BEAM DIAGNOSTICS IN THE RCNP RING CYCLOTRON

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ABSTRACT

Various beam diagnostic devices showed sufficient performances for commissioning of the RCNP ring cyclotron. They worked successfully for an acceleration of 300 MeV proton or polarized proton at a limited current less than 1 nA. By adding filter circuits, more r.f. and static shields and by changing the wire assemblies of monitor head, enough signal to noise ratio was obtained. Beam phase was monitored with a heterodyne method by using a frequency of 5/3 multiple of acceleration frequency for a few nA proton beam, while the width was measured with nuclear gamma-ray and r.f. coincidence via time to amplitude converter.

1. INTRODUCTION

"RCNP Ring Cyclotron Facility" consists of a six-separated sector cyclotron (400 q^2/A) and a beam circulation ring linked to a ultra-high precision dual magnetic spectrograph system.[1)] The beam extracted from the RCNP AVF cyclotron (140 q^2/A) are transported through one of the beam lines and injected into the ring cyclotron.

2. TRANSVERSE PLANE

The beam shape and position are measured with three wire profile monitor (TPM-1, -2, -3, -4,

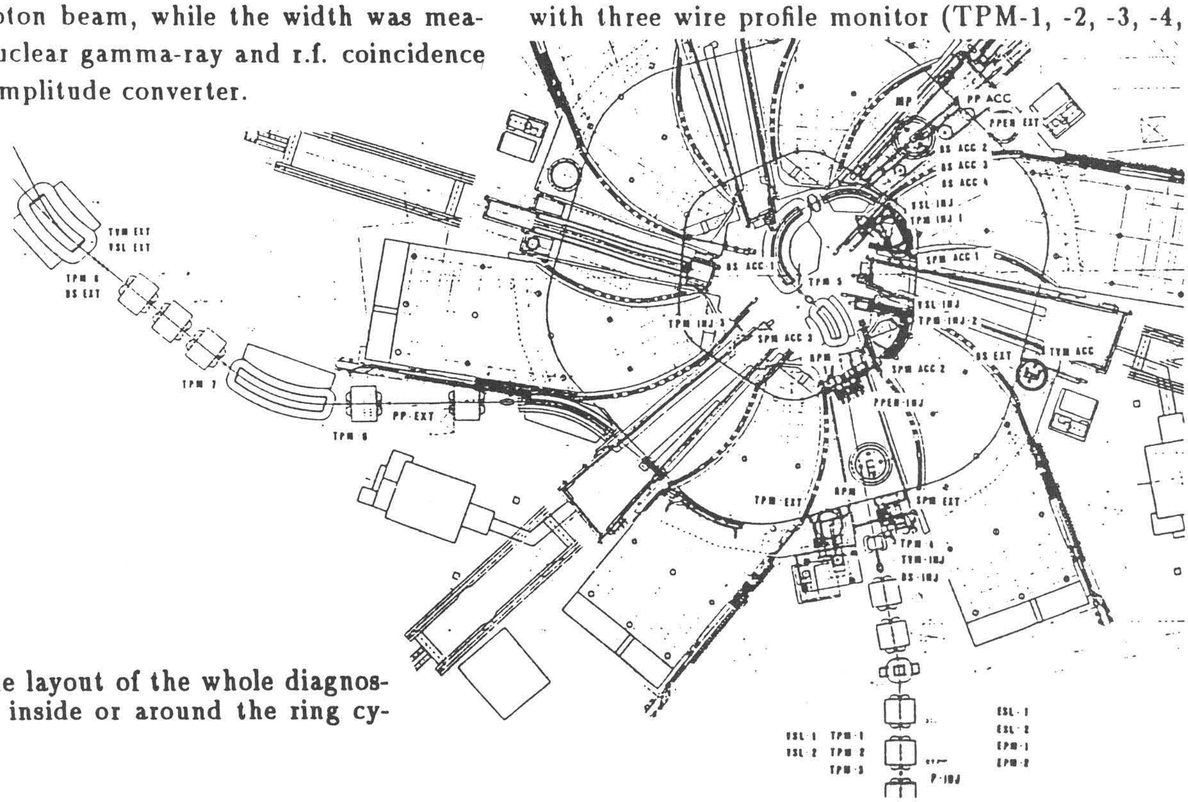

Fig. 1. The layout of the whole diagnostic devices inside or around the ring cyclotron.

