Optical Widefield Magnetic Resonance Microscopy Using Quantum Sensors in Diamond

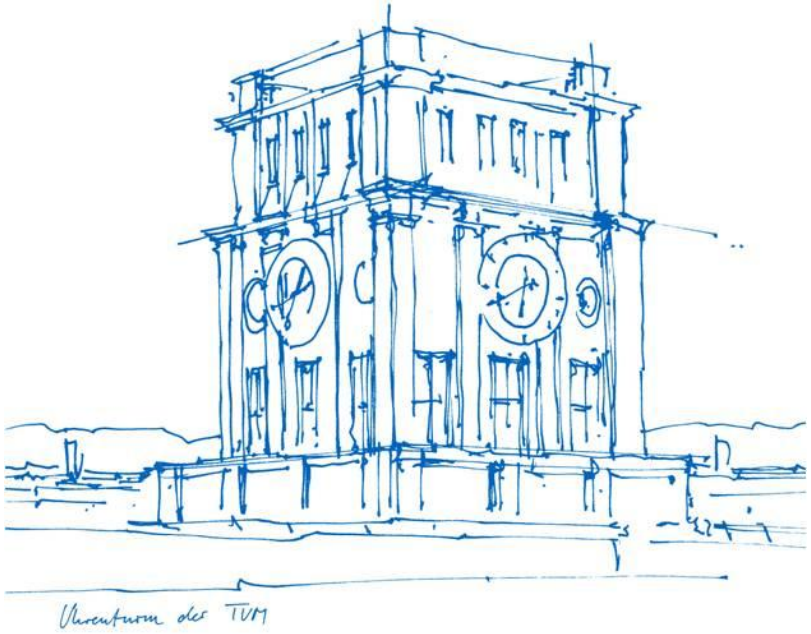
Xiaoxun Chen

Prof. Dr. Dominik Bucher

Professorship for Quantum Sensing

Technical University of Munich

QSL, May 20st, 2026

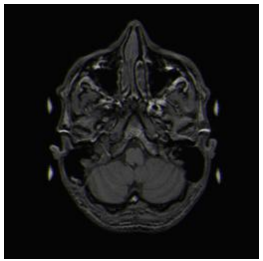


Nuclear magnetic resonance: Motivation

MRI

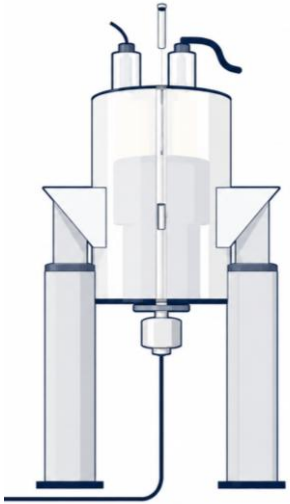


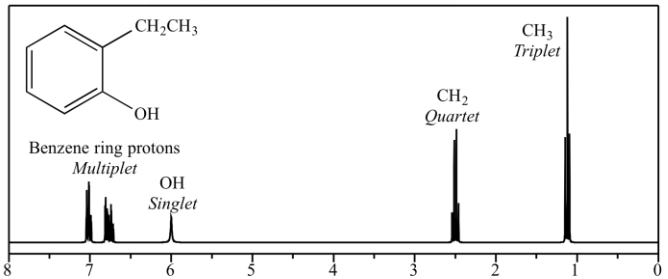
Designed by Christoph Hohmann



https://de.wikipedia.org/wiki/Magnetresonanztomographie

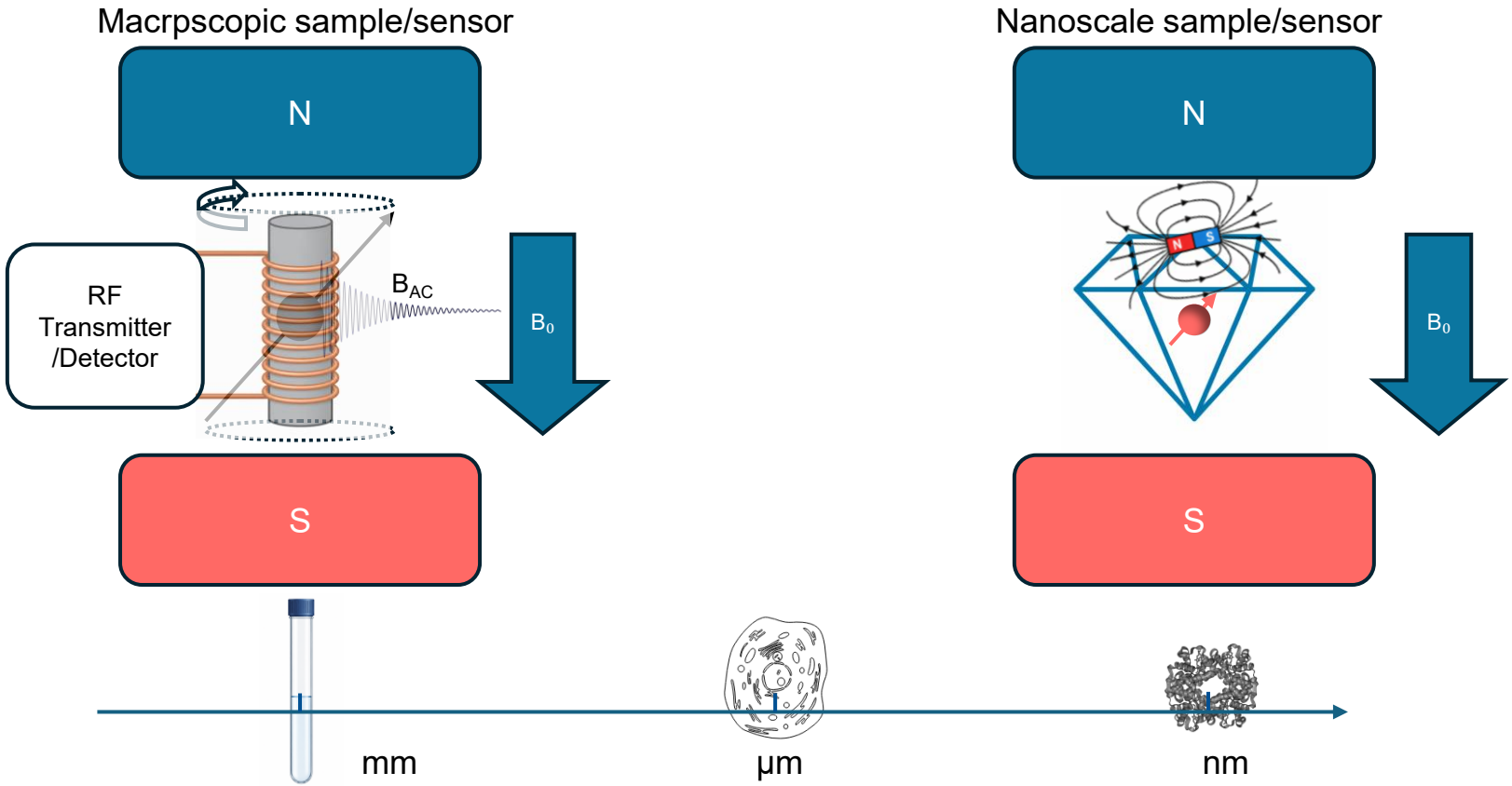
NMR





Chemical shift

Nuclear magnetic resonance spectroscopy



