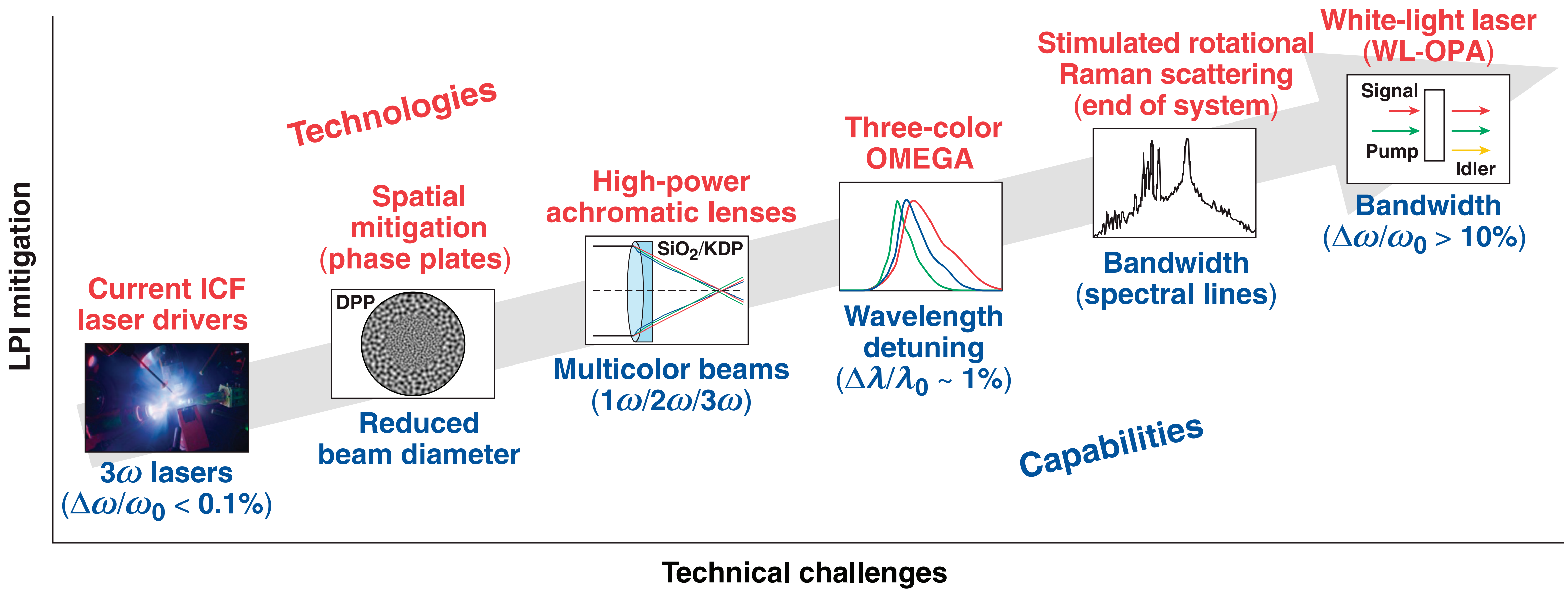
Plasma Physics and Broadband Lasers—
A Path to an Expanded Inertial Confinement Fusion Design Space



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Summary

Laser–plasma instabilities (LPI's) set the design space for all three approaches to inertial confinement fusion (ICF)

- Mitigation of cross-beam energy transfer (CBET) on OMEGA is the largest lever for improved hot-spot pressures on OMEGA, but will also require control of hot-electron production
- Modeling suggests that beam-to-beam wavelength shifts ($\Delta\lambda$ ~ 1 nm) could mitigate both CBET and hot-electron generation on OMEGA
- Could ultrawide-bandwidth laser technologies open the ICF parameter space

