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The Dawn of Inertial Fusion Energy Research

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The recent demonstration of ignition marks a historic milestone, culminating decades of progress in inertial confinement fusion (ICF). After overcoming immense challenges in implosion symmetry, instability control, and target design, indirectly driven implosions at the National Ignition Facility (NIF) now produce multi-megajoule energy yields from deuterium-tritium plasmas in a single shot—a 2,000-fold increase since NIF's first experiments. However, to realize fusion as an unlimited energy source, we need targets that can be delivered at high repetition rates of 10 Hz with the required nuclear fuel mass and implosion performance to produce target gain of 100. As we transition from proof-of-principle to practical energy generation, a new era of Inertial Fusion Energy (IFE) research is emerging, with national momentum galvanized by new U.S. Department of Energy initiatives such as IFE-STAR and FIRE.

At SLAC National Accelerator Laboratory, we aim to provide the high-precision data needed to design next-generation, high-yield fusion targets. Central to this effort is measuring key material properties, such as the equation of state of compressed nuclear fuel. Using advanced X-ray diagnostic techniques developed at the Linac Coherent Light Source (LCLS), including imaging, scattering, and fluorescence, we probe the structure and evolution of novel IFE target materials, such as foams and cryogenically wetted foams [1]. These experiments, performed at facilities including LCLS, SACLA, OMEGA, and NIF, are enabling measurements with unprecedented spatial, temporal, and spectral resolution, providing essential data needed to design future fusion power plant targets.

References

[1] Martin, W. M., et al. "Characterizing laser-heated polymer foams with simultaneous x-ray fluorescence spectroscopy and Thomson scattering at the Matter in Extreme Conditions Endstation at LCLS." Physics of Plasmas 32.7 (2025).