Imaging the magnetic order in antiferromagnets using scanning NV magnetometry

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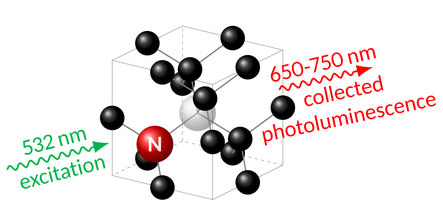
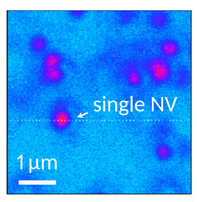
NV centers for magnetometry at the nanoscale

Nitrogen-Vacancy center

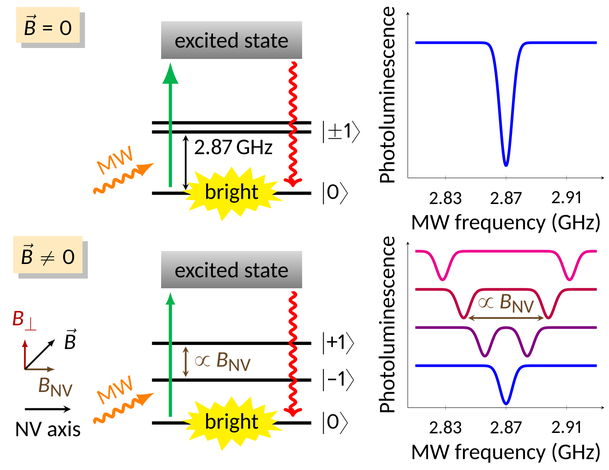




A. Gruber *et al. Science* 276 (1997), 2012–2014

Equivalent to an artificial atom with discrete energy levels inside the gap of the diamond

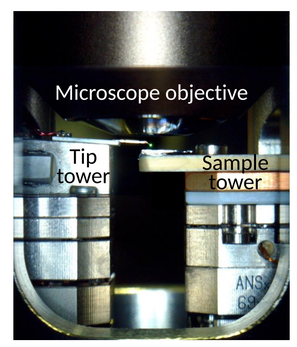
Optically Detected Magnetic Resonance

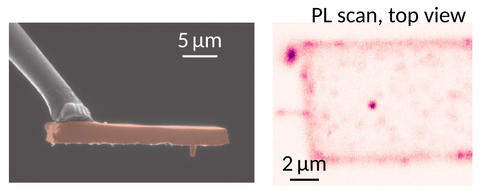


- **Atomic-size** magnetometer
- **Optical** detection
- Operation under **ambient conditions**

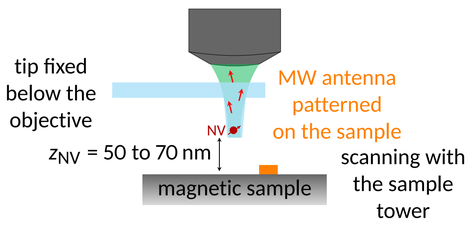
→ Perfect tool to probe the tiny stray field produced by antiferromagnets

Experimental setup





P. Maletinsky *et al. Nat. Nano.* 7 (2012), 320–324



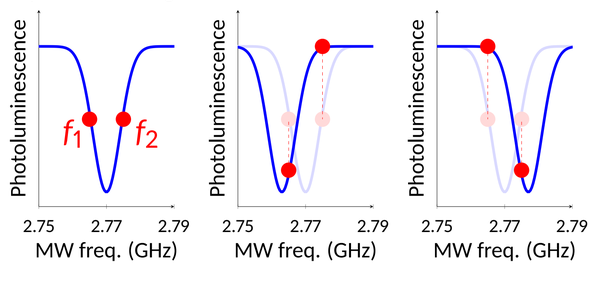
Effect of epitaxial strain on the cycloid in $BiFeO_3$

