Ultracold ion beams using laser cooling

Friday 10:00 - 10:30

Ultracold ion beams using laser cooling

Edgar Vredenbregt,[1,*] Steinar Wouters,[1] Gijs ten Haaf,[1] and Peter Mutsaers[1]

[1] *Department of Applied Physics, Eindhoven University of Technology P.O. Box 513, 5600 MB, Eindhoven, Netherlands*

Focused ion beam instruments are indispensable tools for the semiconductor industry due to their ability to image and modify structures on the nanometer length scale. For milling and deposition, the industry standard is the gallium liquid-metal ion source which enables a resolution of 5-10 nm at a current of a few pA. With the quest towards smaller features on integrated circuits, there is a need for novel ion sources that allow for better resolution. Several research groups are working towards applying laser-intensified alkali-metal ion beams for this purpose [1].

Such ultra-low temperature (1 mK) ion beams can be created by laser-cooling and photo-ionization of a thermal atomic beam or vapor. The Rb ion source under development in Eindhoven in collaboration with FEI Company starts with a high-flux Knudsen cell connected to a collimating tube. The brightness of the atomic beam is greatly increased by laser cooling and compression in the transverse direction using a compact magneto-optical device. Calculations show that, for rubidium-85, an equivalent atomic beam brightness of 10^7 A/m^2 sr eV can be achieved in this way [2]. The resulting cold beam of atoms is converted to an ion beam by near-threshold photo-ionization inside an optical build-up cavity surrounding an accelerator structure.

Subsequent disorder-induced heating can have disastrous effects on the beam's brightness. Particle tracking simulations reveal a strategy to suppress the heating by creating a so-called pencil beam. Analytical calculations [3] that include the finite brightness of the beam as well as chromatic and spherical aberrations of a realistic focusing column nevertheless show that a focal spot of $\approx$ 1 nm at a current of 1 pA or to 5 nm at currents up to 20 pA is possible.

---

[1] For an overview see: Kevin Weatherill and Edgar Vredenbregt, *Physics World* **25** 28 (2012)
[2] S.H.W. Wouters et al., *Phys. Rev. A* **90** 063817 (2014)
[3] G. ten Haaf et al., *J. Appl. Phys.* **116** 244301 (2014)

---

* e.j.d.vredenbregt@tue.nl; http://www.phys.tue.nl/cqt/