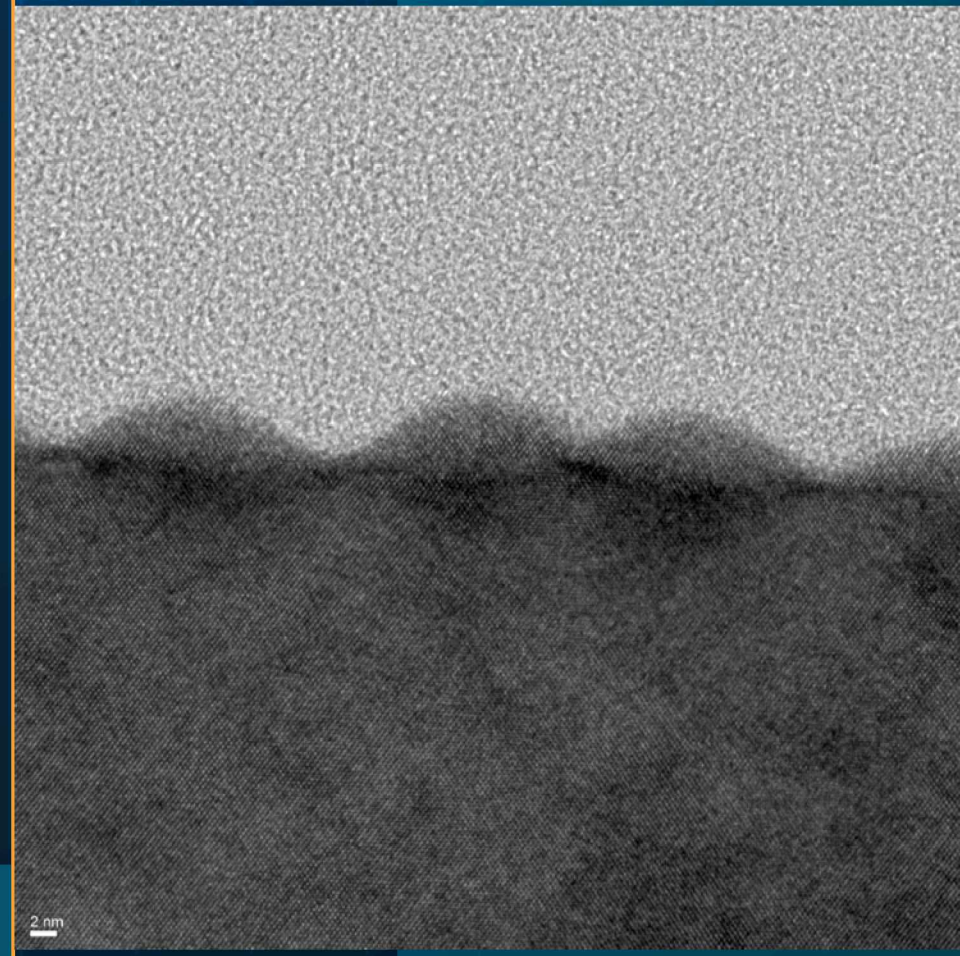
SAND2020-1896PE

MBE-based growth of self-assembled III-V quantum dots



PRESENTED BY

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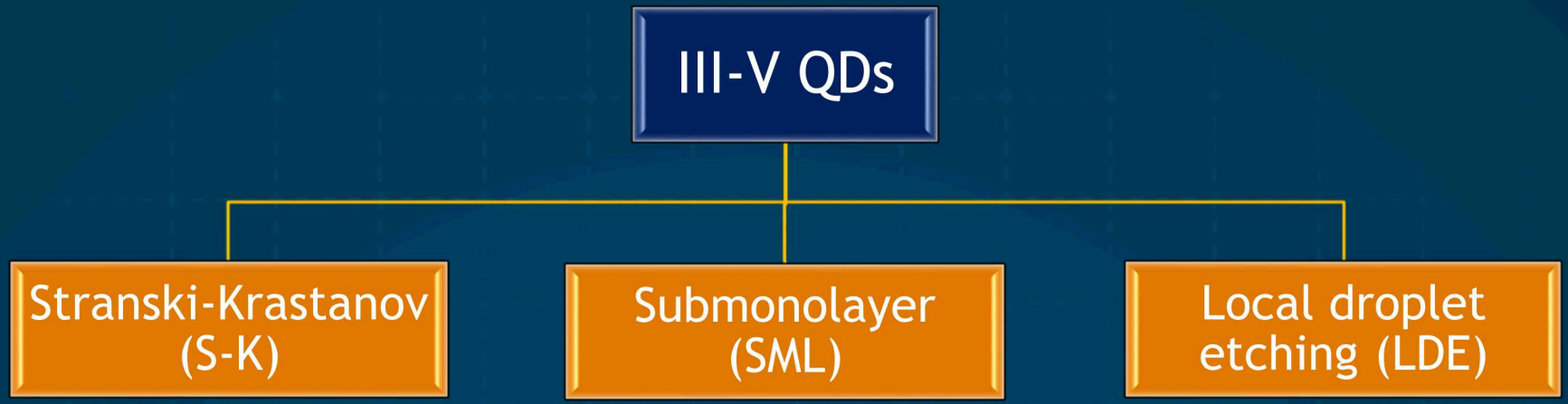
Overview of capabilities

