The effects of self-generated magnetic fields on electron divergence

E-beam energy = 15kJ

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Divergence of high-energy electron beams can be controlled through a resistivity mismatch in structured targets

- Controlling divergence of hot electrons using resistivity gradients in structured targets has been proposed by A. P. L. Robinson and M. Sherlock\(^1\)
- LSP simulations of electron collimation in structured targets have been performed for high-energy electron beams
- A thin Cu fiber embedded in Al collimates well a highly-divergent 15-kJ electron beam

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Self-generated resistive magnetic fields can control divergence of electron beams in plasmas.
Simulations of Robinson and Sherlock confirm electron collimation at early times, before the sign of $\nabla \eta$ changes due to target heating.

FIG. 4. (Color online) Rate of magnetic field generation ($T/s$) in run B due to $\nabla \eta \times j$, term (top), and $\eta \nabla \times j$, term (bottom) at 250, 500, and 750 fs.

LSP simulations of magnetic collimation for a high-energy electron beam have been performed.

Electron beam:

\[ I(r) = I_0 \exp\left(-\left(\frac{r}{r_0}\right)^4\right) \]

where

\[ I_0 = 3.4 \times 10^{20} \text{ W/cm}^2, \quad r_0 = 15 \mu\text{m}, \]

duration = 7.5 ps, constant in time, \( E_{\text{total}} = 15 \text{ kJ}, \)

\[ f_\Omega(\theta) = \frac{dN}{d\Omega} = \exp\left[-\left(\frac{\theta}{\theta_0}\right)^2\right] \]

where \( \theta_0 = 67^0 \), exponential energy distribution with \( \langle E \rangle = 2 \text{ MeV} \).

- Smooth transition from Cu to Al in a layer of thickness = 2 \( \mu\text{m} \),

- Radial mesh size \( \Delta r = 0.125 \mu\text{m} \) in the transition region.

- Thomas-Fermi equation of state, Lee & More resistivities, radiative cooling of Cu due to electron bremsstrahlung
Effective magnetic collimation sets up early in the simulation

\[ t = 0.45\text{ps} \]

Plasma-electron temperature (keV)  
Electron-beam density \((\text{cm}^{-3} \times 10^{22})\)

Temperature, log. scale (keV)  
Azimuthal magnetic field (MG)
Electron beam is effectively collimated later in time

$t = 0.9\text{ps}$
Electron beam is effectively collimated at $t = 7\text{ps}$

Electrons collimated in Cu fiber contain $\sim 45\%$ of the beam energy
Magnetic field reaches the maximum value close to the Al side of the transition layer

$t = 7\text{ps}$
Simulations with a resolution $\Delta r = 2 \mu m$ predict somewhat better magnetic collimation.

$\Delta r = 0.125 \mu m$

$t = 7ps$

$\Delta r = 2 \mu m$

45% of the beam energy is collimated

48% of the beam energy is collimated
Divergence of high-energy electron beams can be controlled through a resistivity mismatch in structured targets

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