APL(EE2703): Simulations(Assignment 6A)

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1 Aim of the Assignment:

- Simulate an 1-D tubelight using python.
- Analyze the the movement of electons and the emissions they make.

This shall be achieved by assigning initial values and updating the values continuously

2 Introduction

Python is very helpful for simulating models. We use a 1-D model of a tubelight.A uniform electric field is present which accelerates electrons. Electrons are emitted by the cathode with zero energy, and accelerate in this field. When the energy crosses a threshold energy E_0, they can drive atoms to excited states. The relaxation of these atoms results in light emission. Electrons reaching the anode are absorbed and lost. Each "time step", an average of N electrons are introduced at the cathode.

3 Simulation

- A sumlation is created where a 1-D tubelight is assumed, which is divided into "n" sections. After every time instant, "M" electrons are injected. The simulations are run for "nk" times.
- The electrons have the potential to excite only after the atoms reach a velocity of "u0". Beyond this velocity, there is a probability p in each turn that a collision will occur and an atom excited. The excited electron's velocity reduces to zero if it collides.
- We need to collect information of the particles and update them after every turn which is being done in the follwing bolck of code.
- The block of code, performing iterations:

```
#Initialising the position, velocity, displacement vectors.
#They are zero matrices which shall be updated.
xx=np.zeros(n*M)
u=np.zeros(n*M)
dx=np.zeros(n*M)

#Initializing the light intensity, electron postion, electron velocity.
#They are empty lists which shall be updated using .extend.
I=[]
X=[]
V=[]

#We find all those electrons whose position is greater than zero.
ii=np.where(xx>0)
```

```python
for k in range(nk):
#<<The Block>>
        #Displacement increases due to electric field.
        dx[ii] = u[ii] + 0.5

        #Advance the electron position and velocity for the turn.
        xx[ii] += dx[ii]
        u[ii]  += 1

        #Determine the particles which have already hit the anode.
        jj = np.where(xx >= n)

        #Update their position and velocity to zero.
        xx[jj] = 0
        u[jj]  = 0

        #To find ionised electrons
        kk = np.where(u >= u0)[0]
        ll = np.where(np.random.rand(len(kk))<=p)
        kl = kk[ll]

        #Inelastic collision. Updating their velocities to zero.
        u[kl] = 0

        #Generating a random number to find the point of collision.
        xx[kl] -= dx[kl]*np.random.rand(len(kl))

        #Updating the I list with photons resulted an emission.
        I.extend(xx[kl].tolist())

        #Adding new electrons.
        m  = int(np.random.randn()*Msig+M)

        #Find the elctrons whose positions are zero.
        mm = np.where(xx == 0)

        #Minimum of(no. of electrons to be added, no. of slots available.)
        minimum = min(len(mm[0]),m)

        #Set their position to 1 and velocity to zero.
        xx[mm[0][:minimum]] = 1
        u[mm[0][:minimum]]  = 0

        ii = np.where(xx > 0)

        #Add their positions to the X and V vectors.
        X.extend(xx[ii].tolist())
        V.extend(u[ii].tolist())
```

4 Plots

From the collected data, the following plots are made:

- Electron Density Histogram: The denisty(availablity) of electrons are plotted against the location they are found at.

