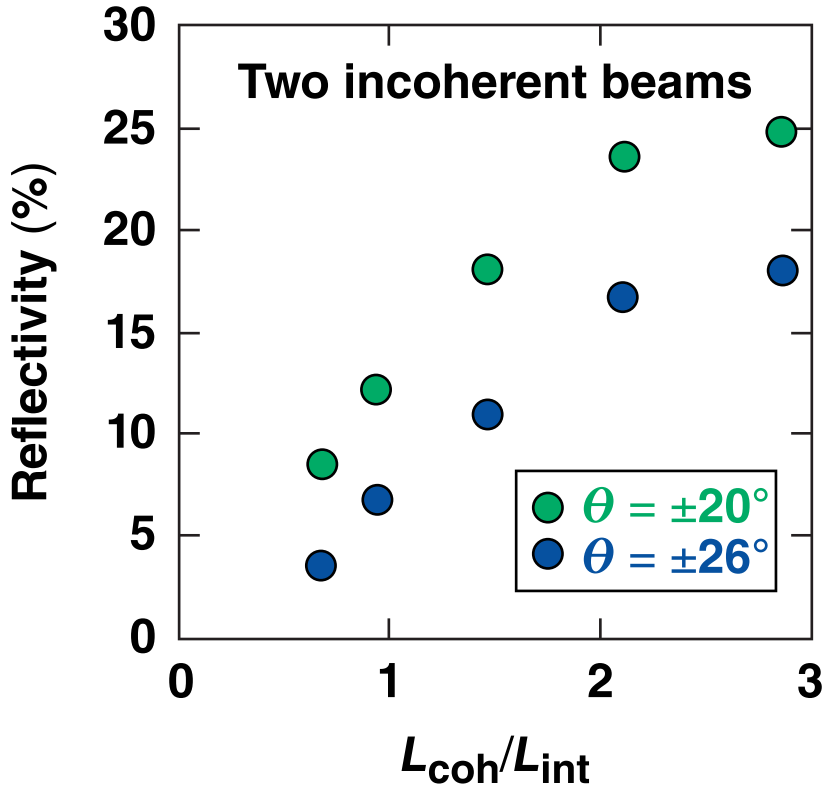
Laser–Plasma Interaction Model for Cross-Beam Energy Transfer



A. V. Maximov,
J. F. Myatt, R. W. Short,
I. V. Igumenshchev, and W. Seka
University of Rochester
Laboratory for Laser Energetics

55th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Denver, CO
11–15 November 2013

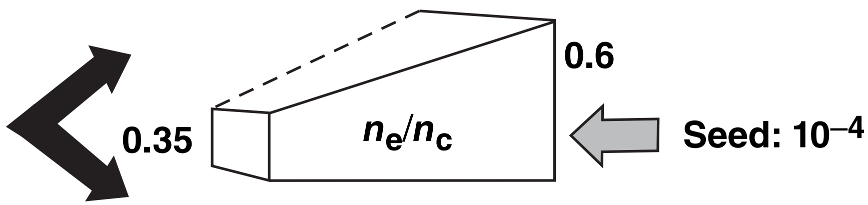
Summary

A model for the scattering of crossing incoherent laser beams in inertial confinement fusion (ICF) plasmas has been developed

- The reflectivity of light decreases with shorter laser-beam coherence lengths
- Crossing incoherent beams can drive common ion waves and scatter off them, increasing the reflectivity
- For irradiation by multiple incoherent beams, the scaling of reflectivity with overlapped intensity is in agreement with the simulation results

