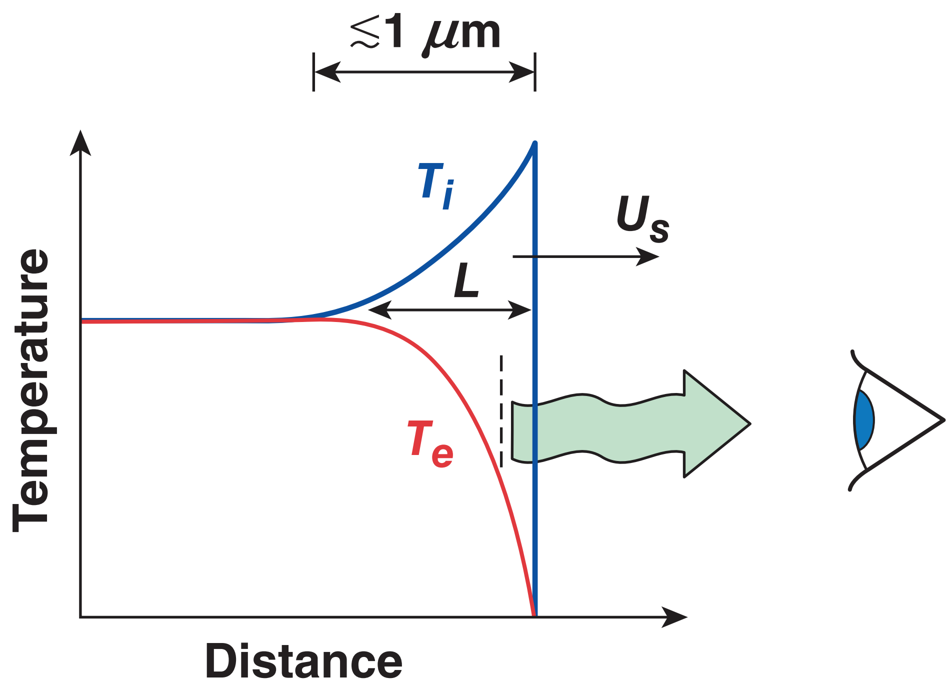
Nonequilibrium Conditions in a Shock Front



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Summary

Temperature measurements in foam are consistent with nonequilibrium conditions at the shock front

- Equation-of-state measurements on foam show abnormal independence of temperature with pressure.

- At low densities and high shock velocities the electron temperature can "lag" the ion temperature, creating a non-equilibrium region that can mask the actual temperature.

- A simple radiation transport model mimics observed temperature dependence with equilibration distances of 500 to 1000 nm.

- Optical diagnosis of this phenomenon may be difficult.

