EE2703: Applied programming Lab
Assignment 6: Tubelight Simulation

Vishnu Varma V
EE19B059

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1 Introduction

In this assignment we will simulate a tube light. As a result of uniform electric field inside the tubelight the electrons are accelerated, they start at cathode with zero energy and accelerate in this field. When the energy reaches beyond the threshold energy they can drive atoms to excited state, when these atoms relax light is emitted, the electron loses all its energy and the process starts again. The simulation is carried out for certain number of timesteps from an initial state of having no electrons.

2 Declaring Variables

The following code declares the variables required for simulation, these are the default values and user input can be given using commandline arguments:

```
n = 100           #spatial grid size
M = 5             #number of electrons injected per turn
nk = 500          #number of turns to simulate
u0 = 5            #threshold velocity
p = 0.25          #probability that ionization will occur
Msig = 2          #Standard Deviation
```

The following code declares vectors and lists to store electron information and information to be extracted from simulation:

```
#vectors to hold electron information
xx = np.zeros(n*M)      #xx : Electron Position
u = np.zeros(n*M)       #u : Electron Velocity
dx = np.zeros(n*M)      #dx : Displacement in current turn

I = []   #I : Intensity of emitted light
```

```
X = []  #X : Electron Position
V = []  #V : Electron Velocity
```

3 Simulation

The electrons are in a chamber, its position must satisy $0 < x < L$ where $L = n$ for this simulation.
So those electrons whose position in greater than zero are active electrons so they are stored and the postion and velocity is updated accordingly as they are accelerated due to the electric field.
Code:

```
ii = np.where(xx>0)
#updating the position and velocity of these electrons
dx[ii] = u[ii] + 0.5
xx[ii] += dx[ii]
u[ii] += 1
```

Those electrons that reached anode are collected and their position and velocity is set to zero.
Code:

```
anode = np.where(xx>=n)
#the position and velocity of these electrons are set to zero
xx[anode] = 0
u[anode] = 0
```

Now finding those electrons that have energy greater than threshold energy it is analogous to find electrons with velocity greater than threshold velocity. After finding it we create a uniformly distributed random vector and find those indices with their corresponding values less than p. Now reverting back these indices to find the indices of those energetic electrons that suffer a collision.
Code:

```
kk = np.where(u>=u0)[0]
ll = np.where(np.random.rand(len(kk))<=p)[0]
kl = kk[ll]
```

Since they suffered an inelastic collision their velocity is set to zero and their position could have occured at any point between previous x_i and current x_i. So assigning it a random position.
Code:

```
u[kl] = 0
xx[kl] -= dx[kl]*np.random.rand()
```

Now again injecting m new electrons which is randomly distributed with mean M and standard deviation M_{sig}. These new electrons are added to the free slots available (The slots of electrons whose position is zero), and setting the position and velocity as done initially.
Now again repeating the same process for the newly injected electrons, finding the active electrons whose position is positive and the same procedure is followed. The Intensity, Position, Velocity vectors are updated for every loop and are plotted.

4 Plots

The Following Plots are obtained considering the default values of the parameters.
n = 100
M = 5
nk = 500
u0 = 5
p = 0.25
Msig = 2
Simulating the Tube light we obtain the vectors of Intensity, Position and Velocity. We plot the electron density, this is generated using the population plot of Position vector. The Plot is as follows:

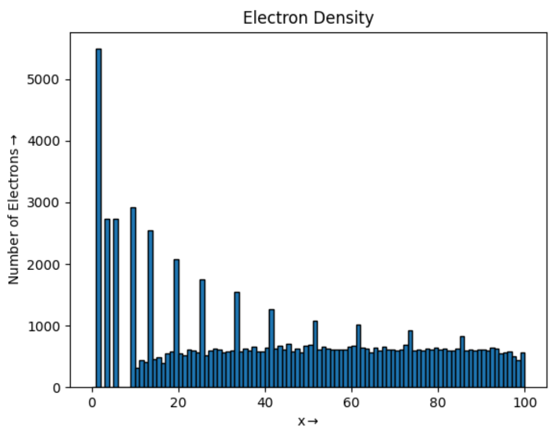

Figure 1: Electron Density

Next we Plot the population plot of the light intensity. The Plot is as follows:

