or by integrating the measured distribution function, the fine structure makes an almost unnoticeable contribution, lying at the limit of the measurement accuracy. This is apparently why the fine structure remained hitherto unobserved by experimenters using the decelerating-field method.

The formation of the plateau on the distribution function and the appearance of the fine structure took place only when the presence of the microwave oscillations could be detected. The oscillation spectrum consists of the main peak, the frequency of which corresponds to the Langmuir frequency of the beam plasma in the region where the beam passes, and a smaller peak observed at lower frequencies. The latter is apparently due to the interaction of the beam with the surface of the plasma-waveguide wave.

The nature of the fine structure is still not clear, but it can be assumed that the discrete singularities on the distribution function are due to the discrete character of the spectrum of the Langmuir oscillations with respect to k, which should result from the finite length of the system.

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MEASUREMENT OF THE LEVEL RELAXATION CONSTANTS BY THE METHOD OF THREE-LEVEL LASER SPECTROSCOPY

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1. A new trend in spectroscopy, using the singularities of the resonant interaction of the atoms and molecules with a strong monochromatic field - laser spectroscopy - is now being intensely developed. Most methods using nonlinear effects in a gas placed in a strong field are based on the phenomenon of formation of dips (peaks) in the velocity distribution of the atoms [1] and a dip in the center of the amplification (absorption) line in the standing-wave field [2]. Effects of saturation in two-level systems (the Lamb dip on the frequency dependence of a gas-laser generation power, the generation-power peak in a laser with nonlinear absorption, the dip at the center of the absorption line in an external cell in a standing or weak opposing wave, etc.), or in three level systems (for example, spontaneous emission in a neighboring transition from the gas-laser resonator) have made it possible to observe experimentally the spectral-line structure, which is masked under ordinary conditions by the Doppler broadening, and to use it for the solution of a number of spectroscopic problems.

However, as before, knowledge of the shape and width of the emission line of an individual atom or molecule in transitions between excited states does not yield any information on the relaxation constants characterizing each level separately. We report here an experimental investigation of a new spectroscopy method, using a 3-level scheme, which makes it possible to measure the relaxation constants of individual levels.

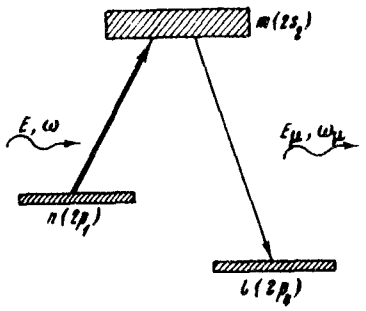

Fig. 1. Level scheme for the observation of stimulated resonant scattering.

2. The method is based on the measurement of the widths of the lines of stimulated (or spontaneous) resonant shifted scattering in a gas (Fig. 1). As was predicted theoretically in [3 - 5], at $k_\mu > k$[1] the forward and backward scattering line widths Γ_- and Γ_0 at frequencies ω_μ are respectively equal to

$$\Gamma_- = \gamma_n + \gamma_l + \left(\frac{k_\mu}{k} - 1\right)(\gamma_m + \gamma_n), \qquad (1)$$

$$\Gamma_0 = \gamma_m + \gamma_l + \frac{k_\mu}{k}(\gamma_m + \gamma_n),$$

where γ_n, γ_m, and γ_l are the widths of the levels n, m, and l, respectively. The first to observe qualitatively the difference between the widths in spontaneous emission was H. Holt [4]. It was subsequently observed in stimulated emission in [7, 8].

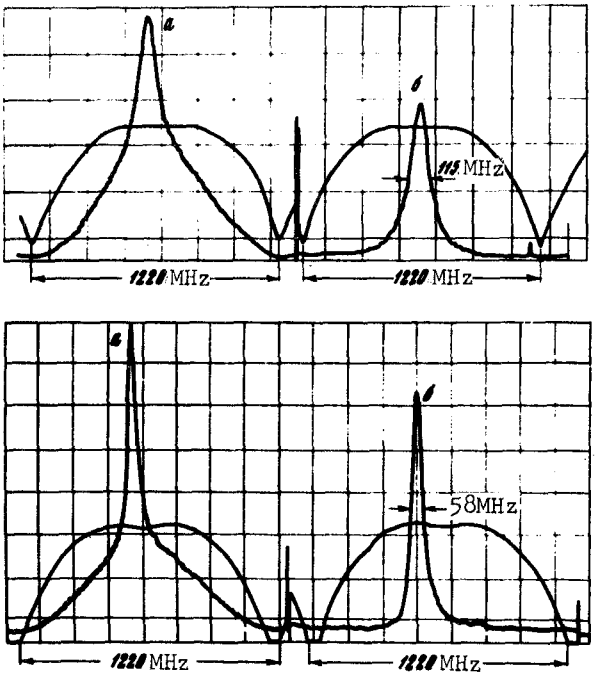

Fig. 2. Line shape of stimulated shifted resonant scattering: a - without compensation for Doppler pedestal, b - pure scattering line. Upper trace - backward scattering (P_{Ne} = 0.5 mm Hg, I_p = 17 mA); lower trace - forward scattering (P_{Ne} = 0.9 Torr, I_p = 15 mA). The broadening by the field amounted to 11 MHz for forward scattering and 6 MHz for backward scattering.

We call attention here to the fact that the difference between the forward and backward line widths scattering is[2]

$$\Gamma_0 - \Gamma_- = 2\gamma_m , \qquad (2)$$

where γ_m is the width of the common level. Thus, measurements of the forward and backward scattering line-width difference yield directly the value of the width of the common level. In the presence of quenching or "strong" collisions, connected for example with resonant exchange, relation (2) can be

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[1] When the condition $k_\mu > k$ is not satisfied, the effect of dynamic Stark splitting may also come into play, cf., e.g., [6].

