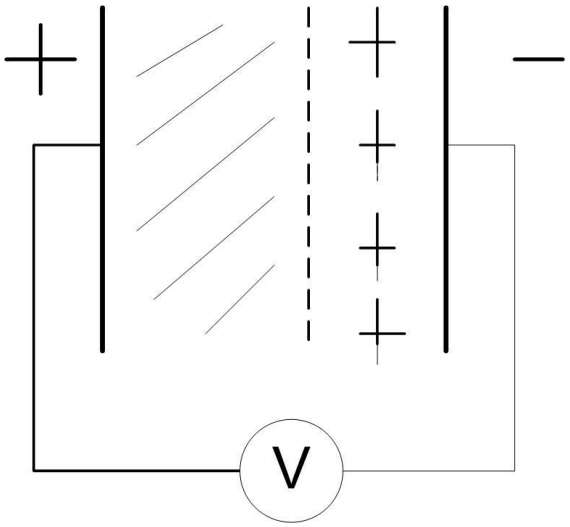
Лекция 4

Емкостный ВЧ разряд



$$v = \frac{eE}{m\nu} = \frac{e}{m\nu L}\left(U - \frac{en}{2\varepsilon_0}x^2\right) = \frac{dx}{dt}$$

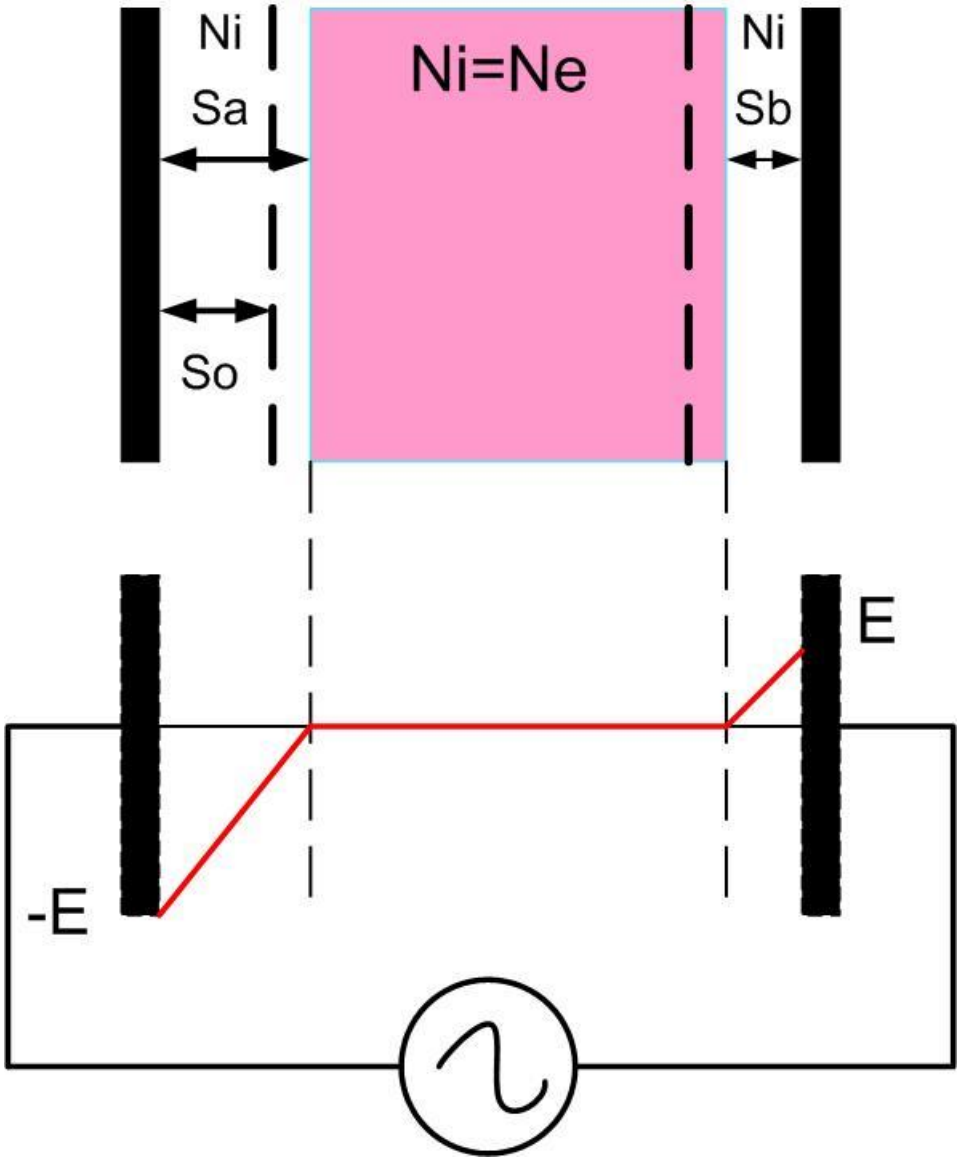
$$\int \frac{1}{\left(U - \frac{en}{2\varepsilon_0}x^2\right)}\,dx = \frac{e}{m\nu L}\cdot t$$

