High Energy Excimer Laser Technologies for High Yield Inertial Confinement Fusion*

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The NRL Plasma Physics Division was formed in 1966 to serve as the focal point for thermonuclear fusion research. Our current research is focused on the physics of laser direct drive inertial confinement fusion (ICF), especially through the development and use of high-energy excimer lasers. The Nike laser at the NRL has been operating for 20 years [1], produces up to 3 kJ at 248 nm on target, and was the culmination of simultaneous advancements in pulsed power, the production and control of large area high-energy electron beams, and excimer laser physics. Nike has demonstrated the excellent beam smoothing via ISI, the ability to avoid CBET via focal zooming [2], the efficient acceleration of targets to high velocity [3], and the suppression of laser imprint via high-Z layers [4]. KrF could also be a candidate for providing laser preheat on a future MagLIF facility at Sandia National Labs.

Success in igniting and eventually producing high yield from a direct drive ICF implosion will require delivering a megajoule [5] of highly uniform laser energy to a capsule with minimal risk of laser plasma instabilities (LPI), including cross beam energy transfer (CBET). Excimer lasers are attractive candidates for this mission because they have broad bandwidth (>1 THz); good target coupling and decreased LPI growth rates (deep UV); and the gas laser media avoids internal damage and facilitates cooling [6]. A proposed path for a KrF direct drive implosion facility is to develop and demonstrate a 20-kJ amplifier and beamline, which would be the building block of a future high-yield facility (e.g. 1 MJ using 50x20-kJ beamlines). Alternatively, we are beginning to explore the development of ArF (193 nm) because of its potential for higher intrinsic efficiency, high coupling efficiency, and decreased LPI. Inertial fusion energy (IFE) will require repetitive operation at 5-10 Hz. The Electra KrF facility was developed as part of the HAPL Program, has produced up to 700 joules at a 5 Hz repetition rate, and achieved 10^5 shot continuous operations with laser-triggered spark gap switched pulsed power. An all solid-state switched pulsed power module has demonstrated $>10^7$ shot operation. Incorporating solid state switching into Electra and scaling to a 20-kJ module will provide the maturation of full-scale components for a fusion test facility (FTF) [7]. We will also present a pulsed power design to drive an FTF amplifier, based upon well-characterized segmented electron beam diodes and linear transformer driver pulsed power, including the conceptual design of a 25kJ electron beam-pumped ArF amplifier.

References

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