

Dense Wavelength Division Multiplexing Technologies for Local Access Networks

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Low-Cost Dense Wavelength Division Multiplexing Technologies for Local Access Networks

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Objective:

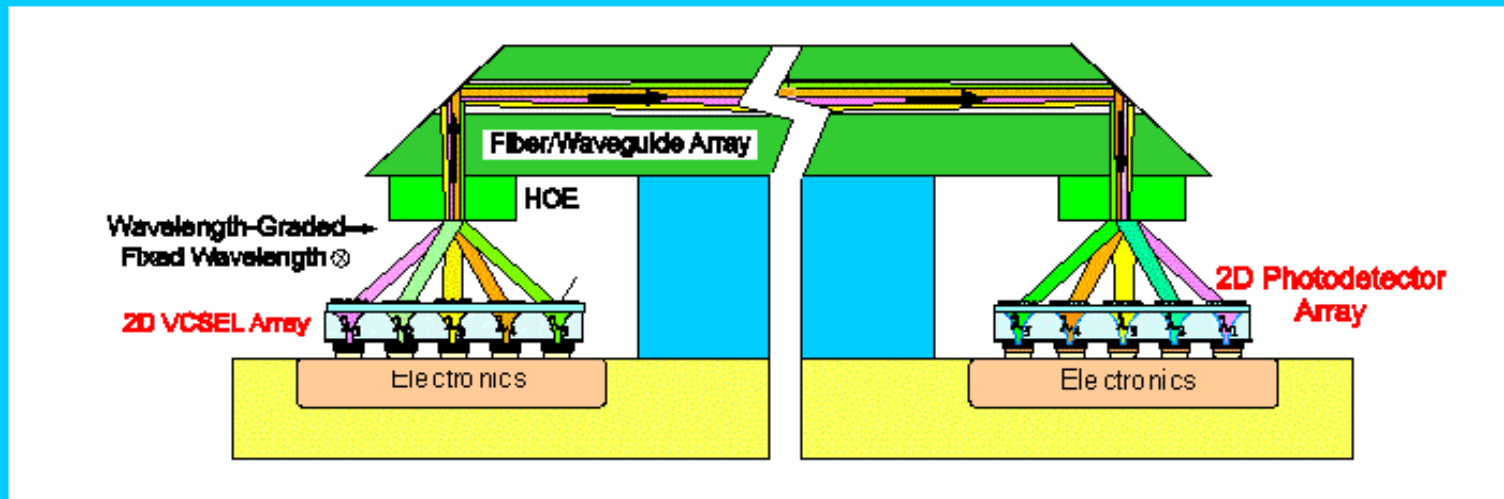
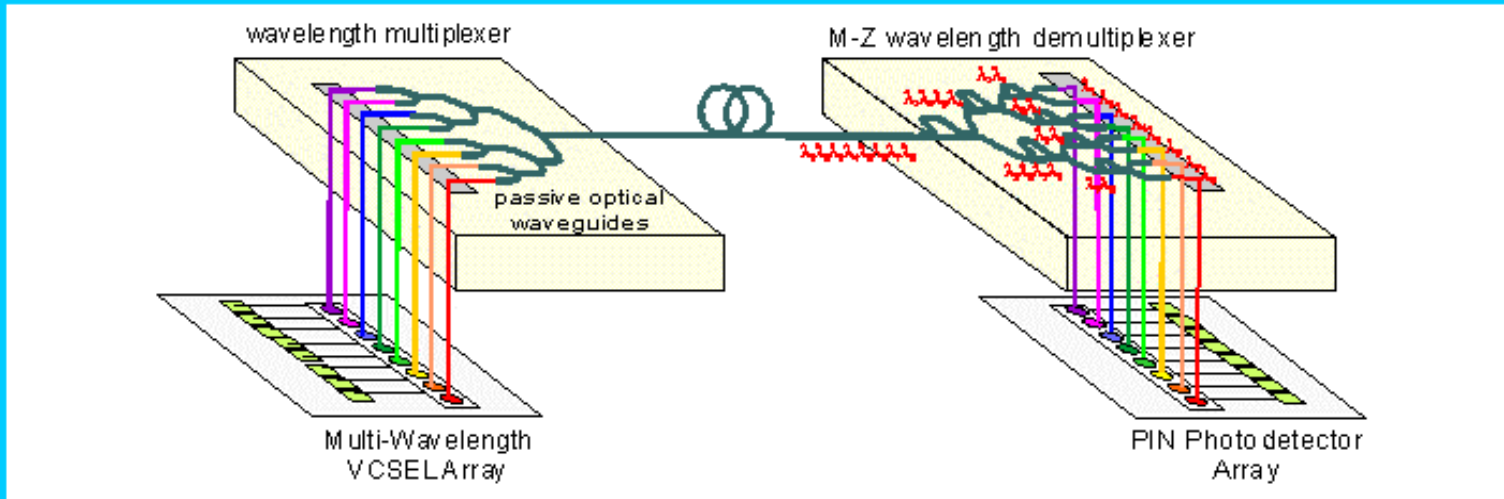
Develop a low-cost, monolithic dense WDM technology for multi-Gb/s LANs consisting of multi-wavelength VCSEL arrays (1x16) with local wavelength regulation, and an add-drop multiplexer technology for wavelength selection.