-5) at several points of the injection line as shown in Fig. 1. They are installed into the beam duct 45° direction in the vertical plane. The head uses 0.1 mmϕ Au plated tungsten wires. At the total current of about 10nA it gives us the resolution for position of 0.1 mm and for width of 0.2 mm respectively. It is driven by stepping motor over 100mm stroke with about five seconds. Every 0.2mm steps, digitized current data are stored into a register and quickly transferred and displayed to color monitor scope as shown in Fig. 2.

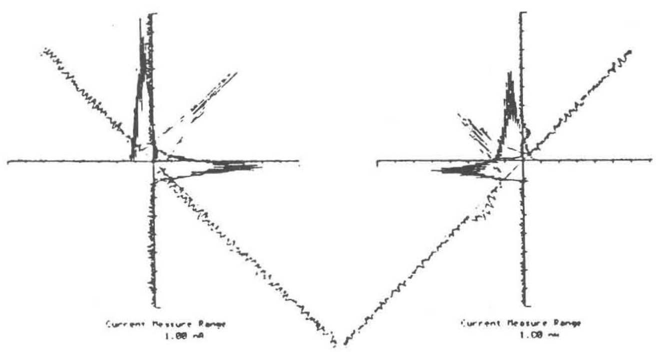

Fig. 2. Beam profiles obtained by three wire profile monitors (TPM-3, -4) in the injection line of the Ring Cyclotron. current range is 1 nA.

In order to obtain good signal to noise ratio for weak beam current down to 1nA, a 30 Hz and 5th order low pass filter circuit is supplemented to the multiplexer after the pre-amplifier in the current monitor system. An integrated circuit of switched capacitor filter (LTC1062) attenuates 30dB for 60-Hz noise component.

The intrusion of higher frequency components from three main cavities and flat top cavity are protected by π-type filter just between the device connector and the signal cable to the current amplifier.

2.1. Injection orbit

Original design of all three-wire profile monitor head employs 0.1 mmϕ gold plated tungsten wire as a sensing tool of current that gave us not enough signal for the beam current less than a few nA in the injection orbit. Thus, we convert this wire to 0.3 mmϕ platinum wire for TPM-INJ-1, 2, 3 and 0.1 mm thick and 1.5 mm wide tantalum ribbon for TPM-EXT (where the vertical wire only). Moreover, geometry of the wiring, where the magnetic field exists near the sector, is crucial to release the electrons produced by the energetic particles. Therefore, these tomography wire should be inclined 10~15 degree vertically to the beam direction. It is noted that cabling between these wire or ribbon to the vacuum feed-through made spurious signal if the cables vibrate accompanied by its stroke movement with a pulse motor accutuator. We improve shielded cables to fix the supporting rods tightly.

From the entrance of the first magnetic inflection channel (MIC-1) on about 2/3 of circumference for the 1st orbit, three three-wire profile monitors, three single-wire monitor (SPM-1,2,3) and one radial beam stop give us precise and sufficient data to match the orbital acceptance. The three spectra taken with the SPM-ACC-1,2,3 determines the vertical position of injected beam after passing the sector magnet 1, 2 and 4 as shown in Fig. 3. Its mechanical movement of 1 mmϕ single wire is ensured by quick rotation of 10 mmϕ aluminum tube via ferrofluidic seal coupled to the pulse motor actuator.

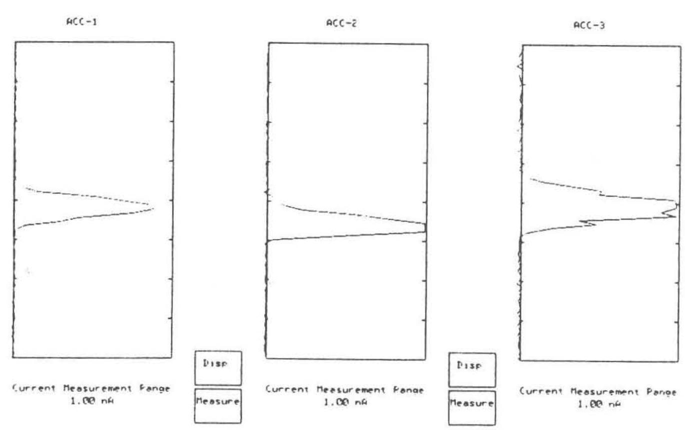

Fig. 3. Three spectra taken with single wire profile monitor at the injection orbit. Full stroke is ±20 mm from the median plane. SPM(ACC)-3 intercepts two or three accelerated beam orbits.