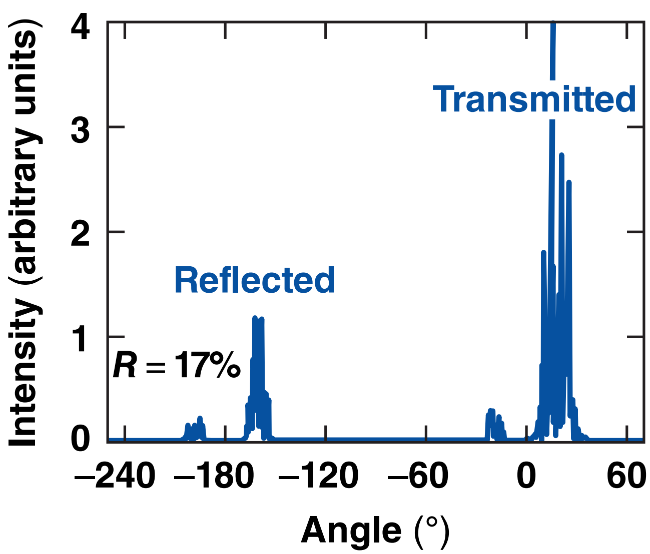
*J. F. Myatt, FR1.00001, this conference (invited review).

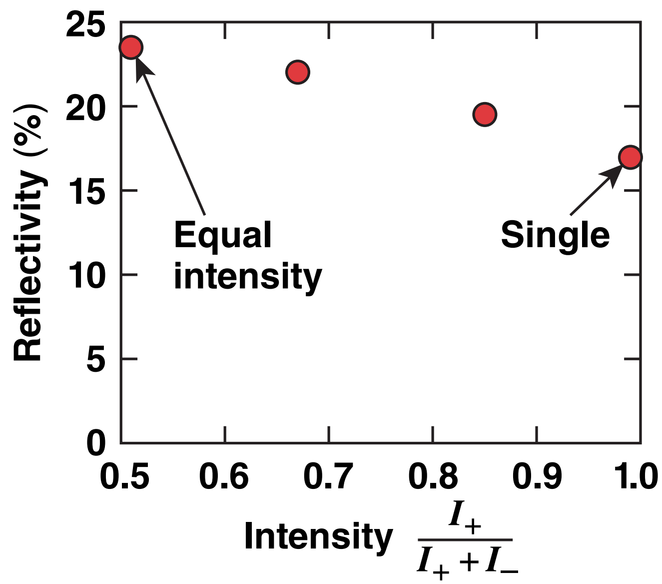
Two-dimensional nonparaxial simulations of nonlinear propagation of crossing incoherent laser beams have been performed



L_n = 140 μm,
T_e = 2 keV

Distributed phase plate (DPP) changes from *f*/7 to *f*/3.4





$\langle I \rangle_{14} = 7$ | $f = 6$

The intensities of the two driving beams differ by a factor of 10

The direction of scattered light is determined by the hot-spot structure of the incident light.

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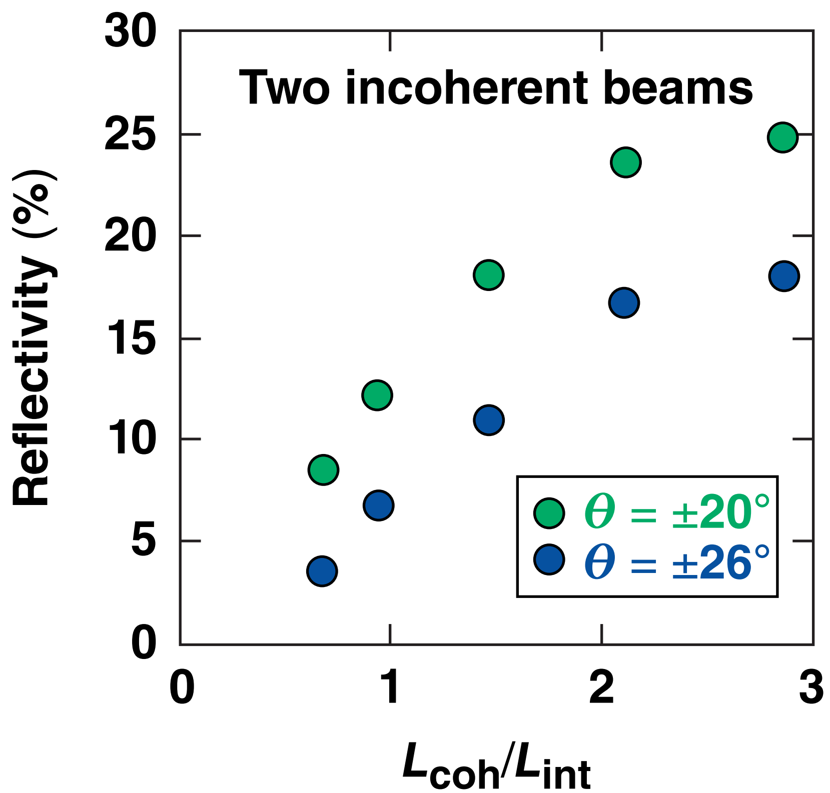
In simulations, the reflectivity is determined by the ratio of the coherence length to the interaction length

