CONCEPTUAL DESIGN OF A HIGH BRIGHTNESS AND FULLY COHERENT FREE ELECTRON LASER IN VUV REGIME*

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Abstract

In this paper we propose a new generation light source based on the High Gain Harmonic Generation (HGHG) Free Electron Laser (FEL) for scientific researches. This facility is designed to cover wavelength range from 50 nm to 150 nm with high brightness and full coherence by using the continuously tuning Optical Parametric Amplifier (OPA) seed laser system and variable gap undulators.

INTRODUCTION

The high gain Free Electron Laser has proved to be the most powerful coherent light source from VUV to hard X-ray for its ultra-high brightness, very short pulse length.

High Gain Harmonic Generation (HGHG) is an FEL scheme proposed by Lihua Yu and first successfully demonstrated on the ATF facility[1] in BNL. Compared with another FEL scheme Self Amplified Spontaneous Emission (SASE)[2], HGHG speeds up the micro-bunching process by introducing the modulator and dispersive section. When electron beam goes through the dispersive section, the energy modulation will cause longitudinal density modulation, i.e. electrons are micro-bunched. Micro-bunched electrons will emit coherent synchrotron radiation when passing through magnetic devices. The most important advantages of HGHG is the much better temporal coherence and stability of the output FEL pulse, and the much shorter power saturation length which means the lower manufacture cost[3, 4].

Compared with the conventional optical laser, FEL has better flexibilities in tuning the wavelength and pulse length. According to the resonance equation $\lambda_{FEL} = \lambda_u(1+{a_u}^2)/2\gamma^2$, where λ_{FEL} is the FEL wavelength, λ_u is the period length of undulator, a_u is the normalized undulator parameter, γ is the electron's Lorentz factor[5],different beam energy means different resonant wavelength. While for the conventional approach, it is rather difficult to generate the laser with wavelength shorter than 200 nm. On the other hand, OPA laser system can provide several μJ laser pulse with wavelength range from 240 nm to 360 nm, which, however, is enough for HGHG FEL's seeding requirement.

DCL is such a facility that combines the advantages of HGHG FEL scheme and OPA seed laser system, and can provide powerful, stable FEL radiation with a wide wavelength range in VUV regime, which wavelength can vary from 50 nm to 150 nm.

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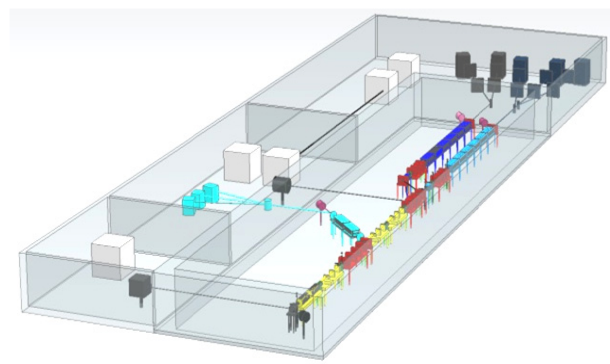

Figure 1: Dalian Cohere Light Source(DCL).

GENERAL CONSIDERATIONS

The layout of DCL (see Fig. 1 and 2) includes a beam injection system, linear accelerator (LINAC) system, undulator system and seed laser system. The detailed parameters can be found from table 1. The injector system and LINAC can provide electron beam with the energy up to 300 MeV, charge up to 500 pC, and the normalized emittance lower than 2 mm·mrad. The undulator system includes the modulator and radiator, with the period length of 50 mm and 25 mm, respectively. The seed laser system is Ti-Sa laser with an OPA system with wavelength range 240- 360 nm, pulse energy up to 10 μJ.

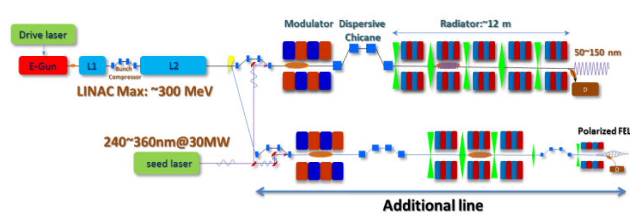

Figure 2: Layout of DCL.

