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INTEGRATION OF STRETCHABLE OPTICAL WAVEGUIDES WITH SOURCES AND DETECTORS

JEROEN MISSINNE

CONTACT: JEROEN.MISSINNE@UGENT.BE

SOME RELATED APPLICATIONS

INTEGRATION OF STRETCHABLE OPTICAL WAVEGUIDES WITH SOURCES AND DETECTORS

Why stretchable/flexible? (for sensing)

Why optical (waveguides)?

Why integrating sources?

Dedicated integration process for precision optical components

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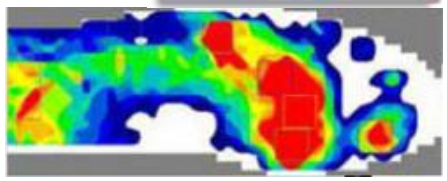
WHY FLEXIBLE / STRETCHABLE (SENSING) SYSTEMS?

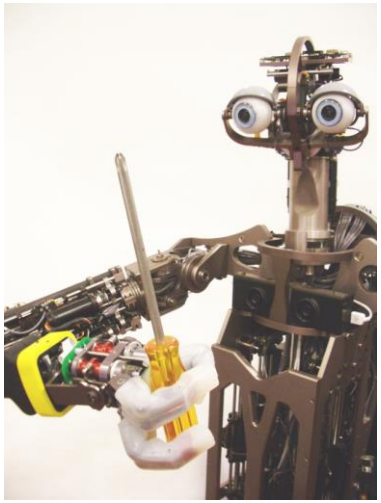
- Making “ultra-thin” (sensing) systems
- Unobtrusive systems → wearable, “on body” applications
- Examples: artificial skin

www.Tekscan.com

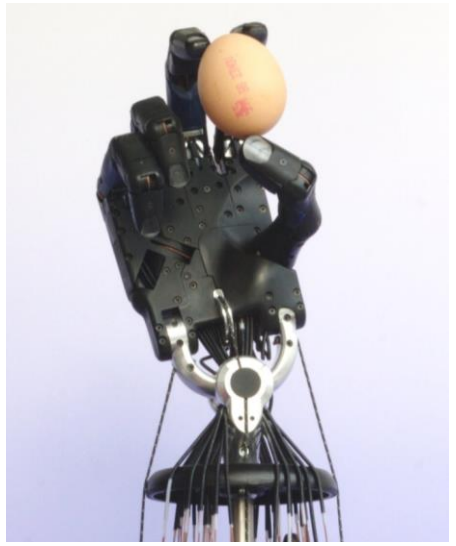
www.OttoBock.com



www.Tekscan.com



“Domo Robot”, Edsinger, MIT



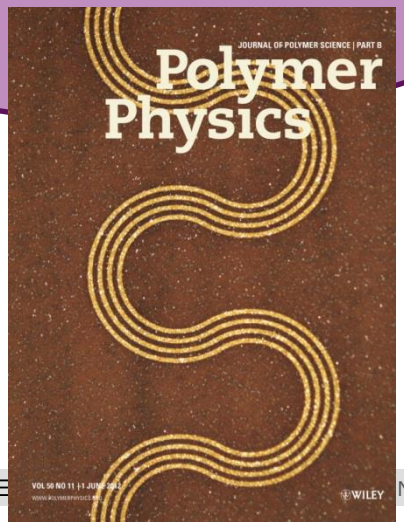
(www.shadowrobot.com)

WHY FLEXIBLE / STRETCHABLE OPTICAL SYSTEMS?

- Stretchable electronics well-known technology
- Optical systems increasingly important
- Number of advantages (e.g. optical sensors vs. electrical)
- Therefore

Stretchable electrical interconnections

Stretchable optical interconnections (=waveguides)



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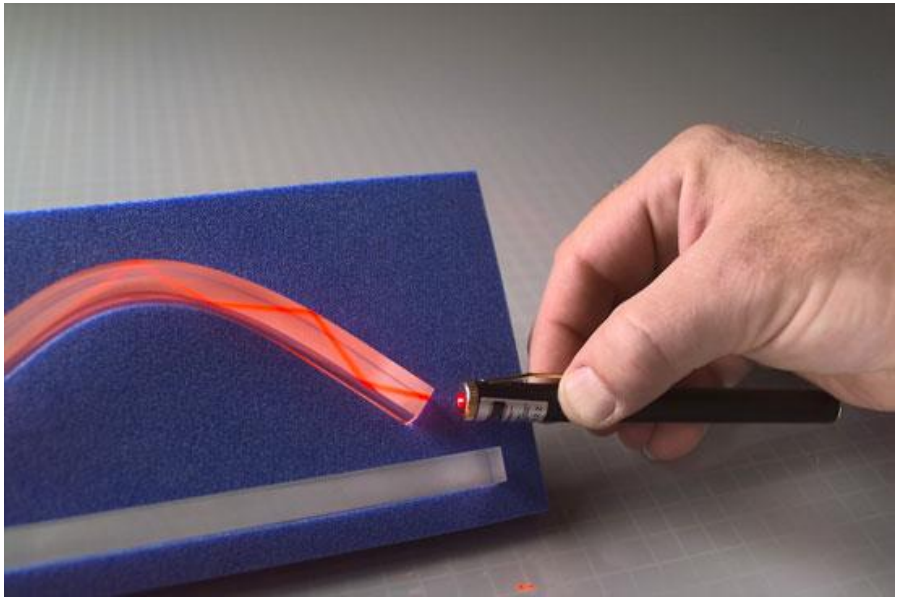
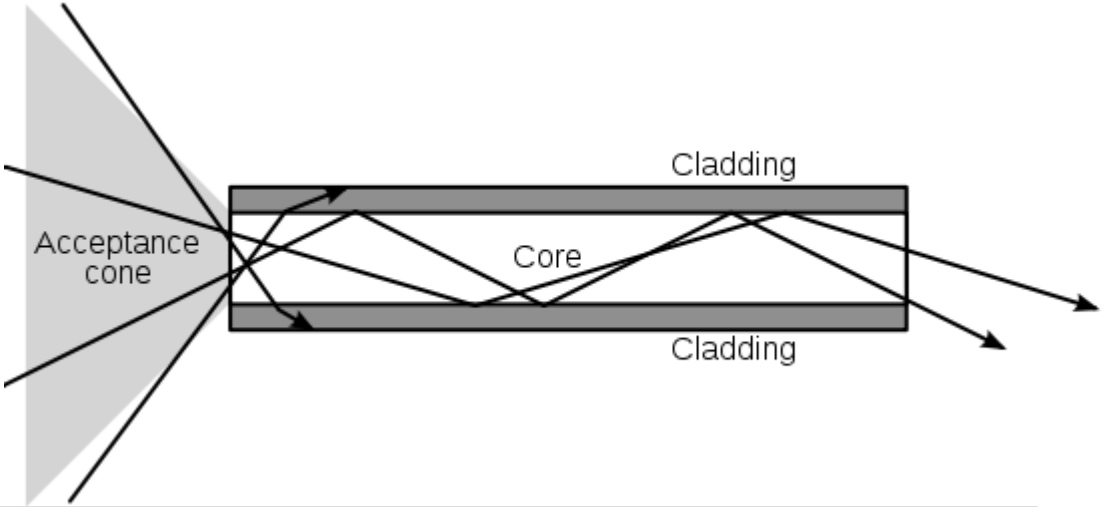
 NNE, CMS

STRETCHABLE OPTICAL WAVEGUIDES: PRINCIPLE



What is an optical waveguide?

How do we make it?



