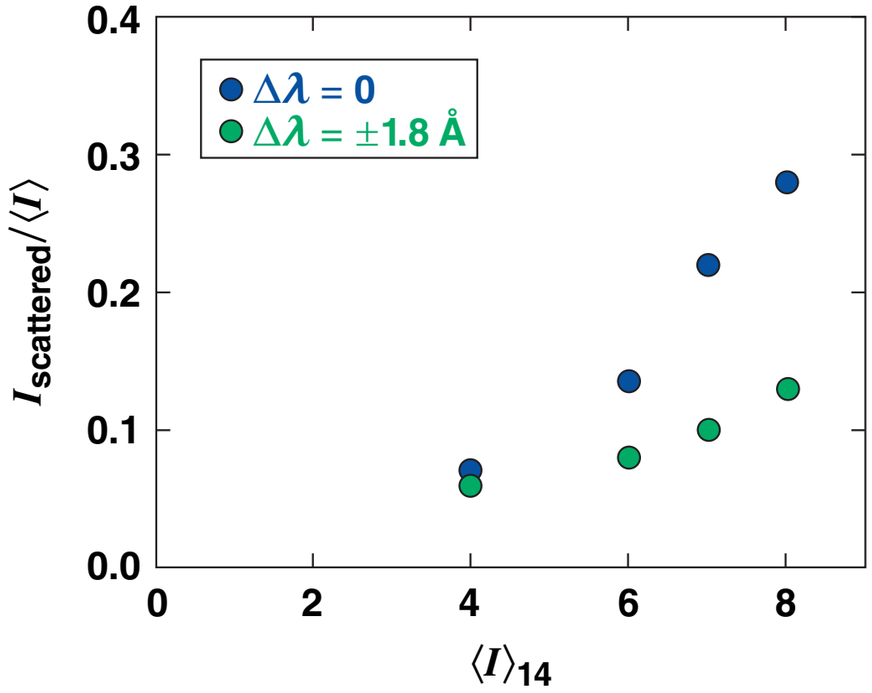
Effects of Beam Incoherence and Colors on Cross-Beam Energy Transfer



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Summary

In direct-drive inertial confinement fusion (ICF) plasmas, the use of colors in incoherent laser beams can mitigate the cross-beam energy transfer (CBET)

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- In dense plasmas (including beam-turning points) CBET is strongly influenced by common ion-wave gratings
- The use of frequency detuning (colors) in laser beams
  - reduces the role of common ion waves
  - increases the frequency broadening of scattered light
- Both of these effects can limit CBET

Outline

- CBET model in dense plasmas (including the turning points of laser beams)
- CBET driven by multiple incoherent laser beams generating common ion gratings
- Influence of beam frequency detuning (colors) on CBET
- CBET between beams with a large intensity contrast

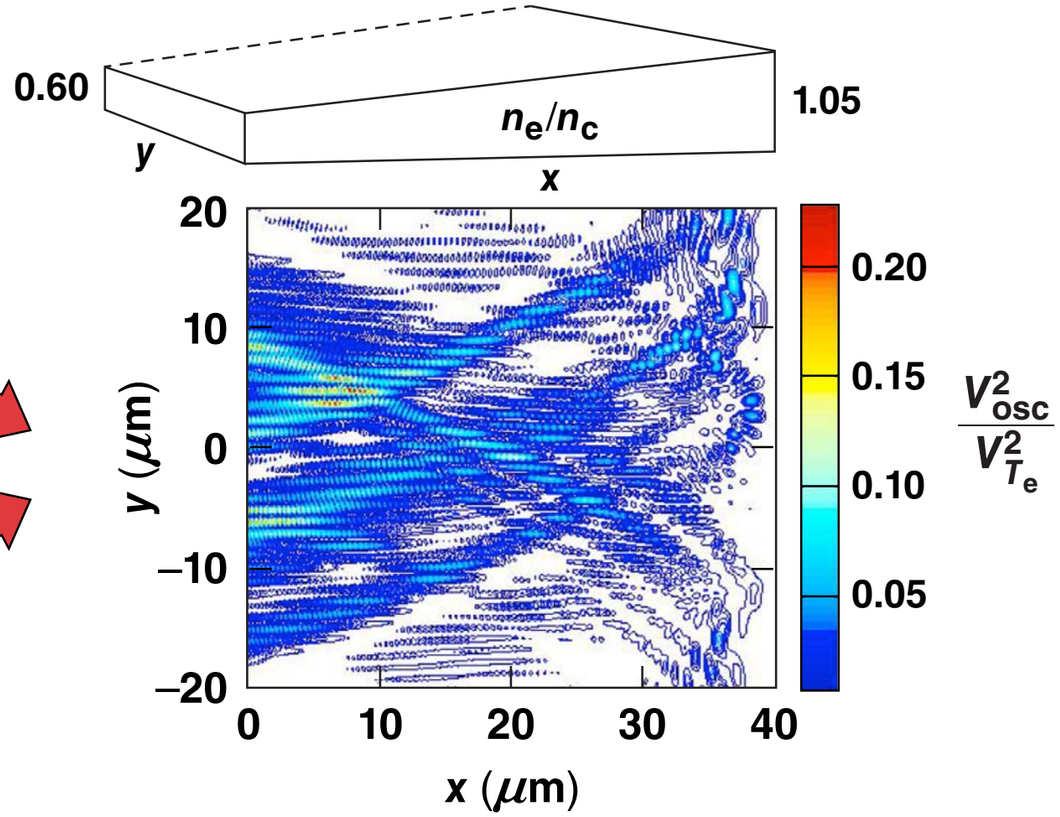
Nonlinear propagation of laser beams with frequency detuning is modeled in dense plasmas

