How Much Laser Power Can Propagate through Fusion Plasma?

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Propagation of intense laser beams in plasma raises outstanding technological and scientific issues. These issues are closely tied with inertial confinement fusion (ICF), which requires precise beam control in order to maintain symmetry of spherical target implosion, and so achieve the compression and heating necessary to ignite the fusion reaction. The National Ignition Facility (NIF), where ICF will be attempted, is now under construction. While most engineering features of NIF are now fixed, there are still crucial choices to be made in target designs. Control of intense beam propagation may be ruined by laser beam self-focusing, when a beam digs a cavity in plasma, trapping itself, leading to higher beam intensity, a deeper cavity, and so on.

In laser fusion, the intensity of laser beams is so large that self-focusing can cause disintegration of a laser beam into many small beams, leading to rapid change in beam angular divergence, called beam spray. (See Fig. 1.) Significant beam spray is absolutely unacceptable for attaining fusion since it requires precise laser beam control. It was commonly assumed that the main source of beam spray in fusion plasma is the self-focusing of local maxima of laser intensity (hot spots) randomly distributed throughout the plasma. Although hot-spot self-focusing can be controlled by reducing beam correlation time, we find that the main limitation of maximum beam power, which can propagate in plasma without significant beam spray, is determined by collective instability that couples the beam to an ion acoustic wave. We call this instability collective-forward-stimulated Brillouin scatter (CFSBS) because it does not depend on the dynamics of isolated hot spots, but rather the intensity fluctuations as temporally smoothed (averaged) by ion inertia. This collective instability is consistent with the first experimental observation of the beam spray onset while hot-spot self-focusing is not. Our theory [1] suggests how to increase that maximum by appropriate choice of plasma composition that affects damping and thermal transport, with implication for NIF designs.

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[1] Pavel M. Lushnikov and Harvey A. Rose, *Plasma Phys. Control. Fusion* **48**, 1501 (2006).

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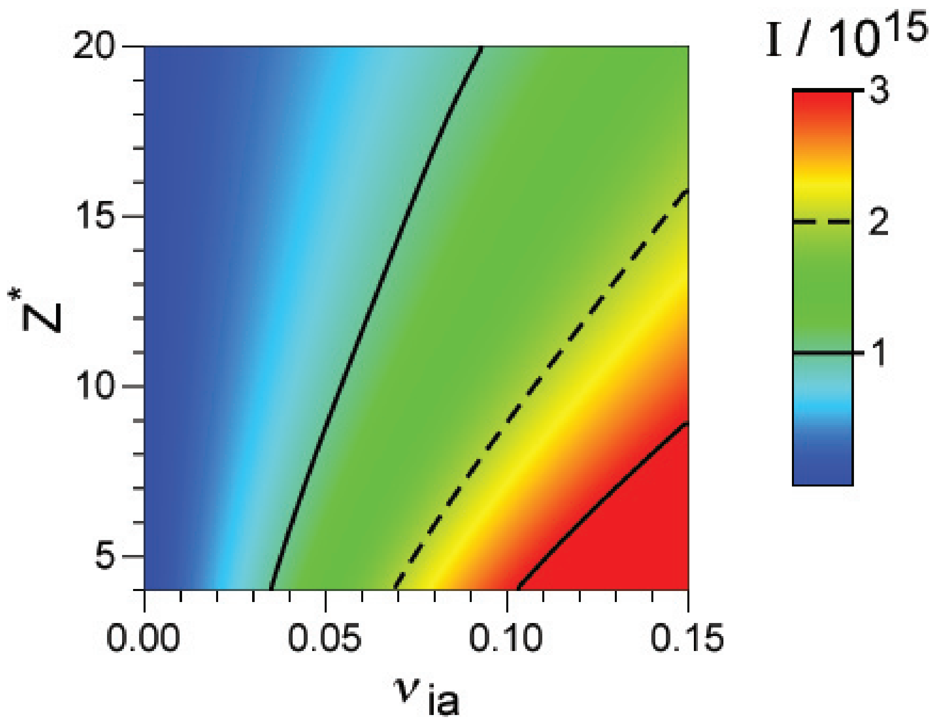

Fig. 1.
Predicted laser intensity, I-in units of W/cm^2, at onset of beam spray regime for NIF parameters, as a function of dimensionless acoustic damping coefficient, ν_{ia}, and effective plasma ionization, Z.*