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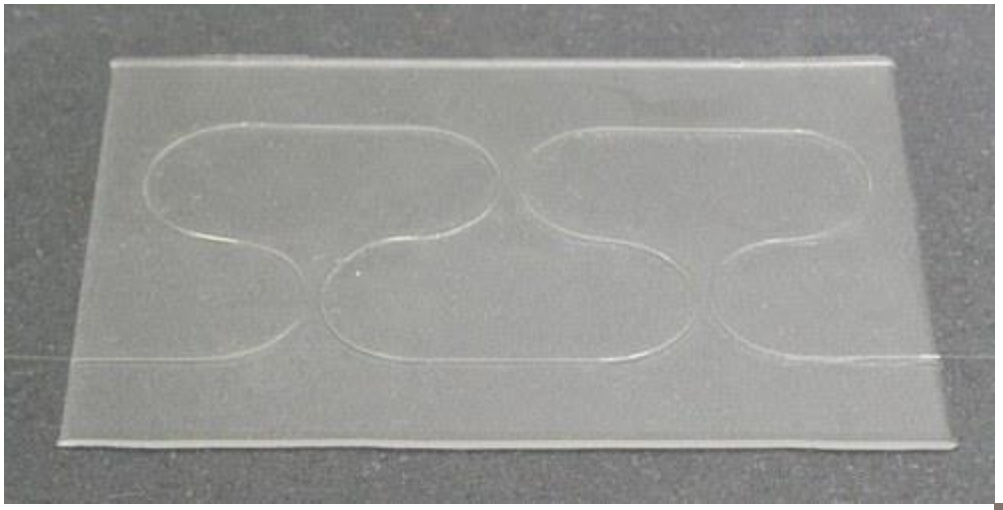
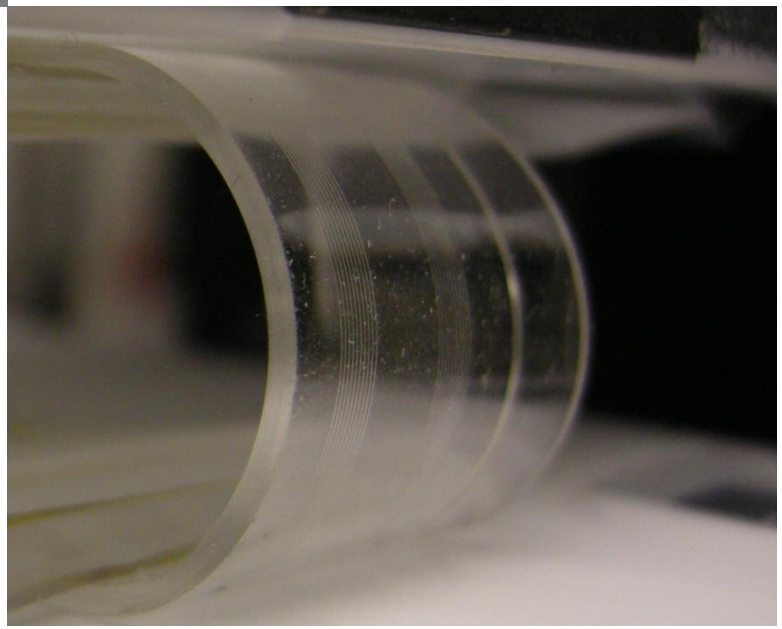
STRETCHABLE OPTICAL WAVEGUIDES: CONCEPT



(B. Van Hoe)

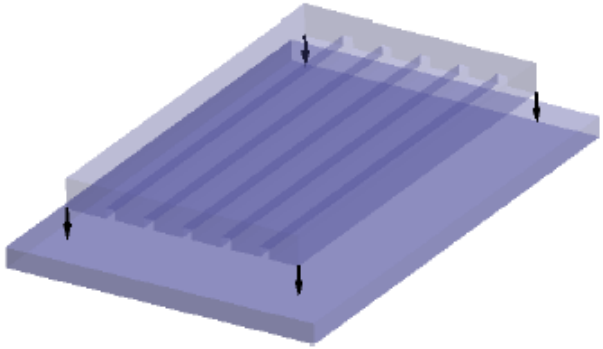
"Only" flexible waveguide, but meandering

Straight waveguide channels, but from stretchable material

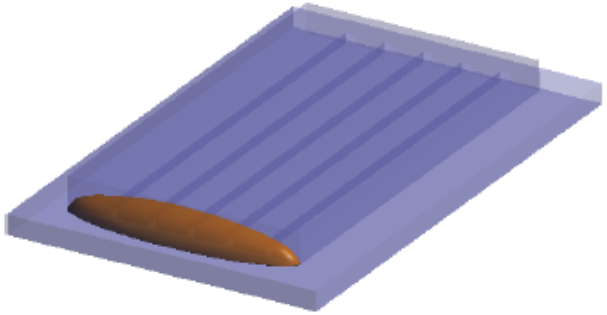


STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION

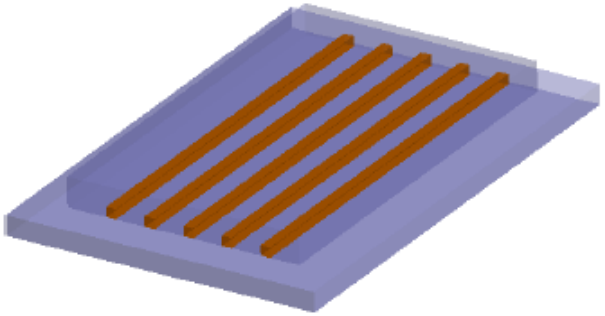
Transparent, rubber-like, "PDMS" materials



(a)



(b)



(c)

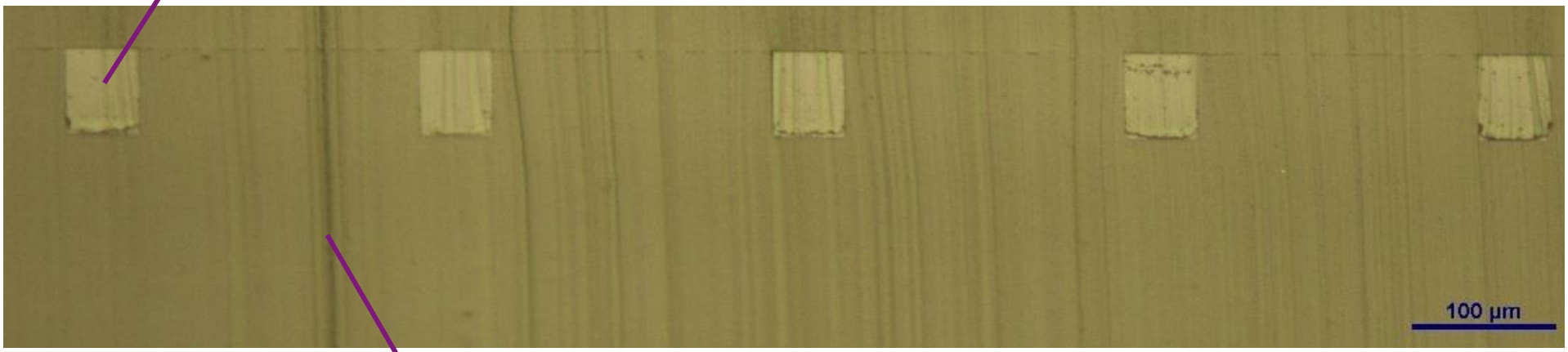
STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION

$NA \triangleq \sqrt{n^2_{core} - n^2_{clad}} = 0.69$

→allows small bending radii

LS-6257 (Nusil)

