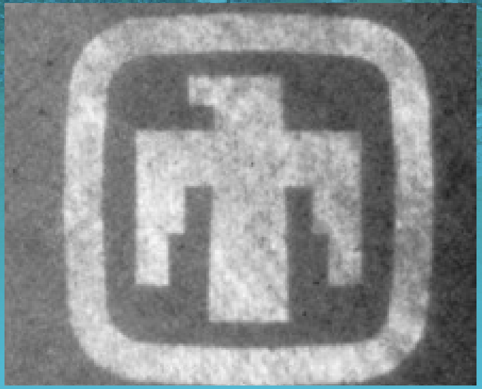
SAND2022-2513C

Sandia National Laboratories

Atomic Focused Nitrogen Ion Beam from a Liquid-Metal Alloy Ion Source



Michael Titze, Aaron Katzenmeyer, Anthony Flores, Yongqiang Wang, Barney Doyle, Ed Bielejec

03/16/2022

U.S. DEPARTMENT OF ENERGY
NNSA

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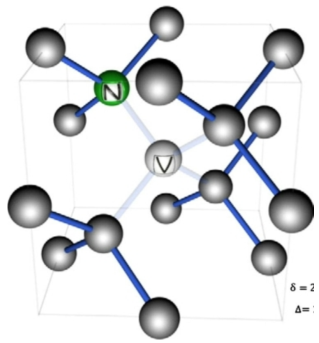
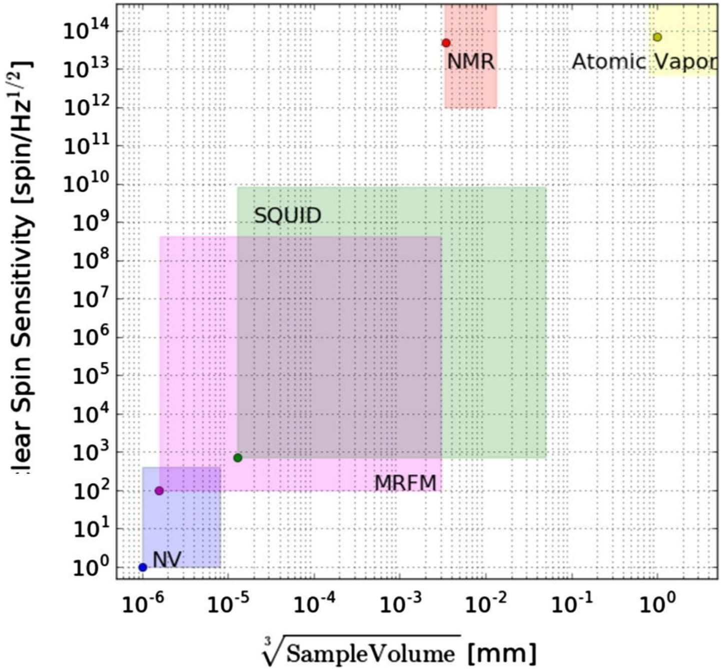
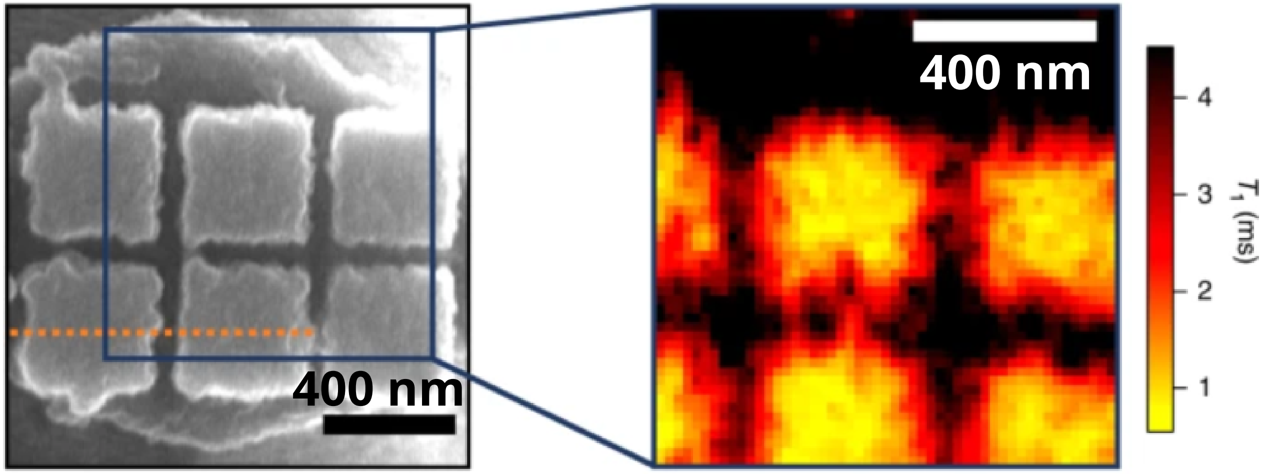
Nitrogen-Vacancy Color Centers in Diamond



