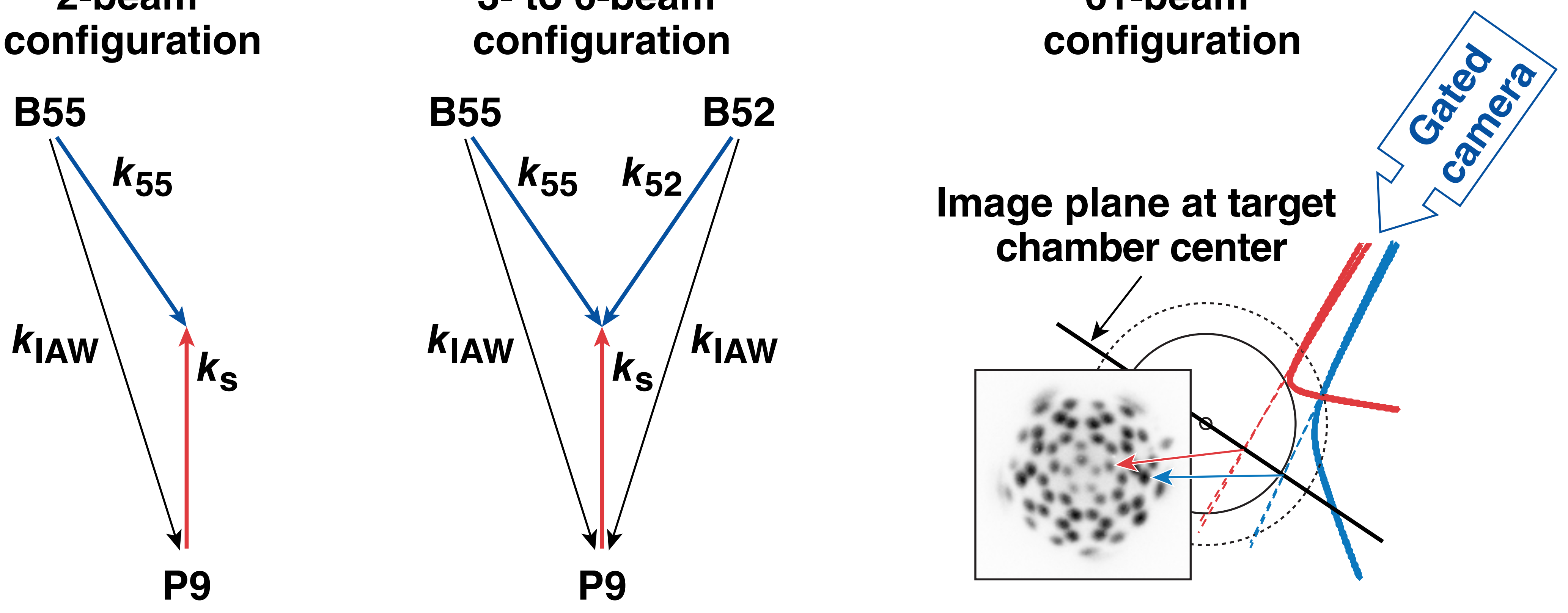
Focused Cross-Beam Energy Transfer Experiments on OMEGA

2-beam configuration

3- to 6-beam configuration

61-beam configuration



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58th Annual Meeting of the
American Physical Society
Division of Plasma Physics
San Jose, CA
31 October–4 November 2016

The objective of these campaigns is to address the current physics uncertainties with cross-beam energy transfer (CBET)

- CBET significantly reduces the hydrodynamic efficiency in direct-drive implosions
- The proposed campaigns will test the limits of linear theory
  - large ion-acoustic waves (IAW's)
  - multiple IAW's within the same volume
- These laser–plasma interaction (LPI) studies will systematically address why the CBET models require multipliers
- This platform will demonstrate wavelength detuning as a mitigation strategy in laser direct-drive OMEGA implosion conditions

Ultimately, these studies will provide confidence in our models that will define the requirements for a multiple wavelength OMEGA.

