DEVELOPMENT OF PHASE PROBE FOR THE NIRS SMALL CYCLOTRON HM-18

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Abstract

The small cyclotron HM-18 of the National Institute of Radiological Sciences (NIRS) allows us to accelerate H^- and D^- ion at fixed energies of 18 and 9 MeV, respectively. It has four trim coils for generation of the isochronous fields. Until recently, currents of the four trim coils had been adjusted only by monitoring the output beam intensity. In order to exactly produce the isochronous fields, a phase probe has been newly installed in the HM-18. The phase probe has a simple structure in which four copper electrode plates of 55~76 mm x 68 mm in area are glued to a copper base plate with a polyimide insulator sheet sandwiched between them. The thicknesses of the copper plates and the polyimide are 0.1 mm. This structure has an advantage that it can be easily installed in the cyclotron; only one part of a pair of upper and lower electrodes, which is usually adopted in cyclotrons, is simply attached on the surface of the (lower) sector pole. The development of the phase probe and some results of a preliminary beam test using it are reported.

INTRODUCTION

The small cyclotron HM-18 of the NIRS has been operated for use in RI production since 1994[1]. The HM-18 cyclotron is a negative-ion accelerator that was purchased from Sumitomo Heavy Industry, Ltd. A layout of the HM-18 is shown in Figure 1. Two carbon-foil strippers are located at a radius of 435 mm for beam extraction; they are located in the opposite sides to each other. In one side beams are delivered to a beam transport line, which is jointed to that of the NIRS-930 cyclotron. In the other side four target ports are attached directly to the beam chamber for production of short-lived radio isotopes such as ^{11}C and ^{18}F. The HM-18 has an internal cold-cathode ion source that produces H^- and D^- ions, which are accelerated up to 18 and 9 MeV, respectively, with the acceleration frequency of 45 MHz. The acceleration harmonics are 2 and 4 for H^- and D^- ions, respectively. Four trim coils are used for generation of the isochronous fields. Until recently, currents of the four trim coils had been adjusted only by monitoring the output beam intensity; the isochronous field was indefinite because the beam phase was not able to be measured. Therefore, a phase probe has been newly installed in order to exactly produce the isochronous fields in the HM-18.

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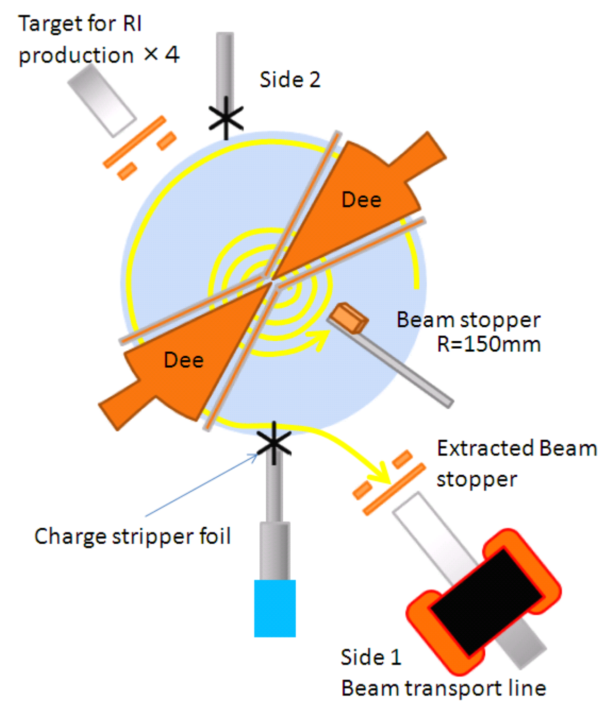

Figure1: Schematic layout of the HM-18 cyclotron.

STRUCTURE OF PHASE PROBE

Photograph and cross-sectional view of the new phase probe is shown in Figure 2. This phase probe has a simple structure. Usually, a phase probe is composed of a pair of upper and lower electrodes, but the new phase probe for the HM-18 is composed only of lower part. It consists of four copper plates of 55~76 mm (azimuthal width) x 68 mm (radial length) in area glued to a copper base plate with a polyimide insulator sheet sandwiched between them. Adhesive double-coated tapes are used for the attachment of them. The thicknesses of the copper plates and the polyimide sheet are 0.1 mm. Semi-rigid coaxial cables are used for transport of beam signals in the beam chamber. The outer conductor of the cable is made of copper tube with 1.2 mm in diameter. The ends of the inner and outer conductor are soldered to the fins of the pickup electrodes and the grounded copper plate, respectively, as shown in Figure 2.

This structure has an advantage that it can be easily installed in the cyclotron. Photograph of the phase probe installed in the HM-18 is shown in Figure 3. The phase probe and signal cables are simply attached on the surface of the lower sector pole with adhesive aluminium tapes.