Magnetic resonance techniques



1. Nitrogen vacancy (NV) centers are solid state spin defects in diamond.

2. They act as atomic-scale quantum sensors capable of detecting magnetic signals.

3. Novel tool to perform optical magnetic resonance (MR) microscopy and spectroscopy

4. Sensing tool with broad applications in:
   - Lab-on-a-chip systems
   - Single-cell analysis
     (e.g., metabolomics, diffusion studies, etc.)
   - Tissue-slice measurements
   - Materials science

Nitrogen-Vacancy (NV) Centers

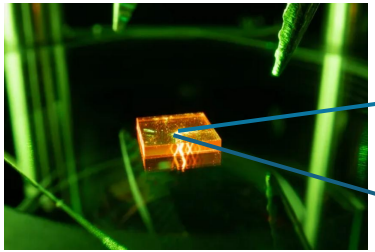
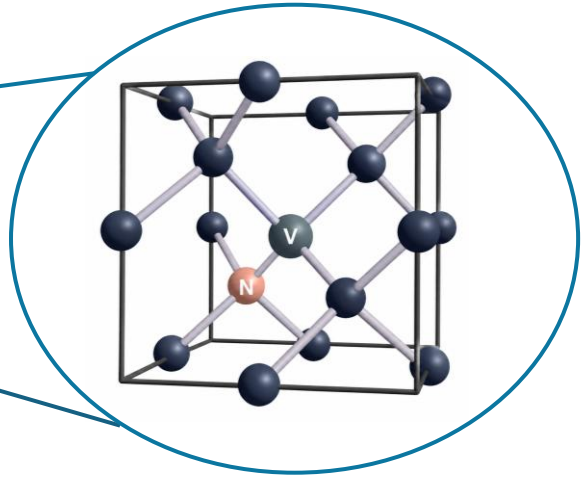
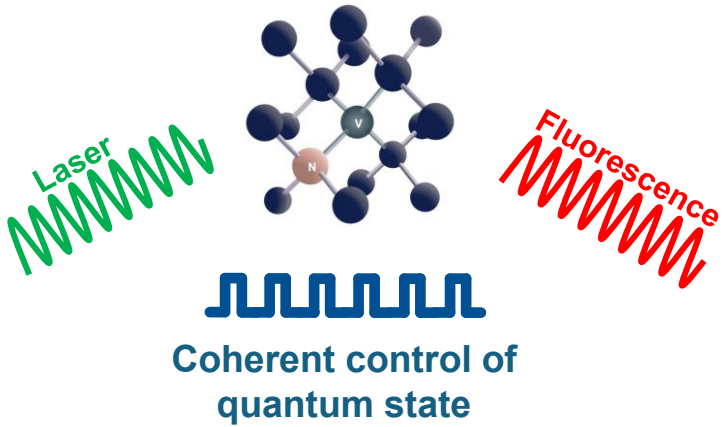


