



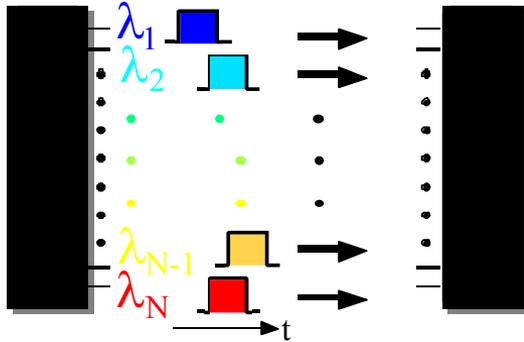
Components for Interconnection and Switching

- **Applications**
 - **Clock Distribution**
Harris/Miller/Horowitz
 - **Wavelength Routing/Time Slot Interchange**
Harris/Fejer/Willner
 - **Reconfigurable Interconnects**
Jain
- **Material Systems**
 - **Microstructured III-V semiconductors**
Harris/Miller/Fejer
 - **Photosensitive/Poled glass**
Jain



Interconnect and Switching Functions

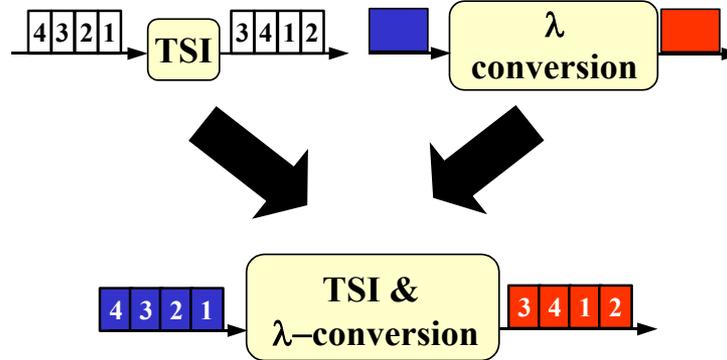
Random turn-on delays



Reduce
turn-on delays
@ transmitter

Recover and
synchronize
@ receiver

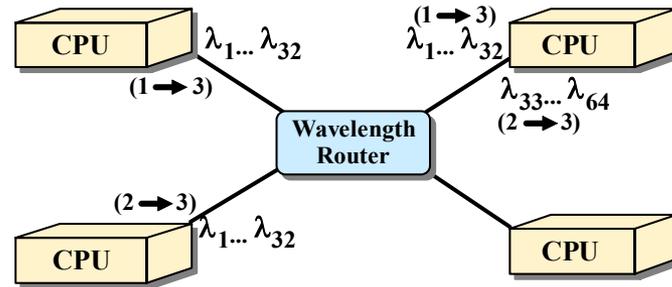
Synchronization



Time Slot Interchange

Approved for public release, distribution unlimited

Contention Resolution



Shifting blocks of λ 's to a
new λ -regime ($\lambda_{33} \dots \lambda_{64}$)

Contention Resolution



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Optoelectronic
Interconnects

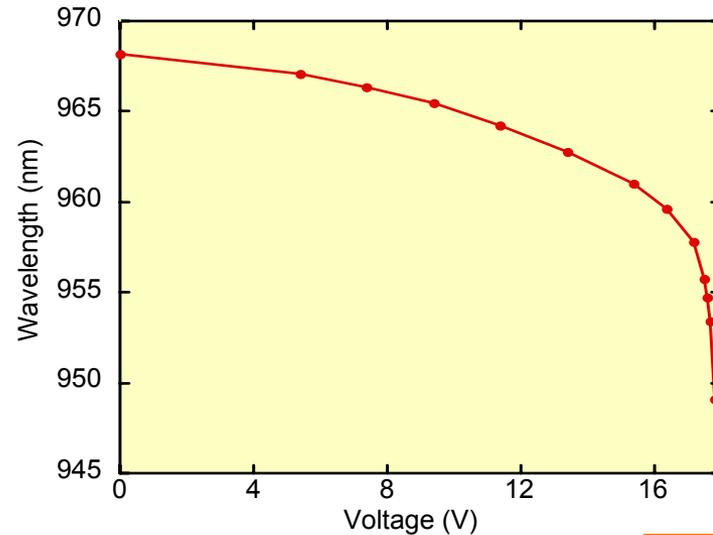
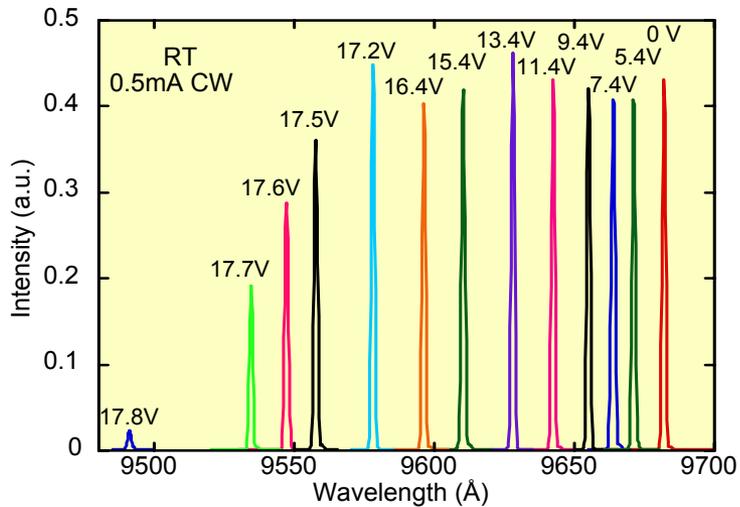
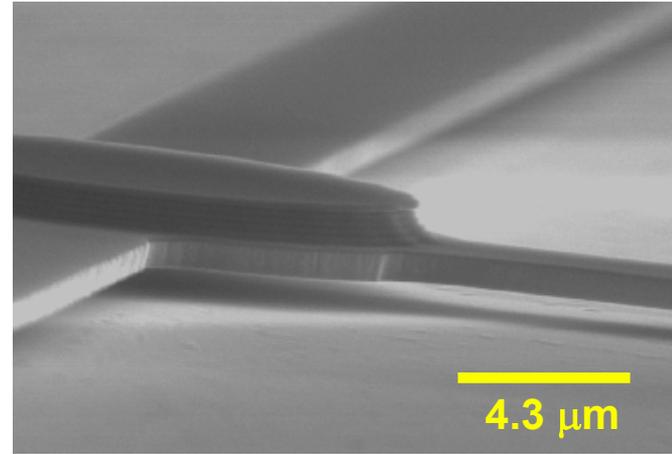
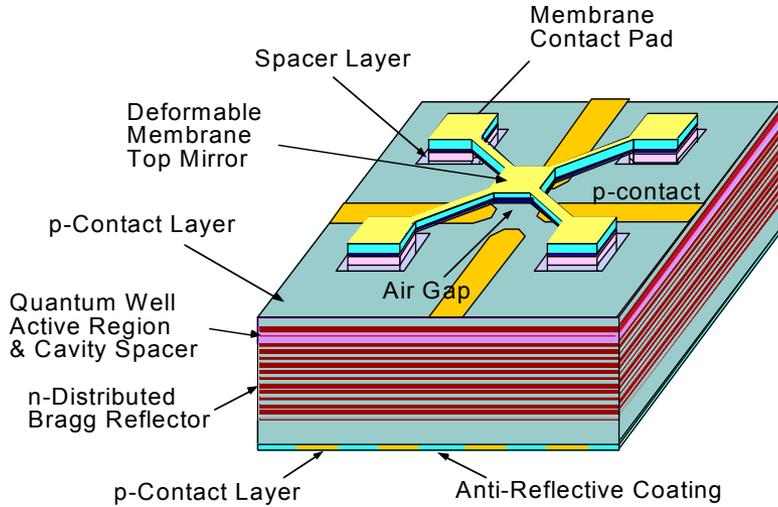
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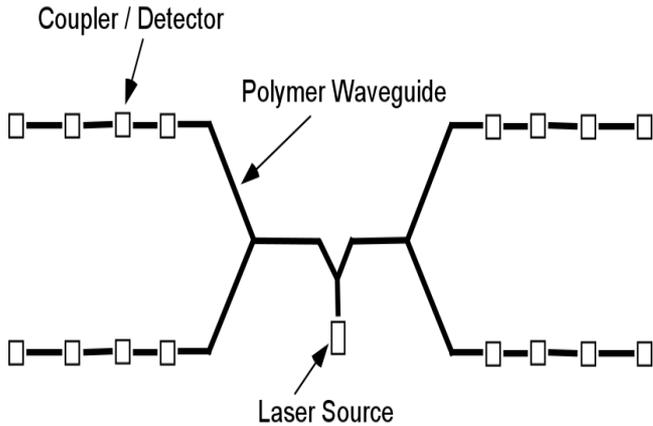
Tunable Micromachined VCSELs



