The Effects of Laser–Plasma Instabilities on Hydro Evolution in Direct-Drive Inertial Confinement Fusion

J. Li
University of Rochester
Laboratory for Laser Energetics

57th Annual Meeting of the American Physical Society Division of Plasma Physics
Savannah, GA
16–20 November 2015
Summary

OSIRIS particle-in-cell (PIC) simulations were performed to obtain a total laser absorption near the $n_c/4$ surface that can be input into the DRACO fluid simulation*

- Laser absorption caused by laser–plasma instability (LPI) is simulated by OSIRIS and then is input to DRACO

- The DRACO simulations show that LPI-induced laser absorption can increase the electron temperature but only slightly changes the density scale length in the corona

---

Collaborators

S. X. Hu and C. Ren
University of Rochester
Laboratory for Laser Energetics
Motivation

Recent PIC simulations* showed an LPI–induced laser absorption of ~15% near the $n_c/4$ surface in typical OMEGA spherical implosions

- It is not known how the 15% absorption of the laser energy near the $n_c/4$ region would change the hydro behavior
- PIC and hydro simulations are coupled together to study this effect

Plasma density profile

$L = 150 \, \mu m$
$T_e = 3 \, keV$
$I = 6 \times 10^{14} \, W/cm^2$

---

An OSIRIS* PIC simulation was used to study the laser absorption near the \(n_c/4\) region for an OMEGA EP long-scale-length experiment.

\[ n_e/n_c = \frac{0.26}{x (\mu m)} \]

\[ V/C = \frac{0.0002}{x (\mu m)} \]

**Plasma and laser conditions near the \(n_c/4\) surface from DRACO**

- \(L = 375 \mu m\)
- \(I = 5.5 \times 10^{14} \text{ W/cm}^2\)
- \(T_e = 2.5 \text{ keV}\)
- \(T_i = 1.5 \text{ keV}\)

\[ \eta = \frac{L \mu \lambda I_{14}}{81.86 T_{\text{keV}}} \] ***

---

Strong pump depletion and a significant amount of forward- and backward-going hot electrons were observed

- The laser energy is depleted by 68% in the simulation box
- The absorbed energy goes to plasma heating (33%) and electrons leaving the box (25% forward and 5% backward)
The energy-balance information is coupled back to DRACO

- The collisional damping of the two-plamon-decay (TPD) plasma waves absorbs 30% of the laser energy between 0.17 $n_c$ and 0.25 $n_c$.
- Hot-electron energy is deposited in the regions with densities above 0.25 $n_c$ and below 0.17 $n_c$ according to their stopping range.
- Hot-electron energy is calculated as follows,* with $f_c$ determined by the PIC simulation ($G_c = 8.7$)

$$G_c = 3 \times 10^{-2} \frac{I_{qc} L_n \lambda_0}{T_e}$$

$$f_{hot} = \begin{cases} 
  f_c (G_c/4)^6, & G_c \leq 4 \\
  f_c (G_c/4)^{1.2}, & G_c > 4 
\end{cases}$$

The LPI-induced laser absorption increases the electron temperature by 100 eV, but only slightly changes the density scale length in the corona.

- The new DRACO simulation raised the electron temperature near the $n_c/4$ surface by 100 eV.

---

*D. Haberberger et al., Phys. Plasmas 21, 056304 (2014).*
The temperature and density profiles are not sensitive to the hot-electron energy

- The simulation results show that the hot-electron energy fraction above 25 keV is ~11% of the incident laser energy, more than the ~2% obtained from the experiment.

- The hot-electron temperature of ~50 keV in the PIC simulation agrees with the experiment.

- The hydro profiles are not sensitive to whether the energy is carried by the hot electrons or the laser.
Summary/Conclusions

*OSIRIS* particle-in-cell (PIC) simulations were performed to obtain a total laser absorption near the $n_c/4$ surface that can be input into the *DRACO* fluid simulation*

- Laser absorption caused by laser–plasma instability (LPI) is simulated by *OSIRIS* and then is input to *DRACO*

- The *DRACO* simulations show that LPI-induced laser absorption can increase the electron temperature but only slightly changes the density scale length in the corona

---