Optical Networking

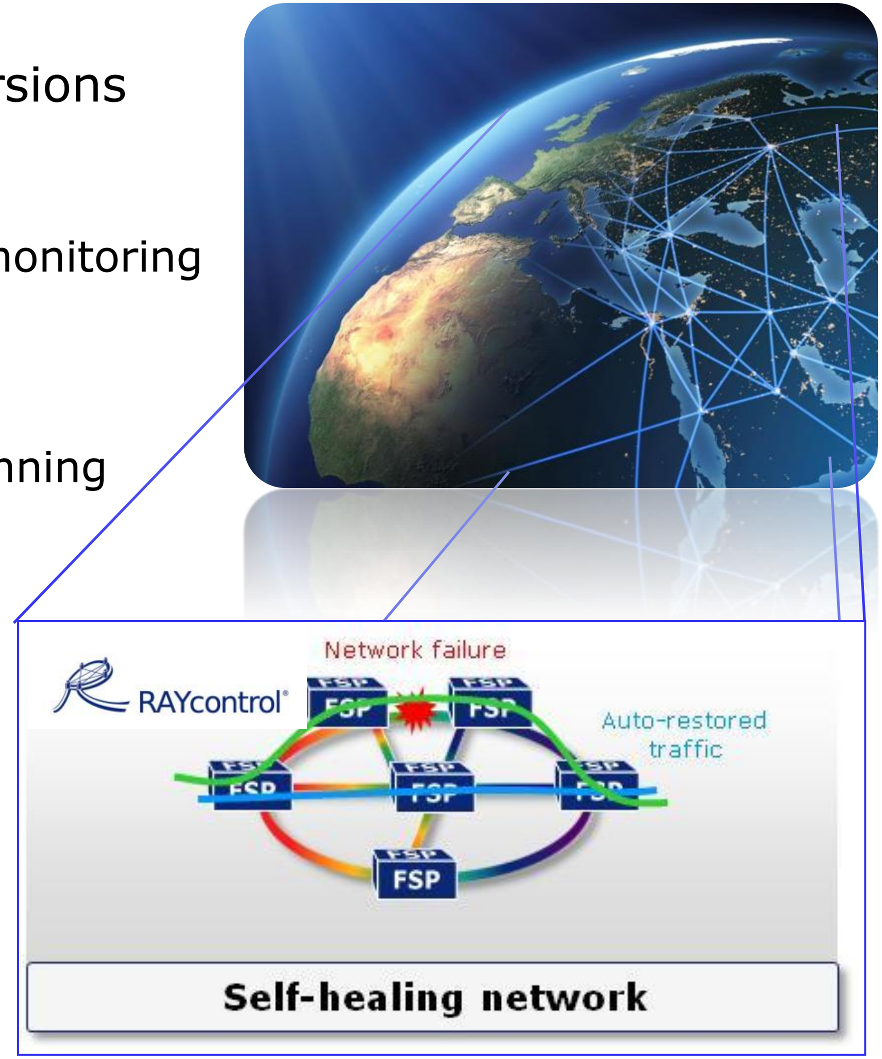
Next Gen optical networks

Jonathan Fowler, May 2012

Dynamic Optical Networks

Dynamic Optical Networks

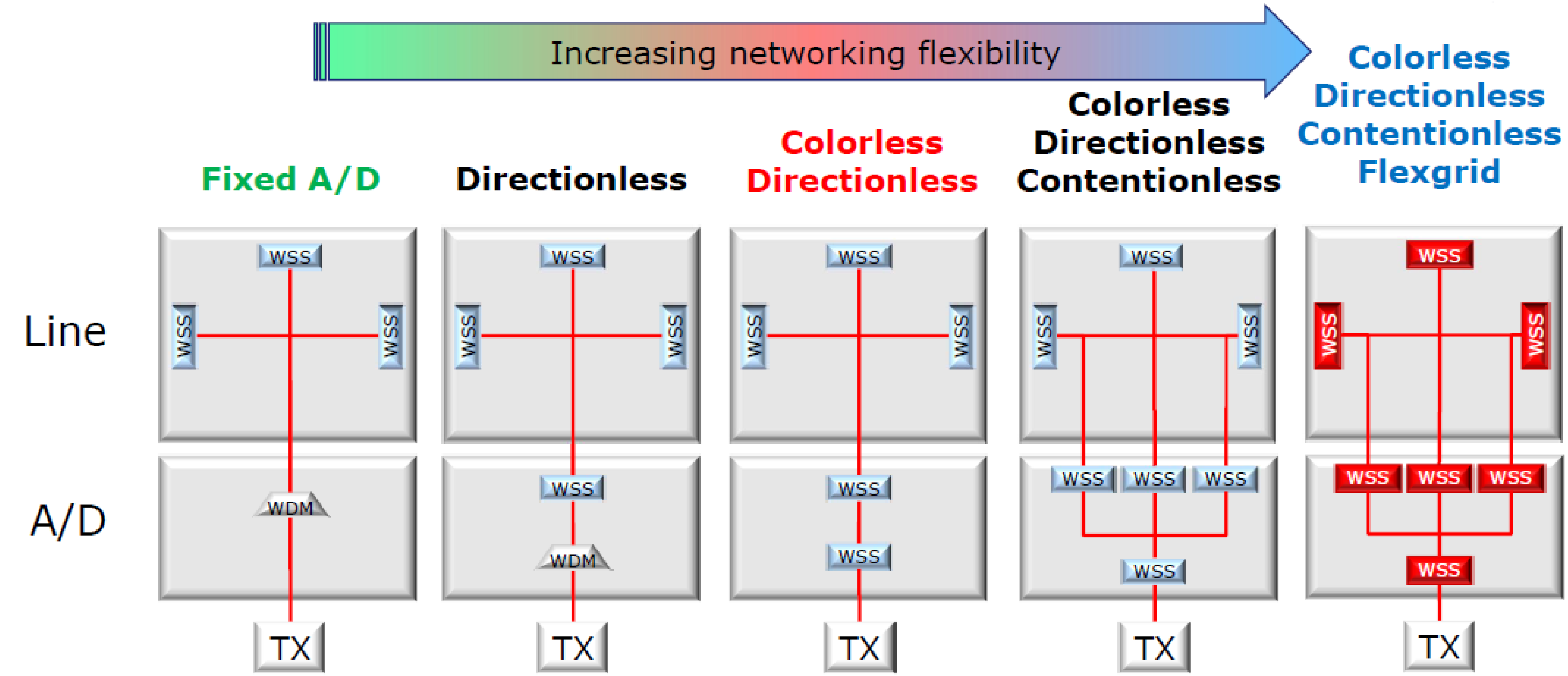
- Eliminates unnecessary O/E/O conversions
  - transparent pass-through
  - hitless network expansion
  - offers optical power management & monitoring
- Increases planning flexibility
  - optimized bandwidth utilization
  - removes uncertainties in capacity planning
- Accelerates service turn-up
  - facilitates point-and-click provisioning
  - eliminates intermediate site visits
- Facilitates new functionalities
  - optical layer restoration
  - second, third line of defense
  - bandwidth on demand



What is a ROADM ?

