Characterization bench dedicated for focused ion beam sources.

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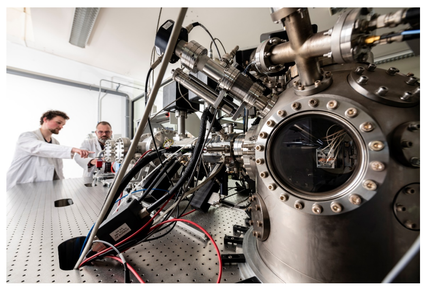
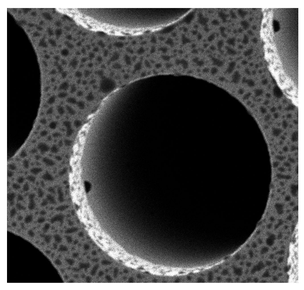
Background

The common laboratory CiCLOp (between the CIMAP and Orsay Physics) aims to improve focalized ion beam (FIB) technics. To do so, we develop new ion sources, ion optics, detector and analysis technics.
The EVOL platform is an example of a new type of FIB which can focalise multicharged ions that are produced with an ECRIS. This platform has several other equipment such as: a focus electron beam (FEB), a secondary electron detector (SED), a backscattered ion detector and a scanning probe microscope.
To study our new sources and optics designs, we design a characterization bench.



EVOL platform is dedicated to implantation, nanostructuration, and in situ characterization.

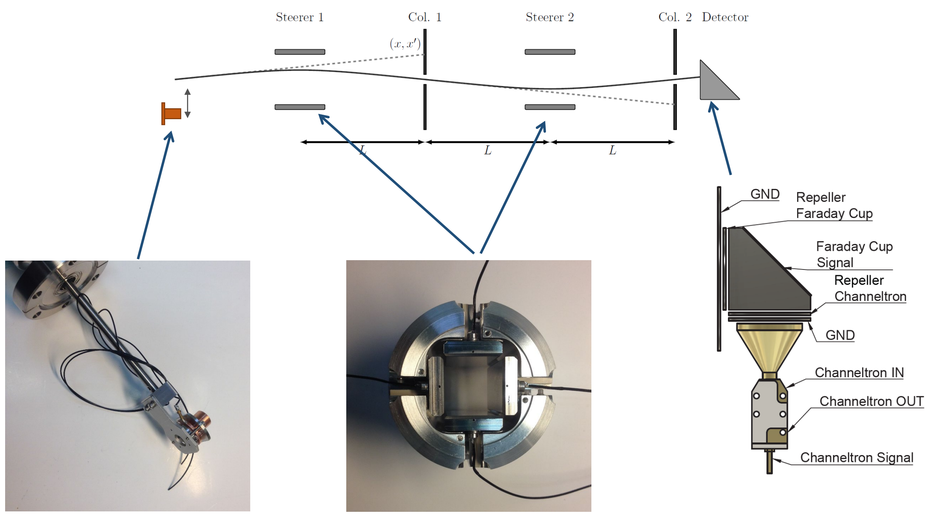
Objective lenses of the FIB, FEB and tip of the SED.



Secondary electrons image of an MCP from a 40keV O^{2+} focused ion beam (Field of view 15µm, Image resolution 37nm)

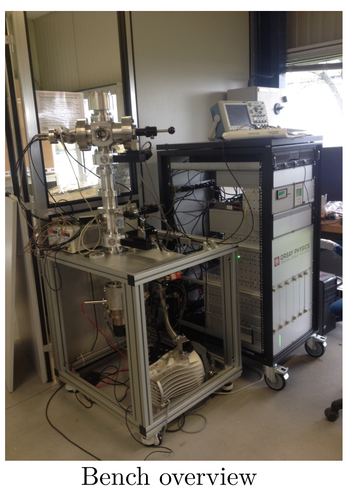
Description of the characterization bench

The ion sources used for FIB need to provide a low emittance and a low energy spread beam. The characterization bench can measure these properties. A Faraday cup measure the total beam current to compute the beam brightness.
The emittance meter is based on a double Allison type emittance scanner[1]. The scan is perform in two dimensions allowing the measurement of the 4D emittance. Unlike conventional Allison scanner, the beam is scanned by an electrostatic steerer in front of the first slit/collimator.
Collimators are embedded on motorized variable aperture (MVA) that allows the change of the aperture diameter from 800µm to 10µm.
The beam portion is measured with a high dynamic detector that can be used as a Faraday cup, or for low intensity beam, with a channeltron.

