

Experimental demonstration of 1 to 1024 optical division using slightly etched rib silicon-on-insulator waveguides

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Abstract:

Experimental demonstration of successive optical divisions from one input to 1024 output points is presented using slightly etched submicron rib SOI waveguides. Excess loss per division of 0.7 dB has been measured.

Silicon-on-insulator substrates (SOI) have generated an increasing interest in the recent years, for both microelectronic and nanophotonic applications. Silicon nanophotonics is developed for optical telecommunications in order to achieve low cost devices [1], or for optical interconnects to overcome the limitations of metallic global interconnects in microelectronic circuits [2].

The use of SOI substrates for silicon-based nanophotonics and optoelectronics has several advantages. First, they are compatible with widely used CMOS technology and large wafer are available. Furthermore, the light can be strongly confined in submicron waveguides, due to the large refractive index difference between silicon and silicon oxide ($\Delta n \sim 2$). This leads to a high potential for optical device integration.

Lateral confinement of the light can be obtained either by partial etching of the silicon film or by full etching down to buried silicon oxide to get rib or strip waveguides respectively. Single mode strip SOI waveguides suffer from propagation losses due to the sidewall roughness induced by the technological steps. The lowest optical losses reported using submicron strip SOI waveguides are 2-3 dB/cm [3-4]. For comparison, slightly etched submicron rib SOI waveguides are much less sensitive to scattering loss because of low interaction between optical mode and side wall roughness. Ultra-low propagation loss lower than 0.4 dB/cm has been measured [5]. The height and width of the rib waveguides were 380 nm and 1 μm , respectively and the etching depth was 70 nm. Such a geometry was designed to yield single mode propagation at 1.31 μm . Figure 1 presents the fundamental mode profile in such waveguides.

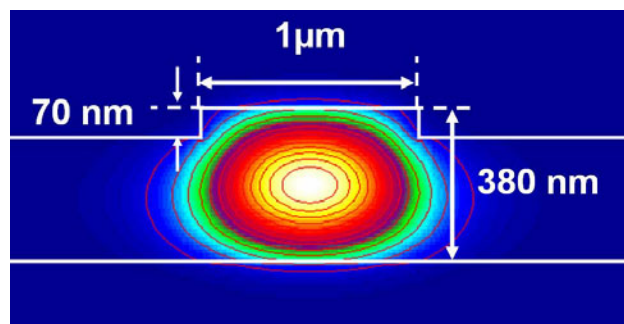


Figure 1: Rib waveguide geometry and optical mode profile

Optical interconnects, and especially optical distribution of clock signal on a microelectronic chip, need different elements: an optical source which has to be modulated properly, an optical distribution from one to several points and integrated photodetectors at every end points. The optical distribution circuit, from one input to several outputs requires low-loss optical waveguides, 90°-turns, and compact beam splitters. The optical power at each output should be sufficient to ensure light detection. The distribution size has to be compatible to microelectronic chips (length ~ cm).

Experimental demonstration of an optical division from one input to 1024 output points is presented. The realized optical circuit is schematically reported in figure 2-a.

