【Grant-in-Aid for Scientific Research(S)】
Science and Engineering (Engineering Ⅰ)

Title of Project : Study of photon pair quantum entanglement generated from solid photon sources and their application to quantum information and communication

Ikuo Suemune
(Hokkaido University, Research Institute for Electronic Science, Professor)

Research Area : Engineering, Electric and electronic engineering, Electronic materials
Keyword : Thin film, Quantum structures, Quantum dot

【Purpose and Background of the Research】

Highly secure and safe networking is prerequisite in the present society, and the importance of quantum information and communication (QIC) is more and more recognized these days. For the realization and advancement of such quantum-information networking, quantum entangled photon pair (QEPP) sources are important, and the parametric down conversion (PDC) has been used as the standard photon source. However the generation of QEPPs is not predictable based on the Poisson statistics and the PDC is not regarded as the practical source in the near future applications. Quantum dots (QDs) have been the prominent candidate for realizing "on-demand" single-photon-(pair) sources, but the photon extraction from semiconductors with high refractive indices and the coupling to single-mode optical fibers have been difficult.

In this work, we pursue (1) the enhancement of photon extraction efficiency by embedding a semiconductor pillar with QDs inside in high-reflection metals such as Ag, (2) the improvement of single photon purity generated from QDs, (3) generation of QEPPs in the 1550-nm optical-fiber communication band, (4) generation of QEPP simultaneously with radiative recombination of a Cooper pair, and (5) generation of QEPP employing optical cavity enhancement effect. We study the application of such photon sources to QIC.

【Research Methods】

This research relies on the Pauli's exclusion principle on energy states of QDs and this makes single photon emission from QDs possible. Especially, (1) we embed semiconductor photon sources in Ag as shown in Fig. 1 and realize high efficiency coupling of generated photons to a single- mode optical fiber, (2) we minimize the semiconductor volume that may generate noise photons by embedding in metal, (3) we apply our method to QDs emitting at the 1550-nm optical-fiber communication band as shown in Fig. 2 and realize single photon and QEPP emitters in this band, (4) the new principle of simultaneous QEPP generation with a Cooper pair recombination will be directly confirmed, (5)the simultaneous QEPP generation based on optical cavity enhancement will be combined with (1) for realizing highly efficient QEPP sources.

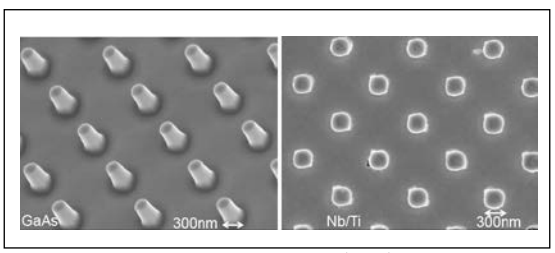

Figure 1 Pillar structure (left) and after their embedding in Ag (right).

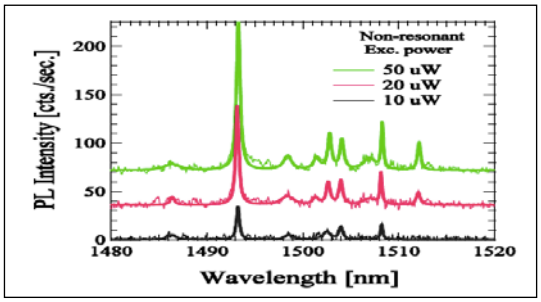

Figure 2 1500-nm band single QD emission.

【Expected Research Achievements and Scientific Significance】

Realization of efficient QEPP sources based on new physics will bring an impact to QIC.

【Publications Relevant to the Project】

- H. Sasakura,….. H. Kumano, I. Suemune: "Enhanced Photon Generation in a Nb/ n-InGaAs/ p-InP Superconductor/ Semiconductor -diode Light Emitting Device" Phys. Rev. Lett. **107** (2011) 157403.
- H. Kumano, K. Matsuda, S. Ekuni, H. Sasakura, and I. Suemune: "Characterization of Two-photon Polarization Mixed States Generated from Entangled-classical Hybrid Photon Source" Opt. Express **19** (2011) 14249-14259.

【Term of Project】 FY2012-2016
【Budget Allocation】 165,000 Thousand Yen
【Homepage Address】
http://nanophoto.es.hokudai.ac.jp