EE2703: Applied Programming Lab
Assignment 6
Tubelight Simulations

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Contents

1 Aim:

The aim of the assignment is to:

1. Simulate the environment inside a tubelight using Python
2. Solve for the steady state light intensity profile
3. Plot the electron phase space plots, position and light intensity histograms

2 Thoery:

2.1 Physics behind the working of tubelight:

Inside the tubelight, electrons are injected from the cathode into the tube periodically. And the number of electrons is random with some standard deviation and a mean. The electrons accelerate under the external electric field and move in the tubelight. They gain velocity in the porcess and once, they get enough threshold velocity, they can bombard with the surrounding elctrons and can emit light in the process. This collision process is again random, i.e., the energised electrons need not undergo collision always. However, they are assumed to undergo inelastic collision and hence, stop at that location and light is emitted in the process. Once the electrons reach the anode, they immediately travel back to the cathode through the external loop and again repeat the process as long as the electric field is present (Switch is ON).

2.2 Dark spaces:

As we all know, there can be some dark spaces in a tubelight. These are the locations which are usually dark, meaning collisions won't happen frequently there when compared to other locations. These locations are also qualitatively found in this assignment. They are the local minimas present in the histogram of the intensity population plot.

3 Procedure:

3.1 Variables used:

1. xx = Vector to store the positions of electrons
2. u = Vector to store the speeds of electrons
3. dx = Vector to store the instantaneous displacements of the electrons
4. I = List to store the positions of energetic electrons which had undergone collision
5. X = List to store the positions of all electrons
6. V = List to store the velocities of all electrons

3.2 Parameters used:

1. Tube length (in terms of number of divisions) = n (100 by default)
2. Average number of electrons injected per timestep = M (10 by default)
3. Standard deviation in the number of electrons = Msig (2 by default)
4. Number of iterations to be performed = nk (500 by default)
5. Threshold excitation speed = u0 (5 by default)
6. Probability of collision = p (0.25 by default)

Note: All the plots shown in this graph are with respect to the default values

3.3 Main code:

```
for i in range(nk):
    ii = pl.where(xx>0)[0]
    dx[ii] = u[ii]+0.5
    xx[ii] = xx[ii]+dx[ii]
    u[ii] = u[ii]+1

    end = pl.where(xx[ii]>n)[0]
    xx[ii[end]] = 0; u[ii[end]] = 0; dx[ii[end]] = 0
    non_zero_x = pl.array(list(set(ii)-set(ii[end])),dtype=int)

    kk = pl.where(u[non_zero_x]>=u0)[0]
    ll = pl.where(pl.rand(len(kk))<=p)[0]
    kl = non_zero_x[kk[ll]]
    u[kl] = 0

    rho = pl.rand(len(kl))
    xx[kl] = xx[kl]-(dx[kl]*rho)

    m = int((pl.randn()*Msig)+M)
    space_inds = pl.array(list(set(all_inds)-set(non_zero_x)),dtype=int)
    slotnum = min(len(space_inds),m)
    xx[space_inds[:slotnum]] = 1; u[space_inds[:slotnum]] = 0; dx[space_inds[:slo

    I.extend(xx[kl].tolist())
    X.extend(xx.tolist())
    V.extend(u.tolist())
```

This is the important code snippet of the program. This for loop basically iterates over the number of timesteps (say 500) and in each timestep, the following updates are done:

1. The positions and speeds of electrons which have x>0 (Which are inside the tube) are updated.

2. The electrons whose x value is more than n (Tube length) are reset to zero state (x=0,dx=0,u=0 meaning they are waiting at the cathode to be injected again).

3. Out of the electrons with speed more than $u0$, some are assumed to undergo collision (based on the p value) and hence, their speeds are reset to zero (Inelastic collision).