- Beams with wavelength detuning are used to limit beam-to-beam coupling
  - two-dimensional non-paraxial model near turning points
  - related to parameters from simulations of OMEGA experiments (flow velocity $\ll C_s$)

$T_e = 2$ keV
$\Delta\lambda_0 = 0, \pm 1.8$ Å

$\theta = \pm 15°$
$f/6$

$\langle I_{14} \rangle = 8$



TC12176

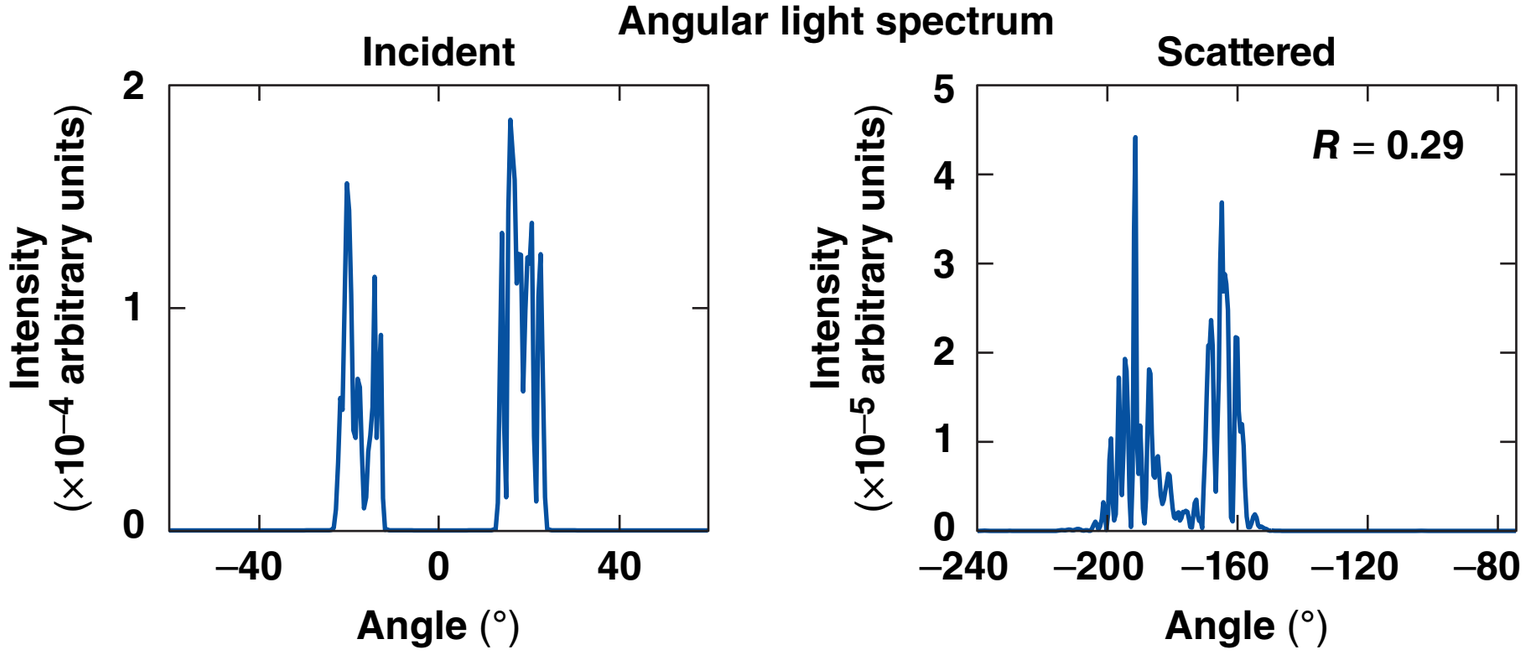
The laser–plasma interaction model includes backward and forward stimulated Brillouin scattering (SBS), beam self-focusing, field swelling, and absorption

- Beam-to-beam coupling can be described by backward SBS gains

$$\frac{dG_{SBS}}{d\ell} = \frac{\omega_0^2}{2c^2 n_c}\,\mathrm{Re}\left\{\frac{n_e k_s^2 c_s^2 \times I_0}{2\nu_i \omega_s + i\left[(\omega_s + k_s v_0)^2 - k_s^2 c_s^2\right]} \times \frac{1}{2k_{0x}}\right\},$$

