UVSOR

Beam Physics

Improvements of optical resonator and control system in the UVSOR-FEL

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Free Electron Laser (FEL) has been developed in the UVSOR. First lasing of the FEL was achieved in 1993 [1]. The wavelength of 239nm was attained in 1997 [2] and the UVSOR-FEL was temporally shutdown due to interference with development of the beam line BL5A.

As next step of the FEL research, we aim to provide feasibly stable FEL light for user experiments and to study further detailed mechanism of FEL. For the purpose, we are developing new optical resonator and control system. Schematic figure of the FEL system is shown in Fig. 1. The system consists of the resonator, an optical klystron and those control system.

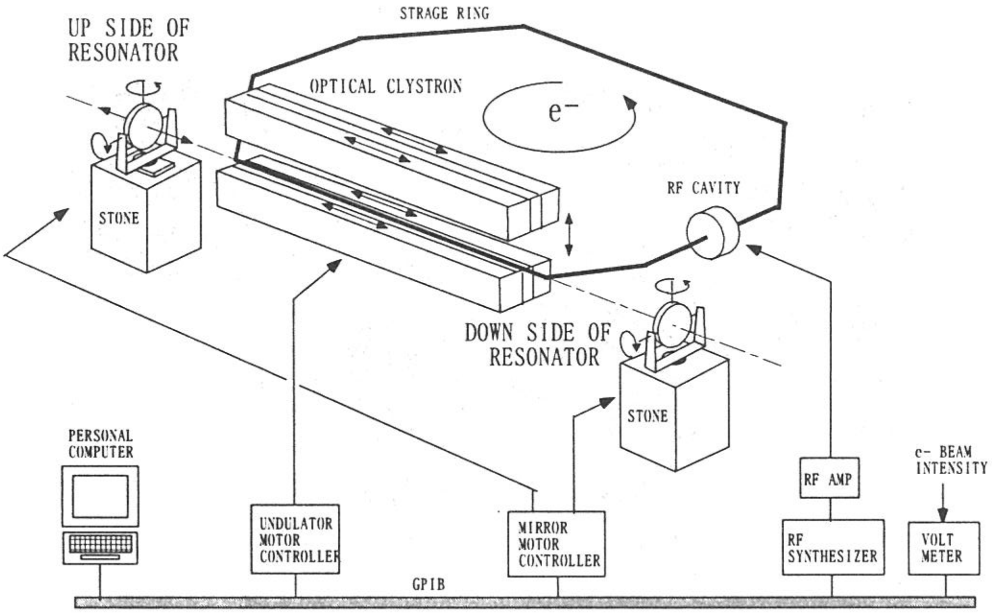

Fig. 1 Schematic view of improved FEL system in UVSOR.

In the development of the resonator, it is important to reduce mechanical movement, which produces directly instability of the FEL. In addition, it is required to be compact to avoid conflicting with the beam line of BL5A. Detail of the resonator is shown in Fig. 2. To escape complicated mechanical resonance and to decrease amplitude of mechanical oscillation, the structure of the resonators is simplified and heavy stones are employed as the resonator base. The control axes of mirrors are reduced from ten axes of an old FEL system to five axes. The bases of the resonator are changed from steel frames of the old FEL system to bulks of stone. The stones are heavy stones with density of 3.0 g/cm^3 . The stone weights of the up and down side in Fig. 2 are values of 2.2 t and 1.7 t, respectively. The stone of the down side in setting is shown in Fig. 4.

