Emittance measurements at the LBNL ECR and AECR-U ion source using a pepper-pot emittance scanner

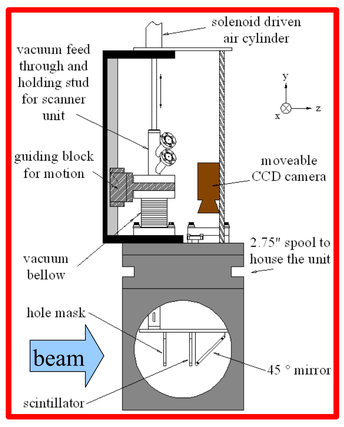
M. Strohmeier[1,*,2], J. Benitez[1], D. Leitner[1], C. Lyneis[1], D.Winklehner[1], D. Todd[1] and M. Bantel[2]
[1] Lawrence Berkeley National Laboratory, One Cyclotron Road, Berkeley, California 94720
[2] University of Applied Sciences Karlsruhe, Moltkestr. 30, 76133 Karlsruhe, Germany

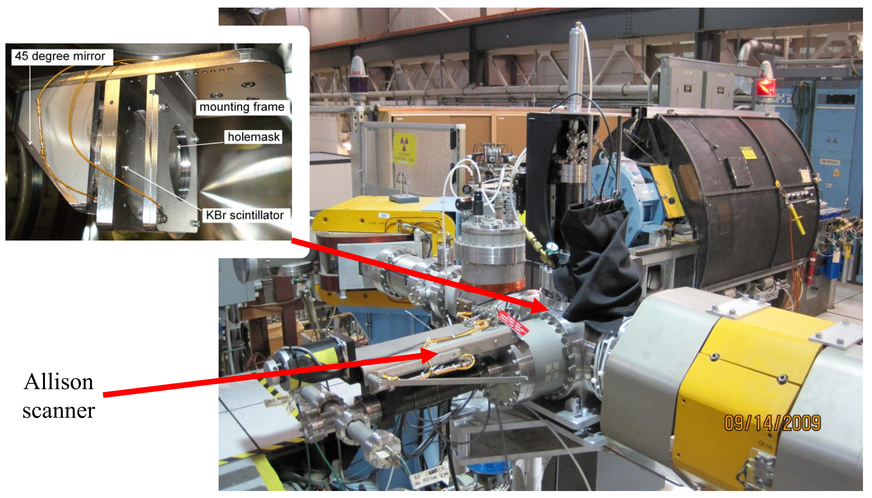
* email: MMStrohmeier@lbl.gov, phone: +1 (510) 486-6196

Abstract

Two Electron Cyclotron Resonance (ECR) ion sources are currently available to inject beams into the 88-Inch Cyclotron at Lawrence Berkeley National Lab (LBNL). The recently commissioned pepper-pot emittance scanner at LBNL was used to measure the beam emittance for various ion species of both sources. A pepper-pot scanner is capable of extracting the full four-dimensional transverse phase space of the beam, allowing for the calculation of the cross coupled emittances xy' and yx'. This is especially of interest for ECR ion sources where asymmetric beams are extracted in the presence of a strong solenoid field. The axial field adds a rotational momentum to the extracted beam resulting in a transverse emittance growth, which depends on the magnetic stiffness of the extracted species. In this paper, the pepper-pot set up is described and emittance data from both LBNL ECR sources are presented and compared. The data confirm a strong mass dependence of the normalized emittance for ions with the same mass to charge state ratio as previously also measured by other groups. This dependence indicates a different particle distribution at the extraction aperture for different ion species.

Experimental Setup





The pepper-pot scanner and Allison type scanner are located at the same z-location of the LBNL ECR beam line in order to compare both principles.

