Micro-optical switches for future telecommunication payloads : achievements of the SAT 'N LIGHT Project

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3) Contraves Space

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4) imt

Micro-optical switches for future telecommunication payloads

- I. Sat´n Light
- II. Performance of sercalo´s 4x4 ***cascaded*** optical MEMS switch
- III. Performance of the 8x8 ***monolithic*** optical MEMS switch
- IV. Conclusion

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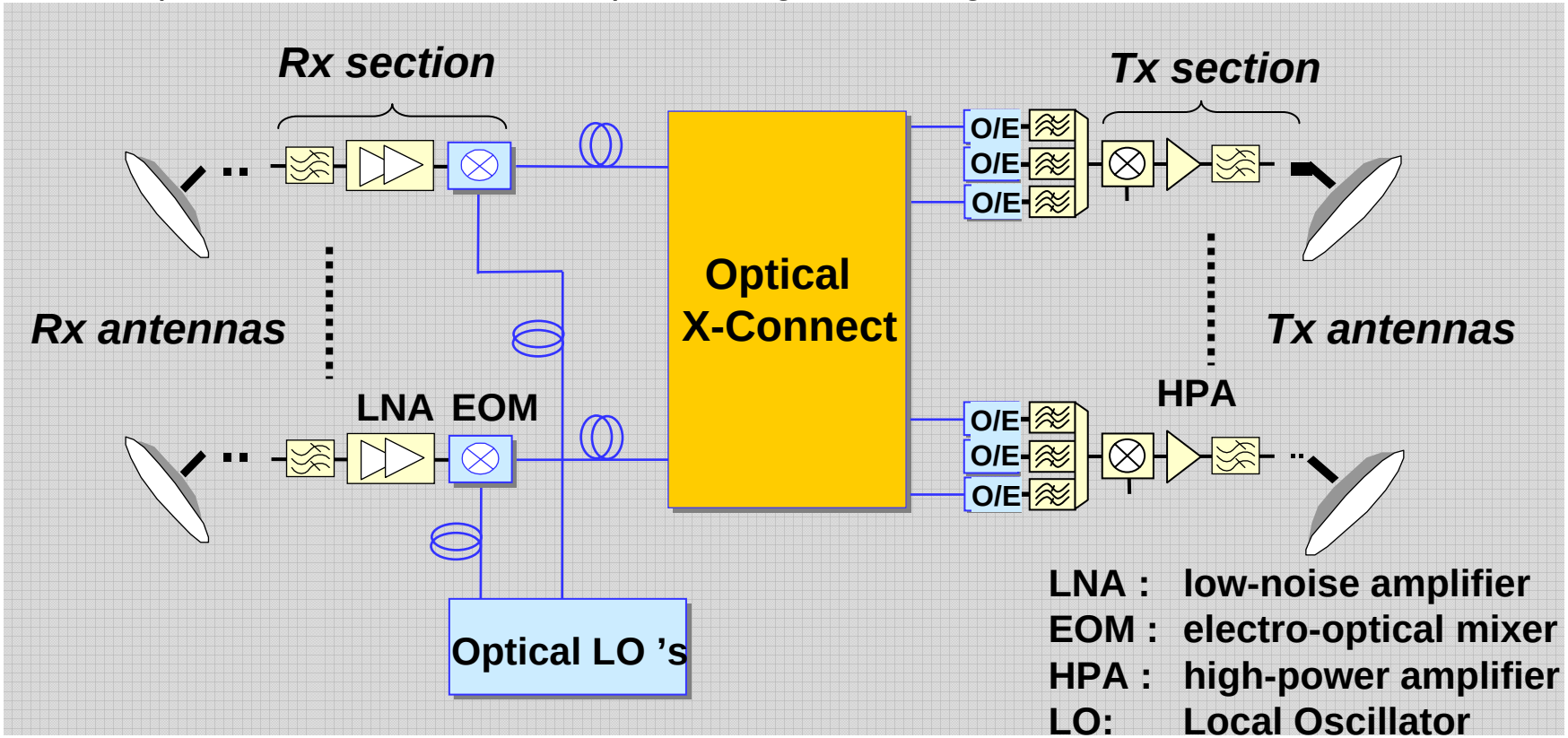
- Activity Title : *Optical Handling of Microwave and Digital Signals*
- Nickname : *SAT 'N LIGHT*
- Funding : ESTEC contract n°15695/01/NL/ND (Technology Research Programme)
- Objectives
  - Study and demonstrate the use of optical techniques and technologies for all possible applications of electronic signals of any form on-board of satellite payloads
  - Assess the potentials of optical technologies for such applications, by contributing to new payload designs, designing payload functional blocks based on all-optical or hybrid optoelectronic modules, and demonstrating their performance through breadboarding of a selected number of modules / systems

Satellite telecom payload with flexible beam-to-beam connectivity

- optical generation & distribution of high-frequency LO's (> 10 GHz)
- optical frequency mixing and down-conversion, e.g. from Ka (30GHz) to C (4GHz)
- optical cross-connection of µ-wave signals through MOEMS switches



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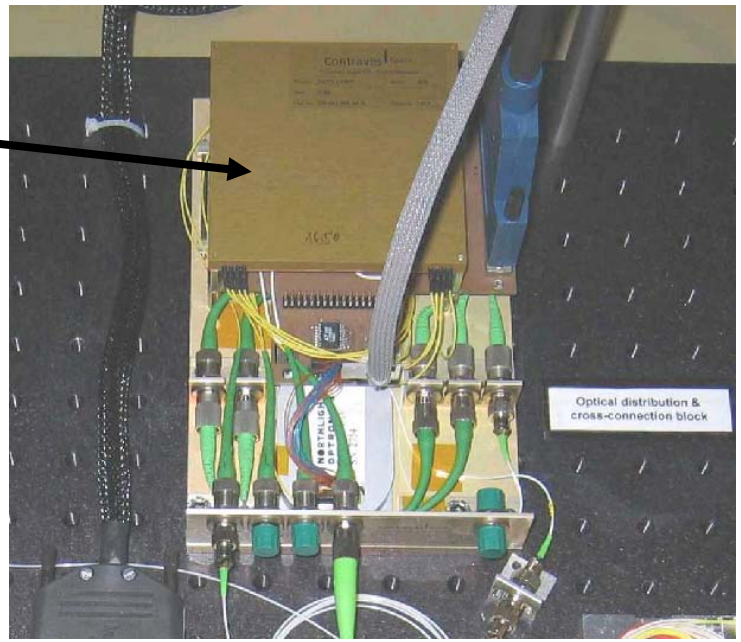
Why MEMS based high-performance optical cross connect ???

