WDM PICs for 100G nR4 using Silicon Photonics

IEEE 802.3 Next Gen 40G & 100G Optical Ethernet Study Group - July 2012 Plenary

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WDM PICS Using Integrated Photonics - Supporters

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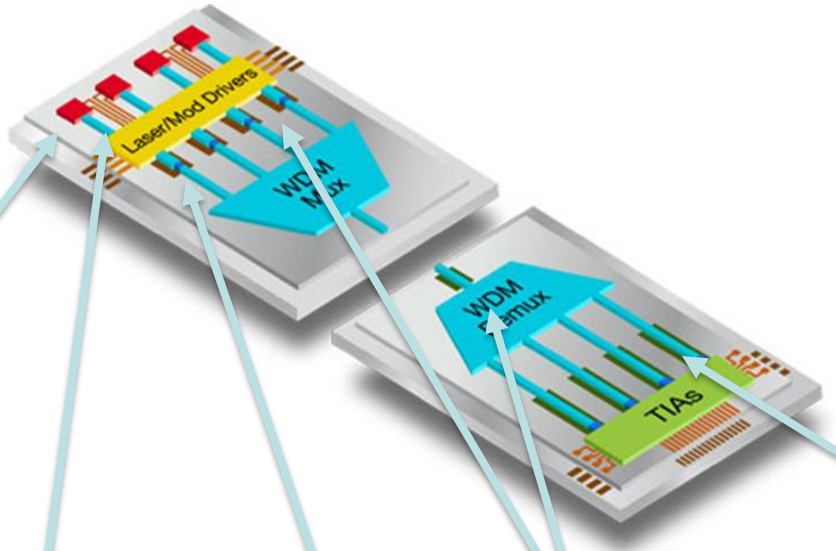
- Stephen Bates, PMC-Sierra
- Atul Sharma, Volex
- Ed Cady, Volex

Motivation for WDM PICs

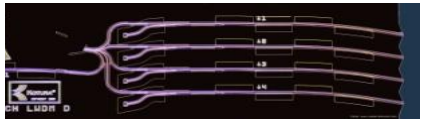
- For the transceiver
  - “Reduction of number of components is key to achieve the lowest cost solution for data center applications” src: anderson_01_1111
- For data center cabling
  - Lowest cabling cost (by far) is 2 fiber SMF, source Cole_01_0512 (Abbott, Cole, Coleman, Kolesar, and Swanson)
- This presentation shows that WDM silicon photonics solutions:
  - Are small enough to fit either QSFP or CFP4 package
  - Achieve a high level of integration to reduce cost
  - Use standard SMF cabling
  - Support multiple channel plans
  - Provide a migration path to 400G and 1 Tb/s

Integration Enables WDM 100G in Two Tiny Chips

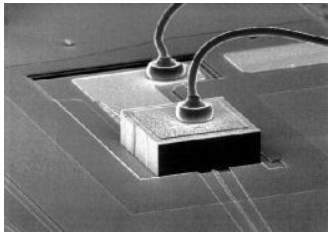
Opto-electronic integration of all components except laser eliminates dozens of piece parts



