probability of 55%, the recorded events should include decay modes of the form given by (1).

Our results also show that, for a reliable detection of the decay mode (1), one should use not only higher-intensity beams but also thinner targets or methods of detecting the decays in flight so as to reduce the background due to $\pi^+ \to e^+ + \nu_e + \gamma$ decays.

The authors are indebted to V. P. Dzhelepov, L. I. Lapidus, and B. M. Pontecorvo for help and interest in this research, D. Yu. Bardin and S. M. Bilen'kiĭ for valuable discussions, V. A. Enchevich for scanning the enormous number of photographs, N. A. Kuchinskiĭ, I. Yu. Levenberg, S. A. Panchuk, and N. L. Savel'ev for assistance in the processing of the data, and G. K. Kocheshkov, E. N. Ul'yanov, and I. M. Shirokov for participation in the preparation of the equipment and in carrying out the experiments.

[1)]The part of the structure-dependent decay that is sensitive to the formfactor ξ does not produce correlated pairs either (see Sec. 6).

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Translated by S. Chomet

Ultrahigh resolution spectroscopy based on wave competition in a ring laser

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(Submitted September 8, 1975)
Zh. Eksp. Teor. Fiz. 71, 78–87 (July 1976)

A novel method in which "Lamb dips" are not employed is developed for nonlinear laser spectroscopy. Its feasibility is based physically on the competition between spectral and spatial bleaching effects of the gas lines and of phase interaction of ring-laser traveling waves. The hyperfine structure of the absorption line of excited neon for the $4p\,[3/2]_2 \to 5s\,[1/2]_1$ transition, which is due to the presence of isotopes in the absorbing medium, is studied by this method. The superiority of a ring laser over a linear one is confirmed: its sensitivity is much higher and the registration is considerably simpler (such studies have not been performed at all with linear lasers). Precision measurements of Zeeman splitting of the methane absorption line belonging to the $F_1^{(2)}$ component of the ν_3-group $P(7)$ branch are made with a ring laser with a resolution 2×10^{-6} cm^{-1}. It is demonstrated that the sensitivity and accuracy of a nonlinear ring-laser spectroscope when used to investigate the hyperfine structure of weakly absorbing gases can be enhanced by operating in self-oscillation generation regimes.

PACS numbers: 07.45.+r, 42.60.Qm

INTRODUCTION

The presently employed methods of nonlinear laser spectroscopy (NLS) without Doppler broadening (see, e.g., [1]) are based on effects of spectral saturation of the gas in the field of a strong light wave, [2–4] which leads to the onset of narrow nonlinear resonances against the background of a broad Doppler gain contour or absorption contour of width equal to the homogeneous line width (the so-called "Lamb dips"[4]). The sensitivity and accuracy of these methods are determined by the magnitude and width of the Lamb dips, while the resolution is determined by the homogeneous line width of the amplifying or absorbing gas. In the optical band, the ratio of the Doppler width $\Delta\omega_D = ku$ to the homogeneous width Γ is $ku/\Gamma \sim 10^2 - 10^4$, i.e., the resolving power of NLS exceeds the resolving power of linear spectroscopy by several orders of magnitude.

For weakly absorbing transitions, however, for which $G_{0(-)} = g_{0(-)} l_{(-)} \ll 10^{-2}$ ($g_{0(-)}$ is the linear absorption coefficients per unit length, $l_{(-)}$ is the length of the absorbing cell), the contrast of the Lamb dips becomes small and laser spectroscopy based on the effects of spectral saturation of the gas becomes difficult. Further advances in modern NLS methods are connected with the possibility of obtaining ultranarrow and highly contrasting nonlinear resonances. High-Q resonances satisfying these requirements can be obtained in a ring laser with nonlinear absorption, which makes it possible to separate at the center of the Doppler-broadened line spectral structures with widths much smaller than the homogeneous line width, and with 100% contrast.[5]

We present here the results of a study of ultrahigh resolution spectroscopy using power resonances in the emission of the gas laser with a ring resonator; this spectroscopy makes it possible to register the hyperfine structure of a Doppler-broadened line even in the case of small absorption coefficients of the investigated gas. This possibility is based physically on the competition of the effects of spectral saturation of the gas line, the spatial modulation of the laser medium, and the synchronization of the frequencies of the opposing waves of the ring laser, which cause the appearance of high-Q resonances at the centers of the special components of the Doppler contour. The advantage of a spectroscopy method using the composition of the ring-laser waves over methods of power resonances of lasers in the field of a summing wave or in the field of opposing waves of equal intensity[1,6-12] consists in the following: a) there is no need for sensitive recording apparatus, inasmuch as the small-amplitude Lamb-dips (the maximum contrast of which is several percent) are transformed into high-contrast (up to 100%) resonances; b) the accuracy of the spectral measurements can be increased by several orders of magnitude, since the widths of the resonances turn out to be much smaller than the natural line width.

