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THE SEED LASER SYSTEM FOR THE PROPOSED VUV FEL FACILITY AT NSRRC

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Abstract

The possibility of establishing a free electron laser (FEL) facility in Taiwan has been a continuing effort at National Synchrotron Radiation Research Center (NSRRC) in the past several years. The Baseline design of the envisioned NSRRC FEL is a high gain harmonic generation (HGHG) FEL seeded by a 266 nm laser. The seed laser is produced by adding an optical parametric amplification (OPA) system pumped by upgrading the existing IR laser system. To provide broad tunability of the FEL radiation, the seed laser will be tunable. The spectrum considered for seeding the FEL is between 266 - 800 nm with peak power of 200 MW. The spatial and temporal overlap between the sub-100 fs electron bunch and the 100 fs UV seed laser is under study.

INTRODUCTION

An FEL facility aimed for VUV and THz radiation is being studied at NSRRC in Taiwan. One unique consideration is to use an existing undulator for the dual functions of the THz radiator and the modulator of an HGHG section. Design emphasizes versatility of operation and beam quality control and compensation of nonlinearities, with an envision that it will allow as much as possible future upgrades as well as later R&D of FEL physics. With the installation of a new 3-GeV storage ring, the Taiwan Photon Source (TPS), it is a good time to renew this effort on the feasibility of an FEL facility.

THE PROPOSED FEL FACILITY

With the existing hardware and the possible upgrades in the limited space, we consider the Baseline design of the envisioned NSRRC FEL as na HGHG FEL seeded by a 266 nm laser to generate the VUV radiation at 66.5 nm which is the 4th harmonic of laser wavelength. A schematic of the overall layout is shown in Fig. 1. The length of the accelerator system from the gun to L_3 exit is 27 m. The length of the diagnostics and FEL stations is 6 m. Including a 4 m $\times$ 5 m experimental area for users, the whole facility tightly fits into the existing 38 m $\times$ 5 m long tunnel in the TPS Linac Test Laboratory.

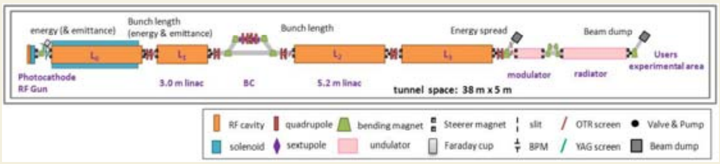

Figure 1: Layout of the proposed FEL facility at NSRRC.

In the HGHG operation, the seed laser interacts with the electron bunch in the 1-m EPU56 modulator to imprint energy modulation on the electron bunch. Through a small chicane, the energy modulation is converted into density modulation. This pre-bunched electron beam will readily radiate coherently in the radiator undulator leading to an exponential growth and reach saturation in its 3-m length as shown in Fig. 2.

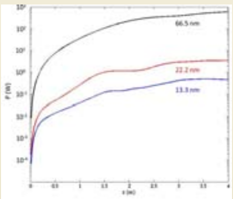

Figure 2: The growth of the radiation power in the undulator. The fundamental (66.5 nm), the 3rd harmonic (22.2 nm), and the 5th harmonic (13.3 nm) radiations are marked as black, red and blue lines, respectively.

The FEL resonant wavelength in the radiator is λ= 66.5 nm, which is the 4th harmonic of the 266-nm seed laser. The saturated peak power near the 2-m position is 200 MW for the fundamental mode and 2 MW and 200 kW respectively for the 3rd and the 5th harmonics. To provide broad tunability of the FEL radiation, the seed laser will be tunable. Linac energy and undulator strength *K* are then adjusted accordingly to maintain FEL resonance. The existing seed laser will be upgraded by adding an OPA system. Radiation with wavelength range between 66.5 – 200 nm and the brightness of 3.3 – 5.7x10^{28} photons/μm^2/0.1% is expected when an appropriate laser system is included. The seed laser with wavelength between 266 – 800 nm with peak power of ~ 100 – 200 MW is adopted in this estimation.

Table1: Estimated beam performance and radiation of the VUV FEL at NSRRC.

