The Superconducting Multipole Lens for SNAKE

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The new nuclear microbeam facility SNAKE (Superconducting Nanoscope for Applied nuclear physics [Kernphysikalische] Experiments) started its operation in August 1999 [1]. It is designed to focus protons up to 30 MeV as well as heavy ions with energies up to 200 MeV Q^2/A to a submicron beam spot. This is achieved in a two stage ion optical system, where the first stage consists of a standard quadrupole doublet lens. The requirements for a strong magnetic field gradient combined with low aberration coefficients at the second stage made it necessary to develop a new lens design [2].

The lens basically functions as a quadrupole doublet but consists of three sections, with Cobalt Iron pole pieces and superconducting NbTi filament coils. In order to compensate spherical aberrations a ray-tracing code has been developed to determine higher order multipole corrections for the lens. Table 1 shows the calculated values which are implemented in the three sections via high precision grinding of the pole pieces. By pressing all 12 pole pieces onto a central ceramic tube, their relative and absolute position is well defined. The hole superconducting lens is operated in a helium bath cryostat.

In order to measure all magnetic parameters of this superconducting lens a magnetic field detection device has been developed which is able to operate under vacuum conditions and at 4K temperatures [3]. The magnetical properties of the lens in the superconducting mode have been measured using this device before the first beamline experiments took place.

The multipole field components contain important information about the geometric aberrations of the lens. A complete set of multipole components of section 3 can be seen in the fourier spectrum of the voltage induced in the rotating coil of the field detection device (Fig. 1). The extracted multipole contributions to the magnetic field are plotted in table 1. The measurements show that the octupole field - being the largest intended correction component - meets the designed value within 10% accuracy in all three sections. Concerning the sextupole field, which has the strongest impact on parasitic aberrations, it was only possible to give an upper limit of 0.4% due to imperfection of the rotating coil axis. It is planned to reduce this limit in forthcoming measurements.

The maximum magnetic field gradient of the quadrupole field is 1 T/cm at a current of 8A. This allows about 5 times higher mass-energy-product than in existing microlenses [4].

Concerning the alignment of the three sections the mechanical concept proofed to be very efficient. The maximum rotational misalignment of the three magnetic sections is 0.025(3)°, which is less than specified. The magnetic axis shows a standard deviation better than 5 μm for each singlet and 12 μm concerning the whole lens.

Fringe field measurements show qualitatively the designed properties, but are not quantitatively evaluated up to now.

Since the superconducting lens revealed a good performance and most of the parameters were within the requirements, first beam line tests have been carried out in the summer and fall 1999. Thereby a beam size of 700 nm in single ion mode was achieved with a 90 MeV ^{32}S-beam [1]. The relative energy stability of the beam has been determined with a high precision spectrometer to be 3.8×10^{-5} [5]. Calculation with this value show that chromatic aberration is not the limiting factor of measured beam spot size. In order to reduce geometric aberrations, the magnetic properties of the lens will be measured again, with special emphasis to the implemented superconducting correction mechanisms.

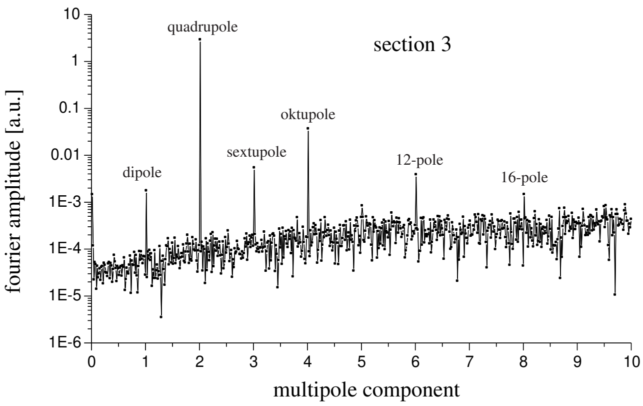

Fig. 1: Fourier plot of induced voltage of section 3 in superconducting mode

	quadrupole	octupole [%]	12-pole [%]	16-pole [%]
section 3	100%	2.85	0.52	-1.05
measured		2.77(1)	0.88(2)	-1.24(9)
section 2	100%	-2.31	-0.05	+0.07
measured		-2.49(1)	0.27(1)	< 0.4
section 1	100%	-0.40	+0.07	+0.01
measured		-0.39(1)	0.50(5)	< 0.4

Table 1: Calculated and measured multipole field of the three sections (all values are normalised to the quadrupole field at the poletip radius of 10 mm)

References

[1] G. Dollinger *et al.*, this report, p.89
[2] G. Datzmann *et al.*, Nucl. Instr. Meth. **B158** (1999) 74
[3] G. Datzmann *et al.*, Jahresbericht 1997, p. 107
[4] U.A.S. Tapper *et al.*, Nucl. Instr. Meth. **B77** (1993) 17
[5] A. Hauptner *et al.*, this report, p.92