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Collaborators

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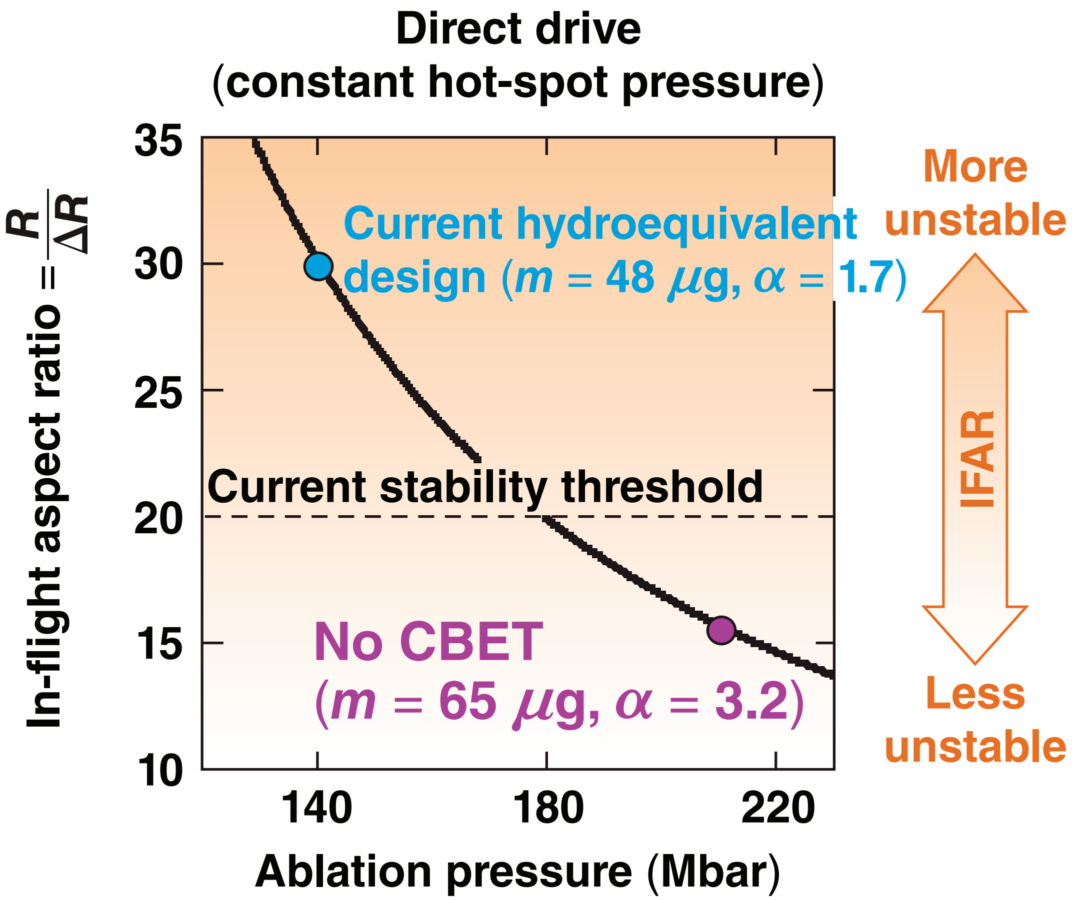
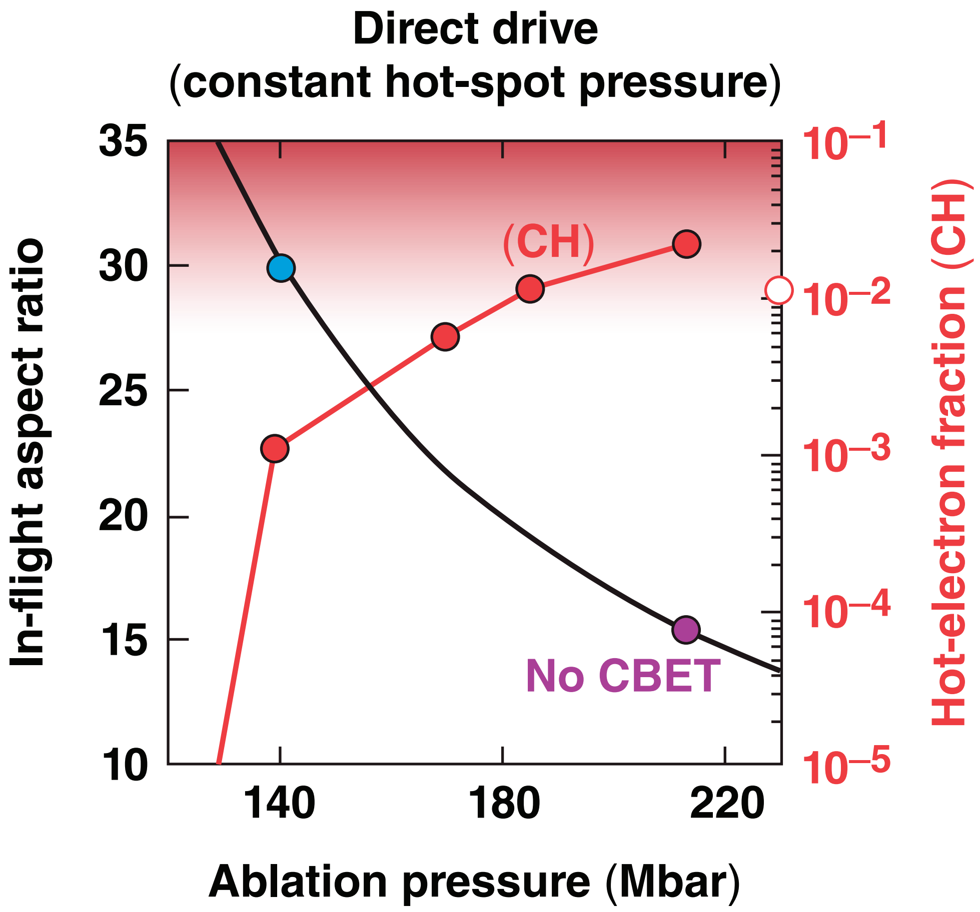
Naval Research Laboratory

L. Divol and P. Michel

Lawrence Livermore National Laboratory

Improved stability and/or CBET mitigation is likely required to achieve 100 Gbar pressures on OMEGA





Solutions to expand the ICF design space by mitigating LPI must consider both CBET and two-plasmon–decay (TPD) instabilities.

*IFAR: in-flight aspect ratio

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A multiwavelength LPI platform was implemented on OMEGA for focused experiments to study both CBET and electron plasma wave physics

