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Realization of a Diffraction-Grating Autocorrelator for Single-Shot Measurement of Ultrashort Light Pulses Duration

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Abstract. The realization of a recently proposed diffraction-grating autocorrelator for single-shot background-free measurement of picosecond light pulses is described. Some usefull practical considerations are discussed and the results of pulse-width measurements of a mode-locked Nd: glass laser are presented.

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Due to wide-spread applications of ultrashort laser pulses the methods of controling their pulse-width become of great importance. The direct measurements, using streak-cameras, cannot be afforded by most of the laboratories. Therefore in recent years much attention was paid to methods for autocorrelation in a single shot [1–6], as an inexpensive alternative. It is most desirable, that the method is background-free. Noncolinear second-harmonic generation is used usually for this purpose [2–6]. Recently a simple autocorrelator, utilizing a diffraction-grating mirror system was proposed [7]. In this paper we demonstrate the feasibility of this autocorrelator and discuss some practical considerations.

Autocorrelator Design

The basic idea of the autocorrelator design was described in [7]. However, slight modifications are made, which allow easy alignment and background-free measurements. Figure 1 shows the experimental arrangement for the pulse-width measurements. The light beam is expanded by a $20\times$ prism expander PE. A plane-parallel 1 cm thick glass plate D, inserted into the expanded beam devides the latter into two equal parts A and B. The glass plate is tilted at 45°, thus displacing the beam A in vertical direction and introducing a time delay of 19 ps between the two parts. The beams A and B illuminate the mirror-grating system with an angle of incidence to the grating being $\pm\alpha = 39.14°$. This angle is determined by the 600 1/mm grating, used in the experiment. The mirror was a dielectric one with maximum reflectance at 1.06 μm. The deflected beam A impinges on the grating G and is diffracted normally to its surface, while the other beam B is reflected by a mirror M and after diffraction by the

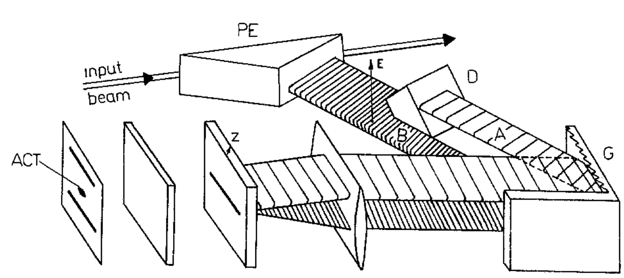


Fig. 1. Experimental arrangement for single-shot background-free ultrashort light pulse measurements (PE: prism beam expander; D: glass plate; G: diffraction grating; M: dielectric mirror; CL: cylindrical lens; NC: nonlinear crystal; F: filter for SHG; PF: photographic plate; ACT: autocorrelation trace; E: direction of the laser beam polarization; Z: axes of the nonlinear crystal)

grating G propagates normally to the grating as well, but at different height. The result is two parallel beams with variable time delay with respect to the beam cross-section, which is utilized for single-shot pulse-width measurements.

The two beams are focused by a cylindrical lens CL of 25 cm focal length into a 0.3 cm-long nonlinear KDP crystal.

The second-order autocorrelation function ACF is recorded on a photographic film ORWO NP27 type, denoted as PF in the figure.

