The Effect of Laser Preheat in Magnetized Liner Inertial Fusion at the Omega Laser Facility

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An important effect in magnetized transport is represented by the Nernst term in Ohm's law that advects magnetic fields down electron temperature gradients.[1–3] This term has been shown to be dominant over the fluid motion in plasmas below the critical density of the preheating laser. It is also possible that magnetic-flux transport in the hot spot is dominated by Nernst advection.[4] The preheat laser can also lead to material from the window or wall of the targets mixing with the fuel region.[5] This summary is focused on modeling the effect of preheat on the dynamics of the fuel in magnetic liner inertial fusion (MagLIF) experiments and the importance of certain terms in the magnetohydrodynamics model, specifically the Nernst effect, as well as the effect of wall material being mixed with the fuel within the capsule. Three-dimensional simulations are used to characterize the effects on yield and implosion characteristics when varying the preheat laser energy.

Three-dimensional radiation-hydrodynamic simulations show there is an optimal laser preheat energy for laser-driven MagLIF on OMEGA, with a 27-T initial magnetic field, resulting in a peak in neutron yield. A similar peak in neutron yield as a function of laser preheat energy was observed in experiments; however, the experimental yield and the optimal laser preheat energy were lower than predicted in simulations. By comparing simulations that do or do not include the Nernst effect, it was found that the Nernst effect is necessary to properly model how laser preheat affects the field dynamics in the fuel region of MagLIF. The drop from the peak in neutron yield with increasing laser preheat energy past the optimal value is larger with the Nernst effect. It is noted that with increasing preheat laser energy, there is less magnetic-field enhancement due to compression and the radial profile of the density becomes less dominated by edge effects.

A 2-D slice of the magnetic field was normalized to the initial seed magnetic field with and without Nernst effect at bang time where the fuel region is outlined. In the case without the Nernst effect, the magnetic field peaks at the radial edge of the fuel region in the center of the z axis. The magnetic field at the edges is convected with the blast wave during the preheat stage, remains at the edge throughout the implosion, and experiences flux compression. In Fig. 1(a) where the simulation includes the Nernst effect, flux compression occurs at the overdriven ends; however, the magnetic field at the center of the z axis has largely been advected out of the fuel region.

Simulations using a mix model show that including mix in implosions leads to yield degradation and can also shift the optimal laser preheat energy to a lower value. The use of premixed region limits the simulation's ability to exactly match the material penetrations occurring in experiments, but gives some insight to the effects of mix. Unlike MagLIF at Sandia National Laboratories, the primary-yield degradation mechanism from mix in MagLIF on OMEGA is not only from radiative losses (since neutron-averaged ion temperatures are not consistently lower between clean simulation and simulations with mix). The added mass from mix lowers the convergence ratios and the Hall parameter across the capsule fuel region, modifying plasma transport coefficients. Simulations also suggest that higher seed magnetic fields available from upcoming generations of MIFEDS (magneto-inertial fusion electrical discharge system) will further enhance yield in D–D cylindrical implosions. A future expanded study

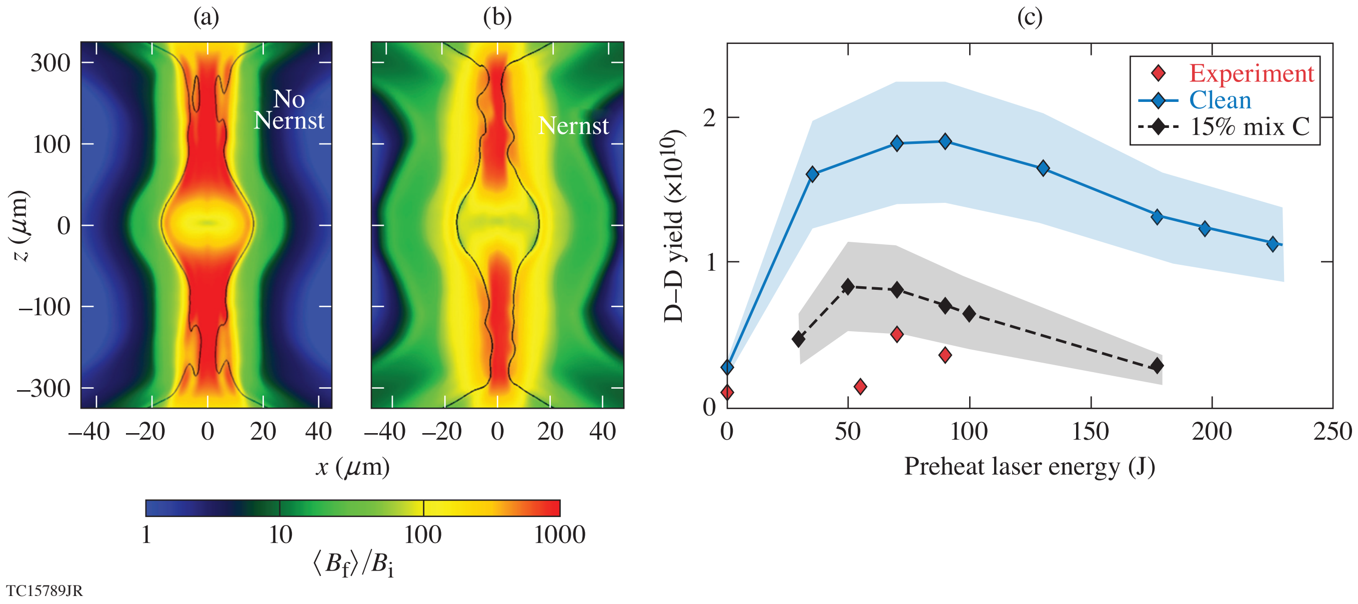

Figure 1
Two-dimensional slice of log scale magnetic-field enhancement (magnetic field over the initial seed field) at bang time for 90-J preheat laser energy and 27-T seed magnetic field from simulations (a) without the Nernst effect and (b) with the Nernst effect where the fuel region is outlined in black. (c) D–D neutron yield over varying preheat laser energies from experiments (red), clean simulations (blue), and simulations mixed with 15% C in the fuel region (black) with 27-T seed field including the Nernst effect.

of the mix effect will be needed to ascertain the degree to which mix products may penetrate the core, as well as its behavior at different preheat laser energies. Simulations can then attempt to model mix nonuniformly to study the impact on transport in the fuel region. As simulations with the mix model see a large drop in yield, they can lead to estimates on when yield degradation from increasing preheat laser energy could impact future experiments.

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