$$I_0 = |E|^2 / 4\pi n_c T_e$$

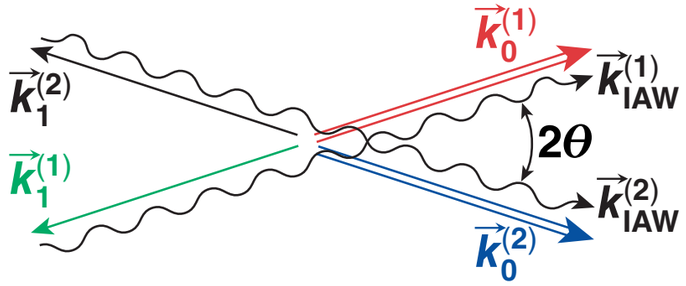
$\langle I_{14} \rangle = 8$

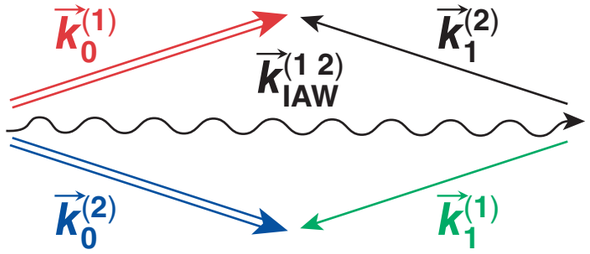


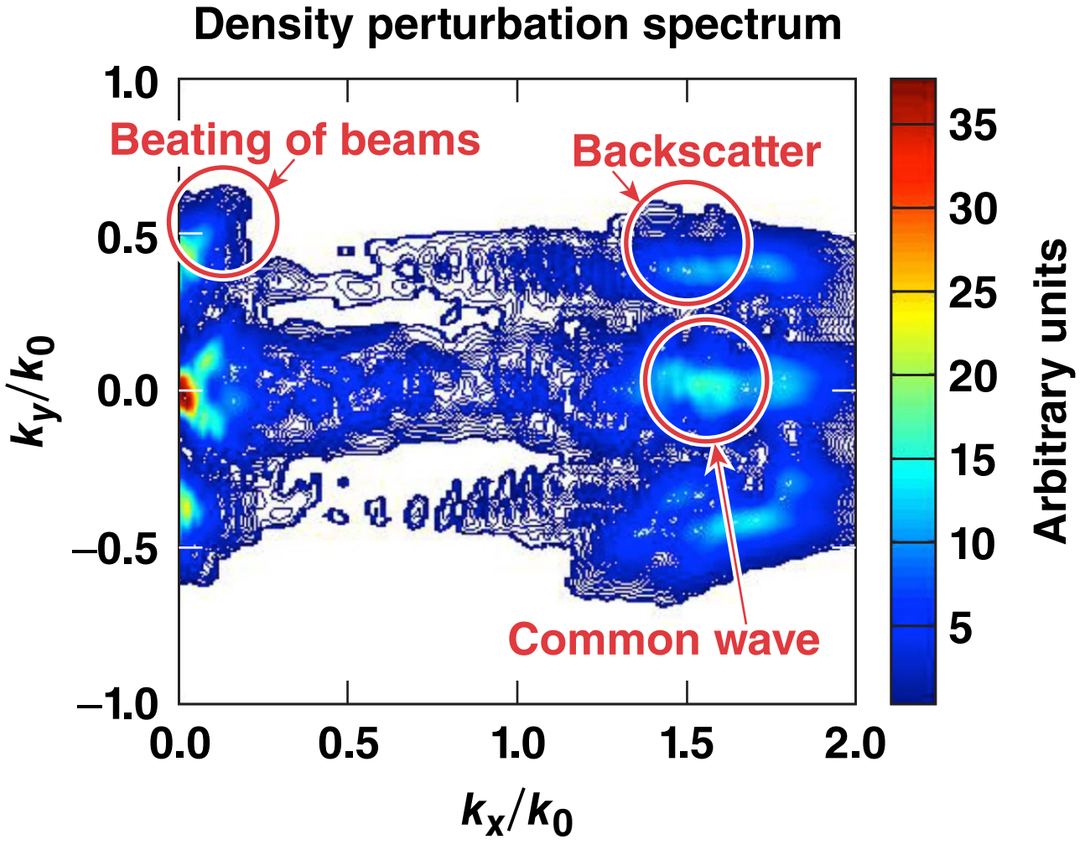
The angular width of scattered light is increased

TC12177

Crossing laser beams can backscatter off common ion waves







$$k_0 = \frac{\omega_0}{c}\sqrt{1-\frac{n_B}{n_c}}$$

$$\langle I_{14} \rangle = 8$$

TC12178

IAW: ion-acoustic wave

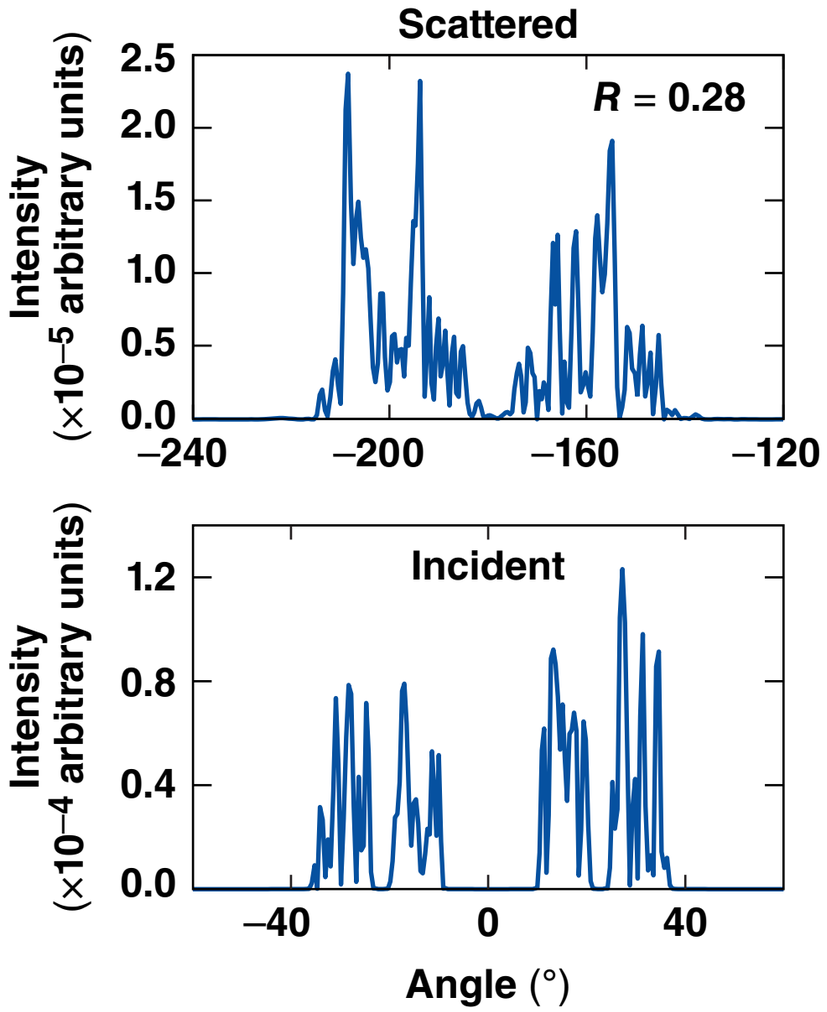
Crossing multiple laser beams in dense plasmas generates multiple common ion waves

