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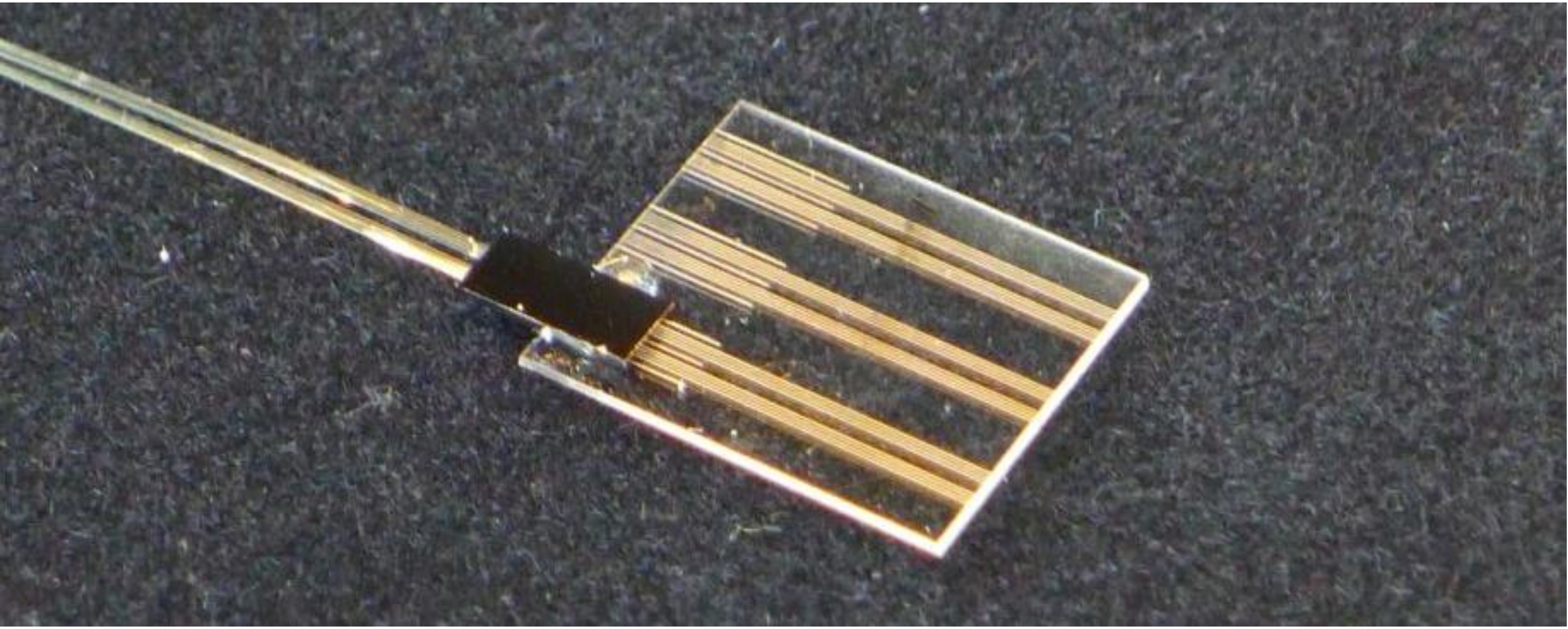

Passively aligned fiber-coupling of planar integrated waveguides

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SPPL-Event: Miniaturized Photonic Packaging – Alpnach

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vario-optics ag

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- Research published:

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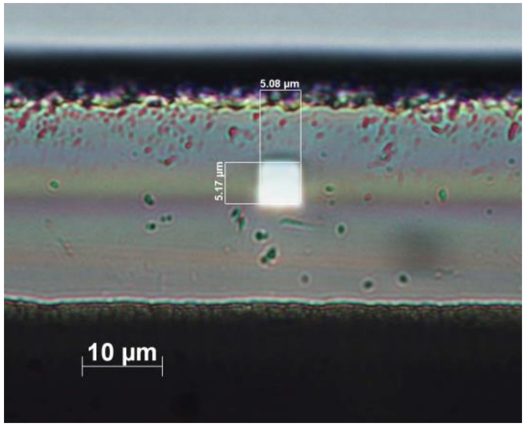
Motivation

