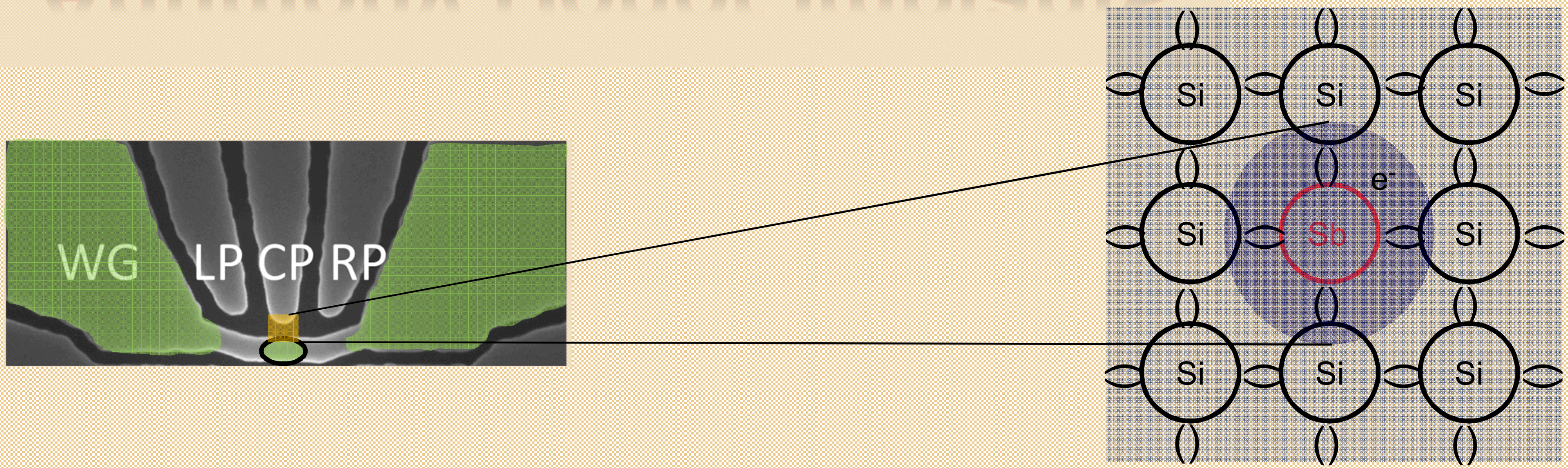
SAND2016-2233C

Silicon Quantum Dots with Counted Antimony Donor Implants



M. Singh, J. L. Pacheco, D. R. Luhman, E. S. Bielejec, M. P. Lilly and M. S. Carroll

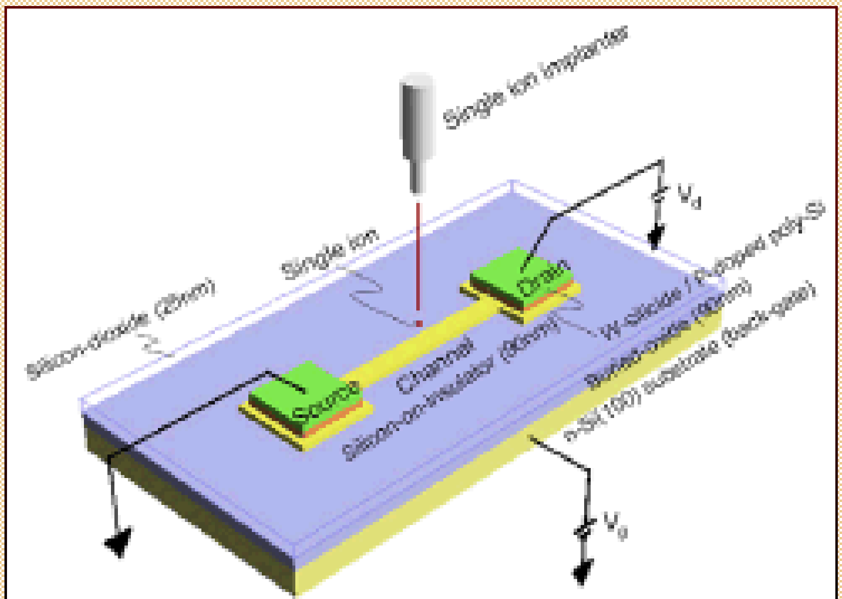
This work was performed, in part, at the Center for Integrated Nanotechnologies, a U.S. DOE Office of Basic Energy Sciences user facility. The work was supported by Sandia National Laboratories Directed Research and Development Program. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a Lockheed-Martin Company, for the U. S. Department of Energy under Contract No. DE-AC04-94AL85000.

Why count donors?

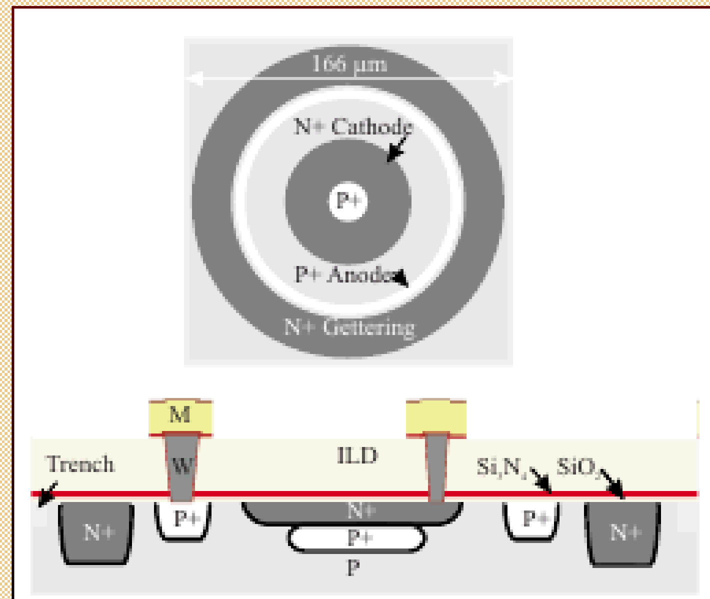
Two qubit experiments require deterministic control over number of donors