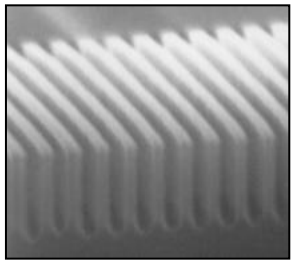
4x25 RX



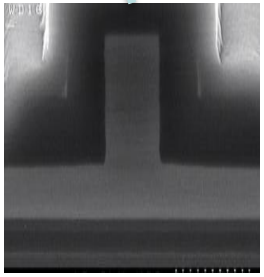
4x25 TX



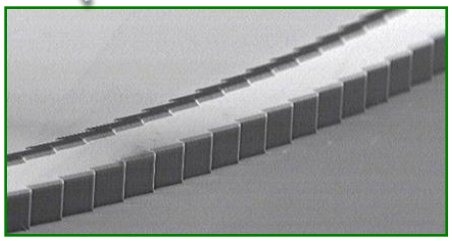
Light source



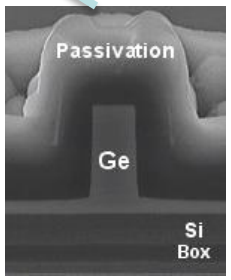
Grating



Modulator



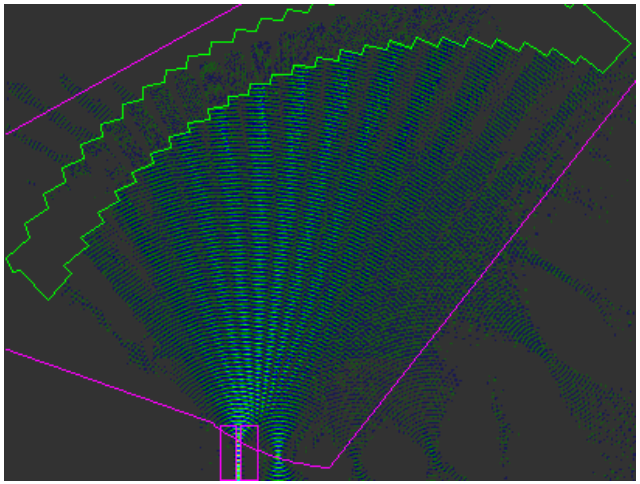
WDM Mux/Demux

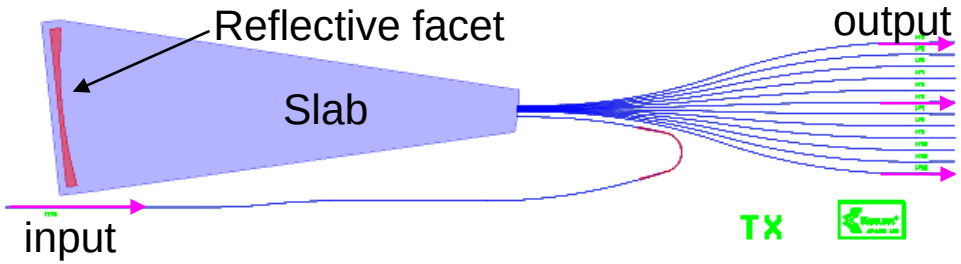


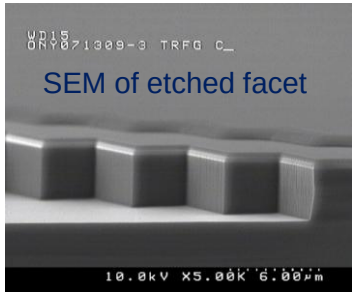
Detectors

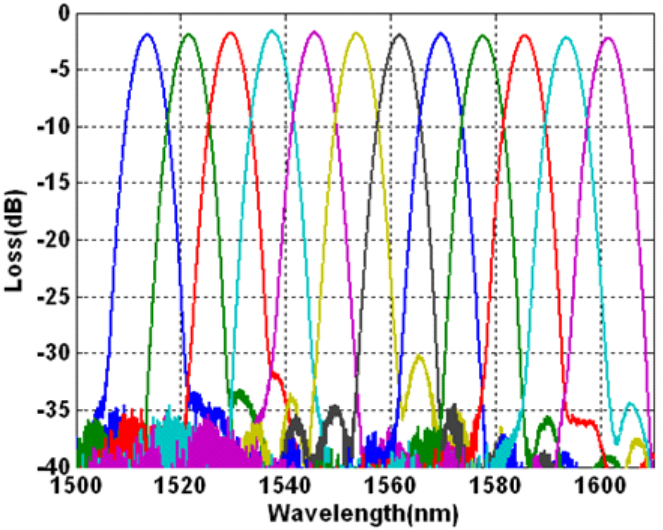
Echelle Gratings as Mux/Demux

- Kotura has invested significantly to develop high performance echelle grating on 3um SOI waveguides
- Echelle gratings can be up to 10x smaller than AWGs
- Better control of wavelength registration and very low cross talk