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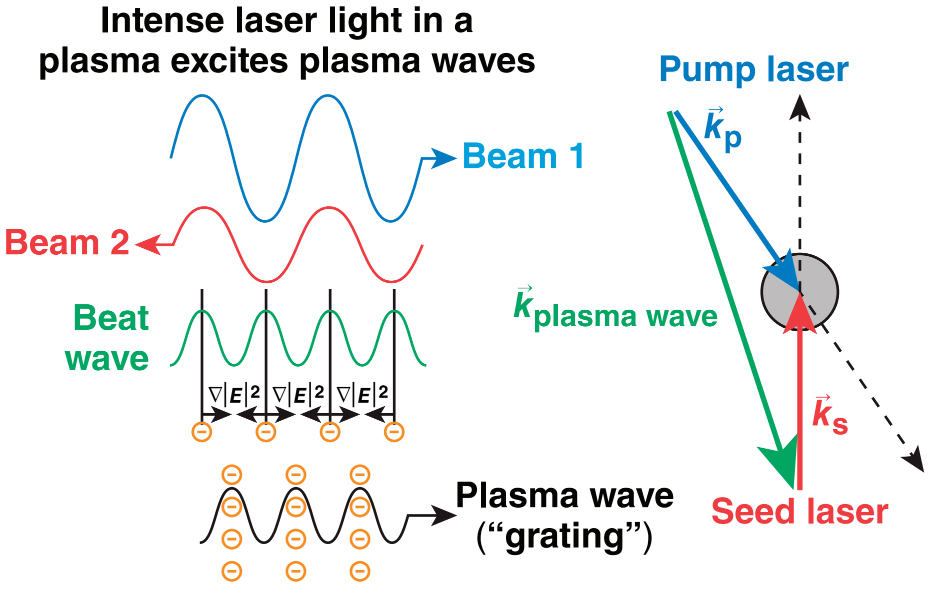
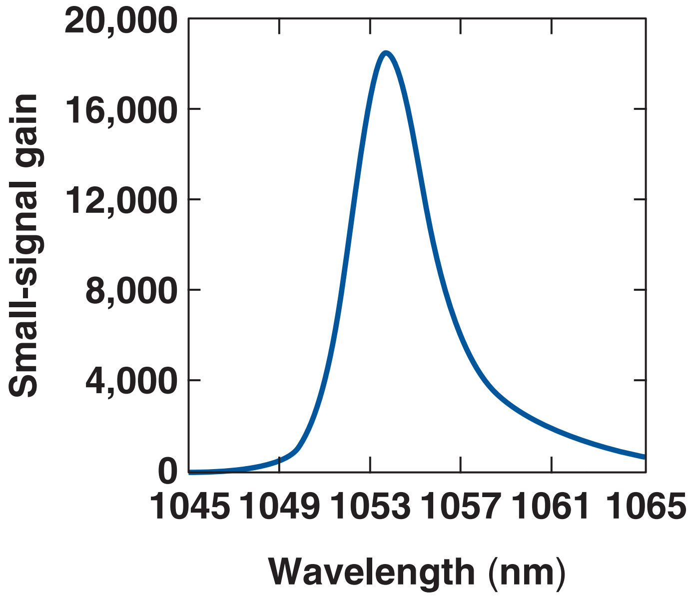
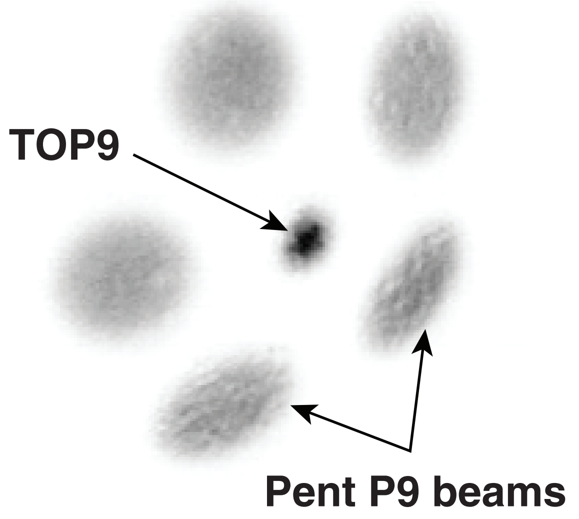
The wavelength of the seed determines the instability that is driven: IAW ($\Delta\lambda$ ~ 1 nm), EPW ($\Delta\lambda$ ~ 100 nm)



The laser team developed a novel tunable system using the OMEGA EP OPA to achieve $\Delta\lambda_{UV}$ = 3 nm

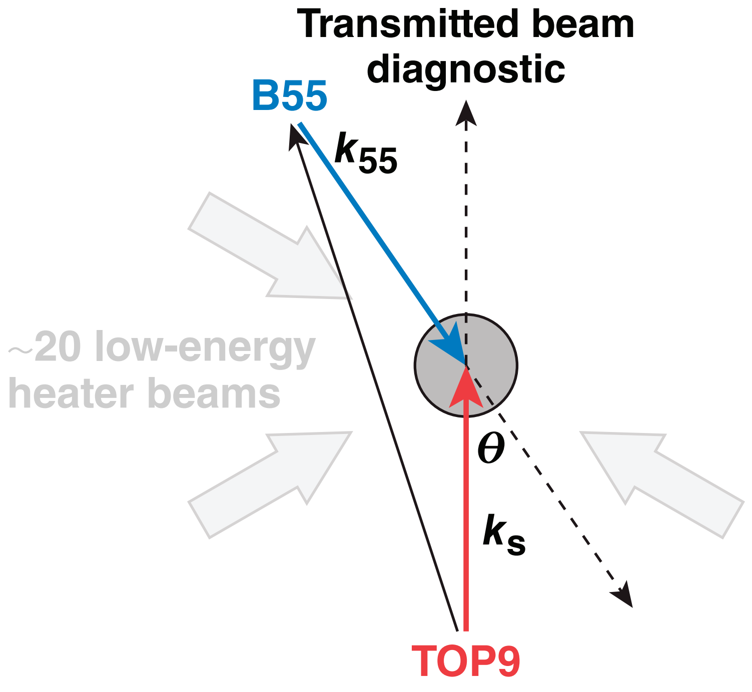


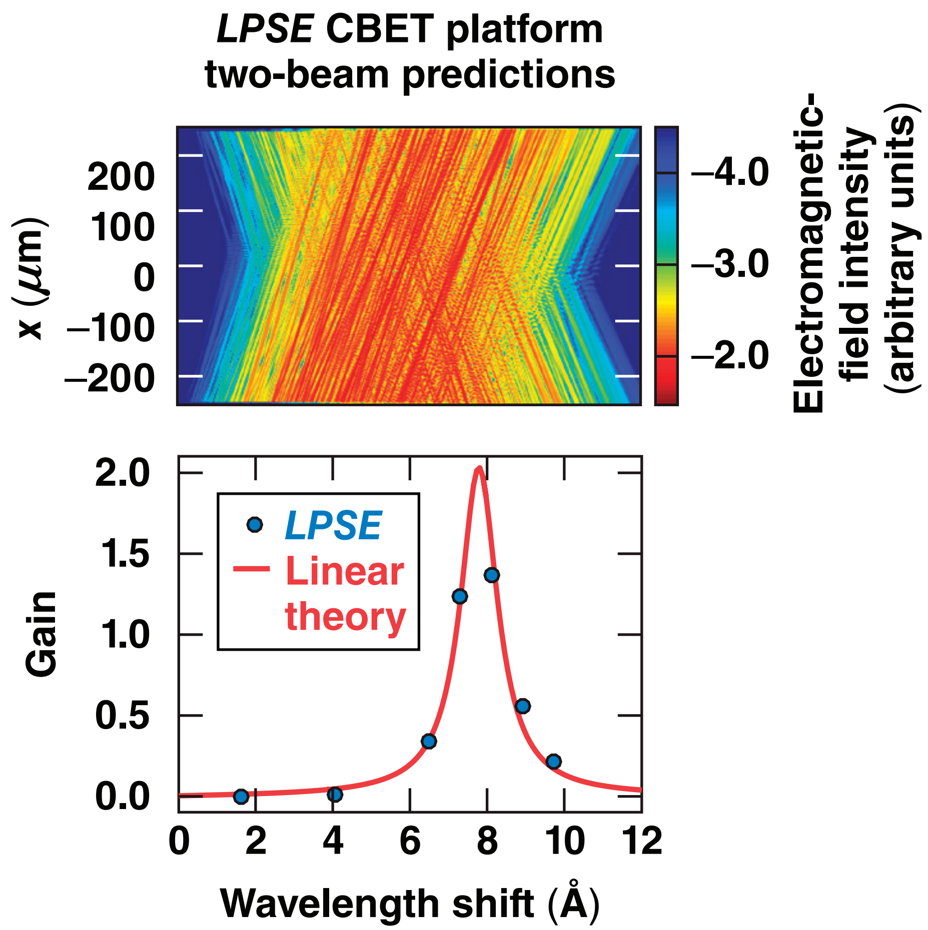
Tunable OMEGA Port 9 (TOP9) was activated on 8 June 2018

