The Superconducting Multipole Lens

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A new microbeam facility SNAKE (Supraleitendes Nanoskop für Angewandte Kernphysikalische Experimente) at the Munich tandem accelerator is currently under construction [1]. Protons with energies up to 30 MeV as well as heavy ions up to 200 MeV q^2/A shall be focused to a beam spot of 100 nm diameter for standard analysis. The planned facility aims to investigate micro and nano structures in solid state physics, biology and geology.

The small beam diameter will be achieved by a two stage ion optic, with an intermediate focus. For the first stage of the imaging system a standard quadrupole doublet will be used. The main demagnification is performed by the second lens. Since the magnetic field gradient of commercial quadrupole lenses is not sufficient in this case, a completely new type of lens has been designed bottom up. The implementation of superconducting coils results in a poletip field of 1.2 T being three times higher than in standard microlenses [2]. Furthermore the superconductivity enables auto correction mechanisms for obtaining magnetic field symmetry. The connection of two neighbouring poles in a superconducting current loop prevents an unbalanced magnetic flux through the poles. This leads to an elimination of all 2n-pole fields with odd n.

To get an optimal focus point all kinds of aberrations must be carefully considered. Chromatic aberrations are lower than 100 nm as long as $\Delta E/E < 10^{-5}$. The energy distribution of 20 MeV protons will be smaller than this value, if the stabilazation of the tandem accelerator is optimized. Very small apertures (20 μm) in front and behind the analysing magnet will then ensure the required energy distribution.

Geometrical aberration of the first quadrupole doublet lens is negligible due to the very small beam aperture compared to the poletip radius, whereas the second lens needs a careful consideration. The intrinsic aberrations of the magnetic lens due to high aperture ($\frac{3}{4}$ of the poletip radius) and contribution of the fringing fields prohibit to use a pure quadrupole field. In order to compensate these aberrations a special ray-tracing code was developed which was able to determine an optimum magnetic field including 3-dimensional fringe field calculations. The result of this optimization process was a dominant quadrupole field with additional contributions of octupole, 12-pole and 16-pole fields. Instead of positioning separate high order multipole magnets, the hyperbolic surface of a quadrupole magnet has been specially shaped containing the correction fields inherently. The calculation of the remaining aberration in terms of a broadening of the beam spot with the used aperture are plotted in Fig. 1 for different orders of corrections. It shows that a beam diameter of 100 nm should be achievable at $\frac{3}{4}$ of full aperture, if higher field corrections are included.

A lot of constructional efforts have been undertaken to minimise parasitic aberrations due to mechanical imperfections and misalignment of the lens elements. By pressing all 12 poles of the three quadrupole sections on a common central ceramic tube (Al_2O_3), the relative and absolute position will be defined. The outer surface of this tube has been successfully grinded according to the pole contour with tolerance lower than 5 μm (Figure 2). The symmetry of the four contours in a magnetic section is even better. The Cobalt-Iron poles will get their finish in January 98.

Between the pole of each section, superconducting NbTi-foil are positioned on the ceramic along the desired field lines. Induced superconducting currents shall eliminate the magnetic field normal to the foil surface. The NbTi-foils are fixed to the ceramic surface by a thin adhesive film. A thickness of only 4 $\pm$ 1 μm could be achieved rolling fluid epoxy on the ceramic. Thereby its original shape is preserved within the required tolerances [3]. Technical data of the multipole lens can be found in [4]. The whole multipole lens will be operated in a helium bath cryostat, that will be delivered from the Cryovac GmbH in spring 98.

Magnetic field properties of the multipole lens will be measured with special developed devices [5].

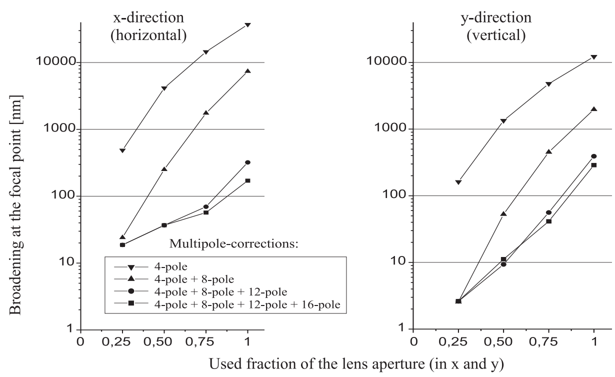

Fig. 1: Intrinsic geometrical aberrations of the multipole lens.

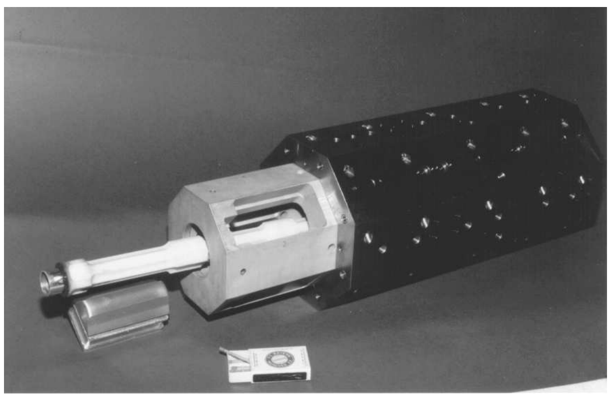

Fig. 2: Superconducting multipole lens split up in its parts. Octagonal yoke right, aluminium cage, ceramic tube and one pole.

References

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