E25689

Collaborators

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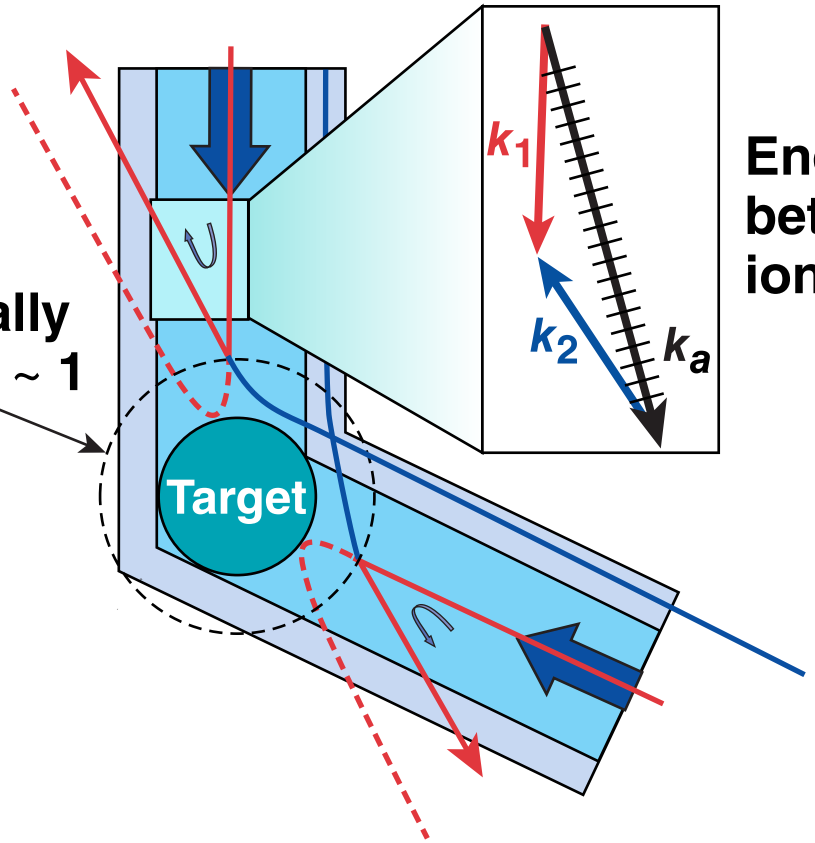
CBET reduces the energy coupled to the fusion capsule by transferring energy from the incident light to the outgoing light

