MULTIPOLE MAGNETS FOR THE METROLOGY LIGHT SOURCE (PTB, BERLIN)

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Abstract

The Metrology Light Source (MLS), a specialized synchrotron radiation source (electron energy up to 600 MeV) being built at the PTB in Germany [1, 2]. The multipole magnets of the Storage Ring consist of 24 quadrupoles, 24 sextupoles and 4 octupoles manufactured by the Budker INP. The main features of magnetic modeling and manufacture are described in the paper. The multipoles were magnetically measured by Rotating Coil System and main results of the magnetic measurements are also presented.

INTRODUCTION

The total circumference of the MLS is 48 m. The MLS has two long and two short straight sections. The electron energy is ramped to the desired value between 200 MeV and 600 MeV. The user operation is scheduled to begin of 2008.

The MLS magnetic structure contains of 24 quadrupole magnets (SRQ), 24 sextupole magnets (SRS) and 4 octupole magnets (SRO). The main design parameters of multipole magnets are presented in Table 1 [3].

Table 1: Design parameters of multipoles.

	SRQ	SRS	SRO
Aperture radius	35 mm	38 mm	43 mm
Yoke length	165 mm	80 mm	80 mm
Strength	13 T/m	280 T/m^2	2400 T/m^3
Good field radius	30 mm	30 mm	30 mm
High-order harmonics	$\leq 2 \cdot 10^{-3}$	$\leq 2 \cdot 10^{-2}$	$\leq 2 \cdot 10^{-2}$
Magnetic length	200.6 mm	100.2 mm	99 mm
Current	92.7 A	34 A	6.1 A
Power loss	1.3 kW	240 W	12 W

The magnetic modeling and design of multipole magnets were fulfilled by Budker INP.

MANUFACTURING

The yokes of all multipole magnets were produced by means of the high temperature gluing of laminations from 0.5 mm steel of M940-50A (from EBG, Germany) with the two-sided glue layer (Sabolit70). The laminations were stamped with high accuracy: ± 15 μm for quadrupole and sextupole magnets, and ± 50 μm for octupole magnets.

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The coils of the quadrupole magnet (Fig.1) were produced from rectangular hollow copper conductor from Outokumpu (Finland) of 6.5x6.5 mm^2 in size and cooling by water. Every 4th coil had been thermal stress cycled (20 cycles, 30°C→ 95°C → 30°C). The each main coil is equipped with a trim coil. The qadrupole yoke consist of four quadrants with special chamfers of 45°x5.3 mm on the pole tips to cancel the dominant systematic harmonics within the good field radius.

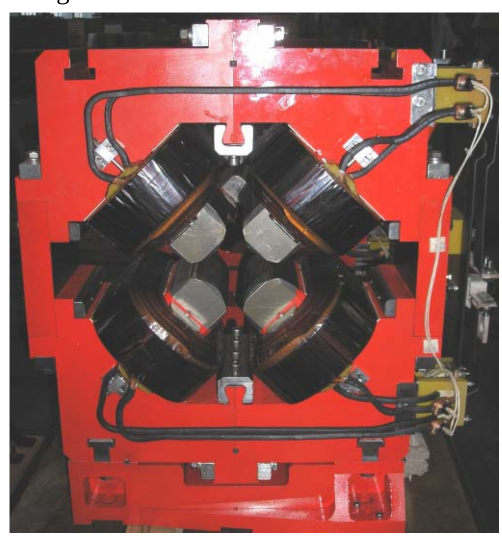

Figure 1: MLS SR quadrupole magnet.

The average values and dispersions of mechanical parameters for 24 quadrupole magnets in comparison with the reference values are shown in Table 2 [4].

Table 2: Main dimensions of the SRQ.

Parameter	Reference	Measured
Aperture, mm	70±0.02	70.023±0.014
Shim gap, mm	22±0.02	21.999±0.008
Yoke length, mm	165±0.4	165.081±0.18
Distance between chamfers, mm	154.4±0.08	154.463±0.018

A 4.3x3.5 mm^2 rectangular copper conductor from Outokumpu (Finland) is used for the main coils of the sextupole magnet (Fig.2). Two additional coils are integrated on each pole to use the sextupole magnets also as horizontal and alternatively as vertical dipole correctors. The main and correction coils have special cooper shields to remove heat. The sextupole yoke consists of three sectors separated by soft magnetic spacers which used to minimize irregular harmonics during dipolar correction. A chamfer of 45°x6 mm is applied to the pole tips.