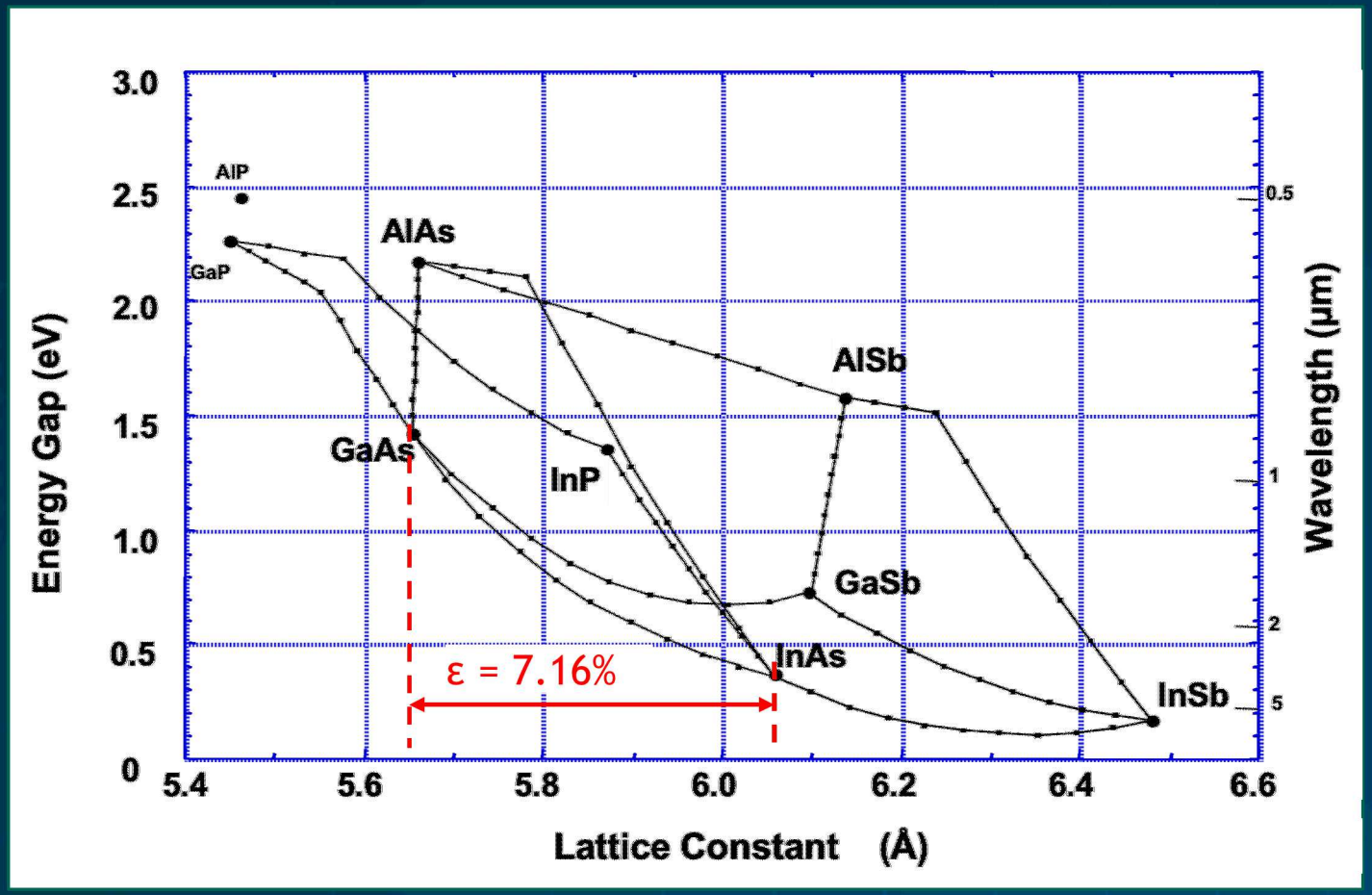
- III-V sources
  - Ga
  - In
  - Al
  - Valved As cracker
- High-mobility system
- Si for n-doping and C for p-doping

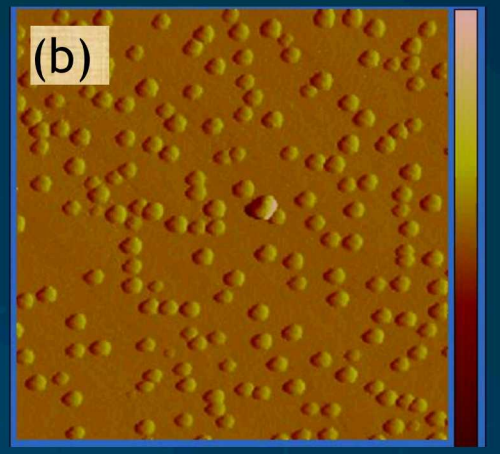
QDot growth summary



- Growth mechanism
- Control over areal density / size
- Emission wavelength
- Preliminary device results