CBET is spatially limited near $M \sim 1$

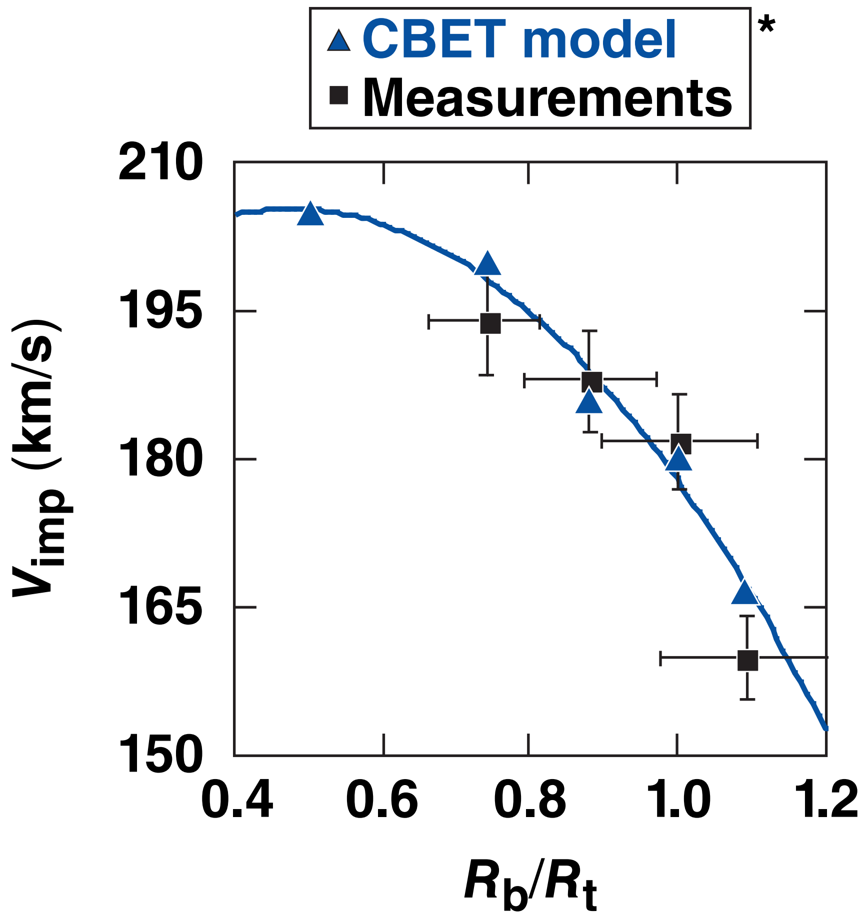


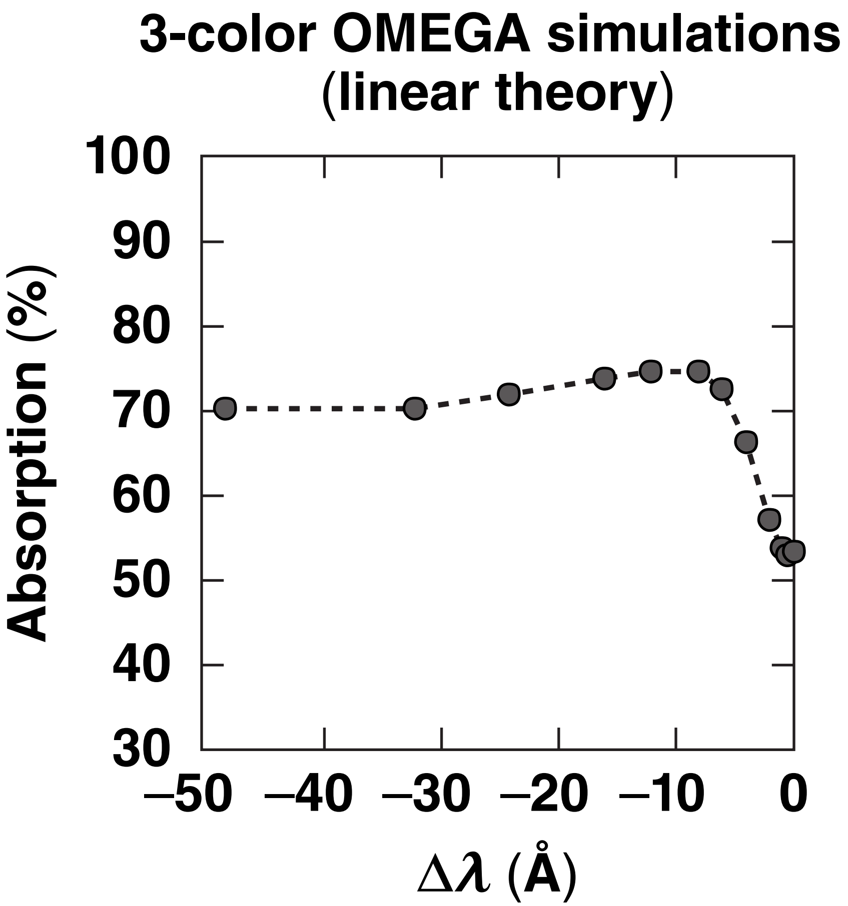
Energy is transferred between beams by ion-acoustic waves

CBET reduces the direct-drive hydrodynamic efficiency on OMEGA by ~35%.

I. V. Igumenschev *et al.*, Phys. Plasmas 16, 082701 (2009).

Experiments have demonstrated that CBET can be mitigated in direct-drive implosions





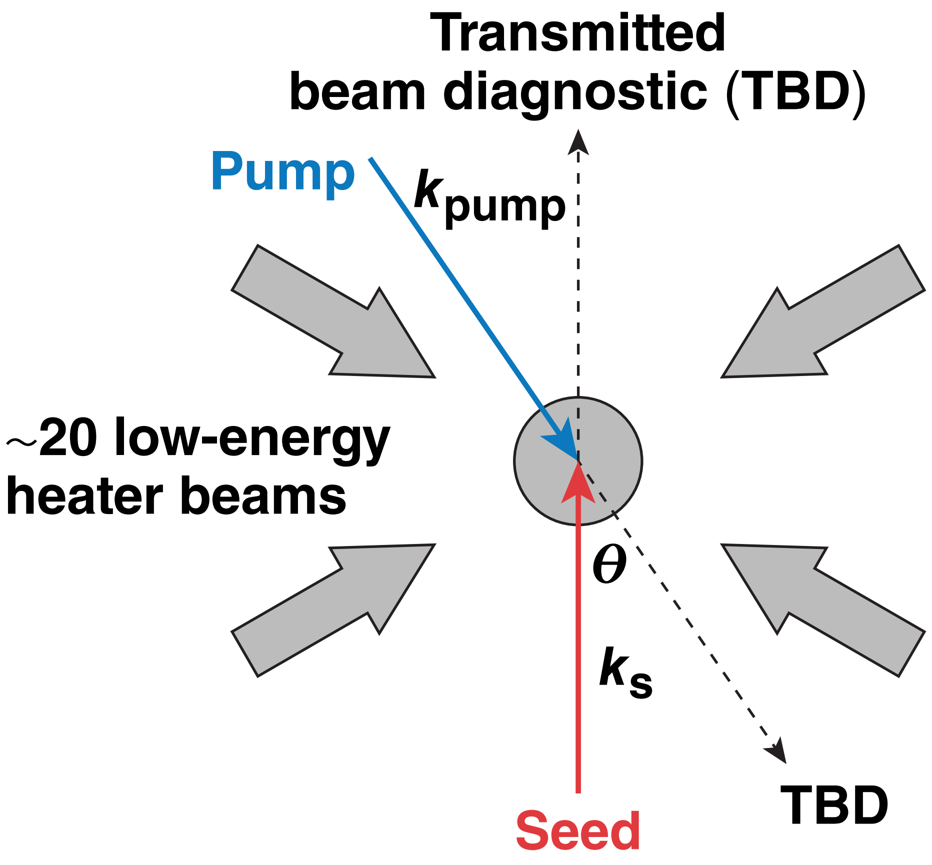
Reduced beam spots will recover some of the energy lost to CBET but, ultimately, multiple wavelength beams will be required to achieve 100-Gbar hot-spot pressures on OMEGA.