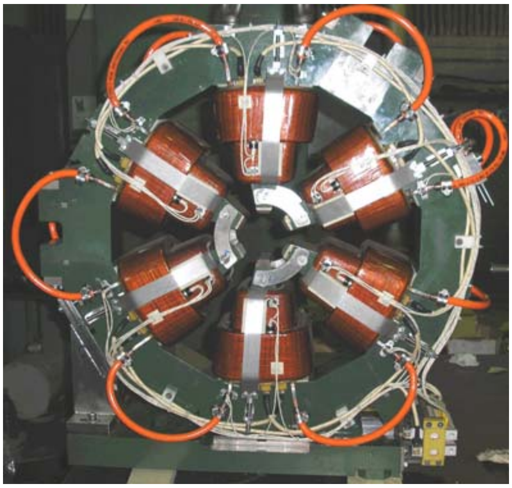

Figure 2: MLS SR sextupole magnet.

The mechanical parameters of the average sextupole magnet (from mechanical measurements of 24 ones) in comparison with the reference values are shown in Table 3 [4].

Table 2: Main dimensions of the SRS.

Parameter	Reference	Measured
Aperture, mm	76±0.03	75.978±0.018
Shim gap, mm	22±0.03	21.985±0.008
Yoke length, mm	80±0.25	79.967±0.2
Distance between chamfers, mm	68±0.06	68.050±0.01

The coils of the octupole magnet (Fig.3) were produced from rectangular copper conductor from Kamkabel (Russia) of 2x3.15 mm^2 in size. The octupole yoke consists of four sectors.

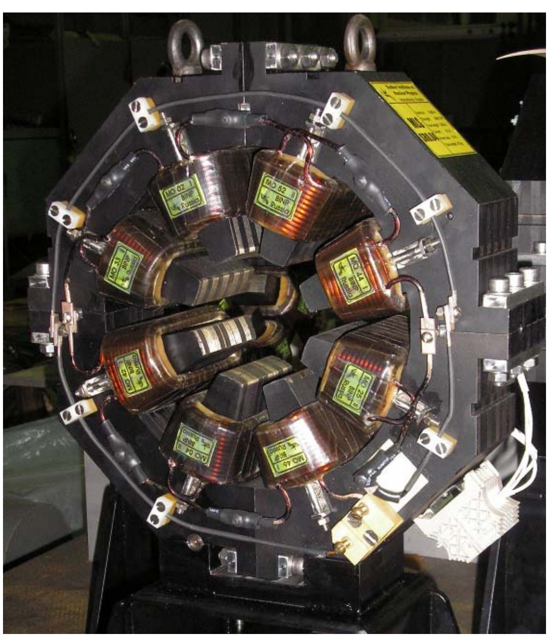

Figure 3: MLS SR octupole magnet.

The average values and dispersions of mechanical parameters for 4 octupole magnets are shown in Table 3 [4].

Table 3: Main dimensions of the SRO.

Parameter	Reference	Measured
Aperture, mm	86±0.03	86.006±0.002
Shim gap, mm	16.99±0.03	16.985±0.003
Yoke length, mm	80±0.4	80.088±0.14

MAGNETIC MEASUREMENTS

The MLS multipoles had been magnetically measured by means of the Rotating Coil System (Fig. 4).

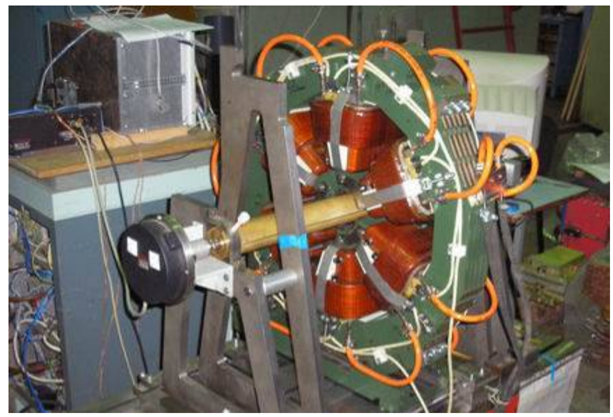

Figure 4: Rotating coil system with SRS magnet.

A coil is being rotated inside the magnet and the induced voltage has been analysed as a function of rotation angle and gives harmonic components [5]. The measurement coil is produced on the multilayered flat textolite plate with the accuracy of 0.1 mm and contains of 8 wires, coil radius is 33 mm and coil length is 700 mm.

The one quadrupole magnet has been measured at 5 excited currents including nominal (97.2 A). Before measuring procedure the hysteresis cycles were executed at excitation currents from 0 A up to 140 A at both polarities of power supply. The dependence of the quadrupole gradient from excited current (for up and down ways) is shown on Fig.5.

