STRETCHER OPERATION OF THE 100 MEV DISC-LOAD ELECTRON LINAC AT ICR, KYOTO UNIVERSITY

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Abstract

Stretcher operation of the electron storage ring, KSR has been tested with 80 MeV electron beam. Beam injection with closed orbit control and beam extraction channel consisting of the electrostatic septum with 70 kV/cm and septum magnet of 5kG with septum thickness of 14 mm have been completed. Beam spill can be enlarged to ~1 s by the slow extraction with combined use of the third order resonance and RFKO.

1 INTRODUCTION

The 100 MeV s-band disc-load type electron linac at ICR, Kyoto University consists of a thermic electron gun, a standing-wave type buncher and three acceleration tubes with traveling wave type. It has been under operation since October 1995 [1] and has been utilized for experiments such as parametric X-ray radiation (PXR) [2], transition radiation and calibration of gas Cherenkov counter and so on.

The pulse width and repetition of the linac are, 1μsec and 20 Hz at maximum, respectively and the duty factor of the beam is limited at the small value of 2×10^{-5}. In order to avoid the pile up of the signals from the detector, peak current of the linac available up to 100 mA is reduced to ~1mA for the case of PXR experiment, where pulse width is also reduced to 10 ns. In order to improve this situation, the electron storage ring, KSR is proposed to be utilized as a stretcher of the output beam of the linac [3]. Beam from the linac is injected into the ring during 1 turn and then slowly extracted in 1 second operating the linac with 1 Hz. So duty factor larger than 90 % is expected.

In the present paper, the stretcher operation of the linac is presented.

2 STRETCHER OPERATION

2.1 Beam Injection into KSR

The output beam from the electron linac is injected into the KSR ring by shifting the closed orbit with use of a perturbator. In order to make the aperture minimum at the entrance of the electrostatic septum (ESS), an orbit bump is made by a steering magnet and correction coils in dipole magnets, BM6, BM1 and BM2 shown in Fig. 1.

2.2 Slow Beam Extraction Scheme

In order to extract the circulating electron beam from the KSR ring, the third order resonance, $3\nu_H=7$, is utilized. With the excitation of a resonance-exciter sextupole magnet, SXR shown in Fig.1, beams with larger betatron amplitude is unstable and increase in the amplitude, while beams with smaller amplitudes remain stable as shown in Fig.2. The calculated separatrix in Fig. 2 represents the case with the operating point of (2.366, 1.22) and the sextupole strength ($B''l/B\rho$) of $1.6(1/m^2)$. In the ordinary extraction, the separatrix size is reduced according to the extraction process proceeds by adjusting the lattice quadrupole magnet to push the operating point to the resonance. With this method, however, the direction of the extracted beam (dx/ds in Fig. 2) changes during the extraction process. In the present scheme, the separatrix size is fixed and the betatron oscillation amplitude of the

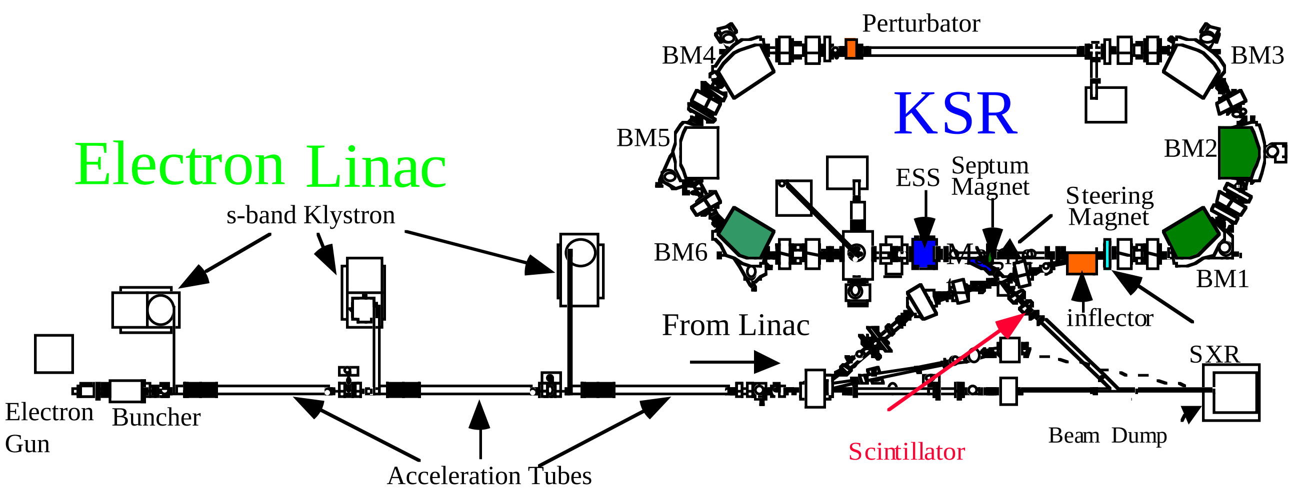

Fig.1 Layout of the 100 MeV electron linac and its pulse stretcher, KSR.