Photo taken by Christoph Homann





Coherent control of quantum state

1. Optical preparation of the quantum state

2. Coherent manipulation of the quantum state with microwave (MW) pulses

3. Optical readout of NV quantum state

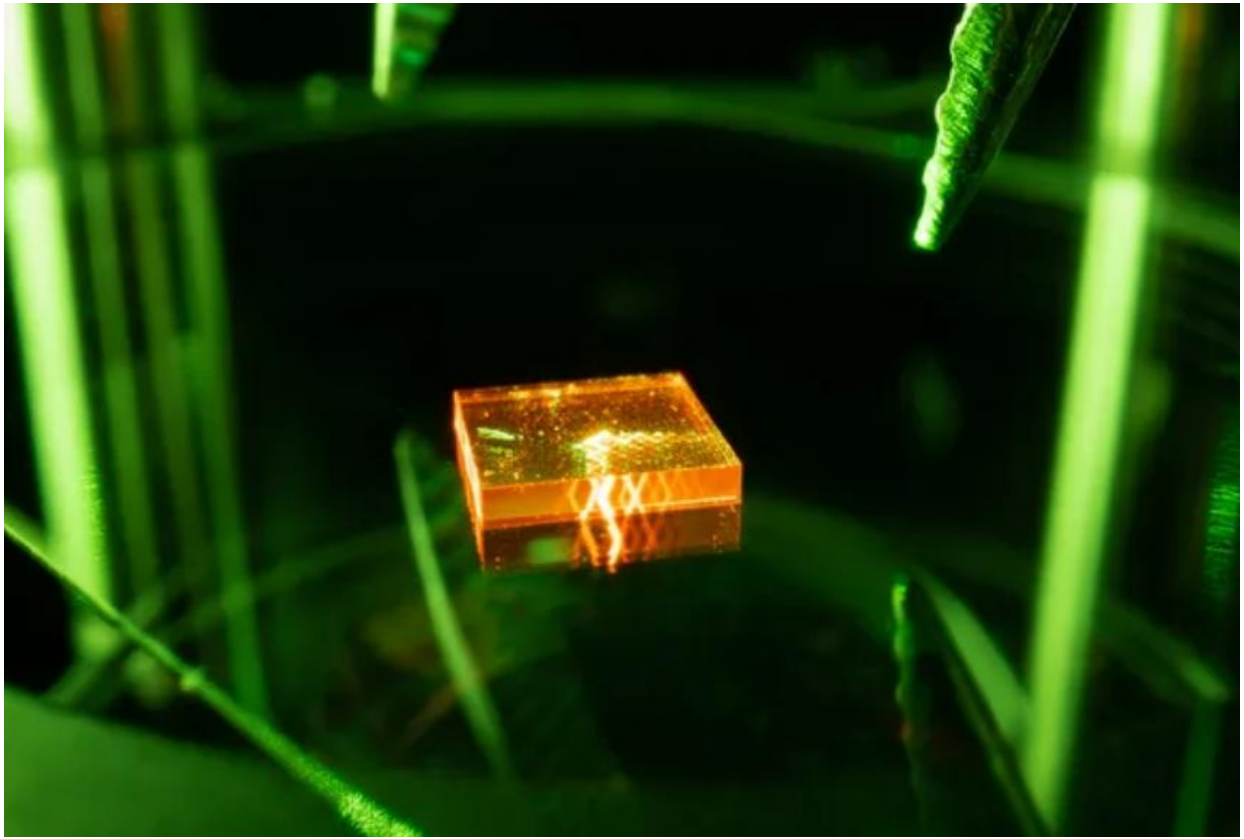
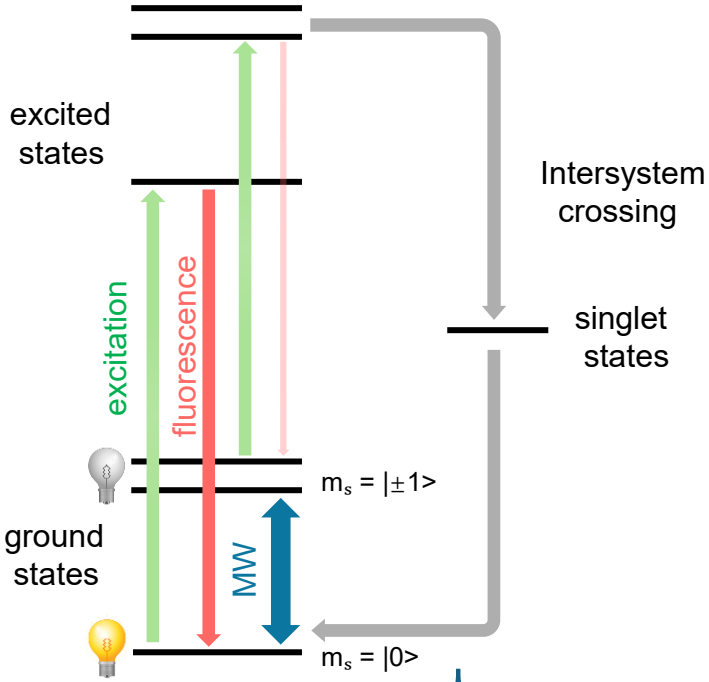
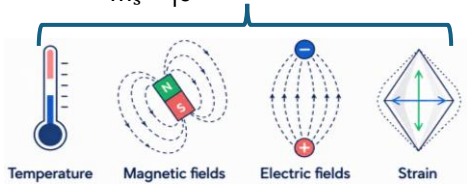