[2] Relation (2) corresponds exactly to the classical result for the width difference of resonant forward and backward scattering for a moving harmonic oscillator that is damped within a time $1/\gamma_m$.

rewritten in the form

$$\Gamma_0 - \Gamma_- = 2(\gamma_m + 2\nu), \quad (3)$$

where ν is the collision frequency of the atom or molecule in the state m.

3. The experimental investigations were performed on the neon transitions $2s_2 - 2p_1$ ($\lambda = 1.52\ \mu$) and $2s_2 - 2p_4$ ($\lambda = 1.15\ \mu$), which have a common level $2s_2$. In general outline, the experimental setup was similar to that described in [8] and used to investigate the diffusion of excitation in the dragging of resonant radiation. An important difference in the experimental setup was the the fact that the setup made it possible to record the line shape after subtracting the effect of the Doppler "pedestal" due to the dragging of the resonant radiation. This greatly facilitated the observation and reduction of the measurement results of the scattering line shape in the part connected with the appearance of narrow resonances with widths Γ_0 and Γ_-. The high stability of the laser frequency ($\sim 10^{-9}$), the careful alignment of the phase fronts, and the choice of the discharge conditions in the investigated cell have made it possible to obtain a signal/noise ratio larger than 20 dB (Fig. 2) and to carry out detailed investigations of the widths in a wide range of pressures and intensities of the strong field.

The reduction of the results with extrapolation to zero field yielded the following values for the forward and backward scattering line widths Γ_- and Γ_0 as functions of the pressure:

$$\Gamma_0 = (87 + 46p) \pm 3\ \text{MHz},$$

$$\Gamma_- = (32 + 17p) \pm 2\ \text{MHz},$$

where p is the neon pressure in mm Hg. We then get for the width of the $2s_2$ level

$$\gamma_{2s_2} (27.5 + 14p) \pm 5\ \text{MHz}.$$

4. In the first experiments with which we demonstrate the new method, it is not so important to obtain the exact relaxation constant as to prove the feasibility of this method in principle. The level admits of a comparison of results obtained by various methods. In [9], using a multichannel technique of delayed coincidences and registration in the region of vacuum untraviolet, we measured the lifetime $\tau_{2s_2} = 7.78 \times 10^{-9}$ sec, which yields for the level width γ_{2s_2} a value 20.5 ± 2.1 MHz. The results of reduction of the width of the Lamb dip in the generation power at 1.15 μ and at low Ne pressure, with allowance for the known lifetime of the $2p_4$ level, yielded a value 26 ± 2 MHz [8]. These values are in good agreement with the direct measurements of the width of the $2s_2$ level, indicated above, and demonstrate the feasibility of the proposed method. Finally, the agreement between the obtained widths when the widths are extrapolared to zero field and zero pressure can be regarded as the first quantitative confirmation of the theory of [3 - 5].

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OSCILLATION OF THE CHARGE EXCHANGE CROSS SECTIONS IN THE Na^+-Ne SYSTEM

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In an earlier investigation [1] we observed the structure of the energy dependence of the cross section of the process $He^{2+} + He \rightarrow He^+ + He^+$, which we ascribed to an effect connected with the intersection of the He^{2+}-He term with terms of the systems $He^+(n\ell)$ - He(1s) and He^{2+} - $He^*(1s, n\ell)$. On the basis of an analysis of the experimental data [2], a model of atomic collisions was proposed in [3] to explain the conditions for the oscillation of the dependence of the cross sections of inelastic processes on the collision energy. With the aid of this model it was possible to obtain certain information on the terms of the quasimolecule that is produced in the atomic collisions, by investigating the effective cross sections of these collisions. In this paper we continue the study of the cross sections of ion-atomic collisions in the low-energy region, where the presence of intersections or of close approaches of the terms of the quasimolecule can become manifest in the form of a structure on the cross sections of the inelastic processes.

The effective cross section of the charge exchange process

$$Na^+ + Ne \rightarrow Na + Ne^+, \quad \Delta E = -16.42 \text{ eV} \tag{1}$$

was investigated in the interval of kinetic energies of the Na^+ ion $400 \leq T \leq 2500$ eV. To find the effective cross section σ of the process (1) by the method described in [1], we measured the summary cross sections σ_{Ne^+} for the formation of Ne^+ ions in process (1) in the ionization process

$$Na^+ + Ne \rightarrow Na^+ + Ne^+ + e \tag{2}$$

and the cross section σ_e for the production of free electrons in Na^+-Ne collisions. Since the potentials for the ionization of Na^+ (47.5 eV) and of the double ionization of Ne (62.5 eV) greatly exceed the ionization potential of Ne (21.5 eV), the main contribution to the cross section σ_e is made in the investigated interval of T by the process (2). Therefore the charge exchange cross section (1) can be defined as the difference $\sigma = \sigma_{Ne^+} - \sigma_e$. Principal attention is paid in the present paper to the accuracy with which the function $\sigma(T)$ is determined. Figure 1 shows the obtained $\sigma(T)$ dependence. The errors (mean arithmetic deviations) in the determination of the relative cross sections $\sigma(T)$ are indicated in Fig. 1 in the form of bars. The absolute value of the cross section at T = 2000 eV is estimated by us at 1×10^{-17} cm^2 (±40%).

As seen from Fig. 1, the cross section σ of the charge exchange (1) oscillates as a function of the energy T. A plot of the dependence of the cross section on the reciprocal collision velocity v^{-1} reveals, within the limits of