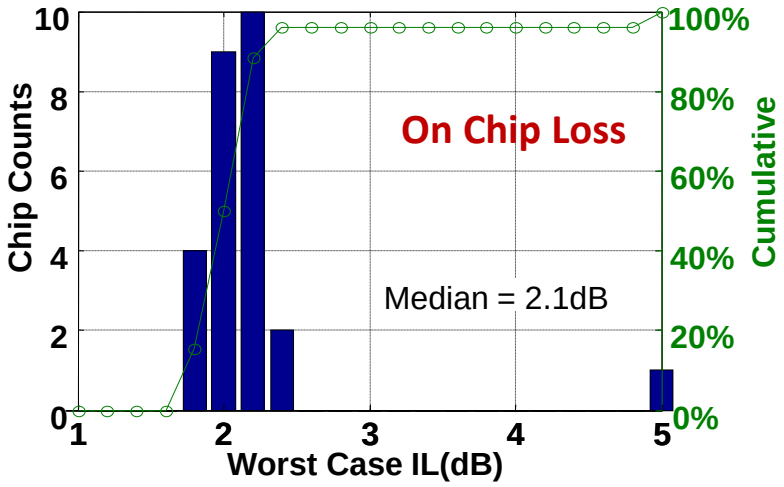


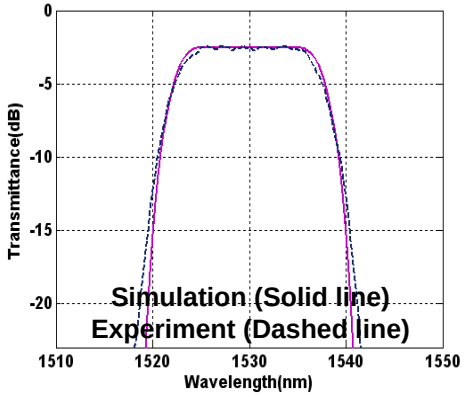




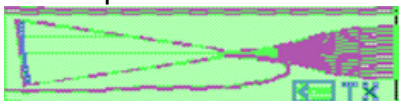
Measured 12ch spectra

WDM: Echelle Gratings on u-scale (3um) WGs

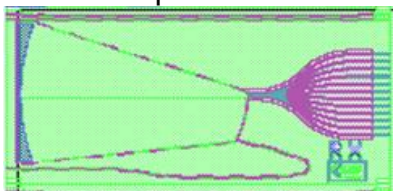


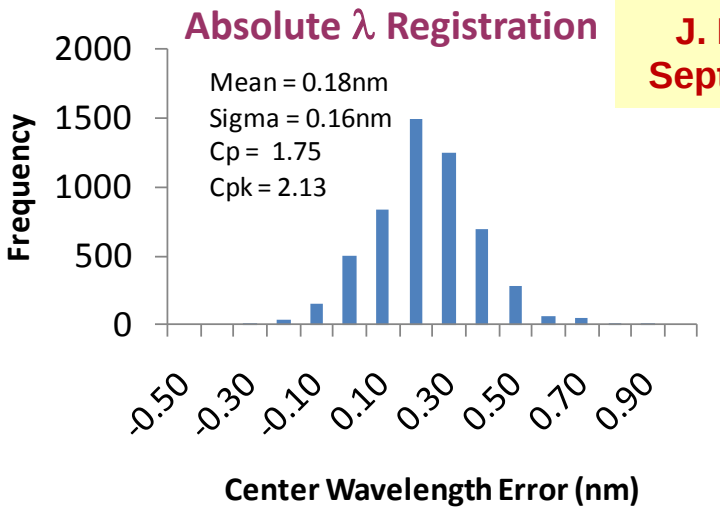


Tx Chip

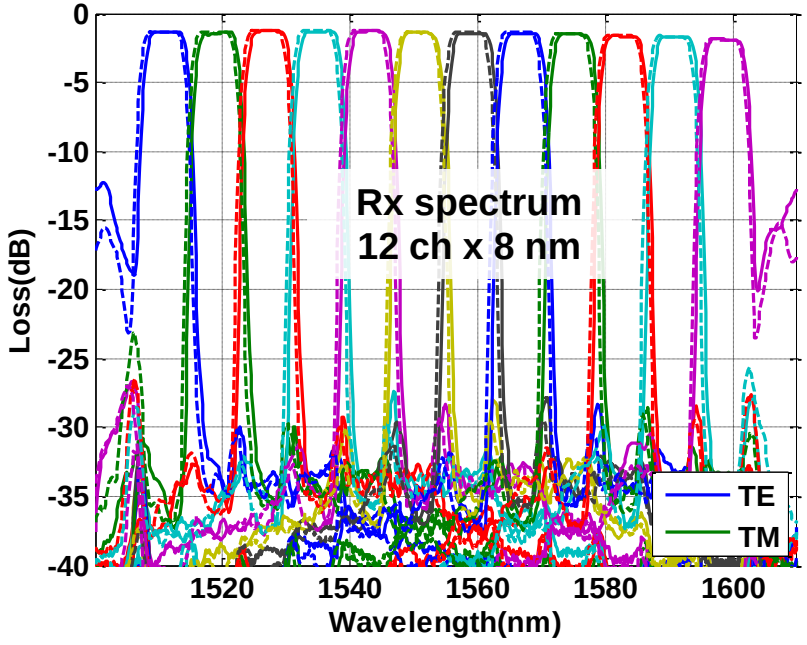


Rx Chip