* D. H. Froula *et al.*, Phys. Rev. Lett. 108, 125003 (2012).

E23469d

An LPI platform is being implemented on OMEGA to study CBET in a well-characterized plasma

- A 1-mm-diam gas-jet target will provide a uniform plasma
- ~20 low-energy beams will uniformly heat the gas jet
- The transmitted pump and seed beams will be well characterized
  - transmitted power
  - spectrum



Thomson scattering will characterize the plasma conditions.

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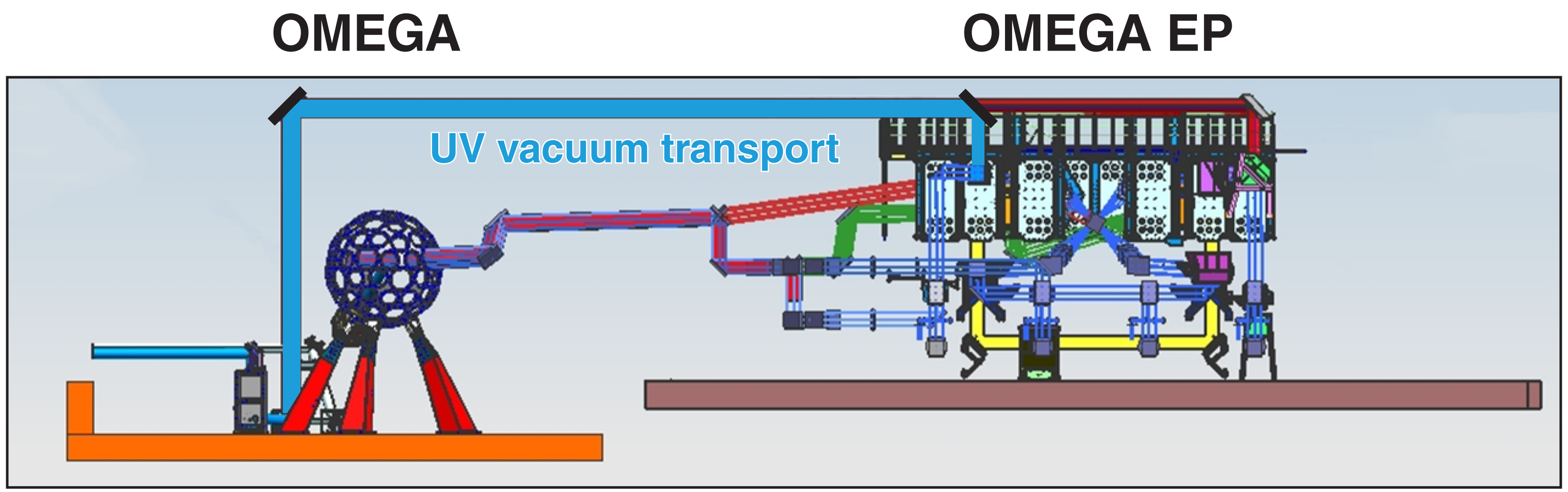
OMEGA EP will provide a beam with >2-nm (UV) of wavelength tunability on OMEGA



Requirements

- Maximum energy > 100 J/ns (100 GW)
- UV tunable wavelength range: 350.2 nm to 353.4 nm, $\Delta\lambda = 3.2$ nm
- Beam smoothing [distributed phase plate (DPP), distributed polarization rotator (DPR), no smoothing by spectral dispersion (SSD)]
- Polarization rotation
- Pulse shaping will be limited to square pulses (0.1 ns to 3 ns)