Collaborators

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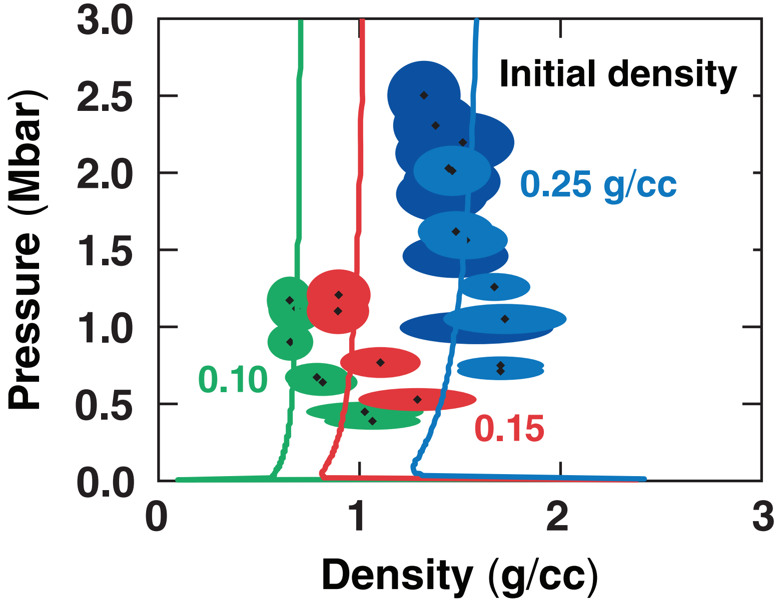
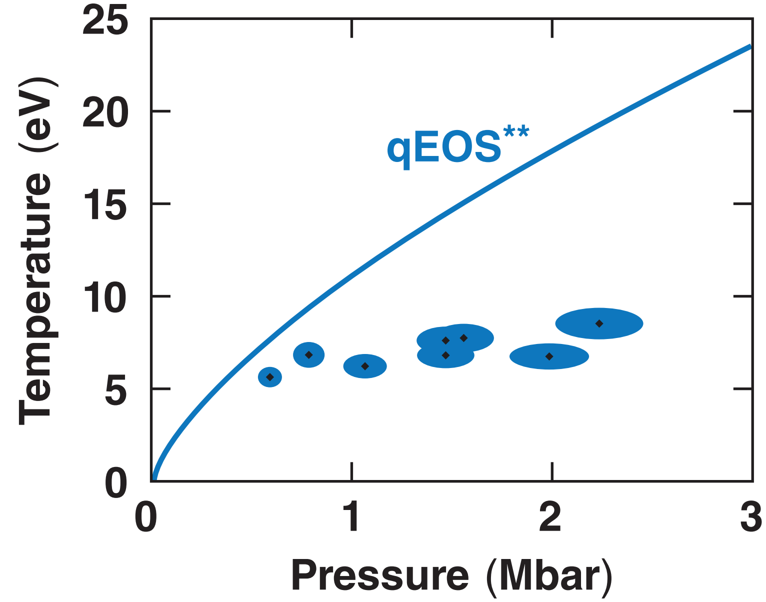
EOS measurements* on Ta_2O_5 foams exhibit temperatures considerably lower than expected

