Phase stabilization of injection beam to RIKEN Ring Cyclotron

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Abstract

When RIKEN Ring Cyclotron (RRC) is coupled with its one of injectors, a heavy-ion linac (RILAC), the beam transmission rate through RRC is sometimes limited by the phase instabilities of the injection beam from RILAC. Recently we tried to reduce the phase instabilities by a closed loop system and to improve the efficiency of the beam transmission through RRC.

1 Introduction

The RRC has two injectors, the RILAC and the AVF cyclotron. The RILAC has six rf cavities which are frequency tunable between 17 and 45 MHz. In the case of the RILAC injection, the beam transmission rate through the RRC has been 60 to 95%, depending on the rf conditions of the RILAC.

From a signal by a capacitive pick-up probe installed in a beam line between the RILAC and the RRC, a instability of a beam phase is sometimes observed and it has several tens deg. in rf. The instability which has a frequency range of 10 - 100 Hz is caused by the fluctuation of the rf voltages of some cavities of the RILAC. The beam energy at the exit of the RILAC is affected by this fluctuation and the beam phase spreads after drifting along the long beam line (60m). It sometimes becomes beyond the phase acceptance of the re-buncher which is installed on a half way of the beam line. Naturally, some particles in the beam overflow the phase acceptance of the RRC and the beam transmission efficiency through the RRC becomes worse.

At present, it is needed to increase the beam intensity beyond 1pμA to meet requirements of a nuclear physics experiment on a super-heavy element research. Moreover, in the future, much more beam intensities will be required as an injector of 'RI beam factory' [1]. In these circumstances, the beam transmission rate must be improved as high as possible.

The beam phase fluctuations are tried to suppress by adjusting a phase of the rf voltage of the final cavity of the RILAC correspondingly, and as the result, it was observed the improvement of the beam transmission rate through the RRC. Details are mentioned in the following sections.

2 Beam phase measurement

A beam phase is measured by using a capacitive pick-up probe with a ring-shape electrode whose length and diameter of aperture are 40 mm and 40 mm, respectively. A bi-polar signal induced on the electrode by a beam bunch can be easily observed by using an oscilloscope after proper amplification. A zero-cross point of the wave-shaped signal means the time when a charge-center of a beam bunch passes through the electrode. It is observed that the signal from the probe installed in the beam line from the RILAC to the RRC has some fluctuations of this zero-cross point on a time axis.

In order to convert the fluctuation into simple electric signals, the measurement system of a beam phase is used as shown in Fig.1. The system extracts a second-harmonic component from the signal and converts it into a signal with an intermediate frequency of 455 kHz. Fig.2 shows the details of the phasemeter. By the phasemeter, two kinds of outputs are obtained; A$\cos\phi$ and A$\sin\phi$. 'A' is corresponding to a beam intensity and 'ϕ' is the beam phase relative to rf. The system has a response of 1 kHz. These two signals are got through an interface-board of DIM [2] at every 2 ms. The data are stored in an 8 kB memory in DIM. These data are calculated and converted into two parameters; A and ϕ when they are transferred to a host computer.

The result is shown in Fig.3. The 2000 measurement points (A, ϕ) are plotted on the graph indicating the two-dimensional distribution. The beam at a moment is expressed by one plot, and a distance between the data point and the origin (A) is corresponding to a relative beam intensity. The angle between α and β is the beam phase relation to rf (ϕ).

