STEPS Students Report

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The report is devoted to describe experiments conducted during short-term internship at Arakawa Lab, Institute of Industrial Science, the University of Tokyo, Japan. The work is focused on experimental investigation of ultrafast spectral diffusion (SD) in a single photon emission of GaN interface fluctuation quantum dot (QD).

Such structures could be a basis for prospective single photon sources (SPS), which is a device able to emit on demand light pulses containing one and only photon. SPSs are of crucial importance for prospective quantum information processing (QIP) such as quantum key distribution via photon state distribution.

One drawback hurdle for future application of QD in QIP is SD of QD emission manifesting itself as random jumps in the emission wavelength of spectral line. Such broadening is due to Coulomb interactions of emitter with the fluctuating electronic environment. The effect is prominent in III-nitride QDs and is critical issue as it leads to linewidths that can reach up to several meV even at cryogenic temperature.

We use an alternate method to reveal the time-scale of the diffusion in GaN fluctuation QDs via careful measurements of the intensity autocorrelation within spectral line. This technique gives time resolution 3-4 orders of magnitude higher than conventional ones.
The experimental setup is proposed and used for the first time by Henbury Brown and Twiss (HBT effect), see Fig.1. In order to get temporal resolution higher than APD rise-time the difference between events is detected with help of time amplitude conversion that return number of counts as a function of time delay between photon arrival event. Measuring of event counts gives us information about second order coherence of this light that is proportional to intensity autocorrelation.

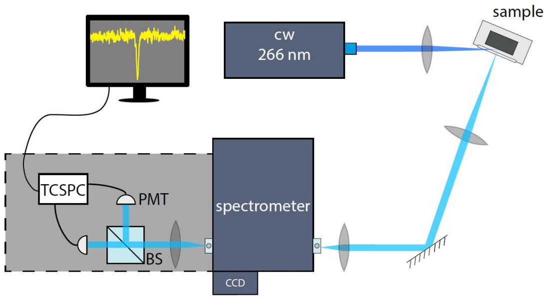
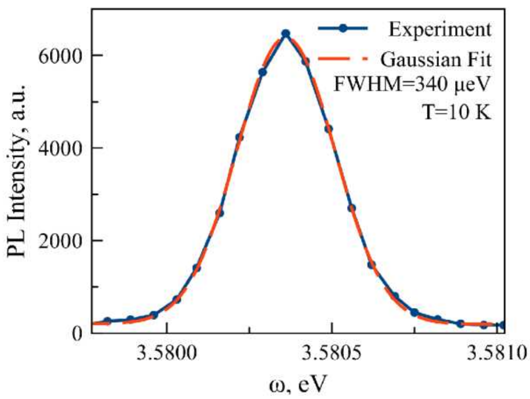


Figure 1. Experimental setup: CW – constant wavelength laser, CCD- charge coupled device, BS- 50/50 beamsplitter, PMT – photo multiplier tube, TCSPC - time-correlated single-photon-counting data acquisition

Micro photoluminescence (PL) experiments were conducted using a 266 nm Continuous Wave (CW) laser with the sample loaded in a continuous flow helium cryostat under vacuum and cooled down to a temperature of 10 K. Emissions from individual QDs are distinguishable without any process. Once the emissions from the QDs were located, photon autocorrelation measurements were performed using a standard HBT setup. Dual exit slits spectrometer is used in order to select spectral window within PL linewidth.



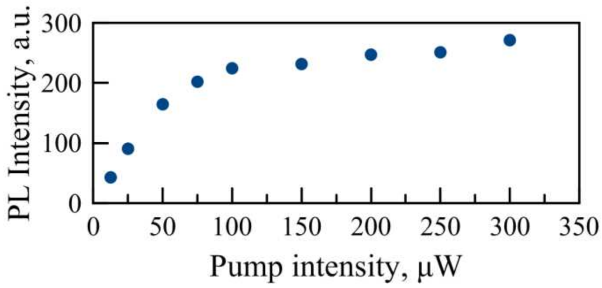


Figure 2. Single QD PL stpectrum (left) and PL Intensity maximum as a function of Pump Intensity (right)

One can see in Fig. 2 that PL spectral line from an isolated QD is inhomogeneously broadened and Gaussian fit is the most relevant for this case. Right hand figure shows presence of QD saturation at Pump Intensities above 100 uW. That is why we used range between 100uW and 200uW for pumping in order to get the maximum speed of counts. Below the results of auto-correlation experiments are depicted.

