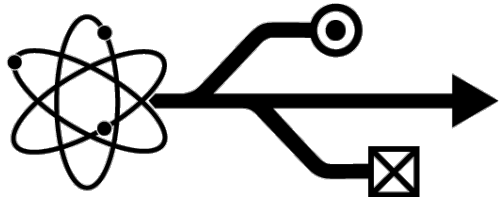


Hybrid Quantum Systems: Coupling Diamond Color Centers to Superconducting Cavities

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University of Science and Technology of China



中国科学技术大学
University of Science and Technology of China

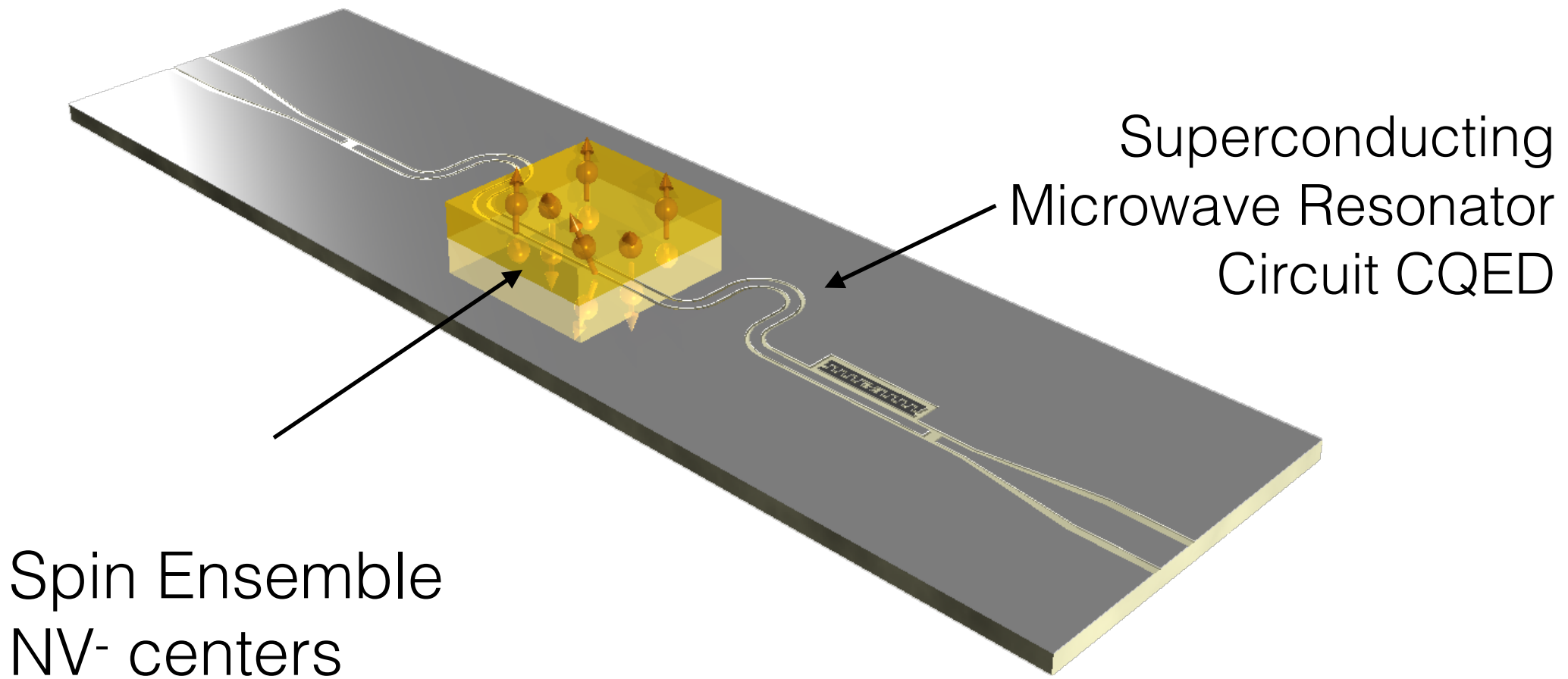
Quantum Spinoptics, SPICE June 2023

Overview

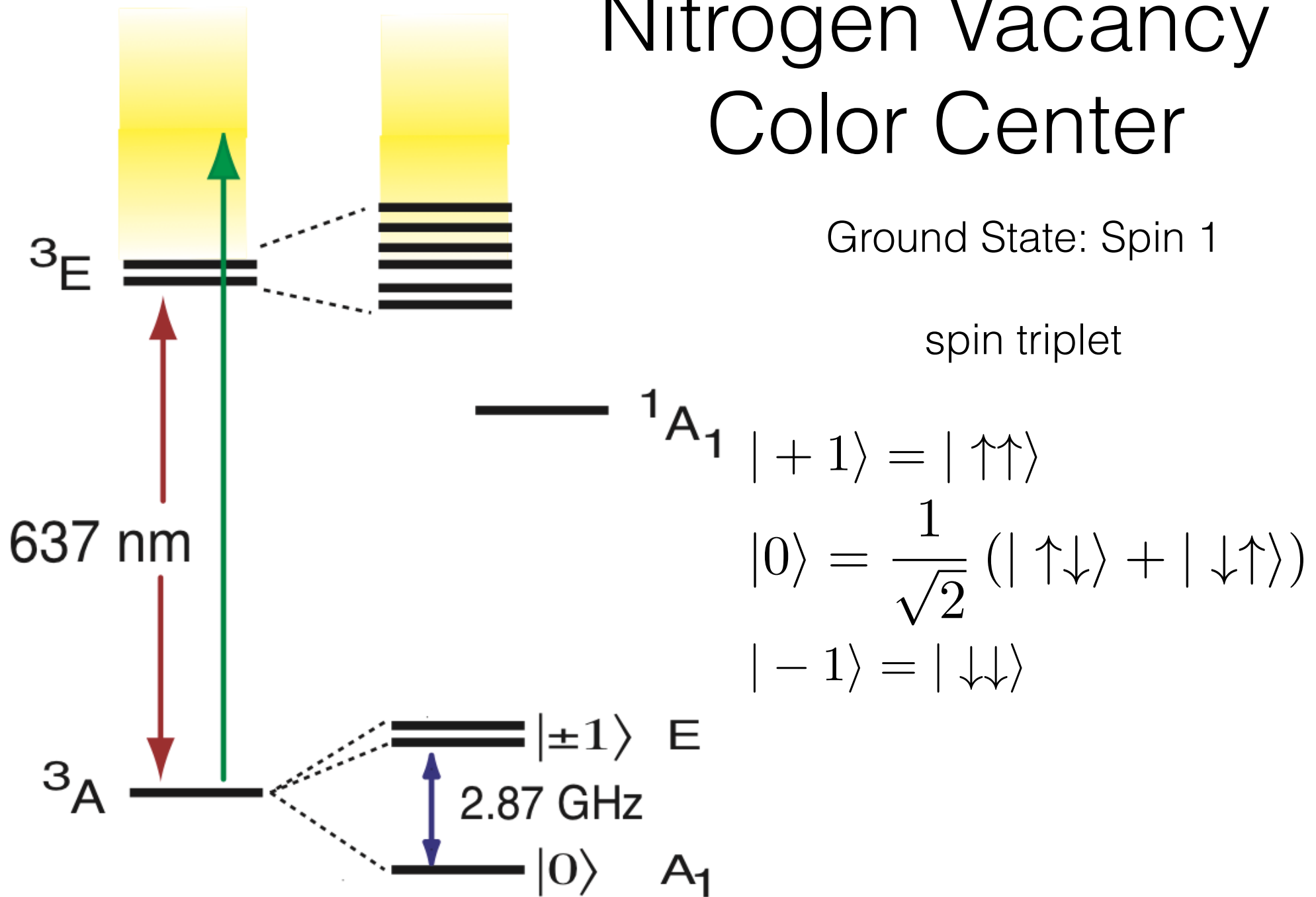
- Introduction
- 3D Lumped Element Resonator
- Superradiance
- Relaxation Time

Hybrid Quantum System

Quantum Optics with Spin Ensemble
and Microwave Resonators



Nitrogen Vacancy Color Center



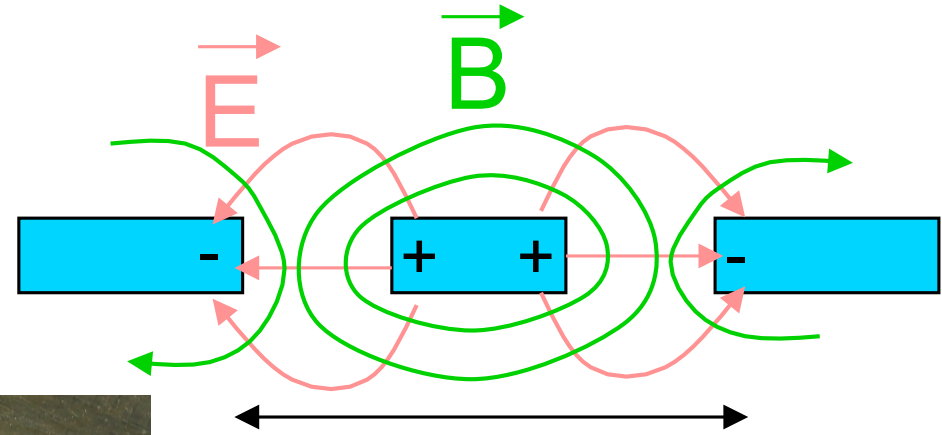
$$\mathcal{H} = DS_z^2 + E(S_x^2 - S_y^2) + g\mu_B \vec{B} \vec{S}$$

