Contribution ID: **71** Type: **not specified**

The "Nexawatt": A Path to Exawatt Capability Enabled Fusion Laser Technology

Friday, 16 October 2015 16:00 (30 minutes)

Existing high peak power, chirped pulse amplification (CPA) systems are limited by intensity dependent damage of final optics, i.e. intensity-depended damage of final compressor gratings and downstream focusing optics. For kJ-class pulse production these systems are further limited in the amount of energy that can be safely extracted from the laser amplifier by the limited duration of the stretched pulse during amplification. The duration of this pulse is ultimately set by the physical delay that can be produced by the finite size of the compressor gratings. For 1 meter gratings used in the highest energy CPA systems today, this stretched pulse duration is of order 1.5 ns and the extracted energy from the amplifier is less than 1/10th of that potentially available. This presentation will introduce the concept of chirped beam amplification (CBA) and will show how the combination of chirped pulse amplification and chirped beam amplification can be used to effectively create a 20-ns duration pulse prior to amplification and compression and in doing so enable the full extraction of the stored energy from a modern, Nd:Glass laser beam line such as those that are part of the 192 beam, 2MJ, fusion laser system at the National Ignition Facility. Chirped pulse juxtaposed with beam amplification (CPJBA) creates the potential for production of 20 kJ, sub-100-fs pulses from single laser amplifier. The novel compressor architecture required to recompress these chirped beam pulses will be described as well as techniques for creation of diffraction limited output, circumvention of final optics damage and application of these systems to dipole focusing architectures. The "NIF exawatt" or "Nexawatt" architecture requires only existing fabrication technologies and optics operated below established damage limits. This architecture is fully compatible with high efficiency diode-pumped laser architectures that have been developed for laser inertial fusion power plant concepts. Sub-scale versions these fusion energy laser concepts are currently being constructed and demonstrated at the 100's of J scale. Such lasers will ultimately produce from a single amplifier, diffraction-limited, >10 kJ, <100-fs pulses at repetition rates of >10 Hz and with wall plug efficiencies of > 20%. As such, the "Nexawatt" short pulse amplification architecture presents new opportunities for practical extension of laser-wakefield field accelerator schemes to well beyond 100 GeV in a single stage at high overall electrical efficiency.

Summary

This presentation introduces novel short-pulse amplification architectures that enable exawatt-scale pulses from a signal, large-aperture Nd:glass laser amplifier similar to those used in inertial fusion research. These concepts can be further extended to emerging, multi-kJ-scale, diode-pumped laser technologies designed for laser inertial fusion energy power systems and in doing so offer the potential for creation exawatt-scale pulses at >10 Hz repetition rates and with > 20% wall plug efficiency for next-generation, 100-GeV-scale, single stage, laser-wakefield accelerators.

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Session Classification: Frontiers in laser technology

Track Classification: Presentations