- ROADM = Reconfigurable Optical ADD & DROP Multiplexer
- A ROADM is an optical network element which is capable to pass through any separate wavelength between DWDM node line interfaces and add/drop any separate wavelength from DWDM line interfaces to add/drop ports.
- The re-configurability is software based. Therefore remote re-configuration via management systems is possible.
- In general a ROADM is optical transparent. This means that the ROADM is transparent for the data-rate, the framing or the modulation format of the wavelengths.
- Why is ROADM important to the UK

ROADM Functionalities



ROADM Generations

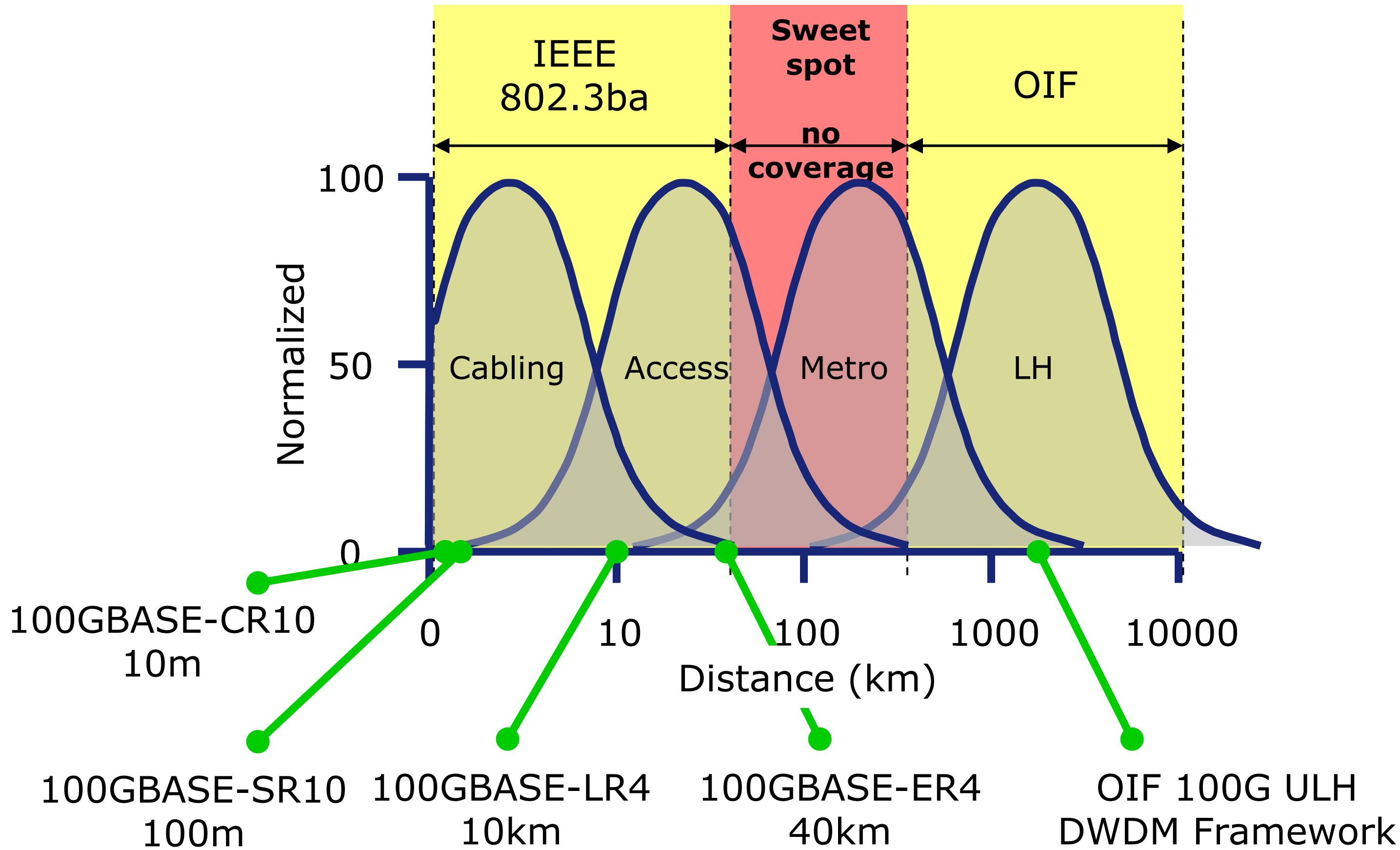
- 1st generation ROADMs: **Wavelengths Blocker based ROADMs**
  - 2 degree nodes only
  - 100 GHz channel spacing
  - Add/Drop only
  - No channel equalization capability
  - Neither colorless nor directionless
- 2nd generation ROADMs: **PLC/iPLC based ROADMs**
  - 2 degree nodes and very limited multi degree functionality
  - 100 GHz channel spacing
  - Add/Drop only
  - Channel equalization capability
  - Neither colorless nor directionless node support
- 3rd generation ROADMs: **WSS 1:N based ROADMs**
  - Multi degree node support
  - 50 GHz and 100 GHz channel spacing
  - Channel equalization capability
  - Colorless and directionless node support
- 3rd+ generation ROADMs: **WSS LCoS based ROADMs**
  - Multi degree node support
  - Flexible channel spacing
  - Future proof on
  - Channel equalization capability
  - Colorless and directionless node support
  - Contentionless node support

Next Generation Roadm

- Intended for coherent DWDM interfaces only
  - 100G (2012)
  - 400G (2015/2016)
  - 1T (20xx)
- Directionless, colourless, gridless and contentionless (triple A) multi degree ROADM functionality
- No chromatic dispersion compensation needed
- Intensive use of RAMAN amplification
- GMPLS Control Plane multi vendor interworking
- Add/drop ports drop multiple wavelengths
  - The coherent receiver is able to select/separate the own wavelengths due to the integrated reference laser
- Support of more or less any fiber type

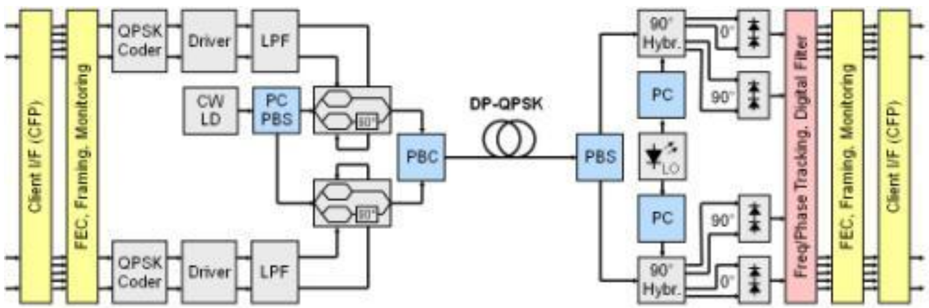
100Gb

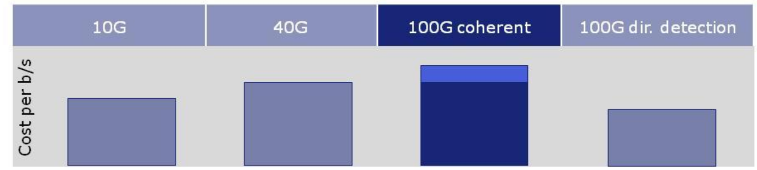
NextGen ON to utilize highest capacity
100G standards coverage



There is a gap in standards coverage

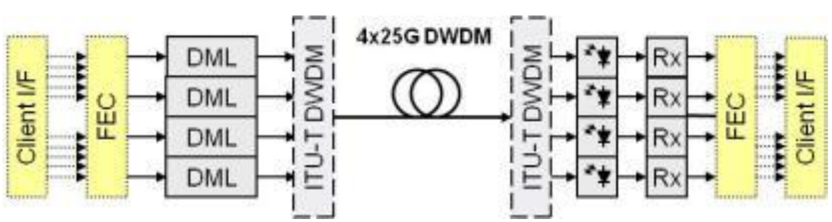
FSP 3000 High-Speed Solutions
100Gbit/s Long Haul & Metro interface technology

