RADIAL AND VERTICAL BETATRON OSCILLATION FREQUENCIES OBSERVED BY A SCINTILLATION PLATE AND A THREE WIRE TOMOGRAPHY MONITOR

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We have developed a new probe head of a scintillation plate on the main probe. A mirror 45-degree inclined to the median plane is viewed with a T.V. monitor camera outside the vacuum chamber. The whole view for the radial behaviour about 2-m can be observed by changing the angle of the mirror and T.V. camera. The beam behaviours are simultaneously observed with a three wire tomography monitor. The radial and vertical betatron oscillation frequencies have been deduced with these measurements.

1.Introduction

To clear the problems on the beam loss and the beam qualities concerned with accelerated beam dynamics in RCNP Ring Cyclotron[1], we developed a beam viewing system with TV camera and a phosphor covered scintillation plate. It enable us to take a continuous picture of beam position and size in the full radius of acceleration. The scintillation plate is mounted in front of the copper beam stopper of the main probe head. The combination of the scintillation plate and tomography monitor can afford a precise analysis for the behaviour of the accelerated particles. We can deduce the vertical and radial oscillation frequencies in each radial position. The measurement has been done for 400Mev proton beam.

2. T. V. camera and scintillation plate

The phosphor plate which has scintillating surface obtained by spraying ZnS on an aluminum plate (1mm thickness) is mounted in front of the copper beam stopper on the main probe head for an integral current monitor)[2]. The viewing port for this is set at the valley region beyond the one sector magnet from the main probe location. The T.V. monitor camera outside the vacuum chamber views the inside mirror inclined 45-degree to the median plane of the accelerator. In order to look over the whole view for the radial range of the main probe, the setting of the mirror and T.V. camera should be changed several times. The scintillation plate on the main probe moves at the speed of 20mm/sec by taking a picture for the monitor with POLAROID camera at B-mode. The observed vertical oscillation is shown in Fig. 1.

3. Main probe and tomography monitor

A main probe can also measure the current and the transverse shape of the beam in the Ring Cyclotron. It consists of a tomography head of three thin platinum wires and an indirectly cooled beam stop. The probe can be adjusted for the probe head to face the tangential direction of the beam orbit at any radius. At the beam tuning, the current

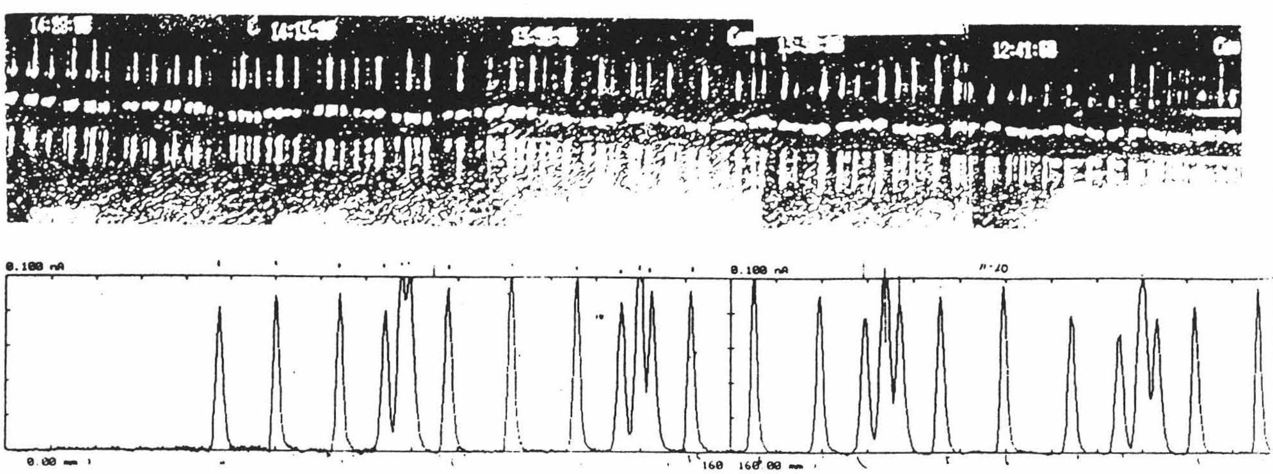

Fig. 1. Observed vertical oscillation with a scintillation plate (in the upper photo, five pictures are assembled) and intensity versus radius measured simultaneously with a tomography monitor. This shows intensity versus radius measured with a vertical wire.

