Experimental investigations of laser-plasma instabilities and of mitigation strategies at Shock Ignition laser intensities

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In the context of Inertial Confinement Fusion (ICF), the impact of parametric instabilities is a great concern, because it can significantly deteriorate laser-plasma coupling. The issue is particularly serious in the Shock Ignition (SI) scheme of Direct-Drive approach, where the intensity of the laser spike (~10^{16} W/cm^2) is an order of magnitude higher than in the classical direct-drive scheme. Parametric instabilities as Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS), in fact, can scatter a significant amount of laser energy, increasing the requirements for the laser driver. Moreover, parametric instabilities driving electron plasma waves, as SRS and Two Plasmon Decay (TPD), can produce large fluxes of suprathermal hot electrons (HE), that can preheat the cold fuel preventing the ignition of the fuel.

Despite the large effort devoted to the investigation of parametric instabilities in the last 30 years, the knowledge about their growth in Direct-Drive conditions is still inadequate because of the difficulty of performing full-scale experiments and simulations. In addition, the interaction of laser pulses at SI intensities ~10^{16} W/cm^2 can be significantly different with respect to that obtained in the classical Direct-Drive scheme, because of the higher laser intensity and the strongly non-linear character of the instabilities. Experimental results involving SI intensity with long density scalelength plasmas, for example, revealed a major role played by filamentation and SRS, even in the side-scattering geometry, often neglected in previous experiments. A detailed understanding of these processes therefore calls for experiments carried out in interaction conditions as close as possible to those envisaged in SI, i.e. laser intensities ~10^{16} W/cm^2 impinging on multi-KeV and 100s-μm scalelength plasmas. The final aim of this research is identifying the proper ways to control or mitigate the effects of such instabilities to reach an effective compression and ignition of the fuel.

The present talk will summarize recent experimental results obtained by the Intense Laser Irradiation Laboratory group in campaigns at PALS and VULCAN laser facilities, carried out in the framework of the EuroFusion research program. Experiments were aimed at understanding the role of plasma and laser parameters on the growth of Back SRS, Side SRS and TPD as well as identifying the mechanisms generating HE in conditions relevant for SI.

Results obtained at VULCAN facility and preliminary results of experiments at PHELIX laser at GSI, aimed at investigating the effects of frequency chirp and laser bandwidth, respectively, on laser-plasma interaction will be finally shown and discussed.

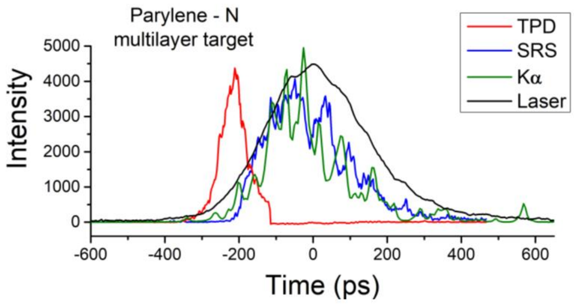

Figure 1: Temporal profile of TPD, SRS and Cu Kα emission, tracing HE, compared to the laser profile, suggesting the dominant role of SRS in HE generation [4].

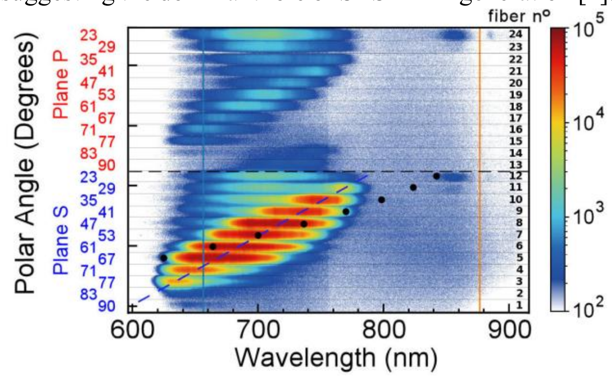

Figure 2: Angular resolved spectra of scattered light in planes parallel (P) and perpendicular (S) to the laser polarization axis, showing the wavelength-angle relation typical of Side-SRS instability [5].

References

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