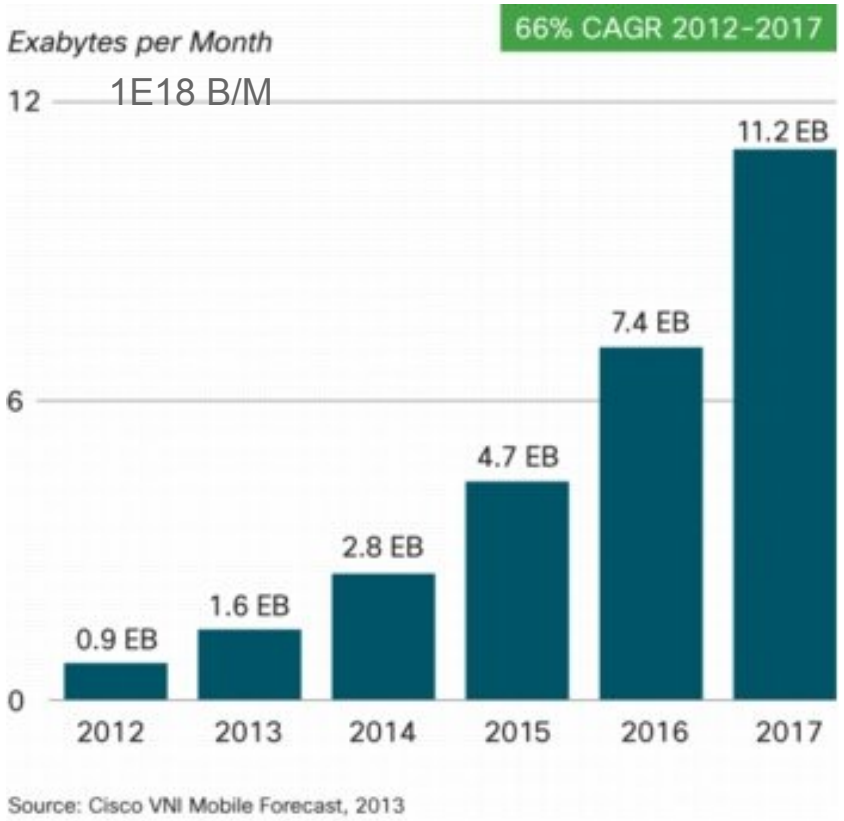
Fast Non-blocking N×N Optical Switch Using Diffractive MOEMS

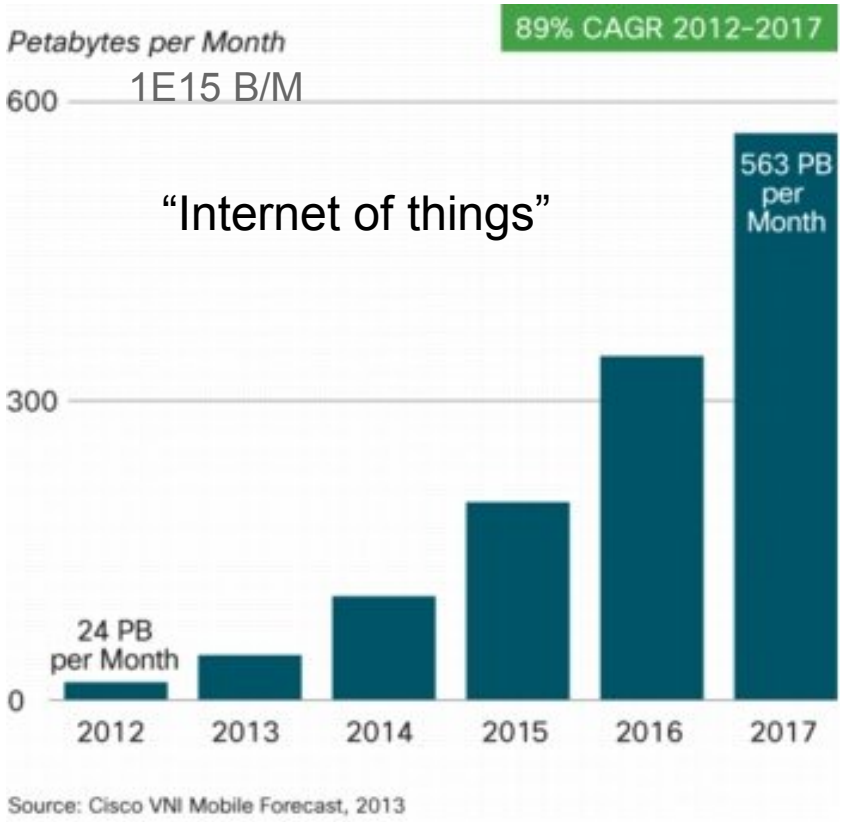
P.-A. Blanche

http://www.optics.arizona.edu/pablanche/

Market driver

- Exponential increase of the data traffic due to cloud computing, mobile devices (tablets, smartphones), social networking.

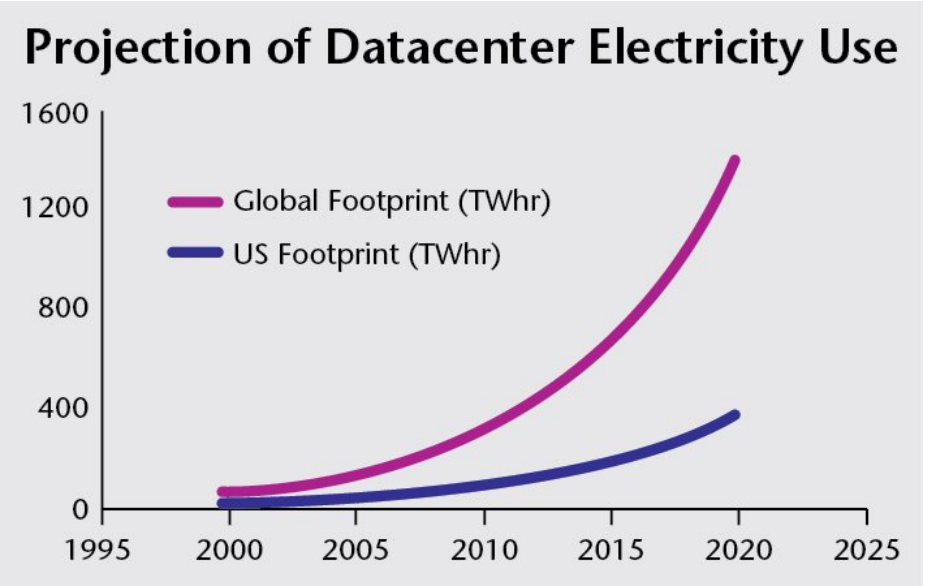




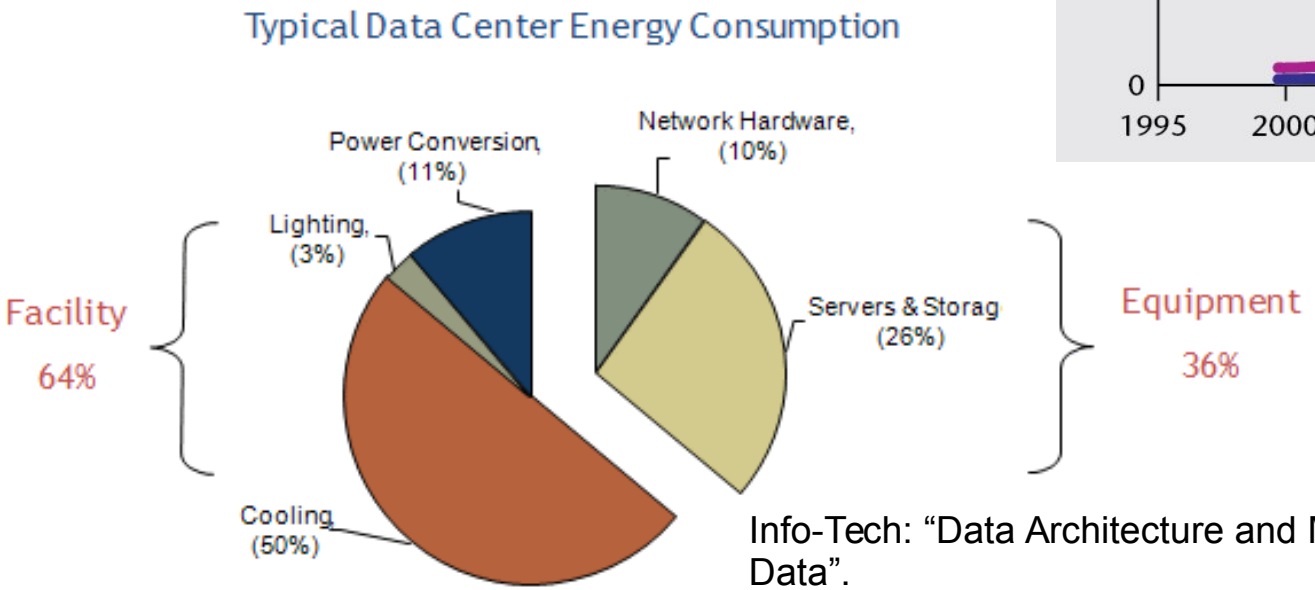
* Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2012–2017. http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

Market driver

- Up to 50% energy use in data center is for cooling.
- “Most data centers spend as much in electricity than in hardware”. Rodney C. Adkins, IBM Senior Vice President, Strategic Partnerships.



/icrosoft CorpSource: McKinsey Report. Revolutionising Data Center Efficiency”

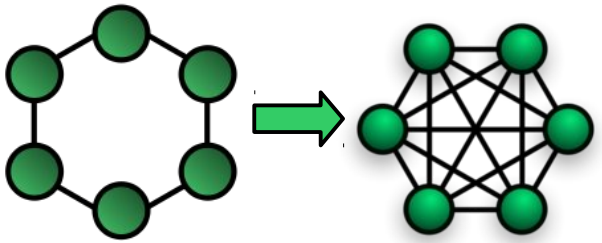


Info-Tech: “Data Architecture and More Data”.