should be less than 10nA inorder to avoid the unnecessary irradiation in the vacuum chamber. Since the commissioning of the accelerator, signal to noise ratio has been improved so much. As a result, now we can get a good signal to noise ratio for the current down to 1nA. The main improvements are as follow. A 30 Hz 5th order(30dB/Oct.) low pass filter is used. Moreover, the attenuation of 30dB for 60Hz was achieved by using an integrated circuit of switched capacitor filter LTC1062. Simultaneously observed pattern of tomography monitor together with a photograph of scintillation plate are shown in Fig. 1.

4. Induced radio activities

After the 4-years operation the residual activities on the surface of the acceleration electrodes in three cavities were investigated with a commercial GM-counter. These were measured at the 25 points on the surface of each cavity every 100mm radial intervals from radial minima to maxima along the gap of the cavity structures. Vertical behaviour also was measured for three cavities at the surface of the upper and lower electrodes. These measured points are illustrated in Fig. 2.

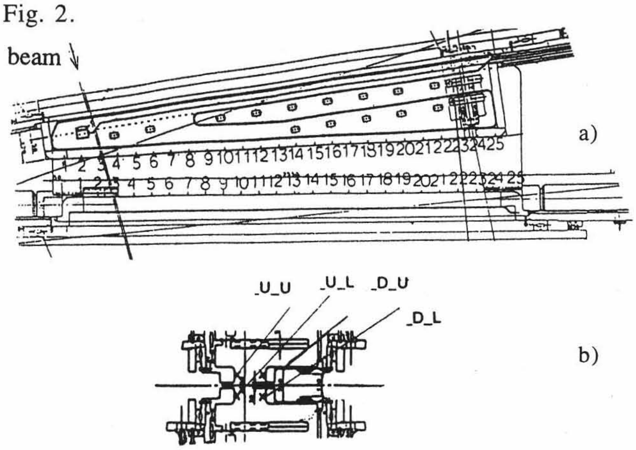

Fig.2. Measured positions on the surfaces of acceleration electrodes. Plan view a) and sectional b) are shown respectively. Numbers and D,U,L show the position at which we measured the residual activities

5.Results and discussion

The developed method is more simple and effective to observe the dynamic behaviour for the accelerated particles than that obtained by a fixed geometry of camera and scintillator.

5.1 Vertical oscillation

Both from the observed pattern for the vertical beam oscillation and from the recorded turn numbers obtained with the three-wire tomography monitor, we can deduce the turn numbers in each oscillation cycle as shown in Fig.1. Thus, there are two results when the cycle is estimated from the successive top peak positions or from the bottom peak positions in the observed figures. Specified radial length in Fig.3. shows this oscillation intervals and specified ones are described at the middle of the cycle in the radial axis. The betatron oscillation frequency can be estimated from the reciprocal number of turns in this cycle plus one. Less than about 1500mm in radial, the pattern of tomography monitor can be distinguished turn by turn, although some of them are a little overlapped each other which introduced more errors.

With these procedures, we can obtain vertical betatron oscillation frequency at each radial intervals as shown in Fig.3.

