Quantum Engineering with site-controlled Pyramidal quantum dots

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The requirements for practical applications of QDs in quantum information are very demanding. Among them are site-control, emission uniformity, spectral purity, high QD symmetry, high photon conversion/extraction efficiency, and many others depending on the specific application. Herein we would like to navigate through some aspects of site-controlled InGaAs QDs grown by Metalorganic Vapor Phase Epitaxy (MOVPE) in inverted pyramidal recesses. Important achievements (wavelength uniformity, spectral purity, entangled-photon emission) and potential for practical applications have been already discussed [e.g. 1-3]. The system's most recent highlight has been polarization-entangled photon emission from site-controlled μLED exploiting a selective current injection scheme (Fig. 1a).

We will address now some recent advances based on the pyramidal QD (PQD) system, highlighting its engineering flexibility and some challenging open issues. We present our recent advances in the tackling of two photon resonant pumping, as well as the application of a stress field to suppress the residual fine-structure splitting, facing some hurdles linked to the non-planarity of the system. We will discuss a number of open challenges and the possible technical solutions currently explored (in collaboration with JKU, Linz). On the other hand, further engineering possibilities include the ability to stack an arbitrary number of precisely designed QDs, possibly building well-reproducible QD-molecules (Fig. 1b), and transferring pyramids (potentially one by one) on external substrates and surfaces, such as flexible films or onto the core of an optical fiber allowing, e.g., decoupling the quantum-light source from a photonic chip (Fig. 1c).

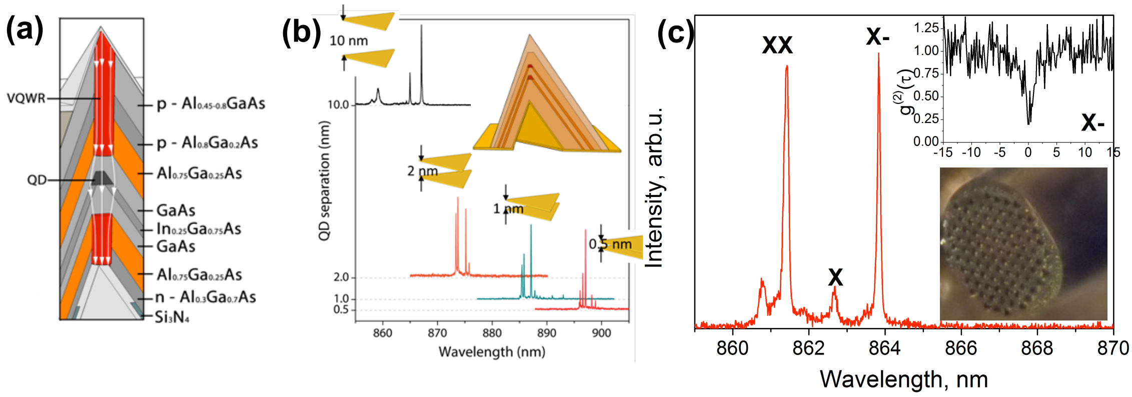

Figure 0: (a) A lower band-gap region – a vertical quantum wire (VQWR) – along the epitaxial pyramidal structure to inject carriers into a PQD. (b) Emission energy dependence on the separation between two stacked QDs. (c) Pyramid transfer procedure which enables integration of pyramidal structures on the external surfaces. Spectrum and single photon emission detected from an optical fiber with an integrated pyramidal QD attached to it.

[1] L. O. Mereni et al., Appl. Phys. Lett. 94, 223121 (2009). [2] G. Juska et al., Nature Phot. 7, 527 (2013); [3] M. A. M. Versteegh et al., Phys. Rev. A 92, 033802 (2015).