S-K QDs : InAs / GaAs

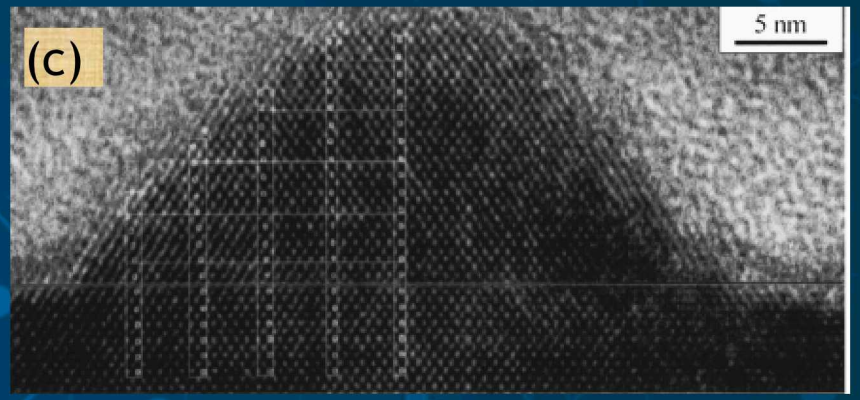




1 X 1 μm AFM scan

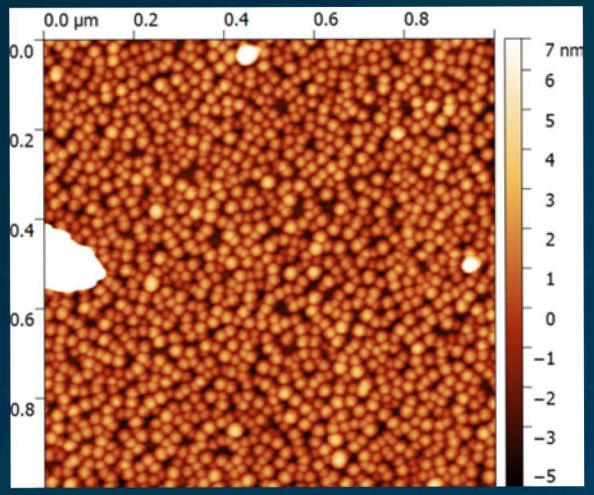
InAs QDots

Height: 7-9 nm
Width : 40-50 nm

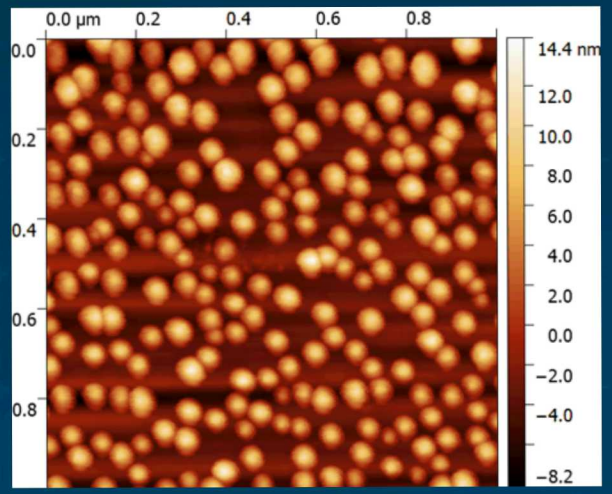


TEM image of InAs QD

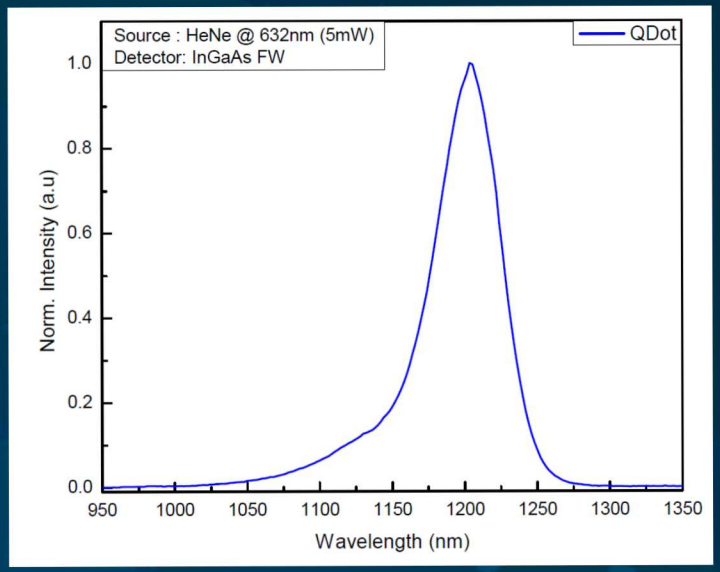
Areal density and emission λ

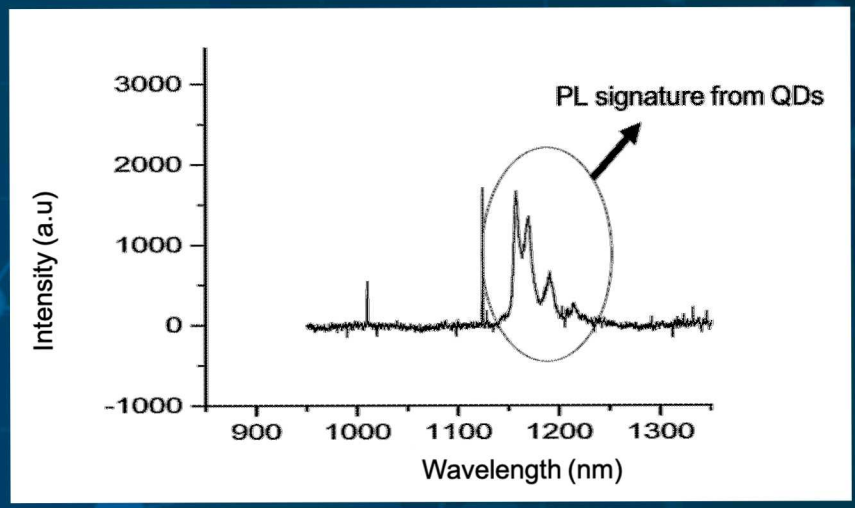