Quantum Sensing

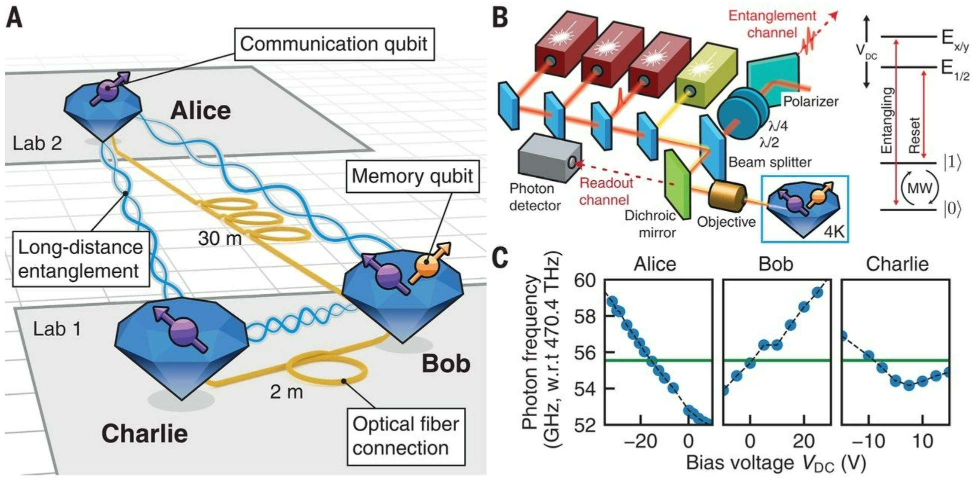


J. Wrachtrup, A. Finkler, J. Magn. Reason. 269 (2016)



A. Ariyaratne et al., Nat. Commun., 9, 2406 (2018)

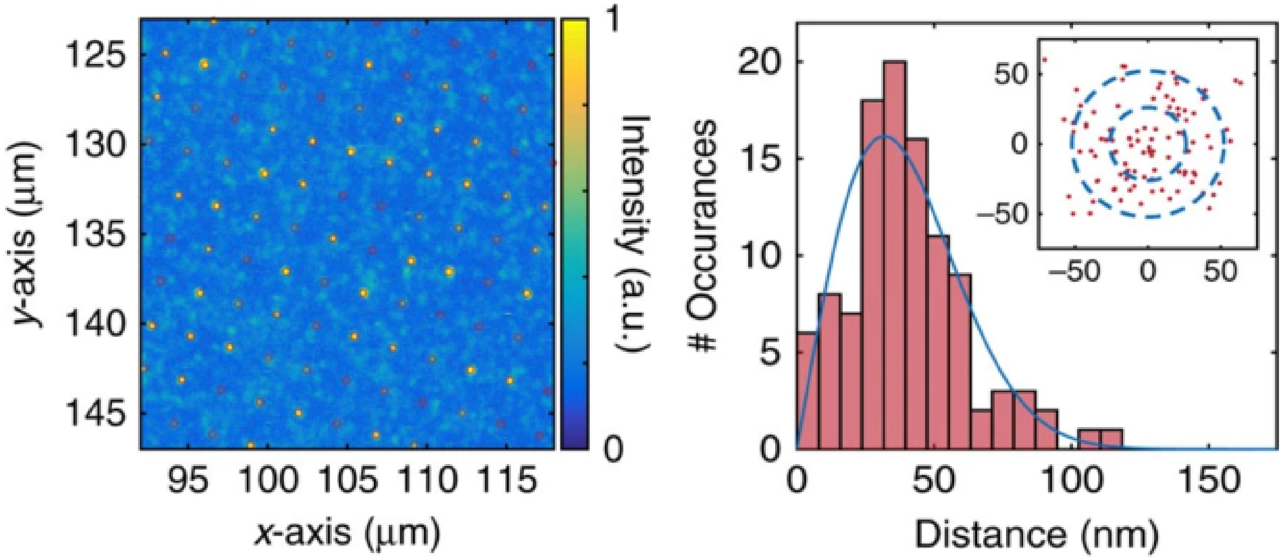
Quantum Networking



M. Popili et al., Science, 372, 6539, 259 (2021)

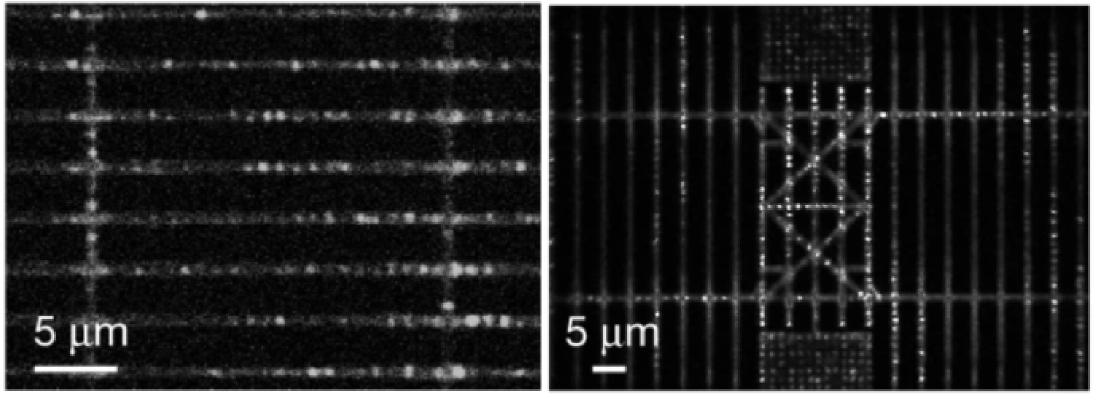
Focused Ion Beam Implantation Enables Precision Placement

< 50 nm Targeting Resolution



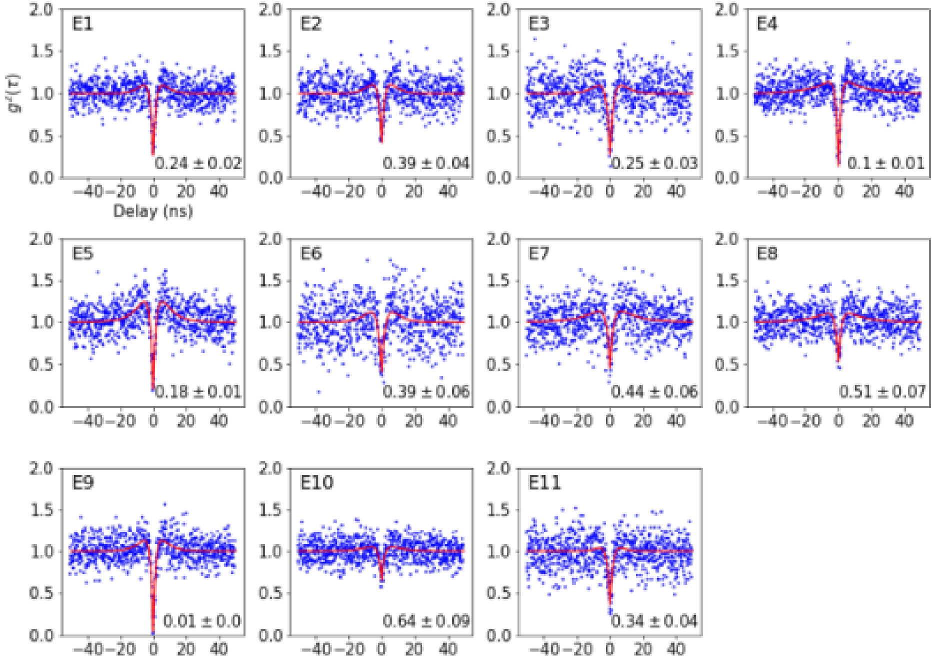
T. Schroder et al., Nat. Communs., 8, 15376 (2017)

