

PRESENT STATUS OF THE ELECTRON LINAC AS THE INJECTOR FOR KSR

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Abstract

At Kyoto University, a 300 MeV electron storage ring, KSR, has been constructed for the research of the synchrotron radiation light. As an injector of the ring, an S-band electron linac with the energy of 100 MeV was constructed in October, 1995, and have been operated since then. We measured the transverse emittance of the 100 MeV electron beam using a profile monitor made of a fluorescent screen and quadrupole lenses. The horizontal and vertical ones are 0.44π -mm-mrad and 1.3π -mm-mrad, respectively. The beam from the linac is being used for the experiment of the parametric X-ray radiation from the silicon crystal at rather low duty factor.

1 KSR AND LINAC SYSTEM

1.1 KSR

An electron storage ring, KSR, is under construction at the Nuclear Science Research Facility, Institute for Chemical Research, Kyoto University. This ring will be used for the research with the synchrotron radiation light from bending magnets and an insertion device. It is also planned to be used as a pulse stretcher of the electron beam from the linac. Figure 1 shows the layout of KSR and a Linac. The circumference of the ring is 25 m and

the maximum energy is 300 MeV.

1.2 Linac

As the injector for KSR, the electron linac has been ready for injection. The main parameter is shown in the Table 1.

Table 1 Main parameters of the injector.

| | |
|----------------------------------|--|
| Output beam Energy | 100 MeV (100 mA) |
| Typical current | 100 mA |
| Pulse width | 1 nsec ~ 1 μ sec |
| Maximum repetition | 20Hz |
| Acceleration structure | $2\pi/3$ mode, constant gradient type |
| Length of accelerating structure | 3 m*3 |
| Operation frequency | 2857 MHz |
| Acceleration electric field | 15 MV/m (without beam loading) |

The electron gun has a thermionic cathode with a maximum extraction voltage of -100 kV. The cathode and grid assembly is Y796 (Eimac). The beam pulse width can be changed from 1 ns to 1 μ s. A standing wave reentrant cavity is used as a prebuncher and the resonant frequency is 2857 MHz, which is the same as that of the

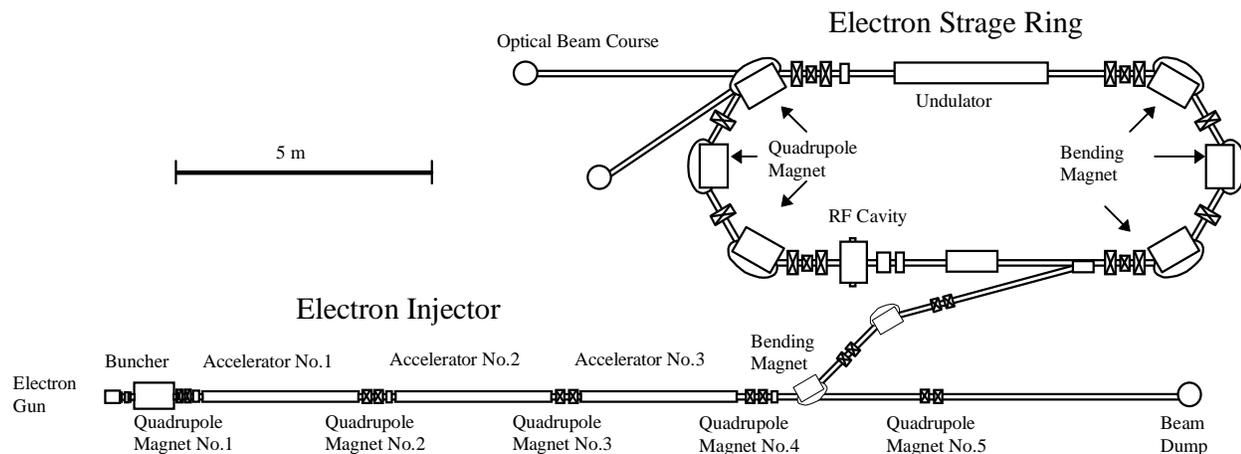


Fig. 1 The layout of the KSR and the injector.

main accelerating structures. A buncher subsequent to the prebuncher is a traveling waveguide with 21 cells. 4 sets of solenoid-focus coils surround the buncher.

The accelerating structure has constant gradient with $2\pi/3$ mode. For the beam focusing, quadrupole lenses are installed in the high energy section. Four ITT-8568 klystrons are used as RF sources for the accelerating structures. The maximum output peak power of these klystrons is 21 MW. Their maximum repetition rate is 21 Hz.

