NMR SYSTEM FOR MAGNETIC FIELD MEASUREMENTS AT THE MARK-3 FREE ELECTRON LASER

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Abstract

A NMR system for precise magnetic field measurements (hereafter "Magnetometer") has been developed at the Budker Institute of Nuclear Physics. The Magnetometer provides multichannel, precise measurements of magnetic fields in the range of 0.5-40 kGs.

The Magnetometer is used for magnetic field measurements in eight mechanically adjusted permanent chicane magnets in the range of 2.5-5.1 kGs on the MARK-3 Free Electron Laser at the Duke University. These magnets deflect the beam around the cavity end mirrors. Each electron beam energy requires a precise and different set of field values in the magnets. Taking into account a low temperature stability of permanent magnets (about 0.1% per 1°C) one can see the necessity of precise field measurements.

The difficulty of the magnetic field measurements in these magnets is connected with too narrow gaps, in which the probes should be placed. The gap width limits the probe dimension along one of the coordinates by 1.3 mm without hard restriction along the others. Special tube probes have been designed to solve this problem.

1 OPERATION PRINCIPLES

The Magnetometer operation is based on a well known spin-echo nuclear magnetic resonance effect. The spin-echo frequency F_{nmr} and the magnetic field B are connected by gyromagnetic ratio g [1]:

$$B=F_{nmr}/g$$

The physical constant g for different kinds of nuclei is precisely known, so the field strength measurement accuracy is determined by the spin-echo frequency measurement accuracy. Nuclei of the substance in the probe are excited by two short pulses of RF field with the frequency close to the NMR frequency, thus causing the spin-echo signal.

A simplified scheme of the Magnetometer is shown in Fig.1. Each probe is connected to NMR exciting and receiving electronics by a multiplexer . A frequency synthesizer is used for both exciting and receiving the spin-echo signal. A measuring cycle is organized by a control module.

There are some limiting factors which decrease the measurement accuracy. The most significant of them are the signal-to-noise ratio and finite duration of the spin-echo signal defined by field inhomogeneity in the probe volume. Some special techniques in the NMR system are employed to decrease their influence [2]. Low-noise preamplifiers are placed near every NMR probe to decrease losses of the spin-echo signal in RF cable between the probe and the Magnetometer. The amplified

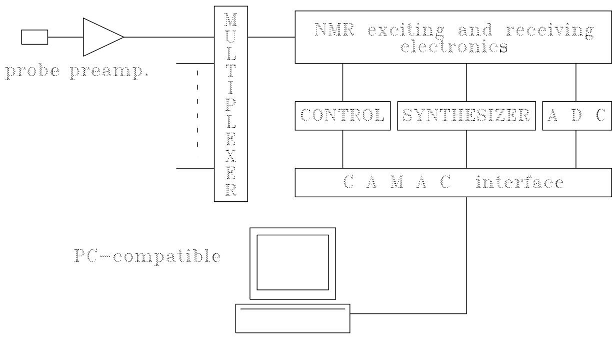

Fig 1 Scheme of the Magnetometer

signal is shifted to a low frequency region by multiplying it by two orthogonal signals of precisely known reference frequency close to F_{nmr}. After narrow band low-pass filtering the output signals are digitized by ADC. In computer they are multiplied by Gaussian shaped pulse which width is equal to the spin-echo signal to maximize the signal-to-noise ratio. The carrier frequency is determined according to the spectrum obtained by Fast Fourier Transform. The data measured can be accumulated to give further increase in the relative accuracy of the magnetic fields measurements.

2 CONSTRUCTION

All the modules are made in the CAMAC standard and work under PC-compatible computer control.

Preamplifiers of NMR signal for probes are located near every probe. Each of them is connected with Magnetometer by a single coaxial cable. This cable is used to transfer signals and power as well. Length of the cable can be up to 150 m.

A simplified construction of special probes is shown in Fig.2. As it was previously noticed the probe dimension along one of the coordinates is hardly restricted by the size of the gap between the vacuum chamber and the magnet pole. Contrary to a usual construction of NMR probes the substance is placed into the plastic tube. Ends of the tube with clamps on them are placed outside the magnet thus permitting easy refilling the probe. The spin-echo signal is excited and received by a coil, which is placed on the tube. Twisted pair is used for leading the signal out. The probe is covered with a shield to eliminate an external interference. It is connected with the preamplifier via connecting box fixed on the external side of the magnet.

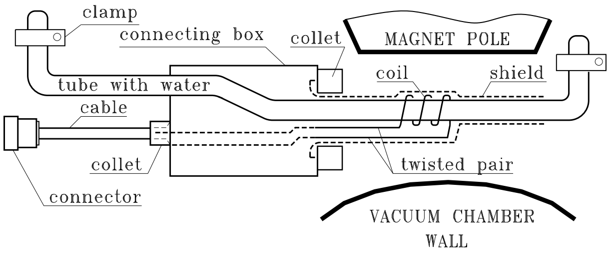

Fig 2 Tube Probe

The tube probe filled with water has a 1.5 mm external diameter, but the construction allows us to press it to 1.3 mm. The sensitive area dimensions are 0.6*1.4*4 mm in this case.

3 SUMMARY

At present the NMR probes are installed in four of eight MARK-3 chicane magnets. The field gradient in the probe volume is about 0.1% per cm. A relative accuracy of ±0.5 ppm for the whole range of the magnetic field strength change has been achieved. This Magnetometer provides a fast and precise tuning of the Free Electron Laser. In future, the NMR probes will be installed in all MARK-3 chicane magnets.

REFERENCES

[1] A.Abragam, "The principles of nuclear magnetism", 1961.

[2] N.I. Zinevich et al., "System of magnetic field measurement by spin-echo method". Proceedings of Tenth All-Union Conference on Particle Beam Accelerators, Dubna, 1987, V.1, p.342.