Fabrication of optical 1x2 POF couplers using the Laser LIGA technique

T.Klotzbücher, T.Braune, M.Sprzagala, D.Dadic, A.Koch, U.Teubner

Institut für Mikrotechnik Mainz GmbH
Carl-Zeiss-Str. 18-20
D-55129 Mainz
Germany

contact: klotzbuecher@imm-mainz.de

supported by the European Comission under Grant # G4RD-CT2000-00142

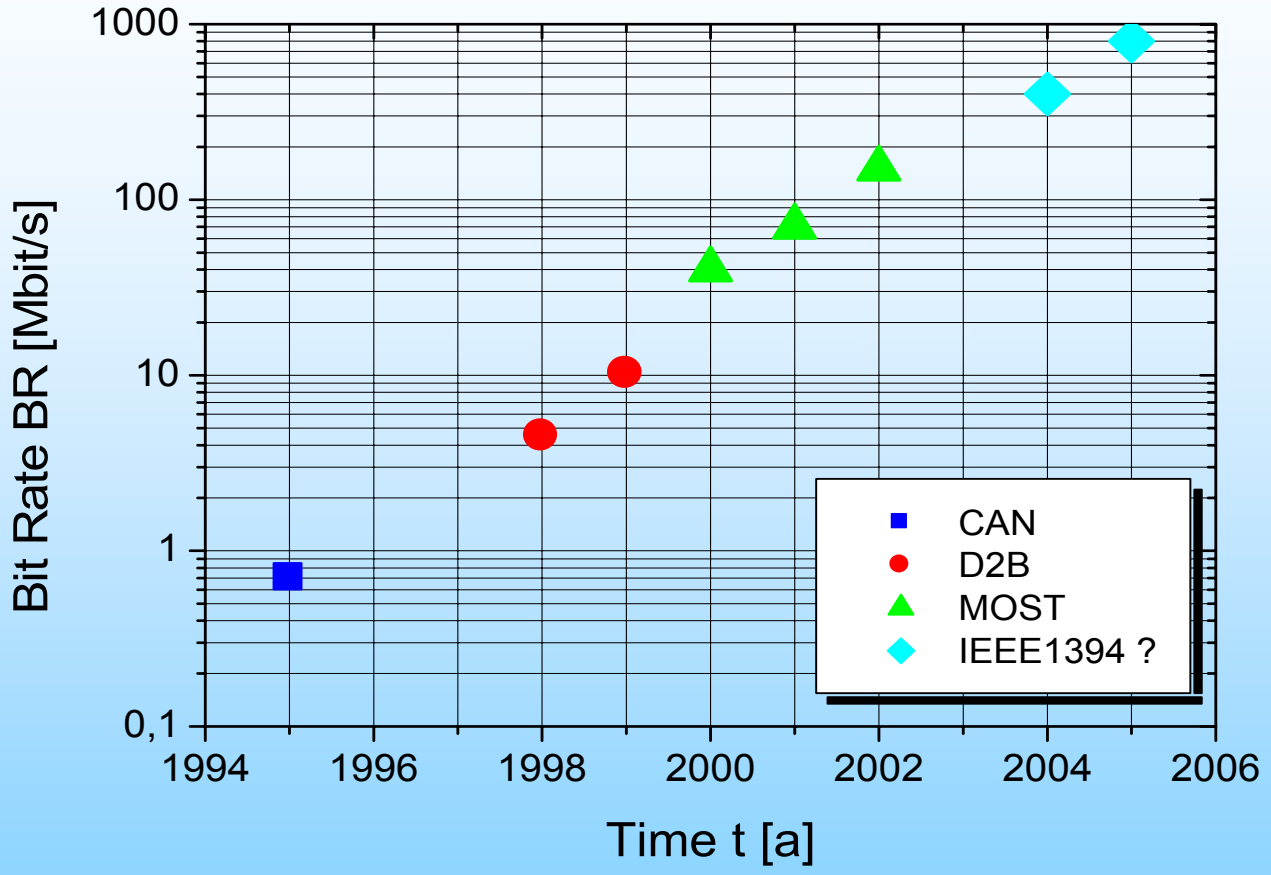
CONTENTS

- Introduction
- POF couplers, basics & technologies
- Optical simulation by ray tracing
- Fabrication and characterization
- Summary & Outlook

PROPERTIES OF POF

- POF = Plastic Optical Fibre, 1 mm Ø
- Core: Ø 980 µm, n_2=1.56
- Cladding: ø 20 µm, n_1=1.49
- NA=0.47
- Robust fibre, easy to handle
- Cheap components (plastic)
- High mode dispersion, low band width

BIT RATE DEVELOPMENT IN AUTOMOTIVE



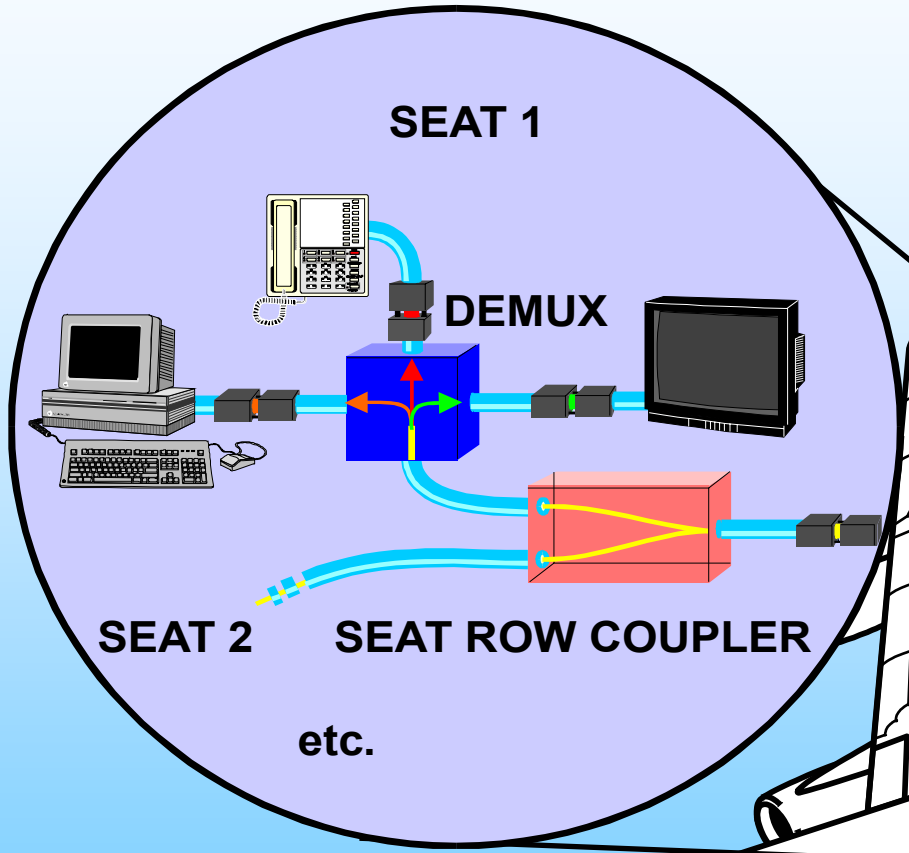
POF networks in automotive become more complex, data rates increase