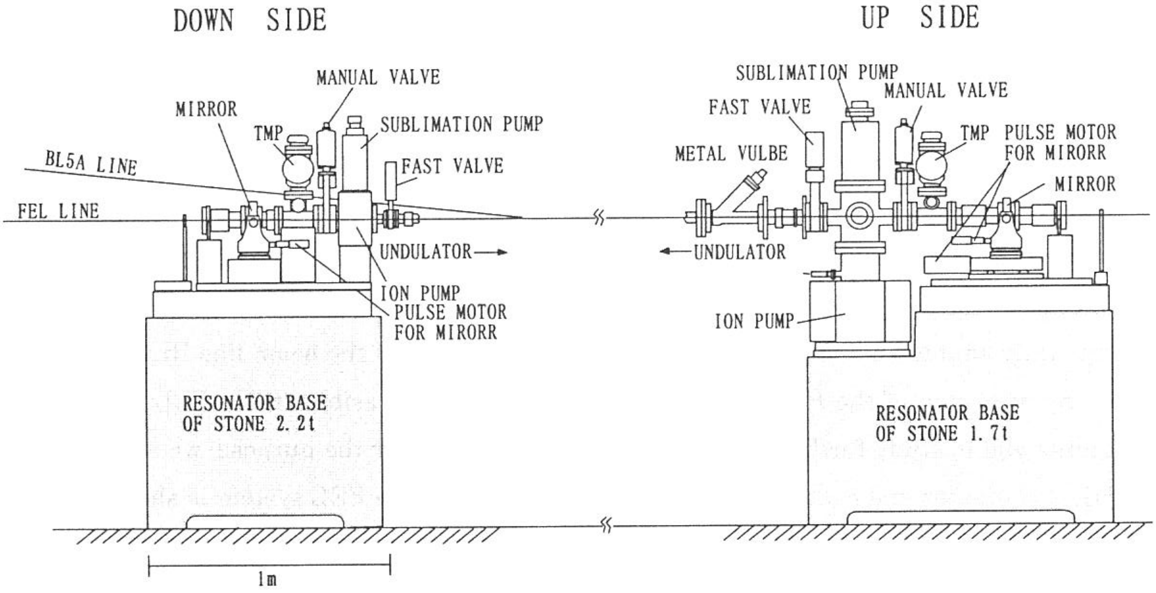

Fig. 3 Detail of FEL resonator.

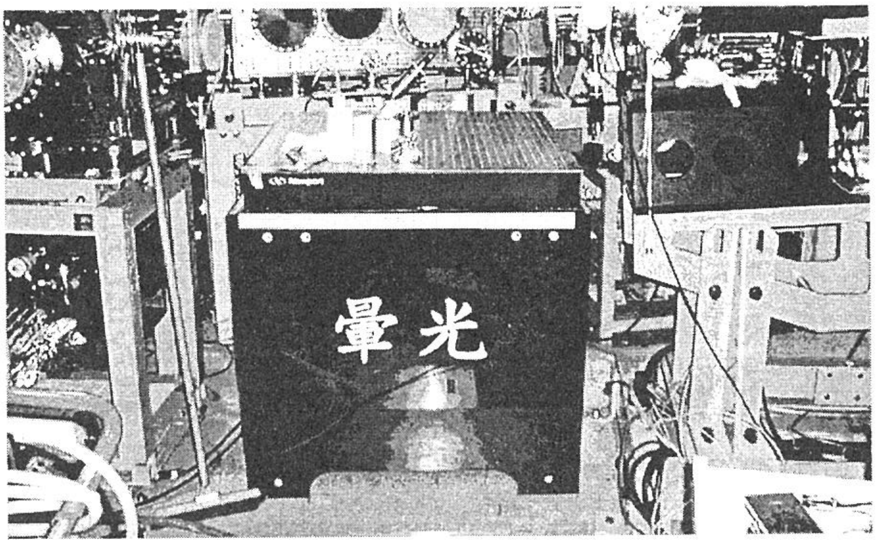

Fig. 4 The resonator base-stone of down side in setting

In development of control system, distributed and individual control of each devices in the old system are concentrated to a personal computer via a GPIB network (Fig. 1). The control system, which works on LabView, is finally going to control and monitor a RF synthesizer for the UVSOR cavity, five motors of the optical klystron, five motors of the resonator mirrors and a digital volt-meter for monitoring e^- beam intensity.

Construction of the resonator has almost completed. The control system is under construction but the system has been partially used for machine study using the optical klystron. First FEL experiment with wavelength of 270nm will be started in May, 1999.

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Measurement of misalignment of quadurupole magnets of the UVSOR storage ring

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In order to improve the performance of the UVSOR storage ring, we are determining a 'golden orbit' in which the electron beam passes through the magnetic center of all the quadruple magnets. In the effort, we have deduced spatial relationships between beam position monitor (BPM) centers and quadrupole centers using a beam based technique.

The basic idea of the measurement comes from so called 'K-modulation' method used in different storage ring laboratories[1]. A beam passing through a quadrupole magnet in a storage ring with a horizontal (or vertical) displacement of x_0 gains a dipole kick of $B = klx_0$, where k and l are the focusing strength and the length of the quadrupole magnet, respectively. When the focusing strength is changed by Δk, the deviation in the i-th BPM is

$$\Delta x_i = \frac{\sqrt{\beta_Q \beta_i}}{2\sin(\pi\nu)} \cos\left(\pi\nu - |\Delta\psi|\right) \cdot l\Delta k x_0, \qquad (1)$$

where β_Q and β_i are the betatron functions in the quadrupole magnet and the i-th BPM, respectively, $\Delta\psi$ is the difference between the betatron phases and ν is the betatron tune. Accordingly, the mean square value of the closed orbit deviations measured by using all BPMs with which the storage ring is equipped is given by

$$\overline{\Delta x^2} = \frac{1}{n}\sum_i^n \Delta x_i^2 \propto x_0^2, \qquad (2)$$

as a function of x_0 where n is the total number of BPMs. If the horizontal difference between the center of the quadrupole and the BPM mounted into it is x_Q, an arbitrary value of x_0^2 is given by $(x_{BPM} - x_Q)^2$ where x_{BPM} is a value of a beam position measured using the BPM. The value of x_Q can be deduced by fitting a parabola to the data points of $\overline{\Delta x^2}$ for different x_{BPM}s.

