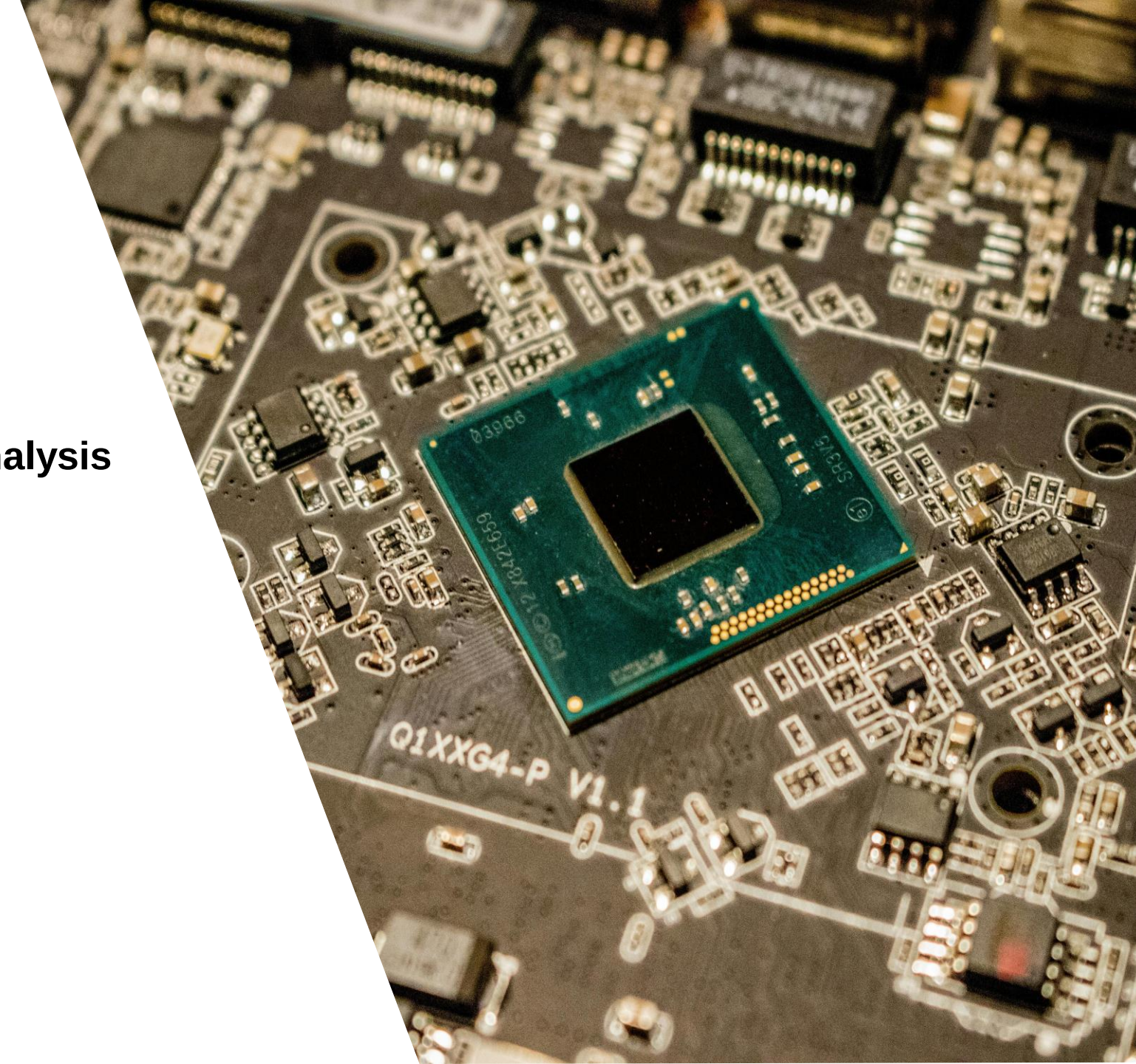
QUANTUM DIAMONDS
SENSOR TECHNOLOGY

NV-based Imaging and IC Failure Analysis

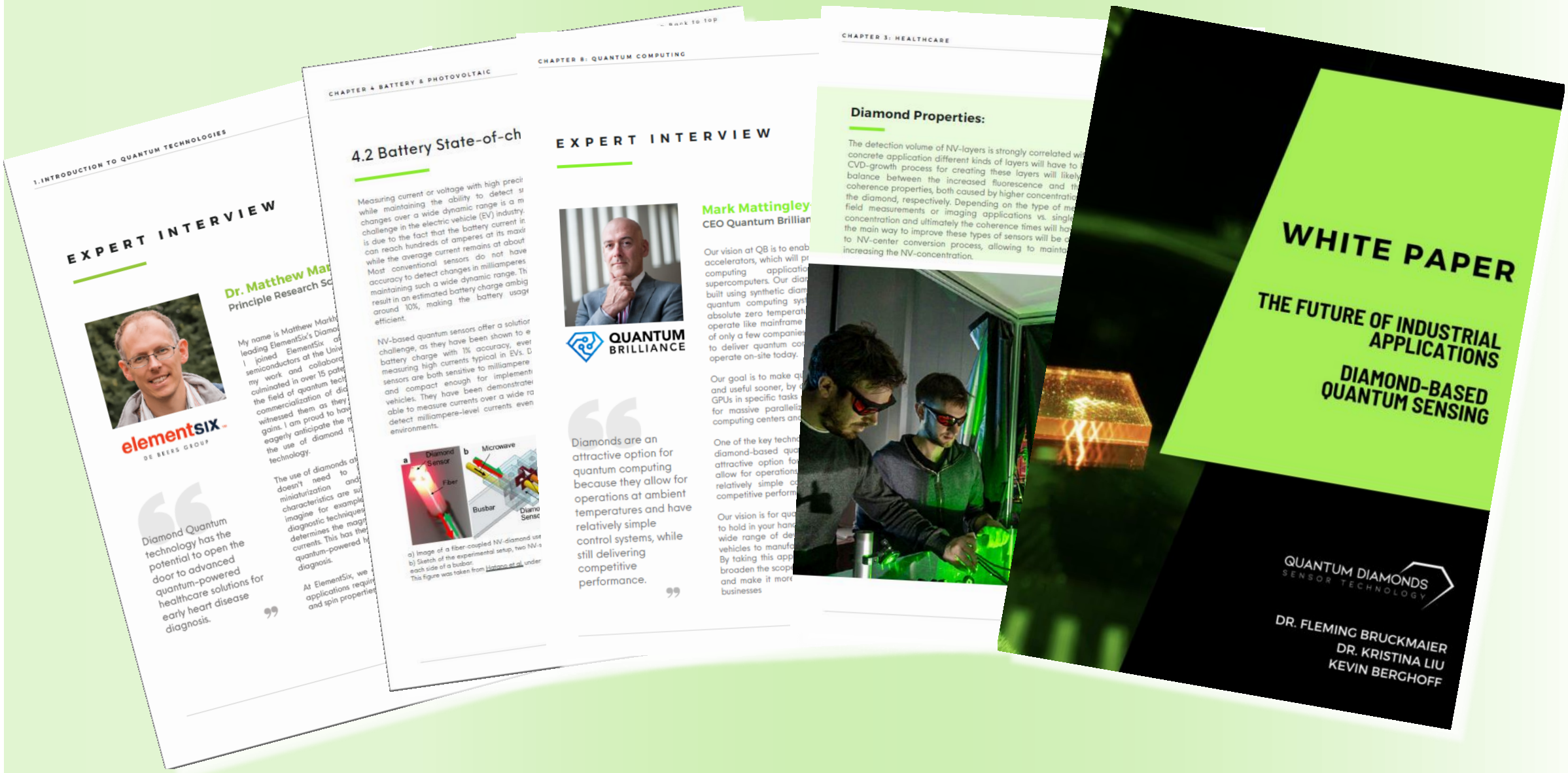
April 24th, 2024



NDT 4Industry

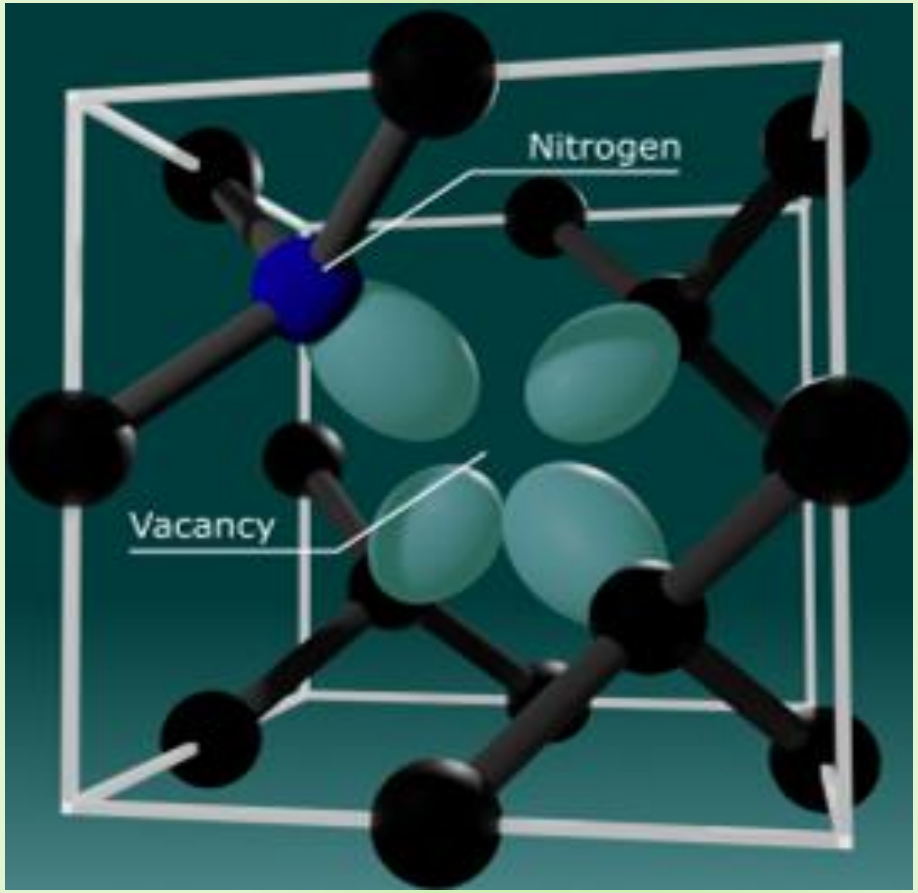
Quantum Sensors Linz 2024

If you are curious: We wrote a whitepaper you can access on our website

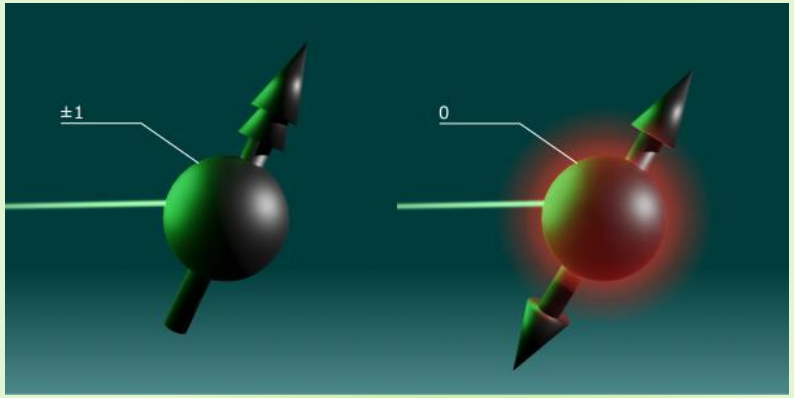


NV centers in diamonds and their use for diamond-based quantum sensing