B.E. Kane, Nature **393**, 133 (1998)

How to count donors:



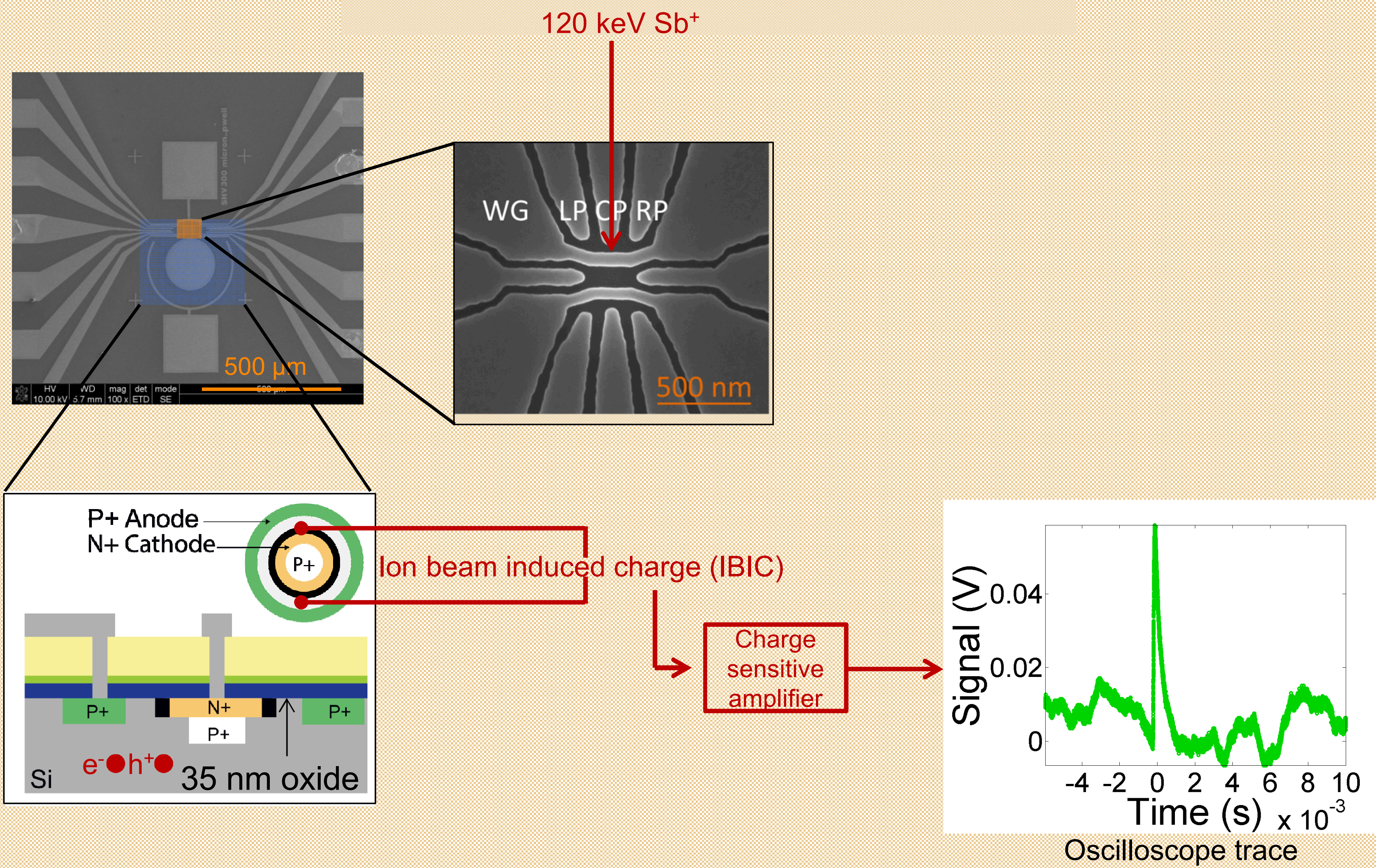
T. Shinada et al., Nanotechnology 19, 345202 (2008)