Approaches and Goals:

- develop a quasi-planar single-growth technique for achieving multi-wavelength VCSEL and REPD arrays
- demonstrate local wavelength tuning to regulate the wavelengths of individual VCSELs
- demonstrate multi-channel WDM transmission at >2.5 Gb/s/channel
- achieve a 16 channel WDM VCSEL array with a channel spacing of ~ 2 -3 nm (40 Gb/s aggregate throughput)
- monolithic ADM technology for wavelength selection



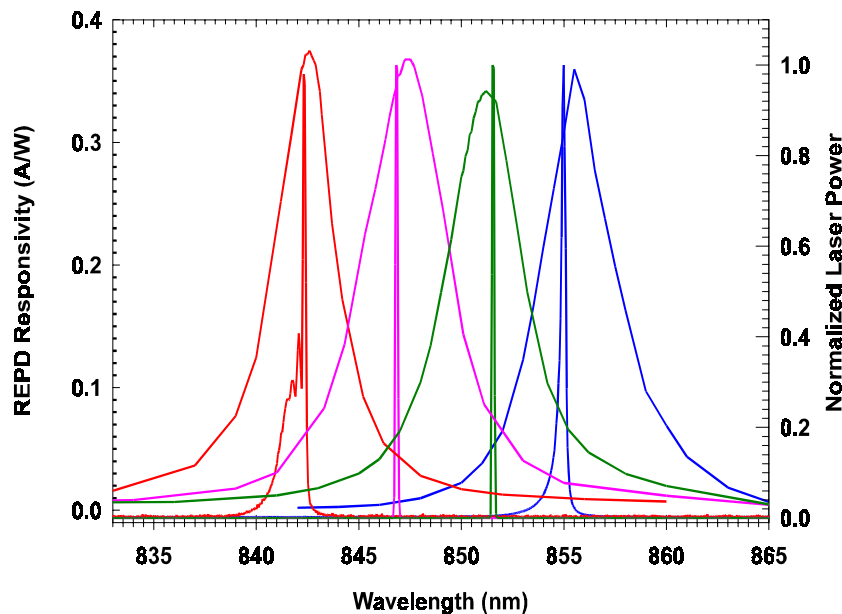
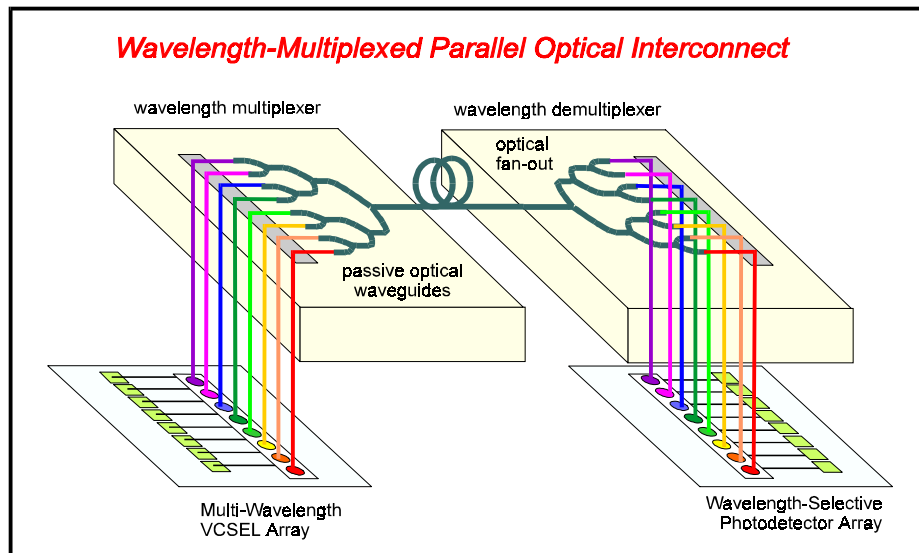
**Wavelength-Multiplexed Parallel Optical Interconnect
using Multiple Wavelength VCSEL Arrays and a Passive Demultiplexer**