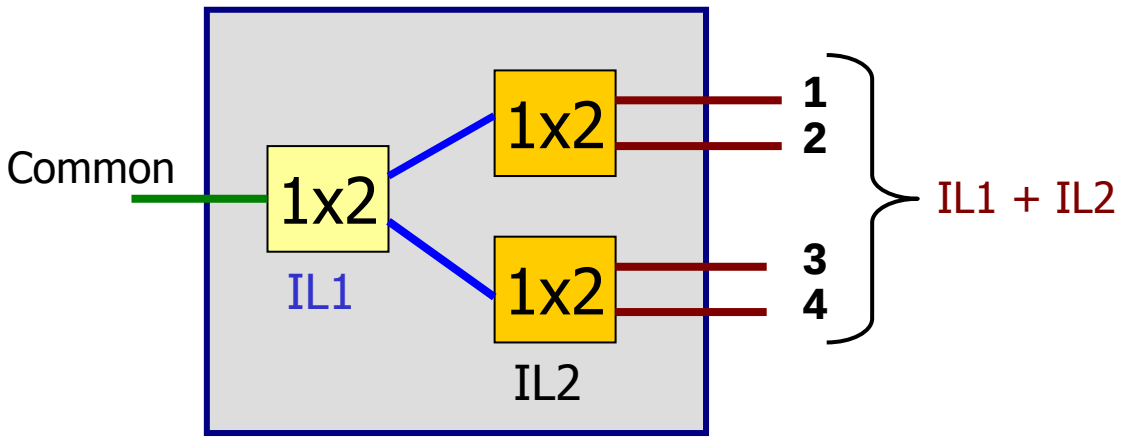
Sercalo´s MEMS based optical 4x4 latching switch

Integrated by CONTRAVES Space AG



- Solid state reliability
- NO observable RF crosstalk (< -70 dB) whatever the OXC configuration
- NO degradation of the linearity performance
- NO observable increase of phase noise of microwave signals

1x4 Cascading principle

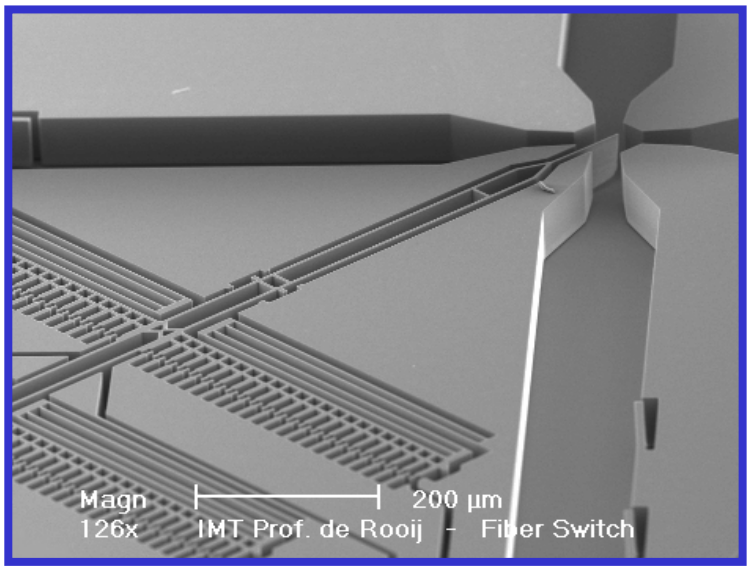


Advantages

- ✓ Low insertion loss at small port count
- ✓ Flexibility in design
- ✓ 6 years market proven

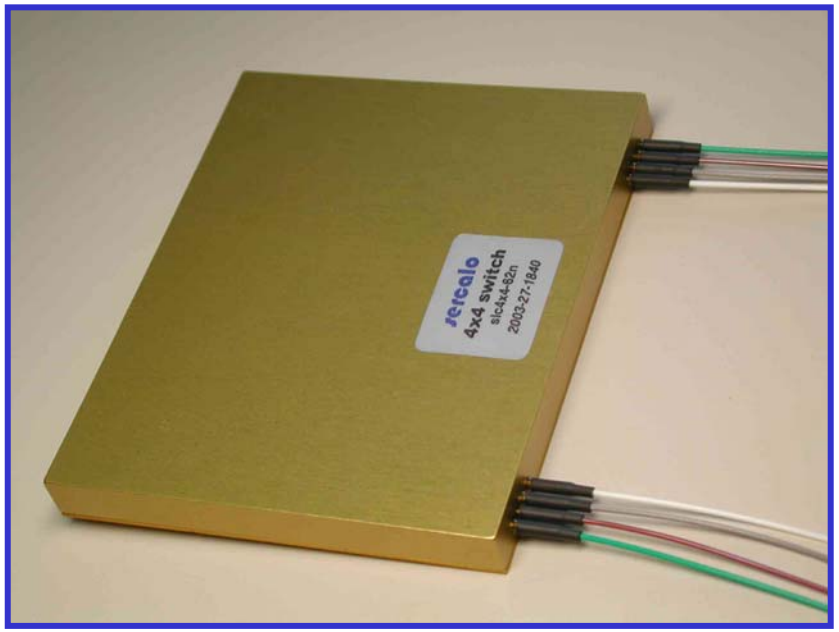
Disadvantages

- ✓ Large size due to fiber bends
- ✓ Very labor intensive assembly
- ✓ Almost impossible assembly at large port count
- ✓ Reliability decreases with complexity