⇒ Need for POF couplers, also implementation on airplanes

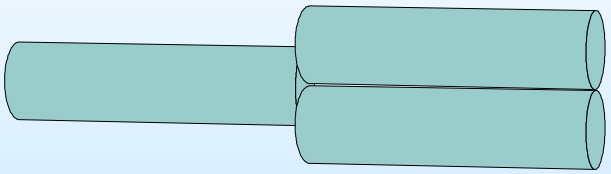
POF COUPLERS FOR IFE-NETWORKS

In-Flight-Entertainment

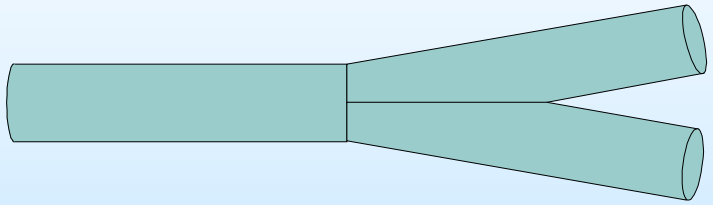
Distribution of of optical signals to different cabin seats (100 MBit/s, Fast Ethernet, 150 m)



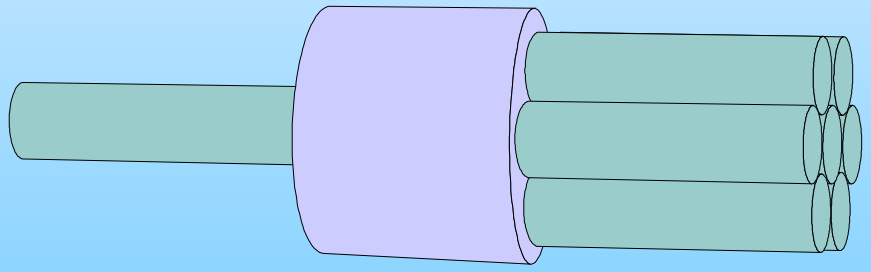
PRINCIPLES FOR POF COUPLERS



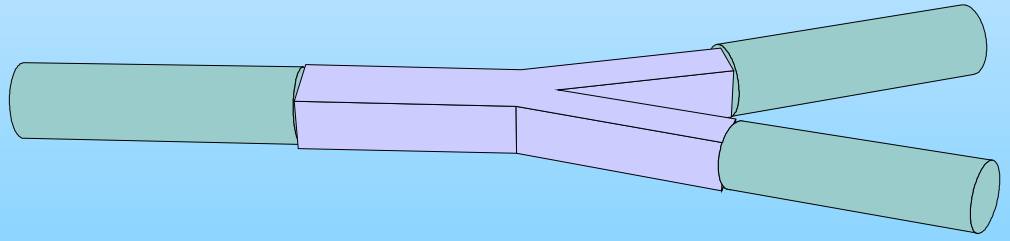
Butt Coupling



Wave Front Division



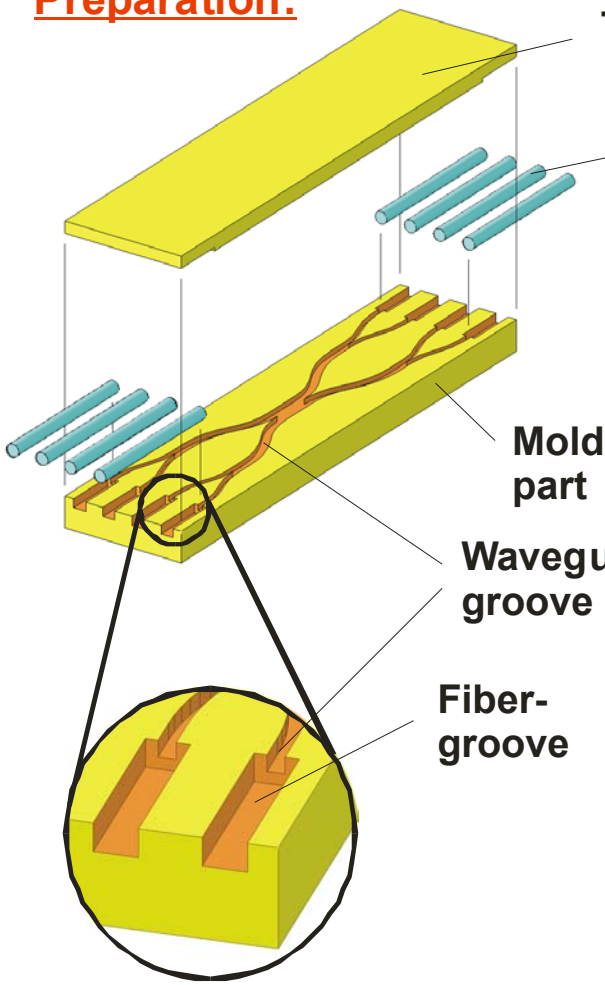
Mode Mixing



Waveguide Coupling

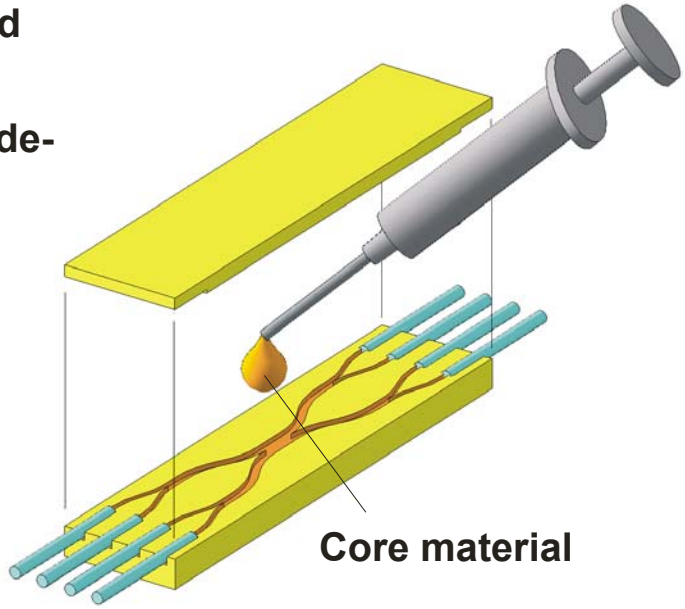
POLYMER WAVEGUIDE COUPLERS: FABRICATION

Preparation:

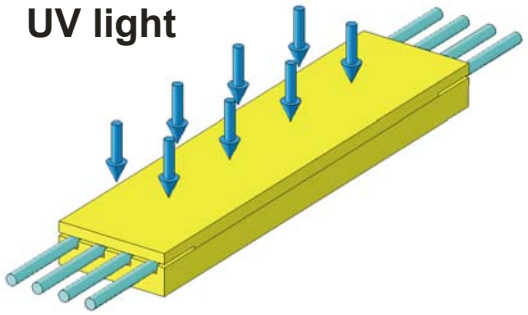


- ☒ Cost-effective production by micro injection molding
- ☒ Passive fiber coupling with high precision
- ☒ Simple, reliable assembly
- ☒ High port density

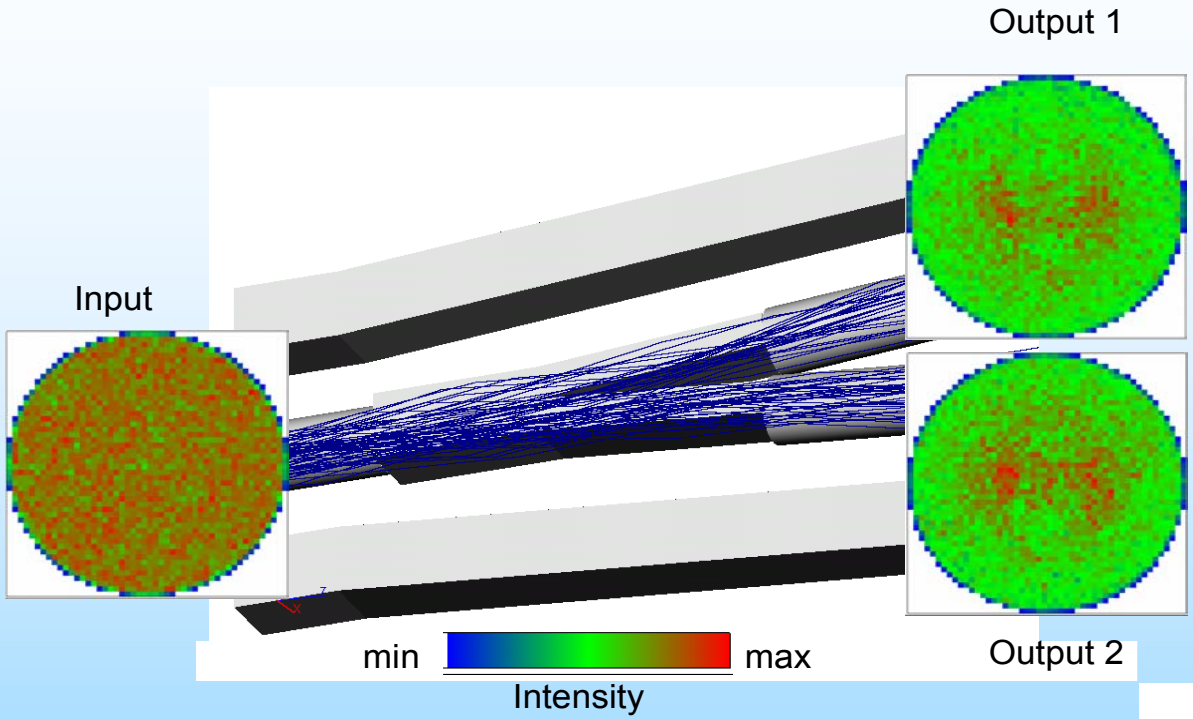
Inserting fibers / Injection of core material:



Pressing on top plate/ UV hardening:



OPTICAL SIMULATION BY RAY TRACING

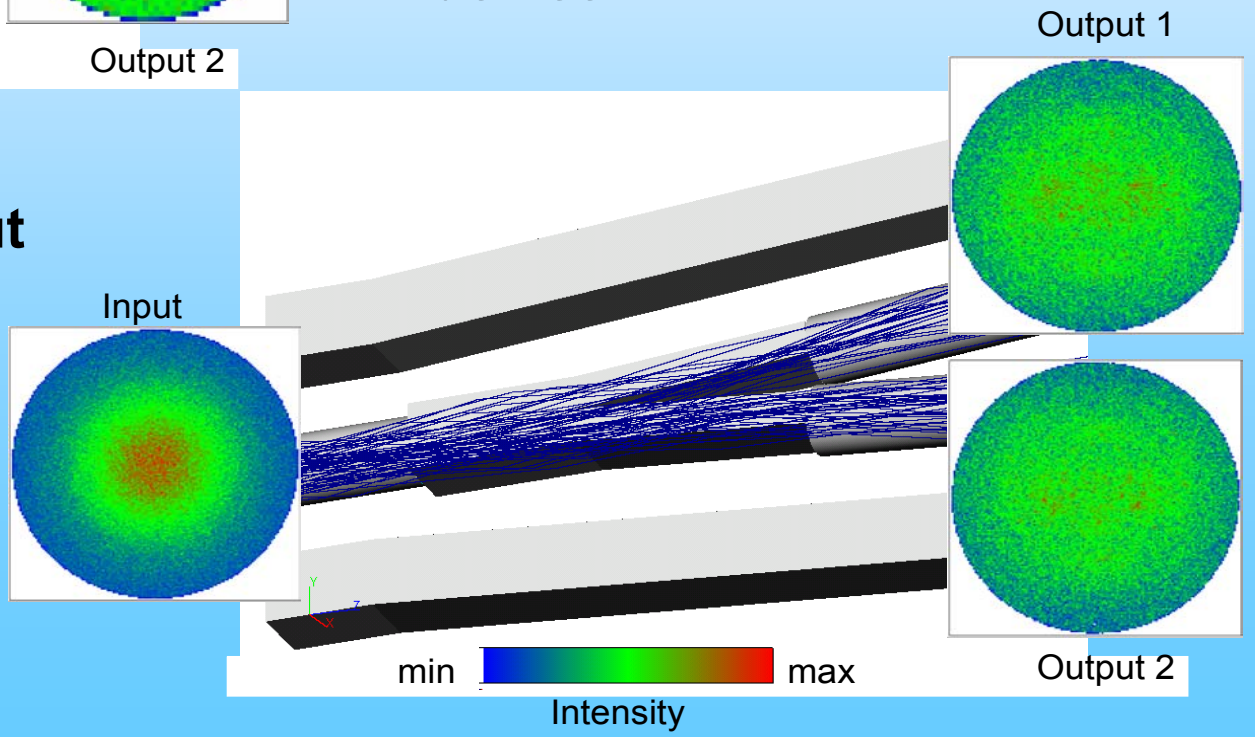


$$V = \frac{2\pi}{\lambda} \cdot \frac{d}{2} \cdot \sqrt{n_2^2 - n_1^2} = \frac{\pi \cdot d}{\lambda} \cdot NA$$