Molecular Structure of an NV Diamond



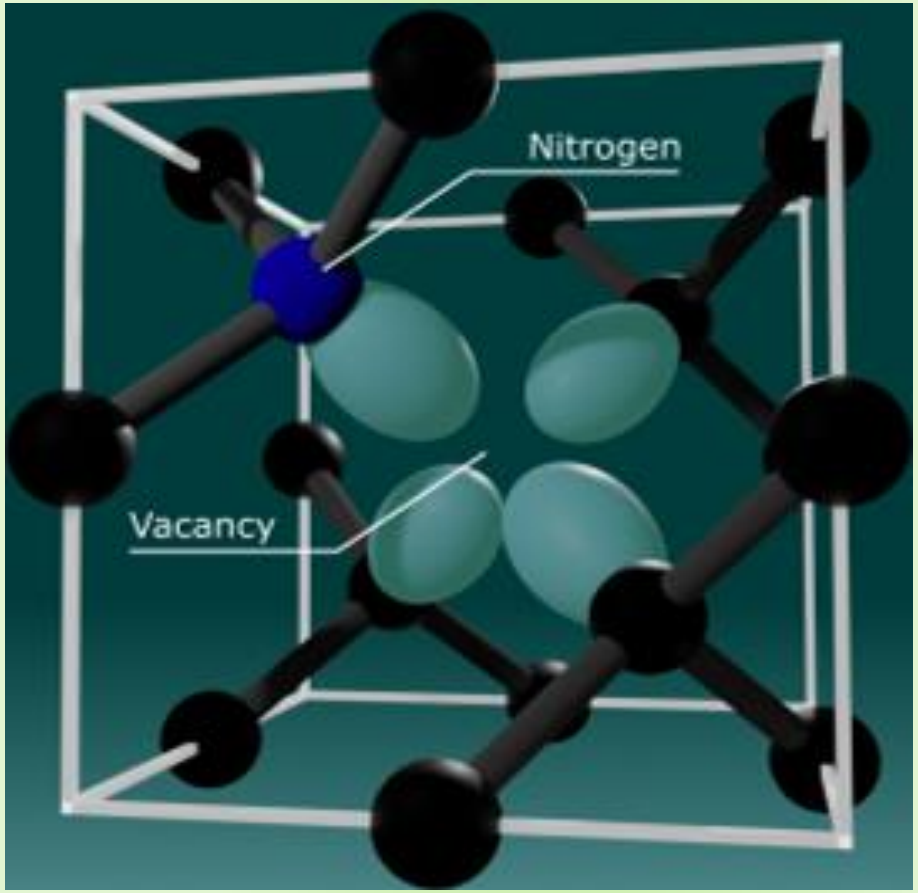
What is Diamond-based Quantum Sensing?



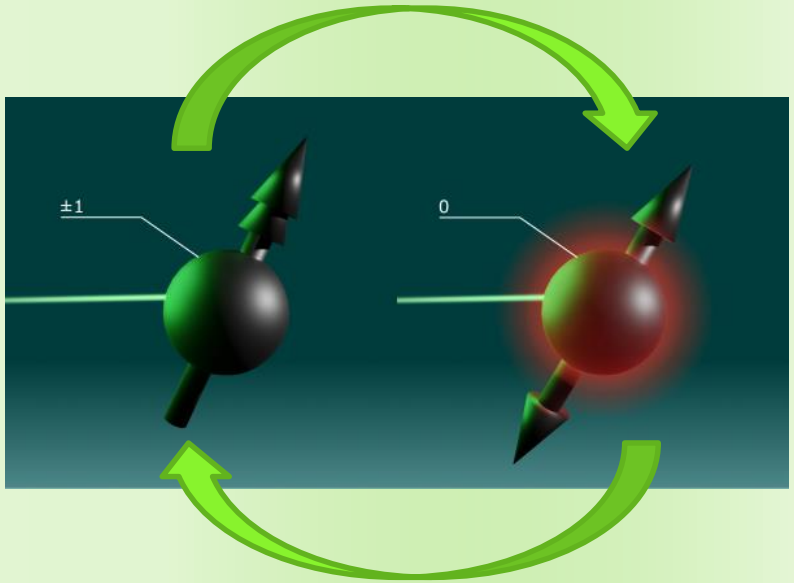
Red light depends on the quantum state

NV centers in diamonds and their use for diamond-based quantum sensing

Molecular Structure of an NV Diamond



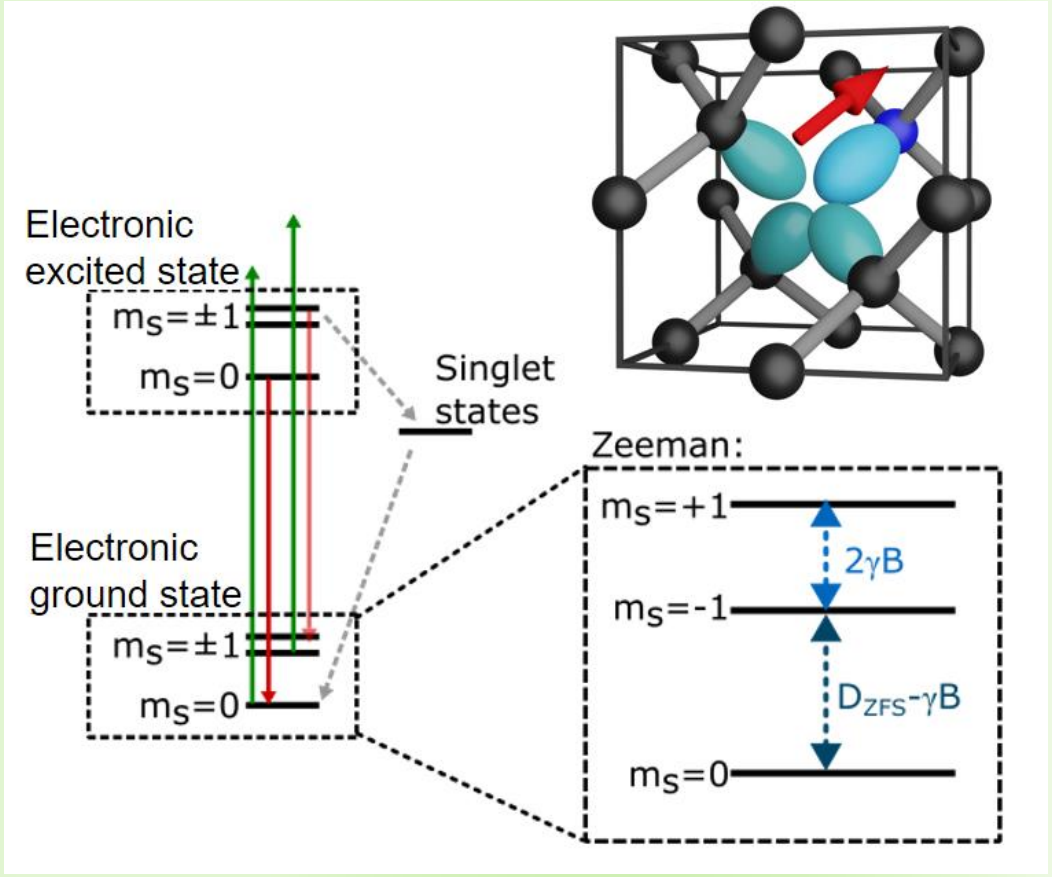
What is Diamond-based Quantum Sensing?



