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Local droplet etched quantum dots as quantum light sources

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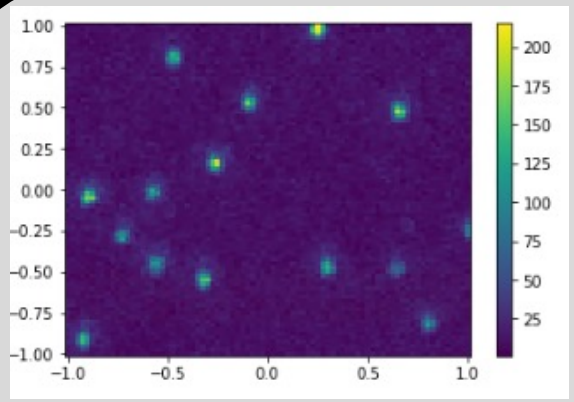
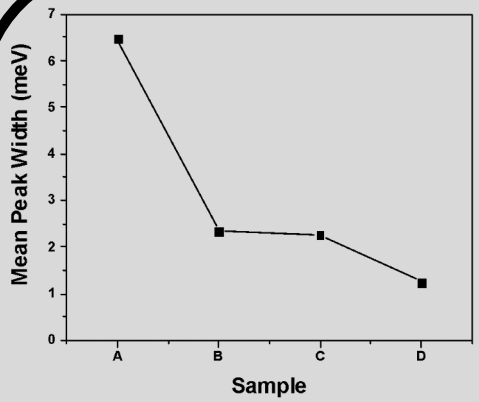
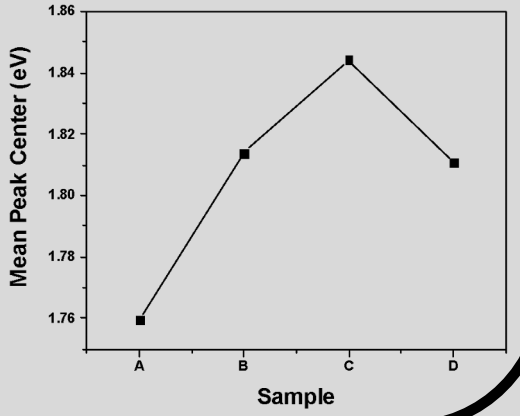
Summary

