University of Strathclyde Science

Magnetometry Optimisation in Unshielded Environments

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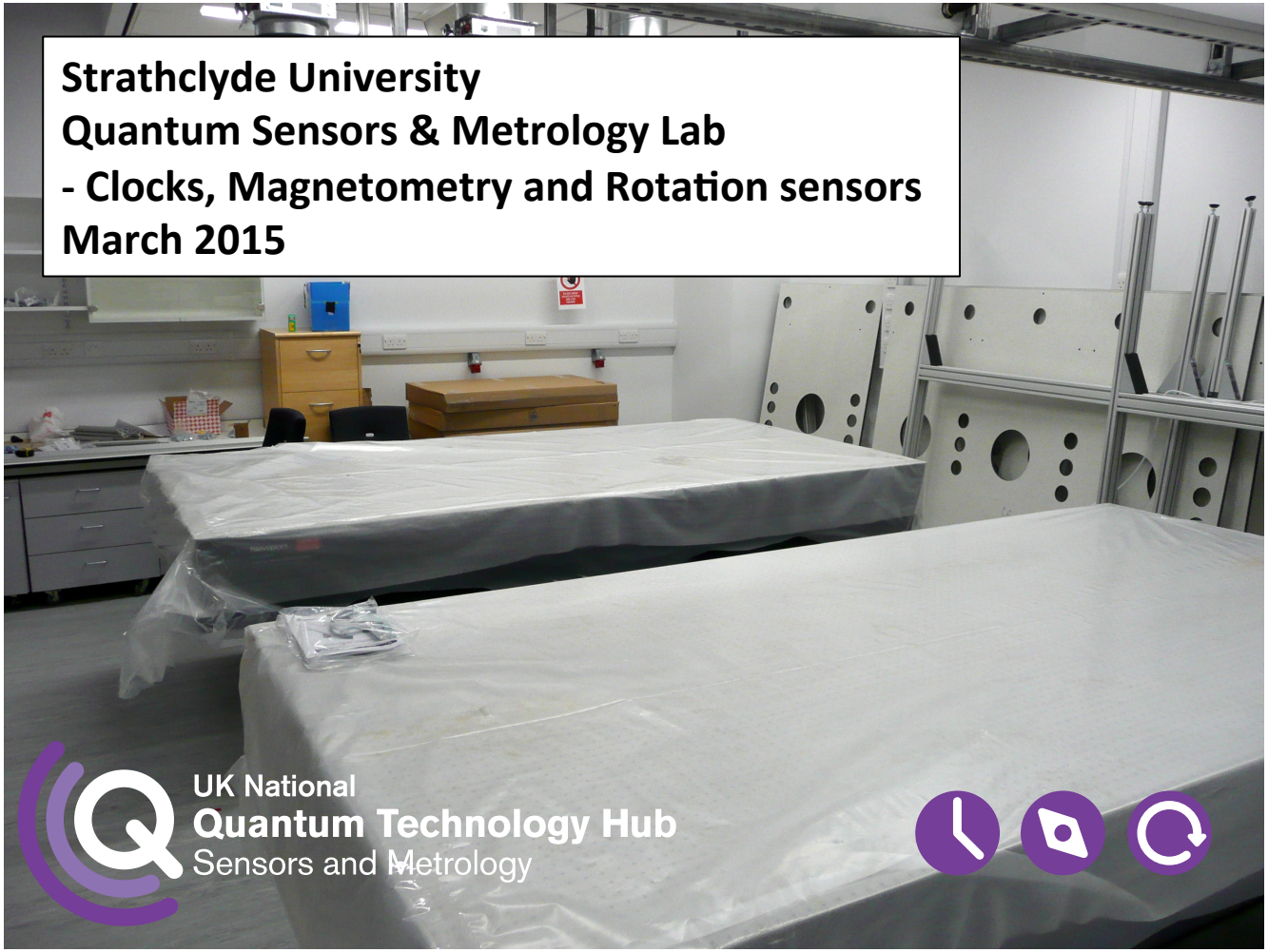
Strathclyde University

Glasgow

UK National Quantum Technology Hub Sensors and Metrology

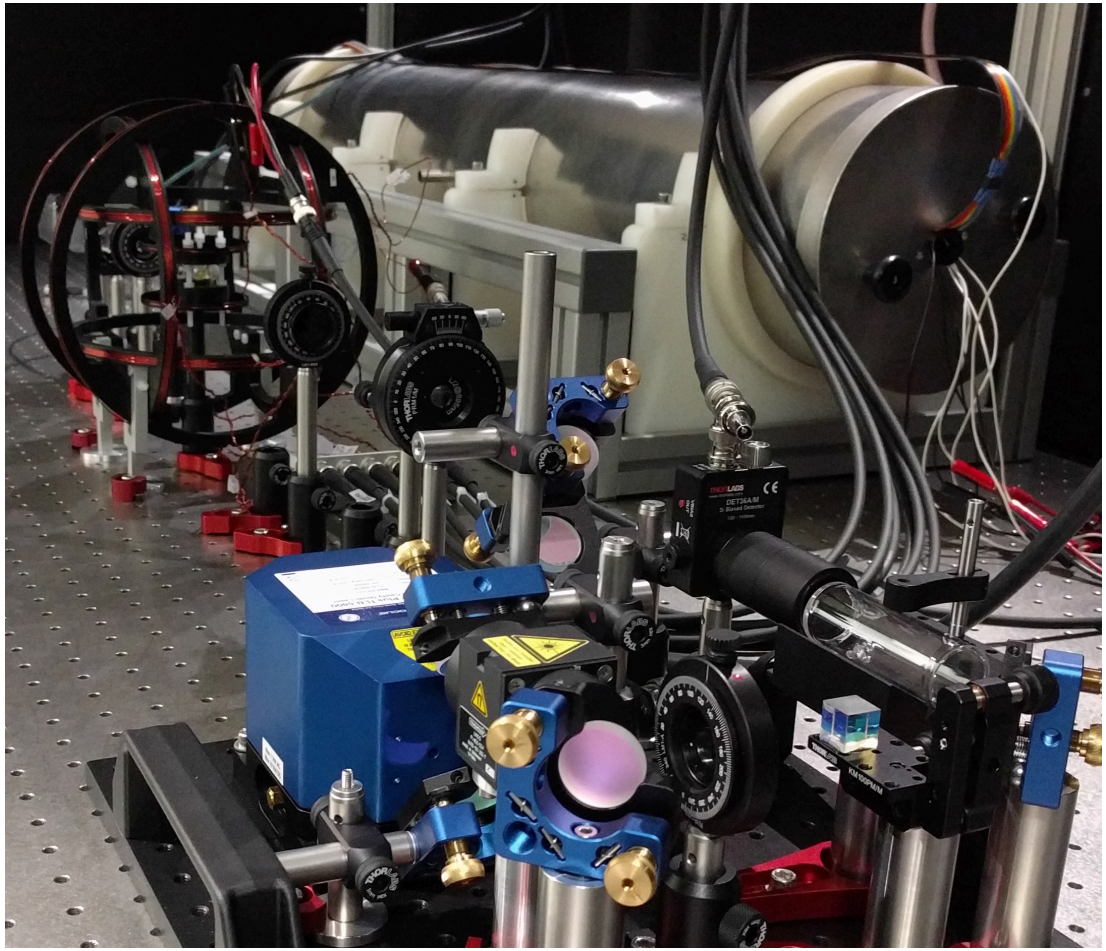
EPSRC Engineering and Physical Sciences Research Council

Introduction



Introduction

- Unshielded Magnetometry
  - Surveying
  - Seismology
- Performance criteria
  - Sensitivity
  - Bandwidth
  - Portable & scalable
  - Arbitrary fields
  - Noise rejection