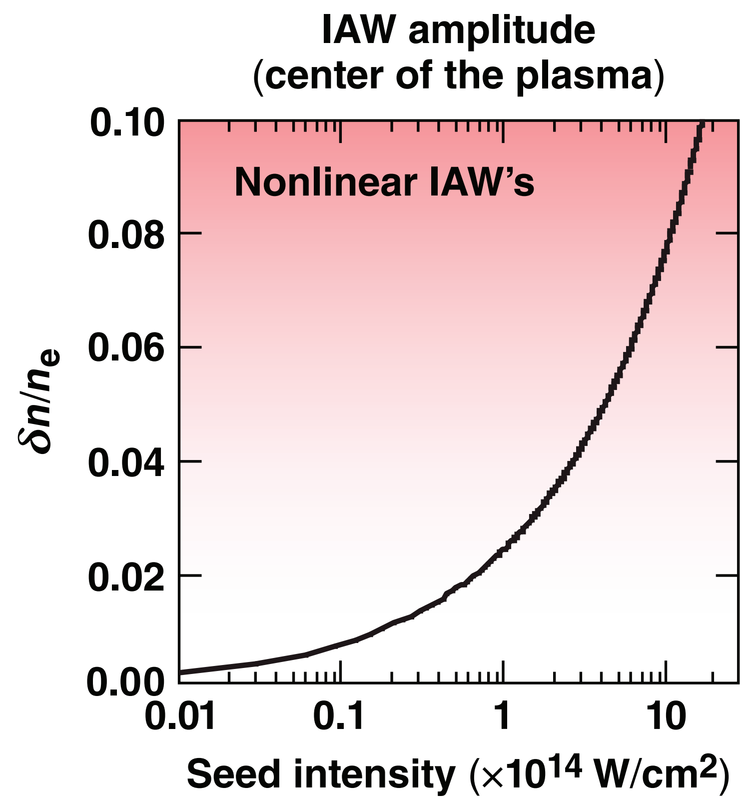


IAW: ion-acoustic wave
EPW: electron plasma wave
OPA: optical parametric amplifier

The CBET experiments will test the limitations of the CBET models that are implemented in our codes (*LPSE*, *LILAC*, *DRACO*, *HYDRA*)







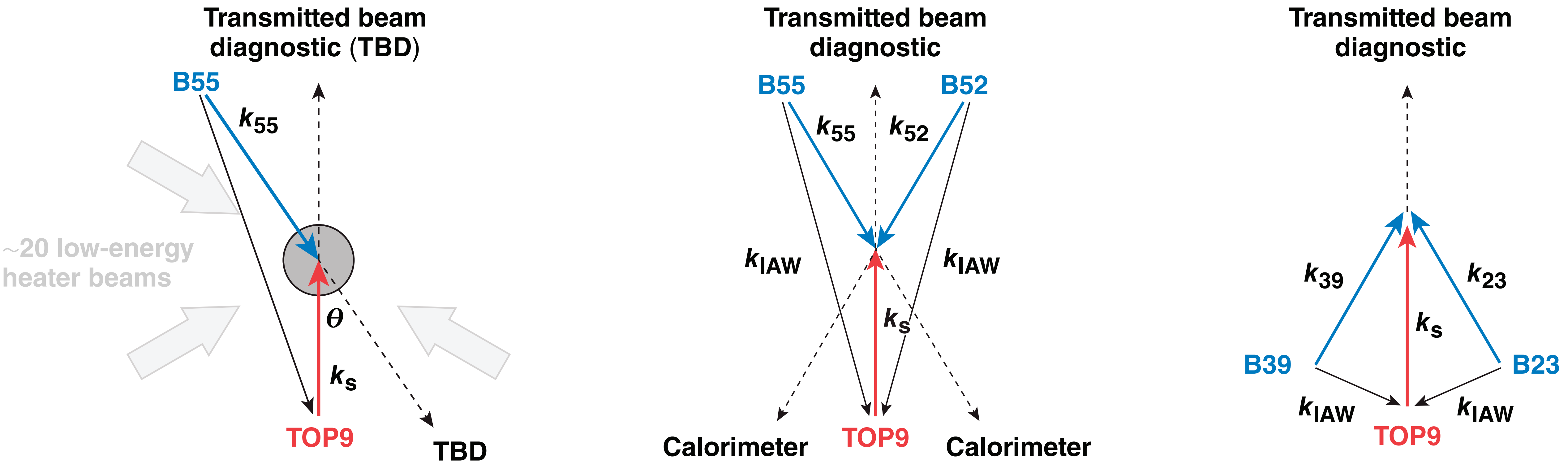
Experiments will investigate the effects of beam smoothing (SSD, phase plates), transient effects on CBET, and the nonlinear plasma wave response.