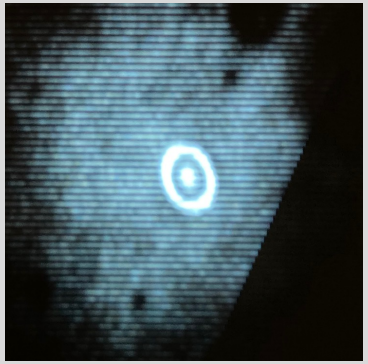


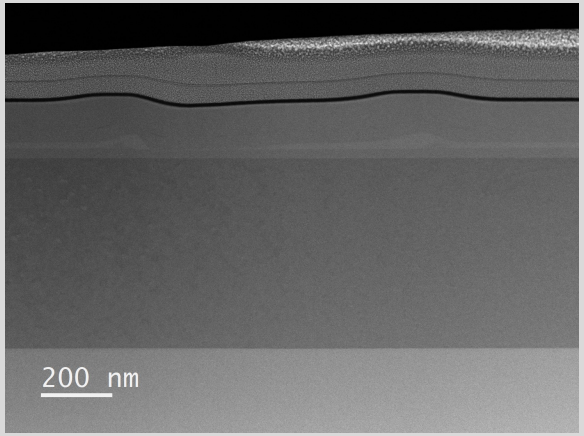
THE GOOD





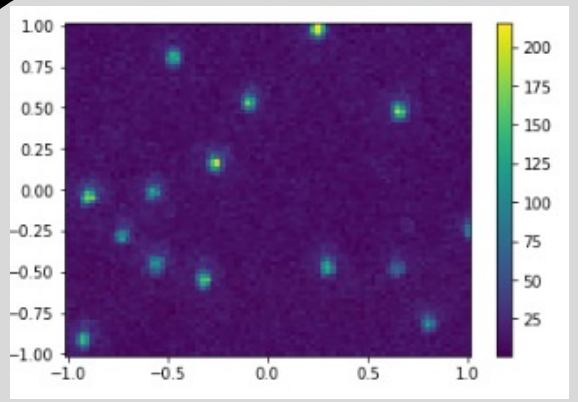
THE BAD

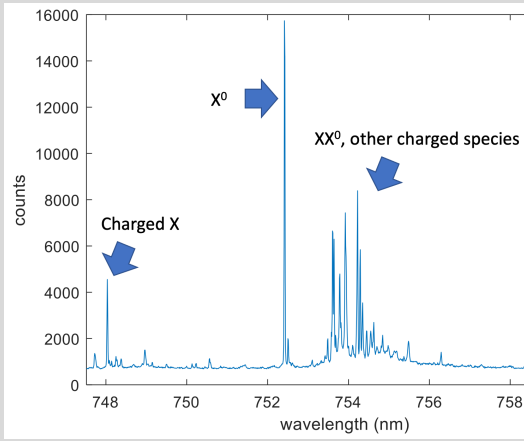


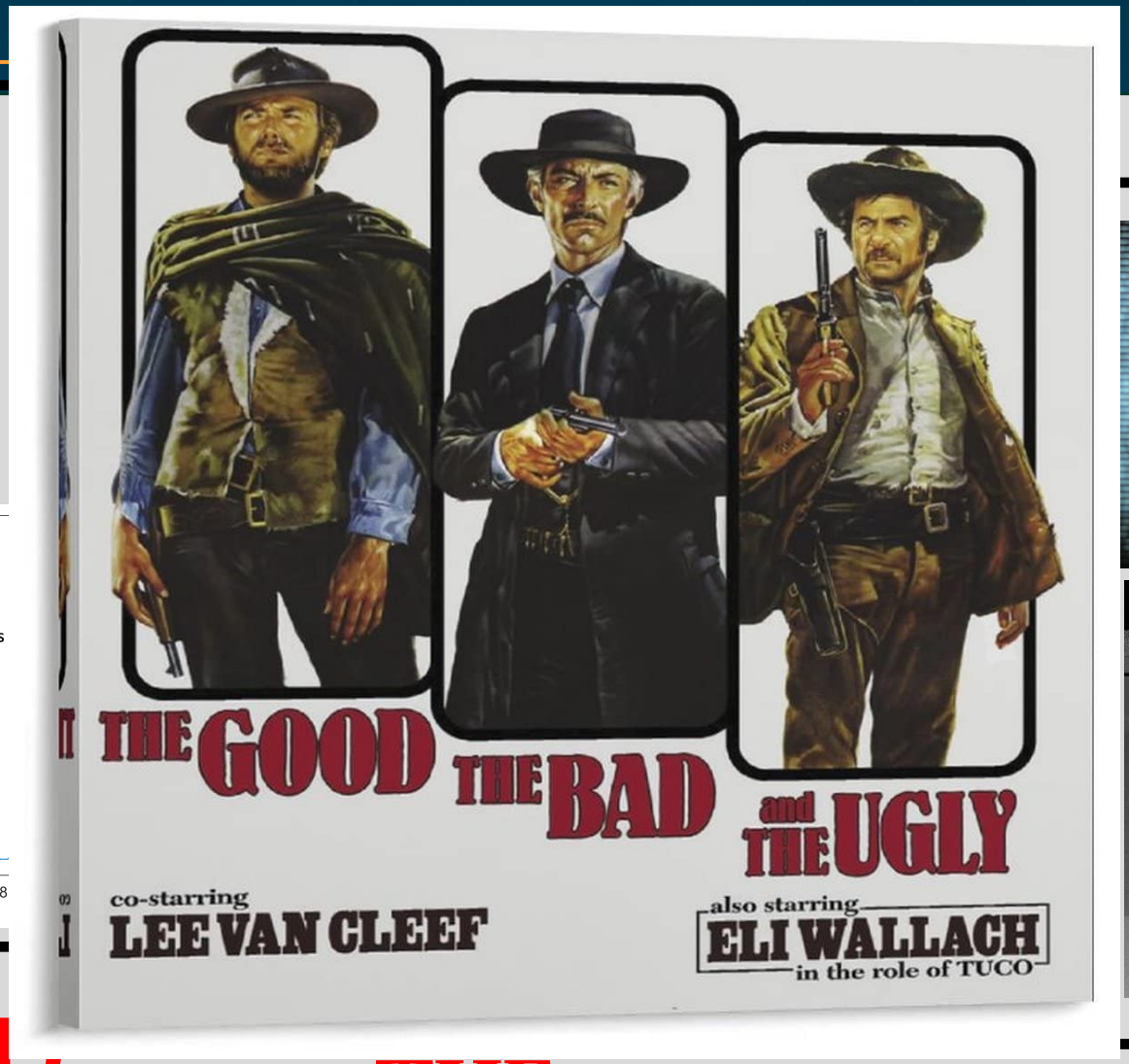


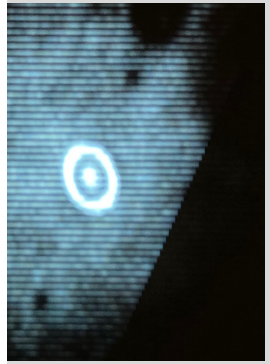
and THE UGLY

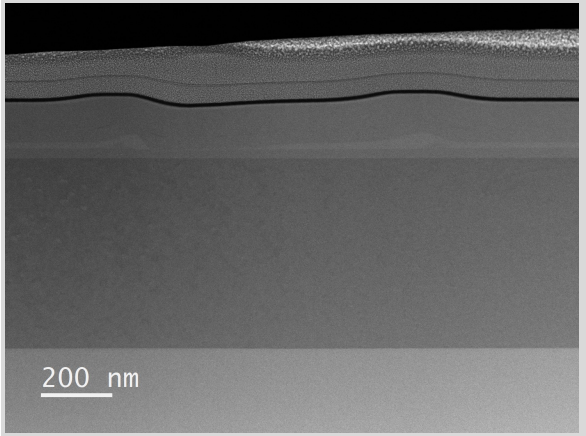
Summary







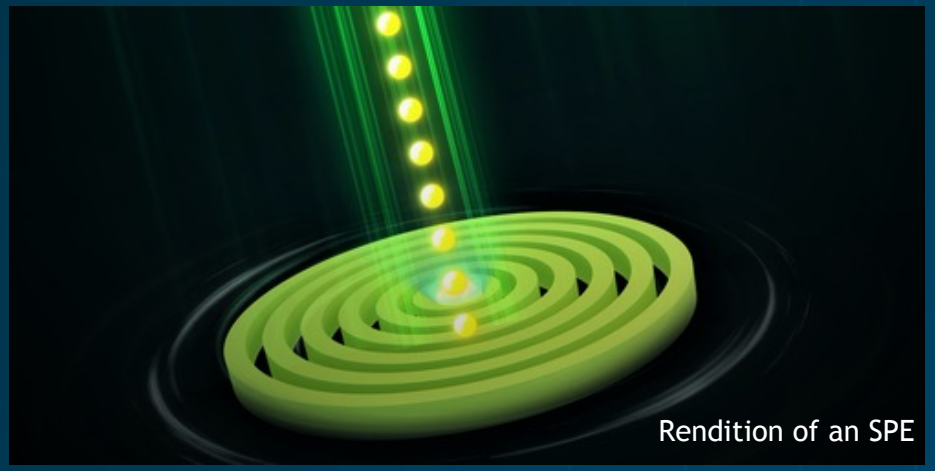




THE GOOD THE BAD and THE UGLY

Why LDE QDs?

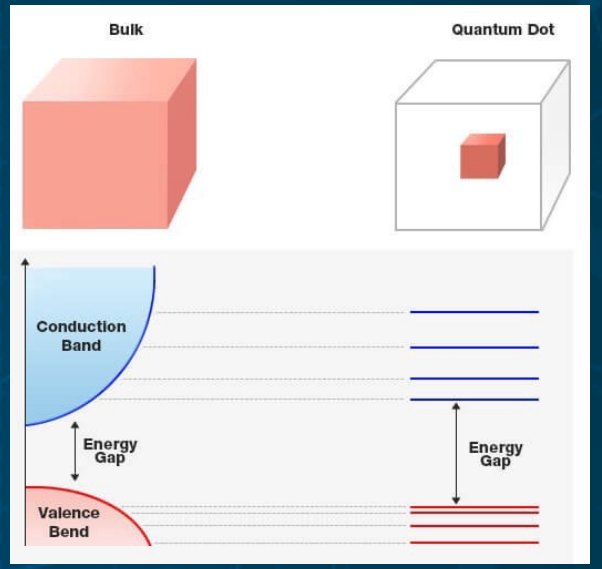
Big picture: realizing efficient **emitters of non-classical states of light**



Rendition of an SPE

Key ingredient for photonic quantum applications

- **Solid-state SPEs** – combine optical properties of atoms with scalability
  - **Semiconductor QDs** have exhibited the best photon metrics



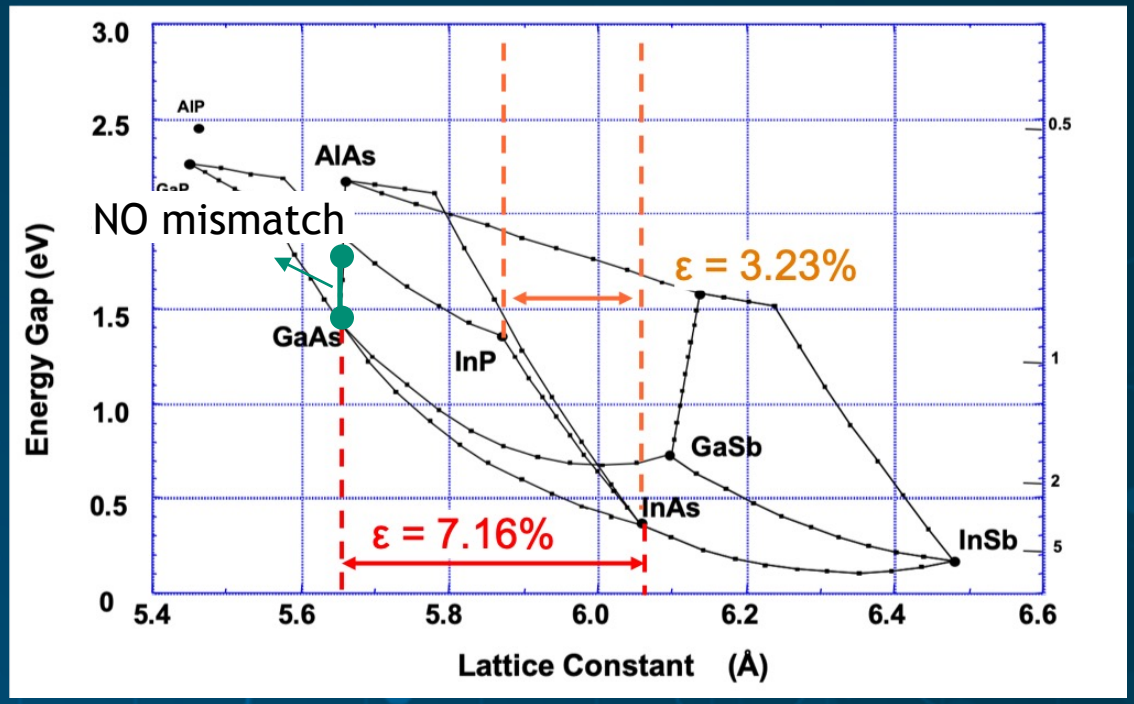
Energy levels: bulk vs QD

APS physics (2020); Medium (2019)

Why LDE QDs?