Performance of sercalo´s 4x4 latching MEMS switch

- **Insertion Loss (IL):** < 1.65 dB
- **Cross Talk (CT):** > 69 dB
- **Polarization Dep. loss (PDL):** < 0.08 dB
- **Return Loss (RL):** > 52 dB
- **Power during switching:** 75mW
- **Power during operation:** 1mW
- **Switching speed:** < 1ms
- **Qualification:** Telcordia 1221



- **1x2 in Space Radiation Environment:** Co60 γ-ray radiation source at a dose rate of 330 rad/h to total dose up to 22.5 krad

(IEEE Transactions on nuclear science Vol.52,No.4, by G. Quadri, French Space Agency CNES)

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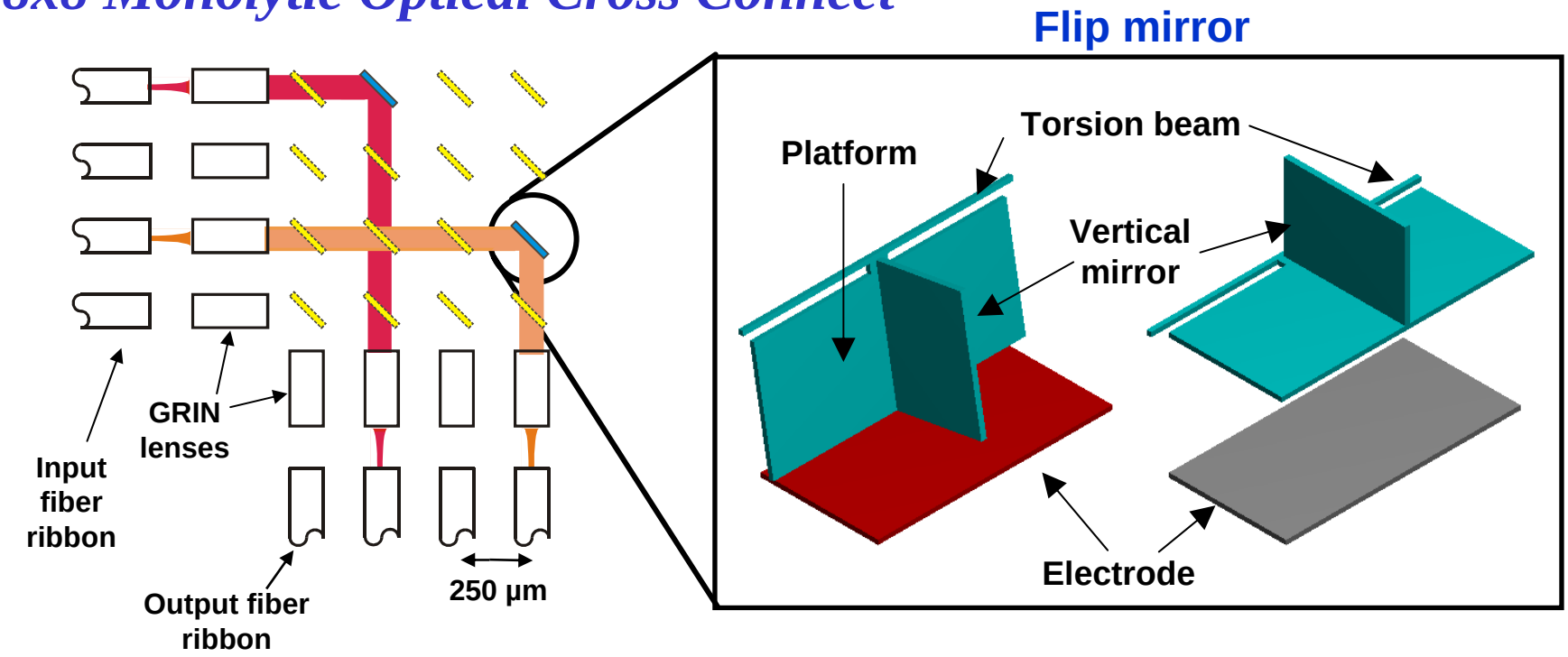
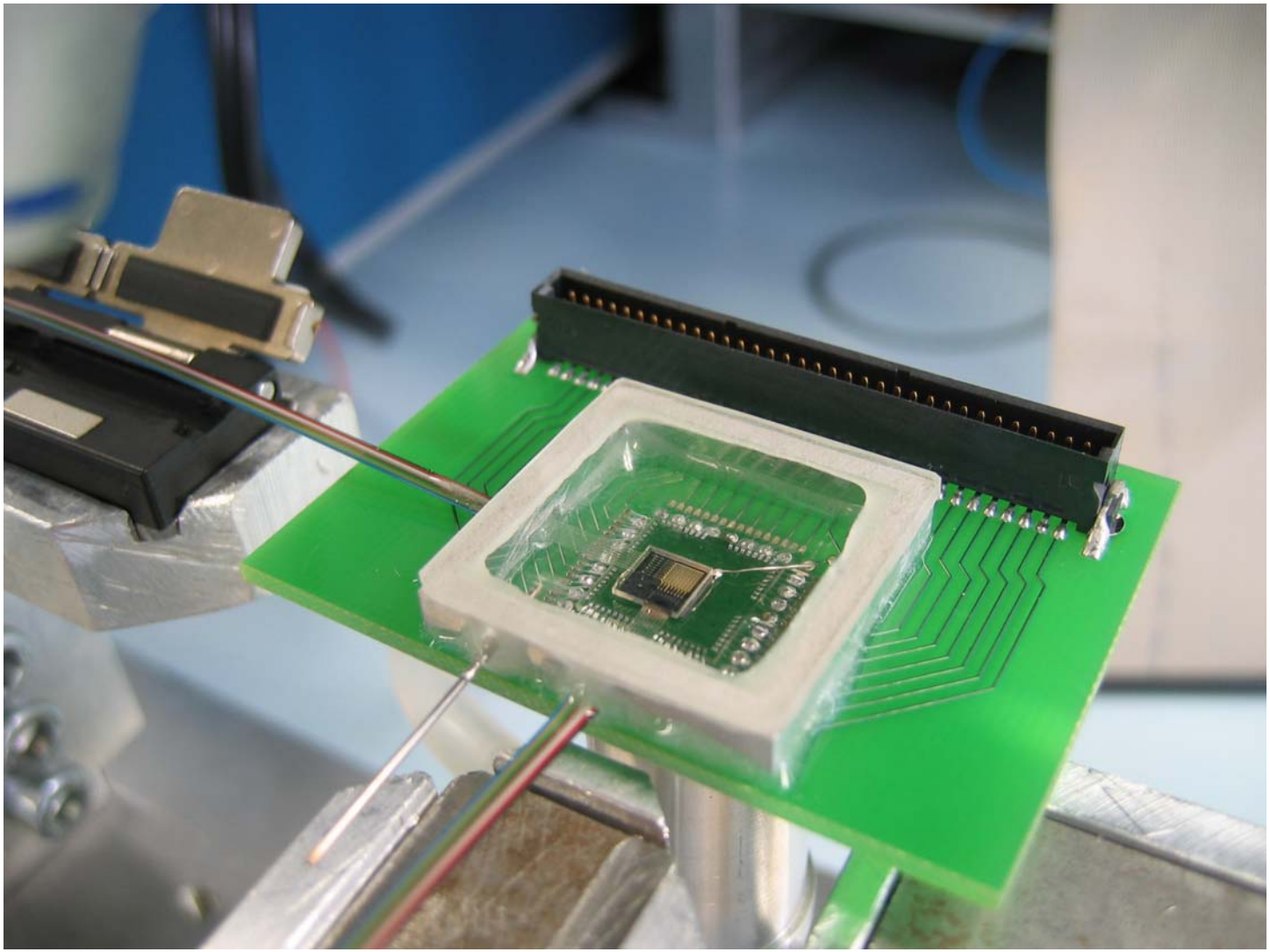
8x8 Monolytic Optical Cross Connect

