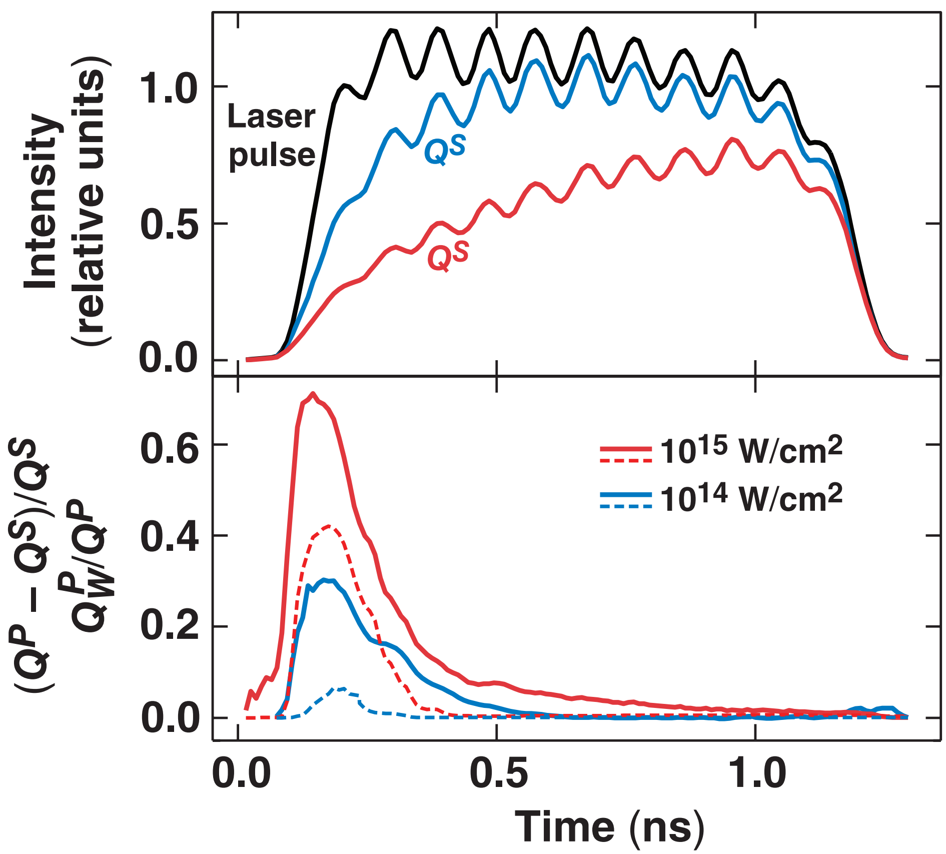
Effects of Resonant Absorption in Direct-Drive Target Designs on OMEGA



I. V. Igumenshchev
University of Rochester
Laboratory for Laser Energetics

48th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Philadelphia, PA
30 October–3 November 2006

Summary

Resonant absorption is important during the rapid increase of laser power in direct-drive target designs on OMEGA