- Fiber coupling of integrated optical systems is important:
  - Communication over long distances
  - Coupling to sources
  - Interlinking of PLCs (Planar Lightwave Circuits)

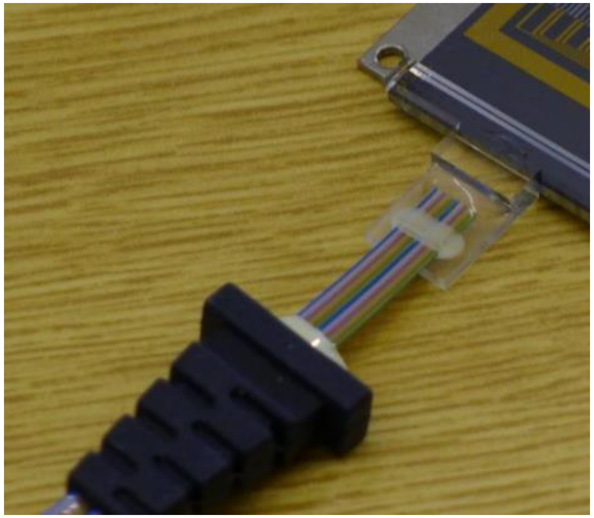
- Properties
  - High integration density of PLCs → Fiber-Arrays
  - Facet-coupling of dielectric waveguides with low index-contrast is most efficient (in terms of IL, space consumption etc.)
  - Small surface area on the facets of the fibers and waveguide-boards limits the durability of a facet joint

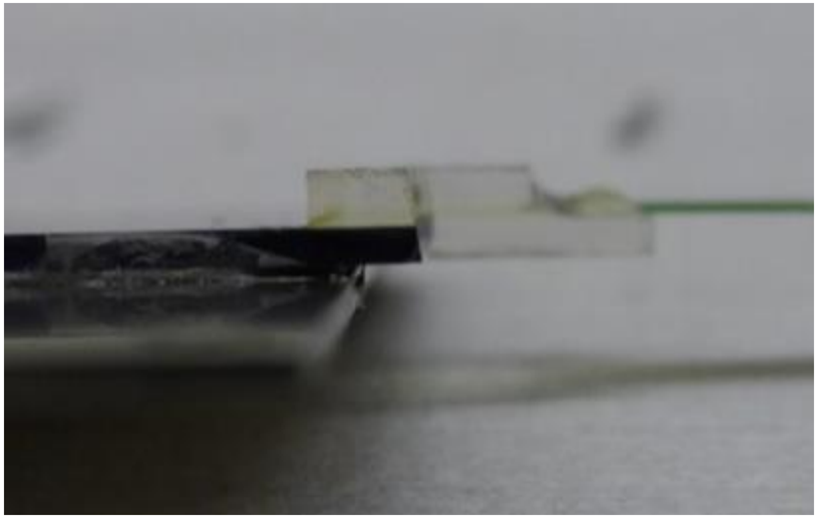


State of the Art

- Active alignment of fiber-arrays and adhesive bonding
  - Apply glass-blocks to enlarge the bonding surface
  - Polishing the facet
  - Active alignment & bonding using and UV-curing adhesive
- Automation difficult & device specific (high volume)

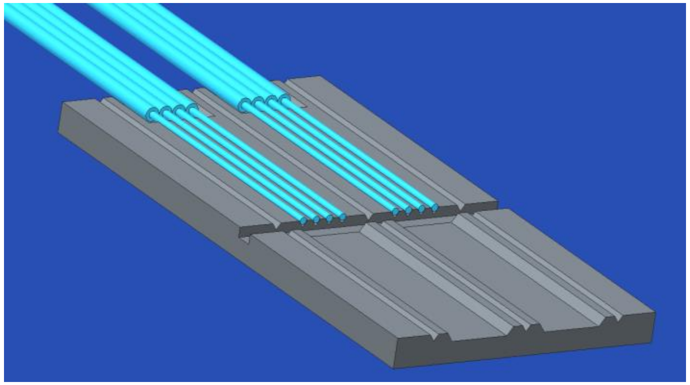
→ Fiber-coupling is a significant cost contributor

