PULSE STRETCHER OPERATION OF THE ELECTRON STORAGE RING, KSR*

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Abstract

An electron storage ring, KSR has been completed as a pulse stretcher of the output beam from 100 MeV disc-load type S-band electron linac with maximum duty factor of $2x10^{-5}$. The beam is injected into the ring by a single turn and slowly extracted with combination of the third order resonance and the RF-knockout method. It is experimentally verified that the beam spill between 0.2 and 40 second is realized with the extraction efficiency more than 50% resulting the duty factor over 90%.

1 INTRODUCTION

With use of the 100 MeV electron beam, experiments such as parametric X-ray radiation [1] and transition radiation had been performed. The maximum pulse width and repetition rate of the 100 MeV electron linac are 1μsec and 20 Hz, respectively, which results in the beam duty factor of $2x10^{-5}$ at maximum. In order to avoid the pile up of the signals from particle detectors, the peak current of the linac available up to 100 mA had been reduced to about ~1mA in the experiments above mentioned. As the cure for such situation, usage of the electron accumulation ring, KSR as a pulse stretcher was proposed [2] and slow beam extraction channel has been completed [3]. By configuration of orbit bump including non-linear sextupole magnets in the bump, it was found that main fraction of the beam could not be extracted through the extraction channel but collided with the inflector. So as to improve this situation, new configuration of bump orbit formation was proposed [4]. With this configuration, main fraction of the circulating beam has been safely extracted resulting the extraction efficiency higher than 50 %. In the present paper, recent experimental attainments are presented.

2 PULSE STRETCHER SCHEME

The output beam from 100 MeV electron linac is injected into KSR by a single turn. The horizontal betatron tune is set close to the third order resonance around 2.336 and the injected beam circulates in the ring keeping the stable oscillation in a separatrix (boundary between the stable and unstable regions) as is illustrated in Fig. 2. For the purpose of slow beam extraction, a transverse RF electric field with the frequency which *resonates with* the horizontal *betatron oscillation (so-called RF-Knockout)* has been applied keeping the separatrix size to be constant instead of reducing the

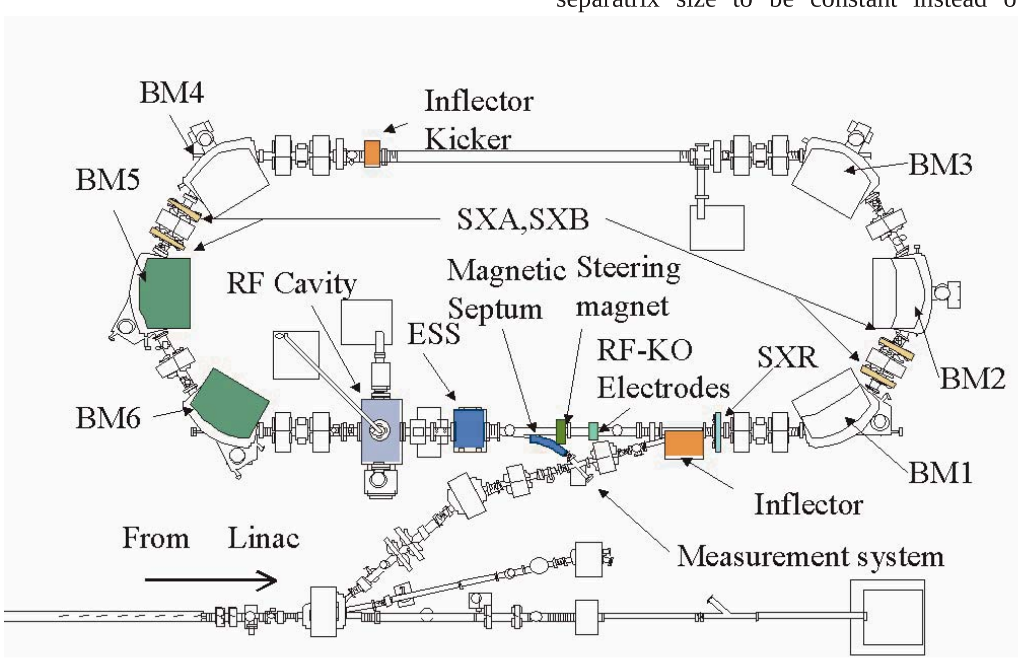

Fig1. Layout of KSR stretcher mode, with new bump configuration.