Manipulate using
Microwave

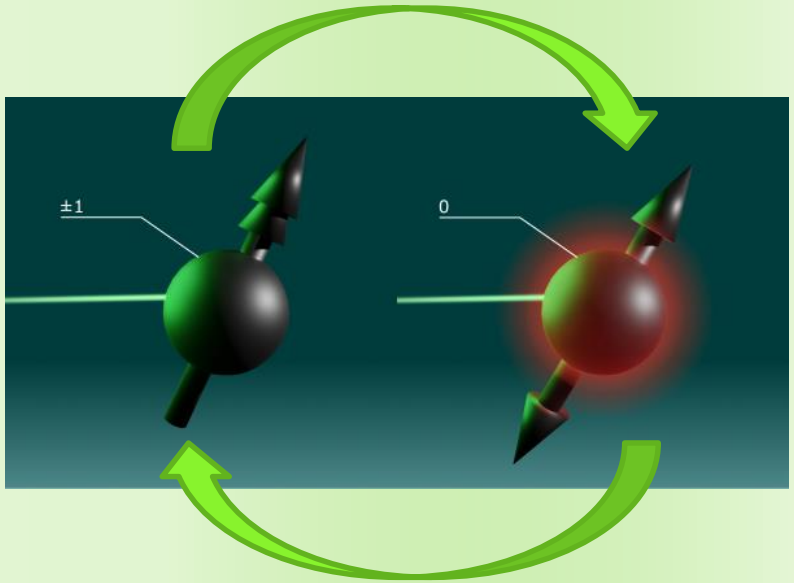
NV centers in diamonds and their use for diamond-based quantum sensing

Molecular Structure of an NV Diamond



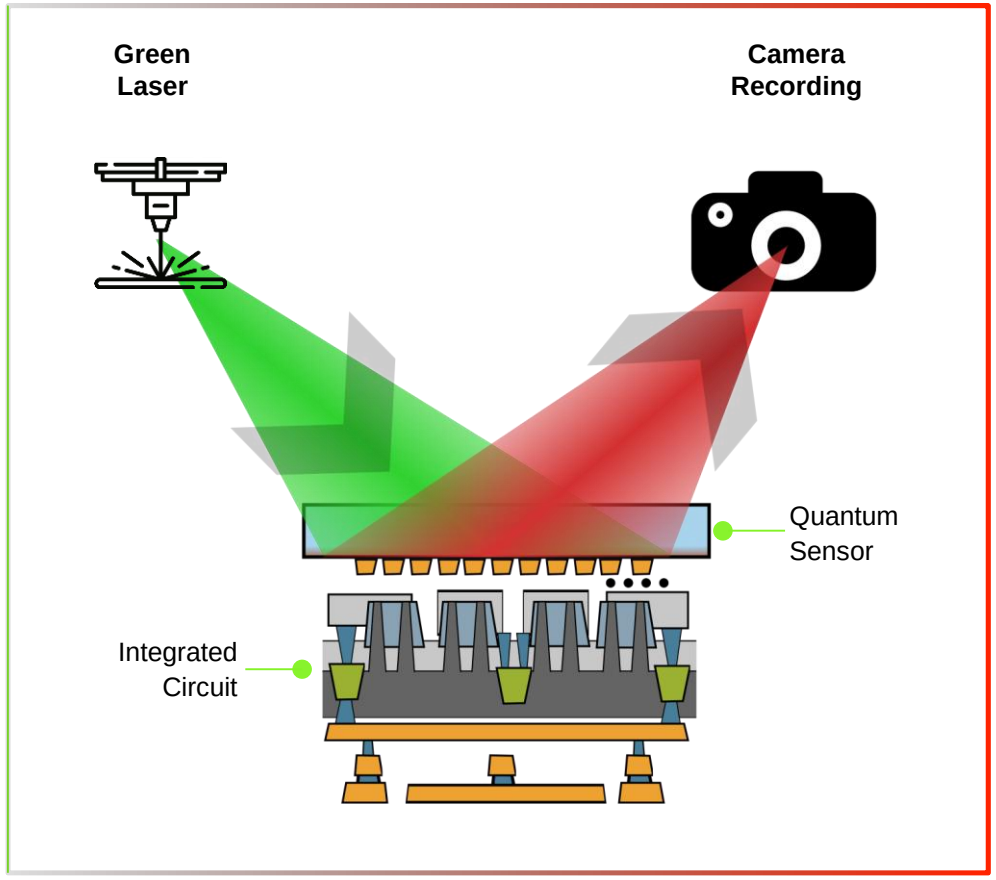
+

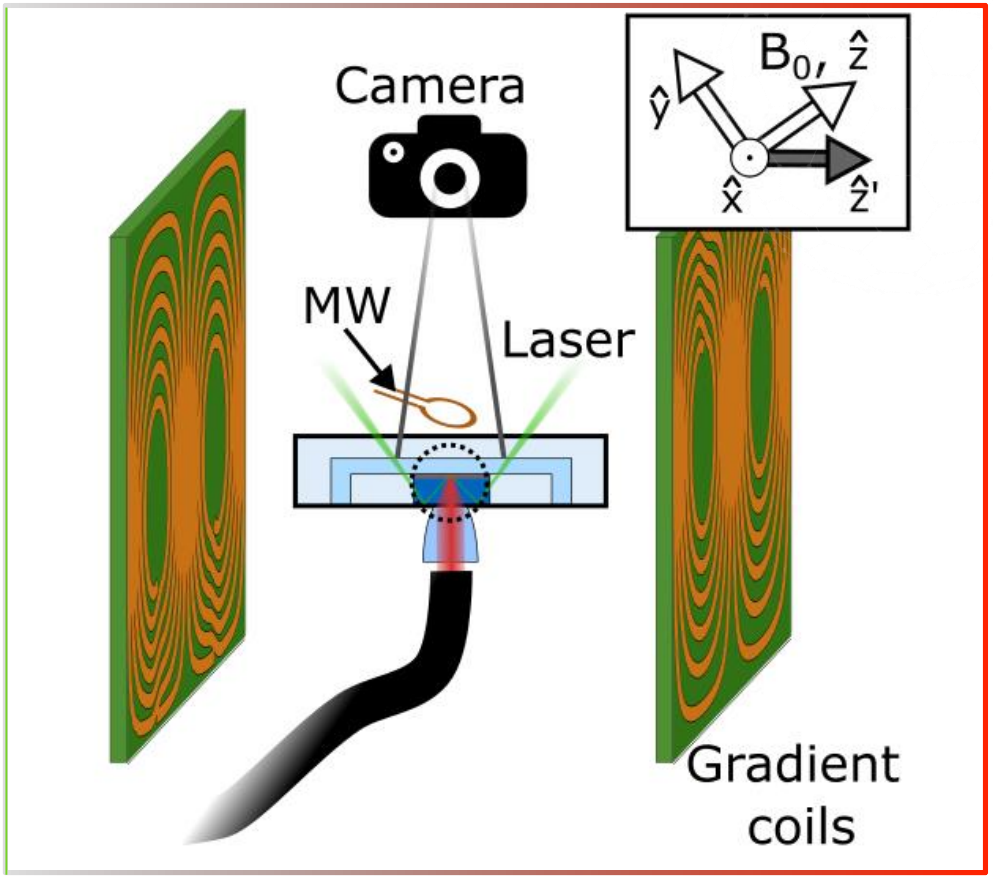
What is Diamond-based Quantum Sensing?



Manipulate using
Microwave

Examples of Experiments using NV-diamonds

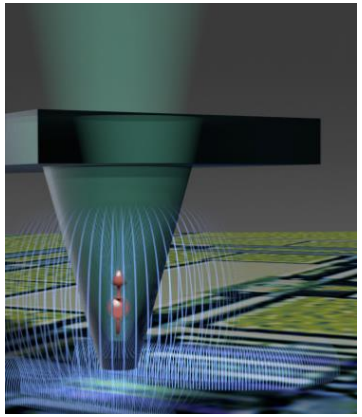


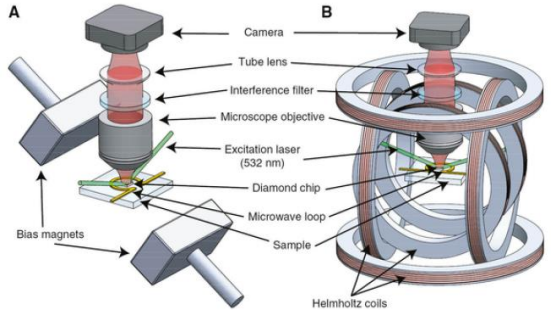


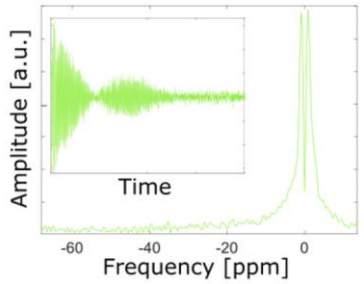
Bruckmaier, Fleming, et al. "Imaging local diffusion in microstructures using NV-based pulsed field gradient NMR." *Science Advances* 9.33 (2023): eadh3484.