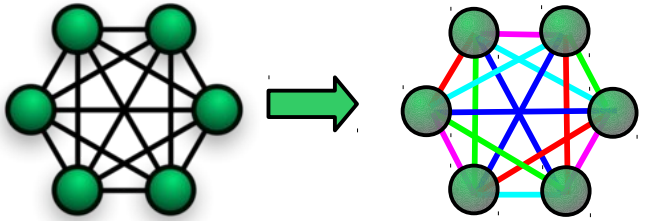
Transition to new architectures

Telecom

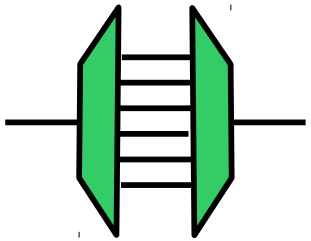
Ring to mesh

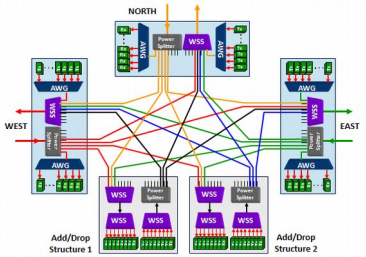


Rigid to flexible (SDN)



MUX/DMUX to CDC ROADM

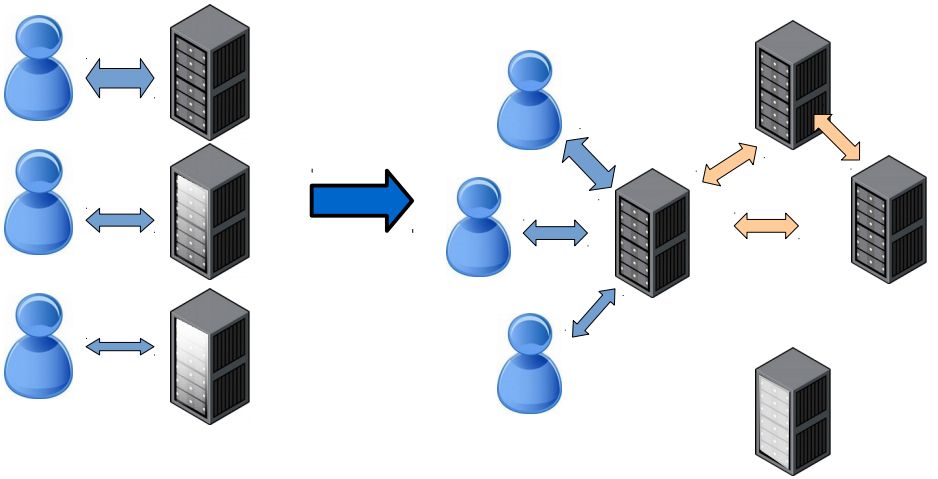




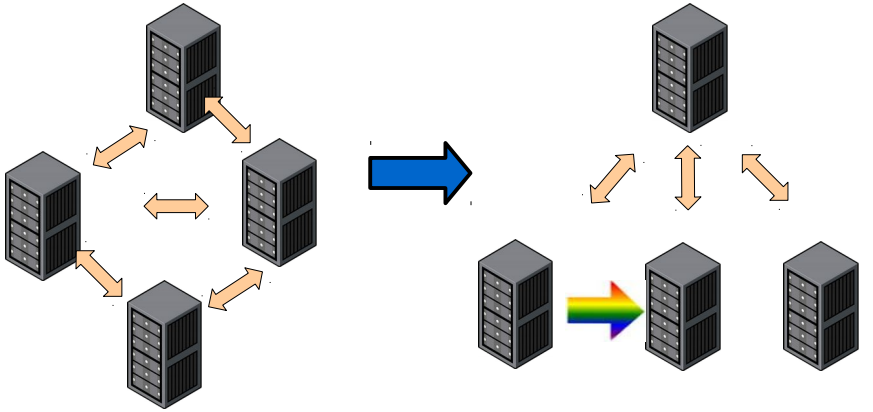
WSS

Datacom

Real to virtual



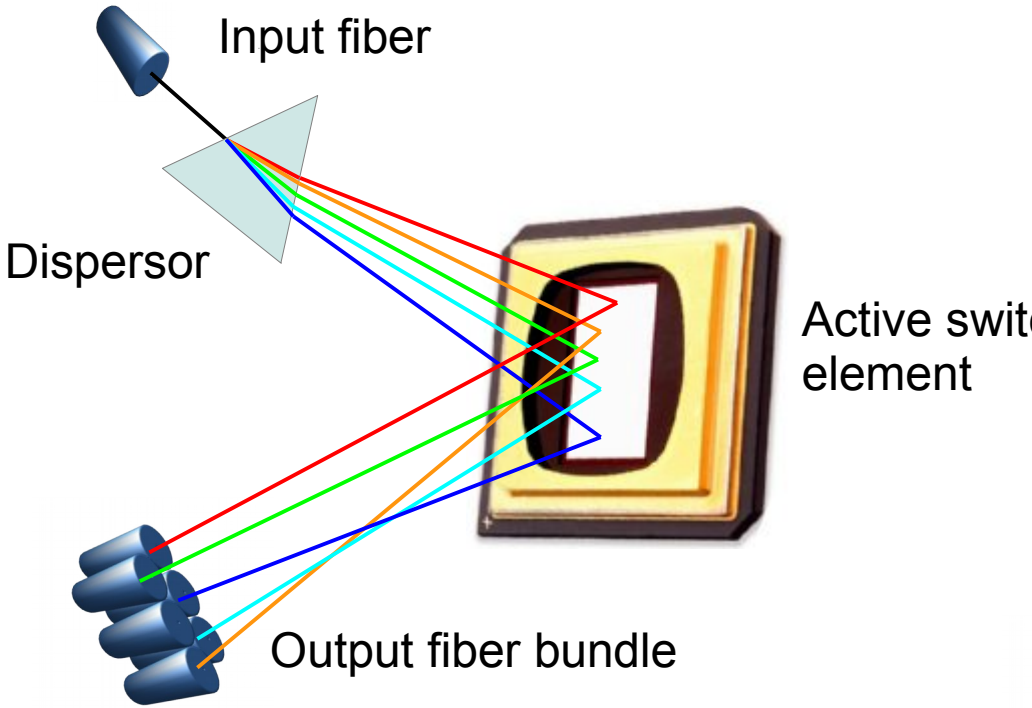
Packet switch to hybrid



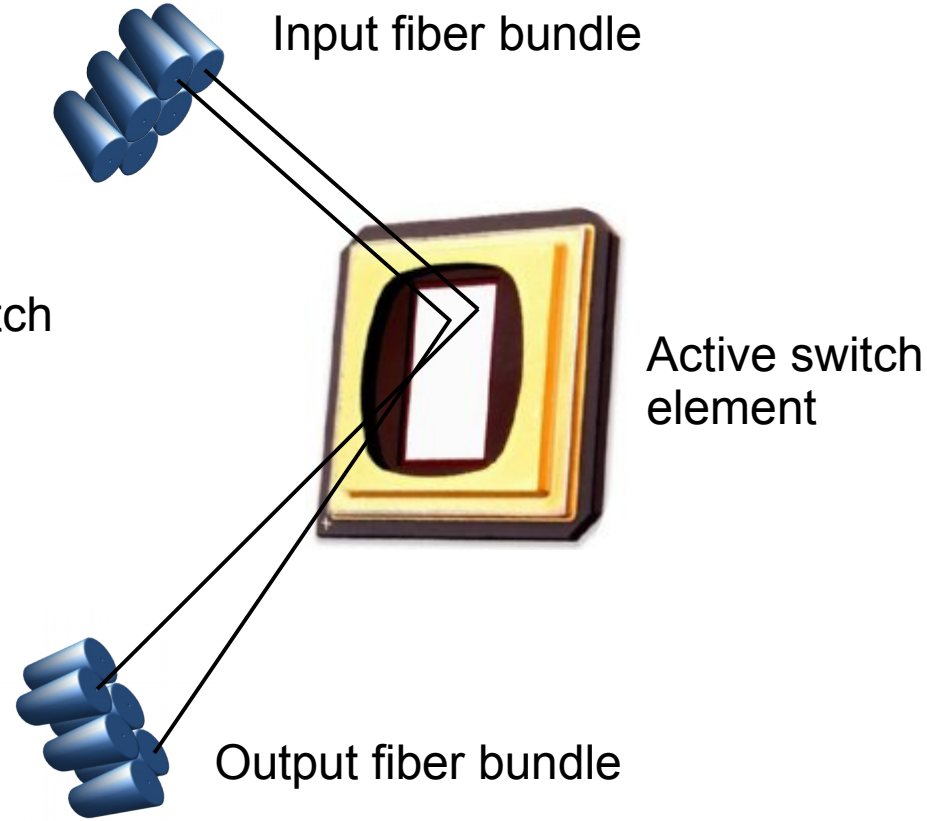
Cross Connect Switch

Switch flavors

WSS

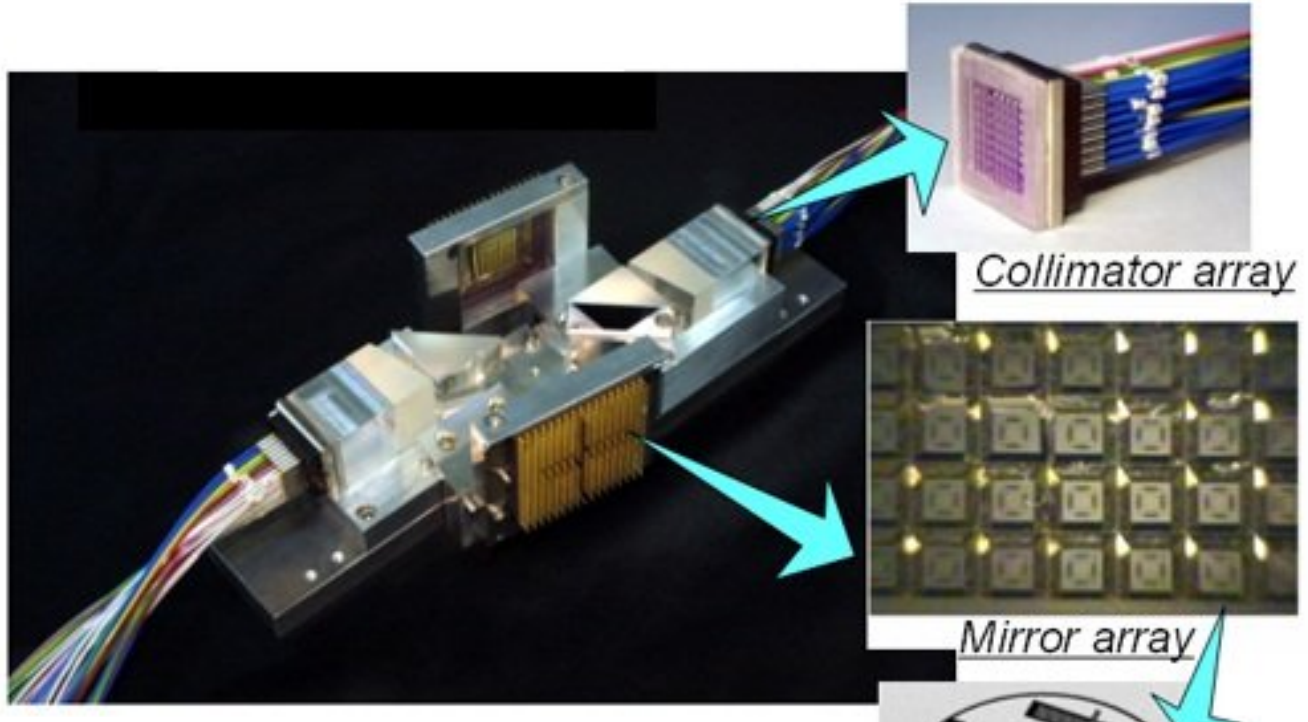


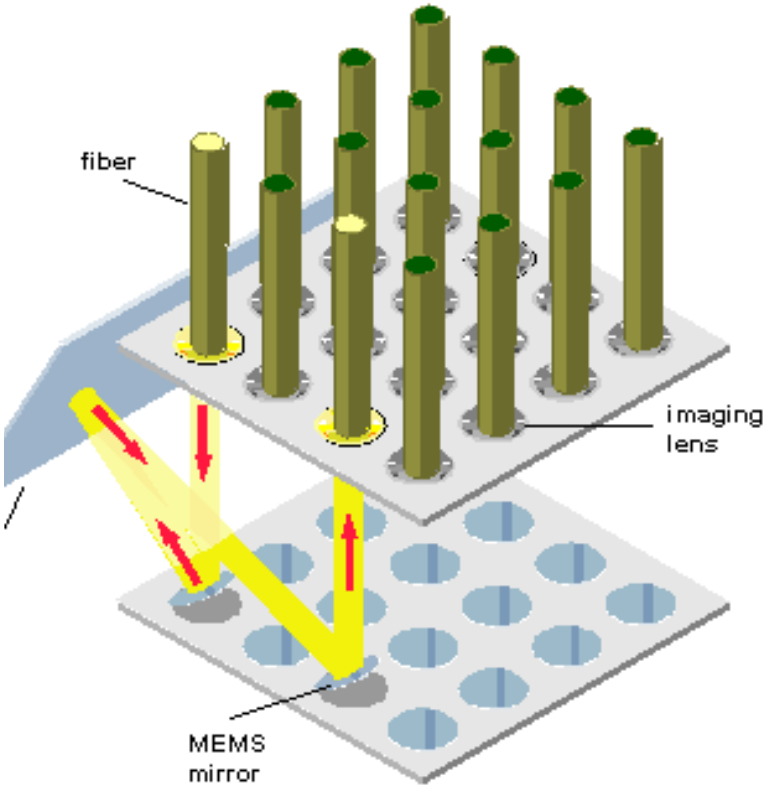
Cross connect



