SEEDING THE FEL OF THE SCSS PHASE 1 FACILITY WITH THE 13TH LASER HARMONIC OF A TI: SA LASER PRODUCED IN GAS.

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Abstract

A seeding configuration, in which the 13th harmonic (60 nm) of a Ti: Sa laser (50 mJ, 10 Hz, 130 fs) generated in a gas cell is used as the external source, will be tested in 2006 on the SCSS test facility (SPring-8 Compact Sase Source, Japan). This facility is based on a thermionic cathode electron gun (1 nC of bunch charge), a C-band LINAC (5712 MHz, 35 MV/m) and two in-vacuum undulators (15 mm of period). The maximum electron beam energy is 250 MeV and the SASE emission from visible to 60 nm can be obtained. The High order Harmonic Generation (HHG) experiment was mounted off-line at the end of last December. The tests have been performed in Saclay at 266 nm, and 60 nm.

INTRODUCTION

Nowadays, high brightness coherent femtosecond (fs) vacuum-ultraviolet to soft-X ray pulses can be produced from different light sources such as Synchrotron Radiation, Free Electron Laser (FEL), X-Ray Lasers (XRL), laser produced plasma and High-order Harmonic Generated in gases (HHG). Among them, HHG presents remarkable properties, and in particular a full coherence [1, 2].

In the FEL community, these last years, most of the new sources were dedicated to the Self Amplified Spontaneous Emission (SASE) [3], which provides with a very high brightness photon beam at short wavelength but with limited temporal coherence. Recently, seeded FEL at 1.06 µm combined to the generation of coherent harmonics has been demonstrated experimentally in Brookhaven, using the HGHG configuration [4]. Consequently, a few FEL facilities, like ARC-EN-CIEL (Accelerator Radiation Complex for Enhanced Coherent Intense Extended Light) a French proposal for a 4th generation light source [5], have adopted a new configuration: a seeding configuration, in which the HHG beam is injected into a FEL, giving its full coherence property to the emitted radiation. It also reduces the saturation lengths in a more compact source [6]. Moreover, such a seeding experiment with HHG was performed in an XRL [7]. In addition, other SASE projects have decided to implement it on their facility: SCSS phase 1 (SPring-8 Compact Sase Source) [8] and SPARC (Sorgente Pulsata e Amplificata di Radiazione Coerente) [9].

A seeding experiment on the SCSS phase 1 facility [10] is proposed here with a seeding at 60 nm radiation (the 13th harmonic of a Ti: Sa laser) generated in a gas cell. The basic layout of the seeding experiment is given in Figure 1.

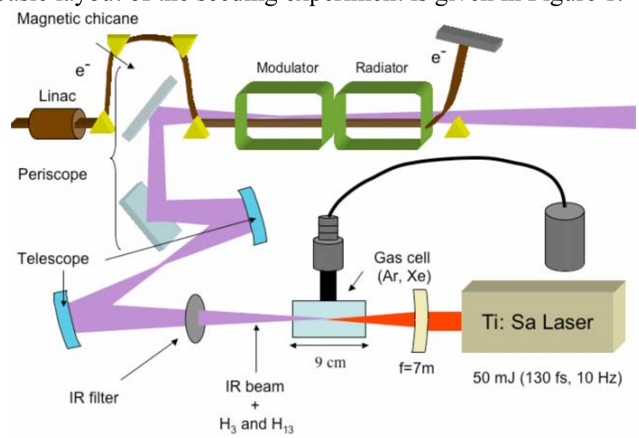


Figure 1: General layout of the seeding experiment with harmonics generated in a gas cell.

CHARACTERISTICS

Table 1 and Table 2 give the characteristics of the SCSS prototype experiment electron beam and undulators. Table 3 presents the Ti: Sa laser and harmonic main optical parameters known or estimated for the seeding experiment.

Table 1: Beam parameters. E is the energy, $\sigma\gamma$ the slice energy spread, τ_e the bunch length, ε the slice emittance, I_P the peak current and β the beta function.

E (MeV)	$\sigma\gamma$ (%)	τ_e rms (fs)	Q (nC)	ε (π mm. mrad)	I_P (kA)	$\beta x/\beta y$ (m)
250	0.004	200	1	1	0.3	4.7/0.5

Table 2: Undulators characteristics: λ_R the resonant wavelength, λ_U the undulator period, K the deflexion parameter, N_P the period number, and N_S the section number

λ_R (mm)	λ_U (mm)	K	N_P	N_S
60	15	1.389	300	1

Table 3: Laser and harmonics characteristics: λ the wavelength, τ the pulse duration, M^2 the Gaussian beam quality factor, P the peak power and Pol the polarization, with V for vertical and H for horizontal.

