ELECTRON STORAGE AND STRETCHER RING, KSR

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Abstract

A stretcher mode on KSR is proposed based on resonant slow beam extraction with additional transverse RF electric field keeping the separatrix size constant. Electrons up to 1.5 x 10^{12} per second (average current of 0.25 μA) is to be provided with duty factor higher than 90 %.

1 INTRODUCTION

KSR, now under construction at ICR, Kyoto University is an electron storage ring, whose maximum energy, radius of curvature and circumference are 300 MeV, 0.875 m and 25.69 m, respectively[1]. The critical wave length of the light from the dipole section is 17 nm and an insertion device such as a superconducting wiggler will be installed to provide the light with shorter wave length[2]. The layout of KSR is shown in Fig. 1. Its injector is an s-band electron linac consisting of a Pierce type gridded gun, buncher and pre-buncher and three disc-load accelerating tubes[3]. The first beam of the linac was successfully accelerated in last October. It is currently used for the experiment of parametric X-radiation from Silicon crystal. The duty factor of the beam from the linac is less than 2×10^{-5} as the duration of the macroscopic pulse and maximum repetition of the linac are 1 μs and 20 Hz at maximum, respectively, which imposes serious limit on the experiment. In order to improve the duty factor of the electron beam for the experiment, a stretcher mode on the KSR at the energy around 100 MeV is proposed. In the present paper, the design of the stretcher operation is given together with the brief description of the recent situation of the electron facility.

2 PRESENT STATUS OF KSR

The construction of the disc-load type electron linac and the electron storage ring, KSR was started from 1994. The electron linac has been completed last year. The measured peak intensity at the first acceleration test is ~80 mA, while the design intensity is 100 mA.

Beam emittance is measured by changing focusing strengths of the quadrupole magnets between the acceleration tubes and it is estimated to be 2 πmm·mrad at the end of the linac[4].

As for the KSR, magnets have been aligned within the precision of ±0.1 mm[2] and the installation of the vacuum chamber is just underway. Some amount of time is necessary before completion of KSR as a synchrotron light source. In the meanwhile we consider the possibility of KSR as a stretcher of the injector linac[5] in order to satisfy the high-duty requirement from the experimental group.

3 STRETCHER MODE ON KSR

By direct use of the electron linac, the peak current and

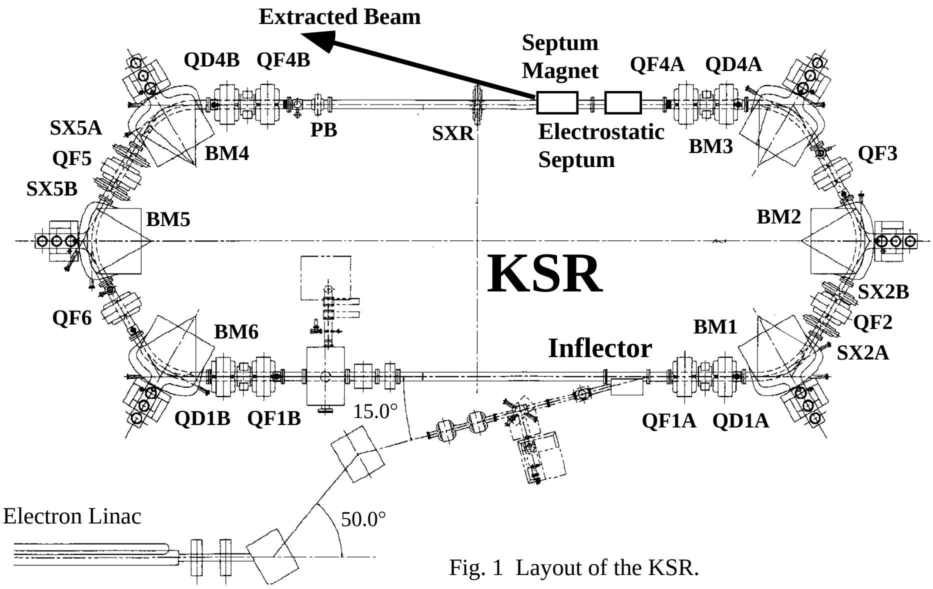

Fig. 1 Layout of the KSR.

