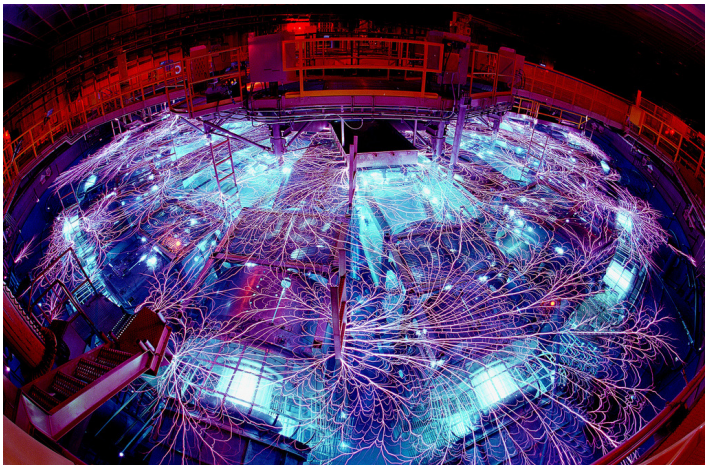
Magneto-Inertial Fusion (MIF)

Magneto-inertial fusion (MIF) needs a credible demonstration of the key physics principles along with validated simulation models in order to be able to adequately assess the prospects for attractive MIF energy production.

SNL and the Laboratory for Laser Energetics at the University of Rochester (LLE) are working collaboratively to investigate the compression and heating of magnetized plasmas at fusion relevant conditions. This work is being conducted through a series of focused experiments based on the MagLIF approach at both SNL and LLE facilities while validating state of the art simulation codes in conjunction with high performance computing for analysis and design. The goal of this work is to not only advance the development of the MagLIF concept, but to advance the understanding of the science of MIF in general.

Magneto-inertial fusion (MIF) has long been proposed as a promising fusion approach using intermediate fuel densities between the lower than atmospheric densities of magnetic confinement fusion (MCF) and the greater than solid densities of inertial confinement fusion (ICF). Both MCF and ICF may be prohibitively expensive to utilize as a fusion energy source in the foreseeable future, even if proven to be successful in the laboratory. By magnetizing the fusion fuel, MIF allows the use of intermediate densities and fusion confinement times that enable relatively low-cost, economically feasible drivers and fuel.

To date, there is relatively little experimental data that validates the key principles of MIF, particularly in fusion relevant plasmas. In late 2013, experiments began on Sandia National Laboratories' (SNL) Z pulsed power facility studying a new MIF approach



The Z accelerator at Sandia National Laboratories where the first integrated MagLIF experiments were performed. Photograph of the Z accelerator firing.

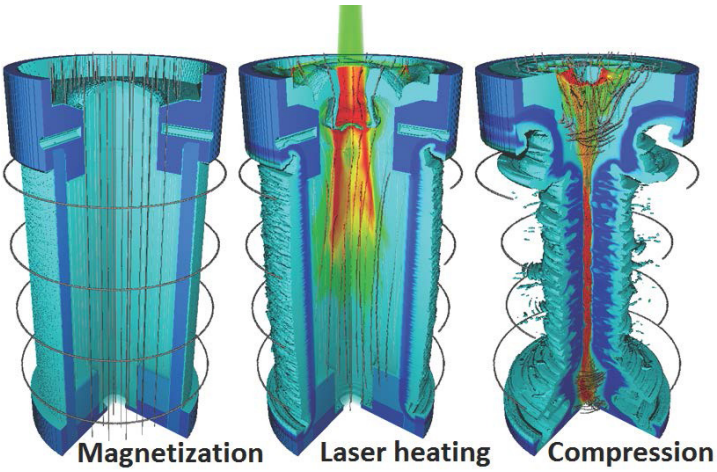
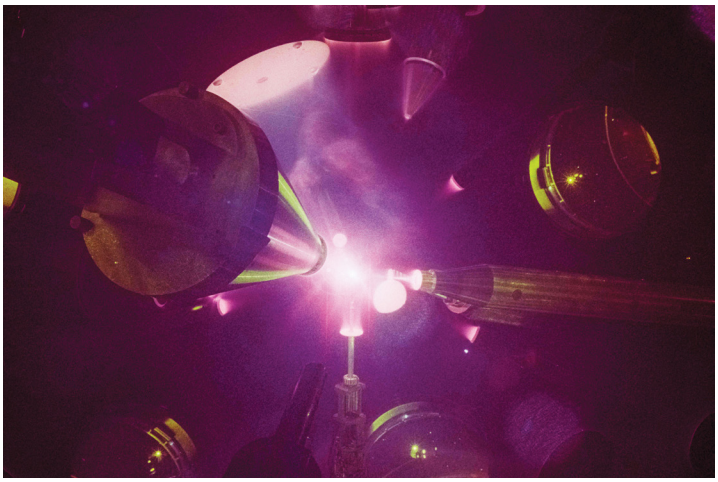


Illustration of the stages of the MagLIF concept on Z. The target is a metal cylinder about 1 cm tall containing fusion fuel (deuterium gas). The entire target is axially magnetized using magnetic field coils (not shown). Then the Z machine applies a current along the axial direction, which creates an azimuthal magnetic field outside the liner and the resulting magnetic pressure begins to compress the liner. Shortly thereafter, a multi-kJ laser pulse from the Z-Beamlet laser is coupled to the fuel through a thin plastic window on one end. This energy is homogenized over the several tens of ns it takes to compress the fuel.

called MagLIF (magnetized liner inertial fusion). These initial experiments showed that a 70 km/s cylindrical liner implosion compressing laser-heated and axially magnetized deuterium (D) gas could produce thermonuclear conditions [1]. Importantly, Deuterium-Tritium (DT) fusion was observed, demonstrating magnetic confinement of the T produced in DD fusion, an essential requirement for successful MIF [2]. While these experiments demonstrated the fundamental physics of MagLIF, we believe their performance was limited by inadequate laser heating. One of the goals of the ALPHA program is to demonstrate improved heating and a quantitative understanding of the optimal initial laser-target parameters for MagLIF.

High fidelity computer simulations predict that yields two orders of magnitude larger are possible within the next three years. If DT were to be used for the fusion fuel instead of DD, simulations suggest fusion yields could exceed the total amount of energy delivered to the fuel (fuel gain > 1). Such an achievement, modeled and understood, would be a clear demonstration of the credibility of MIF as an alternate to ICF and MCF.

MagLIF target on Z being readied to fire



Internal view of the OMEGA Laser's target chamber during a target shot.

[1] M.R. Gomez et al., "Experimental Demonstration of Fusion-Relevant Conditions in Magnetized Liner Inertial Fusion,"Phys. Rev. Lett. 113, 155003 (2014)

[2] P.F. Schmit et al., "Understanding Fuel Magnetization and Mix Using Secondary Nuclear Reactions in Magneto-Inertial Fusion," Phys. Rev. Lett. 113, 155004 (2014)

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