5 X 10^{10}cm^{-2}



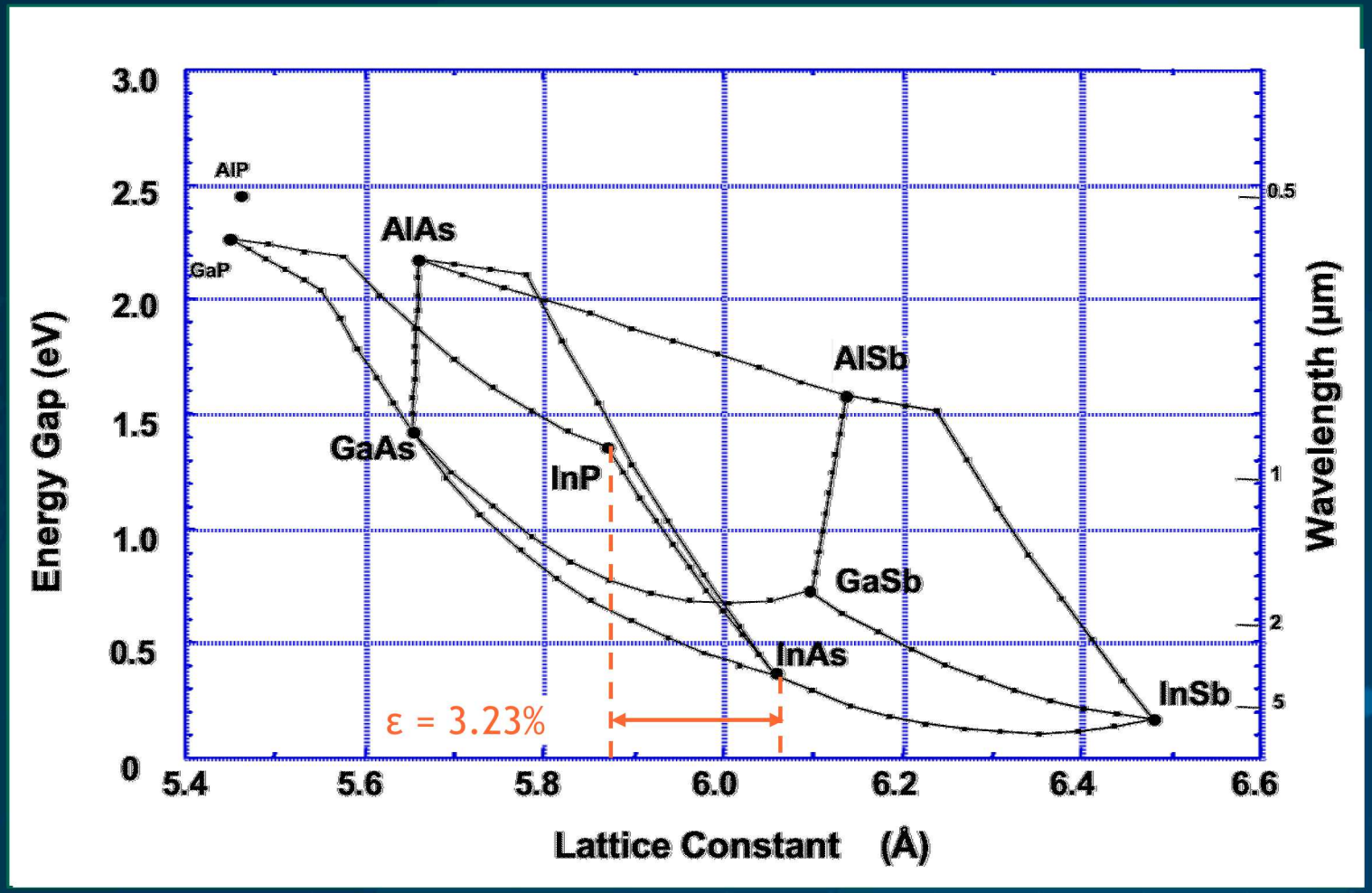
1X 10^{9}cm^{-2}

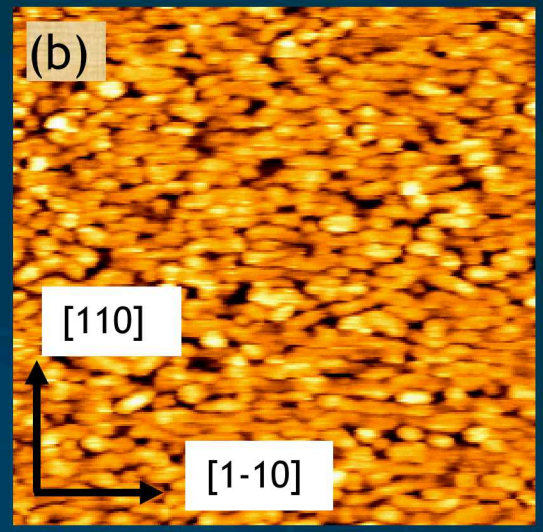




- Areal density controlled by growth conditions – coverage or growth T
- Size/shape will also tune emission wavelength.
- Grown with InGaAs QWs as a Dots-in-a-well structure – 1.3µm and beyond.

