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High Energy Density Science: A New Frontier for Creating Matter Under Extreme Conditions*[1]

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High Energy Density Science (HEDS) spans the extremes of nature and laboratory research, from the interiors of stars and planets to fusion energy. This young field encompasses the interrogation of material properties and physical processes under extreme conditions of temperature, pressure, and magnetic field. HEDS provides a unified approach to understanding the underlying fundamentals of nuclear physics, planetary science, and astrophysics. The central challenge is to understand the rapid transitions between physical regimes upon changes in pressure, temperature, and magnetic field. High power lasers and pulsed power-driven Z-pinches are two tools that are used to create extreme states of matter for applications including thermonuclear fusion, neutron, and x-ray sources. In the case of high power lasers, the basic understanding of the laser energy absorption in the target and particle generation is important. The questions that need to be addressed are; i) what is the role of preplasma on laser energy absorption and particle generation? and ii) how the particle generation could be tailored by modifying the target geometry? In the case of pulsed power-driven Z-pinches, one or more annular shells, or liners, could be used to implode onto a central column or target. As the load implodes, the outer surface becomes susceptible to the magneto-Rayleigh-Taylor instability (MRTI), the mitigation of which is critical to ensure stable and uniform compression and heating for the above-mentioned applications. Two approaches to mitigate the RTI are density profile tailoring and axial pre-magnetization. By altering the initial mass distribution of the load, the implosion trajectory is altered such that acceleration is zero or negative. If there is an axial field pre-embedded in the load, field line tension can act as a restoring force. Details of these approaches will be discussed.

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