Coupling Diamonds

T. Astner, S. Nevlacsil, N. Peterschofsky, A. Angerer,
S. Rotter, S. Putz, J. Schmiedmayer, and J. Majer,
Coherent Coupling of Remote Spin Ensembles via a
Cavity Bus, Phys. Rev. Lett. 118, 140502 (2017)

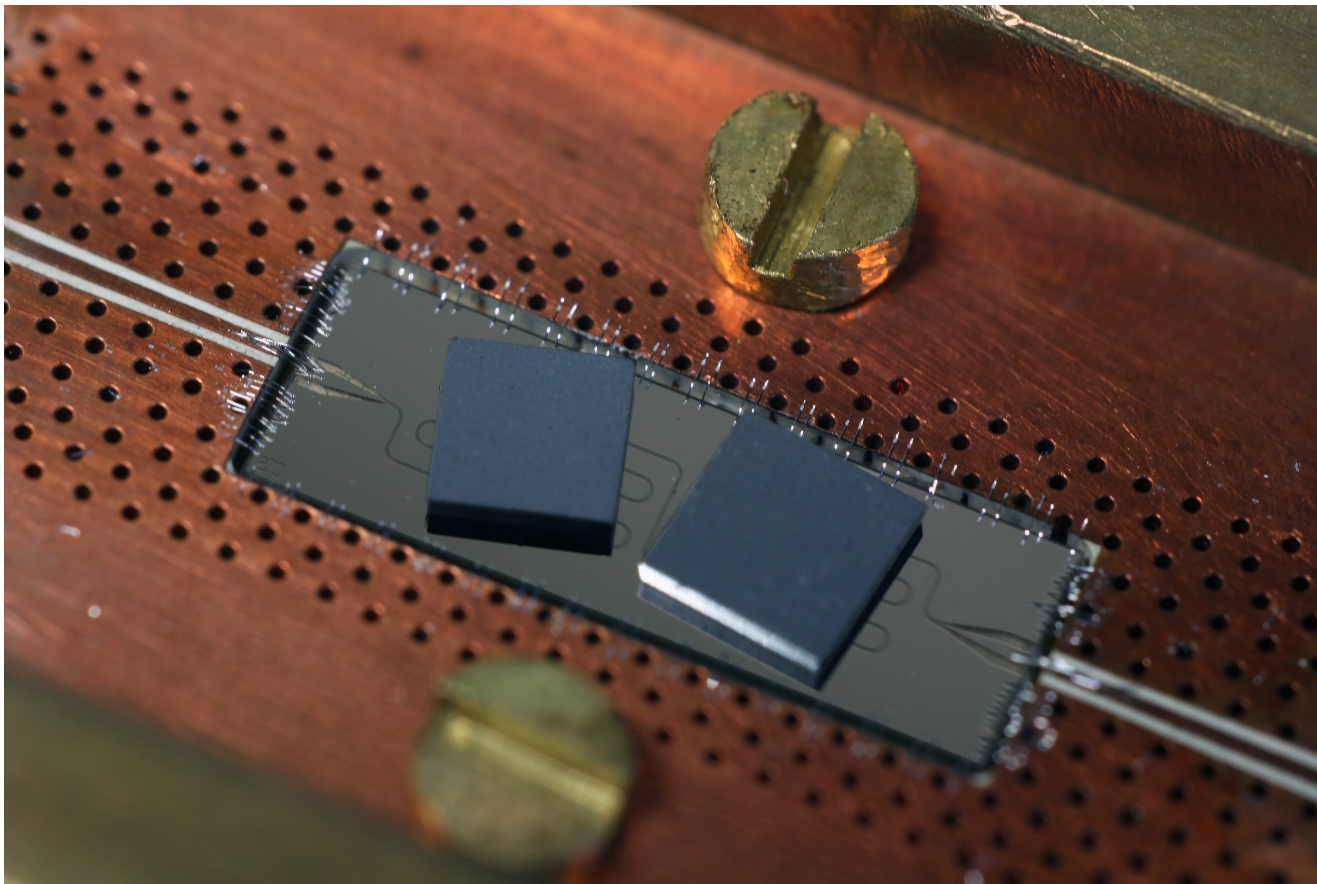


Editors Suggestion

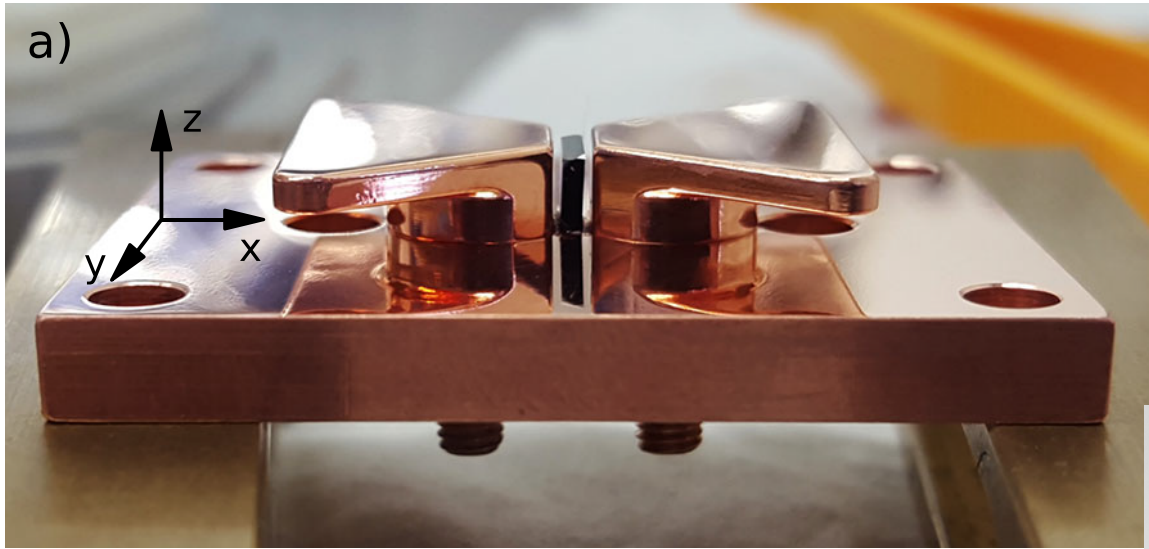


EM Field strongest
in the gaps

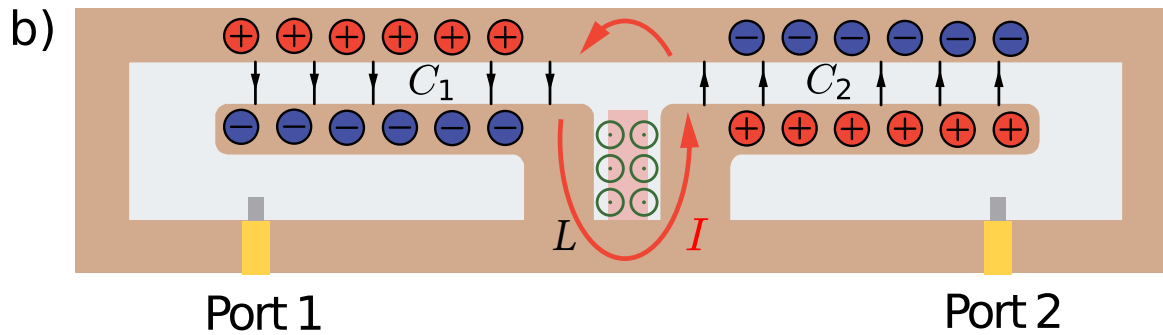
Coupling strength
varies over many
orders of
magnitude