λ (nm)	E /pulse (mJ)	Rep. rate (Hz)	τ_{FWHM} (fs)	M^2	P (MW)	Pol
750-850	0.5-50	10	130	1.5	4 10^3- 4 10^5	V or H
61.5	10^{-4}- 10^{-3}	10	55	3.5	2-20	H

DESIGN OF THE HHG SYSTEM

The harmonic generation in gas results from the strong non linear polarization induced on the rare gases atoms, such as Ar, Xe, Ne and He, by the focused intense electromagnetic field E_{Laser} of a "pump" laser [11]. In our case, a 7 m focal length lens focuses a Ti: Sa laser in a cell (Figure 2) filled with Xenon or Argon gases, which are well-adapted for the generation of 60 nm radiation. The laser passes through the cell and is aligned by means of two pinholes of 1 mm of diameter, made on a Tantalus plate, which creates a constant leak of gas.

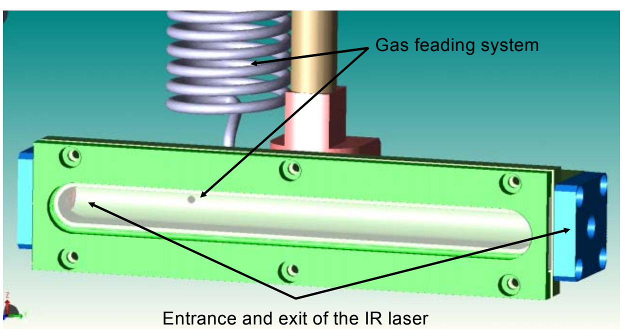


Figure 2: General layout of the HHG system.

The general experiment is based on a system of two chambers (Figure 3), a first one dedicated to HHG (the cell position is motorized for aligning accurately the IR laser and optimizing the harmonic production rate), and a second one (Figure 4) for the adaptation of the harmonic beam at the focusing point in the first undulator by means of two SiC spherical mirrors. A periscope system is used to align the harmonic beam with the e-beam.

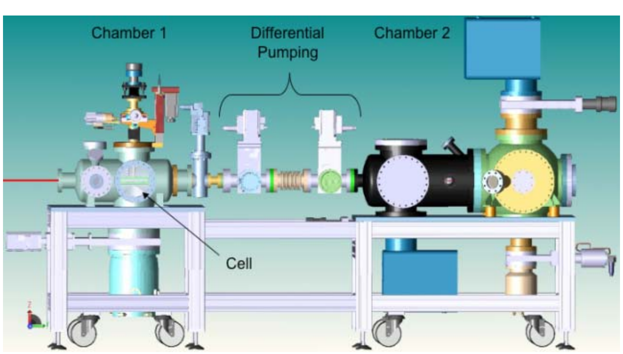


Figure 3: General layout of the HHG system.

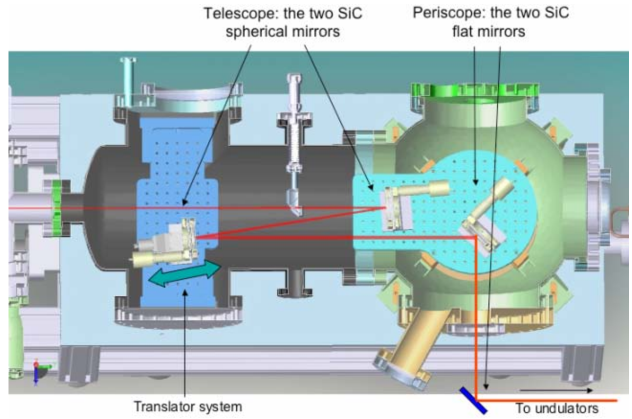


Figure 4: Refocusing system and periscope.

IMPLANTATION ON THE SCSS TEST FACILITY

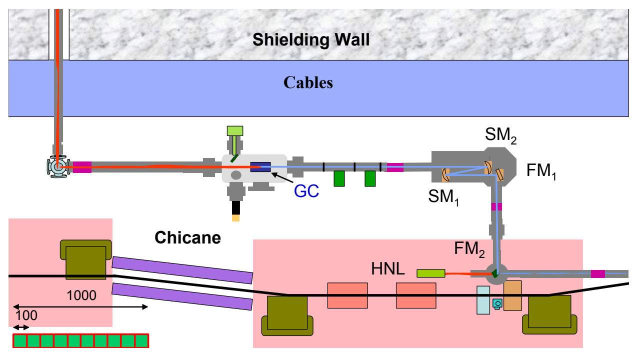


Figure 5: Location for the harmonic generation in gas experiment on the SCSS phase 1 machine. The drawing is at scale (unit: mm).

The harmonic generation experiment will be located in the SCSS phase 1 tunnel, together with the accelerator and the undulators, between the chicane and the shielding wall (Figure 5). The focusing of the intense IR laser comes from the laser hutch, on the opposite side of the shielding wall. On an optical table, the IR beam is adapted for harmonic generation optimization and synchronized with the e-beam.

FIRST HHG TEST RESULTS IN SACLAY

Figure 6 shows the general view of the experiment, in the opposite direction of the Figure 3.

