BEAM PHASE MEASUREMENT AT RIKEN RING CYCLOTRON

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SUMMARY

At RIKEN Accelerator facility, in order to make an isochronous magnetic field in cyclotrons and to match beam timing between RIKEN Ring Cyclotron and its injector, a number of phase probes have been installed inside cyclotrons and in beam lines. A phase meter has been developed to convert signals from these probes into dc signals of the beam phase. Automatic magnetic field tuning will be possible.

INTRODUCTION

RIKEN Accelerator facility has RIKEN Ring Cyclotron (RRC K=540) as a main accelerator and AVF cyclotron (K=70) as an injector for relatively light ions, and a frequency variable linac (RILAC) as injector for heavier ions.

In processes of accelerator operation, adjusting timings or phases when beam bunch appears at one location of acceleration stage and keeping them constant after tuned are very essential for rf accelerator. To do it efficiently, the automatic beam phase measurement system has been required.

In cyclotron tunings, making isochronous magnetic fields is one of most important process. A main and trim coil currents are initially set according to estimation using the field mapping data or to the previous data of same operation. These initial settings are not good enough for making a strict isochronous field. The beam phase measurement is necessary for the further tuning. Inside cyclotron, a set of phase probes is installed, being aligned radially and covering almost all orbital region of beam. The magnetic currents are finally tuned so that signals from these phase probes appear simultaneously. And then good isochronism can be achieved.

In order to tune the beam energy of injector and to adjust parameters of rebuncher, phase probes are installed injection beam lines. Phase probe installed in extraction beam line of RRC is used to monitor the deviation from isochronism after tuning is over.

When beam intensity is strong enough, these measurements can be done without intercepting beam. Therefore, after beam tuning is done, it is convenient to keep beam constant by using these probes.

So far these measurements had been done by observing a zero-cross point of signals on a oscilloscope display. In order to make these more efficiently, a phase meter has been developed.

PHASE PROBE

Installations of the phase probes in cyclotrons and beam lines are shown in Fig.1.

In Cyclotrons, capacitive phase probes of a parallel plate electrode type are installed in a valley of sector magnets. In RRC, twenty pairs of phase probes covering orbital

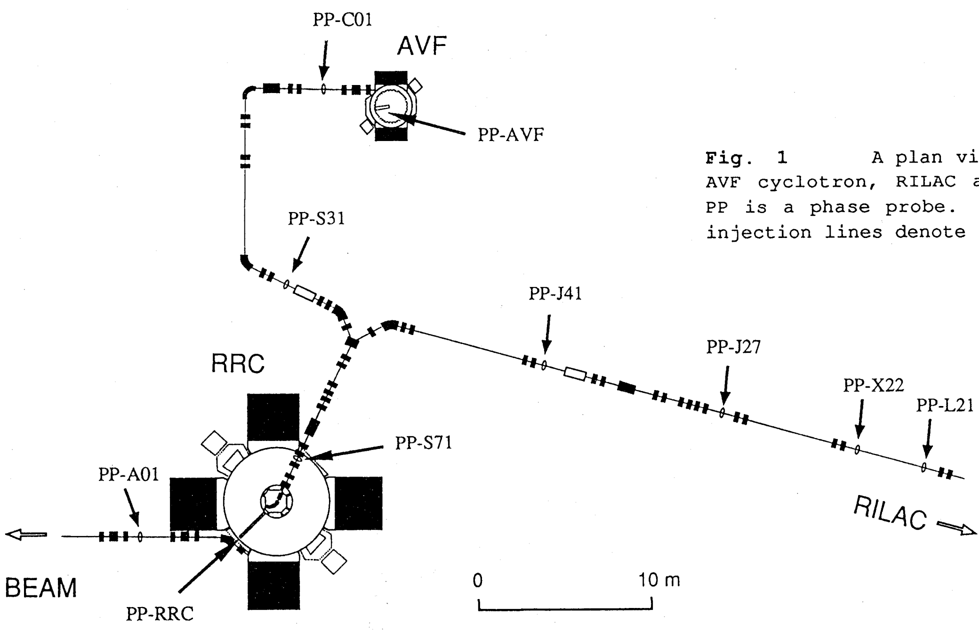

Fig. 1 A plan view of RIKEN Ring cyclotron, AVF cyclotron, RILAC and beam lines btween them. PP is a phase probe. Two open rectangulars in injection lines denote rebunchers.

radius from 1000 to 3220 mm, which corresponds to 82% of whole beam region, are aligned radially in a valley chamber. An electrode shape is square of 100 x 100mm^2 and a gap of two electrodes for beam space is 24 mm. In AVF cyclotron, six pairs of phase probes are installed in the same way. In this case, electrodes are made of etching patterns of copper thin plate on epoxy board. Inside a vacuum chamber, semi-rigid coaxial cables with same length connect these electrodes to vacuum feed through on chamber wall.