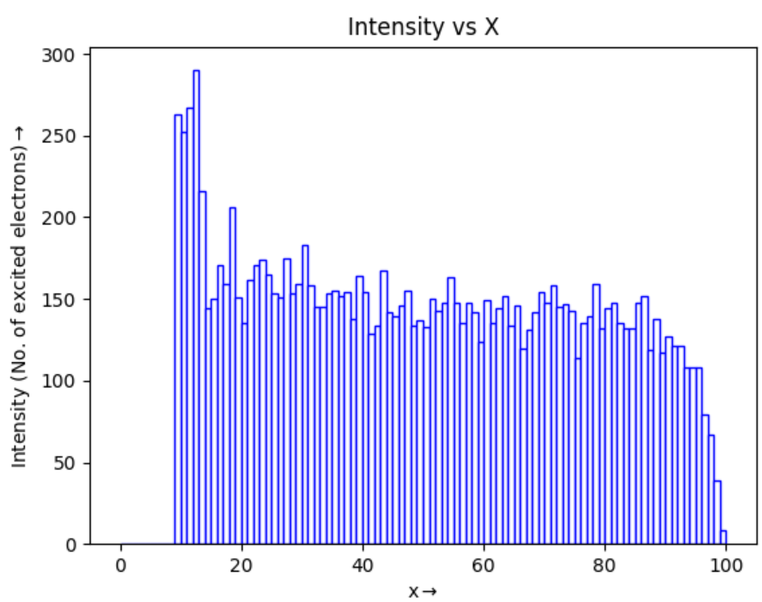
4. Also the positions of electrons, which have undergone collision, are updated as x[i] = x[i] - (dx[i]*ρ) where ρ is a random number in the interval $[0, 1]$.

5. Electrons at the cathode are allocated slots based on the availability of vacancies (x=0 means a vacancy)

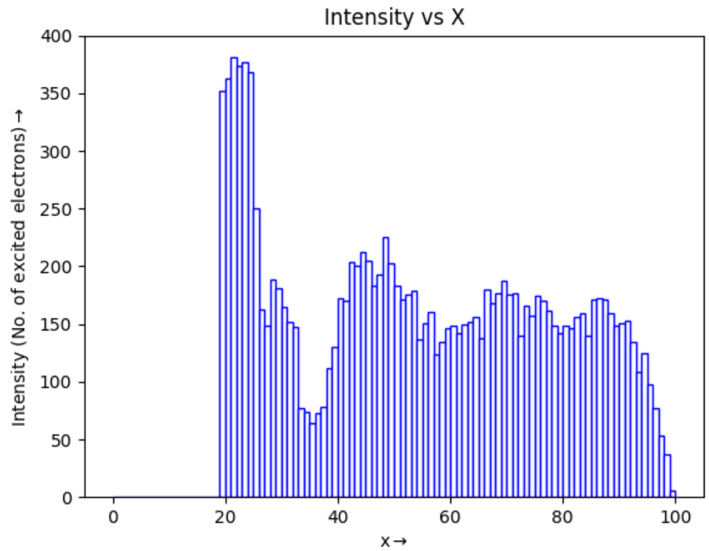
6. The I, X, V lists are updated.

