$$D = -\frac{19}{108}n^2 - \frac{191}{27}n - \frac{298}{27} - \frac{2}{9}(5n+22)\zeta(3) - \frac{12n^2+55n+186}{4\cdot 81}\phi_3 +$$

$$+\frac{(n+8)^2}{24\cdot 81}\phi_1^2 + \frac{28n^2+53n-108}{4\cdot 81}\phi_1 - \frac{n^3+6n^2+150n+572}{8\cdot 81}\phi_2;$$

$$\phi_1 = -\sum_{i=1}^{3}\ln\frac{q_i^2}{q^2}; \qquad \phi_2 = \sum_{i=1}^{3}\ln^2\frac{q_i^2}{q^2};$$

$\phi_3 = \sum_{i,j} f(p_i, q_j)$, with q_j the transferred momentum, q the renormalization momentum

$$f(p_i, q_j) = \int_0^1 \frac{dx}{x}\left[\frac{a^2x(1-x)\ln(a^2x(1-x))}{1+a^2x^2-2abx} - \right.$$

$$\left. - \frac{(1+a^2x-2abx)\ln(1+a^2x-2abx)}{1+a^2x^2-2abx}\right]$$

$a = p_i/q_j$, $b = \cos p_i \hat{} q_j$, and $\zeta(3)$ is a Riemann function.

As follows from (6), the coefficient of a^4 depends on the ratios of the external momenta. It is convenient to introduce a symmetrical normalization point, namely $p_i^2 \equiv p^2$, $q_i^2 \equiv (4/3)p^2$, and $b_i \equiv 1/\sqrt{3}$. At this point, the corresponding coefficient is equal to

$$D = -\frac{19}{108}n^2 - \frac{191}{27}n - \frac{298}{27} - \frac{2}{9}(5n+22)\zeta(3) - \frac{3(12n^2+55n+186)}{2\cdot 81}I, \qquad (7)$$

with $I = -0.740 \mp 0.001$. We thus get at n = 1

$$\Psi(a) = -\frac{3}{2}\frac{a^2}{16\pi^2} + \frac{17}{6}\frac{a^3}{(16\pi^2)^2} - 22\frac{a^4}{(16\pi^2)^3}. \qquad (8)$$

It is easily seen from (8) that $\Psi(a)$ has no zero in this approximation. Obviously, this result cannot be reliable, and to ascertain the possible existence of a non-zero-charge situation it is desirable to investigate this question without the use of perturbation theory [6].

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EXPERIMENTAL OBSERVATION OF EMISSION LINES FROM AUTO-IONIZATION LEVELS OF CESIUM

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Information on the atomic auto-ionization states due to excitation of inner electrons have heretofore been extracted mainly from photoabsorption experiments. In a number of

experiments these states are investigated by observing the Auger-electron spectra and the energy-loss spectra of electrons that collide with atoms.

As to the decay of auto-ionization levels, it has been assumed so far that it proceeds mainly via auto-ionization, so that in most cases their radiative decay can be disregarded. In any case, nothing is said in any of the monographs on atomic physics or spectroscopy of atoms concerning the feasibility of observing radiative transitions from such levels.

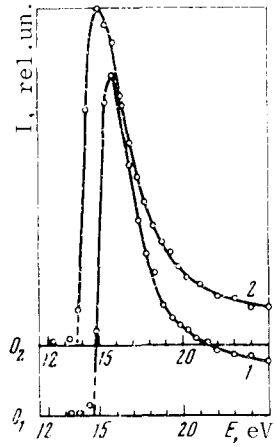

Fig. 1. Excitation function of emission transitions in cesium atom: 1 — λ = 960 Å, 2 — λ = 1085 Å.