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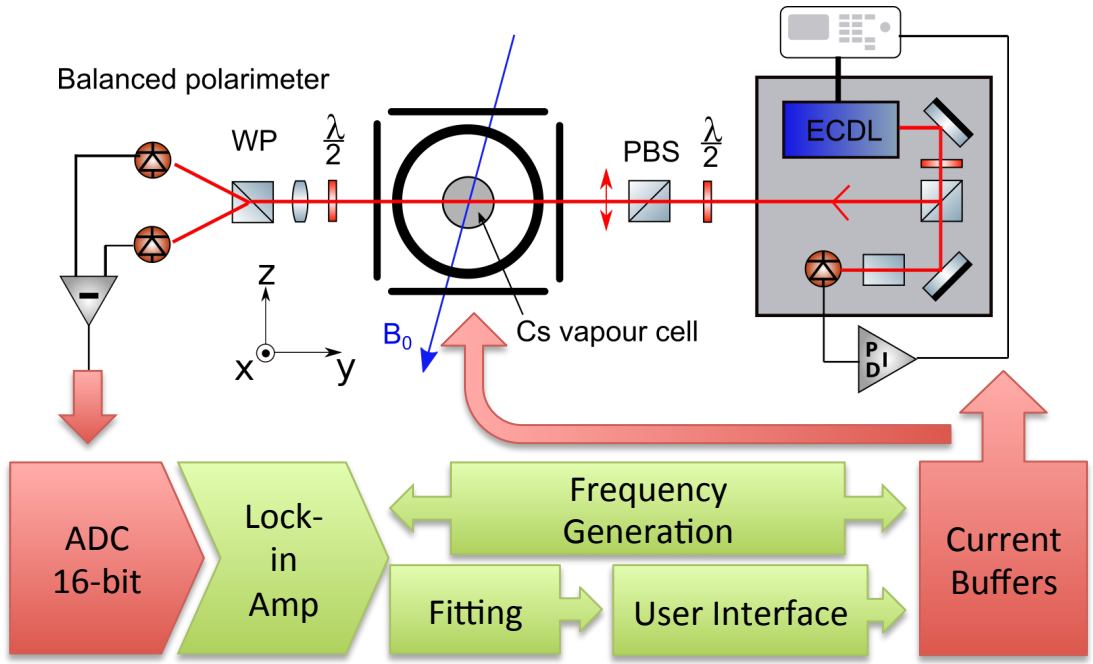

- Single-laser NMOR
- Software control & feedback
- Iterative optimisation

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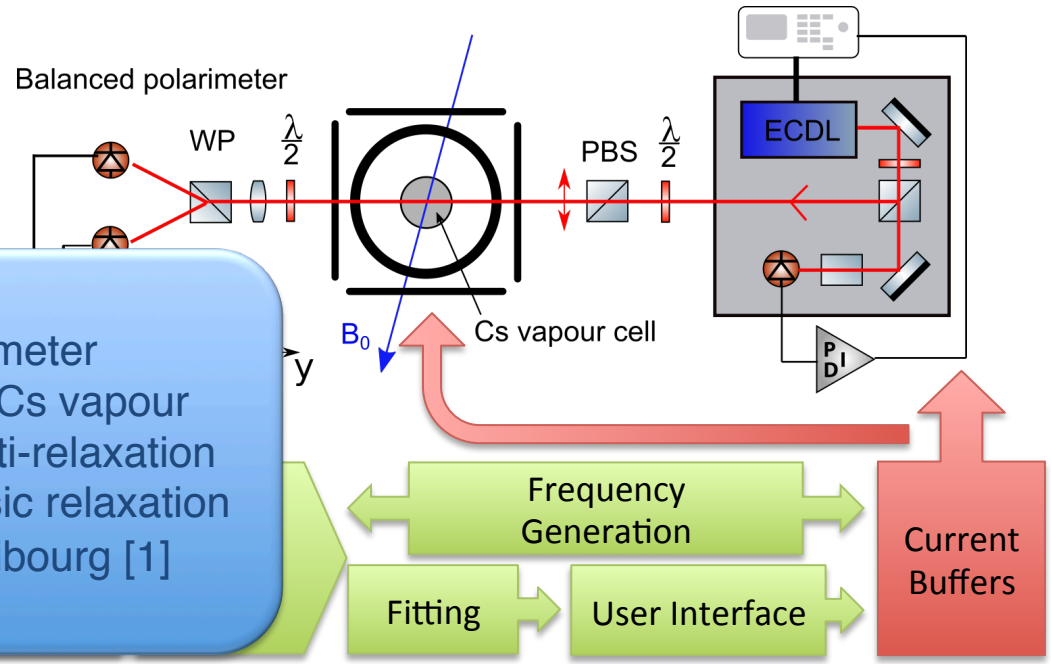
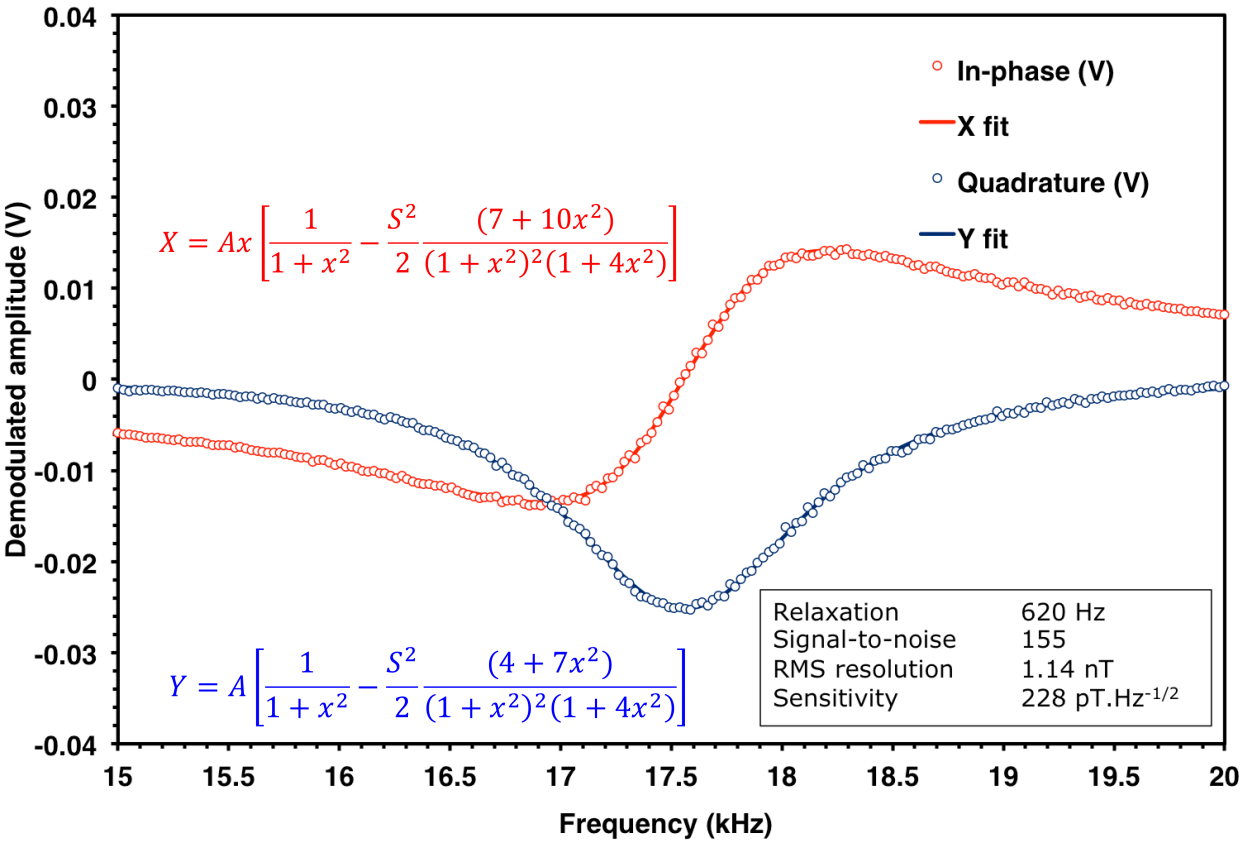


