# All-Optical Wavelength Conversion in Silicon Wire Waveguides

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**Abstract** *We describe the use of two-photon absorption process in submicron silicon wire waveguides for all-optical wavelength conversion by cross-absorption modulation scheme. Optical pulses of 1.6 ps at 1GHz repetition rate have been successfully converted from 1550nm to 1544nm.*

## Introduction

Optical waveguides formed in silicon-on-insulator (SOI) platform have extremely high index contrast ($\Delta$>41%), which allows the realization of submicron size singlemode planar waveguides [1]. Due to the strong optical confinement in such waveguides, ultra-high optical intensity can easily be achieved with input optical powers typically used in telecommunications. The high optical intensities and long interaction lengths in the waveguides may lead to the manifestation of nonlinear optical effects. Most of the current switching devices in silicon are based on plasma dispersion effect. In such devices, excess free carriers are introduced inside the waveguide either by external current injection [2] or optically excitation [3] to introduce the required absorption or phase shift. Thus the speed is always limited by the effective carrier lifetime [4]. Two-photon absorption (TPA), which involves the simultaneous absorption of two photons inside the waveguides, is the dominant nonlinear absorption process in silicon waveguides at telecommunication wavelengths. The TPA process in semiconductor waveguides is an ultrafast process [5], thus making it of potential interest for wideband high speed photonic signal processing applications.

In this paper we report the first use of TPA-based cross-absorption modulation in silicon wire waveguides for wavelength conversion applications. We have successfully converted optical pulses of 1.6 ps pulsewidth and 1 GHz repetition rate from 1550nm to 1544nm. Our results also showed the possibility of wavelength conversion at much higher speed.

## Experiments

Figure 1(a) shows the structure of silicon wire waveguide used in the experiment. The fabrication and characterization of the waveguide was described in [6]. The waveguide core was formed by silicon strip measuring 480 nm x 220 nm. To prevent the leakage of guided mode into the silicon substrate, the buried oxide layer was chosen to be 1 $\mu$m.

As shown in Fig. 1(b), a mode-locked fiber ring laser (MLFRL) was used to generate pump pulses with 1 GHz repetition rate and 1.6 ps pulsewidth at 1550 nm. The pump pulses were then boosted up to high power by an erbium-doped fiber amplifier (EDFA). The continuous-wave (CW) signal was generated from a tunable laser (TL) operated at 1544 nm. An optical coupler combined the pump and signal light, and then coupled into the wire waveguide by a vertical fiber coupler with coupling efficiency of about 20% [5]. The average pump power coupled into the waveguide was estimated to be smaller than 7 dBm. Another EDFA was placed after the waveguide to compensate the insertion loss. We used an optical bandpass filter (OBF) to filter out the pump pulses at the waveguide output. Finally, the cross-modulated cw signal was measured by a 10 GHz bandwidth photodiode and a digital sampling oscilloscope (DSO).

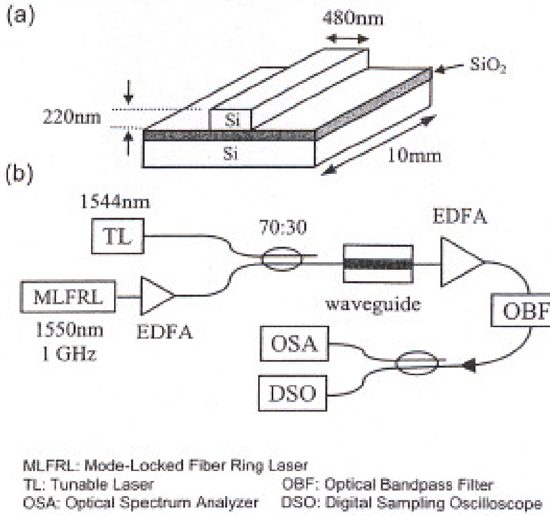


*Fig. 1: (a) Silicon wire waveguide dimensions, (b) Experimental setup*

## Results and Discussion

The optical spectra of combined signals after the waveguide and cw signal after the filter are shown in Fig. 2(a) and 2(b) respectively. To remove the residual pump pulses at the receiver side, high extinction ratio optical bandpass filter is required. As shown in Fig. 2(b), the ratio of cw signal and pump pulses was greater than 50 dB.

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