Light emission from site-controlled GaN quantum dots

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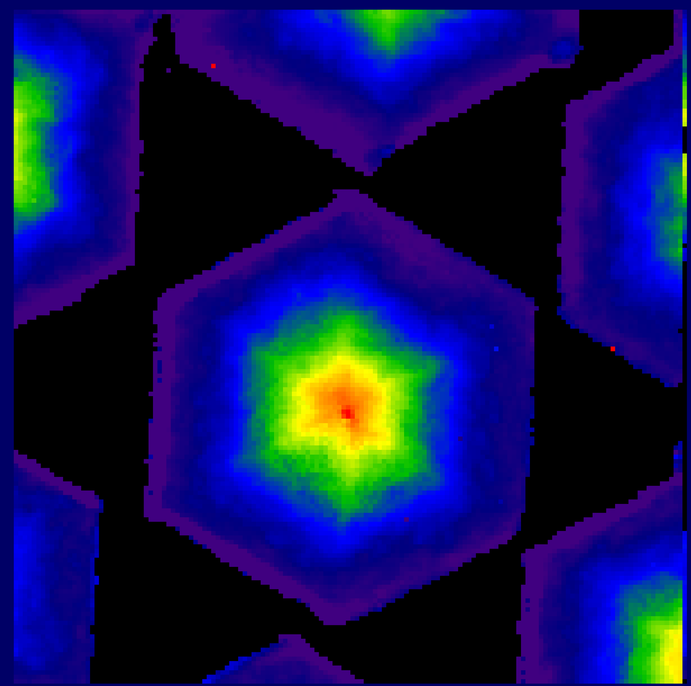
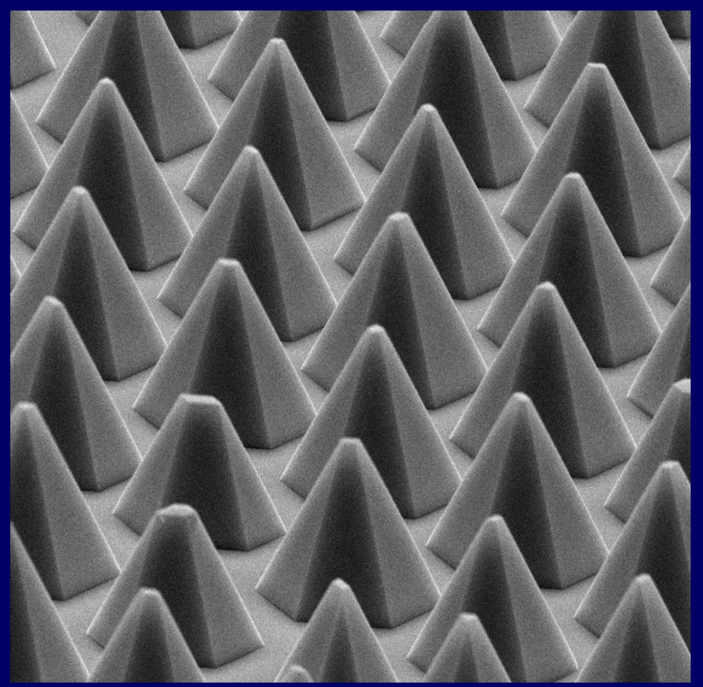




