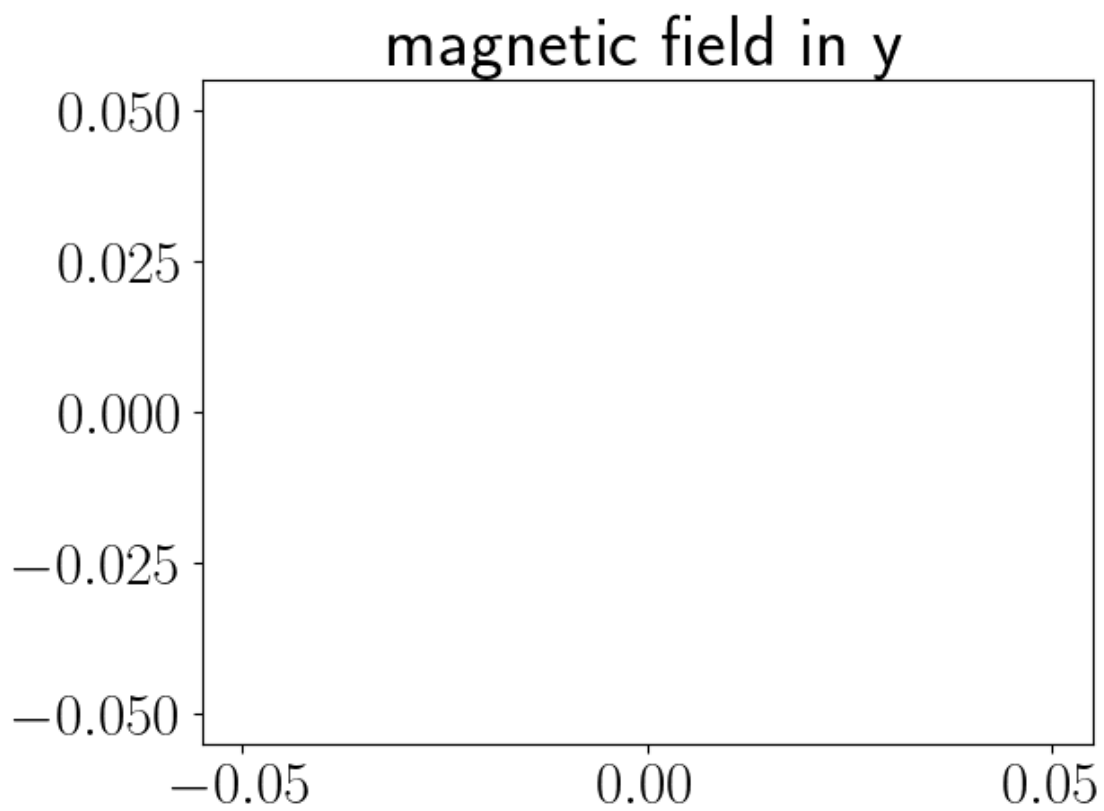






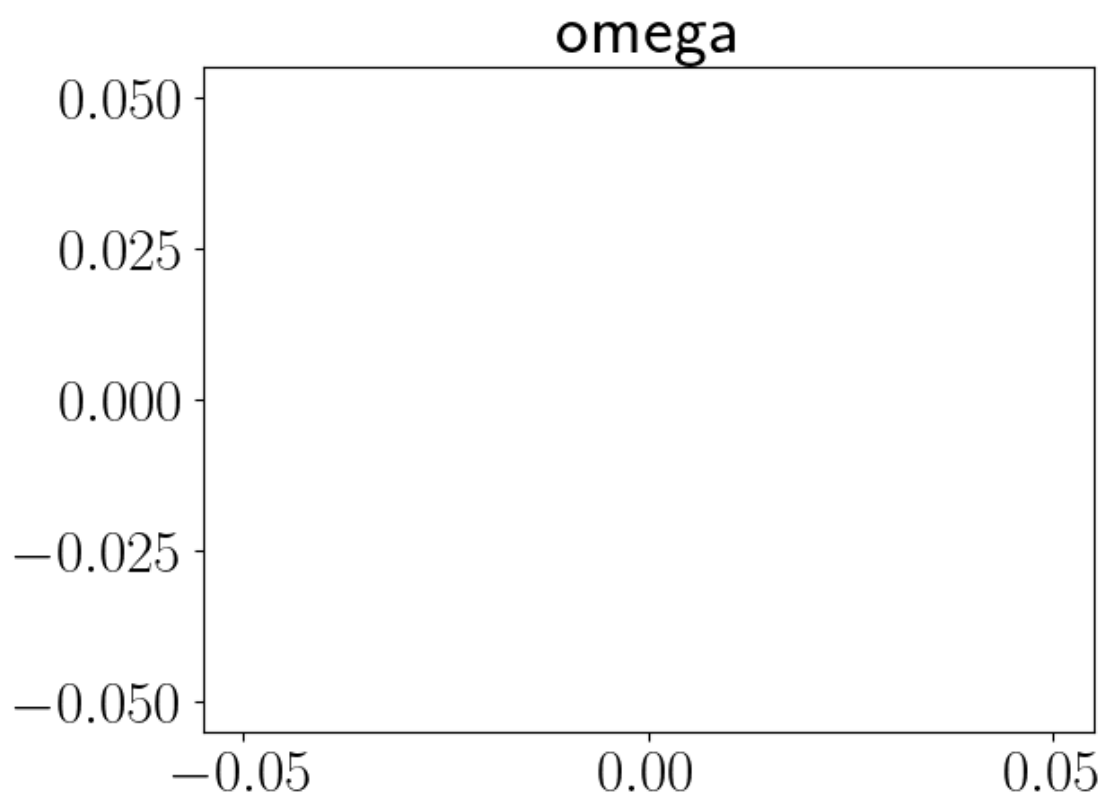




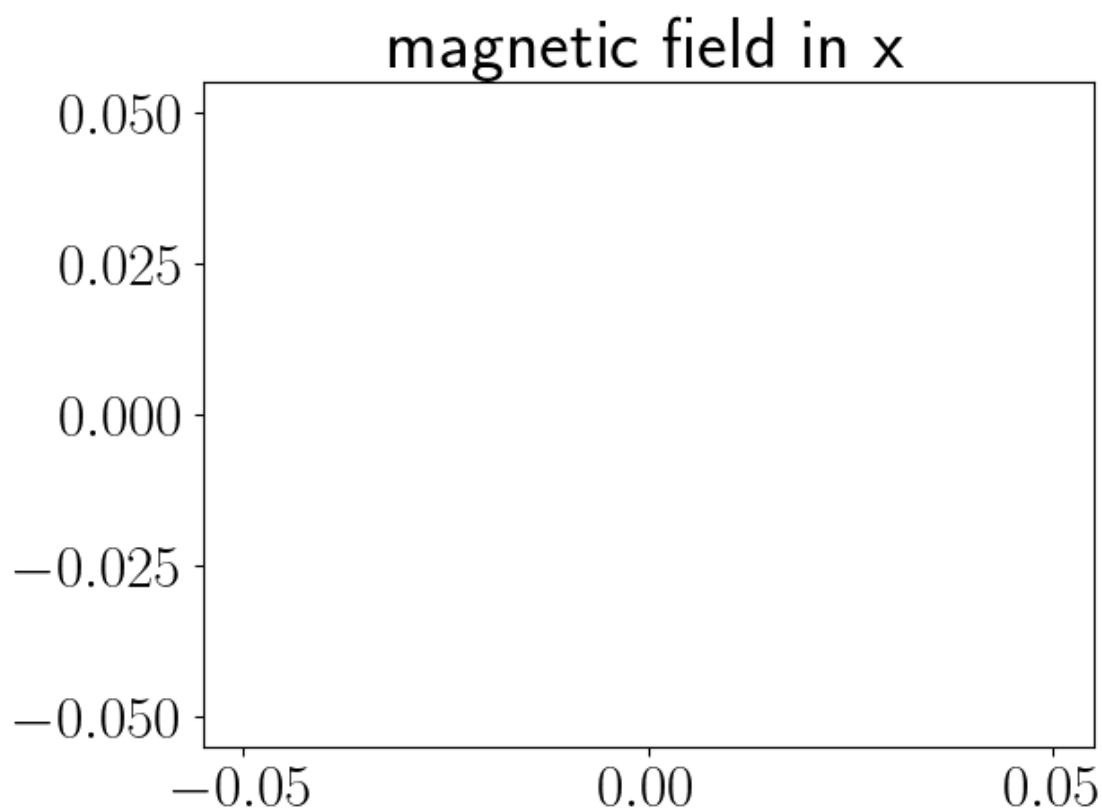
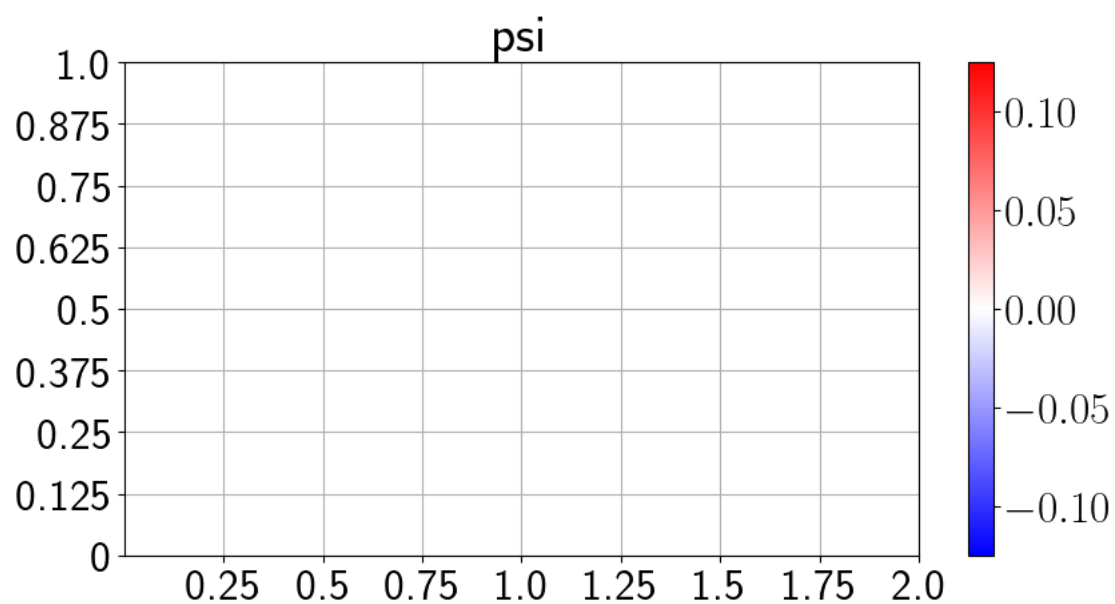


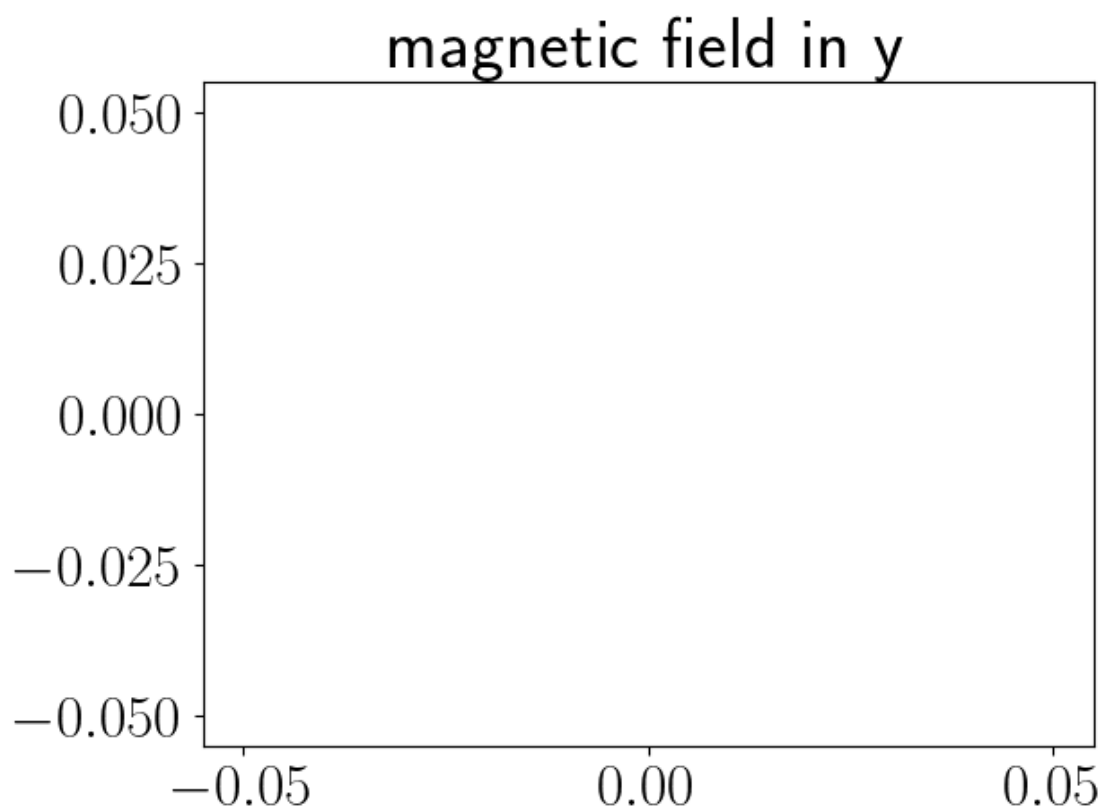
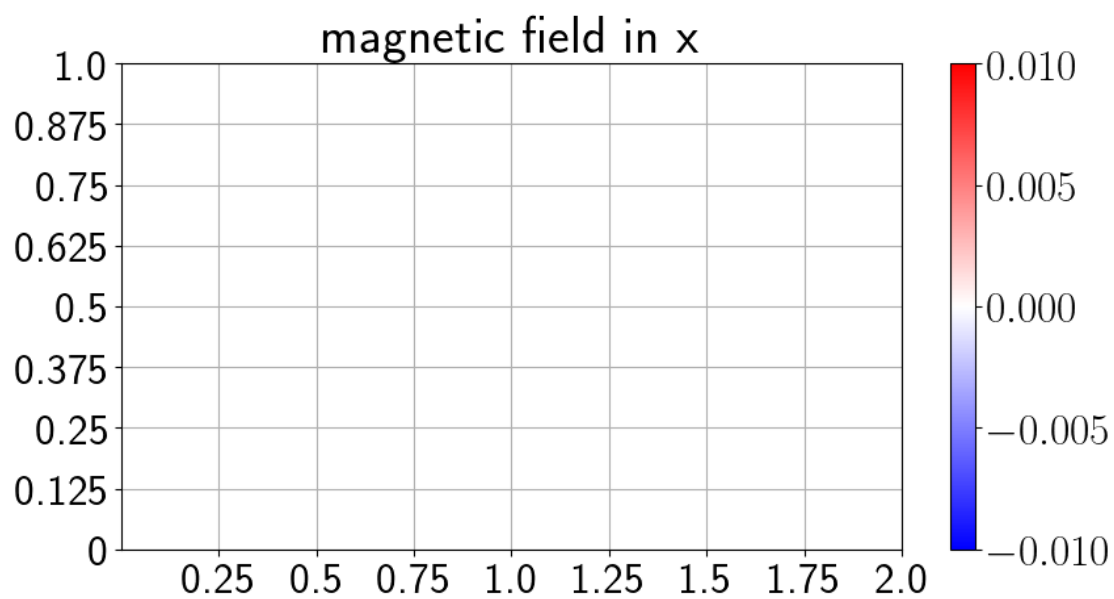






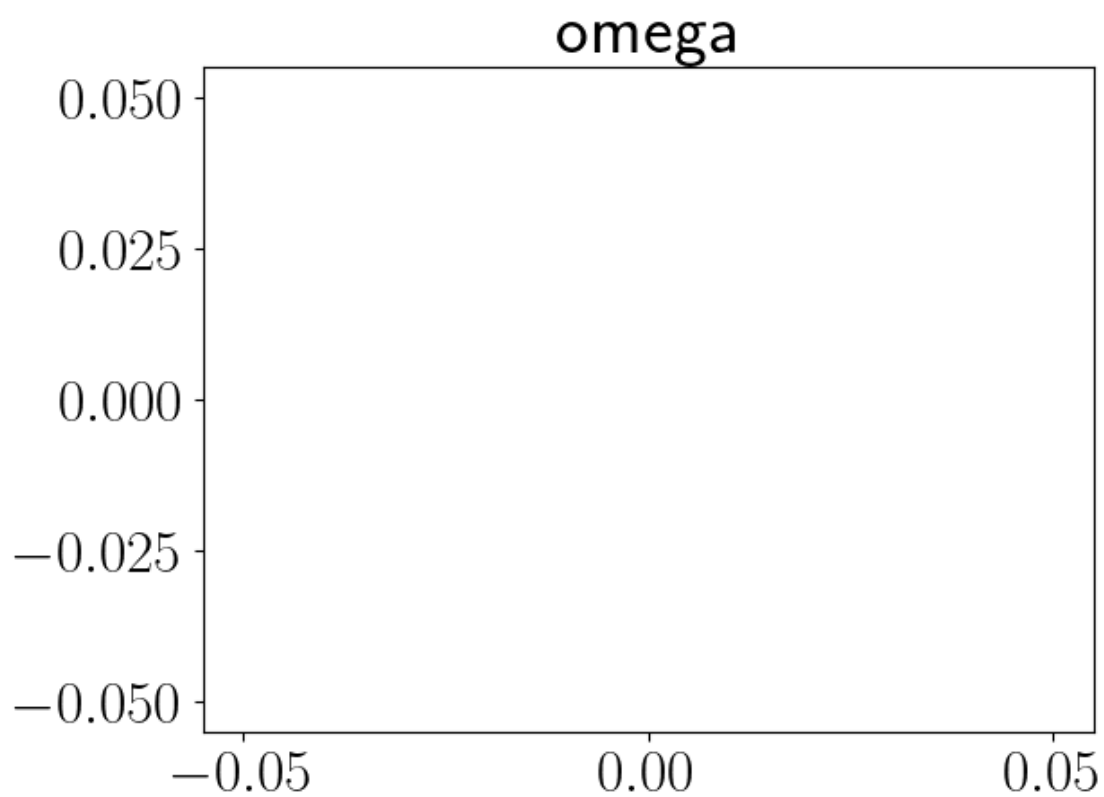
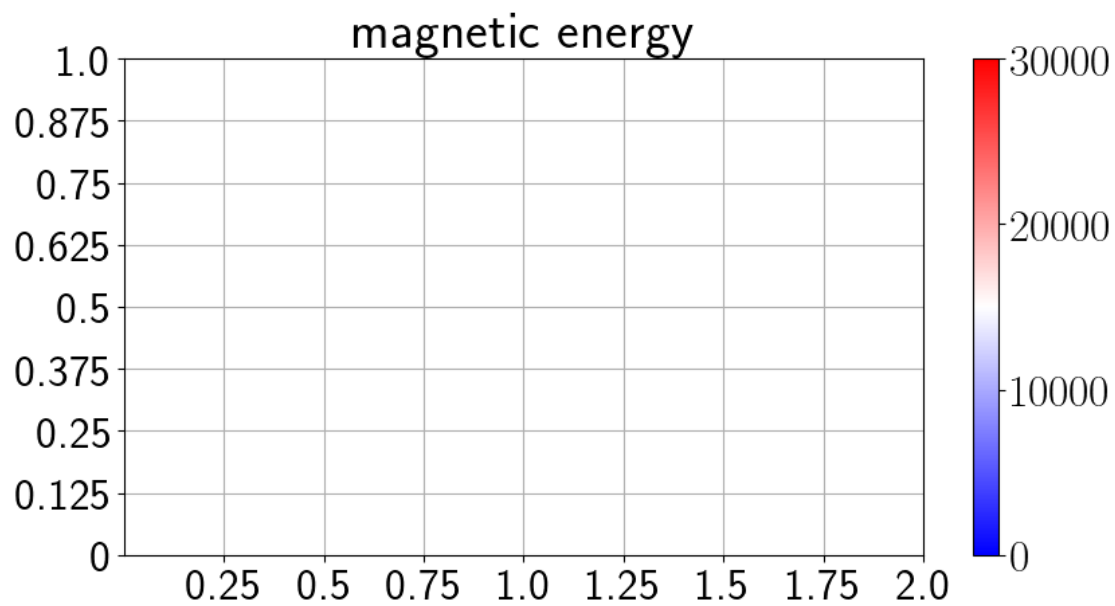


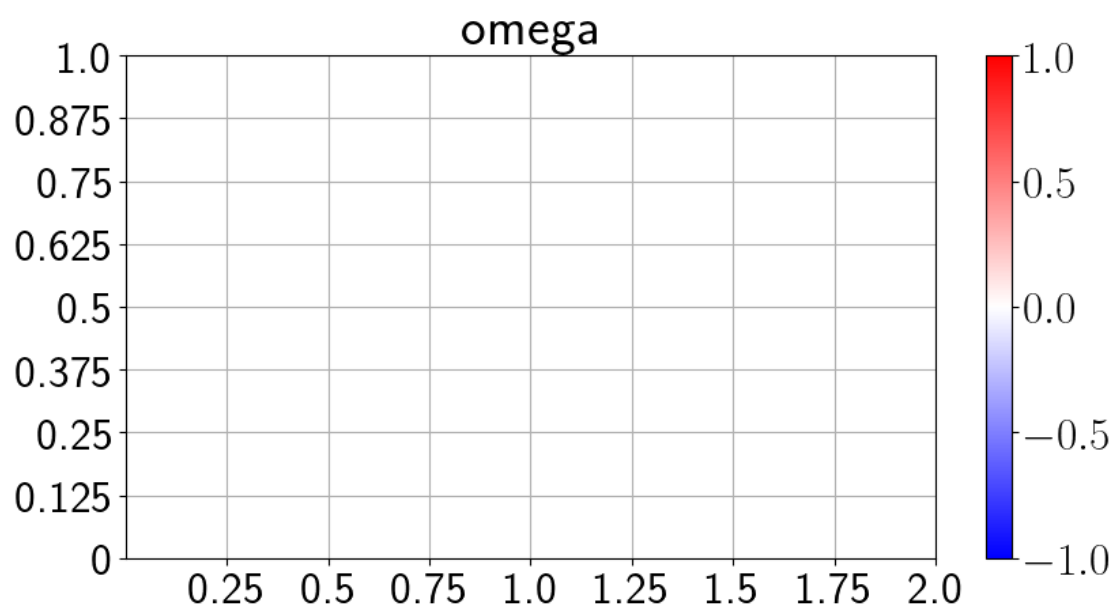


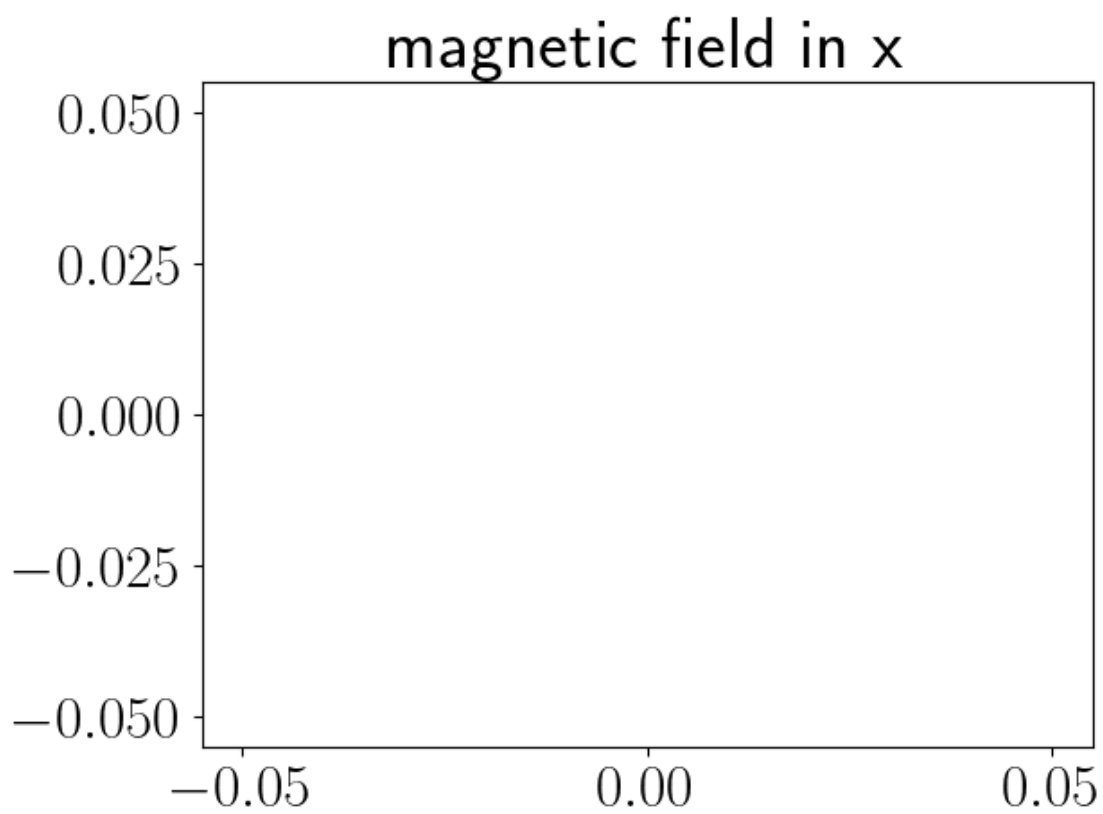
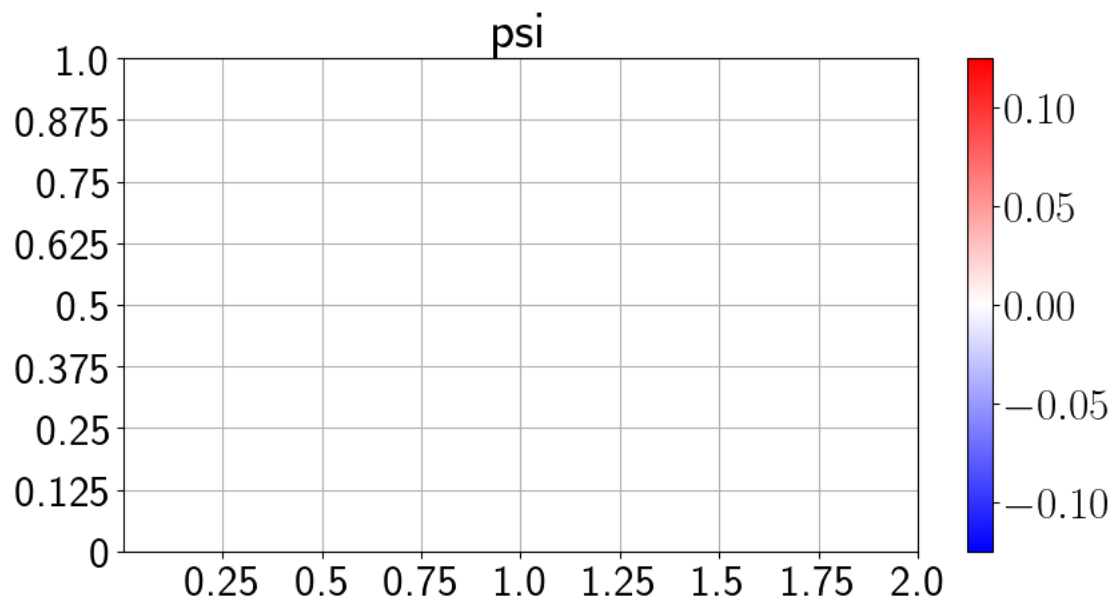


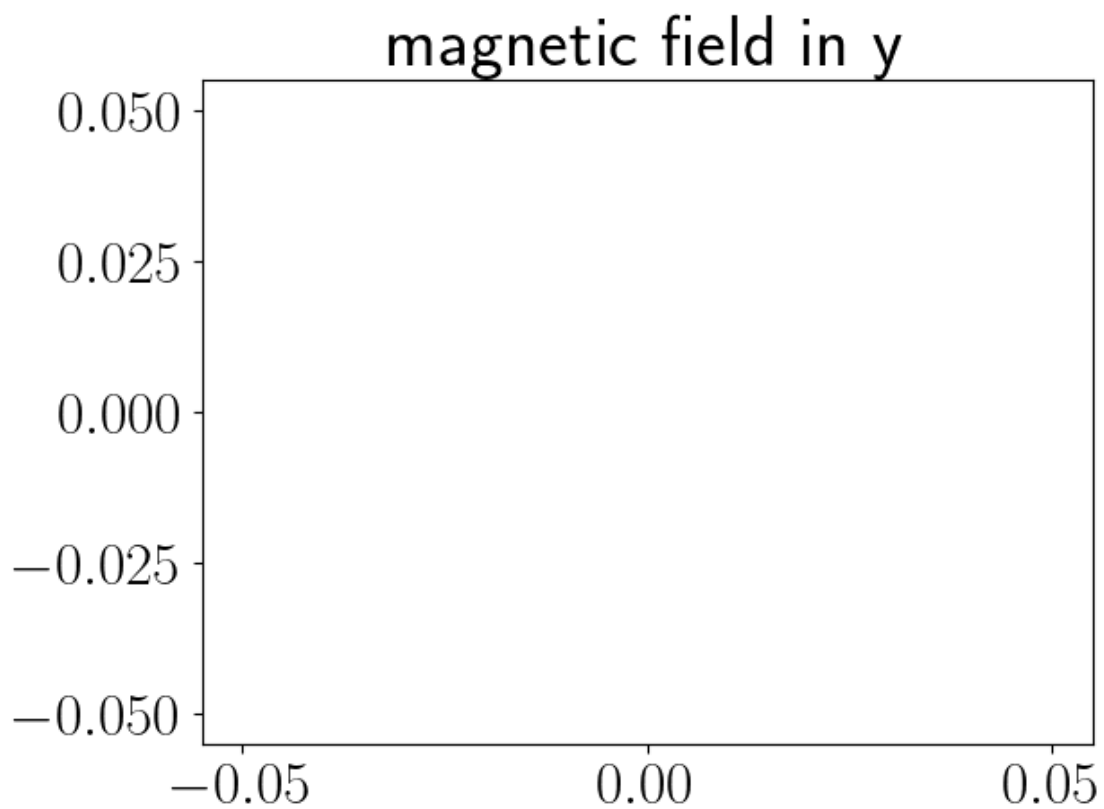






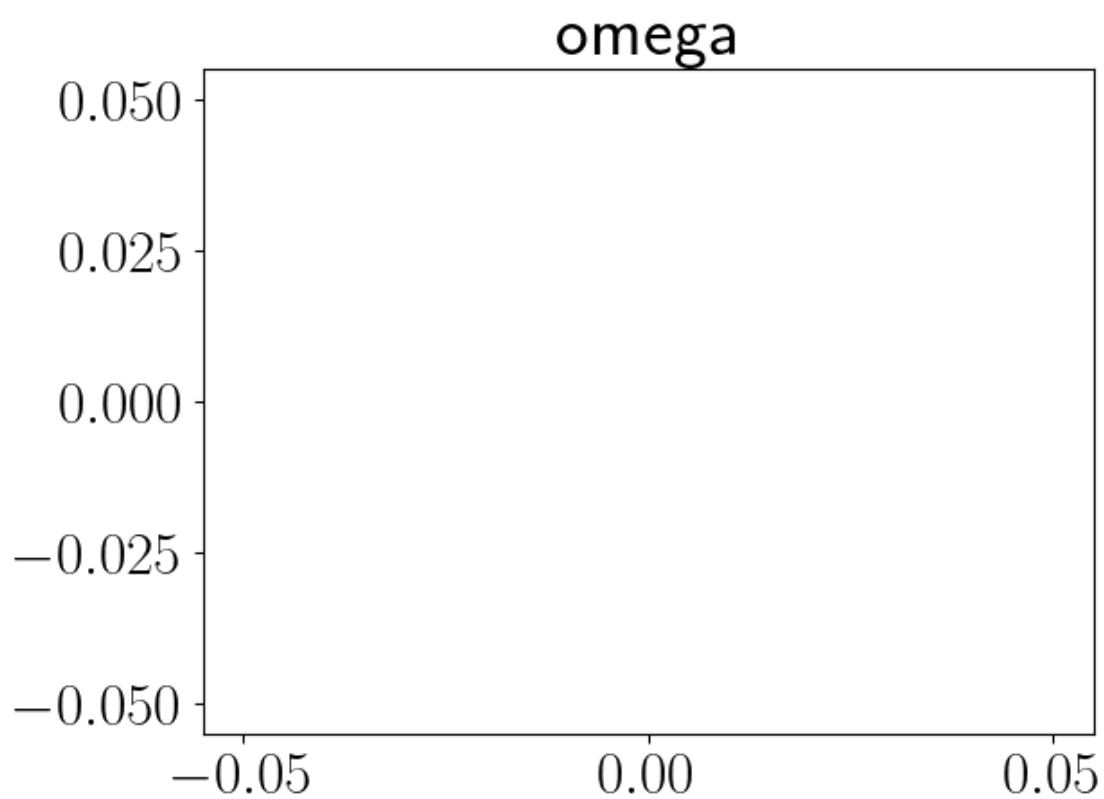
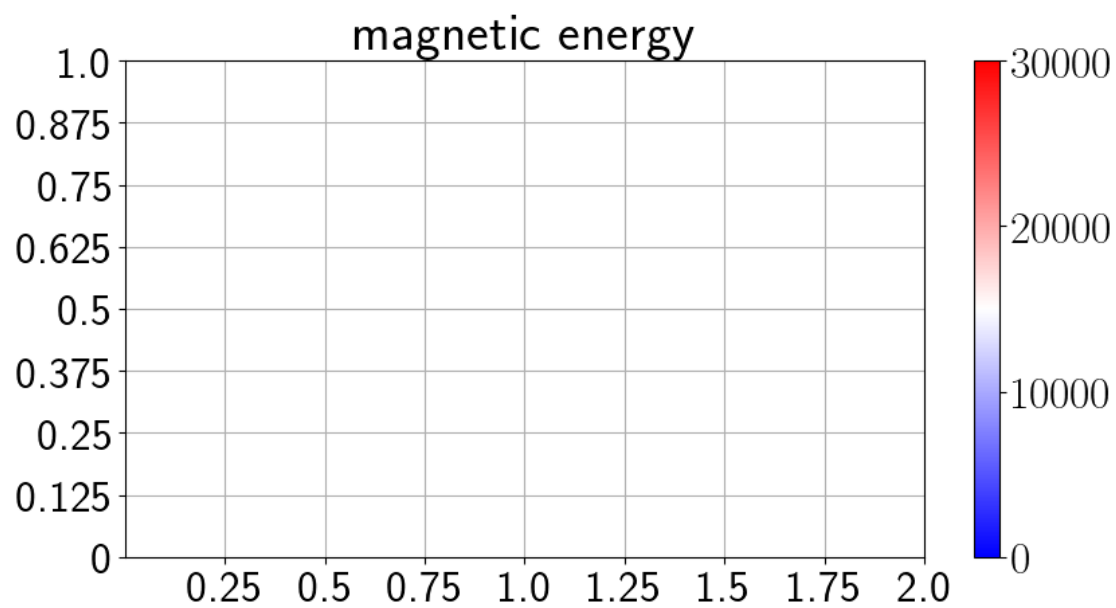


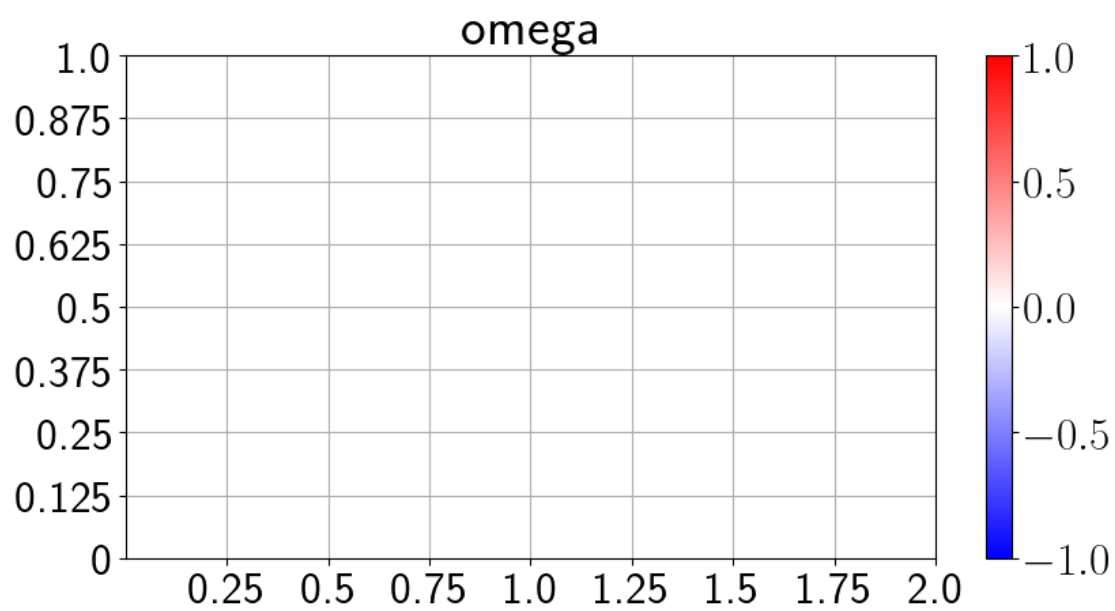


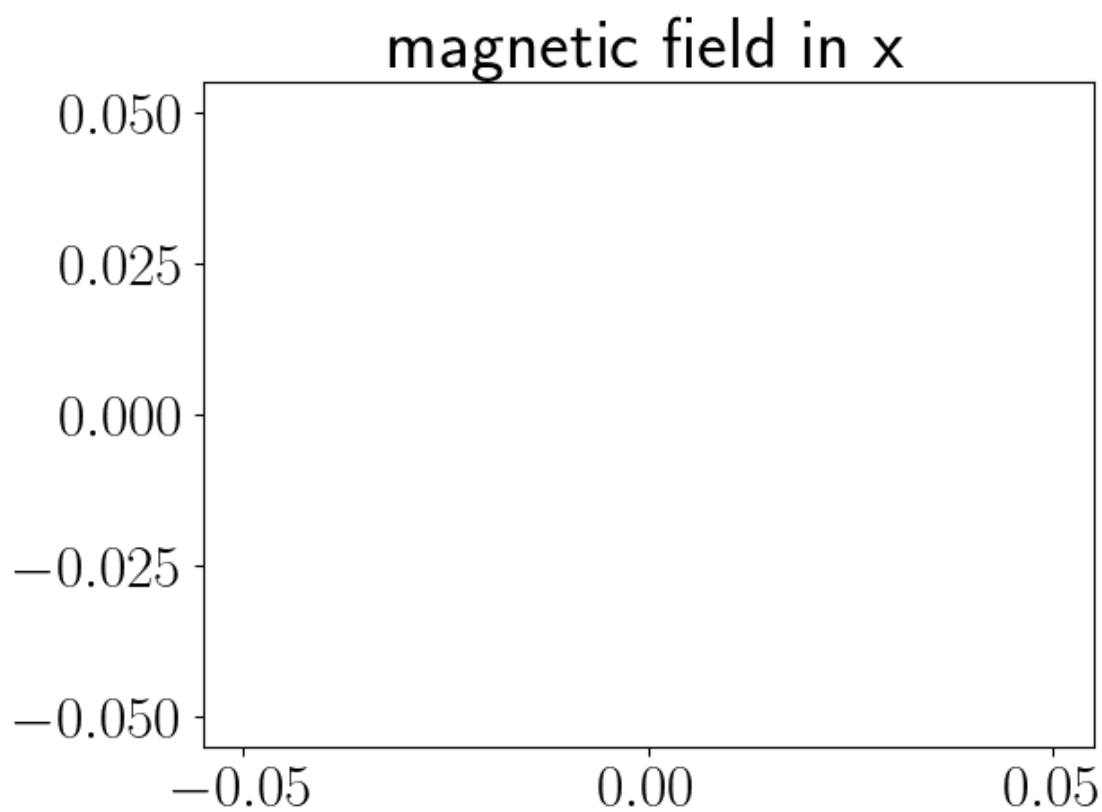
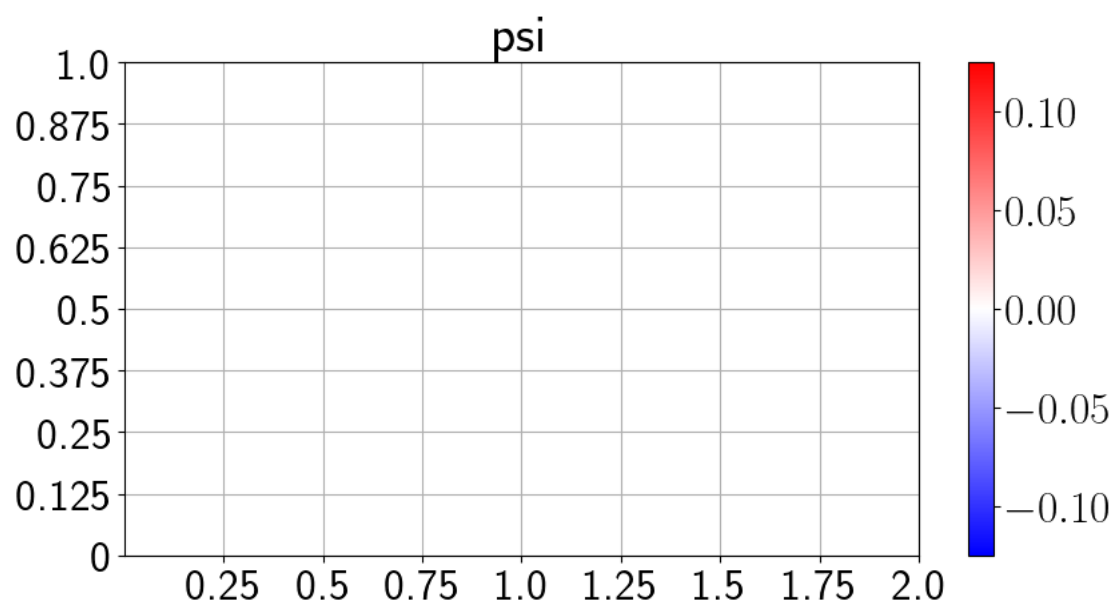


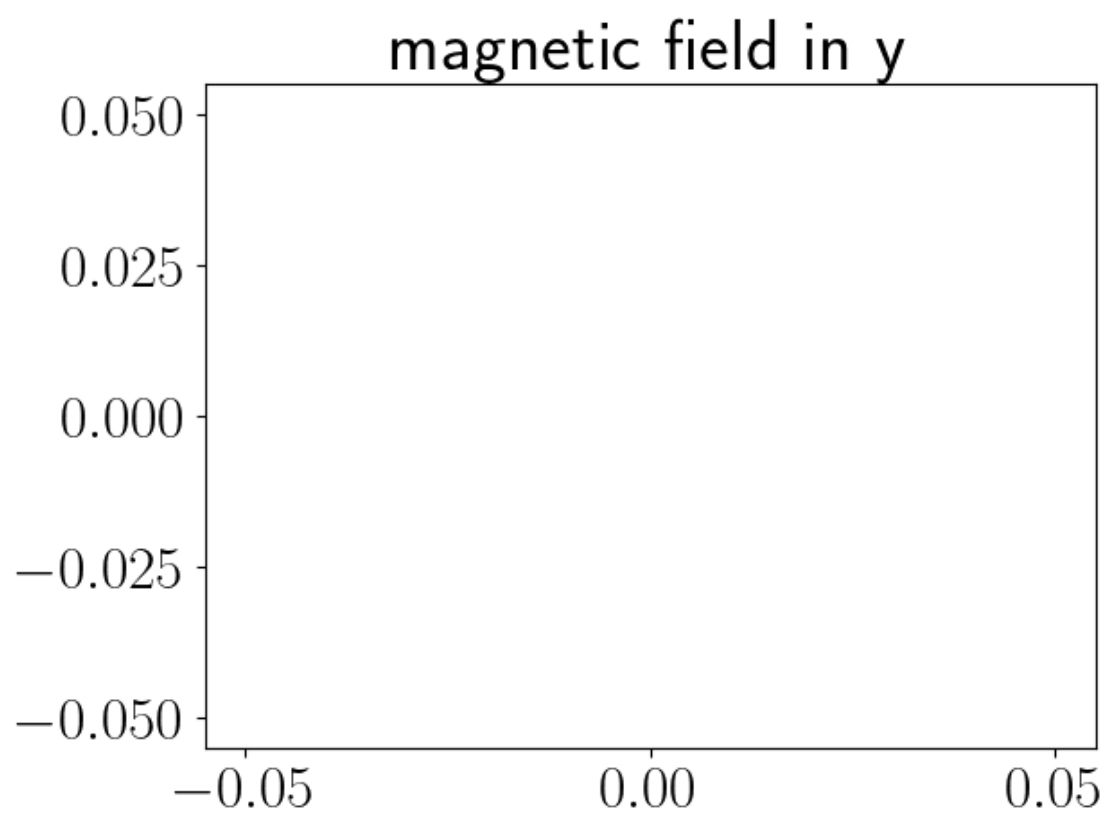
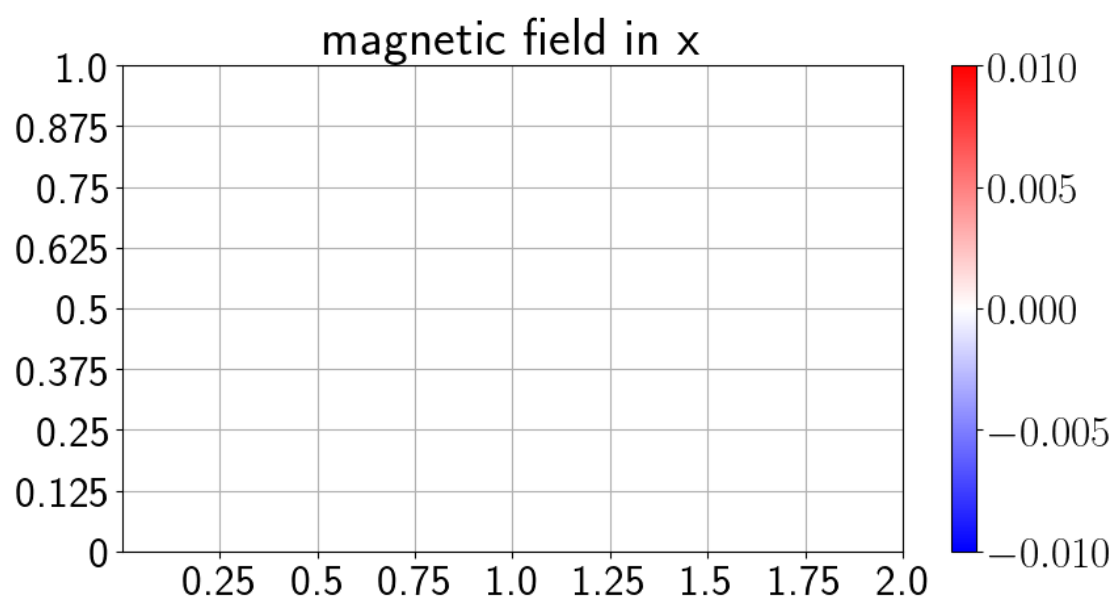






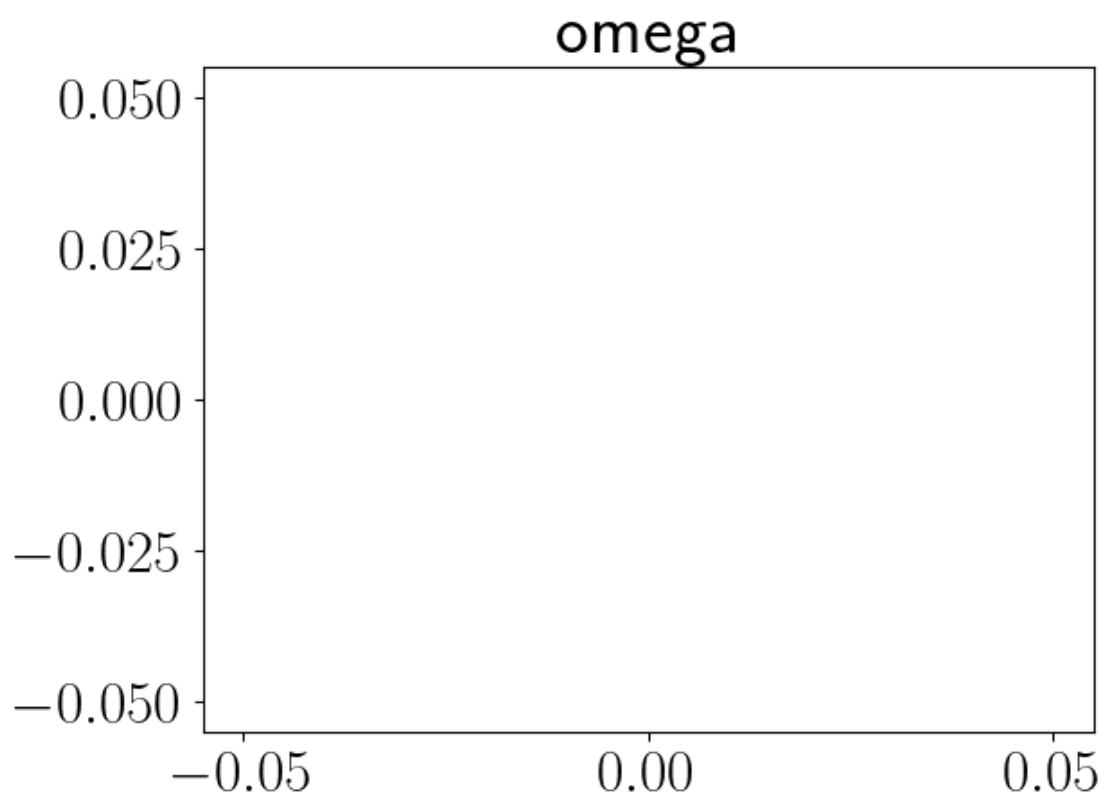




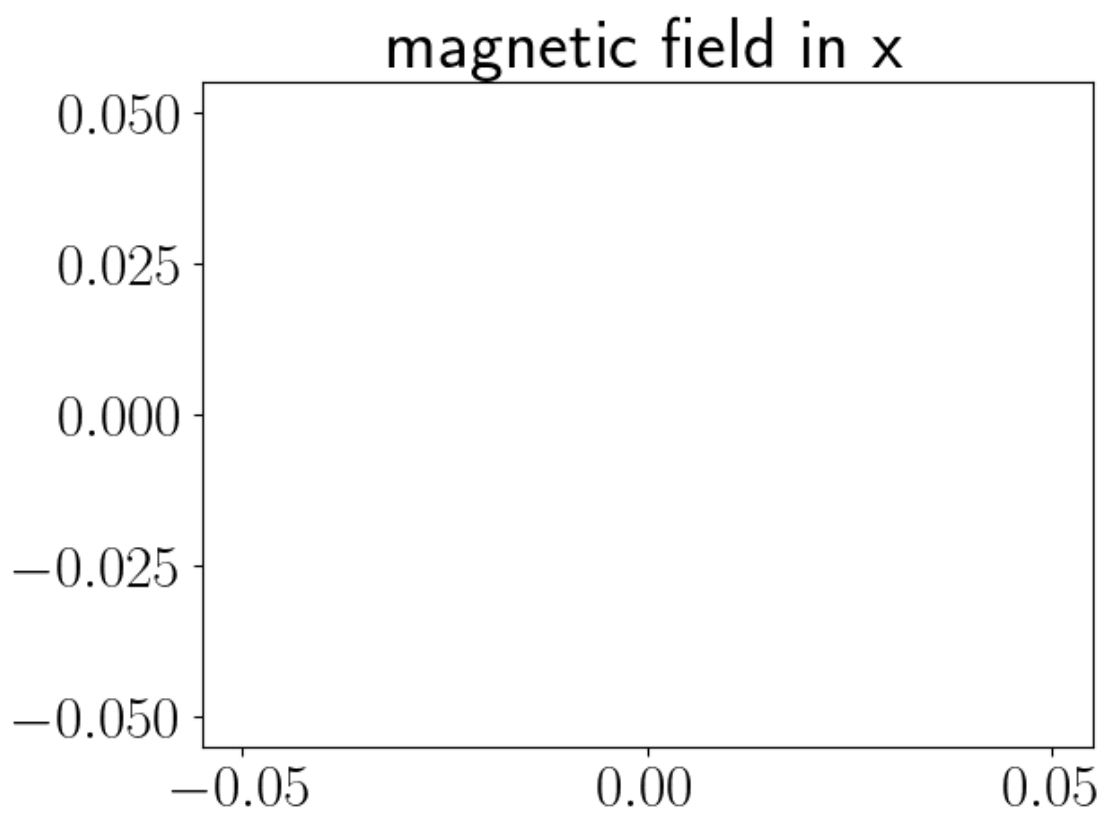
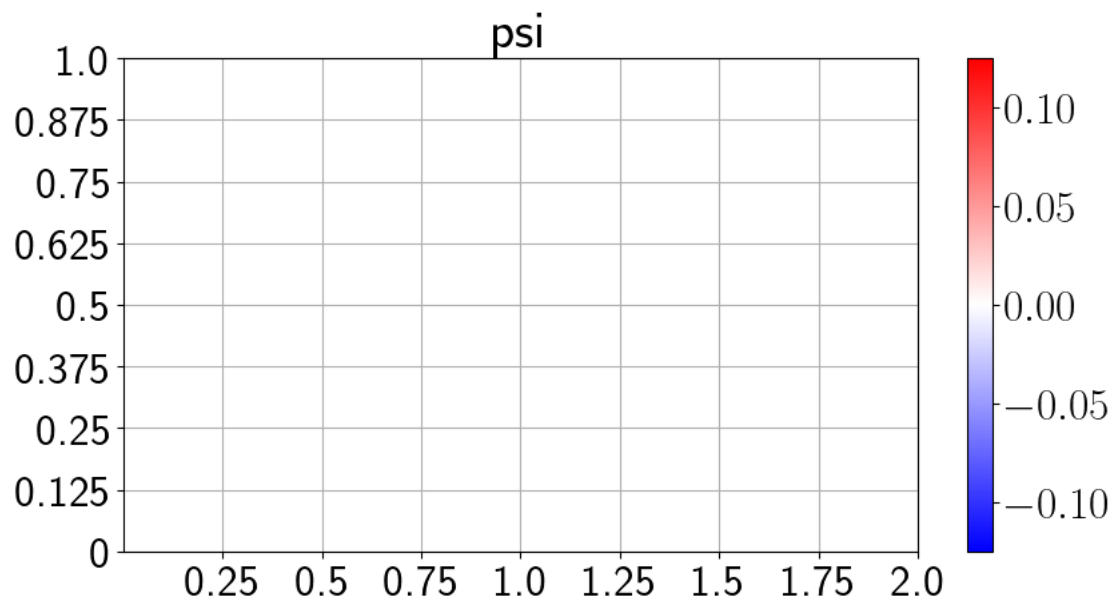


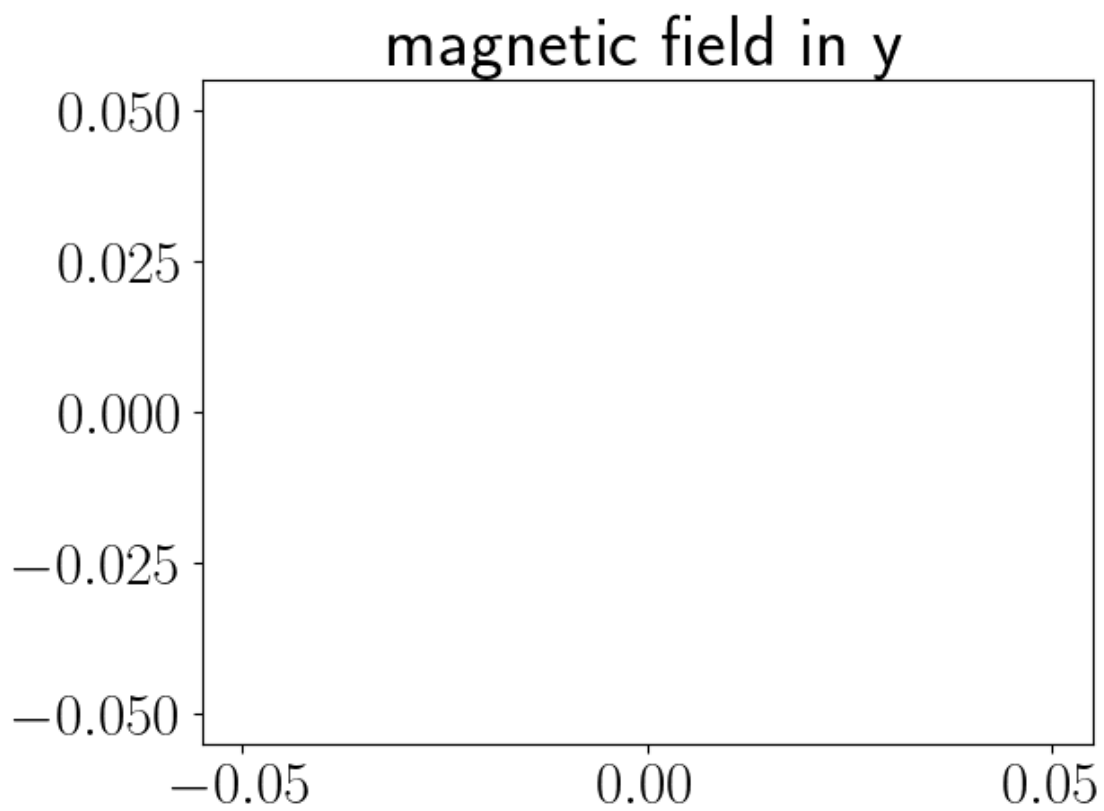




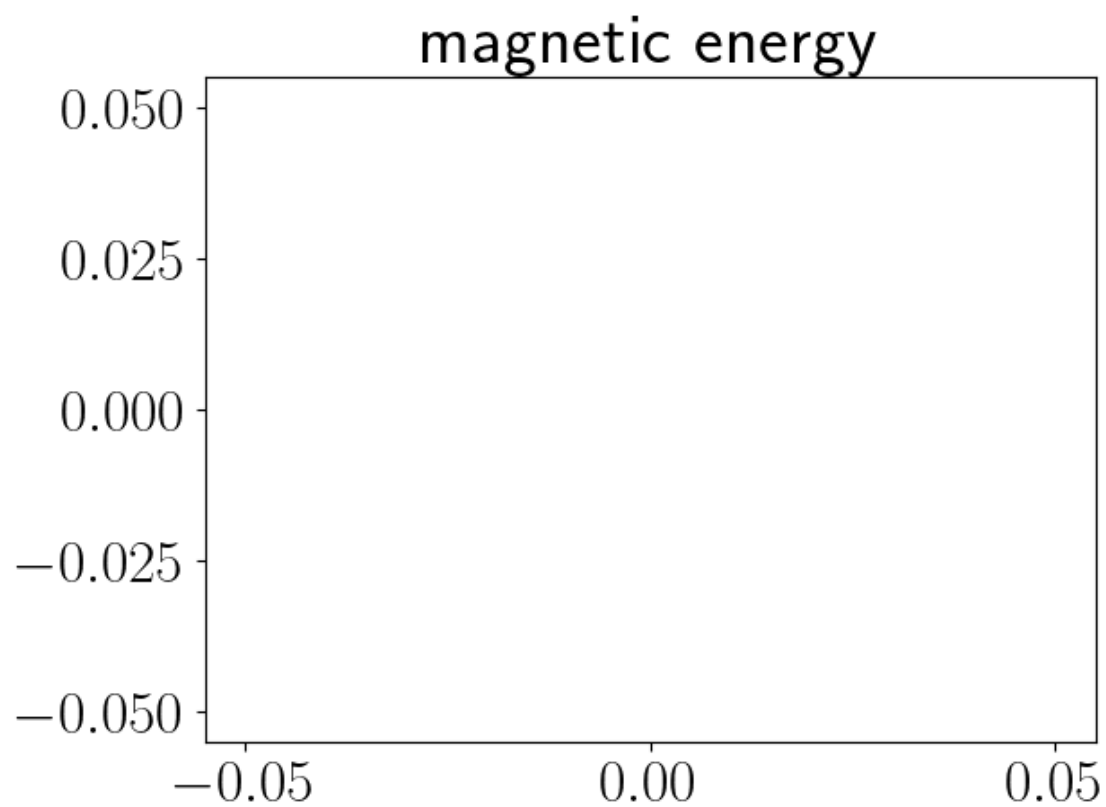
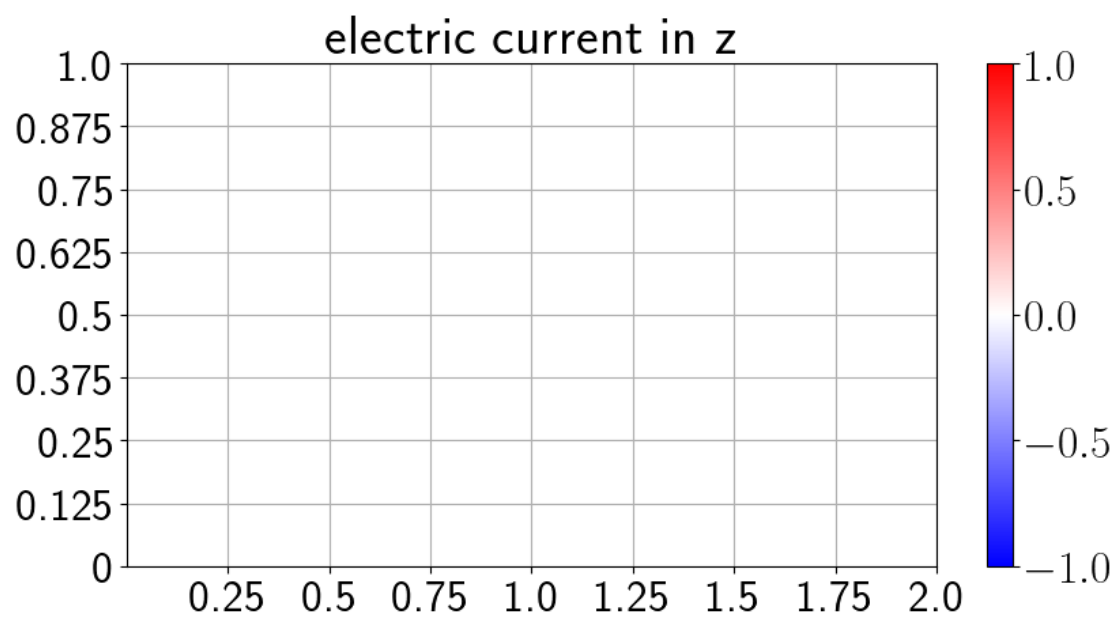


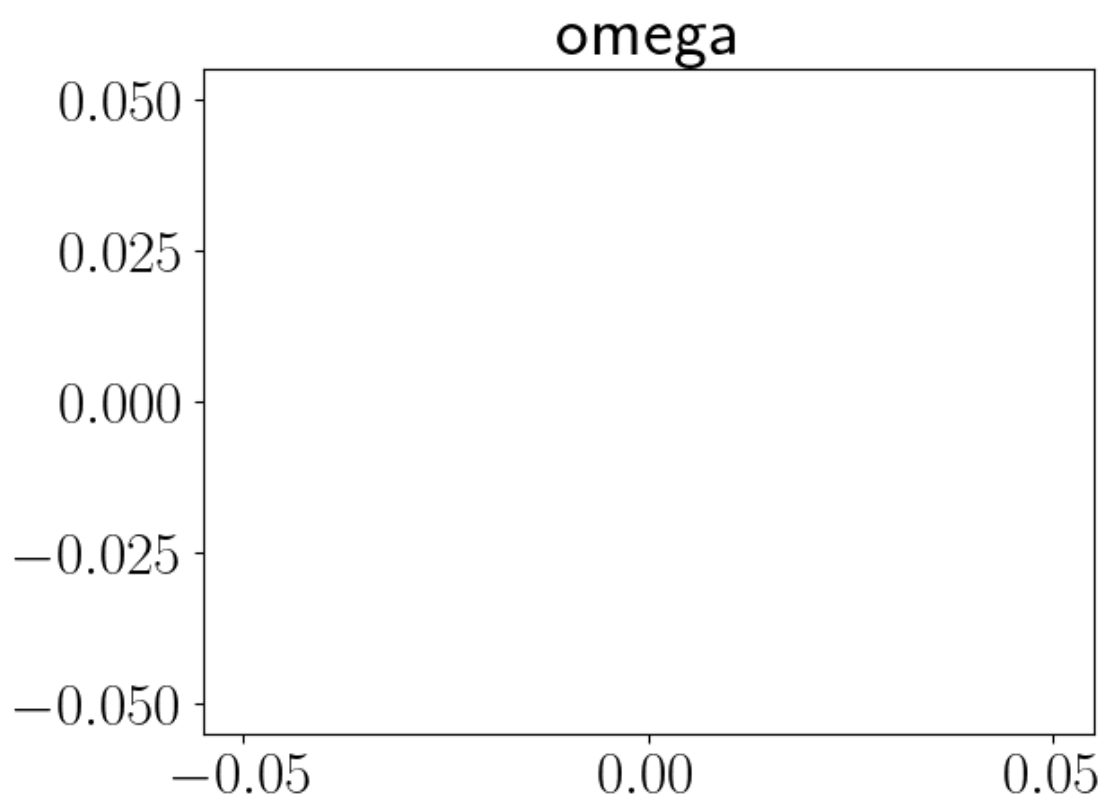
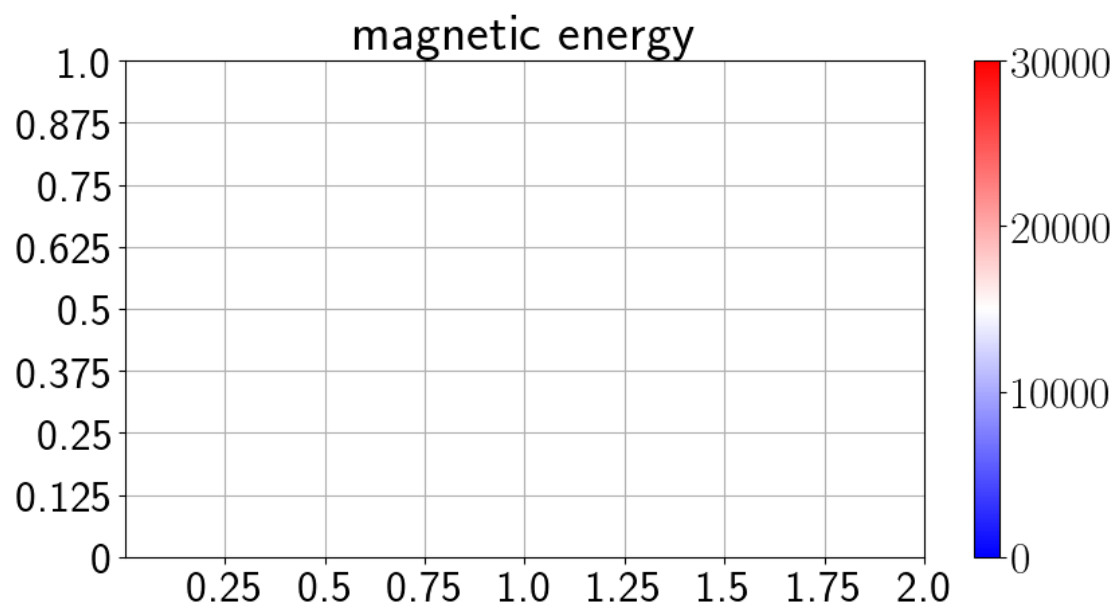


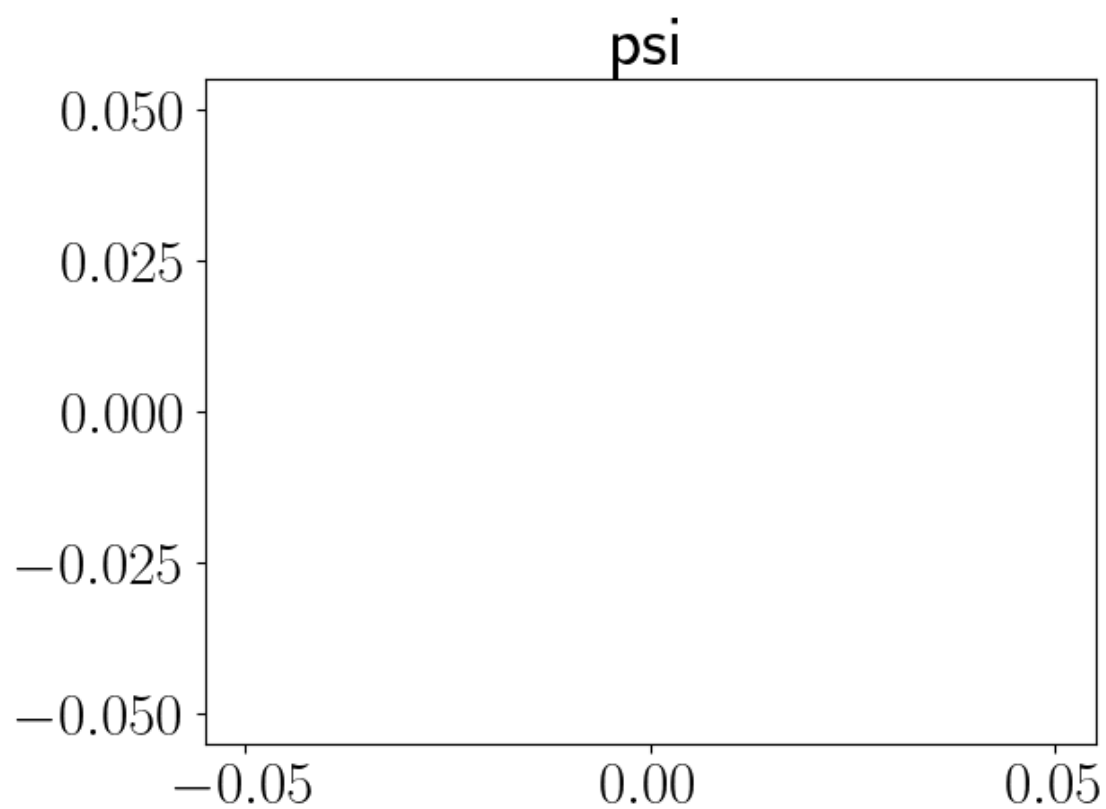
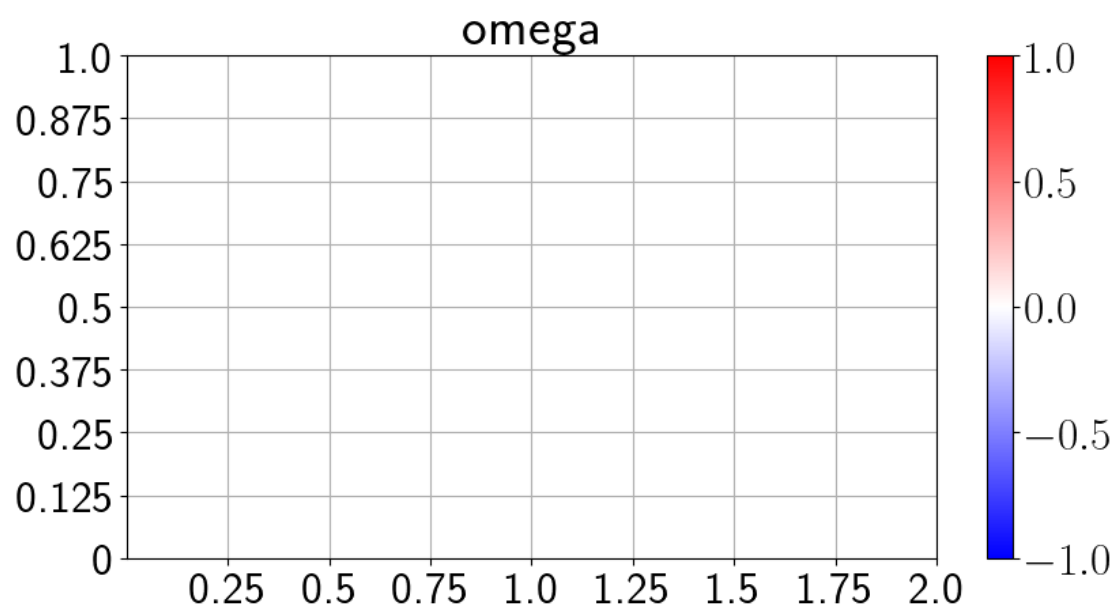


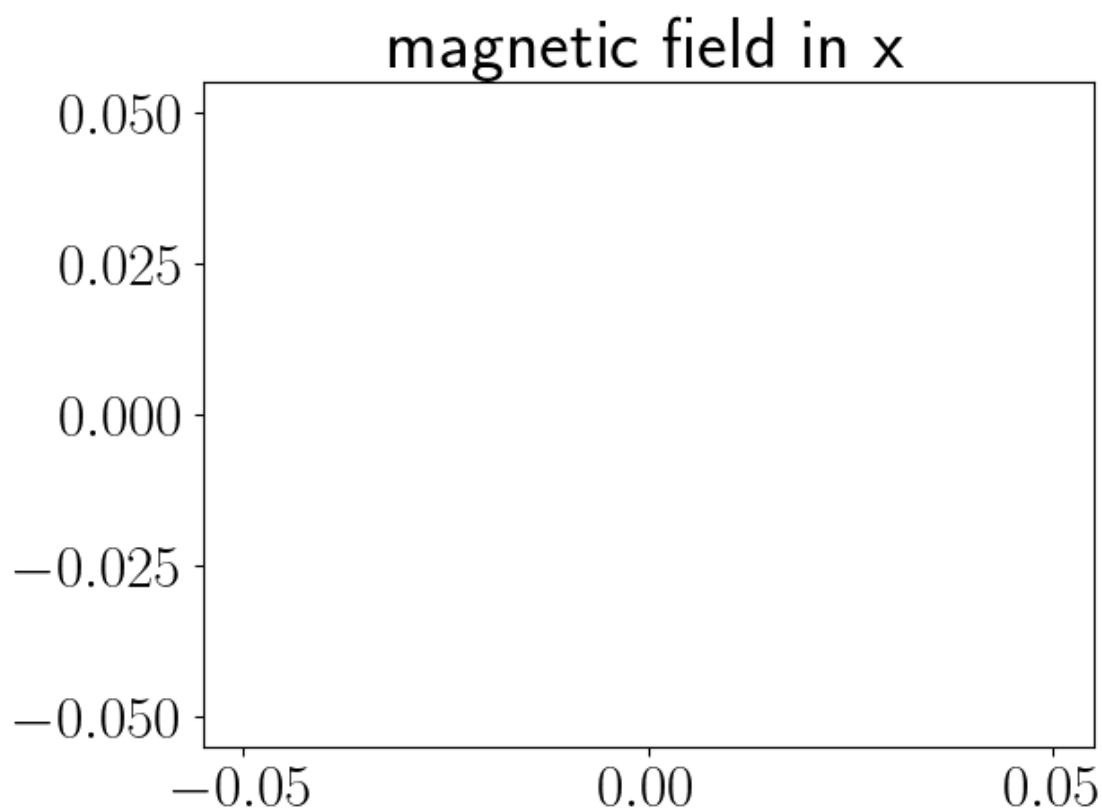
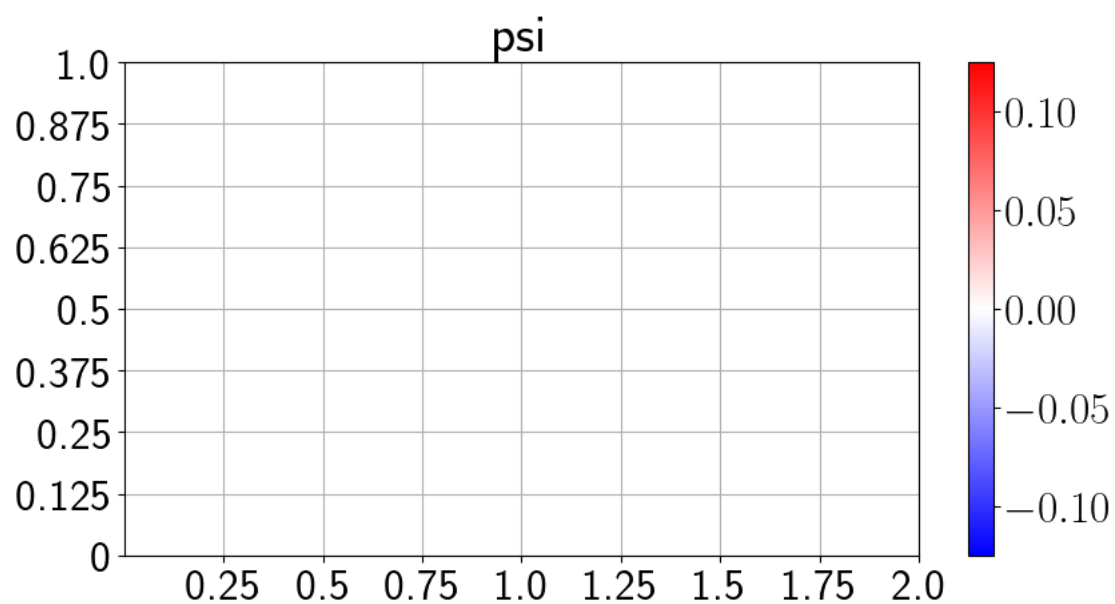


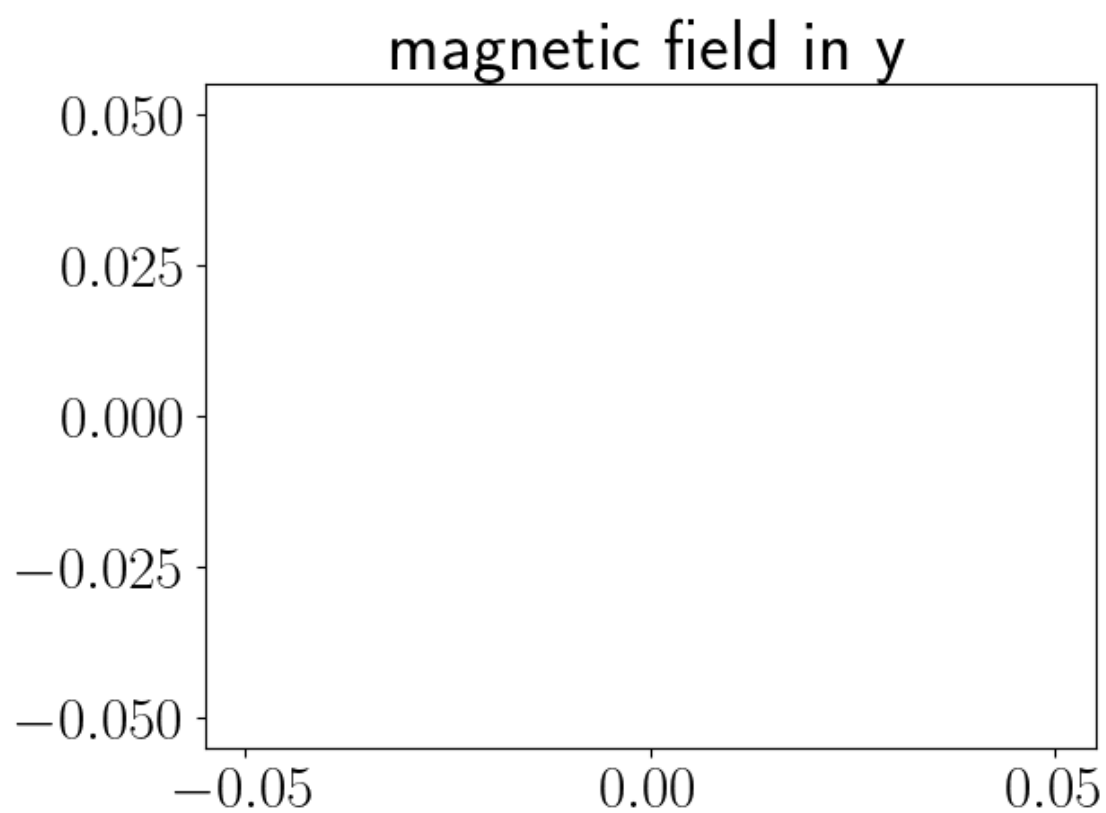
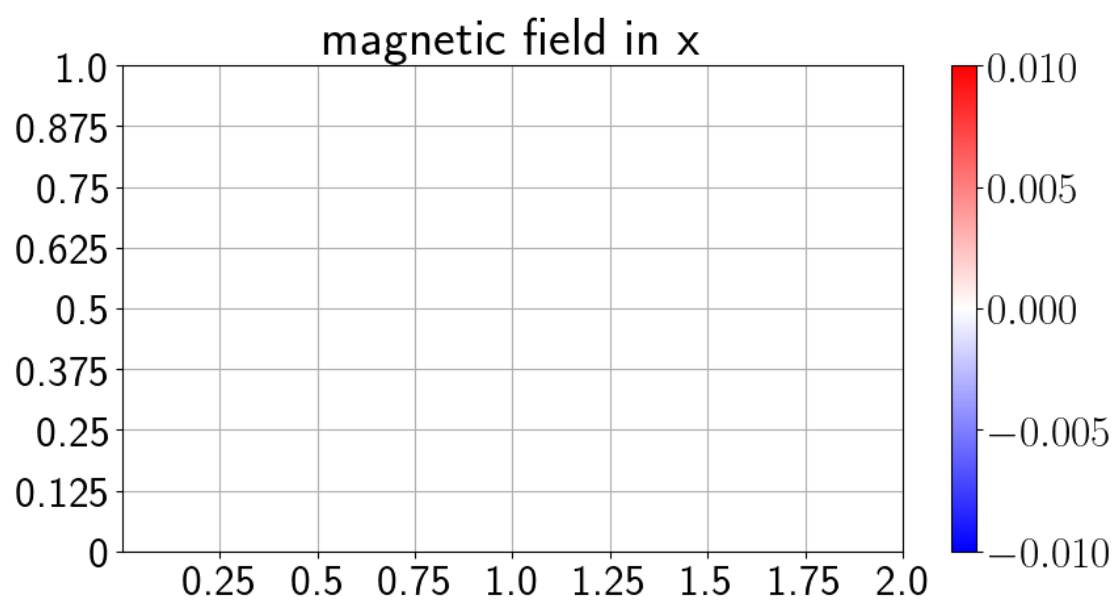






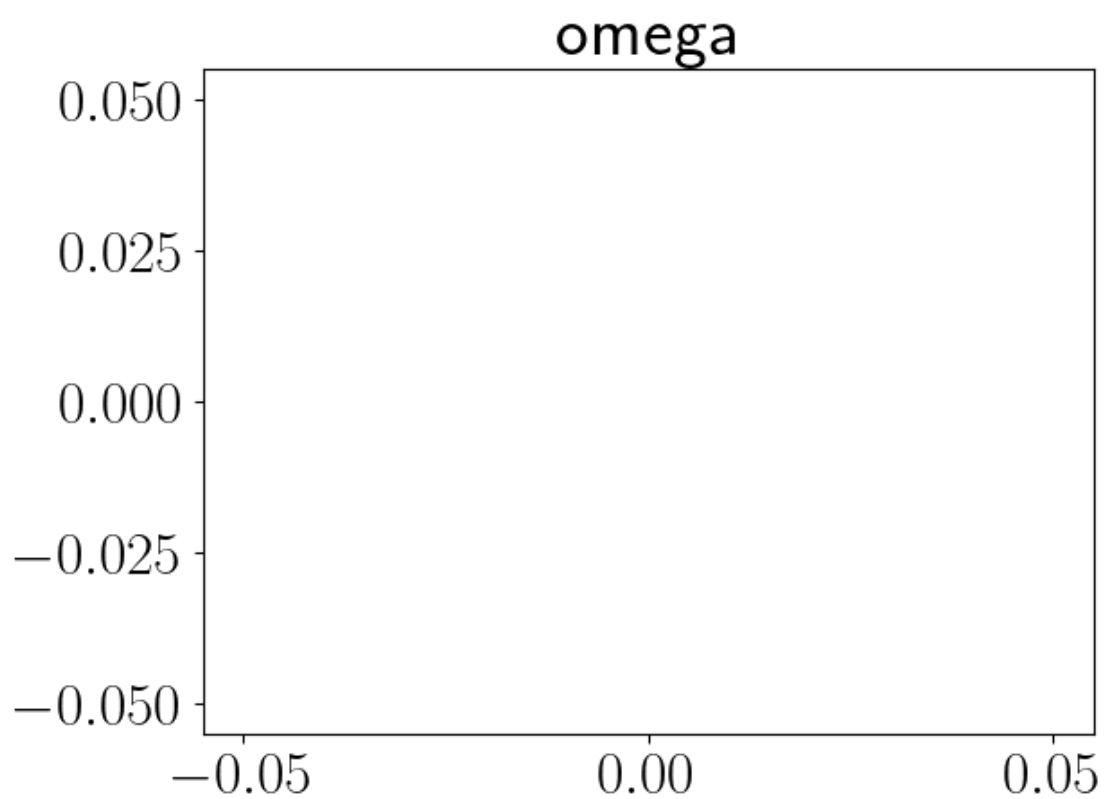
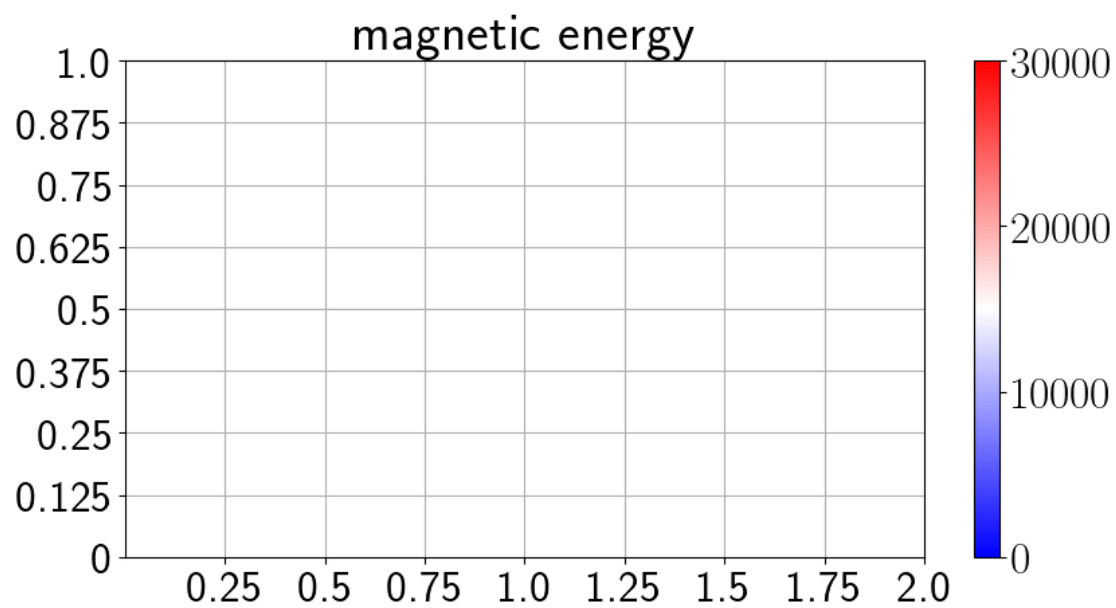


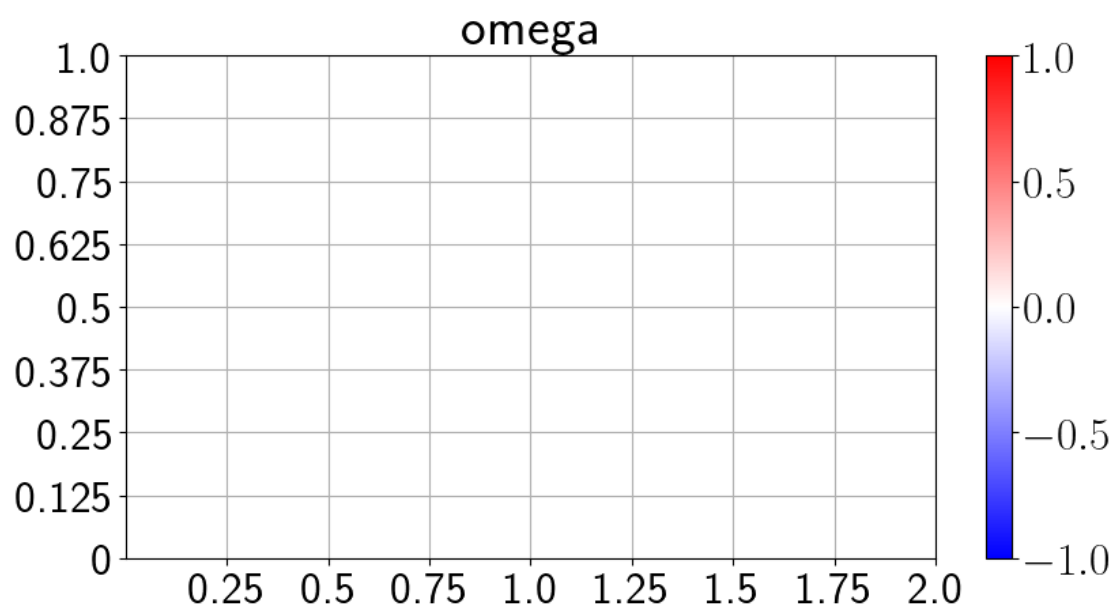


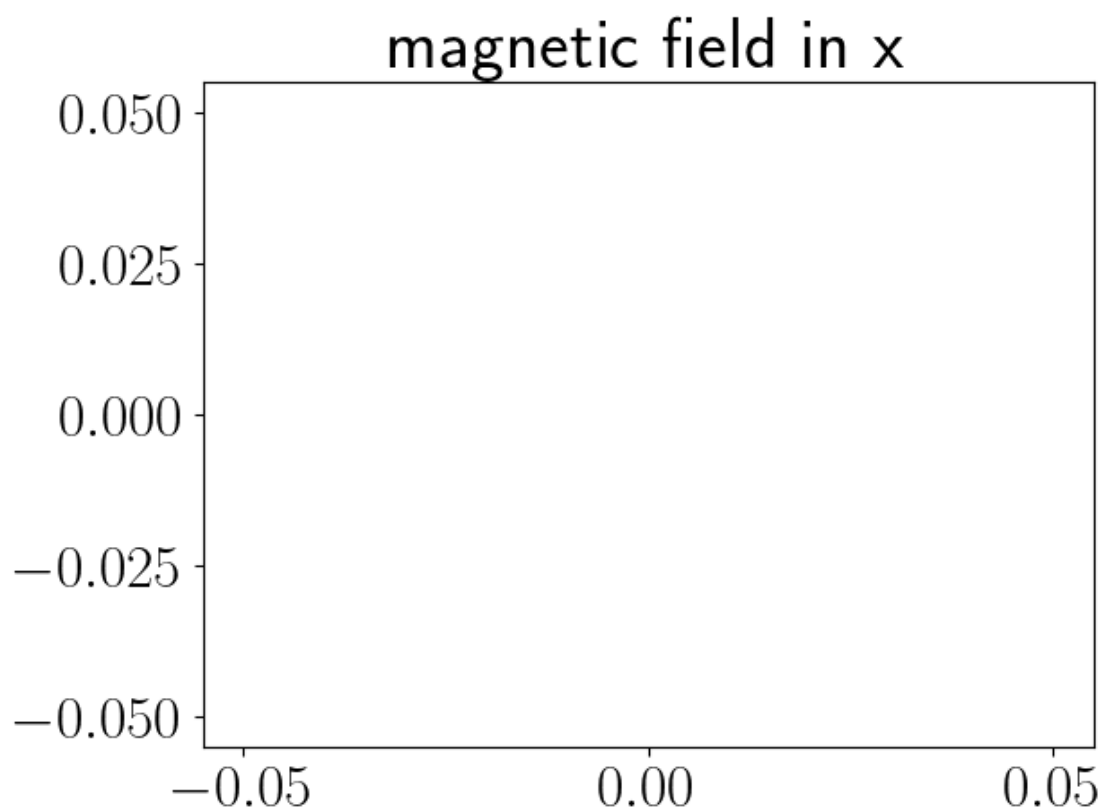


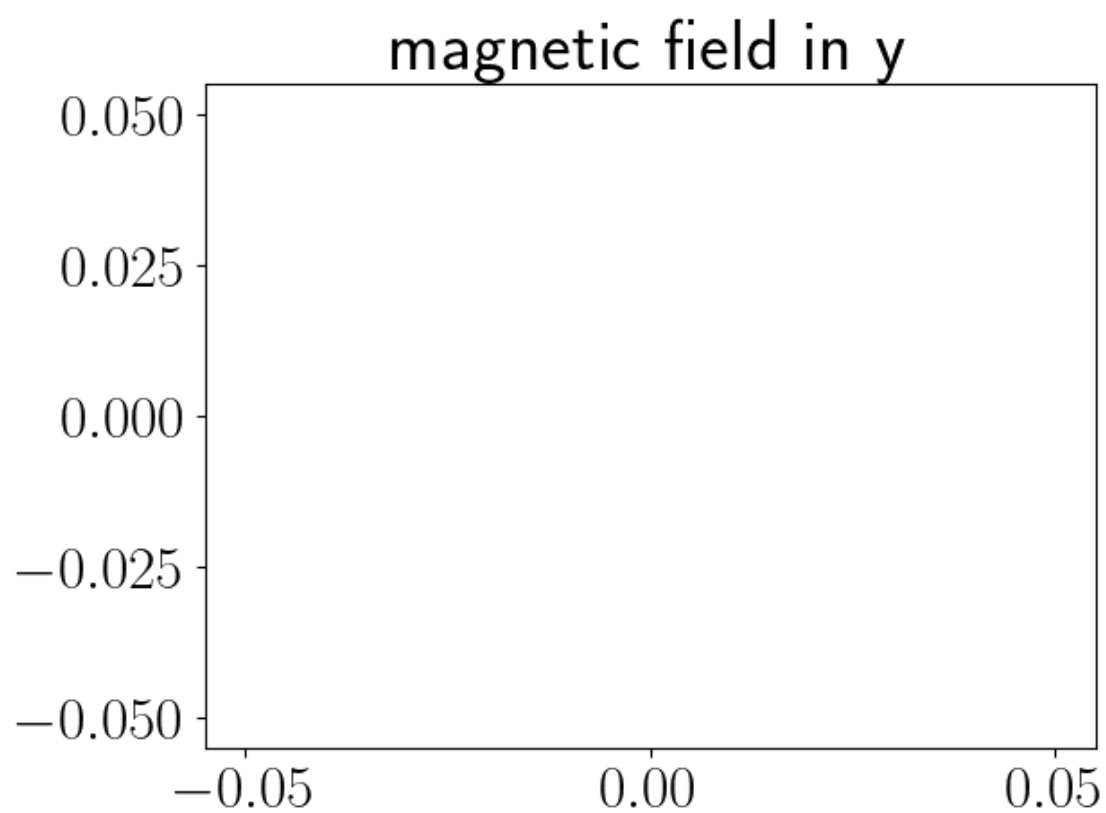
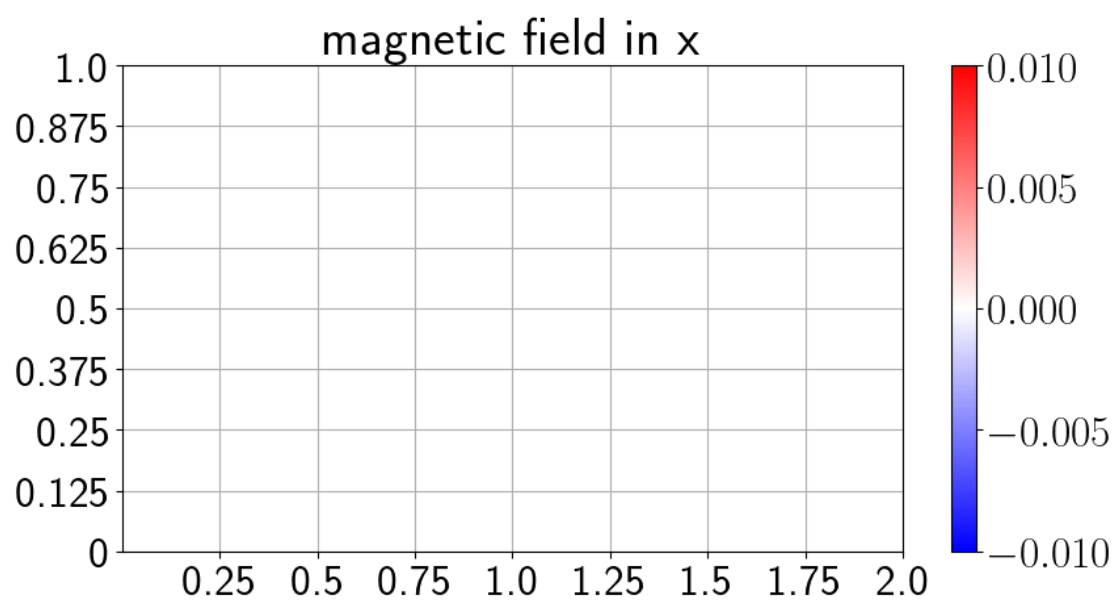


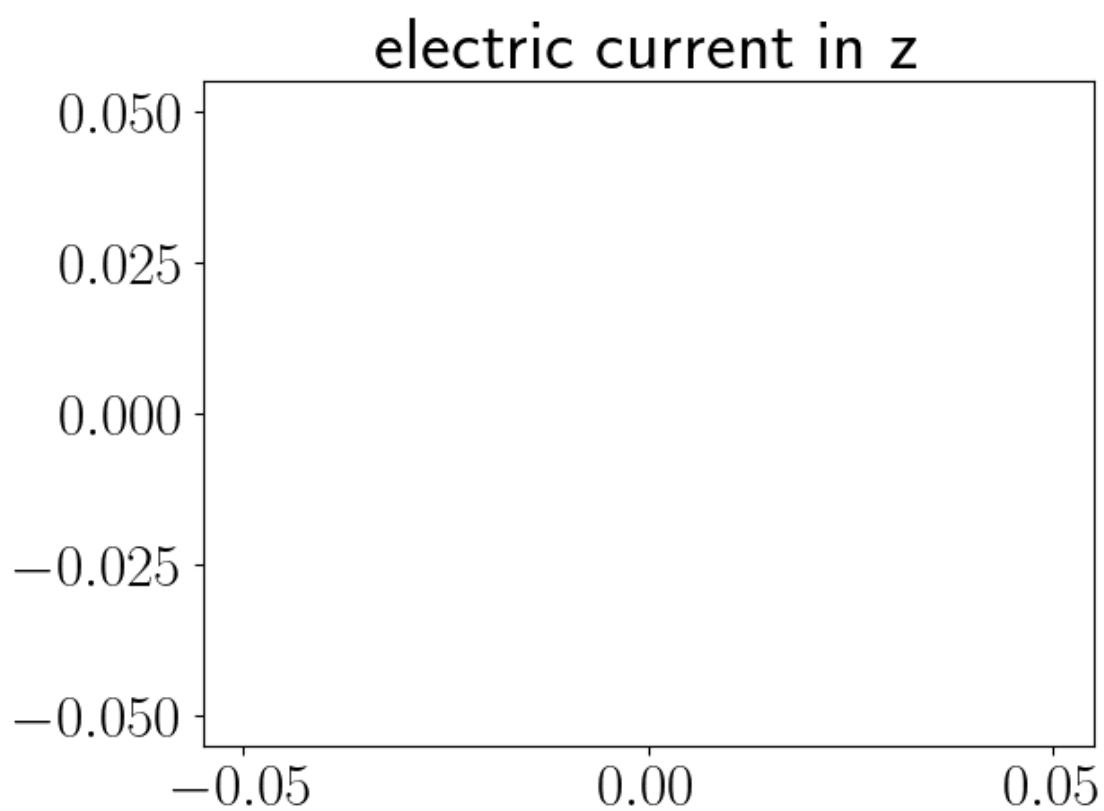
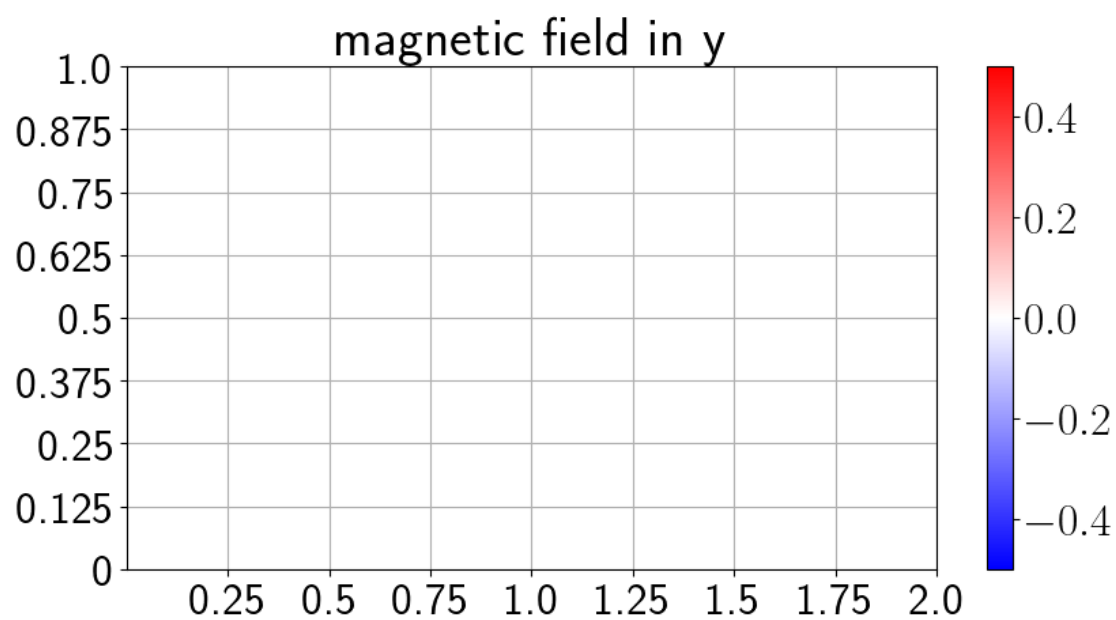




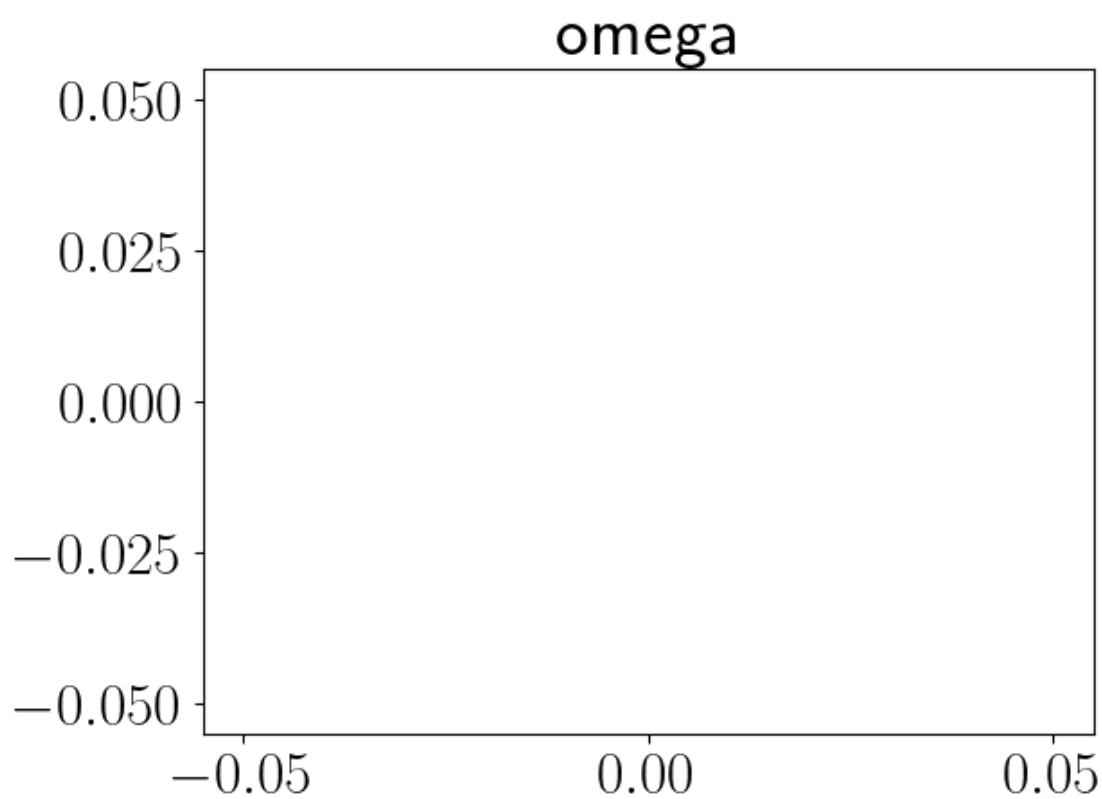
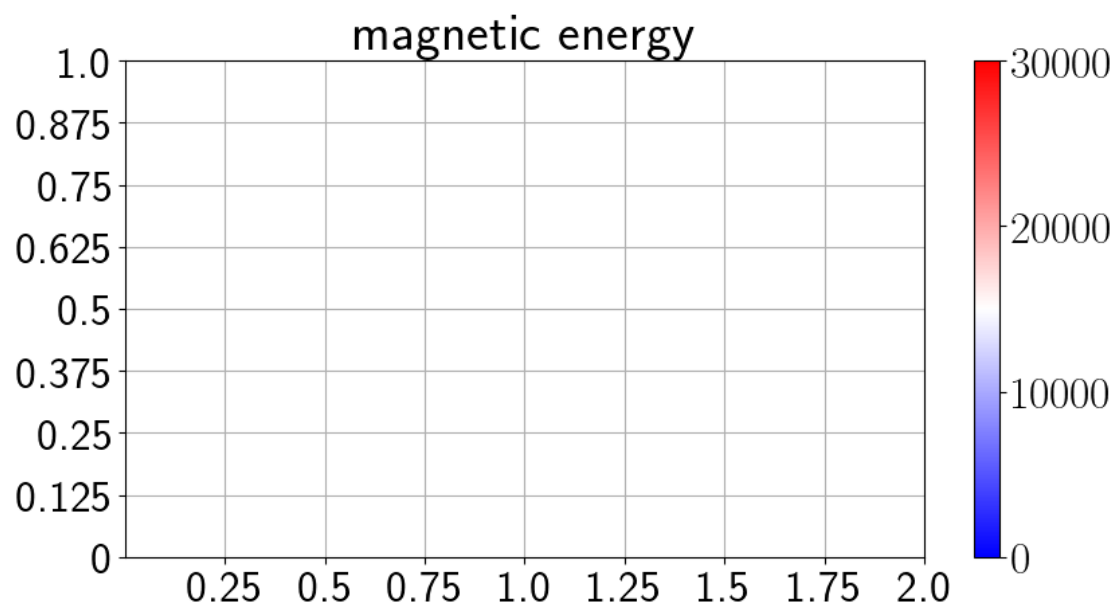


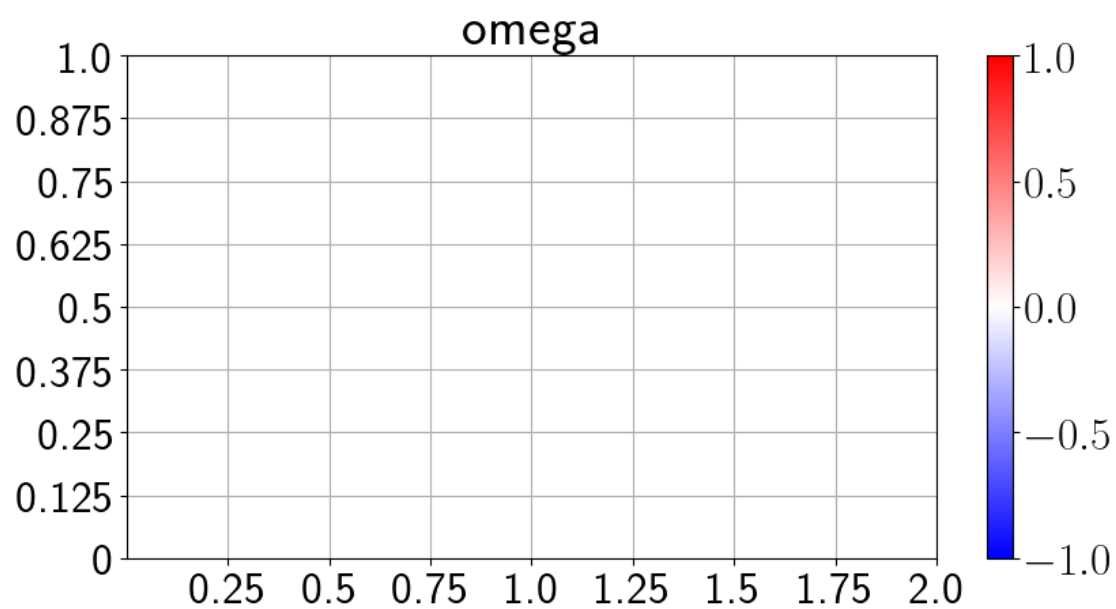


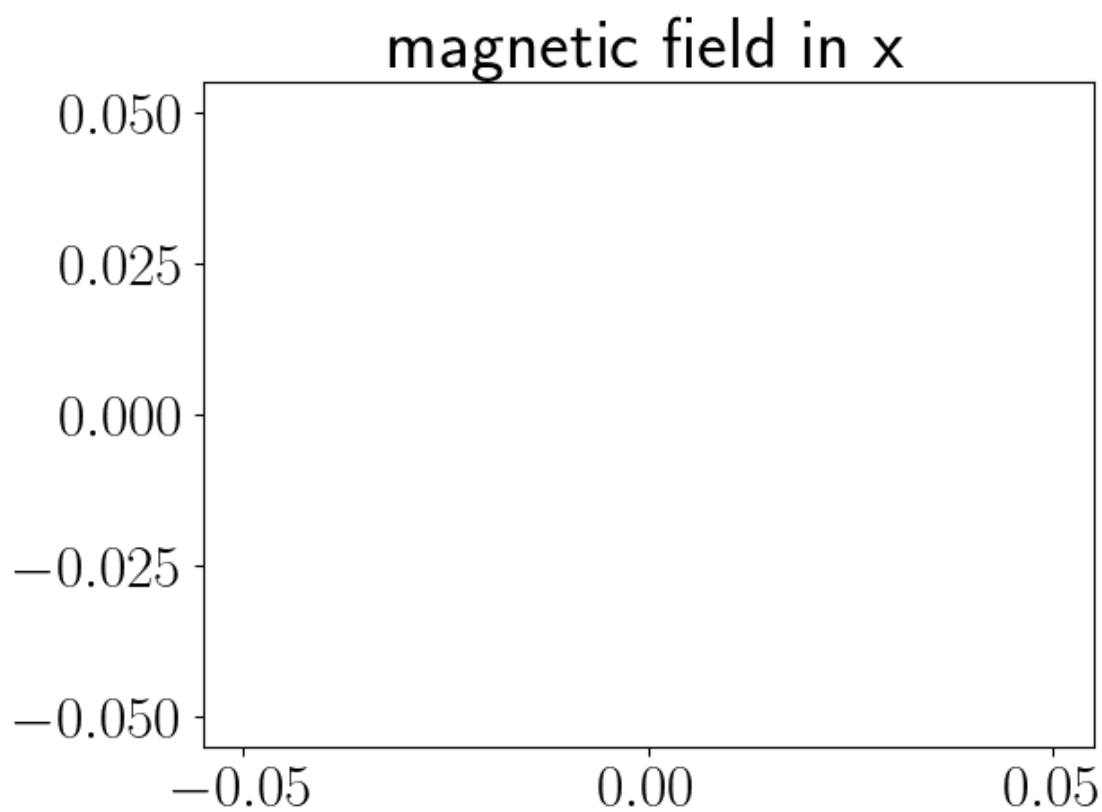
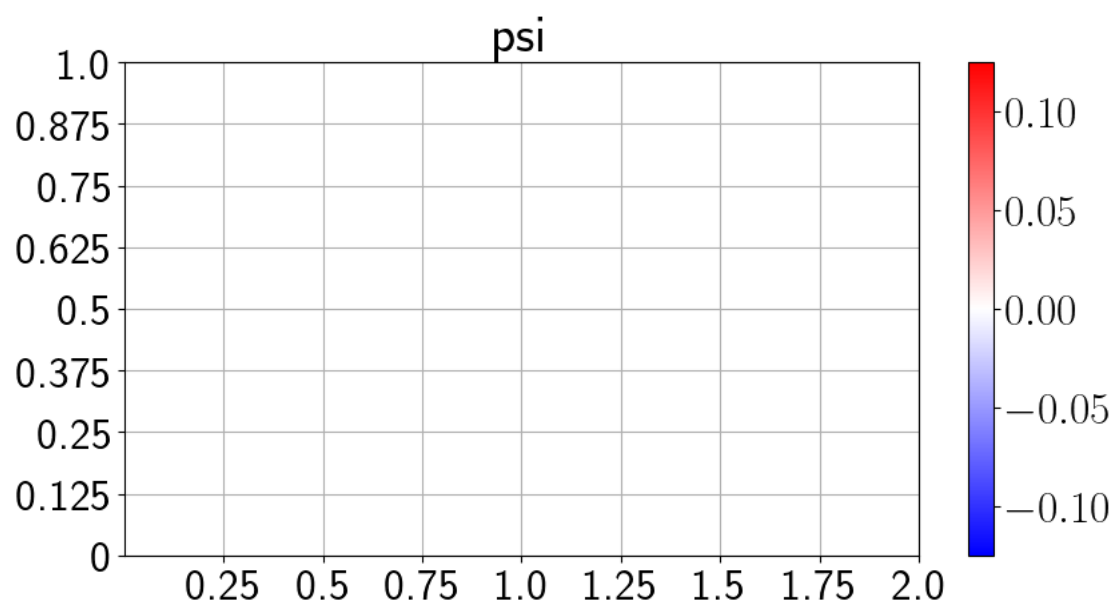


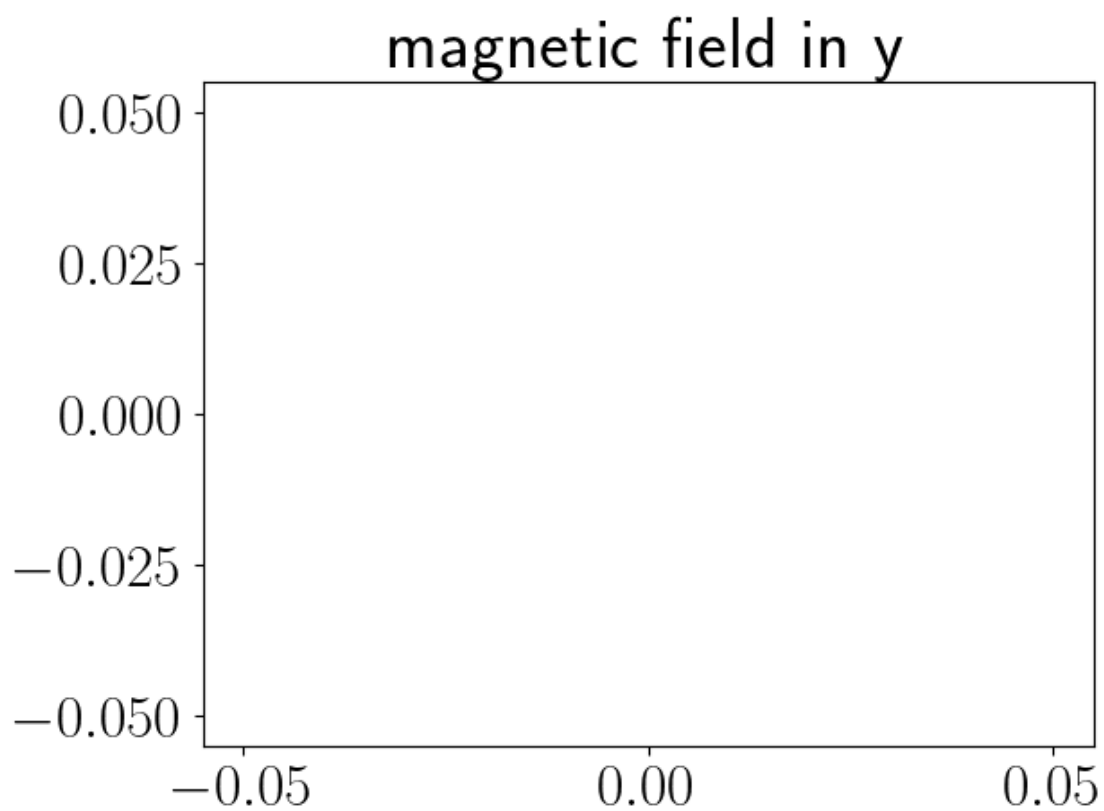
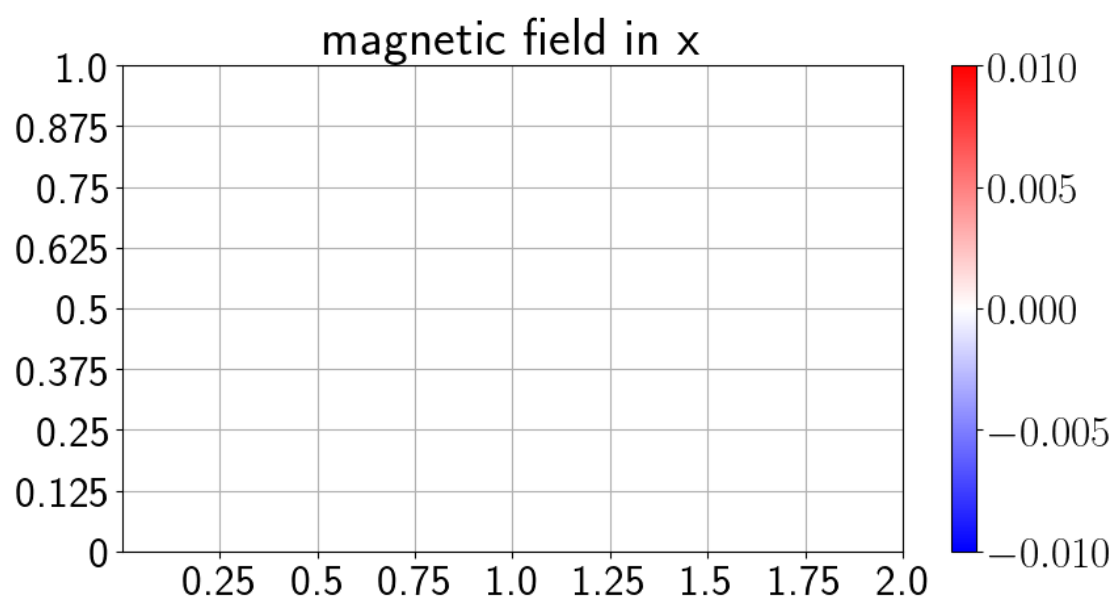


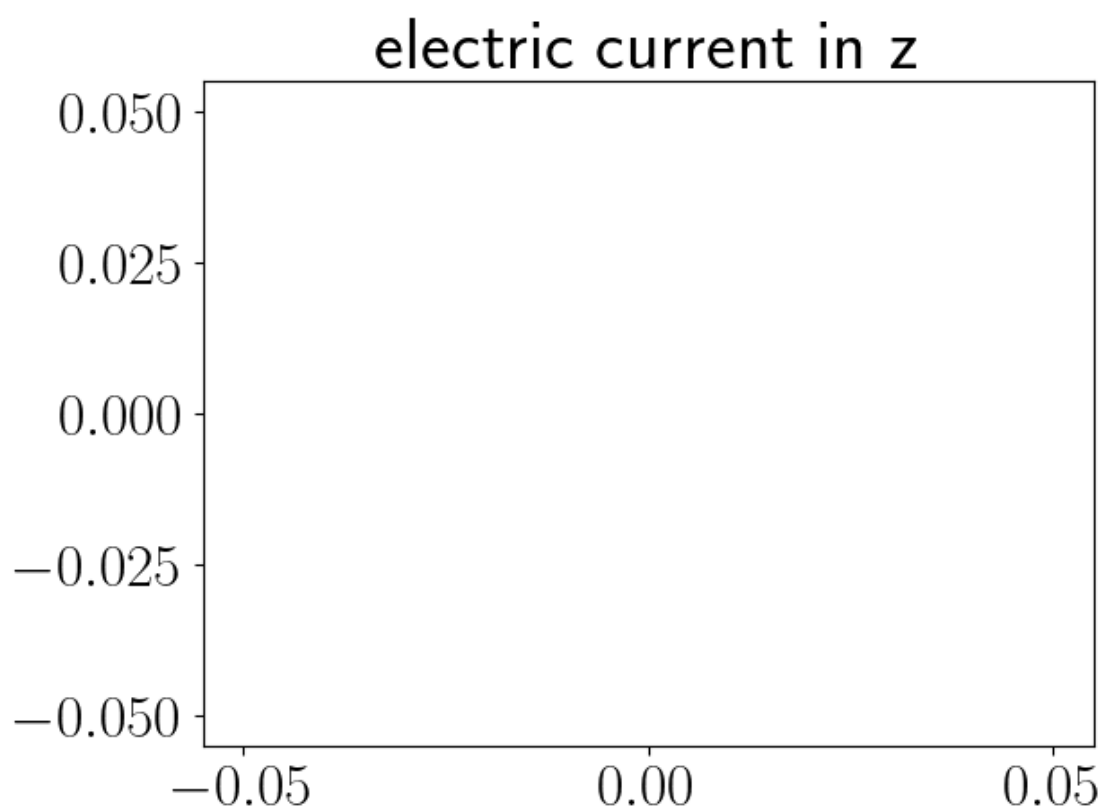
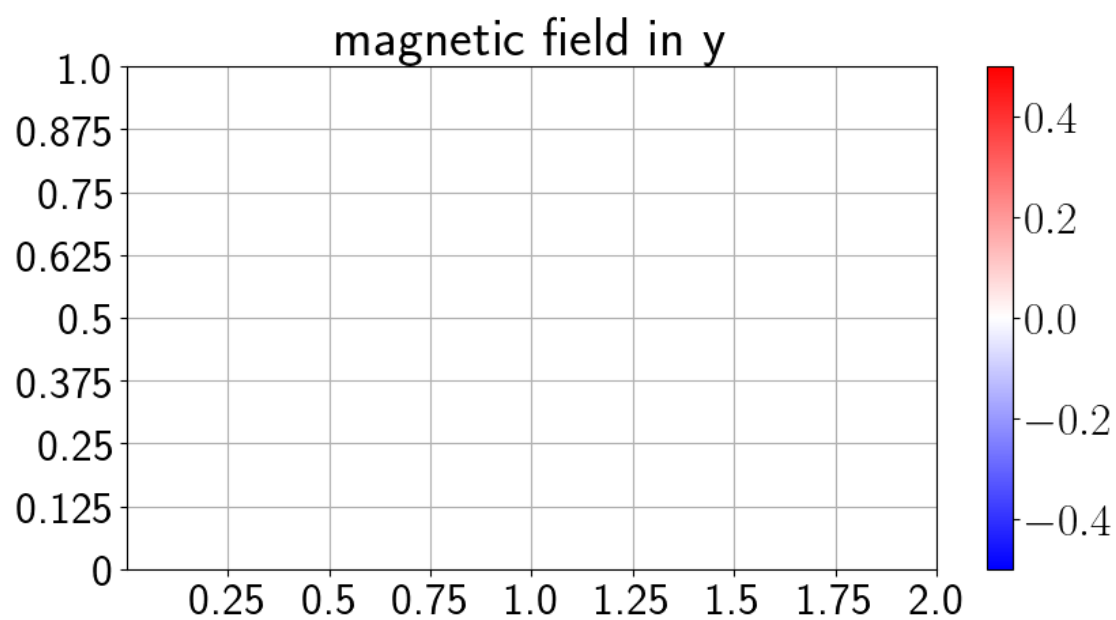




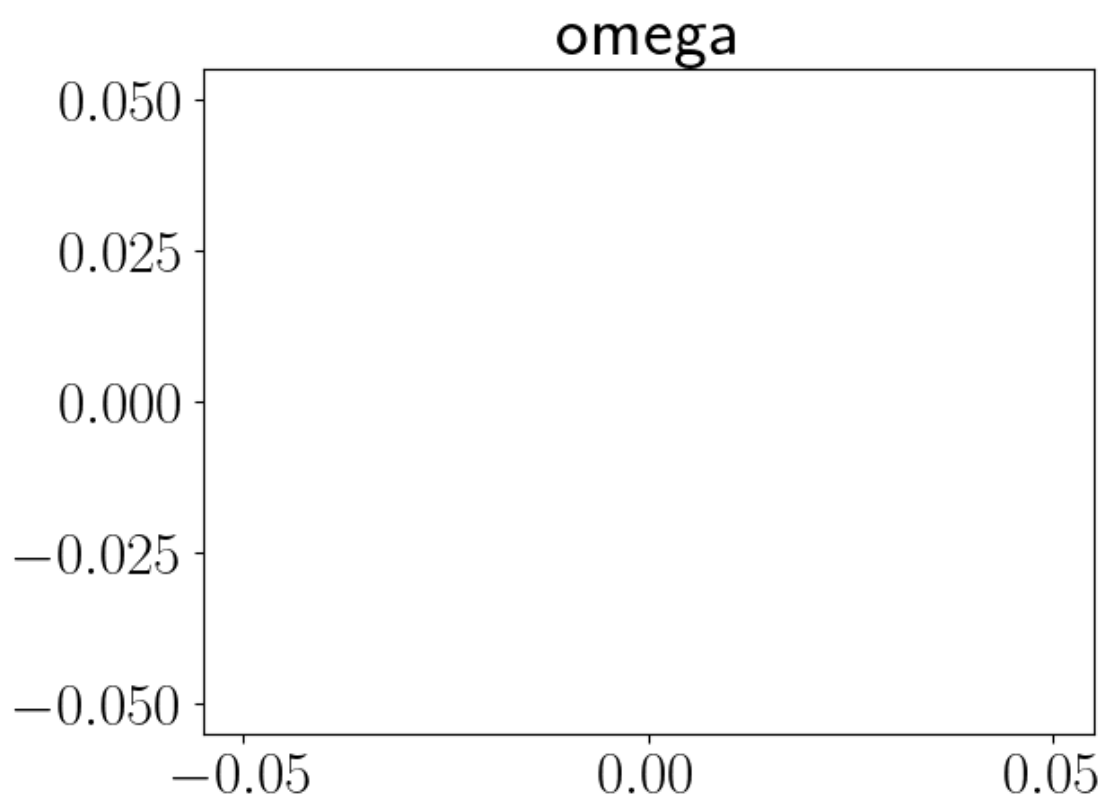
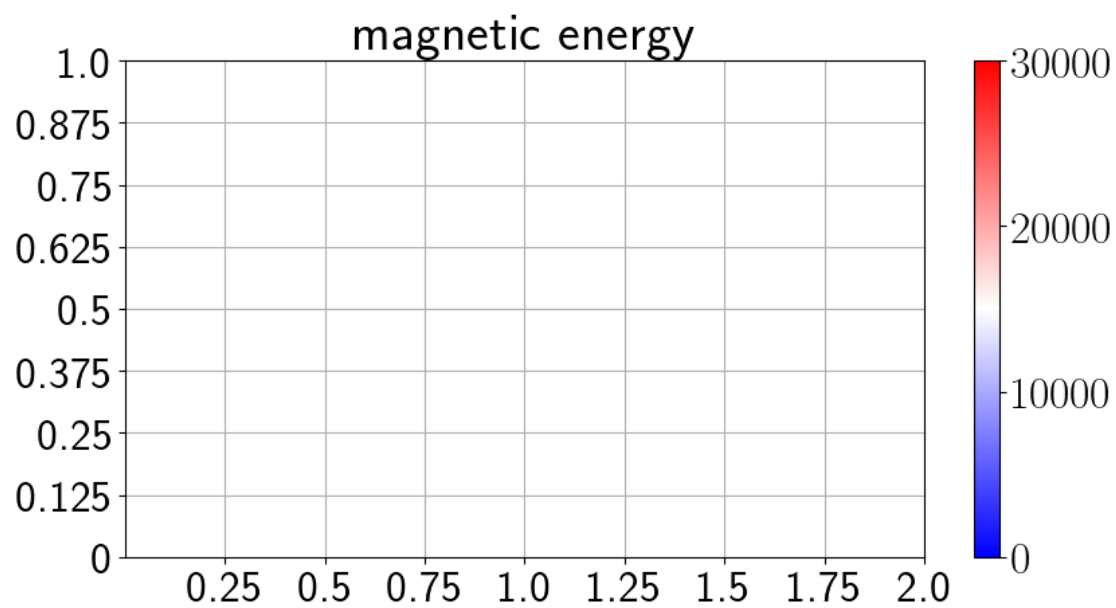


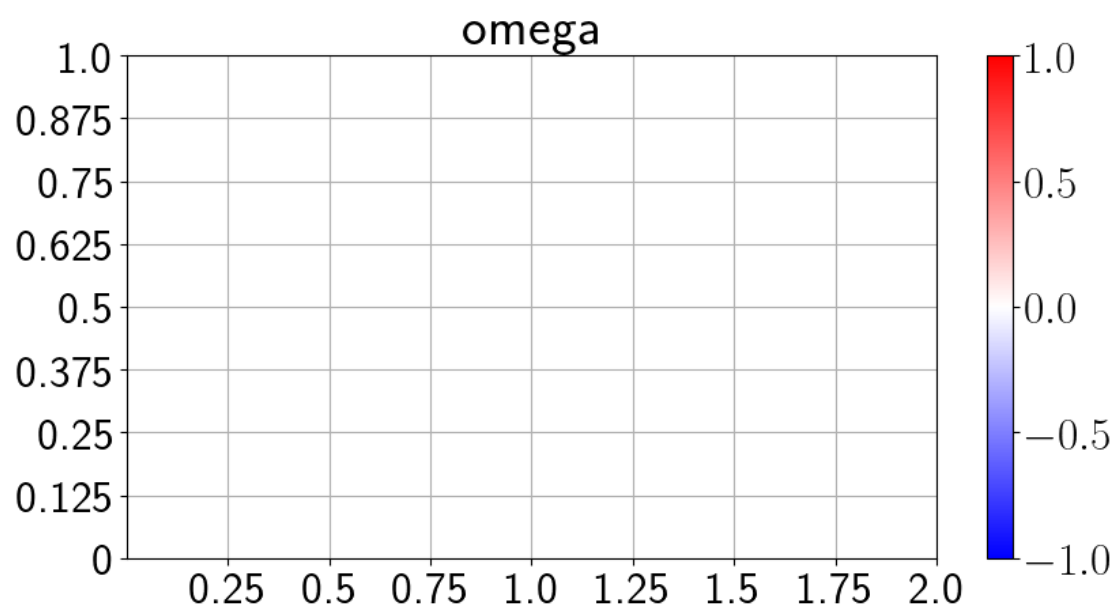


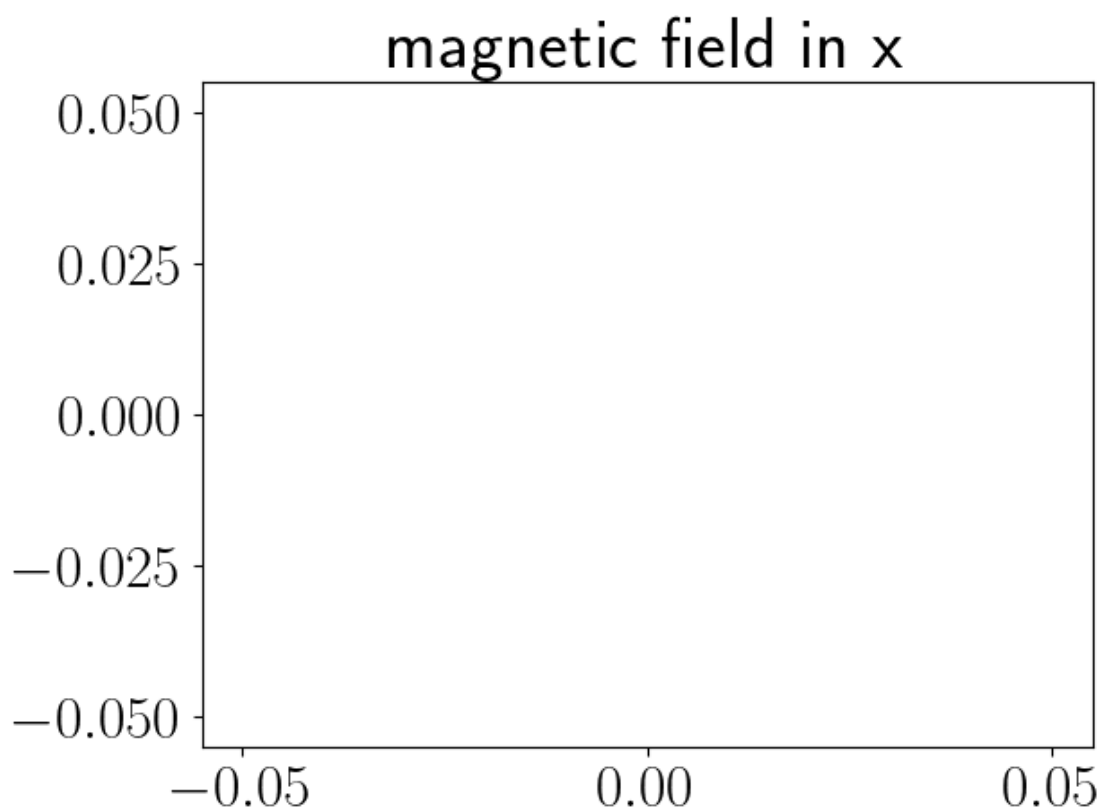
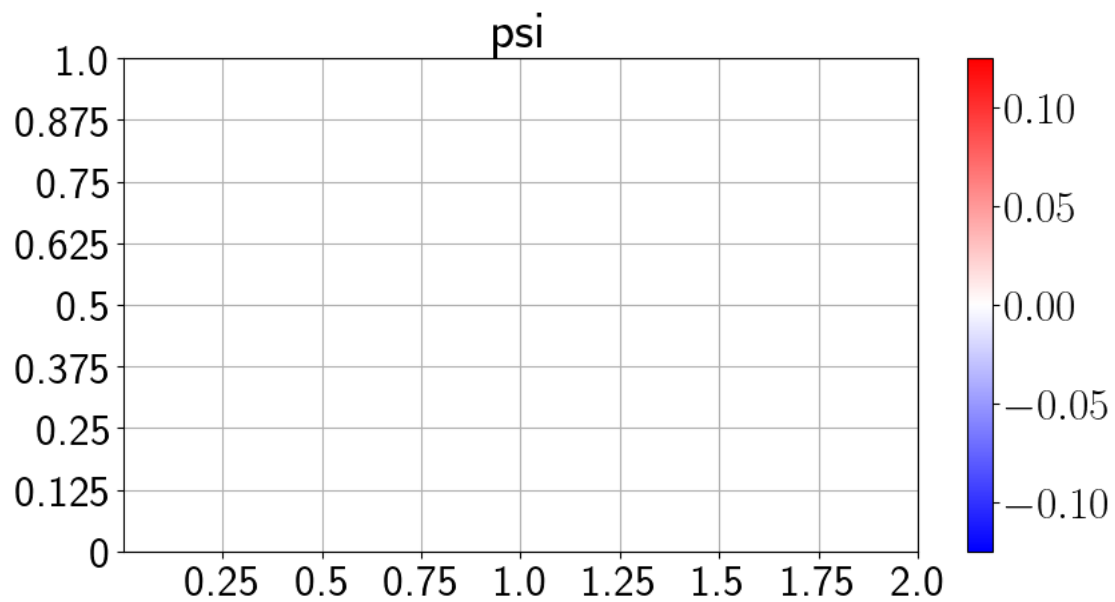


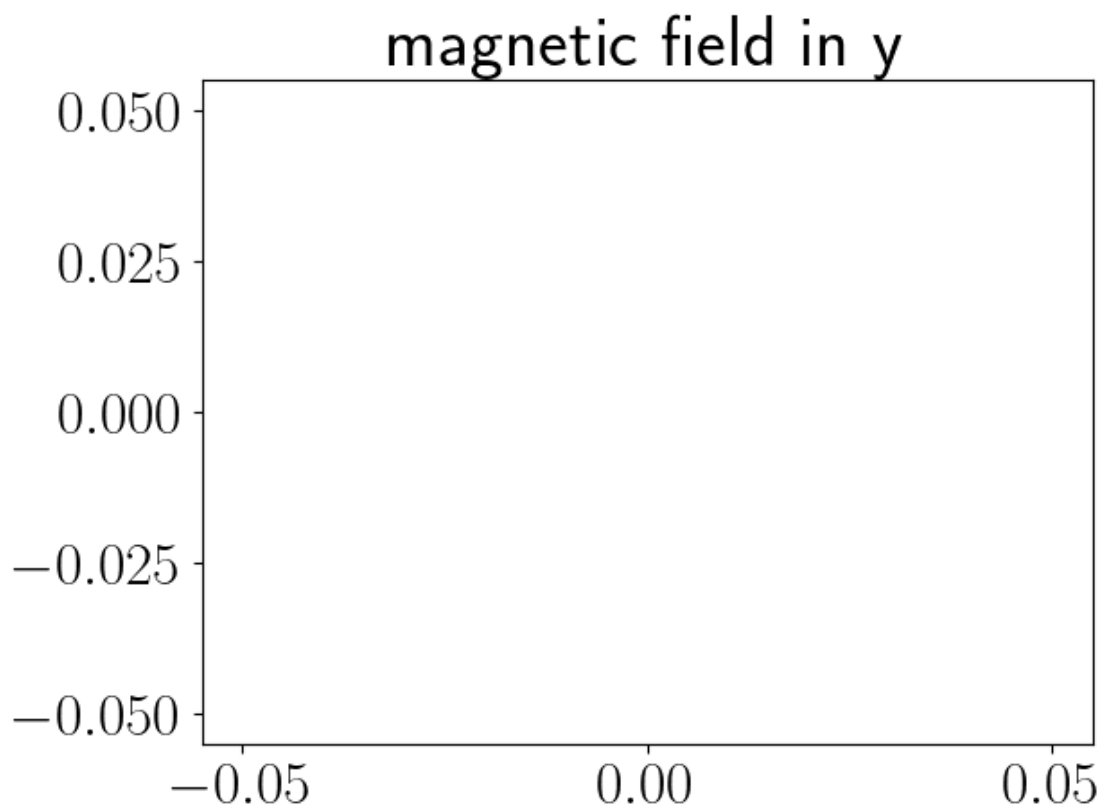






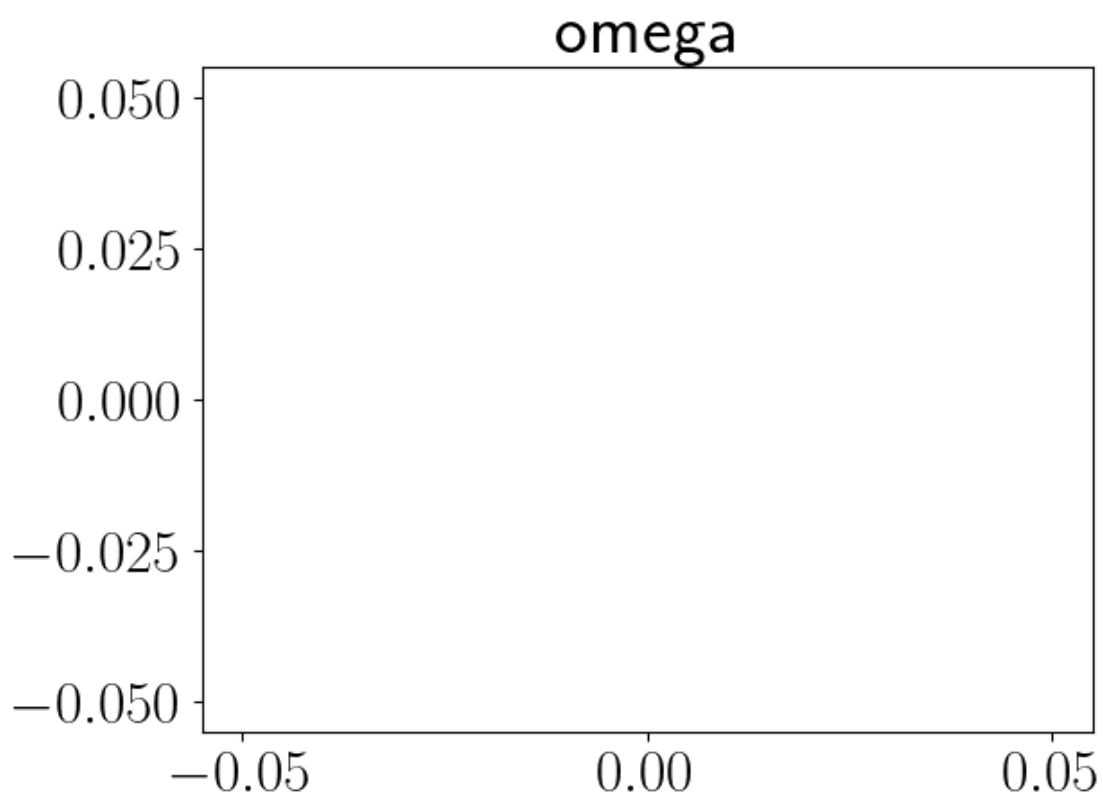


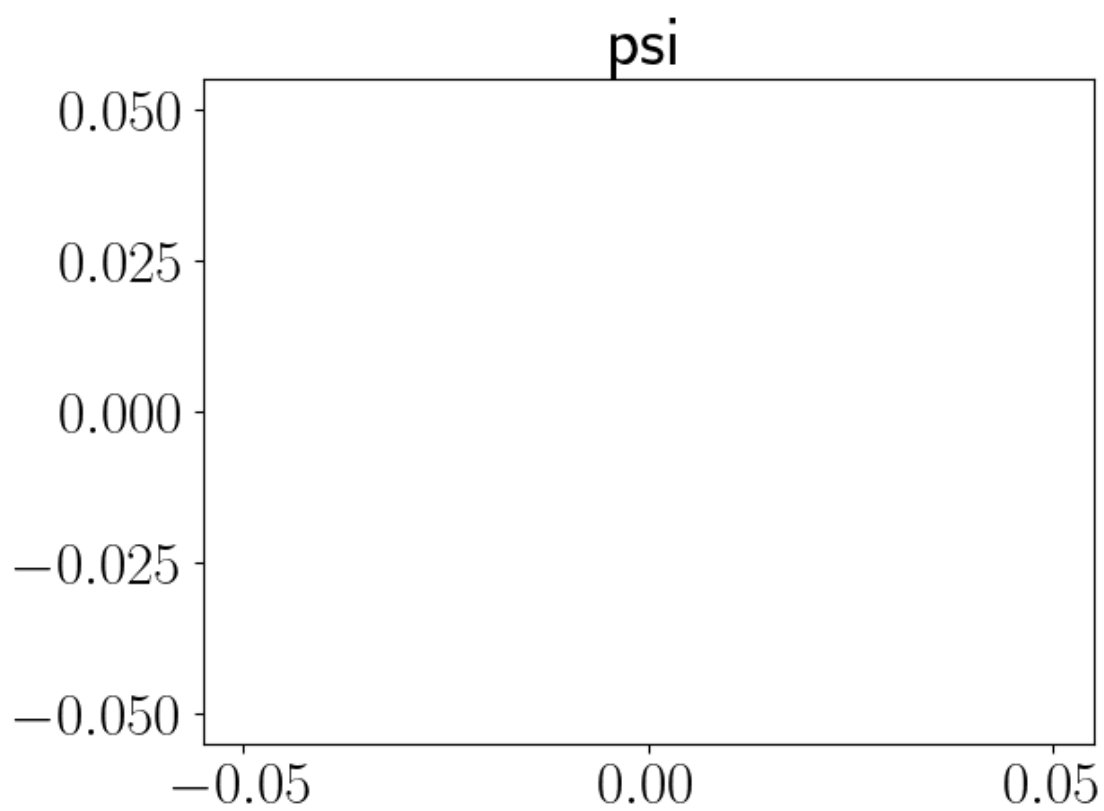
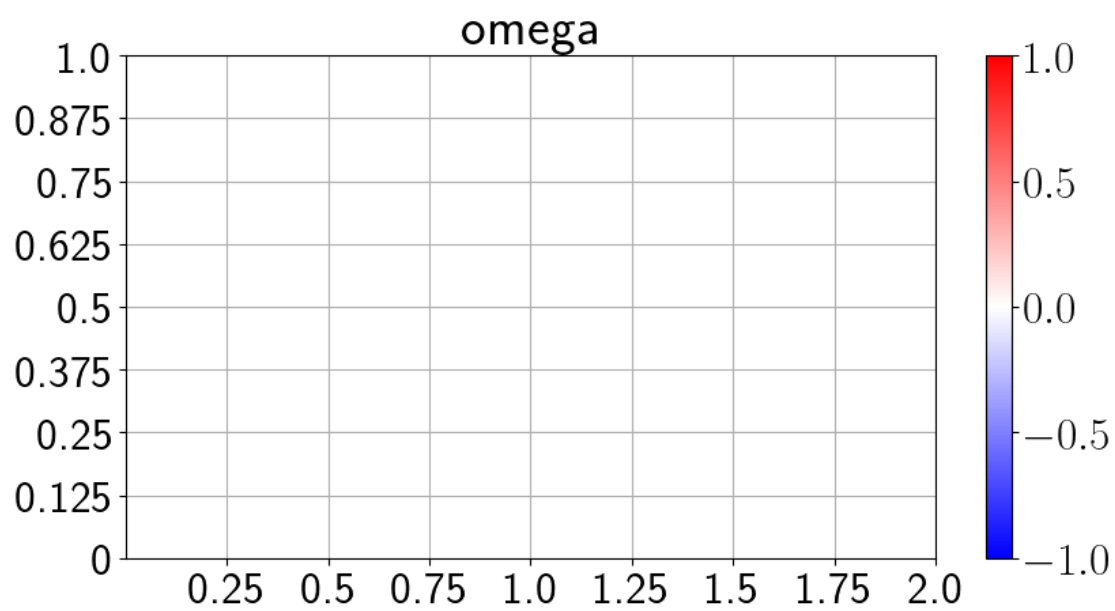


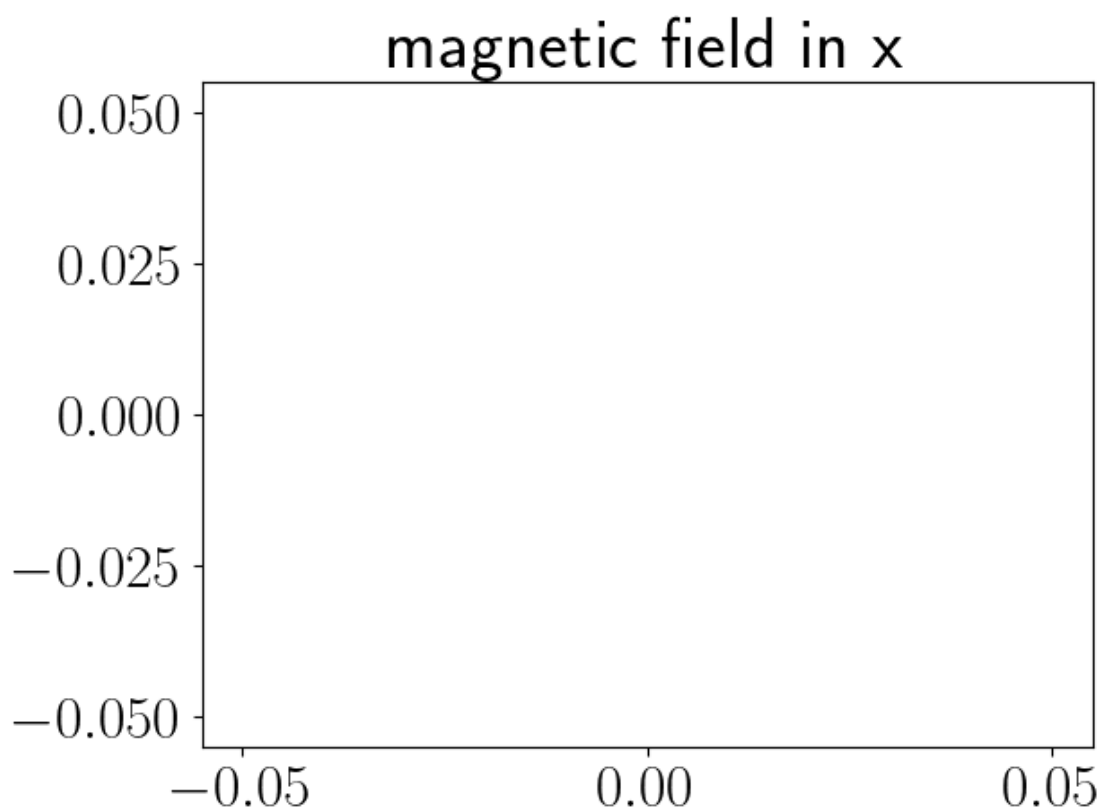
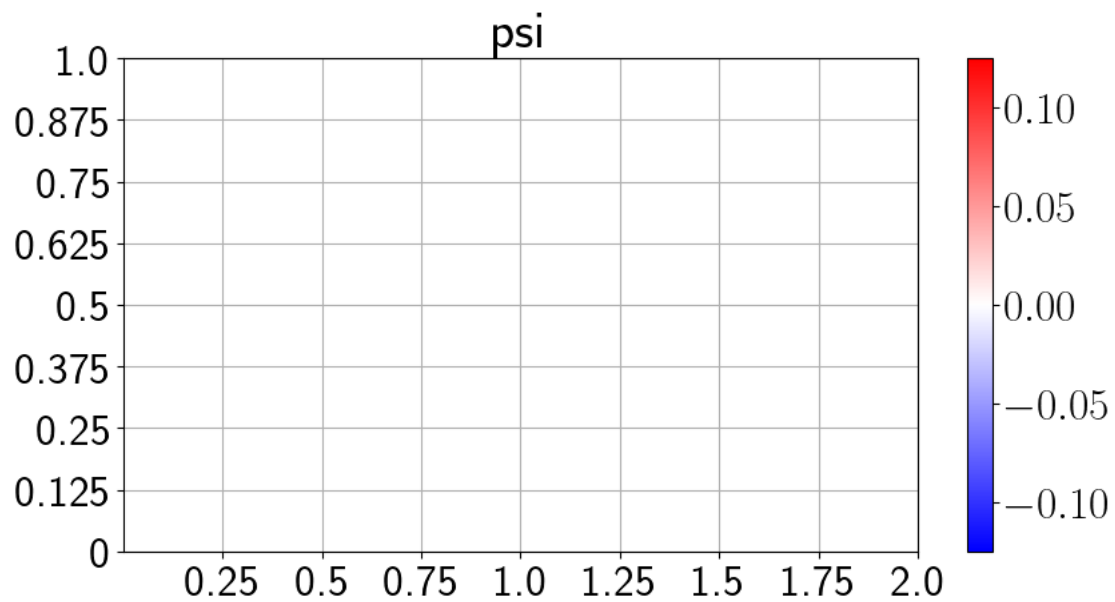


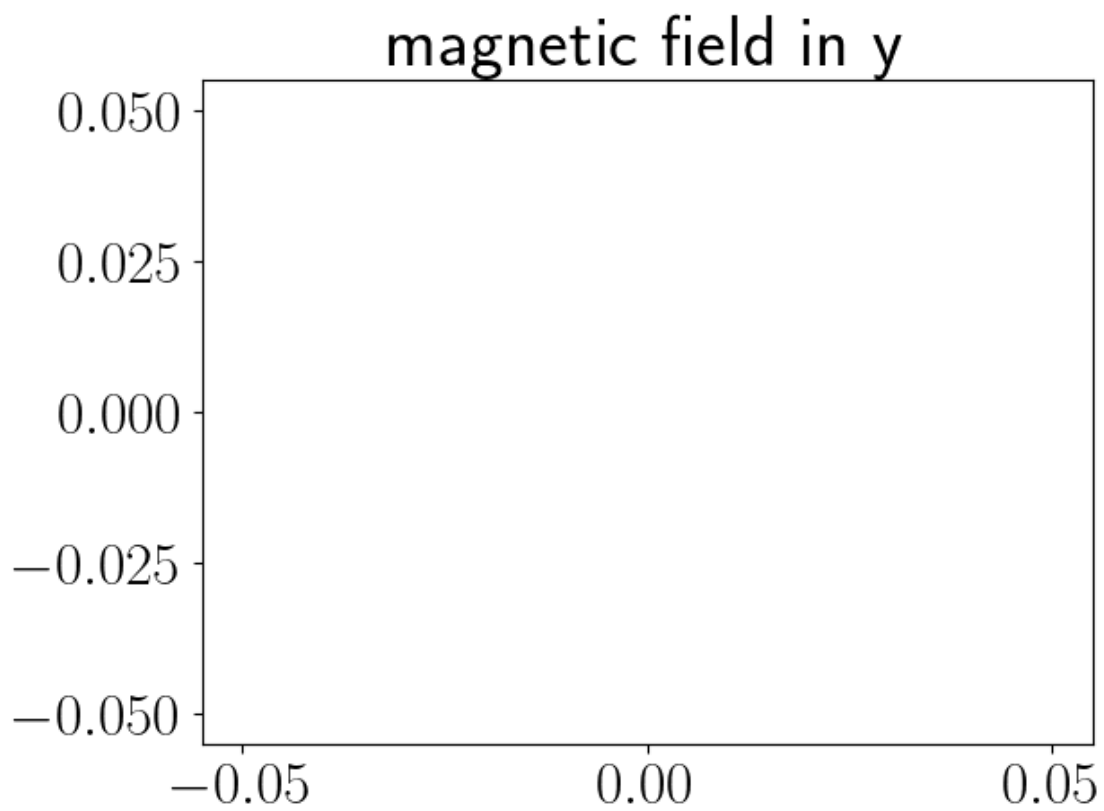






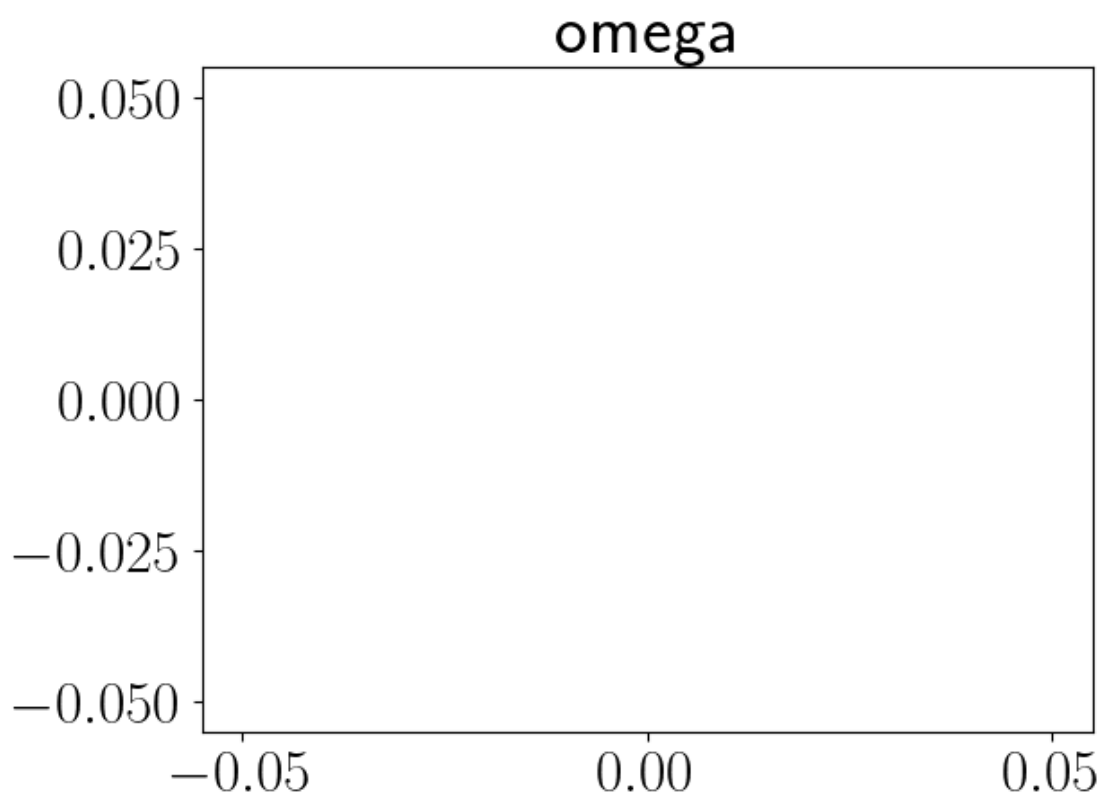
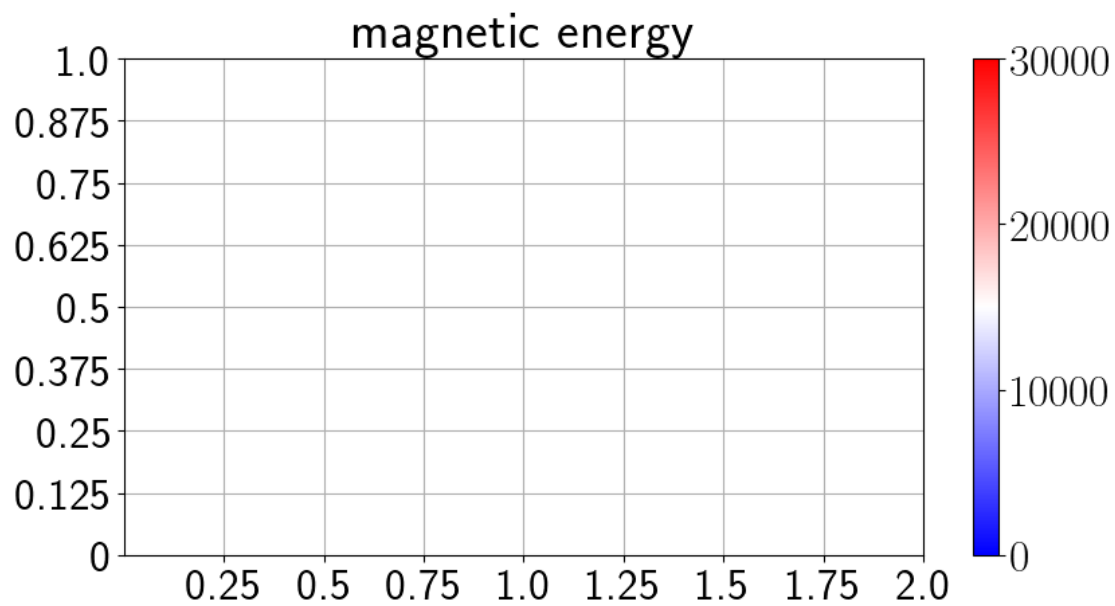


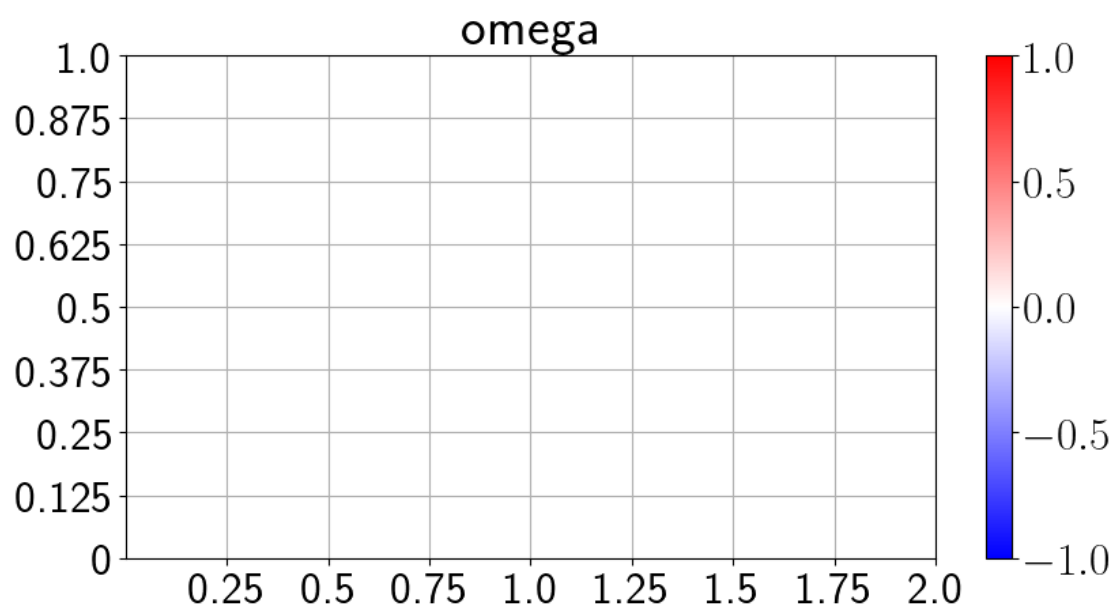


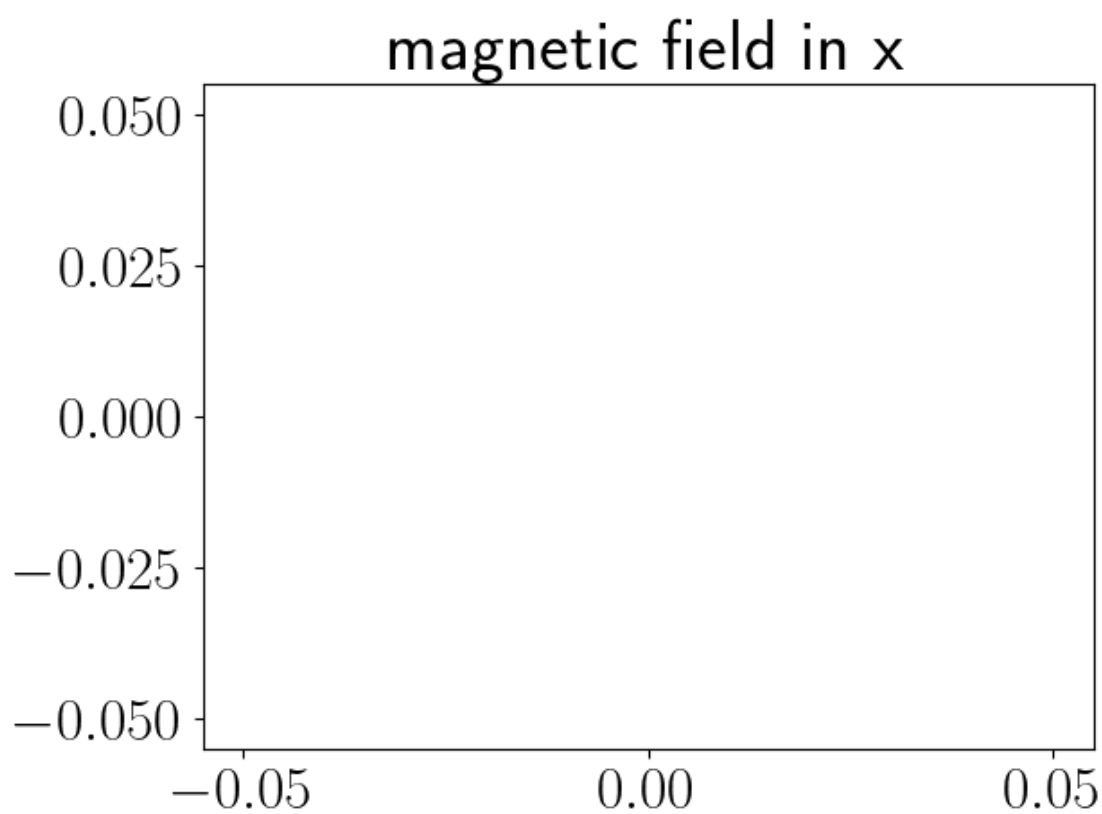








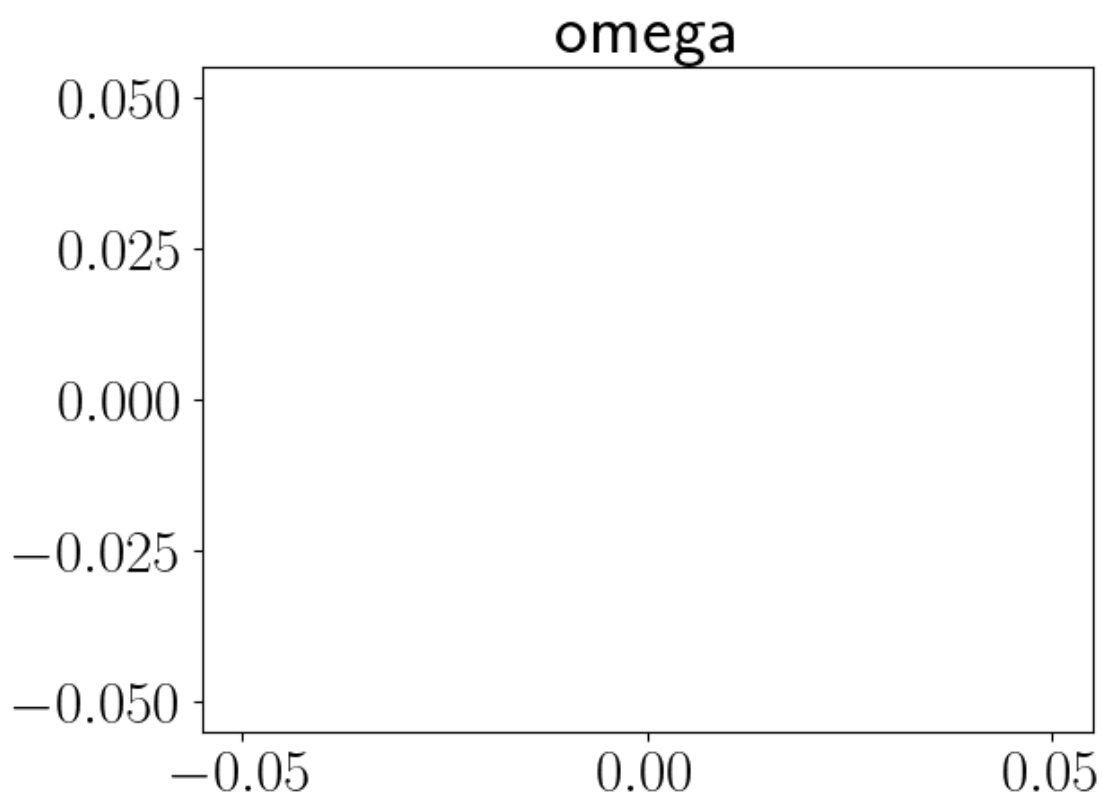




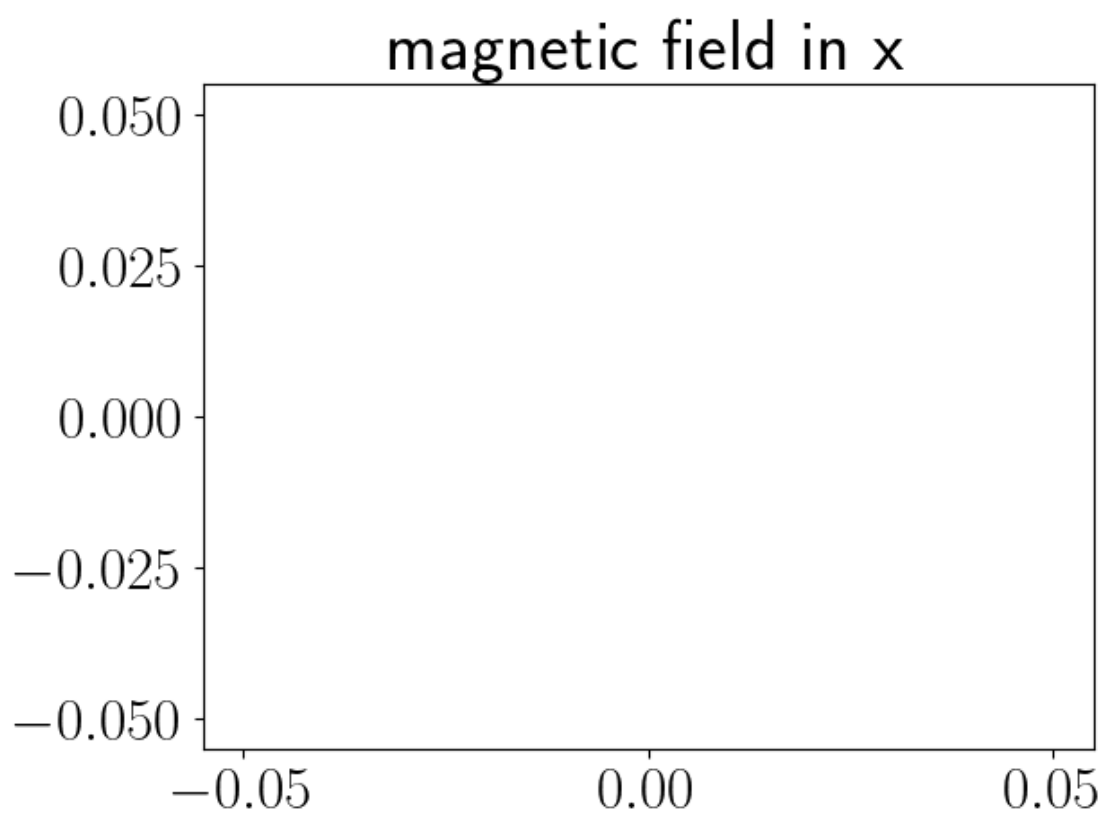
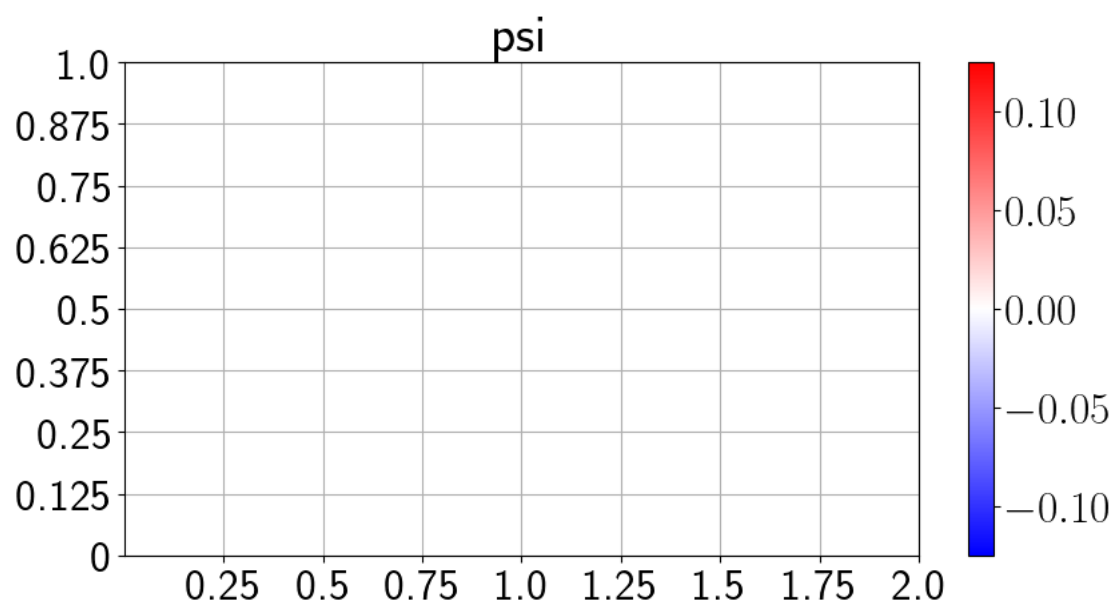


