Time-resolved mix measurements using γ-ray burn history

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Separated reactant experiments are a powerful technique to diagnose fuel-shell mix in inertial confinement fusion implosions, yet a limitation is that many such experiments use time-integrated total nuclear yields. We have developed a new γ-ray measurement technique for time-resolved measurements of the core and mix burn [1]. In hydrogen-tritium gas filled capsule implosions with a deuterated plastic shell, HT fusion originates from the clean core burn while DT fusion occurs from mix of the shell material into the core. Using gas-filled Cherenkov detectors [2], we have developed a new technique to simultaneously measure both the HT-γ (19.8 MeV) and DT-γ (16.75 MeV) burn histories [3].

This new measurement technique has been used on warm OMEGA implosions. Plastic shells, 9 or 15 um total thickness, with an inner deuterated layer were filled with HT gas and imploded using the OMEGA laser. For the 15um shells, the DT (mix) signal is observed ~60ps after the HT (core) signal, meaning that the mix occurs late in time, likely due to a hydrodynamic mixing process driven by Rayleigh-Taylor instability at the unstable fuel-shell interface during deceleration. In contrast, the 9um thick shells show the DT (mix) burn occurring ~60ps earlier than the HT (core) burn, which cannot be explained by a hydrodynamic mechanism. This data suggests a diffusion-driven or other 'kinetic' mechanism is responsible for the mix in this scenario. Future experiments on OMEGA will explore these two mechanisms. We also discuss preliminary modeling work using a variety of hydrodynamic and diffusive mix models.

Techniques to diagnose mix in implosions are important for our pursuit of higher fusion yields in the laboratory, especially for higher-convergence implosions, whether the mix is caused by hydrodynamic instability at interfaces, induced by capsule defects and engineering features, or arises because of long-mean-free-path ion transport. We present conceptual designs for using this technique on full-scale experiments at the NIF, and also discuss a concept to use the separated reactant technique to measure hot-spot formation in a layered implosion.

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References

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