Measurement of the AVF Cyclotron Magnetic Field by NMR

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1. Introduction

The AVF Cyclotron of RCNP has been required more stability, and has improved its power supplies and the control system for the temperature of cooling water, since it used as an injector of the Ring Cyclotron.[1] However, it needs to monitor stability of the cyclotron parameters with high precision because of the inadequacy of beam stability.

The stability of the frequency, phase and voltage of acceleration RF system, magnetic field and so on are important to operate a Cyclotron stably. Especially, the stability of magnetic field and acceleration frequency are essential parameters for stable operation.[2] For that reason monitoring the magnetic field of the Cyclotron with high precision has been demanded.

The most precise measurement of the flux density within the range of magnetic field of the Cyclotron is measurement with NMR. However the uniformity of magnetic field is needed for conventional NMR and it is difficult to measure a magnetic field which has complex distributed magnetic field such as AVF Cyclotron. We finally have succeeded in monitoring magnetic field continuously with high precision, during operation of the AVF cyclotron using improved NMR, selecting appropriate spot for measurement and correcting the magnetic field near the NMR probe.

2. Problem of magnetic field measurement of AVF Cyclotron

The AVF Cyclotron magnet consists of 3 sectors, valleys and hills. There are very narrow flat magnetic field regions. (Figure 1) Conventional NMR probe requires uniformity of the magnetic field better than $1x10^{-4}$ /cm^3. It firmly needs to take measures against RF back ground and radiation inside the acceleration chamber.

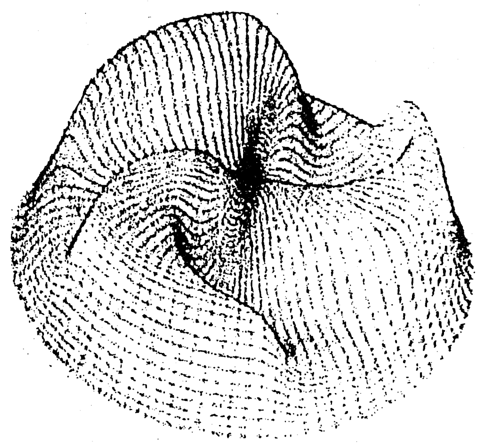


Figure 1 : Distribution of the AVF Cyclotron magnetic field.

3. Refinement of NMR

It should be thin as the probe will be inserted between the magnetic pole and the base plate of the trim coil when measuring. The tip of the probe is thinned to attach the correcting coil on both side of the NMR probe for flattening the gradient of the field formed with the trim coil. Measurement range is limited from 450mT to 1250mT. (This field range corresponds to P=21.95MeV~$^{18}O^{8+}$=246.5MeV) The modulation coil is Revised from ±30(per coil) to 400T.

4. Correcting coil

The distribution of the magnetic field of AVF Cyclotron is formed according to the shape of magnetic pole and the currents of the 16 sets of trim coil and 5 sets of valley coil. As the magnetic field formed with the trim coil is concentrically lopsided from the center of the magnetic pole.

Uniform magnetic field can be formed by making the correcting coil field which has opposite inclination of the field formed with the trim coil and valley coil near(merely very little)the probe of NMR.

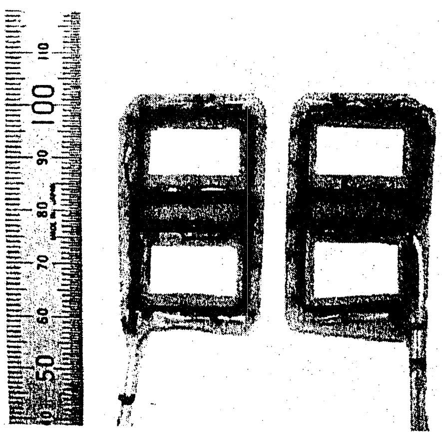


Figure 2 : Correcting coil

5. Specifications and Characteristics of Correcting coil

It should be as thin and small as possible to catch the probe at the both sides(upper and lower),and to correct the magnetic field without disturbing isochronus magnetic field.

A o.2mm formal wire is wound 60 times to form a coil. The coil is hardened and thinned with epoxy resin, and its size is 24mm width x 44mm length x 2.3mm thickness. Two sets of coil are provided. 100mA current passing the coil can correct about 0.8mT/cm magnetic field.

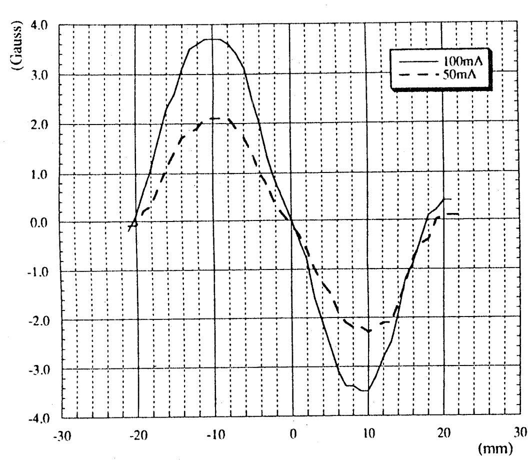
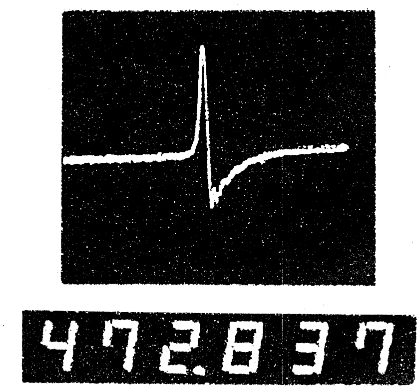


