Diode-Pumped Solid-State Laser Driver for Inertial Fusion Energy

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Flashlamp-pumped Nd:glass lasers have served as the workhorse driver technology to explore the physics of inertial confinement fusion (ICF), owing to their scalability (>10 kJ/beamline) and flexibility in pulse-shaping. Frequency-conversion to the ultraviolet and spectral bandwidth have been accommodated as well. KrF fusion lasers are also a viable driver option with certain advantages, such as very smooth beams. This paper is confined to a discussion of diode-pumped solid-state lasers (DPSSLs), and their ability to address the requirements of ICF and inertial fusion energy (IFE).

Our DPSSL design for IFE is optimized with two amplifier heads arranged in a four-pass architecture known as the Mercury laser. We have previously activated a single amplifier and achieved an energy of 34 J/pulse single-shot, whilst 23 J/pulse has been demonstrated at 5 Hz operation for ~10^4 shots. These results have validated the functionalities of the very large diode arrays, gas-cooling of the Yb:S-FAP laser crystals, and the laser architecture. Although the risk level is significantly mitigated with this demonstration, additional challenges are needed to activate the second amplifier head. In particular, the Yb:S-FAP slabs must operate at higher damage threshold, and the beam modulation at the "reverser" mirror must be reduced. Our main strategy has been to employ a state-of-the-art polishing method known as magneto-rheological finishing to reach our goals, in addition to implementing several optical design improvements. Activation of the second amplifier is expected to commence within a few months, and last for 6 months (while energy levels are raised from 50 J to 100 J).

Our analysis of a full-aperture beamline suggests that 4 kJ should be attainable. We have been analyzing this system, paying careful attention to the fundamental physics issues that may limit its performance, such as stimulate Raman scattering, nonlinear growth, and amplified spontaneous emission. Solid-state laser drivers require frequency conversion and beam smoothing, and our near- and longer-term plans in this area will be discussed. The current status and future of solid-state lasers will be addressed with respect to the efficiency, smoothness, reliability, and repetition-rate requirements of IFE.

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