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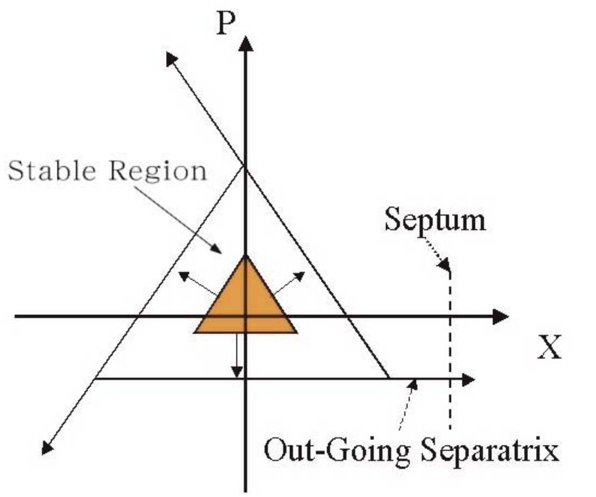


Fig. 2 Illustration of the slow extraction scheme utilizing the third order resonance and RFKO.

separatrix size as is done by the usual extraction by tune shift. The merit of the present method is the fact that the direction of the extracted beam does not change during the whole extraction process.

2.1 Bump COD Formation

At KSR, the beam extraction channel is set in the same straight section as the beam injection line as illustrated in Fig. 1 in order to reserve another straight section for insertion device. From this configuration, it was required to create orbit bump, which make the aperture minimum at the entrance of the electrostatic septum during the beam extraction while the aperture is minimum at the exit of inflector during beam injection. The Closed Orbit Distortion (COD) adopted at the early stage of the stretcher operation utilized correction coils in BM6, BM1 and BM2 together with the steering magnet in Fig.1, which included sextupole magnets SXR and SXA1 and SXB1. With this configuration, main fraction of the circulating beam was not possible to be extracted through the extraction channel, because the COD was not confined between BM6 and BM2, but distortion spread out to whole circumferences affected with the kicks caused by sextupole magnets. So a new configuration to utilize correction coils in BM5 and BM6 together with the steering magnet was adopted [4]. In Fig.3, the new COD calculated with MAD is shown for both cases with and without excitation of inflector kicker by solid and dashed lines, respectively. Measured data just before beam extraction with no excitation of inflector kicker is also shown, which agree well with MAD expectation [5]. From the figure, it is known that minimum aperture is 13 mm at the exit of inflector which locates at 33 mm from the central orbit, while the aperture takes minimum value of 32 mm at the entrance of the electrostatic septum which locates at the position 40 mm apart from the central orbit. This tight clearance between the inflector and the electrostatic septum causes rather limited extraction efficiency.

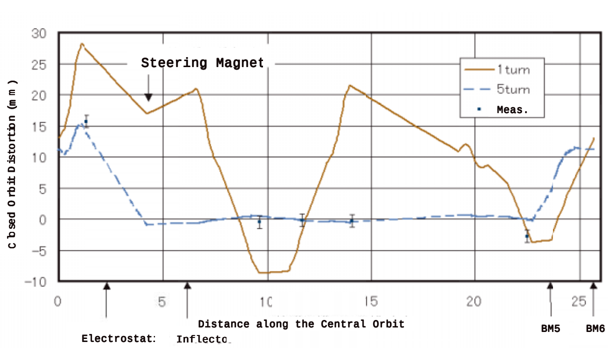


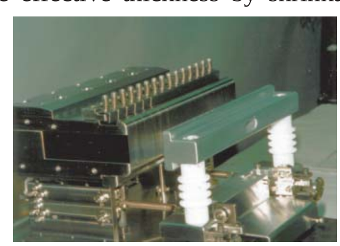
Fig.3 Calculated COD formation by MAD in comparison with the measured data.

2.2 Extraction Channel

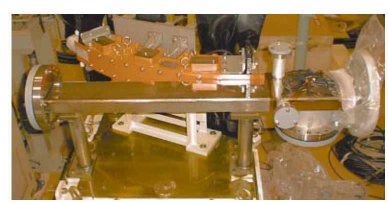
The beam, whose displacement from the central orbit has exceeded a certain value, is deflected as large as 20.5 mrad by an electric field of the electrostatic septum (ESS) and then enters into the septum magnet and is further 45º deflected. The electrostatic septum and septum magnets are shown in Fig.4 (a) and (b), respectively.

The septum of ESS is made of Ti foil 0.1 mm in thickness. The upstream part of the septum is cut into 5 stripes 2 cm in width in order to apply tension separately to avoid increase of the effective thickness by shrinkage of the foil due to beam hit. The positive high voltage is applied to the aluminium electrode, which needed rather longer aging time compared with negative voltage. Up to 70 kV/cm has been applied to the gap of 8 mm.

The septum magnet is designed to be set outside of the vacuum chamber, which contributed to maintain good vacuum around a few times 10^{-10} Torr.



(a) electrostatic septum



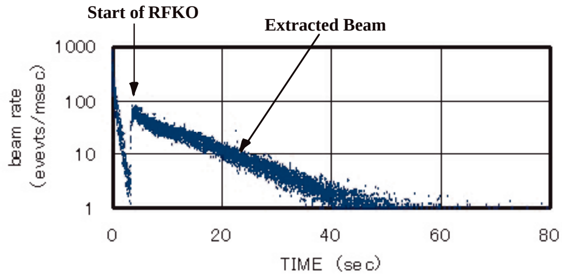
(b) Septum Magnet

Fig. 4 Equipments for slow beam extraction.