Scalable Implantation



N. Wan et al., Nature, 583, 226 (2020)

Formation of Single Photon Emitters

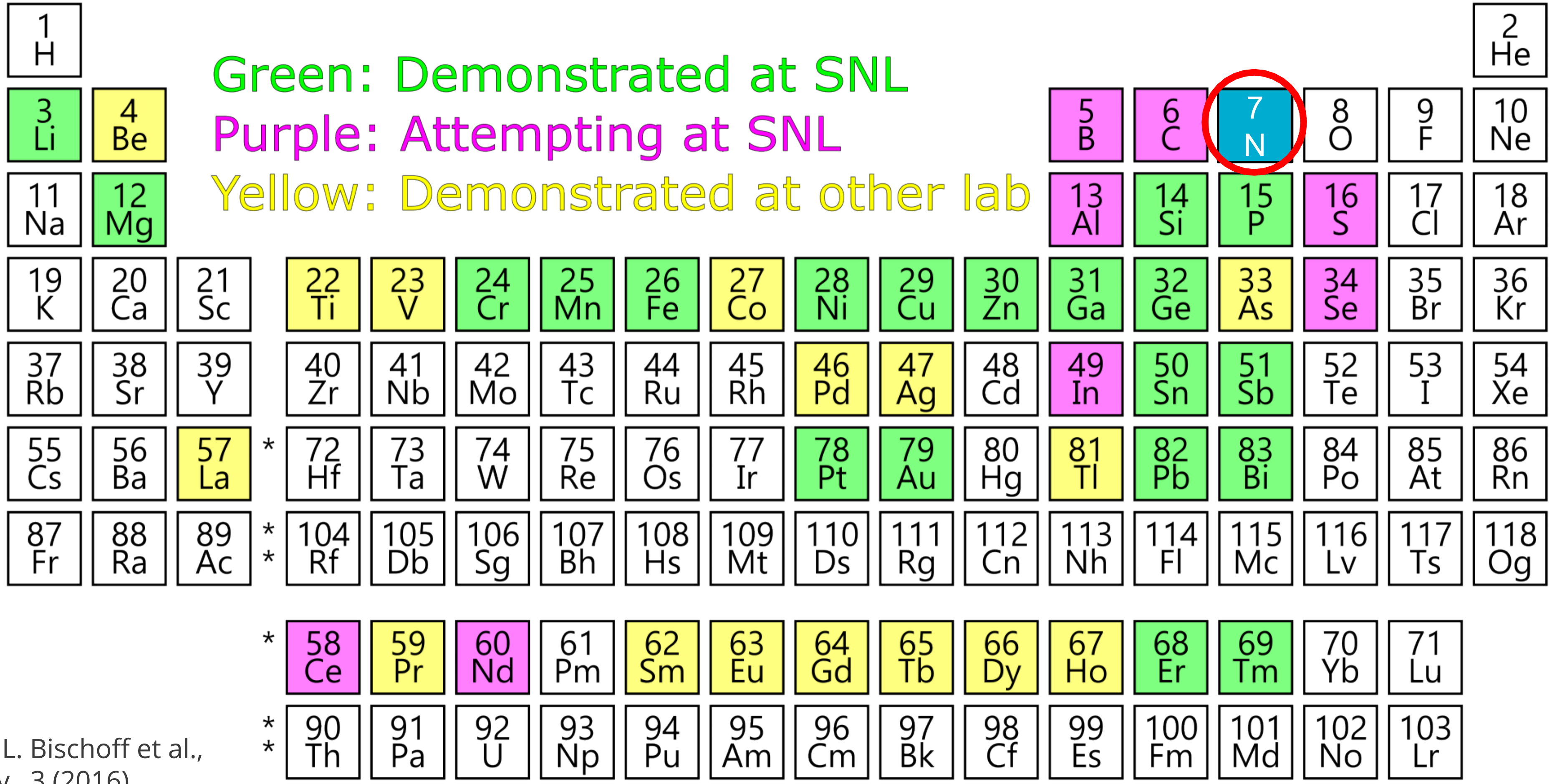


M. Titze et al., arXiv:2112.02049
(accepted Nano Letters)

! All done with SiV in Diamond, not NV !

Liquid Metal Alloy Ion Sources – Available Ions

- Material needs to form a low melting point liquid metal alloy → Nitrides do not apply

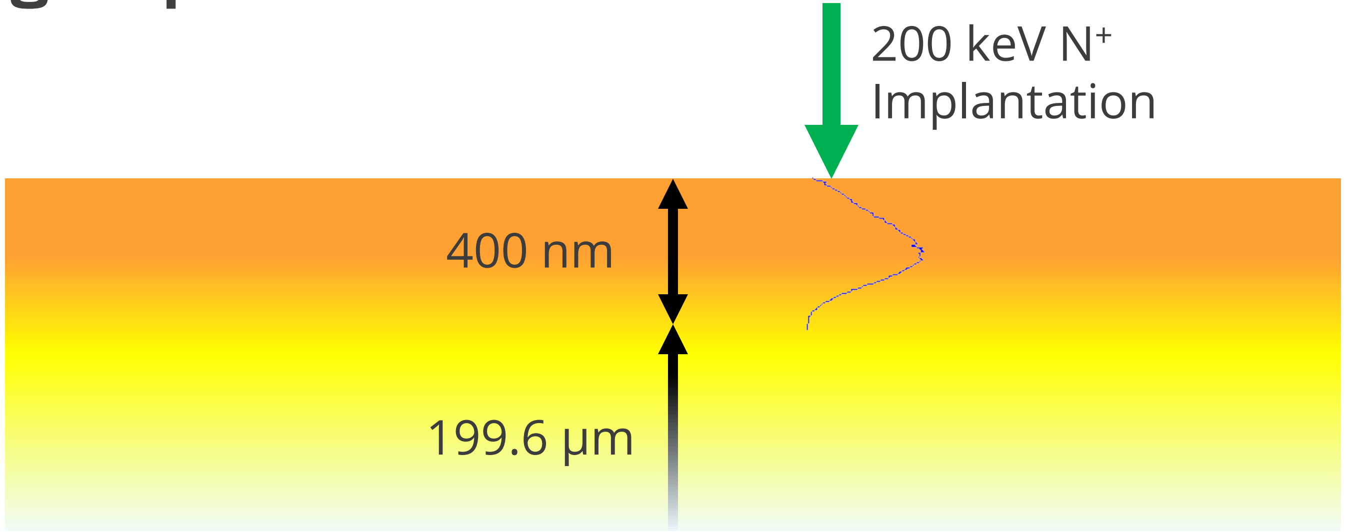


Adapted from L. Bischoff et al., Appl. Phys. Rev., 3 (2016)

Fabrication of a N Containing Liquid Metal

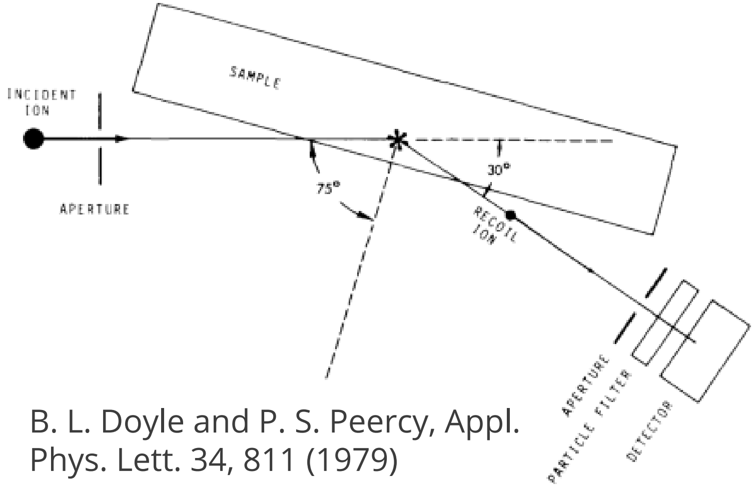
Implantation

- Implanted a $Au_{80}Sn_{20}$ 200 μm thick foil with N to $5x10^{17}$ ions/cm^2
  - Level based on solid-solubility limit for H

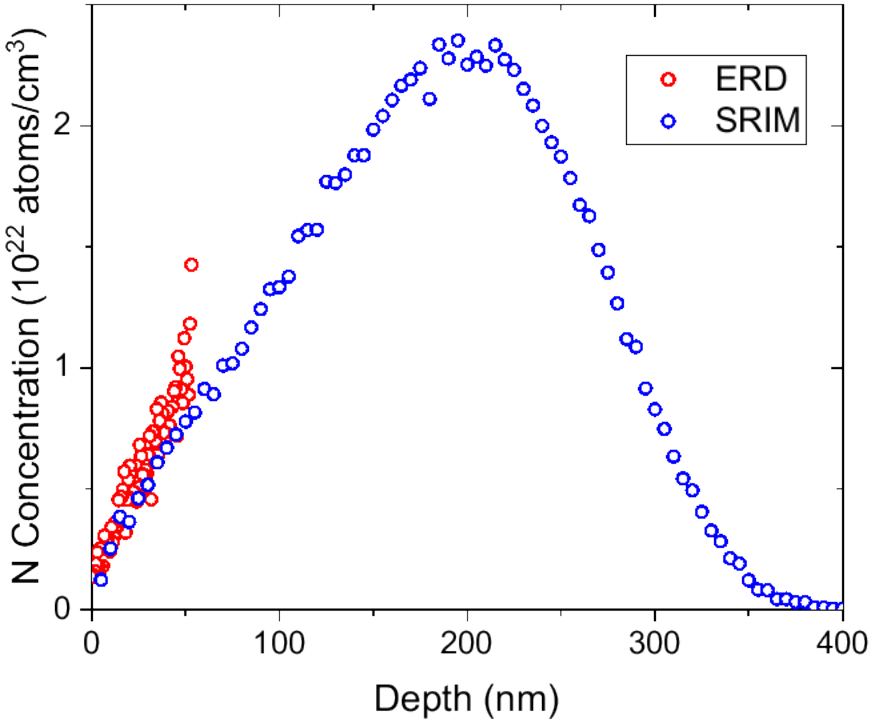


Characterization

- Elastic Recoil Detection (ERD): 50 nm of foil as expected
  - Cannot interrogate deeper due to multiple scattering of deep ions