Cs cell
- 28 mm diameter
- 2×10^{-6} torr Cs vapour
- Paraffin anti-relaxation
- 7 Hz intrinsic relaxation
- Made in Fribourg [1]

- Single-laser NMOR
- Software control & feedback
- Iterative optimisation

[1] Castagna, Bison, Di Domenico, Hofer, Knowles, Macchione, Saudan, Weis, Appl. Phys. B **96**, 763

NMOR resonance

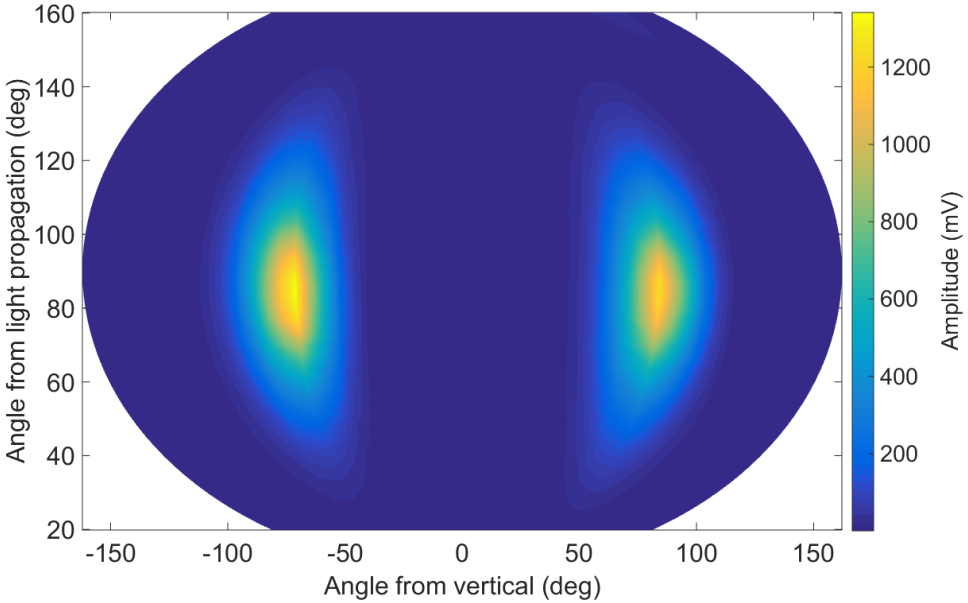


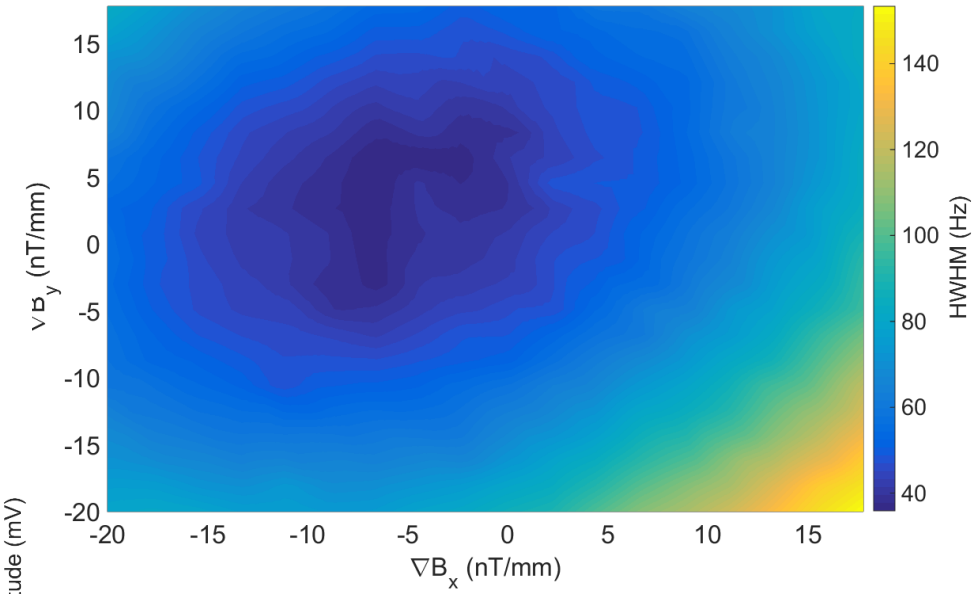
- B_0 // polarisation
- First-harmonic response
- B_{RF} modulation
- Software
  - Demodulation
  - Phase correction
  - Regression

[2] T. Zigdon, A. D. Wilson-Gordon, S. Guttikonda, E. J. Bahr, O. Neitzke, S. M. Rochester, D. Budker, Opt. Express **18**, 25494

B_0 Orientation & Gradient

- B_0 orientation
  - B_0 // polarisation



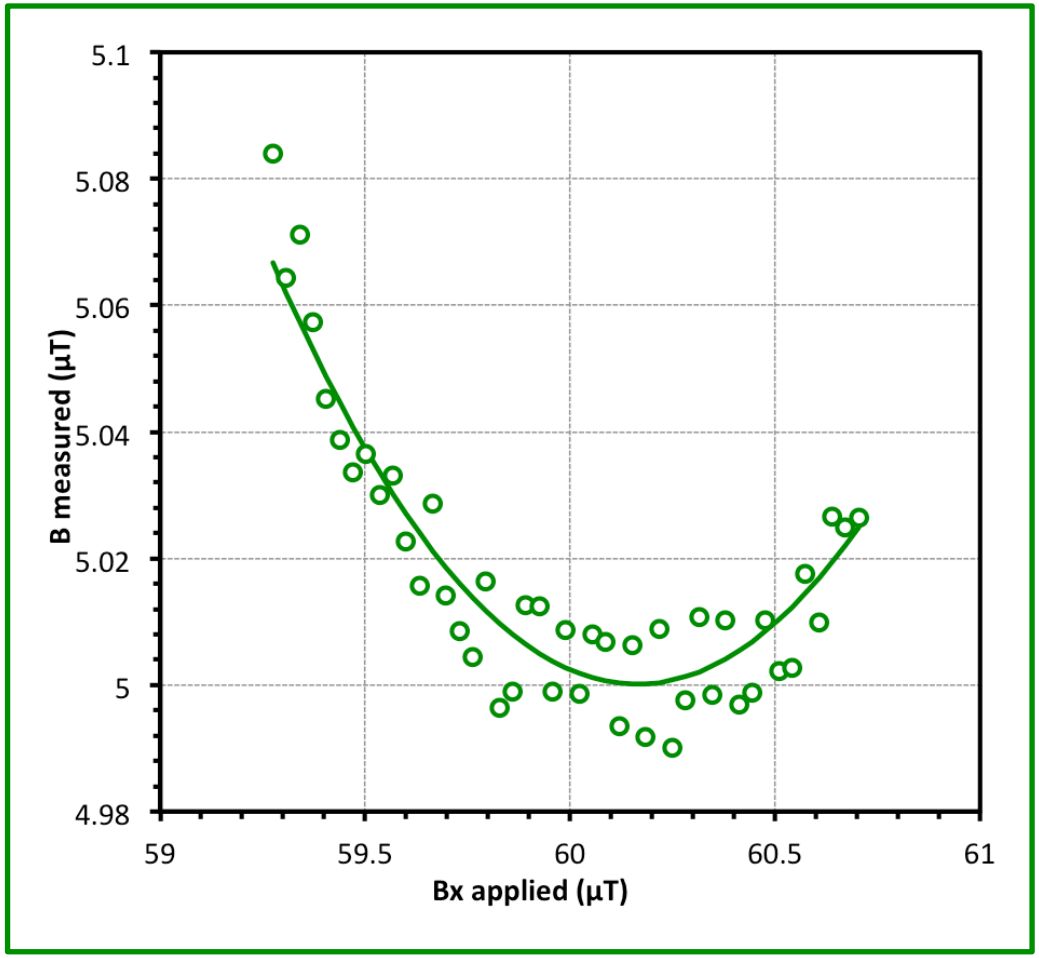


- Relaxation $\Gamma \propto |\nabla B|^2$ [3]

