

NV Centers (Part 2)

Christian Degen

Department of Physics, ETH Zurich, Switzerland

Gokarna – January 29, 2026

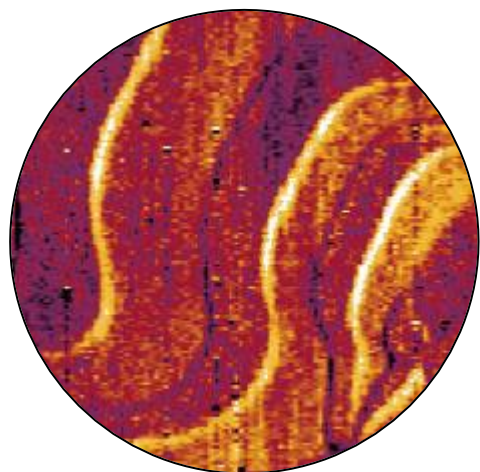
NV Centers (Part 2)

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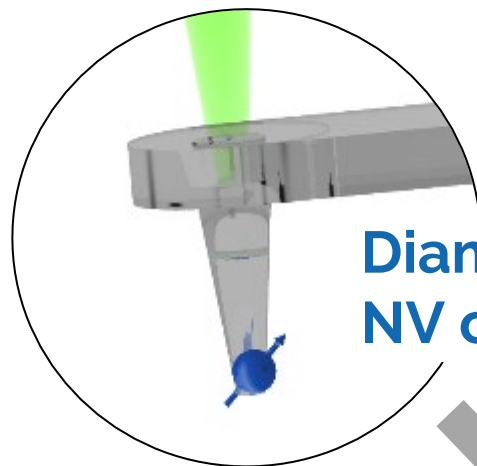
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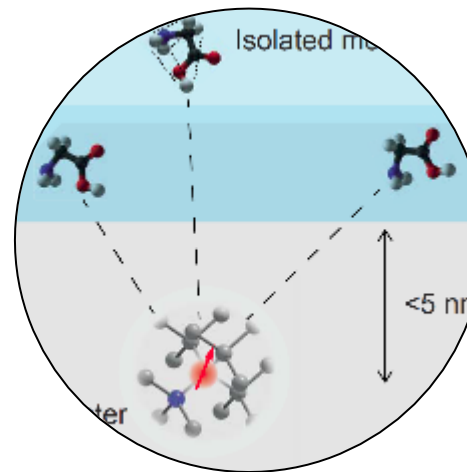
ETH Zurich Activities – Spin Physics



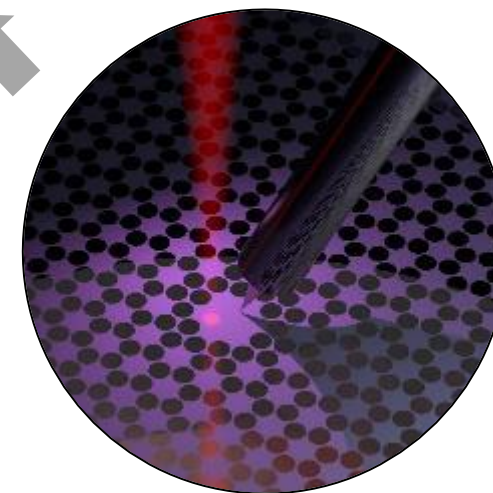
**Imaging of Magnetism,
Spin textures,
Ferroelectrics**



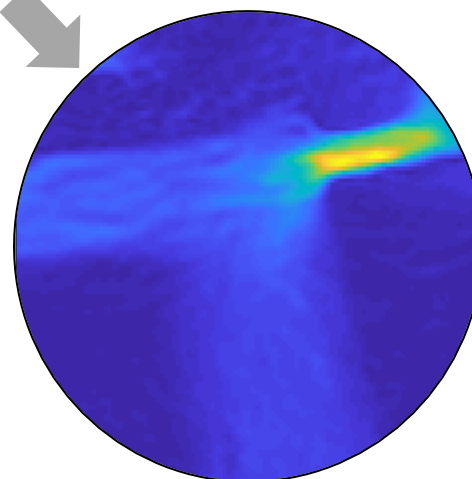
**Diamond
NV center**



**Nuclear spin detection,
Nanoscale MRI**



Nanomechanics

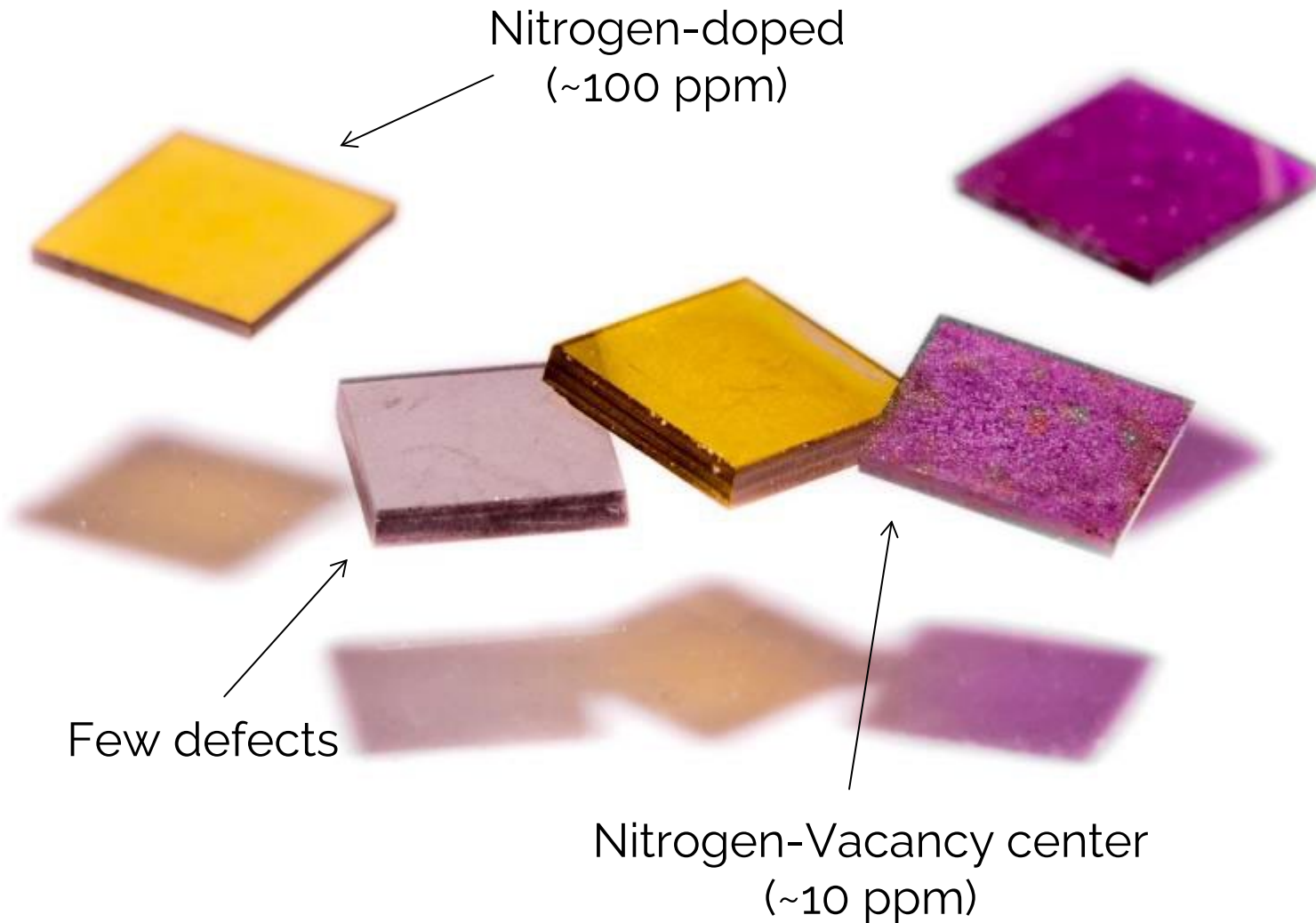


**Imaging of
Mesoscopic Transport**

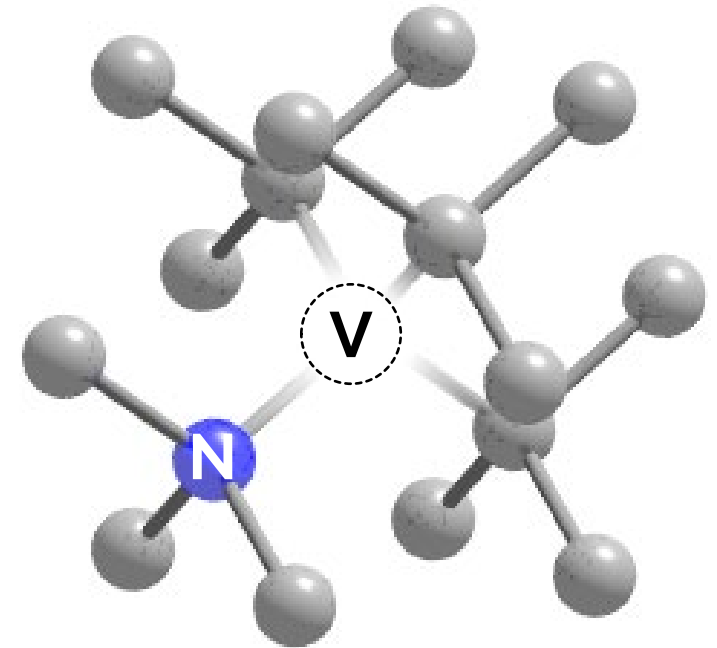
Outline

- Experimental platform
- Single spin experiments with NV centers (electronic and nuclear)
- Outlook: Toward nanoscale NMR of surface molecules
- Outlook: Applications

Color centers in diamond

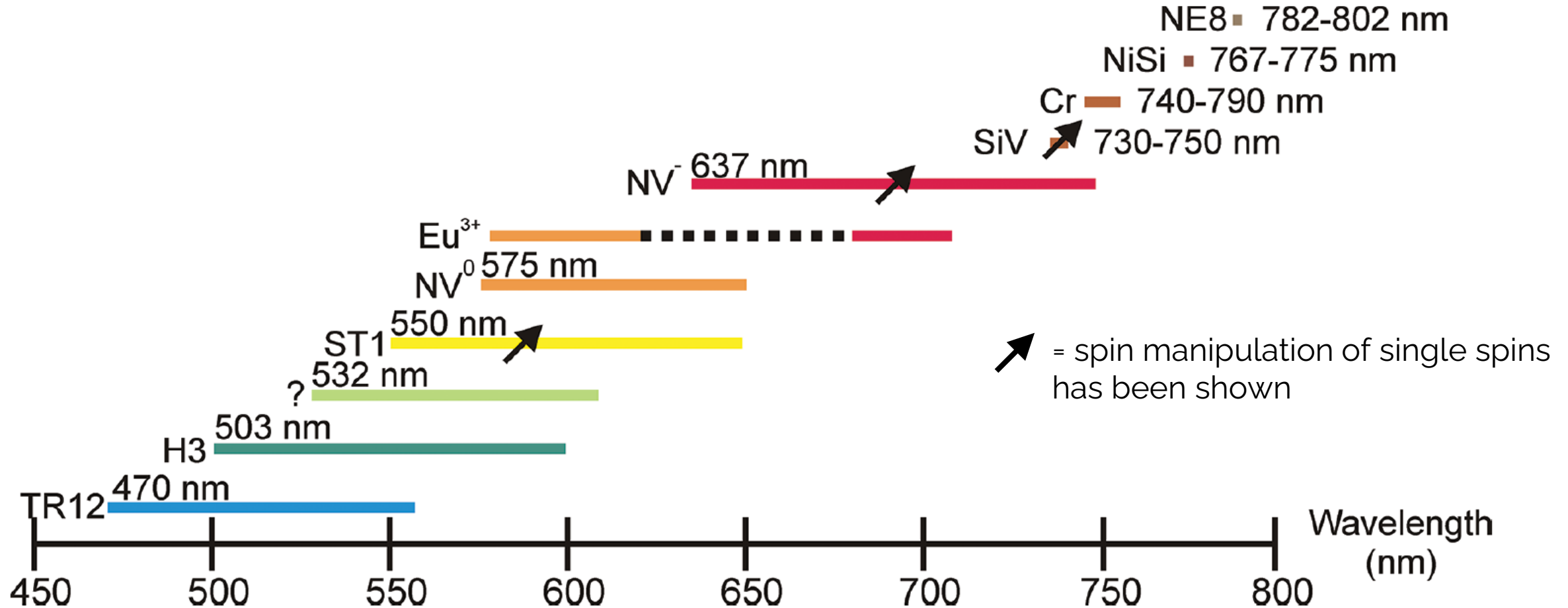


NV center



- Single emitter (630-800 nm)
- Electronic spin $S=1$
- $T_1 \sim 5$ ms
- $T_2 \sim 1-100$ μ s

Color centers in diamond



Single emitters in semiconductors

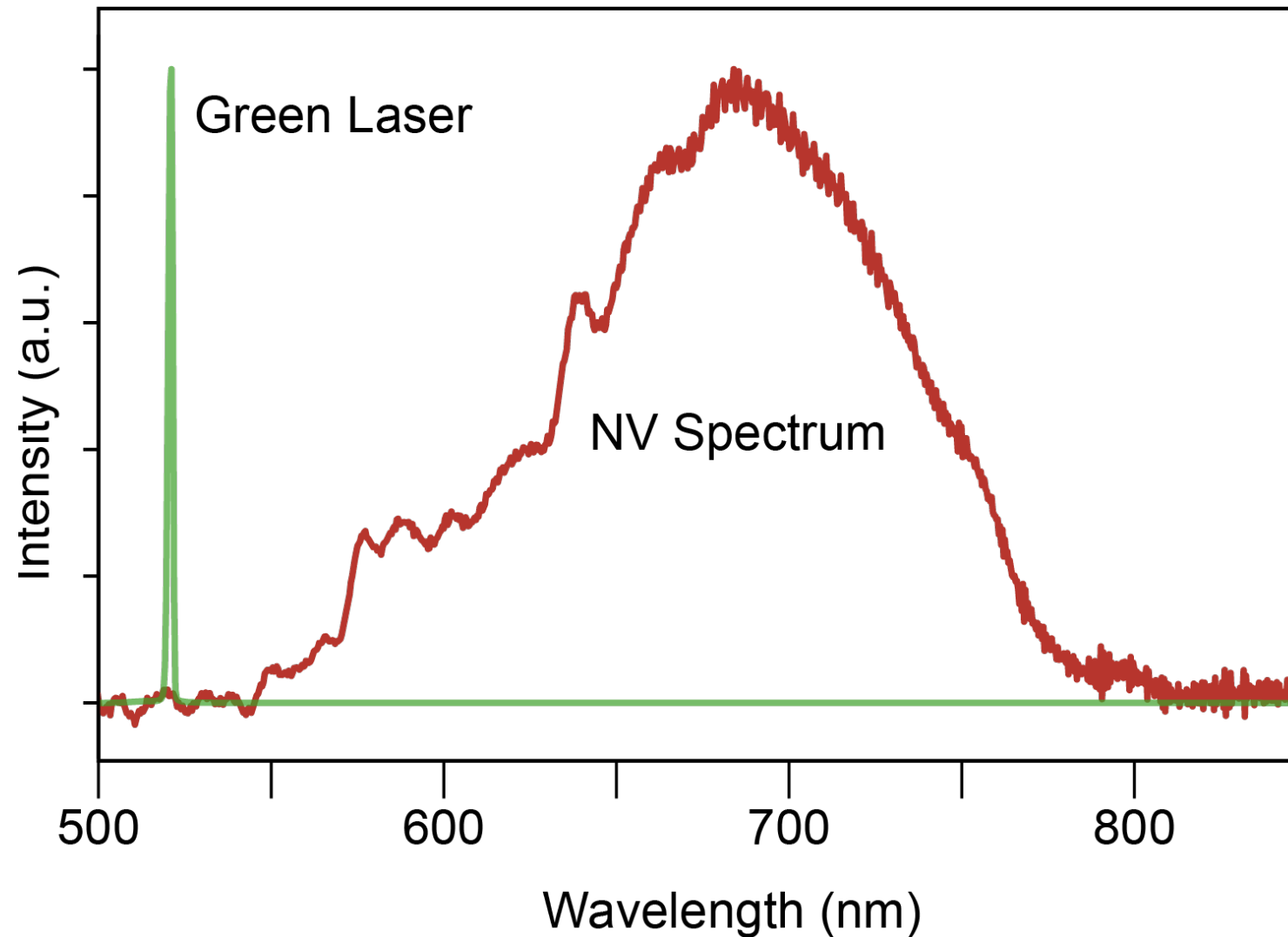


Aluminum oxide (Al_2O_3)