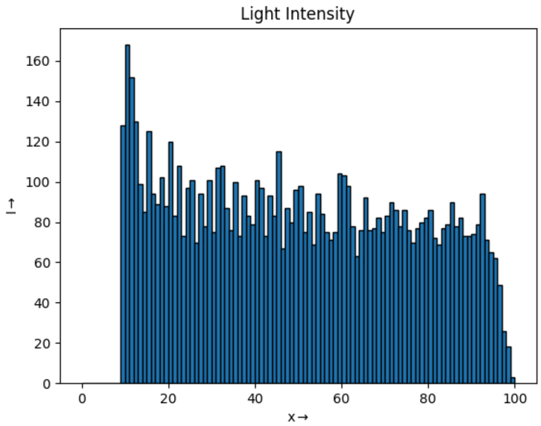

Figure 2: Light Intensity

The Electron Phase Space Plot is as follows:

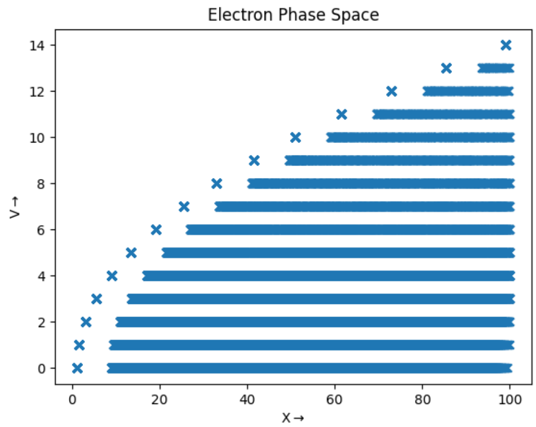

Figure 3: Electron Phase Space

```
Intensity Data :

   xpos      count
 ________  _________

   0.5         0
   1.5         0
   2.5         0
   3.5         0
   4.5         0
   5.5         0
```

6.5	0
7.5	0
8.5	0
9.5	128
10.5	168
11.5	152
12.5	130
13.5	99
14.5	85
15.5	125
16.5	94
17.5	89
18.5	102
19.5	88
20.5	120
21.5	83
22.5	108
23.5	73
24.5	97
25.5	101
26.5	70
27.5	94
28.5	78
29.5	101
30.5	75
31.5	107
32.5	108
33.5	87
34.5	76
35.5	100
36.5	73
37.5	93
38.5	83
39.5	79
40.5	101
41.5	97
42.5	73
43.5	93
44.5	83
45.5	115
46.5	67
47.5	87
48.5	80
49.5	96

50.5	98
51.5	75
52.5	85
53.5	69
54.5	94
55.5	84
56.5	75
57.5	71
58.5	75
59.5	104
60.5	103
61.5	98
62.5	78
63.5	63
64.5	76
65.5	92
66.5	76
67.5	77
68.5	82
69.5	75
70.5	83
71.5	90
72.5	86
73.5	78
74.5	86
75.5	76
76.5	70
77.5	77
78.5	80
79.5	82
80.5	86
81.5	72
82.5	69
83.5	77
84.5	79
85.5	90
86.5	78
87.5	82
88.5	73
89.5	73
90.5	74
91.5	79
92.5	94
93.5	71

94.5	65
95.5	62
96.5	49
97.5	26
98.5	18
99.5	3

5 Different Parameters

Now we plot for a different set of parameters
n = 100
M = 5
nk = 500
u0 = 7
p = 0.5
Msig = 2

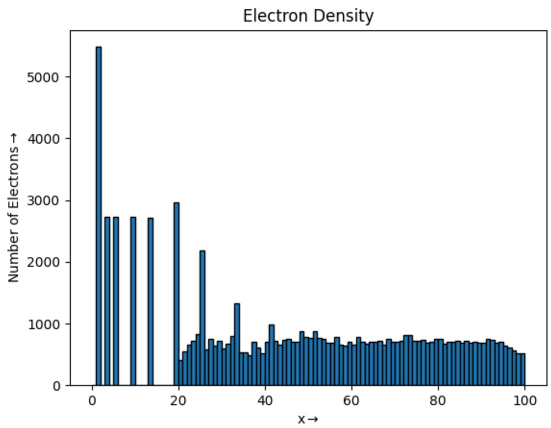

Figure 4: Electron Density

Next we Plot the population plot of the light intensity. The Plot is as follows:

