On-chip time resolved detection of quantum dot emission using integrated superconducting single photon detectors

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Photonic information technologies using semiconductors are ubiquitous and are rapidly being pushed to the quantum limit where non-classical states of light can be generated and manipulated in nanoscale optical circuits [1]. Single photons can be generated on-chip and preferentially routed into waveguides by tailoring the local density of photonic modes experienced by the emitter [2]. Furthermore, effective interactions between photons can be induced by exploiting coherent light-matter couplings [3]. The ability to generate and detect single photons on-chip with near unity quantum efficiency and integrate sources and detectors with nanophotonic hardware would represent a major step towards the realization of semiconductor based quantum optical circuits. Superconducting nanowire single photon detectors (SNSPDs) provide high single photon detection efficiencies, low dark count rates, sensitivity from the visible to the infrared and ps timing resolution [4]. The possibility to integrate SNSPDs onto waveguides results in a drastic increase of the absorption length for incoming photons [5], pushing the single-photon detection efficiency towards unity. In this contribution we demonstrate the on-chip generation of light originating from optically pumped micro-ensembles of self-assembled InGaAs QDs, low loss guiding over ~ 0.5 mm along a GaAs-AlGaAs ridge waveguide and high efficiency detection via evanescent coupling to an integrated NbN SNSPD [6]. Fig 1a shows a schematic representation of a typical sample showing the QD loaded waveguide and integrated NbN SNSPD. A typical spatial dependence of the detector count rate as then excitation laser is scanned over the sample is presented in fig 1b for excitation above (λ_{exc} = 632.8 nm, main panel) and below (λ_{exc} = 940 nm, insets) the GaAs bandgap. By comparing measurements performed with optical excitation above and below the GaAs bandgap and exploring the temporal response of the system (fig 1c), we show that the detector signal stems from QD luminescence with a negligible background from the excitation laser. Power dependent measurements confirm the single photon sensitivity of the detectors and show that the SNSPD is two orders of magnitude more sensitive to waveguide photons than when illuminated in normal incidence [7]. The performance metrics of the SNSPD integrated directly onto GaAs nano – photonic hardware confirms the strong potential for on-chip few-photon quantum optical experiments on a semiconductor platform.

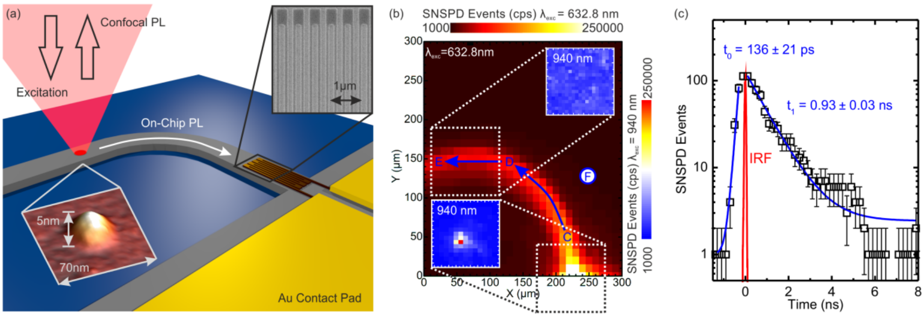

Figure 1 (a) Schematic of samples studied-QD loaded GaAs waveguide with integrated NbN SNSPD. (b) Spatial dependence of detector count rate when scanning the laser spot on sample with above and below gap excitation. (c) In-situ detected time resolved signal confirming the origin of the detector signal as arising from QD emission measured with a fast timing resolution of 72 ps.

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