J. A. Seamons et al., APL **93**, 043124 (2008)

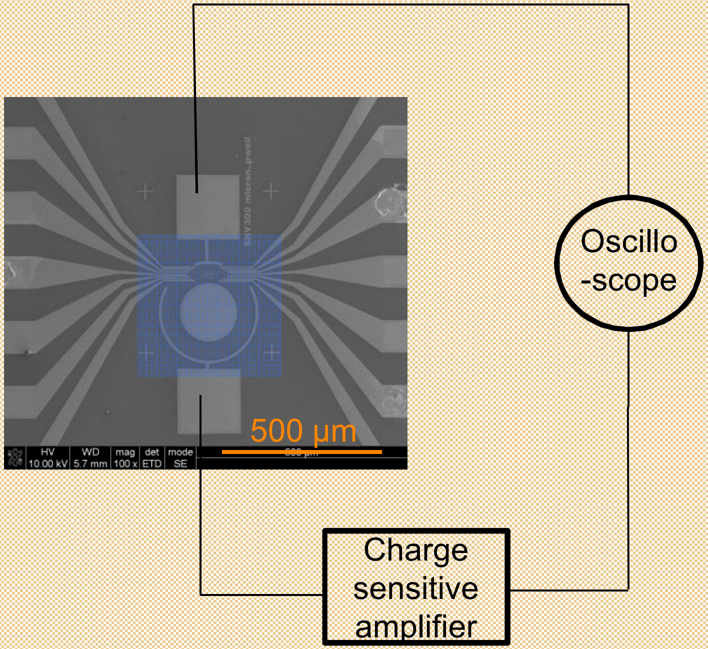
Sandia National Laboratories

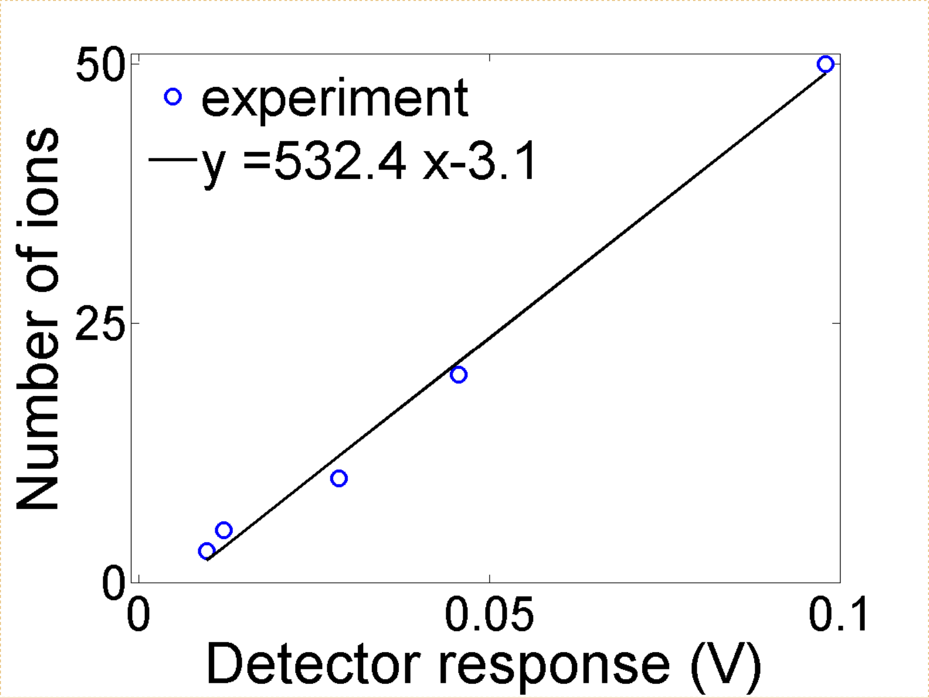
How do we count



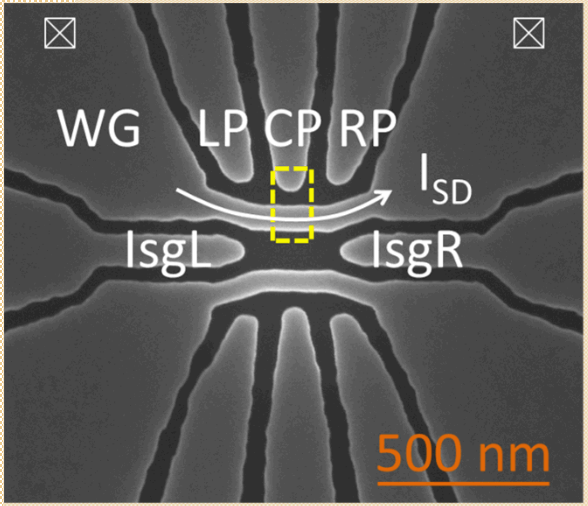
Making devices with counted no. of donors

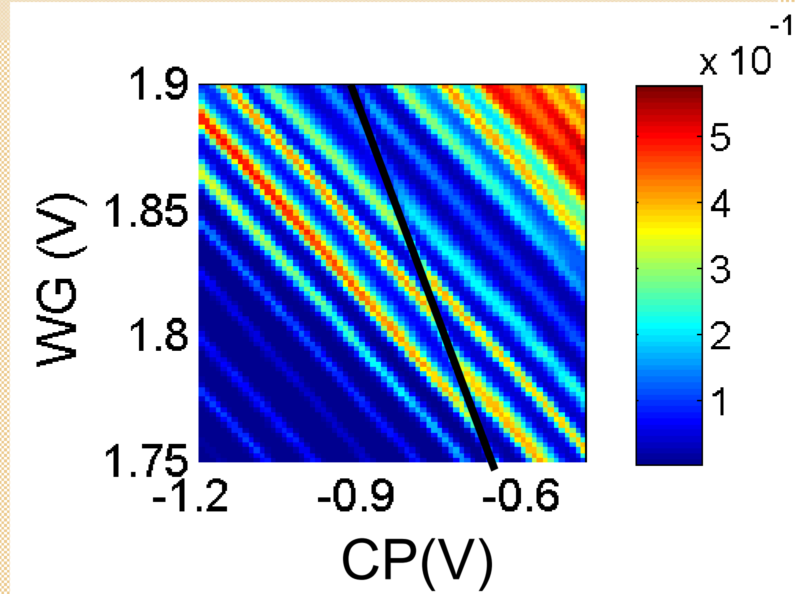
Counting the ion implants

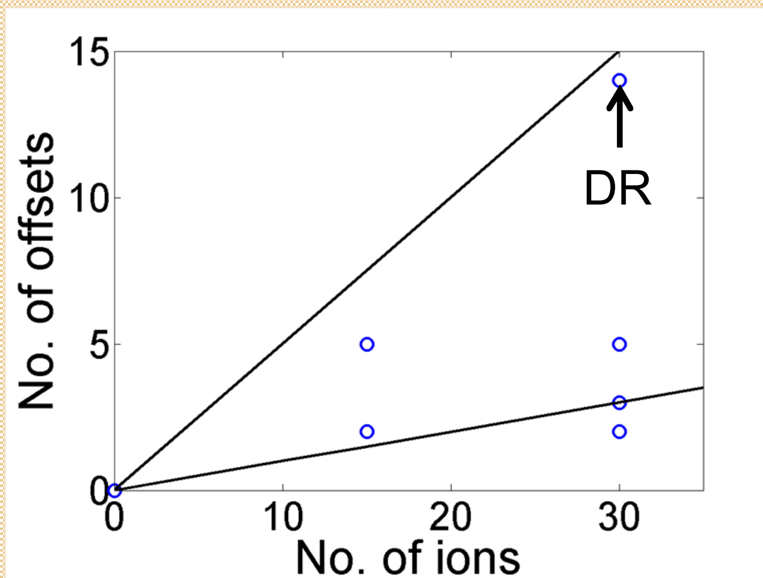




Does the SET work/see the donors?

