

Optically detected spin transitions in an Er-doped whispering-gallery resonator

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Outline

Introduction

- Whispering-gallery resonators

- Optical coupling to rare-earth ions

- Microwave cavity

Motivation

- Upconversion

- Optically-detected magnetic resonance with strong coupling

Results

Conclusion

Introduction

Whispering-gallery resonators

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- Discs of dielectric

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- Trap light around the rim



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Whispering-gallery resonators

- Discs of dielectric
- Trap light around the rim
- High Q factor



Erbium doping

- Introduce low linewidth optical and microwave transitions into the medium

Erbium doping

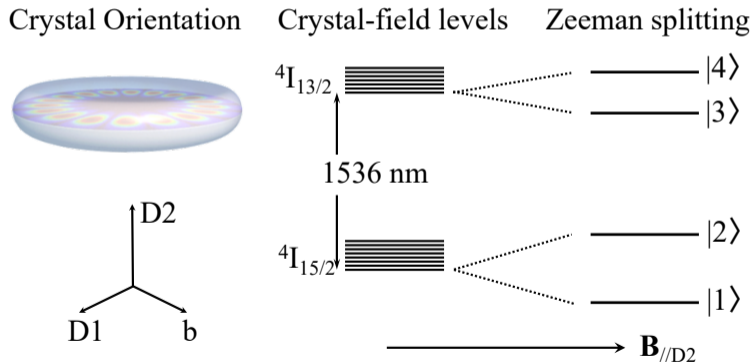
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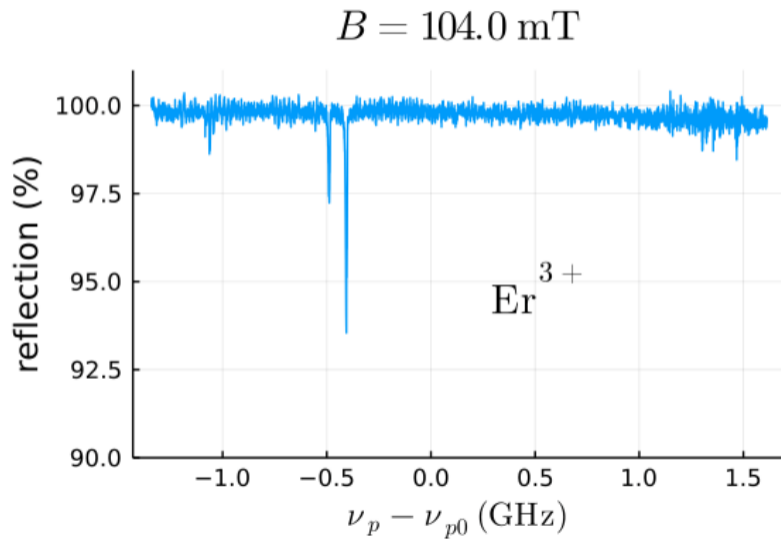
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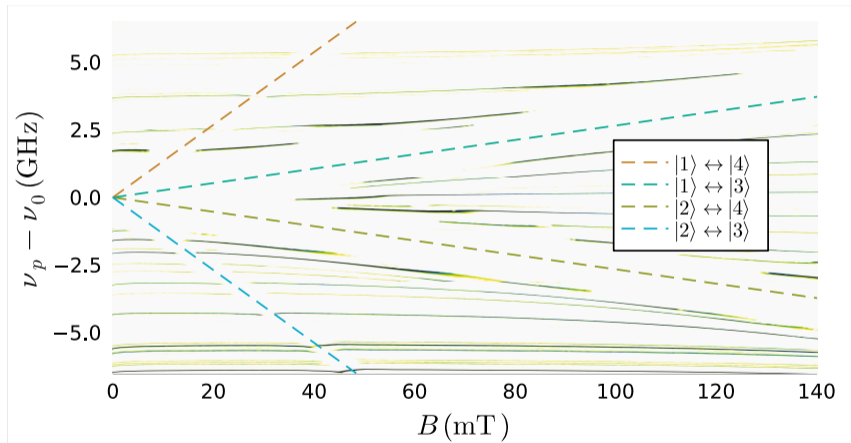