- NOT a strain-driven mechanism – unlike state-of-the-art SK QDs
  - Opens up material combinations → emission λ
  - Variation of droplet epitaxy
  - Improved quality
- Demonstrated excellent optical properties
  - Low FSS
  - Short lifetimes
  - Indistinguishability

SK
LDE



Lattice constant vs bandgap

Growth process / mechanism

AlGaAs barrier on GaAs

↓ Absence of arsenic

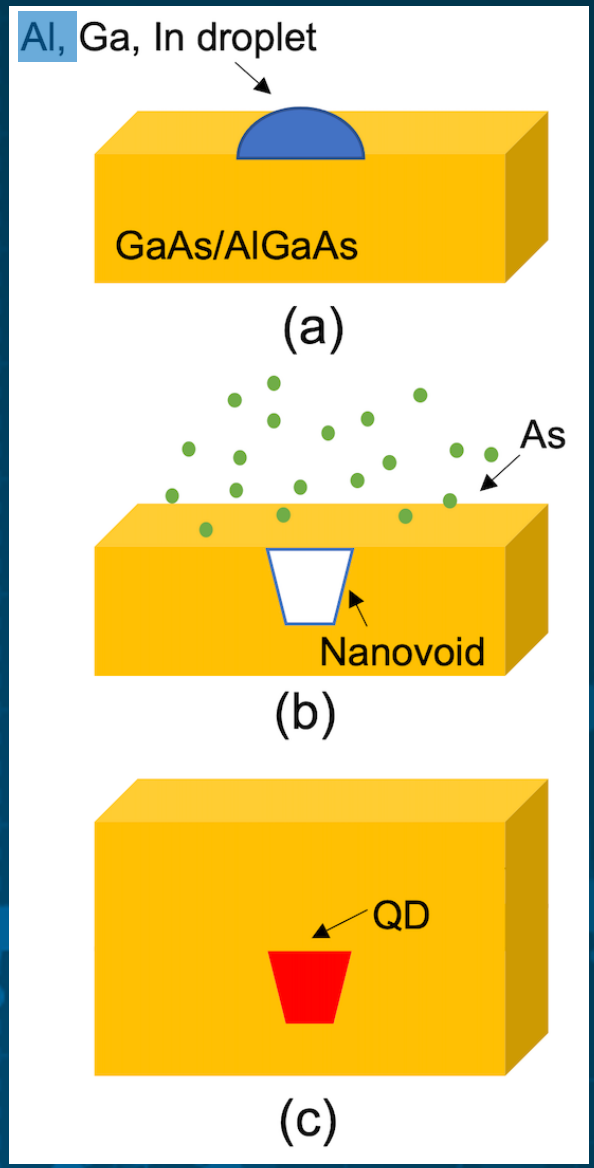
Al droplets

↓ Al reacts with AlGaAs

Nanovoid formation

↓ Migration-enhanced GaAs

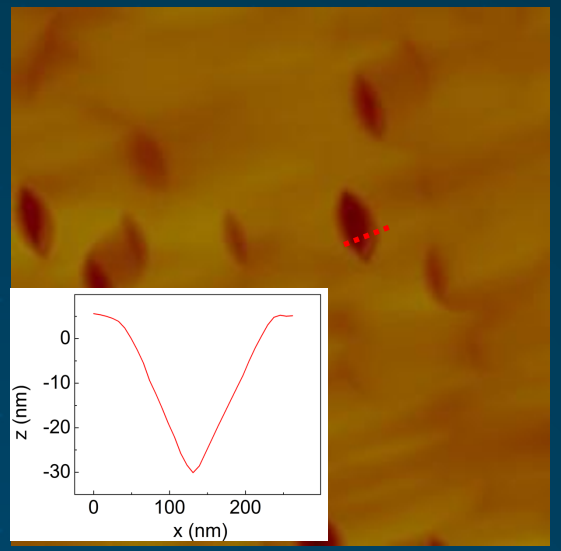
QD growth



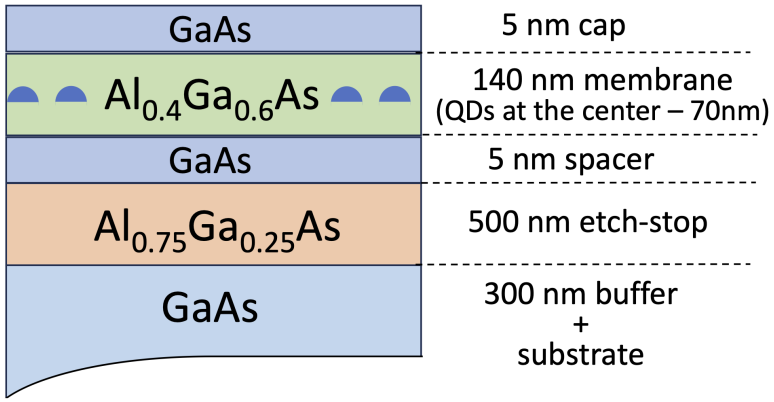
LDE growth mechanism

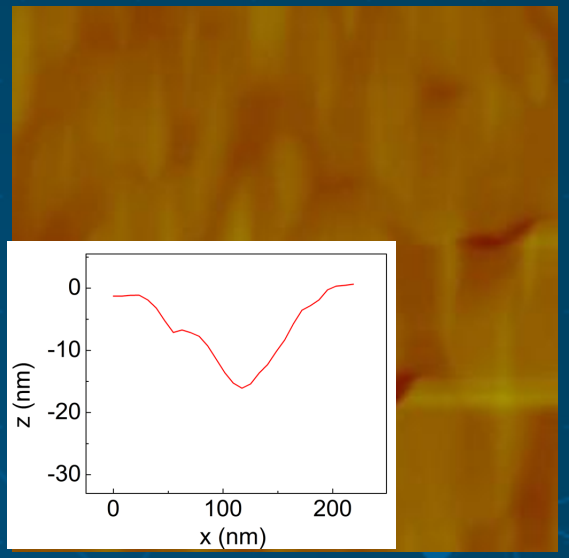
Structural characterization

AFM profile of nanovoid

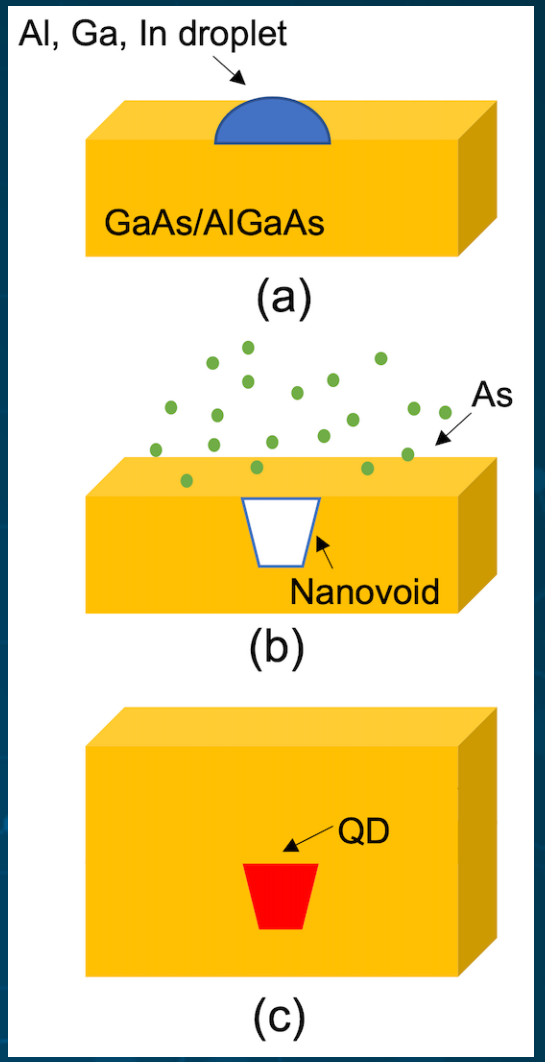


Structure





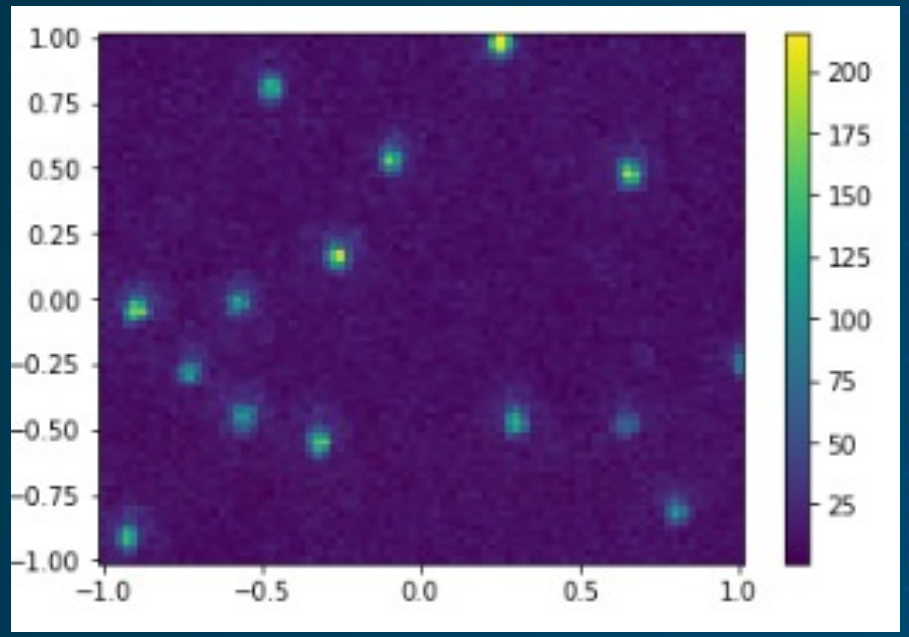
AFM profile of filled void (QD)



