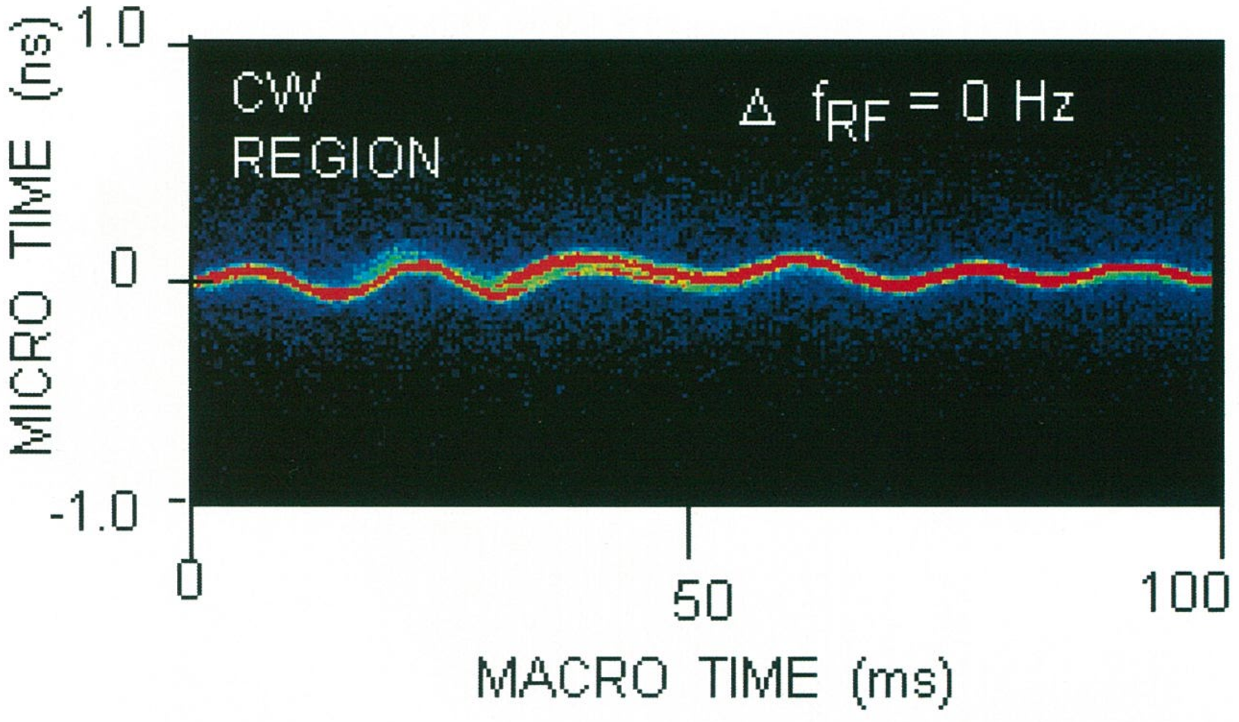

Beam Physics

Performance of the UVSOR-FEL with new optical cavity

Shigeru. KODA, Jun-ichiro YAMAZAKI, Masahito HOSAKA, and Hiroyuki HAMA
UVSOR Facility, Institute for Molecular Science, Myodaiji, Okazaki, 444-8585, Japan

After shutdown due to a conflict between the FEL mirror and the beam line BL5A, an FEL optical cavity and a control system were newly installed in the UVSOR-FEL[1,2]. The optical cavity was designed to reduce mechanical vibration, which is considered to spoil the lasing stability of the FEL. To escape from complicated mechanical resonances, the structure of the mirror chamber was simplified. Number of control axes for the cavity mirrors were reduced from ten axes of the former UVSOR-FEL[3] to five axes. In addition, to decrease mechanical vibrations, marble stones with weight of 2 t were employed as the bases of the optical cavity mirrors.

