Quantifying Magnetism at the Nanoscale

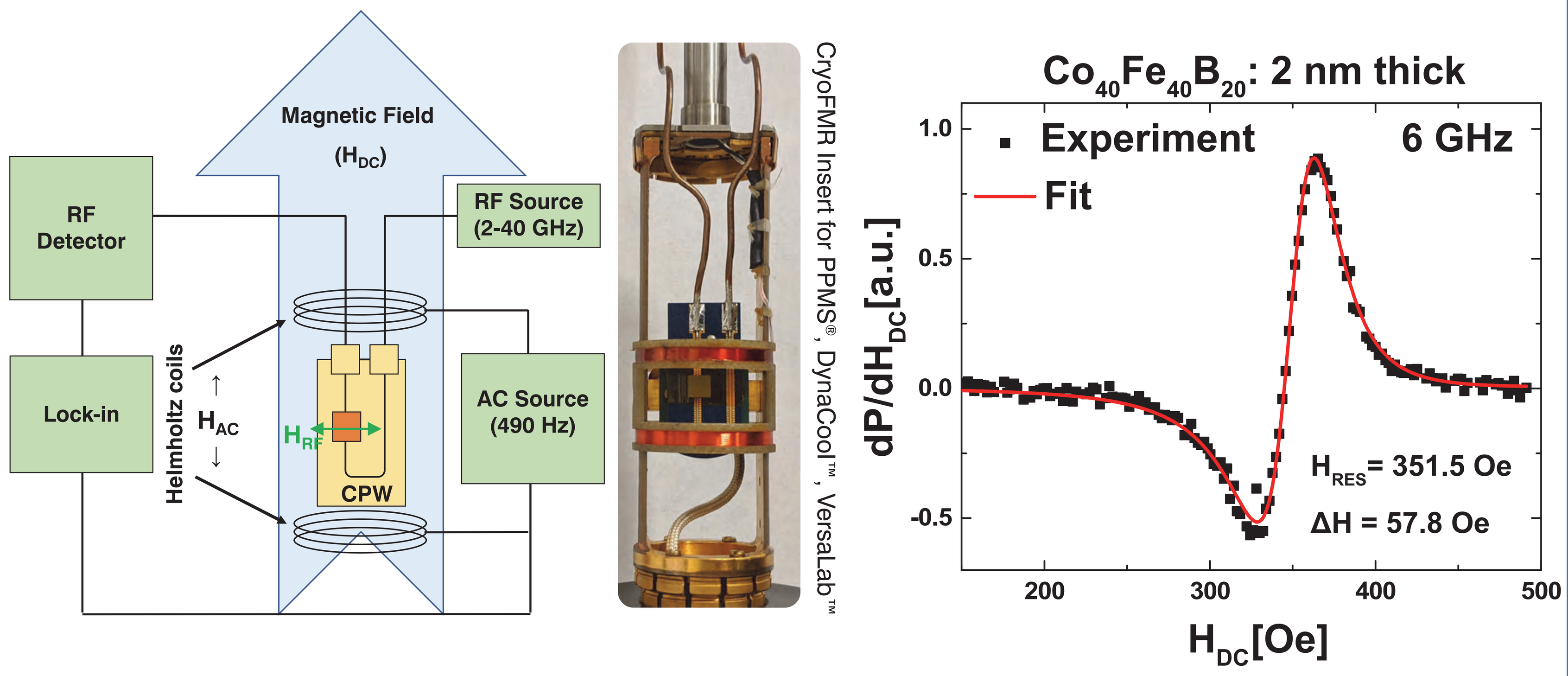
Since the inception of the world's first fully automated SQUID-based magnetometer in 1982, Quantum Design has been at the forefront of magnetic characterization. Continuing innovations have enabled DC and low-frequency magnetic property measurements at temperatures ranging from 50 mK to 1000 K at applied fields up to 16 tesla.

