

We-1.

Ion beams - advances in spectral and efficiency control

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As the physical processes controlling the transfer of energy between the driving laser, the intermediate electrons and the ions becomes more fully understood, new methods for controlling the accelerated ion beam become accessible. Here, two optically based techniques will be examined which have the ability to enhance the production efficiency and modify the spectral content of the beam.

In an experiment conducted using the Vulcan Nd:glass laser, pulses of 0.7 ps were directed onto thin Al foils. The spectral content of the ion beam produced from the Al targets was monitored as the laser focal spot size on target was increased from 5 microns to 300 microns. As the spot size is increased the intensity reduces and it is possible to use thinner targets. Generally, the flux of ions increases as the foil thickness decreases until a critical minimum thickness is reached for a given irradiance. This result gives a clear demonstration of the effect of refluxing on the ion beam spectrum and maximum energy. Results showing the scaling and efficiency of this technique will be reviewed.

In a second experiment, a dual pulse drive was used to modify the spectral content of the ion beam. Results showing the sensitivity of this technique to the relative ratio and timing between the two drive pulses will be presented.

We-2.

Inertial Fusion Energy with Krypton Fluoride Lasers

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We are developing the science and technologies needed for a practical fusion energy source using high energy krypton fluoride (KrF) lasers. The physics basis for this work is a family of simulations that exploit the unique advantages of KrF lasers. KrF lasers provide uniform enough laser light to illuminate the capsule directly, greatly improving the laser-target coupling efficiency, as well as simplifying the target design. KrF's shorter wavelength allows higher ablation pressures and helps suppress laser-plasma instabilities. These advantages are being demonstrated on the NRL Nike KrF laser facility. A particularly promising approach is shock ignition, in which a high intensity laser pulse drives an intense shock at peak compression. Simulations with experimentally benchmarked codes predict a 1 MJ KrF laser can produce 200 MJ of pure fusion energy. We have similarly advanced the laser technology. We have developed a KrF laser, using technologies that scale to a reactor beamline, that fires 5 times per second for long duration runs and is projected be efficient enough for a reactor.

The science and the technology for the key components are developed at the same time as part of a coherent system. A multi-institutional team from industry, national labs, and universities has developed credible solutions for these components. This includes methods to fabricate the spherical pellets on mass production basis, a means to repetitively inject the capsules into the chamber and precisely hit them with the laser, scaled tests to develop the laser optics, and designs for the reaction vessel.

Based on these advances NRL and its collaborators have formulated a three stage plan that could lead to practical fusion energy on a much faster time scale than currently believed. Stage I develops full scale components: a laser beam line, target factory and injector, and chamber technologies. Stage II is the Fusion Test Facility (FTF).

Simulations show a 500 kJ, 5 Hz KrF laser and could produce more than 100 MW of fusion power. It would optimize the target physics and demonstrate integration as well as be used to validate materials and sub modules in a fusion environment. It could be operating by 2025. Stage III would be a demonstration power plant based on the FTF, and would probably be led by industry.

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We-3.

Radiation resistance of transmissive optics for IFE reactor chamber and KrF laser driver

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Laser driver of the Inertial Fusion Energy (IFE) power plant should operate at repetition rate of 5–10 Hz uninterruptedly for two years with pulse energy ~1 MJ and overall efficiency ~7%, producing totally ~ 3⁸ 10⁸ pulses [1]. Among present candidates only DPSSL and e-beam-pumped KrF lasers can satisfy these severe conditions [2]. High radiation stability is required for laser and reactor chamber optics suffering from different kinds of ionizing radiation. For instance, cumulative absorbed doses ~1 MGy of hard X-rays in KrF laser or target chamber windows during operation run was shown to reduce their transmittance significantly [3].

We performed comprehensive studies of transient and residual absorption induced in VUV, UV and visible ranges in fused silica glasses Corning 7980, Russian KU-1 and KS-4V, crystals CaF₂, MgF₂, and Al₂O₃, being irradiated at several pulsed facilities by 280-keV e-beam, high-intensity UV laser light, and bremsstrahlung X-rays [4]. Optics response to hard X-ray photons ($h\nu \sim 400$ keV), which are usually generated during e-beam pumping of KrF amplifiers, was measured at a linac-based powerful quasi-CW X-ray source. It allowed X-ray dose rate ~40 Gy/s and amassed doses absorbed in samples volume ~1 MGy [3]. Another test bench rep-rate X-ray source based on high-voltage glow discharge produced average irradiation intensity 2–3 mW/cm² in a 50-Hz train of ~1- μ s pulses with photon energy of $h\nu = 6$ –20 keV. Being absorbed in a thin surface layer it provides dose rates up to 5 Gy/s. Just in the same soft X-ray range there is the most release of an imploding fusion target. Also, at $h\nu \sim 2$ keV characteristic K lines of Ar and Kr (contained in a working gas) make significant contribution into X-ray spectrum illuminating KrF laser windows.

The obtained results show that transient absorption at both 248-nm (KrF) and 353-nm (3 ω DPSSL) wavelengths hardly affect on optics transmission, while residual absorption results in rather high losses especially for UV laser light. Annealing at elevated temperatures should be anticipated, which will reduce color centers formation and keep the initial optics transmission.

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