Photo taken by Christoph Homann

The NV center as a qubit

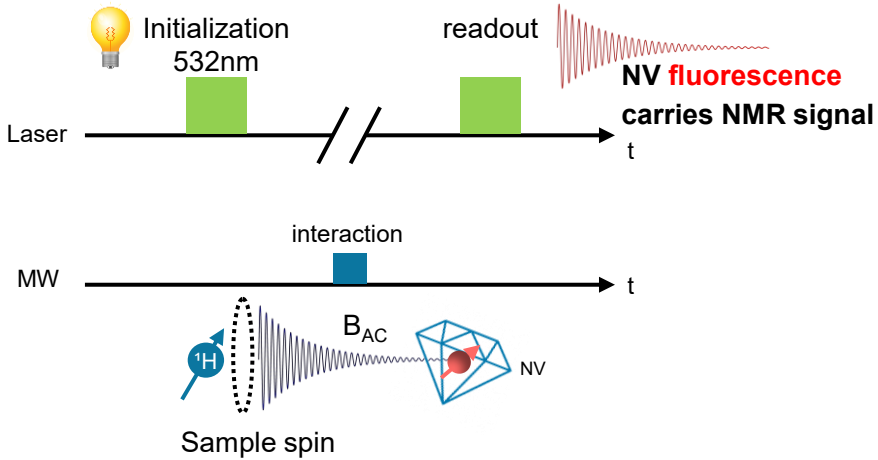


Depending on the sensing protocol :