3D Lumped Resonator

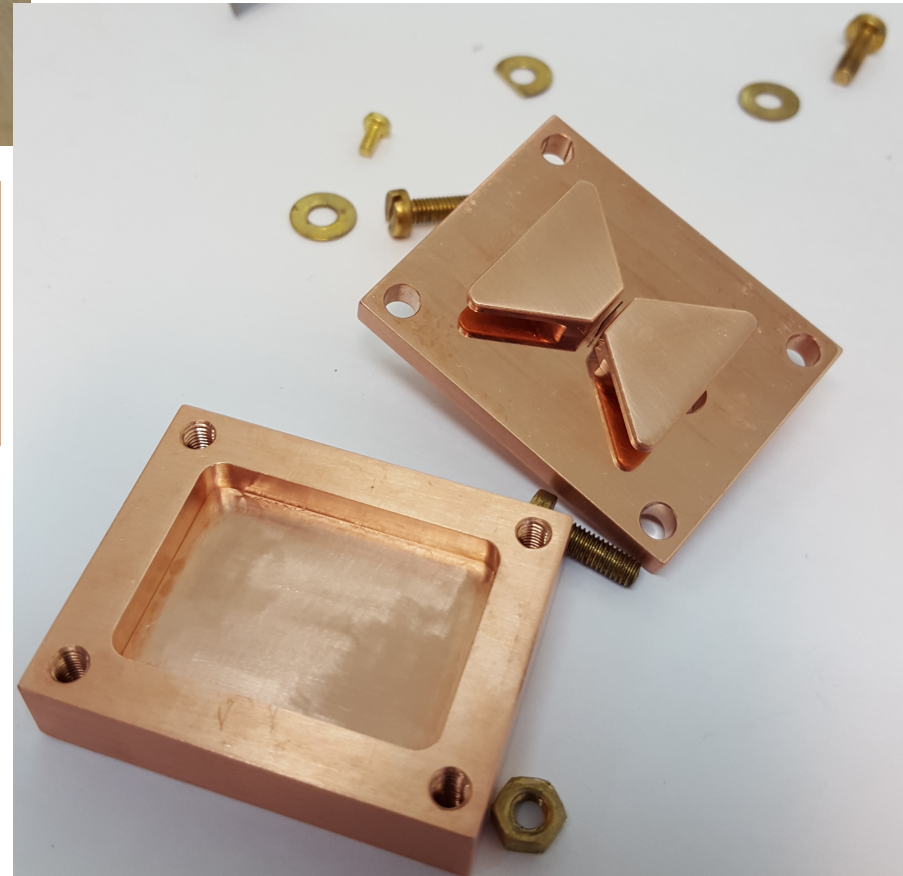


LC Resonator

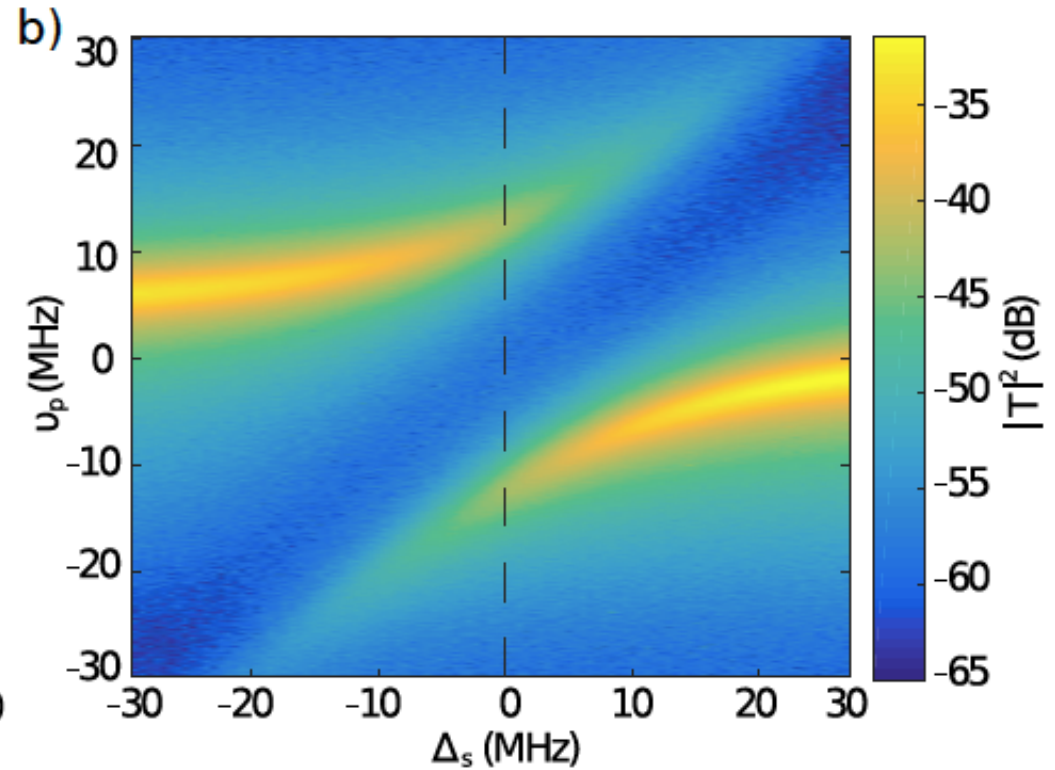
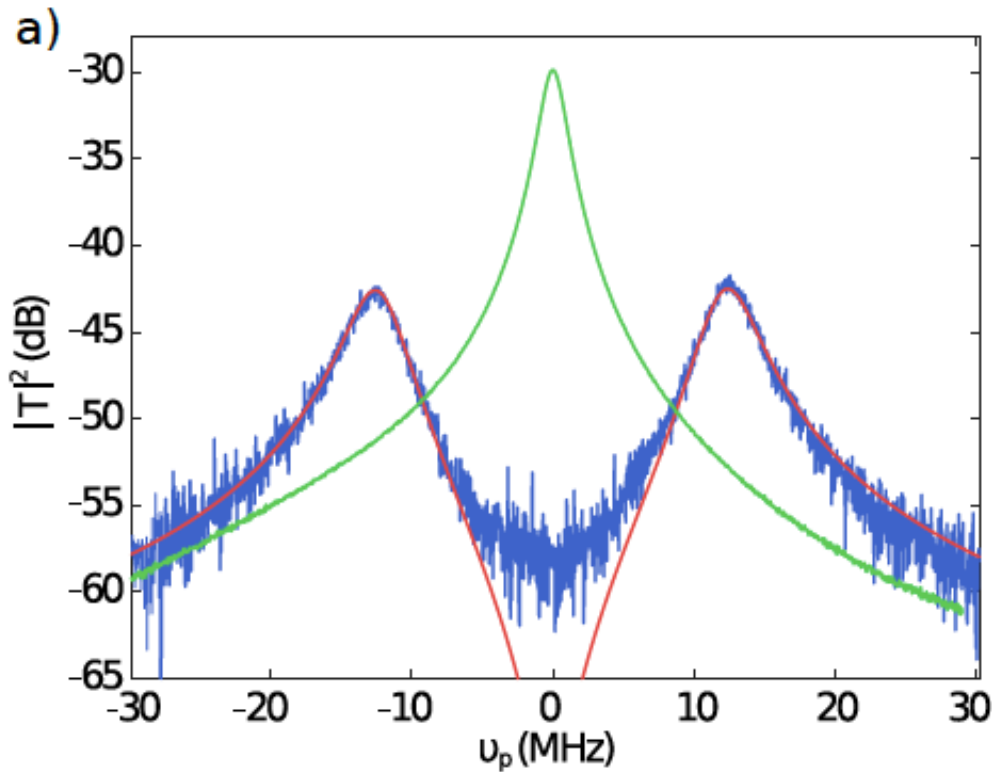