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Wavelength Division Multiplexing using Monolithic Wavelength-Graded VCSEL and Resonance Enhanced Photodetector Arrays



- Multiple wavelength channels can be multiplexed together using a wavelength-graded VCSEL array
- Data is demultiplexed using wavelength-selective resonance-enhanced photodetectors
- Monolithic VCSEL and REPD arrays with matching wavelengths have been achieved

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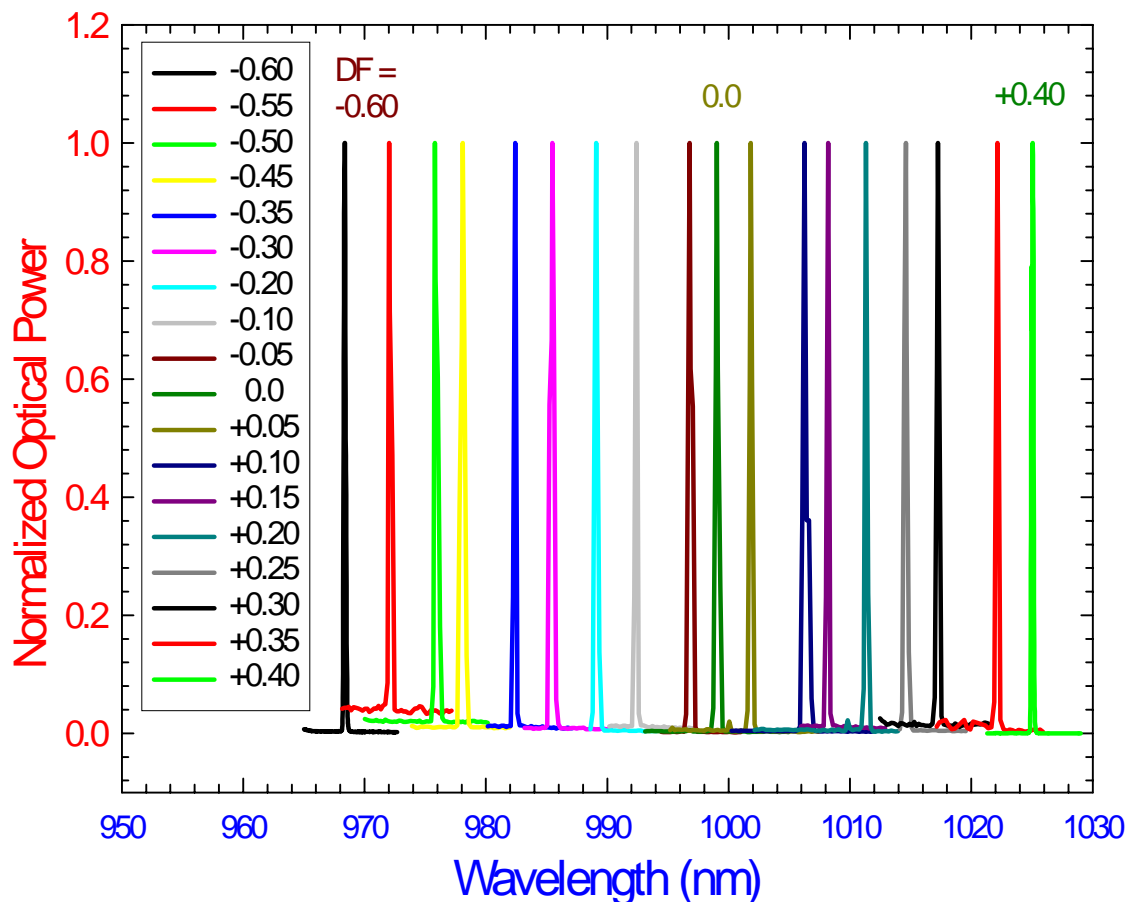
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Monolithic, Oxide-Confined, Multiple-Wavelength VCSEL Arrays with a 57-nm Wavelength Grading Range

