Iontozvukové vlny (silně teplotní závislost elektronů) 11

my jsme uvažovali izotermální elektrony

$\rightarrow$ limita $\underbrace{\lambda_T}_{\text{tep. vodivost}} \rightarrow \infty$

rovnice vedení tepla

$$\frac{3}{2} n_e k_B \left(\frac{\partial T_e}{\partial t} + \vec{u}\nabla T_e \right) + \operatorname{div} \vec{q}_e + p \operatorname{div} u = 0$$

linearizace

$$\frac{3}{2} n_{e0} k_B \frac{\partial T_1}{\partial t} \quad \cancel{=} \lambda_{T_e} \frac{\partial^2 T_1}{\partial x^2} + p_{e0} \frac{\partial u_1}{\partial x} = 0$$

$n_{e0} = Z n_{i0}$

iontozvukové vlny – předpoklad kvazineutrality

$n_{e1} = Z n_{i1}$ $\qquad u_{1i} = u_{1e} = u_1$

$i\omega n_{i1} = n_{i0} i k u_1$ $\qquad p_{e1} = n_1 k_B T_{e0} + n_{e0} k_B T_1$

$$-i\omega M_i \underbrace{v_{i1}}_{= u_1} = -\frac{\nabla p_{i1}}{n_{i0}} - \frac{\nabla p_{e1}}{n_{i0}} = -ik\gamma_i k T_i \frac{n_{i1}}{n_{i0}} -$$

$$- ikZk_B T_{e0} \frac{n_{i1}}{n_{i0}} - ikZk_B T_1$$

$$\left(-i\omega + \frac{2\lambda_{Te} k^2}{3 n_{e0} k_B}\right) T_1 = -\frac{2}{3} ik T_{e0} u_1 = -\frac{2}{3} i\omega T_{e0} \frac{n_{i1}}{n_{i0}}$$

$$T_1 = \frac{2}{3} T_{e0} \underbrace{\frac{n_{e1}}{n_{e0}}}_{=\frac{n_{i1}}{n_{i0}}} \Big/ \left(1 + i\frac{2}{3}\frac{\lambda_{Te} k^2}{n_{e0} k_B \omega}\right)$$ A2

pokud $\lambda_{Te} = 0 \Rightarrow p_{e1} = \underbrace{\left(1+\frac{2}{3}\right)}_{\gamma} n_1 k_B T_{e0}$

pro
$$\frac{\lambda_{Te} k^2}{n_{e0} k_B \omega} \simeq \frac{\lambda_{Te} k}{n_e k_B c_s} \gg 1$$

$$|T_1| \ll \frac{2}{3} T_{e0} \frac{n_{e1}}{n_{e0}} \Rightarrow T_1 \simeq 0$$

a! $\lambda_{Te} \sim T_e^{5/2}$ $\quad c_s \sim T_e^{1/2}$

elektrony obstarávají při vyšší teplotě
izotermální při vyšší

pokud $\frac{\lambda_{Te} k^2}{n_{e0} k_B \omega} \simeq 1 \Rightarrow$ silné tlumení

tepelná vodivost $\Rightarrow$ útlum vl.

$$\alpha = \frac{2\lambda_{Te}}{3 n_{e0} k_B} \Rightarrow T_1 = \frac{2}{3} T_{e0} \frac{n_{i1}}{n_{i0}} \frac{1}{1+i\alpha\frac{k^2}{\omega}}$$

dosadíme do rovnice pro u_1 a ~~u_1 dosadíme~~

za u_1 dosadíme z rovnice kontinuity

$\alpha k \approx 0$ ⑬

$$\omega^2 = k^2\left[\frac{1}{M_i}\left(\gamma_i k_B T_i + Z k_B T_e\right) + \frac{2}{3 M_i}\frac{Z k_B T_e}{\left(1+\frac{\alpha^2 k^4}{\omega^2}\right)} - i\,\frac{2}{3}\frac{Z k_B T_e}{M_i}\frac{\alpha k^2/\omega}{1+\frac{\alpha^2 k^4}{\omega^2}}\right]$$

$\alpha = 0$

$$\omega^2 = k^2\left[\frac{1}{M_i}\left(\gamma_i k_B T_i + \frac{5}{3} Z k_B T_e\right)\right]$$

$\alpha \to \infty$

$$\omega^2 = k^2\left[\frac{1}{M_i}\left(\gamma_i k_B T_i + Z k_B T_e\right)\right]$$

max Dämpfung

$$\frac{d}{d\psi}\left(\frac{\psi}{1+\psi^2}\right) = 0 \Rightarrow 1\cdot(1+\psi^2) - \psi 2\psi = 0$$

$$1+\psi^2 - 2\psi^2 = 0$$

$$\psi^2 = 1$$

für $\frac{\alpha k^2}{\omega} = 1$

$$\omega^2 = k^2\left[\frac{1}{M_i}\left(\gamma_i k_B T_i + \frac{4}{3} Z k_B T_e\right) - i\,\frac{2}{3}\frac{Z k_B T_e}{M_i}\frac{1}{2}\right]$$

Aufg $\frac{\alpha k^2}{\omega} = 1$

für $T_i = 0$

$\alpha k = c_s$

$$\omega^2 = k^2\left[\frac{4}{3}\left(1 - \frac{i}{4}\right)\frac{Z k_B T_e}{M_i}\right]$$

oder

$$\omega^2 = k^2\,\frac{4}{3}\,\frac{Z k_B T_e}{M_i}\left(1 - \frac{i}{4}\right)$$