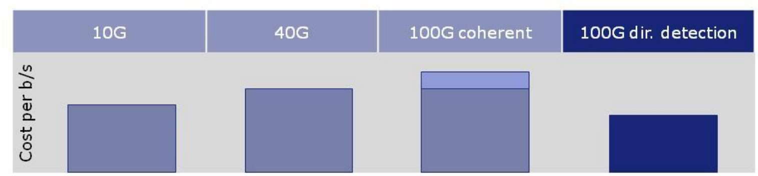




LH transport (up to 2500km):

- DP-QPSK modulation format (25GBd)
- Lowest loss/highest reach
- 50GHz spectral occupancy
- 2500km reach





Metro transport (up to 500km):

- 4x28Gb/s DWDM channels (50GHz grid)
- Derived from IEEE 802.3ba standard
- 200GHz spectral occupancy
- Max. density, lowest cost & power consumption
- 500km reach

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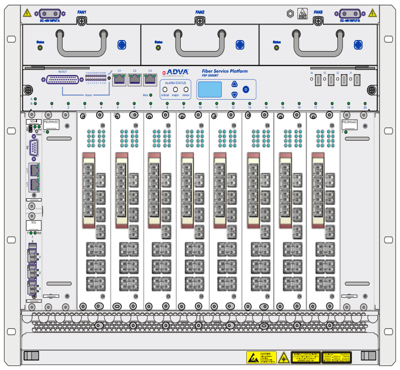
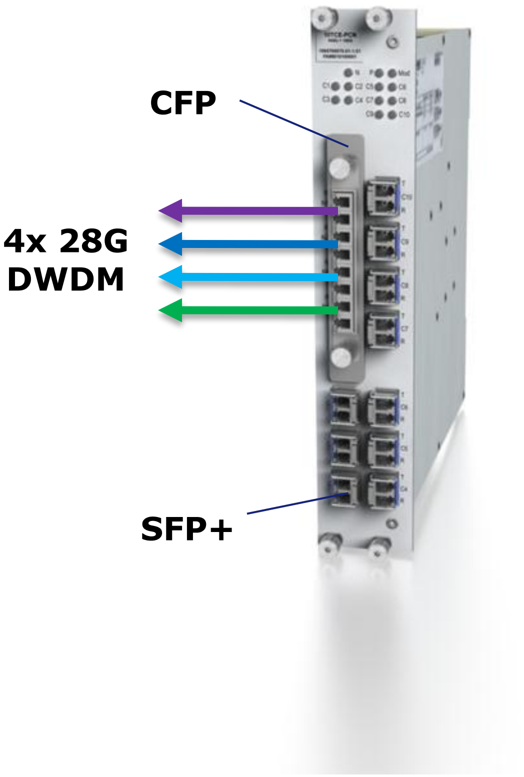
Cost optimized Metro/Enterprise Transport

- Based on 4 x 28Gbps non-coherent technology
- Improved efficeny
  - Cost : Lowest cost-per-bit transport
  - Space: Industry leading compact Design
  - Power: Low power consumption
  - Spectral Efficiency





Summary

- There is no “one size fits all” approach for 100G networking
- 100G serial/coherent solution is only required where networks are wavelengths constrained (e.g. Carrier Core)
- 100G coherent transport in carrier networks allows for a new optical layer with improved distances
- Enterprise customer will introduce 100G only if it comes at lower cost points than today’s 10G technology
- Near term only a 100G metro transport solution can address the required cost points (as well as power and space requirements)

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Thank you

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IMPORTANT NOTICE

Underlying Technologies

Wavelength Selective Switches (WSS)

Available 1xN / Nx1 / NxN WSS devices are based on 3 common concepts:

- Propagate light through free space
- Disperse the DWDM signal to separate wavelengths
- Route wavelengths using "switching" elements

Switching element (WSS) technologies:

- **2D-MEMS (mirrors)**
- **DLP (Digital Light Processing)**
- Liquid Crystals Cells (LC)
- **Liquid Crystals on Silicon (LCoS)**
- Hybrid (LC + MEMS)

Less relevant WSS technologies:

- Piezo-electric actuated mirrors
- Thermally switched Mach-Zehnder interferometers in PLCs

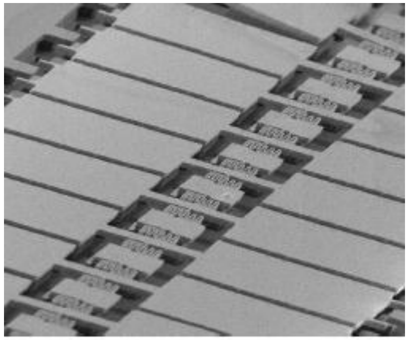
WSS Technology Comparison

- **MEMS**
  - **MD-ROADMs, colorless, directionless**
  - **Fixed grid (not gridless)**
  - **High port counts possible**
- **DLP**
  - **Colorless, directionless, gridless**
  - **Limited number of supported degrees**
- Liquid Crystals
  - MD-ROADMs, colorless, directionless
  - Most likely fixed grid only (not gridless)
  - Limited number of ports (up to 16)
- **LCoS**
  - **Colorless, directionless, gridless**
  - **MD-ROADMs**
  - **Medium port counts possible**
- Hybrid LC + MEMS
  - MD-ROADMs, colorless, directionless
  - Fixed grid (not gridless)
  - High port counts possible

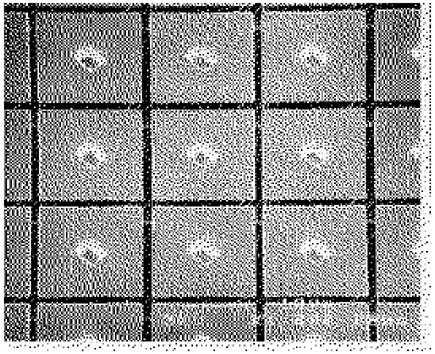
WSS Switching Technologies

<u>WSS switches are able to control wavelength separated beams using:</u>

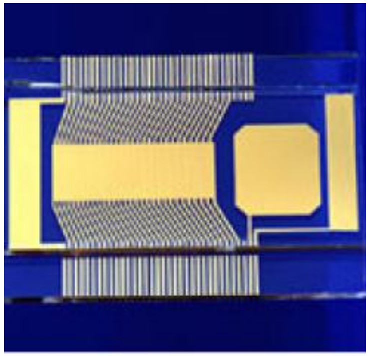
- Phase
- Polarization
- Angle
- Displacement



