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Non-linear Phase Chirp Retrieval of a 1.55μm Gain Switched Pulse Laser using Two Photon Absorption Autocorrelation

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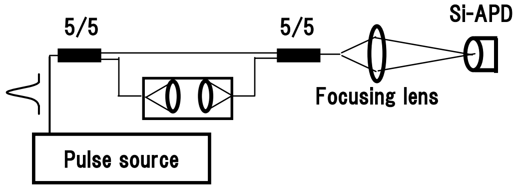
Abstract

We suggest a new scheme to retrieve phase chirp of a gain-switched short pulse using a simple interferometric TPA autocorrelation trace and have confirmed the accuracy of the retrieved phase chirp with linear pulse compression.

Complete analysis of fast optical pulses down to subpicosecond requires information about both the amplitude and the phase of the pulses. The phase information of a pulse has received a great deal of special interest because the minimized chirp is one of the conditions to generate the shortest pulses [1,2]. Several methods have been developed to obtain the intensity and the phase chirp information of a pulse [3,4]. Of all, frequency resolved optical gating (FROG) has been used mostly to characterize optical pulses, but it is very sensitive to phase matching conditions in a nonlinear crystal and requires relatively expensive components and complicated algorithm to retrieve pulses [5]. In this paper, an interferometric TPA autocorrelator using a Si-APD was utilized to diagnose a gain-switched pulse laser. In general, a gain-switched pulse includes an inherent problem of a large frequency chirp across the pulse due to variations in carrier density in the gain region of an LD during the buildup time of a pulse [6-8].

A new scheme based on fitting analysis of an autocorrelation trace to reconstruct the phase chirp of a pulse was introduced. Comparing the intensity autocorrelation curve and the envelope of the second-harmonic (SH) interference fringe in an autocorrelation trace with some fitting analysis, we were able to retrieve the phase chirp of a gain-switched pulse. For practical applications of gain switched laser pulses, chirp compensation is usually employed to make pulses temporally narrower. After fitting analysis we did a linear pulse compression experiment using a dispersion compensating fiber (DCF) in order to verify the retrieved phase chirp of the pulse. We compared measured pulsewidths with those of numerical simulation for linearly compressed output pulses after propagating different lengths of a DCF. For the calculated initial phase chirp of a gain-switched pulse the linearly compressed pulse widths after propagating various lengths of a DCF agree quite well with the simulated results. We have shown that this complete pulse characterization method with a simple fitting process of an autocorrelation trace allows us to predict a condition for the optimized pulse compression for a gain-switched pulse.

The schematic setup of interferometric TPA autocorrelator is sketched in figure 1. The various semiconductor devices such as photodiodes, laser diodes and light emitting diode can be used as two photon absorbers [9-11] and in this experiment we used a Silicon Avalanche photodiode whose internal multiplication factor is 100. A step motor was used to scan an optical delay line of a Mach-Zehnder interferometer. The sweeping speed of the motor was 3.1 ps/sec, which gives the center frequency of corresponding fringe resolved autocorrelation trace near 600Hz. To improve the efficiency of two photon absorption the output pulse of the autocorrelator was focused on the Si-APD with about a 50 um spot size.



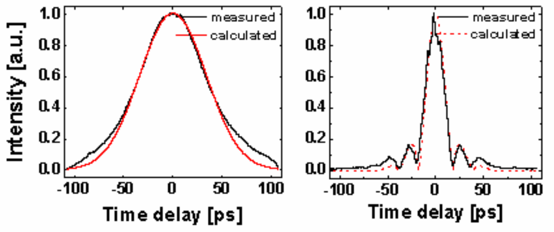
[Fig.1 Schematic diagram of autocorrelator]