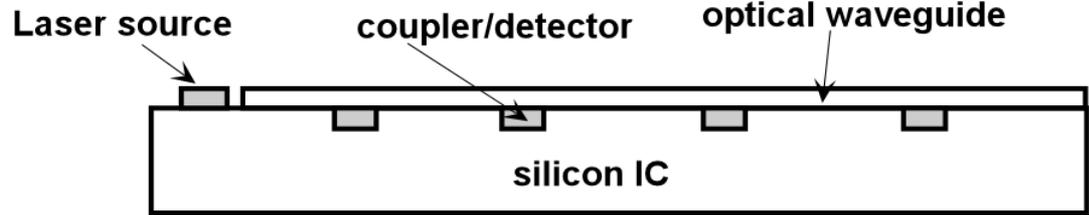


Waveguide Approach to Optical Clock Distribution

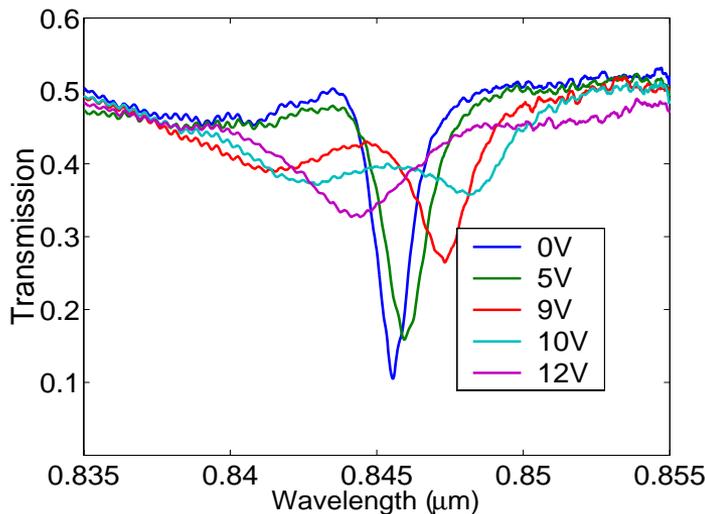
Optical Clock Distribution



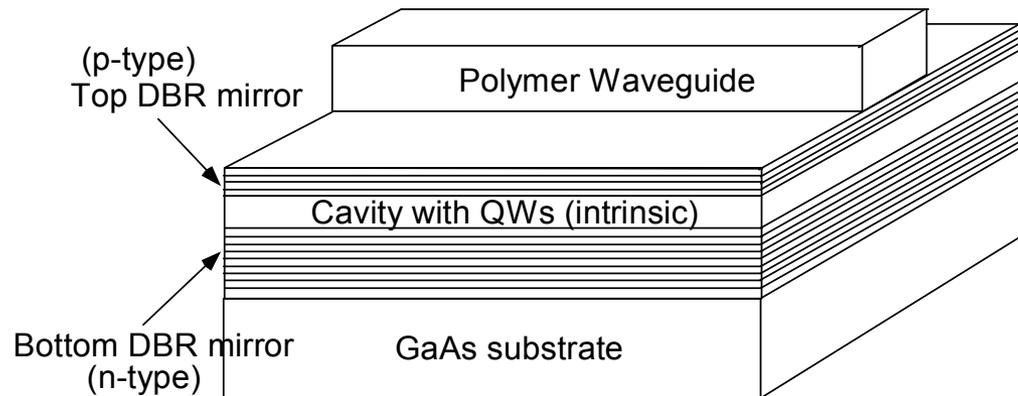
Waveguide Clock Distribution



Coupled Fiber QW Modulator

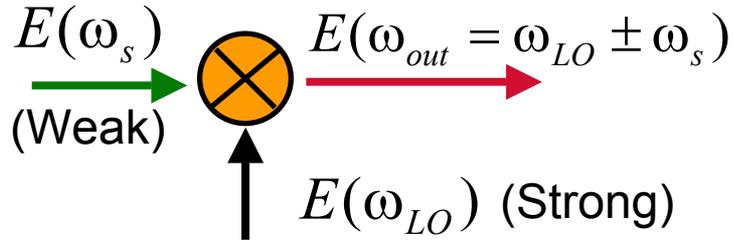


Proposed ARROW QW Source



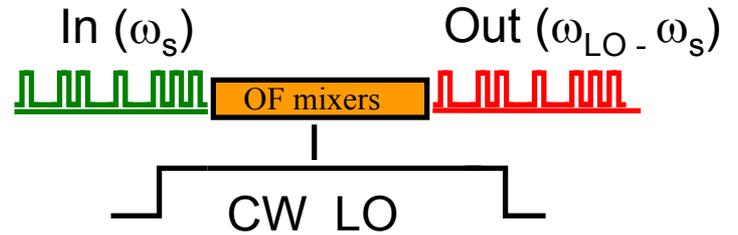
Frequency Mixers

Radio Frequency

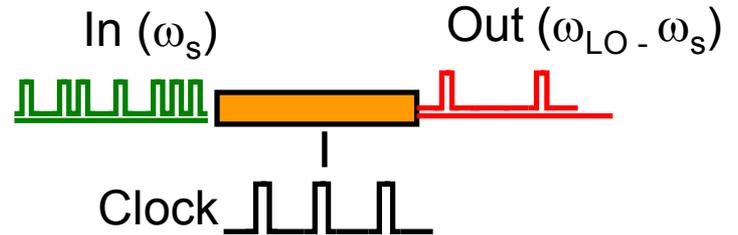


Optical Frequency