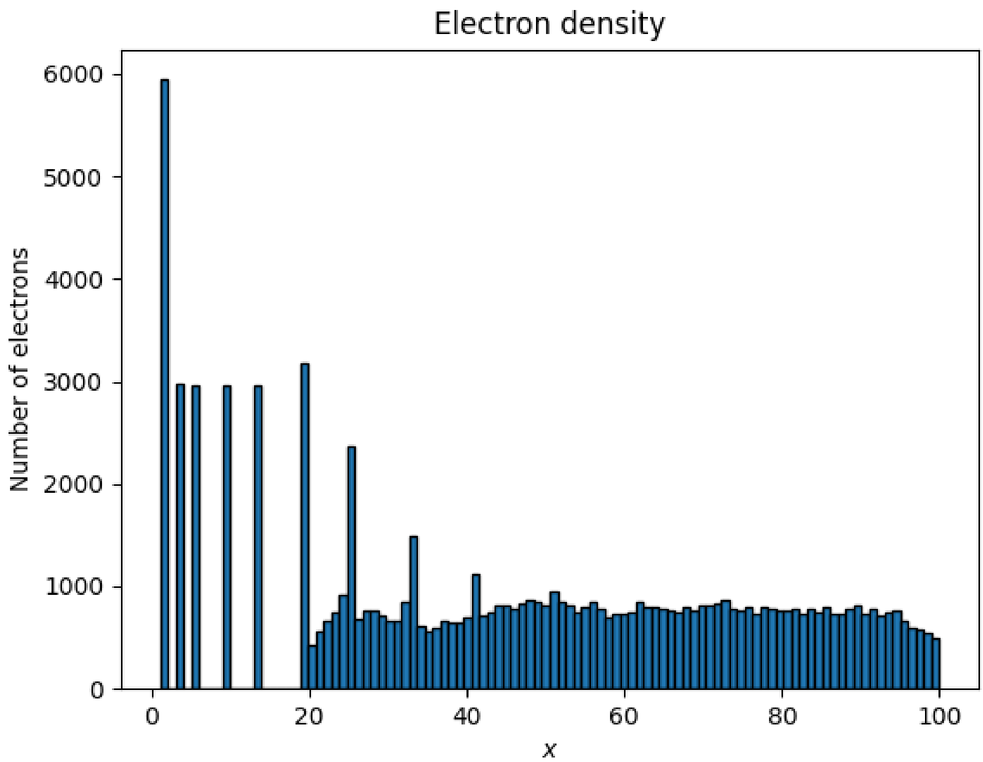

Figure 1: Electon Density Histogram

- Emission Intensity Histogram:
  The intensity of emissions made by atoms are plotted against the location of emission Some of the data that is being used to plot the following diagram is printed below.

```
Intensity data:
xpos    count
19.4    165
20.21   178
21.02   161
21.83   173
22.64   187
23.44   207
24.25   195
25.06   173
25.87   96
26.68   76
27.48   85
28.29   78
29.1    82
29.91   80
30.72   72
31.52   86
32.33   84
33.14   53
```