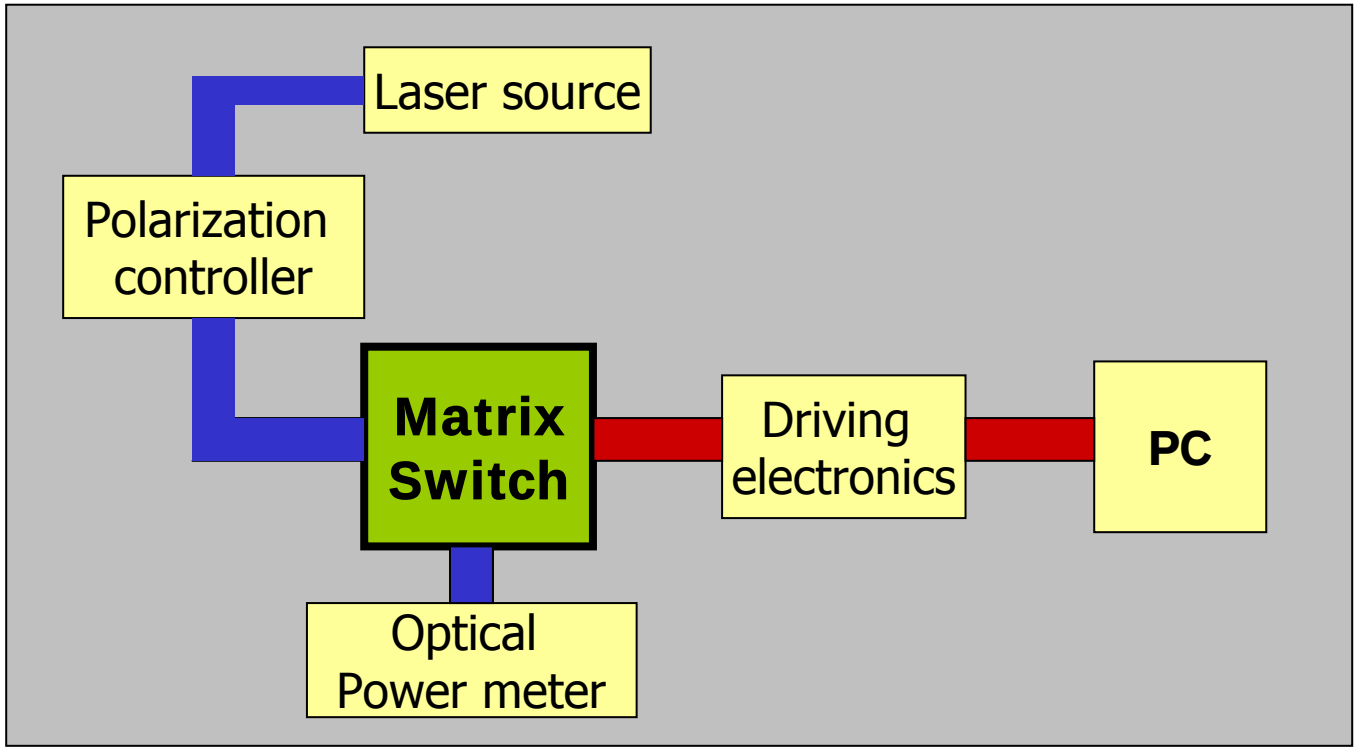


- Pitch of mirrors = pitch of fiber ribbons (250 µm)
- GRIN lenses for coupling efficiency at small foot print
- Flip mirrors with torsion hinges and bottom electrodes
- Mirror chip: silicon bulk micromachining (DRIE)
- Electrodes on separate chip