Kinematic properties are well modeled



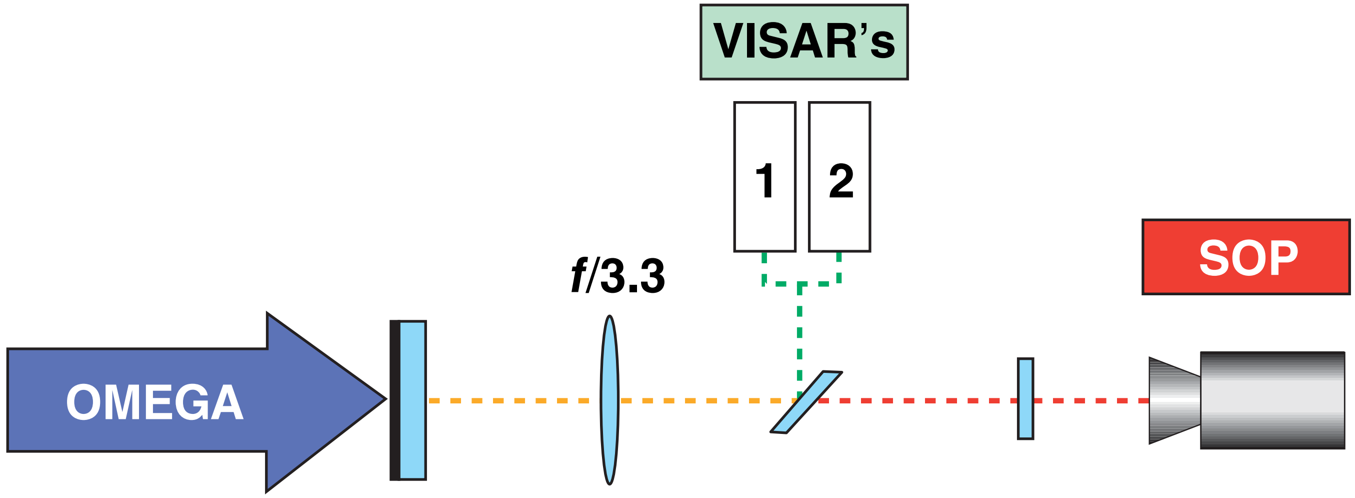


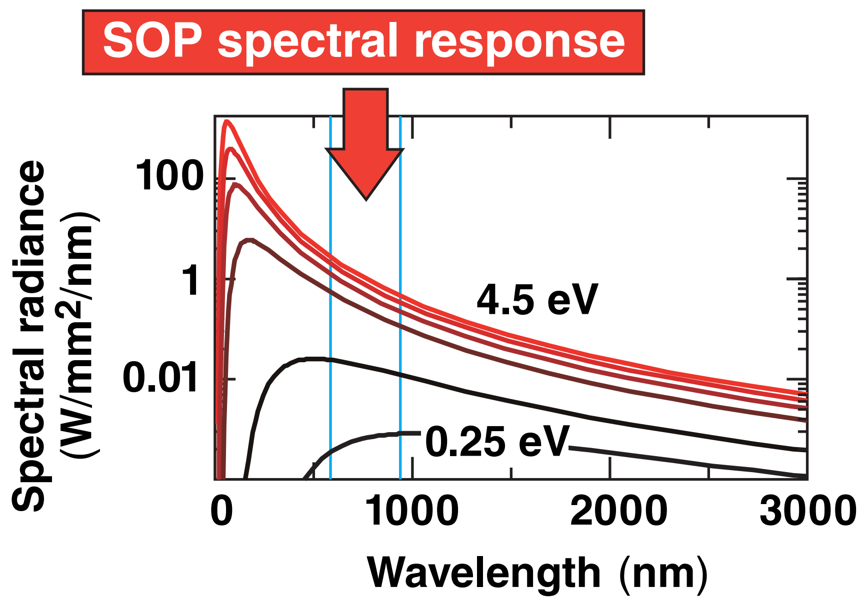
* J. Miller *et al.*, "Equation-of-State Measurements in Ta_2O_5 Aerogel," to be published in the *Proceedings of the 15th APS Topical Conference on Shock Compression of Condensed Matter* (2007).

** qEOS courtesy D. Young, LLNL

E16294

Optical self-emission data are acquired simultaneously with shock velocity from VISAR





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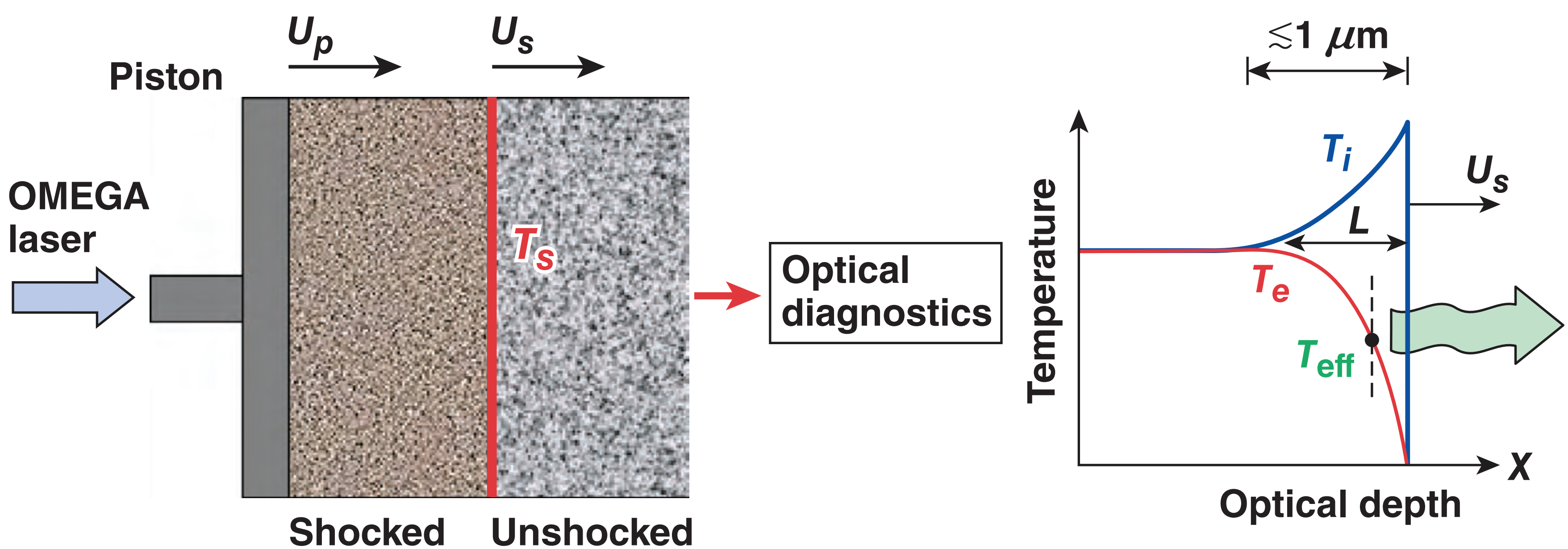
Shock energy is initially carried by the ions, then transferred to the electrons by collisions