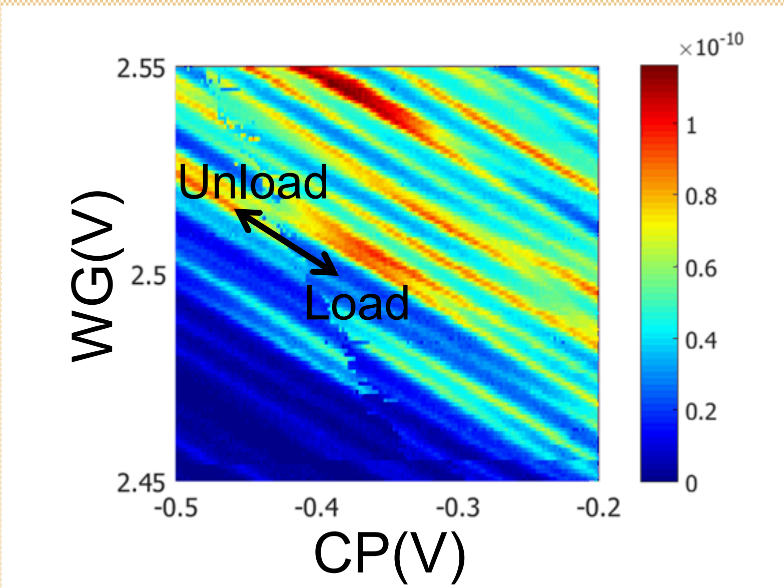


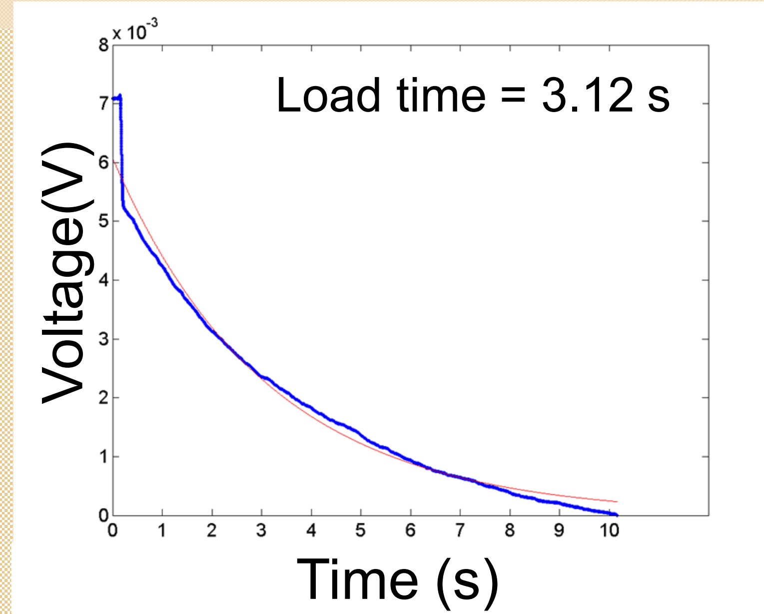


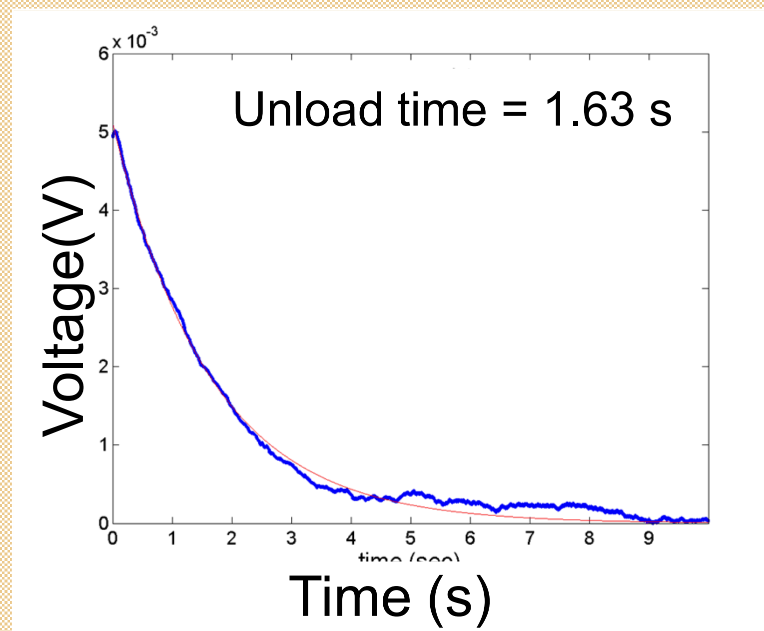


Tunneling Time Measurement on Counted Donors

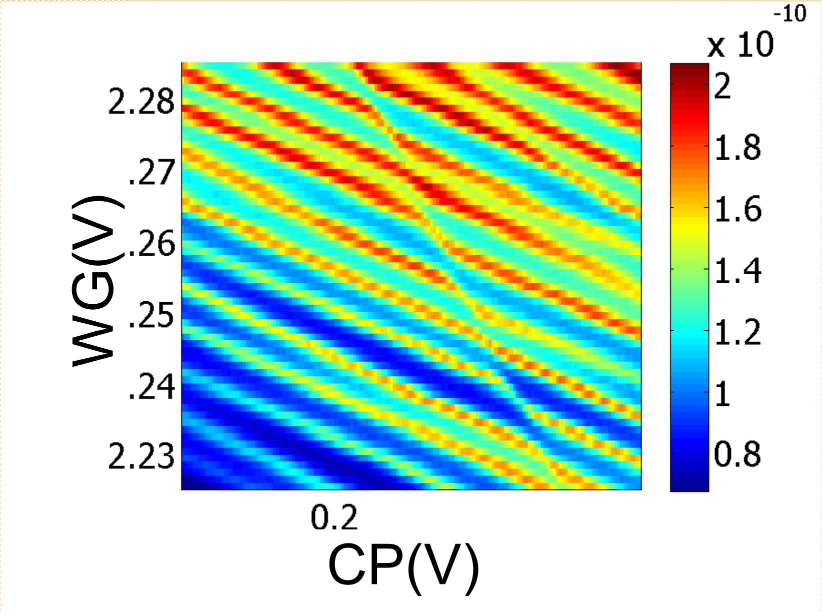
Some offsets are very slow

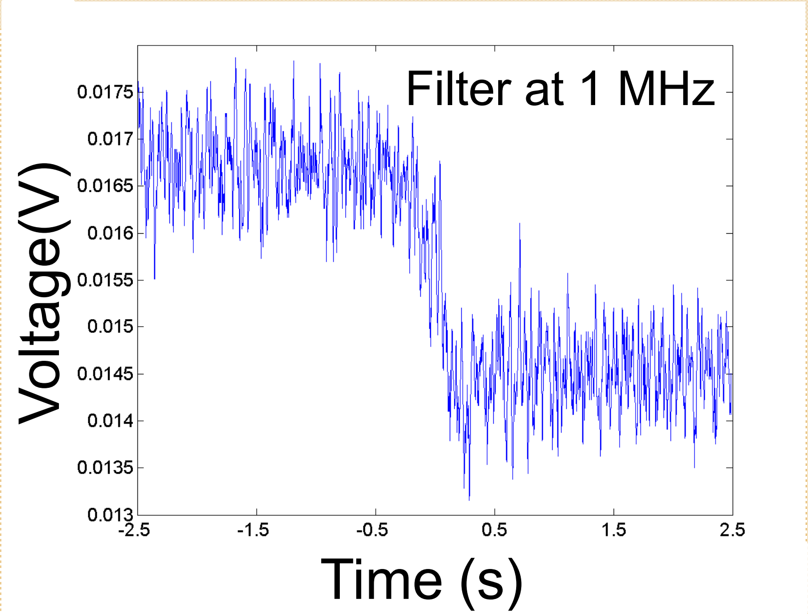




