g-Pack – a generic testbed package for Silicon photonics devices

L. Zimmermann[1] , H. Schröder[2] , T. Tekin[2] , W. Bogaerts[3] , P. Dumon[3]
[1]Technische Universität Berlin, Fachgebiet Hochfrequenztechnik HFT4 , Einsteinufer 25, 10587 Berlin, Germany
[2]Fraunhofer Institute for Reliability and Microintegration (IZM), G.-Meyer-Allee 25, 13355 Berlin, Germany
[3]Ghent University – IMEC, INTEC, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium

Abstract- **g-Pack is a low-frequency packaging approach to breadboarding of Silicon photonics chips. It provides optical i/o through a fiber array coupled to gratings couplers, and multiple DC i/o through a pin grid array (PGA) carrier.**

I. INTRODUCTION

The fabless approach to Silicon photonics fabrication is becoming an increasingly successful alternative to owning the complete technology chain of Silicon micro-fabrication. One of the most popular sources of nanophotonic devices is the ePIXnet Silicon Photonics Platform, short ePIXfab [1]. They provide multi-project type access to standardized waveguide fabrication on 8” Silicon-on-Insulator substrates (SOI). The technology is based on microelectronic fabrication techniques, such as DUV lithography. The versatility of ePIXfab products is greatly enhanced by including in the platform’s portfolio an on-chip interface to standard single mode fibers (SMF), which is based on grating couplers. This way, design effort can concentrate on the actual device, and device testing is easily accomplished by optical probing with SMF. That requires an optical probe setup with micrometer precision. Optical probes are, however, not practical in case of devices with multiple optical input/output. Probes also lack mechanical rigidness as needed for long term stability. Additionally, many applications require electrical connections, e.g. integrated resistors used for thermal tuning. Multiple electrical & optical i/o and mechanical stability are usually realized by the package of the chip. To keep costs low for multi-project users on the one hand, and on the other hand to provide a possibility for stable multiple i/o testing of Silicon photonics chips, ePIXfab sought a solution different from custom designed packages. The solution to this problem is standardization, which allows for cost sharing between different users of the same packaging solution. A standardized testbed solution, g-Pack, is now under development in a joint effort of ePIXfab and ePIXpack (the ePIXnet packaging platform). The following paper will provide details of the design of g-Pack and first experimental results of grating coupler array packaging.

II. G-PACK DESIGN

g-Pack will provide rigid fiber array coupling plus low-frequency electrical connections to ePIXfab chips that feature a grating coupler array of standardized geometry. The standardized ePIXfab chips are already available and have a size of 10×14 mm^2. The package makes use of as much as possible commercially available components to reduce the final costs. Electrical connections are established by wire bonding to a commercial pin grid array (PGA) carrier. The top view of the schematic layout of g-Pack is depicted in Fig. 1.

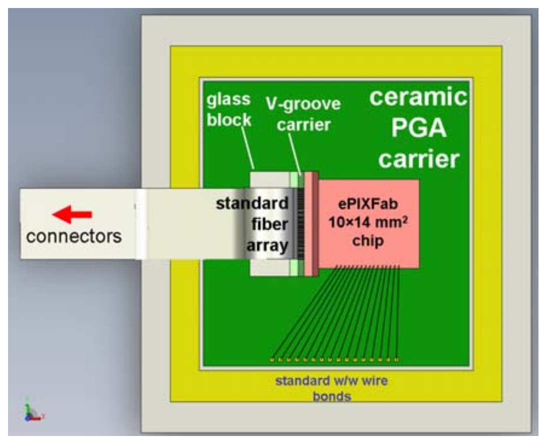

Fig. 1 g-Pack, top view. The ePIXFab chip is optically coupled to a commercial fiber array (up to 32 fibers), while electrical connections are established via standard wire bonding techniques.

The approach of g-Pack is intended for use in testbed applications, i.e. at the stage before prototyping. Therefore, g-Pack does not offer hermetic housing or small footprint. Electrical connections are limited to low frequencies because of the choice of the ceramic carrier (PGA). We shall use a commercially available PGA by Kyocera, which is compatible with standard sockets to allow easy-plug operation and interchangeability of devices. The package is optimized for a large number of DC connections (>60). If temperature control or heat dissipation is required it should be implemented via the socket. The side view of g-Pack is shown in Fig. 2

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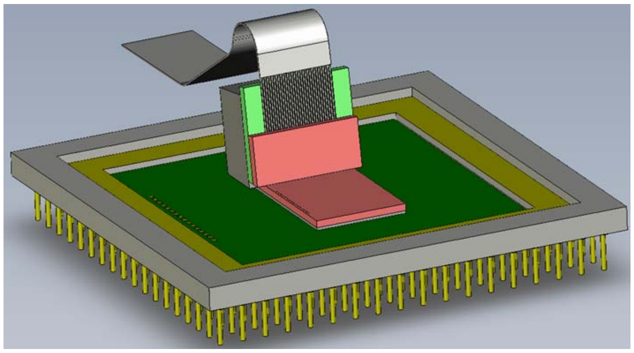

Fig. 2 g-Pack, side view. The pin grid array carrier was chosen to provide a large number of DC connects & to comply with standard socket dimensions.