Rare-earth-ion doped crystals

Fluorescence spectrum of NV centers

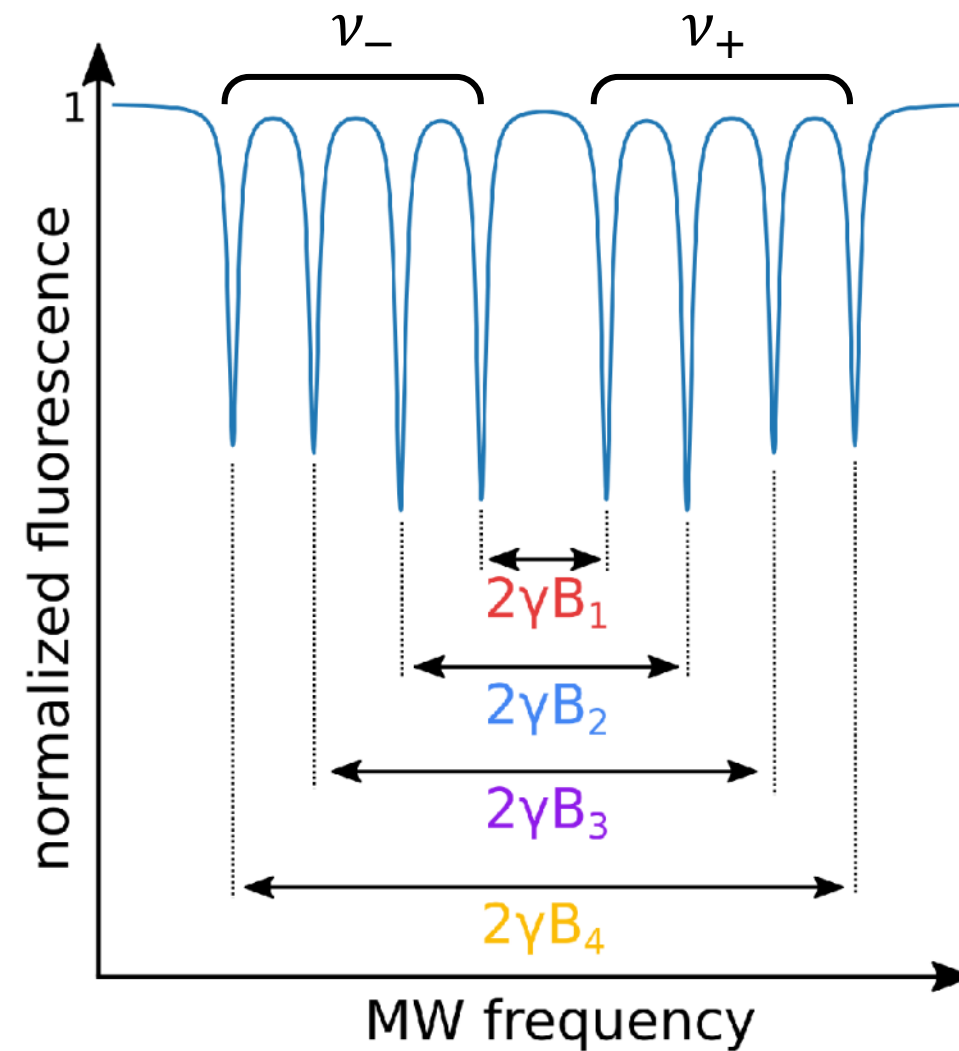
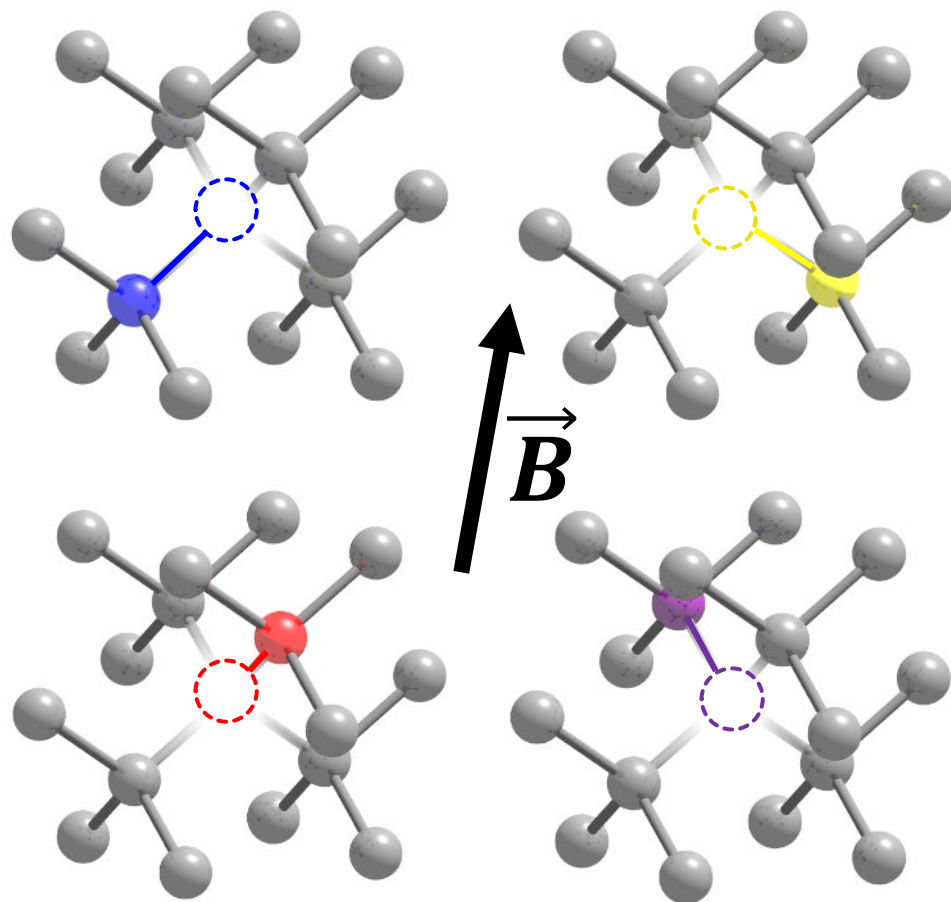


Optically detected magnetic resonance (ODMR)



Spin $S = 1$

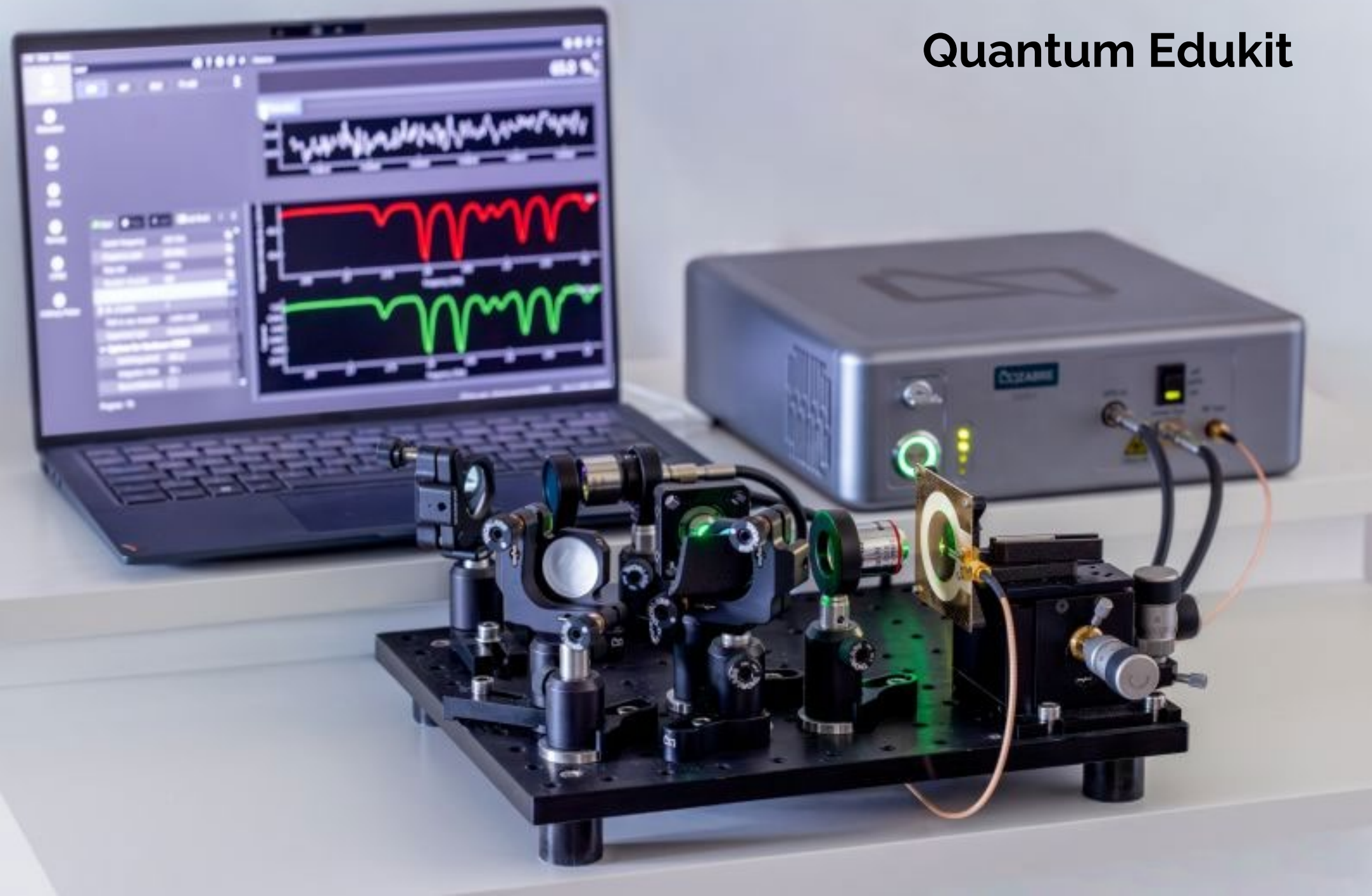
Optically detected magnetic resonance (ODMR)