[3] S. Pustelny, D. F. Jackson Kimball, S. M. Rochester, V. V. Yashchuk, D. Budker, Phys. Rev. A **74**, 063406

B_0 optimisation

- Finite-field optimisation
  1. Minimise B_x B_y
  2. Set B_z
  3. Minimise HWHM wrt ∇B_x ∇B_y ∇B_z



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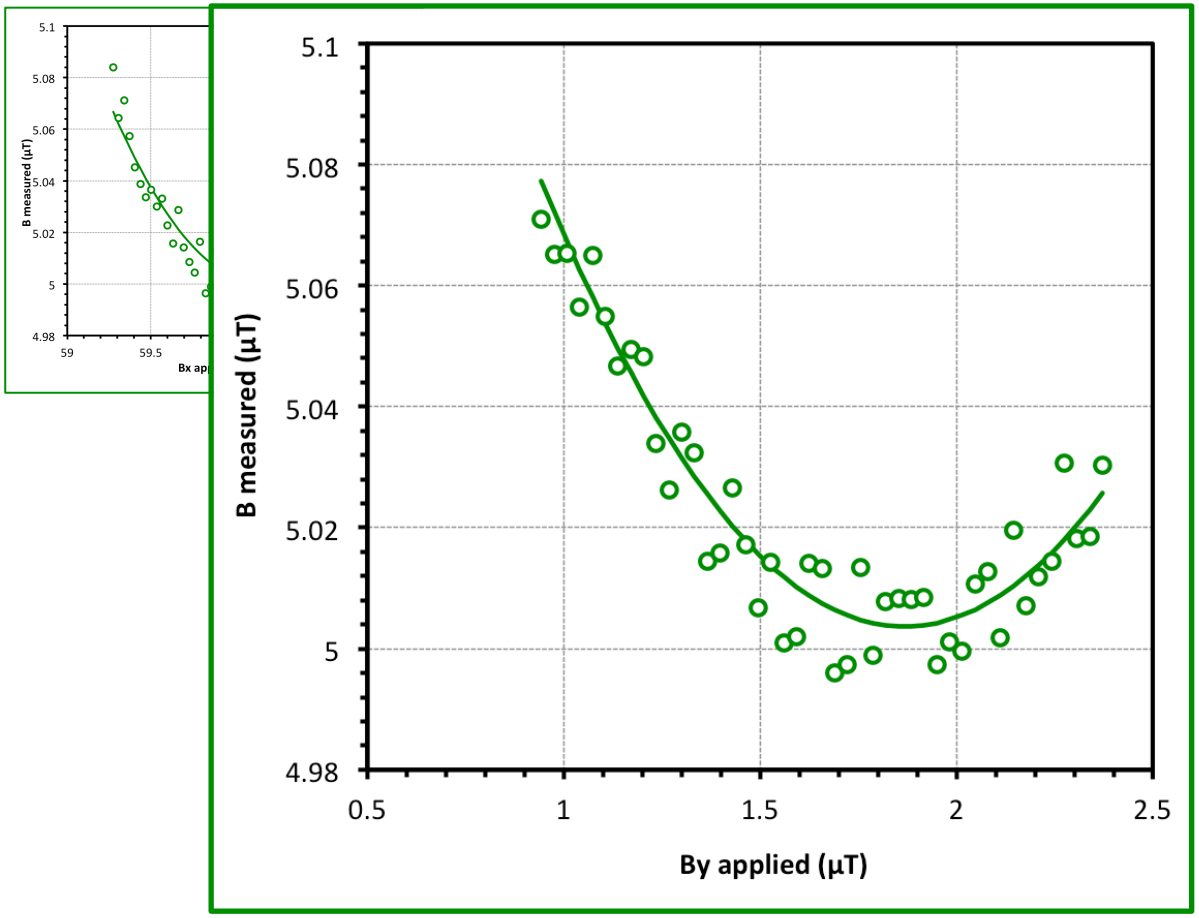

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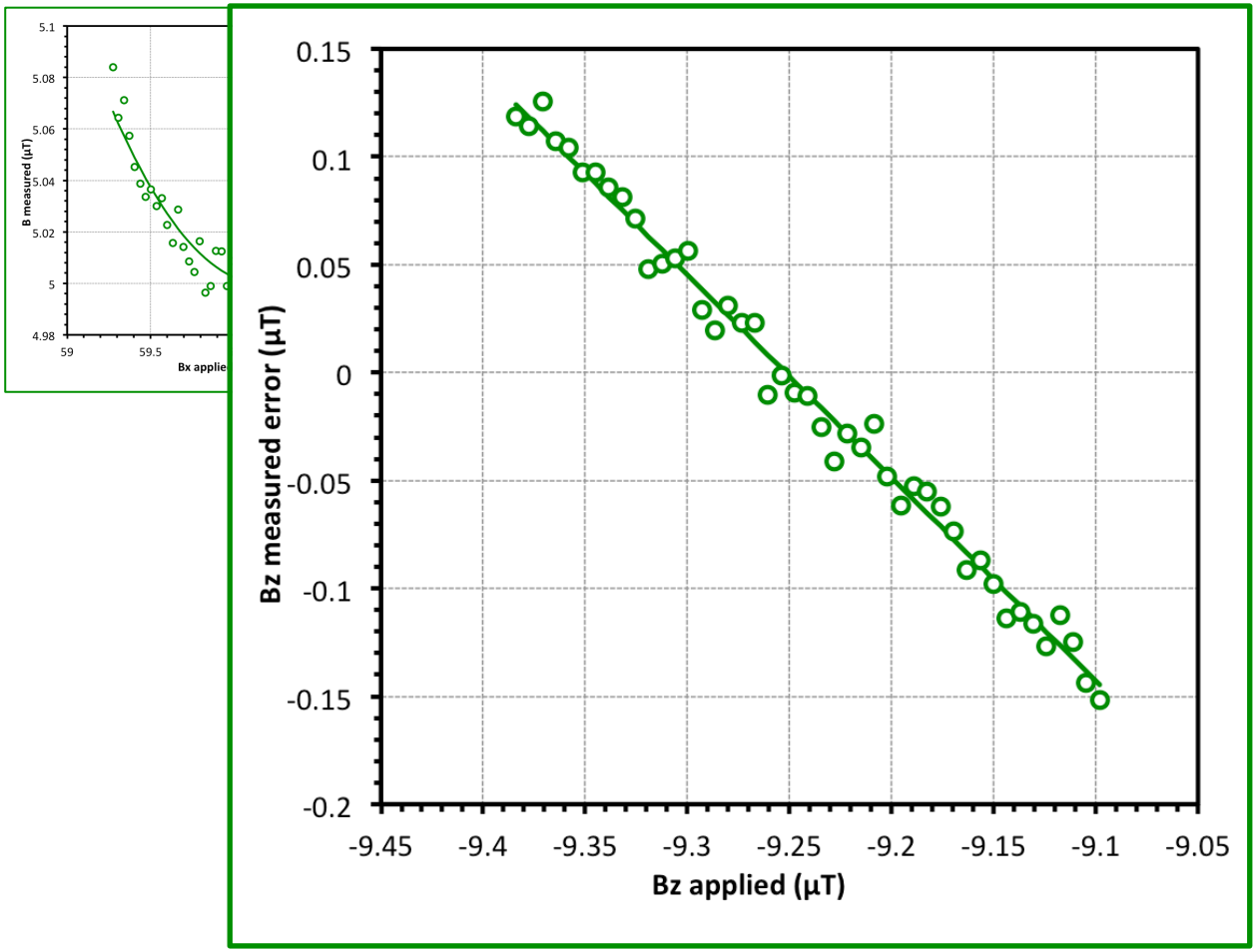