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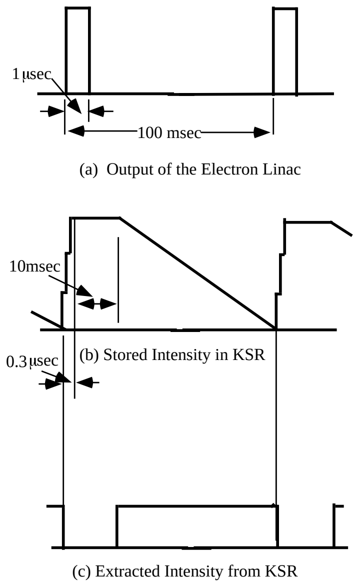

Fig. 2 Scheme of KSR Stretcher Mode.

duration have to be reduced to ~1 mA and 10 nsec, respectively for the PXR experiment[6]. At this condition the peak and average numbers of electrons(denoted as N_{peak} and N_{av}, respectively) impinging on the target are 6 x 10^{15} (electrons/sec) and 1.2 x 10^{9} (electrons/sec), respectively. It is necessary to reduce N_{peak} from the view point of avoiding pile up of the detector while as high value of N_{av}, as possible is preferable to attain high yield. So as to improve this situation, the stretcher mode on the KSR is proposed, which is operated with 10 Hz as shown in Fig. 2. The linac is operated at 10 Hz with peak intensity of 100 mA as shown in Fig.2(a) and the output beam from the linac is injected into KSR by three turn-injection and then slowly extracted utilizing the $2\frac{1}{3}$ resonance. The typical time variation of the stored intensity in KSR and extracted beam from KSR are shown in Fig. 2 (b) and (c), respectively. In this scheme, the expected values of N_{peak} and N_{av}, are 1.7 x 10^{12} and 1.5 x 10^{12} , respectively as the duty factor higher than 90 % is expected as is described later. It should be noted that N_{peak} is reduced more than three orders lower

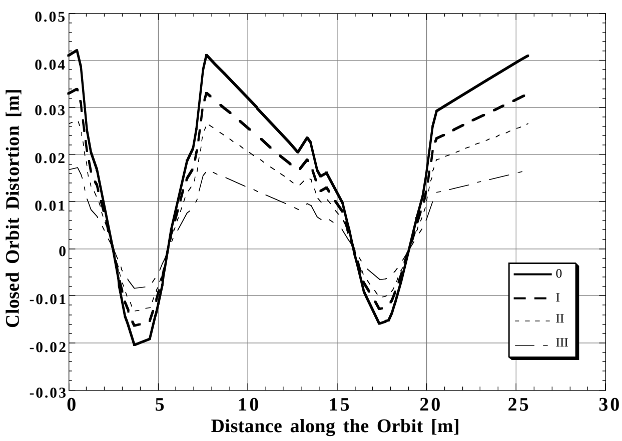

Fig. 3 Closed Orbit Distortion caused by a Perturbator.

increasing N_{av}, more than three orders higher compared with the direct use of the linac.

3.1 Three-Turn Injection

The beam is injected into KSR through an inflector(a magnetic septum) located at the position indicated in Fig. 1. The closed orbit is distorted by a perturbator (PB) located just half circumference away from the inflector as shown in Fig. 1 and the collision of the circulated electron beam with the septum is avoided. The orbit distortion at the distance s, $\eta(s)$, when the deflection with the rate of $\Delta B/B\rho$ is applied at the position τ, is given by the following formula,

$$\eta(s) = \frac{\sqrt{\beta(s)}}{2\sin\pi\nu}\int_{s}^{s+C}\sqrt{\beta(\tau)}\cos\{\pi\nu + \mu(s) - \mu(\tau)\}\frac{\Delta B}{B\rho}d\tau,$$

where ν, $\beta(s)$ and $\mu(s)$ are betatron tune, betafunction and betatron phase at the position s, respectively. The orbit distortion is decayed in 5 turns by the pulse excitation of the perturbator. In Fig. 3, the closed orbit distortions during the first four turns are shown. The starting point of the figure is the exit of the inflector. The behavior of the injected beams in the horizontal transverse phase space at this azimuthal position and the septum positions during the first several turns are given in Fig. 4. It is expected that the main beam from the electron linac will not hit the inflector septum if we limit the duration of the linac less than three turns (3 times 85.6 nsec). From the results, the injected beam is in the ellipse of the area 250 πmm·mrad.