$$\int \frac{1}{a^2 - b^2 x^2}\,dx = \frac{1}{2ab}\cdot \ln\left(\frac{a + bx}{a - bx}\right)$$

$$x(t) = \sqrt{\frac{2\varepsilon_0 U}{en}}\cdot\frac{\exp(\delta t) - 1}{\exp(\delta t) + 1}$$

$$\delta = \frac{2eU}{m\nu L}\cdot\sqrt{\frac{en}{2\varepsilon_0 U}} = 2\cdot\frac{V_0}{X_0}$$

$$V_0 = \frac{e\cdot E_0}{m\nu} \qquad E_0 = \frac{U}{L} \qquad X_0 = \sqrt{\frac{2\varepsilon_0\cdot U}{en}}$$



$$\varepsilon_0 \cdot \frac{dE}{dx} = en$$

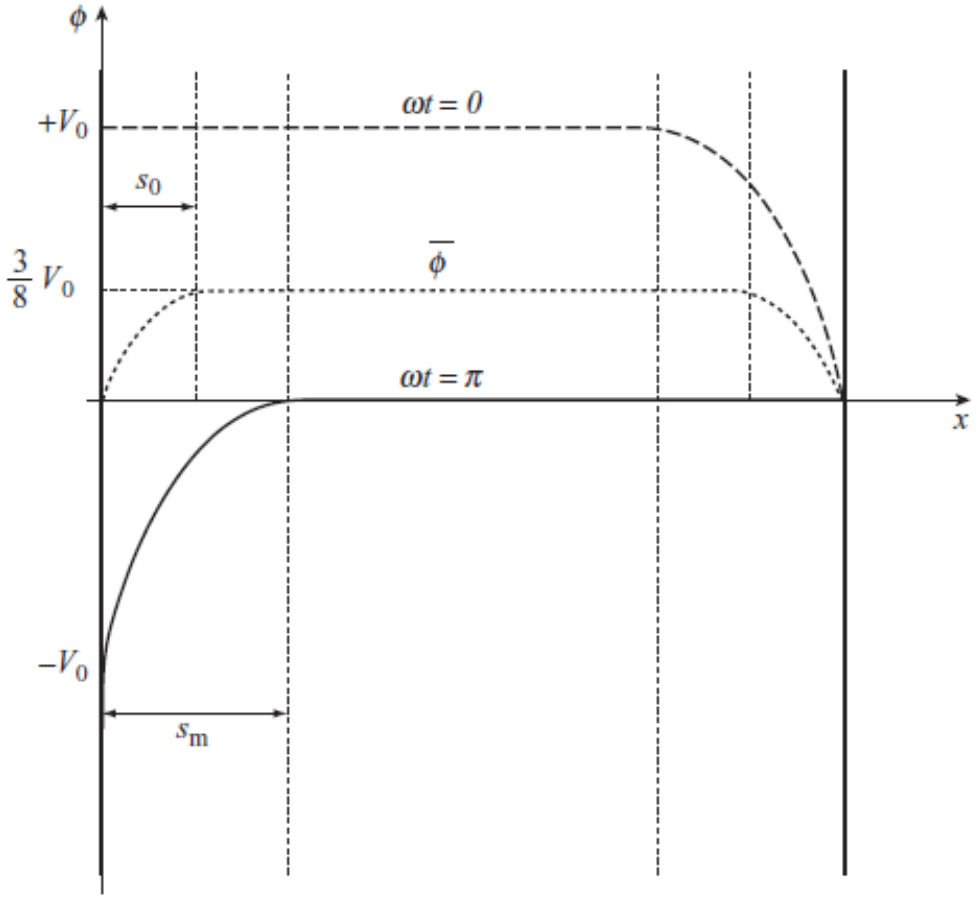
$$E(x) - E_0 = \frac{en}{\varepsilon_0} \cdot x$$