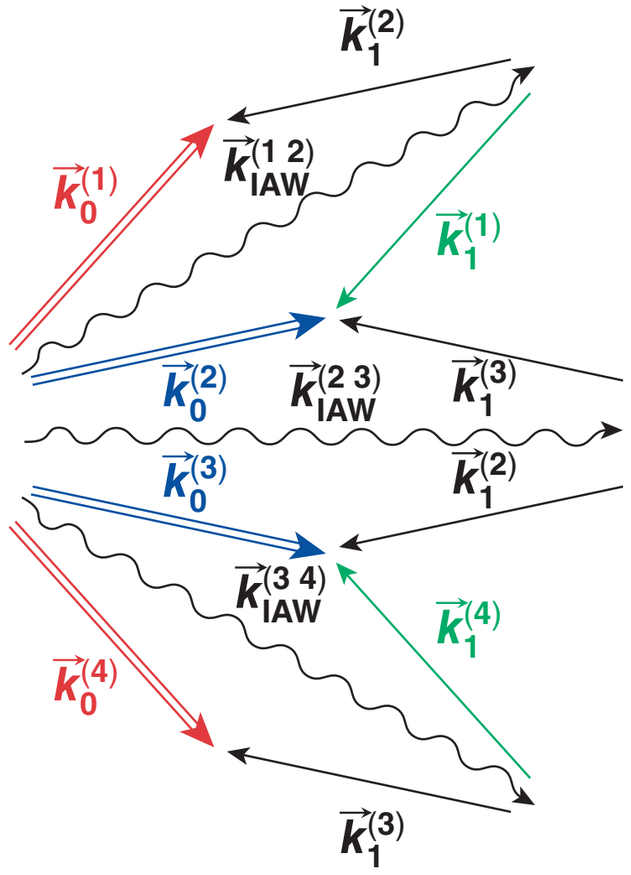
The angular width of scattered light is increased