UR LLE

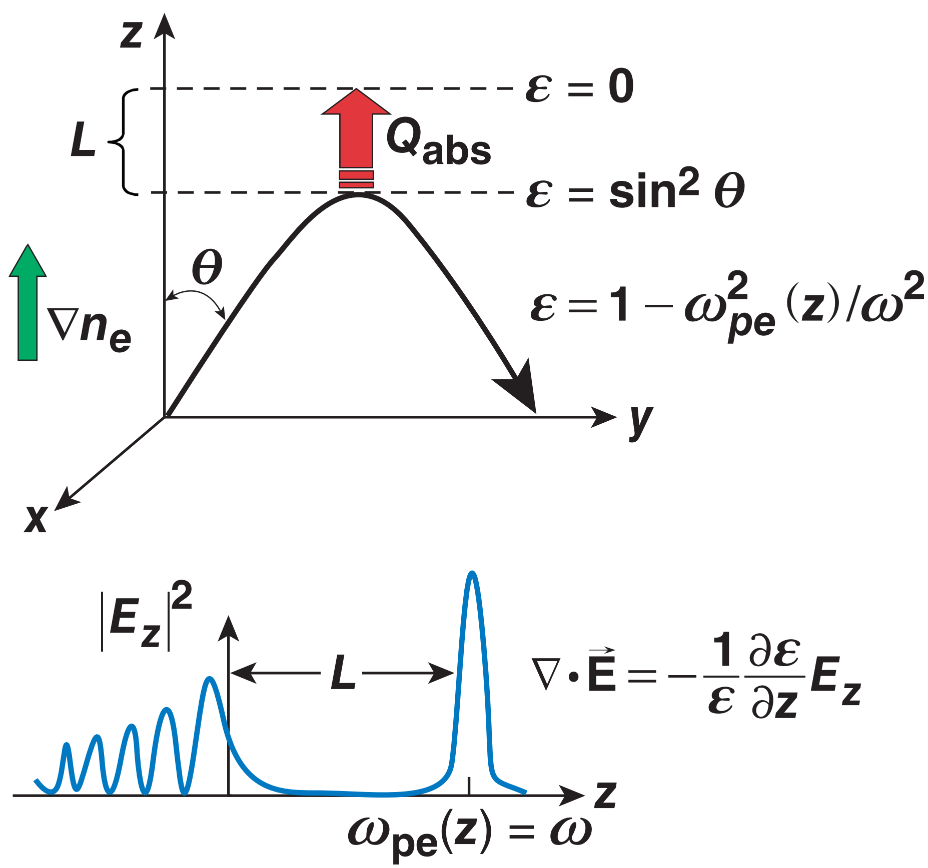
- Resonant absorption on OMEGA is determined by linear effects.
- Resonant absorption is important during laser pickets or at the beginning of long laser pulses, when the density length scale near the critical surface is relatively small, $L < 2\ \mu\mathrm{m}$.
- In spherical implosions, resonant absorption can enhance the earlier-time laser absorption up to 20%.
- Planar OMEGA experiments will validate theoretical predictions with the use of inclined *s*- and *p*-polarized laser beams.

Collaborators

V. N. Goncharov
W. Seka
D. H. Edgell
V. A. Smalyuk
T. R. Boehly
J. A. Delettrez

A simplified model of resonant absorption predicts a very large electric field at the resonance peak

An oblique ray incident onto a cold inhomogeneous plasma slab $z > 0$



- Ponderomotive force $\left[\sim (\nabla \vec{E})^2\right]$ can be important in the resonance region.
- Mechanisms limiting the field:
  - electron–ion collisions
  - thermal convection
  - nonlinear wave breaking

TC7513

The effect of Langmuir waves has been included in the calculation of laser absorption in the 1-D code *LILAC*

UR LLE

- **The linearized electron-momentum equation**

$$\frac{\partial \vec{u}_e}{\partial t} = -\frac{e}{m_e}\vec{E} - \nu \vec{u}_e - \boxed{\frac{1}{m_e n_e}\nabla P_e}$$

combined with Maxwell's equations,[1]

$$\left.\begin{aligned} &\Delta\vec{E} - \nabla(\nabla\cdot\vec{E}) + \frac{\omega^2}{c^2}\left(\vec{E} + i\frac{4\pi}{\omega}\vec{j}\right) = 0, \\ &\vec{j} = i\frac{\omega_{pe}^2\vec{E}}{4\pi(\omega + i\nu_{em})} - \boxed{i\frac{3v_{Te}^2\nabla(\nabla\cdot\vec{E})}{4\pi(\omega + i\nu_w)}}\,. \end{aligned}\right\} \text{1-D planar geometry}$$

- **Solutions for *s*- and *p*-polarized light are independent**
- **Laser absorption in *LILAC*: $Q = \vec{j}\cdot\vec{E}$.**

[1]Forslund *et al*., Phys. Rev. 11, 679 (1975).