The first lasing of new FEL system was achieved in May, 1999. The lasing experiment was operated with an electron beam energy of 607 MeV with a maximum beam current of about 50 mA/bunch. An experiment at a visible wavelength of 520 nm was performed in order to check the FEL system and another experiment in the UV region was also carried out at a wavelength of 270 nm. Multi-layered mirrors of HfO_2/SiO_2 were used as the cavity mirror. Measured FEL spectra around 270 nm lasing are shown in Fig 1. The out-coupled power of the FEL was fairly stable in the CW region around the best synchronism between the electron bunch and the FEL micropulse. A measured intensity variation of 520 nm is shown in Fig. 2. The average power was 12 mW for the electron beam current of 30 mA/bunch, which corresponded to an energy of 1 nJ/pulse. Since observed rms width of an FEL micropulse in the CW region was approximately 10 ps, the out-coupled peak power reached at least 40 W. For the 270 nm lasing, a mirror with large transmission of 0.06% was employed for the backward mirror and the averaged lasing power was attained to be 10 mW for the electron beam current of 40 mA/bunch. Detuning dependence for the RF frequency was measured as two-dimensional time spectra by a dual-sweep streak camera. Typical cases are shown in Fig. 3. In a region of the small detuning around the best synchronism, a CW lasing was observed, which is shown as a case of $\Delta f_{RF} = 0$ Hz in Fig. 3. In the region of the large detuning of $\Delta f_{RF}=10$ Hz, a macropulse structure arose. Continuous lasing called quasi-CW was observed in the larger detuning region of $\Delta f_{RF}=100$ Hz. In the former UVSOR-FEL experiment, the lasing around the best synchronism was unstable and it was difficult to maintain the CW lasing [4]. In the new system, the CW region was clearly observed and stable in both points of the micropulse time jitter and the FEL intensity.

In summary, we carried out the FEL experiment with new optical cavity, which had the heavy and simple structure, and measured the lasing performances in visible and UV regions. The lasing stability was especially improved relative to former UVSOR-FEL and the stable lasing was easily maintained in the CW region.

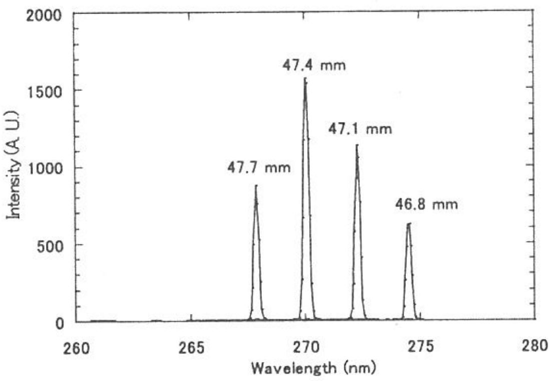

Fig. 1 Typical FEL spectra at wavelengths arround 270 nm for various gap lengths of the helical optical klystron.

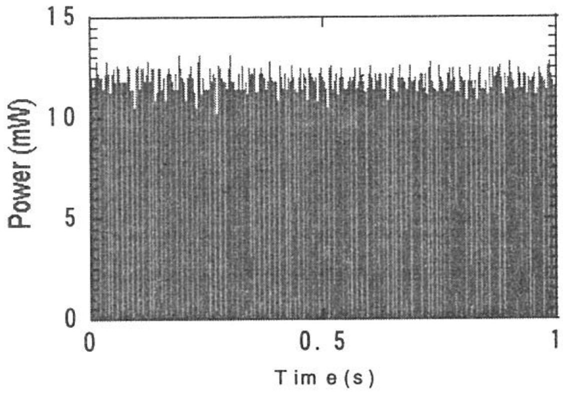

Fig. 2 Typical intensity variation at wavelength of 520 nm.