$$E_0 = 0$$

$$E(x) = \frac{en}{\varepsilon_0} = \frac{-d\Phi}{dx}$$

$$\Phi(x) = \frac{en}{\varepsilon_0} \cdot \frac{x^2}{2}$$

Распределение потенциала



$$I(t) = I_0 \sin(\omega t) = env(t) = en \cdot \frac{dS_a}{dt}$$

$$S_a(t) = S_0 + S_0 \cos(\omega t)$$

$$S_b(t) = 2 S_0 - S_a(t)$$

$$\Phi_a(t) = \frac{en}{2 \cdot \varepsilon_0} \left(S_0 + S_0 \cos(\omega t)\right)^2$$

$$\Phi_b(t) = \frac{-en}{2 \cdot \varepsilon_0} \left(S_0 - S_0 \cos(\omega t)\right)^2$$

$$U_0 \cos(\omega t) = \Phi_a(t) + \Phi_b(t) = \frac{2en \cdot (S_0)^2}{\varepsilon_0} \cdot \cos(\omega t)$$

$$S_0 = \sqrt{\frac{\varepsilon_0 \cdot U_0}{2en}}$$

$$I(t) = en \cdot \frac{dS}{dt} = en\omega S_0 \sin(\omega t) = I_0 \sin(\omega t)$$

$$I_0 = en\omega S_0 = \omega \cdot \sqrt{\frac{en\varepsilon_0 U_0}{2}} \qquad U_0 = \frac{2 \cdot (I_0)^2}{\varepsilon_0 en \cdot \omega^2} \qquad S_0 = \frac{I_0}{en\omega}$$

Средний потенциал плазмы

$$\Phi_p = \langle \Phi_a(t) \rangle = \frac{en \cdot (S_0)^2}{2\varepsilon_0} \langle (1 + \cos(\omega t))^2 \rangle$$

$$\Phi_p = \frac{3}{4} \cdot \frac{en \cdot (S_0)^2}{\varepsilon_0} = \frac{3}{8} \cdot U_0$$