In the figure, it can be said that the beam intensity is

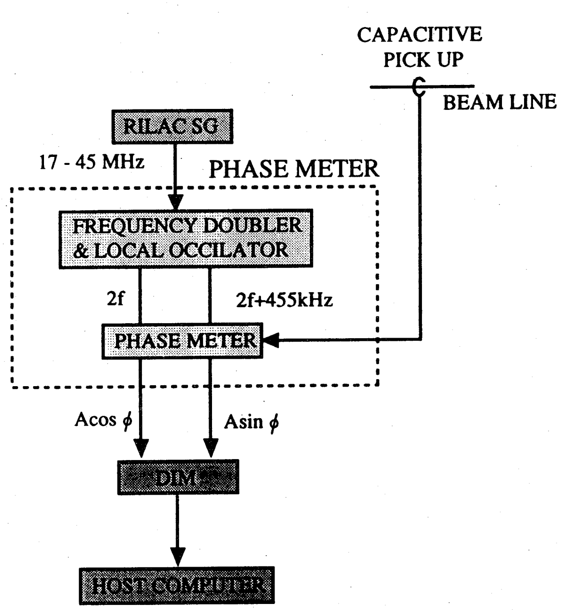

Fig.1 The measurement system of the beam phase

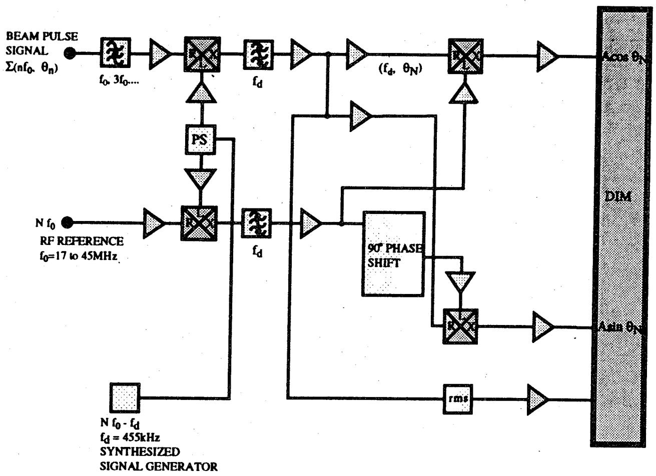

Fig.2 The block diagram of the phase meter

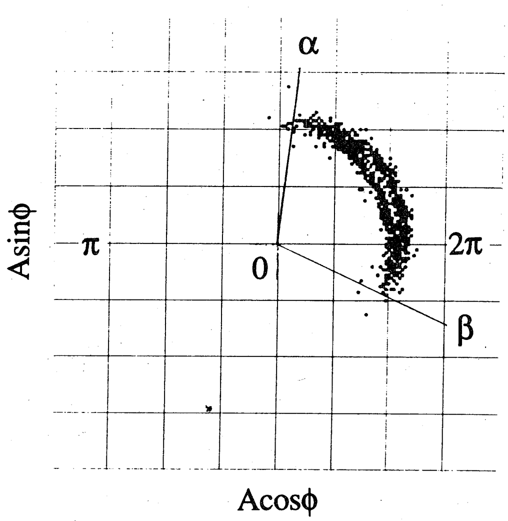

Fig.3 Observed beam phase at RILAC. The $\Delta\phi$ in FWHM is 28.4deg. The beam condition is 7.5 MeV/u ^{129}Xe at f=18.8 MHz. The beam energy at the probe is 0.5 MeV/u.

relatively stable, but the beam phase changes widely. The spread of the beam phase, $\Delta\phi$, was 28.4 deg in FWHM.

The probe is set in 10m downstream from the exit of the RILAC. This phase spread is mainly due to the energy fluctuation of the beam of the RILAC. After drift along the beam line, the energy fluctuation is converted into the phase one. Since there is still 20 m drift distance until the re-buncher, this phase spread is too large to ensure that all beam is accepted by it.

3 The signal feedback system

The phase and the energy of the beam are given as functions of the rf amplitudes and phases of every cavities in use. Among them, the energy depends smoothly on the rf phase of the final cavity in use. In other words, the

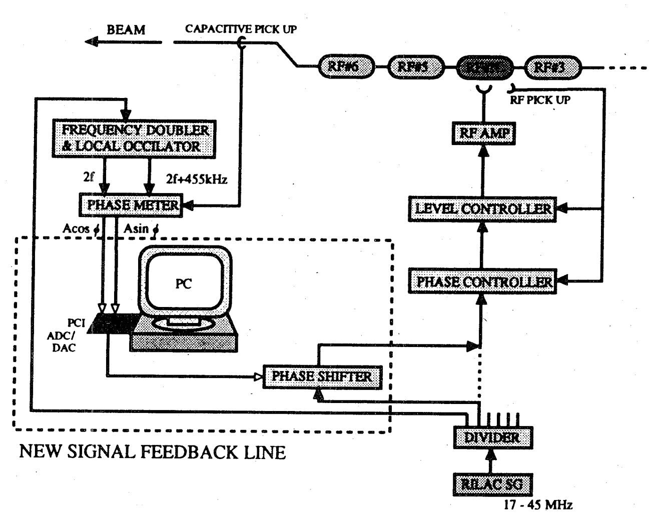

Fig. 4 The signal feedback system of the beam phase to the rf tank of the RILAC. The surrounded part by the dot line is the new additional feedback line.

