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ROBINSON INSTABILITY AND PHASE FEEDBACK IN A DOUBLE RF SYSTEM FOR LANDAU DAMPING

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Abstract To suppress the Robinson instability additionally induced in the double RF system for landau damping of a longitudinal instabilty, a phase feedback loop was constructed in the system. Experimantal results of this feedback are presented.

INTRODUCTION

In SOR-RING a longitudinal coupled bunch instability is induced above the threshold current of 0.24 mA at a beam energy of 308 MeV.[1] We have constructed a Landau cavity with the second harmonic RF frequency, and succeded in damping the instability. But this success was limited below a beam current about 30 mA, above which an additional phase instability was induced, and then the longitudinal instability was not damped. For Landau damping the beam bunch should locate at the optimum phase where the total RF voltage or the sum of main and Landau cavity voltages becomes flat to produce the widest synchrotron oscillation frequency spread. According to the present experiment the beam bunch slips away from the optimum phase at a beam current higher than 30 mA, and the total voltage deforms considerably.

Previously we have shown that this additional instability can be explained by the Robinson instability;[2] the beam bunch is stable if the bunch locates at a decreasing phase of the sum of the voltages produced by generators in two cavities. At a higher beam current this condition is broken because of the additional condition that the synchronous voltage of the total cavity voltage should be equal to the radiation energy. In order to suppress the Robinson instability or the phase slip, we have made a phase feedback loop to lock the beam bunch at the optimum phase, and succeded in increasing the threshold current up to 110 mA.

EXPERIMENT

Figure 1 shows the optimum phase relation of main RF voltage V_{RF}, Landau cavity voltage V_{cL}, and total RF voltage V_t with respect to the beam bunch, which locates at the phase about $90^{\circ}$of V_{cL}. In the same figure are shown the potentials associated with the RF voltages. The total potential becomes flat at the bottom, where the beam bunch loactes. The synchrotron frequency spread is increased drastically and the bunch is lengthened about twice.

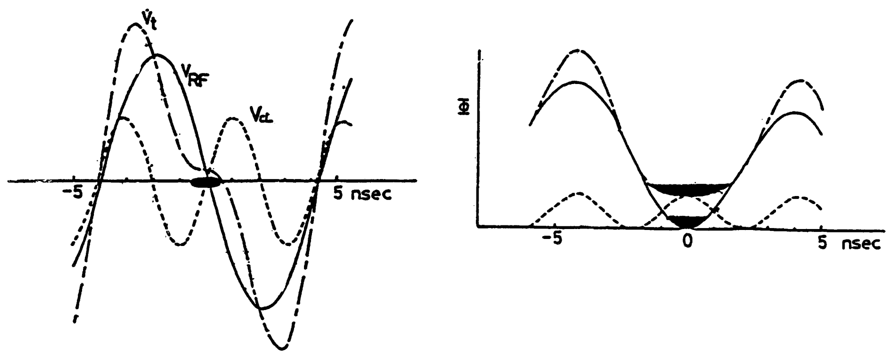

FIGURE 1 Optimum phase relation of main RF voltage V_{RF}, Landau cavity voltage V_{cL} and total RF voltage V_t with respect to beam bunch (left), and corresponding RF potentials (right).

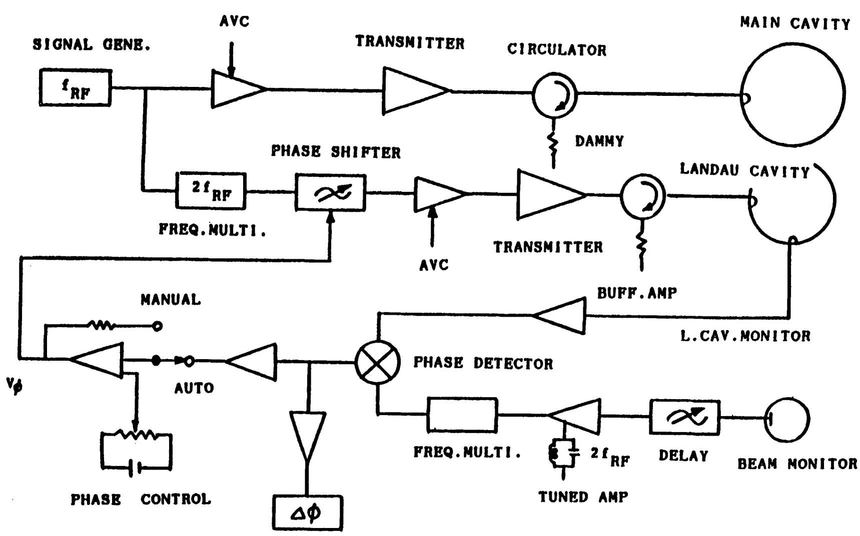

FIGURE 2 Block diagram of phase feedback loop.