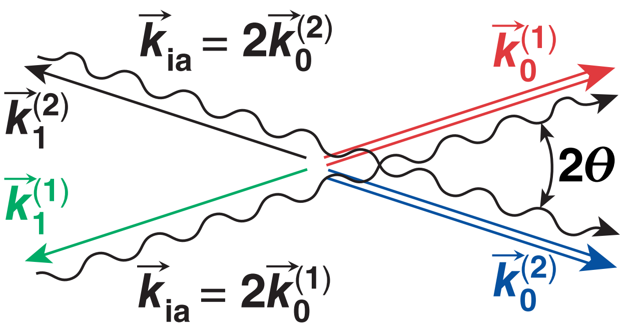
$\langle I \rangle_{14} = 7$



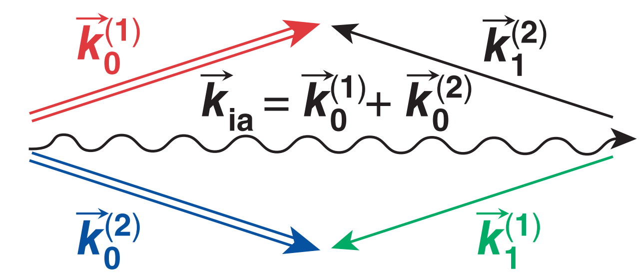
- **The coherence length $L_{coh} = 2\pi \cdot f^2 \lambda_0$ was changed by changing the *f* number of incident laser beams from *f* = 7 to *f* = 3.4**
- **The interaction length L_{int} (in the simulation region) was not changed**

The density spectra in simulations show different perturbations, including common ion waves