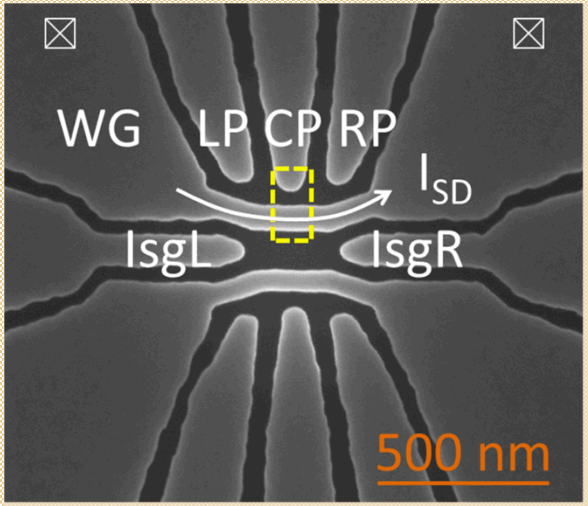


Tunneling Time Measurement on Counted Donors





Others are very fast

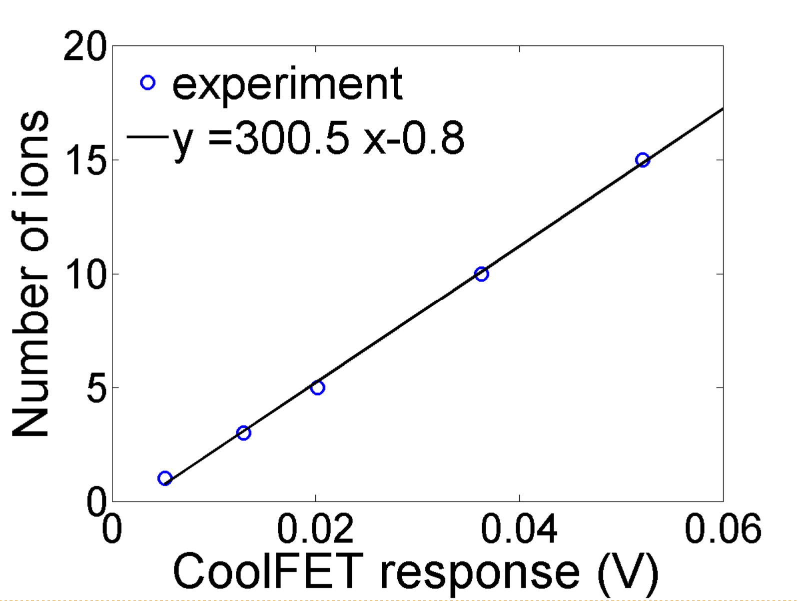


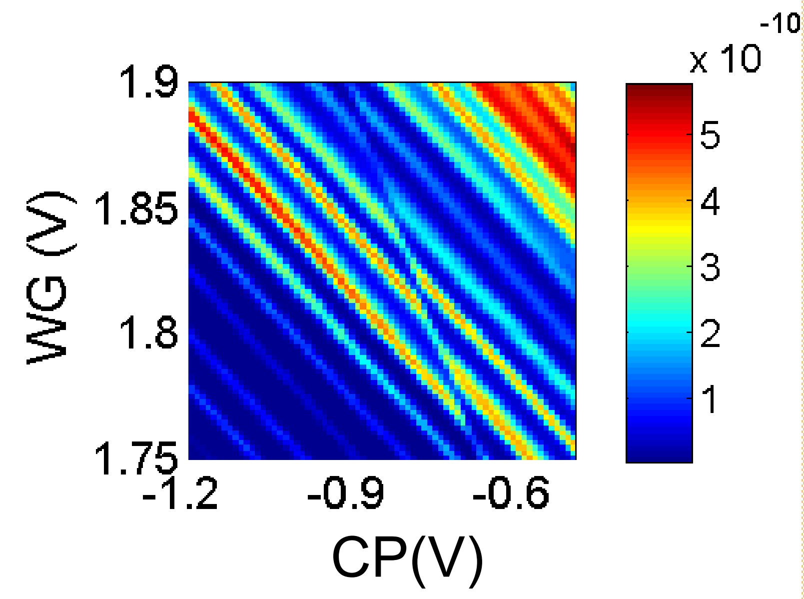
1. With focused ion beam system and lithography, we can control lateral position to ~ 10 nm