LDE growth mechanism

Optical characterization

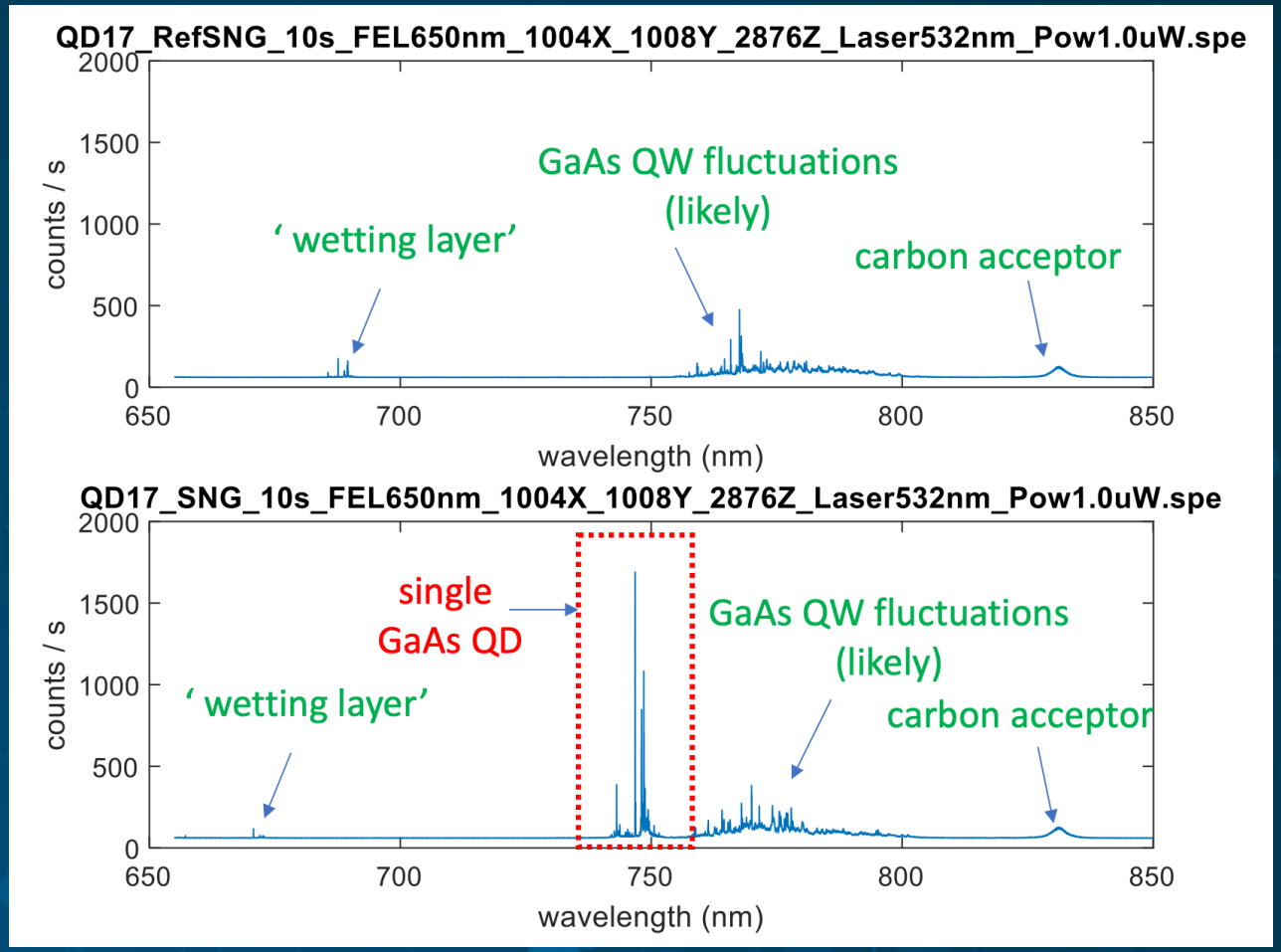
PL imaging - 15 dots in ~ 20 x 20 um



off QD

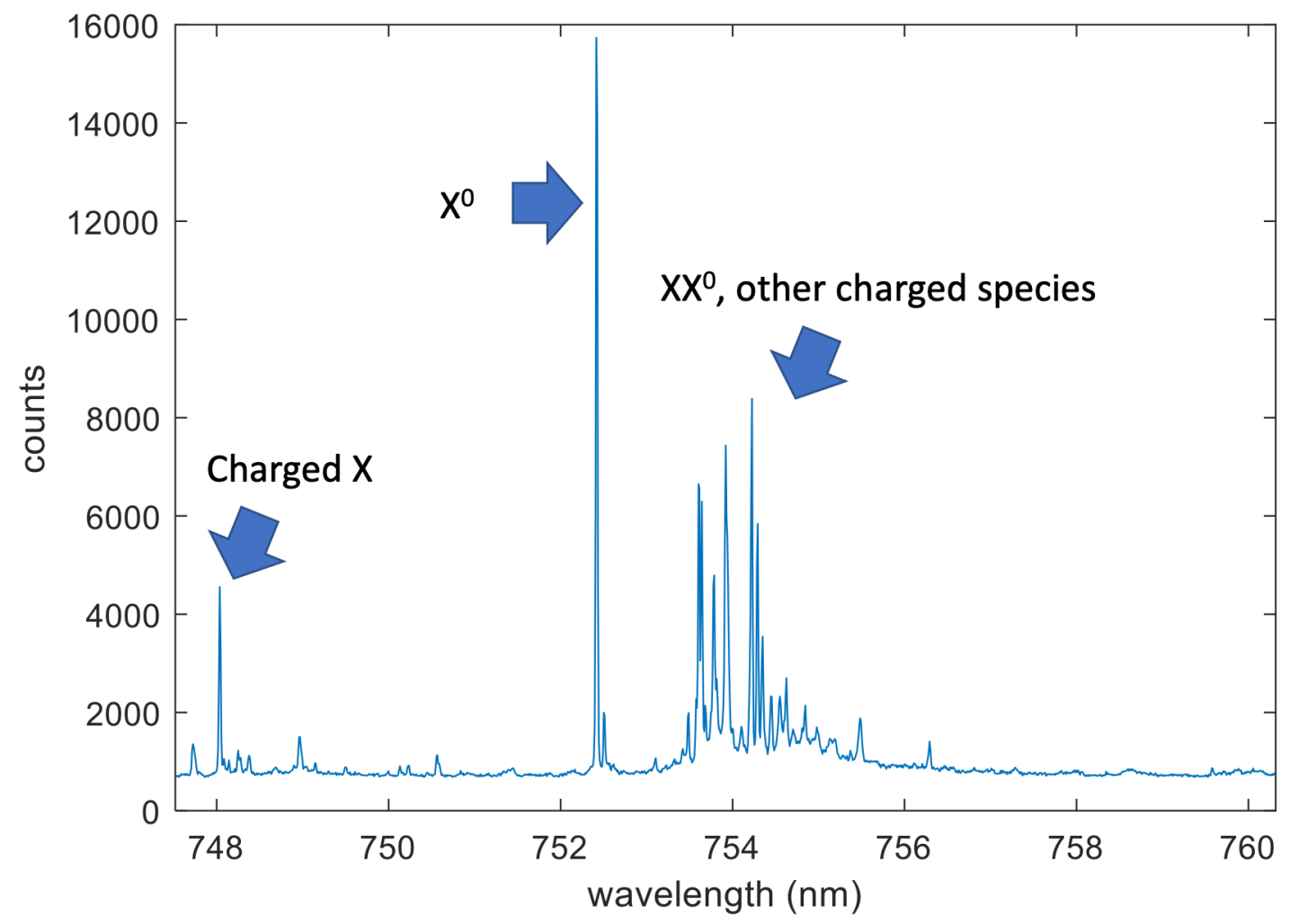
on QD

Spectrum measurements

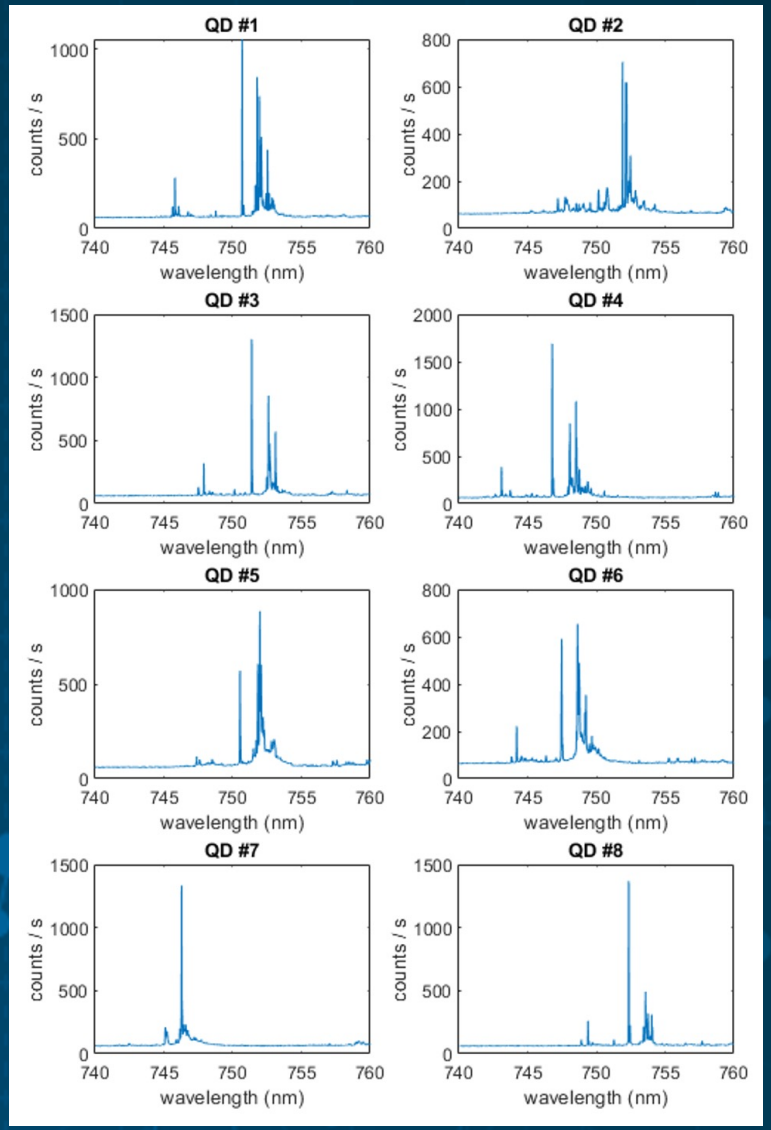