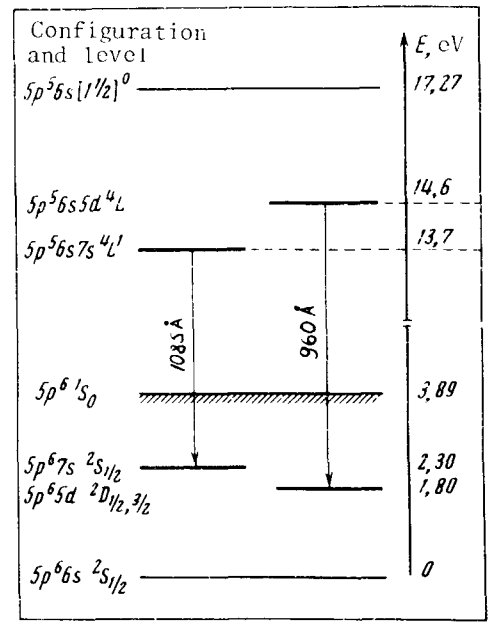

Fig. 2. Cesium level scheme, explaining the origin of the observed emission lines.

However, detailed investigations of ionization [1] and excitation [2, 3] of cesium atoms (as well as of other alkali elements) by electron impact, previously carried out in our laboratory, offer strong (albeit indirect) proof of appreciable probability of radiative transitions from auto-ionization levels to ordinary excited levels of these atoms. For direct experimental observation of this radiation, as shown by an analysis of this problem, it is necessary to use a setup with crossing electron and atomic beams, in conjunction with a vacuum monochromator and corresponding registration of radiation located in the far ultraviolet.

Our laboratory has now in operation one variant of such a setup. It was used to measure carefully the spectral interval 750 — 1150 Å, excited by electron impact in cesium atoms at various electron energies. An investigation of this spectrum, which was obtained at a residual-gas pressure less than 10^{-6} Torr in the collision chamber, has shown the lack of any noticeable spectral lines or bands due to residual gases. The only source of the observed seven lines can be only cesium atoms (in a neutral or ionized state).

The three most intensive lines λ = 813 Å, λ = 901 Å, and λ = 926 Å, which disappear completely from the spectrum at an electron energy $E \leq 17$ eV, can be easily identified as the transitions of CsII from the resonance levels $6s'[1/2]^0$, $5d[1^1/_2]^0$, and $6s[1^1/_2]^0$ to ground states of the ion. As to the remaining four lines (960, 1069, 1085, and 1100 Å), it is impossible to attribute them to cesium ions. For two of them, 960 and 1085 Å, we measured the dependence of intensity on the electron energy; the result is shown in Fig. 1. Allowing for the energy scatter of the electrons in this experiment ($\Delta E \sim 1$ eV), we can state that the excitation of their upper levels is nearly resonant at the threshold. This enables us to estimate with sufficient reliability the experimental excitation thresholds, 14.6 and 13.7 eV for the 960 and 1085 Å lines, respectively.

Since the energy of the lowest excited level of the Cs^+ ion (resonant level) is much higher and equal to 17.2 eV, we must conclude that the only way these lines can appear is by formation of states due to excitation by electron impact of one of the electrons of the outer closed $5p^6$ shell and lying above the potential of the simple ionization of the cesium atom. Then taking into account the results obtained in this experiment on the wavelengths of the observed lines, on their energy thresholds in the spectrum, and on the corresponding selection rules for the auto-ionization levels, we can identify these lines as the result of radiative transitions from the levels $5p^5 6n\ell(^4L)$ to the lowest levels of the sideband series of the cesium atom, due to excitation of the 6s valence electron (see Fig. 2).

Our investigations show that the radiative decay of the auto-ionization states of the atom can occur with an appreciable probability. The observation and investigation of such emission spectra uncovers new possibilities of identifying the mechanism whereby the internal shells of the atoms are excited, and greatly broadens the arsenal of the atomic spectroscopy in the study of the structure of matter.

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NONLINEAR EFFECTS IN n-InSb at 77°K IN THE SHORT-WAVE PART OF THE MILLIMETER BAND

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Experimental studies of nonlinear effects in the millimeter and submillimeter bands is of great interest for the diagnostics of nonlinear properties of semiconductors, properties connected with the interaband motion of the carriers. In particular, by investigating the power-law dependence of the current density on the electric field intensity, $j(E) = \sum_{n=1}^{\infty}\sigma_n E_n$, we can obtain information on the nonlinearity mechanisms that act in the semiconductor and on the carrier distribution function.