Laser absorption can be split into two components

$$Q = \nu_{em} \frac{\omega_{pe}^2}{\omega^2 + \nu_{em}^2} \frac{E^2}{8\pi} + \nu_w \frac{3v_{Te}^2}{\omega^2 + \nu_w^2} \frac{(\nabla \cdot \vec{E})^2}{8\pi}$$

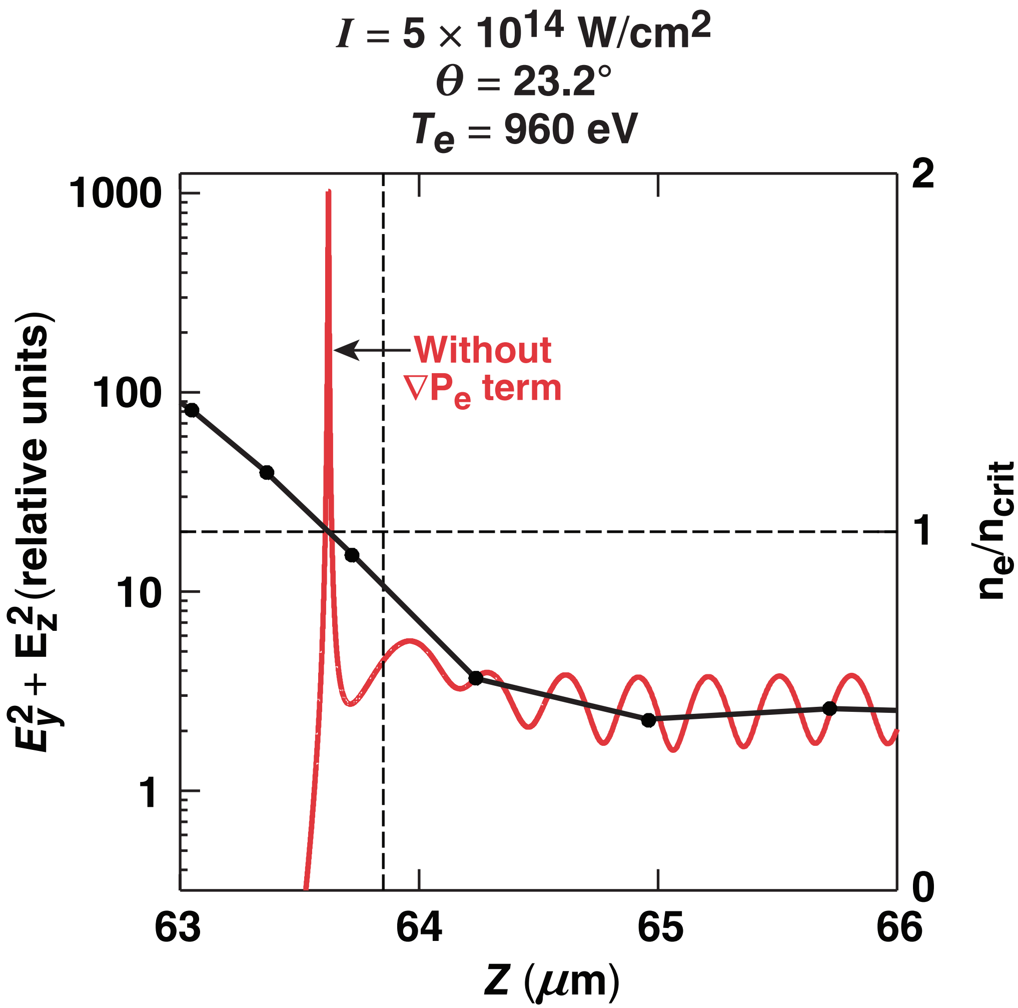
EM component **Wave component**

Thermal electrons **Hot electrons**

ν_{em} = (collisional damping)

ν_w = (collisional damping) + (Landau damping)

Generation of Langmuir waves is the dominant mechanism that limits the amplitude of resonant fields