We present here the results of experiments on a precision spectroscopic measurement of the infrared absorption spectrum of methane CH_4 and the resolution of the hyperfine structure of the $4p'[\frac{3}{2}]_2 - 5s'[\frac{1}{2}]_1$ neon absorption line, due to the presence of the isotopes Ne^{20} and Ne^{22}. The resolution attained in the experiment is $\sim 2\times 10^{-6}$ cm^{-1}.

1. PROCEDURE OF SPECTROSCOPIC MEASUREMENTS WITH A RING LASER

The feasibility of ultrahigh-resolution NLS on the basis of the competition between the waves in a ring laser was demonstrated experimentally in an investigation of the hyperfine structure of the absorption lines of methane and of excited neon. We chose for the monochromatic radiation source a ring He–Ne laser operating at a wavelength $\lambda = 3.3922\ \mu$. The nonlinearly absorbing component was either methane (rotational-vibrational transition of the $F_1^{(2)}$ component of the $P(7)$ branch of the ν_3 group[13]) or else neon (electronic transition $4p'[\frac{3}{2}]_2 - 5s'[\frac{1}{2}]_1$).

The homogeneous absorption line width of the methane at its working pressure (10^{-2}–10^{-3} Torr) is ~ 300 kHz, the pressure-induced line shift is ~ 75 Hz/mTorr, and the broadening is ~ 7.4 kHz/mTorr.[9,14] The line experiences negligibly small shifts in electric and magnetic fields.[15] The absorption coefficient is appreciable, 0.18 cm^{-1}Torr^{-1}. The neon absorption line at the indicated transition has the following approximate parameters: radiative width ~ 10–20 MHz, increase of homogeneous width with pressure ~ 35 MHz/Torr, line shift with pressure 20–30 MHz/Torr (see, e.g.,[16]). The distance from the ground level of the neon to the lower level ($4p[\frac{3}{2}]_2$) of the working transition of the He–Ne laser at $\lambda = 3.39\ \mu$ is 20 eV. Therefore the excited neon absorbs practically no radiation at the wavelength $\lambda = 3.39\ \mu$. When it is excited by a discharge, the level $4p[\frac{3}{2}]_2$ becomes populated from the metastable levels $3s[\frac{3}{2}]_2^0$ and $3s[\frac{1}{2}]_1^0$, and it begins to absorb. The absorption coefficient of neon, however, while dependent on the degree of its excitation, is small. The Doppler widths of the investigated absorption lines of methane and neon equal approximately 320 MHz.

The experimental setup consisted of a ring laser, the resonator of which was made up of three mirrors with reflection coefficients $R_1 = R_2 = 96\%$ and $R_3 = 80$–90%. The resonator length was varied from 0.3 to 3 m during the course of the experiment. Single-mode operation of the long ring laser was ensured by the quasi-homogeneity of the gain contour at large active-medium pressure. The length of the active tube was 0.25–1.5 m, and the diameter of the capillary was 2–50 mm. The ends of the gas-discharge tube were cut at the Brewster angle and were hermetically sealed with quartz stoppers 2 mm thick. The gas-discharge tube was connected to a vacuum post, with the aid of which the necessary active-medium pressure was produced. To investigate the frequency characteristics of the ring laser, its length was scanned with the aid of a piezoceramic on which one of the mirrors was mounted. The scanning voltage was applied from a sawtooth generator. The voltage amplitude was 0–600 V at a frequency 50 Hz.

During the investigation of the nonlinear-absorption ring laser, a cell with methane with excited neon was placed in the resonator. The cell length was 0.25 to 1 m and the diameter 2–4 cm. To regulate the phase coupling of the opposing waves, a plane-parallel quartz plate was placed in the resonator. The coupling varied when the plate orientation relative to the resonator axis was changed. The laser radiation was extracted from the resonator through a semitransparent mirror and was incident on photoreceivers of the Ge–Au type, cooled with liquid nitrogen. The signal was amplified with broadband amplifiers and was fed to the input of a two-beam oscilloscope. The oscilloscope synchronization was by means of a signal from the sawtooth voltage generator.