S-K QDs: InAs / InP

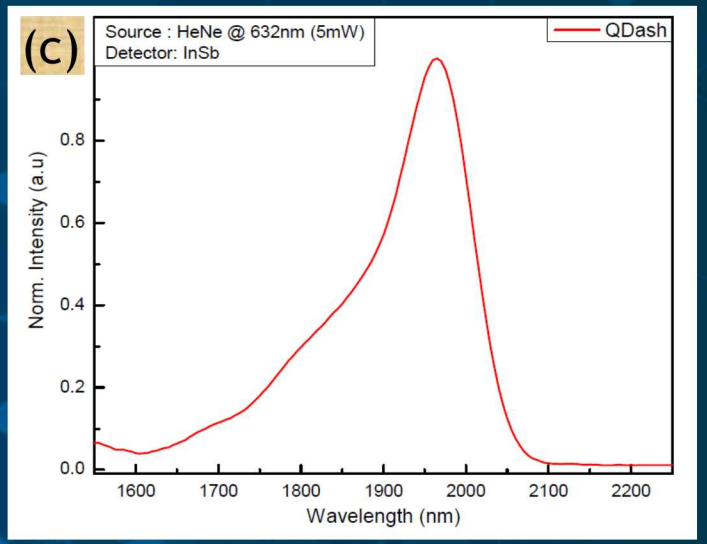




1 X 1 μm AFM scan

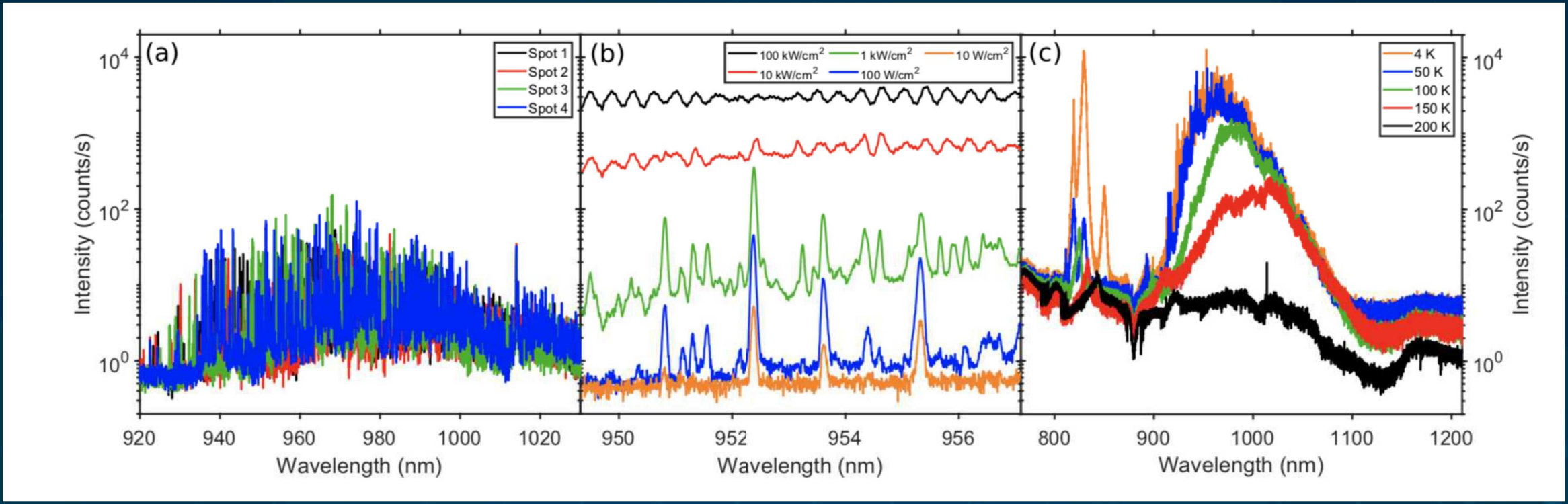
QDashes

Height: 2 – 3 nm
Length:50-200 nm
Width: 20 nm



RT photoluminescence measurements

Preliminary single-photon results

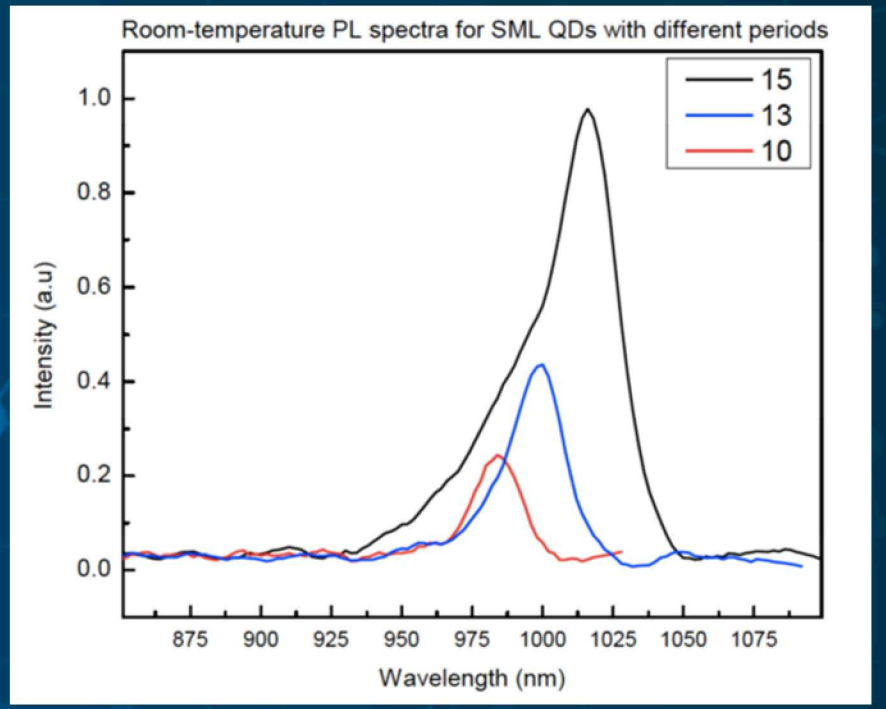


- At 4K, narrow QD PL observed at multiple wavelengths (930-1030nm)
- Low-density QDs preferred for single-photon measurements

Submonolayer InAs/GaAs (SML) QDs

Schematic showing difference between S-K and SML QDs

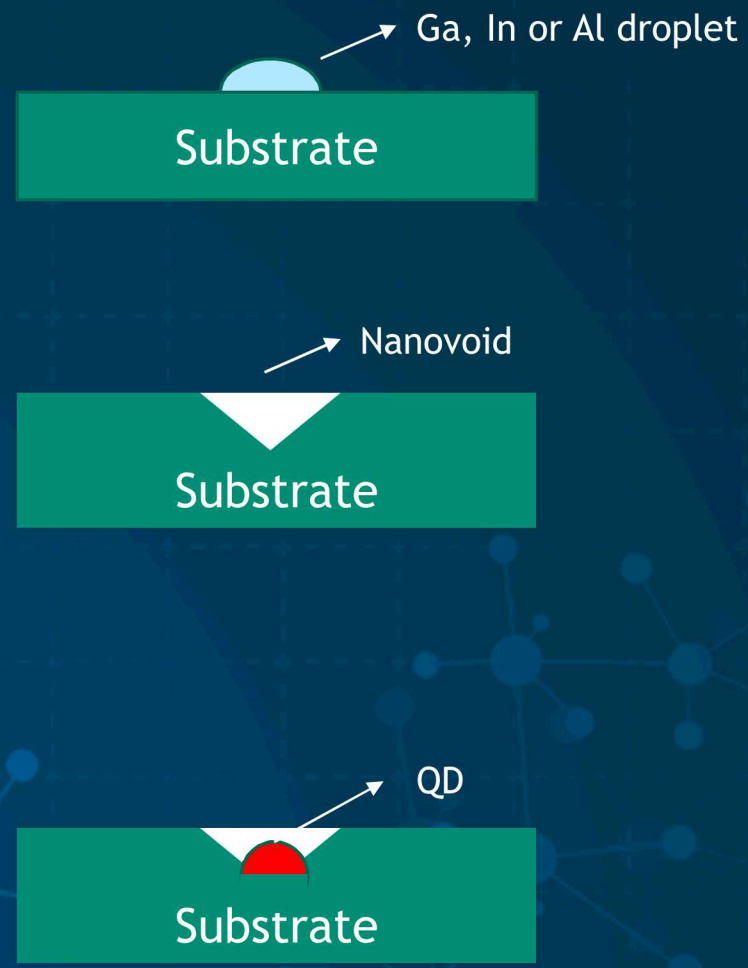
- Stacked alternating deposition of InAs (SML) and GaAs
- Compared to S-K QDs:
  - No wetting layer
  - Higher areal density
  - Adjustable height – tuning emission wavelength
  - Better confinement



