Magneto-optical double resonance of a single NV center in diamond for photon-spin state transfer

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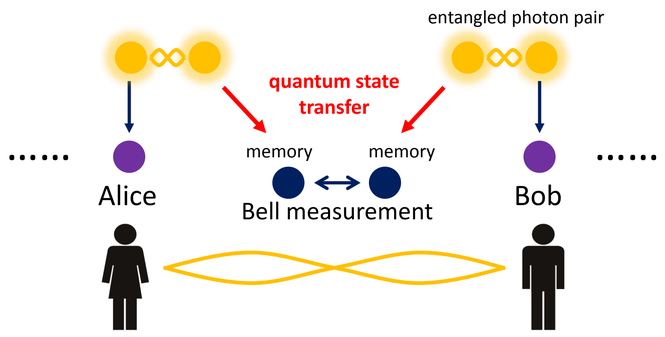
Motivation

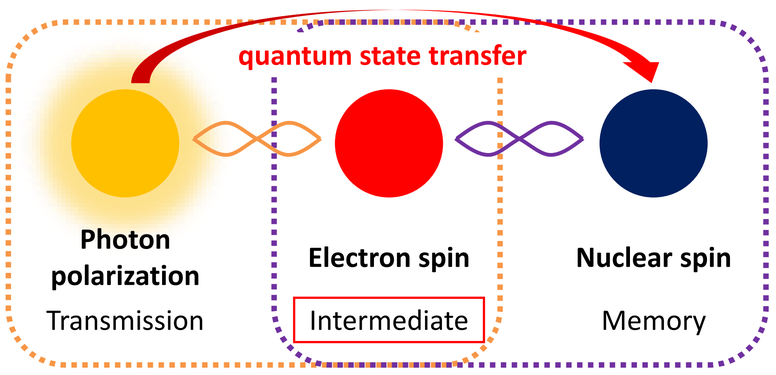
We demonstrate magneto-optical double resonance of a single NV center in diamond for quantum media conversion from a photon to a nuclear spin via an electron spin.

■ Quantum information communication

- Fundamentaly secure communications
- Communication distance is : 200km (present)→ >1000km (future)
  - ➢ **A quantum repeater is required**

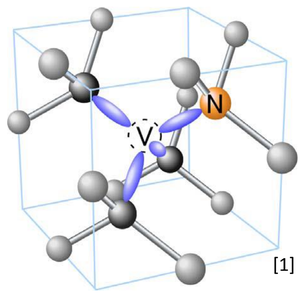


■ Quantum repeater



Quantum state transfer from a photon to a nuclear spin via an electron spin

■ NV center in diamond



[1]

N : Nitrogen
V : Vacancy

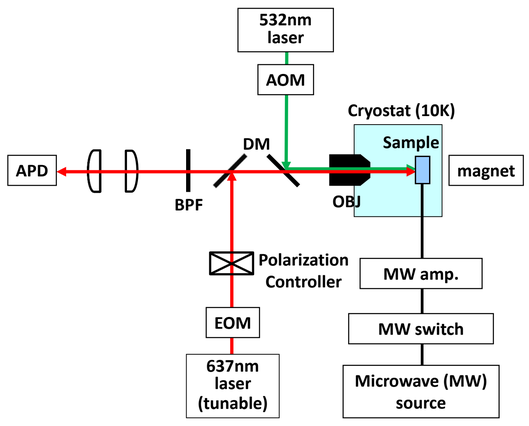
[1] N. Mizuochi et al., Nature Photonics **6**, 299 (2012)
[2] G. Balasubramanian *et al*., Nat. Mater. **8**, 383 (2009)
[3] M. V. G. Dutt *et al*., Science **316**, 1312 (2007)
[4] P. C. Maurer *et al*., Science **336**, 1283 (2012)
[5] A. Gruber *et al*., Science **27**, 276 (1997)

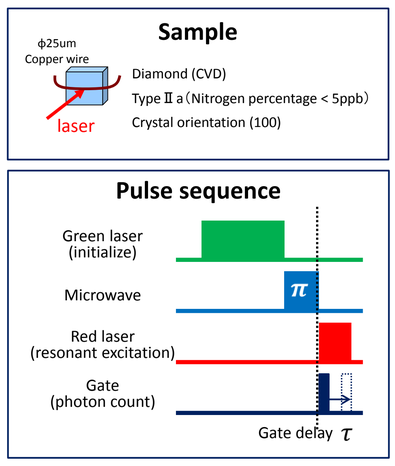
- **Long coherence time (T^2_e>1ms, T^2_n>1s at RT)** [2],[3],[4]
- Single electron/nuclear spin manipulation [5]
- Optical Initialization & readout of electron spins [5]

