Nano Aperture Ion Source

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We want to make bright and monochromatic ion beams as this enables higher resolution in focused ion beam instruments. Another driver for our work is the desire for different ionic species. For efficient milling we like heavy ions, while for imaging, lighter elements minimize sample damage. Furthermore, preventing or employing chemical reactions can open up a variety of applications.

Ion production in the Nano Aperture Ion Source (NAIS) is based on electron impact gas ionization inside a sub-micron sized gas chamber, see figure 1. An important part of recent efforts [2] was devoted to understanding how the relevant physical processes determine the ion beam performance. The influence of initial velocity and position distributions of the neutral gas particles, their ionization cross sections, the electron current density, ion-neutral scattering, Coulomb interactions and the electric fields around the double membrane structure are studied by analytical models, numerical calculation, and ray tracing.

An important finding is that the current and the brightness tend to keep increasing with increasing particle density, despite increasing ion-neutral scattering. Ion-to-ion Coulomb repulsion is found to pose a final limit to the achievable brightness.

The optical effects due to the electric fields, the ion-neutral scattering, and Coulomb interactions are studied simultaneously using Monte-Carlo ray tracing. In a realistic configuration, the simulations predict a brightness of about 3×10^6 A/m^2srV in combination with an energy spread of 1 eV.

An ion focusing and scanning column in combination with a knife-edge ion transmission detector was built for the purpose of measuring brightness. The setup was used to experimentally demonstrate a brightness of $B = 1x\ 10^5$ A/m^2srV, which we consider a milestone result because it is already a competitive brightness when compared to a Ga LMIS while there is clearly room for improvement. We identify poor electron beam performance, too weak ion acceleration field, and too low ion lens voltage as improvable aspects. The measured brightness matches reasonably well with the simulated values for this sub-optimal configuration. Earlier energy spread measurements already indicated an obtainable spread of 1 eV [1].

For a 1 keV electron beam we expect the beam to consist of about 88% single charged argon, 8% double charged argon, 2% triple charged argon, and 2% diatomic single charged argon.

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[1] David S. Jun, Development of the Nano-Aperture Ion Source, PhD Thesis TU Delft, 2014.
[2] Leon van Kouwen, The Nano-Aperture Ion Source, PhD Thesis TU Delft, 2017

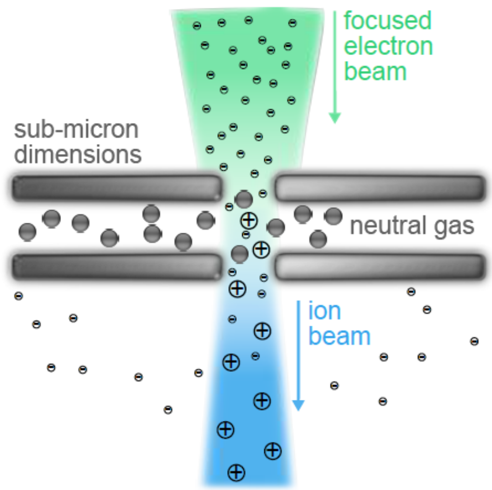

Figure 1: Principle of the Nano Aperture Ion Source: A tightly focused electron beam ionizes gas atoms or molecules in a very small volume.

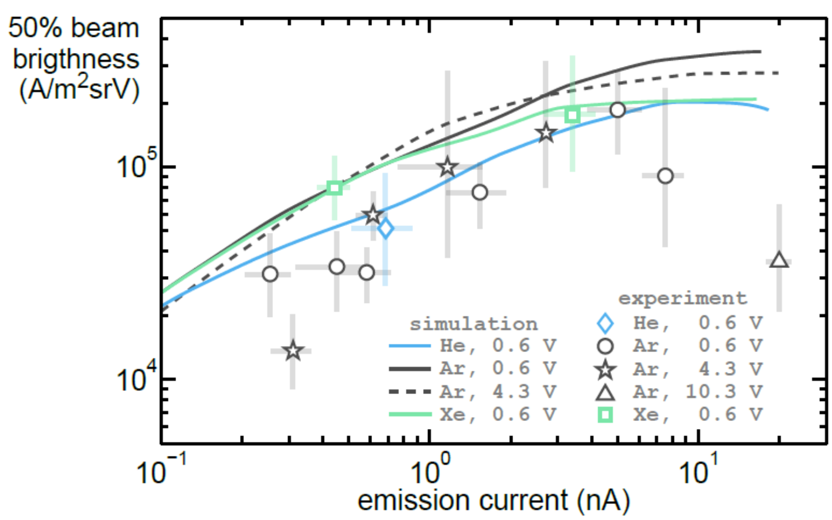

Figure 2: Simulated and measured brightness versus ion beam current: The current was varied by changing the gas inlet pressure. The chip used for these measurements had a spacing of 1200nm, an aperture of 800 nm diameter. The electron landing energy was 1 keV and the beam had 121 nA of current.