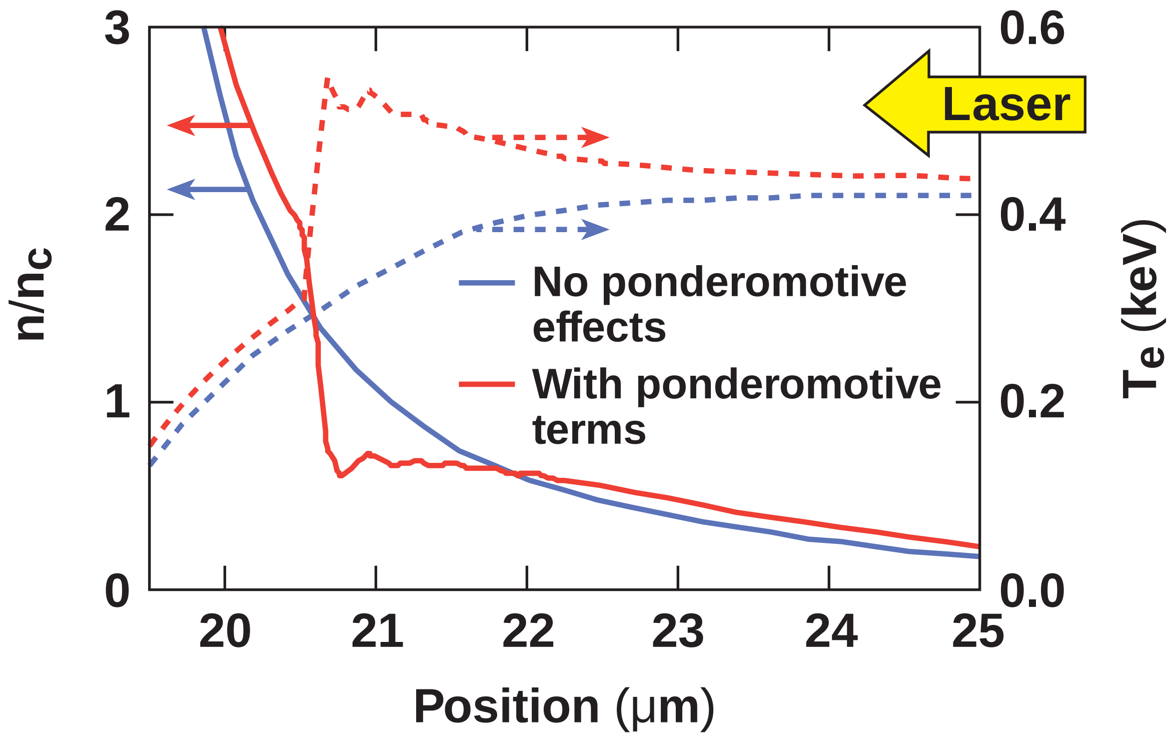
Effects of Ponderomotive Terms in Thermal Transport on Hydrodynamic Flow in ICF Experiments



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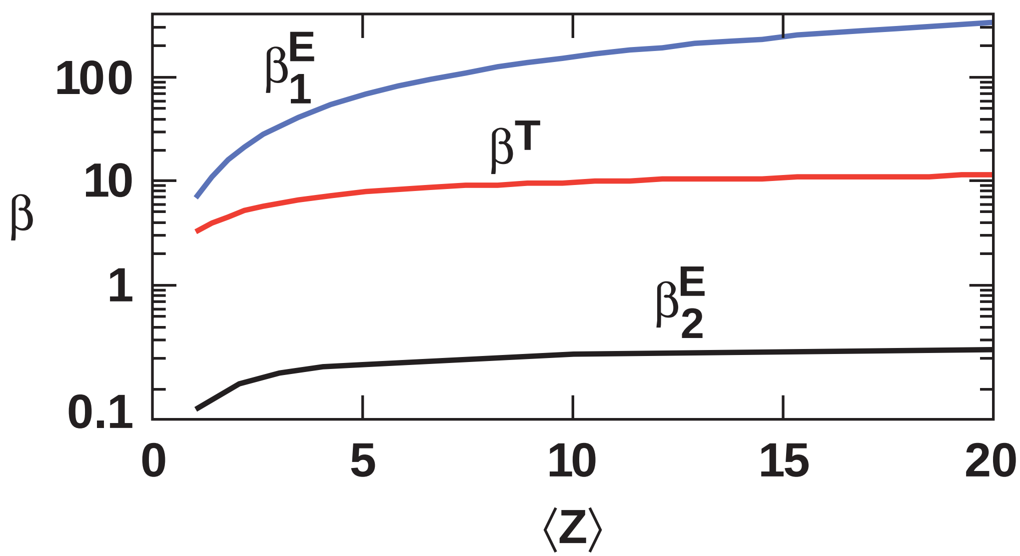
Summary