JDSU MEMS



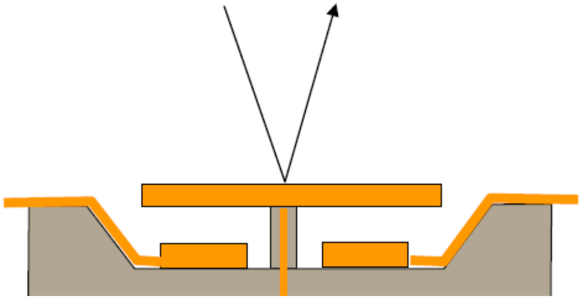
TI DLP™ chip

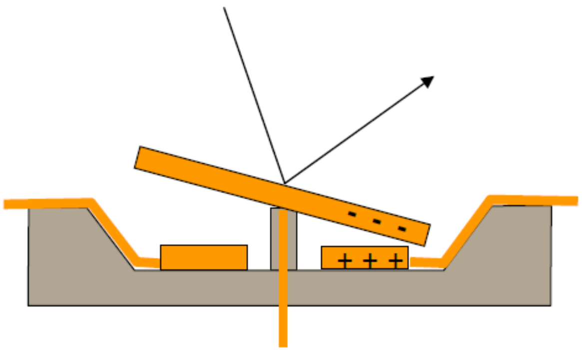


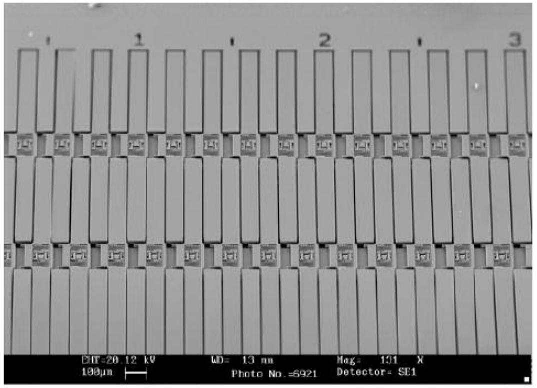
JDSU Blocker LC

2D-MEMS

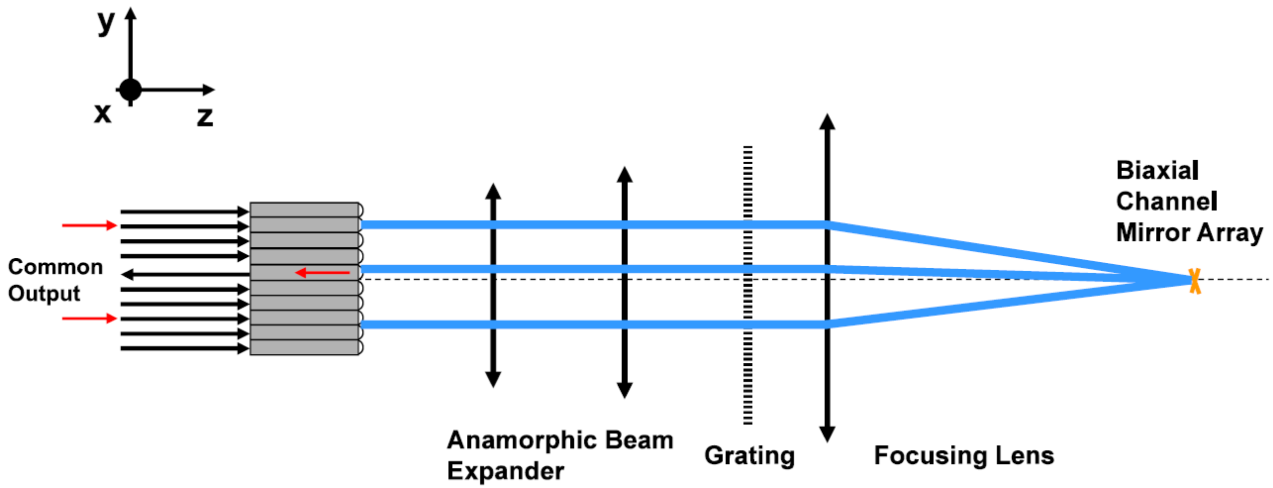
- 2D-MEMS are based on an array of mirrors (one mirror for each supported wavelength) which can be adjusted/switched via electronic signals.
- Voltage applied to the mirror electrode causes mirror to tilt due to electrostatic attraction.
- Per channel attenuation provided by tilting to offset the beam slightly at the output fiber.
- 2D-MEMS are dual axis mirrors. Adjustment via the second axis (y-axis) is required to prevent hits of other wavelengths during the switching adjustment.