SSD: smoothing by spectral dispersion

D. Turnbull *et al.* Plasma Phys. Control. Fusion 60, 054017 (2018).

Extending the platform to six interaction beams will investigate the limitations of current multibeam CBET modeling

Backscattering geometry single-beam measurements	Backscattering geometry three- to six-beam measurements	Forward-scattering geometry three- to six-beam measurements



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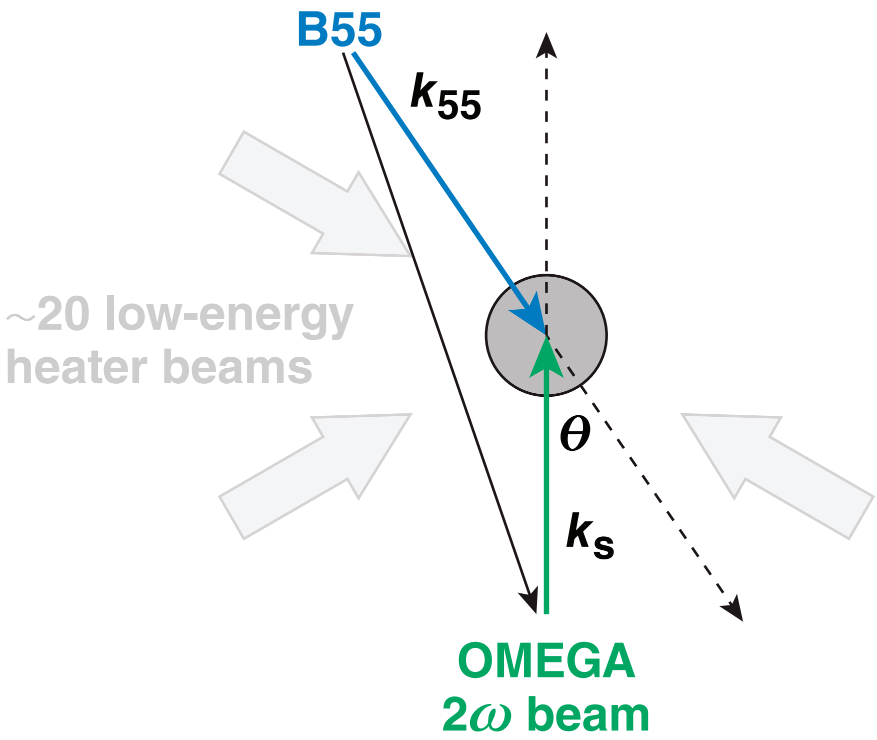
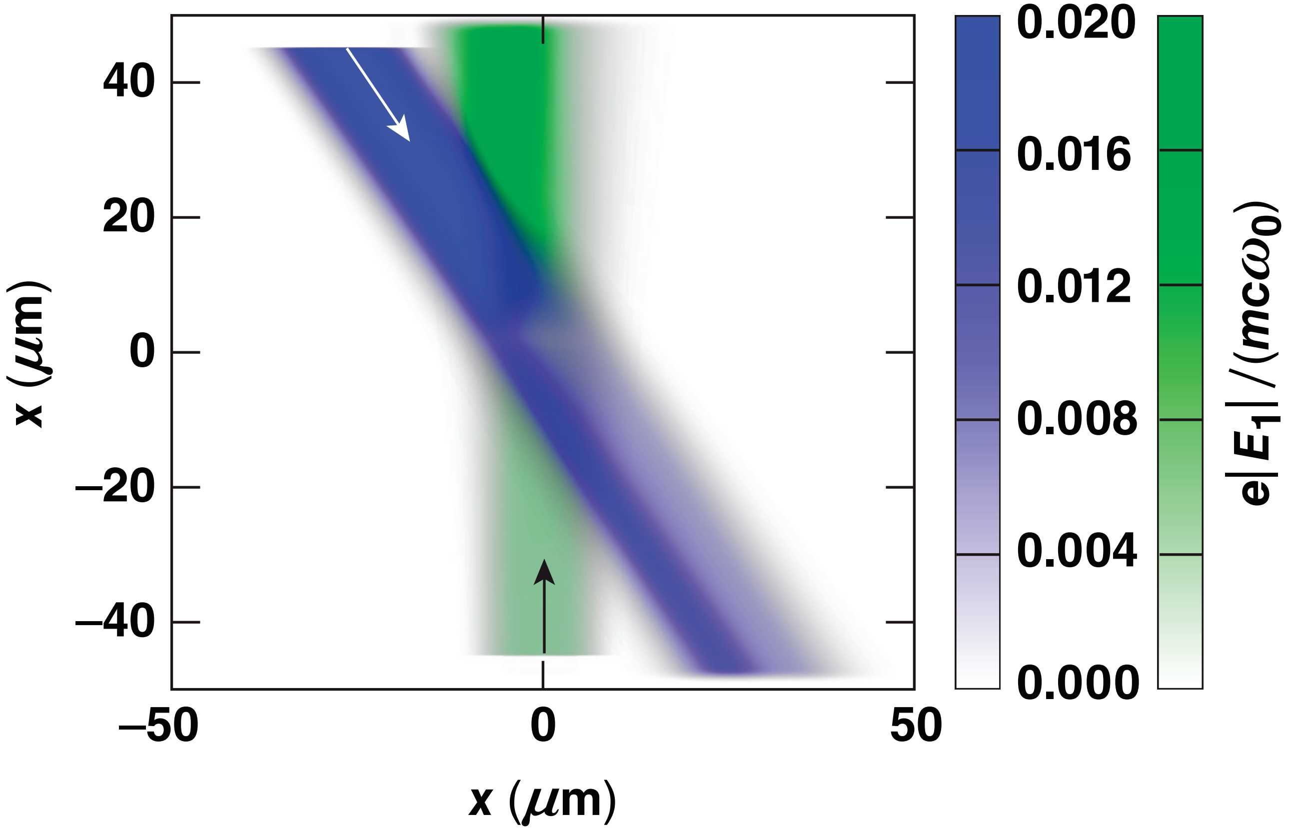
Using a 2ω (527-nm) seed beam will enable electron plasma wave studies very similar to the CBET (IAW) studies

Transmitted beam diagnostic



A stimulated Raman scattering (SRS) module is currently being implemented in *LPSE*



These experiments will test the linear response of electron plasma waves and the amplitude for hot-electron generation in both single-beam and multibeam configurations.

