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Strain tunable single-photon source based on a quantum dot-micropillar system

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Scalable quantum photonic architectures demand highly efficient, high-purity single-photon sources, which can be frequency matched via external tuning. Among different kinds of quantum emitters epitaxially grown self-assembled quantum dots (QDs) have been shown to be one of the leading candidates for efficient single photon generation. In order to maximize the number of photons extracted from the device, QDs are frequently embedded into photonic structures such as micropillar or photonic crystal cavities. Once the QD is positioned inside an optical cavity, the Purcell effect ensures that light is emitted predominantly into the cavity mode. However, the exploitation of the Purcell effect requires a careful spectral alignment of the QD emission and the cavity mode lines. Various methods have been applied to achieve spectral control of the QD emission characteristics, including temperature and electrical Stark effect tuning. Mentioned techniques are associated with drawbacks which can reduce the optical performance of the device like the photon indistinguishability, brightness or efficiency and sometimes require elaborate sample growth. An alternative proposal is a strain-tuning implemented by integration of the emitter onto a piezoelectric material such as PMN-PT.

In this work, we demonstrate a single-photon source based on an InAs quantum dot embedded in a micropillar resonator, which is frequency tunable via externally applied stress (Fig. 1(a)). Our platform combines the advantages of a Bragg micropillar cavity and the piezo-strain-tuning technique enabling single photon spontaneous emission enhancement via the Purcell effect and QD wavelength control via piezo-voltage tuning. Our optomechanical platform has been implemented by integration of semiconductor-based QD-micropillars on a piezoelectric substrate. The application of an external stress produces roughly a linear shift of the QDs emission wavelength, which allows to tune the QD emission through the micropillar cavity resonance (Fig. 1(b)).

The fabricated device exhibits spontaneous emission enhancement with a Purcell factor of 4.4±0.7 and allows for a pure triggered single-photon generation with over (93±2) % purity under resonant excitation (Fig. 1(c)). A QD emission energy tuning range of 0.75 meV for 27 kV/cm electric field applied to the piezo substrate has been achieved. Our results pave the way towards the scalable implementation of single-photon quantum photonic technologies using optoelectronic devices.

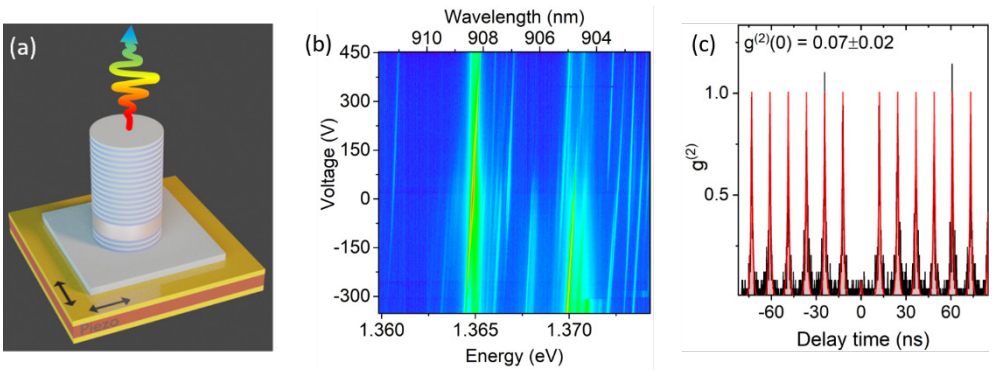

Fig.1. (a) Artistic sketch of a QD-micropillar cavity integrated with the piezoelectric substrate. (b) Color-coded microphotoluminescence intensity spectral maps of the QDs emission as a function of the voltage applied to the piezo substrate. (c) Second-order autocorrelation histogram as a function of delay time between subsequently emitted photons recorded under pulsed s-shell resonant excitation with a π-pulse area.