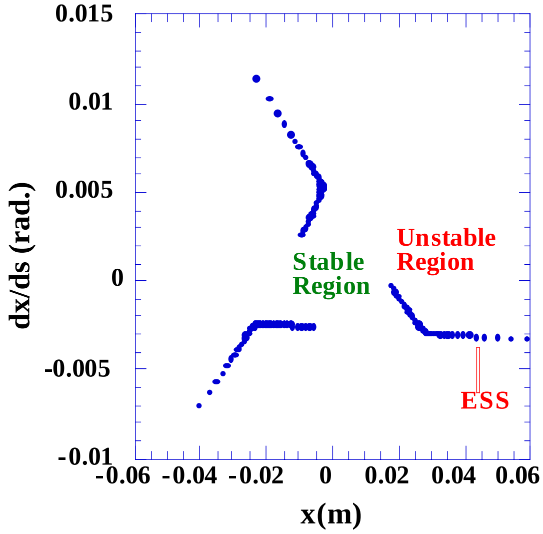

Fig.2 Separatrix (boundary of the stable and unstable regions) in the transverse phase space

stable region is enlarged by the application of the transverse RF electric field (RFKO), which results in the fixed direction of the extracted beam throughout the whole extraction process. Such method has already been successfully applied for ion beams [4,5]. For the electron beam, the radiation damping of the oscillation amplitude is anticipated. In the present case with the maximum energy of 100 MeV, the damping time is estimated to be longer than 3.5 s, which can well be applied for 1 Hz operation.

2.3 Beam Extraction Channel

Beam that reached at the separatrix goes out along three branches as shown in Fig. 2. The beam, which entered into the aperture of the ESS as the first septum, is deflected by 21 mrad with the electric field 70kV/cm at maximum. The deflected beam by the ESS will enter into the aperture of the septum magnet, which locates ~1.2 m down stream from the exit of the ESS, and then is

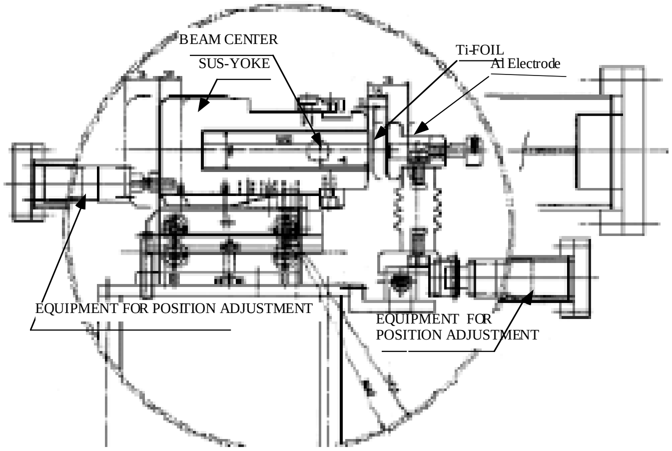

Fig.3 Cross-sectional view of the Electrostatic Septum (ESS).

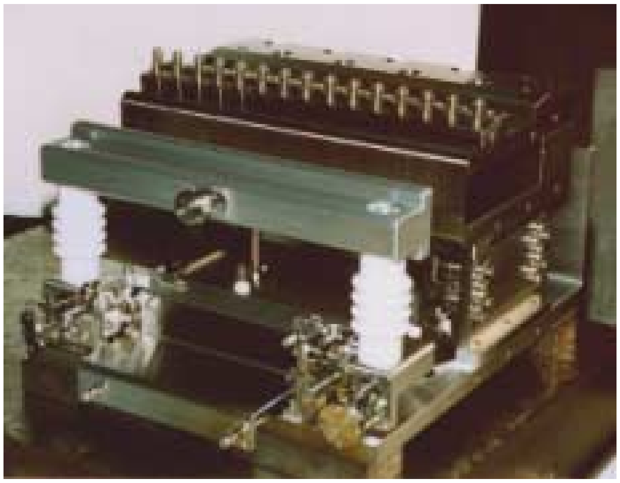

Fig. 4 Overall view of the electrostatic septum before installation into the vacuum vessel.

deflected as large as 45˚ with the magnetic field of 5 kG at maximum.

2.3.1. Electrostatic Septum (ESS)

The electrostatic field up to 70 kV/cm is applied between a Ti foil, 0.1 mm in thickness, and an electrode made of Al as shown in Fig. 3. In order to avoid the wrinkle in the TI foil due to heat up by collision of the electron beam, upstream part, 10 cm in length, is cut into 5 sheets, 2cm in width, and each sheet is applied tension with a screw separately as shown in Fig. 4, while the total length of the ESS electrode is 300 cm.

In order to extract the electron beam, a positive high voltage is required to be applied to the Al electrode and in general, it is considered to be more difficult to apply positive high voltage than negative one. For the present case where the vacuum pressure of the order of ~10^{-10} Torr is realized, high voltage up to 65 kV/cm has been applied to the gap of 0.8 cm without any difficulty although some aging time was needed. Design goal of 70 kV/cm required for 100 MeV electron will be attained soon by further aging process.

