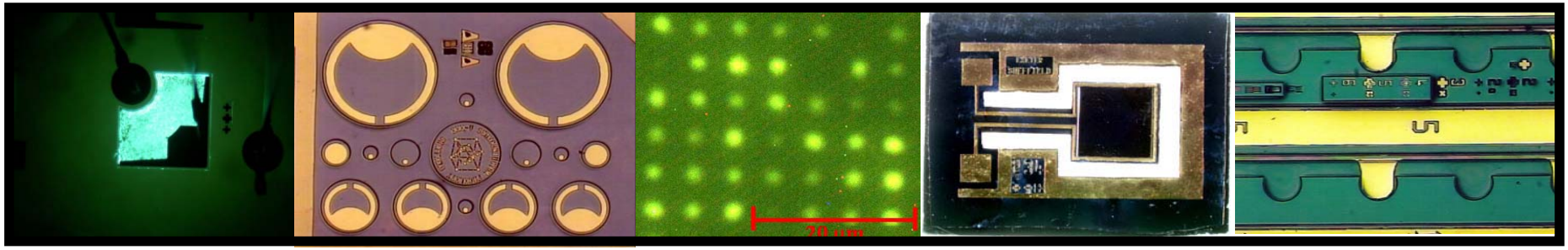
EPSRC National Centre for III-V Technologies
Device Fabrication – Sheffield partner



"Providing direct collaborative access to a comprehensive range of unique III-V research and development facilities"

Outline

Introduction

Grants supported

Capabilities & Development Projects

People

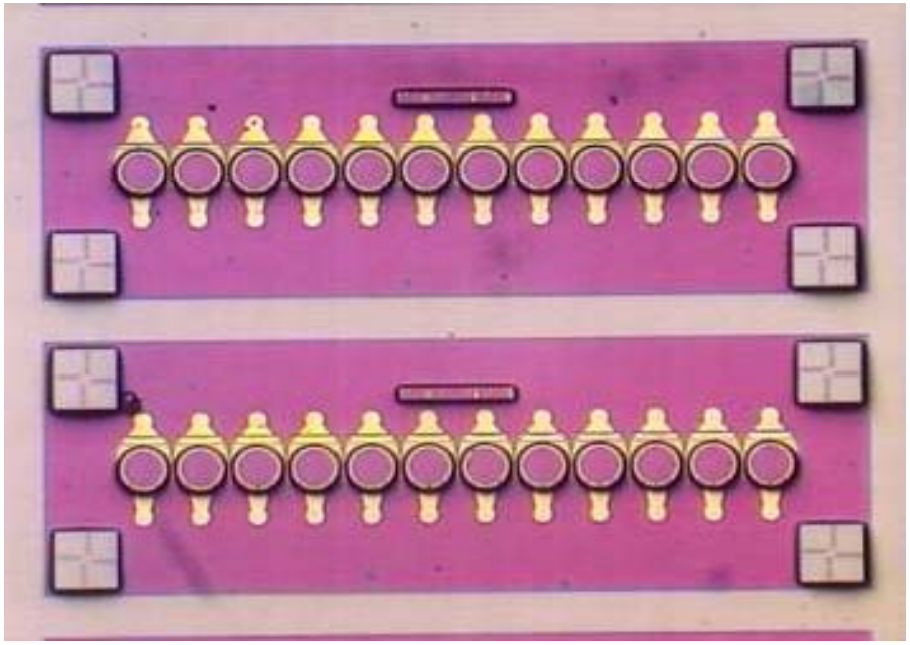
Equipment & Processes

Training

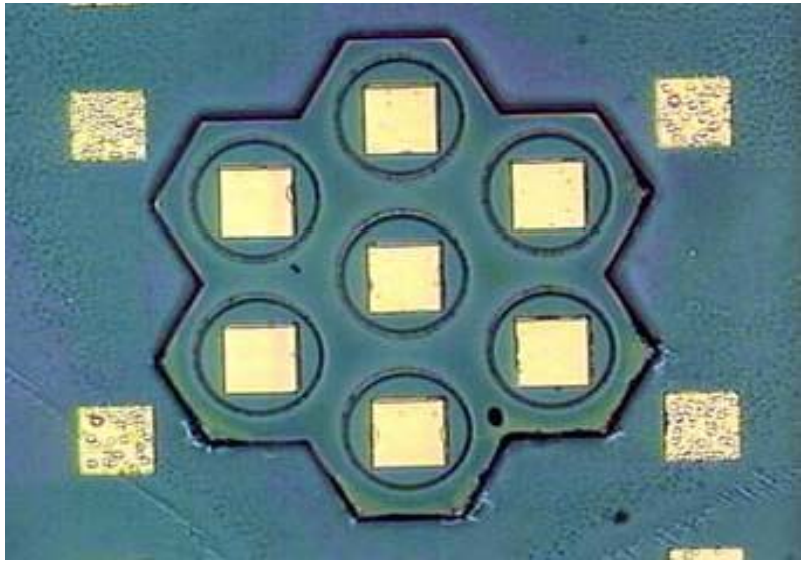
Summary

Introduction

These slides provide a snapshot of activities for the Sheffield component of The EPSRC National Centre for III-V Technologies Device Fabrication



Current Work

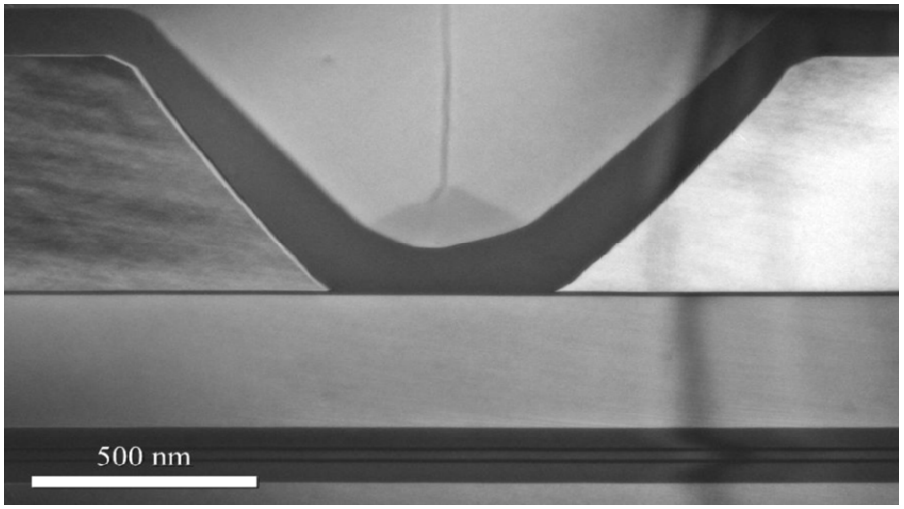


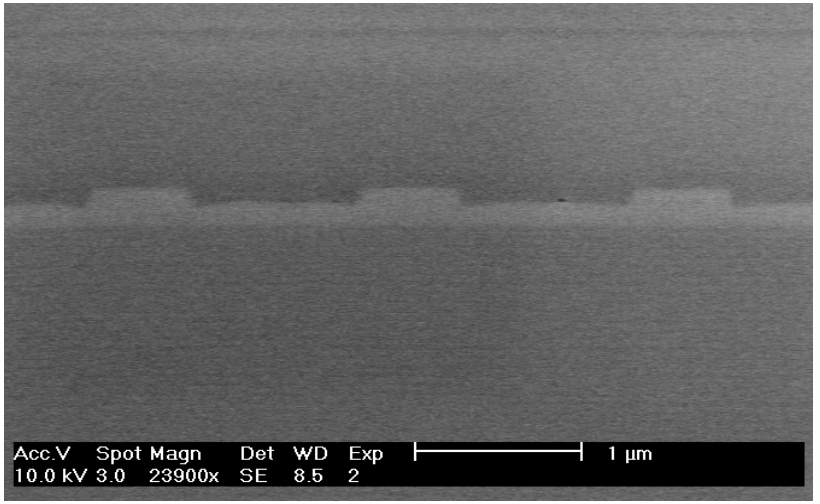
Solar Cells
Dilute Nitride Electronic Devices
APDs/Single Photon Emitters
Spintronic Devices
Quantum Chaotic Devices
Integrated Doped Glass & III-V Devices
QD Lasers & SLEDs
GaN UV LEDs
Quantum Cascade Lasers
Hybrid bio-devices
GaAs Buried Heterostructure Lasers

Integrated Facility

~50 % of epitaxial material worked on is from external sources

New capabilities in regrowth of InP and GaAs – making full use of the integrated fabrication and epitaxial facility

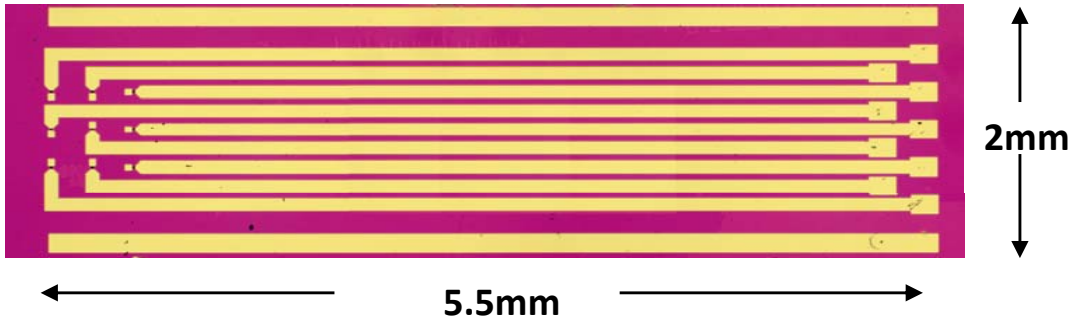




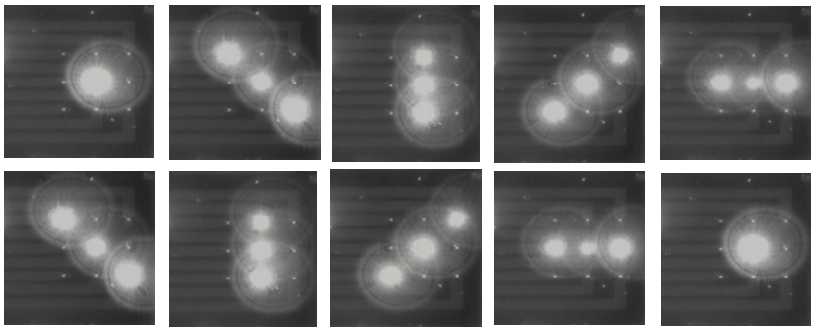
Bespoke Devices

Increase in demand for bespoke opto-electronic devices by non-specialists in III-V semiconductors