Dual iso-B measurement

Reference spectrum resonance shifted by a permanent magnet

Spectrum for $B_{NV}^{sample} > 0$

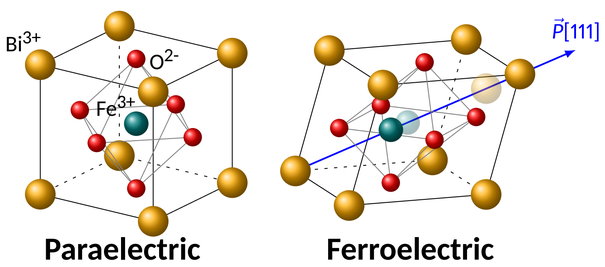
Spectrum for $B_{NV}^{sample} < 0$



ΔPL = PL(f_2) − PL(f_1) ΔPL > 0 ΔPL < 0

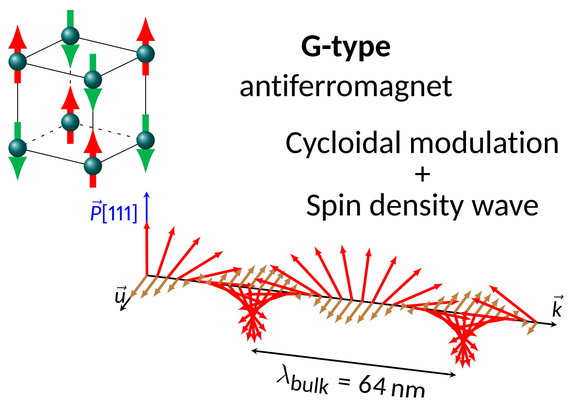
→ **Faster**, but the field value is unknown

Order coexistence in $BiFeO_3$

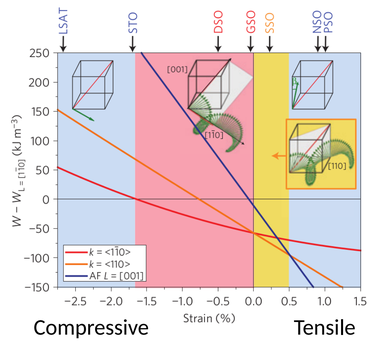


Paraelectric (T>1100 K) **Ferroelectric (T<1100 K)**

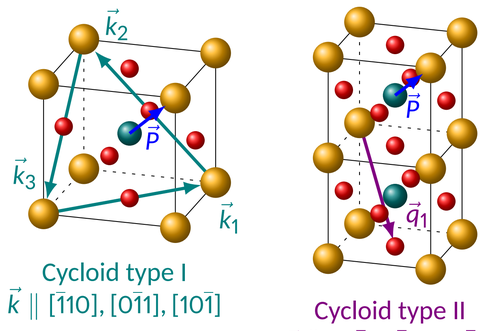
Large polarization P = 100 µC cm^{-2}



Two cycloid types



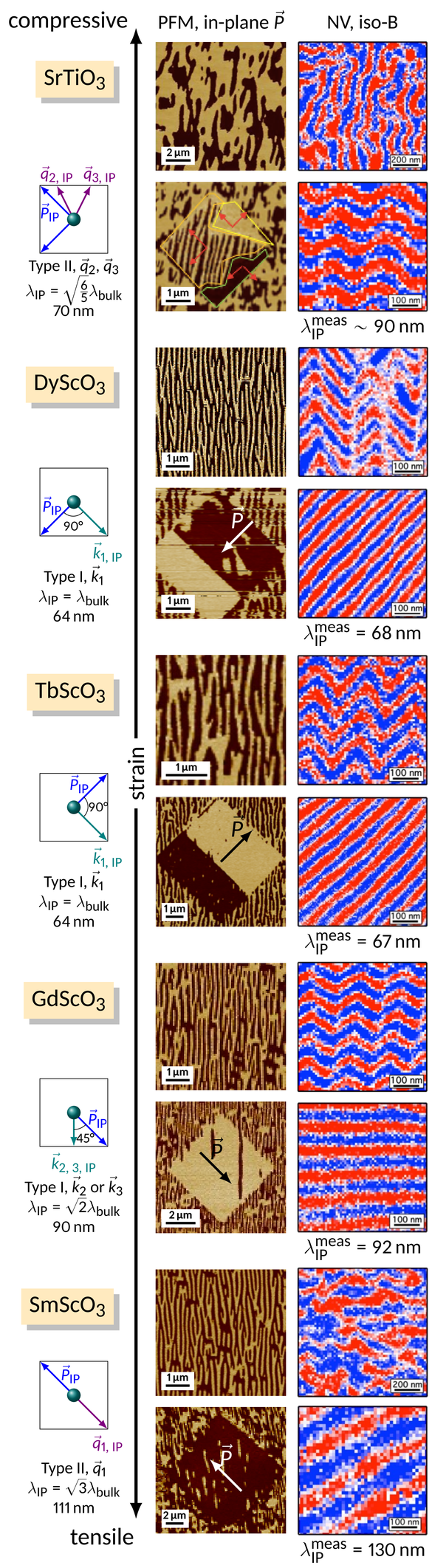
D. Sando *et al. Nature Materials* 12 (2013), 641–646



