Engineering opportunities with MOVPE grown site-controlled Pyramidal quantum dots

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Quantum Dots (QDs) are sources of non-classical light – single and entangled photons – a resource which can be used to implement quantum information processing. However, the requirements for practical applications are very high, far more demanding than most of the current QD systems can deliver. Among them are site-control, emission uniformity, spectral purity, high QD symmetry, and high photon conversion/extraction efficiency. Fulfilling them all is a hardly achievable goal with randomly formed QDs, such as the Stranski–Krastanov ones. Thus herein we would like to highlight a different QD fabrication approach which significantly reduces problems inherited by randomly formed QDs – site-controlled InGaAs QDs grown by Metalorganic Vapor Phase Epitaxy (MOVPE) in inverted pyramidal recesses etched in (111)B oriented GaAs substrates. The superior properties (wavelength uniformity, spectral purity, entangled-photon emission), and potential for practical applications, of these QDs have been already demonstrated [1-3]. In this work, we highlight recent advances based on the Pyramidal QD system, thanks to its engineering flexibility.

First, we will present the first site-controlled light emitting diode of polarization-entangled photon pairs. Its successful design is largely based on a selective current injection scheme (Fig. 1a) achieved through epitaxial growth so to direct charge carriers to the QD and overcome fabrication issues arising because of structural non-planarity. High quality of entanglement was demonstrated by the violation of Bell's inequality. Second, a proof of concept demonstrating the possibility to apply a tuning strategy – a stress field – to suppress the remaining, though statistically small, fine-structure splitting, so to recover entanglement quality, will be shown (collaboration Linz). Third, a unique feature – the ability to stack an arbitrary number of precisely designed QDs, possibly making well-reproducible, QD-molecules – will be presented (Fig. 1b). Finally, the results of a newly developed technique to transfer pyramids (potentially one by one) on external substrates and surfaces, such as flexible films or a core of an optical fiber to decouple the quantum-light source from a photonic chip, will be discussed (Fig. 1c).

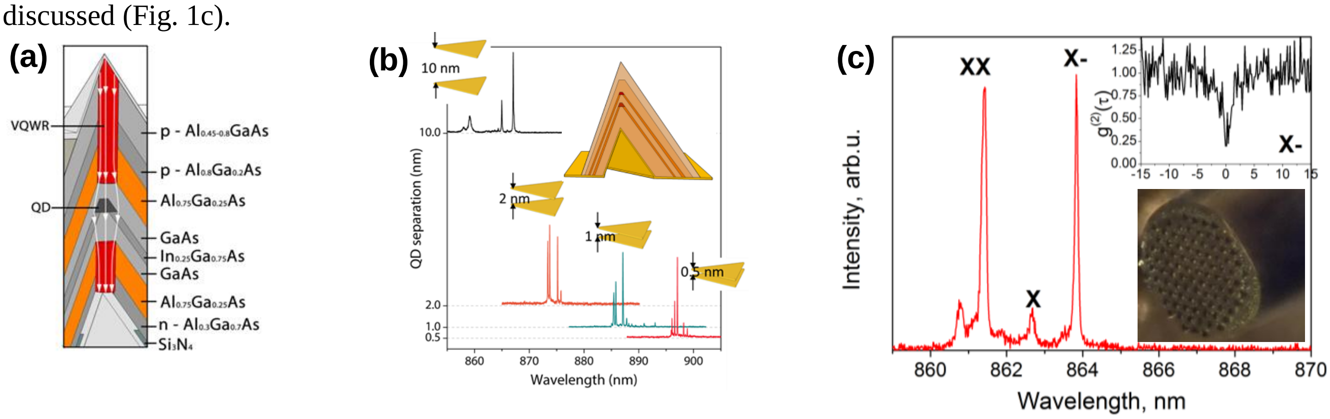

Figure 1. (a) A lower band-gap region – a vertical quantum wire (VQWR) – along the epitaxial pyramidal structure to inject carriers to the region of a QD. (b) Emission energy dependence on the separation between two stacked QDs. (c) Pyramid transfer procedure which enables integration of pyramidal structures on the external surfaces, such as flexible films or fiber cores (an optical microscopy image shown). The spectrum and single photon emission detected from an optical fiber with an integrated pyramidal QD.

References

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