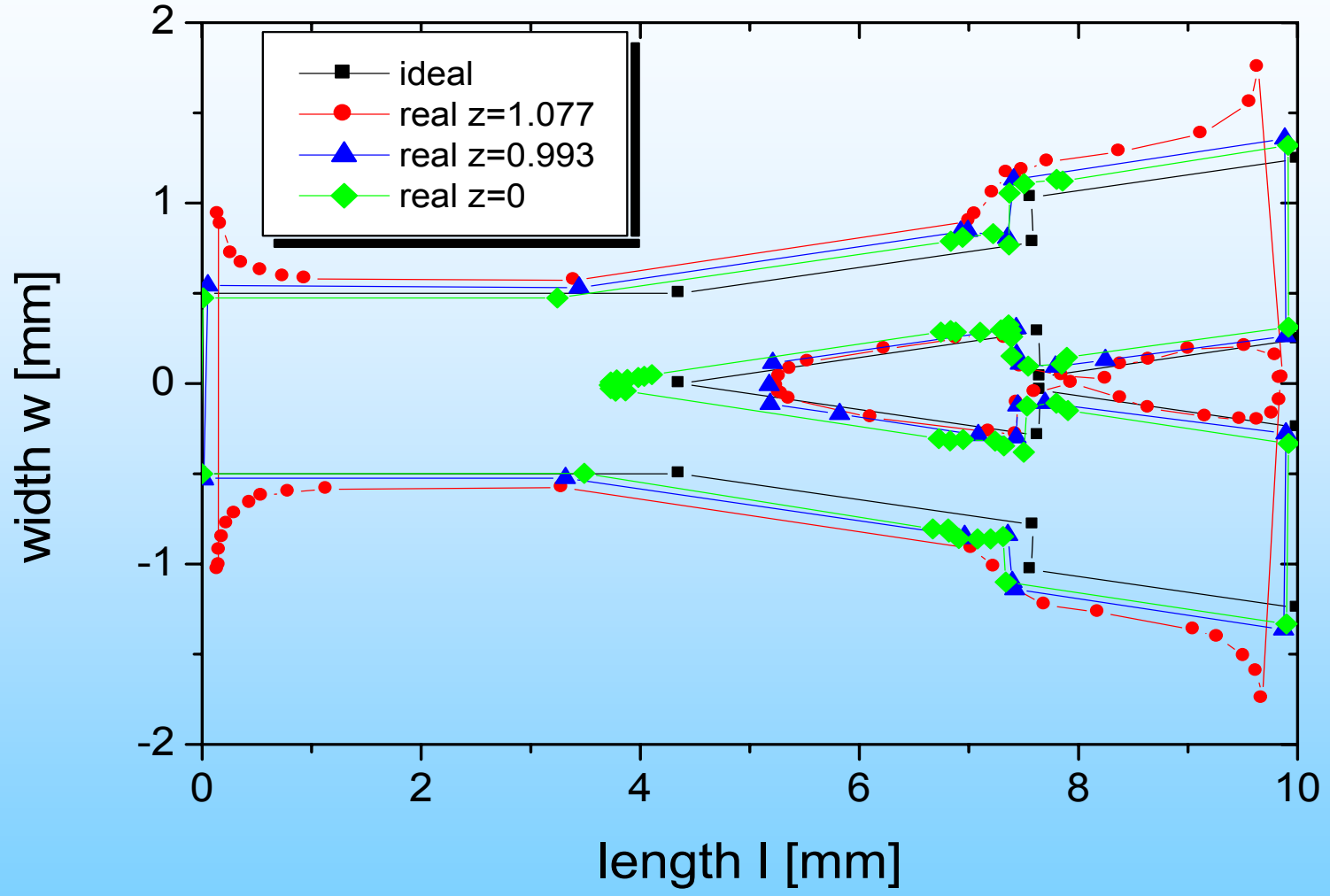
V>>1 ⇒ ray tracing possible

POF of 1 mm length are simulated together with the device

1) **planar source (LED) at input (most realistic szenario)**
2) **gaussian source at input (homogenization by mode mixing)**



