Fourth-Generation Laser for Ultra-Broadband Experiments—Expanding the ICF Design Space Through Mitigation of Laser Plasma Instabilities

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A Fourth-Generation Laser for Ultra-broadband eXperiments (FLUX) is being built to demonstrate the laser technologies at scale and provide a broadband beam on OMEGA for LPI studies

- Simulations predict $\Delta \omega / \omega > 1\%$ laser bandwidth will mitigate LPI in direct-drive implosions

- An ultrawide bandwidth ($\Delta \omega / \omega > 1\%$) UV long-pulse laser is being developed at LLE

- Efficient ($> 75\%$) amplification efficiency (narrow $1\omega \rightarrow$ broadband $1\omega$) has been demonstrated at high-powers

- Summed frequency generation (broadband $1\omega$ + narrow band $2\omega \rightarrow$ broad band $3\omega$) is currently being tested as an efficient method to create broadband UV light
Collaborators

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For direct-drive experiments, the maximum drive pressure is set by the intensity threshold for hot-electron generation.

Solutions to expand the ICF design space by mitigating LPI must consider both CBET and TPD instabilities.
LPI modeling predicts that $\Delta \omega/\omega > 1\%$ bandwidth can mitigate both CBET and hot-electron generation in hydrodynamic-equivalent ignition implosions on OMEGA.

**Cross-Beam Energy Transfer (Increased Drive Pressure)**

$I = 10^{15} \text{ W/cm}^2$

Increasing $\Delta \omega/\omega > 0.5\%$ will allow stable implosions on OMEGA (IFAR=15)

IFAR: in-flight aspect ratio

**Two-Plasmon Decay (Hot-Electron Mitigation)**

Increasing $\Delta \omega/\omega > 1\%$ will mitigate both CBET and hot electrons and allow for hydro-equivalent ignition

**Improved Imprint (<1-ps asymptotic smoothing)**

Improved imprint will further expand the direct-drive design space by increasing the hydro-stability threshold

See J. Wilson NO5.00002 (Wed. 930A)
From the beginning of laser-plasma instability research (1970s)*, theory showed that bandwidth could mitigate LPI, but glass lasers could not support it.

High-bandwidth technologies developed to support short-pulse lasers are being used at LLE to build the next-generation driver for ICF.

Current Ultrashort Noncollinear Optical Parametric Amplifier Technology

Noncollinear Optical Parametric Amplifiers are inherently inefficient

LBO* OPA preamplifier

* LBO: Lithium triborate
Adapting the Noncolinear OPA provides an efficient broadband amplifier

The co-linear OPA provides efficient conversion (>75%) of narrow band $2\omega$ light to broadband $1\omega$

Proposed Co-Linear OPA Amplifier Technology

Joule level experiments demonstrate high efficiency amplification

The diagram shows the process of signal amplification using a noncolinear OPA. The narrow band pump signal interacts with a nonlinear crystal to produce a broadband amplified signal. The fluorescence and four lines are depicted with different colors and markers for various pump energies.
A novel summed frequency generation concept is being tested to efficiently produce broadband UV light.
LPSE was used to determine the ideal bandwidth format when considering collinear optical parametric amplification.
A Fourth-Generation Laser for Ultra-broadband eXperiments (FLUX) is being built as an additional laser beam on OMEGA.

The FLUX laser will be used with the LPI Platform on OMEGA to test the effects of bandwidth on CBET and hot electron generation.
A successful technology demonstration (FLUX) will lead to a design for an upgraded OMEGA with ultra-wide bandwidth.

A conceptual layout for a “OMEGA FLUX-60” leverages the existing infrared laser system, target area, and diagnostics.
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