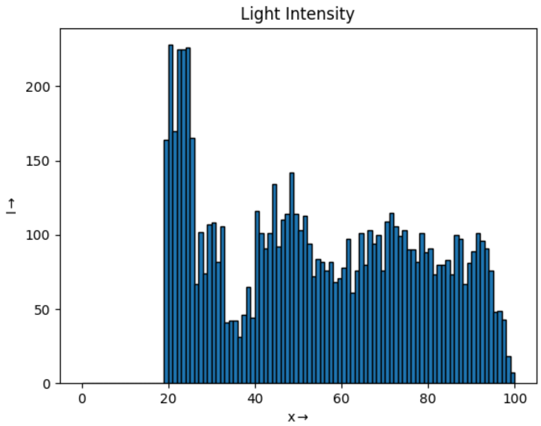

Figure 5: Light Intensity

The Electron Phase Space Plot is as follows:

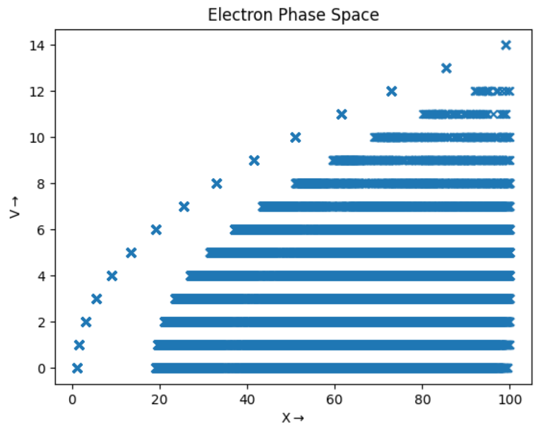

Figure 6: Electron Phase Space

```
Intensity Data :

   xpos      count
 -------   --------
    0.5          0
    1.5          0
    2.5          0
    3.5          0
    4.5          0
    5.5          0
```

6.5	0
7.5	0
8.5	0
9.5	0
10.5	0
11.5	0
12.5	0
13.5	0
14.5	0
15.5	0
16.5	0
17.5	0
18.5	0
19.5	164
20.5	228
21.5	170
22.5	225
23.5	225
24.5	226
25.5	165
26.5	67
27.5	102
28.5	74
29.5	107
30.5	108
31.5	82
32.5	106
33.5	41
34.5	42
35.5	42
36.5	31
37.5	46
38.5	65
39.5	44
40.5	116
41.5	101
42.5	91
43.5	101
44.5	134
45.5	92
46.5	110
47.5	114
48.5	142
49.5	114

50.5	103
51.5	113
52.5	94
53.5	72
54.5	84
55.5	82
56.5	76
57.5	82
58.5	68
59.5	71
60.5	78
61.5	97
62.5	61
63.5	76
64.5	101
65.5	80
66.5	103
67.5	94
68.5	100
69.5	76
70.5	109
71.5	115
72.5	106
73.5	99
74.5	103
75.5	90
76.5	90
77.5	82
78.5	101
79.5	88
80.5	91
81.5	73
82.5	80
83.5	80
84.5	83
85.5	73
86.5	100
87.5	97
88.5	67
89.5	81
90.5	89
91.5	101
92.5	96
93.5	91

94.5	76
95.5	48
96.5	49
97.5	43
98.5	18
99.5	7

6 Inferences

From the Intensity Histogram we can observe that the electrons don't cause excitation of the atoms until they cross a certain threshold velocity, this threshold velocity varies as the gas is varied. After travelling for some distance we can observe the highest peaks , because the majority of electrons collide with the atoms at this distance, After this too there are some peaks but they are less intense than the initial peaks. Until the electtrons collide they will have a constant acceleration but after collision they will have a random motion. The trajectory seperated from the others which is parabolic this corresponds to those electrons which move from cathode to anode without any collision, while the others correspond to inelastic collision and random motion.
Comparing the plots from two different sets of parameters :
The threshold velocity is higher in the second case which causes the photon emission to occur at a farther distance compared to a lower threshold velocity. Since the probability of ionization is greater for the second case the peak intenstiy is higher for it compared to the the one with lower probability. So a gas with lower threshold and higher probability causes the photon emission by travelling a smaller distance and will have a high intensity so this is well suited for the purpose.

7 Conclusion

In this assignment we simulated a tube light, the electrons moving in the tube light was simulated and the Intensity, Position, Velocity vectors were obtained and plotted. The population plot of Electron Density and Light Intensity was plotted along with the Electron Phase Space. Now the same plots were plotted changing the threshold velocity and the probability of ionization and corresponding inferences were made comparing the plots.