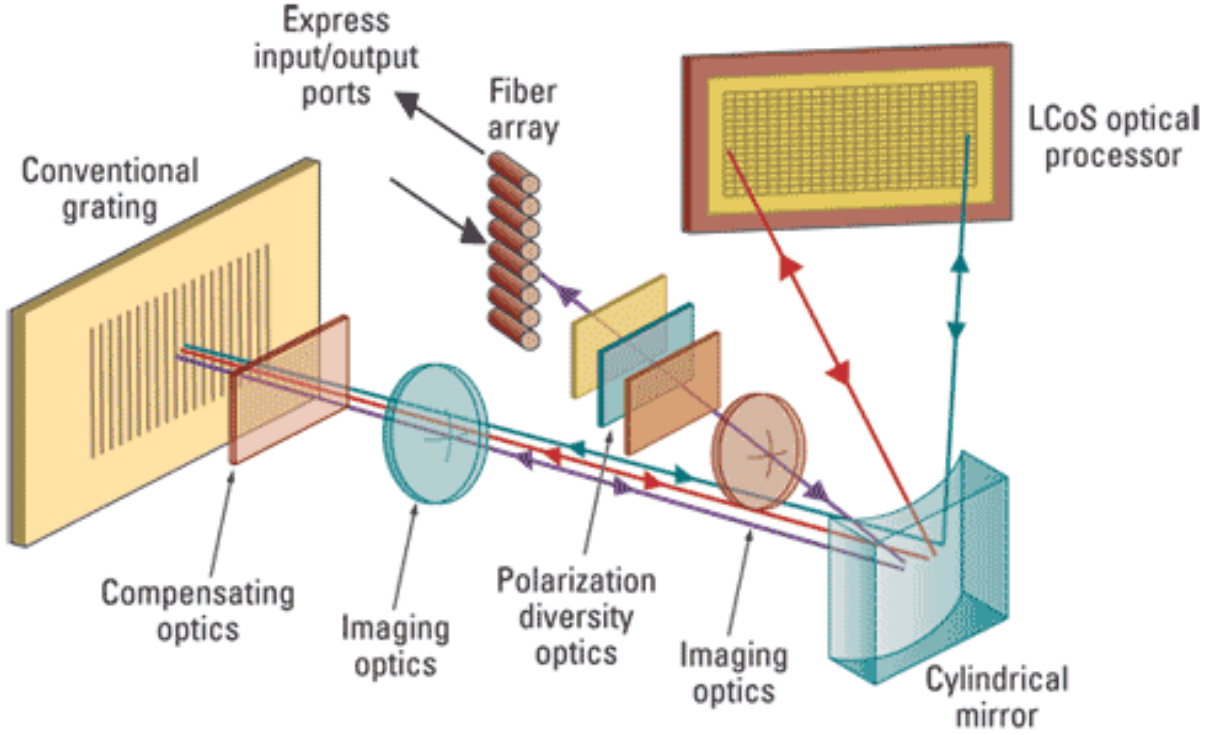
Cross Connect
- Leading technology -

- O-MEMS based
- Mirrors on gimbals mount
- Mirror reoriented to redirect the beam

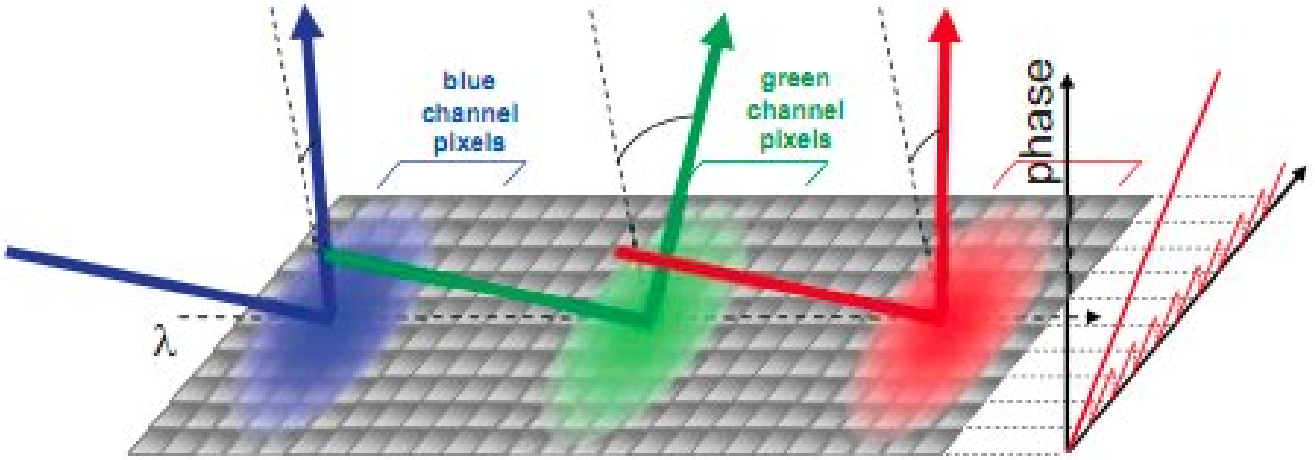




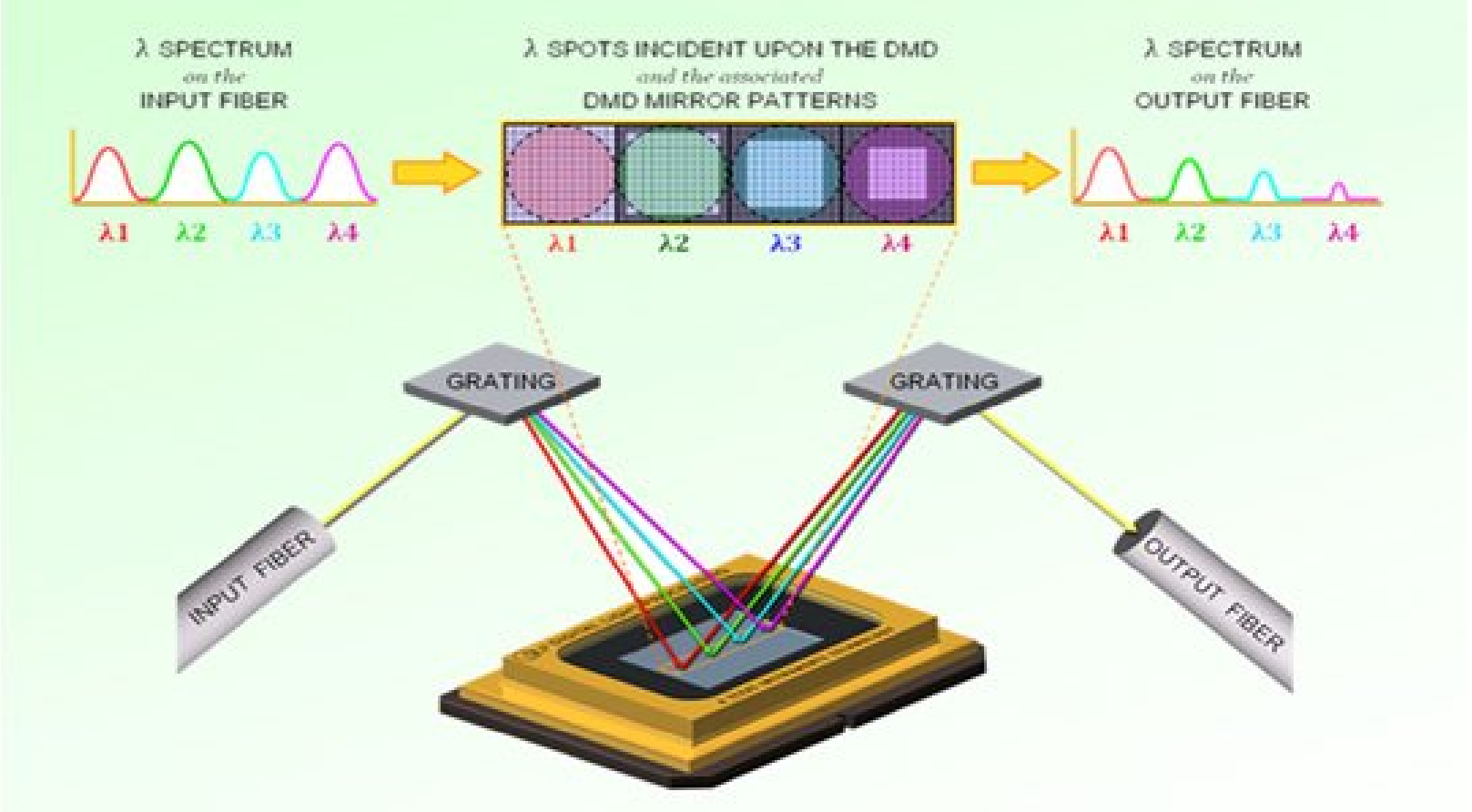
WSS
-Leading technology-



Flexible grid



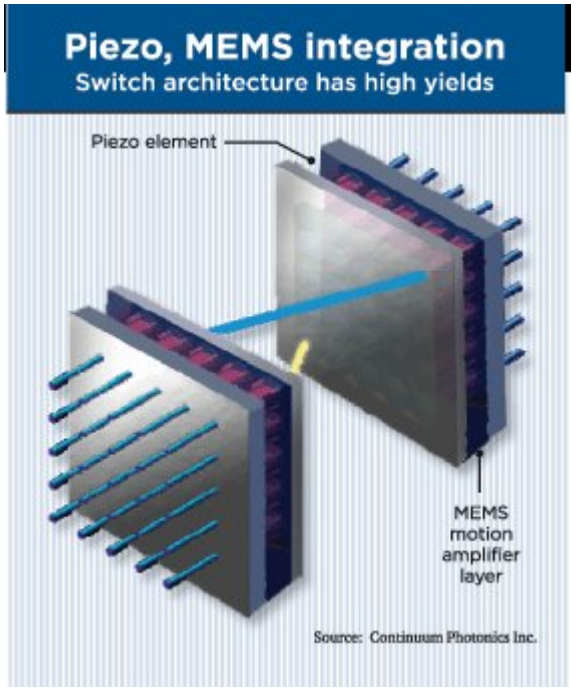
DLP Switch



On-off switch, no redirection of the light

Other technologies

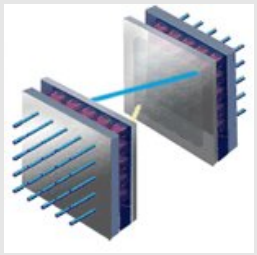
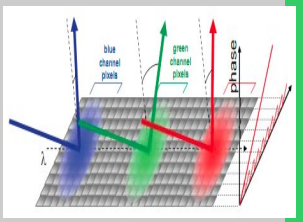
- Acousto-optic modulator (Bragg gratings)
- Piezo electric transducer
- Liquid lens
- ...