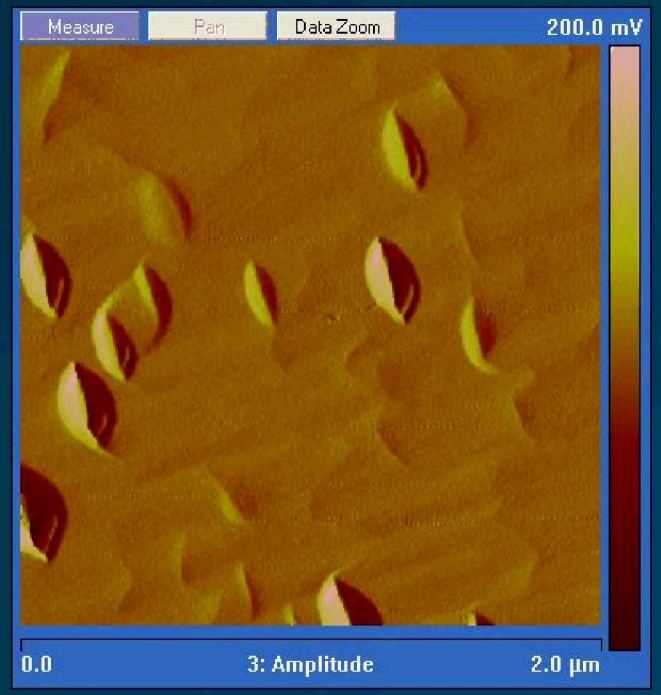
Local droplet etching (LDE) QDs

- Recent evolution of droplet epitaxy technique – overcomes low T limitation
- Defect and impurity-free nano-patterning
- Properties:
  - High symmetry
  - Low areal density
  - Surface mounds

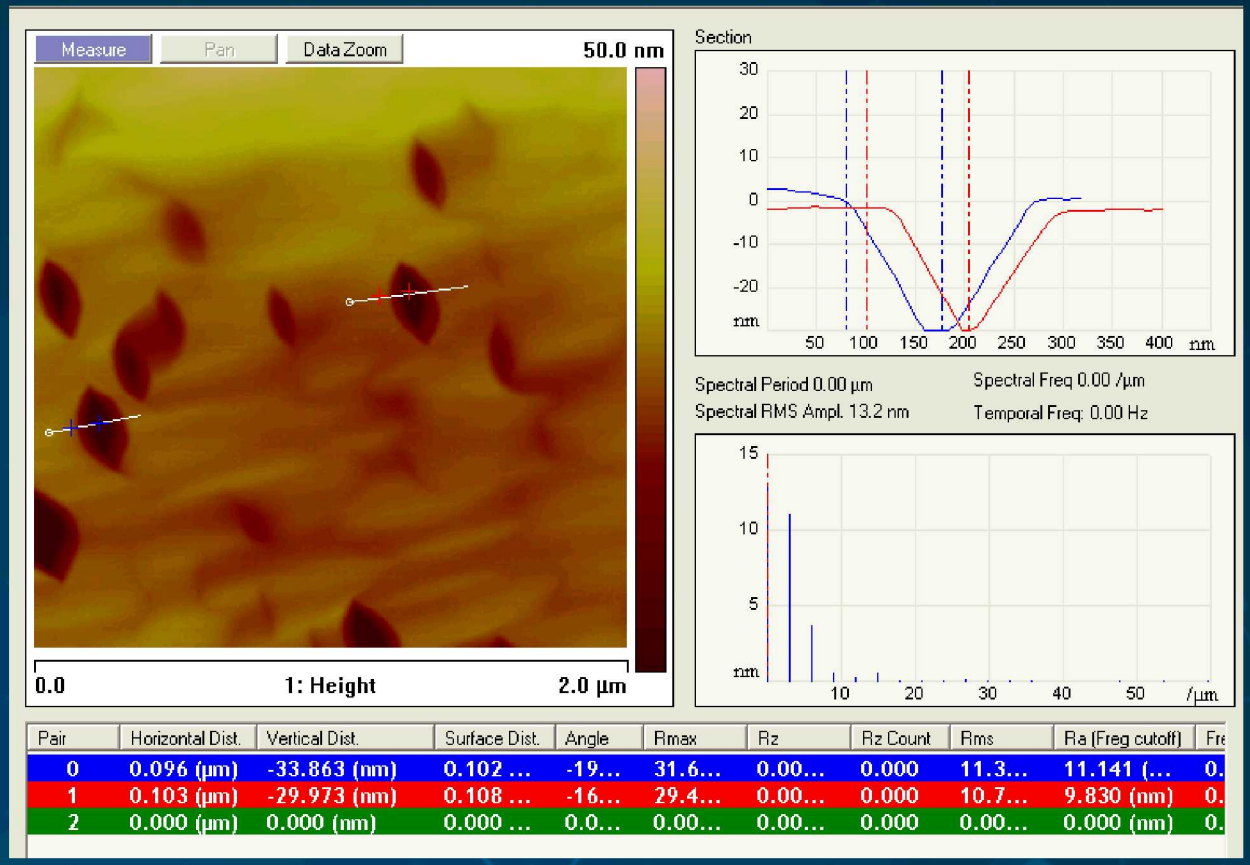
  } Ideal for single-photon emitters
  - Choice for QD material



