5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

High-threshold stimulated Raman side scattering in direct-drive implosions

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Inertial confinement fusion (ICF) utilizes multi-beam lasers to directly or indirectly implode and compress deuterium-tritium fuels to the thermonuclear ignition conditions, leading to sustainable burn for inertial fusion energy. When laser beams propagate through underdense coronal plasmas, laser-plasma instabilities (LPI), such as stimulated Raman scattering (SRS) or two-plasmon decay (TPD) instability, could be resonantly driven via electron plasma waves. These processes will reduce the energy coupling efficiencies. Energetic electrons may also be generated which deleteriously reduce the implosion performance by preheating the fuels prior to the final compression. Apart from the historic investigations back to 1980s, the SRS instability plays a less important role, compared with TPD in most direct-drive ICF experiments. It has been discovered recently that SRS becomes dominant over TPD as the plasma conditions switch from the OMEGA- to NIF-relevant direct-drive parameters. Stimulated Raman side scattering (SRSS) is recognized as one of the major concerns in the research of direct-drive inertial confinement fusion.

In this talk, I will report the experiment results that were performed to investigate the SRSS process in planar direct-drive implosion experiments at ignition-scale driver intensities on targets using four beams of the SG-II upgrade laser facility. Large angles among driver beams were adopted to mitigate the predominant collective backward SRS. Broadband spectra from 550 nm to 650 nm were observed, in larger angular directions than the laser incidence angle on targets, indicating the domination of the side scattering. The time-resolved scattering spectra show that the SRSS thresholds were significantly higher than that of the absolute SRS near the quarter-critical density surface and that of the absolute SRSS at lower densities. Moreover, it varies with different detection angles. The temporal features of the scattered spectra have no dramatic changes for single laser or overlapping beams. This strongly implies that the SRSS threshold is mostly due to the single-beam effect. The nonlinear dependence of the time-integrated SRSS signals on overlapped laser peak intensities up to 3×10^{15} W/cm^2 suggests the importance of collective effects on SRSS growth. To understand the underlying physics of broadband spectrum generation and cutoffs at long and short wavelenths, a series of simulations using radiation-hydrodynamic code FLASH and 2D/3D PIC code EPOCH were performed. The complexity and discrepancy of our findings from previous observations would advance our understandings on laser-plasma instability processes in ignition-scale conditions

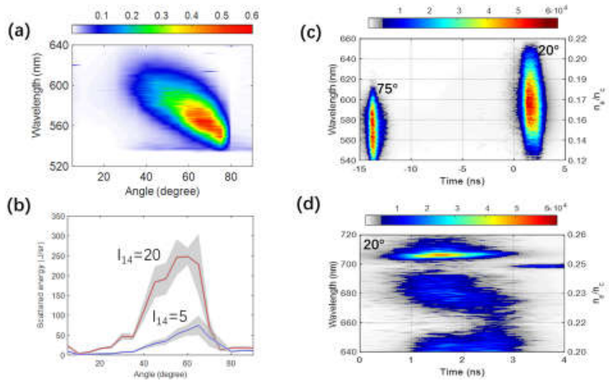

Figure 1 (a) Scattered light angular-spectral distribution of SRS and spectrum-integrated angular profiles for two overlapped laser peak intensity (b). The intensity is unit of 10^{14} W/cm^2. The shaded areas are respective errors due to shot-to-shot variations. Time-resolved scattered spectra measured along 20° and 75° with detection center wavelength of 600 nm (c) and 20° of 680 nm illustrating both TPD and SRSS (d).

References

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