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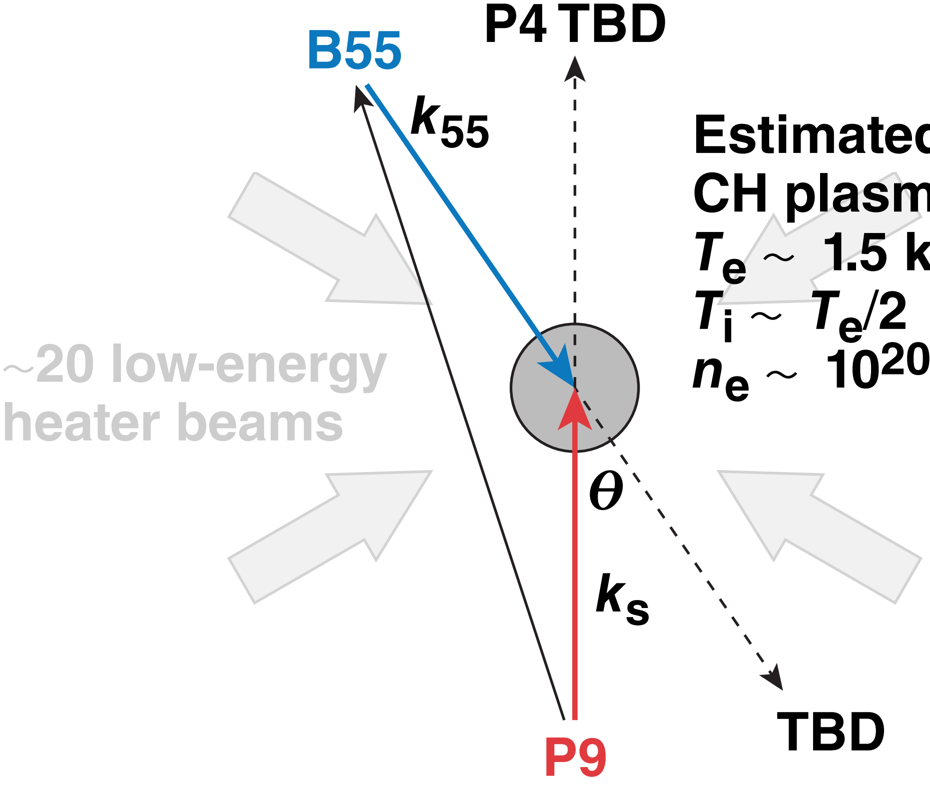
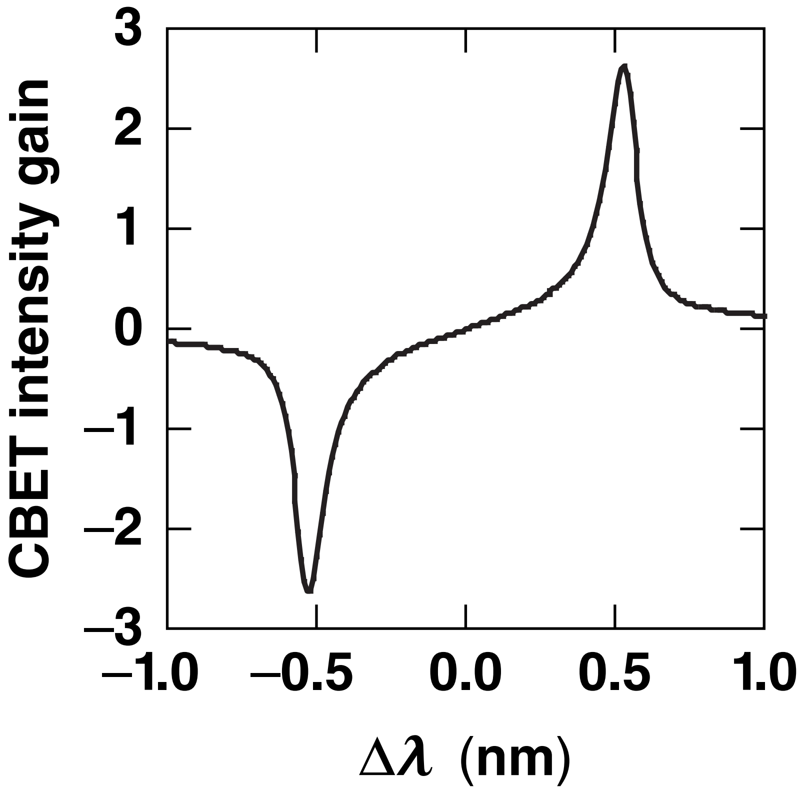
The two-beam tuning experiments will validate linear CBET theory with laser smoothing using DPP's, DPR's, and SSD

Pump: 250-μm diameter
I_p = 500 J/1 ns = 10^{15} W/cm^2



Estimated conditions:
CH plasma
$T_e \sim$ 1.5 keV
$T_i \sim T_e/2$
$n_e \sim 10^{20}$ cm^{-3}

Seed: 250-μm diameter
I_p = 5 J/1 ns = 10^{13} W/cm^2



Wavelength shift for resonant transfer:

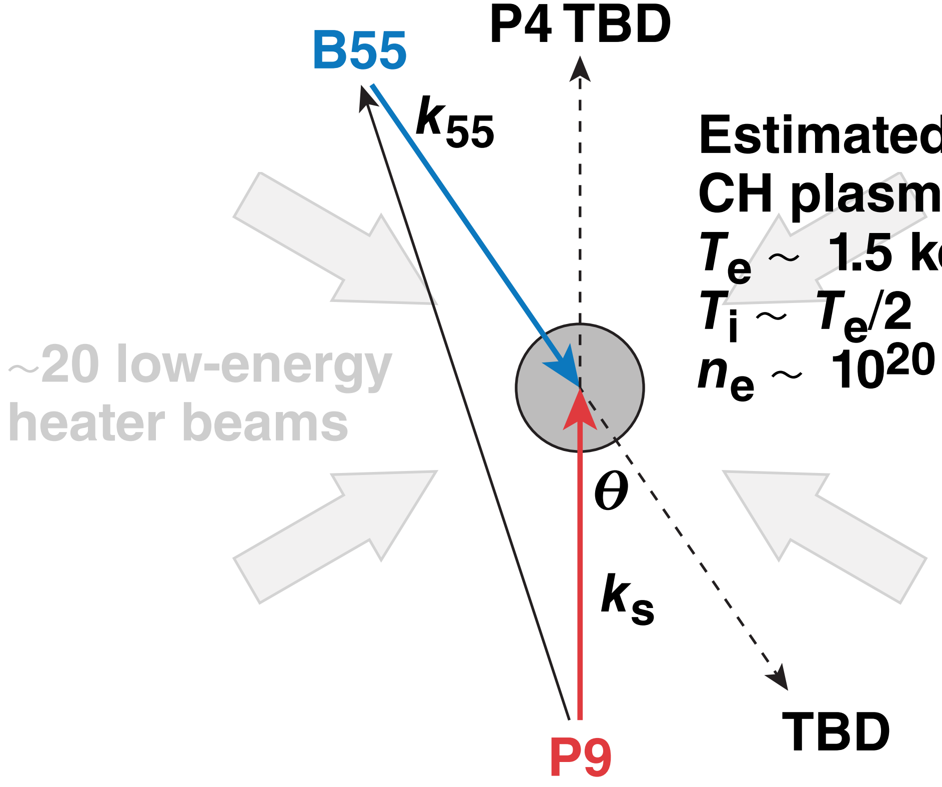
$$\Delta\lambda \approx \frac{\lambda_0 c_s}{c}\left[1+\cos(\theta)\right] < 0.8\ \text{nm}$$

D. Turnbull *et al.*, CO5.00013, this conference.

E25692

Increasing the seed intensity will drive large ion-acoustic waves and test the limits of linear theory

Pump: 250-μm diameter
I_p = 500 J/1 ns = 10^{15} W/cm^2



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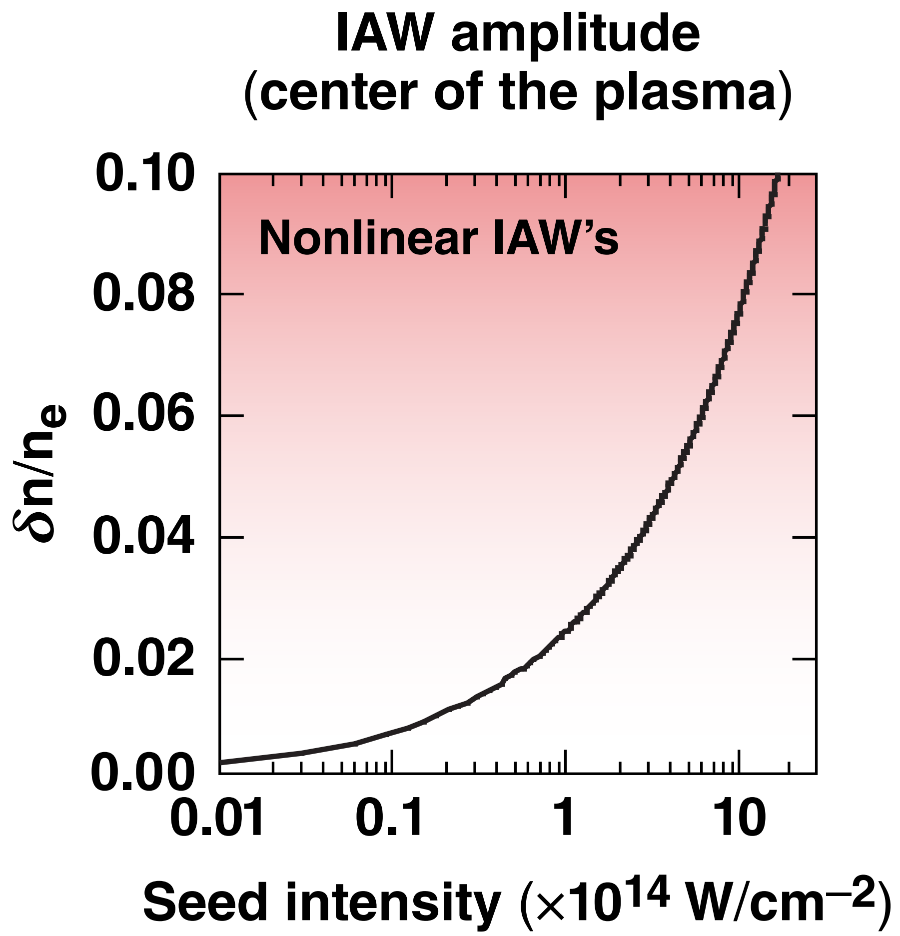

