

## Problem Set 9 Optical Waveguides and Fibers (OWF)

will be discussed in the tutorial on January 20, 2016

### Exercise 1: LP-modes, hybrid modes and cut-off frequencies

The facet of a Corning SMF-28 fiber is illuminated with a green laser (wavelength of 532 nm). You can find all relevant parameters of the fiber in its datasheet: ([http://www.corning.com/media/worldwide/coc/documents/Fiber/PI1450\\_3-2015.pdf](http://www.corning.com/media/worldwide/coc/documents/Fiber/PI1450_3-2015.pdf)).

- a) How many LP-mode families are guided?
- b) How many different modes are guided by the fiber?
- c) Sketch the intensity profile of all guided mode families.

### Exercise 2: Photonic wire bonds and cut-off frequencies

Fig. 1 shows so-called photonic wire bonds connecting two silicon-on-insulator (SOI) waveguides, a four-core multicore fiber and SOI waveguides, and a horizontal-cavity surface-emitting laser (HCSEL) and an SOI waveguide. Taper structures are used to match the modes of the SOI waveguides, the multi-core fiber, and the HCSEL to the modes of the photonic wire bonds. The bond consists of a polymer (trade name IP-Dip, a commercially available photoresist), and has a refractive index of 1.53 at  $\lambda = 1550$  nm. The structure is surrounded by air. In the following you can assume that the wire bond waveguide has a circular cross section, and that the bend radius is large compared to the bond diameter, such that the structure can be approximated by a straight waveguide.

- a) Which condition must the diameter of the bond fulfill, such that the bond is a single-mode waveguide at a wavelength of 1550 nm?
- b) Does the LP-mode model apply in this case?
- c) Discuss ways to increase the diameter and thus the mechanical stability of the wire bond while maintaining single-mode operation at a wavelength of 1550 nm.

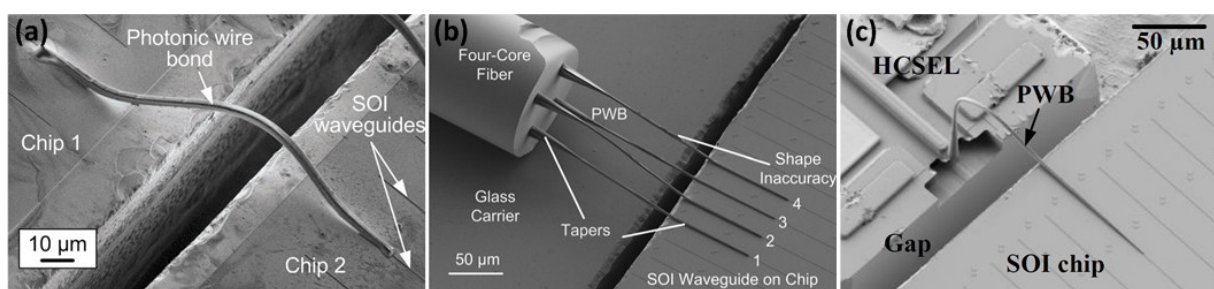


Figure 1: (a) A photonic wire bond between two silicon waveguides [1]; (b) Four photonic wire bonds between four cores of a multi core fiber and four SOI waveguides [2]; (c) A photonic wire bond between a HCSEL and an SOI waveguide [3]

[1] Lindenmann et al., “Photonic wire bonding: a novel concept for chip-scale interconnects”, *Optics Express*, vol. 10, no. 16, pp 17667-17677, 2012.

[2] Lindenmann et al., “Connecting Silicon Photonic Circuits to Multicore Fibers by Photonic Wire Bonding”, *Journal of Lightwave Technology*, vol. 33, no. 4, pp 755-760, 2015.

[3] Billah et al., Multi-Chip Integration of Lasers and Silicon Photonics by Photonic Wire Bonding”, in CLEO: 2015, OSA Technical Digest (online) (Optical Society of America, 2015), paper STu2F.2.

**Questions and Comments:**

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