J. Luff, ECOC September, 2010



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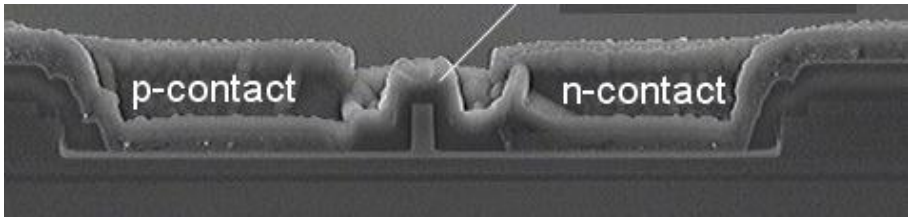
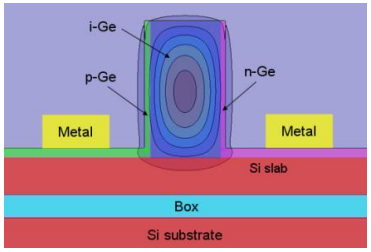
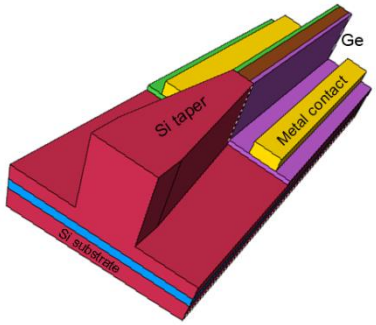
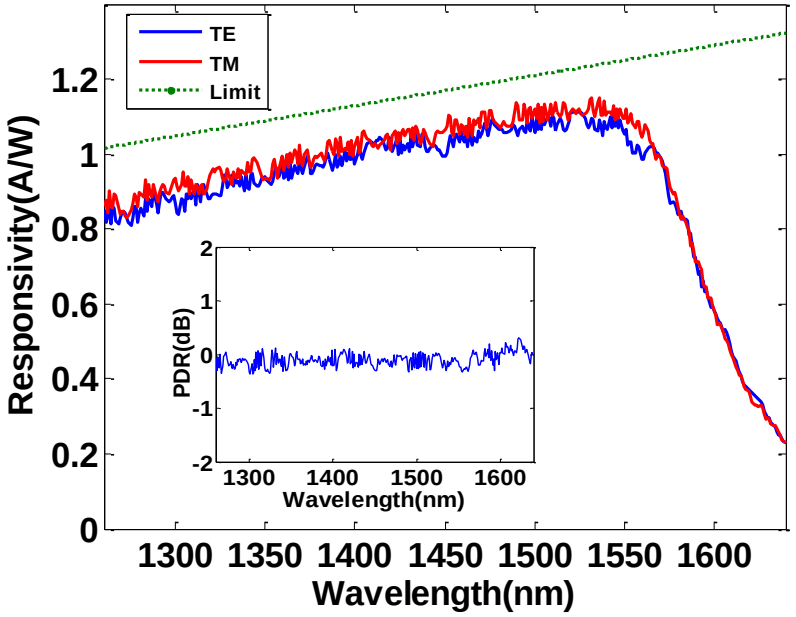
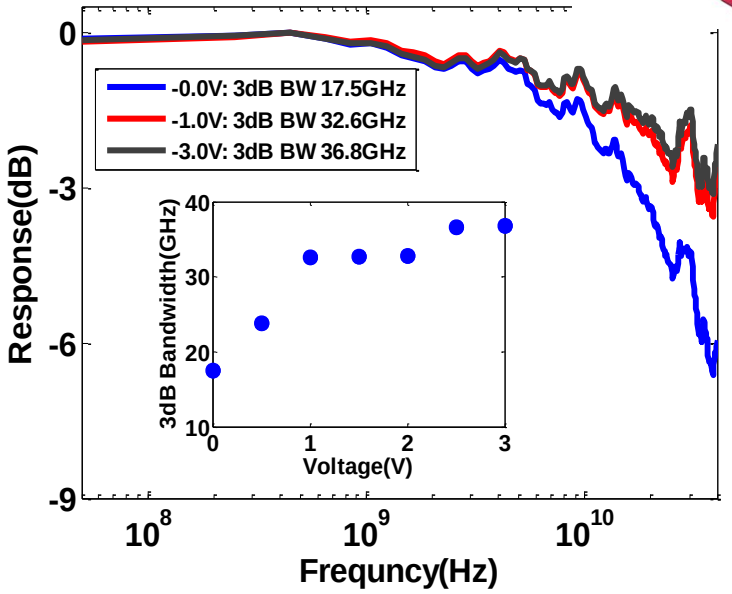
25G Ge Detectors Integrated with WDM