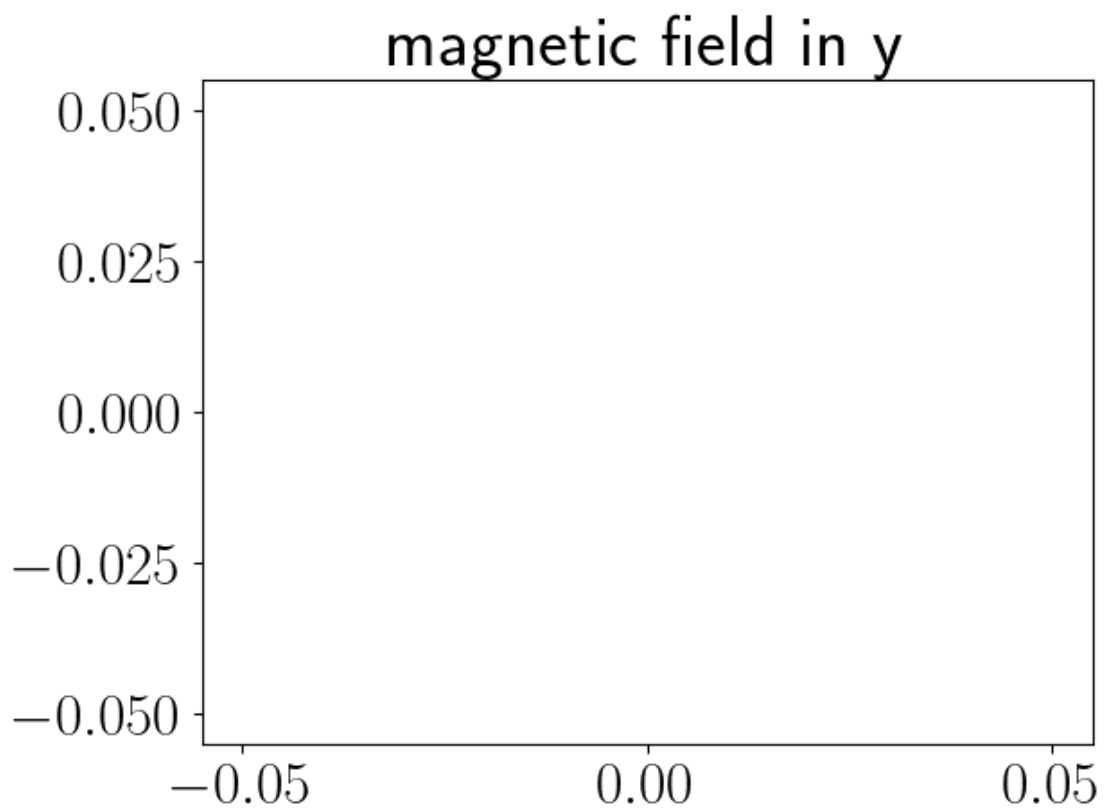






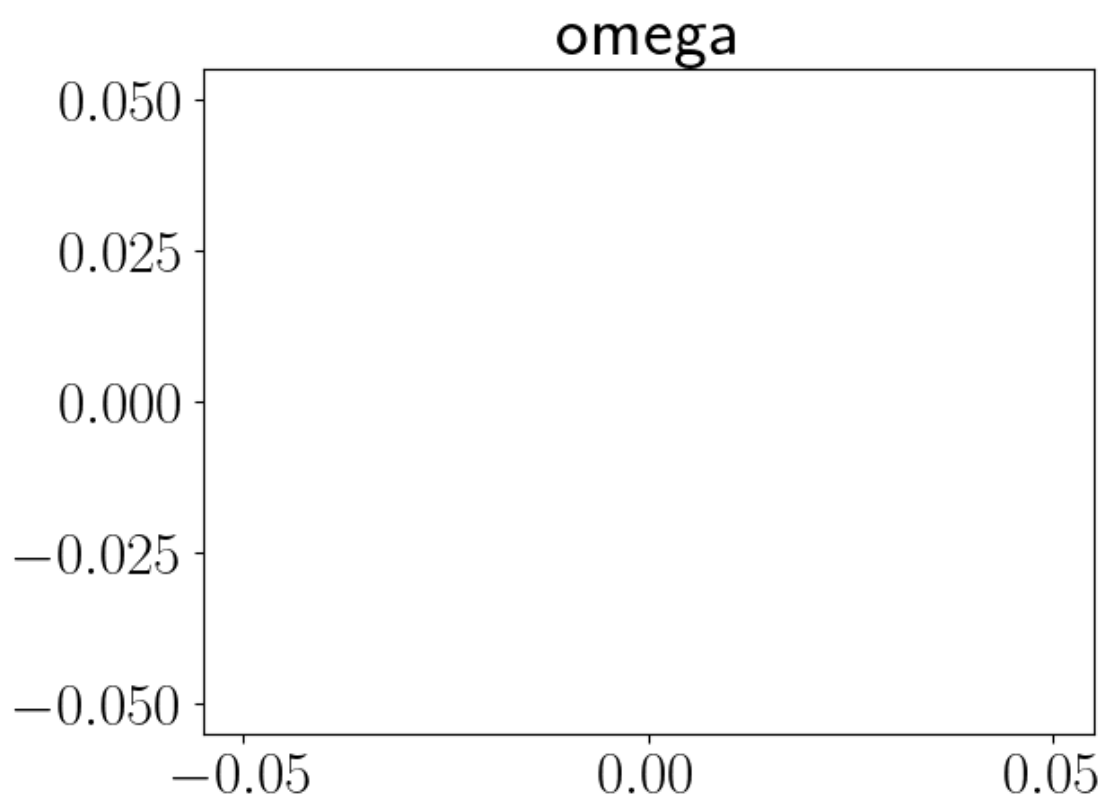
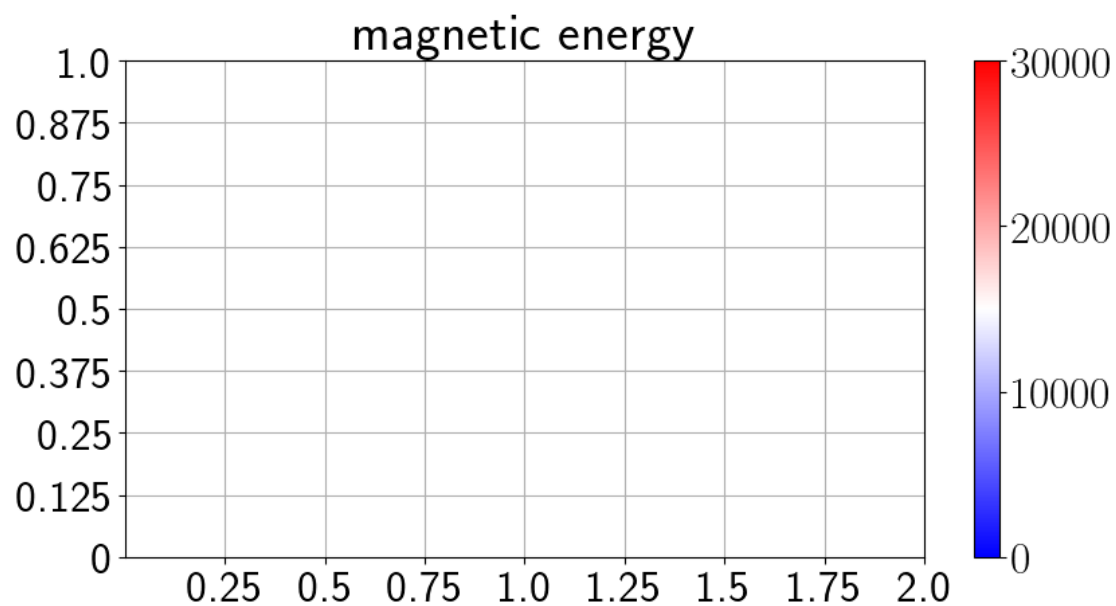




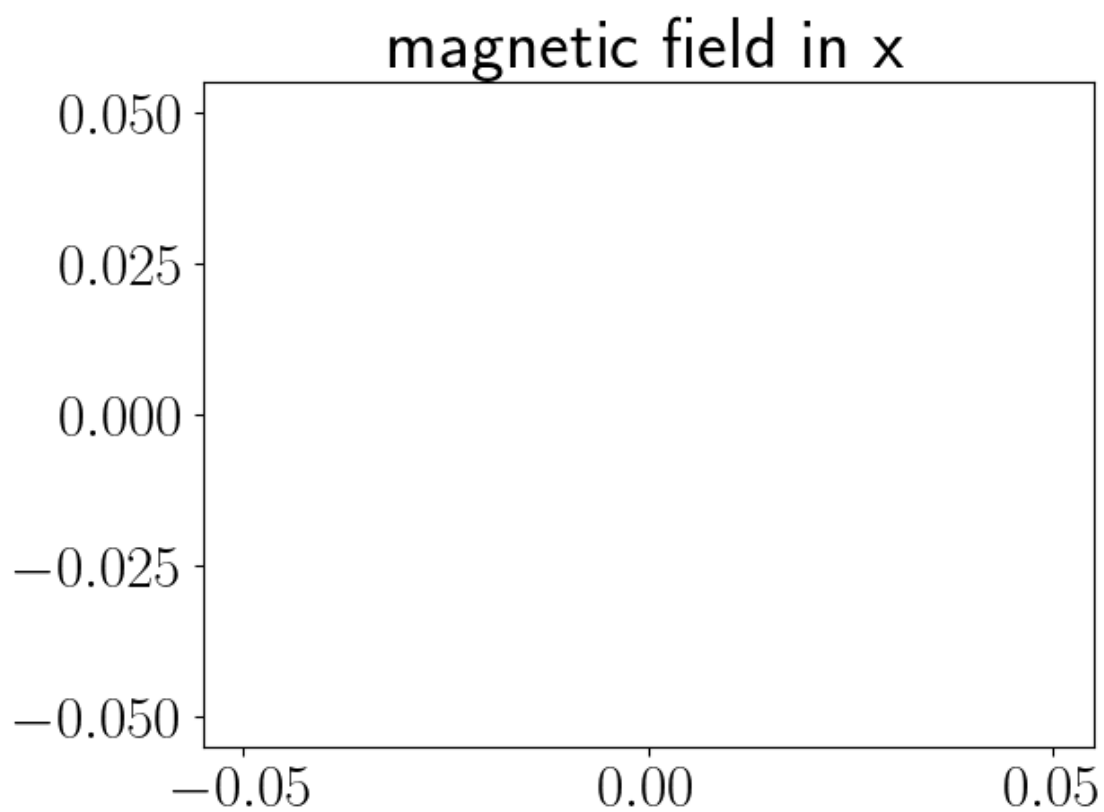
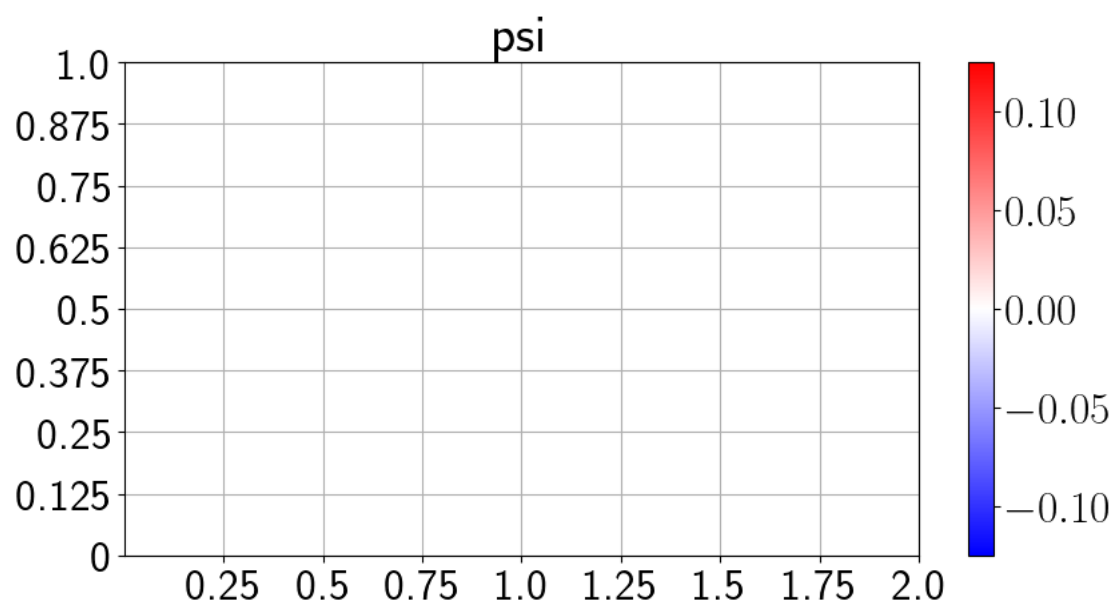


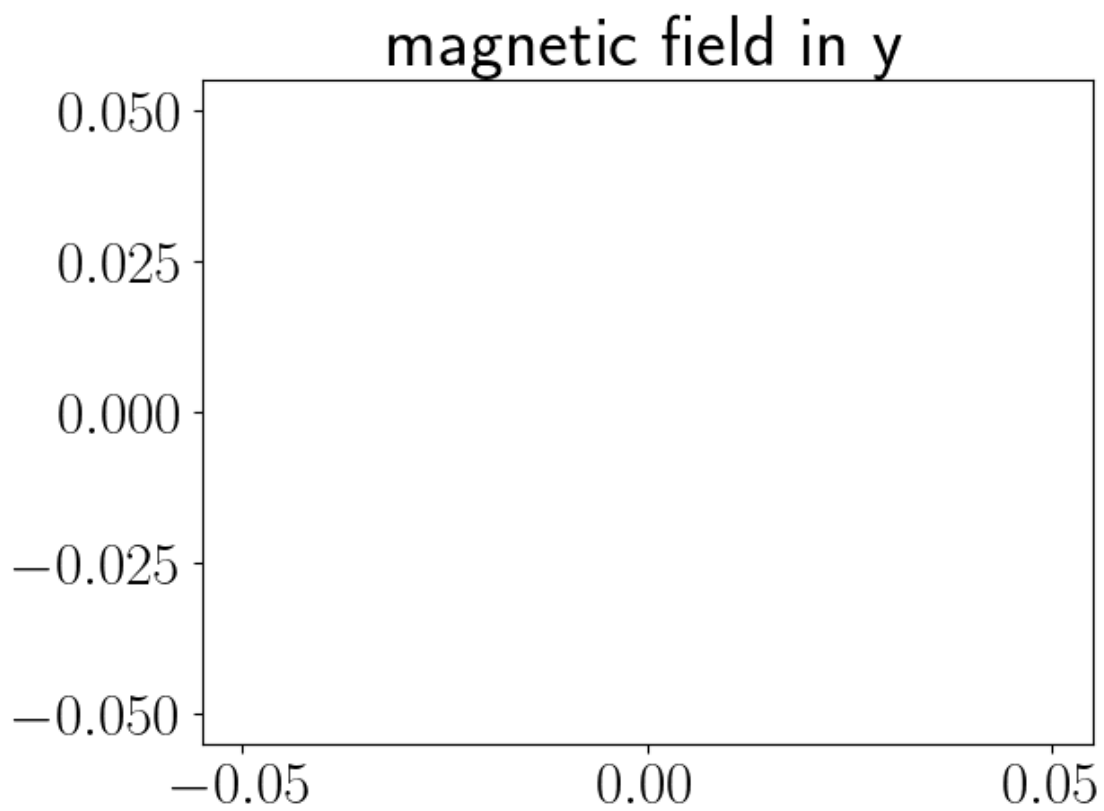






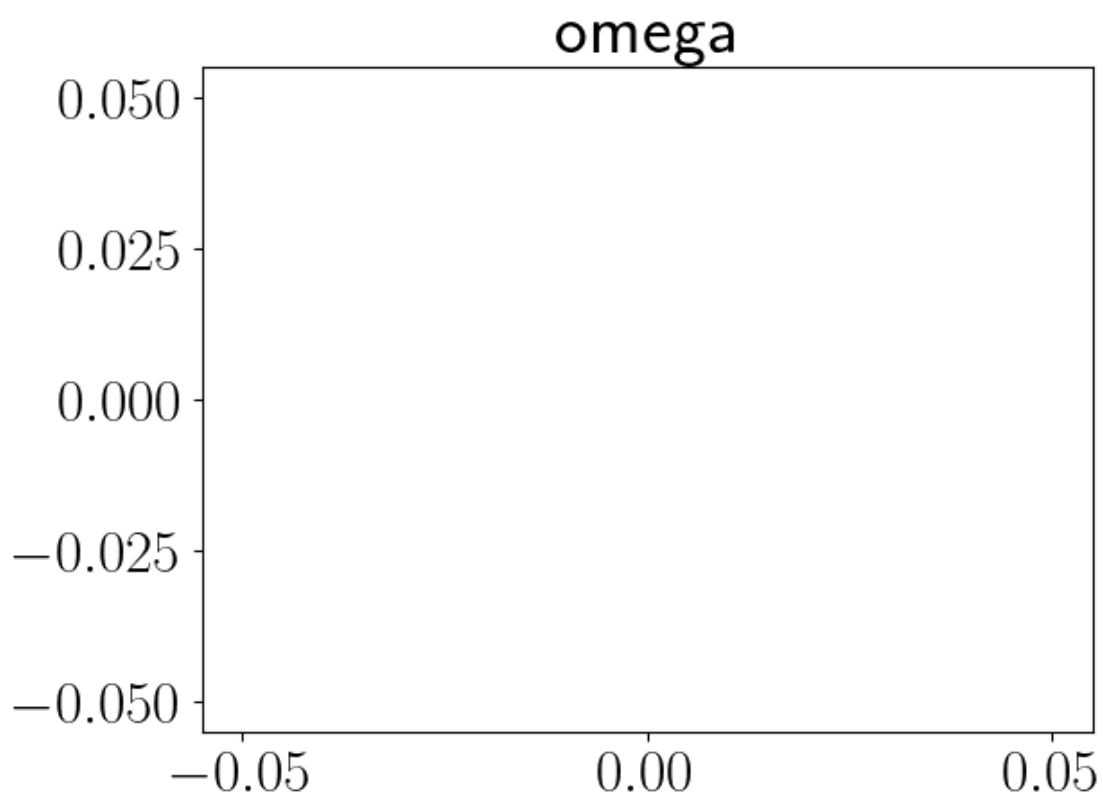




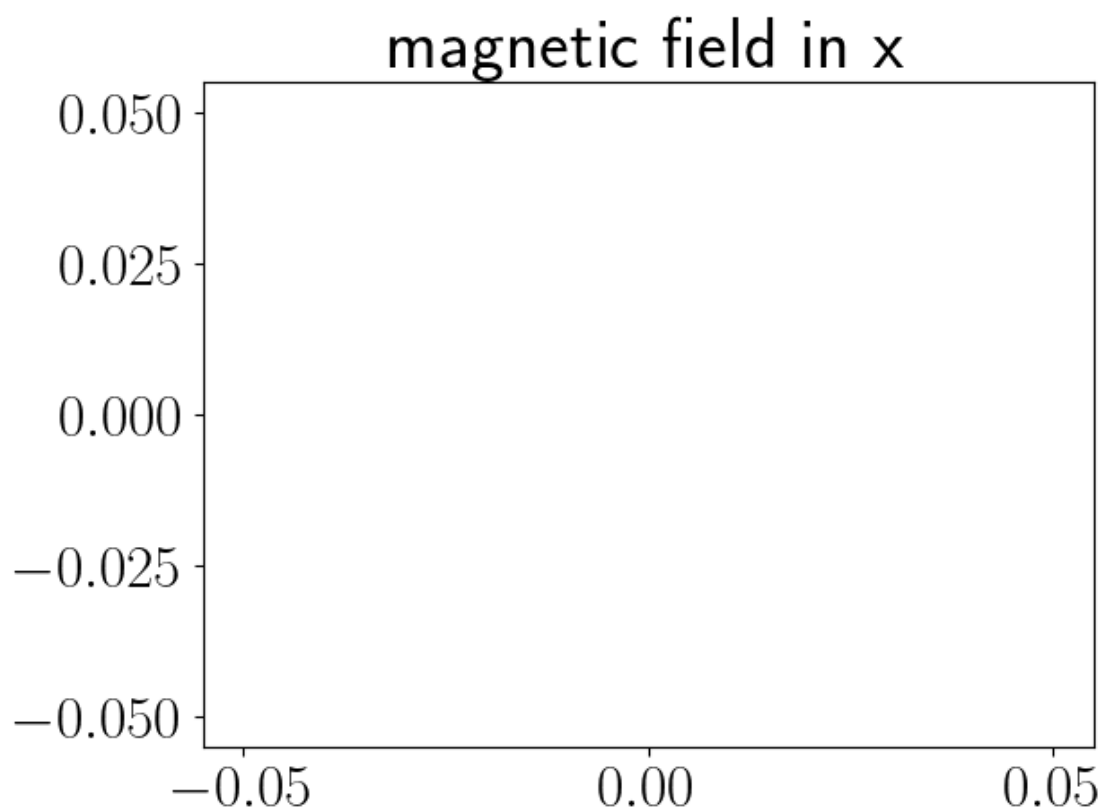
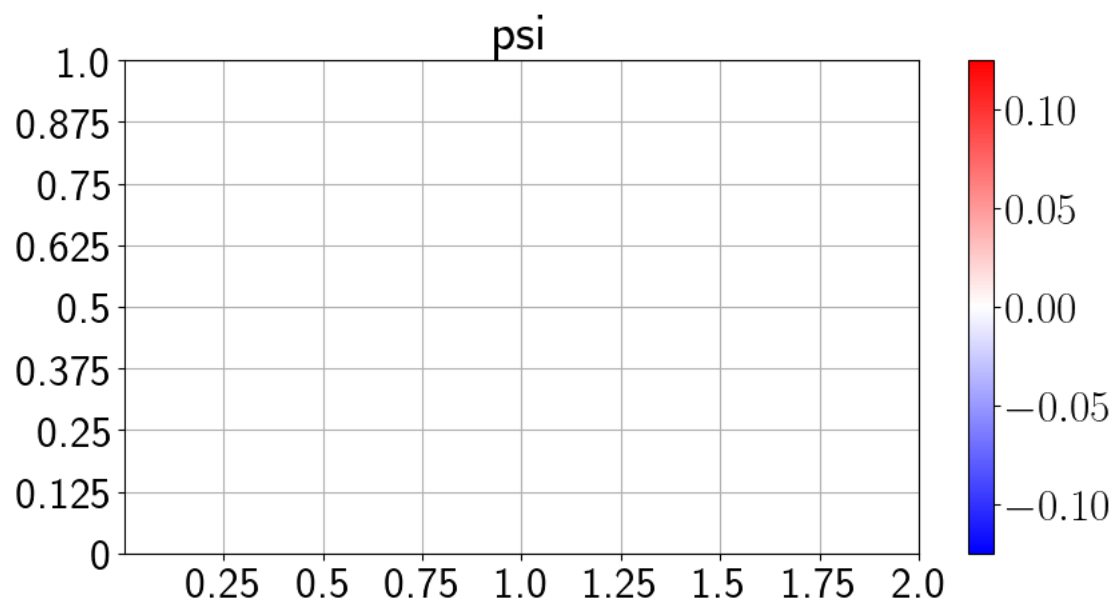


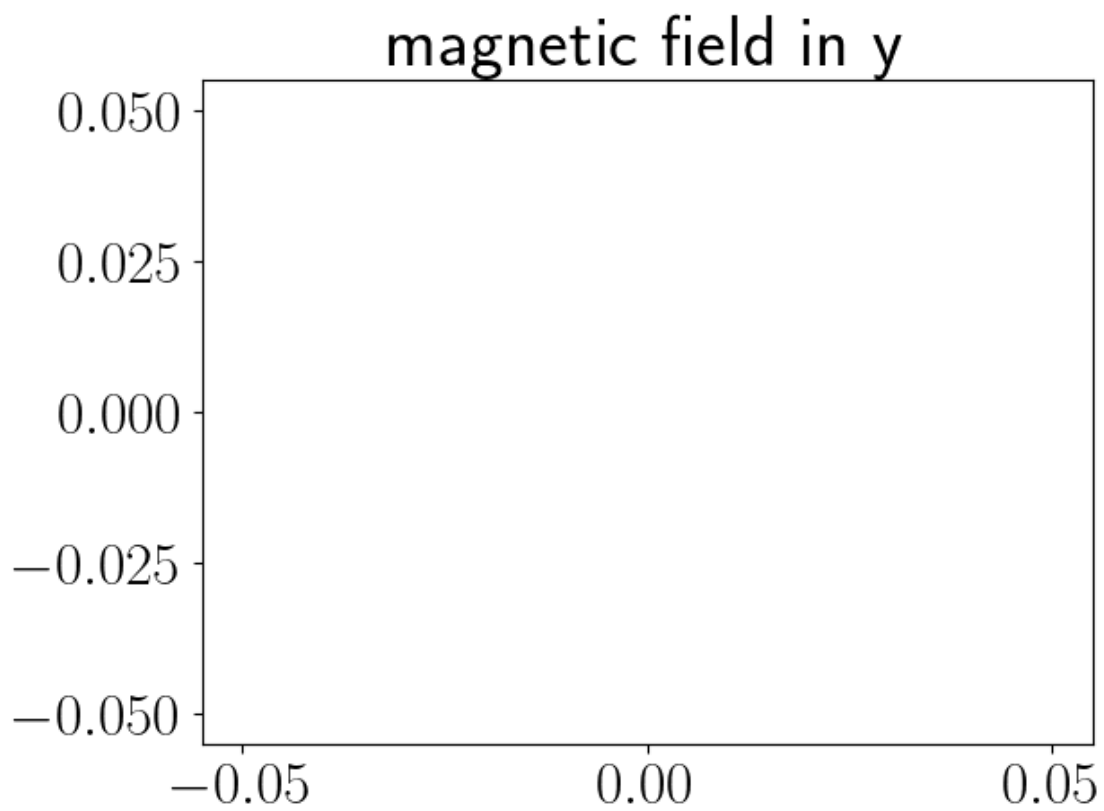




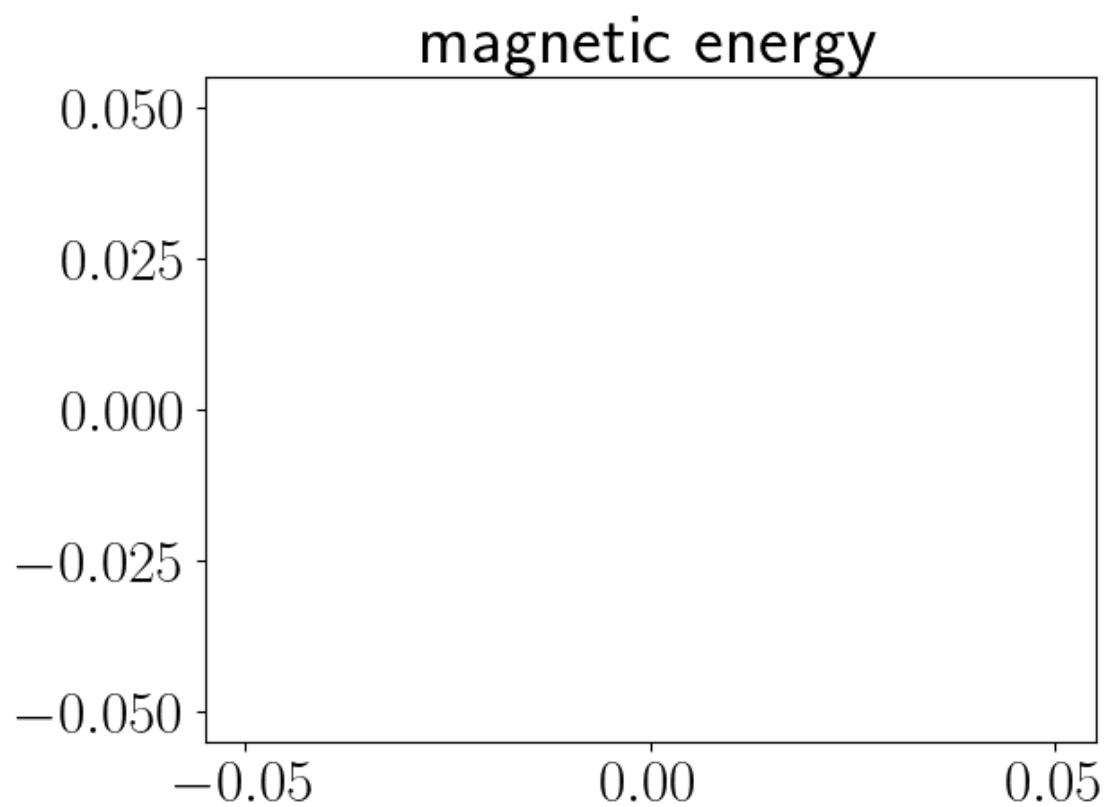
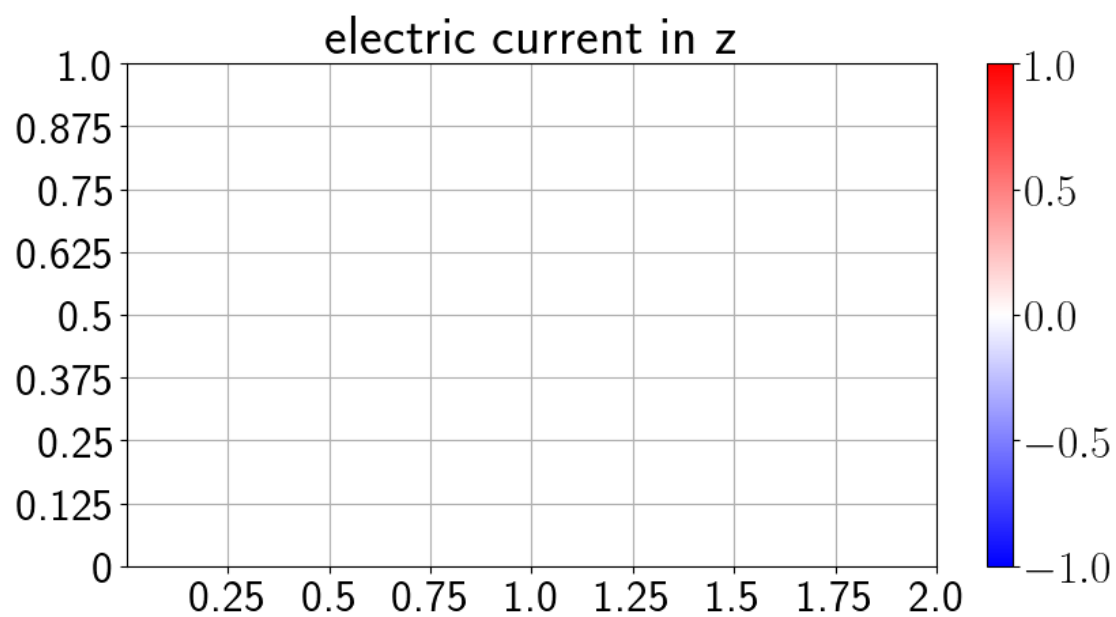


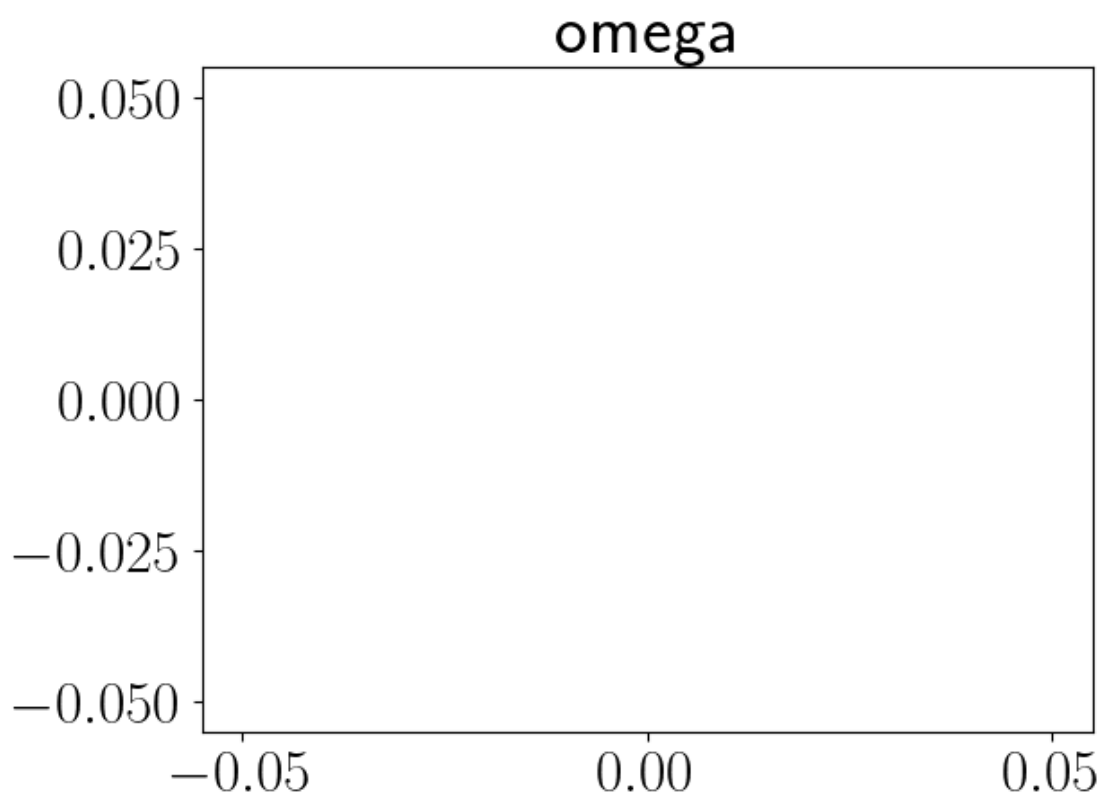
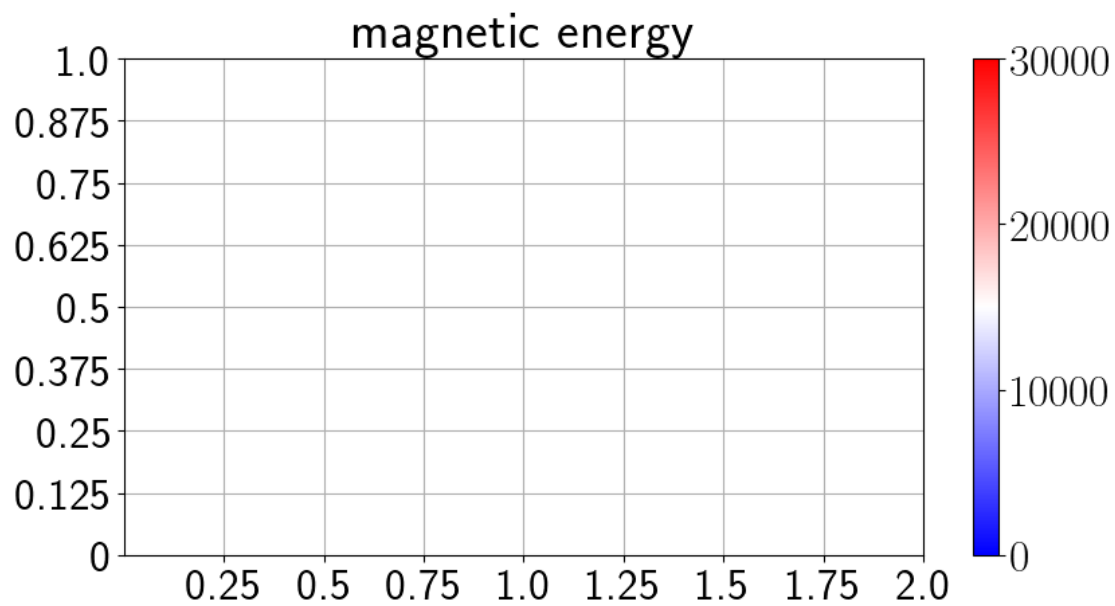


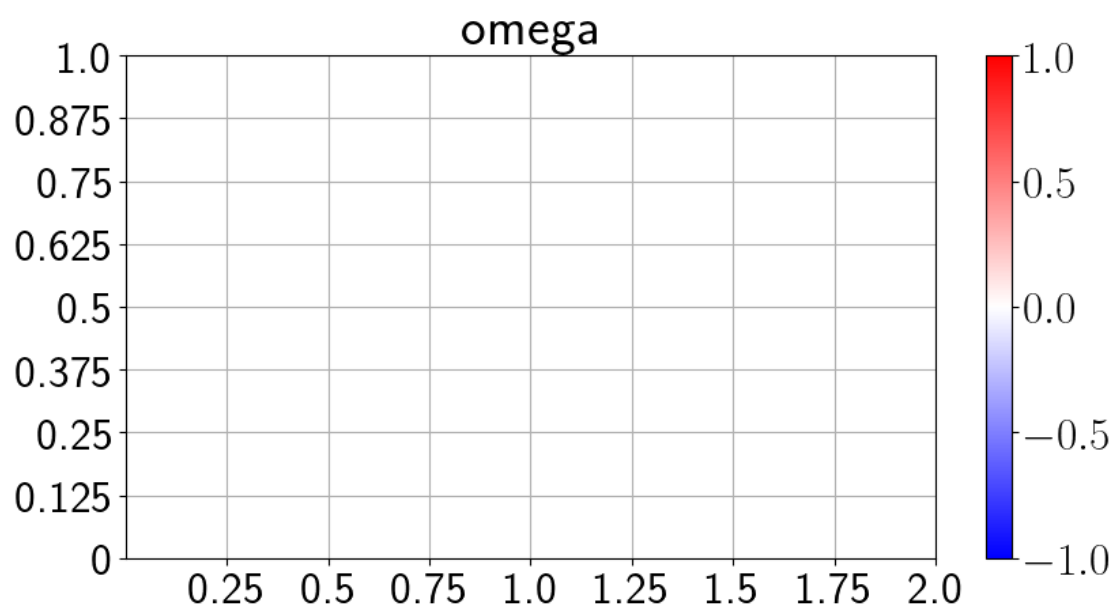


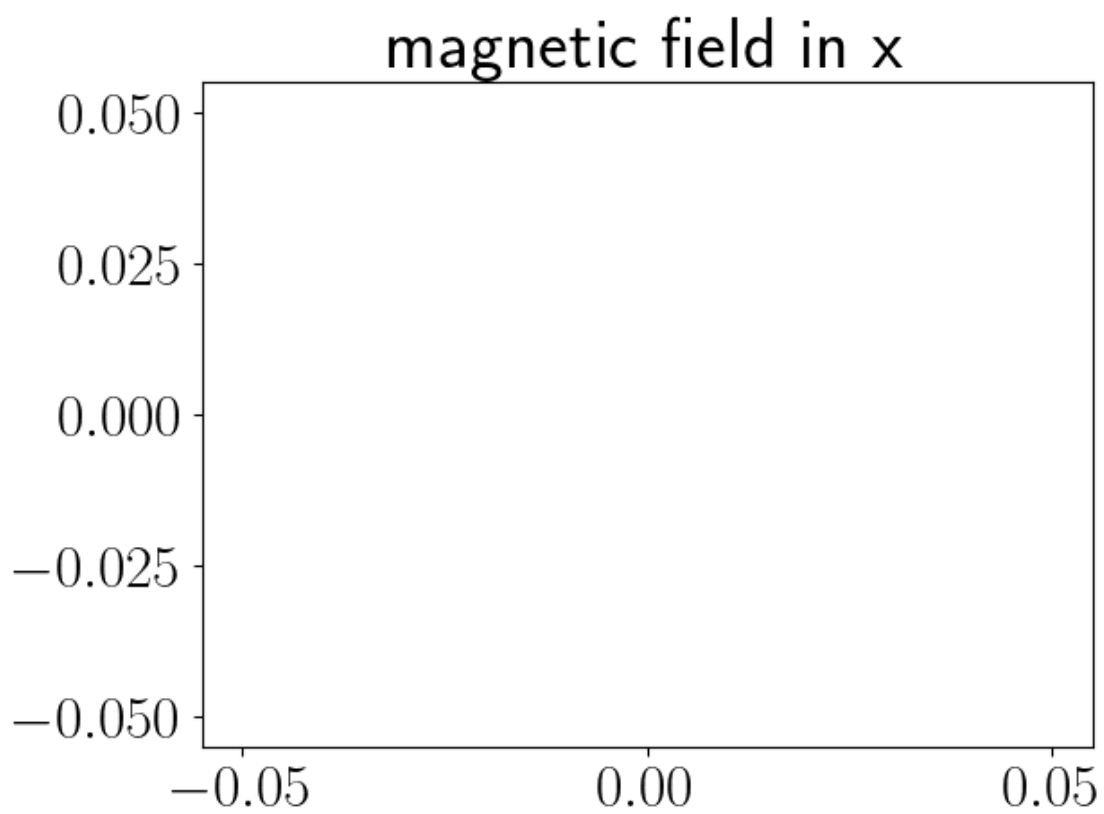
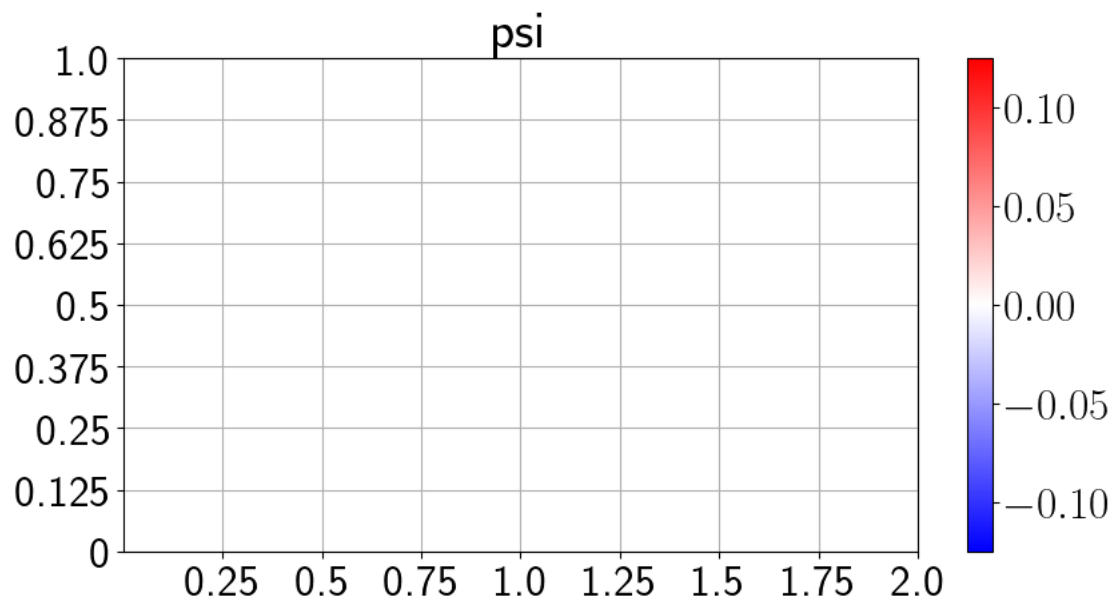




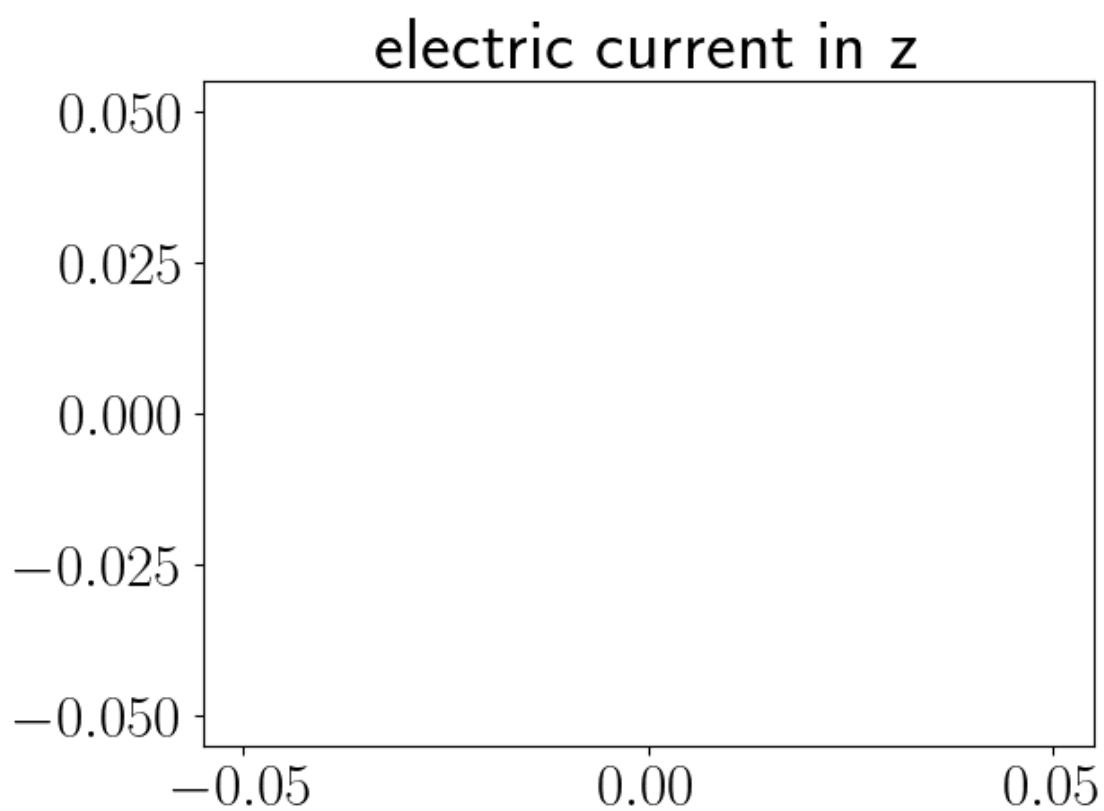
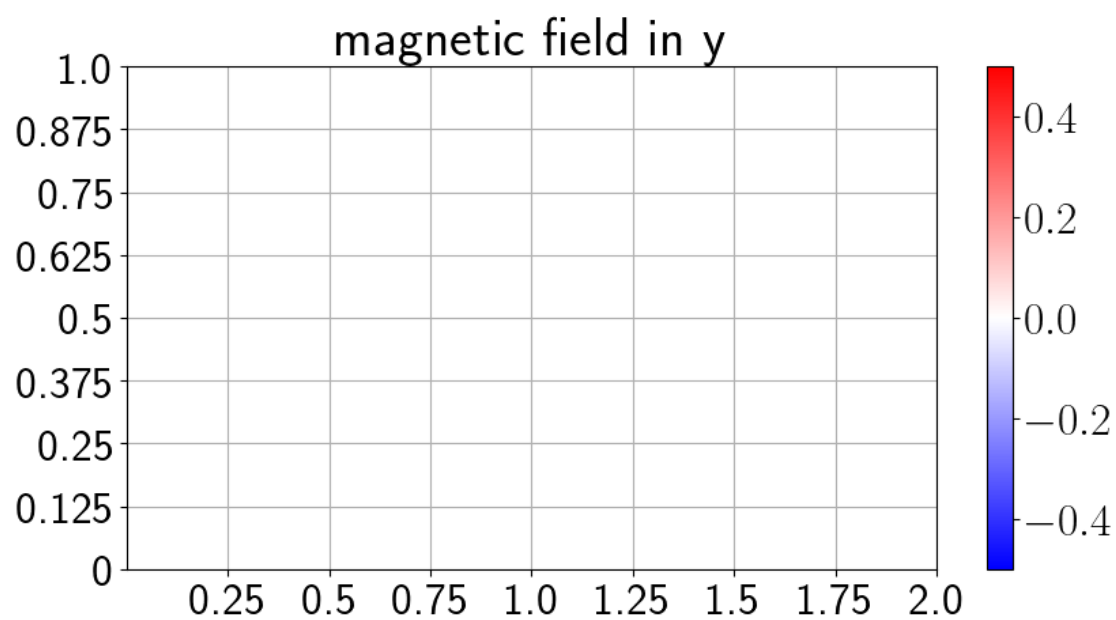




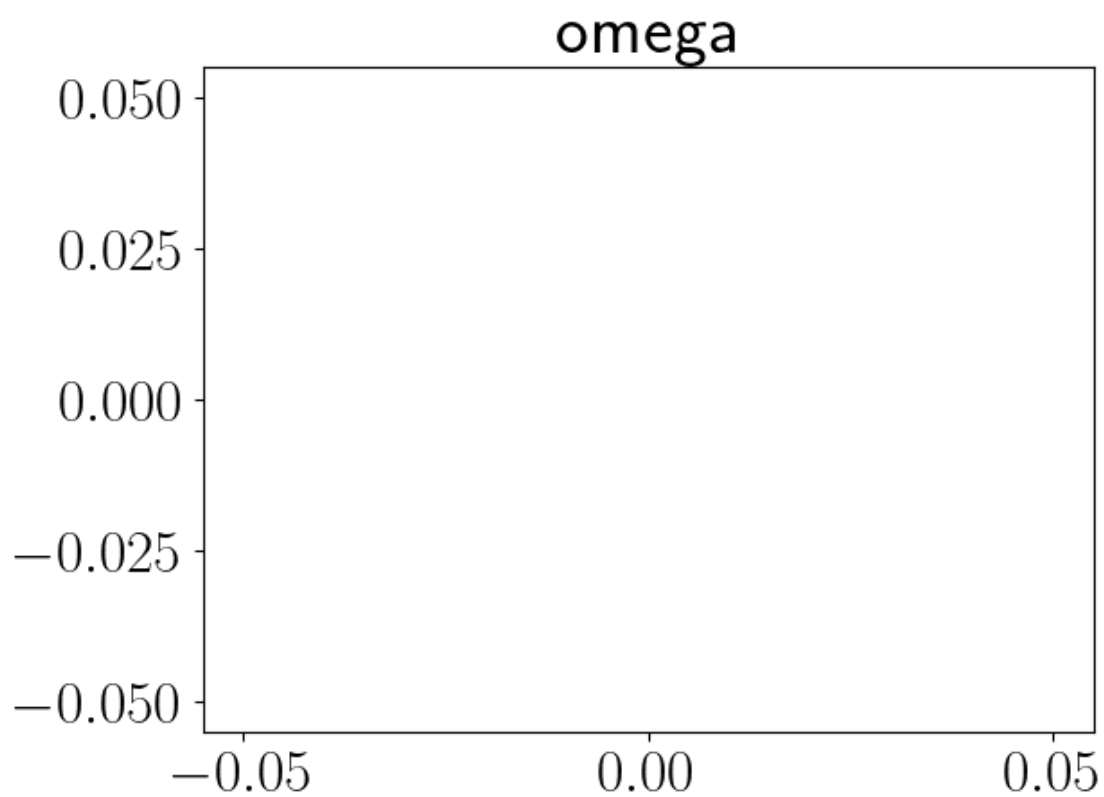




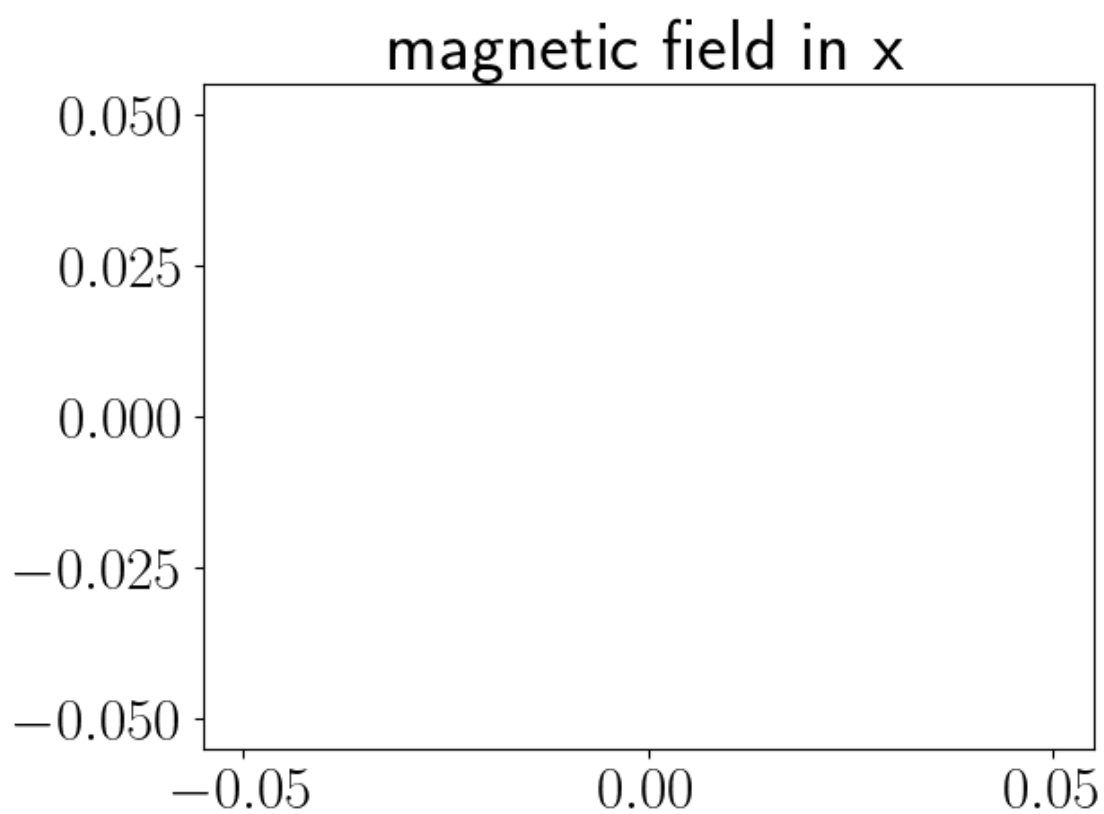
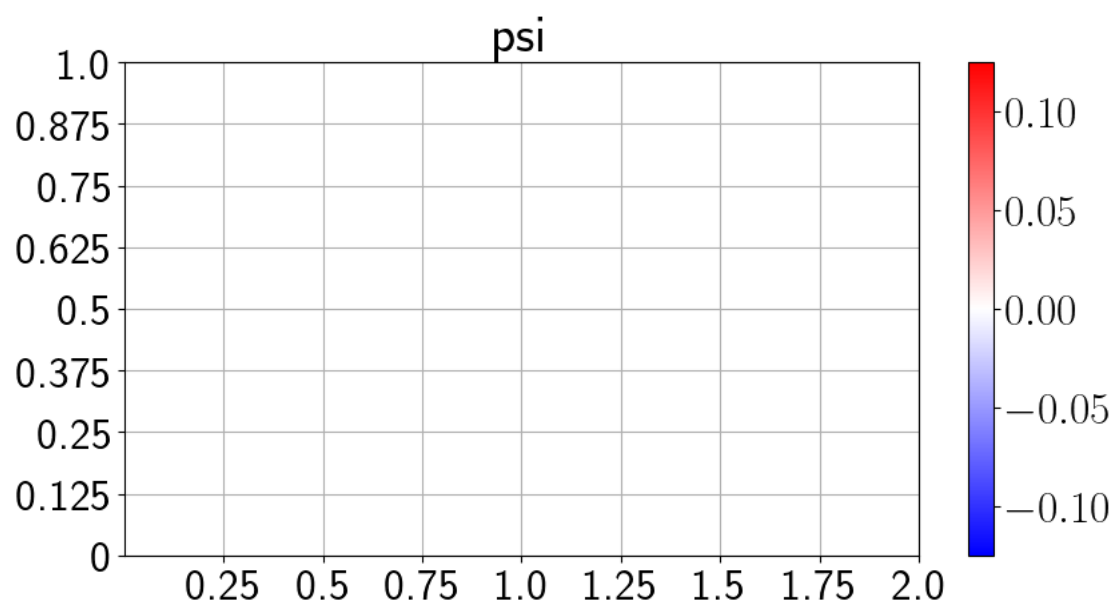


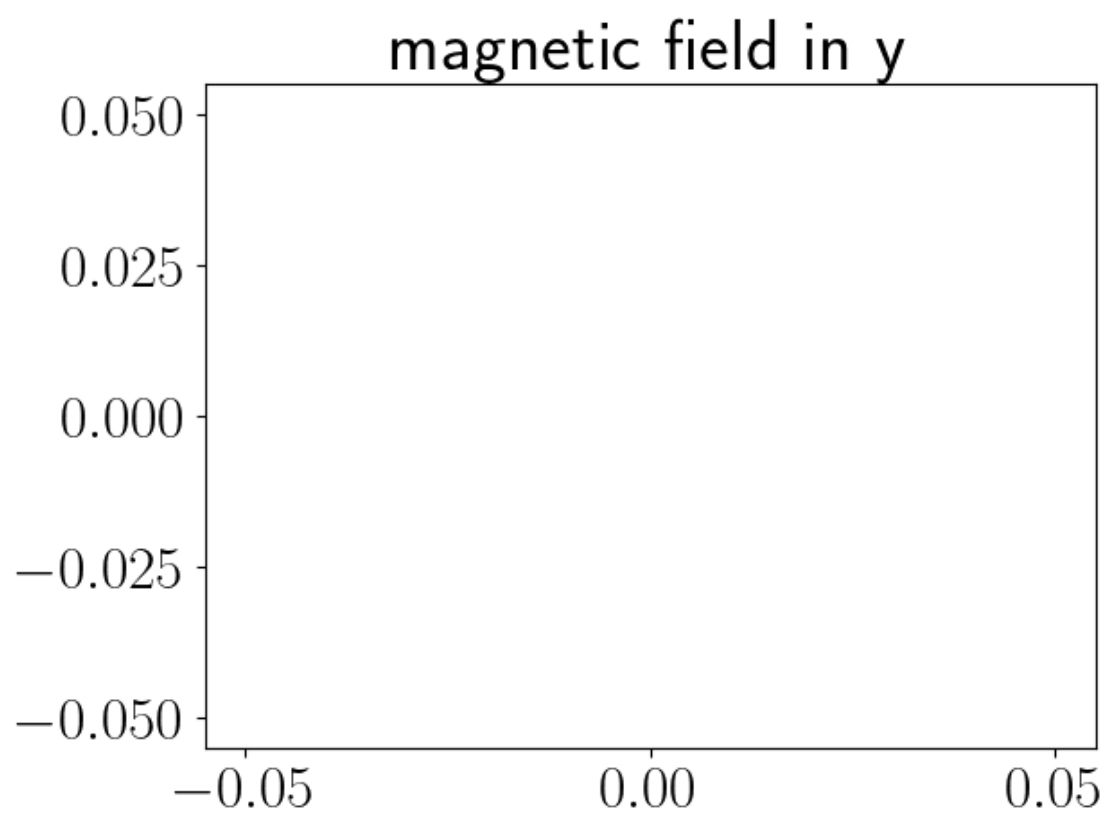
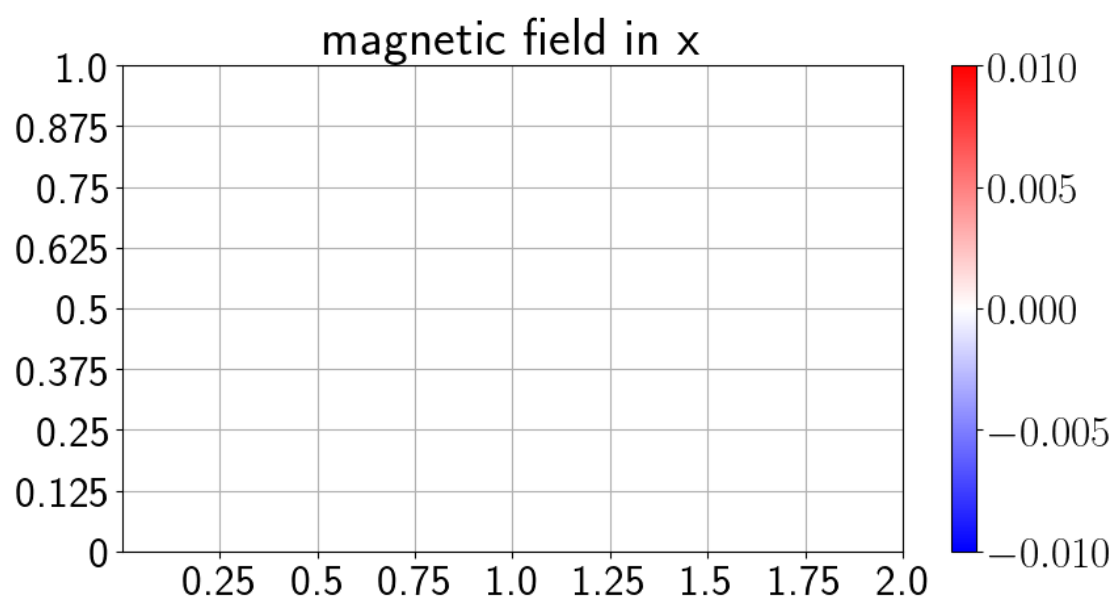




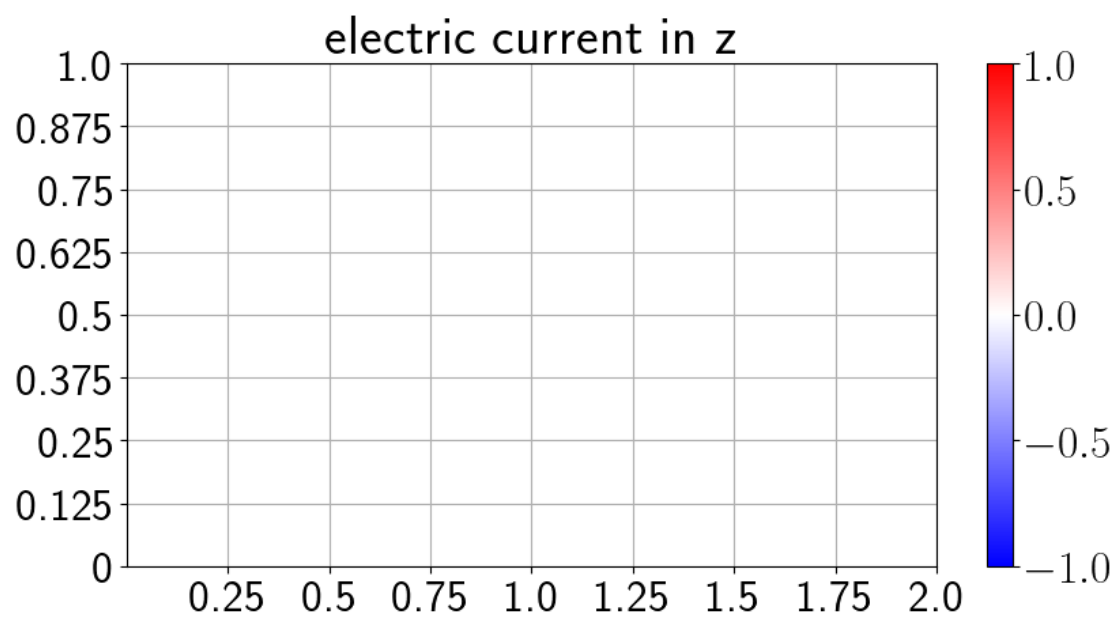


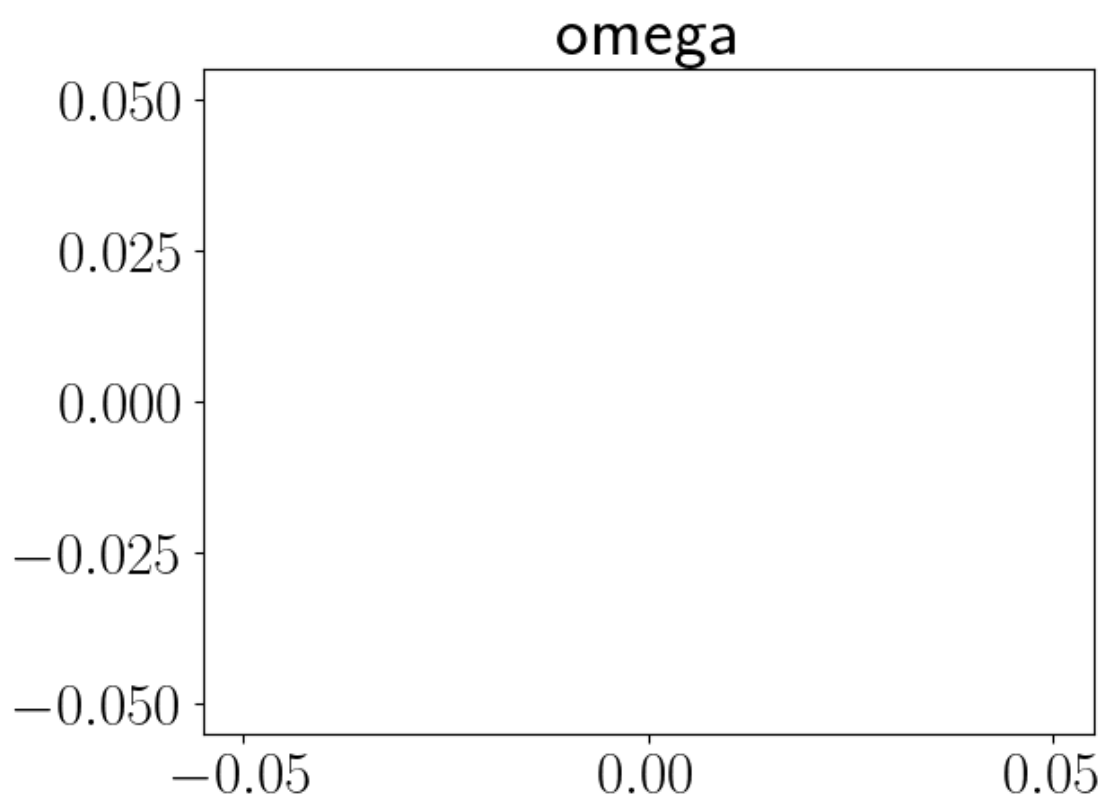
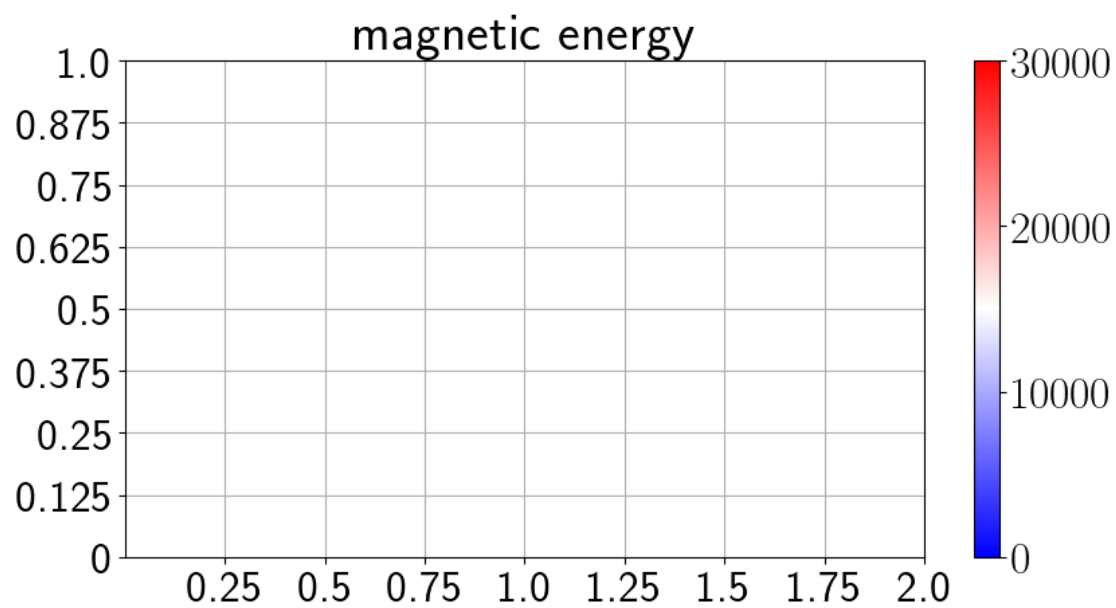




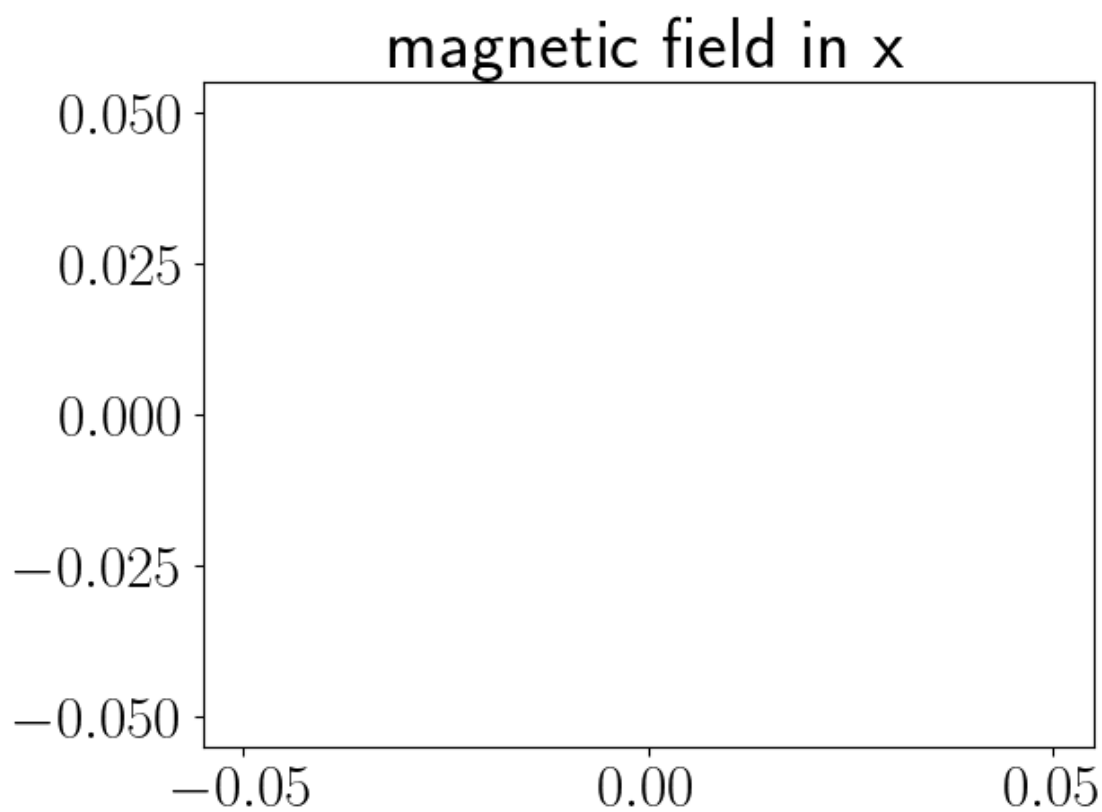
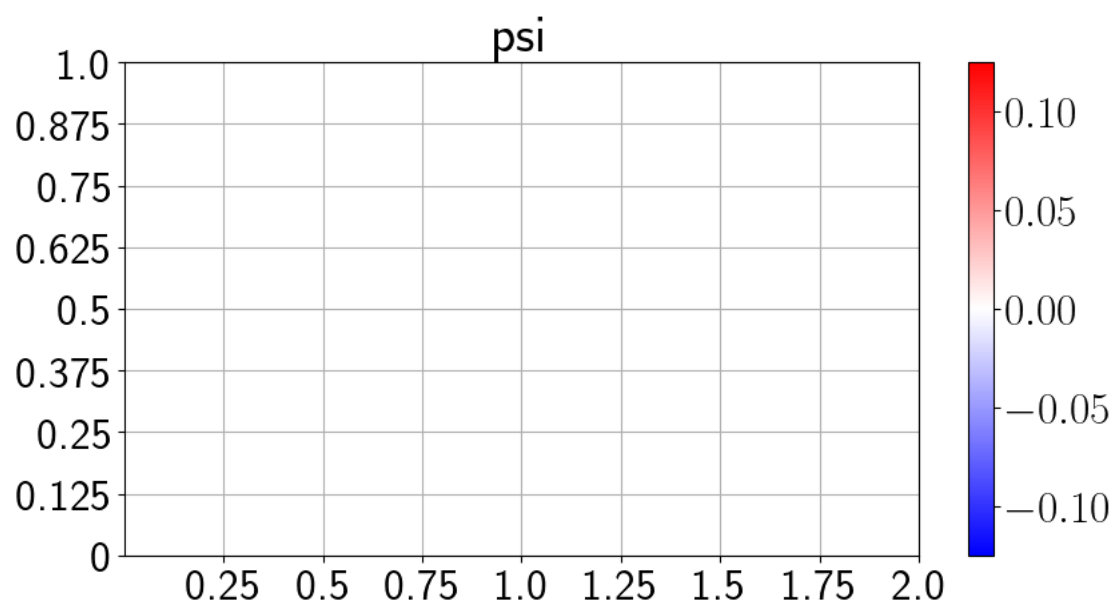


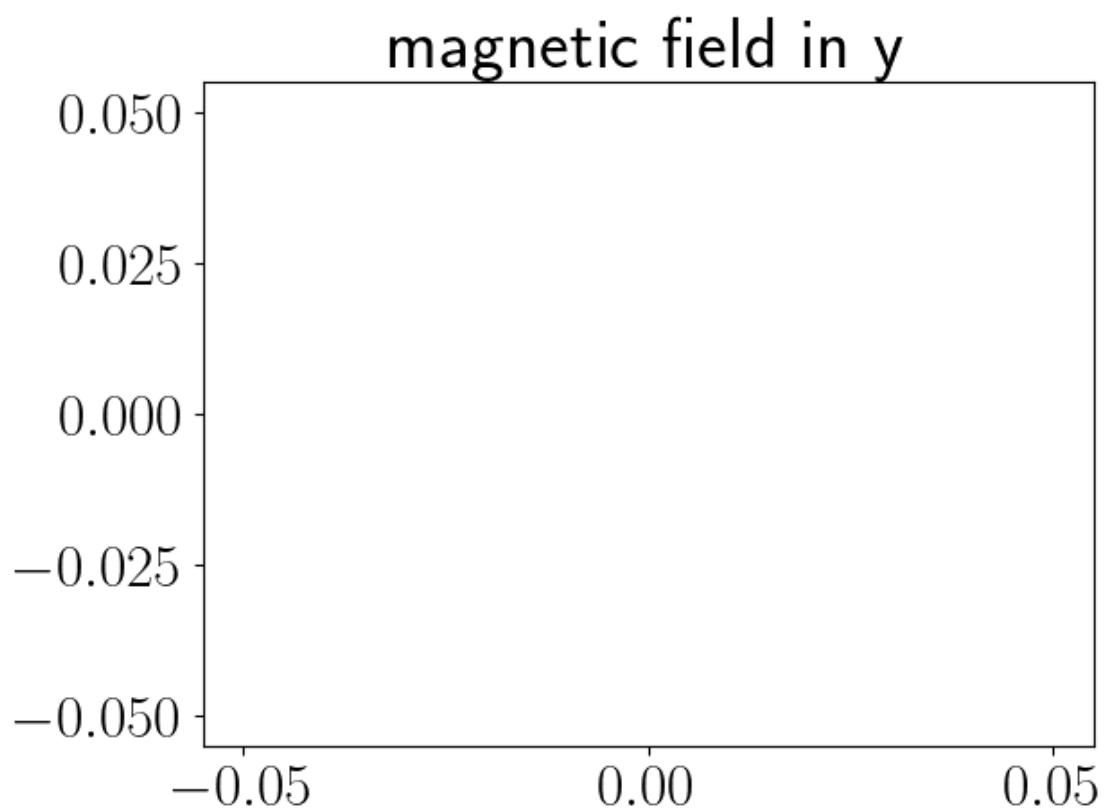
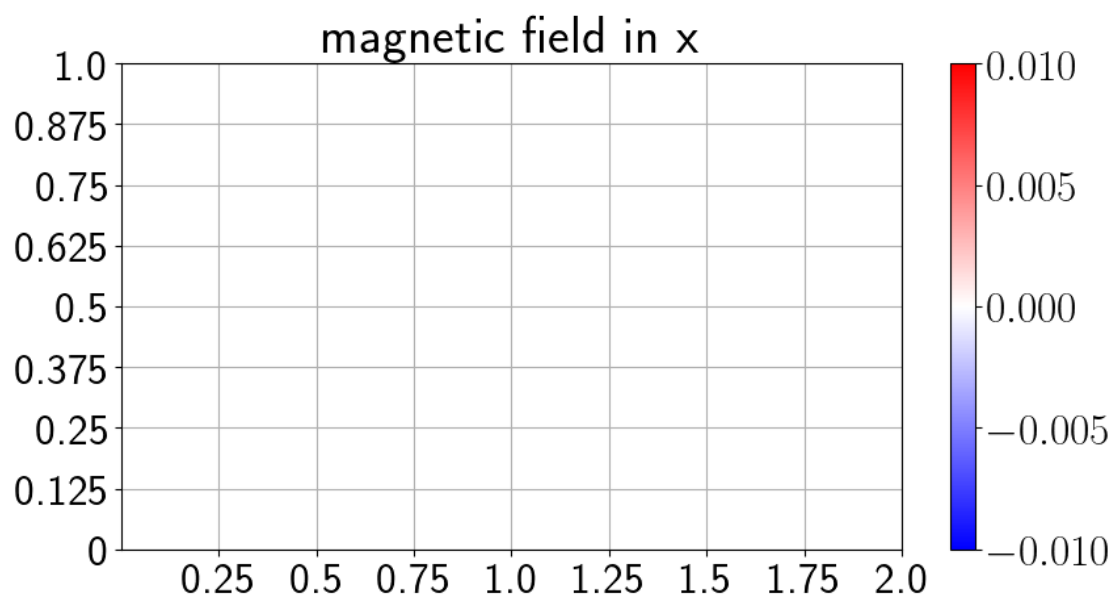




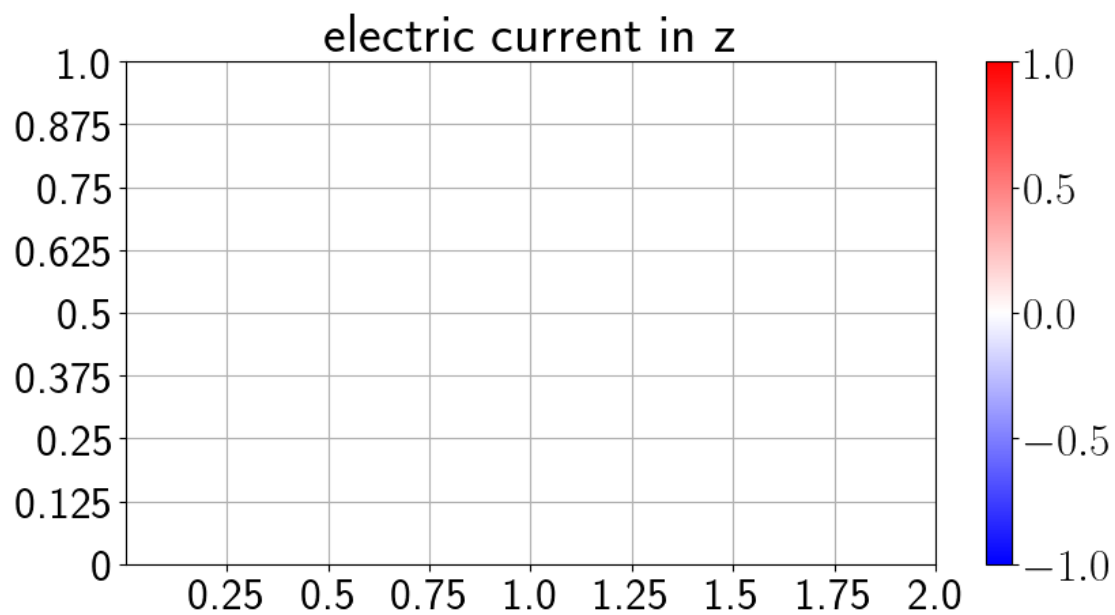


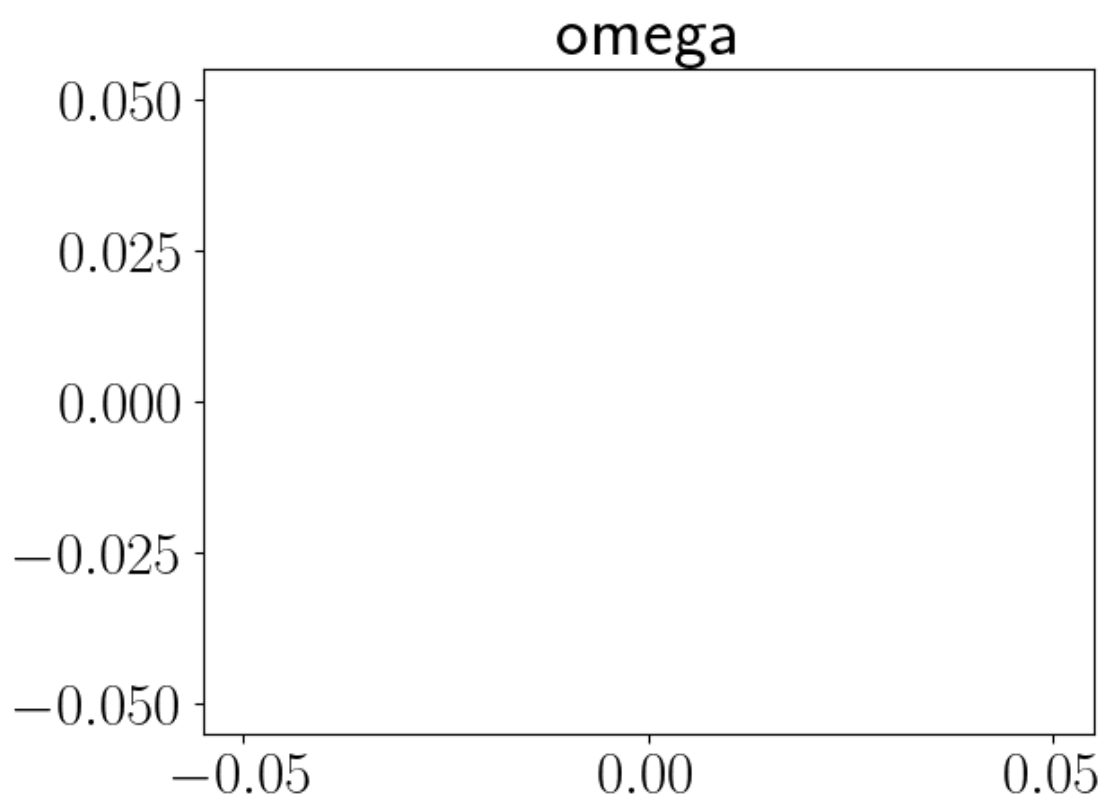
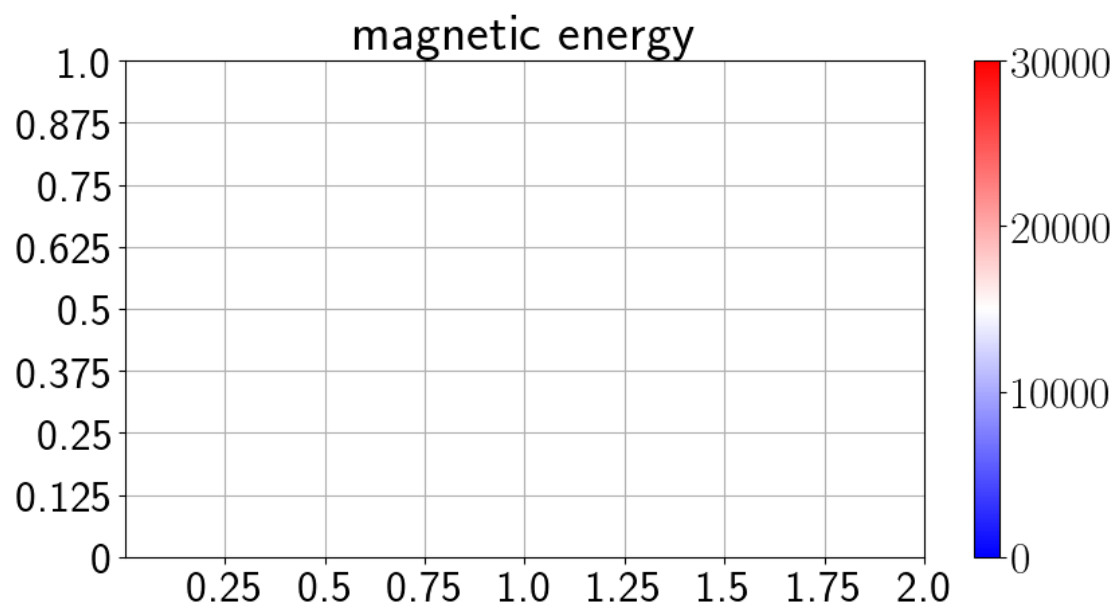




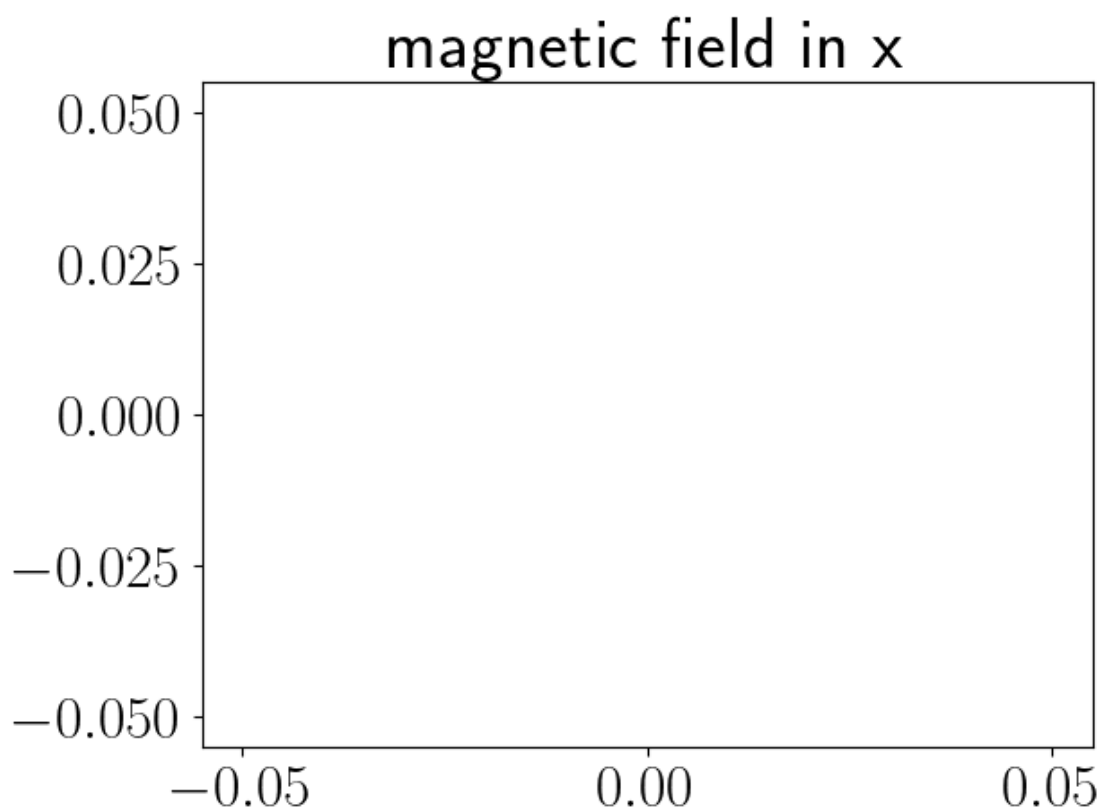
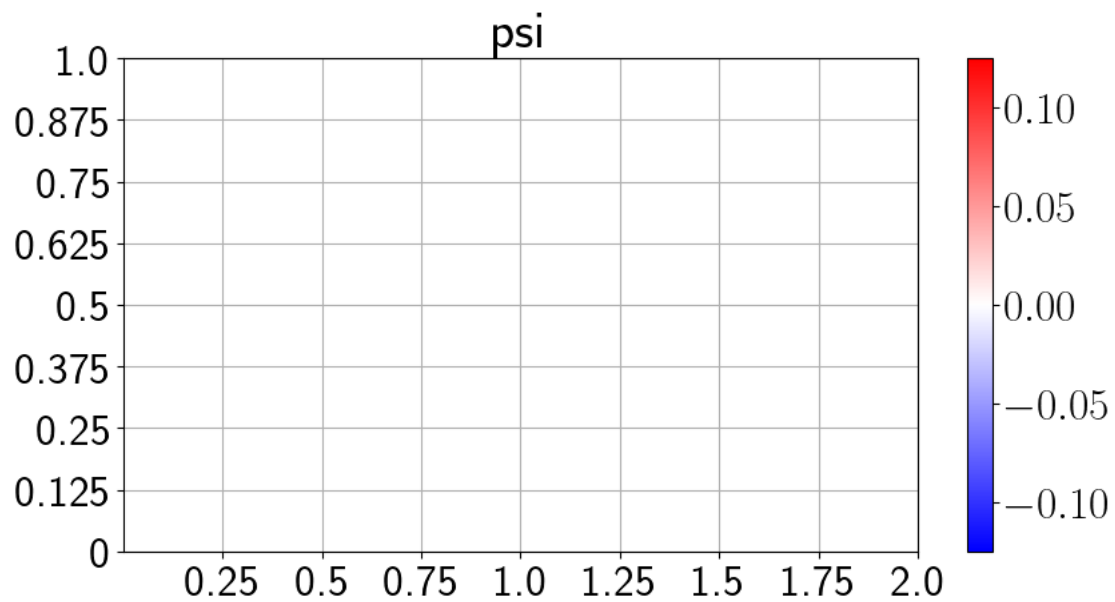


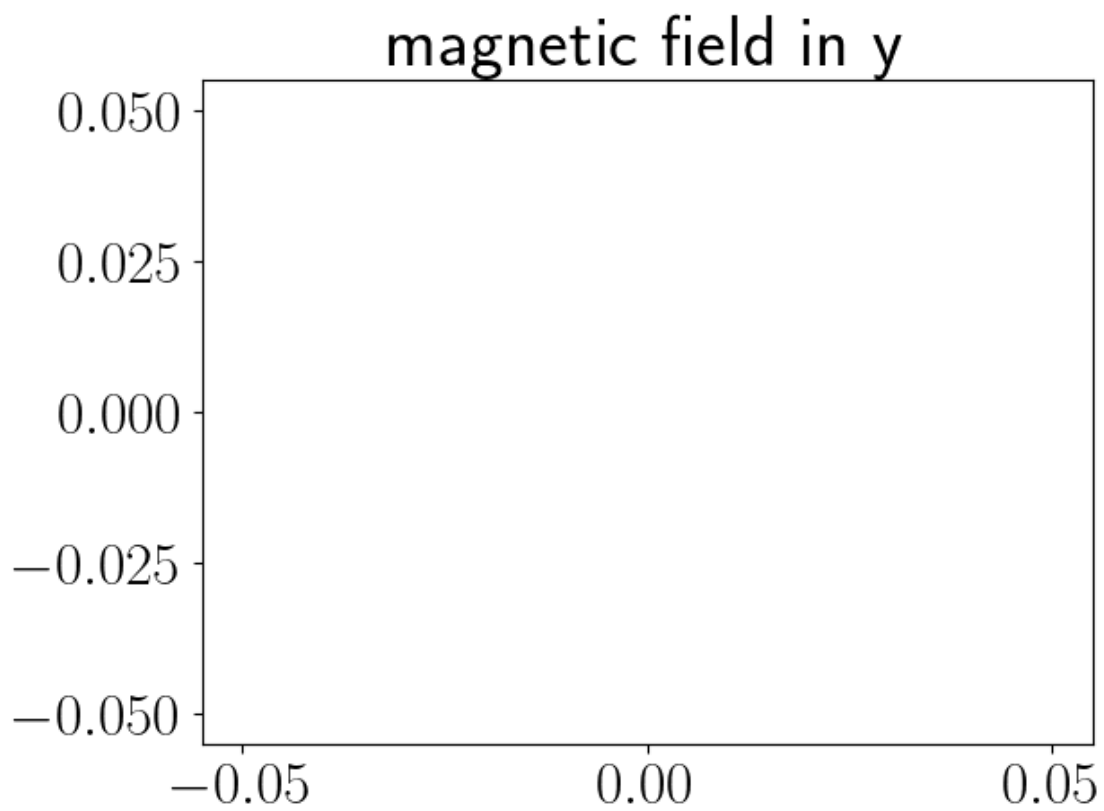


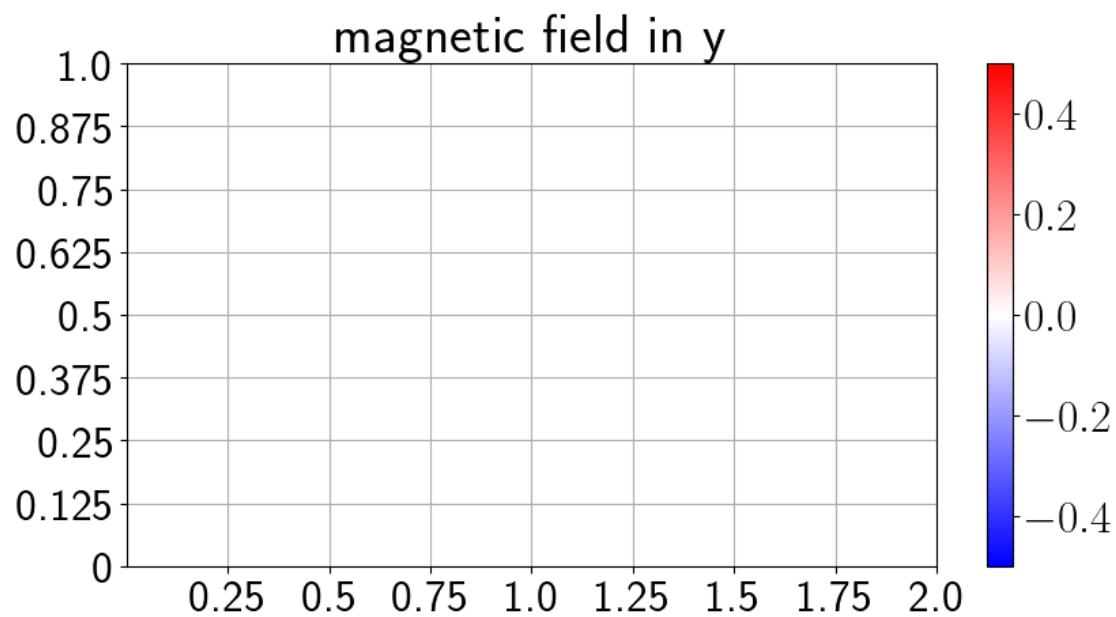




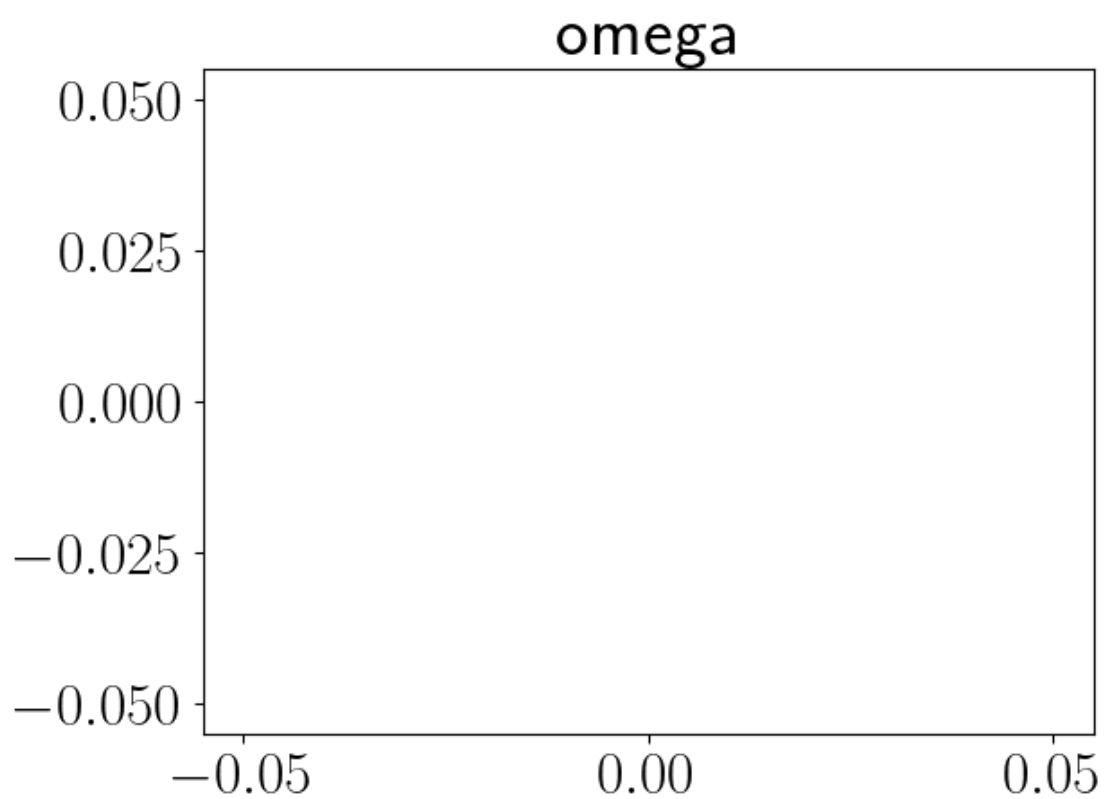
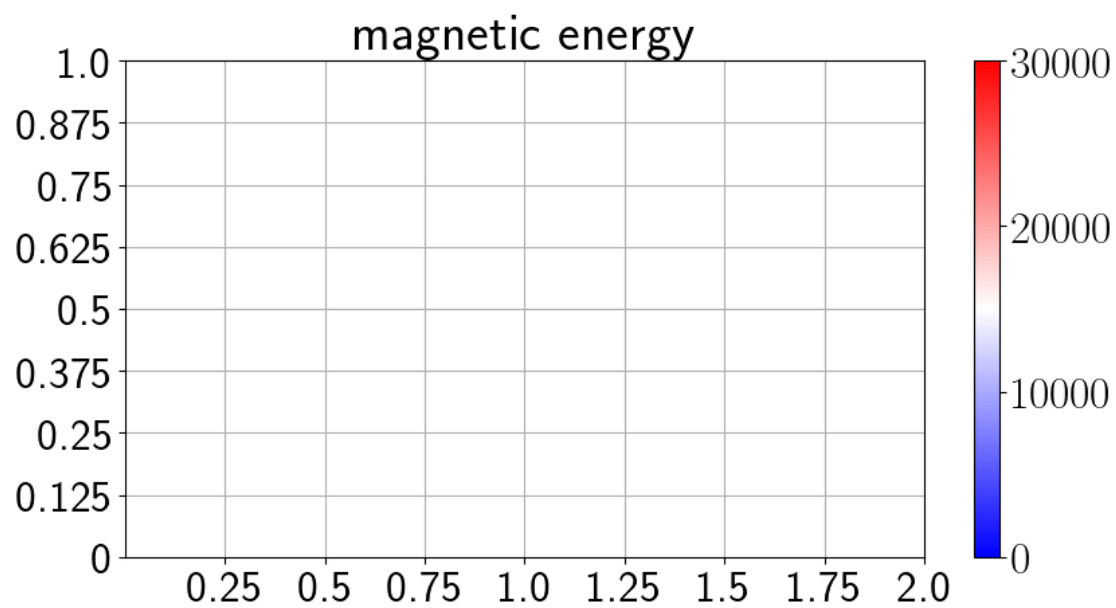


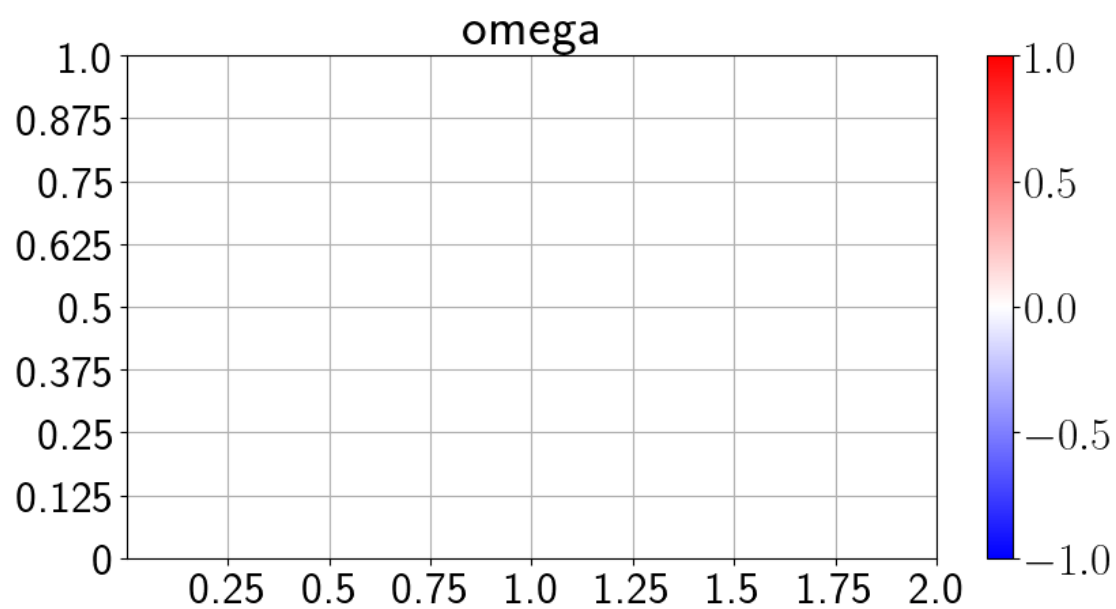


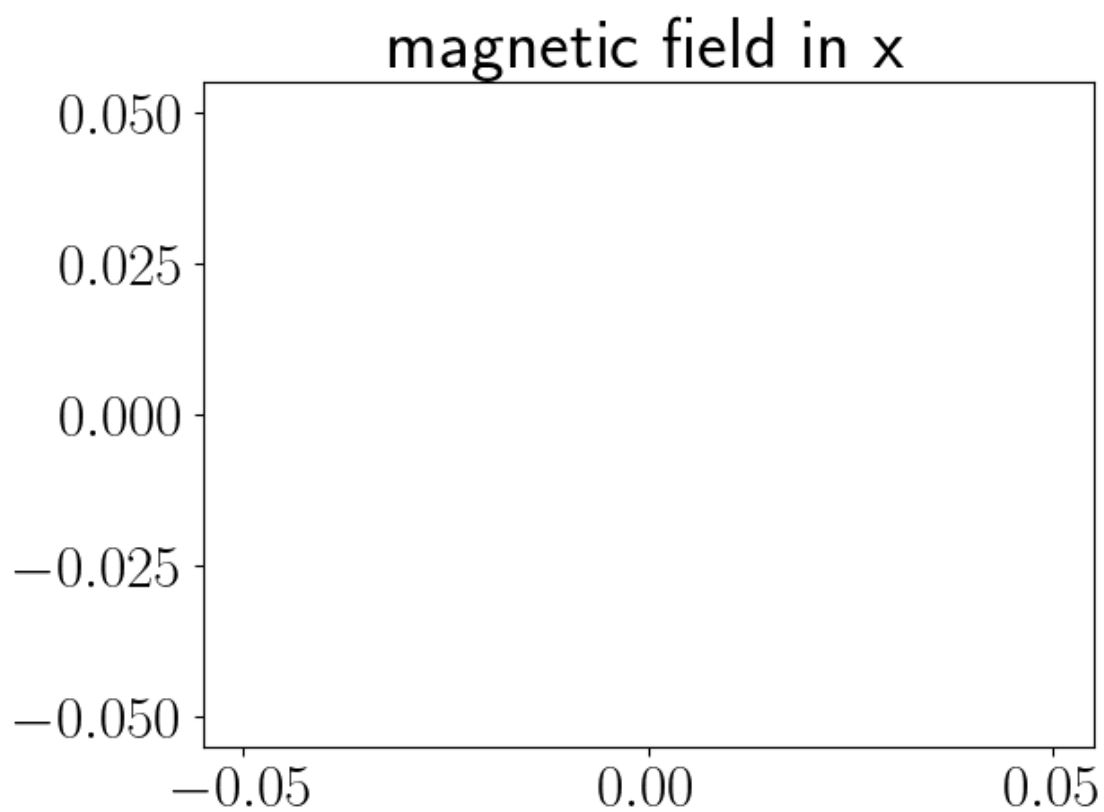




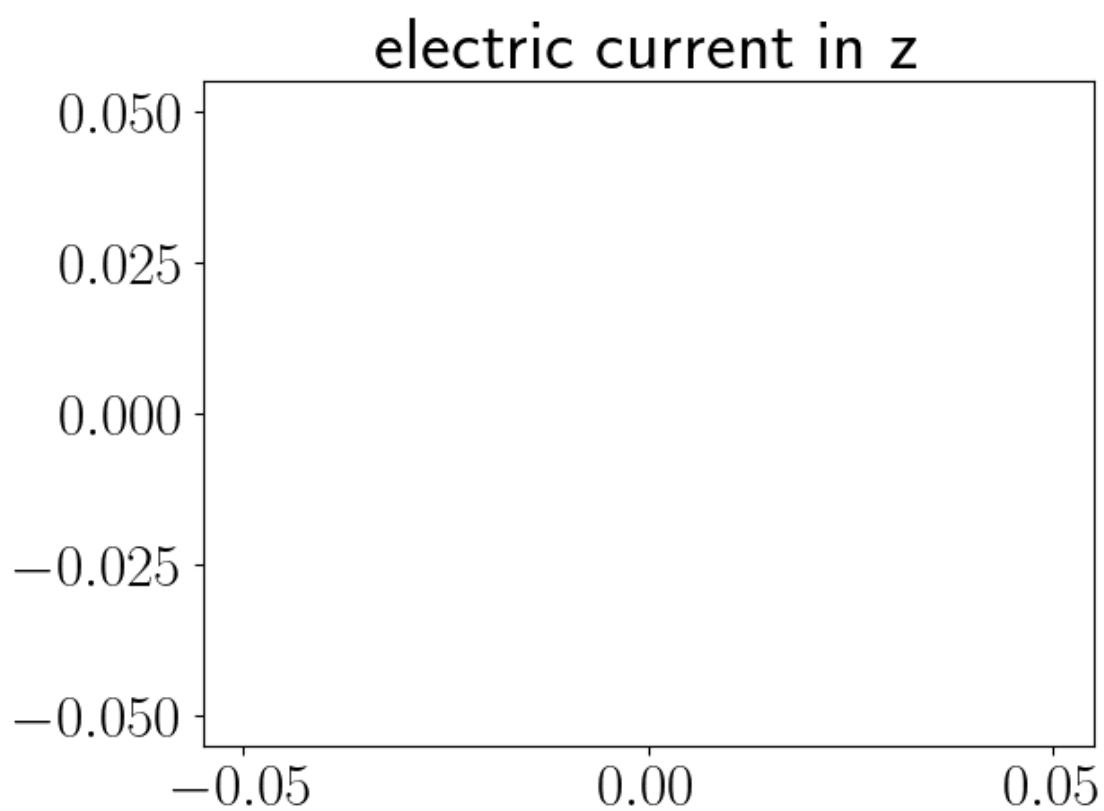
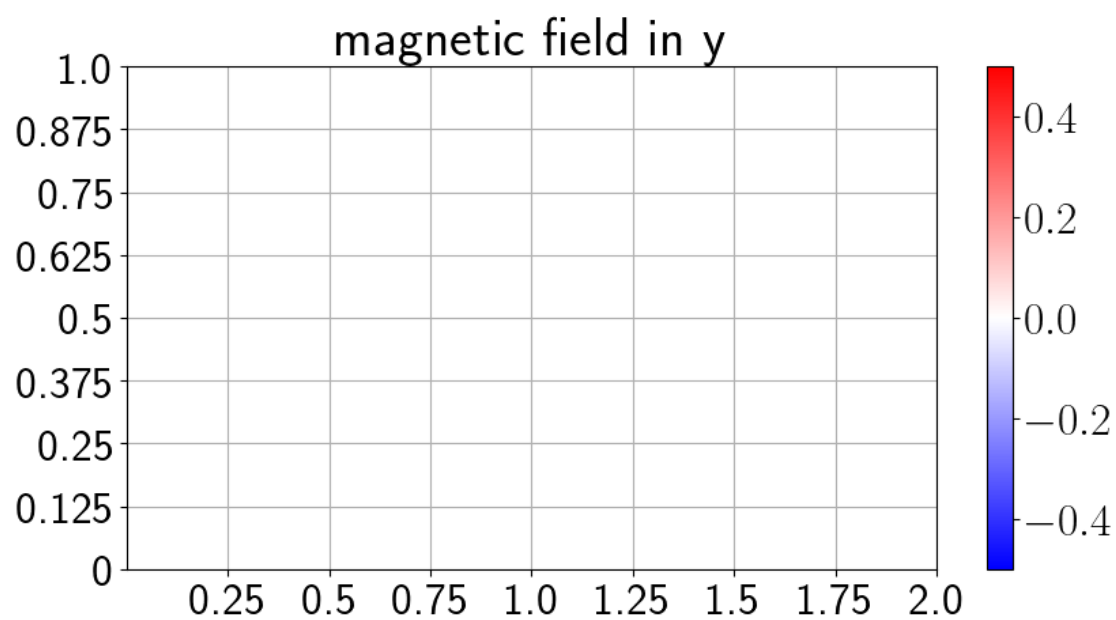




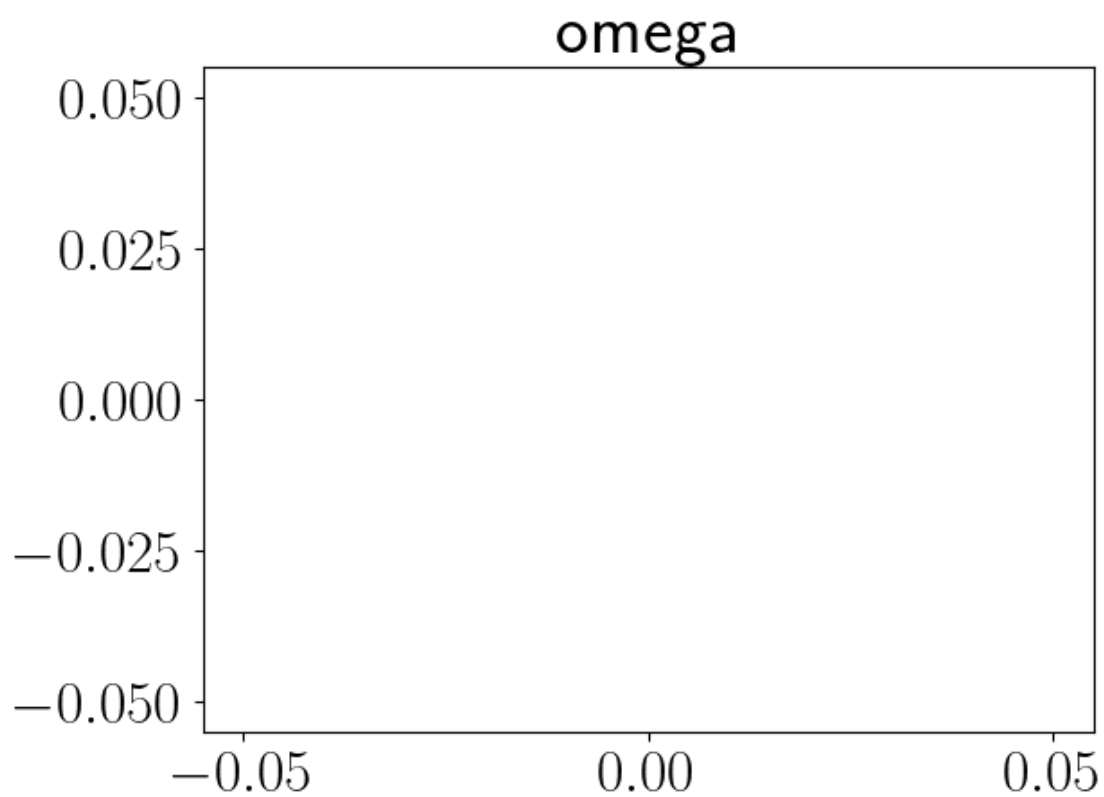




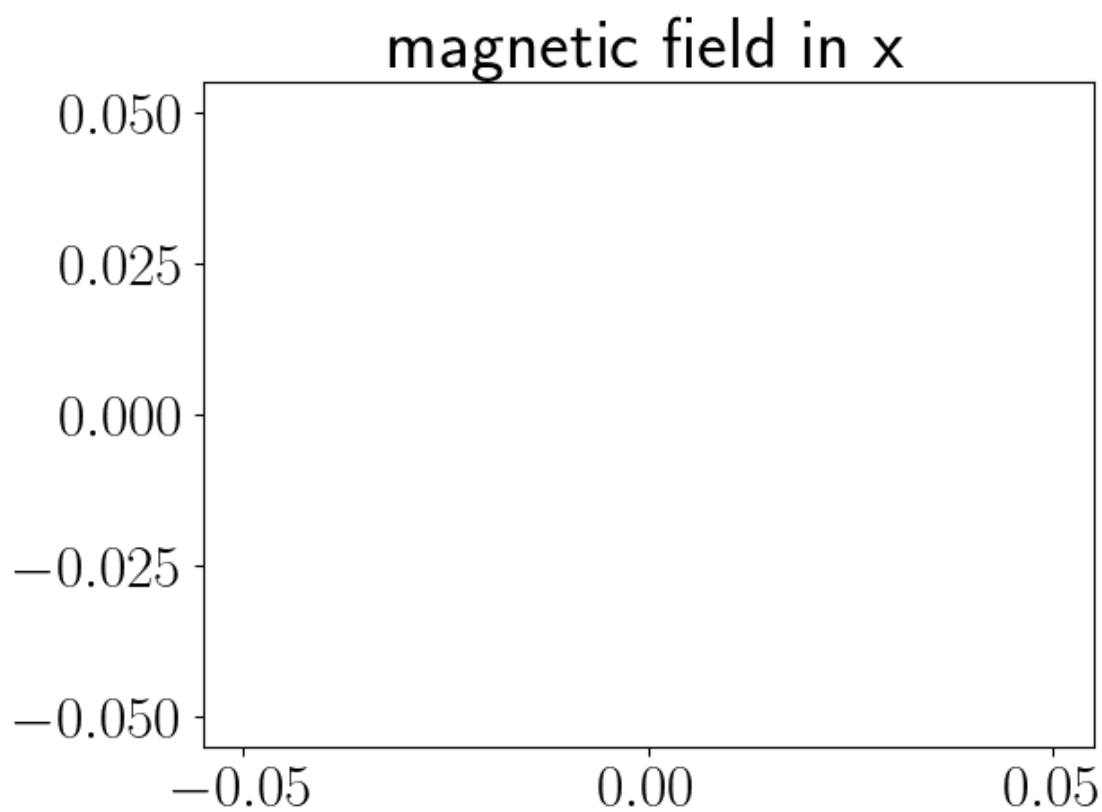
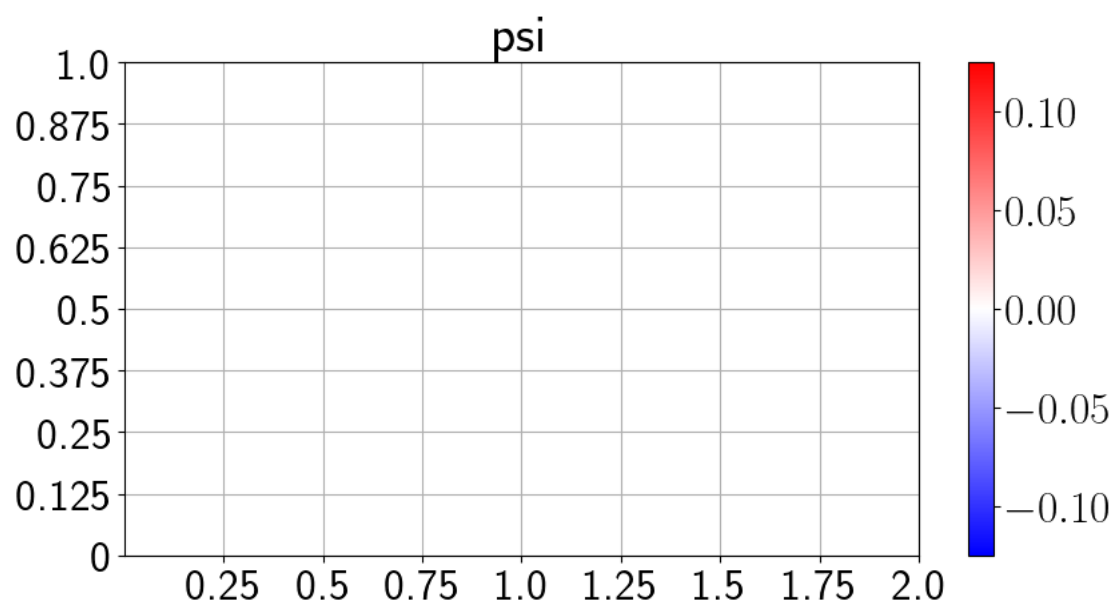


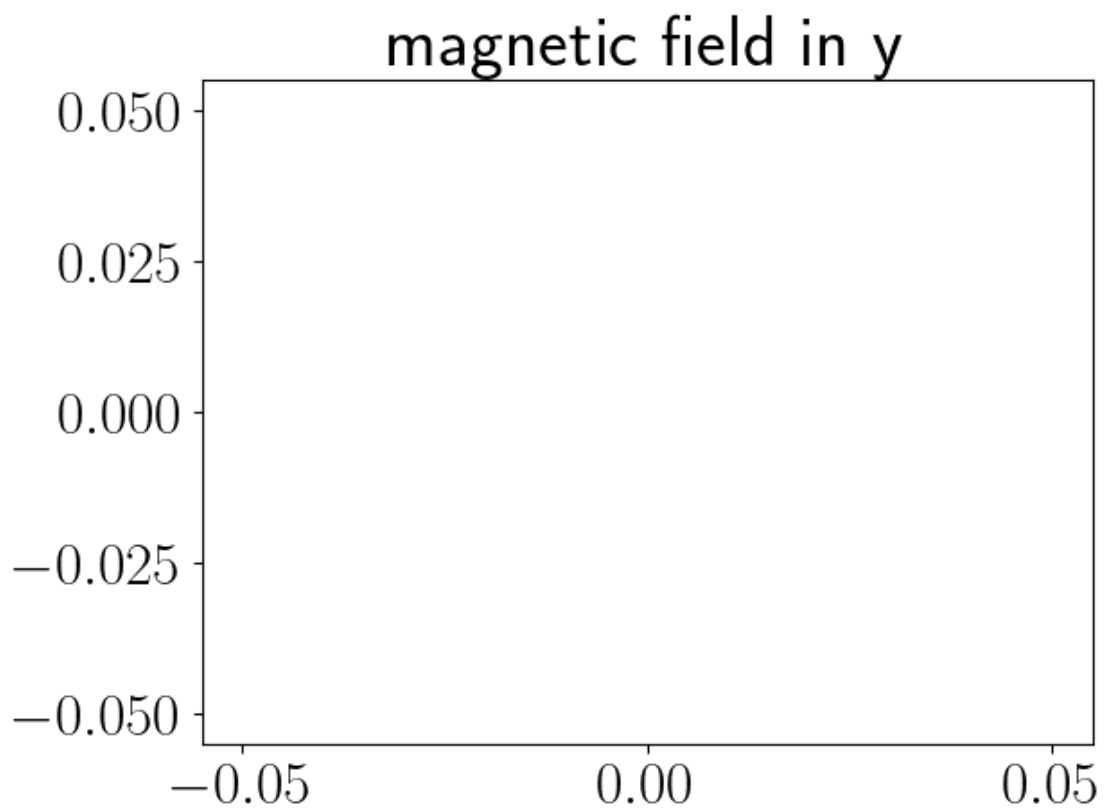


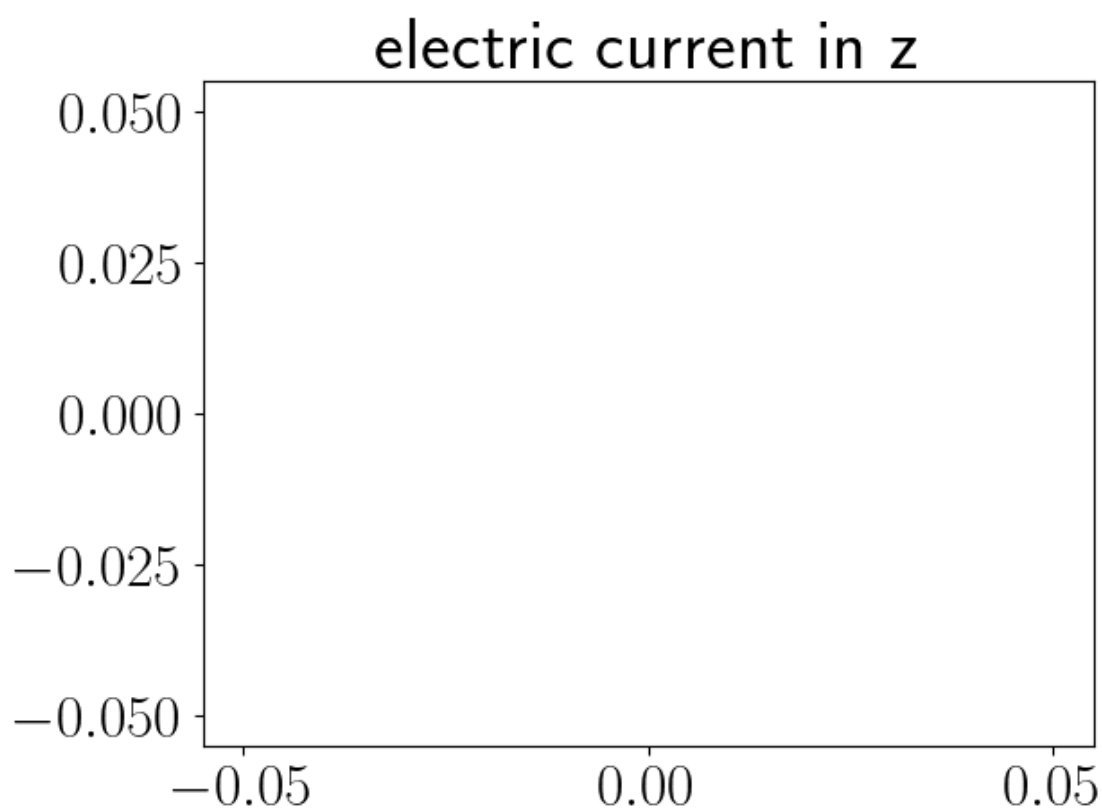
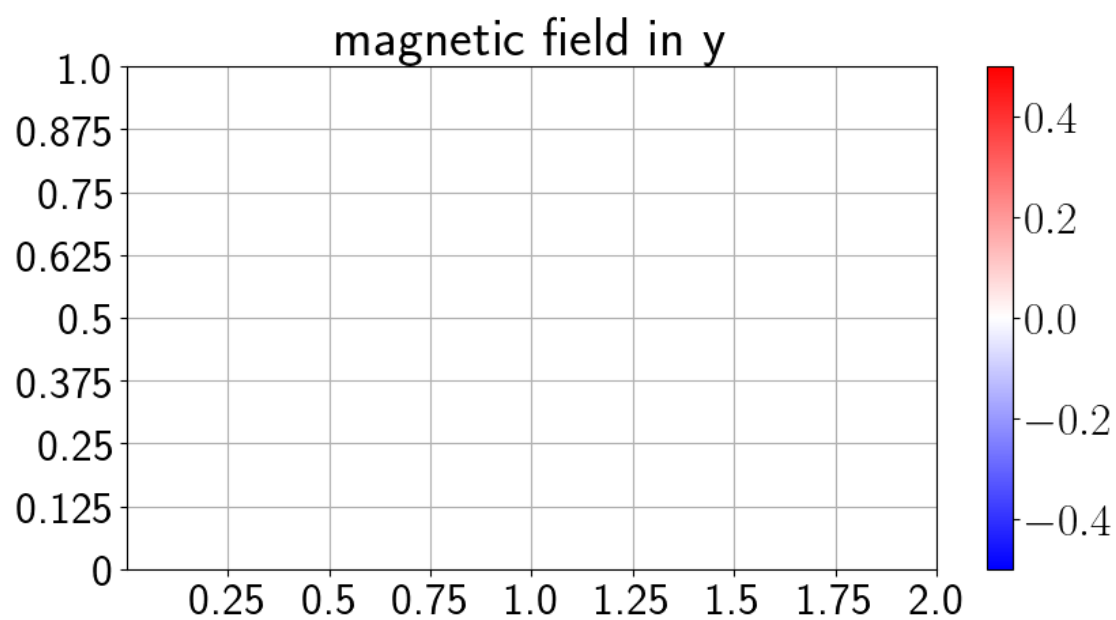


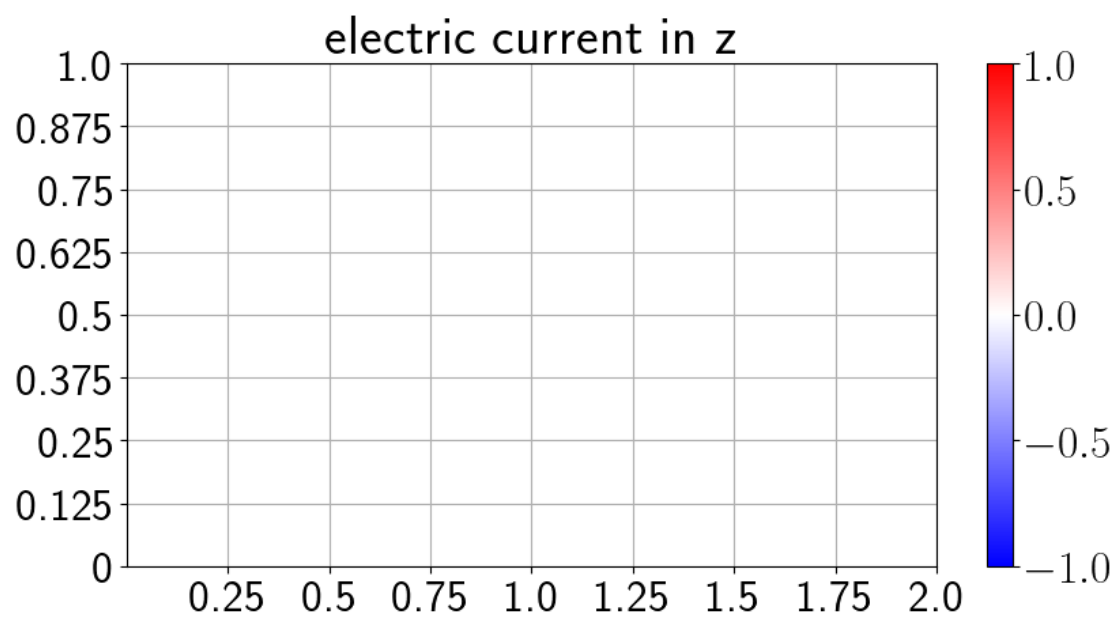


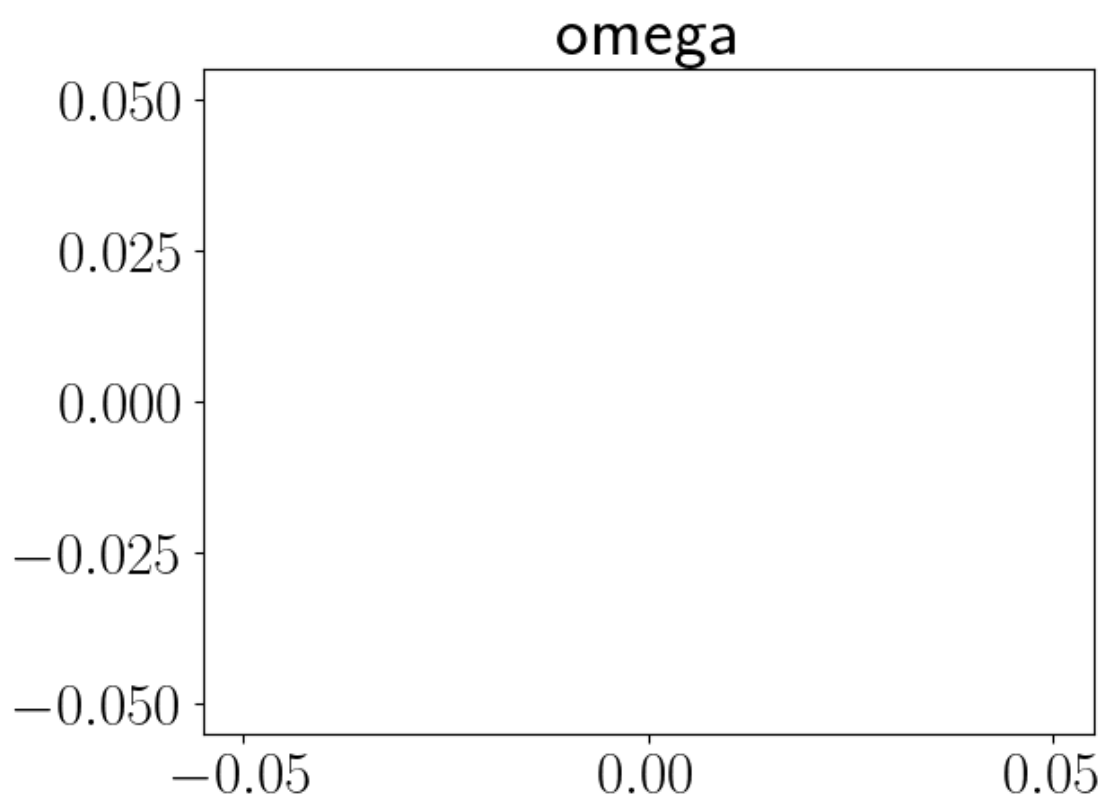
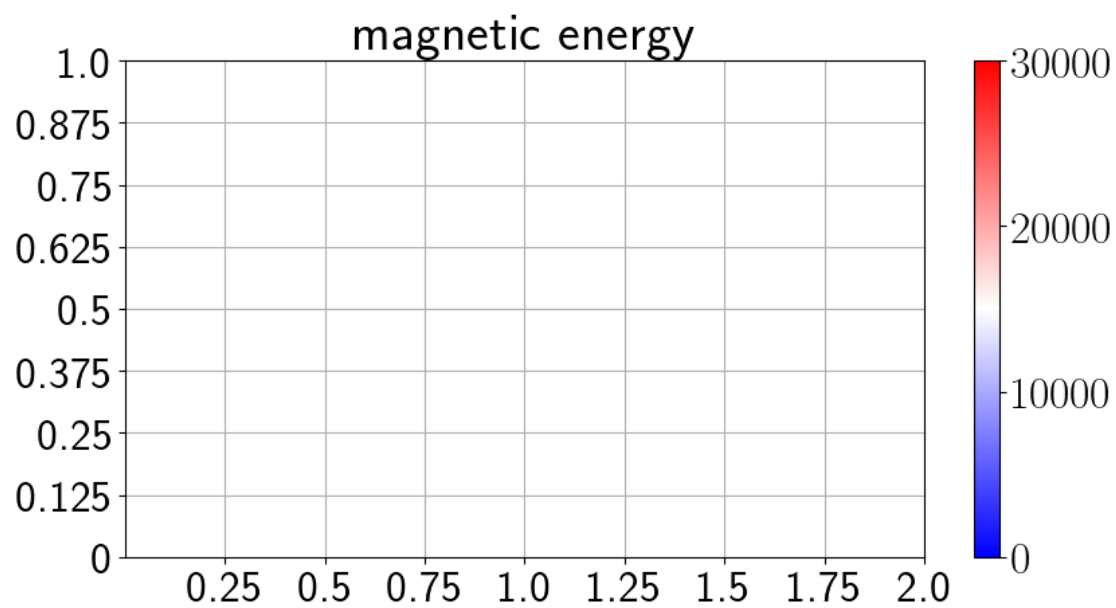


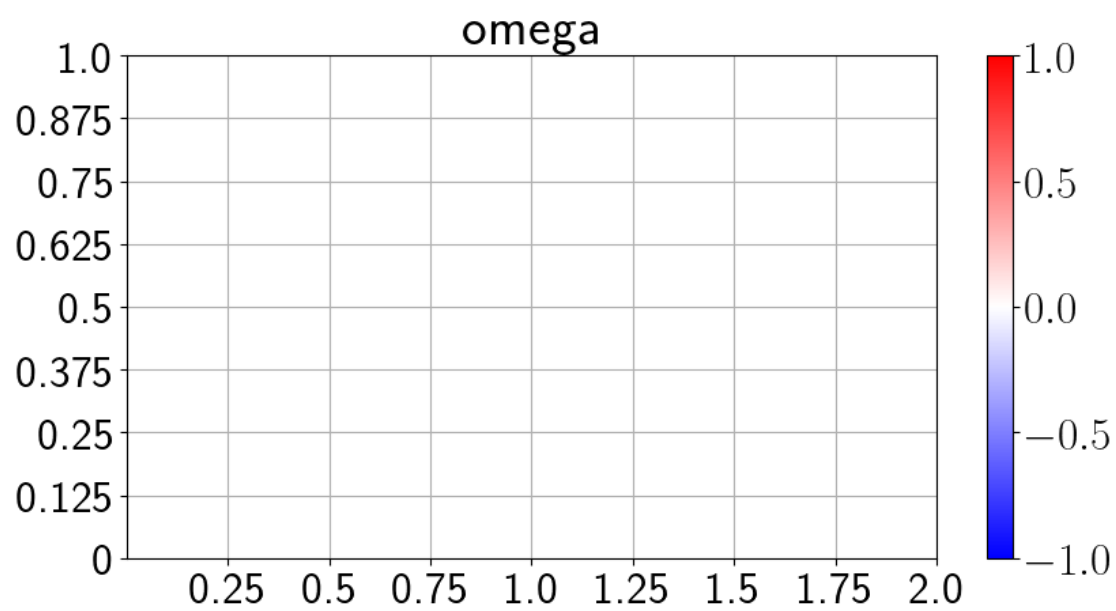


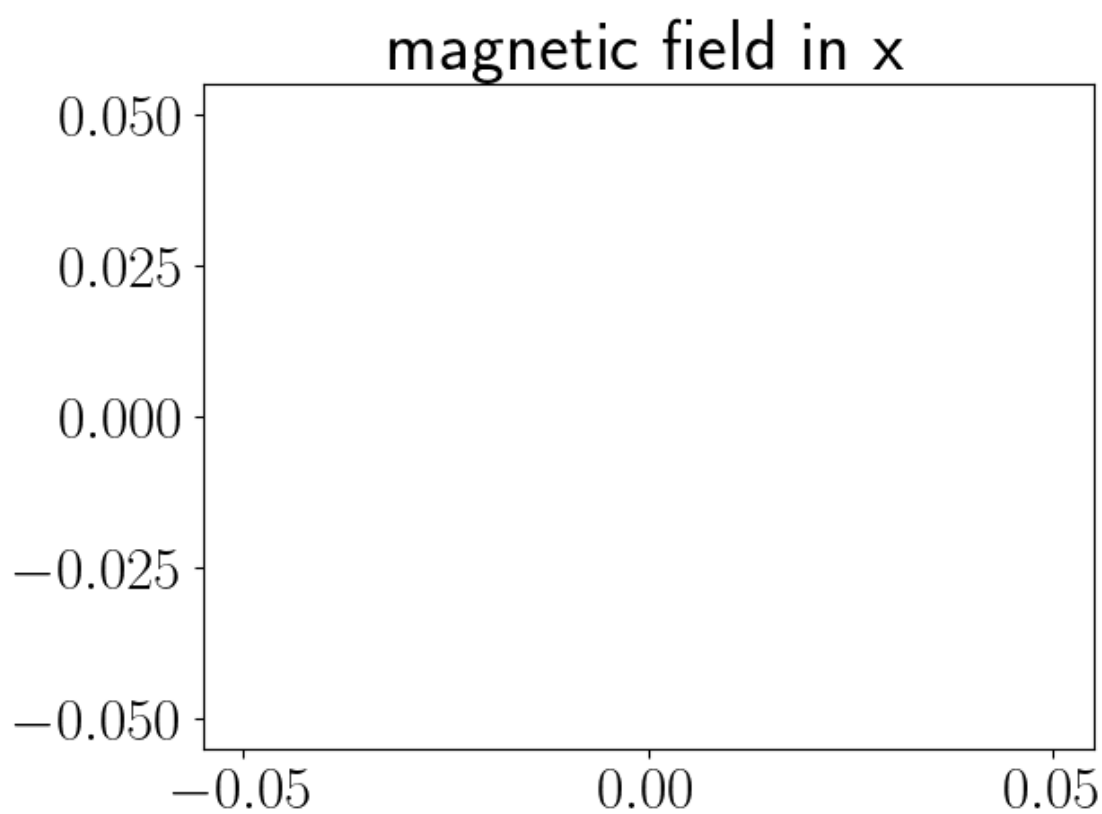
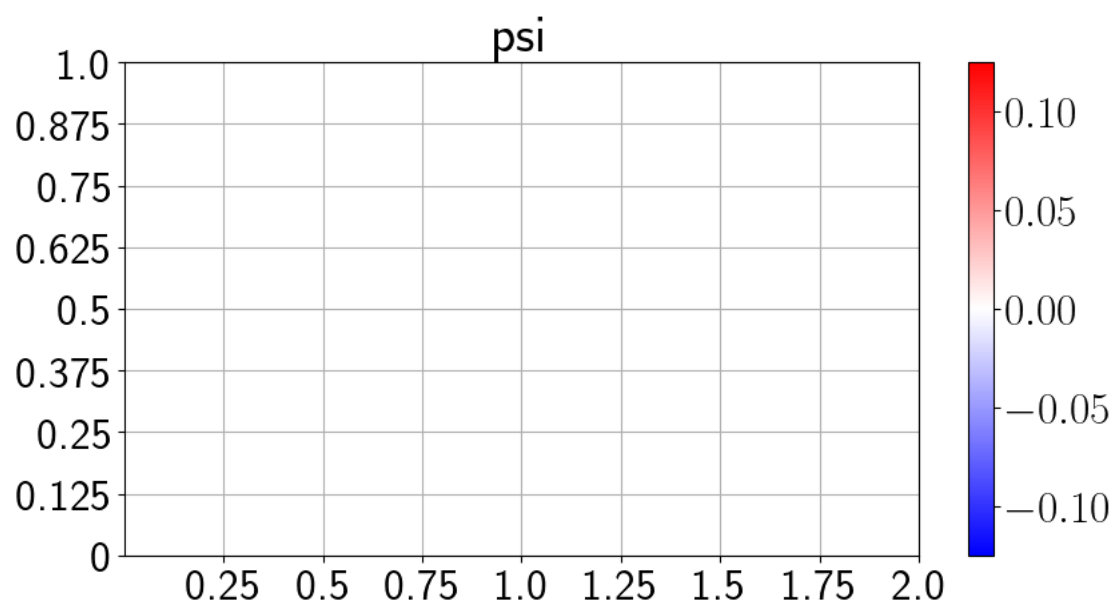


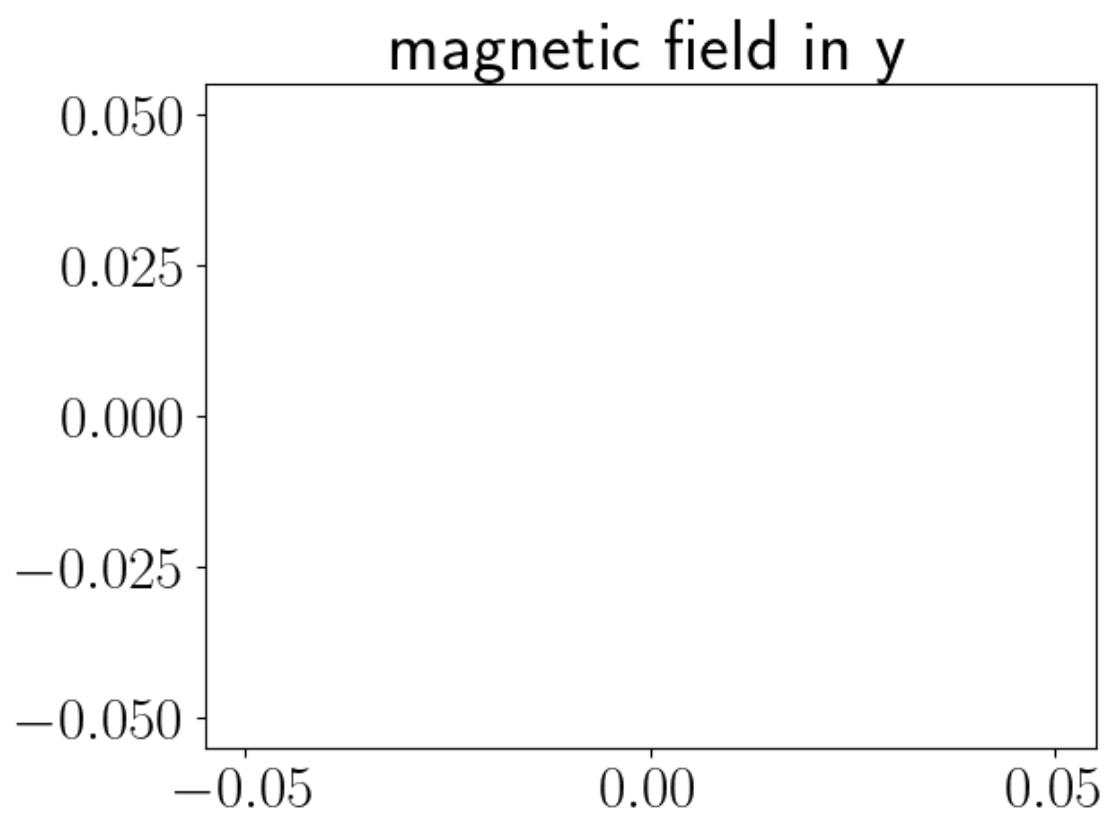
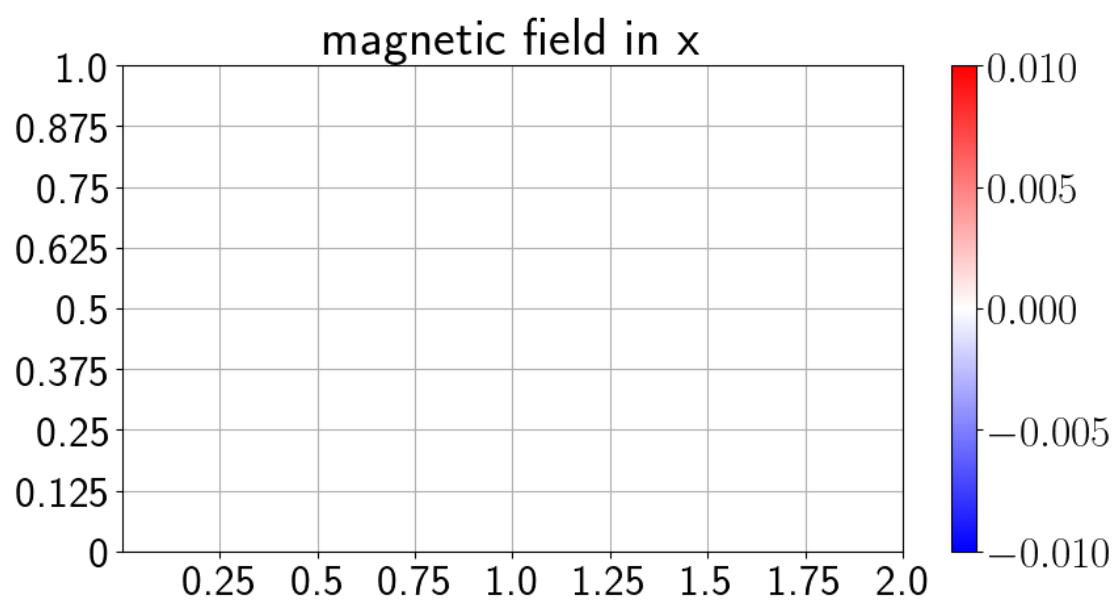






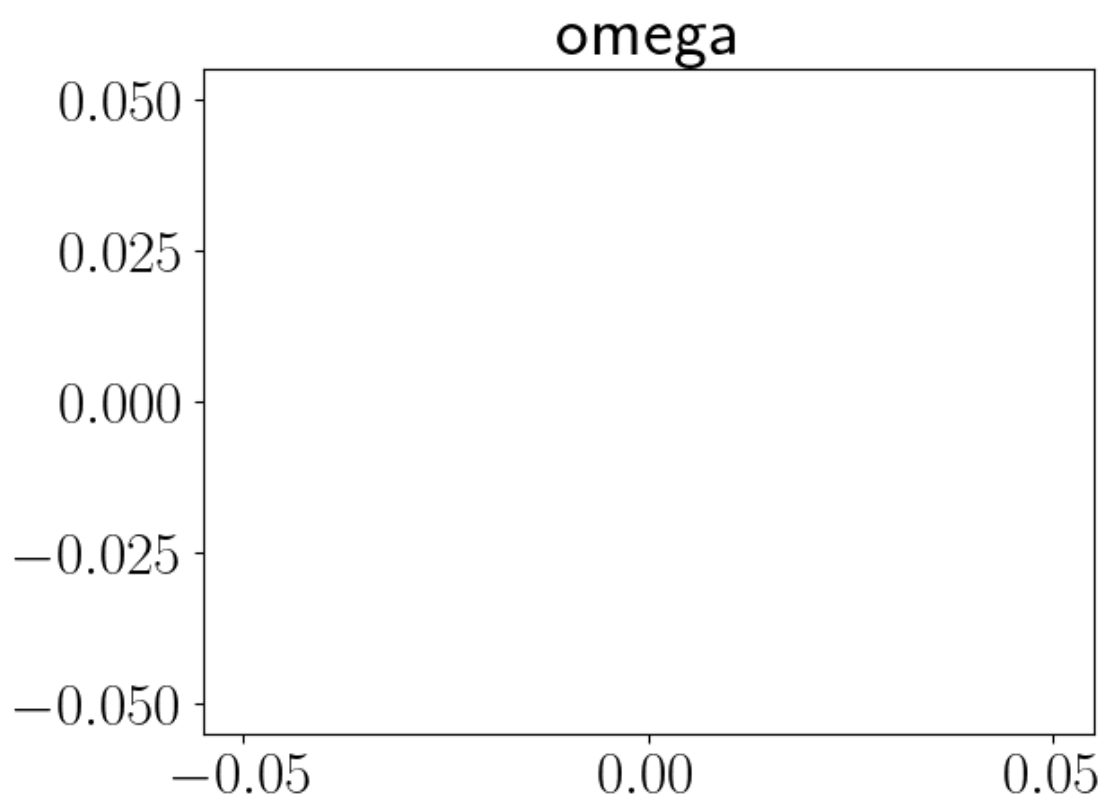
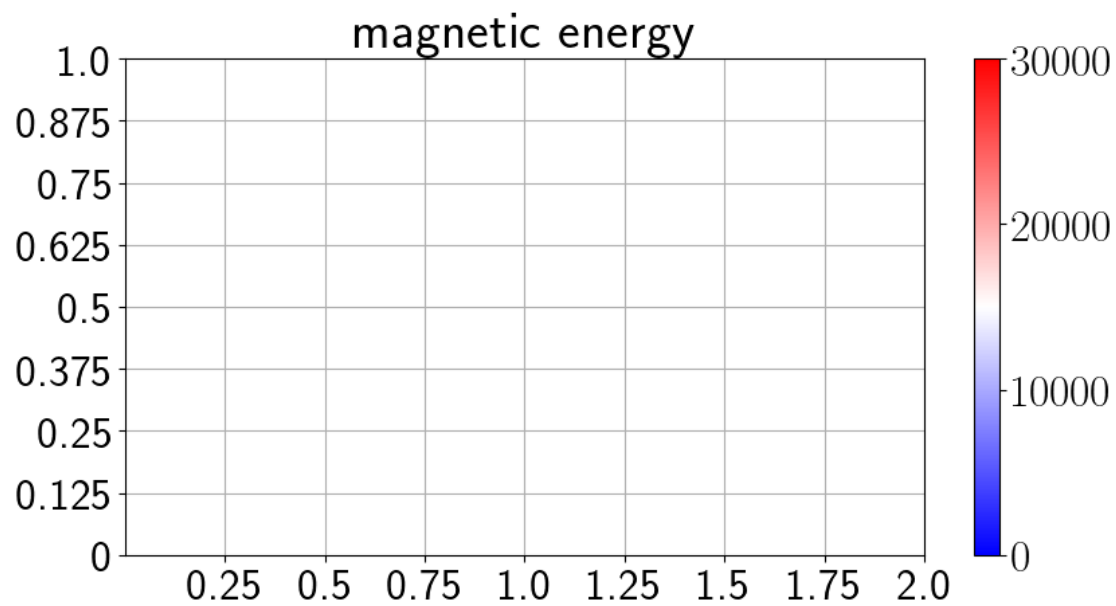




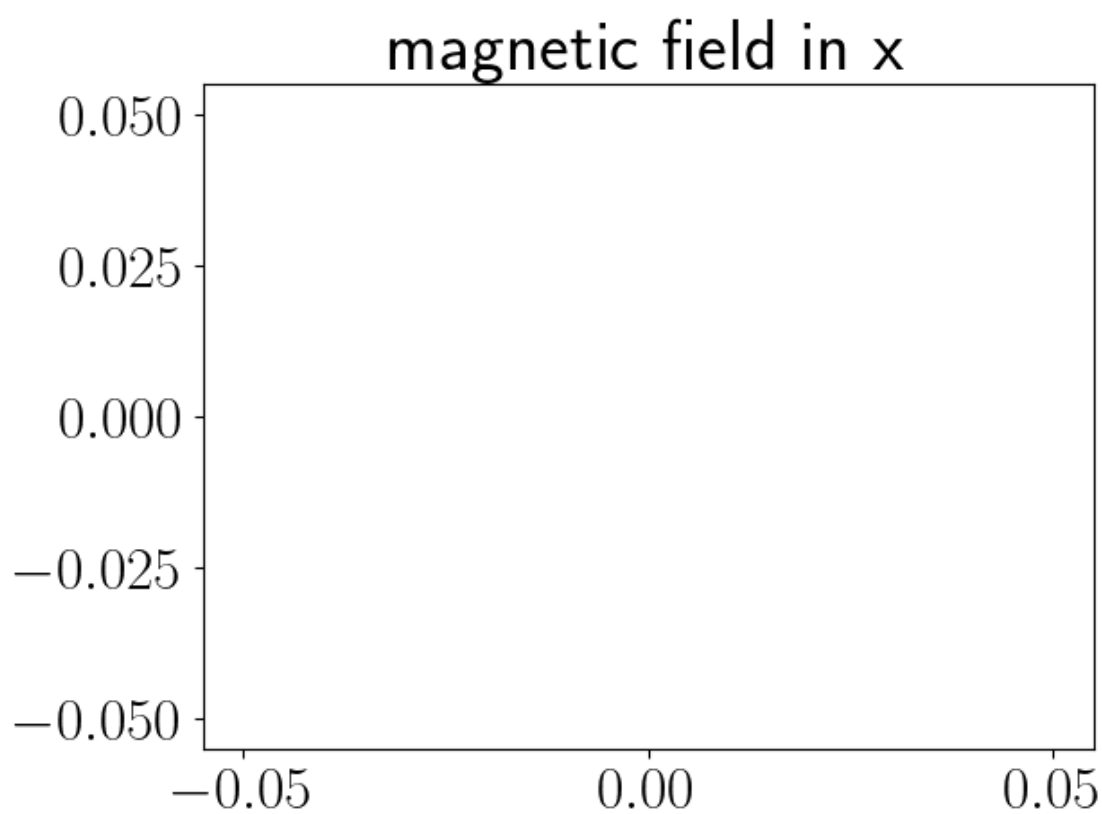
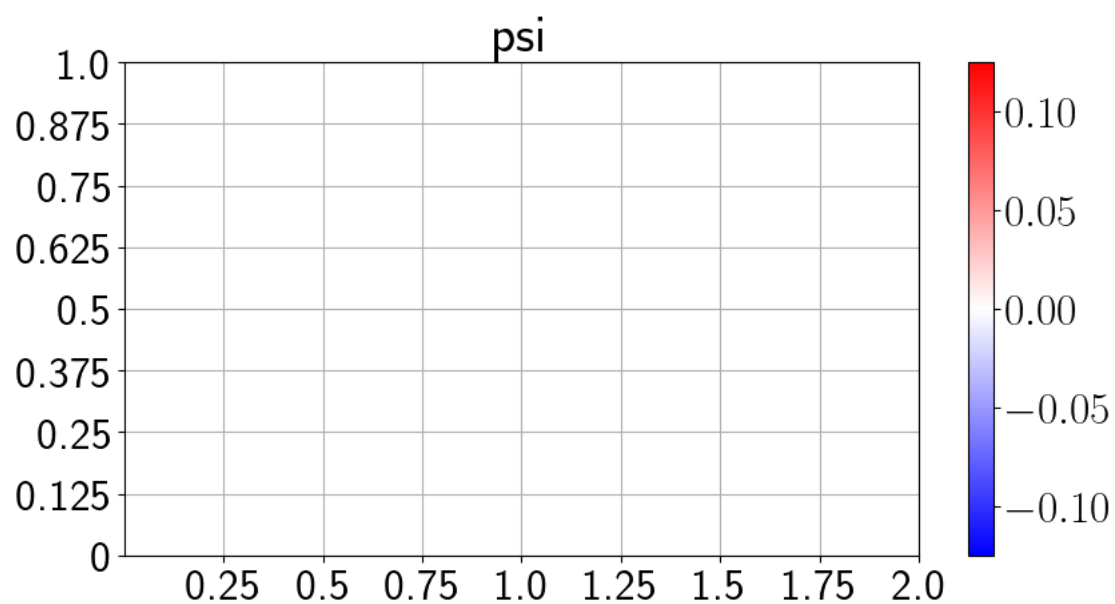


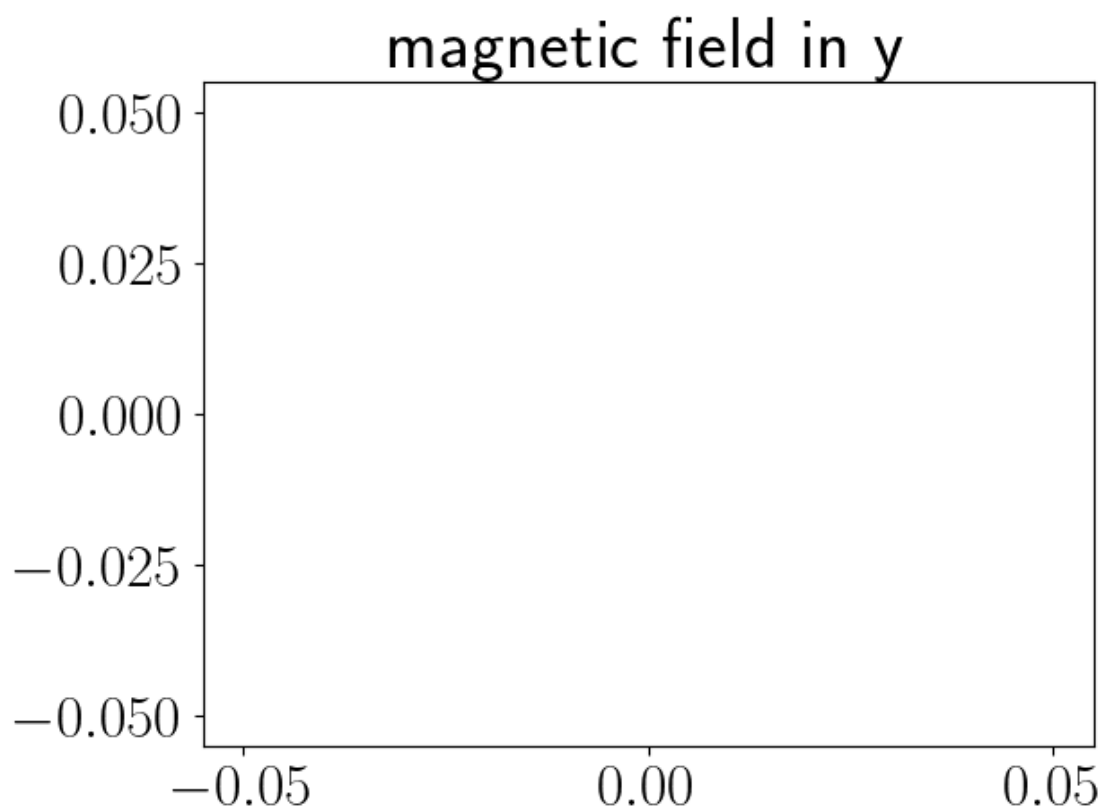
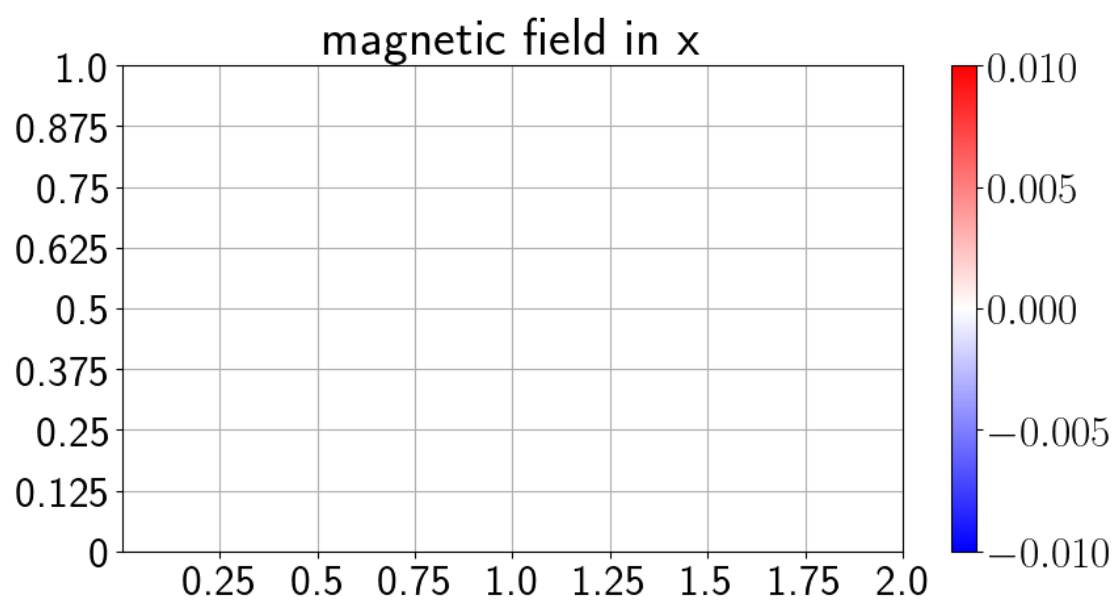


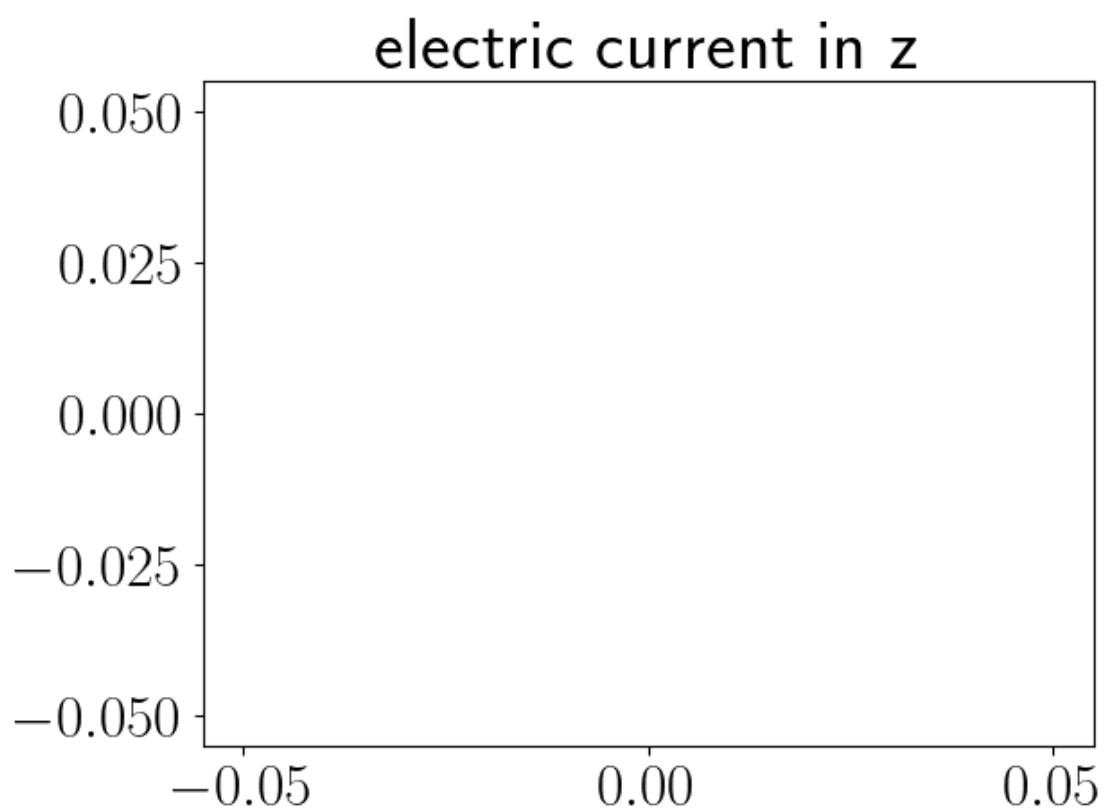
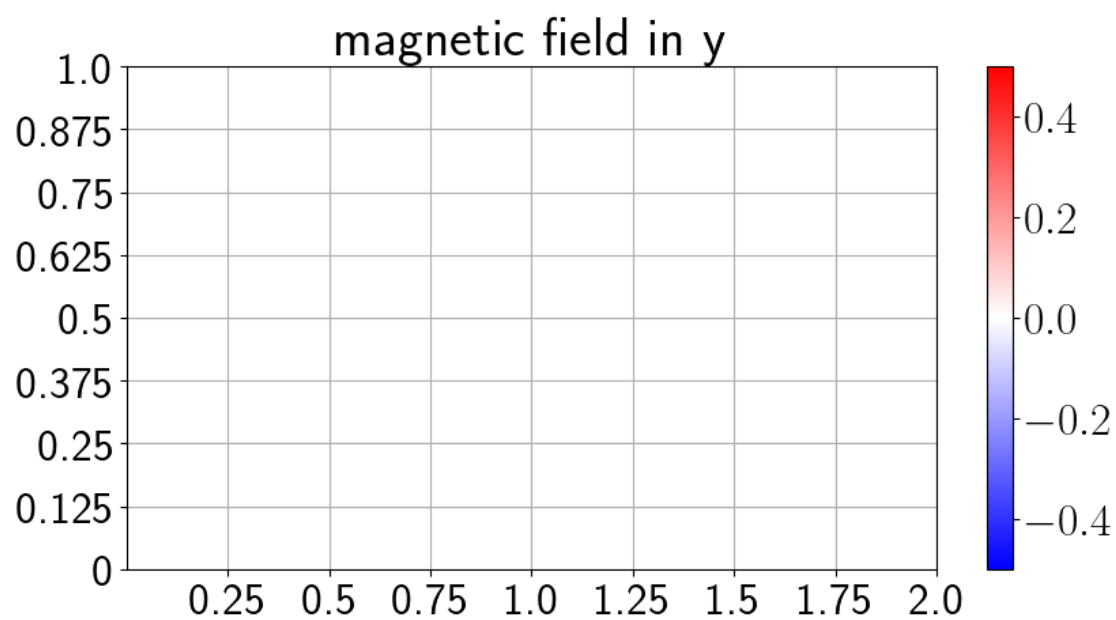


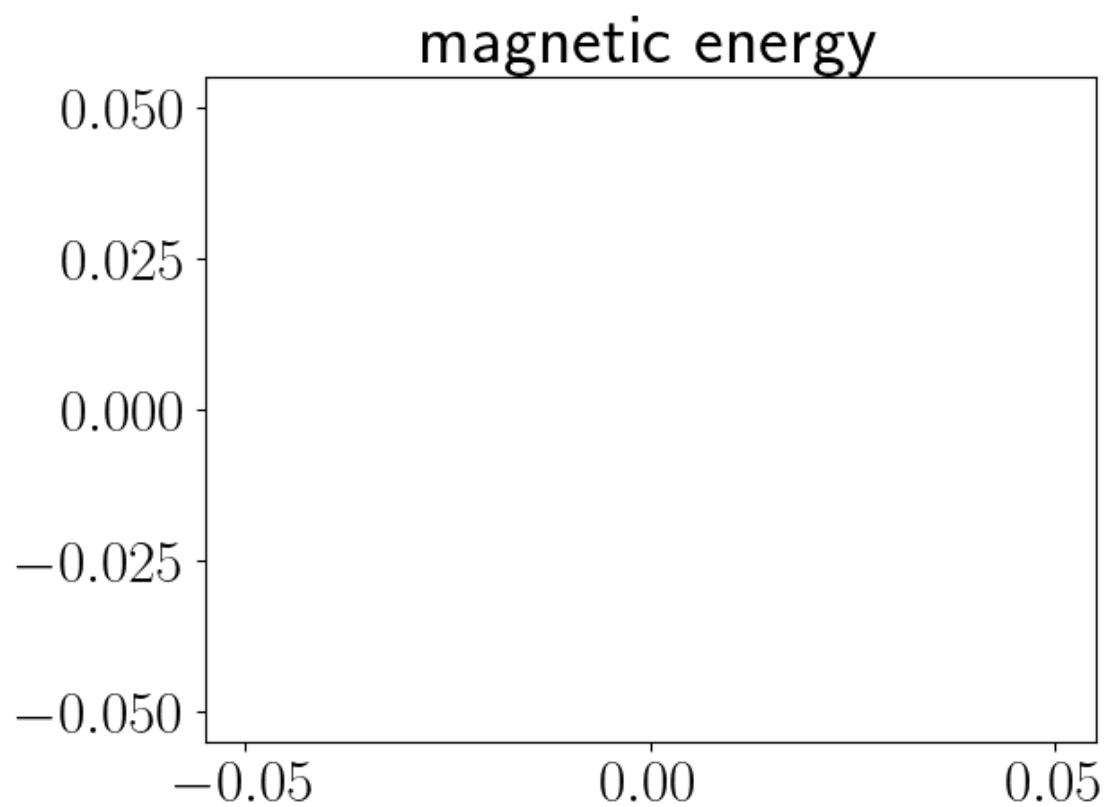
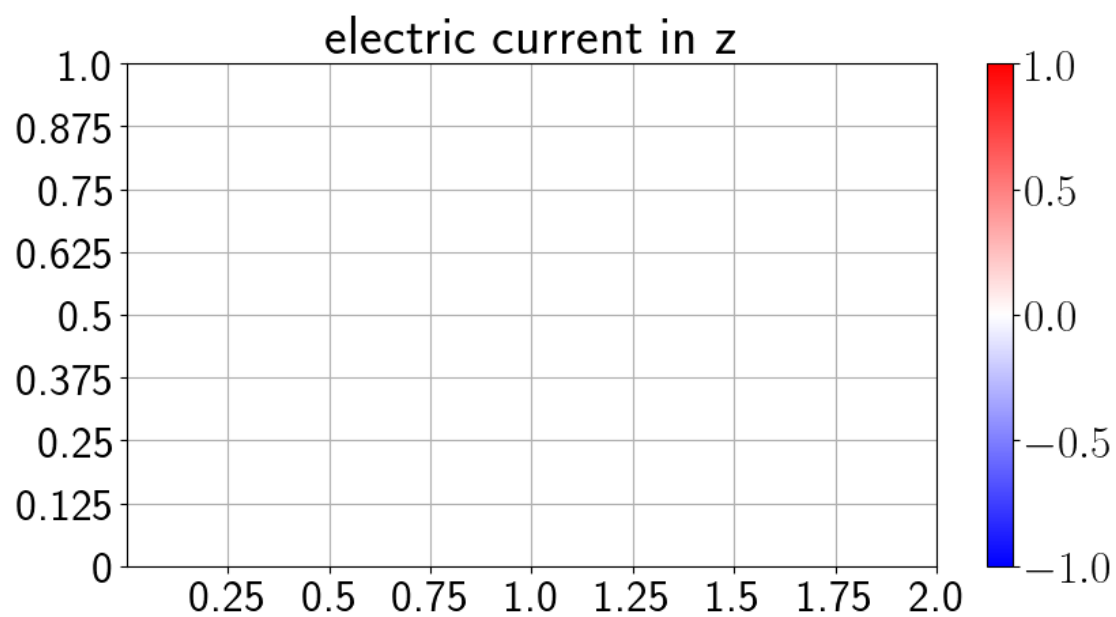