INCLUSION OF REAL CONDITIONS



1) **Deviations from ideal geometry after moulding by hot embossing**

2) **Bubble formation in the waveguide channels**

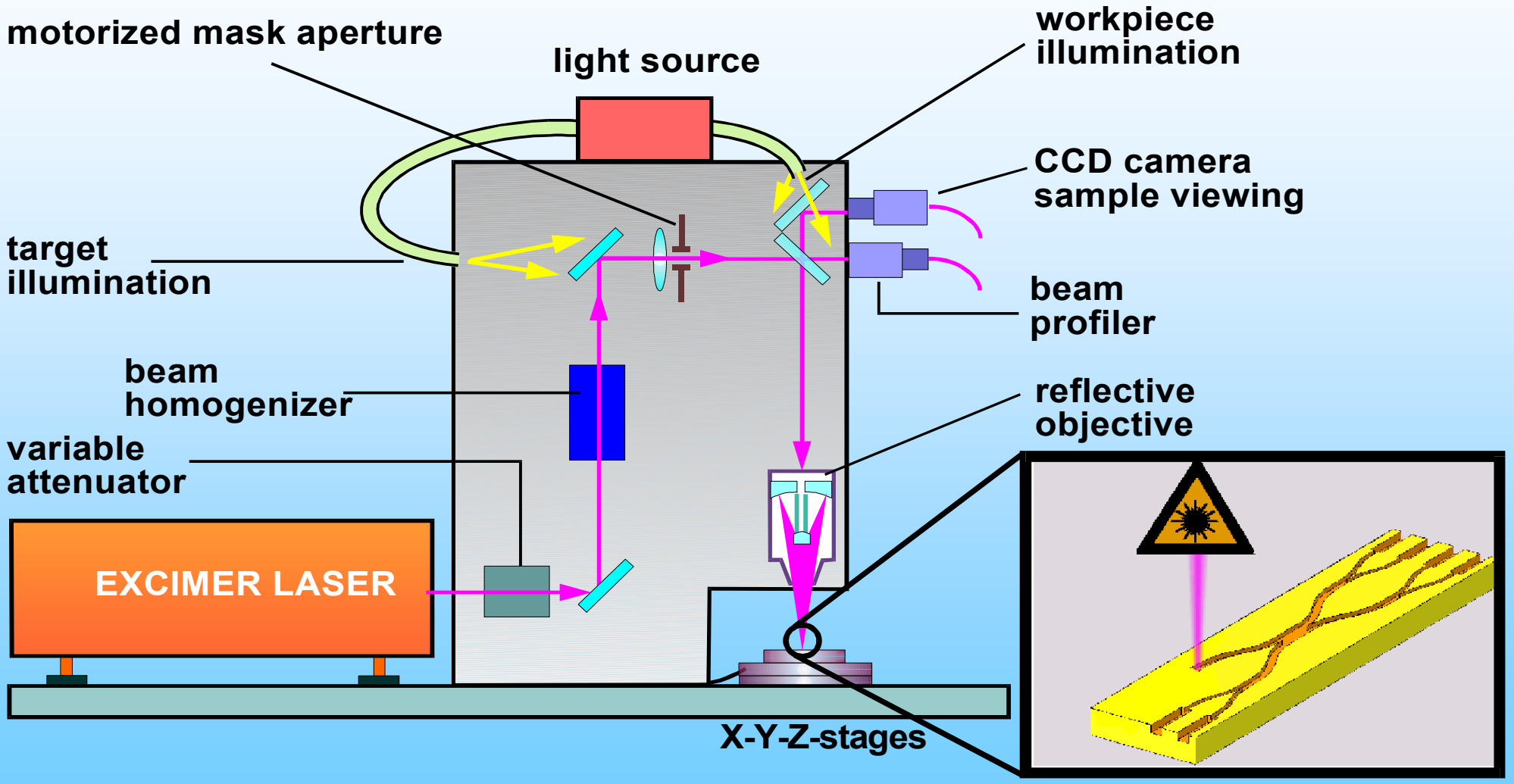
OPTICAL SIMULATION BY RAY TRACING

Geometry	NA	Split loss 1 [dB]	Split loss 2 [dB]	Uniformity [dB]	Excess loss [dB]	Insertion loss 1 [dB]	Insertion loss 2 [dB]
ideal	0.3	3.51	3.48	0.03	0.3	3.73	3.76
ideal	0.53	3.32	3.31	0.01	0.35	3.62	3.61
real	0.3	4.37	4.49	0.12	0.3	4.67	4.79
real	0.53	4.23	4.34	0.11	0.35	4.58	4.69
real + 100 µm bubble	0.3	4.41	4.5	0.09	0.3	4.71	4.8
real + 100 µm bubble	0.53	4.26	4.37	0.11	0.35	4.61	4.72
real + 300 µm bubble	0.3	4.89	4.48	0.41	0.3	5.19	4.78
real + 300 µm bubble	0.53	4.77	4.39	0.38	0.35	5.12	4.74

POSSIBLE FABRICATION TECHNIQUES

- **Conventional milling** (direct formation of metal mould insert possible, but no perferctly shaped contours)
- **EDM** (direct formation of metal mould insert possible, but surface roughness too high)
- **LIGA** (expensive because deep X-ray lithography required)
- **Laser Ablation** (not suitable for large numbers, too slow)
- **Laser LIGA** (cheaper compared to standard LIGA and quality of mould insert is good enough)

LASER ABLATION SETUP



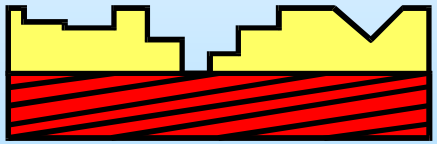
Source: Exitech Ltd.