Optical characterization

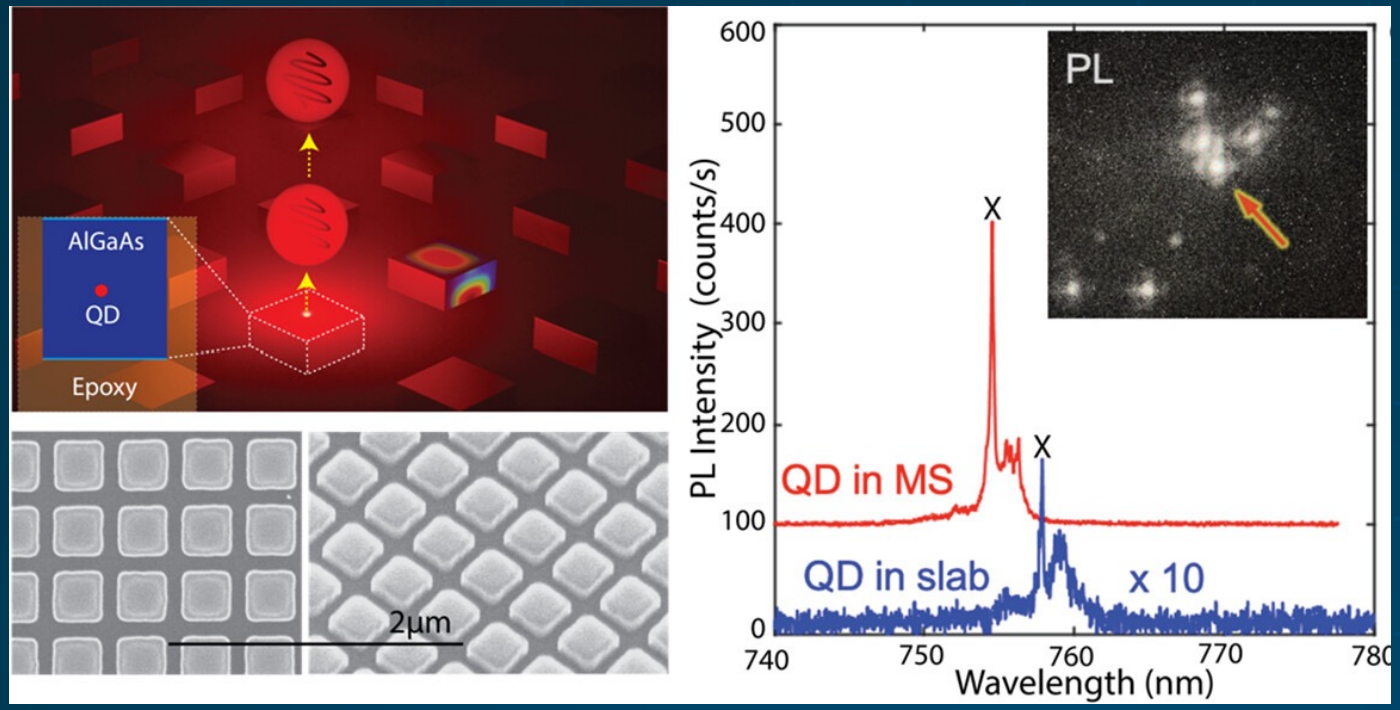
Typical peak assignments



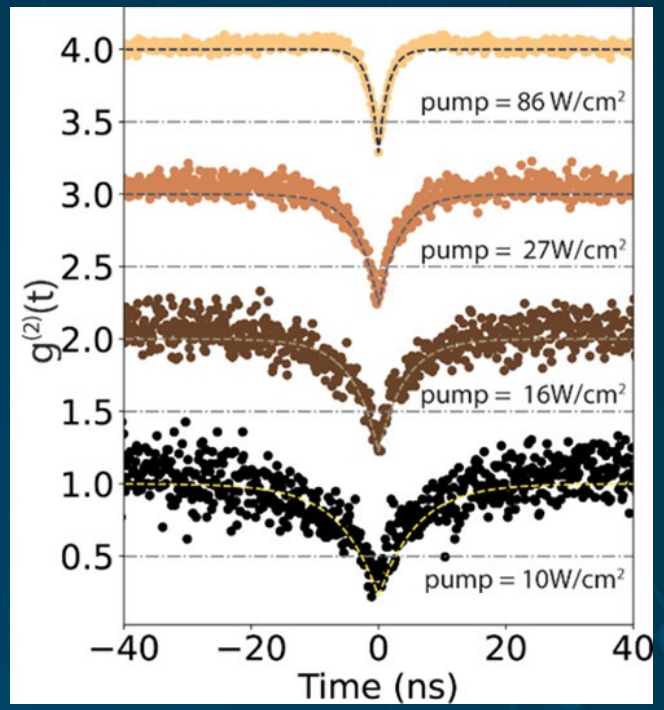
Hint of bad…



Integration of LDE QDs



Metasurface illustration & PL spectra (& imaging)