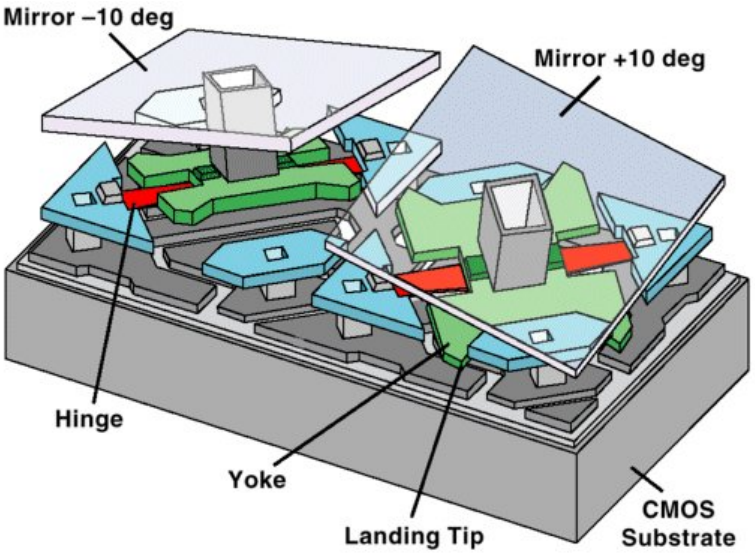
Metrics:

- Number of ports (scalability)
- Power consumption
- Loss (6-9 dB)
- Reconfiguration speed
- Price per port

Metrics table

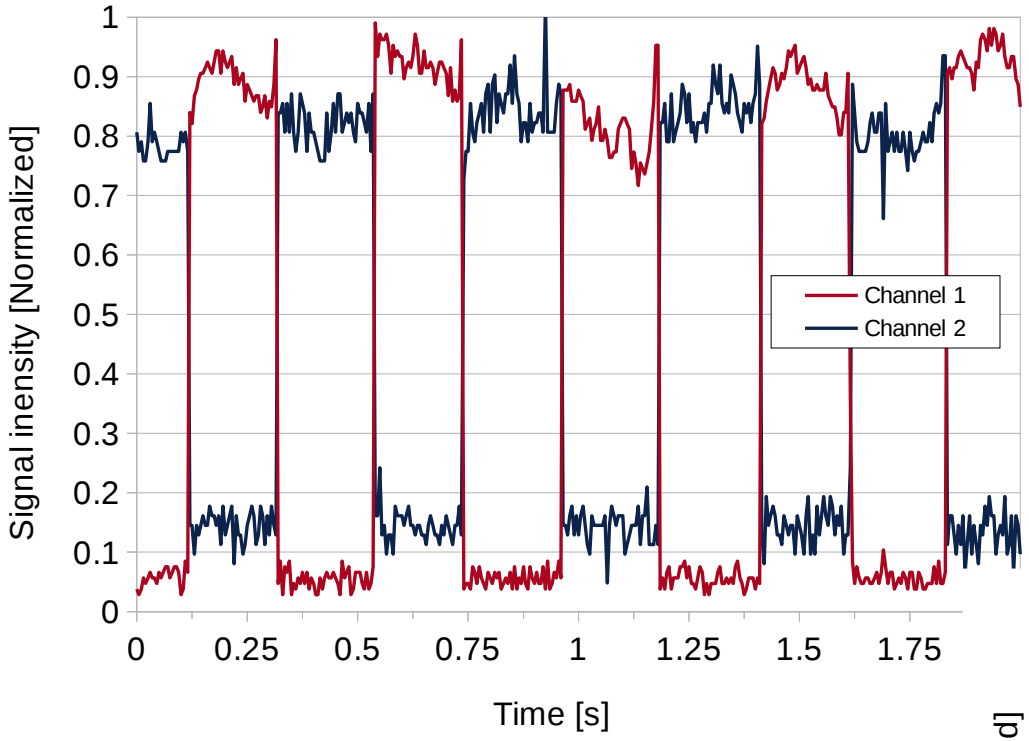
Technology	Port count	Loss	speed	Power	Reliability
3D MEMS 	High	Low	ms	45 W	Low
Micro-actuation 	Moderate	Low	ms	128W	Good
LCoS 	High	Low	ms	1W	High
DMD (on-off)	High	Low	µs	1W	High

Texas Instruments DLP



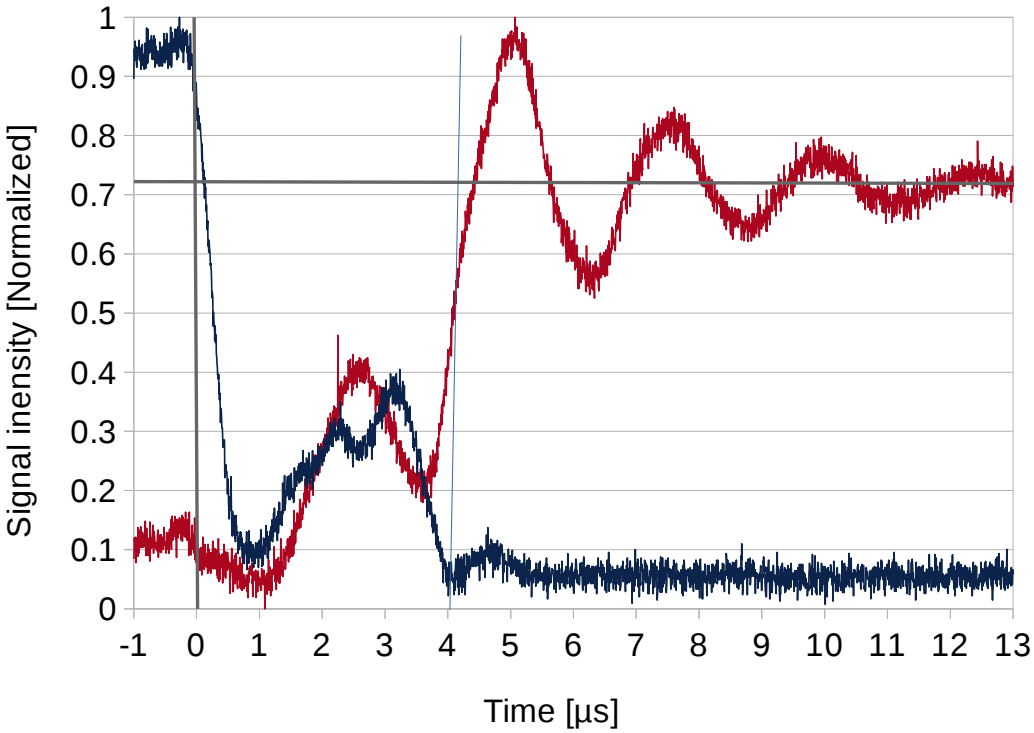
Speed

Refresh Rate vs Lost of Light Time



Refresh rate: <30 µs
Limited by controller electronic

Lost of light time: 12 µs
Limited by mirror resonance

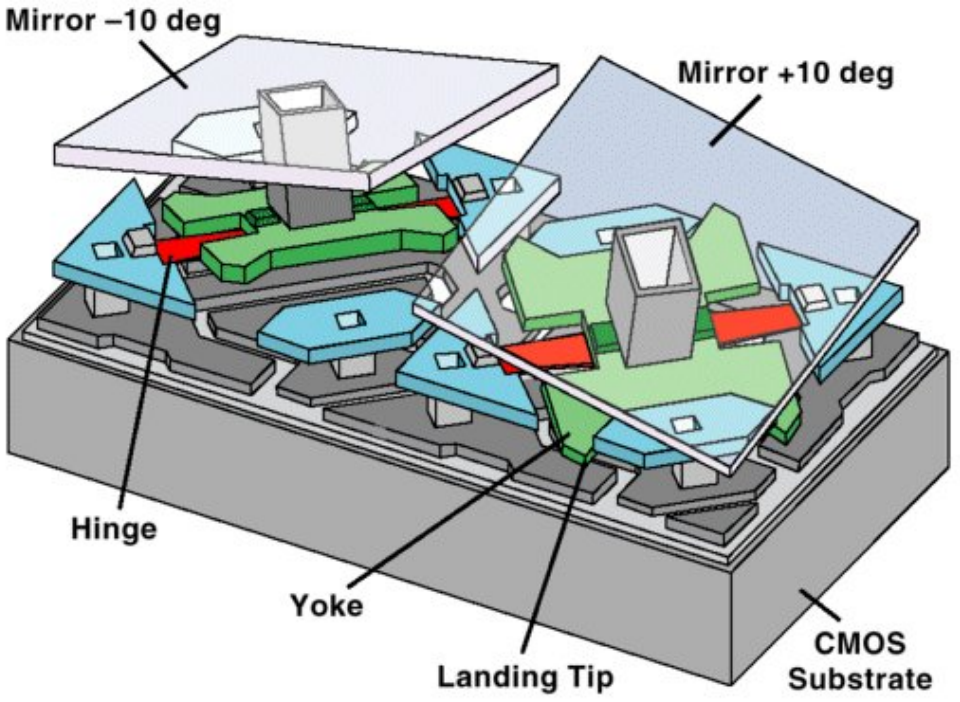


Redirecting the Light

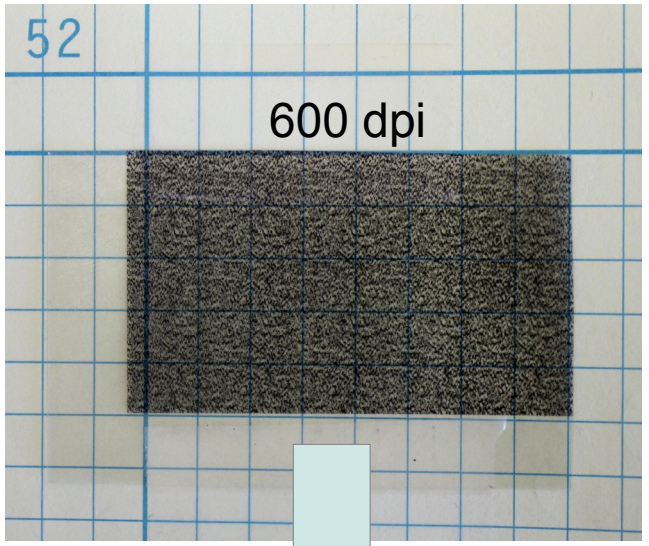
Digital = 2 positions → No control of the reflection angle

