MEMS-assisted fiber-chip coupling

Xaveer Leijtens¹, Rui Santos², Marcel Tichem³, Kerstin Wörhoff⁴ and Kevin Williams¹

1. Institute for Photonic Integration, TU Eindhoven
2. Smart Photonics, Eindhoven
3. Delft University of Technology, Delft
4. LioniX BV, Enschede
outline

• fiber-chip coupling
  • mode mismatch: fiber ↔ waveguide
  • alignment requirements

• MEMS solution for easy sub-micron alignment
  • concept
  • results

• conclusions
fiber-chip coupling

- problem: mode mismatch: fiber ↔ waveguide

- increase spot size at PIC waveguide
  - long taper
  - pitch \( \geq 127 \, \mu m \)

- decrease fiber spot size
  - pitch ?
  - sub-micron alignment accuracy
MEMS-based solution

- TriPleX interposer for adapting spot size from fiber to InP waveguide
- Placement on carrier with moderate accuracy (~2 μm)
- MEMS actuated waveguides for precision alignment (< 100 nm)

**interposer functions:**
- Spot size reduction
- Pitch reduction
- Flexible waveguides
- Actuators for 3 critical motion directions: $T_x, T_y, R_z$
alignment procedure

- position InP: $\sim 2 \, \mu m$
alignment procedure

- position InP ~2 μm
- position silicon/TriPleX ~2 μm
alignment procedure

- position InP ~2 μm
- position silicon/TriPleX ~2 μm
- actuate MEMS <0.1 μm
fabricated structures

- two sets of actuators: left-right
- separate waveguides and actuators
- up/down and roll movement

![Image of fabricated structures]

- Silicon underneath silicon removed
- Actuator beams
- Waveguide beams
- Actuator beams

\[ 16 \times 16 \, \mu m^2 \]

\[ \approx 750 \, \mu m \]
lateral movement

\[ T_x, R_z \]
lateral movement

\[ T_x, R_z \quad \text{and} \quad T_y \]
lateral movement

$T_x, R_z$  $T_y$

“chevron” actuators
required alignment tolerance

- \( T_z = 1.5 \pm 0.5 \, \mu m \). No actuation
- \( \pm 0.1 \, \mu m \) waveguide-to-waveguide actuation with 3 actuators, \( T_x, T_y, R_z \).

1/e\(^2\) diameter
\(~3 \, \mu m\)
**mode shape in waveguide beam**

**mode profiles**

1/$e^2$-diameter ~3 µm

spot at tip of flexible beam

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XL-13
movement range of actuators

- movement of spot-center on camera
  - 0—10 V ↔ 0—100 mW

- ~ 8 µm movement range
- 0.1 V ≈ <0.1 µm
lab-bench test: coupling InP ↔ TriPleX

11-axis alignment
measurement results

- MEMS flexible waveguide beams spaced at 250 µm
- coupled to two InP photodetectors on Oclaro test chip
- optical power versus displacement
conclusions

- fiber-chip interposer with MEMS actuators fabricated
- MEMS actuation of flexible waveguides demonstrated
- movement range of 8 μm sufficient to overcome initial misalignment
- sub-micron positioning resolution demonstrated
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Thank you!