Pyrometry detects T_{eff}

At sufficiently high velocity and low density, the electron temperature can "lag" the ion temperature.

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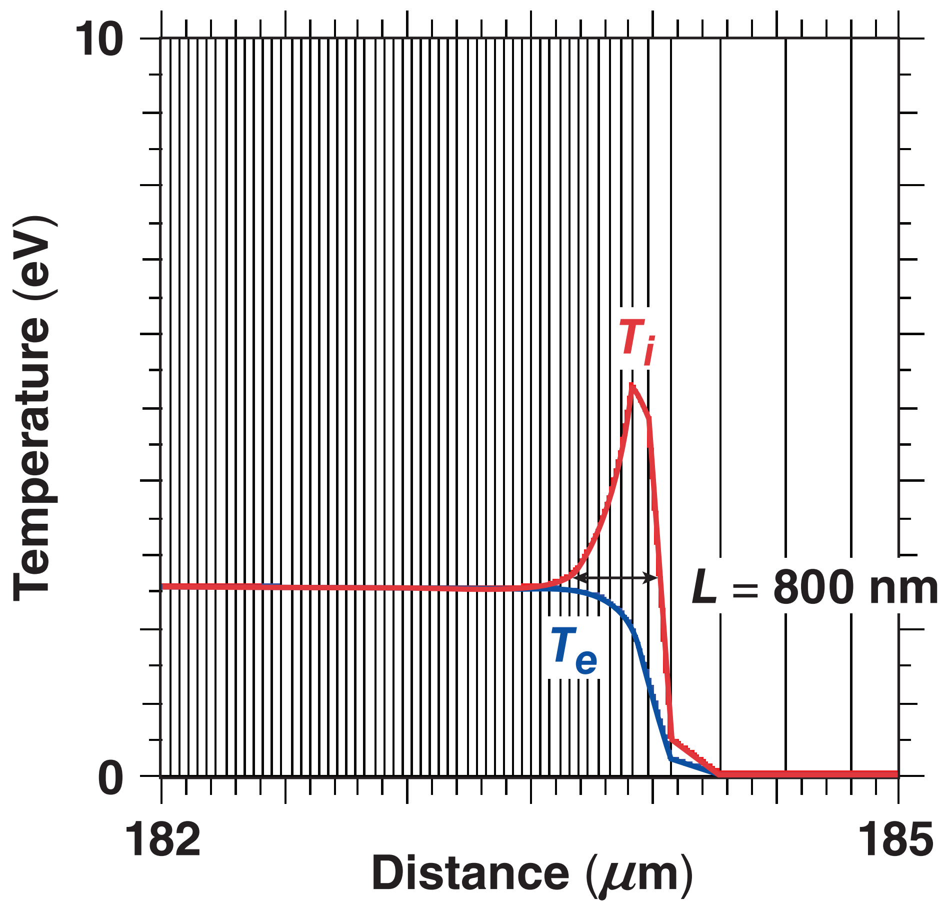
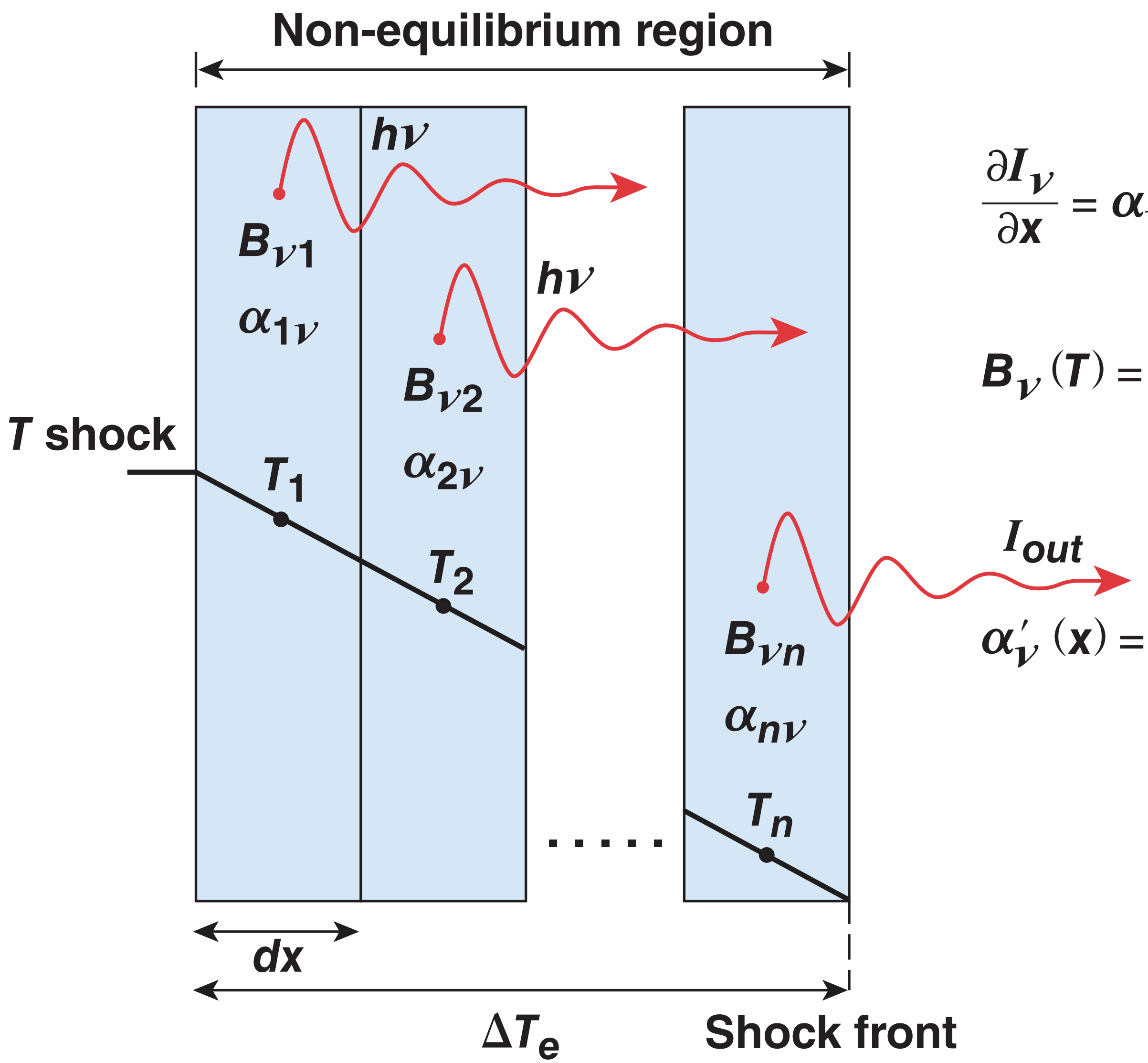
Hydra-simulations predict ~800-nm equilibration depth in foam



E16239

M. Marinak *et al*., Phys. Plasmas 5, 1125 (1998).

A radiation transport model describes sources and absorption of light in a nonequilibrium plasma



$$\frac{\partial I_\nu}{\partial x} = \alpha'_\nu(x)\{B_\nu[T(x)] - I_\nu\}$$

$$B_\nu(T) = \frac{2h\nu^3/c^2}{\exp[h\nu/kT(x)] - 1}$$

$$\alpha'_\nu(x) = \alpha_\nu(x)\{1 - \exp[h\nu/kT(x)]\}$$

E16240

The absorption coefficient is derived from the optical properties of a "conductive" medium