In beam line, a number of capacitive phase probe with a ring shape electrode are installed. In injection beam line from RILAC, three sets of probes, PP-L21, -X22, and -J27 are used for absolute energy measurements of injection beam by a TOF method[2]. Also PP-J41 and PP-S31, which are installed half way of the injection lines, are very sensitive to injection energy change. PP-S71 is used for tuning of rebunchers. At PP-A01, relative change of beam phase means the deviation of magnetic field in RRC from the setting value.

The block diagram of electronics in phase measurement system are shown in Fig.2. After coaxial switches, signal is brought to control room via cable (8D4AF) with length of about 100 m. And then it is amplified by a wide band amplifier (the gain is 40 dB and the band width 1 - 400MHz). A gain control is done by a variable attenuator after that. A signal can be observed on a oscilloscope (real time, 400MHz) and also feed to a phase meter.

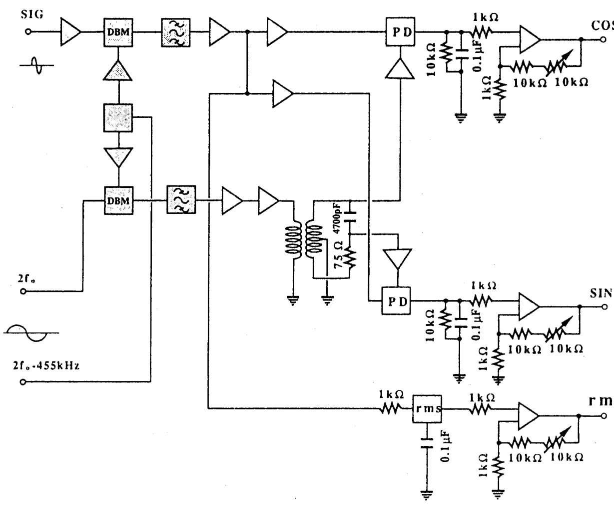

Fig. 3 Block diagram of phase meter. Shadow triangles show wide band amplifier of 1 - 400MHz.

PHASE METER

A block diagram of the phase meter is shown in Fig.3. As a reference signal, rf signal from master oscillator fo (same as RRC frequency and two times higher than AVF cyclotron frequency). The phase meter needs two kinds of signals with frequencies, 2fo and 2fo-455kHz. With a double balanced mixer and narrow band pass filter (455+1kHz), a 455kHz signal having a phase information of 2fo-component is only selected. With two phase detecter, PD, two components of $A\cos\theta$ and $A\sin\theta$ are obtained, where A is amplitude and θ the beam phase. A is also obtained with a rms converter.

These three dc signals are feed into analog input (AI) of interface board, DIM (Devise Interface Module)[3]. In DIM, the signals are converted into 12-bit digital signals every 1ms and stored into a memory of 8kB RAM inside. After the memory is full, data are transferred to a host computer.

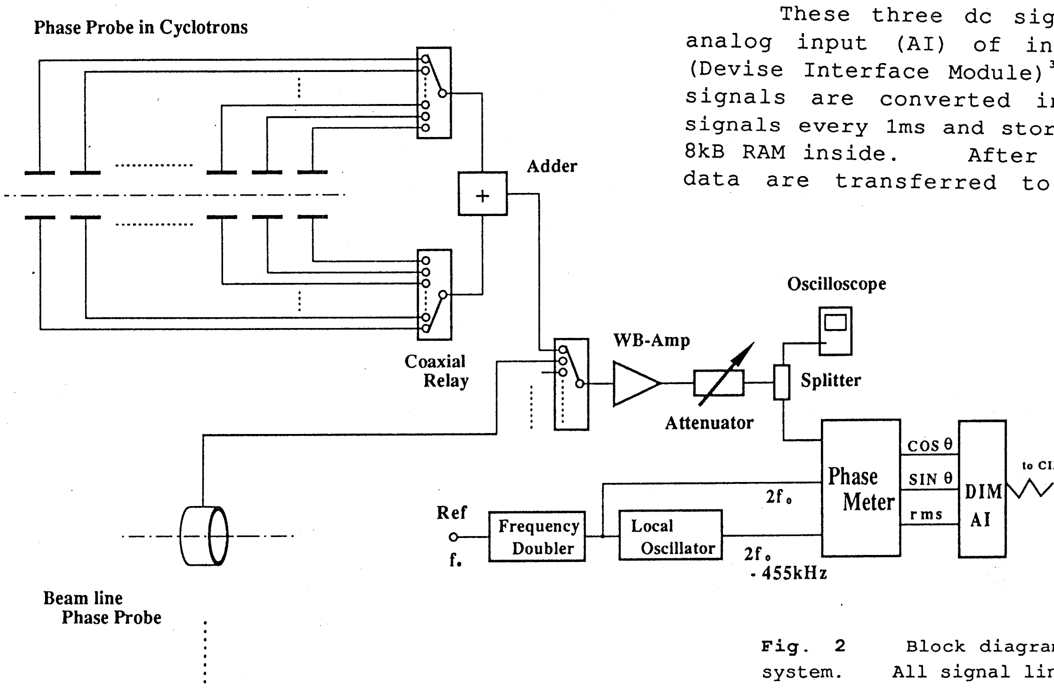

Fig. 2 Block diagram of phase measurement system. All signal lines shown here by solid line are 50Ω coaxial cables.