Particle trapping, harmonic generation, and frequency detuning are expected to limit the ion-acoustic wave amplitudes.

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Extending the platform to six beams in the 23° cone will test multiple-beam CBET modeling

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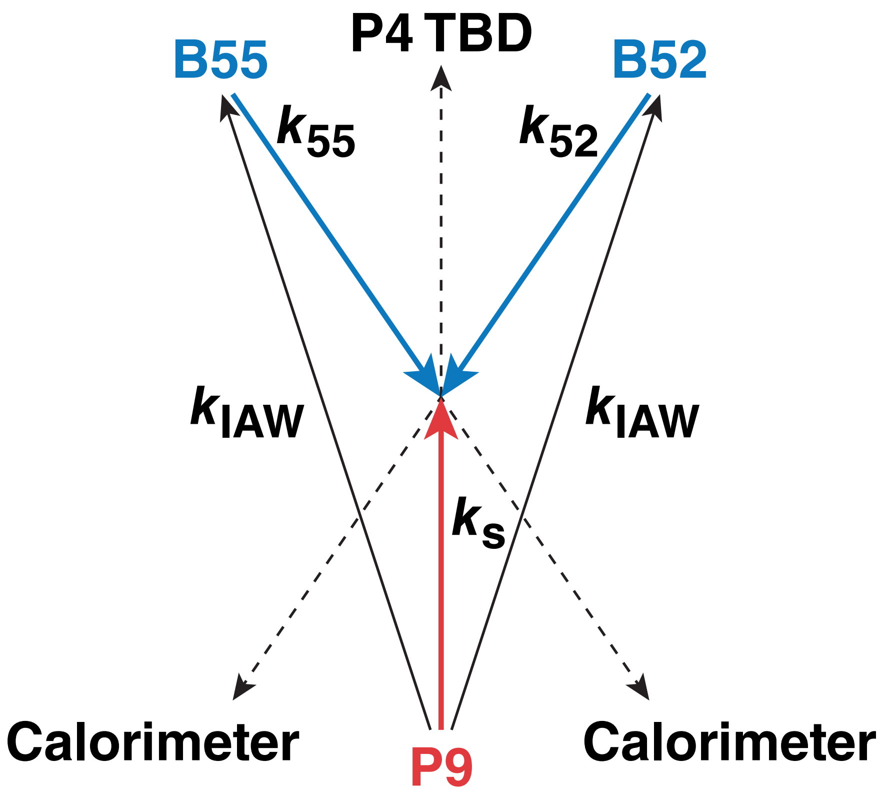
- Multiple-driven ion-acoustic waves may interact with each other, limiting CBET
- A forward-scattering geometry could be used to test CBET in the indirect-drive configuation

3- to 6-beam measurement



This experiment will test linear CBET theory in the presence of multiple-driven ion-acoustic waves.