2.3.2. Septum Magnet

The septum magnet is designed to locate outside the vacuum vessel in order to realize a ultra-high vacuum and additional 8.6 mm is needed for the chamber wall and so

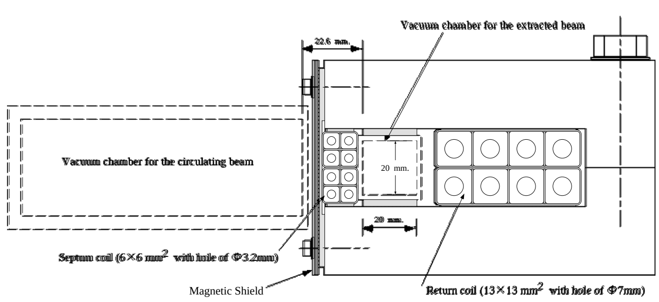

Fig.5 Cross-sectional view of the septum magnet.

on as shown in Fig. 5 except for the septum coil space of 14 mm.

3 PRELIMINARY EXPERIMENT

The beam extraction line shown in Fig.6 has been completed and slow beam extraction experiment has been started with use of the 80 MeV electron beam because of the trouble of one of the klystrons. In Fig. 7, the beam current observed by a DCCT is shown for the case with (lower) and without (upper) RFKO. It is known that circulating beam is made unstable by the RFKO and is gradually extracted from the KSR ring during ~1sec[6].

The time structure of the extracted beam is also observed with use of a thin scintillation counter set just downstream of the septum magnet as shown in Fig. 1. The output signal rate from the photomultiplier attached to this scintillator is measured every 100 μs interval. And the obtained result is shown in Fig. 8 during 800 ms. .It is known that beam is extracted in the time interval ~1 s although there still remains a large peak in early 50 ms time interval, which will be optimized by closed orbit correction and amplitude modulation of the applied transverse RF used for RFKO from now on.

4 SUMMARY

The stretcher operation of KSR which utilize the slow extraction with the combined use of the third order resonance and RFKO has been proved to work well also for the electron beam for the rather lower energy up to 100 MeV. Beam spill as long as ~1 s can be realized with the present method although flattening of the spill is the scope of further work. Quantitative measurement of the extraction efficiency, which needs a beam stopper of the electron beam, is under preparation.

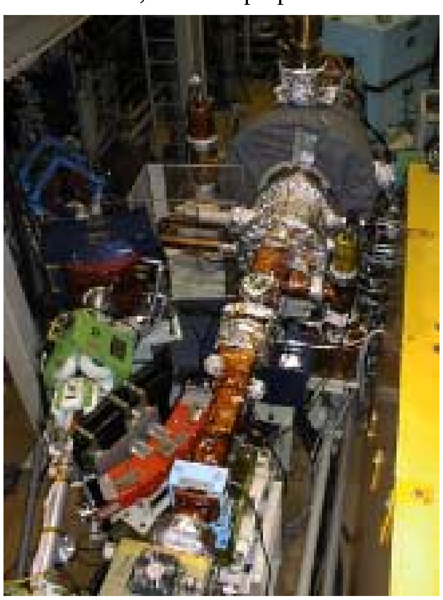

Fig. 6 Beam extraction line from the KSR

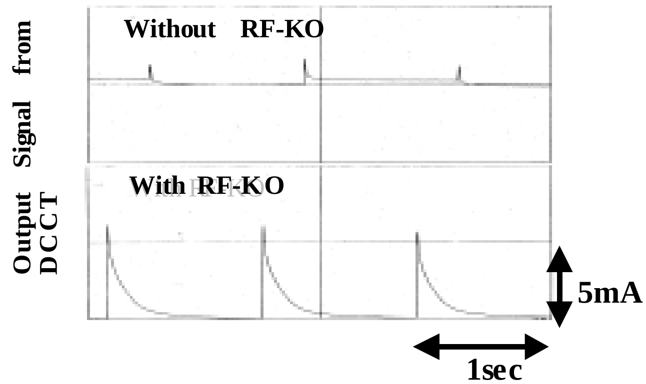

Fig. 7. Circulating beam signal observed by a DCCT without (upper) and with (lower) RFKO.

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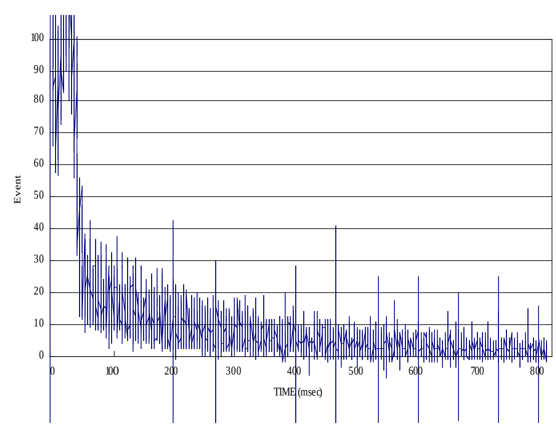

Fig. 8 Count rate of the scintillator in 100 μsec time interval during 800 msec.