2. By thinning oxide to 7 nm in the implantation region, we can use lower energy ions and reduce depth straggle

Results

THIS WORK:
Correlation between no. of donors implanted and no. of charge offsets in transport measurement is seen (APL **108**, 6, 062101 (2016))

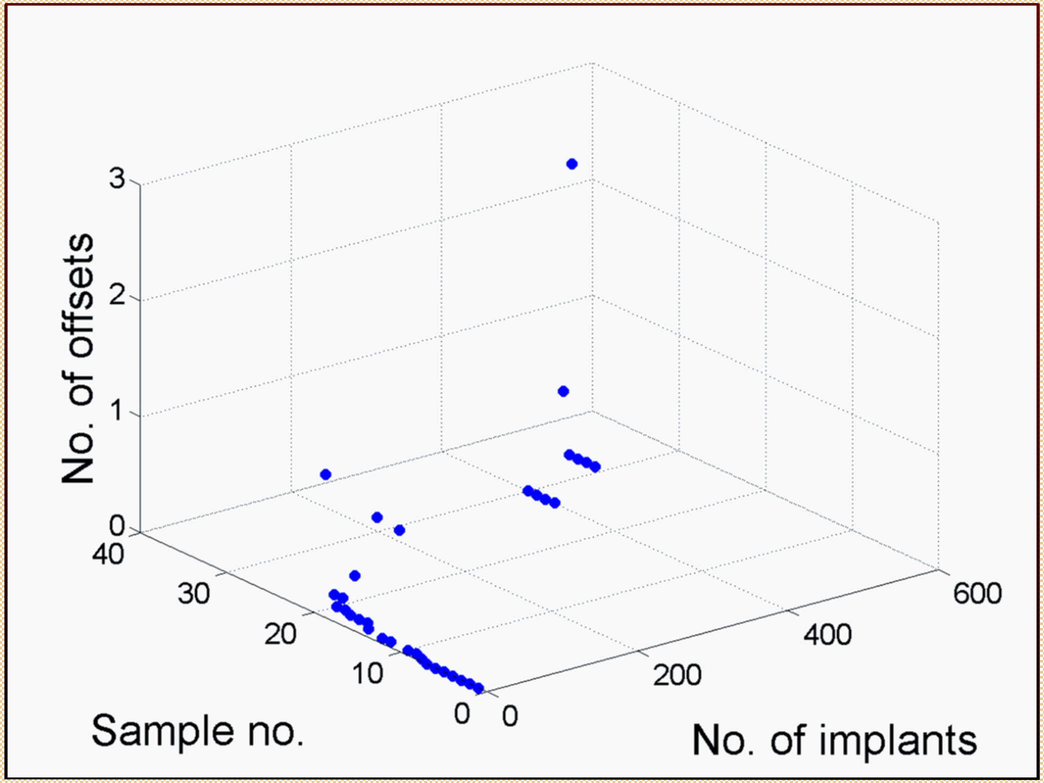




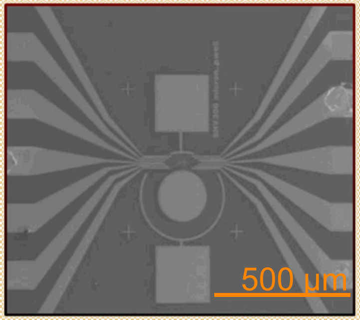
Thank you

Additional Information

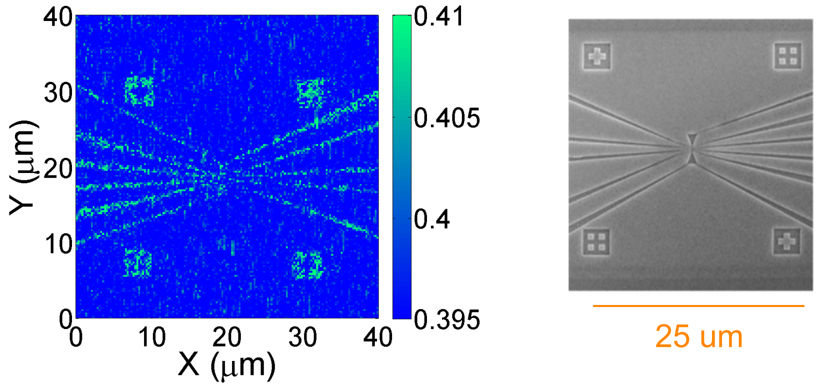
7 nm counted implants



Single ion detection and functional SET



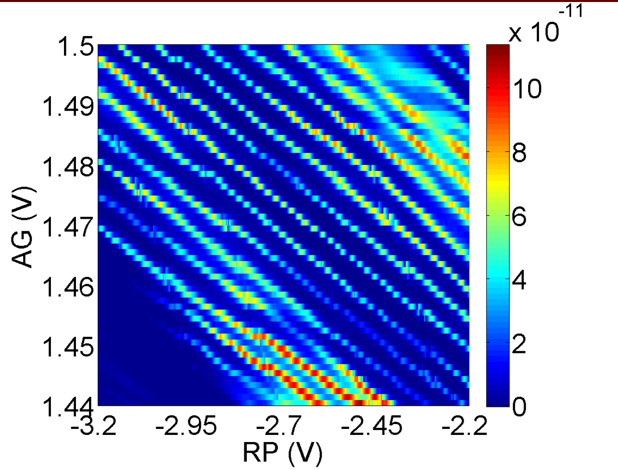
Single ion detection



Ion beam induced current map with 50 keV Sb <1> ion/pulse and SEM image of device

Diode detectors that can detect a single ion integrated with functional SETs.