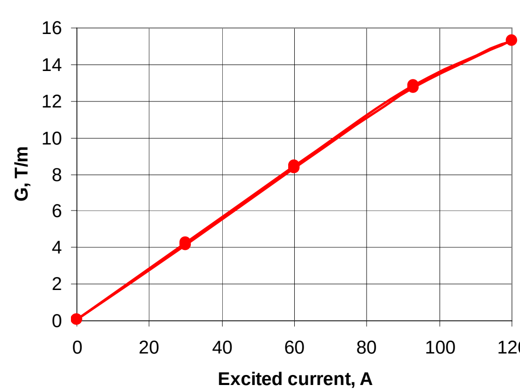

Figure 5: Dependence of the SRQ gradient from excited current.

The same measuring procedures had been used for one of sextupole and one of octupole magnets. The hysteresis cycles for sextupole magnet were executed at excitation currents from 0 A up to 36 A and for octupole magnet from 0 up to 6.2 A.

The values of sextupole strength at different currents (up and down ways) are presented in Fig 6.

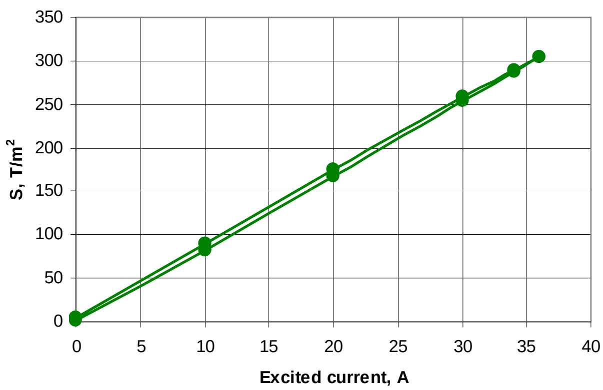

Figure 6: Dependence of the SRS strength from excited current.

The values of octupole strength at different currents (up and down way) are presented in Fig 7.

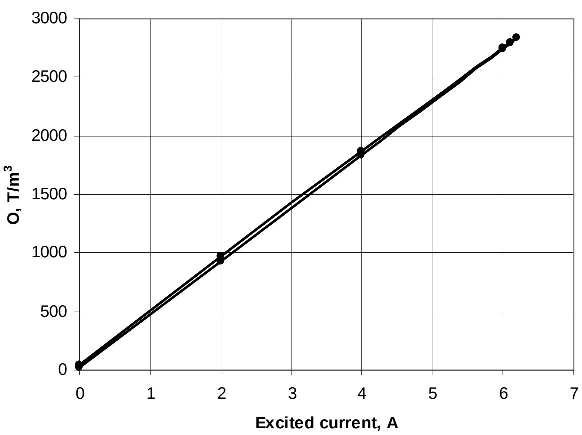

Figure 7: Dependence of the SRO strength from excited current.

The measured integrated harmonic coefficients were normalized by effective magnetic length (see Table 1) and the comparison of measurement and calculation results for reference radius 30 mm for all types of multipoles are presented in Table 5.

Table 5: Magnetic parameters of the multipole magnets.

Param.	SRQ (92.7 A)	SRS (34 A)	SRO (6.1 A)
	Meas.(Calc.)	Meas.(Calc.)	Meas.(Calc.)
G, T/m	12.76 (12.65)	-	-
S, T/m^2	-	289.7 (286.0)	-
O, T/m^3	-	-	2798 (2778)
High-order harmonics	$6.8\cdot10^{-4}$ ($2.9\cdot10^{-4}$)	$9.4\cdot10^{-3}$ ($1.4\cdot10^{-2}$)	$4.6\cdot10^{-3}$ ($4.9\cdot10^{-3}$)
Accuracy	$5\cdot10^{-5}$	$1.5\cdot10^{-4}$	$7\cdot10^{-4}$

The magnetic measurements results are in the good agreement with the magnetic modeling. The reproducibilities of the magnetic measurements were checked at the nominal currents on the up way of excitation current (Table 5).

CONCLUSION

The 24 quadrupole magnets, 24 sextupole magnets and 4 octupole magnets for the MLS have been designed, manufactured and measured by the Budker INP. Mechanical and magnetic parameters of the multipole magnets have been in compliance with the requirements of Specification [3].

Since all multipole magnets are delivered on PTB site and installed on the special girders. The adjustment of the magnets have been done with two Taylor Hobson Balls mounted on the overall cross bar. At present all girders with the multipole magnets installed at the MLS Storage Ring (Fig. 8).

Figure 8: Multipoles at MLS Storage Ring.

REFERENCES

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