Dynamic initialization of a carbon nuclear spin with a coherent microwave around zero field

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Abstract: We demonstrated initialization of a ^{13}C nuclear spin with 65% fidelity together with initialization of a nitrogen nuclear spin with 76% fidelity under an effective zero magnetic field with a temporal square magnetic field.

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1. Introduction

Toward realization of quantum information technologies such as quantum repeater, quantum computer, and quantum sensor, we need to prepare quantum platform in which we can handle a large enough number of qubits to implement quantum information processors. We have recently proposed a degenerate quantum platform [1-3], where the logical qubits cannot be rotated with the conventional method. We have demonstrated quantum entanglement measurement and quantum teleportation from a photon to nitrogen nuclear spin in our quantum platform [4]. In this work, we demonstrate that our quantum platform is scalable by showing that we can handle carbon nuclear spins together with a nitrogen nuclear spin in a nitrogen-vacancy (NV) center in diamond (Fig. 1a,b).

2. Experimental setups

We used a native NV center in a high-purity type-IIa high-pressure-high-temperature grown bulk diamond with a <001> crystal orientation (from Sumitomo electric) without any electron-beam dose or annealing. A negatively-charged NV center located at about 10 μm below the surface was found using a confocal laser microscope. A 25-μm copper wire mechanically attached to the surface of the diamond was used to apply a microwave. An external magnetic field was applied to carefully compensate the geomagnetic field of about 0.045 mT using a permanent magnet. The NV center used in the experiment showed hyperfine splitting caused by ^{14}N nuclear spin and ^{13}C nuclear spin at 2.2 MHz and 6.5 MHz, respectively. All experiments were performed at room temperature.

Reduction of entropy by a green laser (532 nm, 100 μW) and unitary manipulation by a microwave (~2.87 GHz) and a radio wave (~5 MHz) initializes the electron spin, the ^{14}N nuclear spin and ^{13}C nuclear spin to the ground m_s=0 state, the ground m_I=0 state, and the up state, respectively. During manipulating the ^{13}C nuclear spin state, a temporal square magnetic field was applied. All the light beams were focused onto the sample using a 1.4 NA 100x objective lens.

3. Experimental results

After the spin states were initialized by a green laser, a microwave, and a radio wave, we checked the fidelity of initialization by Optically Detected Magnetic Resonance (ODMR).We used a temporal square magnetic field in both initializing the spin states and checking the fidelity. We demonstrated initialization of a ^{13}C nuclear spin with 83% fidelity (Fig. 2a). We also demonstrated initialization of a ^{13}C nuclear spin with 65% fidelity together with initialization of a ^{14}N nuclear spin with 76% fidelity under an effective zero magnetic field with a temporal square magnetic field (Fig. 2b).

4. Acknowledgements

We thank Yuichiro Matsuzaki, Kae Nemoto, William Munro, Norikazu Mizuochi, Fedor Jelezko, and Joerg Wrachtrup for their discussions and experimental help. This work was supported by National Institute of Information and Communications Technology (NICT) Quantum Repeater Project, and by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (24244044, 16H06326, 16H01052) and Ministry of Education, Culture, Sports, Science and Technology (MEXT) as “Exploratory Challenge on Post-K computer” (Frontiers of Basic Science: Challenging the Limits).

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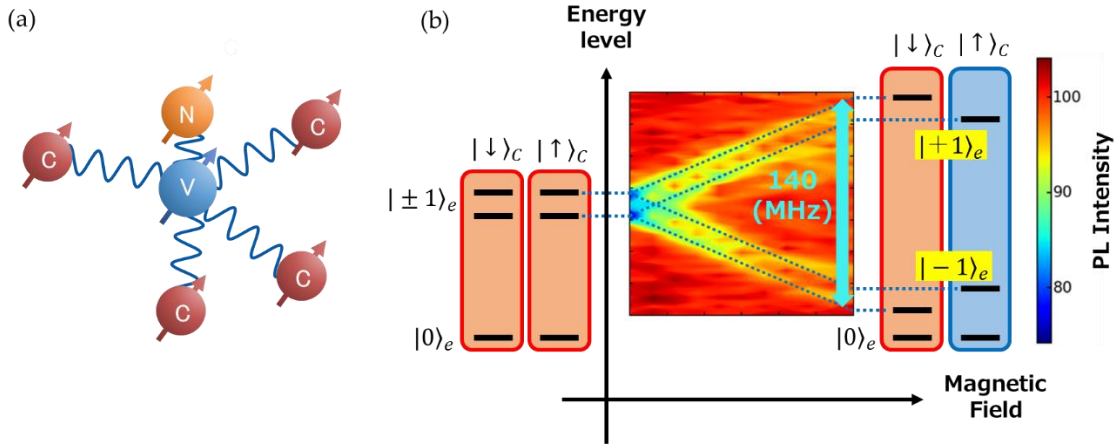

Fig.1 (a) Nitrogen-vacancy center with carbon isotopes in diamond. (b) Concept of dynamic nuclear spin initialization around zero magnetic field.

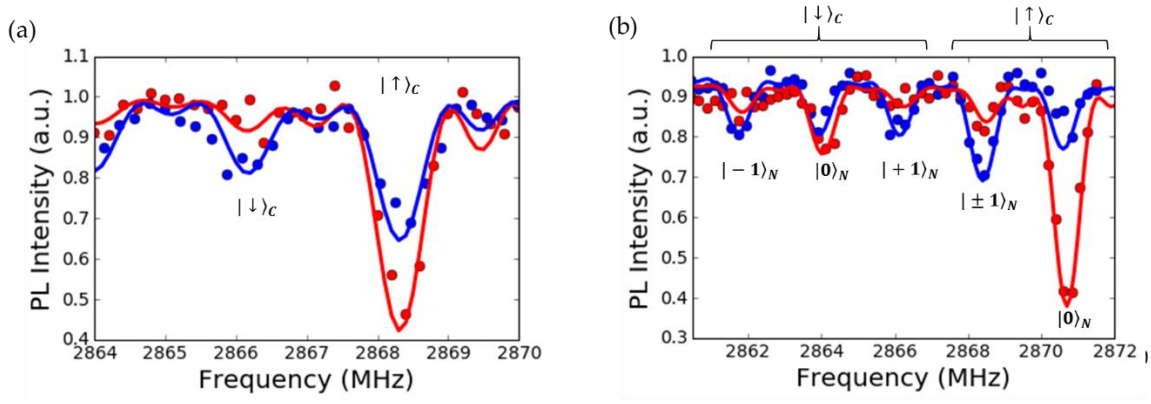

Fig.2 (a) ODMR spectra after (a) initialization of carbon nuclear spin into the up state and (b) initialization of carbon and nitrogen nuclear spins into the up and 0 states, respectively, at the same time.