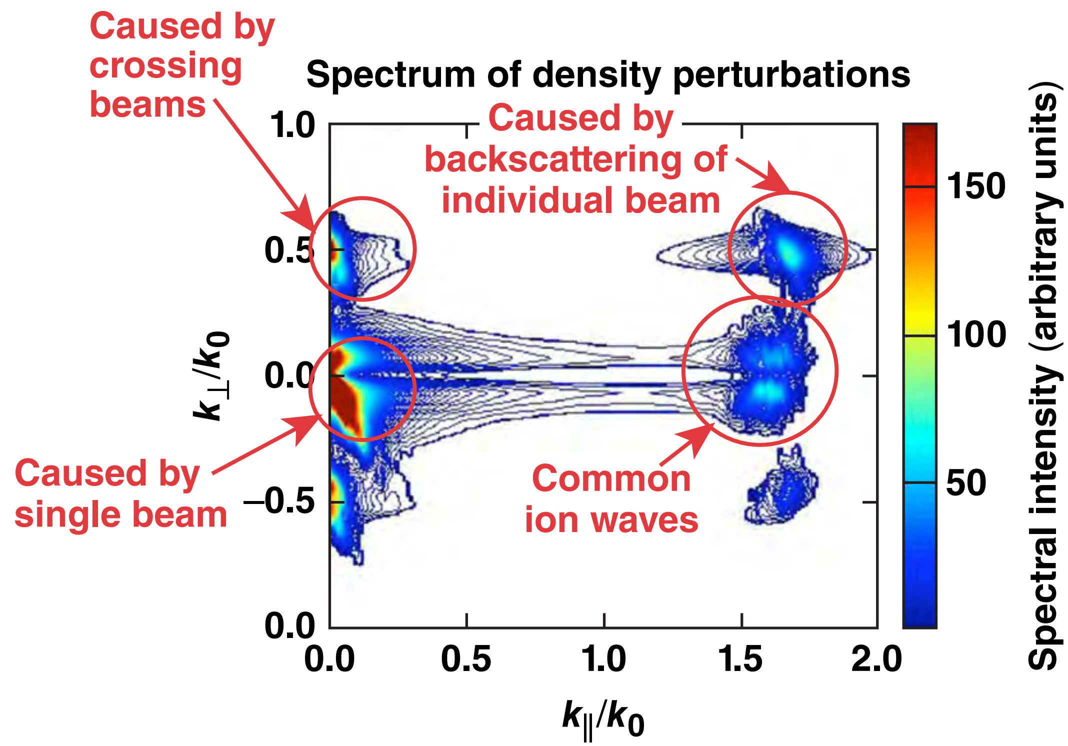
Backscattering of individual beams



Scattering of common ion waves



Spectrum of density perturbations



$\langle I \rangle_{14} = 8$ | $L_n = 140\ \mu m$ $T_e = 2$ keV | $f/6$

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The scattered-light gain can be significantly increased because of scattering off common ion waves

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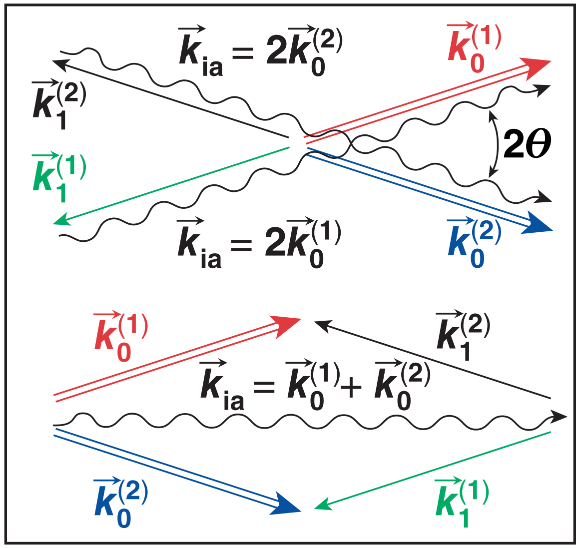
$$A_{1,2} = E_1^{(1,2)} E_0^{(1,2)} \qquad I^{(1,2)} = \left| E_0^{(1,2)} \right|^2$$



$$\frac{dA_1}{d\ell_1} = g\left[\vec{k}_0^{(1)} + \vec{k}_0^{(2)}\right] \cdot \left\{ I^{(2)} A_1 + I^{(1)} A_2 \right\} + g\left[2\vec{k}_0^{(1)}\right] \cdot I^{(1)} A_1$$

$$\frac{dA_2}{d\ell_2} = g\left[\vec{k}_0^{(1)} + \vec{k}_0^{(2)}\right] \cdot \left\{ I^{(1)} A_2 + I^{(2)} A_1 \right\} + g\left[2\vec{k}_0^{(2)}\right] \cdot I^{(2)} A_2,$$

where $g\left[\vec{k}_{ia}\right] = \dfrac{\omega_0^2}{16\pi n_c^2 T_e c^2} \times \dfrac{n_e k_{ia}^2 c_{ia}^2}{2\nu_i \omega_{ia} + i\left[\left(\omega_{ia} - \vec{k}_{ia}\vec{v}_0\right)^2 - k_{ia}^2 c_{ia}^2\right]} \times \dfrac{1}{2k_{0x}}$