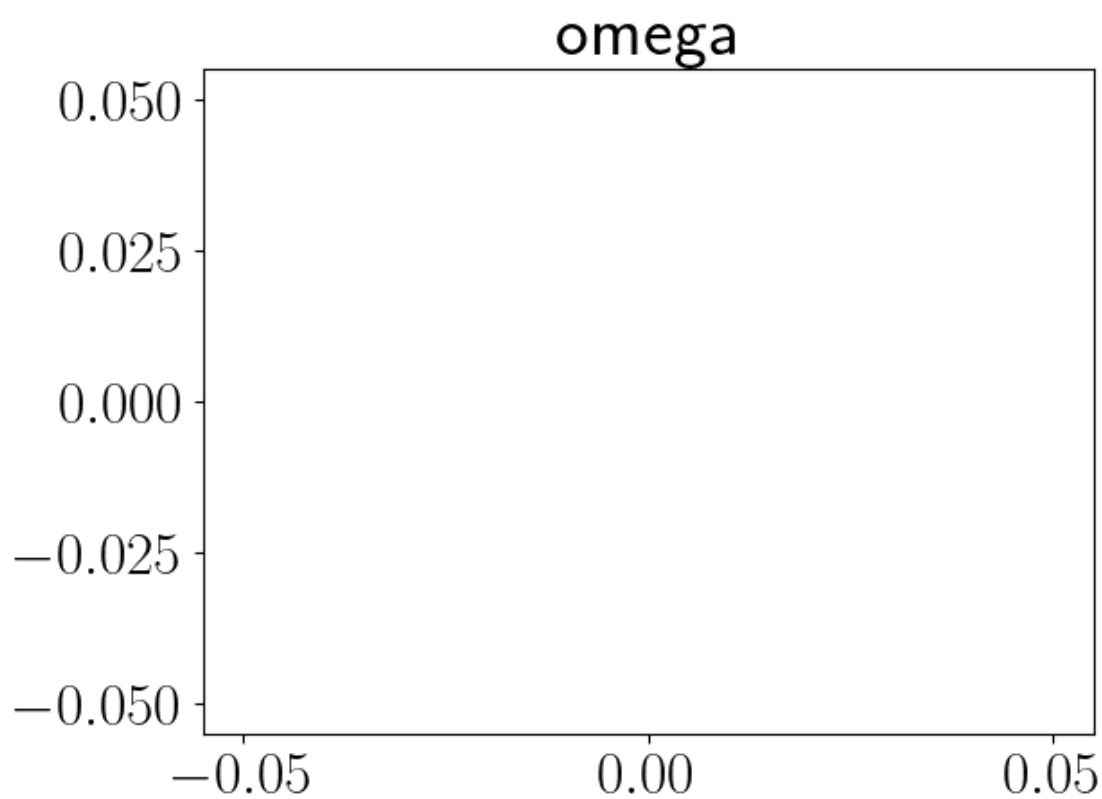
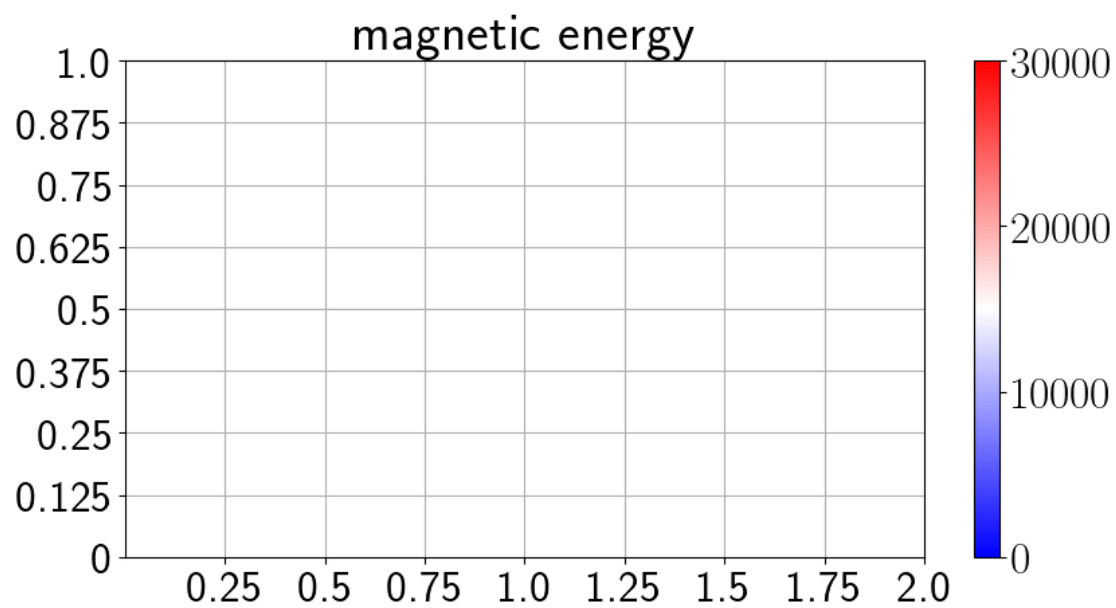


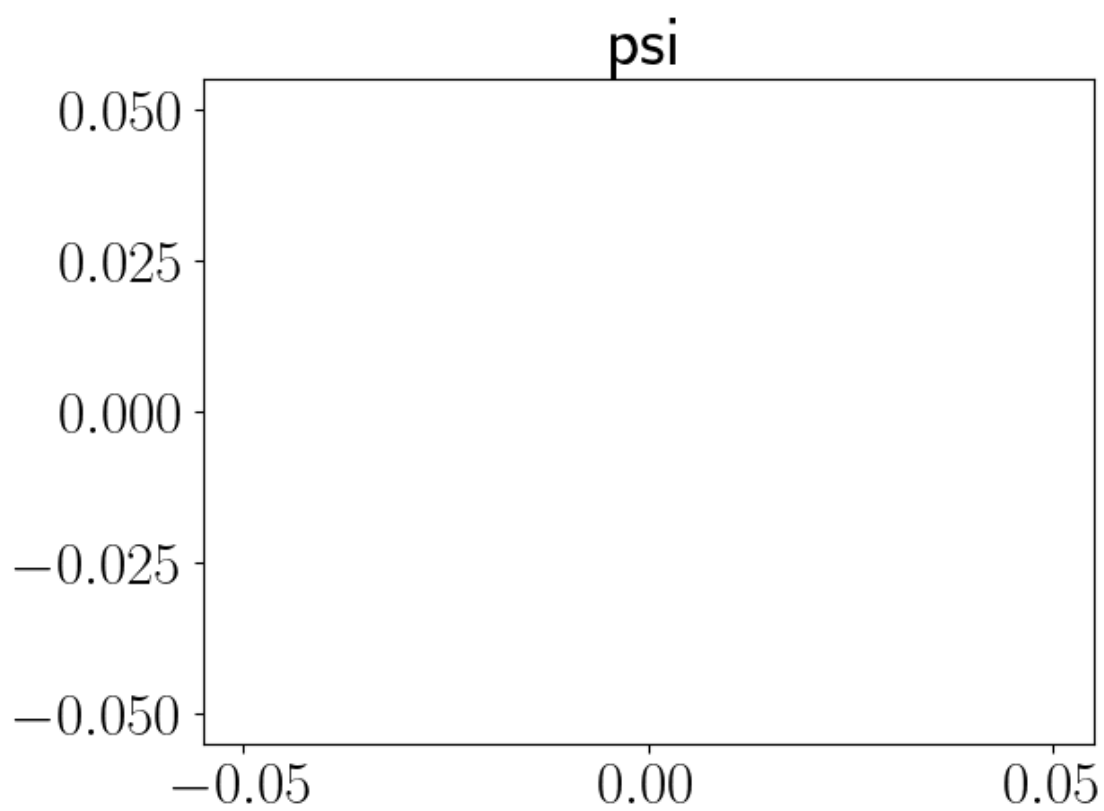
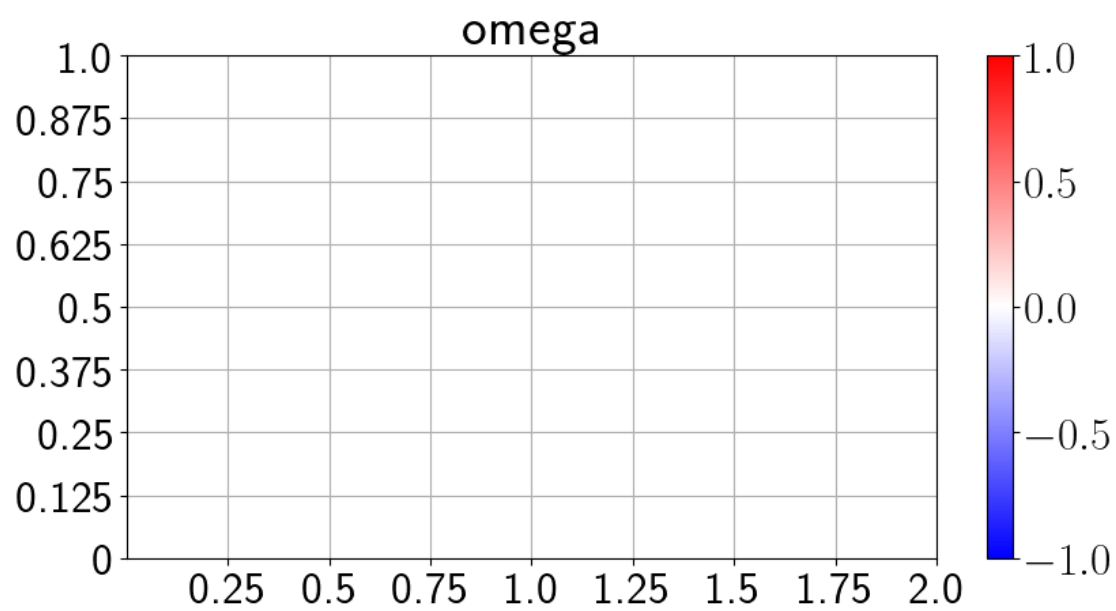


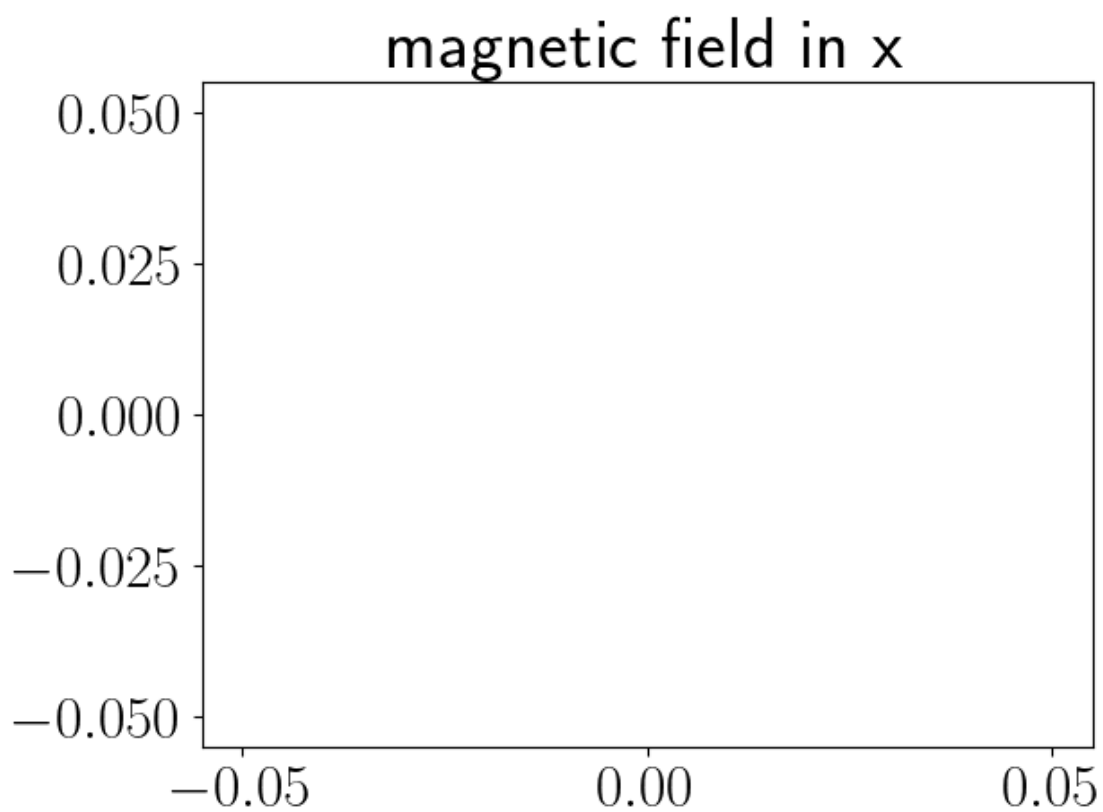
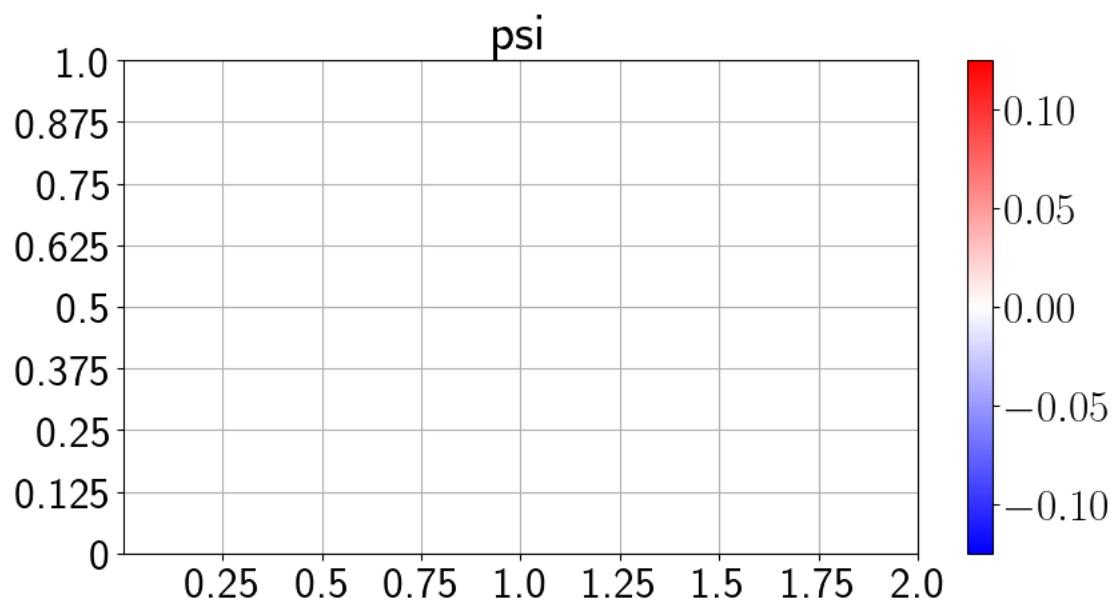


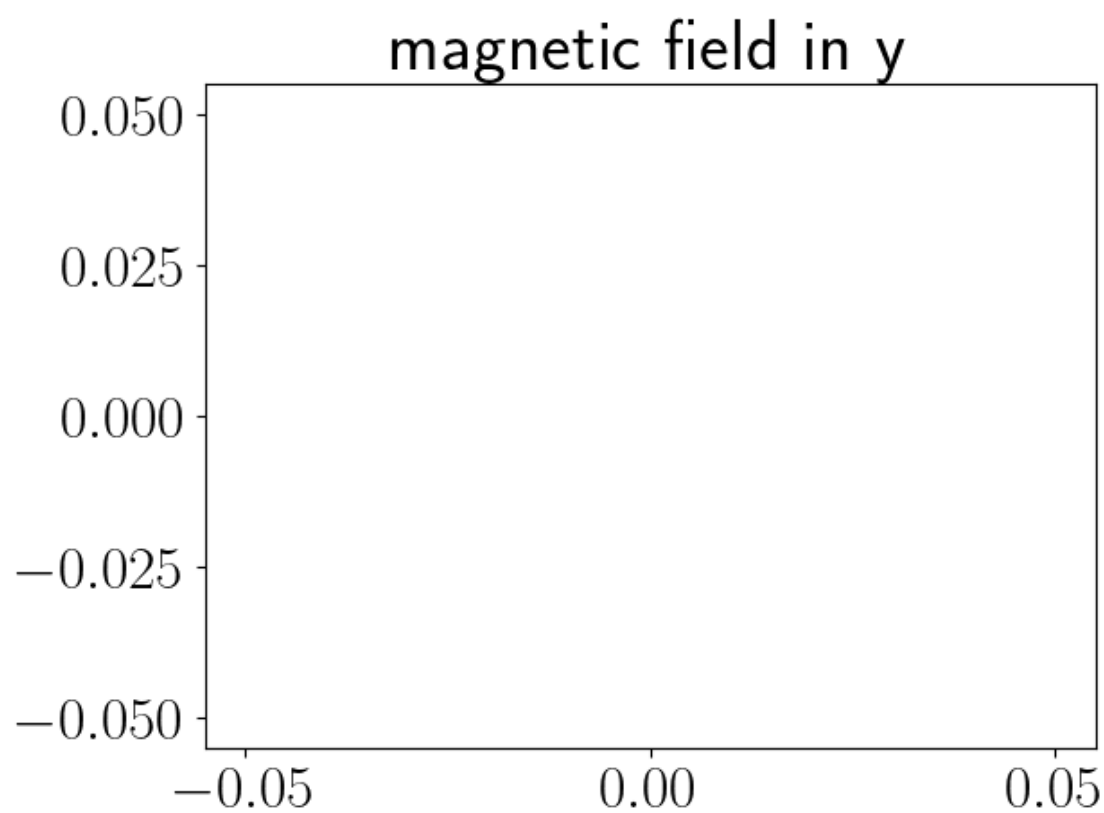
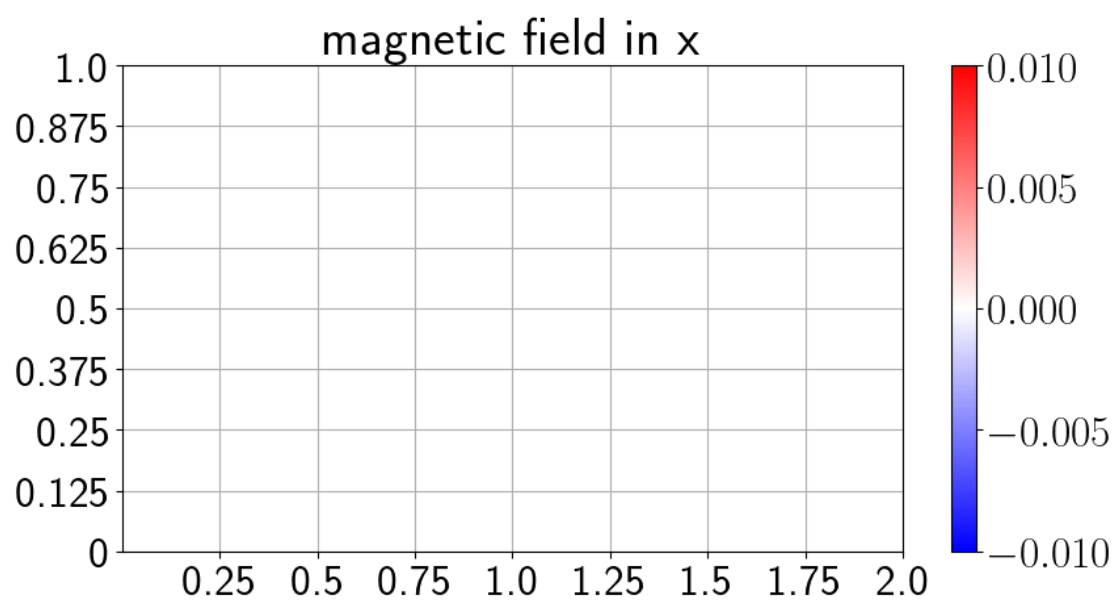


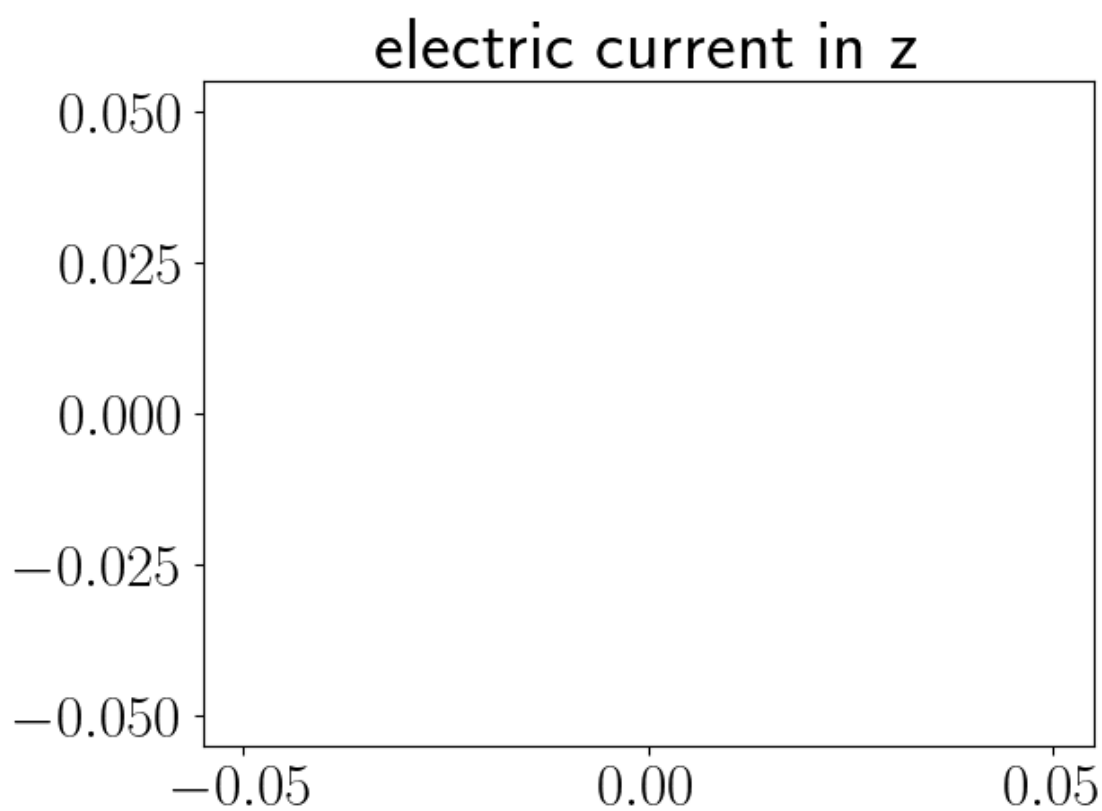
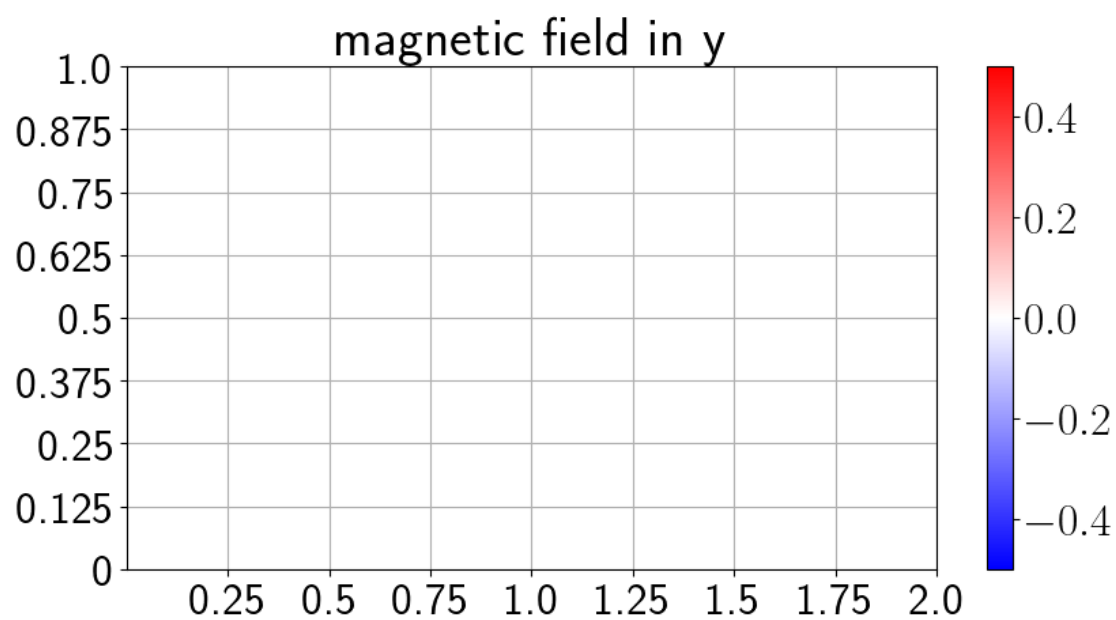


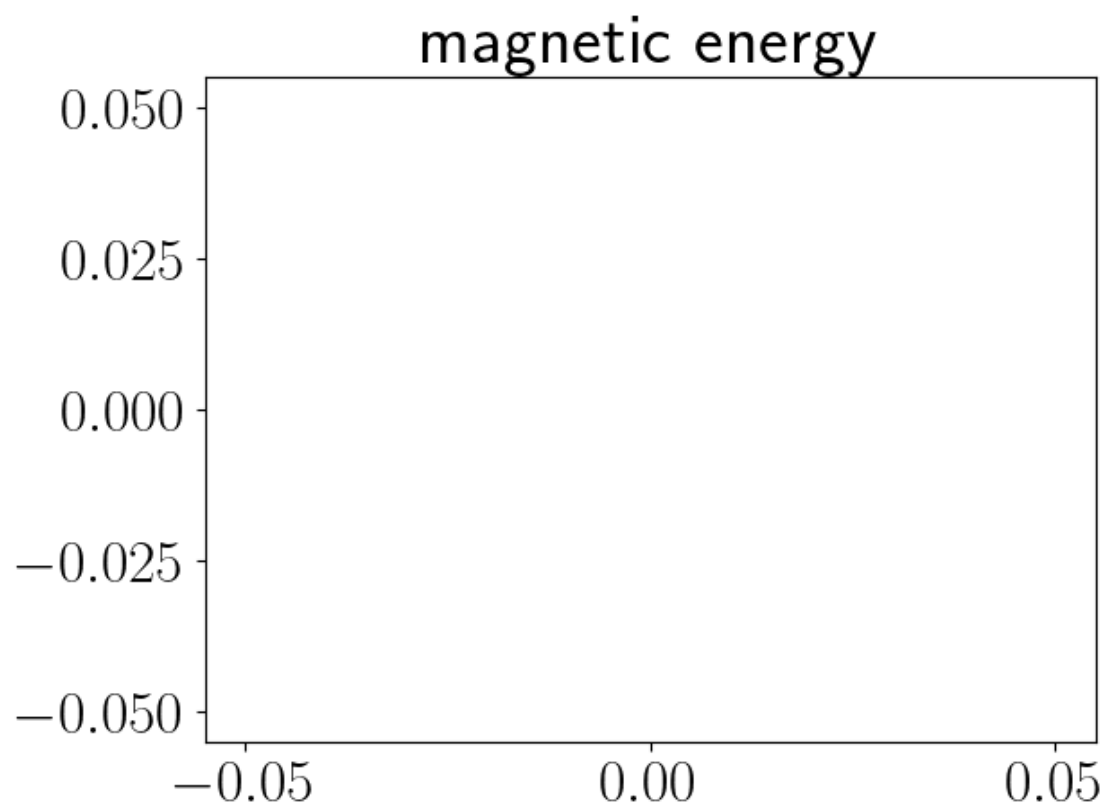
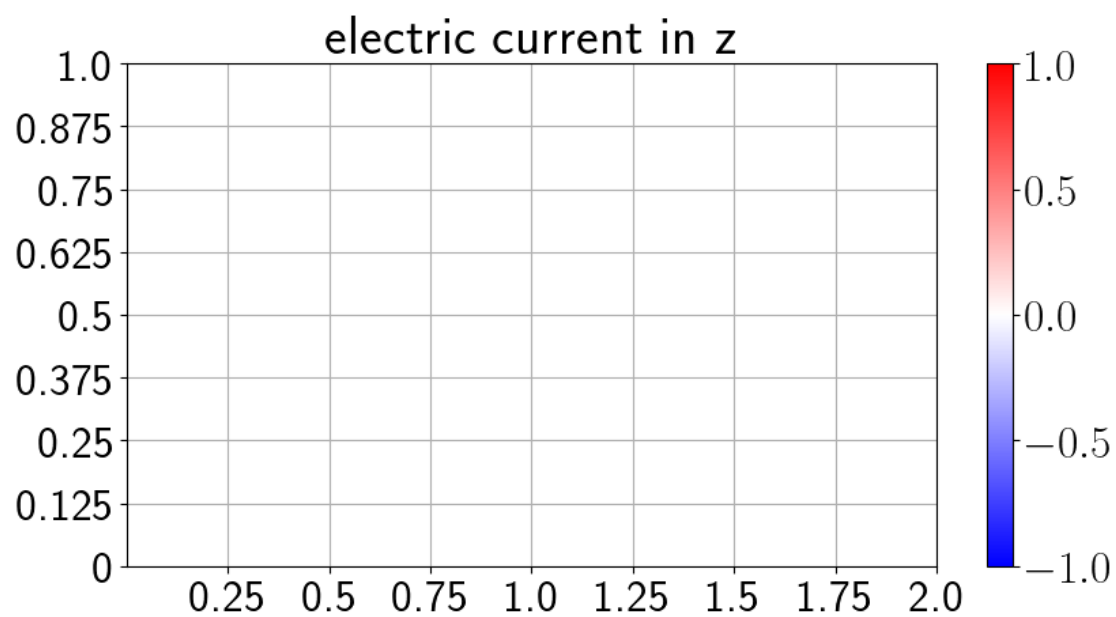


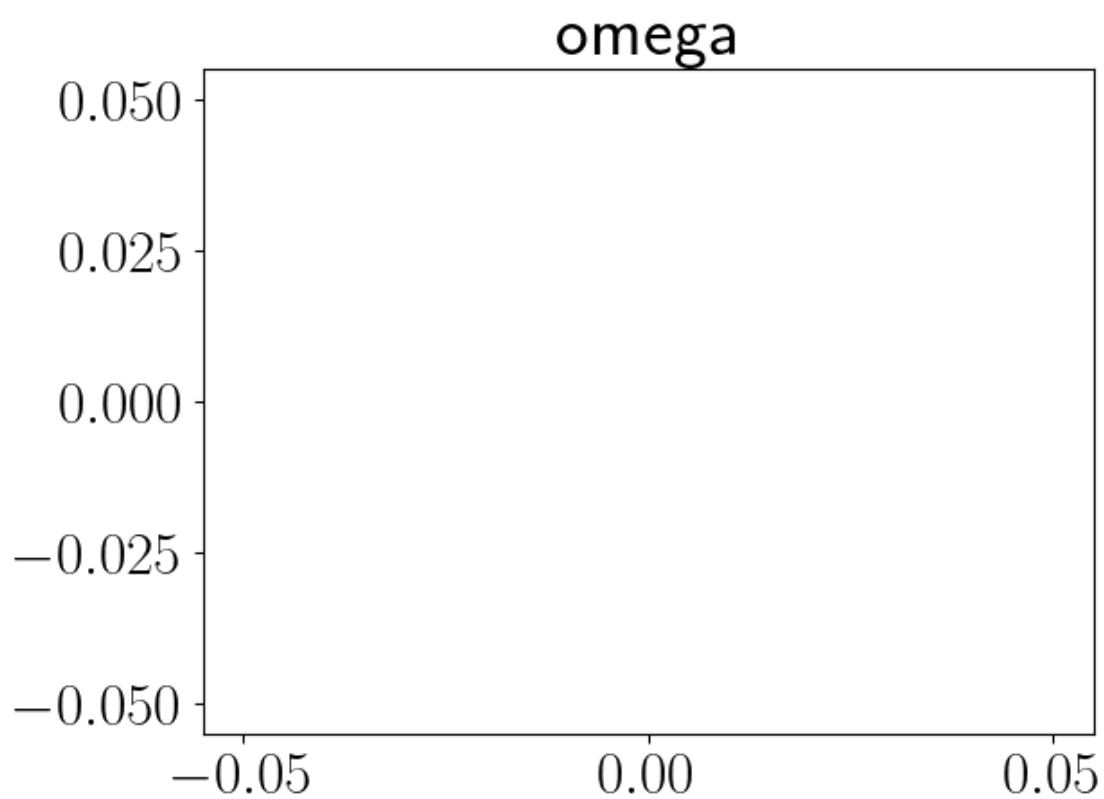
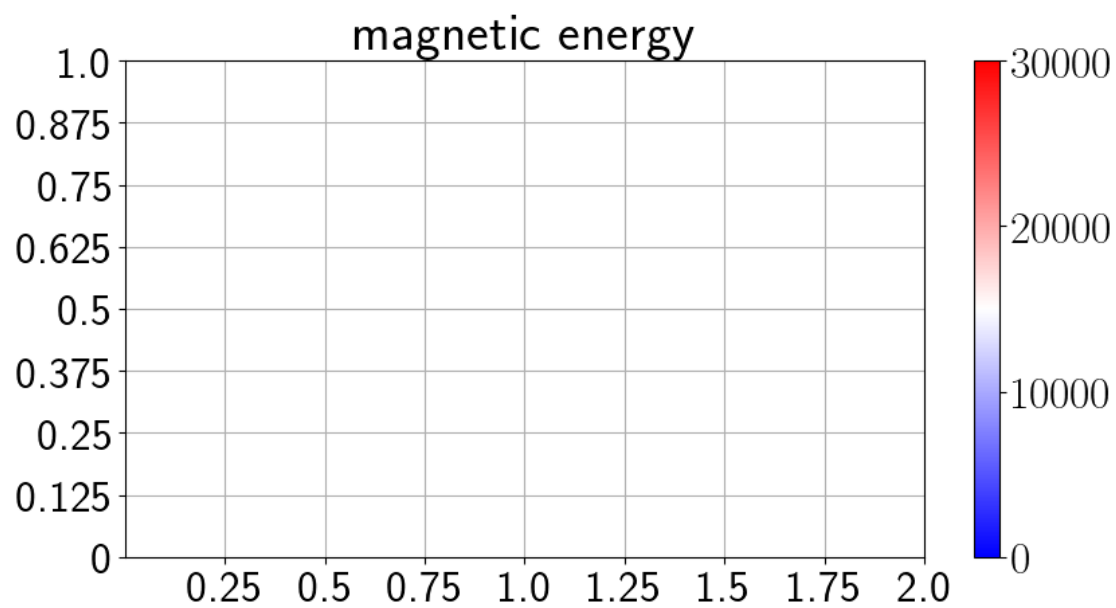


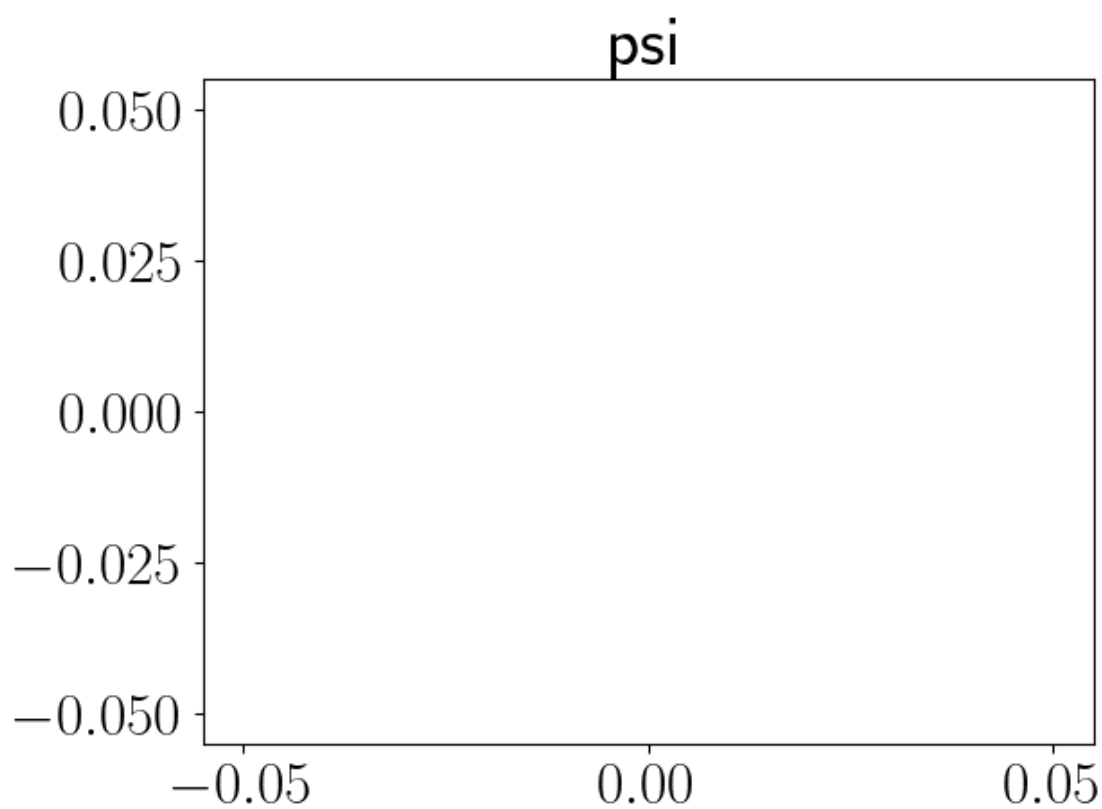
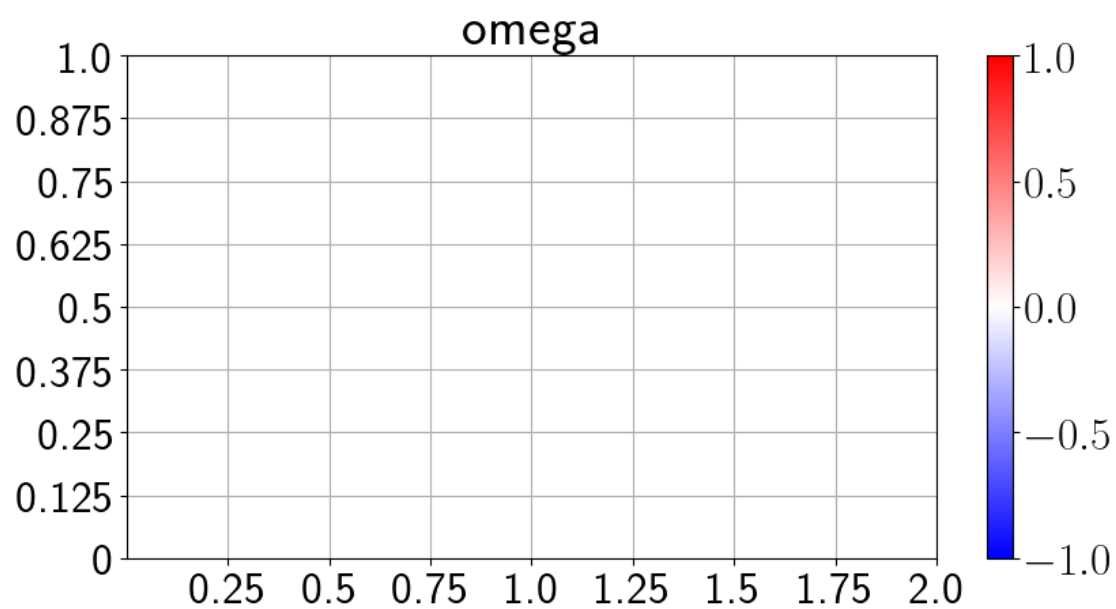


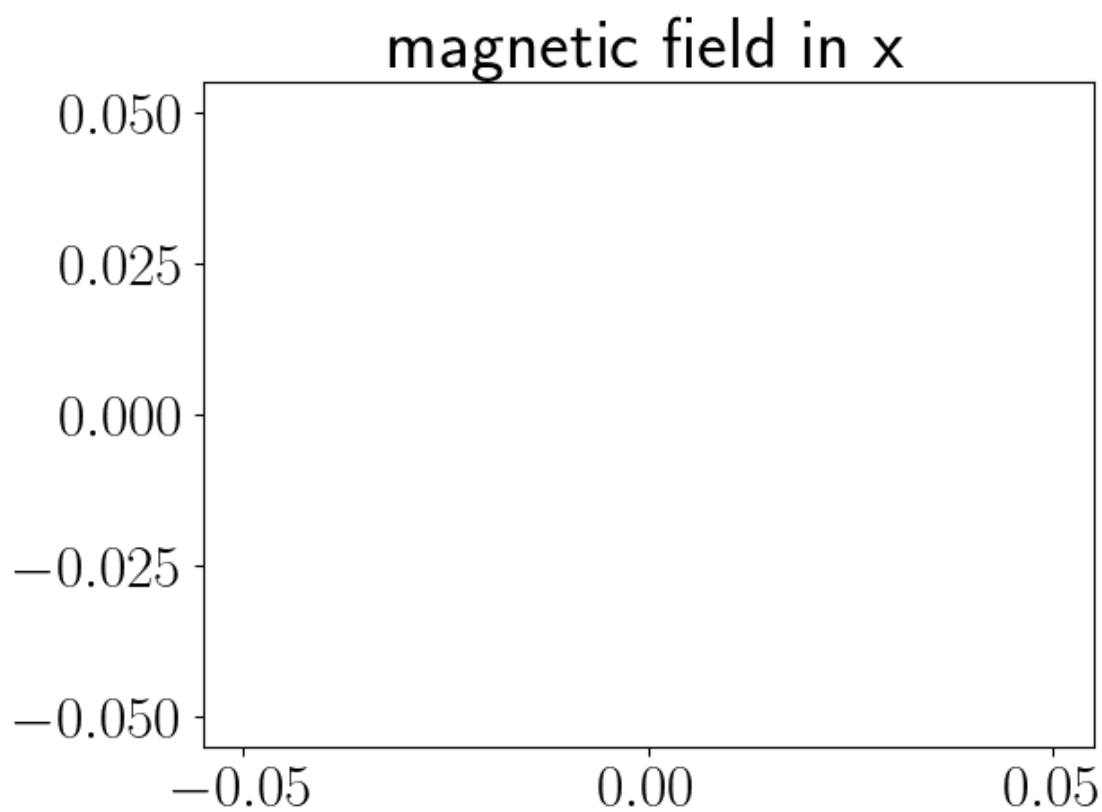
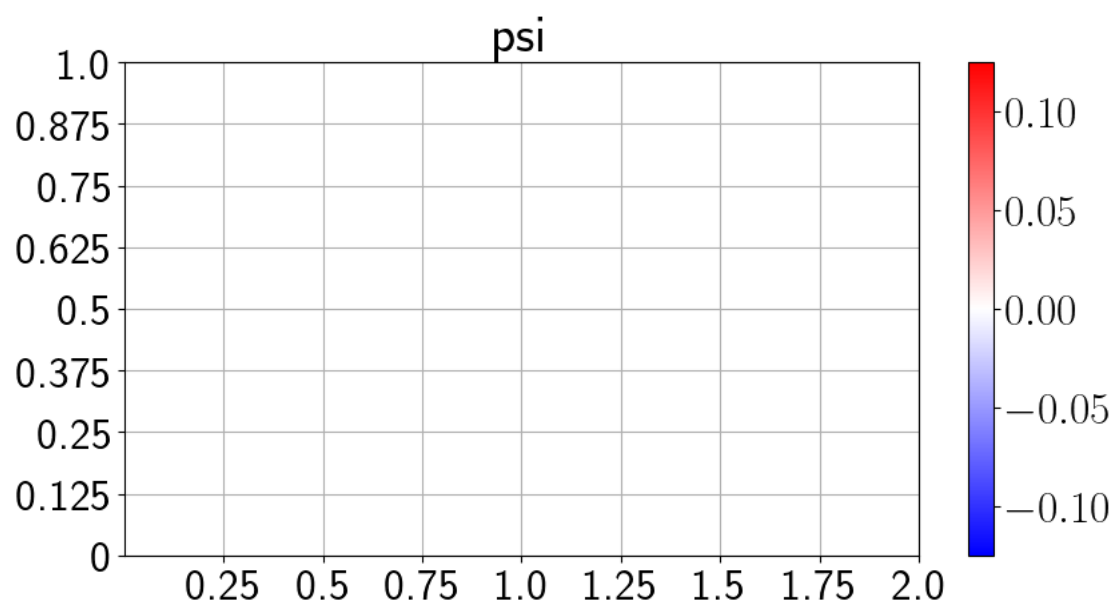


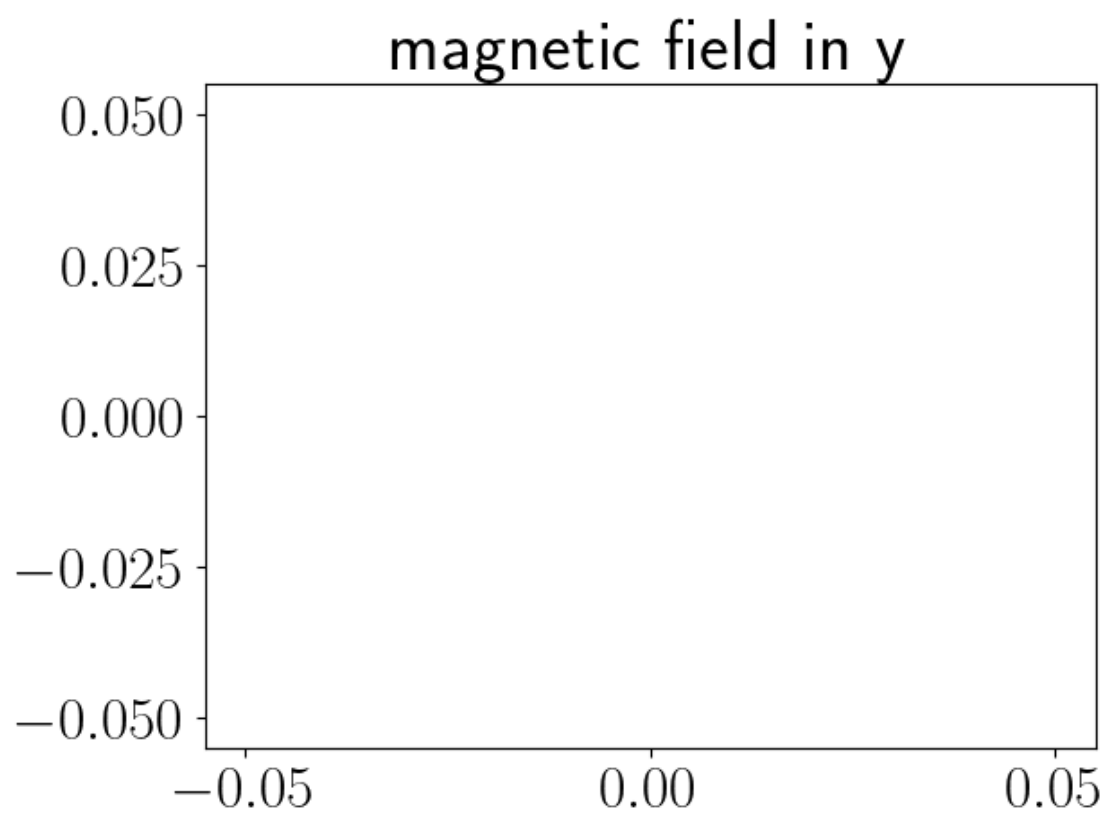
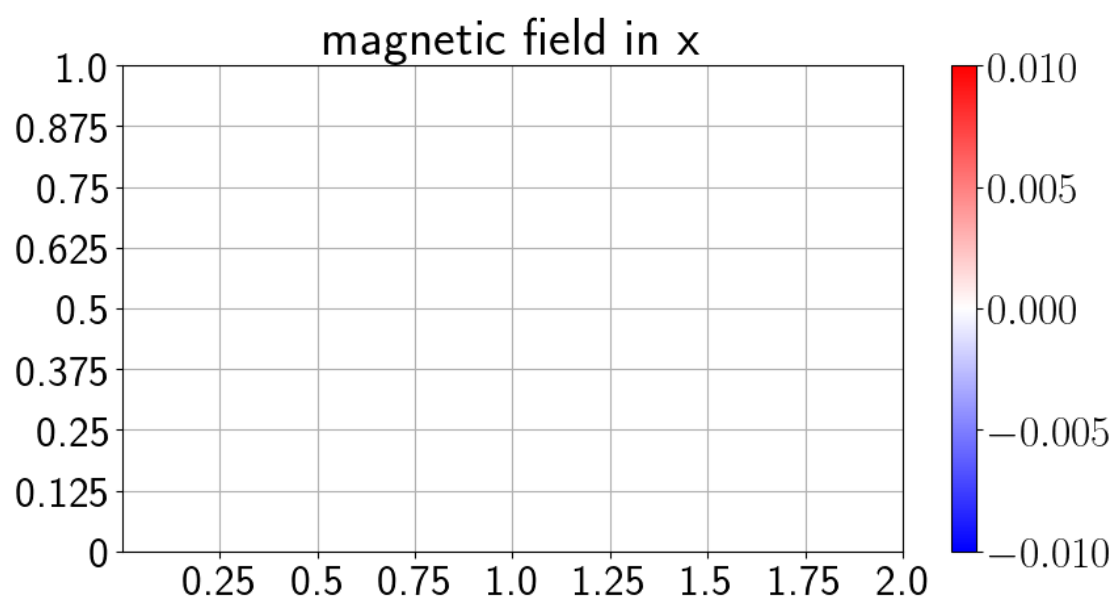


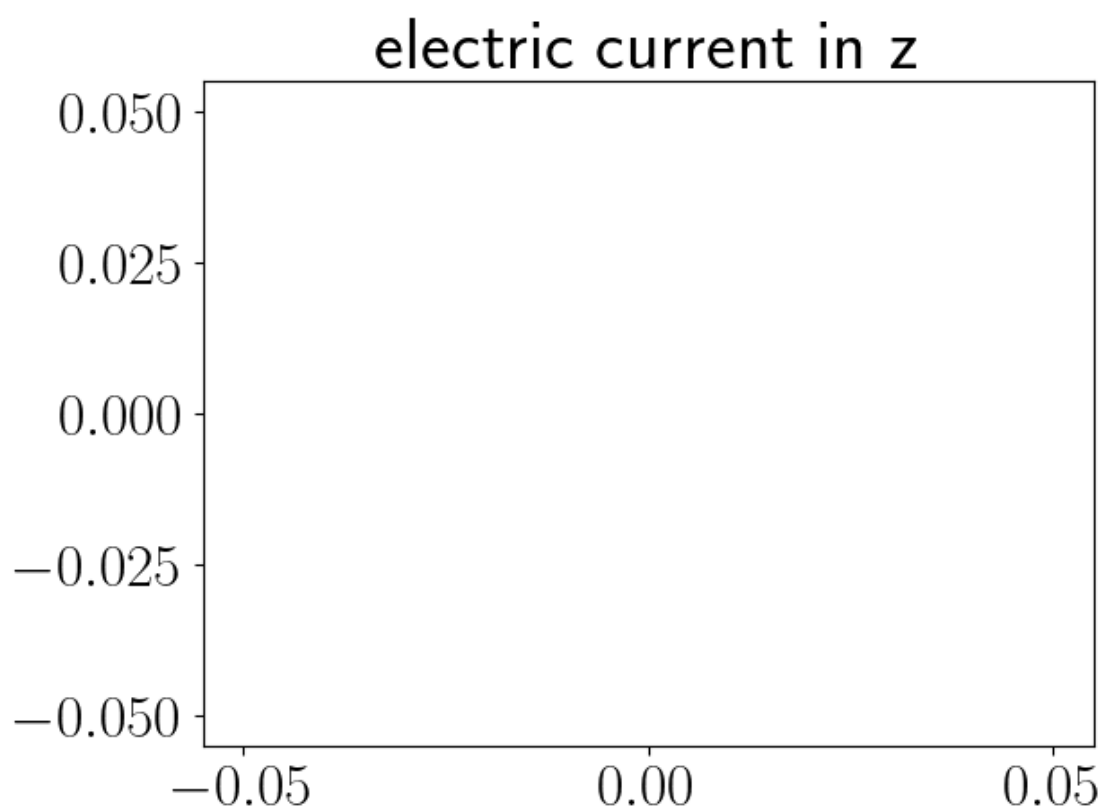
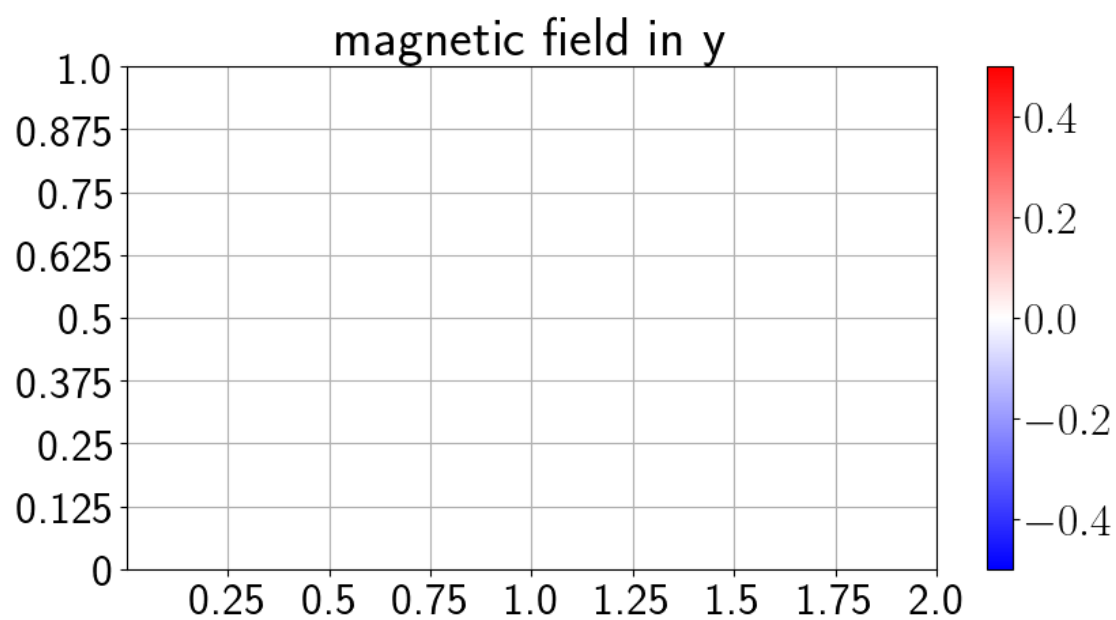


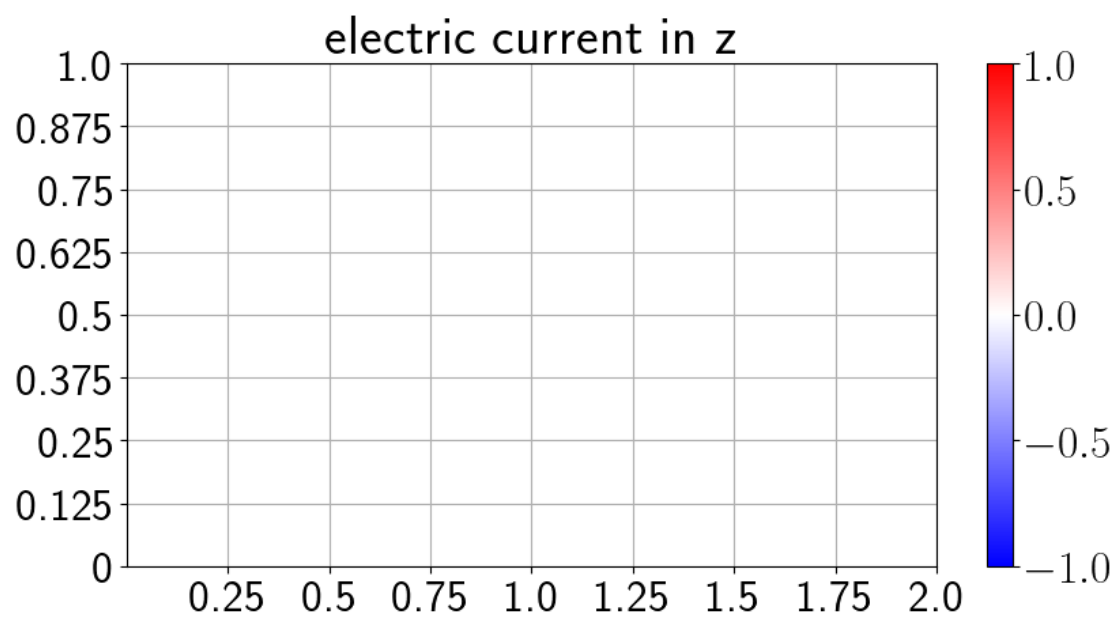


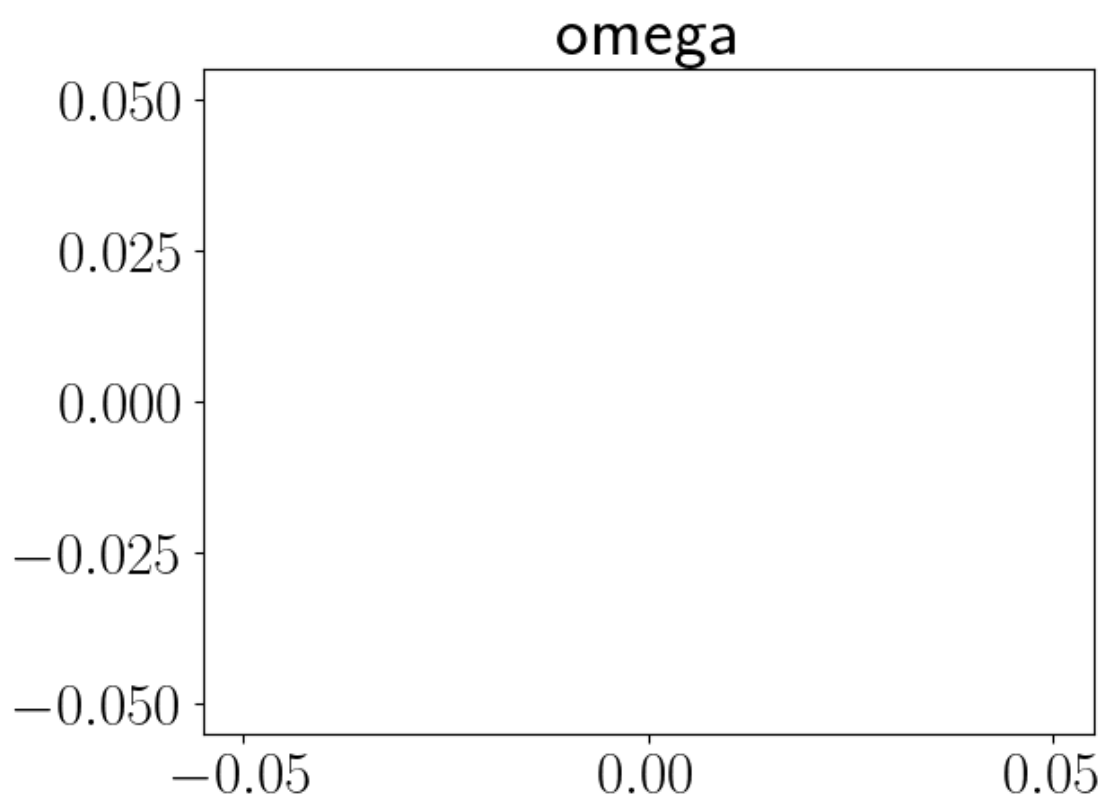
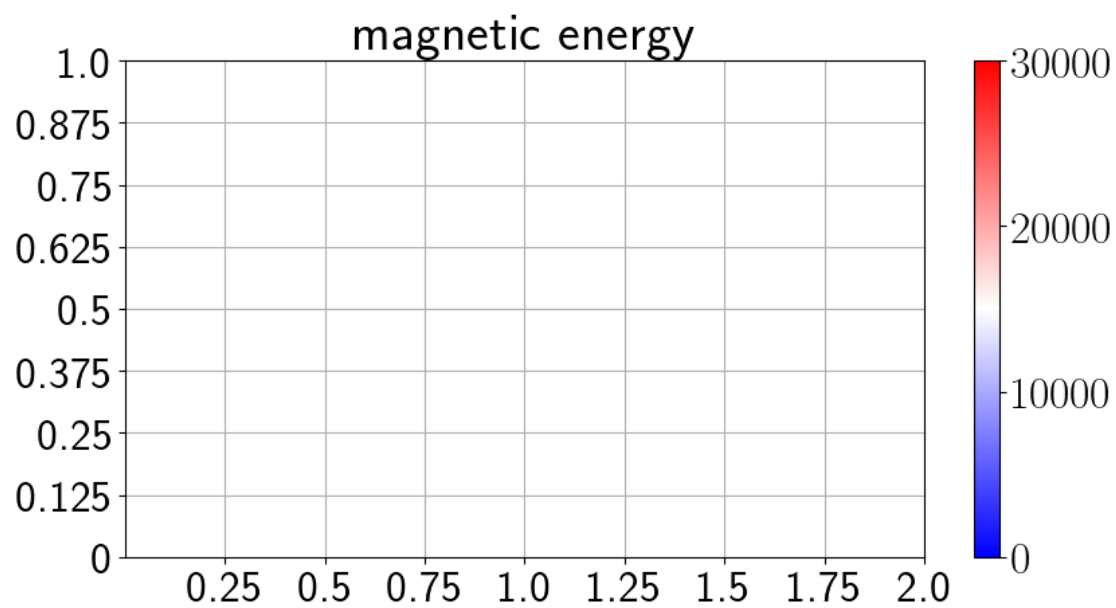


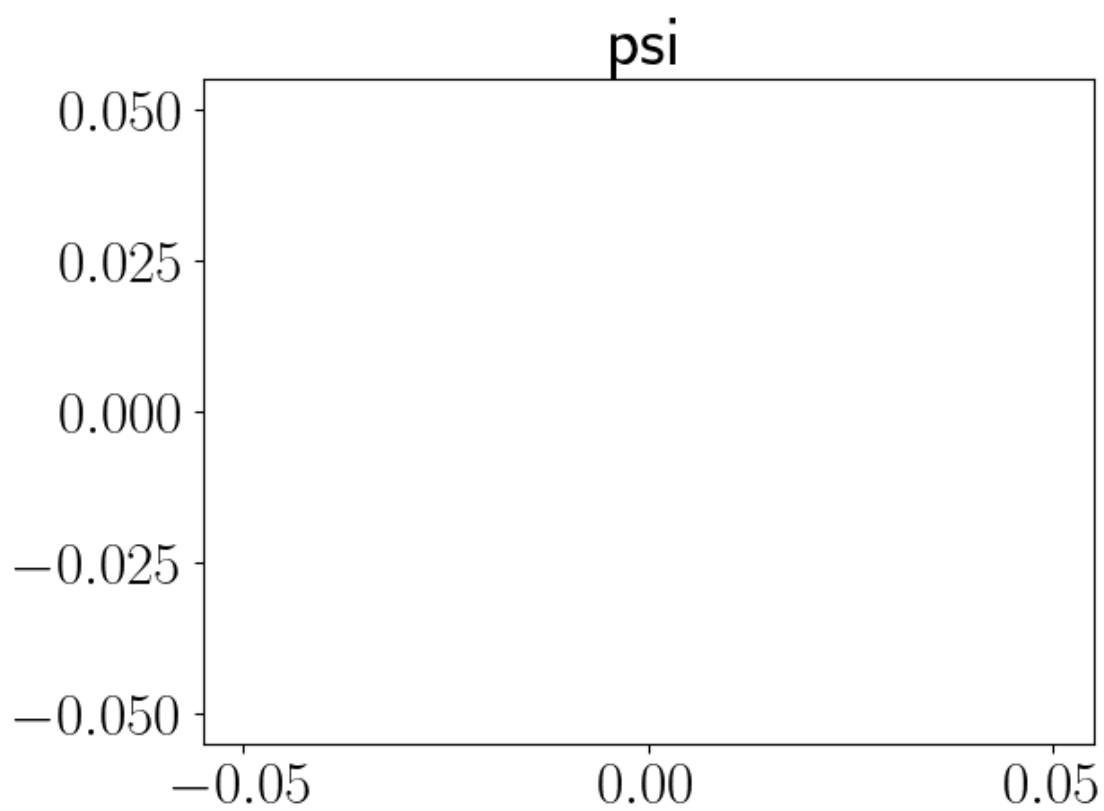
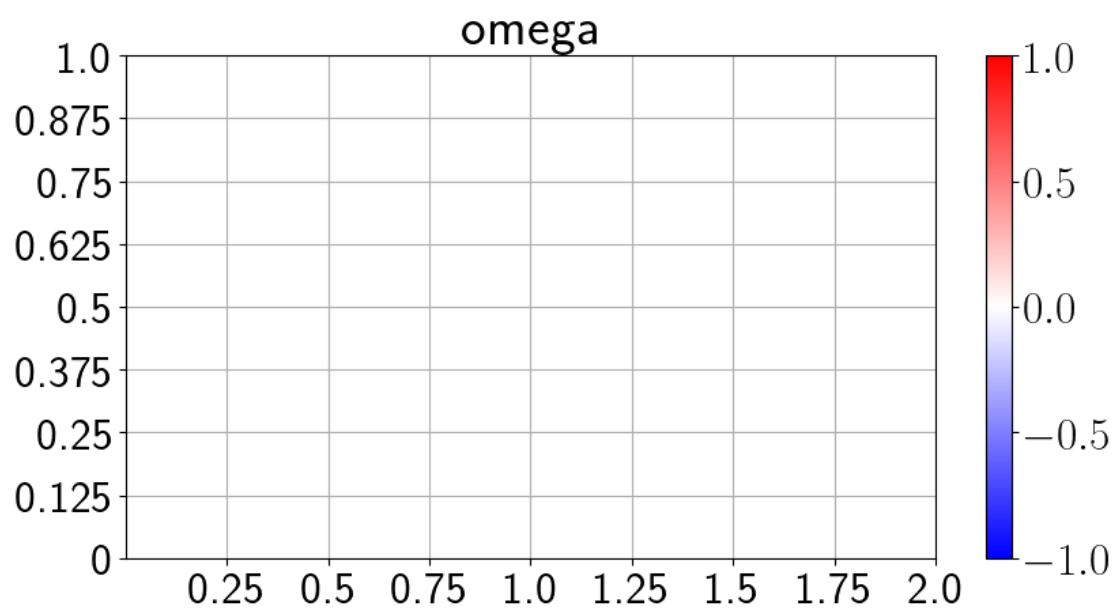


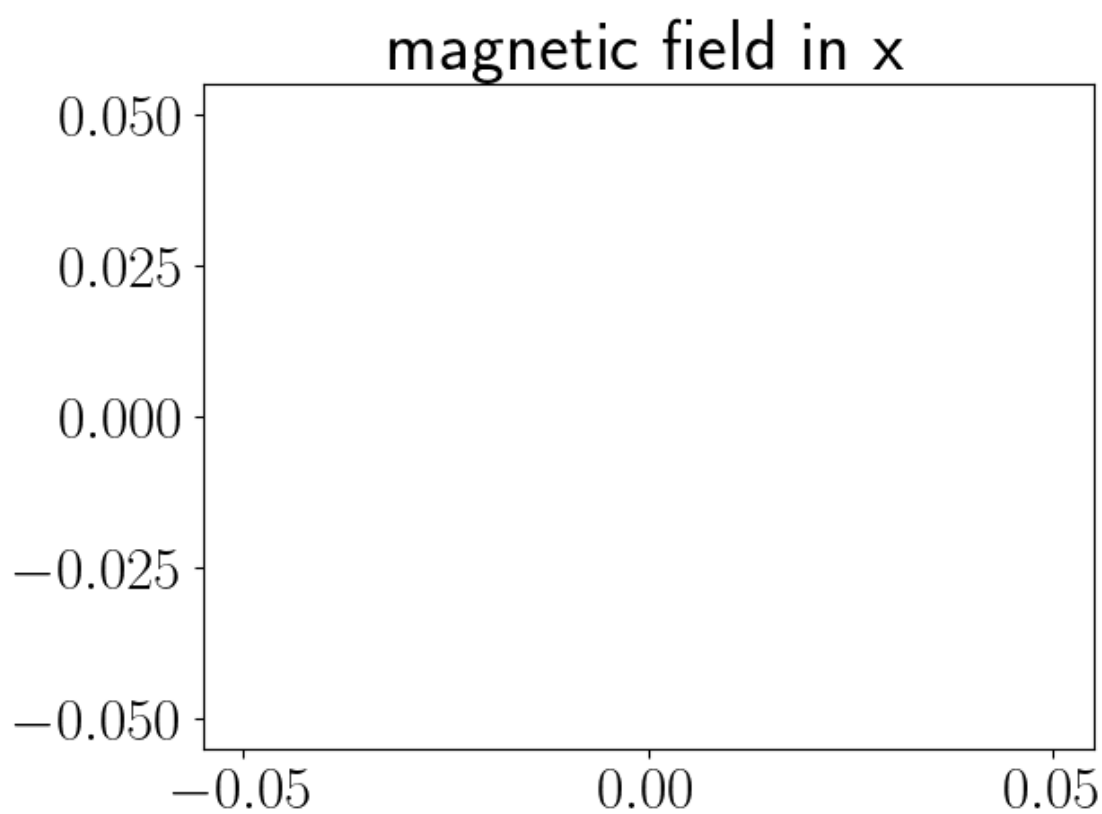
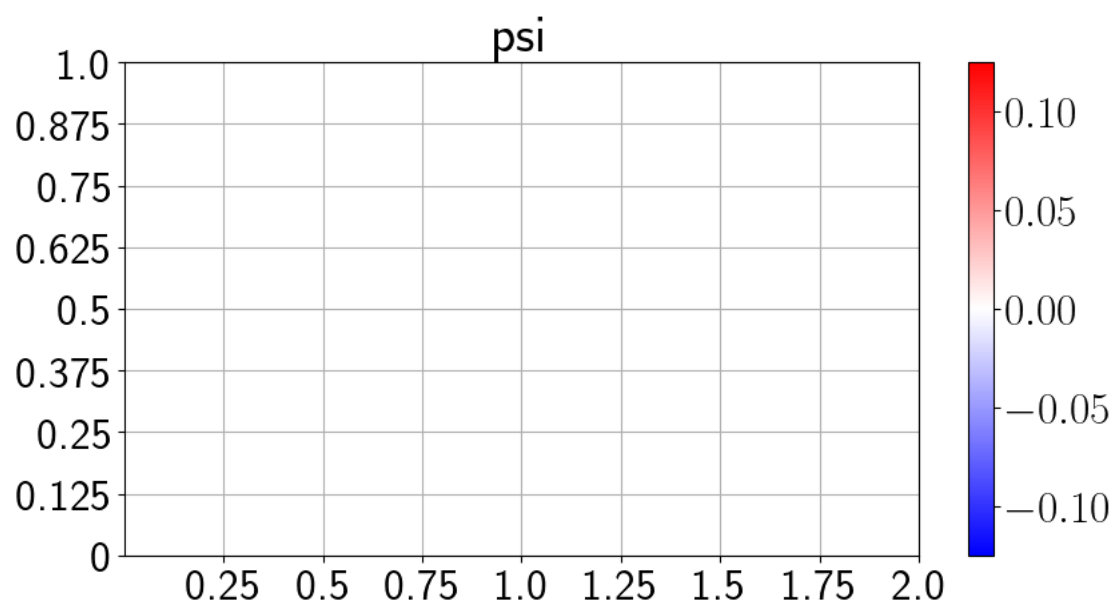


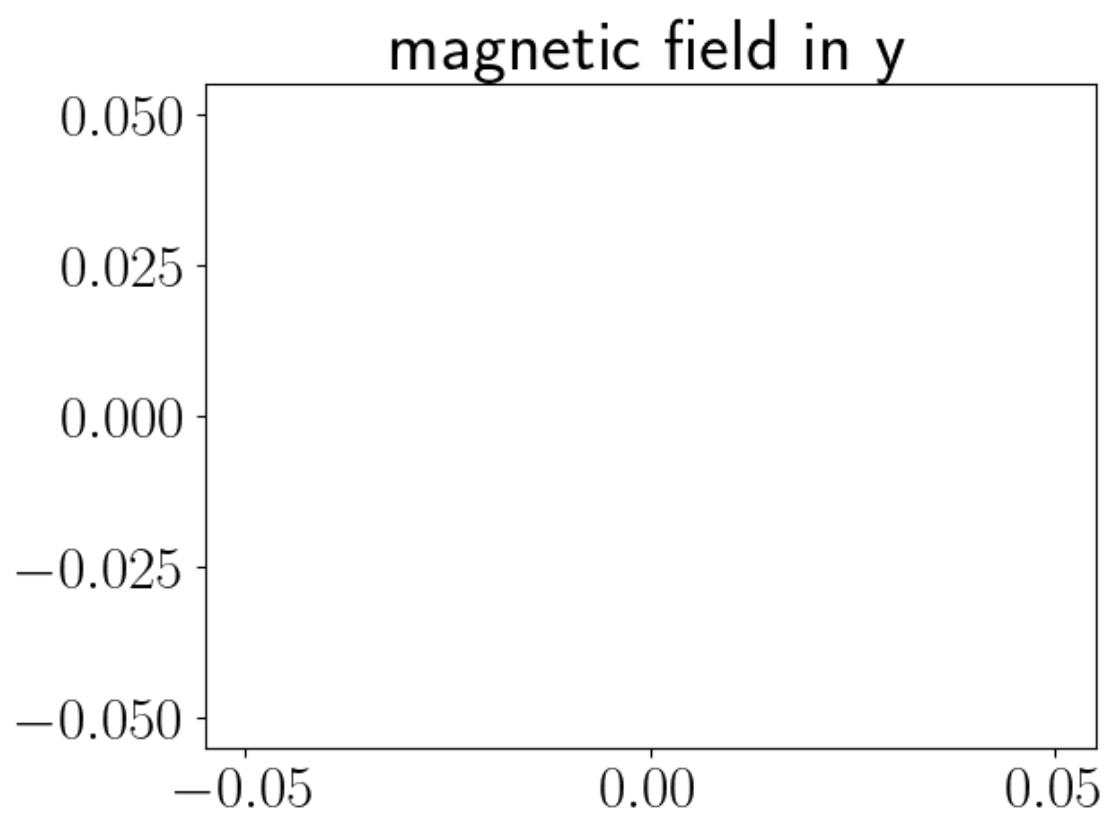
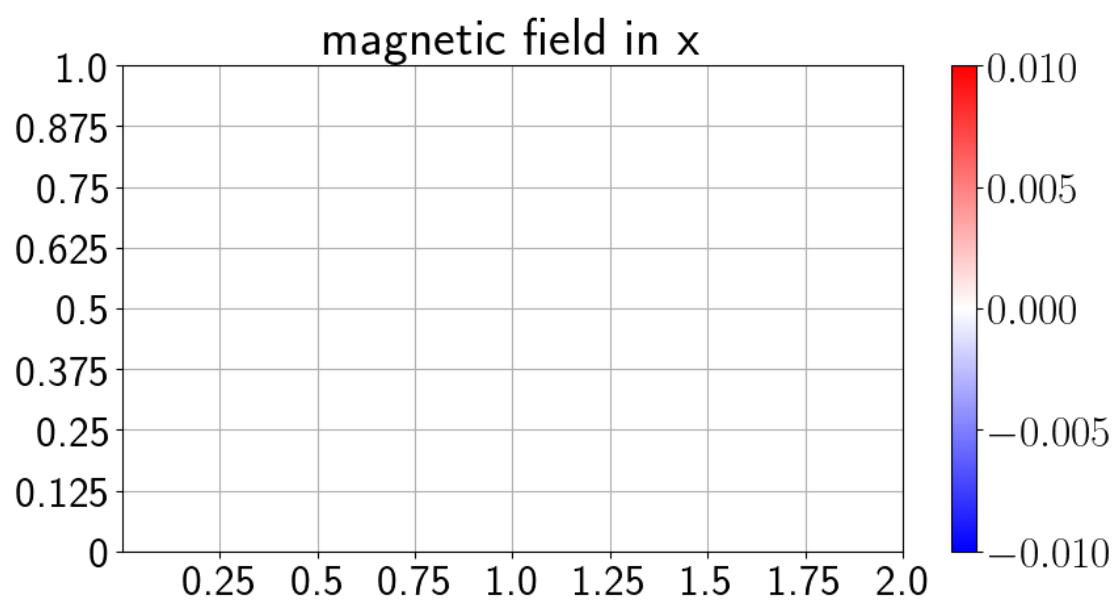


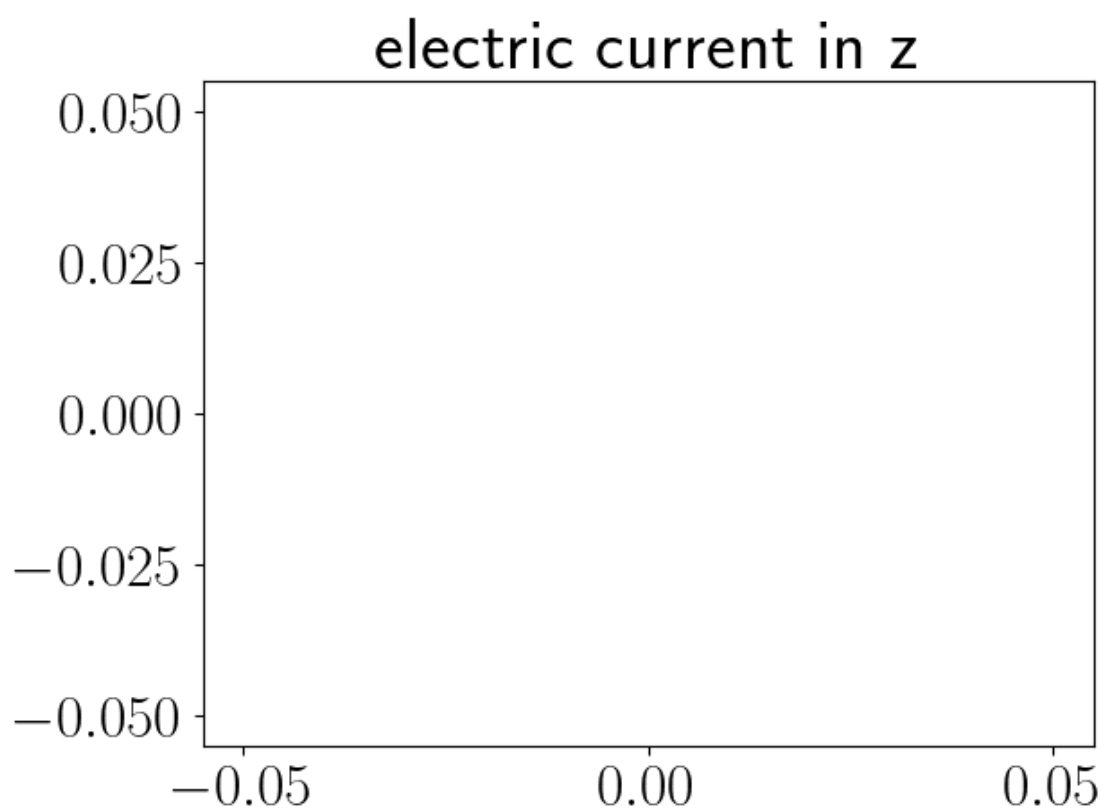
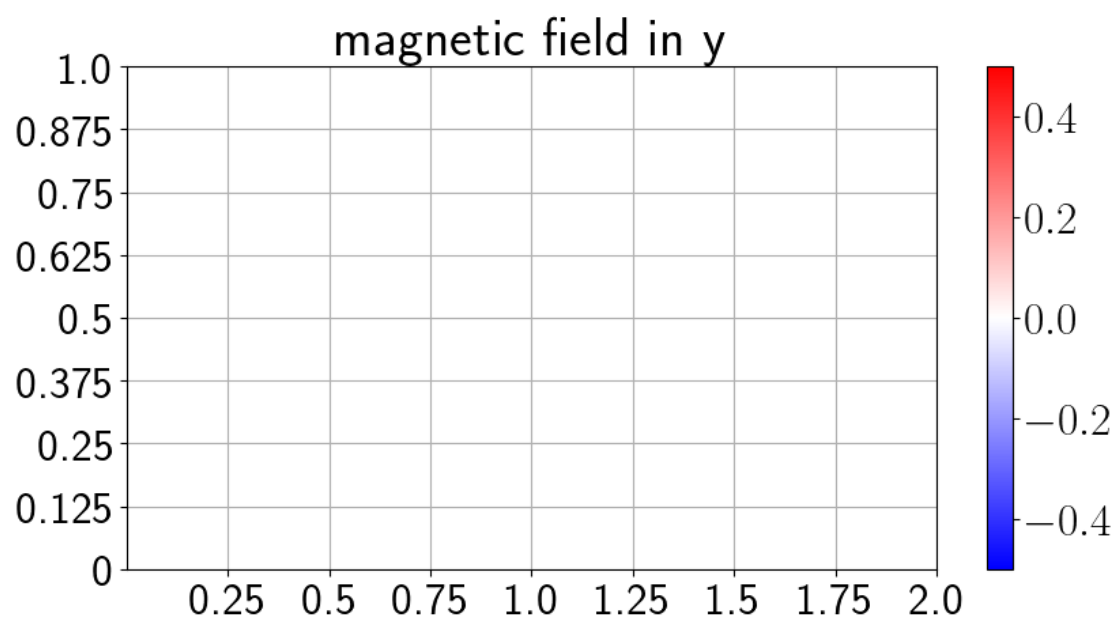


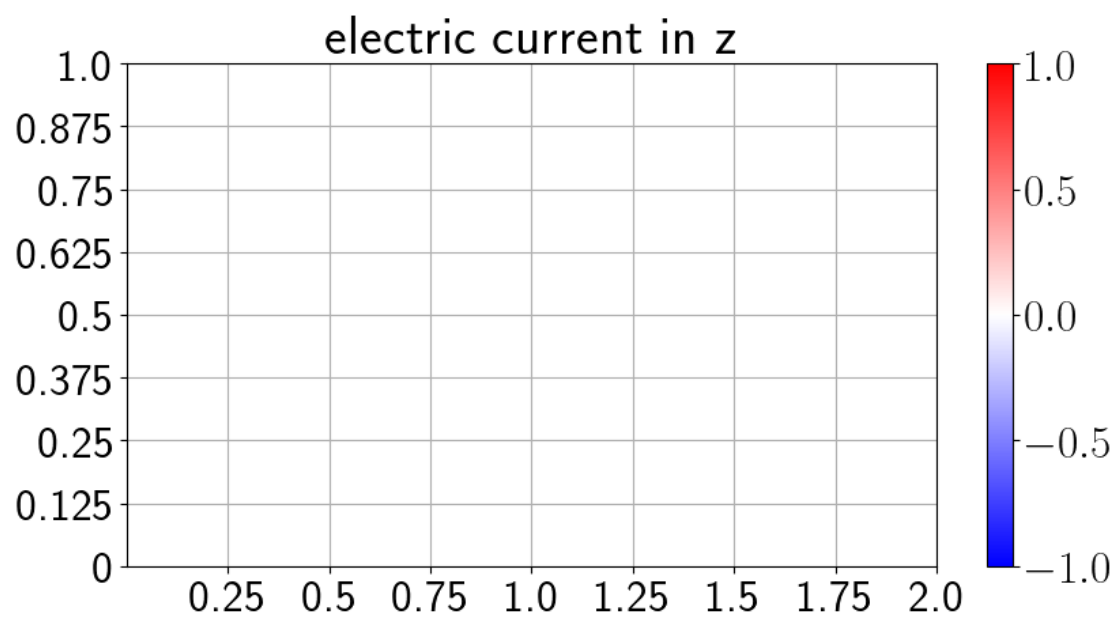


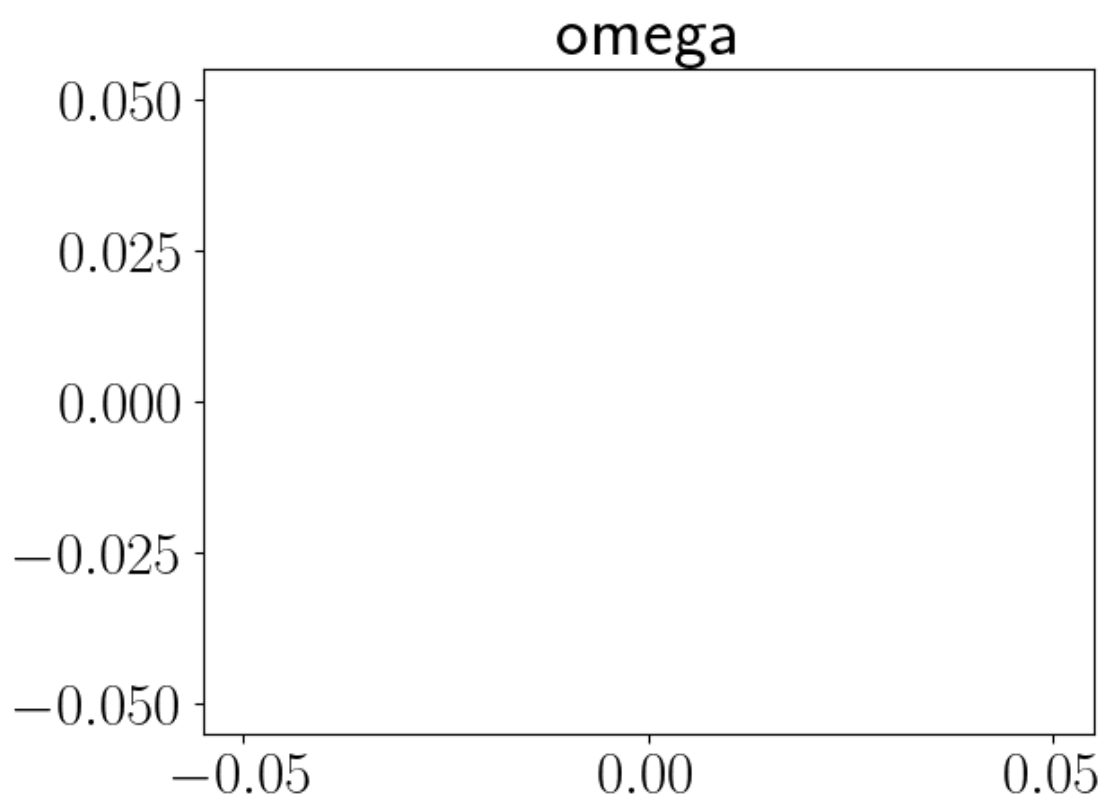
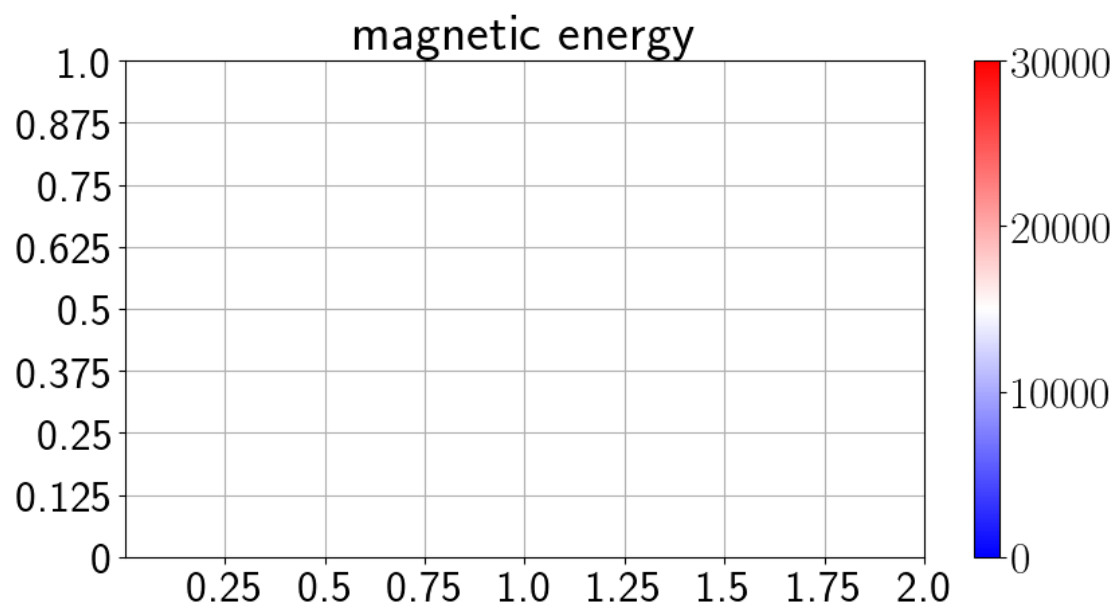


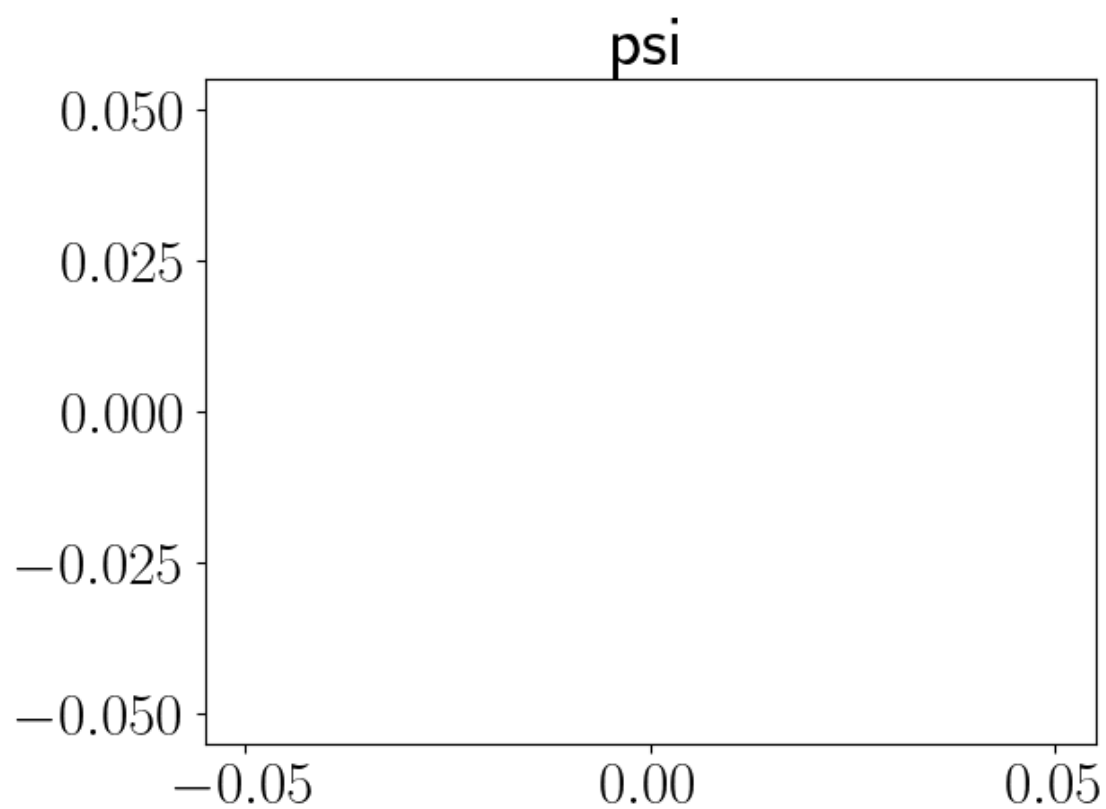
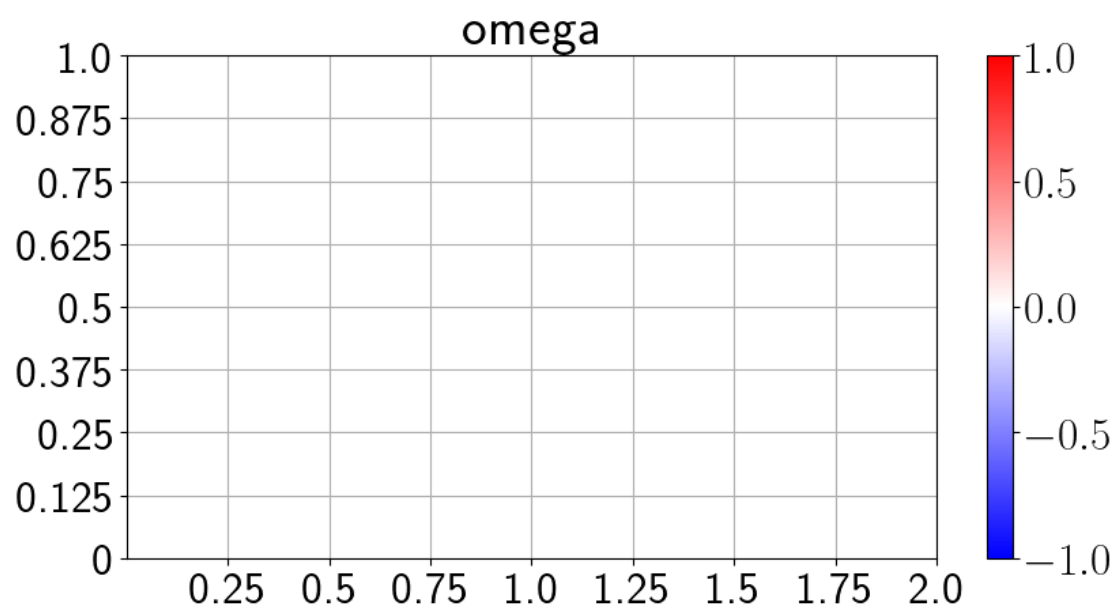


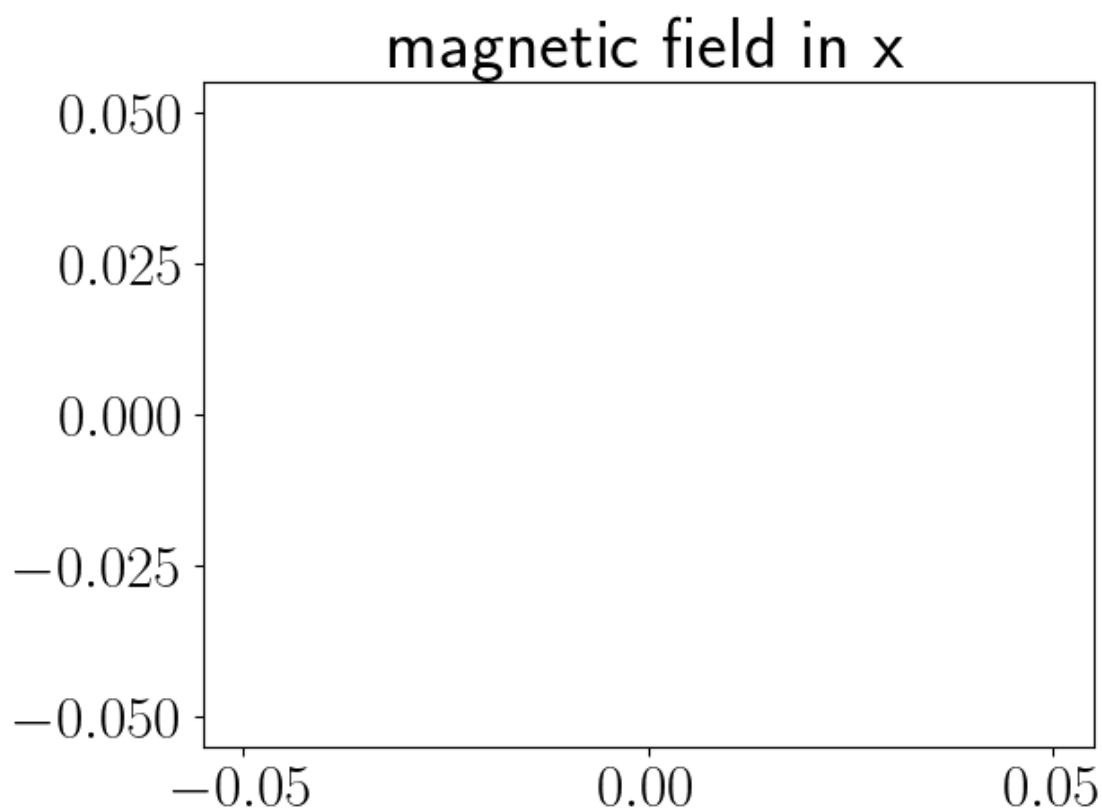
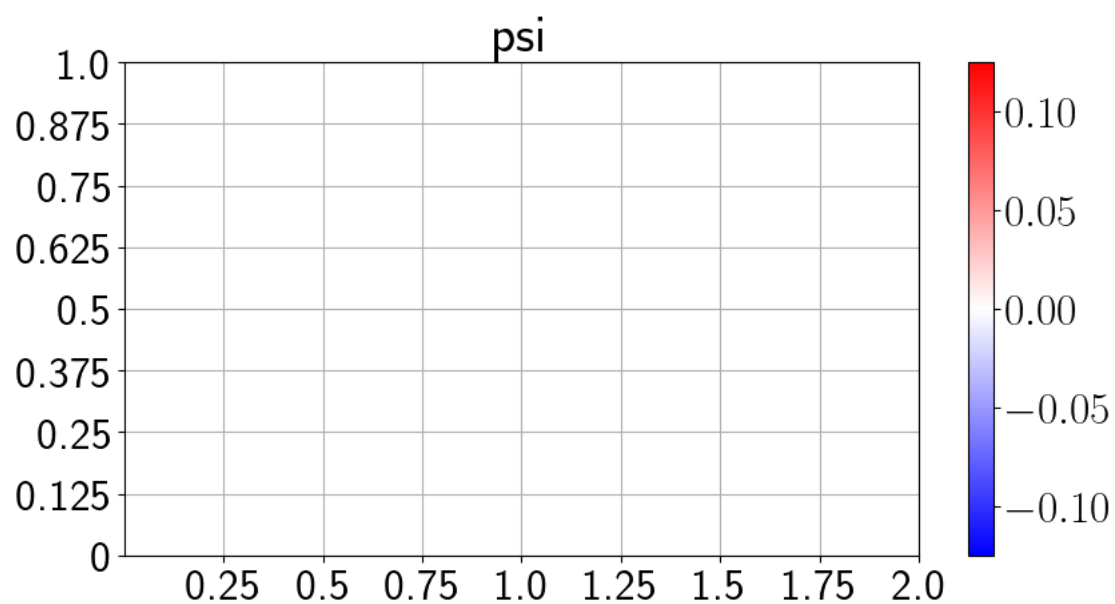


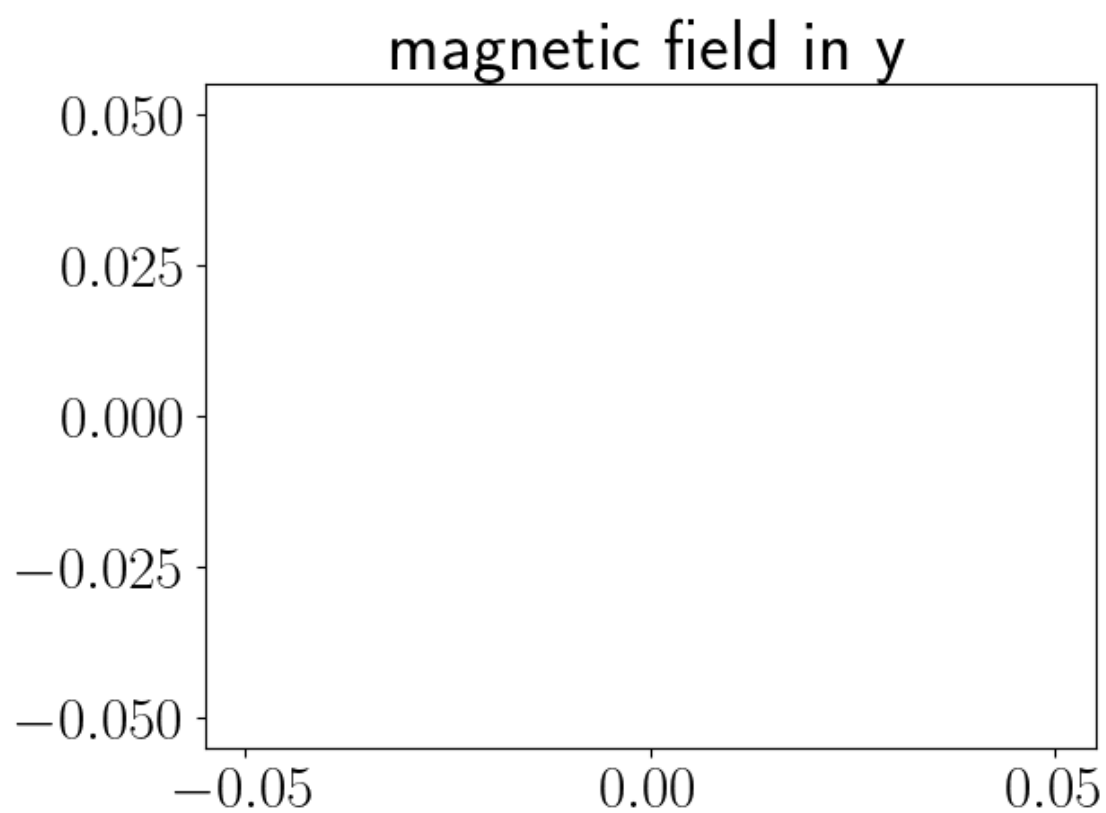
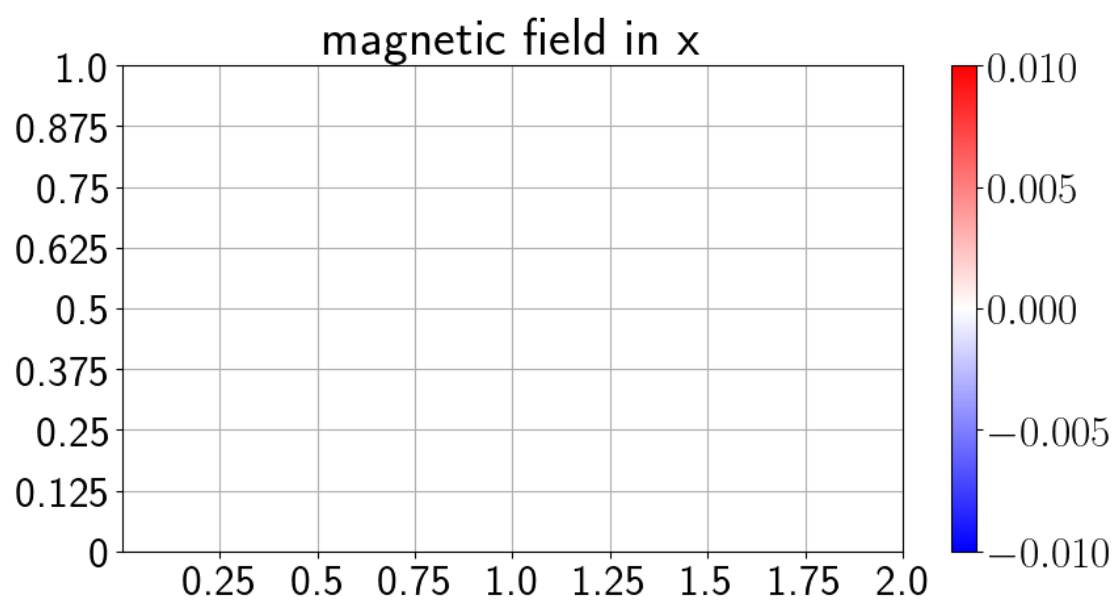






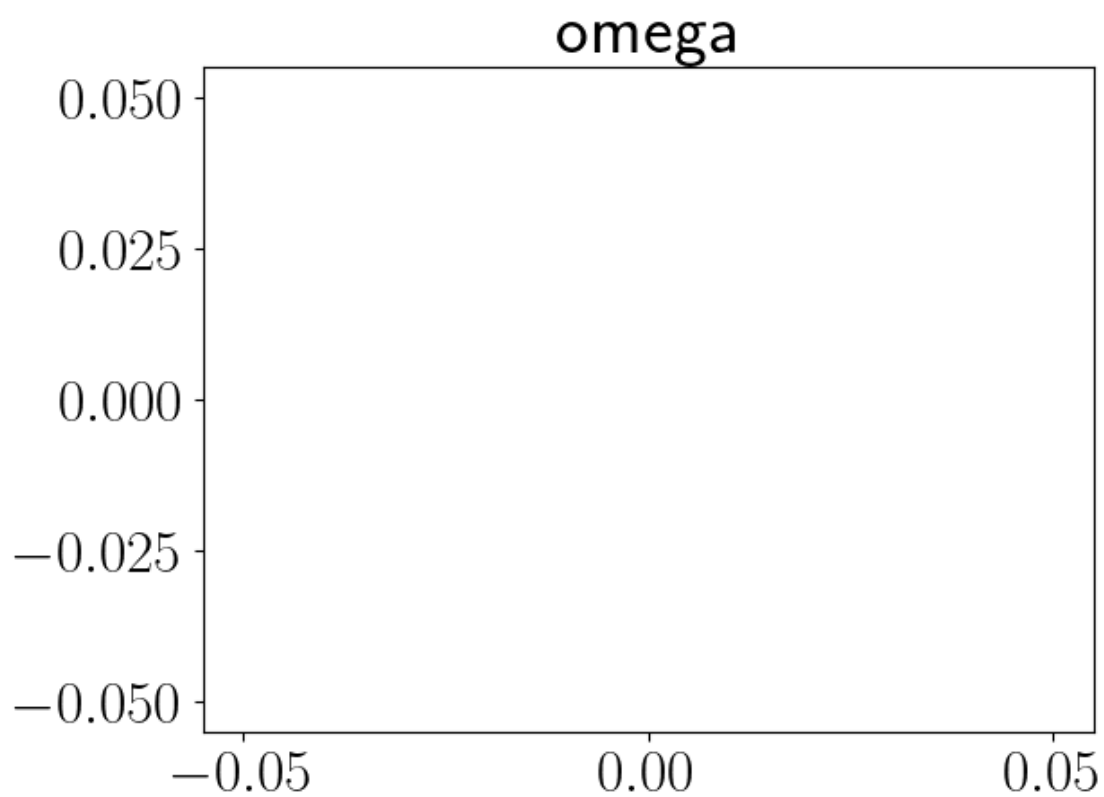
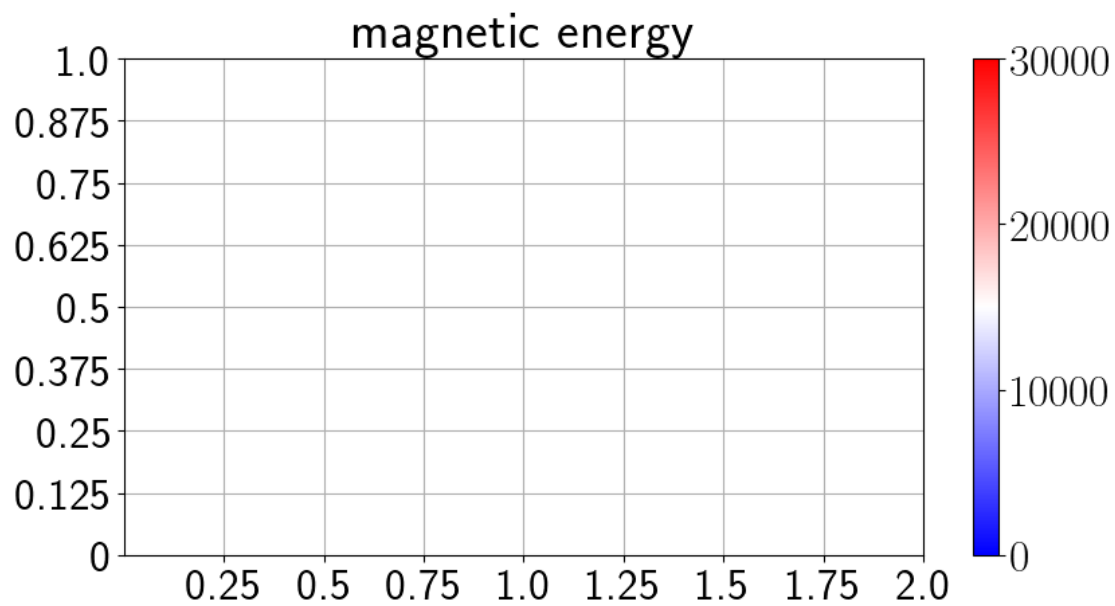


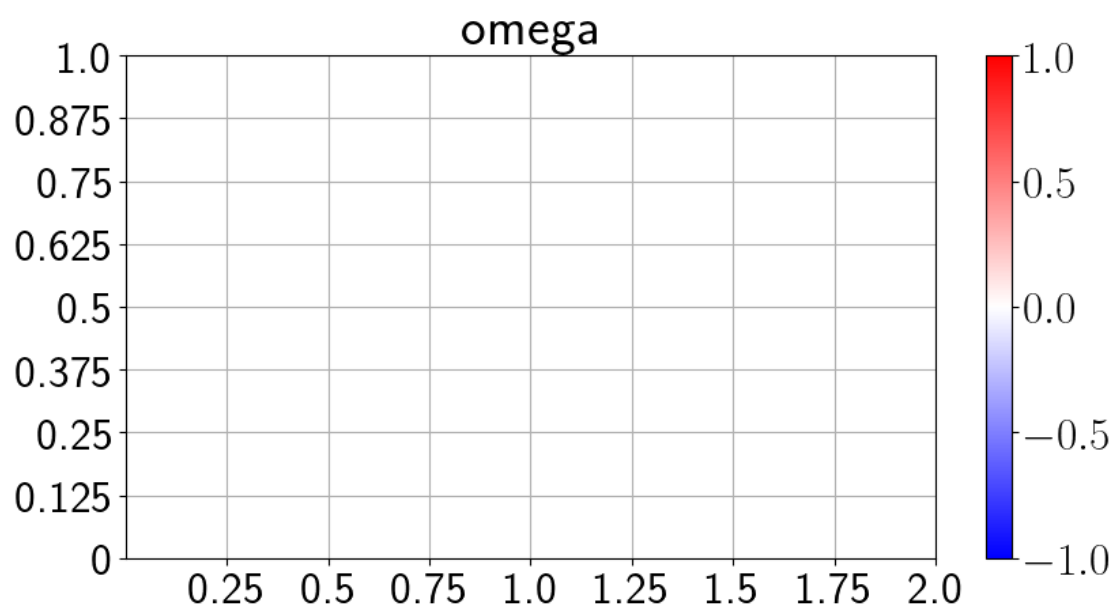


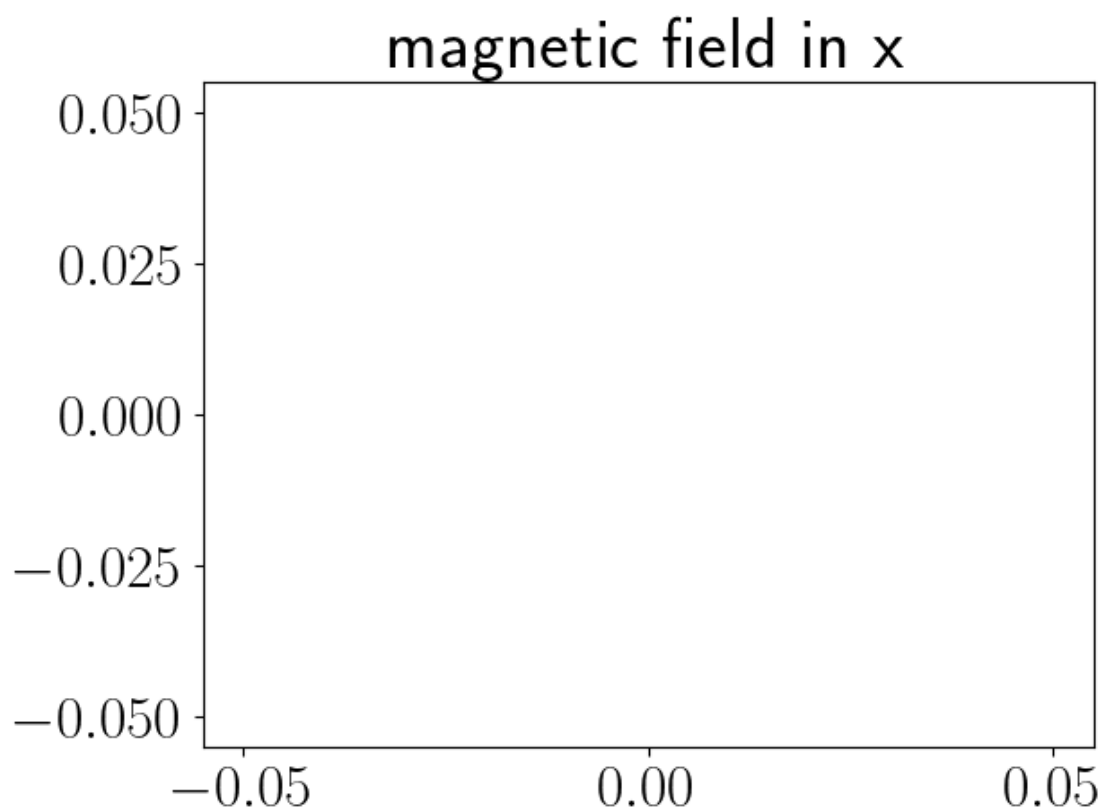


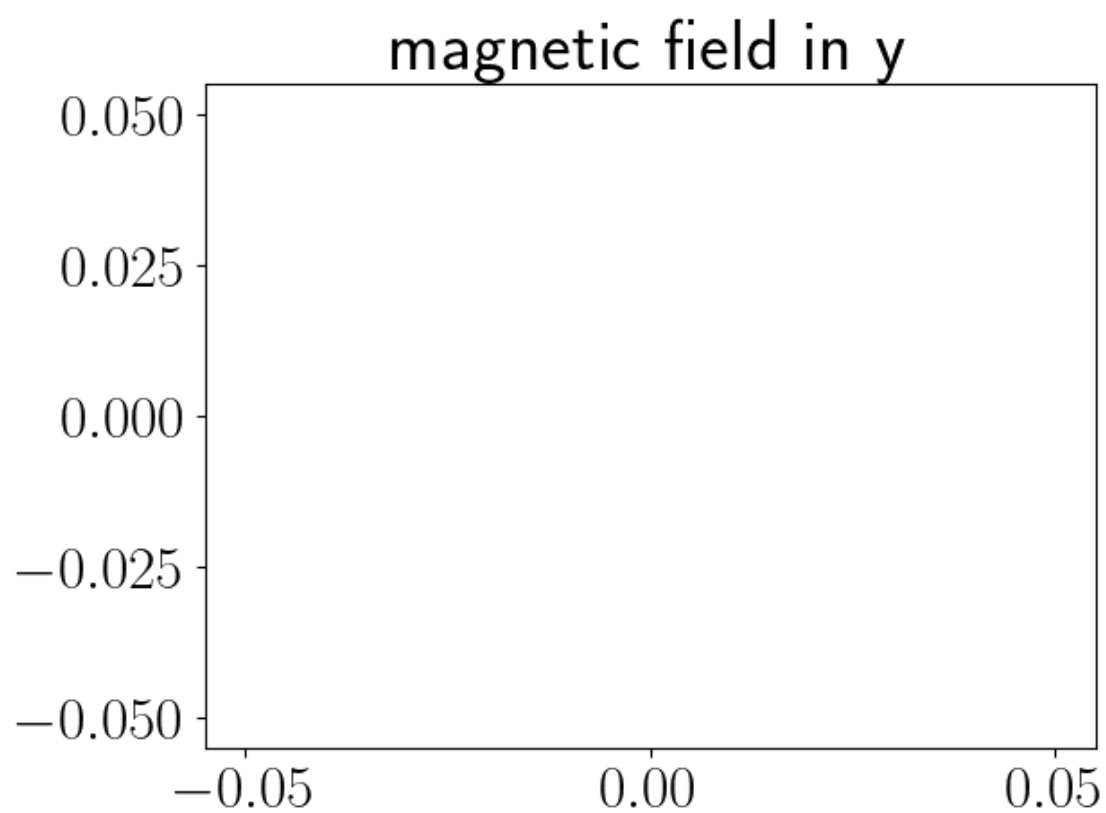
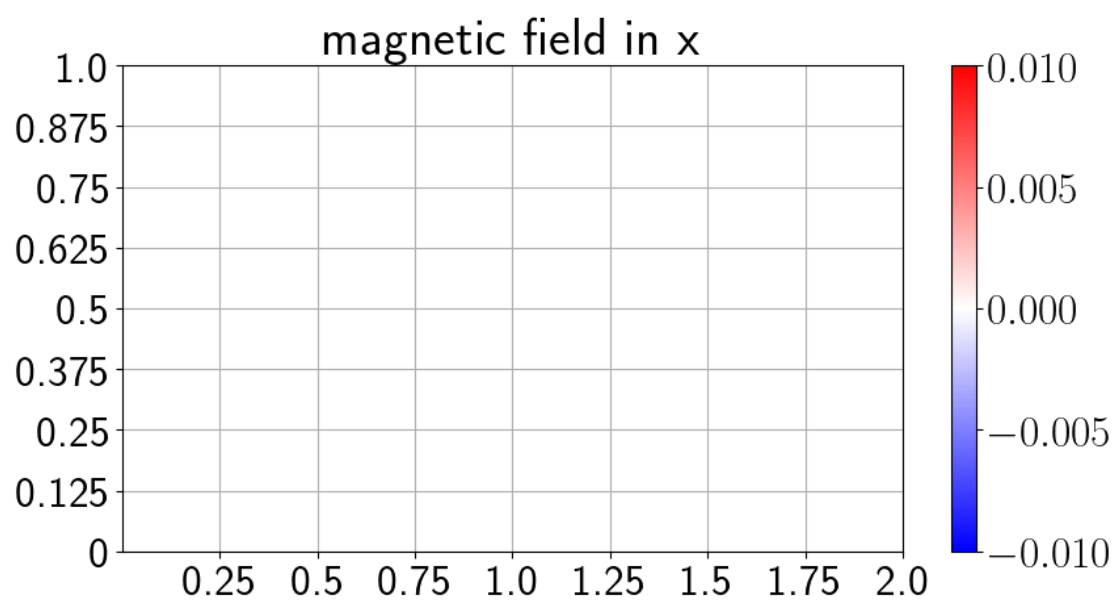


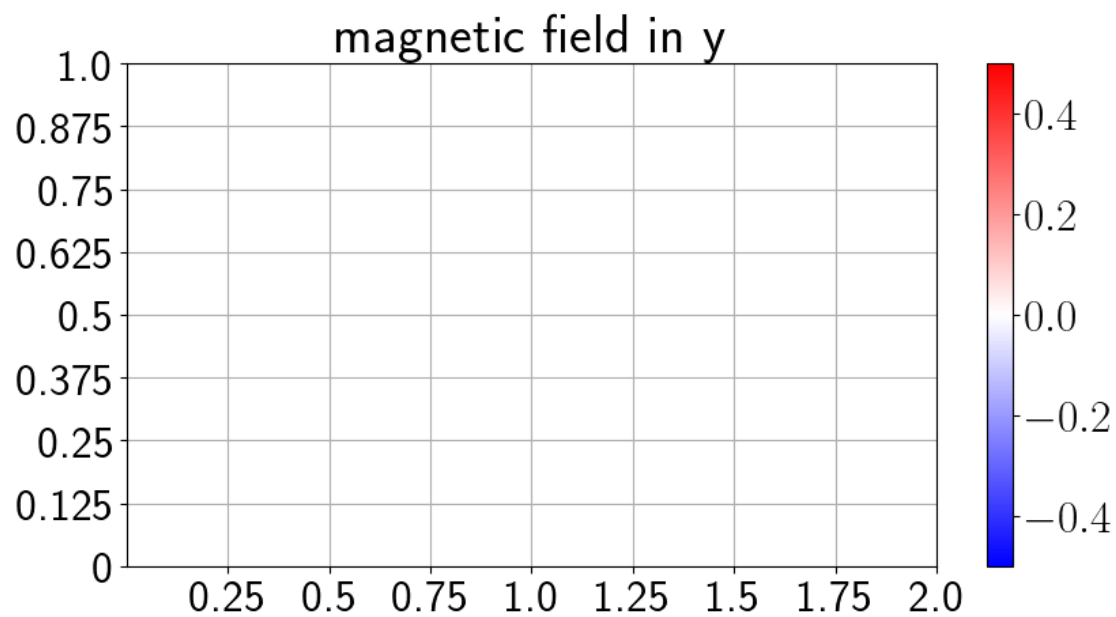


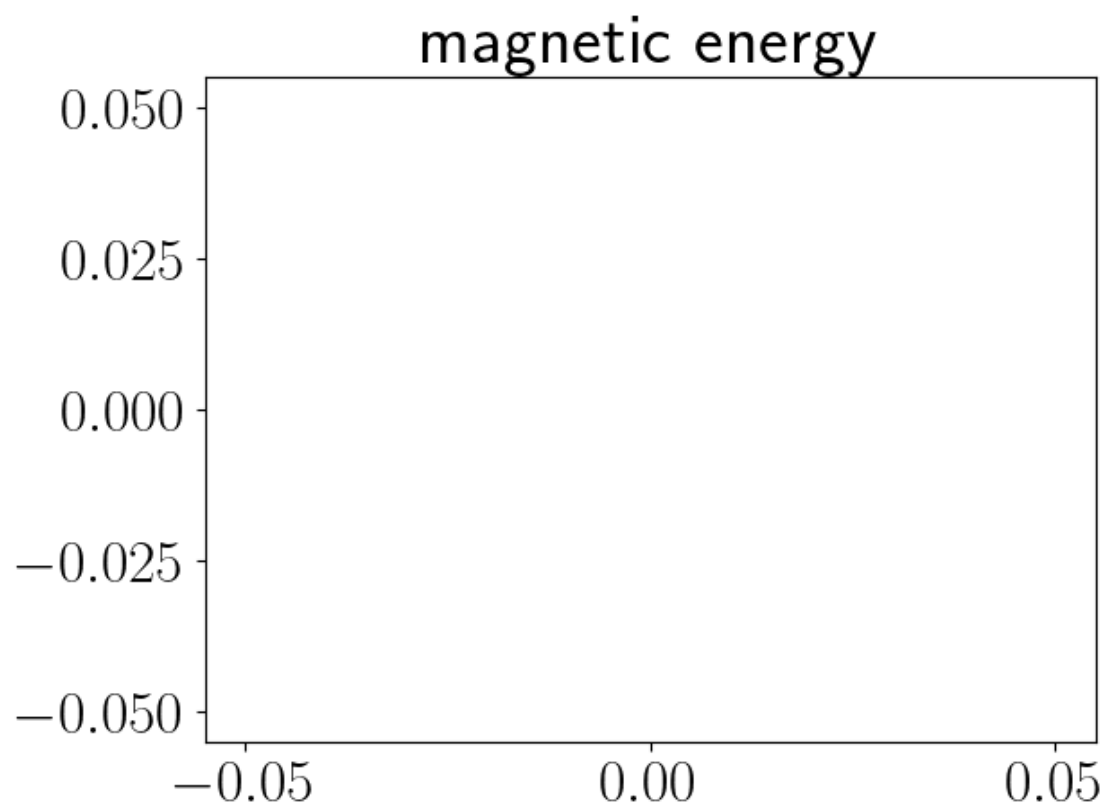
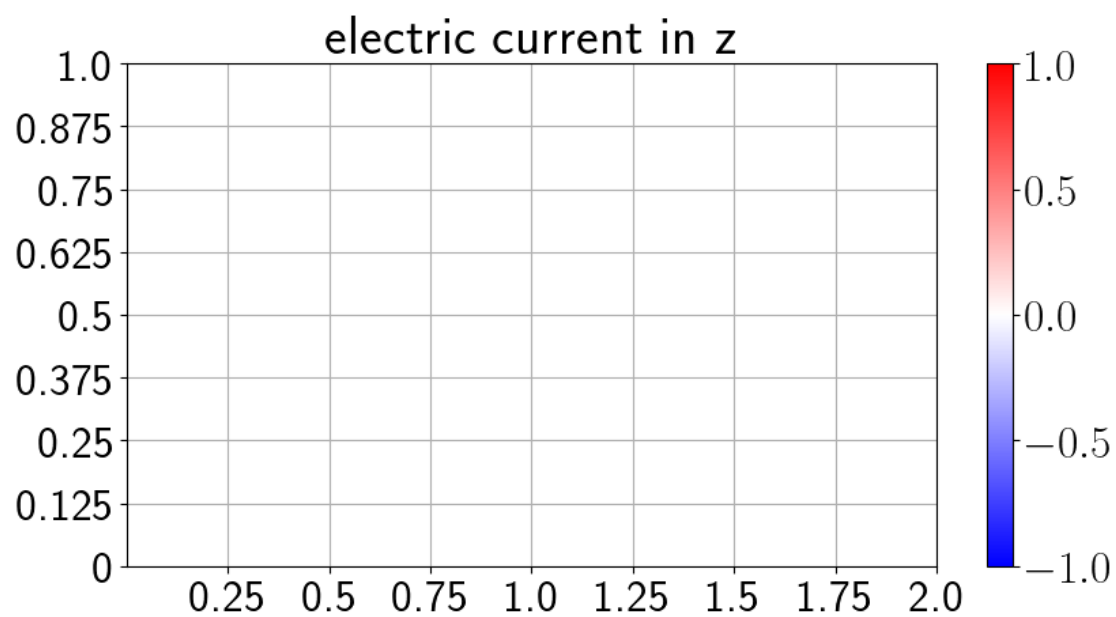


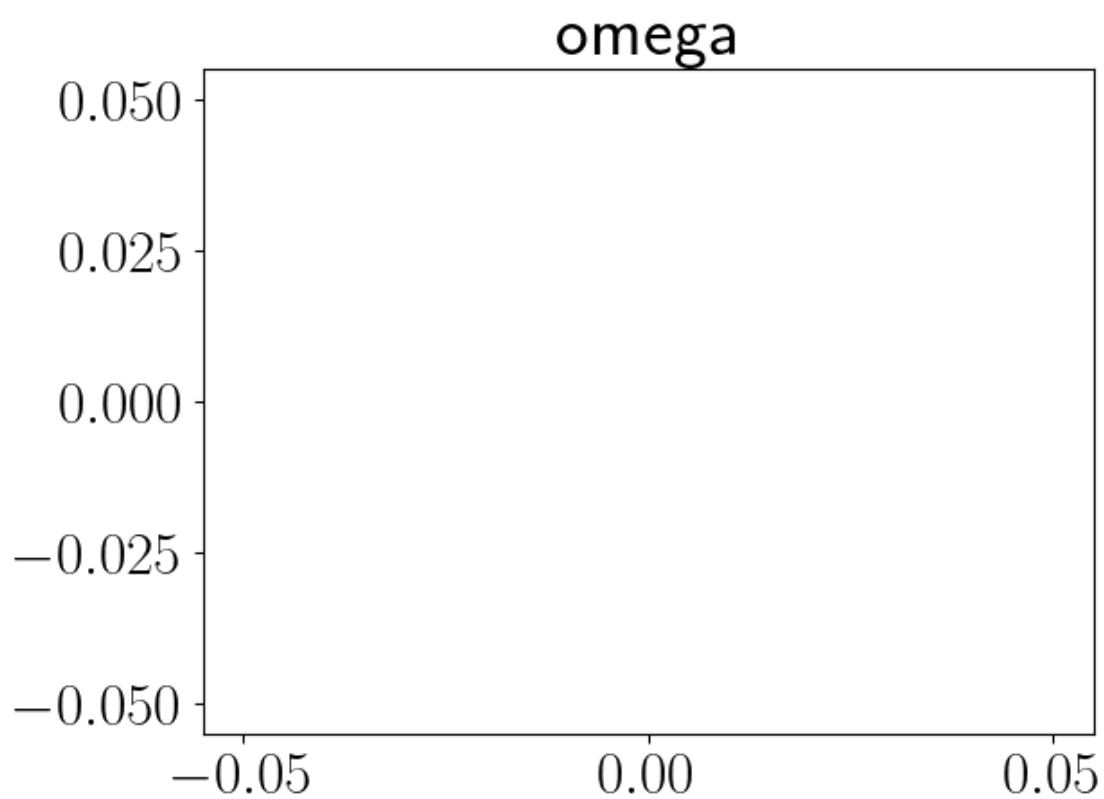
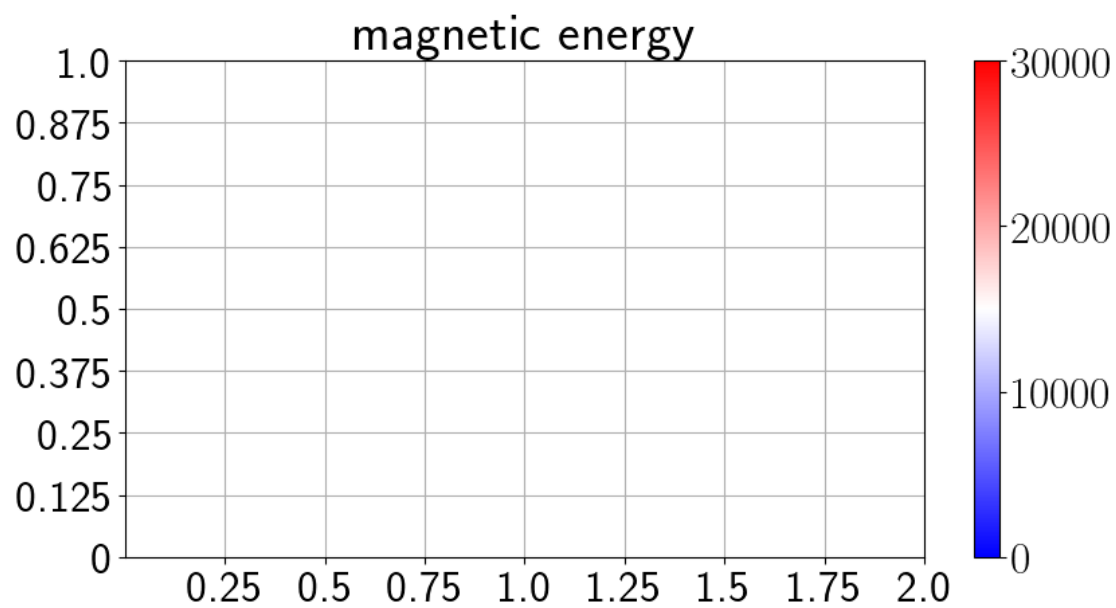


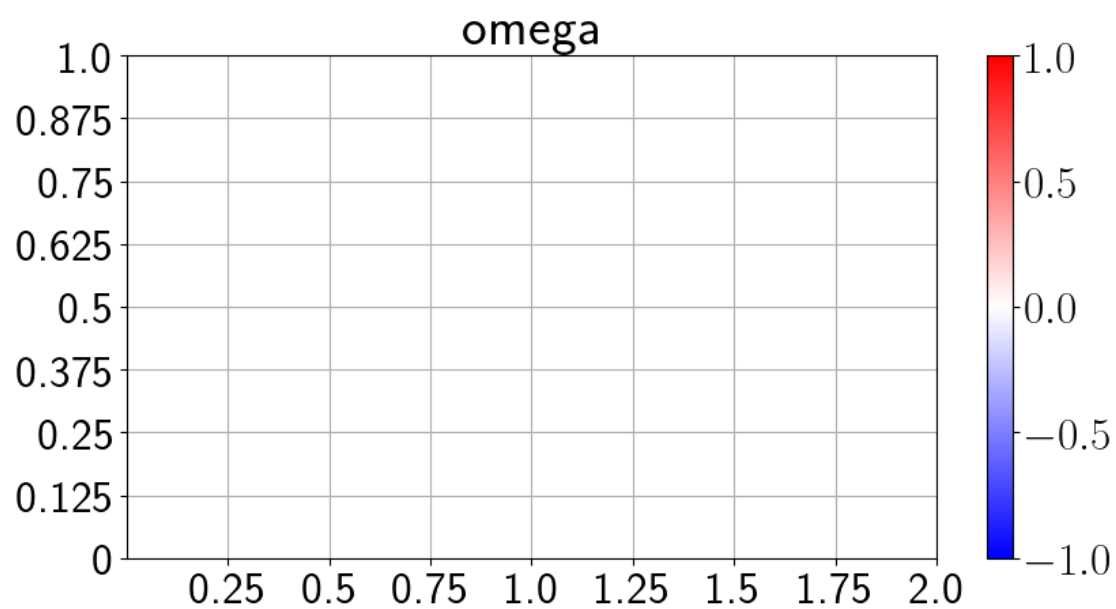


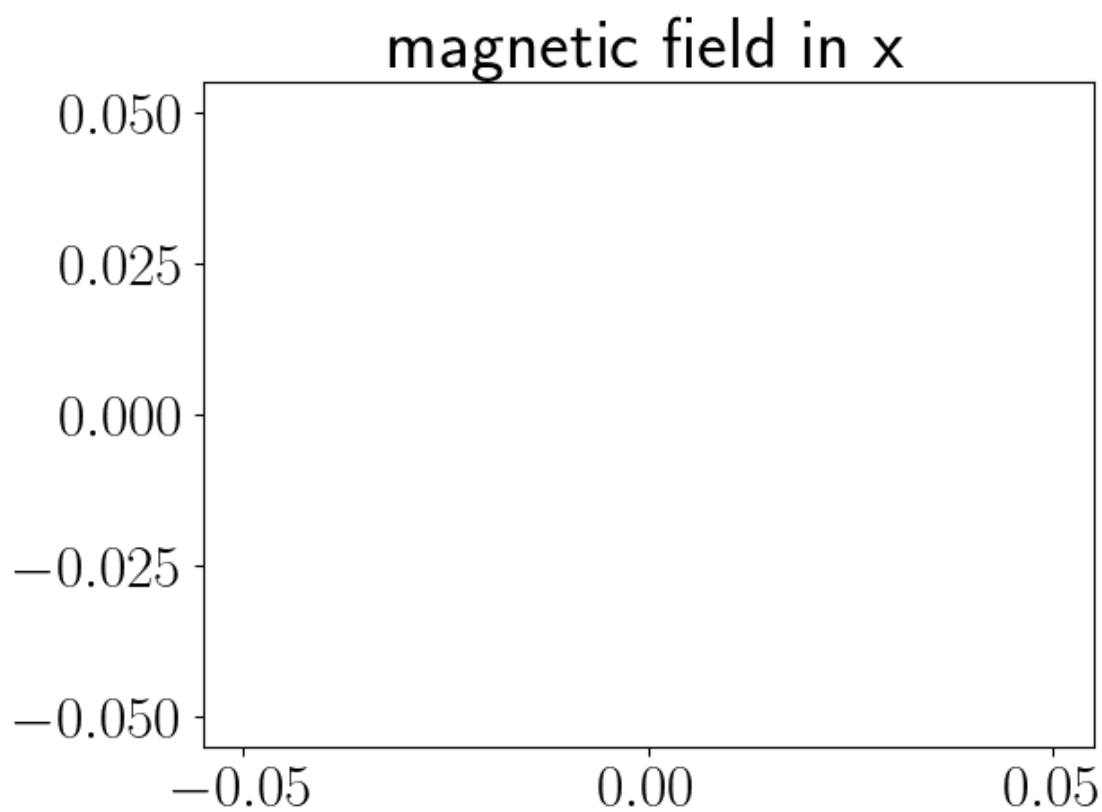
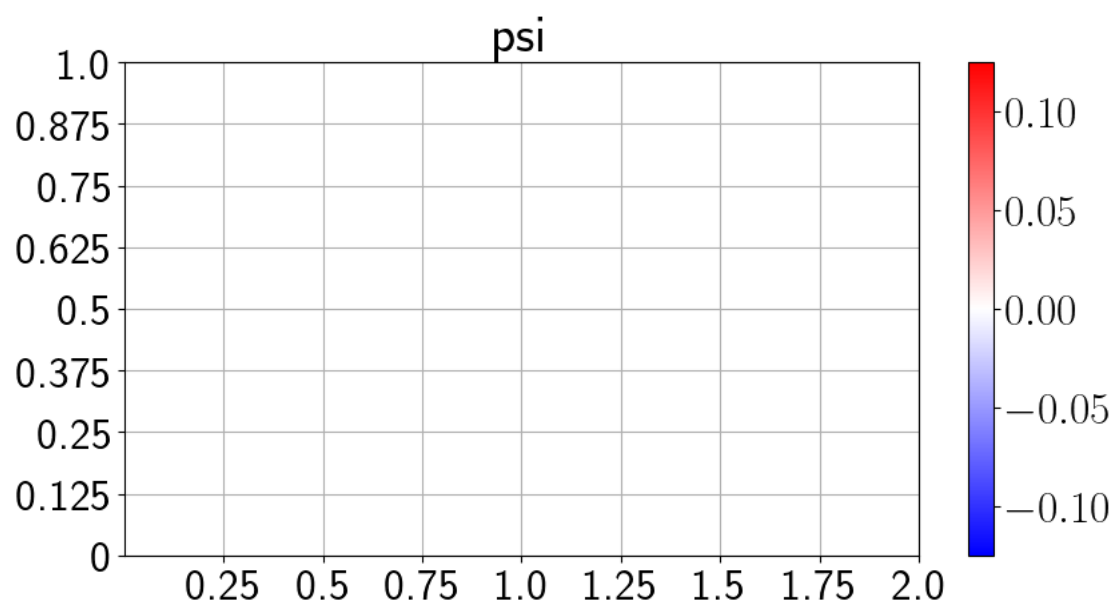


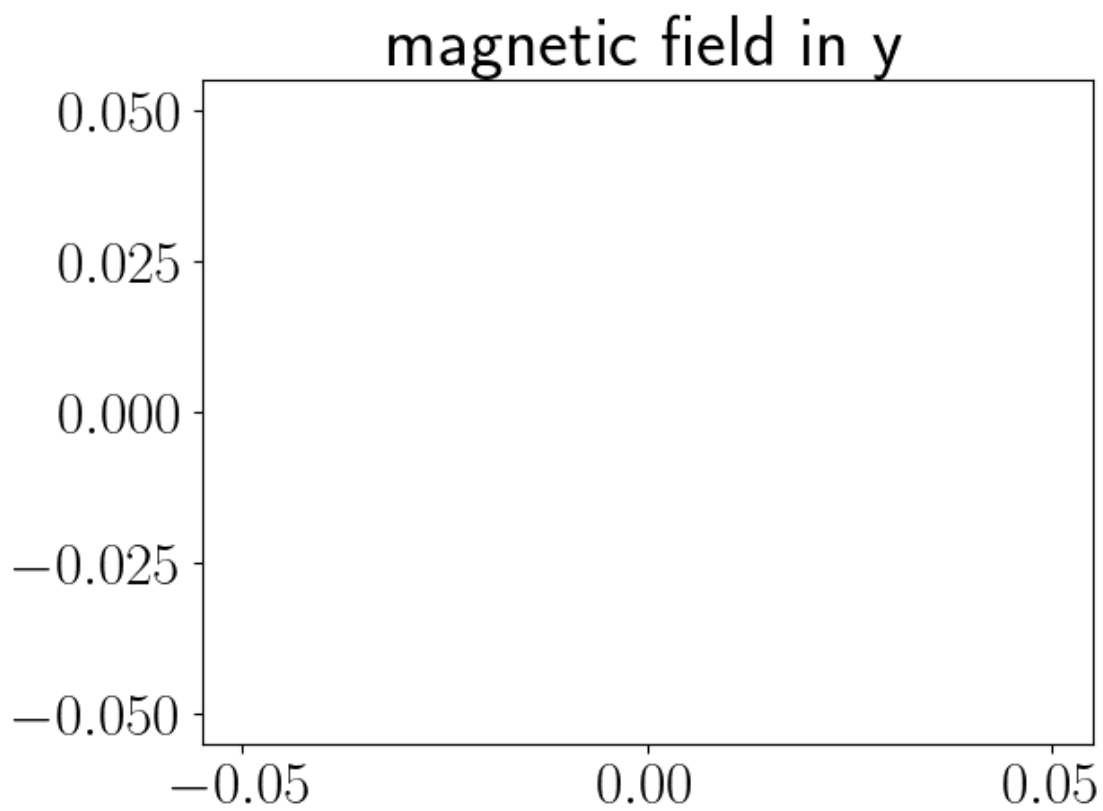






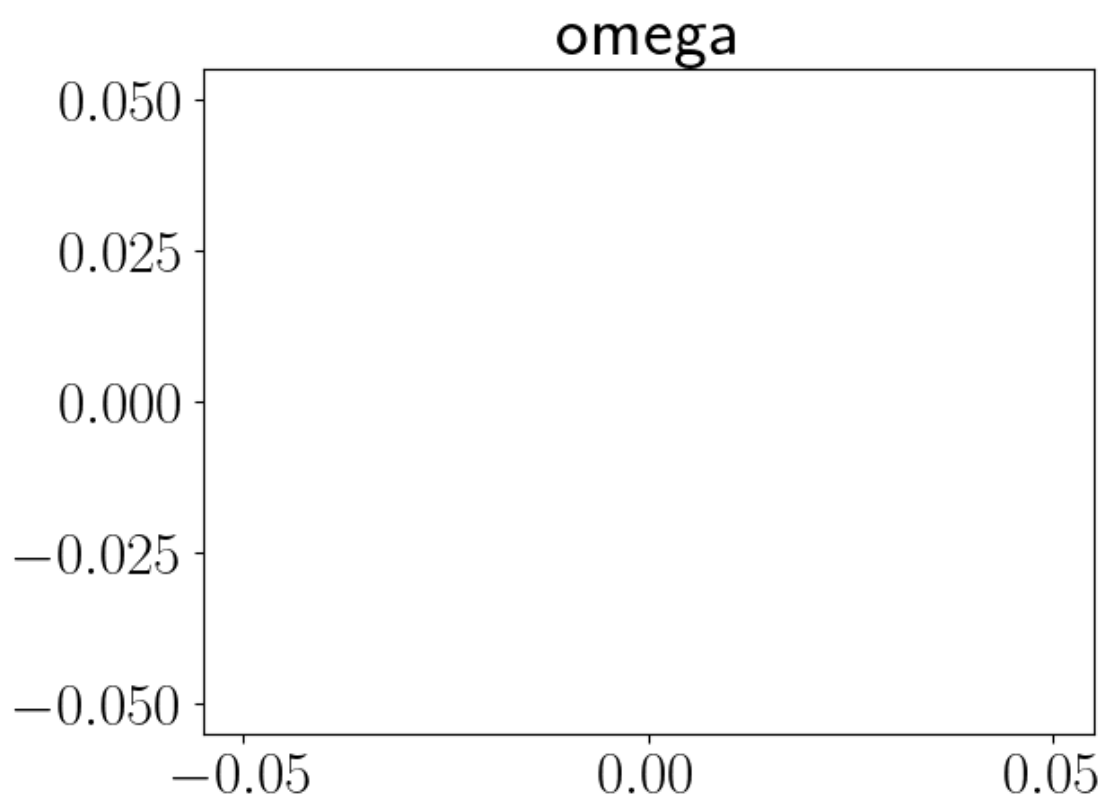
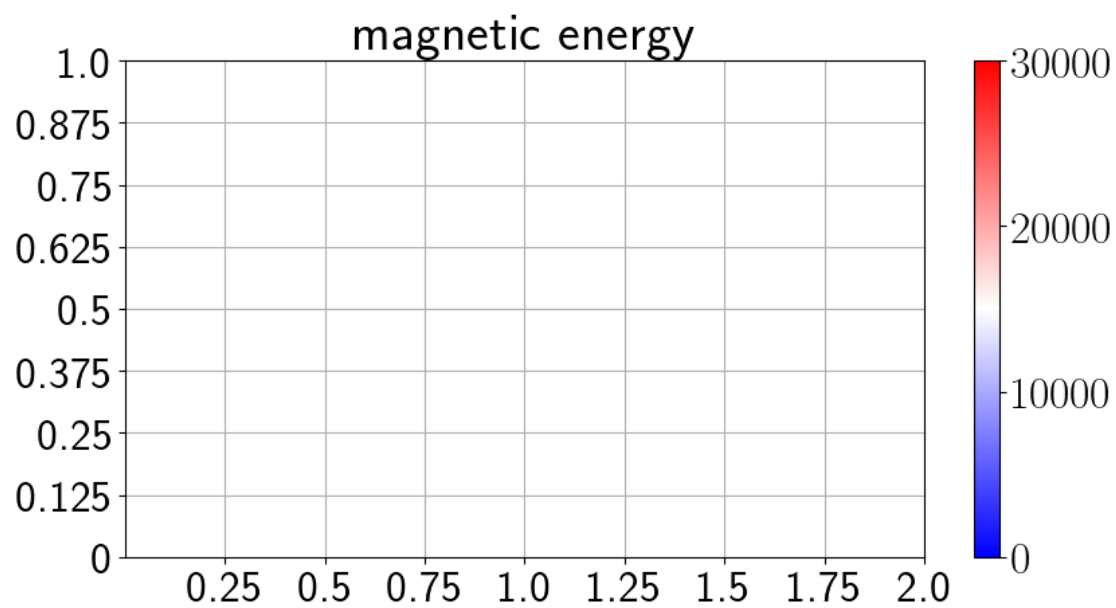


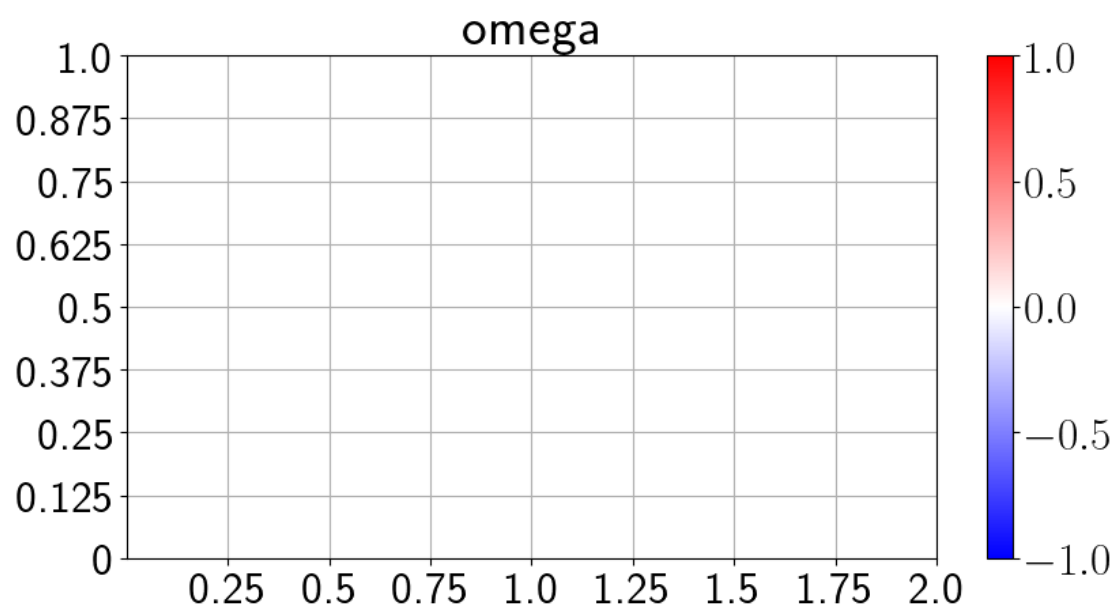


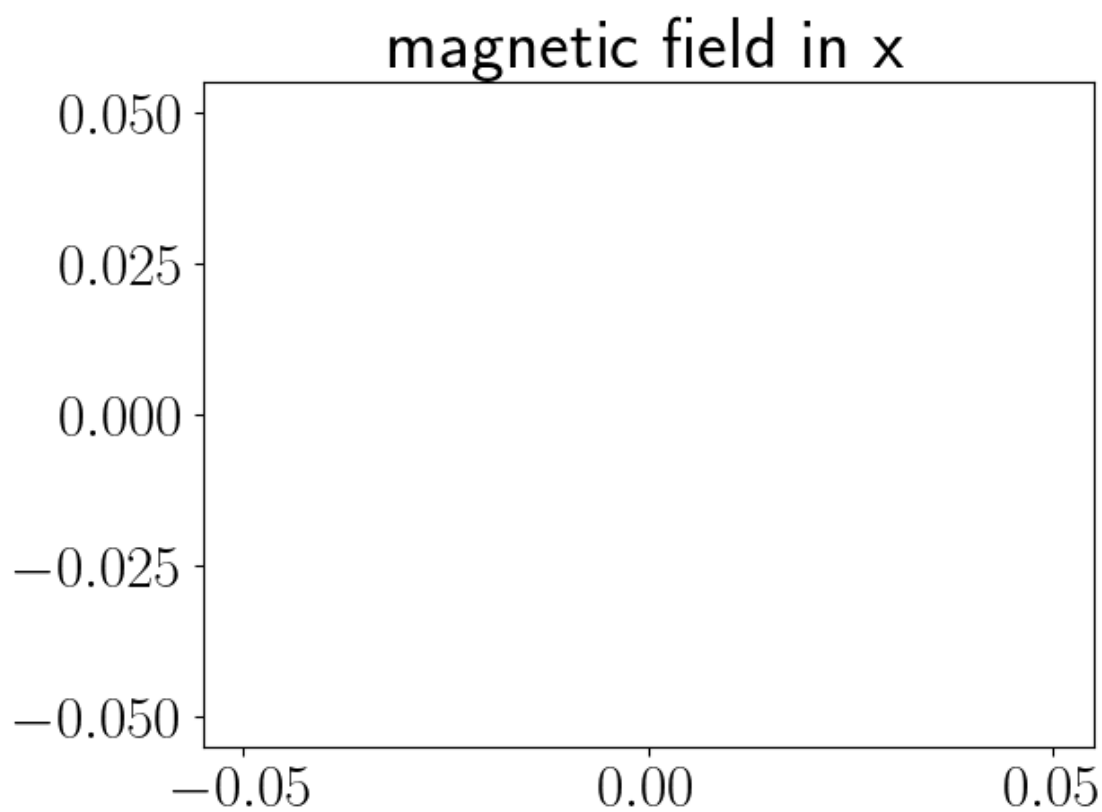
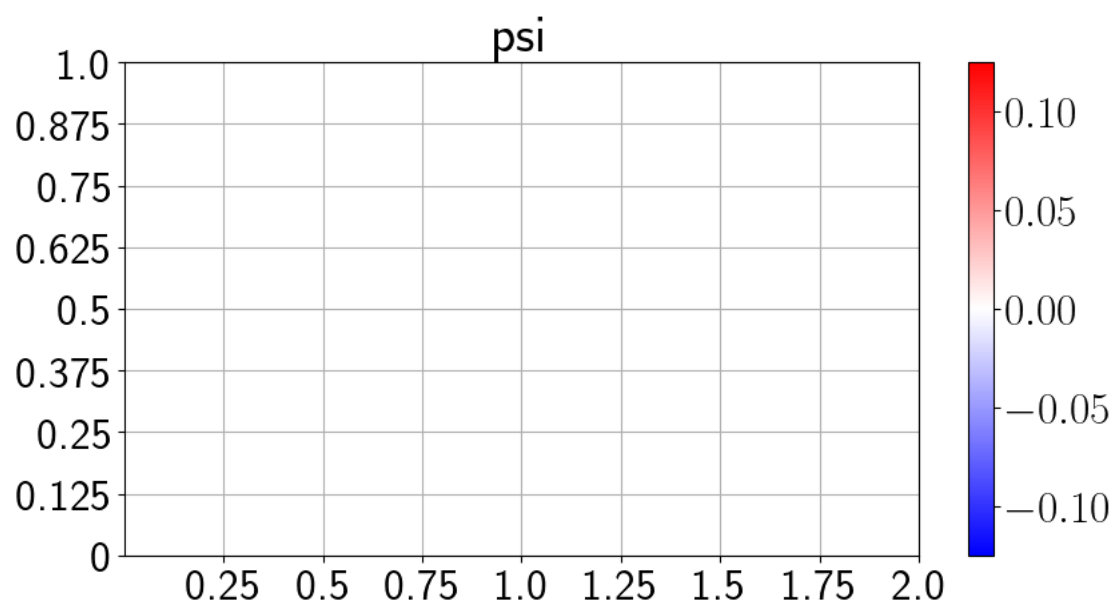


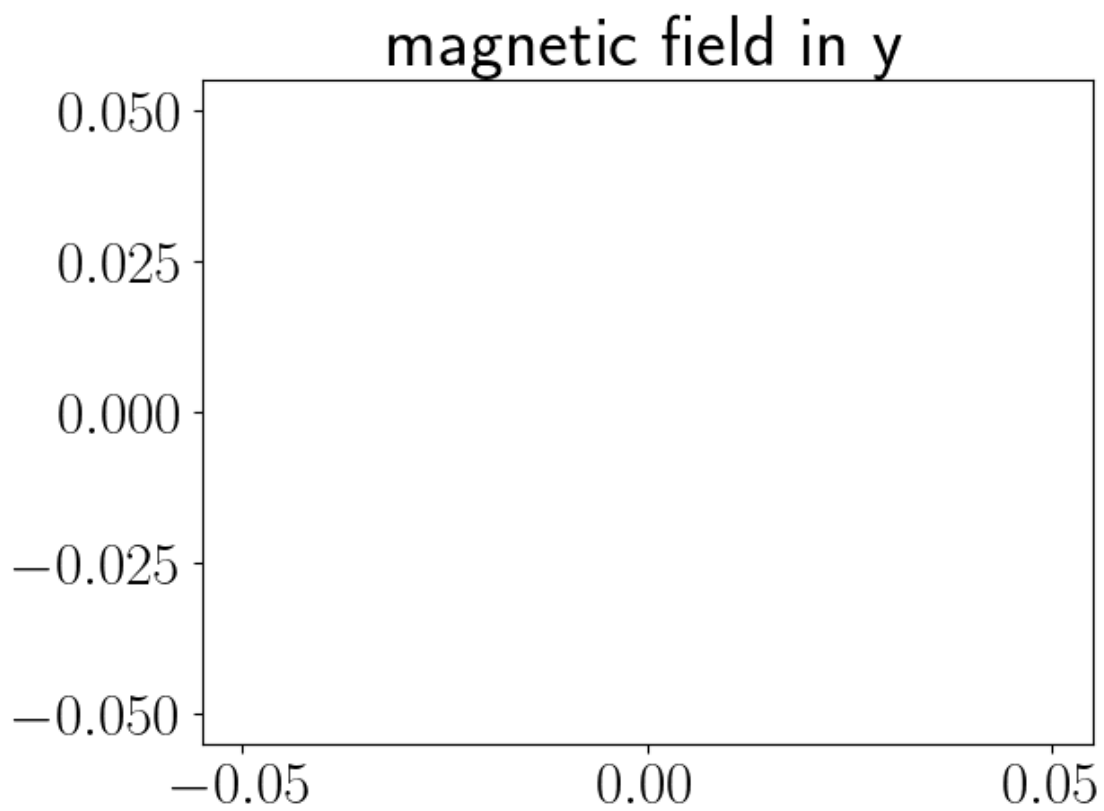






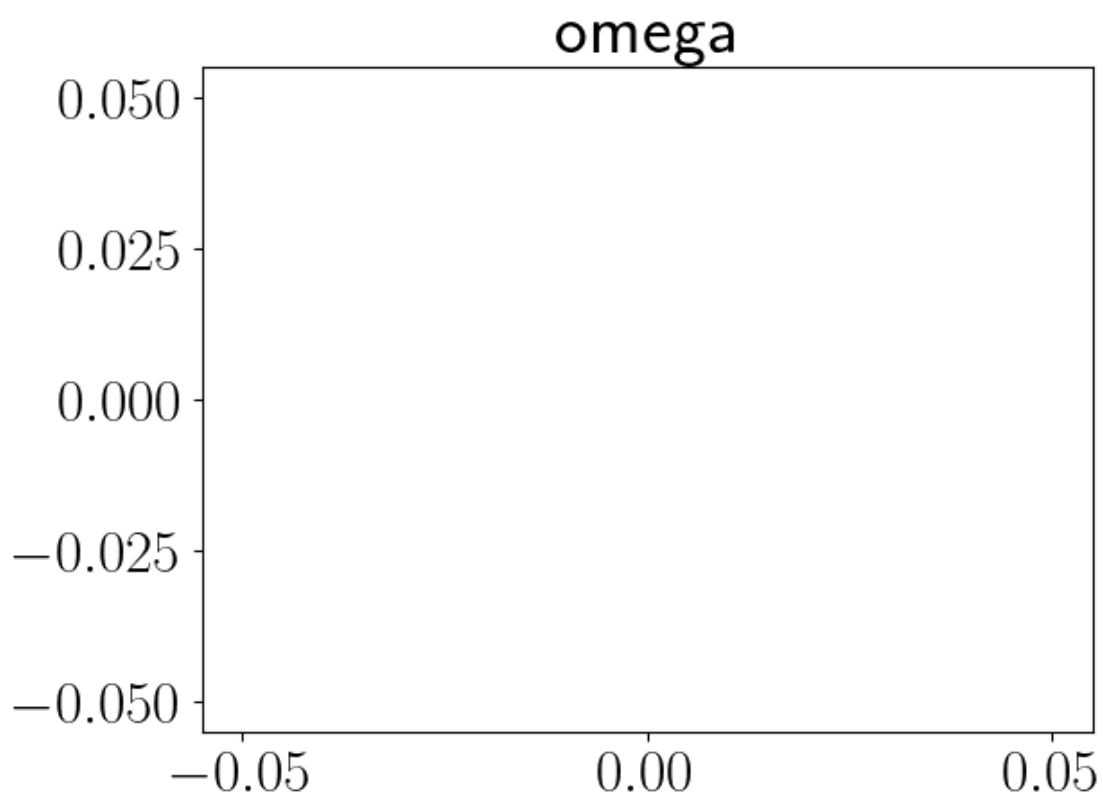




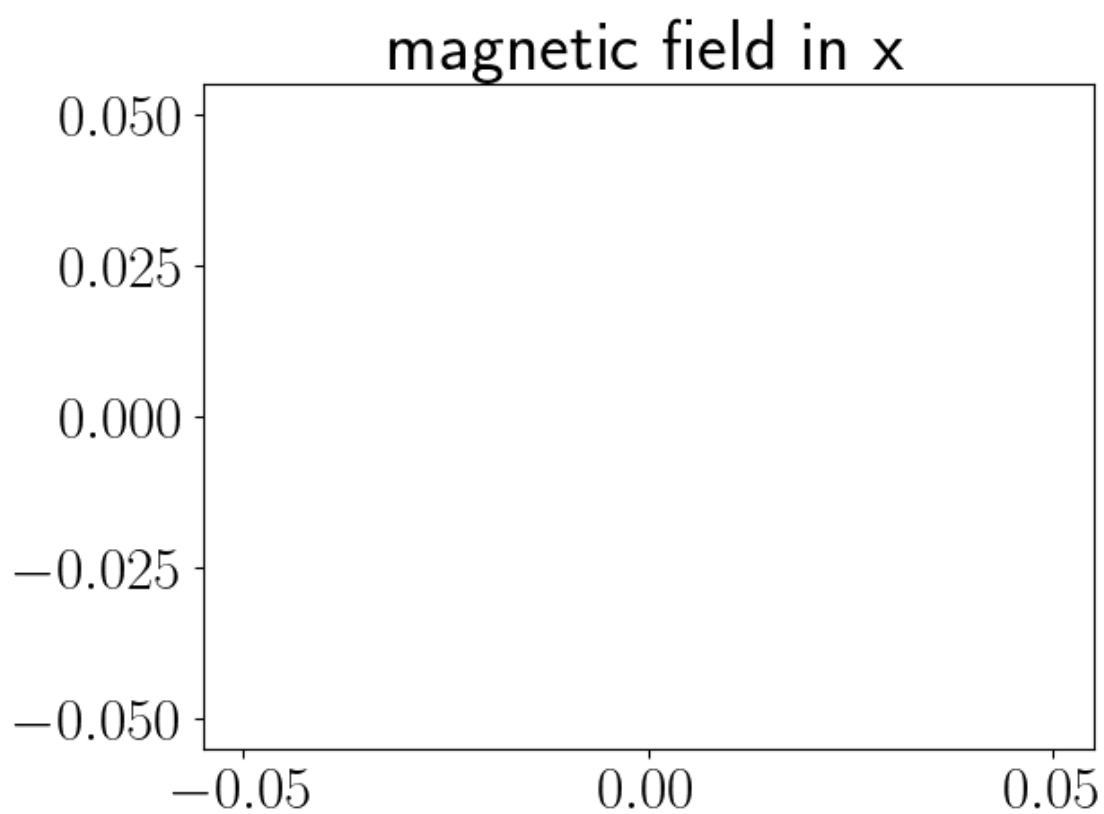
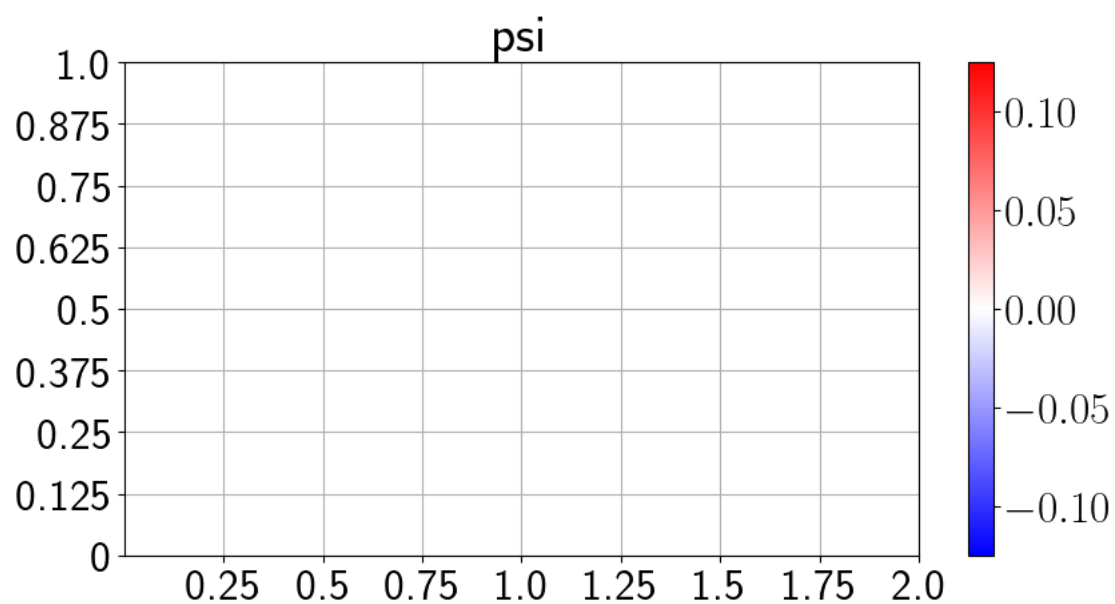


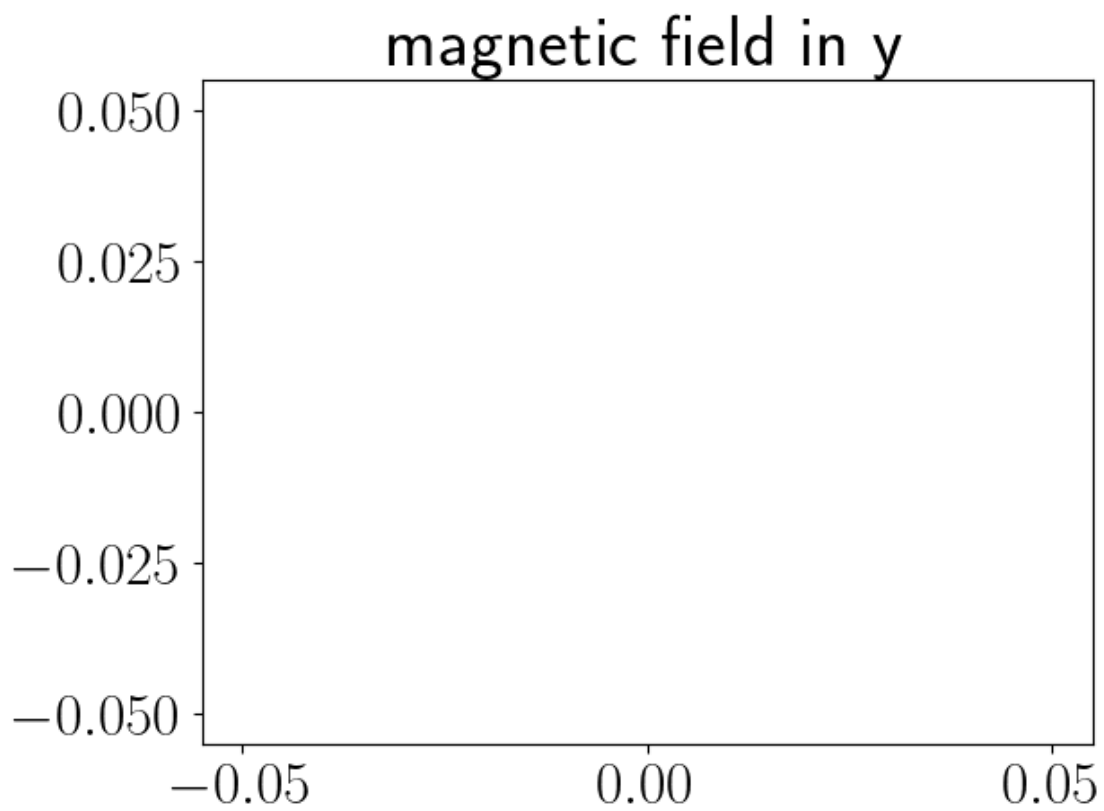


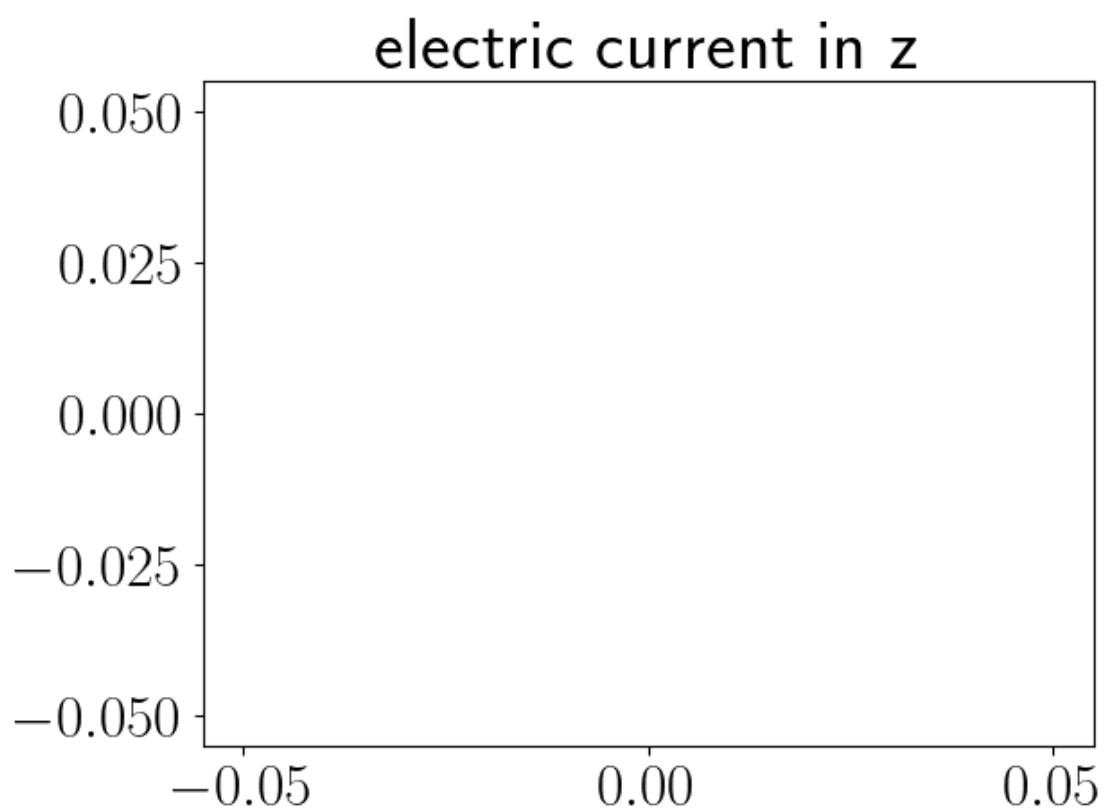
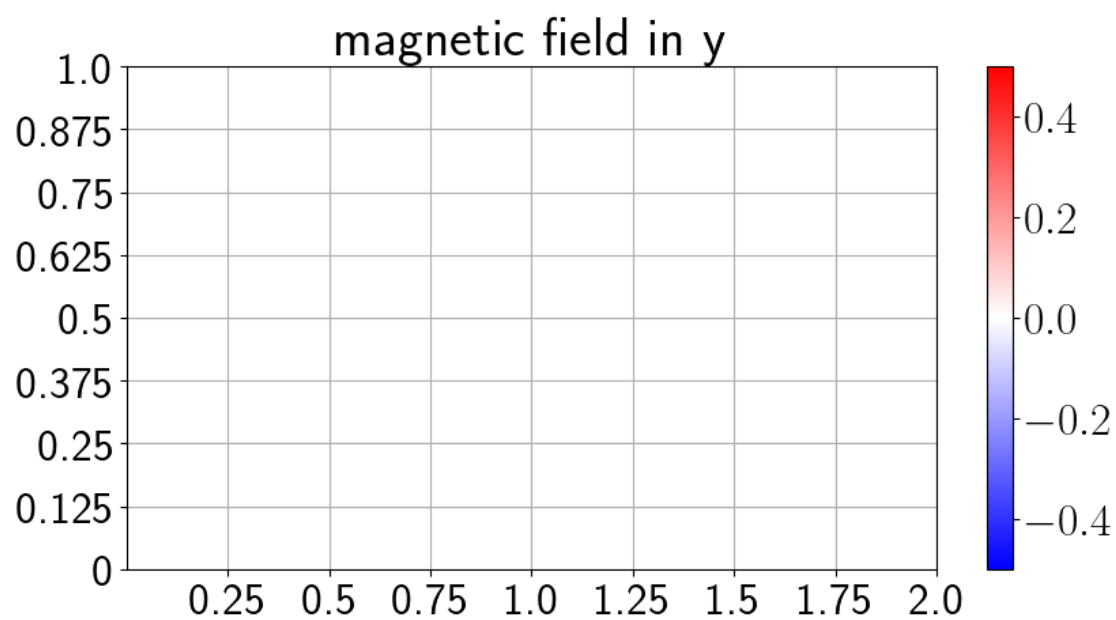