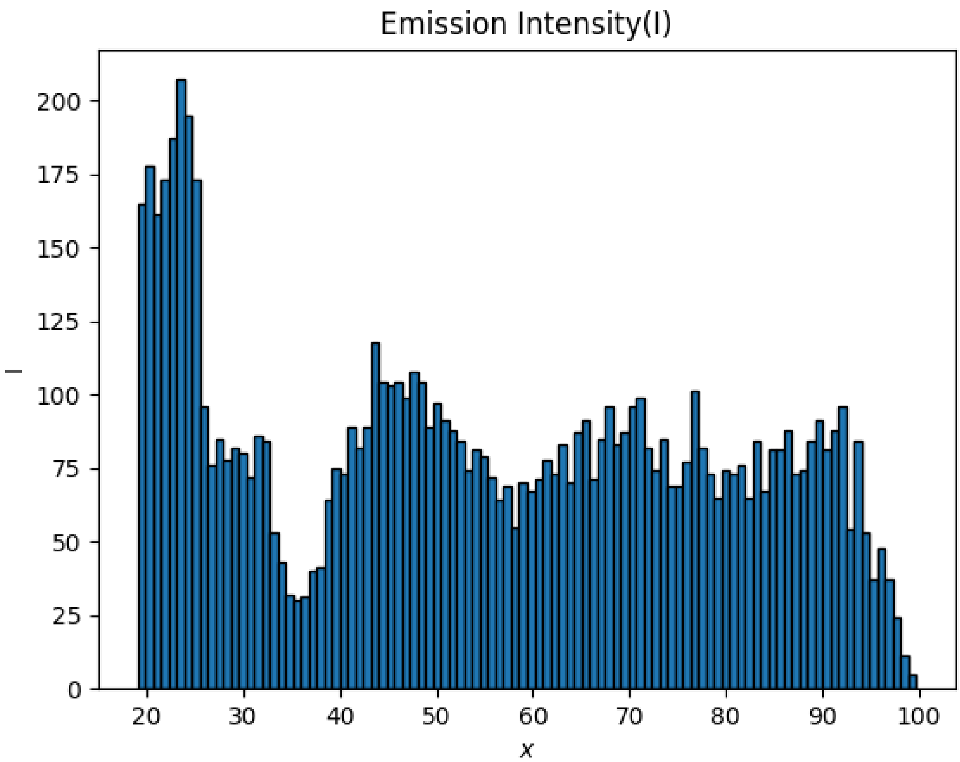

Figure 2: Emission Intensity Histogram

- Electron Phase space diagram:
  The velocity of the electons are plotted against the locations

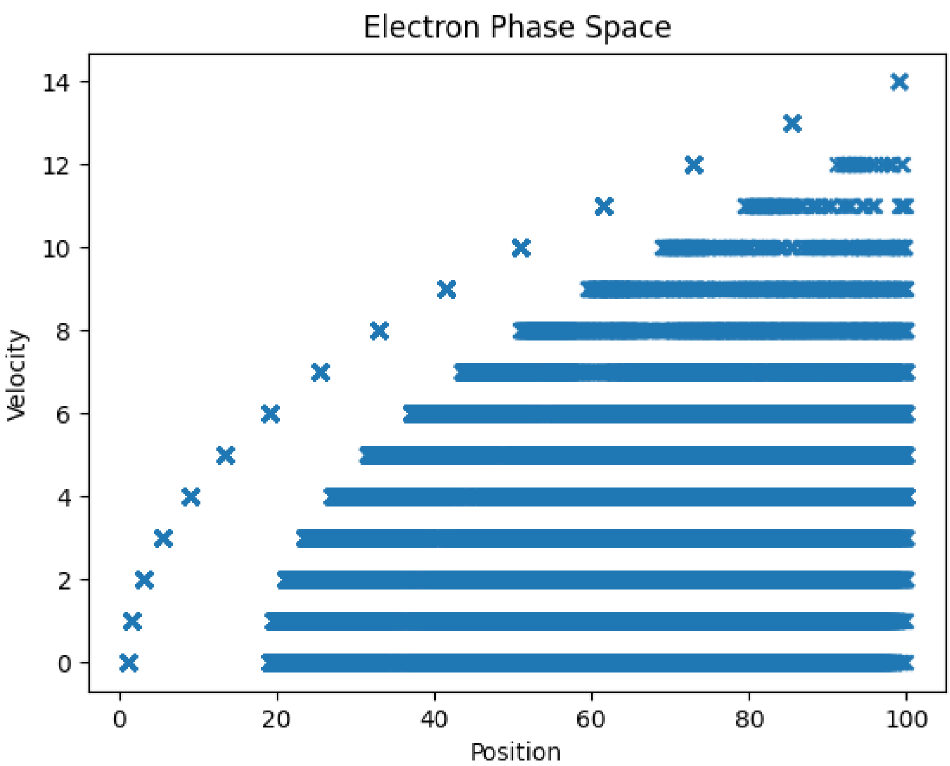

Figure 3: Phase Space Diagram

5 Conclusion

- Electrons get excited due to electric field, start gaining velocity and hence move around.
- The same happens with other electrons and electrons start to collide with each other and other atoms, leading to exchange of energy.
- Most of the current passes through bottom side of the plate as there is complete path for current to flow unlike the other sides of the plate.
- These energy excitations and de-excitation causes emissions, giving out light.