The width of the investigated resonances were measured by the following procedure. The radiation of a single-mode heterodyne laser was mixed with one of the beams of the ring laser and fed through a broadband amplifier to a tuned amplifier whose frequency ν_0 could be adjusted in a wide range. Since the bandwidth of the

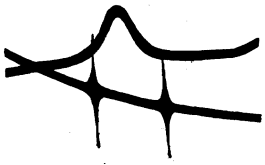

FIG. 1. Illustrating the procedure of determining the spectral line width.

tuned amplifier was exceedingly narrow, the beats of the scanned ring laser and of the heterodyne laser took the form of two markers, the distance between which was equal to $2\nu_0$ (see Fig. 1). Knowing the resonant frequency ν_0 of the amplifier, we could determine the width of the resonance. The frequency intervals were measured with accuracy ± 5%.

2. EXPERIMENTAL RESULTS

A. Experimental realization of precision measurements of the infrared Zeeman absorption spectrum of methane

The methane molecule in the ground state has only a nuclear magnetic moment on the order of a fraction of a nuclear magneton. To study the Zeeman effect of the Doppler-broadened absorption line of methane by linear-spectroscopy methods one must therefore use magnetic fields on the order of several hundred kOe. By using wave-competition effects, the Zeeman effect can be investigated in magnetic fields smaller by three orders of magnitude. To this end we introduced into the ring-laser resonator, besides the gas-discharge tube, a methane absorbing cell placed in a solenoid. A solenoid 1.5 m long produced a uniform magnetic field of intensity up to 0.5 kOe over a section 0.7 m long. The instability of the solenoid power supply was ± 0.5%. The gas discharge tube diameter was 50 mm, the diameter of the methane absorbing cell was 40 mm, while the active and passive cells were 0.7 m long. At these system parameters, the homogeneous absorption line width (at an absorbing-medium pressure $p_{CH_4} = 5 \cdot 10^{-4}$ Torr) was not more than 60 kHz (see, e.g., [17]).

Introduction of a nonlinear absorbing medium into the resonator of a ring laser alters radically the lasing regimes of the traveling and standing waves in a narrow frequency region at the central frequency of the Doppler-broadened absorption line, as a result of which a high-Q nonlinear-absorption resonance sets in. [5] The width of the methane resonance in our case was 20–30 kHz. When the magnetic field is turned on, the methane absorption line splits into two components, the distance between which is $\delta = 2g\mu_{nuc}H/\hbar$, where μ_{nuc} is the nuclear magneton.

Figure 2a is an oscillogram of the ring-laser power, obtained by scanning the laser length, and showing the methane resonance l. As seen, the contrast of the methane peak is close to 100%. The shape of the resonance at small scanning amplitudes is shown in Fig. 2b. Turning on the magnetic field leads to a splitting of the methane resonance, corresponding to the Zeeman σ^+ and σ^- components of the line (Fig. 2c). The splitting amounted to 100 kHz at $H = 210$ Oe. The frequency distance between the resonances was determined by the procedure described in Sec. 1.

By measuring the frequency distance between the resonances, and by the same token the magnitude of the Zeeman splitting of the methane line, we can determine the value of the g-factor with much greater accuracy and in a much simpler manner (compared with the experimental procedure of Uzgiris *et al.* [8]). According to these measurements, $g \sim 0.312$. The minimum frequency distance at which two separate methane resonances can still be observed was ~ 60 kHz. Consequently, the resolution attained in this experiment is $\sim 2 \cdot 10^{-6}$ cm^{-1} ($R = \omega_0/\Delta\omega = 2 \cdot 10^9$).

B. Experiments on the resolution of close spectral components of a weakly absorbing gas

In these experiments, the two-component absorbing medium was excited neon with isotopic composition Ne^{20}: $Ne^{22} = 1:1$. In the present experiment the setup consisted of an He–Ne ring laser, in the resonator of which was located a gas-discharge tube and two cells with the investigated isotopes Ne^{20} and Ne^{22}. The neon was excited by a high-frequency discharge. The discharge tube and the absorbing cells were ~ 0.25 m long. The nonlinear-absorption resonances at the central frequencies of the Doppler contours of the Ne^{20} and Ne^{22} lines were observed under the following conditions: the coupling of the opposing waves was close to critical, [19] and the excess of the laser pump over threshold was negligible. Under these conditions the resonance amplitude had a sufficient contrast, 10%–30%.