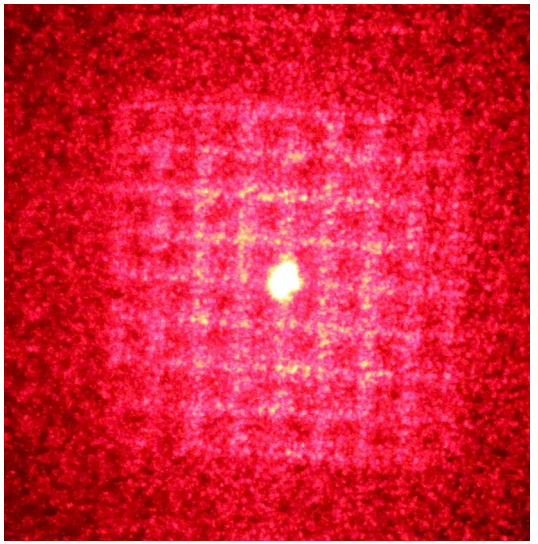
↓

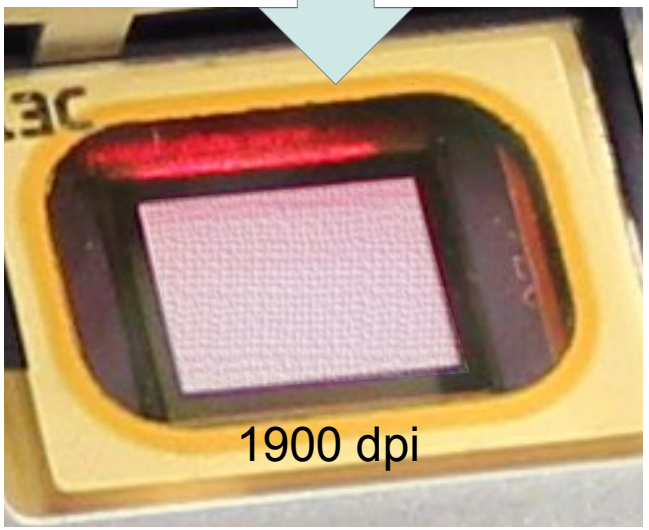
Use diffraction

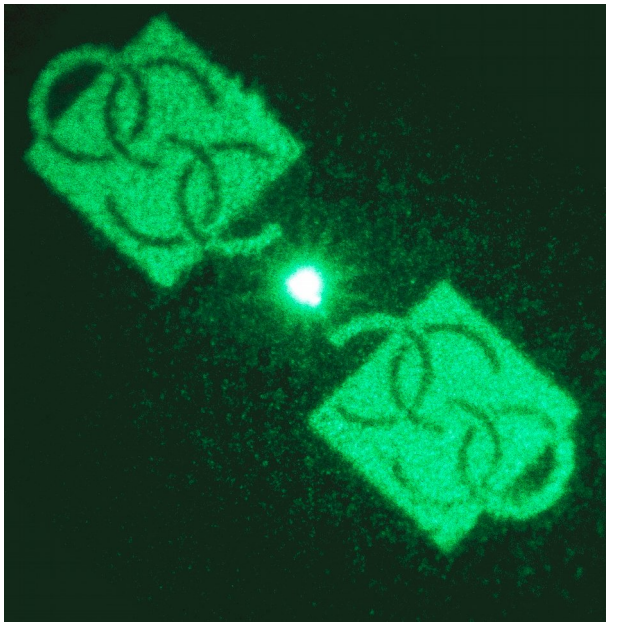


Diffraction

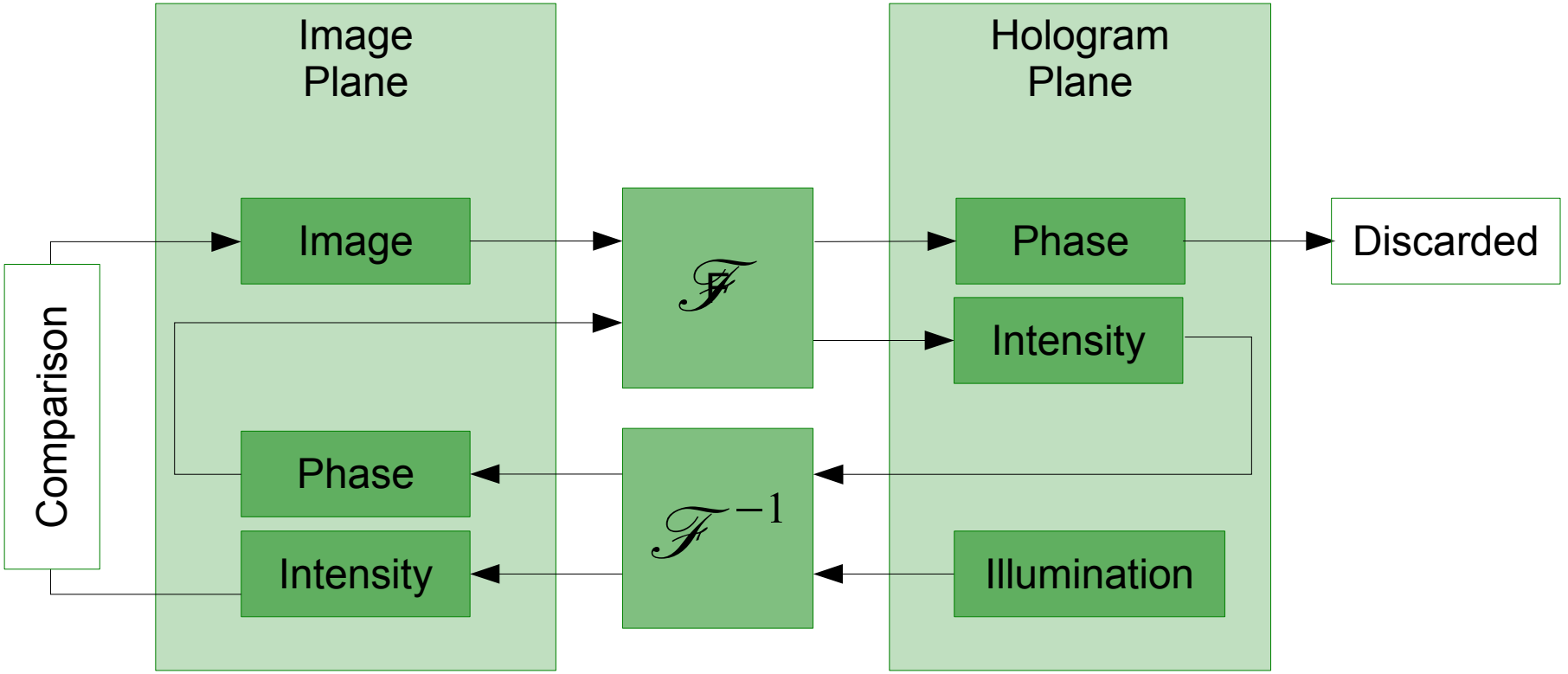






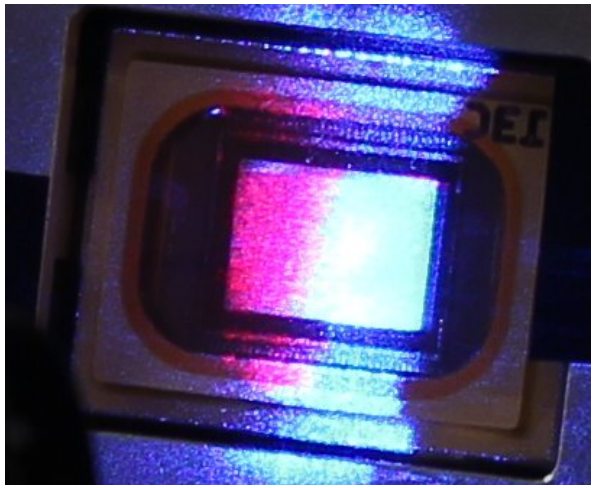


Hologram computation
Gerchberg-Saxton iterative algorithm

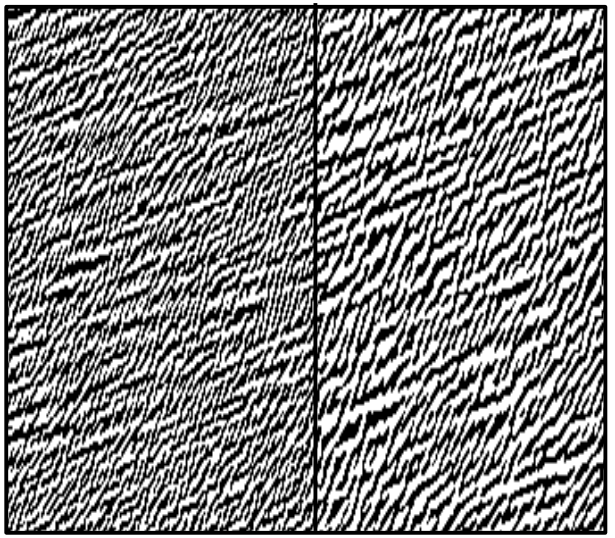


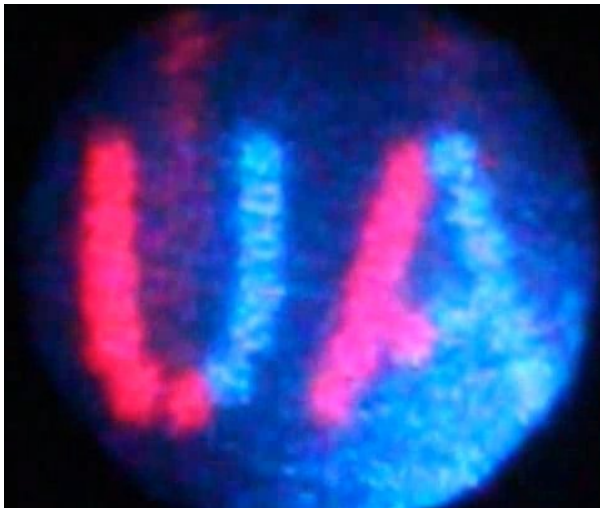
Example:
Multiple IN to multiple OUT

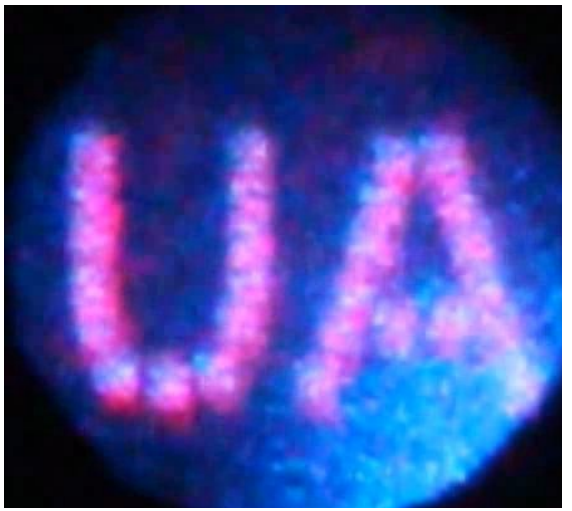
DMD illuminated with
2 different sources