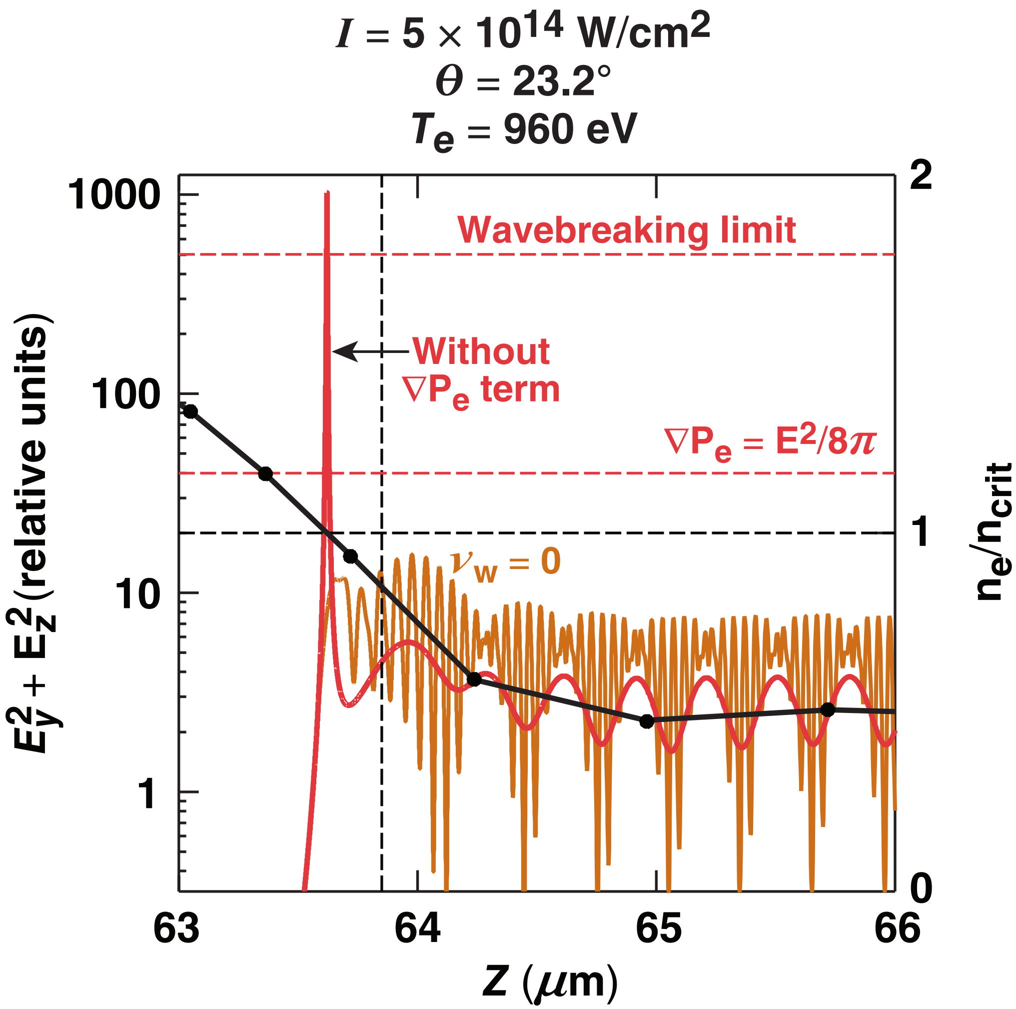


- Under typical conditions on OMEGA,
  $\lambda_{las}^2 I \approx (1 \text{ to } 10) \times 10^{13} \cdot \text{W/cm}^2$,
  $L \approx 1$ to 2 μm, $T_e \approx 0.5$ to 1 keV,
  $P_e >> E_{fs}^2/8\pi$, CH – targets;
  the convection of the Langmuir waves reduces the amplitude of the resonance field below the wave-breaking limit.
- Landau damping of Langmuir waves produces hot electrons with $T_h \approx 5$ to 10 keV.
- The ponderomotive force does not exceed the pressure-gradient force and has a small dynamic effect.

TC7516

Generation of Langmuir waves is the dominant mechanism that limits the amplitude of resonant fields

