Direct-Drive-Ignition Designs with Gradient-Density Double Shells

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60th Annual Meeting of the American Physical Society
Division of Plasma Physics
Portland, OR
5–9 November 2018
Summary

MJ neutron yield could be possible for direct-drive double-shell implosions with gradient-density shells

- Direct-drive double-shell designs for inertial confinement fusion (ICF) have been performed with the 2-D hydrocode DRACO using the best physics models currently available

- Gradient-density inner shells are found to be essential for igniting a double-shell target in which the outer shell can be driven at a very high adiabat ($\alpha \sim 8$ to 10)

- Our DRACO simulations show that such designs could survive both laser-imprint and classical Rayleigh–Taylor (RT) instability growth, leading to the production of ~MJ neutron yields
Collaborators

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Indirect-drive double-shell designs have been investigated for noncryogenic targets* in the past.

Mixing between the inner shell and DT fuel is always a concern for double-shell targets.

Results of P. Amendt et al. (2002)

*W. S. Varnum et al., Phys. Rev. Lett. 84, 5153 (2000);
P. Amendt, J. D. Colvin et al., Phys. Plasmas 9, 2221 (2002); P. A. Amendt et al., Phys. Rev. Lett. 94, 065004 (2005);
J. Milovich et al., Phys. Plasmas 11, 1552 (2004);
Interest in indirect-drive *cryogenic* double-shell (or multiple-shell) targets has been recently renewed because they may provide an alternative path to ignition.

**Results of D.S. Montgomery et al. (2015)**

- 1.8-MJ laser energy
- 1-D clean yield ~3 MJ (22% burn)
- 1-D fall-line mix ~1 MJ
- 1-D *RAGE* with BHR mix ~0.5 MJ
- 30-μm Ti tamper outside Au improves 1-D performance; Be tamper is also proposed to use for indirect-drive double-shell designs

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†E. Loomis, presented at the 22nd Target Fabrication Meeting, Las Vegas, NV, 12–16 March 2017.

BHR: Besnard–Harlow–Rauenzahn
Recent progress to make gradient-density shells* at General Atomics could significantly help to mitigate the classical Rayleigh–Taylor instability for double-shell target designs.

A density gradient for the inner shell could reduce the Atwood numbers at interfaces for double-shell targets.

High-adiabat ($\alpha \approx 8$ to 10) direct-drive double-shell designs with a gradient-density inner shell were examined using DRACO with comprehensive physics models (NL + CBET + FPEOS).

1-D yield: $\sim 1.8 \times 10^{18}$ (~5.1 MJ)

Direct drive can couple more energy to targets: $E_k$ (outer shell) $\approx$ 90 kJ and $E_k$ (inner shell) $\approx$ 40 kJ.

- CH foam (5 mg/cm$^3$)
- Liquid DT
- Be: 60 $\mu$m
- W-doped Be: 50 $\mu$m (W: 1% $\rightarrow$ 97% $\rightarrow$ 1%)
- TC14474
- High-adiabat ($\alpha \approx 8$ to 10)

$\alpha \approx 8$ ($E_{\text{total}} = 1.9$ MJ)

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**DRACO** simulations with long-wavelength drive nonuniformities (up to $\ell = 50$) have indicated an impact pressure of $P \sim 4$ Gbar when the outer shell stagnates on the inner shell.

Long-wavelength modes have “imprinted” on the imploding inner shell.
The low-mode *DRACO* simulation has resulted in an igniting double-shell target with a neutron yield of \(\sim 3.2\)-MJ energy.

\[ Y \approx 1.14 \times 10^{18} \text{ and } \langle T_i \rangle = 22.9 \text{ keV} \]
Setting the outer shell on high adiabat ($\alpha \approx 8$ to $10$) helps to reduce laser-imprint effects in high-mode \textit{DRACO} simulations (up to $\ell = 150$).

High-mode \textit{DRACO} simulations with laser imprinting are in progress (MJ yield is expected).
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