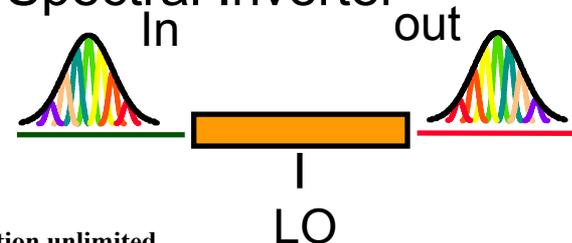
(1) Wavelength Converter



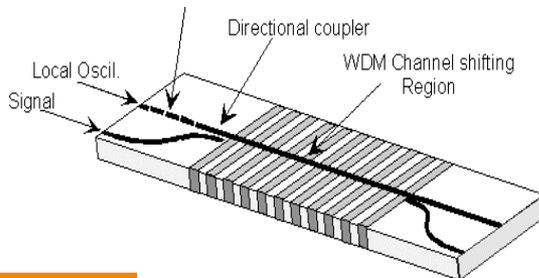
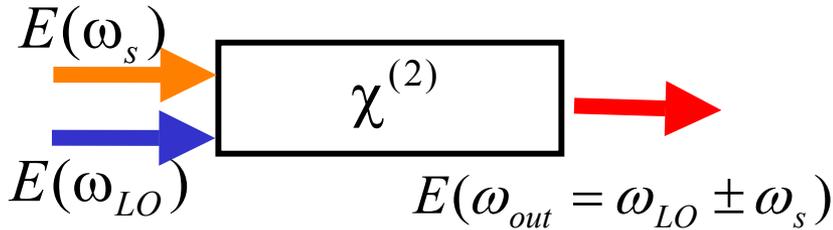
(2) Optical Gated Mixer



(3) Spectral Inverter

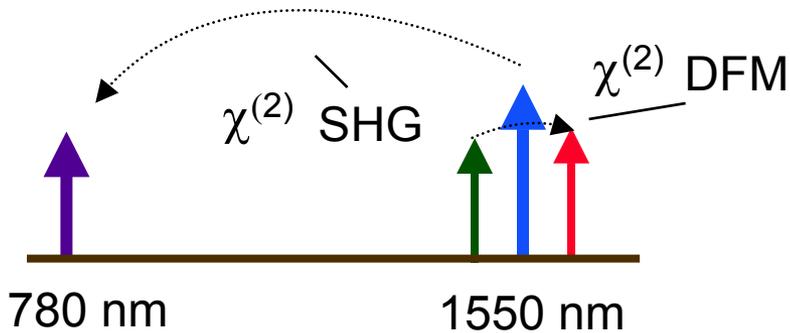
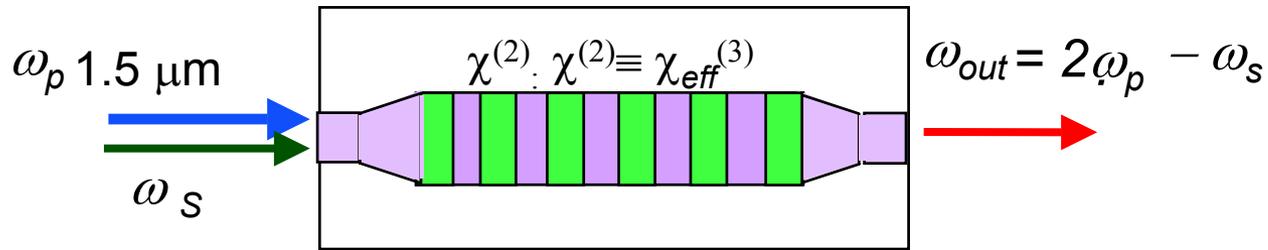


Nonlinear Optical Material





1.5 μm band λ -conversion by $\chi^{(2)}$; $\chi^{(2)}$



Same " $\chi^{(3)}$ " as





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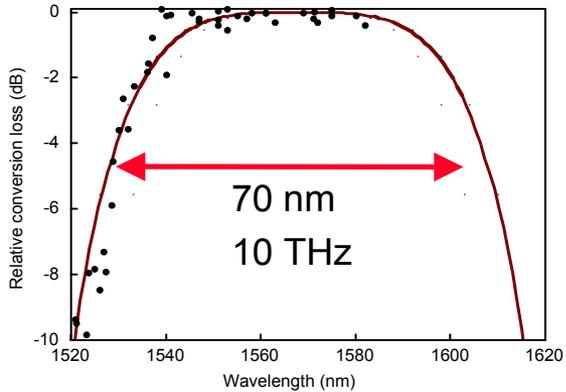


