the induced transitions[1)], and then, after equalization of the populations, to the spontaneous transitions from the 5D levels. The population inversion should be produced in this case first for the 6P levels, since there is a higher probability of transition from the 5D levels to these levels than to the 5P levels. The second minimum at the excitation wavelength 7800 Å (see Fig. 3) can be due to an increase in the probability of the two-photon transition near the single-photon resonance $5^2S_{1/2} - 5^2P_{3/2}$, and also to the increase of the role of SRS from the $5^2P_{3/2}$ level, as a result of the effective population of this level. We note that in this case there was observed an intense anti-Stokes SRS, connected with the transition of the atom from the $5^2P_{3/2}$ level to the $5^2P_{1/2}$ level (see Fig. 2b). Owing to the effective level $5^2P_{3/2}$, the excitation of the electronic SRS is possible at rubidium vapor pressures ∿0.05 mm Hg (exciting-radiation intensity 2 MW/cm^2).

[1] S. Vatsiv, W.G. Wagner, G.S. Picus, and F.J. McClung, Phys. Rev. Lett. 15, 614 (1965).
[2] M.E. Movsesyan, N.N. Badalyan, and V.A. Iradyan, ZhETF Pis. Red. 6, 631 (1967) [JETP Lett. 6, 127 (1967)].
[3] S. Barak, M. Rokni, and S. Vatsiv, IEEE J. of Quant. Electron. QE-5, 448 (1969).
[4] Yu.M. Kirin, D.P. Kovalev, S.G. Rautian, and R.I. Sokolovskii, ZhETF Pis. Red. 9, 7 (1969) [JETP Lett. 9, 3 (1969)].
[5] Yu.M. Kirin, S.G. Rautian, B.M. Chernoborod, and A.E. Semenov, ibid. 11, 340 (1970) [11, 226 (1970)].

SCATTERING OF LIGHT BY A PERIODIC STRUCTURE OF EXCITED AND UNEXCITED ATOMS

E.I. Shtyrkov

Submitted 19 June 1970
ZhETF Pis. Red. 12, No. 3, 134 - 137 (5 August 1970)

In connection with the development of applied holography, great importance attaches to low-delay recording and reconstruction of wave fronts of light. However, the presently available holographic receivers have large time lags, owing to the appreciable time interval between the final stages of the holographic process. Therefore great interest attaches to the possibility of reducing this interval by using the phenomenon of resonant absorption in substances with small relaxation times. By transferring the atoms from the lower state of the resonant transition to the upper one it is possible to produce a spatial distribution of the absorption coefficient.

This can be experimentally realized, for example, in the particular case when a resonator is placed in a medium at the point of intersection of two beams of coherent light $E_1 \exp\{i(\omega t - \vec{k}_1 \cdot \vec{r})\}$ and $E_2 \exp\{i(\omega t - \vec{k}_2 \cdot \vec{r})\}$ with plane fronts and with wave vectors $\vec{k}_1$ and $\vec{k}_2$. The time-averaged value of the spectral density of the radiation at the point of intersection of the beams will have the form, as a result of interference,

$$\rho_\nu = \frac{\epsilon}{8\pi}\left[(E_1^2 + E_2^2) + E_1E_2 \exp\{-i(k_2 - k_1)r\} + E_1E_2 \exp\{i(k_2 - k_1)r\}\right], \quad (1)$$

where ε is the dielectric constant of the medium. To find the dependence of the absorption coefficient on ρ_ν, we use a probability method of calculating the

[1)] A contribution to the population of the 6P levels may also be made by SRS from the $5^2P_{3/2}$ level.

the level populations [1] and assume that the upper state in the two-level system is populated by absorption, while the decay occurs spontaneously, in a stimulated and non-radiative fashion. Assuming the light pulse to be rectangular with duration τ_p, we can obtain in first approximation the spatial distribution of the spectral absorption coefficient in the form

$$K_\nu = -\sigma_{21} N_0 \frac{g_2}{g_1}\left[\left(1+\frac{g_2}{g_1}\right)\frac{B_{21}(\nu)\,\rho\,(1-\exp A\,\tau_u)}{A} - 1\right], \tag{2}$$

where σ_{21} is the absorption cross section, N_0 is the concentration of the atoms in the ground state prior to the irradiation, $\rho = \int_0^\infty p_\nu d\nu$ is the radiation density, g_1 and g_2 are the statistical weights of the levels,

$$A = B_{21}(\nu)\,\rho\left(1+\frac{g_2}{g_1}\right) + A_{21} + d_2 ,$$

A_{21} and $B_{21}(\nu)$ are the Einstein spectral coefficients, and d_2 is the probability of nonradiative decay of the upper state.