$\langle I_{14} \rangle = 8$

$\theta = \pm 15°, \pm 30°$

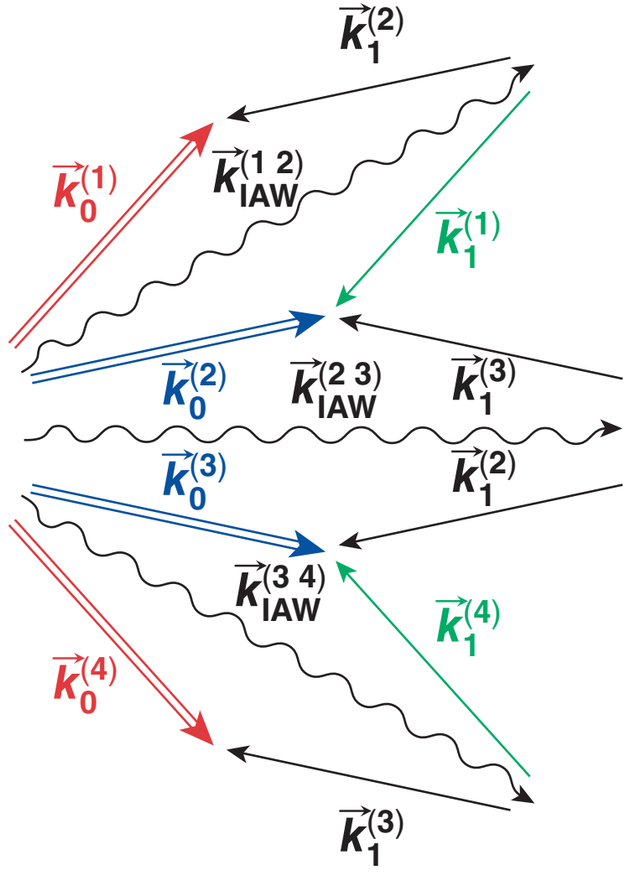
$\Delta\lambda = 0$

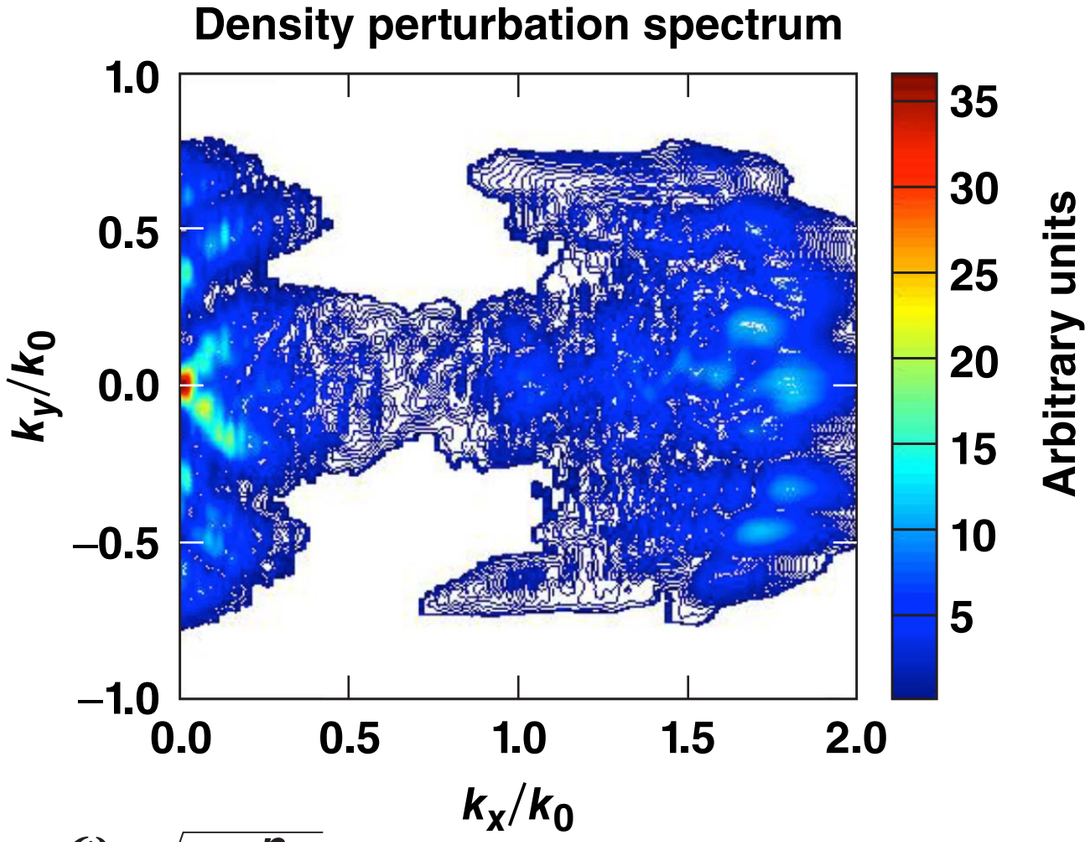




TC12179

Irradiation by multiple beams leads to broad spectra of density perturbations



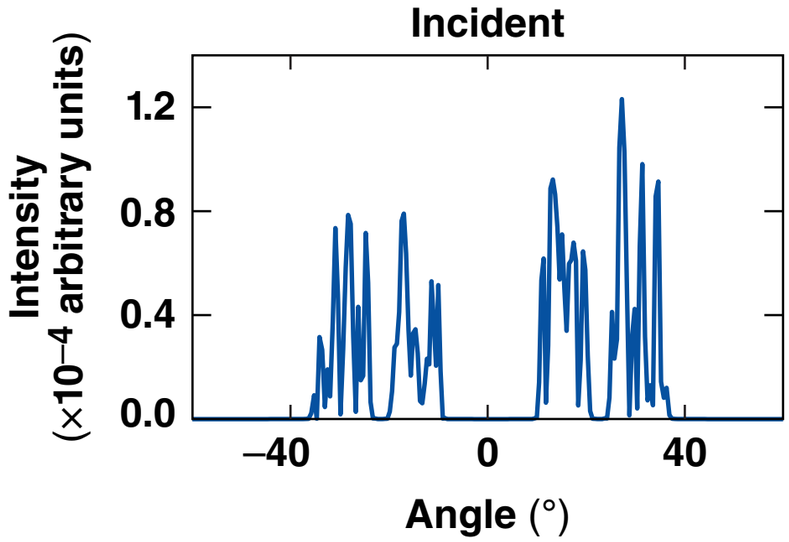


$$k_0 = \frac{\omega_0}{c}\sqrt{1-\frac{n_B}{n_c}}$$

$$\langle I_{14} \rangle = 8$$

TC12180

CBET is significantly reduced when frequency detuning (colors) is applied to crossing laser beams