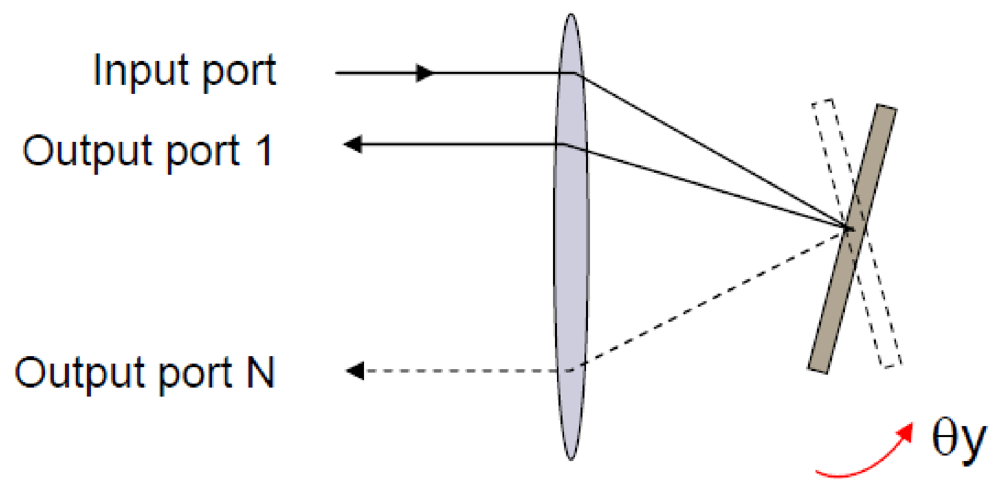




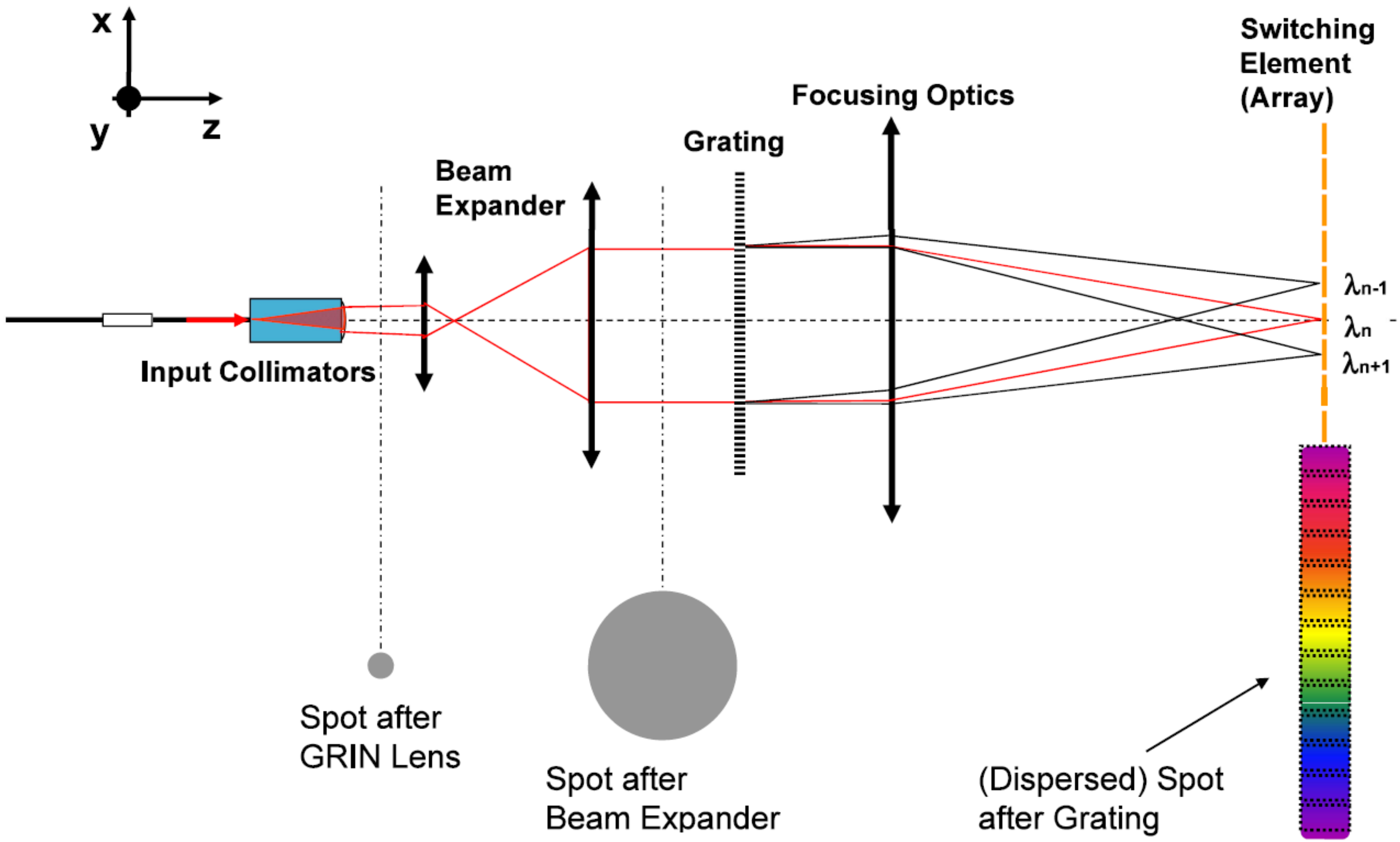


2D-MEMS


y
x
z
Common
Output
Anamorphic Beam
Expander
Grating
Focusing Lens
Biaxial
Channel
Mirror Array

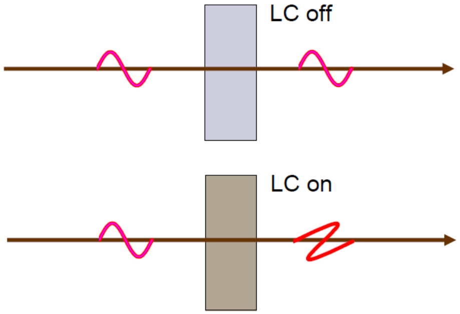

Input port
Output port 1
Output port N
θy

2D-MEMS Based WSS Architecture

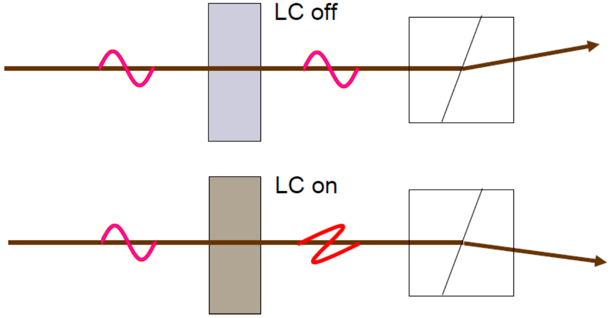


Liquid Crystals (LC)

A Liquid Crystal cell selectively controls the polarization state of transmitted light by application of a control voltage (polarization rotator)



For switching, the LC cell must be followed by a polarization dependent optical element to alter the path of the transmitted light



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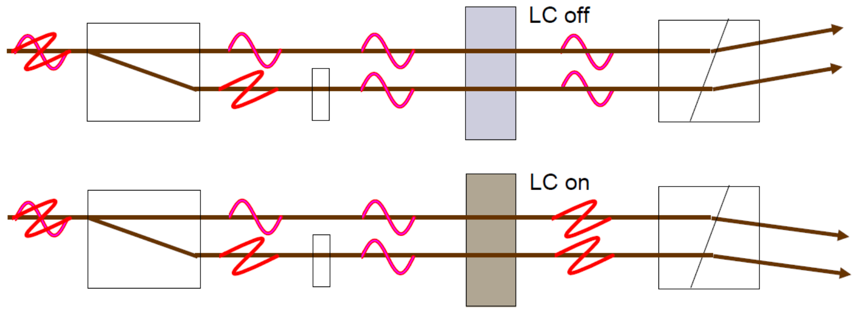
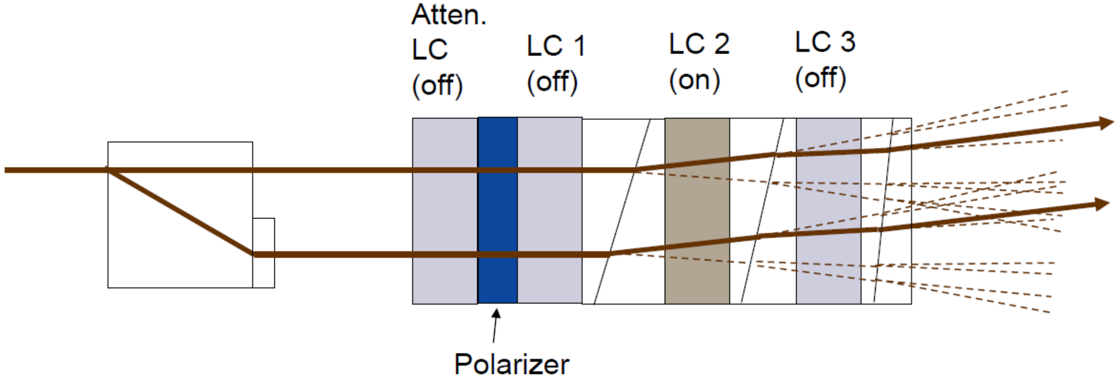
Liquid Crystals (LC)

Randomly polarized input ingress channel signals must be separated into two orthogonal polarizations.

