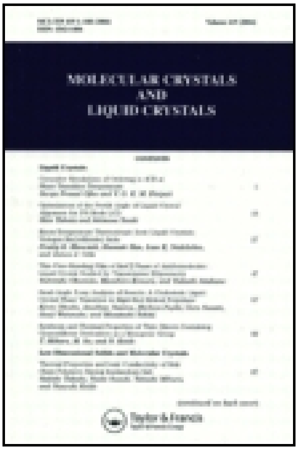

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Frequency-Selective Time-Domain Data Storage and Processing by the Interference of Stimulated Photon Echoes

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FREQUENCY-SELECTIVE TIME-DOMAIN DATA STORAGE AND PROCESSING BY THE INTERFERENCE OF STIMULATED PHOTON ECHOES

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Abstract Controlled picosecond time-domain interference of photochemically accumulated stimulated photon echoes excited by different laser pulses have been analyzed theoretically and observed experimentally in octhaethylporphin-doped polystyrene at 2K. The methods of segmentwise storage and reconstruction of light signals in a selected time interval and performing operations af addition and subtraction have also been demonstrated. Potential applications of observed time-domain interference of different type coherent responses in spectral hole-burning media have been discussed.

INTRODUCTION

Time-and-space-domain holography[1-3] by photoburning of persistent spectral holes[4,5] provides a means of storing temporal and spatial properties of an ultrafast-varying light signal and recalling its authentic replica at any later moment. The possibility of recording complex time shapes of light pulses, which also means time-domain optical data storage, is based on the ability of frequency-selective absorbers to store with high accuracy the temporal Fourier components of the incident light[1-3,6,7]. The time-domain frequency-selective optical storage of binary or analog data[6] is an alternative approach to the concept of frequency-selective high-density data storage[8], that provides a parallel ultrafast data storage and processing in the frequency domain[9-16]. The concepts of optical information processing in frequency selective media are developed in [10,11,17-20].

In this paper, we report to our knowledge for the first time on the controllable interference of stimulated photon-echo-type coherent responses and demonstrate the method of selective storage and reconsrtruction of light signals in a selected time interval. We also present recent results on observation of time domain interference of time delayed impulse responses of spectral filters and point to their practical significance for optical information processing.

THEORETICAL CONSIDERATIONS

The concept of utilizing controlled time domain interference of accumulated stimulated photon echoes for selective recording and recall of the time segments of signal events was first proposed theoretically for the scalar optical field in[21] and later, generalized for vector field optical signals[21,22].

To follow the interference of accumulated photon echoes, one has to record (accumulate)[1-3] in the absorption spectra of the sample at least two light (signal) pulses, replicas of which are recalled during the echo formation. If these echo pulses overlap in space and in time, they interfere. The shape of this interference pattern depends on the intensity and the phase of interfering pulses.

To achieve control over the interference the recording process of the two pulses has to be carried out in two successive exposures by two different reference pulses, applied at different moments (delays) t_{R1} and t_{R2}, and at different directions with respect to the signal pulse. In this case the optical paths of the reference pulses, that are later used as the reading ones, are separated spatially, and one can change the relative intensity and the phase of one of the reading pulses and this way control the interference of stimulated echoes.

If coherent responses of the frequency selective sample with burnt in hole pattern are generated without angular or temporal selectivity by successive excitation pulses having delay less than the decay of the response signal at the output, successive responses, partially overlapping in time and in space, will also interfere. In that case one can observe interference between two signals of the same shape, having mutual delays, amplitudes and polarization states determined by the excitation pulses. Practically more interesting situation appears when signals consist of regular pulse sequences like in case of time-domain binary information storage. In first experiments we used for burning hole-patterns and creating sequential responses of hole pattern, the pulse trains formed by the same Fabry-Perot ethalon.

EXPERIMENTAL EXAMPLES

To observe time-domain interference of stimulated echoes experimentally a train of picosecond light pulses was recorded in octhaethylporphin-doped polystyrene at 2K in two successive exposures by different reference pulses incident at angles 3° and 5°with respect to the direction of propagation of the signal pulse train.