Summary

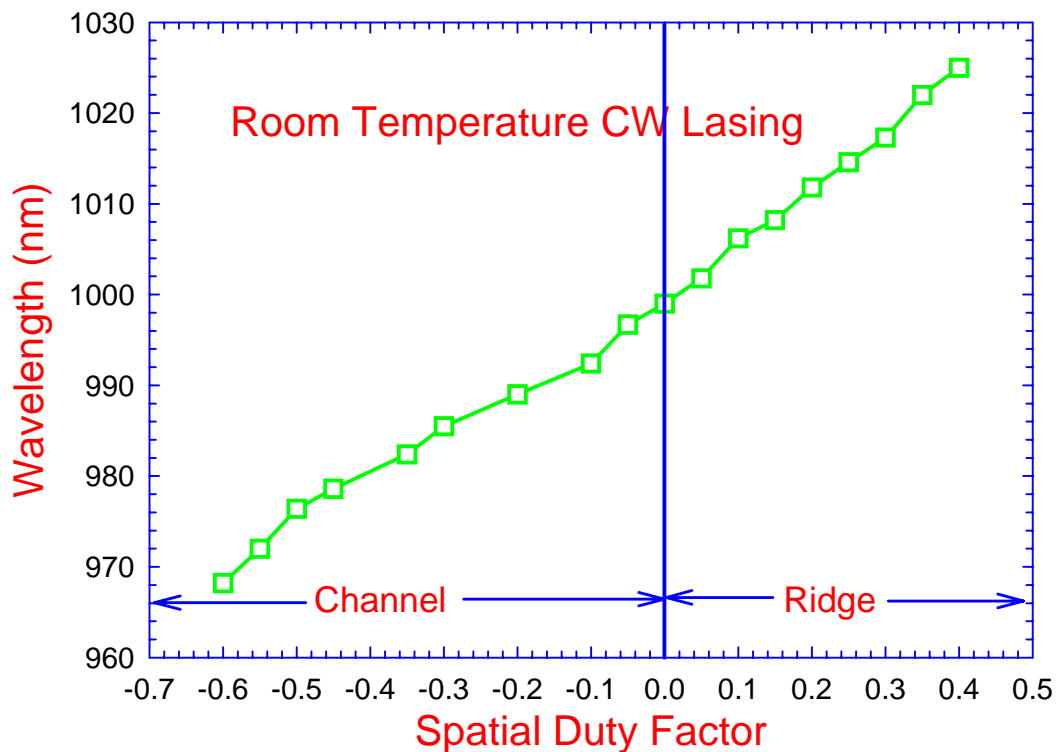
- **Monolithic, multiple-wavelength, oxide-confined VCSEL arrays with a large periodic wavelength grading span of 57 nm (968 nm to 1025 nm) have been achieved under room temperature, CW lasing operation.**
- **Nearly linear wavelength grading is achieved with even spacing (~3 nm) by using MOCVD growth on a patterned substrate.**
- **An extended wavelength range is achieved by:**
 - (1) scaling the growth rate of all the epilayers to minimize optical loss dispersion,**
 - (2) using a selectively-oxidized upper DBR mirror with a flattened optical reflectance spectrum**

The Normalized Room-Temperature CW Lasing Spectra of a Monolithic, Wavelength-Graded VCSEL Array with a 16 μm Oxide Aperture



- The single-mode cw lasing spectra are almost evenly spaced over a 57 nm wavelength range (968 -1025 nm)