Effects of the laser electromagnetic field in thermal transport lead to steepening in density and temperature profiles near the critical surface

- Gradients in the electromagnetic field amplitude lead to ponderomotive terms in electron thermal conduction.
- Such terms are proportional to $\nabla \alpha_L = \nabla \left(Z v_E^2 / v_T^2 \right)$.
- The Langdon parameter α_L is small for ICF plasmas, the electric field gradient, however, is large near the turning point and the critical surface.
- Large field gradients affect the thermal transport and lead to modifications in the electron density and temperature at the critical surface.

Second-order heat flux is proportional to the intensity gradient[1]

$$q_j = nTv_T\lambda_e\left\{-\beta^T\frac{\partial \ln T}{\partial r_j} + \frac{e^2}{m_e^2\omega^2 v_T^2}\left[\beta_2^E\frac{\partial E_{jk}}{\partial r_k} + \beta_1^E\frac{\partial E^2}{\partial r_j}\right]\right\}$$



$$E_{jk} = E_jE_k^* + E_j^*E_k - \frac{2}{3}\delta_{jk}E^2$$

Contributions from ∇T and ∇E^2 have opposite signs.

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

Maxwell's equations are solved using an intensity-dependent dielectric function

- **S-polarization** $$E'' + \frac{\omega^2}{c^2}\left[\in(z) - \sin^2\theta\right]E = 0$$ θ = **incidence angle**

- **P-polarization** $$B'' - \frac{\in'(z)}{\in(z)}B' + \frac{\omega^2}{c^2}\left[\in(z) - \sin^2\theta\right]B = 0$$

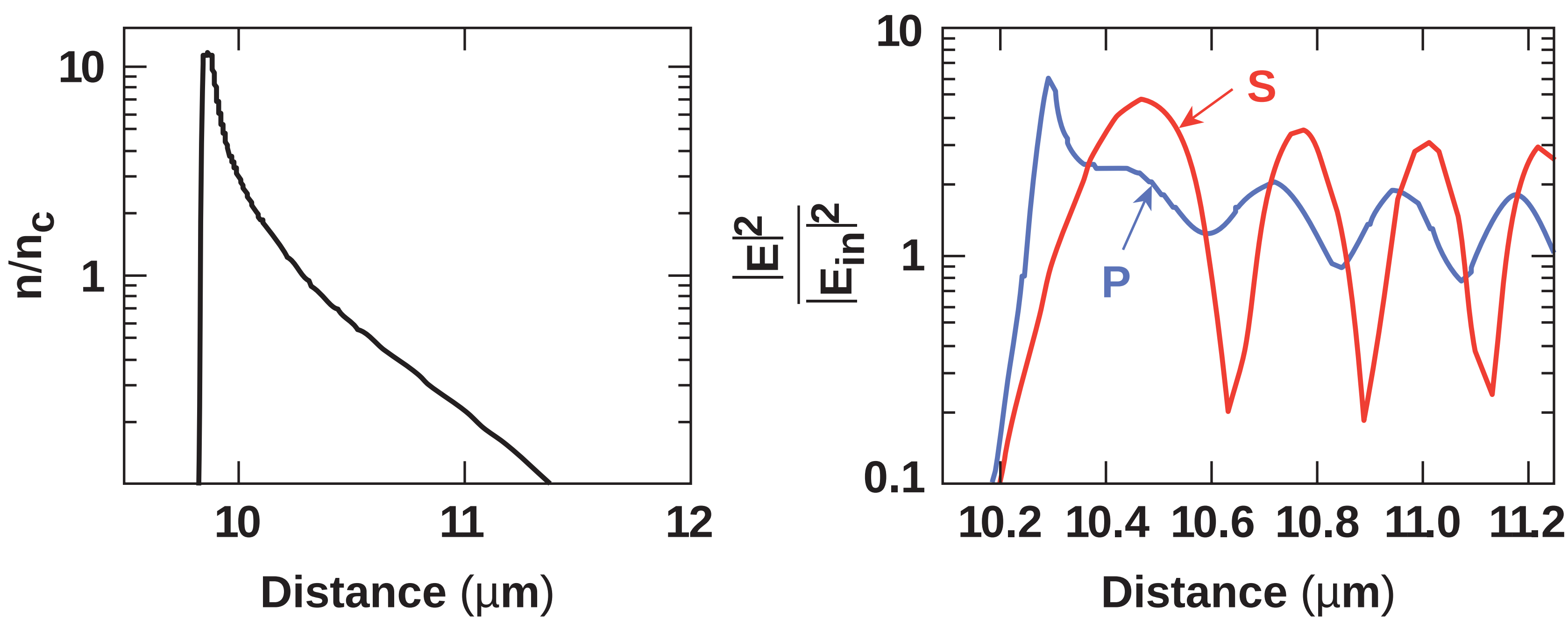
- **Dielectric function** $$\in(z) = 1 - \frac{\omega_p^2}{\omega(\omega + i\nu_{ei})}$$