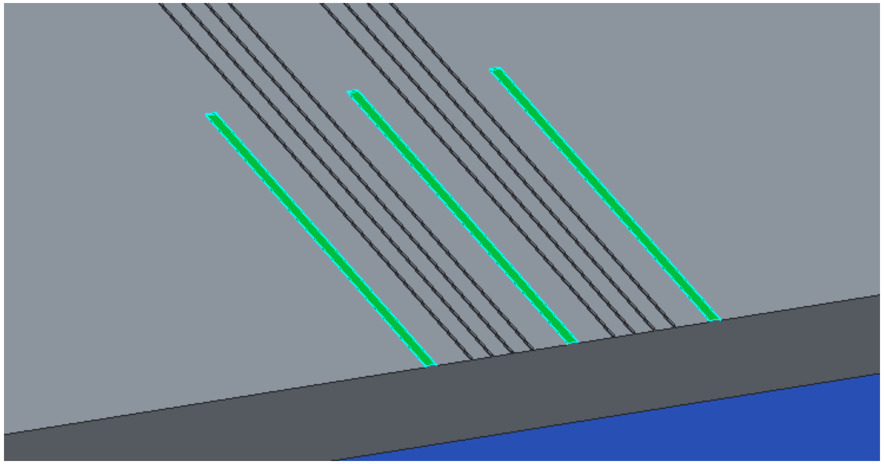


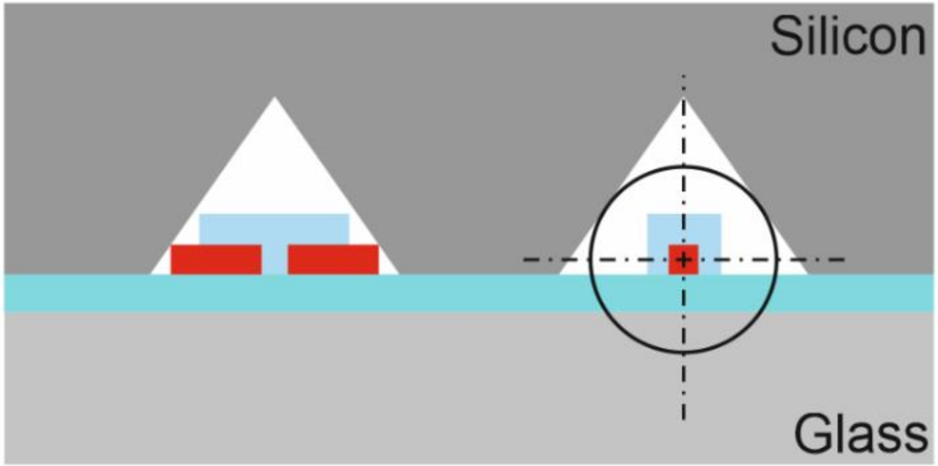


Approach

- Goal: passively aligned multi-channel fiber coupling of PLCs
- Silicon-element with V-Grooves
  - V-Grooves as Fiber-Holder
  - V-Grooves as alignment feature
- Coupling interface on PLC board
  - Structured cladding
  - Core structures as alignment feature