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The layout of the new phase probe and four trim coils (C1~C4) in the HM-18 is shown in Figure 4. The inner edge of the first electrode (PP1) is set at the radial position of 150 mm from the cyclotron center, and the outer edge of the fourth electrode (PP4) is set at 425 mm.

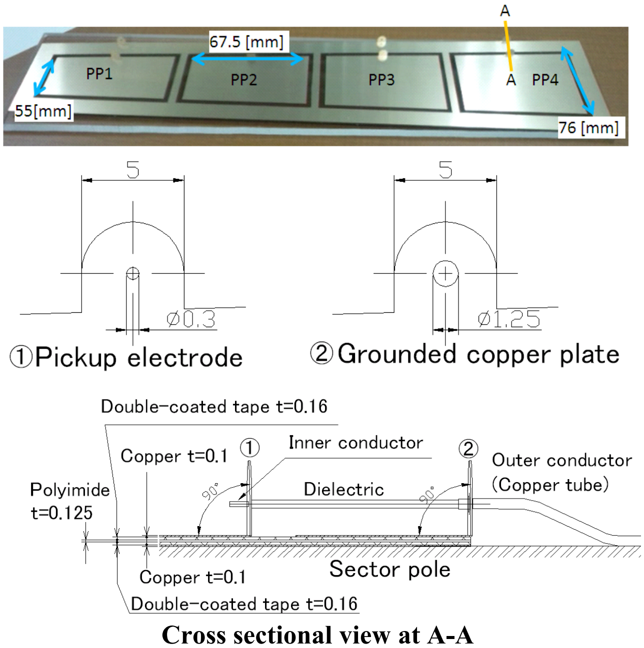

Figure 2: Photograph and cross-sectional view of the phase probe.

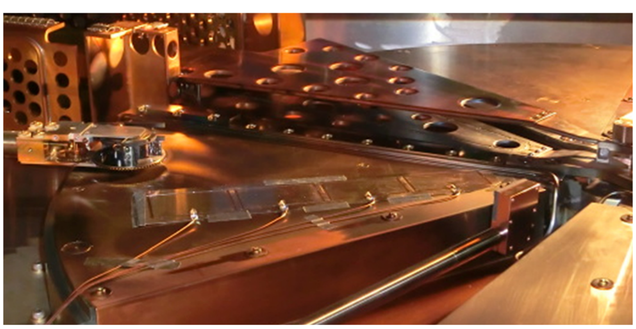

Figure 3: Photograph of the phase probe installed in the HM-18.

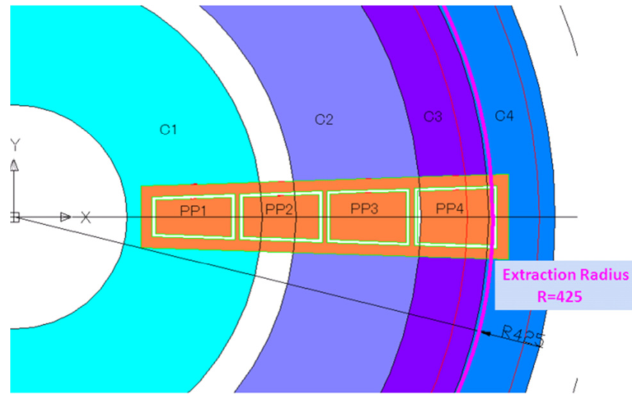

Figure 4: Layout of the new phase probe and four trim coils (C1~C4).

MEASUREMENT OF BEAM PHASE AND ADJUSTMENT OF TRIM COIL CURRENTS

Beam pickup signals from the phase probe were observed with an oscilloscope. An example of waveform for a 18 MeV H^- beam is shown in Figure 5. In this case the beam intensities were 22 μA at the radial position of 150 mm and 20 μA at the extraction of the cyclotron.

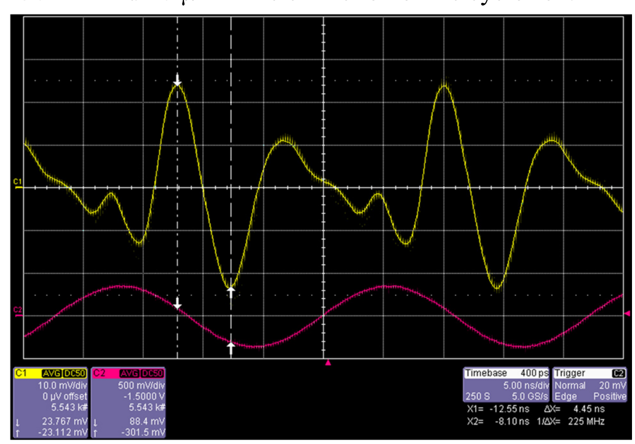

Figure 5: Waveform of a beam pickup signal from the PP1 for a 18 MeV H^- beam along with the rf signal. The yellow line indicates the pickup signal and the red line the rf signal (45 MHz). The pickup signal was obtained by taking the difference between the two signals when the beam is on and off. The beam intensity was 20 μA.

