High Efficiency Fiber-Chip Coupling

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Principal Investigator(s): Jaime Cardenas
User(s): Sushant Kumar

Affiliation(s): The Institute of Optics, University of Rochester

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Contact: jaime.cardenas@rochester.edu, skumar31@ur.rochester.edu

Research Group Website: https://www.hajim.rochester.edu/optics/cardenas/

Primary CNF Tools Used: JEOL9500, ASML PAS 5500/300C DUV Stepper, Oxford PECVD, LPCVD Furnace, Oxford 100 Etcher, Unaxis 770 Deep Silicon Etcher, Plasma-Therm Versaline Silicon Etcher, Xactix Xenon Difluoride Etcher

Abstract:

We design and fabricate silicon photonic chips for high efficiency Polarization Maintaining optical fiber-chip coupling.

Summary of Research:

The need for increasingly large amounts of data and bandwidths has been driving the growth of Silicon Photonics for telecom and data-center applications. But this has also let to an increasing share of power consumption in the optical data-networks leading to development of more energy efficient designs like co-packaged optics [1], ring-based modulators [2], etc. These designs while being energy efficient are very sensitive to polarization. To ensure clean polarization devices can integrate laser sources on chip [3], which increases heat density on chip and introduces associated thermal instability and cross coupling issues that require more expensive cooling and careful design. More modern system designs [4] include external laser sources to reduce the heat density on chip but require PM fiber connections to the chip. To our knowledge there are no good industry level solutions for PM fiber connections.

Most widespread packaging solutions for PM fibers rely on micro lens assemblies and some recent work on angle thin polished PM fiber connection uses on chip gratings and epoxy [5], which makes the connection limited in bandwidth and heavily temperature dependent due the use of epoxy. In this project we designed high efficiency couplers for PM-fiber-chip coupling and measured to verify any depolarization effects caused by the connection itself.

We designed the SiO2 Mode Converter (MC) by matching the optical mode at the MC-fiber interface. This is done by optimizing the dimensions for the MC at the interface. This allows not only for efficient coupling of optical power due to minimized mode matching, but also increases the alignment tolerance of the fiber-chip connection by making the mode 10 μm in diameter as compared to regular waveguide tapers which have 3-4 μm diameter optical modes. On the other end of the MC, the dimensions of the MC and waveguide taper are optimized to maximize the power transfer. Since at this interface everything is lithographically designed, misalignment is not a concern and only the power coupling efficiency is of import. The input and output ports are offset laterally to eliminate any scattered light polluting the measurements.

We start with 5.75 μm of OXFORD-PECVD SiO2 on a blank Si wafer and then use a 300 nm thick OXFORD-PECVD deposited Si3N4 layer for waveguide layer. The waveguides are defined using the ASML-PAS-500 stepper and etched using the OXFORD-100 ICP-RIE. We deposit 5.75 μm SiO2 via OXFORD-PECVD and then pattern the SiO2 (MC) using the ASML PAS-5000. The SiO2 is etched using the OXFORD-100. Fiber grooves are etched into the chip using either UNAXIS 770 or the Plasma-Therm Versaline Deep Silicon Etcher. Once the grooves are etched the chips are undercut using the Xactix Xenon Difluoride Etcher to optically isolate the mode while it propagates in the SiO2 mode converter. The wafer is diced into chips using the DISCO dicing saw. Further details on the design and fabrication of devices can be found in the published paper [6].

For testing the coupling efficiency and the polarization extinction ratio (PER), light coming out of the PM fiber is used as baseline and the fiber is aligned to TE orientation using a free-space linear polarizer. Then the light is launched onto the chip and collected at the output using a high NA microscope objective to estimate the propagation loss of the chip. At this point the pre-fusion PER is also estimated and largely matches the

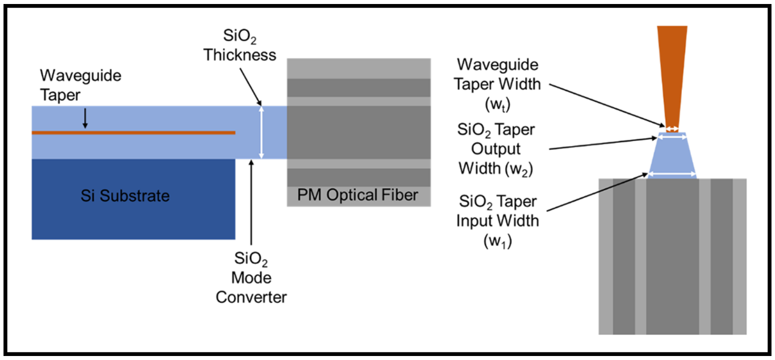

Figure 1: Chip design and material configuration.