Figure 3a shows an oscillogram illustrating the change of lasing regime when the resonator length is varied, in the case of one amplifying medium consisting of a mixture of helium with Ne^{20}. The resonance l occurs at the central frequency of the Doppler contour of the amplifying gas. When a cell filled with Ne^{22} is introduced into the laser resonator and its excitation is turned on, resonance 3 is produced in the laser power at a frequency that corresponds exactly to the center of the Ne^{20} absorption Doppler contour (Fig. 3c).

Resonances 2 and 3 were used as frequency references for the neighboring spectral components of the weak-absorption neon line. By registering the frequency position of the centers of the Ne^{20} and Ne^{22} absorption lines with the aid of these resonances, we determined the isotopic shift of the absorption lines of Ne^{20} and Ne^{22}.

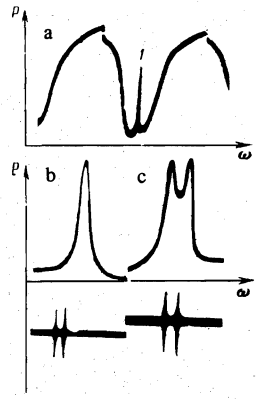

FIG. 2. Oscillograms illustrating the splitting of the nonlinear absorption resonance of methane in a magnetic field: a) Overall view of the scanning zone (1—methane resonance), b) shape of the resonance at small scanning amplitudes, c) splitting of the resonance in a magnetic field $H = 210$ Oe. The distance between the frequency markers is 100 kHz.

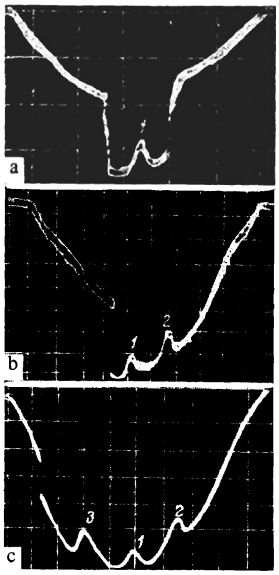

FIG. 3. Oscillograms of the emission regimes of a ring laser in the presence of phase coupling between the traveling waves in the case of an amplifying medium (a) and an absorbing medium (b) and an amplifying medium and two absorbing media (c). 1—Resonance at the center of the Doppler gain contour, $p_{He-Ne^{20}} = 2.4$ Torr; 2, 3—nonlinear-absorption resonances corresponding to isotopic splitting of the neon absorption line, $p_{Ne^{20},Ne^{22}} = 0.5$ Torr. Distance between modes 270 MHz.

As a result of the experiment it was found that the hyperfine (isotopic) splitting of the neon absorption line amounts to $\delta = 84 \pm 4$ MHz. We note that the realization of such an experiment in a laser with a Fabry–Perot resonator is extremely difficult, for in this transition the absorption coefficient of neon is small and observation of the Lamb dip at the center of the Doppler-broadened absorption line in the field of the standing wave of the laser is practically impossible.

The resolving power of the laser-spectroscopy method was verified experimentally on the basis of the wave competition. To this end we determined the minimum frequency distance at which two spectral lines led to the appearance of one resonance. Figure 4a shows the case of high pressures of the absorbing gas (neon pressure 1 or 2 Torr), when the inhomogeneous line width Γ exceeded the frequency distance δ between the spectral components of the line. Only one resonance is observed in the output power of the laser. In the case of low pressures of the absorbing gas, $p_{Ne} = 0.5$ Torr (Fig. 4b), when the relation between Γ and δ is reversed ($\Gamma < \delta$), two separate resonances appear in the laser power and determine the hyperfine (isotopic) splitting of the neon absorption line. Consequently, in this spectroscopy method, the resolution of adjacent lines is possible at a line separation exceeding the homogeneous line width.