Room-Temperature CW Lasing Wavelength for Individual Elements of a Monolithic Wavelength-Graded VCSEL Array as a Function of the Spatial Duty Factor



- The spatial duty factor:
 $DF = \pm(1-w/p)$
- w = width of channel (-)
or ridge (+)
 $p = 250 \mu\text{m}$ pitch
- linear array of VCSEL's
each with a $16 \mu\text{m}$
oxide aperture
- room temperature CW
lasing operation with a
wavelength grading
span of 57 nm

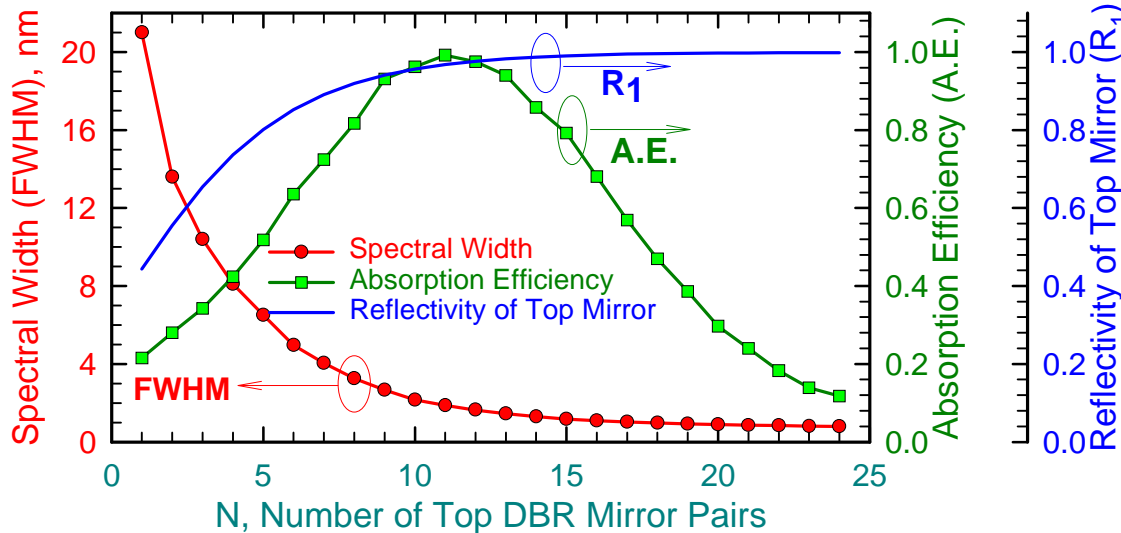
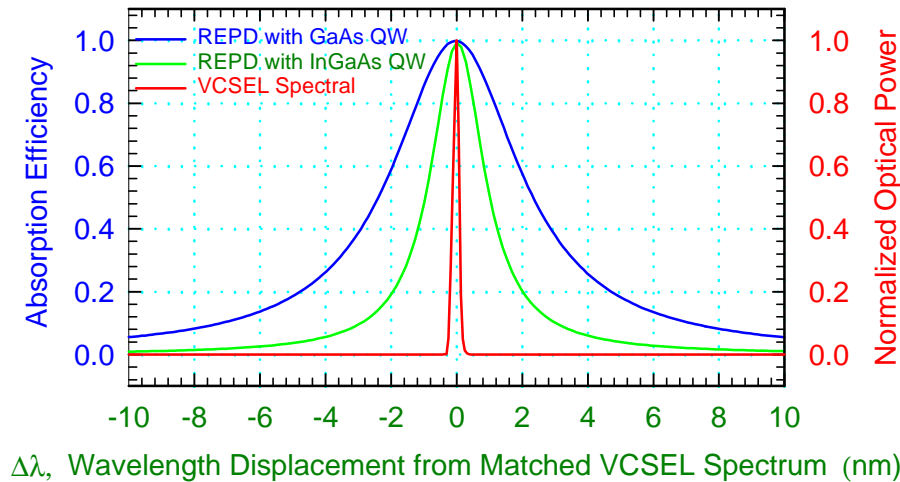
Monolithic Integration of the VCSEL and the Resonance Enhanced Photodetector on the Same Epilayer Structure for Closer Wavelength Matching

