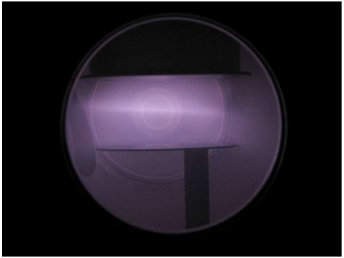
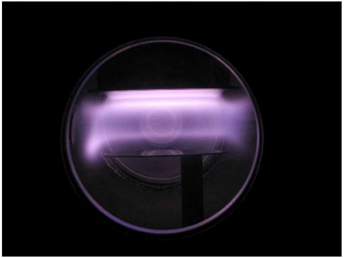
# Heating mechanisms of capacitively coupled discharges



$H_2$, 2 Pa



$H_2$, 120 Pa

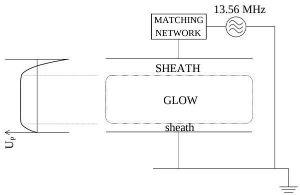
# Capacitively coupled discharges

- electrons accelerated by the electric field between electrodes
- $\omega_{pi} < \omega \ll \omega_{pe}$
  (electrons are fast, they are able to follow the field
  ions are not able to follow the electric field)
- plasma size $\ll \lambda$

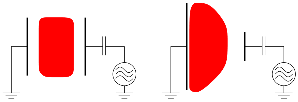
# Capacitively coupled discharges – structure

- Bulk plasma
  - electrons present during the whole RF period
  - high conductivity, weak electric field
  - inductive character

$$\sigma = \frac{ne^2}{m(\nu + i\omega)} + i\omega\varepsilon_0$$




- Sheaths
  - strong electric field with a DC component
  - repels electrons
  - capacitive character
  - nonlinear nature

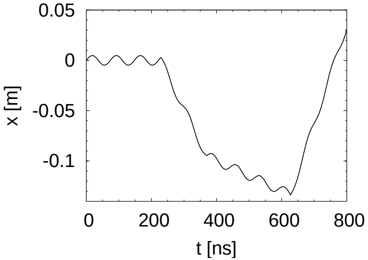


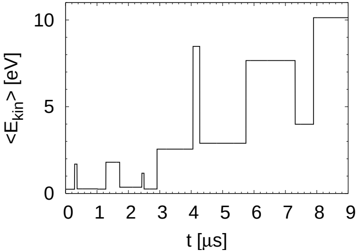
# Ohmic (collisional) heating

$$\sigma = \frac{ne^2}{m(\nu^2+\omega^2)}(\nu - \mathrm{i}\omega) + \\ + \mathrm{i}\omega\varepsilon_0$$

$$P_{ohm} \approx \frac{1}{2} j^2 \frac{m}{e^2} \int_V \frac{\nu}{n} \mathrm{d}V$$

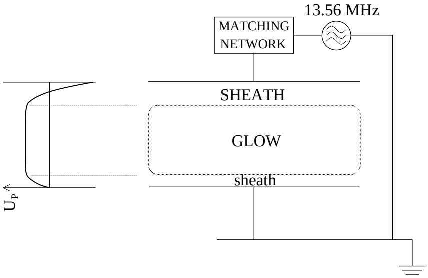
- namely in the bulk plasma (high *n*)
- needs collisions – depends on pressure

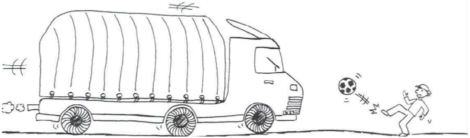


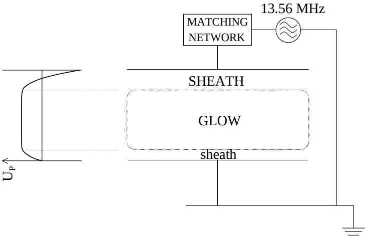
# Stochastic heating

- sheaths repel electrons
- electrons reflected from expanding sheath gain energy,
  electrons reflected from collapsing sheath lose energy
- more electron-sheath collisions during the expansion
- energetic electron beams

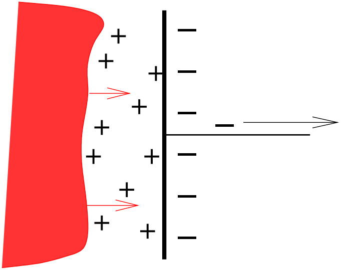


# Field reversal




- During fast sheath collaps electrons may be unable to react on the electric field.
- Sheath (positive) charge may be higher than electrode (negative) charge.
- Electrons are accelerated towards the sheath.



# $\gamma$-heating

- Few ($\sim$1 %) ions emit an electron from an electrode (potential emission)
- The electron is accelerated towards bulk plasma
- and obtains energy sufficient for ionization.
- At sufficient pressure – electron avalanche