PRINCIPLE OF LASER LIGA

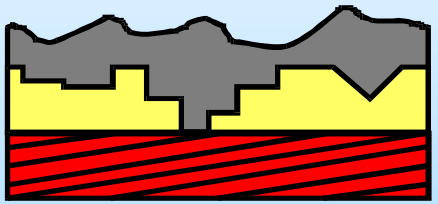
1. Polymer-Coated Ti-Wafer

- Polymer
- Ti base plate

2. Microstructuring with Excimerlaser



3. Thermal Evaporation and Electro-Plating

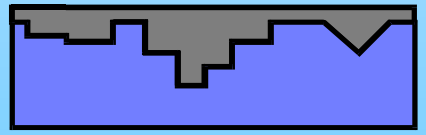


- Ni

4. Machining and Separation

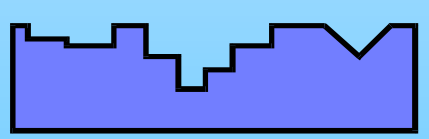
- Mould Insert

5. Injection Moulding



- Moulded Polymer

6. Demoulding

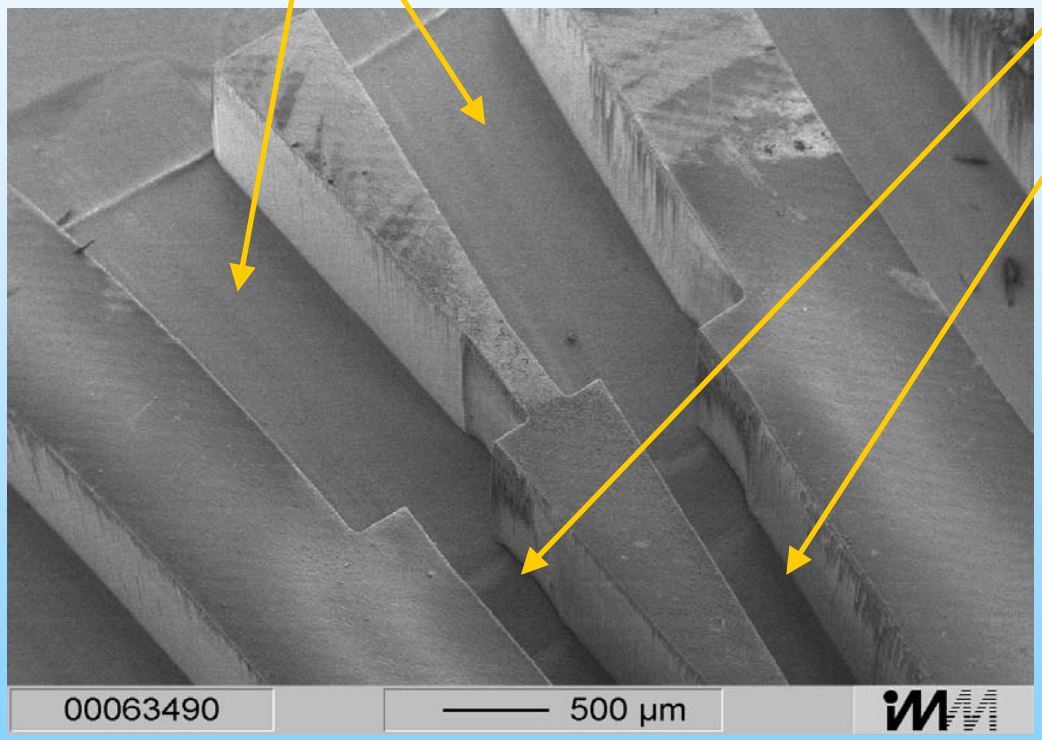


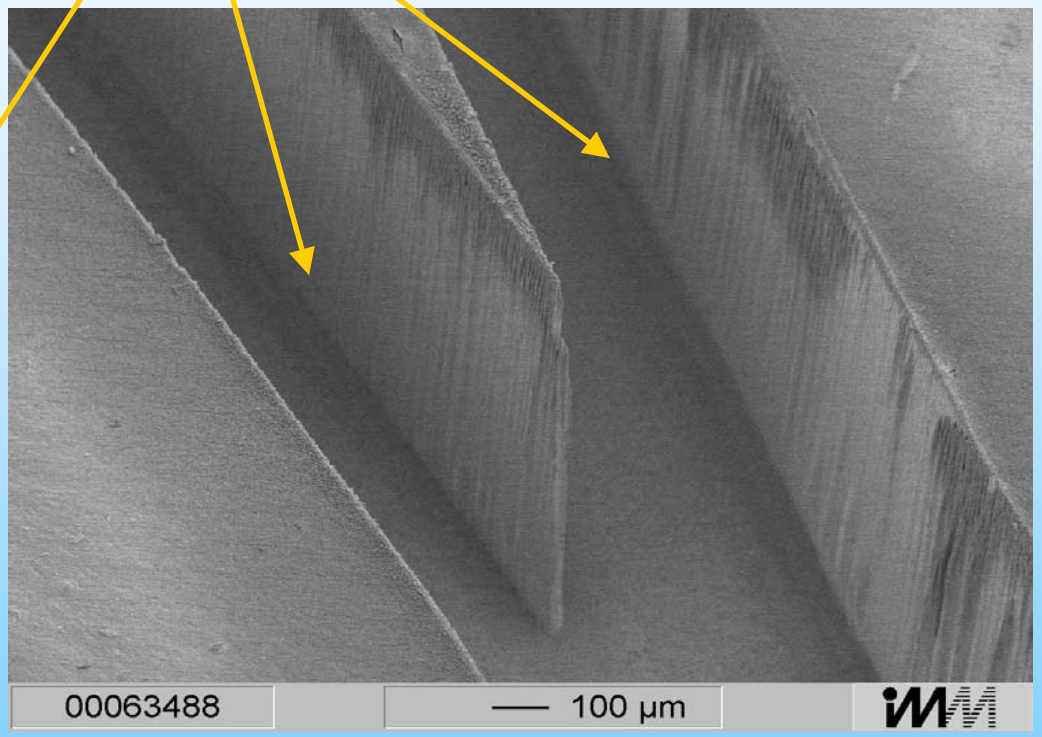
- Mould

ABLATION RESULTS

Fibre grooves

Waveguide grooves (after refilling)

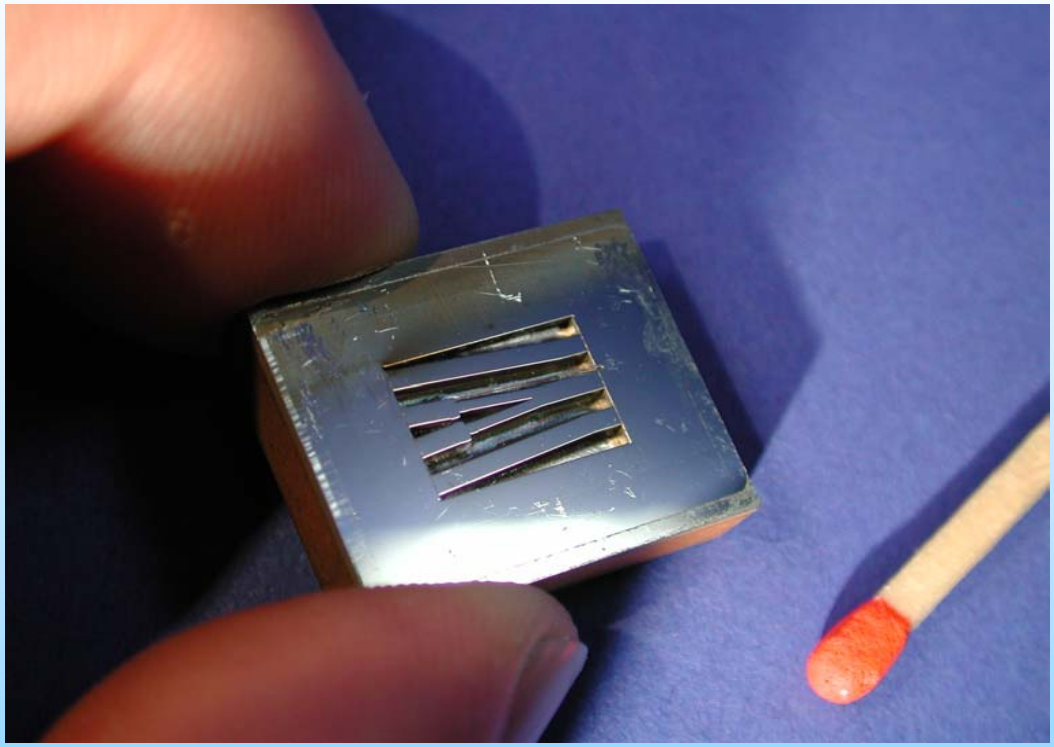




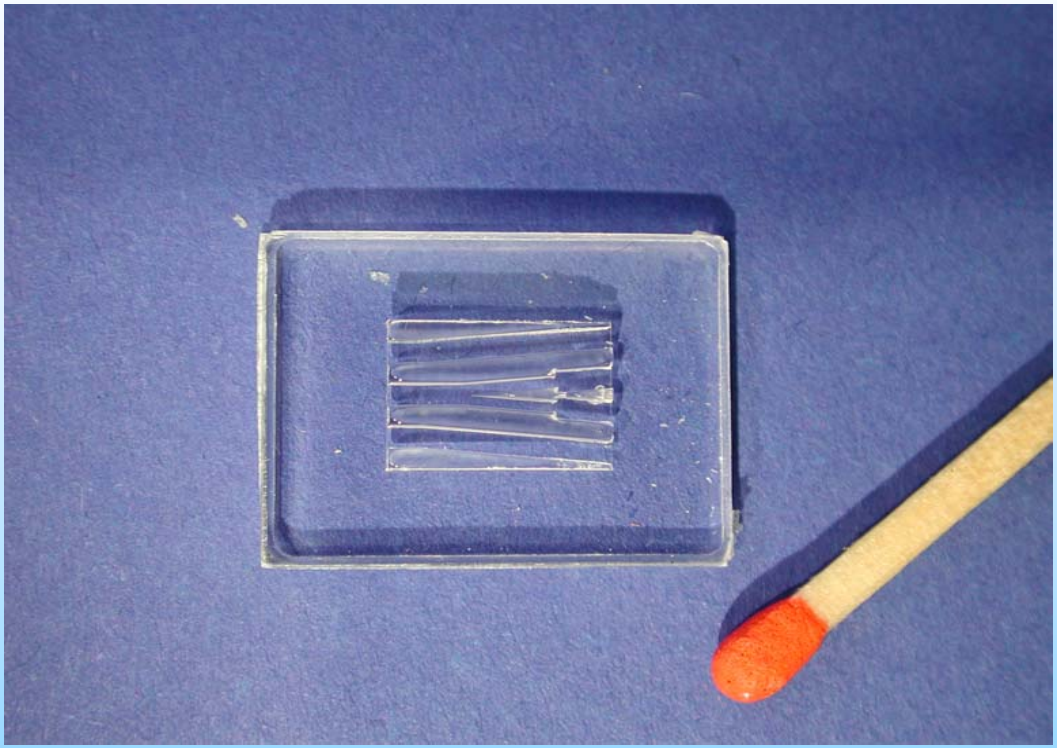
Fibre coupling region

Splitting region

MOULD INSERT AND HOT EMBOSSING



Mould insert
(polished on back side)