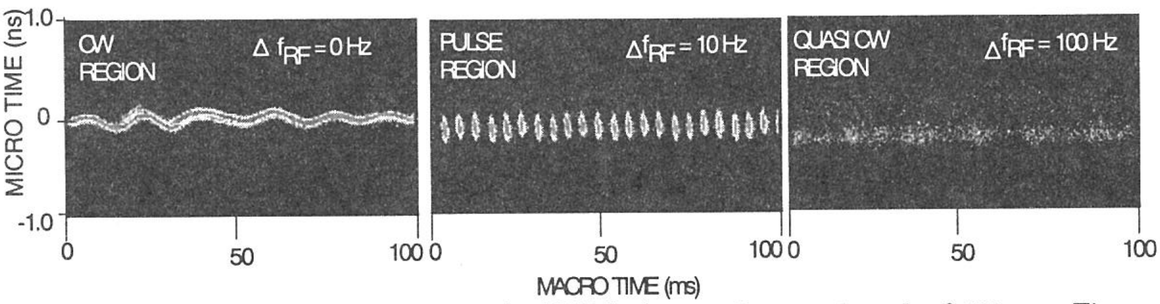

Fig. 3 Typical detuning dependence in the FEL lasing at the wavelength of 520 nm. Time structures of the CW, the pulse and the quasi-CW lasings were observed in order of detuning of the RF frequency. The rf frequency of the best synchronism was 90.101MHz.

References

[1] S. Koda, H. Hama, M. Hosaka, J. Yamazaki and K. Kinoshita, UVSOR Activity Report 1998, UVSOR-26 (1999)

[2] S. Koda, J. Yamazaki, M. Hosaka and H. Hama, Proceedings of 4th Asian Symposium on Free Electron Lasers and Korea-Russia Joint Seminar on High-Power FELs, Taejon, to be published.

[3] S. Takano, H. Hama and G. Isoyama, Nucl. Instr. and Meth. in Phys. Res. A331 (1993) 20.

[4] H. Hama, K. Kimura, M. Hosaka, Yamazaki and T. Kinoshita, Proceedings of the third Asian Symposium on Free electron Lasers, Ionics Publishin, Tokyo (1997) 17.

Development of a longitudinal feedback system for the UVSOR-FEL

Shigeru KODA, Masahito HOSAKA, Jun-ichiro YAMAZAKI and Hiroyuki HAMA
UVSOR Facility, Institute for Molecular Science, Myodaiji, Okazaki 444-0867

Synchronism between an FEL micropulse and an electron bunch is crucial to maintain lasing stability of storage ring FEL. However, in actual lasing, the synchronous condition is continuously disturbed by various factors such as thermal deformation of the optical cavity mirrors due to spontaneous radiation. We are developing a feedback system which corrects an longitudinal length of the optical cavity by changing the storage ring rf frequency. The control accuracy of the time deviation between the micropulse and the bunch has been required to be less than 10 ps that is the temporal width of the FEL micropulse. A phase detection technique was employed as a measurement method of the time deviation. The feedback system based on this method is different from systems developed in other FEL facilities of Super ACO[1] and Duke University[2].

The FEL light signal $f_{FEL}(t)$ and the electron bunch signal $f_e(t)$ can be expanded by harmonics of a round-trip frequency f_0 in the optical cavity as following

$$f_{FEL}(t) = f_0 \sum_{n=-\infty}^{\infty} F_{FEL}(2n\pi f_0) e^{2n\pi f_0 t i},$$

$$f_e(t) = f_0 \sum_{n=-\infty}^{\infty} F_e(2n\pi f_0) e^{2n\pi f_0 t i},$$

where n is a harmonic number and $F_{FEL}(2n\pi f_0)$, $F_e(2n\pi f_0)$ are Fourier transforms for the pulse shapes of an FEL micropulse and an electron bunch with angular frequency $\omega = 2n\pi f_0$, respectively. When the time deviation Δt of the micropulse signal occurred with respect to the electron bunch signal, the phase between the micropulse and the bunch is changed as $\Delta\phi = 2\pi n f_0 \Delta t$ in harmonic number of n. The time deviation Δt can be decided by measuring the phase $\Delta\phi$. The sensitivity for the time deviation is directly proportional to the number n in principle.

The schematic diagram of the feedback system is shown in Fig. 1. Band pass filters extract one harmonic component from signals of the electron bunch and the FEL light. The phase in the harmonic component is measured by a phase detector and then the rf frequency is controlled according to the detected phase. Considering the tradeoff between S/N ratio and the phase angle sensitivity, we measured the phase in a frequency component of 270 MHz, which corresponds to the 24-th harmonic component for the round-trip frequency f_0 of 11.3 MHz.