The difference in the resonance width is $\sim(\sin\theta)^2$

- If $g\left[\vec{k}_0^{(1)} + \vec{k}_0^{(2)}\right] \approx g\left[2\vec{k}_0^{(1)}\right] \approx g\left[2\vec{k}_0^{(2)}\right] = \bar{g}$

  equations are equivalent to a single equation with an incoherent pump

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For the interaction of two incoherent beams, the scaling of reflectivity with intensity has been obtained

From an equation with incoherent pump*

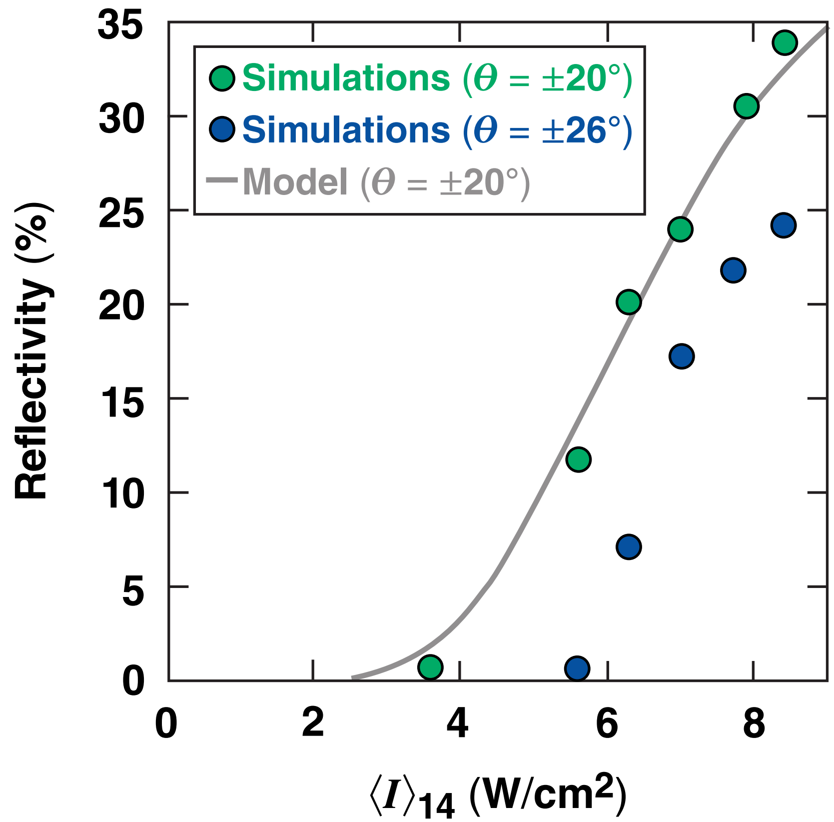
$$R_{\text{speckle}} = \varepsilon \cdot \exp(G_{\text{SBS}}),$$