Figure 3 : Field of the Correcting coil

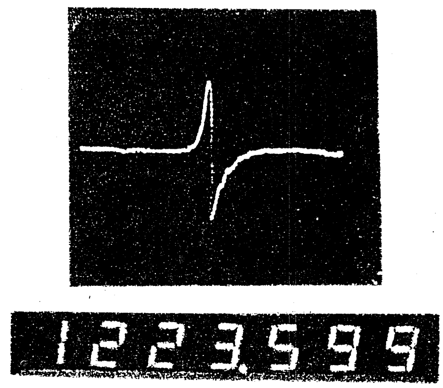
6. Installing position of the Probe

To research the influence of temperature change of the magnetic core, it needs to measure at least two points on the pole. Two probes will be inserted in 20mm opening between the magnetic pole of the valley and the trim coil base plate. The base plate is made of 10t copper, which matches to RF shield. The position is hard to get influence of radiation for it is apart form MP.

7. Result of Measurement

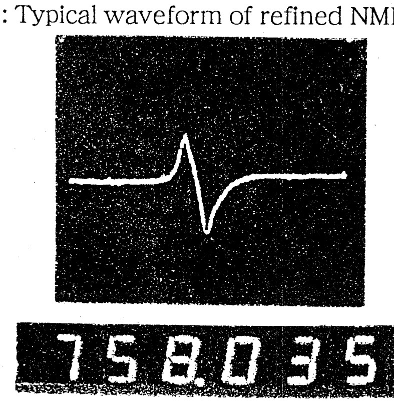


NMR waveform corresponding to a field for P=21.95MeV(mT)

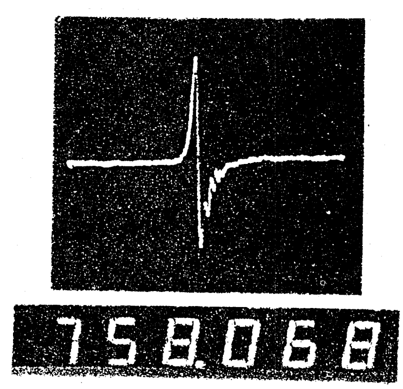


NMR waveform corresponding to a field for $^{18}O^{8+}$=246.5MeV(mT)

Figure 4 : Typical waveform of refined NMR prove



NMR waveform corresponding to a field for P=64.31MeV(mT) (without correcting current)



NMR waveform corresponding to P=64.31MeV(mT) (with turning on the correcting coil at 100mA)

Figure : 5 Effect of the correcting coil.

8 . Preliminary measurement of thermal effect on the magnetic field of the AVF cyclotron

The structure of the AVF magnet is different from those of the RING sector magnets. Heat transfer from the main coil or the trim coils is little and effect of temperature change appears slowly. A response of the field variation to temperature change of cooling water for the main coil and the trim coil is shown in Figure 6. The data show effect of thermal expansion of the magnet pole.

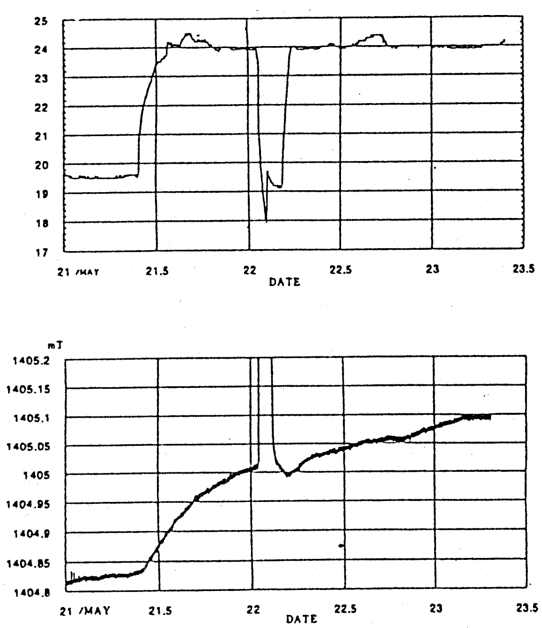


Figure 6 : Field variation with time after temperature change of cooling water for the main and the trim coil of the AVF cyclotron.
Upper : Temperature change of cooling water.
Lower : Field variation monitored with NMR.

References

[1] H. Ikegami, Proc. of the 12th Int. Conf. on Cyclotrons and their Applications, Berlin (1989) , 30–39

[2] T. Saito et al. , Proc. of the 15th Int. Conf. on Cyclotrons and their Applications, Caen (1998) , 609–612