$$\alpha_\nu = \frac{4\pi\nu n_{imag}}{c}$$

$$n = n_{real} + i n_{imag}$$ Refractive index

$$n^2 = 1 - \frac{\omega_p^2}{\omega^2}\left[\frac{1}{1 + i/\omega\tau_{ei}}\right]$$ Dispersion relation

$$\omega_p^2 = \frac{4\pi n_e(T)e^2}{m_e}$$ Plasma frequency

$$n_e = n_0 T^{3/2} \exp\left(-\frac{E_g}{2\,kT}\right)$$ Electron density

$$\tau_{ei} = \frac{R_0}{v_e}$$ Electron-ion collision time

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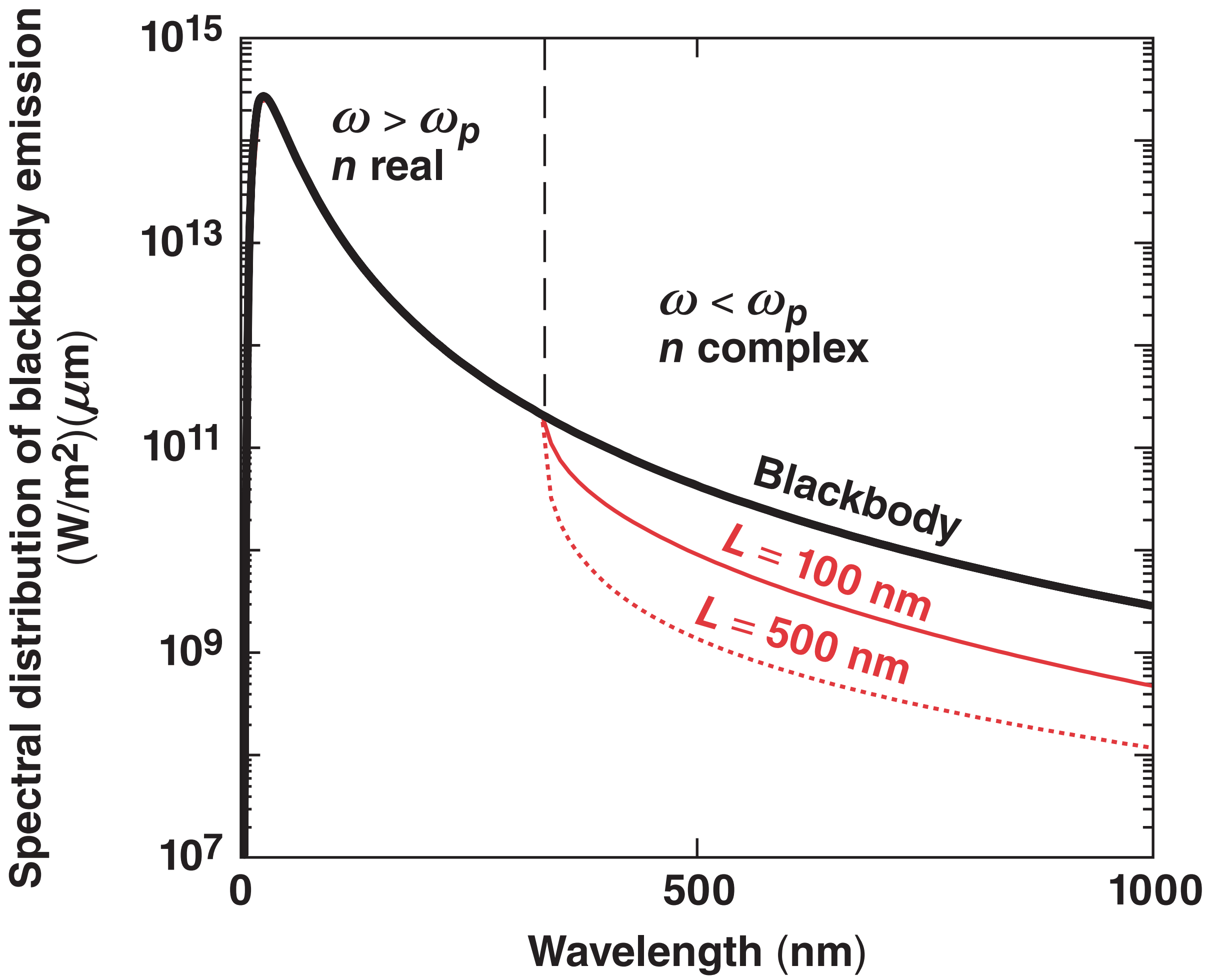
In a simple collisionless plasma model, attenuation of the Plankian spectrum begins at the critical density