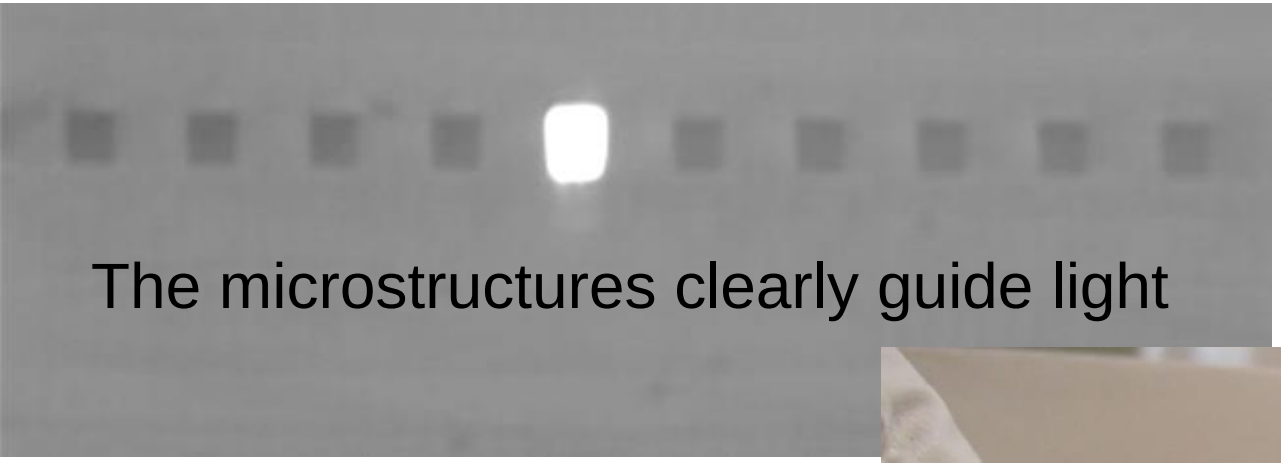
$n_{core} \approx 1.57$



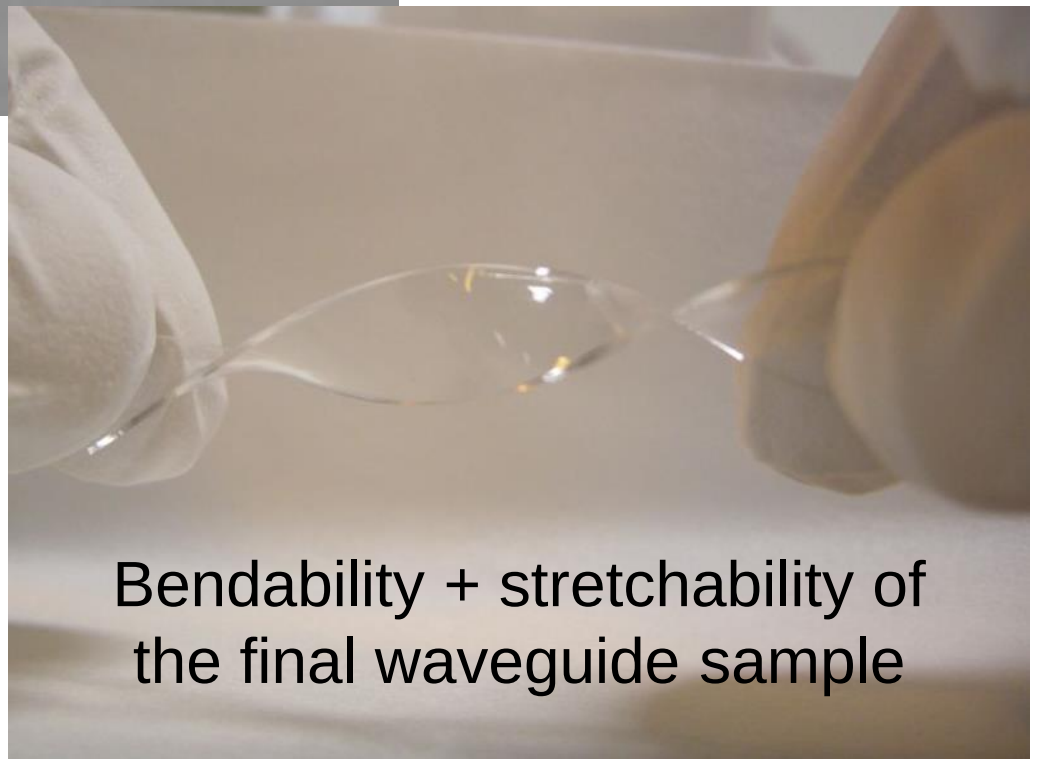
Sylgard®184 (Dow Corning)

$n_{clad} \approx 1.41$

STRETCHABLE OPTICAL WAVEGUIDES: FABRICATION



The microstructures clearly guide light



Bendability + stretchability of the final waveguide sample

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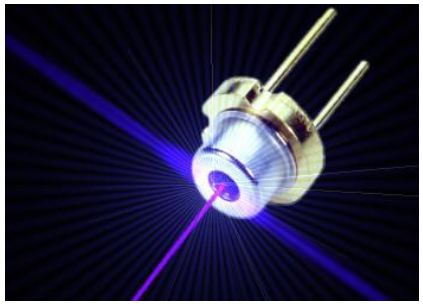
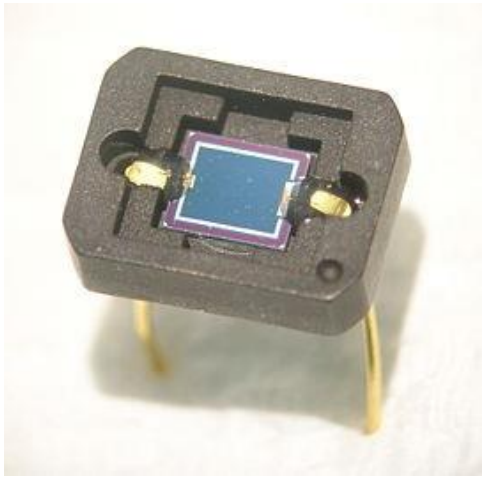
WHY INTEGRATING SOURCES AND DETECTORS?

- Waveguide without sources, detectors = useless
- Integration = needed for operation under deformation

- Micrometer waveguide dimensions
  - ➔ Requires integration on the micrometer level
  - ➔ Bulky, packaged components cannot be used
  - ➔ We propose: ultra-thin, flexible OE package



- Additional advantage: the complete system becomes deformable, wearable, portable.



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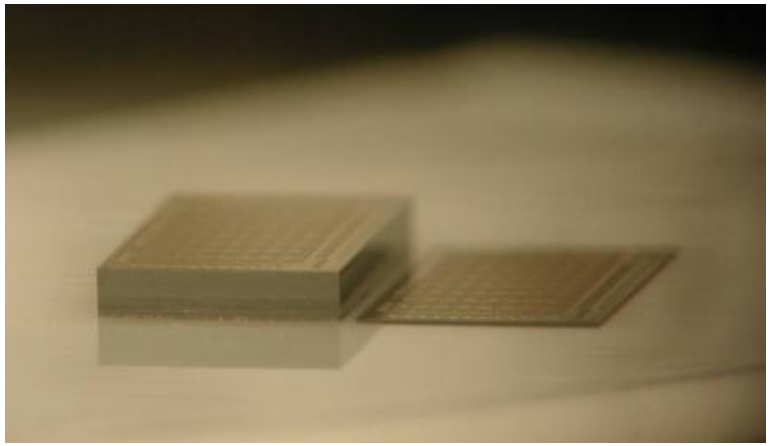
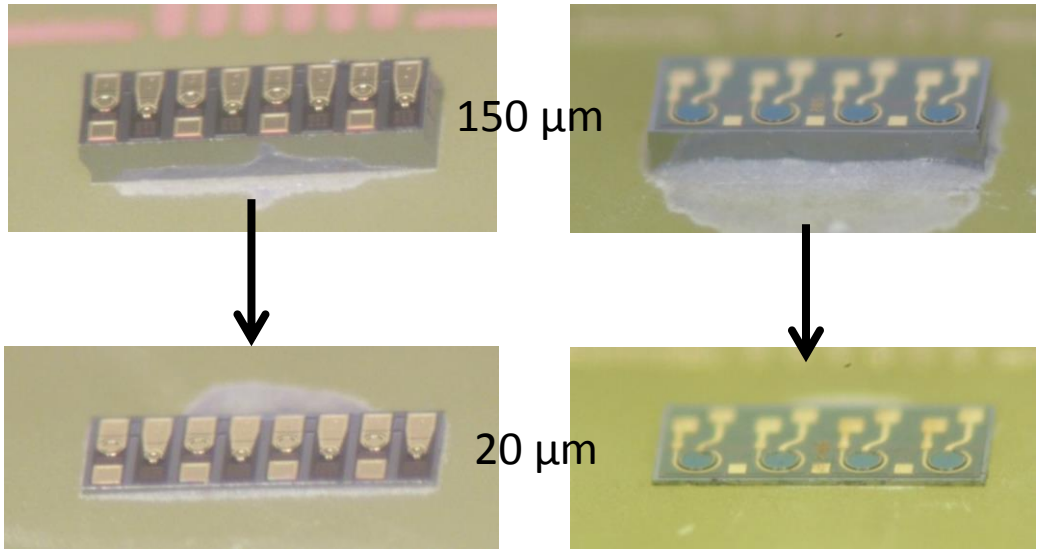
INTEGRATING SOURCES AND DETECTORS: ULTRA-THIN OE PACKAGE

1st step: use of bare die chips + thinning

- Final (bare die) thickness ~20µm
- Lapping & polishing steps
- (re-)apply back contact if needed (single mode VCSELs)

2nd step: embedding of thinned bare dies





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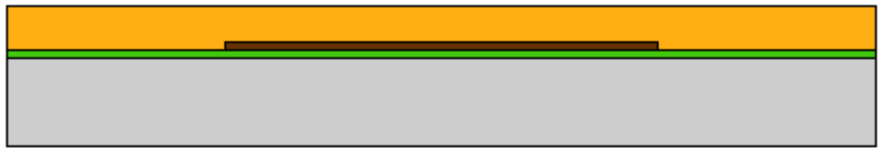
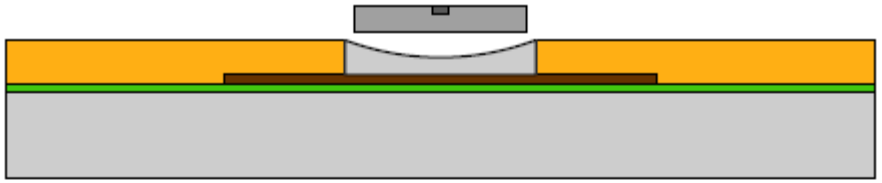
EMBEDDING OF BARE DIES