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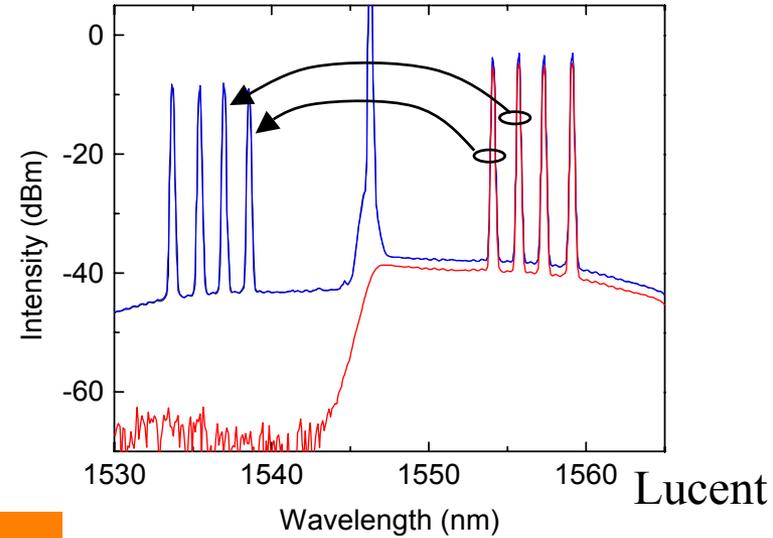


Optical Mixing Functions

Broad Bandwidth

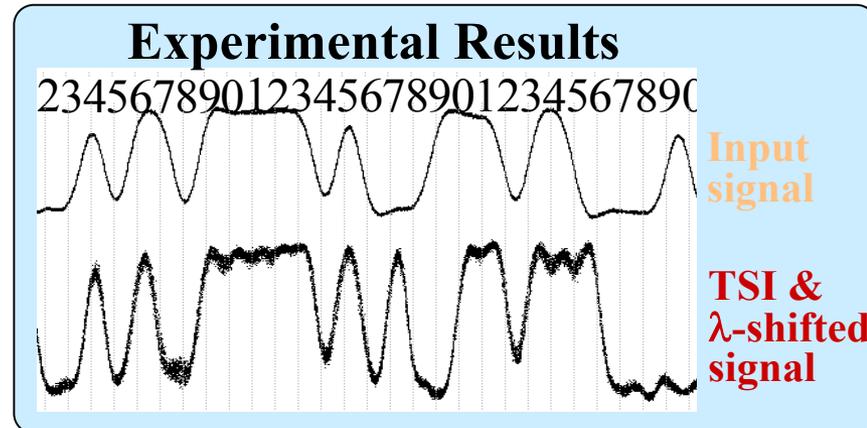
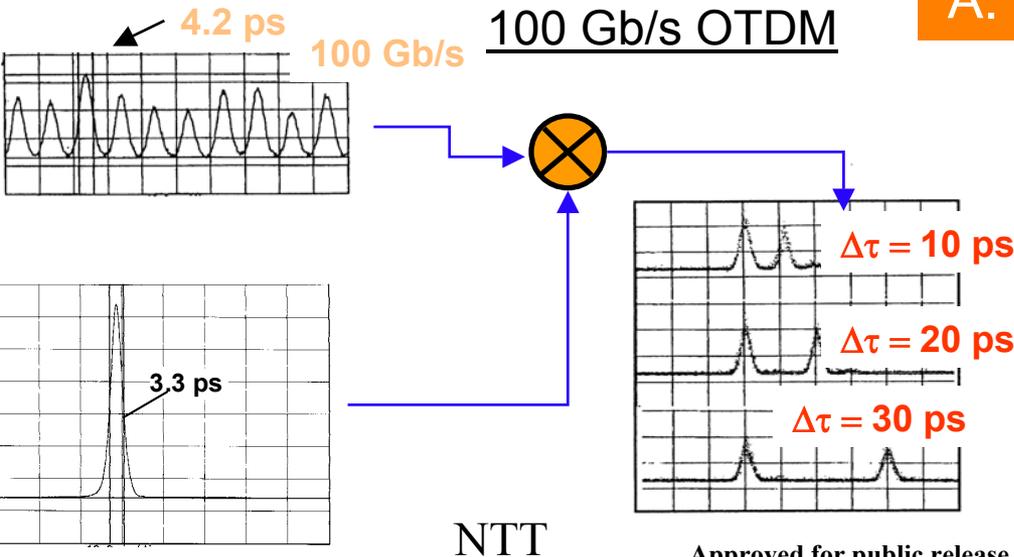


Multichannel Conversion



M. Fejer
A. Willner

Time Slot Interchange





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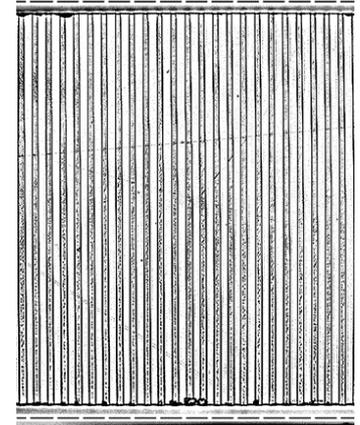


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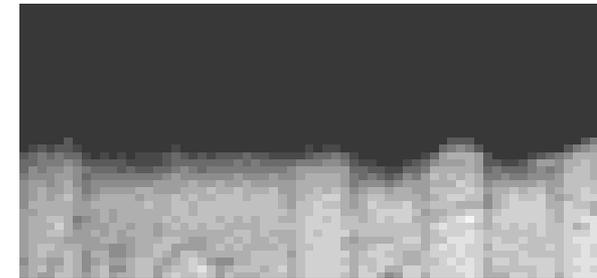
Orientation-Patterned GaAs

- **Current Technology: Periodically-poled lithium niobate**
suitable for system demonstration

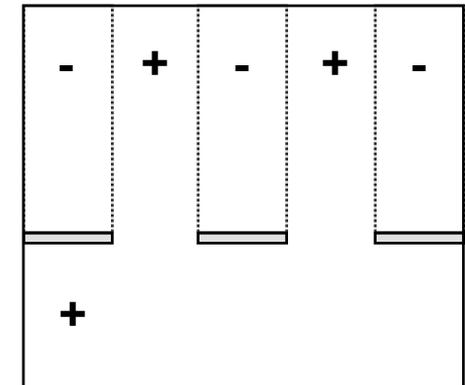
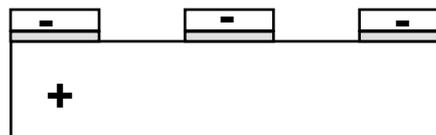