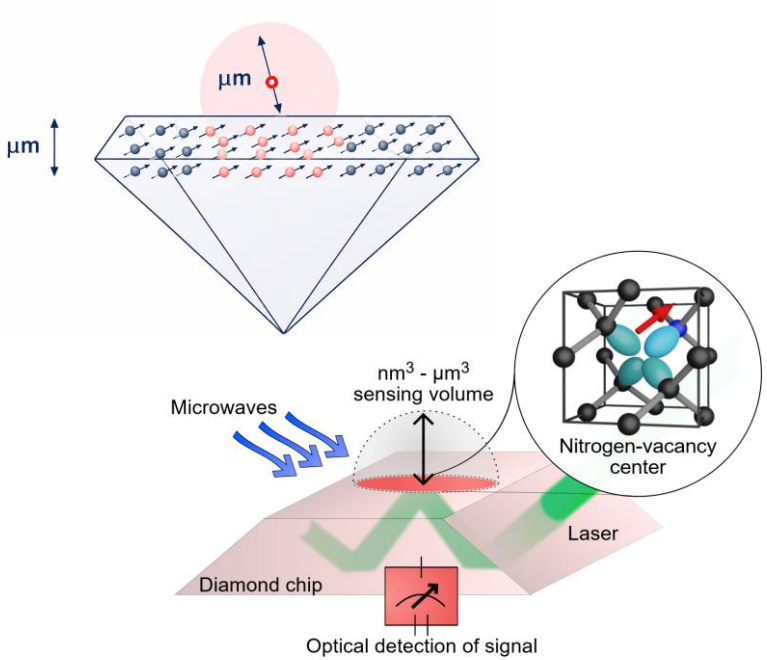


Quantum sensing protocol

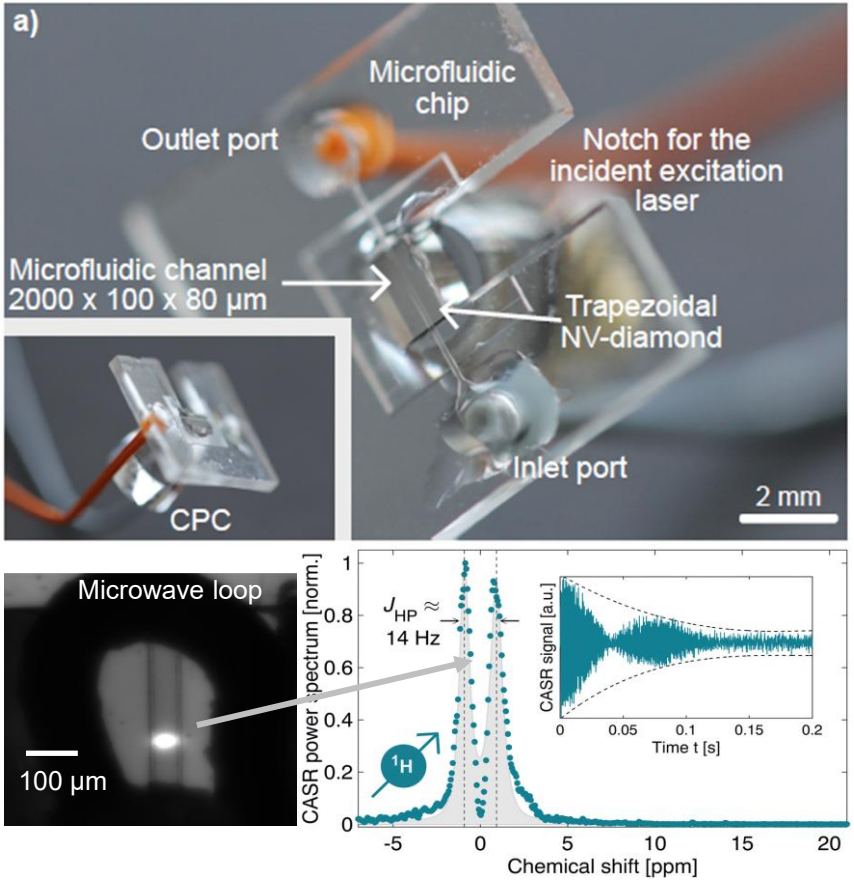
- Initialization
- Signal and sensor coupling
- Readout of spin state dependent fluorescence



Microscale NV-NMR on-a-chip



Detection volume ~ hemisphere
with radius = average
depth of NV center

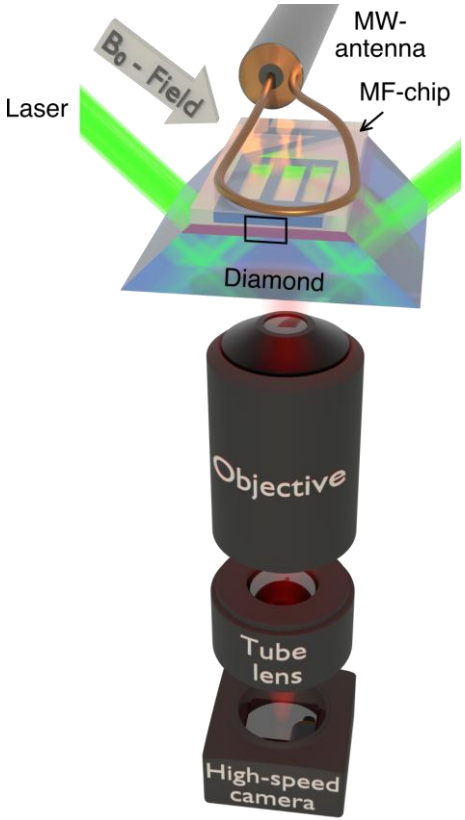


R.Allert et al., **Lab Chip**, 2022, **22**, 4831-4840

Wide-field NMR imaging?