e.g. VCSEL array below

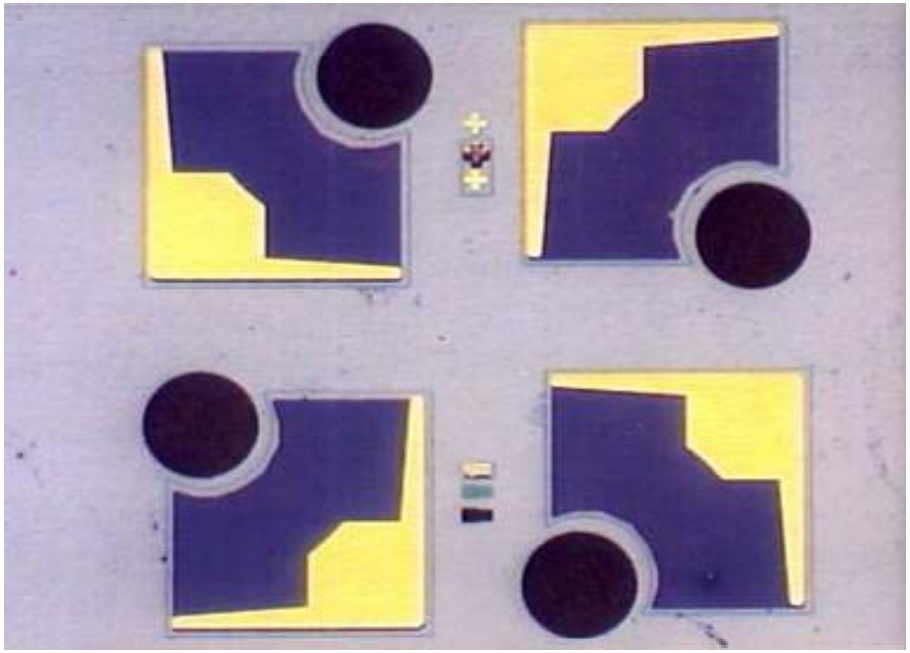


Custom VCSEL Array Chip



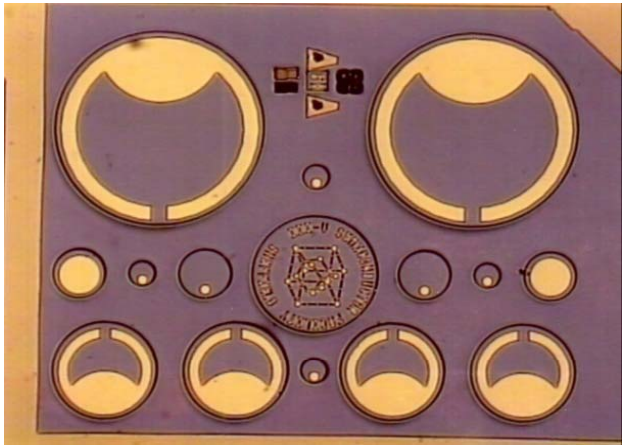
Custom Chip in Opperation

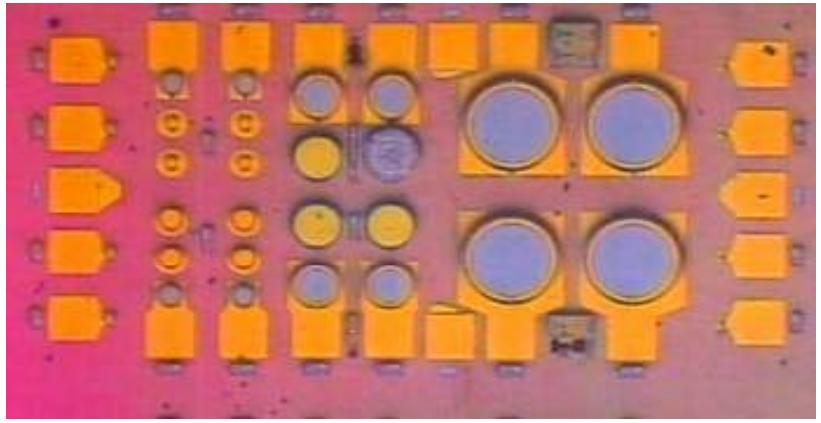
Standard Devices Include;



- Mesa diodes
  - Optical access mesas
  - Single QD devices
  - Solar Cells
  - LEDs
  - APDs
- Lasers
  - Broad area laser
  - RF compatible
  - SLED
  - Quantum Cascade DFB

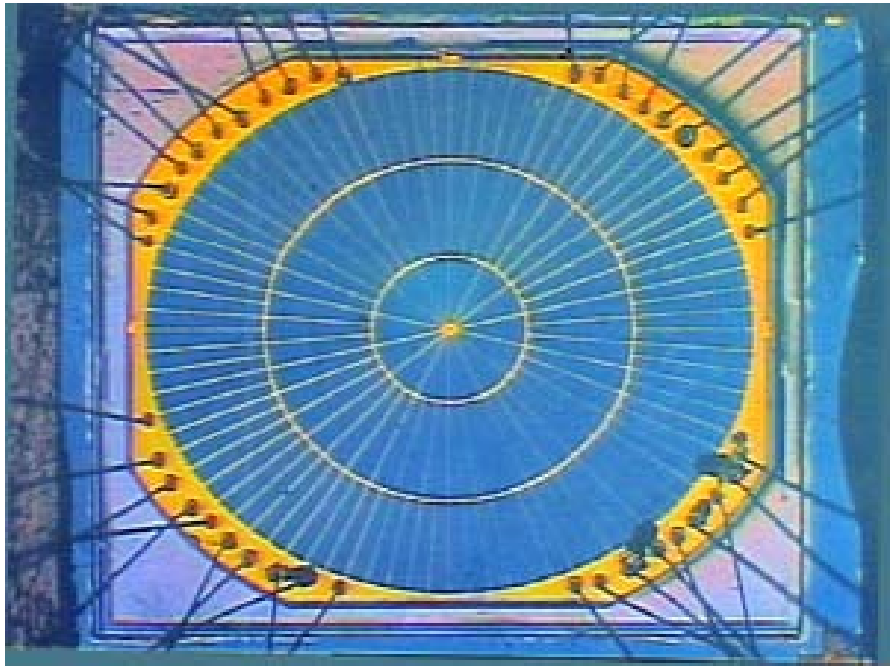
Optical Access Mesa Diodes





Devices such as MQW pin photodiodes, optical modulators, resonant tunnelling diodes and barrier diodes can all be studied using this structure type.

Concentrator Solar Cells

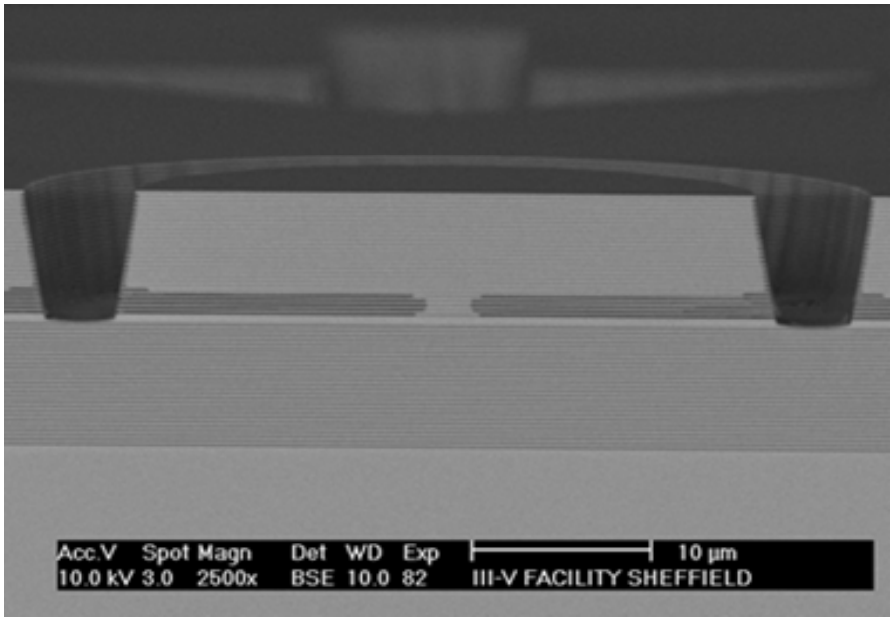


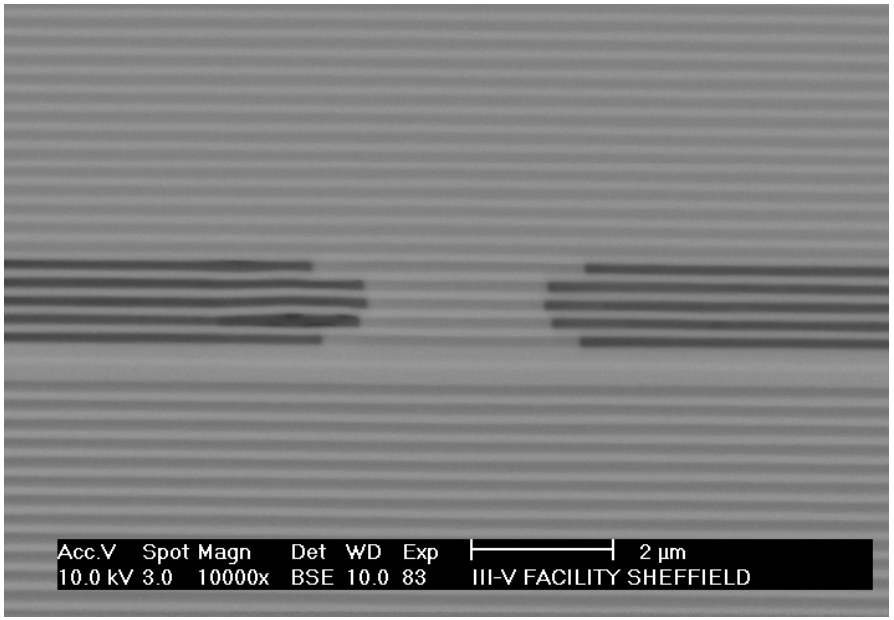
InGaAs/GaAsP multi-quantum well concentrator solar cells

26.2 % efficiency at 308 suns

Work is being undertaken to reduce the series resistance and enable higher efficiencies to be achieved at intensities of 500 suns.

