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Remagnetization of PMQ lenses for PRIOR and PUMA proton microscopes

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As the result of the first experiment with 3.6 GeV proton beam at PRIOR facility at GSI [1] it was found that the parameters of permanent magnetic quadrupoles (PMQ) [2] lenses was changed. For the analysis of radiation damage of PMQ its magnetic field was rescanned. The gradient of magnetic field is decreased of about 10%, there was a decrease in the quadrupole magnetic field component with an increase in the dipole component and higher order harmonics. Similar radiation damage at the PUMA[3] led to a decrease in the magnetic field gradient of 4% at one side of one of the lens. A high-voltage generator with a solenoid and measurement software package was developed to restore the characteristics of the magnetic field of PMQ lenses. Measurement of parameters of PMQ was performed by scanner for radial component of the magnetic field (scanning of the magnetic field is performed on the cylindrical surface near the aperture range of the PMQ lens) and a set of programs needed to carry out calculations of all components of the magnetic field at any point within the aperture of the lens. Calculation of the parameters was performed with developed analytical model [2]. Testing of remagnetization method was performed with PMQ lenses of PUMA proton microscope at ITEP. The high voltage generator with the voltage amplitude of $U=1.8$ kV (3.5 T magnetic pulse), the pulse duration of 5.5 ms, maximum current of about 4 kA and solenoid with inner diameter of 60 mm was used for remagnetization. As result, was restoring the original characteristics of the lens.

[1] Varentsov D. et al., "Commissioning of the PRIOR proton microscope", Review of Scientific Instruments, 2016, 87, issue 2, pp. 023303/1–023303/8.

[2] Kantsyrev A. V., Skachkov V.I.S., Panyushkin V.A. et al., "Quadrupole Lenses on the Basis of Permanent Magnets for a PRIOR Proton Microscope Prototype", Instruments and Experimental Techniques, 2016, Vol. 59, No. 5, pp. 712–723.

[3] Kantsyrev A.V., Golubev A.V. et al., "TWAC-ITEP proton microscopy facility", Instrum. Exp. Tech., 2014, no. 1, pp. 1-10.

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