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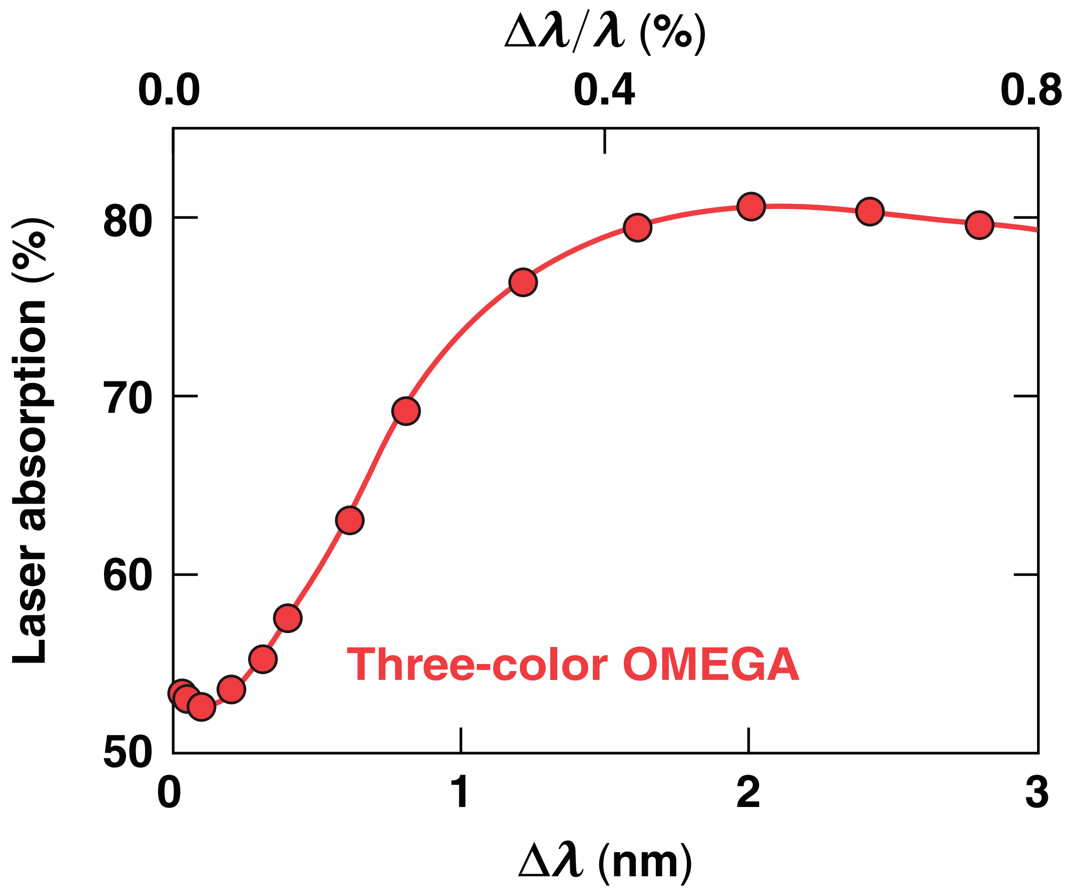
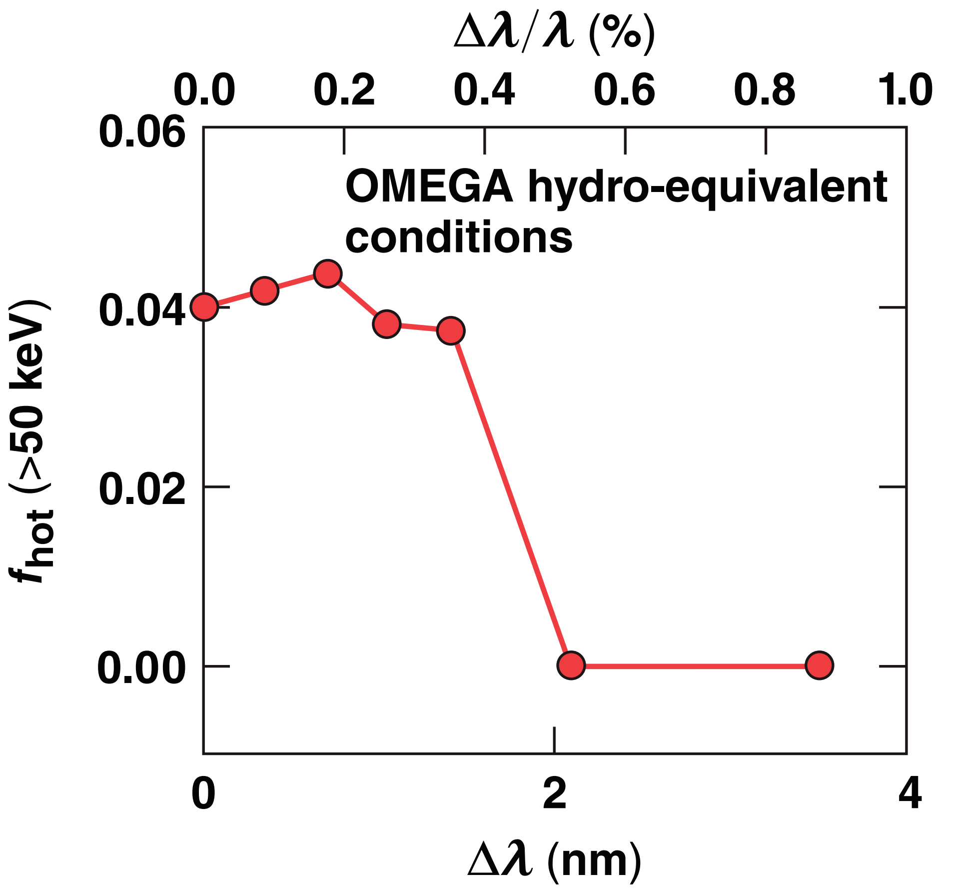
A three-color OMEGA is predicted to mitigate both CBET and hot-electron generation

CBET mitigation*



Hot-electron mitigation**



*D. H. Edgell *et al.*, Phys. Plasmas 24, 062706 (2017).
**R. K. Follett *et al.*, Phys. Rev. Lett. 120, 135005 (2018).