To control the interference of the two recalled echo pulses, one of the reference pulses was passed through a variable

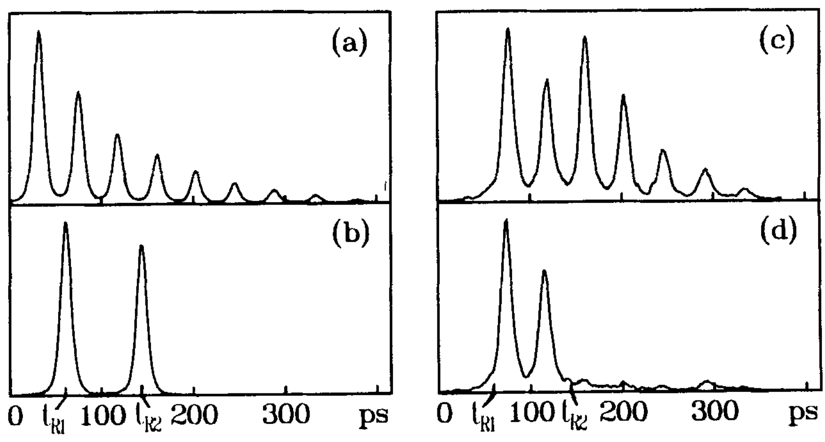

FIGURE 1. Recorded streak camera traces.

attenuator and a glass slab of ~1 mm thickness. The latter was mounted on a turnable stage, which enabled the optical path to be changed with the required accuracy. A temporal analysis of the "interference pattern" was performed by means of a streak camera coupled to an optical multichannel analyzer with 15-20 ps time resolution. Figs. 1a, b, depict the temporal order of the signal shaped by using a Fabry-Perot etalon and of the reference pulses. One can see that the first reference pulse is incident ~37 ps after the front edge of the signal, while the delay between the reference pulses is ~72 ps.The shapes of the output signal after interference jare depicted in Fig.1c,d. As one can see (Fig.1c), if the phase of the second readout pulse remains unchanged, the intensity of the output signal grows rapidly at the moment t_{R2} due to constructive interference in the region of overlapping. A destructive interference pattern (Fig.1d) appears when an extra $\lambda/2$-delay is introduced into the optical path of the second readout pulse. Only a part of the original signal, corresponding to the time interval of 72 ps between the two reference (and readout) pulses, is observed. Like in the previous case, the leading part of the signal ($t<t_{R1}$) is absent due to the causality of spectral holograms[2] whereby the tail of the signal is suppressed because of destructive interference. Thus, we have demonstrated a method for selective storage and recall of only a segment of the signal in a fixed time interval from t_{R1} to t_{R2}.

Experiments on interference of coherent responses of spectral filters were performed in chlorine doped polystyrene at 2K. The hole patterns were formed by the same ethalon which was used above (Fig. 1a). The impulse response of the filter after the first burning cycle is depicted on Fig. 2a. Readout of the filter by the pulse train used for burning creates the serie of equivalent time shifted overlapping responses which interfere constructivly. After introducing phase-shift of $\lambda/2$ between the pulses in the reading train, the response of the filter to pulse train wanishes (see

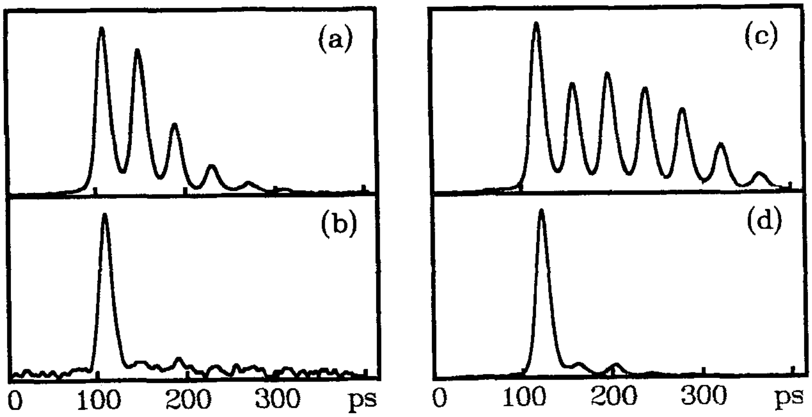

FIGURE 2. Responses of frequency-selective filters.

