High energy and average power laser drivers via large aperture cryogenic composite thin disk method

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***Abstract*—We are constructing chirped-pulse multipass amplifiers capable of delivering high energy (to 1-J) at high repetition rate (to 1-kHz) using liquid nitrogen cooled Yb:YAG gain-elements of composite disk geometry. Recent experimental progress that yielded 160 mJ at 250 Hz will be discussed. The ongoing effort in scaling to 1-J/1-kHz output will be presented.**

OCIS codes: *(140.3280) Laser amplifiers; (140.3538) Lasers, pulsed; (140.3480) Lasers, diode-pumped.*

SUMMARY

The Center for Free Electron Laser Science (CFEL) at the Deutsches Elektronen-Synchrotron (DESY) is chartered to advance science with next generation light sources and lasers. Funded by the ERC, the AXSIS program is a multi-disciplinary 5-year effort to demonstrate a laboratory scale x-ray source. Towards this end CFEL's Ultrafast Optics and X-Rays Division is developing a table-top free-electron laser source (Fig. 1).

The primary photons for the AXSIS machine will stem from ultrafast NIR laser drivers. These lasers have characteristics which are beyond the capability of available commercial equipment. Several hundred mJ will be employed in the production of single cycle and multi-cycle THz pulses in the planned THZ electron-gun and THz-LINACs. A Joule-class NIR laser is also necessary as the optical undulator for the FEL like x-ray source. A repetition rate of 1 kHz is projected to render its usefulness in serial crystallography applications.

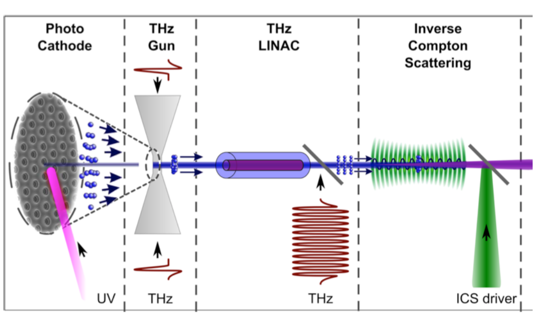

Fig. 1. Schematic of the AXSIS x-ray source

A common thread in the architecture of our laser systems is a cryogenic composite Yb:YAG/YAG thin-disk design that generates high-gain by mitigating the deleterious effect of amplified spontaneous emission (ASE) by diluting and rejecting fluorescence. This enables the operation of a single element within a passively switched, strictly relayed multipass arrangement. In addition, significant engineering leverage is gained by operating at cryogenic temperature resulting in intrinsic several-fold improvements in thermo-optic and thermo-mechanical properties thus diffraction limited output at high average power is attainable without resorting to the complexities of adaptive optics and/or birefringence compensation schemes.

We have demonstrated chirped-pulse amplification of 100x in 12 passes with a first generation device producing 100 mJ output at 250-Hz [1] confirming our performance expectations in a 4-mm aperture. More recently we extracted 160 mJ in 6 passes from the same aperture by injecting 20 mJ. The small signal gain saturation was measured precisely providing clear scaling parameters towards 1-Joule output from a ~20-mm aperture which, we are in the process of building and will discuss at the conference.

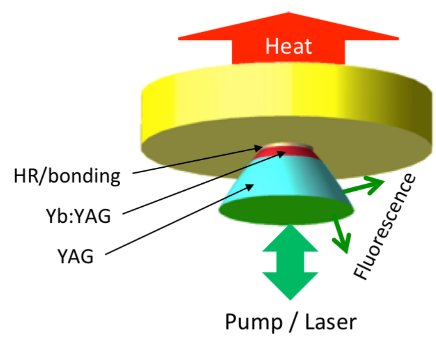

Fig. 2. Scaled 3D model of the composite thin disk tested in [1}. The main elements and basic operational principle are depicted

We also propose a scaling approach towards multi-Joule pulses at multi-kW average powers based on a monolithic array of ASE-limited gain cells.

[1] L. E. Zapata, H. Lin, A.-L. Calendron, H. Cankaya, M. Hemmer, F. Reichert, W. R. Huang, E. Granados, K.-H. Hong, and F. X. Kärtner, Opt. Lett. 40, 2610 (2015)