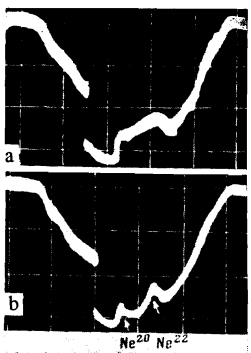

FIG. 4. Illustrating the procedure of determining the laser-spectroscopy resolution on the basis of the competition of the ring-laser waves. a) Case $\Gamma > \delta$, absorbing-medium pressure $p_{Ne} = 1.2$ Torr; b) case $\Gamma < \delta$, absorbing-gas pressure $p_{Ne} = 0.5$ Torr.

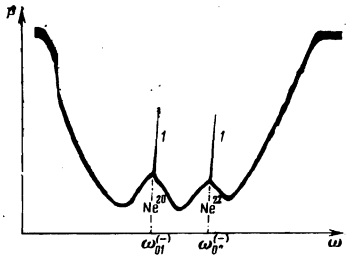

FIG. 5. Oscillograms illustrating the onset of high-Q self-oscillation resonances in the case of hyperfine splitting of the line of a weakly absorbing gas.

Further increase in the accuracy of the spectral measurements is limited by the appreciable width of the resonance at the central frequency of the Doppler contour of the gain line, amounting to several MHz. As shown in[19–21], a self-oscillation regime is possible in a ring laser, in the form of extremely narrow (several kHz) resonances with 100% contrast. It is of interest in this connection to use the self-oscillation regimes to increase the accuracy and sensitivity of the NLS on the basis of a ring laser. Figure 5 illustrates such a possibility. By increasing the wave-coupling coefficient to its critical value,[19] it was possible to observe, for the first time, high-Q resonances at the centers of the spectral components of a Doppler-broadened line of a weakly absorbing gas.

3. DISCUSSION OF EXPERIMENTAL RESULTS

The physical essence of the new NLS methods described above consists in the following. At a lasing frequency close to the frequency of any of the spectral components of the Doppler-broadened line of the gas placed in the resonator, the traveling waves of the ring laser turn out to be strongly coupled. This wave interaction leads to a redistribution of the energy among them and gives rise to power resonances in the laser emission. Thus, at a lasing frequency coinciding with the center of the line of the investigated transition, the effect of spectral saturation of the line[2–4] leads to suppression of one of the traveling waves (we consider for the sake of argument the case of an absorbing gas), while the effect of spatial modulation of the laser medium leads to generation of two traveling waves: the spatially-modulated laser field experiences a smaller absorption. Finally, the phase interaction of the traveling waves of the lasers, due to the energy transfer from one wave propagation direction to the other, manifests itself resonantly when the generation frequency coincides with the line transition frequency and consequently, also fixes the frequency of the spectral component. The power resonances produced by these effects in the emission of a ring laser can be noticeably narrower (by several orders of magnitude) than the homogeneous line width.

At a sufficiently strong coupling between the traveling waves, additional self-oscillation resonances appear in the laser emission and are due to the periodic transfer of energy from one wave to the other (they were reported theoretically earlier[20–21]). The width of these power resonances amounts to $\sim 10^4$ Hz and is much less than the homogeneous line width Γ ($\Gamma \sim 10^{10}$–10^8 Hz).

Thus, a ring laser is an exceedingly promising in-

strument for precision spectroscopic measurements.

Let us examine the possibility of resolving adjacent spectral components within the Doppler contour with the aid of the nonlinear resonances of a ring laser. The equations for the time variation of the amplitudes $E_{1,2}$ and of the phase difference $\Phi = \Phi_1 - \Phi_2$ of the traveling waves of the laser are

$$\dot{E}_{1,2} = E_{1,2}\left[\eta_{1,2} - \sum_i a_i G_{0i}(\alpha_i E_{1,2}^2 - \beta_i E_{2,1}^2)\right] \mp m E_{2,1}\sin\Phi,$$
$$\dot{\Phi} = \left[\frac{m\cos\Phi}{E_1 E_2} - \frac{1}{2}\sum_i \frac{(\omega-\omega_i)a_i G_{0i}}{(\omega-\omega_i)^2+\Gamma_i^2}\right](E_1^2 - E_2^2), \quad (1)$$

where $\eta_{1,2}$ is the excess of the pumps over threshold, $\omega - \omega_i$ is the deviation of the lasing frequency from the central frequency ω_+ of the gain line or ω_- of the absorption line, $G_{0+(-)}$ are the linear gain (absorption) coefficients; a_i is the saturation parameter, $\alpha_{+(-)}$ and $\beta_{+(-)}$ are the saturation coefficients of the amplifying (absorbing) medium by the self-field and the field of the opposing wave, [21] and m is the coefficient of the phase coupling of the traveling wave, which leads to synchronization of their frequencies. [22] The summation in (1) is over the amplifying and absorbing media. Depending on the values of the parameters G_{0i}, α_i, β_i, m, $\eta_{1,2}$, and $|\omega_+ - \omega_-|$, the system (1) describes different laser generation regimes.

