A New Test Setup for the RF Ring Electrode Cooler

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A new concept for ion confinement while buffer-gas-cooling low-energy (10 - 100 eV) ion beams has been developed and investigated during the last two years. Instead of applying the well-established technique of Radio Frequency Quadrupoles (RFQs) where the ions are transversely confined by a quadratic pseudo potential we are using a stack of thin ring electrodes supplied by an RF field (RF funnel) which creates a box-shaped potential well (Fig. 1). First experimental investigations in June 2003 at the IGISOL facility in Jyväskylä (Finland) with ion currents up to 20 nA revealed a very promising transmissin characteristics which qualifies the RF funnel as high-current cooler [1].

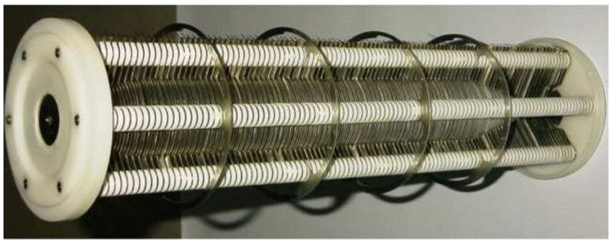

Fig. 1: Photo of the RF ring electrode cooler.

During the year 2004 a dedicated test setup for offline investigations of the RF funnel has been developed and assembled at LMU (Fig. 2). A surface ionization source has been built which is delivering intense beams of ^{133}Cs with charge state 1^+ and currents up to a few μA. Cs-beams have several features which make them most suitable for our application. On one hand Cs-atoms can easily be ionized via surface-ionization and hence intense beams can be created which are necessary to test the performance of the RF funnel up to the desired region of 100 nA. Since the cooler is also of great interest for an application with neutron-rich fission fragments which have usually masses around A= 95 and A= 140, ^{133}Cs lies well within this region.

The ion source is separated from the beam line by an isolator and is put on high-voltage with respect to the rest of the beam line which leads to an acceleration of the Cs-ions to an energy equal to the applied voltage. However, the ion beam has to be injected into the cooler with energies not larger than 100 eV. Otherwise the ions cannot be stopped in the Helium buffer gas at pressures around 0.1 mbar and will be lost on the electrodes. Two possibilities for the injection beam line have been developed. The ions can either be directly extracted with 100 eV from the source and focussed with a combined einzellense/steerer into the entrance aperture of the cooler. The other possibility is the more effective method of extracting the beam with an energy of several kV from the source similar to the situation when the cooler will be run at the accelerator facility. In this case the cooler has to be placed on a high-voltage platform where the applied voltage is slightly below the beam energy in order to decelerate the beam to low energies before the injection into the RF funnel. The focusing of the ion beam is here done by two einzellenses in the injection line which are separated by a high-voltage break. Both systems offer a very high transportation efficiency with (simulated) values of 100% for the high-energy beam and 95% for the 100 eV beam.

The beam cooling itself takes place in the 50 cm long and 6 cm diameter RF funnel which is enclosed in a stainless steel cylinder to keep a buffer gas pressure of ~ 0.1 mbar in its interior. For beam injection and extraction the cooler is foreseen with two apertures of 6 mm and 2.5 mm diameter, respectively. Additionally a 10 mm aperture is separating the injection beam line from the cooler vacuum tank for differential pumping. Two Faraday cups can be inserted into the beam line immediately in front of and behind the cooler. The transmission of the RF funnel is then obtained by the ratio of the beam current at the cooler exit and at the cooler entrance.

First investigations of the RF funnel have started in late 2004 with the 100 eV beam. The best results obtained up to now are a transmission of $\sim 75\%$ for a beam current of 12 nA and with optimized cooler parameters (buffer gas pressure, RF and DC electric fields). In comparison, from Monte Carlo simulation results a maximum transmission of $\sim 90\%$ can be expected. Systematic investigations of the transmission in dependence of the input current are presently running. Further investigations were focused on the reduction of the beam energy spread due to the cooling process. The beam energy spread of the uncooled beam was determined by applying a positive retardation voltage on the entrance aperture of the Faraday cup in front of the funnel and monitoring the beam intensity in dependence of this voltage. In such a way a beam energy distribution of 100 ± 8 eV (FWHM) was found. The energy spread after the cooler was determined with the same method. The beam was reaccelerated to an energy of 40 eV and a half width of < 1 eV was found, where 1 eV was the limit of the measurement sensitivity in these experiments.

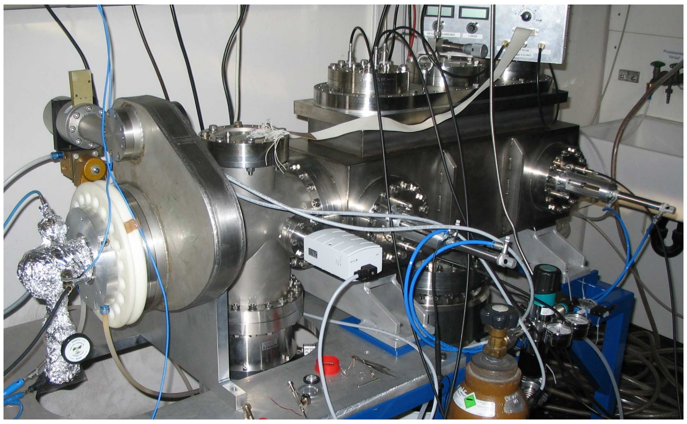

Fig. 2: The cooler test setup.

References

[1] S. Heinz *et al.*, Nucl.Instr.Meth **A533** (2004) 239