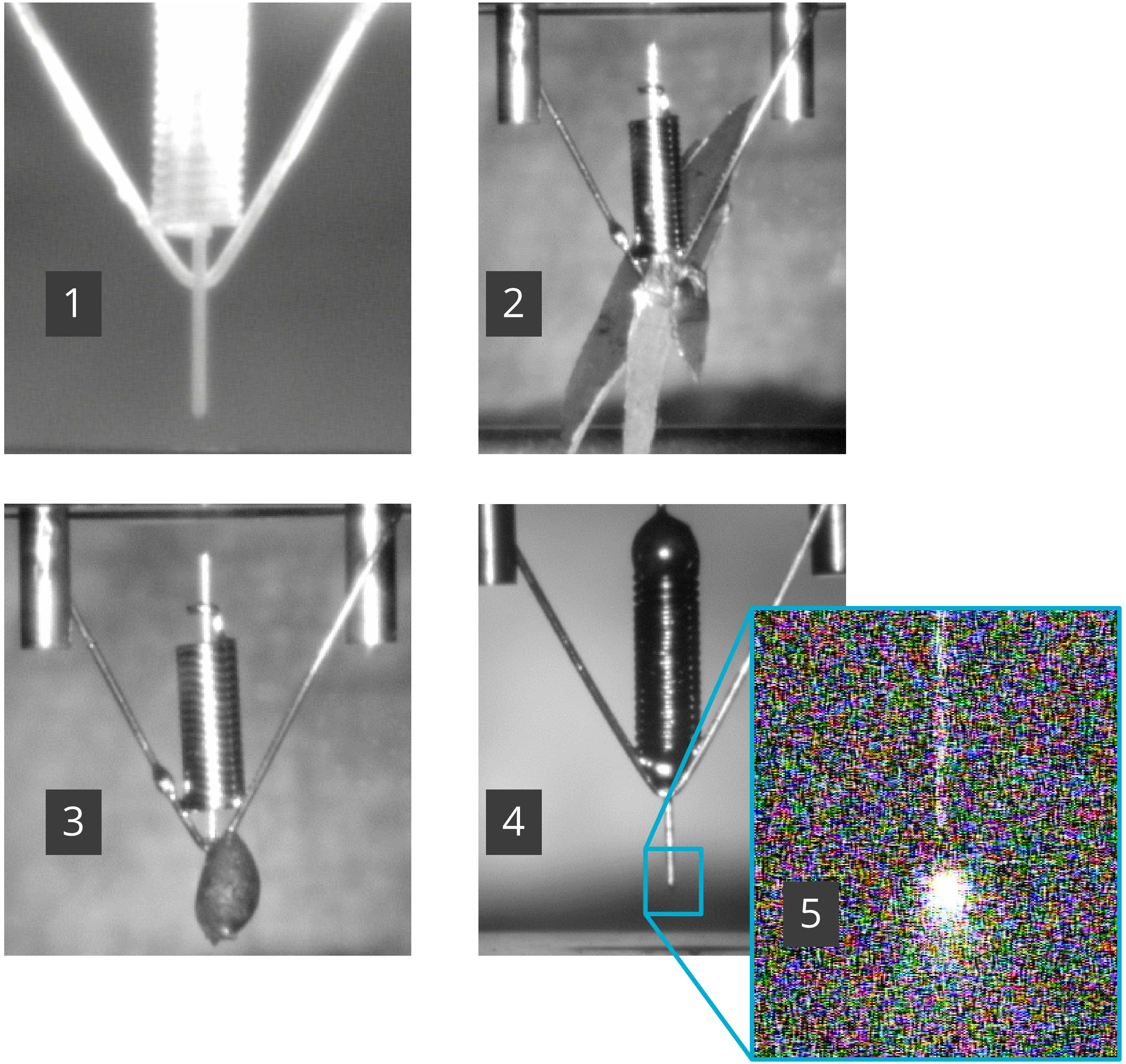


B. L. Doyle and P. S. Peercy, Appl. Phys. Lett. 34, 811 (1979)

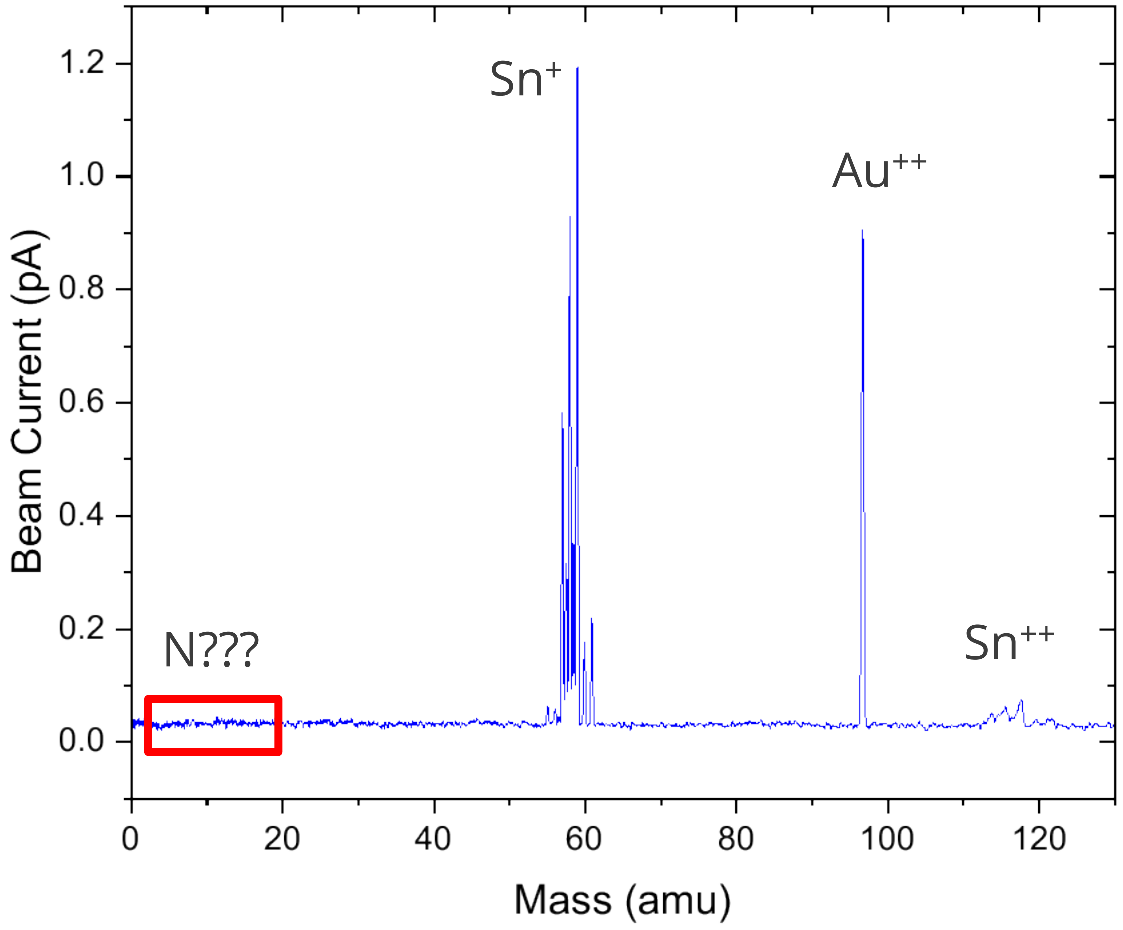


Tip Fabrication from AuSnN foil

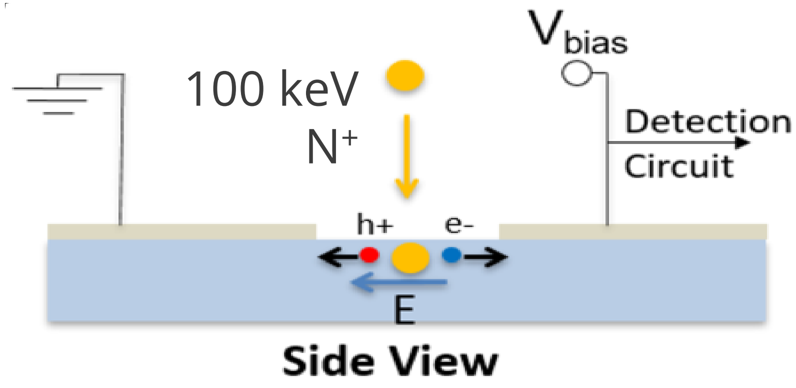
1. Heat W tip to remove surface contaminants
2. Tack weld foil to the tip
3. Heat tip to melt foil onto tip
