Design of Scaled Magnetized Liner Inertial Fusion Experiments on OMEGA

<table>
<thead>
<tr>
<th>$B_z$ (T)</th>
<th>$T_{\text{preheat}}$ (eV)</th>
<th>$Y_n \times 10^8$</th>
</tr>
</thead>
<tbody>
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<td>5</td>
</tr>
<tr>
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<td>100</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
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<td>290</td>
</tr>
</tbody>
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P.-Y. Chang  
University of Rochester  
Laboratory for Laser Energetics and Fusion Science Center

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OMEGA MagLIF targets are designed to demonstrate significant yield enhancement with magnetic field and preheated gas

- Scaled magnetized liner inertial fusion (MagLIF) experiments will be conducted on OMEGA
- OMEGA’s high shot rate makes it possible to perform target parameter scans
- OMEGA’s suite of diagnostics enables accurate measurements of the plasma conditions and magnetic fields
- Simulations using LILAC-magnetichydrodynamic (MHD) simulations show that the ion temperature triples and the neutron yield increases 60-fold in OMEGA experiments when a 15-T seed magnetic field and a 100 eV gas preheat are applied
Collaborators

J. R. Davies, D. H. Barnak, G. Fiksel, and R. Betti

University of Rochester
Laboratory for Laser Energetics
and Fusion Science Center

A. J. Harvey-Thompson and D. B. Sinars

Sandia National Laboratories
Significant yield enhancement was observed with an initial seed field and heating prior to the compression in a MagLIF experiment at Sandia National Laboratories.*

OMEGA experiments will test the scaling of MagLIF

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Magnetic-flux compression was demonstrated using cylindrical implosions on OMEGA* and will be used to study the MagLIF concept.

- Field compression in cylindrical implosions have been demonstrated
- Laser preheat will be added to study the physics of the MagLIF concept

The target size is scaled down according to the kinetic energy that can be coupled to the implosion.

Sandia target*

- $L = 7.5 \text{ mm}$
- $\rho = 0.7 \sim 1.5 \text{ mg/cm}^3 \text{ D}_2$
- $B_0 = 10 \text{ T}$
- $\Delta = 465 \mu\text{m Be}$

OMEGA target

- $L = 1 \text{ mm}$
- $\rho = 1 \text{ mg/cm}^3 \text{ D}_2$
- $B_0 = 15 \text{ T}$
- $\Delta = 25 \mu\text{m CH}$

- The Sandia design couples $\sim 1 \text{ MJ cm}^{-1}$ to the liner**
- OMEGA will couple $\sim 0.01 \text{ MJ cm}^{-1}$ to a cylindrical shell

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A cylindrical target will be compressed using 38 OMEGA beams.

- About 12 J of energy is needed to heat the gas to 100 eV
- 38 OMEGA beams using SG2 phase plates deliver 10.4 kJ of energy over a length of 1 mm
LILAC-MHD is used to design the scaled-down MagLIF experiment on OMEGA

- Physics included in LILAC-MHD
  - 1-D resistive MHD
  - Braginskii heat transport
  - flux-limited Nernst effect
- Laser parameters
  - 2.5-ns square pulse
  - Laser energy: 10.4 kJ
- Initial conditions of the target
  - IR = 275 μm
  - Δ = 25 μm CH
  - ρ = 1 mg/cm³ D₂
  - T₀ = 0 ~ 200 eV
  - B₀ = 0 ~ 20 T
The neutron-averaged ion temperature triples if the gas is preheated to 100 eV with a 15-T seed magnetic field.

- The neutron yield with a preheated gas temperature over 50 eV increases with a higher seed field.
- There is a significant ion-temperature increase (3×) and yield enhancement (60×) when the gas is preheated to 100 eV with a 15-T seed magnetic field.

<table>
<thead>
<tr>
<th>$B_0$ (T)</th>
<th>$T_0$ (eV)</th>
<th>$\langle T_i \rangle_n$ (keV)</th>
<th>$Y_n$ ($\times 10^8$)</th>
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</tr>
<tr>
<td>15</td>
<td>100</td>
<td>3.00</td>
<td>290</td>
</tr>
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*Nernst effect is included.
The Nernst effect reduces the central temperature

- Magnetic-field outward advection increases because of the Nernst effect
- The neutron yield is less affected than the ion temperature since the fusion volume is larger; even the peak temperature is lower
Summary/Conclusions

OMEGA MagLIF targets are designed to demonstrate significant yield enhancement with magnetic field and preheated gas temperature

- Scaled magnetized liner inertial fusion (MagLIF) experiments will be conducted on OMEGA
- OMEGA’s high shot rate makes it possible to perform target parameter scans
- OMEGA’s suite of diagnostics enables accurate measurements of the plasma conditions and magnetic fields
- Simulations using LILAC-magnetohydrodynamic (MHD) simulations show that the ion temperature triples and the neutron yield increases 60-fold in OMEGA experiments when a 15-T seed magnetic field and a 100 eV gas preheat are applied
The ion temperature at stagnation is not necessarily higher with higher preheated gas temperature.

• With higher preheated gas temperature, the convergence ratio is lower, leading to higher neutron yield because of the larger hot spot.
The neutron-averaged ion temperature triples if the gas is preheated to 100 eV with a 15-T seed magnetic field.

- Convergence ratio is $\sim 45$
- Implosion velocity is $\sim 167$ km/s
- There is a significant ion-temperature increase ($3\times$) and yield enhancement ($60\times$) when the gas is preheated to 100 eV with a 15-T seed magnetic field.