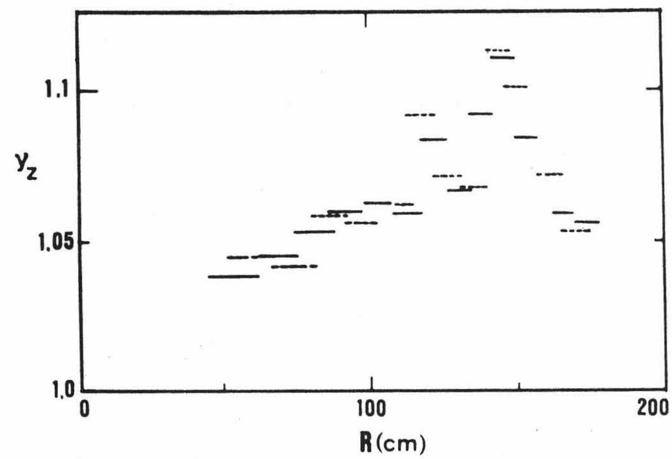

Fig. 3. Deduced vertical oscillation frequency

5.2 Radial oscillation

We assume that the radial betatron oscillation of the beam is enhanced with miss matching in the injection to the Ring Cyclotron and purely introduces the unequal separation in successive turns. Thus, we measured dr separation in each turn of the radial spectra observed with vertical wire of the tomography monitor from injection to the distinguished turn about 1600mm where we can put the turn number 260-revolutions. Thus, we plotted dr separation to this revolution numbers. It shows oscillatory pattern with a increase of the radial position as shown in Fig. 4. Between the successive dr maxima or dr minima in this figure we can measure the turn numbers in the one cycle from which we estimated radial betatron frequencies. Over the 1000mm in radius the figure shows an irregular pattern mixed with two or three cycles of oscillation intervals. Even taking into account the regular increase of the radial betatron oscillation frequency, the observed structure was somewhat disturbed with several processes such as unequal acceleration process in beam phase, imperfect isochronous field and considerable amount of beam dispersion in energy. As a result, we can deduce the radial betatron frequencies from injection to almost full acceleration radius as shown in Fig.5.