- **Under development: Orientation-patterned AlGaAs on Ge/GaAs**
new type of epitaxial patterning
requires lattice matched nonpolar layer (Ge)
lithographic patterning of 90° twins around [100]
higher efficiency
larger $\chi^{(2)}$
tighter confinement
more integrable

M. Fejer
J. Harris

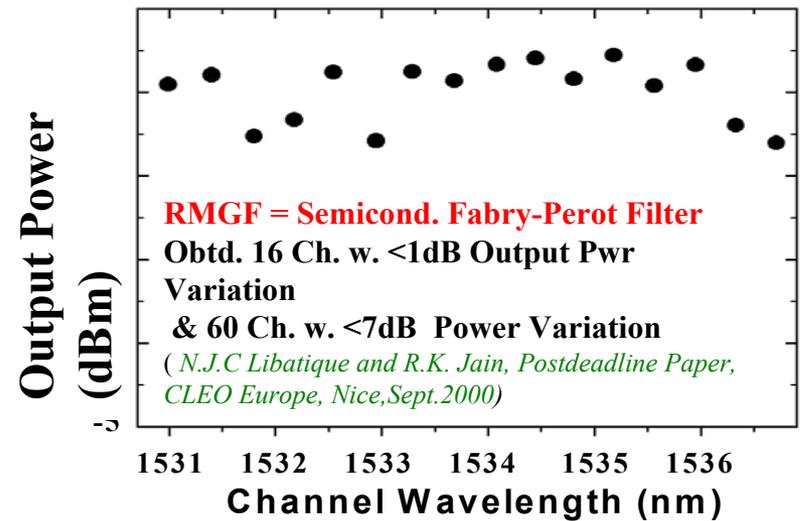
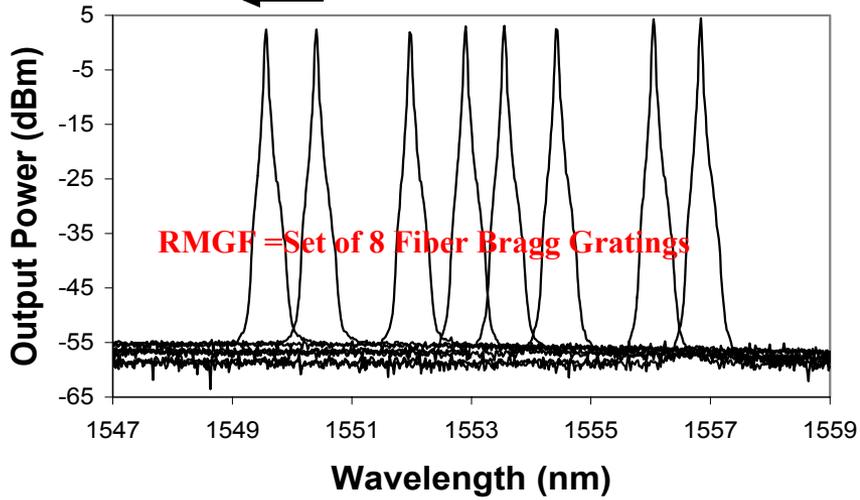
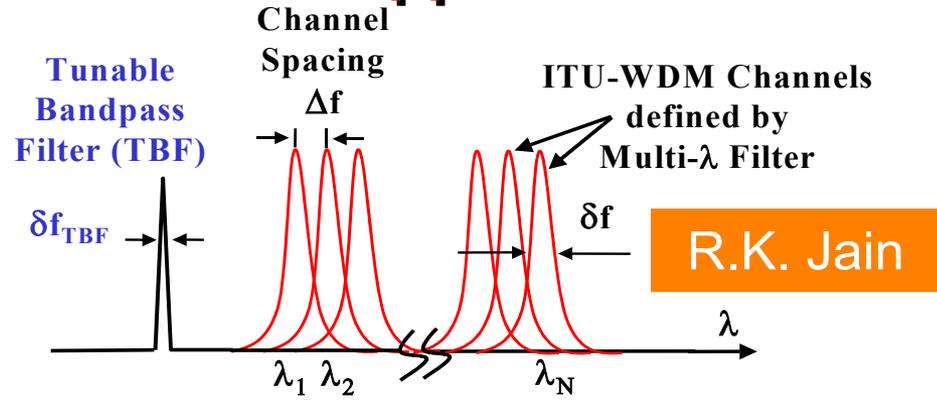
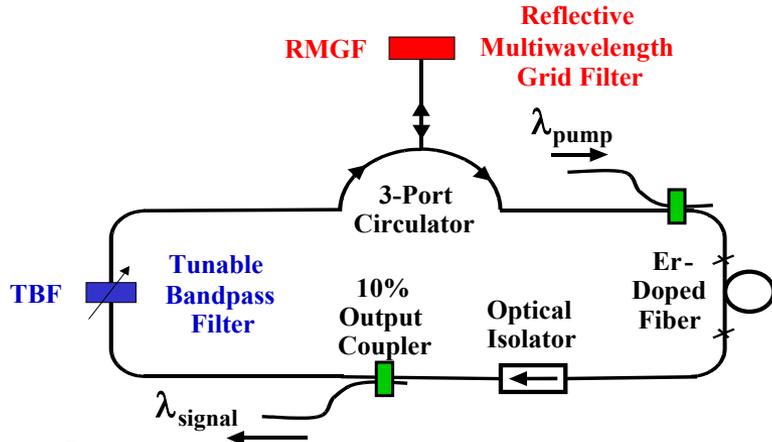