8x8 Monolytic Optical Cross Connect



Optical Performance



Equipment:

Laser source: Profile LDS 1550 at 1550nm wavelength

Laser power meter: Agilent 8164A with eight 81634A Power sensors

Polarization Controller: Agilent 11896A

Optical Performance

Best Value: 4.5 dB

Worst Value: 14dB

Insertion Loss [dB]

	Out 1	Out 2	Out 3	Out 4	Out 5	Out 6	Out 7	Out 8
In 1	N/A	6.5	5.7	6.3	7.5	7.9	8.9	10.9
In 2	4.5	6.5	7.9	8.8	9.6	10.4	9.8	13.5
In 3	7.2	9.1	10.4	9.9	11.2	10.7	13.3	13.3
In 4	6.5	8.0	8.6	9.3	10.1	10.0	12.4	12.0
In 5	7.5	9.8	8.9	9.5	11.1	10.2	11.7	12.4
In 6	9.7	10.7	10.3	10.2	11.2	11.1	N/A	N/A
In 7	12.7	13.9	14.1	12.8	12.6	13.4	N/A	N/A
In 8	10.1	11.1	12.0	N/A	N/A	N/A	N/A	N/A

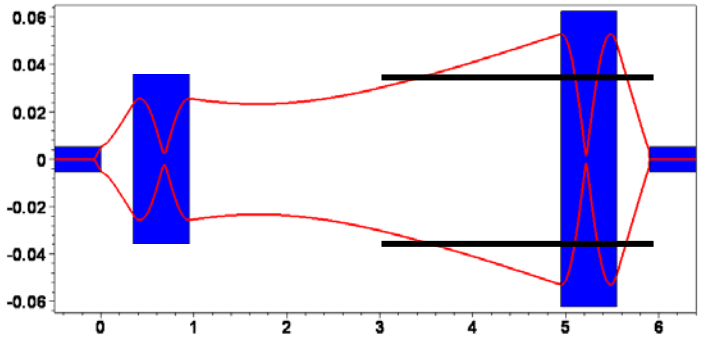
Polarisation depending Loss: 0.5dB
Actuation voltage : 260V
Spacer: 150µm

IMPROVING HIGH INSERTION LOSS

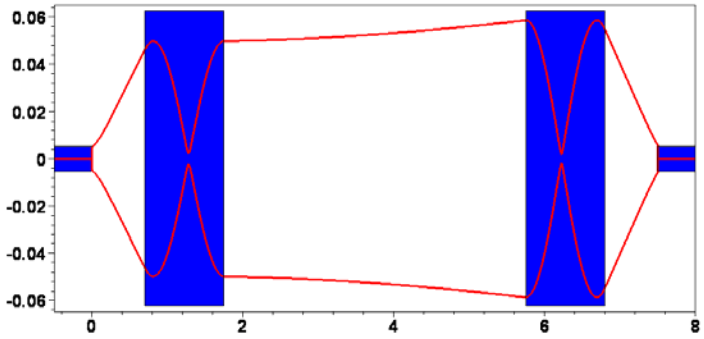
- refining the sputter process (better mirror reflectivity)
- new GRIN lenses