- High responsivity from 1260 nm to 1580 nm. 1.1 A/W @ 1550 nm demonstrated
- Low PDL < 0.3 dB
- High speed > 32 GHz, capable of detecting 40 Gbps optical signal
- Dark current <1μA @ -1 V (0.2-0.5uA typical)

D. Feng, Appl. Phys. Lett. 95, 261105 (2009)

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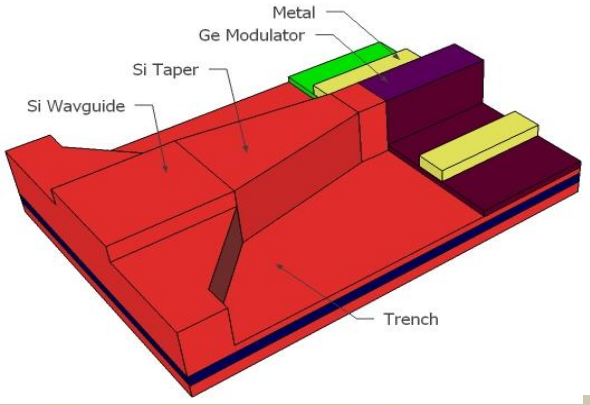
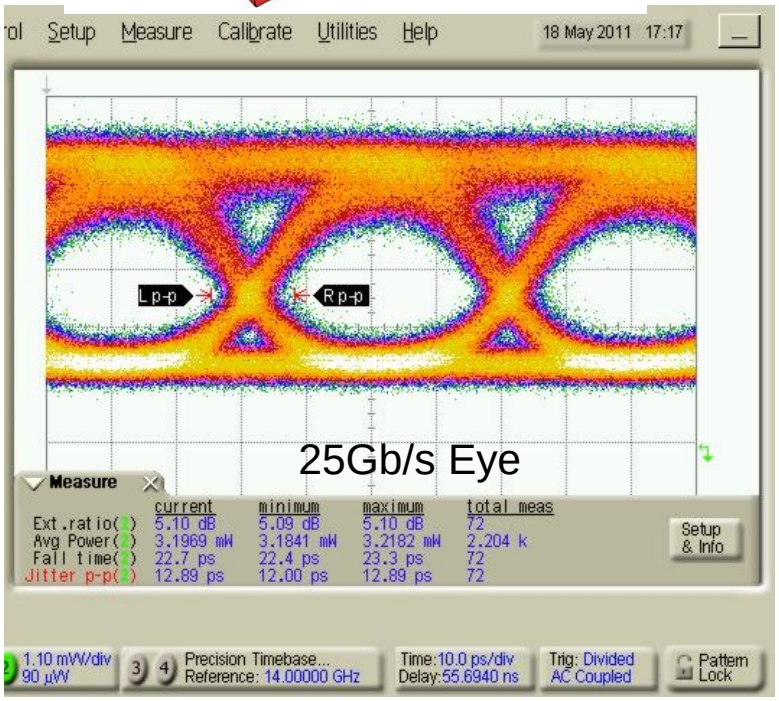
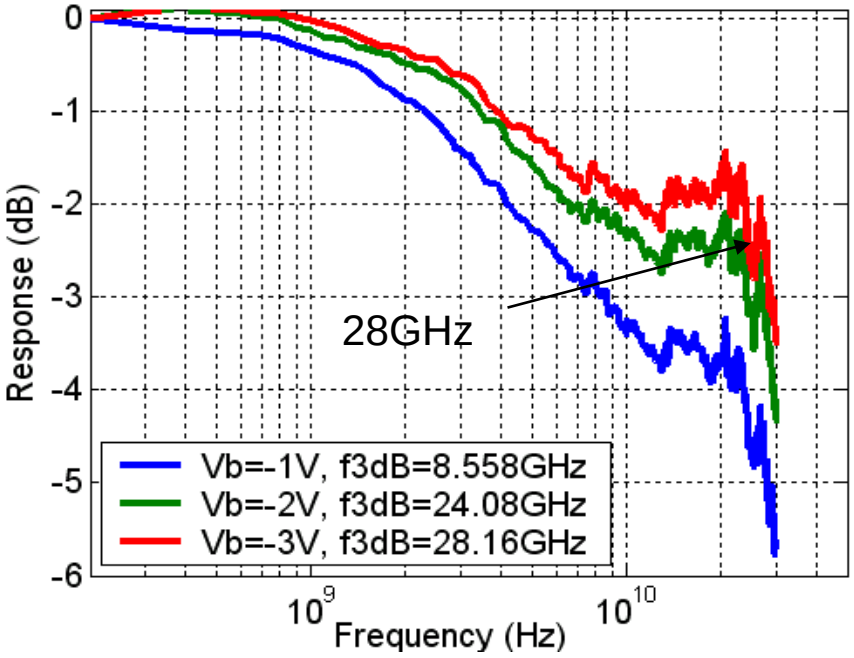
Measured Modulator Results at 25G





