STAND FOR PRECISE MEASUREMENTS OF MAGNETIC LENSES FIELD QUALITY*

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Abstract

Strict requirements are imposed on the field quality of magnetic elements in today's synchrotron radiation sources. For example, magnetic field harmonics of quadrupole lenses (currently manufactured in BINP) of main ring NSLS-II, should have no more than one or two ten-thousandths parts of main harmonic at the 75% of lens aperture. The stand is designed for precise measurement of the quadrupole lenses. The well-known technique with a rotating coil was used. The design and location of coils used in the measuring shaft and the method of commutation allow to compensate for both quadrupole and dipole components of the magnetic field. This, in turn, minimizes shaft beats effect and power supply noises effect on the accuracy of the results. During measurements, the shaft is rotated without stopping, and the data received from the gauge angle and digital integrators are processed "on the fly" strictly synchronous. The measurement procedure is performed in one and a half turn of the shaft and takes six seconds. The report describes mechanical design of the stand, principle of work, parameters of the equipment, and software. Results of measurements of the quadrupole lenses synchrotron source NSLS-II are given in conclusion. The results demonstrate possibilities of the stand.

INTRODUCTION

Six types of quadrupole magnets for main ring NSLSII [1] were manufactured in Budker INP. The total quantity of magnets was 127. The high quality of magnetic field [2] was achieved by tuning directly on magnetic measurement stand. This stand was developed specially for similar task.

Requirements for MMS:

- Accuracy of magnetic field harmonics measurement is at level 10^{-5} relative to main quadrupole component.
- Short time required for one measurement with obtaining results.
- Automation of carrying out a series of measurements.
- Suitability for usage in mass production.

MECHANICAL CONSTRUCTION

All the construction is set on the girder (see Fig.1 and Fig.2). During the measurements the magnet is installed on the support, which provides the positioning of magnet in 3 coordinates. The rotating coil is installed on special supports. The rotating system is easily removable so that one can set or remove shaft in few minutes. The self-aligning shaft bearings are arranged on special steel bases, which are removable on one side due to the provided removability of shaft. Cable connections are at the both ends of shaft and they are fixed, which means that wires are rotating with the shaft. Lengths of cables were chosen for unobstructed shaft rotation of 3-4 turns in each direction.

Figure 1.Magnetic measurement stand.

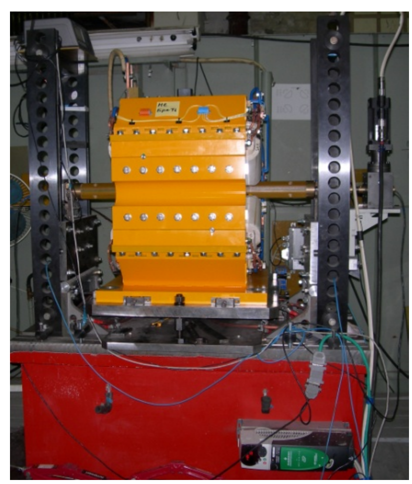

Figure 2. Mechanical construction of MMS.

The scheme of MMS interconnections is shown on Fig. 3. The integrators (VsDC3) were developed in the Budker INP [3].

MEASUREMENT SHAFT

The compensation scheme of rotating coil is shown on Fig. 4. Such connection of coils provides compensation of dipole and quadrupole components of magnetic field, so we get better signal for higher harmonics.

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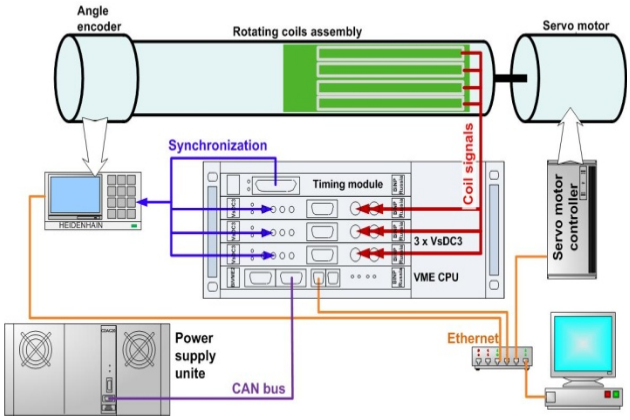

Figure 3. Interconnections of MMS.

