# Sub-ps optical pulse compression in ultra-silicon-rich nitride waveguide

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**Abstract:** We demonstrate the optical pulse compression of 2ps laser down to 230fs pulse resulting in 8.7 times compressed using a USRN waveguide, faciliating to generate high-order soiliton combined between high nonlinear parameter and anomalous GVD.



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## 1. Introduction

Optical pulse compression has been highly demanding to generate ultrafast pulses in the applications of supercontinuum generation [1], ultrafast spectroscopy and biology [2]. Pulse compression generally relies on soliton-effect induced by the interplay between self-phase modulation (SPM) and anomalous group velocity dispersion (GVD). Positively chirped pulse imposed by SPM is de-chirped by negatively chirped part by anomalous GVD, therefore it creates temporally compressed pulse [3]. Anomalous GVD is provided by photonic structures in a waveguide[4] as well as post elements such as Bragg grating [5] and grating pairs [6]. However, for these methods, the compression system or fabrication/design scheme needs to be complicated with additional insertion loss. Our ultra-silicon-rich nitride (USRN) platform, a backend CMOS compatible platform, possesses high nonlinearity and negligible TPA at 1550 nm of wavelength, that has already been used to obtain wideband supercontinuum [7] and spectral broadening [8], and high gain optical parametric amplification [9]. The USRN waveguide has high nonlinear parameter of 530$W^{-1}$/m and anomalously designed of -0.25$ps^2$/m at 1550nm of wavelength, which enables to generate high-order soliton effect resulting in optically compressed pulse down to sub-picoseconds. In this work, we demonstrate sub-picosecond pulse compression using a USRN waveguide without post compression and complicated waveguide design.

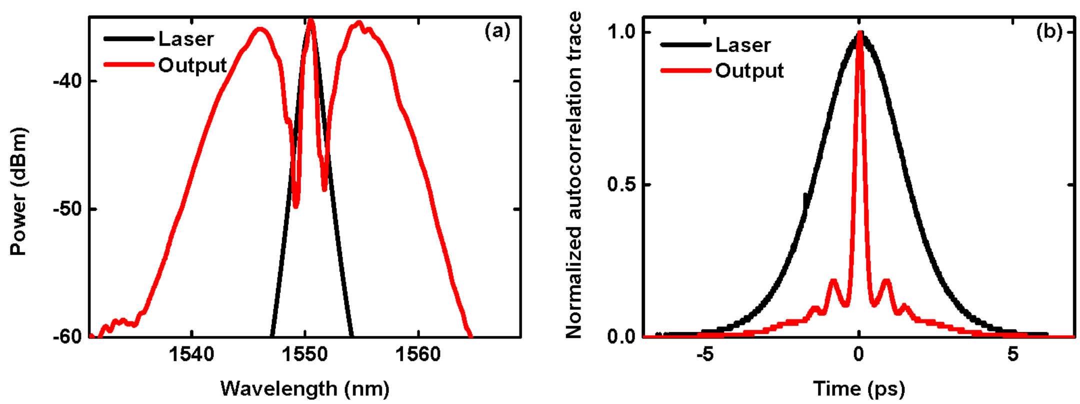


Figure 1. (a) The measured spectra and (b) temporal traces of input laser and output after the waveguide.

## 2. Result and discussion

A 2ps laser centered 1550nm with 20MHz of repetition rate is used as an input. The input laser is coupled into the waveguide with a tapered fiber and then output is coupled out to optical spectrum analyzer and autocorrelator to measure spectrum and temporal trace, respectively. The $SiO_2$ cladded waveguide is designed with the 550nm of height, 300nm of width, and 7mm of length possessing anomalous dispersion at 1550nm.

The measured spectra and temporal traces of the input laser and output after the waveguide are shown as Fig. 1. The output experiences SPM-induced spectral broadening due to the high nonlinear parameter as shown in Fig. 1(a). Simultaneously, the anomalous GVD of the waveguide enables to compress the temporal pulse of the 2ps input down to 230fs as shown in Fig. 1(b). The compression factor ($F_c$), defined as the ratio of the pulse width at full-width-half-maximum ($\Delta t_{FHWM}$) of the input pulse to that of the compressed pulse, is obtained to be 8.7. Due to the high coupled peak power of 8W, the pedestral remains as a evidence of the residual energy which doesn't contribute to the temporal compression as shown in the red curve of Fig. 1(b). The quality factor ($Q_c$) defined as $P_c/F_c$, where $P_c$ is the coupled peak power of the compressed pulse normalized to the input pulse, is calculated to ~0.49, that implies not all input energies is converted to make pulse compressed [3].

$\Delta t_{FHWM}$ as a function of coupled peak power is measured as shown in Fig. 2. Time-bandwidth product (TBP) of input laser is ~0.33 which is near-ideal hyperbolic secant. TBP at the compressed pulse is 0.39, beyond the 5% variation in the Fourier limit of hyperbolic secant pulse (TBP~0.315), therefore the output pulse is slightly chirped [4]. At the coupled peak power of 8W, $\Delta t_{FHWM}$ reaches the limitation as the SPM-induced spectral broadening is much dominant than GVD-induced chirp compensation. The residual in spectral broadening, which doesn't contribute to pulse compression, results in the pedestral at the temporal trace.

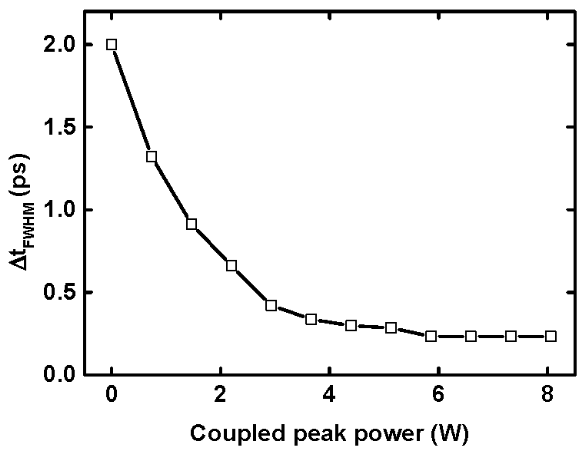


Figure 2. The pulse width at FWHM ($\Delta t_{FHWM}$) as a function of coupled peak power. $\Delta t_{FHWM}$ is estimated using autocorrelation trace.

In summary, we demonstrate the optical pulse compression of 2ps laser down to 230fs pulse resulting in 8.7 of compression factor using a USRN waveguide. Due to the high nonlinear parameter and anomalous GVD of the waveguide, high-soliton and sub-picosecond compression is easily achieved without any other post compressions and complicated designs in a waveguide.

## 3. References

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