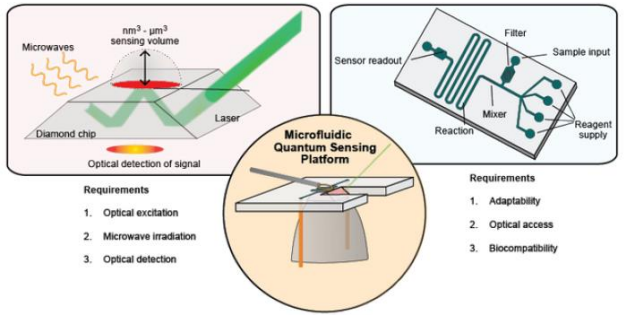
Many applications of NV-sensing

High Resolution



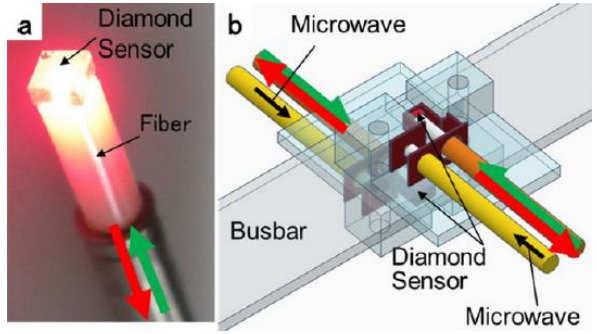


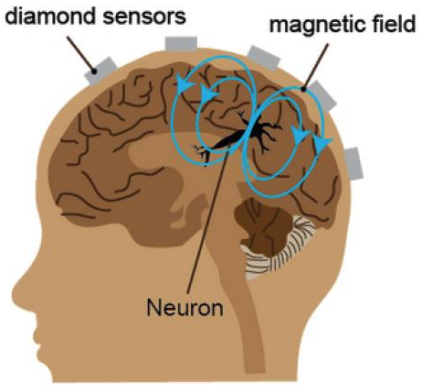


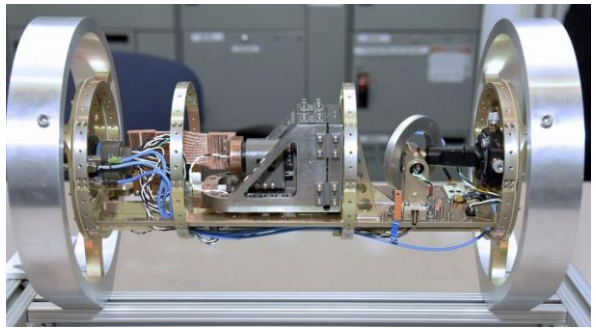


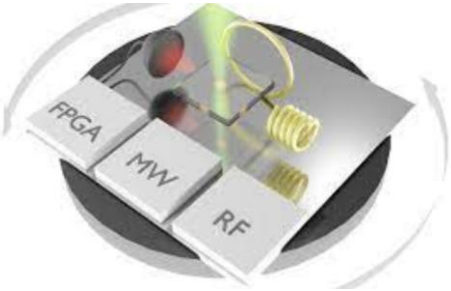
Scanning tip: https://www.iaf.fraunhofer.de/en/customers/quantum-systems/expertise-quantum-sensing.html
QDM: https://www.degruyter.com/document/doi/10.1515/nanoph-2019-0209/html?lang=de2019, pp. 1945-1973. https://doi.org/10.1515/nanoph-2019-0209

Macroscopic fields





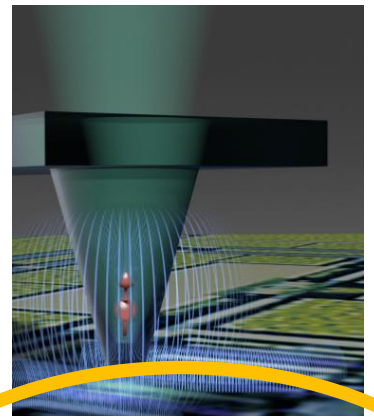


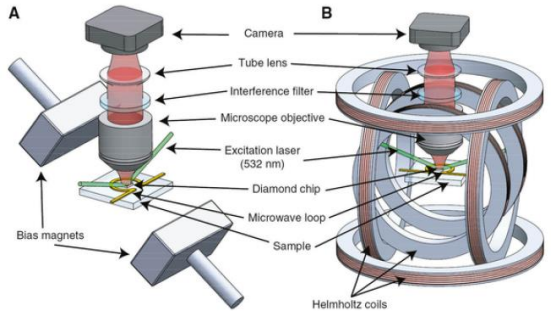


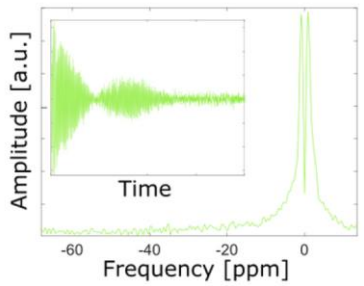
Busbar:. https://doi.org/10.1038/s41598-022-18106-x
Gyro: https://arxiv.org/pdf/2009.00916.pdf
Bottom: https://www.lockheedmartin.com/en-us/news/features/2019-features/tech-thats-cool-as-dark-ice.html

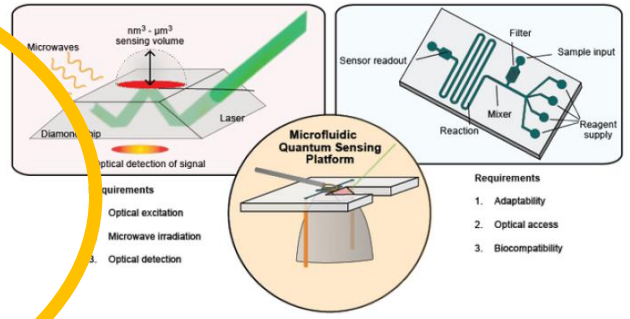
Many applications of NV-sensing

High Resolution



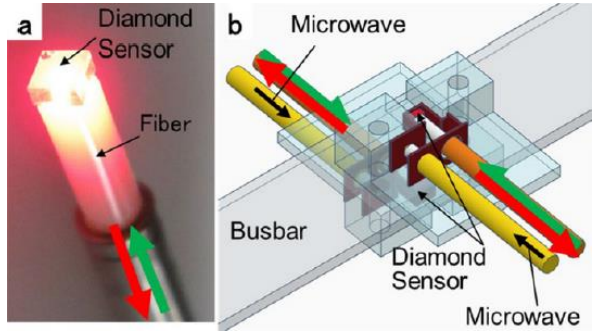


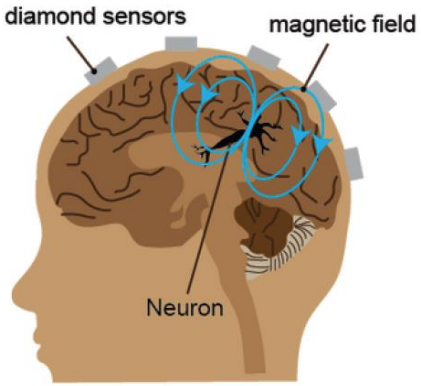


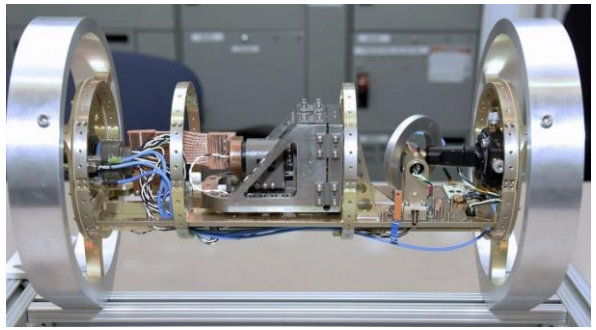


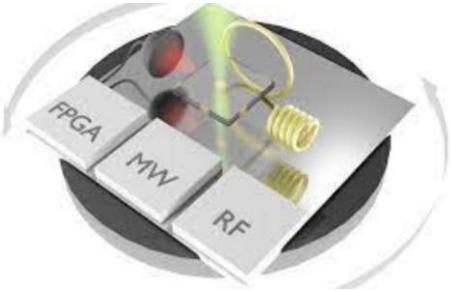
Scanning tip: https://www.iaf.fraunhofer.de/en/customers/quantum-systems/expertise-quantum-sensing.html
QDM: https://www.degruyter.com/document/doi/10.1515/nanoph-2019-0209/html?lang=de2019, pp. 1945-1973. https://doi.org/10.1515/nanoph-2019-0209

Macroscopic fields









Busbar:. https://doi.org/10.1038/s41598-022-18106-x
Gyro: https://arxiv.org/pdf/2009.00916.pdf
Bottom: https://www.lockheedmartin.com/en-us/news/features/2019-features/tech-thats-cool-as-dark-ice.html

Working towards microscale MRI

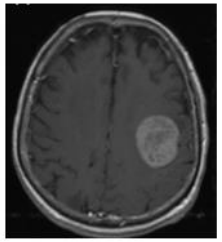
Diffusion-MRI



NV-NMR

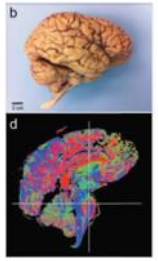


1 mm — 0.1 mm — 10 µm — < 1 µm



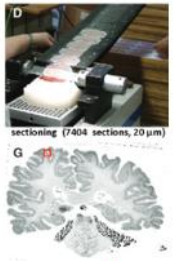
In vivo cancer research

Padhani, Anwar R et al. "Diffusion-weighted magnetic resonance imaging as a cancer biomarker: consensus and recommendations." *Neoplasia (New York, N.Y.)* vol. 11,2 (2009): 102-25.