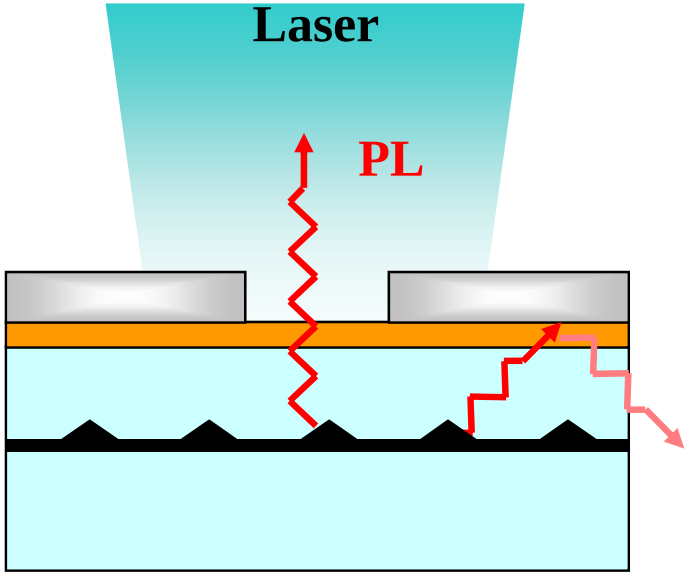
VCSELs





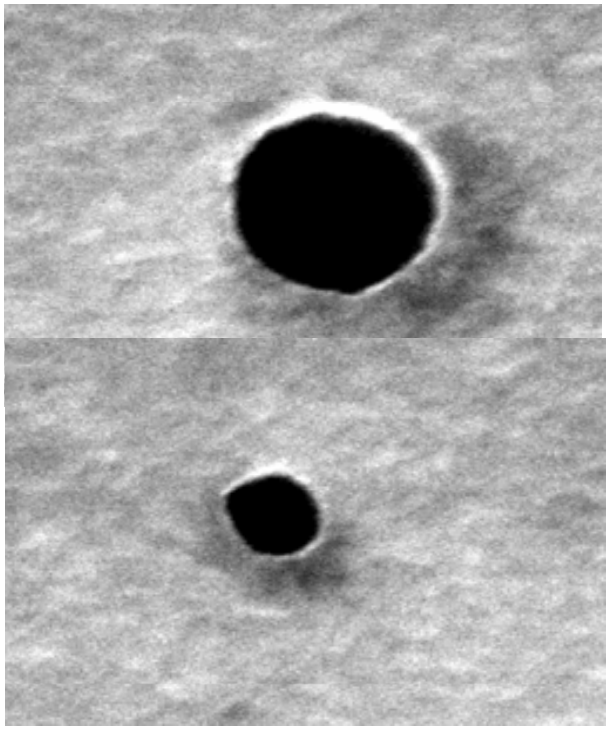
Selective steam oxidation of AlGaAs structures for electrical and optical confinement

Apertures for Single QDs

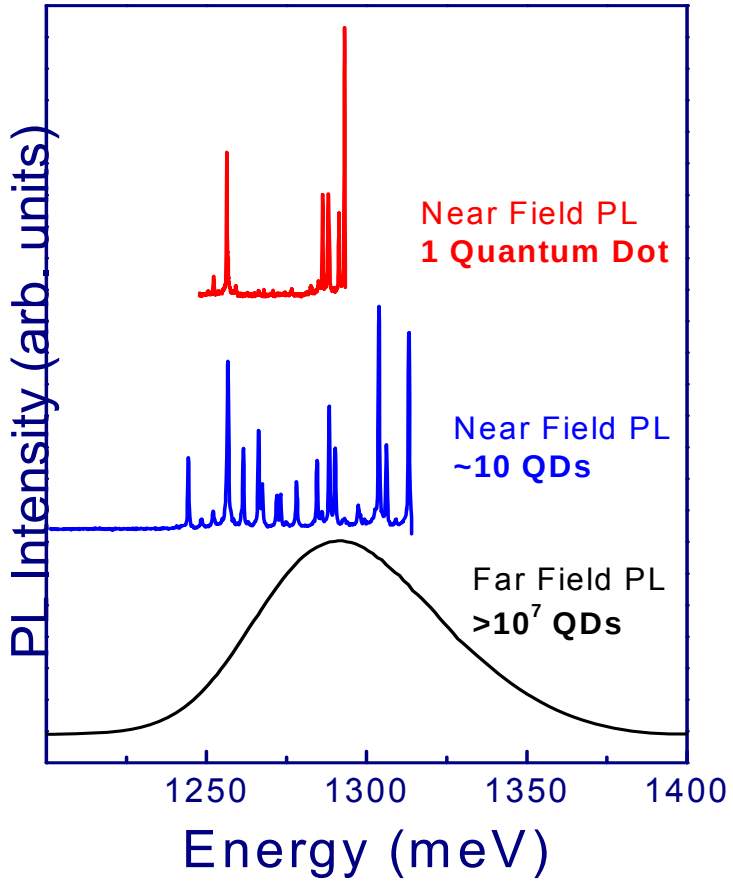


- Easy to fabricate.
- Easy to add electrical contacts.

Aperture diameter ~500nm

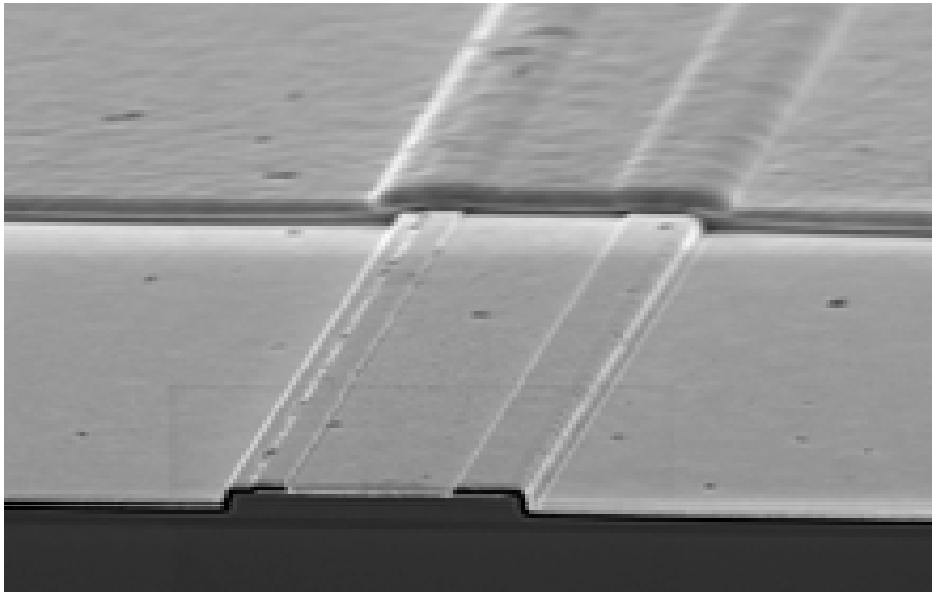


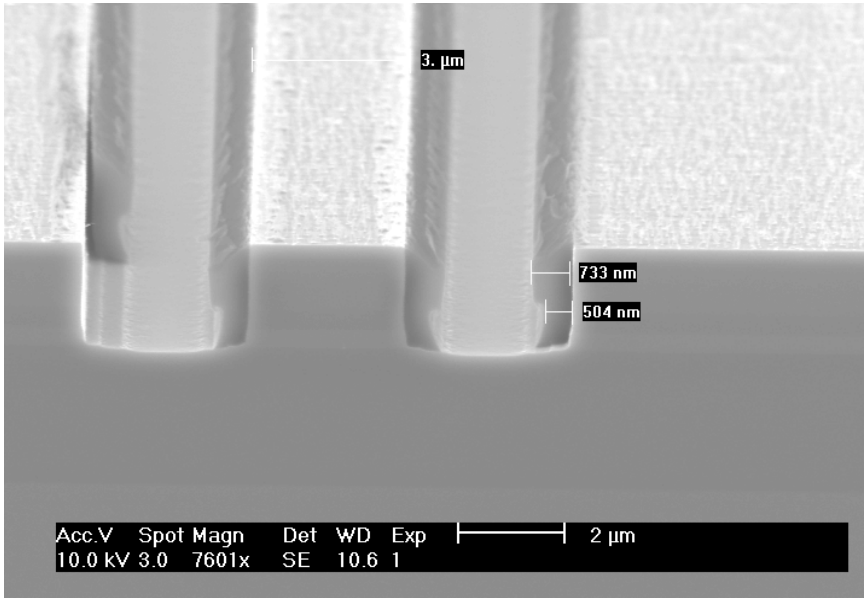
Aperture diameter ~200nm



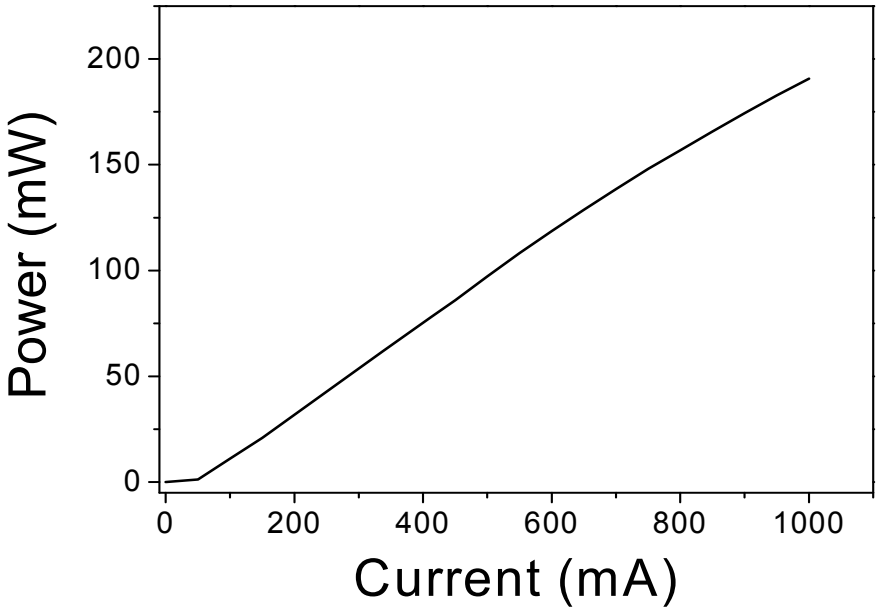
Standard Laser Masks

- Various ridge widths 100 μm down to 3 μm ridges
- Made to order: wet/dry, shallow/deep etc.