The wavelength control of DCL which is an important feature can be achieved mainly by varying the electron beam energy and seed laser's wavelength as well as the gap of undulators. DCL will use normal room-temperature undulator, in which gap can be varied around nominal value to provide the flexibility of beam controlling. According to the FEL theory, FEL parameter (ρ) determines the final quality of FEL radiation, smaller ρ means shorter undulator length needed for FEL power saturation.

Table 1: Main parameters of DCL

Electron Beam					
Energy	Max: 300 MeV				
Energy Spread	0.001% ~ 0.005%				
Emittance	1 ~ 2 mm·mrad				
Peak Current	100 ~ 500 A				
Charge	100pC ~ 500pC				
Seed Laser					
Wavelength	240 ~ 360 nm				
Peak Power	10 MW/1 MW*				
Pulse Width	130 fs/ 1ps				
Modulator					
Period	5 cm				
Period No.	10				
Radiator					
Period	2.5cm				
Period No.	60 (6 sections in total)				
Dispersive Section					
Bend	150 mm				
Drift	285 mm				
Bfield	400 ~ 1200 Gauss				
Total L_c	2025 mm				
FEL Radiation **					
Pulse Width	130fs / 1ps				
λ[nm]	50	75	100	125	150
W_{FEL} [μJ]	15/55	18/62	25/77	42/80	50/85
Ph.flux [10^{12}]	3/14	7/23	13/39	27/50	38/65

* 10 MW and 1 MW are the seed laser's peak power, which width is 130 fs and 1 ps (FWHM), respectively.

**electron bunch charge is 250 pC, normalized emittance is 2 mm·mrad.

Fig. 3 shows the relationship between the normalized FEL parameter and the undulator's gap. It indicates that the optimized gap value is around 9.3 mm. Fig. 4 shows the FEL amplification output at different positions (simulated by GENESIS [6]). Taking all these into consideration, the radiator with 25 mm period length and 11 mm nominal gap value is chosen.

SUMMARY

The conceptual design of Dalian Coherent Light Source has been done. With the help of OPA laser system and the HGHG FEL principle a novel method of wavelength tunable coherent light source is studied. As a result the DCL is expected to be a high performance coherent light source that can provide FEL radiation with pulse energy more than 100 μJ, photon flux up to the level of 10^{13}. And the last but not the least, such device has the ability to serve the users with 50-150 nm continuously tunable powerful FEL radiation.

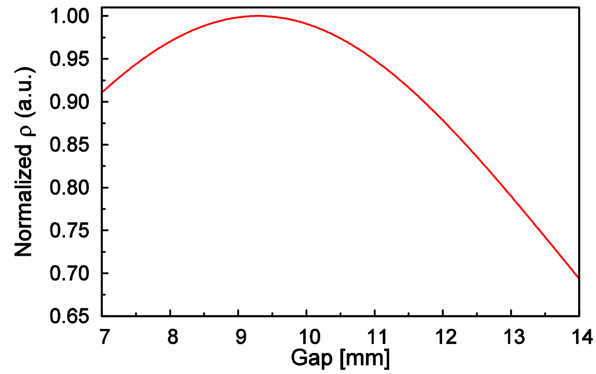

Figure 3: Normalized FEL efficiency vs. the gap of radiator undulators.

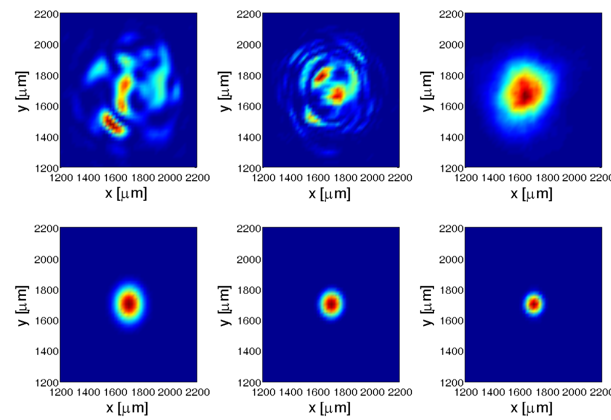

Figure 4: FEL amplification output at different positions, SASE mode (upper) vs. HGHG (lower).

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