Simple Similaritonic Alternative to the Autocorrelation Technique for Determination of Femtosecond Laser Pulse Duration

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We report an alternative to the autocorrelation technique for determination of femtosecond laser pulse duration. The technique is based on the self-shaping of nonlinear-dispersive (NL-D) similariton in a passive fiber (without gain) and measurement of its spectral bandwidth (or duration). The spectral bandwidth of NL-D similariton ($\Delta\omega_{sim}$) is given by the initial peak power (P_0) of the pulse, which is reshaped into a similariton [1]: $\Delta\omega_{sim} \sim \sqrt{P_0}$. Since the fiber losses accumulated on the distance required for NL-D similariton shaping are negligible, the energy E of the similariton is the same as that of the input pulse: $E = P_0\Delta t_0$ (Δt_0 is initial pulse duration). Thus, the initial pulse duration Δt_0 may be determined by measuring the bandwidth and energy of NL-D similariton: $\Delta t_0 \sim E/\Delta\omega_{sim}^2$. In practice, for high repetition rate lasers, it is convenient to measure the average power $p \sim E$ instead of the single pulse energy. Thus, for the initial pulse duration, we have $\Delta t_0 \sim p/\Delta\omega_{sim}^2$. For the technique implementation, it is also important that the NL-D similariton is of spectronic nature, with the linear chirp $\omega_{sim}(t) = Ct$, and its duration is determined by its bandwidth: $\Delta t_{sim} = \Delta\omega_{sim}/C \sim \sqrt{E/\Delta t_0}$. This allows, for the fiber lengths of ∼1 km, to measure the similariton duration in real time with a nanosecond oscilloscope instead of bandwidth measurement, as in the dispersive FT method [2], and to determine the duration of the initial pulse from $\Delta t_0 \sim p/\Delta t_{sim}^2$.

We carried out experiments to demonstrate the relevance of this approach. Laser pulses (100fs @800nm) were stretched in SF11 glasses of different thickness or alternatively in a prism-DDL providing anomalous dispersion. We measured the input pulse duration by an autocorrelator. The other part of the input radiation was coupled in a ∼1-m long piece of single-mode fiber, where NL-D similariton was generated. Then, the bandwidths $\Delta\lambda_{sim}$ of the NL-D similariton and the radiation average power p were measured in a spectrometer, and the pulse durations were subsequently calculated. We compared these data with the ones given by the autocorrelation measurements. Studies were carried out for the pulse durations Δt_0∼100-300 fs in the range of average powers p∼50-500 mW. The experimental points match well with the theoretical curve of $\tau_{AC} = \sqrt{2}\Delta t_0 = f(\Delta\lambda_{sim}/\sqrt{p})$, in agreement with the $\Delta t_0 \sim p/\Delta\omega_{sim}^2$ relation, evidencing that duration measurements performed by means of similariton spectral analysis correspond to the ones derived from autocorrelation traces. Afterwards, we carried out temporal measurements of NL-D similariton, shaped in a 600-m fiber. On these lengths of fiber, the duration of similariton achieves nanosecond domain, where it can be measured by a nanosecond oscilloscope. Experimentally, we shaped the initial pulses of different durations (with autocorrelation durations from 187 to 451 fs) and measured the durations of corresponding similaritons by an oscilloscope (from 5.5 to 3.8 ns). The results are in a quantitative agreement with our prediction.

Thus, a simple similaritonic technique for measurement of the duration of femtosecond laser pulses has been developed. The power meter, spectrometer or oscilloscope, and fiber, the standard tools in an optics laboratory, suffice to implement the method that may be used for regular checking of femtosecond laser performance.

References

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