Characterisation of the Superconducting Multipole Lens for SNAKE

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The nuclear microprobe SNAKE [1] (**S**uperconducting **N**anoscope for **A**pplied (**K**ern-) nuclear physics **E**xperiments) is a dedicated instrument at the Munich tandem accelerator. It is capable of focussing protons as well as heavy ions, to spot sizes of 1 micron diameter and below. SNAKE is a interdisciplinary tool for materials research and for micro- and nanoscale modifications.

A completely new designed superconducting multipole lens is the most essential part of SNAKE [2]. It is operated in a helium bath-cryostat at a temperature of 4.2 K, in order to make use of the superconduction for a high quadrupole field gradient and magnetic field shaping. The mechanical and technical design is describe in [2,3]. The magnetic properties of the lens were investigated using the multipole detection device described in [4]. A quadrupole field gradient of 1 T/cm is achieved in all three magnetic sections before saturation effects significantly show up. This is about three times higher than the usable magnetic field gradient in commercially available lenses for nuclear microprobes. Therefore ions with a maximum mass energy product of 160 MeV·u can be focussed within a distance of 170 mm behind the lens. This is about one order of magnitude higher than in most other ion microprobes.

The lateral resolution of the microprobe is mainly determined by the ionoptical quality of the focussing lens. Basically two types of aberrations need to be considered. The parasitic aberrations of the lens, due to mechanical imperfections and misalignment, and intrinsic aberration. The most dominate part of the latter ones are the spherical aberrations, especially at SNAKE with its very high demagnification factor of 200. Raytracing calculations revealed, that submicron beam spot sizes at full aperture can only be achieved with optical corrections. Therefore small contributions of higher order multipole fields have been implemented in the three quadrupole singletts, by shaping the contour of the pole pieces. The measured values are in good agreement with design values optimi sed in a raytracing code, as can be seen in table 1. (The relative octupole contribution is independent on the strength of the quadrupole field, and remains constant along the optical axis of one magnetic section. Recalculations with these measured multipole contributions of the lens show, that submicron beam spots are possible at almost full aperture.)

Table 1: Higher order multipole field for correction of the spherical aberration for the three magnetic sections. The design values and the measured values are given relative to the quadrupole field

	octupole [%]	12-pole [%]	16-pole [%]
section 1	-0.40	+0.07	+0.01
measured	-0.36(5)	+0.09(1)	+0.02(3)
section 2	-2.31	-0.05	+0.07
measured	-2.41(4)	-0.14(1)	+0.15(3)
section 3	+2.85	+0.52	- 1.05
measured	+2.91(4)	+0.49(1)	-0.89(2)

Concerning the parasitic lens aberrations, measurements of the parameters for the optical axis along the three magnetic sections are in good agreement with the design values. This is valid for the rotational alignment, that deviates only ±0.015° as well as the for the axial alignment. The angles between the three axes are smaller than ±1.1 *mrad*. This demonstrates that the mechanical concept is successful, since these values have been measured without any alignment procedures. To ensure a high grade of field symmetry, superconducting correction loops between two neighbouring pole pieces, respectively, have been introduced. Magnetic measurments prove, that these loops can be opened and closed reliably. An external current can be delivered in two of the four loops per section. This provides a very important active correction parameter for the field symmetry, as can be seen in [5].

Superconducting NbTi-foils (8 μm thick) are positioned along desired magnetic field lines to prevent the ion beam to be distorted from parasitic field coming from outer regions. Measurements of the central 12-pole field - which is the first higher order component to be influenced - demonstrate, that data meets the design values significantly better, when foil are superconducting (fig. 1).

The operation in the superconducting mode as well as the cool-down and worm-up procedures are routine and show no problems. Since these magnetic measurements revealed a good performance the lens has been installed in the beamline of the munich tandem accelerator. The achieved lateral resolutions of the nuclear microprobe system and first experiments are presented in [5].

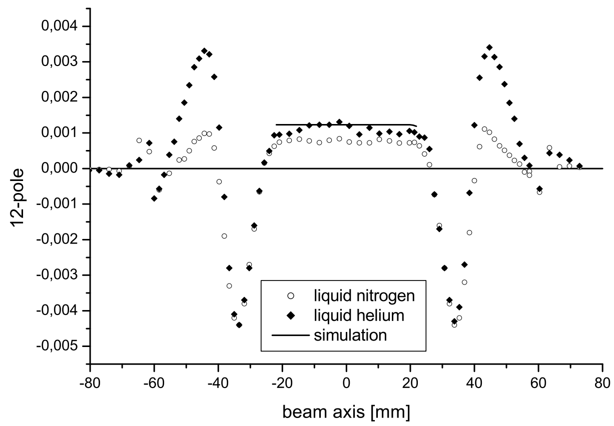

Fig. 1: Measured 12-pole field along the beam axis of one section of the lens. The measurements were performed in liquid helium, where the foils are superconducting, and in liquid nitrogen, where the foils have no influence on the magnetic field

References

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