Panel 5: High Energy Density Matter Crosscut

Ignition implosions access an unprecedented range of high energy density (HED) states. In order to simulate and interpret these implosions a sufficiently accurate and complete set of materials data are needed. This panel will interrogate current models used "in-line" in ICF calculations, and discuss a plan to evolve a next-generation of benchmarked physics models expressly focused on the interpretation of experiments and optimization of future fusion designs. Physics areas include equation of state (EOS), Opacity (local thermodynamic equilibrium, LTE, and non-thermodynamic equilibrium, NLTE), nuclear cross sections, nuclear decay spectra, kinetics, electric and magnetic field generation, and several transport quantities such as thermal conduction, electron-ion equilibration, ion stopping power, and viscosity.

Starting from an ignition hohlraum, ~1.3 MJ of laser energy is converted to 1 MJ of x-ray energy through the collisional absorption of laser energy. Losses include scattered light and the acceleration of non-thermal high-energy electrons produced by laser plasma instabilities (LPI). These **"**hot-electrons**"** can pre-heat the capsule, making ignition more difficult. The detailed spectral dependence of the absorption and emission of x-ray energy requires detailed opacity (LTE and NLTE), equation of state, and electron transport for a wide range of hohlraum states.

The transport of x-ray energy from the hohlraum wall to the capsule results in ~120 KJ of energy at the ablation front. Modeling the absorption and propagation of x-rays through the mix of hohlraum blow off and ablated plasma from the capsule requires LTE and NLTE opacities and EOS's for both pure and mixed regions of materials. Modeling capsule ablation relies on accurate x-ray absorption, re-emission, ionization, and sound speed for matter near the ablation front. These quantities set the ablation velocity which lead to an imploding shell (fuel) kinetic energy of ~20 KJ (12 KJ).

During the early stages of the implosion, the x-ray energy increases with time, driving a series of shock waves through the ablator and into the DT fuel, so as to compress the cold DT to a dense-Fermi-degenerate layer on the interior of the ablator shell and then accelerate the ablator and fuel to peak velocities of near 370 Km/s with the ablator and fuel reaching 10-20 g/cc and ~10 eV. During this phase, the stability of the fuel-ablator interface is set by the density profile of the ablator and fuel, which are set by the x-ray absorption, thermal transport, and equation of state. At stagnation, the hot spot (100 g/cc, 5 KeV) is tuned to a size and density to be able to stop alpha particles (~300 mg/cc). The dense fuel (1kg/cc, 50 eV) (and remaining ablator) is tuned to allow enough inertial confinement time for hotspot initiation and setting up a propagating burn wave. Needless to say, there is not much data to constrain physics models at these conditions. The successful hotspot initiation is a race depending on many transport properties. Thermal transport from the hotspot into the cold fuel, electron-ion equilibration, ion stopping power, nuclear reaction rates, and x-ray emission/absorption.

Of course many other physical processes may be important in correctly optimizing ignition implosions such as ion kinetics, large electric or magnetic fields, viscosity etc. While significant effort was made to ensure that the materials models used in designing ICF capsules were good enough, most remain untested over the full range of extreme conditions accessed by the ICF implosion.

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