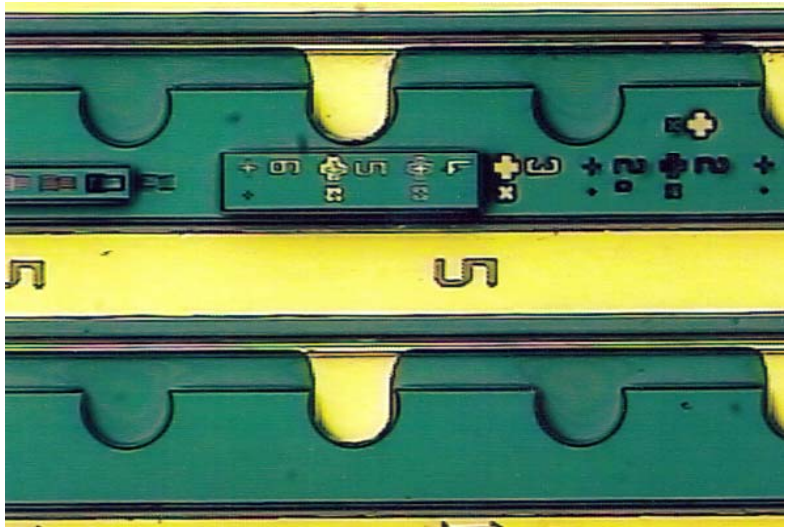


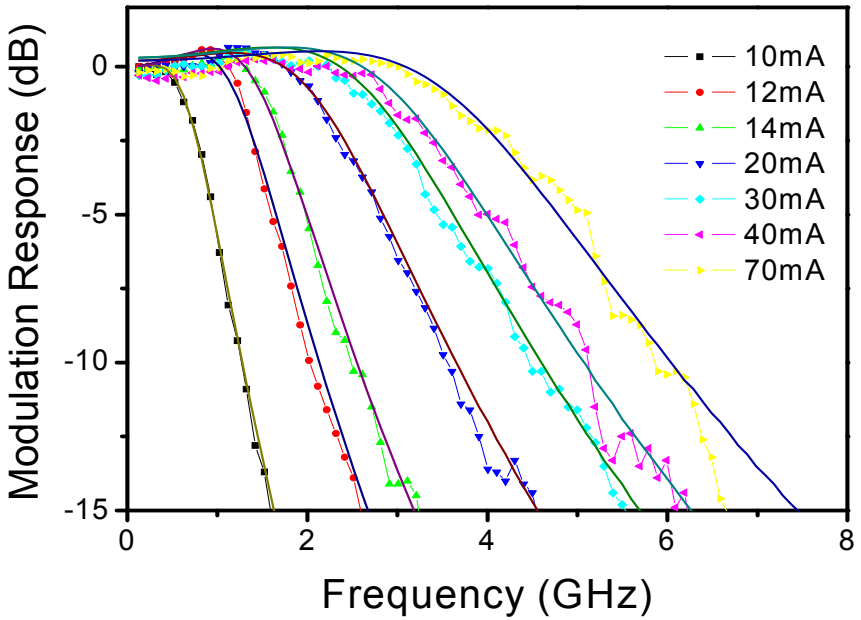
Bespoke Lasers



Bespoke single-mode fibre coupled devices
e.g, 1200nm quantum dot laser

RF Compatible Lasers

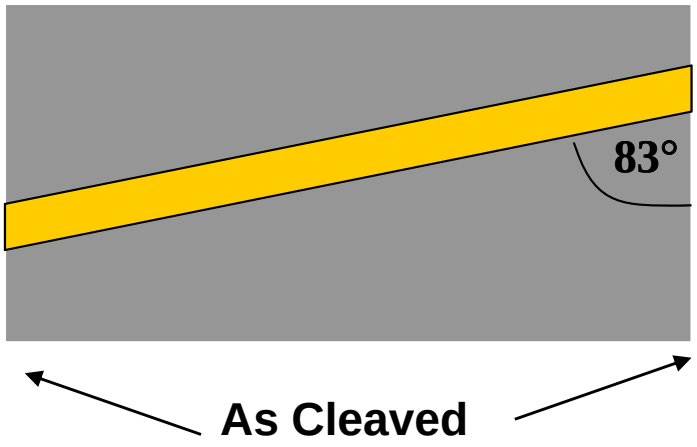


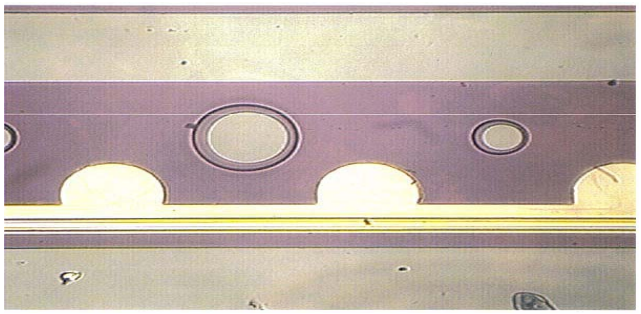


- 3, 5, 15 µm wide ridge lasers
  - Coplanar contacts (picoprobes)
  - Minimum gold coverage

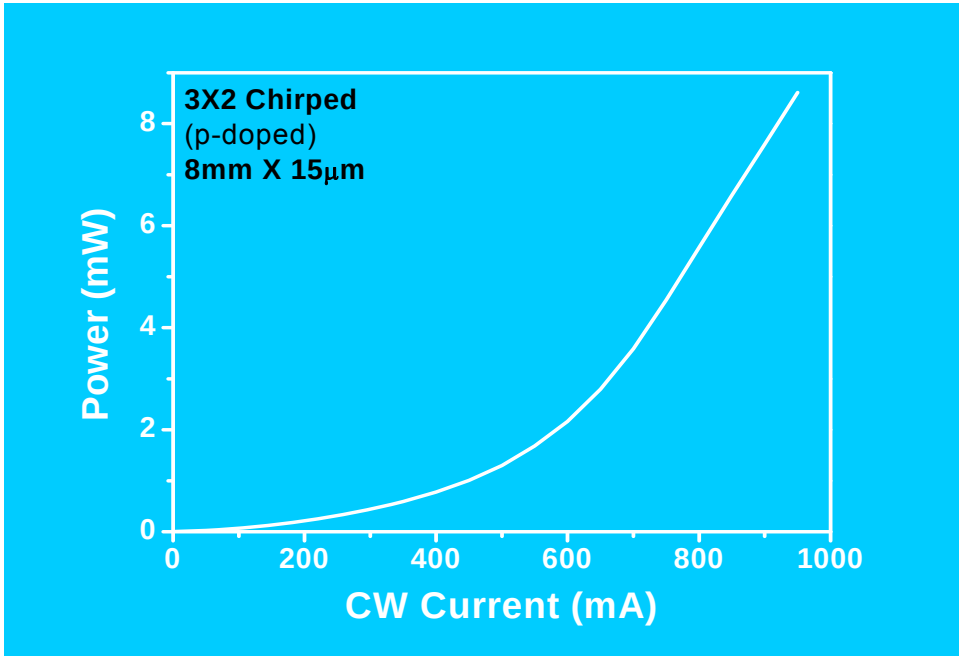
• Allows modulation dynamics study (1.3µm QDs above).

Superluminescent Diodes



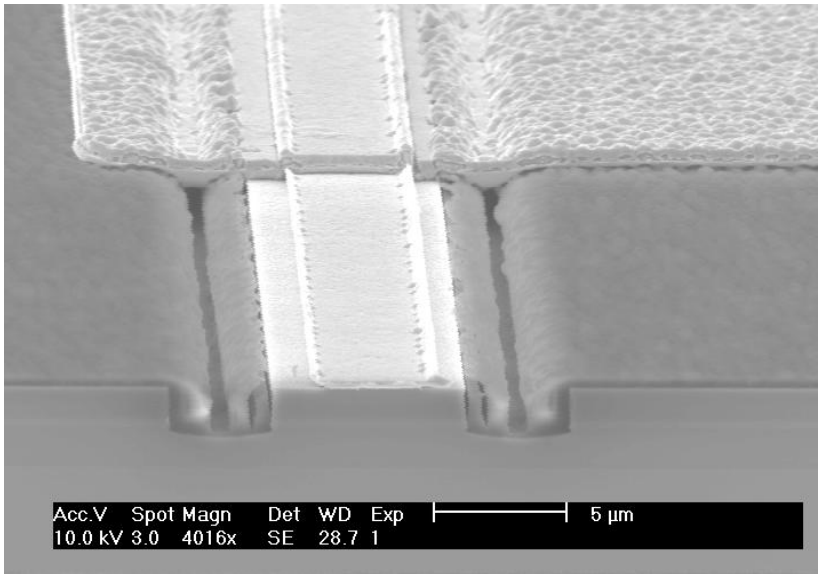


Standard laser fabricated 7° off axis



Chirped QD SLED

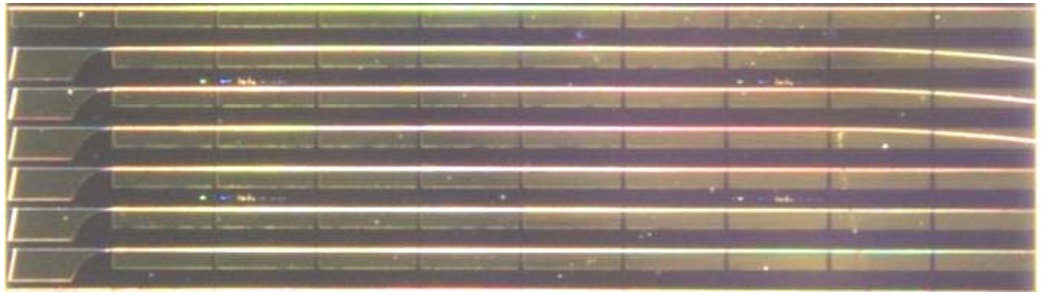
Multi-Contact Laser/SLD – Fabrication



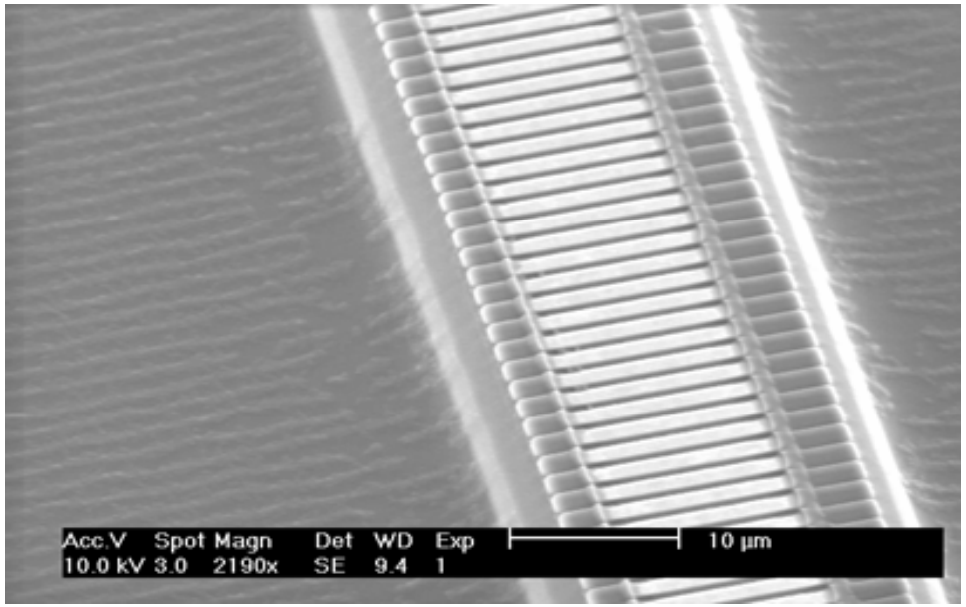
Developed originally for superluminescent diodes

Number of design features to inhibit lasing

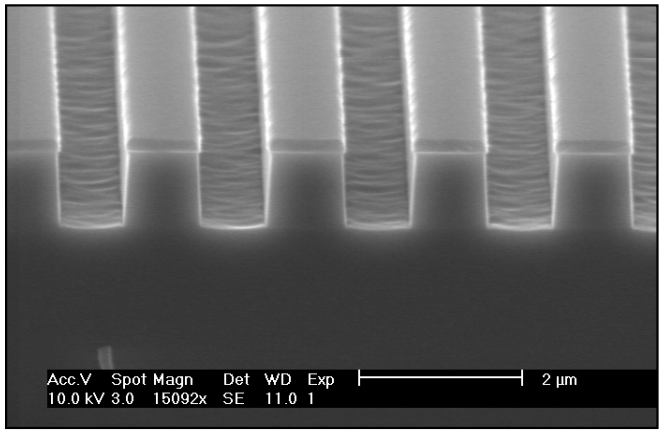
Isolated multiple contacts provides capability to utilise for laser material characterization