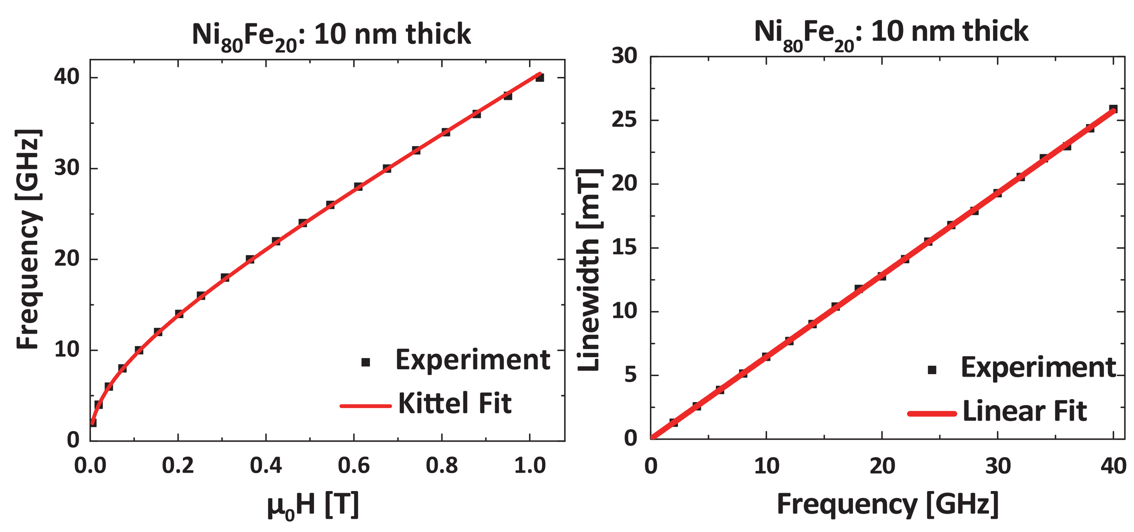
Here, we at Quantum Design highlight two of our latest offerings that enable quantitative magnetic measurements at:

Nanosecond (GHz) Timescales

Instrument	Bandwith	Temperature Range	Magnetic Field
PhaseFMR	2-8, -18, -40, -60 GHz	Room Temperature	User Supplied Voltage Controllable Power Supply/Electromagnet
CryoFMR	2-8, -18, -40 GHz	5*– 400 K: PPMS®/DynaCool™ 55*– 400 K: VersaLab™	±9, 12, 14, 16 T ±3 T

*Minimum temperature dependent on modulation amplitude and RF frequency





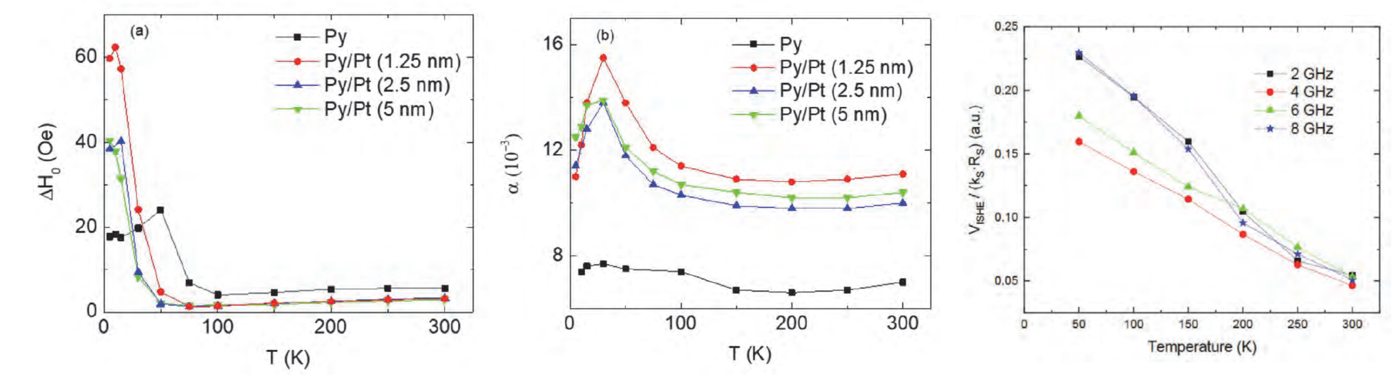
Easy to use software interface calculates:

- EffectiveMagnetization (M_{eff})
- Gyromagnetic Ratio(γ)
- GilbertDamping (α)
- Inhomogeneous Broadening (ΔH_0)

Enables one to also measure:

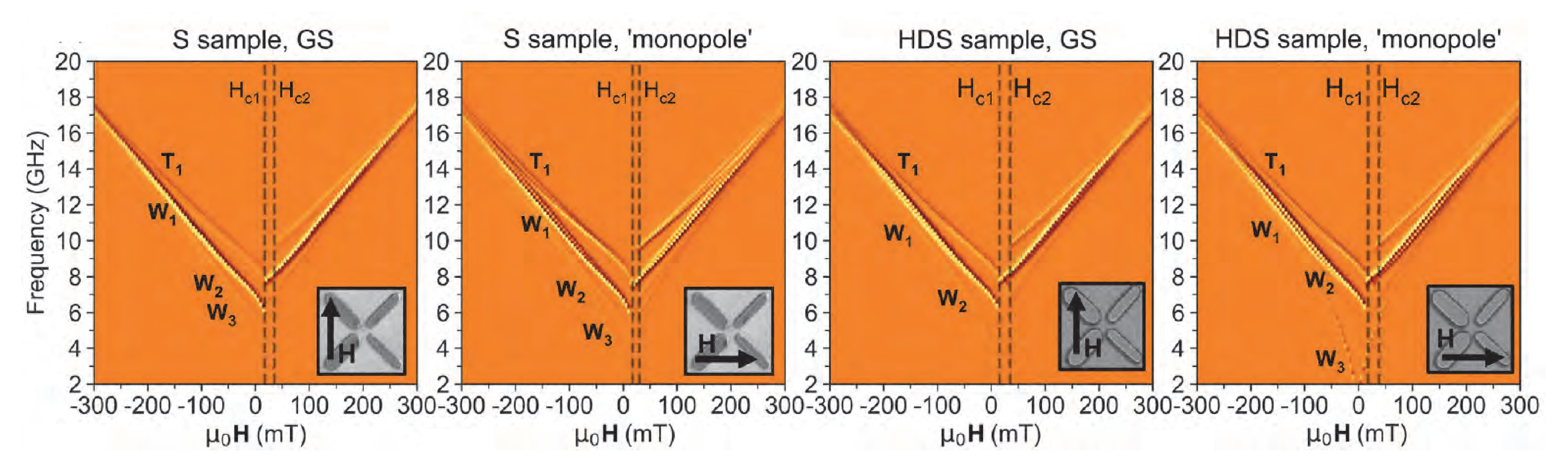
- Exchange Stiffness (A)
- Inverse Spin Hall Effect (ISHE)

Recent Research Highlights



As shown above,the temperature dependence of spin pumping and the inverse spin Hall effect is studied in permalloy/Pt bilayers.