Мощность, выделяемая в плазе и в слое

$$I_0 = env_e = en \cdot \frac{e \cdot E_0}{m\nu} = \frac{e^2 n}{m\nu} E_0$$

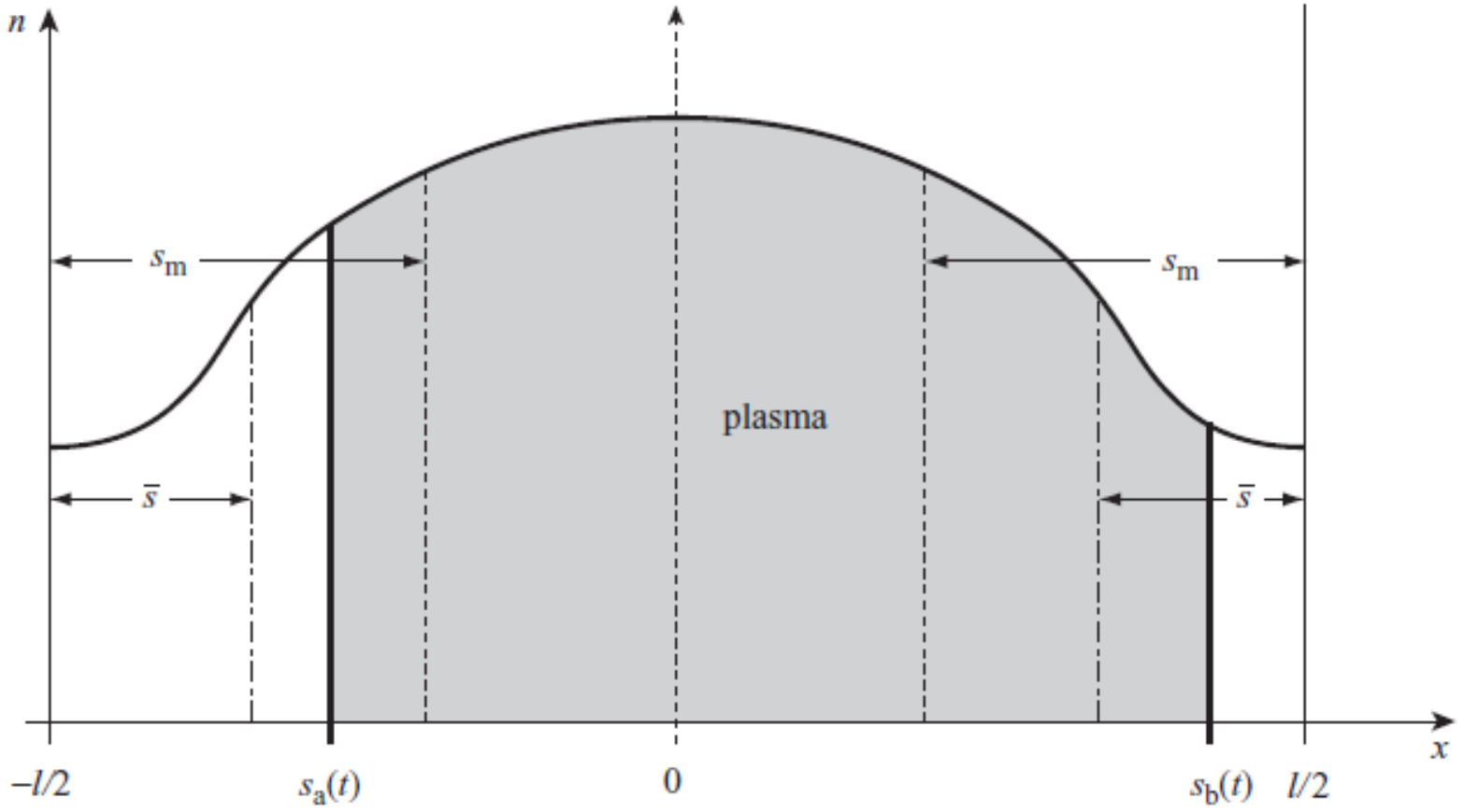
$$P_{pl} = \frac{1}{2} \cdot I_0 \cdot E_0 \cdot L_{pl} = \frac{1}{2} \cdot \frac{m\nu}{e^2 n} \cdot (I_0)^2 \cdot L_{pl}$$