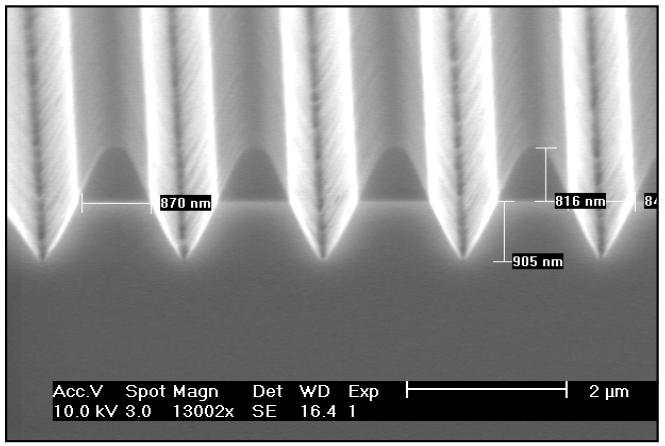


Surface Grating QCDFBs



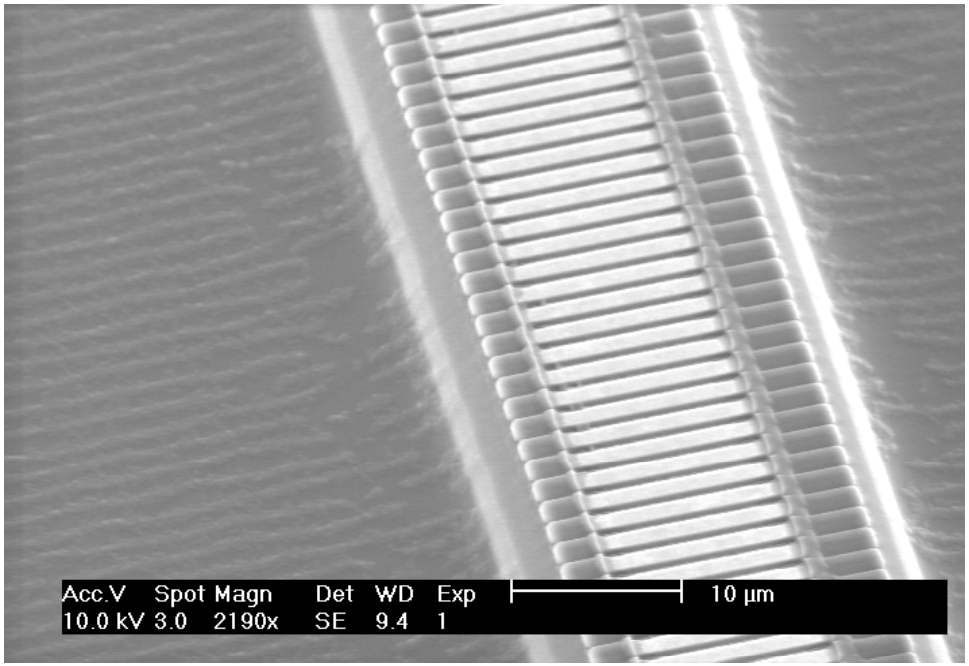
Contact lithography, e-beam and interference lithography for grating definition





Dry etch control for profile control

Quantum Cascade DFB Lasers – gold filled surface gratings

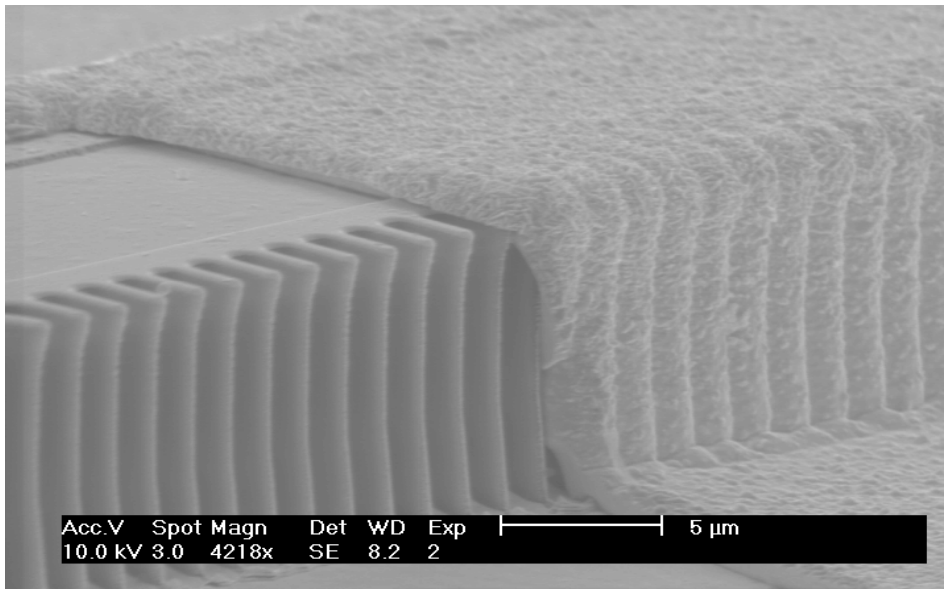


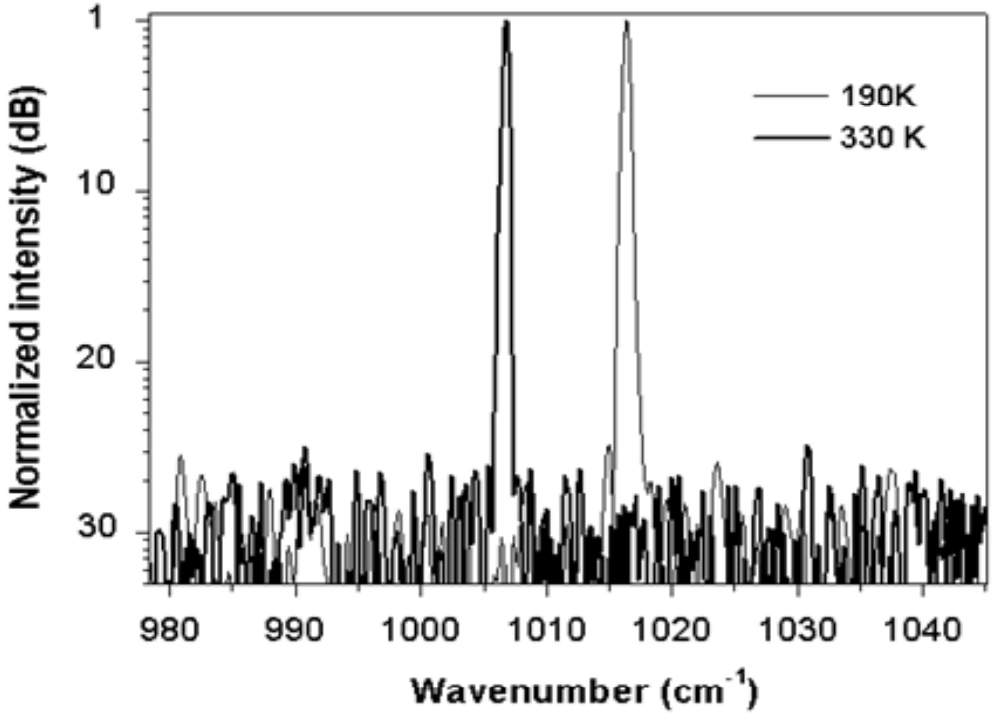
Conventional Approach

Single mode yield is good

– wavelength control function grating depth, ridge width

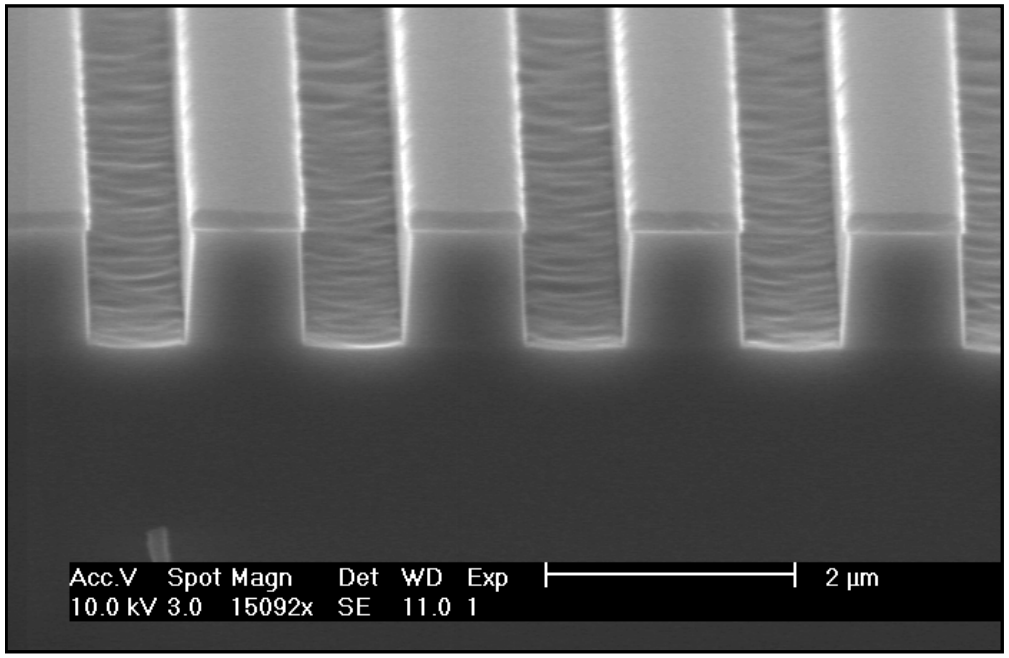
Quantum Cascade DFB Lasers – Lateral Grating