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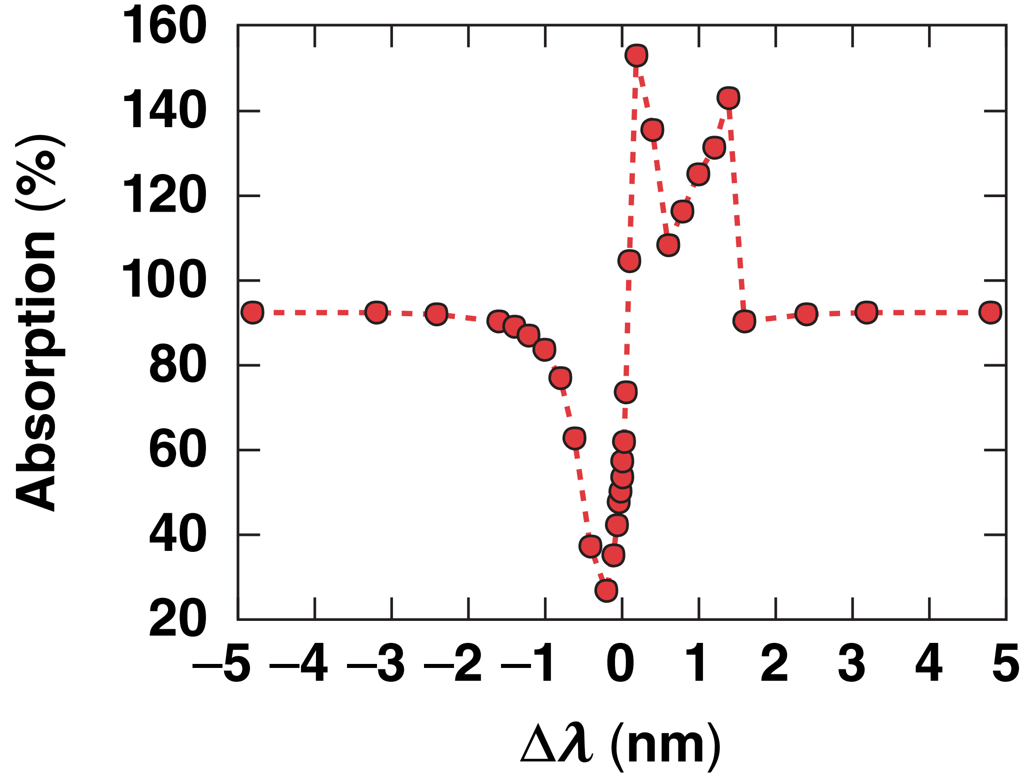
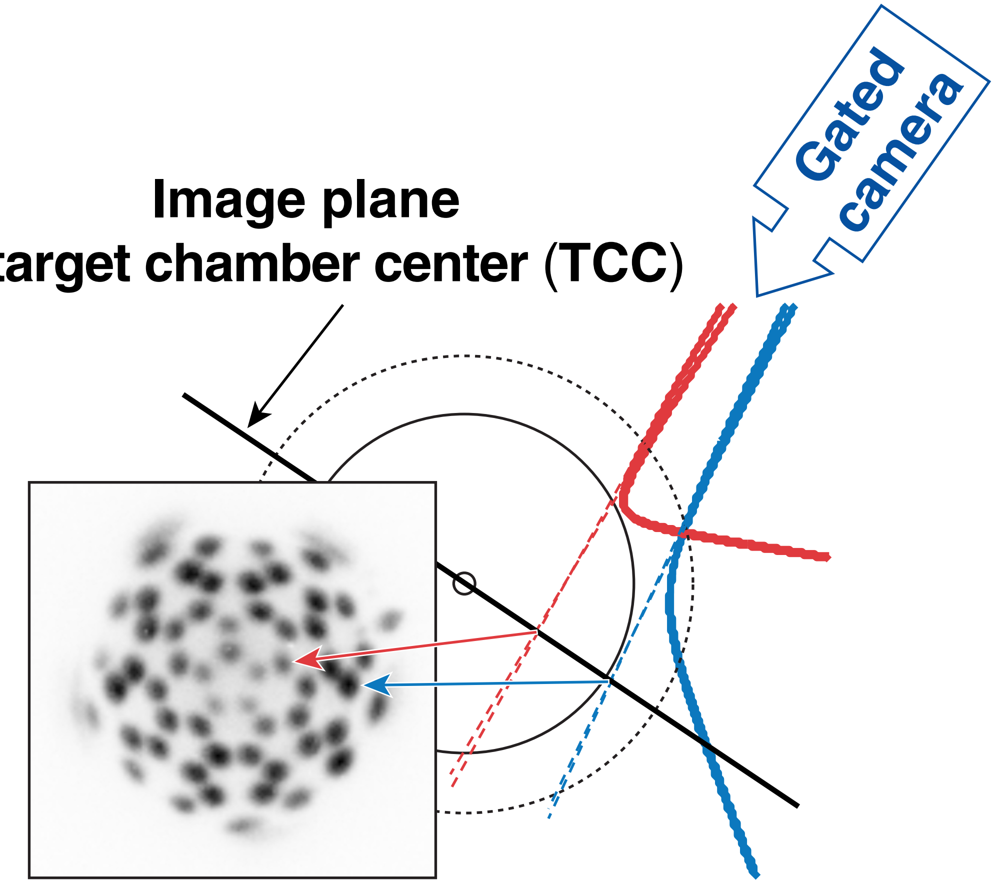
A frequency-shifted 61st beam will be used with the CBET beamlets diagnostic* to demonstrate a quantitative understanding of wavelength tuning in direct-drive experiments

Single-beam wavelength shift (simulation)





This configuration will be a robust test of our integrated CBET hydro-models and demonstrate CBET mitigation using wavelength shifting.

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* D. H. Edgell *et al.*, UO9.00011, this conference.