2.2. Accelerated beam orbit

The radial distribution during the acceleration can be properly observed with a main probe (M.P.) which has a 2000mm stoke. It is shown in Fig. 4. It measures the current and the transverse shape of the accelerated beam. It consists of tomography head of three thin platinum wires and ribbon and an indirectly cooled beam stop. The probe can be adjusted for the head to face the tangential direction of the beam orbit at any radius. The driving speeds can be chosen between 20mm/sec and 200mm/sec (it is helpful to use it in a smaller radial position).

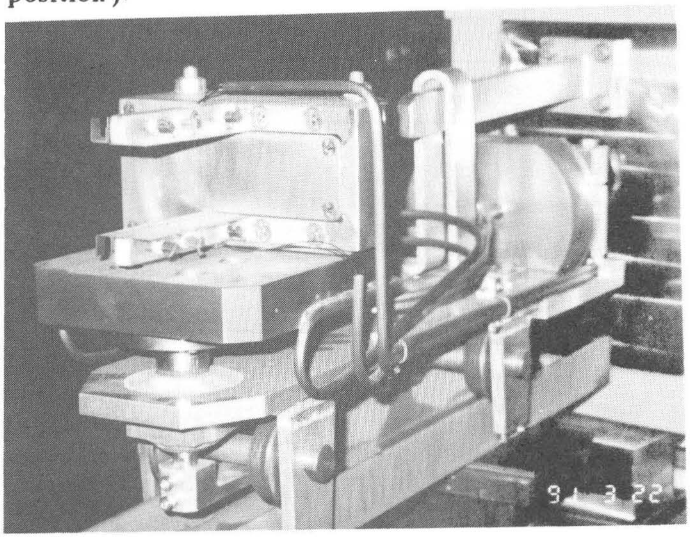

Fig. 4. Main probe.

2.3 Extraction orbit

Along the extraction orbit, TV-monitor (TVM-ACC), single-wire profile monitor (SPM-EXT) and three wire profile monitor (TPM-EXT) can observe the turn separation of the final few turns around the extraction orbit and behavior of a radial gain per turn by varying the r.f. phase or by tuning the phase history with correction of the magnetic field defect upon the radius $\delta B(r)$. The main probe is also useful to measure these features by repeating stroke around this region with a short intervals.

3. LONGITUDINAL PLANE

The phase acceptance of the ring is 20° for a flat-topping acceleration mode with beam energy resolution 10^{-4} while the value is 10° to do the neutron time of flight experiment. Especially for the axial injection mode, new dee-insert played very effective role to reduce the width at moderate current reduction.[2)]

3.1. Beam phase width

An r.f. and gamma-ray coincidence technique was applied for the phase width measurement at a beam current less than 10 nA. Spectrum of the time to amplitude converter is shown in Fig. 5. Time width for the injected beam obtained so far is less than 1.1ns. In these measurements, instrumental time resolution is less than 0.5 ns.

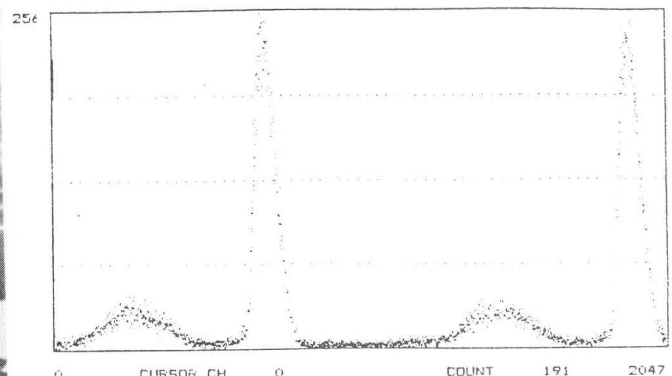

Fig. 5. An r.f.-gamma coincidence spectra obtained at the final radius of the AVF cyclotron. Two peaks is separated by 63.8 ns.

3.2. Beam phase relative to the acceleration r.f.

The actual phase of the beam from the injector cyclotron relative to the acceleration r.f. can be measured by a non-intercepting capacitive pick-up (PP-INJ) when the beam not less than 10 nA

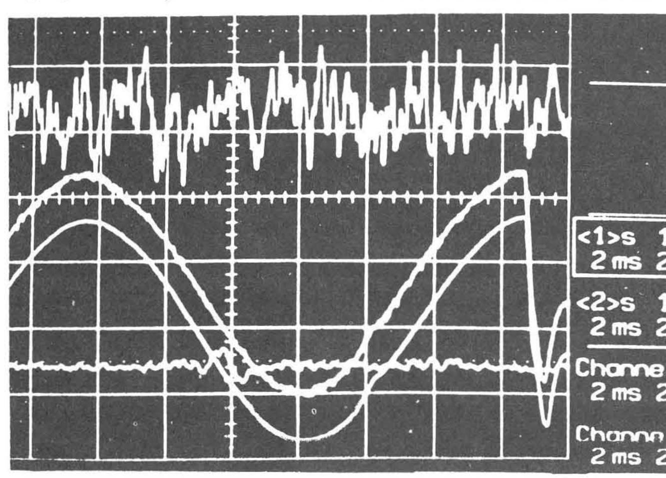

Fig. 6. Beam phase relative to the acceleration r.f. observed with a non-intercepting capacitive pick-up (PP-INJ) when the current was about 50 nA.