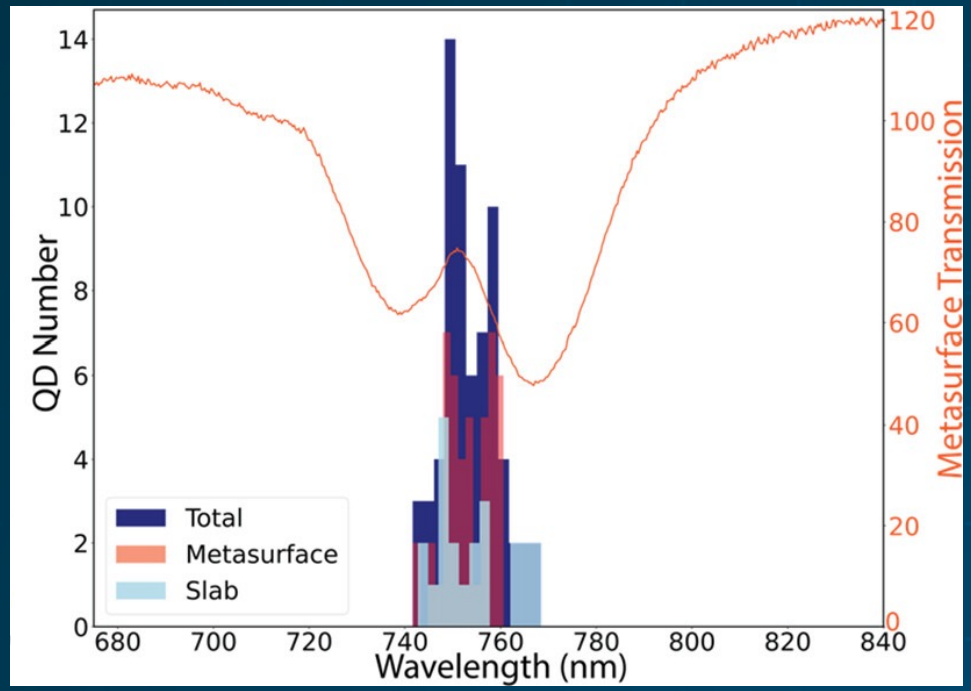


Autocorrelation function

- GaAs/AlGaAs LDE QDs embedded in a Huygens' metasurface
- 1 order of magnitude increase in the collection efficiency and emission lifetime control
- Anti-bunching dip observed at t=0

Iyer, …, Addamane et al., Nano Lett. (2024)

Challenges



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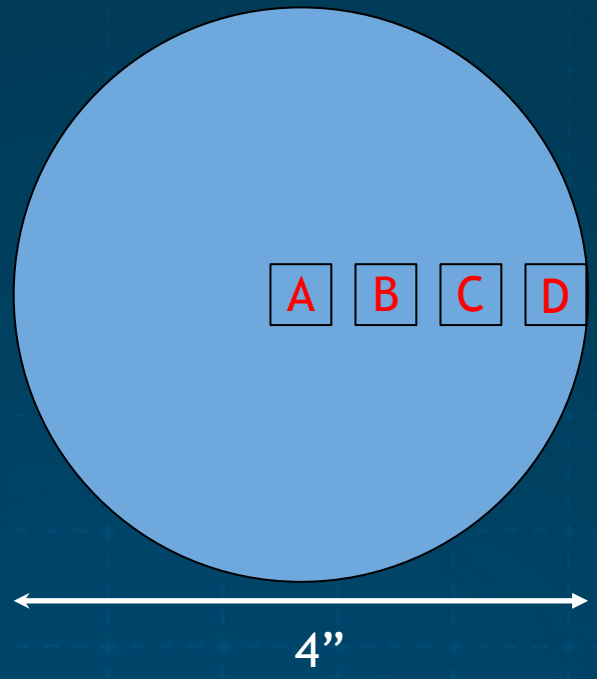
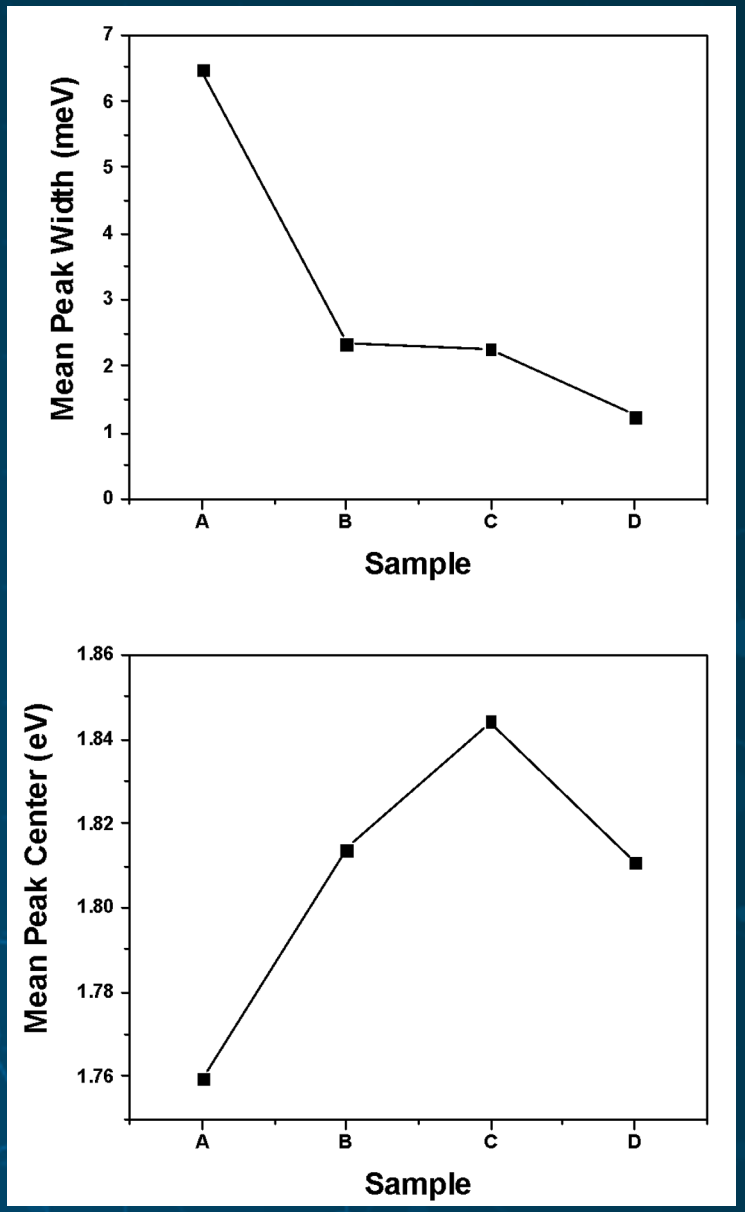
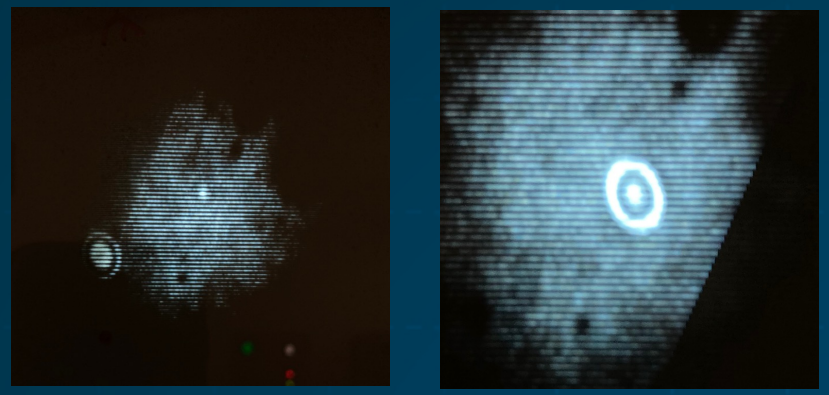