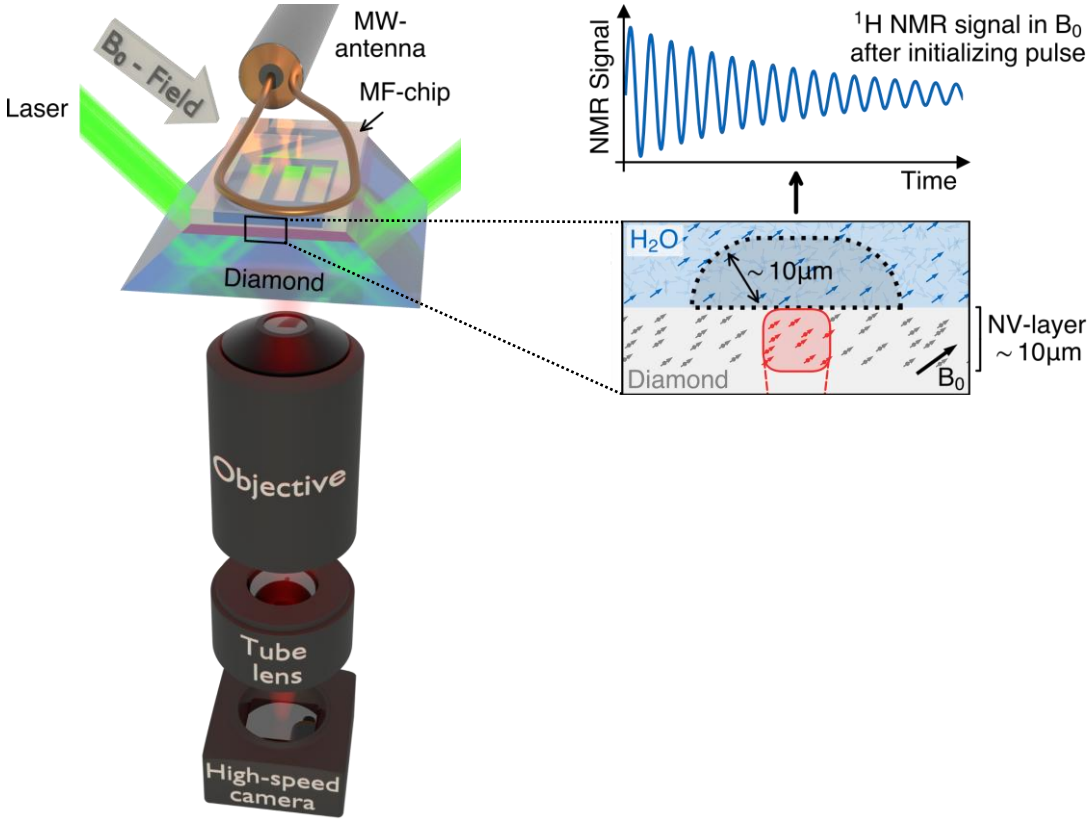


Microscale NV-NMR microscopy



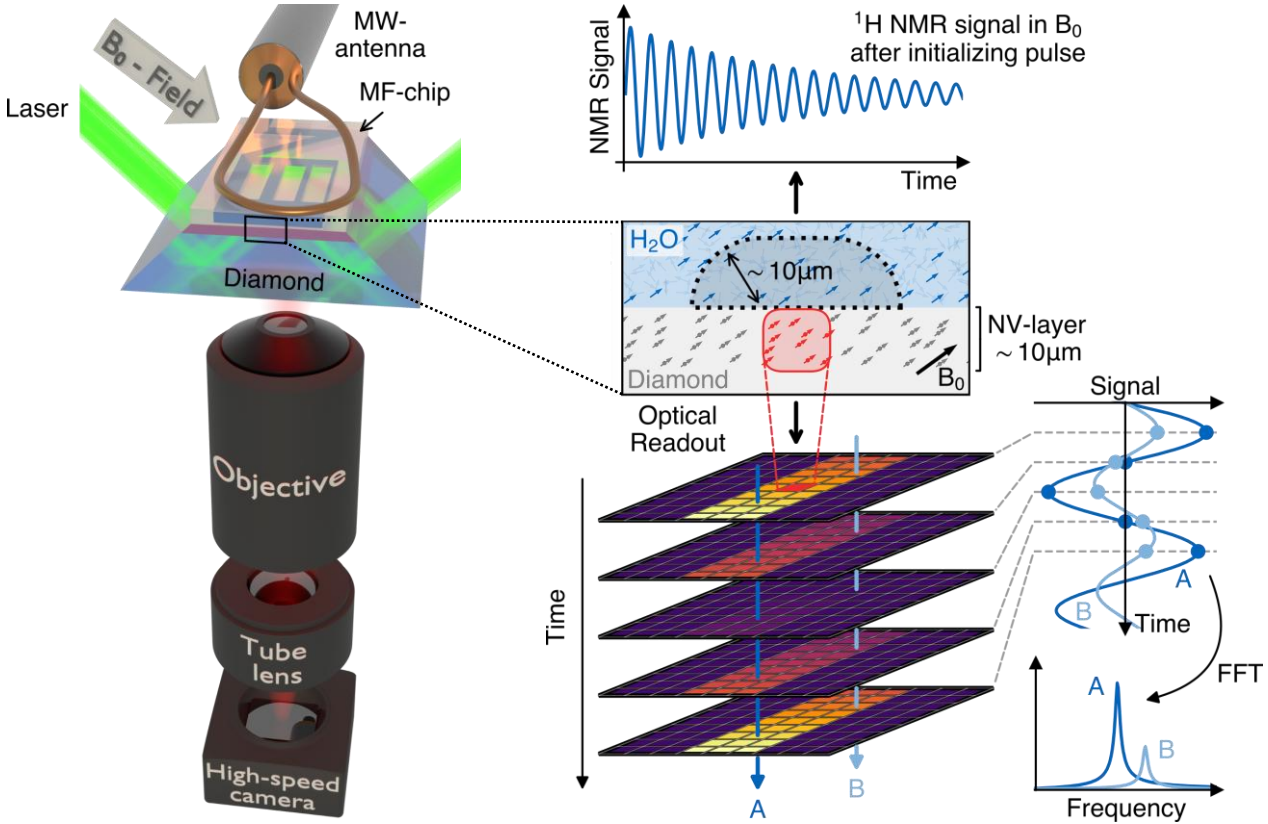
K.D. Briegel et al., Nat Commun 16, 1281 (2025)