Simulation based on ABCD Matrix

62,5 µm GRIN lens



125 µm GRIN lens

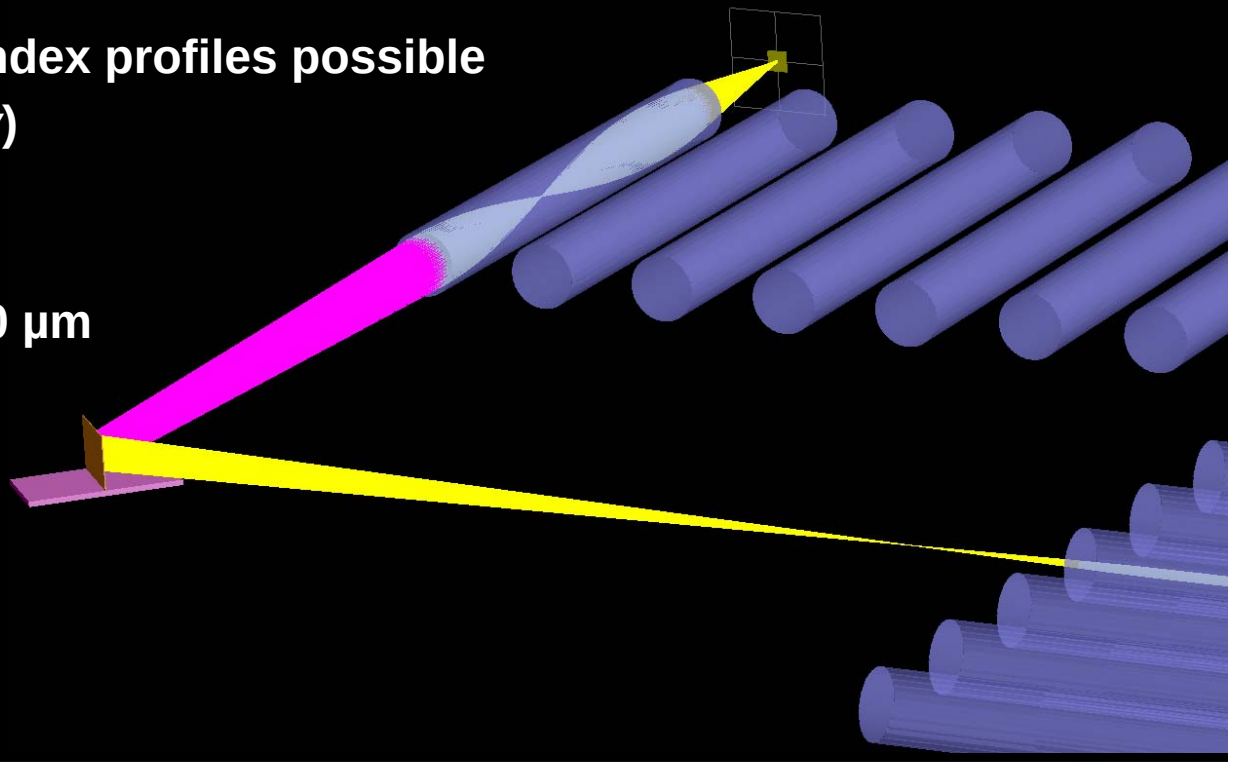


- NO Diffraction
- NO Fresnel loss
- NO Loss origin from too big beam diameter

} in simulation included

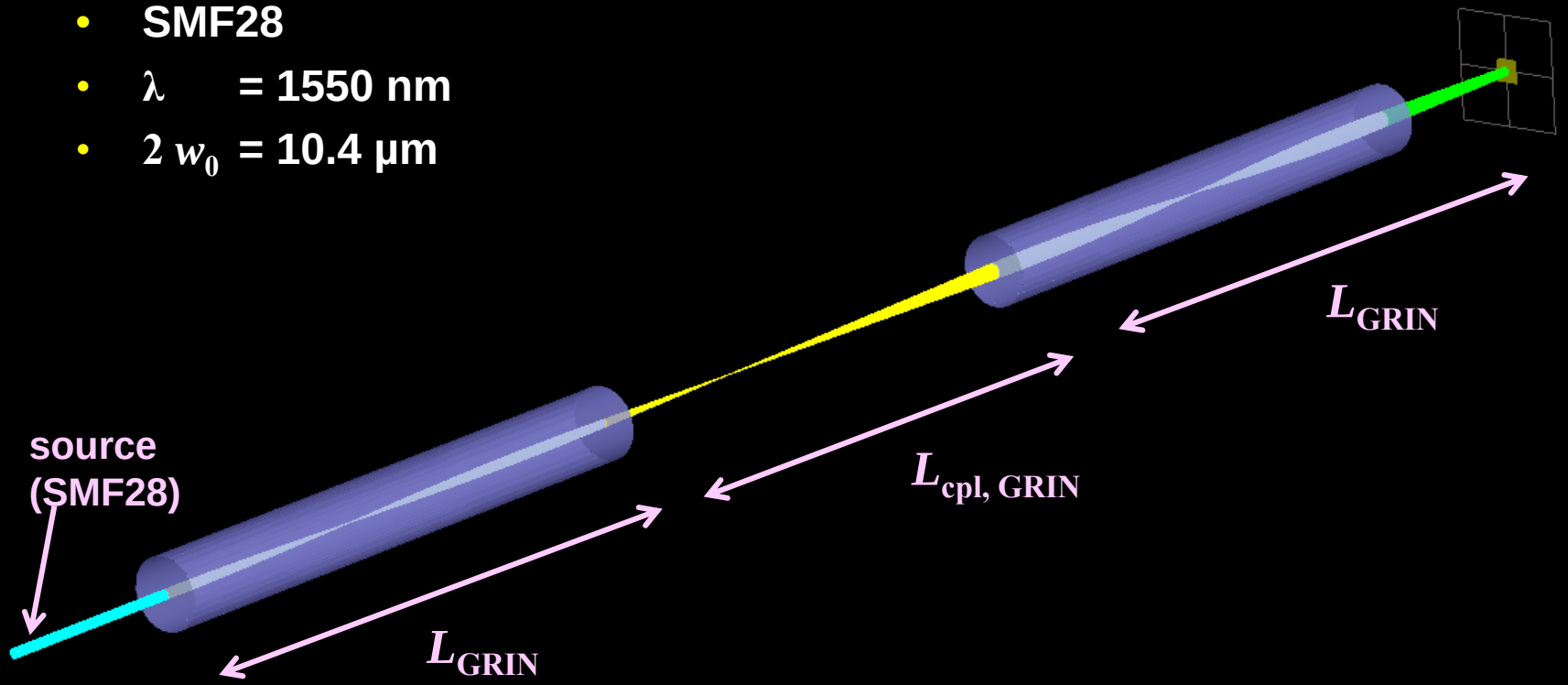
Optical Simulation - Fiber Switch 8x8

- FRED from *Photon Engineering*
  - → Raytracing
  - → Gaussian beamlets
  - → Diffraction effects
- Arbitrary 3D refractive index profiles possible
  - → GRIN lenses: n(*x*,*y*)
- µ-GRIN lenses:
  - $ø_{MMF}$ = 125 µm
  - $ø_{core}$ = 66 and 110 µm
  - Length varied
- Index matching fluid



Insertion Loss 62,5µm vs 110µm GRIN lens

- Simple line-up of two µ-GRIN lenses:
  - Diameter = 125 µm
  - Length and distance are varied
- Source
  - SMF28
  - λ = 1550 nm
  - $2\,w_0$ = 10.4 µm