- 5dB ER with 2.8 Vpp
- 2 Vpp possible
- Integrates w/WDM



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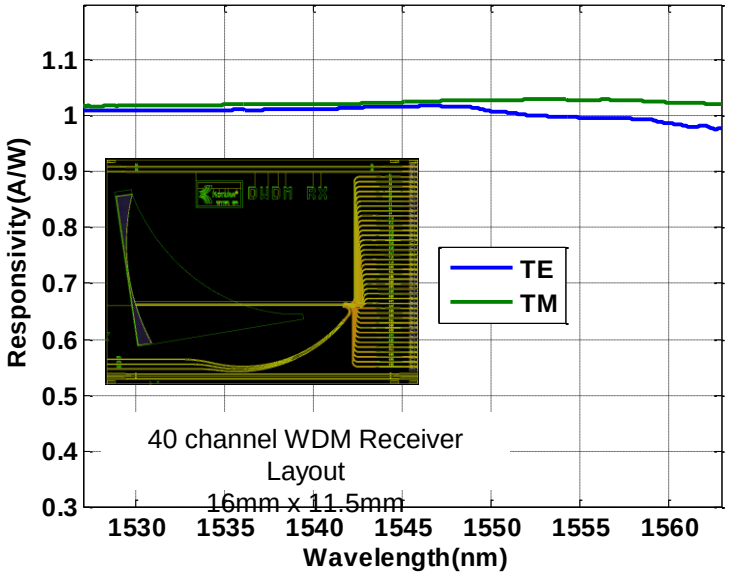
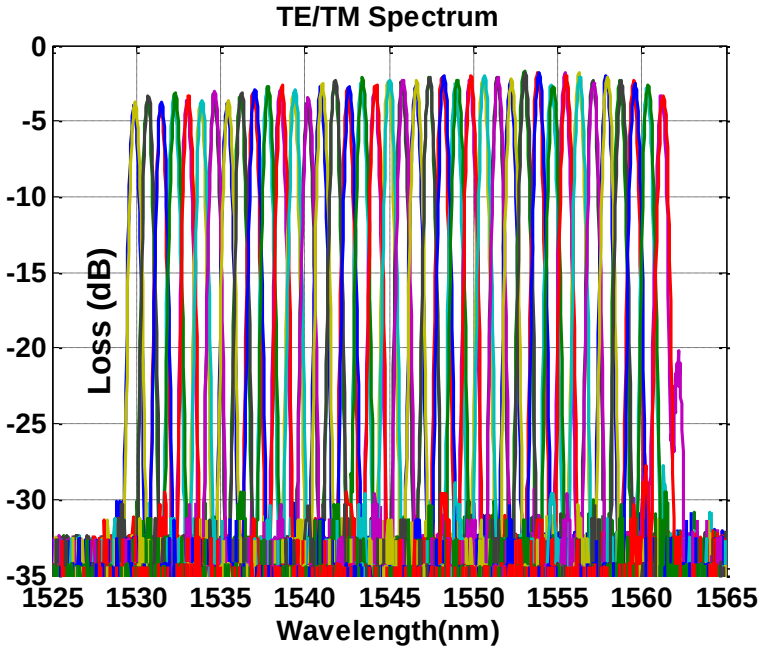
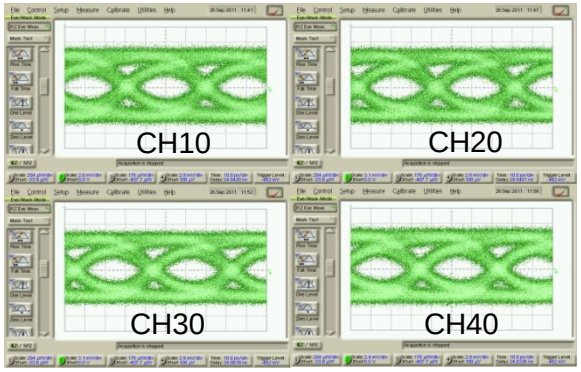
Measured Results: 40 channel WDM w/detectors