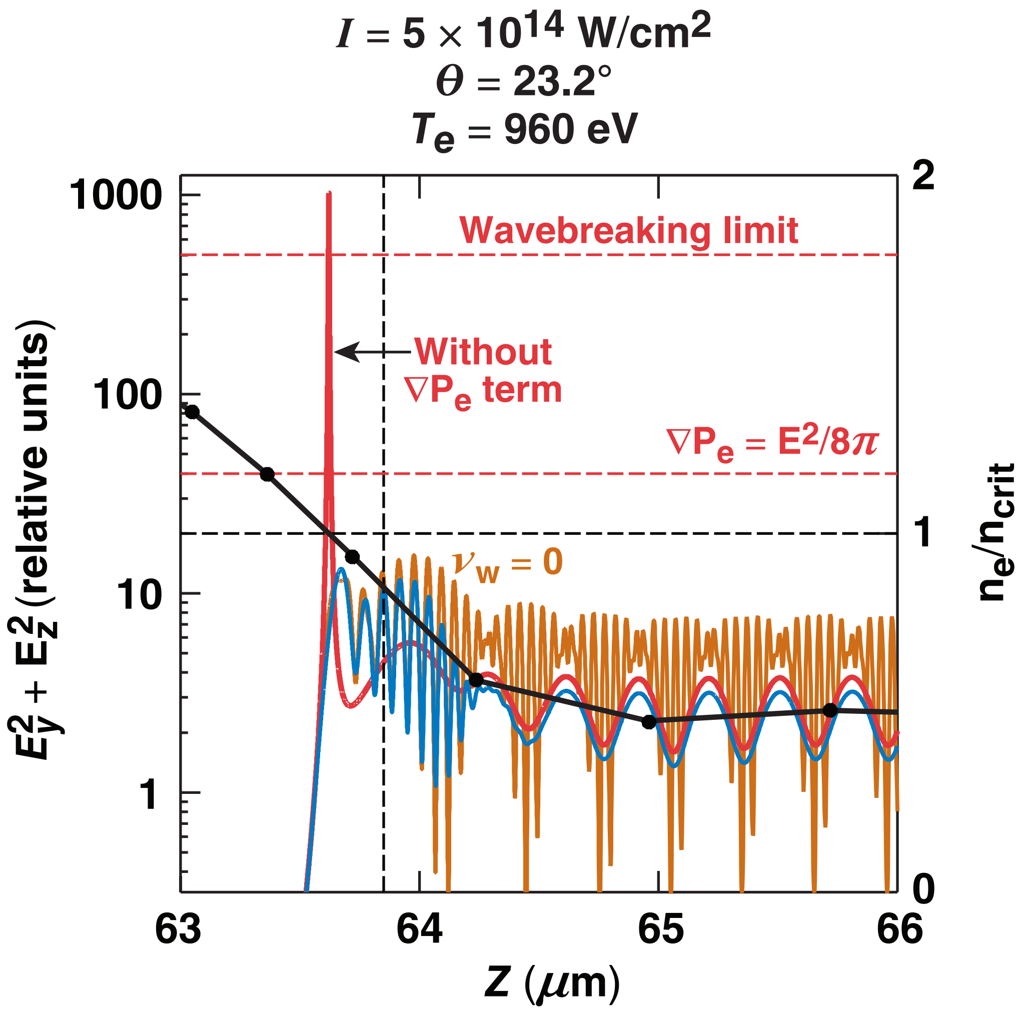
UR LLE



- Under typical conditions on OMEGA, $\lambda_{las}^2 I \approx (1 \text{ to } 10) \times 10^{13} \cdot \text{W/cm}^2$, $L \approx 1$ to $2\ \mu$m, $T_e \approx 0.5$ to 1 keV, $P_e >> E_{fs}^2/8\pi$, CH – targets; the convection of the Langmuir waves reduces the amplitude of the resonance field below the wave-breaking limit.
- Landau damping of Langmuir waves produces hot electrons with $T_h \approx 5$ to 10 keV.
- The ponderomotive force does not exceed the pressure-gradient force and has a small dynamic effect.

TC7516a

Generation of Langmuir waves is the dominant mechanism that limits the amplitude of resonant fields

