NEW DEVICES FOR THE MAGNETIC CENTER LOCATION OF QUADRUPOLE MAGNETS

J. LE BARS, F.KIRCHER
CE/SACLAY, DSM/DAPNIA/STCM
F 91191 Gif-sur-Yvette Cédex

Abstract

A system is presently under development at SACLAY for determining the location of the magnetic center of superconducting quadrupole magnets. It uses magnetic crystals in garnet film form, with vizualisation of the results by an optical method.

This paper will describe the sensors, the measuring methods and the results which have been obtained so far; they are quite encouraging for long superconducting quadrupoles, for which the classical mechanical methods have reached their limits.

1. INTRODUCTION

Up to now, the magnetic axis of a quadrupole magnet has been classically determined using stretched wires. But the mechanical limit of this method is now reached with the new generations of superconducting quadrupoles for which the length is increasing while their useful aperture is reducing. So, alternative methods have been proposed: colloidal solutions [1,2], moving wire [3] ...

The method which is described here is based on previous works [4]; it uses magneto-optic sensors and enables to work in a large range of field gradient (typically from 5 T/m up to 100 T/m), needing only a small space for the sensor which determines locally the magnetic plane of the quadrupole; the magnetic axis can be found by repeating the measurement along the axis of the quadrupole, and using two sensors at right angles (Fig.1)

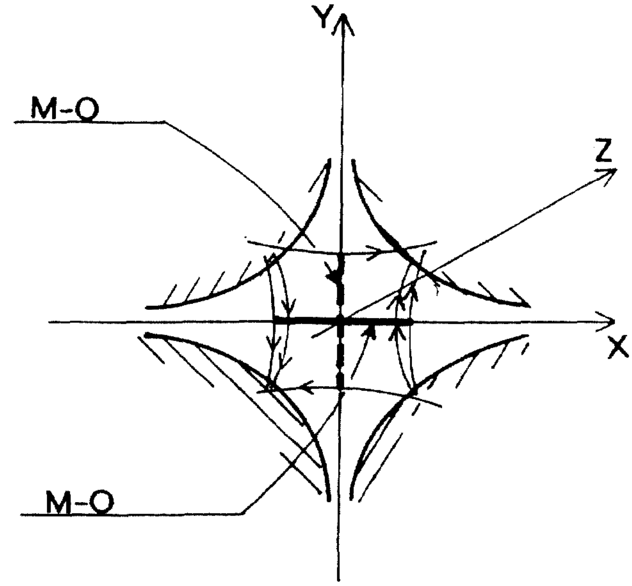

Fig.1 - Principle of the measurement

2. THE SENSORS AND THEIR USE

The sensitive part of the sensor is made of a magneto-optic garnet film. A detailed description of the properties of this kind of films is given in Ref. [5]. Their main properties are :

- Ferrimagnetic garnet film, containing rare earths and bismuth, which strongly enhance certain magneto-optical properties, and obtained by liquid phase epitaxy on a crystalline substrate.

The composition of the elements used for the experiments are :

*for the film:
$Bi_2\ YFe_{5-z}\ Ga_z\ 0_{12}$ (z = 1,3)
*for the substrate:
$(GdCa)_3\ (ZnMgGa)_5\ 0_{12}$
* film tickness : 6 to 8 μm
* film useful diameter : 2 mm

- **Main characteristics** :

* large uniaxial anisotropy
* saturation field : H_S : 4 to 60 Oe
* coercitive field : H_c : 0.3 to 1.7 Oe

The magneto-optical properties of the garnet film are based on the Faraday effect, which changes an incident beam of linearly polarized light into a transmitted beam of elliptically polarized light.

The experimental apparatus is shown on Fig.2. It consists of :

- an optic fiber bundle ($\phi \leq 20\ \mu$m) for the incident light transport.
- a polarizer put above the magneto-optic sensor.
- the magneto-optic sensor.
- an analyser to collect the transmitted light.
- a second optic fiber bundle to carry the transmitted light towards a visual (microscope, video camera) or analogic data acquisition system.

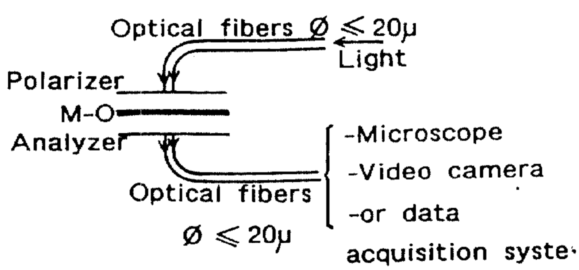

Fig.2 - Sketch of the system

An optical target, laid by a photocarving procedure on the magneto-optic film, is used to locate the various zones of the film (Fig.3).

