

## Ultracold ion beams using laser cooling

***Citation for published version (APA):***

Vredenburg, E. J. D., Wouters, S. H. W., ten Haaf, G., & Mutsaers, P. H. A. (2015). Ultracold ion beams using laser cooling. In *iCoRD Book of Abstracts: International conference on Rydbergs at Durham* (pp. 61). Durham University.

***Document status and date:***

Published: 01/01/2015

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

***General rights***

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

***Take down policy***

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Friday 10:00 - 10:30

## Ultracold ion beams using laser cooling

Edgar Vredenburg,<sup>1,\*</sup> Steinar Wouters,<sup>1</sup> Gijs ten Haaf,<sup>1</sup> and Peter Mutsaers<sup>1</sup>

<sup>1</sup>*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<sup>2</sup> 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 Vredenburg, *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.vredenburg@tue.nl; <http://www.phys.tue.nl/cqt/>