Objectives

I. **Excitation to $|A_2\rangle_e$ state, where orbit and spin are entangled, by magneto-optical double resonance**
II. **Generation of electron spin coherence with microwave and its readout with light**
III. **Transfer of photon polarization coherence to electron spin coherence**

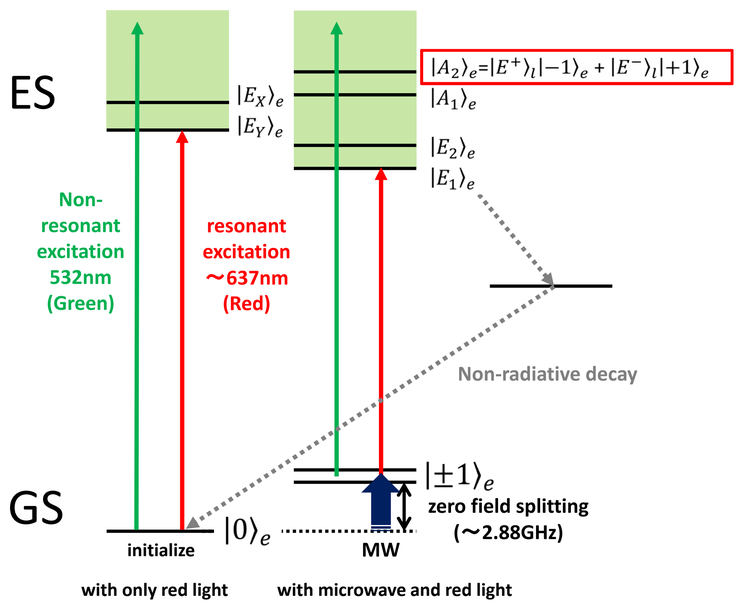
Experimental setup



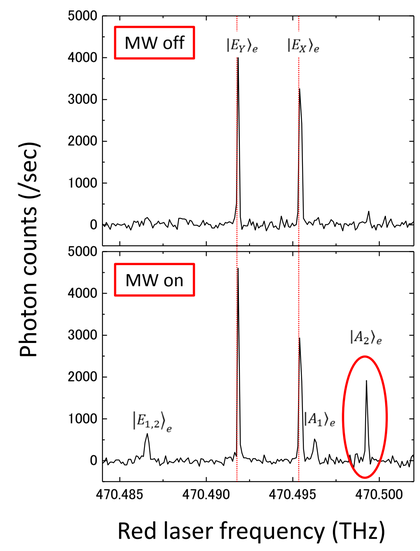


Approach

- Magneto-optical double resonance
- Degenerate Λ-v system



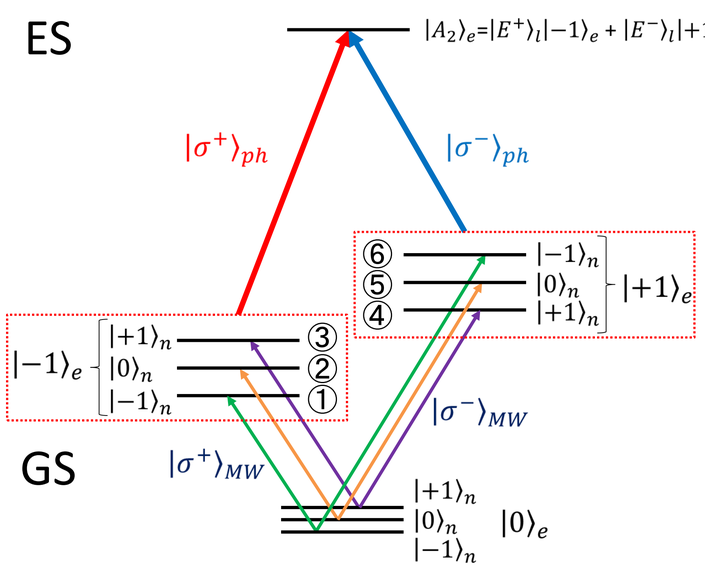
- Photo-excitation spectra



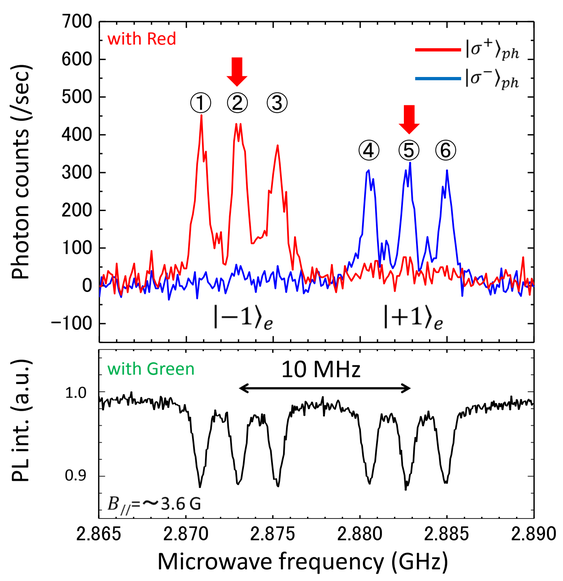
Excitation to $|A_2\rangle_e$ state, where orbit and spin are entangled, was observed by magnet-optical double resonance.

