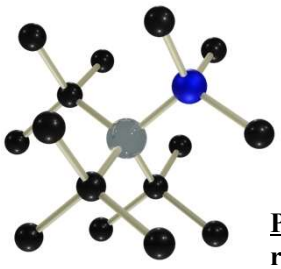
IRES²研究プロジェクト

ダイヤモンドリング共振器による量子磁気センシング

プロジェクトメンバー: 1 電気・電子情報工学系, 2 東大大学院工学系研究科, 3 IRES²
髙田晃佑[1,2]、 勝見亮太[1,2]、 河合健太[1]、 佐藤大地[1]、 飛沢健[3]、 赤井大輔[3]、 八井崇[1,2]

Introduction



Quantum sensing by nitrogen vacancy center

◎ High spatial resolution
◎ Solid state material
◎ Robust to environment

Problem: maintaining both spatial resolution and sensitivity is hard

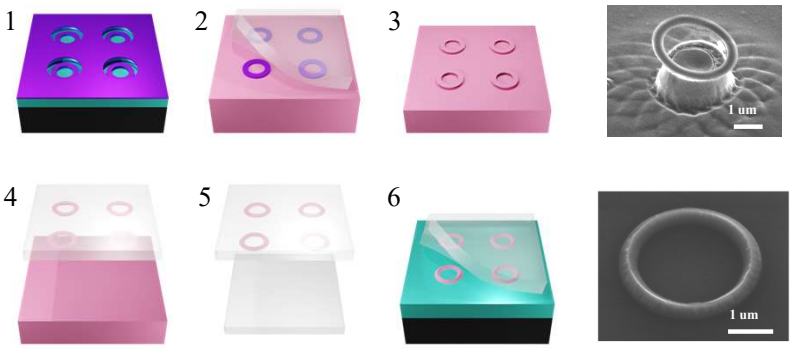
Diamond nanocavity

-- Optical cavity
◎ Emission rate enhancement (Purcell effect)

-- Nanophotonic structure
◎ High Purcell factor (nanocavity)
◎ Low-loss optical path
◎ On-chip packaging

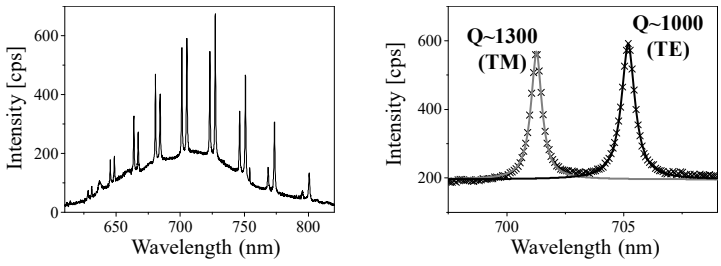
∋ Ring cavity
◎ High spatial resolution (~few μm)
◎ Large number of NV centers
◎ Easy to waveguide-coupling

Fabrication of ring cavities



Pick-flip-and-place [1]
◎ High yield integration
◎ Mechanically stable

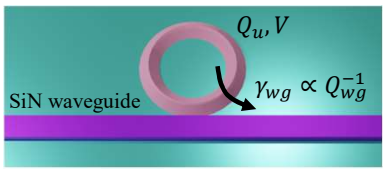
PL characterization



→ Highest Q factor among ensemble nanostructures

Waveguide coupling

※ Numerical demonstration



Loaded quality factor: $Q_L^{-1} = Q_u^{-1} + Q_{wg}^{-1}$

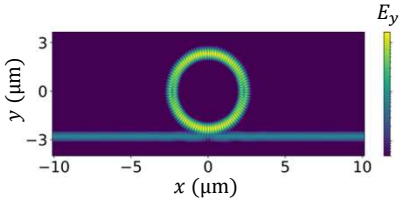
Purcell factor: $F_{ZPL} = \frac{3\lambda^3}{4\pi^2 n^3} \frac{Q_L}{V}$

NV → Cavity:

$$\beta = \frac{F_{ZPL}F_{DW}}{F_{ZPL}F_{DW}+1} = 94\ \%$$

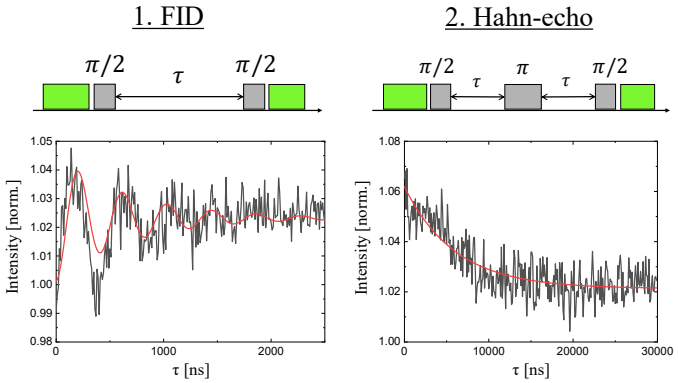
Cavity → Waveguide:

$$\eta = \frac{Q_{wg}^{-1}}{Q_L^{-1}} = 95\ \%$$



∴ Total coupling efficiency:
$\beta\eta = 89\ \%$

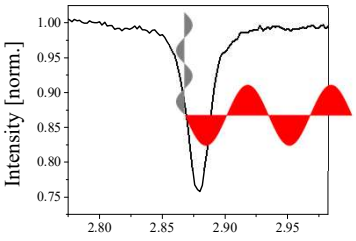
Spin properties after the fabrication

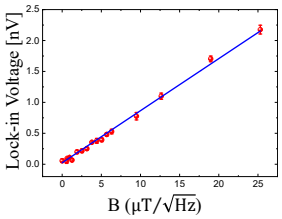


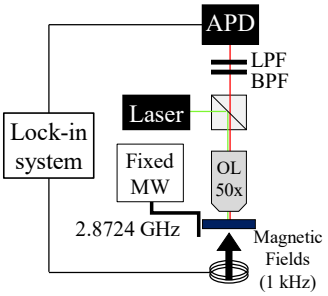
T_2^*: 1 μs [3] → 700 ns

T_2: 200 μs [3] → 6.0 μs

Magnetometry sensitivity







High spin contrast ~ 25 %

Noise floor: ~ 0.1 nV

→ 1 μT/√Hz

Conclusion

- Successfully fabricated high-Q diamond ring cavities
- Experimentally demonstrated sensitivity

Publications

- R. Katsumi, K. Takada, S. Naruse, K. Kawai, D. Sato, T. Hizawa, and T. Yatsui, Appl. Phys. Lett. **123**, 111108 (2023).
- R. Katsumi, K. Takada, K. Kawai, D. Sato, and T. Yatsui, submitted (2024)

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Corresponding author
takada.kosuke.wu@tut.jp