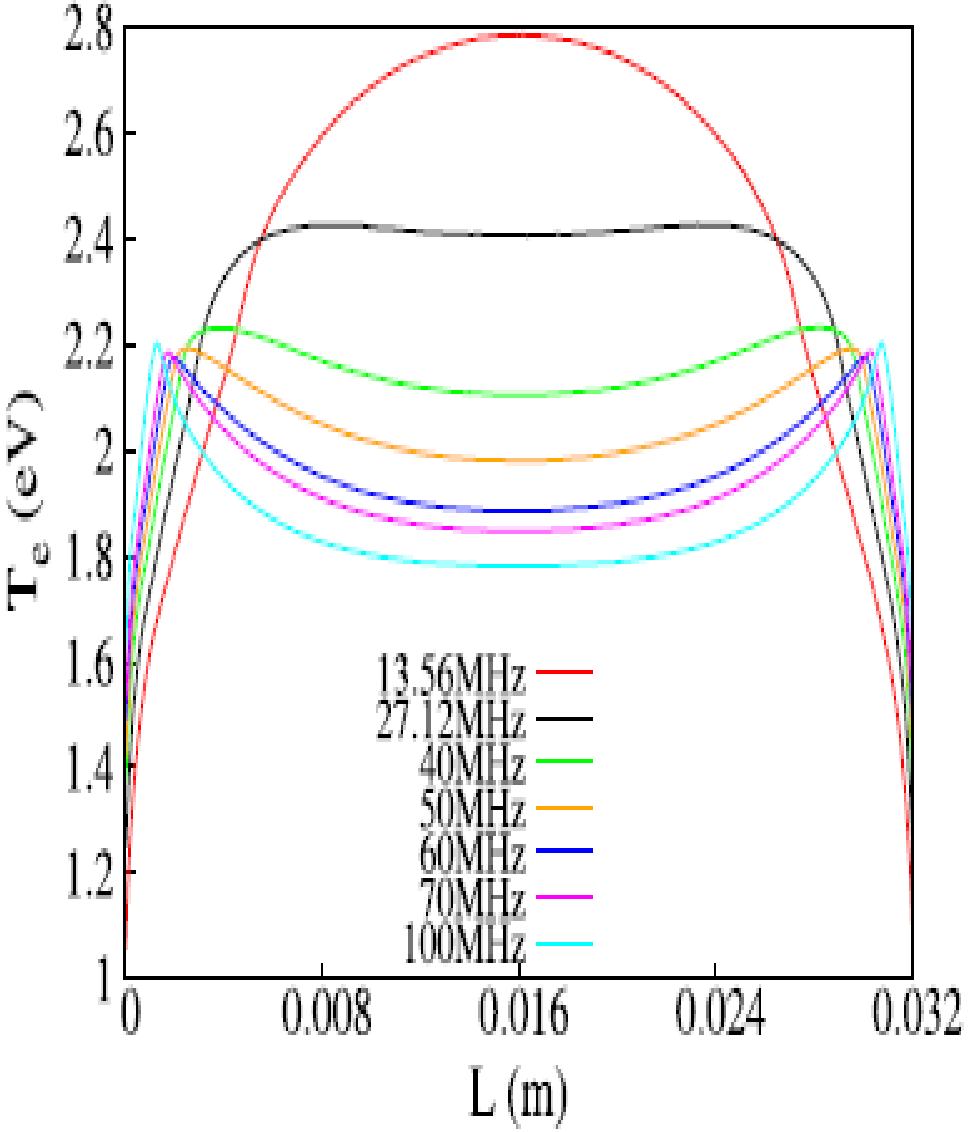
$$P_{pl} = \omega^2 \cdot \frac{m\nu}{4e} \cdot \varepsilon_0 U_0 \cdot L_{pl}$$