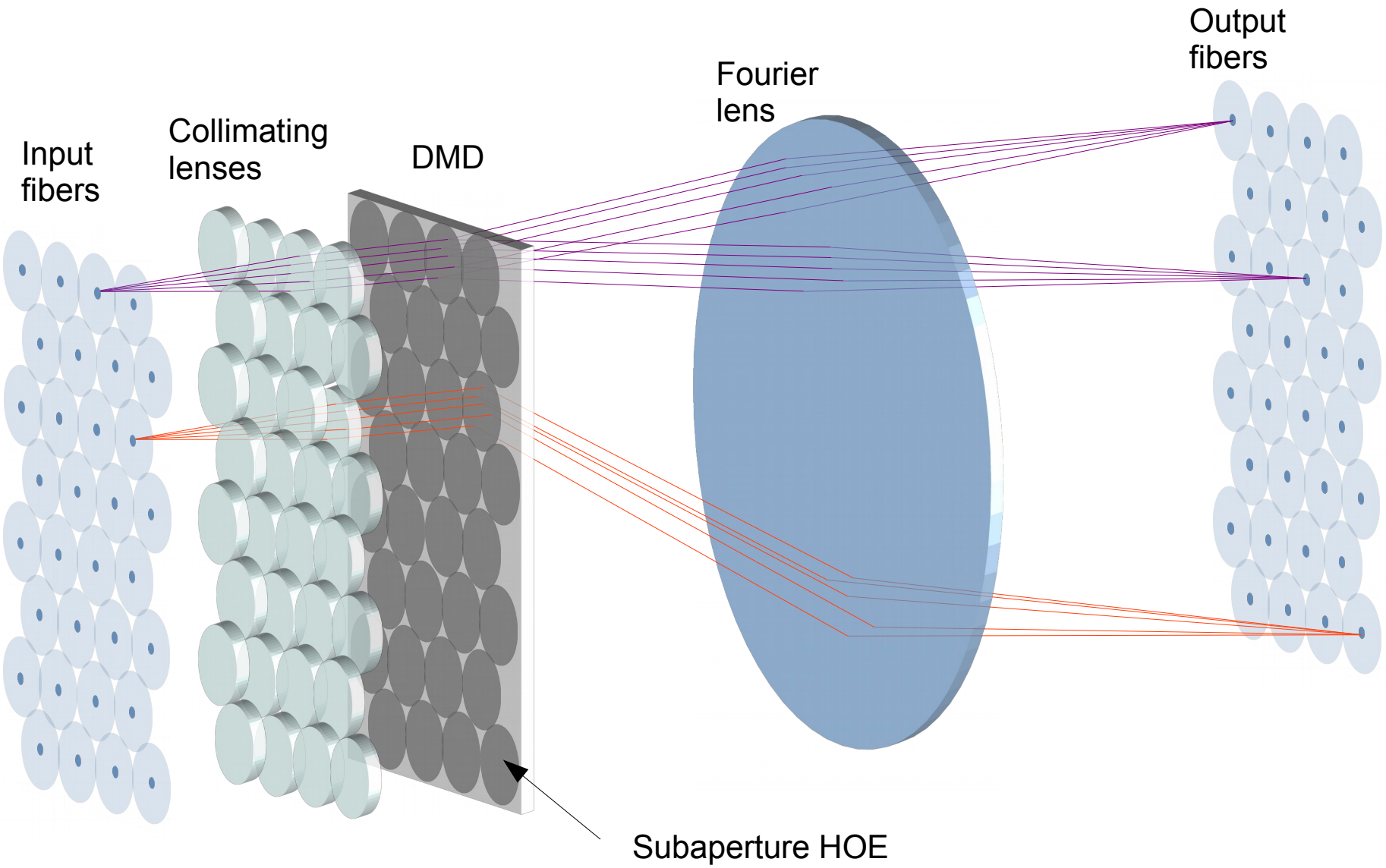
2 diffraction patterns



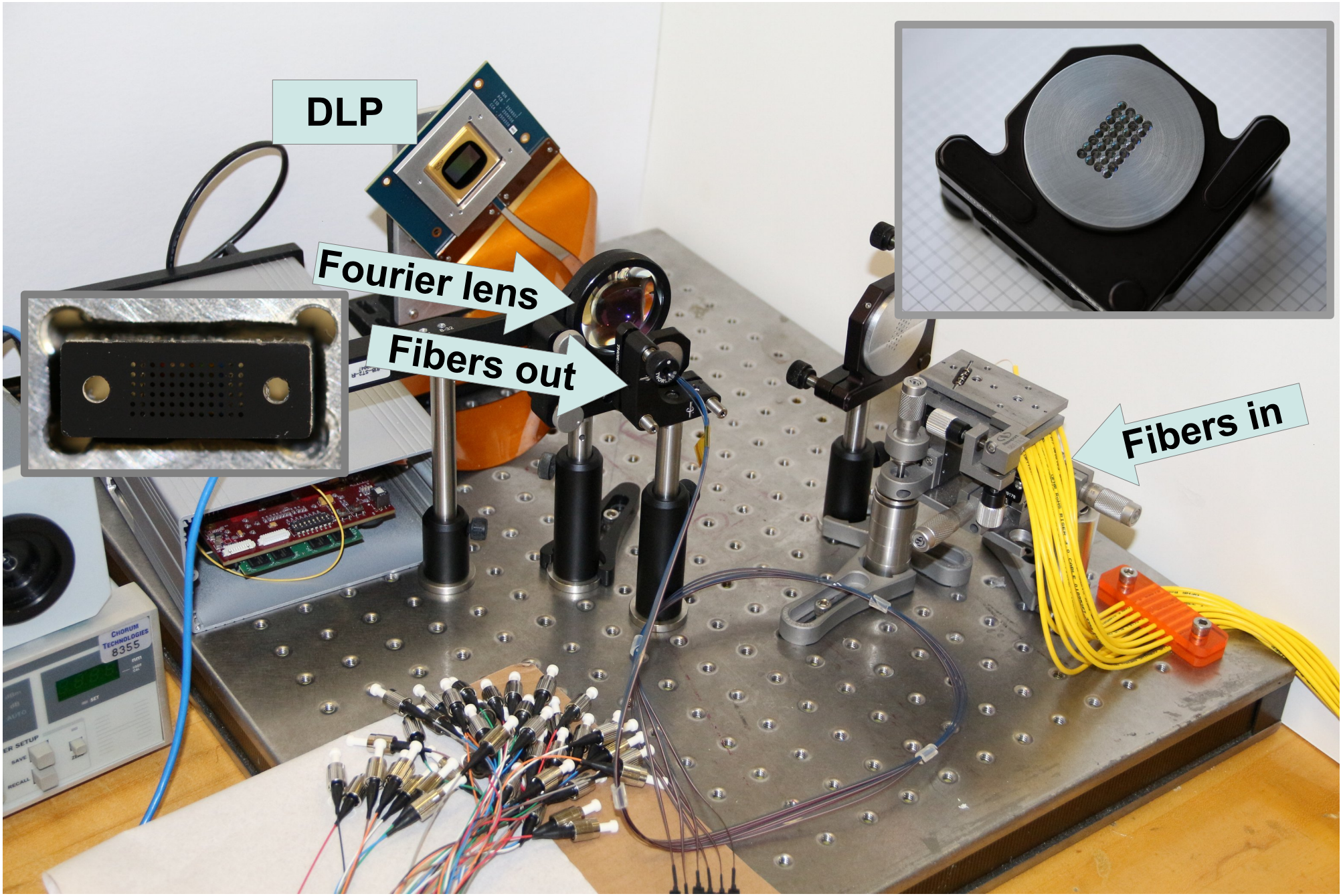




Cross connect schematic

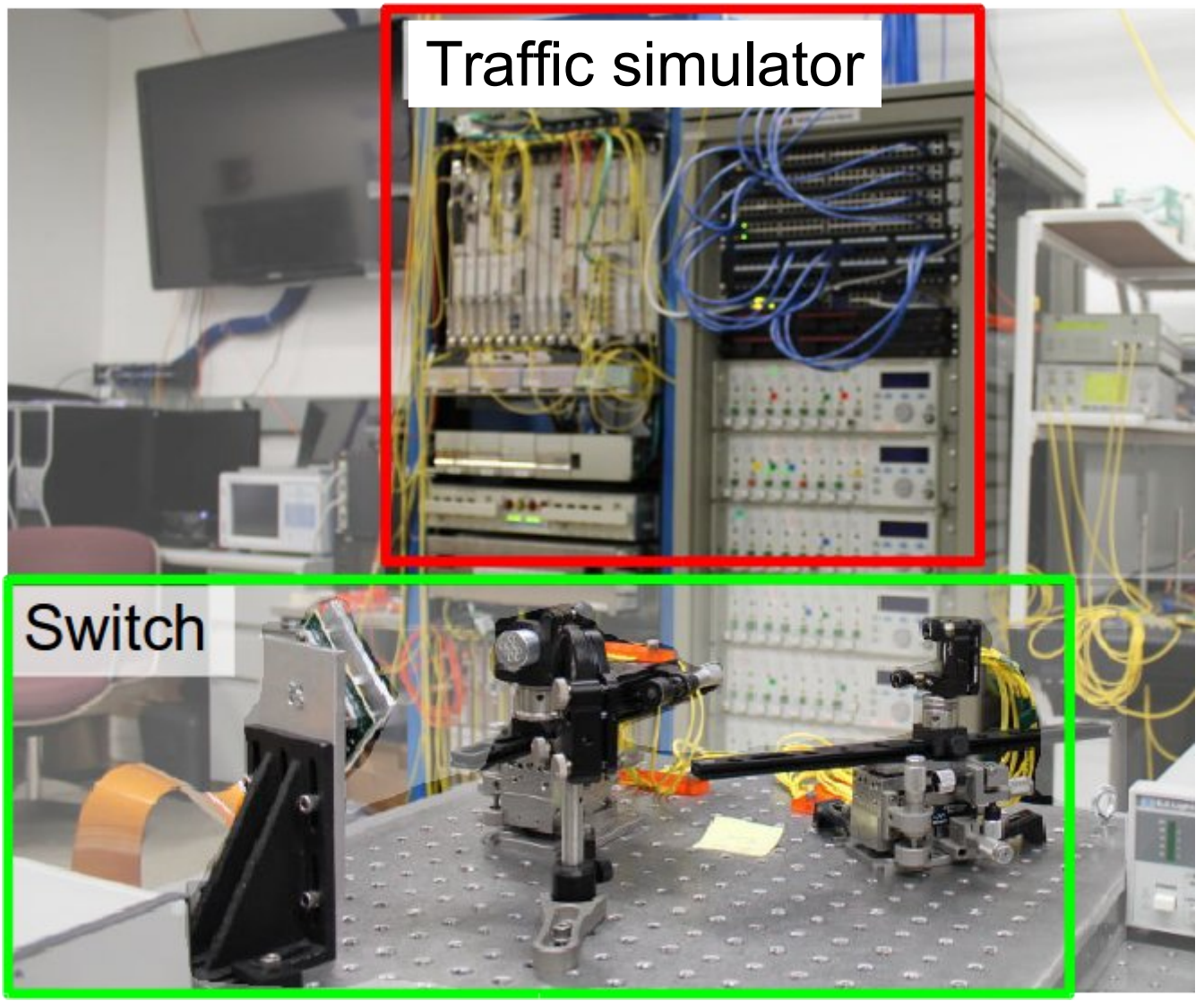


Switch Prototype

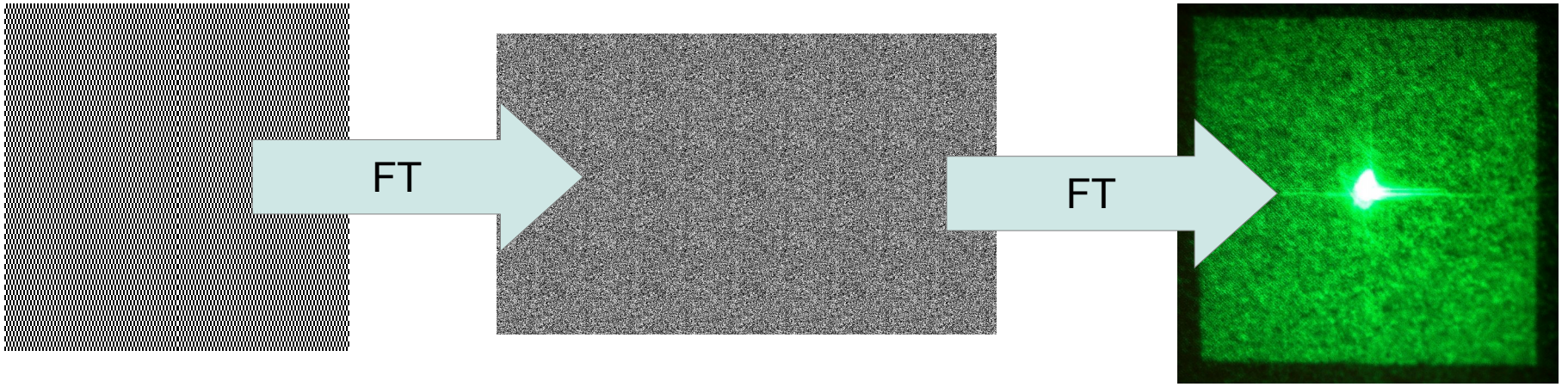


-Characterization-

Testbed insertion & video transmission ✓



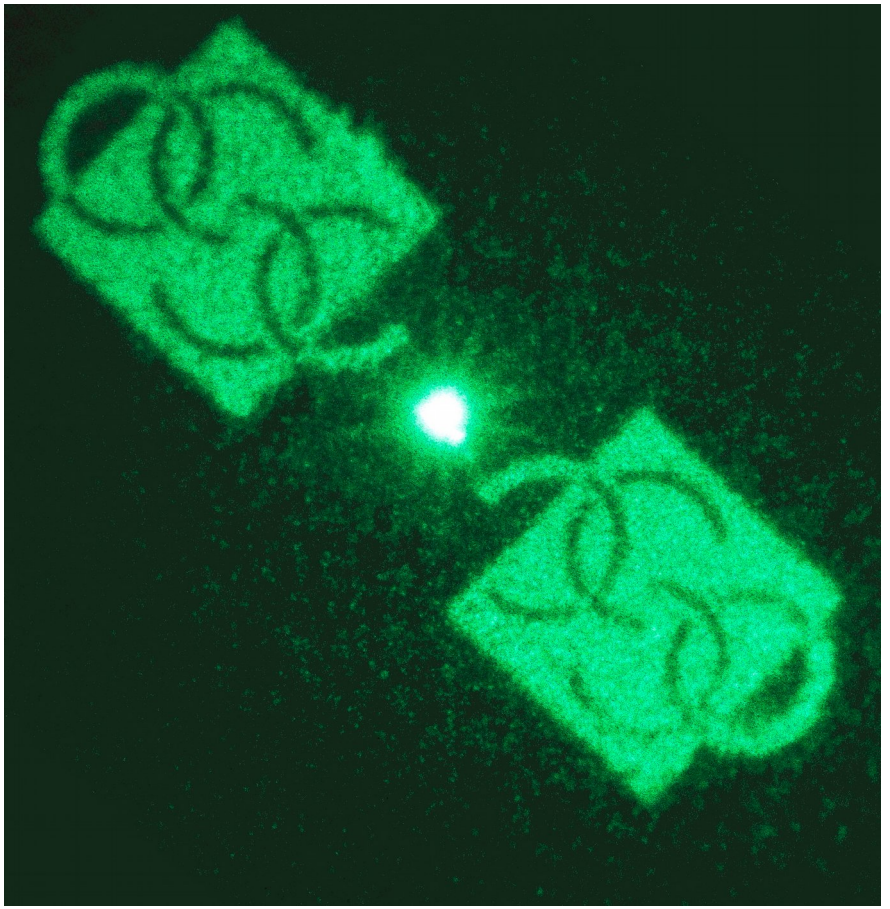
Scalability ?



DMD resolution: 1024x768 (786,432) → 1024x768 (786,432)

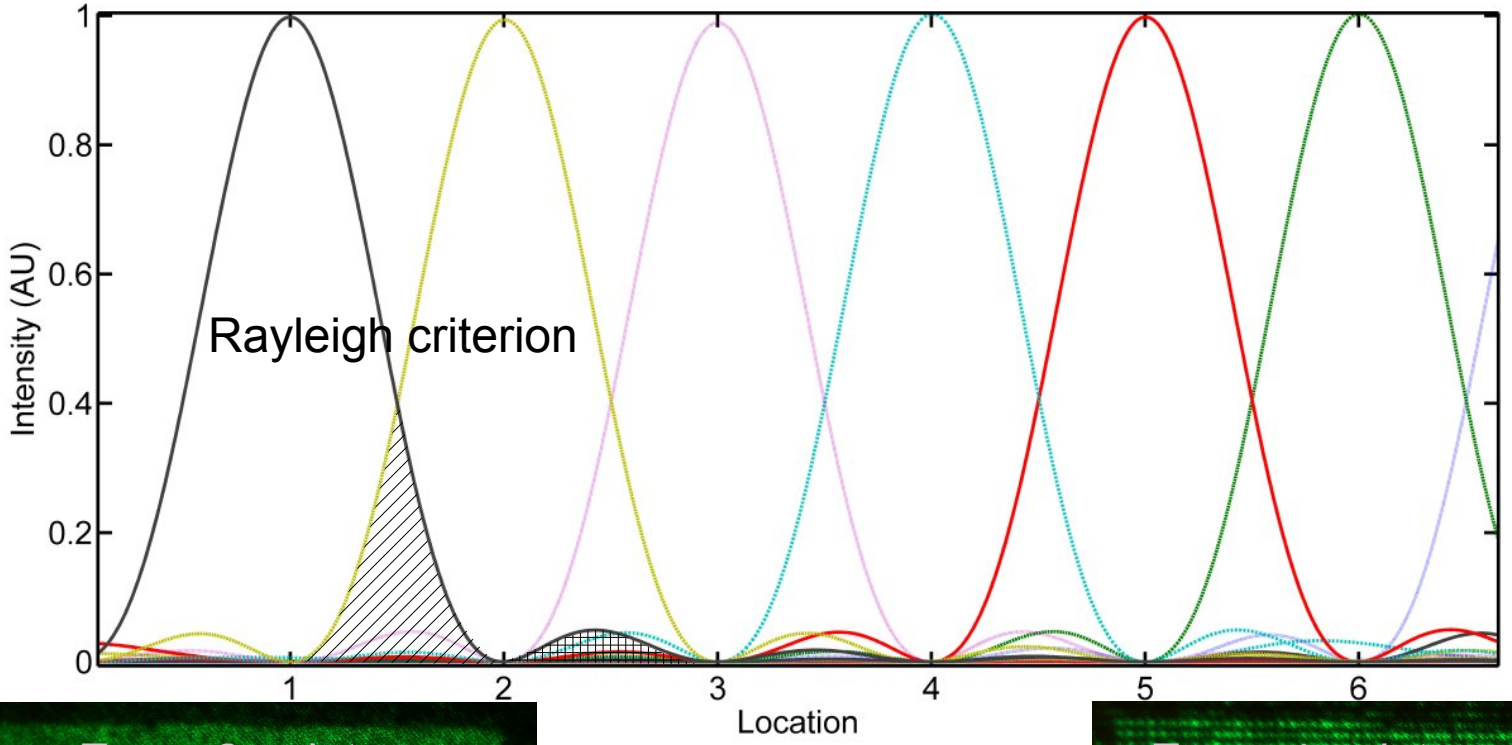
But ...

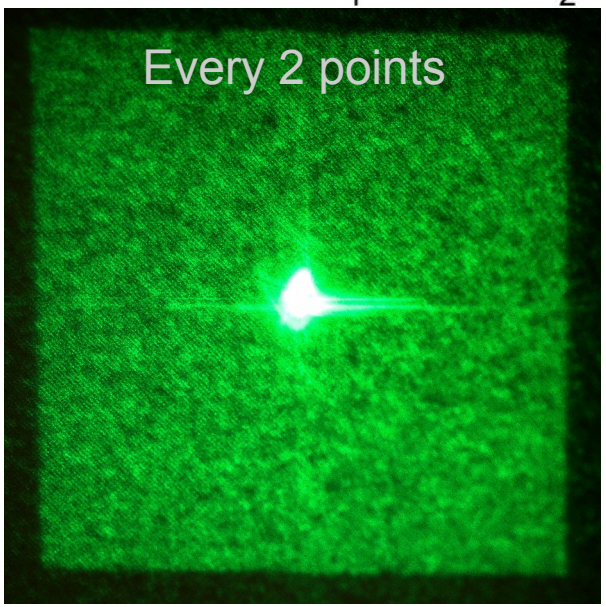
+1, -1 Orders

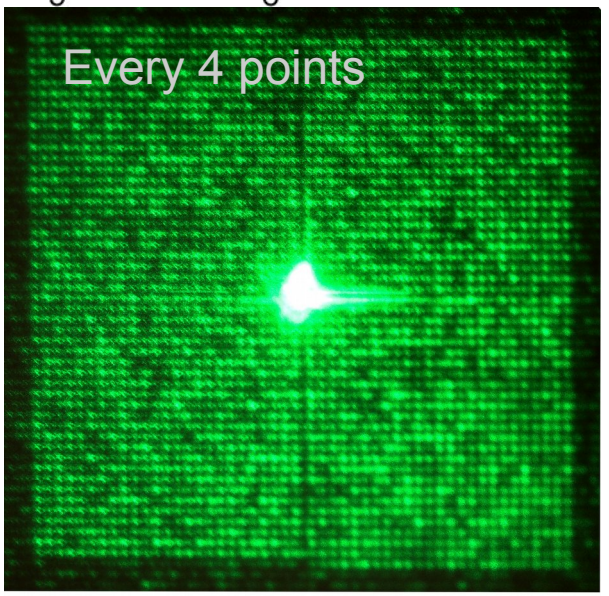


pixels / 2