Microscale NV-NMR microscopy



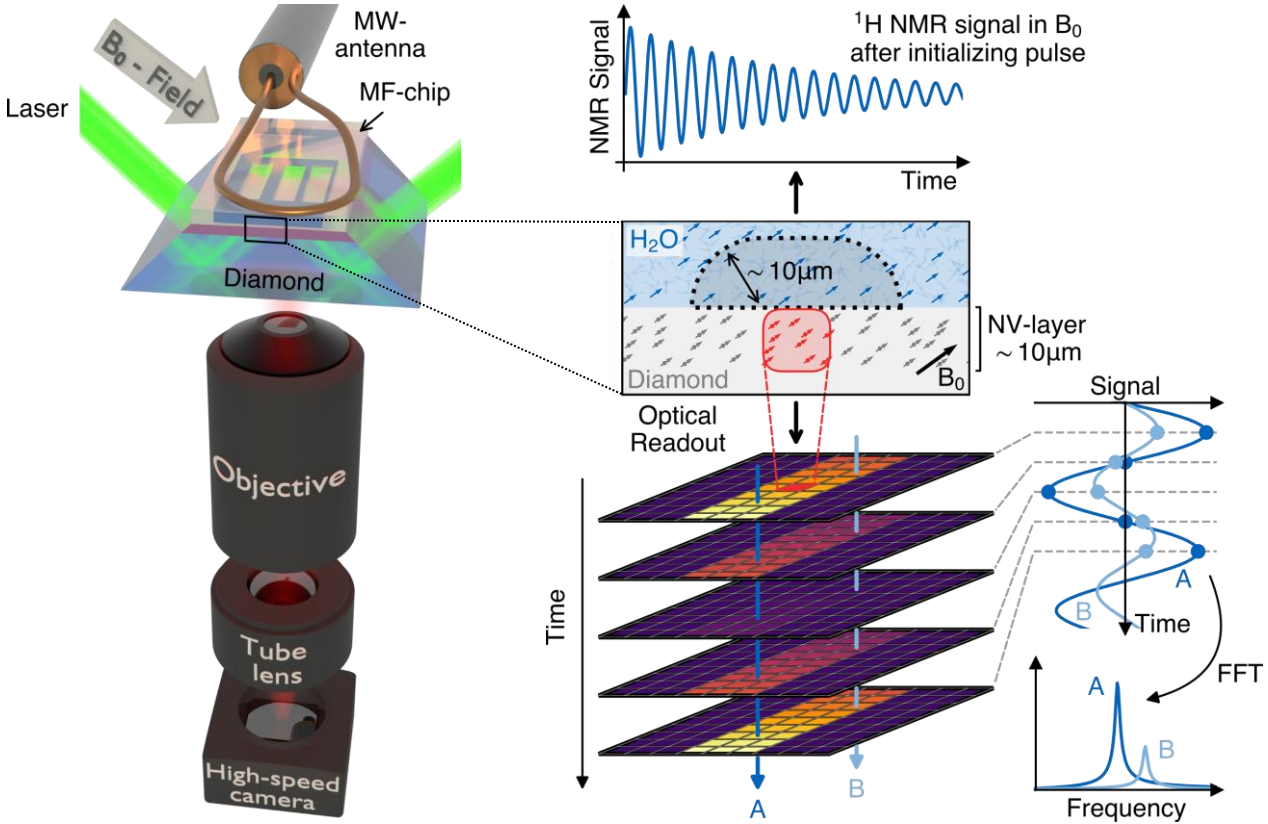
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Microscale NV-NMR microscopy



K.D. Briegel et al., Nat Commun 16, 1281 (2025)

