BEAM SPILL CONTROL WITH FREQUENCY MODULATION IN ELECTRON SYNCHROTRON

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Abstract

The uniform beam spill of the INS electron synchrotron is obtained by frequency modulation of the rf system.

1. Introduction

In the INS electron synchrotron, the beam debunching has been so far made by rf perturbation method[1]. The spill control at low energy (≤700 MeV) operation by this method has not been successful enough. Another disadvantage of this method is that the fine structure in the beam spill due to the synchrotron oscillation is enhanced.

The new scheme of the spill control is as follows: At the final stage of the acceleration, the operating frequency of the accelerating system, 137.989 MHz, is increased by nearly 670 kHz, which leads the shrinkage of the equilibrium orbit by 27 mm, and the beam is very close to the internal radiator. The operating frequency is further but slowly increased, and the beam gradually hits the radiator. The amount and the duration of this slow change of the operating frequency correspond to the beam diameter and to the beam spill time, respectively. Since the electrons stay in the stable phase region of the accelerating field until they hit the radiator, the beam spill can be controlled stably.

2. Experimental Apparatus and Results

The block diagram of the apparatus is shown in Fig. 1. The signal generator can be operated with frequency modulation of at maximum 1% of the center frequency, and with phase lock mode for the period not frequency-modulated. The results are shown in Figs 2 and 3.

3. Discussions

The Q-curve of the rf cavity is given in Fig. 4. The resonant frequency of the cavity (without the beam) is set lower than the operating frequency by 50 ∿ 100 kHz in order to increase the beam capture efficiency[2]. Thus the modulation of the operating frequency for the spill control should result in the decrease of the power flow into the cavity nearly 5% of the generator power. The beam loading effect, however, shifts the resonant frequency of the cavity towards higher frequency. The experimental data of Figs.2 and 3 together with Fig. 4 show that the resonant frequency shift due to the beam loading is about +110 kHz.

In Fig. 5 is shown the minimum cavity voltage necessary for the beam to circulate stably around the maximum energy. To provide the required voltage, input power to the cavity should be increased following the increment of the frequency. Owing to the beam loading effect, power flow into the cavity with the beam is greater than that without the beam. Based upon the above-mentioned effects, the spill control is feasible even with the present rf power.

In the low energy operation, since the synchrotron radiation loss is small, the shrinkage of the equilibrium orbit is brought by keeping the electrons in the decelerating rf phase. As shown in Fig. 5, the cavity voltage during the spill time should also be negative in very low energy operation.

In the present rf system, the available rf power is 20 kW at maximum, and not enough for this spill control scheme to be valid in high energy (≥900 MeV) operation. In addition, increasing reflection power may cause trouble in the generator. Further improvement should thus involve the introduction of a circulator and a fast acting tuner of the cavity.

References

1) T. Fukushima, T. Katayama, T. Yamakawa and S. Yamaguchi, INS-TH-72 (1971)
2) T. Katayama, T. Fukushima and T. Yamakawa, to be published in Japanese Journal of Applied Physics (1980)

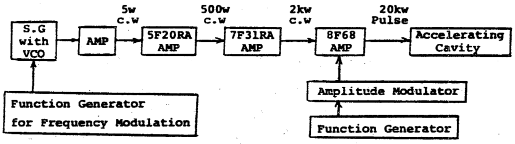

Fig.1, The block diagram of the rf system

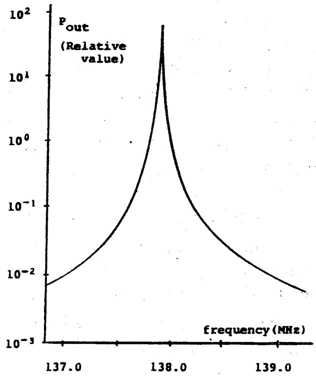

Fig.4, Q-curve of the cavity

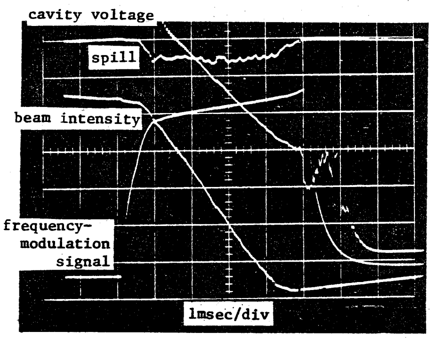

Fig.2, Experimental result at 400 MeV (with the beam)

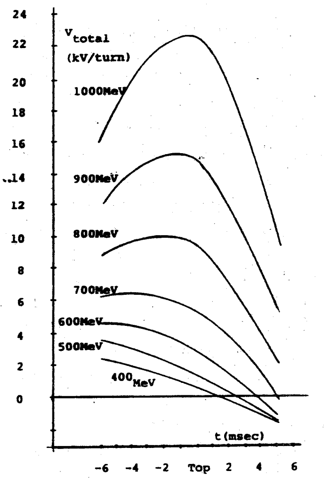

Fig.5, Minimum cavity voltage necessary for the beam to circulate.

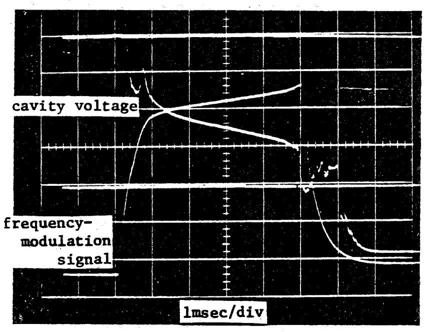

Fig.3, Experimental result at 400 MeV (without the beam)