Cross talk


Rayleigh criterion
Intensity (AU)
Location
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6

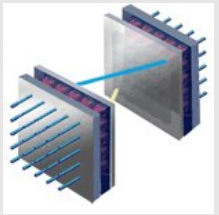
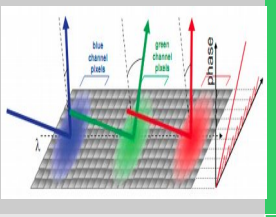
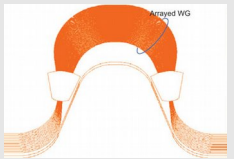

Every 2 points


Every 4 points

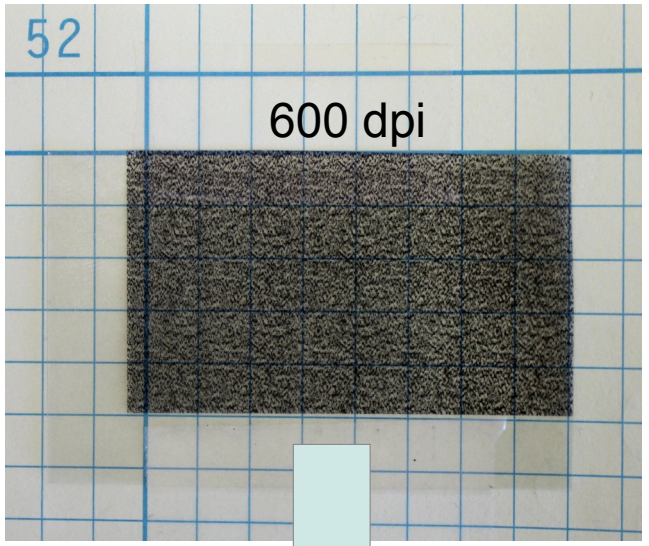
Number of output ports

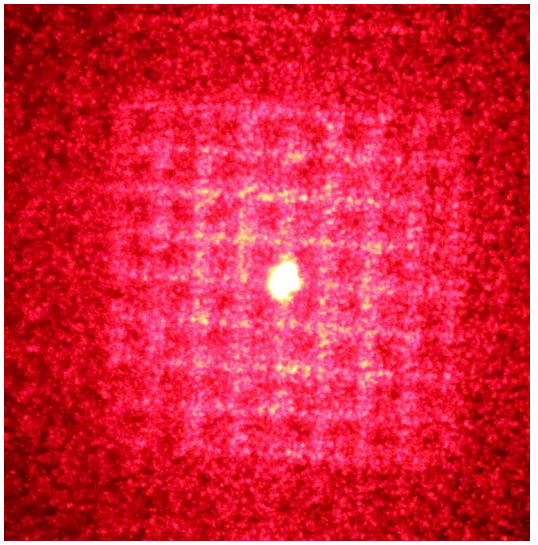
	Number of Accessible Locations (XGA)	Crosss-talk (dB)
Theory	786,432	-
+/- 1 order (1/2)	393,216	-5.77
2nd neighbor (1/4)	98,304	-29.76
3rd neighbor (1/9)	43,690	-35.06
4th neighbor (1/16)	24,576	-41.29