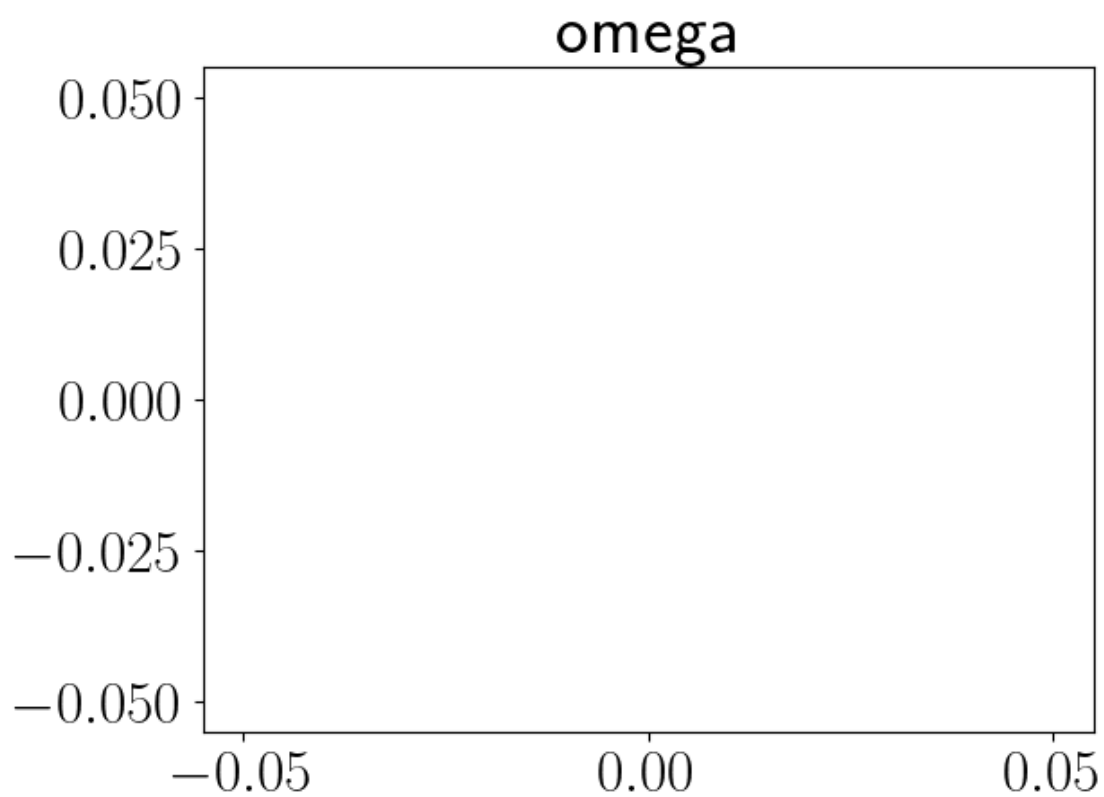
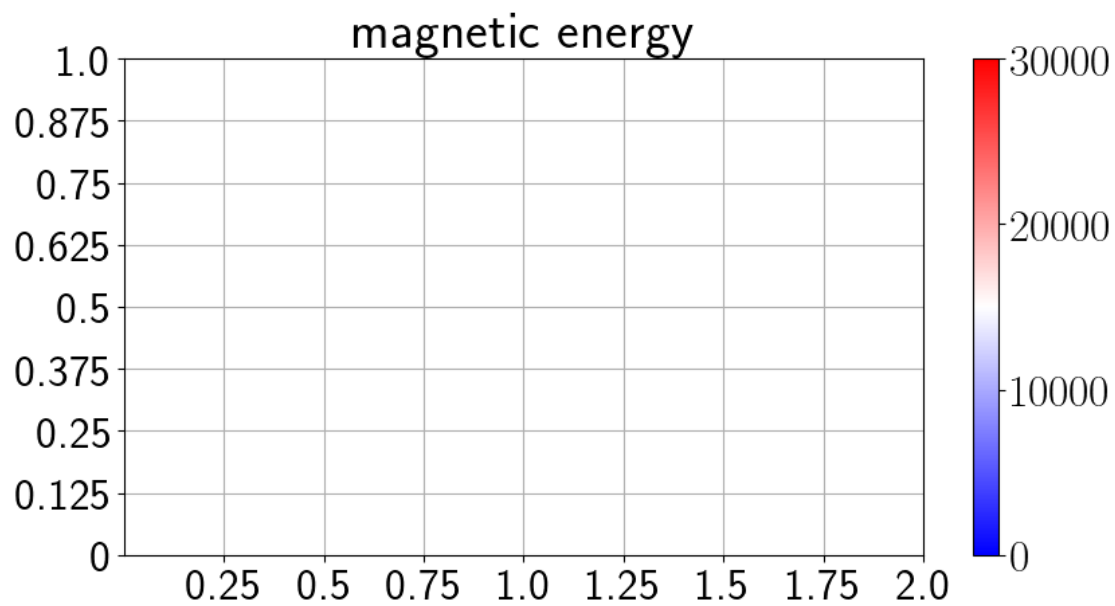


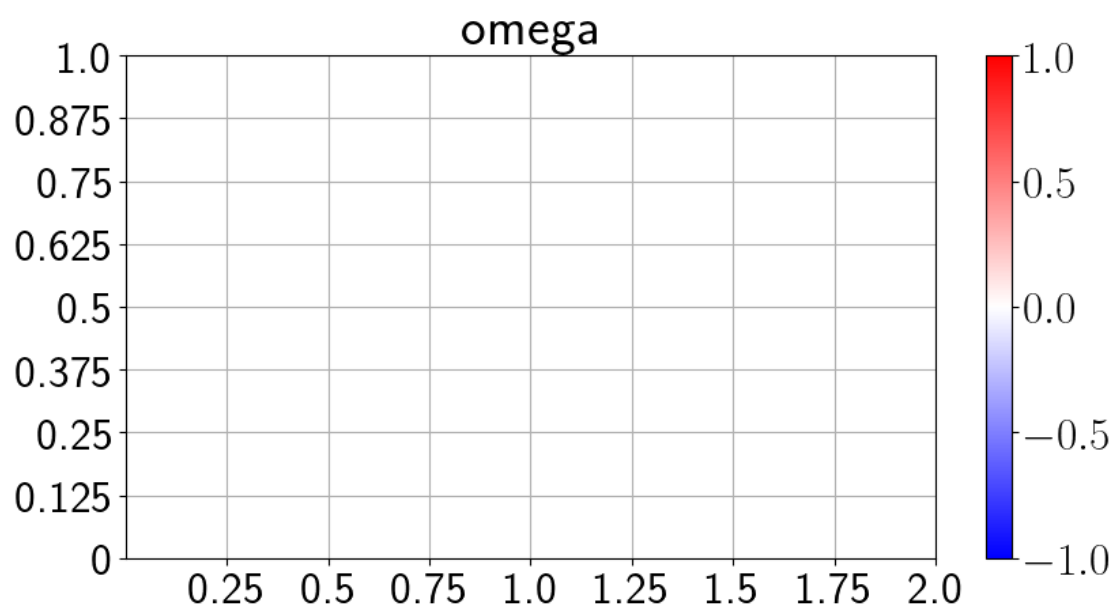


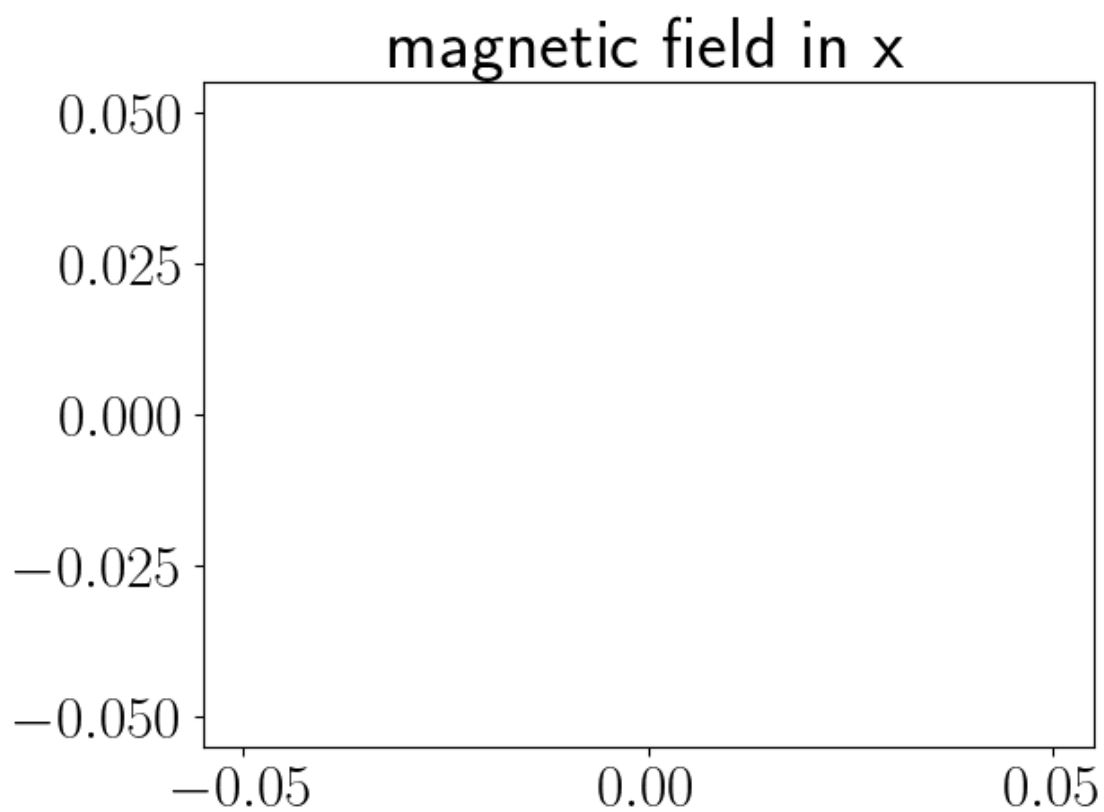
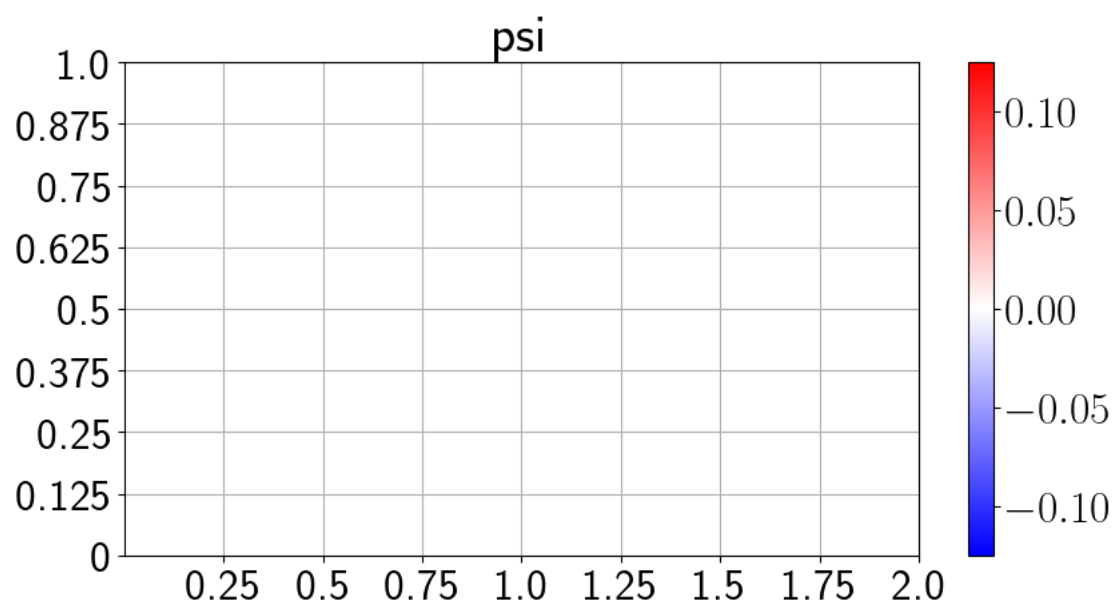


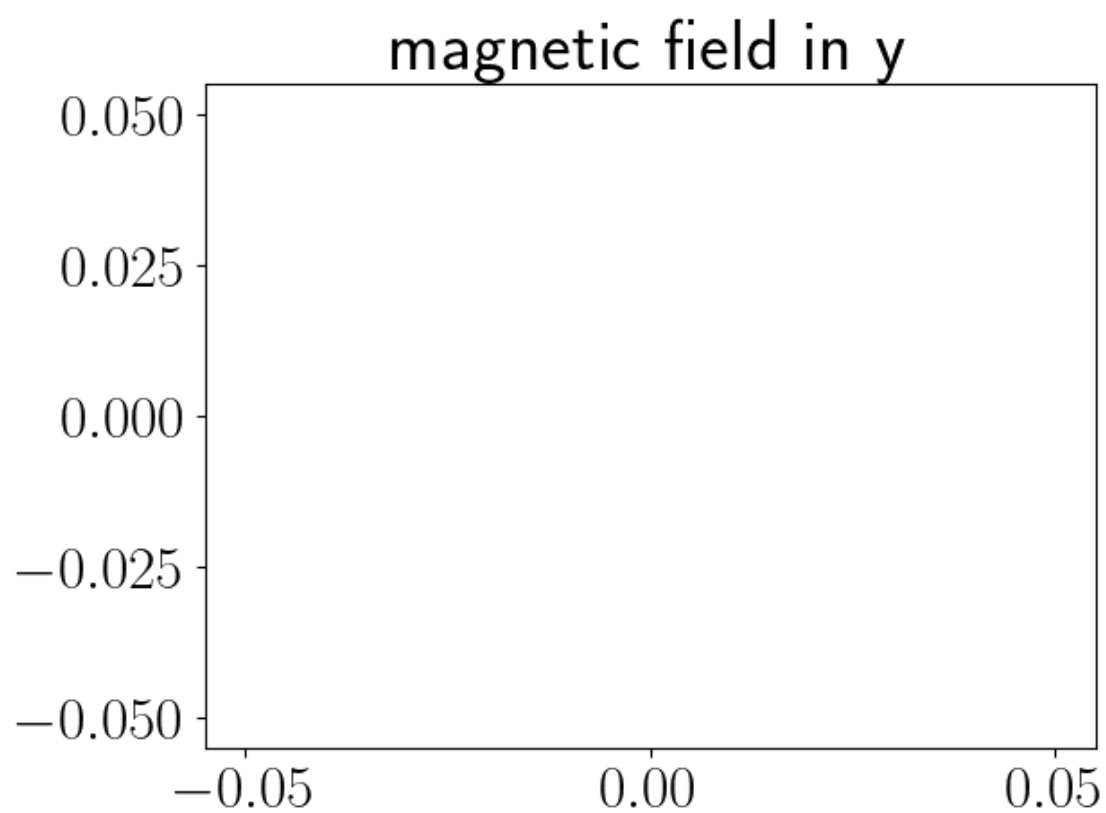
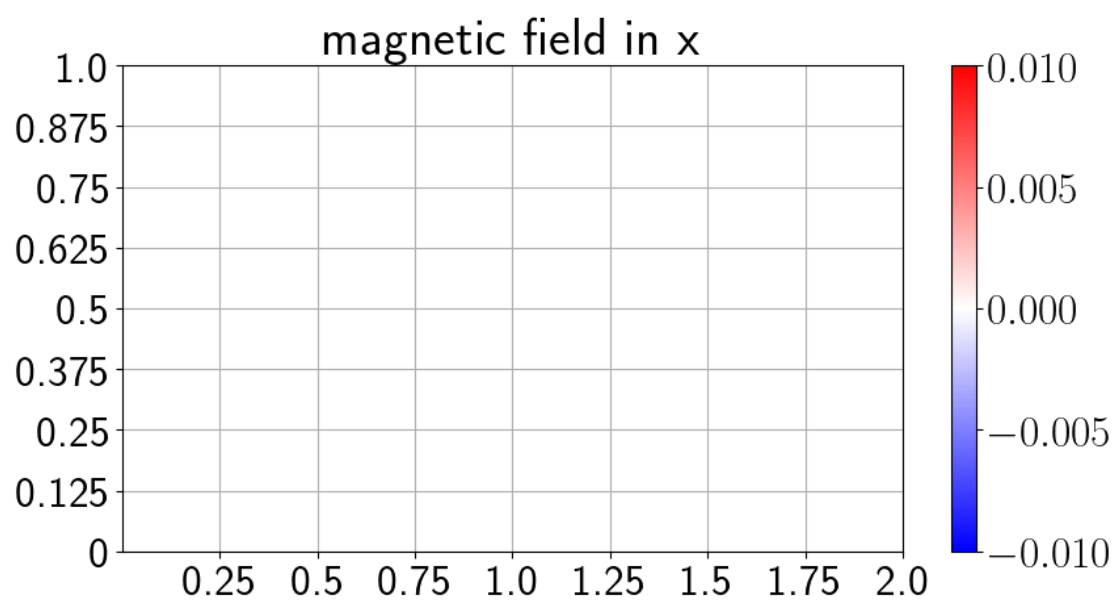






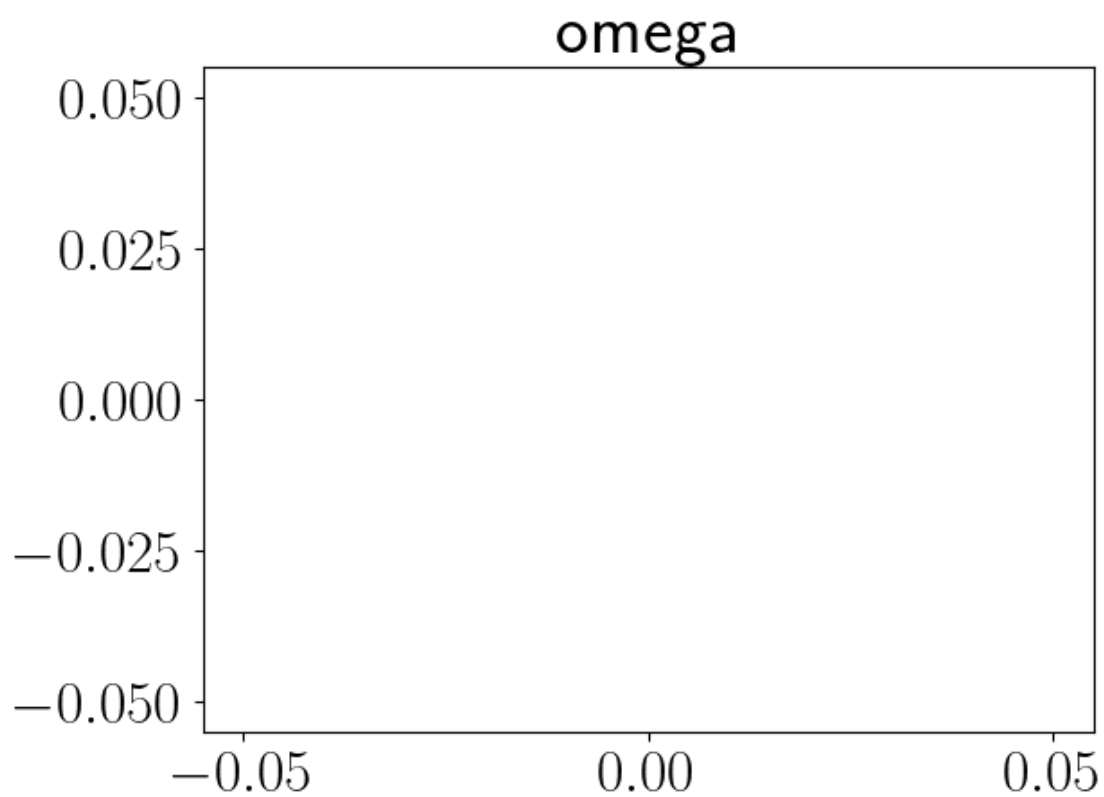




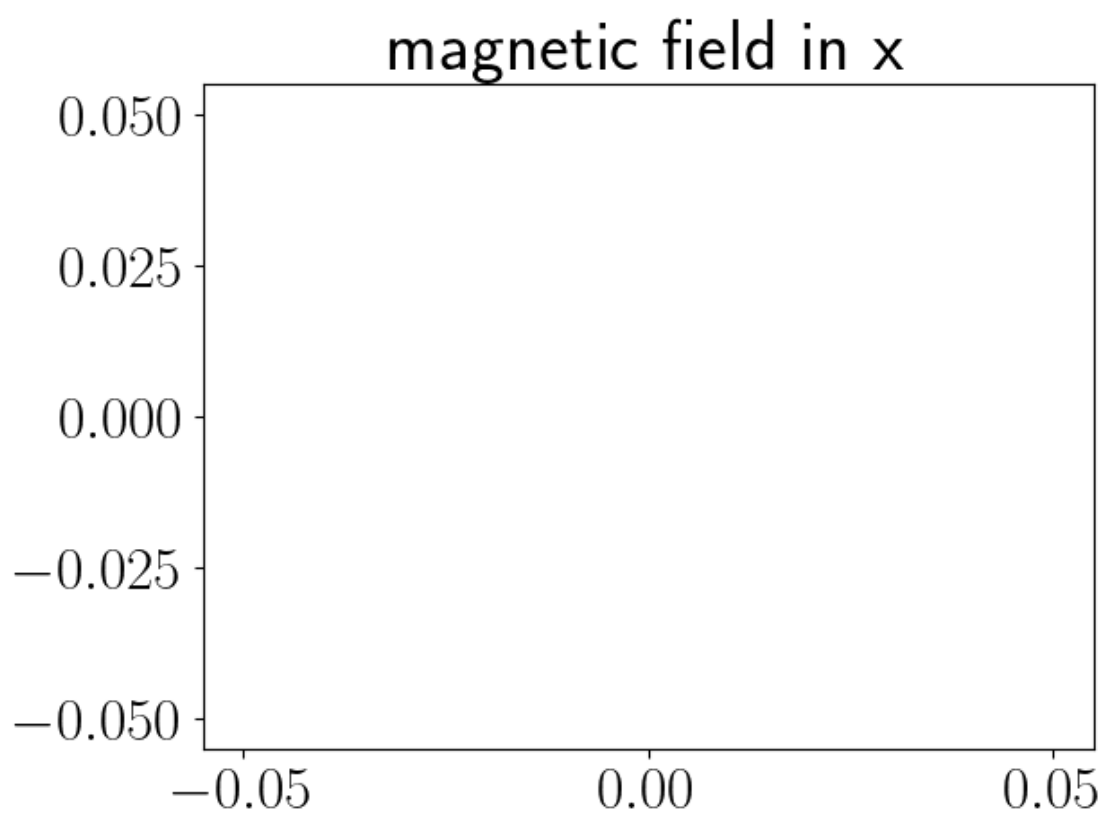
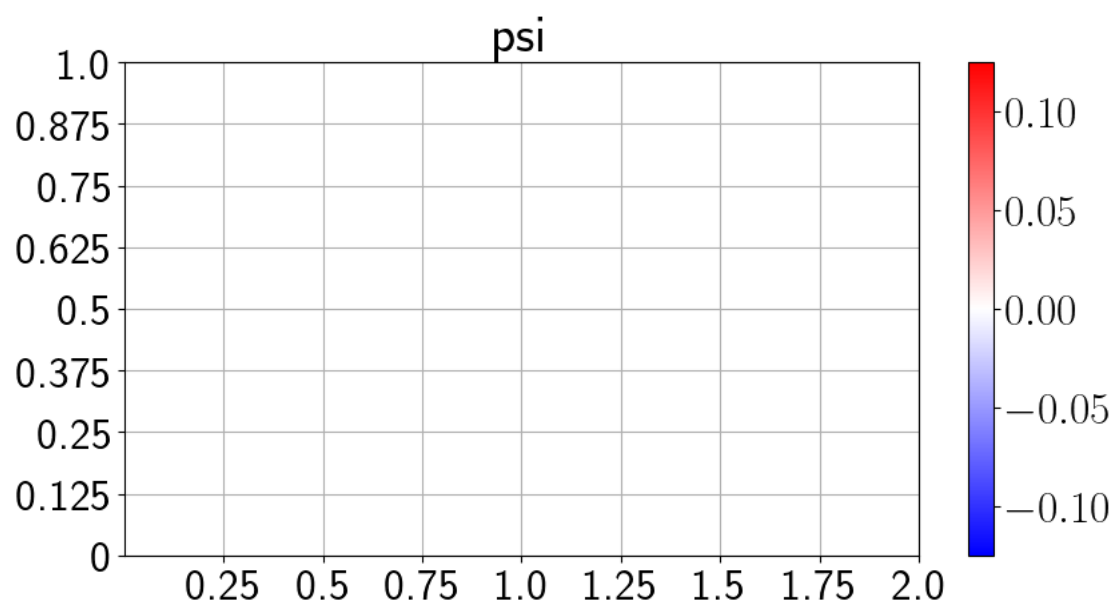


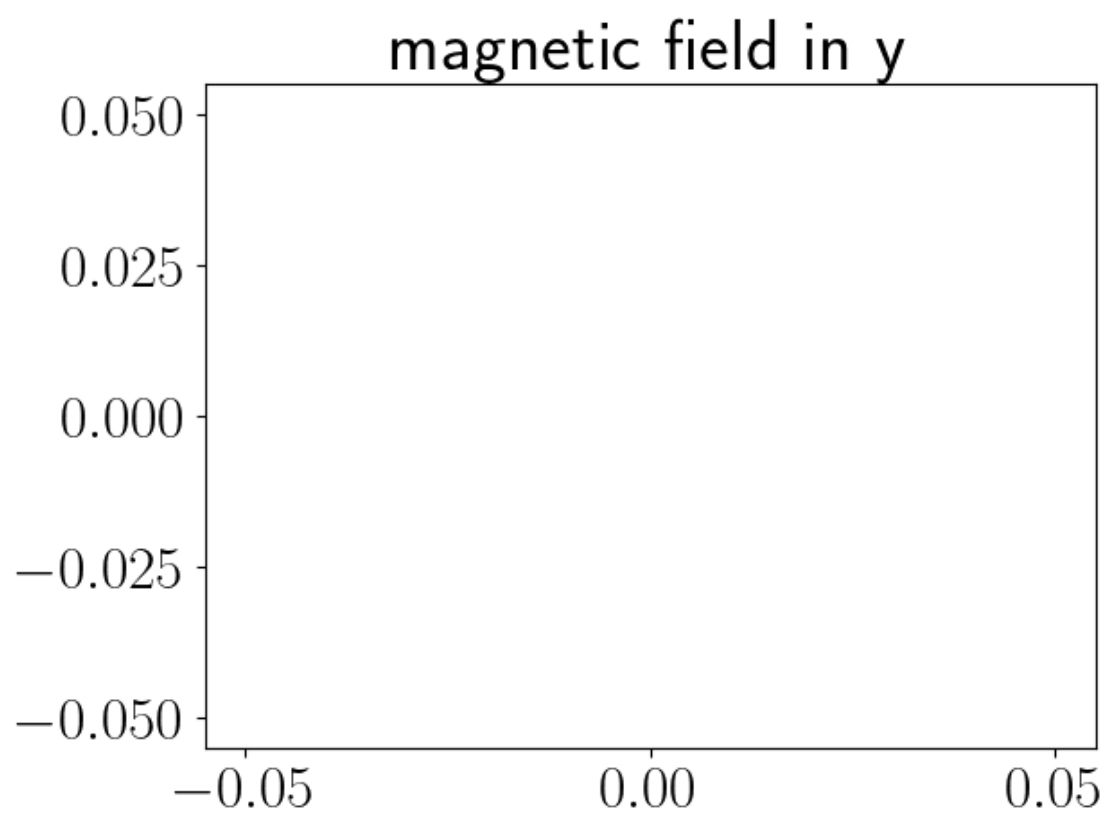
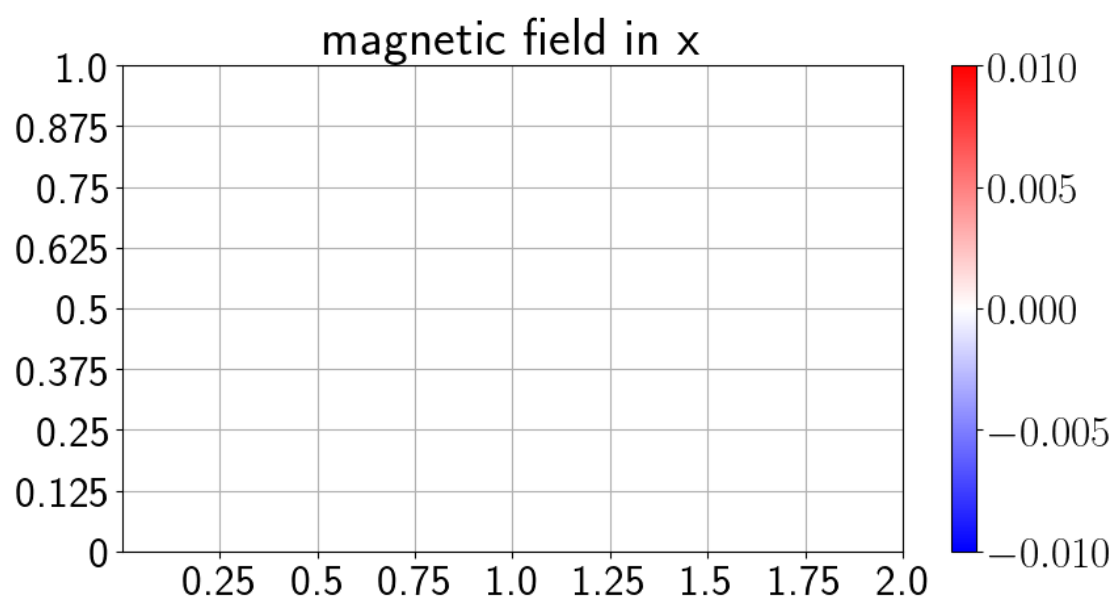


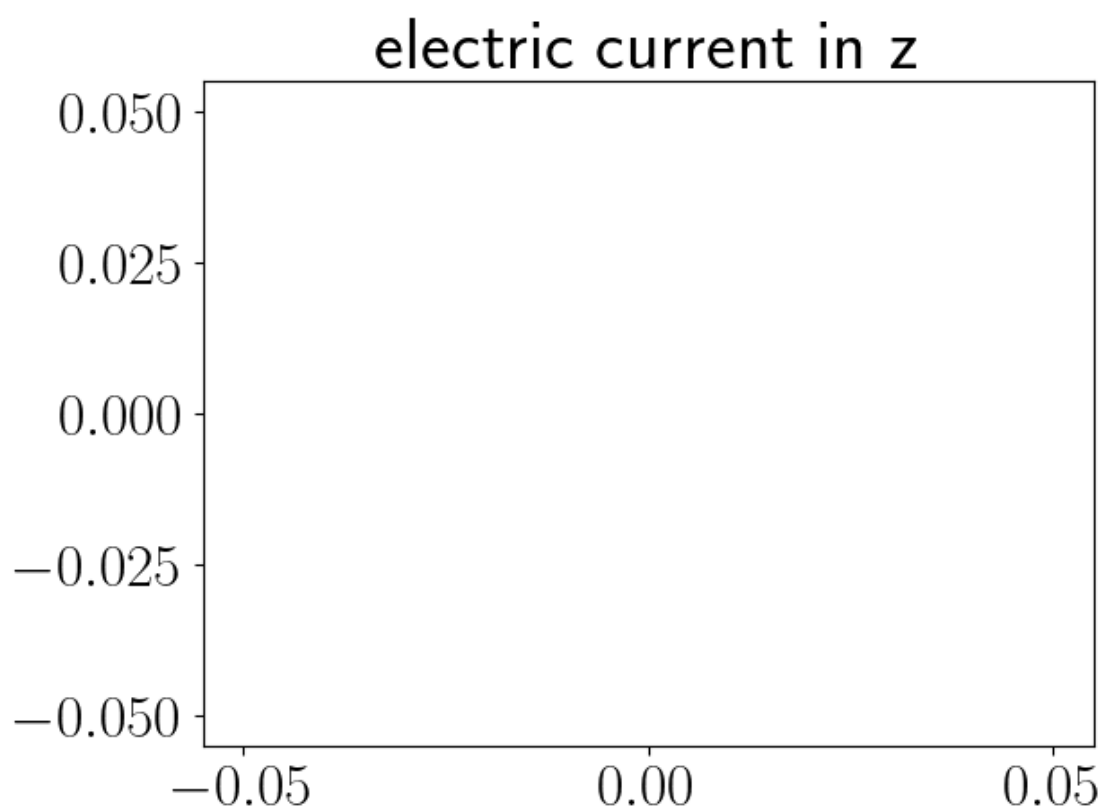
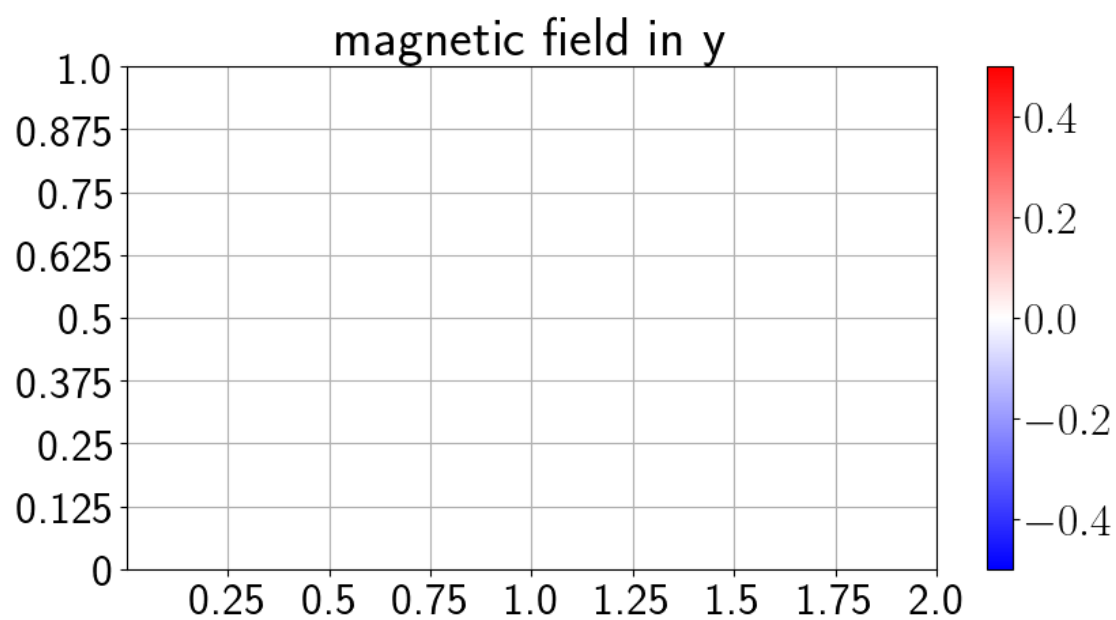




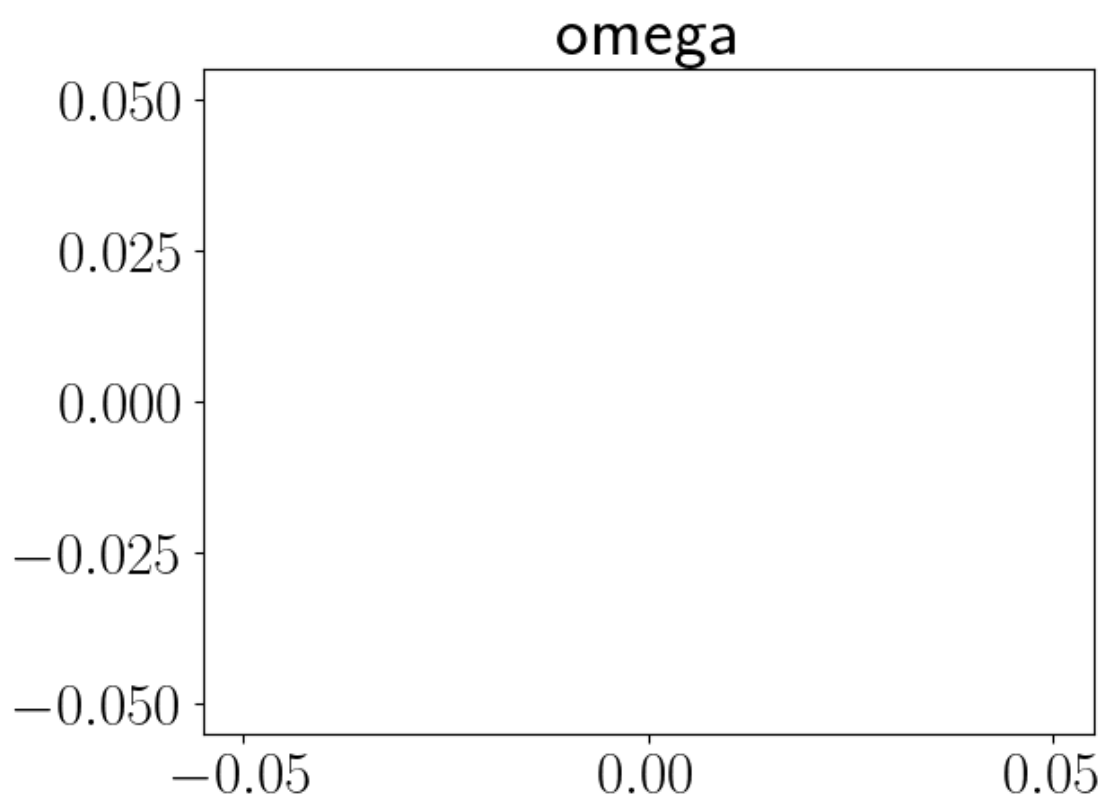
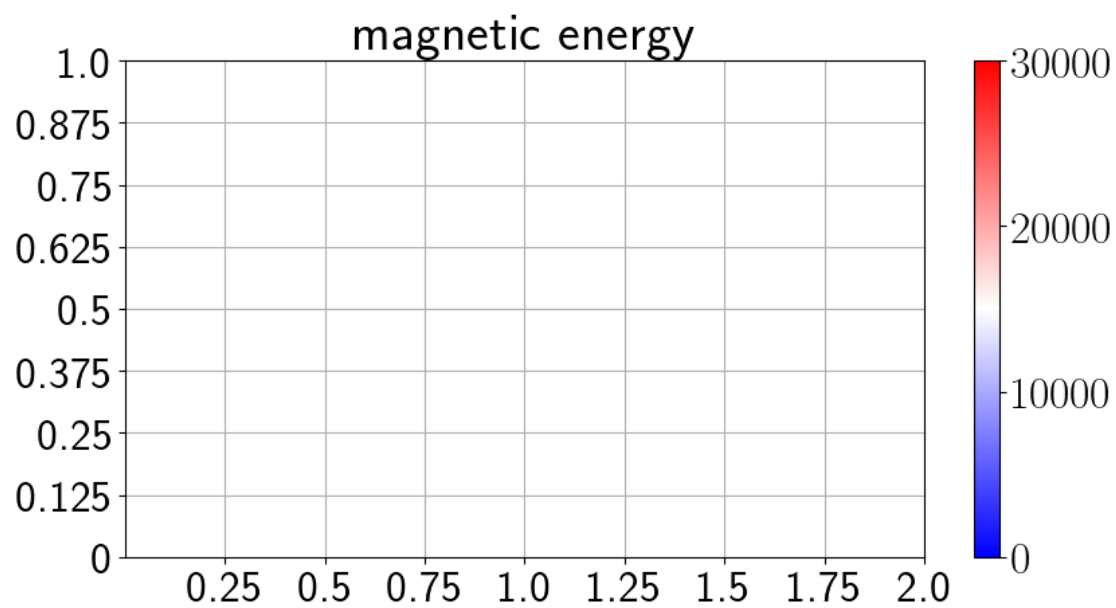


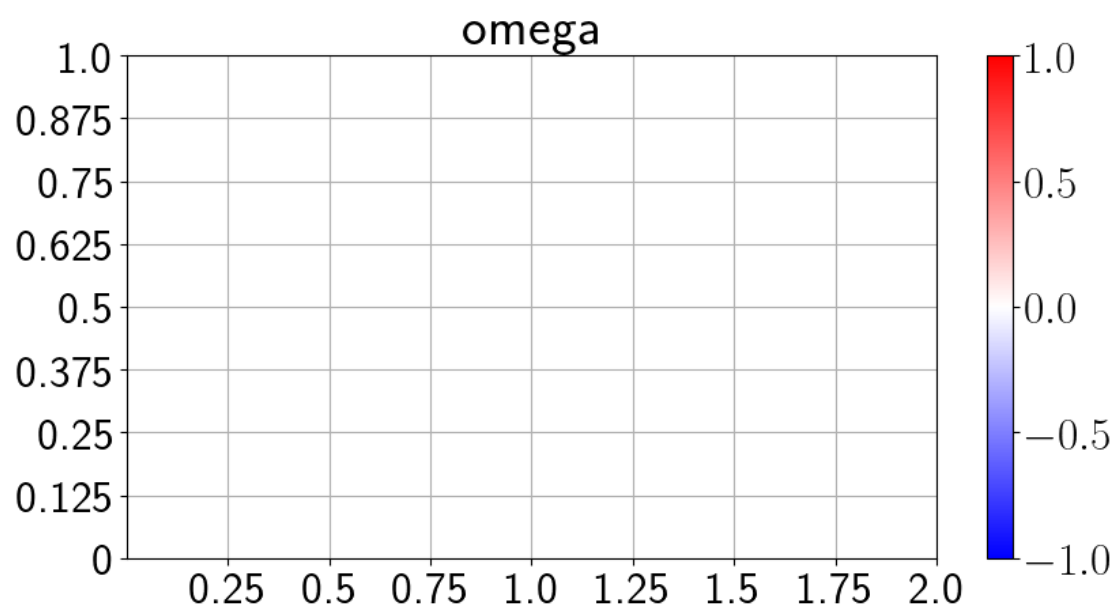


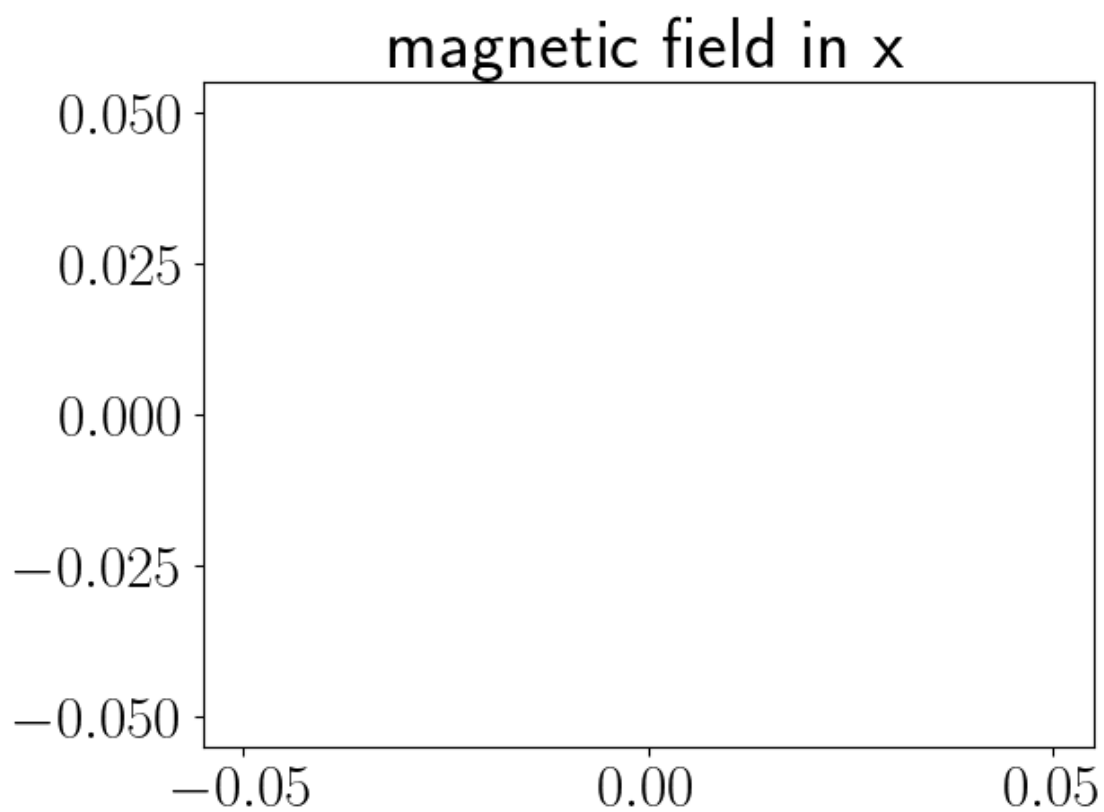
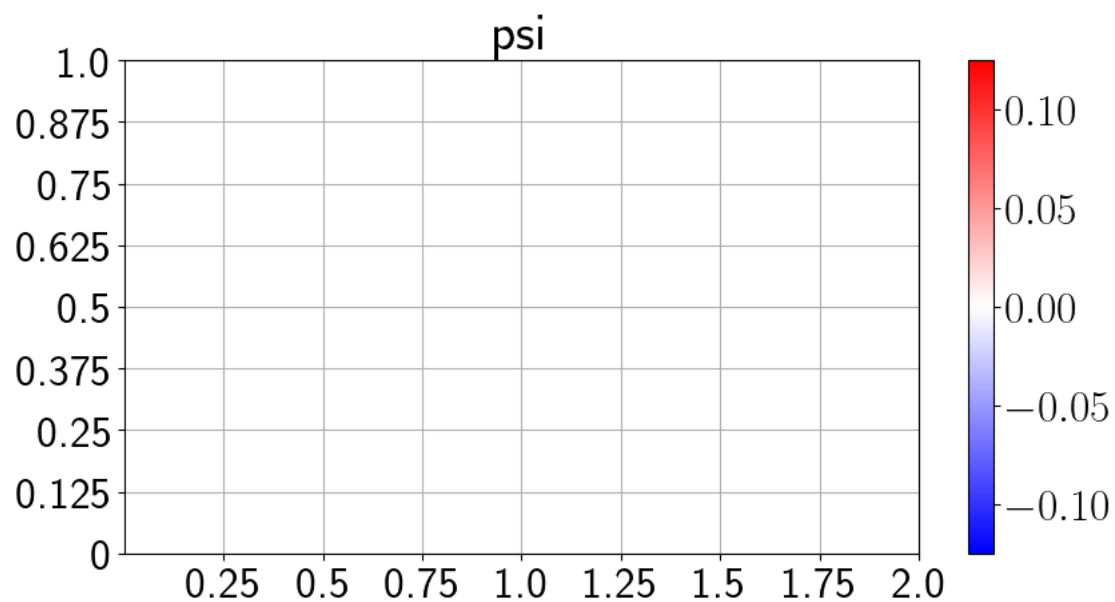


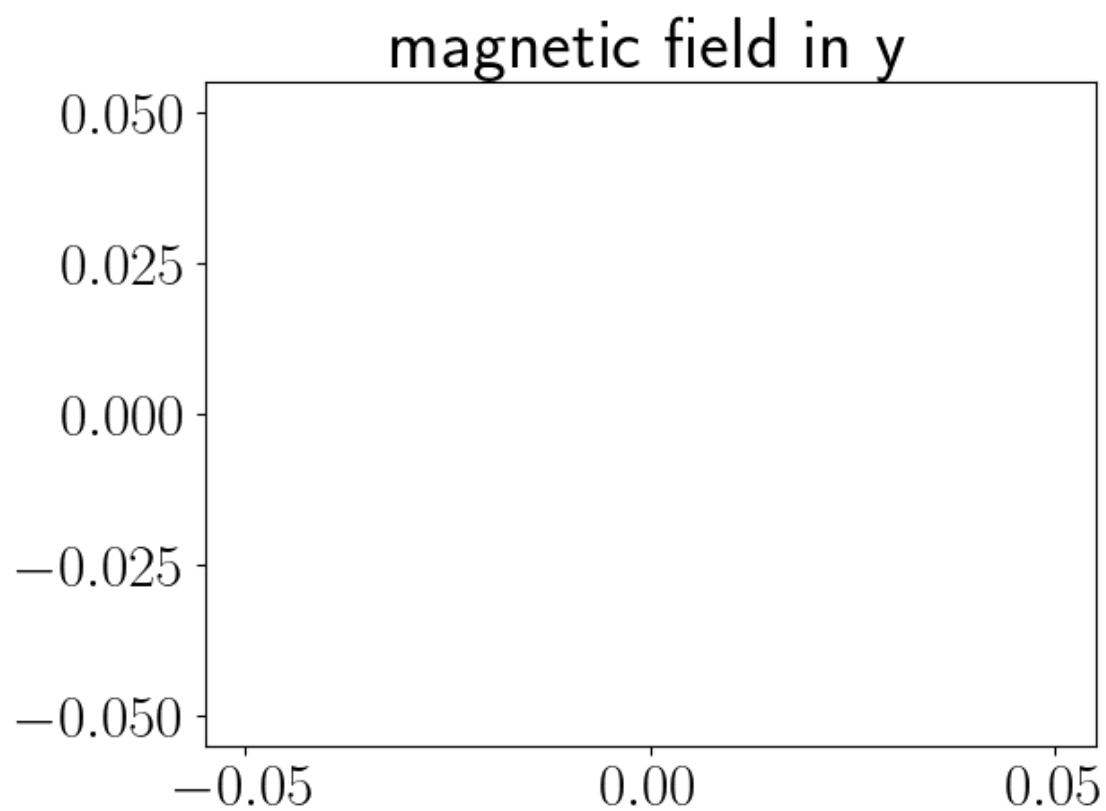
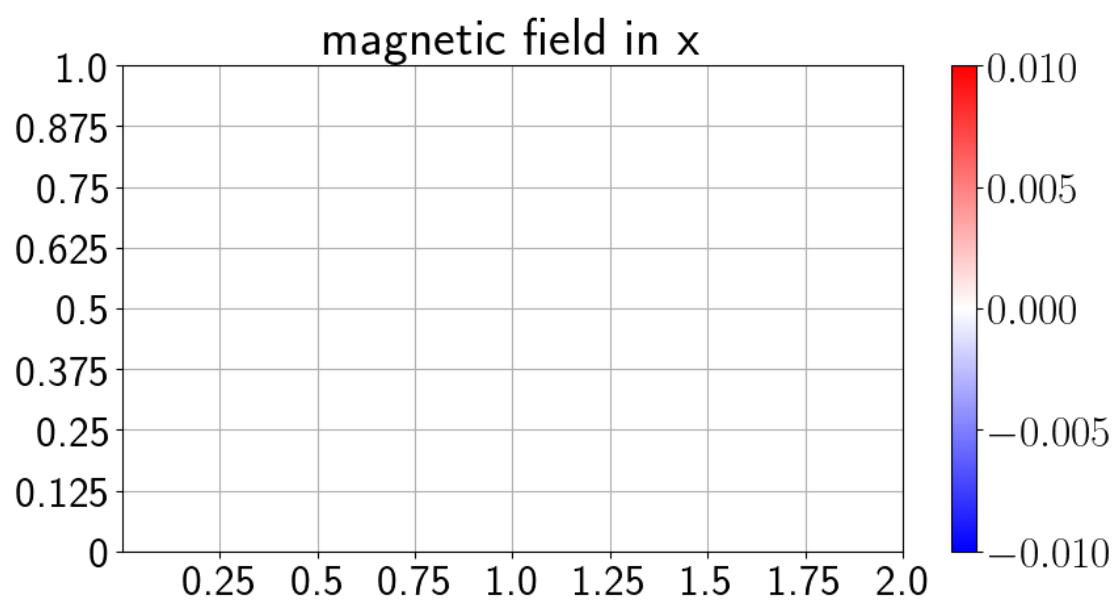






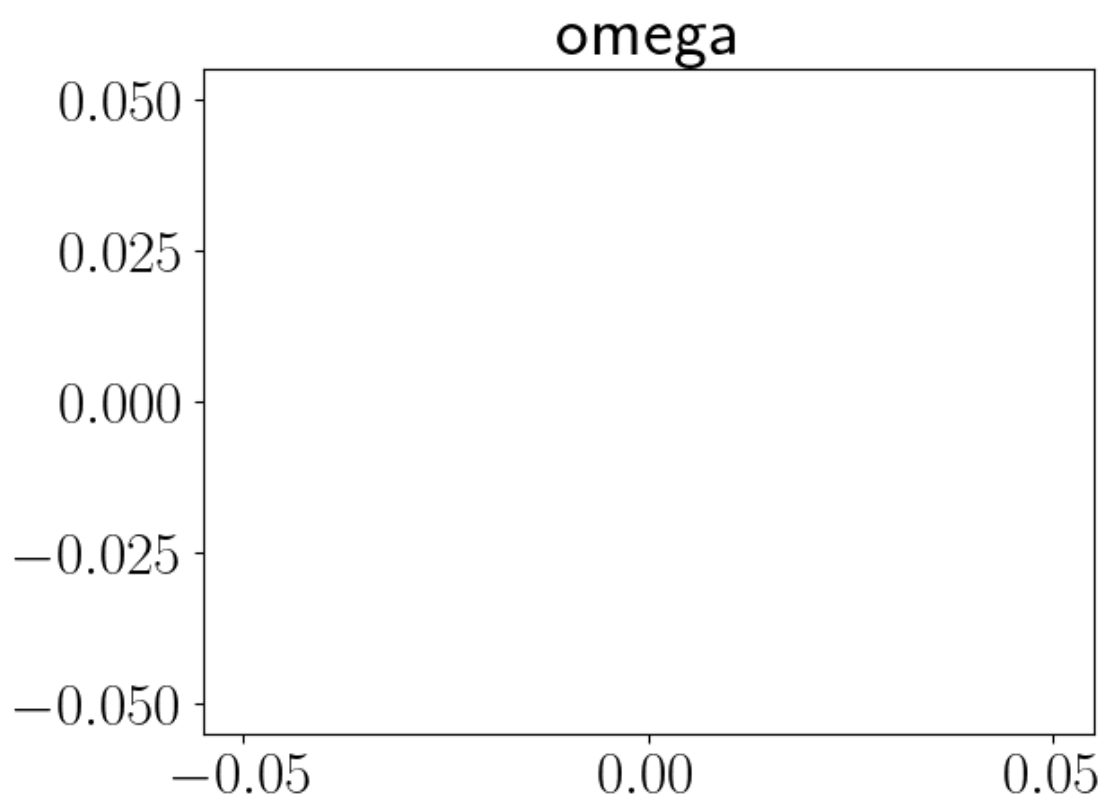
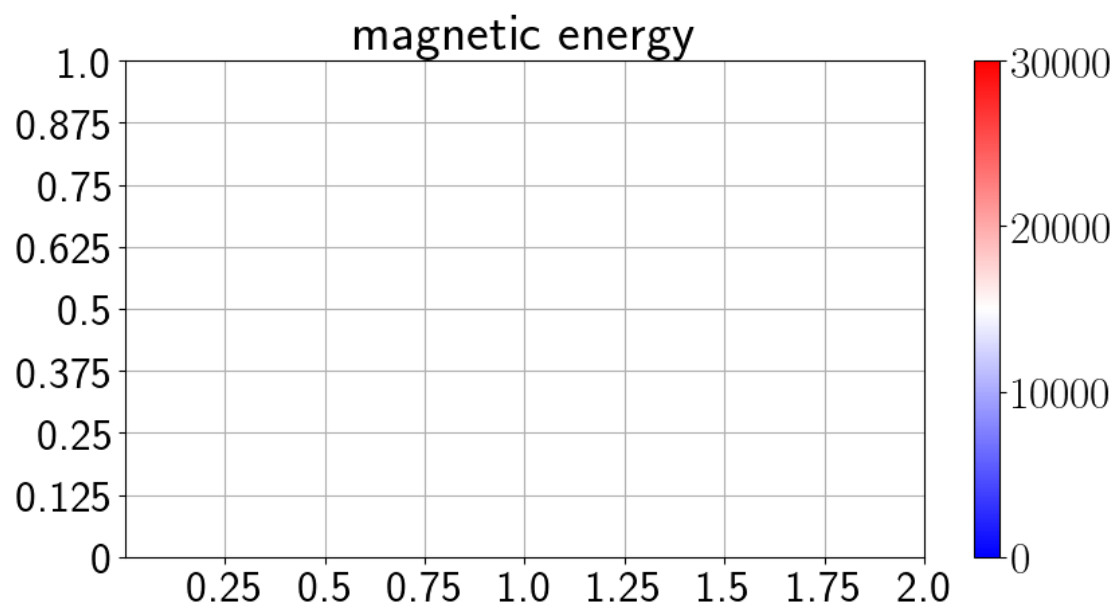


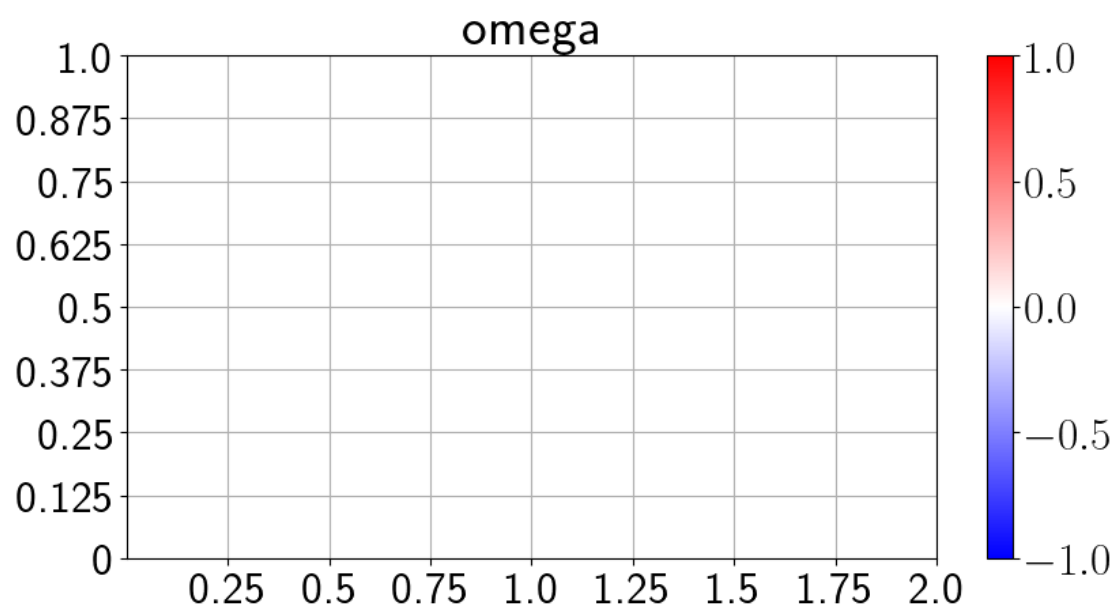


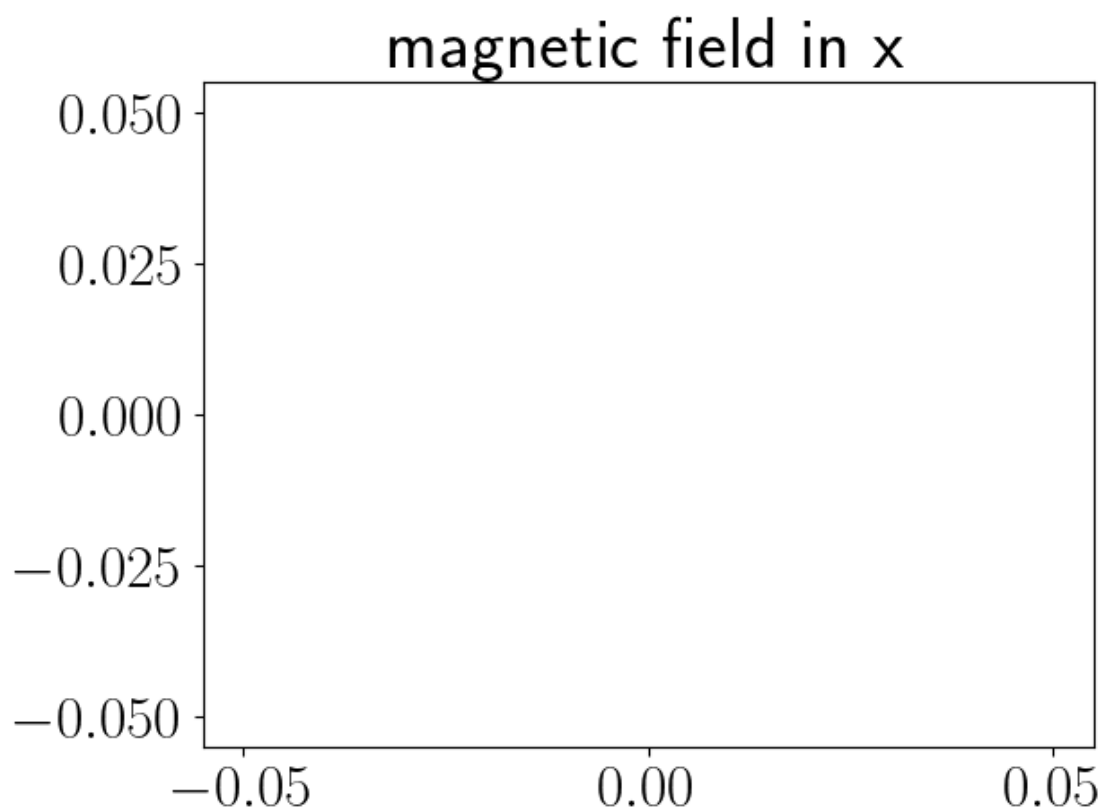
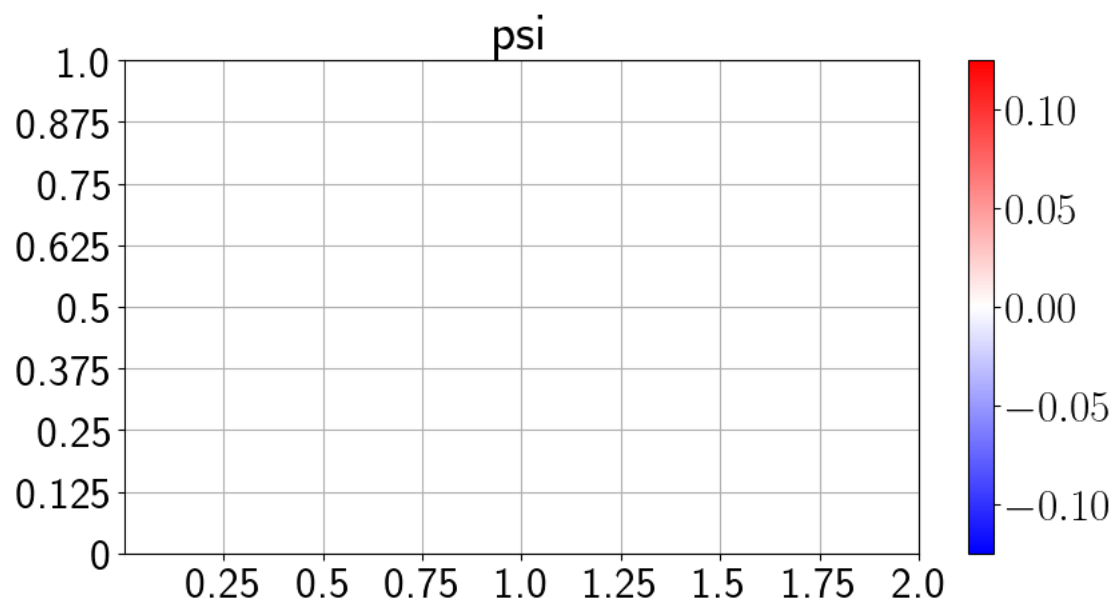


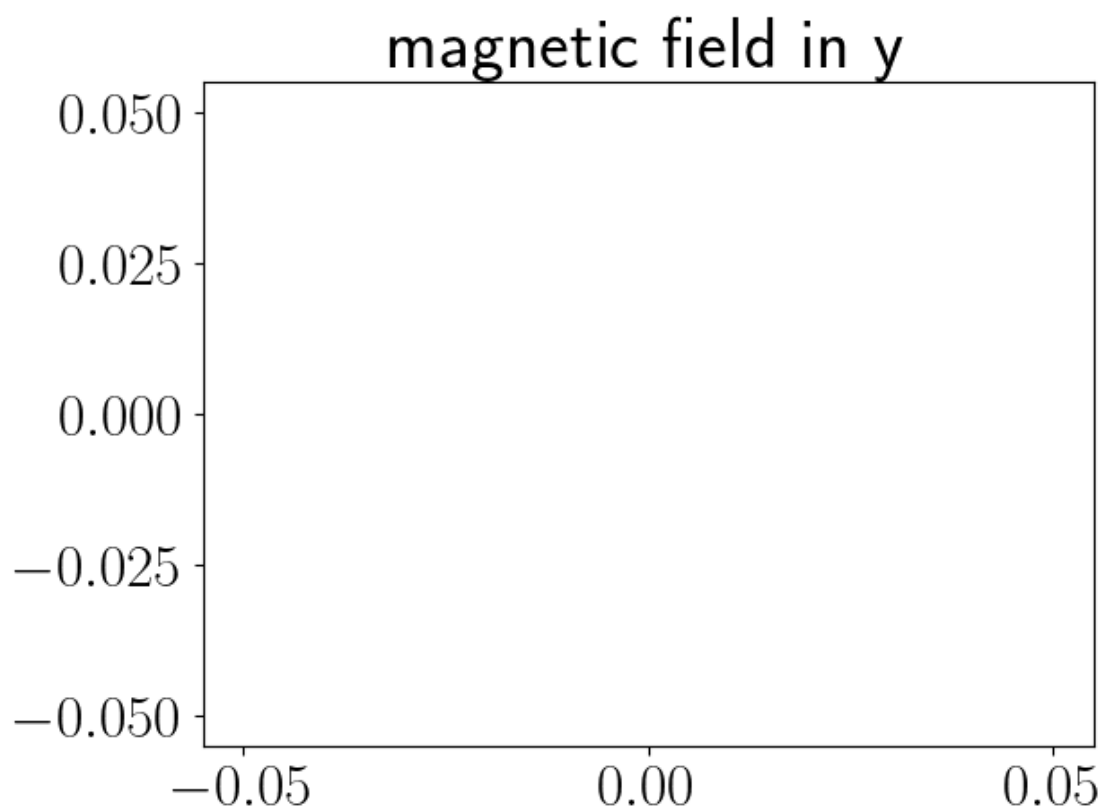
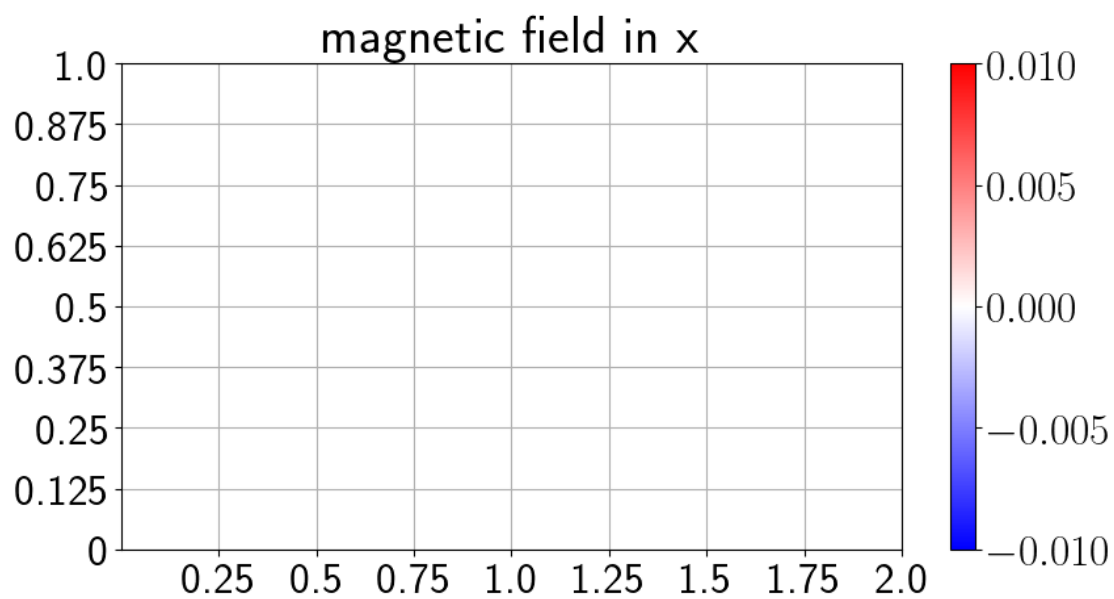


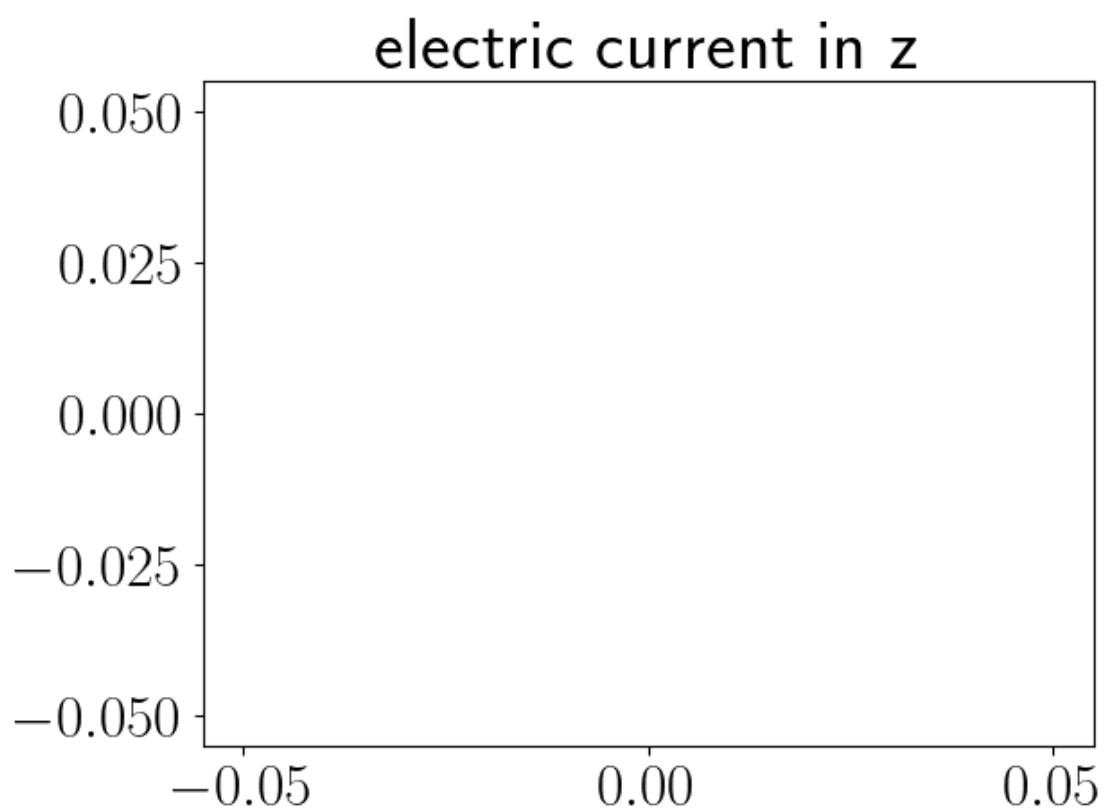
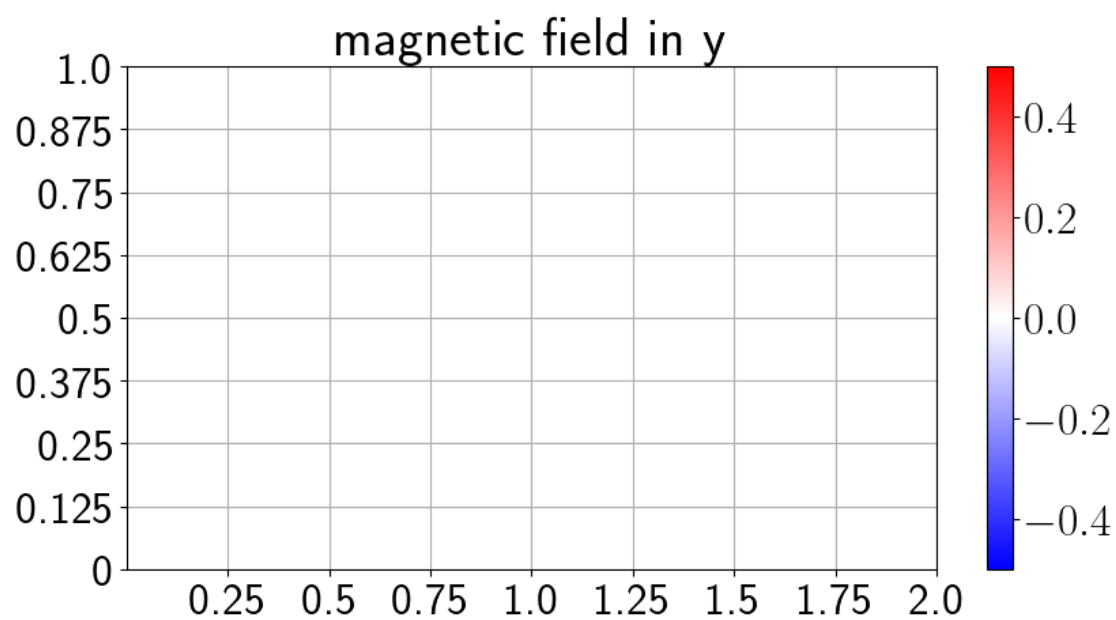




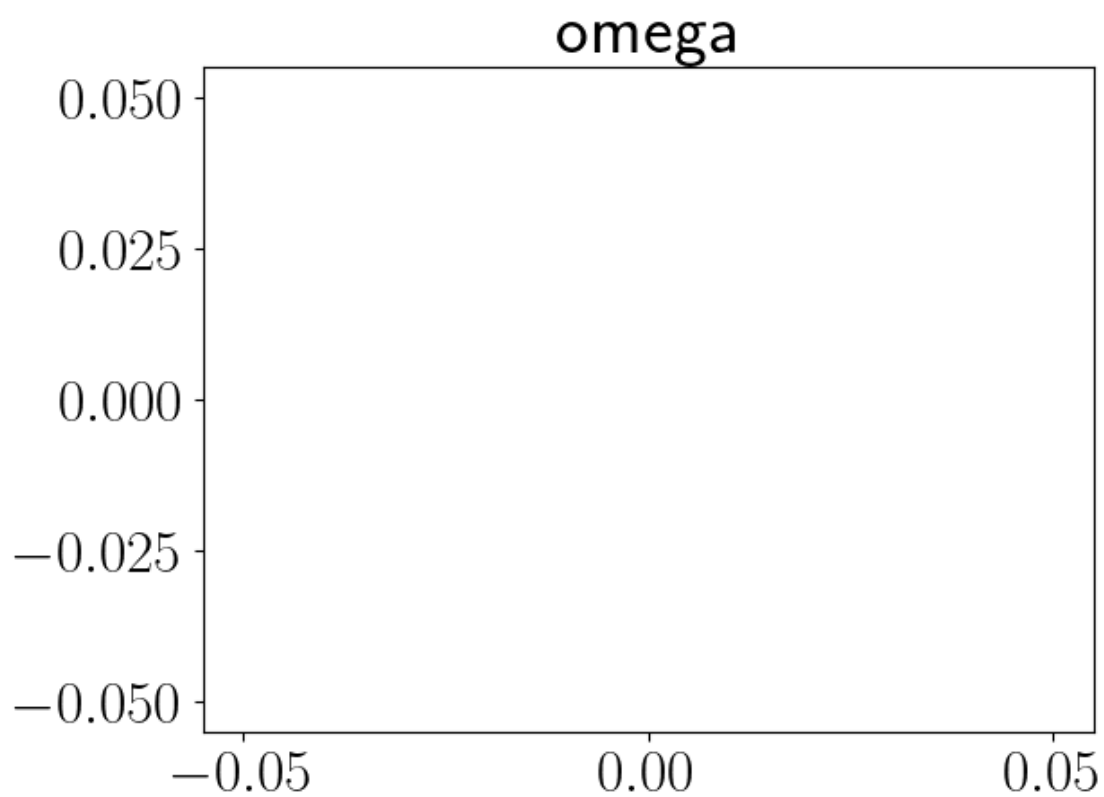
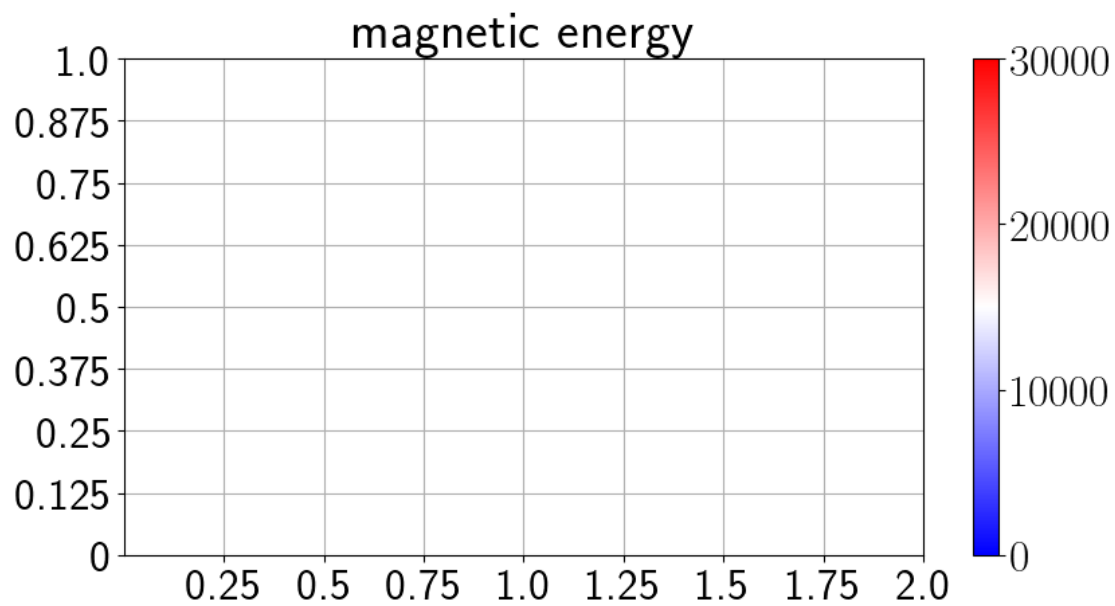


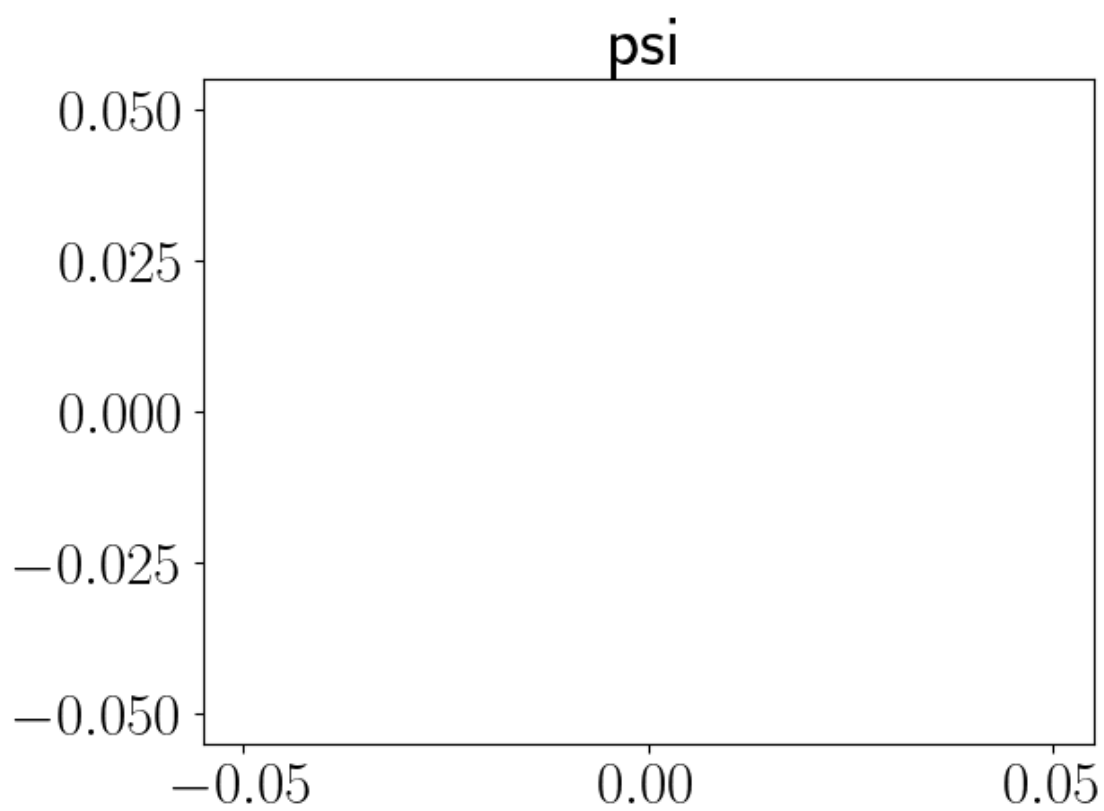
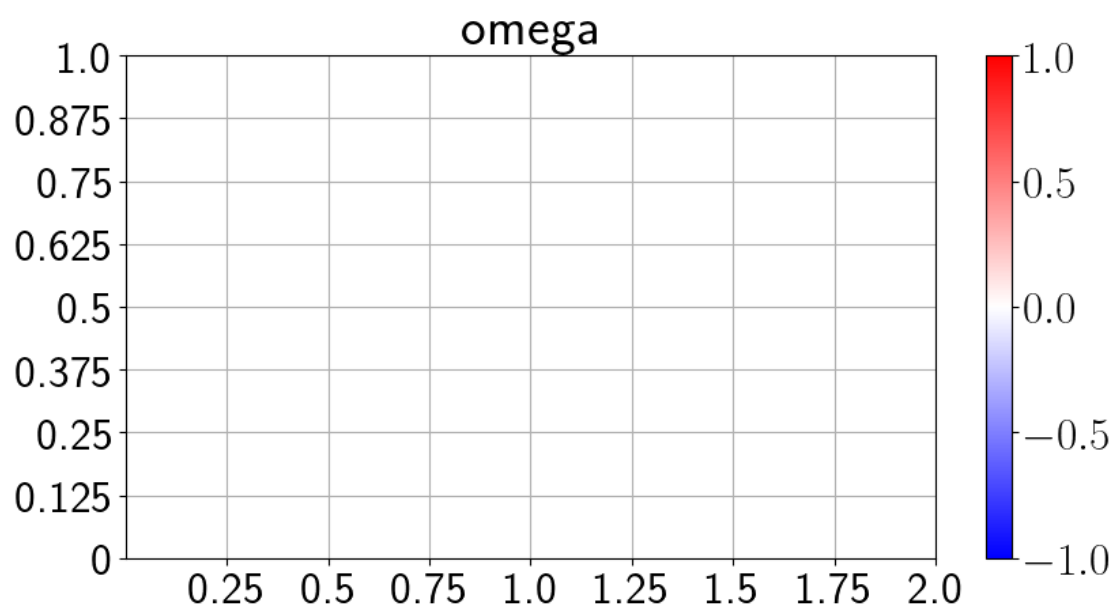


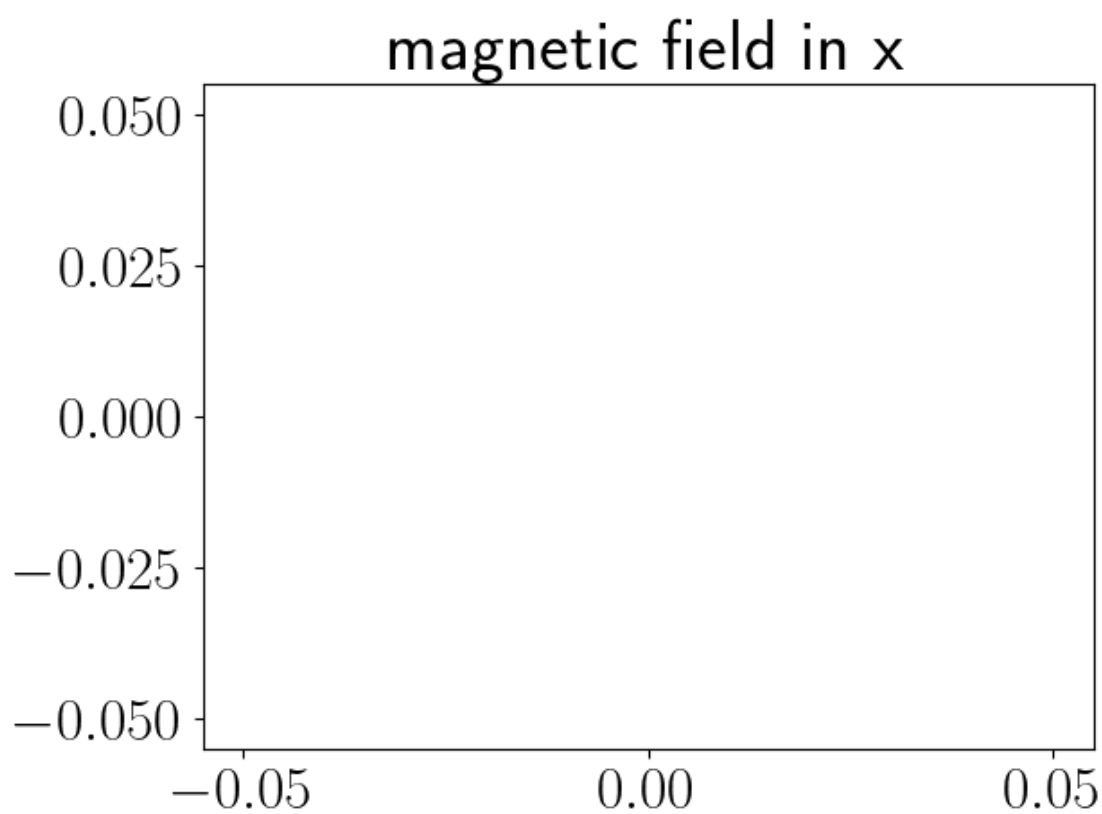




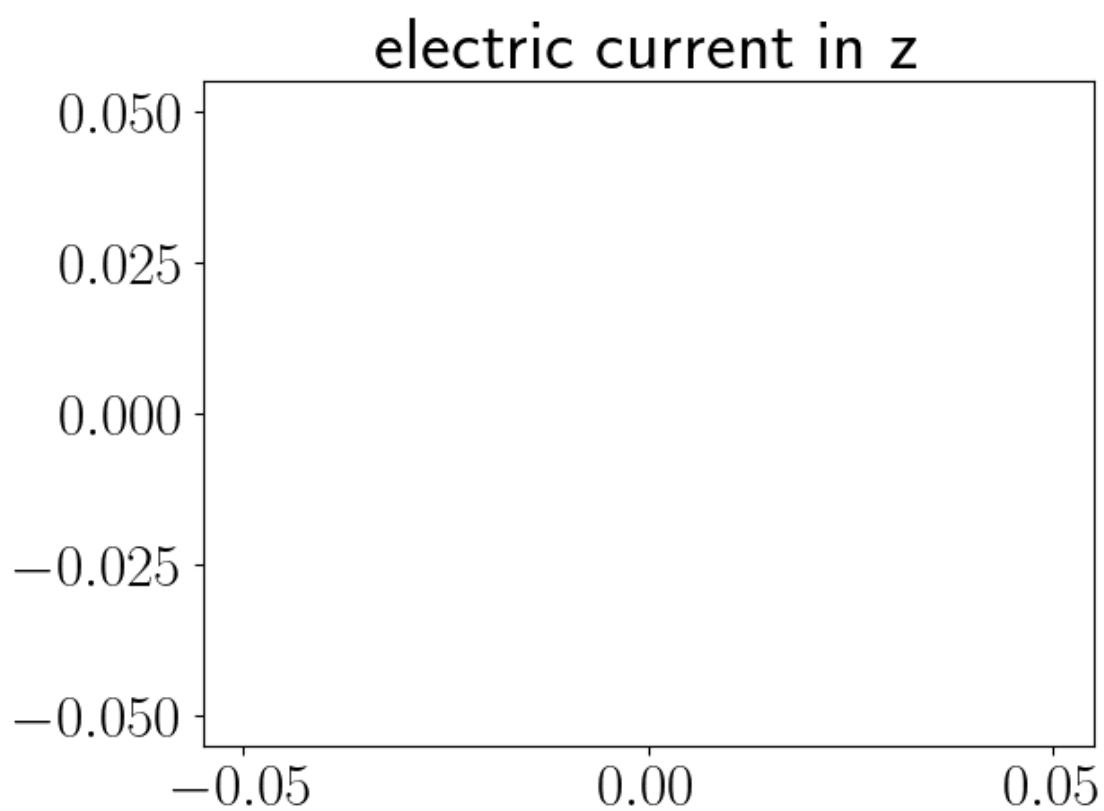
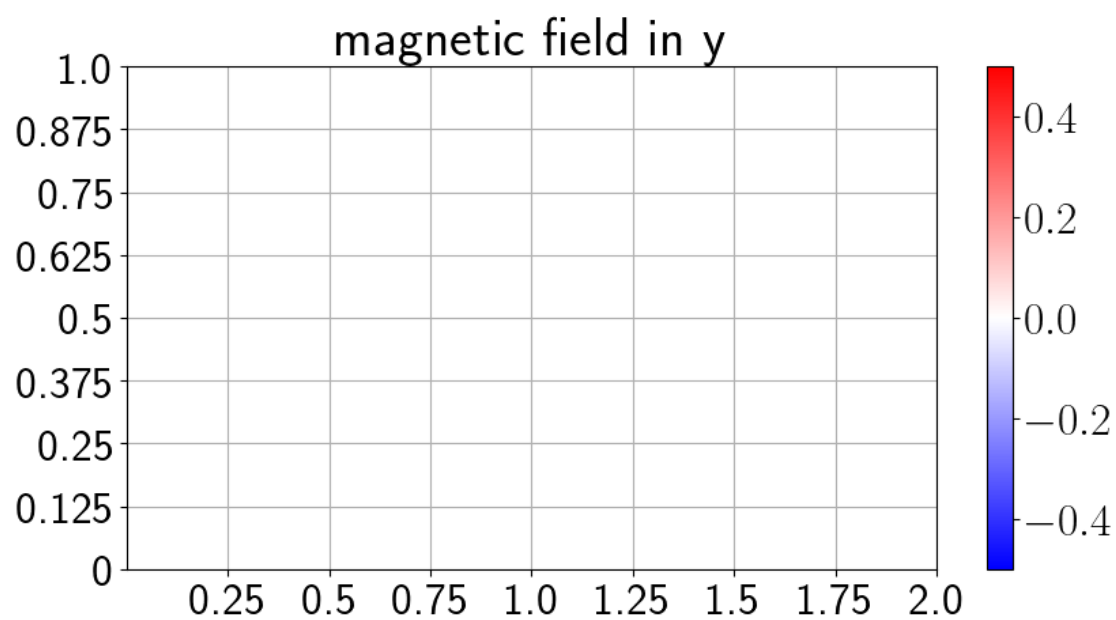


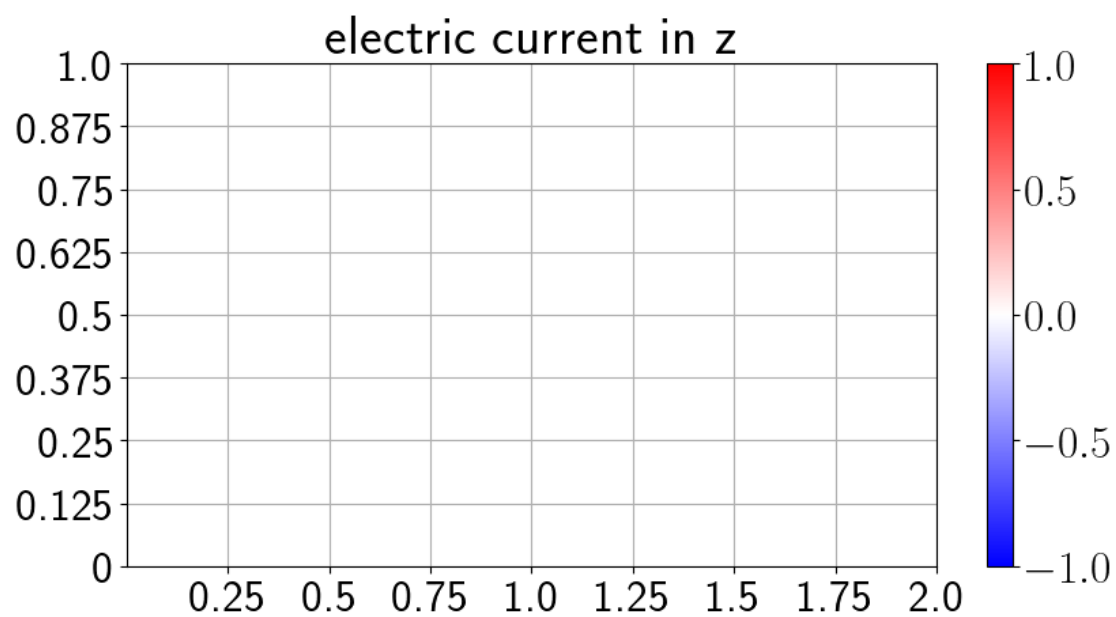


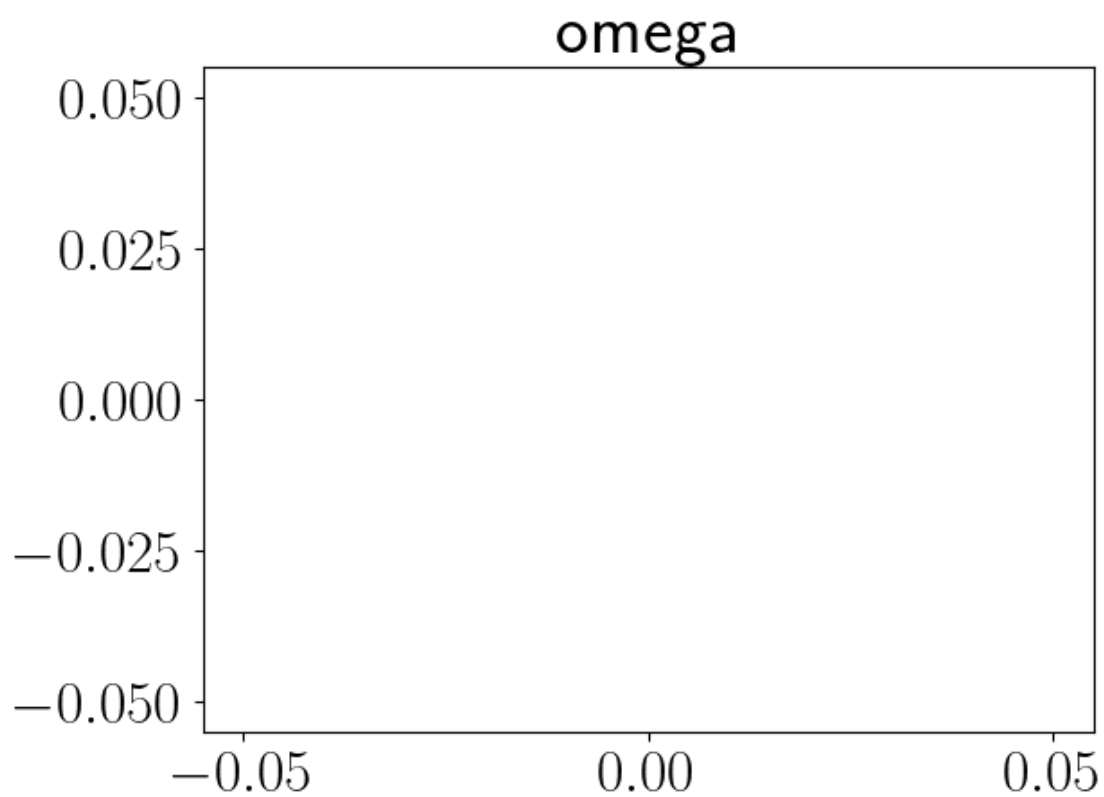




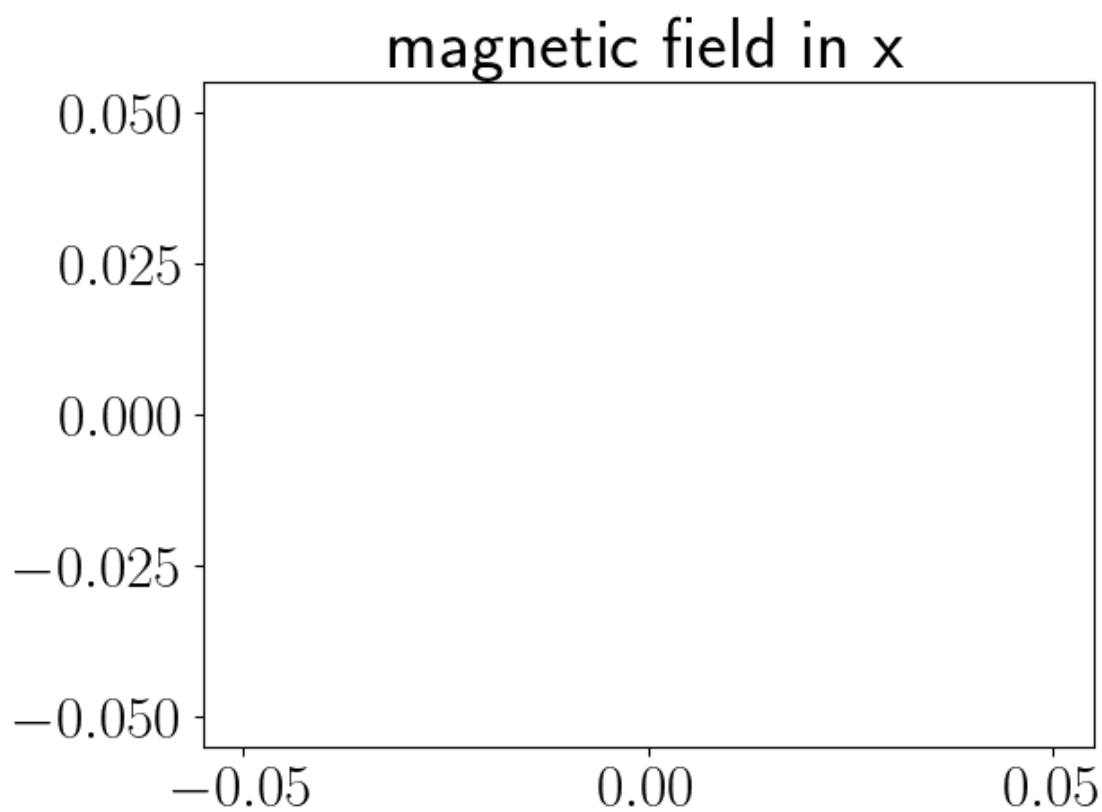
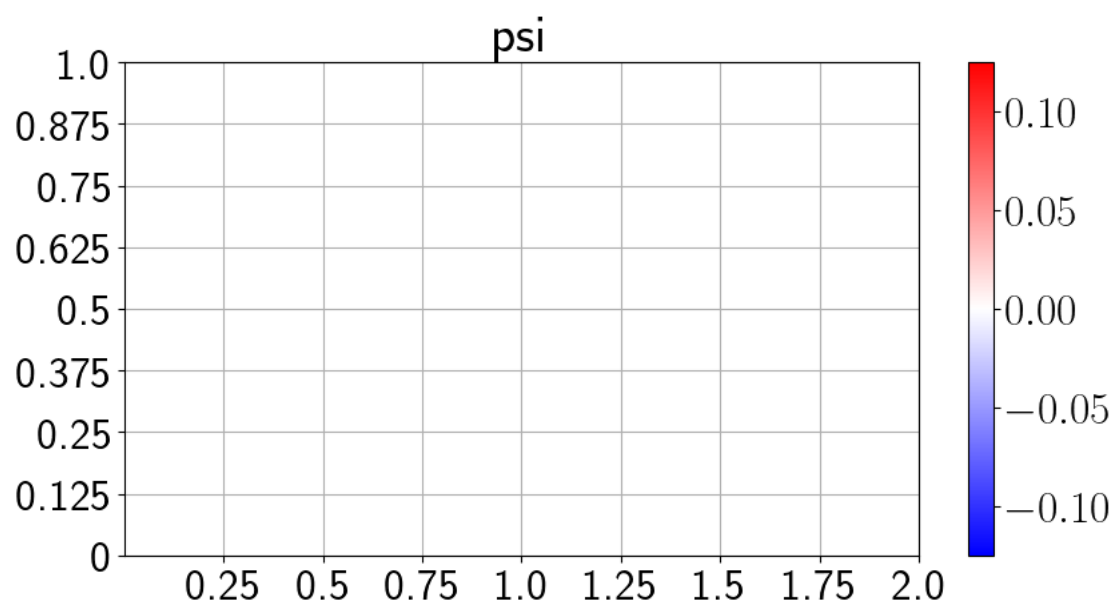


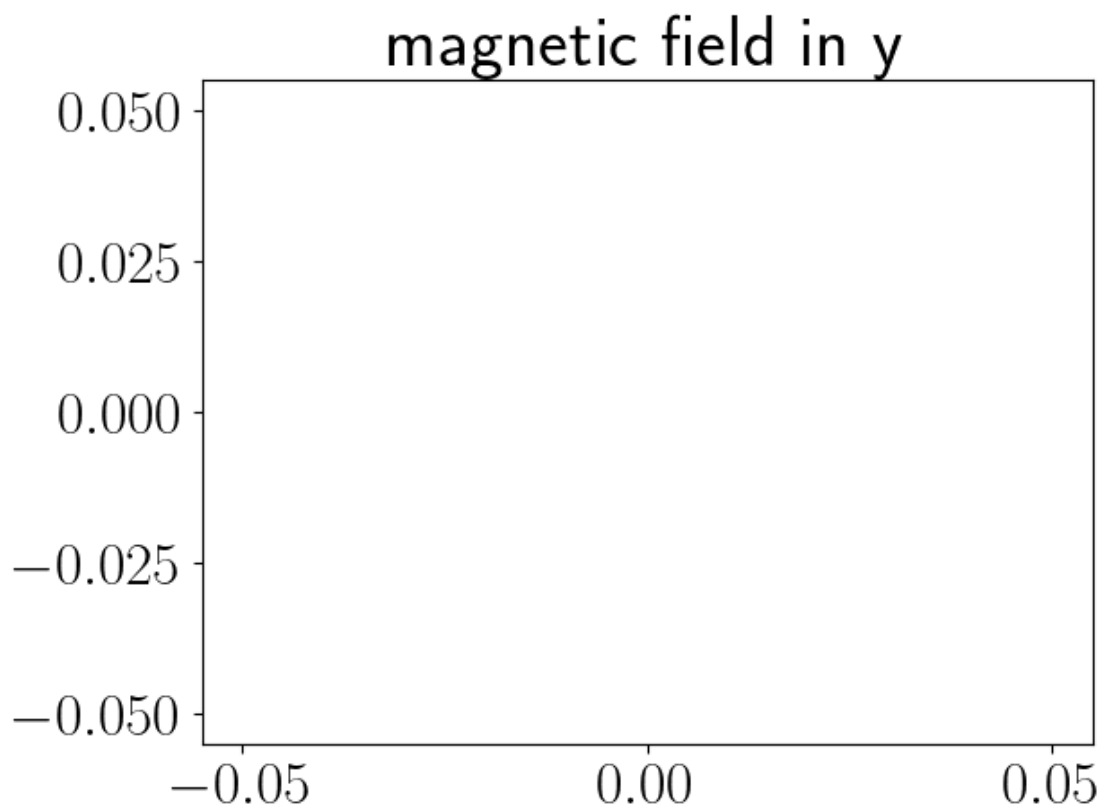






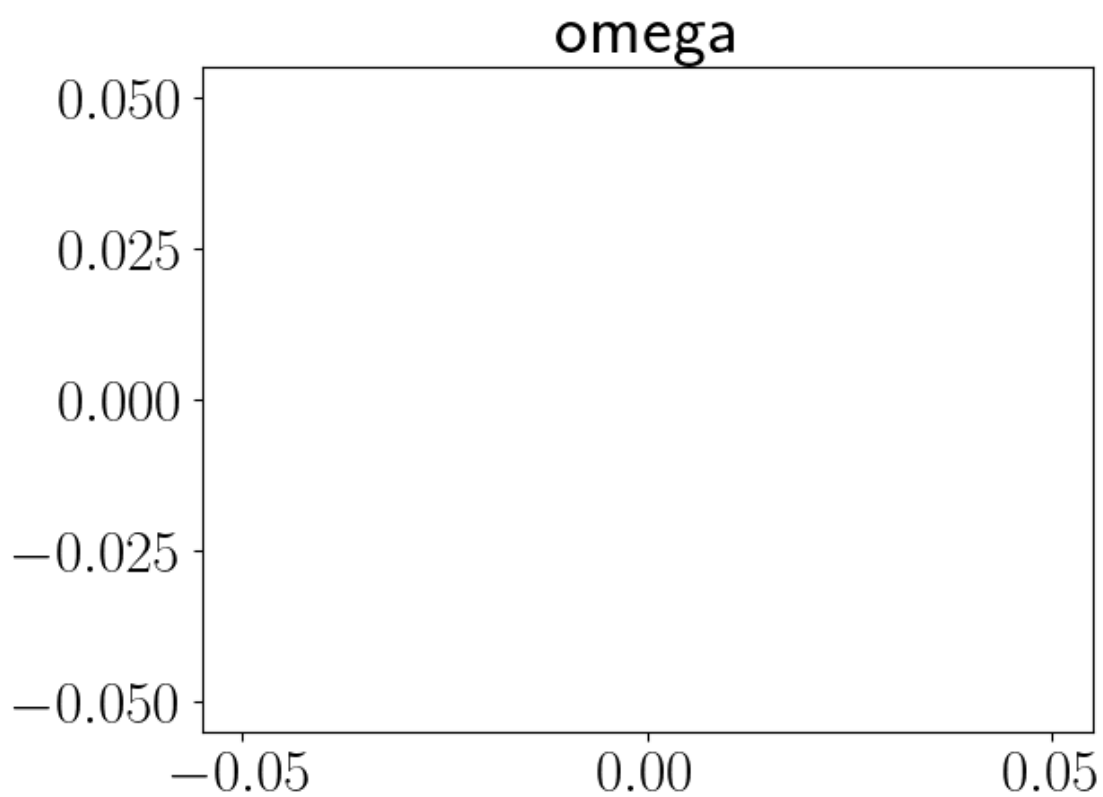




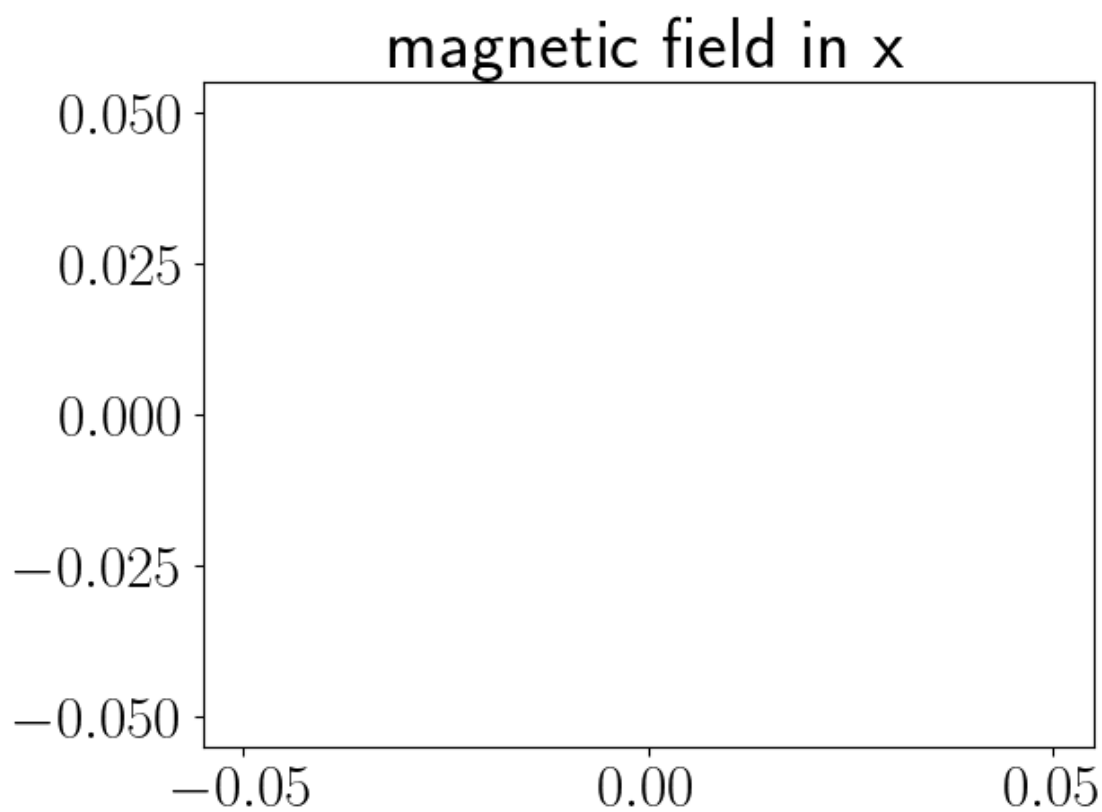
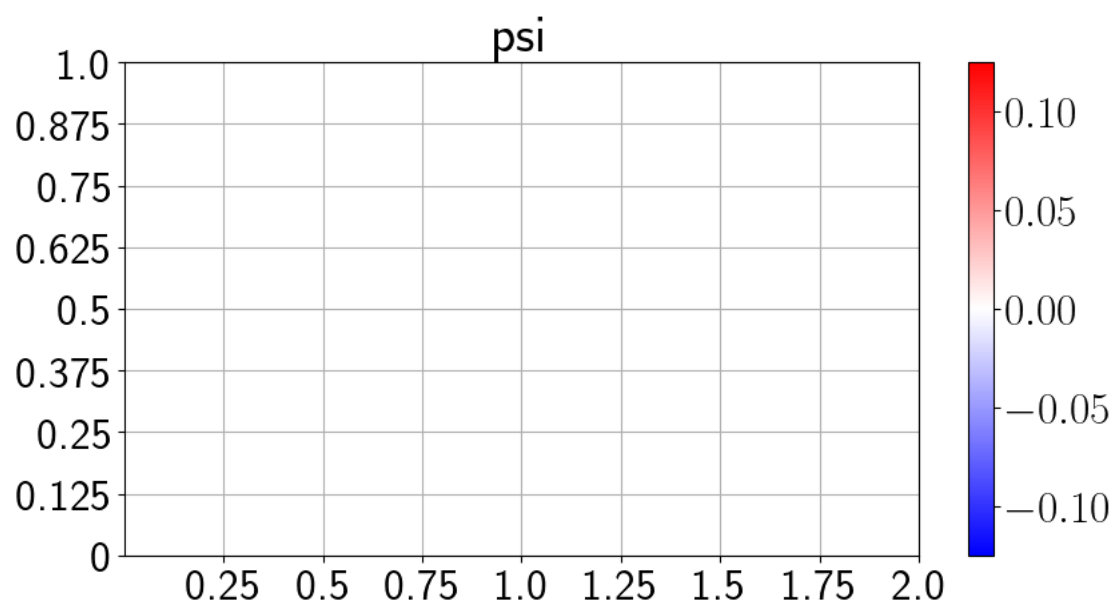


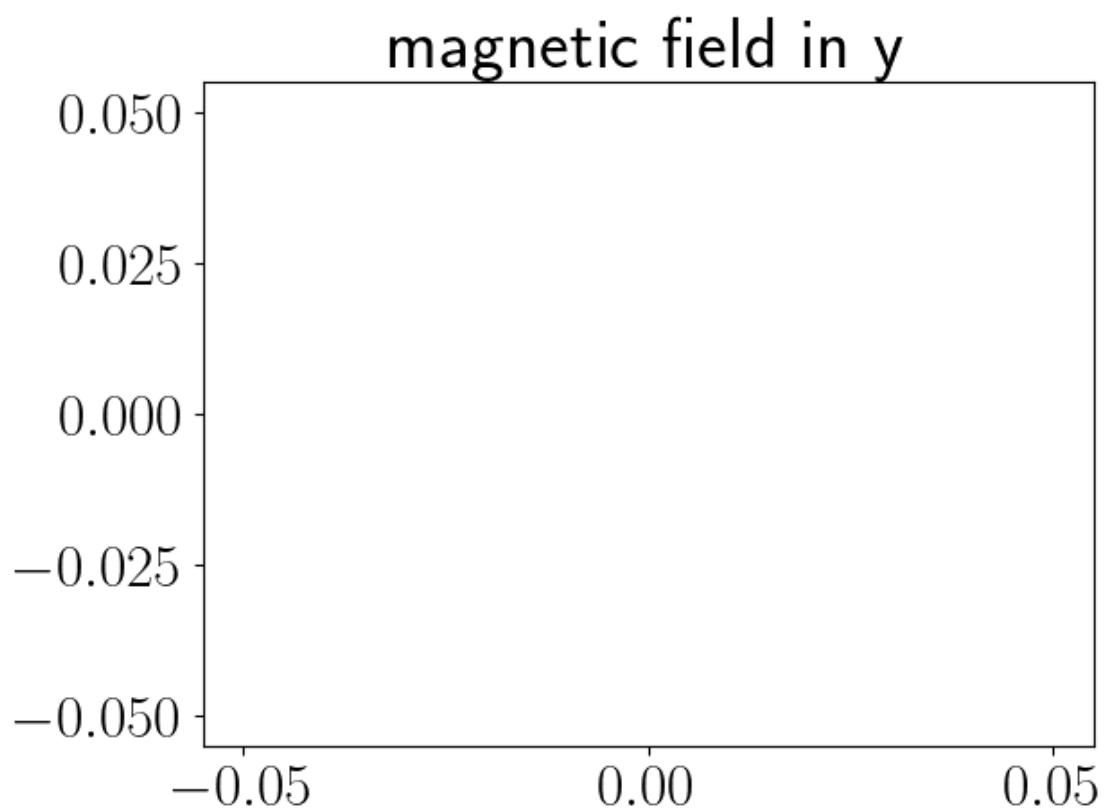
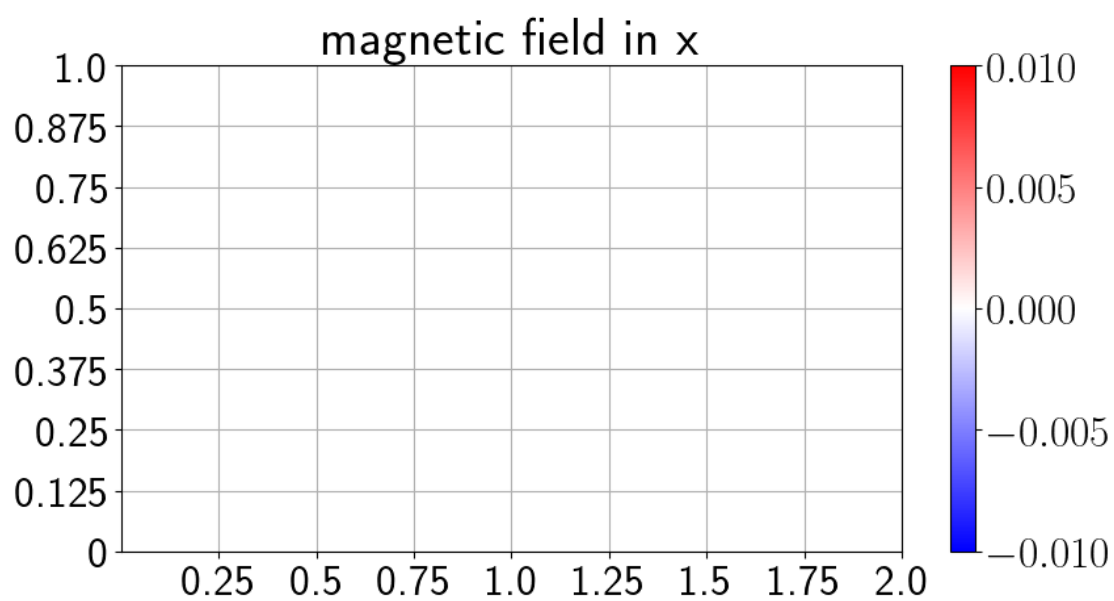






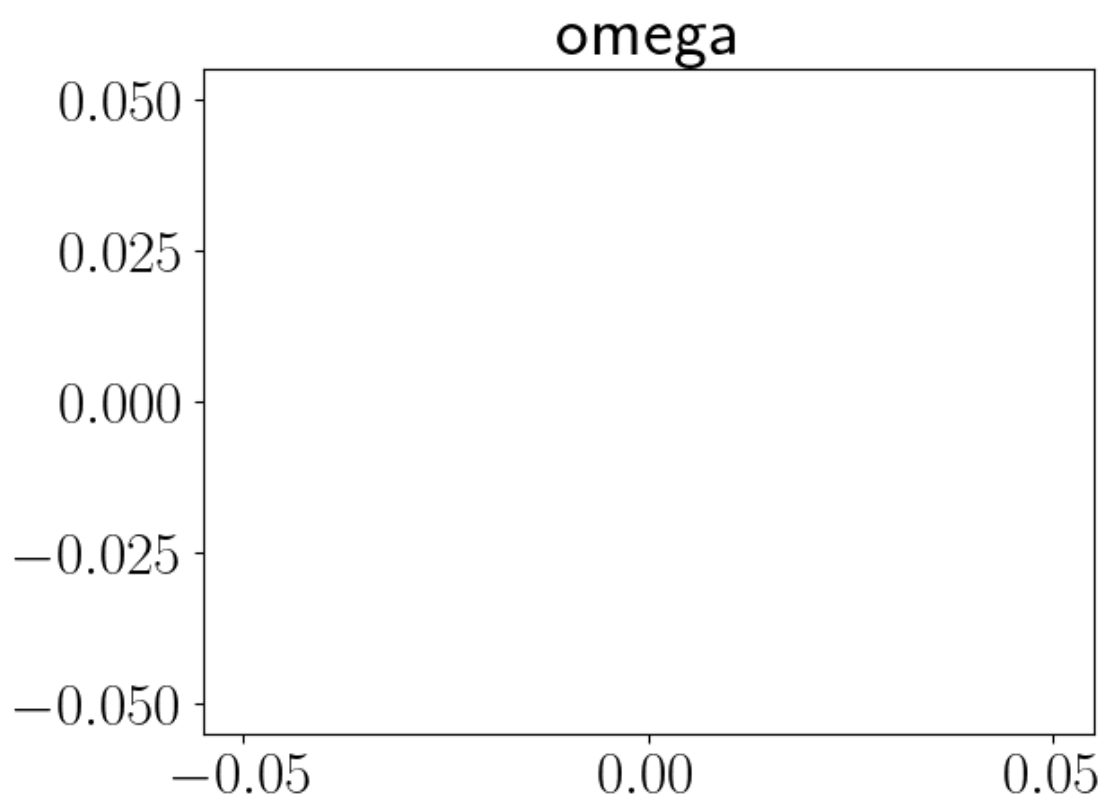
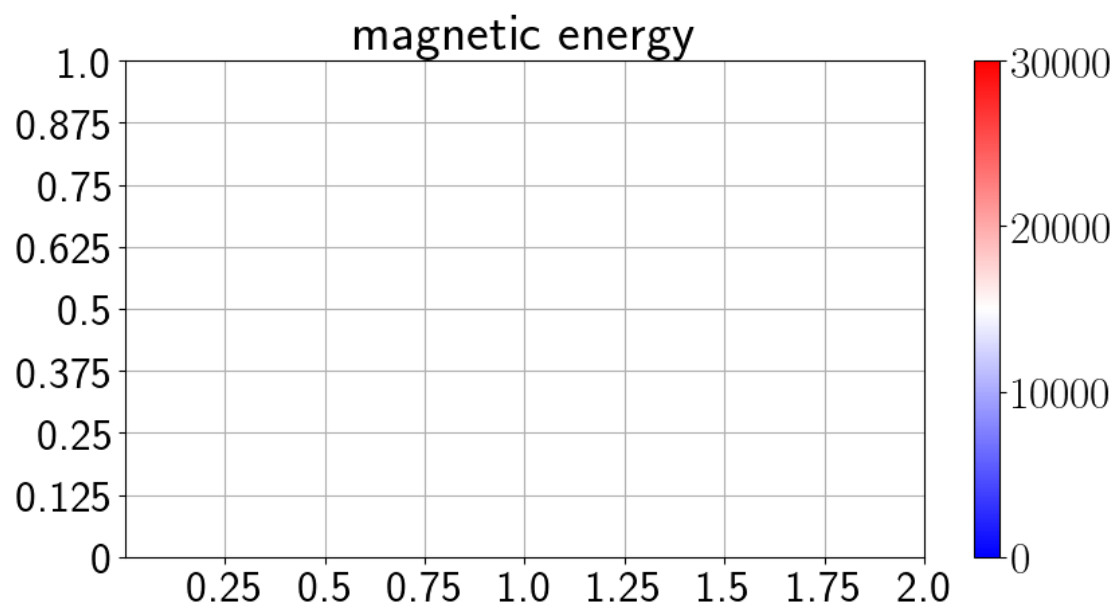




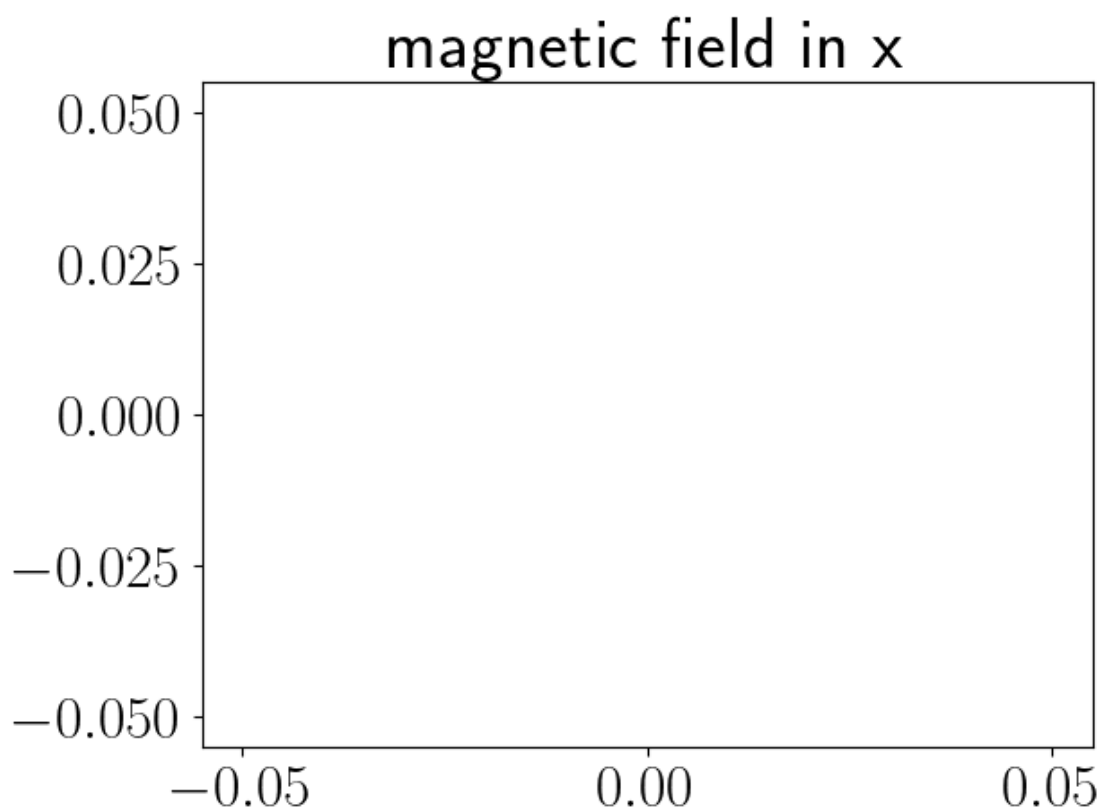
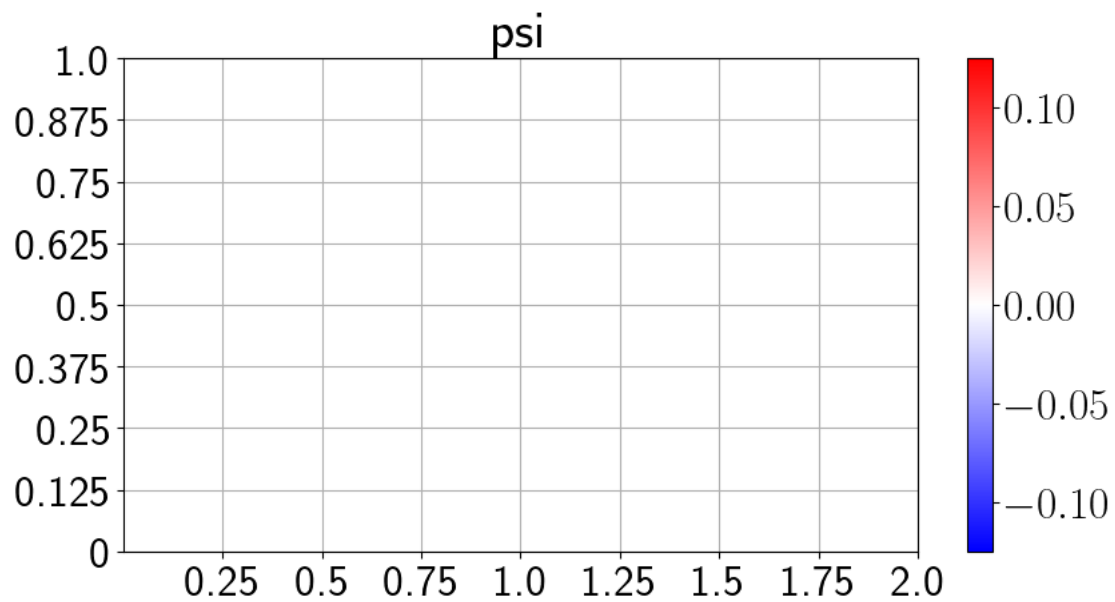


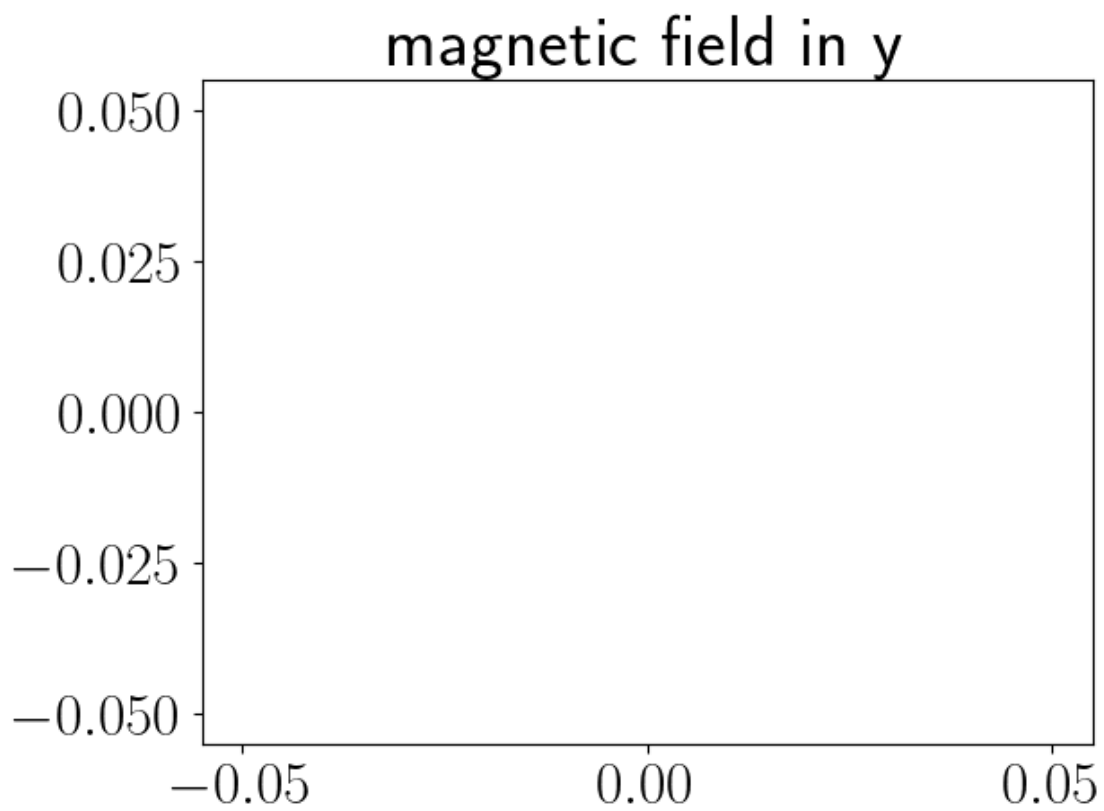






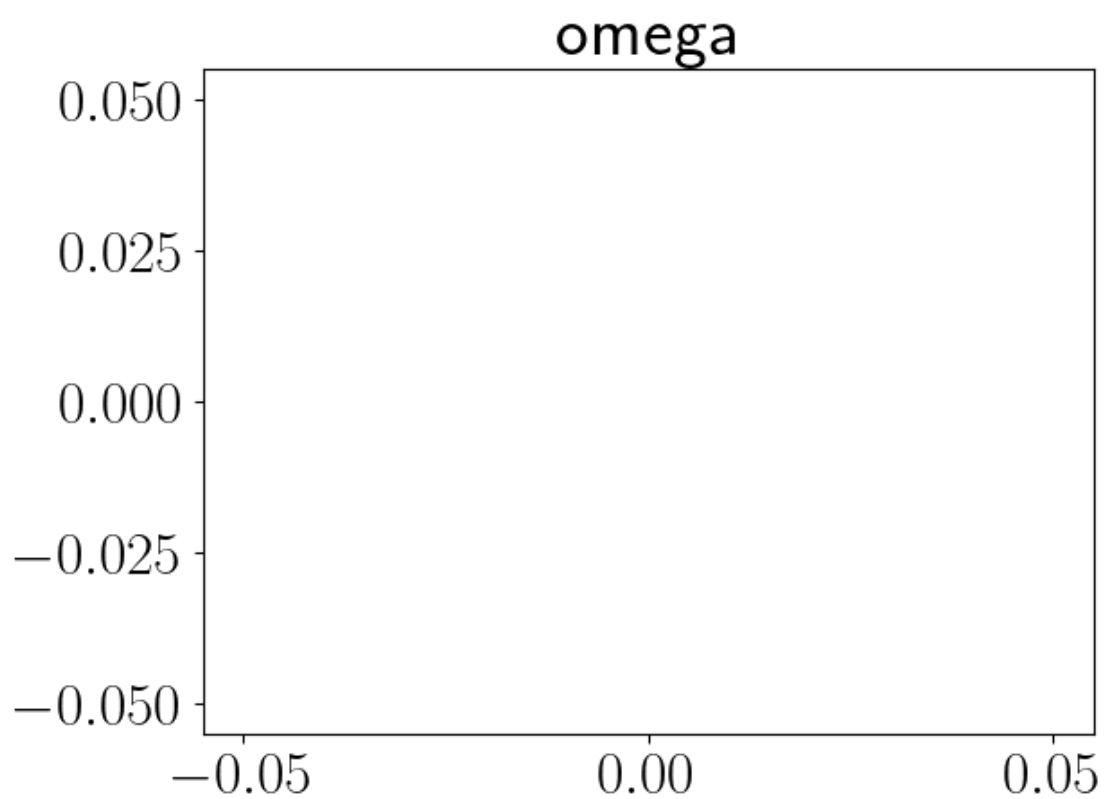
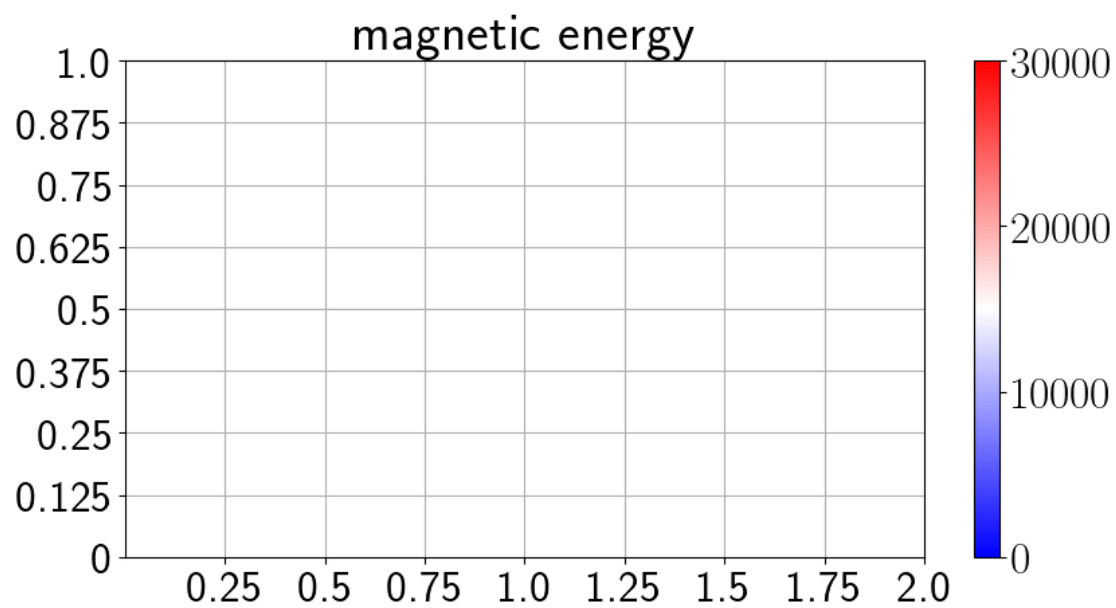


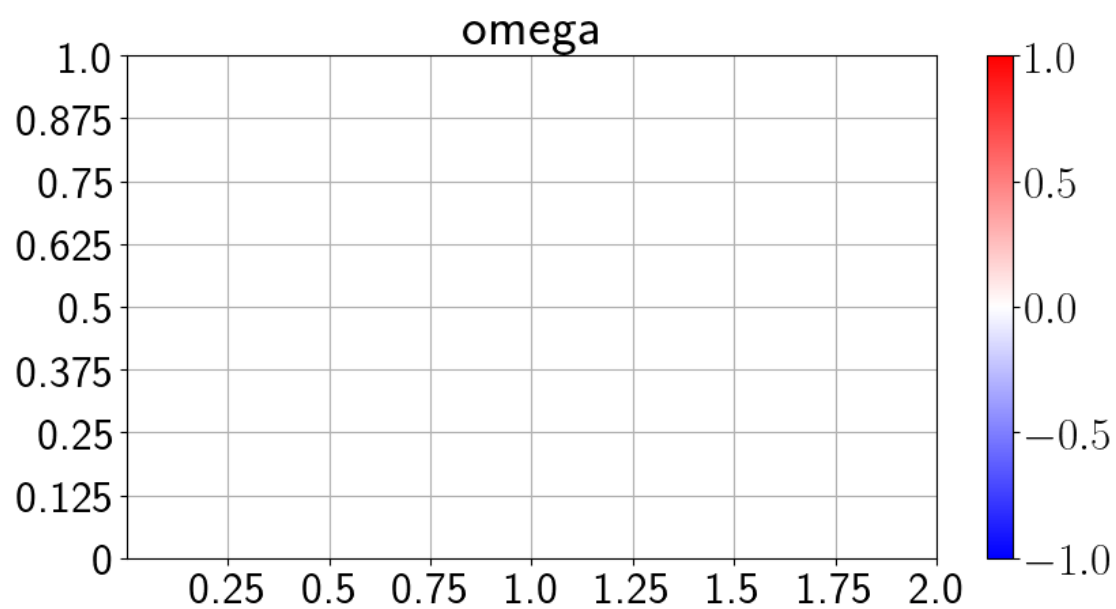


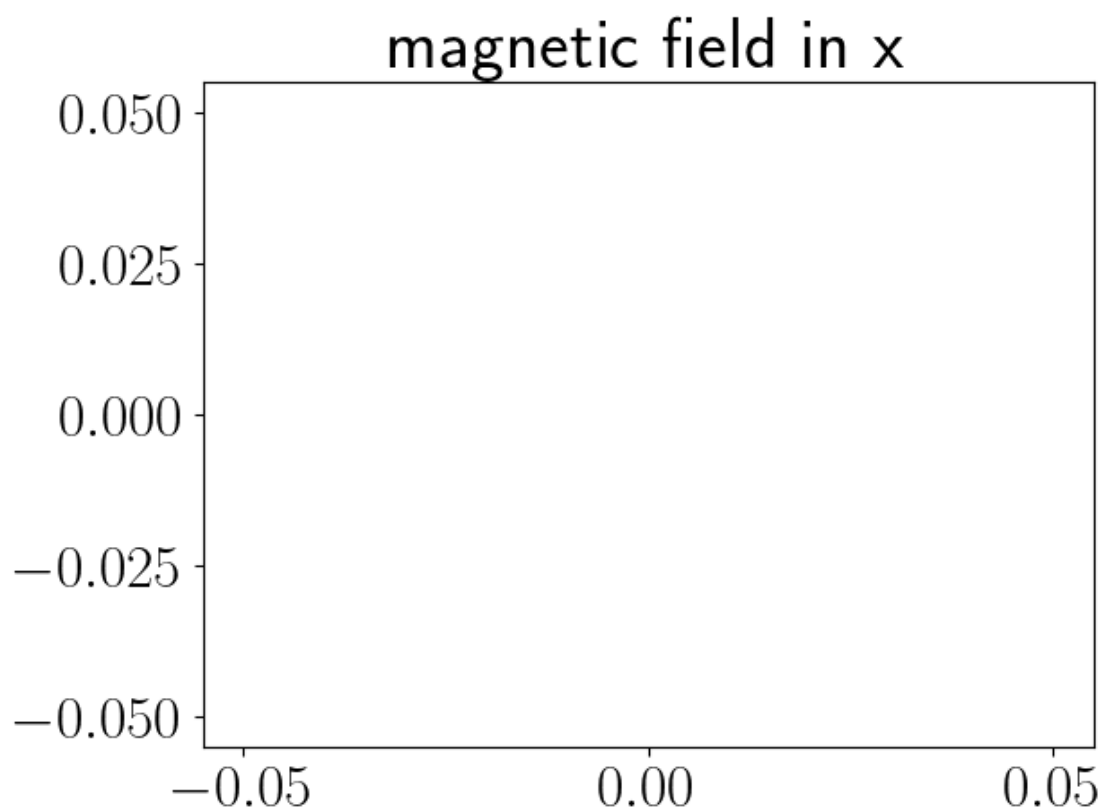


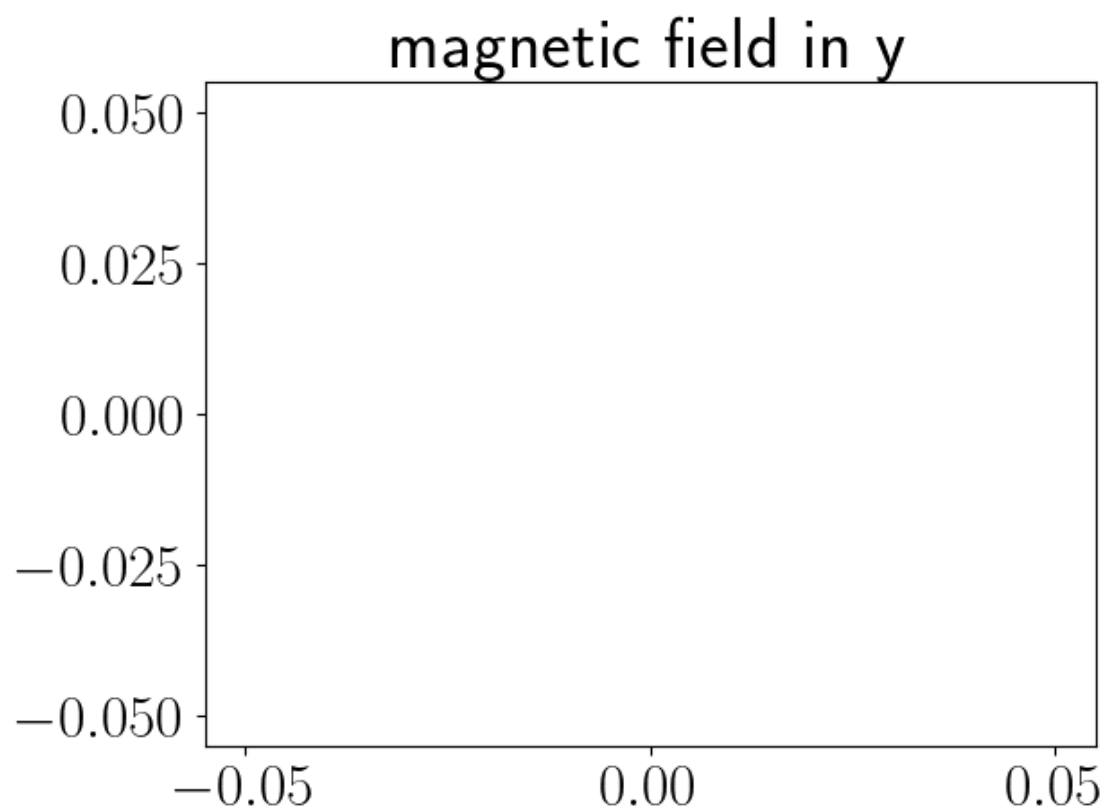
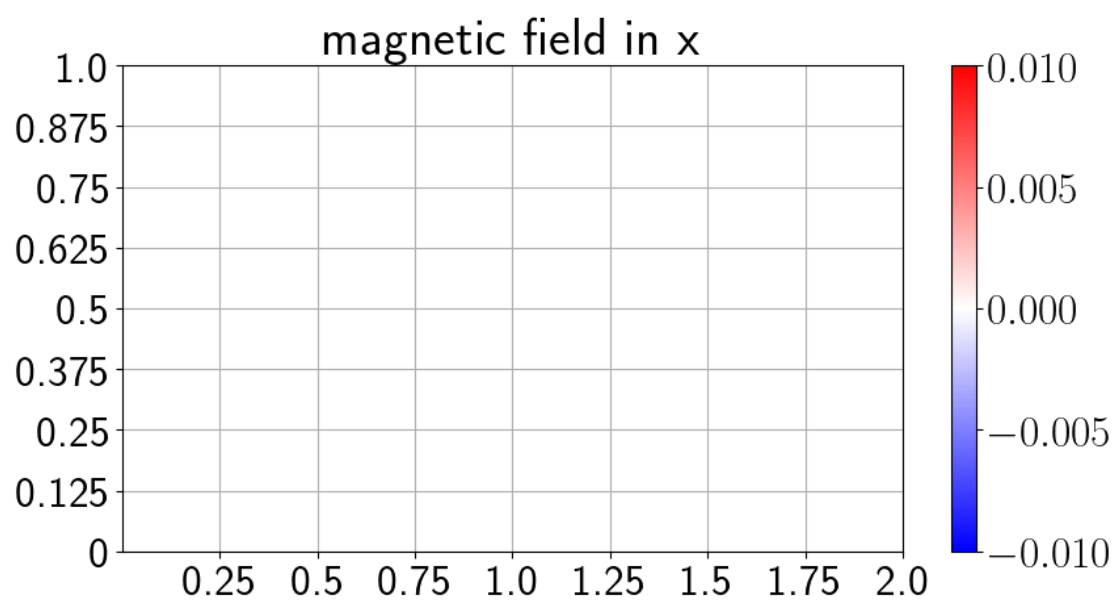


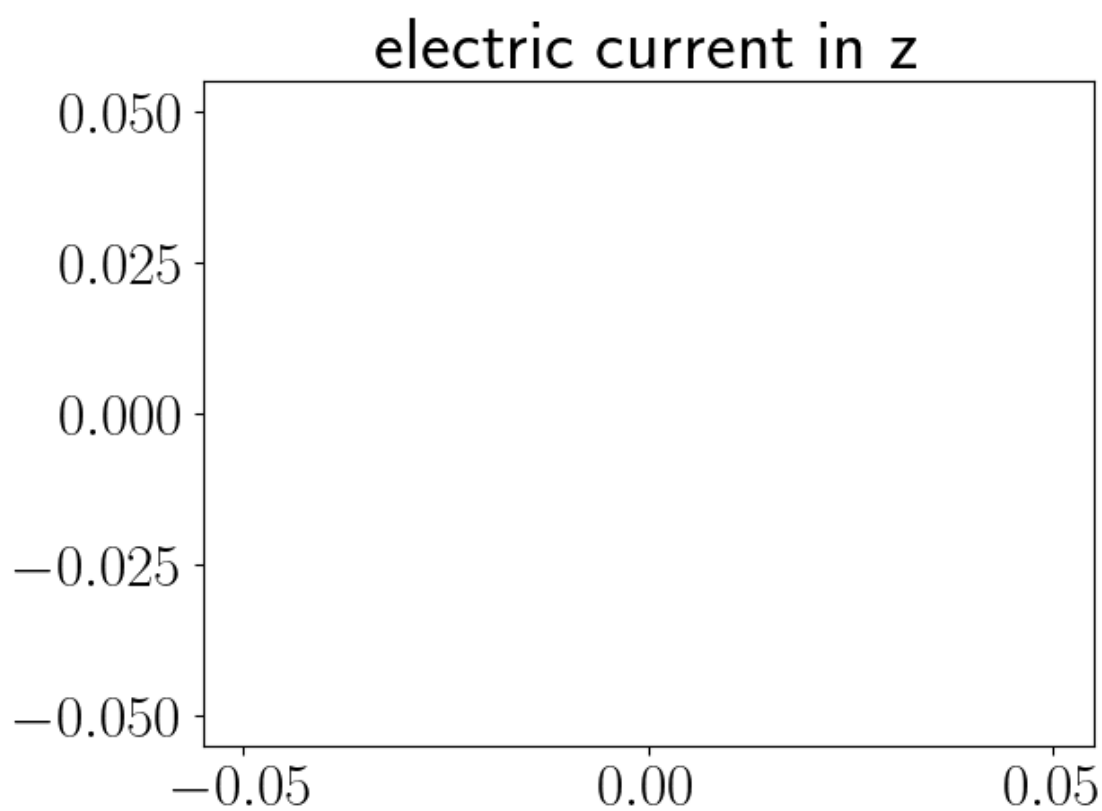
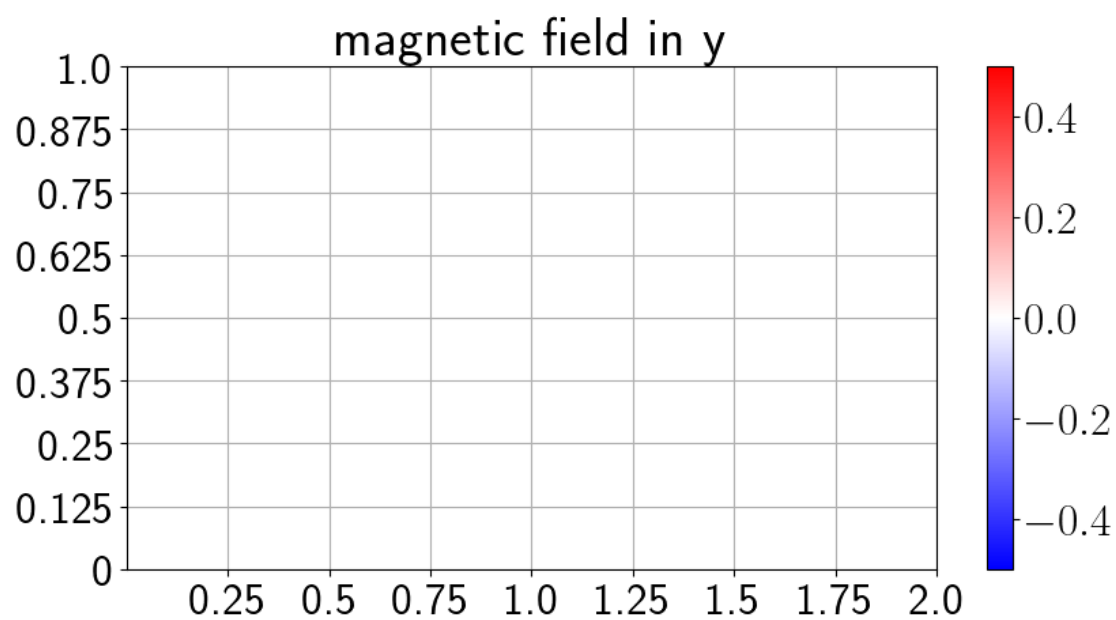


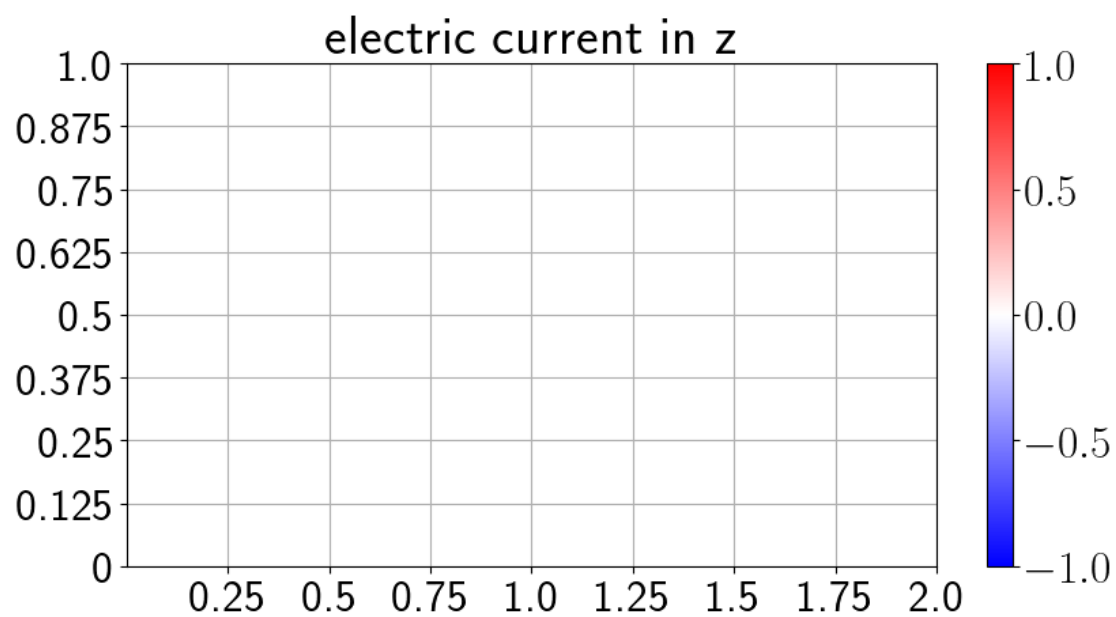


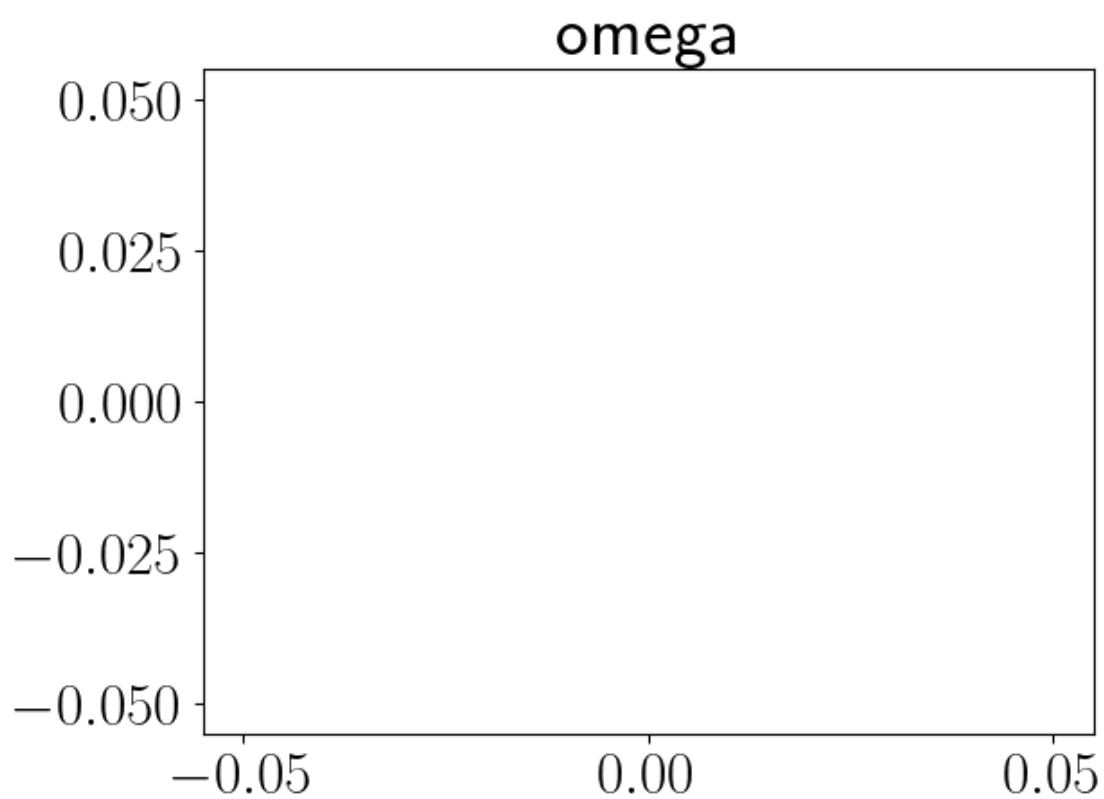
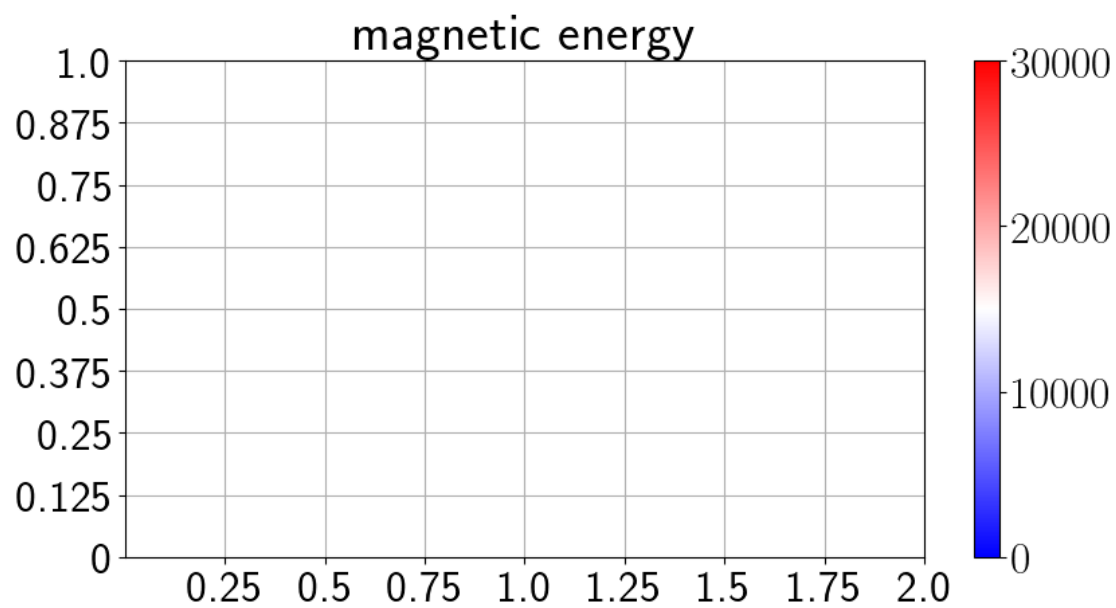


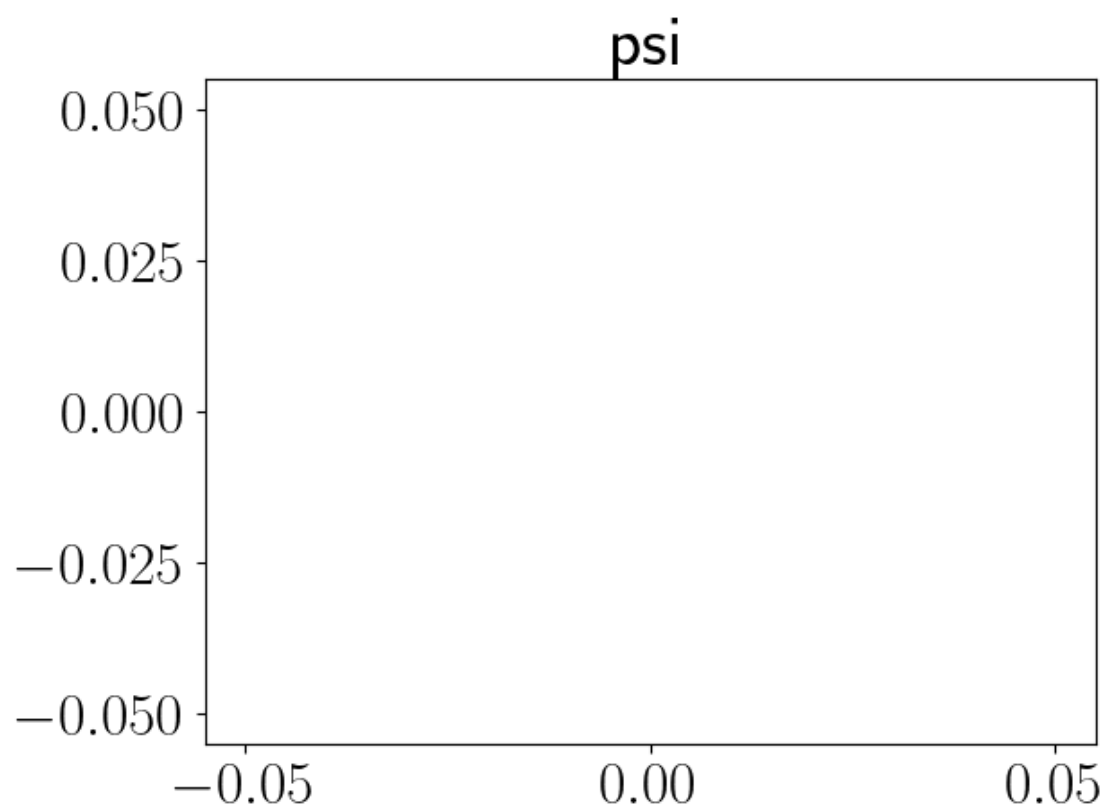
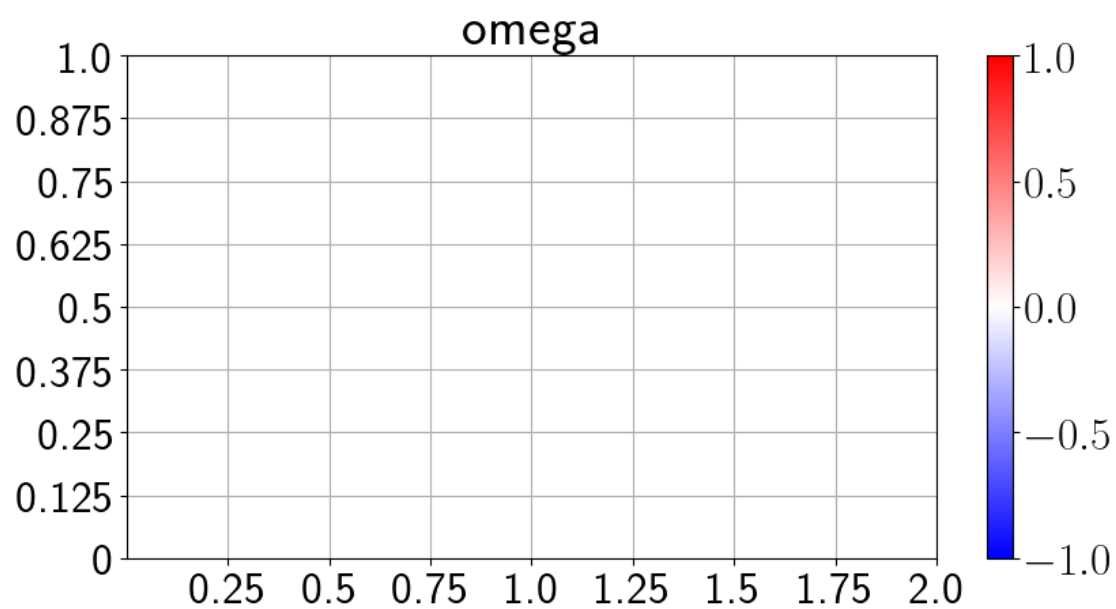


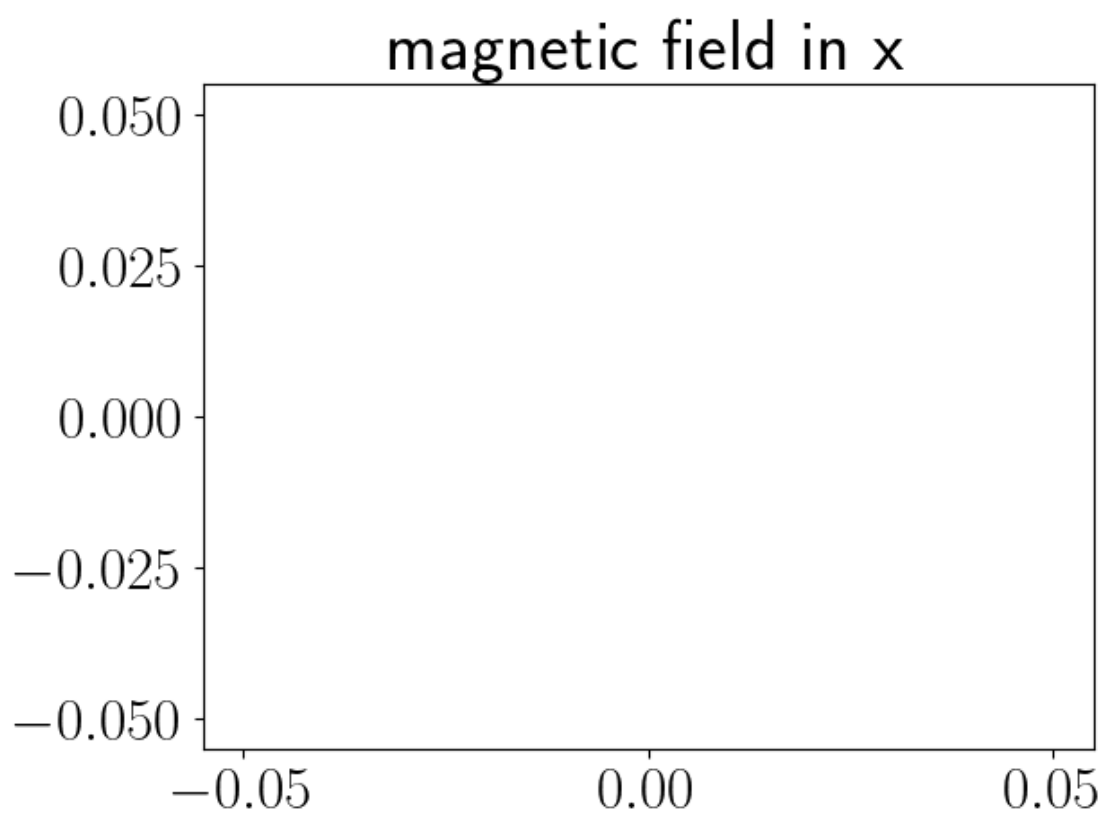
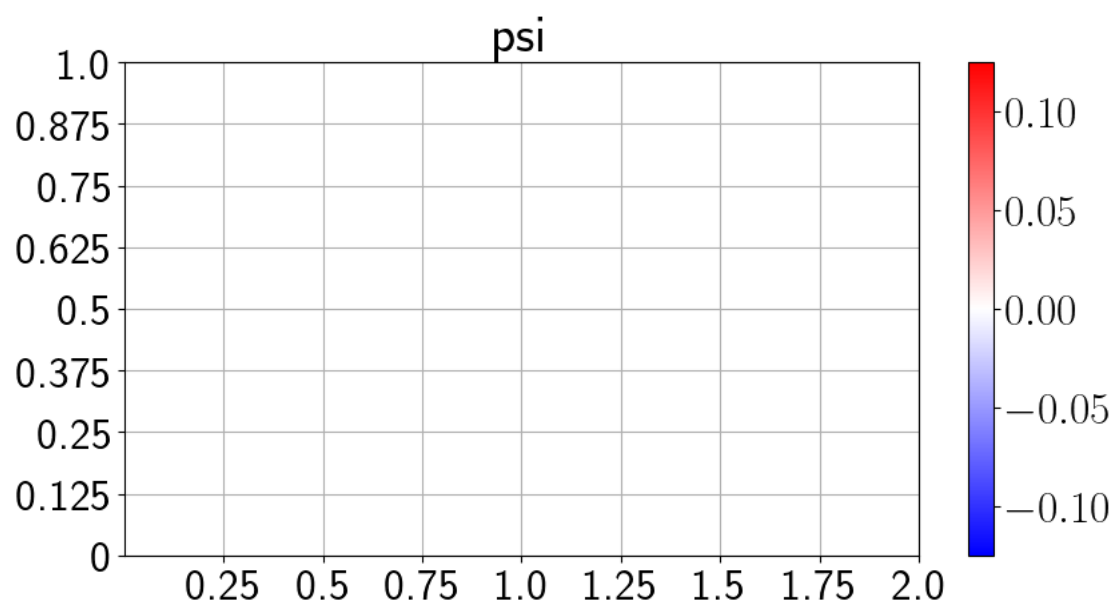


