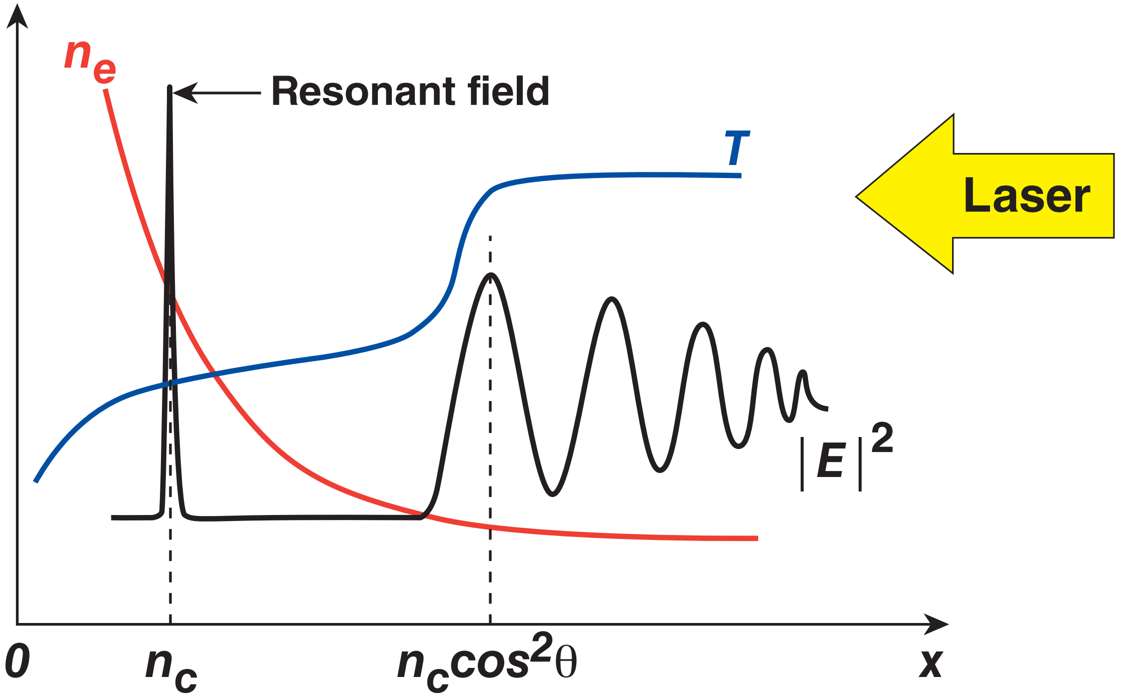
The Effect of Electromagnetic Fields on Electron-Thermal Transport in Laser-Produced Plasmas



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Summary

Ponderomotive terms modify thermal conduction near the critical surface

- Gradients in the laser-induced electric fields introduce ponderomotive terms in the electron heat flux.
- The ponderomotive transport coefficients, previously derived in the limit of $Z >> 1$,* are obtained for an arbitrary ion charge *Z* using the Chapman–Enskog method.
- The electric field gradients near the laser turning point and at the critical surface modify thermal transport and hydrodynamic profiles.**

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*A. V. Maximov *et al*., Sov. J. Plasma Phys. 16, 331 (1990).
**V. N. Goncharov (next talk in this session).

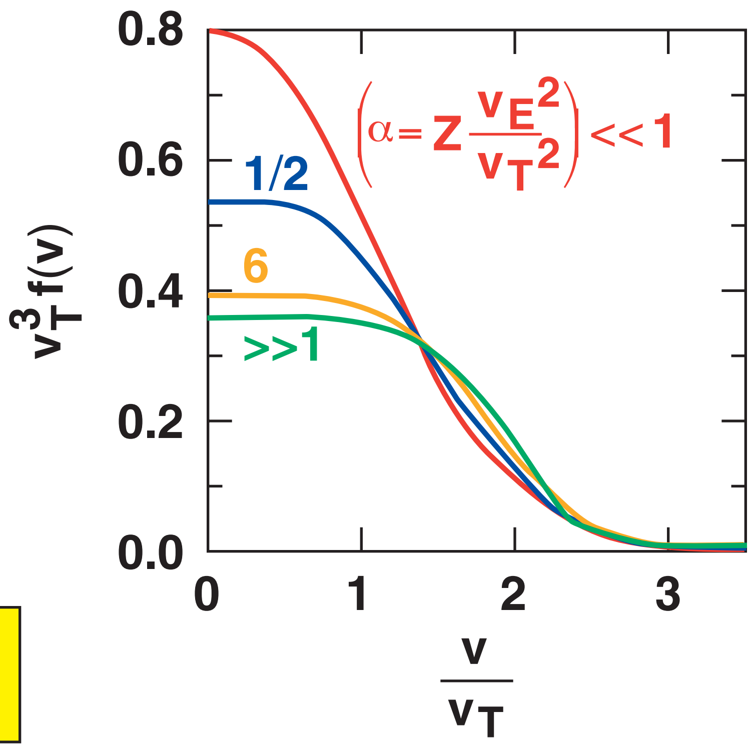
The effect of laser electromagnetic fields has previously been considered in the symmetric part of the distribution function*

