Advances on Laser-Plasma-Interaction Diagnostics for Inertial Confinement Fusion and Particle Acceleration

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The development of advanced diagnostic techniques is crucial for understanding complex physics at the base of laser-plasma interaction at high energy and intensity. The extreme conditions generated during these experiments, characterized by ultra-intense fields, evolving plasmas, and broadband radiation emission, pose significant challenges for diagnostics, requiring innovative approaches to get measurements useful to interpret the underlying physics and control the interaction process. This is particularly true for example in advanced Direct-Drive (DD) schemes of ICF or in most laser-driven particle acceleration schemes.

In ENEA, we have long historical experience on fusion, laser-generated plasmas and radiation (both electromagnetic emissions and accelerated particles), and related diagnostics. The characterization of laser-generated plasmas and of the associated radiation is a crucial aspect for ongoing research on ICF, laser-plasma acceleration and on application of laser-plasmas to a multidisciplinary range of different areas, such as medical studies and material science. Tailored diagnostics are the key for enabling optimization and control of the laser-plasma interaction mechanisms, since they provide feedback for operating on the development of suitable advanced targets.

This presentation will provide an overview of the main results achieved in recent years by our ENEA group, in collaboration with both national and international research teams, with focus on innovations and specific requirements posed by these particular fields of application. Recent advancements in diagnostic instrumentation and data analysis methods will be discussed. In our work, we paid particular attention to the high repetition rate regime of operation, fundamental for future ICF reactors and particle acceleration facilities, the high sensitivity of the diagnostic instruments and the broad energy range that they are capable of analyzing, important for getting deeper insight in the physics of laser-matter interaction in advanced DD-ICF schemes, like Shock Ignition and Fast Ignition, in particle acceleration schemes and also for the characterization of low-yield laser-triggered nuclear fusion reactions, such as p-^{11}B. These features put these diagnostic methodologies well beyond the state-of-the-art, and enhance their role in advancing the frontiers of plasma physics knowledge, pushing beyond our understanding of plasma processes.