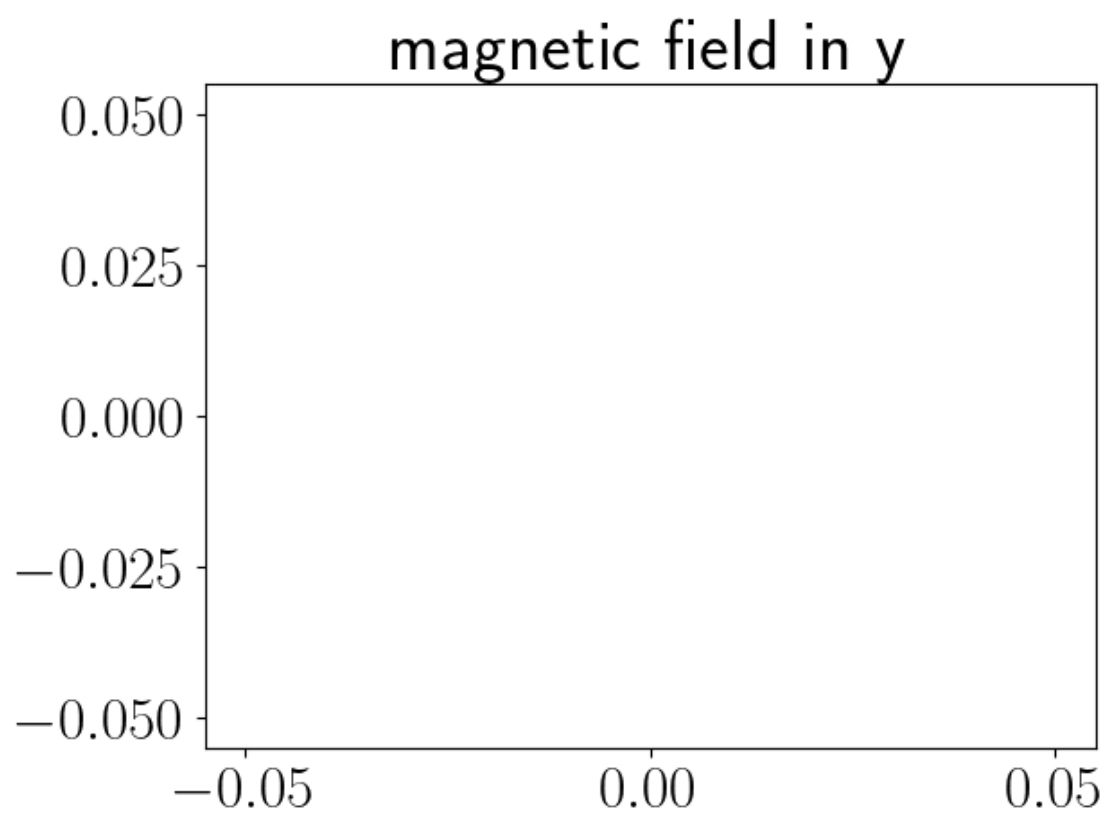
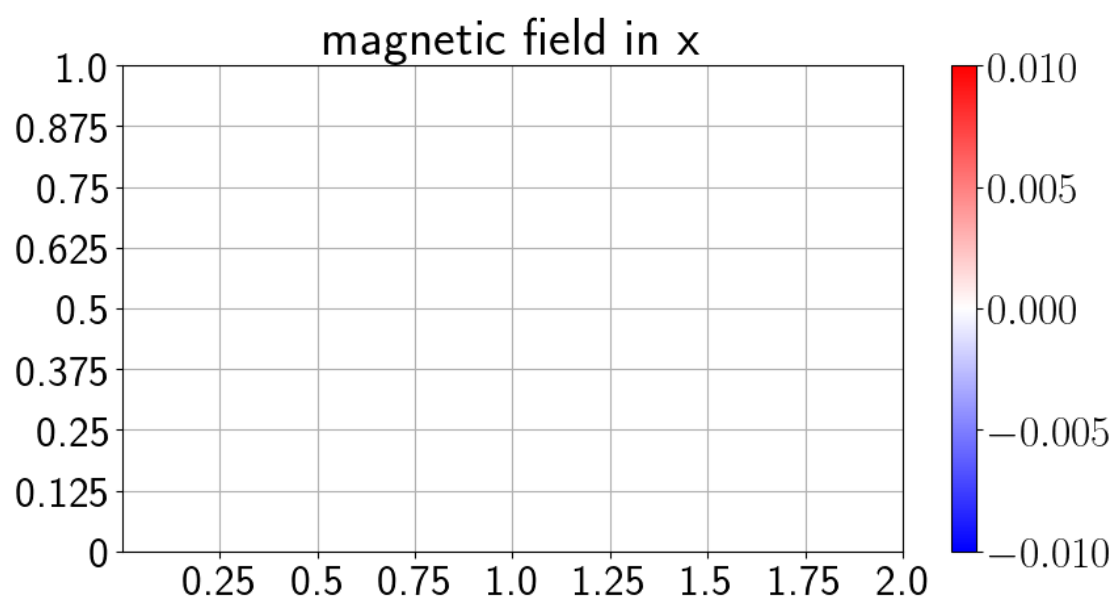


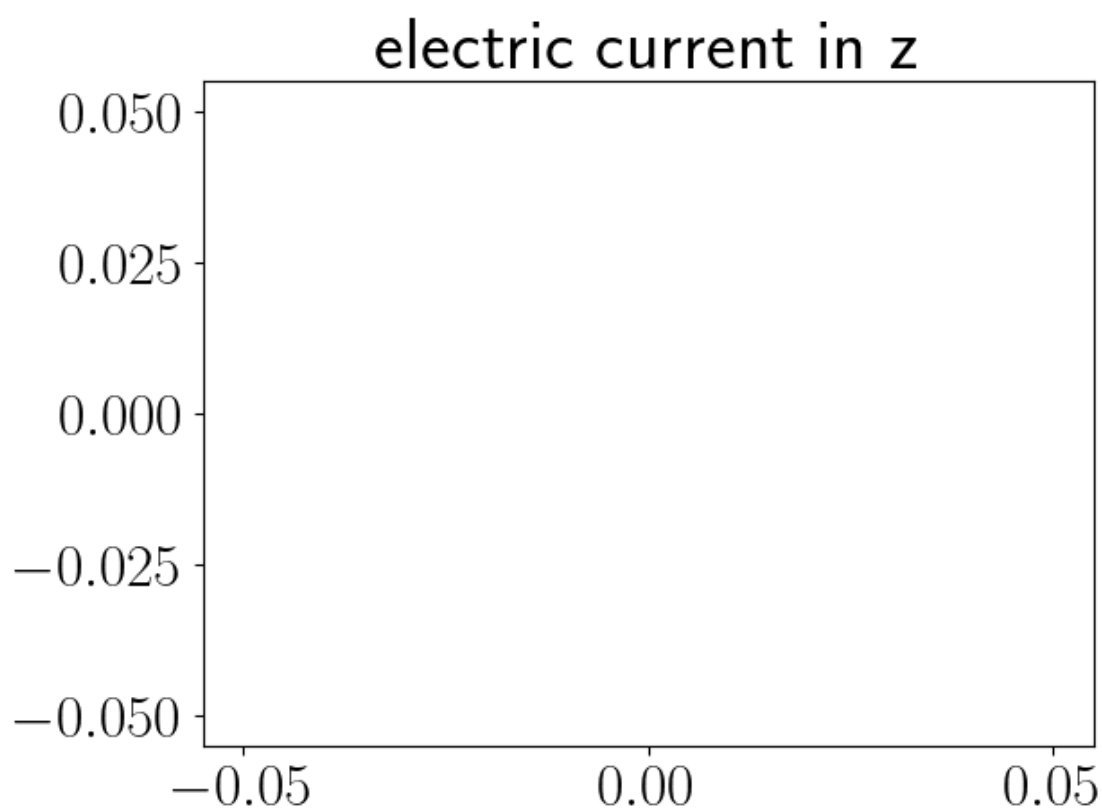
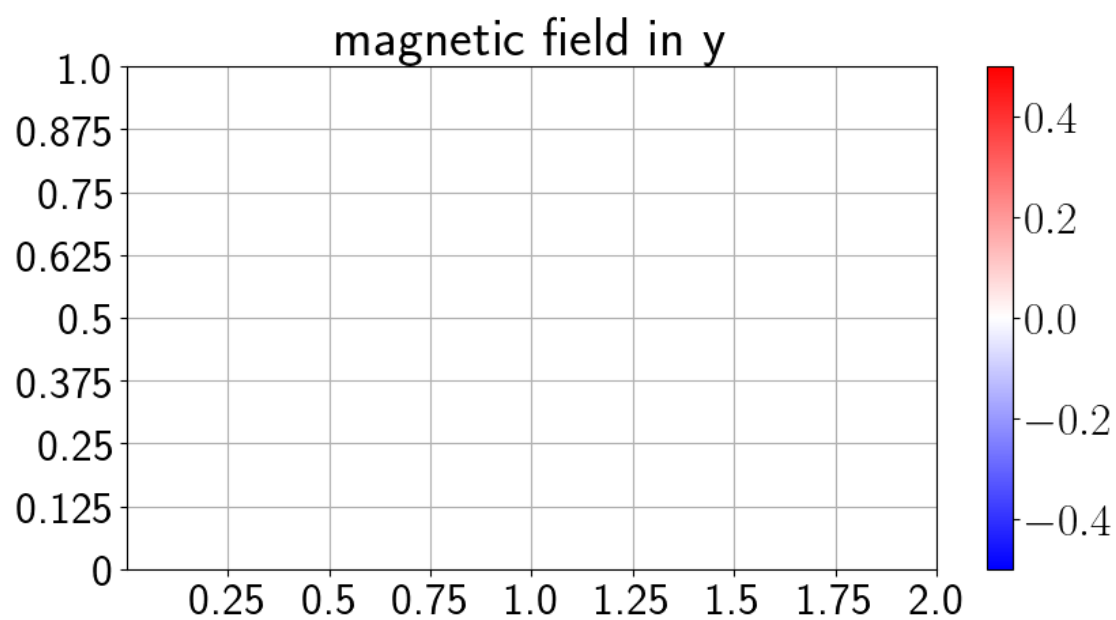


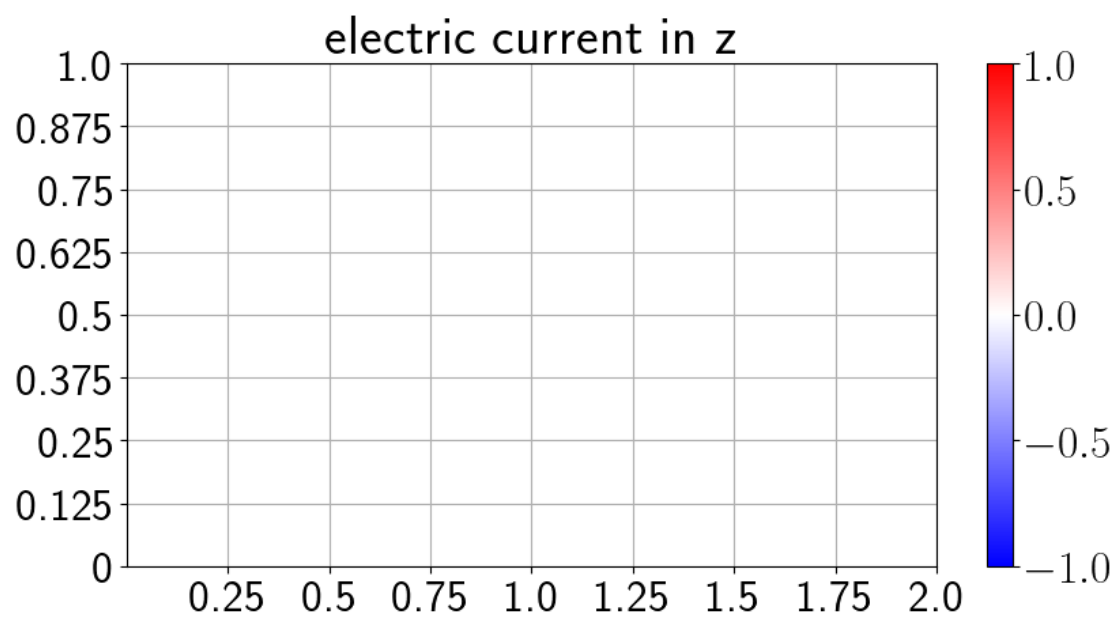


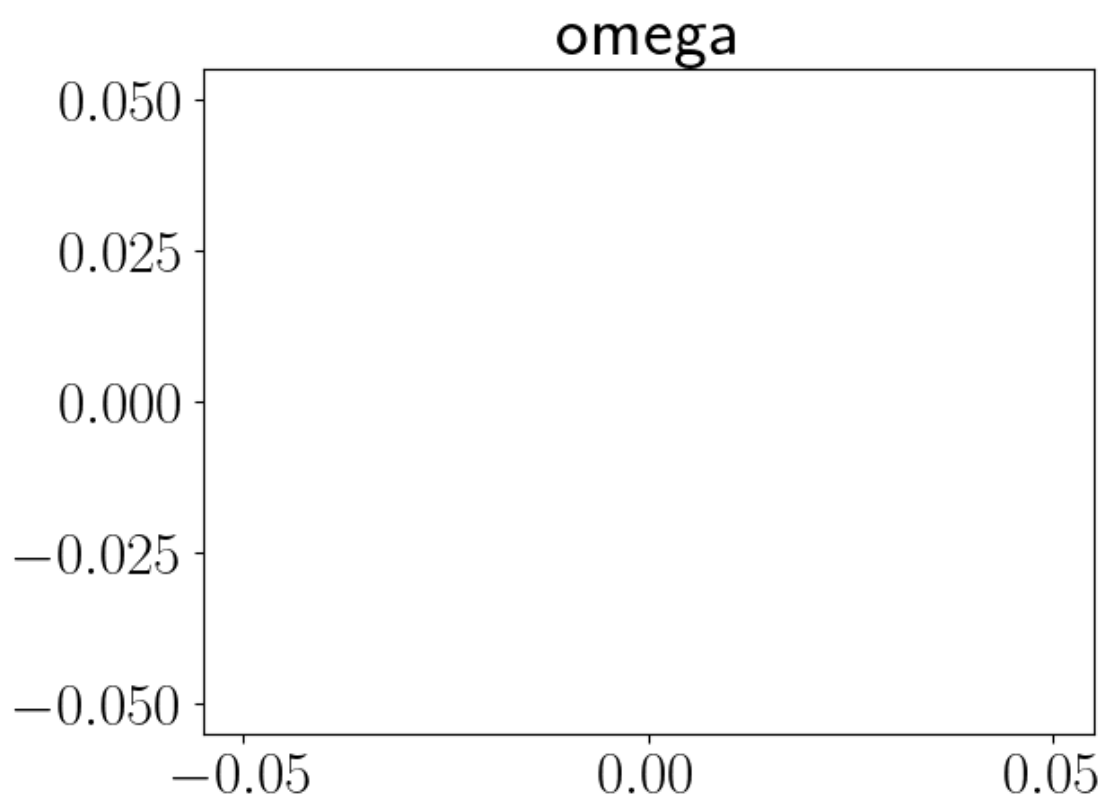
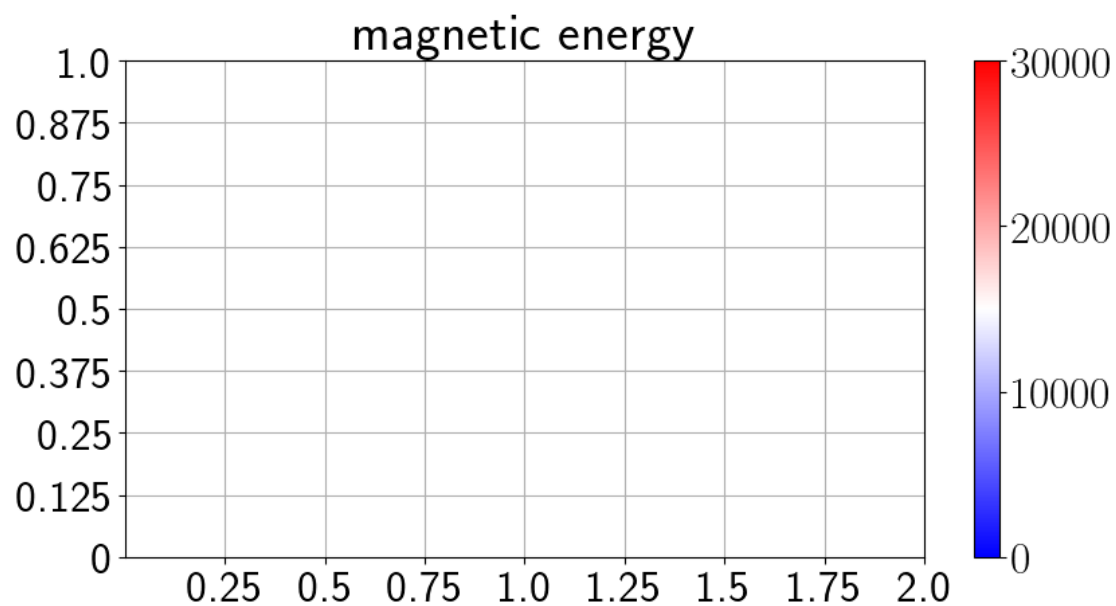


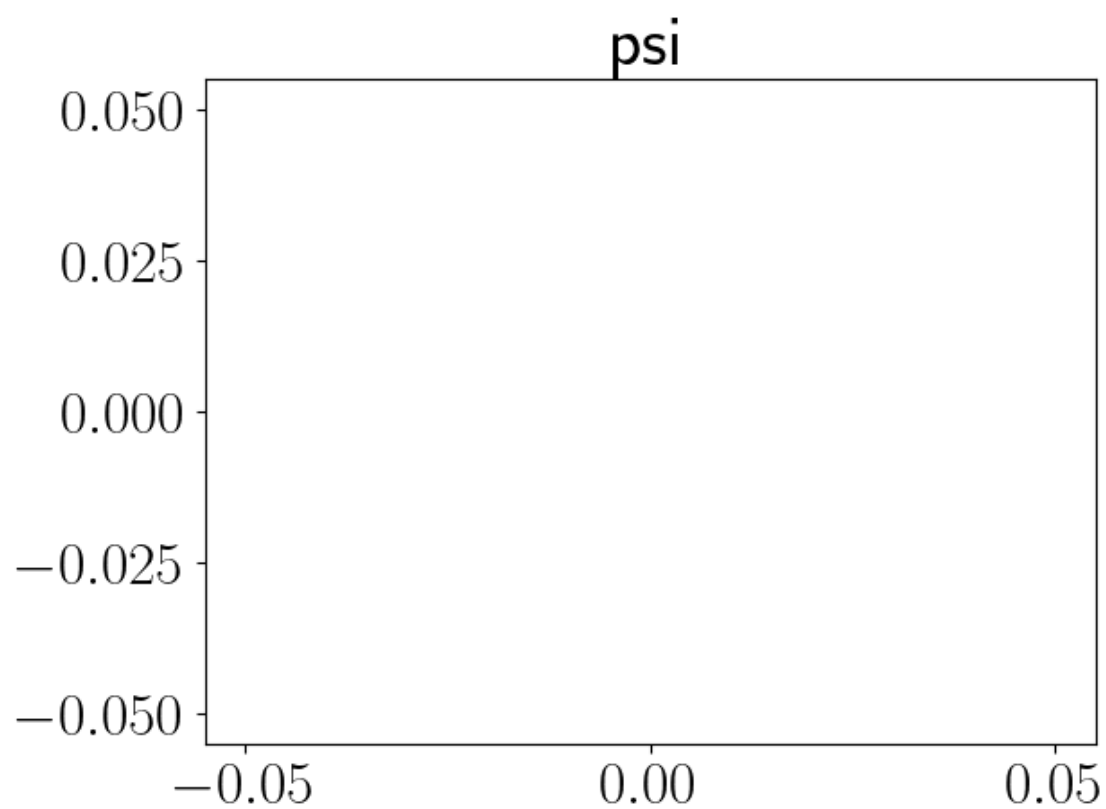
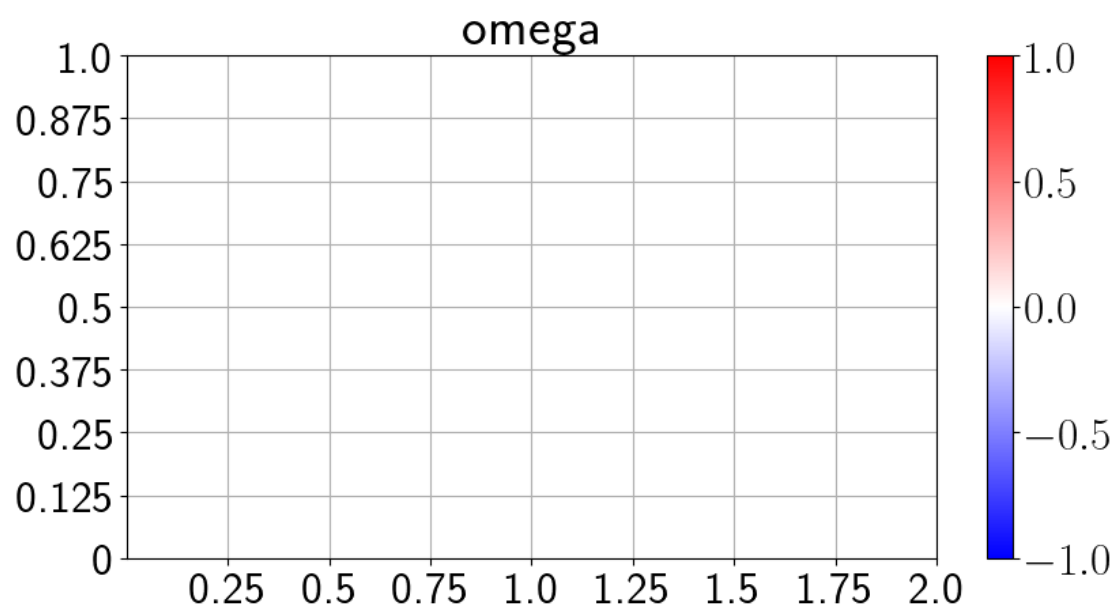


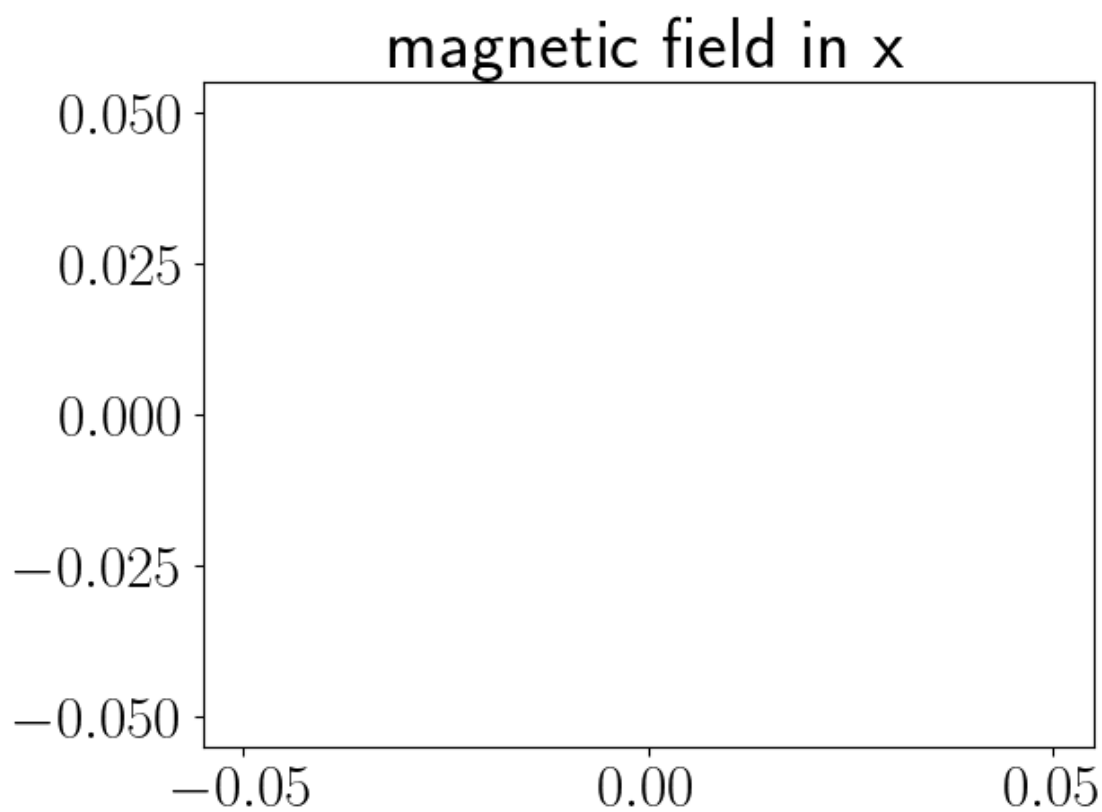
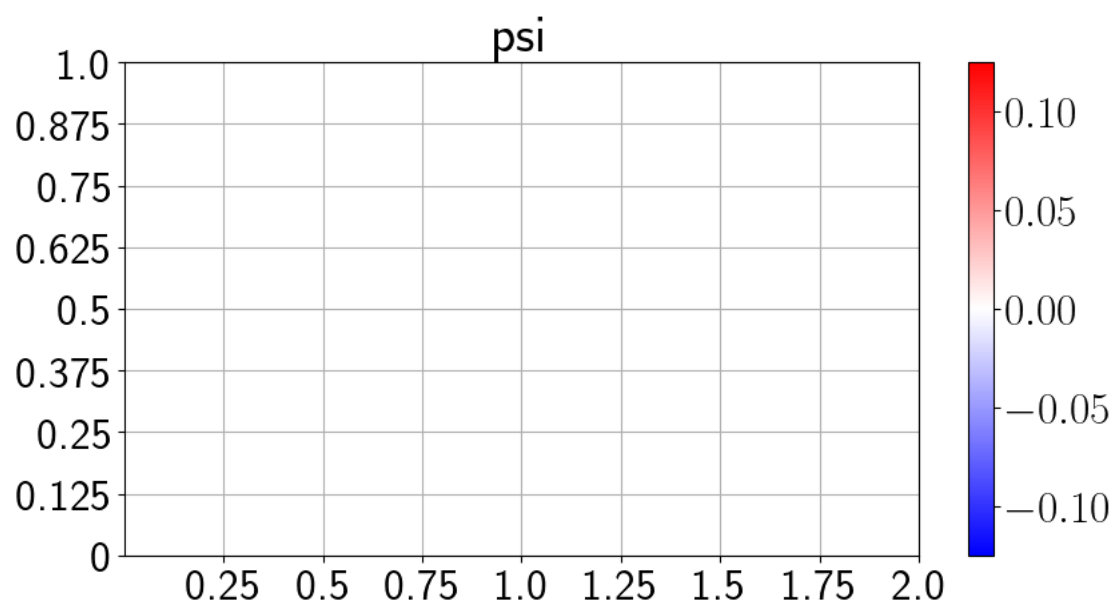


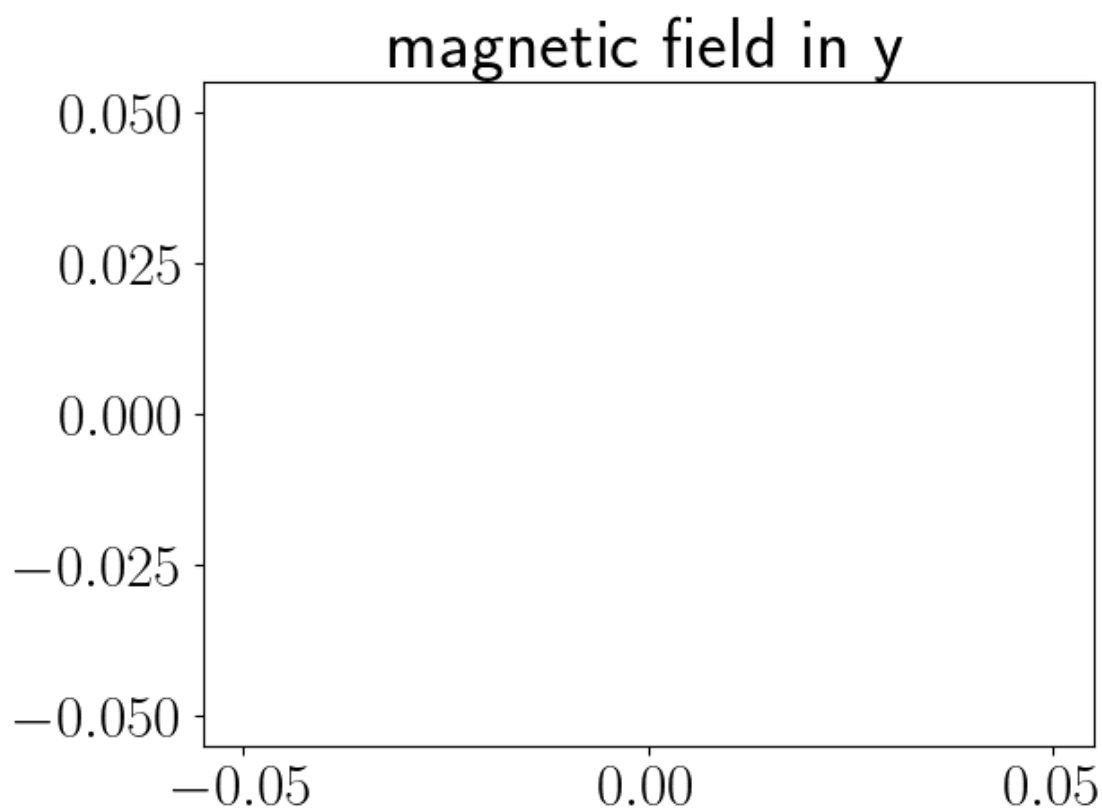
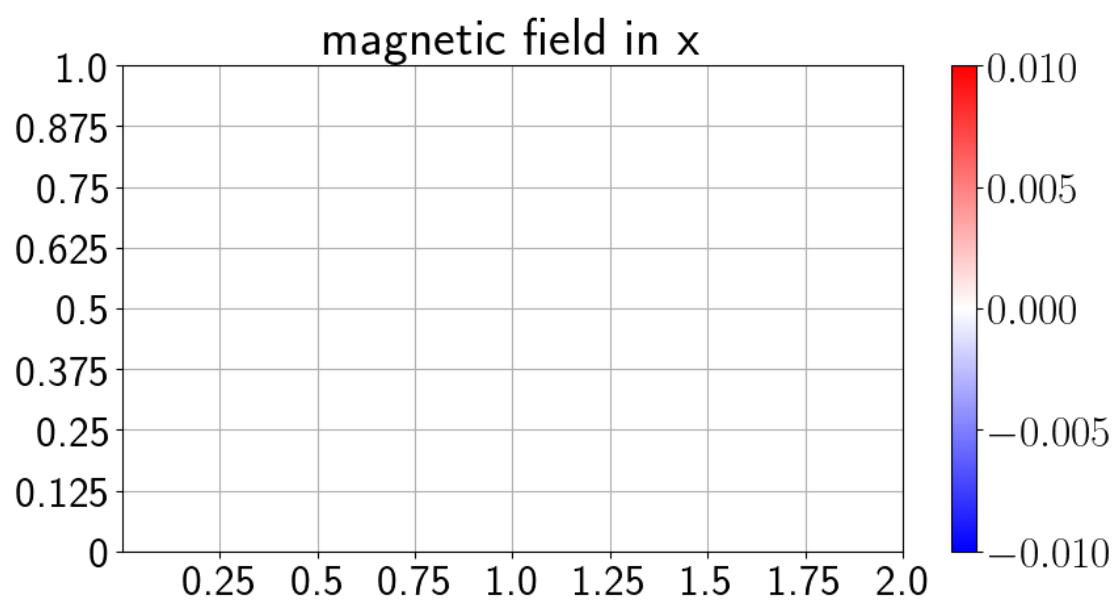


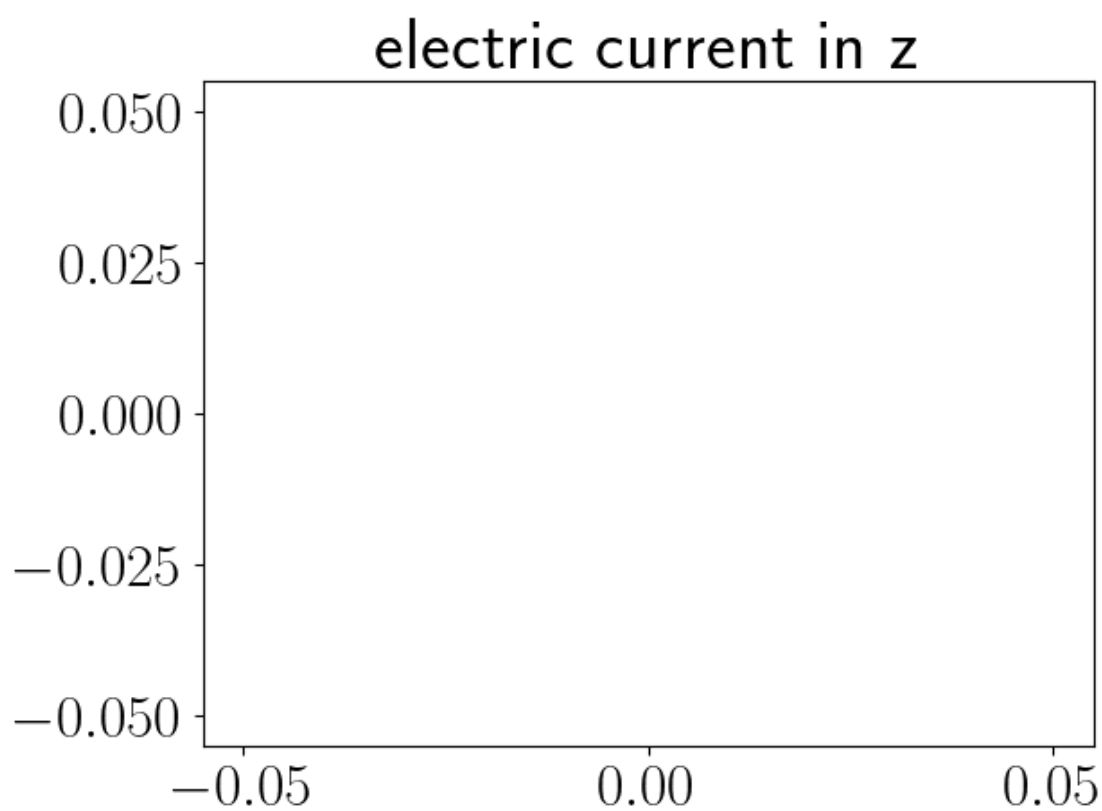
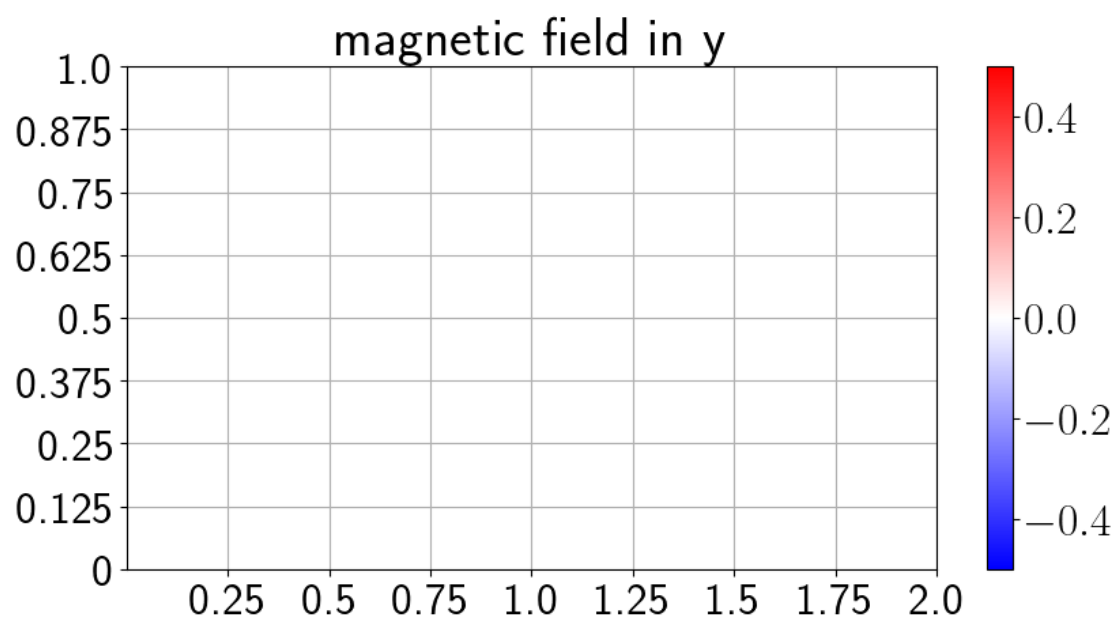




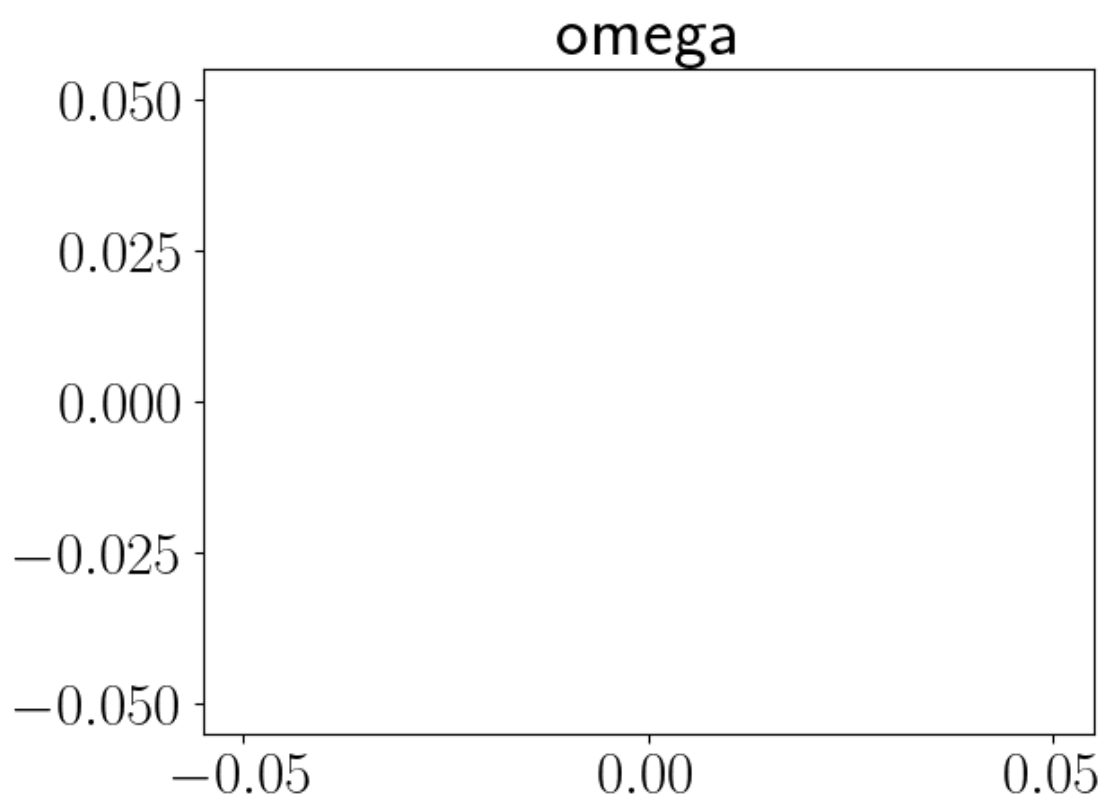
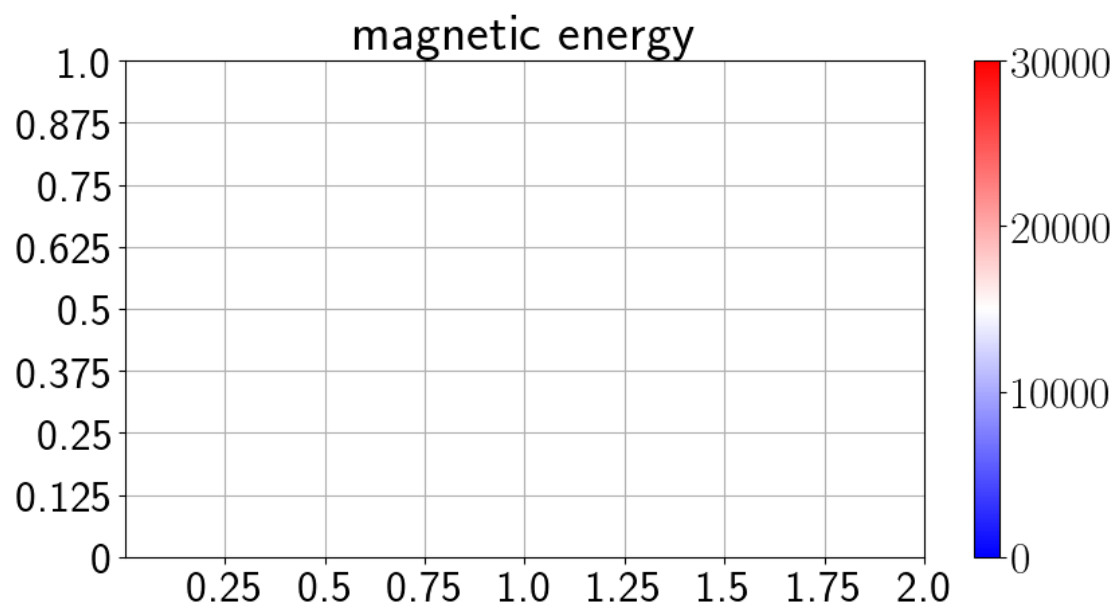


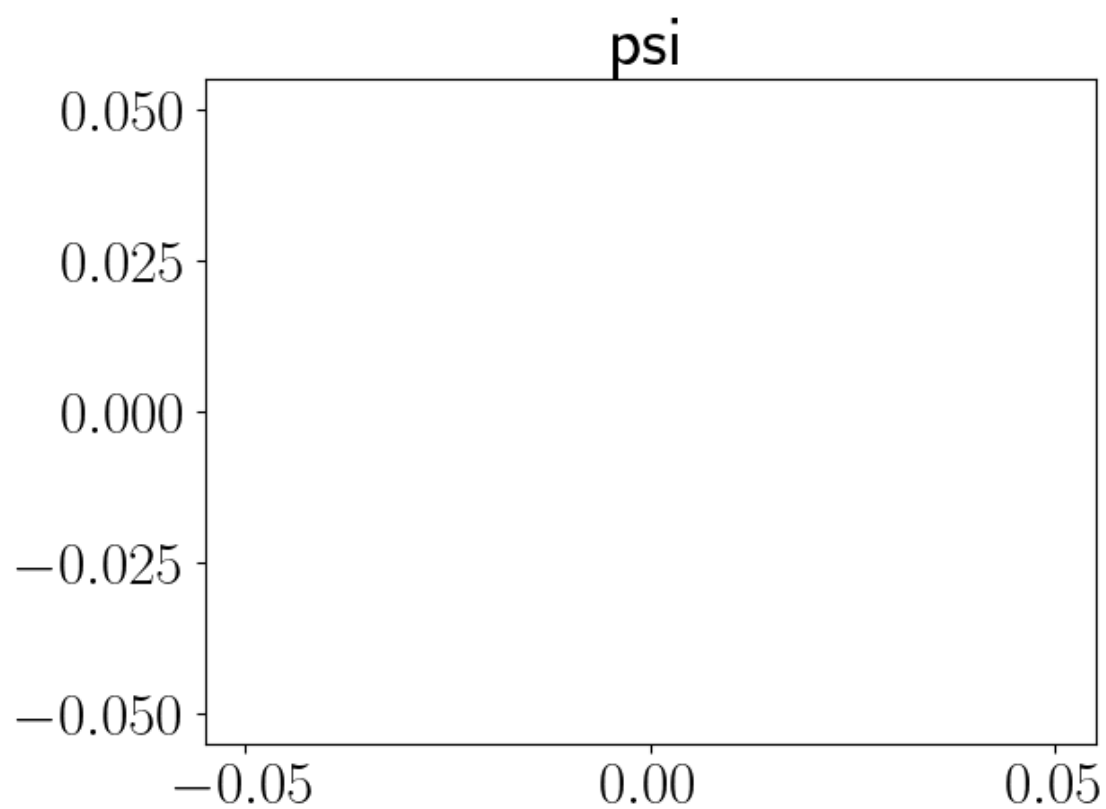
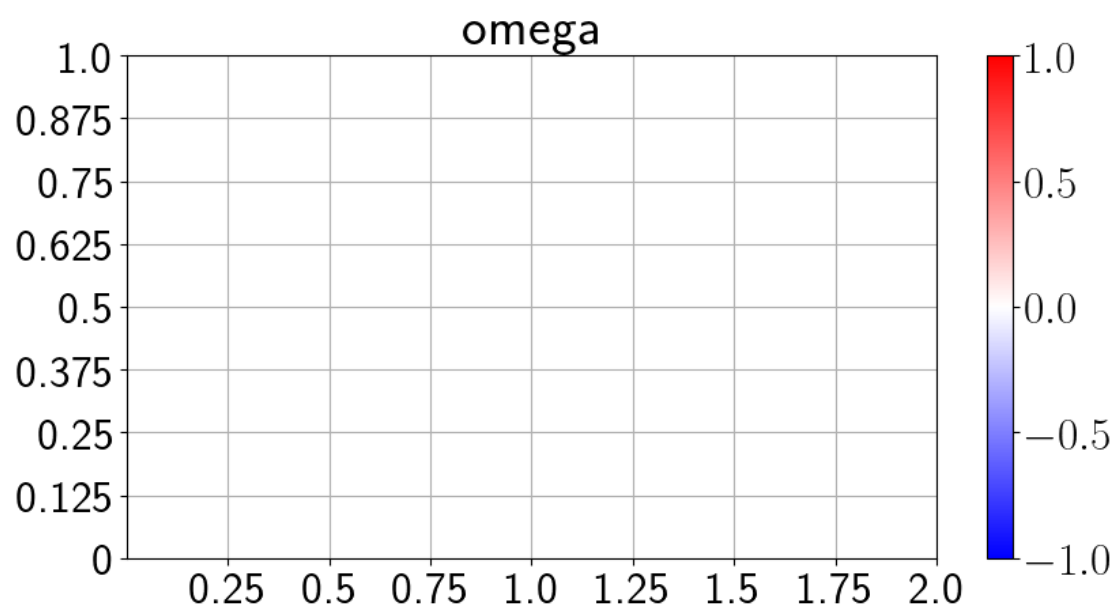


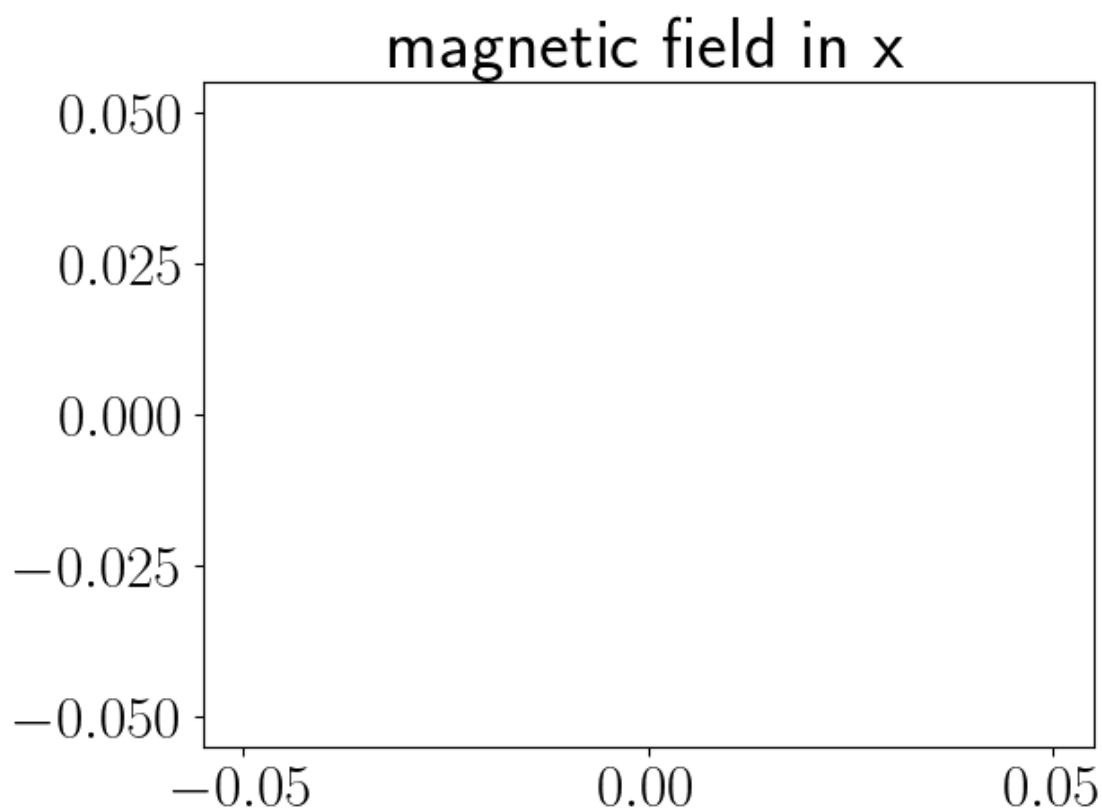
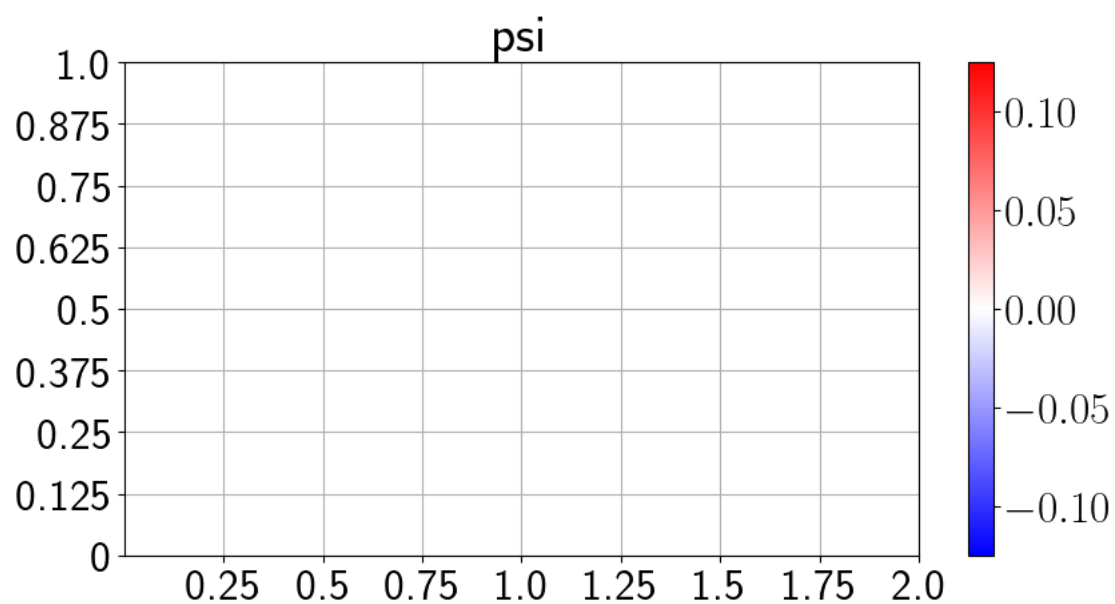


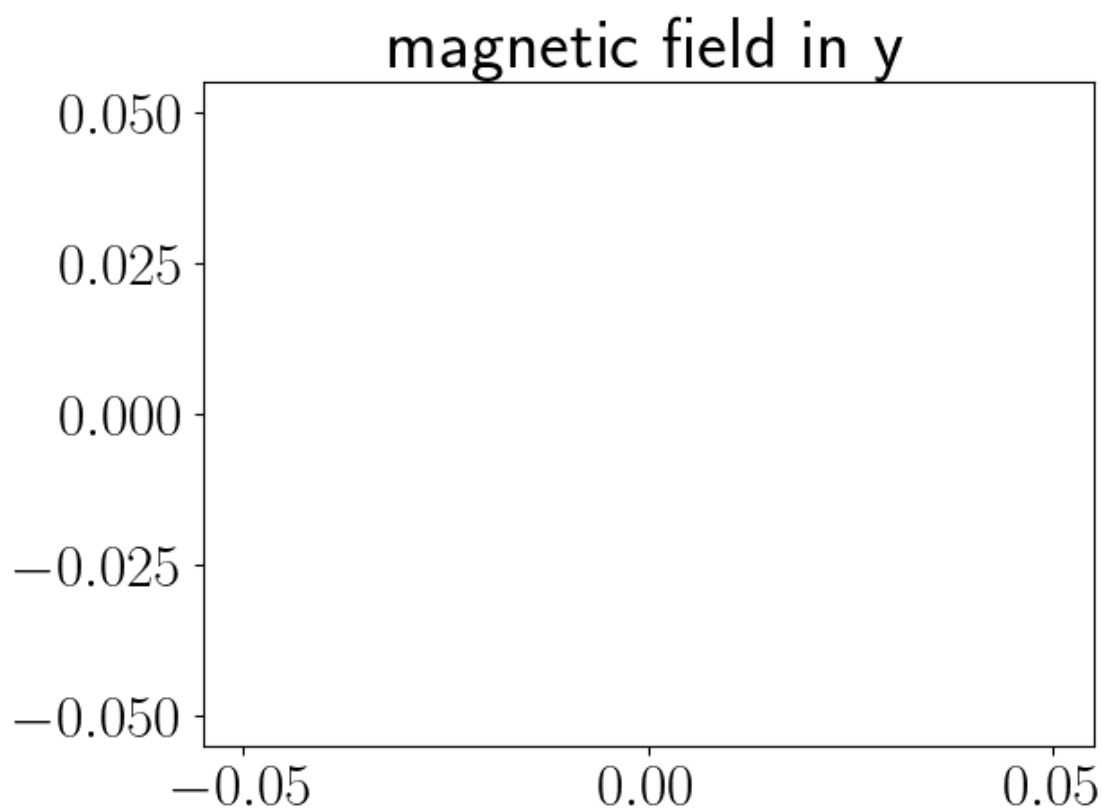
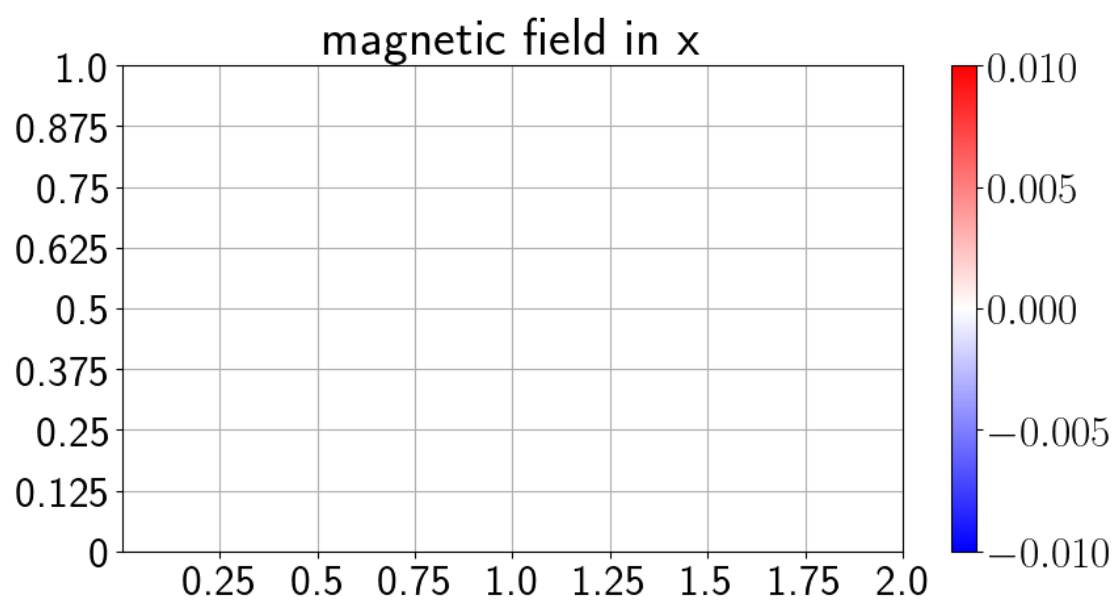


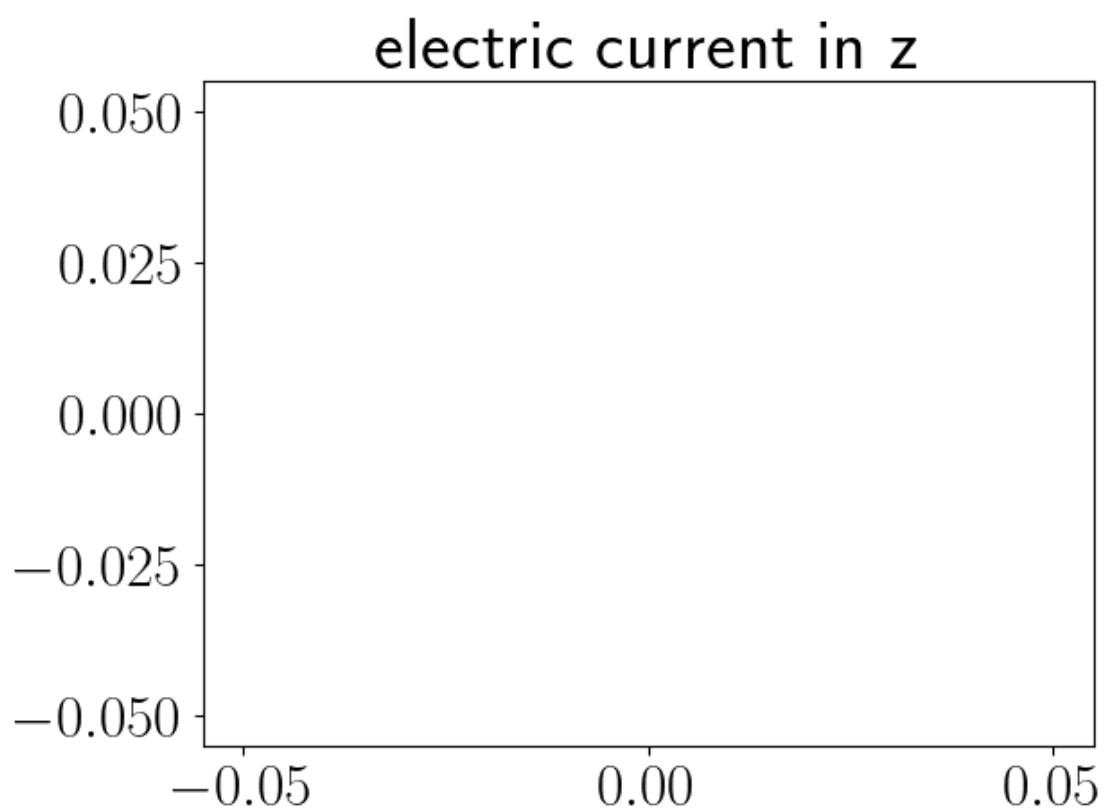
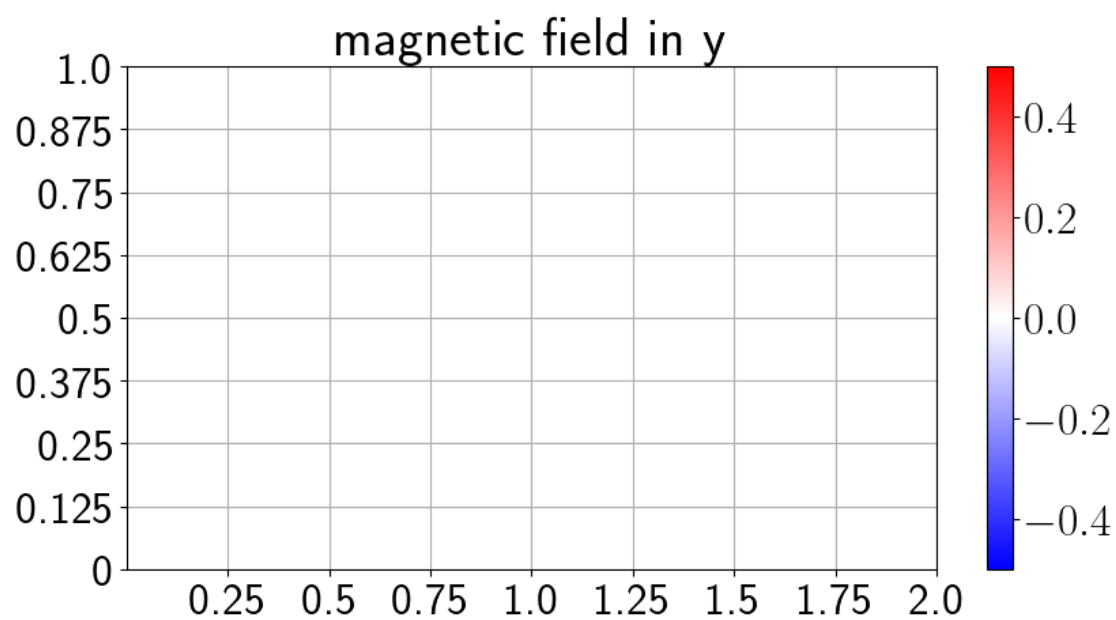


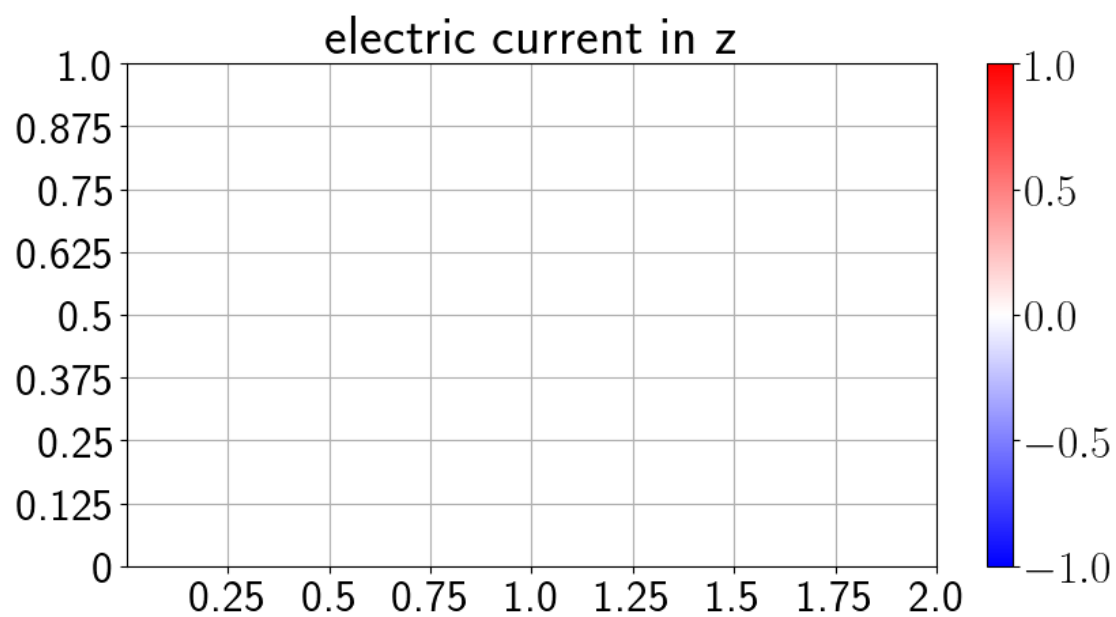


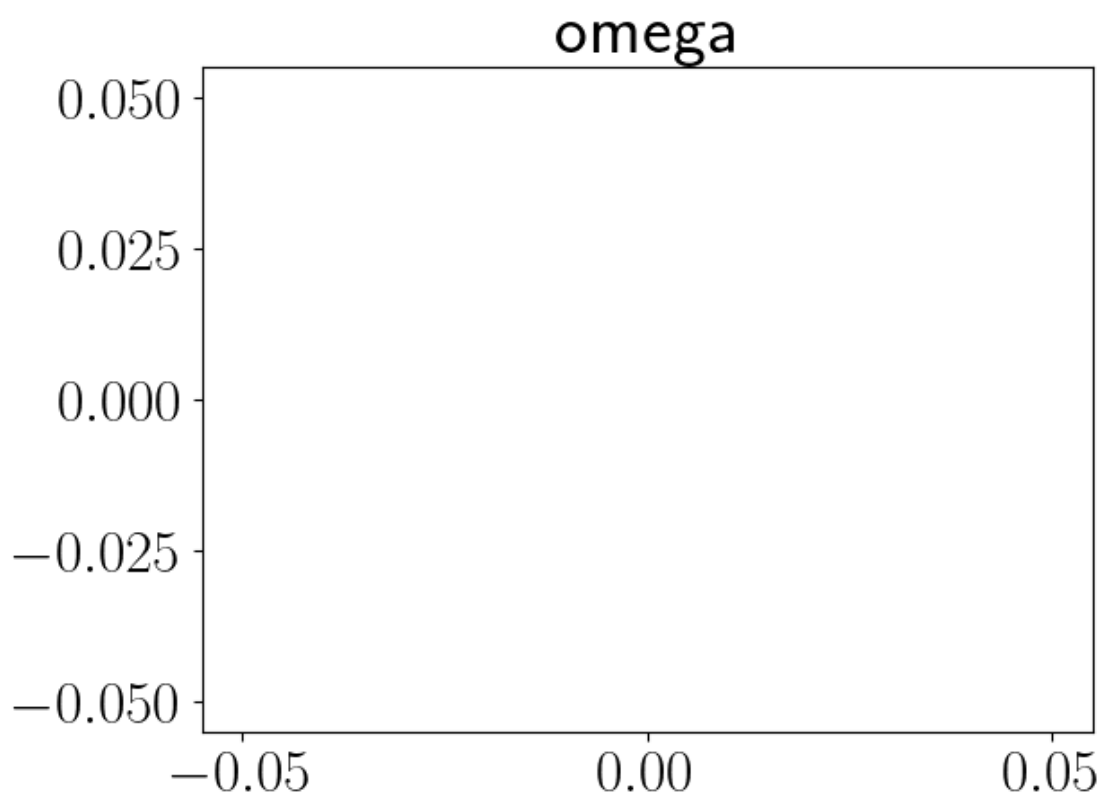
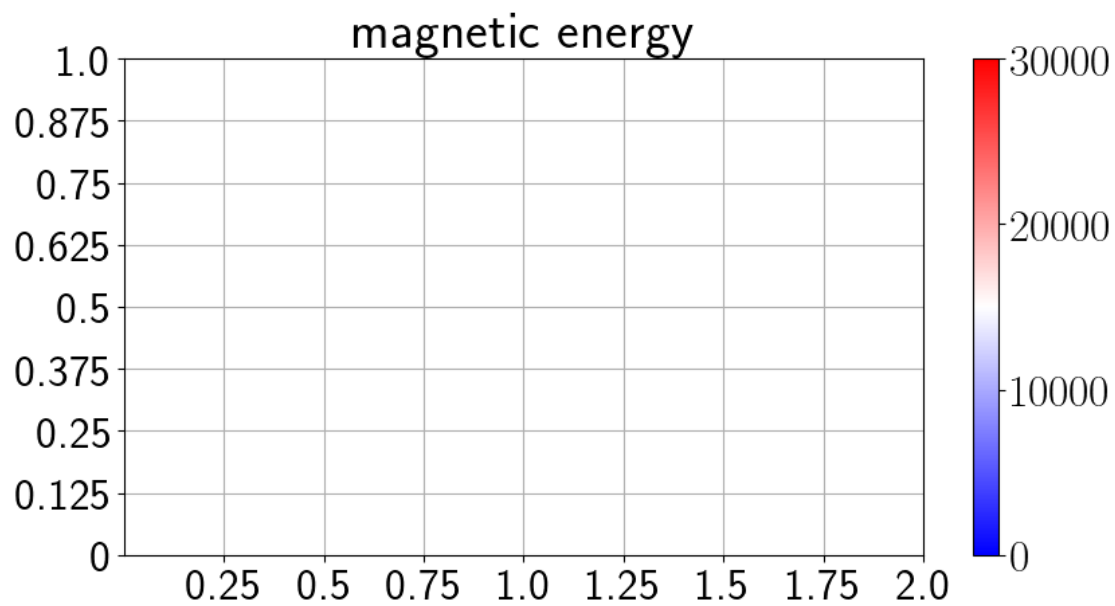


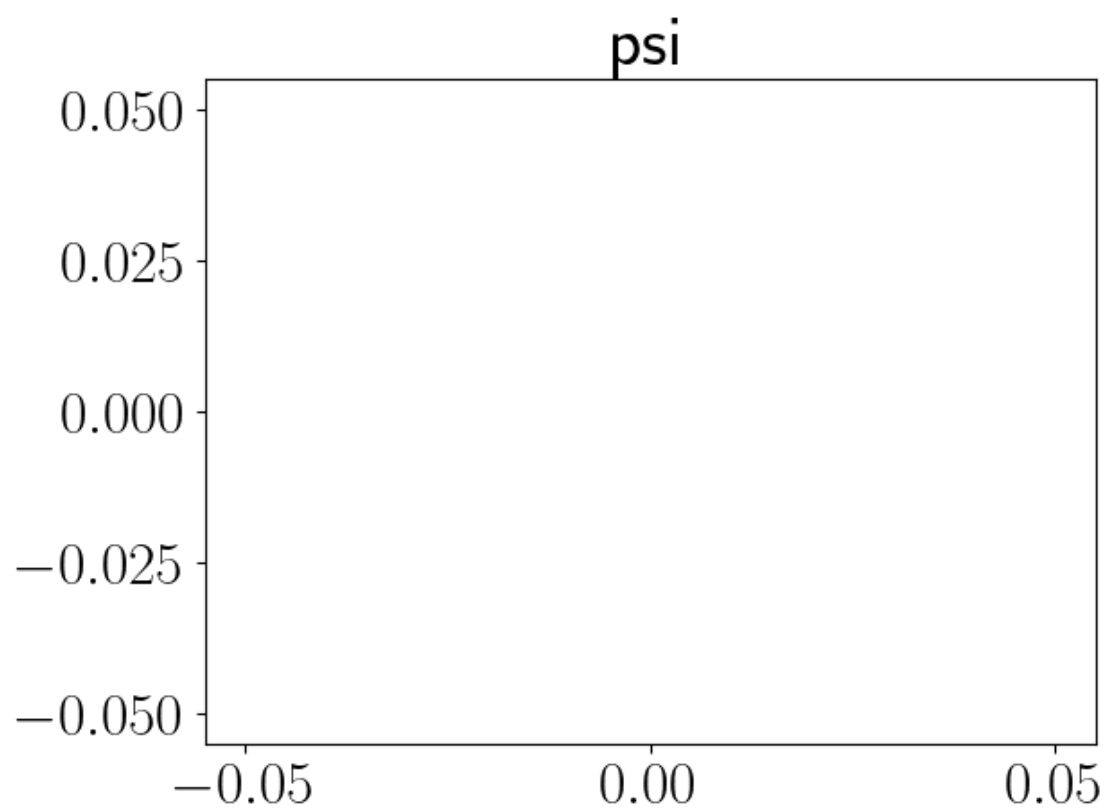
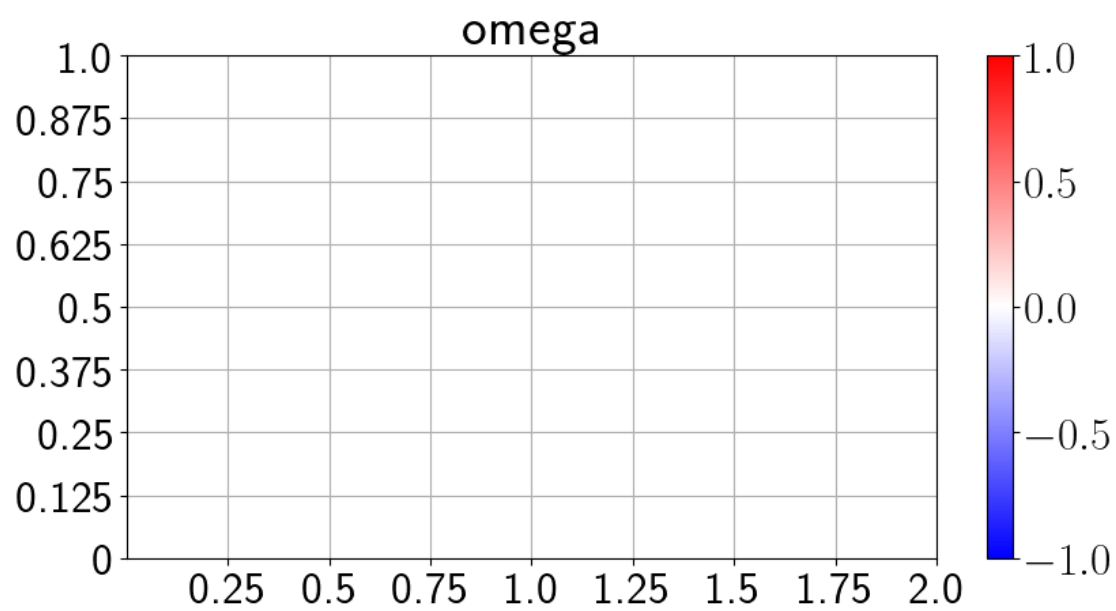


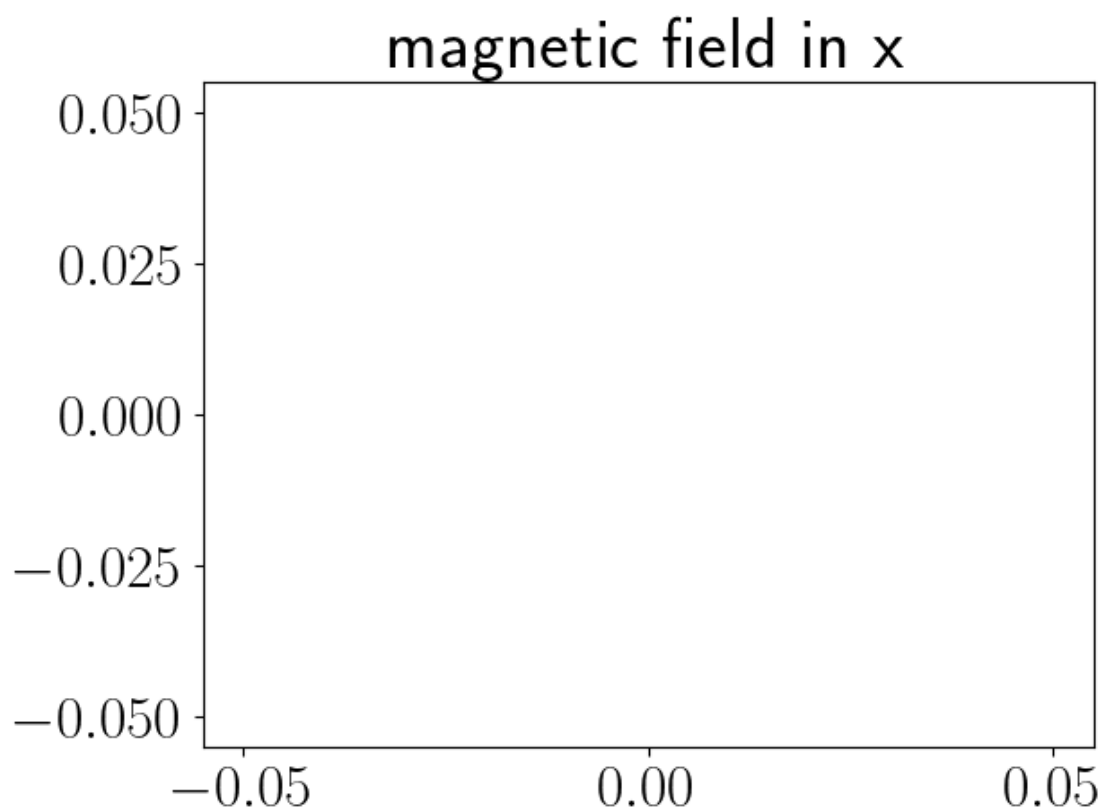




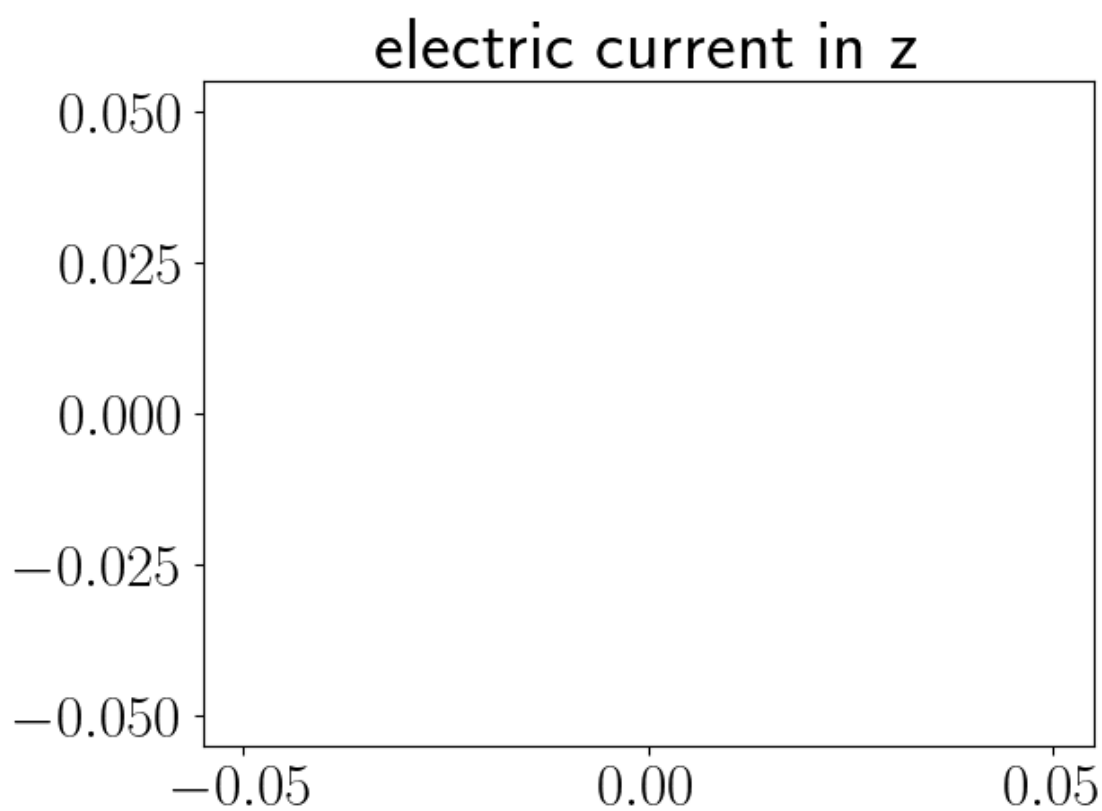
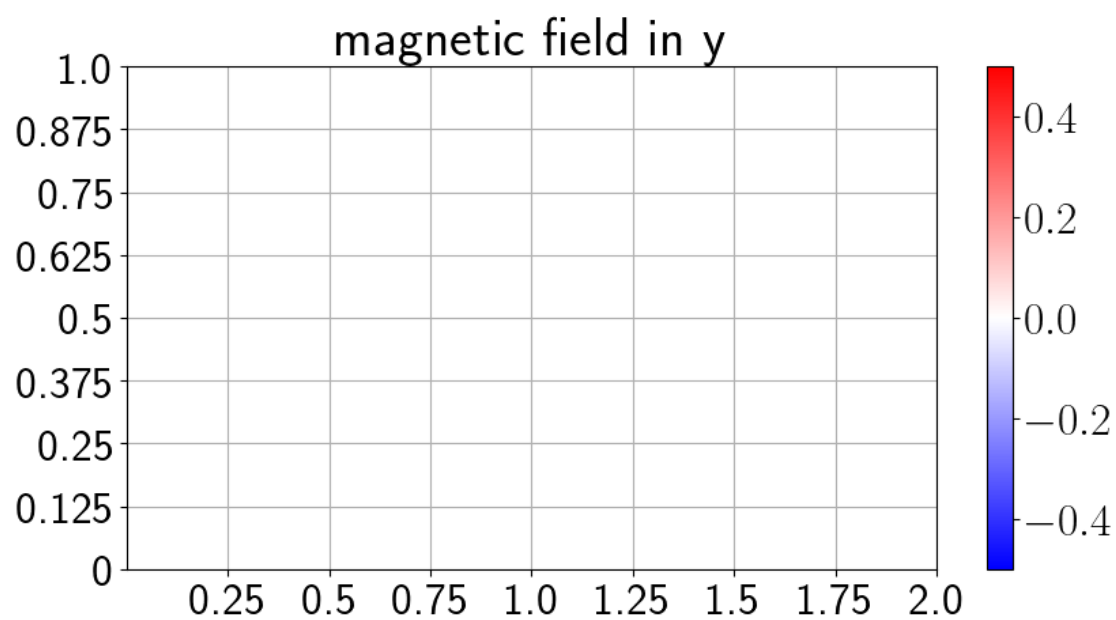


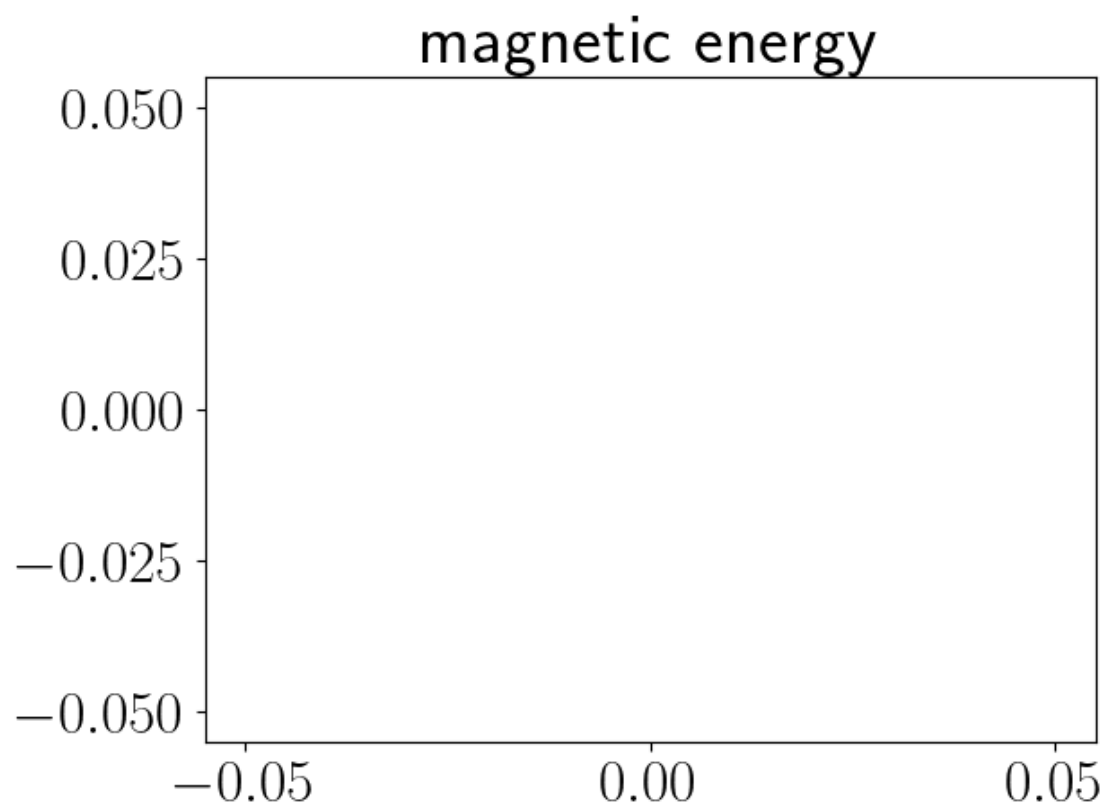
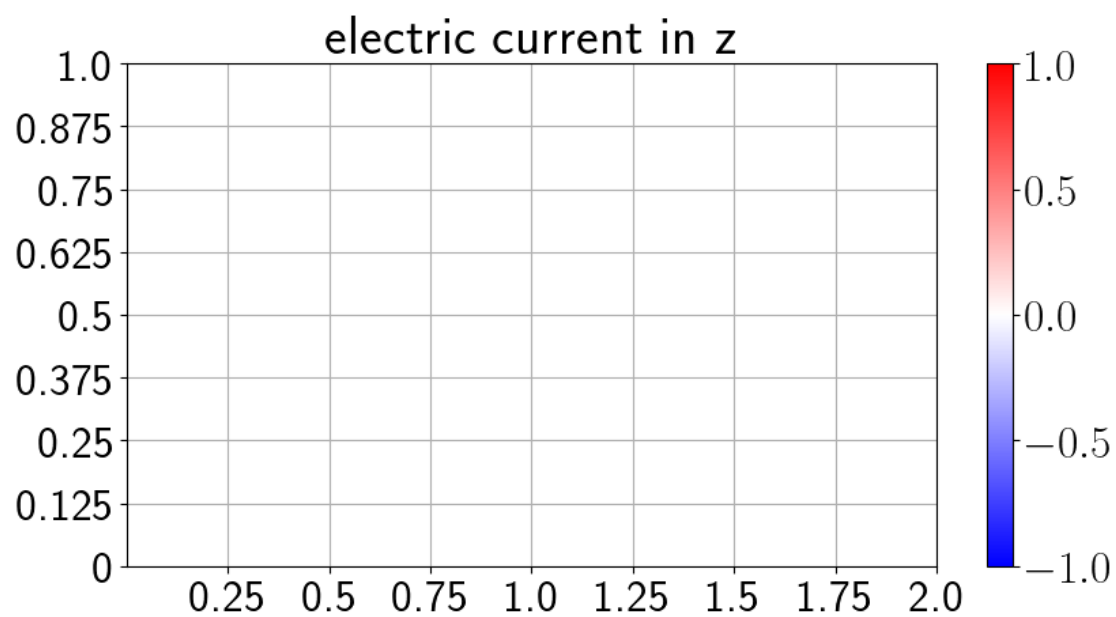


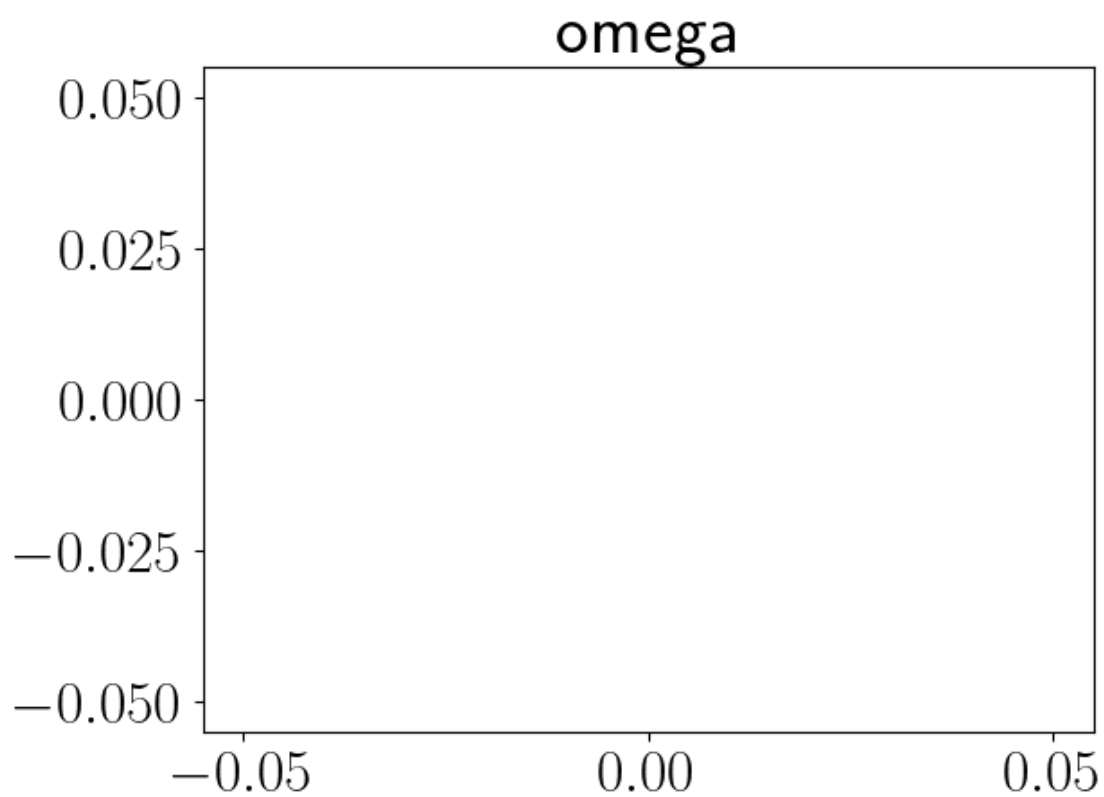
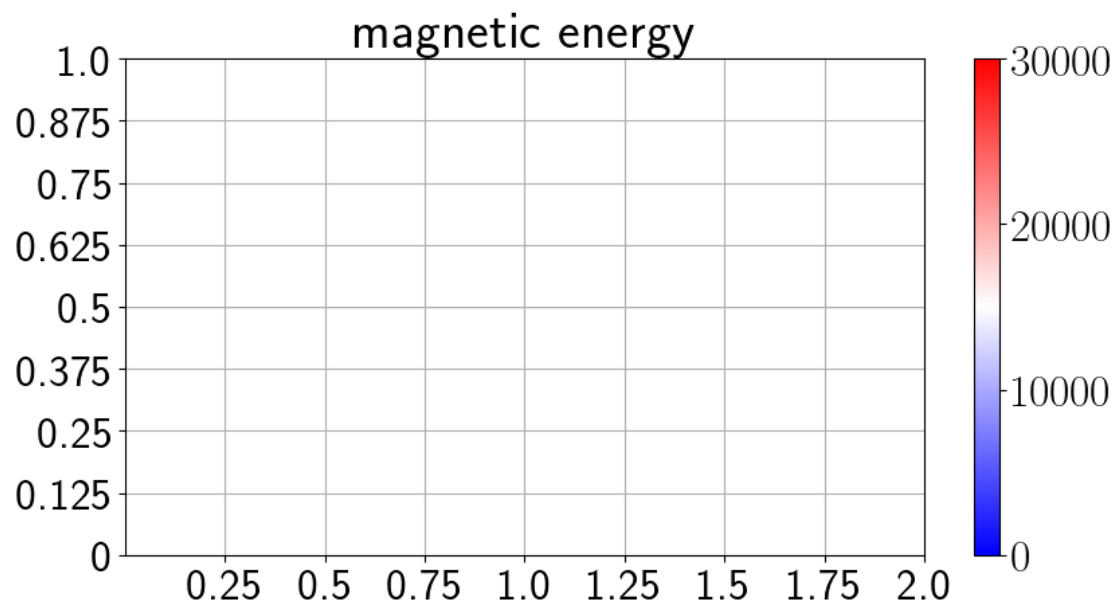


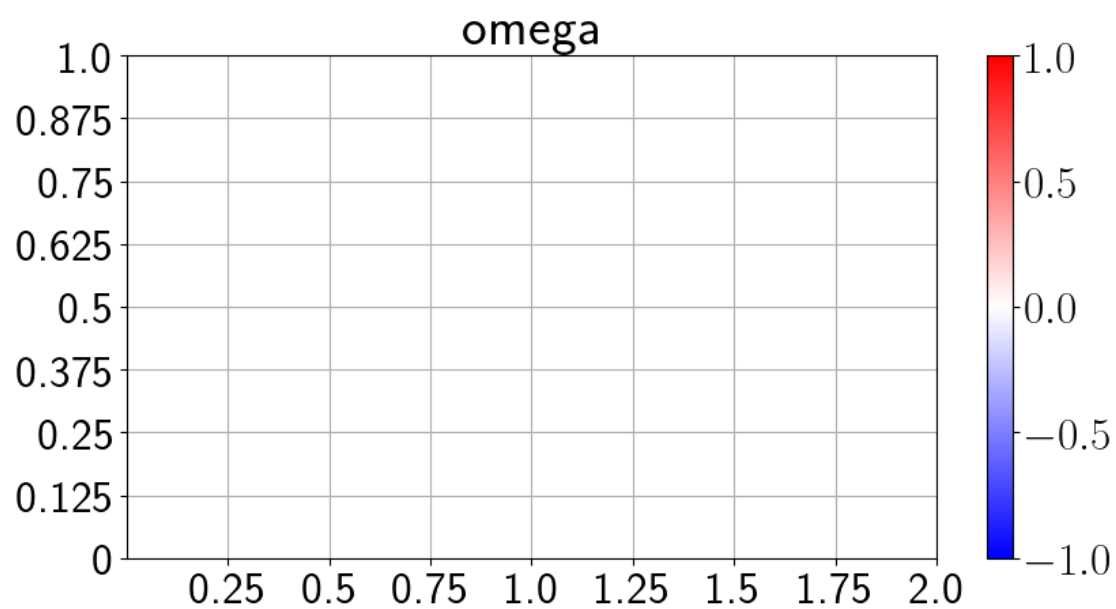


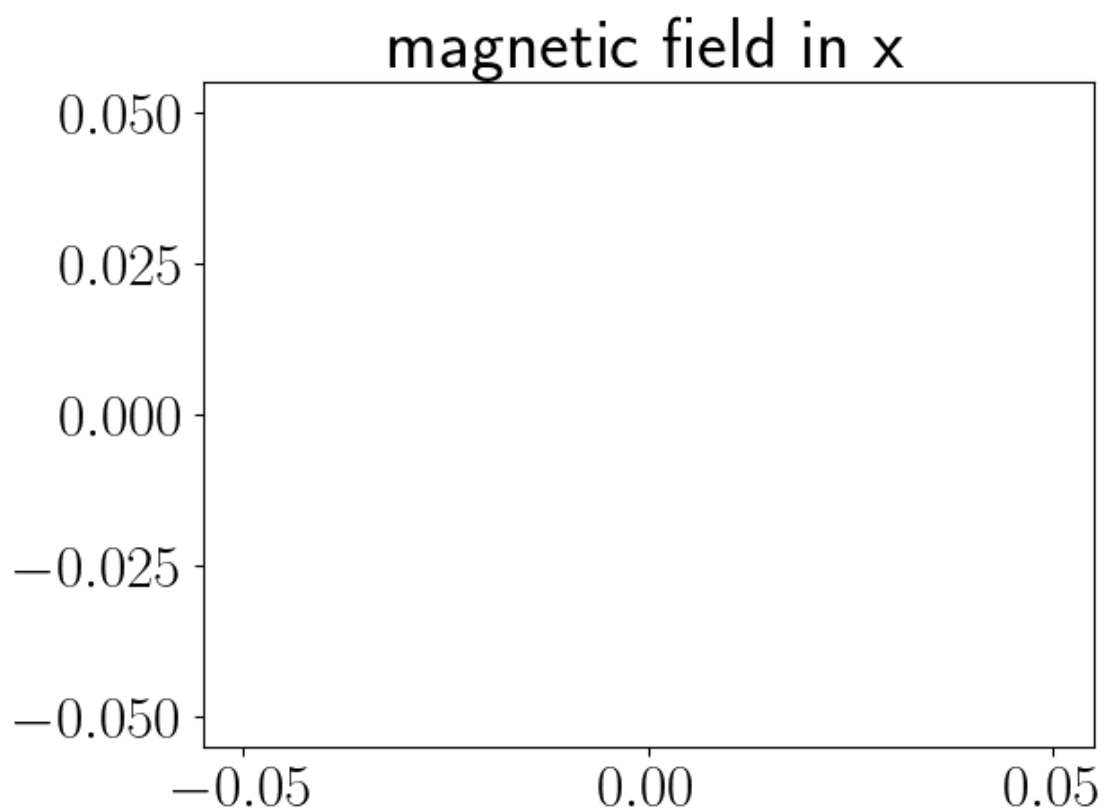
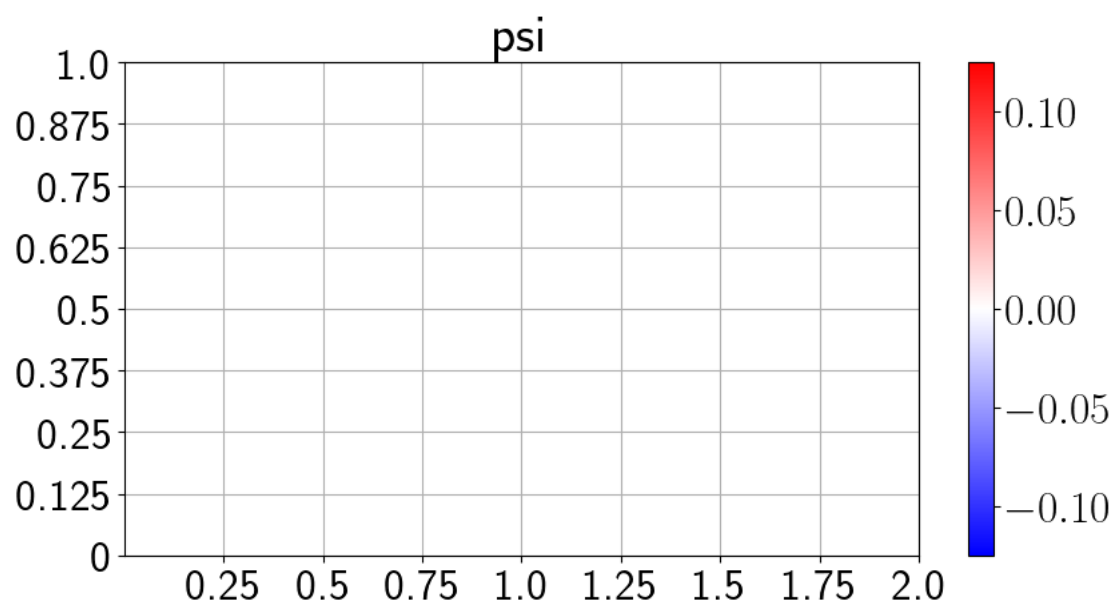


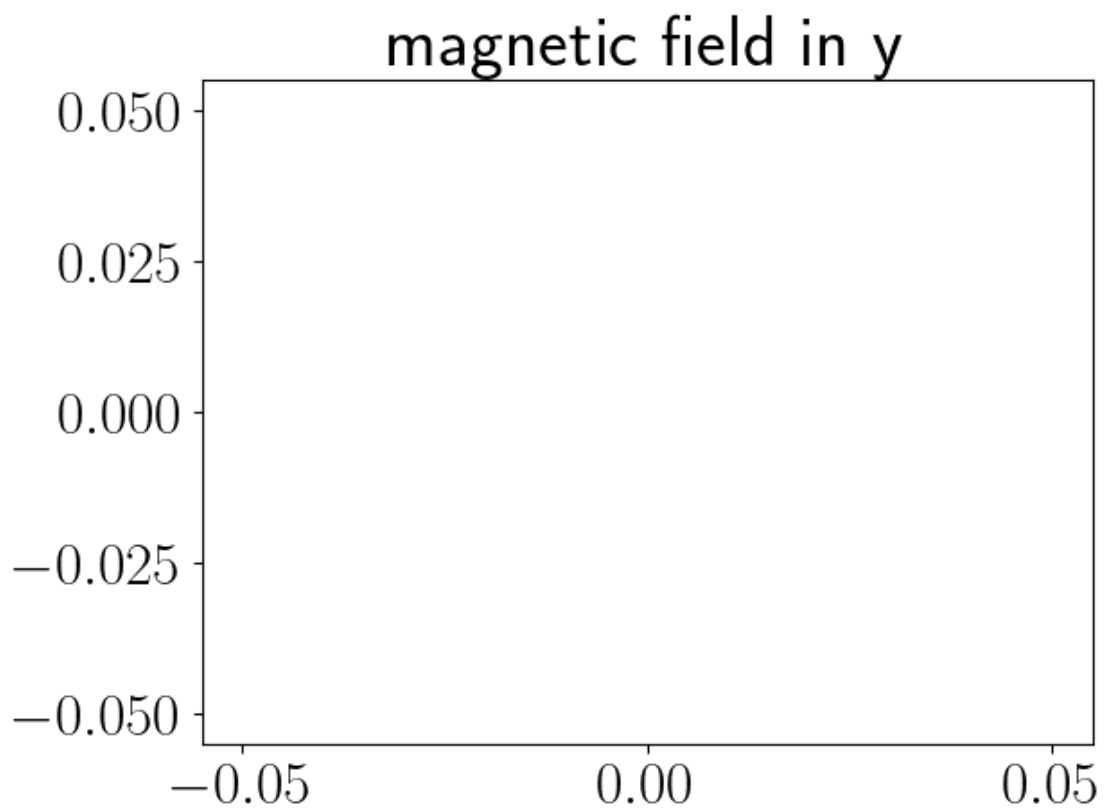


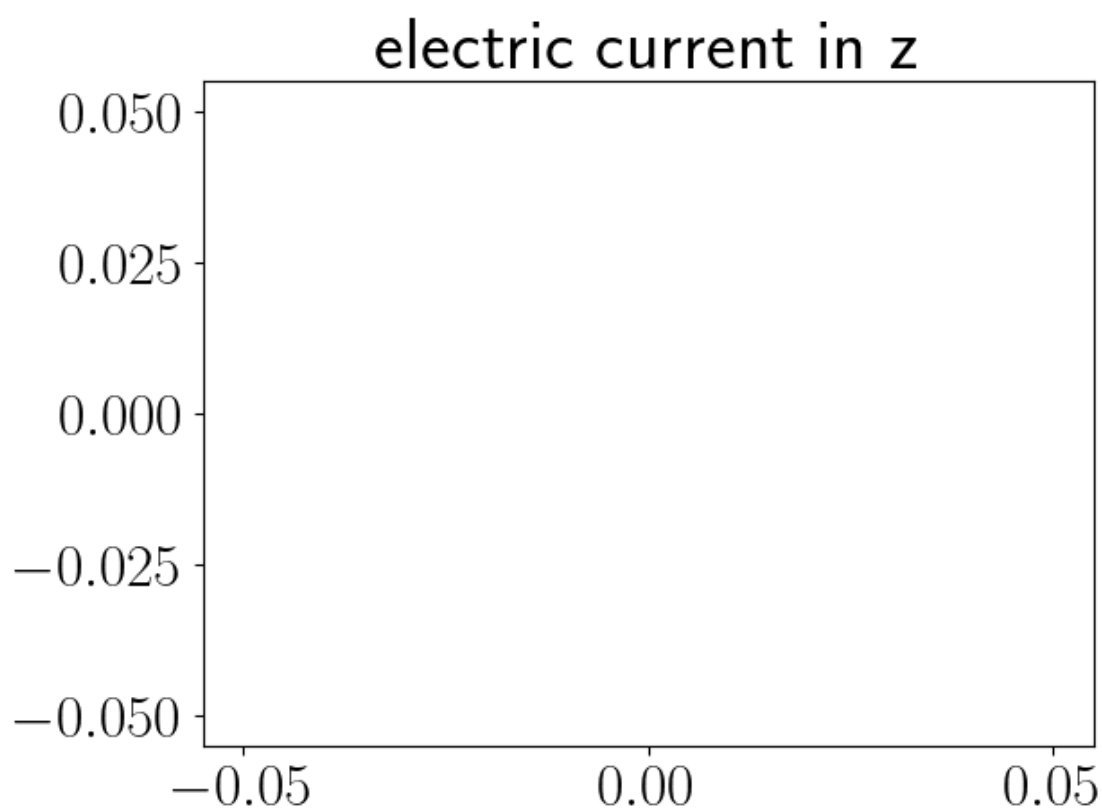
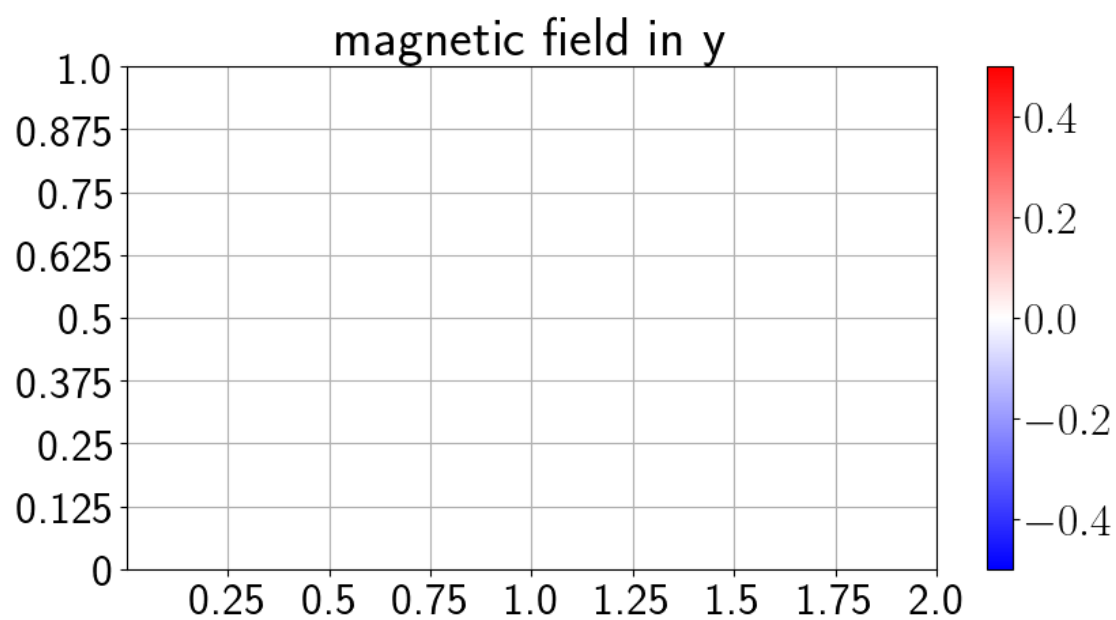


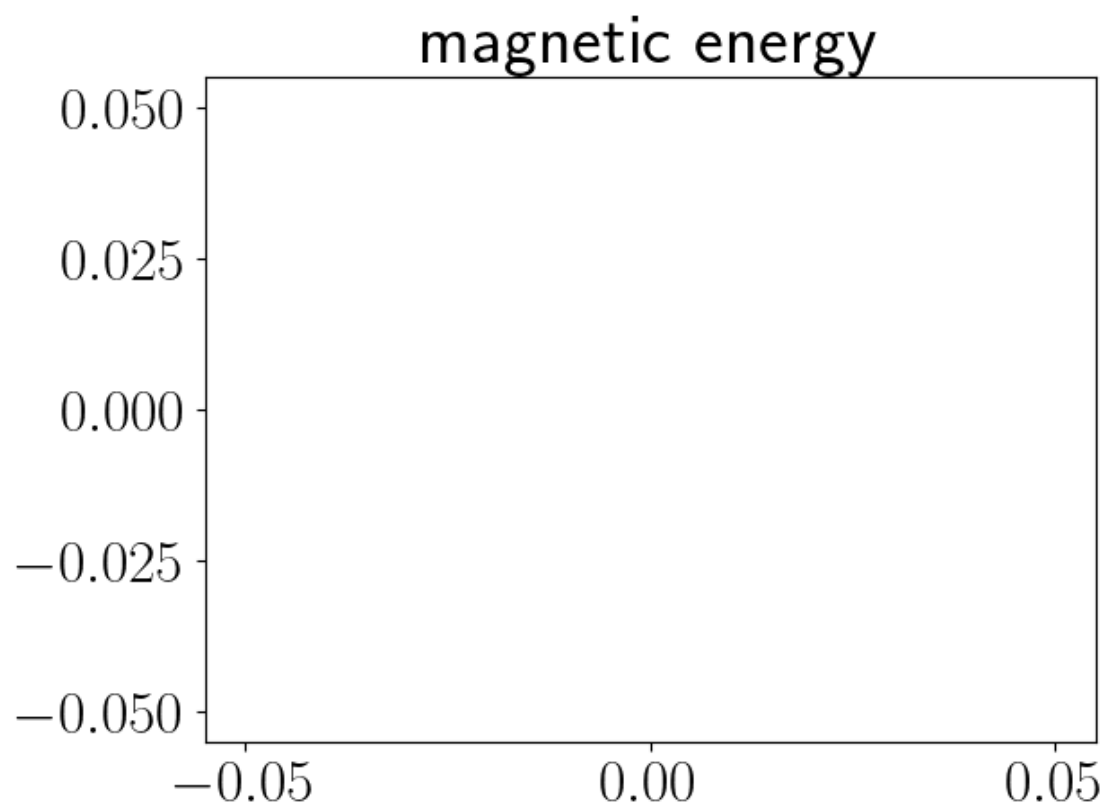
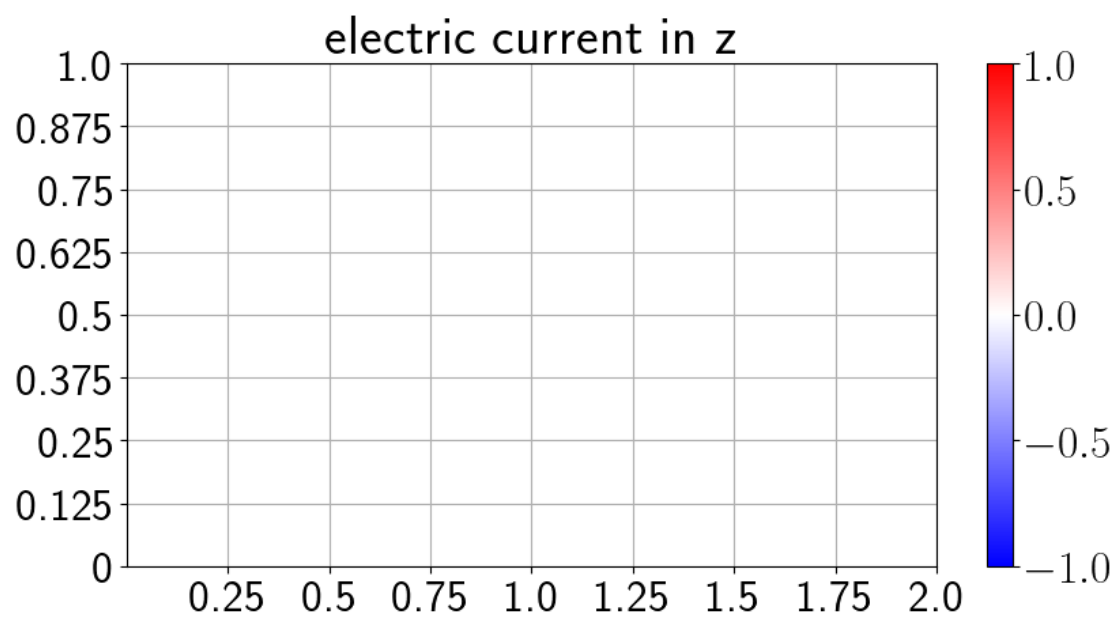


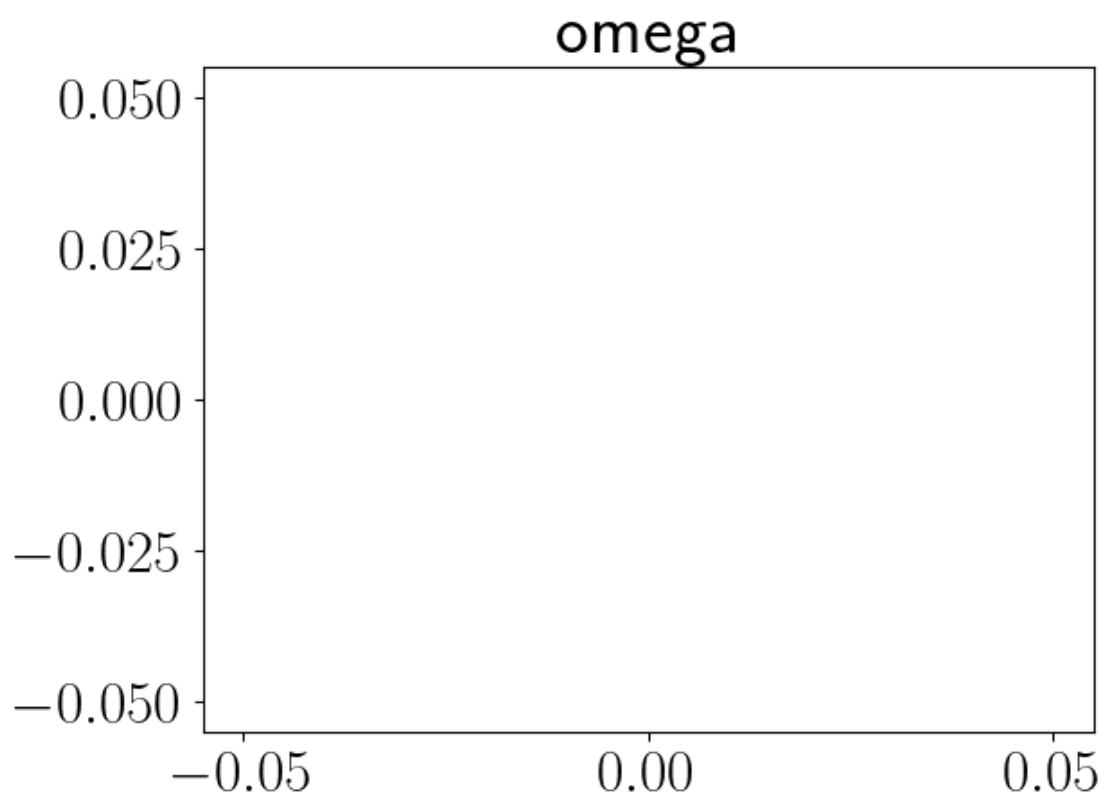




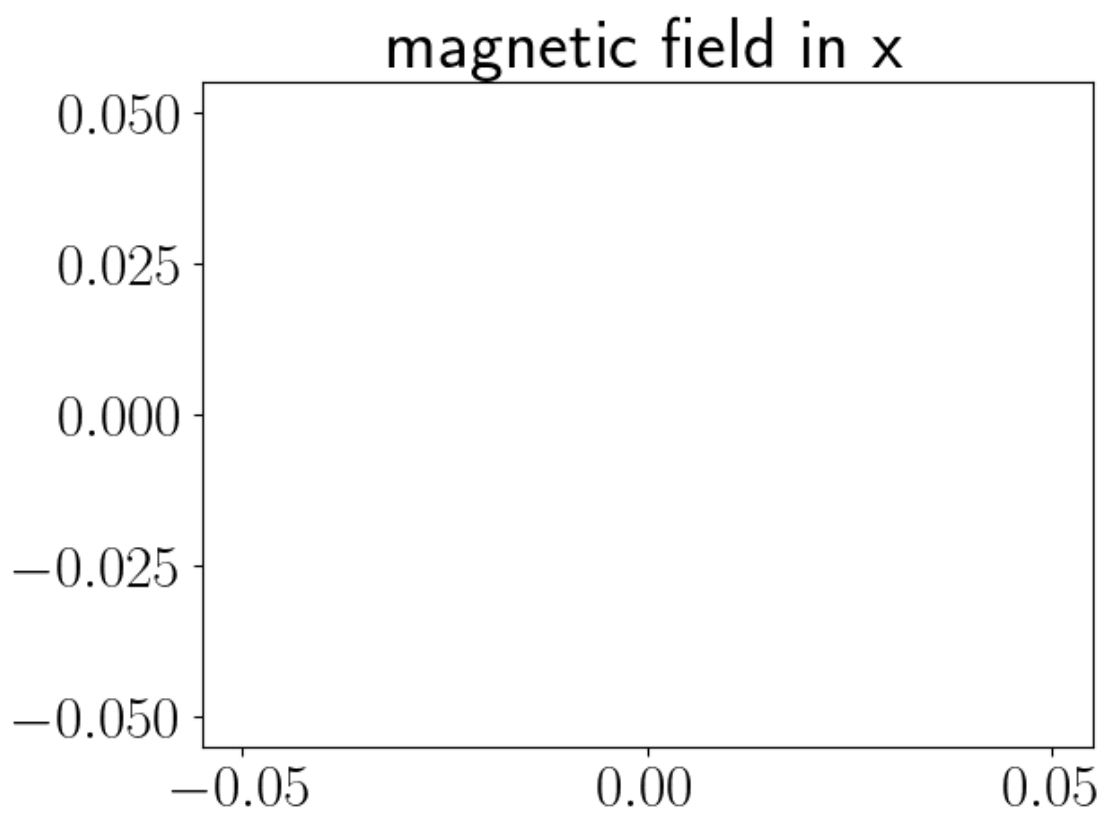
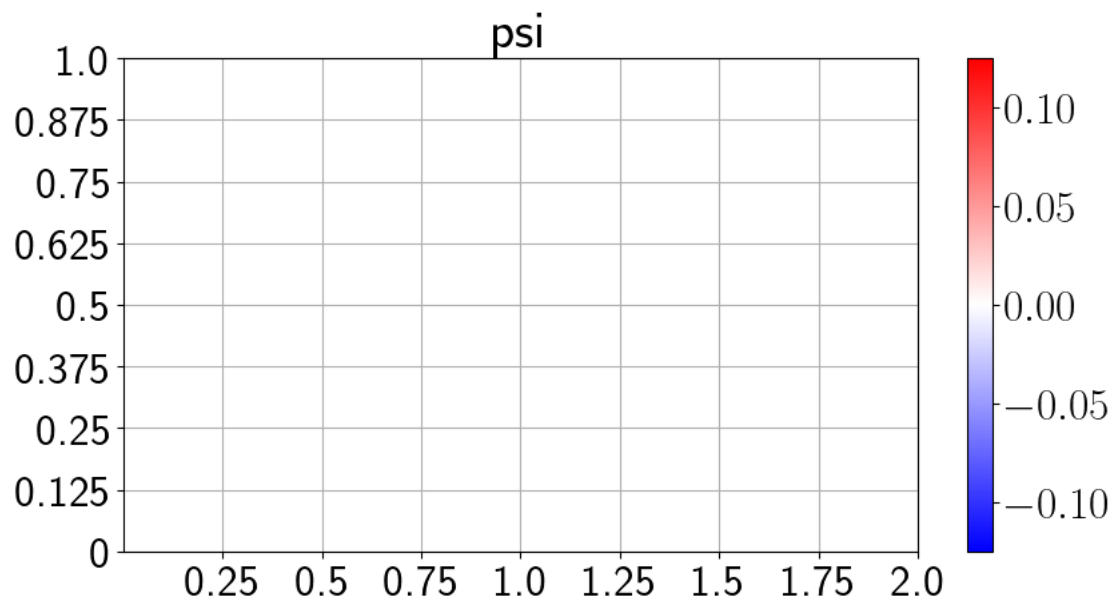


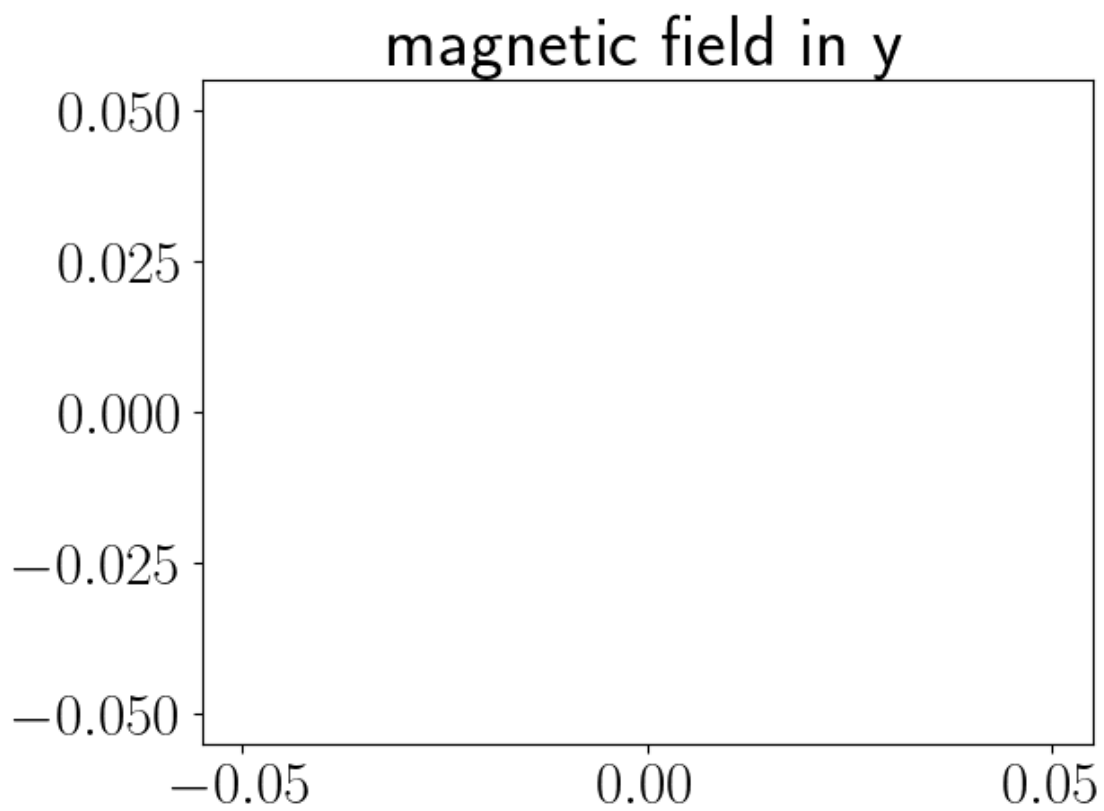


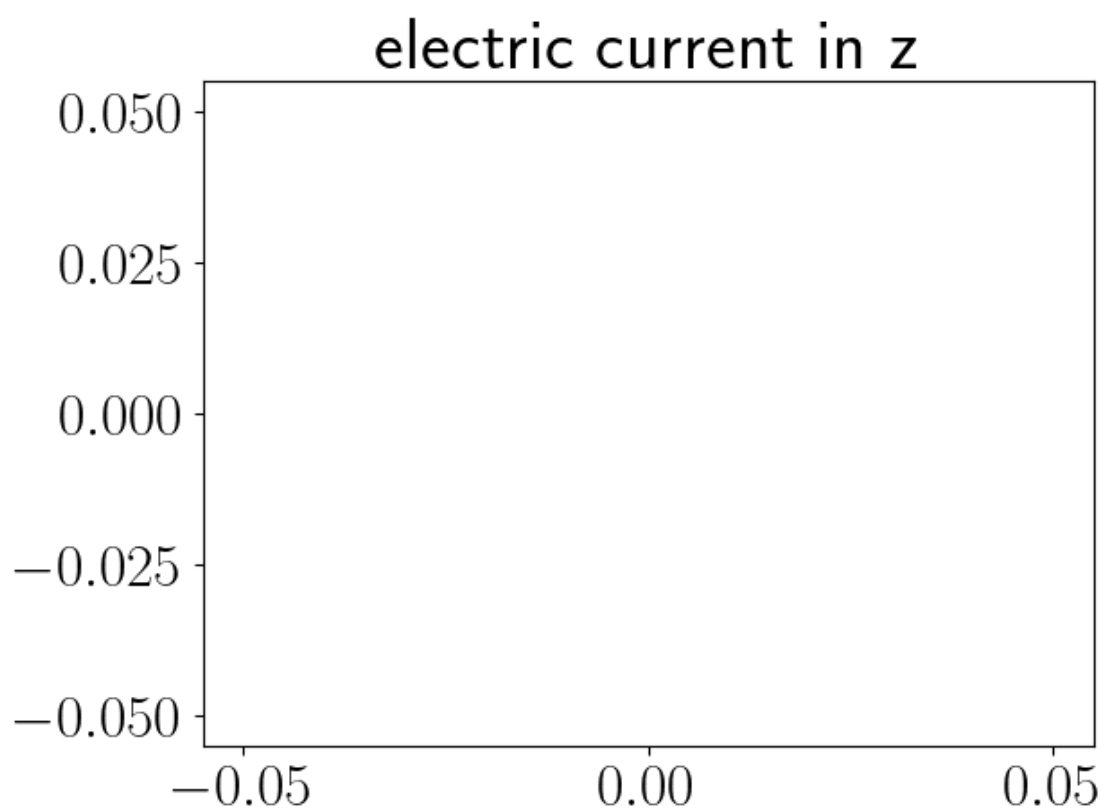
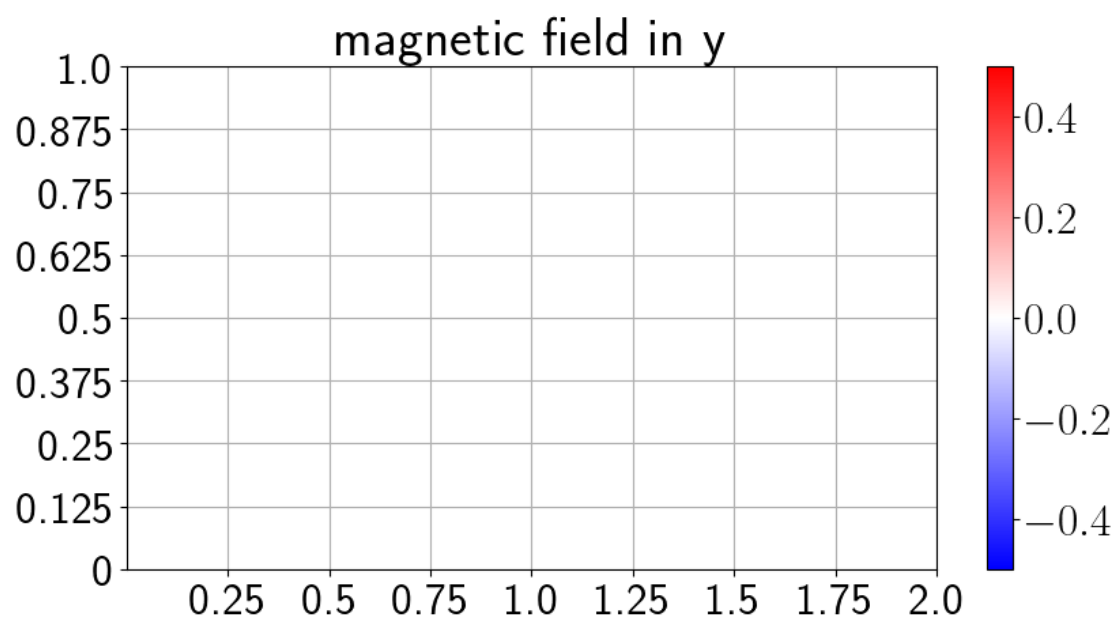




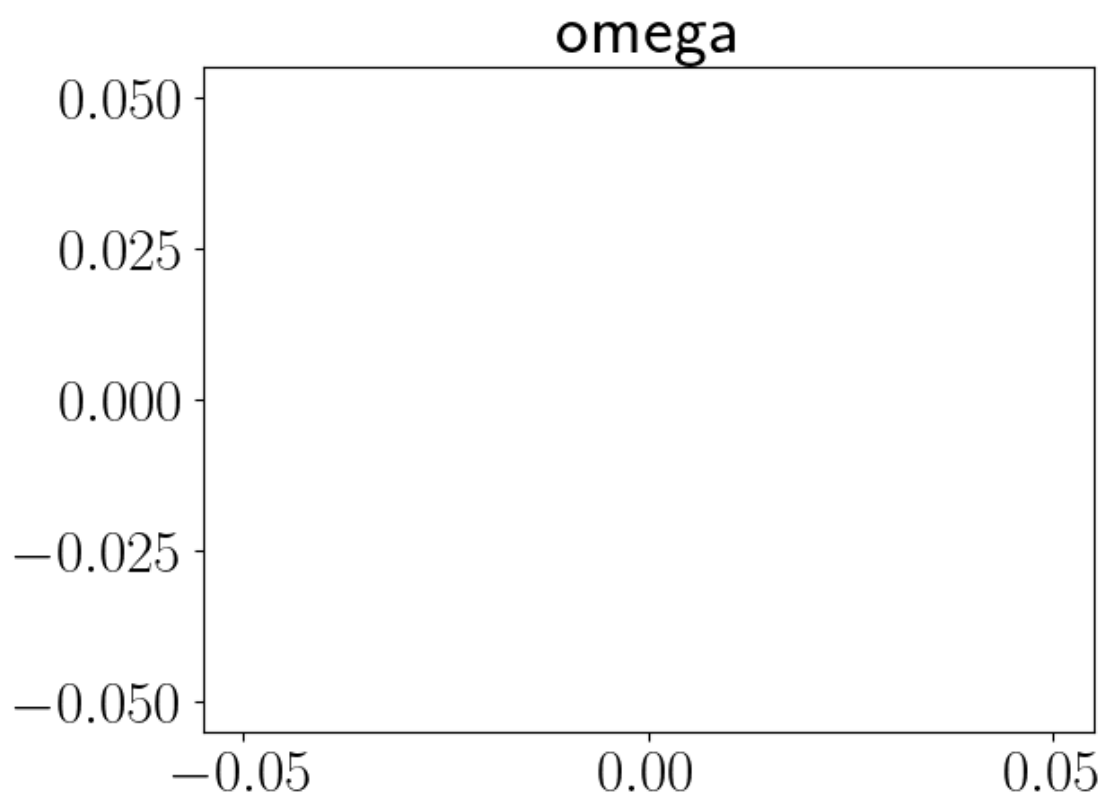




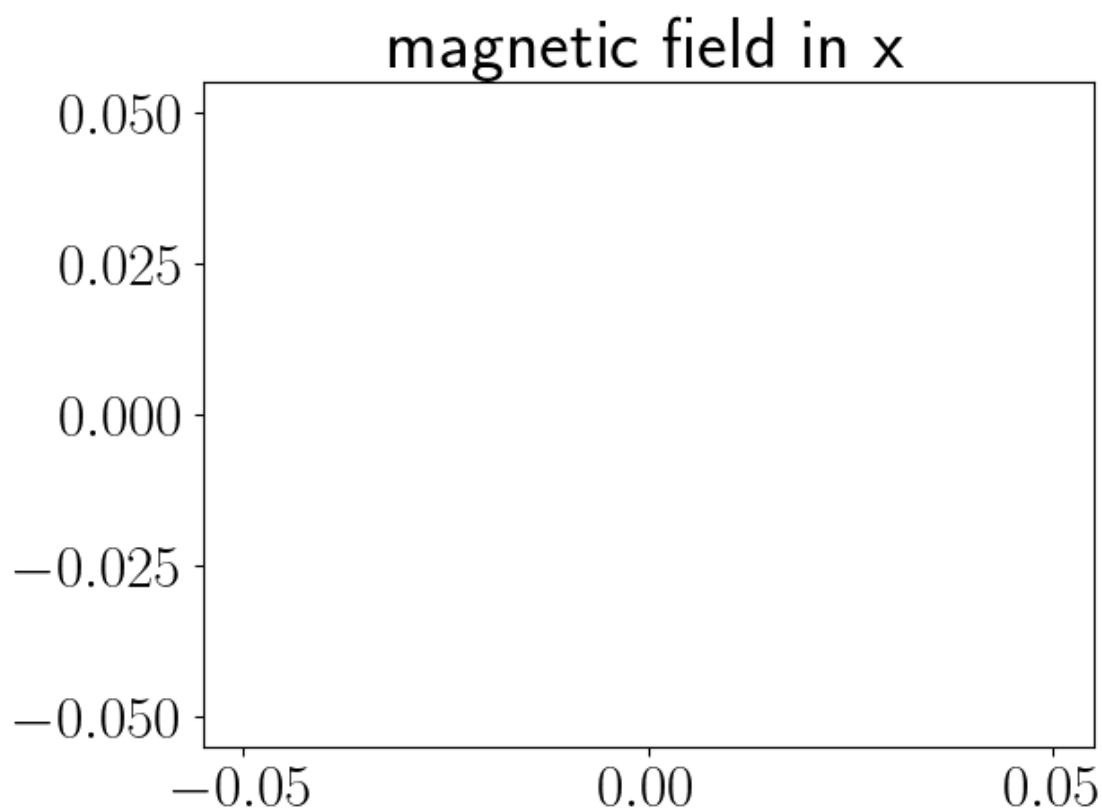
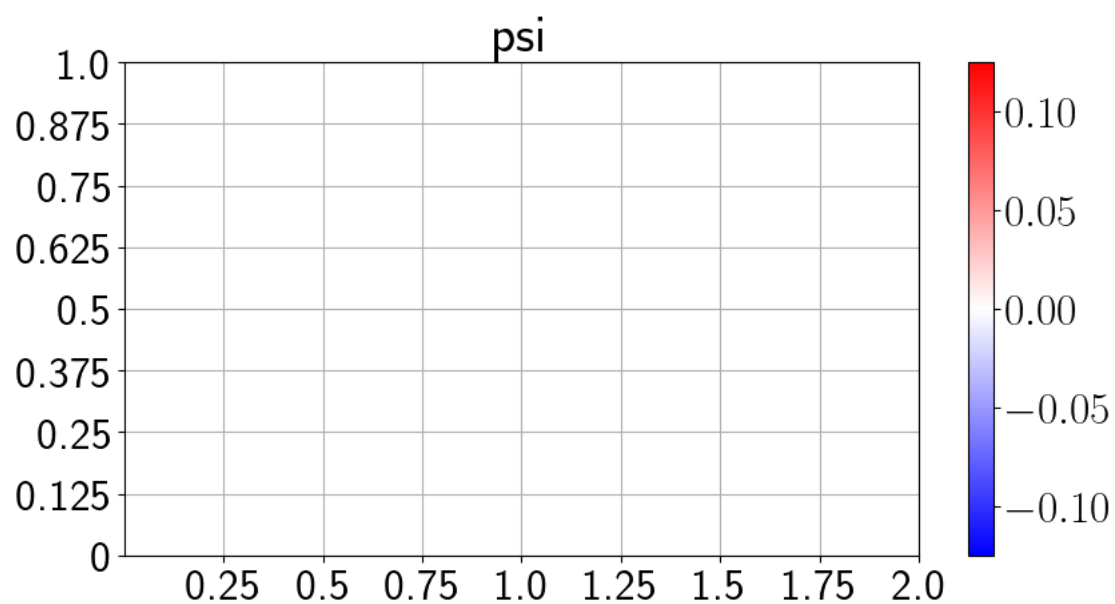


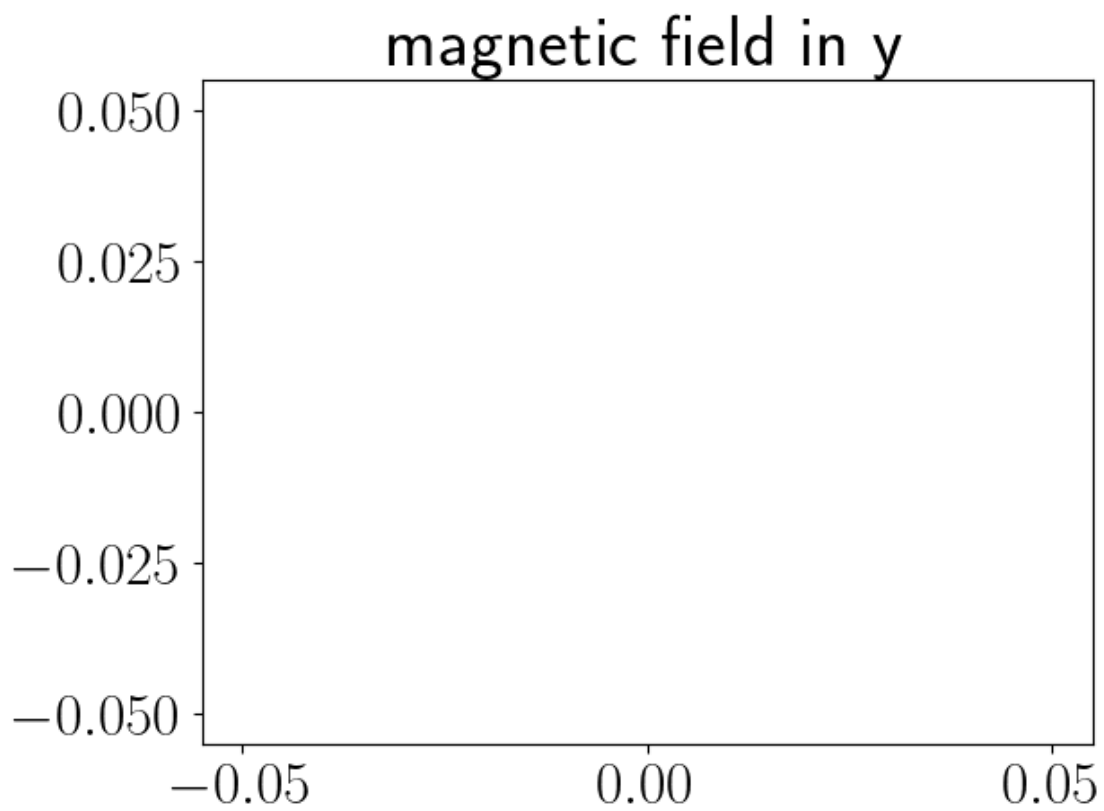






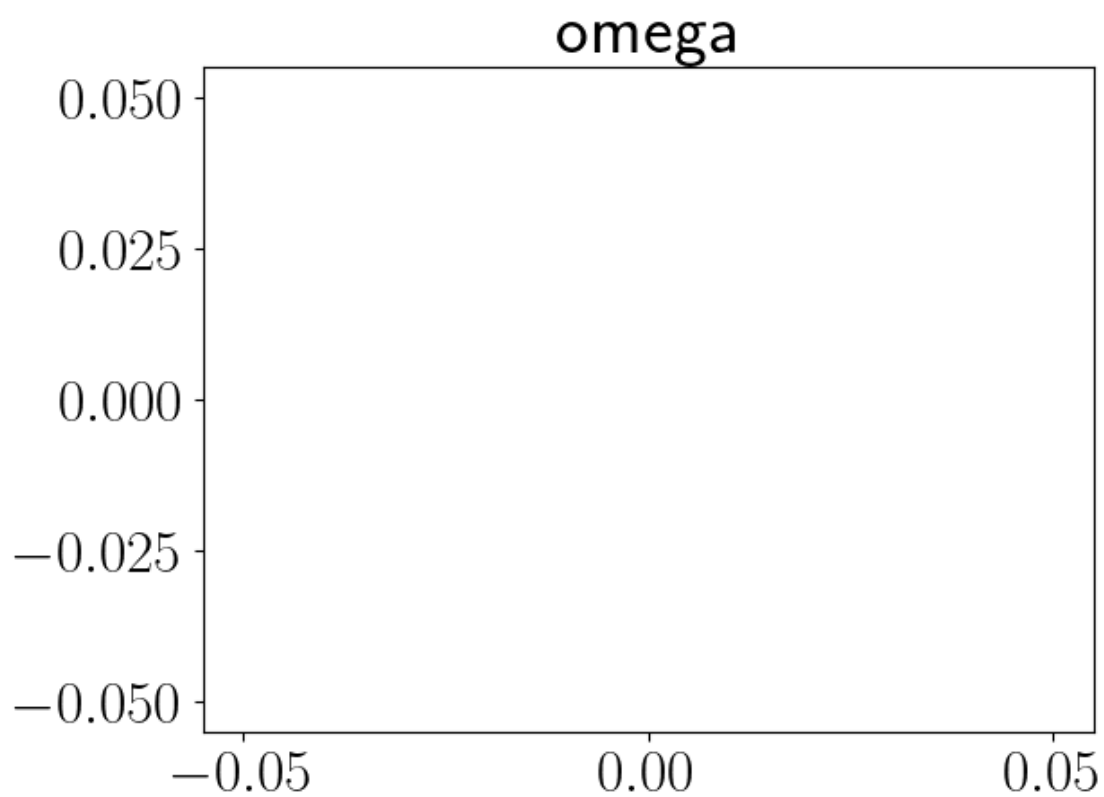
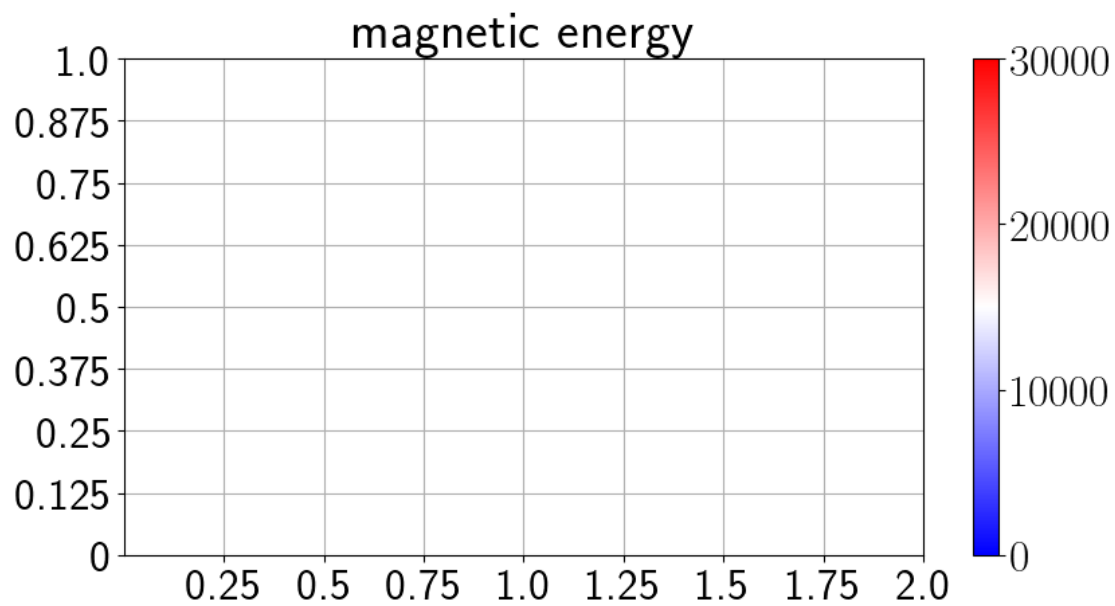


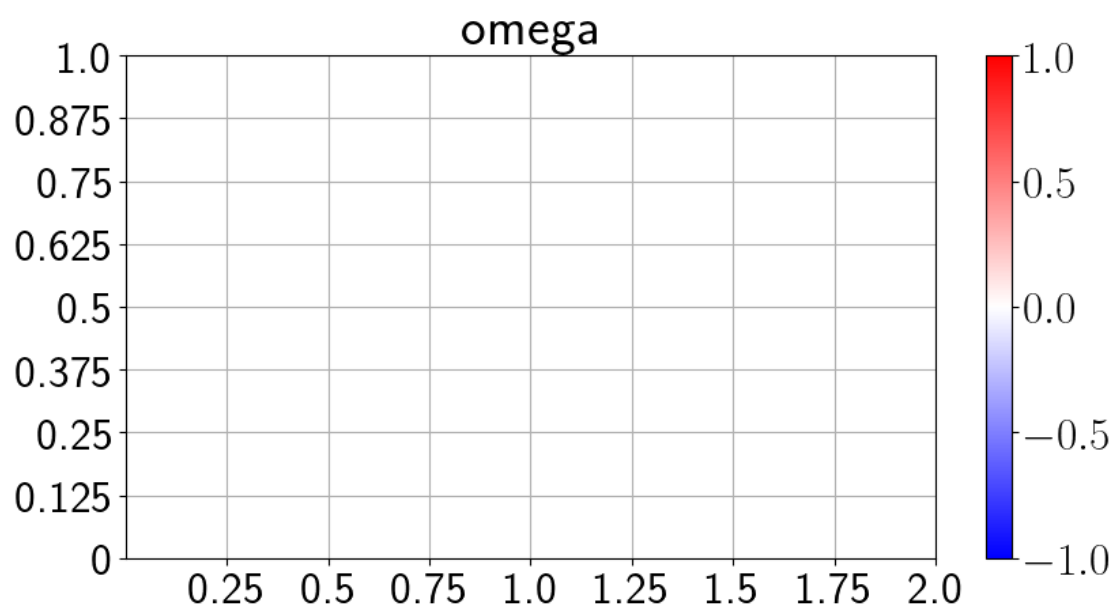


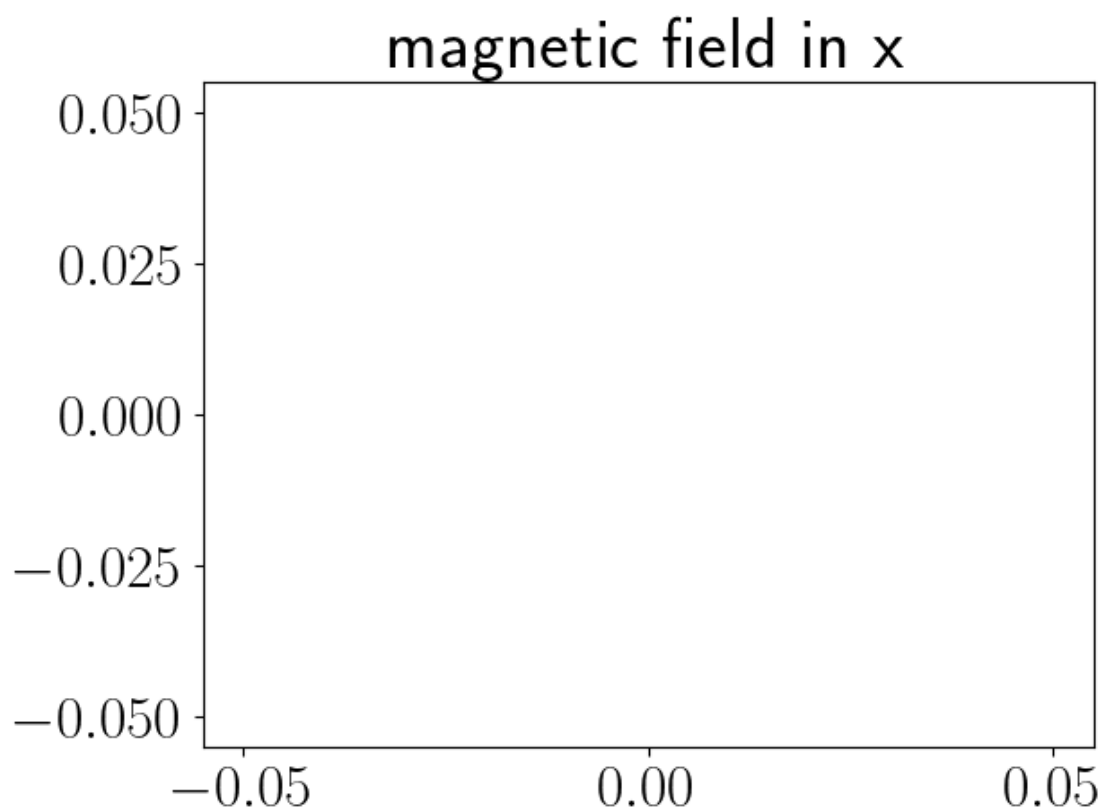


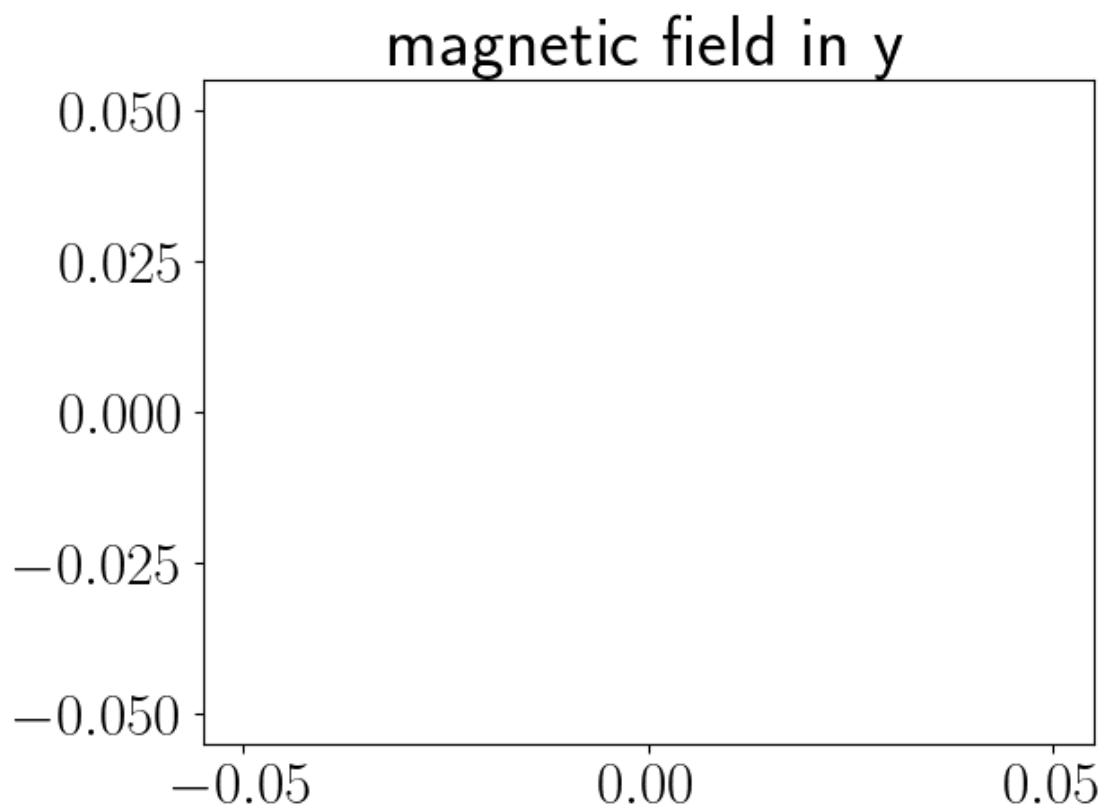






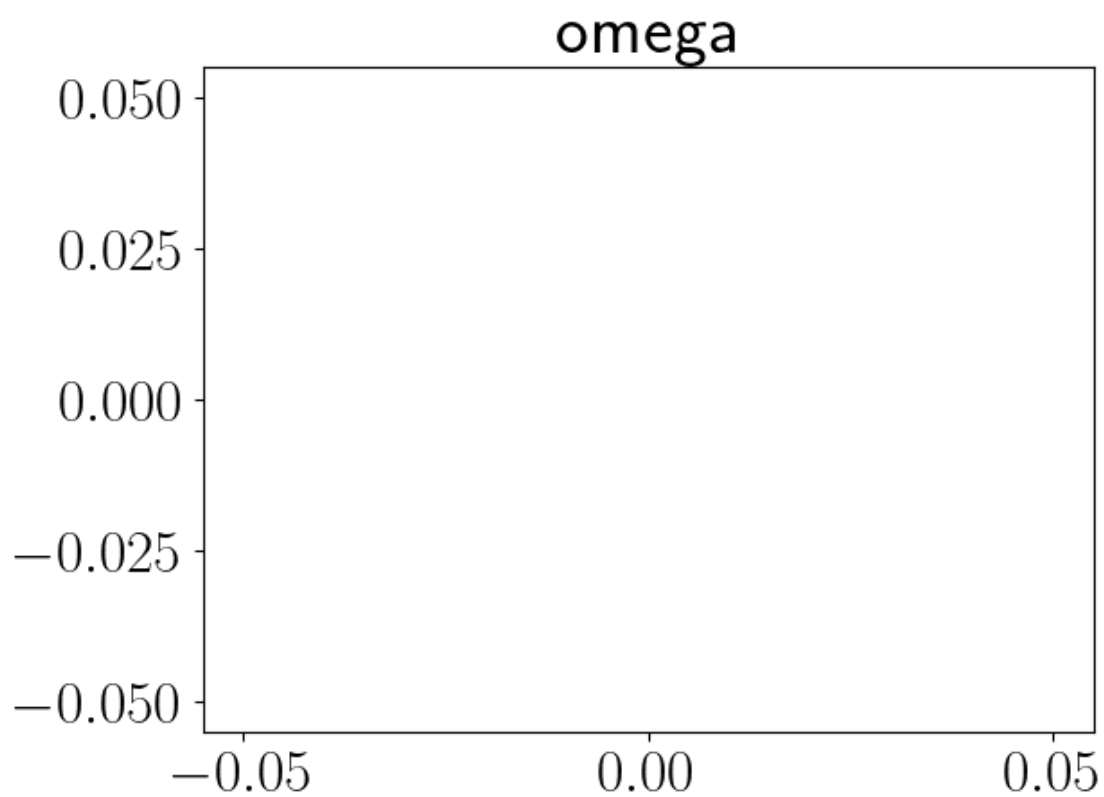
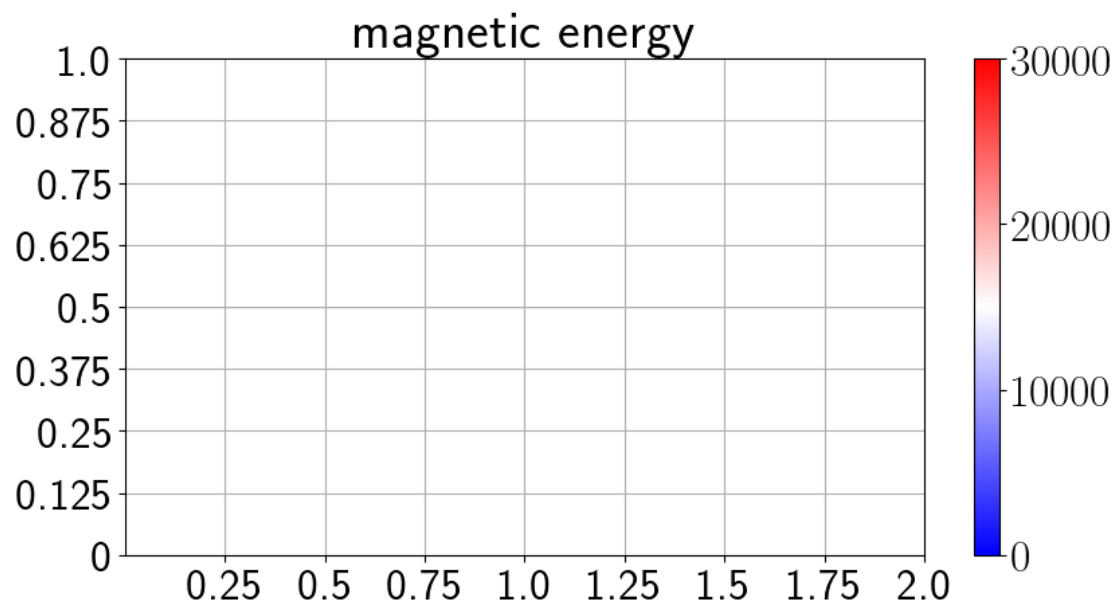




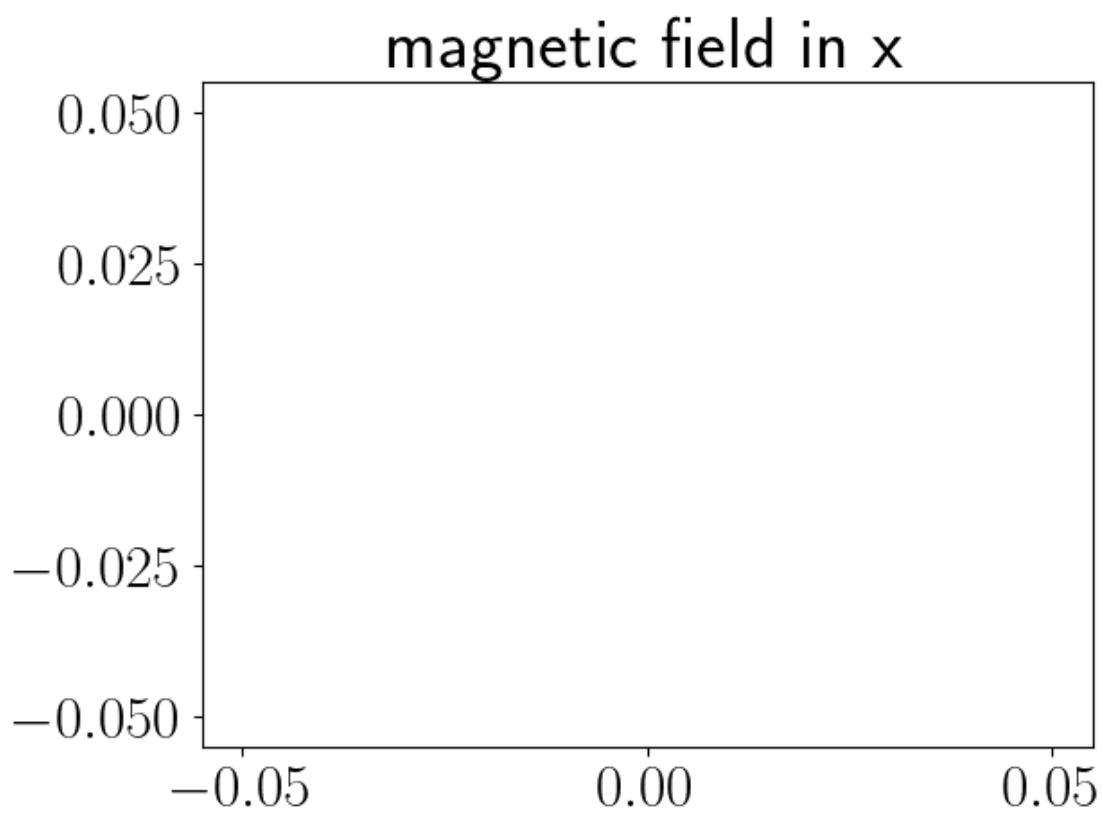
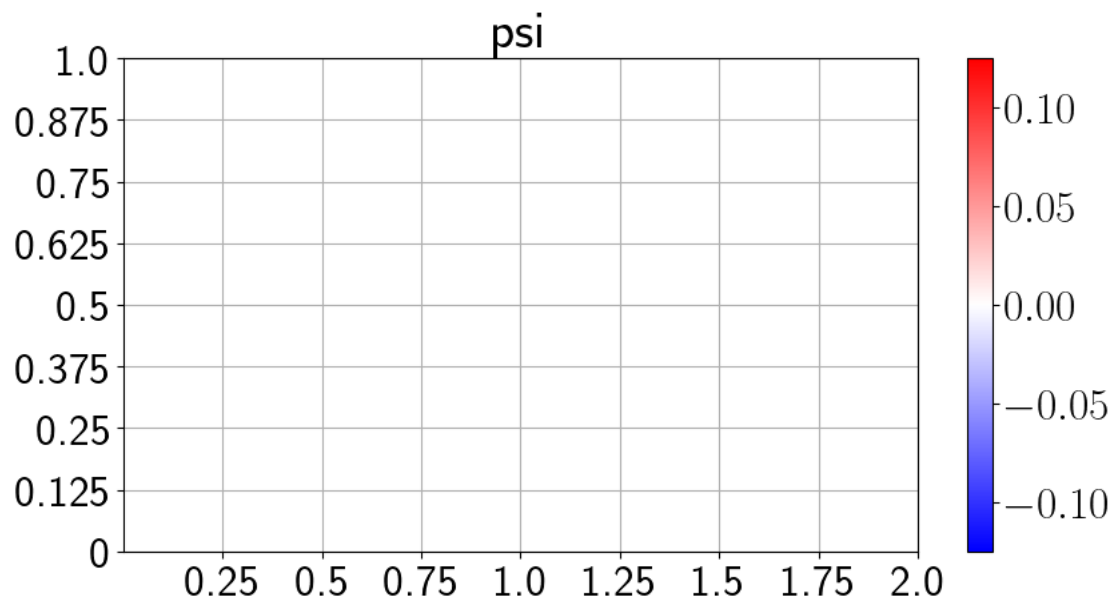


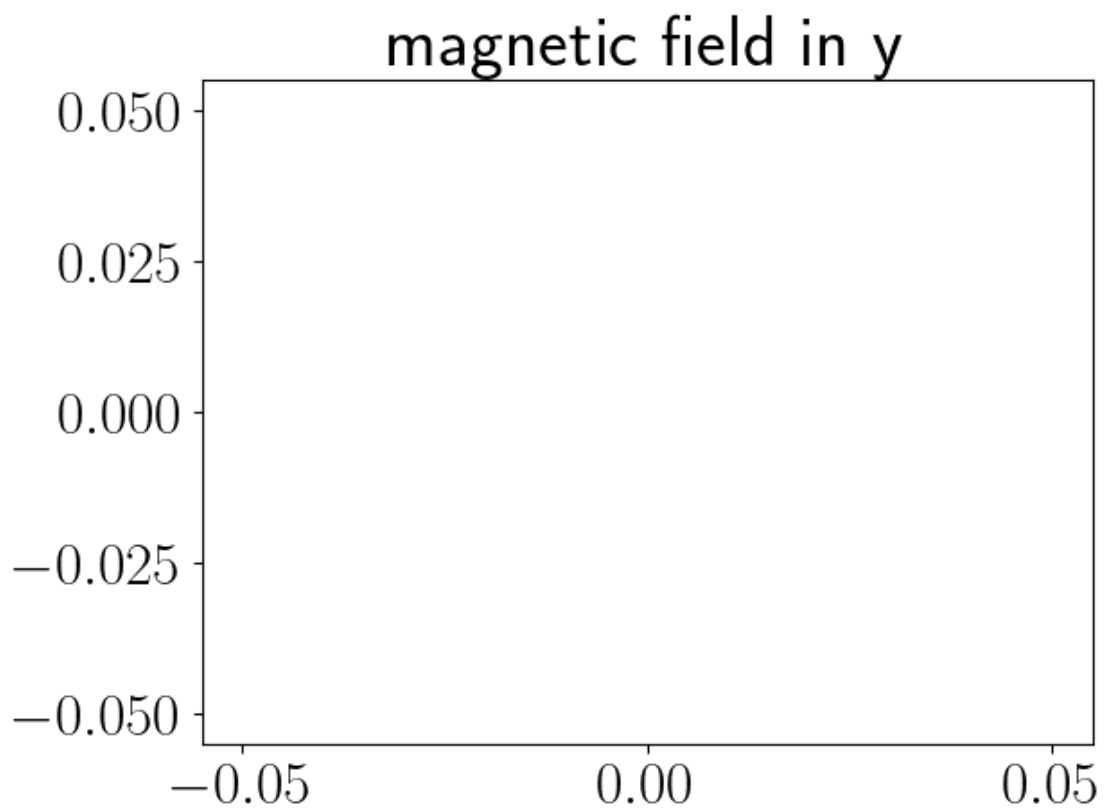






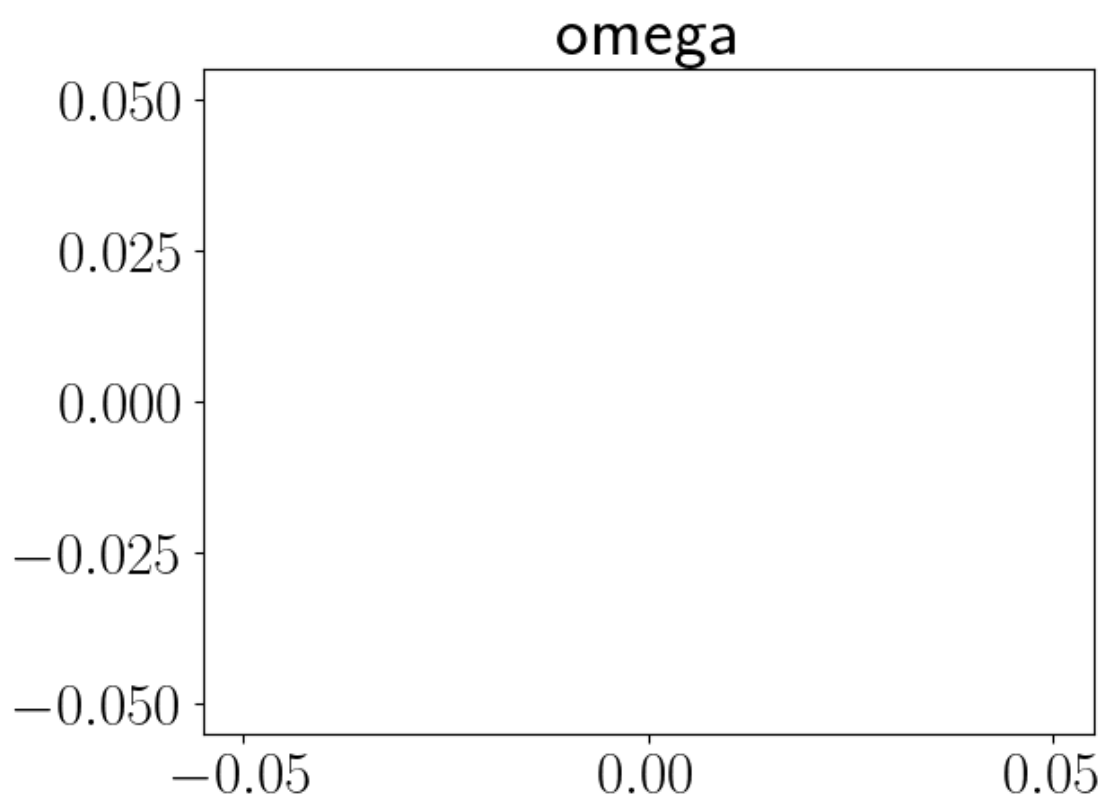
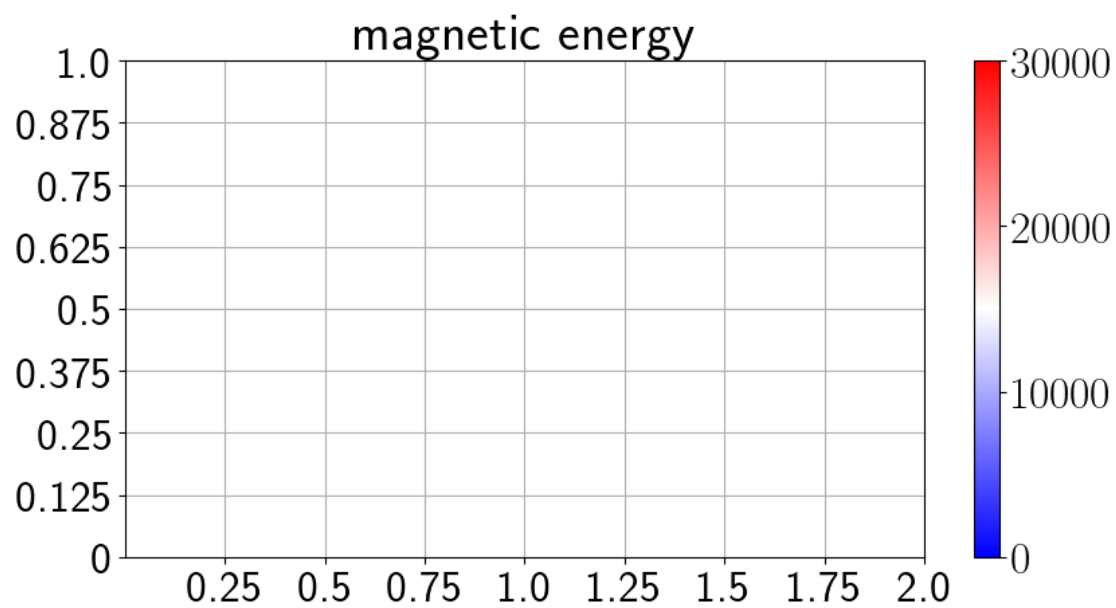




