Megawatt Power Seeded FEL Amplifier Tunable in the 0.5-9 THz Range

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Abstract— **A high-power, single pass seeded FEL amplifier driven by a photoinjector is being built at the Neptune Laboratory at UCLA. A narrow-band seed pulse in the 0.5-3 THz range is generated by difference-frequency mixing of CO_2 laser lines in a GaAs nonlinear crystal.**

I. INTRODUCTION

FREE-ELECTRON LASERS (FELS) are well established as a versatile source of high-power tunable laser radiation in a wavelength range where other laser sources are scarce. The THz range of the electromagnetic spectrum can be conveniently covered by FELs because the required electron beam parameters are relatively easily met using current technology. Two FEL configurations can provide THz pulses: either an FEL oscillator or a single-pass amplifier. An FEL oscillator requires a few microsecond long electron beam pulse with a low peak current (or a train of subpicosecond pulses synchronized with the cavity round trip time) in combination with a long undulator to reach a high-power level from a self-amplified spontaneous emission (SASE). An alternative to a SASE FEL is a seeded single-pass FEL amplifier which can significantly shorten the undulator length, thus opening the possibility of driving FELs with a short, high peak current beam and achieving very high FEL gain. However, this promising amplification technique has not been studied yet in the THz range.

At the Neptune Laboratory at UCLA we have launched an experimental program with the goal of developing a high-gain, single-pass FEL amplifier seeded in the 0.5-3 THz range. The main objective of the study is to generate multi-megawatt radiation pulses with a duration of 10ps (bandwidth <10%) and tunable in the range of 0.5-9 THz. Here we present results of ongoing efforts towards this goal.

II. RESULTS

A high-gain seeded THz FEL amplifier at UCLA consists of four main subsystems: an RF photoinjector, a THz seed source, a two-stage FEL undulator separated by a chicane and THz diagnostics.

The Neptune S-band photoinjector can provide a 8-14 MeV, 10 ps long (FWHM) electron beam with a peak current up to 100 A. It is proposed to use a difference frequency of two CO_2 laser lines mixed in a nonlinear crystal as a narrow-band seed source. The THz source based on difference frequency generation (DFG) in GaAs was built with an output up to 2 kW of power in the spectral range of 100-500 μm at 1 Hz [1]. This seed pulse will be focused into a waveguide within a planar undulator and potentially amplified to ~10 MW level. Note that even with the step-tunable CO_2 laser pumped source (40 GHz step), the 10 ps amplified THz pulse with a section transform limited bandwidth of ~100 GHz will cover continuosly the entire spectral window mentioned earlier.

The FEL undulator is a planar permanent magnet with a period of 3.3 cm designed in two sections: a 2-m long (60 full periods) and a ~1-m long (30 periods) separated by a chicane. Such a configuration allows to fill the entire range of 0.5-9 THz with a seed source tunable only in the 0.5-3 THz window via the following mechanisms. I) Frequency range 0.5-1.5 THz- a single-pass FEL amplification of ~ 1kW seed in a 2-m long undulator to 2-10 MW power level corresponding to saturation power. 2) Frequency range 1.5-3.0 THz – Optical klystron scheme where the first undulator seeded at the 10-100 W level modulates the electron beam longitudinally, then the electromagnet chicane transforms the energy modulation into a current modulation and the 1-m long undulator-radiator produces MW power pulses. 3) Frequency range 3-9 THz – High Gain Harmonic Generation (HGHG) scheme where a beam modulated at a seed frequency of 1-3 THz will be upconverted to the 3 rd harmonic of the seed in the 1-m long undulator-radiator tuned to 3-9 THz simply by adjusting the gap. Extensive modeling of the processes using 3-D time dependent code GENESIS, which includes the space charge effect, confirmed a multi-MW power output [2]. Currently all magnets are being manufactured and will be installed in 2009. Note that there is no US facility capable of generating narrow-band THz pulses of MW power for high-filed studies.

Table 1. Parameters of the seeded waveguide THz FEL amplifier.

E-beam parameters		Undulator parameters	
Energy	8-14 MeV	Period	3.3 cm
Bunch length	10 ps	Strength	K=2.506
Peak current	40-60 A	Gap	8-20 mm
Beam size	200μm rms	Waveguide	ID=5 mm
Emittance	5-15mm-mrad	Length	2 m +1 m
THz radiation		parameters	
Wavelength		100-600 μm (33-99 at 3ω)	
Seed power		10-1000 W	
Pulse repetition rate		1 Hz	
Amplified THz power		**<10 MW**	
THz pulse length		**10 ps FWHM**	

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