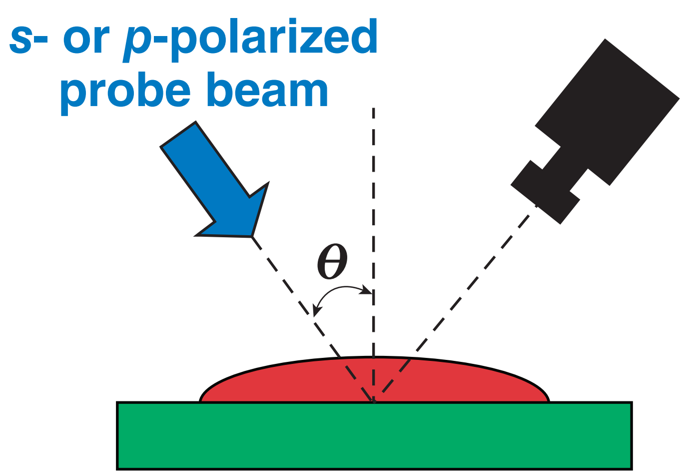


- Under typical conditions on OMEGA,
  $\lambda_{las}^2 I \approx (1 \text{ to } 10) \times 10^{13} \cdot \text{W/cm}^2$,
  $L \approx 1$ to $2\ \mu$m, $T_e \approx 0.5$ to 1 keV,
  $P_e >> E_{fs}^2/8\pi$, CH – targets;
  the convection of the Langmuir waves reduces the amplitude of the resonance field below the wave-breaking limit.
- Landau damping of Langmuir waves produces hot electrons with $T_h \approx 5$ to 10 keV.
- The ponderomotive force does not exceed the pressure-gradient force and has a small dynamic effect.

Reflected laser-light measurements in the planar OMEGA experiments will validate theoretical predictions