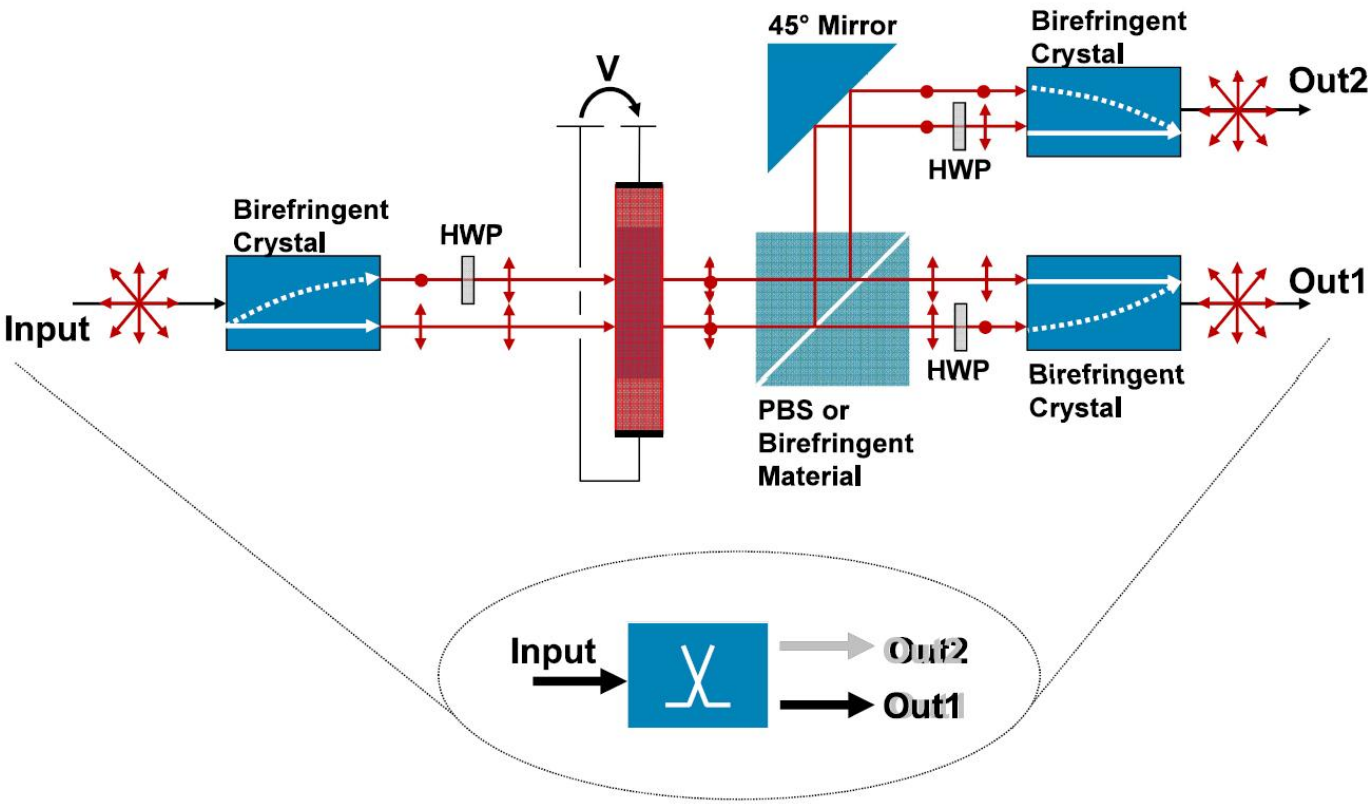


An addition Liquid Crystal cell and an additional polarizer are required to enable wavelength attenuation tuning.



LC cells are capable to support wavelength broadcast. To broadcast a wavelength the LC cell is tuned in an intermediate polarization state.

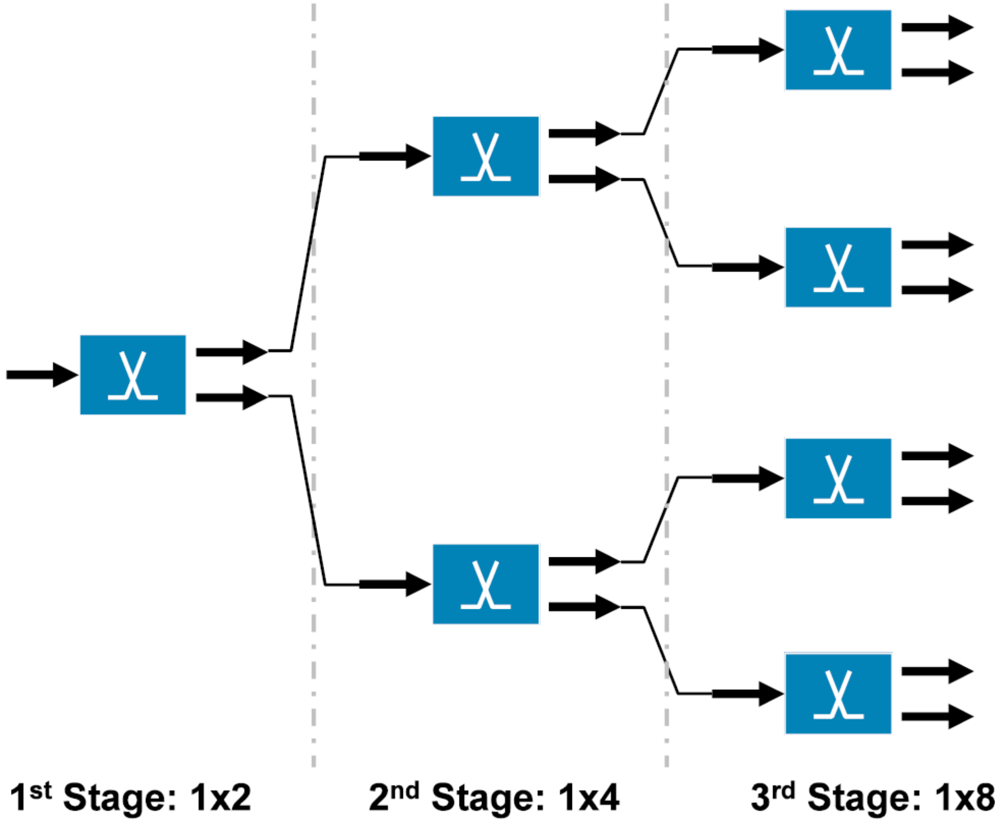
Liquid Crystals based 1x2 Switch



Liquid Crystals based 1x8 WSS

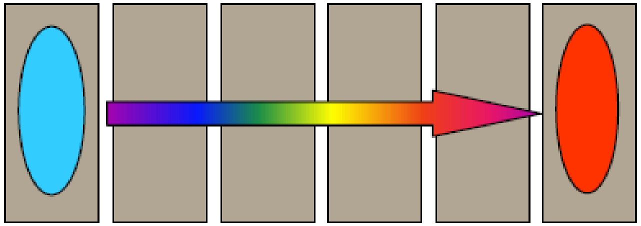
Liquid Crystals based switches are limited to binary operation (1x2). Therefore it is necessary to cascade multiple LC based 1x2 switches to realize multi degree ROADM devices.

LC based 1x8 WSS architecture



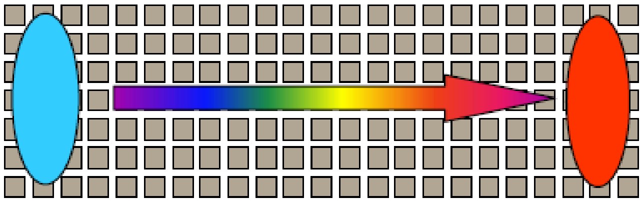
1D + 2D Switching Arrays

<u>1D arrays</u>



- Single switching element per wavelength
- WSS technologies: MEMS and LC based PoL switches
- Advantages:
  - Available from several vendors
  - Relatively simple control electronics and control software
- Disadvantages:
  - Fixed channel bandwidth (can not be used for gridless switching)
  - Limited or ability to split power between output ports

<u>2D arrays / phased arrays</u>



- Multiple small switching elements per wavelength
- WSS technologies: LCoS , DLP and PLZT
- Advantages:
  - Variable channel bandwidth possible (gridless switching)
  - Capable to split optical power between multiple output ports
  - Limited dispersion compensation capability (up to 150 ps)
- Disadvantages:
  - Availability of gridless and/or contentionless ready devices
  - Relatively complex control electronics and control software