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At first, the phase excursion of the beam was deduced from the pickup signals thus obtained of the four electrodes for the parameter set of main and trim coil currents that had been used in routine operation. The result is shown in Figure 6 by blue diamonds. The deviation of the beam phase was 17° at the maximum. Then, the coil currents, mainly those of the main and C2 coils, were adjusted in order to make the phase excursion as small as possible. The obtained result is shown by red squares in Figure 6. The phase excursion could be reduced to 9° at the maximum. The beam intensity was not improved by this adjustment.

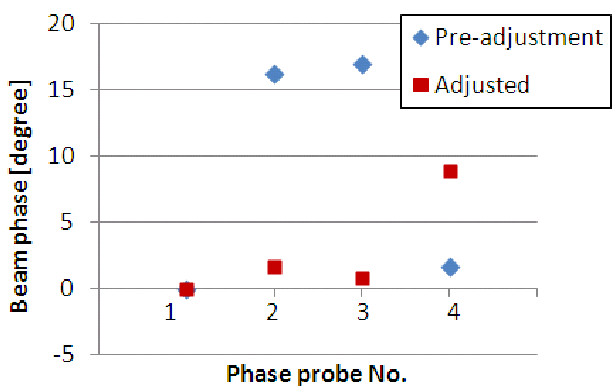

Figure 6: Phase excursion of a 18 MeV H^- beam. The blue diamonds indicate the excursion for the parameter set of main and trim coil currents that had been used in routine operation. The red squares indicate the one obtained after adjustment mainly of the main and C2 coil currents.

The measurement of the phase excursion and the adjustment of the coil currents were also performed for a 9 MeV D^- beam. The results are shown in Figure 7. The blue diamonds indicate the excursion for the parameter set of main and trim coil currents that had been used in routine operation. The phase increased almost monotonously with the radius up to 60°. This phase excursion was improved by adjustment mainly of the main coil current; however, the beam intensity decreased from 14 µA to 11 µA. This means that for the optimization it is necessary to adjust not only the magnetic field distribution in the acceleration region but also the one in the center region, which affects the beam intensity significantly.

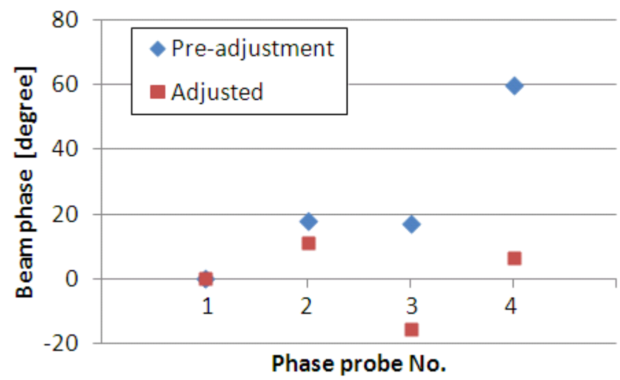

Figure 7: Phase excursion of a 9 MeV D^- beam. The blue diamonds indicate the excursion for the parameter set of main and trim coil currents that had been used in routine operation. The red squares indicate the one obtained after adjustment mainly of the main current. The beam intensity decreased from 14 µA to 11 µA in this adjustment.

CONCLUSION

In order to help measure the phases of 18 MeV H^- and 9 MeV D^- beams, which are accelerated in the existing HM-18 cyclotron, a phase probe has been newly developed. It has a simple structure consisting of four copper electrode plates, a polyimide insulator sheet and a copper base plate that are sandwiched and glued with adhesive double-coated tapes. The thicknesses of the copper plates and the polyimide sheet are 0.1 mm. The phase probe is simply attached on the surface of the lower sector pole with adhesive aluminium tapes.

It was confirmed that this phase probe could provide signals sensible with an oscilloscope for the phase measurement. It was found that the magnetic field distributions of the HM-18 were not necessarily isochronous ones: in particular for a 9 MeV D^- beam. The phase probe is expected to allow us to obtain the optimum magnetic field distributions for the HM-18.

The flexible structure of this phase probe can be applicable in other places such as the inner surface of a pipe in a beam transport line.

REFERENCES

[1] S.Hojo et al., "Present status of cyclotrons (NIRS-930, HM-18) at NIRS", Proceedings of the PASJ2012, WEPS008, (2012).

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