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Optical collective phenomena with participation of metastable atoms in decaying plasma of pulsed discharge

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Considering new methods of nonstationary plasma diagnostics, we investigate an appearance of a new type of laser spectrum generation, which is a direct consequence of underlying principles of light-matter interaction. The spectrum "condensation" and amplification observed originate from the collective coherent interaction between atoms of a dense resonant medium trough the electromagnetic field.

With a view to develop new methods of nonstationary plasma diagnostics, experiments on probing the decaying plasma of pulsed discharge, which contains great amount (10^{13} cm^{-3}) of metastable atoms, were carried out by the intracavity-laser-spectroscopy method using a dye laser. The essential role of collective phenomena under interaction between polychromatic laser radiation and a dense resonantly absorbing medium was shown for this method of plasma diagnostics. The principle possibility for two types of generation spectrum to appear is proved under intracavity spectroscopy with broadband pumping: (1) ordinary type, with a deep at week absorption lines, (2) the so-called "collective" type of generation spectrum.

On the basis of experimental and theoretical results obtained, a new method of light generation under intracavity interactions with broadband pumping is proposed and proved – parametric excitation of collective effects under interaction of electromagnetic field and matter, which is accompanied by the so-called "condensation" of lasing spectrum.

In the intracavity experiments, decaying plasma of a Ne pulsed discharge (initial gas pressure is 4 Torr, current density is tens of A/cm^2, current pulse duration is 10–100 μs) was placed inside a dye laser with lamp pumping. Figure 1 shows a set of "condensation" spectra corresponding to generation close to 594.5 nm spectral line, that were obtained at different phases of pulsed-discharge plasma decay.