As required by the grating couplers, the fiber array is mounted slightly tilted with an angle of 8° off the vertical. Commercial fiber arrays are available with standard single mode fibers and polarization maintaining fibers. The optical i/o count of the package can go up to 31.

III. Fiber Coupling

Fibers are coupled to the nanowaveguides via grating couplers. The coupling to silicon photonic wires through high-index contrast gratings is attractive because of the relaxed alignment tolerances compared to facet coupling and the use of standard single mode fibers. Because of the high index contrast, the grating can be short (25 periods) and achieve a relatively large bandwidth. Simple one-dimensional grating couplers with a uniform fill factor etched into a broad waveguide, achieve a coupling efficiency of around 30% with a 40nm 1dB bandwidth (per coupler) for a single polarization [2]. Detuned gratings with a coupling angle of 8º to 10º are used in order to avoid coupling to the wrong direction. The grating couplers can be optimized in various ways to improve the efficiency or size.

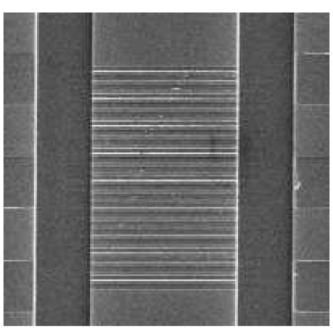

Fig. 3 Uniform fibre coupler etched in a 10µm wide SOI waveguide.[2]

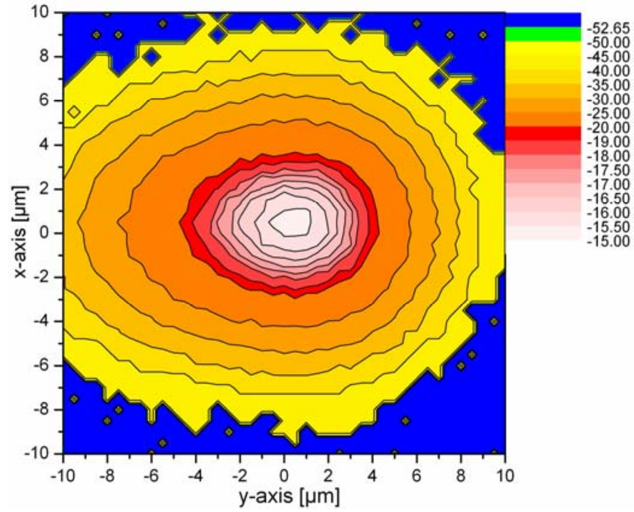

Fig. 4 Measured signal due to lateral alignment. The z axis is the waveguide propagation direction and the x axis is parallel to the grating grooves; each 0.5dB contour lines are shown

IV. Fiber Array coupling

The key to successful fiber array coupling is a large alignment tolerance at each individual coupling point. The measured alignment tolerance of a waveguide grating coupler for a 1dB loss penalty is ±2µm (Fig. 4). Specified tolerances of fiber arrays are ±1.0 µm for the fiber position (x, y), and ±0.5 µm for the core/cladding concentricity. Tolerances in z-direction are also of the order of 1.0 µm, but have a much less significant impact.

For better understanding & possibly preventive measures during the packaging process we measured lateral deviations of a commercial v-groove holder (fiber array) from the ideal by scanning along the array with a SMF as an optical probe and detecting the received signal as a function of position (Fig. 5). The positions of the respective fibers are listed in Table 1.

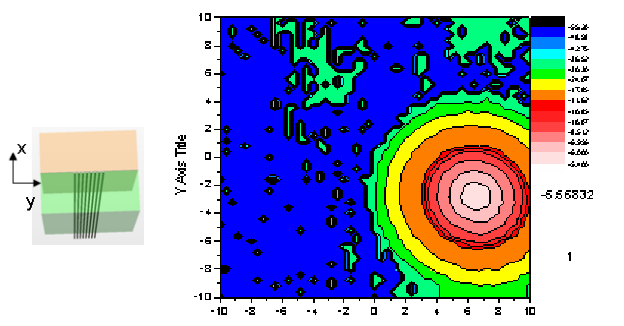

Fig. 5 Position of the first fiber in a v-groove holder. Note, y is direction of the pitch of the array (horizontal), x is the vertical position.