- **Possible future direction: GaP on Si**



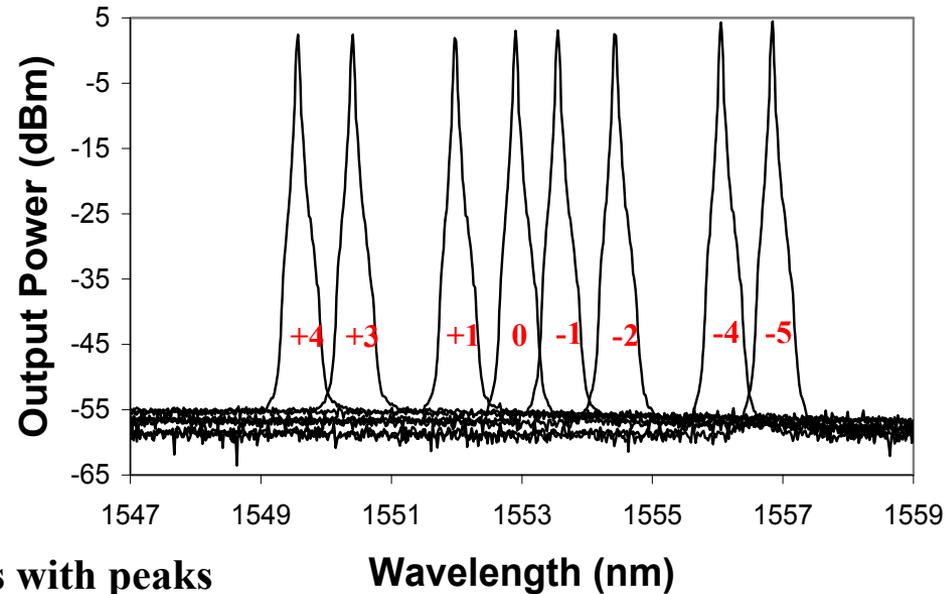
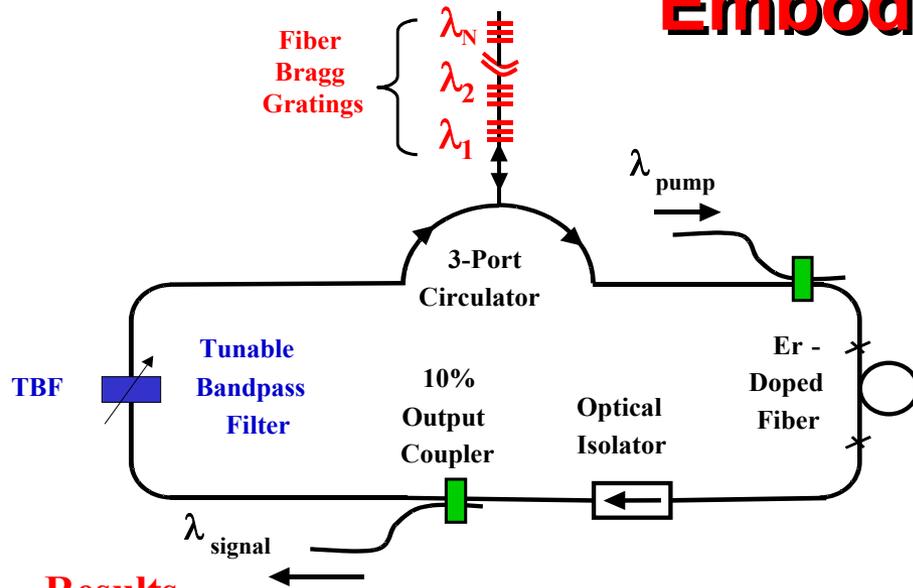


λ-Selectable Sources for WDM Applications



- Demonstrated interchannel switching times of 25 μs with the use of an FFP (Fiber Fabry-Perot) as the tunable bandpass filter (*N.J.C. Libatique & R.K. Jain, IEEE Photon. Techn. Lett., vol. 11, #12, 1584-1586, 1999*)
- Typical SMSRs (side mode suppression ratio) ~ 35 dB, and spectral stability ~ 1 GHz
- ➔ Applications include sources for λ-reconfigurable opt. networks & for WDM component testing

Embodiment No. 1



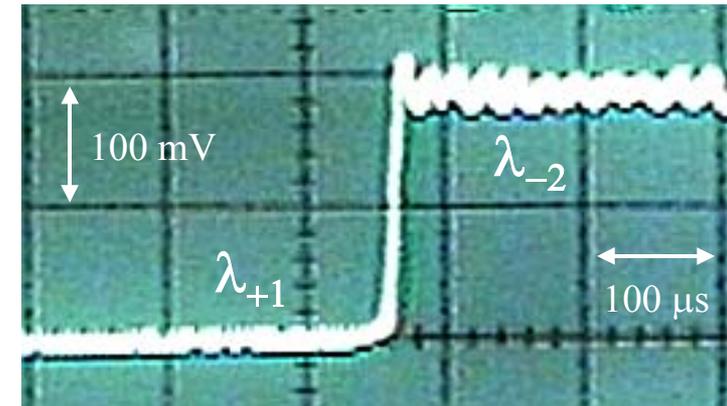
Results

- Switchable- λ emission defined by discrete FBGs with peaks at eight ITU channels (+4, +3, .., -5)
- 10's of μ s switching (i.e. 25 μ s between channel +1 & -2)
- Output powers from 2 dBm (1.6 mW) to 4.5 dBm (2.8 mW)
- Side mode suppression ratios: 55 dB to 60 dB
- Spectral stabilities \sim 1 GHz (8 pm)

R.K. Jain

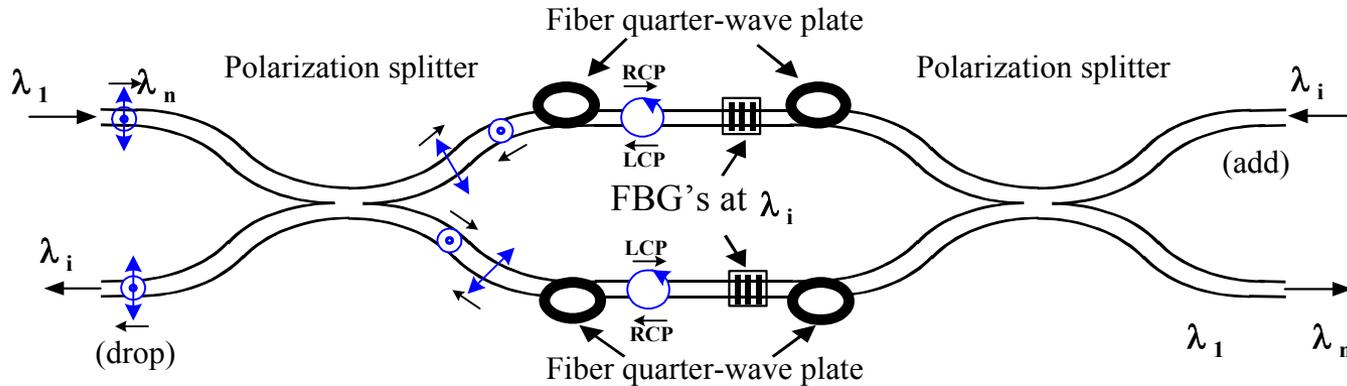
Future Work

- Use sampled FBGs, closed-loop control for more precise locking & stabilization, athermal FBG packaging
- Look at methods for chip-scale implementation (i.e. WBGs for FBGs, glass waveguides for fibers)