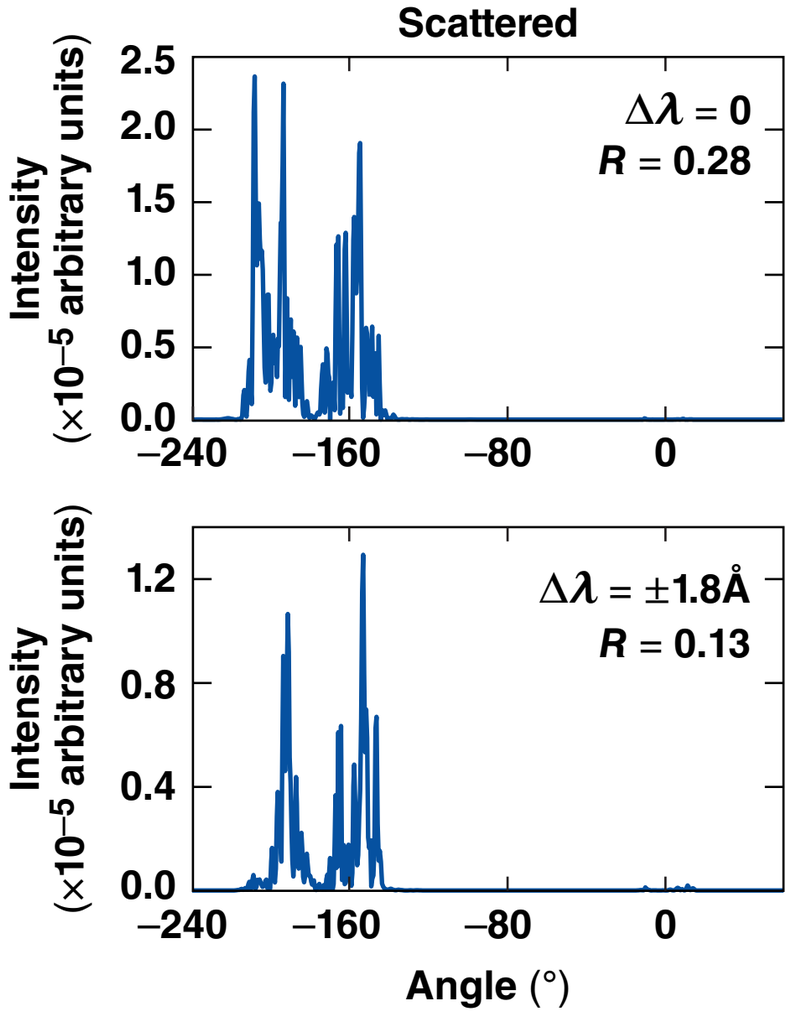


Four laser beams

$\theta = \pm 15°, \pm 30°$

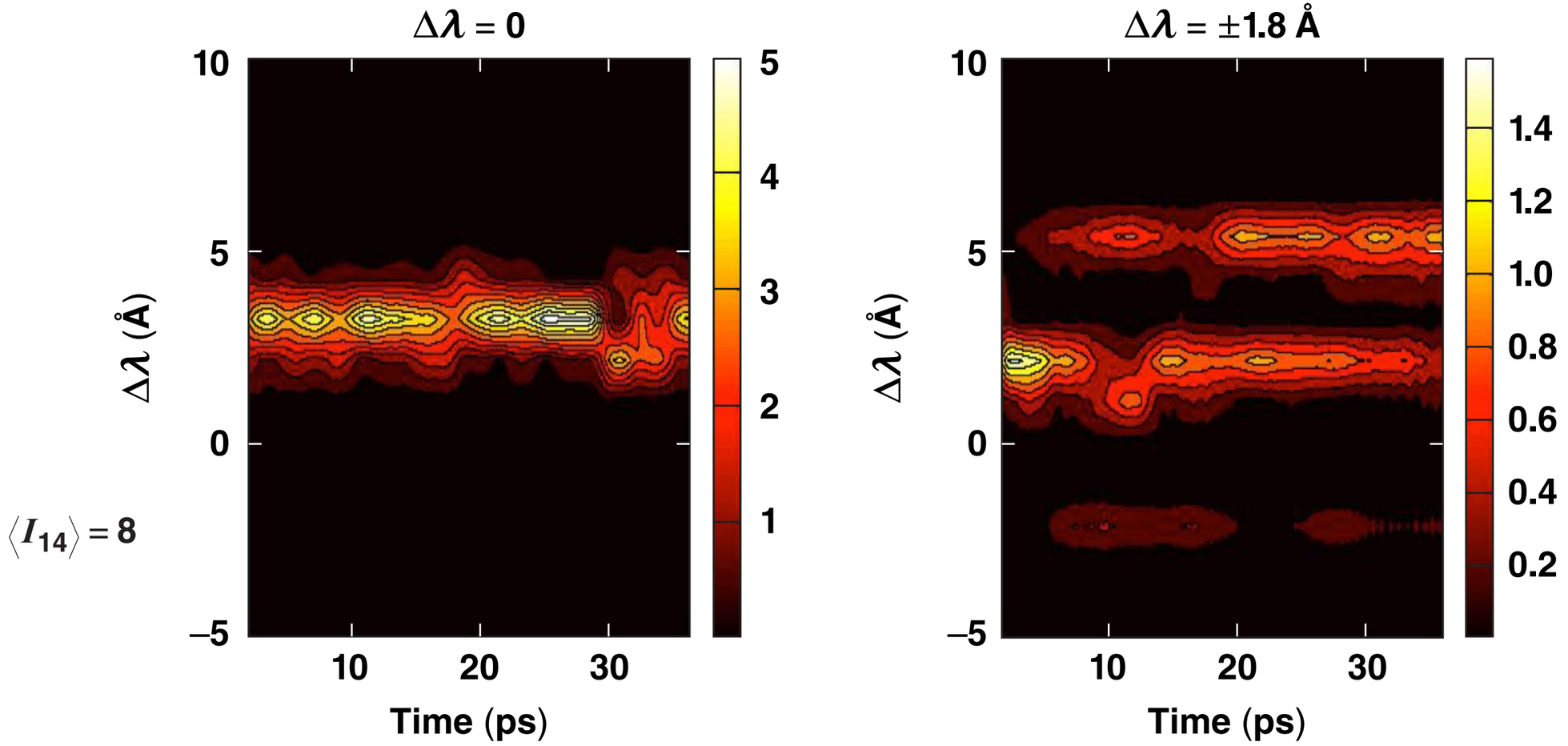
$\langle I_{14} \rangle = 8$

$I_{\text{outer}} / I_{\text{inner}} = 1$



TC12181

The frequency spectra of scattered light from multiple crossing beams are strongly modified by the beam frequency detuning



