Device for Multipole Analysis of Magnetostatic Fields

G. Datzmann and G. Dollinger

A new device has been developed and constructed to measure multipole components of magnetostatic fields. It is mainly aimed to determine the multipole distribution in the superconducting focusing lens for the forthcoming nuclear microprobe SNAKE (Supraleitendens Nanoskop für Angewandte Kernphysikalische Experimente) [1]. Nevertheless the apparatus can be applied to related problems.

The measurement is based on the rotating coil method. The small induction coil is mounted on a glass tube, which is rotated by a DC motor with variable speed (Fig. 1). The whole equipment is placed on a linear transporter to scan e.g. along the axis of a magnetic lens.

Due to the special requirements of the superconducting lens, the choice of a rather complex data transmission was made. Namely that the whole apparatus is designed to work under vacuum conditions, and is not sensitive to a temperature gradient form room temperature to 4.2 K.

The voltage signals from the coil can be variably amplified up to a factor of 10^5. The sinusoidal signals (presuming a constant rotation frequency in a multipole field) are converted into a modulated frequency signal. These pulses are sent by an IR-Diode in the center of the rotating glass tube to photodiodes outside the rotating system. A standard PC equipped with a frequency counter card provides the Data Acquisition System. The incremental signal of the rotation motor gates the data collection to 64 equidistant points per one turn of the coil. This limits the highest detectable multipole theoretically to the 64-pole. The data points, corresponding to the voltage behaviour in time, are analysed in a harmonic fourier transformation. Thereby the obtained frequency amplitudes like one sine or two sines per turn belong to dipole and quadrupole strengths, respectively. The phase of the FFT gives information about the angular orientation of the multipole field. In order to enhance the statistics many turns of the coil (64, 256) can be collected.

To calculate the magnetic field from the voltage signals of the coil, a special program code was developed, since experimental calibration especially for the higher multipole fields is not trivial [2]. The comparison of the experimental data form a calibrated dipole and quadrupole magnet is in good agreement with the simulation within an error of only a few percent.

The main features of the magnetic field gauge are:

- Detection of very small magnetic fields.
- Possibility of measuring high order multipole fields.
- Measurements of small multipole contributions in a dominating 2n-pole field.

Fig. 2 (top) shows the measured fourier amplitudes of a magnetic steerer with a dipole field (n=1) of 11 mT. Since background in this 64-turn measurement lies about 4 order of magnitude lower, a detection limit for dipole field is approximately a tenth of the magnetic field of the earth (complies to a maximum induced voltage lower than 1 μV). The upper plot also indicates that a sextupole field (n=3) is the largest higher order contribution arising from slight field inhomogenities. The strength amounts 0.5 % of the dipole strength (at radius of 10 mm).

The measurement of a standard quadrupole magnet is plotted in Fig. 2 (bottom). Besides the strong quadrupole peak at n=2, many other contributions about two orders of magnitude smaller can be seen. Considering the background amplitude to be lower than 0.001 the calculated detection limit for octupole field is better than 0.12 % and for a 12-pole field 0.6 % for the used rotating coil. The appearing non integer multipole components and the broad peaks in this measurement are mainly due to vibrations in the ball bearings. It can not be excluded that these effects also influence the value of the multipole fields. For the final analysis of the multipole lens the fake peaks are about 5 times to large in order to achieve the desired accuracy. Hence a new mechanical setup with precision skewed bearings reducing this vibrations is already under construction.

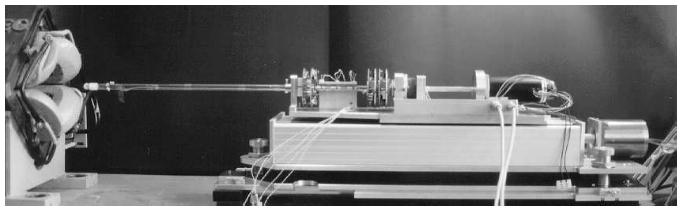

Fig. 1: Multipole analysing device. The small white induction coil is situated at the left end of the glass tube.

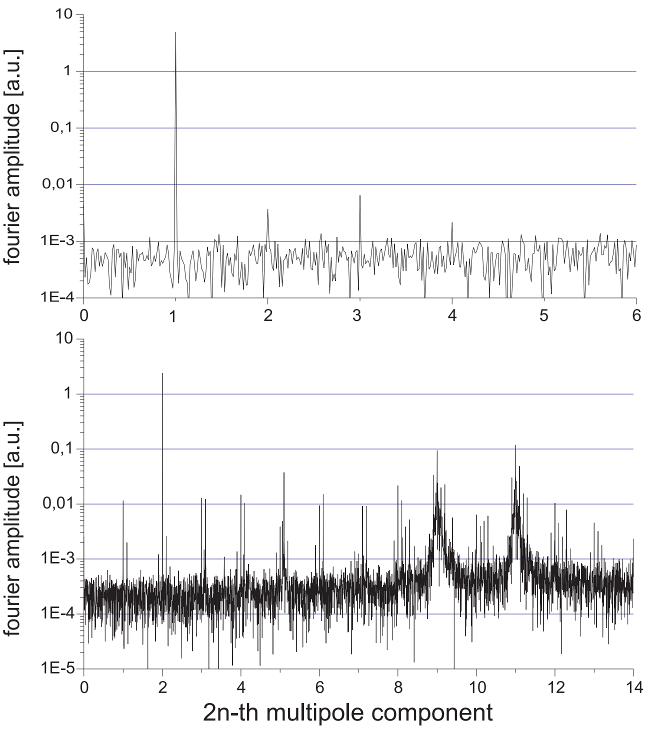

Fig. 2: Top: Fourier analysis of a magnetic steerer. Bottom: Fourier analysis of a standard quadrupole magnet.

References

[1] G. Datzmann, *et al.* this report p. 106
[2] G. Datzmann, diploma thesis, TU München, 1997