- Laser energy is absorbed by subthermal electrons

Collision frequency

$$\frac{\partial f}{\partial t} = \sqrt{\frac{\pi}{8}}\,\frac{\nu_{ei} v_T^3 v_E^2}{v^2}\,\frac{\partial}{\partial v}\left(\frac{1}{v}\frac{\partial f}{\partial v}\right) + J_{ee}[f] \quad \left(v = \frac{eE}{m\omega}\right)$$

$$\int dv\,\frac{\partial f}{\partial t} v^2 \Rightarrow \frac{\partial T}{\partial t} = (2\pi)^{3/2}\,\frac{m}{3n}\,\nu_{ei} v_T^3 v_E^2 f(0)$$



Electromagnetic fields reduce f(0); this leads to a reduction in absorption.

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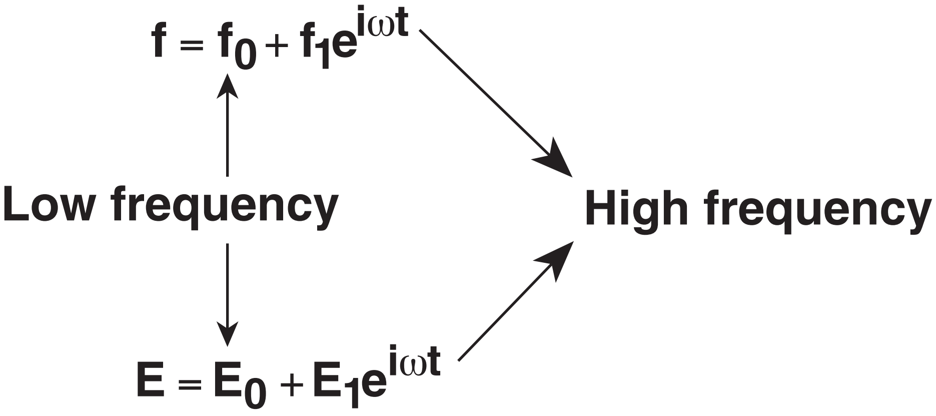
*A. B. Langdon, Phys. Rev. Lett. 44, 575 (1980).

The Boltzmann equation is solved in the presence of laser electromagnetic fields using the Chapman–Enskog method

$$\frac{\partial f}{\partial t} + v\frac{\partial f}{\partial r} + e\left(E + \frac{v \times B}{c}\right)\frac{\partial f}{\partial p} = J_{ee}\left[f,f\right] + J_{ei}\left[f\right]$$



$$f = f_0 + f_1 e^{i\omega t}$$

Low frequency

High frequency

$$E = E_0 + E_1 e^{i\omega t}$$

$$f_0 = f_M(1 + \psi) \qquad |\psi| << 1$$

$$\psi_1 \sim \nabla T,\ |E|^2;\ \psi_2 \sim \nabla |E|^2$$

The Chapman–Enskog method yields ponderomotive terms in electric current and heat flux*

$$j = env_T\lambda_e\left[\alpha_{j1}^{T}\nabla\ln T + \alpha_{j2}^{T}\left(\nabla\ln nT\boxed{-\frac{eE_0}{T}}\right) + \alpha_{j2}^{E}\,\frac{\nabla v_E^2}{v_T^2}\right]$$

$$q = nTv_T\lambda_e\left[\alpha_{q1}^{T}\nabla\ln T + \alpha_{q2}^{T}\left(\nabla\ln nT\boxed{-\frac{eE_0}{T}}\right) + \alpha_{q2}^{E}\,\frac{\nabla v_E^2}{v_T^2}\right]$$

The neutrality condition $j = 0$ determines E_0

$$q = nTv_T\lambda_e\left[-\beta^{T}\nabla\ln T + \beta^{E}\,\frac{\nabla v_E^2}{v_T^2}\right]$$