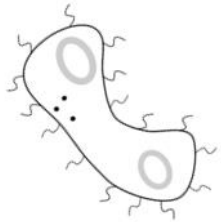
Ex vivo biological tissues

McNab, Jennifer A et al. "The Human Connectome Project and beyond: initial applications of 300 mT/m gradients." *NeuroImage* vol. 80 (2013): 234-45.



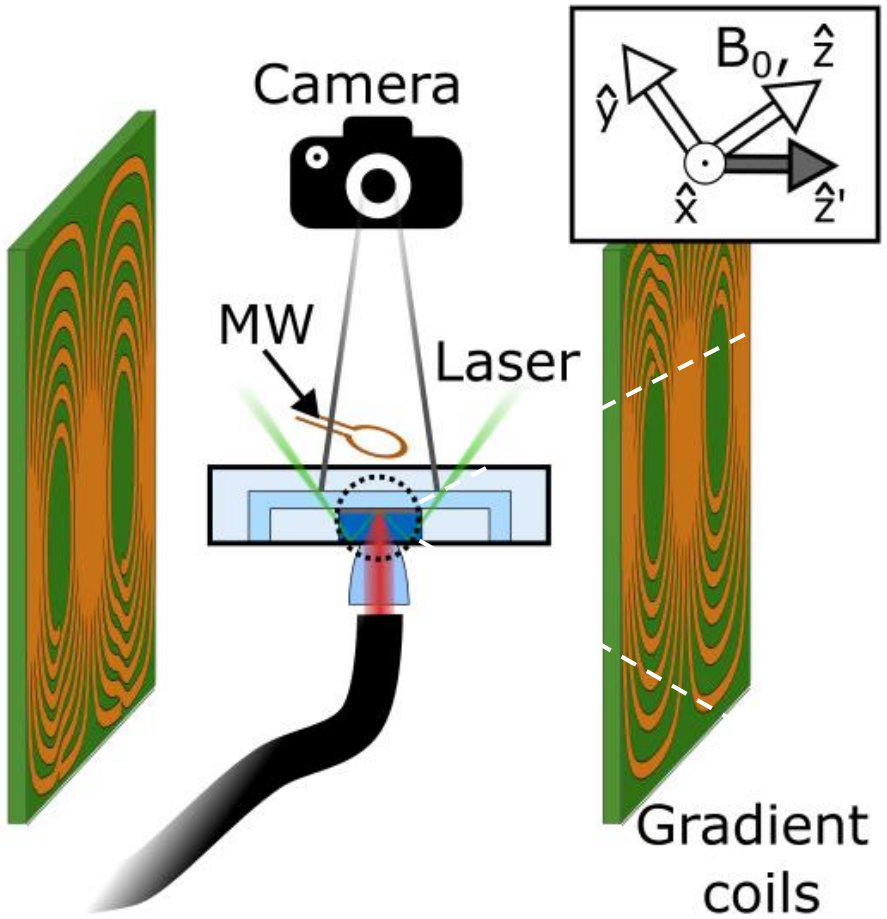
Tissue slices

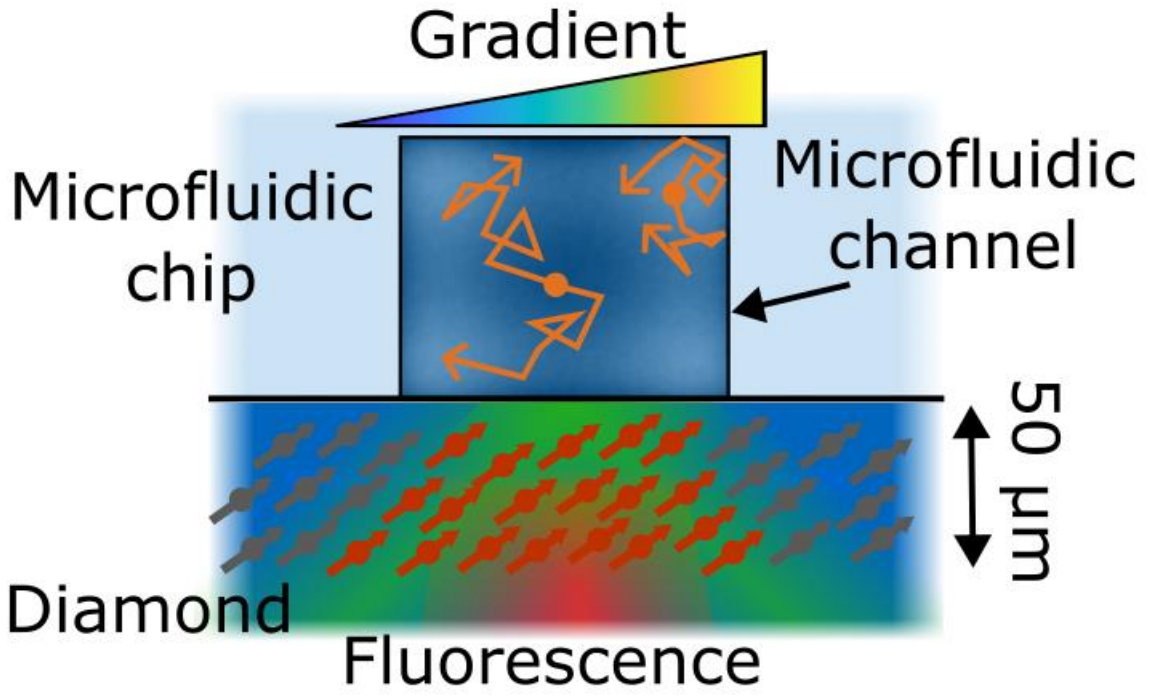
Amunts, Katrin et al. "BigBrain: an ultrahigh-resolution 3D human brain model." *Science (New York, N.Y.)* vol. 340,6139 (2013): 1472-5. doi:10.1126/science.1235381



