Strong Pulsed Magnetic Quadrupole Lens

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In a recent test experiment we could successfully focus for the first time a high-energy heavy ion beam at the FRS using a high-current pulsed quadrupole lens. Such a lens, most frequently used in accelerator technology, can be built by arranging four electric conductors parallel to the optic axis. Pulsing a strong electric current through neighbouring conductors in opposite directions will produce a magnetic field distribution of fourfold symmetry.

The overall length of the used quadrupole lens was 97 mm with an aperture diameter of 20 mm. The pulse generator consisted of a capacitor bank of 1640 µF with a maximal charging voltage of 3.2 kV which corresponds to a stored electric energy of 8.4 kJ. The pulse period of the current oscillation was ≈500 µs [1]. The electric current was controlled by a power thyristor with a maximal current rating of 34 kA. In this case the achievable magnetic field gradient in the quadrupole is more than 1000 T/m [2].

In the experiment the FRS was mainly used as a transport system. The pulsed quadrupole was placed approximately 2 m behind the final triplet of the FRS. Another 300 mm downstream from the pulsed quadrupole a scincillator target was set and the beam profile was monitored by a CCD camera (Fig.1).

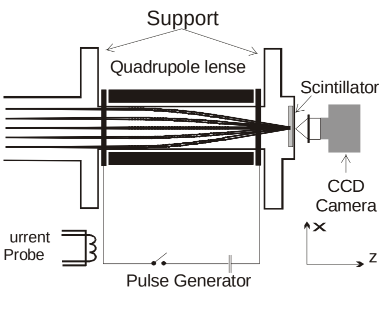

Fig. 1. Experimental setup to focus an initially parallel high-energy heavy ion beam with a pulsed quadrupole.

In the experiment a $^{197}Au^{79+}$ heavy ion beam was used with an energy of 650 MeV/amu which corresponds to a magnetic rigidity of the beam of about 10.5 Tm. The final quadrupol triplet of the FRS provided a parallel beam at the entrance of the pulsed quadrupole. The SIS was operated in the fast-extraction mode where 4 bunches per spill are extracted in ≈1µs. Since the flat-top of the current oscillation is about 10 µs a quasi constant magnetic field is put up during the beam extraction

To determine the focusing properties of the quadrupole the pulse generator was charged stepwise from 0 to ≈2.5 kA and for each step the resulting beam profile on the scintilator screen was measured. The smallest beam size was observed at a charging voltage of 1.4 kV. This corresponds to a peak current of about ≈11 kA and a magnetic flux density of ≈4.65 T respectively at the surface of the quadrupole wires. The beam, which was initially ±10 mm, was focused to approximately ±2.5 mm which is limited by the emittance of the beam. Applying higher charging voltages leaded to a defocusing of the beam.

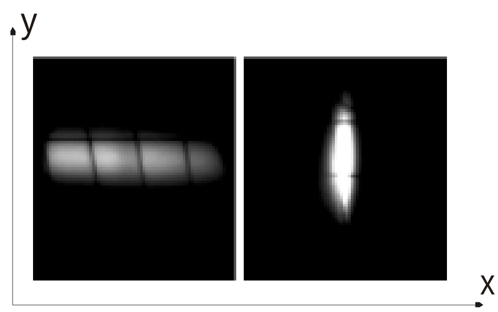

Fig.2. CCD snapshots: a beam with an initial size of ±10 mm (left) could be focused to ±2.5 mm (right). The grid size is 5 mm .

One of the feasible applications for pulsed quadrupole lenses is a short focal length condenser system (Fig.3.), with which it's possible to increase the transmission for nuclear reactions products [3]. Such condenser lenses must be arranged shortly behind a reaction target and have a focal lengths as short as possible. Corresponding quadrupole lenses thus should have small apertures and high field gradients. One such condenser system has been designed for the projectile fragment separator at GSI, Darmstadt [4].

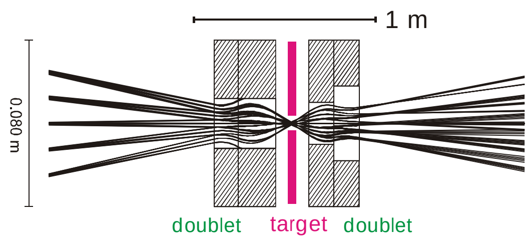

Fig. 3. A condenser system as a possible application for strong focusing lenses.

References

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