- **Langdon effect is included in absorption**

$$\nu_{ei} \propto \nu_{ei}^{M} f(0),\ \nu_{ei} = \nu_{ei}^{M}\left[1 - \frac{0.553}{1 + (0.27/\alpha_L)^{0.75}}\right];\ \alpha_L = Z\frac{v_E^2}{v_T^2}$$

Initial profiles are created in 1-D simulations using Spitzer conductivity

- ***LILAC*** **simulation of 10-μm CH foil**
- **Square pulse with $I_{max} = 5 \times 10^{13}$ W/cm^2, $\theta = 23°$ incidence angle**
- **Ponderomotive force is not important.**



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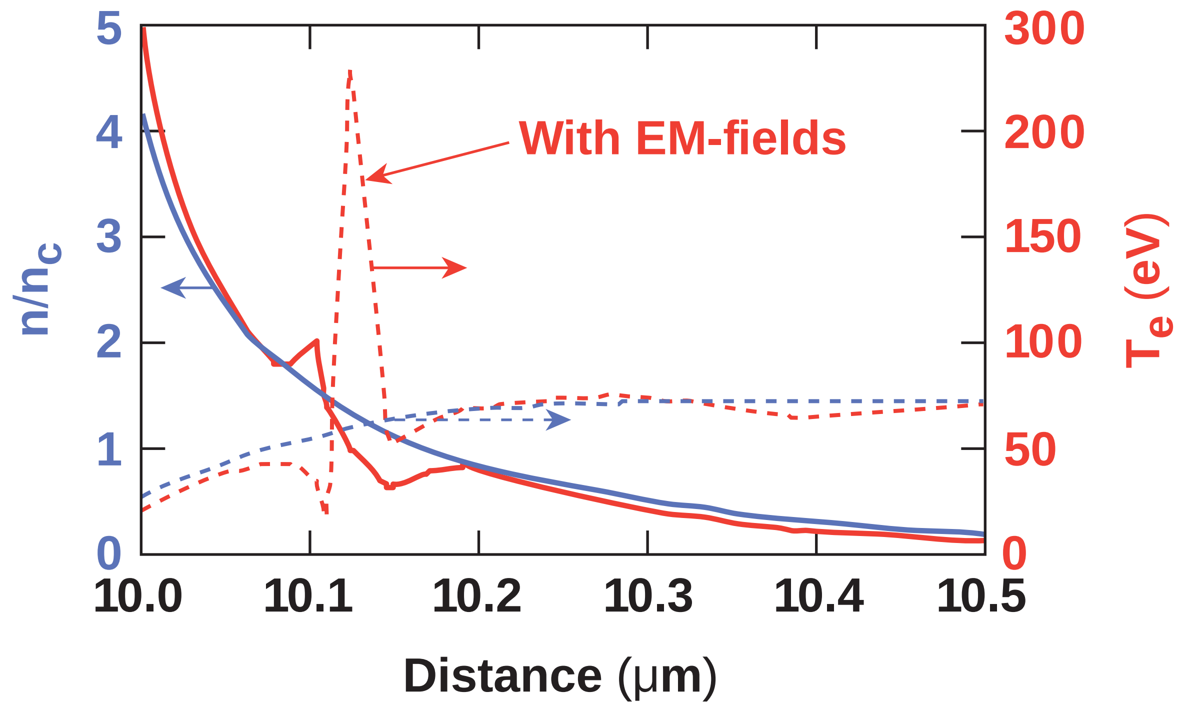
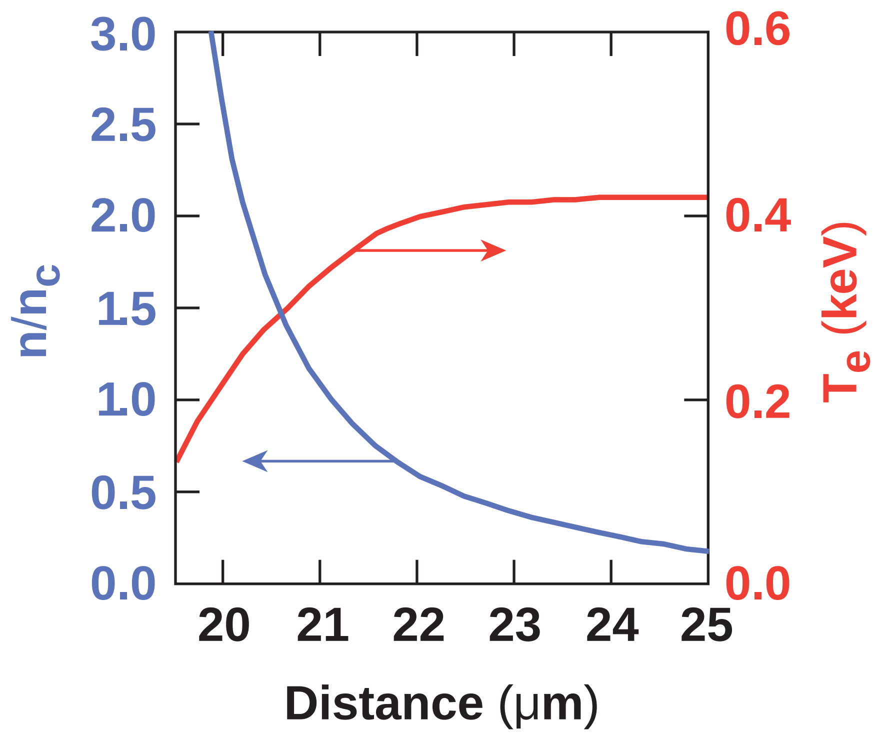
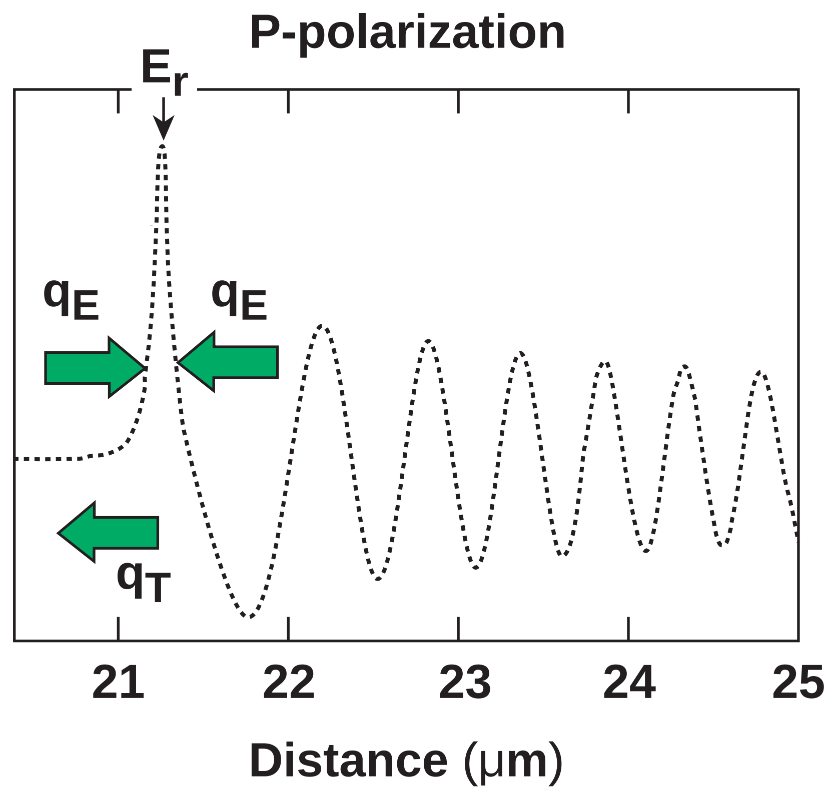
The profiles near the critical surface are modified by ponderomotive terms in the heat flux

- **5 ps after introducing the ponderomotive terms**



Linear heat conduction at the critical surface leads to an instability





Local increase in $T_e \Rightarrow$ reduction in $n_e \Rightarrow$ critical surface close to turning point $\Rightarrow$ increase in $E_r \Rightarrow$ instability

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Effects of the ponderomotive terms are studied also using the nonlocal diffusion model[1]

- **Heat flux:** $Q_t = \int_{4\pi} q(\Omega, r)\,\Omega\, d\Omega$ $\qquad Q_L$ – heat flux from linear theory

- **Multigroup diffusion:** $\left(\frac{1}{\lambda_g} - \nabla \frac{\lambda_g}{3} \nabla\right) H_g = -\nabla \bullet \left(Q_L^g\right)$

m.f.p.