S. Martín-Rio, *et al.*,JMMM. **500**, 166319 (2020)

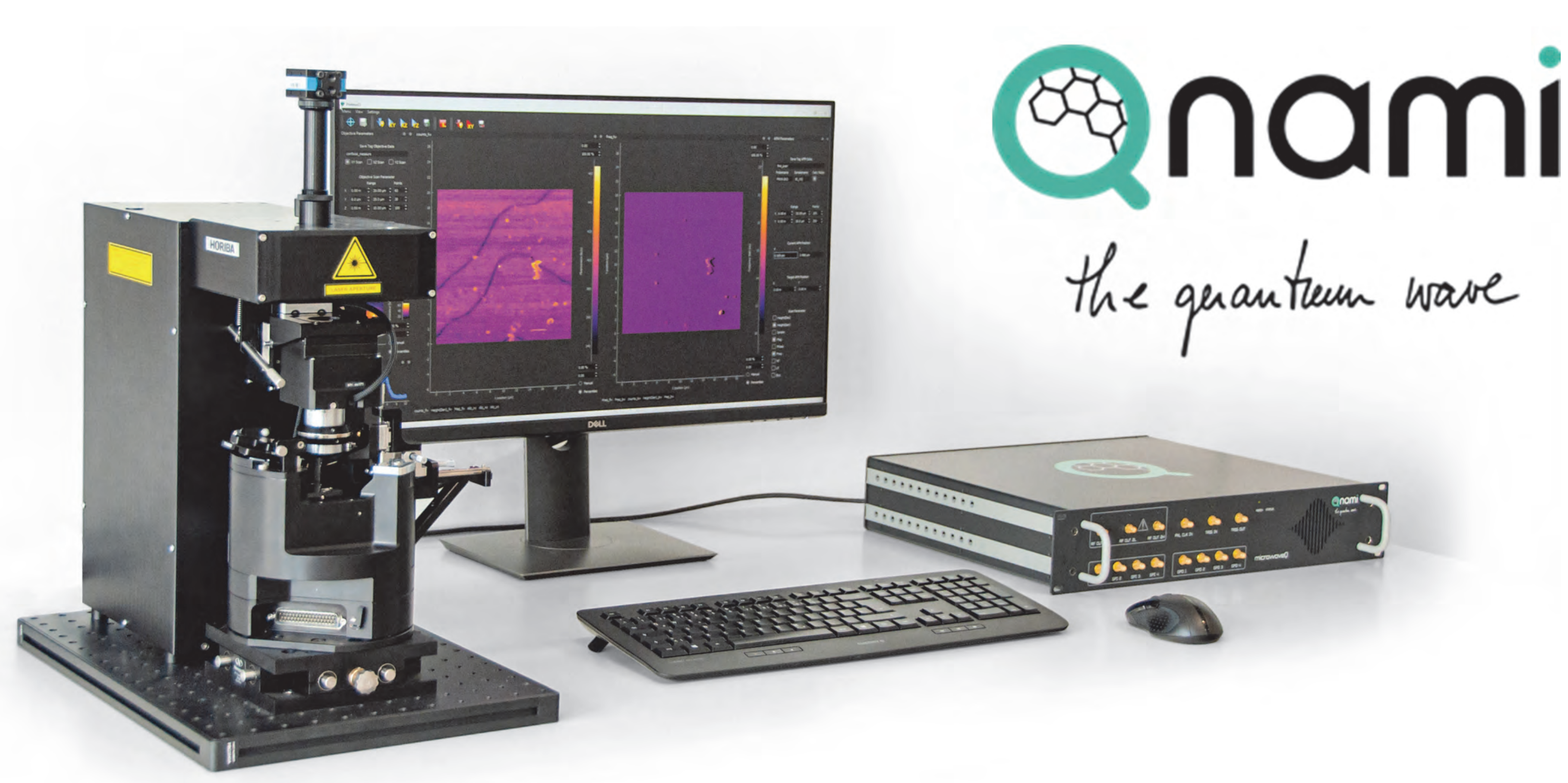


Strongly-interacting nanomagnet arrays, e.g. artificial spin ices, show promise for reconfigurable magnonics applications. The strong coupling allows for the reproducible generation of unique microstates. As shown above, the spectrally distinct microstates are probed with broadband FMR, which can serve as a quantitative fingerprint of the ensemble average response.