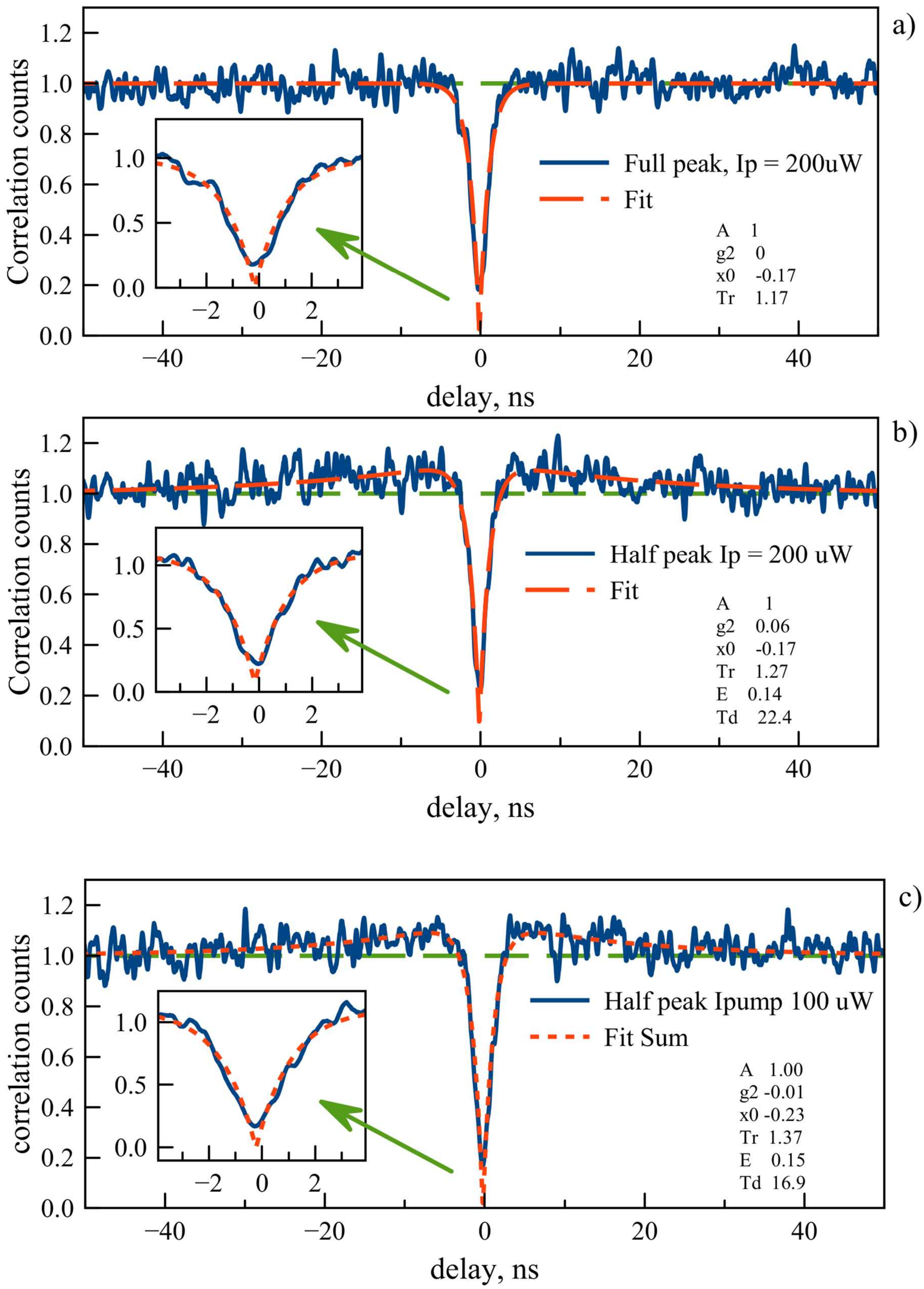
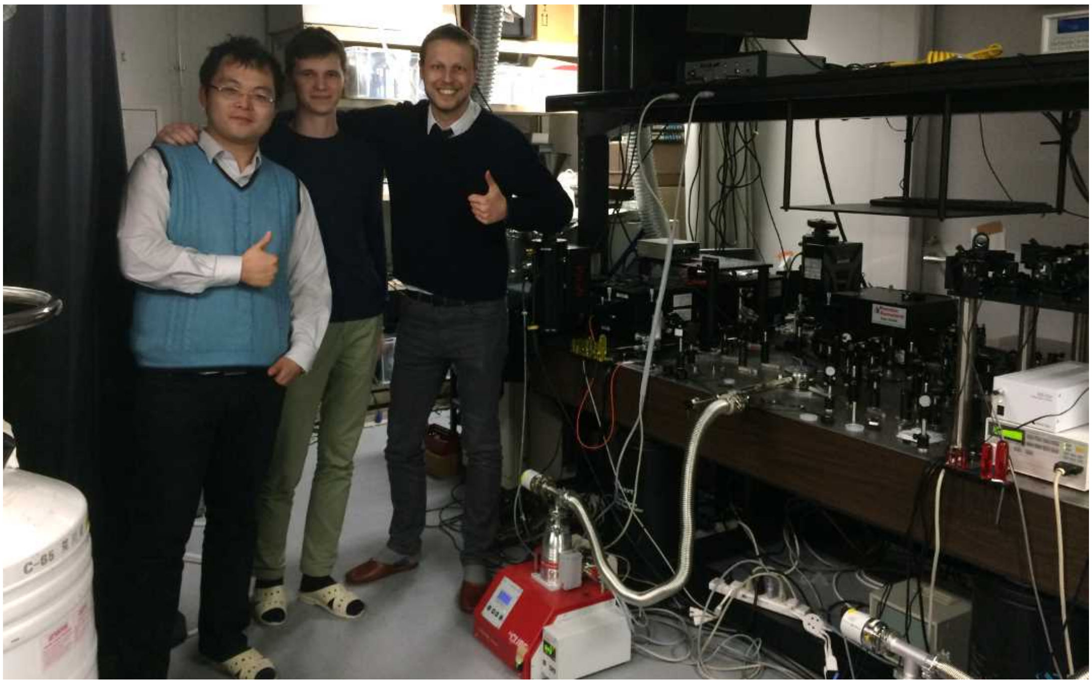


Fig. 3 Autocorrelation function from whole spectral line (a) and from right half of the peak [(b) and (c)].

Fig 3.a illustrates autocorrelation measurement of the whole emission peak from an isolated QD that reveals the typical anti-bunching behavior for a single quantum emitter, corresponding to Sub-Poisson photon statistics, with $g^{(2)}(0)$ as low as 0.2.

However, when selecting only one half of the peak (right side of the PL peak) for autocorrelation,(Fig.3 b and c) an additional bunching appears due to the spectral diffusion of the peak into and out of the selected spectral window. This provides us for the first time an information about ultrafast SD diffusion in such QD. An interesting fact is that SD time τ_D depends on a pump intensity that could be interpreted as sensitivity of QD environment to pumping. However there is a need of further investigation experimentally as well as theoretically. Basically we need to get more data about the τ_D as a function of Ipump.

Finally by means of auto-correlation measurement of photon statistics the existence of SD in a such structure was shown. This measurement provides us with direct information on the temporal scale of the SD process for the first time in these QDs, which will have important implications for the generation of indistinguishable photons for advanced applications.



Associate Professor Mark Holmes (right), me(center) and PhD student Gao Kang (left)