Tab. 1 Measured deviations of fiber positions within an eight fiber array. Only six fibers are included because fibers 4&5 are not used during the experiment. Loss is the maximum transmission value. Fiber 8 suffered from a defective splice.

Fiber #	1	2	3	6	7	8
Mismatch in y [µm]	-2.2	0.8	0.3	0.1	0.0	2.0
Mismatch in x [µm]	0.0	4.0	1.7	-2.5	-4.3	0.0
loss [dB]	5.56	5.26	5.39	6.94	6.43	8.97

Tab. 1 shows that the total deviation from the ideal position can amount to more than what would be expected from the manufacturer's specifications. In this particular case the pitch deviated by 4 µm from the expected between fiber 1 & 8. The relatively large loss values can be attributed to the used fiber probe (coming from a fiber-optic connector). Increased loss of 1 dB, 1.5 dB and 3.5 dB for fibers 6, 7, and 8 was due to connector problems.

An SOI chip with grating couplers and the measured fiber array were packaged. The SOI chip consisted of 6 spare grating coupler ports, which were shortened by nano-waveguides (Fig. 6).

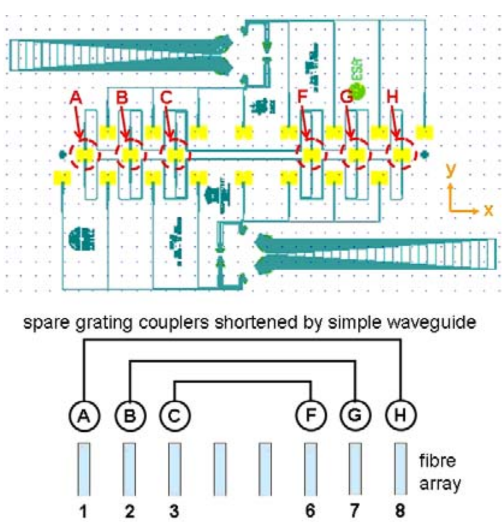

Fig. 6 Layout of grating coupler array with couplers shortened by waveguides. The labeling of ports is shown in the lower part.

The position (x, y, z, and rotation) of the SOI chip was varied and the transmission through the ports AH, BG, and CF was monitored. The corresponding transmission curves for the maximum transmission AH are plotted in Fig. 7. Curves were recorded for optimized polarization state. After alignment, the chip-array position was fixed by UV-curing epoxy. No significant change in transmission signal was observed after the curing process. Taking into account the fiber-optic losses from Tab. 1, the transmission curves in Fig. 8 have a comparable performance, and non-uniformity amounts to ± 1dB. However, insertion loss still amount to approximately 12 dB, with typical shape of grating coupler filter curves.

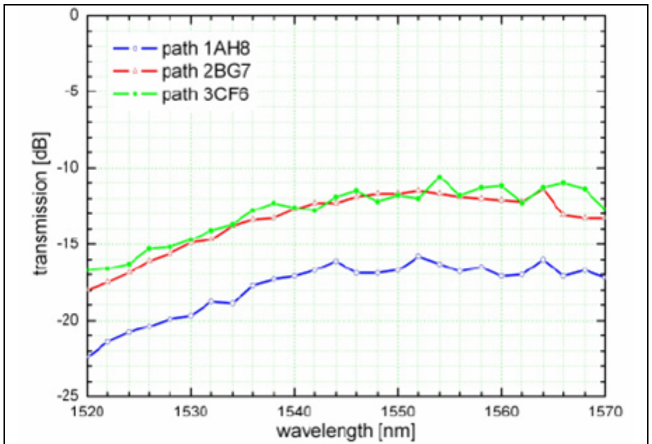

Fig. 7 Transmission characteristics through fibers A to H, B to G, and C to F. via the respective grating couplers.

V. Discussion and Conclusions

First results of fiber array on grating coupler array packaging have been presented. Qualitative evaluation shows that uniform coupling is well possible in a package. We also observed that deviations of fiber positions in a commercial fiber array were larger than we had expected. This required rotation (i.e. a misalignment) of the chip to maximize signal from fiber A to H (alignment ports). The misalignment would lead to additional loss at other ports, delivering over all a reduced coupling performance (i.e. larger insertion loss). To improve performance, arrays with more stringent specifications could be purchased; yet, this would have a drastic impact on the price. On the other hand, slightly larger alignment tolerances of the grating couplers could help solve this problem. However, to some extend we would then trade off insertion loss for tolerances. Detailed simulations are required to determine to what extend grating coupler alignment tolerance should be enlarged. Other sources of loss such as waveguide loss or angular deviations of the fiber array have not been investigated. The results indicate that the planned similar scheme of fiber array packaging in g-Pack is well suited for the task.

Acknowledgments

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