- Describe the research frontier and importance of the scientific challenge

One of the broad research frontiers with plasma physics encompasses the propagation, absorption, scattering, and coupling of high intensity laser light in high temperature and density plasmas. Significant challenges remain in correlating the spatial and temporal evolution of laser-plasma interactions between the scales of laboratory plasmas (mm to cm; ns) and the laser driver (100-1000's nm; fs to ps), especially when the processes can occur nonlocally, nonlinearly, or both. Advances in this research could remove some of the obstacles to achieving laser driven fusion and would contribute to the continued vitality of plasma physics by fostering higher precision methodologies and expanding experimental capabilities.

- Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required

The proposed avenues extend current research deeper into the ultraviolet and explore the effects of enhanced laser bandwidths (> 1 THz). Excimer lasers can provide high energies (kJ's or more) at shorter wavelengths (as low as 192 nm) than contemporary solid state systems that have difficulty reaching high energies below 351 nm. Development of deep ultraviolet lasers could realize a new light source for Thomson scattering and establish new methods to generate ultrahigh intensity pulses.

A long term research goal has been to construct predictive models for instabilities that occur when high intensity laser light drives plasma modes such as electron plasma waves or ion acoustic waves.[1] Three major processes studied in laser fusion research include stimulated Raman scattering (SRS), stimulated Brillouin scattering (SBS), and the two plasmon decay instability. It has been known for a long time that these instabilities occur when the laser intensity exceeds an approximate threshold value which depends inversely on laser wavelength.[2] The onset of instabilities may be further mitigated by the incorporation of temporal and spatial incoherence in the laser pulse.[3-5] Such results spurred the adoption of decreasing laser wavelengths for successive generations of facilities as well as various beam smoothing techniques.[6] Investigations with high energy, deep UV lasers will extend this trend and expand the accessible plasma conditions, e.g. higher densities, higher collisional damping, and higher ablation pressure.

Excimer lasers could also provide a significant increase in bandwidth. A potential research program would be to determine if laser plasma instabilities (LPI) may be significantly suppressed when the bandwidth is increased by a large factor over current values (i.e. well beyond the current 1 THz regime). The maximum bandwidth of existing systems can be extended to ~3 THz and it may be possible to use nonlinear effects (e.g. stimulated rotational Raman scattering) to increase the effective output bandwidth further. Along with greater bandwidth, narrow output spectra with a shifted central wavelength can be also be generated in excimer lasers. Bandwidth changes and wavelength shifts can support new studies of SBS and cross-beam energy transfer (CBET). CBET reduces the energy available to drive a target and can spoil the desired spatial uniformity of the focal profile.[7-8] Finally, these systems support a range of experiments by providing pulse shaping (down to ~1 ps long

pulses), highly uniform laser beams (via echelon-free induced spatial incoherence), and flexible choices for focal profile - including dynamic changes in the on-target focal profile during a laser pulse (focal spot zooming).[9-10]

The current limit of very high energy excimer systems is the krypton-fluorine (KrF) system operating at 248 nm. However, the argon-fluorine (ArF) laser operating at 192 nm can easily produce 10's of Joules required for a potential Thomson scattering light source. Thomson scattering is a versatile plasma diagnostic that uses a laser to quantify fluctuations that are related to the electron and ion distribution functions.[11] The observed spectra can record the evolution of instability growth with temporal and spatial resolution. A deep ultraviolet laser would have clear benefits: the probe can penetrate higher density regions, shorter scale fluctuations can be measured, and the observed light may be less contaminated by unwanted light from an experiment's main drive laser. It should be noted that the best current candidate for a deep ultraviolet solid state laser requires fifth harmonic generation (213 nm) and may require substantial materials development to yield a viable high energy system. Components for a 192 nm excimer laser with sufficient energy exist either as commercial products or could be realized as a straightforward extension of established systems operating at 248 nm.

Lastly, an important avenue of research for high energy deep ultraviolet lasers would be to explore new avenues for generation of ultrahigh intensity pulses. Because focal spot sizes generally decrease as the square of the laser wavelength, wavelength reductions can quickly lead to rapid gains in focal intensity. Deep ultraviolet short-pulse lasers would be a significant advance for ultra-high intensity laser research. Current work typically uses chirped pulse amplification at longer wavelengths where further intensity increases may be limited by the use of gratings. High intensity deep ultraviolet lasers could utilize Raman compression either integrated into the amplifier design or to resonantly transfer output power to a shorter duration seed pulse in a tailored target plasma. If the latter case can be explored with the requisite pump laser beams, then use of a plasma medium may yield much higher intensities than could be achieved with optical gratings.[12]

- Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit.

The exploration of laser-plasma interactions driven by deep ultraviolet excimer lasers continues the historic trend to shorter wavelengths, higher bandwidths, and more capable systems. In addition to fundamental studies of critical LPI topics, this research would have a wider impact in plasma science by providing an advanced diagnostic tool and exploring a path to higher laser intensities. The most direct societal benefit of this research is its potential contribution to the realization of fusion energy with laser drivers.

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