Yu. T. Mazurenko. *Holography of time-varying waves through diffraction of pulsed light.* It is now possible to produce ultrashort light pulses, with duration as short as 10^{-14} s. Wave packets of such pulses have longitudinal dimensions substantially smaller than the typical dimensions of the elements of optical systems. It is thus possible to arrange conditions under which the diffraction of the wave packet by spatial inhomogeneities leads to changes in not only the spatial structure but also the temporal structure of the light. If the spatial distribution of the inhomogeneities corresponds in the appropriate way to the spatial and temporal distribution of the amplitude and phase of some nonstationary wave, then this wave can be reconstructed (under certain restrictions) as the wave packet is diffracted. In particular, direct recording can be carried out in a three-dimensional medium, and a nonstationary wave which is bounded in time can be reconstructed through the use of a plane wave packet as a source of reference light.[1]

A spatial-spectral decomposition of nonstationary waves opens up some broader opportunities. The reciprocal of the frequency resolution of optical spectral instruments can reach $T = 10^{-9}$–10^{-8} s, which is substantially longer than the shortest light pulses which can be produced. During the spectral decomposition of a pulse of length $\tau \ll T$, the field formed near the plane of the spectrum is a wave whose frequency varies over the cross section and which continues for a time T (the left branch of the diagram in Fig. 1). The amplitude and phase distributions in the cross section of this wave reproduce those of the amplitude and phase in the spectrum of the original temporal signal. If the relative time shift of two pulses does not exceed T, the waves of their spectral decomposition may interfere. The interference pattern, recorded on a photographic plate, may be called a "spectral hologram." A spectral hologram contains a record of the amplitude spectrum of a signal pulse with respect to the spectrum of a reference pulse.[2–5] If the spectral-decomposition wave of the reference pulse illuminates the spectral hologram, diffraction will give rise to a reconstructed wave which is a spectral-decomposition wave of the signal pulse, and also to a reconstructed wave conjugate to it. The summation of the frequency components of these waves by means of a spectral instrument working in the return path of the rays (the right branch in Fig. 1) results in the formation of a real temporal copy of the signal pulse and also a time-reversed copy of this pulse[3–5] (Fig. 2). The time resolution of the reconstruction and the maximum duration of the signal

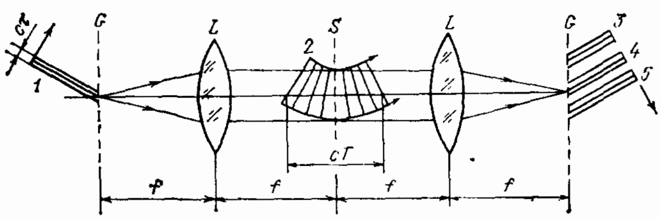

FIG. 1. Coherent spectral decomposition and reconstruction of a light pulse. *G*—Dispersive elements (e.g., diffraction gratings); *L*—lenses; *S*—plane of spectrum and hologram. 1) Incident wave packet; 2) spectral-decomposition waves; 3–5) pulses formed during reconstruction (Fig. 2).

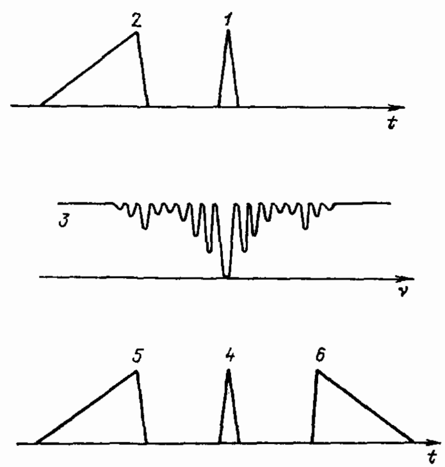

FIG. 2. Reconstruction and time reversal of a light pulse. 1—Reference pulse; 2—signal pulse; 3—energy spectrogram (spectral hologram); 4—reconstructing pulse; 5, 6—direct and time-reversed copies of the signal pulse generated during reconstruction.

pulse are determined by the duration of the reference pulse and by the time T, respectively.

The signal wave packet may contain a moving one-dimensional image in the direction perpendicular to the spectral decomposition. Such an image can be recorded in the form of a two-dimensional spectral hologram which contains records of the spatial and temporal information along the two coordinates; a reconstruction can then be carried out. In the simplest case, a two-dimensional spectral hologram would make it possible to spatially separate reference and signal pulses during recording, while during reconstruction it would be possible to separate the direct and time-reversed copies of the signal pulse.[3–5] Moving two-dimensional images can be recorded and reconstructed on the basis of analogous principles.[6]

In the case of interference of oppositely directed waves of the spectral decomposition of two pulses—this decomposition can be carried out with the help of the double spectral instrument shown in Fig. 1—a standing wave characterized by a fan-shaped arrangement of antinodes forms near the plane of the spectrum. If this wave is recorded, one obtains a three-dimensional spectral hologram. Such a hologram can be used to reconstruct in reflected light only the direct copy or only the time-reversed copy of the signal pulse. The reconstruction efficiency can approach unity.[5]

A natural development of the principle of the three-dimensional spectral hologram is the dynamic spectral hologram. A hologram of this type makes it possible to record and reconstruct an optical pulse in real time. We find a variety of possibilities for ultrafast conversions to time-varying optical signals such as correlation, convolution, or time reversal of a signal. A dynamic mixing of spatial and temporal signals is possible. If, for example, a monochromatic spatial signal is recorded on a dynamic hologram, and it is reconstructed as a spectral hologram, then the result will be a temporal signal which is an analog of the original spatial signal. There is also the possibility of the inverse process: dynamic time-space conversion.[7]

Another field of application of dynamic spectral holography is photochronography. The interference pattern formed as a result of the interference of the spectral decomposition wave of an ultrashort pulse with an oppositely directed monochromatic plane wave is a rapidly rotating three-dimensional grating. The recording of such a grating in a dynamic medium makes it possible to realize a rotating holographic mirror. A mirror of this sort can be used to scan a light beam in the method of photochronography, so that we obtain for photochronography a time resolution which is in principle limited by only the duration of the original ultrashort pulse, say 10^{-12}–10^{-14} s.

An analysis of the general case of the interaction of spectral-decompositon waves in an optically nonlinear medium will make it possible to formulate principles of nonlinear spectral optics as a system of conversions of temporal optical signals through a nonlinear interaction of their spectra. Methods of nonlinear spectral optics present some substantially new opportunities for the conversion of pulsed light signals.[7]

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