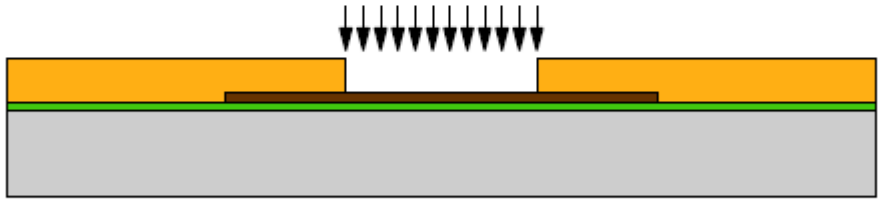
2nd step: embedding in polymer layers



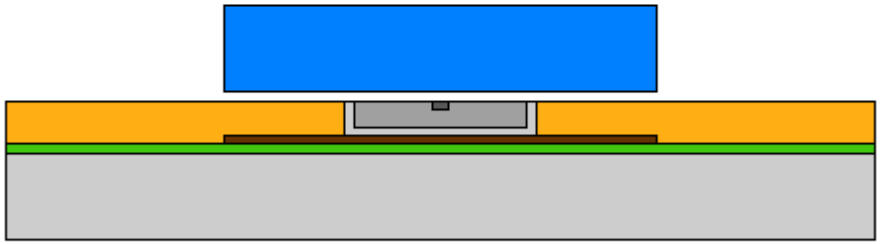
(a) Applying a polyimide and SU-8 layer



(c) Placing the thinned chip in the cavity using a glue



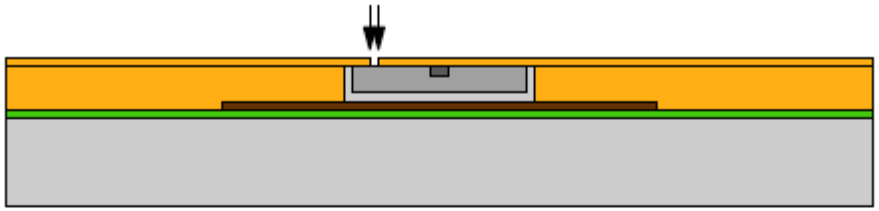
(b) Defining a cavity (via laser ablation or lithography)



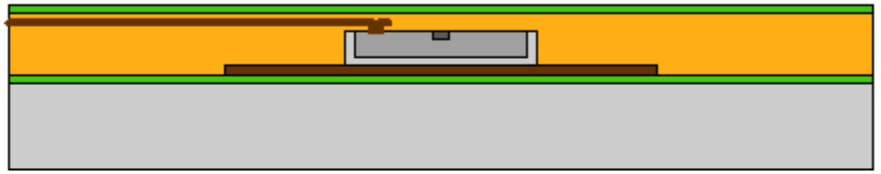
(d) Leveling of the chip in the cavity

EMBEDDING OF BARE DIES

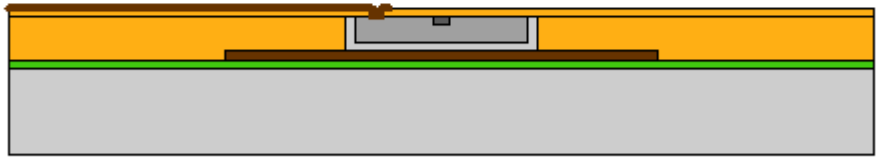
2nd step: embedding in polymer layers



(e) Covering with SU-8 and creating vias to the contacts



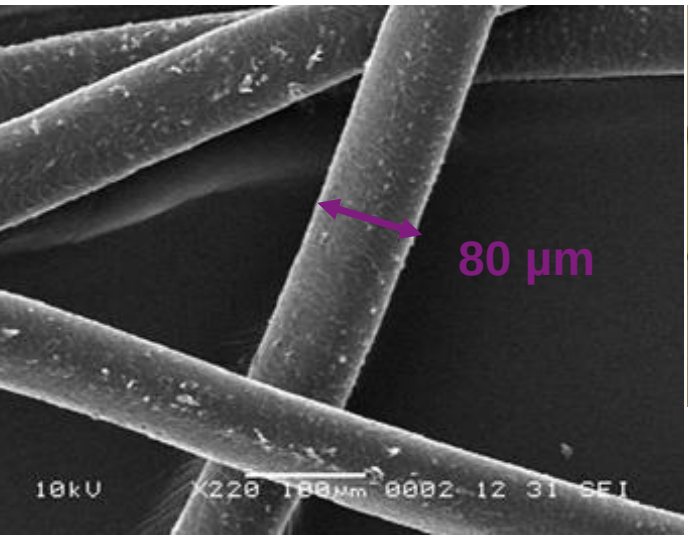
(g) Applying a covering SU-8 and polyimide layer



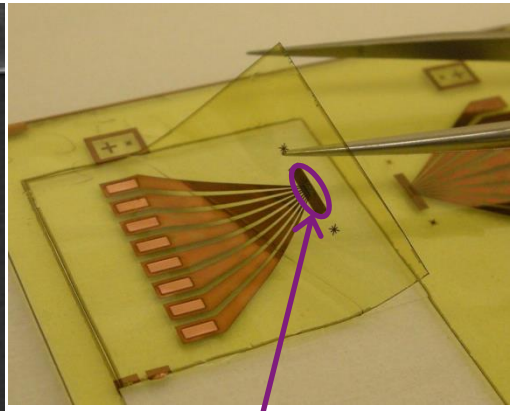
(f) Metalizing the vias

EMBEDDING OF BARE DIES

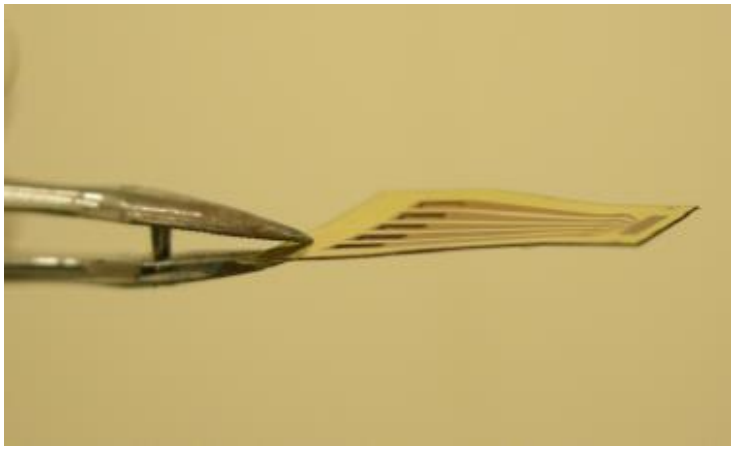
2nd step: embedding in polymer layers: results

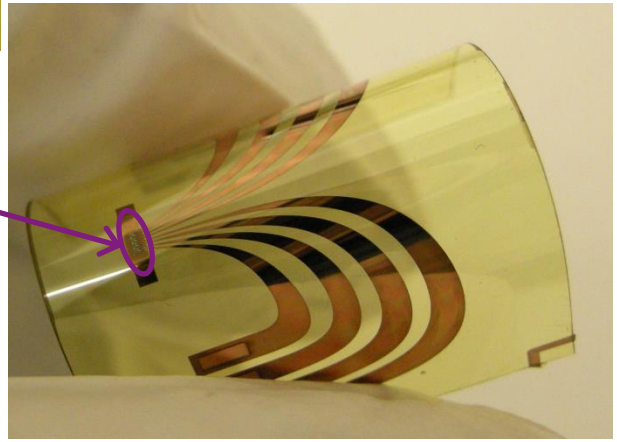


Human hair



Laser / detector chip
~40µm thin foil





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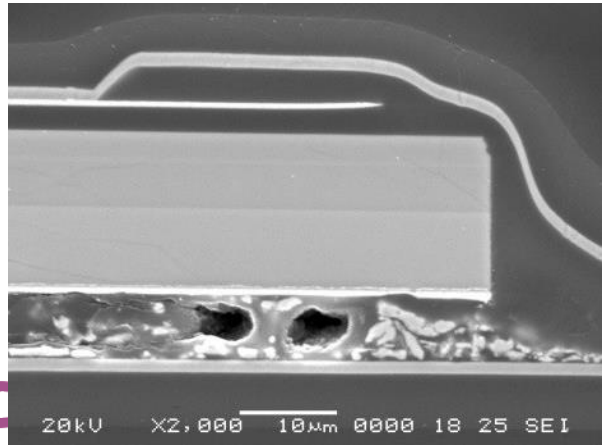
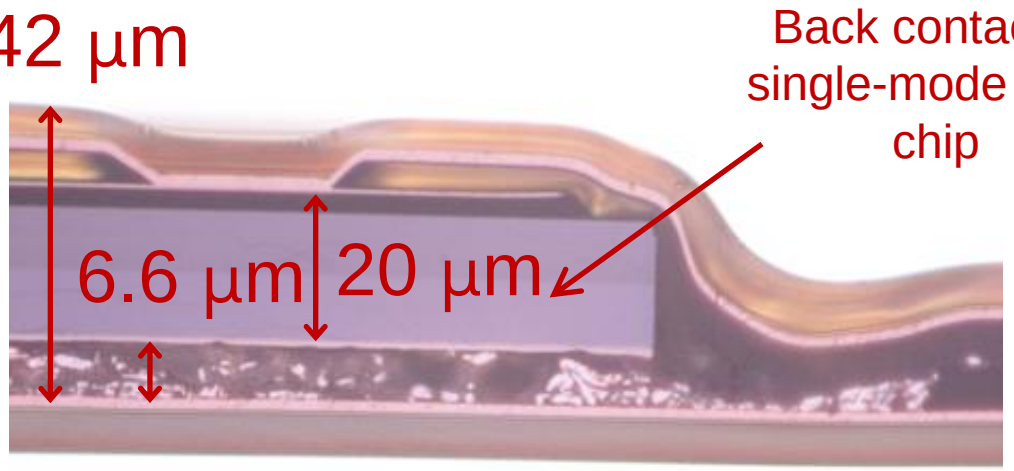
EMBEDDING OF BARE DIES