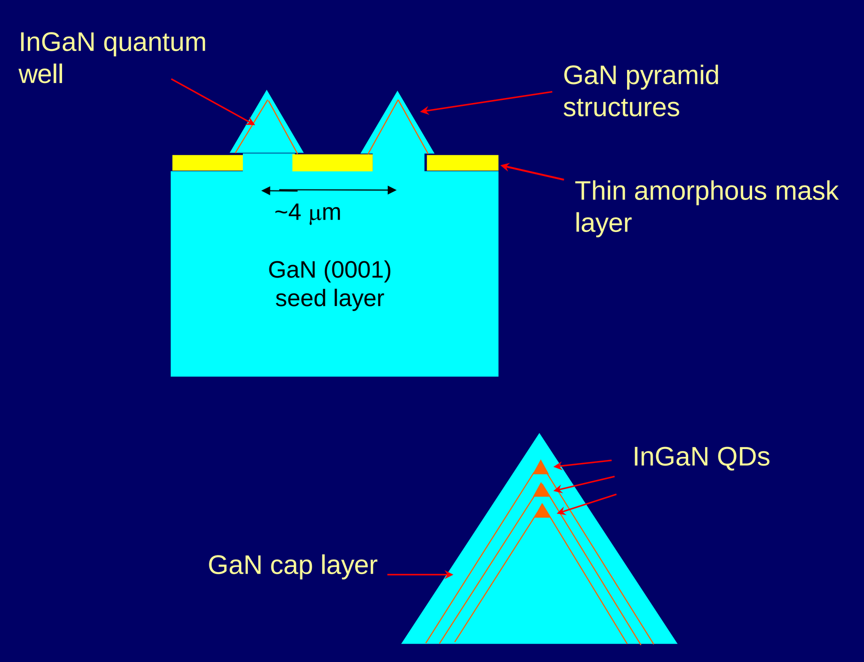
Light emitting quantum dots

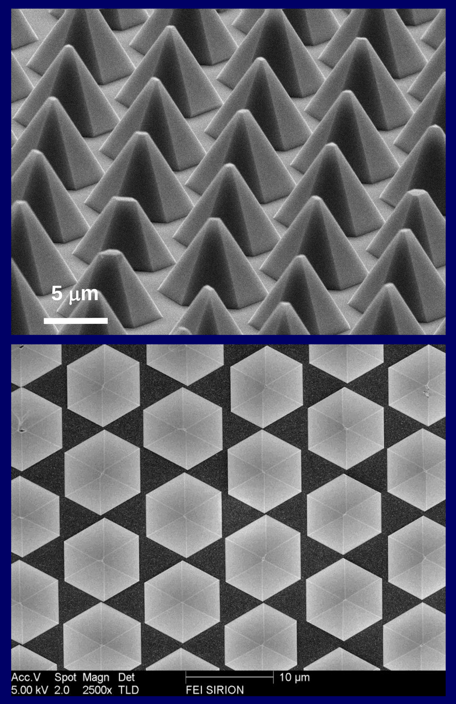
- Ultra-low threshold quantum dot lasers
  modification of density-of-states
- Single photon emitters for quantum information processing
  dephasing times much longer than time for single qubit operation
- Control of position and density of dots
  site-control - e.g. by use of masks

Selectively grown III-nitride micropyramids

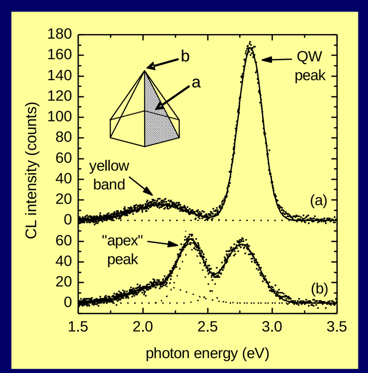
Mask preparation by H. Chong, R. De La Rue (Glasgow University)

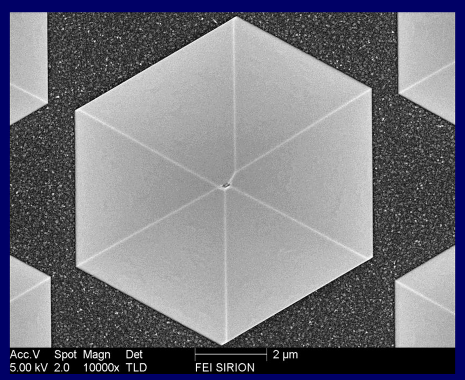
MOCVD growth in Aixtron 200 series reactor at University of Strathclyde