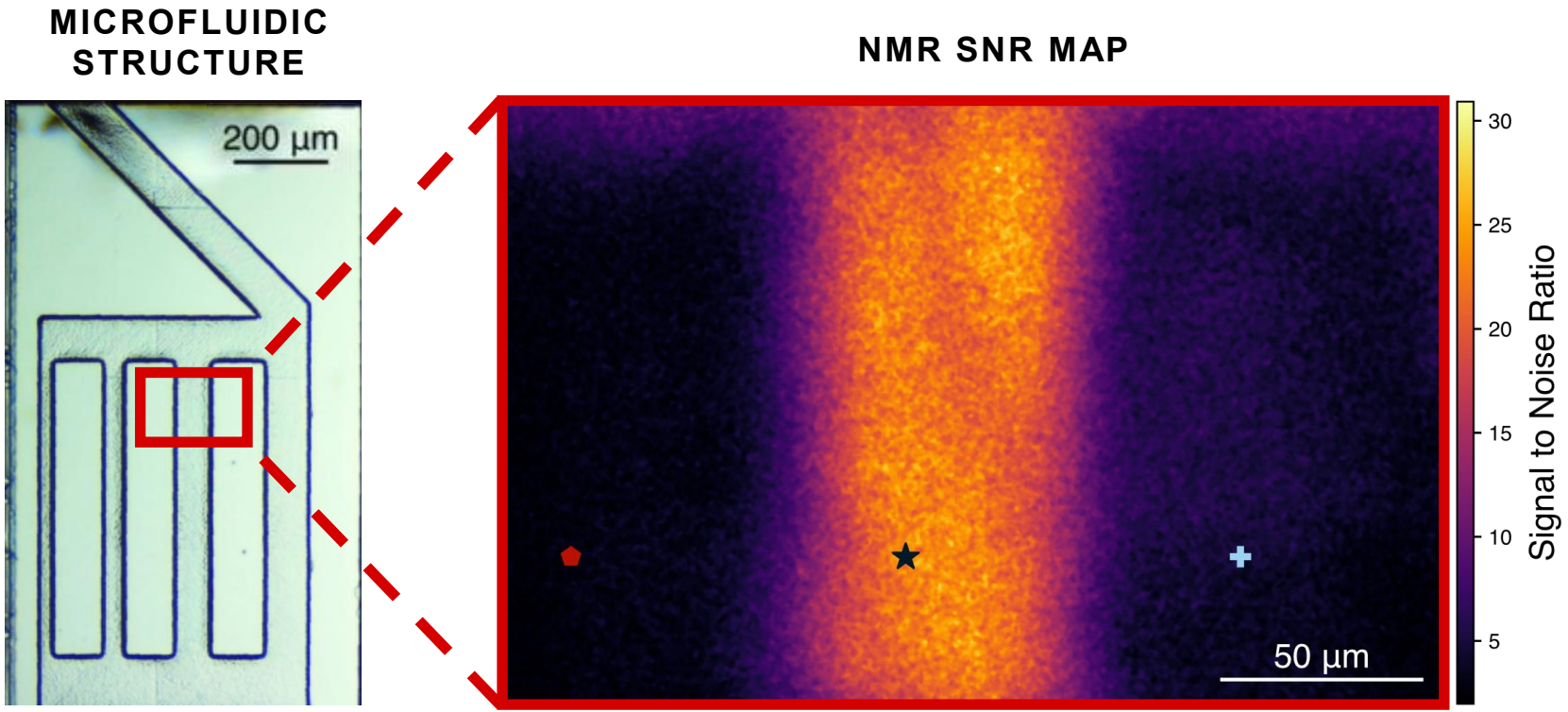
Microscale NV-NMR microscopy



- 1.1 Megapixel camera
- Up to 1.1 million spectra in parallel

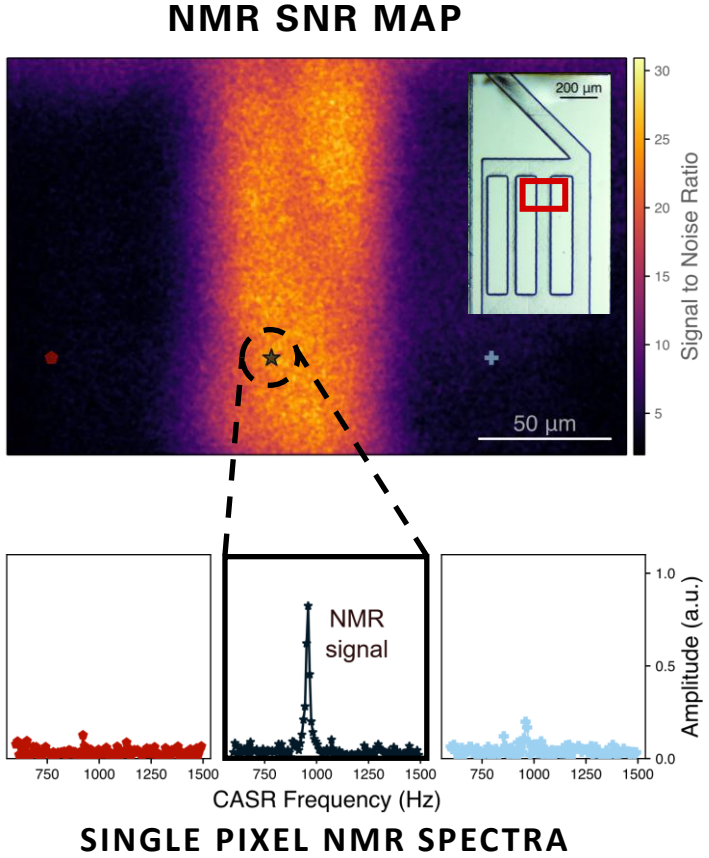
K.D. Briegel et al., Nat Commun 16, 1281 (2025)

Microscale NV-NMR microscopy



K.D. Briegel et al., Nat Commun 16, 1281 (2025)

Microscale NV-NMR microscopy



These pixelwise NMR spectra contain information about:

- Local NMR signal amplitude
- Phase → geometry information
- Frequency and linewidth → magnetic field gradients

K.D. Briegel et al., Nat Commun 16, 1281 (2025)

THANK YOU FOR YOUR ATTENTION!

GROUP AND COLLABORATORS

Prof. Dominik Bucher

Karl Briegel, Nick von Grafenstein, Julia C. Draeger, Robin Allert, Dr. Peter Blümler (Mainz), Dr. Roberto Rizzato, Dr. Linyan Nie, Dr. Utsab Banerjee, Dr. Dileep Singh, Dr. Riley Hooper, Dr. Christopher Einholz, Jens Hermann, Kun Meng, Linda Müller, Himadri Himani, Rodrigo Bautista Pacheco, Lukas Schröding, Lisa Krügerer

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