We see from this expression that the absorption coefficient will be spatially modulated in accordance with (1) only if A is independent of ρ. This can always be done by limiting ρ and choosing a medium with a large probability of decay of the upper state. The distribution (2) exists only during the relaxation time of the medium. Therefore any restoring light beam having the same frequency ω and incident on this medium prior to the end of the relaxation will be spatially modulated and its spectrum will reveal new spatial frequencies. If $K_\nu D < 1$, where D is the sample thickness, the restoring beam with complex amplitude $E_b \exp\{-i\vec{k}_b \cdot \vec{r}\}$ emerging from the medium will take the form

$$E_x = E_b \exp\{-j k_b r\}(K_\nu D). \tag{3}$$

Choosing the corresponding medium and limiting the density of the incident radiation in accordance with the condition

$$B_{21}(\nu)\,\rho\left(1+\frac{g_2}{g_1}\right) \ll A_{21} + d_2 , \tag{4}$$

we can readily see from expressions (1), (2), and (3) that the spatial spectrum of the reconstructing radiation emerging from the medium will contain plane waves with complex amplitudes

$$E_x \sim \exp\{-j k_b r\};\quad \exp\{-j(k_b + k_2 - k_1) r\};\quad \exp\{-j(k_b - k_2 + k_1) r\}. \tag{5}$$

If the direction of the reconstructing beam coincides with the direction of the first beam ($\vec{k}_b = \vec{k}_1$), then its scattering will take place in the direction of $\vec{k}_2$ and $2\vec{k}_1 - \vec{k}_2$.

Analogously, if $\vec{k}_b = \vec{k}_2$ the scattering will take place in the directions $2\vec{k}_2 - \vec{k}_1$ and $\vec{k}_1$. The beams producing the distribution (2) will themselves be scattered in these directions, since the duration of the emission from Q-switched lasers is larger than the time interval during which the distribution (2) is formed. This apparently explains the scattering observed by the author of [2] in a kryptocyanine solution.

We have investigated the possibility of observing scattering in solids, namely KS-19 glass and selenium. These substances have large absorption cross

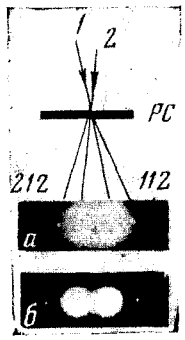

Fig. 1. Scattering produced upon intersection of two coherent light beams: a - in 2 mm of KS-19 glass, b - in a 20 μ layer of selenium.

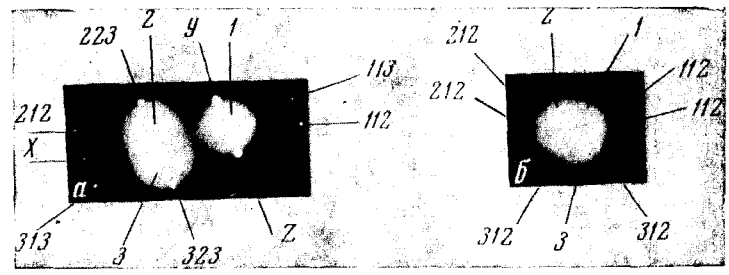

Fig. 2. Scattering upon intersection of three light beams: a - all beams coherent, b - only beams 1 and 2 coherent.

sections and large probabilities of non-radiative destruction of the upper states, making it possible to satisfy condition (4) without difficulty. We used in the experiment a Q-switched ruby laser, with a diaphragm placed in its resonator to separate a single transverse mode. A Mach-Zender interferometer was used to obtain a system of intersecting coherent beams.

Figure 1 shows the picture of the scattering of beams 1 and 2 by a resonant medium (RM) in the directions $2\vec{k}_1 = \vec{k}_2$ (112 denotes scattering of the first beam by structure 12) and $2\vec{k}_2 - \vec{k}_1$ (212 - scattering of second beam by structure 12).

A more complicated picture is observed in the intersection of three coherent beams (Fig. 2a). Beams 112, 212, 113, 313, 223, and 323 can be easily interpreted as the scattering of each of the beams by the structure produced by itself. The beams x, y, and z, on the other hand, can consist of two beams corresponding to mutual scattering of each of the initial beams by the grating produced by the two other beams. In other words, x consists of the diffracted beams 213 and 312, y of 123 and 213, and z of 123 and 312. This can be easily verified by delaying the third beam by a time larger than the coherence time of the laser emission. In this case (Fig. 2b) the third beam does not take part in the formation of the periodic structures 13 and 12, but is scattered by the structure 12. The appearance of second orders of diffraction (Fig. 2b) 212 and 112 is apparently connected with the contribution made to the scattering by the exponential term in expression (2) at large values of radiation density. The scattering intensity is inversely proportional to the angle between the interfering beams. At angles larger than 3° we were unable to observe any scattering at all. The intensity decreases also with increasing delay of the third beam, owing to the destruction of the periodic structure, the lifetime of which in the KS-19 glass turned out to be approximately equal to 50 nsec. The relaxation time can be measured more accurately by using high-speed photoelectric apparatus.

[1] Metody rascheta opticheskikh kvantovykh generatorov (Methods of Laser Design), Vol. 1, Nauka i tekhnika, Minsk, 1966.
[2] H.J. Gerritsen, Appl. Phys. Lett. 10, 239 (1967).

In the article by V. I. Shtyrkov, Vol. 12, No. 3, p. 93, formula (2) should read

$$K_\nu = \sigma_{21} N_0 \frac{g_2}{g_1} \left\{ \left(1 + \frac{g_2}{g_1}\right) \frac{B_{21}(\nu)\,\rho\,[1 - \exp(-A\tau_u)]}{A} - 1 \right\}, \qquad (2)$$