$$n^2 = 1 - \frac{\omega_p^2}{\omega^2}$$



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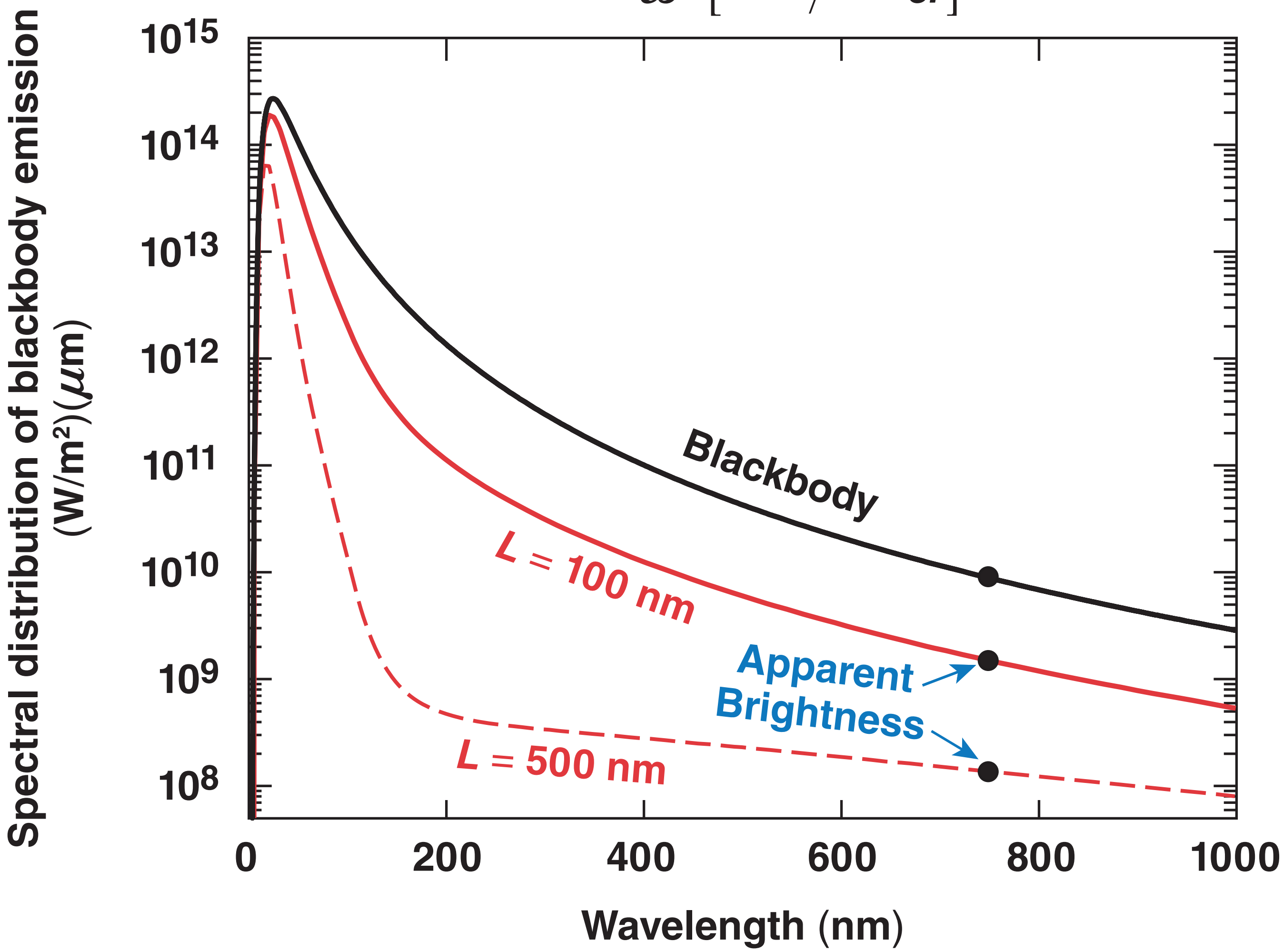
Inclusion of a collisional dispersion relation distributes the contribution of sources and attenuation

$$n^2 = 1 - \frac{\omega_p^2}{\omega^2}\left[\frac{1}{1 + i/\omega\tau_{ei}}\right]$$



