Lecture13

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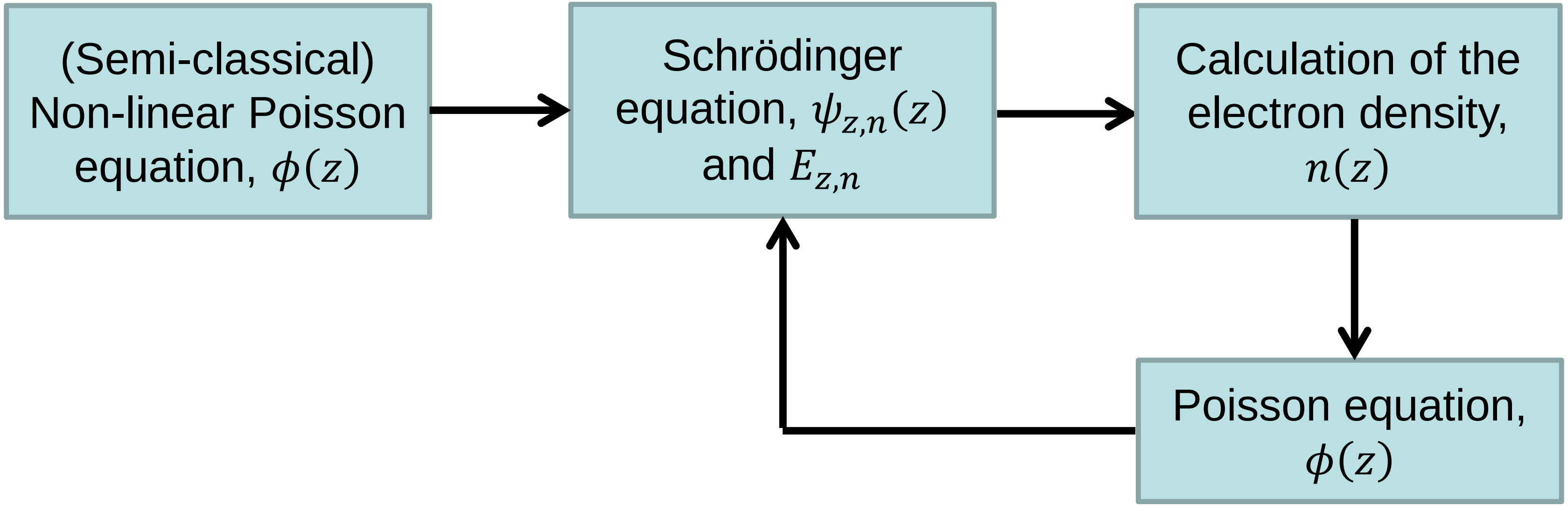
Simulation flow

- Self-consistency
  - The electron density is not consistent with the Poisson equation.
  - Better way?



Homework#13

- Due: AM08:00, October 26 (Next Monday)
- Problem#1
  - Repeat the Homework#12.
  - However, in this time, you must get the self-consistent solution.
  - Check the convergence behavior.
  - Compare the electron densities (the non-self-consistent and self-consistent ones) in the z axis.

Transport

- Central problem of the computational electronics
  - Calculation of terminal currents!
  - Example) Calculate the drain current, when $V_{GS} = V_{DS} = 0.7\ \mathrm{V}$.
- Quantum transport
  - Charge carriers (electrons and holes)
  - Most accurate method
- Semi-classical transport
  - Treat charge carriers as semi-classical particles
  - Still, it can be useful to many cases.

Governing equation

- Boltzmann transport equation
  - It reads

$$\frac{\partial f}{\partial t} + \overset{\text{Velocity}}{\mathbf{v}} \cdot \nabla_r f + \frac{1}{\hbar}\underset{\text{Force}}{\mathbf{F}} \cdot \nabla_k f = \overset{\text{Scattering}}{\hat{S}}$$

  - Time-evolution of f is described.
  - Scattering can change f.
  - Motion of electrons
    - Non-zero velocity: Change its spatial position
    - Acceleration: Change its momentum

Force

- Electric force
  - It reads

$$\mathbf{F} = -q\mathbf{E} = q\nabla\phi$$

- Under the magnetic field,
  - Lorentz force can be considered.
  - (But it is not considered in this course.)

MATLAB example (1)

- Consider an one-dimensional system.
  - Your electrons have the free electron mass, m_0.
  - Since the magnitude of the electric field is E, their (constant) acceleration is given by $-\frac{qE}{m_0}$.

```
E = 1e6; % Electric field, V/m
q = 1.602192e-19; % Elementary charge, C
m0 = 9.109534e-31; % Electron rest mass, kg
acceleration = -q*E/m0; % Acceleration, m/s^2
```

MATLAB example (2)

- Set up the initial distribution.
  - At the initial time, the position and the velocity of your (several) electrons are randomly determined.

```
N = 1000; % Number of electrons
xmax = 10e-9; % Size of x range, m
vmax = 1e4; % Size of v range, m/s
x = (rand(N,1)-0.5)*xmax;
v = (rand(N,1)-0.5)*vmax;
```

MATLAB example (3)

- Time evolution
  - Set up the time interval and the number of steps.

```
dt = 1e-15; % Time interval of each step, s
steps = 1000; % Number of steps
for ii=1:steps
   x = x + v.*dt;
   v = v + acceleration.*dt;
end
```

Result

- E = 1 kV/cm
  - Accel. ~ -1.759X10^{16} m/s^2
- Initial (Blue)
  - In average, zero velocity
- Final (Red)
  - After 1psec