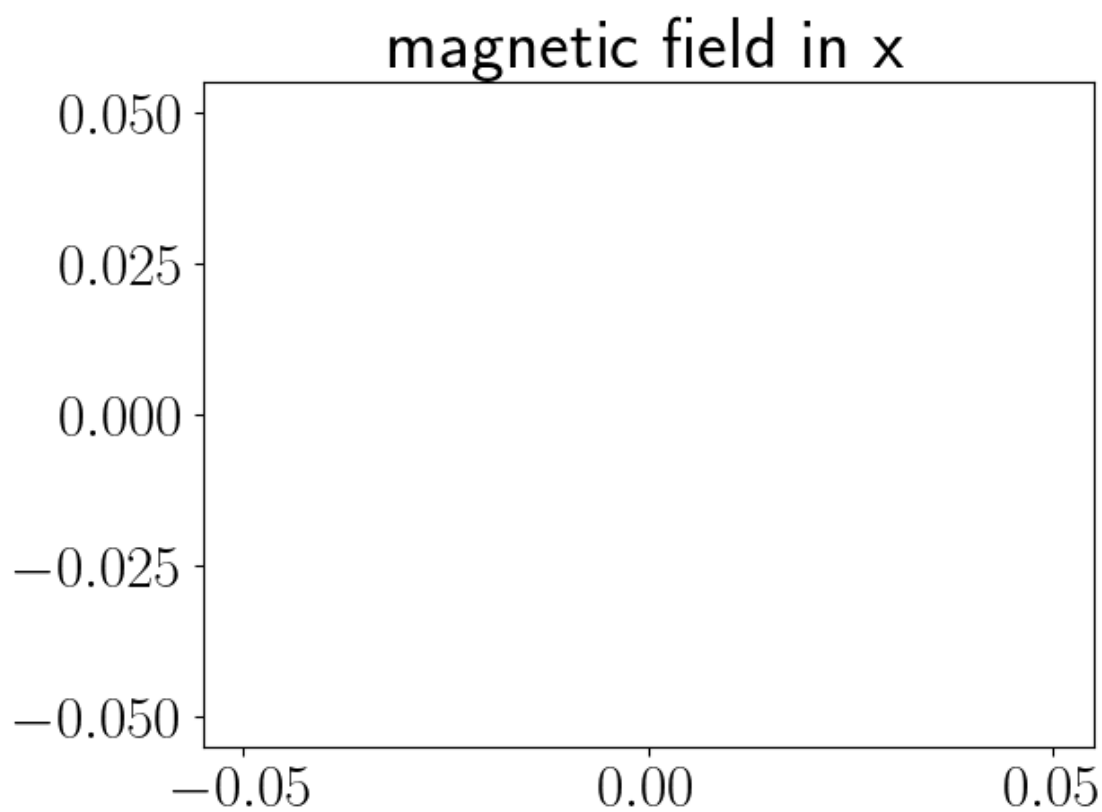
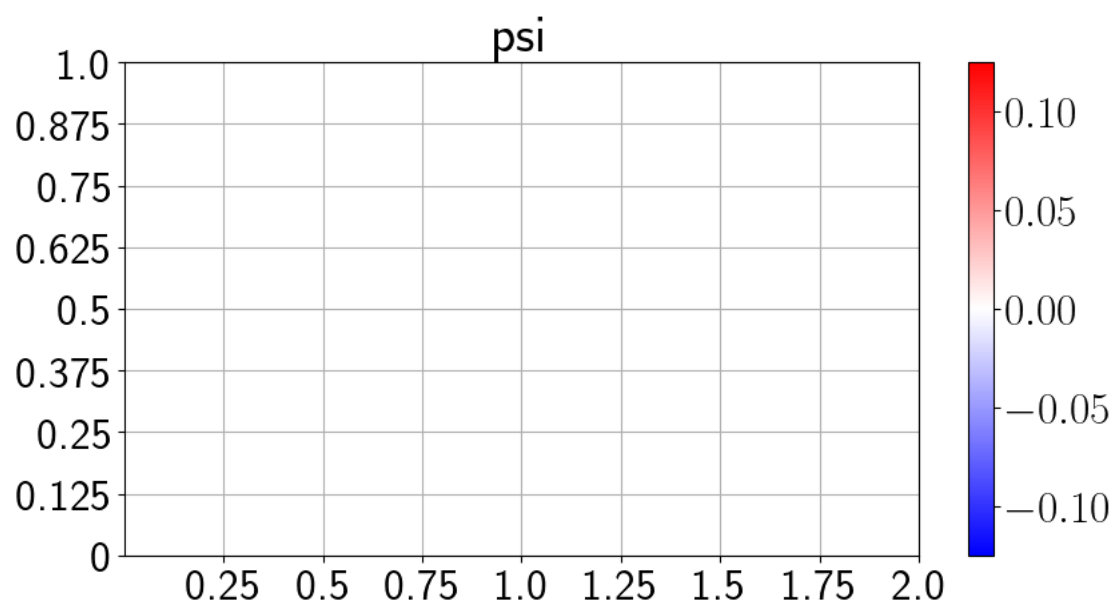


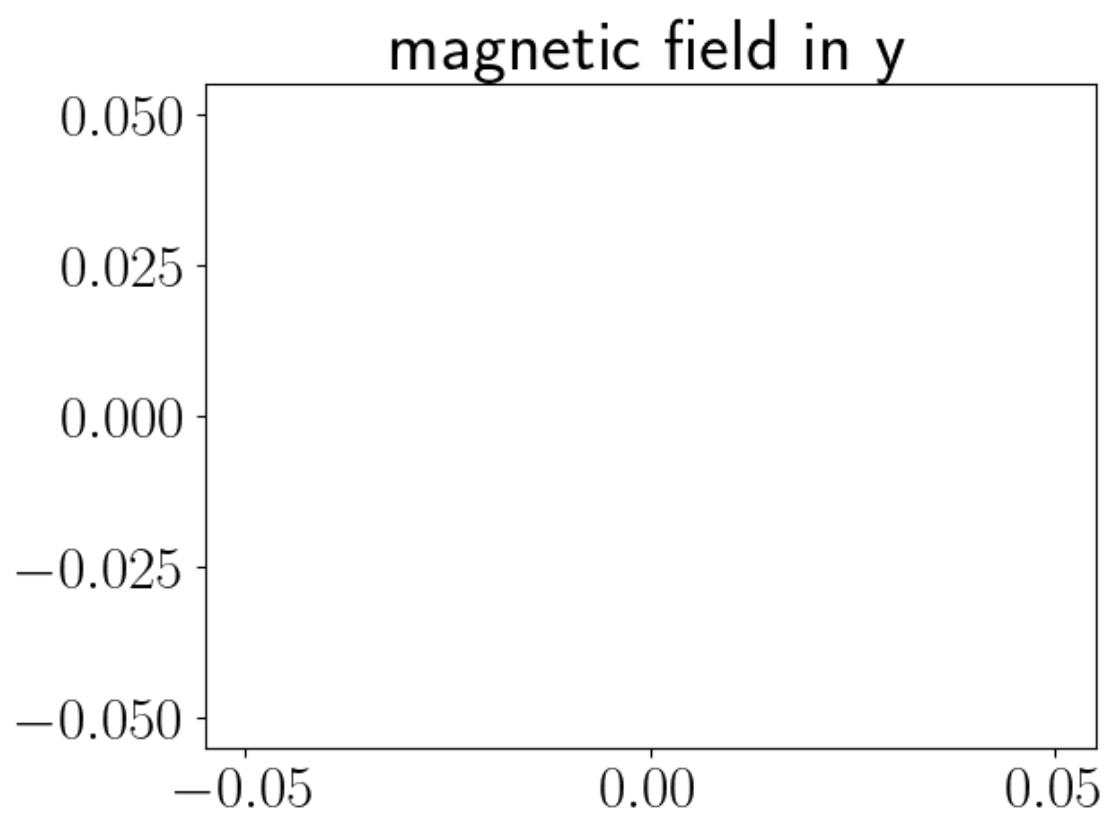
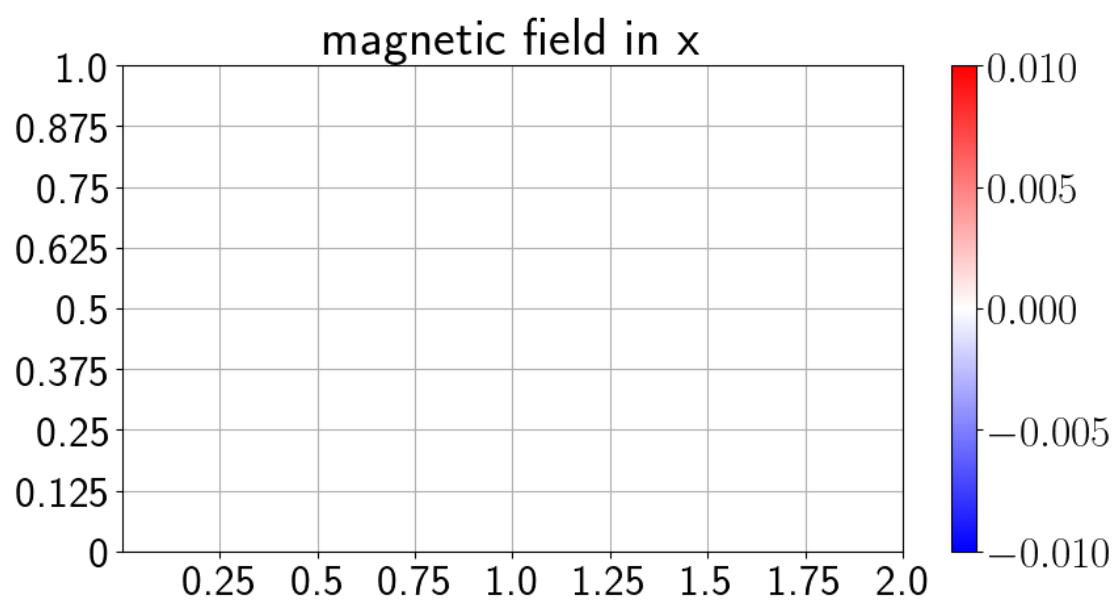


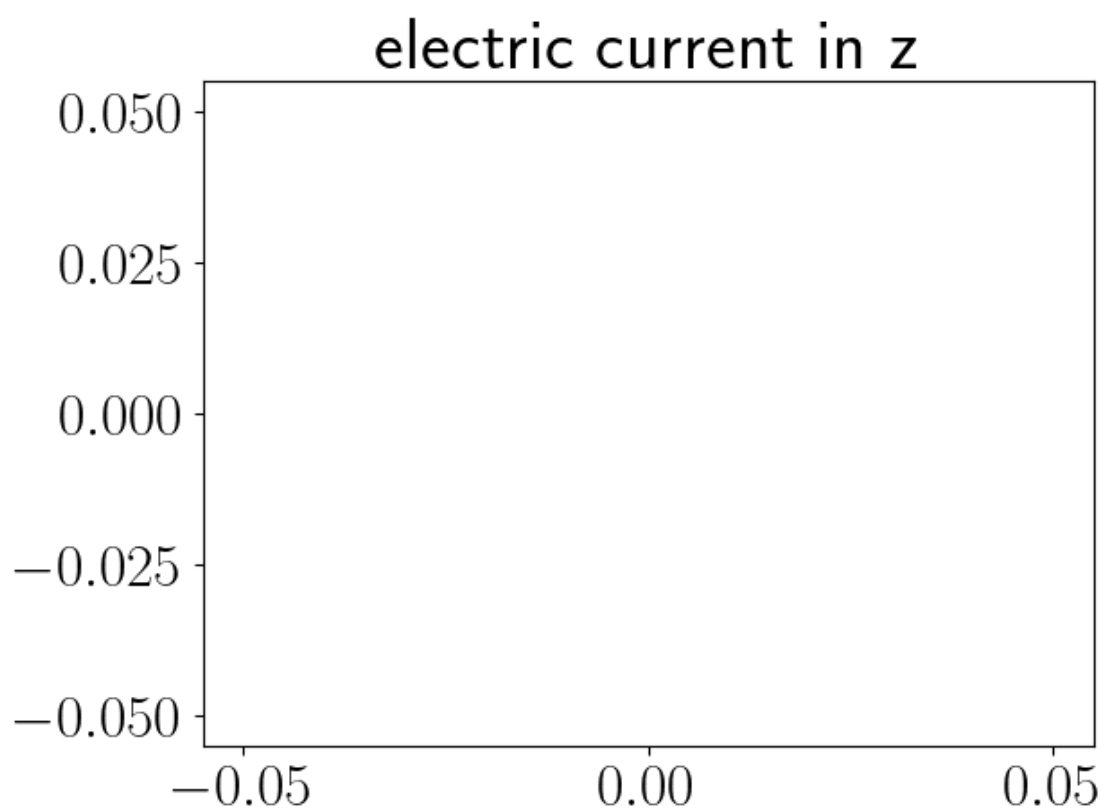
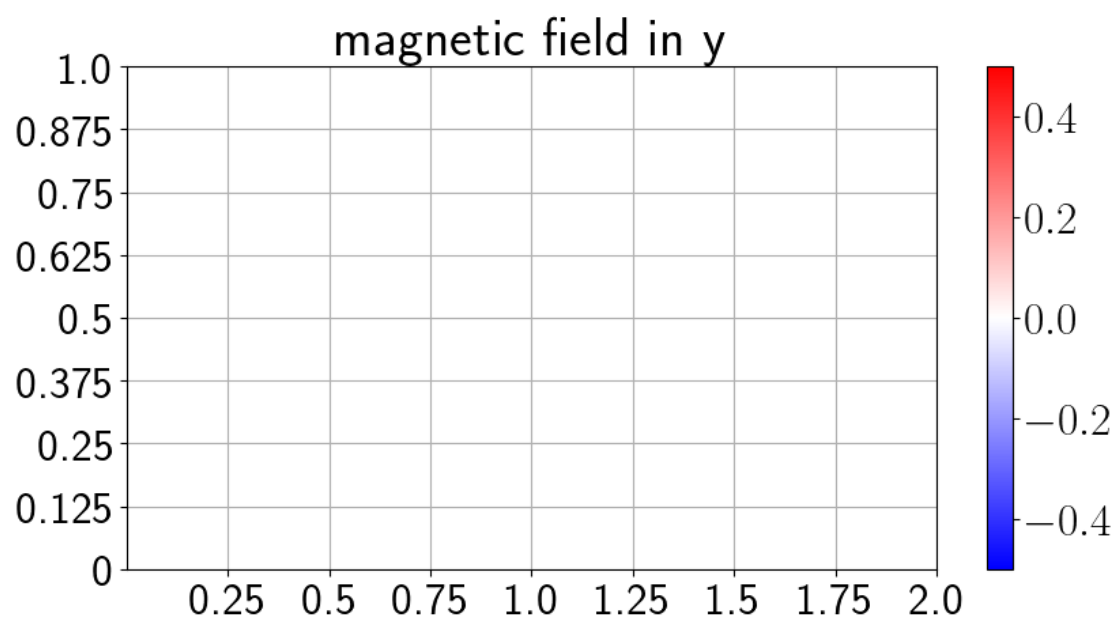


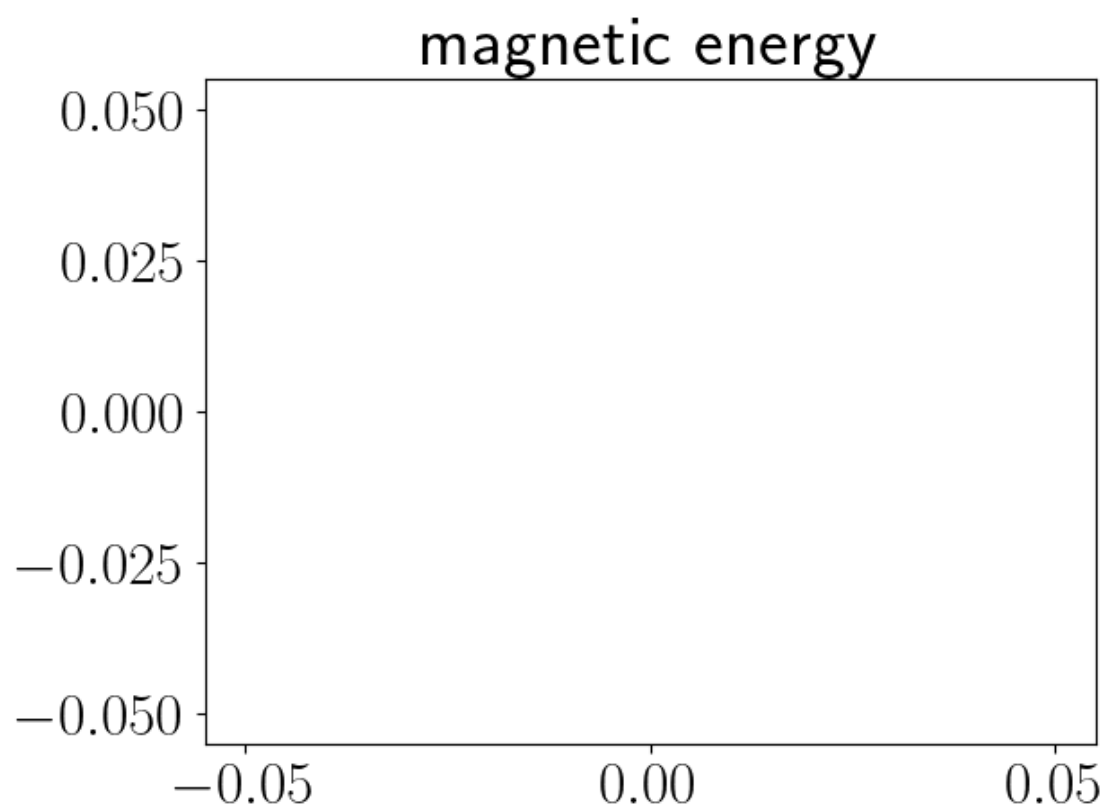
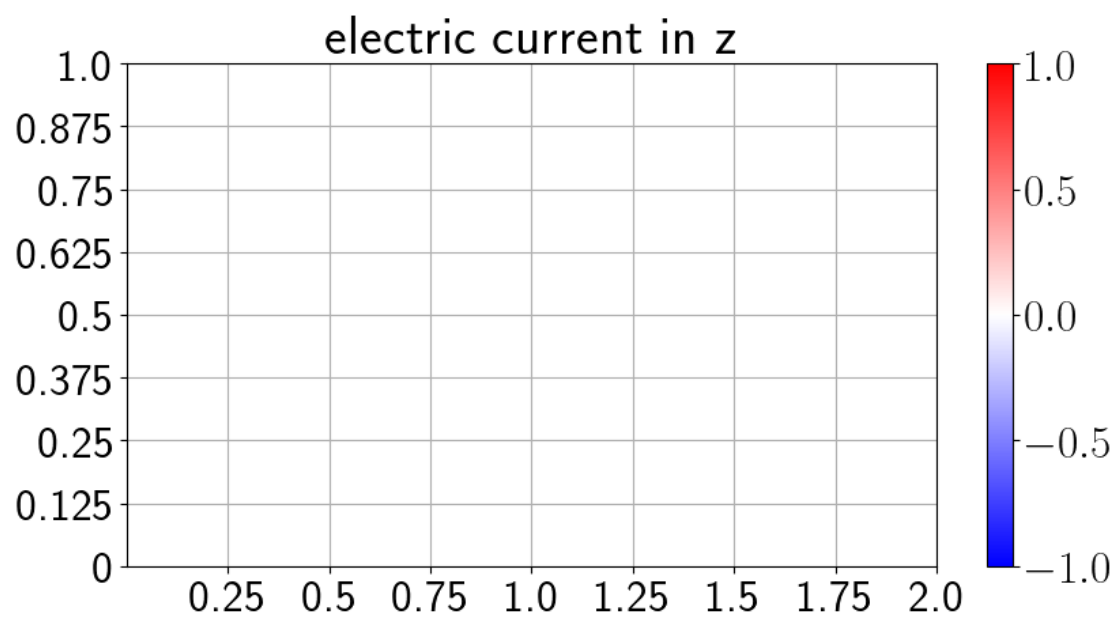


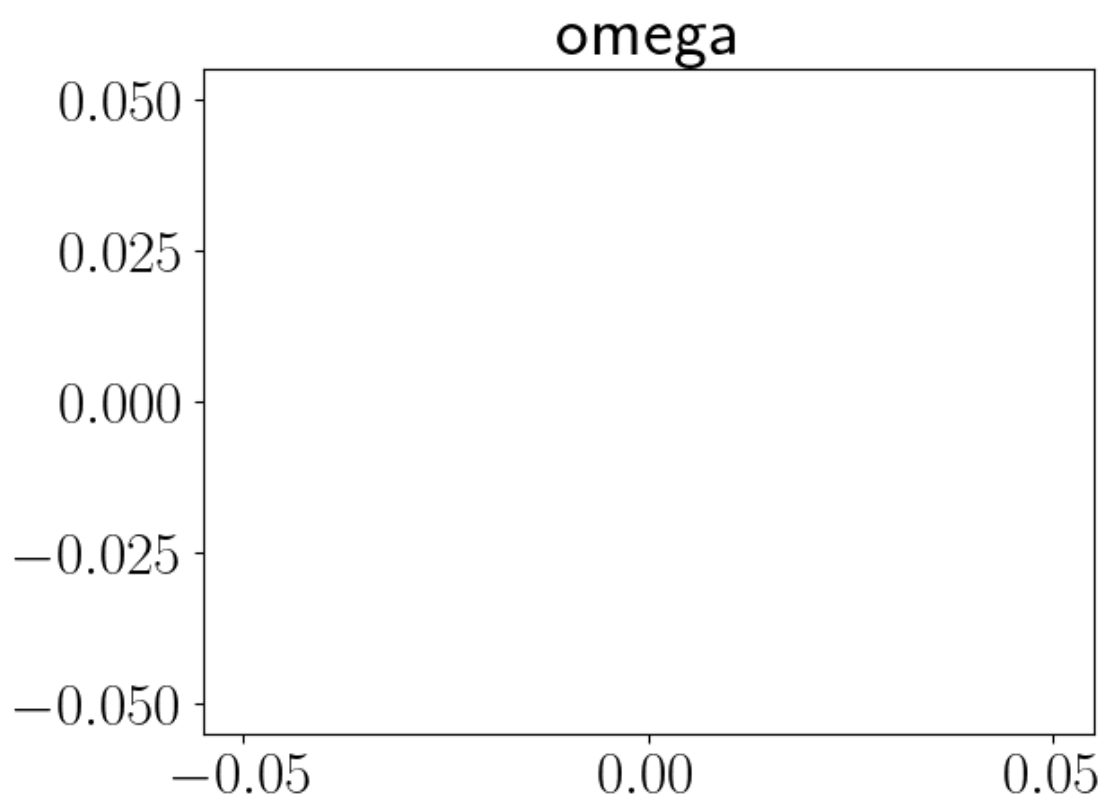
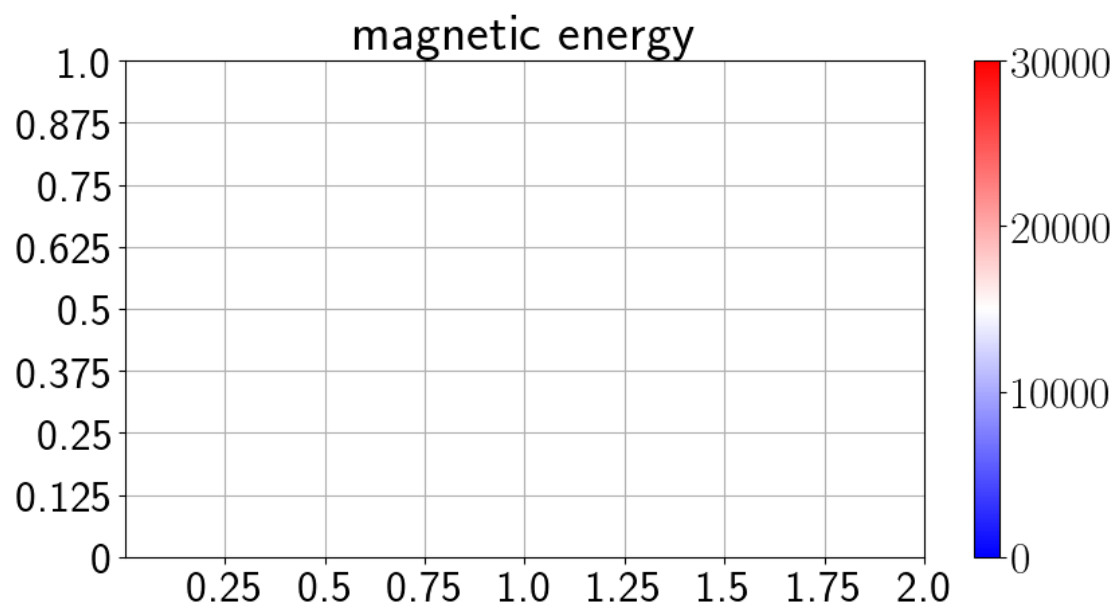


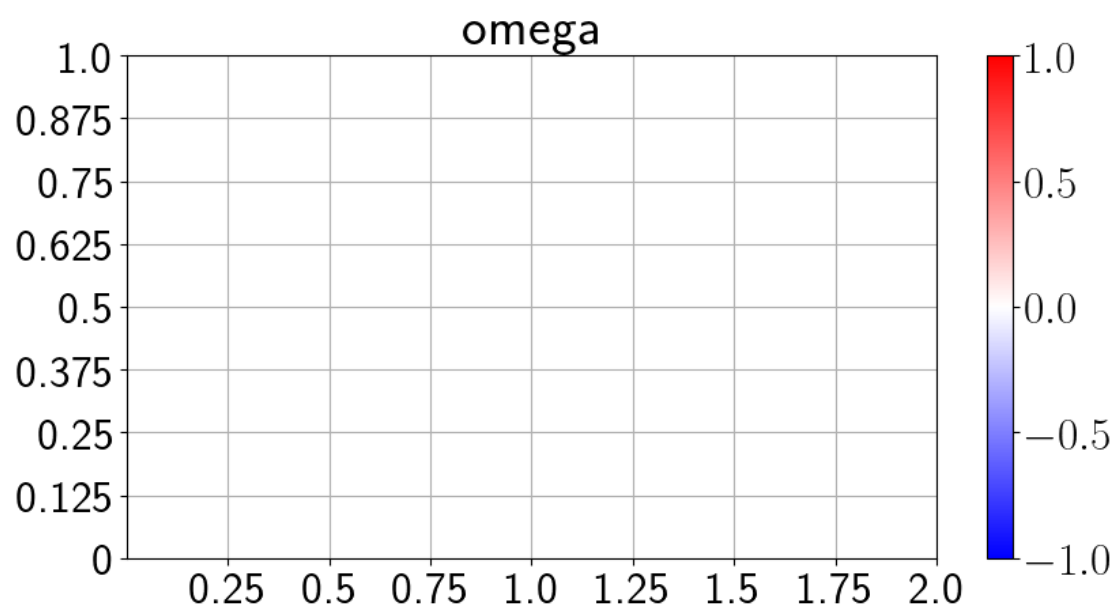


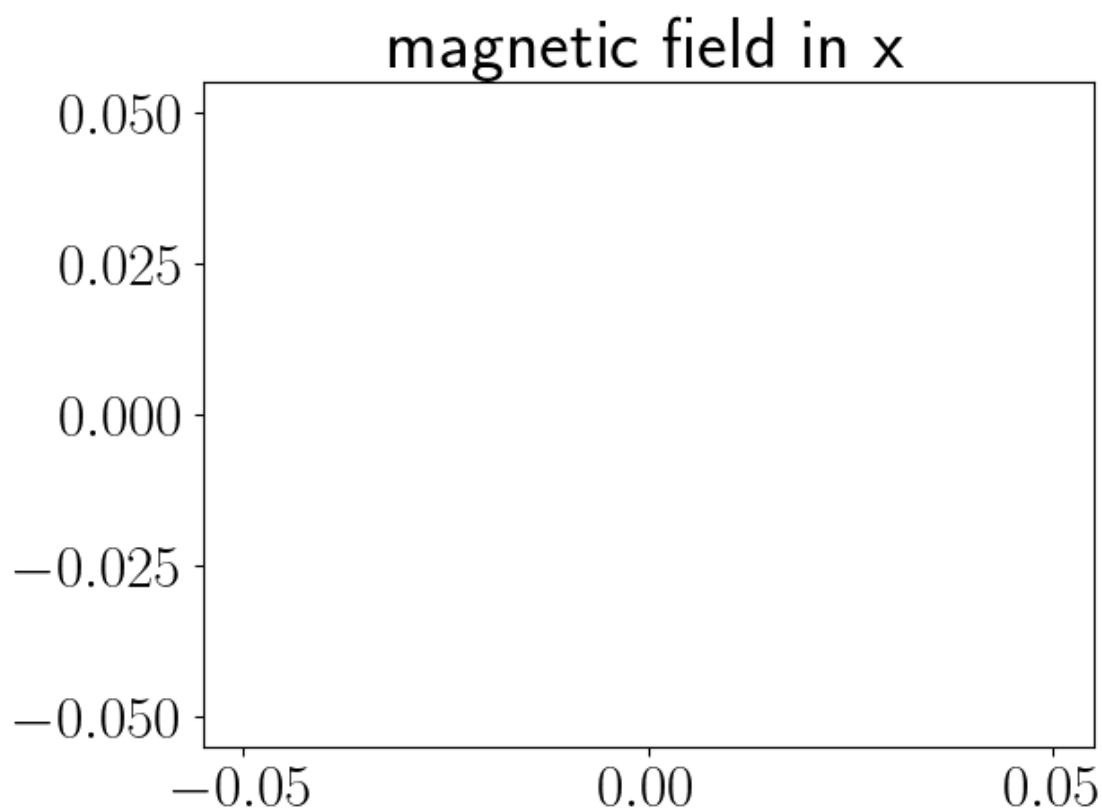
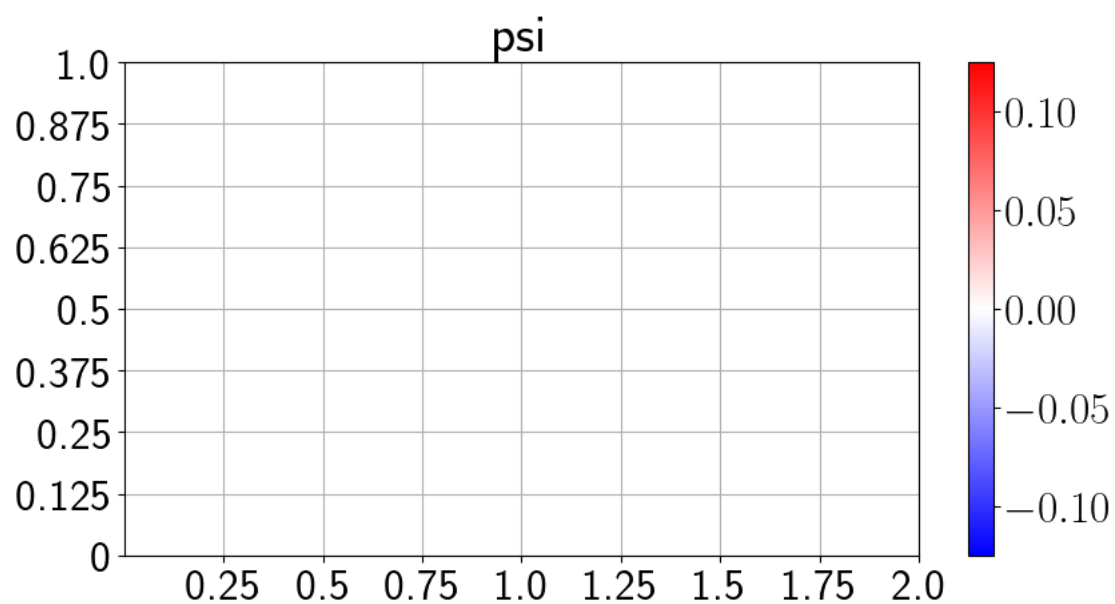


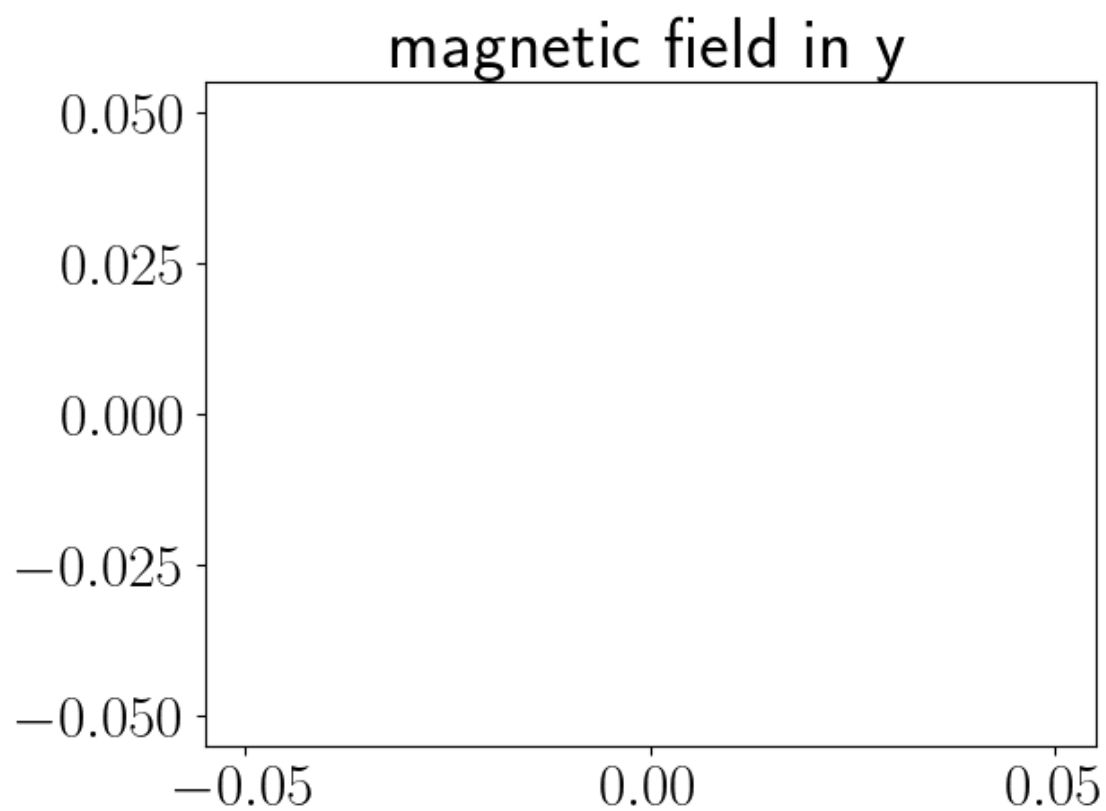
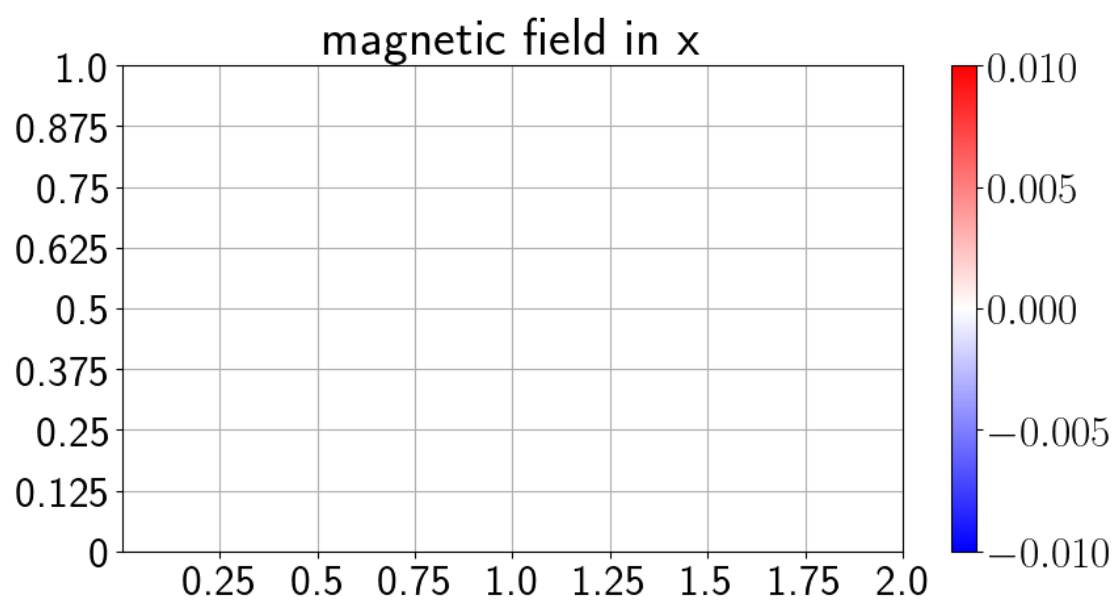


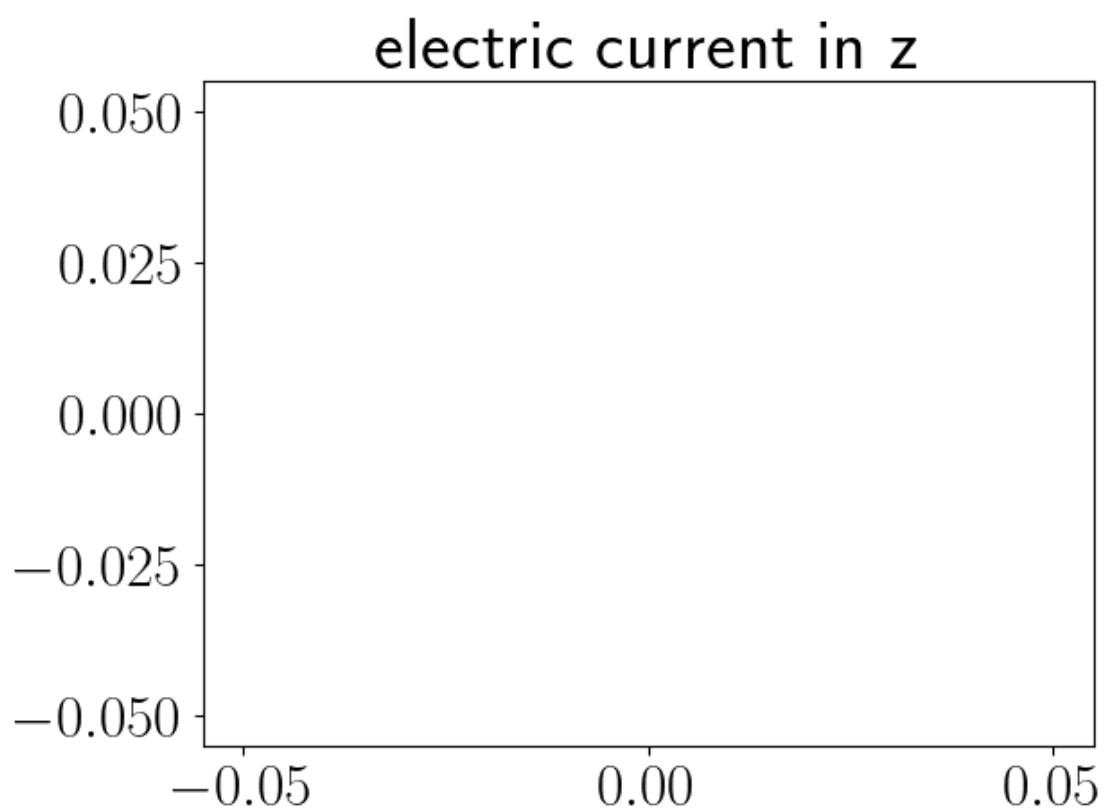
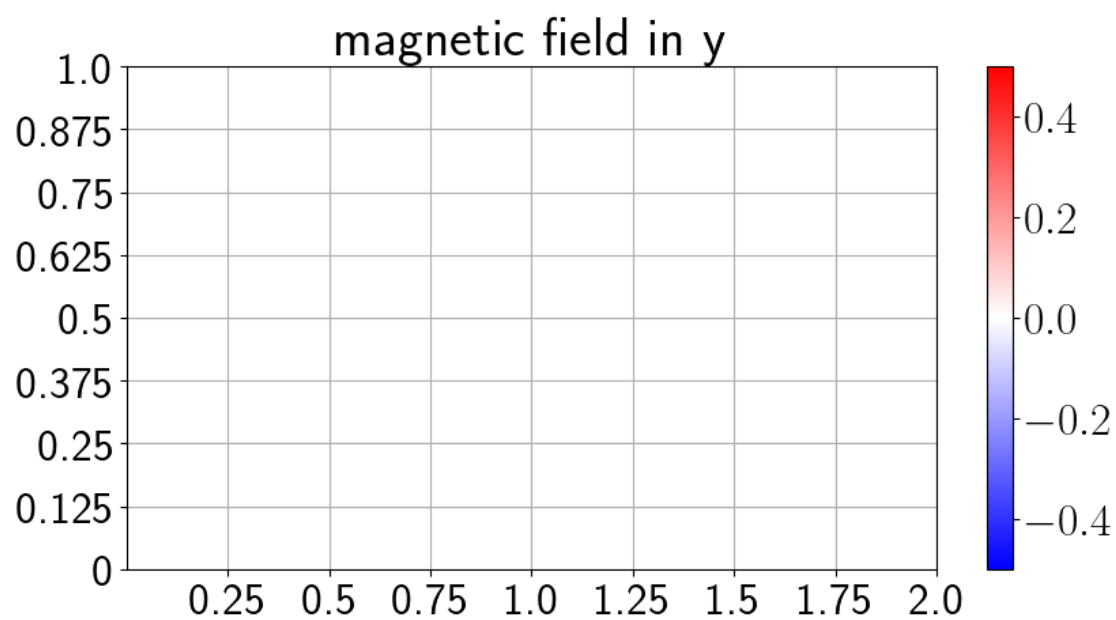




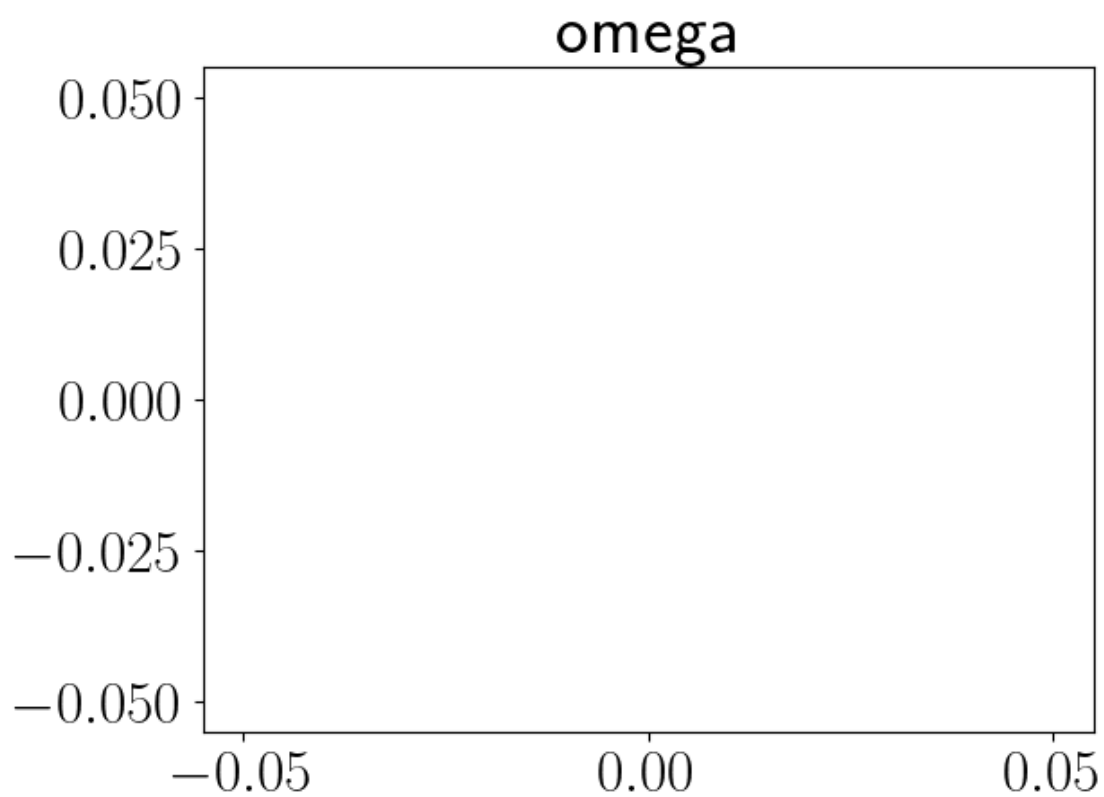
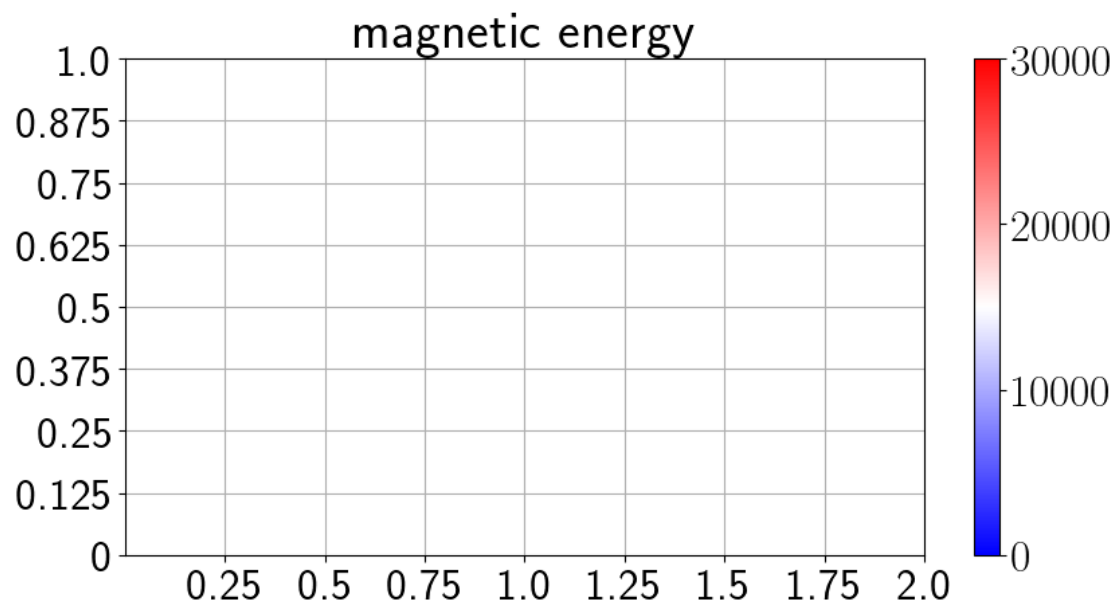


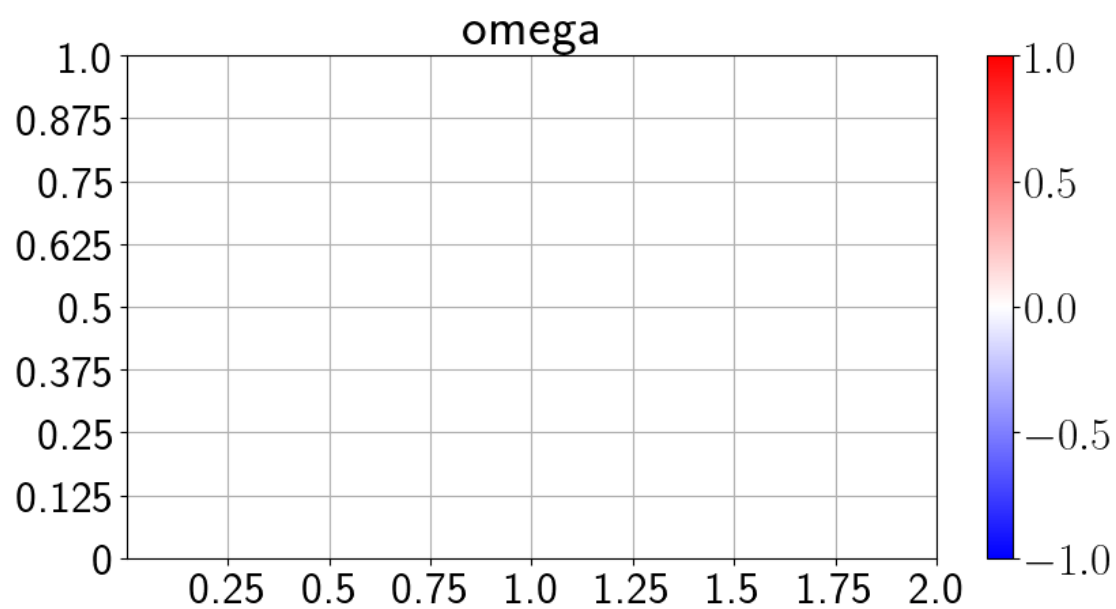


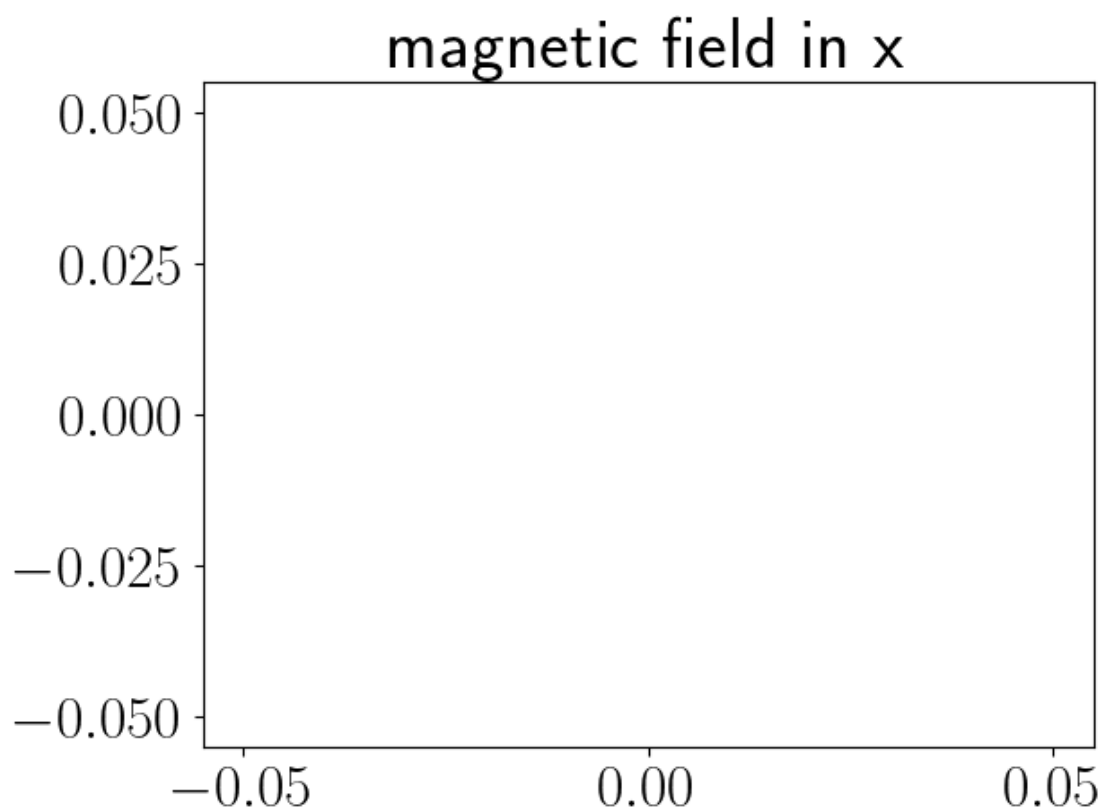


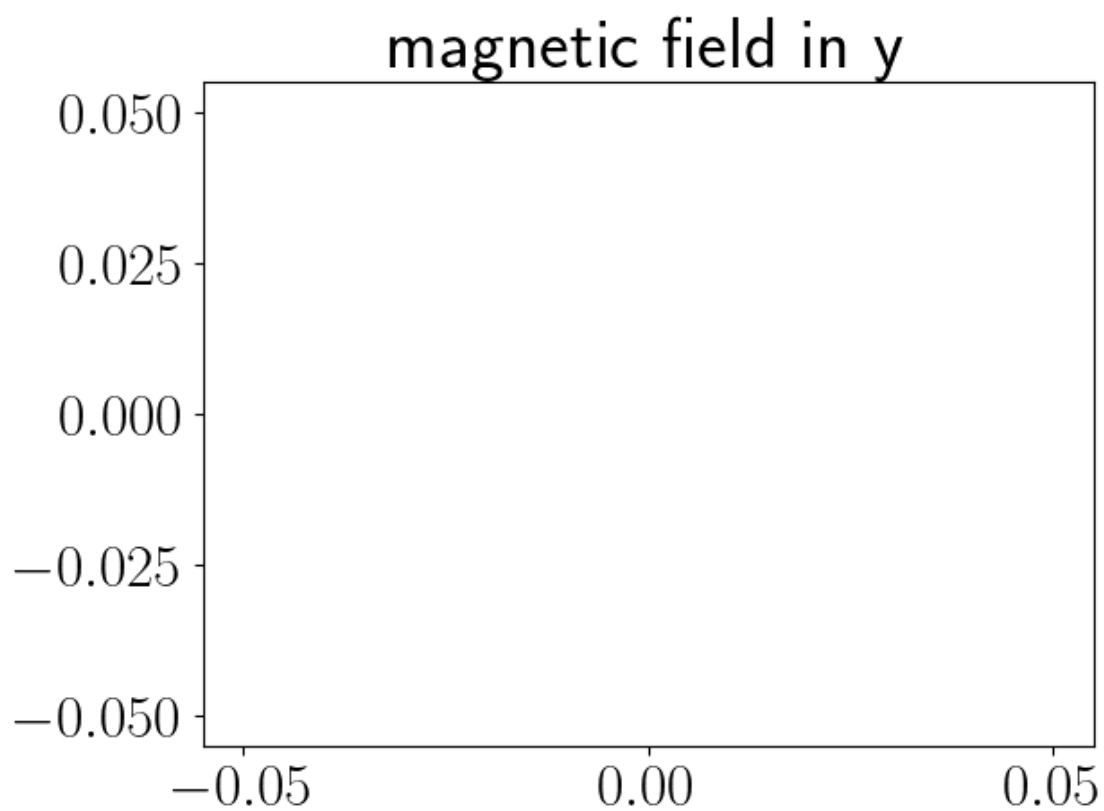
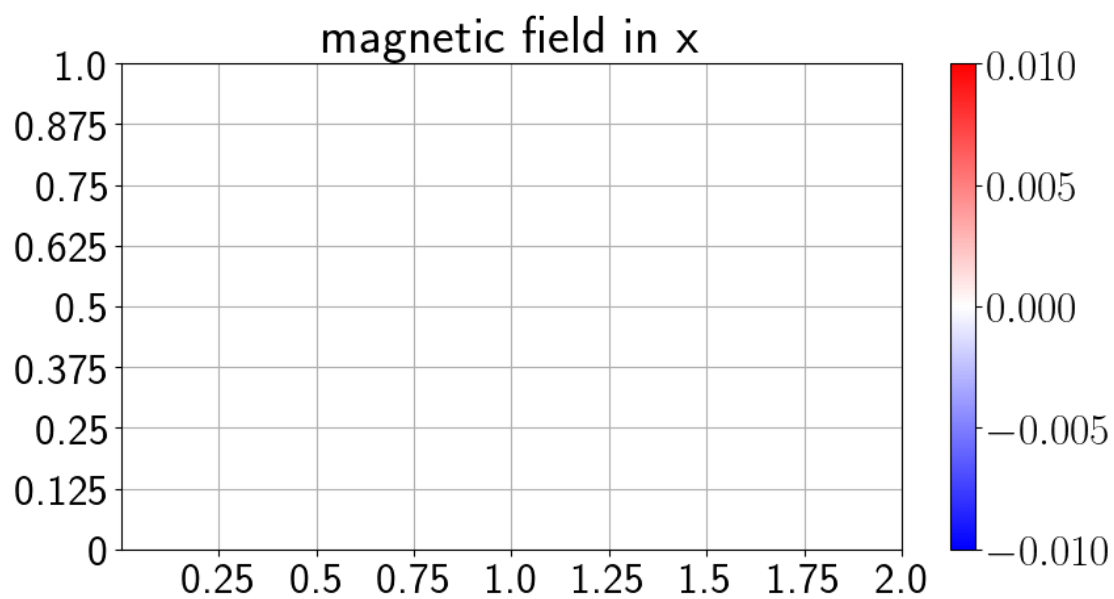






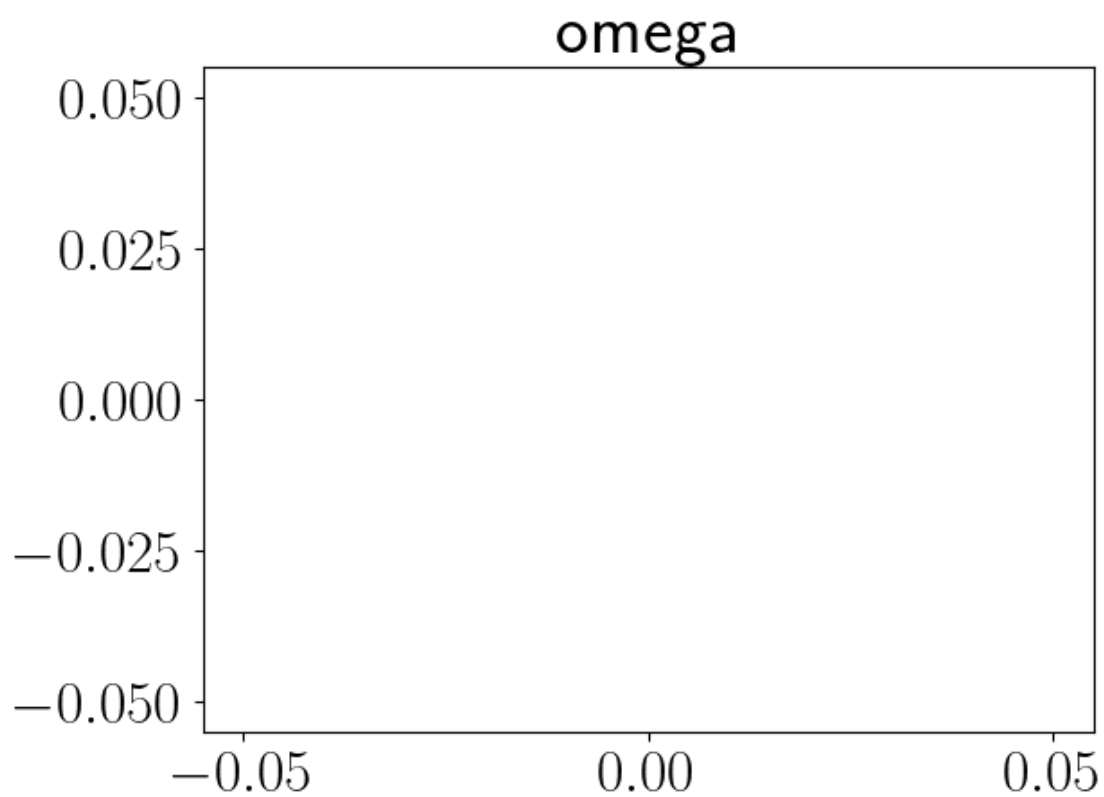




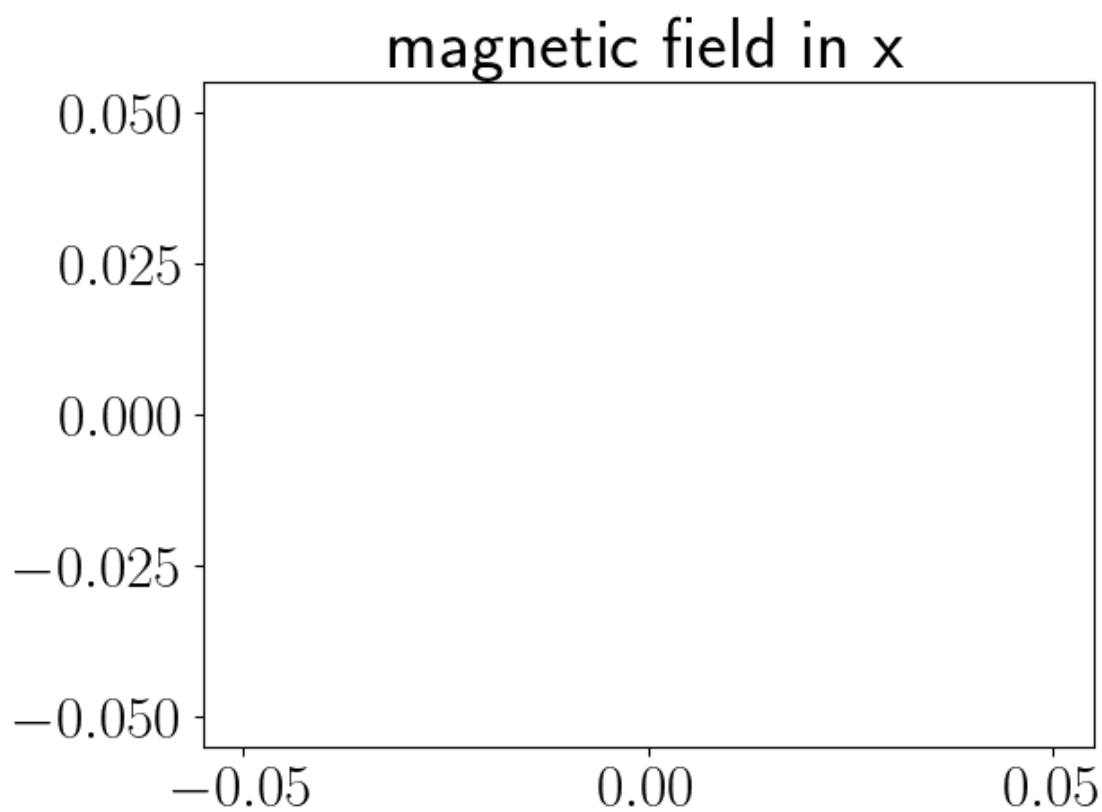
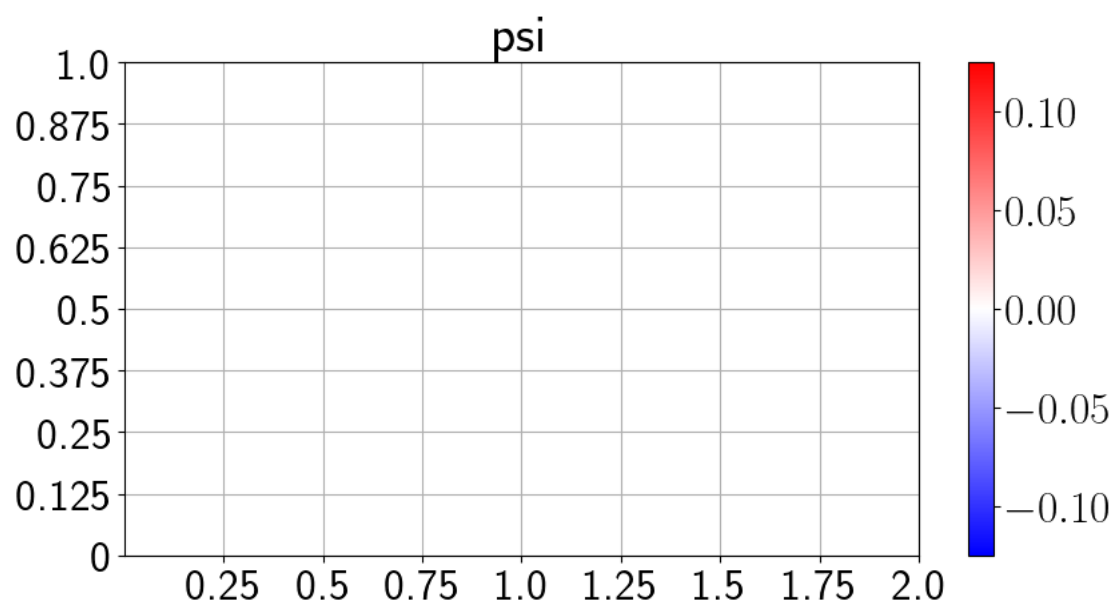


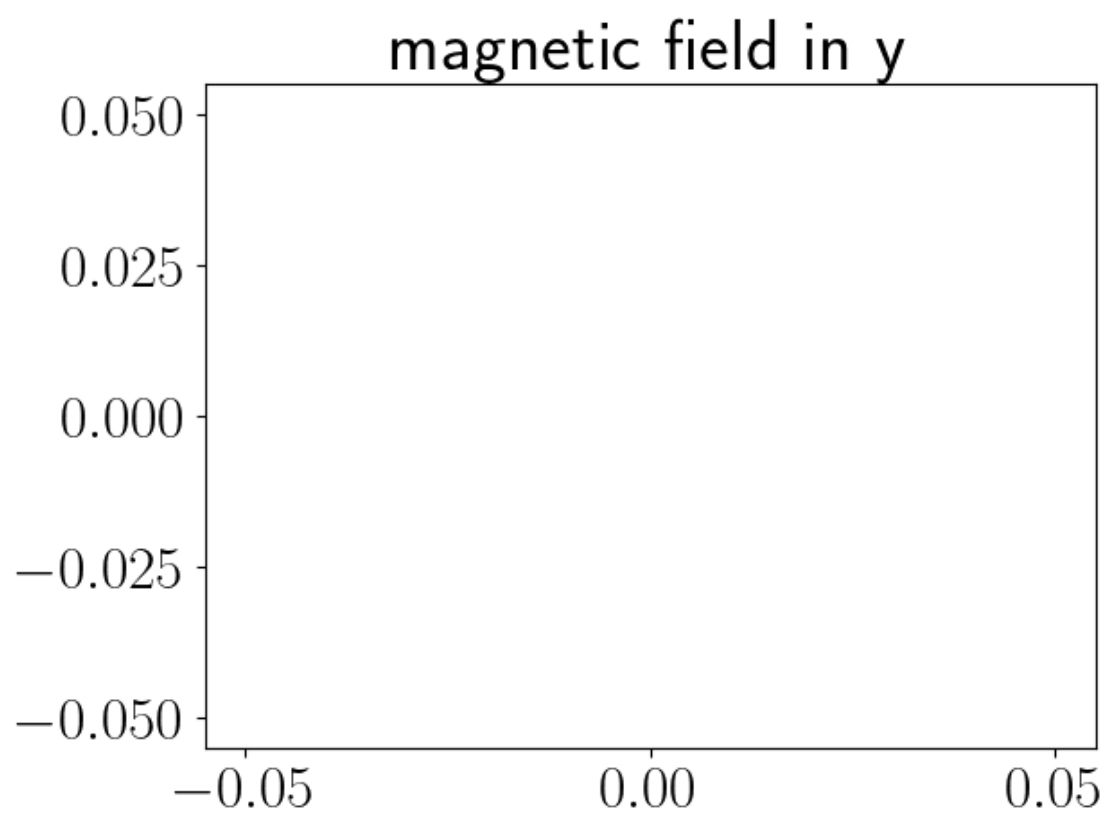
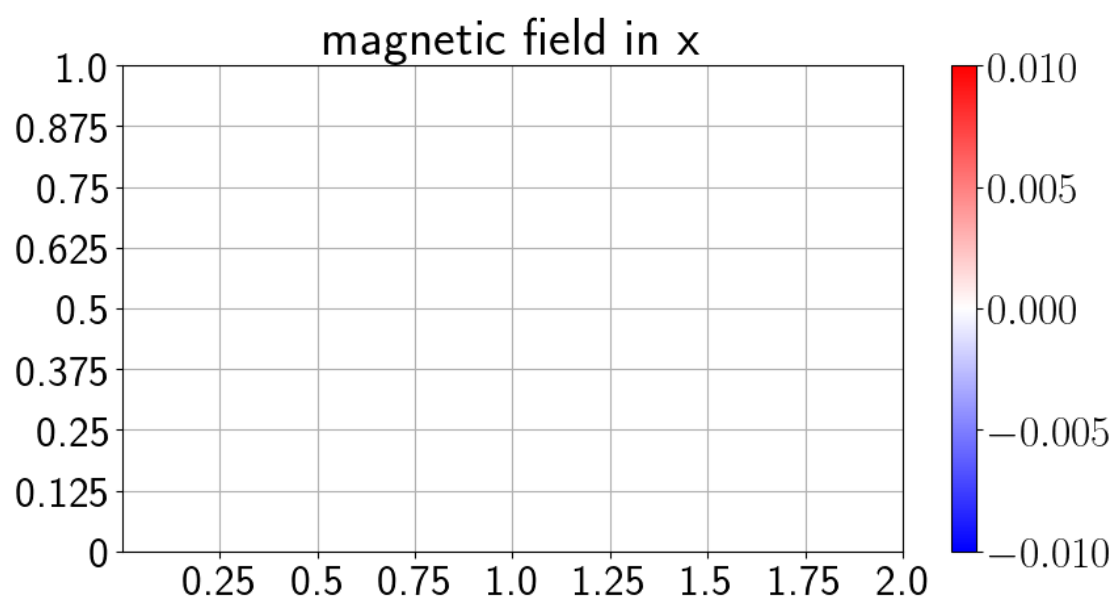




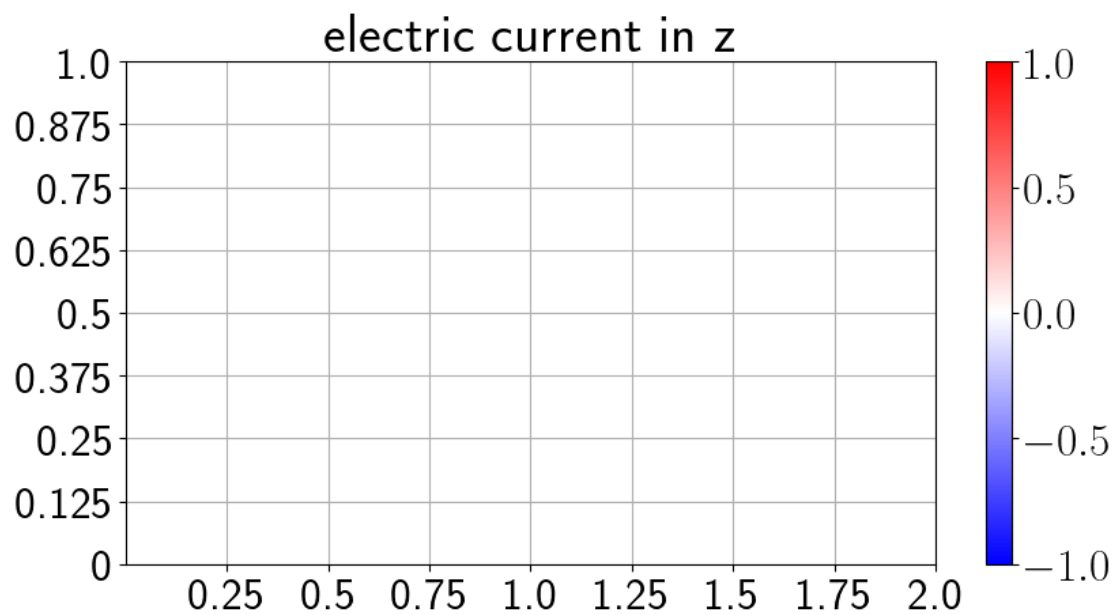


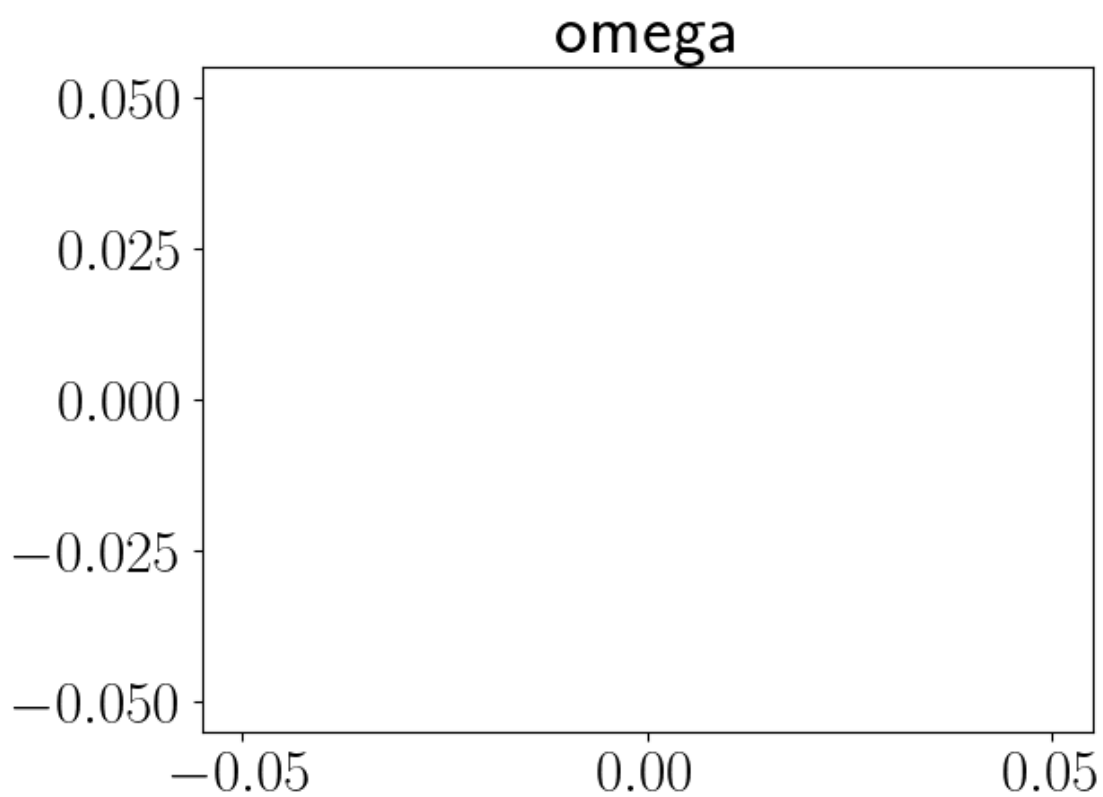




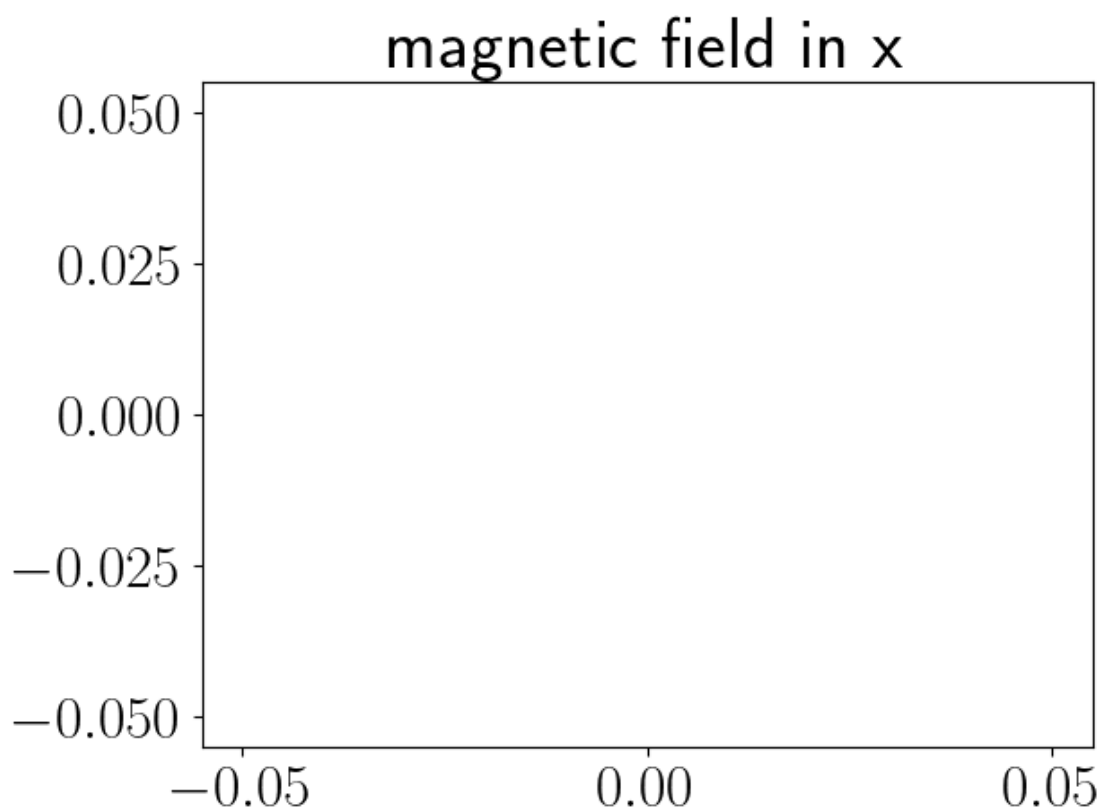
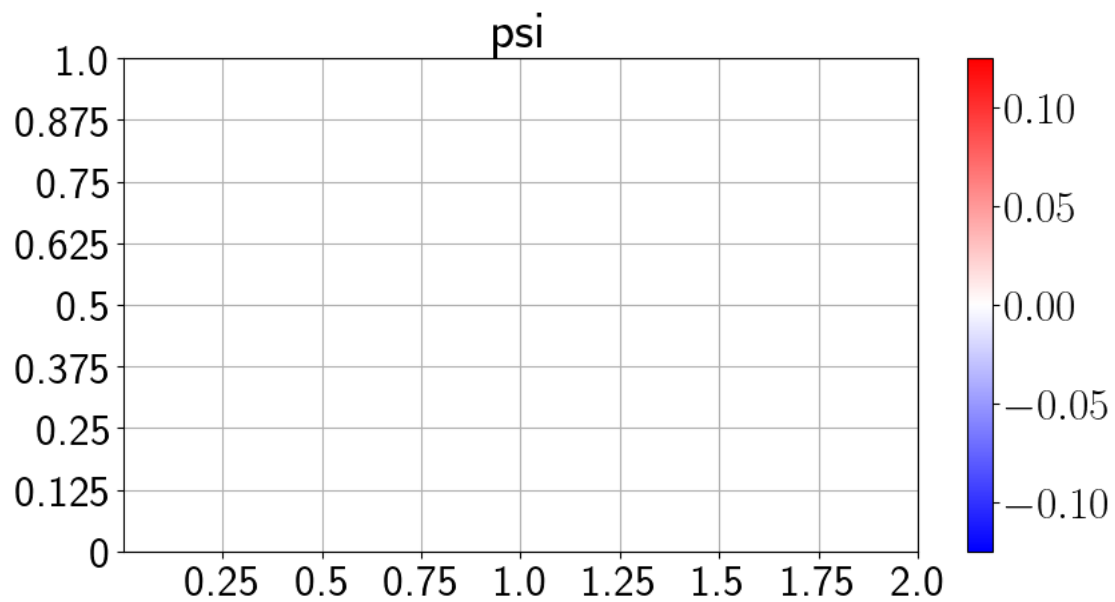


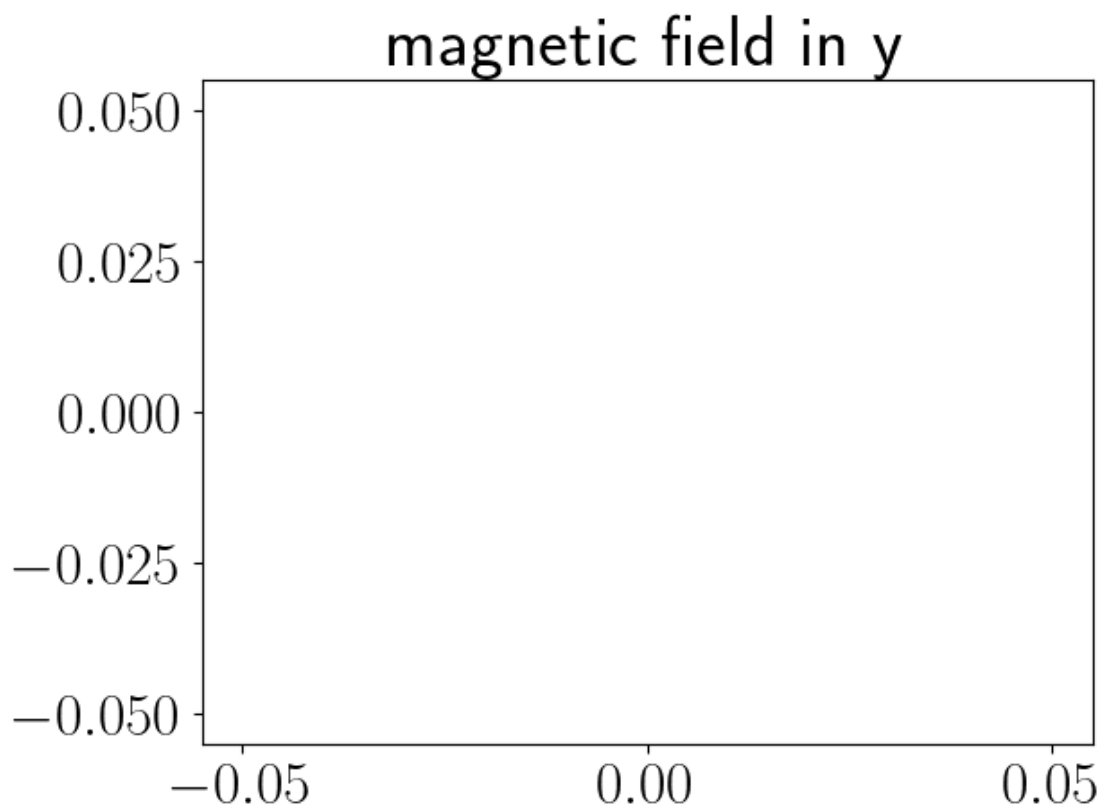




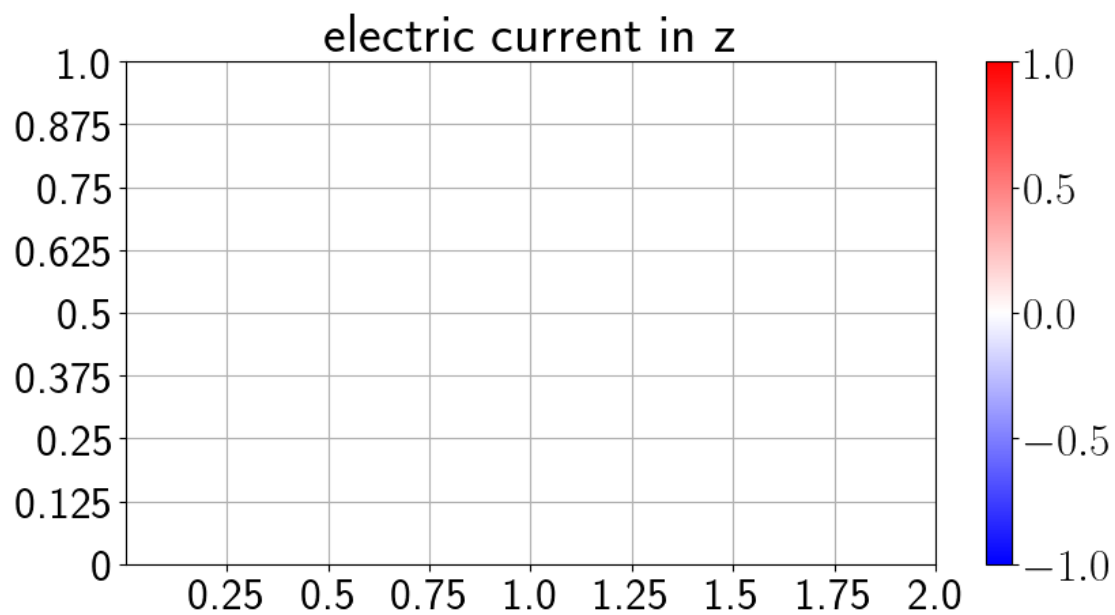


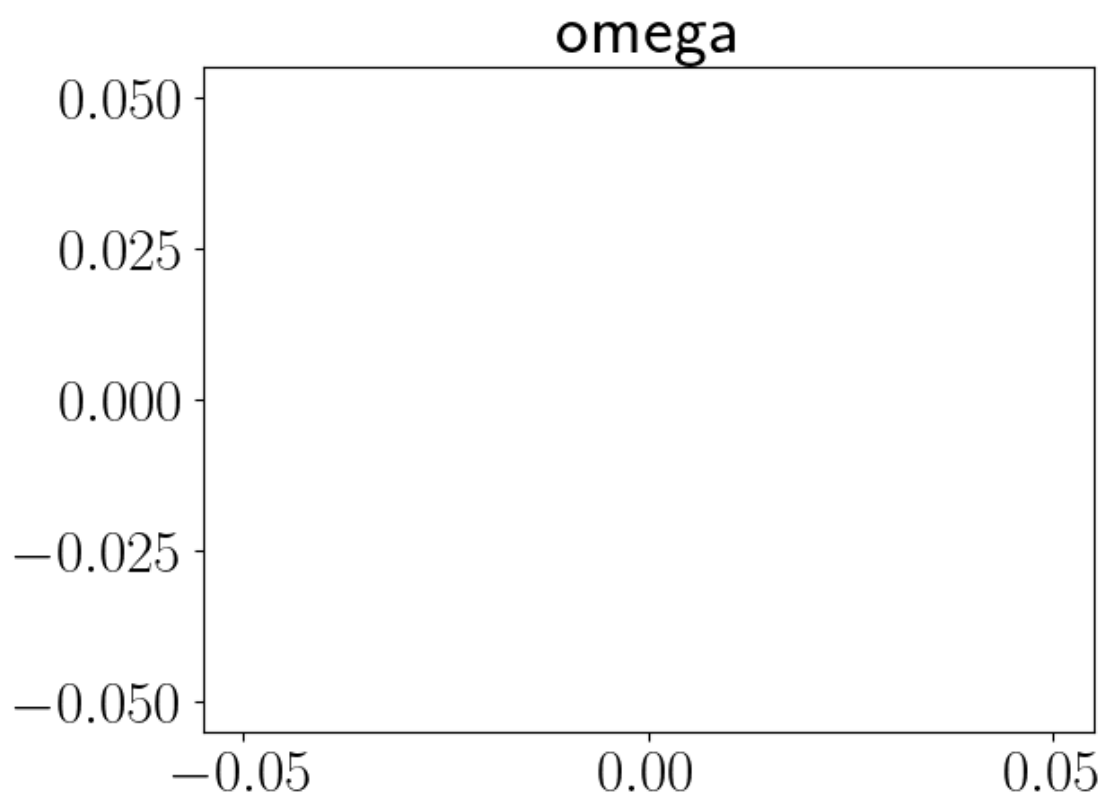




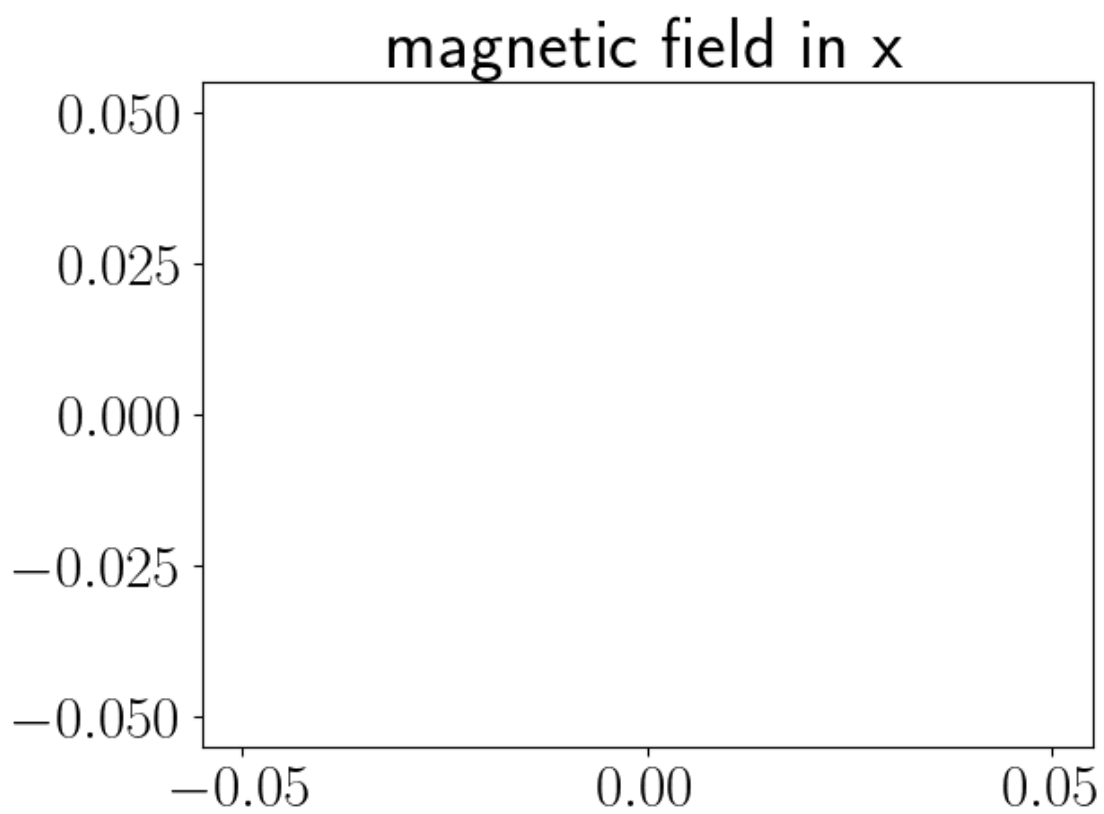
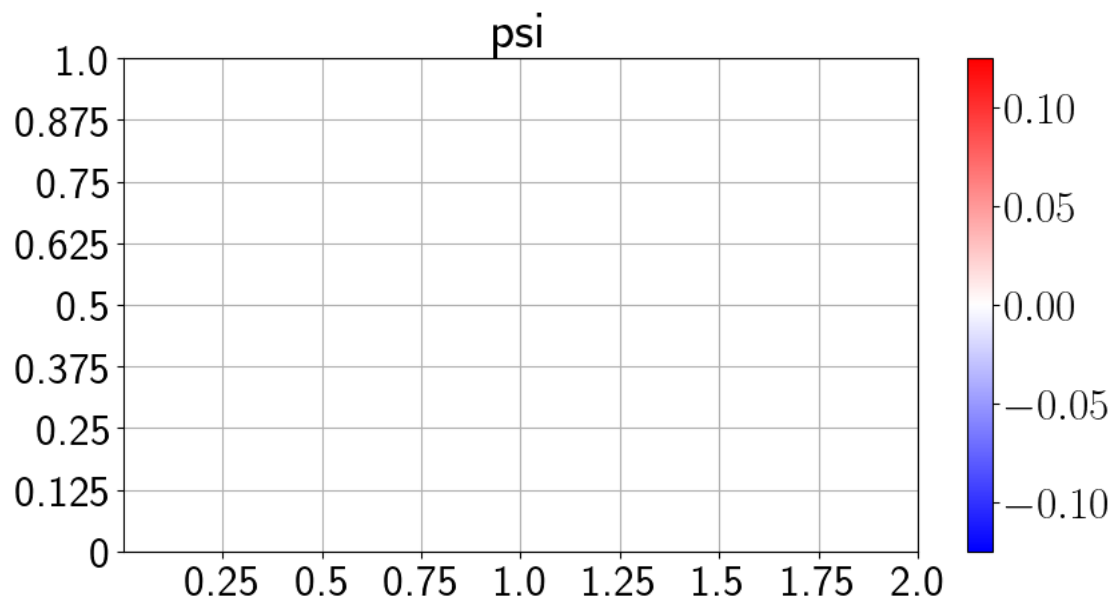


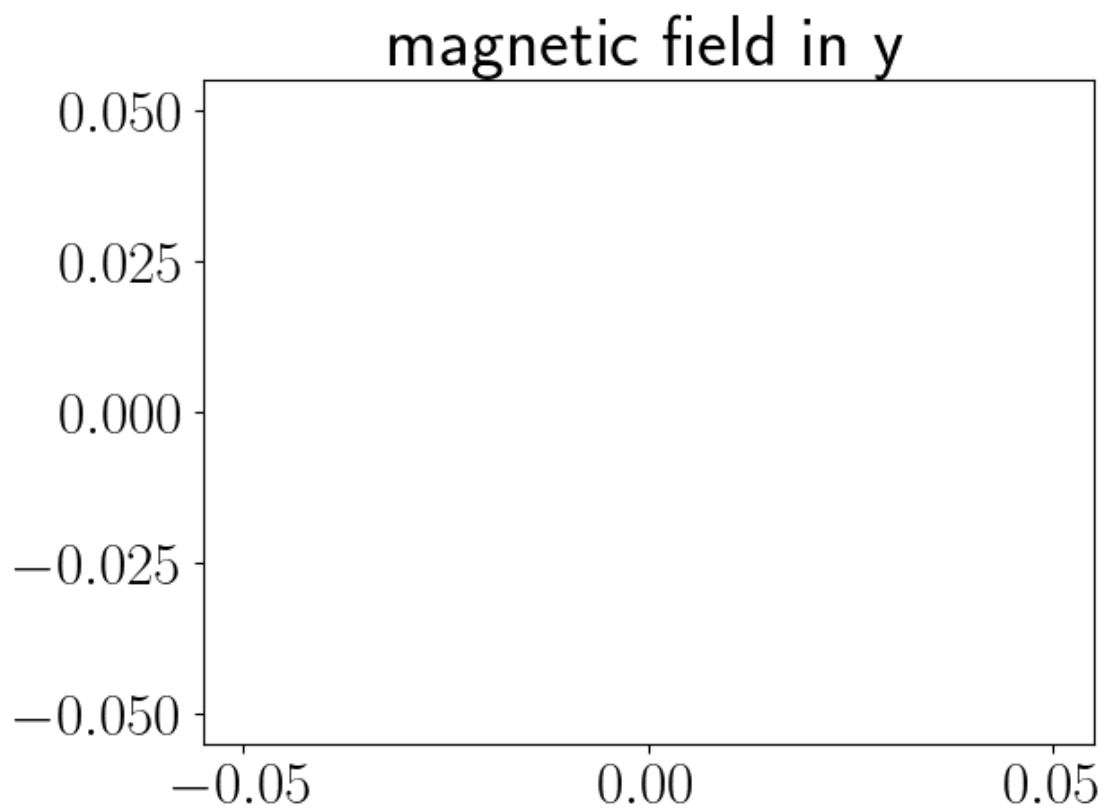




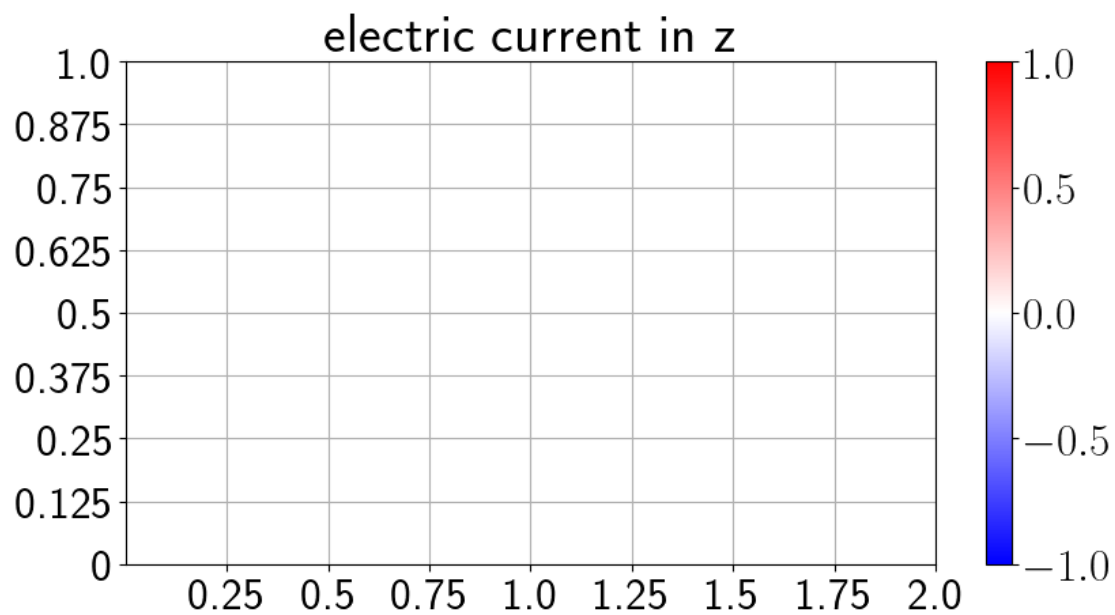


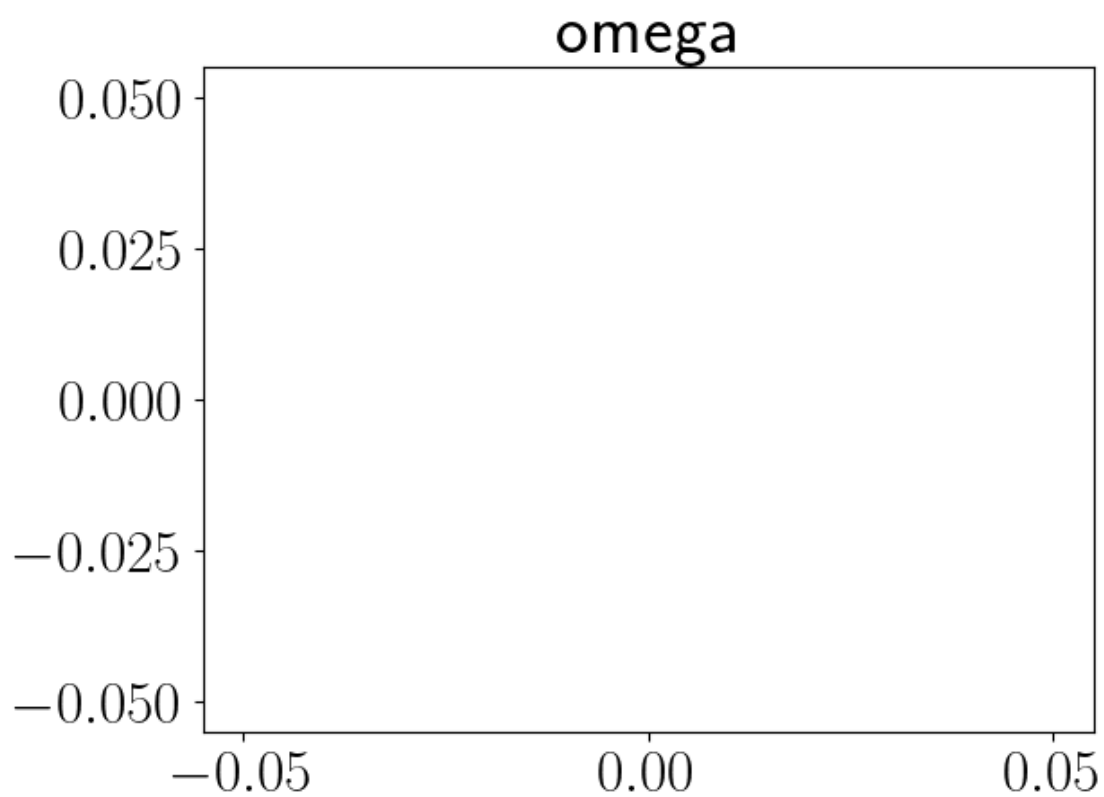
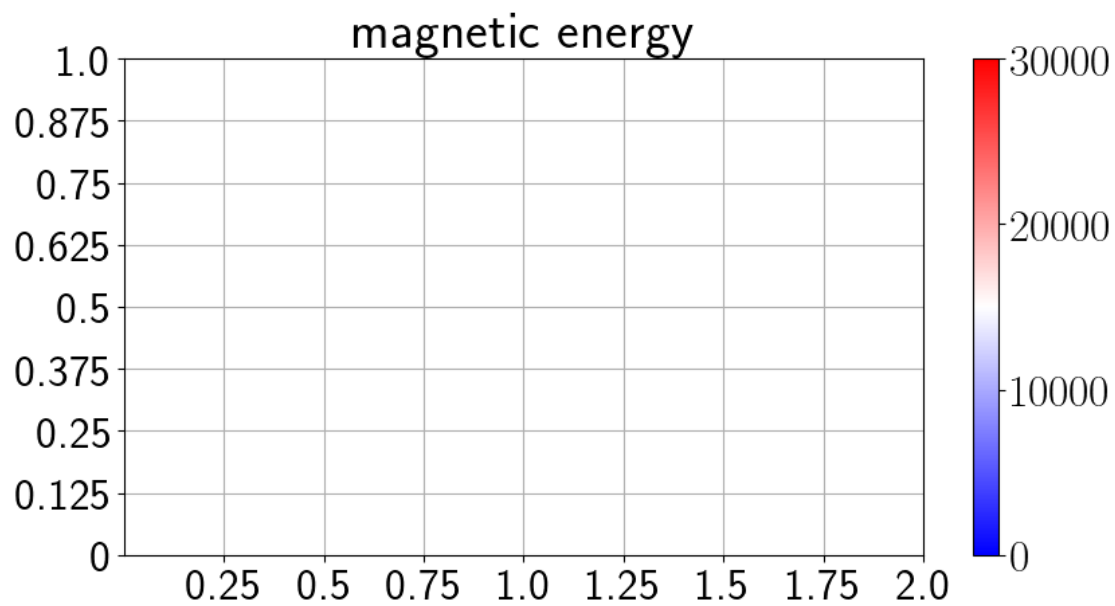


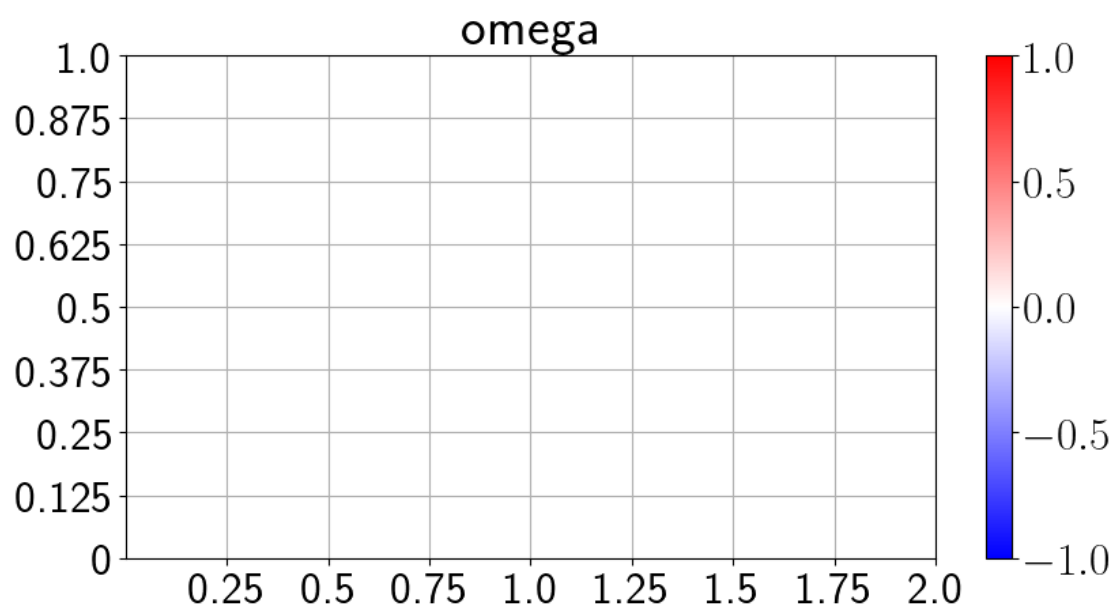


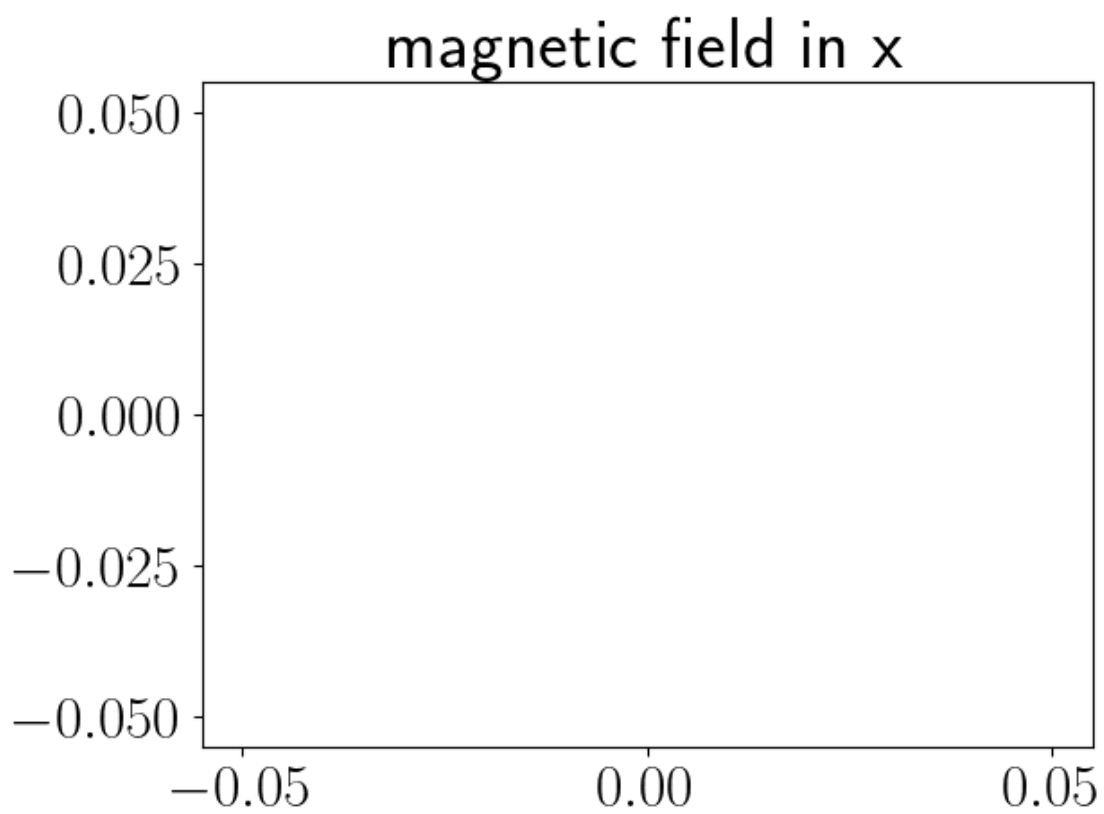
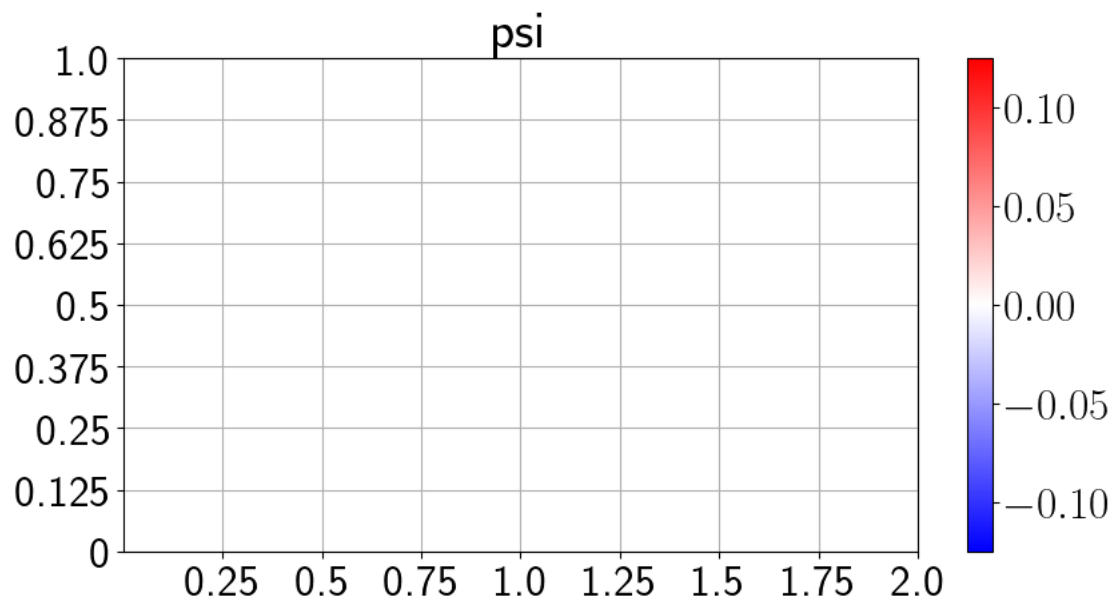








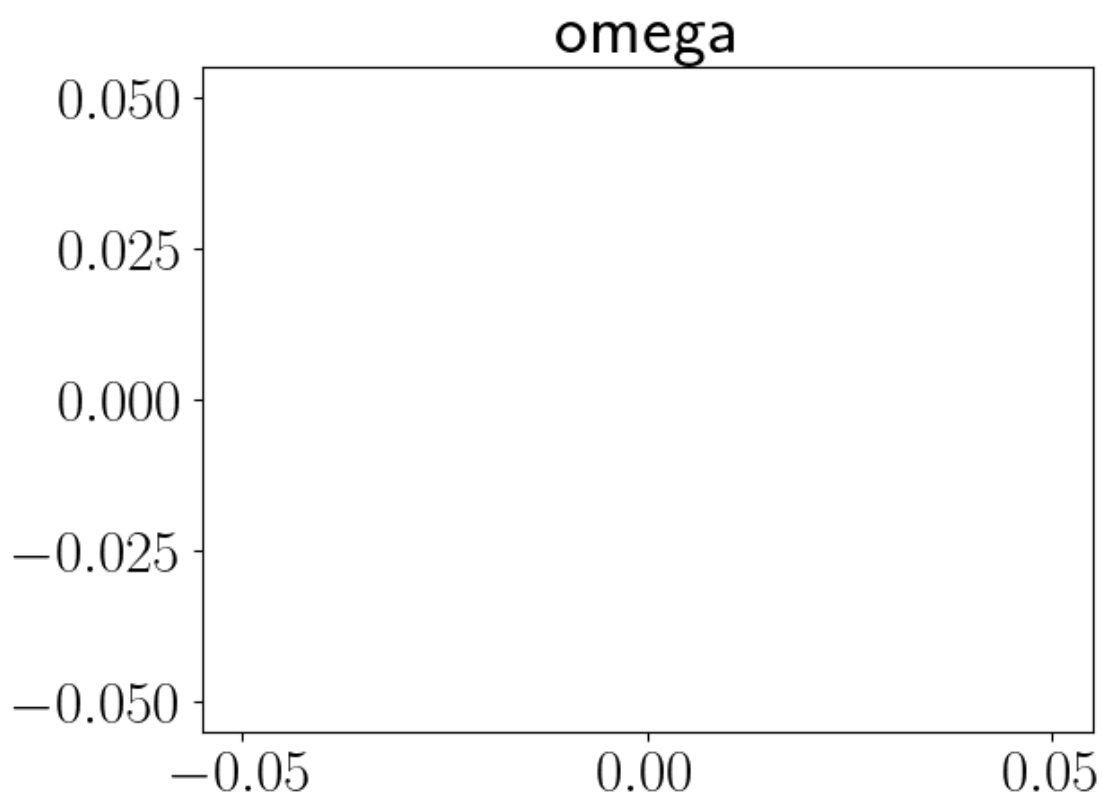




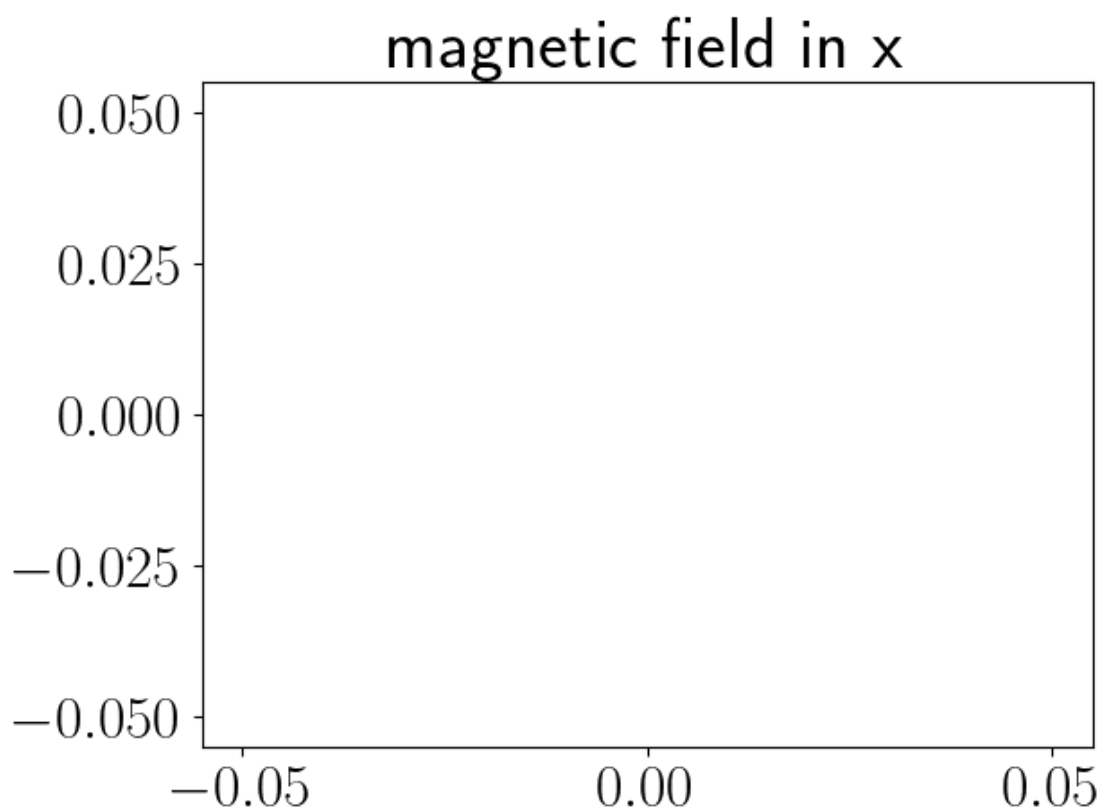
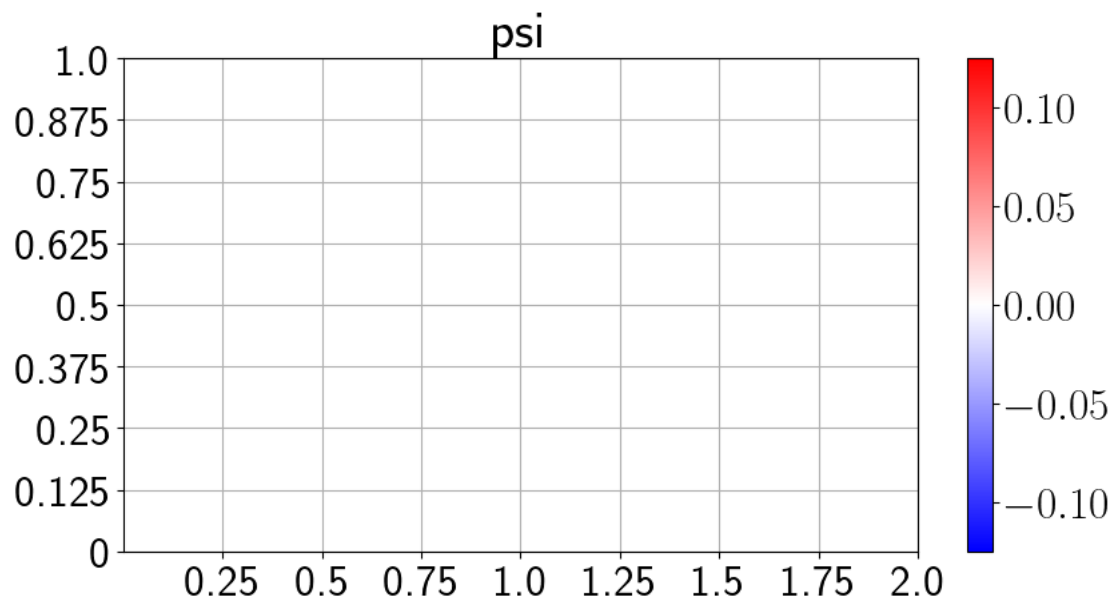


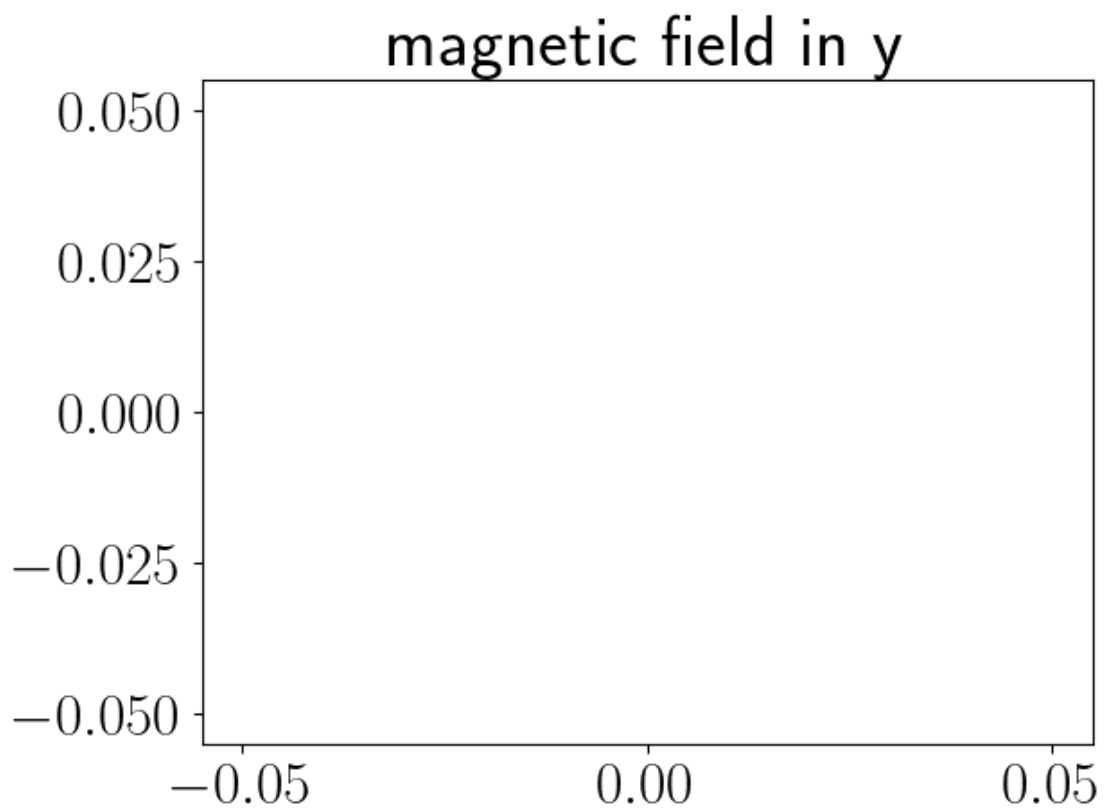






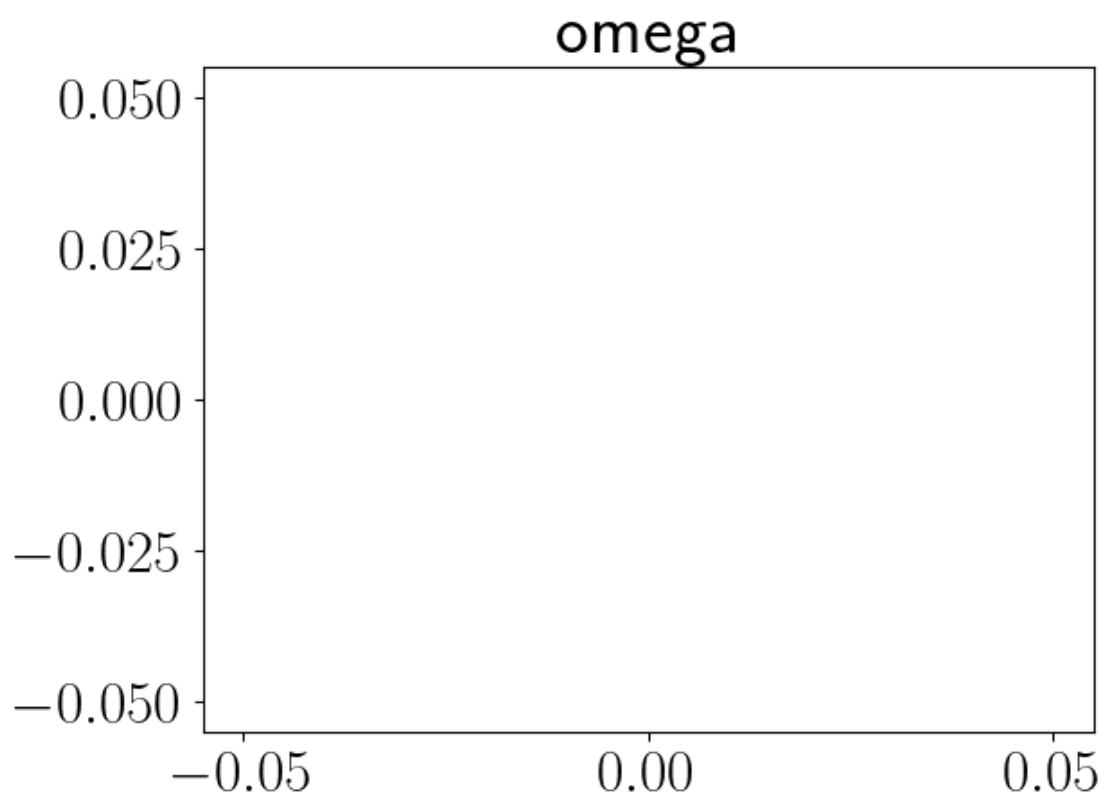




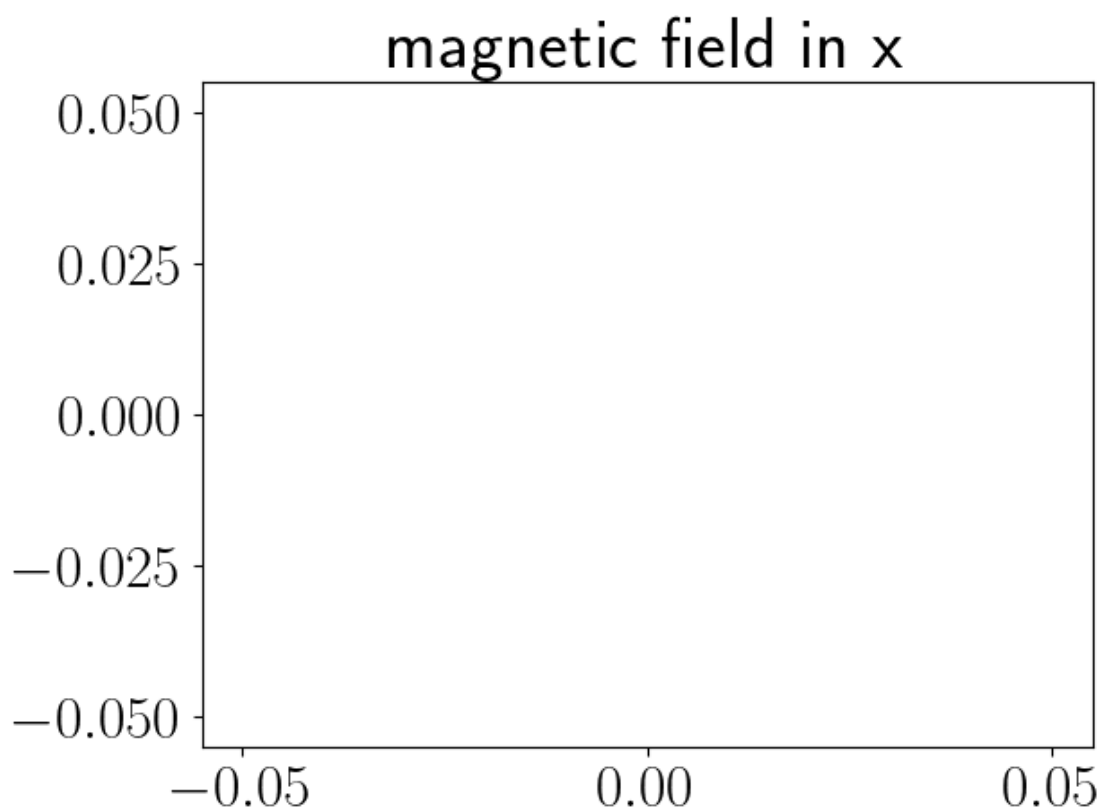
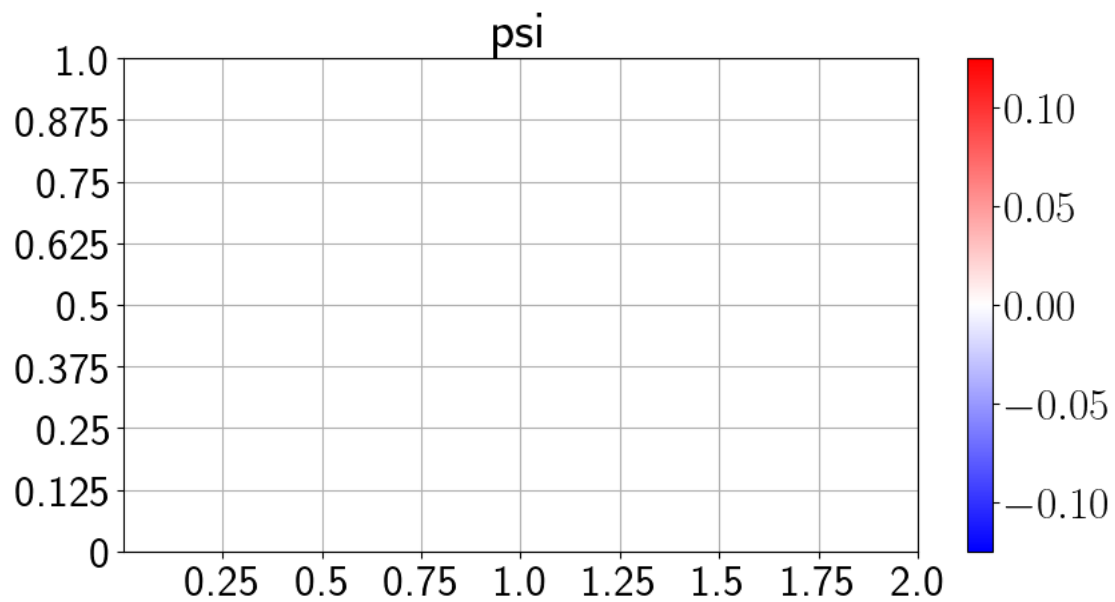


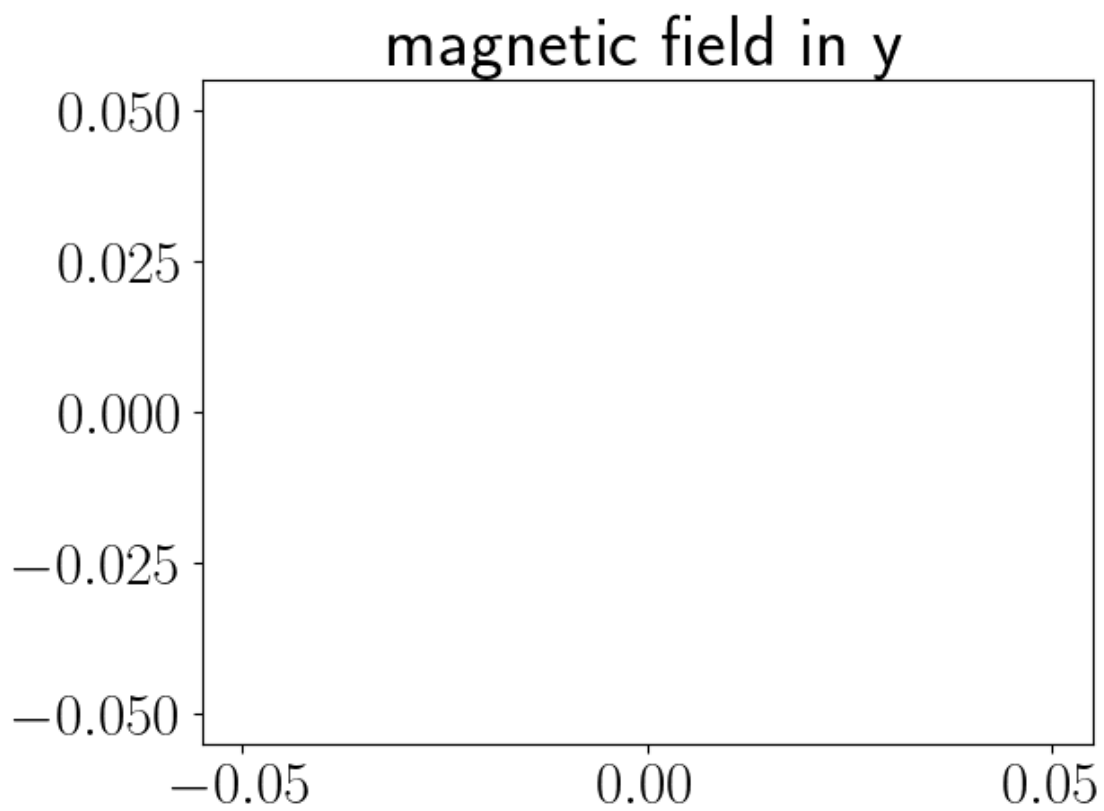






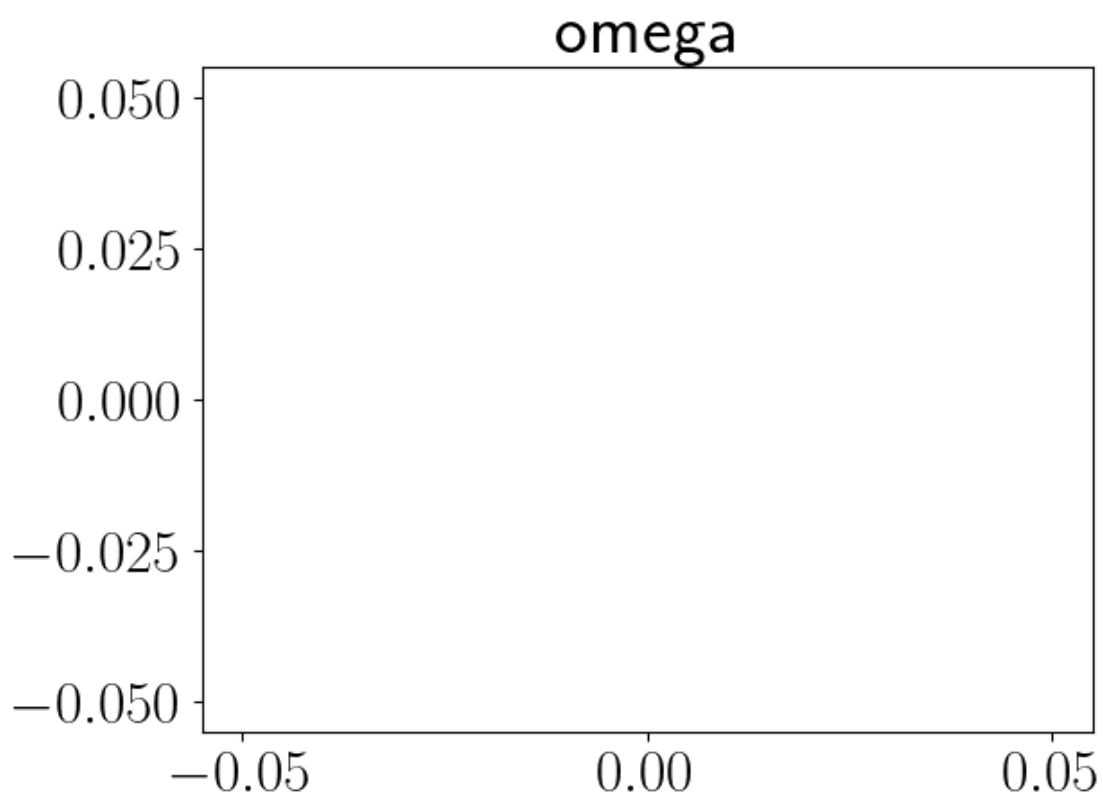




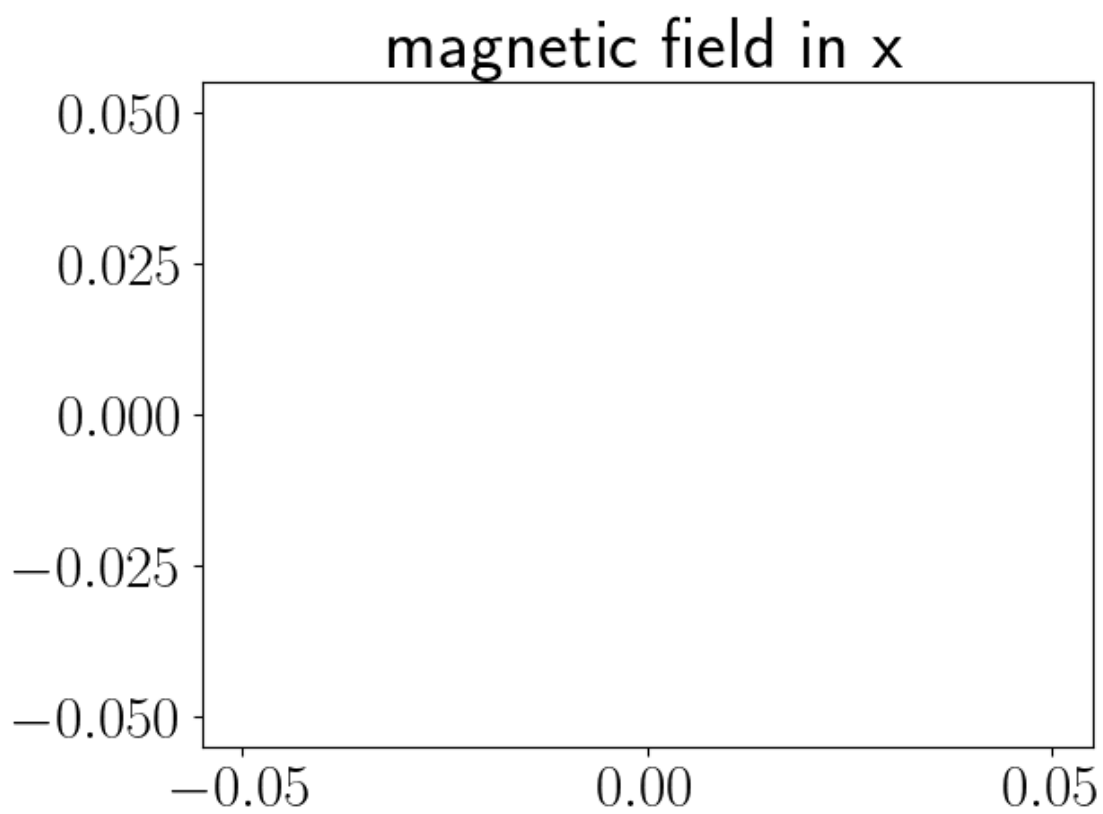
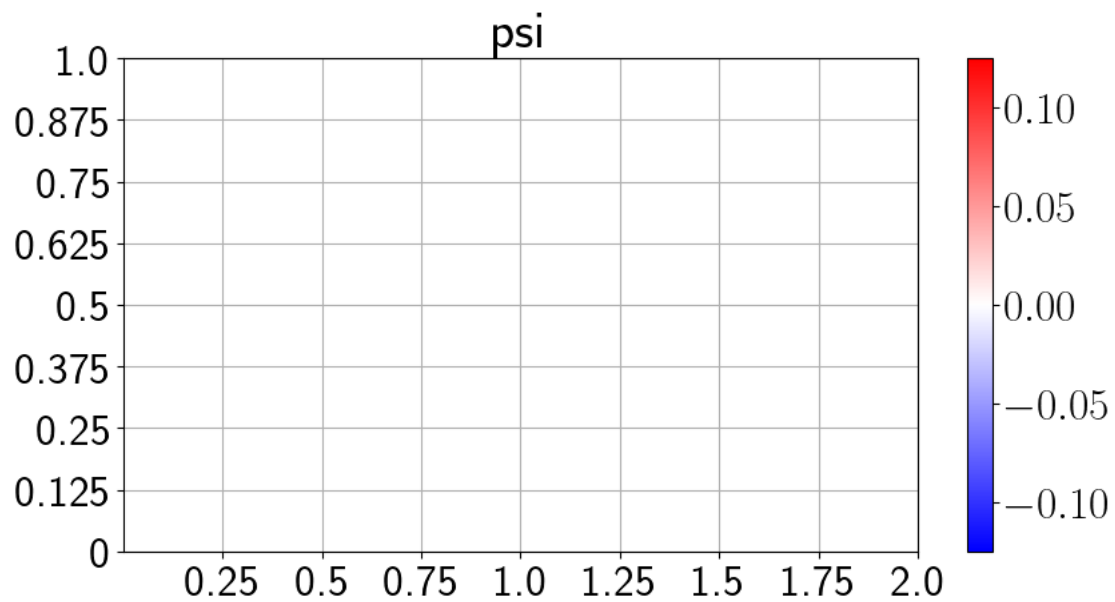


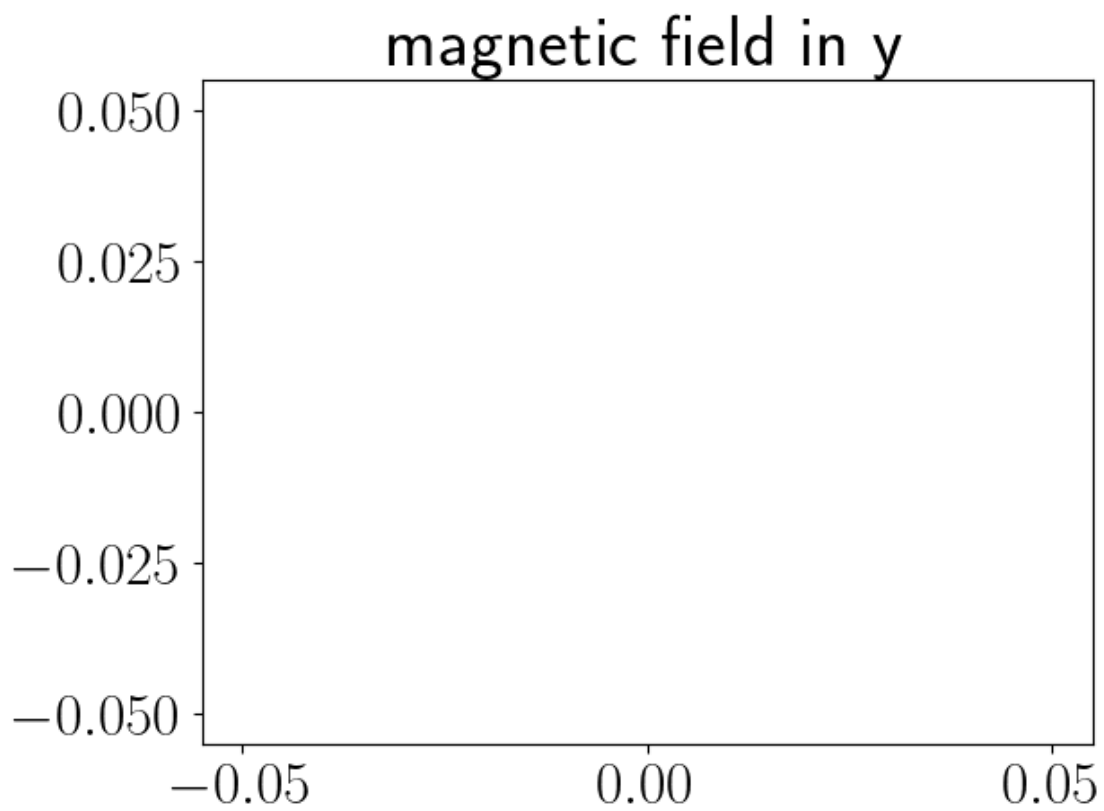






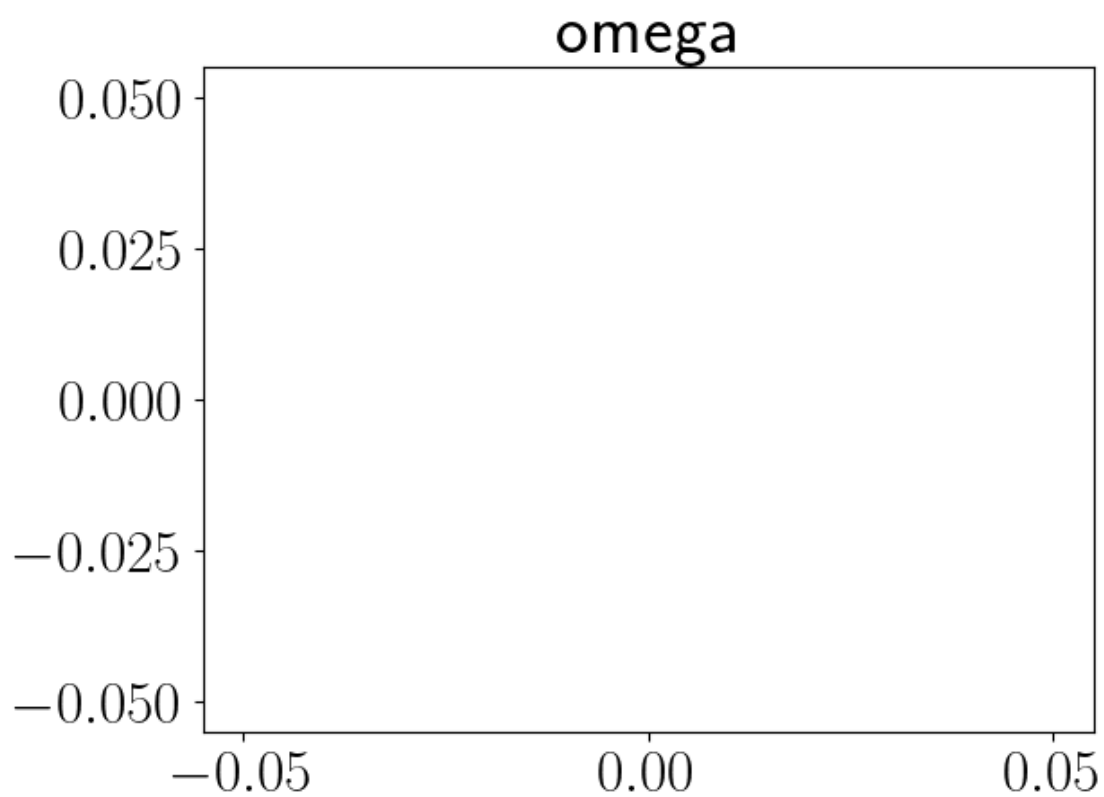
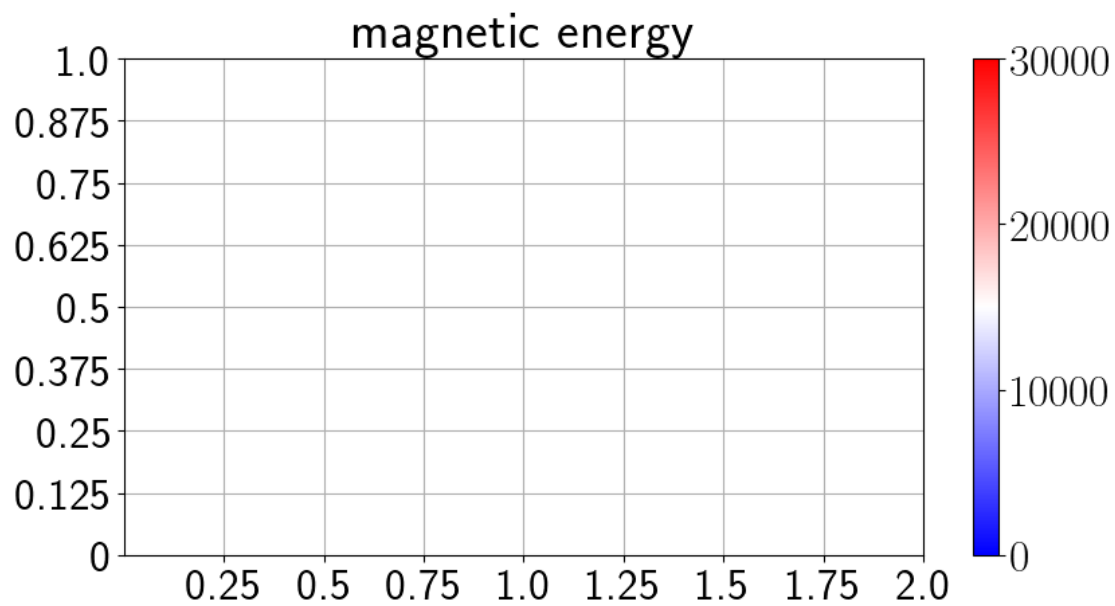


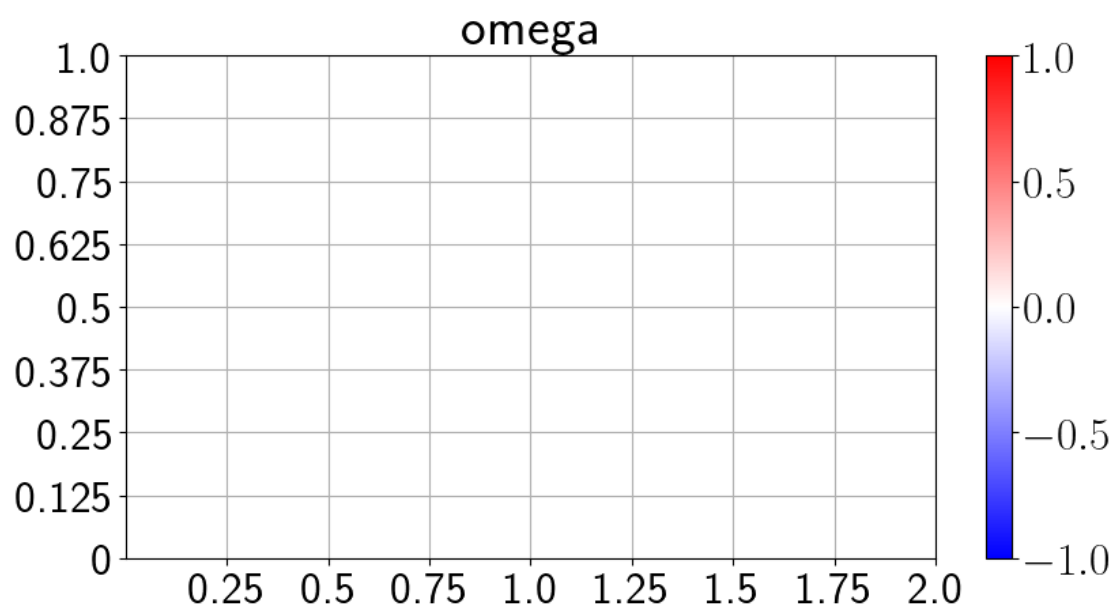


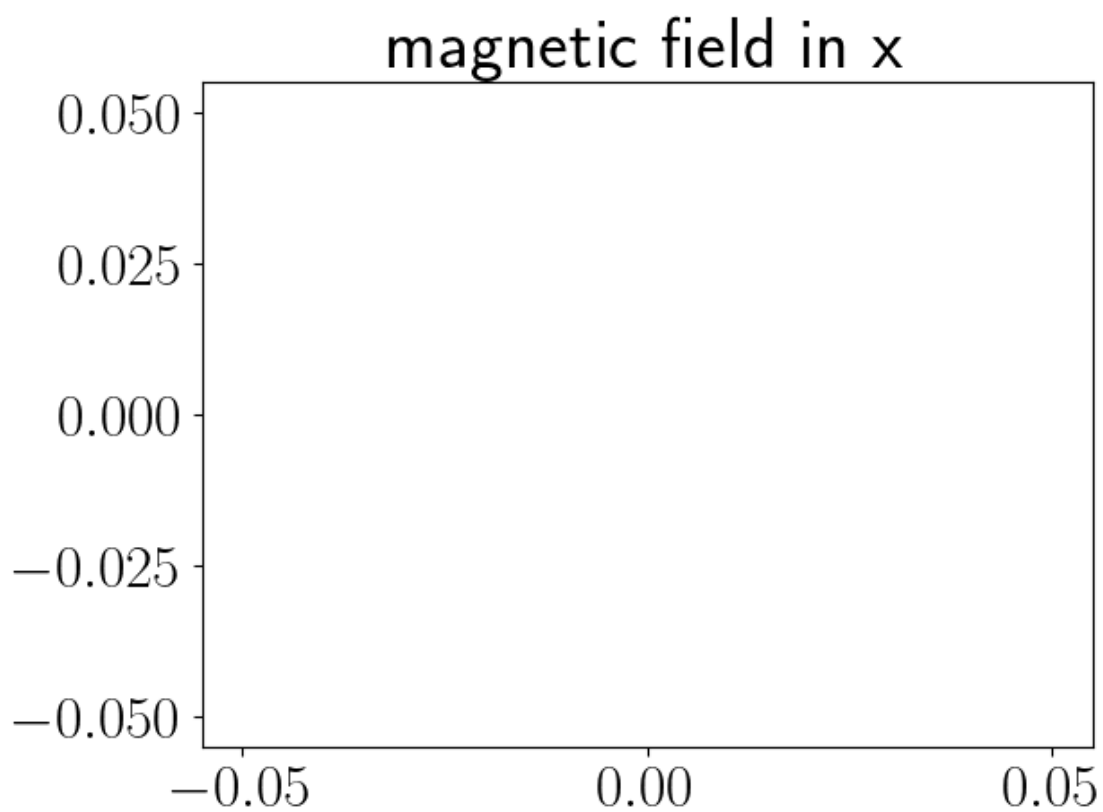
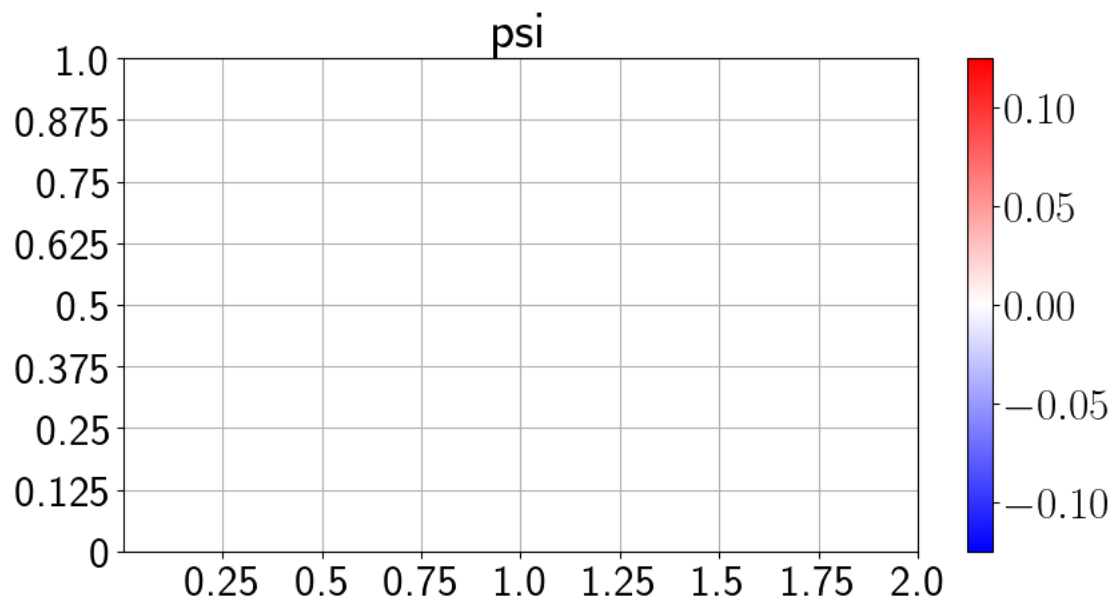






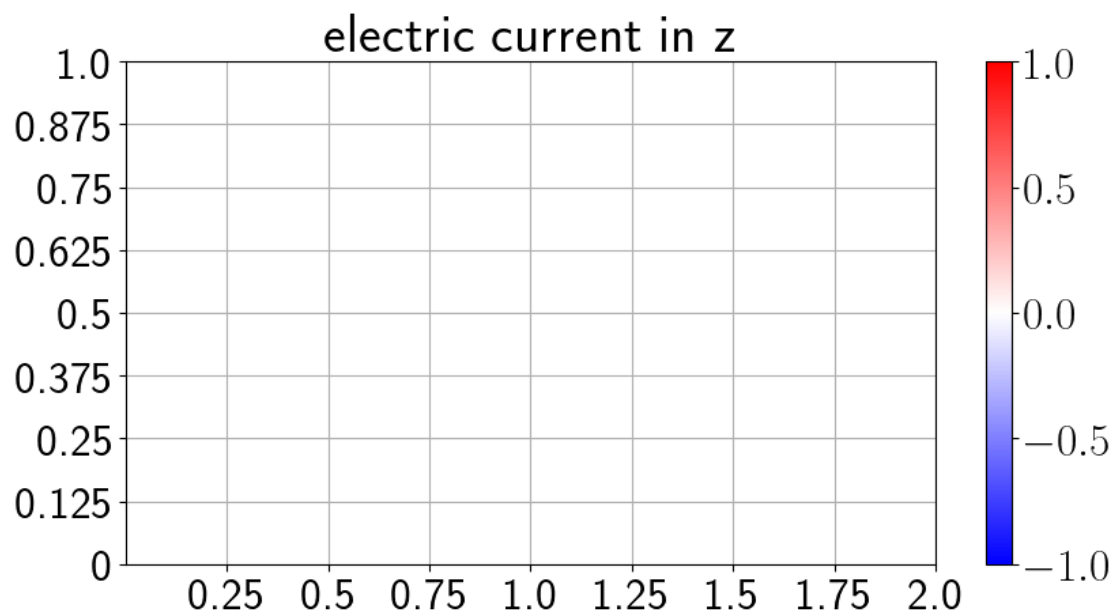


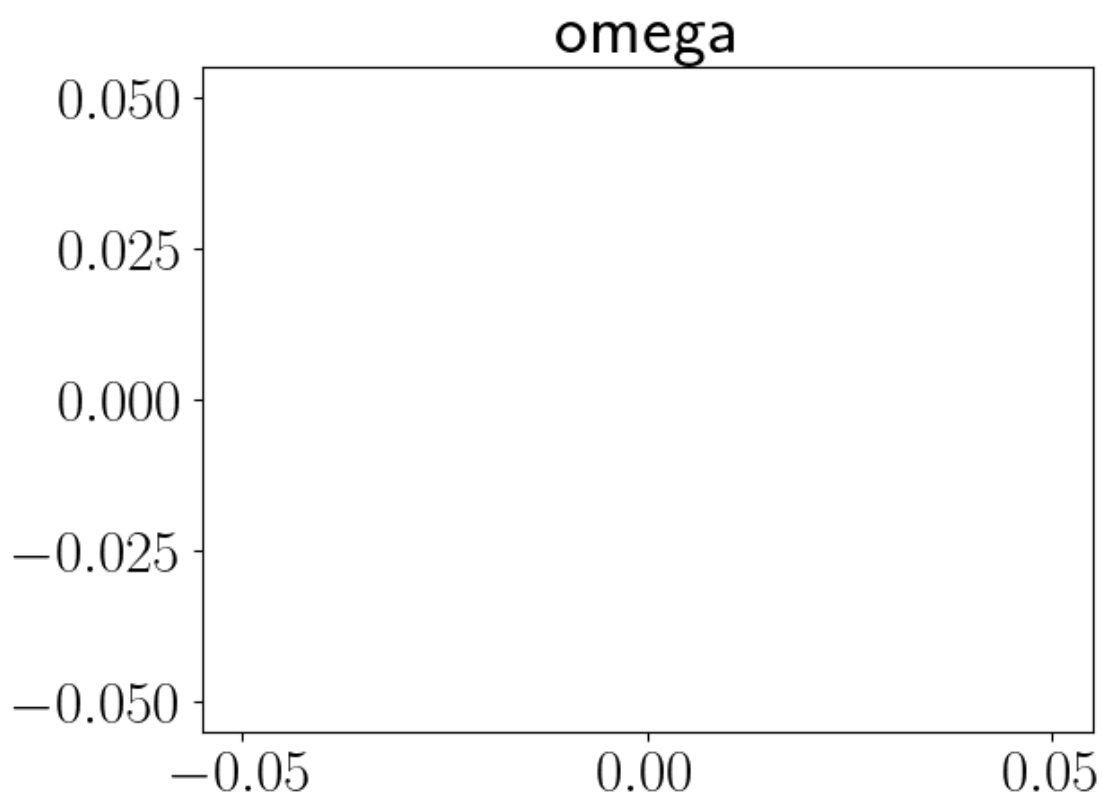




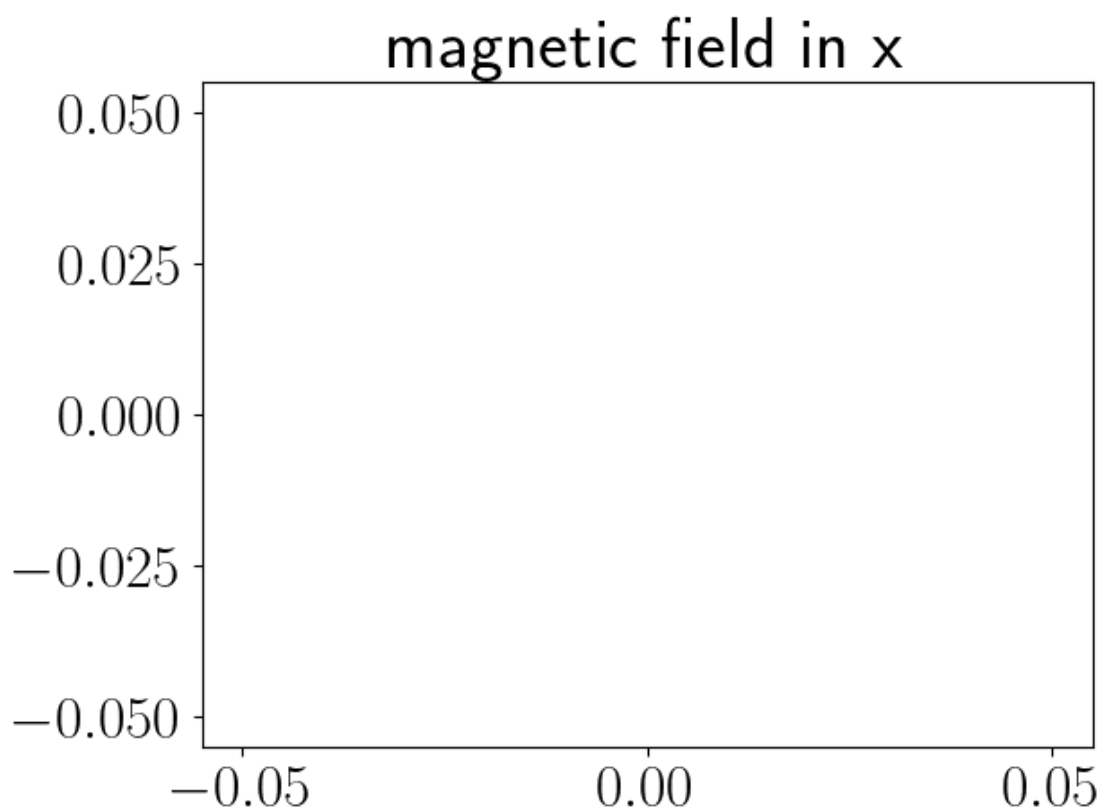
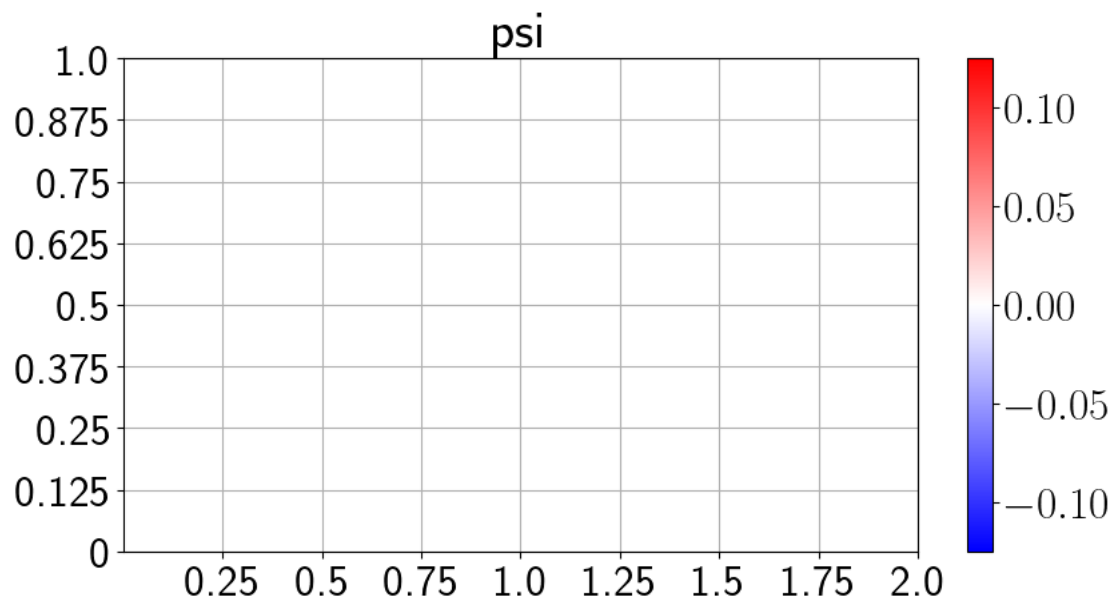


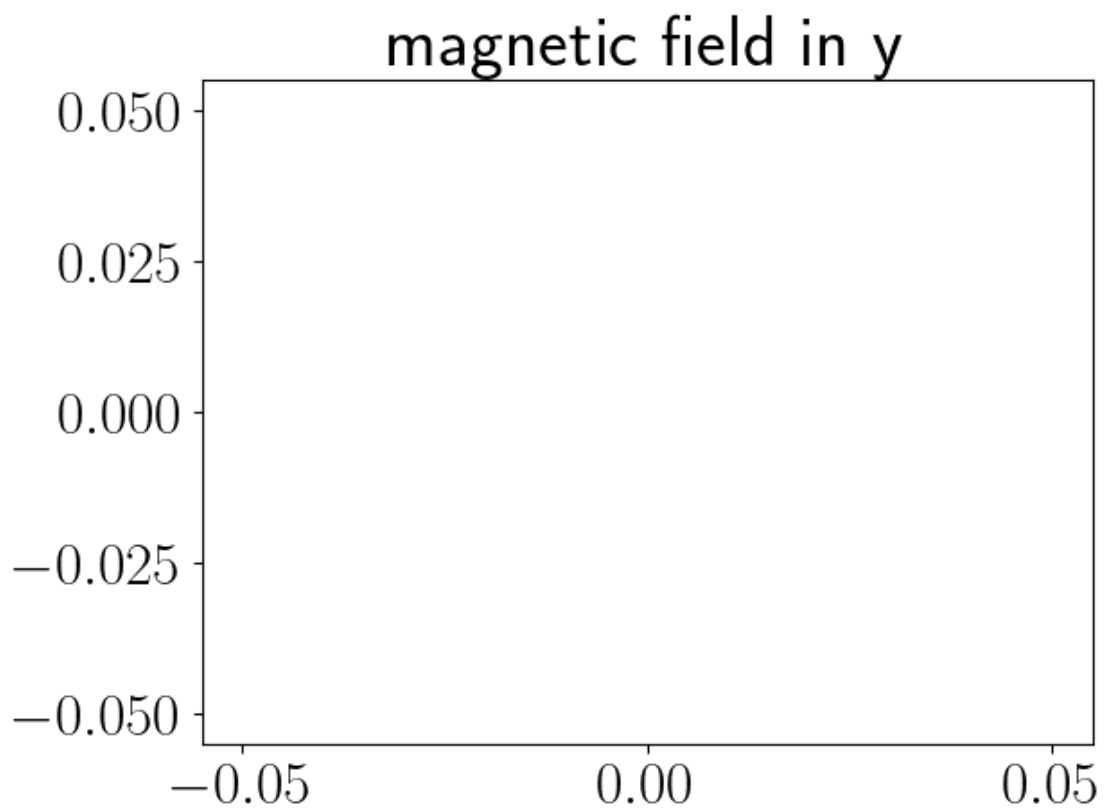




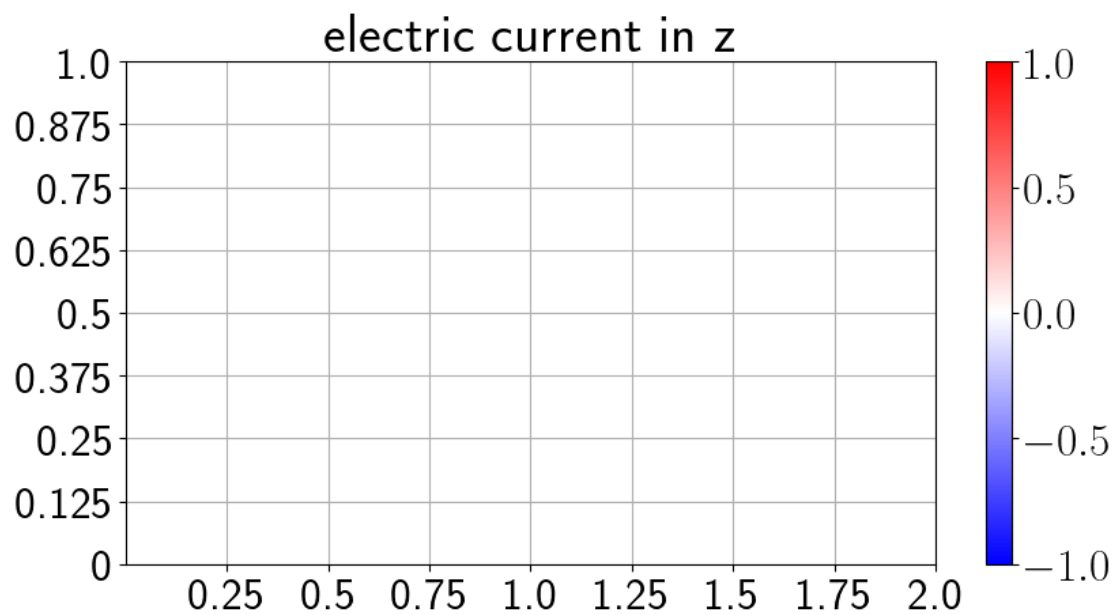


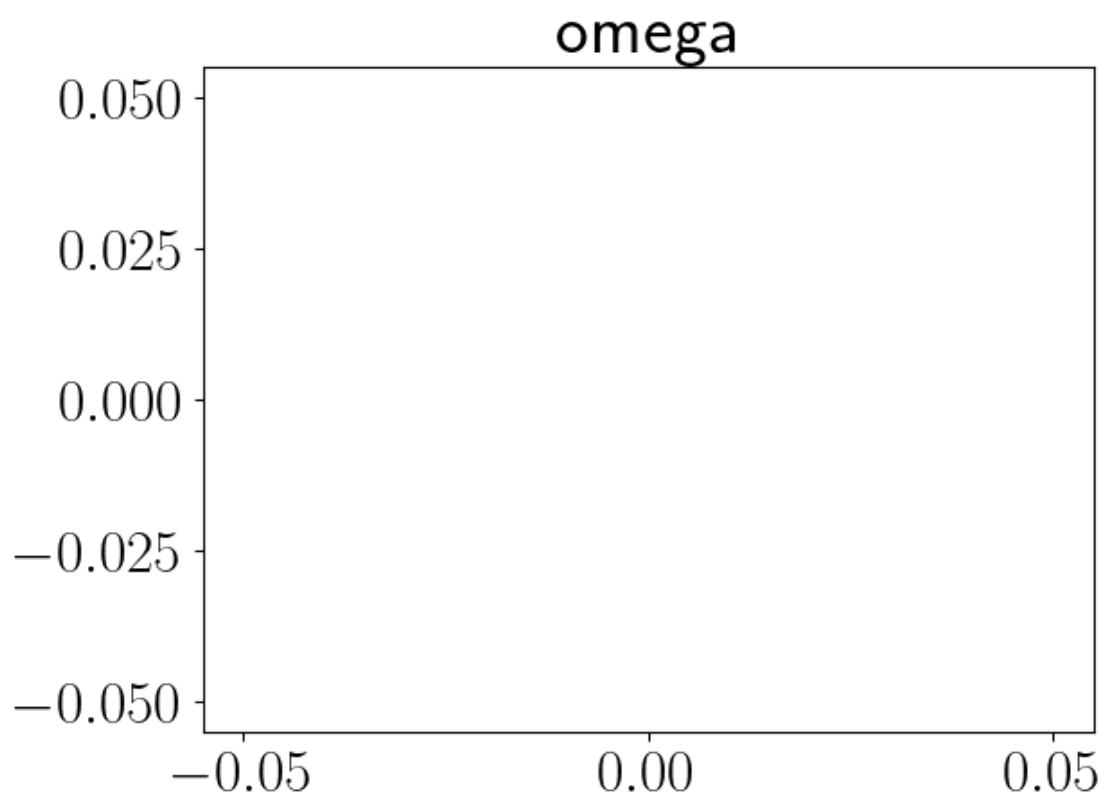




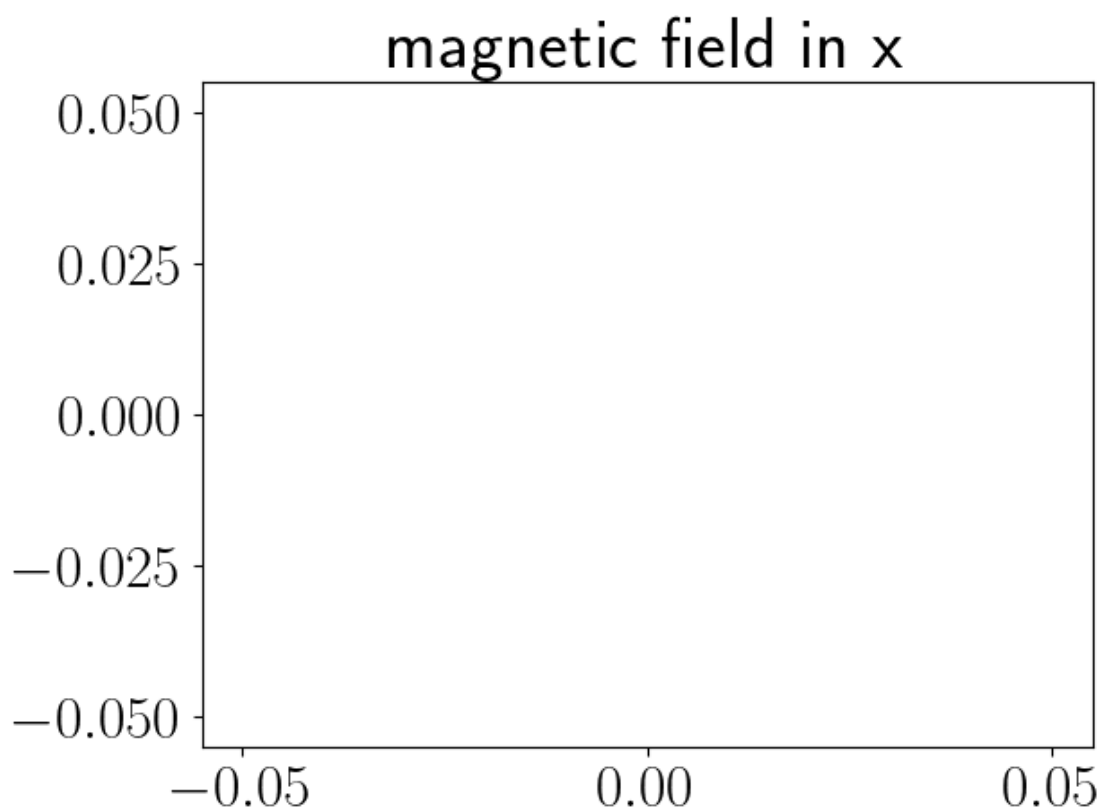
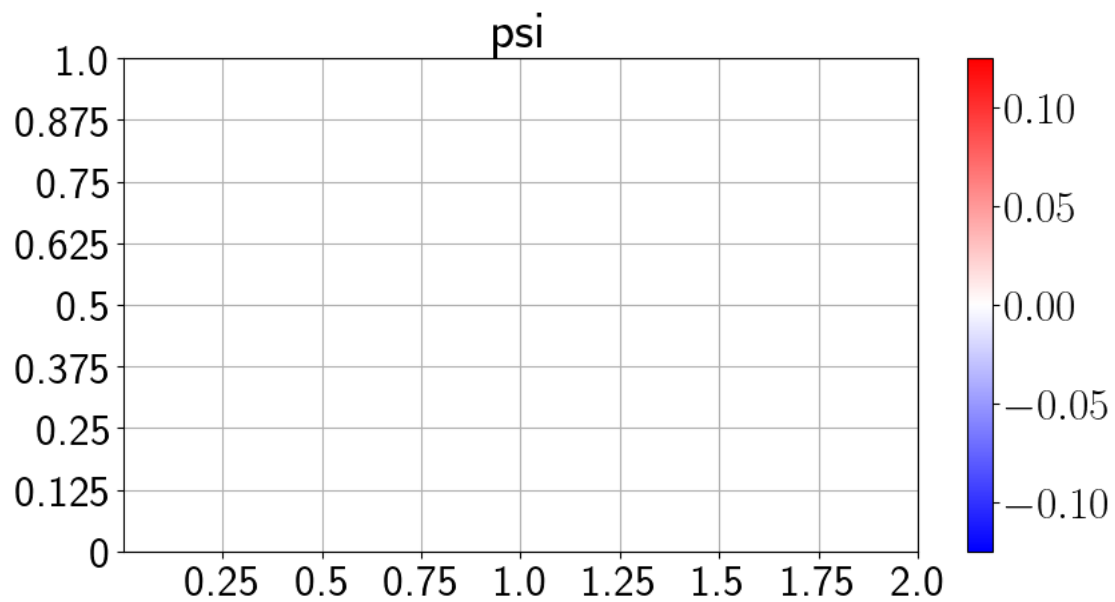