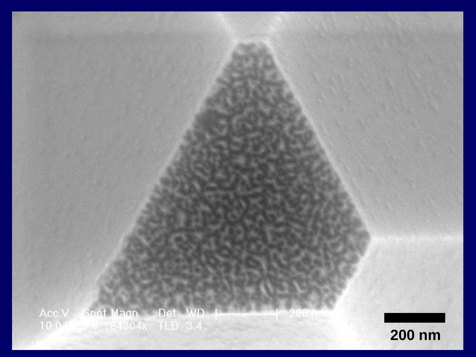




CL spectroscopy from a single micropyramid





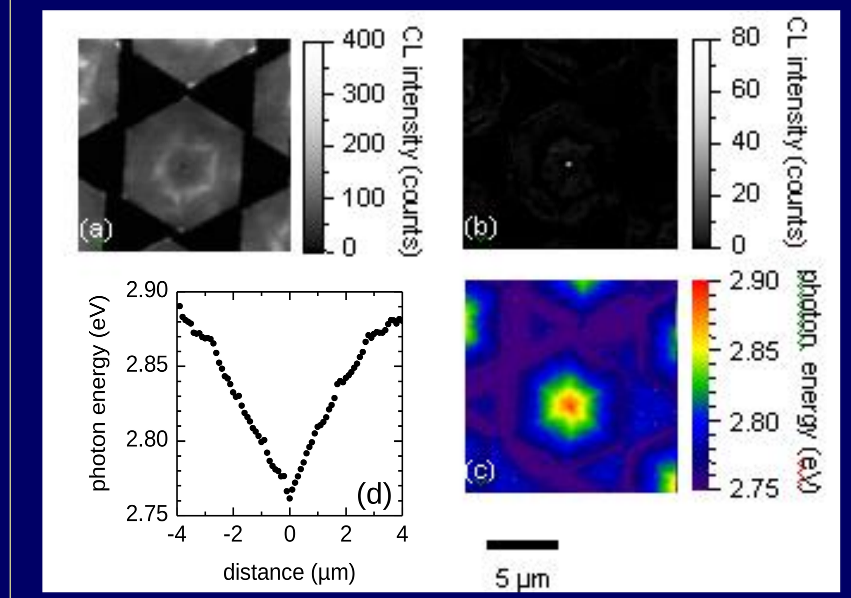


Room temperature CL spectra showing the emission from (a) a facet center and (b) the apex.

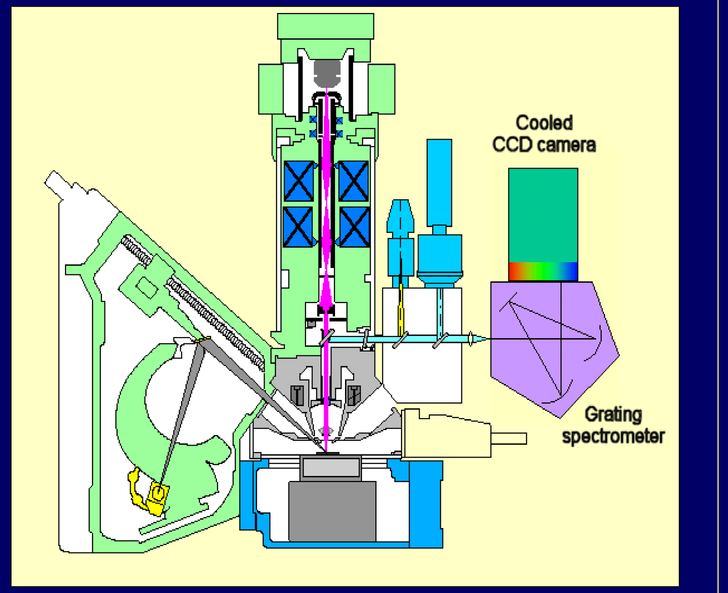
Some pyramids exhibit flattened apices; field-emission SEM shows "honeycomb" texture, suggesting that the longer wavelength emission band from this region could be defect related.