And then averaged values of $X=A\cos\theta$ and $Y=A\sin\theta$ are calculated. These measurements are done with beam (X_s and Y_s) and without beam (X_n and Y_n). Beam can be cut easily by a electrical beam chopper just after ion sources. The duration of cutting beam is 0.5 s for one phase probe. Beam phase is obtained by subtracting the noise effect, that is, using $\theta_s = \arctan(Y_s-Y_n)/(X_s-X_n)$.

RESULT

Typical result of the measurement is shown in Fig.4 for twenty pairs of phase probe in RRC. It shows that the magnetic field is lower than isochronous one for radius around 1800mm and higher than it for radius around 3000mm.

The comparisons between several results of observation are shown in Fig.5. The results with an oscilloscope show the similar tendency but time shift is enhanced for result of phase meter. And the dependence of results on beam intensity is small for range down to 10enA beam intensity.

FUTURE PROGRAM

Using the phase meter, an automaic tuning of isocronous field become possible. The beam intensity is frequently not enough for phase detction becouse of usr's requirement. For the faint beam in such case, other method of beam using a MCP is now under consideration.

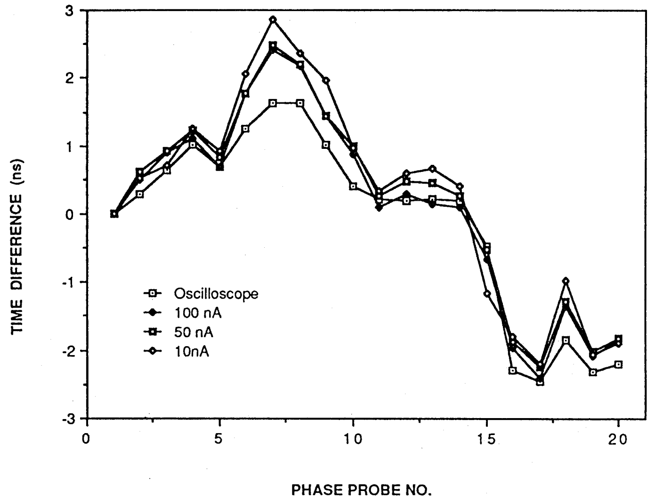

Fig. 5 Dependence of phase meter measurement on beam intensities, 100, 50, 10 enA. Beam condition is the same as in Fig.4. Result by observing with an oscilloscope for 100enA is also shown here.

References

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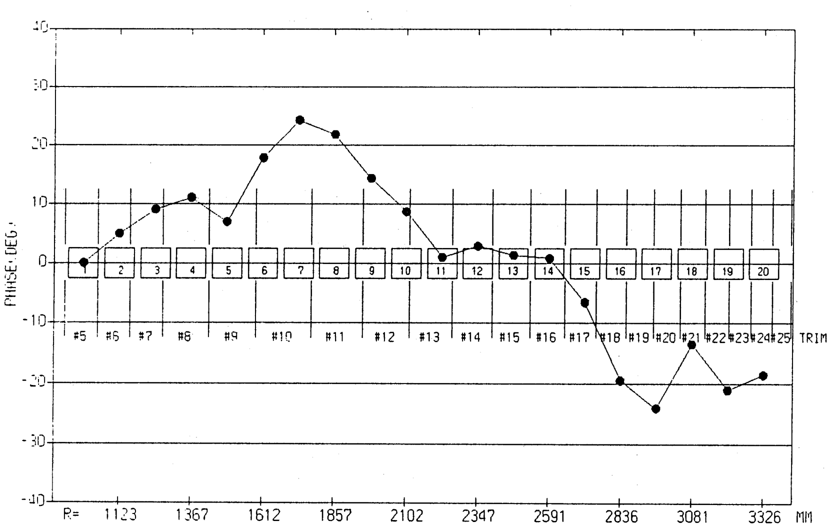

Fig. 4 Typical result of beam phase measurement for twenty pairs of phase probes inside RRC. Horizontal axis is radius of beam orbits and vertical one is the beam phase in deg. Plots in positive phase region means that field is lower than isochronous condition. Squares aligned along 0deg line show the location of phase probes and figures with # the location of trim coils. Beam is 95MeV Ar in f_0=28.1MHz. Beam intensity is 100 enA.