4 Observations and plots:

4.1 Intensity population plot:

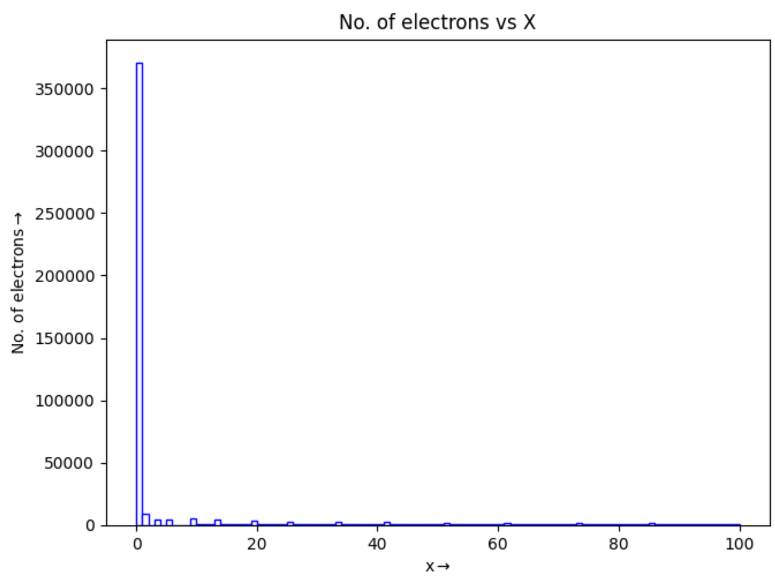


Intensity histogram for default values



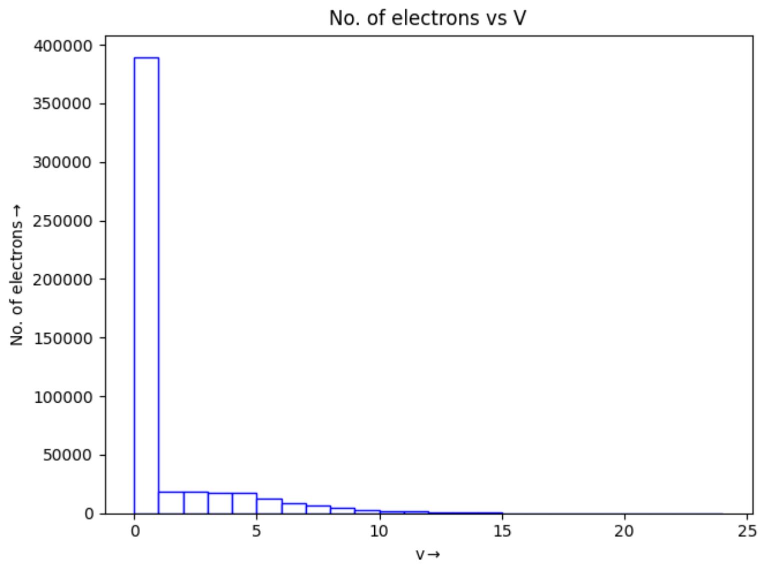
Intensity histogram for u0 = 7, p = 0.5 with other parameters unchanged

4.2 Position population plot:



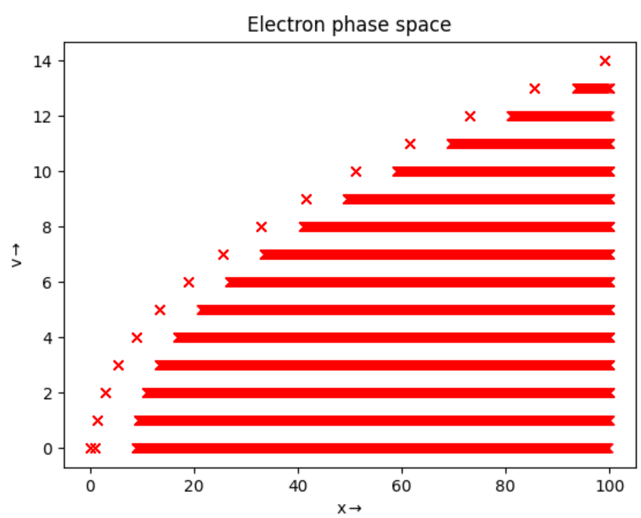
Most electrons are concentrated at x=1 since electrons are injected there at every timestep

4.3 Speed population plot:



Most of the electrons collide before reaching speeds more than 6 to 7 and completely cease to exist at speeds 15 or more

4.4 Electron phase space plot:



Most electrons exist at rest at different locations. However, they have higher velocities only near the anode

5 Conclusions:

1. The intensity plots have their maximum at the distance where the velocity would be approximately $u0$. Let's say $u0 = 7$ and acceleration is 1. Hence, the time required to acquire this velocity from rest is 7 seconds. Now, the distance travelled will be $x = \frac{1}{2}at^2 = 0.5(7^2) = 24.5$ and the second intensity histogram has its global maximum around that location.

2. The position and speed histograms show that the electrons are primarily concentrated at the location $x = 1$ with speed $u = 0$. This is because at every timestep, electrons are injected into the tube with these initial conditions.

3. From the electron phase space plot, we can conclude that the electrons virtually cease to exist at speeds more than 14 for $u0 = 5$. Also, these high velocity electrons are present near the anode only. The electrons with lower velocities are present all over the tube.