The flowchart of the feedback is shown in Fig. 2. The phase was converted to an amplitude signal by the phase detector. The signal is sampled by an ADC with sampling rate of 10^3 samples/sec, and an average phase deviation is calculated. When amplitude of the phase deviation exceeds one threshold value $\Delta\theta_{TH}$, the rf frequency is changed by values of $+\Delta f_{rf}$ or

$-\Delta f_{rf}$ to dump the time deviation. In the experiment, the value Δf_{rf} was set to be the minimum step frequency 0.1 Hz of the rf synthesizer. The ratio of $\Delta\theta_{TH} / \Delta f_{rf}$ was chosen to be equal to a measured ratio $\Delta\theta / \Delta f$ of the phase deviation $\Delta\theta$ for change Δf of the rf frequency in the CW lasing region.

The demonstration data of the feedback is shown in Fig. 3. The lines of upper and lower sides are the measured phase and the change of the rf frequency, respectively. The phase deviation of the FEL micropulse for the electron bunch was able to be maintained within range of σ=0.5 deg which means the time deviation of 5 ps.

The synchronism between the FEL micropulse and the electron bunch was successfully stabilized by the feedback system. As a next step, we are considering to develop more practical feedback system with faster response.

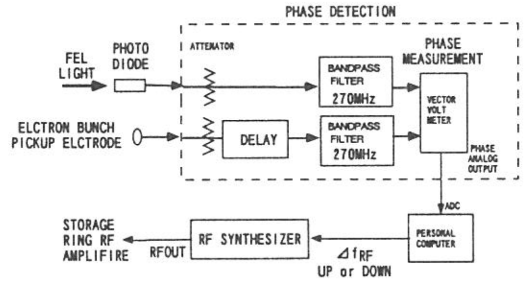

Fig. 1 Outline of the feedback circuit. The system consists roughly of the phase detection and the rf control.

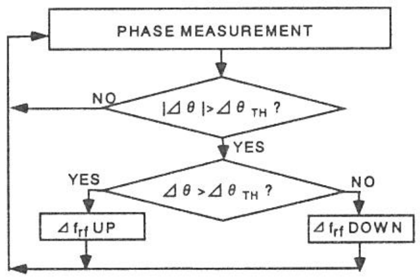

Fig. 2 Flowchart of the feedback program. The program repeats calculation of average phase and control of the rf synthesizer every one sec.

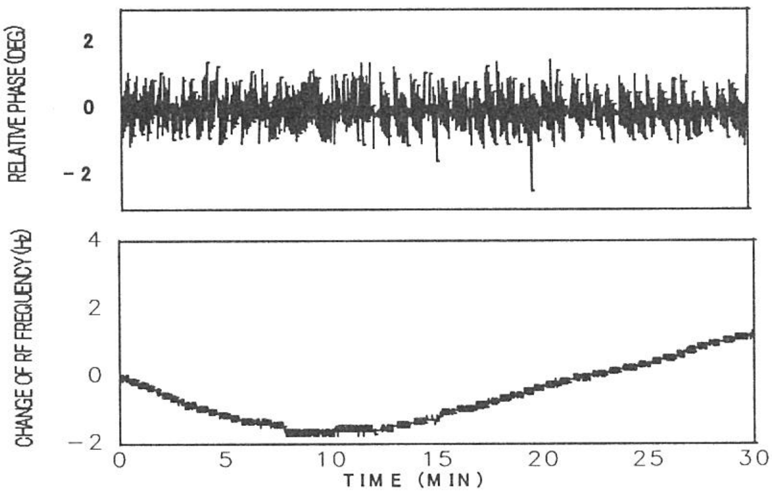

Fig. 3 Demonstration of the feedback operation. Measured phase (upper line) and changed rf frequency (lower line) are shown as a functions of time.

References

[1] M.E. Couprie, D. Garzella, T. Hara, J.H. Codarbox and M. Billardon, Nucl. Instr. and Meth. in Phys. Res. **A358**(1995) 374

[2] V. N. Litvinenko, et al, SPIE **2988**(1997)188