Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (26–27 March 1986)

Usp. Fiz. Nauk 150, 453–463 (November 1986)

A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on March 26 and 27, 1986 at the S. I. Vavilov Institute of Physical Problems of the USSR Academy of Sciences. The following reports were presented at the session:

March 26

1. *V. E. Zakharov.* Semiclassical theory of superradiance.
2. *A. M. Leontovich, A. M. Mozharovskiĭ, and E. D. Trifonov.* Coherent amplification, reflection, and induced superradiance in activated media.
3. *V. V. Zheleznyakov, V. V. Kocharovskiĭ, and Vl. V. Kocharovskiĭ.* Polarization waves and superradiance.
4. *S. N. Andrianov, Yu. V. Naboĭkin, V. V. Samartsev, N. B. Silaeva, and Yu. E. Sheĭbut.* Optical superradiance in a diphenyl crystal with pyrene.

March 27

5. *M. G. Shchepkin.* Majorana neutrino and double beta decay.
6. *O. Ya. Zel'dovich, I. V. Kirpichnikov, and A. S. Starostin.* Double beta decay: experimental status.
7. *L. A. Mikaelyan.* Neutrino experiments on the reactor at the Roven nuclear power plant.

Summaries of five reports are published below.

A. M. Leontovich, A. M. Mozharovskiĭ, and E. D. Trifonov. *Coherent amplification, reflection, and induced superradiance in activated media.* Coherent propagation of light pulses in activated crystals under conditions of retention of the phase memory of active centers was studied theoretically and experimentally. The evolution of light pulses in this case obeys substantially different laws than under conditions which are ordinarily realized in solid-state lasers, when the phase relaxation time of the medium is shorter than the duration of the pulses. The phenomena studied belong to a class of transient optical processes which occur over such short time intervals that during these processes there is not enough time for a stationary value of the polarization, corresponding to the carrier frequency of the pulse, to be established. For the same reason irreversible absorption does not arise and self-induced transparency is observed.

Retention of phase memory also means that superpositional (coherent) states of active centers are manifested in the interaction with the electromagnetic field. In particular, this leads to the addition of dipole moments and the formation of macroscopic polarization of the medium, proportional to the density of radiators. For this reason, in the processes under study, not only is the electromagnetic field coherent, but the state of the active medium is coherent also.

The studies performed have made it possible to construct the general physical picture of coherent optical processes in inverted media. In particular, the relationship between coherent amplification of ultrashort pulses and Dicke superradiance can be traced.

Methods were developed for finding the general solutions to the Maxwell-Bloch equations, satisfying arbitrary initial and boundary conditions and describing exactly the effects of propagation and retardation. In so doing both homogeneous and inhomogeneous broadening of the spectral line were taken into account correctly.[2] This enabled calculations of superradiant pulses and coherent amplification for situations approximating experimental ones quite closely.

Resonance nonlinear reflection was studied theoretically. It was shown that total reflection corresponds to the condition of phase-memory retention in a boundary layer of thickness $\sim\lambda$. In addition, the intensity of the incident field must be such that the Rabi period does not exceed the superradiance time for this layer.

Coherent propagation of light pulses in activated crystals (ruby and Nd:YAG) at 100 K for different areas of the input pulses and different ratios between the characteristic superradiance time, pulse duration, and phase relaxation time was studied: induced superradiance, lethargic amplification, and coherent π-pulse amplification. Analogs of these states in noninverted media were also observed: self-induced transparency and lethargic absorption.

The basic features of the self-similar pulse were observed in experiments on coherent amplification. Pulses with an oscillating envelope were observed.[3] It was established that intensity oscillations correspond to sign-alternating oscillations of the envelope of the field.[4] Compression of the temporal structure of the pulse as it is amplified was recorded. Pulses with durations of 5–10 psec, which is 5 to 10 times shorter than the inverse linewidth of the amplifying transition, were obtained in a three-cascade ruby amplifier.[5]

The splitting of the superradiance spectrum and coherent amplification were predicted theoretically[6] and recorded

 0038-5670/86/111058-07$01.80

experimentally.[7] The doublet structure of the spectrum can be regarded as a manifestation of the dynamic Stark effect in the field of the pulse. The magnitude of the splitting is of the order of the Rabi frequency, and this makes it possible to estimate the intensity of the radiation from its spectrum.