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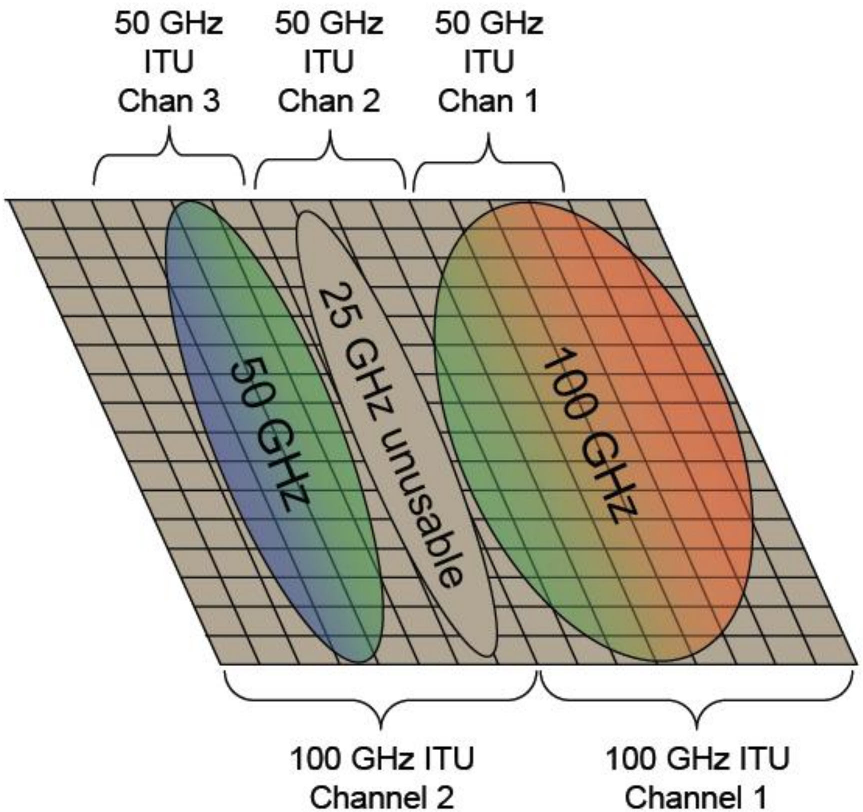
2D Arrays / Phased Arrays

Variable channel spacing / gridless functionality

- Reassign columns of pixels to different channel
- Bandwidth will be compromised on some channels and expanded on others

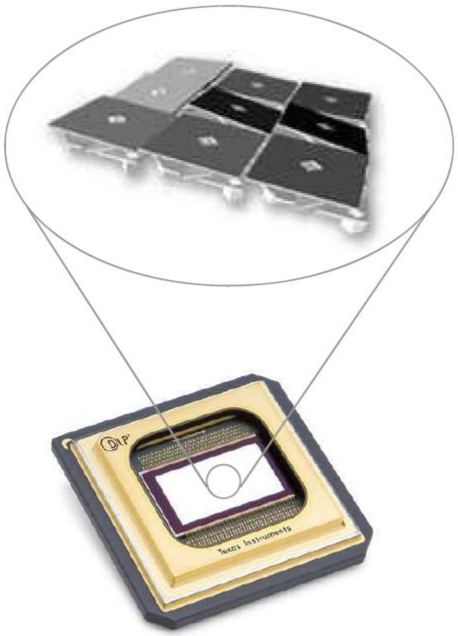


Digital Light Processing (DLP)

- DLP is a data projection technology developed by Texas Instruments.
- The technology is based an a spatial light modulator called a “Digital Micromirror Device” (DMD).
- In general the functionality of MEMS and DLPs is very similar.

<u>DPL differences:</u>

- The DLP uses many small mirrors to switch/control a single wavelengths (MEMS only 1)
- The DLP mirrors have 2 states only (on and off). Wavelengths attenuation is achieved by switching off a subset of the micromirrors.
  - 50 % off = 3dB attenuation
- Binary operation only (1x2)



A TEXAS INSTRUMENTS TECHNOLOGY

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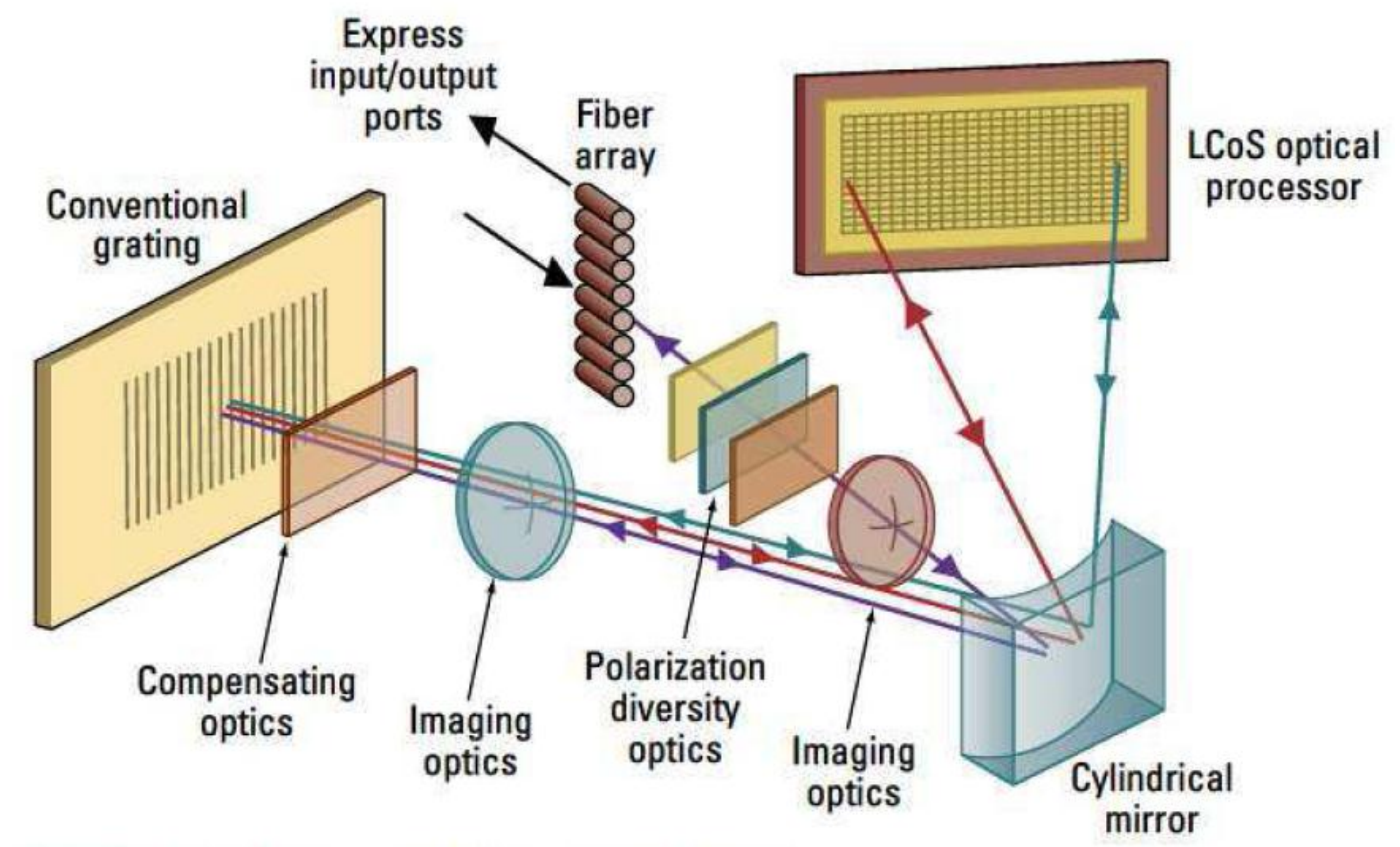
Liquid Crystal on Silicon (LCoS)

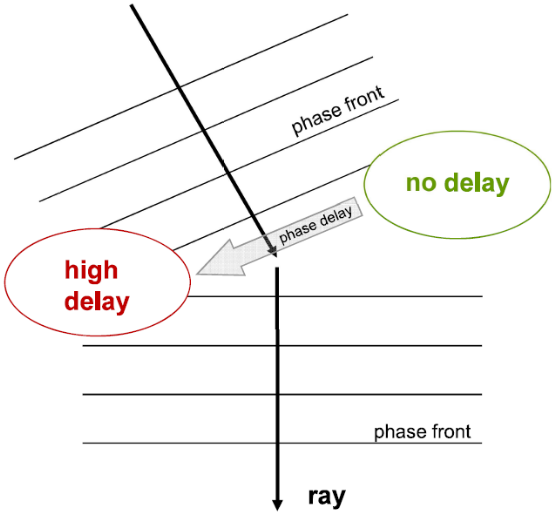
Liquid crystal on silicon (LCoS) is a "micro-projection" or "micro-display" technology typically applied in projection televisions. It is a reflective technology similar to DLP projectors.