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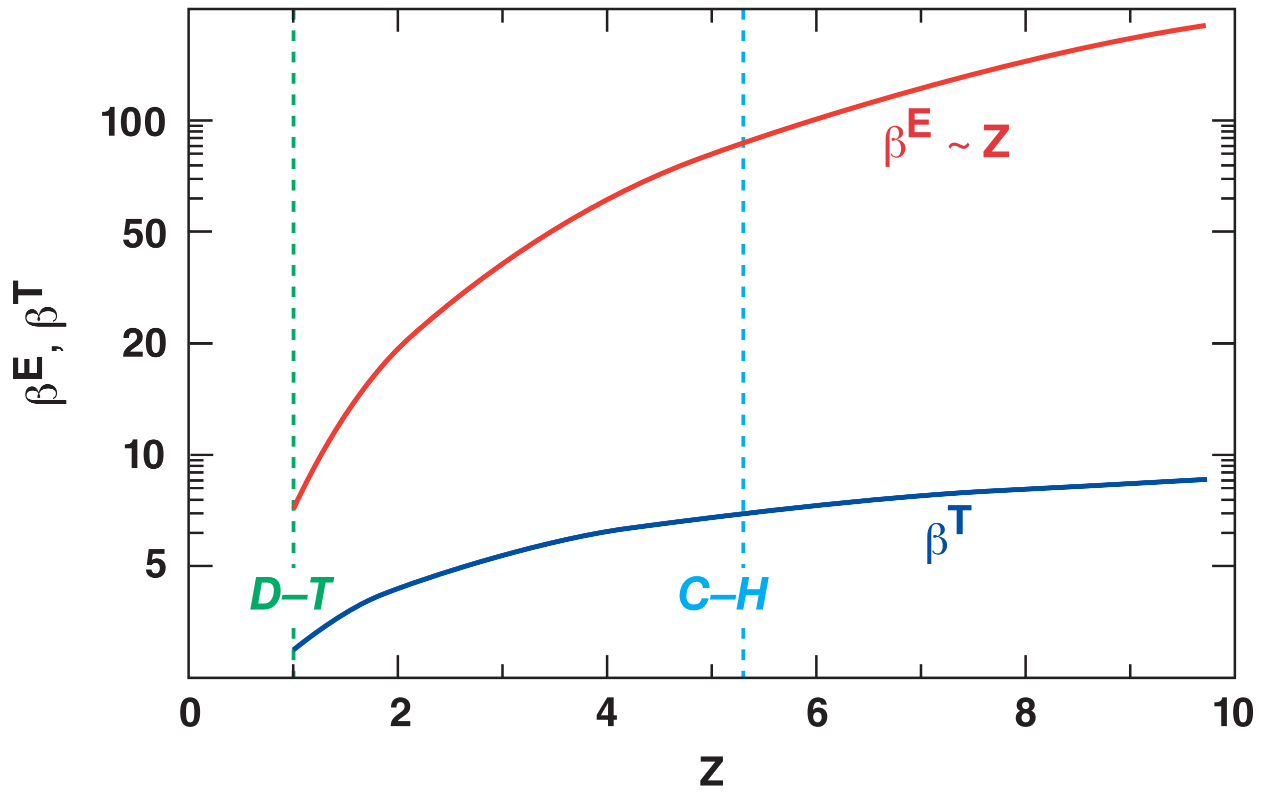
*V. N. Goncharov and G. Li, "Effects of Electric Fields on Thermal Transport in Laser-Produced Plasmas," to be published in Physics of Plasmas.

For typical ICF plasmas $\beta^E > \beta^T$

$$q \sim -\beta^T \nabla \ln T + \beta^E \frac{\nabla v_E^2}{v_T^2}$$



The ponderomotive term has the opposite sign of the thermal term.