coupling to small sample
homogenous coupling

$Q = 2000$



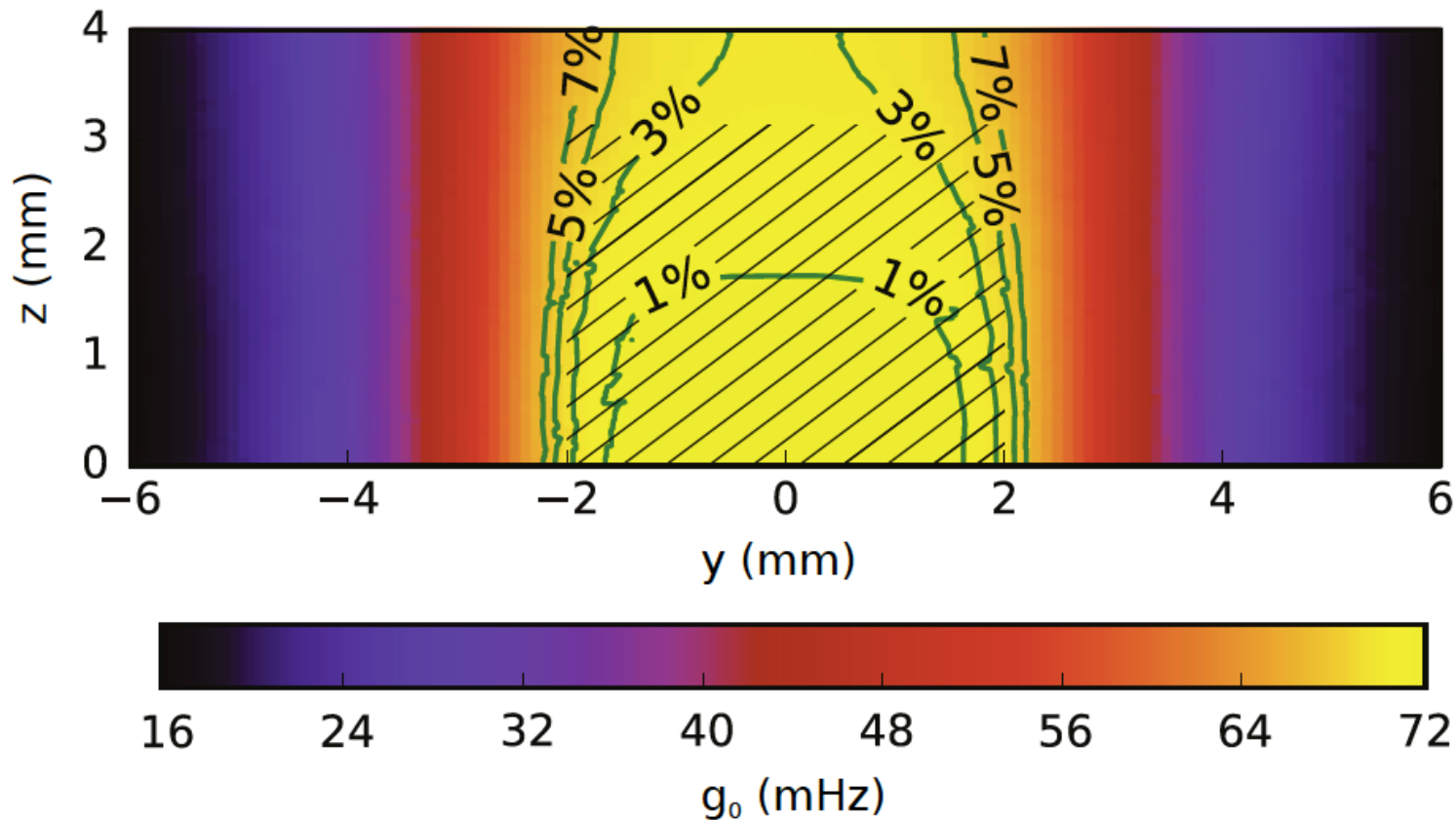
Strong Coupling



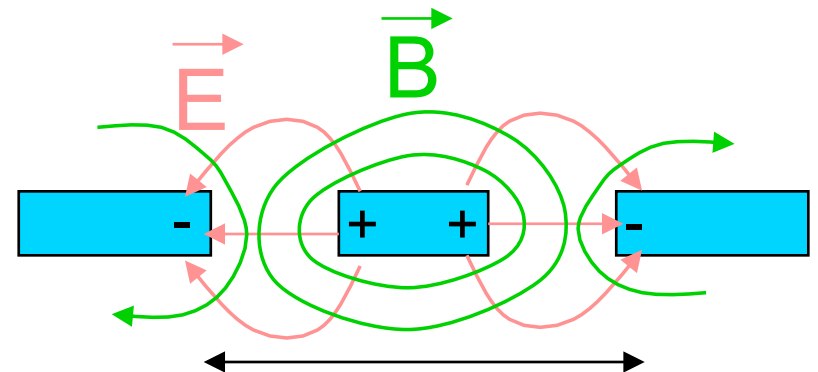
$$\Omega = 12.5\text{MHz}$$

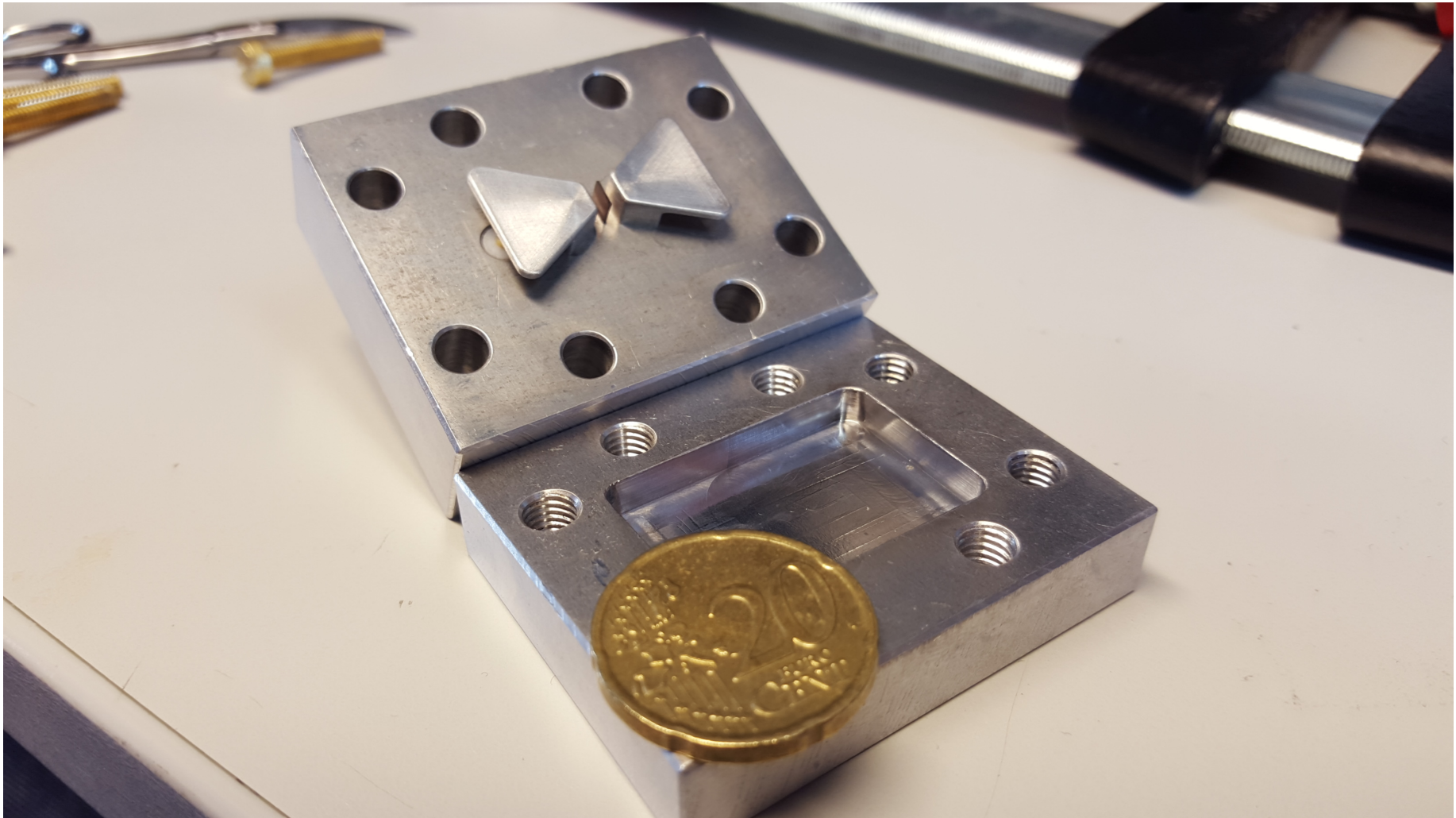
$$C = 27$$

Homogenous Coupling



Andreas Angerer, Thomas Astner, Daniel Wirtitsch, Hitoshi Sumiya, Shinobu Onoda, Junichi Isoya, Stefan Putz, and Johannes Majer,
Collective strong coupling with homogeneous Rabi frequencies using a 3D lumped element microwave resonator,
Applied Physics Letters **109**, (2016)





aluminium
 $Q = 510\,000$

no external field possible (Meissner effect)