Experimental results

■ Electron spin non-degenerate system



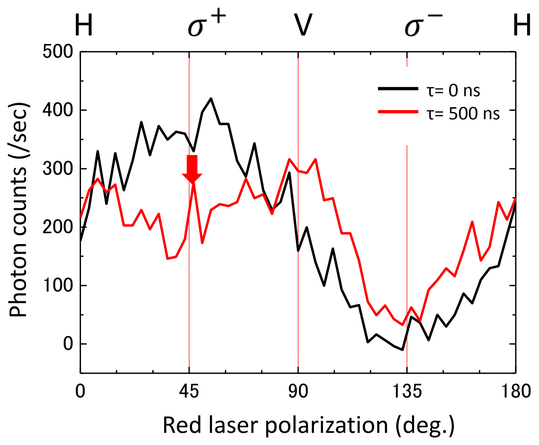
- MW frequency dependence of photoluminescence with green light (down) and with red light (up)



Polarization selection rule of $|-1\rangle_e$ and $|+1\rangle_e$ was observed by magneto-optical double resonance

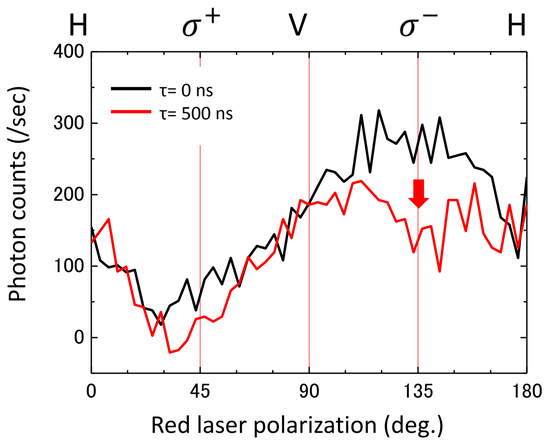
■ Polarization dependence of photoluminescence (non-degenerate system)

- $|-1\rangle_e \rightarrow |A_2\rangle_e$ red light excitation



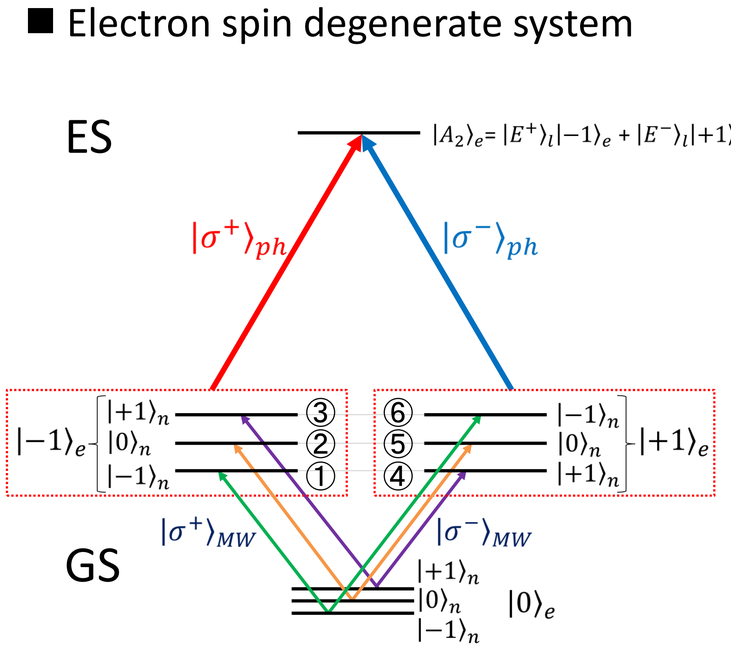
Luminescence saturation observed with $|\sigma^+\rangle$ excitation.
➢ **Spin pumping from $|-1\rangle_e$ to $|+1\rangle_e$ is implied.**