Single cells

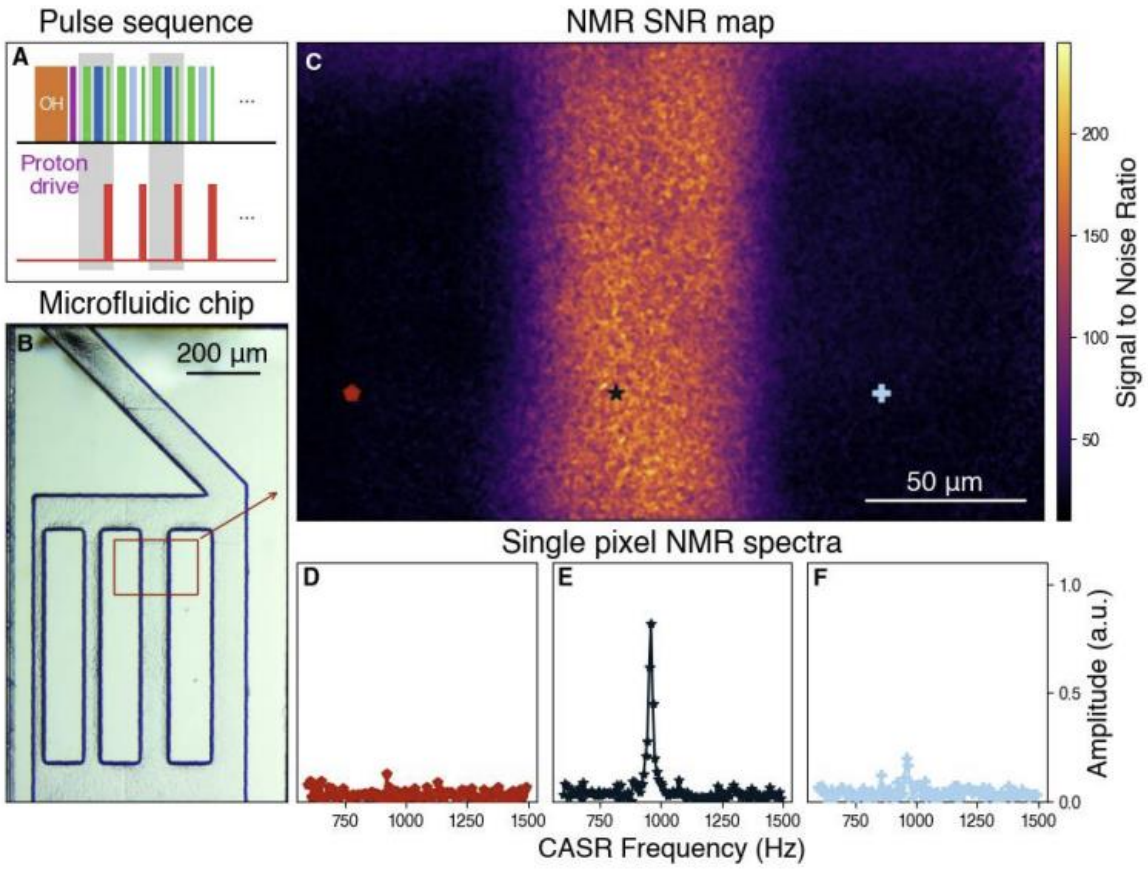
A Microscale MRI Device



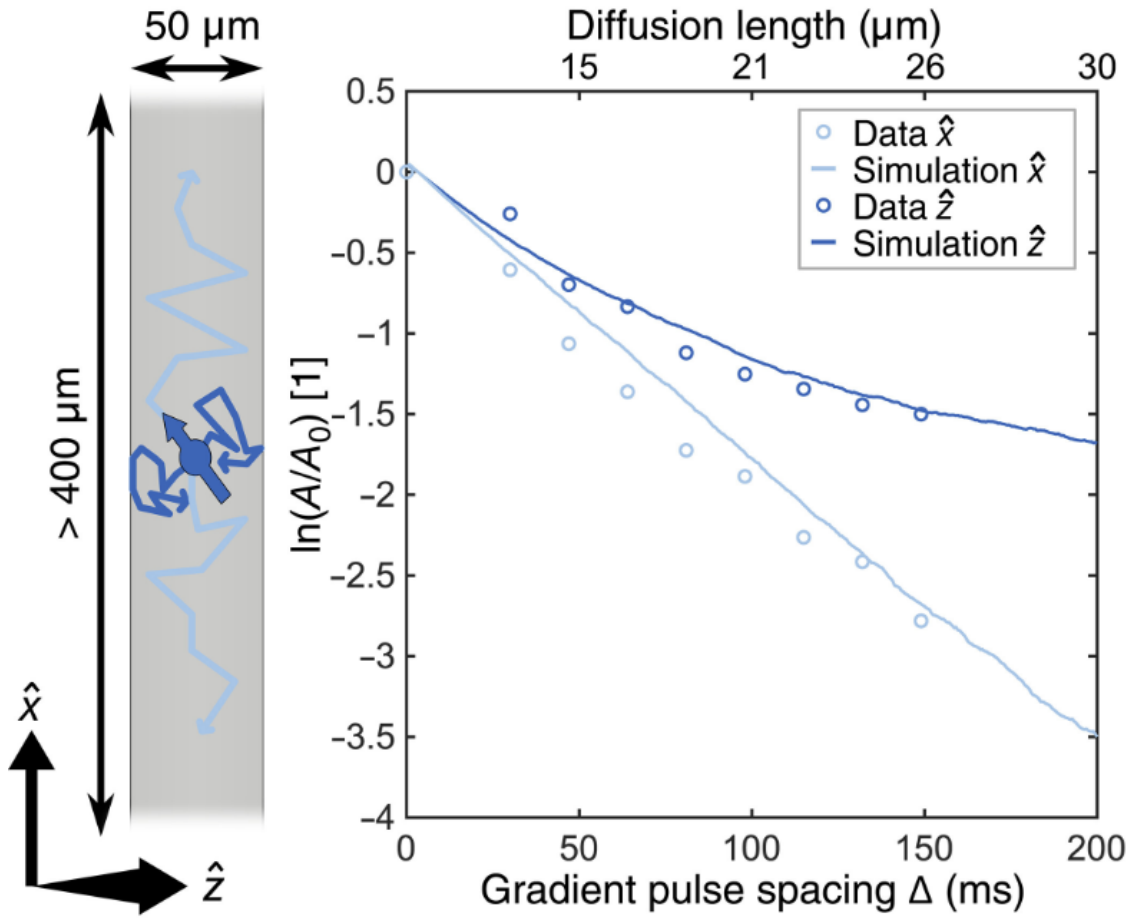


Bruckmaier, Fleming, et al. "Imaging local diffusion in microstructures using NV-based pulsed field gradient NMR." *Science Advances* 9.33 (2023): eadh3484.

A Microscale MRI Device



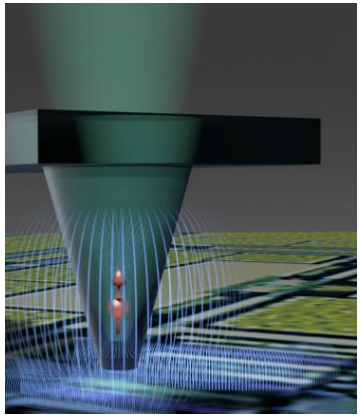
Briegel, Karl D., et al. "Optical Widefield Nuclear Magnetic Resonance Microscopy." *arXiv preprint arXiv:2402.18239* (2024).

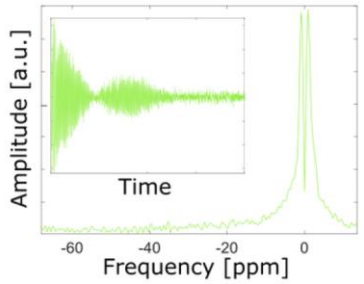


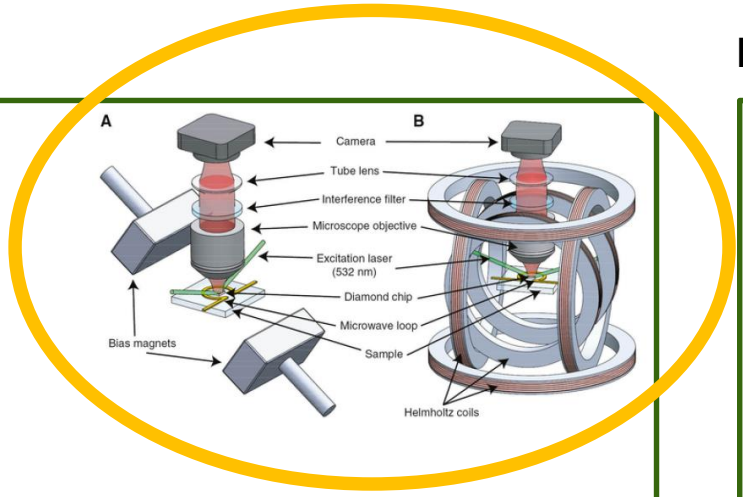
Bruckmaier, Fleming, et al. "Imaging local diffusion in microstructures using NV-based pulsed field gradient NMR." *Science Advances* 9.33 (2023): eadh3484.

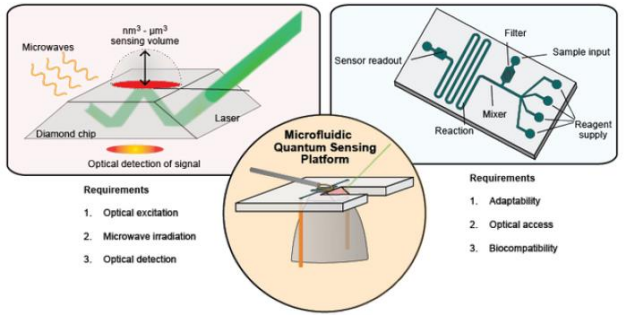
Many applications of NV-sensing

High Resolution



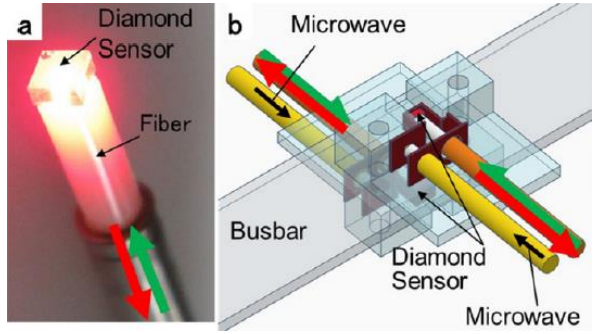


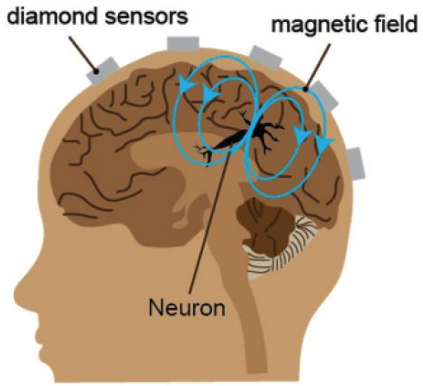


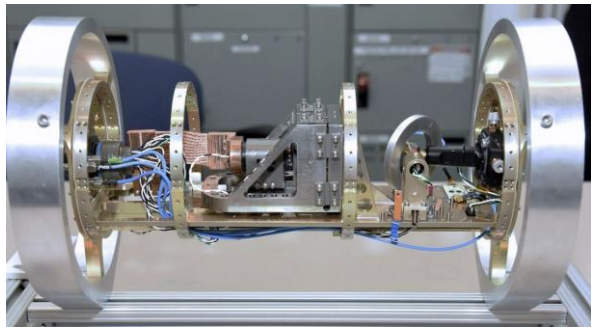


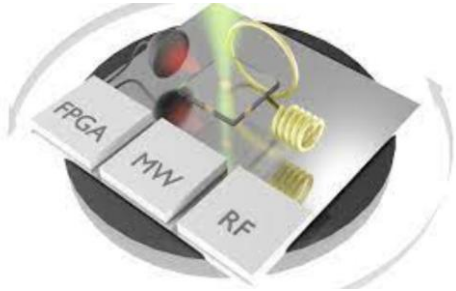
+

Macroscopic fields









Scanning tip: https://www.iaf.fraunhofer.de/en/customers/quantum-systems/expertise-quantum-sensing.html
QDM: https://www.degruyter.com/document/doi/10.1515/nanoph-2019-0209/html?lang=de2019, pp. 1945-1973. https://doi.org/10.1515/nanoph-2019-0209