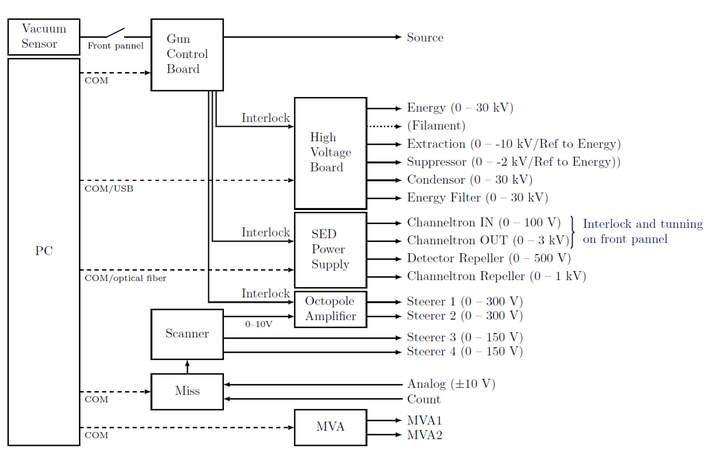


Faraday cup | Steerer | Detector

The bench electronics is based on a commercial FIB electronics, allowing a fast scan of the steerer and a synchronized recording of the detector output.



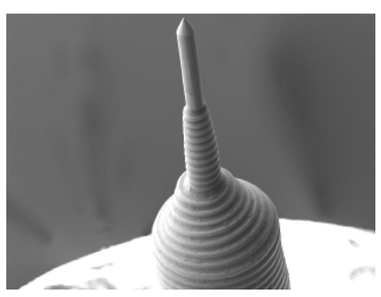
Bench overview



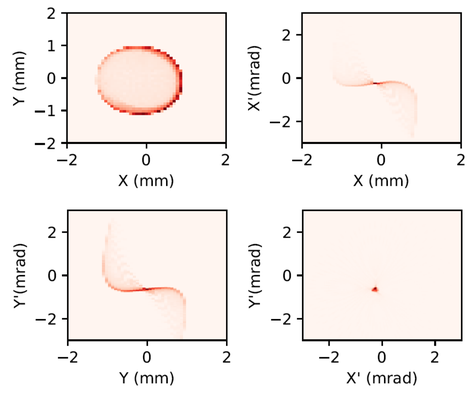
Electronic layout

Validation of the emittance measurement

In order to validate the measurement of emittance, we used a Gallium Liquid Metal Ion Source (LMIS). The beam produced from this source is known to have an extremely low emittance; the virtual source diameter[2] is in the order of 50nm.

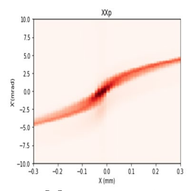


Gallium LMIS tip

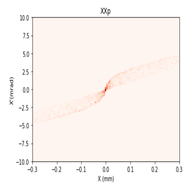


Example of 2D projections of the 4D emittance of a 20keV Ga^+ beam from a LMIS.

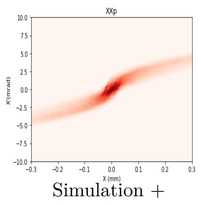
We measured the emittance pattern due to the lens aberrations. This aberration can be simulated and fits with the measurements.