Quantum Edukit



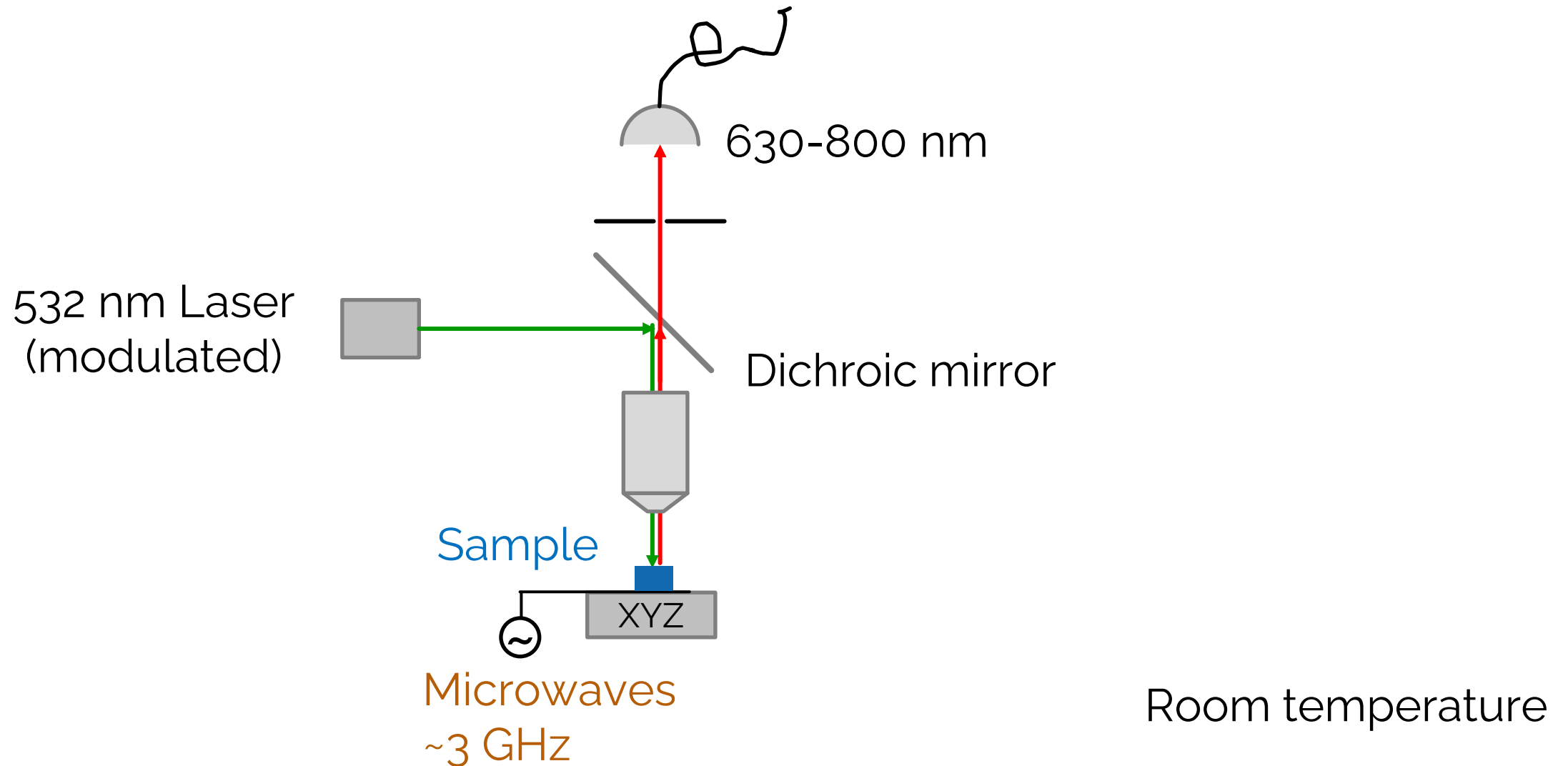
www.qzabre.com



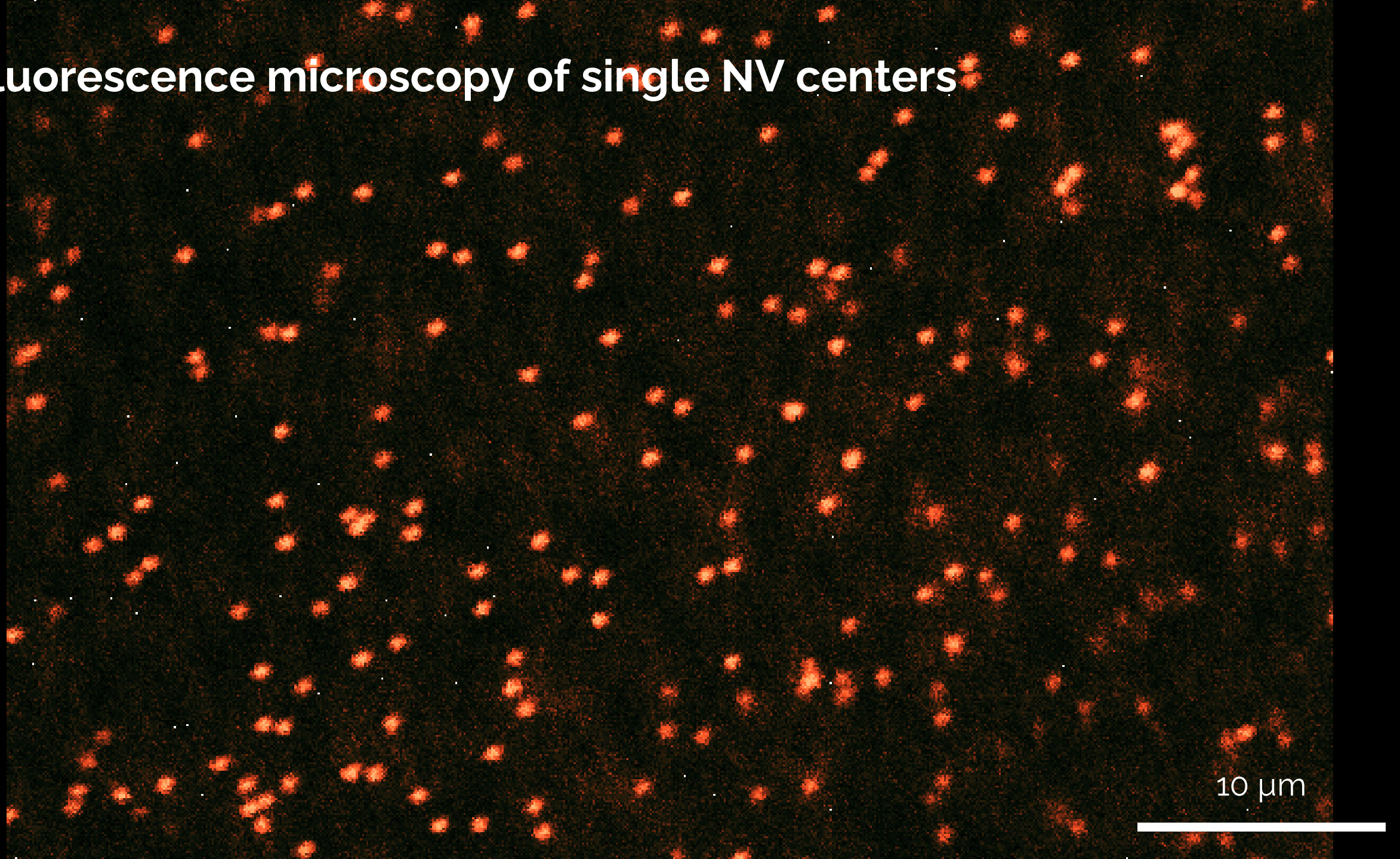
Spinoff

ETH zürich

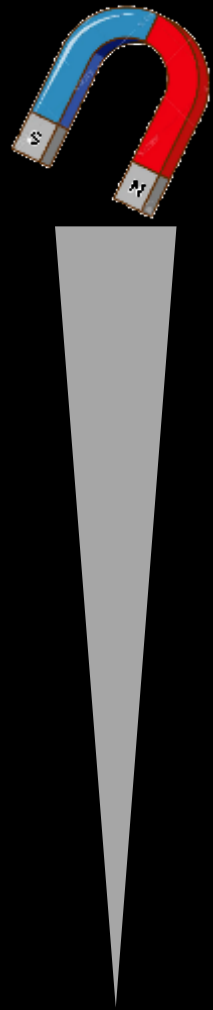
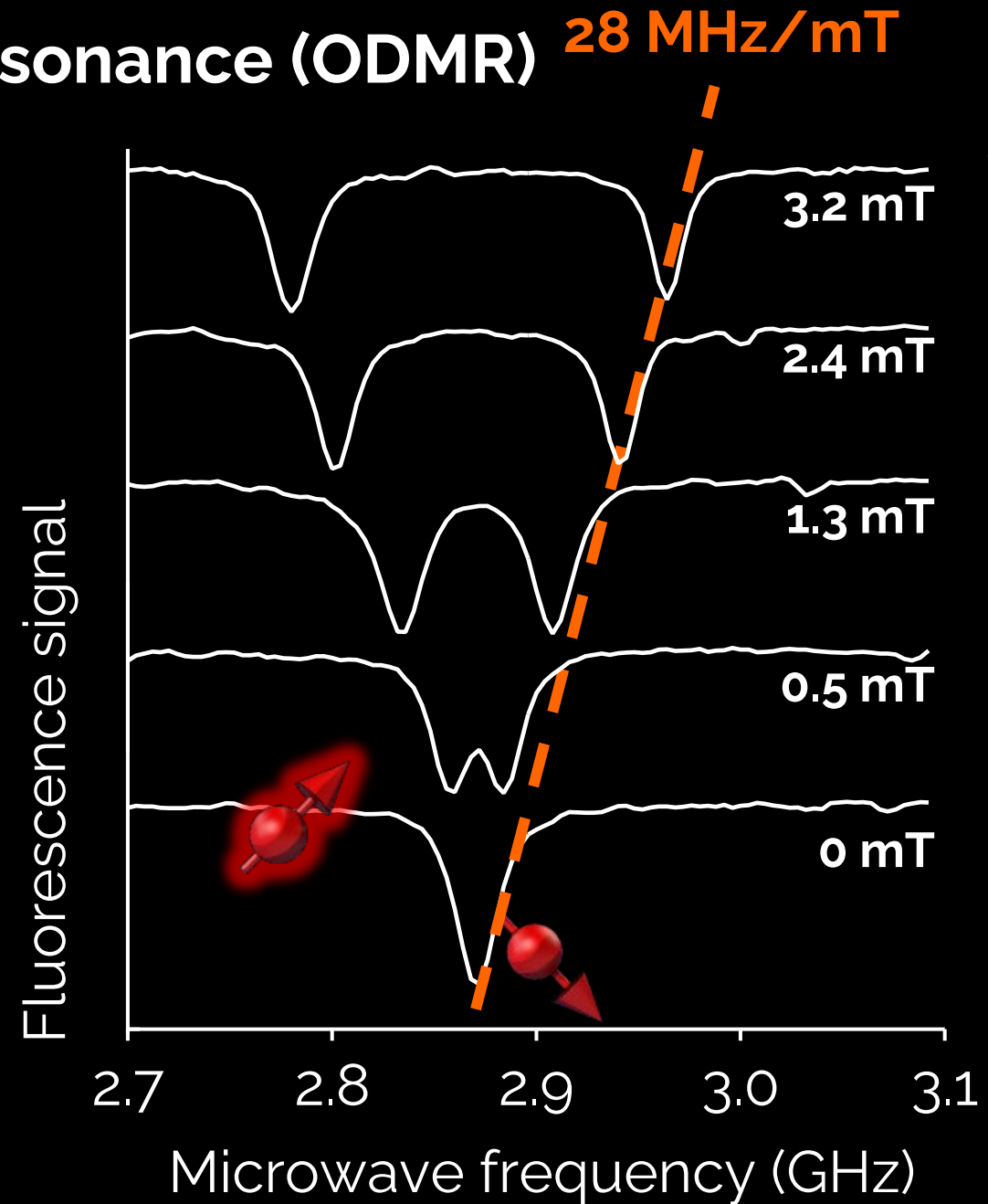
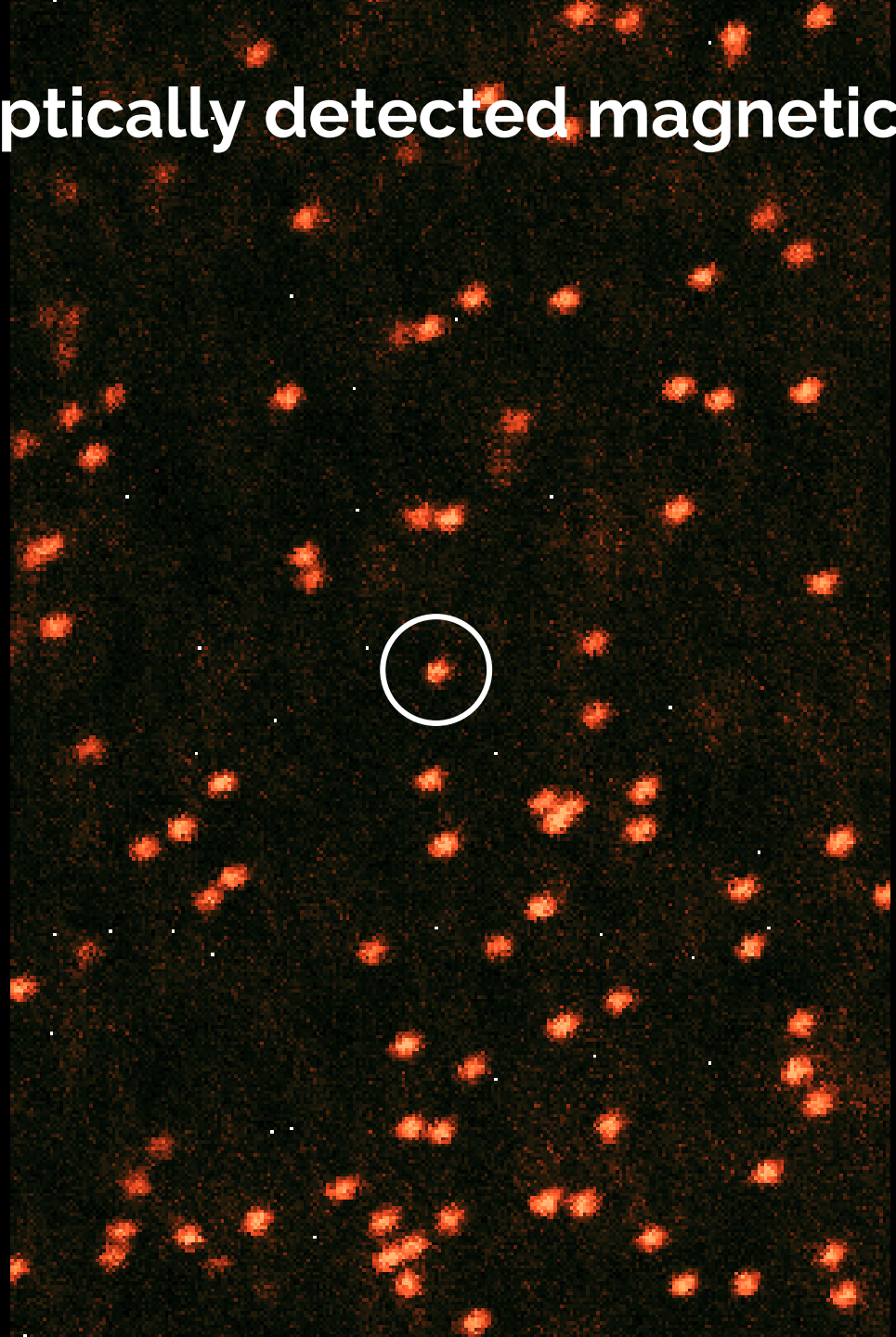
Fluorescence Microscopy



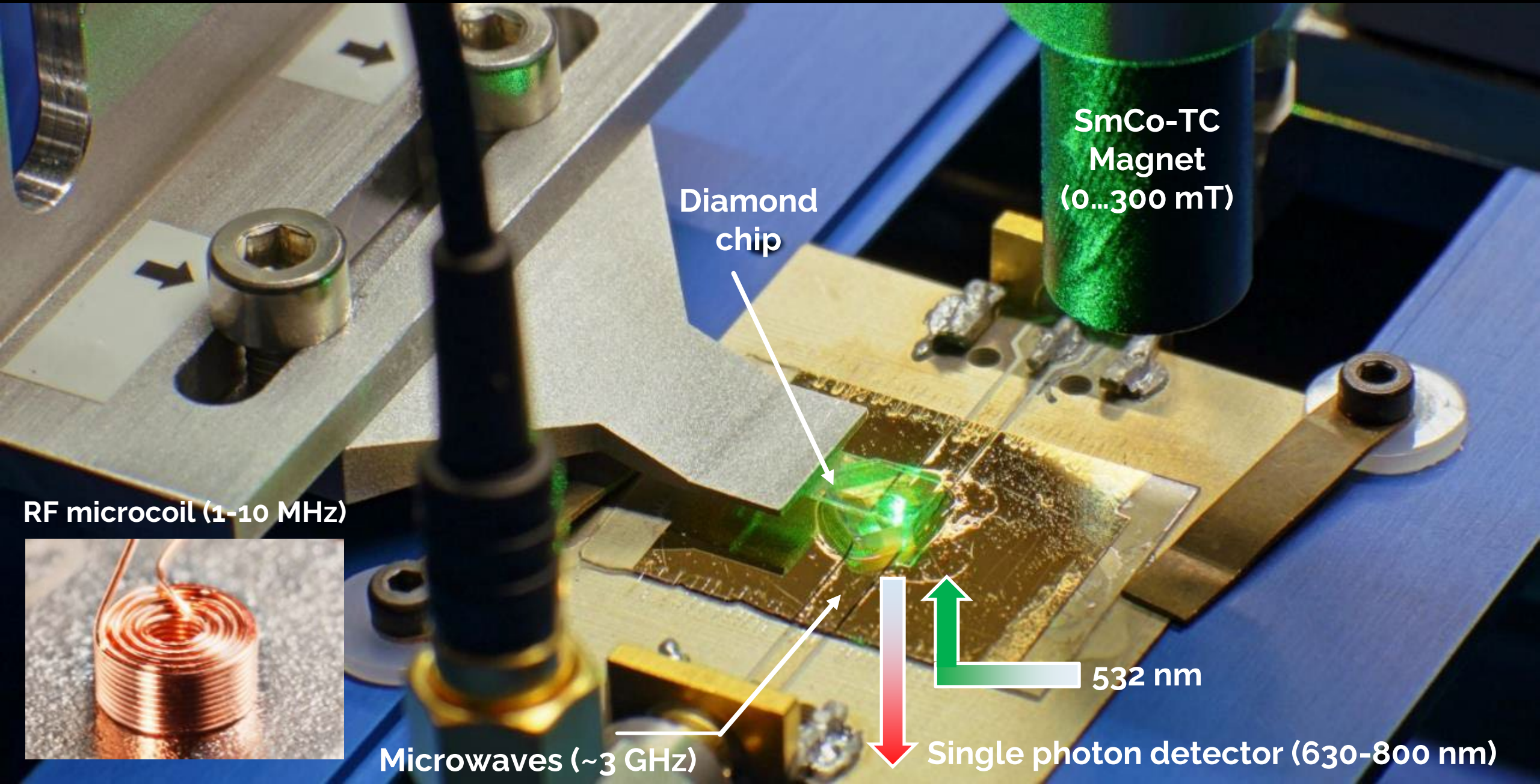
Fluorescence microscopy of single NV centers



Optically detected magnetic resonance (ODMR) 28 MHz/mT

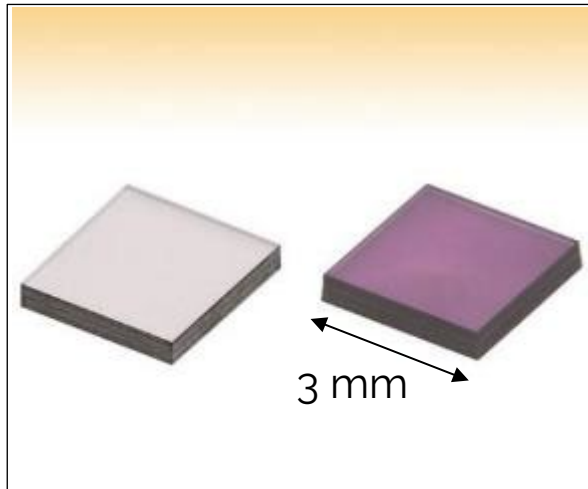


Fluorescence microscope for ODMR of single NV's

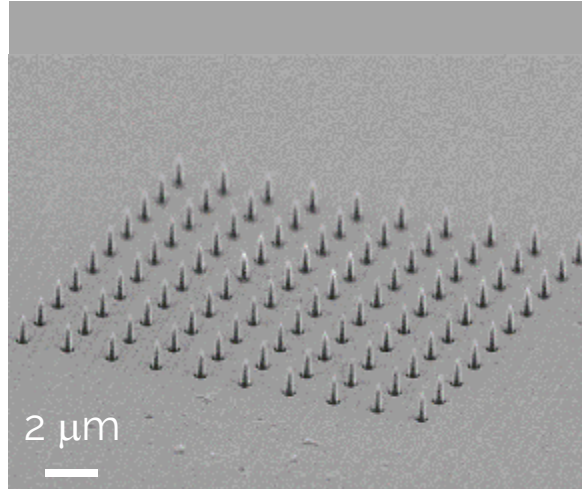


"Modern" NV Center Platforms

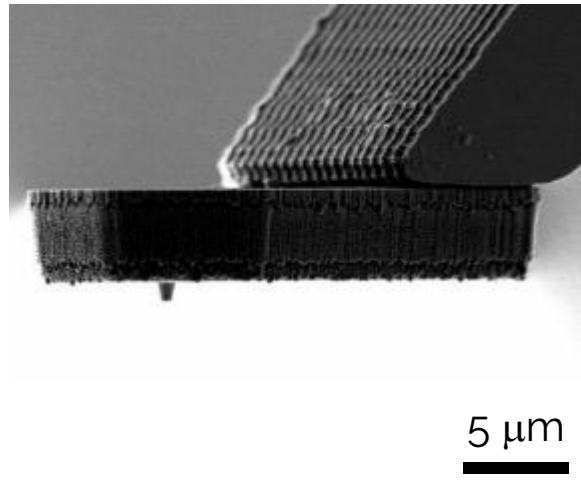
High purity plates



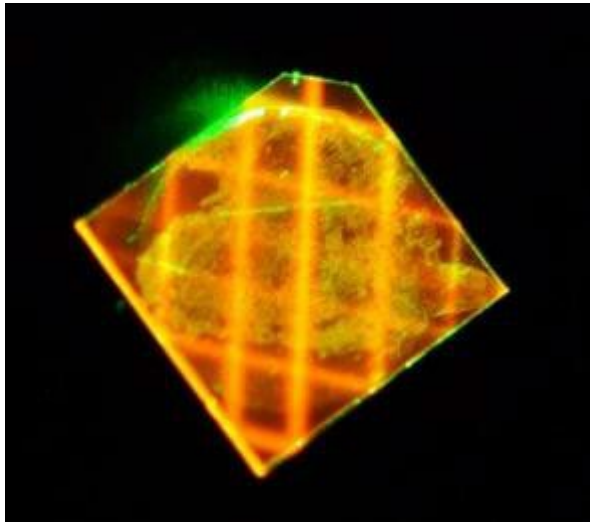
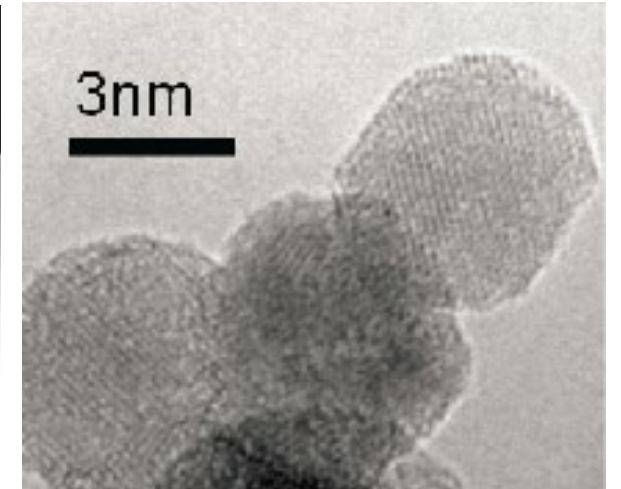
Nanopillar arrays