A multi quantum well distributed feedback (DFB) laser diode operating with a center wavelength of 1.557 μm was used in our experiment. The DFB laser was biased with a 26mA DC current and modulated with a 28 dBm sinusoidal signal at 1.97 GHz frequency from an amplified low noise signal source. The average optical output power of the pulsed laser was around 0.5 mW and the pulse was amplified by an Erbium doped fiber amplifier with 7 dB saturated gain. From a measured TPA autocorrelation trace we have obtained the intensity autocorrelation curve $G(\tau)$ and the envelope of SH interference fringe $F_2(\tau)$ as a function of relative delay time. The phase chirp of a pulse can be expressed in terms of a power series with respect to time, but it accompanies a lot of unknown coefficients. In general, when the chirp caused by spontaneous emission is relatively so small that it can be neglected, the phase chirp of a gain-switched pulse tends to have a form of linear chirp plus a nonlinear chirp whose form is just like the effect of self phase modulation (SPM) [6-8]. Therefore the phase chirp of a gain-switched pulse can be expressed as

$$\varphi(t) = -\frac{C}{2}\left(\frac{t}{T}\right)^2 + spm\cdot\exp\left[-\left(\frac{t}{T}\right)^2\right] \quad -(1)$$

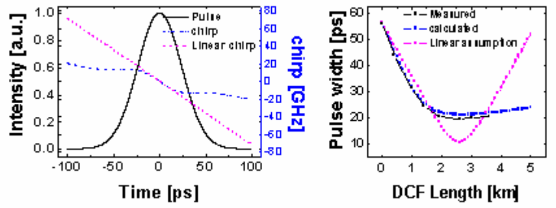
where the pulse intensity is assumed to be a Gaussian function, C is a linear chirping coefficient and spm is a nonlinear chirping coefficient. We have found optimum values for the T, C and spm coefficients by fitting the measured G(τ) and F_2 (τ) curves with calculated G(τ) and F_2 (τ) curves by using the nonlinear phase chirp expression given in eq. (1). Figure 2 shows comparison between the measured and calculated G(τ)'s and F_2(τ)'s. From these curves the pulsewidth was estimated to be 56 ps and the electric field was retrieved as a form of eq. (2). When the pulse was characterized by a TPA autocorreltor the oscillation in F_2(τ) was very interesting. In our simulation it is found to be present only when there exists a nonlinear phase chirp whose form is like the effect of SPM.

$$E(t) = \exp\left[-\frac{1}{2}\left(\frac{t}{T}\right)^2 - \frac{i}{2}*\left\{\omega_0 t + \frac{C}{2}\left(\frac{t}{T}\right)^2 + spm\cdot\exp\left[-\left(\frac{t}{T}\right)^2\right]\right\}\right] -(2)$$



[Fig.2 Measured and fitted autocorrelation trace]

In order to verify the retrieved nonlinear phase chirp obtained from the fitting analysis explained above, we have performed linear pulse compression with a DCF and compared the measured pulse widths with expected pulse widths. We have measured and plotted the output pulsewidths in Figure 3(a) after they were propagated through seven different lengths of a DCF. Chromatic dispersion coefficient D for the DCF is –65 ps/km/nm. The net phase chirp is reduced up to 2.6km of propagation distance, which leads to pulse narrowing. Decreasing tendency of the calculated pulsewidth as a function of propagation distance agrees well with the measured results when we take nonlinear phase chirp obtained by our proposed method as the initial phase chirp of the pulse. While the calculated pulse width does not match with experimental pulse width when we only assume a linear initial phase chirp. Figure 3(b) illustrates the retrieved pulse and the nonlinear phase chirp from our proposed method.



[Fig.3 Retrieved pulse and pulsewidth reduction]

In this paper we have introduced a simple fitting method for obtaining nonlinear phase chirp of a gain switched pulse. With this scheme we can obtain the pulsewidth and the amount of nonlinear chirp in a gain-switched pulse by simple fringe resolved autocorrelation trace of a pulse. We believe that this method is very simple and powerful for analyzing both a gain-switched pulse and a pulse with SPM type nonlinear phase chirp.

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