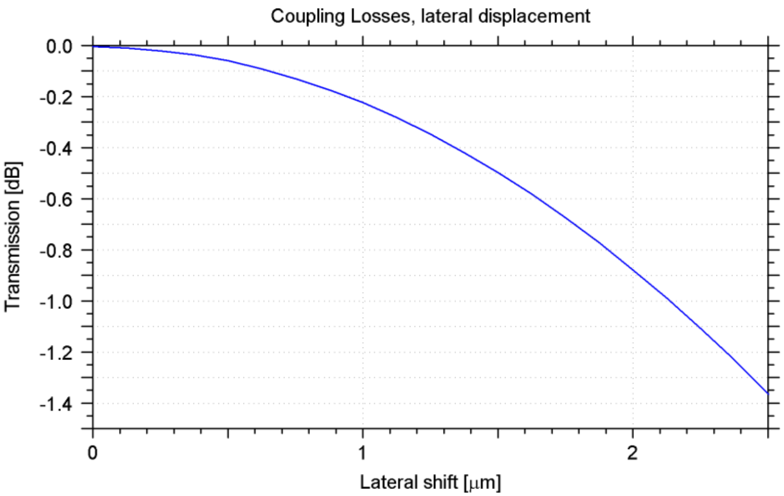


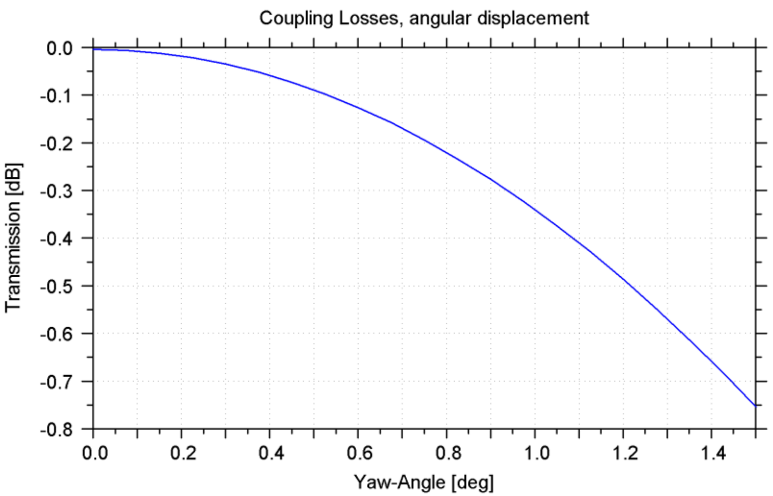


Source: Kremmel et al., Opt. Eng. 56 (2) 2017

Coupling characteristics

- Lateral and angular displacement – coupling efficiency
  - Waveguide: 5µm x 5µm, Δn = 0.006

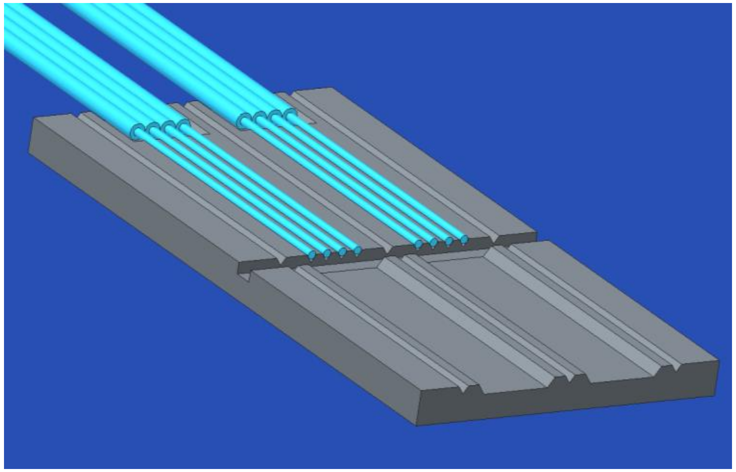


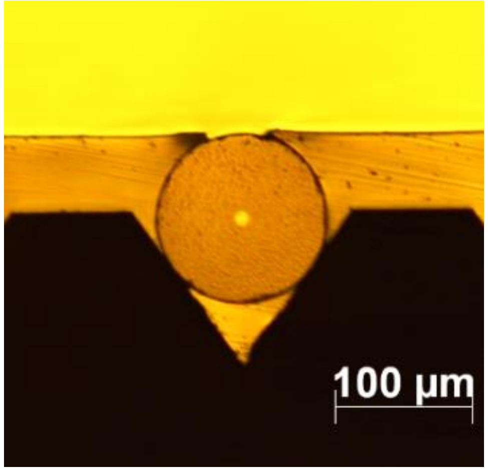


- Accuracy, accepting a displacement loss of 0.5dB:
  - Lateral: <1.5µm
  - Axial: <50µm
  - Angular: <1.2°
  - Losses by Mode-Mismatch: 0.18dB

Silicon-Element

- Precise Etching of V-Grooves in Silicon using KOH
  - Slow etching {111}-Planes for high accuracy
  - 8 Grooves for fibers
  - 3 Grooves as alignment feature
  - Large bonding area: minimal angular deviation, adhesion

