E. I. Shtyrkov. *Generation of spatially periodic structures consisting of superimposed atomic states.* Light-induced dynamic periodic structures in the form of spatial lattices have very diverse applications. Quantum electronics, nonlinear laser spectroscopy, and dynamic holography are a partial list of areas in which new methods for generating light and sound, adjustment of laser beams, optical information processing, measurement of different properties of substances, etc. have been developed based on such structures (see, for example, the reviews in Refs. 1 and 2). The periodicity induced in a medium mainly affects the phase matching of all fields propagating in the structure. However, under conditions of an optical resonance, due to the parametric interaction, the influence of the structure on the magnitude of nonlinear coupling of the pumping waves already increases at quite moderate light intensities. In addition, at resonance a fundamentally new possibility for generating periodic structures in matter appears. It is based on the transition of atoms into a coherent state that is a linear superposition of characteristic state vectors, rather than into the upper energy state of the transition as in the usual resonant dynamic lattice.[3] When irreversible relaxation processes are suppressed, such structures are induced by optical fields even in the absence of interference between them, when the path difference exceeds the coherence length of the radiation used. Moreover, the interval between these fields can greatly exceed their duration.[4,5] Lattice formation with such pumping belongs to a class of transient optical phenomena,[6] based on interference of coherent superimposed atomic states, and has a number of interesting characteristics, since the interval τ between the pumping fields is an additional parameter of the interaction. In particular, the depth of spatial modulation of transient lattices depends on the loss factor of coherence of oscillations in the medium up to the time of arrival of the second pumping wave $\exp(\tau\Gamma)$, where Γ is the half-width of homogeneous broadening of the transition. Such a relation permits measuring homogeneous broadening, which is masked by the stronger inhomogeneous broadening, from the τ-dependence of the diffraction efficiency of the grating. The decay of the induced structure as the system strives toward thermodynamic equilibrium is determined by the longitudinal relaxation parameter, which makes it possible to measure this parameter from the lifetime of the structure. Other parameters (Rabi frequency, transition dipole moment) can be determined from the dynamics of self-diffraction of a second pumping beam,[7,8] as well as by measuring the dependence of the depth of modulation of the lattice on the frequency detuning.[9] Under conditions of detuning from resonance, the lattice background, depth of modulation, and the spatial displacement of the structure are complicated spectral functions, whose form is determined by pulsed pumping areas and transition parameters.[7] In the presence of strong inhomogeneous broadening of the transition, a stationary complex interference pattern, representing a series of lattices with identical frequency, but different amplitudes and spatial displacements, is fixed in the medium after termination of pumping. The nature of the interaction of the probing beam with a medium prepared in this manner depends on the intensity of this beam and on the geometry of the structure (thickness, period). Depending on the conditions, either linear diffraction of the probing wave (an amplitude, thin absorbing lattice) or its coherent nonlinear scattering (Bragg diffraction by a three-dimensional grating) is observed. Under certain conditions, it is possible to observe both signals simultaneously[5] (thin amplitude–phase grating). The nonlinear scattering pulse in a system with phase memory is a result of phasing of the isochromatic polarization waves generated by the probing pulse. Maximum scattering is achieved in some cases with a shift in time relative to the probing pulse (the well-known photon echo[10]), and in other cases directly during passage of the probing wave through the specimen (scattering by phased superimposed structures[11]). In this case, the direction of nonlinear scattering is determined by the characteristics of the periodic lattice induced in the medium, although the appearance of this scattering in itself, in contrast to linear diffraction, does not depend on the presence of this lattice. A coherent system of atoms can be used as a promising medium for recording, reconstructing, and reversing wave fronts of light. Holograms on superimposed coherent atomic states can be obtained both in the form of periodic lattices[12] (in homogeneously and inhomogeneously broadened systems) and based on the use of the photon echo phenomenon[13] (only for inhomogeneous broadening and if the Bragg conditions are satisfied). Holographic recording in this case has four-dimensional properties, since aside from the phase front, the system remembers the temporal characteristics of the fields (the interval between the object and reference waves, as well as the order in which they act on the medium). Such properties of holograms in superimposed states could find application in optical computers and information processing systems, for reversing wave fronts,[14] and for investigating weak optical inhomogeneities by dynamic multiplication of phase disturbances. Lattices induced on superimposed atomic states with the help of optical fields separated in time are apparently promising for use in laser spectroscopy for measuring the parameters of optical transitions and establishing the fundamental characteristics of the interaction of coherent radiation with matter.

In concluding this report, we note that the phase memory of a recording medium must be taken into account when interpreting different interference experiments, which, as is well known, often served as key experiments in establishing the nature of light and matter. The phase memory can also have another, as yet unknown, nature, but taking into account its determining role in interference experiments can greatly affect the validity of the final results, especially in studying interference of particles.

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