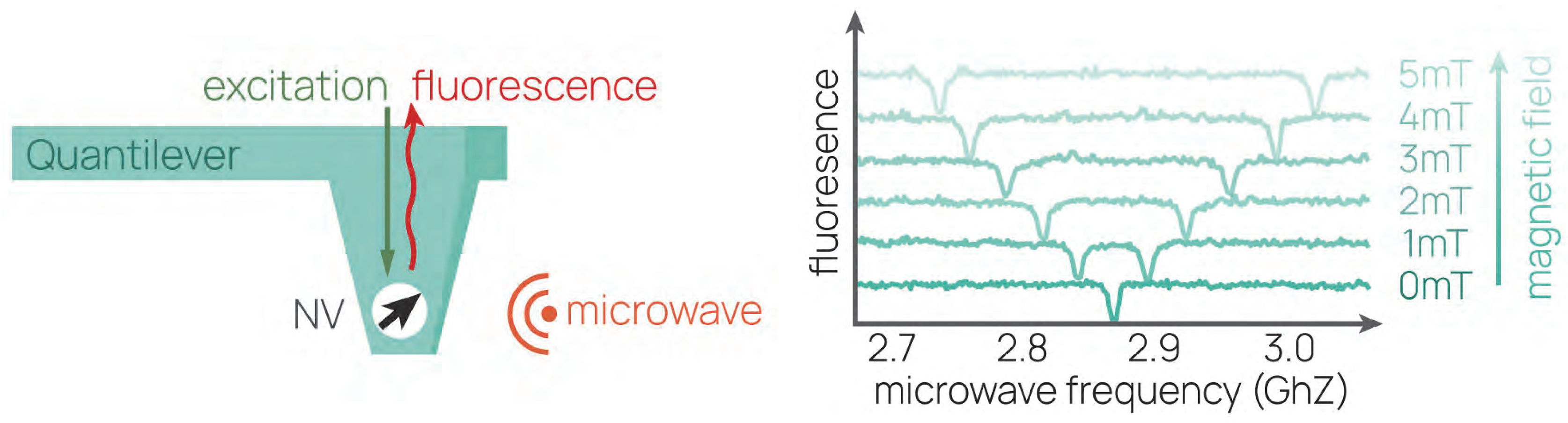
J. Gartside, *et al.*,Nat. Commun. **12**, 2488 (2021)