4. Repeat steps 2. + 3. until tip + parts of reservoir is filled
5. Test tip emits
6. Install tip into nanoImplanter

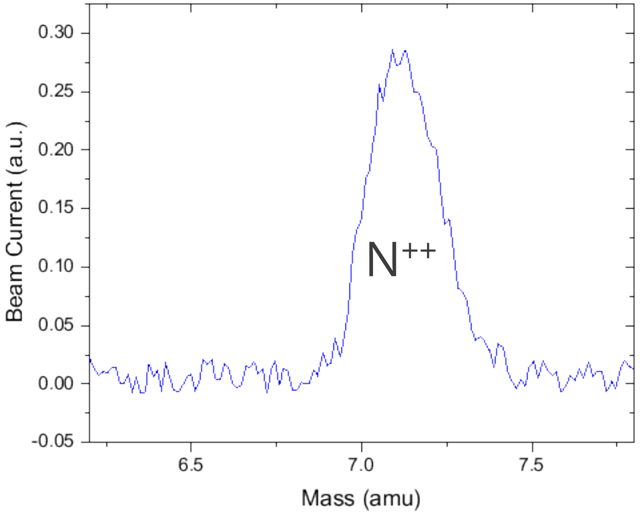


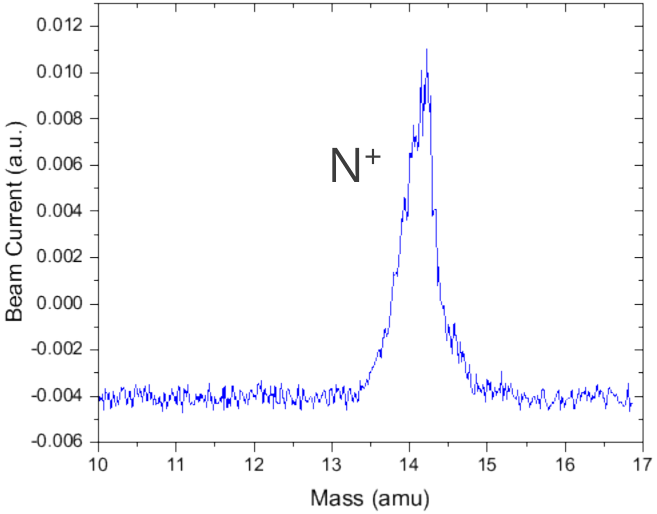
Characterization – Mass Spectrum via IBIC



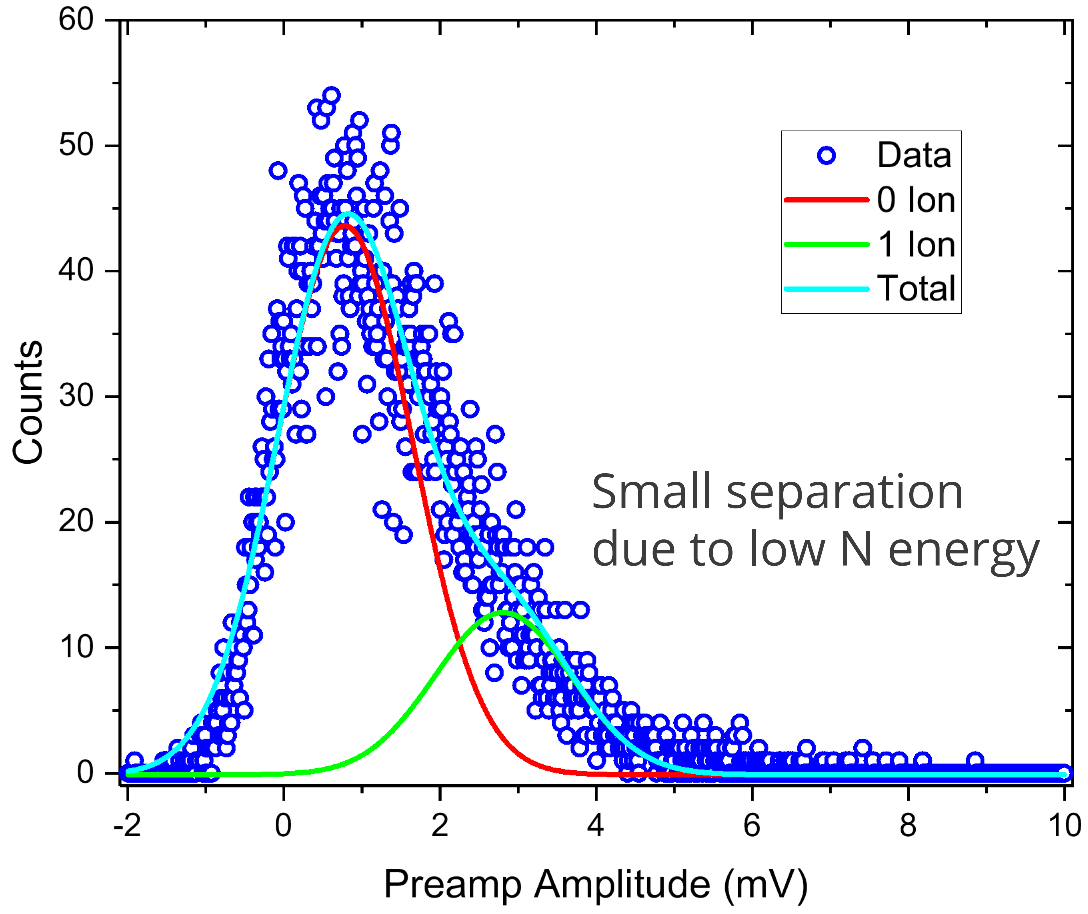
Ion Beam Induced Charge (IBIC) to measure N beam







