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# Enhancement of Luminescence in InAs Quantum Dots employing Cooper-pair Recombination

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On-demand entangled photon pairs (EPP) sources are an important prerequisite for implementing the next generation quantum information and communication (QIC). Semiconductor quantum dots (QDs) based EPP sources have been studied employing biexciton-exciton cascaded photon pairs emission process. However, the limitations of this method are dependence of entanglement on biexciton-exciton emission coherence time and fine structure splitting (FSS) of exciton state, which hinders generation of indistinguishable photon pairs.

We propose a new possibility to generate on-demand EPP in an InAs-QD-based heterostructure by employing Cooper pair radiative recombination. In 2006, we proposed a superconductor-based QD light emitting diode (SQLED) to generate EPP on demand [1]. The theory is based on the conversion of the entangled electron pairs to EPPs via the radiative recombination in a QD. Since the Cooper pairs are bosons, their number states are not controlled. However, in SQLED, We proposed to control the number state of generated photons for the on-demand operation by limiting the hole-pair occupation in the QD ground state in the valence band under the Pauli's exclusion principle [2]. In earlier works, we reported the luminescence intensity enhancement due to Cooper pairs and lifetime reduction below the critical temperature ($T_C$) of superconductor in InGaAs-based heterostructures [2, 3]. In this paper, we demonstrate luminescence of Cooper pairs in InAs QDs at the temperature below $T_C$.

Figure.1 shows the InAs QD heterostructure deposited with a superconducting Nb layer. Temperature dependence of the luminescence was measured with He-Ne excitation at 632.8 nm. We observed three peaks at 0.79 eV, 0.93 eV and 1.16 eV which were identified to be originating from the InAs QDs, $In_{0.53}Ga_{0.35}Al_{0.12}As$ and $In_{0.53}Ga_{0.25}Al_{0.22}As$ barriers, respectively (Fig. 2). We observed that the intensity drastically increases below $T_C$ (~9K) of Nb. The QD luminescence intensity measured below $T_C$ is about three times higher than that at above $T_C$. This behavior is interpreted as follows: The luminescence measured above $T_C$ is the result of normal electron recombination but the luminescence below $T_C$ is the luminescence of Cooper pairs (Fig. 3). The new feature found in this work is the sharp peak and edge (Fig. 3) that reflect the BCS superconducting density of states.

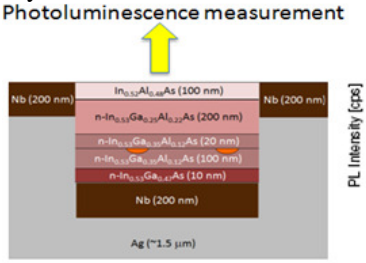


Fig-1

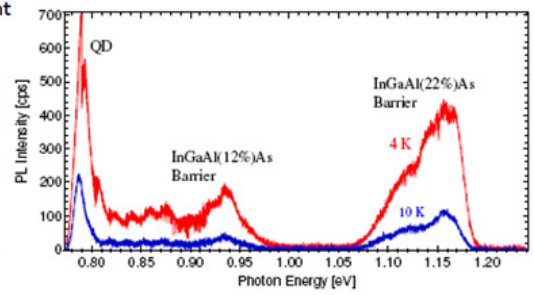


Fig-2

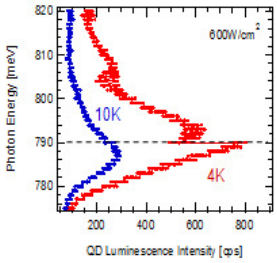


Fig-3

## References

[1] I. Suemune, T. Akazaki, K. Tanaka, M. Jo, K. Uesugi, M. Endo, H. Kumano, E. Hanamura, H. Takayanagi, M. Yamanishi and H. Kan, "Superconductor-based quantum-dot light emitting diodes: role of Cooper pairs in generating entangled photon pairs," Jpn. J. Appl. Phys. 45, 9264 (2006).
[2] H. Sasakura, S. Kuramitsu, Y. Hayashi, K. Tanaka, T. Akazaki, E. Hanamura, R. Inoue, H. Takayanagi, Y. Asano, C. Hermannstaedter, H. Kumano and I. Suemune, "Enhanced photon generation in a Nb/n-InGaAs/p-InP superconductor/semiconductor-diode light emitting devices," Phys. Rev. Lett. 107, 157403 (2011).
[3] I. Suemune, H. Sasakura, Y. Asano, H. Kumano, R. Inoue, K. Tanaka, T. Akazaki and H. Takayanagi, "Photon-pair generation based on superconductivity," IEICE Electronics Express, 9, 1184 (2012)