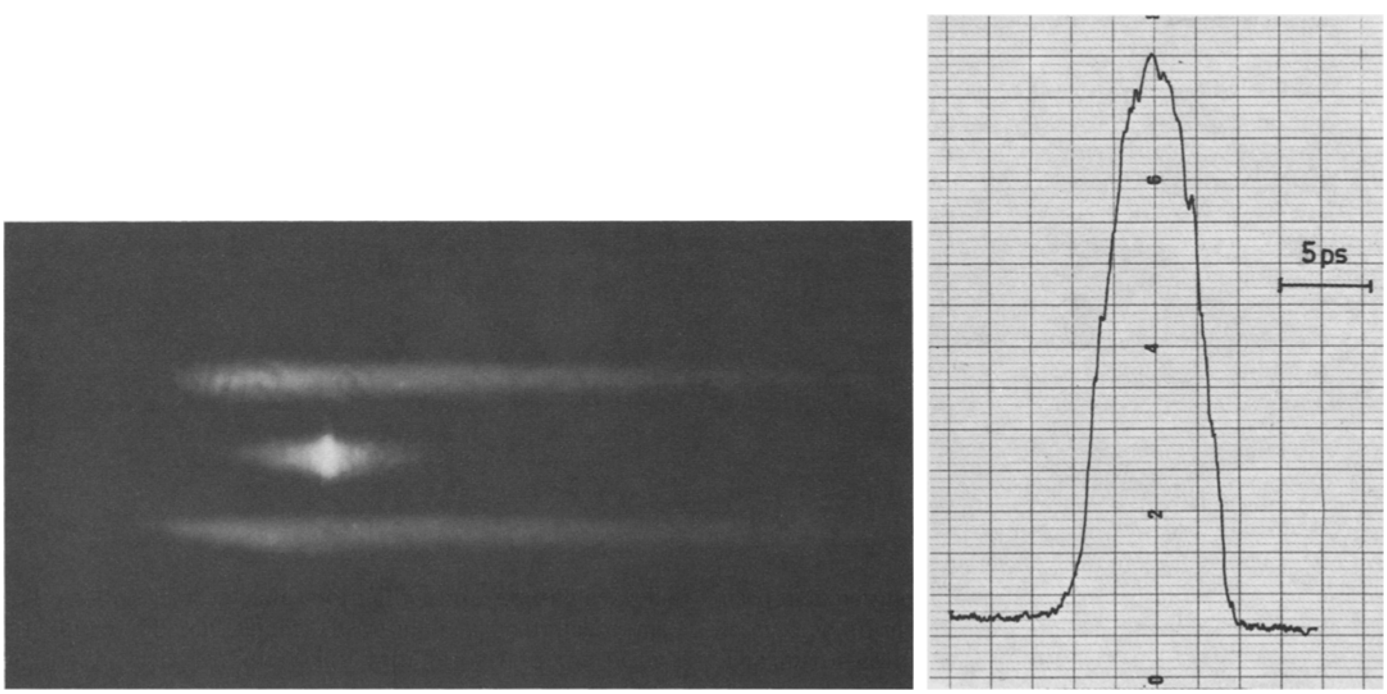
Results and Discussions

We have performed measurements of the pulse width of a home-made passively mode-locked Nd: phosphate-glass laser. The pulse train, produced by the laser, consisted of about 20 pulses of 8 ns time sequence.

In a prealingment procedure we used a He-Ne laser beam, superimposed on the Nd: glass one. The prism beam expander was used in order to illuminate uniformly the mirror-grating system. Although the prism expander introduces higher losses, compared to the cylindrical telescope, besides its simplicity, it has certain advantages, such as easy alignment and low wavefront distortion. However, the remainder of the laser beam reflected by the prism (about 95%), may be used in experiments while only a small fraction of the laser generation is used for pulse-width control.

The mirror-grating system is easy to align, taking into account that in case of first-order diffraction, normal to the grating, at the same time second-order autocollimation takes place for both beams A and B. Once aligned in this way with a He-Ne laser beam, the mirror-grating system is rotated at an angle, calculated for the wavelength of the measured laser pulse.

The lens CL focuses the two diffracted beams into the nonlinear crystal. We utilize oo-e type SHG with polarization of the beams and orientation of the nonlinear crystal, indicated in Fig. 1. The phase-matching condition is practically fulfilled for both A and B beams and for the interaction between them as well. However, the azimuthal angle ϕ differs for the A and B beams. Thus, for the interaction between the two beams we have close to colinear SHG with respect to the phase-matching angle θ, but it is noncolinear with respect to the azimuthal angle ϕ. This provides background-free measurement using conventional nonlinear crystals for SHG. In this way we obtained the pattern, demonstrated in Fig. 2a. The upper and down traces are produced by each beam alone, and the middle trace is the noncollinear second-harmonic generation, representing the second-order background-free ACF. The upper and down traces provide useful information concerning the uniformity of the beams.



a b

Fig. 2 (a) Second-harmonic generation pattern, recorded on the photographic plate (upper and down traces: SHG from B and A beams respectively, middle trace: autocorrelation trace of the measured pulse). (b) Microdensitogram of the autocorrelation trace

The glass plate displaces the zero point of the ACF [7]. We have used this in order to record the total ACF. The time scale can be easily calculated: $\Delta\tau/\Delta x = \frac{2\sin\alpha}{c}$ and in our case was 4.26 ps/mm. This scale may be directly callibrated for Gaussian pulses in pulse duration if devided by $\sqrt{2}$, resulting in a value of 3 ps/mm. The microdensitometer trace of ACF is shown in Fig. 2b, reveiling a pulse duration of 5 ps assuming Gaussian pulses. By inclining the photographic plate the time scale may be expanded to a convenient value.

A unique feature of the grating autocorrelator is that although it introduces a great time delay between the two beams, in a properly aligned mirror-grating system, the wavefronts of the diffracted beams are parallel. This allows easy observation of interference fringes, spaced at a distance λ/ε, where λ is the wavelength, ε is the angle between the two diffracted beams. The interference pattern represents a first-order ACF and may be used for pulse-duration measurements of clean pulses [8]. Such fringes were readily observed with He-Ne laser and in the SHG pattern. For small angle ε, when the distance between the interference fringes is comparable to the size of the autocorrelation trace, the interference distorts considerably the second-order ACF. In order to avoid this, the mirror is rotated at a proper angle with respect to the exact normal to the grating position. Thus the angle between the two beams A and B is high enough to obtain very closely spaced fringes. On the other hand, for sufficiently short crystals the angle between the beams is smaller than the phase-matching angle width. However, in experiments under way we utilize the interference for simultaneous recording of the first and second-order ACF in a single shot.

Conclusion

We have demonstrated the feasibility of a diffraction grating autocorrelator. It features simple construction and easy alignment. Single-shot background-free measurements were performed of the pulse width of a mode-locked Nd: glass laser.

References

1. J. Janszly, G. Corradi, R. Gyuzalian: Opt. Commun. **23**, 293–298 (1977)
2. R. Gyuzalian, S. Sogomonian, Z. Horvath: Opt. Commun. **29**, 239–242 (1979)
3. C. Kolmeder, W. Zinth, W. Kaiser: Opt. Commun. **30**, 453–456 (1979)
4. S. M. Saltiel, S. D. Savov, I. V. Tomov, L. G. Telegin: Opt. Commun. 443–447 (1981)
5. R. Wyatt, E. Marinero: Appl. Phys. **25**, 297–301 (1981)
6. G. Szabó, Zs. Bor, A. Müller: Appl. Phys. B**31**, 1–4 (1983)
7. S. M. Saltiel, K. A. Stankov: Appl. Phys. B**35**, 45–48 (1984)
8. P. Yeh: Opt. Lett. **8**, 330–332 (1983)