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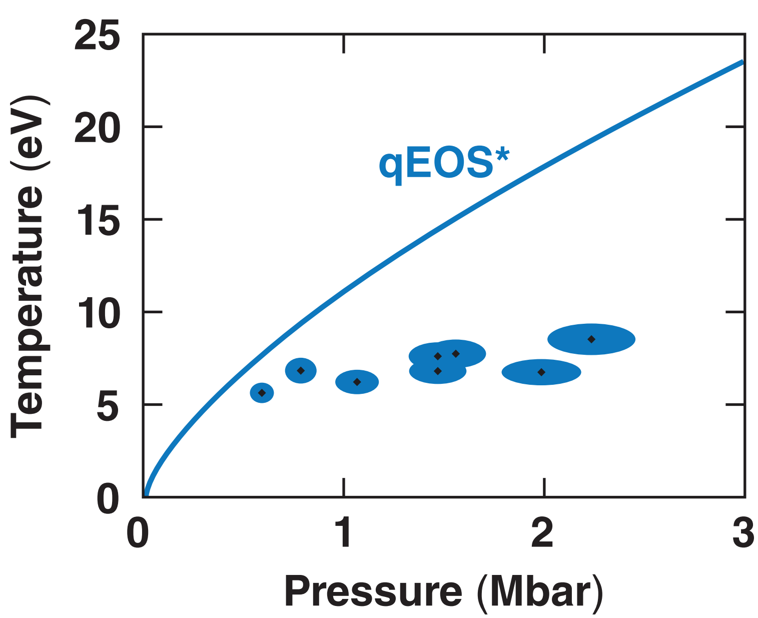
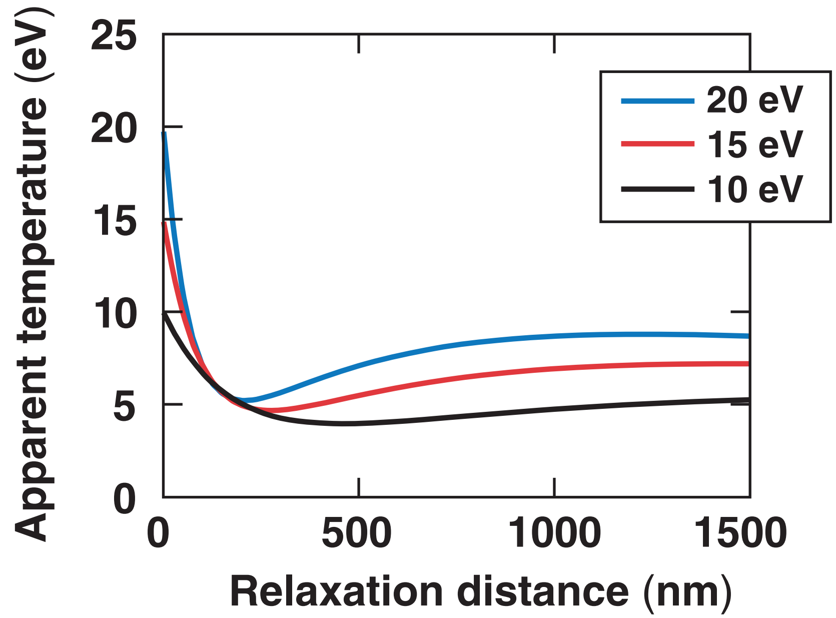
The model indicates that equilibration distances of 500 to 1000 nm explain the foam-temperature data





*qEOS courtesy D. Young, LLNL

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Summary/Conclusions

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