Optical coupling to erbium

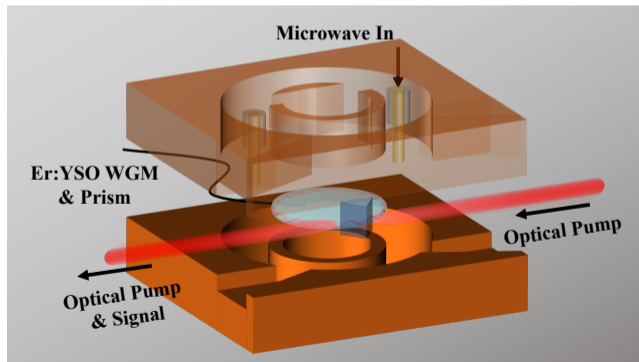


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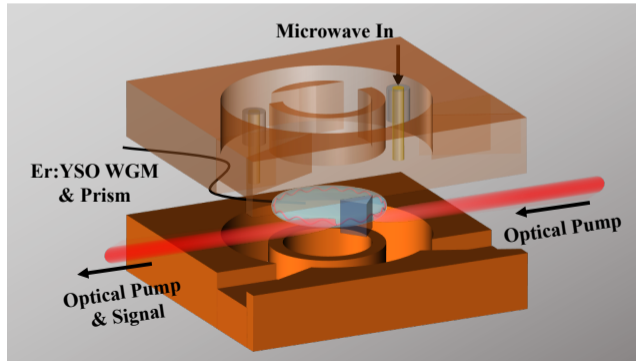


Microwave resonator



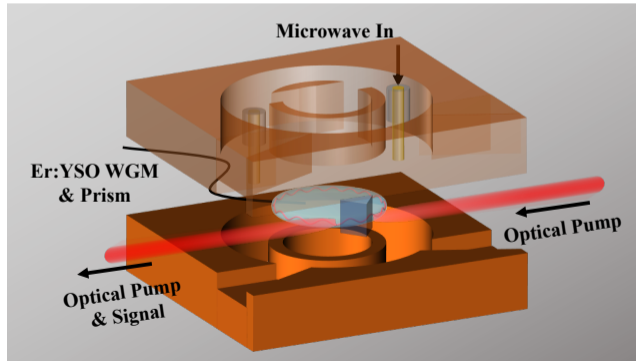
Microwave resonator

- Copper rings “focus” magnetic field onto optical mode volume



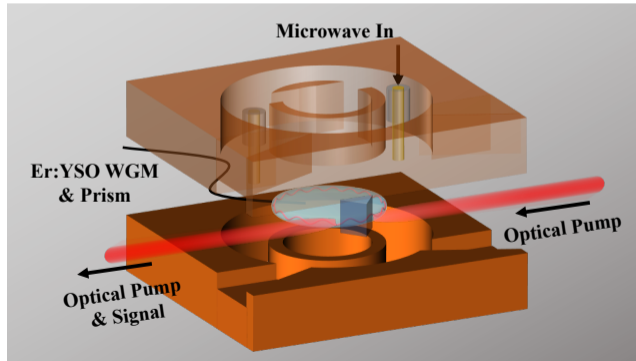
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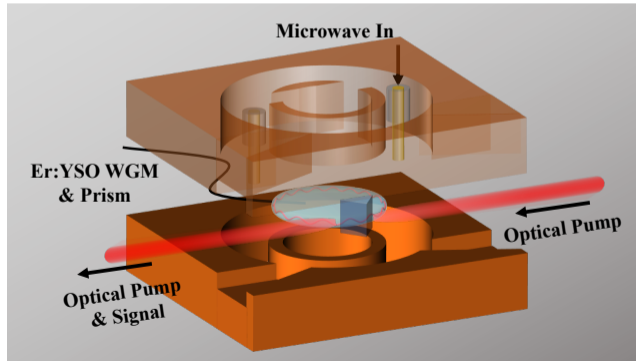
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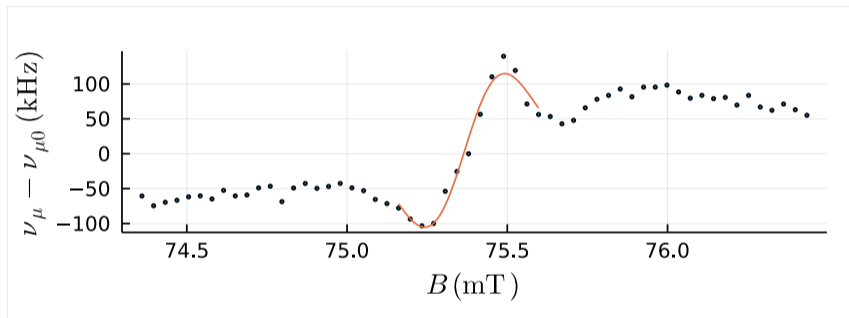
Microwave resonator