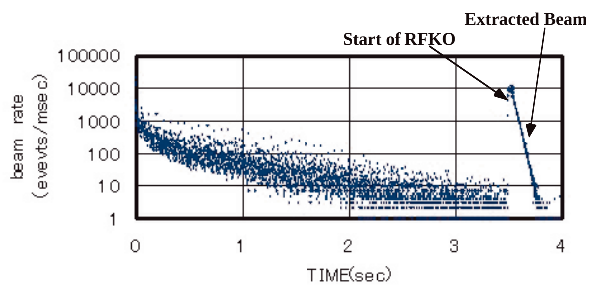
3 EXPERIMENTAL DATA

The performance of the stretcher has been evaluated by measuring the time structure of the extracted beam and extraction efficiency. The former was measured with a scintillation counter 0.1 mm in thickness. The latter was evaluated by combination use of the direct current transformer (DCCT) set in the KSR and a Faraday cup set just down stream of the exit of the septum magnet.

It is known from Fig.5, that the beam duration can be varied from 0.2 sec. to 40 sec. According to the change of power level of the applied RF in transverse direction. In



(a) Beam spill with transverse RF of 0.011 W



(b) Beam spill with transverse RF of 1.9 W

Fig.5 Time structure of the extracted beam.

these measurements, application of RFKO has been started 3.5 second after beam injection in order to assure the beam size has already radiation damped. As the extracted beam rate after injection is reduced to less than 2×10^{6} per second in 20 msec as shown in Fig.6, then duty factor greater than 90 % will be realized with the present scheme if enough high repetition rate is applied and above beam rate is tolerable for aimed experiment, although the present injection system can attain only the repletion rate less than 1 Hz.

The extraction efficiency was evaluated for the beam energy of 70 MeV in order to avoid longer aging time needed for ESS for higher energy case. From Fig. 7, it is known that extraction efficiency of 36 % is attained for this case by integration of the Faraday cup signal. Further careful adjustment of septum position of ESS realized extraction efficiency a little bit higher than 50 %. Septum position much far from stable fixed point will realize higher extraction efficiency, which is largely restricted by the presence of the inflector at the nearby position in the present case.

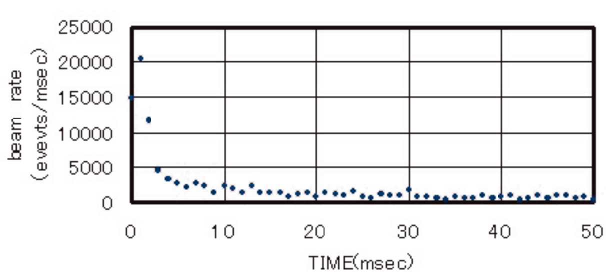


Fig. 6 Enlarged time structure of the extracted beam during injection.

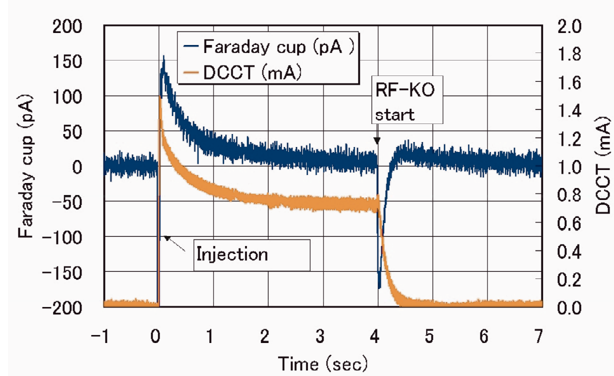


Fig.7 Observed beam signal at DCCT (measures circulating beam intensity) and the Faraday cup (measures the extracted beam intensity).

The exponentially decaying extracted beam intensity is found to be flattened by amplitude modulation as shown in Fig. 8, which will largely contribute to the reduction of peak beam rate.

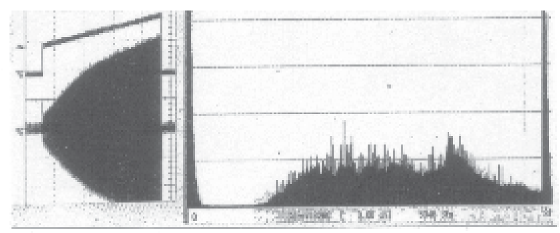


Fig.8 Amplitude modulation of applied transverse RF (left) flattens the extracted beam time structure (right).

4 SUMMARY

Stretcher scheme with use of resonance extraction together with RFKO has been found to be useful to enlarge the duty factor of the beam with moderate extraction efficiency, although careful adjustment of the closed orbit distortion is needed.

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