# Emittance Measurements at the Jyväskylä RFQ-Cooler

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In order to measure the beam emittance of cooled low energetic ion beams from the Jyväskylä RFQ-ion-cooler, we designed an emittance meter for beam energies up to 40 keV. The principle of the construction is a slit methode, shown in Fig. 1.

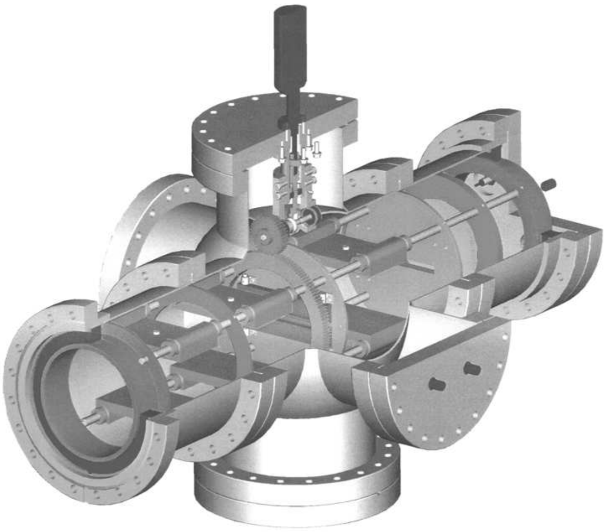

Fig. 1: Principle of the emittance meter, where the beam is incoming from the left side. In the first section a parallel shift of the beam is caused in order to calculate the position y. By the angle deflection in second section the angle y′ is fixed.

In the first section there are two pairs of electrode plates, which are crosswise electrically connected. By changing the voltage V a parallel shift of the beam incoming from the right side is caused. By calculating the shift due to the pair of plates an ion with the corresponding y position can be selected by the small slit. The second section has only one pair of electrodes and in order to get a deflection by the angle y′ the voltage U is applied. So for every ion with values y and y′ there exists exactly one combination of the voltages V and U, where the ion is able to pass both slits. The emittance is calculated using the values of these voltages. The detection of the ion beam at the end of the meter takes place with a self constructed faraday cup. In order to automize the measurements the full construction is controlled by a computer with the LabView software. The peculiarity of the construction is the rotatable cage which makes it possible to rotate the complete optical bank by 90 degrees around the beam axis. In this way it is possible to calculate the emittance in both, x and y direction. The Jyväskylä ion cooler is a typical segmented RFQ cooler [1]. It consists of four cylindrical electrodes, where an RF voltage is applied (100 V; 500 kHz). Opposite cylinders are on same and adjacent cylinders are on the opposite phases. In order to reduce the diameter and opening angle of the beam the cooler is filled with helium buffer gas (0,1 mbar), so the ions are elastically scattered with the gas atoms and loose transverse and longitudinal energy. In order to compensate the friction in beam direction also a DC gradient is applied. For reducing the beam energy of 37 keV to 200 eV there are three deceleration electrodes in front of the cooler. After passing the main RFQ cooler the cooled ion beam enters a mini extraction RFQ via a 2 mm aperture. The cooled beam is then reaccelerated to its start energy of 37 keV.

First, the improvement of the beam emittance due to the cooler has been studied and we found an emittance reduction of about a factor of 20 (4.5 for each direction x and y). Fig. 2 shows the typical phase space ellipses for the y direction.

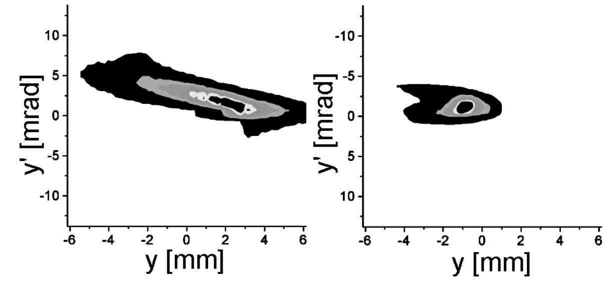


Fig. 2: Phase space ellipses of the uncooled beam (left) and the cooled beam (right).

In addition we examined the dependence of the transmission and the emittance on the beam intensity (20pA up to 40nA) injected into the cooler device. We noticed an increasing emittance for intensities higher than 3 nA due to space charge effects. For the efficiency we found a nearly constant dependence on the beam current up to about 3 nA (60 - 70 %) and then a decrease to about 30 % at 30 nA (Fig. 3). Main reason for the decreasing efficiency are collisions of the ions with the electrodes of the cooler, when the beam emittance is increasing.

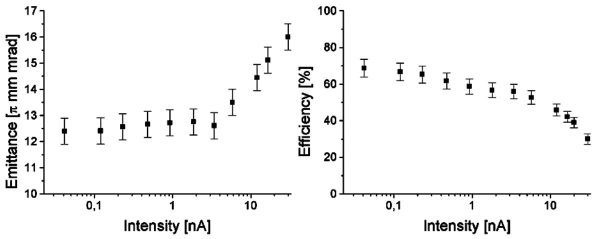


Fig. 3: Emittance (left) and efficiency (right) as function of intensity.

Finally the effect of different beam optics elements in the beam line, e. g. einzellenses and skimmer electrodes, on the emittance could be easily measured with the emittance meter. Details of these measurements can be studied in [2].

## References

[1] A. Nieminen *et al.*, Beam cooler of low-energy radioactive ions, Nucl. Instr. Meth. **A469** (2001) 244-253

[2] A. Wilfart, diploma thesis, LMU München, 2002