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- $Q \sim 350$

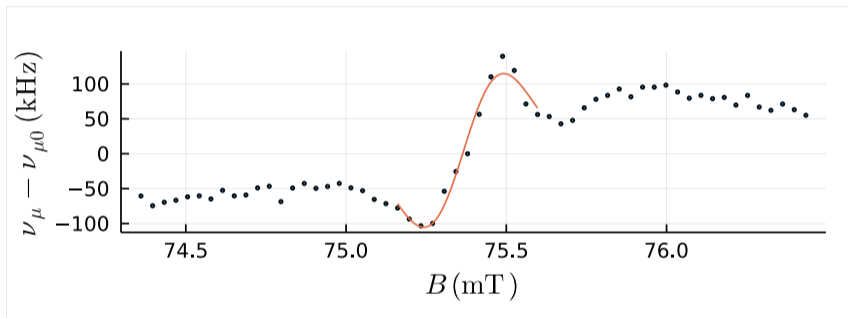


Microwave properties

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Microwave properties



- Erbium inhomogeneous linewidth ~ 40 MHz.

Motivation

Upconversion

- Superconducting qubits operate at ~ 10 GHz and ~ 1 K.

Upconversion

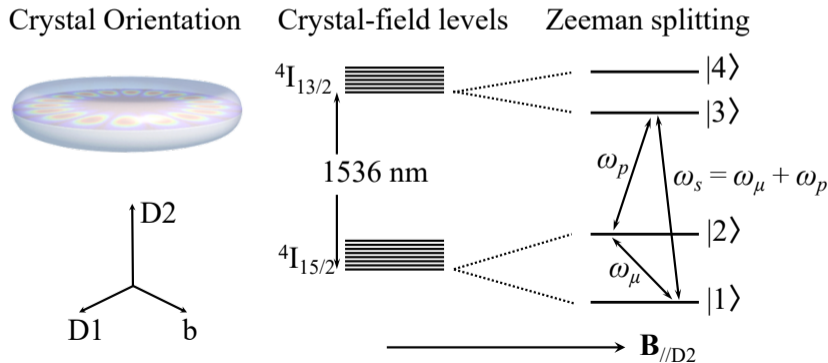
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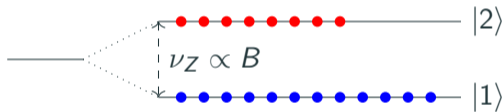
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- Shine light through a medium with a magnetic (microwave) resonance
- Turn microwave field on and off
- Measure changes in absorption at the on/off frequency

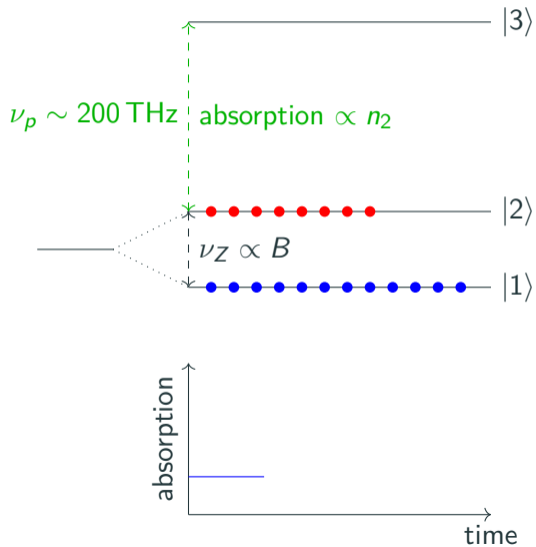
Optically-detected magnetic resonance (ODMR) spectroscopy



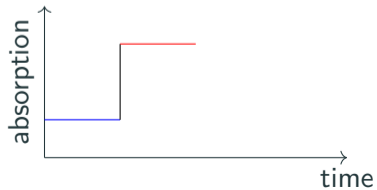
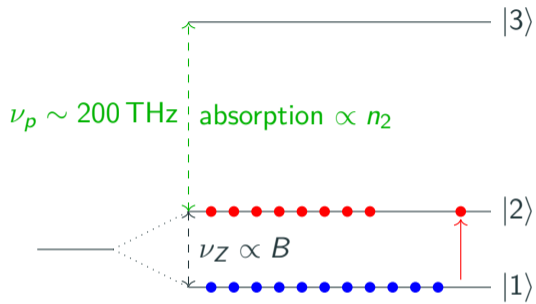
$$\frac{n_2}{n_1} = \exp\left(-\frac{h\nu_Z}{kT}\right) \approx 0.86$$