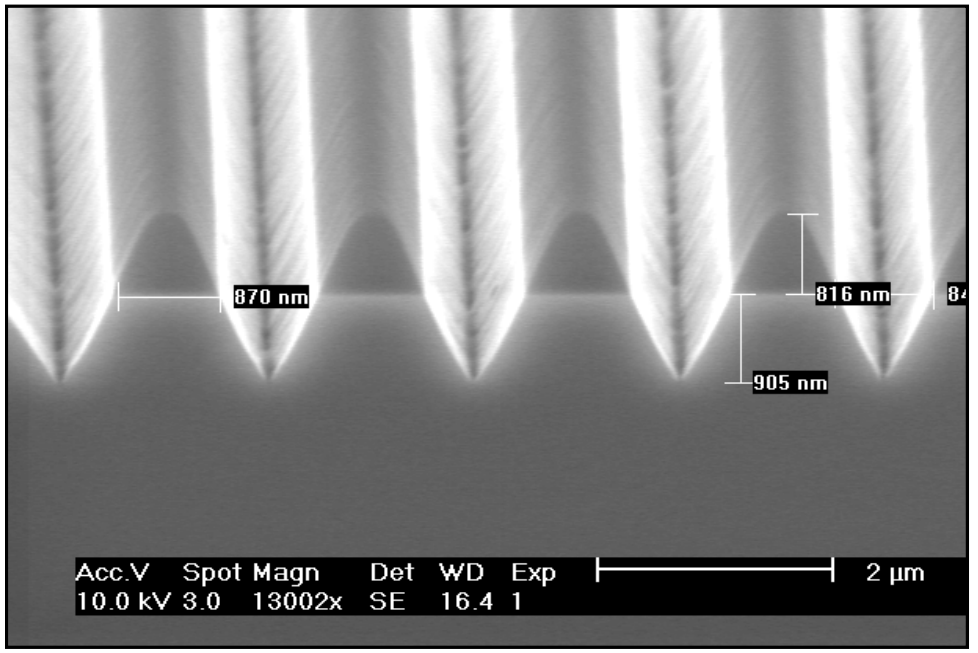




Developed multi-stage deep ICP etch for InP/AlInGaAs

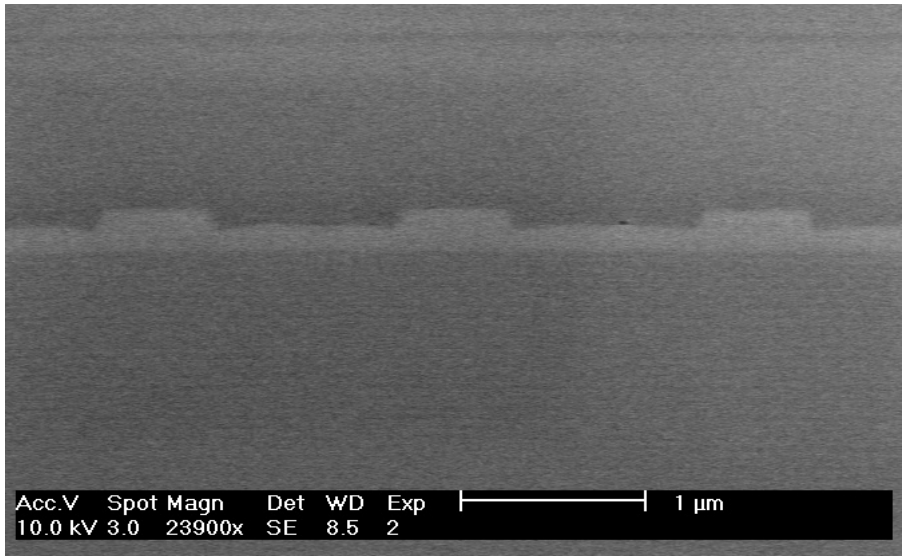
ICP Etching of InP

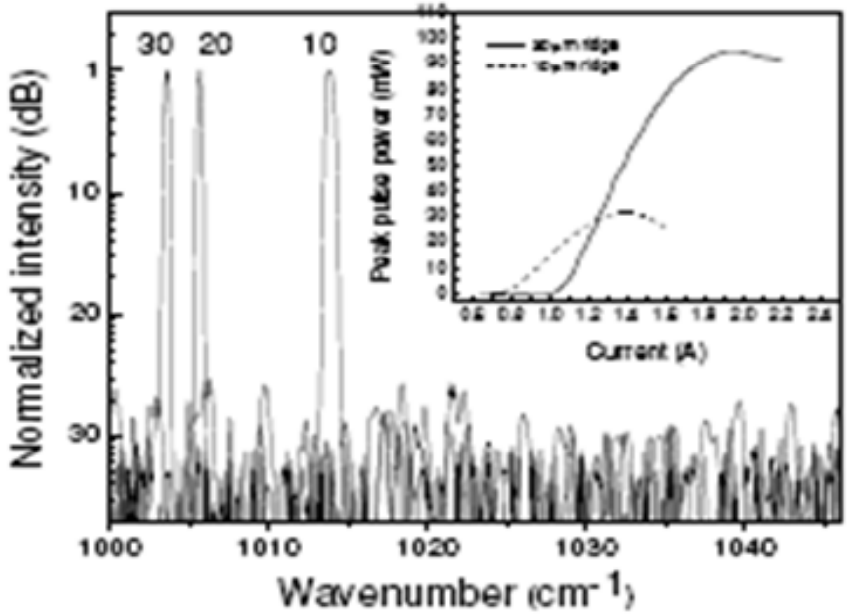




Dry etch control for profile control

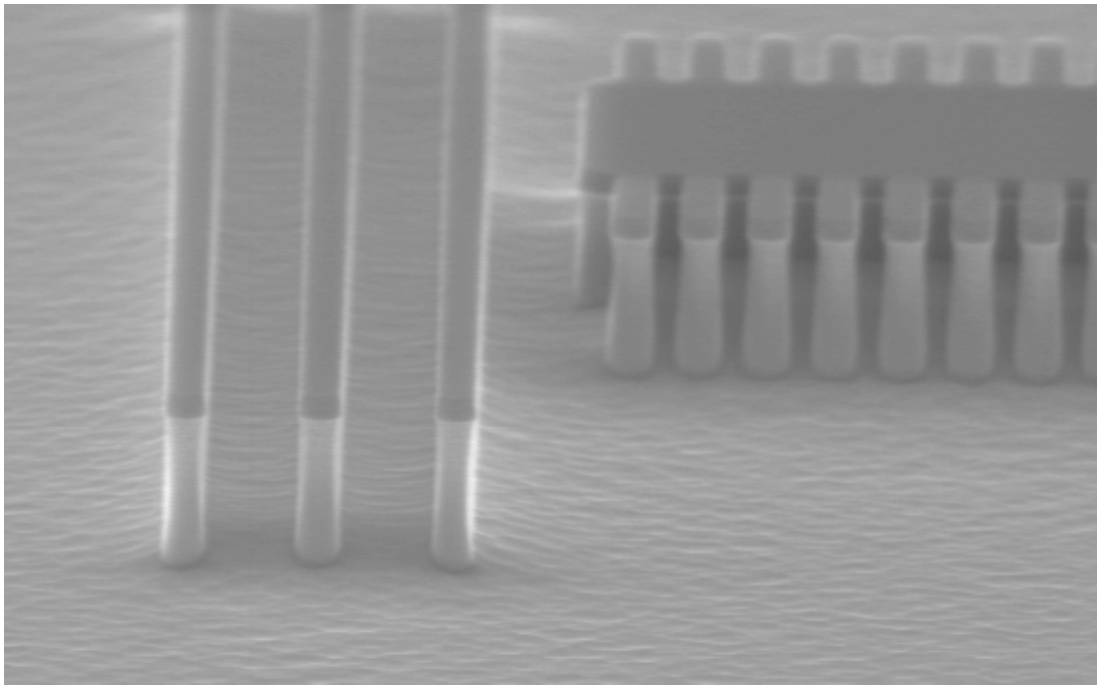
Quantum Cascade DFB Lasers – Overgrown Grating





O/G DFB Array – vary ridge width for spread of wavelengths

New Developments



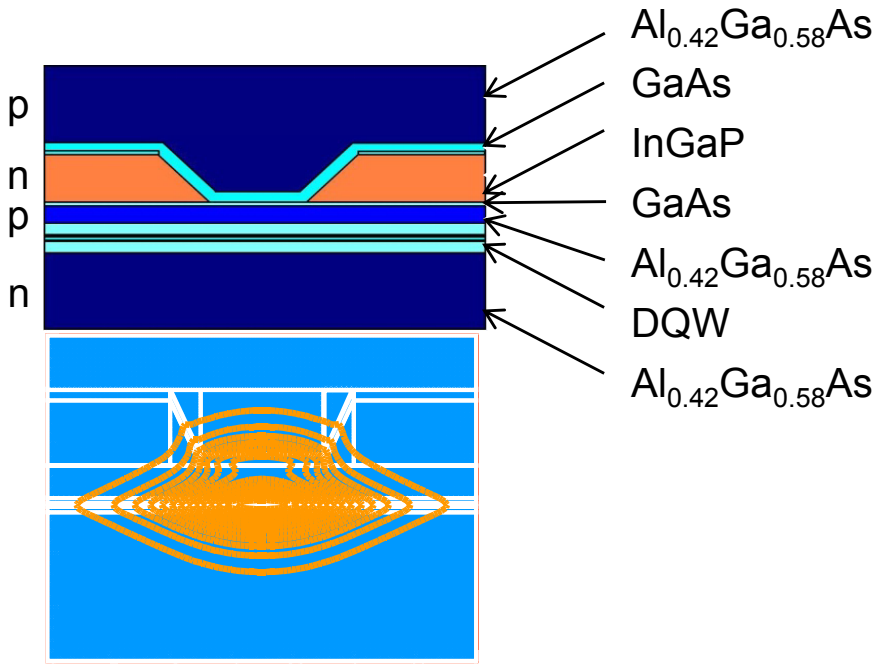
Applications in

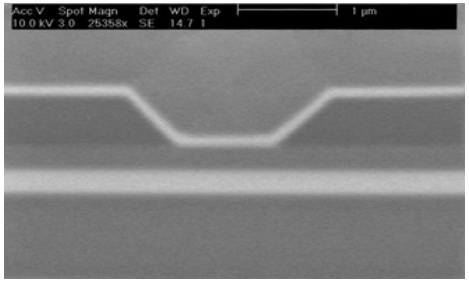
- Grating Couplers
- Deep Bragg Mirrors
- Photonic crystals in InP materials

GaAs Self-Aligned Stripe Laser

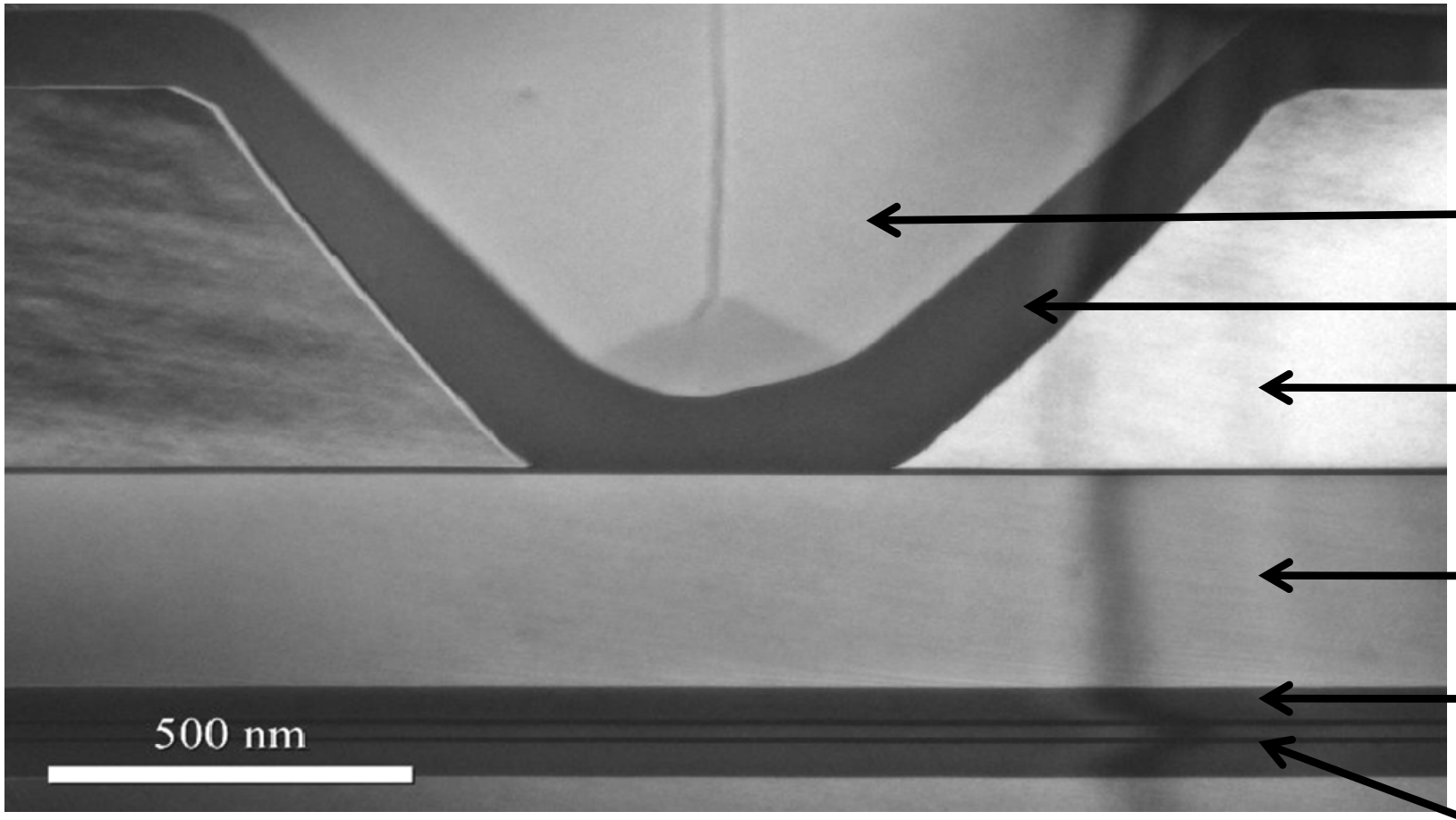
Motivation-
Develop GaAs based fabrication technologies for current and optical confinement to realise advanced devices