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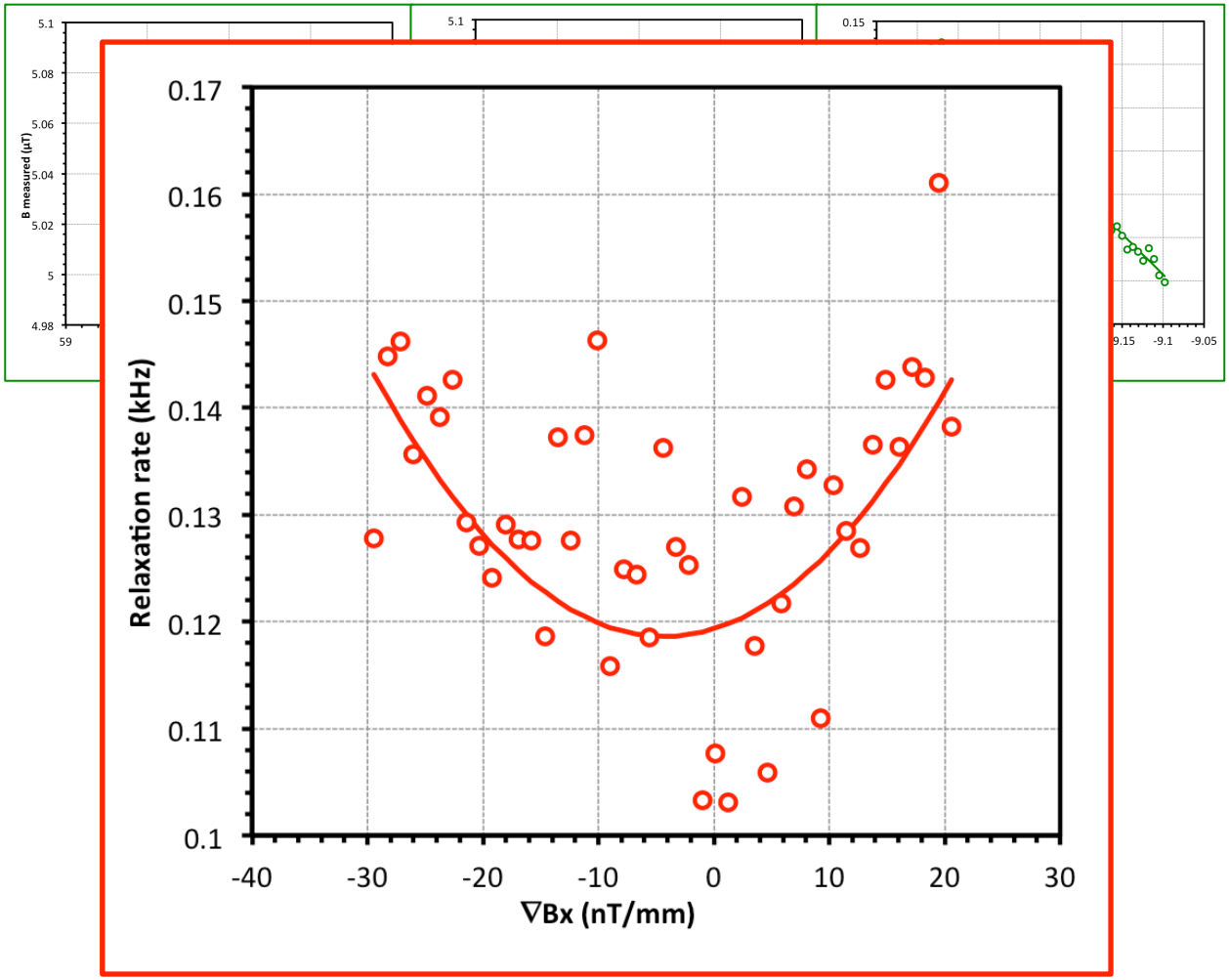

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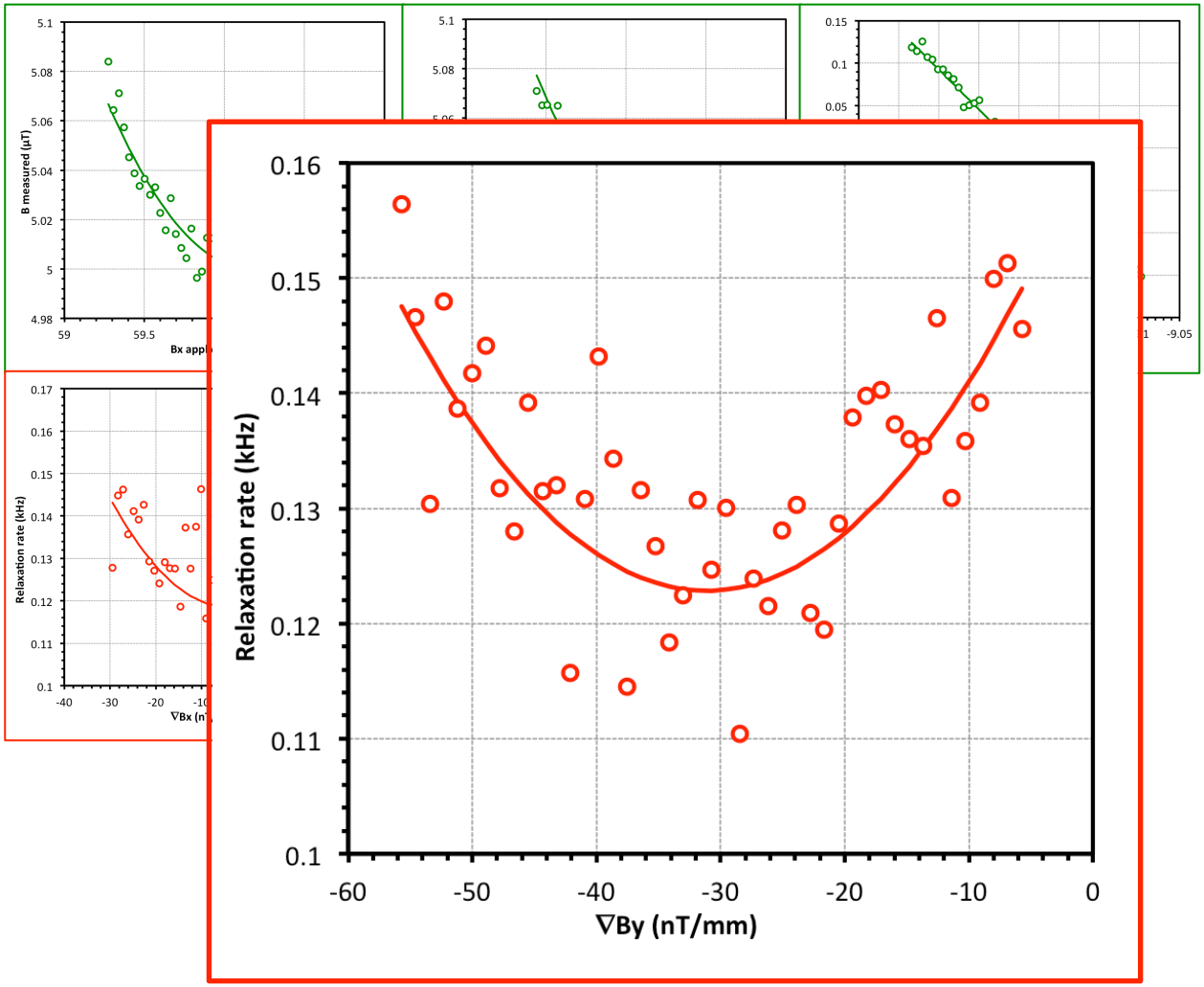