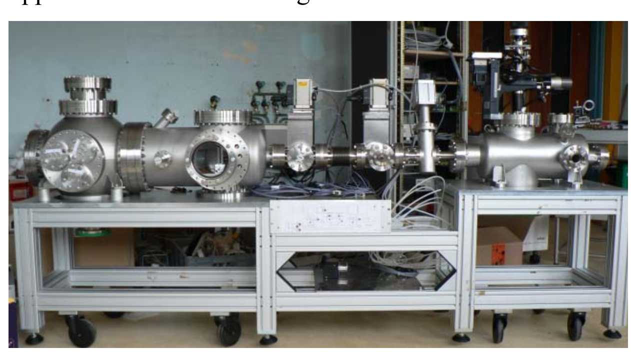


Figure 6: General view of the experiment.

Figure 7 shows the first chamber with the gas cell and the manipulator. The gas is delivered by a very narrow valve aperture in the cell at a pressure of approximately 1 Torr.

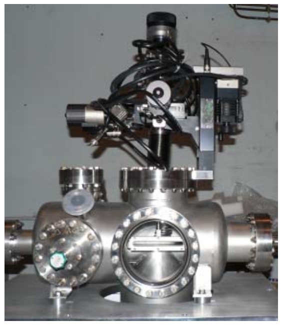
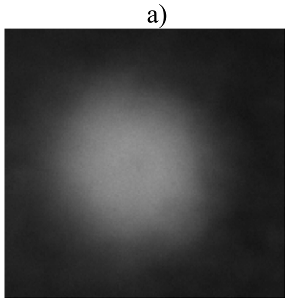


Figure 7: First chamber and harmonic generation cell.

The first tests have been performed in Saclay with the LUCA laser beam (1 to 15 mJ, 20 Hz, 50 fs, 5 m long of focal lens). Figures 8 a and b show the shape of the 13th harmonics observed with a Micro-Channel Plate (MCP, Hamamatsu F2221) and a phosphor screen (P43) associated to a CCD camera and placed after a Sn filter (eliminating the IR laser and selecting especially the 13th harmonics).

a)



b)

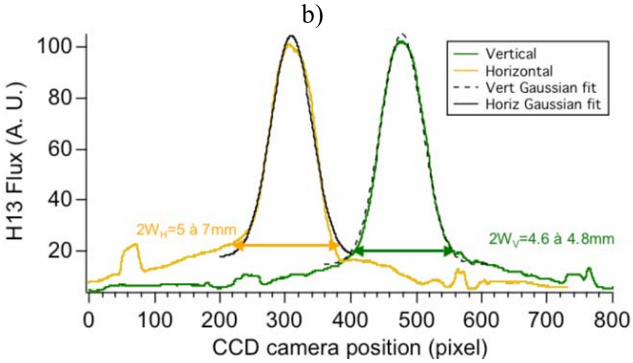


Figure 8: Transverse section (a) and profiles (b) of the 13th harmonics, 3 m after the cell but 8 m before the theoretical focusing point in the first undulator.

The beam section presents some light aberrations particularly visible in the horizontal profile. These one must be really more important in the first undulator, where the interaction occurs with the e-beam (the overlapping can be decreased of 15%), but can be compensated using a toroidal mirror.

The signal can be increased optimizing different parameters such as position of the IR laser focusing point in the cell, energy and pulse duration of the IR laser, gas pressure and type of gas. Figure 9 shows the evolution of the H13 flux and shape as function of the IR laser power from 36 mW to 80 mW. The shape is optimized for an IR power of 53 mW, but not the flux. Above it, the stability is quickly deteriorated. Shape and stability seem to be related.

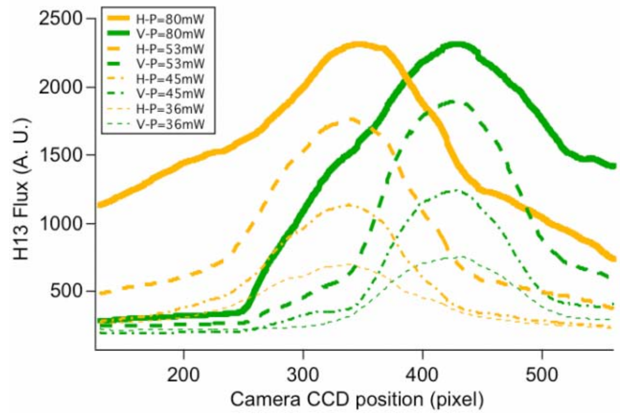


Figure 9: H_{13} beam shape evolution as function of the IR power generated in Xenon gas with the 13 cm long cell. H and V are respectively for Horizontal and Vertical.

CONCLUSIONS

Using state-of-the-art High Order Harmonics in gas for seeding High Gain FEL amplifiers appears very interesting, because the seed radiation is fully coherent and tunable in the VUV-XUV range. From the HHG part, the experiment has been perfectly designed and optimized for producing harmonics. The system of alignment of the Ti: Sa laser, positioning of the cell and optimization of parameters is well adapted for a quick start (around 40 minutes). The behavior of the optical components and of the diagnostics corresponds to what has been expected. The HHG experiment has been send to RIKEN and is now ready for new tests (July 2006) before installing it inside the accelerator tunnel for the seeding experiment (September 2006).

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