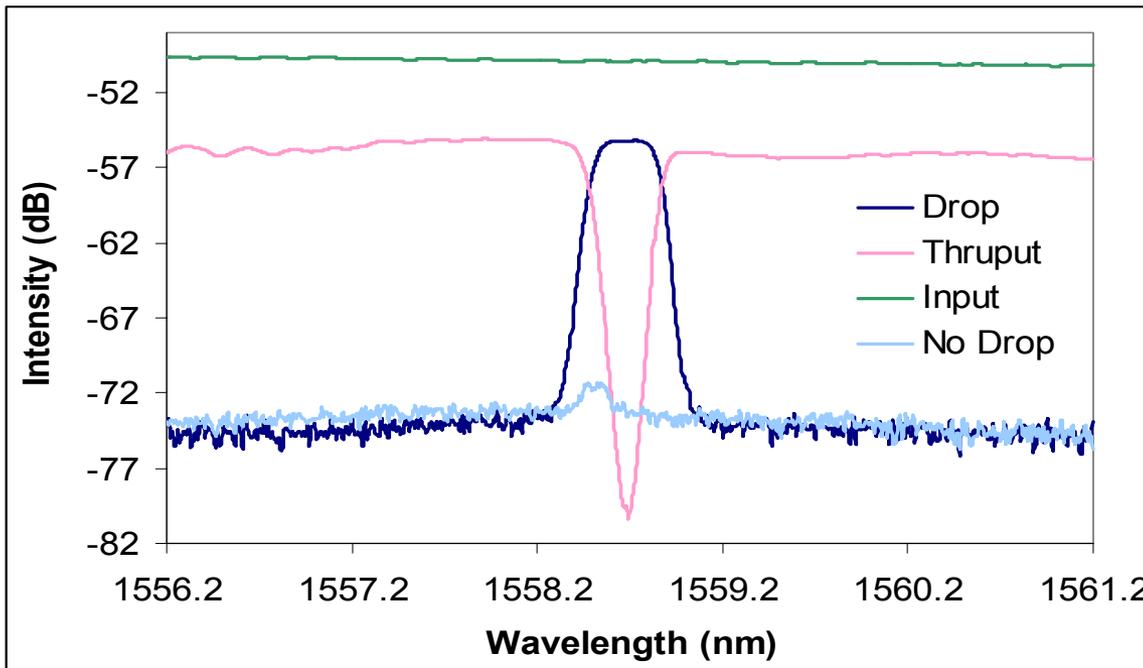


(N.J.C. Libatique & R.K. Jain, IEEE Photon. Techn. Lett., vol. 11, #12, 1584-1586, 1999)

Non-Interferometric All-Fiber Optical Add-Drop Multiplexers



R.K. Jain



- Verified several key performance characteristics of non-interferometric all-fiber reconfigurable OADM's (optical add-drop multiplexers)
 - Crosstalk ~18 dB, limited currently by connector backreflection; thru channel insertion loss ~ 5 dB, limited by high-loss fiber-pigtailed polarization beam splitters used
- ➔ **Future Work: 4 & 8 channel demonstrations, implementation with all fiber waveplates and polarization splitters**



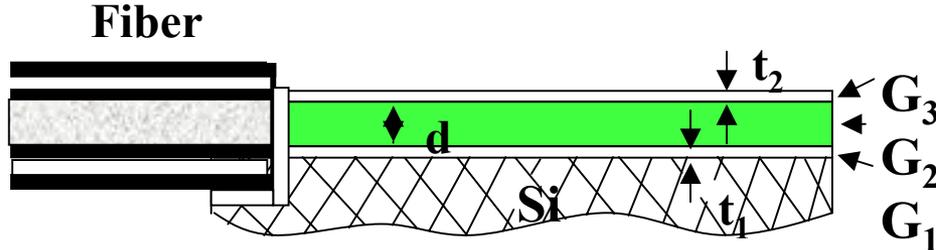
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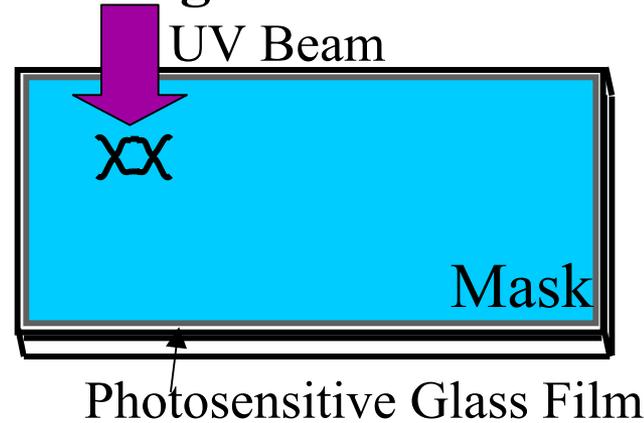
Device Fabrication and Interconnection on P³LCs