- $|+1\rangle_e \rightarrow |A_2\rangle_e$ red light excitation

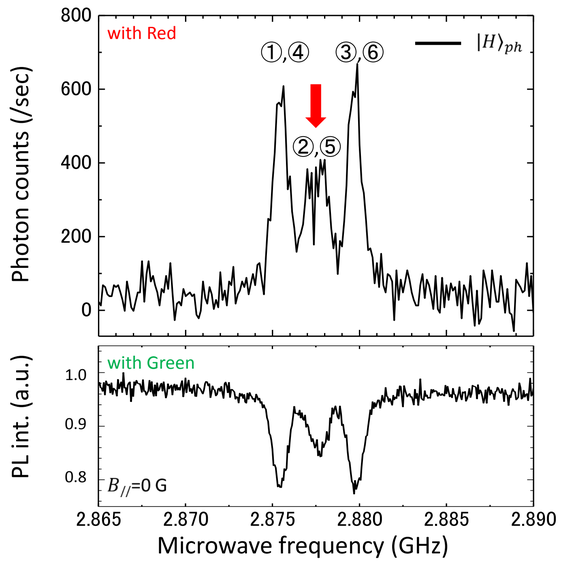


Luminescence saturation observed with $|\sigma^-\rangle$ excitation.
➢ **Spin pumping from $|+1\rangle_e$ to $|-1\rangle_e$ is implied.**

■ Electron spin degenerate system



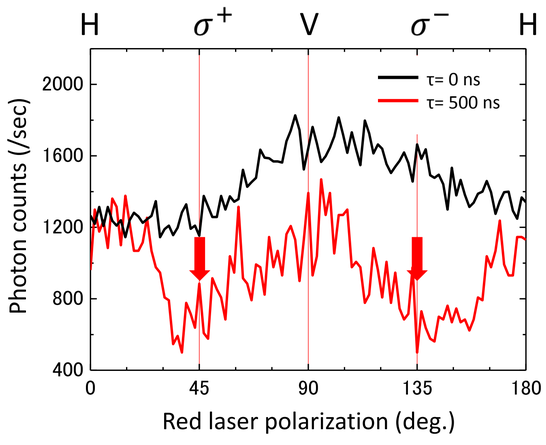
- MW frequency dependence of photoluminescence with green light (down) and with red light (up)



Degenerate electron spin system between $|-1\rangle_e$ and $|+1\rangle_e$ was created with magnetic field cancelation.

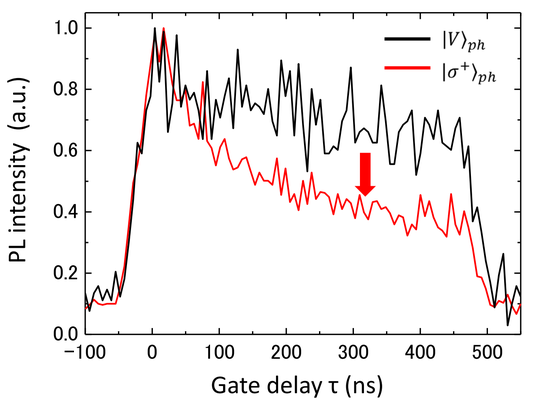
■ Polarization dependence of photoluminescence (degenerate system)

- $|\pm1\rangle_e|0\rangle_n \rightarrow |A_2\rangle_e$ red light excitation



Selective excitation with $|V\rangle$ polarization was observed at τ= 0 ns.
➢ **Generation of electron spin coherence with microwave and readout by light is implied.**
Luminescence saturation observed with $|\sigma^+\rangle$ and $|\sigma^-\rangle$ excitation at τ= 500 ns.

- $|\pm1\rangle_e|0\rangle_n \rightarrow |A_2\rangle_e$ Expose time dependence



Luminescence with $|\sigma^+\rangle$ polarization decays much faster than with $|V\rangle$ polarization.
➢ **Transfer of population from photon polarization state to electron spin state is implied.**

Conclusions (status)

I. **Excitation to $|A_2\rangle_e$ state, where orbit and spin are entangled, by magneto-optical double resonance has been demonstrated.**
II. **Generation of electron spin coherence with microwave and its readout with light has been achieved.**
III. **Transfer of photon polarization population to electron spin population has been achieved.**

Prospect

- Transfer of coherence from a photon to an electron spin
- Quantum state transfer of a photon polarization to a nuclear spin