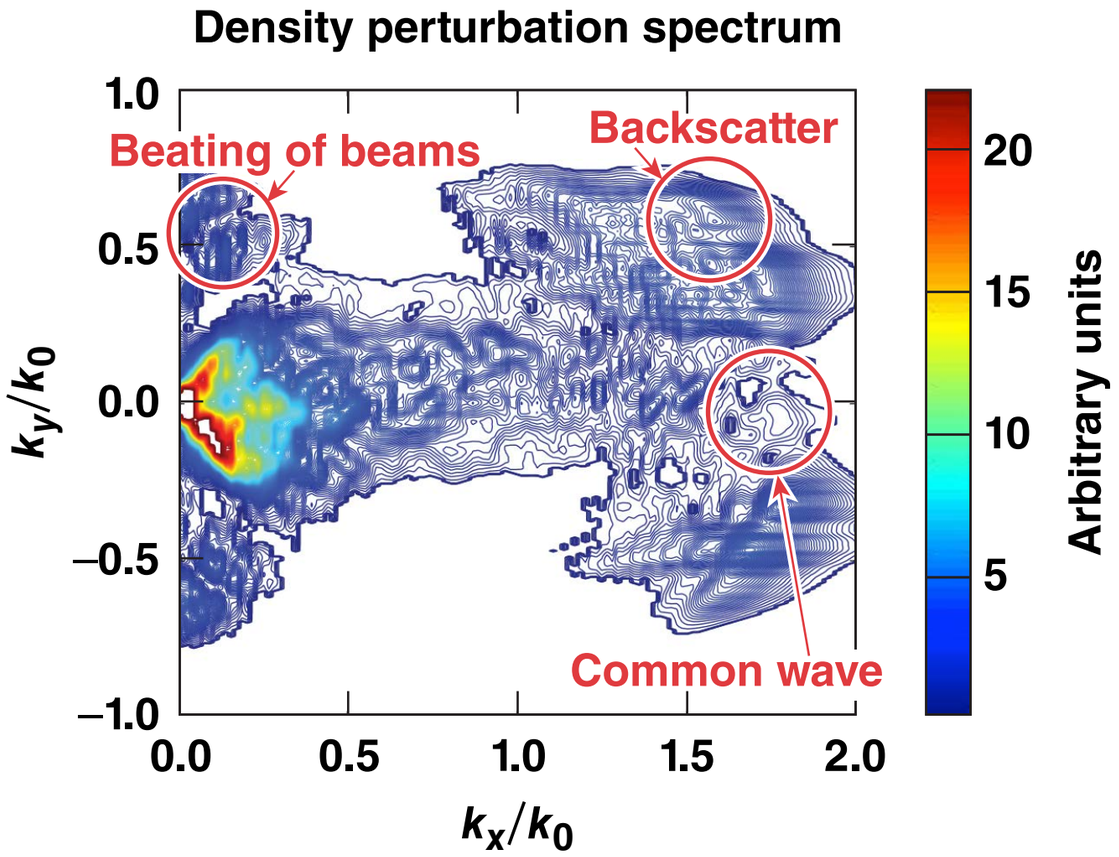
TC12182

The influence of frequency detuning (colors) on CBET in crossing laser beams includes the reduction of common ion waves