Cathodoluminescence (CL) hyperspectral imaging

Measuring the cathodoluminescence spectrum at each point in a 2-dimensional image scan allows a multidimensional (or "hyperspectral") datacube to be recorded. Various 2-dimensional images describing an aspect of the luminescence can then be extracted from this dataset:



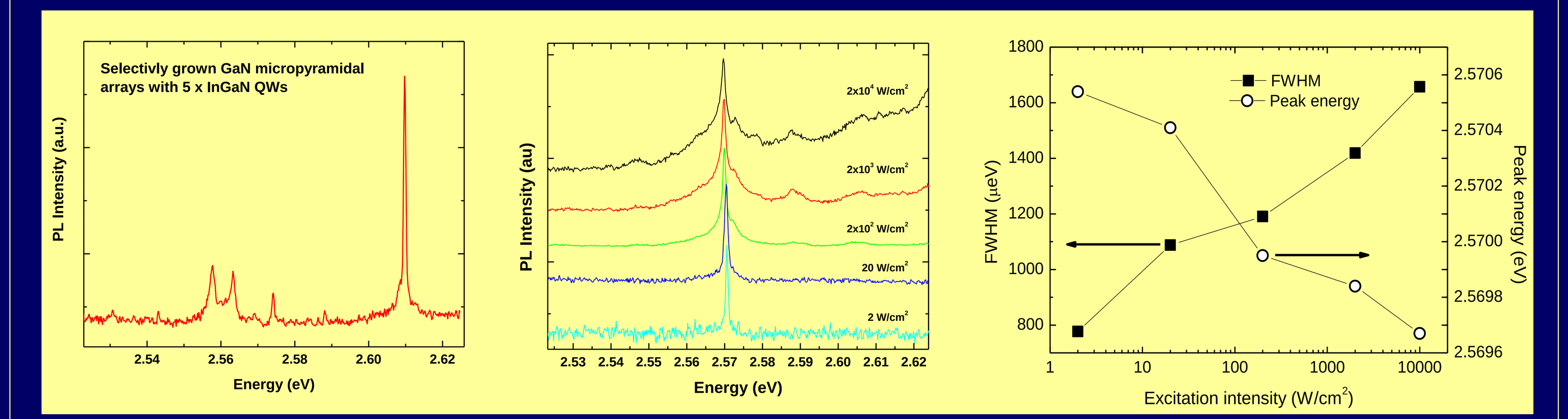
CL spectral imaging. (a) and (c) show the peak intensity and energy respectively of the QW emission from the facets, whilst (b) shows the intensity of the 2.37 eV apex-related band. The linescan (d), showing the QW peak energy varying across the pyramid, was extracted from a horizontal line through the apex in (c).



Strathclyde's modified Cameca SX100 electron microprobe and CL spectrum mapping facility

Low-temperature photoluminescence (PL) spectroscopy

Micro-PL measurements of a single micropyramid apex at 4.2 K



PL spectrum of single micropyramid containing 5 quantum wells

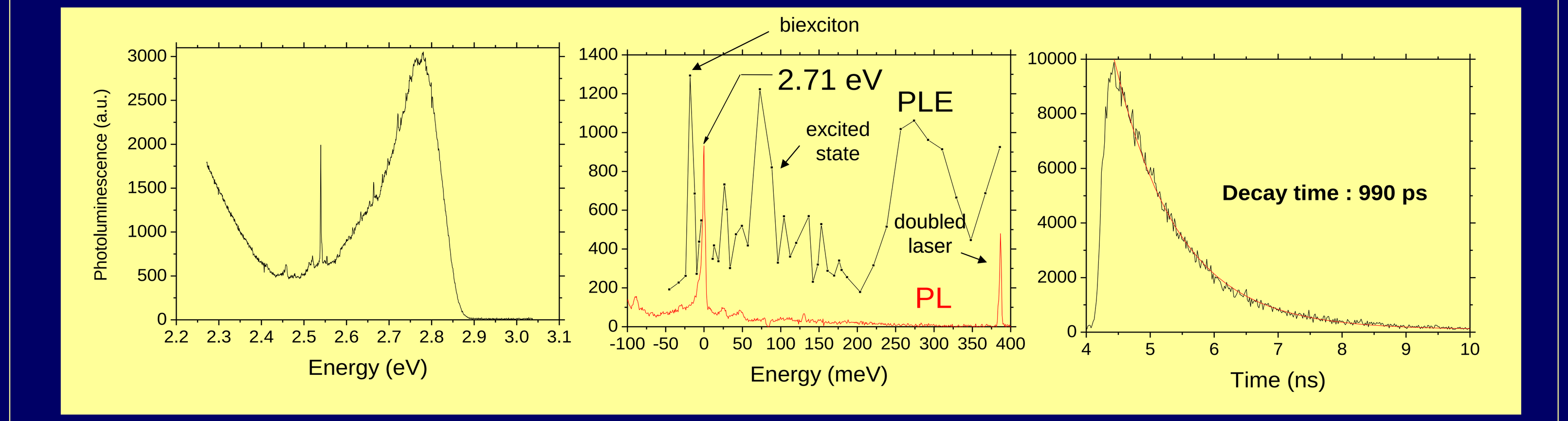
Intensity dependence of quantum dot PL spectrum