Electron beam		VUV radiation	
Energy [MeV]	325	Wavelength [nm]	66.5
Repetition rate [Hz]	10	Peak power [MW]	200
Slice emittance [mm-mrad]	0.8	Gain length [m]	0.17
Bunch length [fs]	51.3	Photons/pulse [10^{13}]	1.1
Peak current [A]	500	Brightness [photons/μm^2/0.1%]	3.34x10^{28}
Slice energy spread [keV]	1.7	Temporal coherence modes	~ 1
		Spatial coherence M^2	~ 2

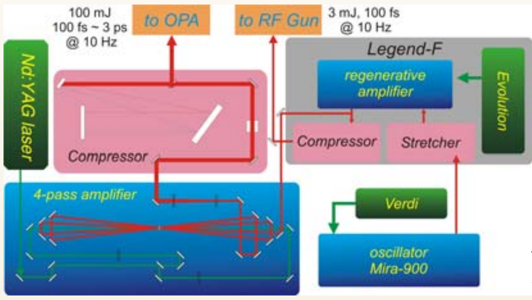

Figure 3: Layout of the upgraded laser system.

THE ULTRAFAST LASER SYSTEM

The ultrafast laser system was purchased from Coherent Corporation and it is a Ti:sapphire laser system based on the chirped-pulse amplification technique. Currently this system consists of an oscillator (Mira-900), a regenerative amplifier (Legend-F), a third harmonic generator (THG), and a UV stretcher. In order to provide sufficient laser energy of the 800-nm laser, which is served as the pump source of the OPA system with high output energy of the UV pulse, we plan to add a 4-pass amplifier to boost the laser energy. Afterward the upgraded laser system will serve the dual functions as the drive laser of the photocathode RF gun and the pump source of the OPA. This 4-pass amplifier will be pumped by a frequency-doubled Q-switched Nd:YAG laser from both ends. This amplifier is made of a 10-mm-long, 1.5-cm diameter, 0.25% doping, normal-cut Ti:sapphire crystal with anti-reflective coating, and seven folding mirrors in a bow-tie configuration. The output energy of the upgraded laser system is expected to be 100 mJ with 100-fs duration after compressed. Figure 3 shows the layout of the upgraded laser system. Table 2 lists the specifications of the upgraded laser system.

Table 2: Specifications of the upgraded laser system.

	for RF gun		for seeding FEL	
	IR	UV	IR	UV
Wavelength	800 nm	266 nm	800 nm	266 nm
Pulse energy	3 mJ	220 μJ (after UV stretcher)	100 mJ	300 μJ (after OPA)
Pulse duration	100 fs	0.8 – 10 ps (ajustable)	0.1 – 3 ps	1.5 ps
Rep. rate	10 Hz			

SYNCHRONIZATION

Synchronization between the laser and the RF system can be carried out by a Synchrolock which was also bought from Coherent. Coherent specifies a time jitter is less than 250 fs RMS when the Synchrolock is used to lock two laser oscillators. Since the oscillator phase noise may have variations, we think the time jitter is < 1 ps RMS when an external RF signal is used to drive the Synchrolock. In order to obtain better synchronization between the UV pulse and the electron beam during seeding process, it is important to lower the time jitter. An optical timing system based on stabilized fiber links has been developed for the LCLS to provide synchronization at the sub-20 fs level. We will improve the time jitter of our system by referring to what has been done at LCLS. We will also plan a full series of measurements to characterize the overall timing stability of the VUV and laser pulses.

CONCLUSION

In this poster, we report the feasibility of building a new light source at NSRRC which delivers the VUV radiation from a 4th harmonic HGHG FEL which will be seeded externally by a tunable laser. The seed laser will be produced by adding an OPA system pumped with the upgraded laser system with a 4-pass amplifier. Installation of the photoinjector system including the beam diagnostics tools and the first linac section is in progress. We expect the upgrade of the laser system will be accomplished in the middle of 2015 and the first lasing of VUV FEL will be in 2016. This FEL facility allows us to pursue a wide range of future possibilities beyond TPS, the newly constructed 3rd generation light source, and it will serve as the foundation for FEL researchers in Taiwan.