The amplification threshold conditions for the development of superradiance were determined. The existence of relaxation processes leads to the fact that below threshold amplification the cooperative process is suppressed. Under these conditions inversion in the active medium can be accumulated with the help of slow pumping in an interval substantially exceeding the characteristic superradiance time. It was shown that under real experimental conditions the excitation is subthreshold and spontaneous development of superradiance is impossible. In this case the superradiance pulse can be initiated by a short pulse with a small area. This effect is called induced superradiance.[8] We have observed an induced superradiance pulse experimentally, though it was strongly suppressed because of rapid phase relaxation.

Coherent propagation of small-area pulses, which do not significantly alter the inversion on the amplifying transition, was observed theoretically and experimentally.[9–11] Deviations from Beer's law governing the increase in the radiation power (so-called lethargic amplification) were observed. The transition to Beer amplification accompanying an increase in the duration of the amplified pulse was observed. Transformations of the pulse shape, which in the temporal description can be explained by the interference of the radiation field and the secondary field generated by the macroscopic polarization created in the medium by the starting field, were recorded. In the spectral description the effects obtained can be regarded as spectral selection.

The new optical phenomena studied are of considerable interest in connection with the development of new types of laser media with long phase relaxation times and femtosecond lasers, in which the pulse duration is comparable to the phase relaxation time in condensed media at room temperature. The effects observed can be used in spectroscopy to study phase-relaxation mechanisms.

[1] A. I. Zaĭtsev, R. F. Malikov, and E. D. Trifonov, Zh. Eksp. Teor. Fiz. **76**, 65 (1979) [Sov. Phys. JETP **49**, 33 (1979)].

[2] R. F. Malikov, V. A. Malyshev, and E. D. Trifonov, Opt. Spektrosk. **53**, 652 (1982) [Opt. Spectrosc. (USSR) **53**, 387 (1982)].

[3] O. P. Varnavskiĭ, A. N. Kirkin, A. M. Leontovich, A. M. Mozharovskiĭ, and I. R. Sataev, Pis'ma Zh. Eksp. Teor. Fiz. **37**, 229 (1983) [JETP Lett. **37**, 271 (1983)].

[4] O. P. Varnavsky, A. N. Kirkin, A. M. Leontovich, and A. M. Mozharovsky, Opt. Commun. **49**, 71 (1984).

[5] A. N. Kirkin, A. M. Leontovich, and A. M. Mozharovskĭi, Kvant. Elektron. **5**, 2640 (1978) [Sov. J. Quantum Electron. **8**, 1489 (1978)].

[6] R. F. Malikov, V. A. Malyshev, and E. D. Trifonov, Opt. Spektrosk. **51**, 406 (1981) [Opt. Spectrosc. (USSR) **51**, 225 (1981)].

[7] O. P. Varnavskiĭ, A. N. Kirkin, A. M. Leontovich *et al.*, Zh. Eksp. Teor. Fiz. **86**, 1227 (1984) [Sov. Phys. JETP **59**, 716 (1984)].

[8] R. F. Malikov and E. D. Trifonov, Opt. Commun. **52**, 74 (1984).

[9] M. G. Benedikt and E. D. Trifonov, Opt. Spektrosk. **59**, 162 (1985) [Opt. Spectrosc. (USSR) **59**, 95 (1985)].

[10] O. P. Varnavskiĭ, V. V. Golovlev, A. N. Kirkin, and A. M. Mozharovskiĭ, Pis'ma Zh. Eksp. Teor. Fiz. **41**, 9 (1984) [JETP Lett. **41**, 8 (1984)].

[11] O. P. Varnavskiĭ, V. V. Golovlev, A. N. Kirkin, and A. M. Mozharovskiĭ, Kratk. Soobshch. Fiz. No. 9, 24 (1985). [Sov. Phys. Lebedev Inst. Rep. No. 9, 23 (1985)].