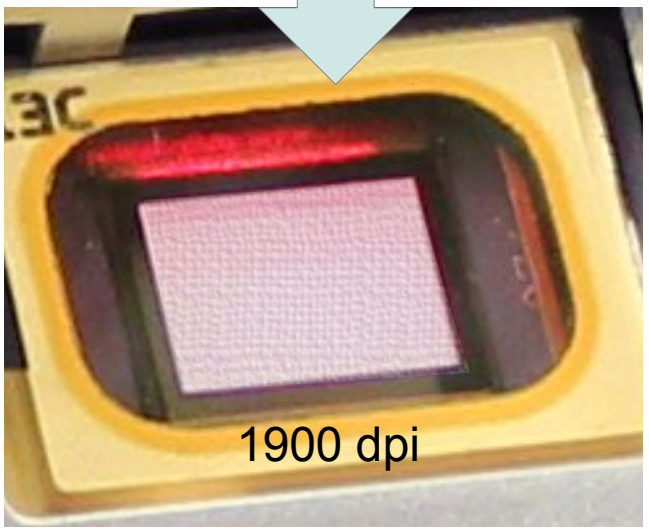
Metrics table

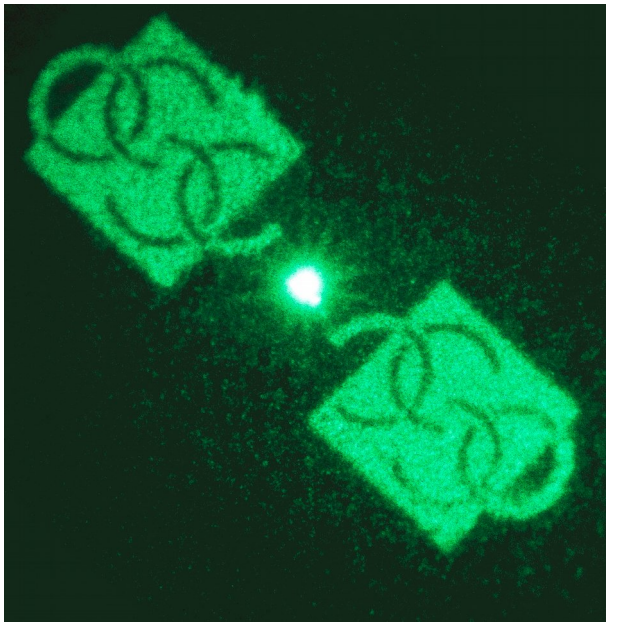
Technology	Port count	Loss	speed	Power
3D MEMS 	High	Low	ms	45 W
Micro-actuation 	Moderate	Low	ms	128W
LCoS 	High	Low	ms	1W
AWG/SOA 	High	Moderate	ns	50W
DLP Holographic	Super High	Moderate	µs	1W

Binary amplitude modulation

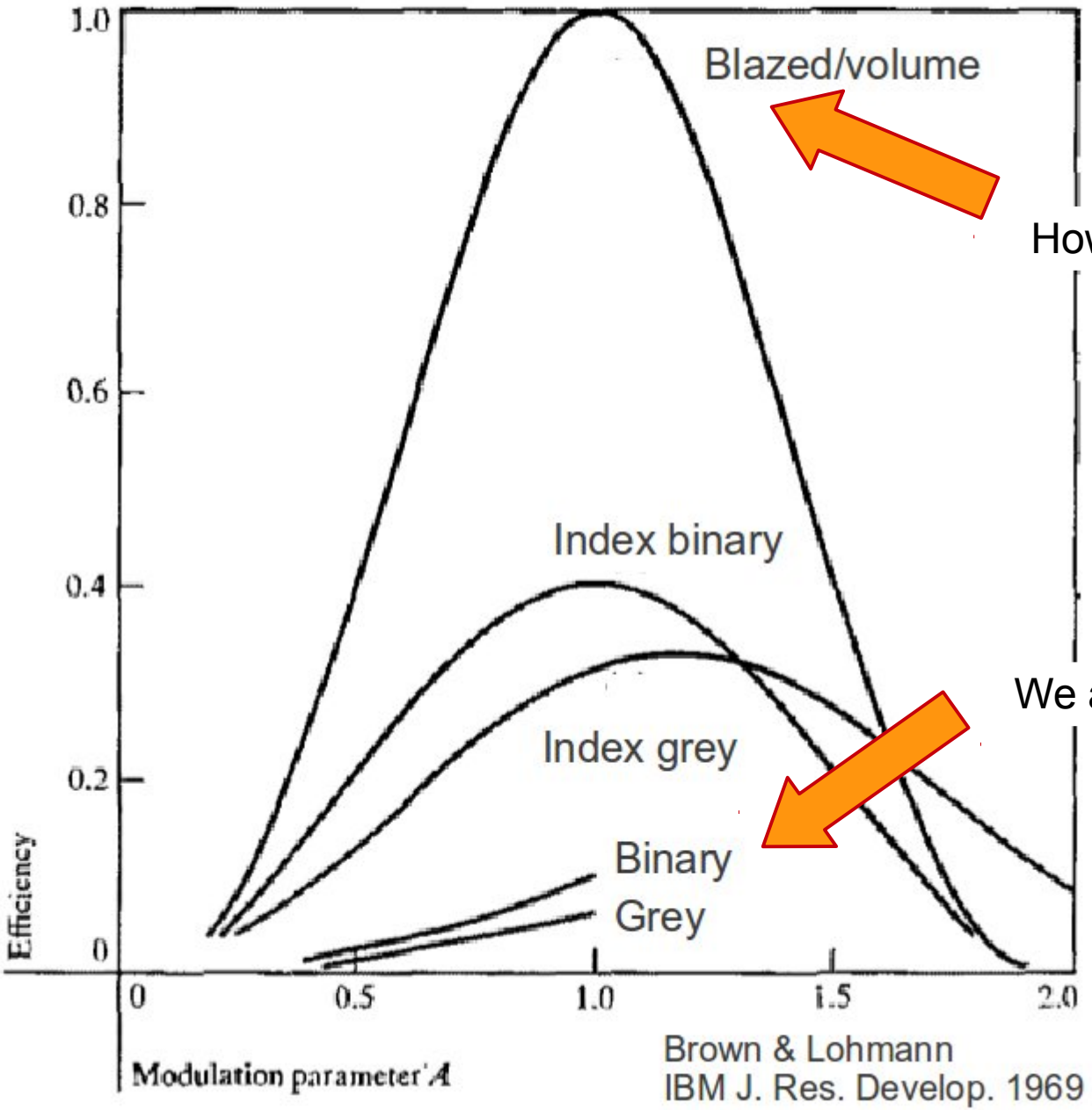








Theory: 10% Efficiency



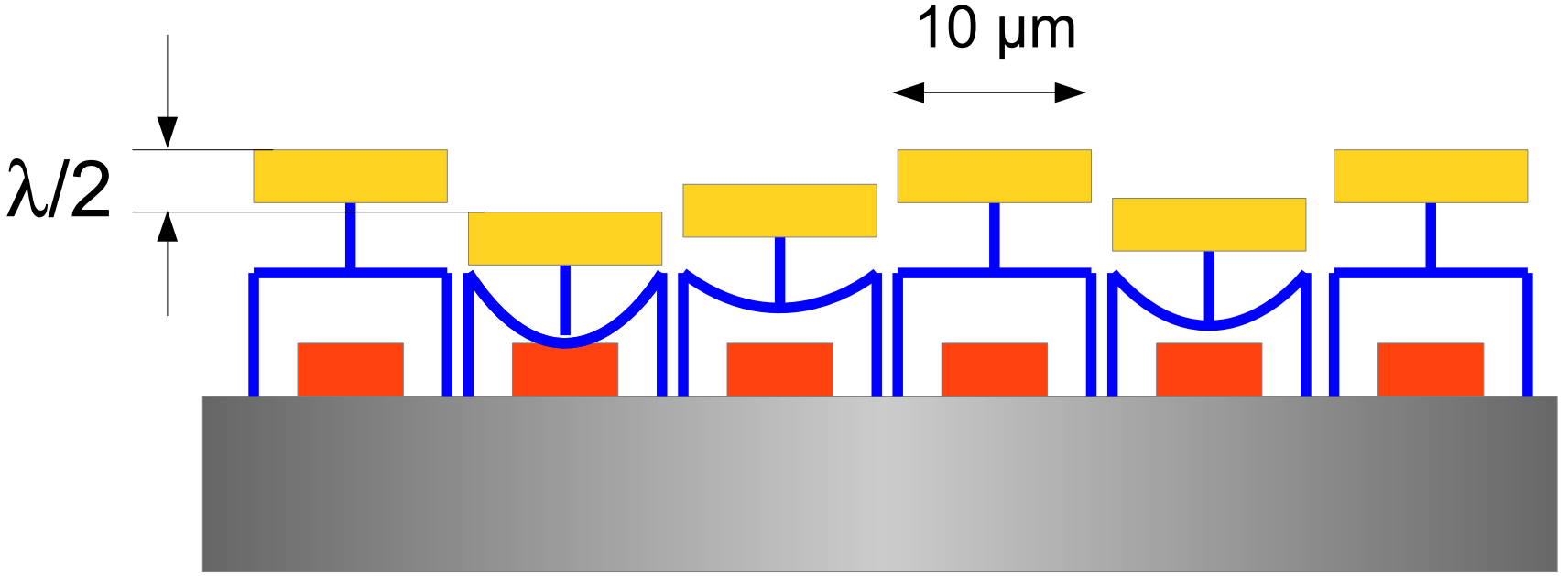
How do we get there?

We are here!

Brown & Lohmann
IBM J. Res. Develop. 1969

Phase modulation

- LCOS → 200 Hz
  Polarization sensitive
- Piston MEMS → π modulation (775 nm)
  10 µm mirrors



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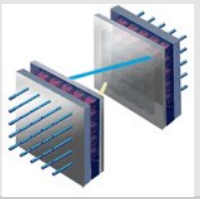
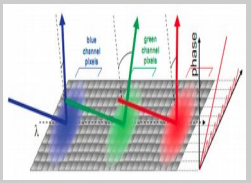
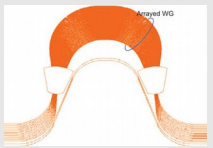
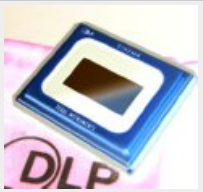
Micro-actuation 	Moderate	Low	ms	128W
LCoS 	High	Low	ms	1W
AWG/SOA 	High	Moderate	ns	50W
DLP Holographic	High	Moderate	µs	1W
Piston MEMS 	High	Low	µs	1W

Texas Instruments piston MOEMS

FLEXURE-BEAM MICROMIRROR SPATIAL LIGHT MODULATOR DEVICES FOR ACQUISITION, TRACKING, AND POINTING

Troy A. Rhoadarmer, Steven C. Gustafson, and Gordon R. Little
Research Institute, University of Dayton
300 College Park
Dayton, OH 45469-0140
and
Tsen-Hwang Lin
Texas Instruments, Inc.
13588 N. Central Expressway
Dallas, TX 75265

ABSTRACT

The new flexure-beam micromirror (FBM) spatial light modulator (SLM) devices developed by Texas Instruments Inc. have characteristics that enable superior acquisition, tracking, and pointing in communications and other applications. FBM devices can have tens of thousands of square micromirror elements, each as small as 20 microns on a side, each spaced relative to

Future works

A commercial high port count reconfigurable optical switch:
ROADM, WSS, OXC … all in one!