Dispersive Measurement



Resonator

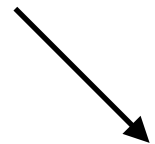
$$\omega_r/2\pi = 3.04\text{GHz}$$

Spins

$$\omega_s/2\pi = 2.88\text{GHz}$$

$$\Delta = \omega_r - \omega_s \gg g$$

$$H_{\text{int}} = \hbar(a^\dagger S^- + a S^+)$$



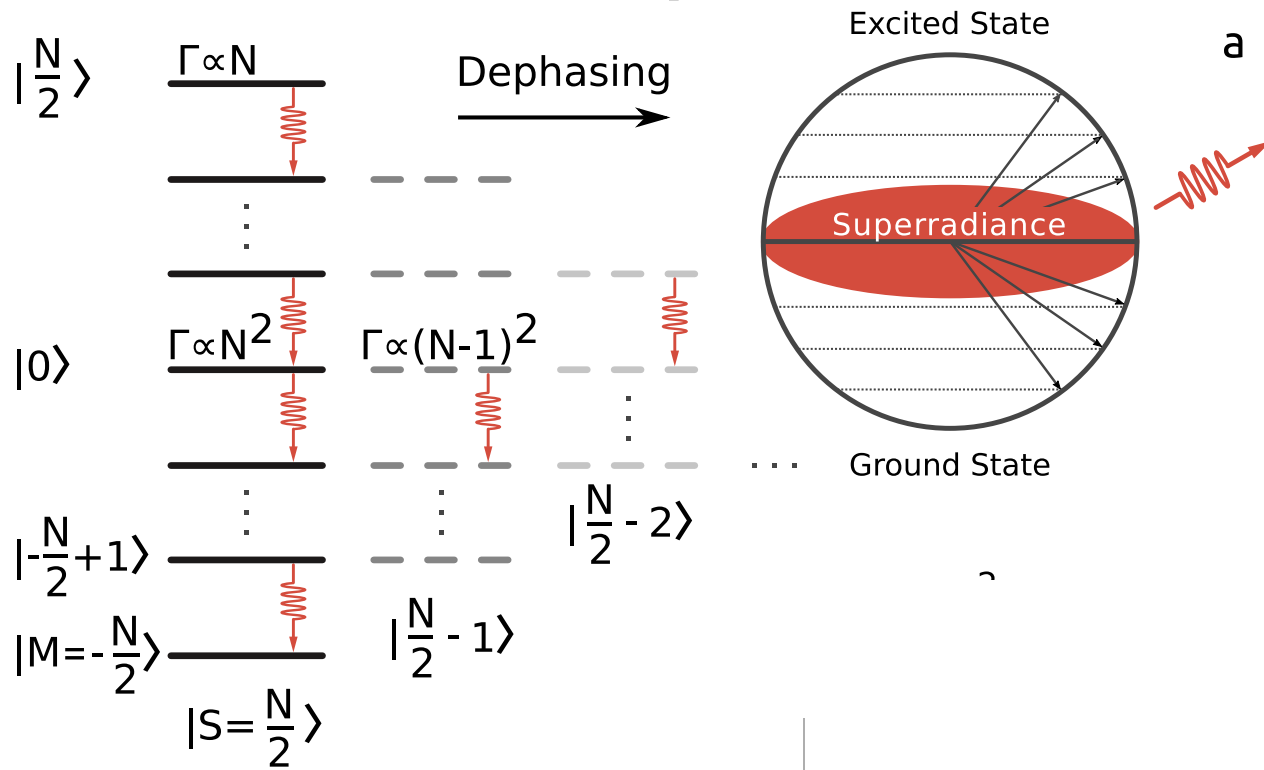
$$H_{\text{eff}} = \hbar \left(\omega_r + \frac{g^2}{\Delta} S_z \right) a^\dagger a + \dots$$

