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Hot-electron preheat and energy deposition in polar-direct-drive experiments at the National Ignition Facility

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In direct-drive inertial confinement fusion (DDICF), an ensemble of laser pulses symmetrically illuminates a cryogenic capsule of deuterium-tritium fuel encased in a thin outer ablator. Mass ejection of the laser-heated ablator forms a low-density plasma corona, in which laser-plasma instabilities can grow. These instabilities can be detrimental for DDICF by generating high-energy electrons that preheat the fuel.

Planar-target laser–plasma interaction experiments at direct-drive ignition-relevant plasma conditions at the National Ignition Facility (NIF) demonstrated hot-electron production close to the levels that can be tolerable in direct-drive–ignition designs but can still significantly constrain the design space [1]. To assess the extent of hot-electron preheat, polar-direct-drive experiments have been performed at the National Ignition Facility to study the hot-electron energy deposition in an unablated shell. The target consists of an outer plastic ablator and an inner Ge-doped plastic layer. Hot-electron transport and energy deposition in the imploded shell is studied by comparing hard x-ray production between the mass-equivalent plastic and multilayer implosions. The experiments demonstrate how the divergence of hot electrons and the extent to which they slow down in the ablator reduce the preheat. Measurements indicate that 0.33±0.05% of laser energy is deposited in the unablated shell, with 0.13±0.05% deposited in the outer 20% portion and 0.2±0.04% deposited in the inner 80% of the imploding shell. Sensitivity of the hot-electron preheat to the incident laser intensity have been investigated. Recent experiments used a buried 4-μm Si layer in the outer portion of the ablator, designed to pass through the quarter-critical region during the period of hot-electron generation in order to suppress laser-plasma instabilities. Analysis indicates a reduction in hot-electron generation by a factor of ~2, showing promise as a preheat mitigation strategy that can expand the ignition-design space to higher intensity.

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