$$(T = 4 \text{ K}, \nu_Z = 12.2 \text{ GHz})$$

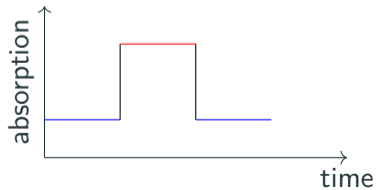
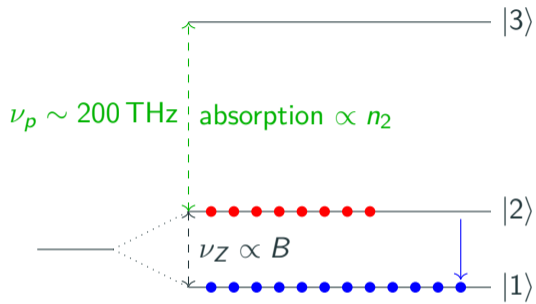
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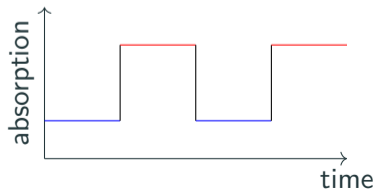
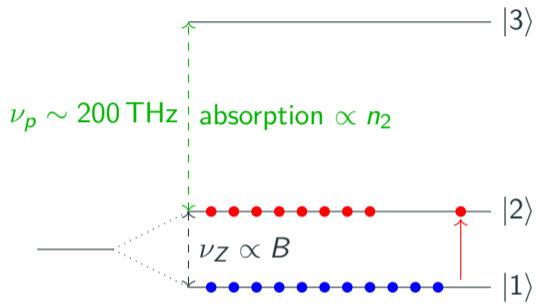
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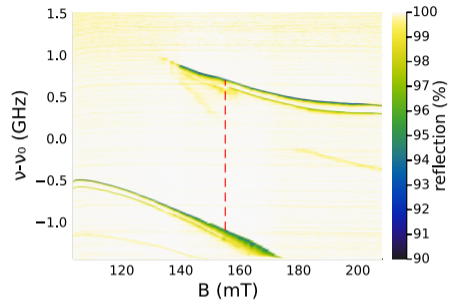
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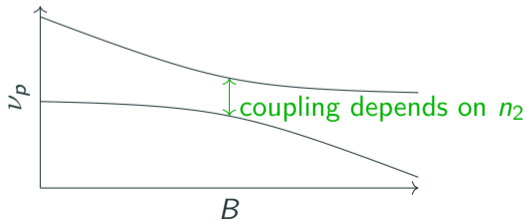
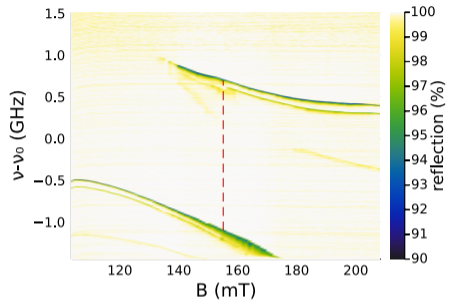
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- Measure oscillations of optical mode *frequency* on the error signal via a lock-in amplifier
- Measure the microwave response of only the erbium ions that reside in the optical mode volume

Modified ODMR

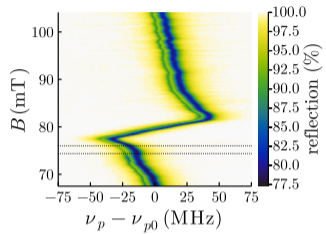


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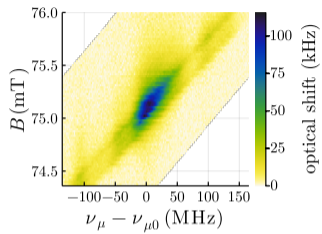
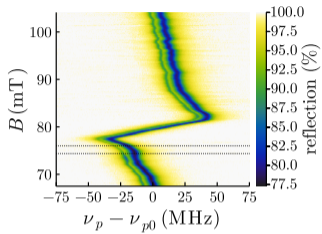