As shown in[5], if a nonlinearly absorbing medium with an appreciable absorbing coefficient (such as methane) is placed in the resonator of a ring laser, the lasing regime can be radically changed from that of a traveling wave to that of a standing wave at frequency ω_-, provided that the central frequency of the absorption-line Doppler contour lies in the region of single-wave lasing $|\omega_+ - \omega_-| < \Delta_0$. In this case, a nonlinear-absorption resonance is produced at the frequency ω_- with an amplitude much larger than the amplitude of the "inverted" Lamb dip in absorption, and with a width smaller than the homogeneous line width Γ_-. If the absorption line has N close spectral components, a separate resonance is produced at the center of each component, with a frequency distance δ_N between them:

$$\Gamma_- < \delta_N < \Delta_0 = \Gamma_+(\gamma_+\Gamma_+)^{1/2}/ku. \quad (2)$$

In fact, the stationary solution of the system (1) describes in this case generation of a standing wave ($E_1 = E_2 \neq 0$) and exists under the condition

$$f(\omega) = \left(\alpha_+ - \beta_+ - \sum_i^N \mu^{(i)}(\alpha_-^{(i)} - \beta_-^{(i)})\right) > 0,$$
$$\mu^{(i)} = a_-^{(i)} G_{0-}^{(i)}/a_+ G_{0+}. \quad (3)$$

Analysis shows that $f(\omega)$ has a maximum at the central frequencies $\omega_-^{(i)}$ of the absorption-line components. If $f(\omega_-^{(i)}) > 0$, then nonlinear-absorption resonances connected with the jumplike transition of the lasing from the single-wave to the two-wave regime will be separately observed at the frequencies $\omega_-^{(i)}$.

The form of the function $f(\omega)$ when two adjacent spectral components are present in the Doppler contour of the absorption line is shown in Fig. 6a. We present below the theoretical and experimentally-observed plots of the output power $P_-(\omega)$ of one of the waves of the ring laser obtained by scanning the resonator length (Figs. 6b and 6c). We note that since the backward reflection of the wave energy is small in the experiments described above, it can be neglected in the case of a strongly absorbing gas (such as methane). If, however, the gas absorption coefficient is small (such as in neon), then allowance for the phase coupling of the waves in Eqs. (1) is of fundamental importance, since the terms proportional to G_{0-} and is responsible for the spectral saturation of the gas line and for the spatial modulation of the medium are comparable in magnitude with the term proportional to m, which leads to synchronization of the frequencies of the opposing waves. The stationary solution of the system (1) describes in this case generation of two traveling waves with different intensities ($E_1 \neq E_2 \neq 0$).

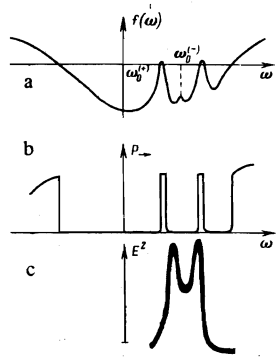

FIG. 6. Formation of high-Q nonlinear-absorption resonances due to the competition of the waves of the ring laser in the presence of two neighboring spectral components in the line of a strongly absorbing gas.

We consider an actual case of a single-component amplifying medium and a two-component absorbing medium. In this case the expression for the intensity $E_2^2(\omega)$ of the weak wave as a function of the generation frequency is given by

$$E_2^2 \sim \frac{1}{\eta_2}\left[\frac{m}{a_- G_{0-}}\right]^2 \left\{\left[\frac{1}{\mu}\frac{x\Gamma_+}{x^2+\Gamma_+^2} - \frac{x+\delta}{1+(x+\delta)^2} - \frac{x-\delta}{1+(x-\delta)^2}\right]^2 + \left[\frac{1}{\mu}\left(\frac{x^2\Gamma_+^2}{x^2+\Gamma_+^2} - \frac{\gamma_+\Gamma_+}{(ku)^2}\right) - \frac{(x+\delta)^2}{1+(x+\delta)^2} - \frac{(x-\delta)^2}{1+(x-\delta)^2}\right]^2\right\}^{-1}, \quad (4)$$