2 EMITTANCE MEASUREMENT

We measured the emittance of the output electron beam from the linac in order to prepare for the beam injection to KSR.

2.1 Basis of the emittance measurement

The transfer matrix M from a point i to another point o , in which there are quadrupole magnet lenses, is given as

$$\begin{pmatrix} x_o \\ x'_o \end{pmatrix} = M \begin{pmatrix} x_i \\ x'_i \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \begin{pmatrix} x_i \\ x'_i \end{pmatrix}, \quad (1)$$

where x is the beam position, and x' means dx/dz .

Using m_{ij} , the twiss parameters is transformed in a following way,

$$\begin{pmatrix} \beta_o \\ \alpha_o \\ \gamma_o \end{pmatrix} = \begin{pmatrix} (m_{11})^2 & -2m_{11}m_{12} & (m_{12})^2 \\ -m_{21}m_{11} & 1 - m_{12}m_{21} & -m_{12}m_{22} \\ (m_{21})^2 & -2m_{22}m_{21} & (m_{22})^2 \end{pmatrix} \begin{pmatrix} \beta_i \\ \alpha_i \\ \gamma_i \end{pmatrix}. \quad (2)$$

If the beam size is measured N times with the various focusing power of the quadrupole magnet, σ and m_{ij} change their values. Let's denote

$$\begin{aligned} (m_{11})^2 &= a_n, \\ -2m_{11}m_{22} &= b_n, \\ (m_{12})^2 &= c_n. \end{aligned} \quad (3)$$

σ_n are expressed in the following way,

$$\begin{pmatrix} \sigma_1^2 \\ \sigma_2^2 \\ \vdots \\ \sigma_N^2 \end{pmatrix} = \begin{pmatrix} \varepsilon\beta_1 \\ \varepsilon\beta_2 \\ \vdots \\ \varepsilon\beta_N \end{pmatrix} = \begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ \vdots & \vdots & \vdots \\ a_N & b_N & c_N \end{pmatrix} \begin{pmatrix} \varepsilon\beta_i \\ \varepsilon\alpha_i \\ \varepsilon\gamma_i \end{pmatrix}. \quad (4)$$

The following formula (6) defines Q .

$$Q = \sum_{k=1}^N \left\{ \varepsilon\beta_k - (a_k\varepsilon\beta_i + b_k\varepsilon\alpha_i + c_k\varepsilon\gamma_i) \right\}^2. \quad (5)$$

The $\varepsilon\beta_i$, $\varepsilon\alpha_i$ and $\varepsilon\gamma_i$ are decided by the least square method with minimizing the Q .

From the relation of,

$$\beta \cdot \gamma - \alpha^2 = 1, \quad (6)$$

ε_k is derived as following,

$$\varepsilon = \sqrt{\varepsilon\beta_i \cdot \varepsilon\gamma_i - (\varepsilon\alpha_i)^2}. \quad (7)$$

2.2 Measurement and result

The fluorescent screen made of aluminum oxide (Al_2O_3) doped with chromium oxide was installed on the beam line at the downstream of the quadrupole magnets. The magnets QD4, QF4 is located at the downstream of the accelerator No.3. Figure 2 shows the layout of the experimental setup. The fluorescence from this screen is observed with a CCD camera through a surface mirror. The image data was taken into the computer through the video image freezer.

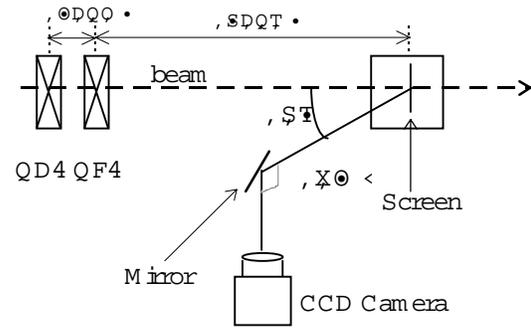


Fig. 2 Experimental setup layout

The image data were projected on the horizontal and the vertical planes. Because it can be assumed that a beam has a gaussian distribution, the least square method was applied. The function form used is given as follows.

$$f(x) = a \cdot \exp\left(-\frac{(x-b)^2}{2\sigma^2}\right) + c, \quad (8)$$

where a , b , c and σ are fitting parameters. The standard deviation of gauss distribution is used as the beam size.

