# Investigation of Photonic Devices using Second-Harmonic-Generation Frequency-Resolved Optical Gating (SHG-FROG)

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The heart of an experiment in ultrafast optics is the pulsed laser source. For any experiment it is essential to know the duration and spectral width of pulses from the laser. The pulse duration from Titanium:sapphire laser source is on the order of $10^{-13}$ seconds, too short to be measured using ordinary electronics. Optical methods, like intensity autocorrelation, can be used to determine the pulse duration. Frequency-resolved optical gating (FROG) is a technique that **fully** characterizes the intensity and phase of the laser pulse. This technique provides the intensity and phase without any *a priori* form of the pulse electric field, which is an advantage over the intensity autocorrelation. Plus, due to the overdetermination of the pulse in the time-frequency domain, FROG has built-in checks (the temporal and frequency marginals) that can be used to determine if systematic error is present in the experiment.

The experiment is shown in the Fig. 1. A pulse is split and recombined in nonlinear optical crystal. One pulse gates the other pulse in the crystal and the generated intensity from the crystal is spectrally resolved. In a second-harmonic-generation (SHG) FROG, the pulse is split by a beam splitter and one portion is delayed by a time $\tau$ with respect to the other. Both portions are focused in a nonlinear optical crystal that doubles the frequency of the laser pulse. The SHG signal field $E_{sig}(t,\tau)$ from the crystal will be proportional to product of the electric field of the pulse $E(t)$ and delayed pulse $E(t+\tau)$. The spectrum of the SHG field is measured for each delay $\tau$, generating the FROG spectrogram: optical intensity as a function of frequency $\omega$ and delay $\tau$. Using an iterative algorithm one can retrieve the phase and intensity of the laser pulse from the spectrogram.

The goal of our research is to use FROG to investigate the performance of ultrafast photonic devices and systems. We are currently investigating nonlinearities and dispersion due to ultrashort pulse propagation through optical fiber. In the future we will investigate the chirp produced in ultrashort pulses due to a semiconductor electroabsorption modulator.

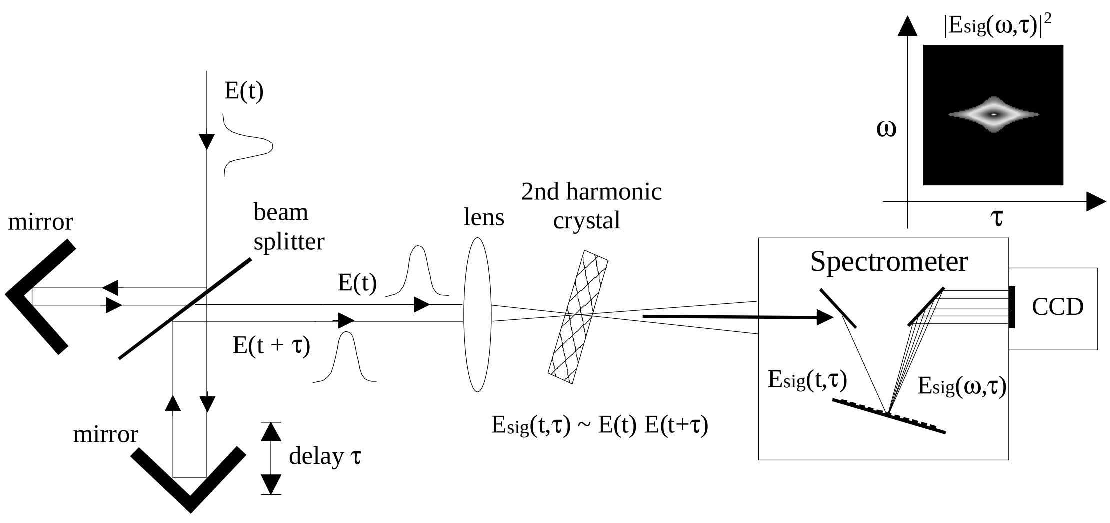


Fig. 1. Experimental diagram for SHG-FROG. A laser pulse is split by the beam splitter and one pulse is delayed a time $\tau$ with respect to the other portion. Both pulses are focused into the crystal and the SHG field $E_{sig}(t,\tau)$ is generated. The spectrometer produces $E_{sig}(\omega,\tau)$, the 1D Fourier transform of $E_{sig}(t,\tau)$. The charged coupled device (CCD) array images the SHG spectrum for each delay $\tau$ to generate the spectrogram $|E(\omega,\tau)|^2$.