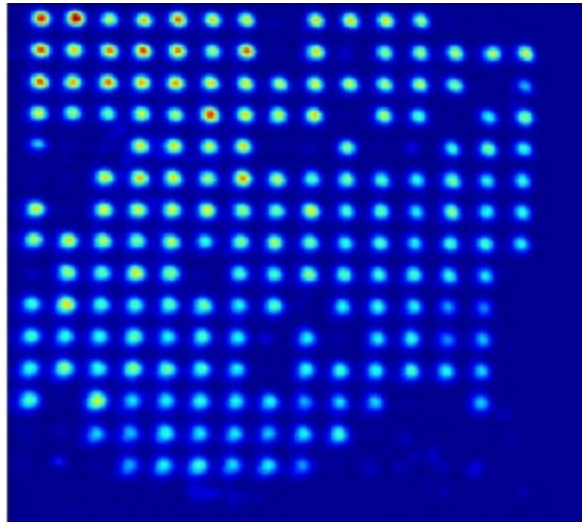
Scanning tips



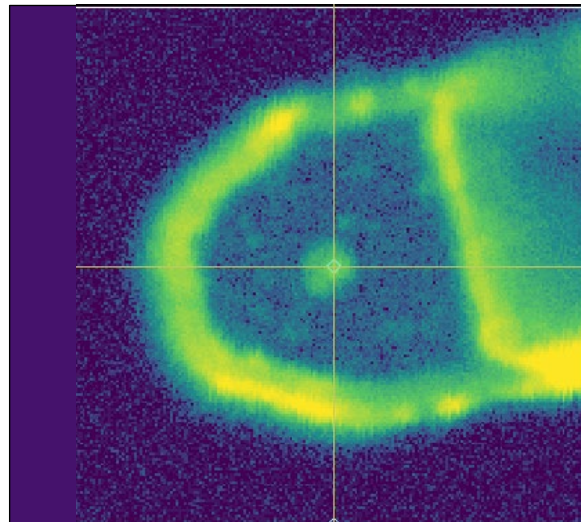
Biomarkers



From: e6/Thorlabs; MIT/Lincoln Lab



Jens Boss – Degen Lab

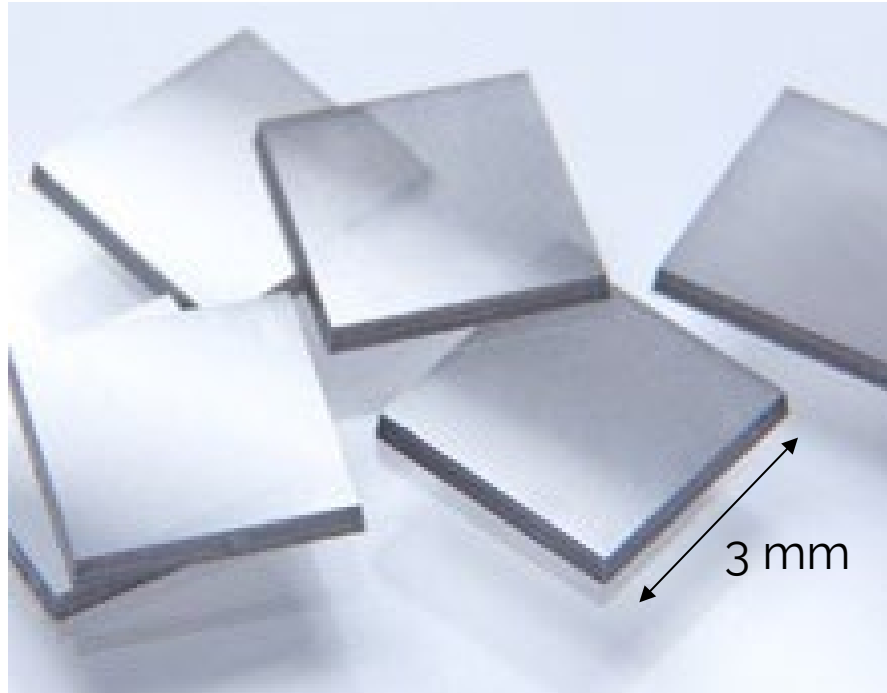


Jan Rhensius – Qzabre Ltd.

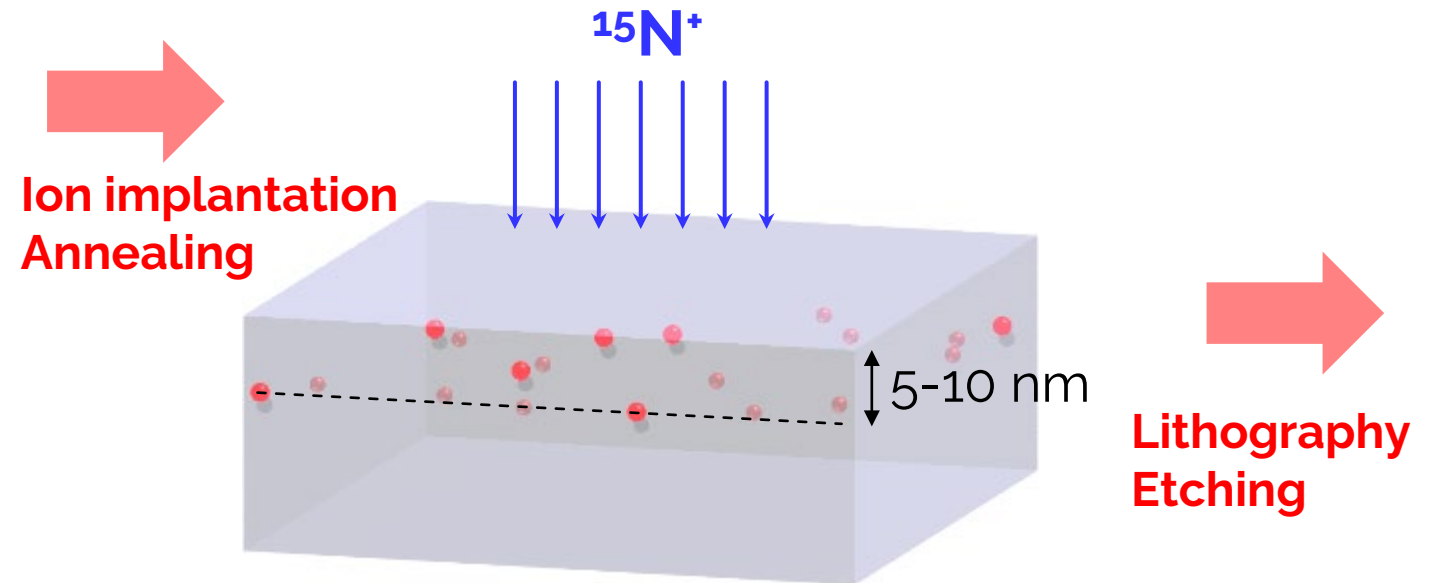


From: Adamas / Mohan, Nano. Lett. 2010

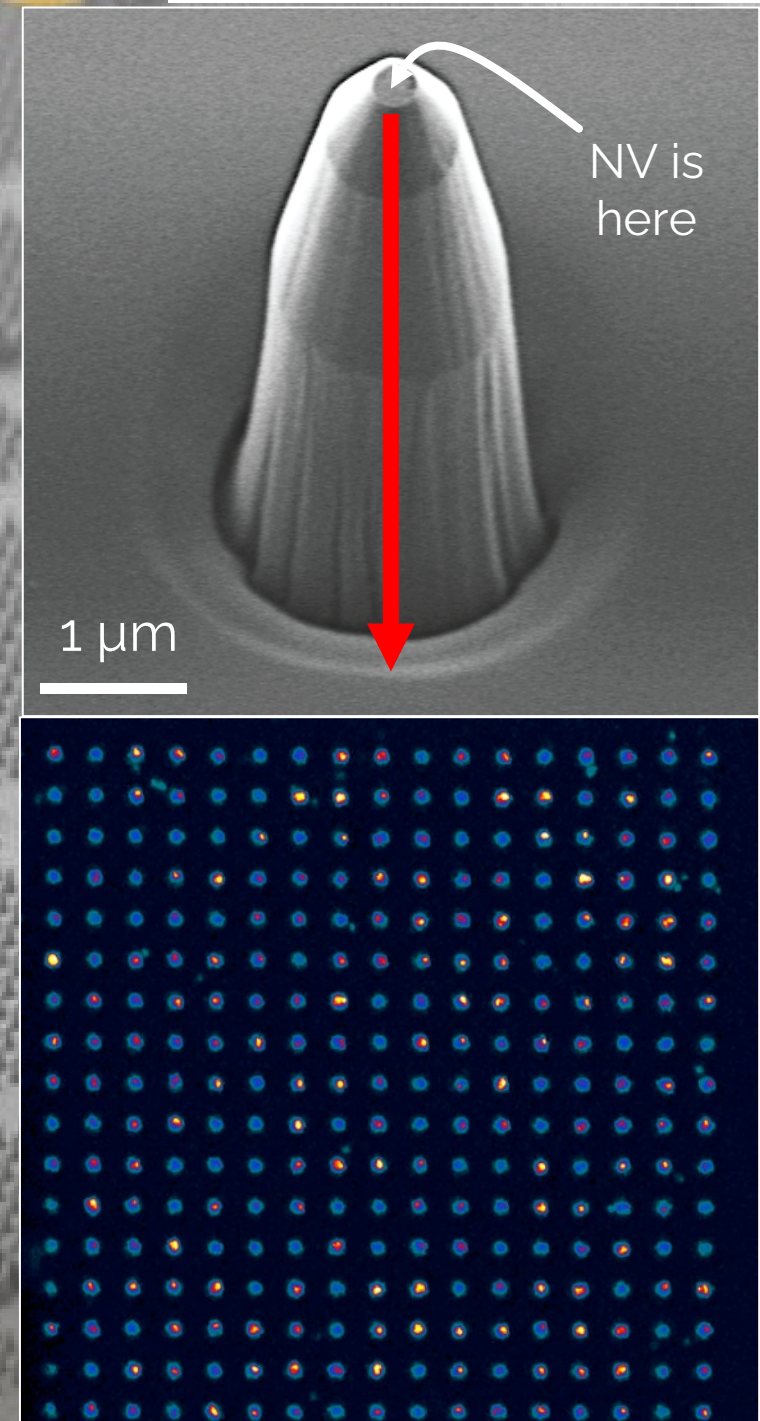
Diamond with shallow NV centers



ElementSix "electronic grade"



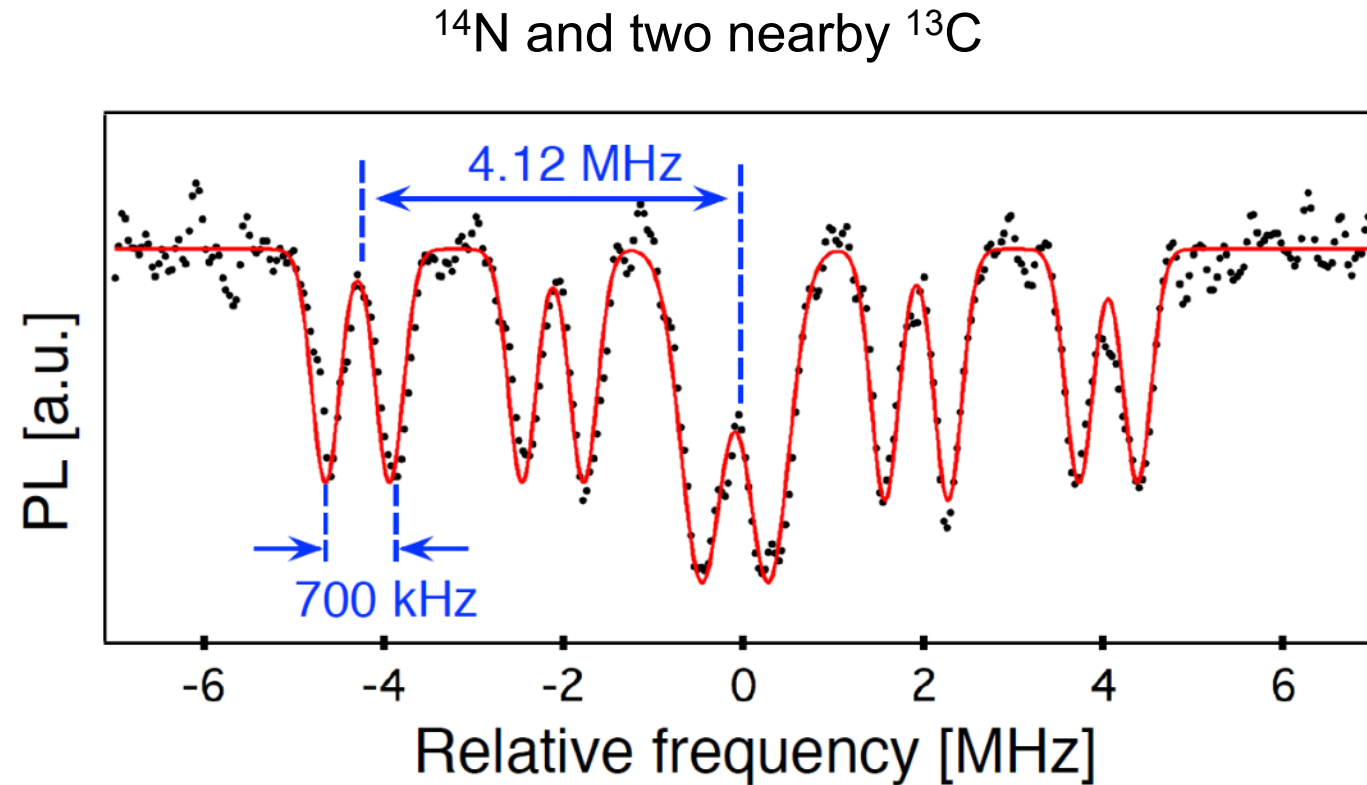
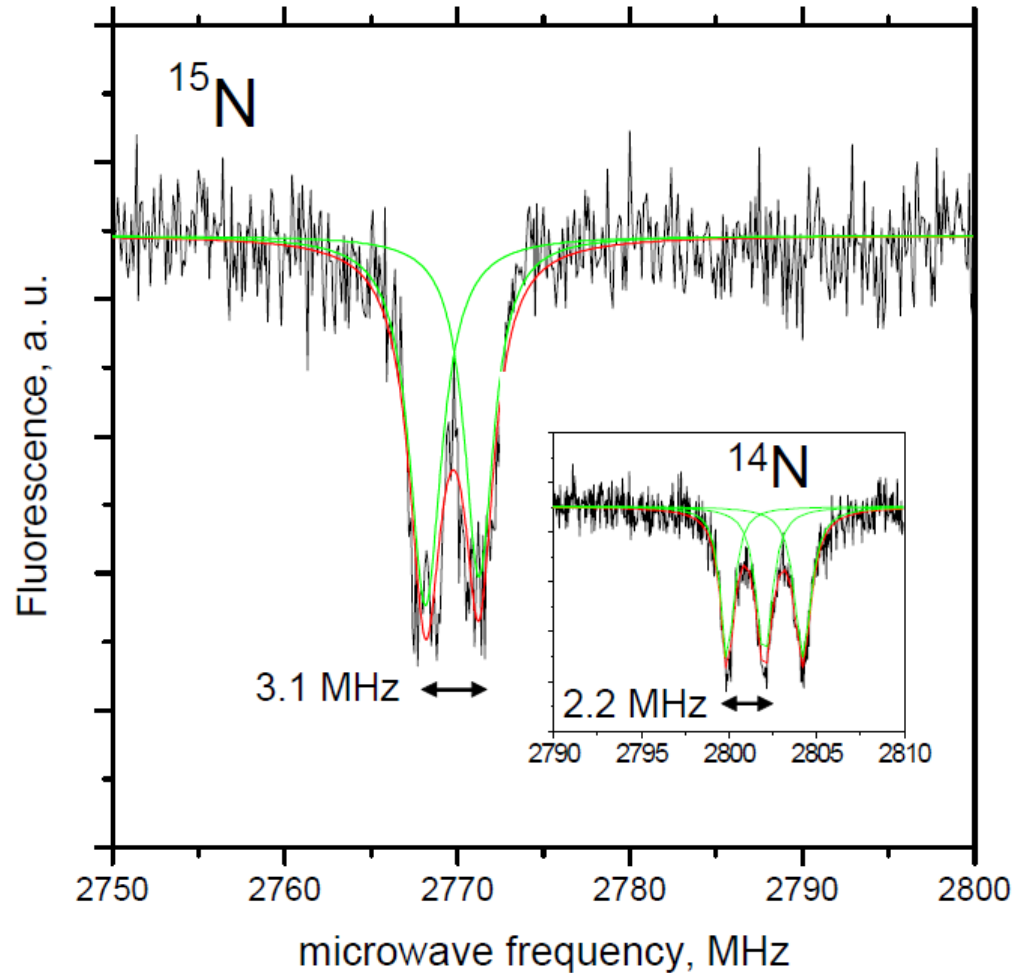
Nanopillar array