Cycloid type I
$\vec{k}$ || [$\bar{1}$10], [0$\bar{1}$1], [10$\bar{1}$]

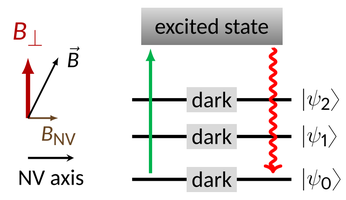
Cycloid type II
$\vec{q}$ || [11$\bar{2}$], [$\bar{2}$11], [1$\bar{2}$1]

Measured epitaxial strain effect

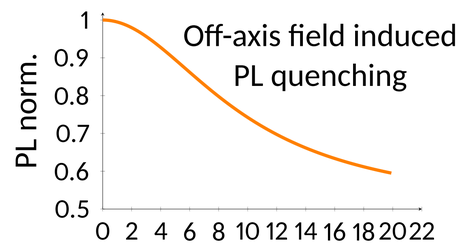


Magnetic noise in a synthetic antiferromagnet

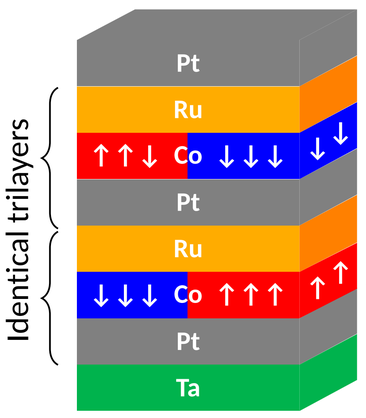
Quenching mode measurements



Large off-axis field
↓
Mixing of the spin states



Synthetic antiferromagnets



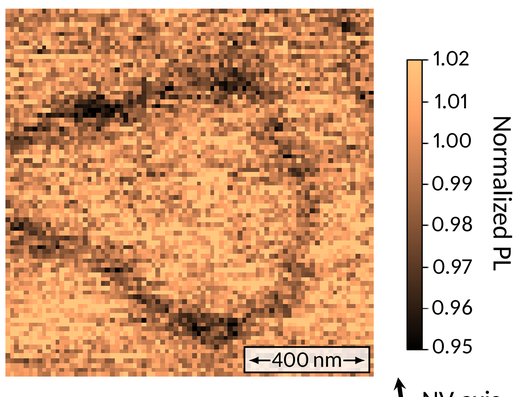
Compensation of the dipolar fields
→ No quenching expected

Antiferromagnetic RKKY coupling through the Ru layer

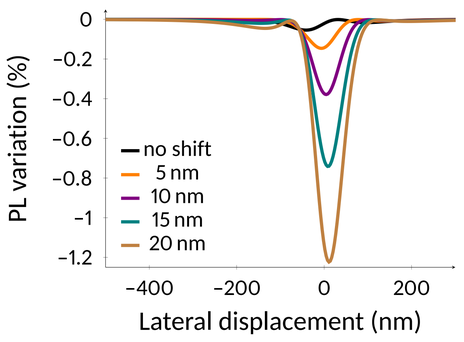
Large Dzyaloshinskii-Moriya interaction

Key parameters
- Probe-sample distance ≃ 100 nm
- Domain wall width from micromagnetic calculations:
  → w_{top} = 24 nm
  → w_{bottom} = 19 nm

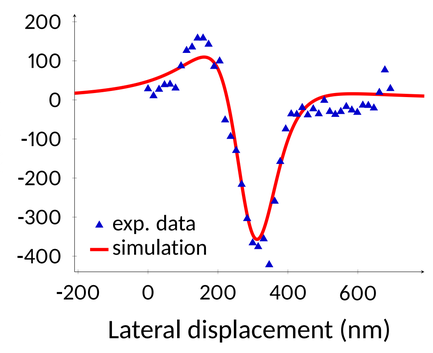
Measurements of magnetic domain walls



Expected signal for laterally shifted walls



Measured and simulated field profiles



Spin relaxation induced by magnetic noise

Optical pumping NV spin polarized in m_s = 0