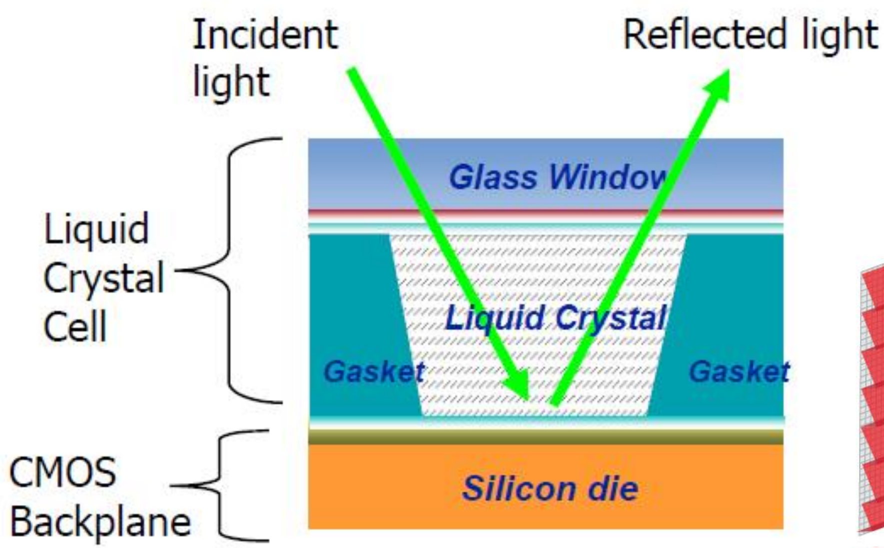


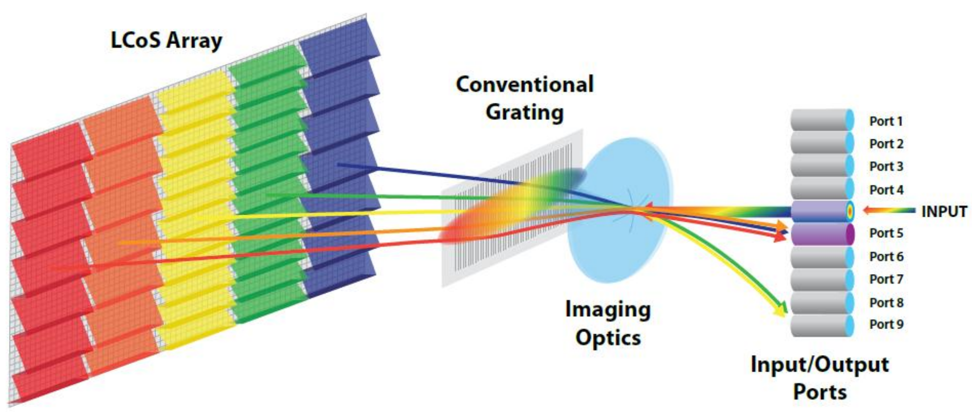
Liquid Crystal on Silicon (LCoS)

Phase delay beam steering

- Wavelength are switched applying differential phase delay along the phase front
- The phase front traveling through higher phase shift is delayed
- As a consequence the phase front is rotated. This determines beam steering.







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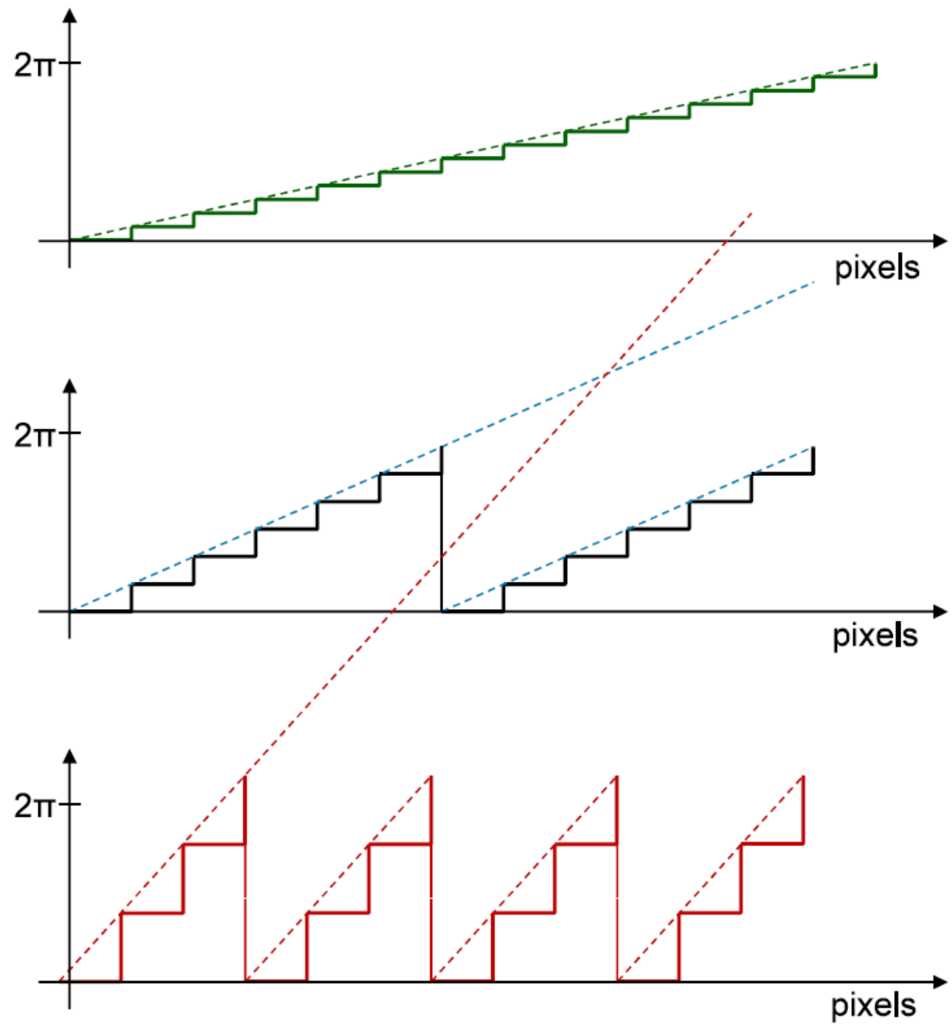
Liquid Crystal on Silicon (LCoS)

- Incoming light can be approximated by a plane wave.
- Steering is obtained by giving a differential phase delay to individual LC pixels along the phase front.
- The maximum phase shift is 2π.
- If the delay is > 2π a phase jump is required.
- The higher the angle the more frequent the phase jumps.



Hybrid LC + MEMS

Hybrid LC + MEMS devices use the MEMS mirror to switch the wavelength. The LC cell in front of the mirror attenuates or blocks the wavelength (channel equalization).

- Relatively simple (single-axis MEMS)
- High port counts theoretically possible
- Gridless functionality not possible (due to the MEMS)