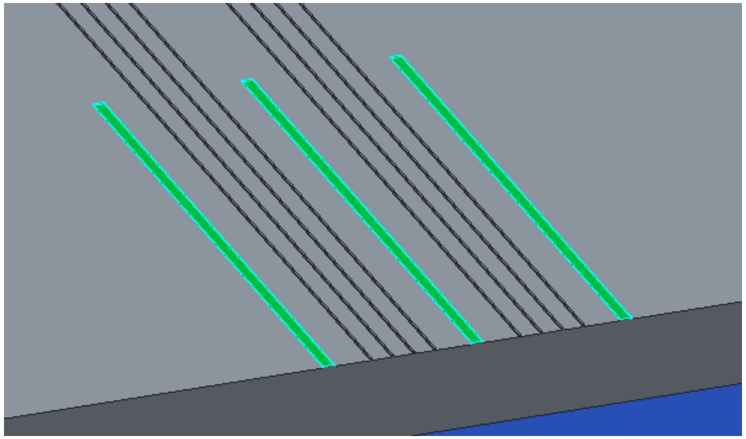


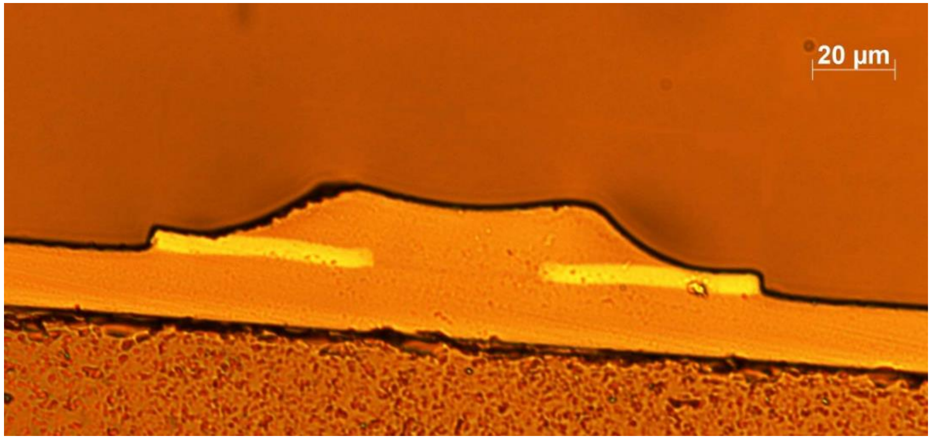


- Assembly
  - Adhesive bonding of the fibers
  - cut and polish the fibers using a wafer dicer
    → all facets in one plane, <30nm RMS

Coupling Interface PLC

- Waveguides with structured top-cladding
  - Structuring by cusing UV-LDI
- Alignment structures corresponding to alignment V-Grooves
  - Alignment features and waveguide-cores in the same process step
  - → Maximum position accuracy