Four beams

$\langle I_{14} \rangle = 8$

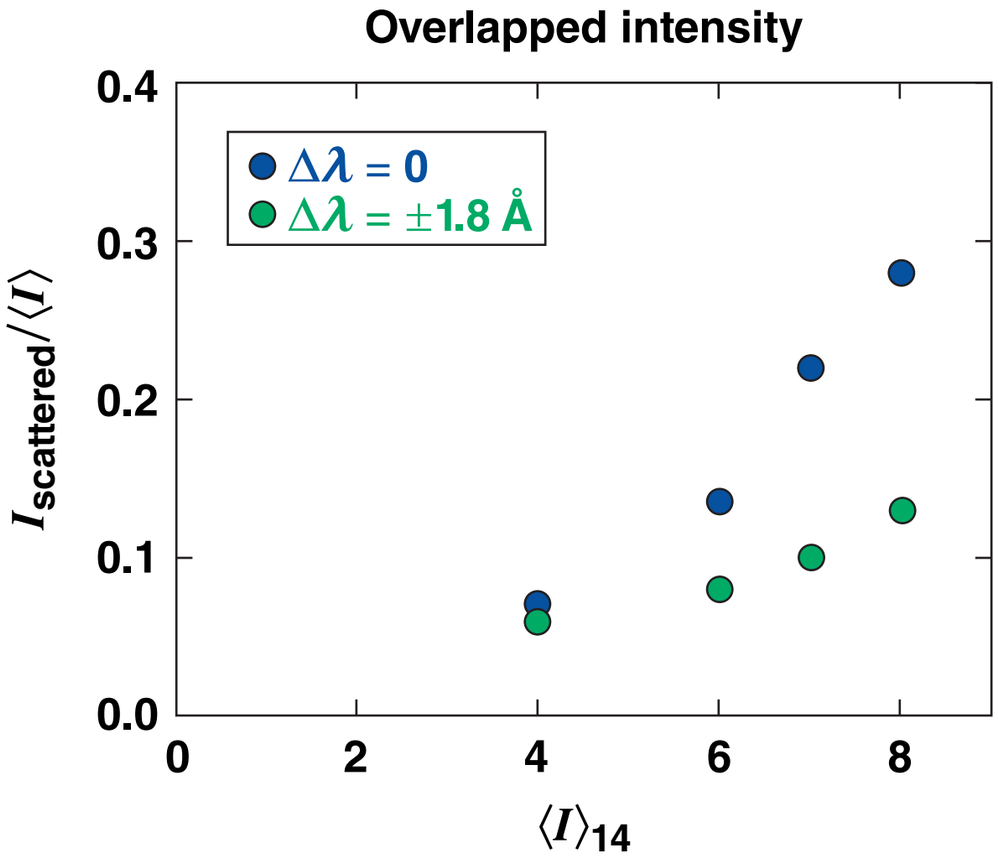
$\Delta\lambda = \pm 1.8$ Å



$$k_0 = \frac{\omega_0}{c}\sqrt{1-\frac{n_B}{n_c}}$$

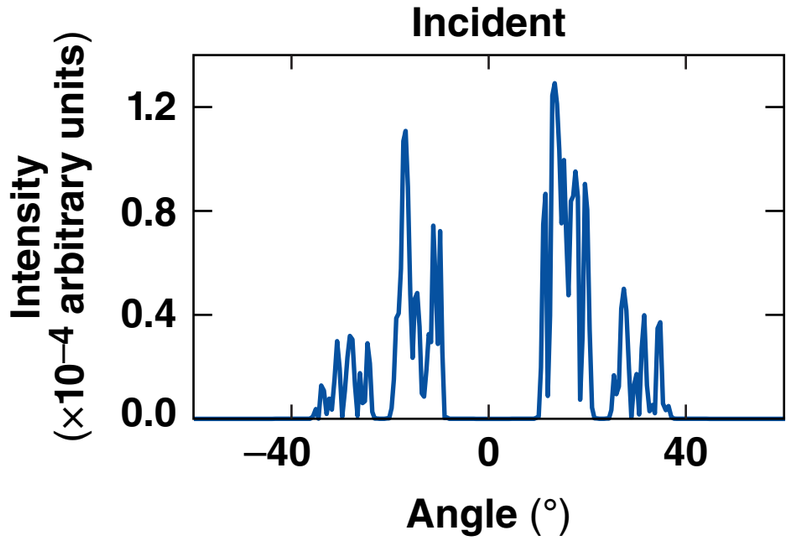
TC12185

Wavelength detuning in incoherent laser beams significantly reduces the intensity of backscattered light



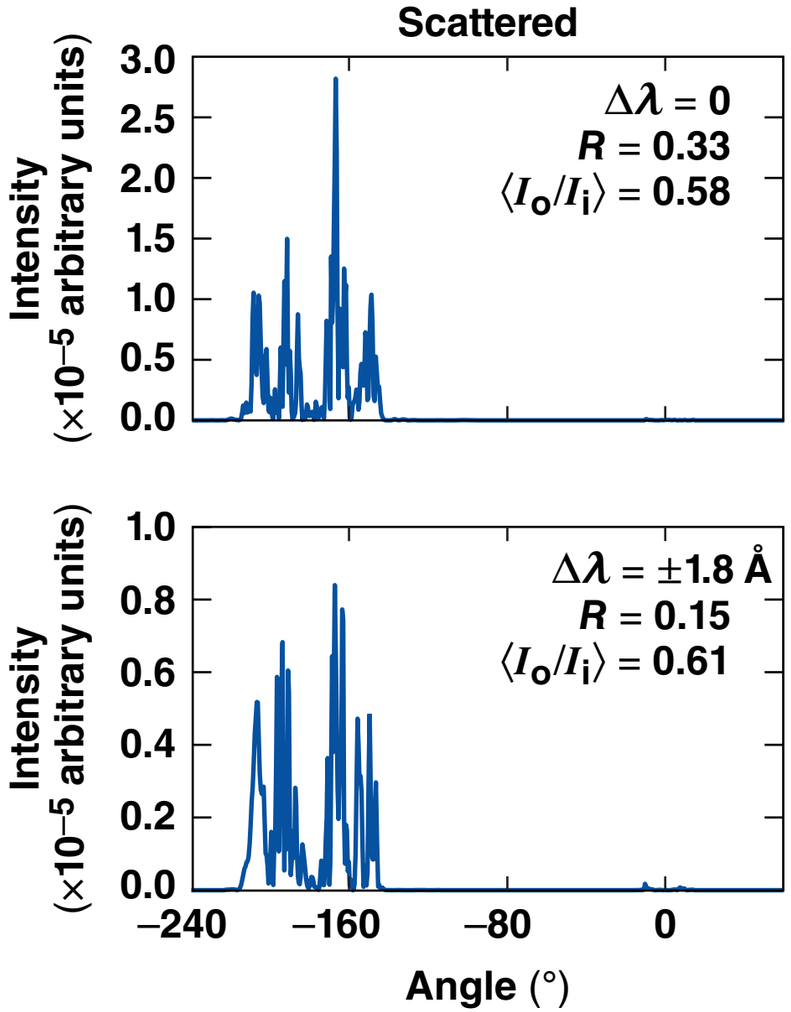
TC12183

CBET driven by incoherent laser beams with a large intensity contrast can increase the backscatter of weaker beams



$\langle I_{14} \rangle = 8$

$I_{outer}/I_{inner} = 0.25$



TC12184

Summary/Conclusions

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