We report here the results of an experimental study of the nonlinear responses in pure single-crystal n-InSb ($n = 7.1\times10^{13}$ cm^{-3}, $\rho = 0.12$ Ω-cm) at liquid-nitrogen temperature and at the combination frequencies $f = f_2 - mf_1$ (m are integers from 1 to 4). The block diagram of the setup is the same as in [1]. The frequencies f_1 and f_2 varied in a wide range (f_1 from 75 to 225 Hz, f_2 from 75 to 400 Hz) and were chosen such that the combination frequency f was equal to 3 GHz[1]. The signal at frequency f was picked off a load matched to the investigated sample, with dimension 0.25×0.24×0.05 mm. The construction of the mixing unit precluded the possibility of effective multiplication of the frequency f ; the response at the combination frequency $f = f_2 - mf_1$ was therefore treated as due to the (m+1)st and the higher terms in the expansion of j in E. In addition to the signal power P_f at the combination frequency, we measured the powers P_{f_1} and P_{f_2} at the input of the mixing unit, the dc resistance R(I) of the sample, and the current I through the sample. The powers absorbed in the semiconductor at frequencies f_1 and f_2 were monitored against the changes of the dc resistance of the sample[2] ($\Delta R_1(P_{f_1}, I)$, $\Delta R_2(P_{f_2}, I)$).

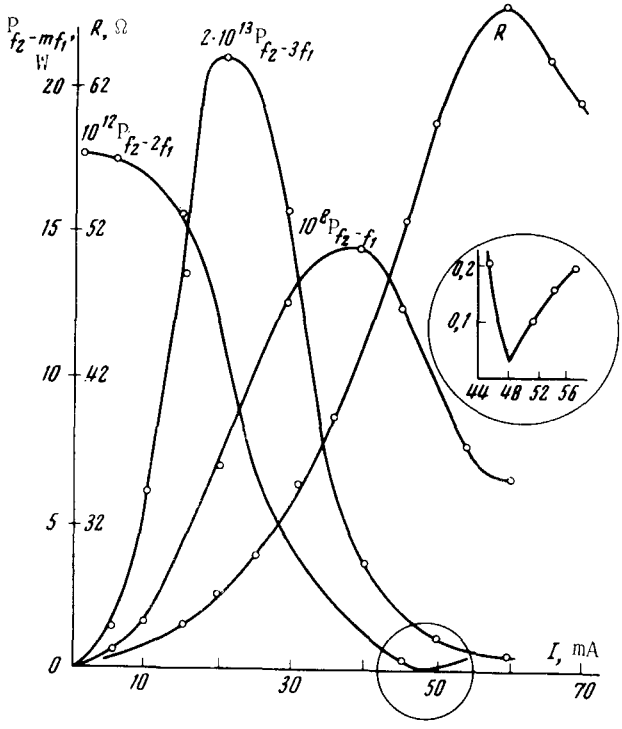

Fig. 1

We note first that in the case of even m, the nonlinear response at the combination frequencies $f = f_2 - mf_1$ was observed with and without a constant bias. In the case of odd m, it was observed only at a constant bias. A typical plot of the signal power at the combination frequency $P_{f_2-mf_1}$ (m = 1, 2, 3) against the current I is shown in Fig. 1. The measurements were performed at fixed powers P_{f_1} and P_{f_2}, the power level was set to obtain an equal increment ΔR_i at a current I_1 = 5 mA ($\Delta R_1(P_{f_1}, I_1) = \Delta R_2(P_{f_2}, I_1) = 10^{-2}R_0$, where R_0 is the resistance at "zero" current and $P_{f_1} = P_{f_2} = 0$). Figure 2 shows the measured values of $P_{f_2-mf_1}$(m = 2, 3, 4) at $I = I_1$