P³LC Platform Geometry

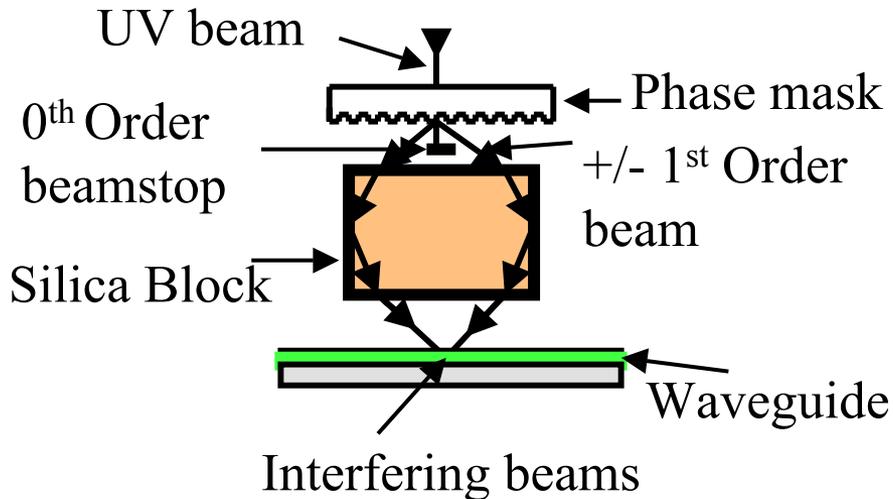


Waveguides may also be RE-doped

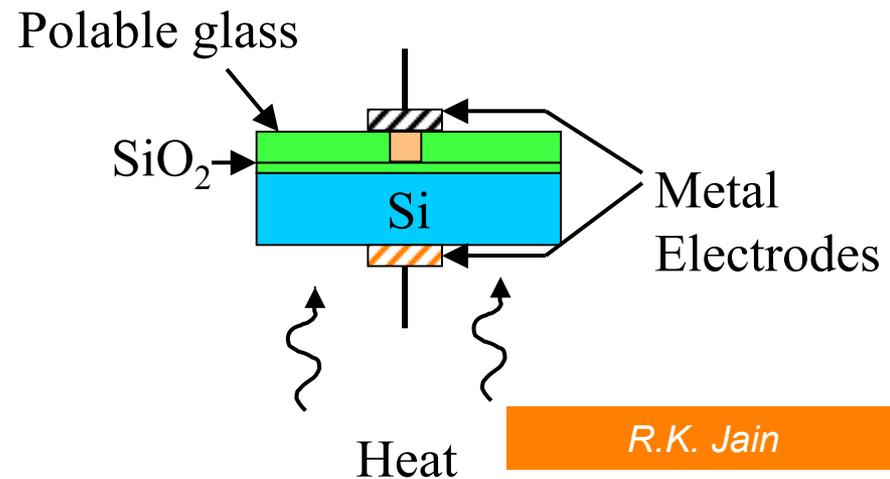
Waveguide Fabrication



WBG Fabrication

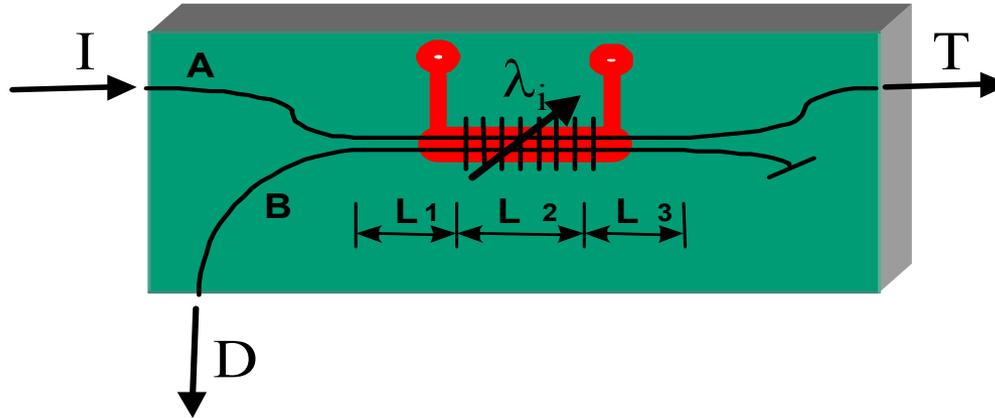


Poling Setup



R.K. Jain

Wavelength-Selective 1X2 Switches on P³LC Platform

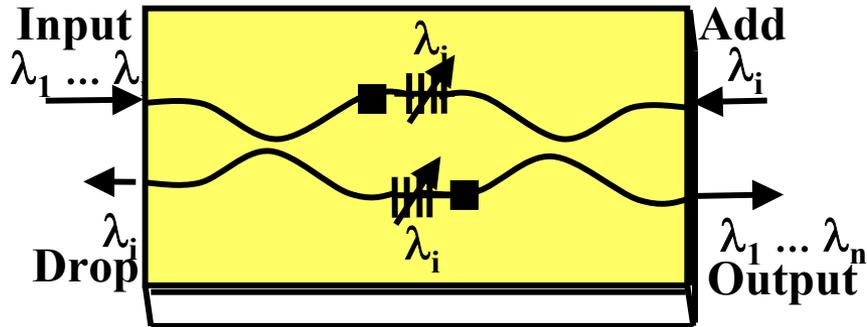


- Waveguide asymmetric coupler* concept
- WBG nominally shifted from resonant wavelength λ_i
- Launched signal input at port I, λ_i exits at through port T
- Dynamic wavelength selectivity provided by thermo-optic (TO) or electro-optic (EO) mechanisms, dropped signal exits at port D
- Source & detector integrated in chip format via TIR coupler

* A.S. Kewitsch et.al., "All-fiber zero-insertion-loss add-drop filter for wavelength-division multiplexing", *Opt. Lett.*, v. 23(#2) pp. 106-108 (1998)

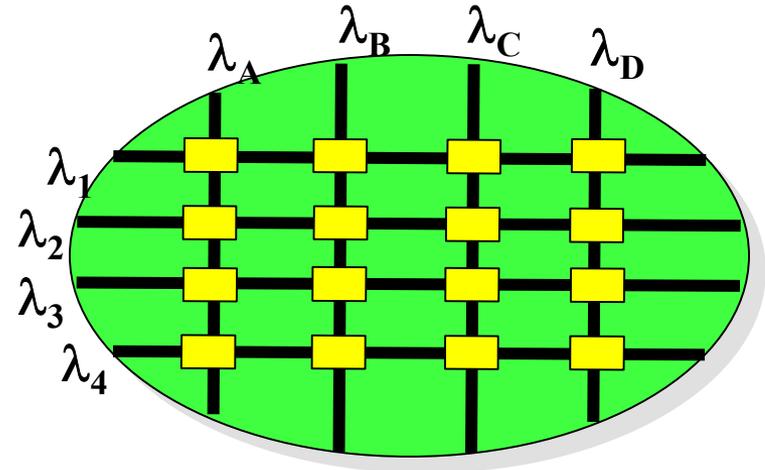
Chip-Scale Optical Information Processing Micro-Systems

(a) Reconfigurable OADM



- Reconfigurable WBGs are written on photosensitive glass and has EO segments for phase-control
- Phase control and tuning of WBGs will also be accomplished with the use of thermo-optic and piezo-electronic stress elements

(b) NxN Reconfigurable Interconnects



- Large number of add-drop channels can be fabricated with just one fabrication sequence
- A key issue is the precise control of the magnitude of the coupling coefficient between the waveguides at the interconnection points

Highly manufacturable modules and systems based on P³LC (*Polable Photosensitive Lightwave Circuit*) technologies!

R.K. Jain