Wafer Map

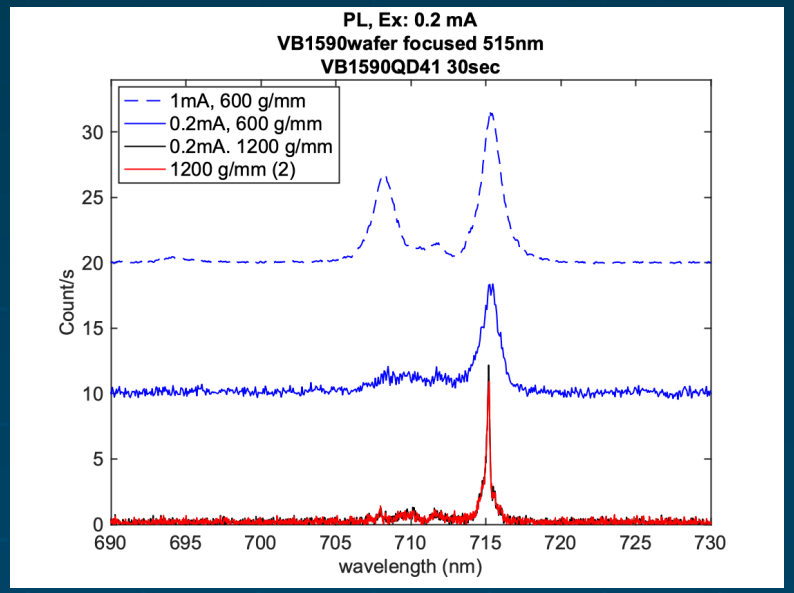


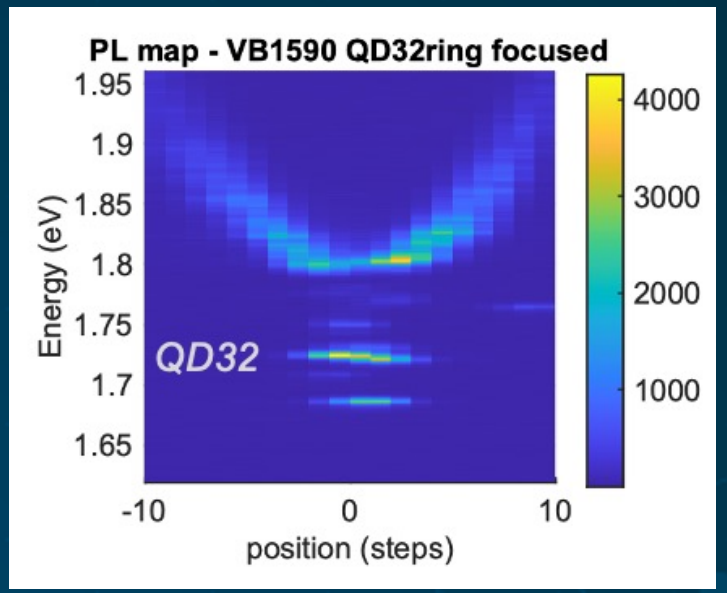
- Distribution in emission λ and linewidth
  - Varying QD size, shape density

Other oddities – "bright" QDs



PL image

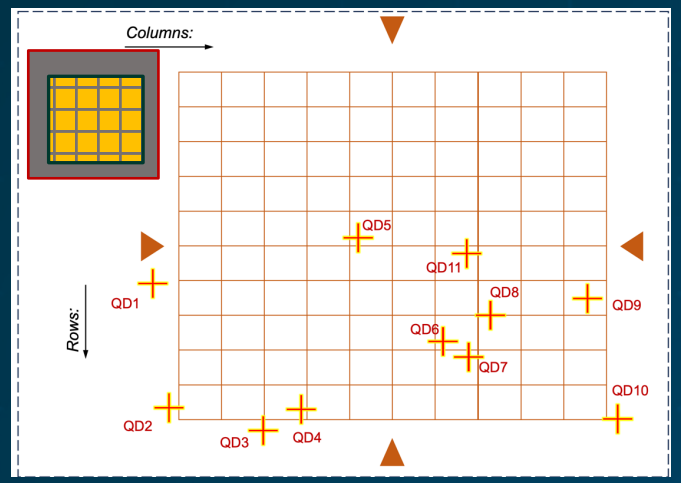




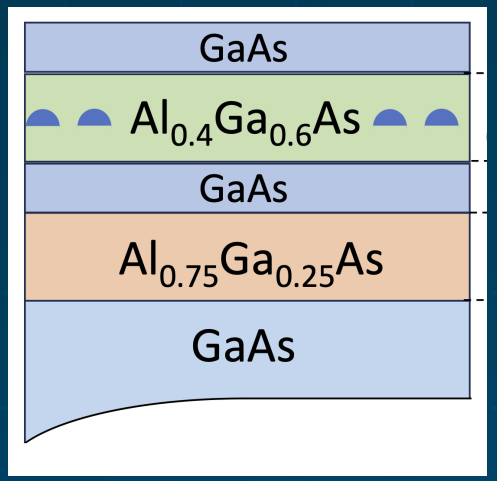
PL spectrum & map

- Certain growth conditions yield bright QDs that are enclosed in "rings"
- Spectrum measurement shows 10x brighter emission compared to other QDs
- Bright QDs have a carrier-funneling structure around caused by the rings.