Intensity dependence of width and energy of QD emission

- Sharp lines appear superimposed on the broad quantum well luminescence band
- Lines broaden and red-shift with increasing excitation intensity
- Hint of a shoulder appearing on the high energy side of the QD line as intensity increases, possibly due to biexcitonic recombination.

Two-photon PL spectroscopy

Two-photon excitation using 1 ps pulses from a Ti:sapphire laser



One-photon excitation, showing QD emission superimposed with a background originating from the QW emission.

Two-photon excitation PL (excited at 1.55 eV) and PLE. Energy scale shown relative to QD emission

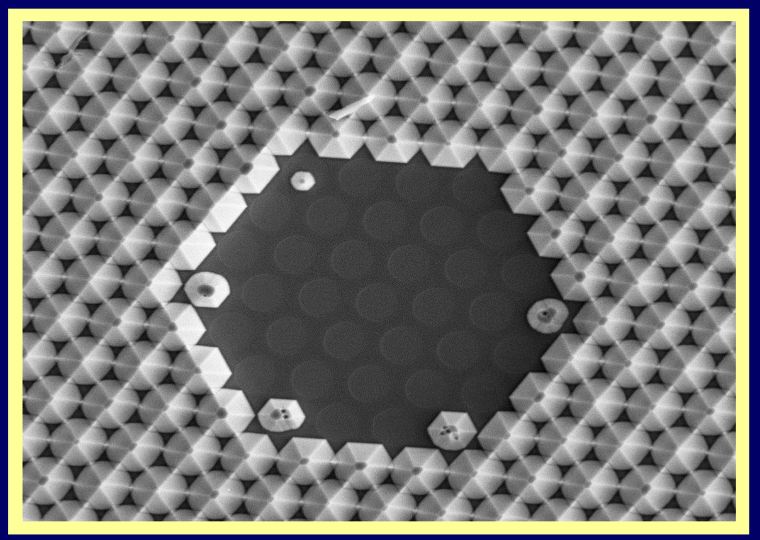
Time-resolved PL from the dot shown on left. The red line is the best single-exponential fit.

- Two-photon technique allows selective excitation of only the QD
- PLE spectrum shows biexciton line (with negative binding energy) and other excited states
- Decay of QD emission possible without need to subtract the effect of QW emission
- Single clear exponential decay with lifetime of 990 ps
- Potential for isolated single photon emitters

Future work

Accidental "corral" formation has been seen on some of our samples…….

……… suggesting the possibility of deliberately engineering the structure to control the QD positions.



Summary

- Site-controlled GaN quantum dots have been fabricated by selective growth.
- Characterised by cathodoluminescence and photoluminescence
- Single dot lifetimes investigated
- Attractive structures for single photon emission

P.R.Edwards, R.W. Martin, I.M.Watson, C.Liu, R.A.Taylor, J.H.Rice, J.H.Na, J.W.Robinson and J.D.Smith (2004) Appl Phys Lett **85** (19) pp.4281-4283