Autocorrelation measurement of ultrafast optical pulses using silicon p-i-n waveguides as two-photon absorption detector

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Introduction: Optical autocorrelation measurement is indispensable for characterizing ultrafast optical pulses in picosecond or femtosecond orders. Traditionally such measurements are performed using autocorrelators which are consisted of free-space optics components and bulk-like photodetectors such as second-harmonic generation (SHG) crystals with photomultipliers and two-photon conductivity (TPC) detectors. Recently, achieving autocorrelation detection using photonic waveguides is believed promising to realize low-cost, small-size, and high-sensitivity autocorrelators [1], which are highly required in miniaturized ultrafast laser systems. Moreover, it could enable integrated autocorrelation functionality for on-chip pulse diagnosis and characterization [2]. In this paper, we demonstrate the autocorrelation detecting of ultrafast pulses utilizing two-photon absorption (TPA) in silicon p-i-n waveguides. Since this waveguide is well-established in silicon photonics and widely used as the phase shifters for modulators and switches, this work shows the feasibility to achieve the truly applicable integrated-type autocorrelators using silicon photonics technology and could enable novel silicon photonic devices utilizing on-chip autocorrelation functionality.

Experiment: The theoretical analysis to utilize TPA in silicon p-i-n waveguides to realize autocorrelation measurement was explained in our previous work [3]. Here we report the experimental verification. Fig. 1 shows the measurement system and the optical microscope picture of the fabricated p-i-n waveguide. The waveguide devices were fabricated on 220nm SOI wafers at the AIST SCR 300mm CMOS line. The 1-ps-wide pulse at 1.55 μm was emitted from the mode-locked fiber laser (FL) and split into two autocorrelated pulses equally through a 3dB splitter.

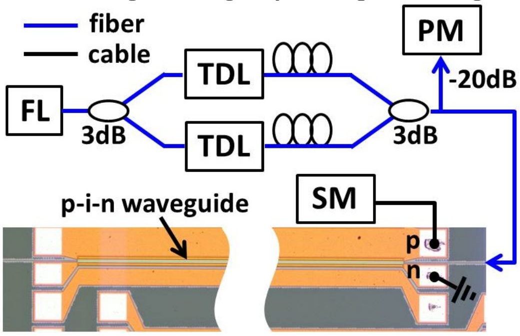

Fig.1. Autocorrelation measurement system using the p-i-n waveguide as two-photon absorption (TPA) detector. FL: mode-locked fiber laser. TDL: tunable delay line. PM: powermeter. SM: sourcemeter.

The delay time can be applied to each of them using tunable delay lines (TDL). For each line, the light was adjusted to TE polarization and then combined into another 3dB coupler to form a Mach-Zehnder interferometer (MZI). After going out from this 3dB coupler, the pulse goes through a -20dB splitter for pulse energy monitor and then was coupled into the p-i-n waveguide chip via a tapered fiber. The pulse energy used in this paper is the fiber energy before coupling into the chip without considering the coupling loss. The p-i-n diode was set to a reverse bias (-10V) and the TPA induced photocurrent was measured using a source meter (SM). When the delay time between the two autocorrelated pulses is tuned, the photocurrent waveform can be measured. The measure waveform for a 500-μm-long p-i-n waveguide and pulse energy of about 0.93 pJ is shown in Fig. 2. The observed fringes are features of interferometric autocorrelation. Since the pulse width measurement is one of the most important applications, we here deduce the pulse width from the waveform. As shown in Fig. 2, the autocorrelated width is about 1.53 ps. As for $sech^2$-shaped pulses, the autocorrelated width is about 1.54 times that of the original pulse. Therefore, the original pulse width is measured ~0.99 ps, which matches well with the value (~1.05 ps) measured by a commercial autocorrelator. This verifies that we can achieve the correct autocorrelation measurement of ultrafast optical pulses using silicon p-i-n waveguides as photodetector.

Acknowledgments
This work was supported by JSPS KAKENHI Grant Number 16K18097.

References

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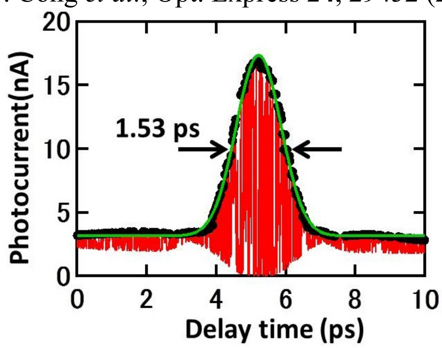

Fig. 2. Autocorrelated photocurrent signal in relation of the delay time at the pulse energy of 0.93 pJ.