The block diagram of the phase feedback loop in the double RF system is shown in Fig.2. Beam monitor signal is phase-shifted appropriately by a delay taking into account the cable length from the monitor, tuned at the RF frequency f_{RF} and multiplied in frequency to $2f_{RF}$. The phase difference between this signal and the Landau cavity monitor signal, detected by a phase detector, is indicated as $\Delta\phi$.

The phase difference $\Delta\phi$ against the phase control voltage V_ϕ for the phase shifter in the open loop of the phase feedback (manual) and in the closed loop(auto) is shown in Fig.3. We see that the phase feedback loop works as expected because the phase difference $\Delta\phi$ are the same in auto and manual for a given voltage V_ϕ . Thus the phase of the Landau cavity voltage is locked with respect to the beam bunch. The open loop gain and phase lag in the feedback loop are shown in Fig.4. The maximum bandwidth of the loop is about 20 kHz with the maximum gain about 30. The optimum

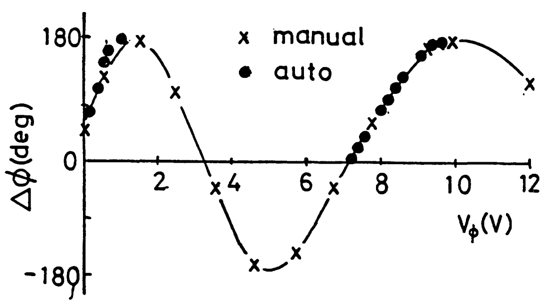

FIGURE 3 Phase difference $\Delta\phi$ against the phase control voltage V_ϕ in open loop (manual) and in closed loop (auto).

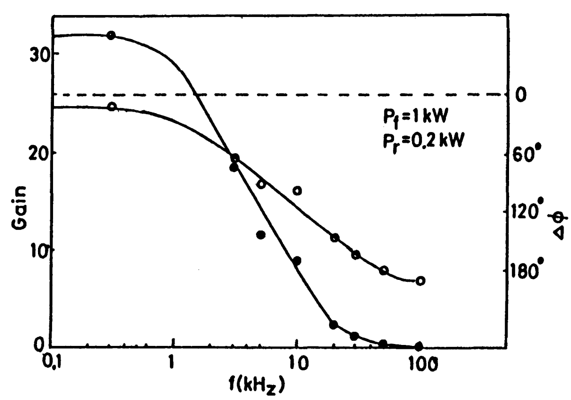

FIGURE 4 Open loop gain and phase lag in the phase feedback loop.

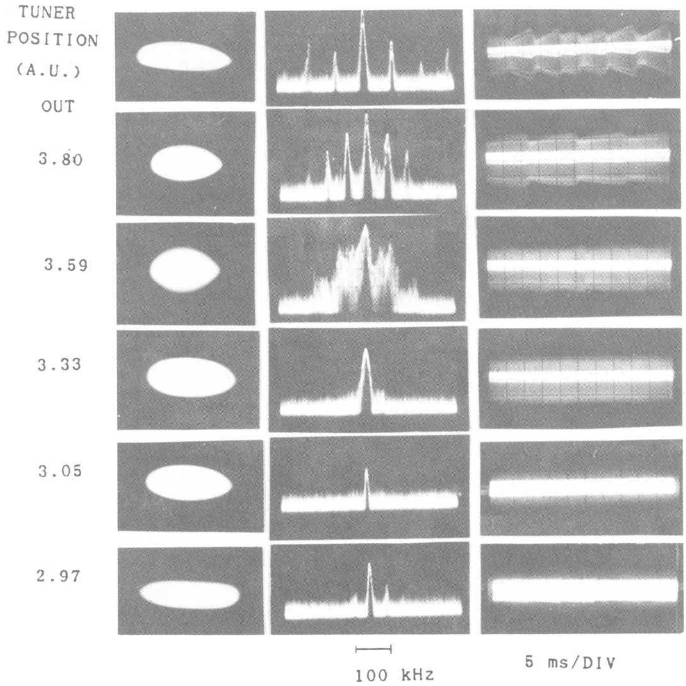

FIGURE 5 Cross section of electron beam, side bands of synchrotron oscillation frequency and beam intensity monitor signal with respect to tuner position.

phase relation can be obtained by adjusting the phase control voltage V_ϕ and the delay. With this feedback loop the threshold current of the Robinson instabilty was increased from 30 mA to 110 mA. The instability becomes stronger at a higher beam current, and it becomes hard to suppresss the instability even with this feedback loop.

