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Authors	Chung, Tung-Hsun;Moroni, Stefano T.;Juska, Gediminas;Gocalińska, Agnieszka M.;Pelucchi, Emanuele
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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Supplementary material

On-demand single-photons from electrically-injected site-controlled Pyramidal Quantum Dots

S. T. Moroni, T. H. Chung, G. Juska, A. Gocalinska, and E. Pelucchi

Sample structure

The results presented in this manuscript were obtained from two samples, which are referred to as Sample A and Sample B, whose structure is shown in Fig.S1. Sample A resulted in the best DC-injected single photon emission presented in the main text, while PQDs from sample B provided the best results in terms of pulsed excitation.

Growth direction

Sample A

Nominal thickness (nm)	Material	Dopants (cm^{-3})
70	GaAs	Undoped
10	GaAs	C: $5x10^{17}$
45	$Al_{0.45\sim0.8}GaAs$	
90	$Al_{0.8}GaAs$	
40	$Al_{0.55}GaAs$	
60	$Al_{0.7}GaAs$	Undoped
50	GaAs	
1.2	$In_{0.25}GaAs$	
30	GaAs	
50	$Al_{0.55}GaAs$	
35	$Al_{0.3}GaAs$	Si: $5x10^{17}$
10	GaAs	

Sample B

Nominal thickness (nm)	Material	Dopants (cm^{-3})
40	GaAs	C: $5x10^{17}$
45	$Al_{0.45\sim0.8}GaAs$	
90	$Al_{0.8}GaAs$	C: $1x10^{18}$
60	GaAs	
45	$Al_{0.75}GaAs$	Undoped
90	GaAs	
0.55	$In_{0.25}GaAs$	
60	GaAs	
45	$Al_{0.75}GaAs$	
30	$Al_{0.3}GAs$	Si: $1x10^{18}$
10	GaAs	

Fig.S1: Epitaxial structures relative to the PQD samples reported in the main text. All alloys' compositions, layers' thickness and doping concentration values are nominal.

The samples were grown by metalorganic vapour phase epitaxy (MOVPE) at a (thermocouple read) temperature of 730°C on (111)B-oriented GaAs substrates which were pre-patterned with 7.5 μm (Sample A) or 10 μm (Sample B) pitch pyramidal recesses.
In each of the structures, each layer fulfills a specific purpose:

- The initial GaAs layer was used as a buffer to minimize the influence of defect states (e.g. impurities, point defects), present on the as-etched pyramidal recesses, on the QD.

- A graded $Al_{0.45\rightarrow0.8}Ga_{0.55\rightarrow0.2}As$ layer and an $Al_{0.8}Ga_{0.2}As$ layer were the so-called etch-stop layers with high aluminum contents, meant to protect the inner layers from being chemically etched during the selective GaAs substrate removal (backetching).
- A p-doped GaAs layer can be optional (included in sample B and not in sample A); after the backetching it can be removed by means of HCl acid (30 s), allowing the exposure of the p-doped GaAs layer for the evaporation of the metallic (gold) top layer for better quality contact.
- The intrinsic $Al_{0.75}Ga_{0.25}As/Al_{0.7}Ga_{0.3}As$ layer was included to form a Ga-rich vertical quantum wire formed due to alloy segregation, yielding an aluminum content < 0.3 in the center of the pyramid to allow the selective current injection.
- The intrinsic GaAs was the quantum dot confinement barrier. Based also on growth modeling simulations, the ~(111)B lateral profile on which the InGaAs QD layer was grown was around 70 nm. It can be noted that the lateral/vertical nominal thickness of the QD didn't have a noticeable effect (in the experiments we performed aside of the ones reported here) on the injection efficiency or single-photon performance, which was instead mostly affected by the structure surrounding the QD. It should also be noted that the GaAs self-limited profile drives the dot lateral size, and only changes marginally with the growth temperature, while the dot thickness is the only actual "free" parameter here.
- The n-doped region was then deposited, made of an AlGaAs layer followed by a GaAs capping layer to prevent oxidation.