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Ponderomotive heat flux is mainly due to modification in the symmetric part of the distribution function

$$\frac{\partial f}{\partial t} = \sqrt{\frac{\pi}{8}}\,\frac{\nu_{ei} v_T^3\, v_E^2}{v^2}\,\frac{\partial}{\partial v}\left(\frac{1}{v}\frac{\partial f}{\partial v}\right) + J_{ee}\left[f\right]$$

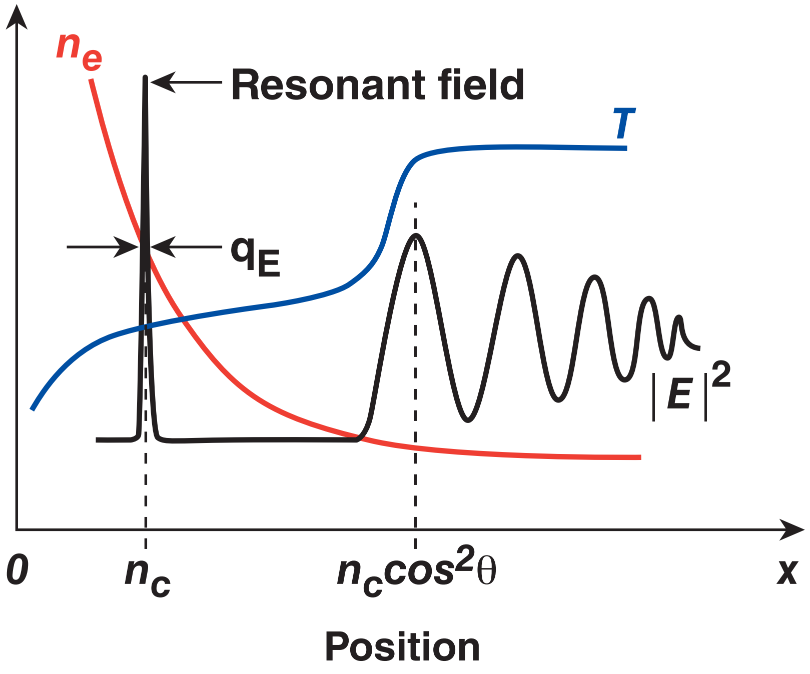
- Subthermal electrons ($v \ll v_T$) ⟶ absorption
- Suprathermal electrons ($v \gg v_T$) ⟶ heat flux

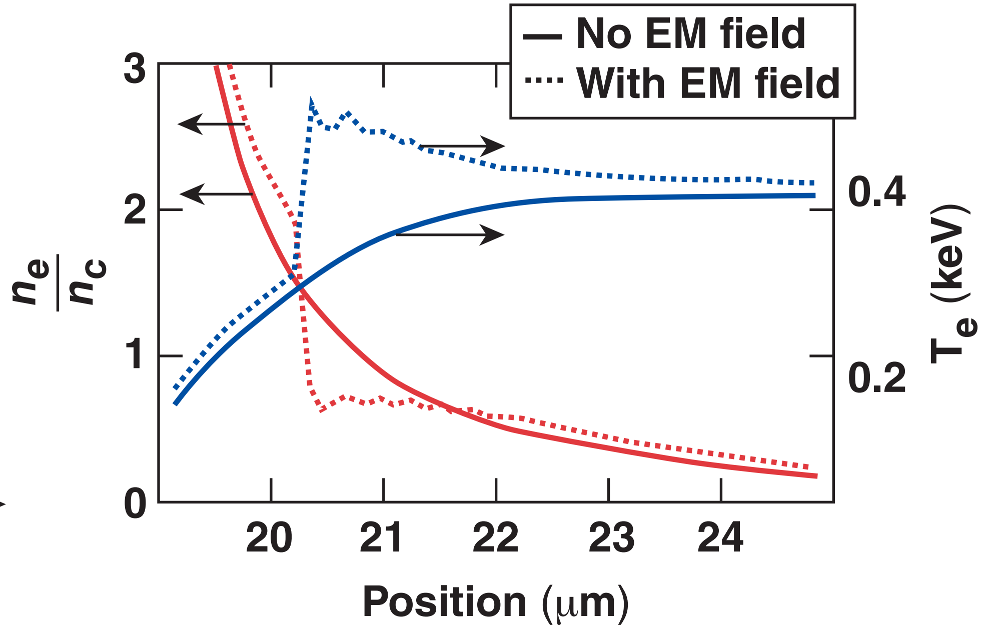
$$f\left(v \gg v_T\right) \sim f_M \exp\left(\frac{-7\,\alpha}{225\sqrt{2\pi}}\,\frac{v^5}{v_T^5}\right) \quad \left(\alpha = \frac{Z v_E^2}{v_T^2} \ll 1\right)$$

$$\nabla f \sim \nabla\alpha \sim \nabla|E|^2$$

$$q \sim \nabla f \sim \nabla|E|^2$$

The ponderomotive terms lead to density-profile steepening*





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*V. N. Goncharov (next talk in this session).

Summary/Conclusions

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