MAGNETIC FIELD MEASURING SYSTEM FOR REMAPPING THE ~~ORIC MAGNETIC~~ FIELD

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Abstract

The Holifield Heavy Ion Research Facility will integrate a new 25 MV tandem electrostatic accelerator into the existing cyclotron laboratory which includes the Oak Ridge Isochronous Cyclotron (ORIC).[1] Computations of ion paths for beam injection from the new tandem into ORIC require field mapping in the regions traversed by the beam. Additional field data is also desired for the higher levels (~19 kG) now used for most heavy ion beams. The magnetic field measurement system uses 39 flip coil/current integrator sets with computer controlled data scanning. The coils are spaced radially at 1 inch intervals in an arm which can be rotated azimuthally in 2 degree increments. The entire flip coil assembly can be shifted to larger radii to measure fields beyond the pole boundary. Temperature stabilization of electronic circuitry permits a measurement resolution of ±1 gauss over a dynamic range of ±25,000 gauss. The system will process a scan of 8000 points in about one hour.

Introduction

The magnetic field of the Oak Ridge Isochronous Cyclotron, ORIC, was mapped[2] some 15 years ago when the cyclotron was under construction. The addition of the Holifield Heavy Ion Research Facility's (HHIRF) 25 MV electrostatic accelerator as an injector has made remapping highly desirable. The original measurements did not cover the fringe field regions which will be traversed by the injected beam, and they were limited to field intensity levels below those which are now used routinely. The new field data will be used for trim coil current prediction and for injection/acceleration/extraction orbit and trajectory studies. The field mapping program began early in February 1977 and was completed in mid-March. This schedule was arranged to coincide with installation of the beam injection equipment and related RF system modifications.[3]

The field measurements were accomplished with a multiprobe system featuring 39 flip coil/current integrator sets, high speed data scanning and conversion, computer control, and computer recording and processing of field measurement data.

The Mapping System

Choice of Probes

In order to minimize the loss of cyclotron experiment time, a multiple probe system was considered essential. For convenience the number of probes was set at 39 to permit simultaneous measurement along a radial line with the probes spaced at 1 inch (2.54 cm) intervals between the magnet center and the pole face outer radius of 38 inches (96.52 cm).

Flip coils were chosen over Hall probes on the basis of accuracy, speed, reliability, cost, and simplicity. Hall probes have served well in previous measurements, and flip coils were subject to some serious shortcomings in the past. However, the present state of the art in solid state operational amplifiers permits the use of low cost integrator circuits which are quite stable and reliable. Flip coils are linear devices requiring calibration at only one field level, and the flip coil/integrator signal level can be at least an order of magnitude larger than that for Hall probes.

The Coils

The flip coils are wound on anodized aluminum forms and have an overall diameter of 0.525 in (1.33 cm) and a length of 0.378 in (0.96 cm) which results in a length/diameter ratio of 0.72. Each coil contains 2500 turns of AWG 36 enameled wire and has an effective area of 1400 sq cm. The radial displacement of the magnetic axis of each coil with respect to its geometric axis (the coil form axis) was measured by rotating the coil about its geometric axis in a gradient magnetic field. Displacements ranging from 1 to 6 mils (25 to 150 μm) were observed with an average value of about 3 mils (75 μm). All 39 flip coils are mounted in a positioner shaft (probe arm) which flips all coils simultaneously about the shaft axis. The coils are oriented so that their radial magnetic axis displacements are perpendicular to the axis of probe arm rotation. Thus for any field with only first order derivatives, the radial displacement error in each coil is cancelled when the coil is flipped.

Coil Temperature Effects

The area of each coil increases with temperature at a rate proportional to twice the linear coefficient of expansion of the conductor material. However, the integrator output decreases with increasing coil resistance. It should be possible (in principle at least) to design a coil/integrator combination with proper choice of coil conductor length and resistance where the two temperature effects cancel each other. On the ORIC flip coils, the area temperature coefficient is dominant and the resultant measured field error is 3.5 parts in 10^5 per degree C. Consequently the flip coil shaft temperature is constantly monitored so that appropriate corrections may be applied.

The Integrators

Each flip coil is connected to its own exclusive integrator (Fig. 1) for signal storage. The integrators are mounted in groups of four in NIM modules with exclusive IC voltage regulators for each integrator. The integrators are derived from the Analog Device 234L amplifier with a 1 μF polystyrene feedback capacitor and a nominal 70k ohm input resistor. Each module has a 4-pole shorting relay for discharging the integrators. The integrator output signals are found from[4]

$$V_o = \frac{G}{G+1}\,\frac{1}{RC}\int V_c\,dt, \text{ and}$$

$$V_c = -\,(\text{coil area})\left(\frac{d\phi}{dt}\right)(10^{-8}) \text{ volts.}$$

Using values of $G = 10^7$, $R = 70\ k\Omega$, $C = 1\ \mu F$, a sensitivity factor of 0.2 mV/gauss is calculated. This sensitivity was especially selected for obtaining a full-scale reading for a nominal ±26 kG magnetic field on an ADC with a dynamic range of ±10 volts. The resistance was adjusted by up to ±10kΩ to obtain nearly uniform sensitivity for each of the 39 coils whose area and feedback capacitors were subject to variations of about ±10%. The integrator configuration with the above parameters has a time constant equal to GRC of 700,000 seconds.

*Operated by Union Carbide Corp. for U.S. ERDA.

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