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Topical Research Conference:
"Research Trends in Laser Matter Interaction 2010"
May 7- 8, 2010
La Jolla, California 92037

KEYNOTE TALK

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Generation and Atmospheric Propagation of High-Average Power IR Free Electron Laser Beams

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Abstract

The free electron laser (FEL) is capable of producing high average power at high efficiency without the thermal management and waste issues associated with other high power laser systems. High-average power IR FELs require, i) high-average current electron injectors capable of generating high-quality electron bunches with a short bunch duration, and ii) high wall-plug efficiency to minimize the size, complexity and cost of the overall system [1]. For high-average power operation the beam injector must generate an electron pulse train with short bunches (~ 50 psec) at a repetition frequency

of ~ 700 MHz, with energies of ~ 5-8 MeV, charge of ~ 1 nC per bunch, transverse emittance of $\varepsilon_n < 15\,\text{mm}-\text{mrad}$, and a bunch radius of $R_b < 0.5\,\text{mm}$. RF-gated gridded thermionic electron guns can provide the necessary bunch parameters. The grid uses a superposition of the fundamental and 3rd harmonic of the rf linac frequency, i.e., 700 MHz and 2.1 GHz to provide shorter bunches and improve the bunch current structure. Simulations of the bunch dynamics, which are fully electromagnetic and include self-field effects, indicate that this approach can provide the appropriate injector beam, i.e., charge per bunch, bunch duration, longitudinal and transverse emittance, bunch radius and repetition rate, for high-average power FELs operating in the IR regime. For directed energy applications, there are a number of advantages in using an optically-guided FEL amplifier configuration. We present analyses and simulations of an optically-guided, tapered high-power FEL amplifier, including finite pulse length effects, slippage, and optical-guiding. The electron trapping efficiency, energy spread of the spent beam, and beam quality of the optical beam (M^2) are evaluated. In a high-average power FEL, the wall-plug efficiency is of critical importance. Upon exiting the wiggler field the electron bunches, which are at ~ 100 MeV, are decelerated in the energy recovery linac, thus recovering most of the kinetic energy of the beam. The wall-plug efficiency for the FEL amplifier is strongly dependent on the energy recovery process. A model for electron beam dynamics in the energy recovery linac is described and applied to the acceleration and deceleration of electron bunches for a tapered FEL amplifier. For the parameters considered, the wall-plug efficiency for the amplifier can be ~ 10%. Finally, we discuss the optimum operating wavelength and beam power for atmospheric propagation. The propagation of high-energy laser beams in the atmosphere is affected by turbulence, molecular/aerosol scattering and absorption and thermal blooming. Thermal blooming can be significantly reduced by choosing a wavelength in the atmospheric transmission window. Full scale atmospheric propagation simulations using HELCAP, including the effects of aerosols, turbulence, and thermal blooming, will be presented.

Acknowledgments: The work was sponsored by ONR and JTO.

[+] *Icarus Research, Inc*

[1] P. Sprangle, J. Peñano, B. Hafizi and I. Ben-Zvi, IEEE-J QE (May, 2010)