dielectric shift of the cavity

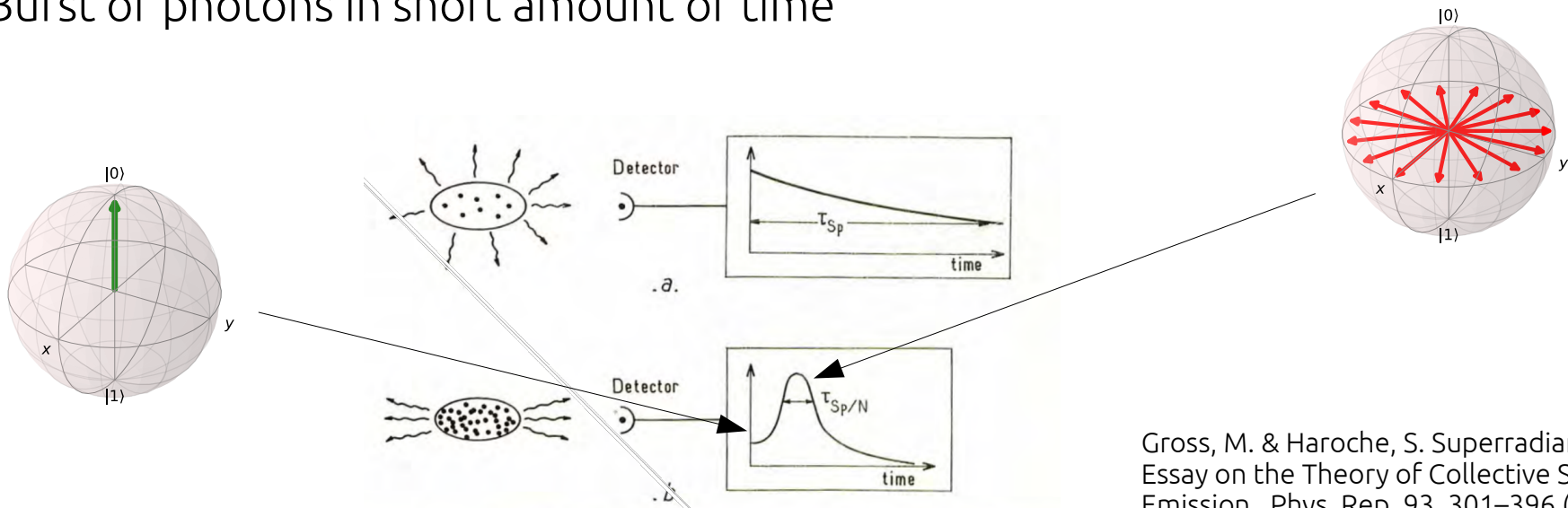
non-destructive

quantum non-demolition
measurement

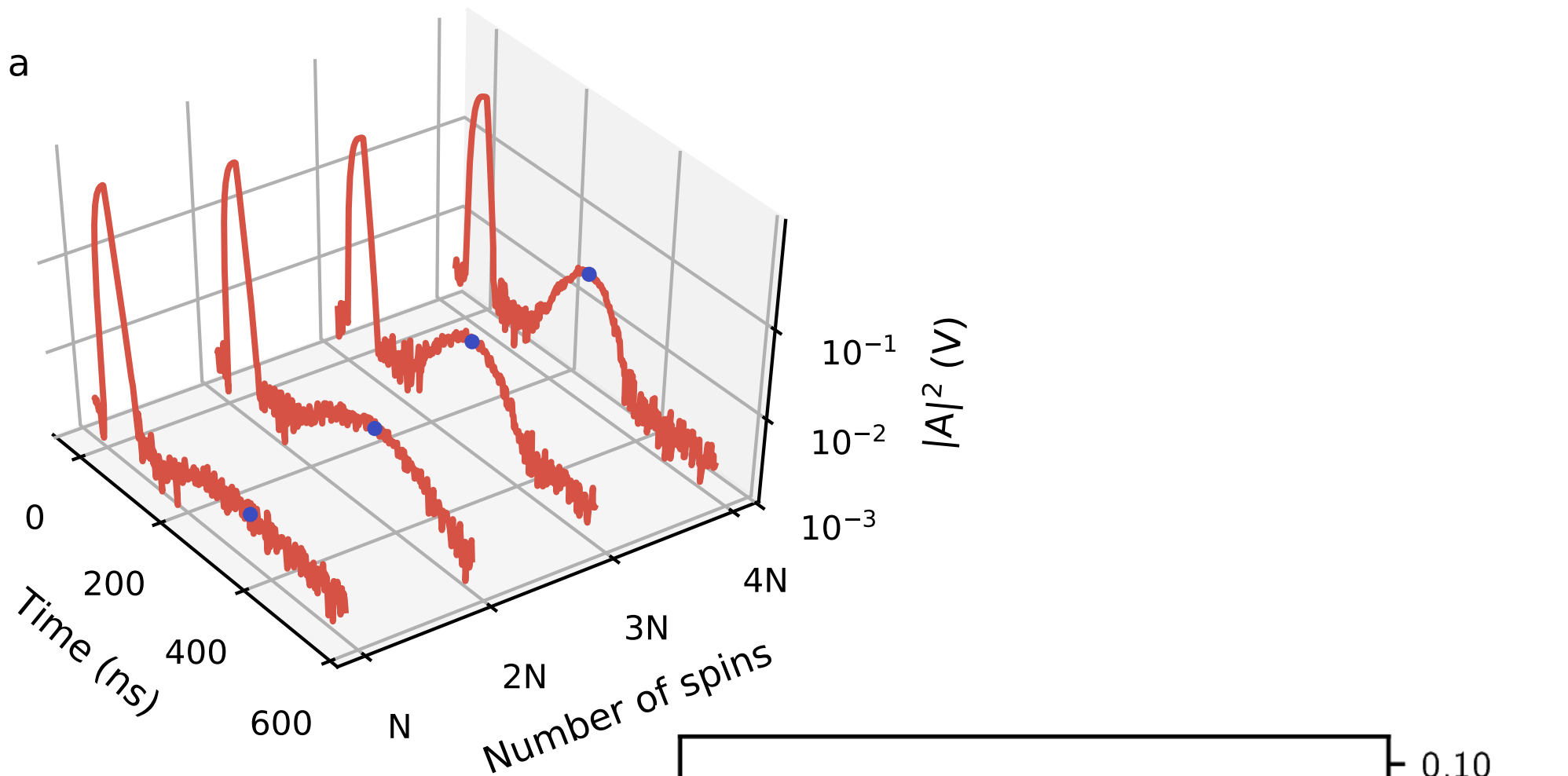
Superradiance



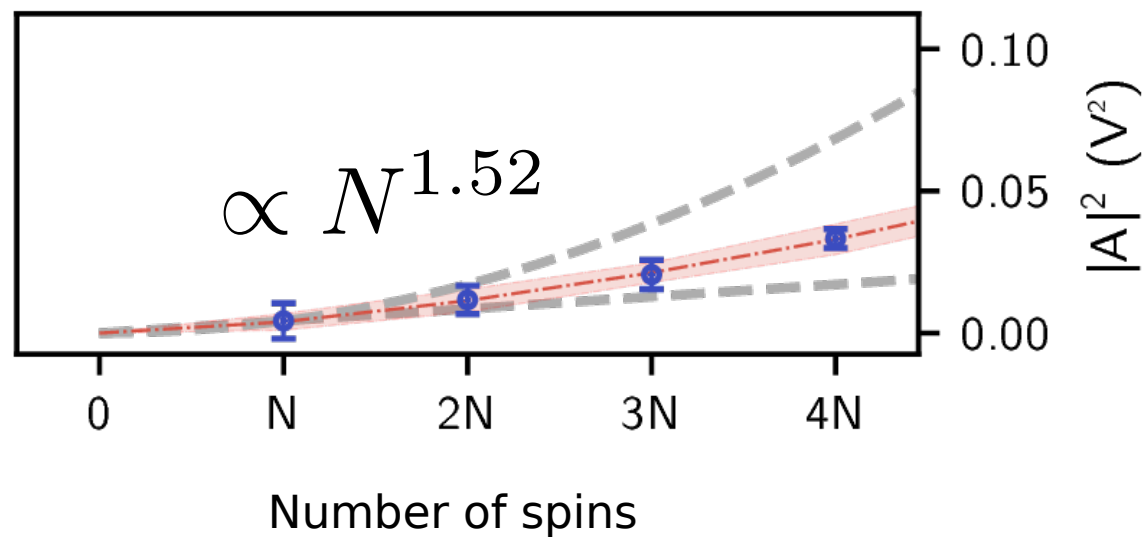
Burst of photons in short amount of time



Gross, M. & Haroche, S. Superradiance: An Essay on the Theory of Collective Spontaneous Emission . Phys. Rep. 93, 301–396 (1982)

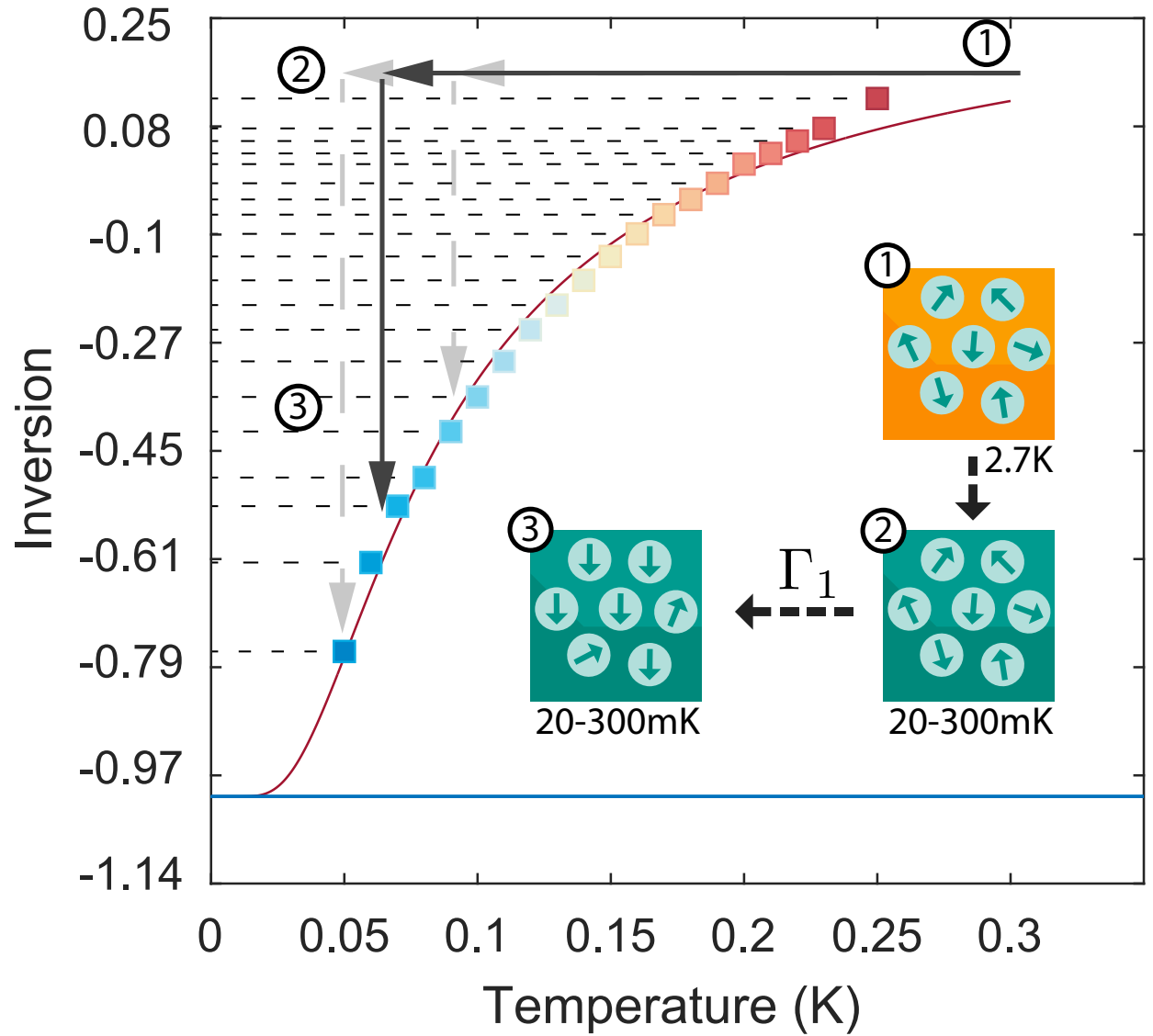


Andreas Angerer, Kirill Streltsov, Thomas Astner, Stefan Putz, Hitoshi Sumiya, Shinobu Onoda, Junichi Isoya, William J. Munro, Kae Nemoto, Jörg Schmiedmayer, and Johannes Majer, *Superradiant emission from colour centres in diamond*, Nature Physics **14**, 1168--1172 (2018)

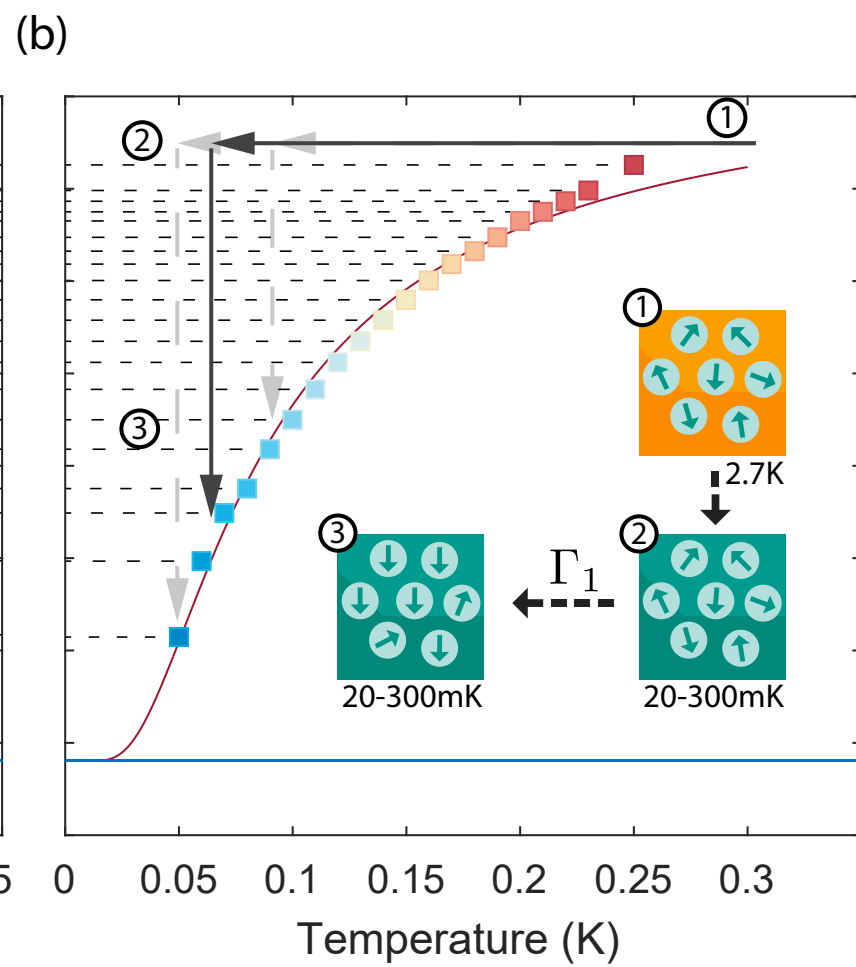
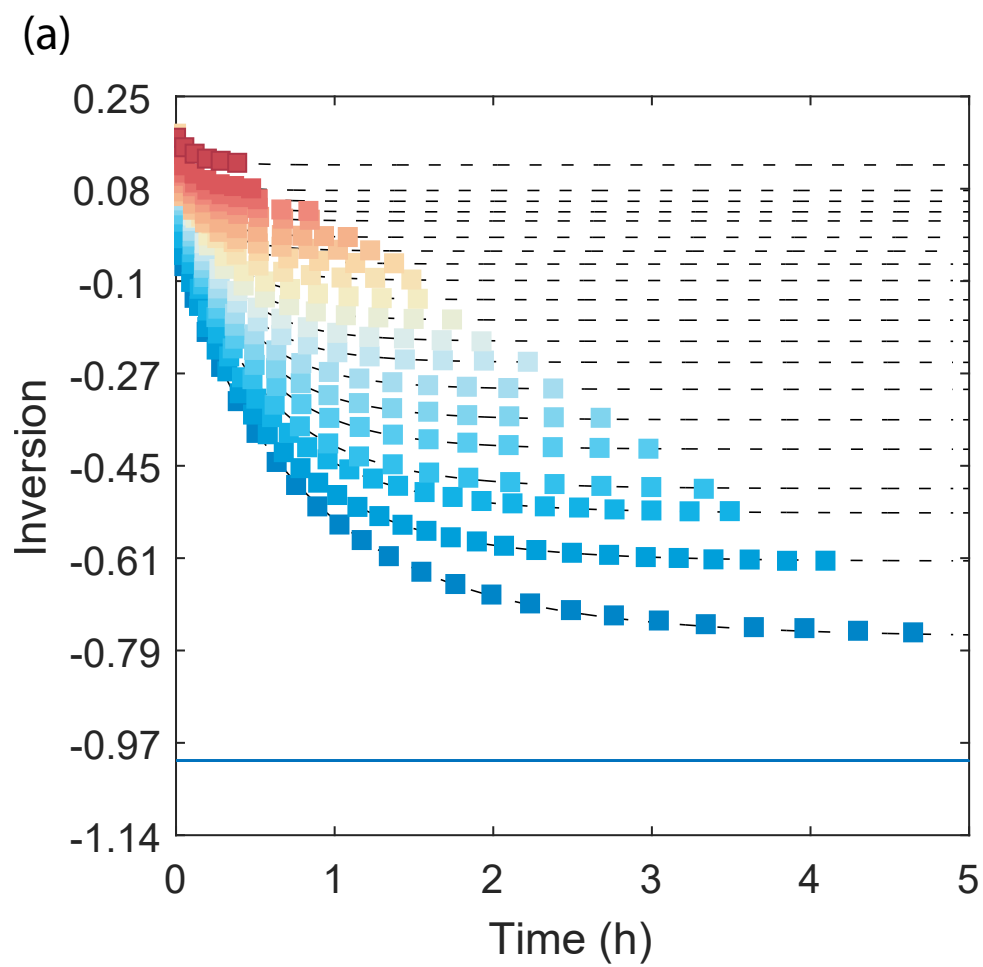


