DESIGN OF A WAVELENGTH CONTINUOUSLY TUNABLE ULTRAVIOLET COHERENT LIGHT SOURCE*

Tong Zhang, Dong Wang#, Zhentang Zhao, Shanghai Institute of Applied Physics, Shanghai, 201800, China
Xueming Yang, Dalian Institute of Chemical Physics, Dalian 116000, China

Abstract

In this paper a novel FEL-based light sources is proposed. Thanks to the high-gain harmonic generation (HGHG) and optical parametric amplification (OPA) techniques, one can extend the wavelength tunability of the seeded FELs. Numerical simulations show that FEL pulse with energy up to 100 μJ and photon number up to 10^{13} from 50 nm to 150 nm could be achieved.

INTRODUCTION

With the great success of the world's first hard x-ray free-electron laser (FEL), i.e. LCLS [1], scientists now have the ability to investigate the realm with the unprecedented spatial and temporal resolution. Meanwhile, the fully coherent light source, i.e. both transversely and longitudinally, is becoming more and more important and attractive. The seeded FEL approaches (HGHG [2], EEHG [3,4], self-seeding [5]) are known as the effective way to achieve the fully coherent radiation. On the other hand, it is still a dream that the fully coherent radiation can even be wavelength continuously tuneable, although all FELs can be tuned at the full spectral range theoretically.

In this paper, a novel approach based on seeded FEL is proposed to fulfil such kind of requirements, i.e. wavelength tuneable in large spectral range and fully coherence properties. As we all know, FEL based on HGHG principle could be working stably and effectively. The final output FEL radiations inherit the optical properties from the seed laser, e.g. the temporal coherence. And the harmonic up-conversion is the most difference from SASE, which is only bearing the transverse coherence. So with the help of OPA, i.e. change the wavelength of the seed laser at some spectral range, combined with the up-conversion feature of HGHG, one can obtain fully coherence FEL radiation at a continuous spectral range.

In the following sections, we study a specific case based on the abovementioned idea. Dalian Coherence Light source (DCL) is a proposed facility working on HGHG; with the help of OPA seed laser which wavelength can be varied from 240 to 360 nm, DCL can provide the powerful FEL radiation from 50 to 150 nm.

PARAMETERS DESCRIPTION

The layout of DCL (see Fig. 1) includes a beam injection system, linear accelerator (LINAC) system, undulator system and seed laser system. 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, the period length is 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, and it can be tuned at 1 ps pulse length (FWHM) or 130 fs mode, so as to generated FEL pulses with different temporal properties.

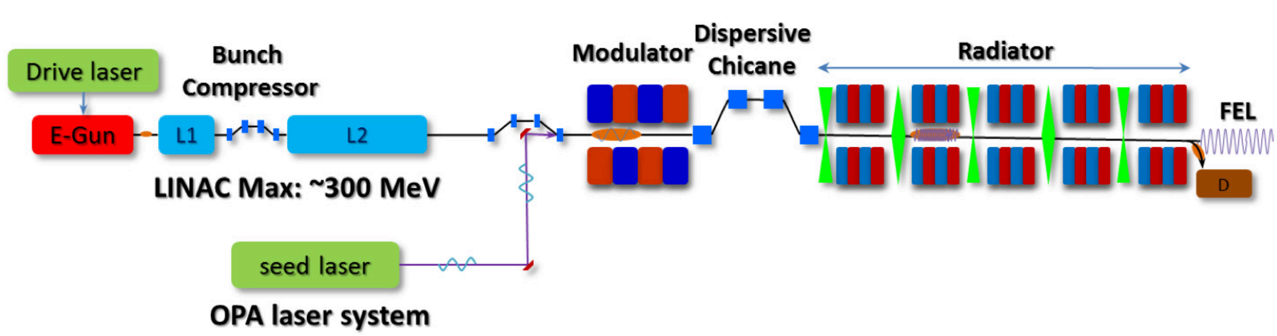

Figure 1: The schematic layout of Dalian coherent light source.

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#wangdong@sinap.ac.cn

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NUMERICAL SIMULATIONS

According to the parameters listed in Table 1, three dimensional numerical simulations have been conducted.

Table 1: Main Parameters of DCL.