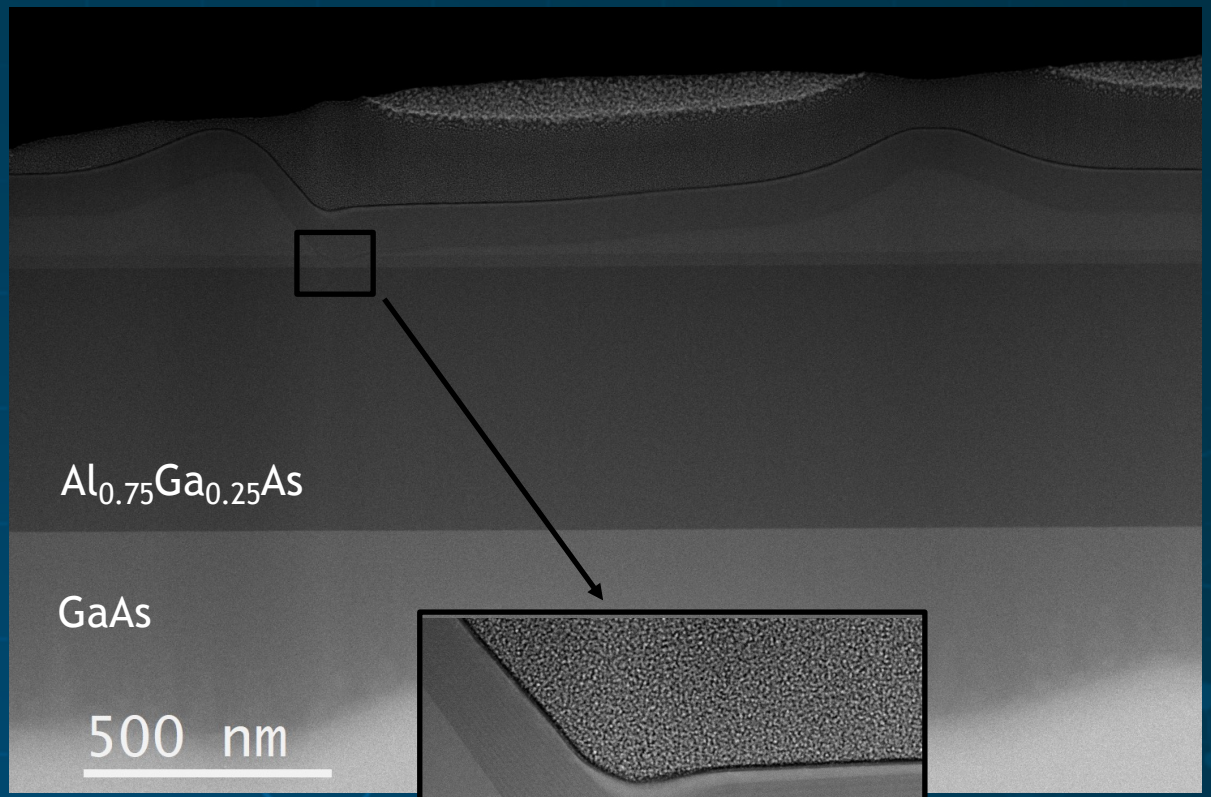
“Bright” QDs



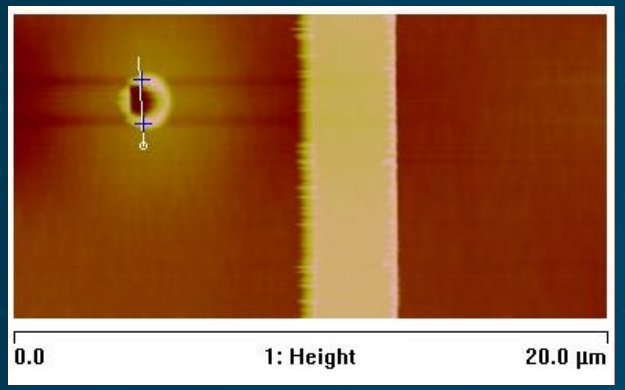
Metallic grid to locate QDs

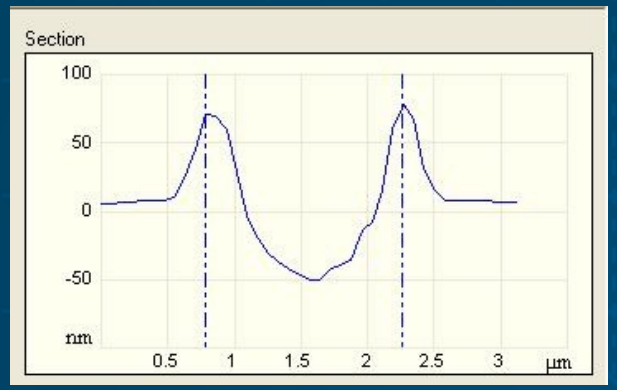


Layer structure



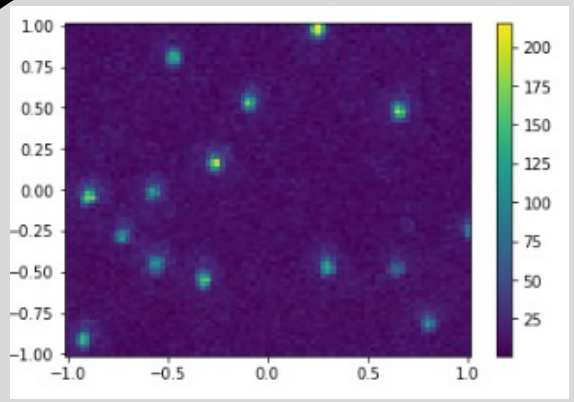
X-sectional TEM



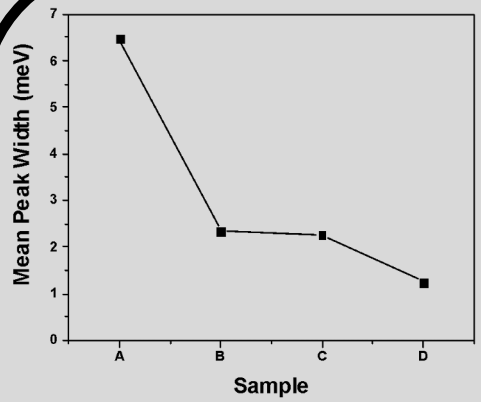


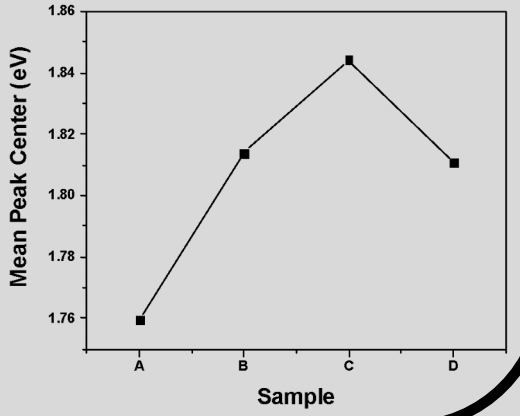
AFM profile

Conclusions



THE GOOD





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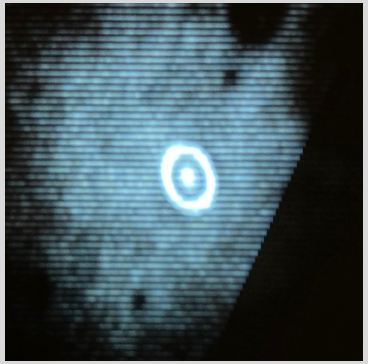
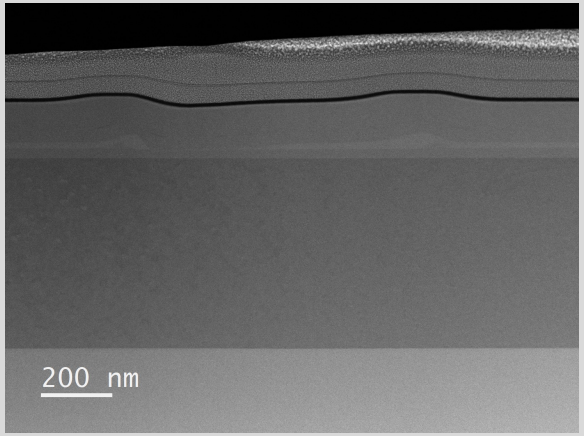
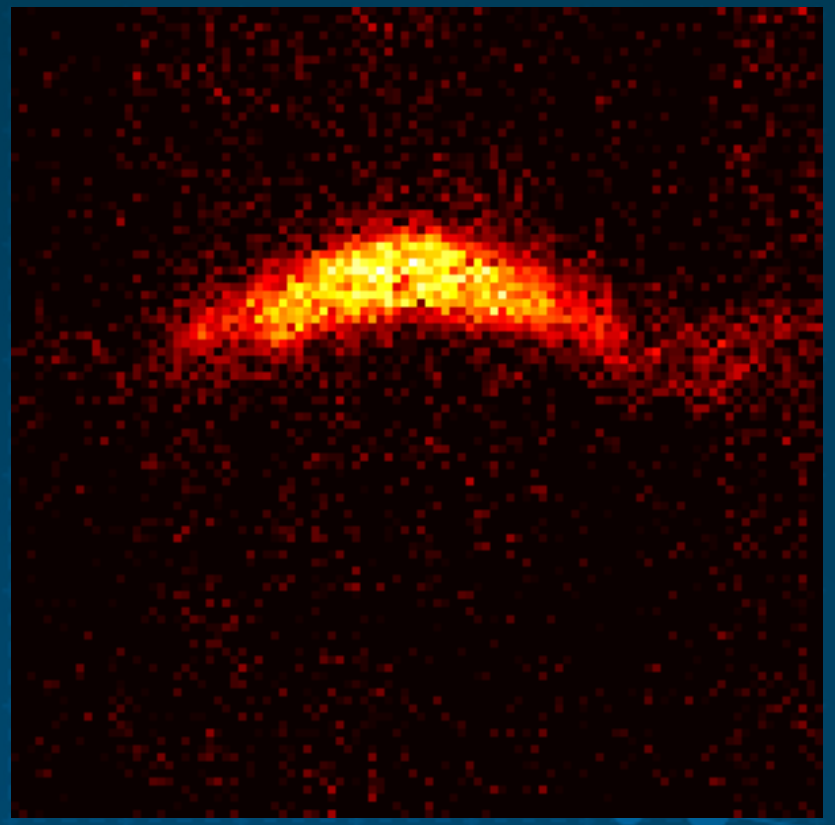




and THE UGLY

Questions?



Ga-As component image