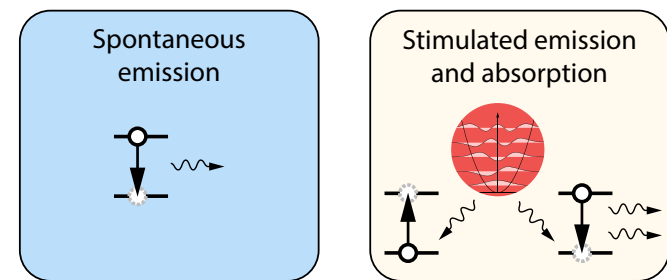
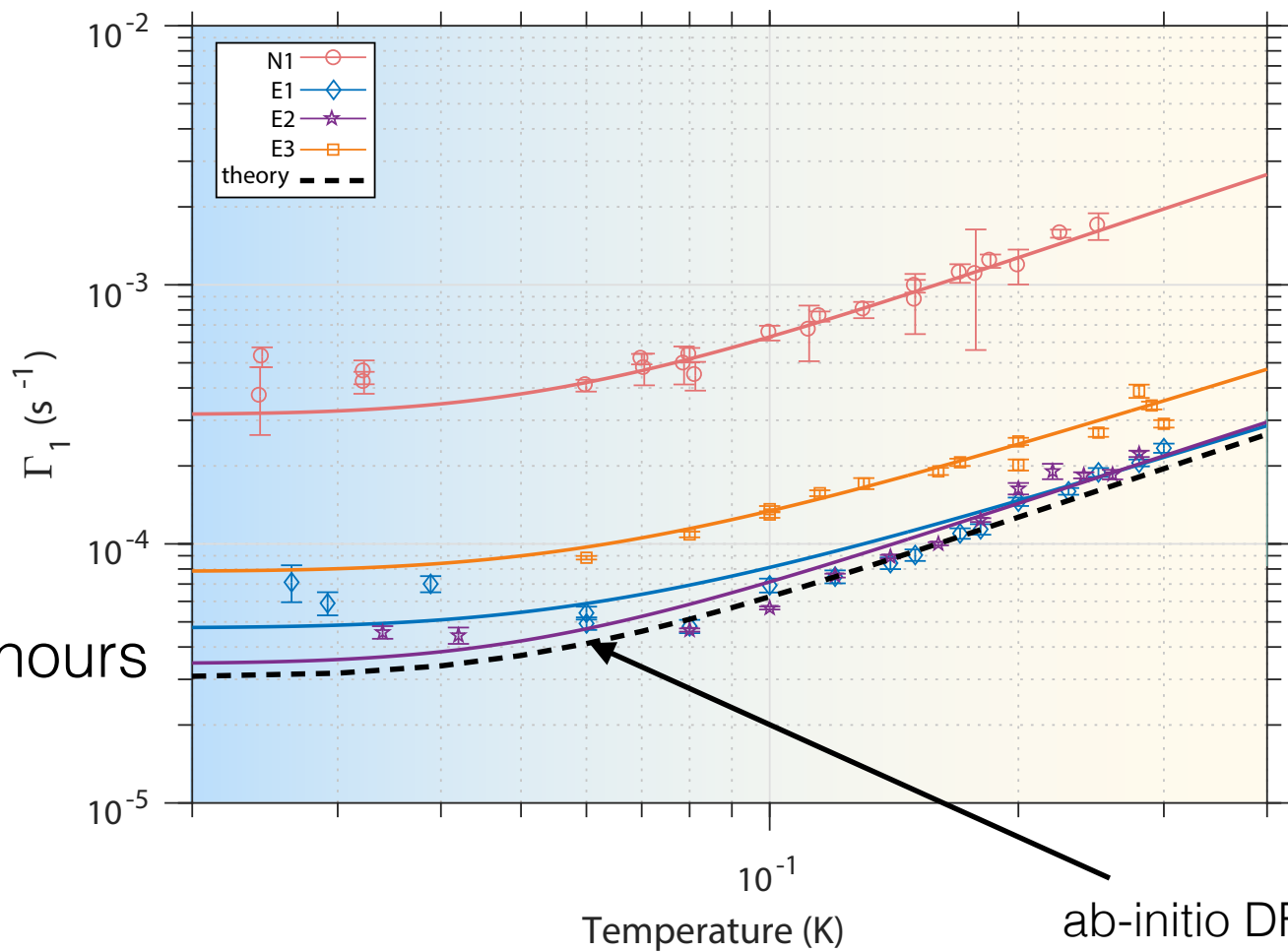
Relaxation Time

$$\langle S_z^2(T) \rangle_{st} = \frac{2}{\frac{\hbar\omega_s}{e^{k_B T}} + 2}$$