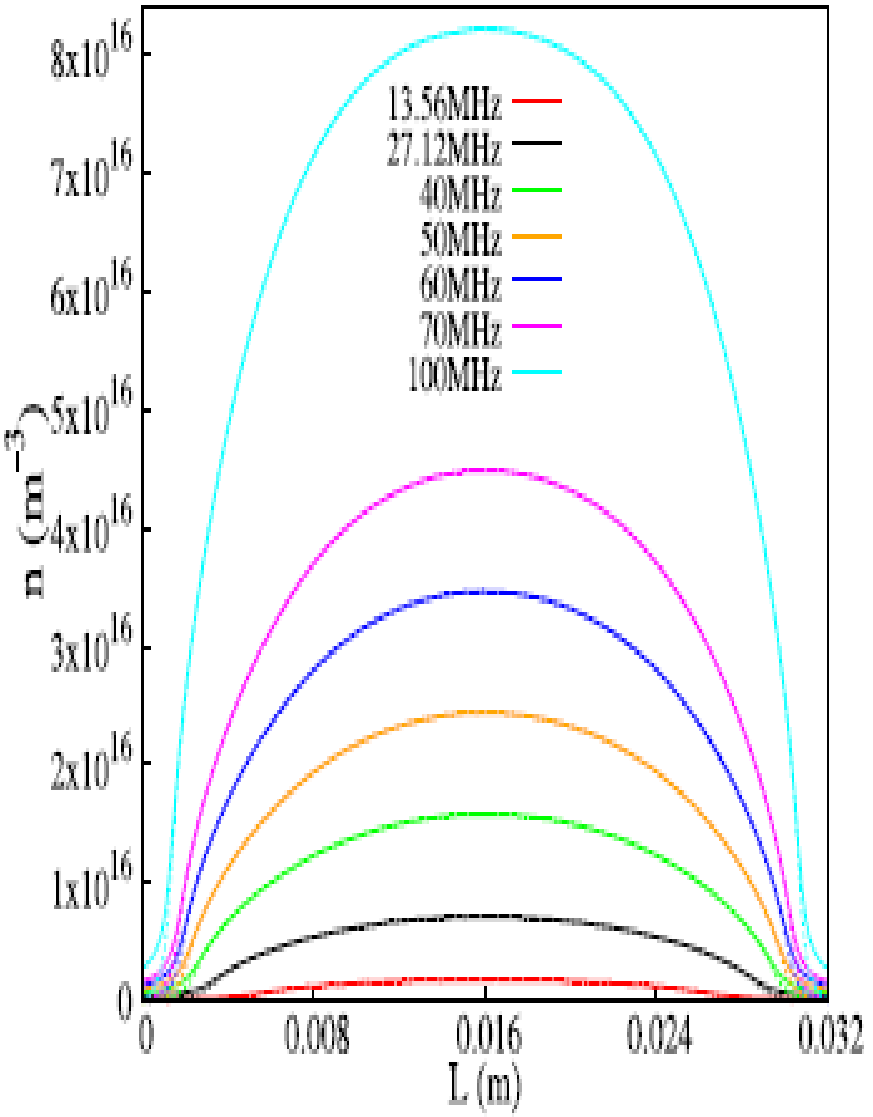
$$P_i = J_i \Phi_{pl} = en \cdot U_b \cdot \frac{3}{8} U_0$$

$$\frac{P_i}{P_{pl}} = \frac{3}{2} \cdot \frac{e^2 n U_b}{\omega^2 m \nu \varepsilon_0 L_{pl}}$$

Неоднородная модель




2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
T_e (eV)
0
0.008
0.016
0.024
0.032
L (m)
13.56MHz
27.12MHz
40MHz
50MHz
60MHz
70MHz
100MHz


$8x10^{16}$
$7x10^{16}$
$6x10^{16}$
$5x10^{16}$
$4x10^{16}$
$3x10^{16}$
$2x10^{16}$
$1x10^{16}$
0
n (m^{-3})
0
0.008
0.016
0.024
0.032
L (m)
13.56MHz
27.12MHz
40MHz
50MHz
60MHz
70MHz
100MHz

Двухчастотный разряд

$$P_{pl} = \omega^2 \cdot \frac{m\nu}{4e} \cdot \varepsilon_0 U_0 \cdot L_{pl}$$

$$P_{pl} - - - \omega^2 U_0$$

$$n - - - P_{pl} - - - \omega^2 U_0$$

$$J_i = enU_b - - - \omega^2 U_0$$

$$\varepsilon_i = \frac{3}{8} U_0$$

$$\varepsilon_i - - - J_i$$

$$U = U_l \sin(\omega_l t) + U_h \sin(\omega_h t)$$

$$\omega_h > \blacksquare > \omega_l$$

$$U_l > U_h$$

$$\varepsilon_i = \frac{3}{8} U_l$$

$$J_i - - - \omega^2 U_h$$