Entangled photon emission at temperatures up to 60 K from droplet epitaxial quantum dots

° X. Liu¹, T. Kuroda¹, T. Mano¹, H. Nakajima², H. Kumano², I. Suemune², Y. Sakuma¹, and K. Sakoda¹

¹National Institute for Materials Science (NIMS), ²RIES Hokkaido Univ.

Email: Liu.Xiangming@nims.go.jp

Introduction In the field of quantum information and communication technology, the achievement of entangled photon sources on demand is a key issue. The radiative cascade of two electron-hole pairs trapped in a self-assembled quantum dot (QD) has allowed us to prepare polarization-entangled photon pairs. Employing droplet epitaxy, we have recently fabricated the highly symmetric QDs [1], which have been used to realize the entangled photon-pair source at 10 K with a fidelity as high as 86% without post-selection [2]. Up to now, generation of entangled photons has been restricted to low temperatures. Toward high temperature emission in a QD, nonradiative decay and spin relaxation should be overcome. In this work, we have successfully realized the entangled photon pair emissions from a GaAs QD at elevated temperatures up to 60 K.

Experiment GaAs QDs were grown on a GaAs (111)A substrate by droplet epitaxy. Single QD spectroscopy was studied by a confocal micro-photoluminescence (μ -PL) setup with a temperature controller. Sharp emission lines corresponding to neutral biexciton (XX) and exciton (X) were observed. With polarization resolved photon correlation measurements, we measured second-order photon pair correlation function $g^{(2)}_{XX-X}(\tau)$ for co-polarized and cross-polarized XX and X lines in rectilinear (H,V), diagonal (D,A) and circular (R,L) polarization bases. We derived the correlation visibility and polarization correlation as a function of delay time to explore the mechanism responsible for the degradation of entanglement.

Results and discussion Figure 1a shows the second-order photon pair correlation function measured for co-polarized and cross-polarized XX and X photons in circular basis at 60 K. Strong bunching behavior is observed for cross-polarized circular (Fig. 1a), co-polarized rectilinear and diagonal (not shown) photon correlation measurements. The visibility in circular basis is larger than those in rectilinear and diagonal bases (see Fig. 1b), which can be explained in terms of the weak coupling of intermediate states due to the spin relaxation in nuclear magnetic fields. Figure 1b shows the correlation visibility as a function of temperature for three polarization bases. The visibility in three polarization bases drops as the temperature increases. The slight decrease at low temperature up to 30 K indicates that the relaxation of the exciton spin state is still week. The temperature-dependent fidelity is presented in Fig. 1c. Over the full temperature range investigated, the fidelity of two-photon polarization state projected on the maximally entangled bell state is well above the classic limit of

0.5 (dotted line), thereby indicating that this QD source indeed emits entangled photon pairs up to 60 K. It can be attributed to the high crystalline quality of droplet QD. The improvement in fidelity is expected by suppressing the depolarization of exciton with post-selection method (i.e., temporal gating [3]) and/or Purcell enhancement of the radiative rate. These results suggest that our droplet dot-based sources of entangled photon pairs can be operated at elevated temperatures up to 60 K for quantum cryptography in the future.

References

- [1] T. Mano et al., APEX 3, 065203 (2010).
- [2] T. Kuroda et al., PRB 88, 041306 (R) (2013).
- [3] H. Kumano *et al.*, arXiv:1406.6843 (2014).



FIG 1. (a) Second-order photon pair correlation function $g^{(2)}_{XX-X}(\tau)$ in circular basis. (b) The visibility and (c) the corresponding fidelity as a function of temperature.