Development-
Self aligned stripe laser utilising InGaP layer for current and optical confinement
Robust manufacturing procedure – AlGaAs never exposed to air





Overgrowth



AlGaAs

GaAs

InGaP

AlGaAs

GaAs

2 x InGaAs QW

Laser Results

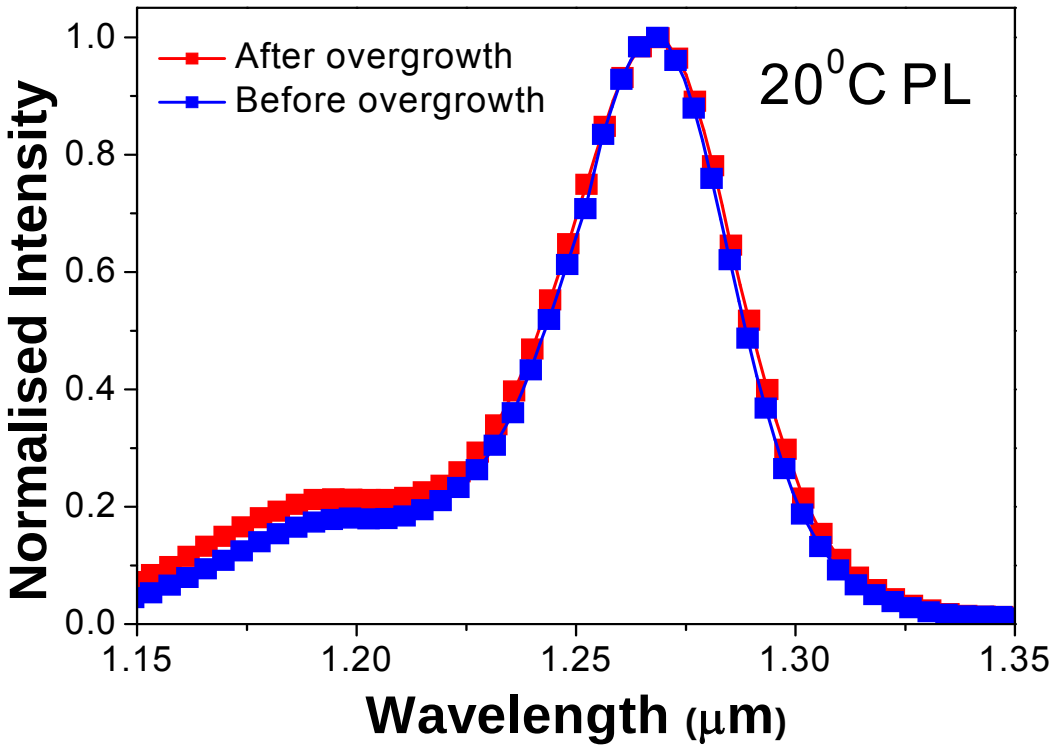
~990nm double QW

~100mW CW single mode emission

(p-side up bar test – no heatsinking)

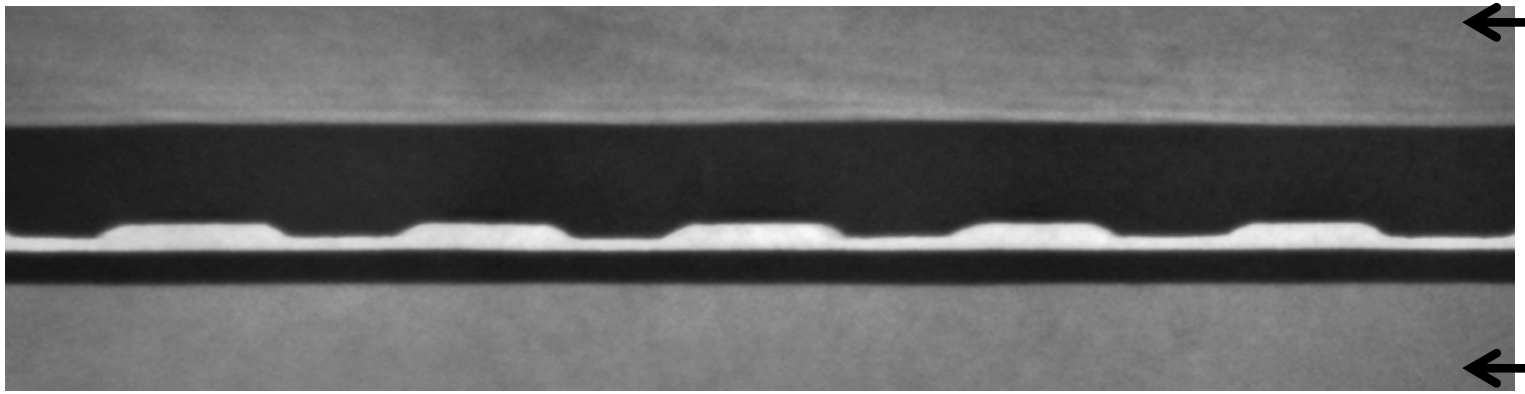
Groom *et al.,* Electronics Letters, 44(15), 905, (2008)

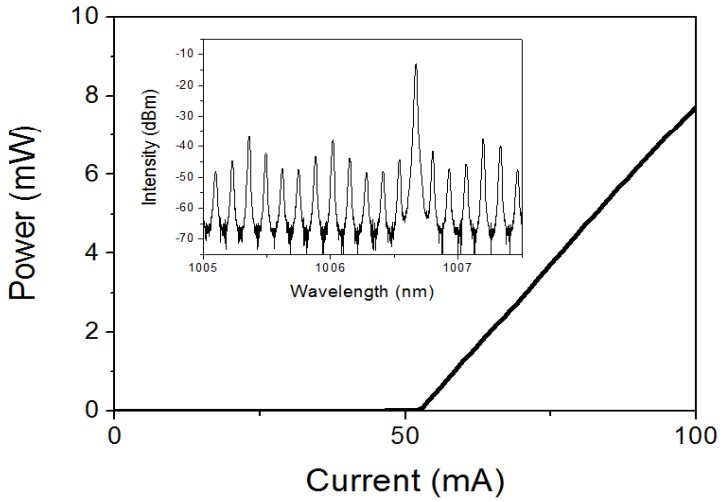
QDs & Overgrowth



- Shift from 1.31 μm to 1.28μm due to move from 0 ° to 3° off substrates – will be corrected
- No evidence for intermixing/annealing of QDs
- Opens way to advanced QD devices

DFBs

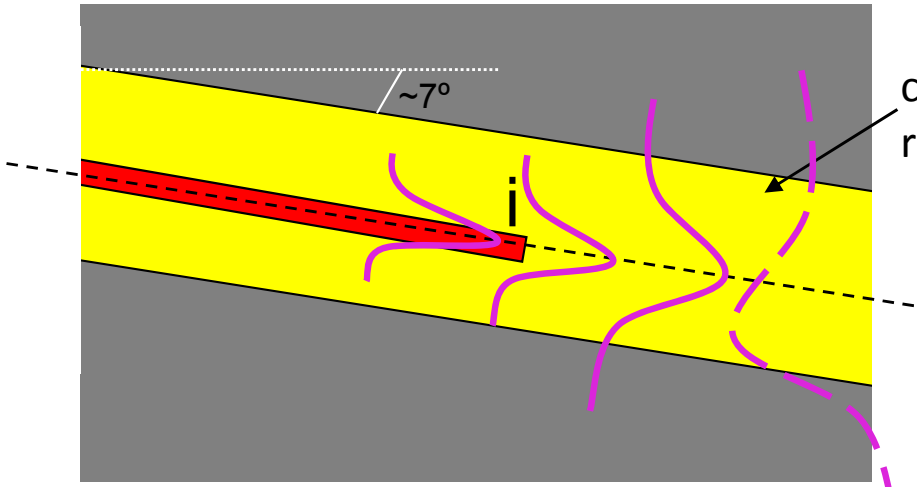


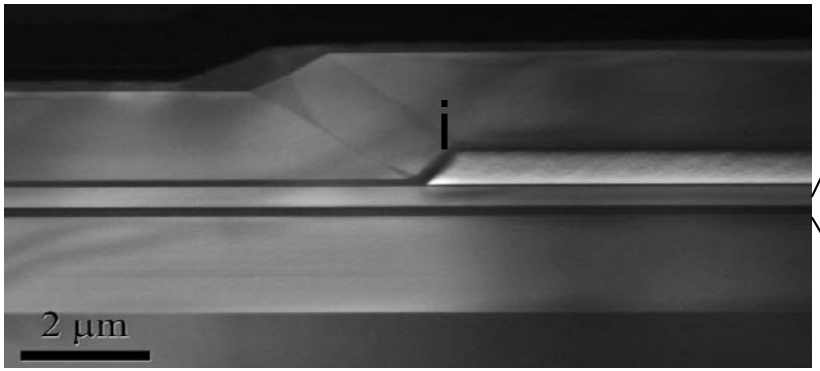


Cleaved / Cleaved facets

>25dBm SMSR

Window Structures





stripe window

20nm GaAs
12.6nm $GaAsP_{0.1}$
8.8nm $In_{0.27}GaAs$
25.2nm $GaAsP_{0.1}$
8.8nm $In_{0.27}GaAs$
35.6nm $GaAsP_{0.1}$
10nm $In_{0.27}GaAs$
23nm $GaAsP_{0.1}$
15nm GaAs

- Effective reflectivity at interface, i, is ~10^{-7} for abrupt interface
- Partially strain-balanced QWs emitting ~1070nm
- Interface is graded
- Reflectivity expected to be better than ~10^{-7}