Fig.2b). One can follow a pulse train incedent onto the sample, while at the output of the filter only a single pulse can be seen. Figuratively seying, filter "swallows up" all the pulses exept one. If we now keep on burning with out-of-phase pulse train, in the end of the second burning cycle one can see that as a result, a new serie of overlapping responses is created (Fig. 2c). But impulse response of the sample to a single short light pulse after burning with two out-of-phase pulse trains successivly (Fig. 2d.), exhibits efficient erazing of the response of the filter, observed after the first burning cycle (depicted on Fig. 2a). The latter is consistent with the procedure proposed in [23] for photon echo memory erasure.

CONCLUSIONS

In this paper, interference between the stimulated photon echoes excited by different light pulses has been observed in a picosecond time-scale. The control of the extra phase shift between the excitation pulses during reconstruction gives a possibility of keeping control of also the interference and of using it for pulse shaping, selective storage and the recall of true or phase-conjugated segments of the original signal and of performing operations of addition and subtraction of vectorial functions. Particularly, it enables the formation of polarized light pulses of pico- and femtosecond scale with the shapes determined by the linear combination of vector functions with phase sensitive multipliers.

The efficient erazing of the response of frequency-selective time-domain optical memories by means of opposite phase light signal is also demonstrated.

REFERENCES

1. A.Rebane, R.Kaarli, P.Saari, A.Anijalg, K.Timpmannn, Optics Comm., 47, 173 (1983).
2. P.Saari, R.Kaarli and A.Rebane, J. Opt. Soc. Am.,B3, 527 (1986).
3. P.M.Saari, R.K.Kaarli, R.V.Sarapuu and H.R.Sõnajalg, IEEE J. Quantum Electron., QE-25, 339 (1989).
4. A.A.Gorokhovskii, R.K.Kaarli, L.A.Rebane, JETP Lett., 20,216(1974).
5. B.M.Kharlamov et al.,Optics Comm., 12, 191 (1974).
6. T.W.Mossberg, Optics Lett., 7, 77 (1982).
7. W.Hesselink, D.A.Wiersma, Phys. Rev. Lett., 43, 1991 (1979).
8. G.Castro, et al., US Patent 4101976 (1978).
9. N.W.Carlson et al., Phys.Rev.A, 30, 1572 (1984).
10. Y.S.Bai et al., Appl. Phys. Lett., 45, 714 (1984).
11. W.R.Babbitt and T.W.Mossberg, Appl. Opt., 25, 962 (1986).
12. W.R.Babbitt and T.W.Mossberg, Opt. Commun., 65, 185 (1988).
13. M.Mitsunaga, M.K.Kim and R.Kachru, Opt.Lett., 13, 536 (1988).
14. M.K.Kim and R.Kachru, Opt. Lett., 14, 423 (1989).
15. M.Mitsunaga and N.Uesugi, Optics Lett., 15, 195 (1990).
16. S.Saikan et al.,H.Oosawa, Optics Lett., 14, 841 (1989).
17. U.Wild et.al., Appl. Opt.,29, 4329 (1990).
18. U.Wild, A.Renn, J. Molecular Electronics, 7, 1, (1991).
19. A.Rebane, O.Ollikainen, Opt. Commun.,83, 246 (1991).
20. O.Ollikainen, Appl. Opt., (to be published).
21. R.Sarapuu, Dipl. Thesis (Tartu Univ., 1986).
22. R.Sarapuu, Ph.D. Thesis (Inst. of Phys., Estonian Acad. Sci., 1989).
23. N.N.Akhmedijev, Opt. Lett.,15, 1035 (1990).