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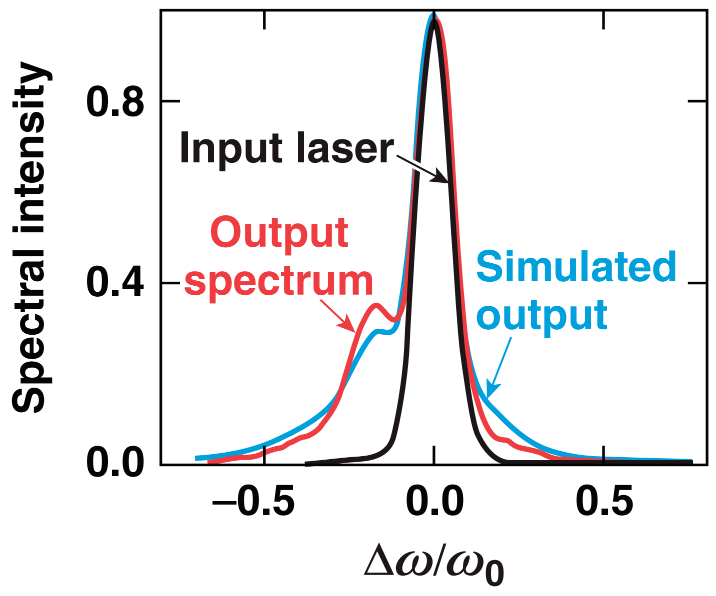
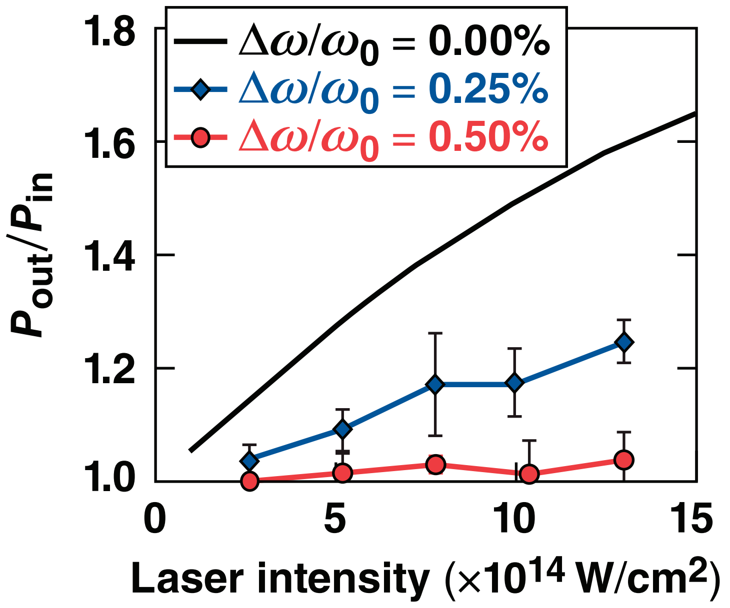
Ultimately a broadband ICF driver could be the avenue to fusion

Stimulated rotational Raman scattering



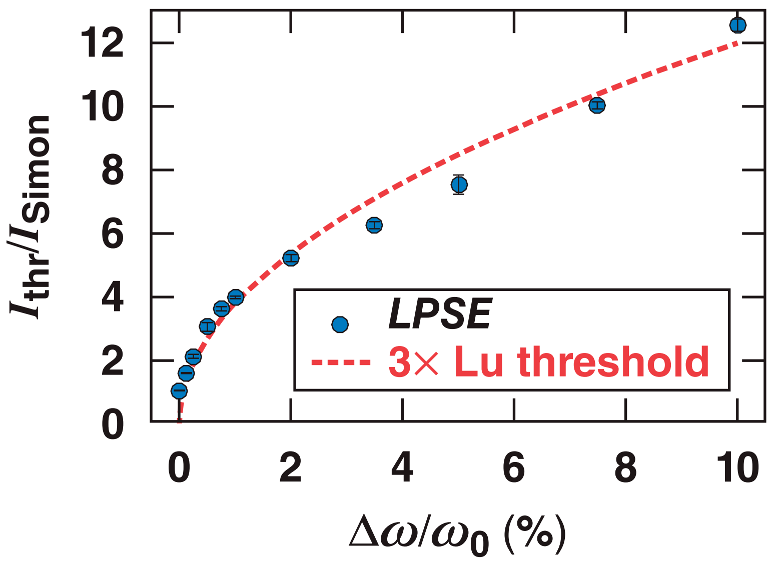
J. Weaver *et al.*, Appl. Opt. 56, 8618 (2017).

Effects of bandwidth on CBET (*LPSE* simulations)



J. Bates *et al.*, Bull. Am. Phys. Soc. 62, BAPS.2017.DPP.CO7.6 (2017).

Effects of bandwidth on TPD (*LPSE* simulations)