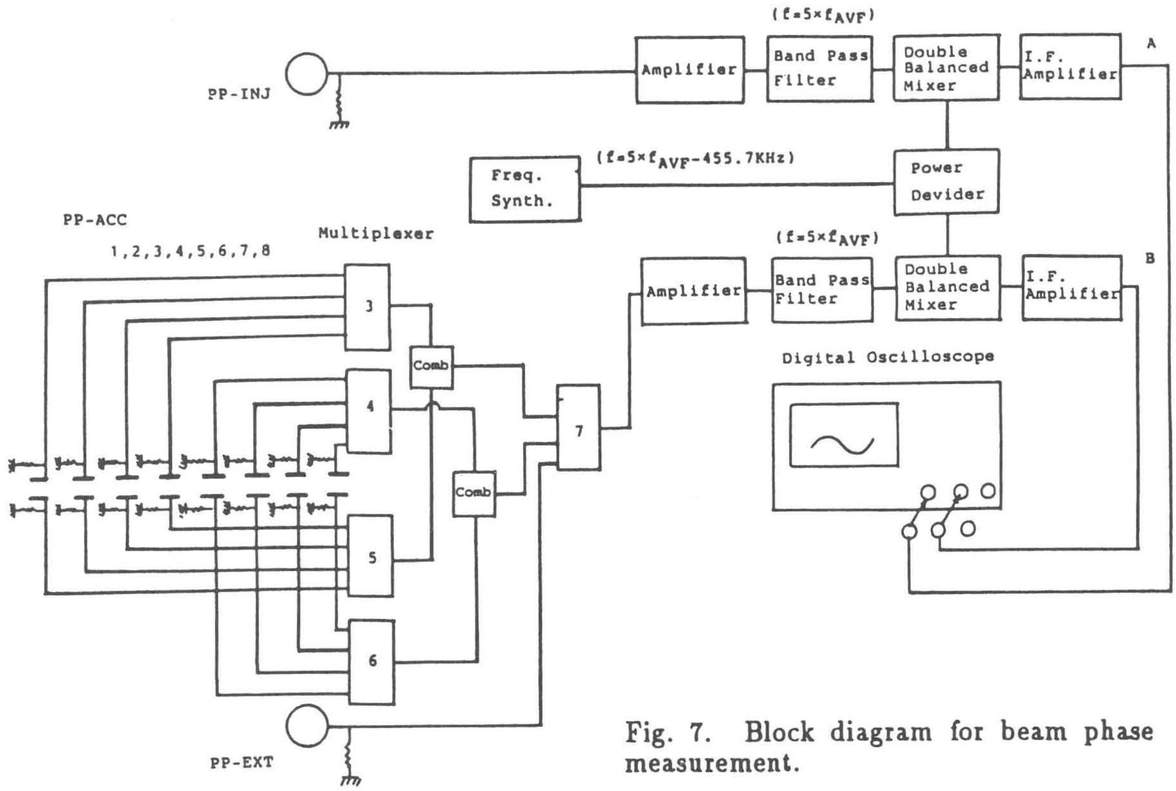

Fig. 7. Block diagram for beam phase measurement.

is injected; rf. caused from three main cavities and flat-top cavities interfered the beam signal severely. It used the sampling pulse circuits and digital oscilloscope. Fig. 6 shows beam phase observed with PP-INJ, when the current was about 50 nA. Beam signal was obtained after averaging and subtracting two signals with a injected beam and without the beam each other.

The beam phases relative to the acceleration r.f. are measured with eight parallel plate detectors (PP-ACC), which are separated by 300 mm each other on a same carriage. Superheterodyne technique applied for measurements gives good signal to noise ratio in existence of large r.f. background. They are measured with the 5th harmonic component of the beam signal. It is designed so as to use 455 KHz for IF stage to any cyclotron frequency: it uses a crystal filter in the IF amplifier. The output signals are averaged by a digital oscilloscope to reduce a thermal noise. The block diagram of the total circuits is shown in Fig. 7.

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