$H_g = \int_{4\pi} q_g\, d\Omega$

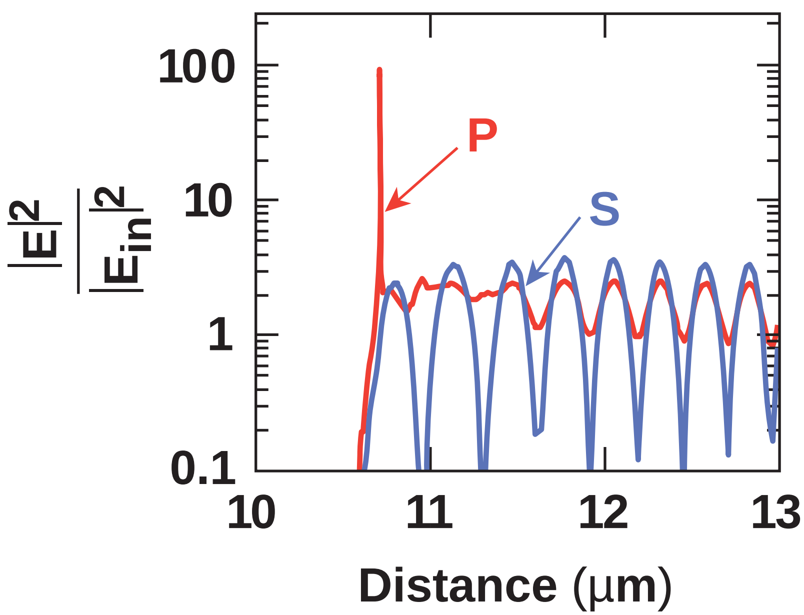
Contribution to Q_L from group g

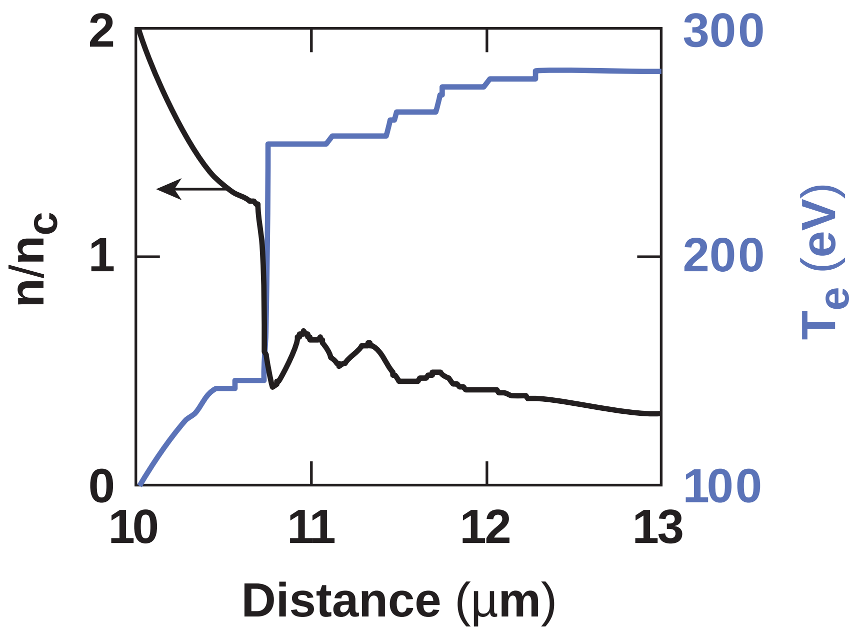
- **Modified heat flux:** $Q_t = Q_L - \sum_g \frac{\lambda_g}{3} \nabla H_g$

[1] G. P. Schurtz *et al.*, Phys. Plasmas 9, 4238 (2000).

Ponderomotive terms in diffusion approximation lead to a density jump at the critical surface

- 30 ps after introducing the ponderomotive terms





Density steepening is predicted in both linear and nonlocal diffusion transport models.

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Summary/Conclusions

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