Electron Beam	Value	Unit
Energy	≤ 300	MeV
Local Energy Spread	0.001% - 0.005%	-
Peak Current	100 - 500	A
Charge	100 - 500	pC
Seed laser	**Value**	**Unit**
Wavelength	240 - 360	Nm
Peak Power	10	MW
Pulse width (FWHM)	130/1000	Fs
Undulator	**Value**	**Unit**
Modulator Period	5	cm
Radiator Period	2.5	cm

The well benchmarked code, GENESIS [6] is used in the numerical simulations. The simulation results show that, under the conditions with the total electron charge of 250 pC, beam energy varied as required (as Fig. 2 shows), the final output FEL radiation can be tuned from 50 to 150 nm, and the photon number per pulse can be up to 10^{13} (Fig. 3)

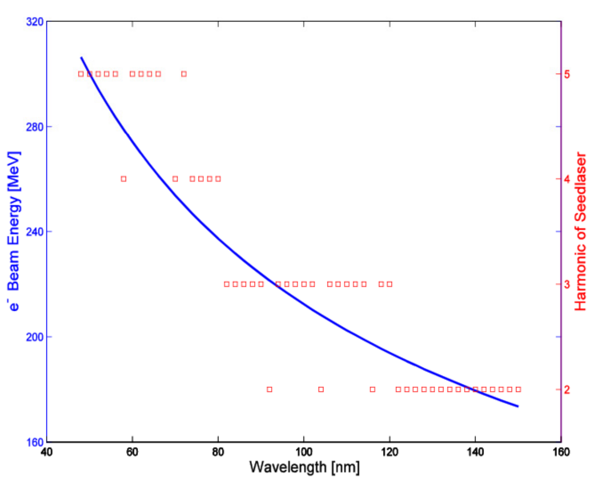

Figure 2: Beam energy tuning with respect to the working wavelength.

It is interesting to put an effect on the cases with the FEL output wavelength around 100 nm, within such spectral the hydrogen atom and methyl radical can be excited more efficiently [7]. When DCL is tuned in such wavelength regime, the beam energy should be changed into 212 MeV and the OPA system should be working on 300 nm with the pulse length of 1 ps (FWHM); and the radiator is tuned at the third harmonic of the seed laser. Figure 4 shows the final simulation results. It is clearly that the FEL radiation shows good temporal coherence and powerful output pulse energy. It is worth to stress that with the undulator tapering technique [8], one could augment the final output pulse energy by a factor of two with no difficulty.

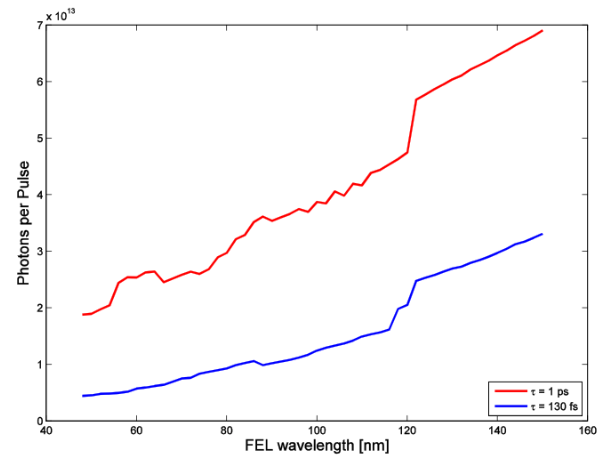

Figure 3: Photon number of FEL pulse.

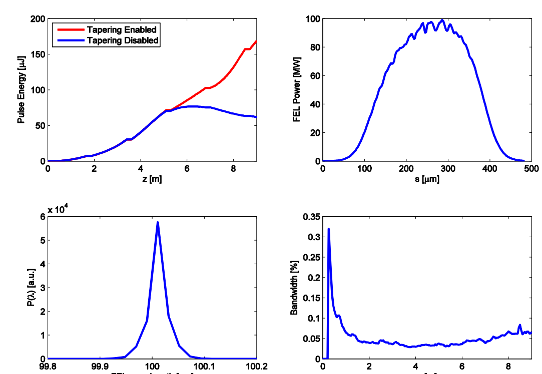

Figure 4: The performance of DCL at 100 nm.

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