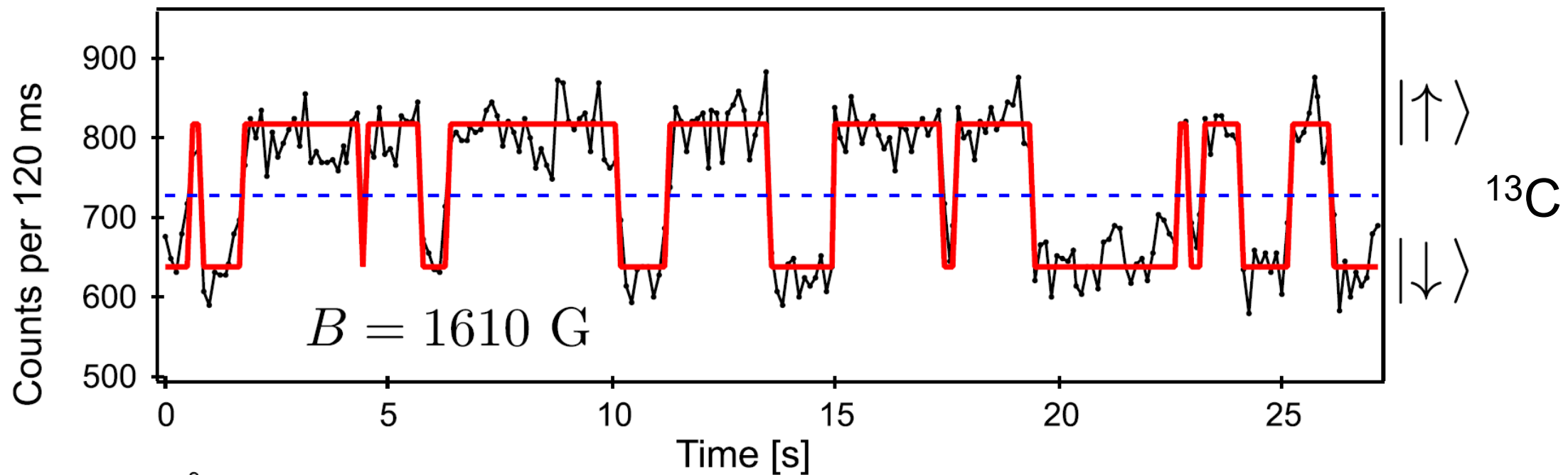
Zhu, Janitz et al, Nano Letters 23, 10110 (2023)
Concept: Loncar, Wrachtrup, Englund, ...

- Single spin experiments with NV centers (electronic and nuclear)

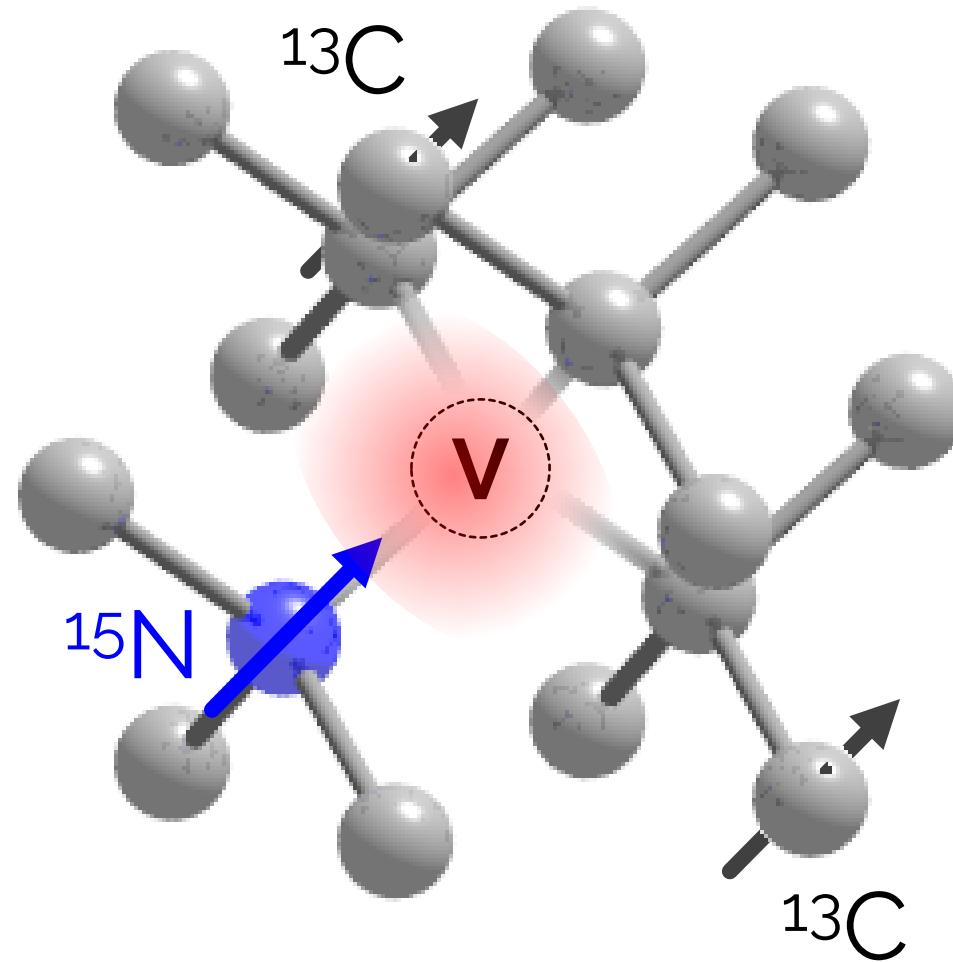
High-resolution ODMR spectra



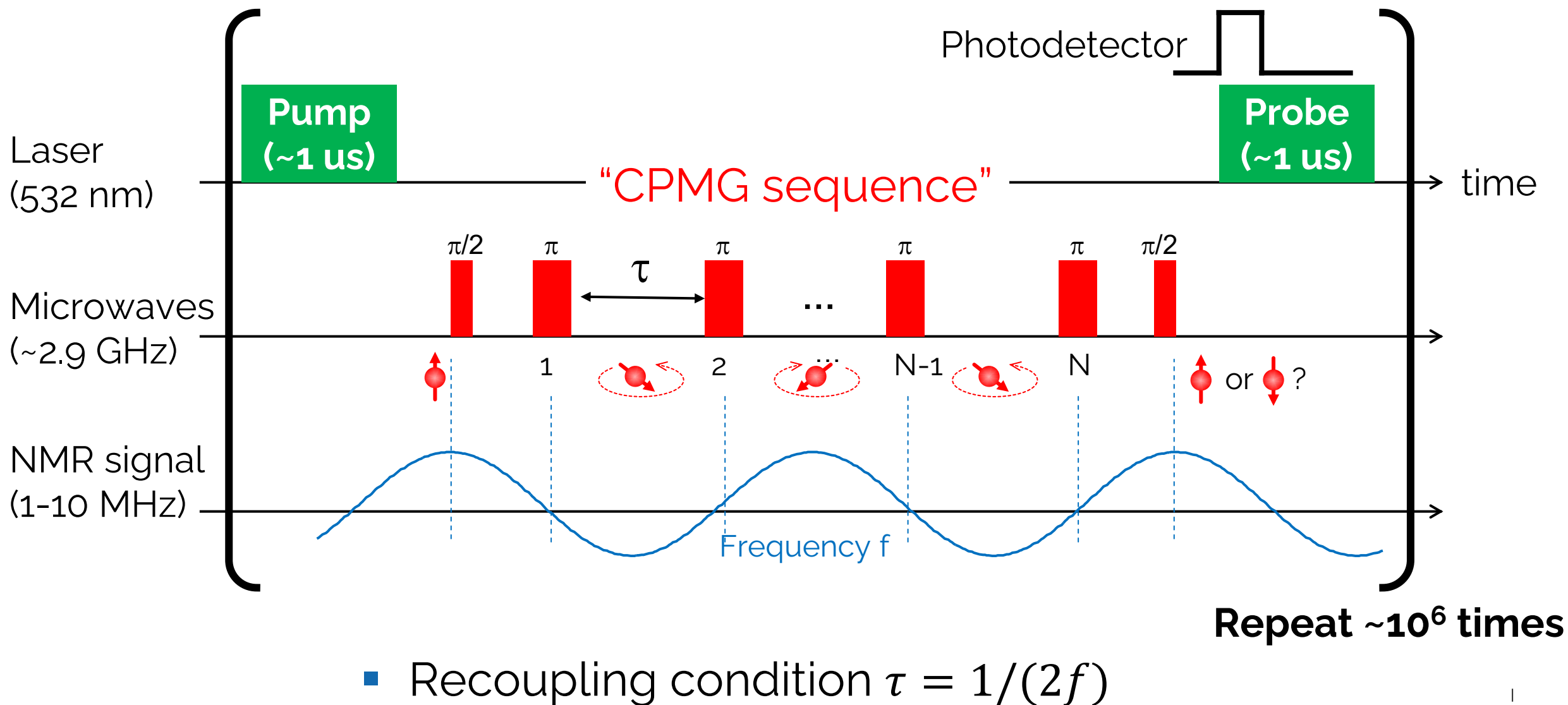
Stochastic flips of single ^{13}C



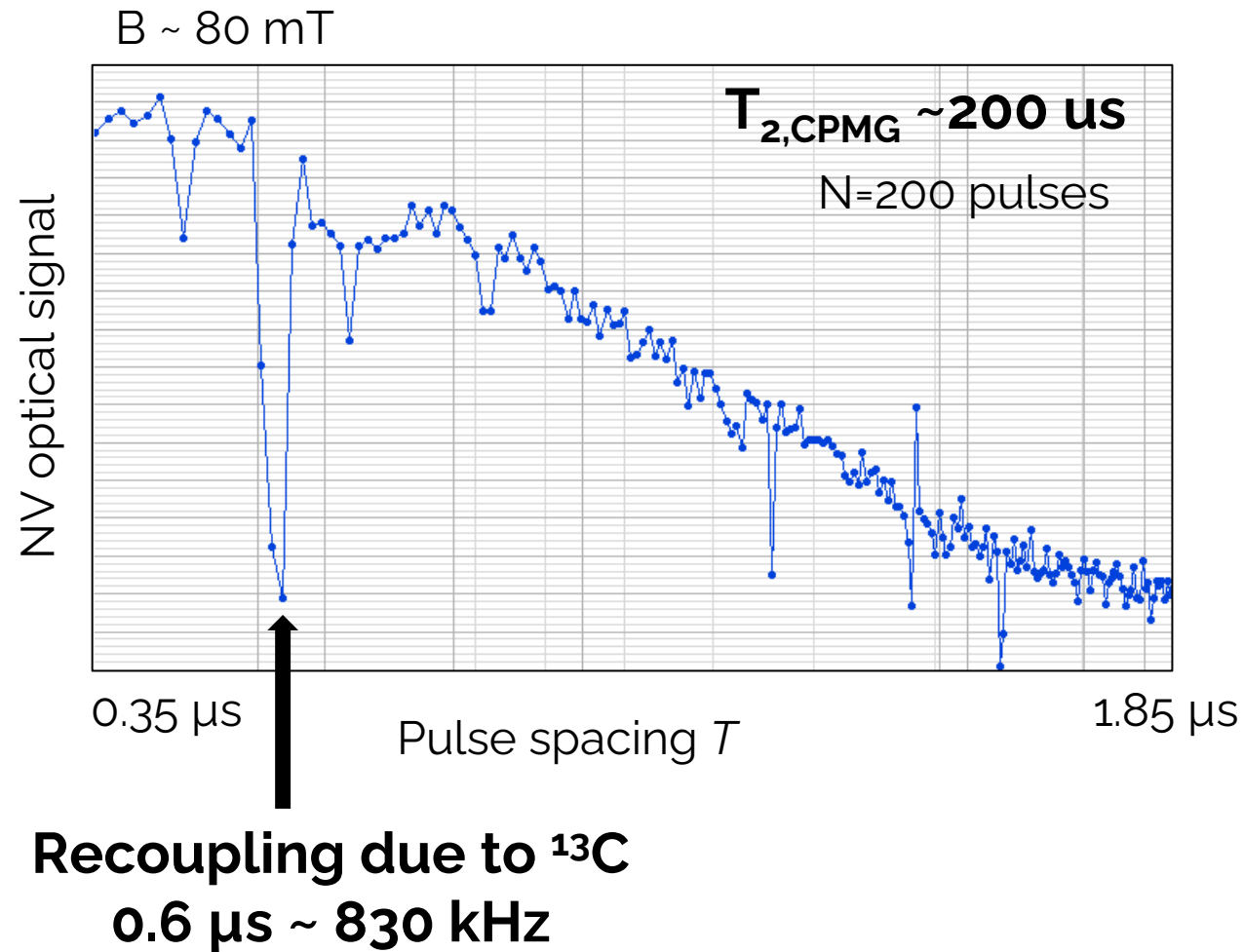
Exploring the neighborhood of the NV center