Insertion Loss 62,5µm vs 110µm GRIN lens

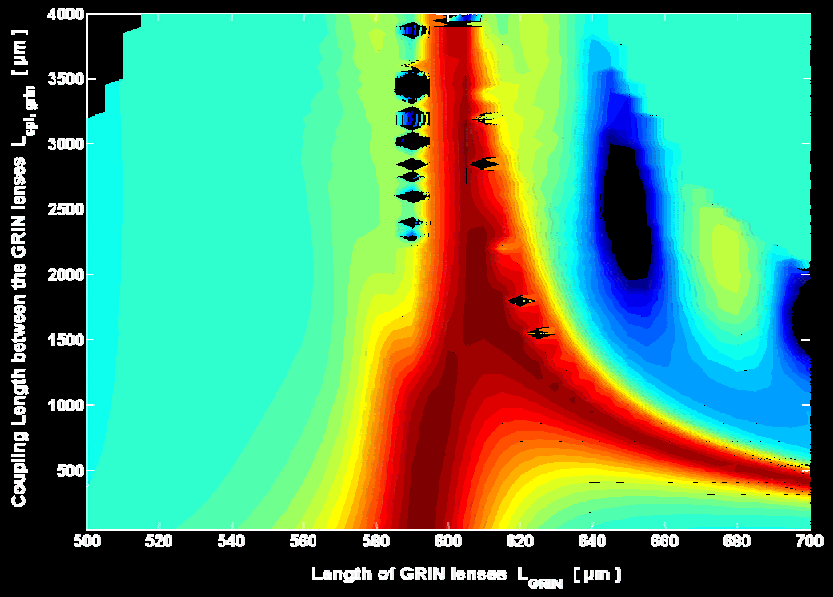
Line-up of µ-GRIN lenses

- $D_{smf,grin}$ = 350 µm
- $ø_{GRIN}$ = 125 µm

$$n_{core}(r) = \sqrt{n_0^{\,2}\,(1-\alpha^2 r^2)}$$

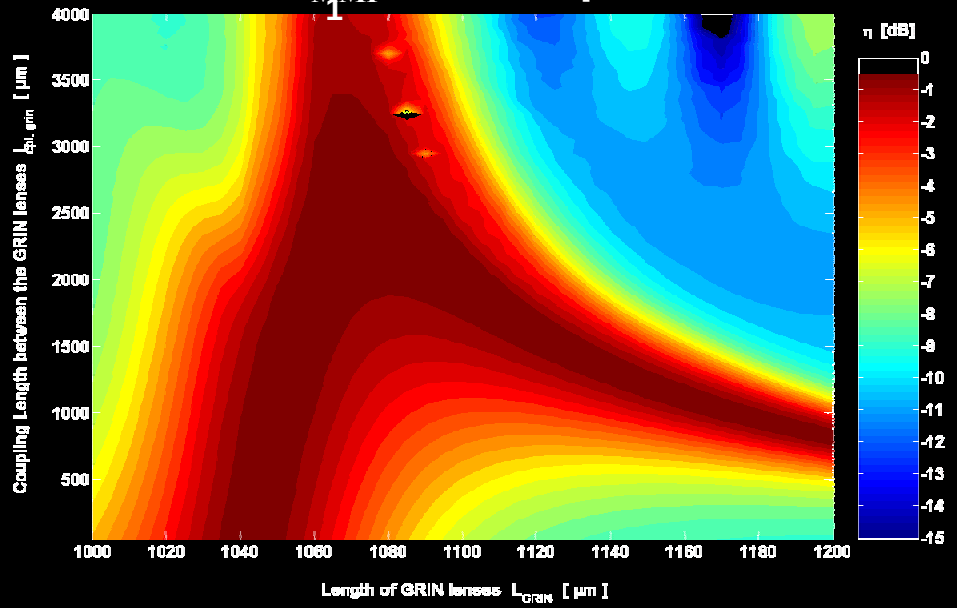
$ø_{core}$ = 66 µm

α_{MMF} = 0.006 µm^{-1}

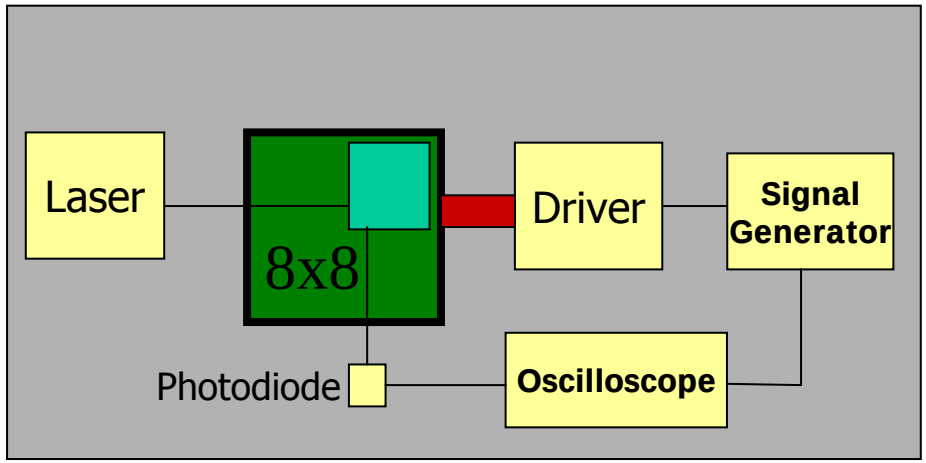


$ø_{core}$ = 110 µm

α_{MMF} = 0.0036 µm^{-1}

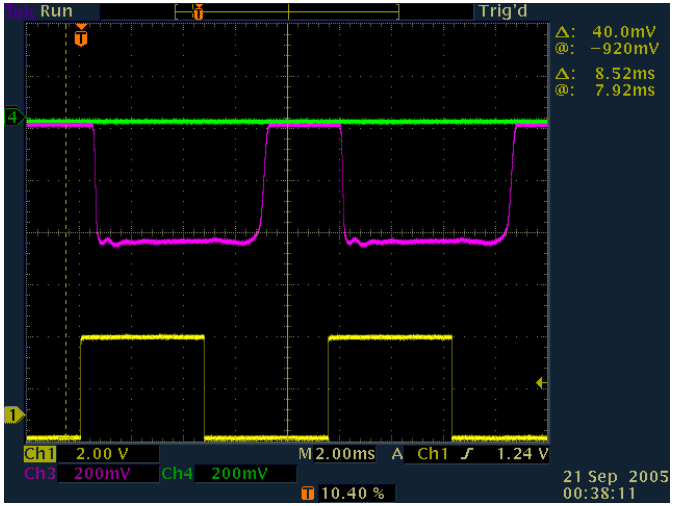


Switching speed

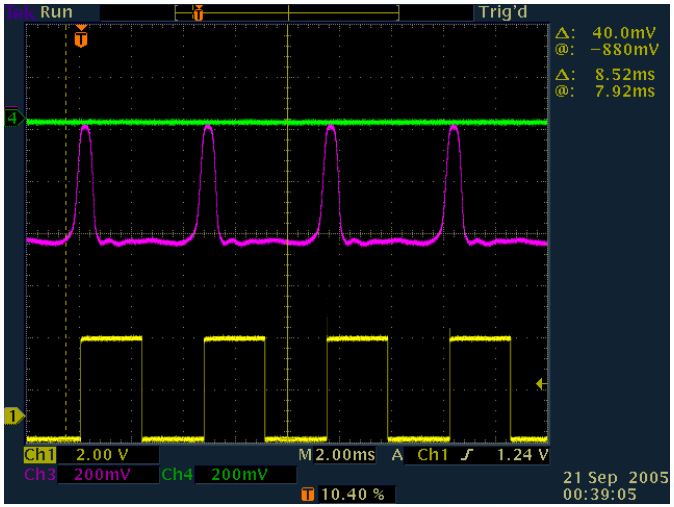


- Actuation Voltage: 330V
- Insertion Loss: 8.7dB
- Switching time down: ~1ms@100Hz
- Switching time up: ~2ms@100Hz

Frequency: 100 Hz

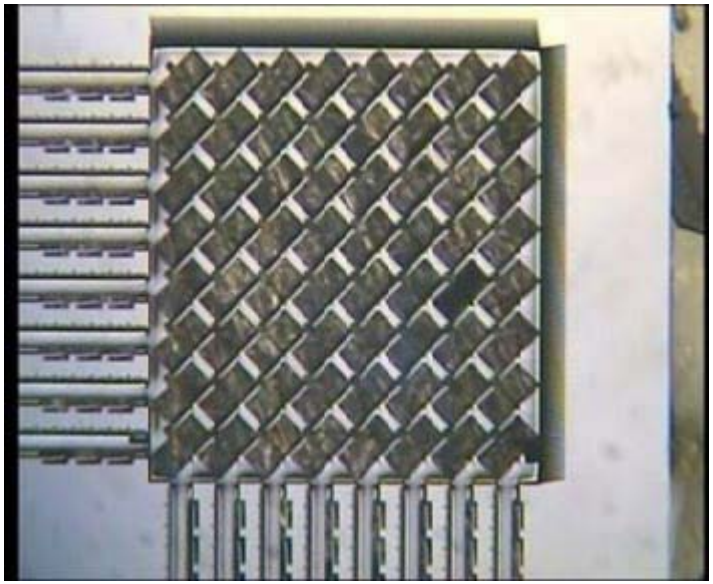


Frequency: 200 Hz



Mechanical Reliability Test

- Actuation Voltage: 330V
- Tilting Angle: 90°
- Switching frequency: 10 Hz



9.0 Million switching cycles