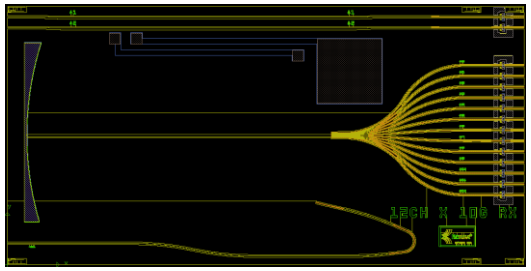


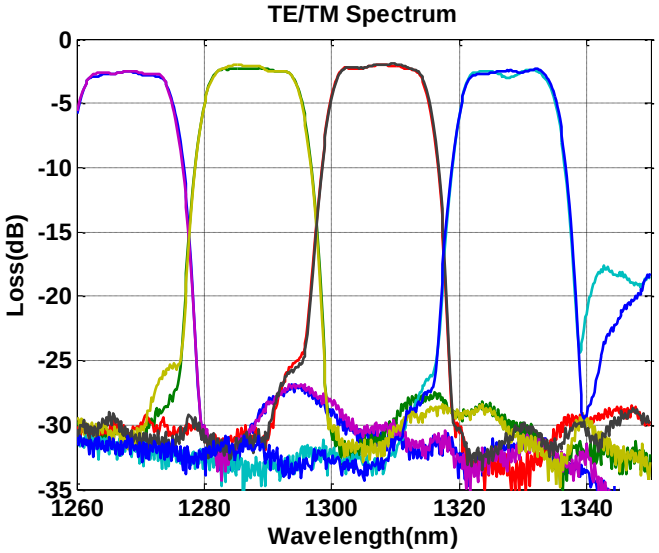
- Responsivity ~ 1.0 A/W in C-band
- Average on-chip loss (all channels) ~ 2.5 dB
- PDL < 0.5dB
- Better than 27 dB isolation
- Overall In-fiber responsivity of WDM receiver ~ 0.4 A/W
- 3dB bandwidth ~ 28.9 GHz, >25 Gbps optical signal
- All 40 channel eyes are open, 25 Gbps limited by test rig
- Total bandwidth of WDM Rx > 1 Tbps (40ch x 25 Gbps)



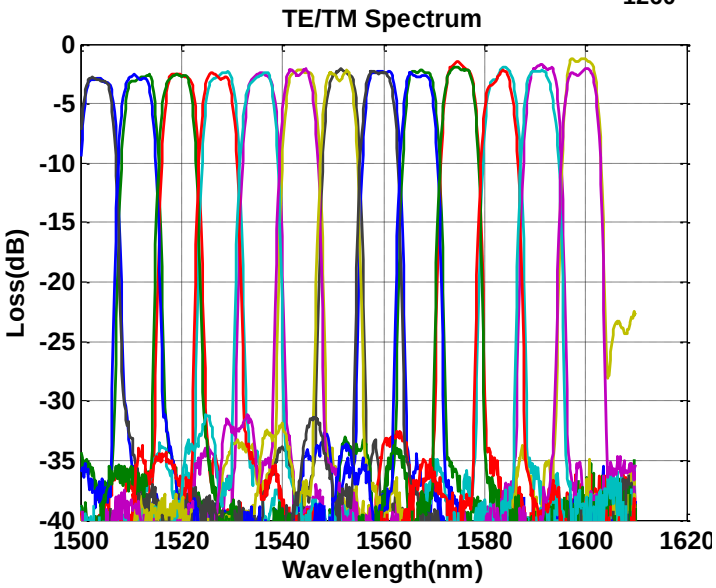
Other WDM Receivers with Integrated Ge PDs