2nd step: embedding in polymer layers: results cross-section images

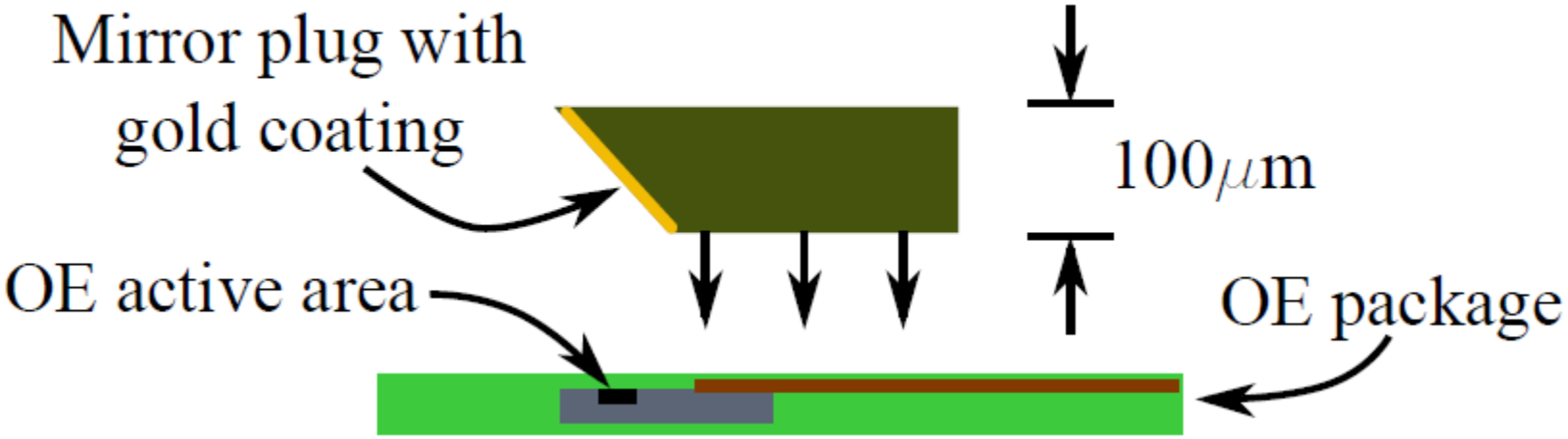




(results B. Van Hoe)