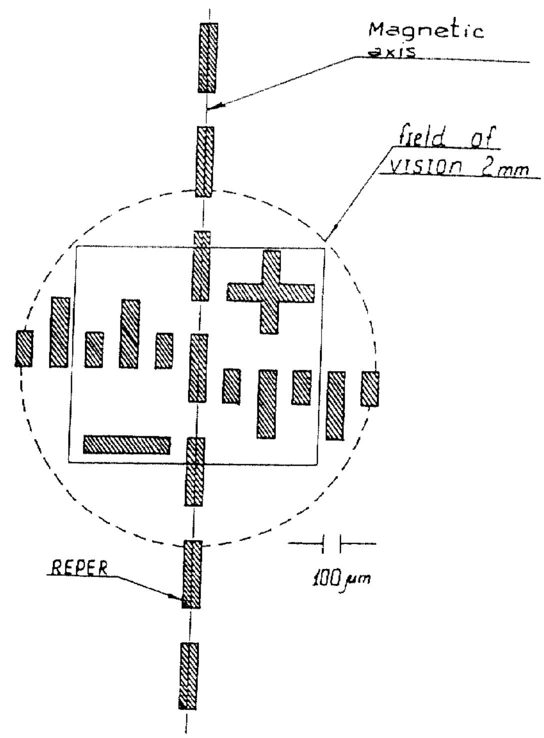

Fig.3 - The optical target

3. EXPERIMENTAL RESULTS

Various types of magneto-optic sensors were provided [6] ; the typical characteristics of some of them are given in Tab.1.

Table 1 : Sensor characteristics

Sensor #	Coercitive field (Oe)	Saturation field (Oe)	Thickness (μm)
2	1.6	5	5.9
5	1.7	40	7.5
6	1.5	4	5.8

Most experiments were done inside a conventional quadrupole, with a maximum gradient of 11 T/m, supplied by a bipolar power supply.

The following results were obtained with the sensor # 6, at the maximum gradient :

- the film surface is shown in different phases on Fig.4 :

a) no magnetic field; the axis of the sensitive part can be seen.

b) positive polarity of the quadrupole: the magnetic plane is vizualized by the line which splits the clear zone and the dark one.

c) transient phenomenon when the magnet polarity is reversed.

d) negative polarity of the quadrupole: the clear zone and the dark one are now reversed but the magnetic plane is shown at the same position.

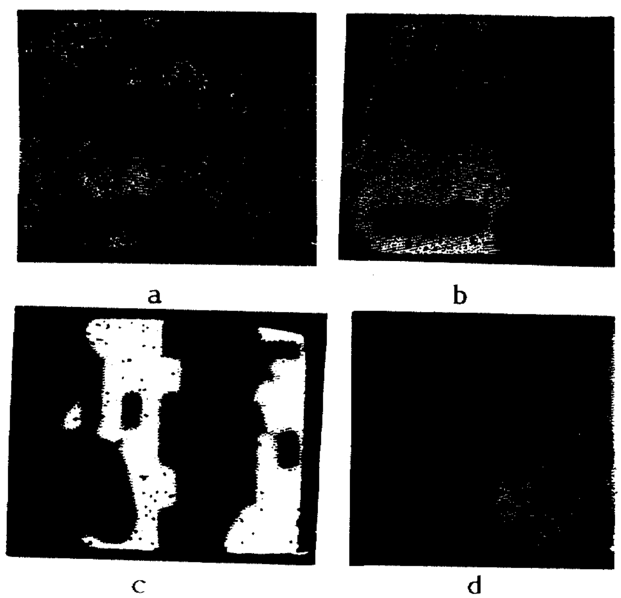

Fig.4 - Different aspects of the film surface

It has been established that a linear move of the film perpendicularly to the flux lines induces the same move of the line which splits the two zones, as long as this move does not exceed half of the sensitive diameter of the sensor. On the contrary, a film move parallel to the flux lines has no influence on the separation line.

These measurements enable to give the accuracy in the magnetic plane determination:

* about $\pm$ 20 μm in translation (the accuracy is mainly due to the diameter of the optic fibers used).

* about $\pm$ 0.6 mrad in rotation (accuracy of the stepping motor used).

4. CONCLUSIONS

These preliminary tests show that these sensors can be used in an accurate mechanic assembly for determining locally the magnetic planes of a quadrupole magnet. The survey of these planes can be done in a classical way, using for example photodiodes and a laser.

More developments are under way to perform the complete determination and survey of the axis, to test these sensors in high gradients produced by superconducting quadrupoles and to improve the sensor performances.

5. ACKNOWLEDGEMENTS

We thank Drs. K.F. GUERTSEV (IPHE/Protvino) and A.J. CHERVONENKIS (Physical and Technical Center, Moscow) for valuable discussions before starting this work. Most of the tests were done at CERN and we thank Drs. J. BILLAN, K. HENRICHSEN and L. WALCKIERS for their hospitality. Mr. M. HUMEAU (Saclay) and Mr. G. PEIRO (CERN) were deeply involved in the tests.

6. REFERENCES

[1] J.K. Cobb, J.J. Muray, "Magnetic Center location in multipole fields", NIM 46 (1967), 99-105.

[2] R. Suguhara, T.K. Kubo, Y. Oosawa, "A colloidal solution of Fe_3O_4 crystallites to optically locate the magnetic centre of multipole magnets", KEK report 89-9, September 1989.

[3] Z. Wolf and P. Pellissier, "Moving wire technique for SSC quadrupole alignment", SSC Laboratory, report MD-TA-209 MTL-002, December 1991.

[4] A. Chervonenkis, N. Kubrakov, "Magneto optic visualization and topographical study of magnetic fields", Sov. Techn. Phys. Lett 8 (6), June 1982.

[5] P. Hansen and J.P. Krumme, "Magnetic and magneto optical properties of garnet films", Thin Solid Films, 114 (1984), 69-107.

[6] The magneto optic sensors with their glass fiber bundles were supplied by the Scientific Development Association "Fisika", Moscow.