Busbar:. https://doi.org/10.1038/s41598-022-18106-x
Gyro: https://arxiv.org/pdf/2009.00916.pdf
Bottom: https://www.lockheedmartin.com/en-us/news/features/2019-features/tech-thats-cool-as-dark-ice.html

Magnetic field sensing is useful in electrical failure analysis

Competing techniques

1. Surface only
2. Slow (hours)
3. Indirect

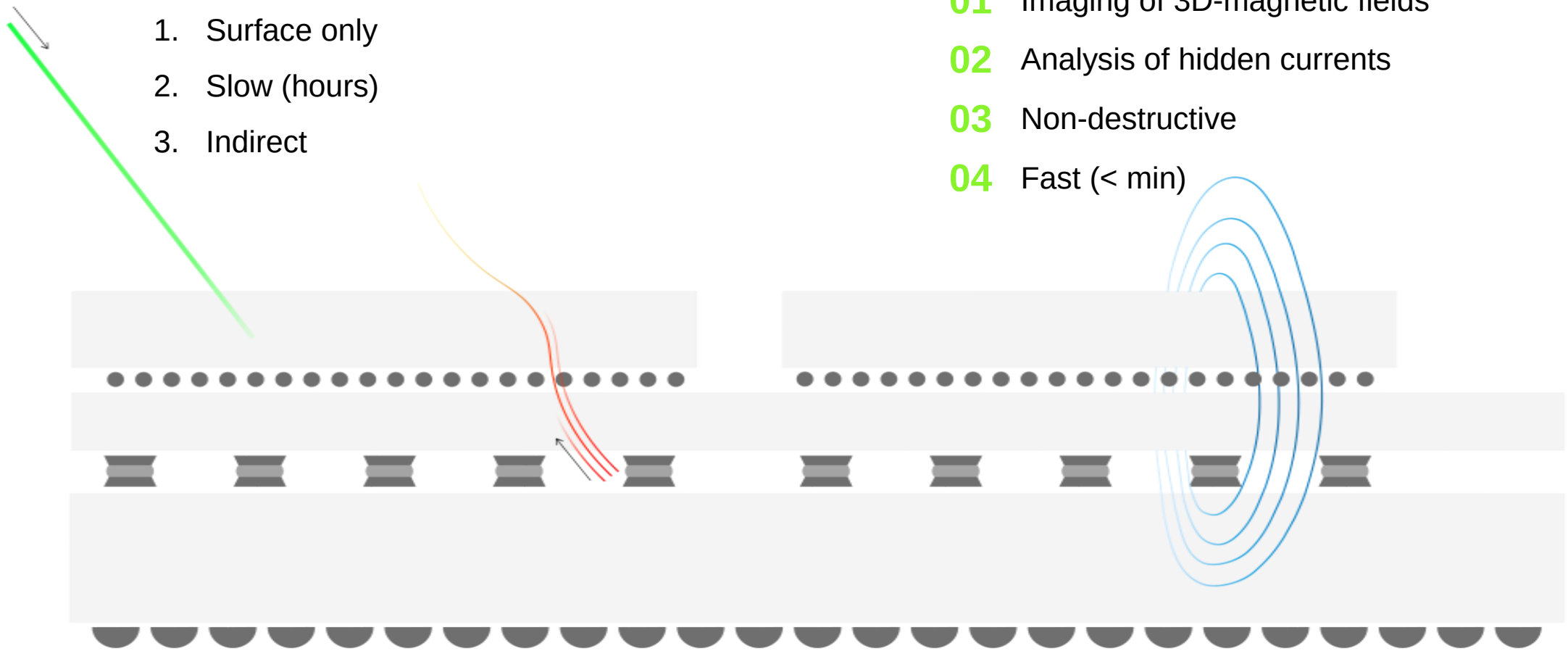
NV-Sensing

01 Imaging of 3D-magnetic fields

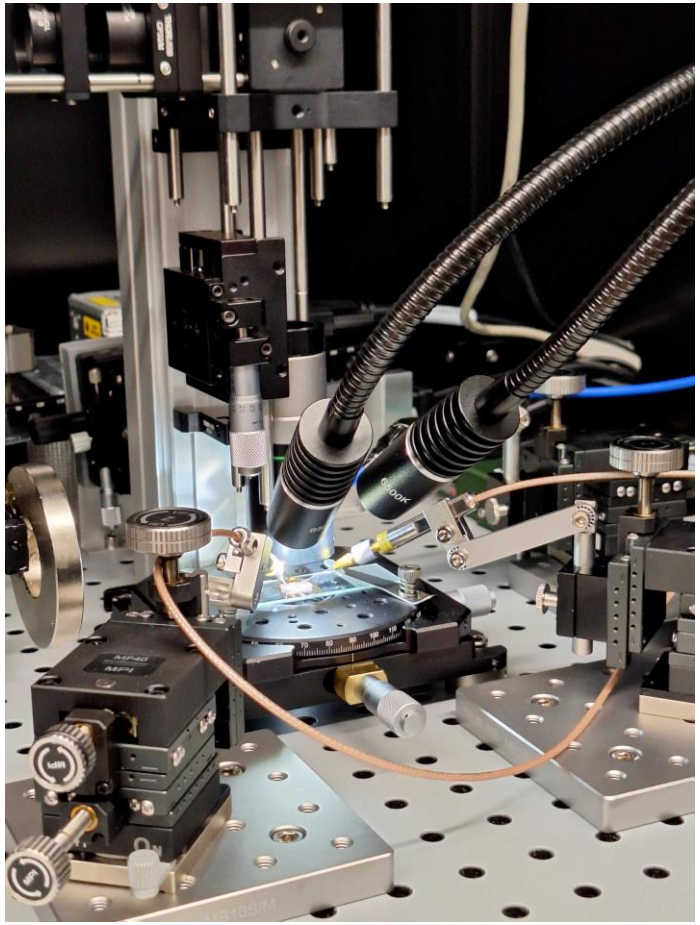
02 Analysis of hidden currents