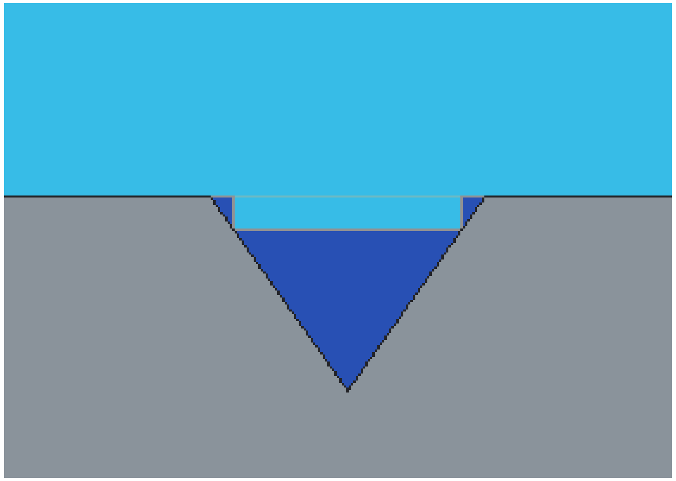


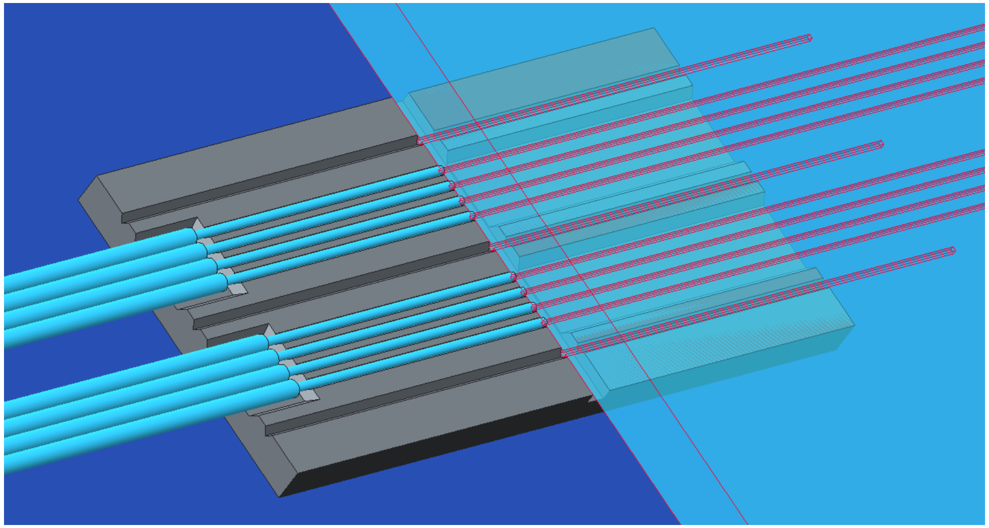
→ Assembly using UV-curing adhesive

Assembly I

- Application of the silicon fiber-ribbon onto the PLC-Board
  - Alignment structures fit to V-Grooves and provide precise lateral alignment
  - Axial alignment: facets act as stop

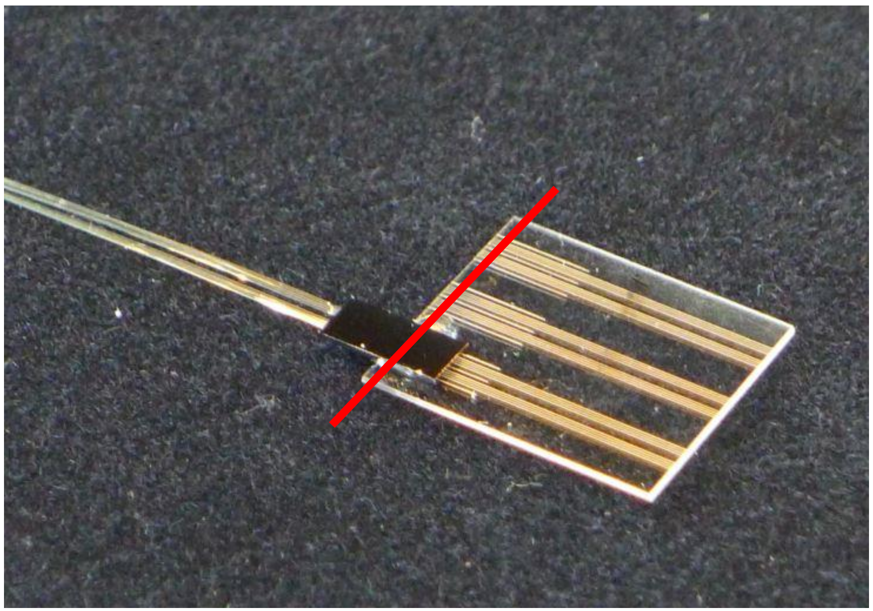
- Mounting using UV-curing adhesive
  - Adhesive as index-matching agent