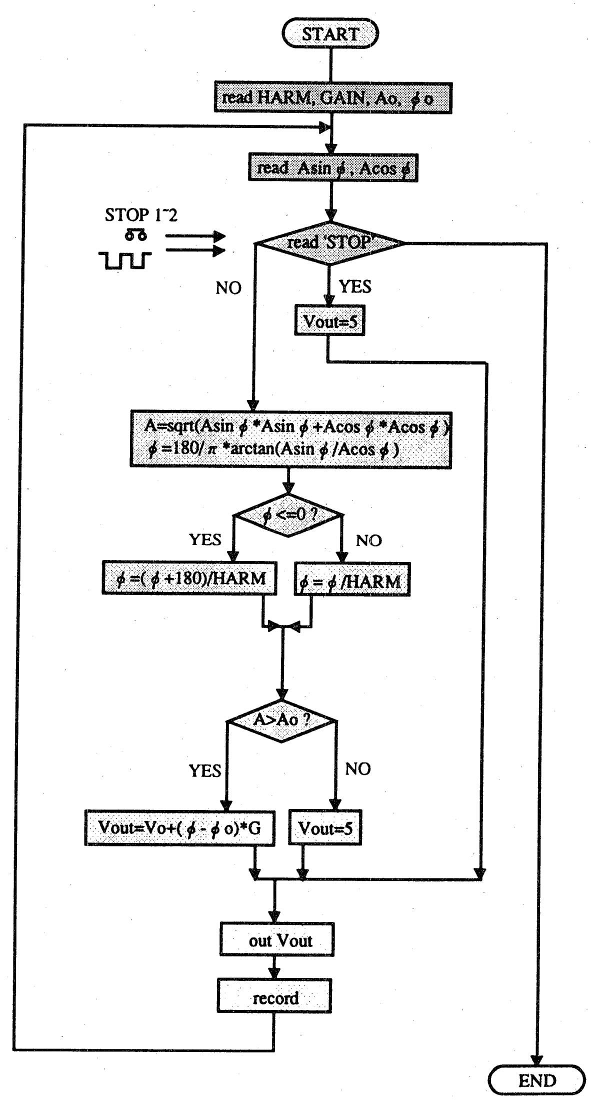

Fig.5 The algorithm for the calculation to revise the beam phase.

energy of the beam from the RILAC can be tuned intentionally by adjusting the rf phase of the final cavity[3]. The fluctuation of the beam energy at the exit of the RILAC might be suppressed by adjusting the rf phase of the final cavity corresponding to the beam phase at the probe location.

According to this expectation, a new feedback system was made as shown in Fig.4. A local computer with the ADC & DAC board was prepared, because the system needs a time response around 1 kHz, . After the two signals from the phasemeter are got into the ADC, a phase control signal is calculated by the program in the PC, and set on the DAC immediatly. The relation function for the output signal is given by

$$Vout=Vo+(\phi-\phi o)*G,$$

where G and Vo are the gain parameter and the pedestal voltage of the system, respectively. Vo is a constant of +5.0V normally. ϕo is a center of the fluctuating phase. The calculation done in the PC follows the algorithm shown in Fig.5. The system gets the signals of Asinϕ and Acosϕ and calculates A, ϕ, and Vout. After that, it sets Vout on the DAC when A is larger than Ao. Ao is a threshold of the beam intensity. The circulation period is around 100 μs.

The output signal from the DAC is fed to the phase shifter which is connected with the master oscillator signal line of the phase controller with a fast responce of 100 kHz.

The data included as shown in Fig.6. It also consisted of 2000 measurement points. The $\Delta\phi$ for this data is 16.5 deg in FWHM, so that the data with almost half straggling value could be taken by using the system. Further, by the use of the system, the improvement of the transmission rate of the RRC was observed.

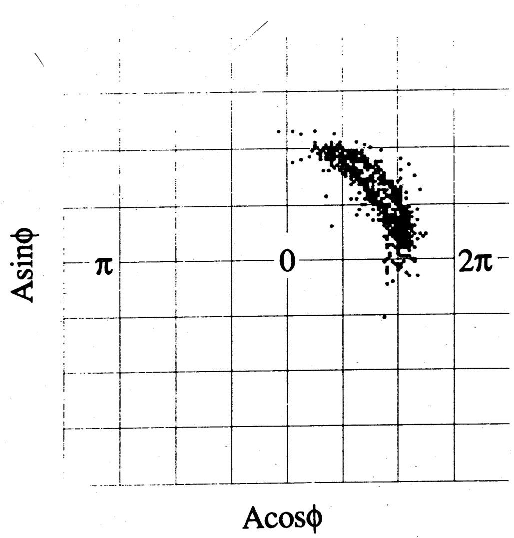

Fig.6 Observed beam phase at RILAC with using the new feedback system. The $\Delta\phi$ in FWHM is 16.5 deg.

4 Conclusion

From the result, it is clear that this new feedback system works effectively. A loss of the beam in the RRC can be almost nothing by this method. Next we are to change the calculation program to set the optimization of the parameters automatically in order to optimize the feedback system.

References

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