Measurement



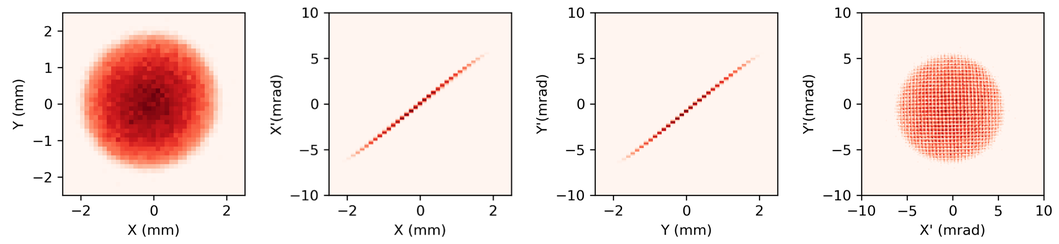
Simulation



Simulation + Convolution (50µm, 1mrad)

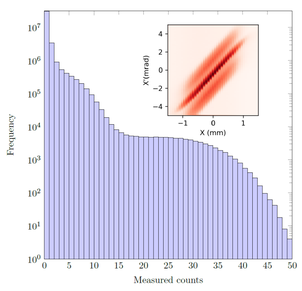
Emittance measurement

Once the bench validated, we measured the beam emittance of a beam produced form an ECRIS.

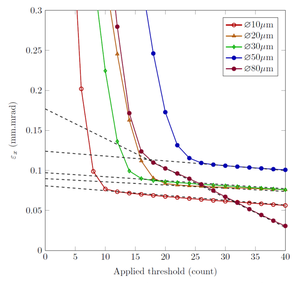


Example of 2D projections of the 4D emittance of a 20keV Argon beam from an ECRIS.

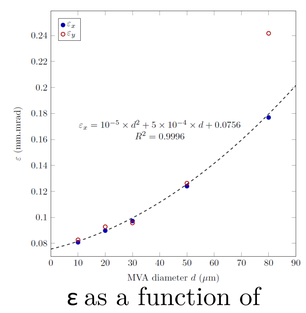
For different collimator diameters, we measured the emittance using a threshold algorihm[3]. We show that the beam 1RMS emittance value is ε=7.6 10^{-2} mm.mrad



Histogram of the pixel values.



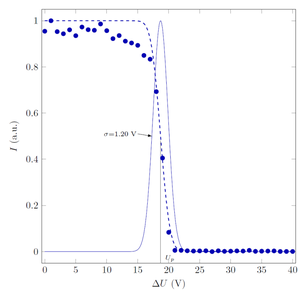
ε as a function of the applied threshold.



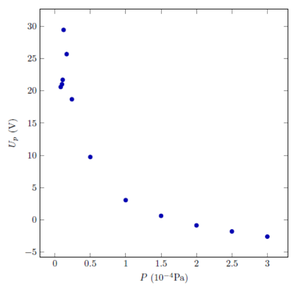
ε as a function of the collimator diameter.

Energy dispersion measurement

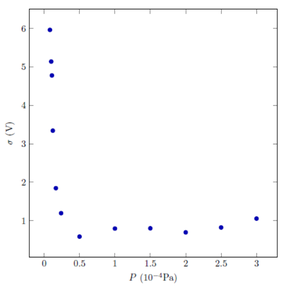
A retarding field analyser was placed before the detector to measure the energy dispersion of the beam. The energy spread and the plasma potential shows a strong dependence to the gas injection pressure.



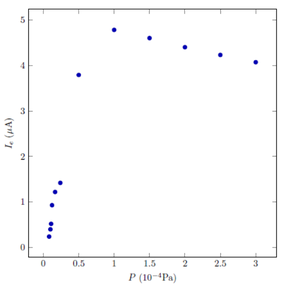
Energy dispersion of a Xe 10keV beam.



Plasma potential as a function of the source pressure.



Energy spread as a function of the source pressure.



Emission current as a function of the source pressure.

Aknowledgement

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References

[1]D. Löffelmacher *et al.* An emittance scanning device for liquid metal ion sources. NIM B 139 (1998).
[2]C.W. Hagen *et al.* Brightness measurements of a gallium liquid metal ion source. Journal of Vacuum Science Technology B: Microelectronics and Nanometer Structures. 26. 2091 (2008).
[3]H. R. Kremers *et al.* A pepper-pot emittance meter for low-energy heavy-ion beams. Review of Scientific Instruments, 84(2) :025117 (2013).