Analyzing Tube light using simulations

EE16B014
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Abstract

In this assignment we are going to see the mechanism in tubelight where the electrons coming from cathode at zero velocity,travelling until the get threshold energy $E_0$where the elctrons can drive atoms to excited state,where the excited atom comes down to give light.So we will try to make a tubelight by injecting electrons and taking the energy of electron becoming zero at time of collision and some other approximations,To procceed and see how the tubelight intensity looks like.

1 Tubelight:

- The Emission of light in a tubelight is mainly because of de-excitation of atoms(Which are excited by the electrons having more than threshold energy) inside the tube.
- Lets create a tubelight which is divided into n sections and M electrons were injected in at every timestep,And the electrons can't excite atoms until they reach a threshold velocity of u_0
- The probability of excitation be p,where the electrons when participating in collisions their velocity becomes zero.
- And lets make the simulation run nk times

```
n    = int(sys.argv[1])   #100
M    = int(sys.argv[2])   #10
nk   = int(sys.argv[3])   #500
u0   = int(sys.argv[4])   #7
p    = float(sys.argv[5]) #0.5
Msig = float(sys.argv[6]) #2
```

Let us create vectors of nM dimension for storing the information of electrons:

1. Electron position xx
2. Electron velocity u
3. Displacement current turn dx

```
xx=zeros((M*n))
u=zeros((M*n))
dx=zeros(M*n)
I=[]
X=[]
V=[]
```

Here I,X,V are lists to hold values of intensity,position,velocity of electrons at every time step.We just keep adding the information's to the lists.

Now we shall consider only the electrons in range $0 < x < L$,The entries of $x > L$ are made to $x = 0$,so the $x > 0$ electrons are those which are inside the chamber. So we use *'where' command* to see indices where $xx > 0$.

```
ii=where(xx>0)
```

Now lets see what happens at every iteration:

- For all electrons whose indices are in ii are inside the tube so because of acceleration due to Field the electrons displace dx_i which is given by:
$$dx_i = u_i\Delta t + \frac{1}{2}a(\Delta t)^2 = u_i + 0.5$$
- Acceleration is taken as one, so$x_i, u_i$are given as:
$$x_i \leftarrow x_i + dx_i$$
$$u_i \leftarrow u_i + 1$$
- Since displacement is only for electrons inside the tube:

```
dx[ii]=u[ii]+0.5
xx[ii]=xx[ii]+dx[ii]
u[ii]=u[ii]+1.0
```

- The Electrons with displacement greater than n should have dx_i, x_i, u_ishould be zero:

```
nn=where(xx>=n)
xx[nn]=0
u[nn]=0
dx[nn]=0
```

Lets consider the electrons whose velocity is more than u_0,Since the chance of electron to collide is having probability p lets define random vector of length as no of electrons having more velocity than threshold,and the values in rand vary from 0 to 1.So we get exactly desired no of electrons to collide by using the following:

```
kk=where(u>=u0)[0]
ll=where(rand(len(kk))<=p)[0]
kl=kk[ll]
u[kl]=0
xx[kl]=xx[kl]-random.uniform(0,1)*dx[kl]
```

The last line of the code is about position of electron after collision is in between $x[kl], x[kl+1]$ so we have used a rand function to get the position. Now lets store the position of collision into list 'I'(intensity).

```
I.extend(xx[kl].tolist())
```

Now we will inject new electrons into the tube by finding the indices other than $0 < xx < n$ (nothing but xx==0) and inject new electrons with xx at those indices as 1.

```
I.extend(xx[kl].tolist())
m=int(randn()*Msig+M)
m=abs(m)
rr=where(xx==0)[0]
k=arange(0,m,1)
xx[rr[k]]=1
```

Now lets store the values of positions and velocities in X,V lists:

```
ii=where(xx>0)
X.extend(xx[ii].tolist())
V.extend(u[ii].tolist())
```

Lets include the whole thing in a for loop:

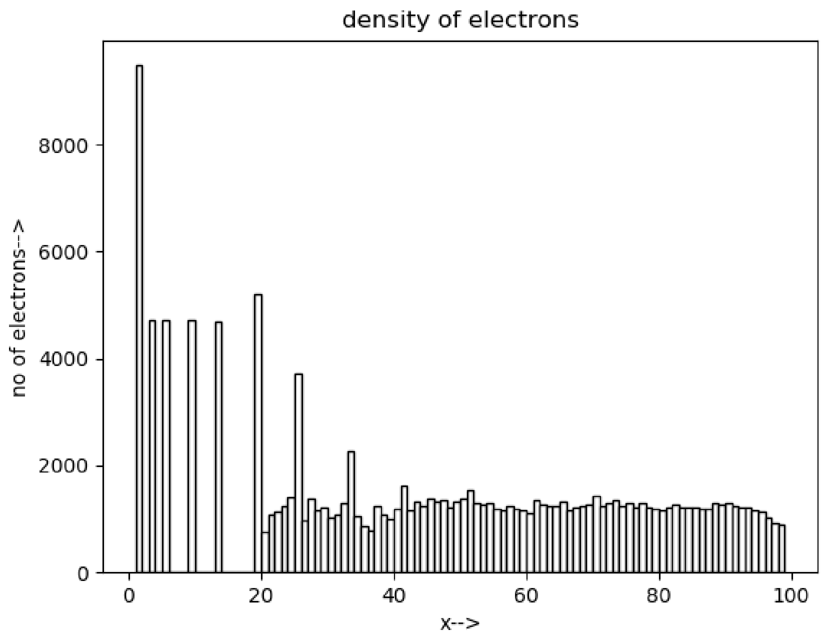
```
for k in range(nk):
        dx[ii]=u[ii]+0.5
        xx[ii]=xx[ii]+dx[ii]
        u[ii]=u[ii]+1.0

        nn=where(xx>=n)
        xx[nn]=0
        u[nn]=0
        dx[nn]=0

        kk=where(u>=u0)[0]
        ll=where(rand(len(kk))<=p)[0]
        kl=kk[ll]
        u[kl]=0
        xx[kl]=xx[kl]-random.uniform(0,1)*dx[kl]

        I.extend(xx[kl].tolist())
        m=int(randn()*Msig+M)
        m=abs(m)
        rr=where(xx==0)[0]
        k=arange(0,m,1)
        xx[rr[k]]=1

        ii=where(xx>0)
        X.extend(xx[ii].tolist())
        V.extend(u[ii].tolist())
```

2 Plotting the Histograms:

Lets see the no of electrons accumulated at position over the range of timesteps:

```
hist(X,arange(1,100,1),color='white',edgecolor='black')
xlabel('x-->')
ylabel('no of electrons-->')
title('density of electrons')
show()
```

Electron Density:

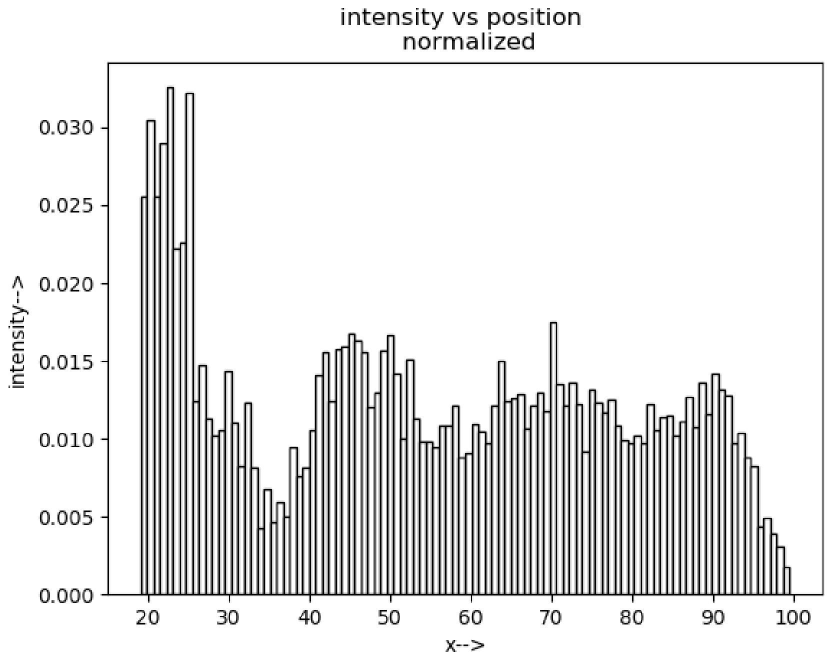


- We are able to see a high peak at the beginning because every electron is injected at $x = 1$.
- until $x = 18$ the nature of the presence of electrons are discrete and after 18 its continuous,That's because until $x = 18$ no collisions are taking place.
- We can derive it from the formula $u_i = u_i + 1$ we can see it takes 7 time steps for u_i to become 7(threshold value),and $x = ut + \frac{1}{2}at^2$ where $u = 0, t = 7$ which implies $x = 24.5$. But at this position collision may take place at $t = 7$ and the position of electron can be anywhere between this position and previous position $x = 18$ since we have given rand function from 0 to 1.We are seeing the graph to be continuous from $x = 18$