UR LLE

Measurement of reflection from a probe beam

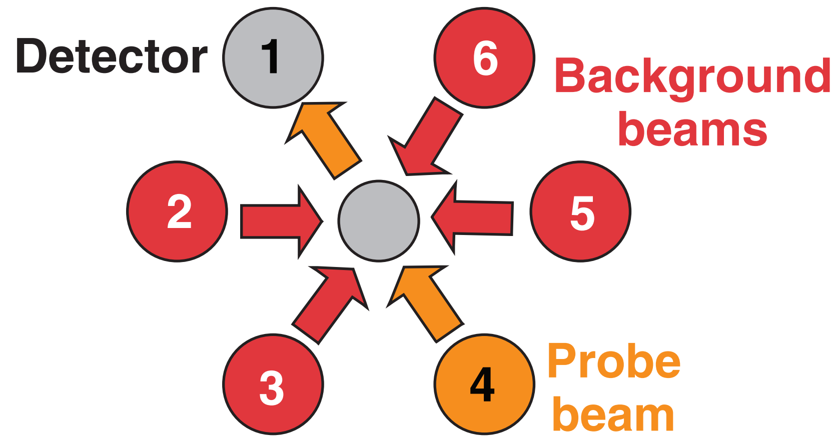


θ = 23°, 48°, and 62°

$I = 10^{14}$ to 10^{15} W/cm^2

Picket or square laser pulses

Several laser beams can be used simultaneously on OMEGA

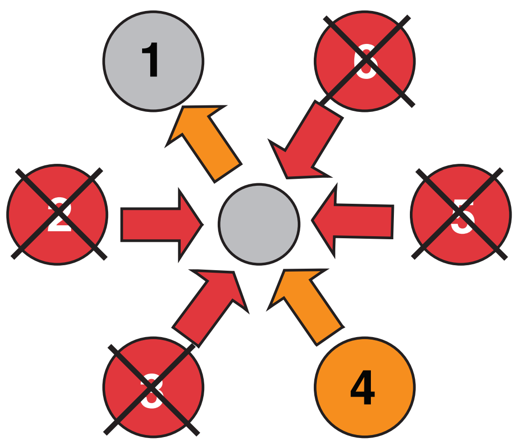


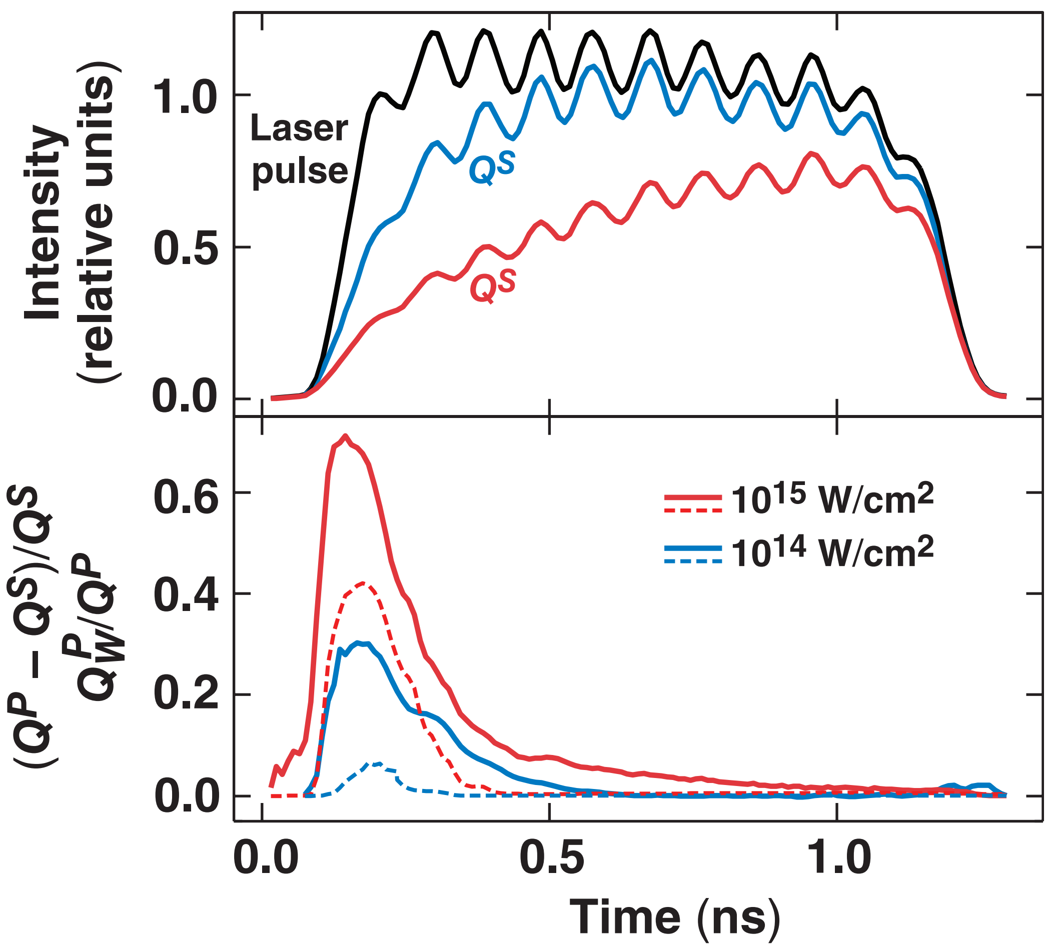
- Five laser beams at 23.2°.
- Background beams have a mixed *s* and *p* polarization.
- Diagnostics will also include shock breakout and x-ray measurements.

TC7517

Simulation of 23°, 1-ns laser beams predict different absorption of *s*- and *p*-polarized light

Simulations with a single 23° laser beam

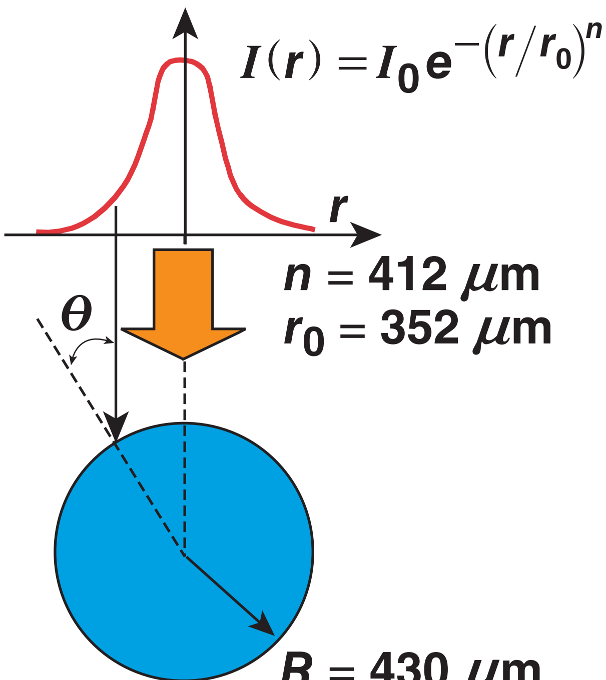




- The effect of resonant absorption is smaller for beams with larger incident angles.