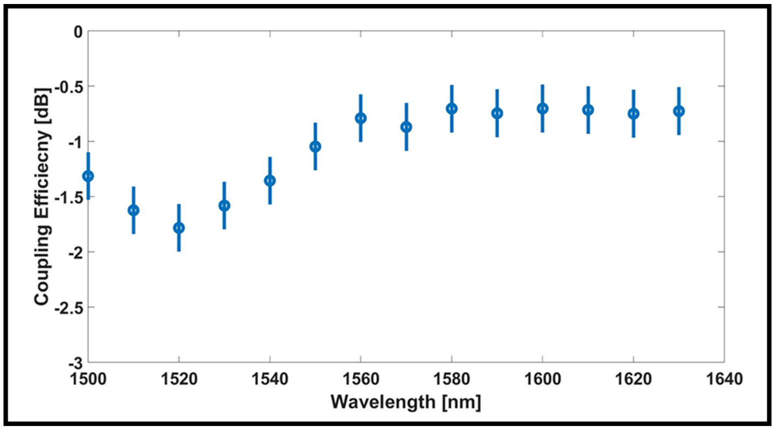

Figure 2: Coupling data for fused fiber-chip connection.

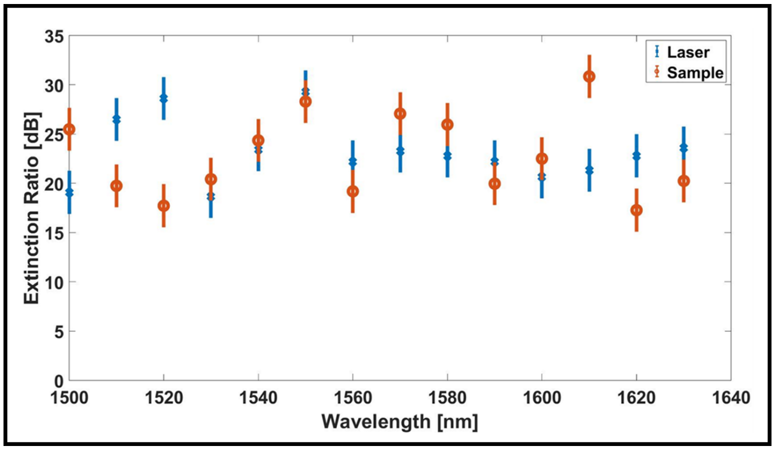

Figure 3: PER data for post-fusion PM-fiber-chip connection.

baseline stablished from the PM fiber. This indicates that the light coming out of the PM fiber doesn't depolarize as it couples to and travels through the chip. Then the objective is replaced with another optical fiber to estimate a pre-fusion coupling efficiency of 1.2dB. Then the fiber is fused to the chip using a CO2 laser and the light is again collected using the optical fiber at the other end and the post fusion coupling is estimated to be 1dB per facet. Then the fiber at the output is replaced with the high NA objective with a liner polarizer in the optical path, to again estimate the PER. As shown in Figure 2.

The PER post fusion also largely follows the baseline established from the PM fiber light leading to the conclusion that the fusion doesn't lead to any damage to the PM fiber structure or any depolarization of the light.

Conclusions and Future Steps:

In conclusion, we demonstrate efficient fiber to chip connection via CO2 laser fusion and show no degradation in polarization of the light that is being couple onto the chip. This demonstrates that the MC design and the laser fusion process are a viable option not only for standard single mode fibers-chip coupling but also for PM fibers. Further design, fabrication and testing is underway for other fiber configurations.

References:

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