# Phase modulators and splitting network on Si PIC for coherent fiber beam combining

**M. Antier[1,2], J. Bourderionnet[1], C. Larat[1], E. Lallier[1], C. Scarcella[3], J. Su Lee[3], P. O'Brien[3], T. Spuesens[4], G. Lepage[5], P. Verheyen[5], P. Absil[5] and A. Brignon[1]**

*1. Thales Research & Technology, 1 avenue Augustin Fresnel, 91767 Palaiseau cedex, France*

*2. now with Thales Optronique SA, 2 avenue Gay Lussac, 78995 Elancourt cedex, France*

*3. Tyndall National Institute, University College Cork, Lee Maltings, Cork, Ireland*

*4. Ghent University-IMEC, Department of Information Technology, Ghent, Belgium*

*5. IMEC, Leuven, Belgium*

Coherent beam combining (CBC) of fiber lasers provide an attractive mean of reaching high output laser power by scaling up the available energy while keeping fiber intrinsic advantages of compactness, reliability, efficiency, and beam quality. In CBC architectures, the power of a master oscillator (MO) is divided into $N$ fibers that are amplified individually. The phase perturbations between channels can be measured using various techniques [1-3] and are corrected by individual phase modulators placed on each fiber before the amplification. In this Communication, we present a Silicon PIC integrating a 1:16 channels splitting network and thermal phase modulators array with low electrical power consumption and a bandwidth compatible with CBC requirements.

In our CBC system, a 1.55µm CW master oscillator directly feeds the Silicon chip through a grating coupler, as shown in Fig.1(a). The power of the master oscillator is first split on chip into 16 channels, each of which including a thermal phase modulator. The outputs of the 16 waveguides are collectively out-coupled from the chip using a PM optical fiber array aligned and glued onto the PIC's output grating couplers array [4]. At the other end of fiber array, the 16 fiber outputs are arranged in a 4 by 4 squared lattice, and collimated by a microlens array to form 16 collimated and parallel beamlets. The phase distribution from channel to channel is derived from the fringe pattern resulting from the collimated beamlets interfering with a reference plane wave on a camera. This signal is fed back to drive the PIC's phase modulators in order to phase lock the 16 fibers channels. The bandwidth of the correction loop is set to 1 kHz.

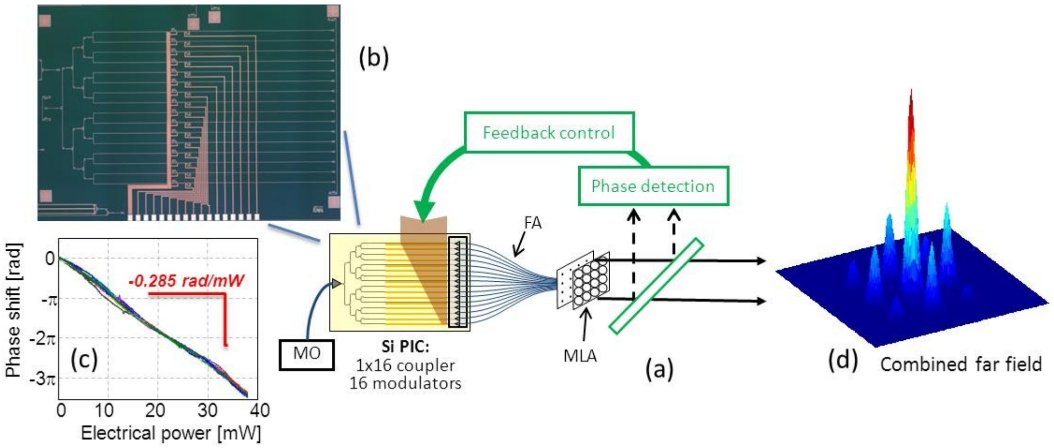


**Fig. 1** (a) Experimental set up of 16 fibers CBC; MO master oscillator, FA: fiber array, MLA: microlens array. (b) Si PIC picture. (c) Phase response of the 16 channels. (d) Experimental combined far field profile.

The channel homogeneity at the output of the PIC is closed to 1dB. The insertion loss of the device is 7dB per channel, excluding the 1:16 ratio of the splitter tree. The phase responses of the PIC's modulators are collectively measured using our CBC set up. As shown on Fig. 1(c), the phase responses of all the 16 channels are very homogeneous, with a slope efficiency of -0.285 rad/mW. Therefore, a 2π phase shift is achieved for 22mW of electrical driving power. The modulation bandwidth of these integrated phase modulators is higher than 10 kHz, which is sufficient for CBC using an interferometric phase measurement [3]. The coherent beam combining of 16 fibers is demonstrated using this device, as shown in Fig. 1(d). The research leading to these results has received funding from the European Community FP7 under Grant Agreement n°318178 PLAT4M.

## References

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