SET with capacitances agree with simulations of an electrostatically defined dot



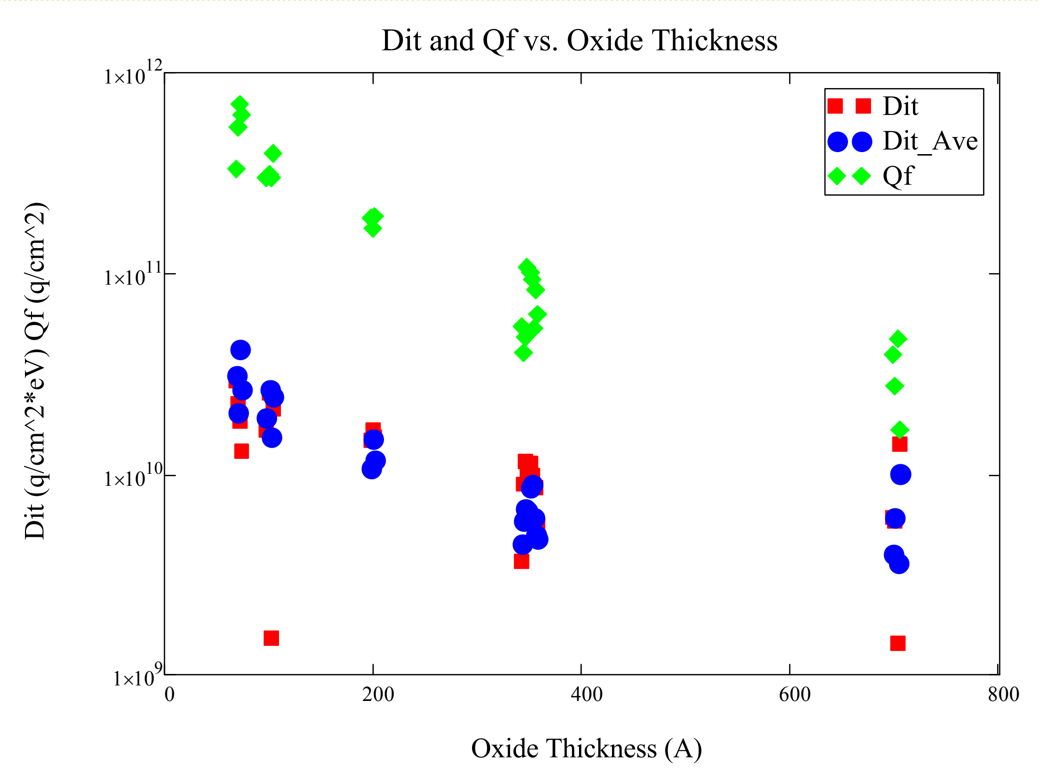
T = 25 mK, C_{AG} = 26.7 aF, C_{RP} = 1.6 aF, C_{CP} = 2.2 aF, C_{LP} = 1.4 aF

Sample Synthesis: 7 nm oxide

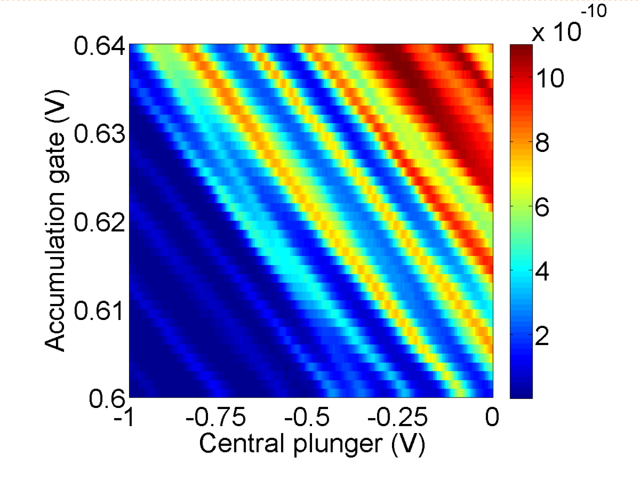
1. Interface trapped charge (D_{it}) and fixed charge (Q_f) are concerns for dots and donors near the SiO_2/Si interface

We require deterministic control over:
1. Placement of donors: needs thin oxide
2. Number of donors