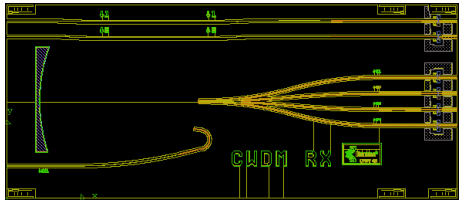
12Ch x 10G WDM Receiver
Chip Size: 6mm x 12mm



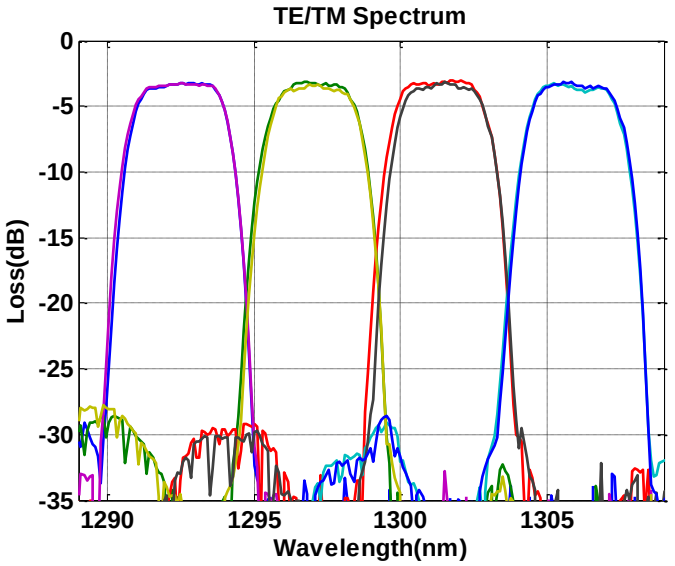


4ch x 25G LWDM Receiver
Chip size: 7mm x 4mm





4ch x 10G CWDM Receiver
Chip size: 7mm x 3mm



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Merits of nR4 Alternative Channel Plans

- Recall 1310 LAN WDM was selected as the best alternative for 10 km and 40 km reach
  - See http://www.ieee802.org/3/ba/public/mar08/cole_01_0308.pdf
- For nR4,1310 CWDM could be considered
  - Compatible with 40G LR4
  - Uncooled to reduce power, parts, and cost
  - Fits in QSFP package, popular for 40G LR4
- C-Band (1550) channel plans should also be considered
  - Can also be uncooled to reduce power, parts, and cost
  - Can also fit QSFP or CFP4 package
  - Can expand to 10, 16 or more channels in future
  - Can support virtually any reach with fiber amps
  - The ITU 40 channel grid has been in use since 1995
  - Huge optical eco system already exists (muxes, amplifiers, opms)
  - Tunable lasers, test equip. and network labs already in place

Migration to 400G and 1.6T

- WDM readily expands from 4 to 40+ channels
  - C and L Band channels defined long ago by ITU
  - Broad market acceptance by Telecom networks
  - Silicon photonics chips with 40 channels have been demonstrated
- SP modulators and detectors can scale from 25G to 40G
- Merits of WDM channel plans should be discussed in task force with path to 400G and beyond

Summary

- WDM solutions can be supported by a variety of PIC technologies
- WDM reuses traditional SMF Duplex fiber
  - No need for expensive fiber arrays and connector arrays
- WDM PIC solutions offer low-power and size supporting QSFP, CFP4 or custom package
- WDM readily migrates to more channels
- Silicon photonics is one WDM PIC example
  - Low-cost, flip-chip bonded Gig E style light source
  - Full integration of laser grating, modulator, mux/demux and detectors
  - Migration to 40G
  - Minimal piece parts
  - Electronics style assembly