The cross section of the electron beam, the side bands of synchrotron oscillation frequency and beam intensity monitor signal with respect to the tuner position of Landau cavity are shown in Fig.5. We see in the figure that the longitudinal instability is damped completely at the tuner position 3.05, although the beam size is the most reduced at the tuner position 3.59 without the complete damping of the instability.

The horizontal(x) and vertical(z) beam sizes in a bending magnet against the beam current before and after the Landau damping are shown in Fig.6. Because of the presence of dispersion in the bending magnet the horizontal beam size increases with the longitudinal instability, which is satisfactorily damped by the Landau damping.

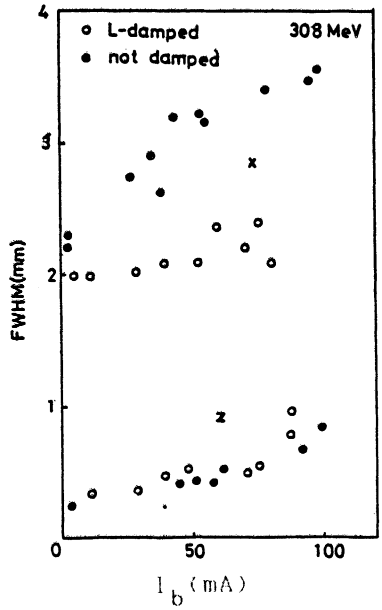

FIGURE 6 Horizontal(x) and vertical(z) beam size against beam current with and without Landau damping.

The longitudinal profile of the beam bunch, being obtained by observing the synchrotron radiation with a fast photo-multiplyer through a time-amplitude converter is shown in Fig.7. The bunch is lengthened about twice as expected. When the Landau cavity voltage V_{cL} is comparable to the main cavity volatge V_{RF}, the profile has two peaks because the RF potential of V_{cL} increases considerably at the center of the bottom of RF potential.

The beam lifetime against the main RF voltage at the operation energy 380 MeV of the storage ring is shown in Fig.8. To have a suffi-

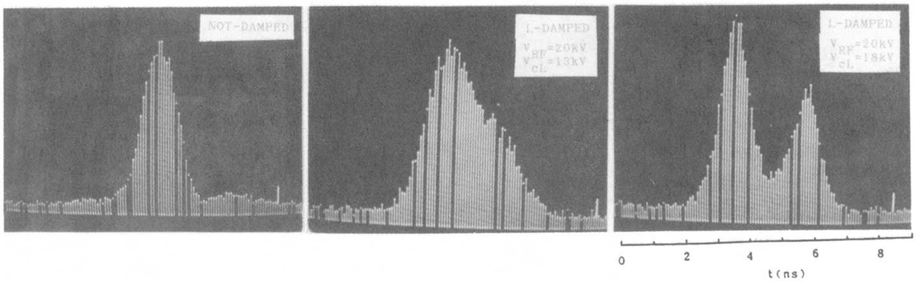

FIGURE 7 Longitudinal profile of beam bunch.

ciently long lifetime it is necessary to increase the RF voltage about twice compared with the RF voltage before the Landau damping. In the same figure is shown the quantum lifetime calculated without the Landau damping. It seems that the higher RF voltage required for sufficiently long lifetime under the Landau damping is related to the quantum lifetime. But in Fig.1 we see that the depeth of the RF potential from the bottom to the top, which is related to the quantum lifetime, is not changed so much with or without the Landau damping. Furthermore the lifetime under the Landau damping is decreased as the futher increase of

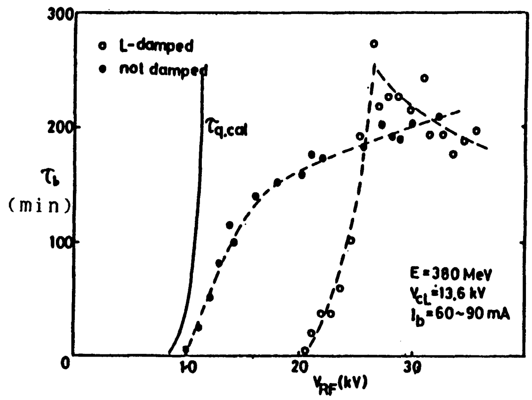

FIGURE 8 Beam lifetime against main RF voltage with and without Landau damping.

the RF voltage as seen in the figure, which is contrary to a simple minded Touschek lifetime. It is necessary to make a detailed investigation to understand the curious behaviour of the lifetime against the RF voltage.

In conclusion it seems necessary to make a more powerful feedback loop by increasing the gain and band width to increase the threshold current of the Robinson instability. It may be also effective to make a phase lock between the main and Landau cavity voltages.

REFERENCES

1. S.Asaoka etal, Nucl. Instr. Methods 215 493 (1983).
2. Y.Miyahara etal, Nucl. Instr. methods A 260 518 (1987).