Mould part
(as fabricated by hot embossing)

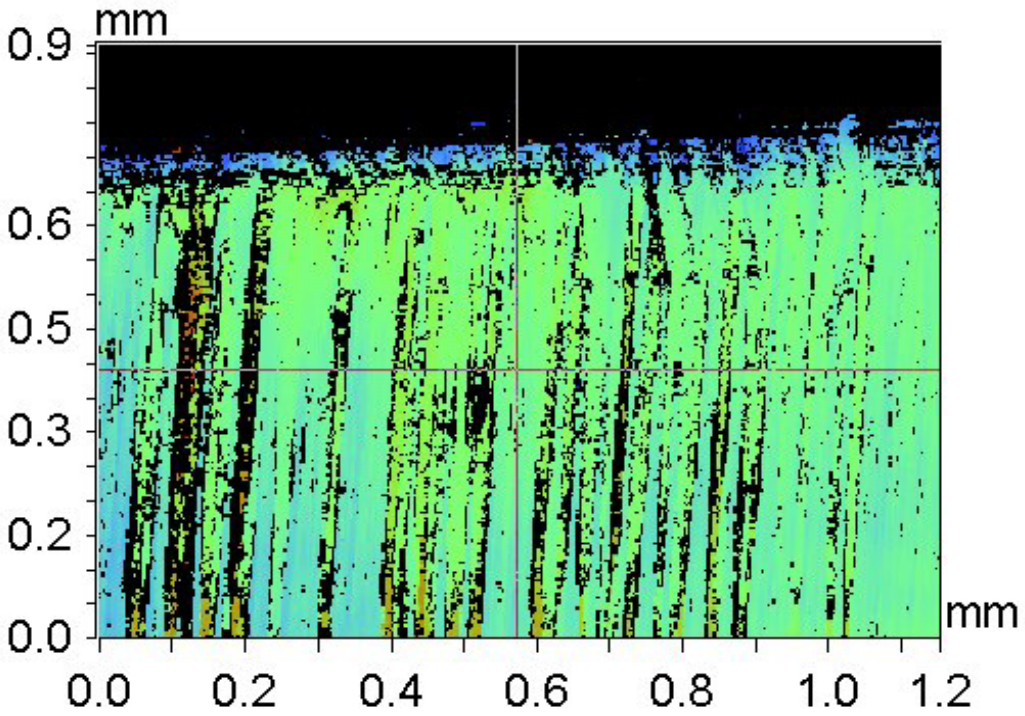
SURFACE ROUGHNESS

WYKO

Mode: VSI
Mag : 5.3 X

08/12/02
17:55:12

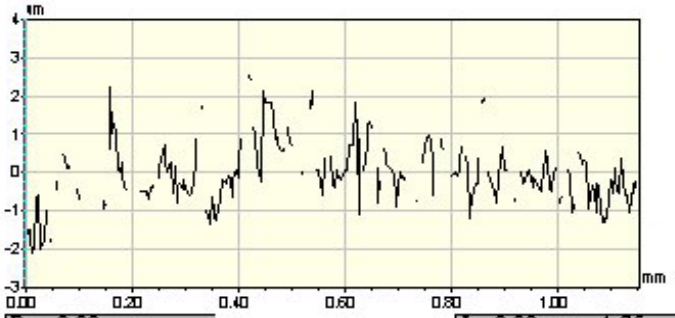
2D Profiles



Size: 368 X 236

1: 182,106

X-Profile / 2 Pt / Radial



Rq: 0.88 um
Ra: 0.64 um
Rt: 5.99 um
Rp: 3.88 um
Rv: -2.11 um

L: 0.00 mm -1.75 um
R: 1.15 mm ---
D: 1.15 mm ---
Angle: ---
Curve: -124.54 mm
Terms: P T
AvgHt: 0.00 um
Area: 0.00 um2

Y-Profile / Circular

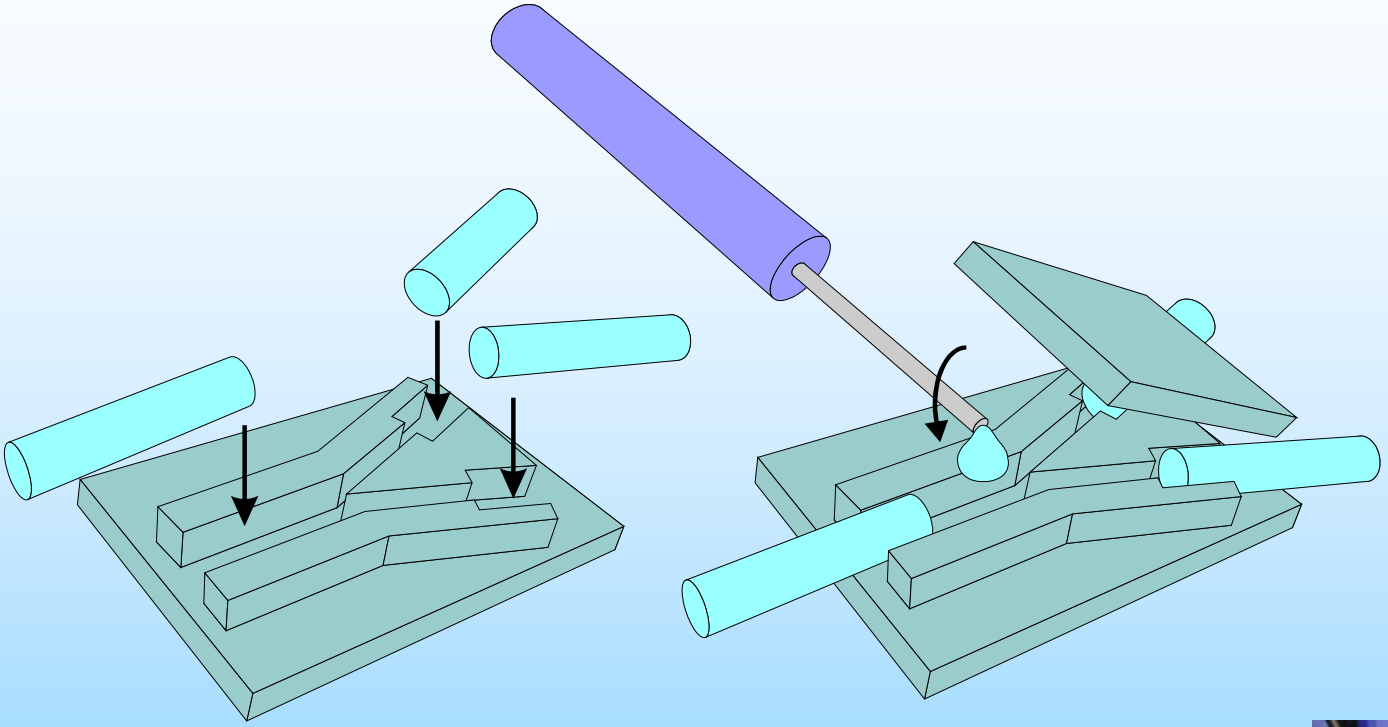
Rq: 1.06 um
Ra: 0.45 um
Rt: 12.74 um
Rp: 1.61 um
Rv: -11.13 um