Besides the compensation scheme consisting of 6 coils, there are 2 additional coils allowing measurement of disposition of shaft axis in relation to magnet axis. White, yellow and blue coils on Fig. 4 are responsible for the compensation scheme while black coils are responsible for the axis disposition measurements and main field integral. The coils were manufactured as multilayer printed-circuit board (see Fig.5).

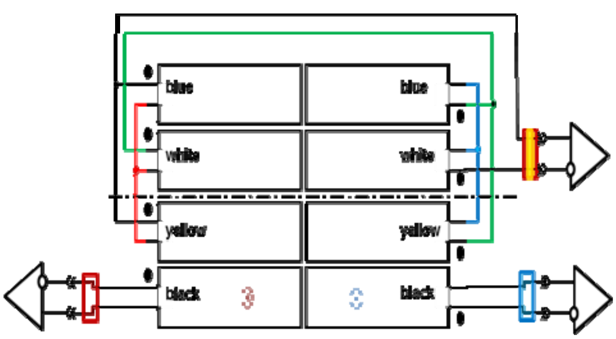

Figure 4. The compensation scheme of measurement coils.

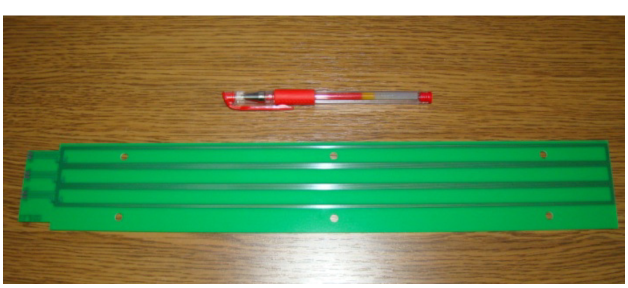

Figure 5. The printed-circuit board of measurement coils.

On the real shaft the main harmonic compensation coefficient was achieved about 5000.

SOFTWARE OF MMS

The software for MMS control consists of two parts interacting by client-server model. The server is a set of programs executed in VME controller managed by OS Linux. The client is a user application of personal computer running the MS Windows 2000/XP. Basic functions of the server part are provision of the client access to the equipment and management of measurement procedure.

To simplify the server structure and make the server easy expandable, it was decided to divide the software of VME controller into two independent services:

1. bivmeCANSrv – plays the role of Ethernet-CAN interface converter and applied for lens power supply unit control.
2. movableCoilsSrv – provides the client with access for measuring devices. This is the basic element of VME controller software.

Each of these services is realized as classic TCP-server of Linux.

In the program complex, the client is Win32 – the program with graphical user interface with the next functions:

1. Configuration of hardware;
2. Measuring, processing and providing data measured;
3. Creation and execution scripts, which allow carrying out the measurement cycle with given parameters, for example, it can be series of measurements for set of currents in lens;
4. Output of data, which assist in adjustment of lens till the alignment of lens magnetic axis with axis of measuring coils rotating;
5. Organization of measured data archive for additional data processing and reviewing.

The user interface of this program is implemented as a window with tabs, each of which is a functionally completed graphical control element used for performing one of software functions.

ALGORITHM OF MEASUREMENTS

Before measuring the operator sets the shaft in zero position by the bubble level (see Fig. 6).