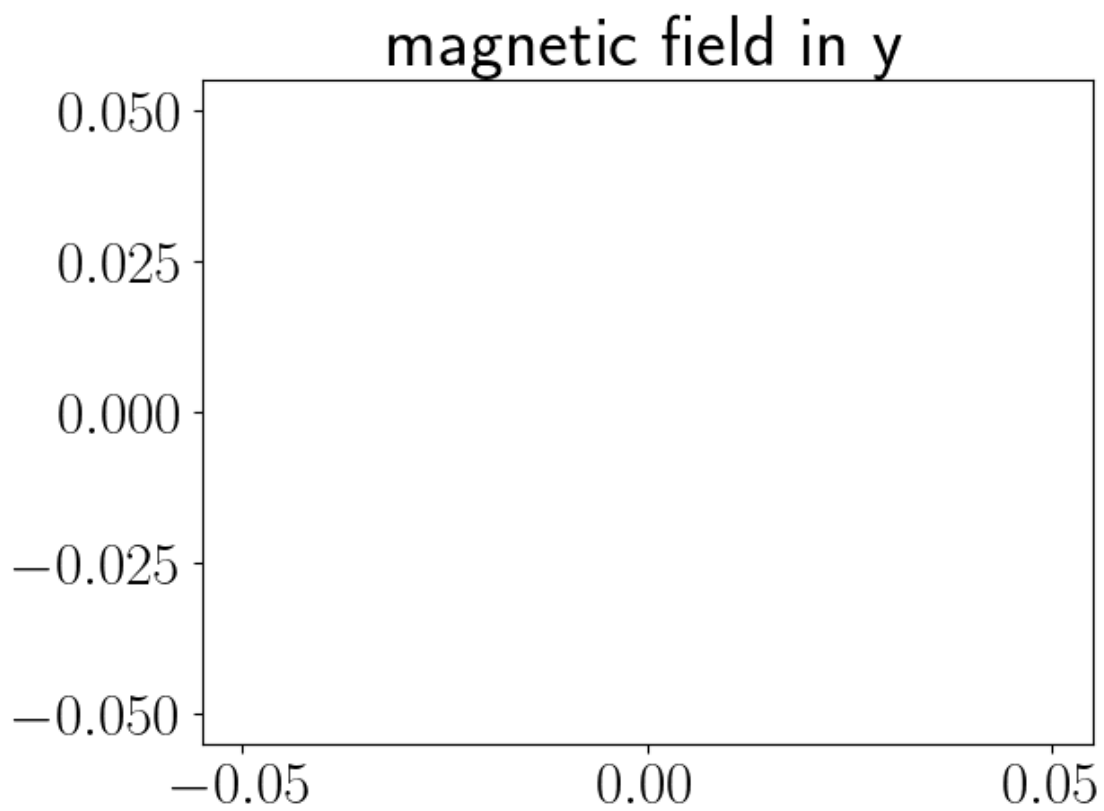






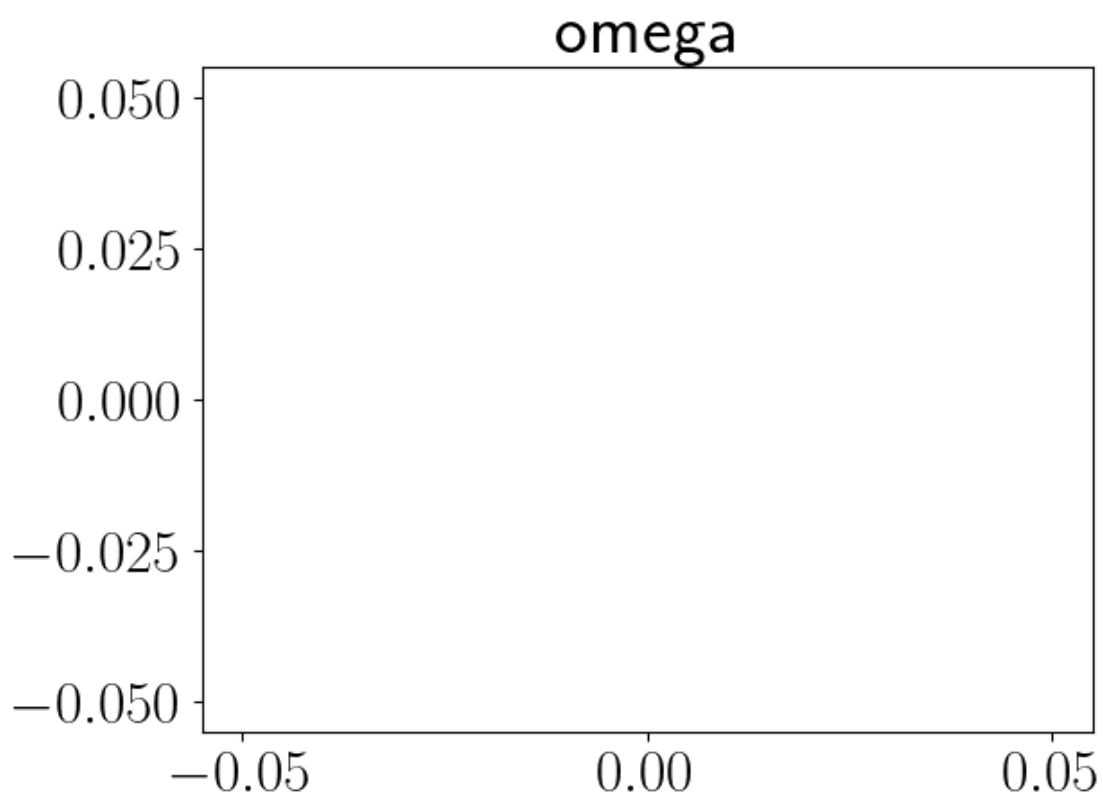




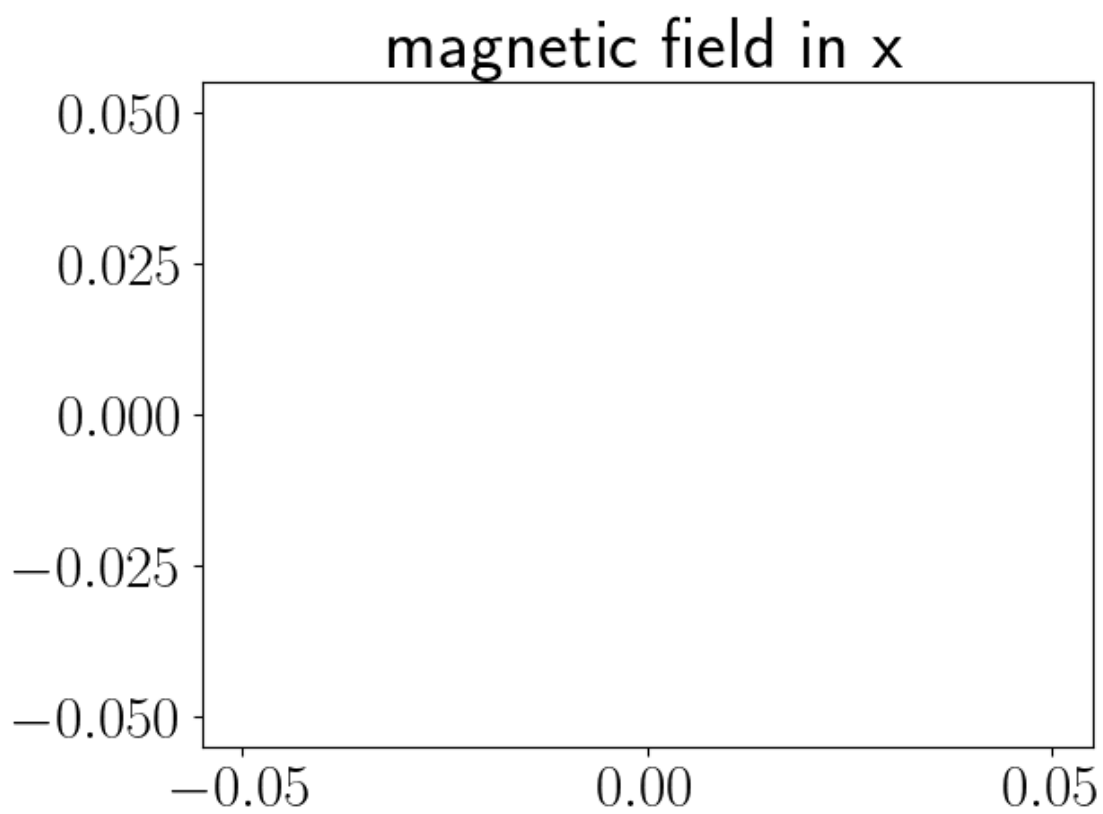
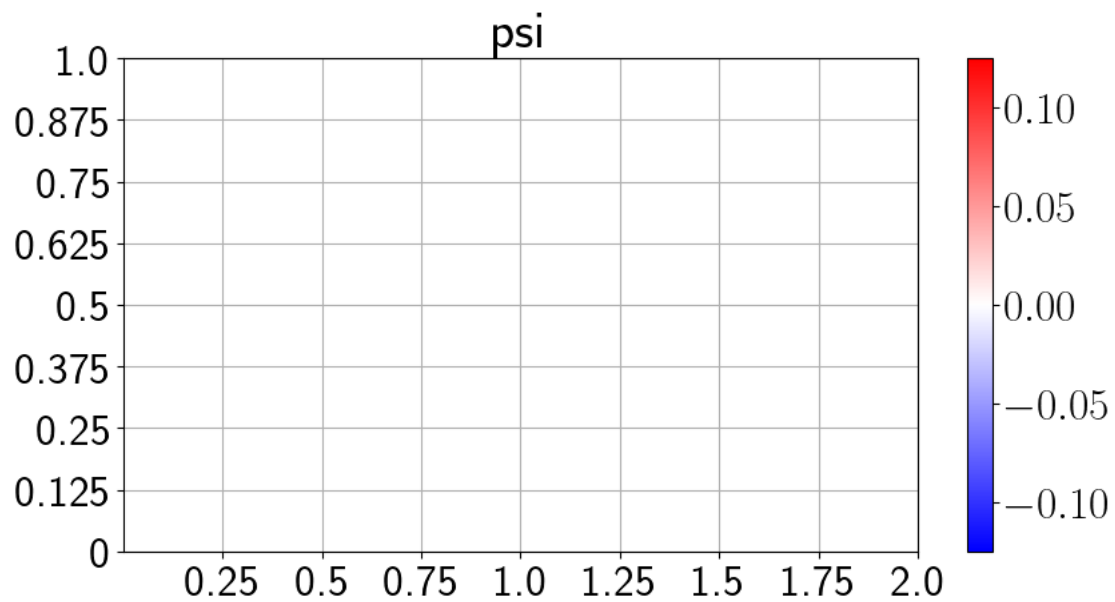


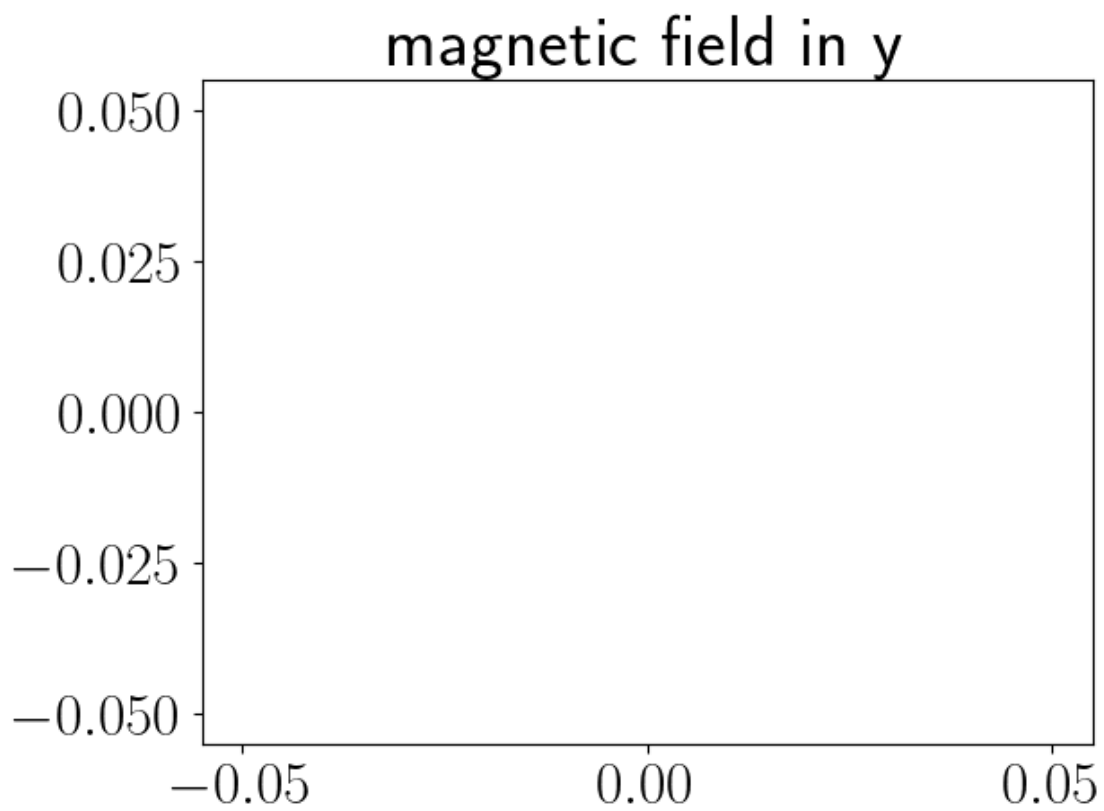






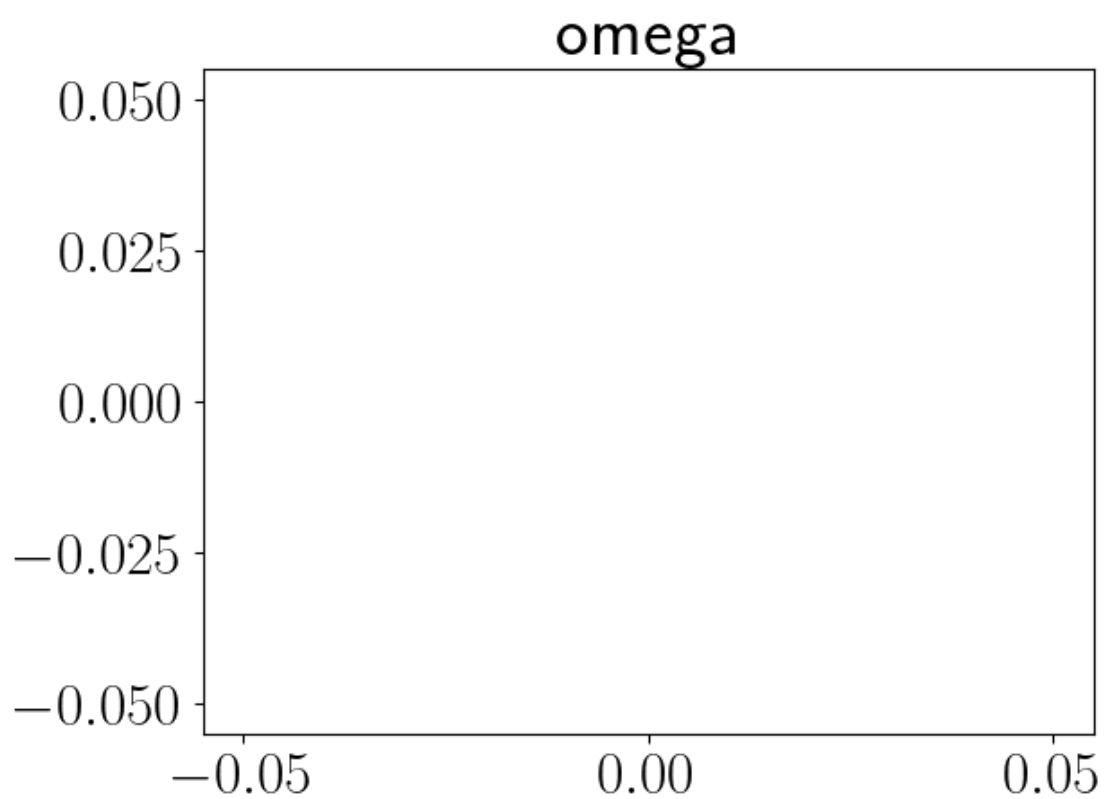
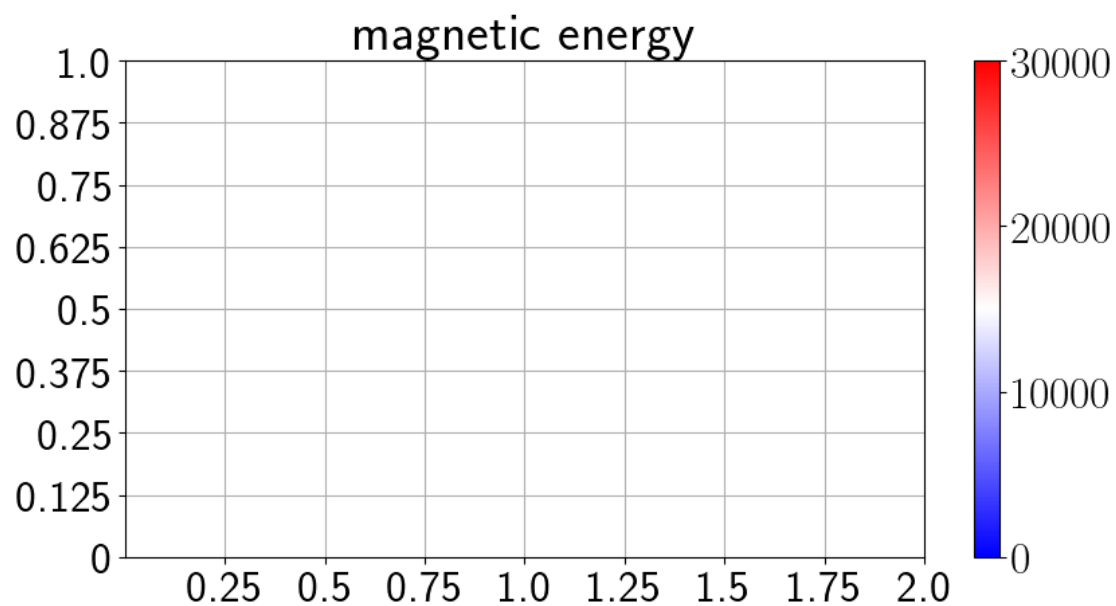


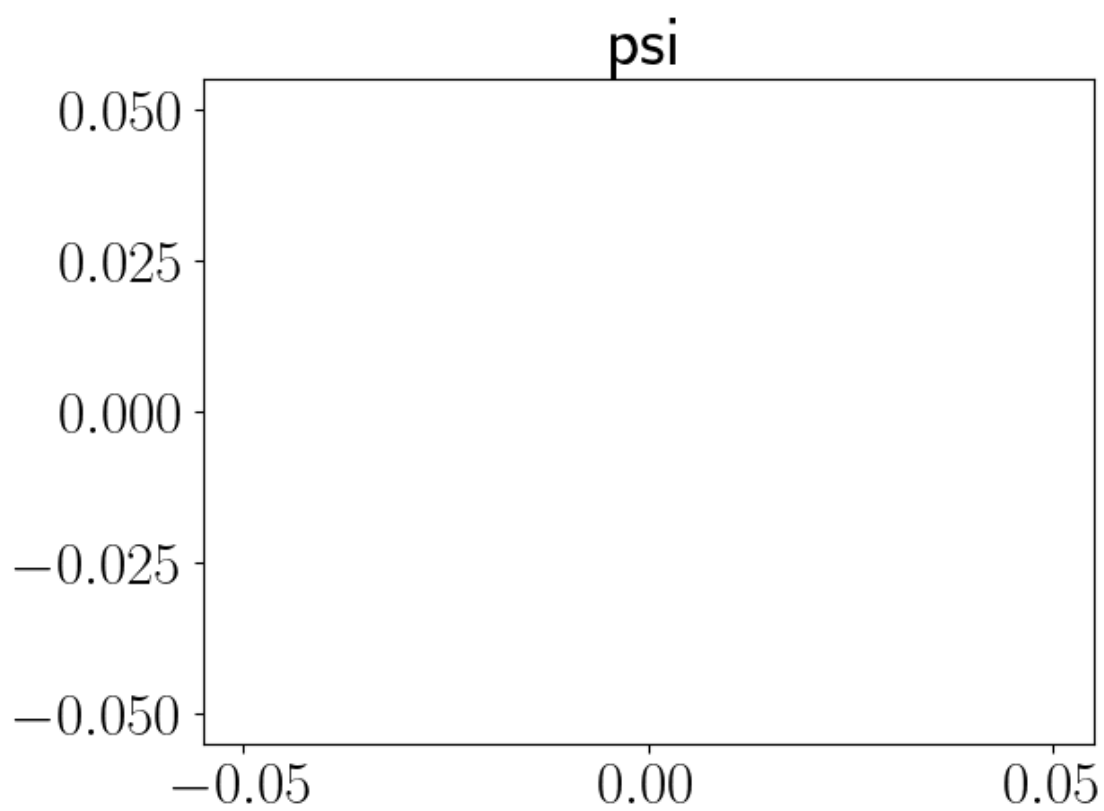
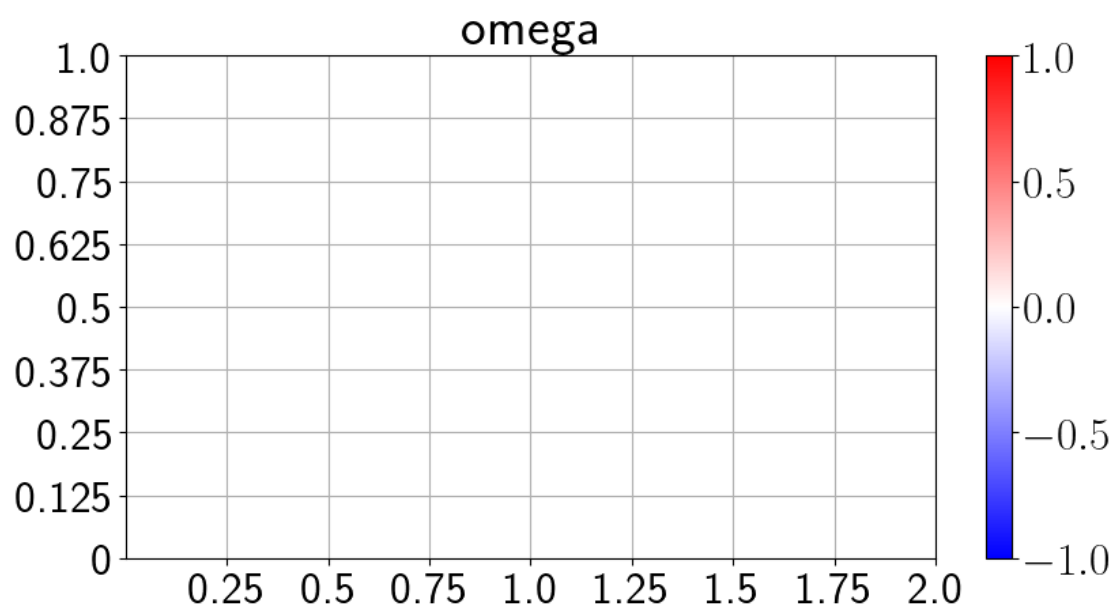


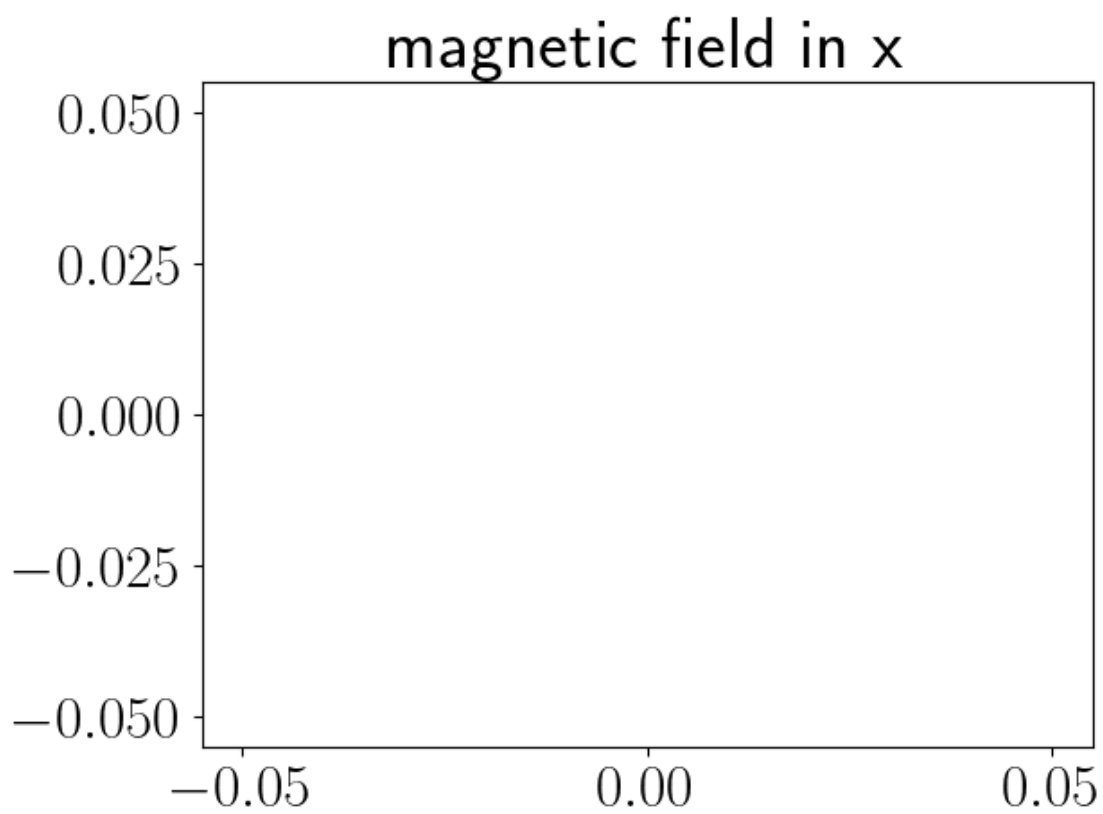
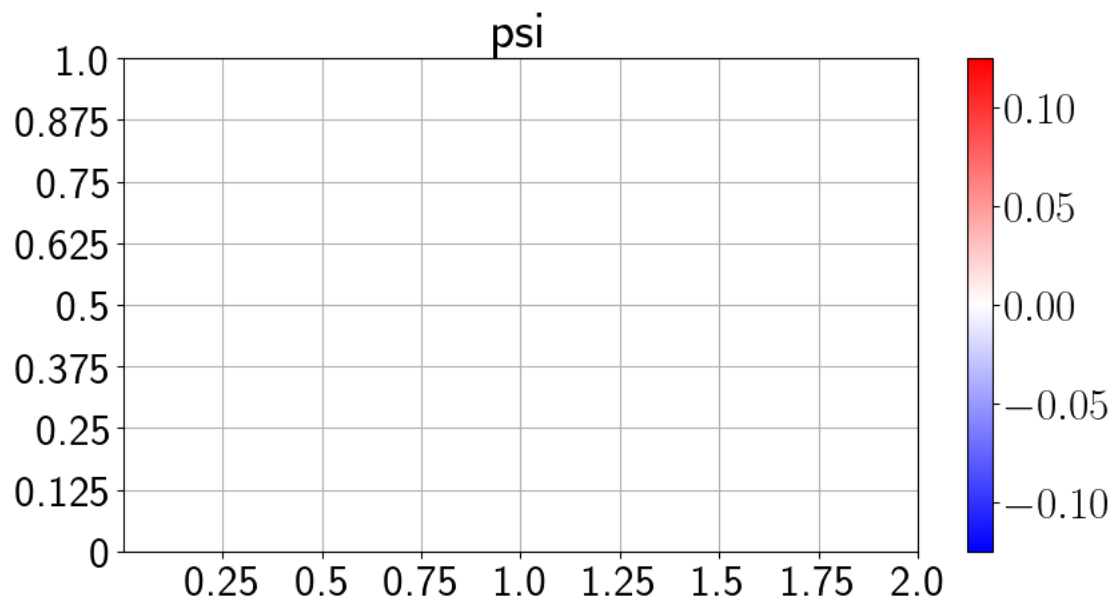








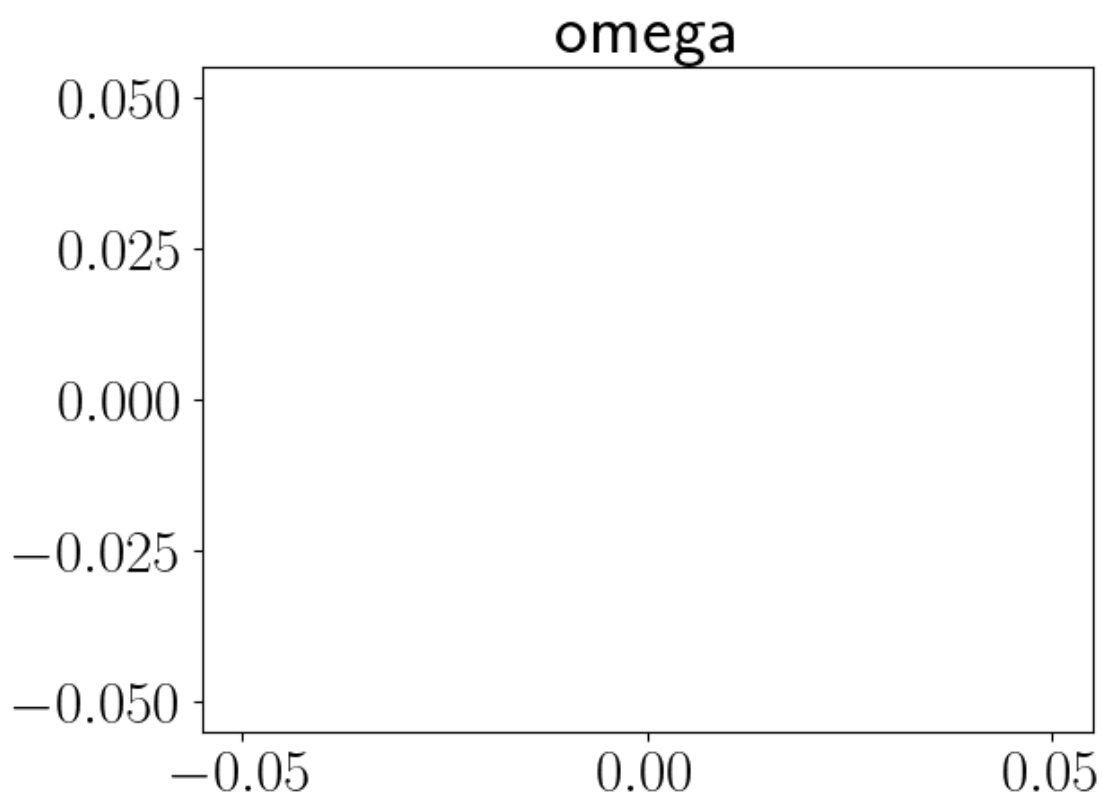




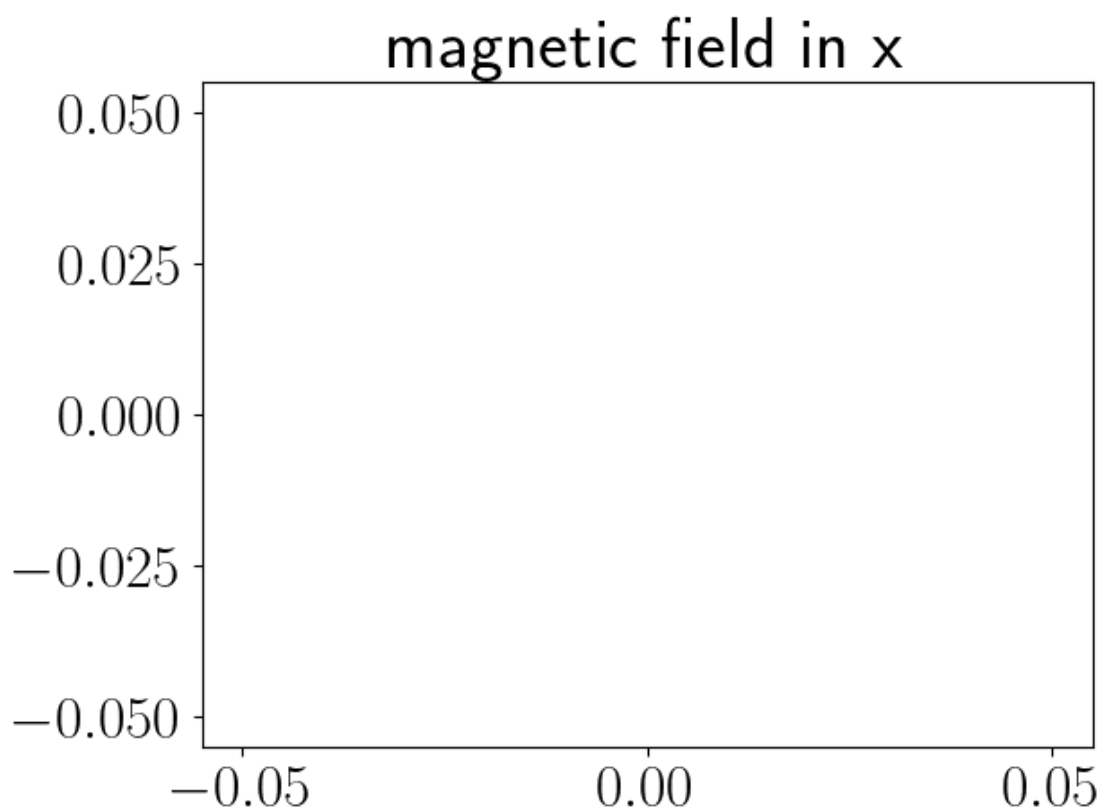
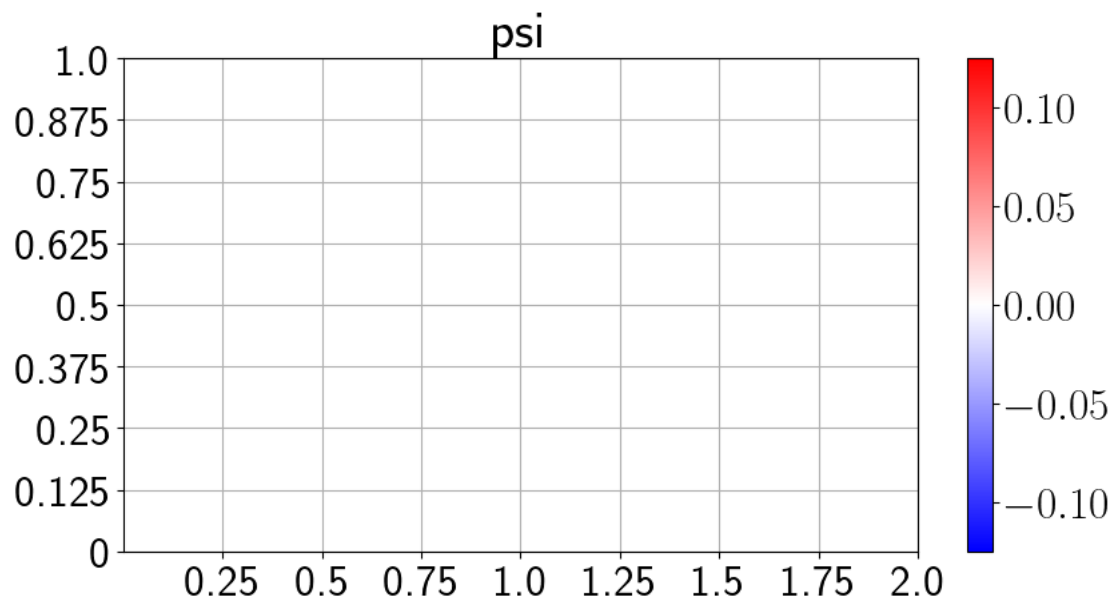


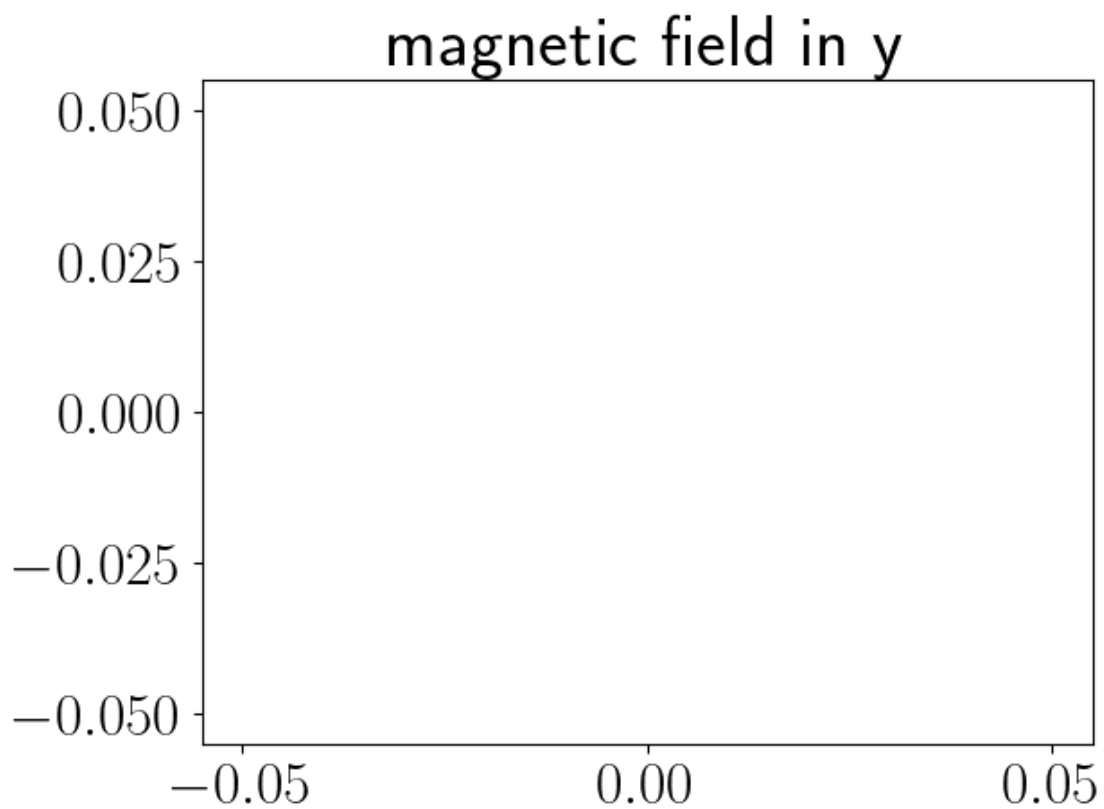




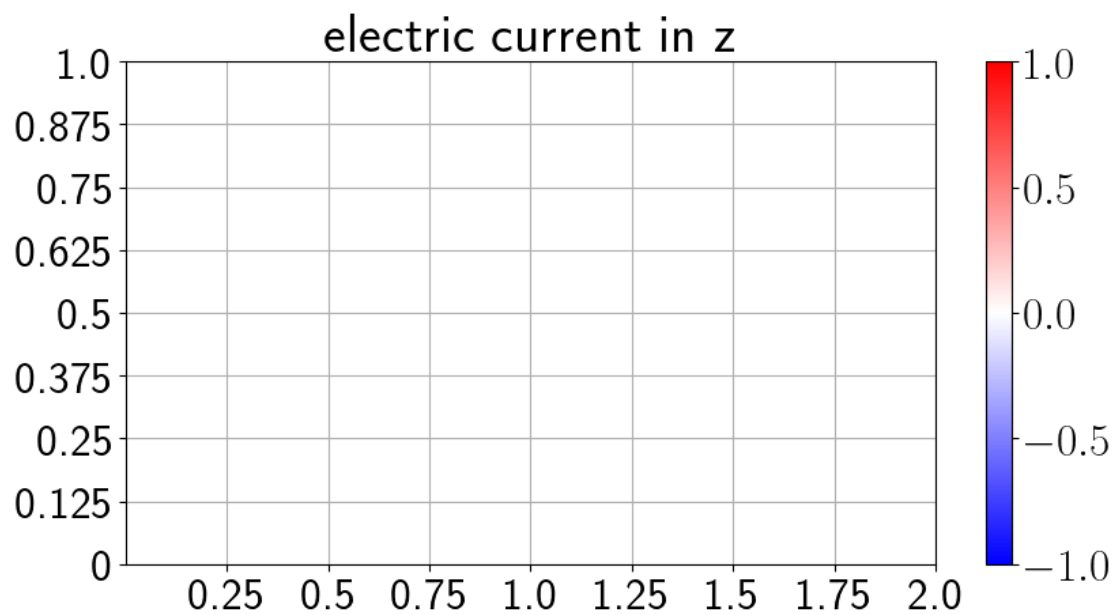


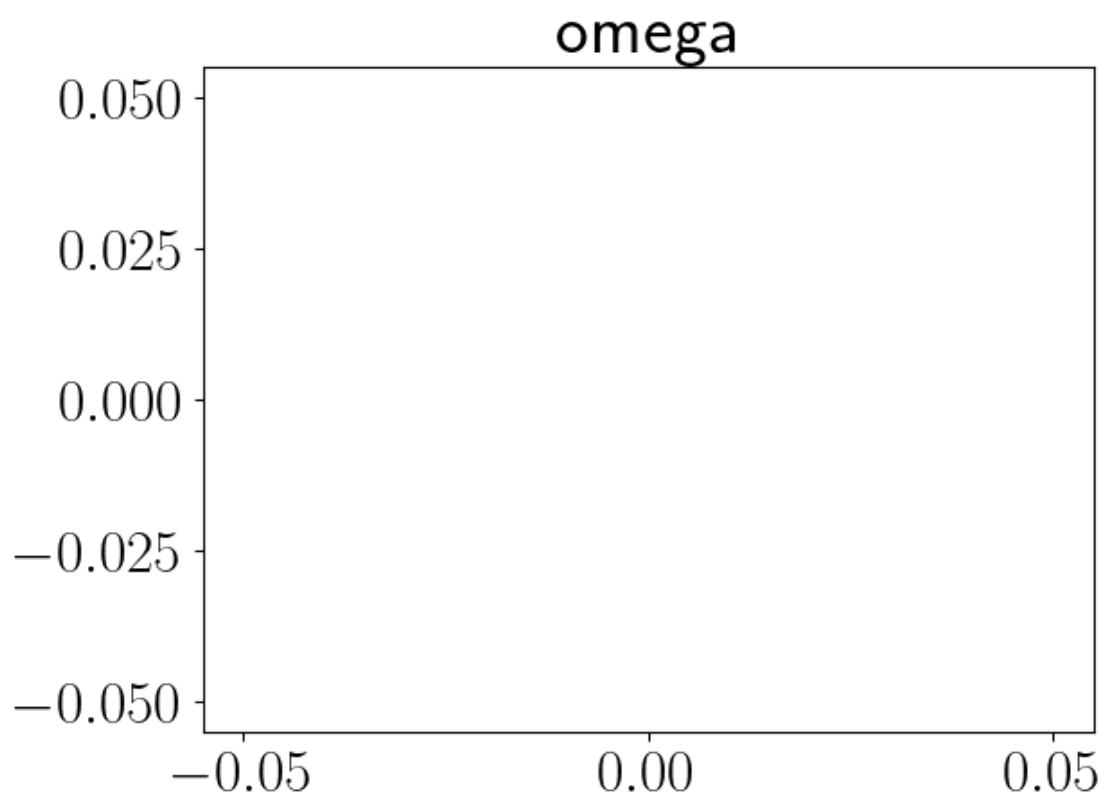




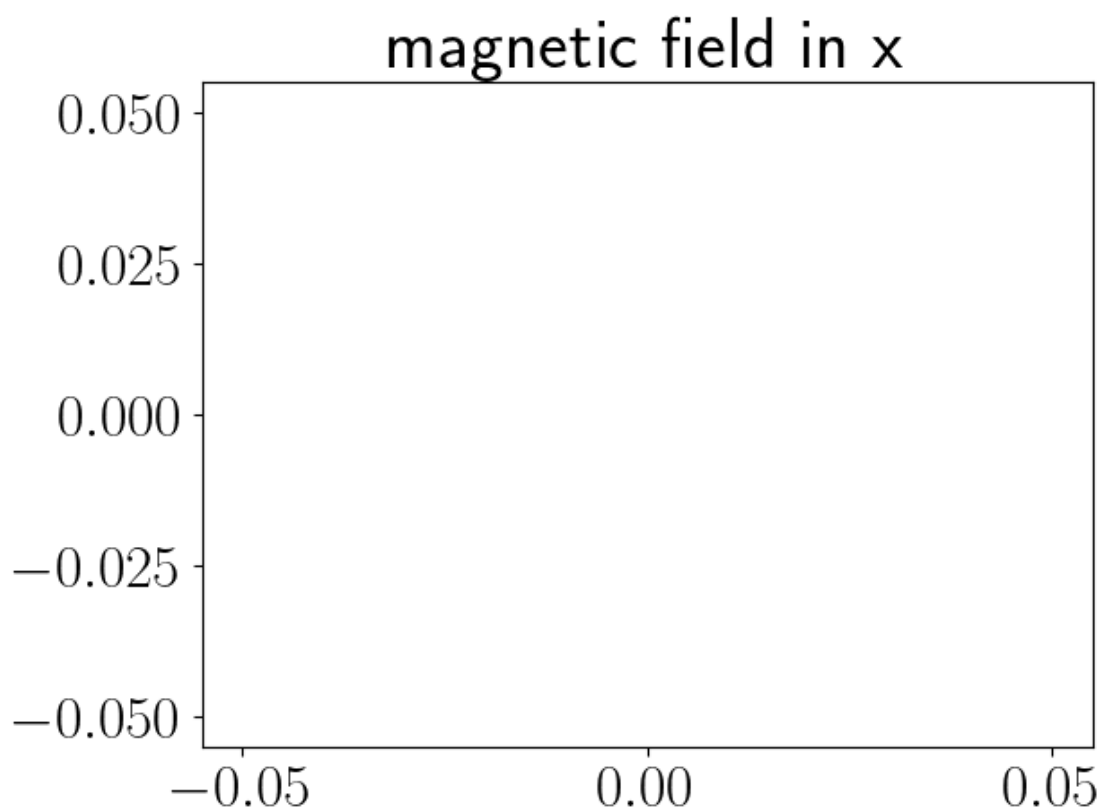
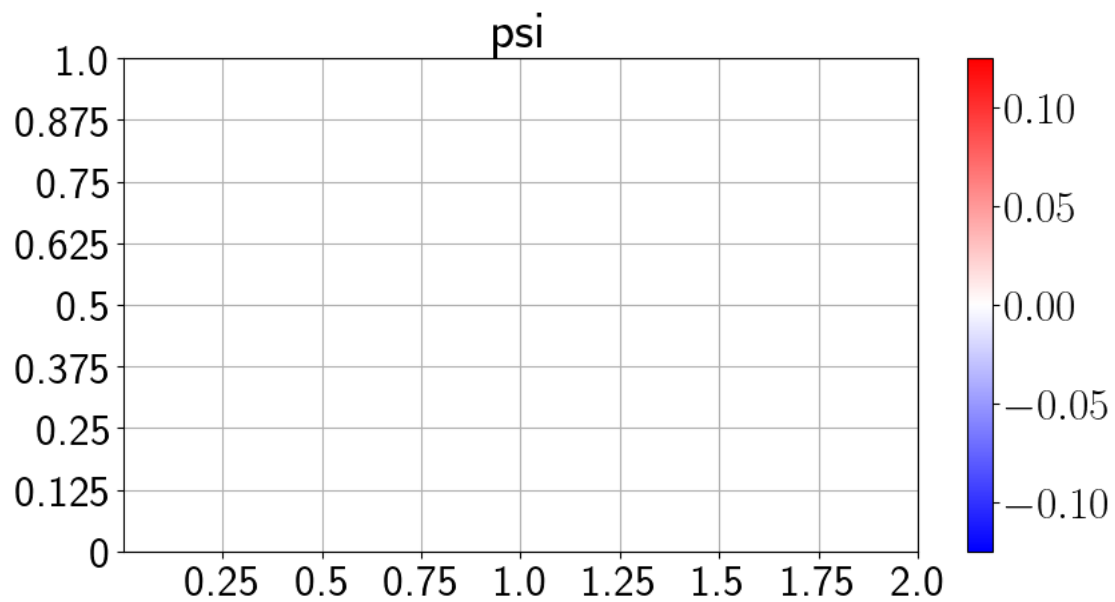


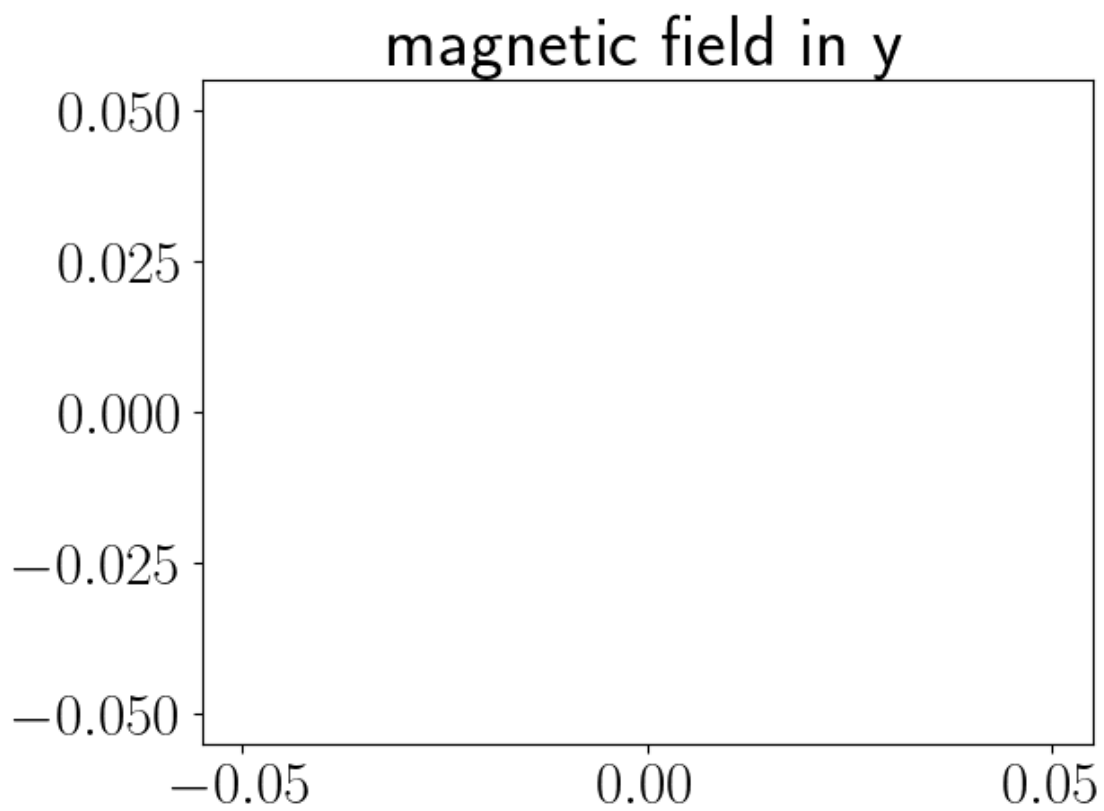




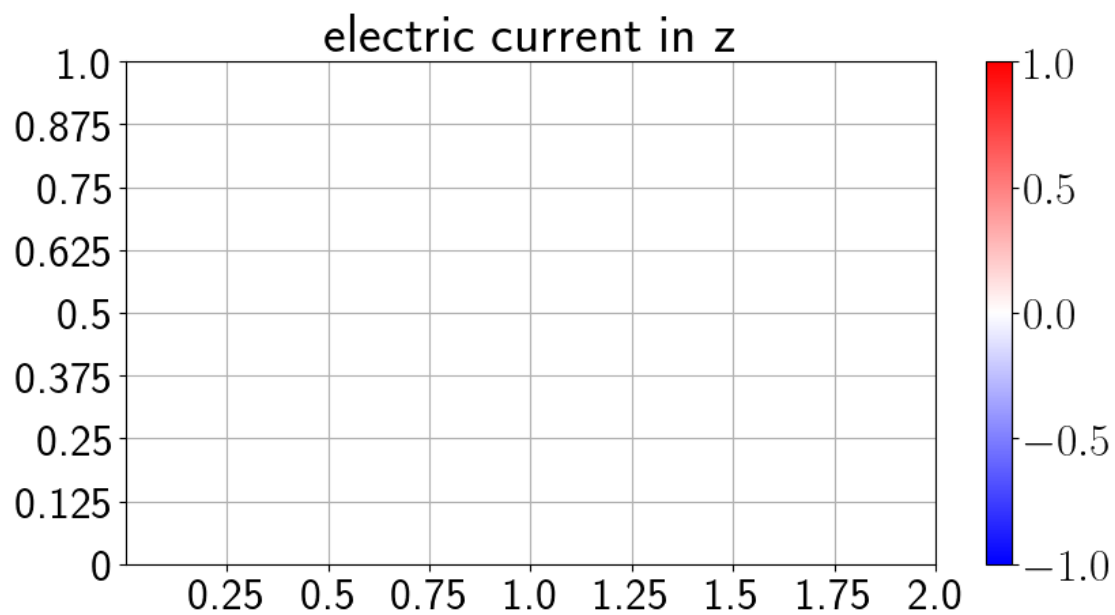


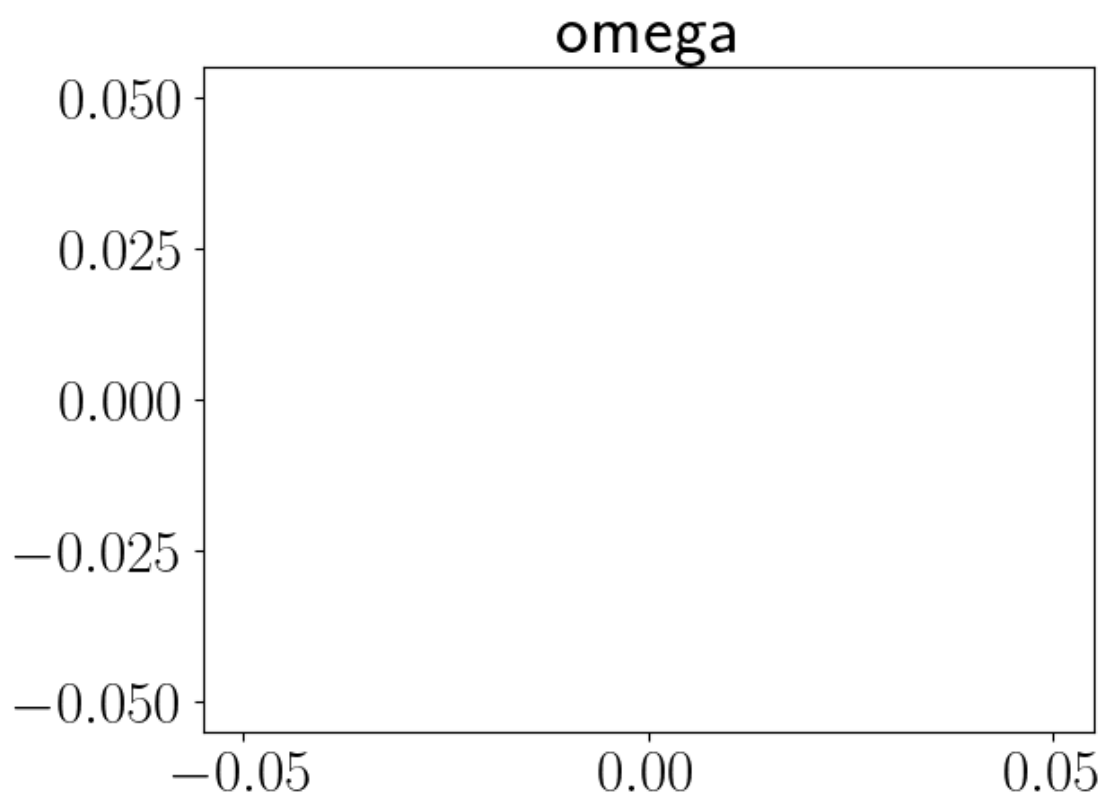




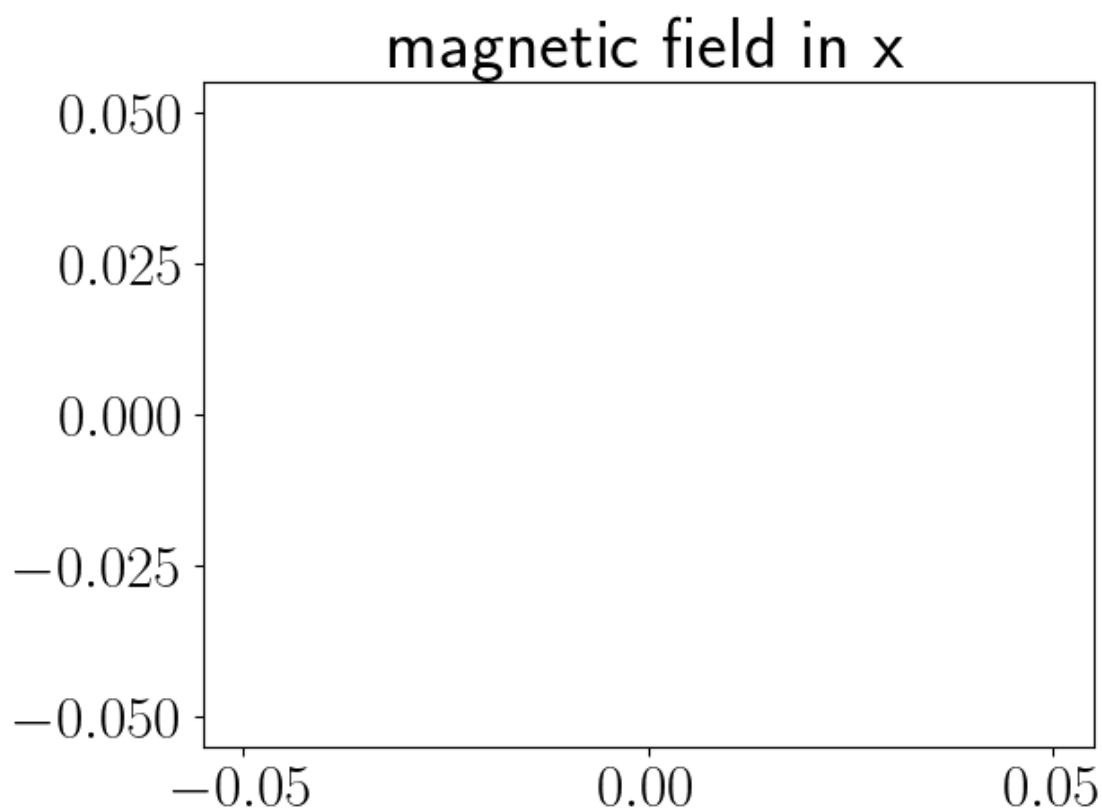
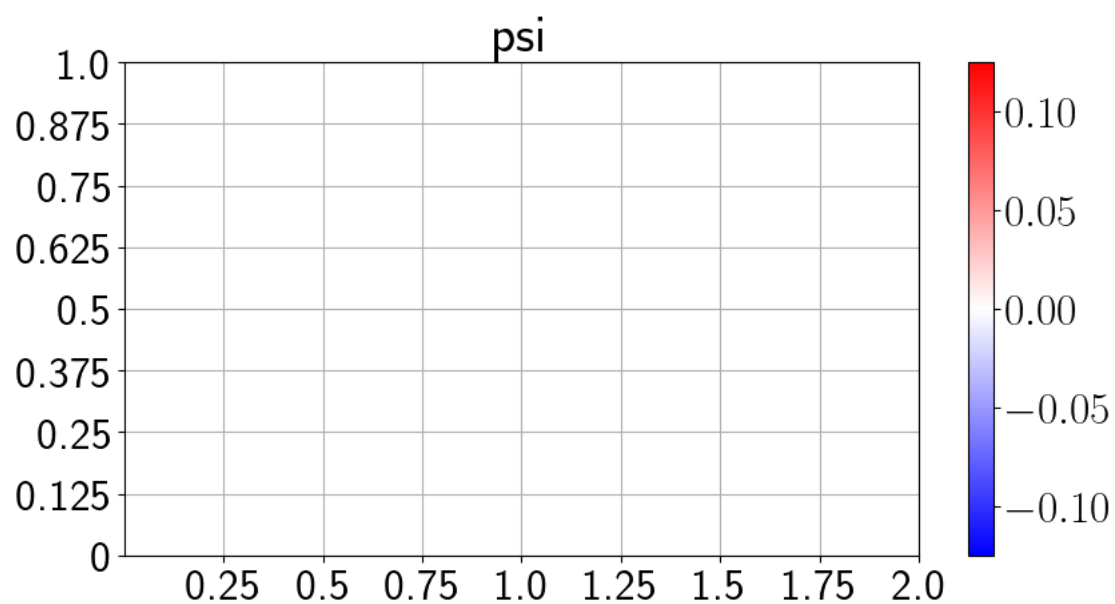


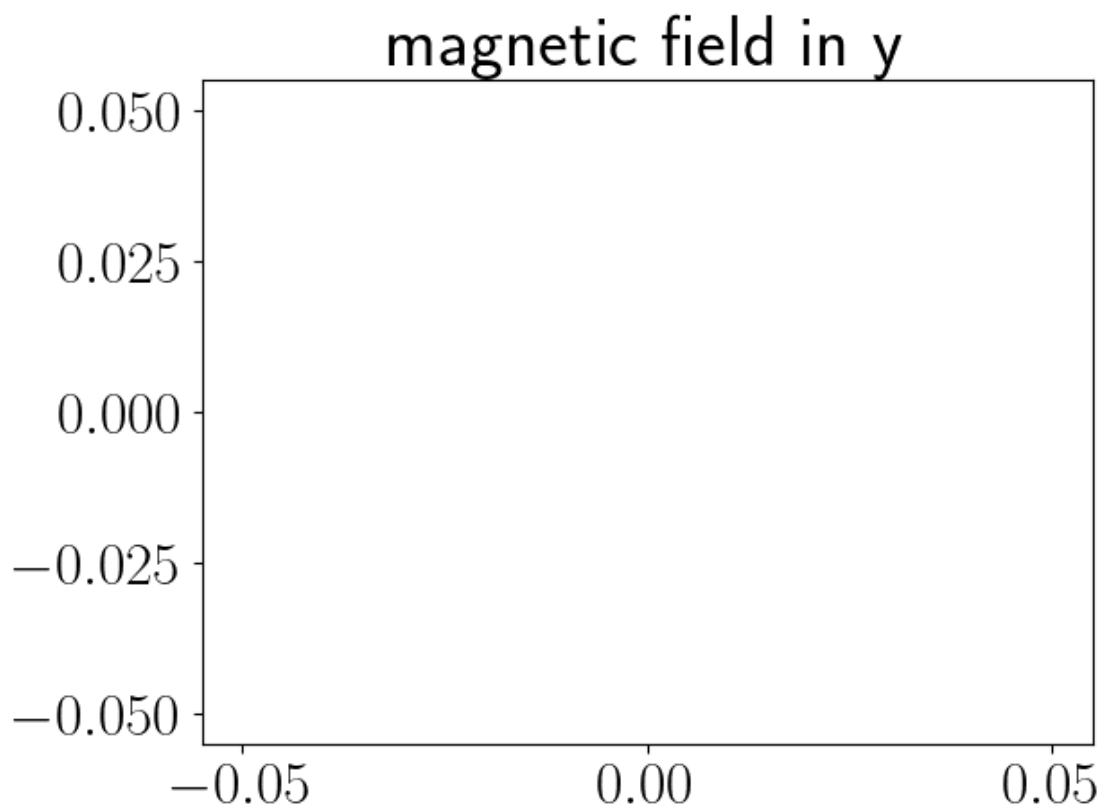






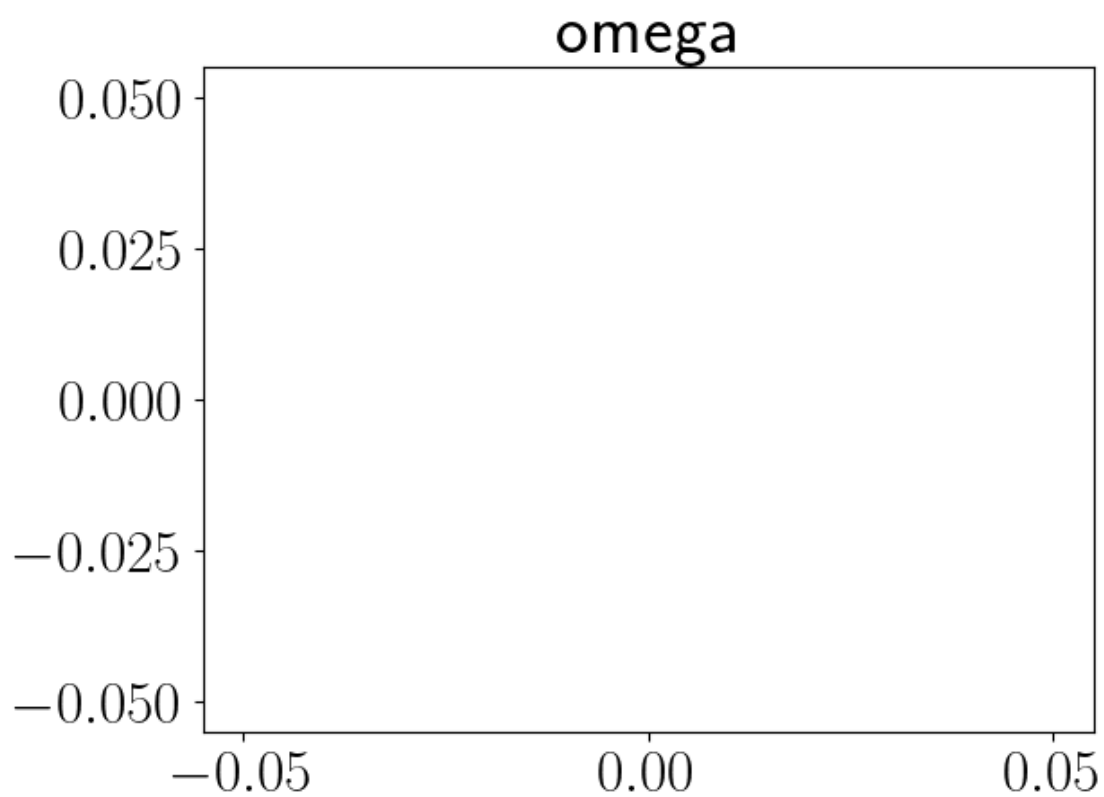
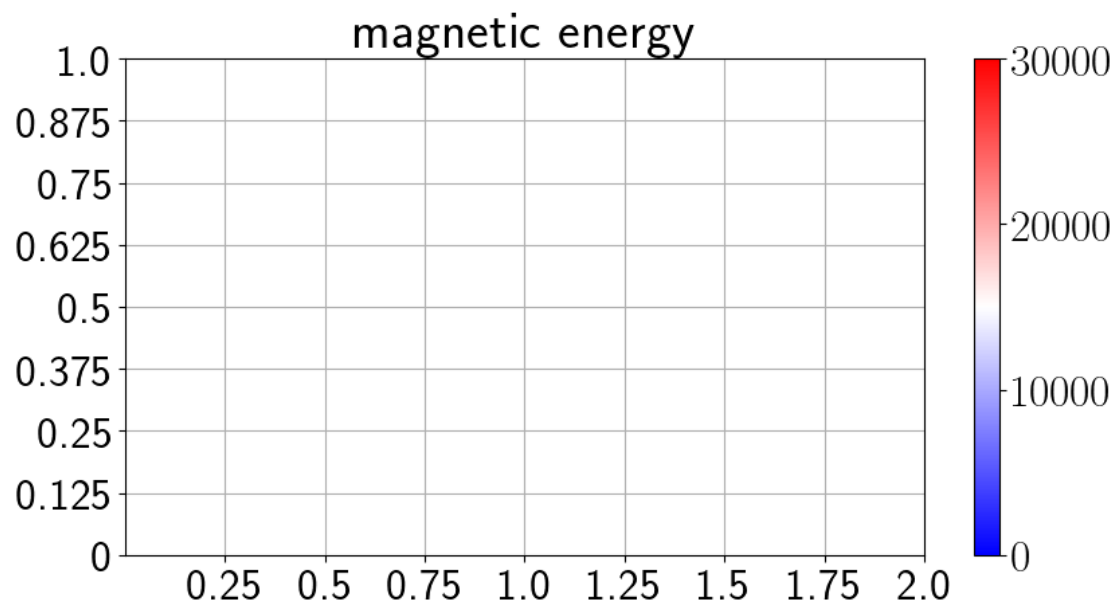


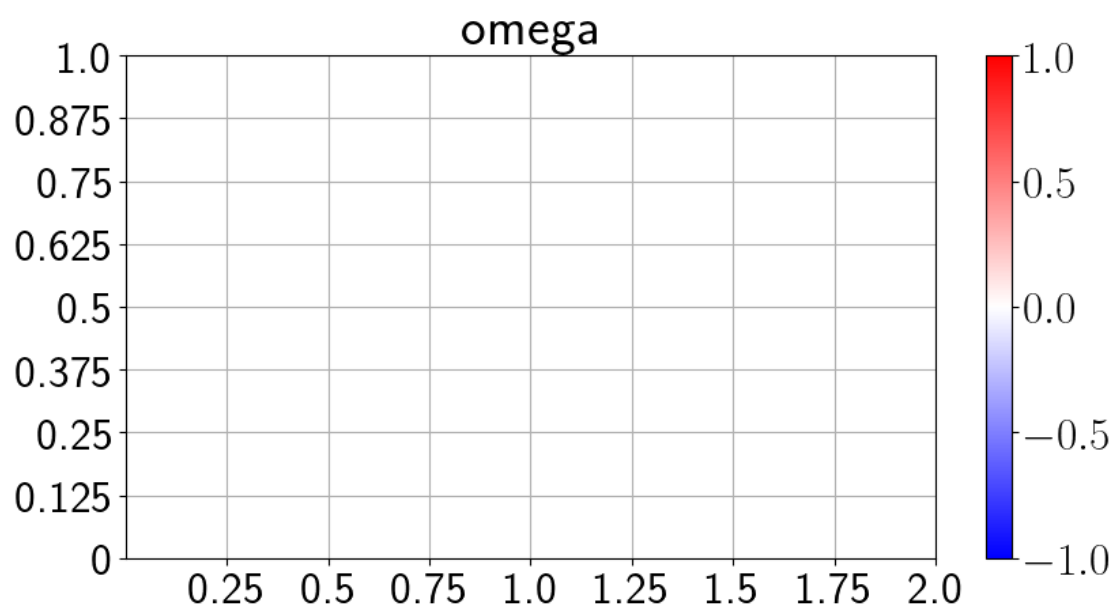


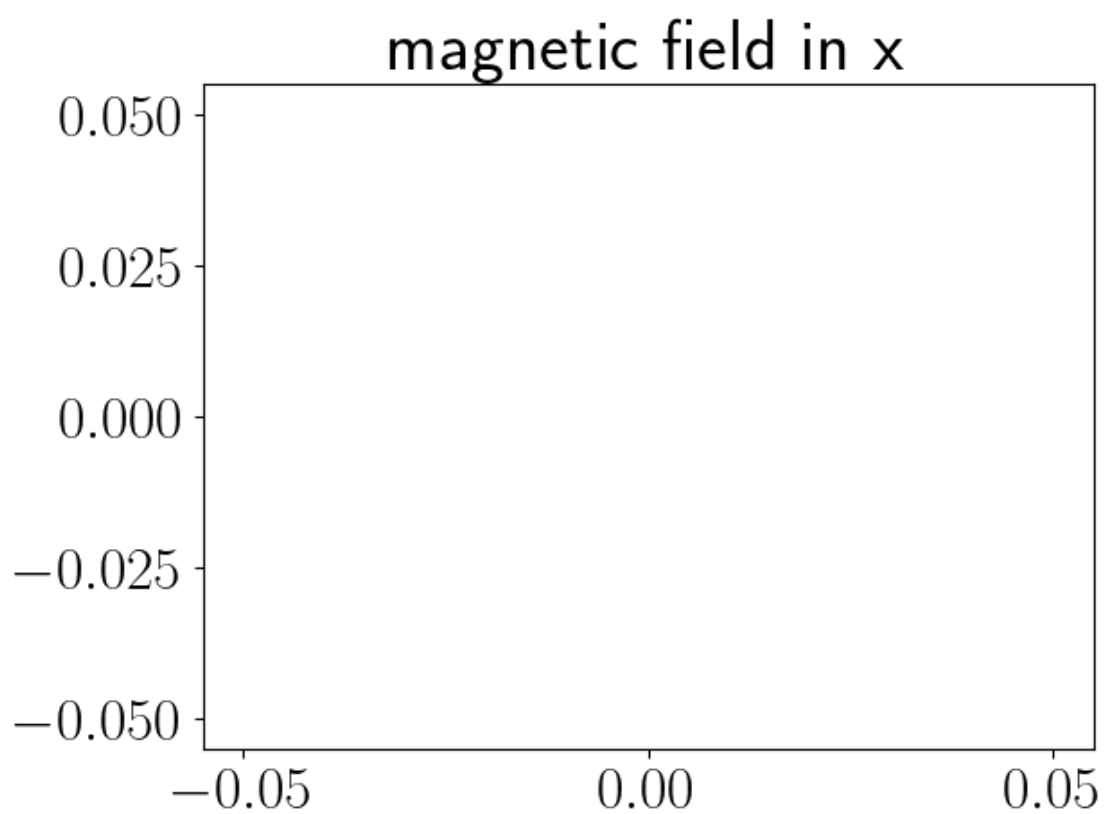






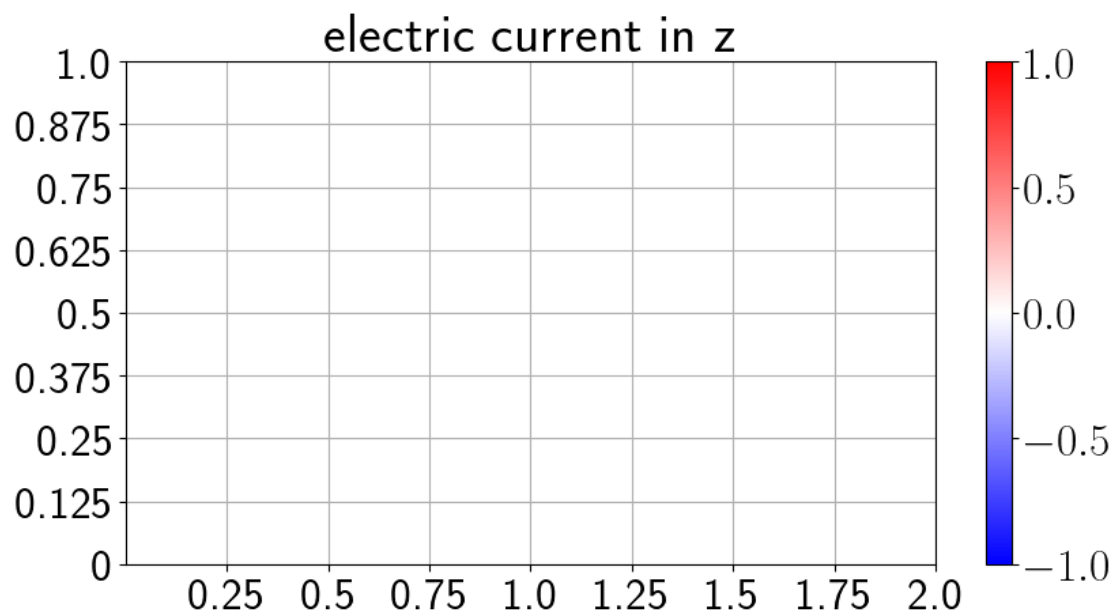


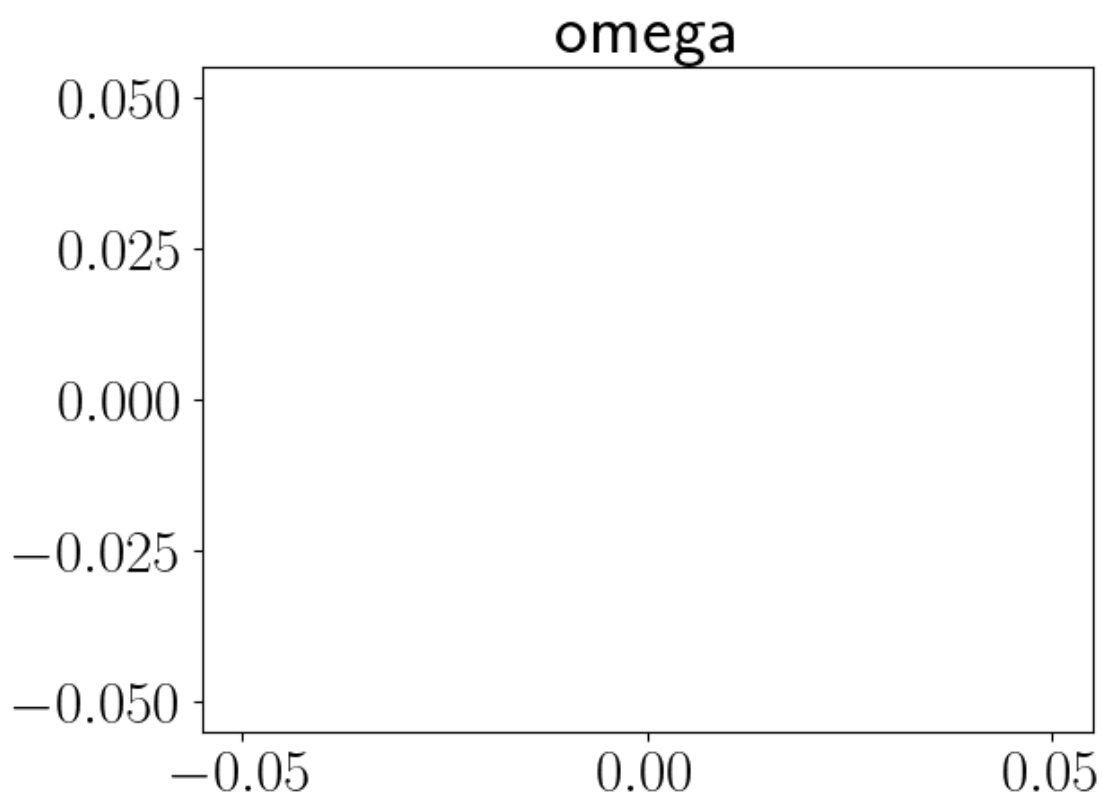




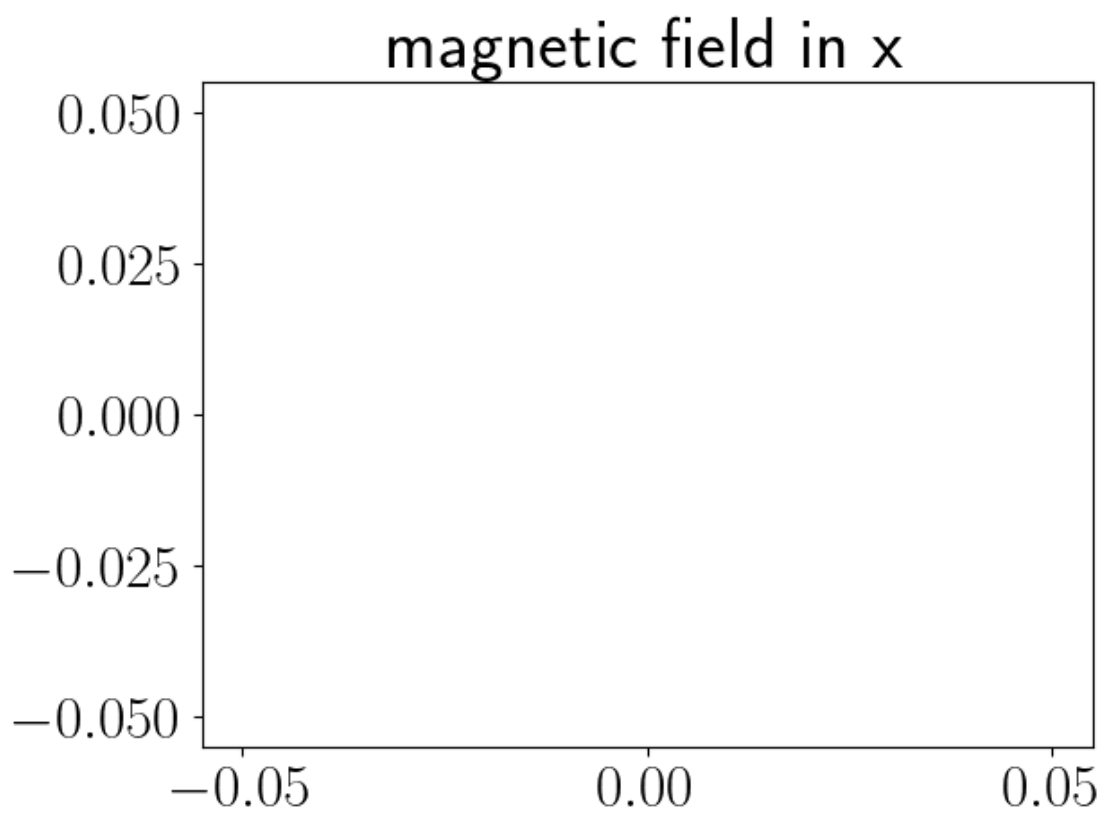
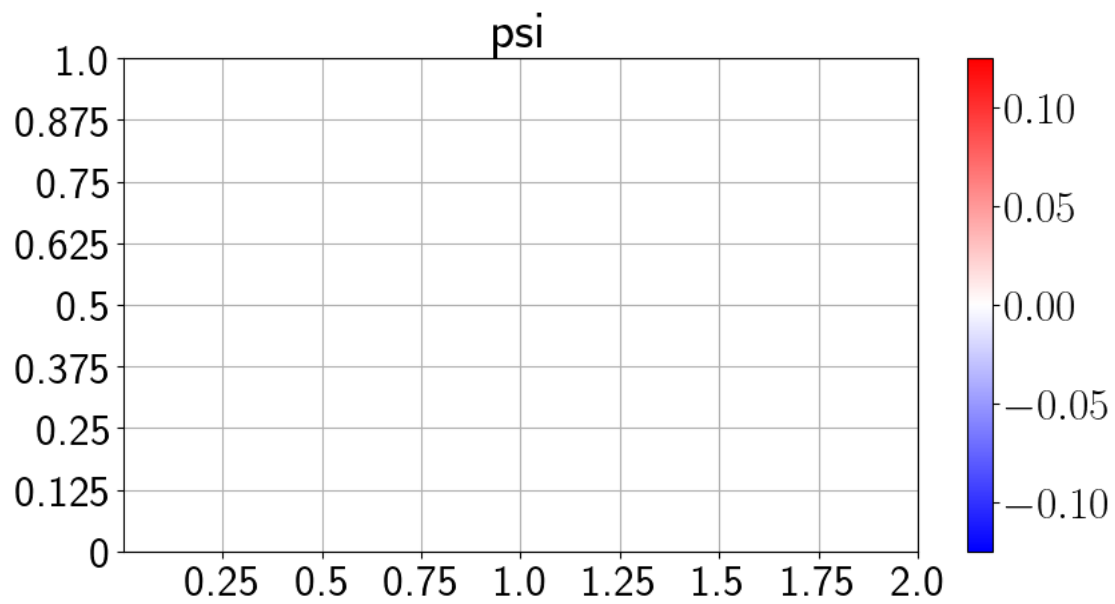


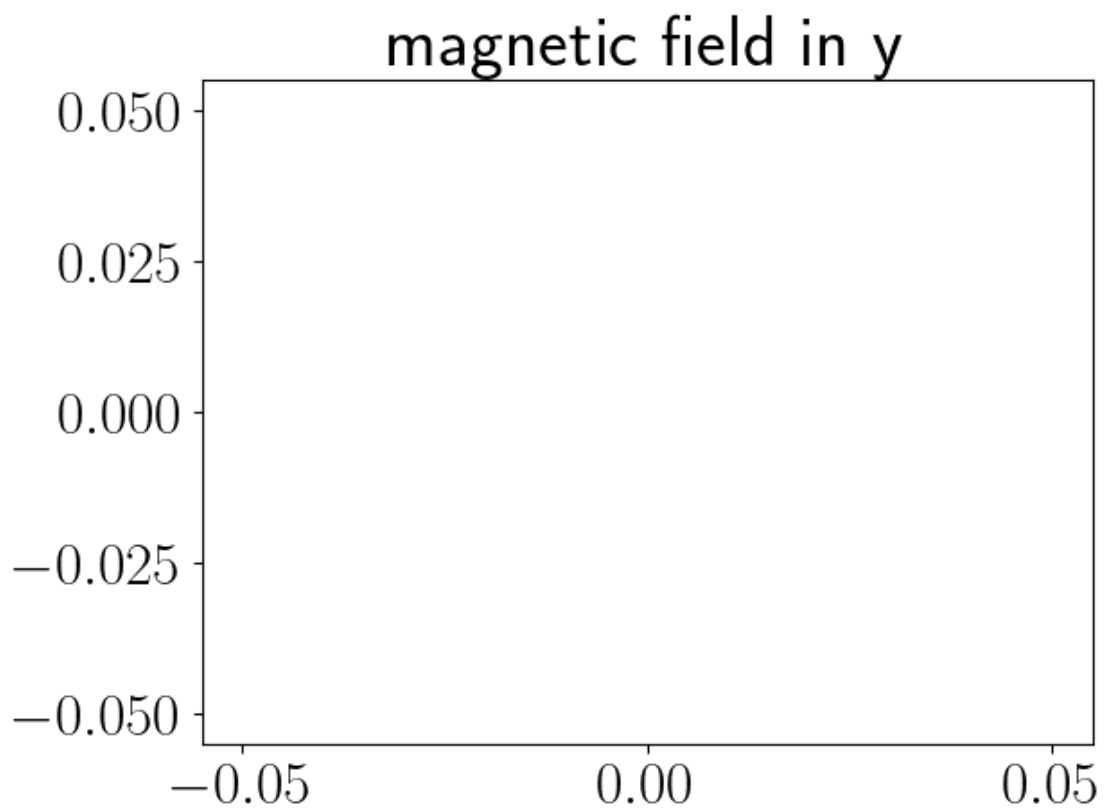






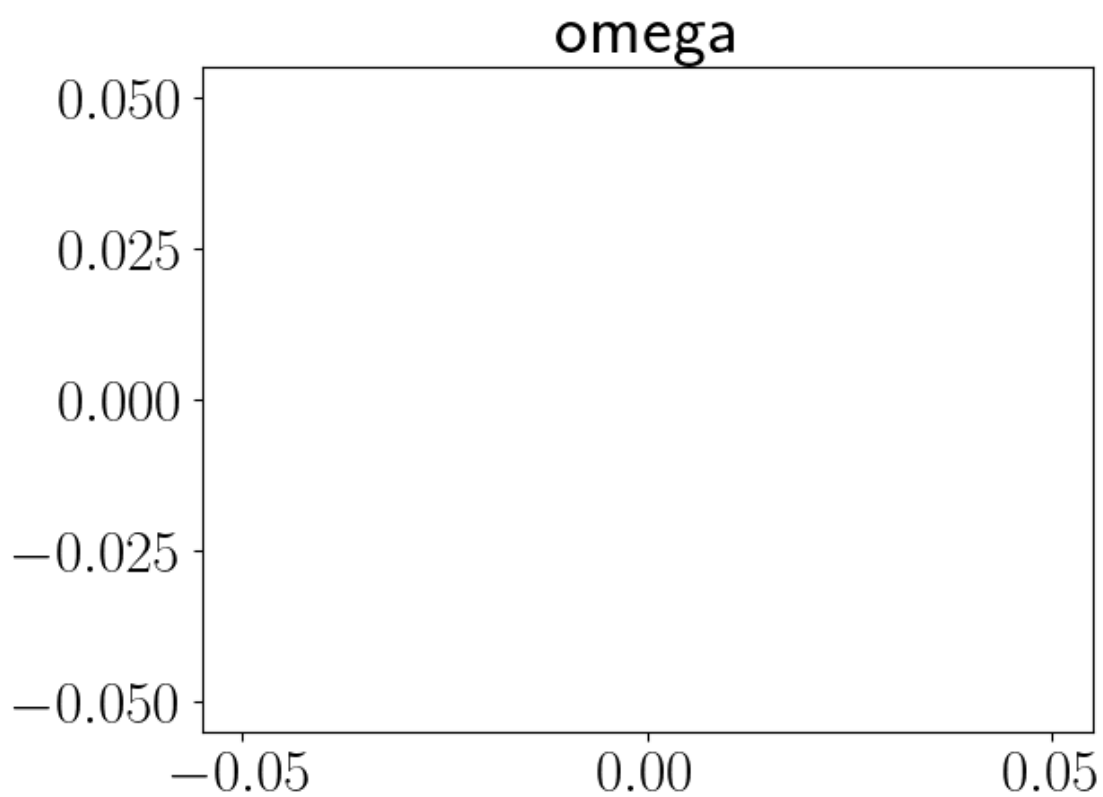




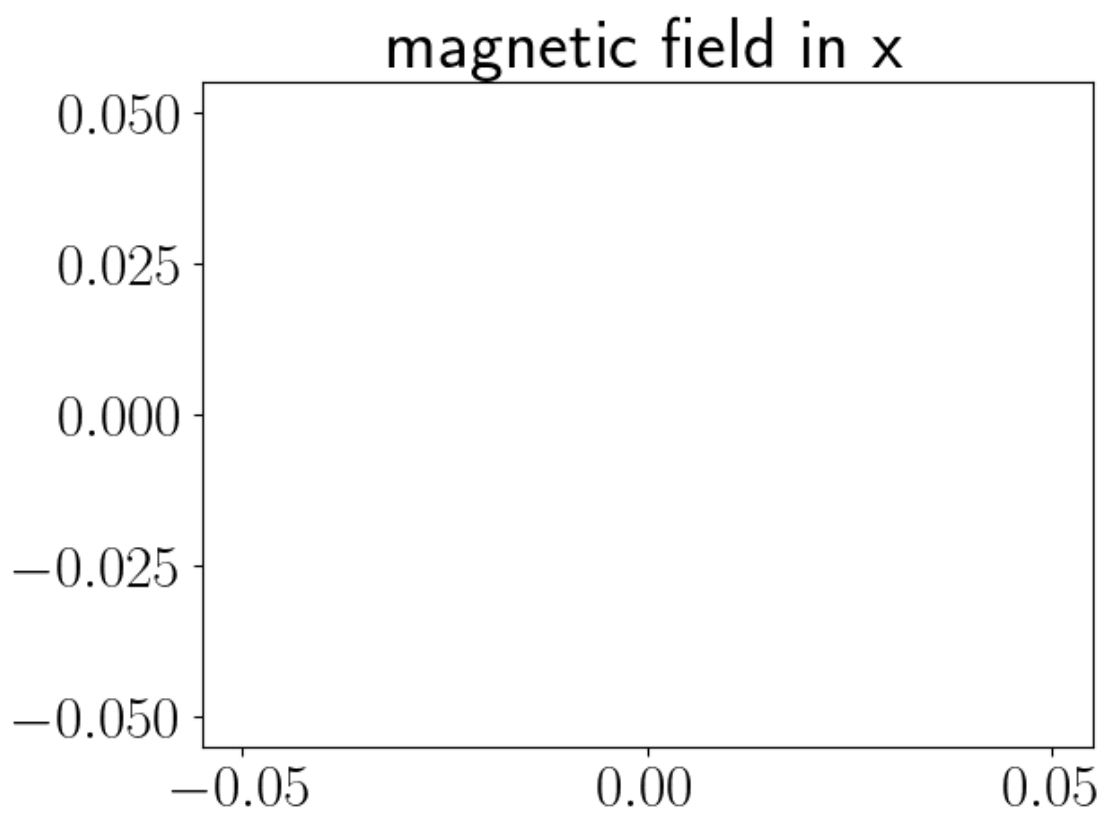
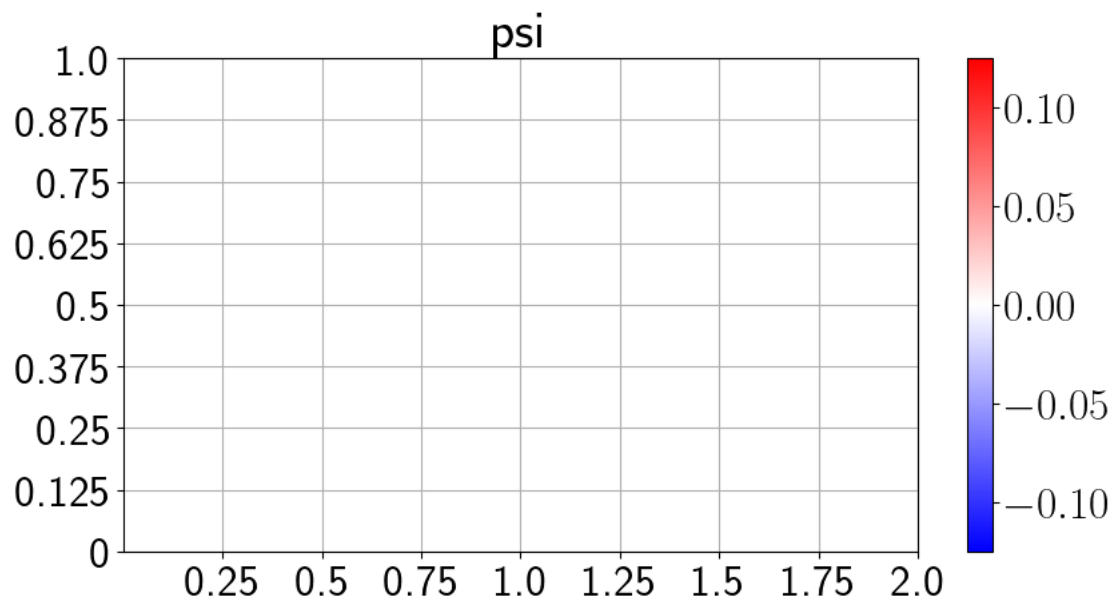


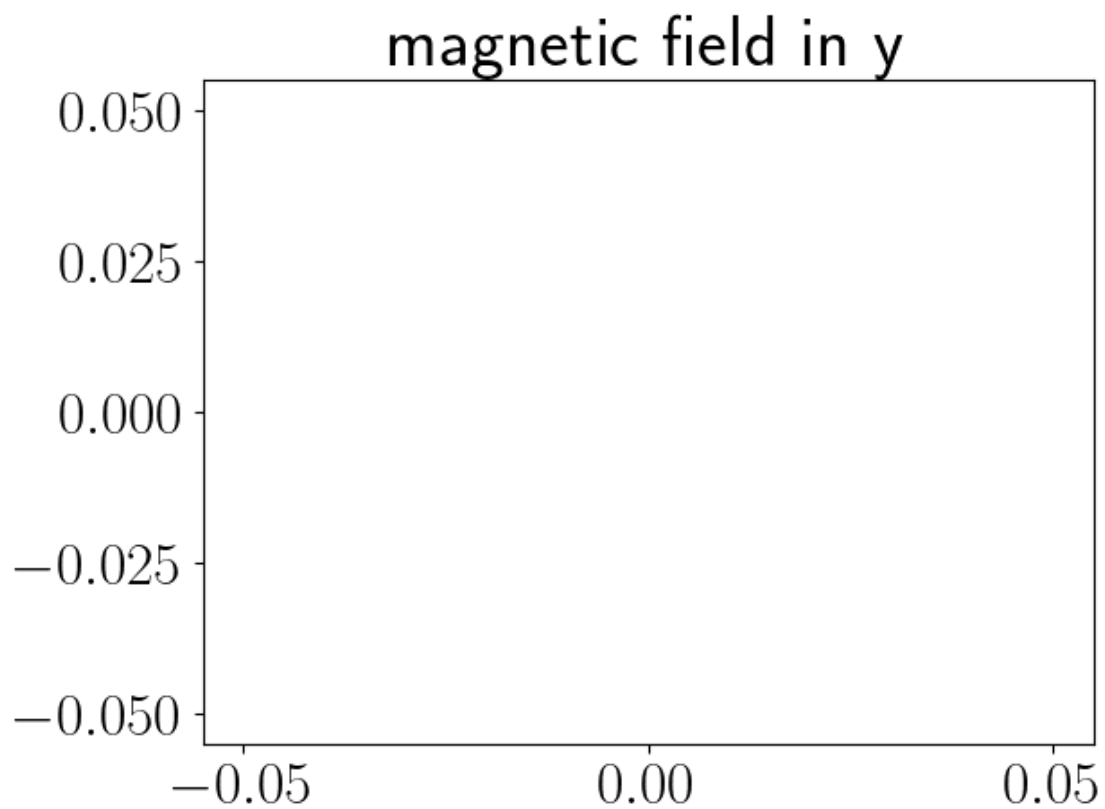






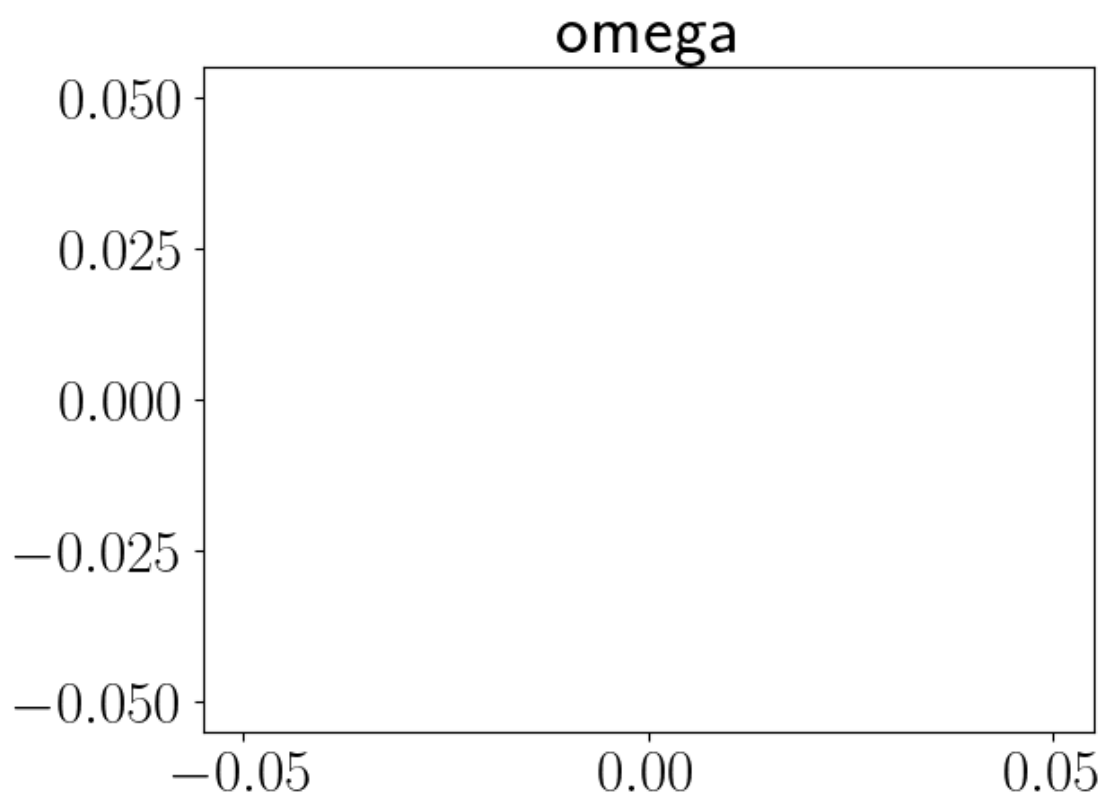




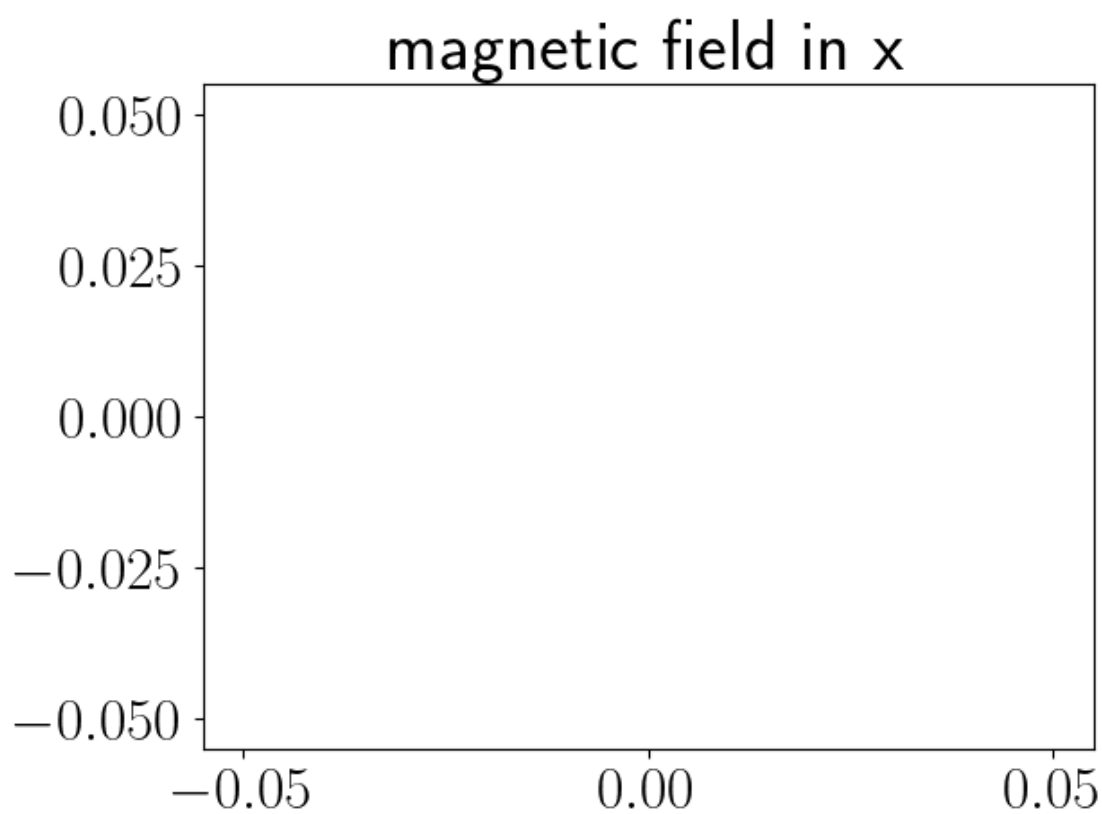
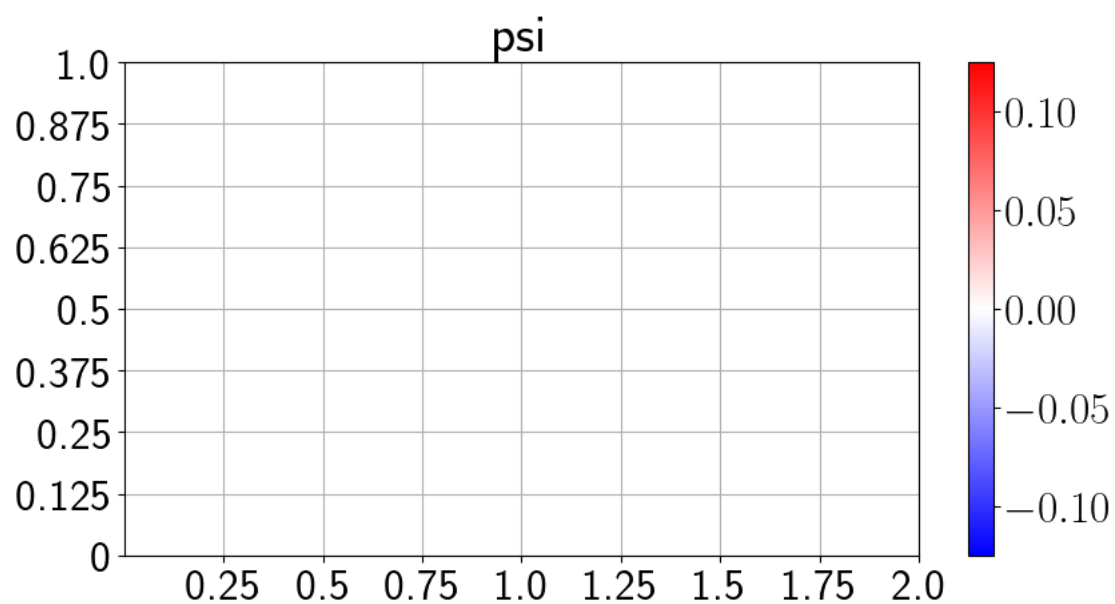


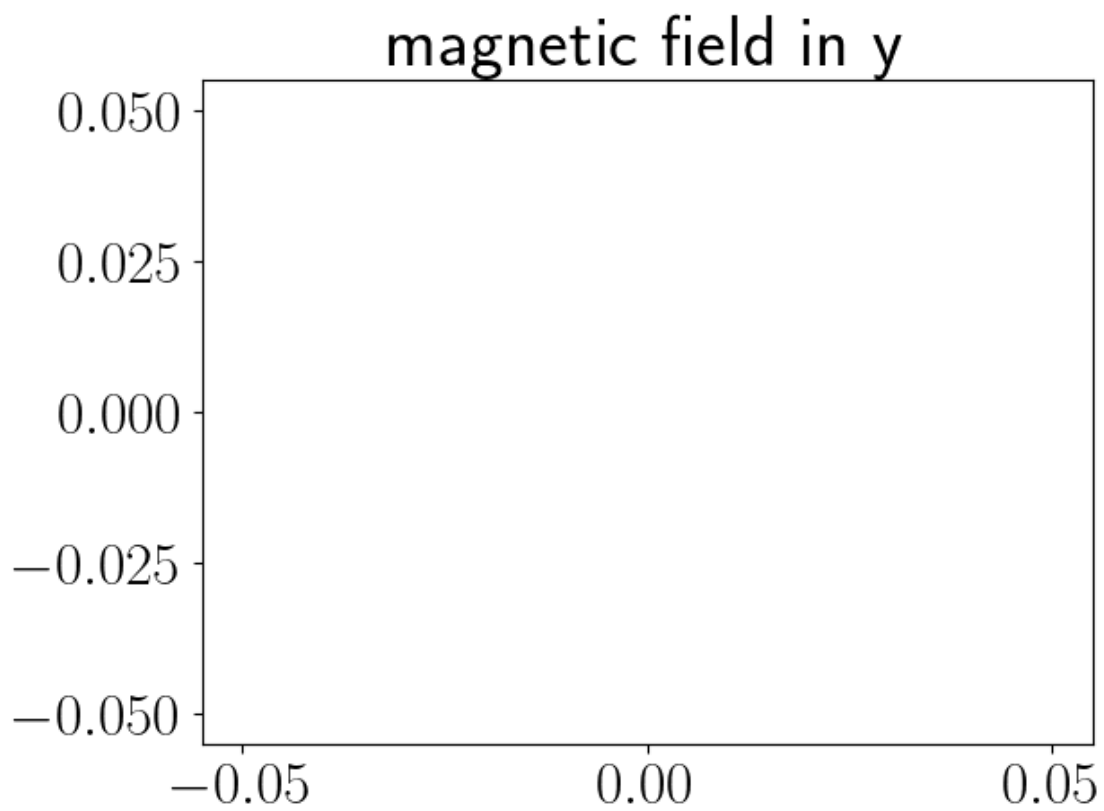






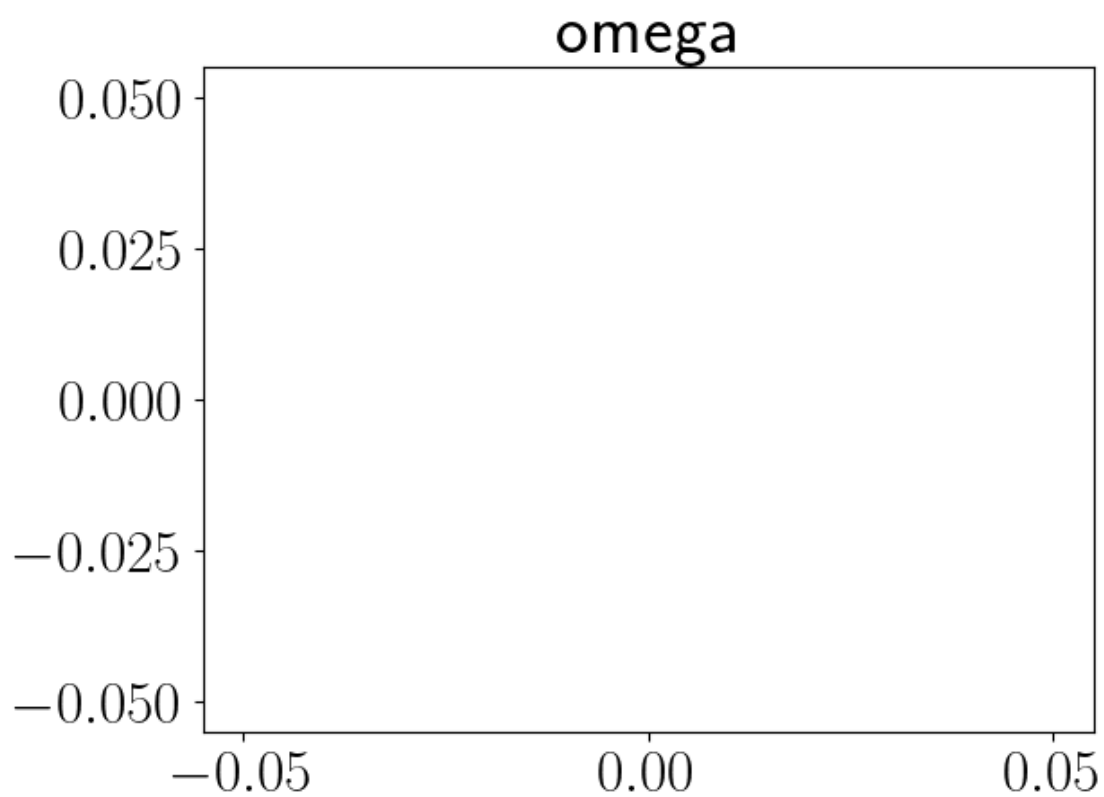
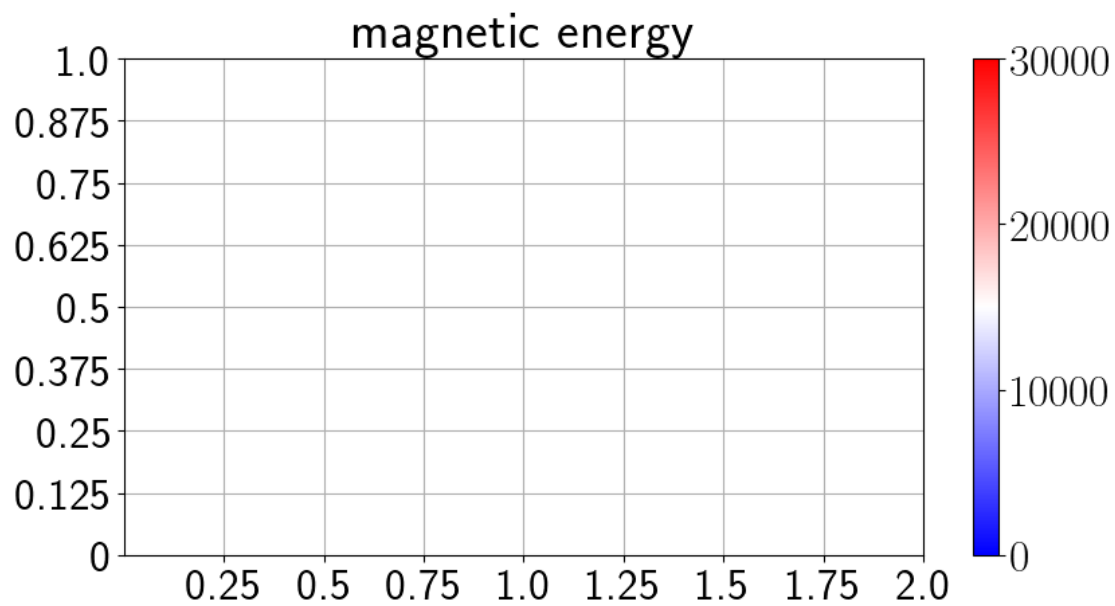


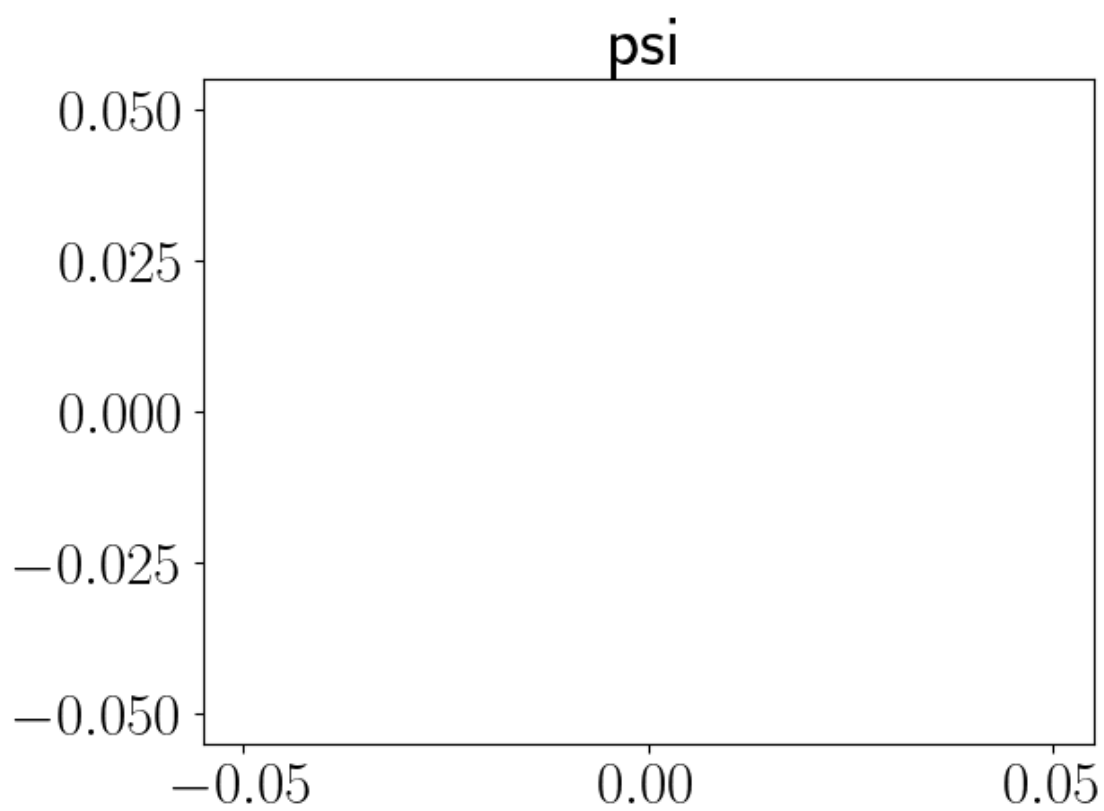
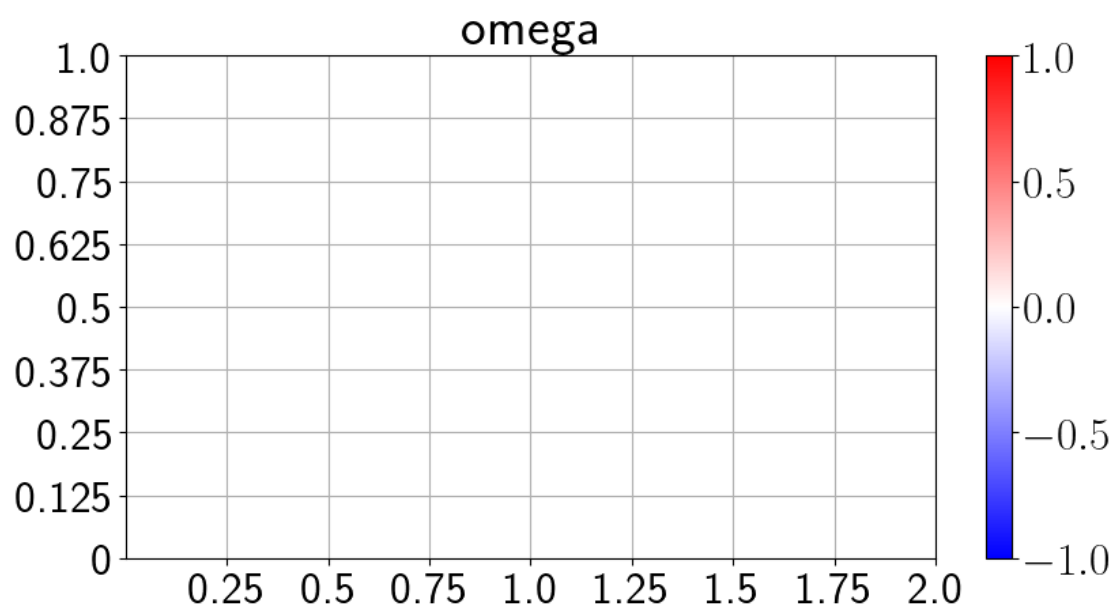


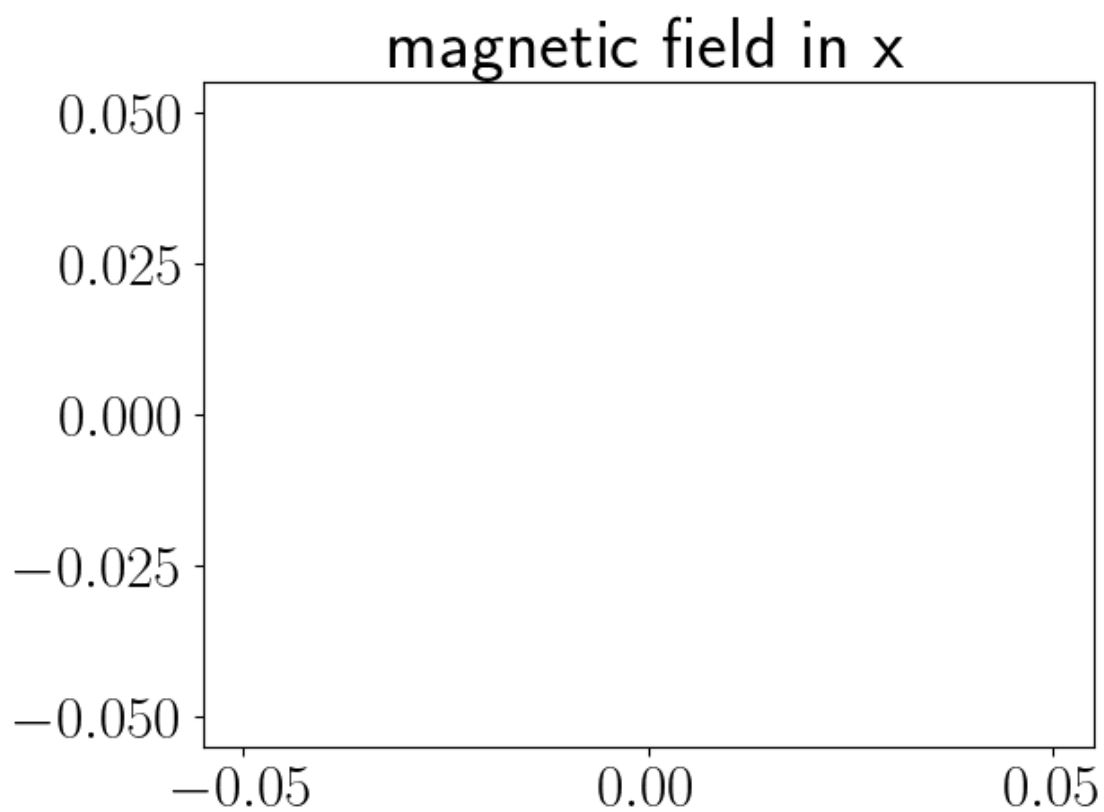
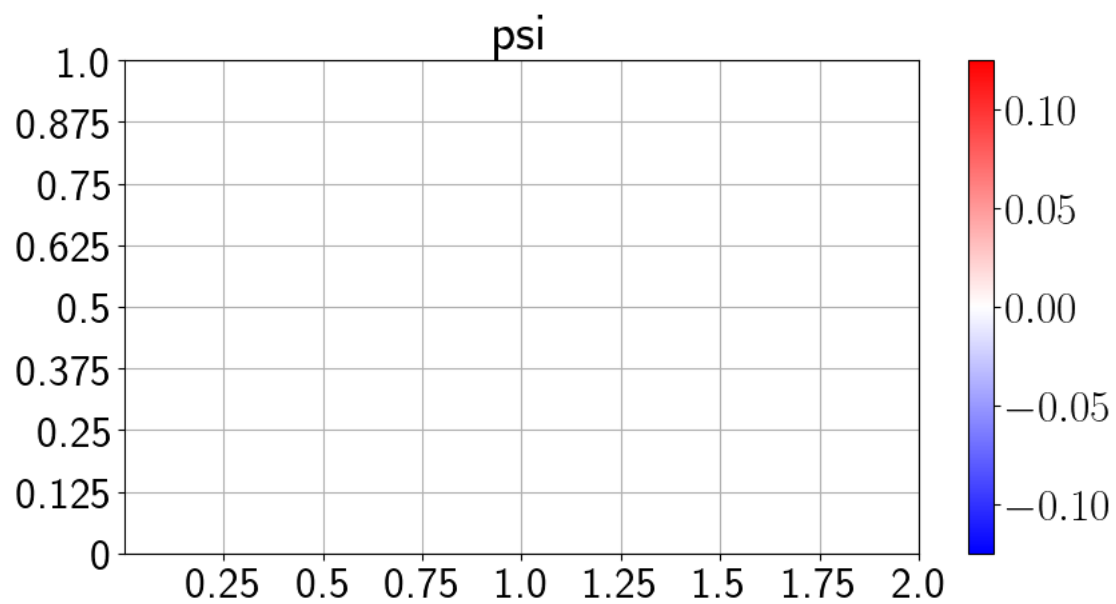


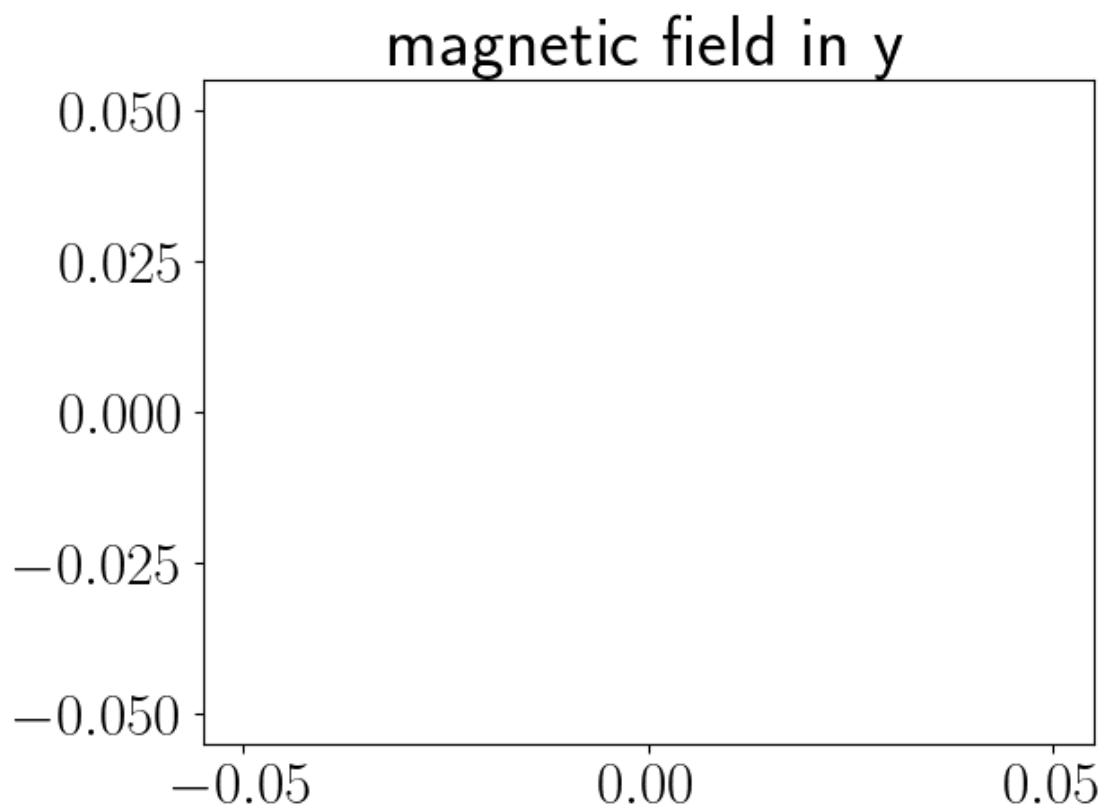
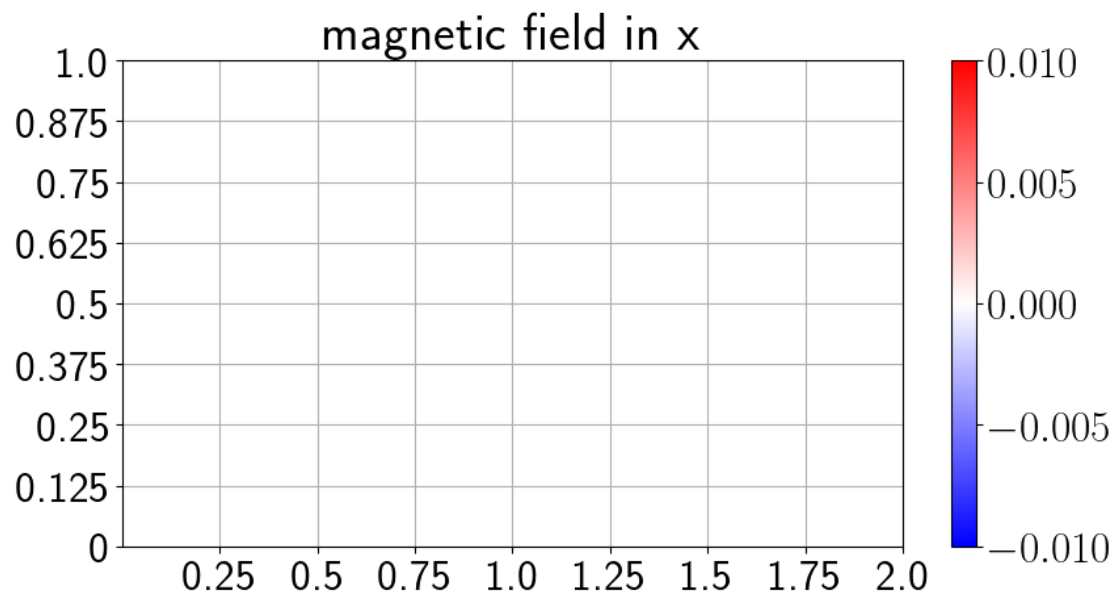






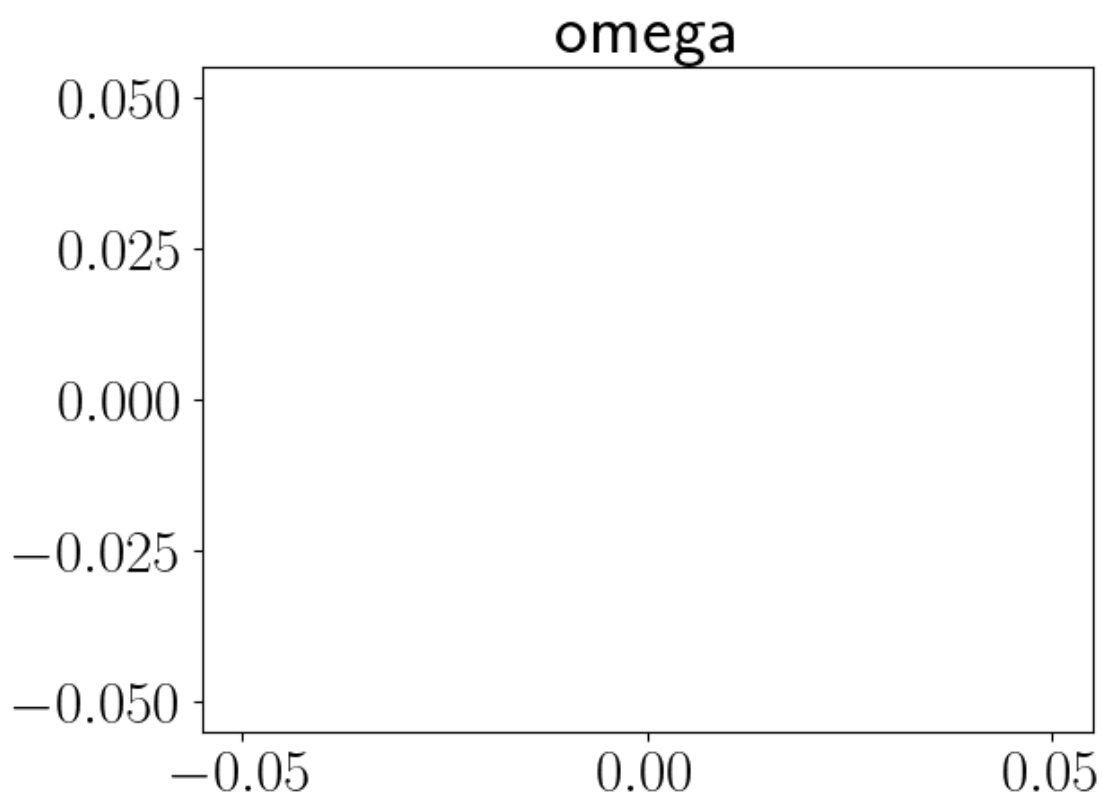




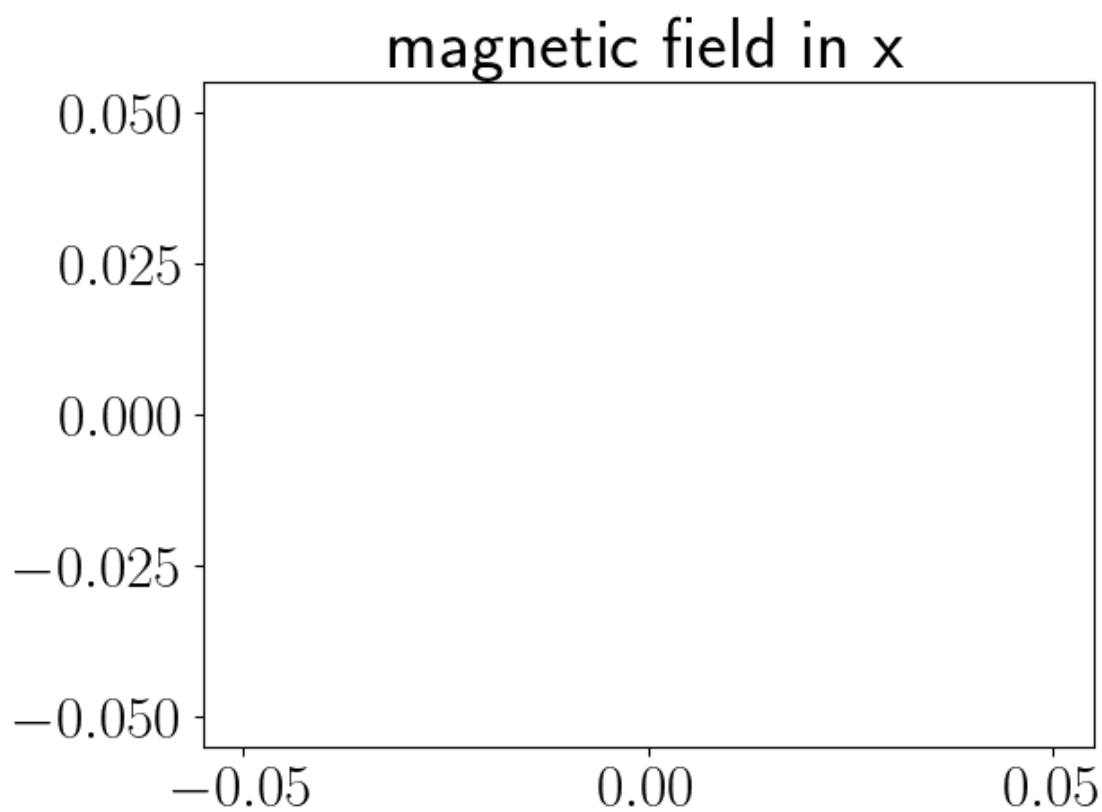
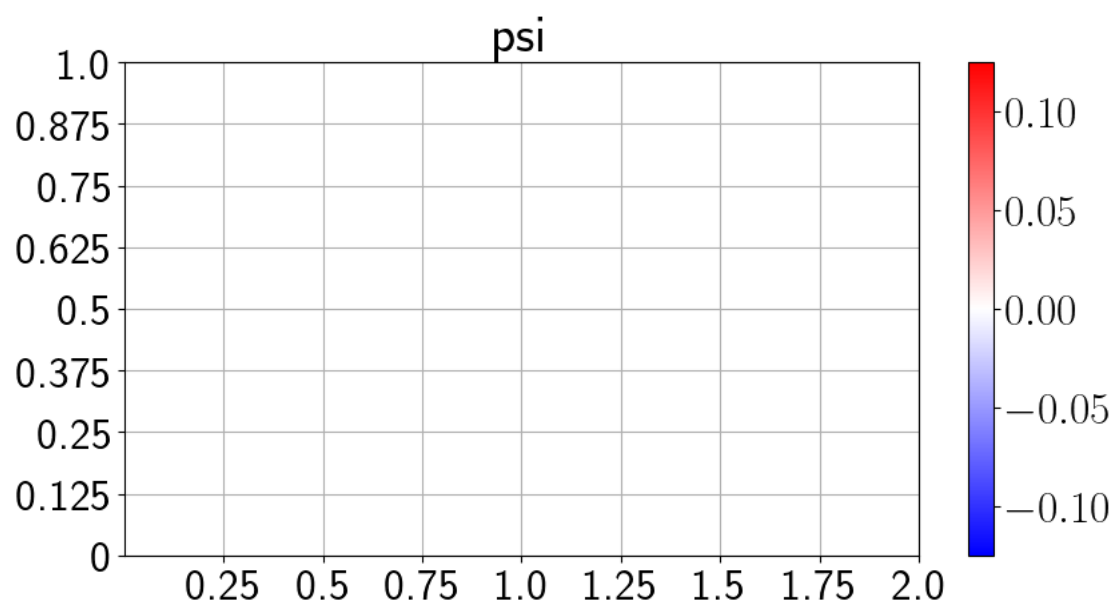


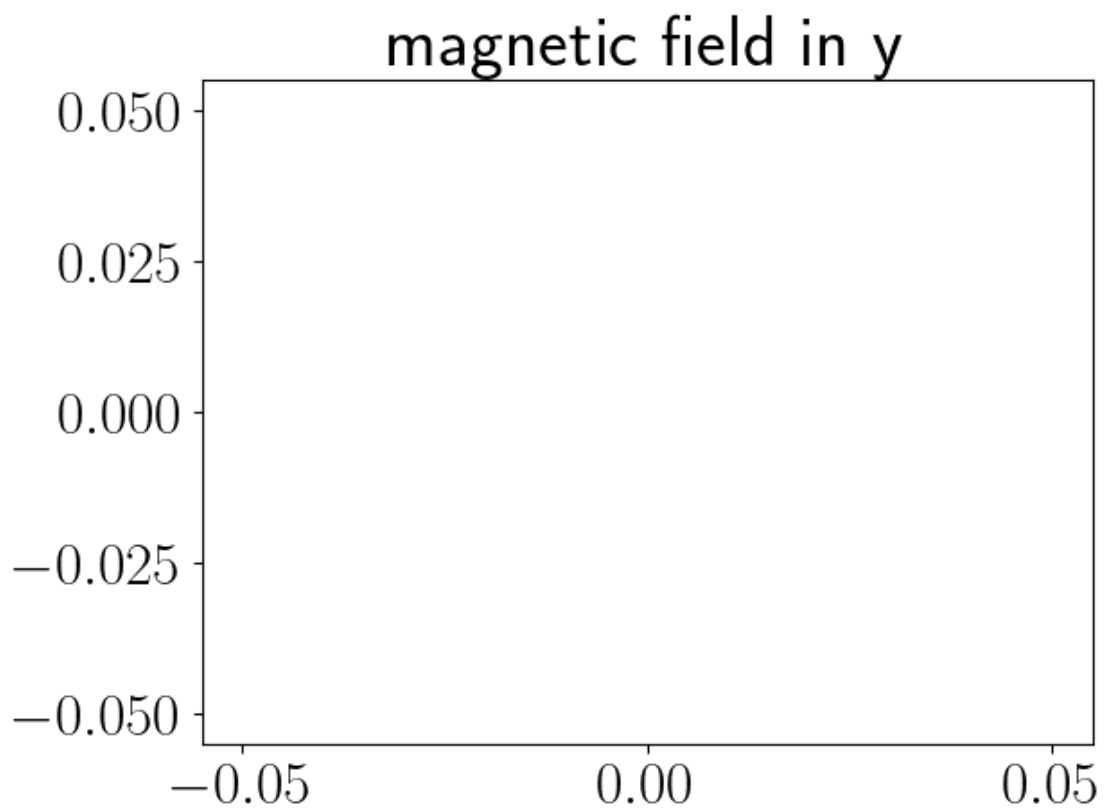




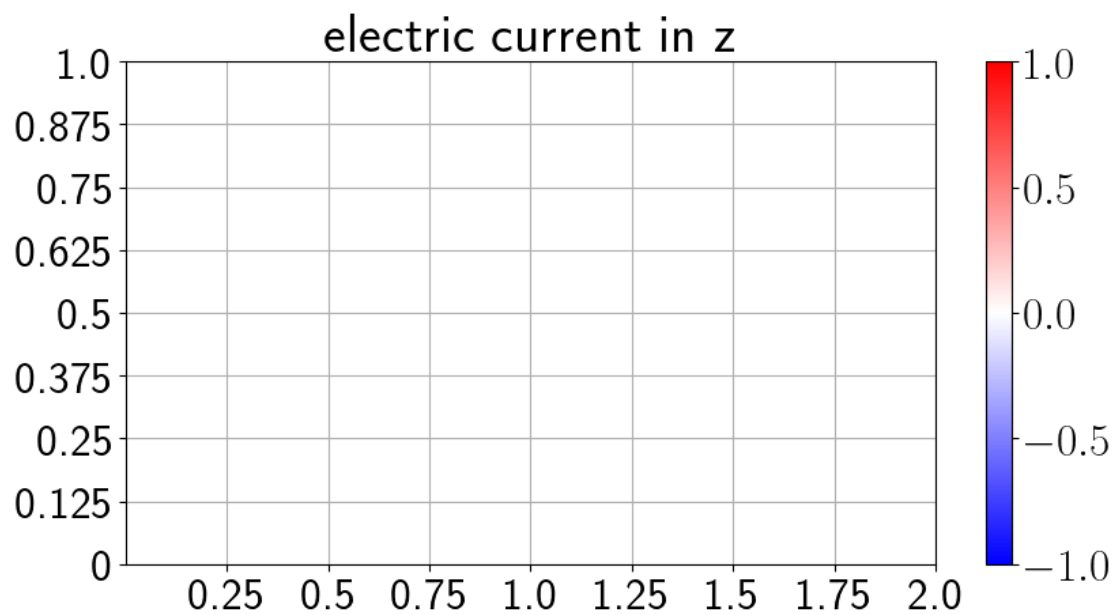


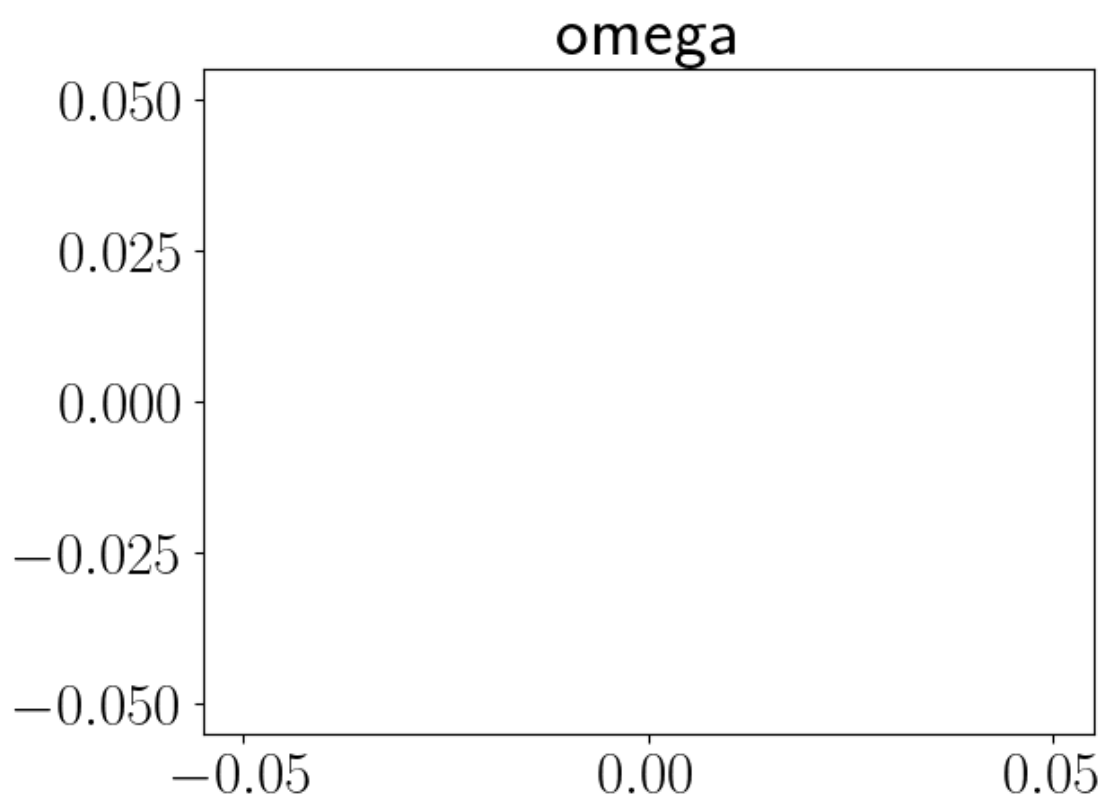
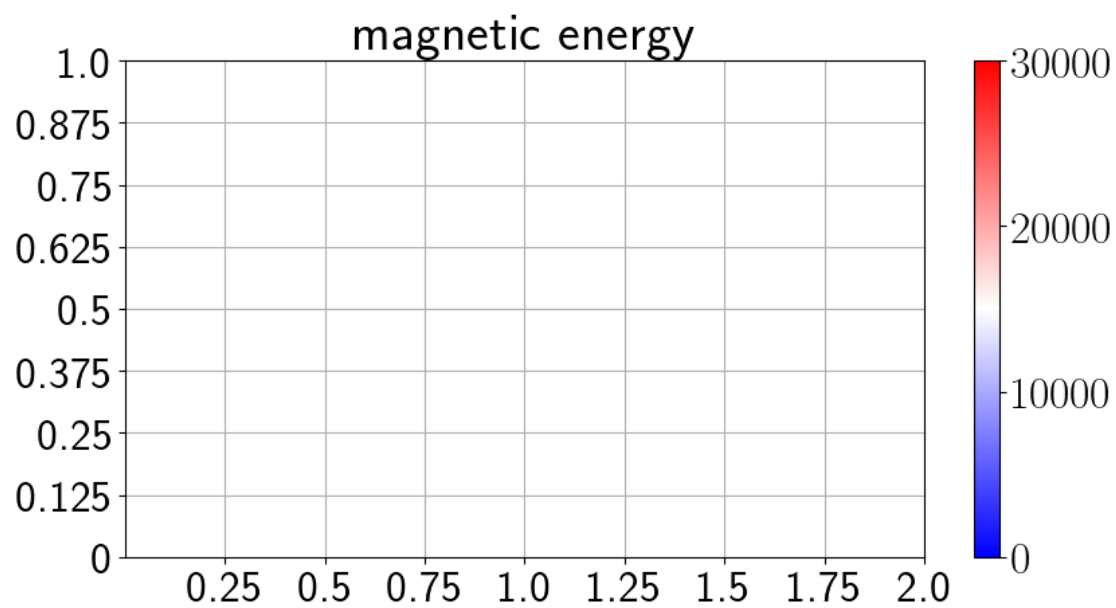




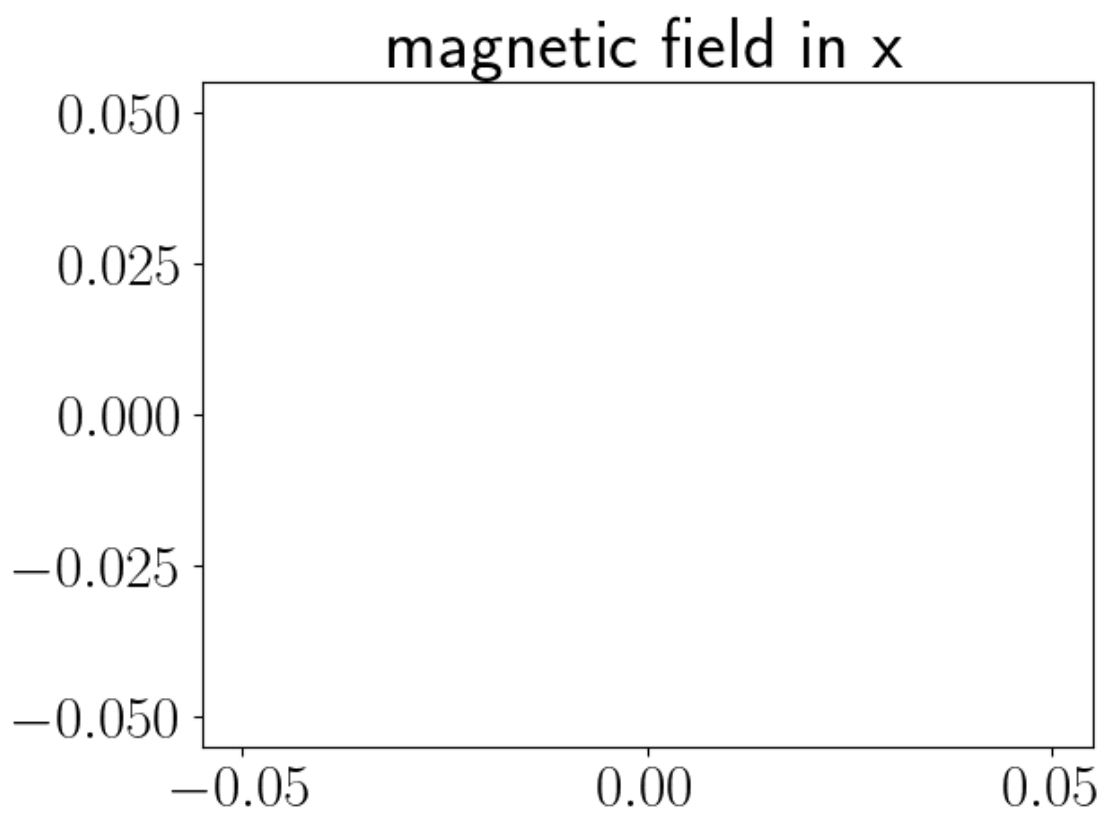
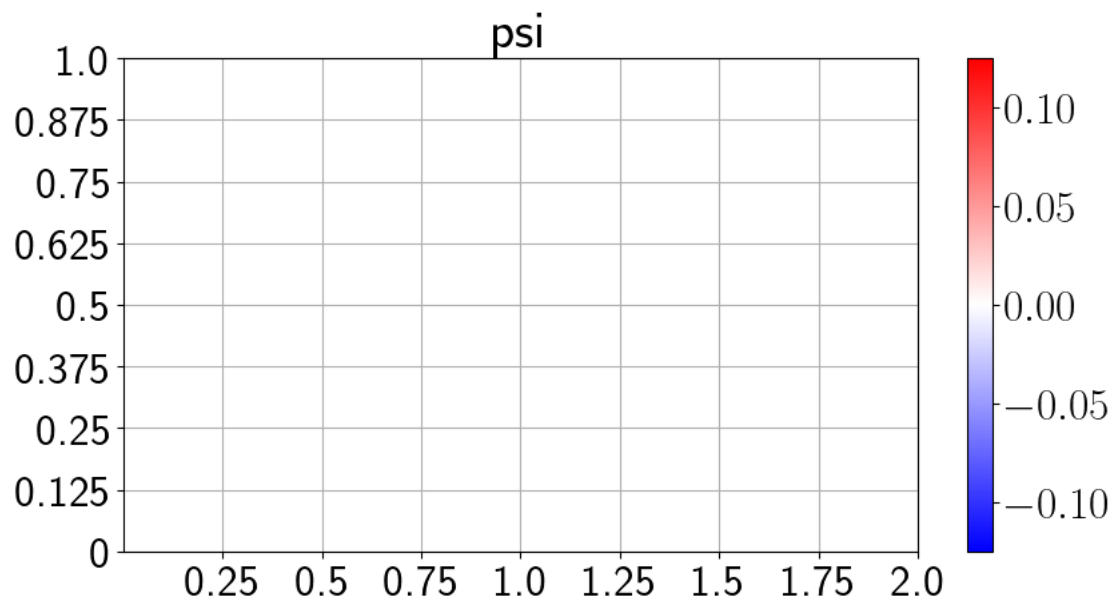


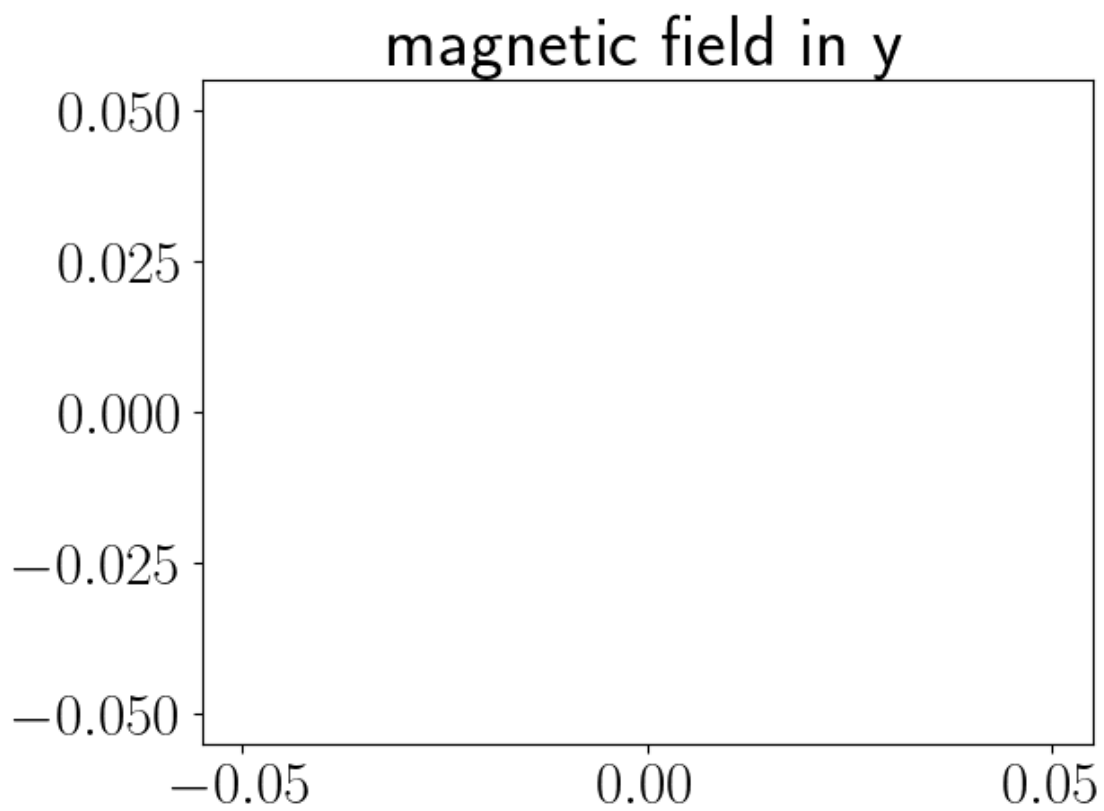






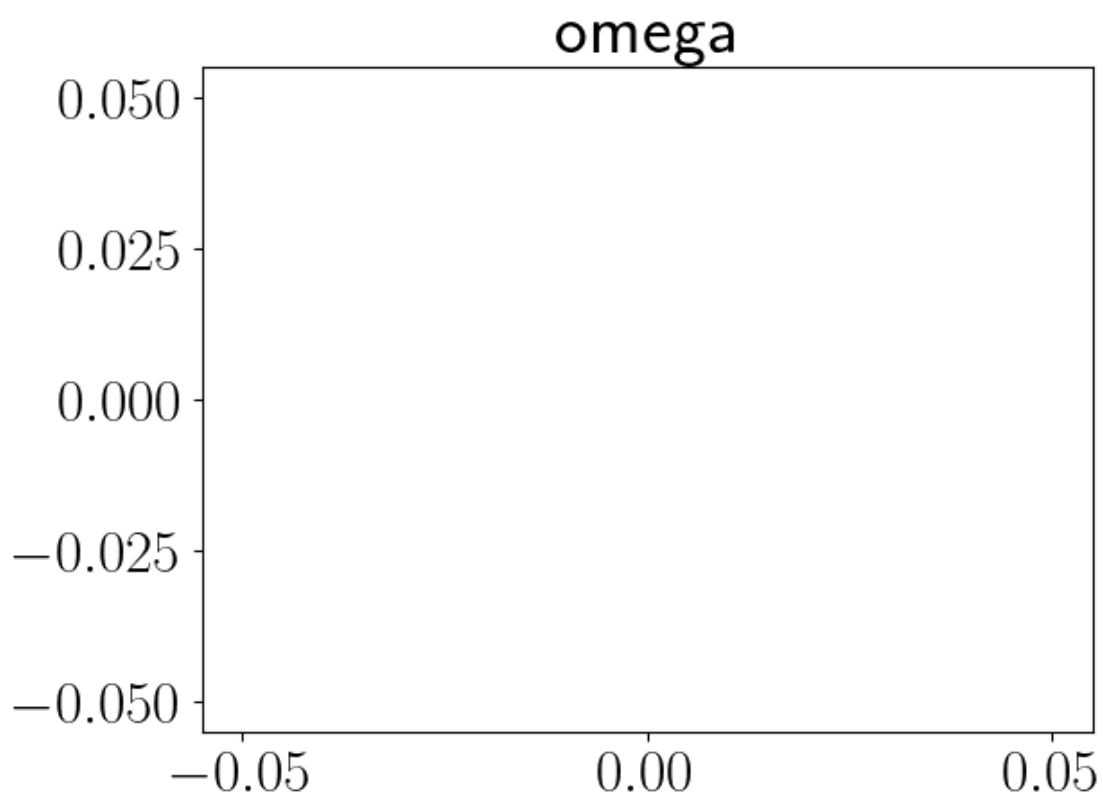




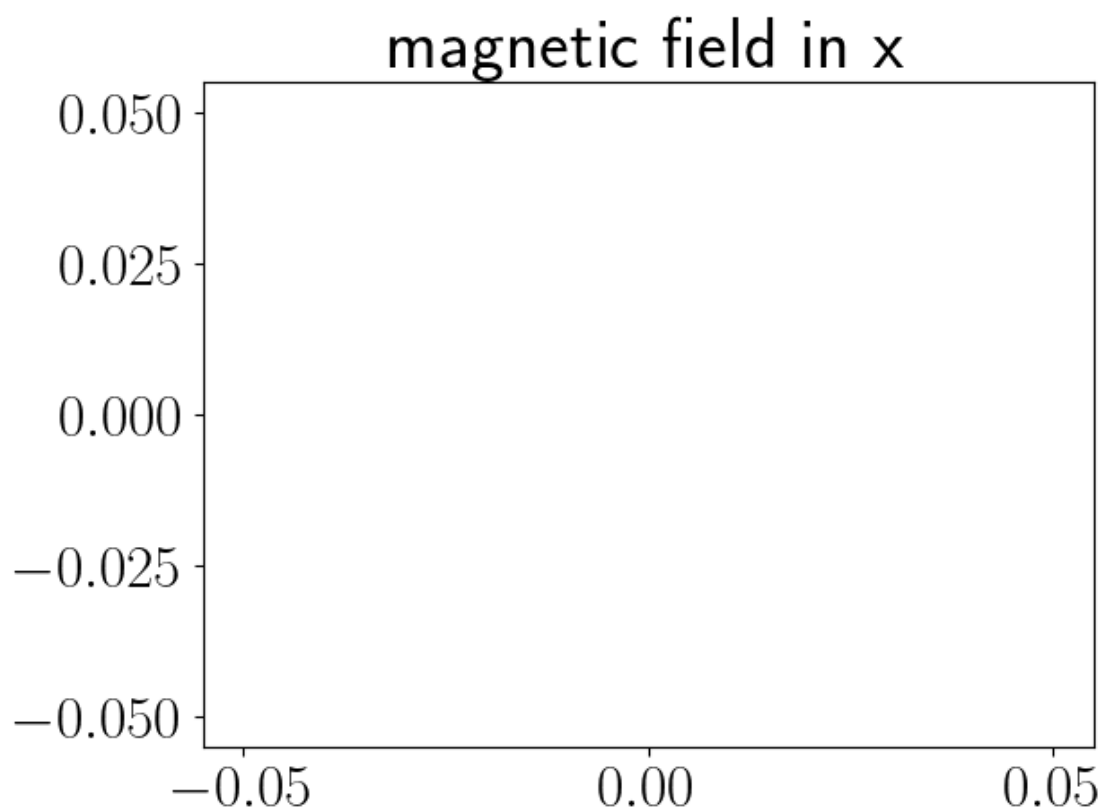
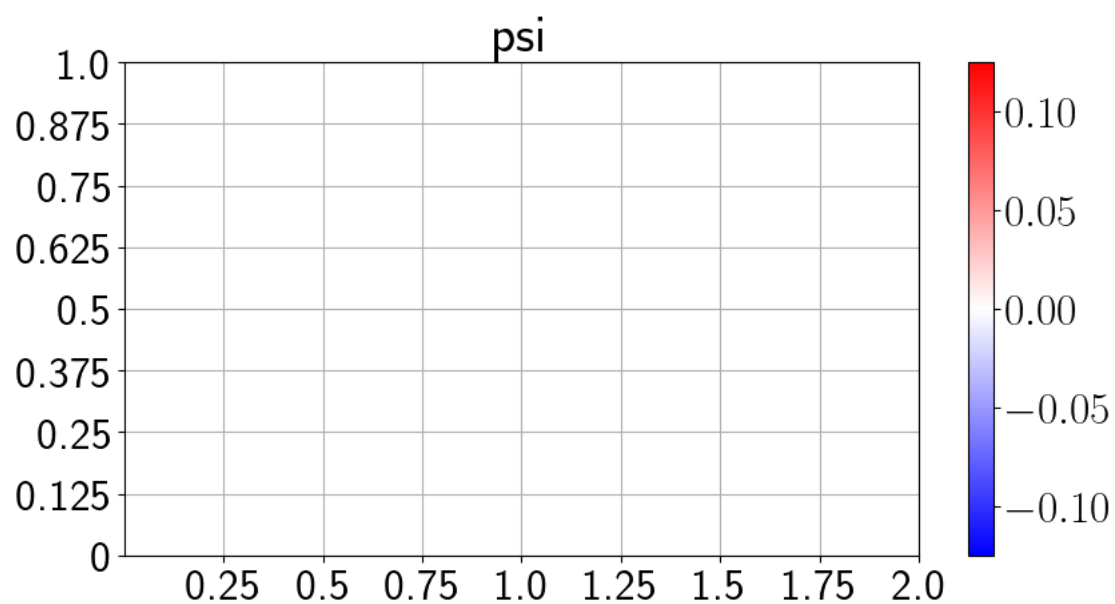


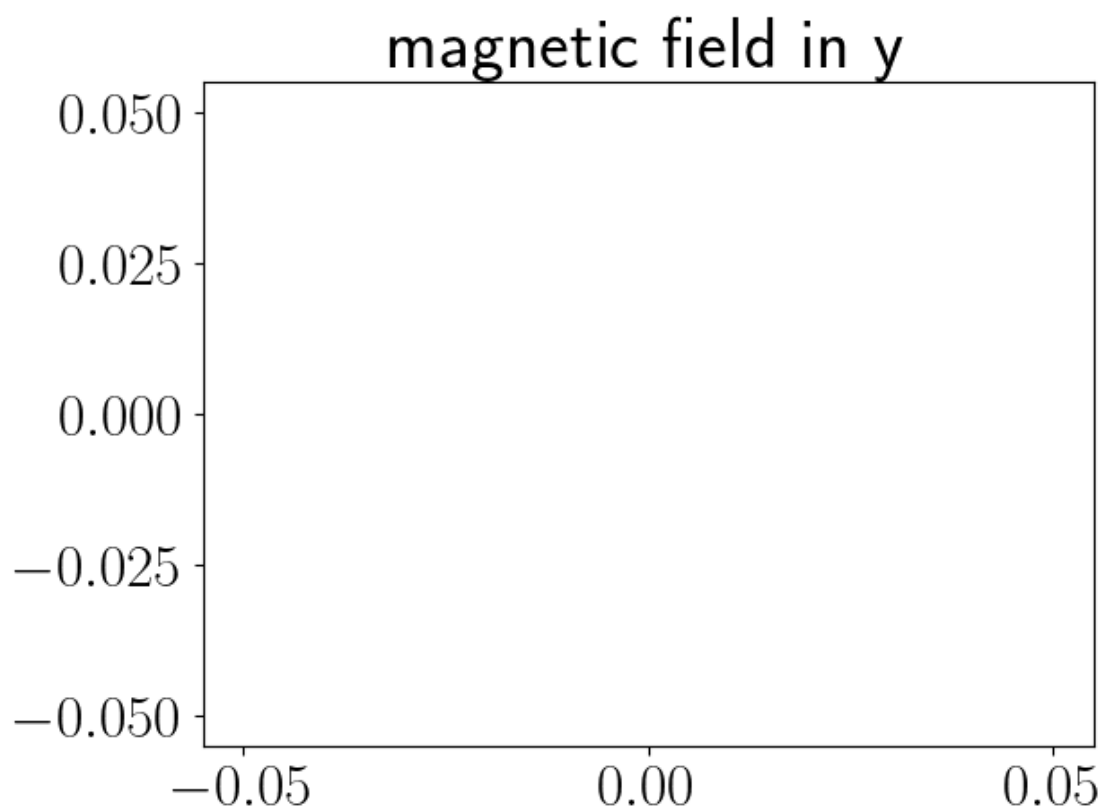
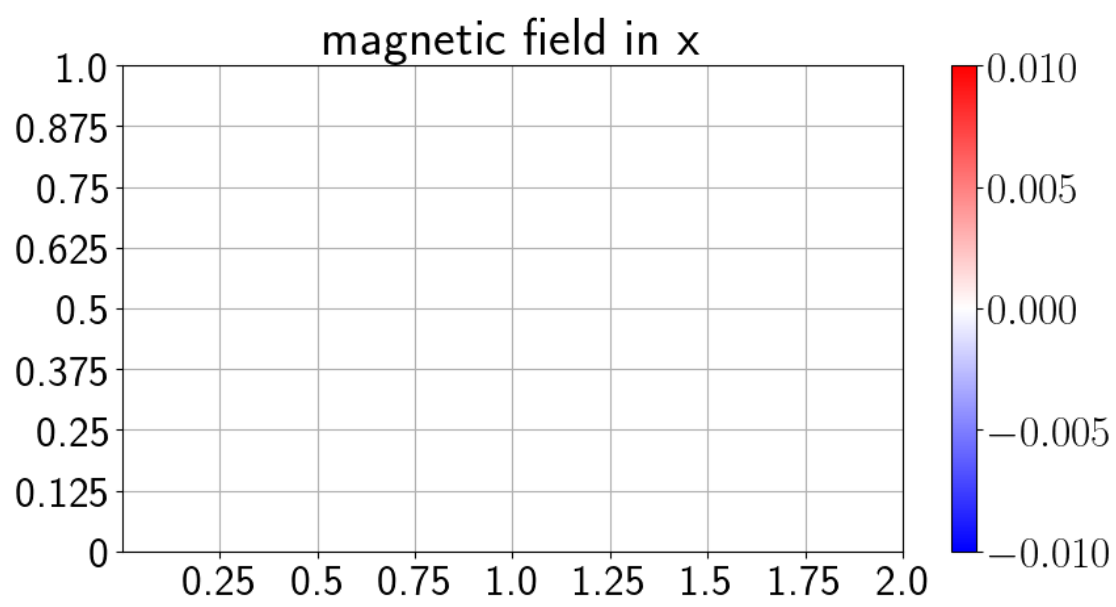