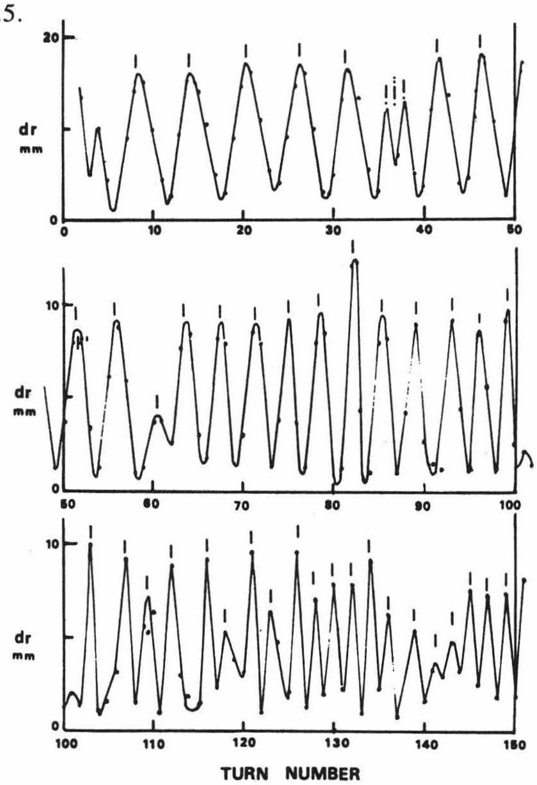

Fig.4. Measured dr separation in each acceleration turn

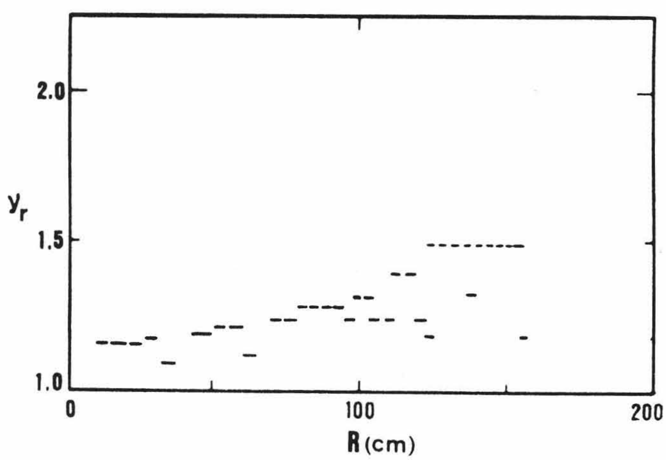

Fig.5. Deduced radial betatron frequency

5.3 Discussion for beam loss

Compared with the betatron frequencies calculated from the data of magnetic sector field, these observed values are roughly consistent with their radial response for both betatron oscillation frequencies[1]. However, vertical oscillation frequency rapidly gets closer ν_z=1.0 around r= 1.7m which may suggest the unstable behavior of accelerated beam induced from magnetic field structure and trim coil parameter optimization.

5.4 Induced radio activities

This phenomena is coincided with the measurement of induced radio activities remained in the acceleration gaps of three cavities as shown in Fig. 6. Manifest observed features of residual activities are as follows; (i) in a radial distribution the maxima at three cavities happen around r=1.7~1.8m and (ii) this appeared strongly in cavity-3.

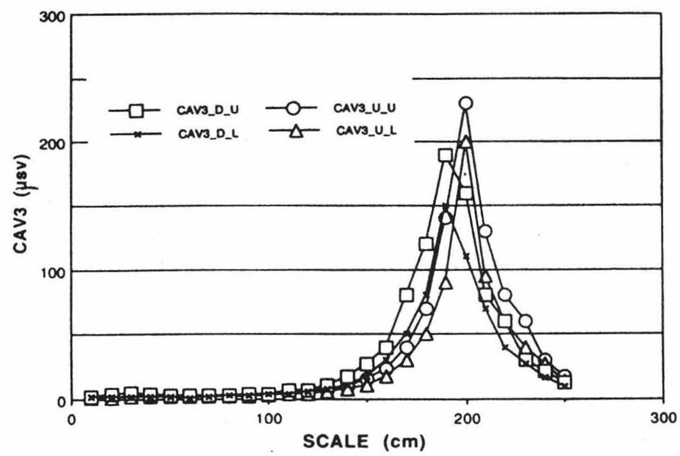

Fig.6. The residual activities measured at cavity-3. The positions shown in this figure are indicated in Figure 2;the first D and U mean the downstream or upstream , the second U and L are for the upper and lower electrodes. The scale should be shortened to the ratio of 1.7/2.0.

Although this oscillation have not brought about a fatal situation for obtaining the full transmission from the injection to the extraction, it needs precise tuning the isochronous field and the phase of the injected beam as shown in Fig.7. The better tuning brought the better transmission.

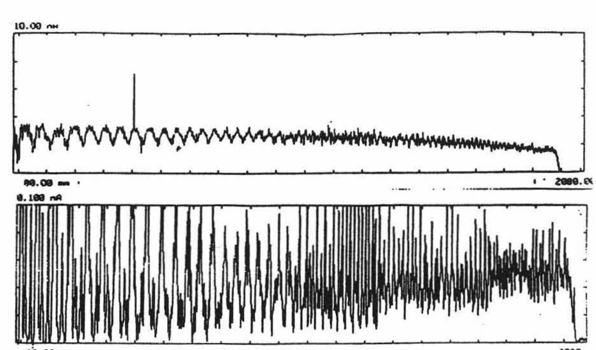

Fig.7.Beam current and turn pattern from the injection to the extraction. Nearly the full transmission is obtained.

After this development, we improved the installation mechanism of the scintillation plate such as the plate should be retractable behind the main probe head without the breakdown of the main vacuum.

Acknowledgments

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