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Resonant Excitation of Single Luminescence Centers in GaAs:N

Michio Ikezawa[1], Naoto Yasuda[1], Liao Zhang[1], Yoshiki Sakuma[2], Kazuaki Sakoda[2] and Yasuaki Masumoto[1]

[1] University of Tsukuba
1-1-1 Tennoudai, Tsukuba, Ibaraki 306-0006, Japan
Phone: +81-29-853-5908 E-mail: ikezawa.michio.fu@u.tsukuba.ac.jp
[2] National Institute for Materials Science
1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan

Abstract

Single nitrogen impurity centers in GaAs were resonantly excited by optical fields. Under continuous-wave excitation, homogeneous width of about 30 μeV was obtained by scanning excitation photon energy. Clear antibunching behavior supports successful excitation of a single center. Under strong ps-pulse excitation, a reduction of resonant fluorescence intensity was observed. It is probably due to coherent population oscillation of the two-level system (Rabi oscillation).

1. Introduction

Resonant excitation of a two-level system, such as two-level quantum dots or impurity centers, is important not only for the full coherent optical control of the quantum states but also for the excitation of highly indistinguishable single photon source [1]. Moreover, ultra-coherent single photon generation is demonstrated by the resonant excitation with a spectral linewidth below the radiative limit [2].

Nitrogen luminescence center in III-V semiconductor is a promising candidate for high quality single photon source because of the high brightness [3] and well-defined emission energy [4]. In this work, we resonantly excite single nitrogen impurity centers in GaAs:N by continuous wave (cw) and ps-pulses, and observe resonant fluorescence (RF) from single luminescence centers.

2. Sample and methods

The sample was a nitrogen delta-doped GaAs, which was grown by metal organic chemical vapor deposition technique on semi-insurating (001) GaAs substrate. The nitrogen sheet density is about 3.9×10^{12} cm^{-2}. To reject strong excitation laser from weak RF signal, we used orthogonal excitation-detection geometry. The sample was kept in an optical cryostat for microscopy, and a single mode fiber was inserted in the cryostat to deliver the excitation laser. An excitation light source was a cw titanium-sapphire (Ti:S) ring laser with 5MHz linewidth. A picosecond pulsed Ti:S laser, which produces 2 ps pulses at 82 MHz repetition rate, was also used. The excitation laser was focused to the side surface of the sample. Photoluminescence or RF signal was collected by an objective lens from top surface of the sample, and was led to a confocal microscope system.

3. Results and discussion

Luminescence spectrum of the sample at 5 K under above gap excitation shows many sharp peaks due to the nitrogen impurity below 1508 meV (not shown). We chose a single luminescence center whose peak energy was 1501.9 meV at 5 K for cw resonant excitation. Figure 1 (a) shows the RF intensity of the luminescence center as a function of the excitation photon energy for three different temperatures. A Lorentz-type resonance was clearly observed. The temperature dependence of the FWHM value and the peak energy are summarized in Fig.1 (b). The resonance width is consistent with our recent results of the temperature dependence of homogeneous width obtained by Fourier spectroscopy [5]. The shift is also consist with the temperature dependence of the emission energy of the luminescence center.

Though the observed signal contains scattering light from excitation laser to some extent, the main part arises from RF of the luminescence center. To confirm this, we performed photon correlation measurement by using a Hanbury-Brown and Twiss setup under strictly resonant excitation condition. The coincidence count actually shows clear antibunching, though the $g^{(2)}(0)$ value is about 0.5 because of the contamination of the residual scattering.

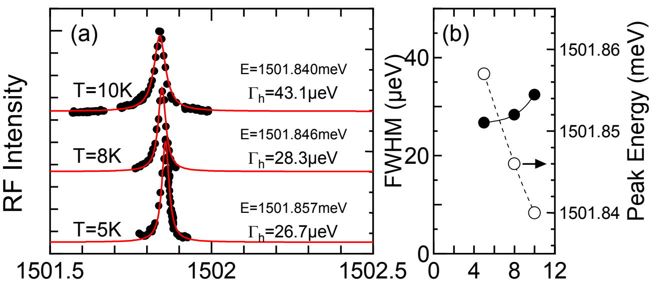

Fig. 1 (a) Resonance fluorescence intensity of a single luminescence center in nitrogen delta-doped GaAs as a function of the excitation photon energy. (b) Temperature dependence of the FWHM value and the peak energy of the resonance peak.

Next, we excited another luminescence center by resonant ps laser pulses. The intensity of RF is plotted as a function of the square root of the input power in Fig. 2. The intensity increases first, and then decrease. We confirmed that it was not connected to excitation induced non-radiative dynamics, for example, heating of the sample. Therefore we conclude that this feature probably originates from Rabi Oscillation.

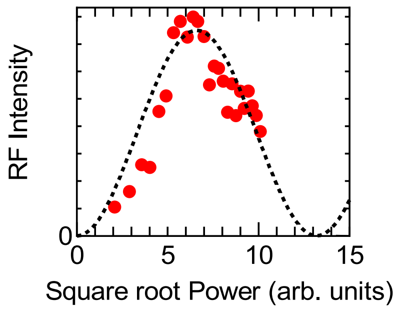

Fig. 2 Excitation power dependence of RF under ps resonance excitation.

4. Conclusions

Resonant fluorescence of single nitrogen impurity centers in nitrogen delta-doped GaAs was investigated. Homogeneous width of about 30 μeV was obtained by scanning the excitation laser. Clear antibunching behavior was observed even under strictly resonant excitation, it supports successful excitation of a single center. Rabi Oscillation was observed under strong ps-pulse excitation.

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