R. K. Follett *et al.*, Phys. Rev. Lett. 120, 135005 (2018).

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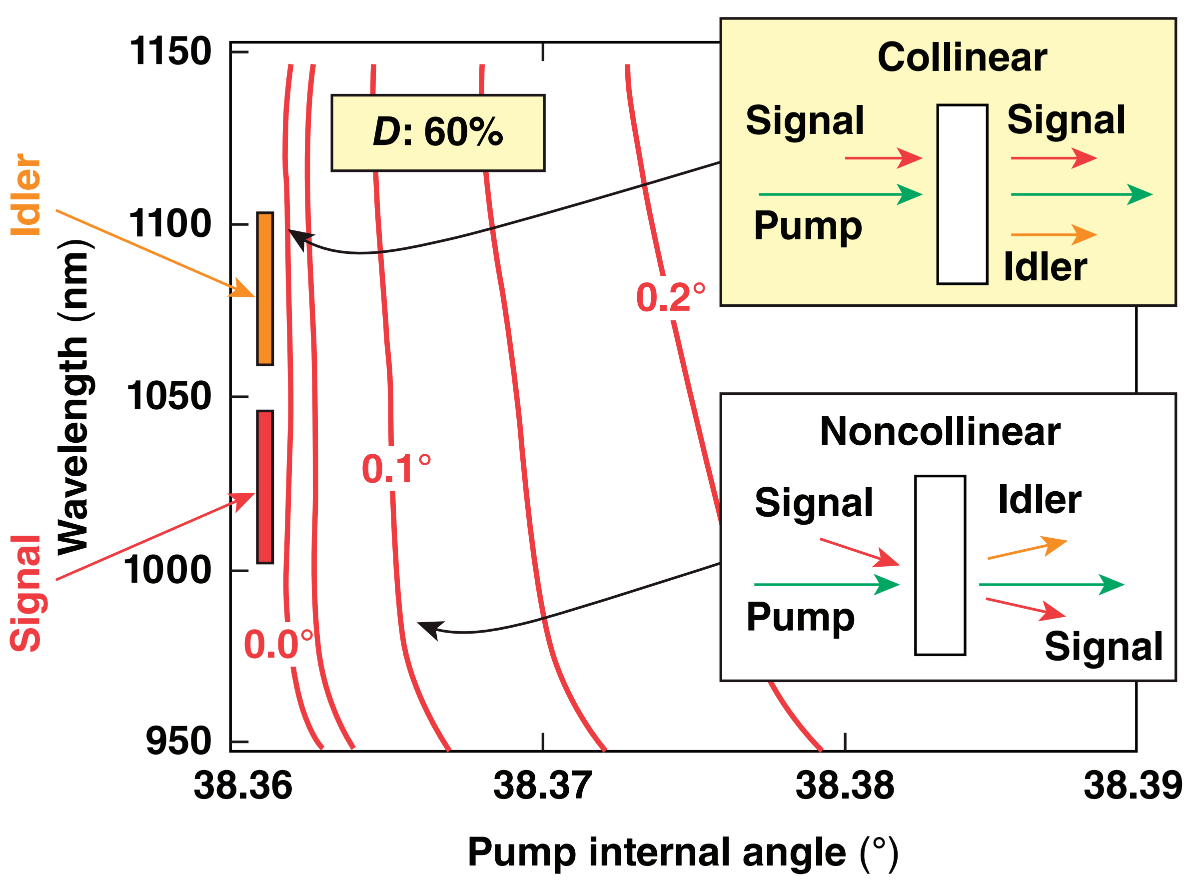
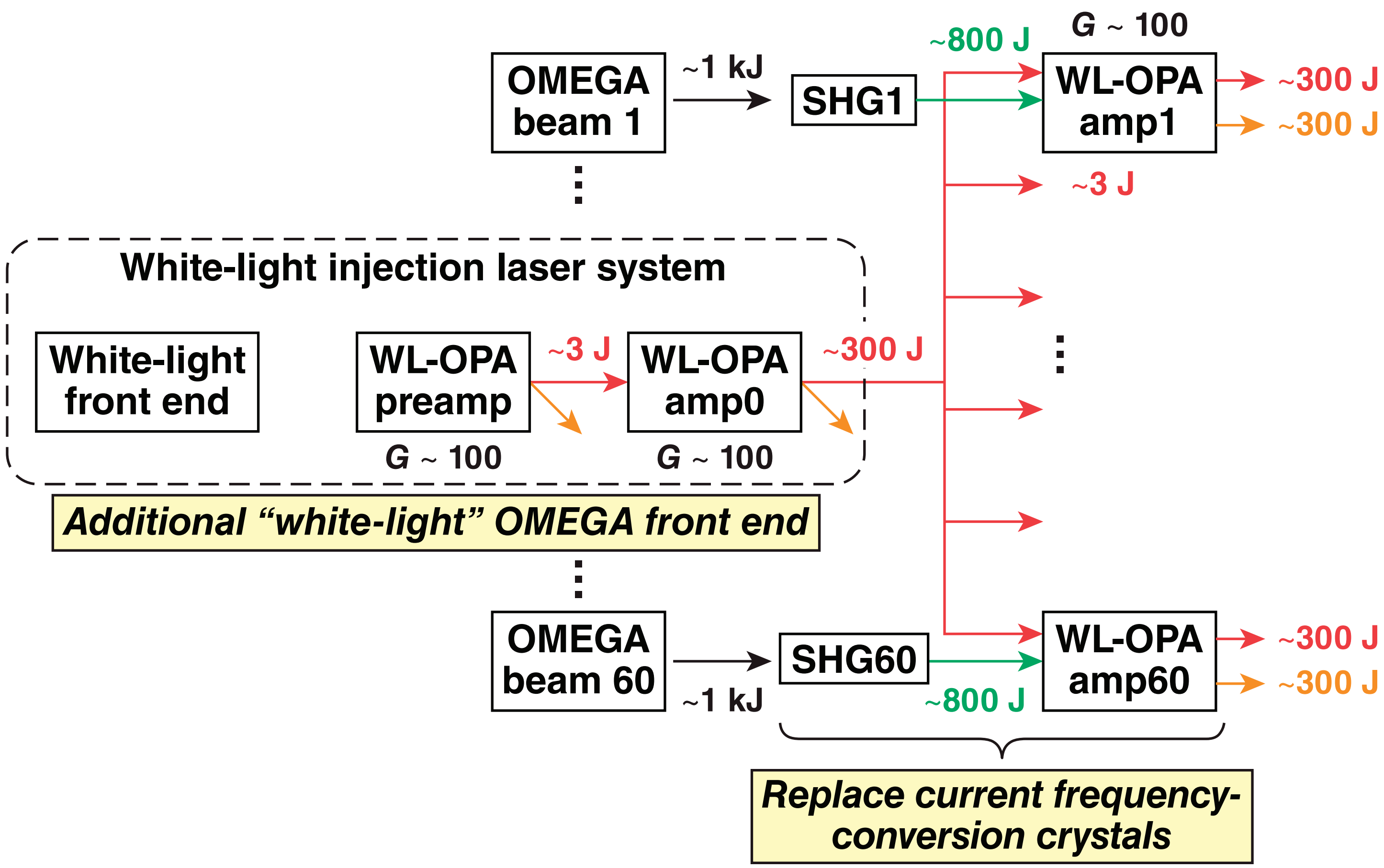
A conceptual layout for a broadband OMEGA employs a modular approach that leverages the existing OMEGA infrared laser system

Broadband DKDP OPA amplifiers





A collinear OPA could provide >10% bandwidth for a modern ICF driver.

SHG: second-harmonic generation
THG: third-harmonic generation

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LPI's set the design space for all three approaches to ICF

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