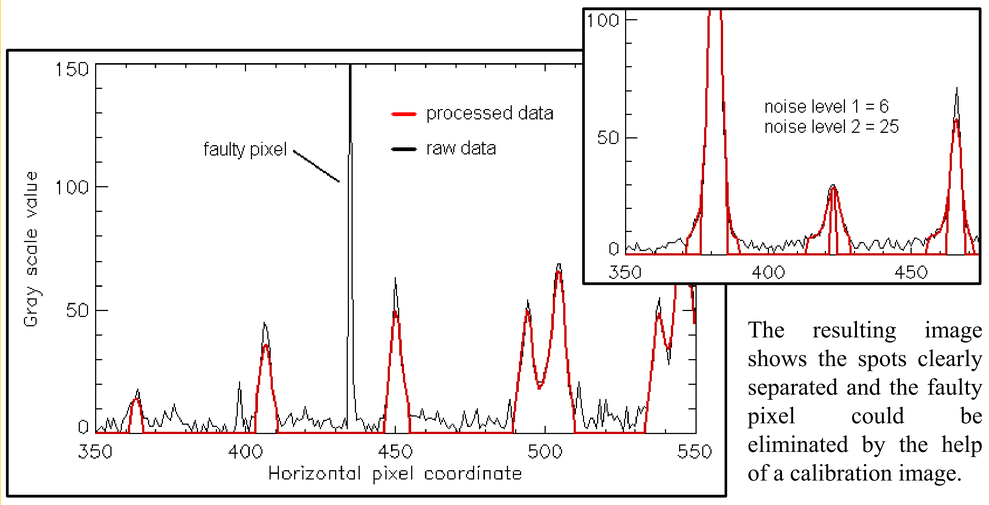
Noise removal

The noise removal mainly consists of the following steps:

1) Faulty pixels have to be located and substituted in a calibration procedure

2) A 3x3 smoothing filter is applied to the image

3) The Image is thresholded with an online adjustable noise level



The resulting image shows the spots clearly separated and the faulty pixel could be eliminated by the help of a calibration image.

The value of the noise threshold is an essential parameter (see right side):

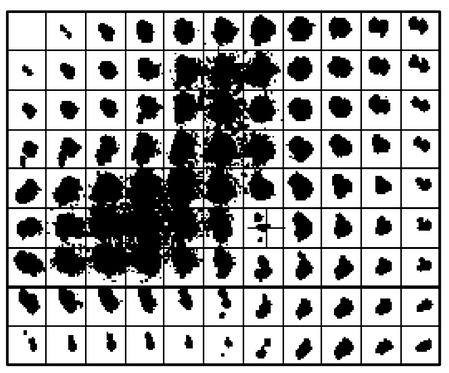
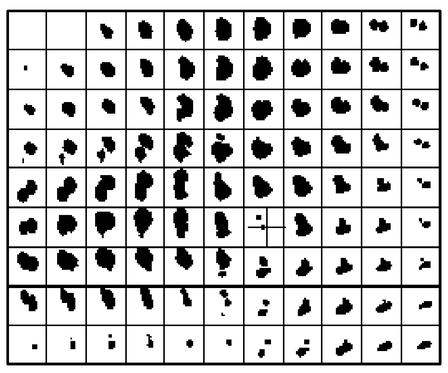
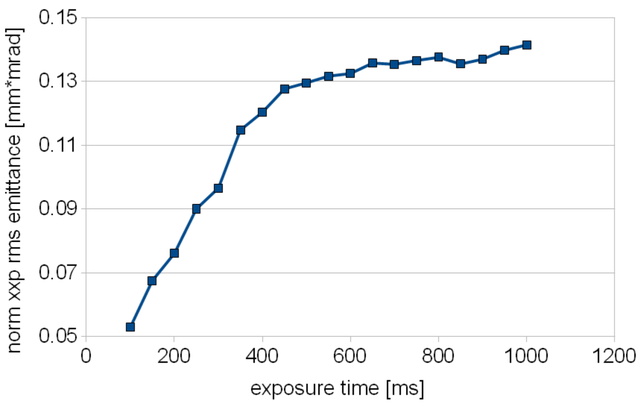


Image with a noise threshold that is set too low. The spots can not be separated and the image can not be processed



After the noise threshold is adjusted, the spots are clearly separated and the image can be evaluated

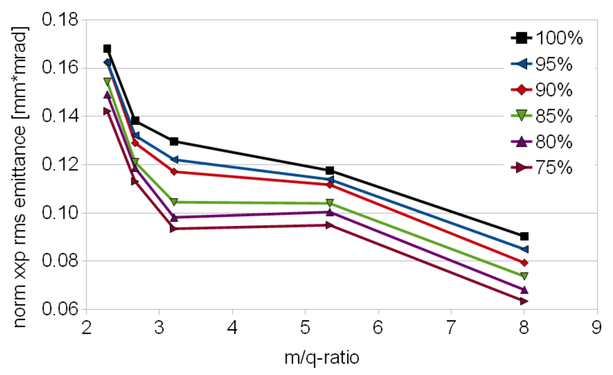
Influence of some acquisition parameters on the emittance



• For small values of the exposure time, the obtained emittance is more sensitive to changes in the exposure time.