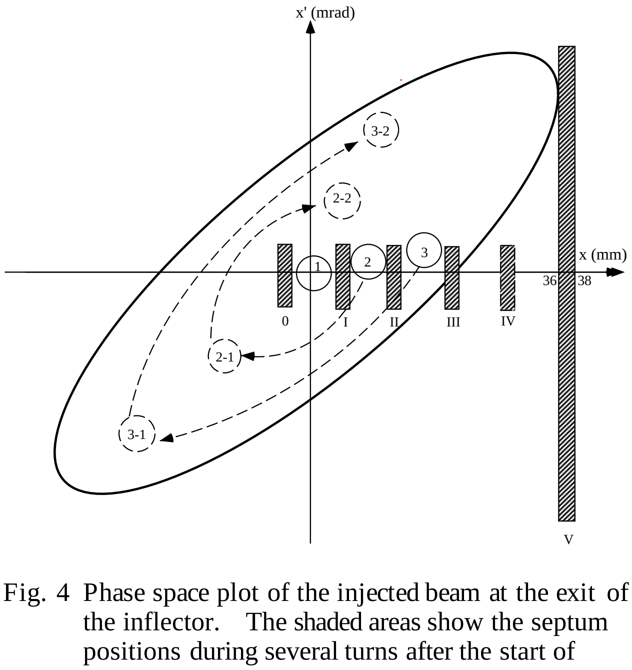

Fig. 4 Phase space plot of the injected beam at the exit of the inflector. The shaded areas show the septum positions during several turns after the start of injection. The number in the circle indicates the injection turn number. The number after hyphen indicates the circulation number of the injected beam.

3.2 Resonance Extraction with Constant Separatrix

For the purpose of stretching the time structure of the electron beam, slow beam extraction scheme is necessary. As the two sextupole families are used with superperiodicity of 2 for chromaticity correction, the third order resonance of $\nu_H = 2\frac{1}{3}$ is preferable, because the contribution to this resonance of the sextupole magnets for chromaticity correction is canceled out as is easily known from the following equation,

$$S\exp(3i\psi_s) = \sum_{m=1}^{M} S_m \exp(3i\psi_m),$$

where M sextupoles of strength S_m located at phase ψ_m add up an amplitude S and a phase ψ_s[7]. As the resonance exciter, a sextupole magnet identical with the ones used for chromaticity correction will be installed at the center of the extraction straight section as shown in Fig. 1. When the sextupole is excited at the level of 9.5 1/m^2 (B"l/Bρ) and the horizontal betatron tune is set at 2.375, the beams injected into KSR in three turns circulate stably, while the beam with the emittance larger than 360 πmm·mrad will be extracted as shown in Fig. 5.

In order to increase the emittance of the circulating beam, a transverse RF electric field resonating with the transverse oscillation will be imposed. This method is already applied for the slow extraction of ion beam[8] and is found to be useful for medical synchrotron[9]. With this method, it is known that the extraction is started within 10 msec for the α beam of 10 MeV/u after imposing the transverse RF electric field of 150 V [8]. As the following relation holds,

$$N_0 V_0 \propto \frac{Amc^2\gamma\beta^2}{qe},$$

where N_0, V_0, m and q are the necessary turn number before the beam with a small amplitude is increased to a certain emittance size, applied amplitude of the RF electric field, mass and charge state of the beam particle, respectively while β and γ are Lorenz Factor and e is unit charge[10], the 100 MeV electron is expected to start to come out within 10 msec at the V_0 larger than 380 V. It should be noted that suitable amplitude modulation is necessary for the transverse RF electric field to realize the flat beam spill as illustrated in Fig. 2(c). At the energy of 100 MeV, the damping time of the electron beam is long enough compared with the time interval of 100 msec and this effect is ignored. Thus the duty higher than 90 % is expected to be achieved. Because the present extraction method utilize the transverse RF electric field instead of the tuning of the quadrupole magnet, the response time is shorter, which contributes to realize the high duty factor.

With the ordinary method which drives the operating point to the resonance reducing the separatrix size, the angle of the extracted beam is anticipated to vary as large as ~4 mrad if we extract the beam with the emittance of 360 πmm·mrad. In the present method, the separatrix size is always kept constant during whole extraction process and the extracted beam comes out along the fixed branch of the separatrix and the extracted beam direction does not change in principle. This characteristic is considered extremely suitable for the PXR experiment which requires highly oriented beam.

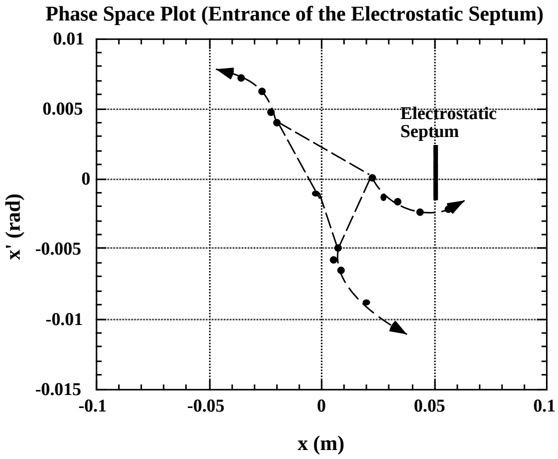

Fig. 5. Amplitude Increase for Larger Emittance Beam (at the Electrostatic Septum for Extraction).

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