ミクロンスケールマイクロ波増強のダイヤモンドNVセンターを用いたイメージング

Microwave field enhancement at micro-scale and imaging by NV centers in diamond

Giacomo Mariani[1], Shuhei Nomoto [1], Satoshi Kashiwaya[2, 3], Shintaro Nomura[1]

Univ. of Tsukuba [1], Nagoya Univ. [2], AIST[3]

E-mail: s1830092@s.tsukuba.ac.jp

Nitrogen-Vacancy centers (NVs) in diamond have been proved as extraordinary platforms for sensing [1], magnetometry and quantum information applications. For these applications, precise manipulation of the electronic spin by means of microwave (MW) fields is essential. Usually, gold wires coated on diamond or MW antennas with a large area are employed to drive MW fields for single or ensemble of spins respectively. However, a simple tool for generating specific MW fields is lacking. Here, we report a micrometer-scale gold pattern which is used to enhance the MW field on the scale of few micrometers. Moreover, we employed an ensemble of NV defects in diamond for imaging the MW field distribution over the gold pattern, proving NVs as a powerful platform for the characterization of MW antennas [2].

In our experimental setup (Fig.1a), a diamond substrate with a near-surface (~10 nm) implanted layer of NVs, is sandwiched between a planar ring MW antenna and a 110 nm thick gold pattern coated on a silicon substrate. The planar ring MW antenna generates a uniform MW field in area of size 0.785 mm^2; at a distance of 1 mm, the gold pattern acts as a receiving antenna and enhance the MW field in a localized area, comparable with its minimum width of ~1 μm. A pulsed laser diode at 70 mW is used for the excitation and read-out of the spin state and the photoluminescence from the sample is collected by an objective lens and focused into a CMOS camera. Note that the gold pattern is not fed by electrical current and it's only excited by our planar ring MW antenna.

We performed the imaging of the MW field by driving the Rabi oscillations of the NV electronic spin and by using the direct relation $\Omega/2\pi = \gamma B_{MW}$, which links the Rabi frequency Ω to the MW magnetic field amplitude B_{MW}, where γ = 28 GHz/T is the electronic gyromagnetic ratio. In Fig.1b, it's shown the MW field imaging in the near-field above the gold pattern, for the transition resonant with the ground spin states m_s = 0, +1 at MW frequency of 3.010 GHz, power of 35.3 dBm, for NV pairs aligned along [111] direction.

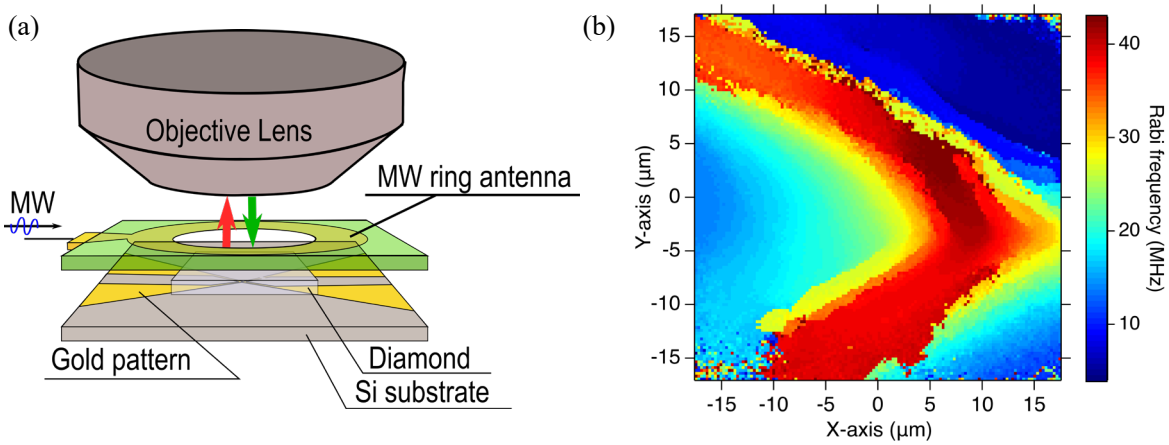

Fig.1 (a) Experimental setup. (b) Imaging of the MW field distribution at MW frequency of 3.010 GHz and power of 35.3 dBm by an ensemble of NVs. The highest Rabi frequencies correspond to the MW field above the gold pattern.

Comparing the maximum Rabi frequency above the gold pattern and in presence of the only planar ring MW antenna, we report an enhancement of about 19 times in case of the gold pattern. The main features of the Rabi frequency distribution have been confirmed by numerical FDTD analysis.

Different shapes of the gold pattern could be chosen to generate specific MW fields e.g. on nano-meter scale, limited only by the precision of nano-fabrication. Moreover, the MW imaging could be improved by extending the Rabi oscillations, reducing noise from the MW source or employing double driving schemes.

References

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