LDE QDs – AFM



2 X 2 µm AFM scans



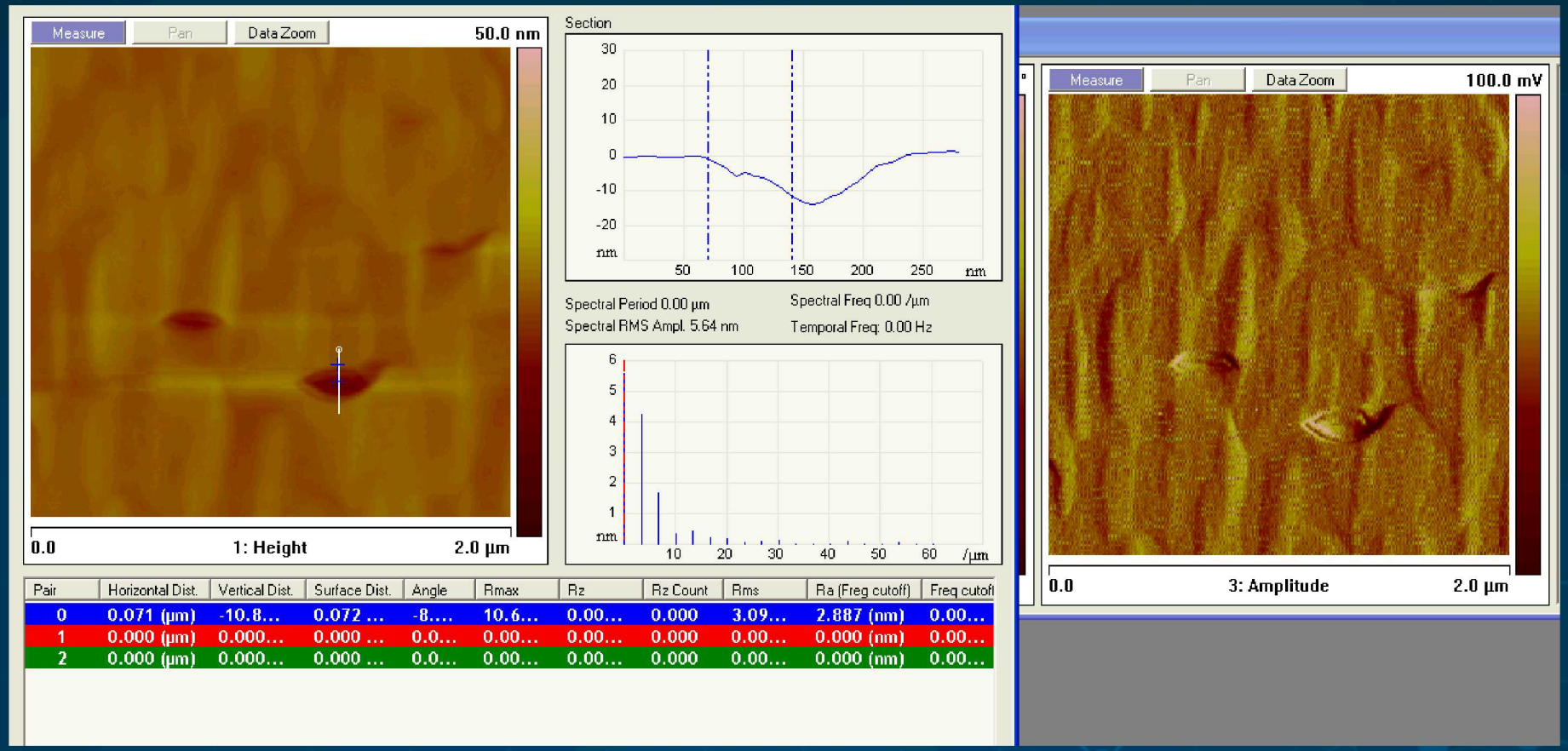
Pair	Horizontal Dist.	Vertical Dist.	Surface Dist.	Angle	Rmax	Rz	Rz Count	Rms	Ra (Freq cutoff)	Fre
0	0.096 (µm)	-33.863 (nm)	0.102 ...	-19...	31.6...	0.00...	0.000	11.3...	11.141 (...	0.
1	0.103 (µm)	-29.973 (nm)	0.108 ...	-16...	29.4...	0.00...	0.000	10.7...	9.830 (nm)	0.
2	0.000 (µm)	0.000 (nm)	0.000 ...	0.0...	0.00...	0.00...	0.000	0.00...	0.000 (nm)	0.

Line profile from AFM

- Nanovoid formation by Ga-droplet etching on AlGaAs surface
- Low areal density ~1X10^{8}/cm^{2}