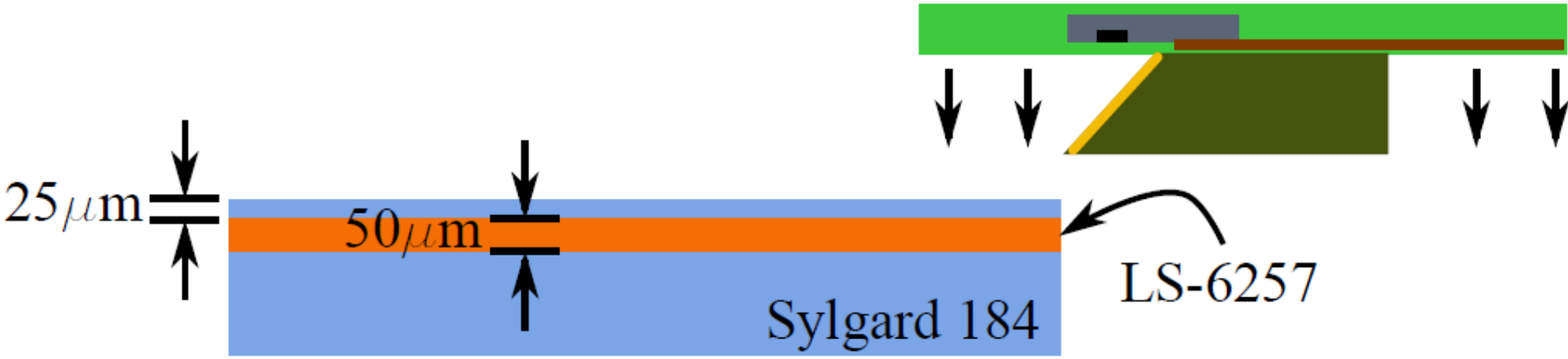
INTEGRATING SOURCES AND DETECTORS

Placement of a 45º mirror-plug on the optoelectronic package



INTEGRATING SOURCES AND DETECTORS

Aligning + bonding with the waveguide array

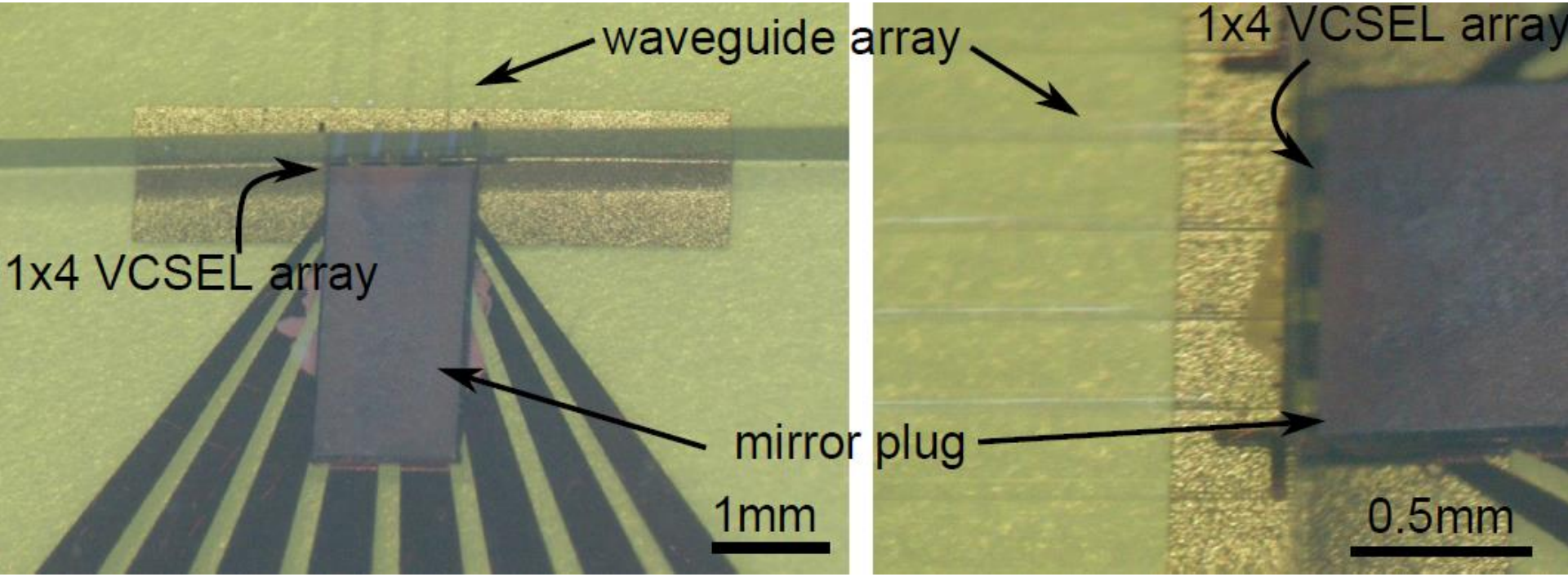


INTEGRATING SOURCES AND DETECTORS

Resulting waveguides + sources / detectors

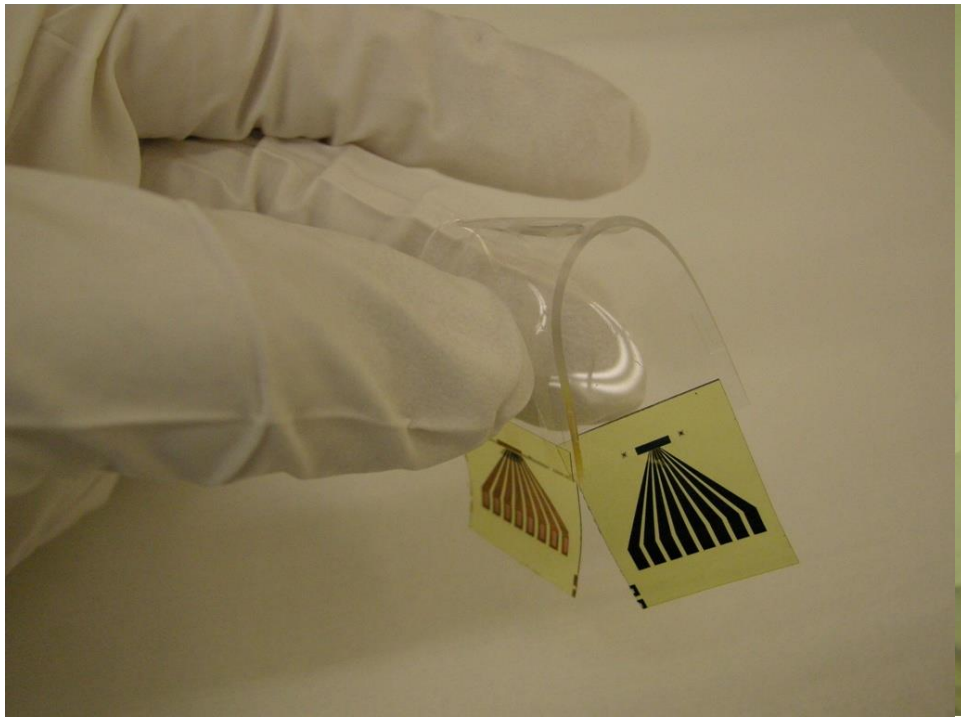
INTEGRATING SOURCES AND DETECTORS

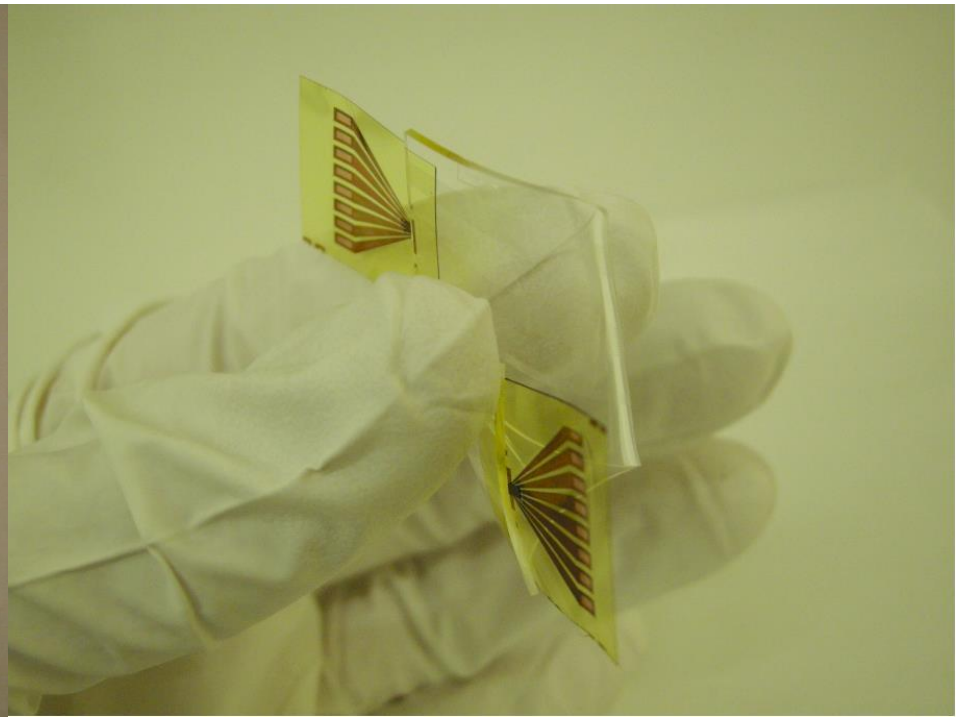
Resulting waveguides + sources / detectors



INTEGRATING SOURCES AND DETECTORS

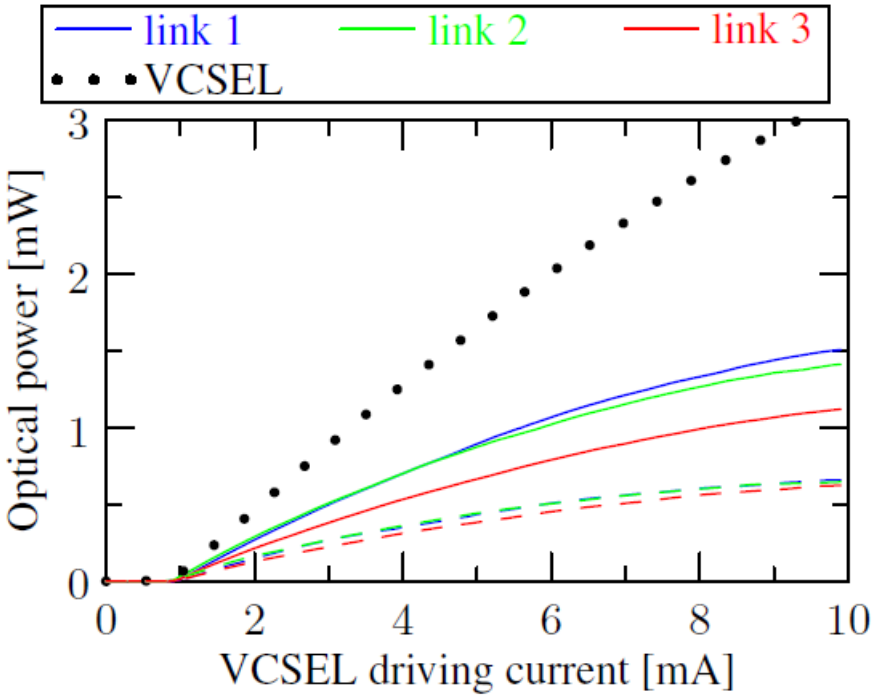
Resulting waveguides + sources / detectors

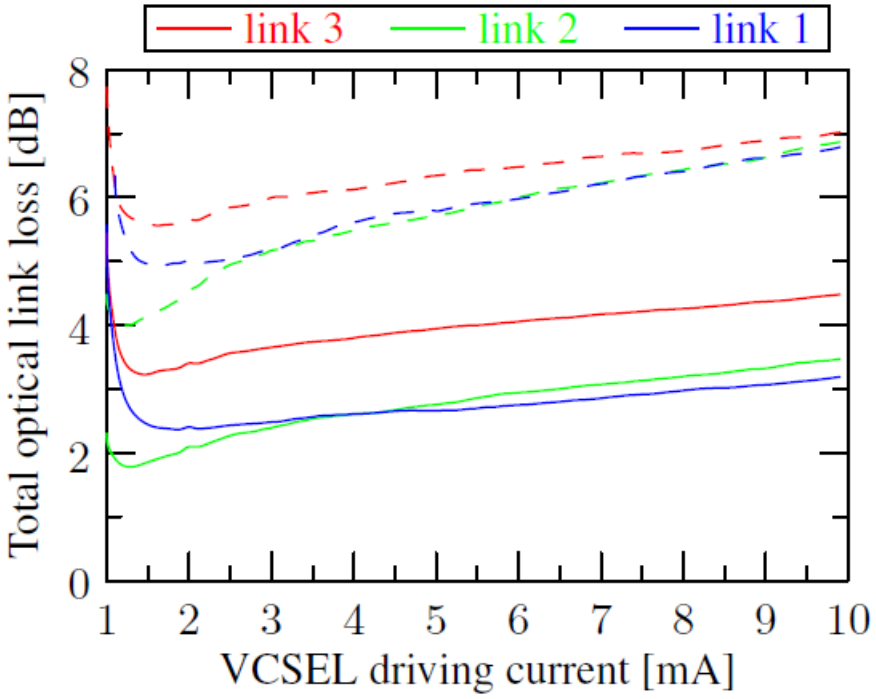




OPTICAL LINK: LOSSES?

Light in ➔ waveguide ➔ light out?





