X-ray Spectroscopy of High Energy Density Plasma for Inertial Fusion Energy Development

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X-ray spectroscopy plays a vital role in the development of inertial fusion energy (IFE), particularly in the fast ignition (FI) scheme, where the separation of fuel compression and ignition phases requires precise control and understanding of high energy density (HED) plasmas. Accurate diagnosis of temperature, density, and ionization states in laser-compressed matter is essential for validating implosion symmetry, determining energy coupling efficiency, and optimizing fuel assembly.

This work presents x-ray-based diagnostics techniques developed at the University of Osaka to probe dense plasmas generated by high-power laser systems such as GEKKO XII and LFEX. We employ mid-Z tracer elements and high-sensitivity X-ray spectrometers to capture keV-range emission spectra from heated targets [1, 2, 3]. The observed spectra are analyzed using the atomic kinetics codes FLYCHK and PrismSPECT, allowing quantitative plasma parameter extraction under extreme conditions.

Particular focus is placed on diagnosing preheat, shock timing, and hot spot formation—all critical for fast ignition. We also discuss the application of X-ray diagnostics to solid-core targets with improved resistance to hydrodynamic instabilities and magnetized implosions, where sub-kilotesla-level fields are applied to suppress thermal conduction and enhance confinement.

These diagnostic capabilities support the experimental validation of IFE target designs and serve as feedback to improve hydrodynamic and radiation transport simulations. X-ray spectroscopy is thus a cornerstone of integrated research efforts toward realizing laser fusion energy.

References

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