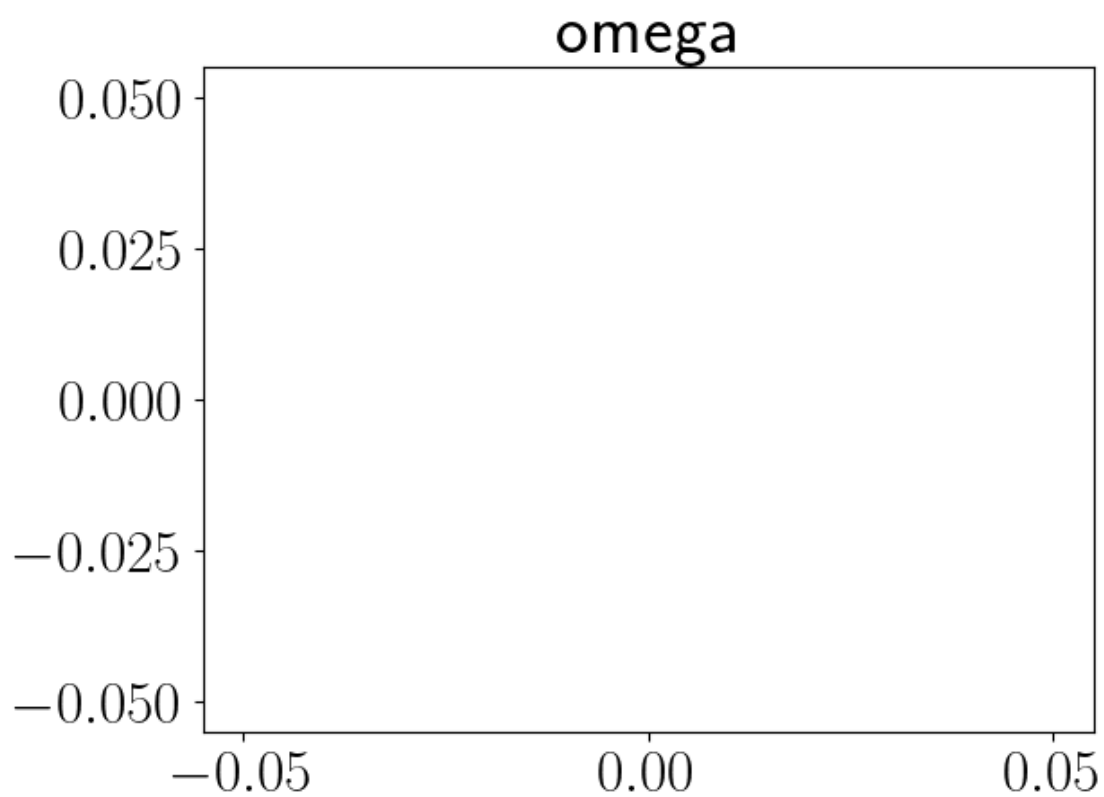
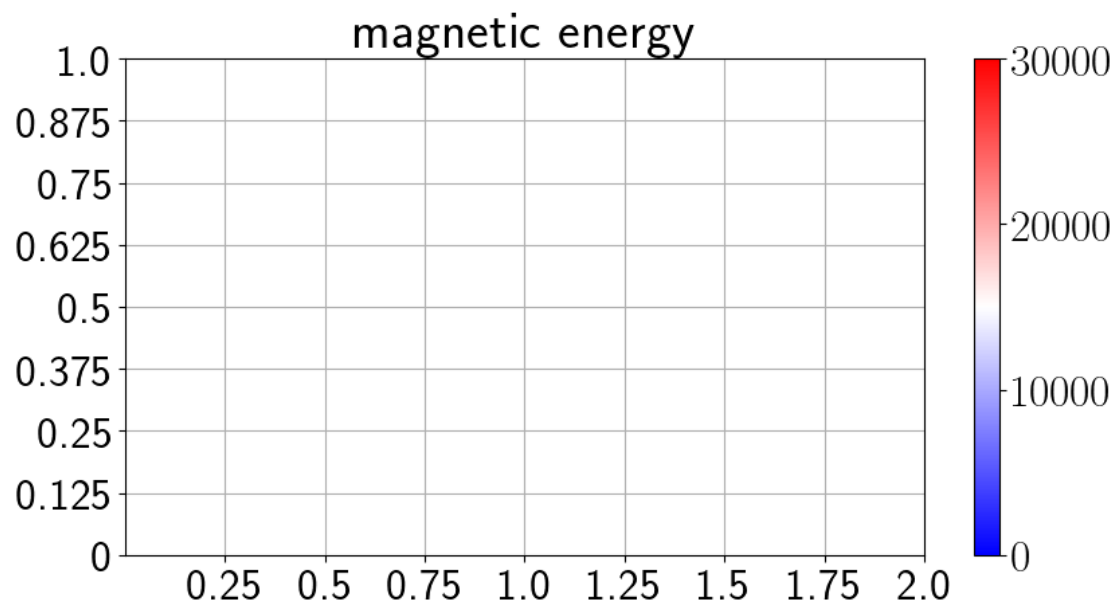


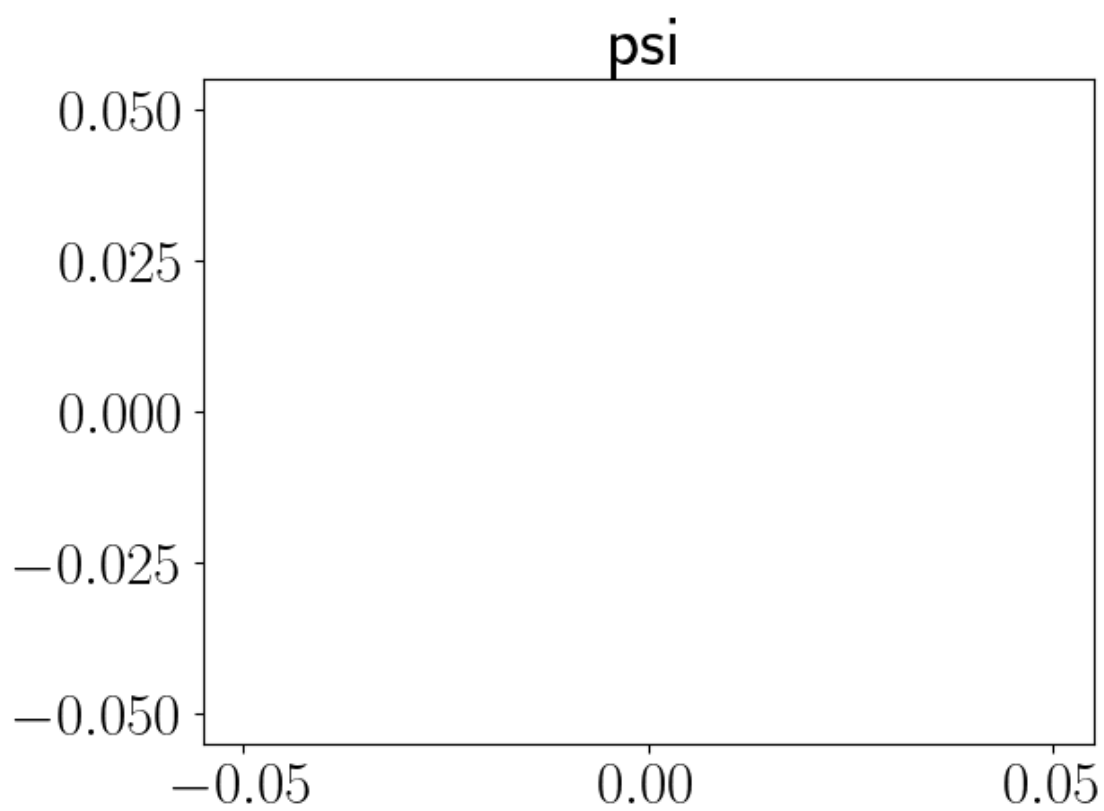
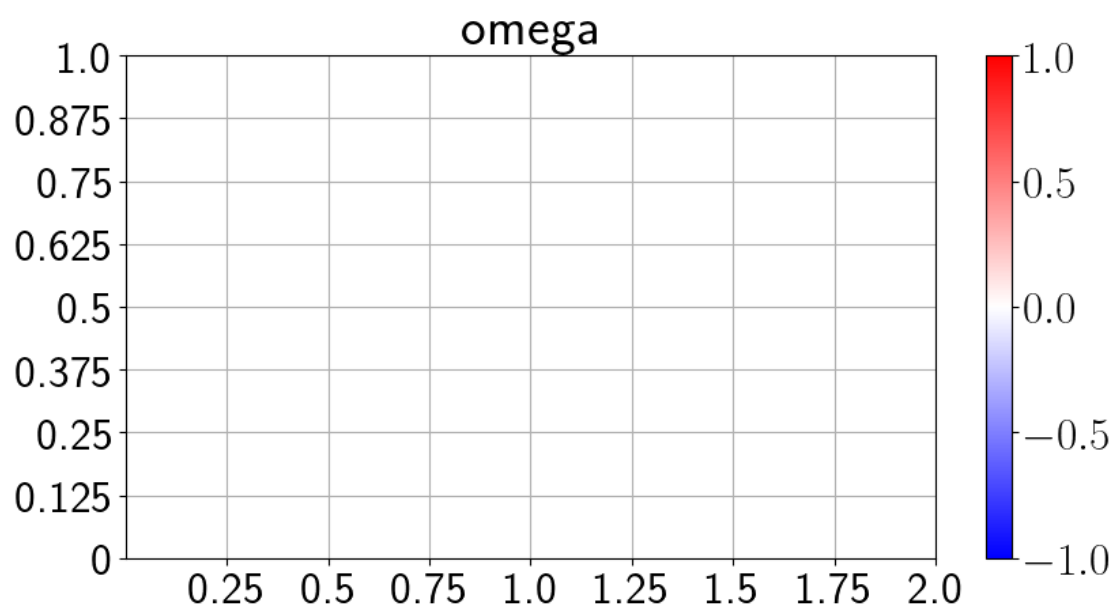


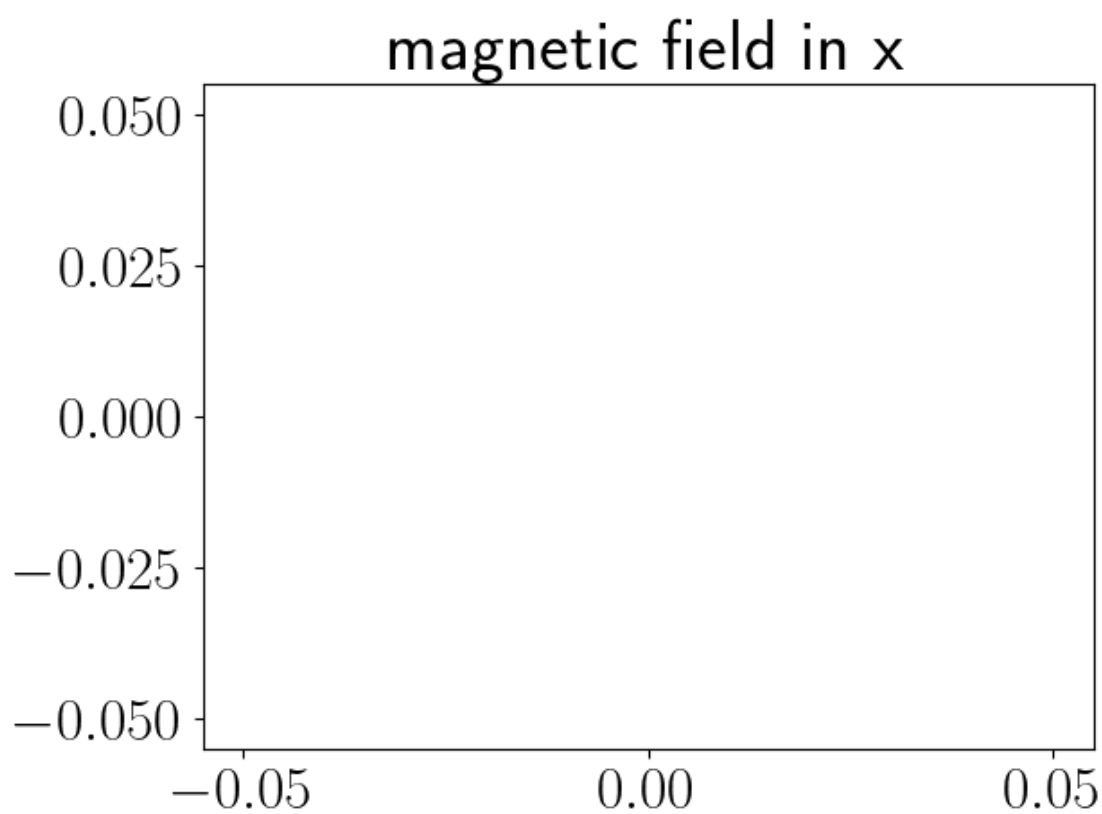


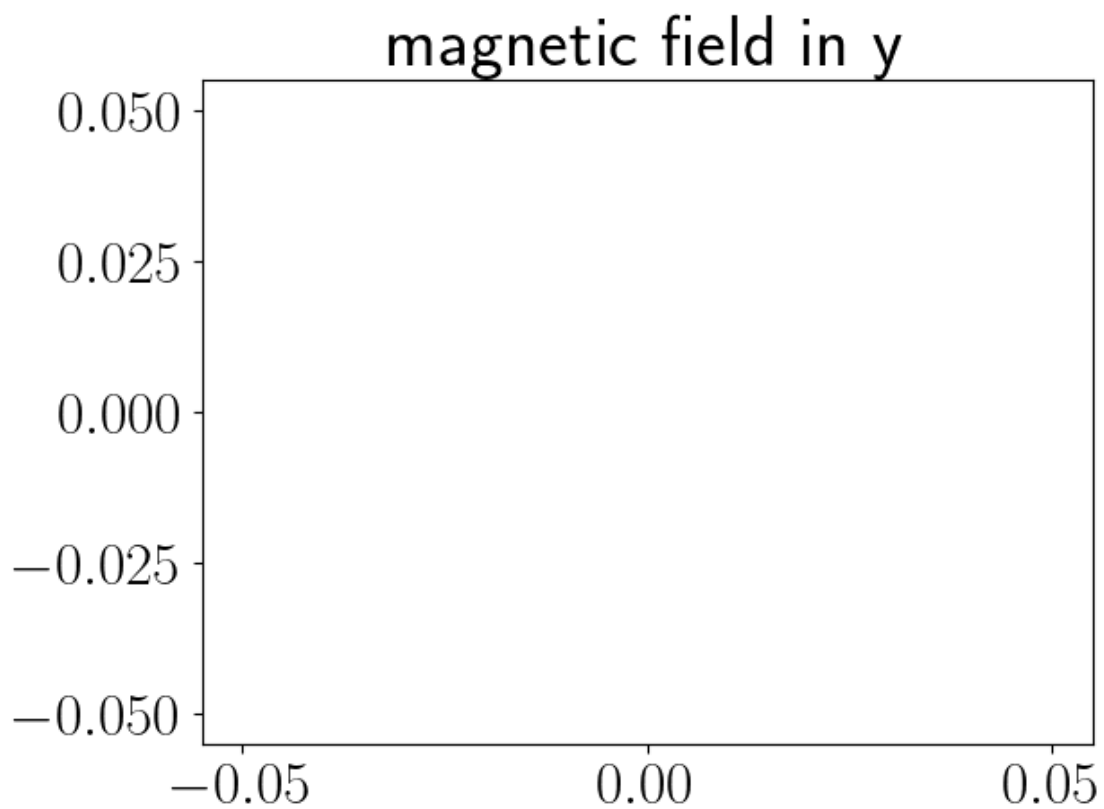






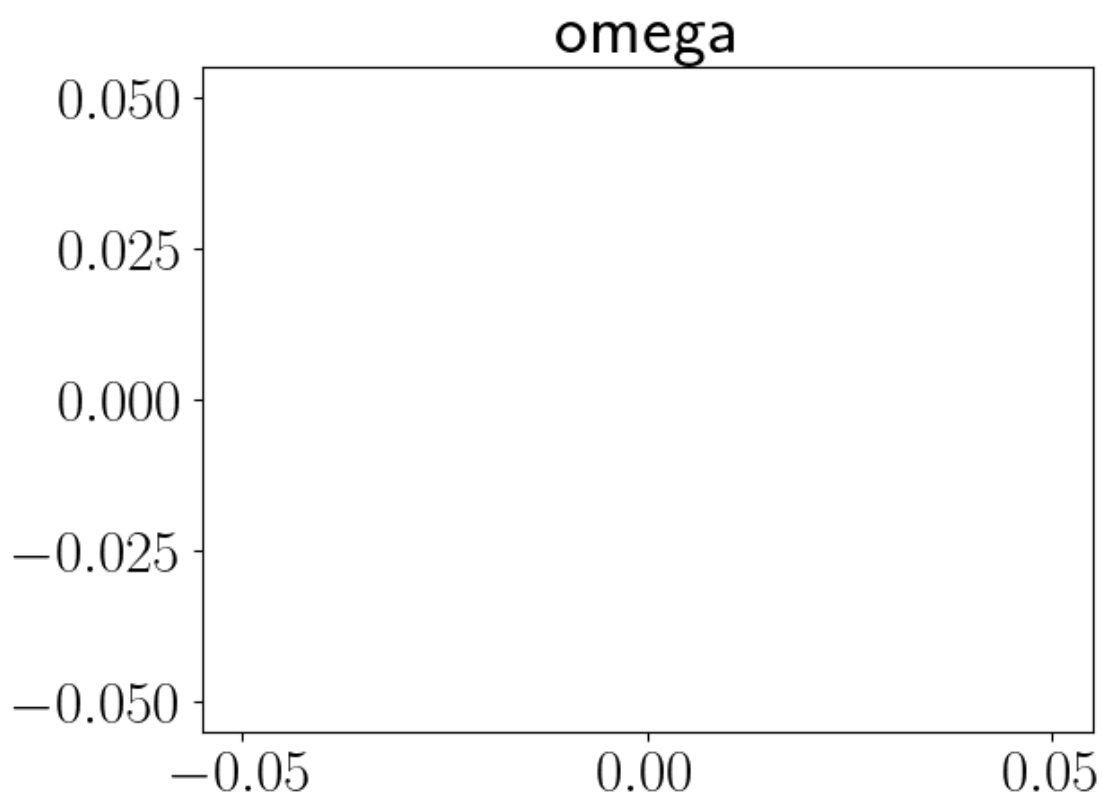




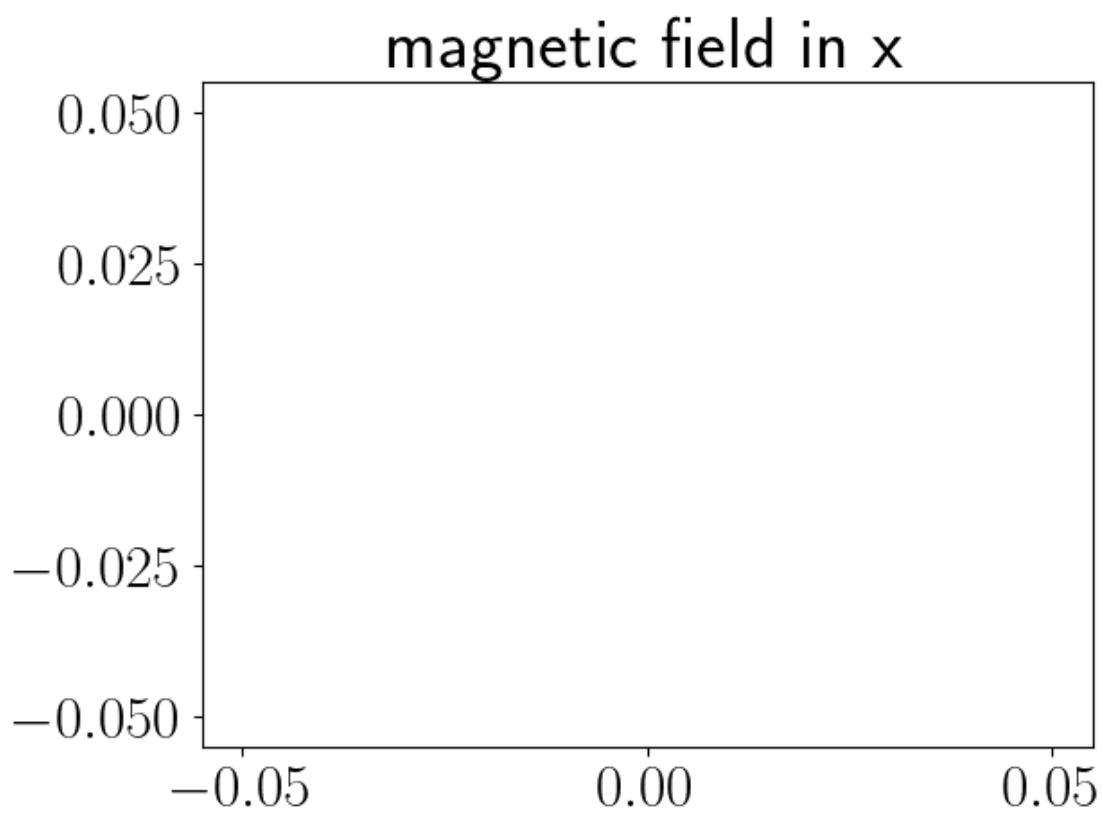
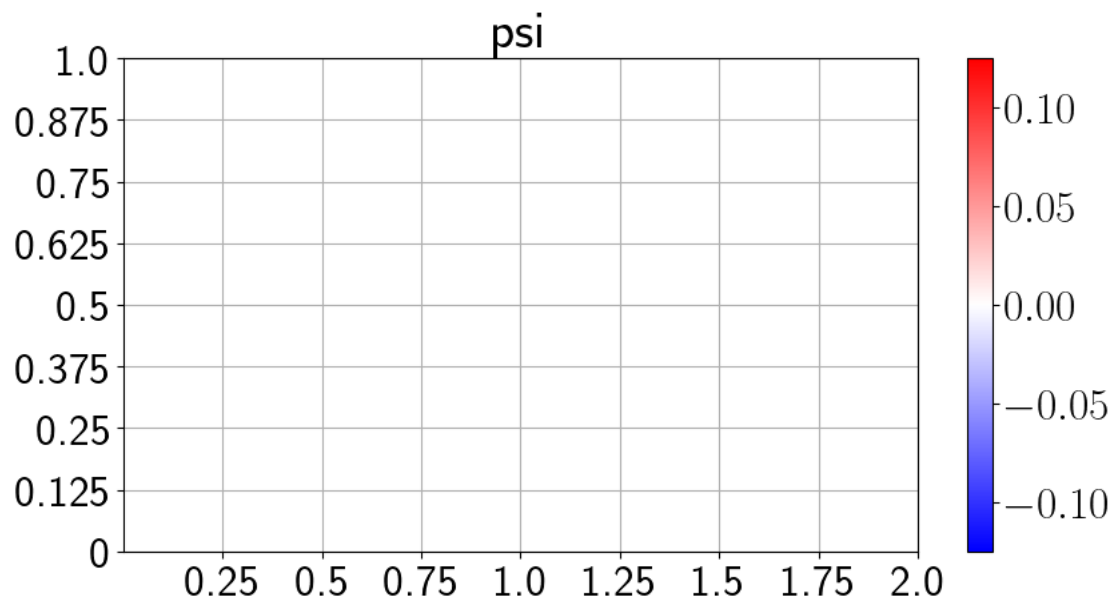


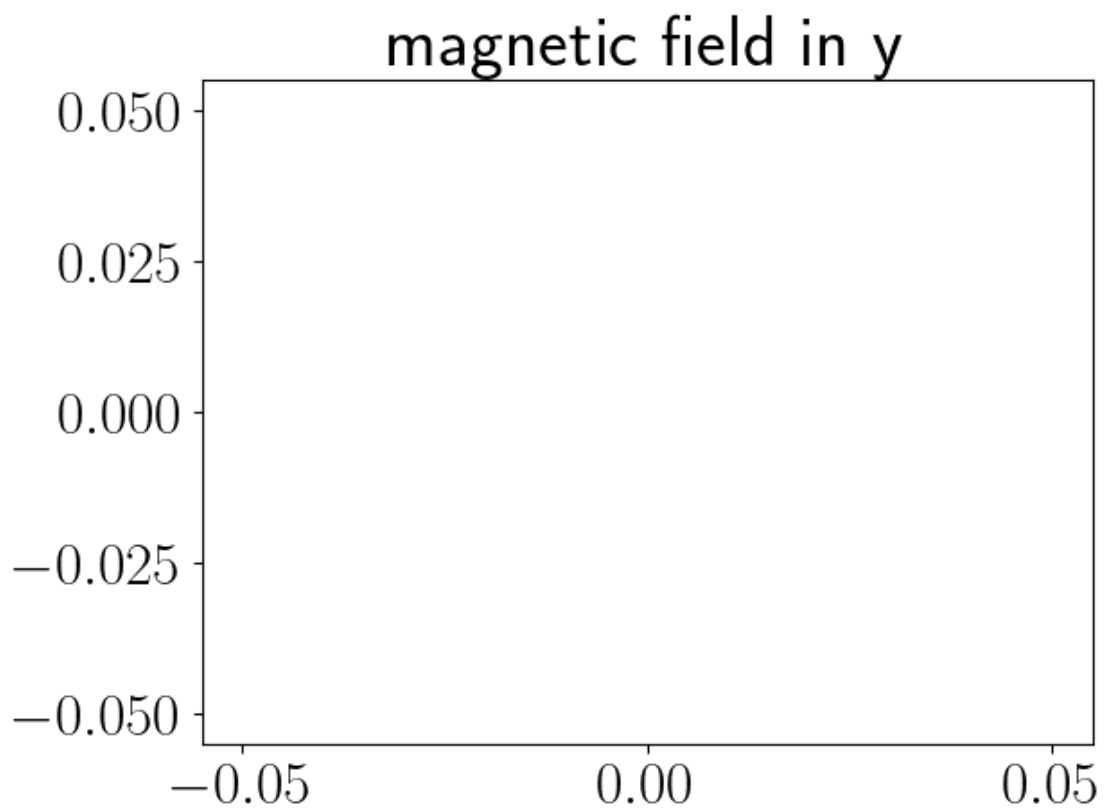




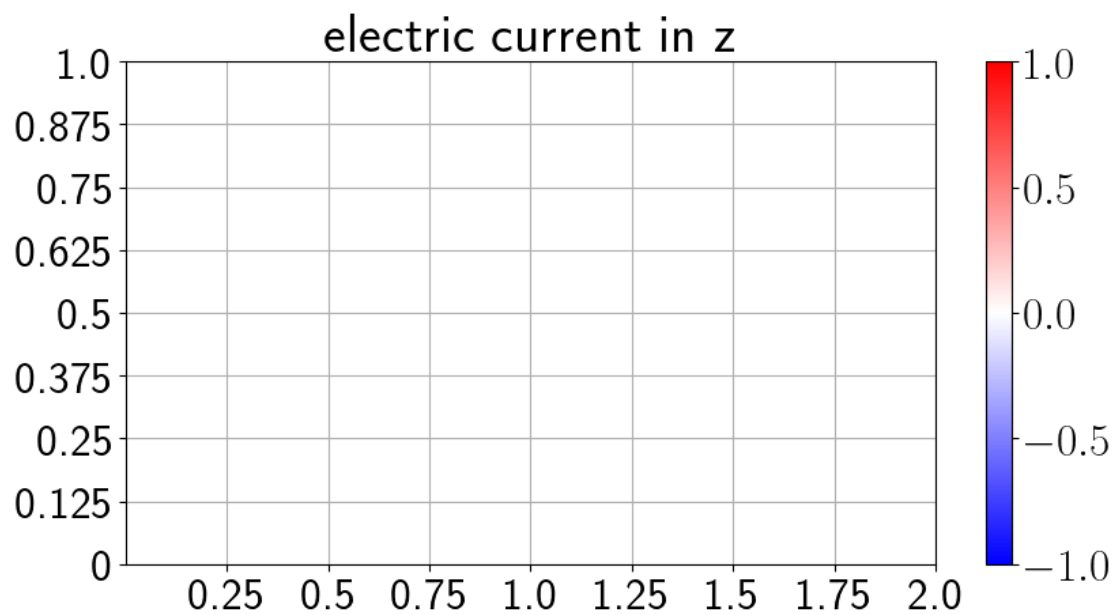


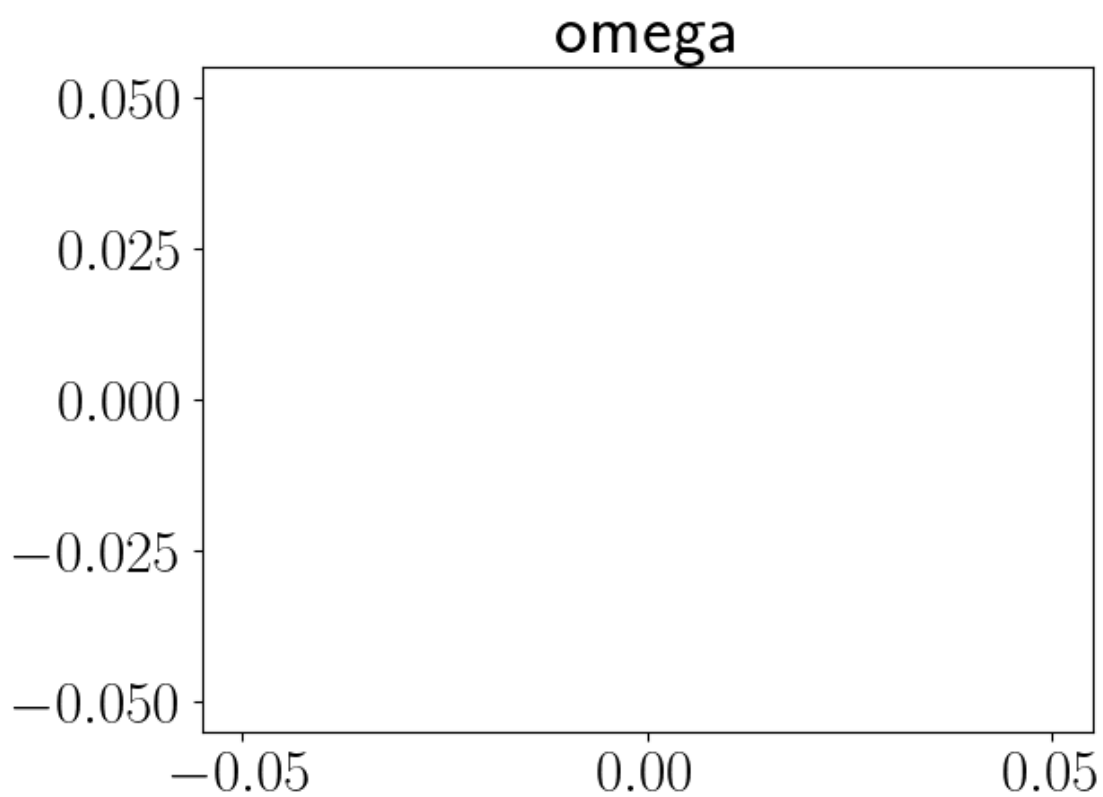




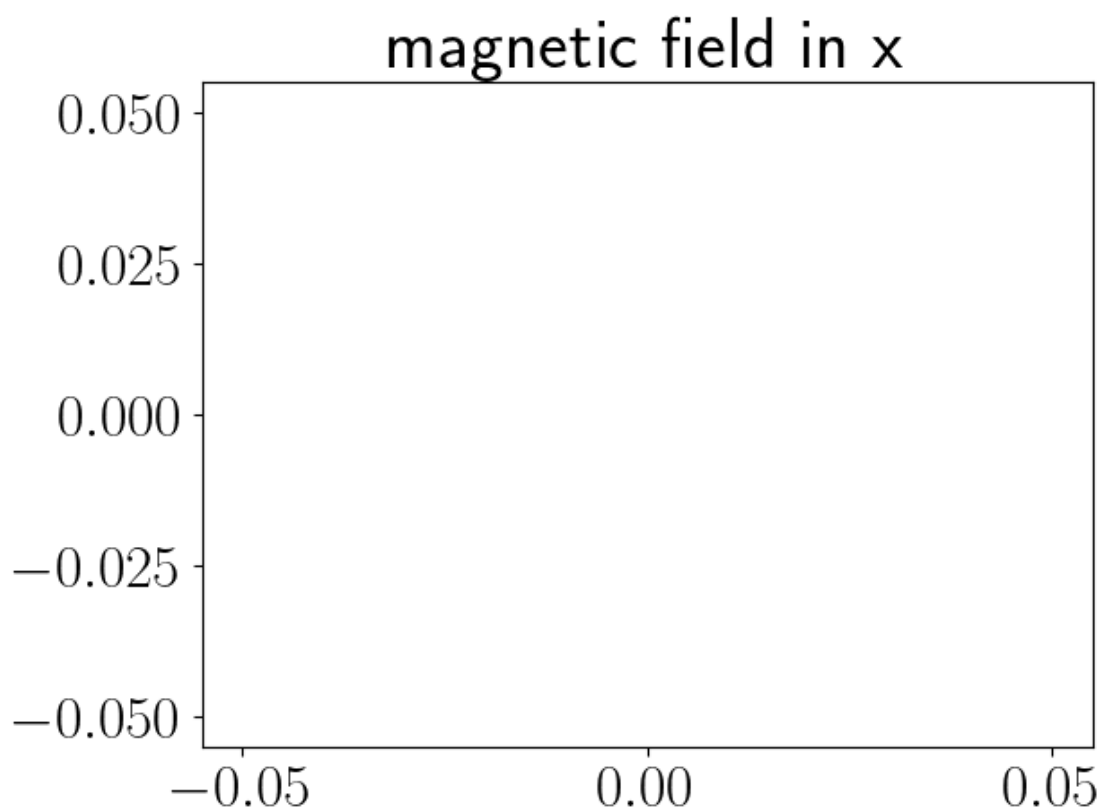
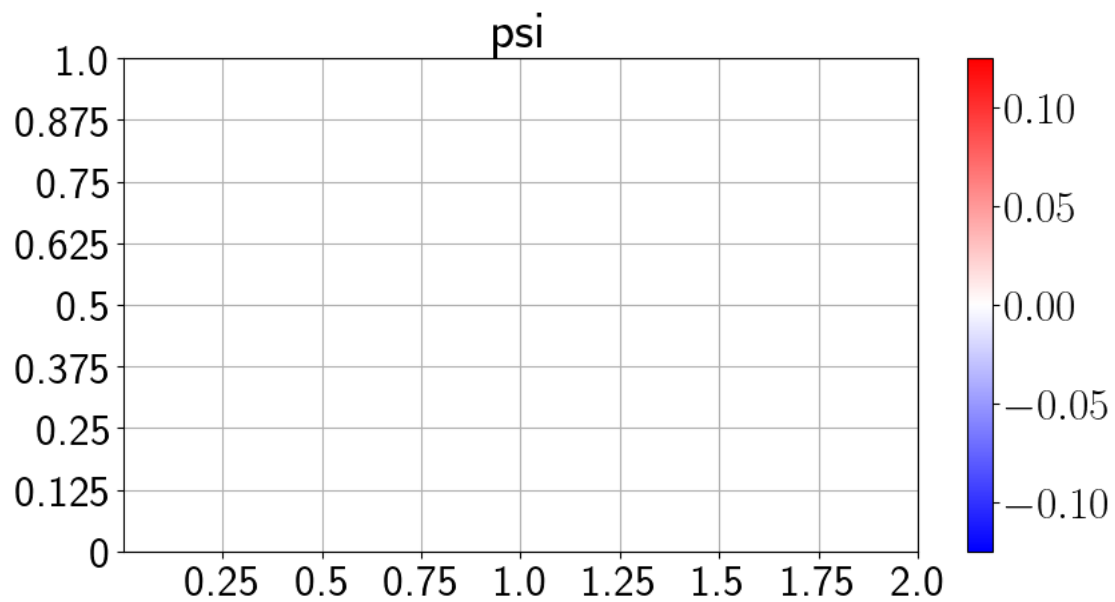


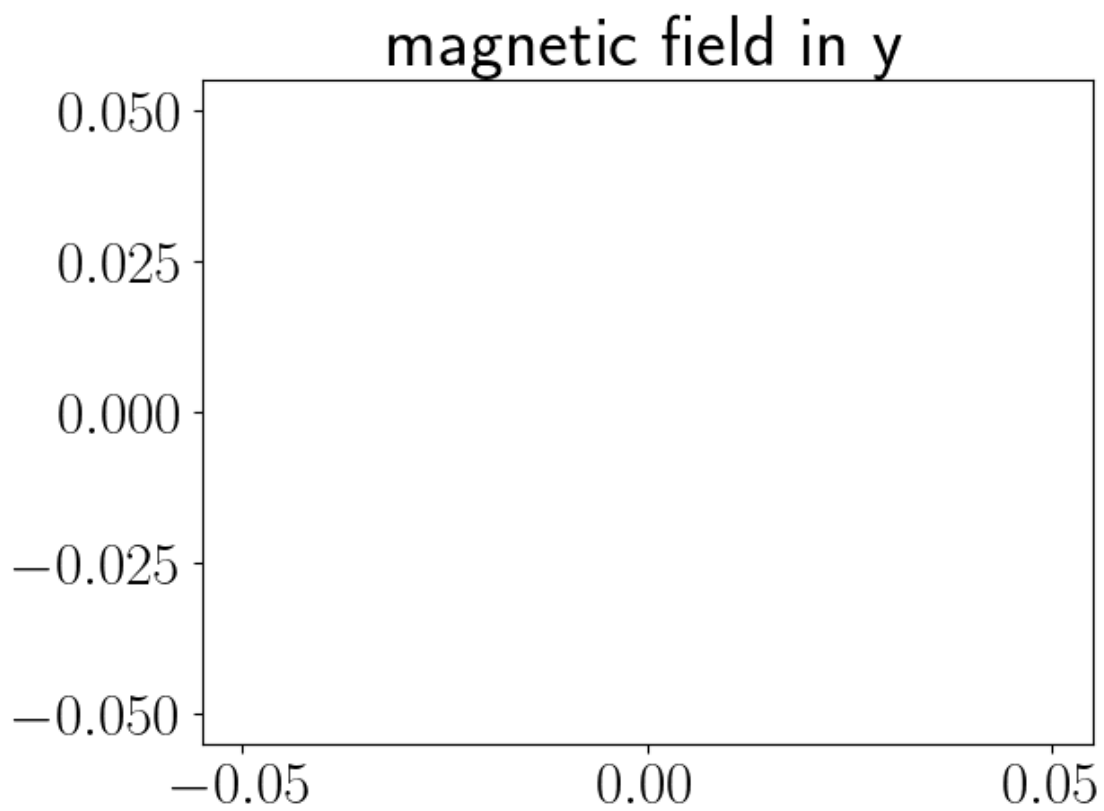




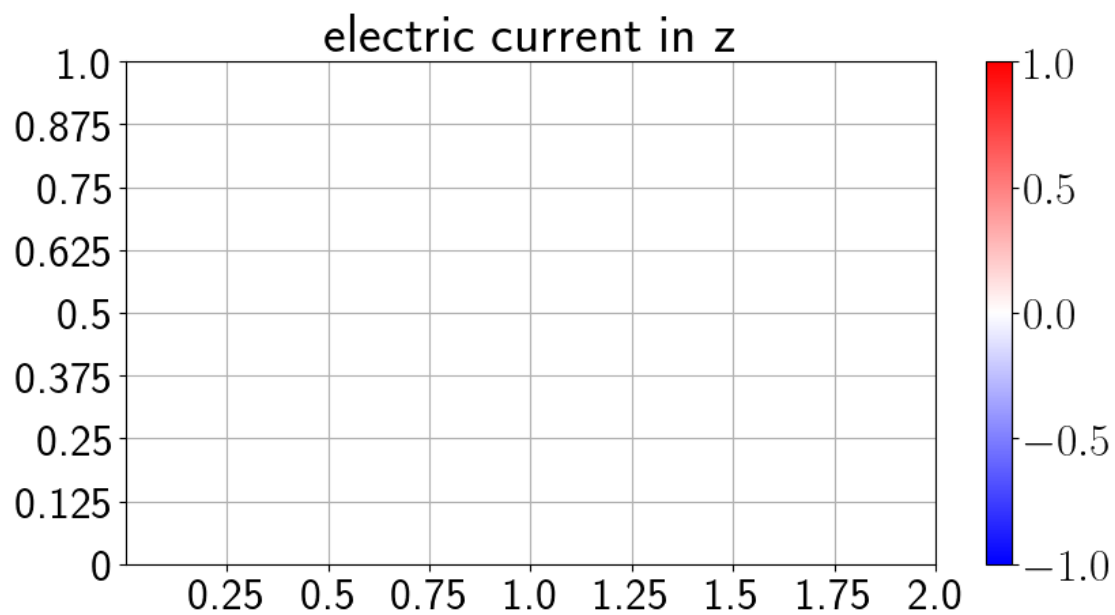


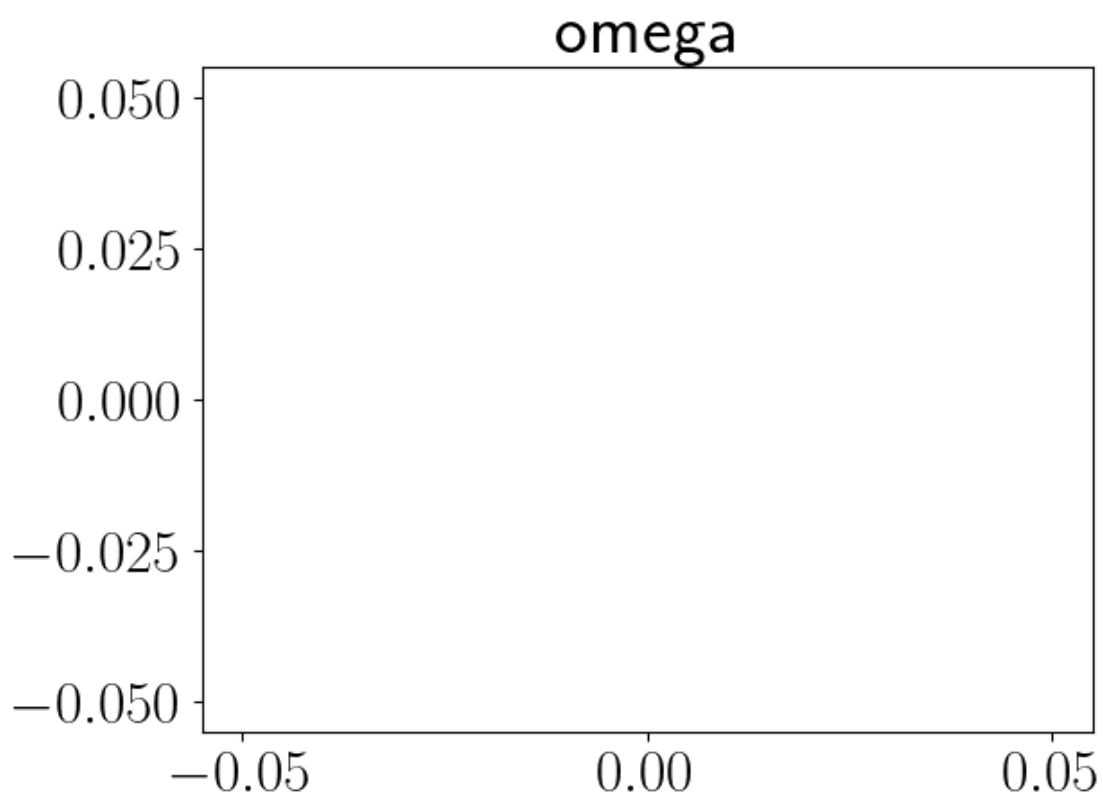




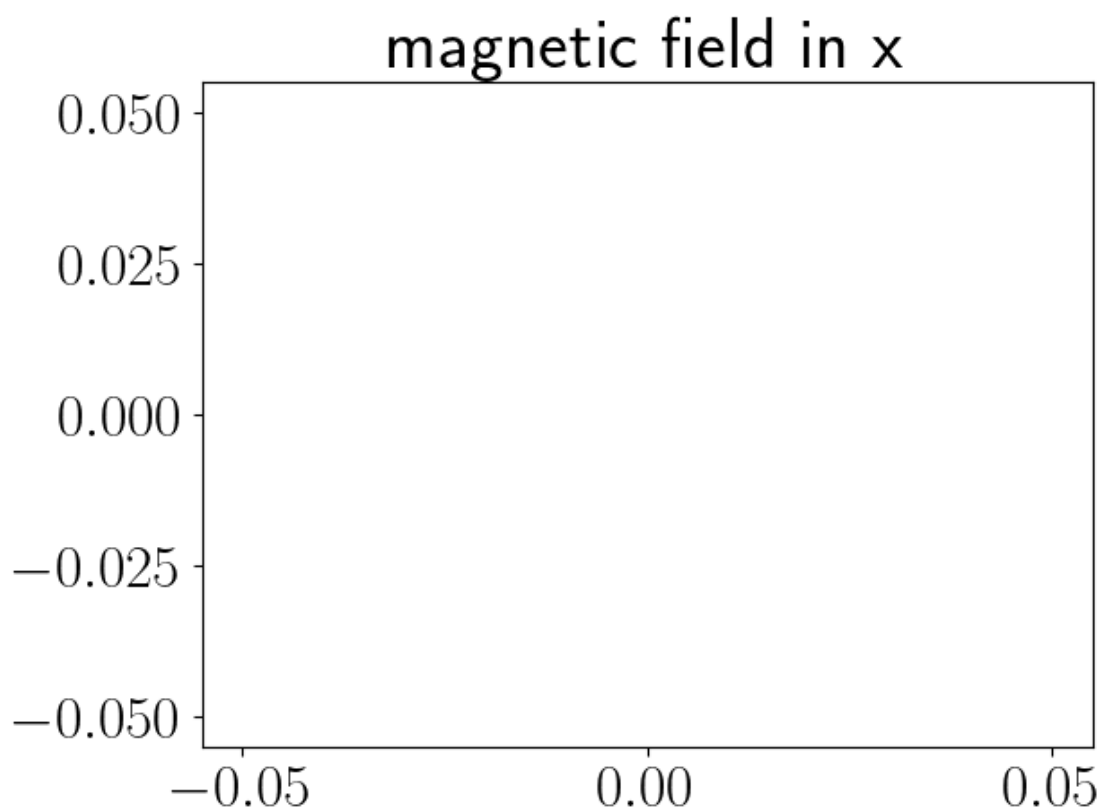
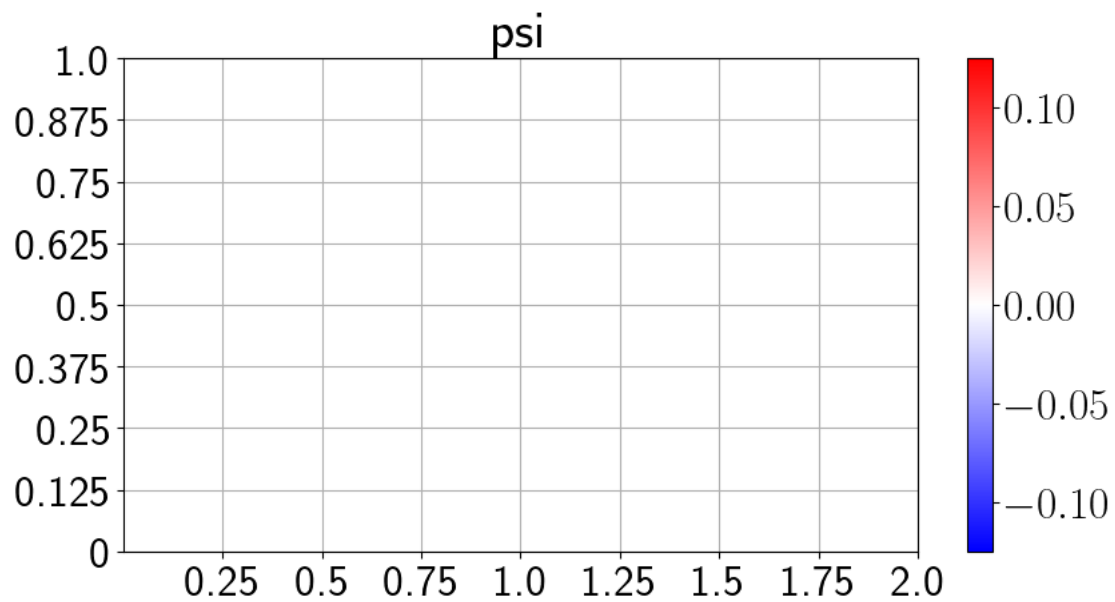


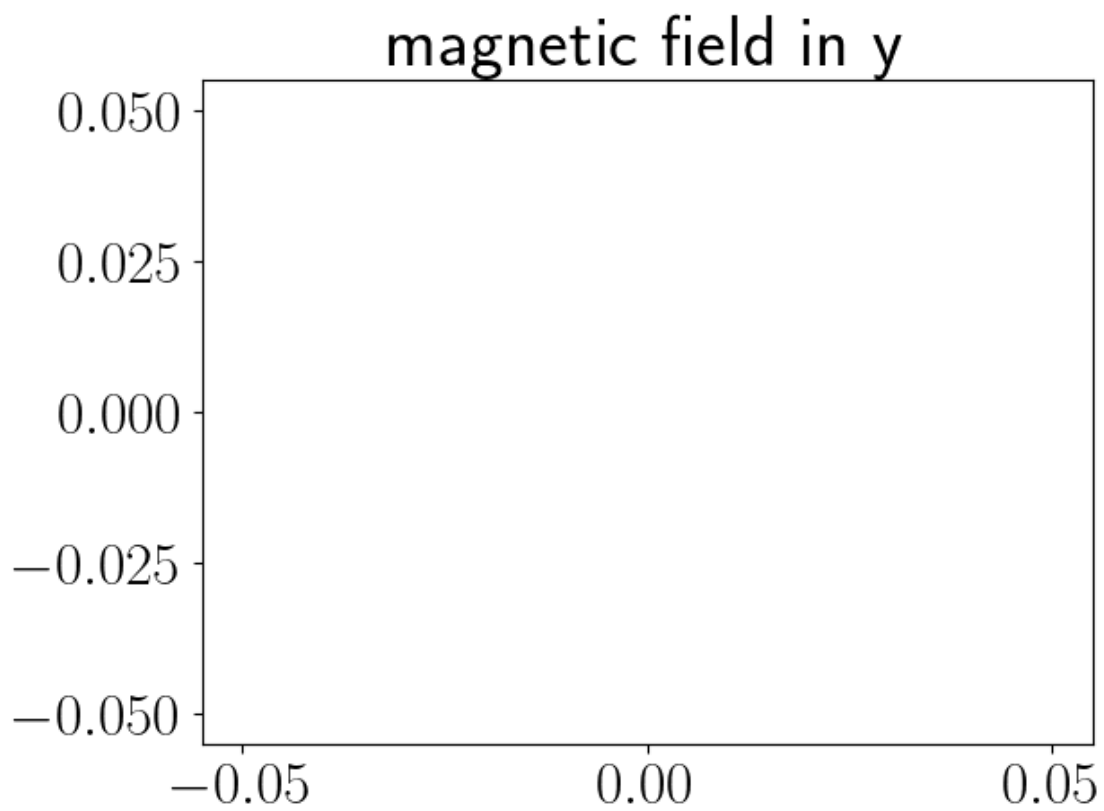




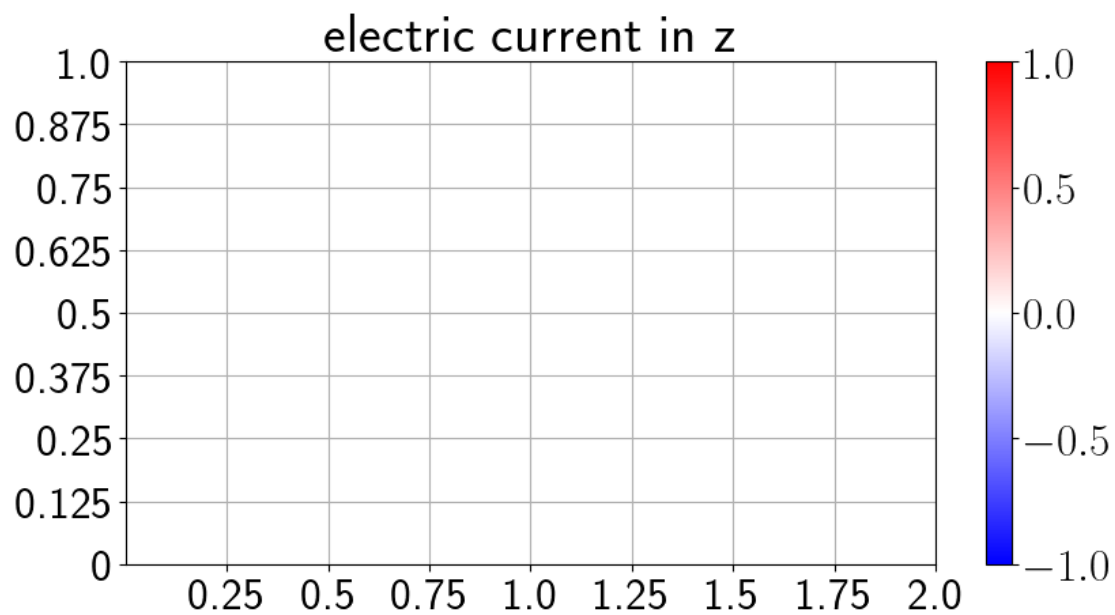


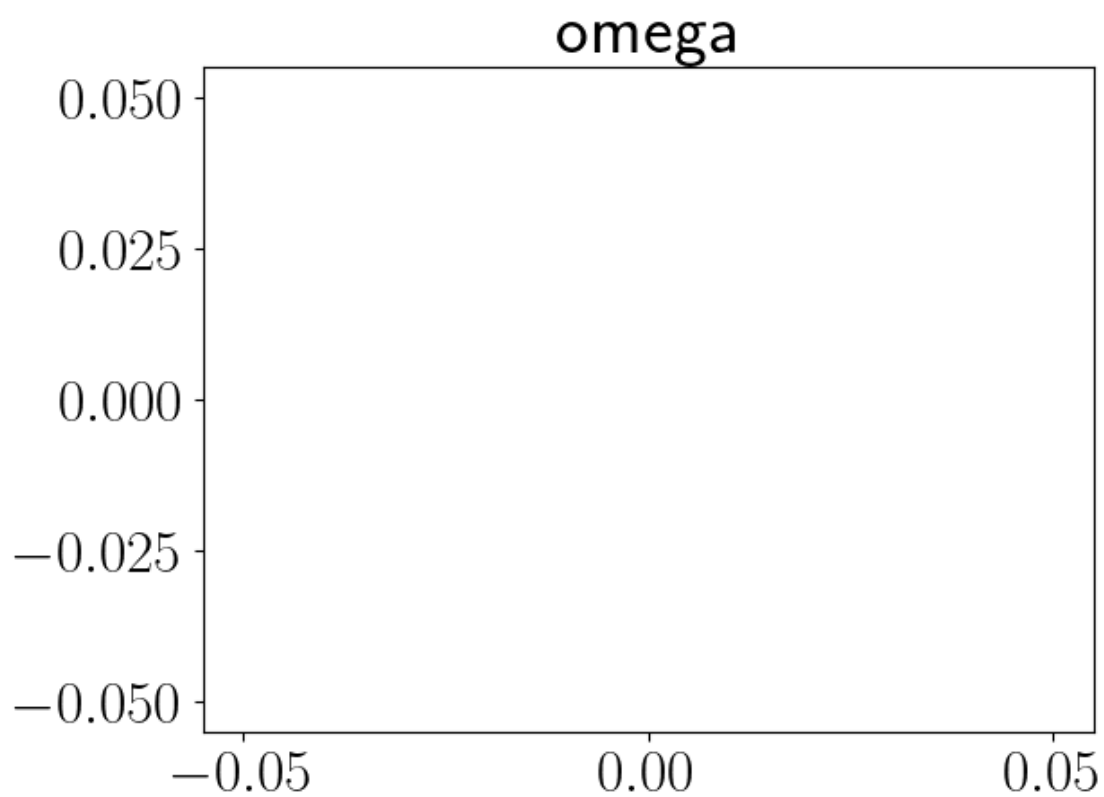
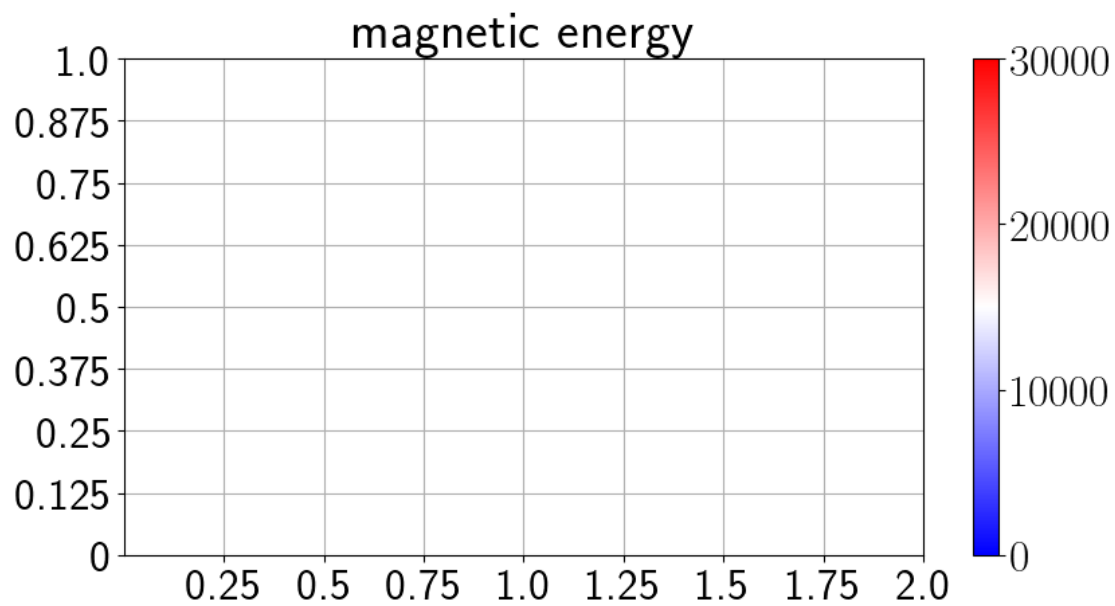


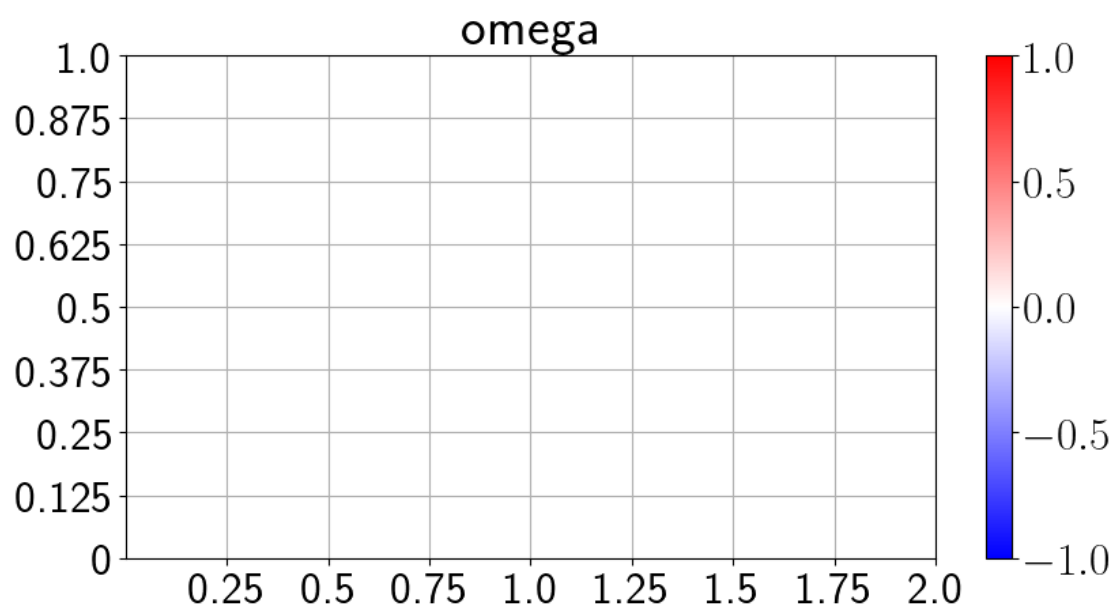


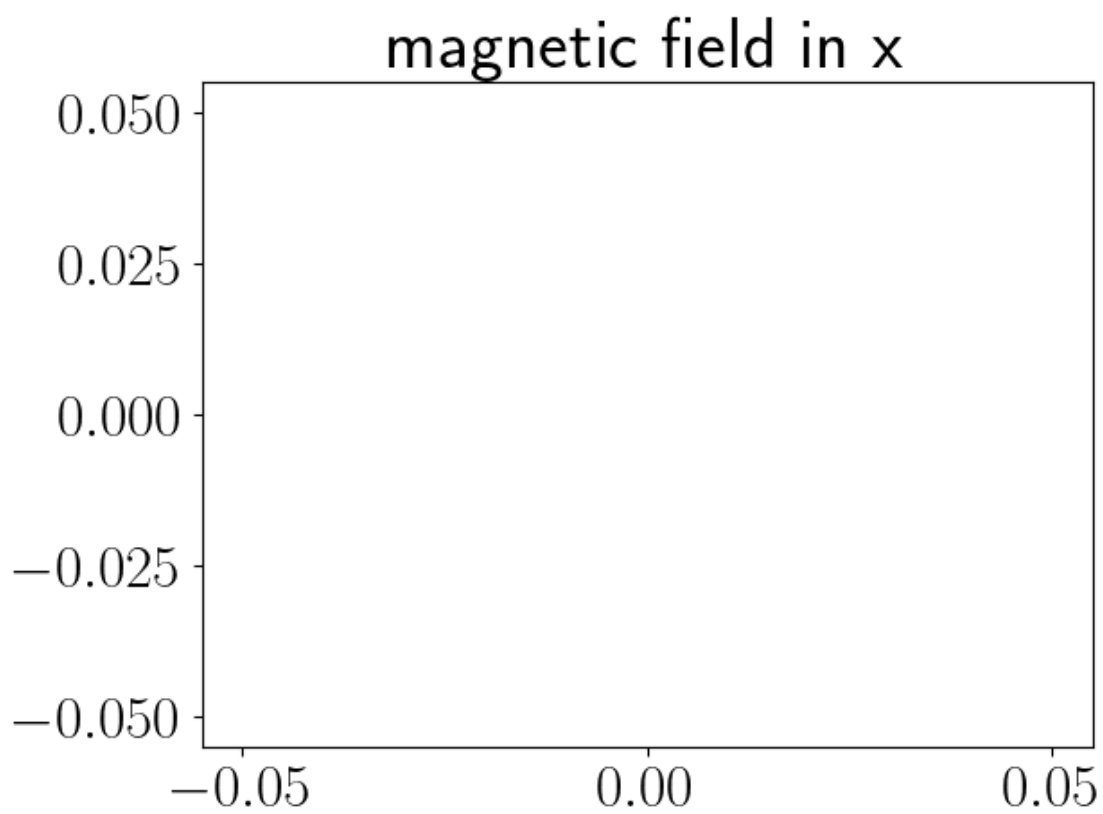
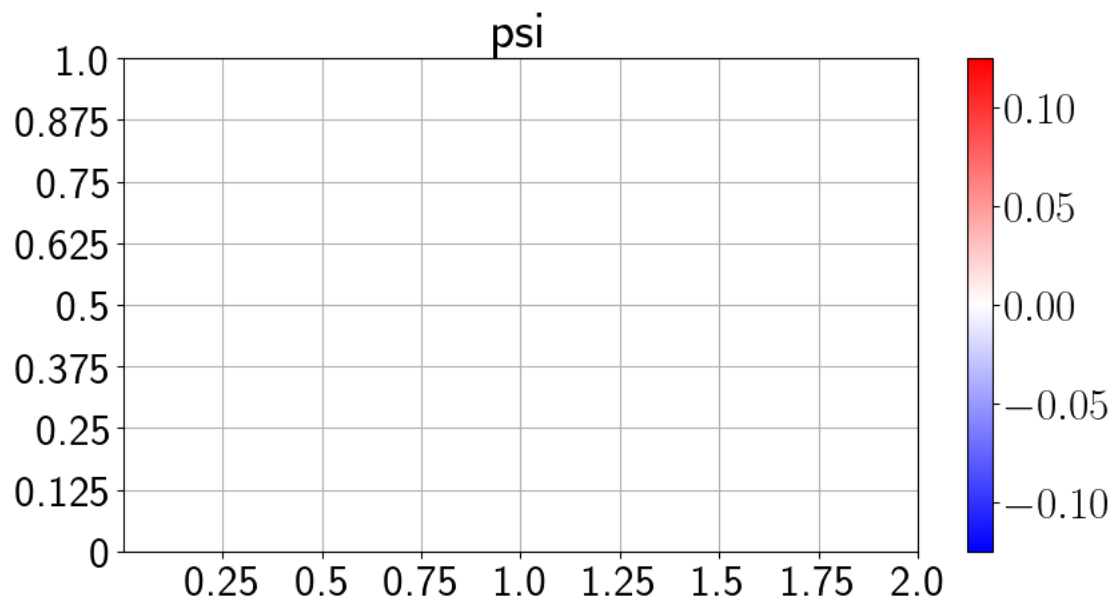








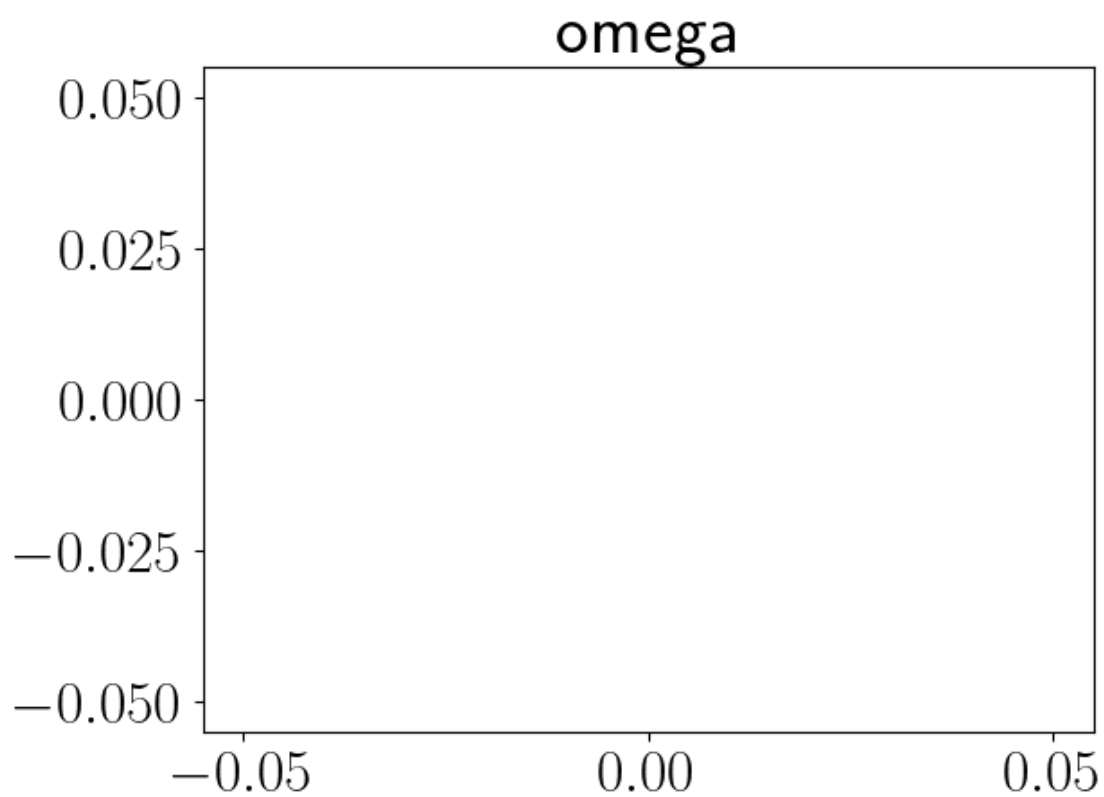




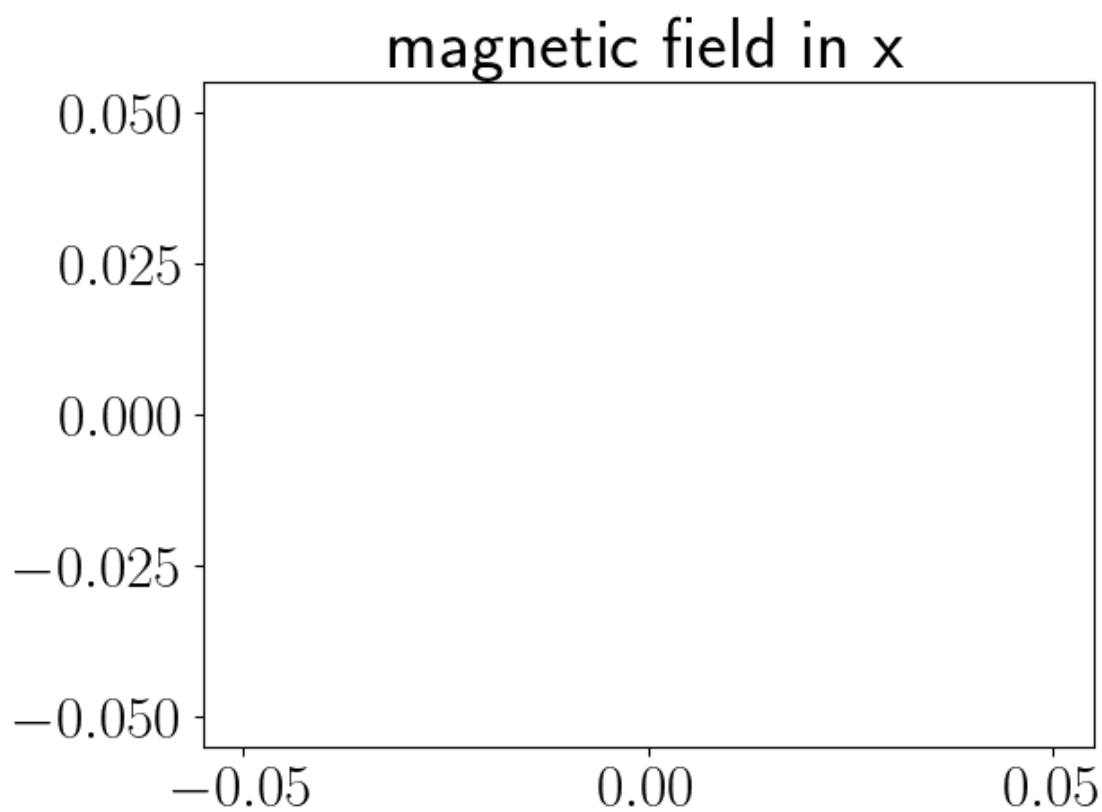
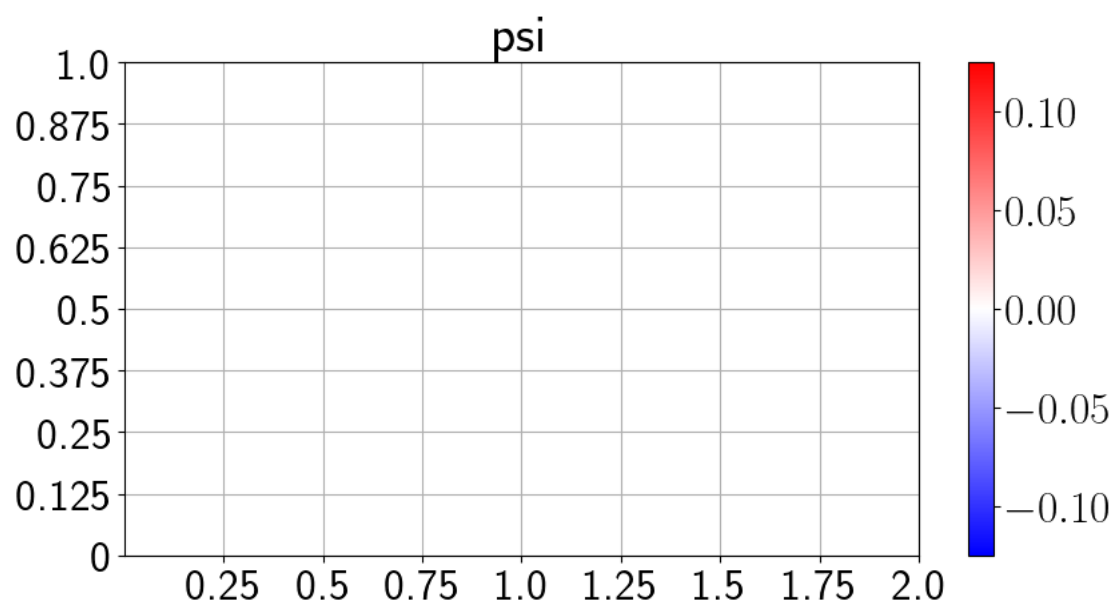


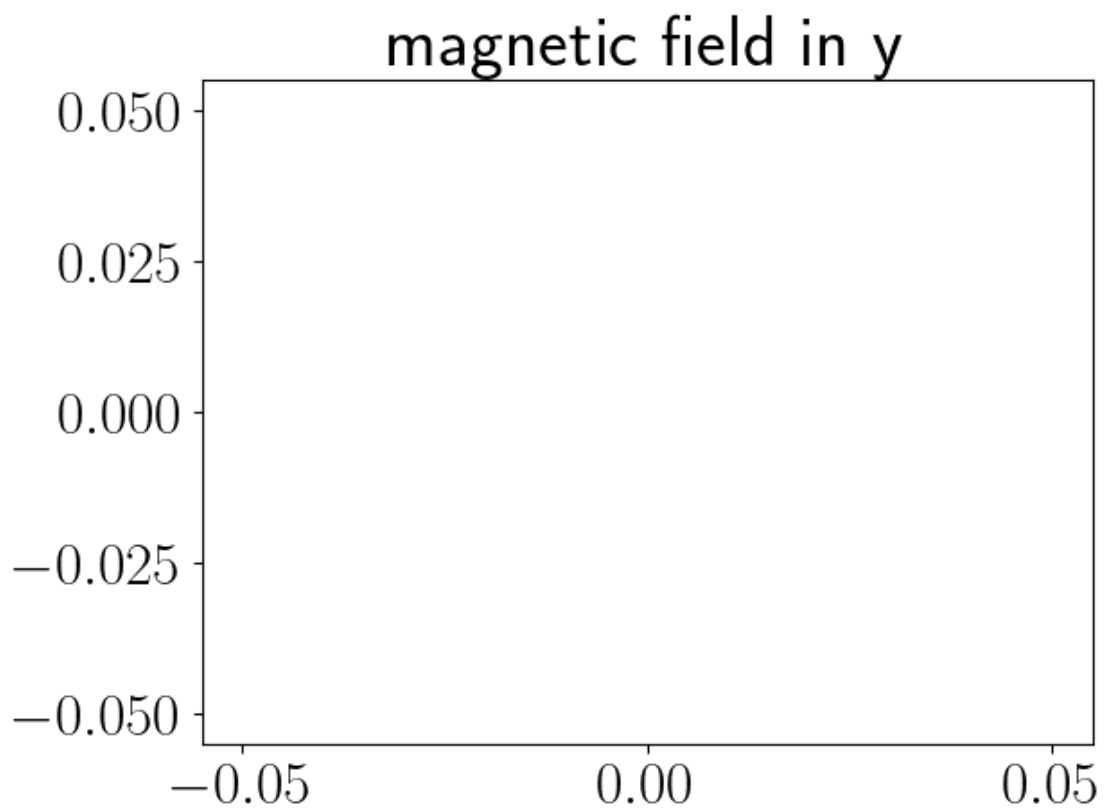


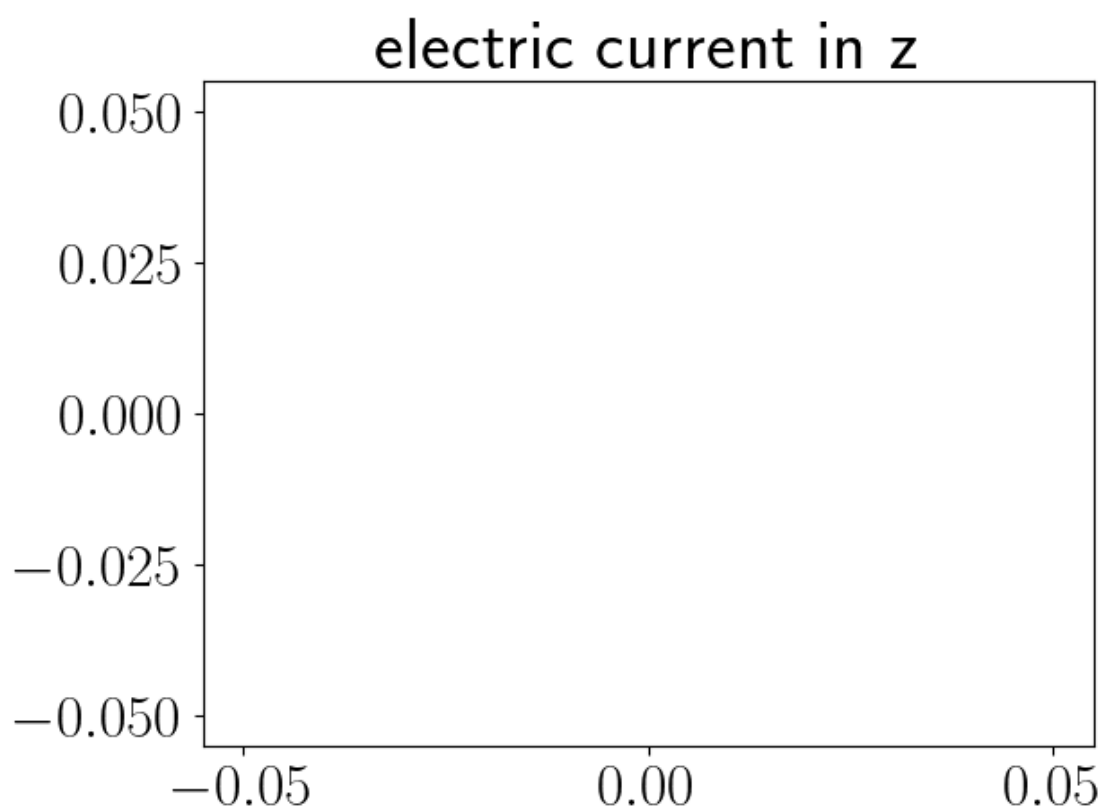
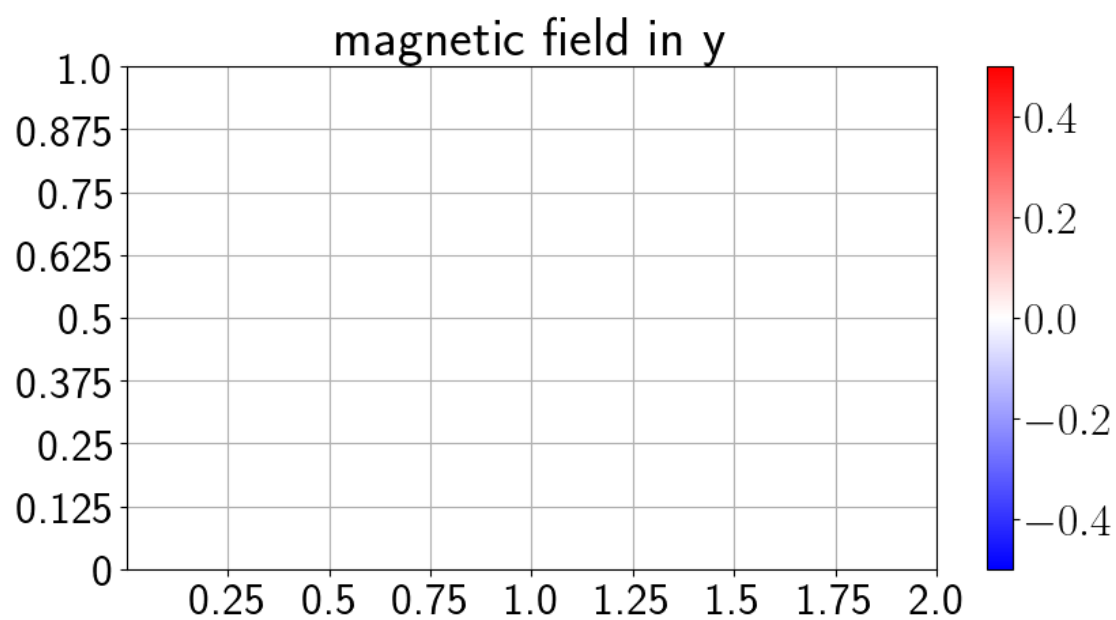




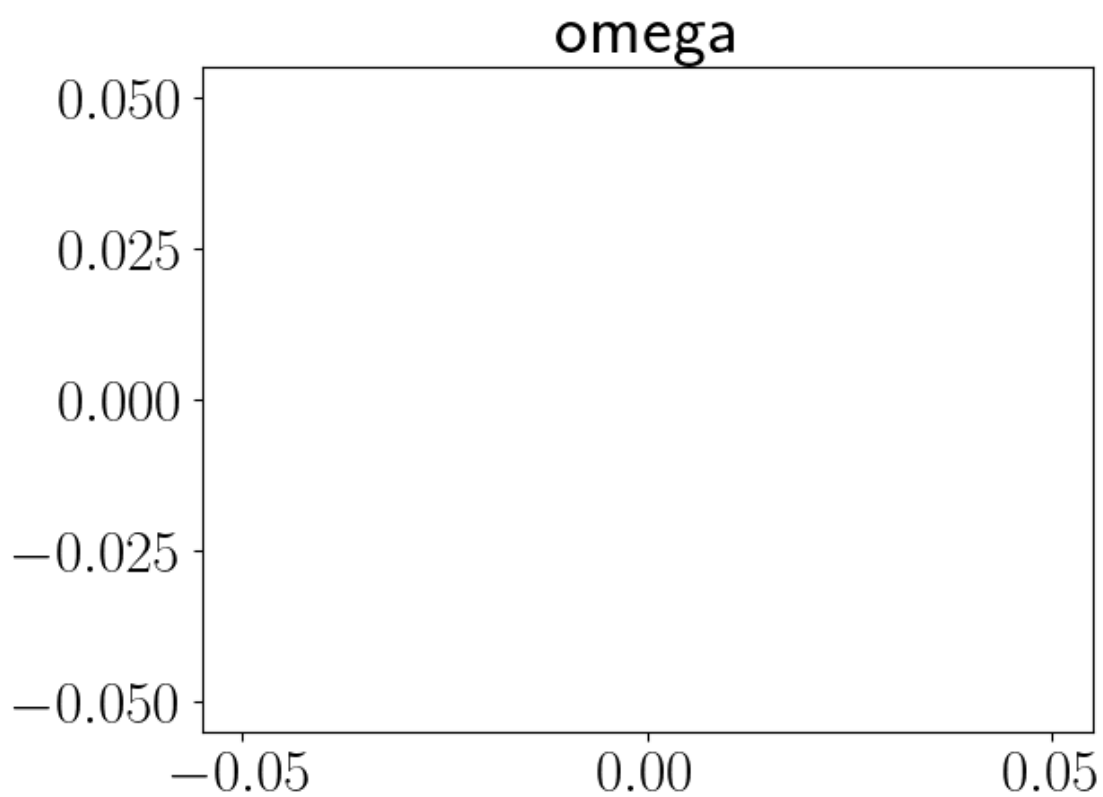




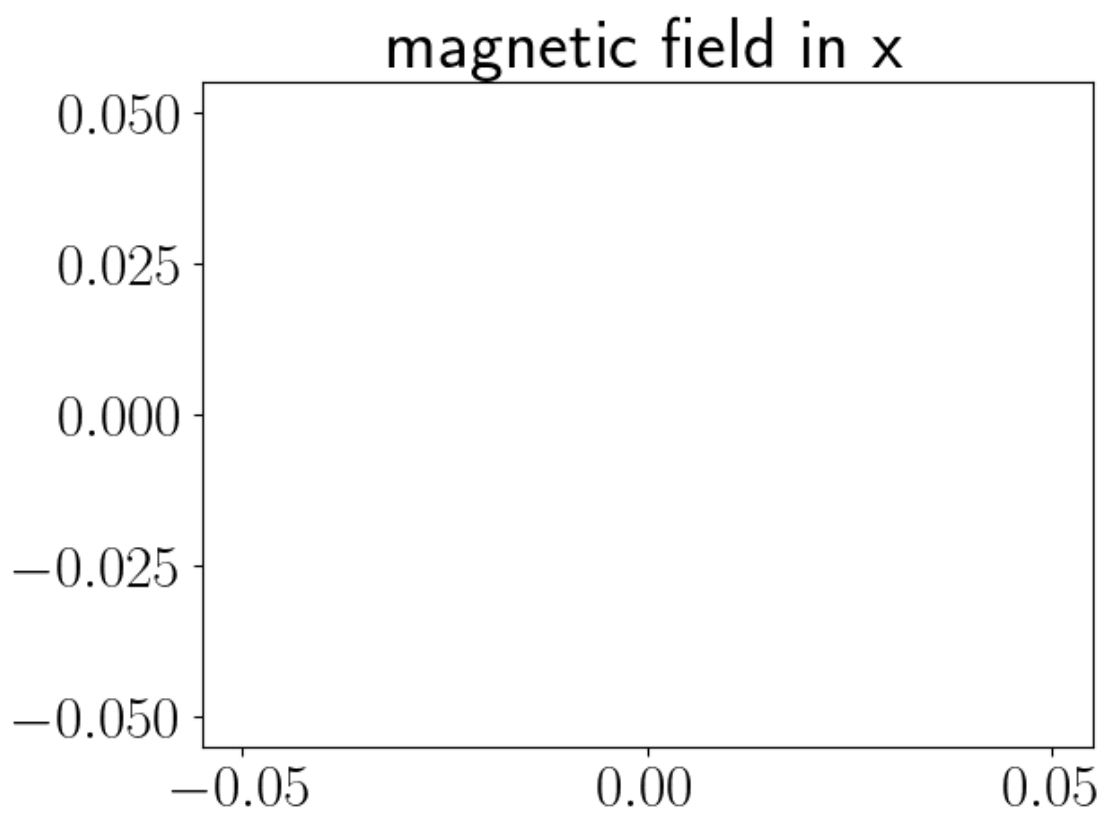
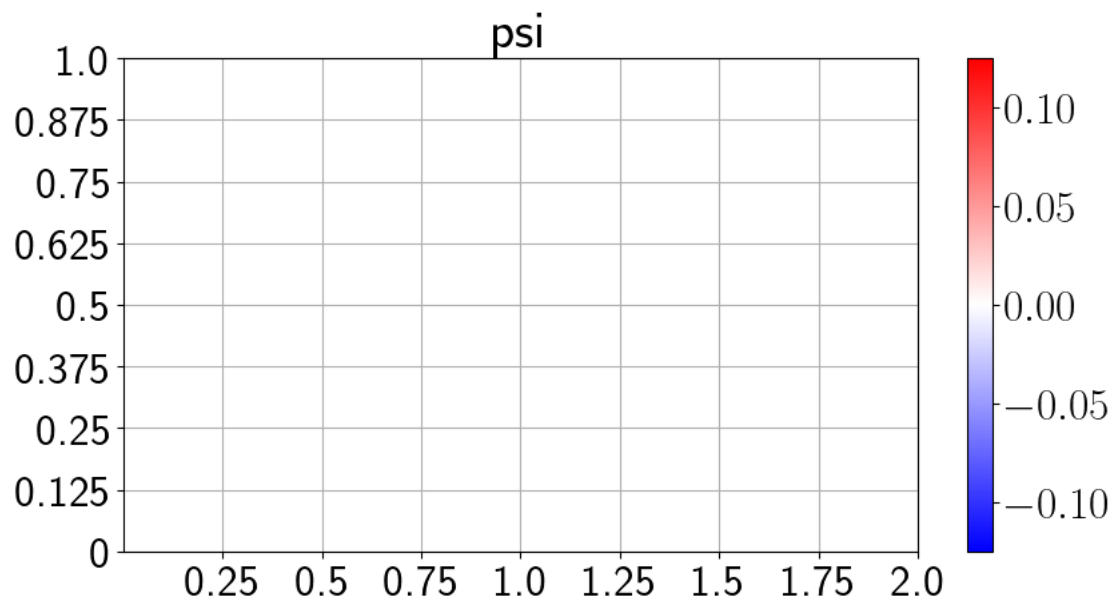


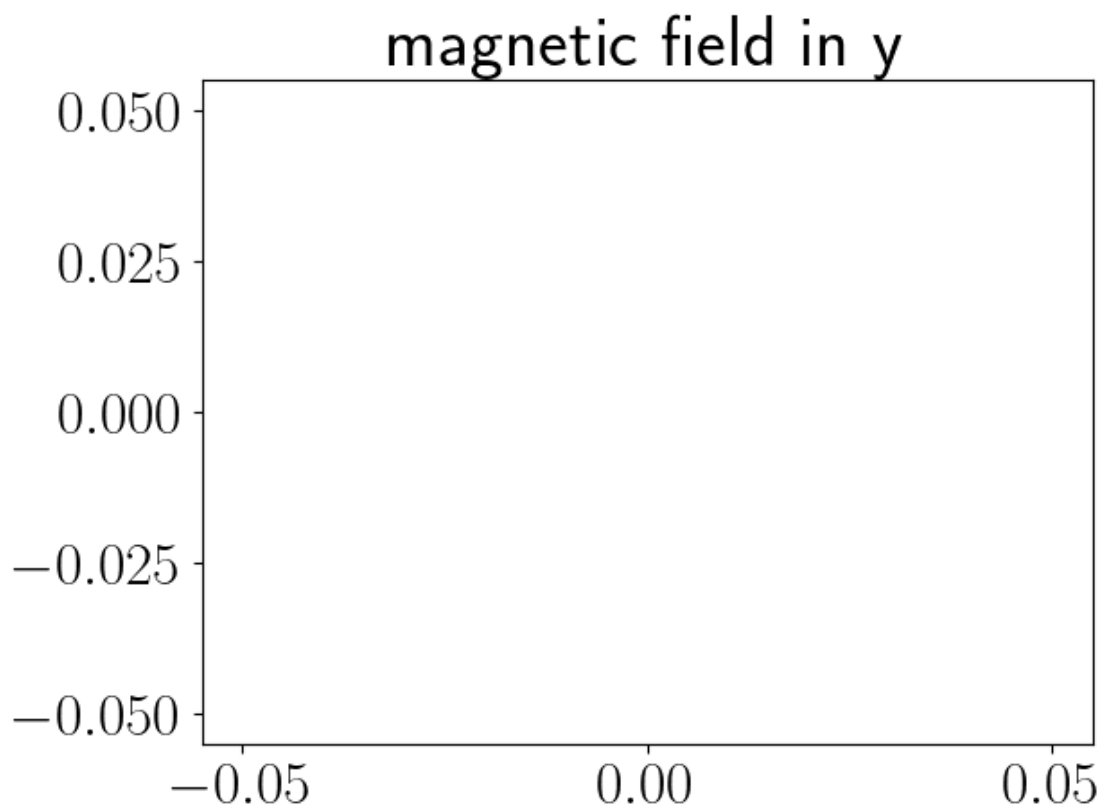




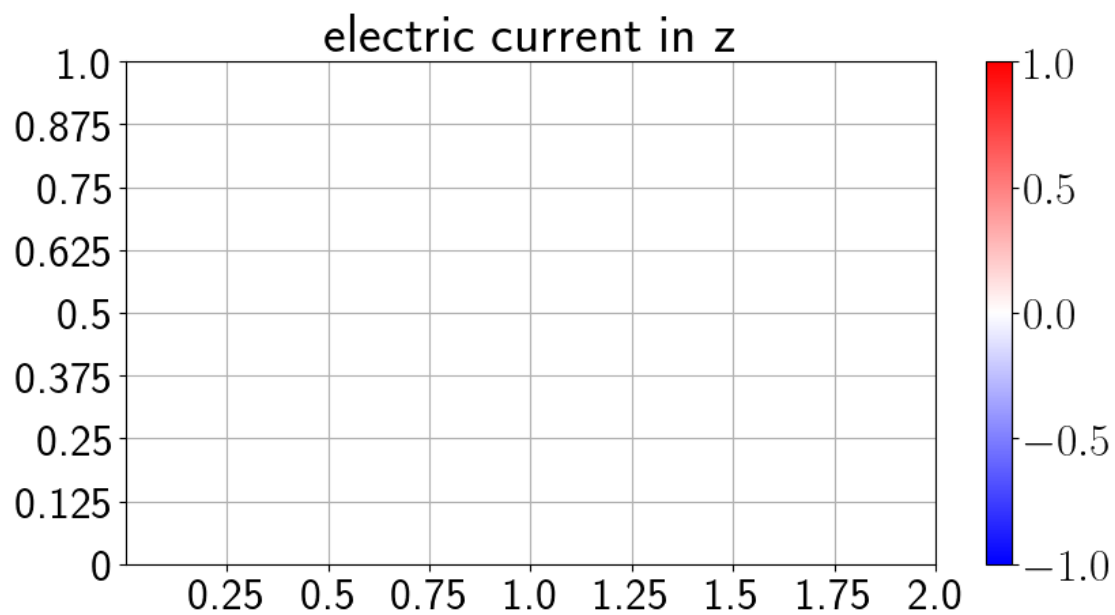


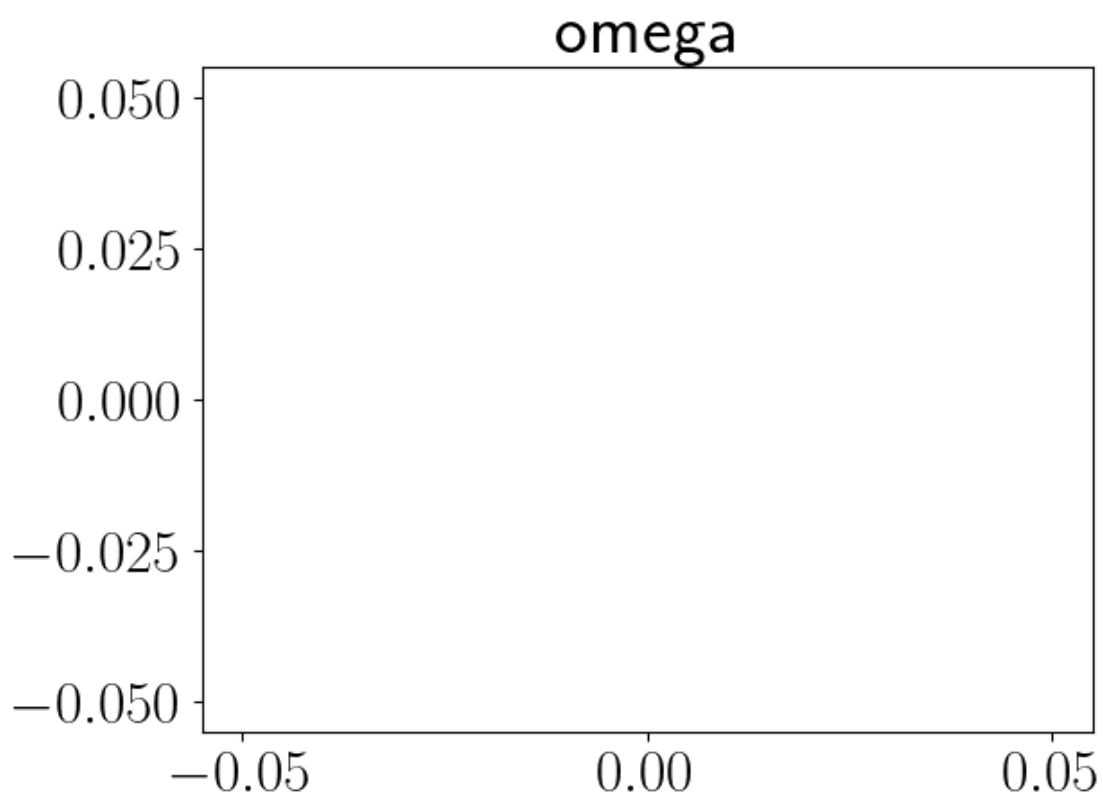




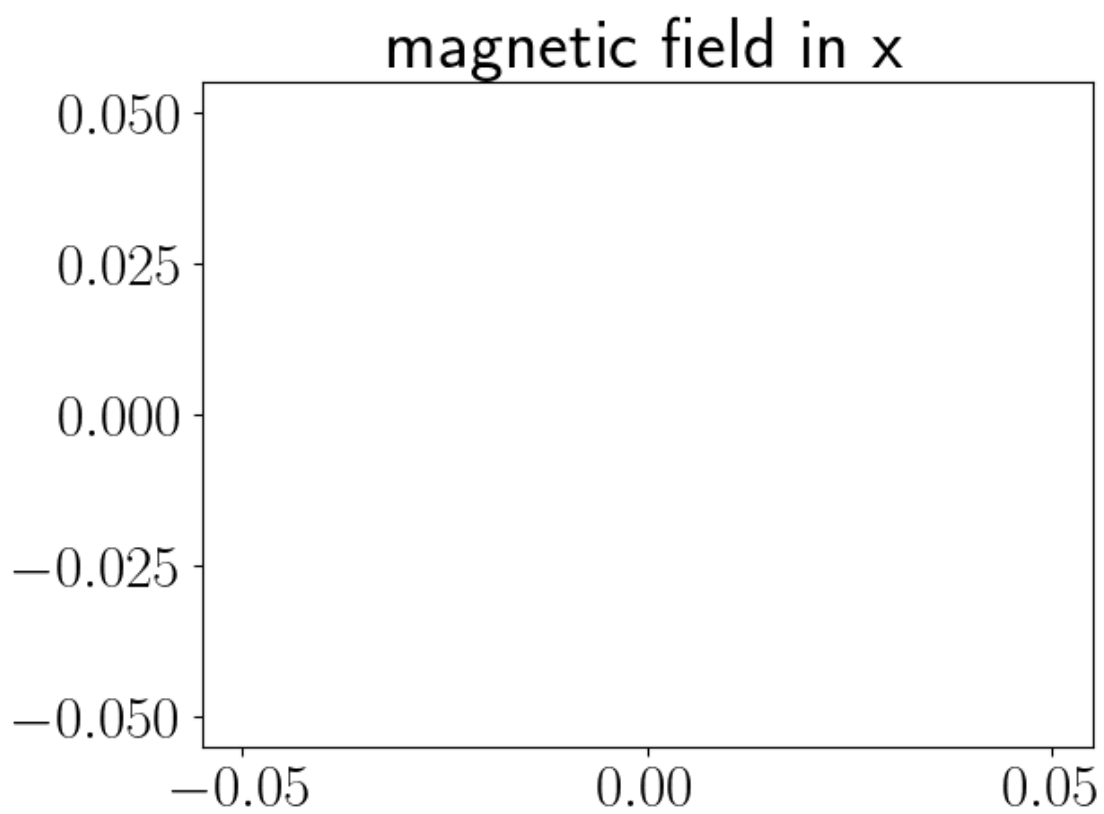
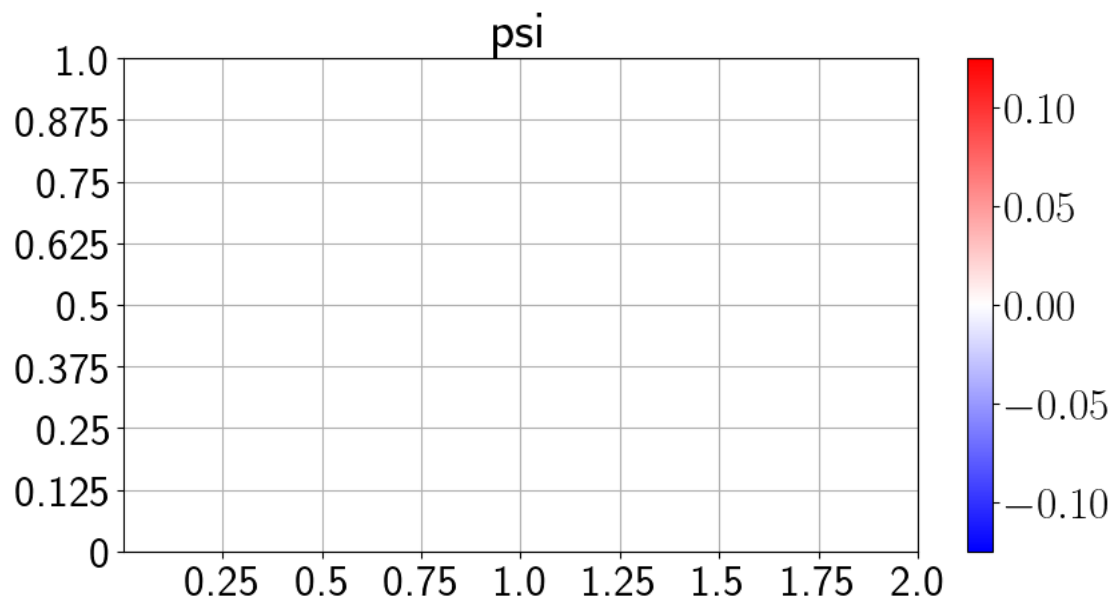


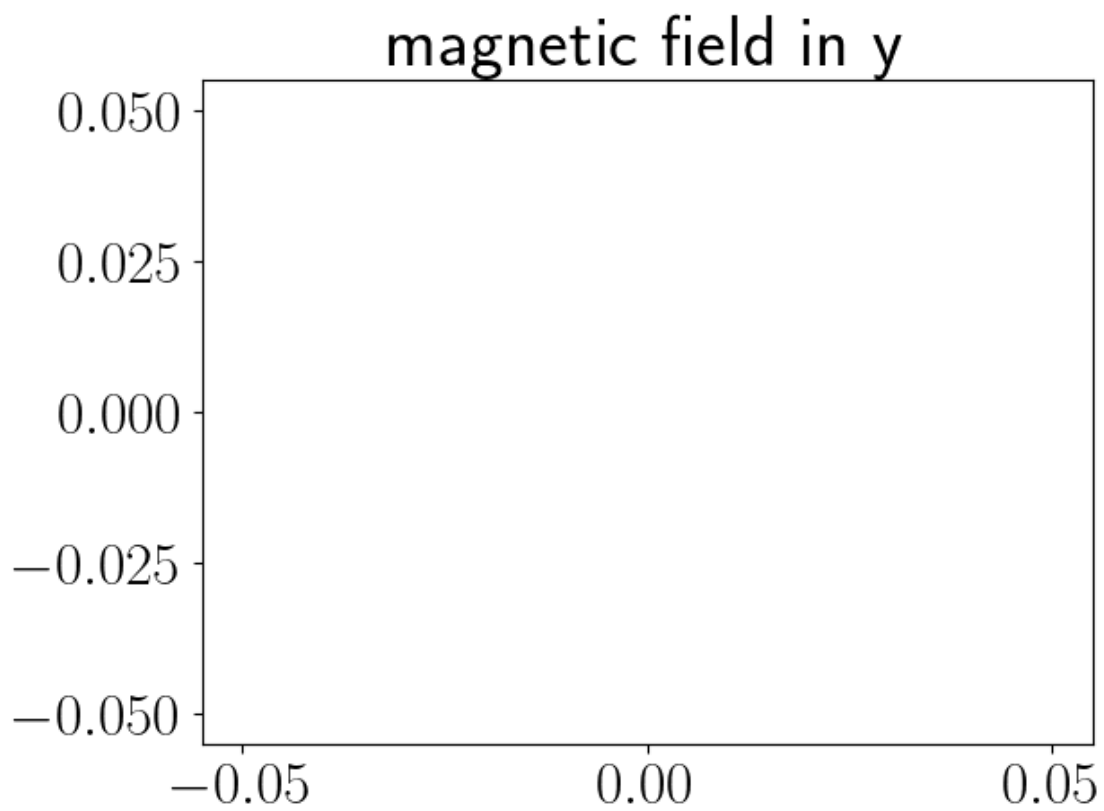






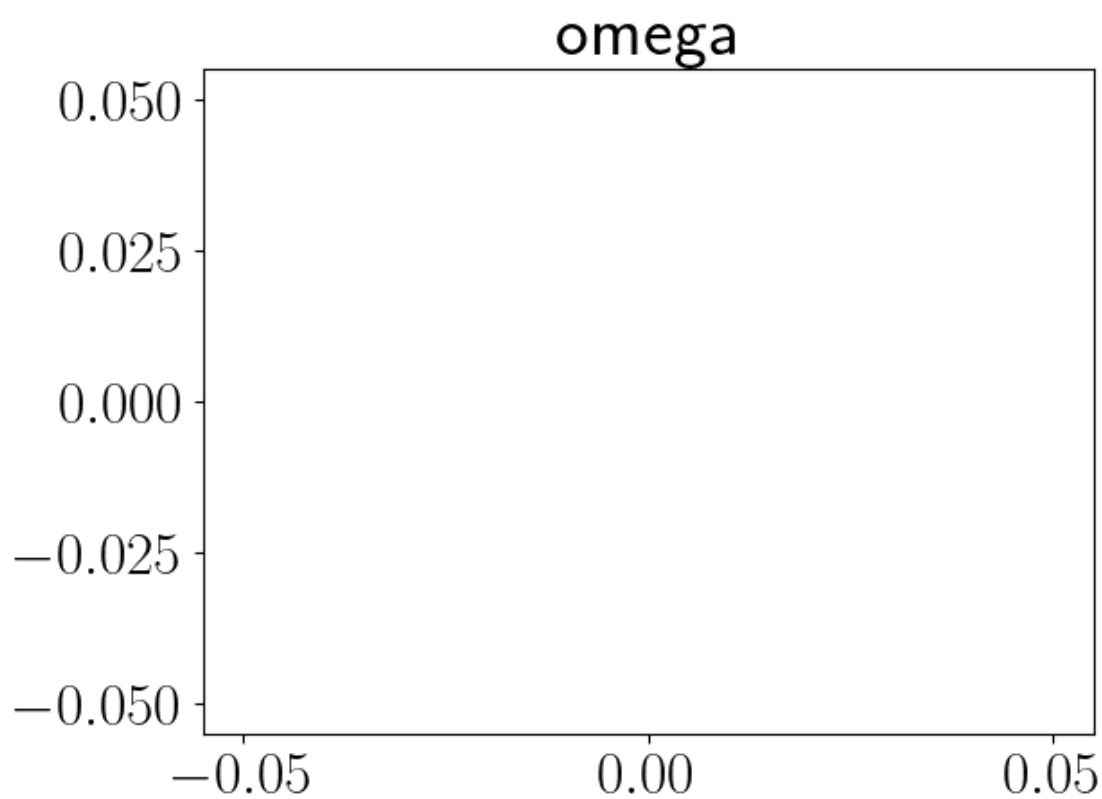
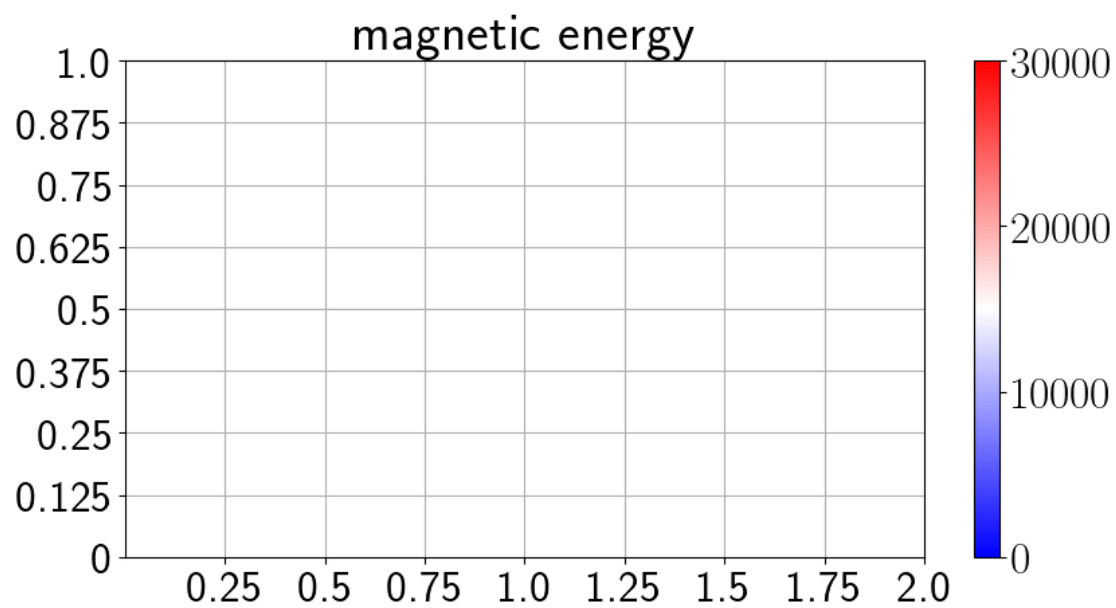


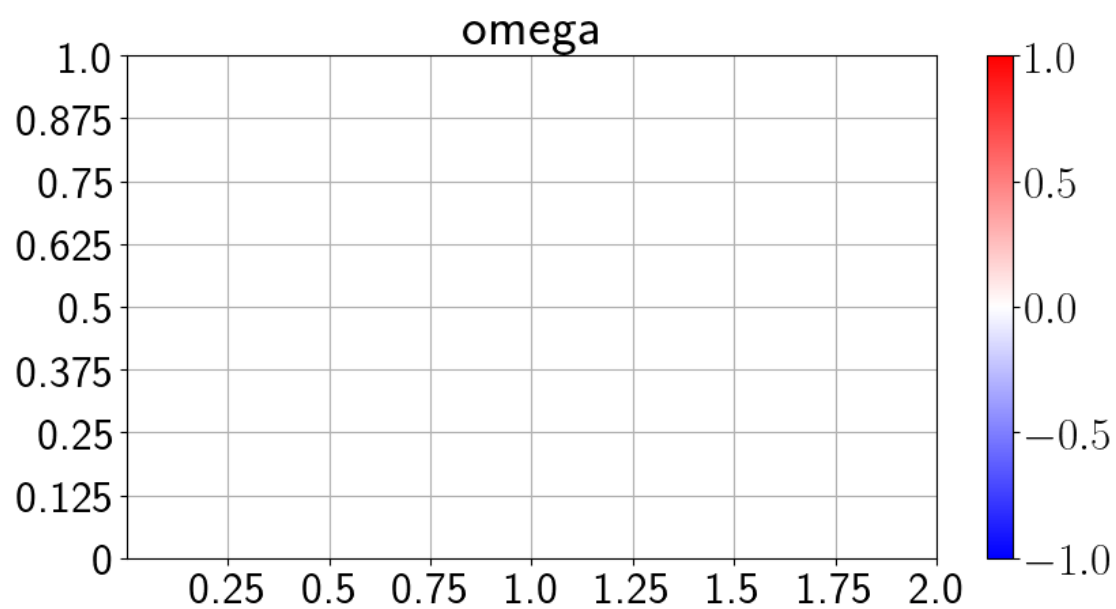


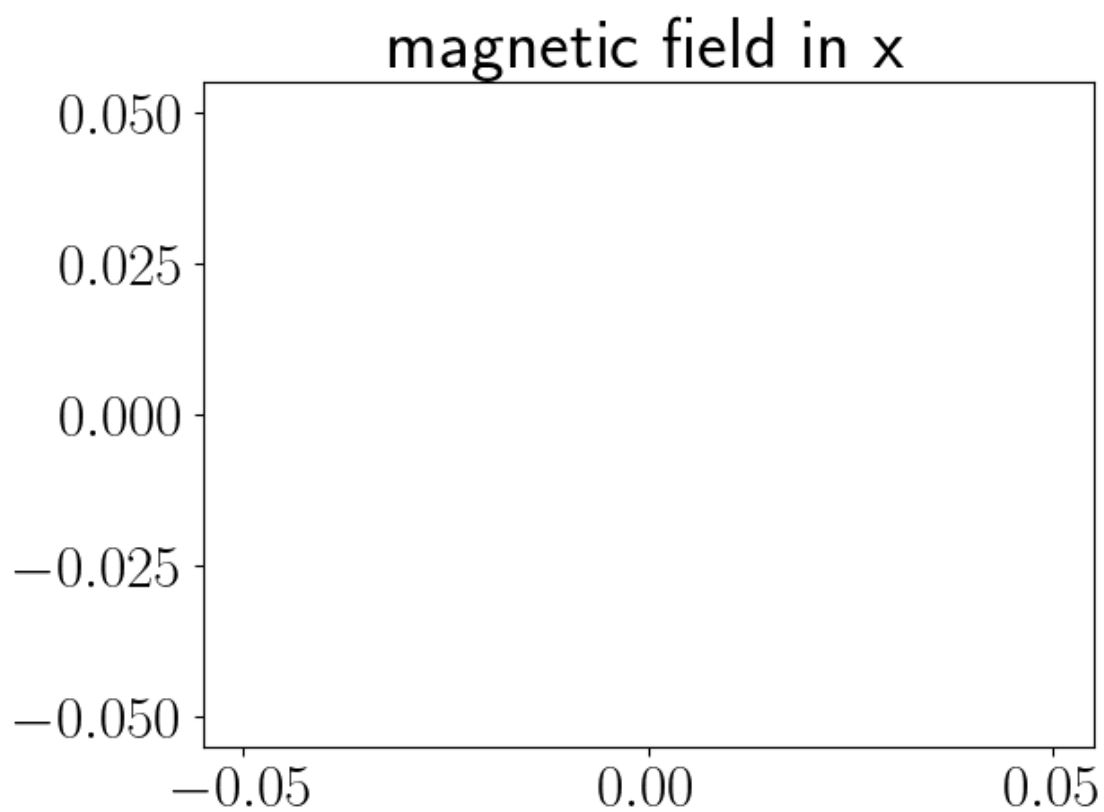
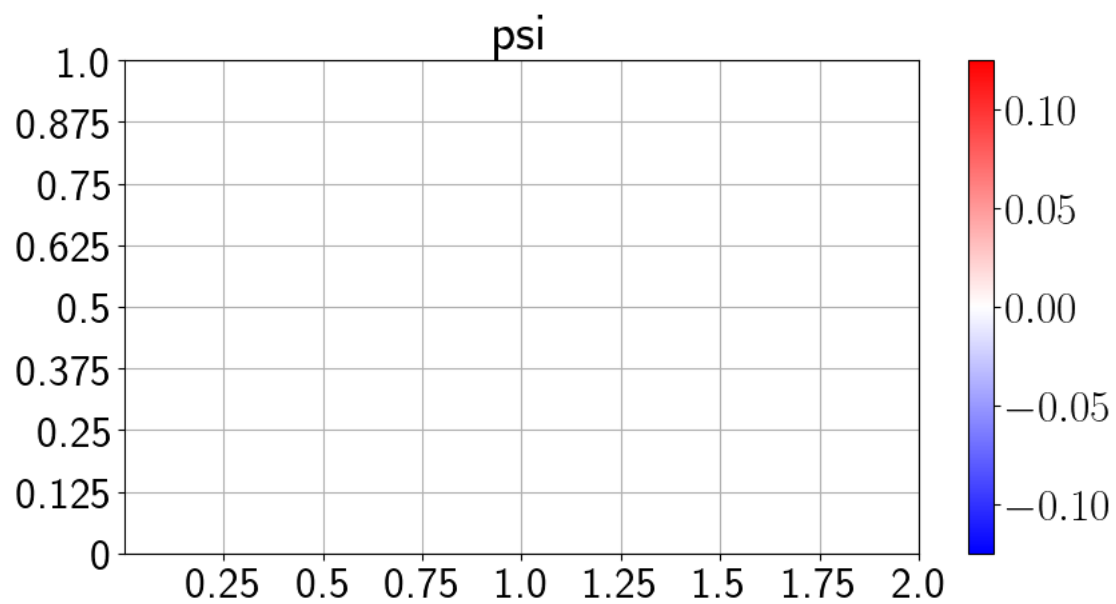






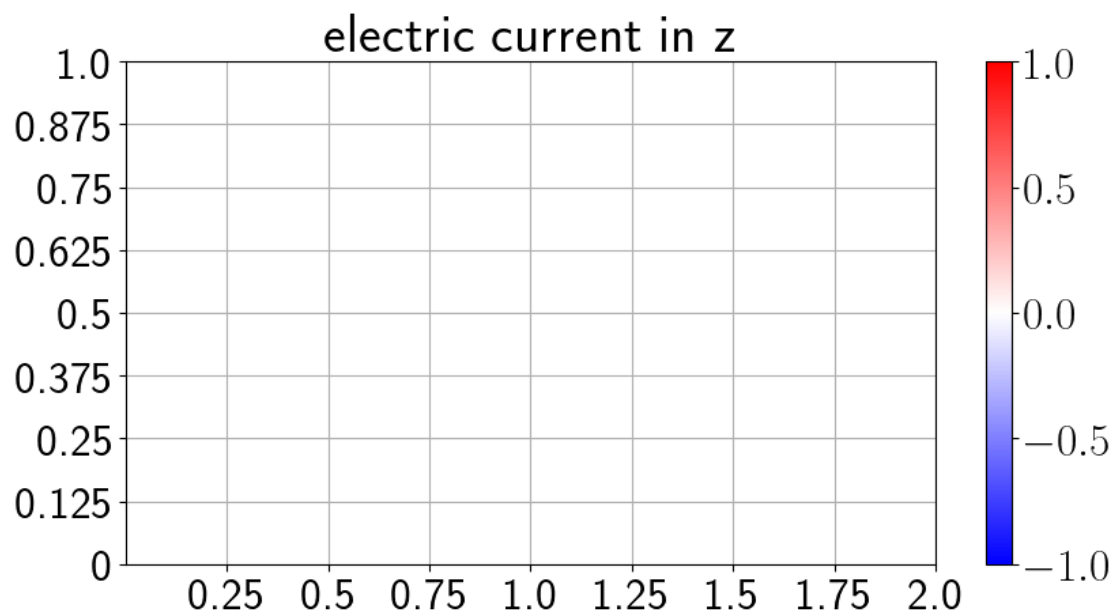


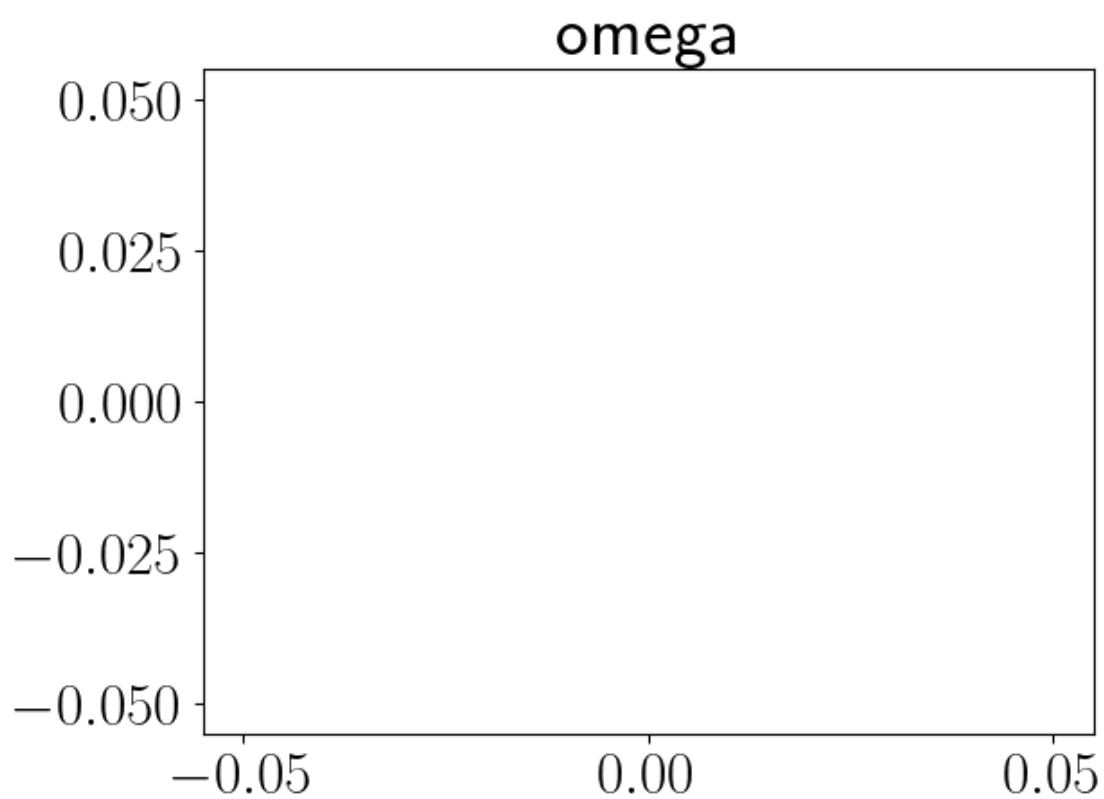
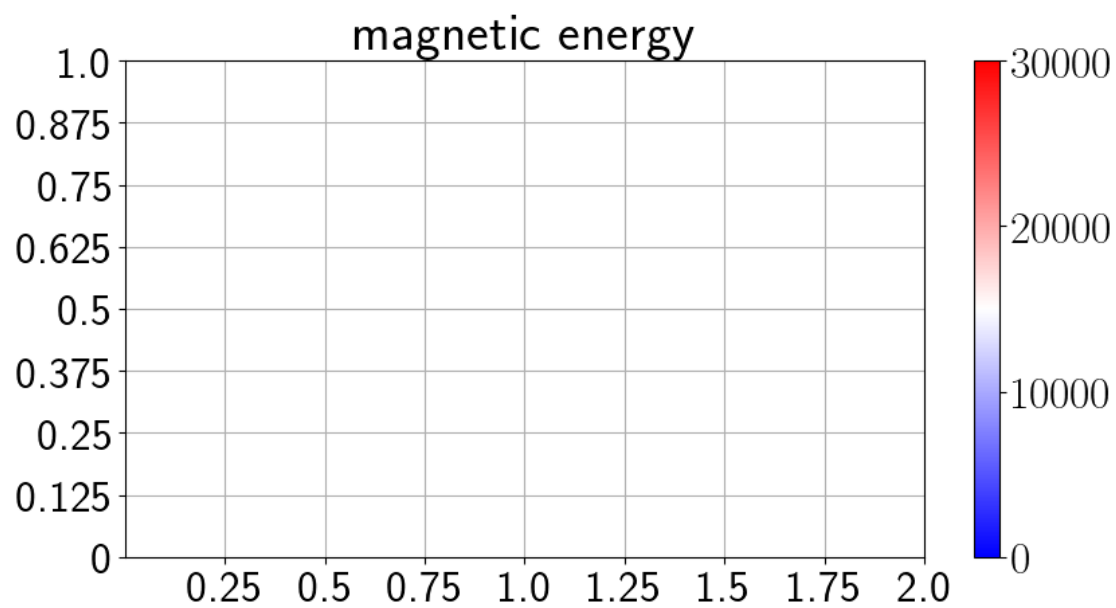


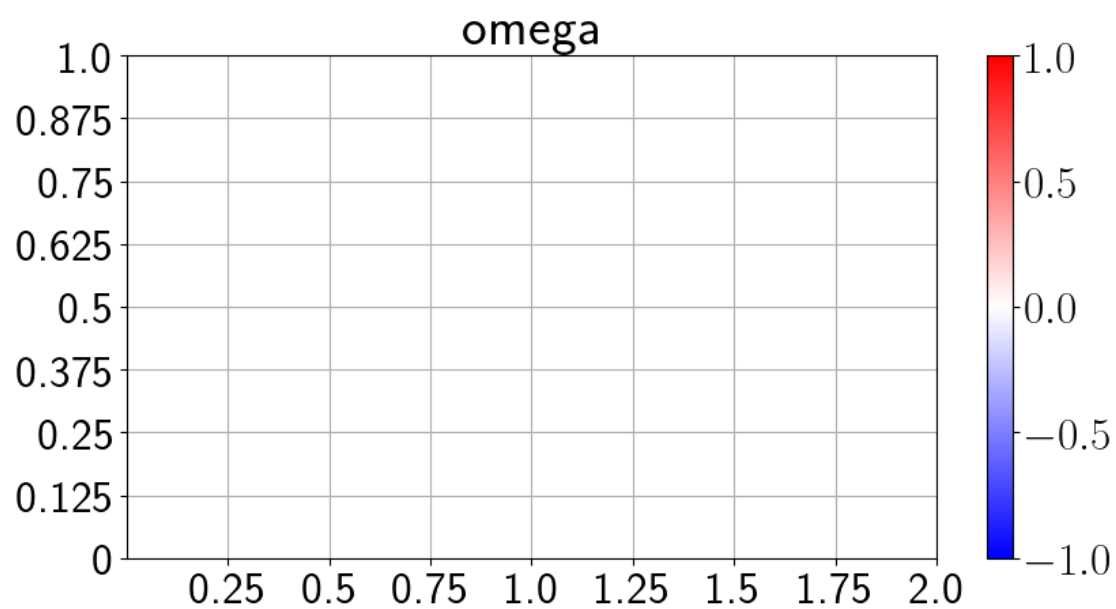


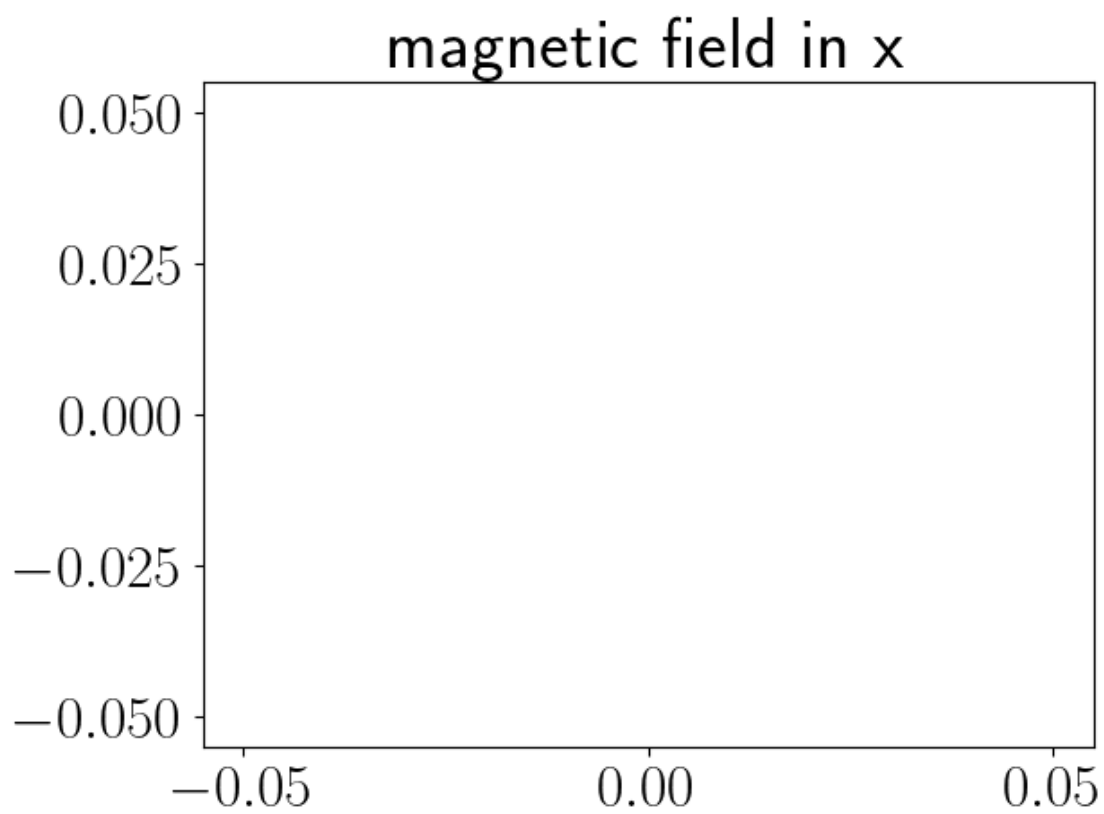
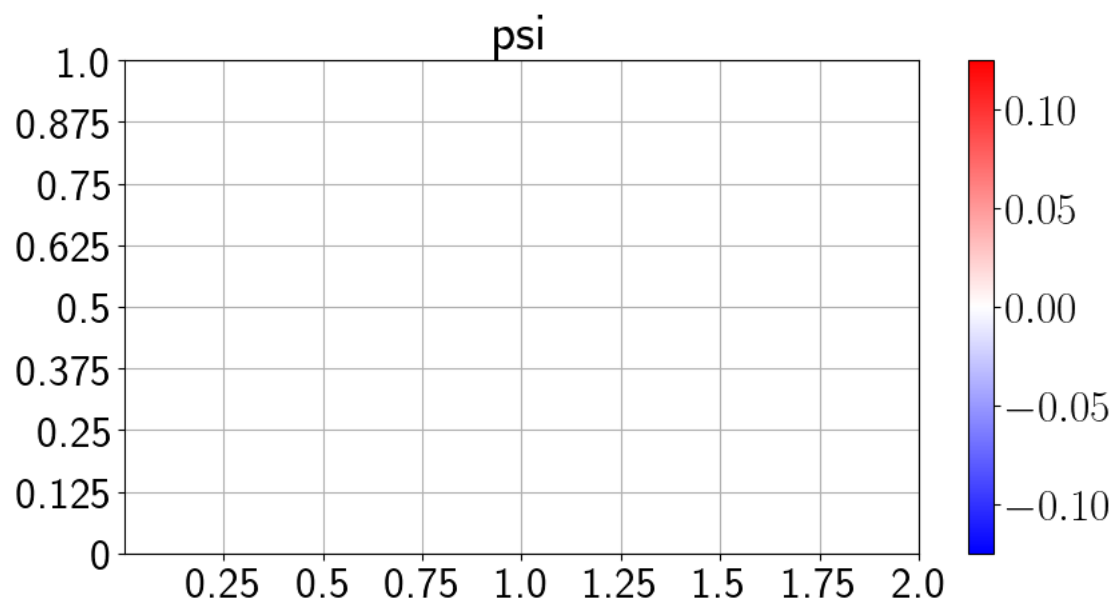


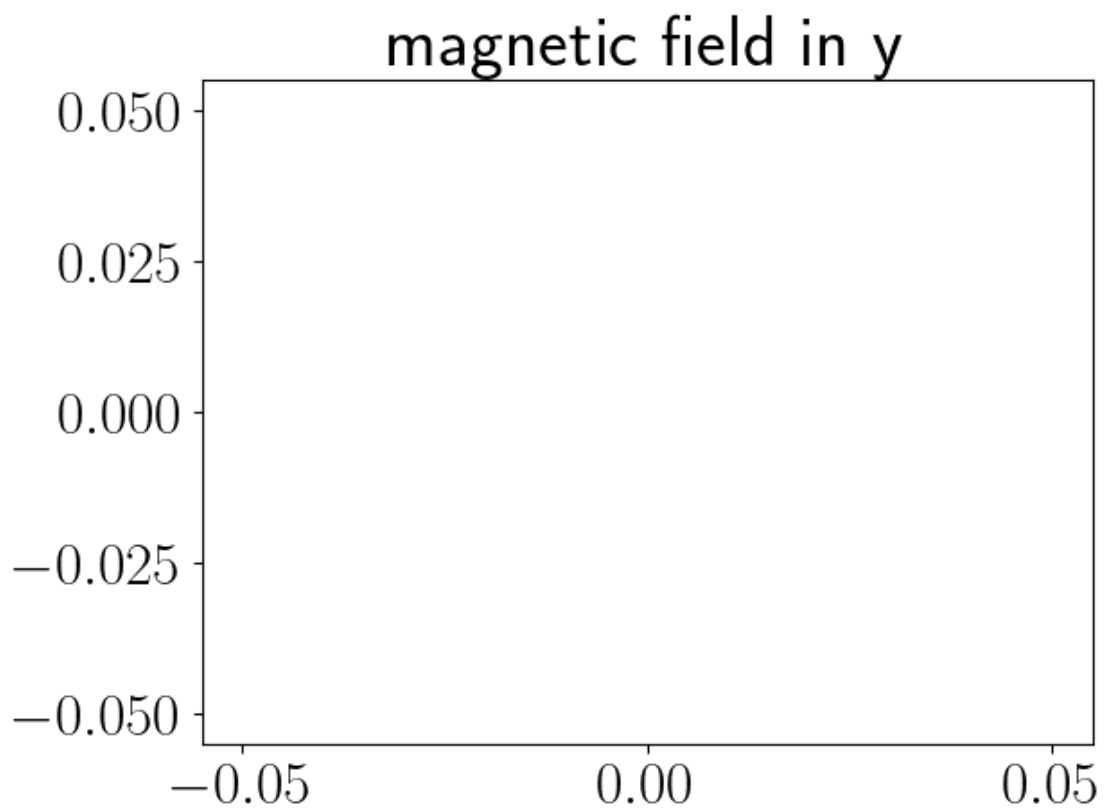






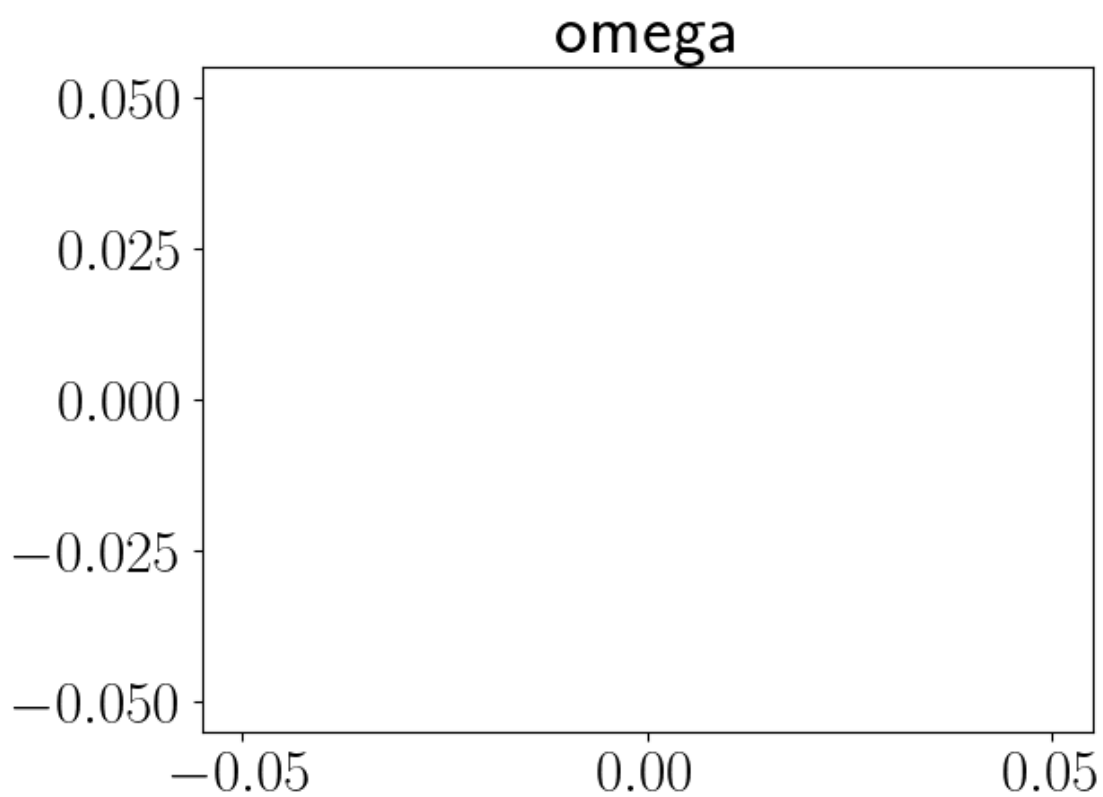




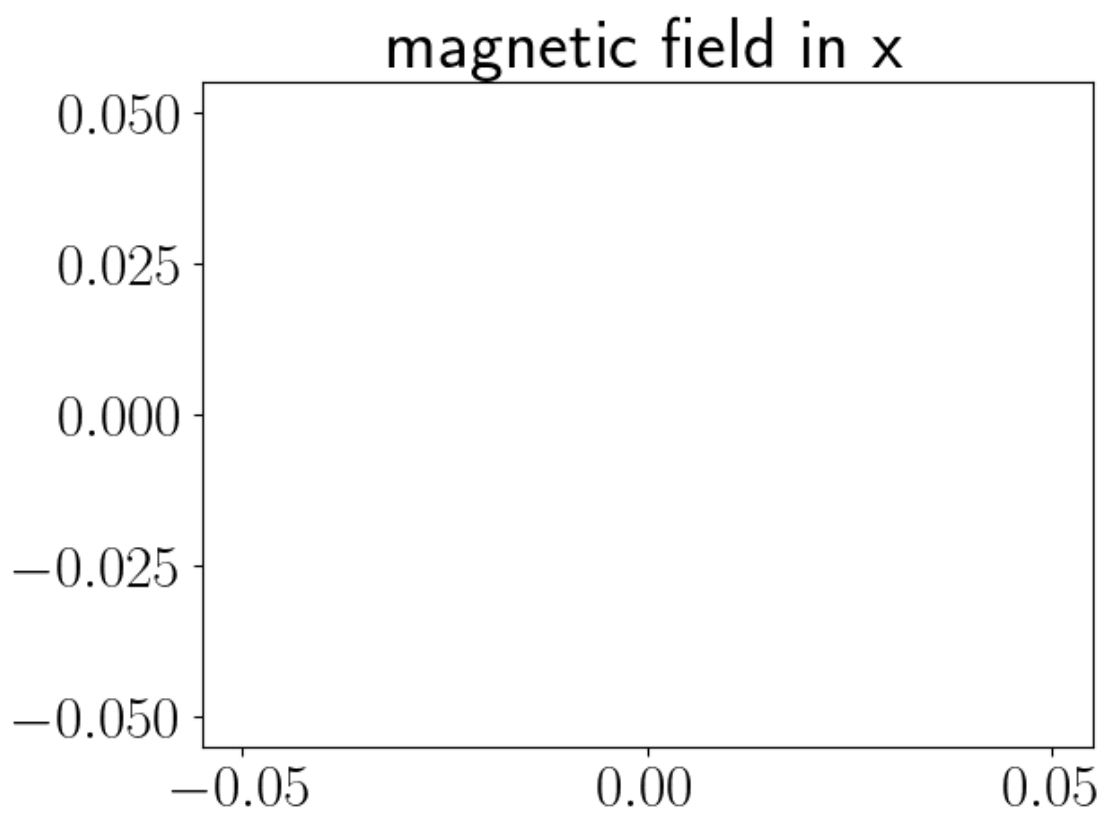
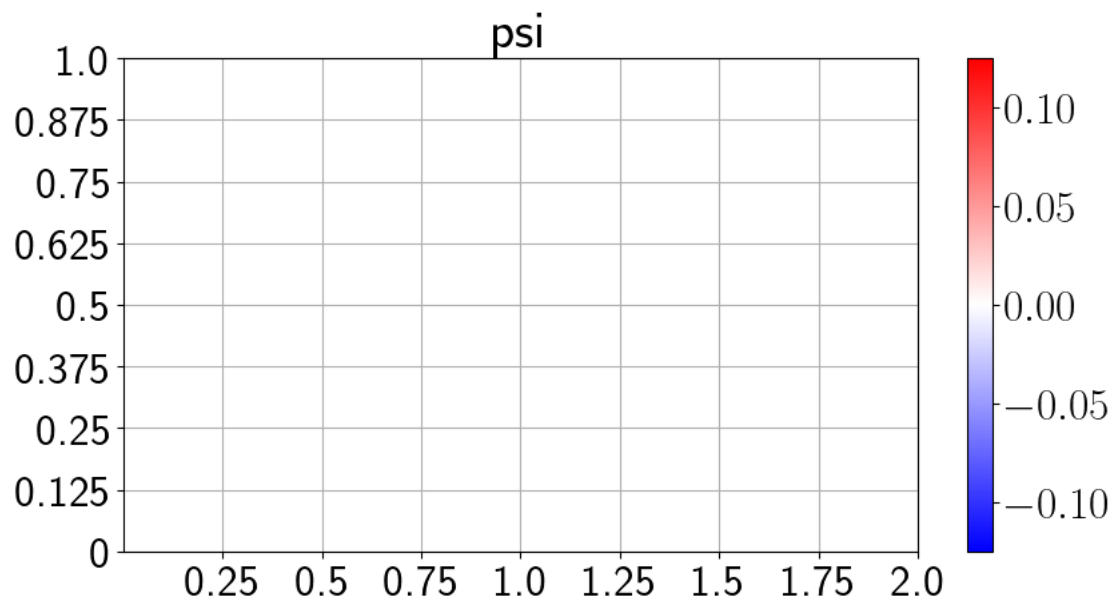


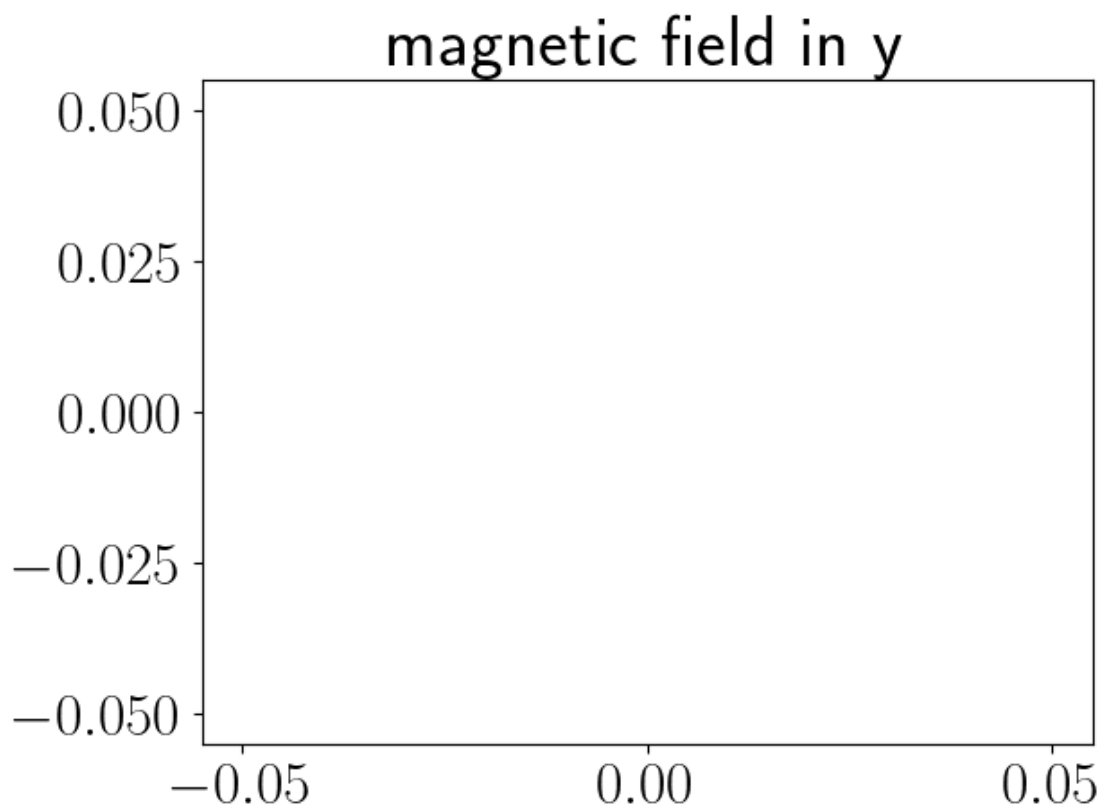






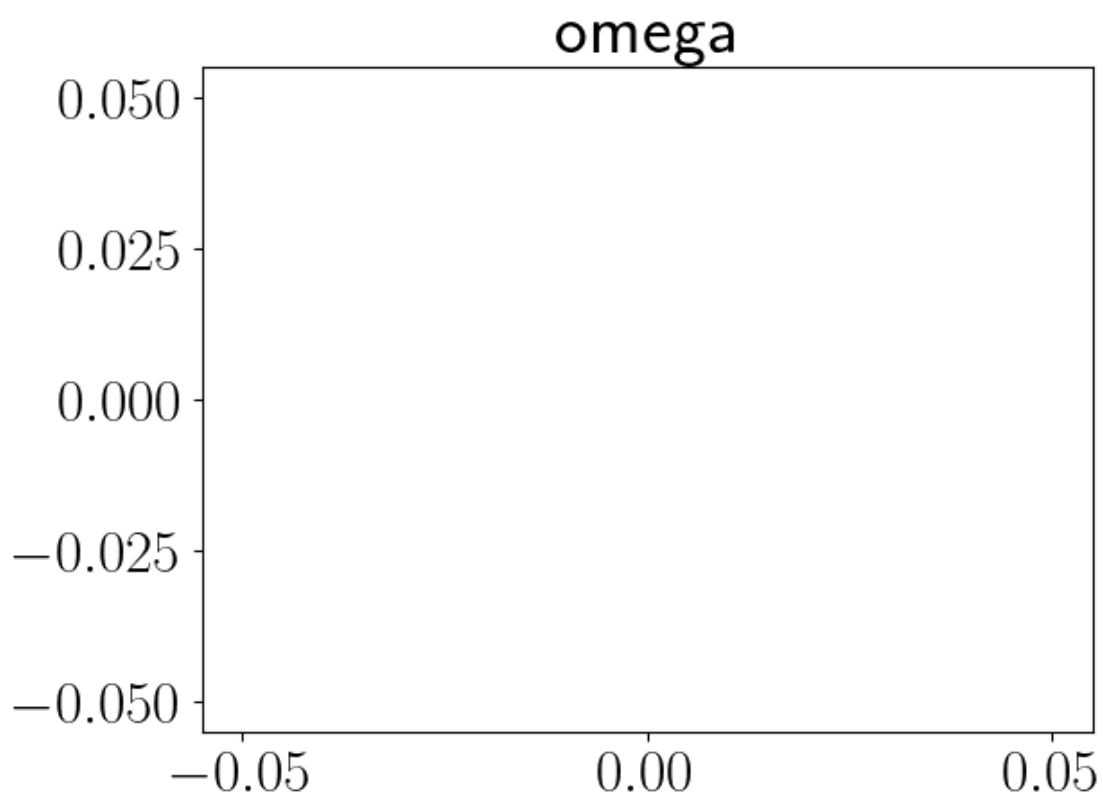




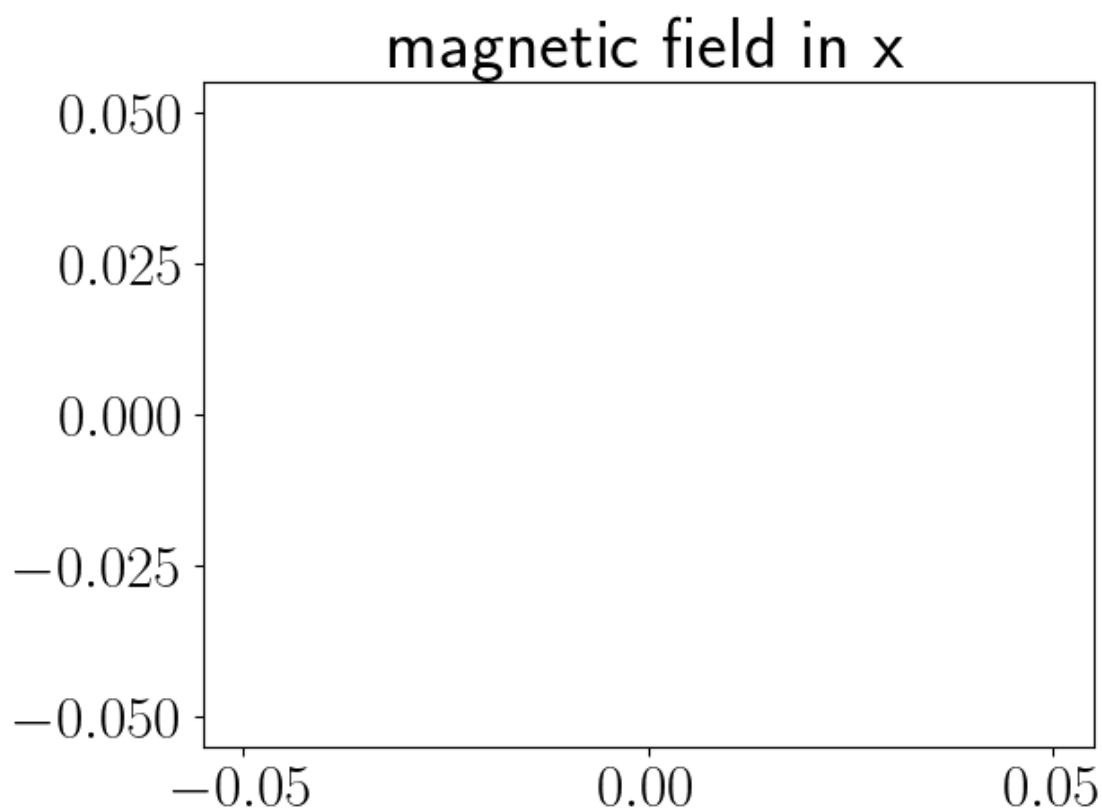
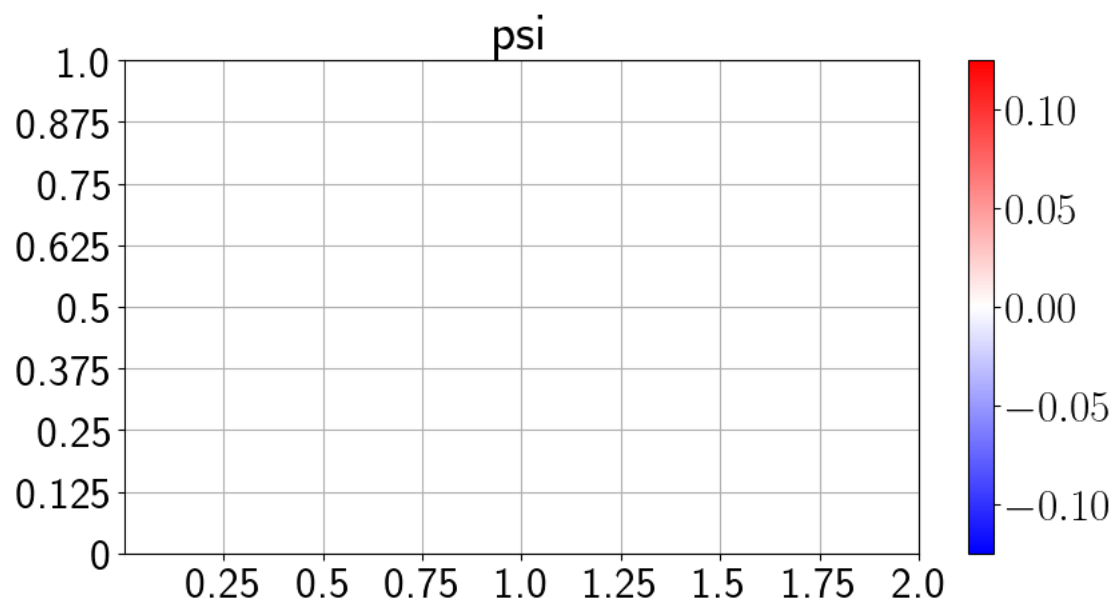


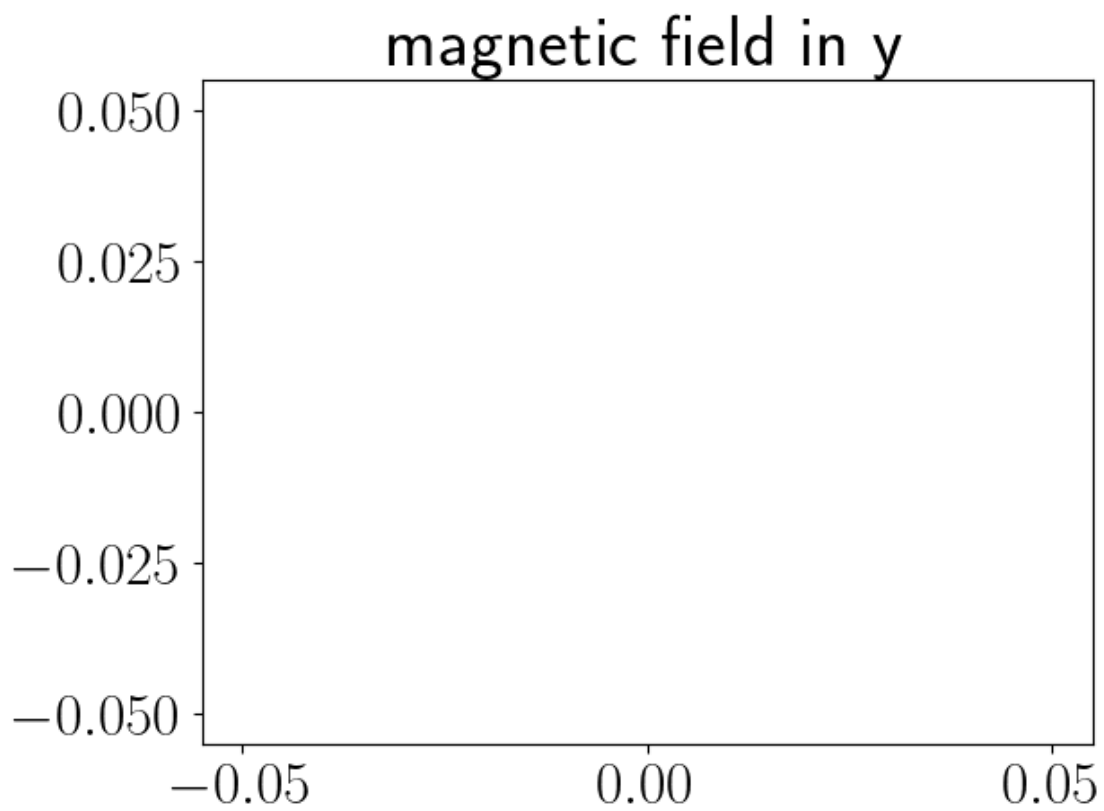






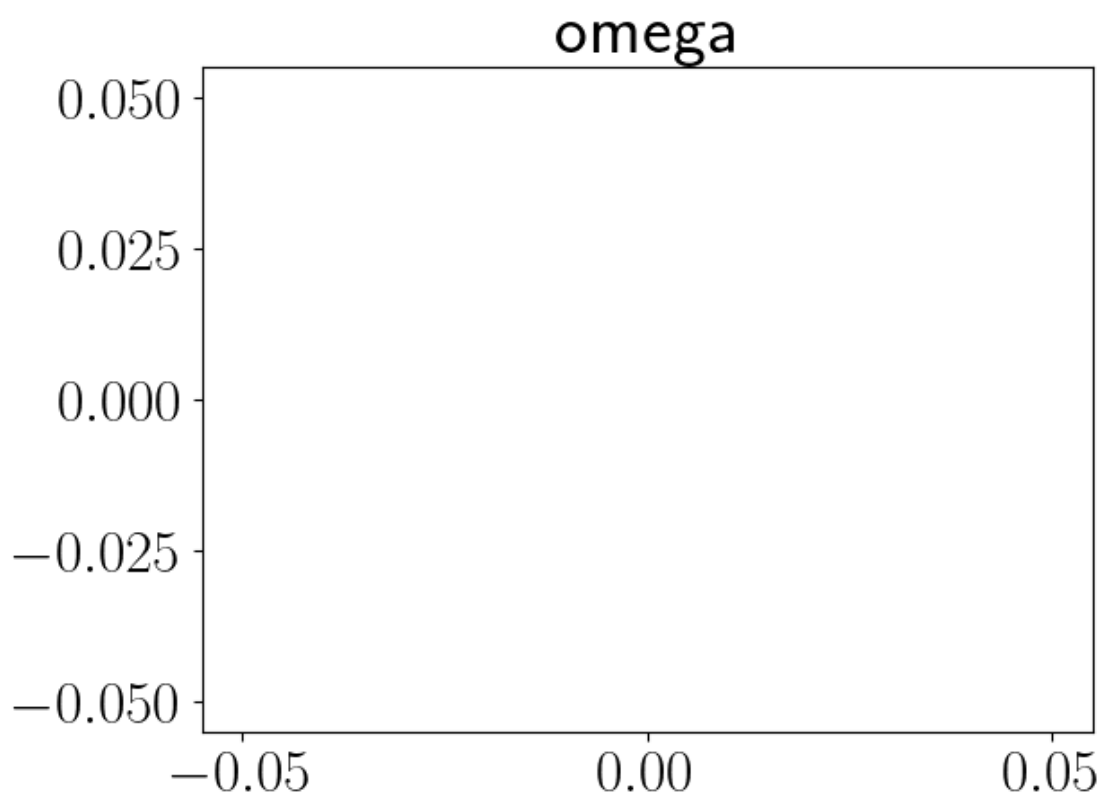
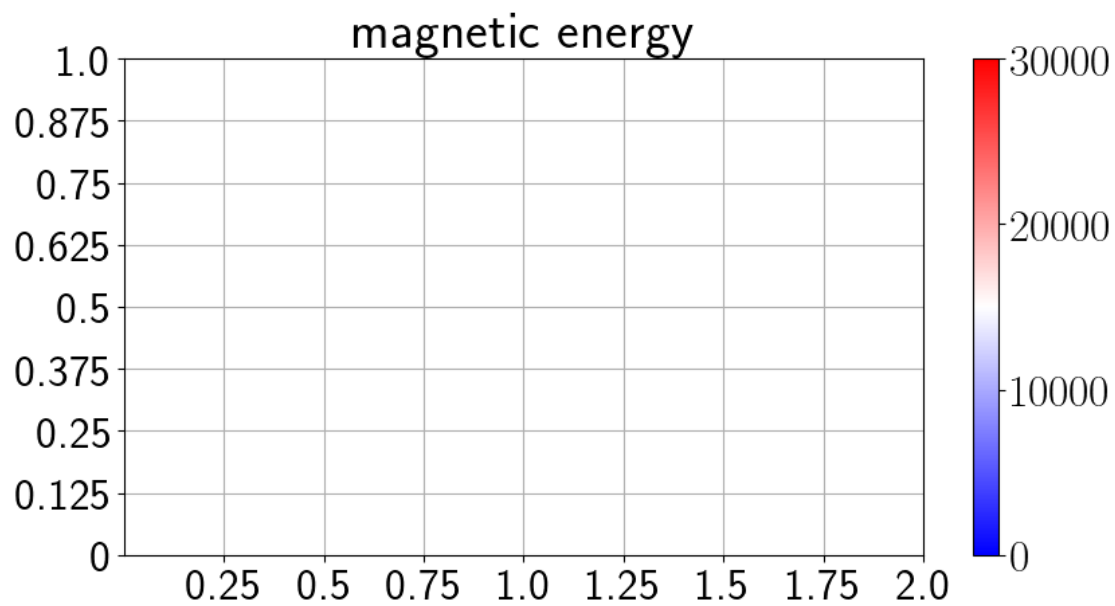


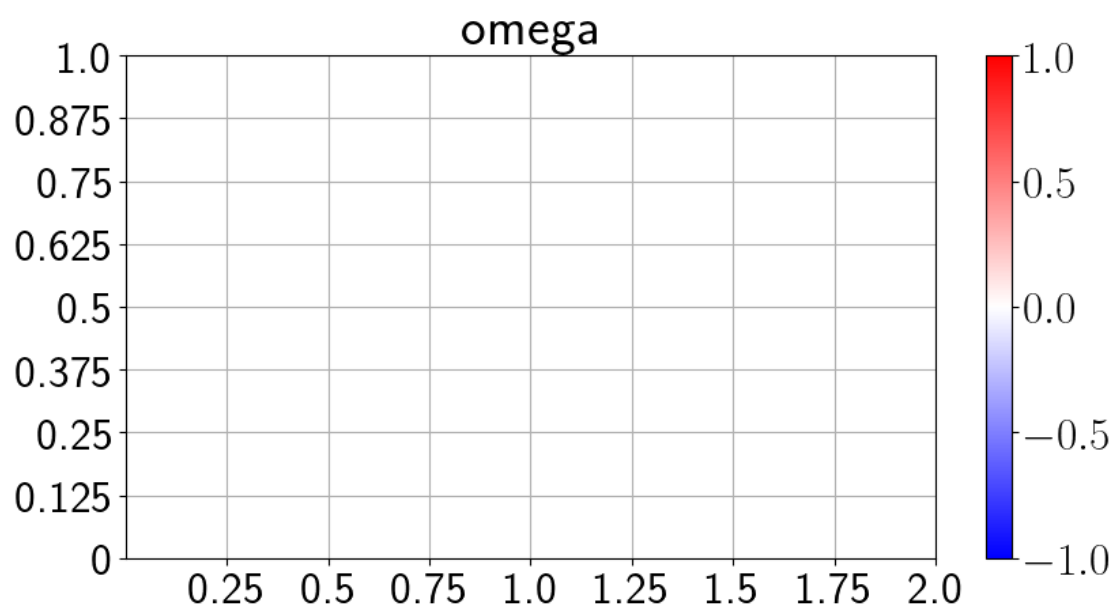


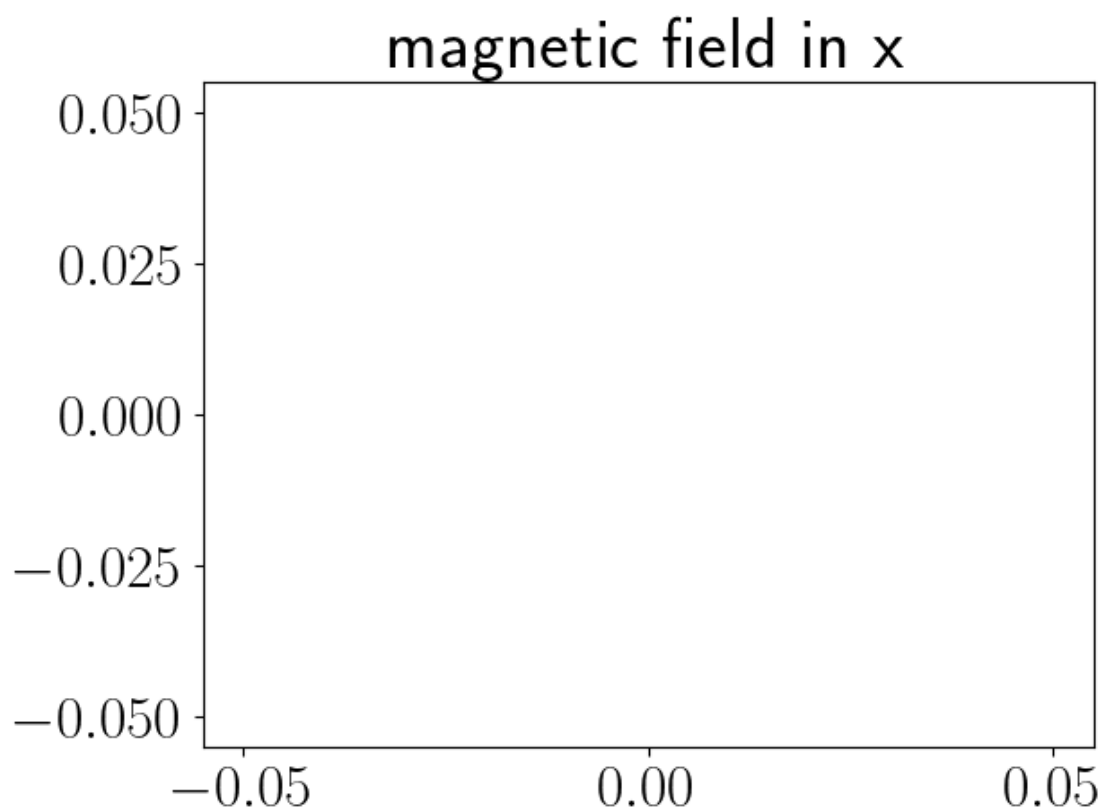








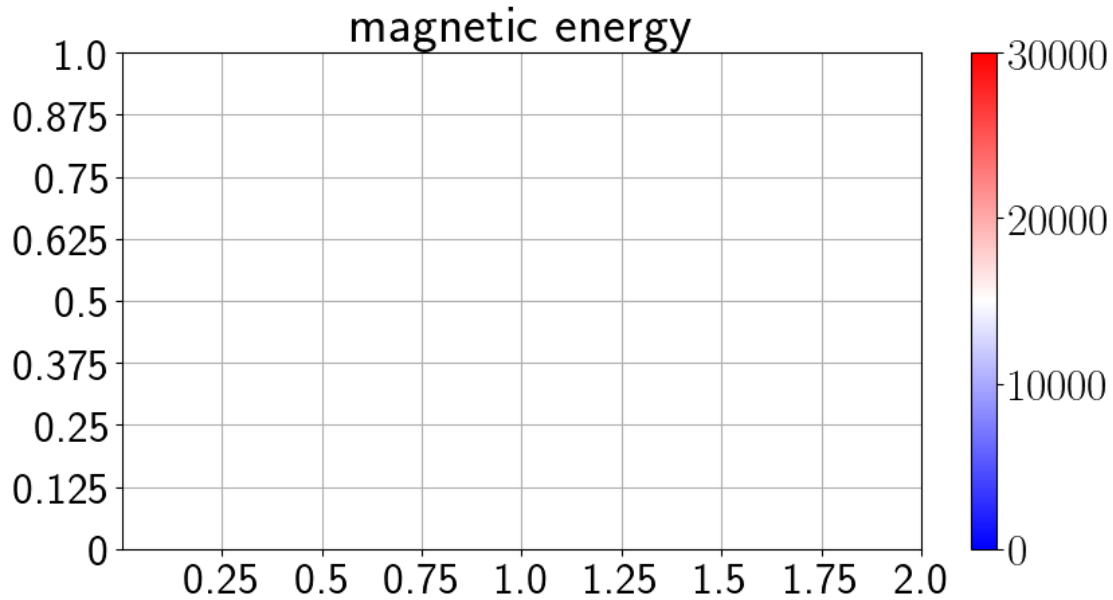












```
[10]: finaltime = time.time()
      timedif = finaltime - inittime
      print("{:.0f}".format(timedif/60), "m", timedif%60, "s")
```

14 m 27.80715012550354 s

```
[11]: E = cp.diff(psi_diff)/(delta_t * alfven_velocity * B_0)
```

```
[12]: print(max(E))
```

5.0296362801403715e+306

```
[13]: mag_erg_avg = 0
      for i in range(n_x):
          for j in range(n_y):
              mag_erg_avg += mag_erg[i, j]
      mag_erg_avg = mag_erg_avg/(n_x * n_y)
      print(mag_erg_avg)
```

nan

```
[14]: if do_dump == True:
      dump(w1, 'dumps/wide/B=0.6/e-7/w.txt')
      dump(psi1, 'dumps/wide/B=0.6/e-7/psi.txt')
      dump(mag_erg, 'dumps/wide/B=0.6/e-7/mag_erg.txt')
      dump(elec_j, 'dumps/wide/B=0.6/e-7/j.txt')
      dump(vx, 'dumps/wide/B=0.6/e-7/vx.txt')
      dump(vy, 'dumps/wide/B=0.6/e-7/vy.txt')
```

```

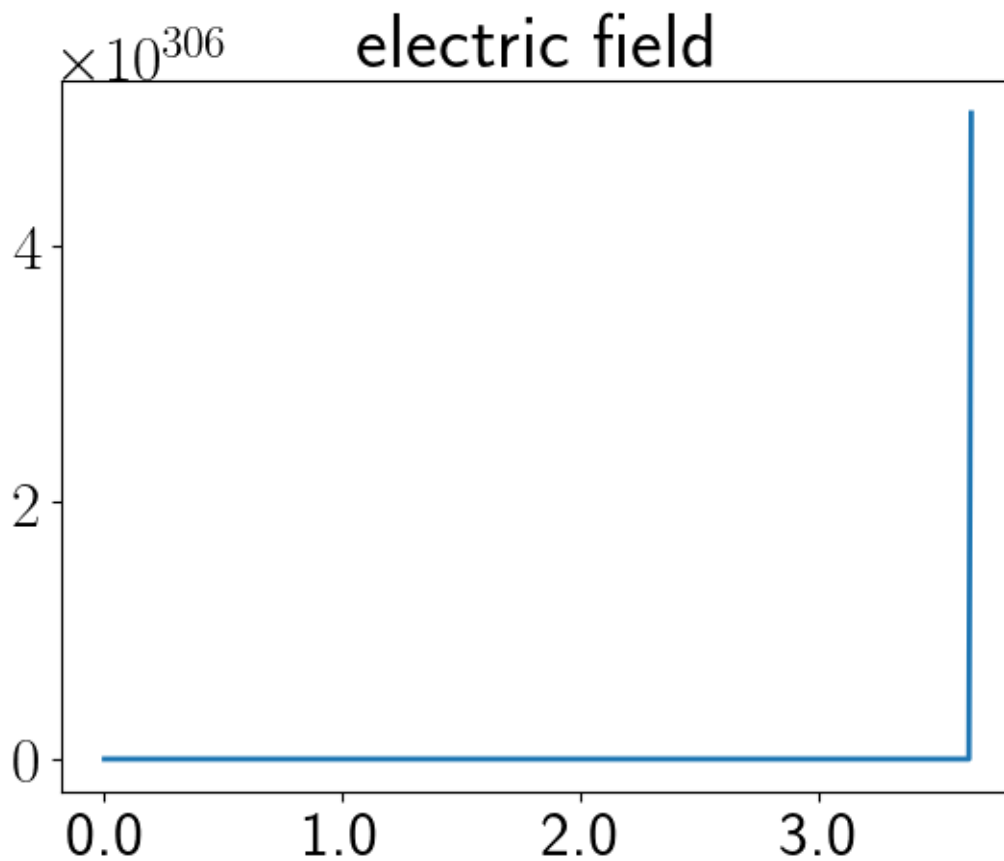
dump(bx, 'dumps/wide/B=0.6/e-7/bx.txt')
dump(by, 'dumps/wide/B=0.6/e-7/by.txt')
efile = open('dumps/wide/B=0.6/e-7/E.txt', "w")
for i in range(n_steps-1):
    efile.write('%s ' % E[i])

```

```

[15]: l = np.linspace(0, int(n_steps/100), int(n_steps/100)+1)
p = np.zeros(int((n_steps/100)+1))
for i in range(int((n_steps/100)+1)):
    l[i] = int(l[i])
fig = E.get()
plt.title("electric field")
plt.xticks(np.linspace(0, 100*int(n_steps/100), int(n_steps/100)+1), l)
plt.plot(fig)
plt.show()

```



```

[16]: # l2norm = 0
# for i in range(n_x-10):
#     for j in range(n_y):

```

```
#         l2norm += (w1[i+5, j])**2  
  
# print(l2norm)
```

```
[ ]:
```