LEHIGH UNIVERSITY

Center for Optical Technologies

Multiple Wavelengths Control Using Quantum Well Intermixing

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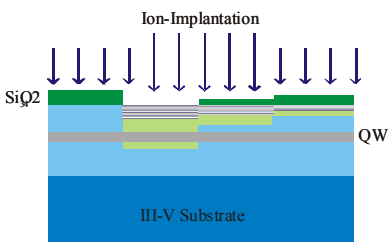
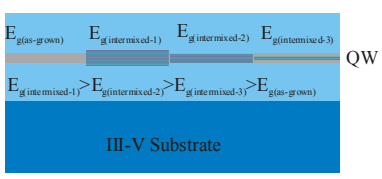
OBJECTIVE

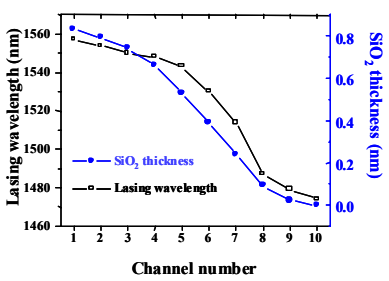
- To develop simple and versatile postgrowth multiple-bandgap engineering processes for III-V photonic integration

PROCESS STEP

- Gray mask lithography
- Equal rate dry etching using CF_4/O_2 mixture
- Phosphorous implantation: $1x10^{14}cm^{-2}$, 360 KeV, 200 °C
- High temperature annealing using RTP at 700 °C, 120 s.

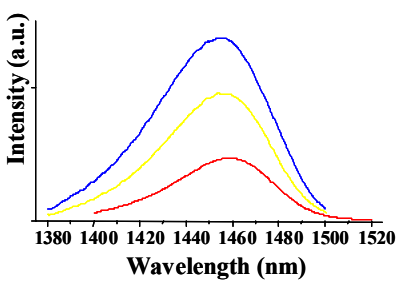






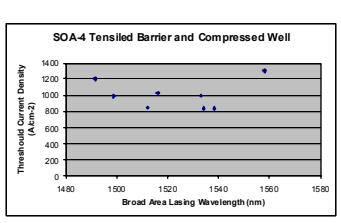
Multiple-wavelength laser chip fabricated in lattice matched InGaAs-InGaAsP structure

- 17% increase in J_{th}, from 1.2 kA/cm² (ch-1) to 1.4 kA/cm² (ch-10)
- Insignificant change in slope efficiency

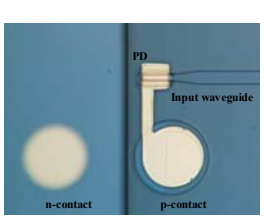


Superluminescence Diodes with electroluminescence spectrum broaden using graded bandgap QWI

- Peak λ = 1454 nm, FWHM = 60 nm, coherent length = 35.24 µm



Bandgap tuned lasers fabricated tensilely strained InGaAs/InGaAsP QW structutre



Integrated Waveguide PD

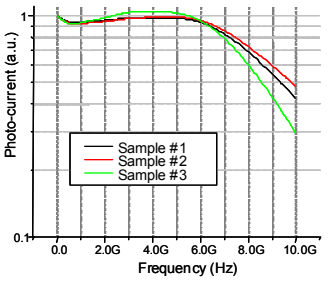
- BW = 2.5GHz, R = 0.63A/W,
- Dark current = 5nA@(-2V), TE/TM=<0.4dB

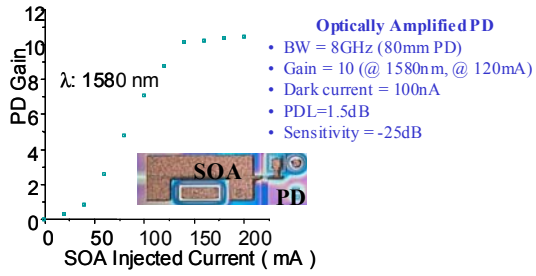
PROCESS CAPABILITY

- Wavegudie and laser qualities (from 100 meV intermixed materials)
  - Passive waveguide loss of ~4 dB/cm
  - Threshold current change <20%
- Resolution & bandgap selectivity
  - Spatial resolution ~2 µm for typical laser structure
  - Differential wavelength shift (active and passive) ~120nm
- QW design dependency & optical property control
  - Effective on both lattice matched & strained QW structures
  - TE/TM different <10% increase for 100nm shifted sample
  - Multiple & graded bandgaps tuning capability
- Lifetime (100nm bandgap tuned InGaAs/InGaAsP lasers)
  - Insignificant change in laser properties for > 5K hours at 85 °C, $2xI_{th}$.

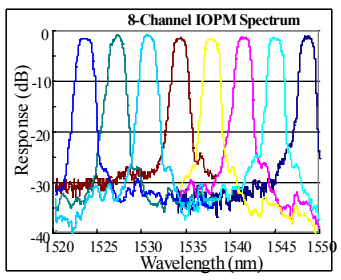
SELECTED INTEGRATED DEVICES

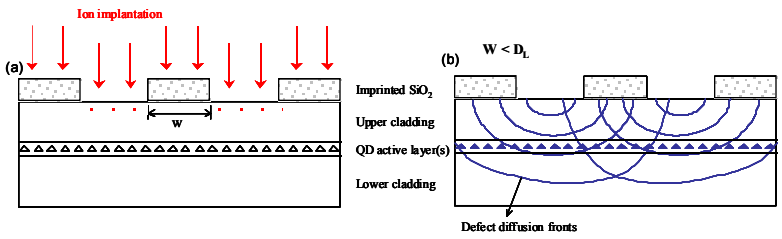
- Optically Amplified Photodetector
  - Monolithic integration of SOA, passive waveguide and PD.
  - Total device length <500 µm
- Integrated 8-Channel Optical Spectrometer
  - Monolithic integration of tapered waveguide, Echelle grating and PD array
  - Total die size of <2x1 mm²
  - Dark current = 17nA, R ~ 0.03mA/mW/chn, SNR < -25dB.



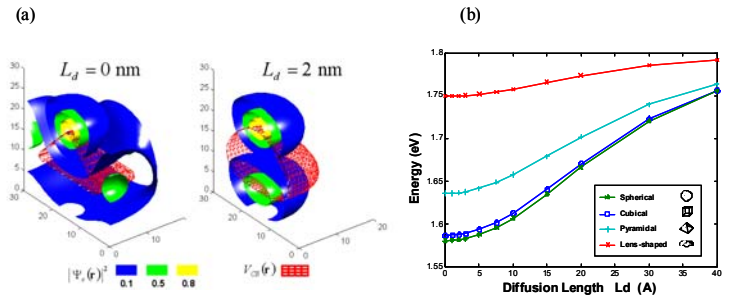


8-Channel Optical Performance Monitor





Process Concept: High mobility point defects result in uniform intermixing if the dimension of the imprinted masked is smaller than the diffusion length of the defects.



3-D excited state wave function and the ground state transition energy as function of diffusion length for interdiffused quantum dot

CURRENT PROJECTS

- Quantum Dots Intermixing using Nano-Imprinted Diffusion Mask
  - Technology:
    - Dot array template fabricated using double Fresnel bimirror holography & dry etching
    - Nano-imprint on sol-gel derived SiO_2 material
    - Low energy implantation and annealing to induce intermixing
- Simulation Tool for Interdiffused Quantum Well and Quantum Dots
- Device Development
  - Broadband light source for biosensors and gyro
  - Multiple-channel quantum dot infrared photodetector for high resolution thermal imaging and bio-agents sensing.
  - Broadband, high efficiency solar cells