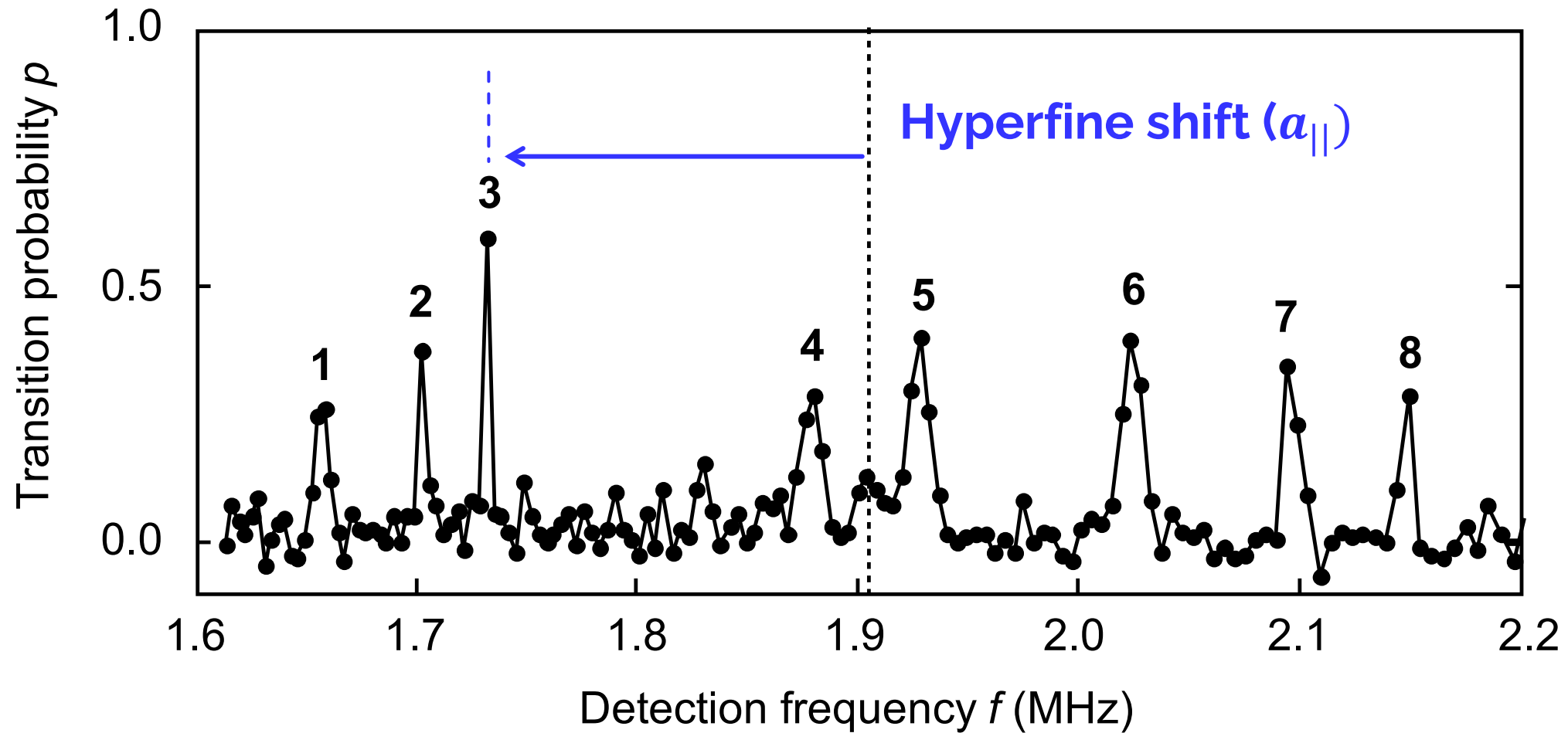
Pulsed experiments



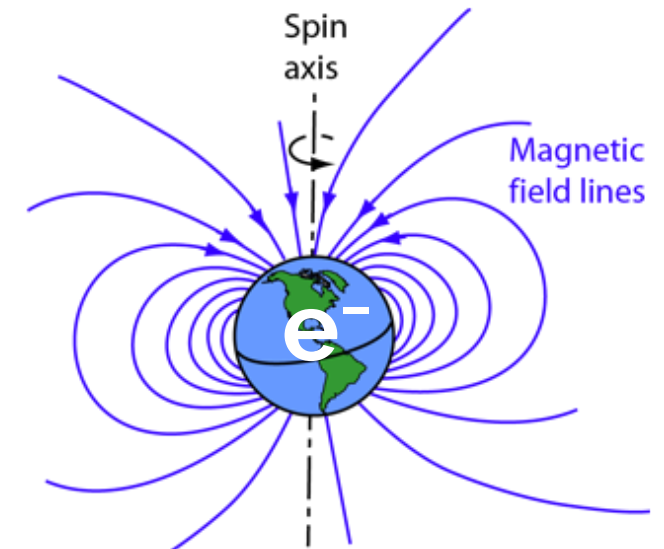
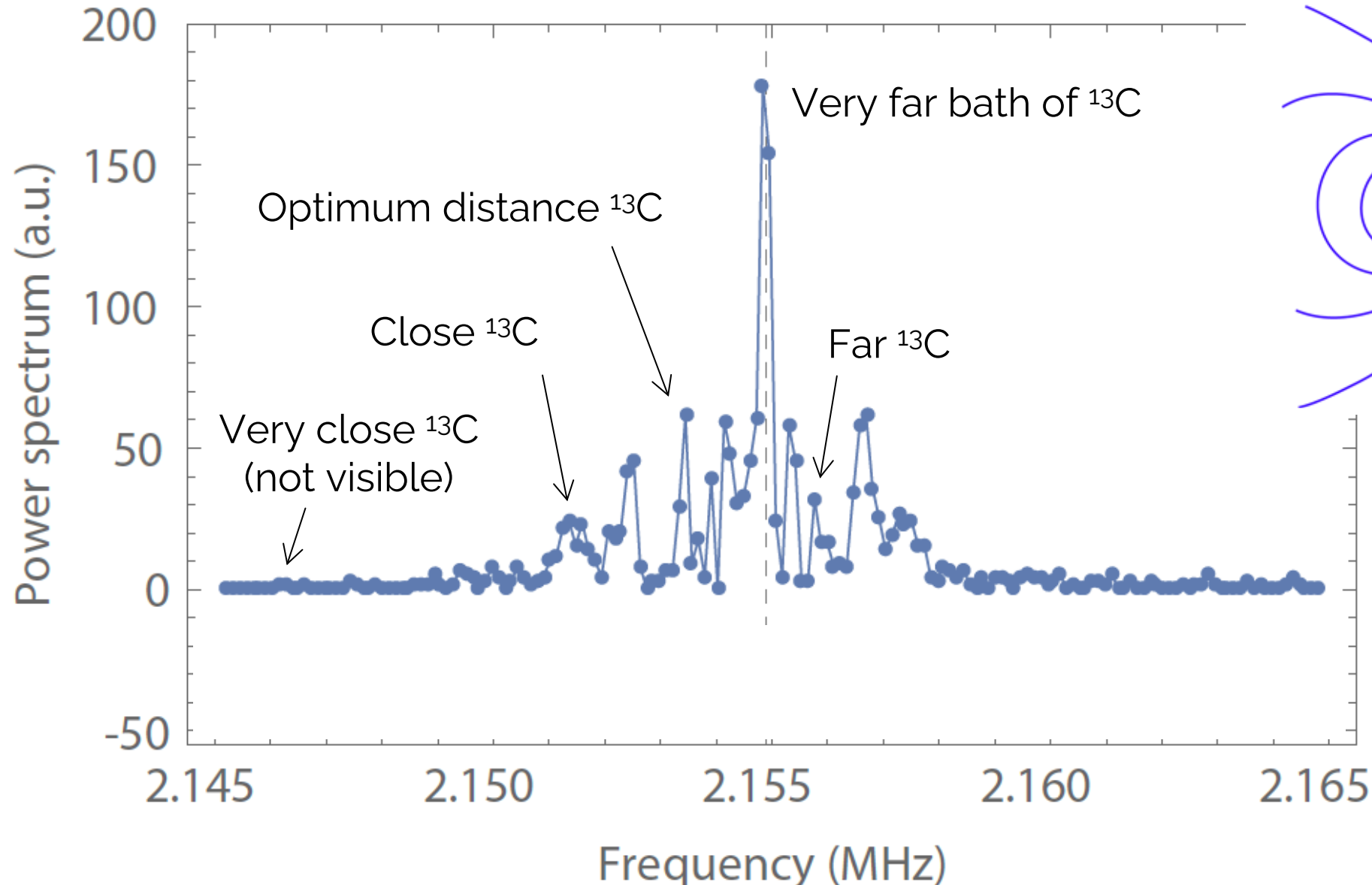
Detection of distant ^{13}C through NV decoherence spectroscopy



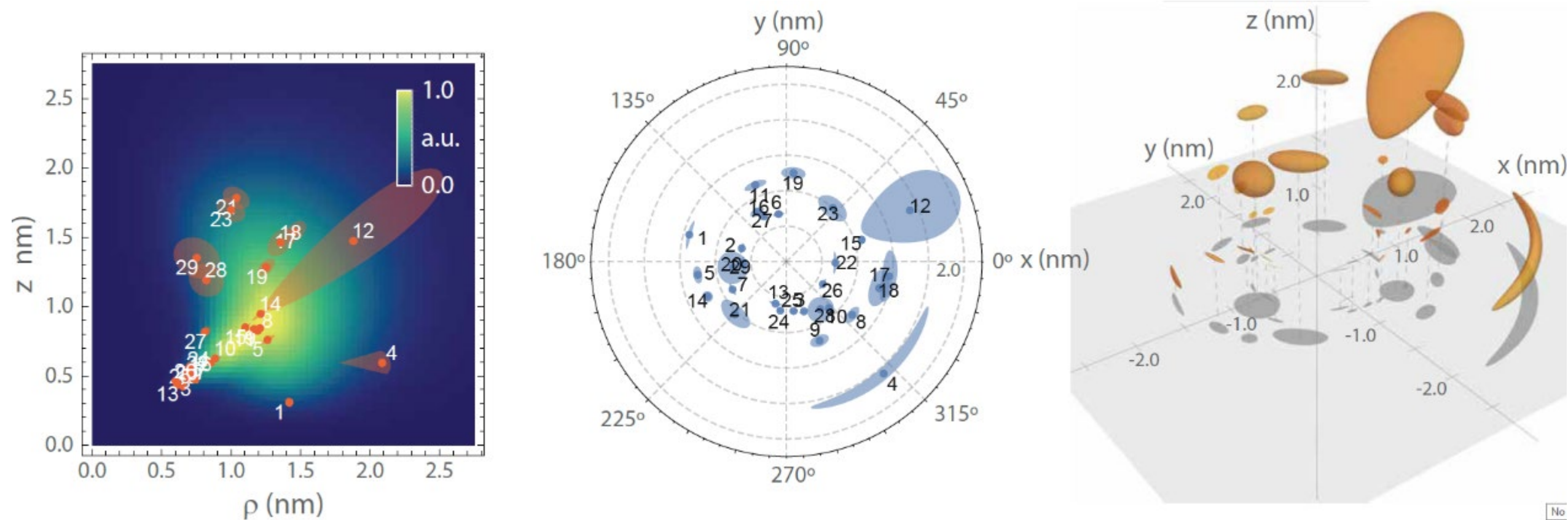
Detection of 8 individual ^{13}C nuclei



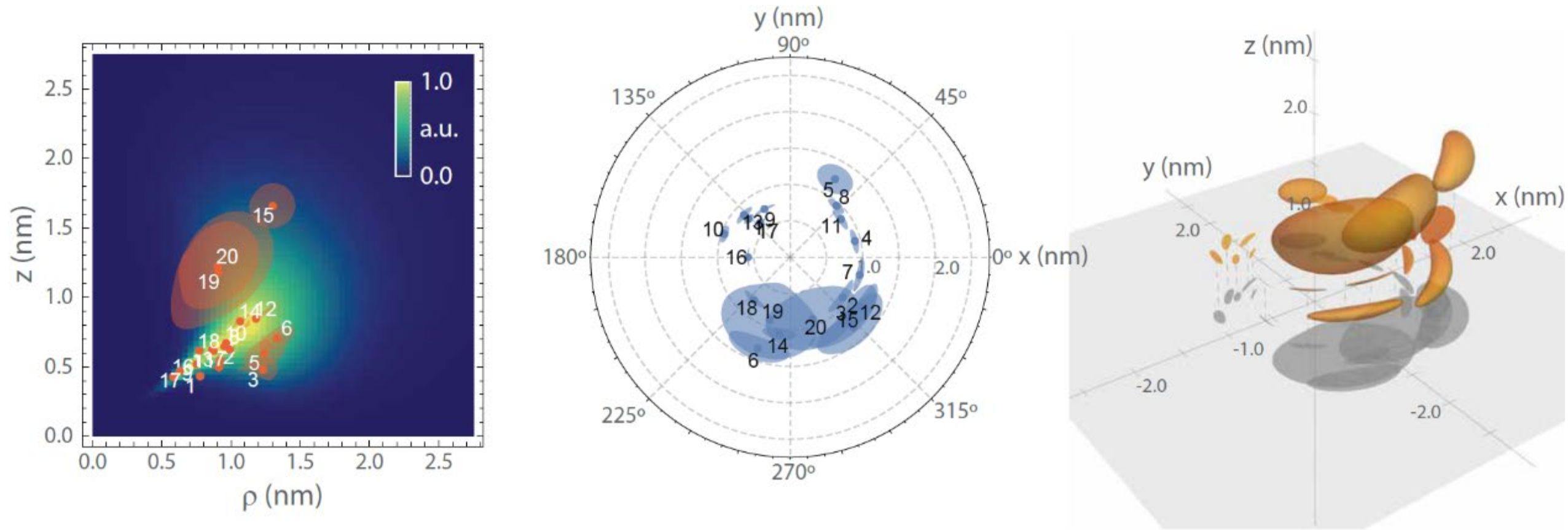
Fourier spectrum of many ^{13}C nuclear spins



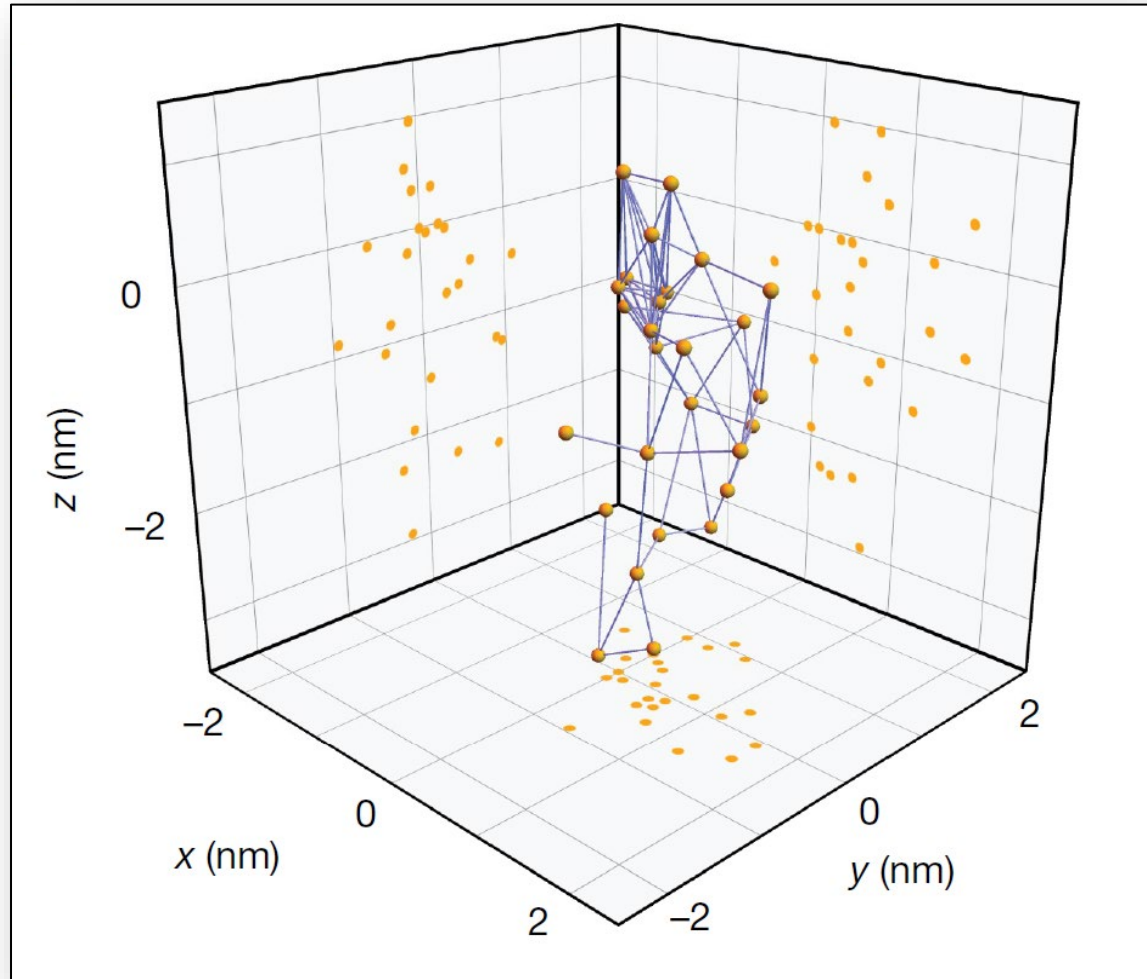
Spatial map (n=29)



Spatial map – second dataset (n=20)



Related work



Article

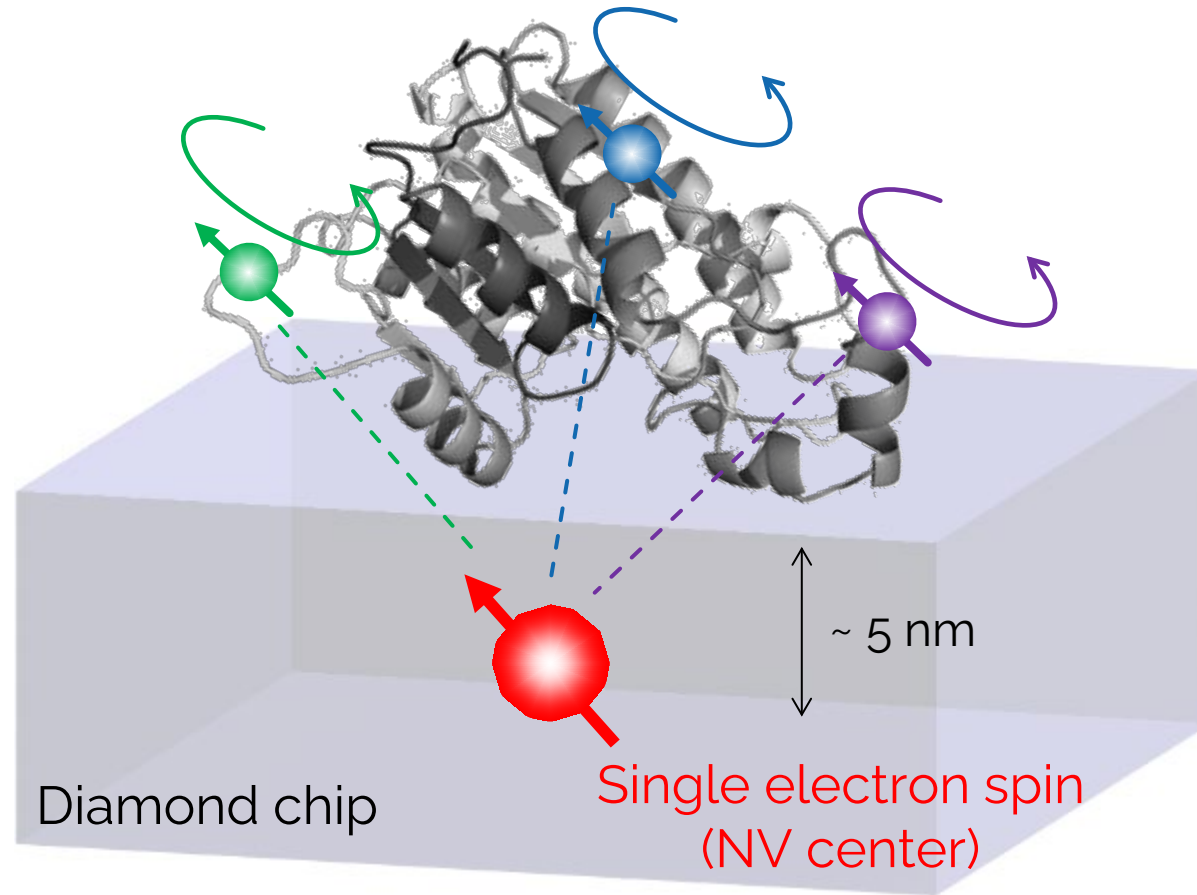
Atomic-scale imaging of a 27-nuclear-spin cluster using a quantum sensor

