# Electrically Controlled Pulse Compression Using a Silicon Waveguide

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**Abstract:** The electrical control of pulse width in a two-photon absorption-based silicon pulse compressor is demonstrated. Approximately 30% improvement in pulse compression rate is experimentally measured under a forward voltage of 3.3 V.

**OCIS codes:** (130.5990) Semiconductors; (130.4310) Nonlinear; (140.4050) Mode-locked lasers

## 1. Introduction

Silicon photonics provides an efficient way to realize low-cost, highly integrated optoelectronic systems. Unfortunately, silicon is an indirect band-gap semiconductor and thus the light emission is very inefficient. It is quite a challenge to achieve silicon-based light emitters or lasers. Recently, an electrically pumped hybrid silicon laser has been demonstrated by combining a III-V quantum-well onto the silicon substrate [1]. Meanwhile, silicon Raman lasers has been realized based on stimulated Raman scattering by using a pulsed pump [2] or a continuous-wave pump with a reverse bias to sweep out the free carriers generated by two-photon absorption (TPA) [3].

TPA is always present in silicon and considered as a detrimental effect to photonic devices. However, the transient behaviors of TPA and TPA-induced free-carrier absorption (FCA) in silicon waveguides can lead to pulse shaping and compression [4]. In such a compressor, it is possible to tune the output pulse by applying a voltage on the silicon waveguide since the free-carrier lifetime and density are tightly dominated. In this paper, we propose an electrically controlled pulse compressor based on an intracacity silicon waveguide with a voltage. Using a forward voltage of 3.3 V, the output pulse is compressed by approximately 30% compared to the case when no forward voltage is used.

## 2. Experimental setup

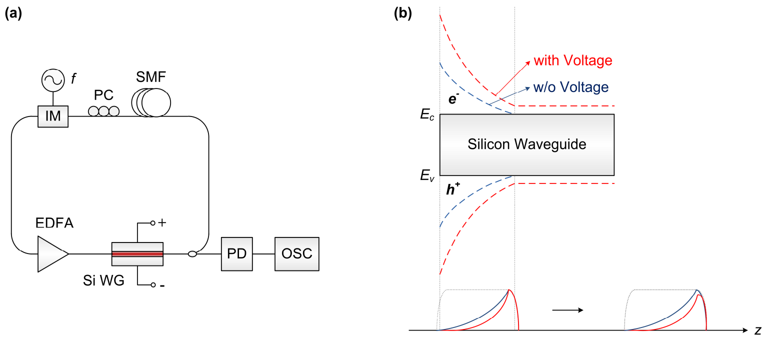

Fig. 1. (a) Experimental setup for the electrically controlled silicon pulse compression. (b) Principle of the pulse compression using a forward voltage on the silicon waveguide.

Figure 1(a) shows the configuration of the pulse compressor based on a silicon waveguide. Here a laser cavity is formed by a 200-mW erbium doped fiber amplifier, a 100-m-long single-mode fiber, an intensity modulator together with a 17-mm-long silicon waveguide with an effective mode area of about 5 $\mu m^2$. The output is the 10% port of a 90/10 coupler and pulses are observed by an oscilloscope via a photodetector. The driving radio-frequency signal is provided by a pulsed current source and the initial pulse width is about 2.1 ns. The driving frequency is tuned to be 1.36 MHz to match the fundamental cavity frequency. In this case, pulse compression occurs since the TPA effect of the pulse's front end accumulates free carriers in the waveguide and hence absorbs the pulse's trailing edge [4]. This effect is tightly related to the free-carrier properties in the silicon waveguide. Recently, it was demonstrated that the free-carrier lifetime can be shortened by applying a reverse bias on the silicon waveguide via a p-n junction [5]. If a forward voltage is applied, as shown in Fig. 1(b), the free-carrier lifetime will be extended and hence the free-carrier accumulation at the front end of the waveguide will be much strengthened compared to that without forward voltage, though some additional free carriers are stimulated along the waveguide and cause an additional loss. Therefore, the trailing edge of the pulse will experience a heavier attenuation, which means a narrower output pulse.

## 3. Simulation and experimental results

Using the theoretical model in Ref. [4], the output pulses after 20 round trips are calculated with the parameters used in the experiment, as shown in Fig. 2(a), where different free-carrier lifetimes and correspondingly different additional free-carrier density are considered. It shows that these pulses can be effectively compressed and moreover the pulse width is narrower if a longer free-carrier lifetime and a larger additional free-carrier density are used. As a result, it will be an available method to control the pulse width by applying a voltage on the silicon waveguide.

The measured output pulses on the oscilloscope for different forward voltages are shown in Fig. 2(b). One can find that the pulse shape and width is almost kept as the same as the voltage-free case when a small forward voltage is used. While the voltage is relatively high, the pulse is found to be compressed compared to the case without forward voltage. In order to further describe the influence of the forward voltage on the output pulse width, the inset of Fig. 2(b) shows the measured pulse width as the forward voltage on the silicon waveguide varies. The pulse width is almost the same when the voltage is less than 1.8 V. As the voltage increases further, the pulse width is compressed. This effect may result in the barrier of the fabricated p-n junction. The free-carrier distribution in the silicon waveguide can not be affected by extending the free-carrier lifetime or providing an additional free-carrier density unless the forward voltage is high enough to overcome the junction barrier. As a result, the output pulse width can be further compressed only after the junction barrier is compensated by the applied voltage.

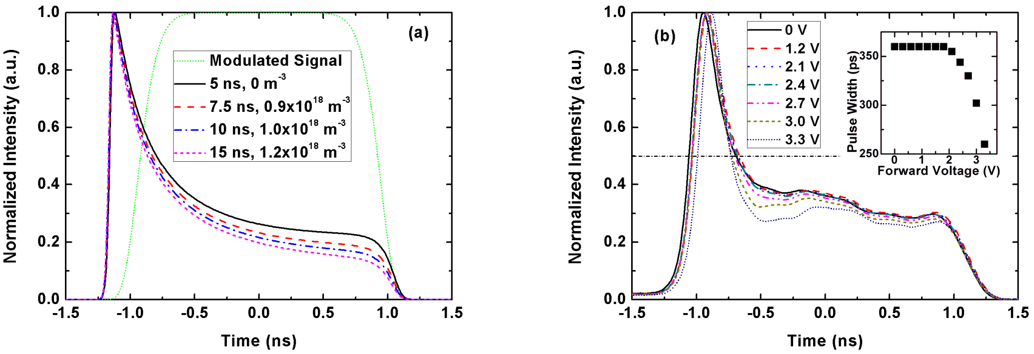

Fig. 2. (a) Simulation results for different free-carrier lifetimes and different additional free-carrier density. (b) Measured output pulses with different forward voltages. The inset shows the pulse width as the forward voltage varies.

## 4. Conclusion

The electrically controlled pulse compressor based on a silicon waveguide has been experimentally demonstrated. By using a forward voltage, the laser pulse can be further compressed by approximately 30% compared to the voltage-free case. The electrically pulse width compression is available only after the applied voltage is high enough to overcome the barrier of the p-n junction on the silicon waveguide.

## Acknowledgement

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