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Planar fiber-chip-coupling using angle-polished polarization maintaining fibers

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We report on our latest developments of a planar fiber-chip-coupling scheme, using angle polished, polarization maintaining (PM) fibers. Most integrated photonic chip components are polarization sensitive and a suitable way to launch several wavelength channels to the chip with the same polarization is the use of PM fibers. Those impose several challenges at processing and handling to achieve a stable, permanent, and low-loss coupling.
We present the processing of the fibers in detail and experimental results for our planar and compact fiber-chip-coupling technique.

Summary (500 words)

High performance optical links using wavelength division multiplexing (WDM) are the future in detector instrumentation to increase data transmission bandwidth and reduce fiber count. A key component of such a system is a compact and efficient fiber-chip-coupling, connecting a photonic chip to the optical glass fibers. As most components of integrated photonic chips are polarization sensitive, one can use lossy on-chip polarization-insensitive couplers and polarization controllers or use polarization maintaining (PM) fibers to feed the required polarization directly from the lasers without the need of further manipulation.
Our fiber-chip-coupling uses optical single mode glass fibers, whose tip is polished to a certain angle, so that light is reflected radially out of the fiber by total internal reflection at a defined angle, as shown in figure a). The fiber is positioned parallel to the chip surface with the tip above an on-chip grating coupler, so that the radially emitted light hits the grating coupler, which diffracts the light into an on-chip waveguide for further on-chip routing [1, 2].
PM fibers, however, are not axially symmetric due to the strain rods close to the fiber core to introduce birefringence (figure b)). Therefore fiber-chip-coupling becomes more challenging, as the angle of in-axis rotation has to be very well defined. For our process the angle is adjusted for the polishing process with an error of less than 0.3°. To achieve this, a special setup was developed (figure c)), which allows a precise fiber rotation before gluing the fibers to a fiber holder for polishing. For alignment, the front facet of a cleaved PM fiber with its core, cladding, and, most important, strain rods is imaged by a camera with a microscope objective. The camera picture is analyzed by a machine vision system, extracting the contours of the fiber and the strain rods, calculating the rotation angle and indicating if the angle is in an acceptable range. To display the glass strain rods inside the cladding glass, special lighting and contrast enhancement is required.
The following polishing process is essential for a low-loss coupling, as the angle of the polished surface to the fiber axis and the surface quality are equally important. To maintain the polishing angle, a special polishing fixture with a parallelogram guidance was developed and 3D-printed (figure d). Several silicon carbide grinding discs and diamond suspensions with decreasing grain sizes were used for polishing. After removing the polished fibers from their respective holders, a final thermal cleaning and fine polishing step was used to get a smooth mirror surface.
We will present the setup to initially adjust the PM fibers for polishing, the optimized polishing process providing a recipe to reproduce the results, as well as measurement results of fiber-chip-coupling experiments.

[1] D. Karnick et al., "Optical Links for Detector Instrumentation: On-Detector Multi-Wavelength Silicon Photonic Transmitters"JINST, DOI 10.1088/1748-0221/12/03/C03078

[2] D. Karnick et al., “Efficient, easy-to-use, planar fiber-to-chip coupling process with angle-polished fibers” , 67th ECTC, DOI 10.1109/ECTC.2017.245

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