Abobeih, Taminiau et al., Nature 2019

(Deep NV and liquid Helium temperature)

- Outlook: Applications

Diamond platform for single-molecule NMR



- Imaging of atomic structure
- Molecular dynamics
- DNP

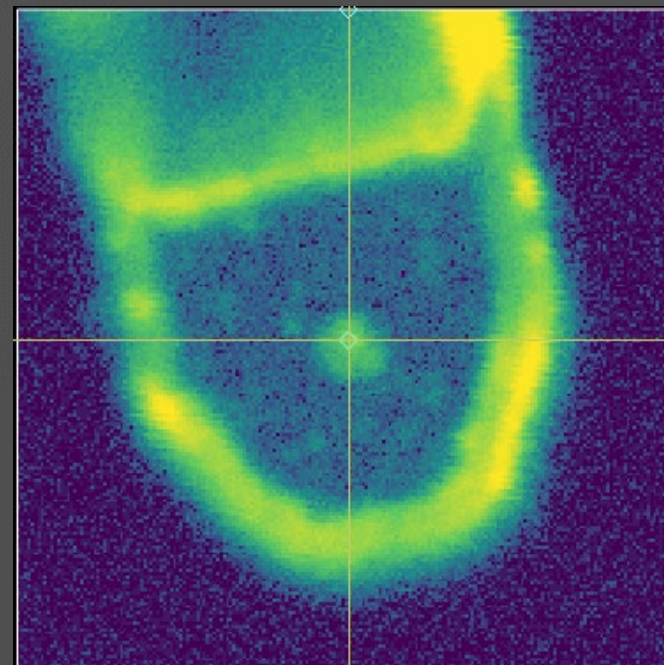
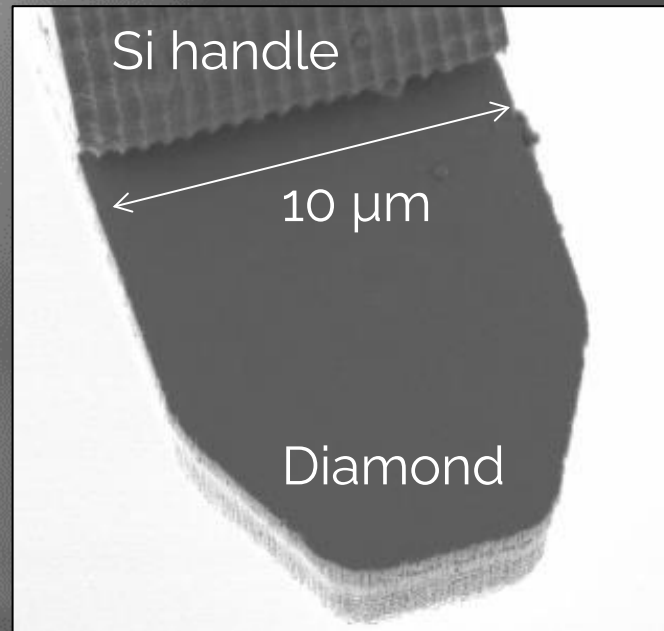
NV scanning probes

Diamond
(single crystalline)

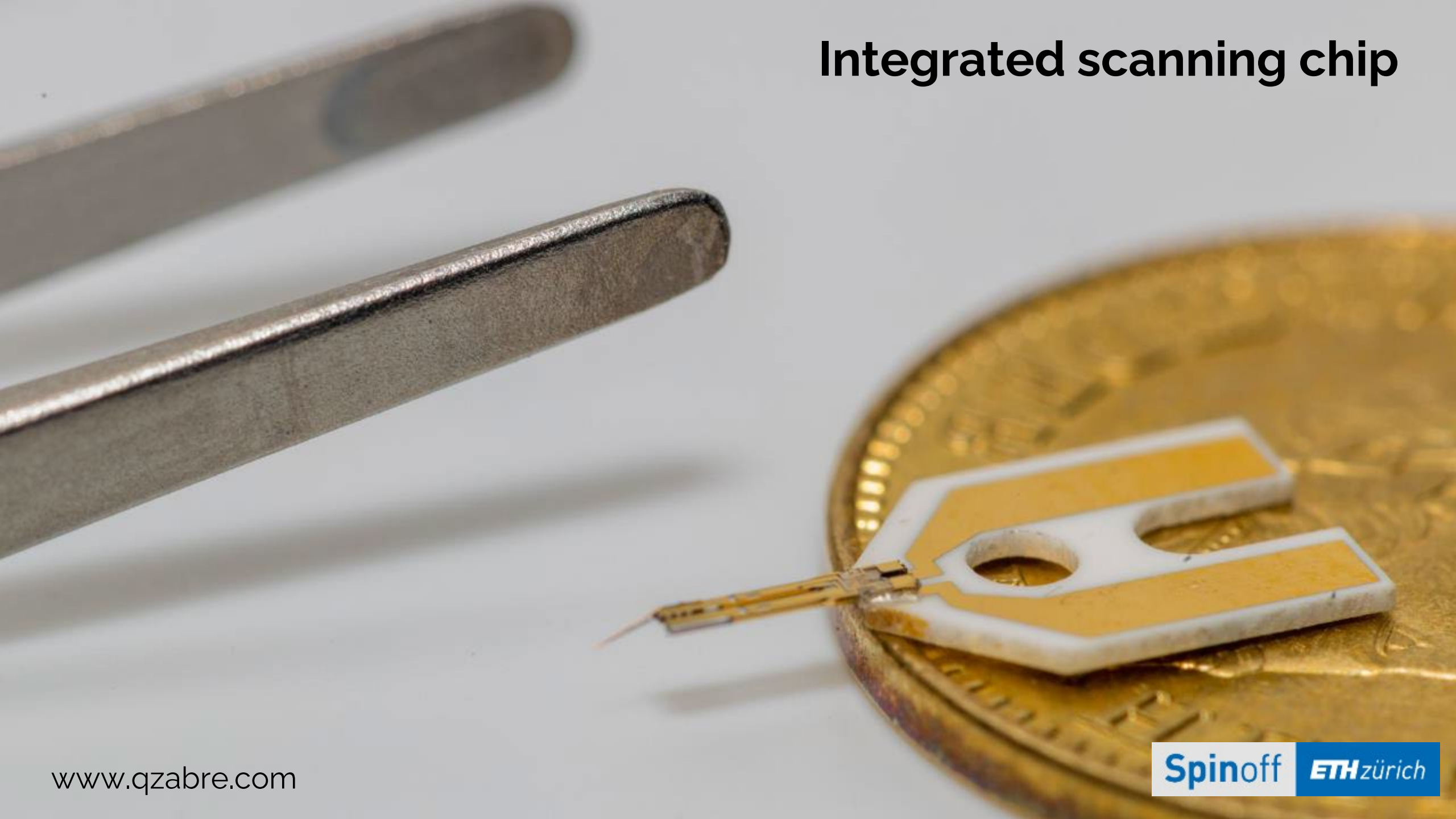
Silicon handle

Diamond tip
w/ single NV center

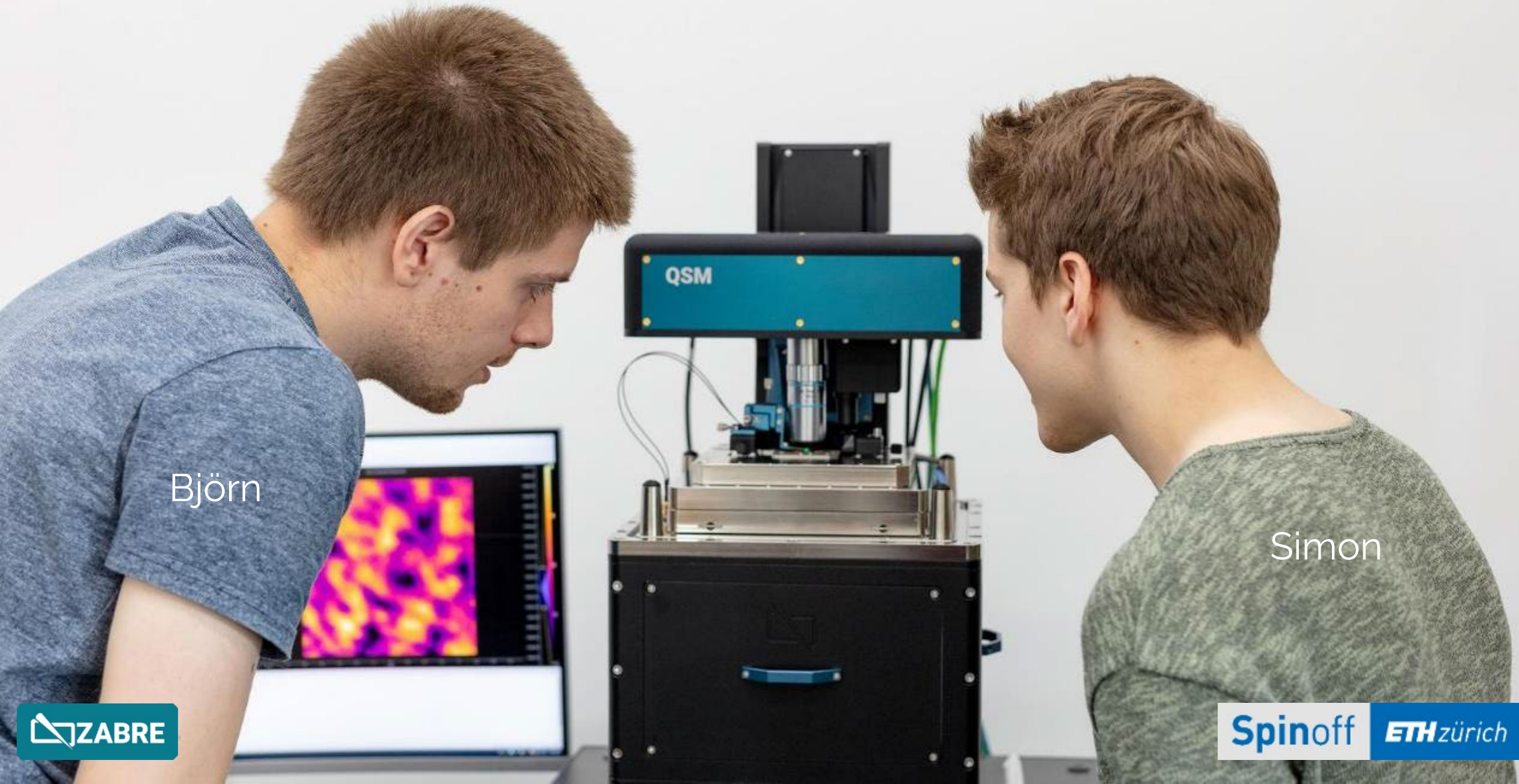
5 μm



Integrated scanning chip



Tech Transfer: Quantum Scanning Microscope (QSM)