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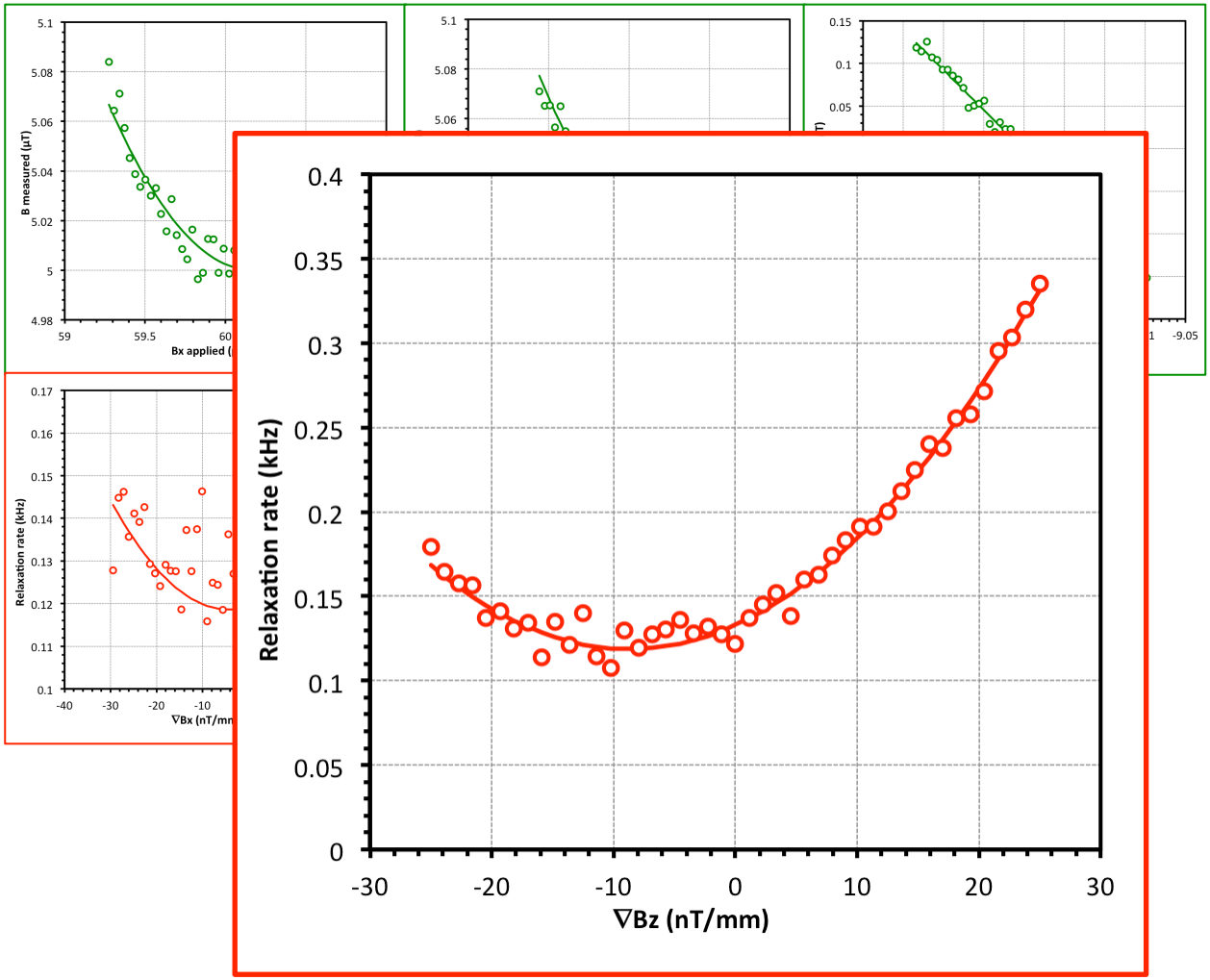