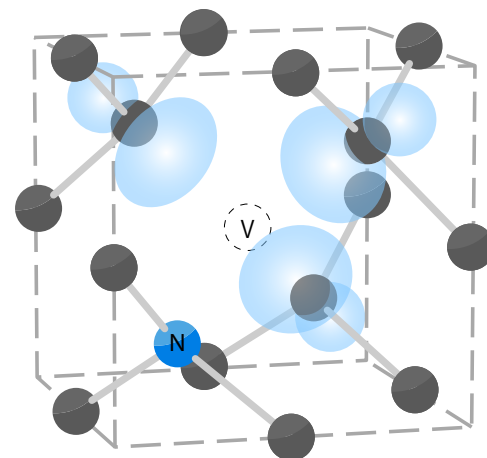


$$2.88 \text{ GHz} \hat{=} 145 \text{ mK}$$



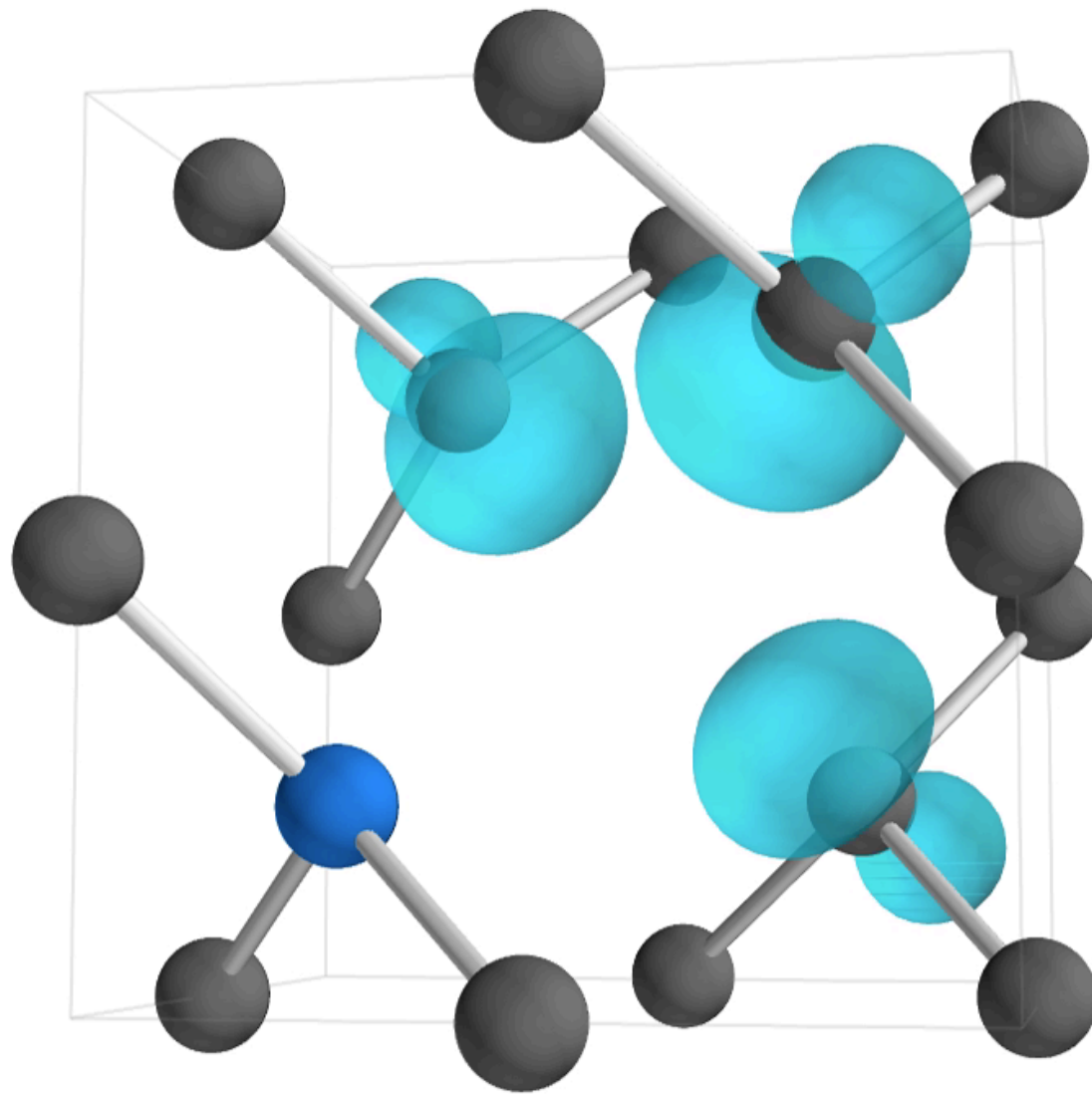


c



ab-initio DFT Calculation
 J. Gugler, P. Mohn

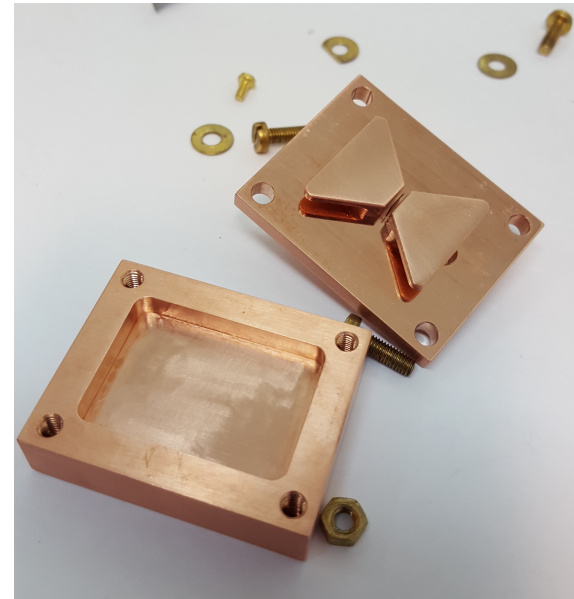
T. Astner, J. Gugler, A. Angerer, S. Wald, S. Putz, N. J. Mauser, M. Trupke, H. Sumiya, S. Onoda, J. Isoya, J. Schmiedmayer, P. Mohn, and J. Majer, *Solid-state electron spin lifetime limited by phononic vacuum modes*, Nature Materials **17**, 313--317 (2018)



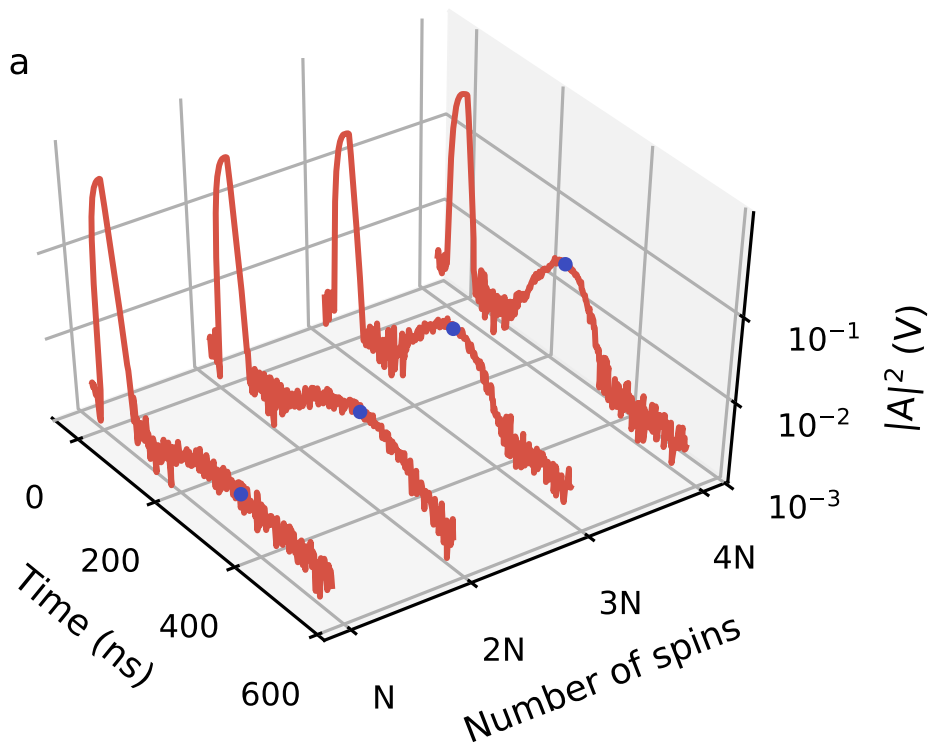
J. Gugler, T. Astner, A. Angerer, J. Schmiedmayer, J. Majer, and P. Mohn, *Ab initio calculation of the spin lattice relaxation time T_1 for nitrogen-vacancy centers in diamond*, Phys. Rev. B **98**, 214442 (2018)

Summary

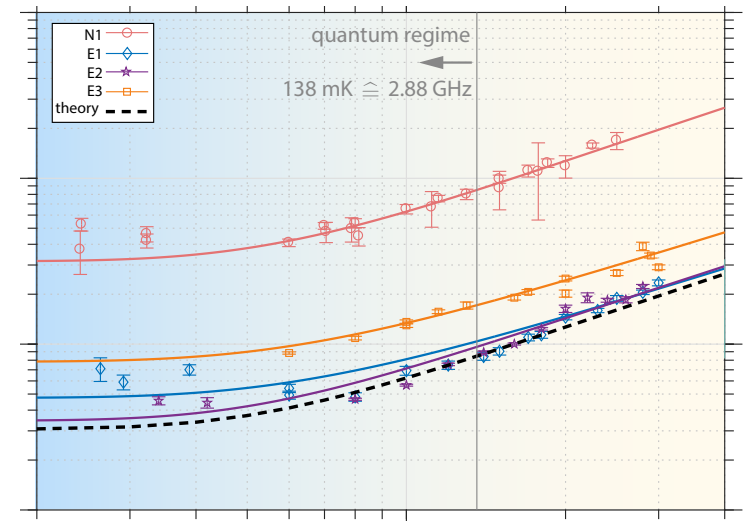
3D Lumped Element Resonator



Superradiance



Relaxation Time



Shanghai



Division of Quantum Physics and Quantum Information



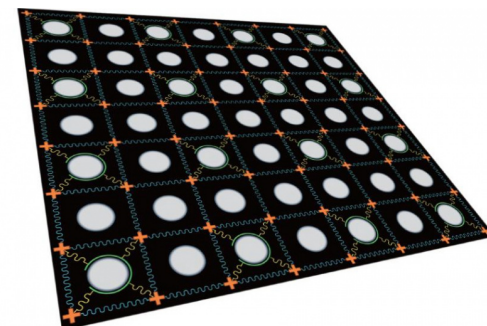
中国科学技术大学
University of Science and Technology of China



JianWei Pan



Photonic quantum computing



62 superconducting qubits



Quantum Satellite Micius

Projects, PhD, PostDoc, ... available



Victor Rollano



Marie Skłodowska-Curie Outgoing Fellowship

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