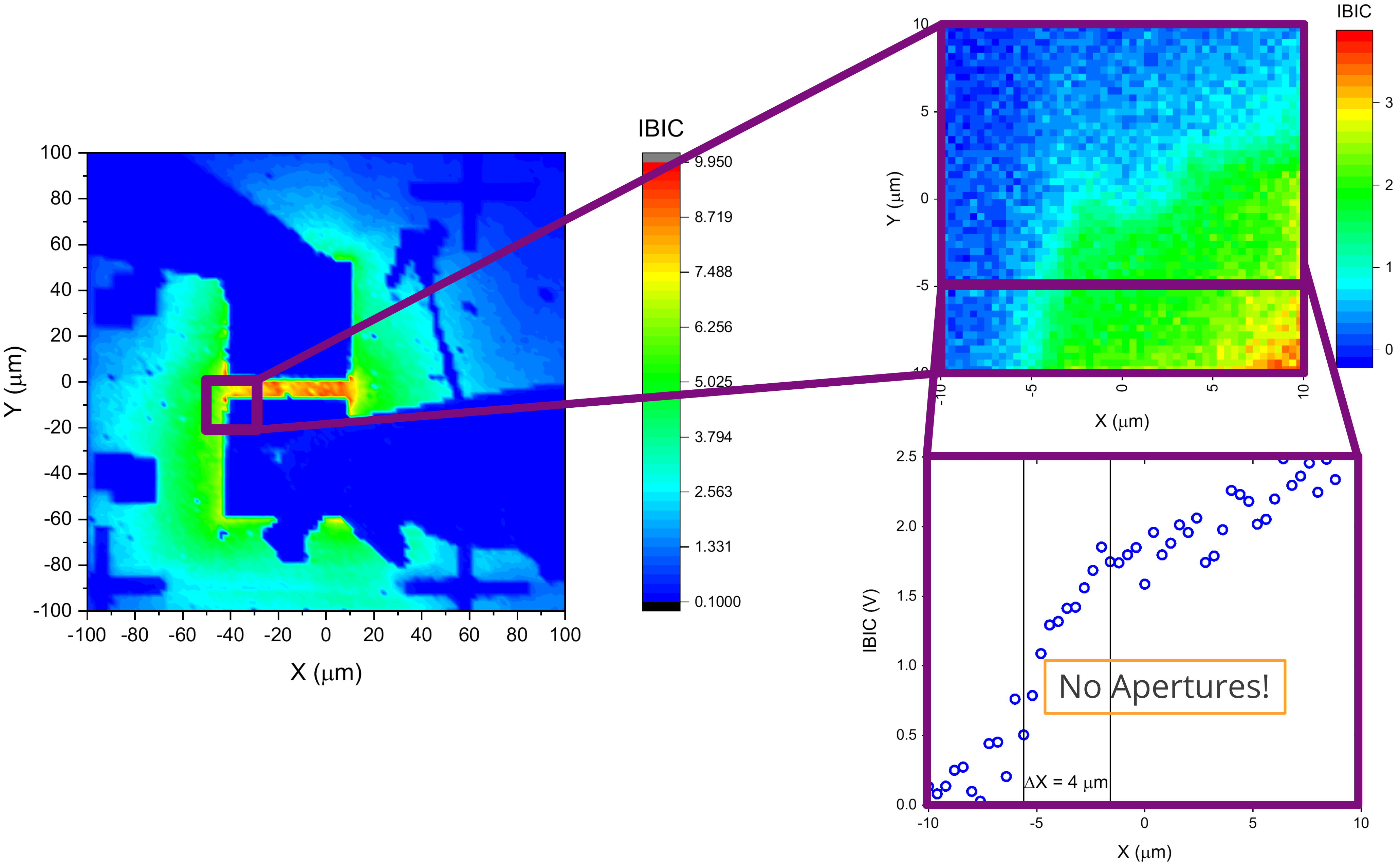
Characterization – Beam Current measured via IBIC



