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Direct measurement of hot electron preheat and its spatial distribution in direct drive implosions[1]

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In laser fusion, a spherical shell of a low-Z ablator (CH, HDC, Be or others) layered with cryogenic DT ice is accelerated inward on a low adiabat to achieve high fusion yields and areal densities with minimal driver energy. Hot electrons generated from laser–plasma instabilities can severely degrade the implosion performance by preheating the DT fuel, resulting in early decompression of the imploding shell and lower fuel areal density. It is shown that, in direct-drive experiments, the hot-electron energy deposited in the DT fuel can be inferred by comparing the hard x-ray signals between a layered DT implosion and its mass-equivalent all-CH implosion. Since a significant fraction of the ice layer is ablated during the implosion, it is important to assess the spatial distribution of the preheat energy into the fuel, in particular within the unablated fuel which determines the final areal density. The spatial distribution of preheat energy was inferred in two experimental campaigns on OMEGA using warm CH targets with Cu-doped plastic payloads of varying thicknesses. The hard x-rays from the Cu-doped plastic implosions were used to infer the hot electron energy deposited in each layer. A hot electron transport and deposition model was derived to match the hard x-ray spectrum and emission in both warm and cryogenic implosion experiments. The calibrated model is used to assess the areal density degradation due to hot electron preheat. A similar experimental campaign on the NIF using Ge-doped shells has led to the inference of the spatial distribution of preheat energy and provided critical information on the scaling of hot electron preheat at megajoule driver energies .

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