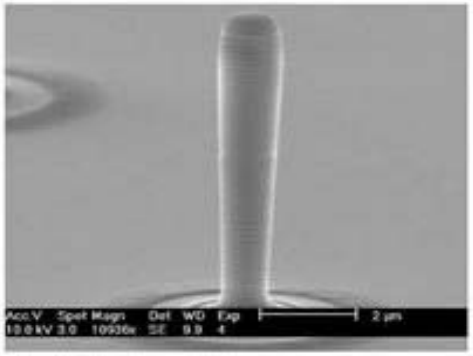
GaN LEDs

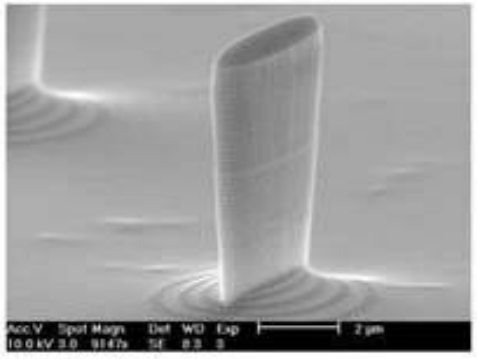
UV-LED grown on AlN buffer layer

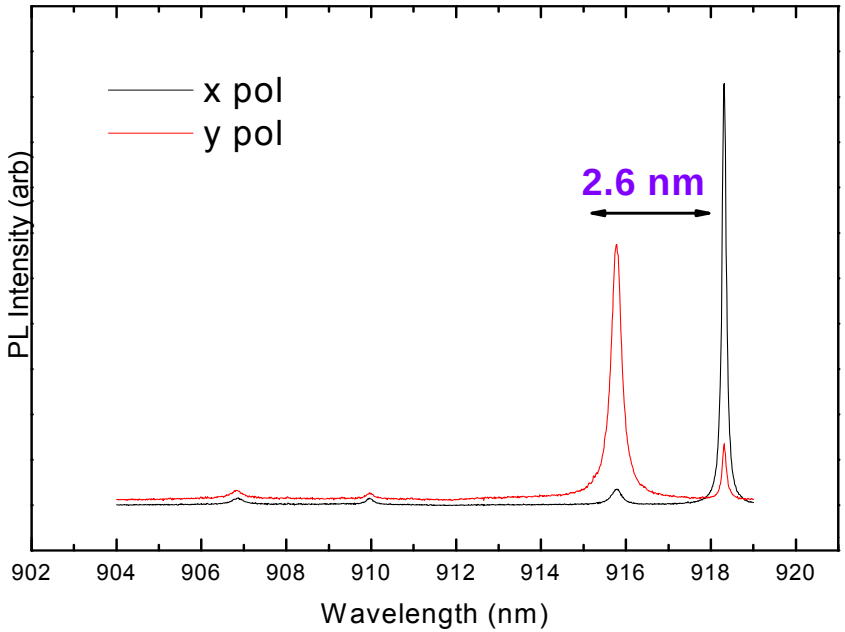
Devices produced by ICP etching of GaN followed by thermal evaporation of contact metals.

UV-LED grown on AlN

Single Photon Emitter – Polarization Control

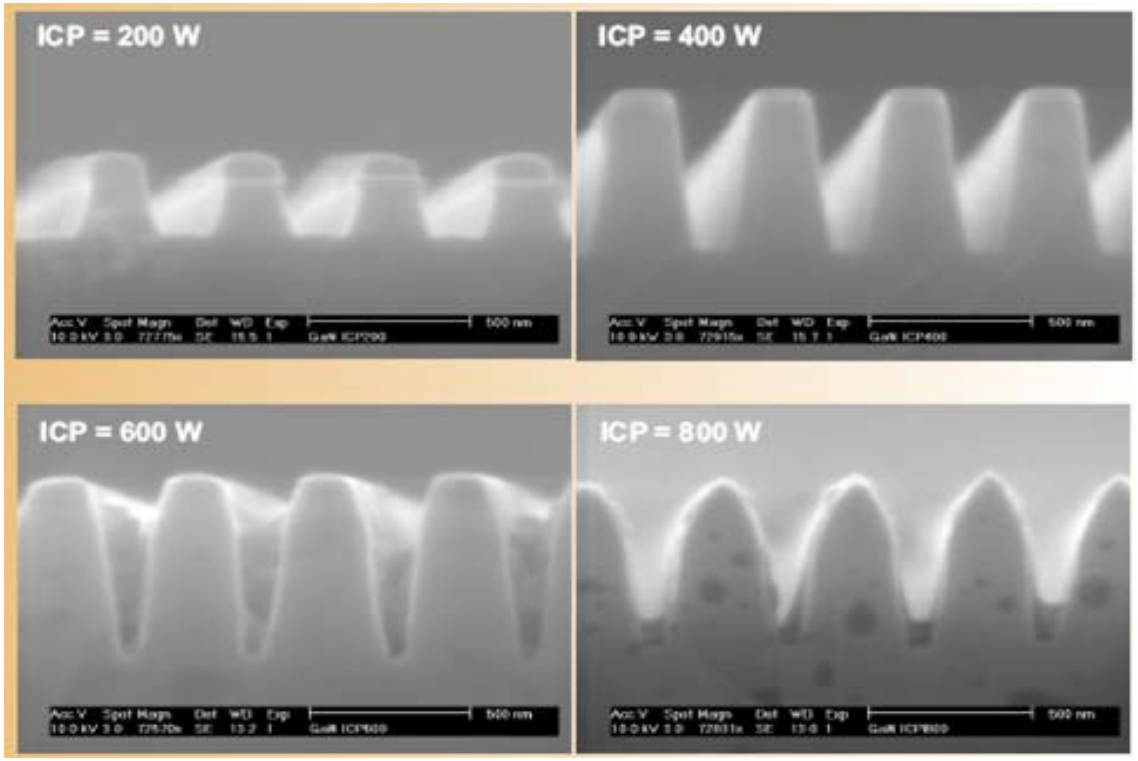






- High Finesse Micropillars
- Control of polarization by elliptical pillar shape

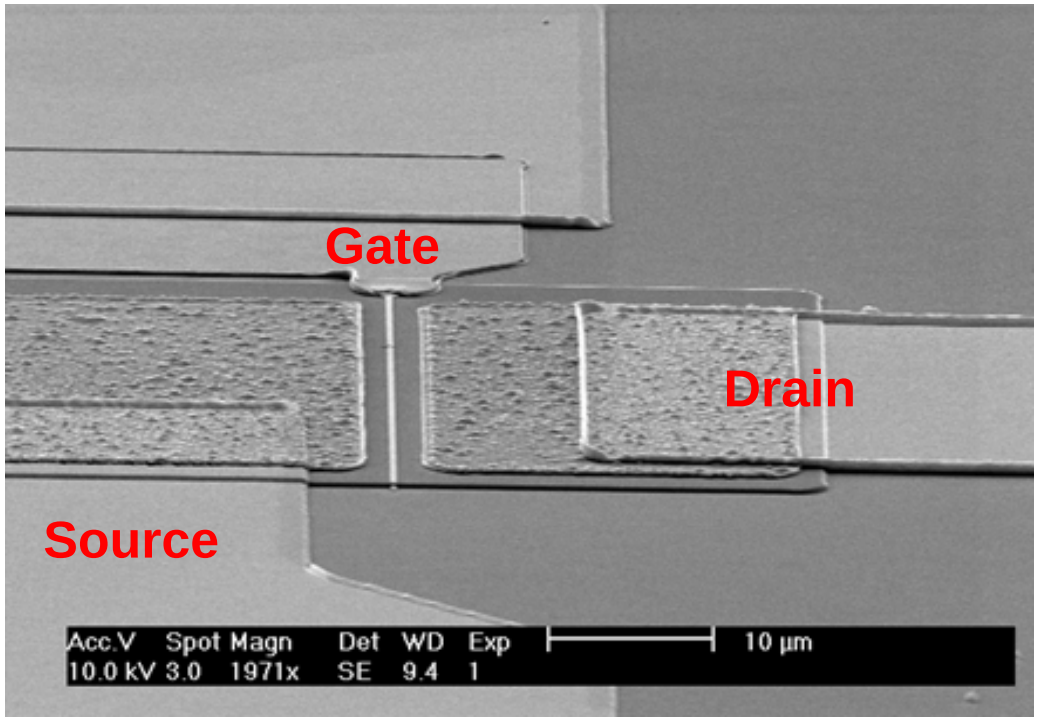
GaN Opto-Couplers

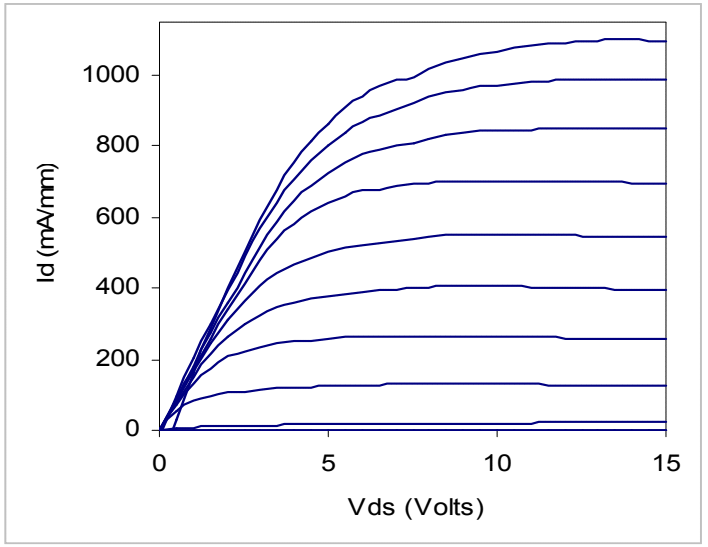


E-beam lithography and ICP etch study using $SiCl_4/Cl_2/Ar$

First realization of grating couplers in GaN planar waveguides

Short Gate GaN HEMTS





$I_{d\text{-}max}$ = 1100 mA/mm, G_m = 153 mS/mm. Operation up to 500 °C

Equipment & Processes

OPT ICP380 Inductively Coupled Plasma Etcher

The ICP Etcher can etch GaAs, InP,
GaN and GaSb based semiconducting materials. Etch rates above 1um/min can be achieved in GaN. It is also fitted with an Intellevation laser endpoint detection system so that etch depth can be measured in real time to determine the etch endpoint. The system can also be used for etching dielectrics such as SiN_x and SiO_2.

Equipment & Processes

Raith150 e-beam lithography system

The Raith150 system can achieve feature sizes of below 20nm over a 6” wafer by use of its laser interferometer stage. Stitching errors between adjacent fields are below 20nm.

Equipment & Processes

SEM, EDAX & EBIC for material & device characterisation and inspection

The Philips XL30 FEGSEM is fitted with a standard secondary electron detector, backscattered detector, EDAX Phoenix energy dispersive X-ray analysis system and specimen current amplifier for EBIC measurements.

Equipment & Processes

PECVD & RTA

The PECVD system is used for depositing films of silicon nitride and silicon dioxide, as well as deposition of dielectric mirror stacks of alternating layers of silicon nitride and silicon dioxide.

The RTA system is used for rapid thermal annealling of ohmic contacts at temperatures from 320C up to 900C, as well as for quantum well disordering of multi-quantum well and quantum dot structures to modify the material band-gap.

Equipment & Processes

Scribe/Break

- New Loomis System
- Excellent quality facets
- Accurate bar length (+/- 0.5µm)
- Individual die

Equipment & Processes

Die Bonding

Cammax ED B80

-Industry standard Au/Sn ‘dry’ soldering

-‘Epi-down’ bonding of lasers (improved heat sinking/performance).

Equipment & Processes

Fibre Alignment

- Two-fibre alignment system

Summary and Next Steps

Presented standard structures and current capabilities for Device Fabrication within the EPSRC National Centre for III-V Technologies

We welcome discussion on development projects with a view to future grant submission

Please contact any of the listed people to discuss any requirements you have

Device Fabrication -People

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