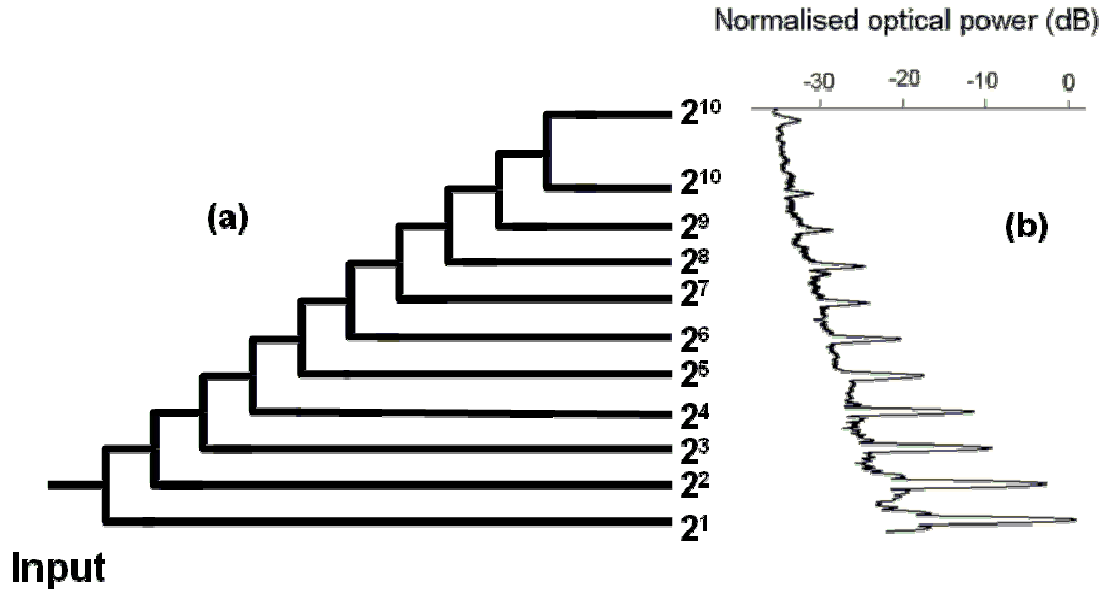


Figure 2: (a) Schematic representation of the optical division circuit (b): Optical power at each output recorded at 1.3 μm with an IR camera

Ten splitting from 1 to 2 waveguides are cascaded which lead to a maximal division from 1 input to $2^{10} = 1024$ points. Compact beam splitters are based on a star coupler [6] followed by a mirror added on each output branch to carry out T-splitters. For the rib waveguide geometry used, such splitters are more compact (16 μm long and 8 μm wide) than conventional ones like multimode interferences (MMI) devices or Y junctions. At each branch of the successive division structure, an additional corner mirror is added in order to get all outputs parallel to the input waveguide, allowing easier characterization. The mirrors are formed by totally etching the silicon film at the crossing of perpendicular waveguides. The length of each branch is about 6 mm. Two successive output waveguides are separated from 20 μm , except the two last which are separated from 40 μm .

The device is characterized using a super-luminescent light emitting diode (SLED) with a central wavelength of 1.3 μm . A linearly polarized light beam is focused on the input waveguide end using a polarization maintaining lensed-optical fiber. Light at the output of the device is then imaged on an IR linear camera using 20X microscope objective. Figure 2b reports the optical power measured with the camera as a function of the output waveguide position. Each output is clearly observed with a regular fall, even after 10 division, which means after a division from one input to 1024.

Optical power measured at the output rib SOI waveguides as a function of the number of successive divisions can be plotted in semi-logarithmic coordinates (figure 3). The slope of the regression straight line gives the average loss value of each division. The average loss is 3.7 dB per division, which corresponds to 0.7 dB excess loss.

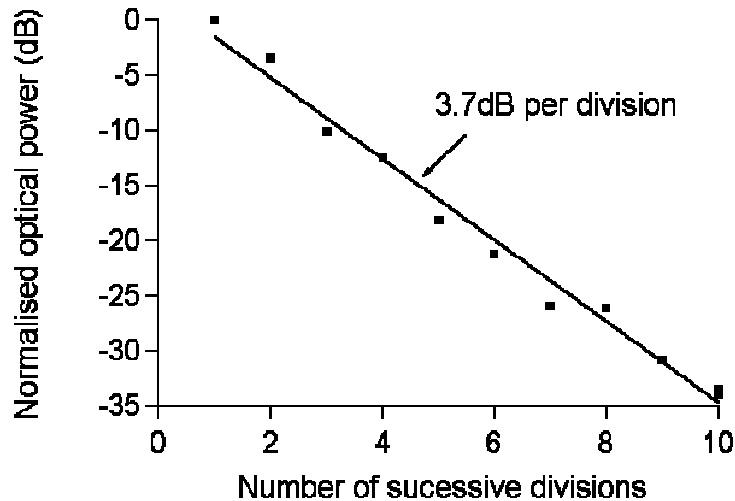


Figure 3: Output optical power as a function of the number of successive divisions. The regression straight line gives the average loss of each division.

This result demonstrates the feasibility of splitting the light from 1 input to 1024 outputs with slightly etched submicron rib SOI waveguides. Indeed, the size of the distribution can be easily made compatible with optical clock distribution for CMOS microelectronic chips (~1cm) due to ultra-low loss of such rib waveguides.

Slightly etched submicron rib SOI structures including waveguides, beam splitters and corner mirrors are good candidates to carry out compact on-chip devices for optical interconnects and telecommunications.

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