Self-Focusing of Plasma Waves and the Control of Laser-Plasma-Instability

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The high-energy-density/inertial confinement fusion HED/ICF program utilizes powerful laser beams, as at the National Ignition Facility (NIF) facility currently under construction at Lawrence Livermore National Laboratory, to create a high-temperature plasma relevant to nuclear weapons research. Design tools, however, do not see the microscopic (submicron length and subpico-second time scale) interaction between the beams and plasma waves. This interaction may lead to plasma turbulence. Although this is well known, experimental data has become available only in the last few years with sufficient detail to distinguish different regimes of laser-plasma-instability (LPI) relevant to NIF. If these instabilities are too energetic, then design code predictions become less reliable. This aspect of design codes, however, has no direct weapons relevance. Work on LPI has been unclassified since its inception 40 years ago.

There has been recent theoretical progress in Theoretical (T) Division on basic LPI issues. One is the nonlinear saturation of stimulated scatter, whose linear theory was worked out by a retired T-Division staff member [1]. Stimulated scatter is when the following coupled processes become an unstable loop as shown in Fig. 1.

If the plasma wave is a high frequency electron oscillation, or a Langmuir wave, the instability is known as stimulated Raman scatter (SRS). At the high temperatures and low densities of NIF ignition plasma, it is possible that the Langmuir wave's propagation is distorted by self-induced changes in its index of refraction. Technically this arises because a finite fraction of electron orbits are trapped by the wave, reducing its frequency, and then in analogy with propagation of an intense laser beam, the Langmuir wave self-focuses, spraying itself incoherently out of the instability loop, thereby controlling the energy diverted by SRS [2].

Comparison of theory [2] with experimental data [3] shows qualitative agreement in the transition between the coherent SRS, and incoherent self-focusing regimes. A Langmuir wave's amplitude may be characterized by an electron's escape speed, which is inferred from experimental data. Its uncertainty is represented by the length of the black bar in the Fig. 2. By positioning that bar horizontally so as to span both regimes, the theoretical boundary between the two regimes is crossed at a plasma temperature, T_e, of 6.5 million degrees (K), while experimentally the actual transition is closer to 7 million degrees.

Further comparison between LPI theory and experimental data is in progress as part of an ongoing process to arrive at LPI predictive capability.

[1] D.F. DuBois and M.V. Goldman, *Phys. Rev. Lett.* **14**, 544 (1965).
[2] H.A. Rose, "Langmuir Wave Self-Focusing versus Decay Instability," *Phys. Plasmas* **12**, 012318 (2005).

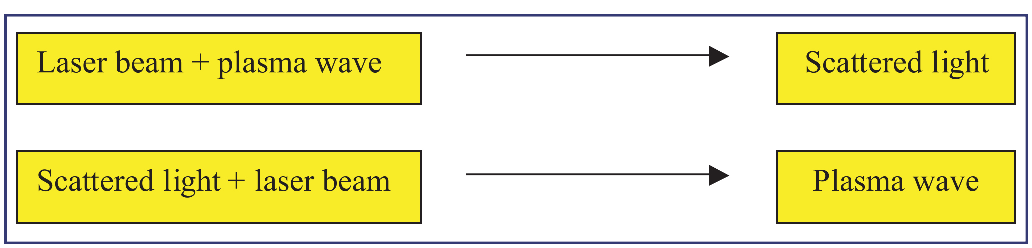

***Figure 1—* Stimulated scatter is when these coupled processes become an unstable loop.**

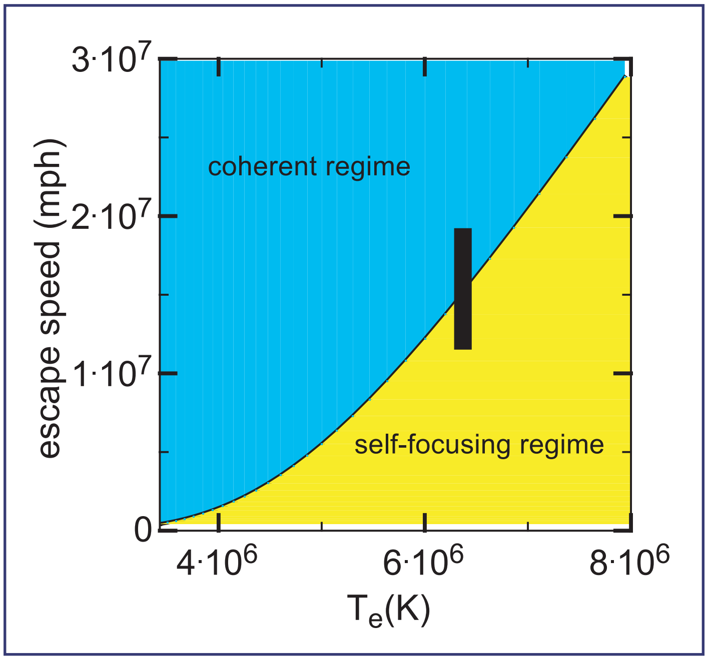

Figure 2—
A Langmuir wave's uncertainty is represented by the length of the black bar.

[3] J.L. Kline and D. Montgomery, "Observation of a Transition from Fluid to Kinetic Nonlinearities for Langmuir Waves Driven by Stimulated Raman Backscatter," to be published in *Phys. Rev. Lett*.

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Acknowledgements
We would like to acknowledge NNSA's Advanced Simulation and Computing (ASC), Materials and Physics Program; and Campaign 10, Inertial Confinement Fusion Ignition, for financial support.