Figure 3 (a) and (b) show the square of beam size as a function of the field gradient of the quadrupole magnet lens. The solid lines show the fitting curves calculated by least square method using eq. (5).

The emittances at the exit of the linac are measured as 0.44π -mm-mrad in the horizontal direction, and 1.3π -mm-mrad in the vertical direction. The Twiss parameters are listed in the Table 2.

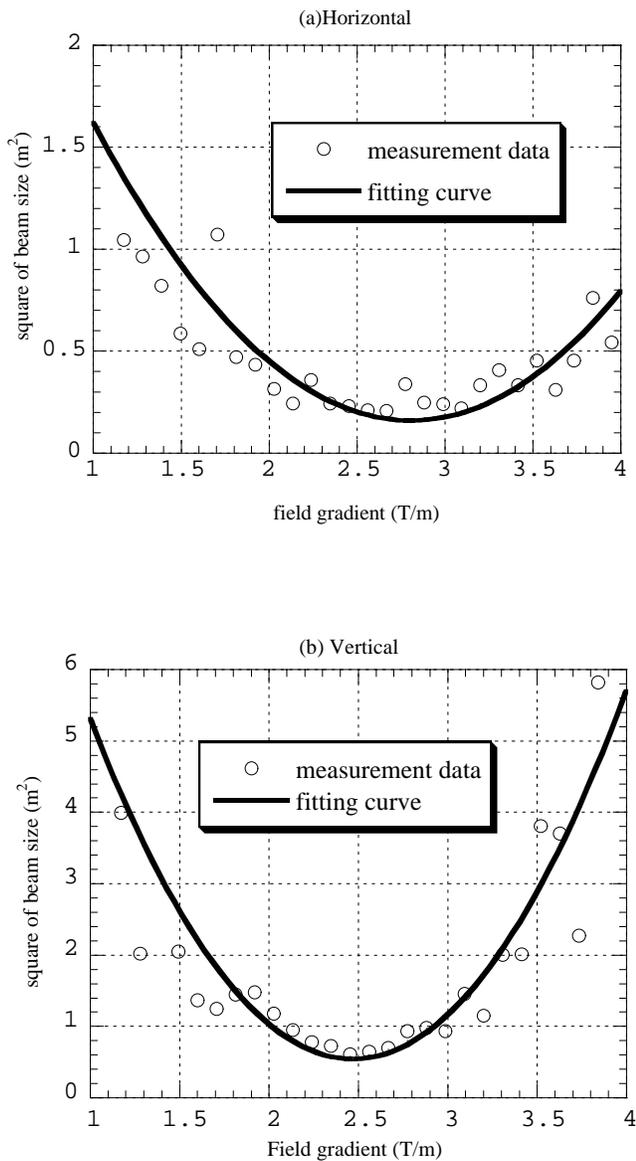


Fig. 3 Square of beam size in horizontal direction (a) and vertical direction (b). Markers show the measured data and a line shows a fitting curve.

Table 2. The measured twiss parameters.

| | β (m) | α | γ (1/m) |
|------------|-------------|----------|----------------|
| Horizontal | 3.3 | -0.79 | 0.49 |
| Vertical | 5.5 | -0.72 | 0.27 |

2.3 Discussion

In KSR the maximum of vertical Beta function and the mechanical aperture are 27 m and 36 mm, respectively. So the beam from the linac can be accepted

by the KSR in vertical direction to say nothing of the horizontal.

Asymmetry in the horizontal and vertical emittance at the exit of linac suggests existence of alignment error of quadrupole magnet lenses.

3 IMPROVEMENT OF CHARACTERISTICS OF THE BEAM FROM LINAC

The Parametric X-ray is being observed using the beam from the linac [7]. In this experiment, the request for the beam emittance is quite severe on the target. But observation of the beam profile on the target is difficult due to the low current and low duty factor, though it is quite necessary for the beam tuning. In order to increase the duty factor the utilization of KSR as a stretcher is proposed [6][8].

The momentum spread of the beam has an influence on the beam size and the efficiency of the injection to the KSR. The measured momentum spread of 100 MeV beam is approximately 2 % even for the pulse width of 100 ns. It is slightly worse than the value obtained by the calculation. To make matters worse, beam pulse width becomes 260ns for 3-turn injection to the KSR whose harmonics number and the revolution frequency are 10 and 116.7 MHz, respectively. This increases the momentum spread. In order to improve the efficiency of the injection in terms of momentum spread, the best operating parameters are being searched using profile monitors, especially in the low energy section of the linac

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