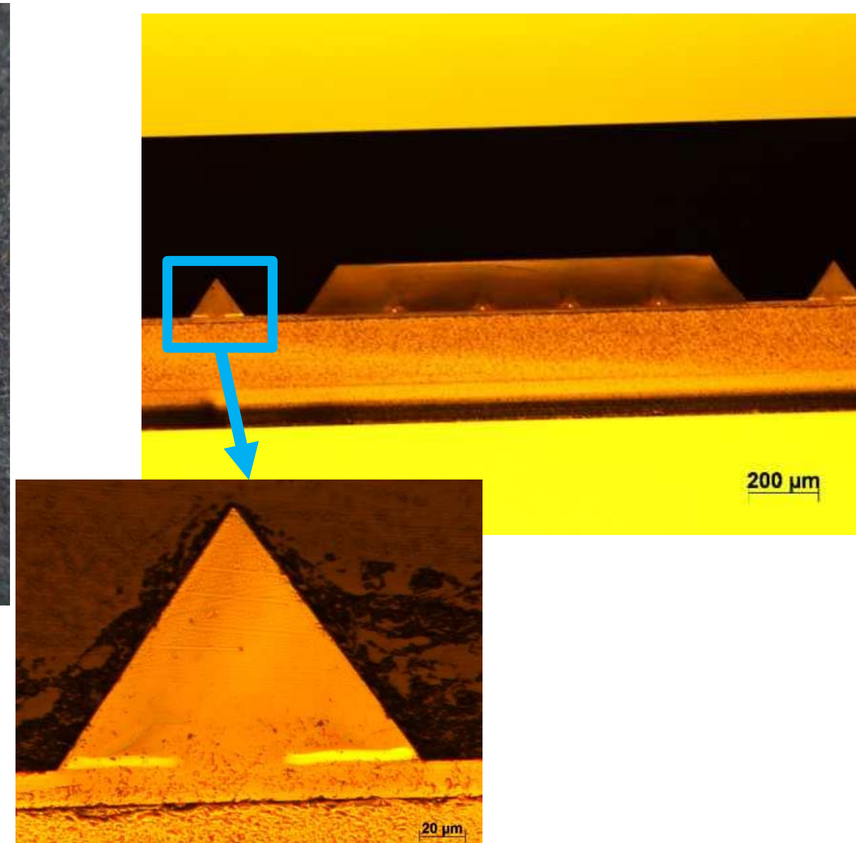




Assembly II

- Microscopy analysis of the Assembly
  - Cross-sections to investigate alignment



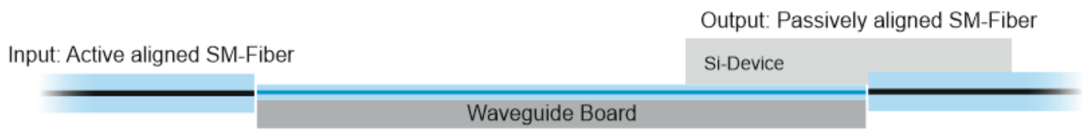


Optical Characterization

- Measurement of the Coupling Loss
  - Compare passively coupled WGs and reference WGs
  - Reference Measurement:

→ Measure light transmitted through WG

  - Measurement passive coupling:



→ Measure light transmitted through WG & coupled into SM-Fiber

Results

T_{Ref} = -1.69 dB

T_{Ribbon} = -1.92 dB

→ Losses by SM-Coupling (CL): 0.23 dB

Losses due to Misalignment: 0.05 dB

- CL – Transition Loss: 0.23dB - 0.18dB

Scattering Losses: 0.22 dB

- Cut-Back Measurement

→ Total Coupling Losses/Interface: (0.45 +/- 0.20) dB

- Transition Loss + Misalignment + Scattering

Results II

- Climate Tests:
  - Thermal Cycling: -30 – 70°C, 10 times
    → Transmission remains unchanged on all channels
  - 85/85-Test for 168h:
    → Losses increase by 1.2dB in average
    → Reference Waveguides stable
    → SEM-Analysis of Cross-Sections: delamination of the adhesive in the gap between fiber and waveguide

Conclusions

- Passively aligned coupling of 8 SM-fibers to 8 SM-WGs has been demonstrated successfully
  - Achieved coupling losses are significantly lower than earlier reports
  - Simple assembly: no additional tools necessary (even by hand)
  - For climate tests → further optimization of assembly process

- Only standard MEMS resp. MOEMS fabrication and packaging processes have been applied
  - Si-etching in KOH
  - Adhesive bonding
  - Wafer dicing