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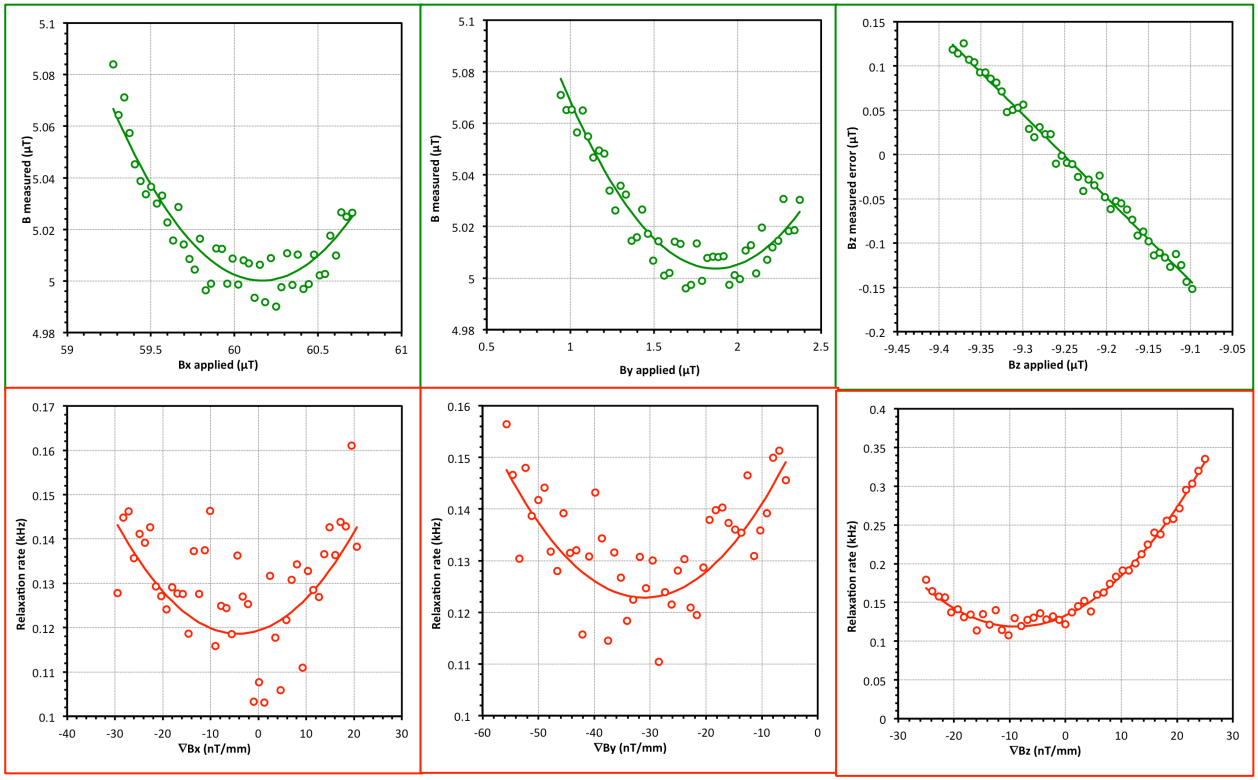
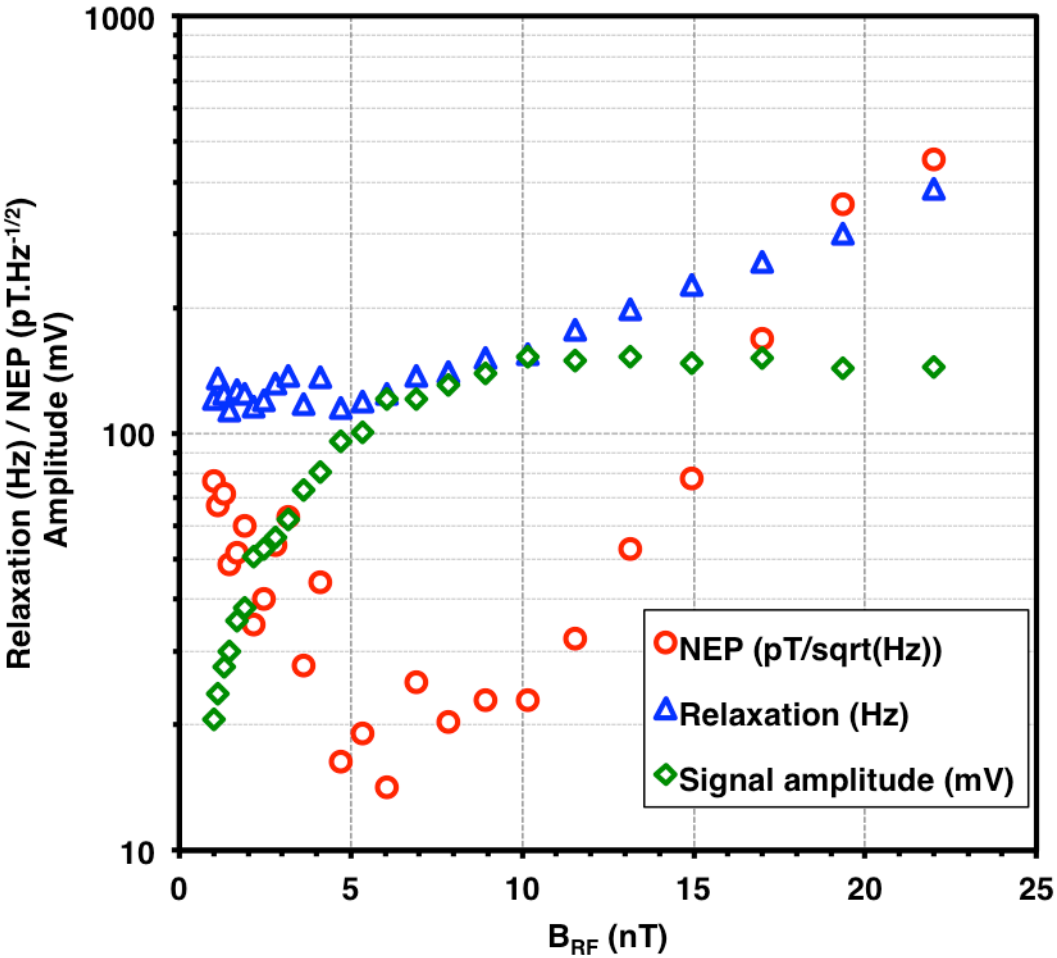