Planar simulations with angle-dependent laser intensity estimate absorption in spherical implosions

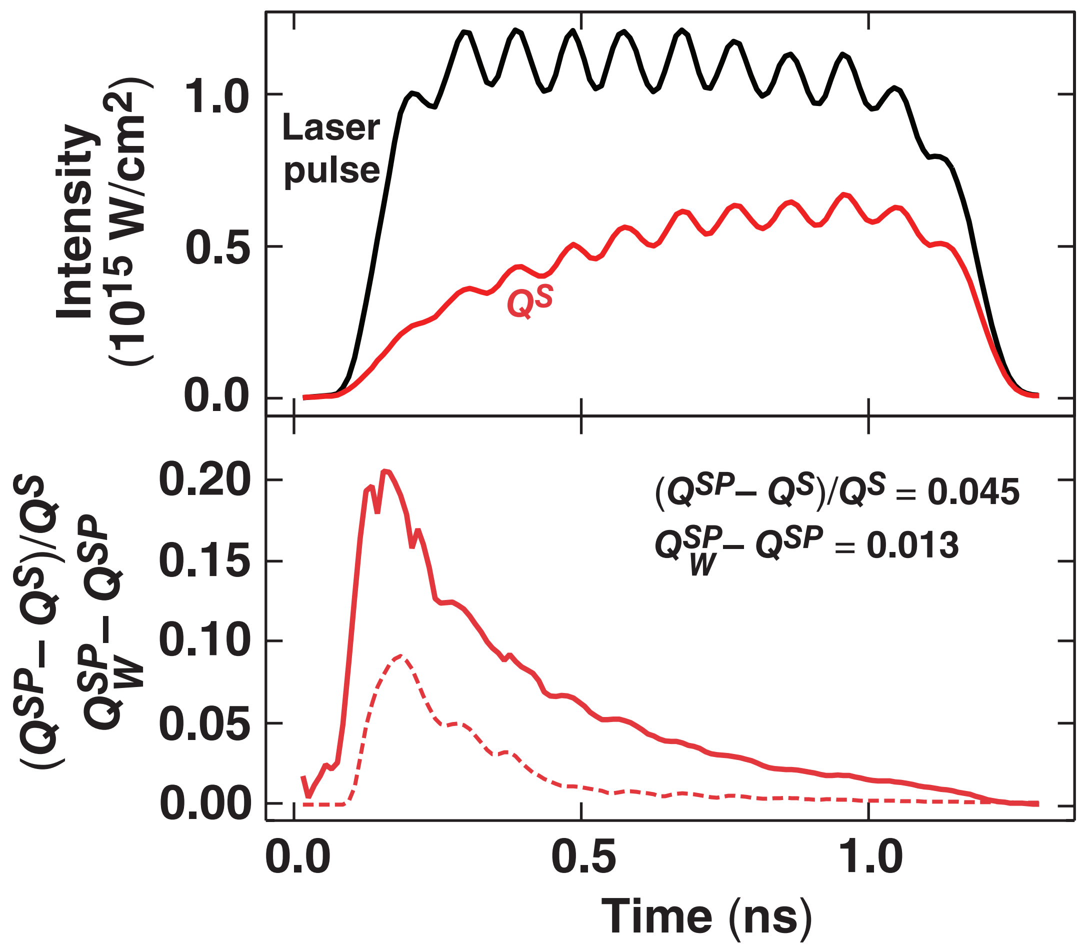
Illumination of a spherical target



$I(r) \Rightarrow I(\theta)$, $\theta = 0 \ldots \pi/2$

- Angle-dependent intensity in planar geometry

Simulated absorption for a 25-kJ implosion



TC7519

Seka *et al.*, ZO1.00002

Summary/Conclusions

Resonant absorption is important during the rapid increase of laser power in direct-drive target designs on OMEGA

UR LLE

- **Resonant absorption on OMEGA is determined by linear effects.**
- **Resonant absorption is important during laser pickets or at the beginning of long laser pulses, when the density length scale near the critical surface is relatively small, $L < 2\ \mu$m.**
- **In spherical implosions, resonant absorption can enhance the earlier-time laser absorption up to 20%.**
- **Planar OMEGA experiments will validate theoretical predictions with the use of inclined *s*- and *p*-polarized laser beams.**