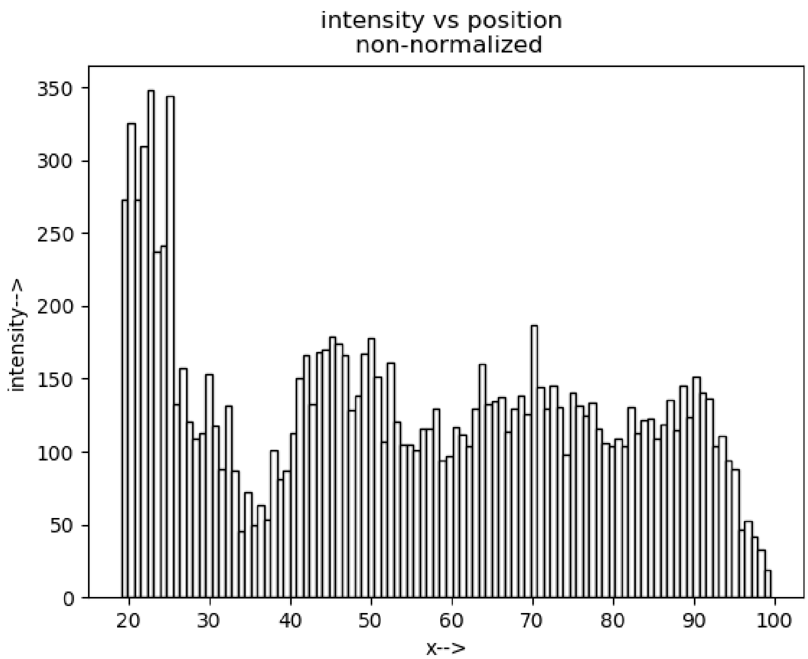
Lets the histogram of intensity:

```
data=hist(I,100,color='white',edgecolor='black')
title('intensity vs position \n non-normalized')
xlabel('x-->')
ylabel('intensity-->')
```

Normalized graph of Intensity:

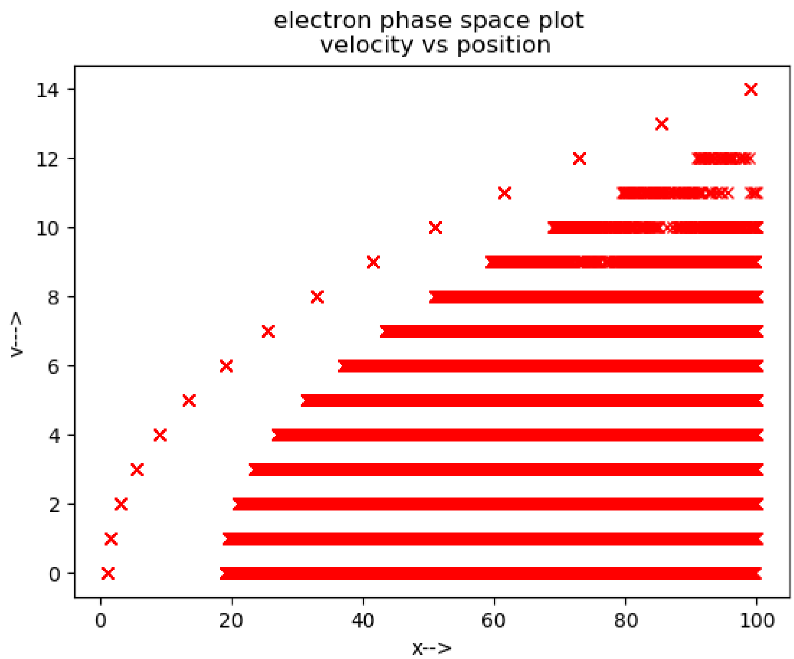


Non Normalized graph of Intensity:



As described earlier since no collision are taking place until $x = 18$ there is no light coming out and intensity is zero.And peak at $x = 18$ because all incoming electrons have threshold velocity at that value so number of collisions are maximum.

Now lets see the electron velocity vs space graph:



- We can see here also no electron has zero velocity for $0 < x < 18$ because of no collisions and all other points except this point has atleast some points with velocity zero because of collisions.
- The points which are looking like single points are the electrons,which didn't have any collisions and reached the cathode.
- We can also see the magnitude of highest velocity possessed by an electron at a particular point is increasing.

3 Optimization:

Here the 'ii' is calculated twice in the for loop in order to avoid it we can write the first 'ii' outside which helps when FOR loop runs for the first time then onwards the second 'ii' which is calculated at the end of FOR loop will be used for the next iteration. Until 'nk' iterations the samething repeats, which was same as the previous two 'ii' calculations.