Stand-alone quantum dot-based single-photon source operating at telecommunication wavelengths

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The ultimate security of the quantum communication protocols/schemes can be ensured by laws of quantum mechanics, but realization of the quantum communication protocols requires, among others, sources of single photons. For such solutions to become practical not only the sources need to be efficient, but also compatible with existing fiber infrastructure (emission at telecom spectral range) as well as semiconductor technology. Preferentially they should be fiber-coupled and operating at room temperature. Semiconductor quantum dots (QDs) provide inherently pure single-photons and they can fulfill almost all abovementioned requirements. The fundamental limit is room-temperature operation which is fundamentally not-achievable for QDs emitting at telecom wavelengths.

In this work we present realization of stand-alone fiber-coupled QD-based single-photon source operating in the 2nd telecom window and cooled down by industrial Stirling cryocooler (T = 40 K) which does not require access to cryogenics. The active element is a single $In_{0.75}Ga_{0.25}As/In_{0.2}Ga_{0.8}As/GaAs$ QD deterministically incorporated [1] into a numerically (finite element method) optimized mesa structure [2] for enhanced extraction efficiency. The especially developed interferometric method has been used to position a specialty highly gradually Ge doped single-mode fiber (NA=0.42) with respect to mesa of a cylindrical shape [3]. The single-photon purity has been evaluated by autocorrelation measurements with superconducting NbN detectors in all-fiber Hanbury-Brown and Twiss configuration with custom-designed fiber elements to deliver the optical pumping but also to filter from the detection channel the laser line and scattering light as well as the emission from a sample except of a single QD transition. In result, there could be obtained a train of single photons at the output of the standard telecom single-mode fiber.

The single-photon rate of the source at the output is 20 kHz which corresponds to coupling efficiency into the specialty fiber of 30%. The best single-photon purity measured under non-resonant pulsed-excitation (80 MHz, 50 ps pulses) corresponds to $g^{(2)}(0) = 0.15$ proving single-photon emission from such stand-alone device at the second telecommunication window.

References

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