

High speed optical transmission at 2 μm in subwavelength waveguides made of various materials

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Abstract: We report the transmission of a 10 Gbps telecommunication signal at 2 μm in waveguides made of three different materials: Si, SiGe and TiO₂. Bit error rates below 10⁻⁹ can be achieved after transmission in the devices with subwavelength dimensions. © 2018 The Author(s)
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1. Introduction

In order to overcome the increasing data traffic and to avoid the so-called ‘capacity crunch’, the exploration of new spectral bands is an attractive solution. Thanks to the emergence of thulium doped fiber technologies, the wavelength band around 2 μm is one of the best candidates. Transmission at this wavelength range through several hundreds of meters of innovative fibers has recently been experimentally demonstrated. Regarding integrated photonics, the silicon-on-insulator platform has been largely studied for the conventional telecommunication wavelengths. The choice of SOI platform has been driven by the high nonlinearity of silicon, its transparency, the possibility to integrate modulators and its compatibility with low cost large-scale production using complementary metal-oxide semiconductor infrastructure. However, the silicon is also transparent at 2 μm where it has lower nonlinear losses.

Therefore, we propose to explore 10 Gb/s on-off keying optical signal transmissions at 2 μm in silicon based waveguides [1]. In addition to SOI devices, we also choose to focus our attention on an alternative platform relatively unexplored to date: the Titanium dioxide (TiO₂) [2]. It is a promising material thanks to a transparency window spanning from the visible to the mid-infrared wavelengths, and a high linear and nonlinear refractive index (respectively > 2.3 and 30 times larger than silica respectively) and a wide bandgap allowing a negligible TPA beyond 800 nm.

2. Subwavelengths waveguides under test

Figure 1 summarizes the geometrical and optical properties of three different samples under test : a 7 cm-long single mode silicon waveguide (900 x 220 nm typical width-thickness) manufactured in a CMOS pilot line (imec) (sample 1, [3]), a 2.5 cm long subwavelength silicon germanium waveguides (1.3 x 1.4 μm typical width-thickness) manufactured at the LETI laboratory (sample 2, [4]) and a 700 μm long TiO₂ single mode waveguide (0.3 x 1.6 μm) designed and produced at the University of Burgundy (sample 3, [2]).

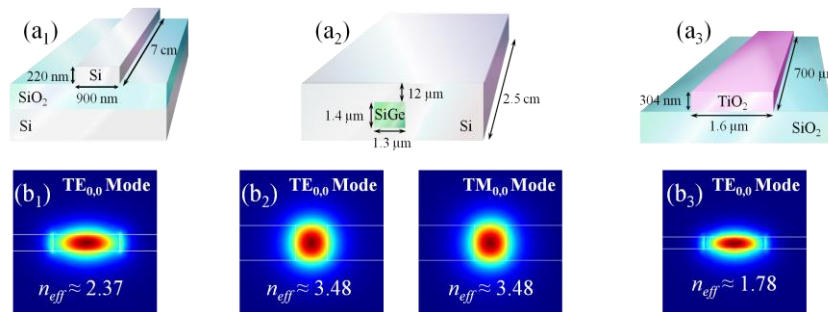


Fig. 1 (a) Side view and typical dimensions of the three subwavelength waveguides. (b) Mode profiles and effective index of propagation. Panels 1, 2 and 3 show results obtained with the Si, Si-Ge and TiO₂ based waveguides respectively.

Depending on the waveguide, one or two optical modes can exist in the optical structure and the effective index may significantly vary according to the material. The coupling and decoupling of light in the component is achieved by a butt-coupling approach using a lensed fiber and a tapered waveguide (samples 1 and 2, typical insertion losses of 10 dB per facet). For the TiO₂ device, we have developed a new coupling scheme based on an embedded metal (Au) grating [5]. Optimal design of the grating (accurate choice of the grating period, filling factor and width) allows us to decrease the coupling losses per facet below 10 dB with an improved stability of the signal.

3. Optical transmission of 10 Gbps signals at 2 μm

A 2³¹-1 pseudo-random bit sequence (PRBS) at 10 Gbps encoded by a non-return-to-zero on-off-keying modulation format is transmitted into the waveguides at 2 μm . Results obtained for the three configurations are summarized in Fig. 2. In all cases, no degradation of the eye-diagram quality is observed. The quality of the transmission was more quantitatively evaluated through systematic measurements of the Bit Error Rate (BER) according to the OSNR on the receiver. Despite the coupling and propagation losses, transmissions with BER lower than 10⁻⁹ are demonstrated. The penalty induced by propagation remains in all cases low (below 1dB).

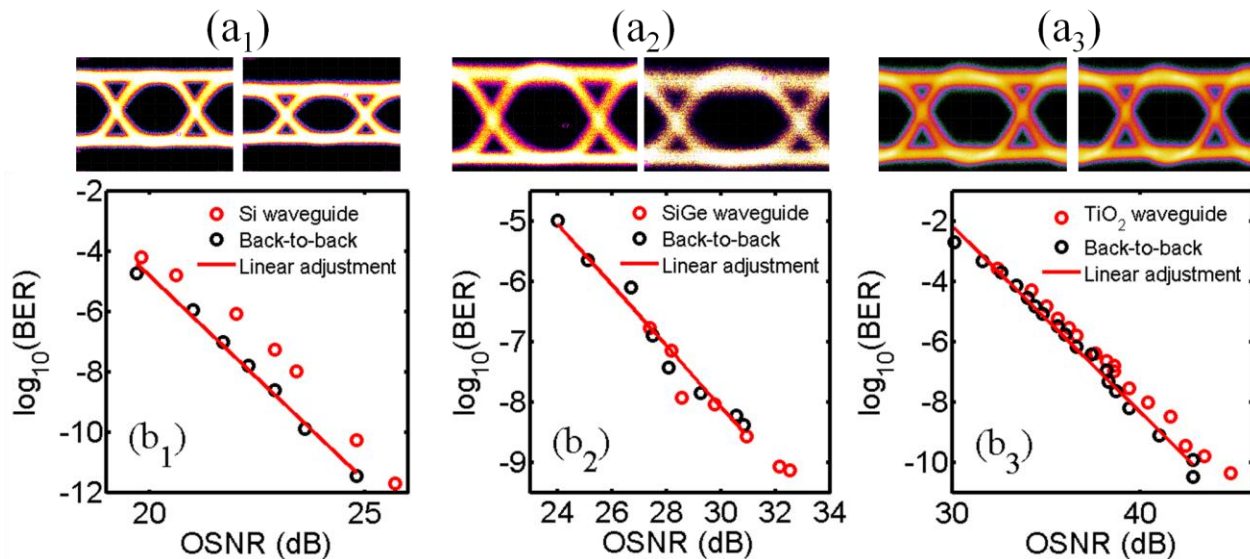


Fig. 2 (a) Eye diagrams of the back to back measurement (left) and after transmission in the waveguide (right). (b) BER measurements. Panels 1, 2 and 3 show results obtained with the Si, Si-Ge and TiO₂ based waveguides respectively.

Our study is a first step to confirm that 2 μm waveband offers new possibilities and that various platforms are already available and may sustain subwavelength dimensions. The apparent ease of such linear transmissions hides actually a real difficulty due to the lack of maturity of the devices commercially available necessary for such experiments. The next step is to demonstrate high bit rate nonlinear processing at 2 μm . Apart the well-known potential of SOI components, this study introduces titanium dioxide as a serious candidate for photonics from the visible to the mid-infrared range.

4. References

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