Void dimensions:
- Depth: ~30nm
- Width: ~150-200nm

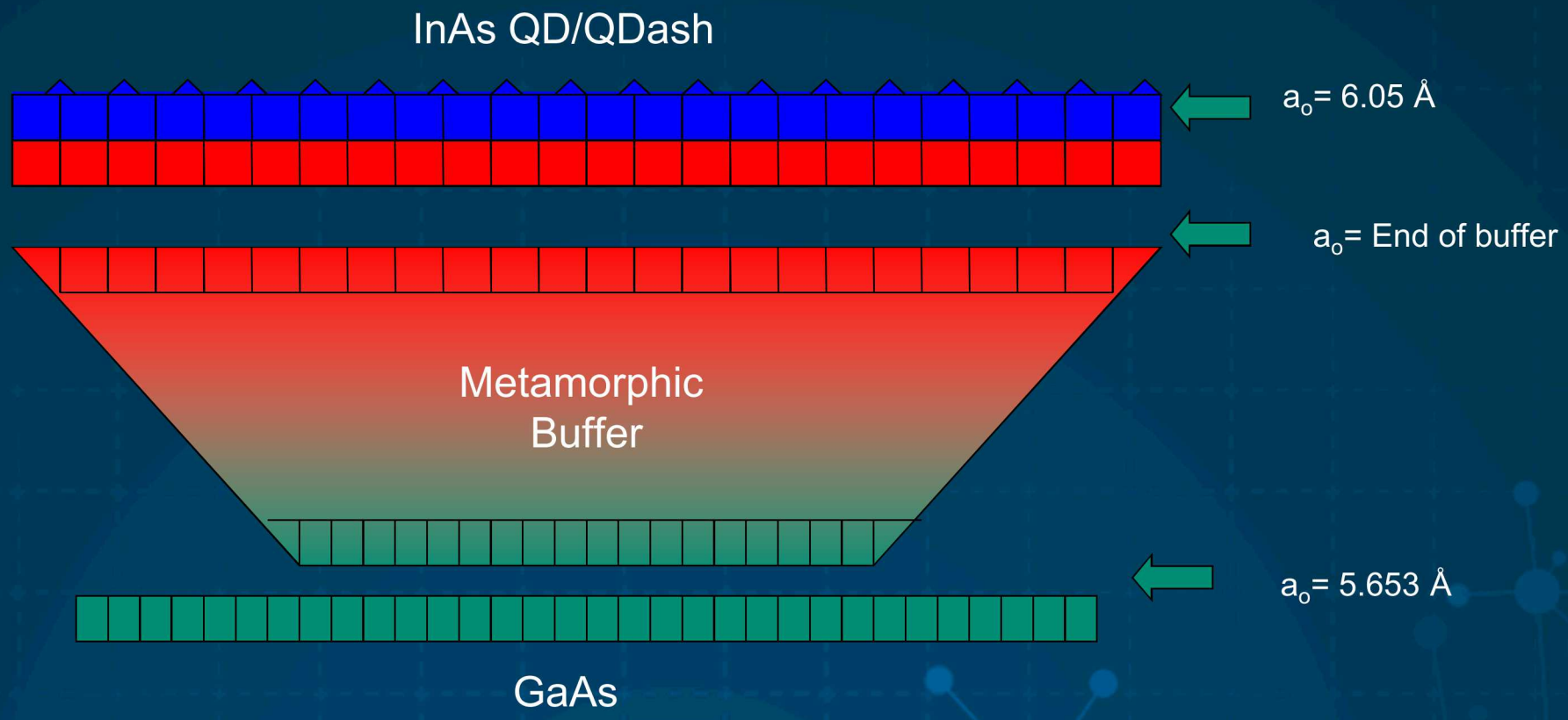
LDE QDs –AFM



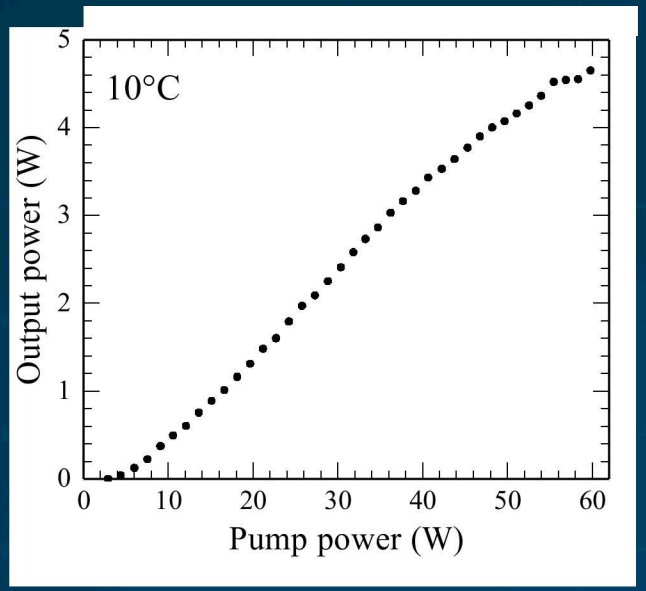
- Nanovoid in-filled with GaAs QDot – nanovoid depth decreases ~10nm
- Capped samples grown for PL

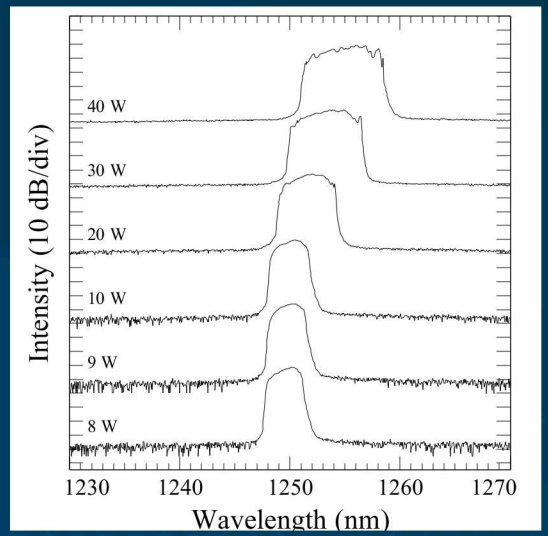
Backup slides

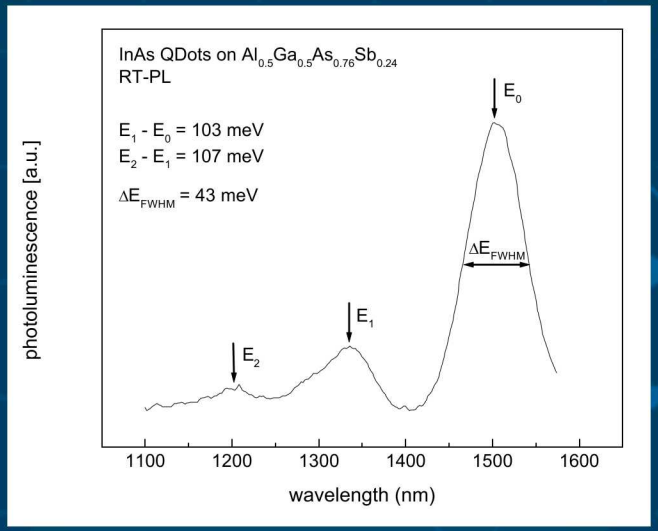
QDs shape/size control

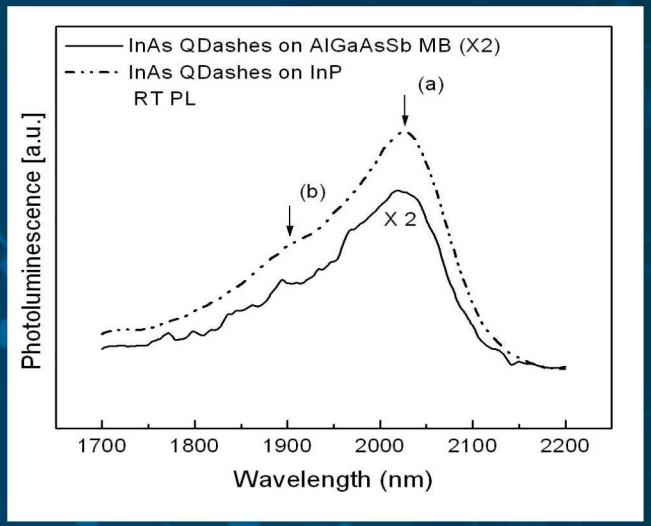


- Metamorphic buffer used to step up lattice constant of substrate
- Step-graded AlGaAsSb buffer with increasing Sb%









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