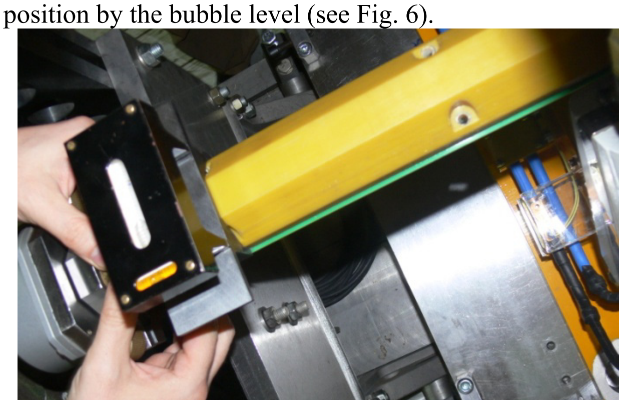

Figure 6.The shaft levelling.

Then the algorithm of measurements proceeds in the steps below:

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1. The shaft begins its movement from -100 degrees in order to provide constant velocity while measuring.
2. During measurements the shaft is rotated without stopping, and the data received from the gauge angle and digital integrators are processed "on the fly" strictly synchronous. The measurement procedure is performed in one and a half turn of the shaft and takes six seconds.
3. After measurement the shaft returns to the initial position.

RESULTS

Harmonics are defined as coefficients in the Fourier expansion of the integrated radial or azimuthal component of the magnetic field. Harmonics are well below 10E–4 of the main field (1 "unit") at a radius of 25 mm. For demonstrating of precision of MMS set of 60 measurements was carried out. The results are presented below (see Fig. 7). All harmonic noise is below 0.01 unit (10E-6) except normal octupole component (b4), which is not a noise of MMS but the lens feature.

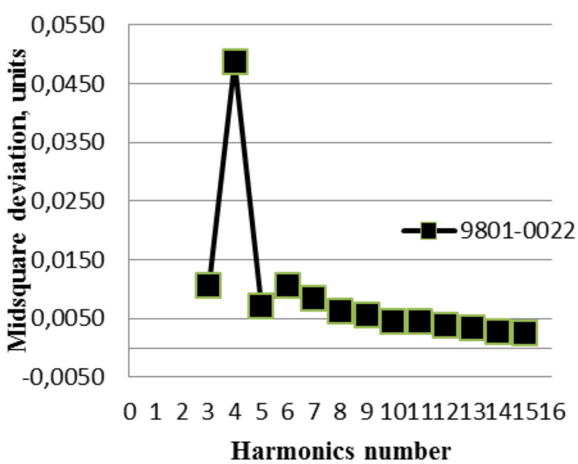

Figure 7. Statistic noise in harmonics, normal components

In order to check the stability of shaft position, the set of 30 measurements with constant current was carried out. The midsquare deviation of axes positions was about 0.7 µm (see Fig. 8).

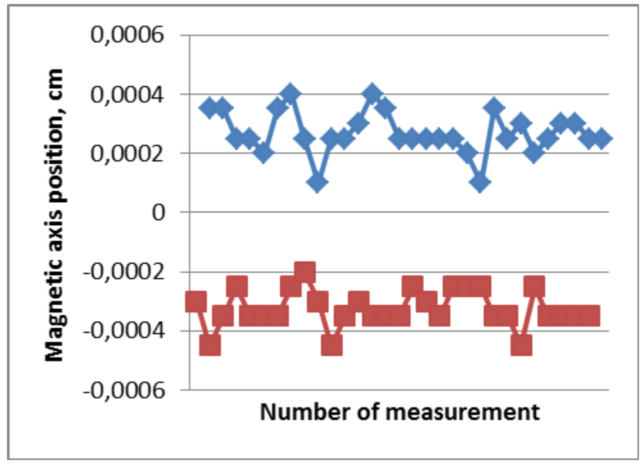

Figure 8. Axes position stability

CONCLUSION

The final parameters of MMS are:

- Precision – about $5 \cdot 10^{-6}$ on sextupole and octupole harmonic terms
- Precision – about $2 \cdot 10^{-6}$ on high harmonic

Thus, measurement precision of stand is high. At the same time the stand is relatively cheap and makes measurements very fast. The set of NSLS-II main ring quadrupole magnets (127 pcs.) were successfully tuned by this stand. Also, two similar MMS were created on the base of experience of practical work.

ACKNOWLEDGMENT

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