1. Fit peak to Gaussians
2. Area under peak corresponds to likelihood of event

<1> ion every 50 μs ≡ 20 k ions/s

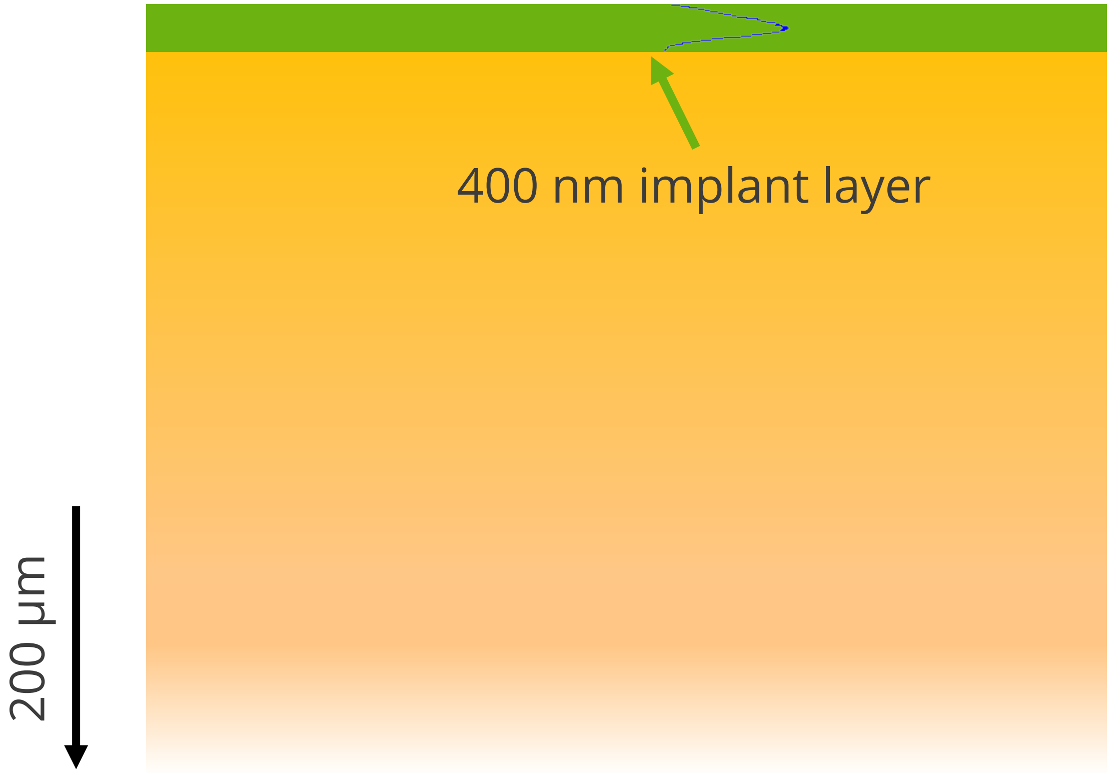
Characterization – Spot Size via IBIC

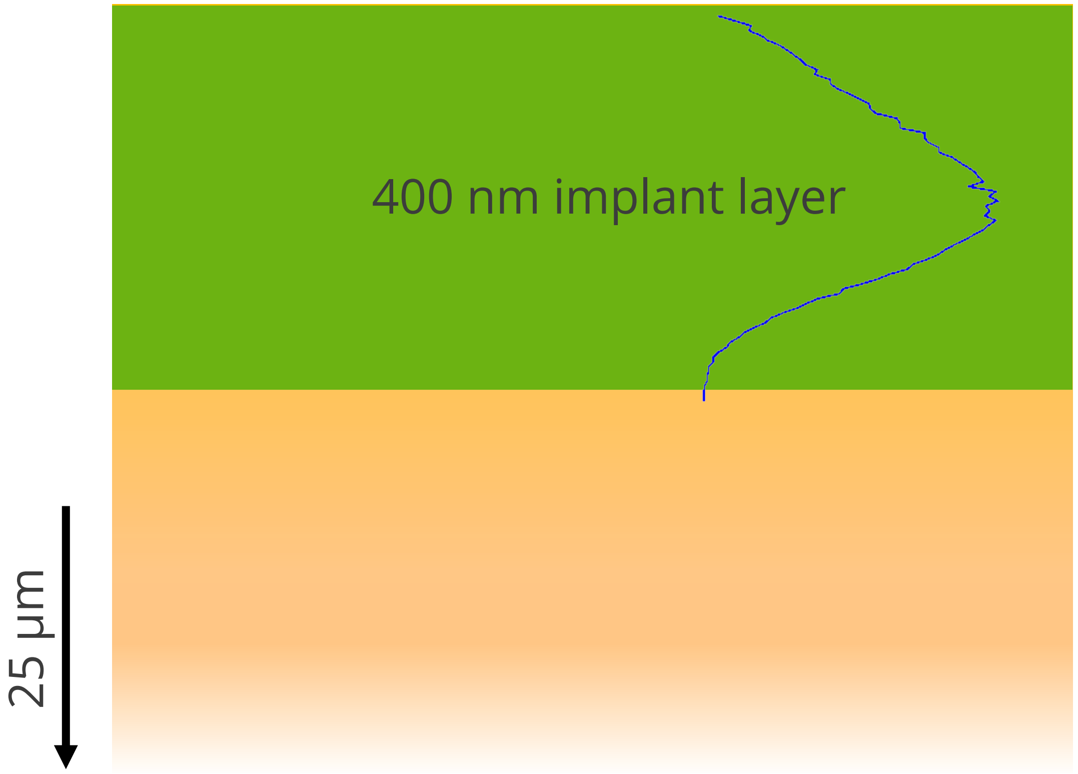


N Source – Improvements

Higher beam current

- Thinner foil to same fluence → higher overall concentration
- Fabrication in N atmosphere → additional N absorption

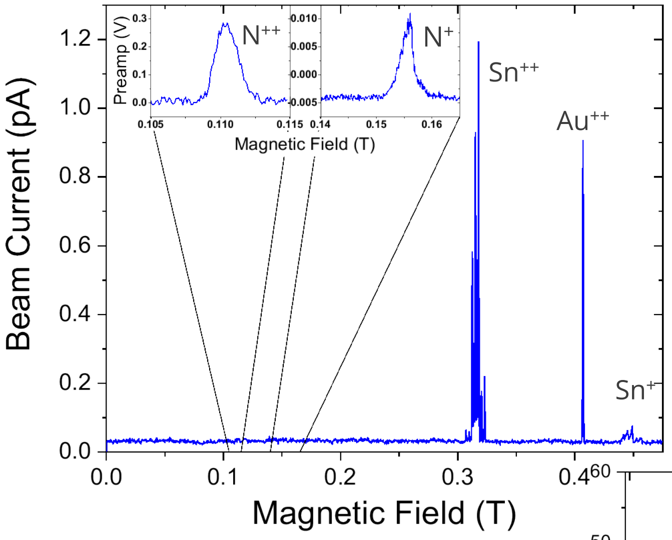


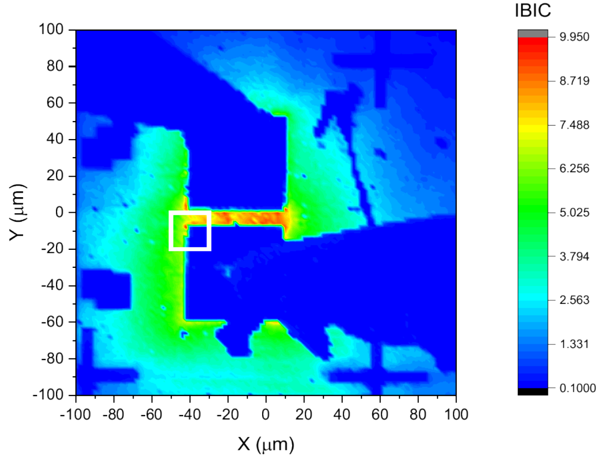


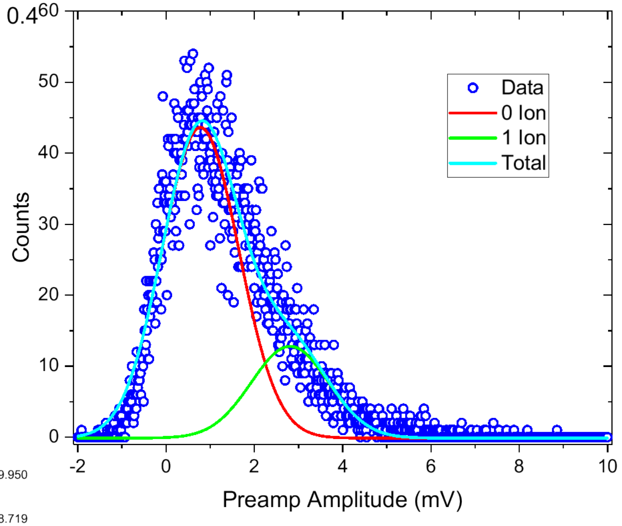
Conclusions

- An atomic N source for FIB enables deterministic placement of NVs
- Ion implantation of N in a AuSn eutectic foil leads to incorporation of N confirmed by ERD
- N source behaves like other LMAIS, but low N current
  - Ion counting to measure mass spectrum, beam current and spot size
- Improved N emission will enable better N source focus + emission current

In total, 6 sources fabricated to date
4 successfully characterized

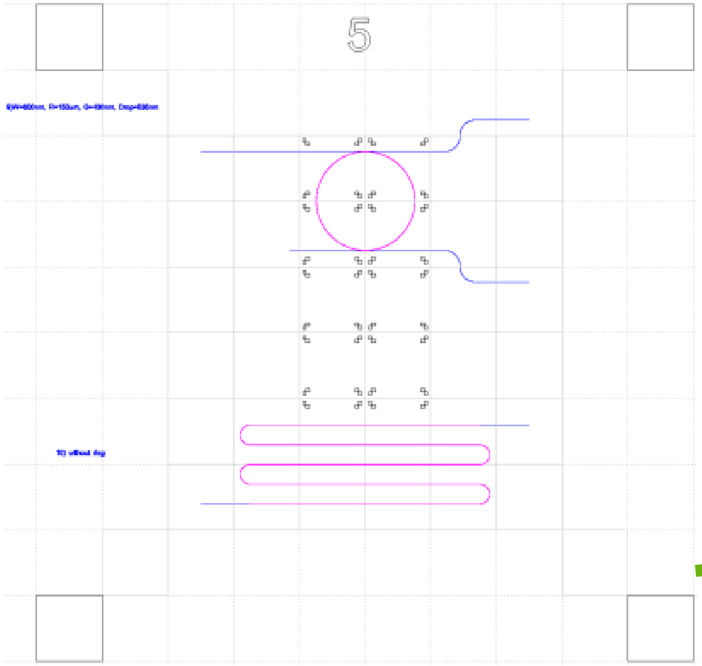






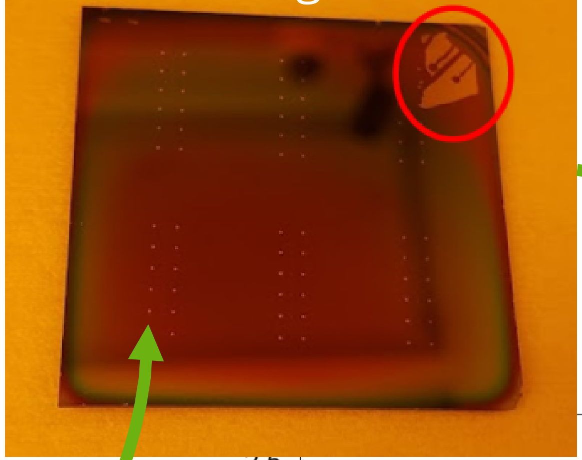
Interaction with CINT Users – Design to Manuscript