For more examples visit:
http://www.nanosc.se/testimonials.html

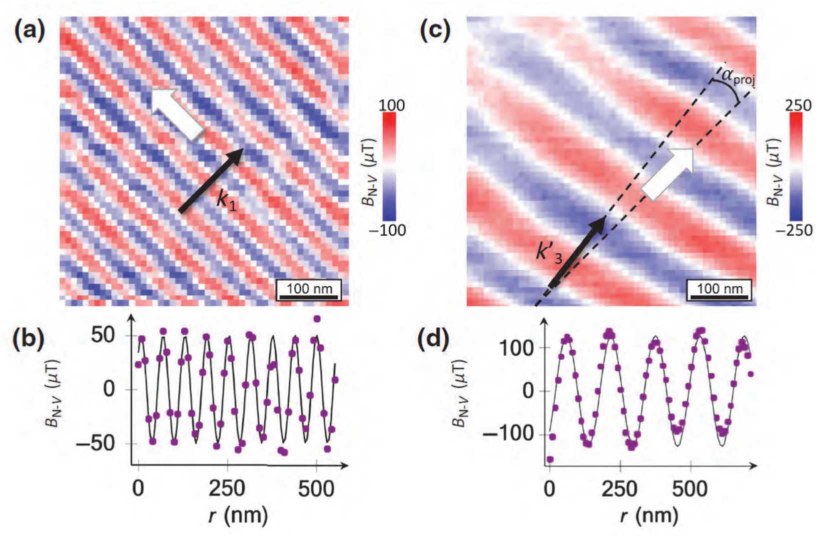
Nanometer Length Scales



the quantum wave



Recent Research Highlights

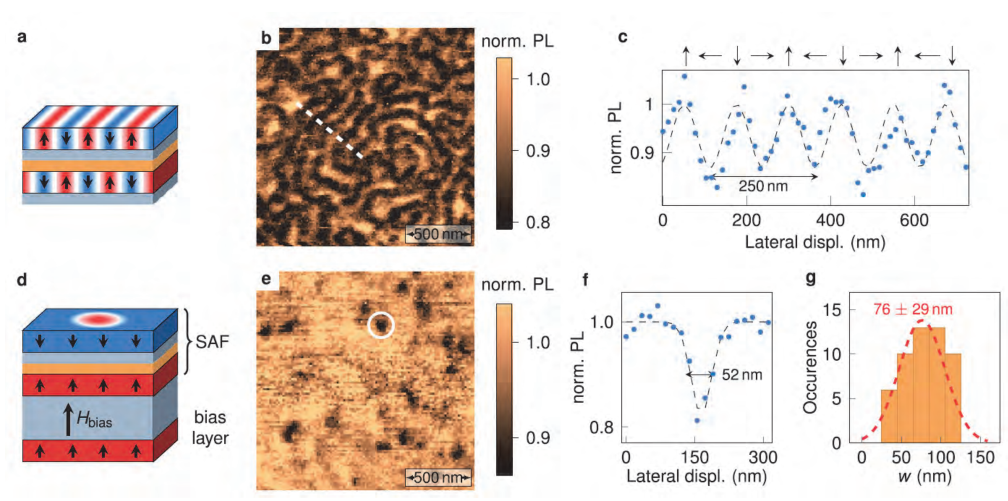


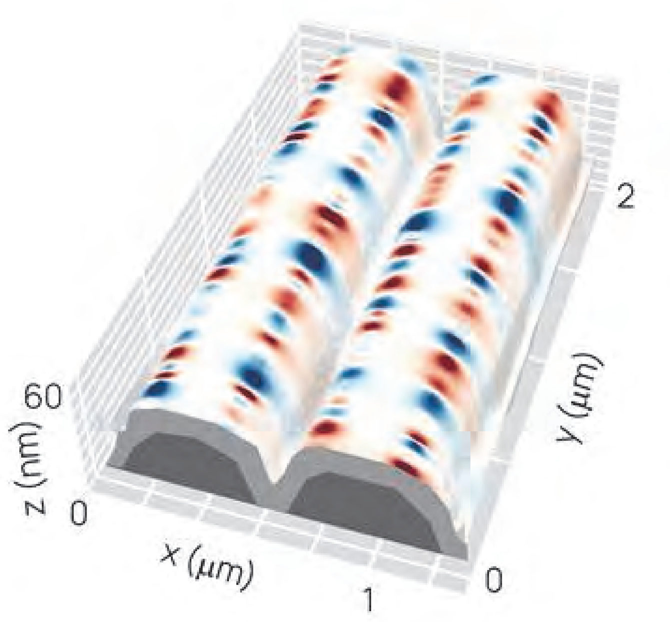
Bismuth ferrite is a promising material for low-power configurable antiferromagnetic spintronics. It is a room-temperature multiferroic material in which the antiferromagnetic spin textures can be controlled by electric fields. As shown to the left, scanning NV magnetometry enables the mapping of different flavors of spin cycloids stabilized in strain-engineered bismuth ferrite thin films. Furthermore, one can extract the relevant physical parameters for each type of cycloid.

H. Zhong, *et al.*, Phys. Rev. Appl. **17**, 044051 (2022)

Antiferromagnets are a promising platform for next-generation spintronics owing to their fast dynamics and insensitivity to parasitic magnetic fields. The flip-side to this coin is that such materials with zero net magnetization remain a major experimental challenge for nanoscale imaging. The figure to the right highlights high-resolution scanning NV center microscopy images of spin spiral (top) and skyrmion spin textures (bottom).

A. Finco, *et al.*, Nat. Commun. **12**, 767 (2021)





Magnetic nanowires are critical components in spintronic devices. Small inhomogeneities are often extremely difficult to detect due to the small physical scale and their weak signals, but can have dramatic consequences on skyrmion and domain wall motion. As shown to the left, the extremely high spatial resolution and sensitivity of scanning NV magnetometry has enabled researchers to quantitatively measure nanoscopic weak magnetic inhomogeneities in CoFeB nanowires.

U. Celano, *et al.*, Nano Lett. **21**, 10409 (2021)

For more examples visit:
https://qnami.ch/applications/

10307 Pacific Center Court, San Diego, CA 92121 | Tel: 858.481.4400 apps@qdusa.com www.qdusa.com