where $2\delta = |\omega_-^{(1)} - \omega_-^{(2)}|$ is the frequency spacing between the spectral components of the absorption line. It is assumed that the centers of the gain line and of the overall absorption-line contour coincide, $\omega_+ \approx (\omega_-^{(1)} + \omega_-^{(2)})/2$, and the generation frequency x is reckoned from ω_+ in dimensionless units (we assume that $\Gamma_{-1} = 1$). It follows from (4) that $E_2^2(\omega)$ has a system of extrema that fix the frequencies ω_+, $\omega_-^{(1)}$, and $\omega_-^{(2)}$ of the line transitions.

A plot of the function $E_2^2(x)$ for the parameters $G_{0-}/G_{0+} = 10^{-3}$, $2\cdot10^{-3}$, $5\cdot10^{-3}$ and $a_-/a_+ = 10$, corresponding to the case of a neon amplifying medium paired with a neon absorbing medium at the transition $\lambda = 3.39\ \mu$, is shown in Fig. 7. The amplitude and width of the resonances at the frequencies ω_+, $\omega_-^{(1)}$, and $\omega_-^{(2)}$ depend, as follows from Fig. 7, on the parameters of the amplifying and absorbing media. With decreasing linear absorption coefficient G_{0-} (with decreasing degree of excitation of

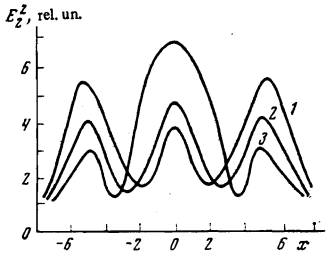

FIG. 7. Theoretical plots of the density E_2^2 of the reflected wave of a ring laser vs the generation frequency x at different gas absorption coefficients: $1 - G_{0-}/G_{0+} = 10^{-3}$; $2 - G_{0-}/G_{0+} = 2 \cdot 10^{-3}$; $3 - G_{0-}/G_{0+} = 5 \cdot 10^{-3}$.

the absorbing cell), the amplitude of the resonances in absorption decreases. However, since the amplitude E_2^2 of the resonances is proportional to m^2, their contrast can be appreciable even at a small absorption coefficient G_{0-} and a low intensity E of the saturating field. Calculation has shown that as the pump level is decreased and the coupling coefficient of the waves increased it becomes possible to register the hyperfine structure of the transition at $G_{0-}/G_{0+} = 0.7 \cdot 10^{-4}$, i.e., even in the case of a weakly absorbing gas.

We present a theoretical estimate of the resonance width. In the case when Γ_- and Γ_+ do not differ greatly ($\Gamma_+ \sim 5\Gamma_-$), and this is precisely the case for the pair of amplifying and absorbing neon media, the expression for the nonlinear absorption resonance width is

$$\Delta_1 \sim \frac{\Gamma_-}{\mu} \left| \left(\frac{\varepsilon}{\Gamma_+}\right)^2 - \frac{\gamma_+\Gamma_+}{(ku)^2} \right|, \qquad (5)$$

where $\varepsilon = |\omega_+ - \omega_-|$. For our case $\Gamma_- = 20$ MHz, $ku \sim 320$ MHz, $\Gamma_+ = 130$ MHz, $\gamma_+ = 40$ MHz, $\mu = 10^{-2}$, and at $\varepsilon \sim 30$ MHz we obtain from (5)

$$\Delta_1 \sim 0.4 \cdot \Gamma_- = 8 \text{ MHz}.$$

In the experiments (see Sec. 2) at these pressures, the width of the resonance was ~ 8 MHz, which is several times smaller than the width of the inverted Lamb dip in absorption. We see that the results of the experiments agree with the theoretical analysis.

It follows also from Fig. 7 that the effects of the divergence of the central frequencies of the resonances from the frequencies of the spectral components of the line are insignificant and do not restrict the measurement accuracy. Spectral investigations of a large group of gaseous media having different parameters are therefore possible on the basis of effects due to wave competition in a ring laser.

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Translated by J. G. Adashko