In the UVSOR storage ring, however, it is not possible to measure x_Q directly, since a BPM is not mounted into each quadrupole but two BPMs are located upstream and downstream of a straight section which consists of 4 quadrupoles (Fig. 2). Then we have developed a modified method of deducing a quadrupole's magnetic center ; we measure a trajectory passing through the center of a quadrupole using the two BPMs located upstream and downstream of it. In a formulation of the transfer matrices method [2] a beam trajectory is described by a position vector $\vec{x} = (x, x')$ where x and x' are a deviation from a reference axis and its divergence angle, respectively. Thus, we can characterize a trajectory as a position vector at the upstream BPM; this position vector is transformed to a position vector at a position of a quadrupole with transfer matrices . We now define the reference axis as the line connecting the center of the upstream BPM and the downstream BPM; displacements of quadrupoles ($x_{Q1}, x_{Q2}, \ldots x_{Qm}$ for the 1-st, the 2-nd, ... the m-th quadrupole) are relative to it. Then a trajectory passing through the j-th quadrupole's center satisfies a relation:

$$x_{Qj} = \left[T_{up\to Qj}\right]_{11} x_{up}(j) + \left[T_{up\to Qj}\right]_{12} x_{up}(j)' + \sum_{i=1}^{j-1} K(i,j), \qquad (3)$$

where $\vec{x}_{up}(j) = (x_{up}(j), x'_{up}(j))$ is the position vector at the upstream BPM, $T_{l\to n}$ denotes transfer matrix from l-position to n-position and $K(i,j) = -\left[T_{Qi+1\to Qj}\left(T_{Qi} - E\right)\right]_{11} x_{Qi}$ is the displacement at the j-th quadrupole position due to misalignment of the i-th quadrupole. The value of $x_{up}(j)$ can be deduced using the upstream BPM and the technique mentioned above. However, the value of $x_{up}(j)'$ can not be deduced directly and we therefore deduce it using the downstream BPM and the following relation:

$$x_{up}(j)' = \left\{ x_{down}(j) - \left[T_{up\to down}\right]_{11} x_{up}(j) - \sum_{i=1}^{m} K(i,m) \right\} / \left[T_{up\to down}\right]_{12}, \qquad (4)$$

where $x_{down}(j)$ is the beam position at the downstream BPM. Consequently, the set of values of x_{Qj} for $j = 1, 2, \ldots, m$ can be obtained solving eq. (3) and (4) for $j = 1, 2, \ldots, m$ simultaneously.

In the UVSOR storage ring, there are 28 quadupole magnets classified into four groups (Q1, Q2, Q3, Q4) and each group has its own power supply. In order to change focusing strength of an individual quadupole magnet, we installed an extra cabling and connected a quadupole magnet to an additional DC power supply. Closed orbit deviations due to the change of the strength of a quadrupole magnet were measured using all BPMs as a functions of the beam position measured using upstream BPM and the downstream BPM and an example is shown in Fig. 1. In figure 2, we present the result of the measurement for one of long straight sections. As seen in the figure, misalignment of the qudrupoles both in the horizontal and the vertical direction are considerably. Consequently, for future improvement of the UVSOR storage ring, accurate realignment of the quadrupole magnets will be necessary.

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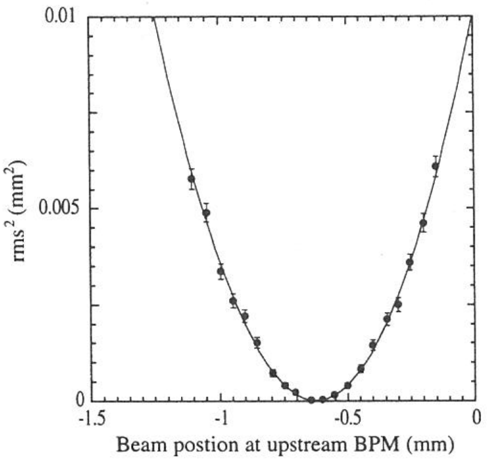

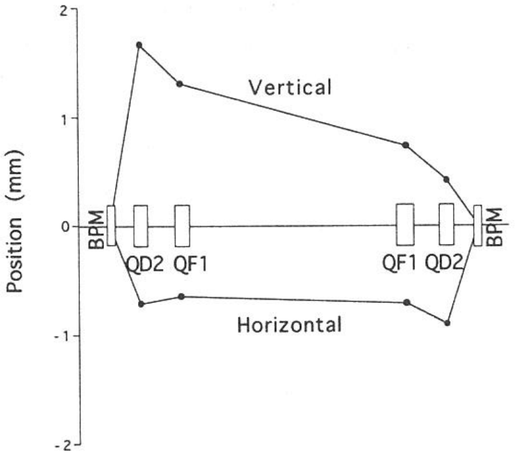

Figure 1 Measured mean square value of the closed orbit deviations due to change of the strength of QF1 as a function of beam positions measured using the upstream BPM. Fitting a parabola to data points , the trajectory passing through the center of QF1 was deduced.

Figure 2 Measured misalignment relative to BPMs in the 3rd long straight section.