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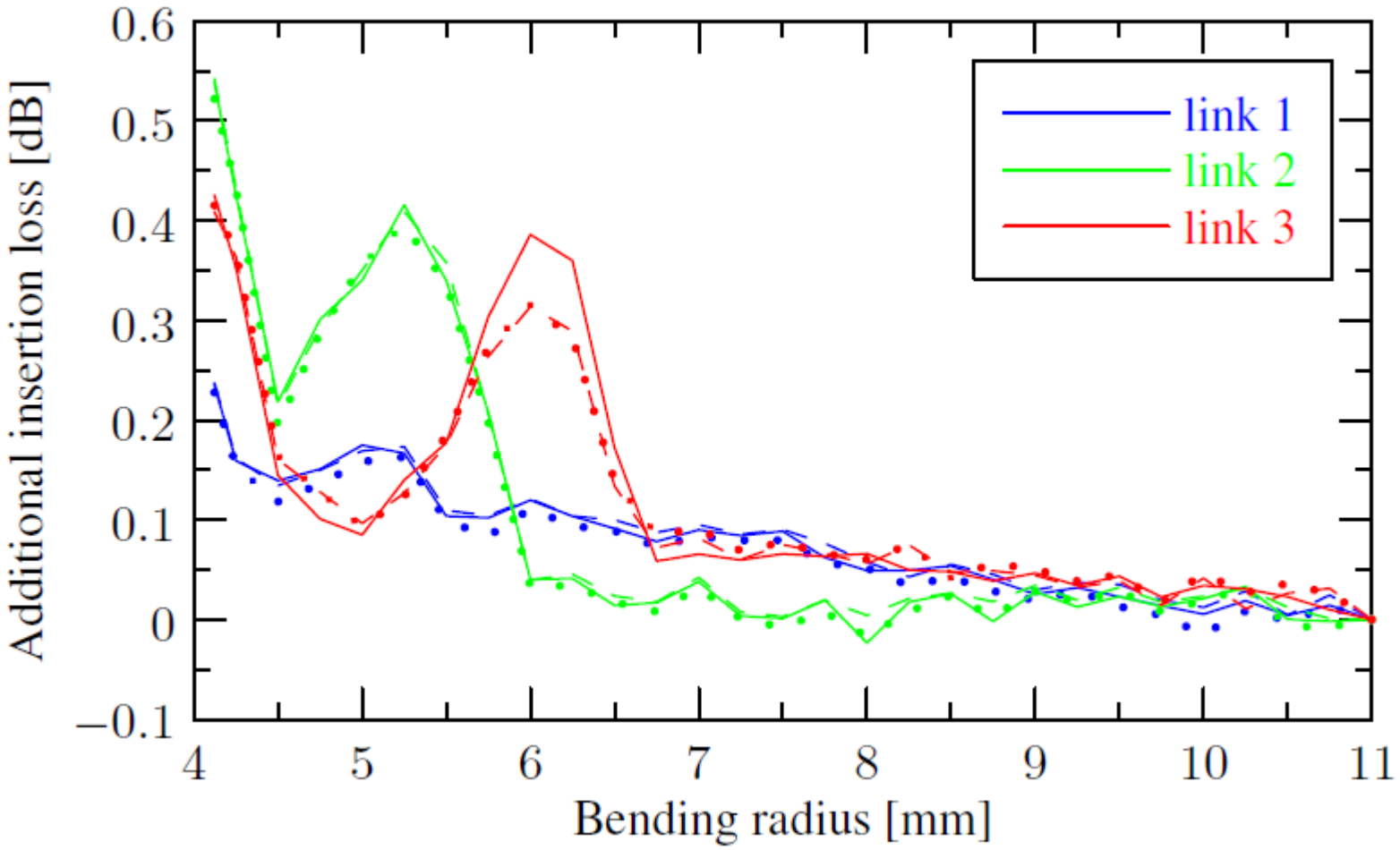
OPTICAL LINK: BENDING LOSSES?

Light in ➔ bended waveguide ➔ light out?



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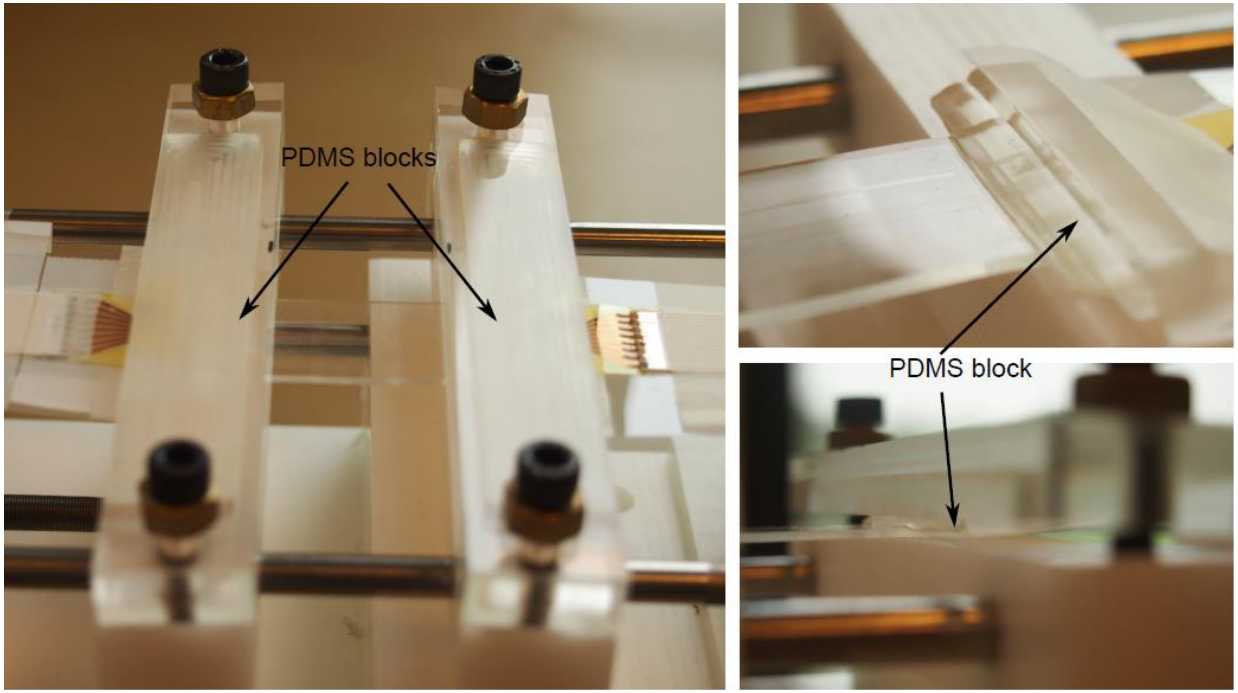
OPTICAL LINK: STRETCH LOSSES?

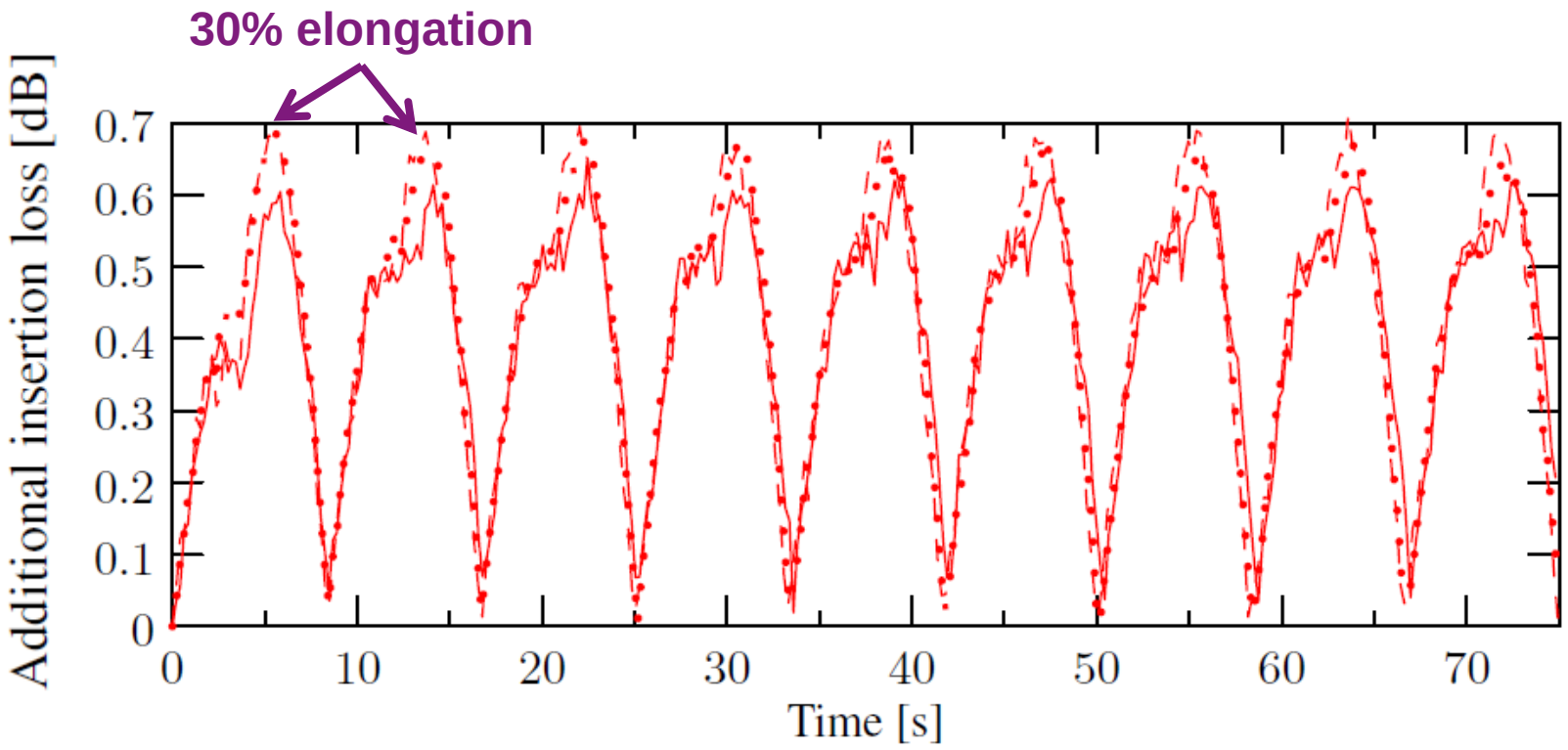
Light in ➔ stretched waveguide ➔ light out?