NO breakage or deformation
by tilting the mirror 90°

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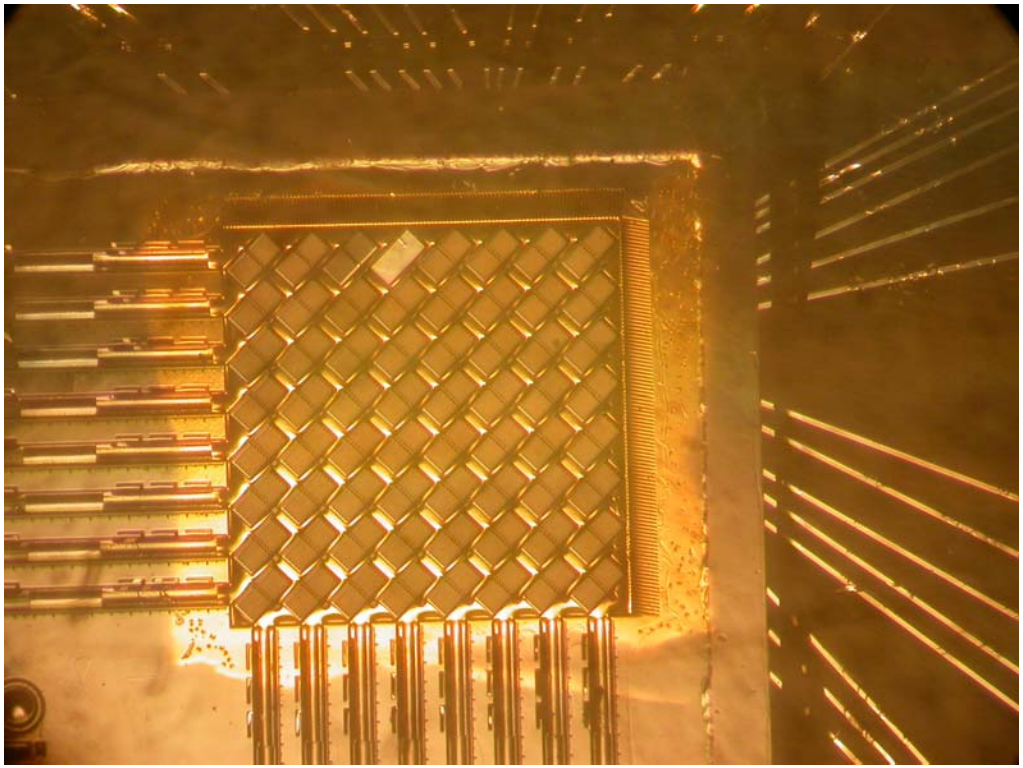
Conclusion

- ✓ *SAT´n Light shows the advantages of using MEMS based optical switches in RF telecom payload*
- ✓ *I presented the exceptional performance of sercalo´s **cascaded** 4x4 optical MEMS based switch with solid state reliability and IL below 1.7dB*
- ✓ *A new **monolytic** MEMS based OXC showed promissing starting values like switching speed of 1-2ms and 9 million switching cycles without noticable decrease of performance*
- ✓ *Future improvements as refining the chip design and usage of bigger GRIN lenses will lead to even better performances in Insertion Loss and homogeinity of the switch*



Thank You !!!

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