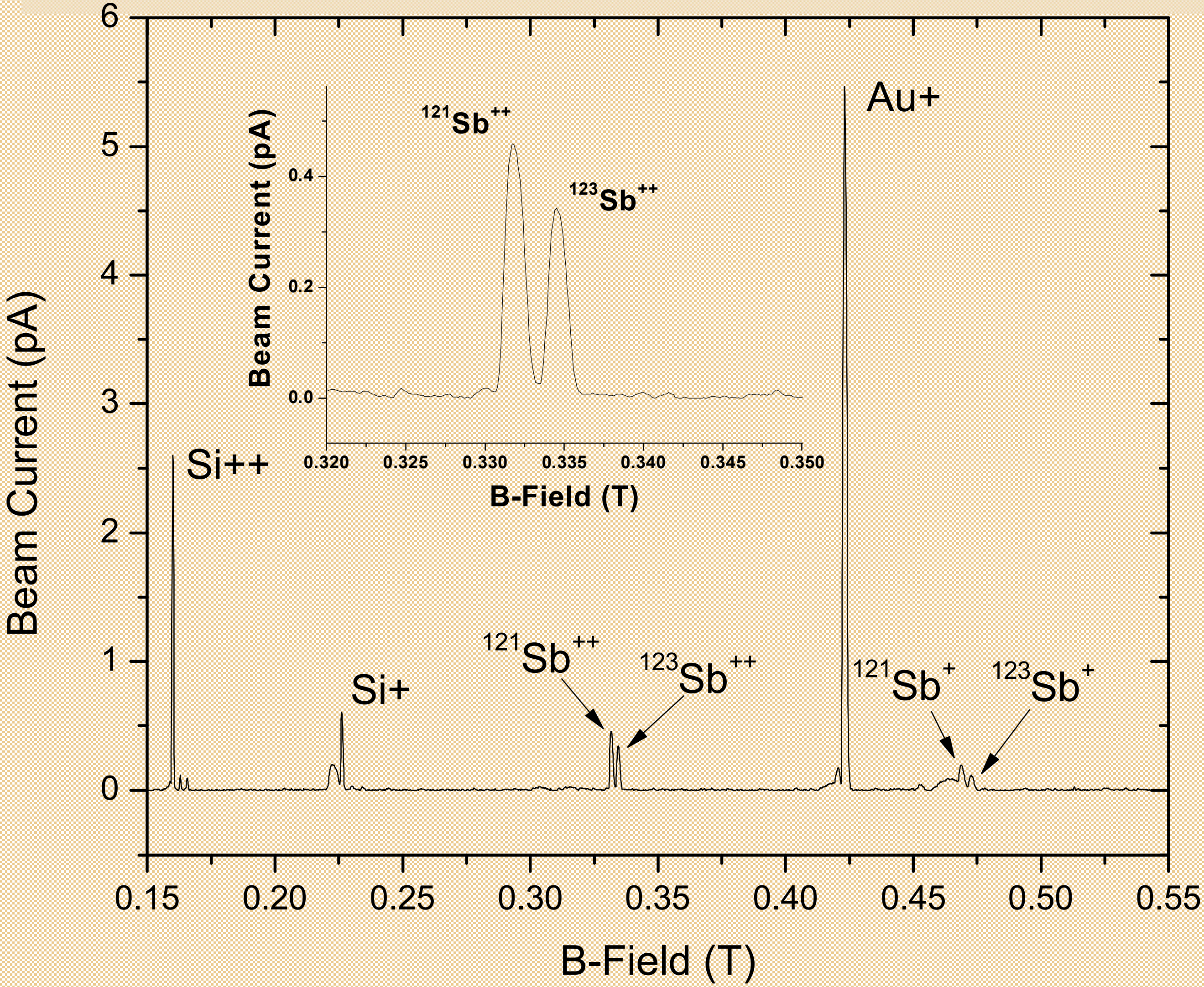
2. Thinner oxides lead to higher fixed charge

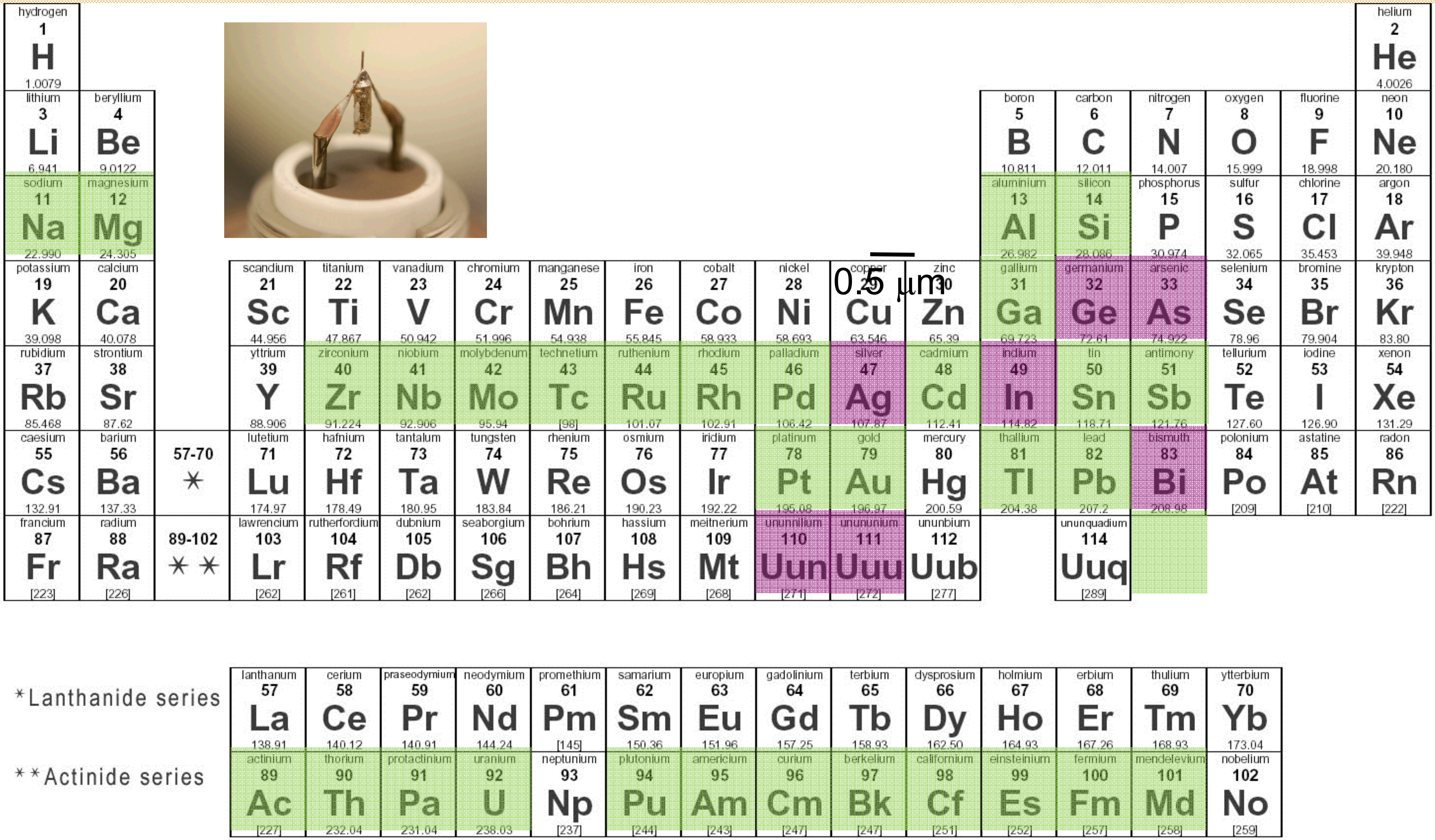


However, we are able to obtain stable single dots in these systems



AuSiSb Mass Spectrum





Capable of Generating Ion Beams from ~$^1/_3$ of the Periodic Table