Up to 30% elongation tested



OPTICAL LINK: STRETCH LOSSES?

Light in ➔ stretched waveguide ➔ light out?

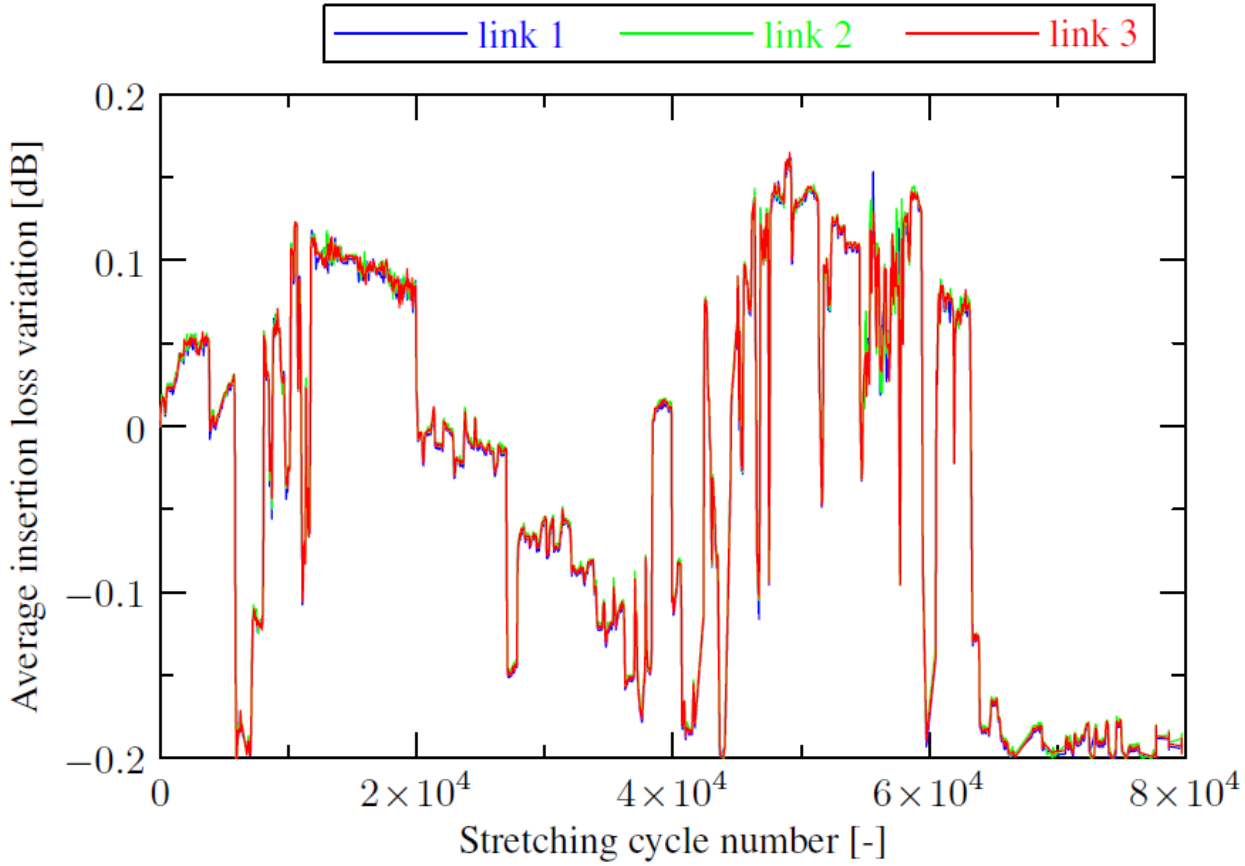


Very limited stretching induced loss!

OPTICAL LINK: RELIABILITY?

Light in ➔ ∞ stretched waveguide ➔ light out?

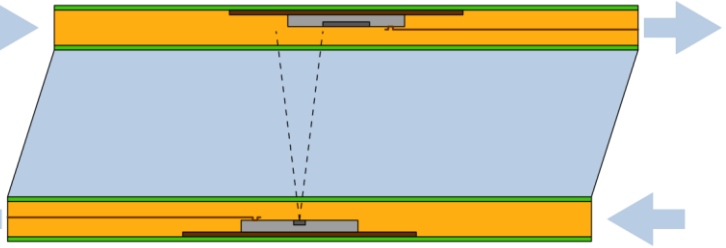
(10% elongation)

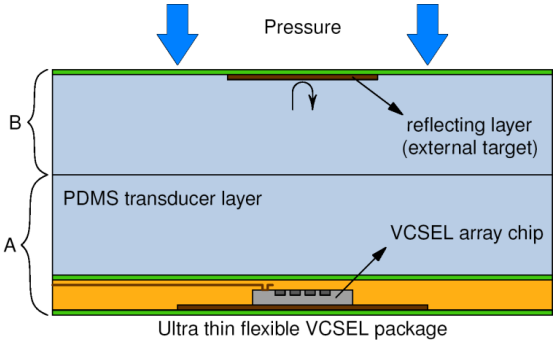


Very limited variation over time!

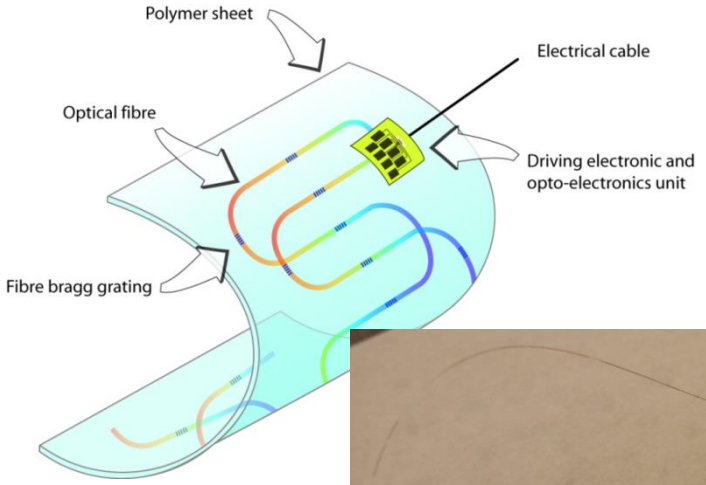
ALTERNATIVE APPLICATIONS

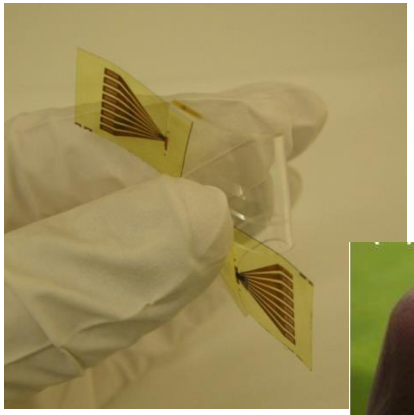
applications: ultra-thin (sensing) systems

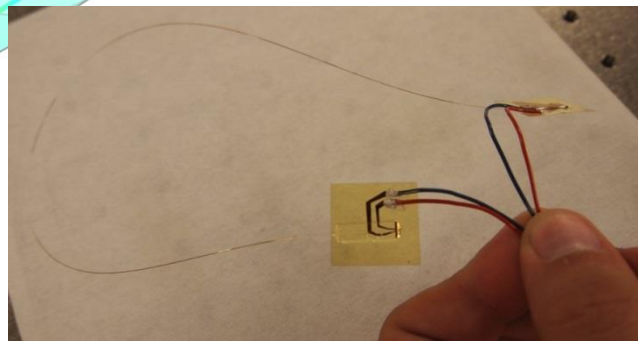


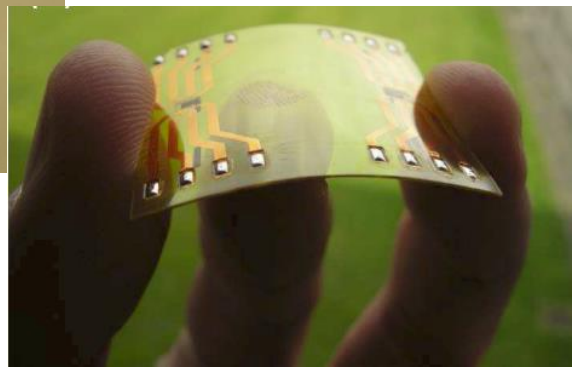


Ultra thin flexible VCSEL package









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THANK YOU

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