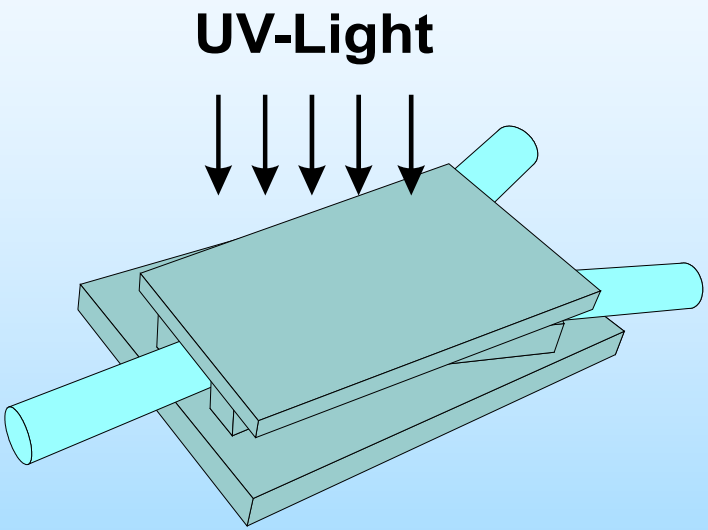
L: 0.00 um 0.13 um
R: 862.15 um ---
D: 862.15 um ---
Angle: ---
Curve: -36.67 mm
Terms: P T
AvgHt: -0.00 um
Area: -0.00 um2

Title:

Note:

ASSEMBLY





1. Positioning of POF´s
2. Filling with resin
3. Covering with top plate
4. Photocuring of resin

OPTICAL PERFORMANCE

Commercial reference

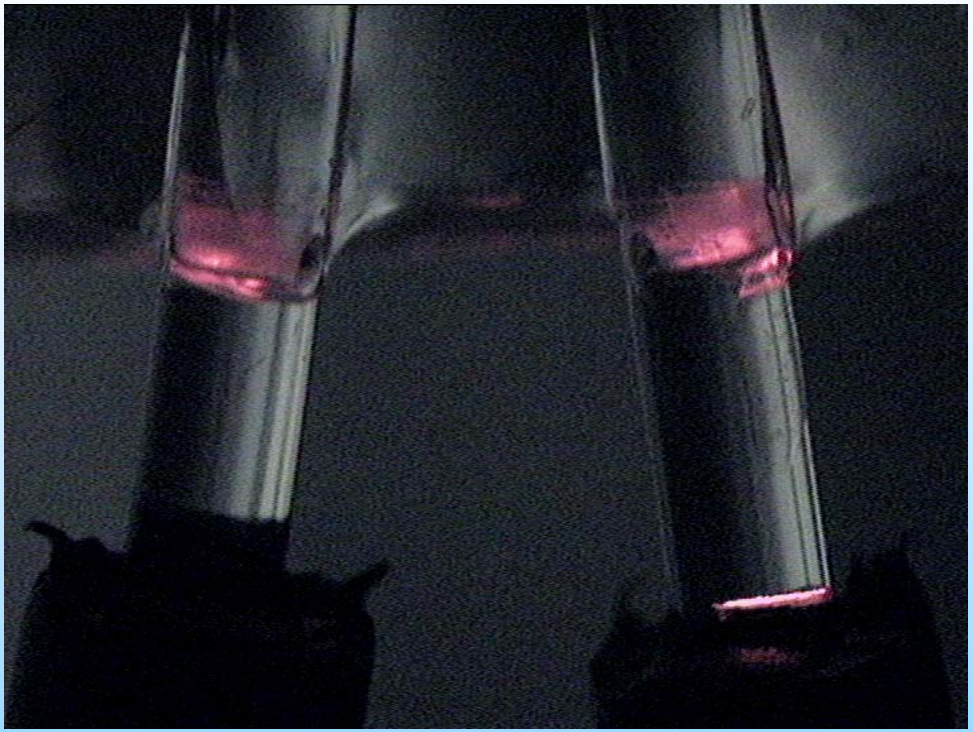
Best value

Mean value for NA=0.3

Mean value for NA=0.53

#	NA of core	Insertion Loss 1	Insertion Loss 2	Uniformity	Description
Ref	0.47	5.7	6.6	0.9	Commercial Wave Front Division
BT1	0.3	8.3	7.1	1.2	Resin not degassed
BT2	0.53	12.4	8.2	4.2	Several bubbles, resin not degassed
BT3	0.53	6.2	5.6	0.6	-
BT4	0.53	7.7	6.6	1.1	-
BT5	0.53	8.9	6.6	2.3	Several bubbles in the waveguide
BT6	0.53	5.8	5.9	0.1	Few small bubbles in the outputarms
BT7	0.53	6.0	7.4	1.4	-
BT8	0.3	5.7	5.6	0.1	Small bubble in front of port 2, resin not
BT9	0.3	6.0	7.8	1.8	Long bubble in front of port 2, resin not
BT10	0.3	6.4	6.6	0.2	Small bubble in front of port 2, resin not
BT11	0.53	6.0	5.6	0.4	Bubbles in front of both output ports
BT12	0.53	6.4	5.8	0.6	Bubble in front of input port
BT13	0.53	7.2	8.5	1.3	Bubbles in front of input port
BT14	0.53	7.0	8.8	1.8	Bubbles in front of output port 2
BT15	0.53	6.9	6.4	0.5	Bubbles in front of output port 2
Mean 0.3	0.3	6.6	6.8	0.83	-
Mean 0.53	0.53	7.3	6.9	1.3	-

OPTICAL PERFORMANCE



Scattering losses (coupler) due to:

- surface roughness of side walls
- bubble formation in the resin
- imperfect moulding

Additional losses (fibre) due to:

- stripping faults
- imperfection of fibre end face

SUMMARY AND CONCLUSION

- POF couplers will probably be needed in future optical networks for automotive and aerospace applications
- Waveguide technology has highest potential for complex couplers
- Laser LIGA technology is suitable for fabrication of mould inserts for cost effective large number fabrication
- Optical performance of 1x2 couplers is comparable to commercial wave front division couplers
- Future work will concentrate on more complex couplers (also for FTH application) and environmental testing