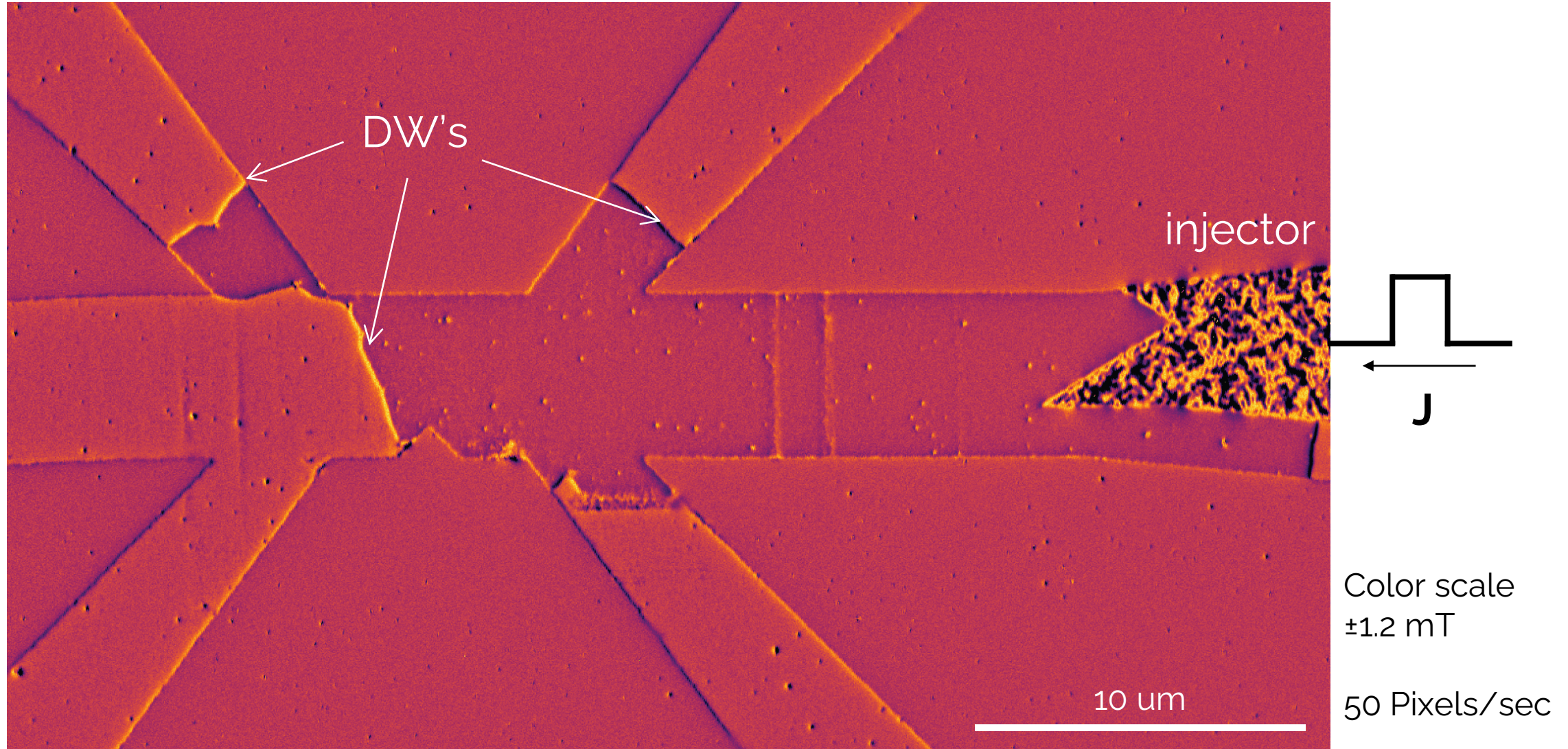


Björn

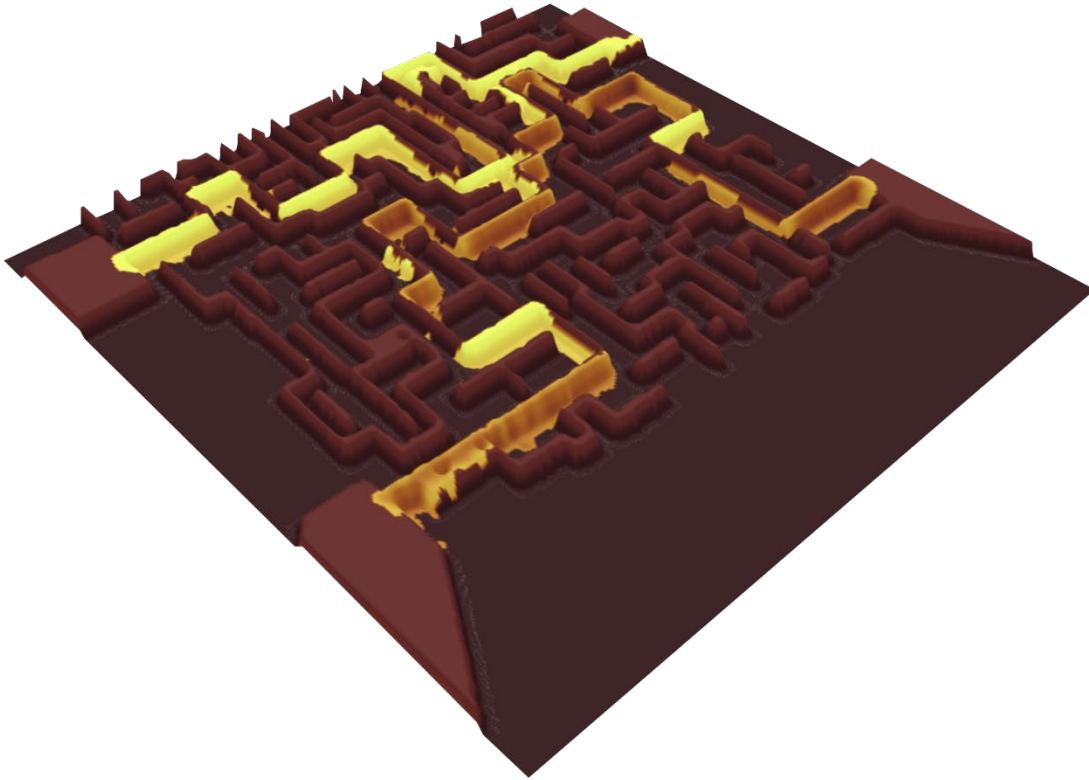
Simon

Example: GdCo ferrimagnetic racetrack

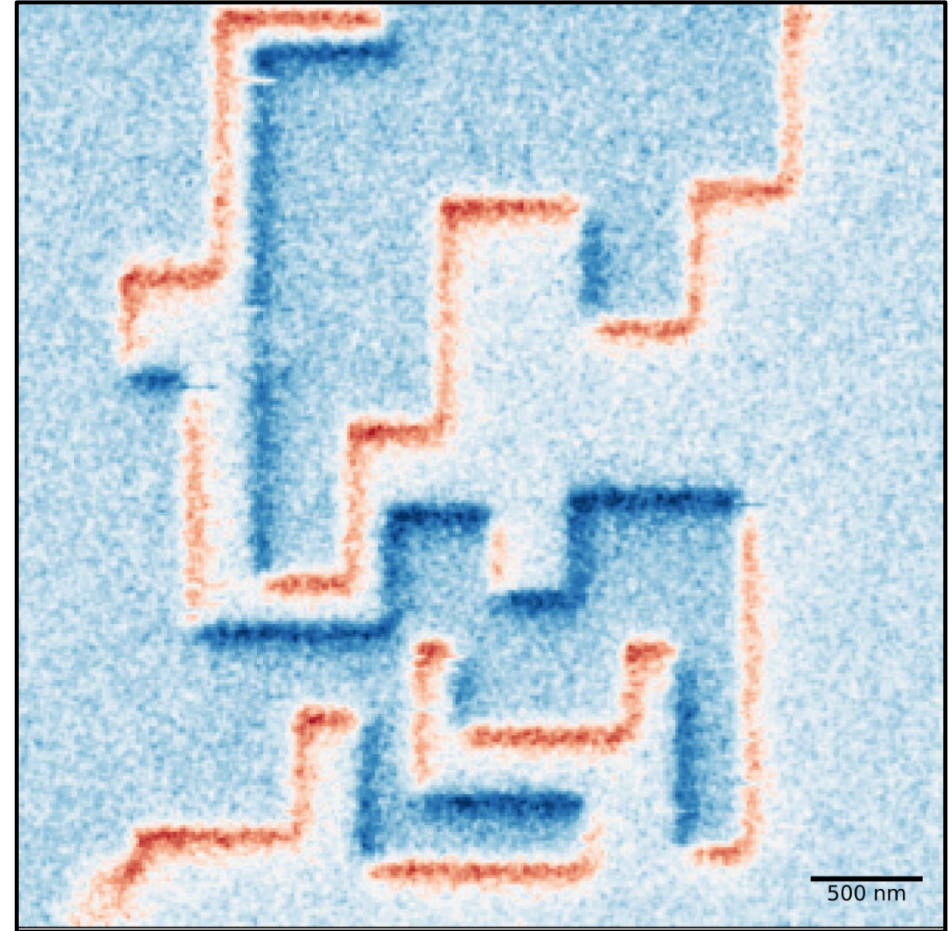
Scanning NV magnetometry



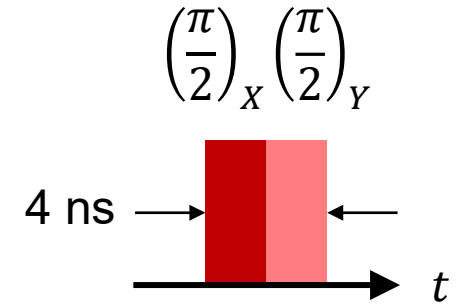
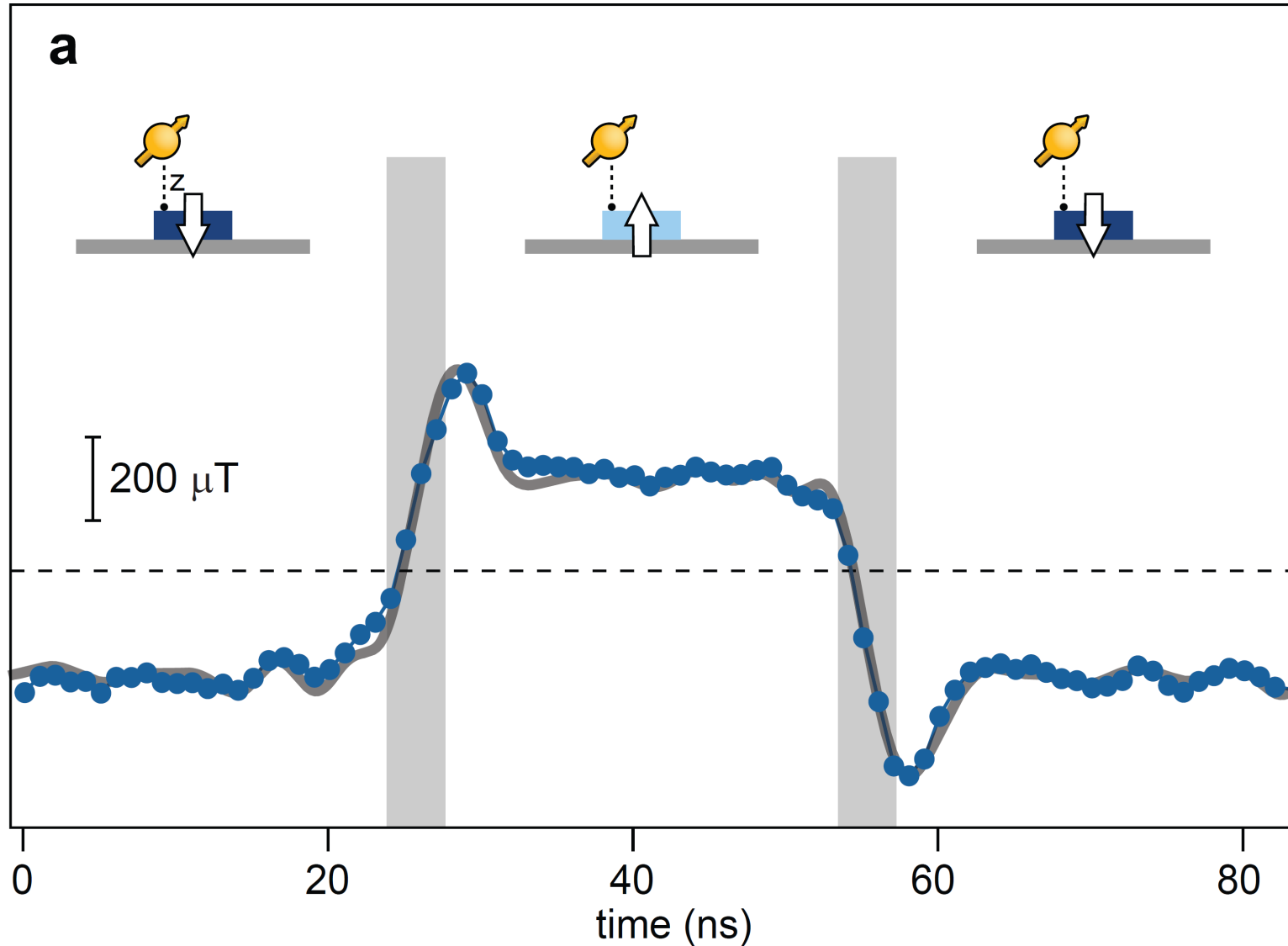
Electrical current mapping



**Current map
overlayed with AFM
topography**

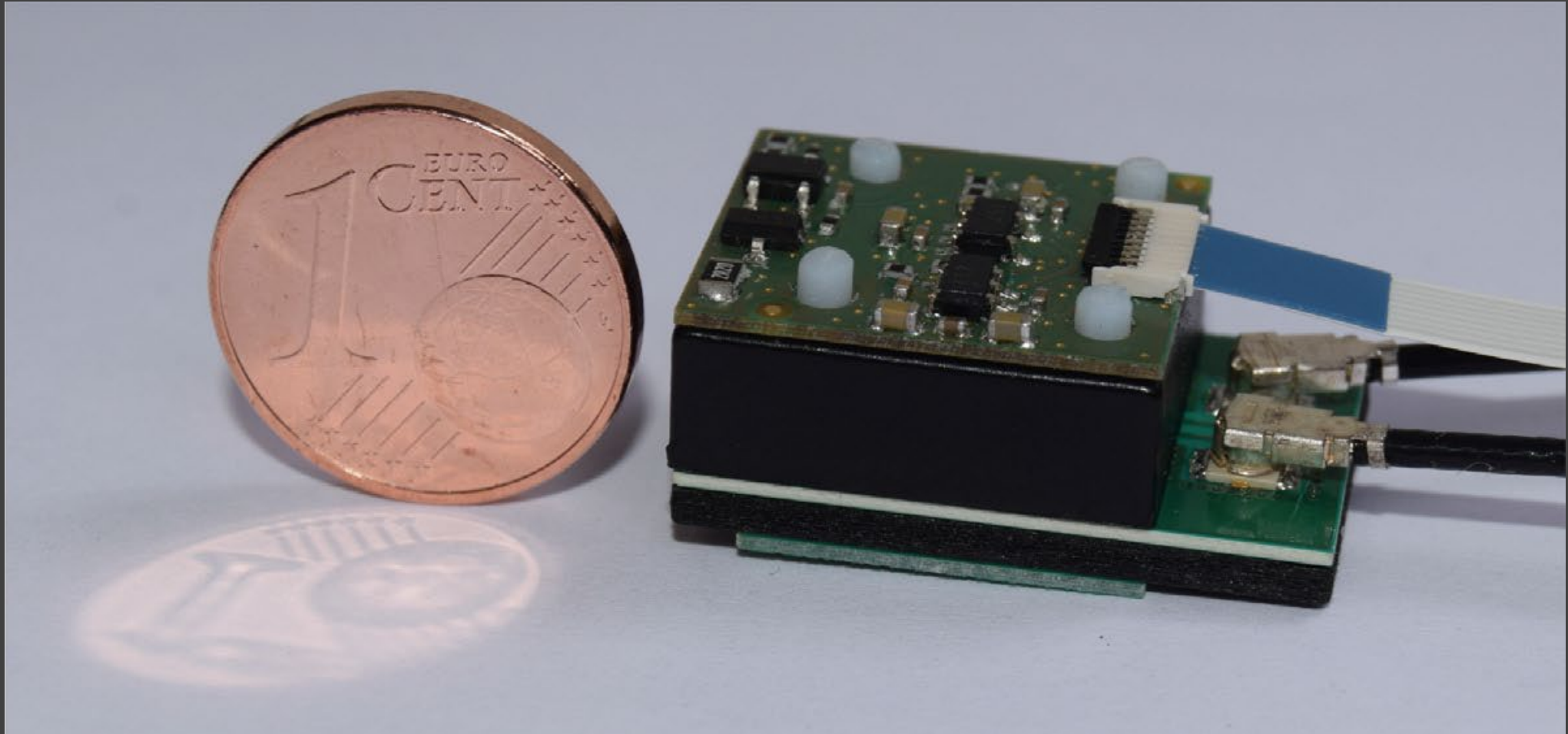


Nanosecond Magnetometry



- Magnetization dynamics
- Photocurrents

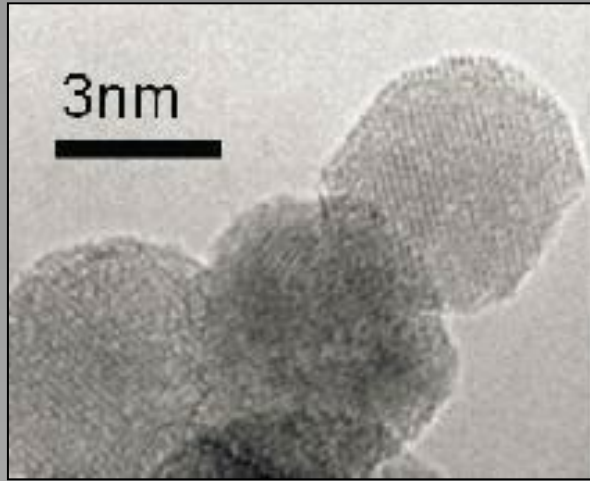
Compact integrated magnetometers



From: F. Stürner et al., Diamond & Related Materials 93, 59 (2019)

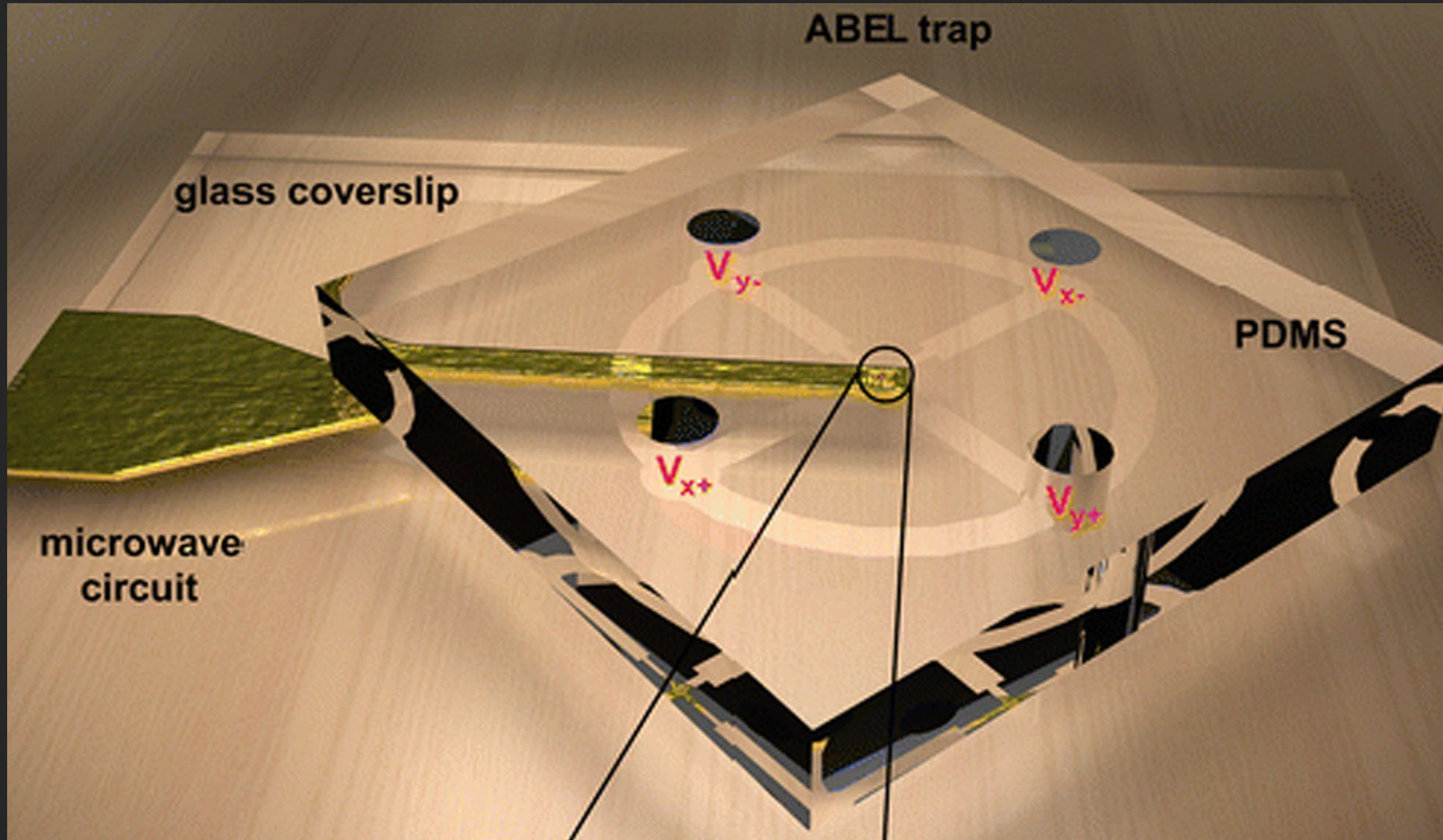
- Sensitivity $\sim 1 \text{ pT/Hz}^{1/2}$ ($10 \text{ pT/Hz}^{1/2}$ for compact sensors)

Biosensing



From: Adamas / Mohan, Nano. Lett. 2010

Microfluidics



Thank you!