M. Hosseini @ Purdue

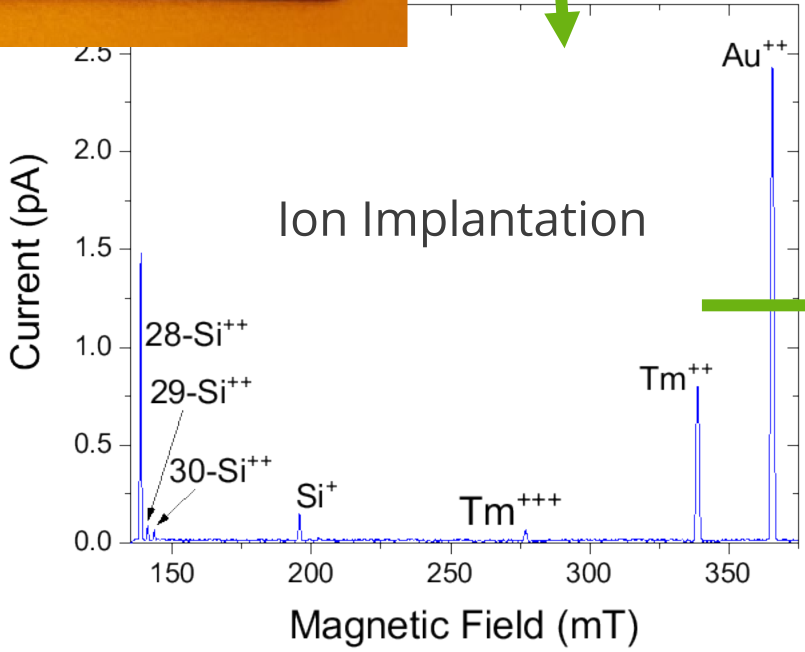


Discussion of design feasibility

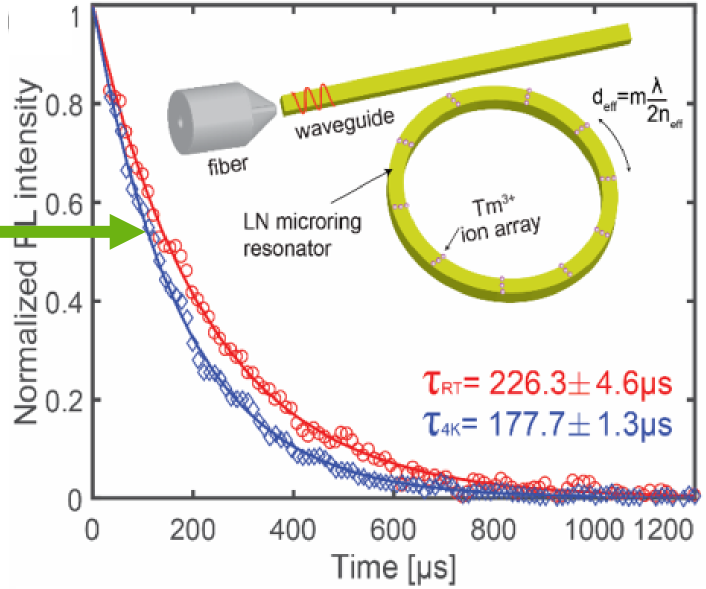
Fabricating Device



Tm for $LiNbO_3$ Photonics



Post-Processing
+ Measurement



Dongmin Pak, ..., M. Titze et al. (in review)

How can YOU access these capabilities? CINT User Proposal

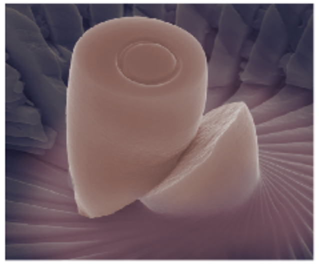
THE CENTER FOR INTEGRATED NANOTECHNOLOGIES

One Scientific Community Focused on Nanoscience Integration

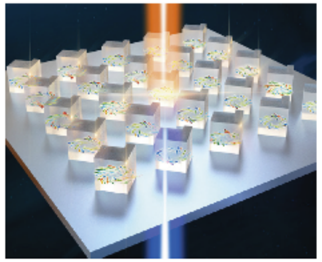
The Center for Integrated Nanotechnologies (CINT) is a Department of Energy Office of Science Nanoscale Science Research Center. CINT offers world-leading scientific expertise and specialized capabilities to create, characterize, and integrate nanostructured materials at a range of length scales, from the nano- to meso-scale. It is jointly operated by Los Alamos and Sandia national laboratories and leverages the unmatched scientific and engineering expertise of the host labs.

Science Thrusts

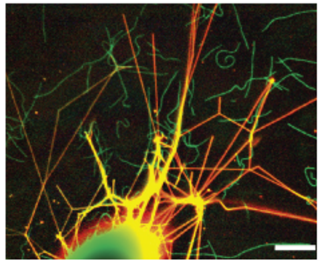
Integration is the key to exploiting the novel properties of nanoscale materials and creating new technologies. CINT's scientific staff and capabilities are organized around four interdisciplinary science thrusts which address different challenges in nanoscience integration.



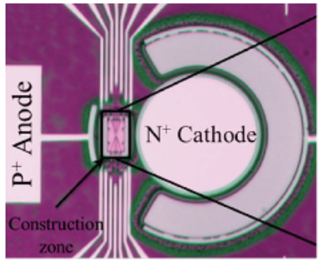
In-Situ Characterization and Nanomechanics
Developing and implementing world-leading capabilities to study the dynamic response of materials and nanosystems to mechanical, electrical, or other stimuli.



Nanophotonics & Optical Nanomaterials
Synthesis, excitation, and energy transformations of optically active nanomaterials and collective or emergent electromagnetic phenomena (plasmonics, metamaterials, photonic lattices).



Soft, Biological & Composite Nanomaterials
Synthesis, assembly, and characterization of soft, biomolecular, and composite nanomaterials that display emergent functionality.



Quantum Materials Systems
Understanding and controlling quantum effects of nanoscale materials and their integration into systems spanning multiple length scales.

User Program

CINT is an Office of Science national user facility. CINT helps the international research community perform cutting-edge research in the areas of nanoscience and nanotechnology, and is available free of charge for open science. As a user facility, CINT has the structure and mission to collaborate widely across academia, industry, and within DOE labs. Access is via peer-reviewed technical proposals. Proprietary research may be conducted in accordance with Federal regulations for full-cost recovery. CINT cannot provide funding to users.

The Center for Integrated Nanotechnologies (CINT)

https://cint.lanl.gov/