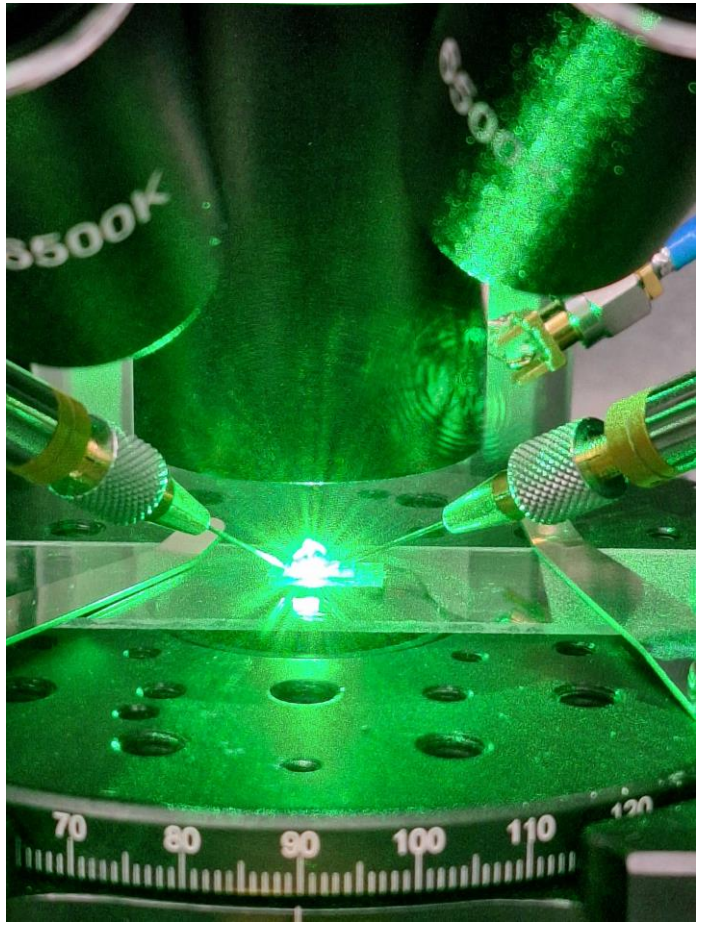
03 Non-destructive

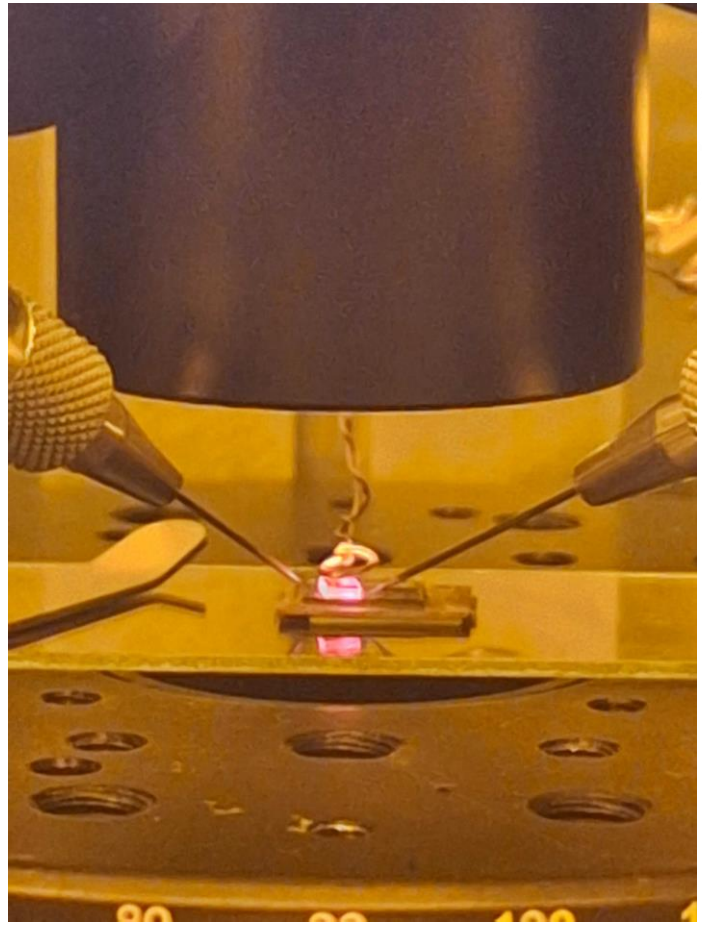
04 Fast (< min)



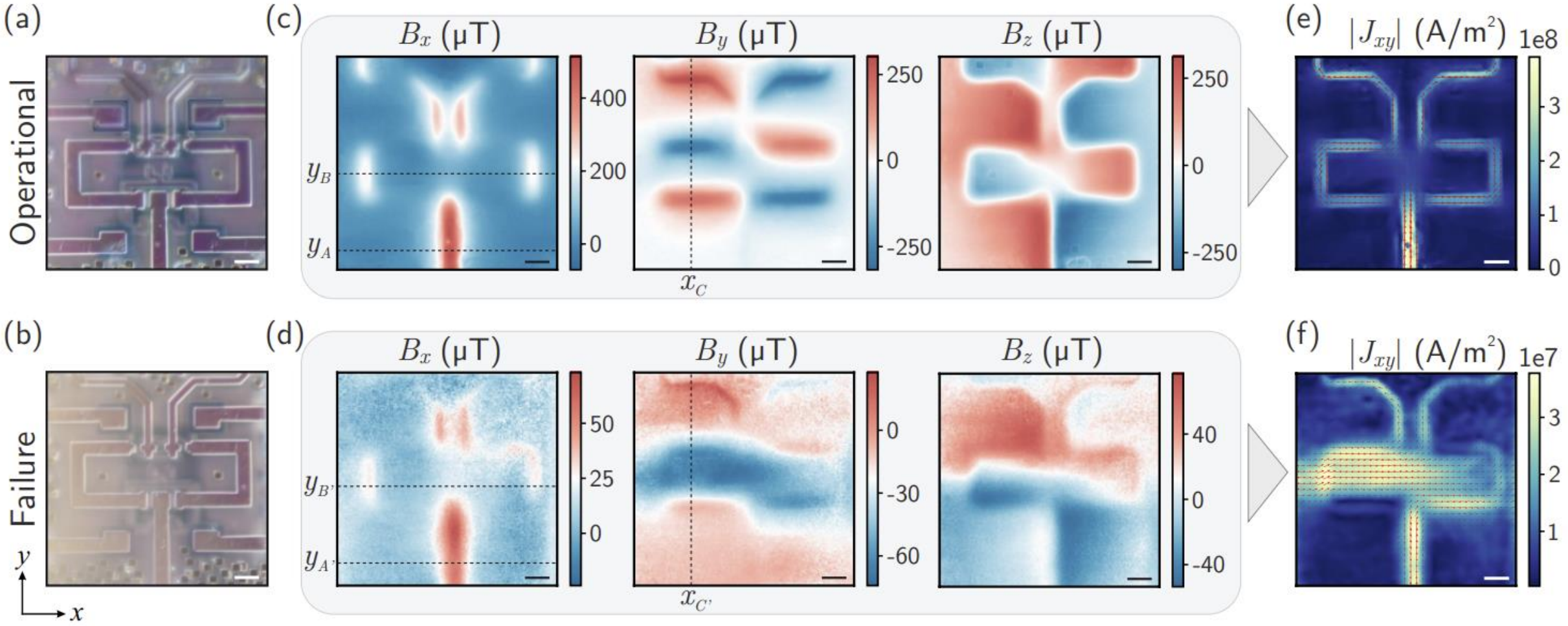
The Microscope in action



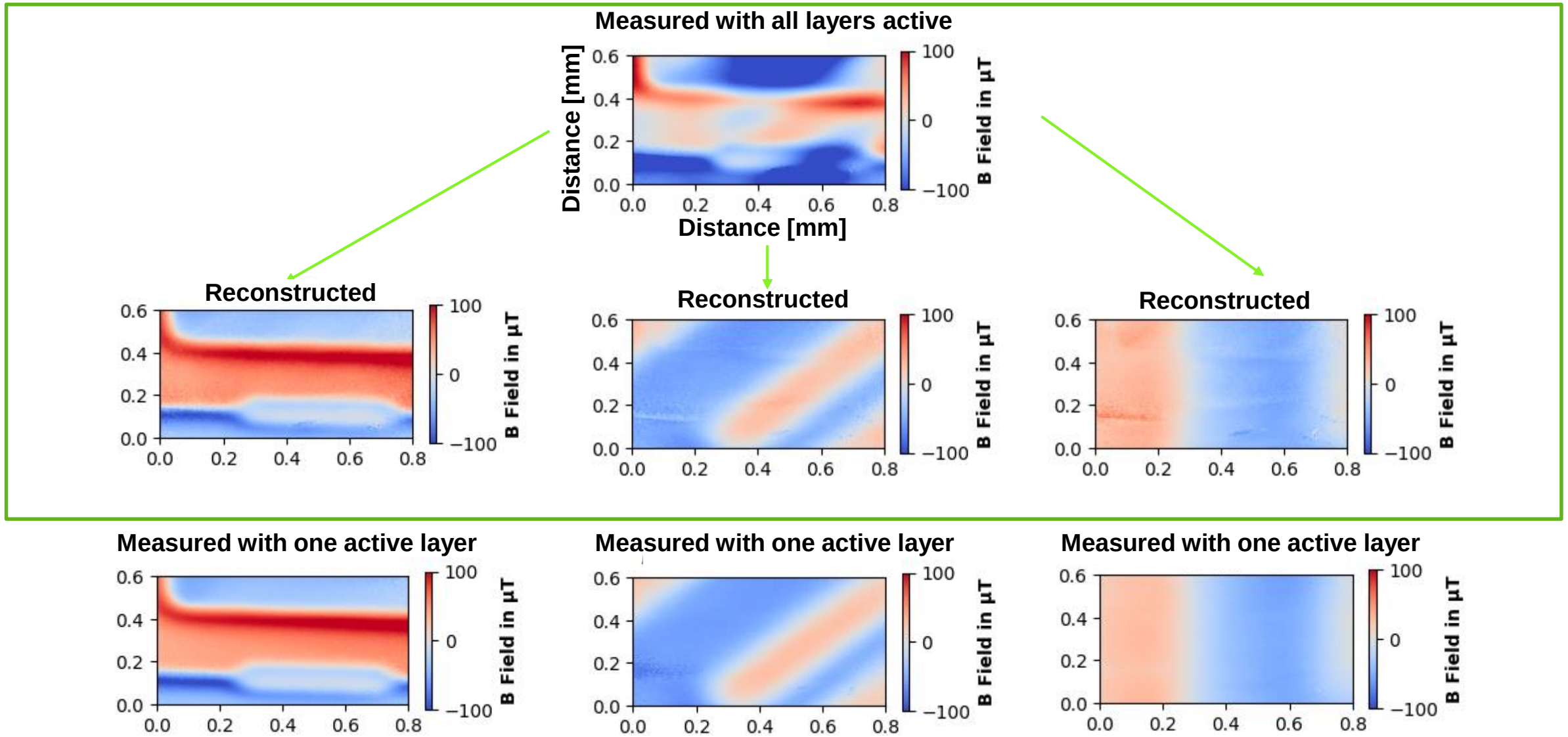




Typical Data of an Integrated circuit



We can reconstruct individual current-carrying layers



QUANTUM DIAMONDS
SENSOR TECHNOLOGY

Get in touch!



Dr. Fleming Bruckmaier

CTO

fleming.bruckmaier@quantumdiamonds

+49 151 730 710 26