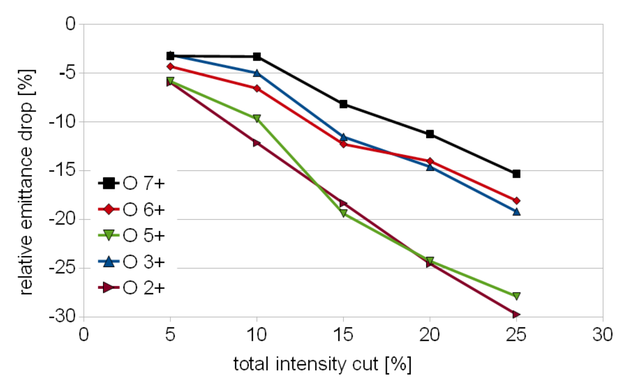
• Other than the camera gain, the exposure time keeps the electrical noise small and therefore increases the signal-to-noise ratio

→ The exposure time is an individual adjustment for every measurement and has to be set to a value where the emittance is least sensitive to its changes.



• The reference curve (100%) was taken with the noise level set to value where the spot just could be separated

•The emittance decreases as the noise level is increased and a greater portion of the spots is neglected. This change is different for every charge state and cannot be generalized.

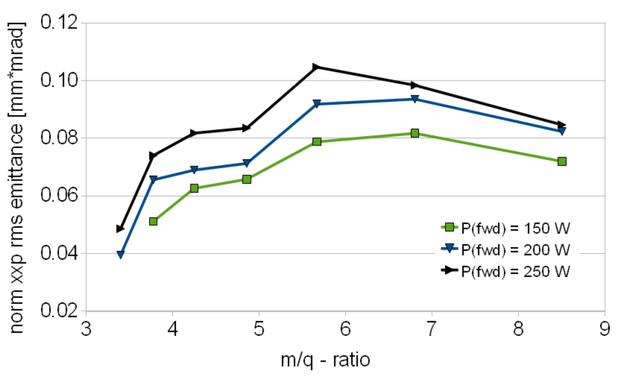


• The fact that the emittance change is not the same for every charge state implies that there is dependence on the shape of every spot in the outer regions.

• The effect of cutting intensity is visualized on the right side where the dependence on the shape can be seen clearly seen.

Emittance Measurements

1) Emittance for different RF powers



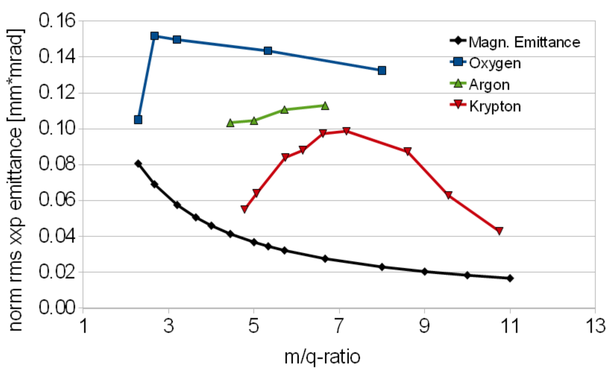
The increasing emittance with the RF power can have two reasons:

1) An increasing RF power results in a higher electron temperature which then increases the (transverse) ion temperature as well and leads to an emittance growth

2) Due to the limited sensitivity of the scintillator, higher beam intensities that are deposited on the crystal will increase the detected spot size and lead to higher emittances.

→ A separation of both effects is not possible at the moment.

2) Emittance for different ion masses



• Heavier ions generally have a smaller emittance as light ions which indicates a lower ion temperature for the heavy ions.

• The decreasing emittance towards higher charge states can be due to the fact that highly charged ions are created and extracted closer to the source axis. This keeps the emittance growth small.

This research was conducted at LBNL and was supported by the Director, Office of Energy Research, Office of High Energy and Nuclear Physics, Nuclear Physics Division of the U.S. Department of Energy under Contract DE AC03-76SF00098.