- Convergence 2-3 iterations
  - $\Delta B_0 < 20$ nT
  - $\nabla B < 10$ nT/mm

B_{RF} optimisation



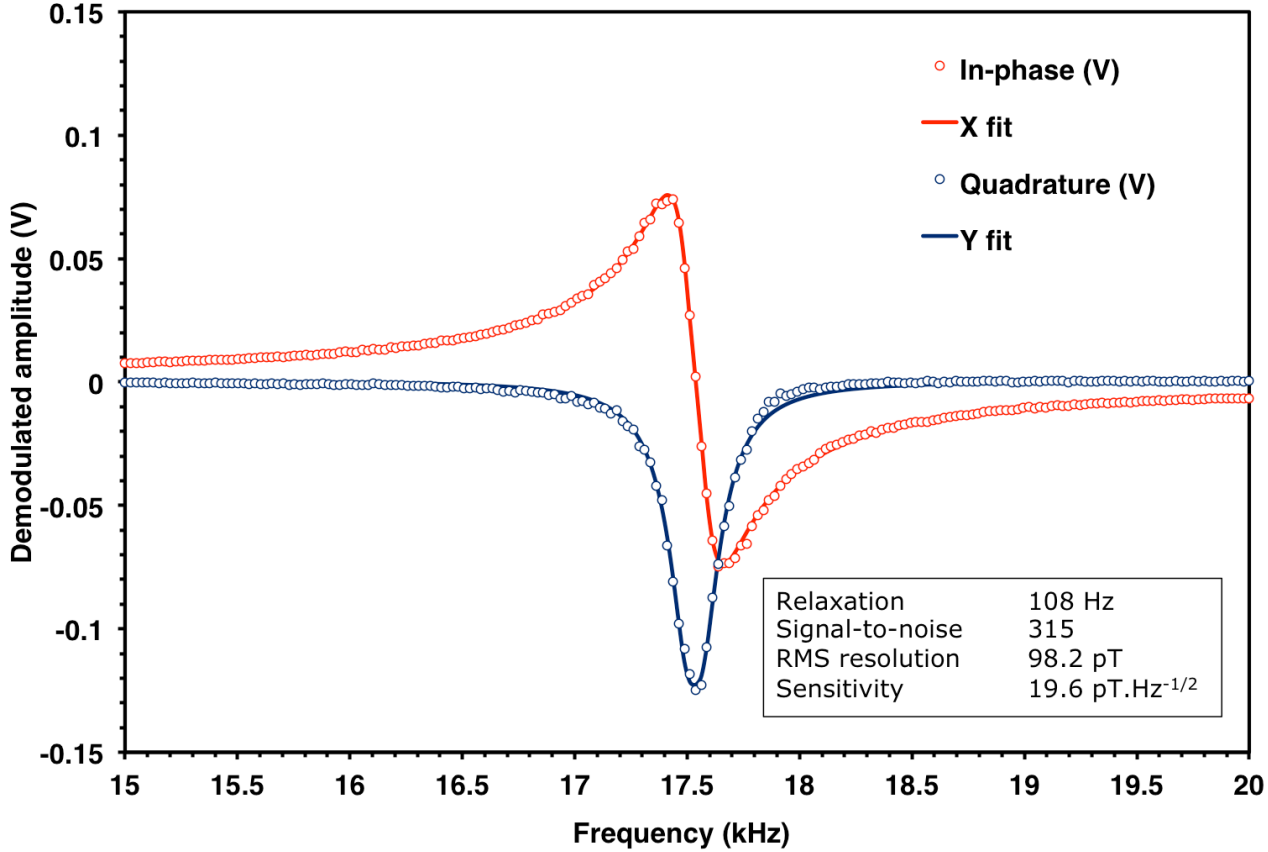
- Signal

$$A \propto B_{RF}$$

- Saturation

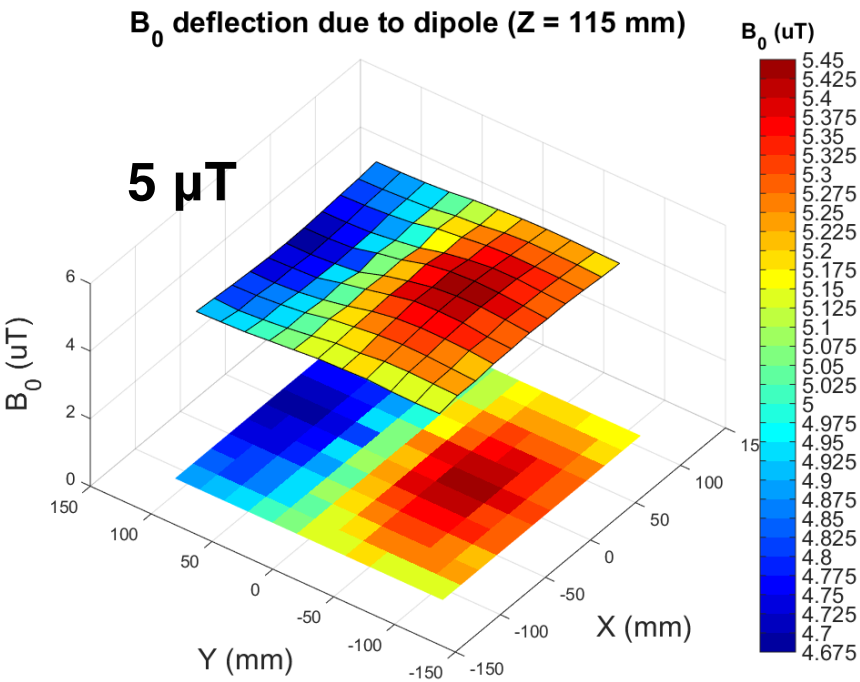
$$S = \frac{B_{RF} g_F}{\Gamma} \approx 1$$

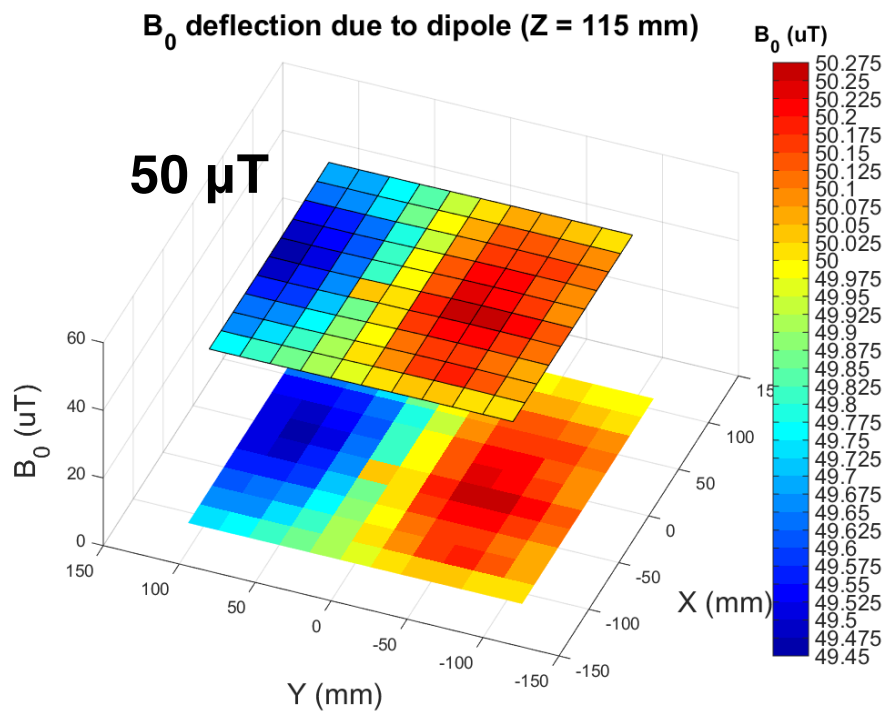
Optimised resonance



- HWHM 680 → 108 Hz (7 Hz intrinsic)
- Sensitivity 228 → 20 pT.Hz$^{-1/2}$

Stability & Dynamic range

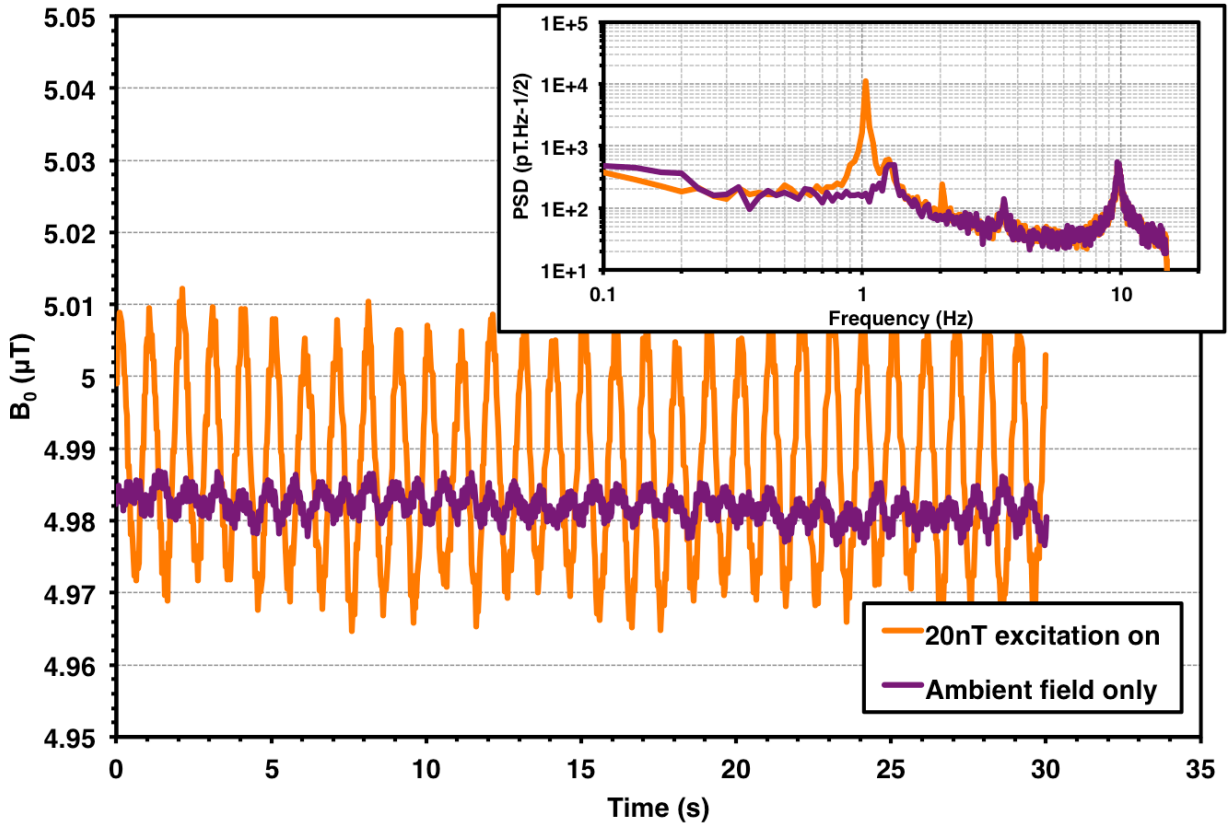




- Dipole ~ 8 mA.m^2
- Location < 5 mm

Response & Noise measurement

- Software PID feedback
  - Self-optimised
    - Phase
    - Gain
- 1 Hz field tracking



Summary

University of Strathclyde Science

- QT Hub: application of QT to devices
- Unshielded vapour cell magnetometry
  - Scalable, flexible ☞ Hardware < Software
  - Arbitrary fields ☞ Studying B_0 & ∇B
  - Sensitivity ☞ Noise rejection

Strathclyde QT Sensors & Metrology Hub
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Victoria Henderson, Rachel Elvin, James McGilligan

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