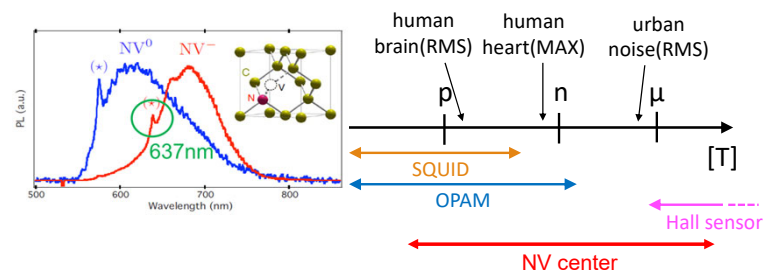


高感度ダイヤモンド量子センサ実現に向けた ダイヤモンド上微細加工構造の集積

R. Katsumi, S. Naruse, and T. Yatsui

Toyohashi University of Technology

Nitrogen-Vacancy (NV) center in diamond



- Color center → Strong PL (red light)
- ○ Wide dynamic range of magnetic sensitivity (pT~μT)
- × High refractive index → Low light-extraction efficiency

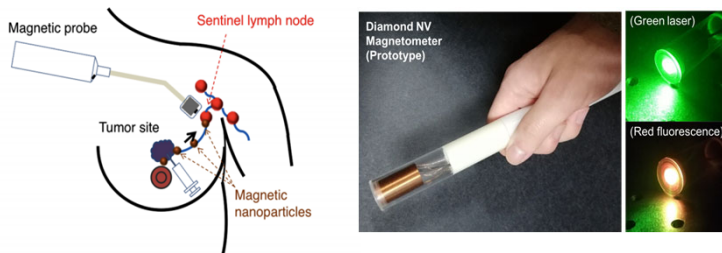
N. Mizuochi et al., *Nature Photonics* **6**, 299 (2012)

M. W. Doherty et al., *New Journal of Physics* **13**, 025019 (2011)

Cohen, D. *IEEE Transactions on Magnetics* **11**, 2 (1975)

Research purpose

- (1) Develop **high-sensitivity magnetic sensor** with NV center



A. Kuwahata, TY, et al., *Sci. Rep.* **10**, 2483 (2020)

- (2) Improve **light-extraction efficiency** (our experimental setup $\approx 10^{-11}$) of NV center using **grating coupler**

$$\eta \propto \frac{\Delta\nu}{C\sqrt{I_0}}$$

η : Minimal magnetic sensitivity of NV center

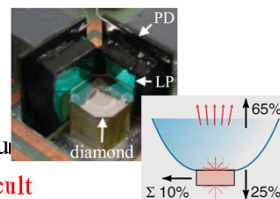
I_0 : PL intensity from NV center

$I_0 \uparrow \Rightarrow$ Better magnetic sensitivity

Improving the emission output from bulk diamond

□ Solutions for efficient collection

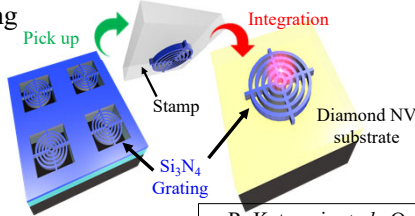
- Side collection, CPC lens: Bulky
→ **Difficult to miniaturize**
- Alternative/Attractive: Photonic structure
→ Fab on diamond: **Technically difficult**



D. Le Sage, et al., *Phys. Rev. B* **85**, 121202 (2012).
T Wolf, et al., *Phys. Rev. X* **5**, 041001 (2015).

In this work:

- New approach to fabricate grating on diamond
- Transfer printing

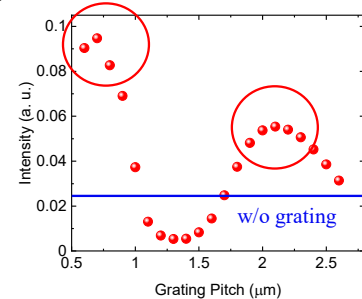
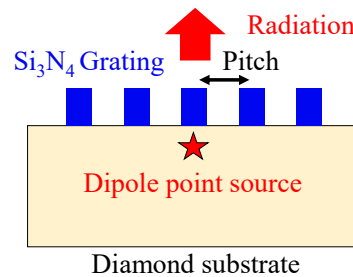


R. Katsumi, et al., *Optica* **5**, 691 (2018)

Numerical simulation

Si_3N_4 :

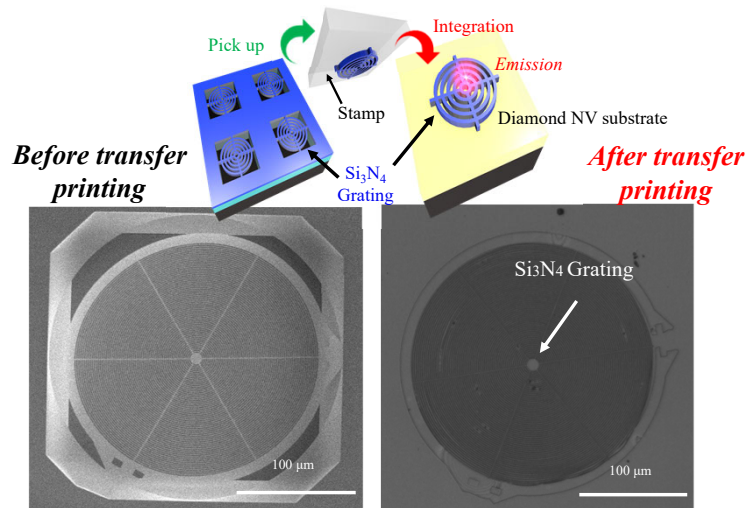
- Transparent for the NV emission (~ 700 nm)
- Developed fabrication technology



For Pitch = 0.7 μm (2.1 μm): x4 (x2.5)

$\Rightarrow$ Confirming efficient output of light radiated by NV centers

Device fabrication



Succeeding in the integration of grating structure on diamond

$\Rightarrow$ Verification of emission increase from diamond

Publications

- A. Kuwahata, T. Kitaizumi, K. Saichi, T. Sato, R. Igarashi, T. Ohshima, Y. Masuyama, T. Iwasaki, M. Hatano, F. Jelezko, M. Kusakabe, T. Yatsui, M. Sekino, *Scientific Reports*, **10**, pp. 2483, 2020
- S. R. Nair, L. J. Rogers, X. Vidal, R. P. Roberts, H. Abe, T. Ohshima, T. Yatsui, A. D. Greentree, J. Jeske, T. Volz, *Nanophotonics*, **9** (15), pp. 4505-4518, 2020
- T. Kitaizumi, A. Kuwahata, K. Saichi, T. Sato, R. Igarashi, T. Ohshima, Y. Masuyama, T. Iwasaki, M. Hatano, F. Jelezko, M. Kusakabe, T. Yatsui, Masaki Sekino, *IEEE Transactions on Magnetics*, **57** (2), pp. 5100405, 2021

Acknowledgement

This work was partially supported by MEXT Q-LEAP (JPMXS0118067395), CAO PRISM, KAKENHI (18H01470, 21K20428). The authors wish to express special thanks to Dr. Takeshi Hizawa (Toyohashi University of Technology) for active support.