Results

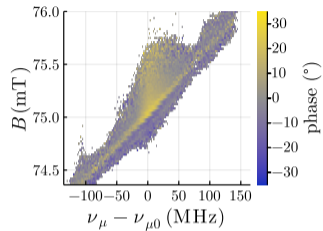
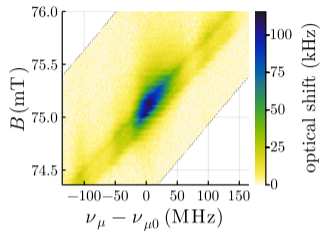
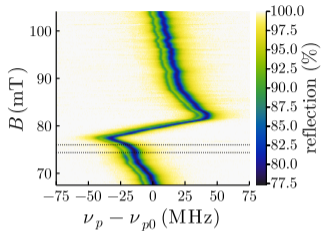
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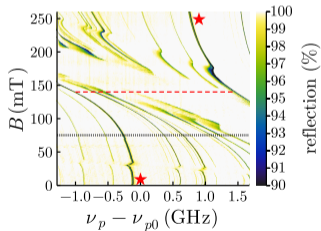
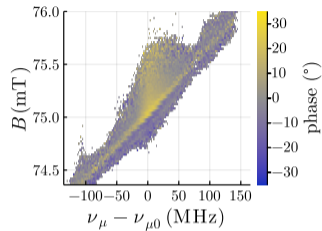
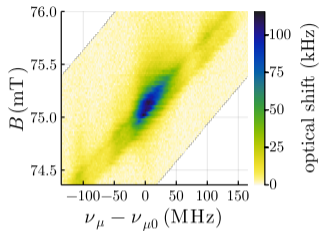
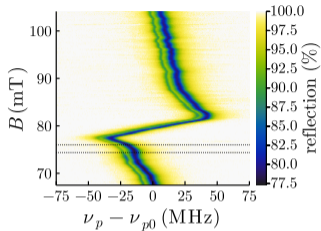
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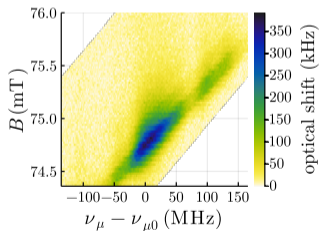
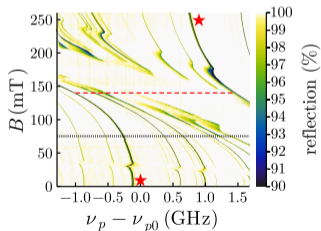
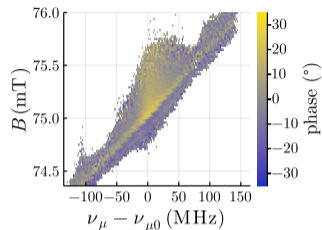
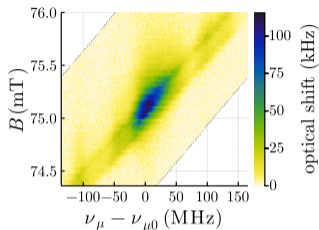
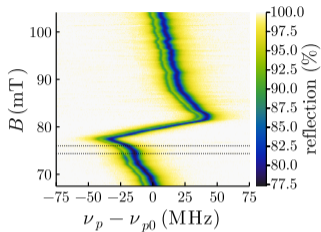
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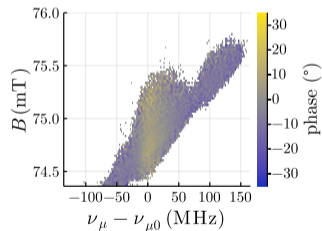
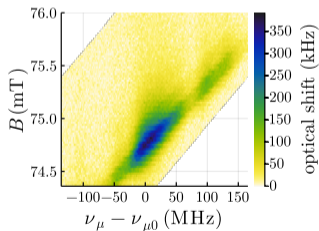
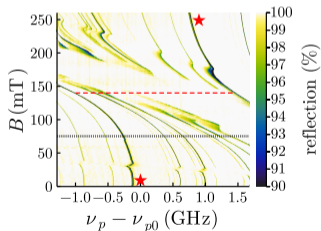
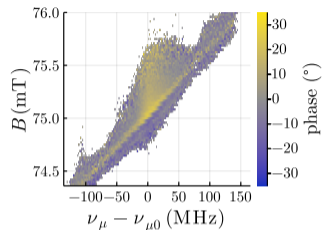
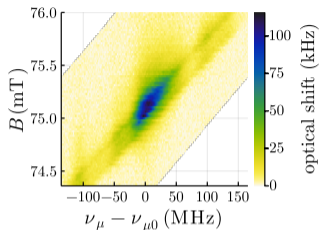
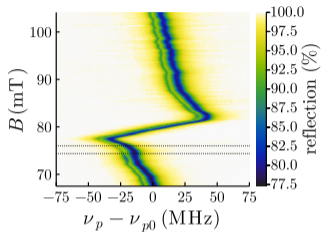
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- Promising to characterise the system to enable upconversion

Thank you

Check out the preprint! [arXiv:2210.13793](https://arxiv.org/abs/2210.13793) [quant-ph]

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