where ε is a seed

$$G_{\text{SBS}} = 0.24 \langle I \rangle_{14} \cdot U_m,$$

$$U_m \equiv \frac{I_{\max}}{\langle I \rangle}$$

leads to reflectivity $\frac{d\langle R \rangle}{dx} \sim U_m^3 e^{-U_m}$



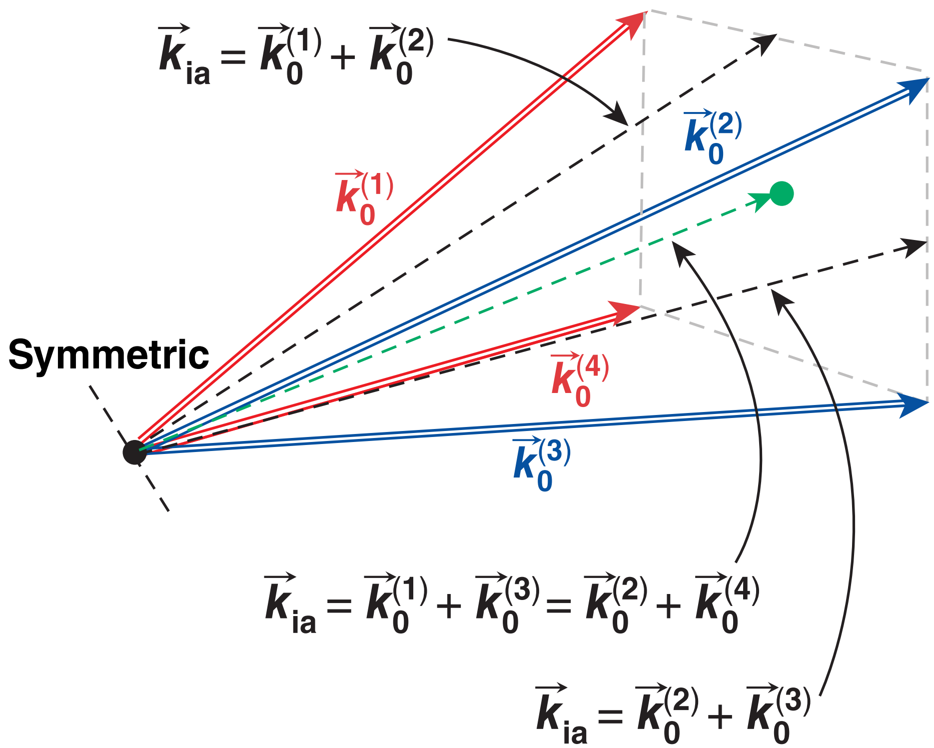
Coupling via common grating is weaker for larger θ

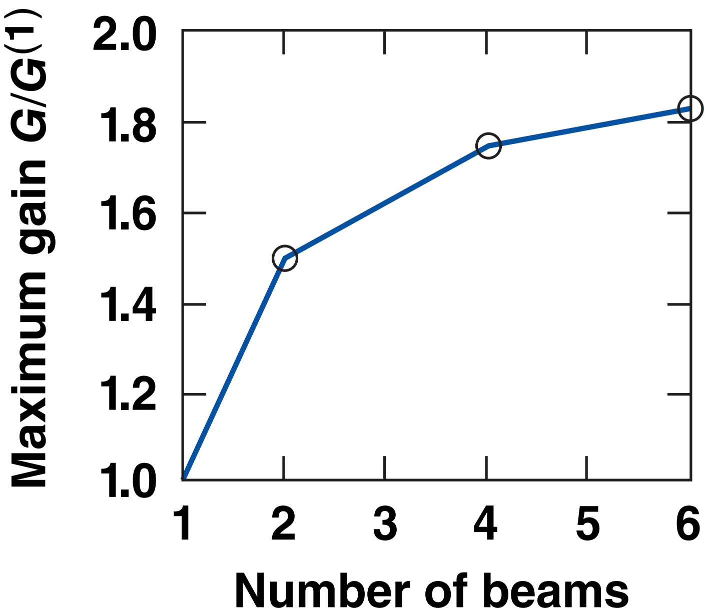
TC9446d

*H. A. Rose and D. F. DuBois, Phys. Rev. Lett. 72, 2883 (1994).

In 3-D, multiple common ion gratings can be close to resonance and contribute to the increase of reflectivity

- In 2-D the maximum gain $G \sim \bar{g}\left[I^{(1)} + I^{(2)} + \sqrt{I^{(1)}I^{(2)}}\right]$ for a constant overlapped intensity of two laser beams $\langle I \rangle$; the gain can reach maximum when the beam intensities are equal: $G \sim \bar{g} \cdot \langle I \rangle \cdot \frac{3}{2}$





- Angles between common ion gratings $\leq \theta$
- Multiple gratings close to resonance at the same time

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Summary/Conclusions

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