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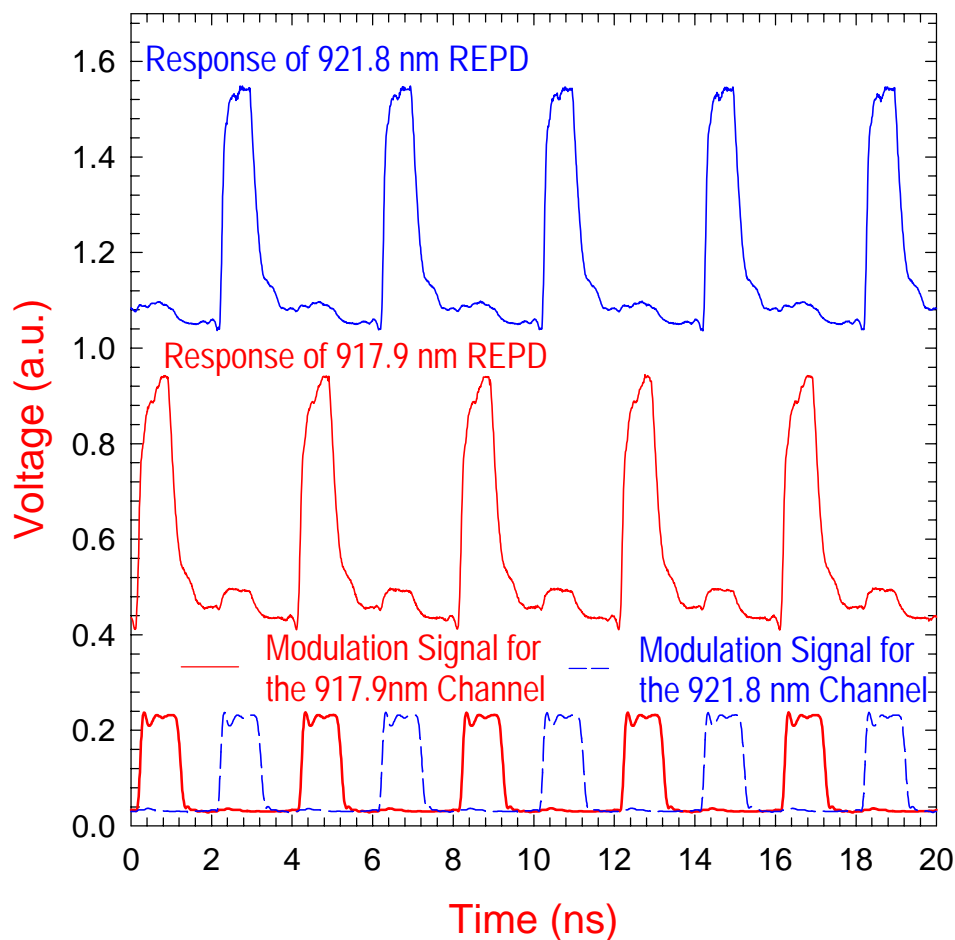
- The REPD shares the same resonance cavity with the VCSEL, and thus has a closely matched resonance wavelength
- REPD's are obtained by removing an optimum number of DBR pairs from the upper mirror of the VCSEL
- VCSEL and REPD performance are individually optimized

Advantages of InGaAs MQW's over GaAs MQW's:

- Improved wavelength selectivity (lower optical crosstalk, higher channel density)
- More optimum trade-off between absorption efficiency and wavelength selectivity (more uniform REPD arrays).



Wavelength Demultiplexing of Two High Speed Modulated Data Channels Using REPD's with a 4 nm Resonance Wavelength Separation



- Two wavelength multiplexed channels with a 4 nm spacing
- Each channel is modulated by 500 Mb/s RZ, 1 ns wide pulses
- Demultiplexing is achieved using REPD's, with an ac crosstalk level of ~ -10 dB

Transmission Performance of a 2-Channel WDM Link with a 4 nm Wavelength Separation at 1 Gb/s per Channel, Showing the Effect of Optical Crosstalk

Upper inset: eye diagram @ BER=10⁻¹¹

Lower inset: emission spectra of VCSELs and responsivity of REPDs