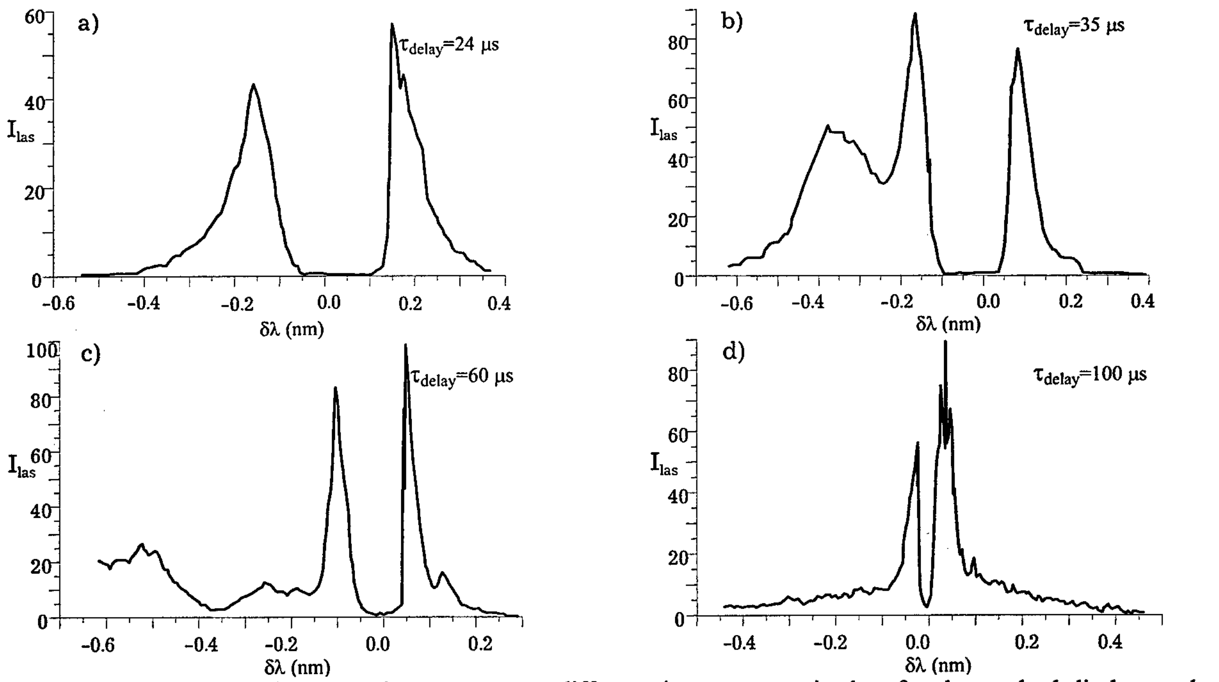

Fig. 1. "Self-splitting" of the generation spectrum at different time moments in the afterglow pulsed discharge, that corresponds to different absorbing metastable atom densities in the intracavity absorbing cell; Ne, λ=594.5 nm.

The density of absorbing atoms, calculated by expression $\Delta = \omega_c^2 T_2$ (Δ is a distance between components of "condensation" spectrum, ω_c is a cooperative frequency, which is also known as optical plasma frequency, T_2 is a phase relaxation time of the corespondent spectral transition), are in agreement, at least in order, with analogous measurements by the Rozhdestvensky "hook" method.

It should be emphasised, that the results obtained are truly the consequence of the fundamental principles of light–matter interactions, but not that of some cavity effects. To demonstrate that, we carried out the free-space experiments on the dye-laser pulse amplification under pumping of afterglow plasma of a Ne pulsed discharge. In these experiments, the decaying plasma was created after a current pulse of 10–100 μs with current density of tens A/cm^2 and initial Ne pressure of 18 Torr. Under certain experimental conditions, the spectrum "condensation" at a strong absorption line was also observed. The correspondent effective amplification coefficient of a laser beam, probing the plasma, is shown in Fig. 2.

References

[1] S.N. Bagayev, V.S. Egorov, I.B. Mekhov, P.V. Moroshkin, I.A. Chekhonin, Opt. Spectrosc. V. 93, N 6, pp. 955 – 962 (2002);

[2] S.N. Bagayev, V.S. Egorov, I.B. Mekhov, P.V. Moroshkin, I.A. Chekhonin, E. M. Davliatchine, and E. Kindel, Opt. Spectrosc. V. 94, N 1, pp. 126 – 133 (2003)

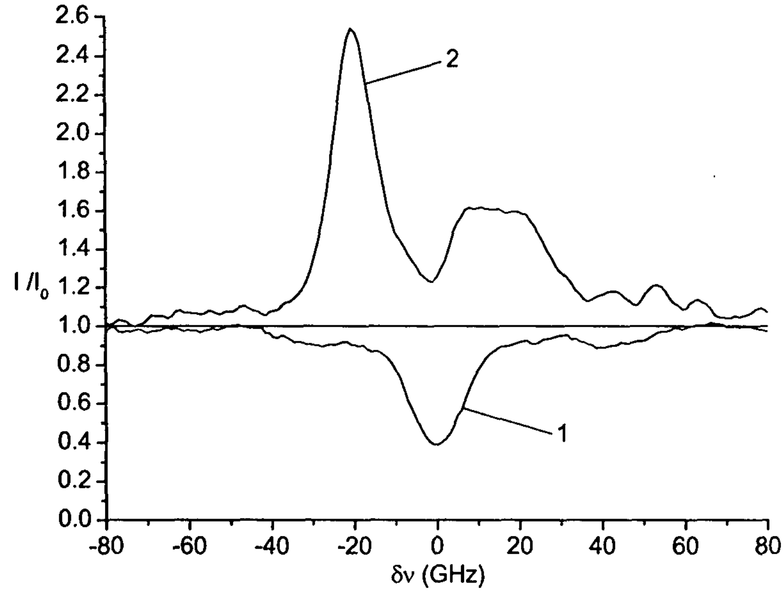

Fig. 2. Transmission of the probe laser field in the absence of the pump beam (1) and it's amplification in the presence of the pump (2); Ne, λ=640.2 nm.