Optical orientation of metastable He^3 atoms and its influence on the electron density and radiation emitted by helium atoms in a plasma

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Atoms of He^3 in the 2^3S_1 state were pumped with light produced by lamps containing He^3 or He^4. The orientation of the metastable He^3 atoms affected the radiation emitted by helium atoms and the electron density in a helium plasma. Investigations carried out under different experimental conditions made it possible to check the hypotheses explaining the phenomena observed earlier in the optical orientation of metastable He^4 atoms.

INTRODUCTION

Sevast'yanov and Zhitnikov[1] discovered that the optical orientation of He^4 atoms in the 2^3S_1 metastable state affected the radiation emitted by helium atoms in the visible part of the spectrum and the electron density in a helium plasma. It was found that the destruction of the spin orientation in the 2^3S_1 state, established by circularly polarized light (λ = 10 830 Å), increased the intensities of all the visible lines emitted by ortho- and para-helium atoms if the discharge was weak but reduced these intensities if the discharge was strong. The number of electrons in the plasma of a helium discharge increased at the moment of magnetic resonance in the 2^3S_1 state, irrespective of the strength of the discharge. Similar phenomena were also observed in unpolarized light but the resonance changes in the emission intensity and in the electron density were over 10 times smaller than in polarized light. No satisfactory explanation of the observed phenomena was given in[1].

Later[2] the following hypotheses were put forward to explain the observed phenomena. It is known,[3] that the principal source of electrons in a helium plasma at 0.1–1.0 Torr is the ionization of metastable atoms resulting from their collisions with one another. The electron yield in this ionization process depends on the relative spin orientation of the colliding metastable atoms. Therefore, the electron density in a plasma of this kind and the related intensity of the light emitted by helium atoms should depend on the degree of spin orientation of the metastable atoms. The experimental results[1] indicate that the destruction of the optical orientation of metastable atoms by an rf magnetic resonance increases slightly the electron density in a plasma. As expected, the intensity of all the lines emitted by helium atoms increases, provided the discharge is weak. However, if the discharge is strong, the sign of the resonance-induced change in the emission intensity becomes reversed, i.e., a resonance of this kind does not increase but reduces the emission intensity although the electron density still rises (the rise is now smaller than in a weak discharge).[1] Obviously, there is some additional competing process which alters the sign of the resonance-induced change in the emission intensity of atoms when the strength of the discharge is increased.

It has been suggested[2] that this competing process is the optical-pumping-induced transition $2^3S_1 \rightarrow 2^3P_1$ followed by the decay $2^3P_1 \rightarrow 1^1S_0$, which reduces resonantly the concentration of metastable atoms (this concentration increases with increasing strength of the discharge). Since the excitation of helium atoms in a plasma occurs mainly from the metastable state, the reduction in the number of the 2^3S_1 metastable atoms under resonance conditions should reduce the intensity of the emission from these atoms. As the strength of the discharge is increased, this reduction in the emission intensity may exceed the increase in the intensity associated with the rising electron density. This may explain the reversal of the sign of the resonance-induced change in the emission intensity, which is observed when the strength of the discharge is increased.

The first of these hypotheses is in good agreement with the strong resonance-induced increase in the electron density and in the intensity of the radiation emitted by helium atoms in very weak discharges.[1]

A direct experimental confirmation of the second hypothesis, concerned with the role of the $2^3S_1 \rightarrow 2^3P_1 \rightarrow 1^1S_0$ transition, would be of great interest especially in view of the very low probability of the intercombination transition $2^3P_1 \rightarrow 1^1S_0$ in helium atoms. Such a check can be made if the phenomena discussed above are observed in the case of optical orientation of metastable He^3 atoms. If these metastable He^3 atoms are pumped by radiation generated in an He^4-filled lamp, the isotopic shift of the spectra[4,5] can excite only the $2^3S_1 \rightarrow 2^3P_0$ transition in the He^3 atoms, whereas the $2^3S_1 \rightarrow 2^3P_{1,2}$ transitions do not occur. The pumping of the same He^3 atoms with a lamp filled with He^3 gives rise to all the transitions $2^3S_1 \rightarrow 2^3P_{0,1,2}$. Therefore, if the hypothesis relating to the role of the $2^3S_1 \rightarrow 2^3P_1 \rightarrow 1^1S_0$ transitions is correct, the pumping of the He^3 metastable atoms with the aid of an He^4-filled lamp should only increase the emission intensity of the atoms irrespective of the strength of the discharge, whereas, in the case of pumping by a lamp filled with He^3, we should observe the usual (involving sign reversal) dependence of the change in the emission intensity on the strength of the discharge (Fig. 4 in[1]).

The present paper describes experiments intended to determine the influence of the optical orientation of metastable He^3 atoms on the emission of helium atoms and on the electron density in a helium plasma. The purpose of these experiments was to investigate the phenomena described above under various conditions and to check the hypotheses explaining these phenomena.

The main difficulties in these investigations are due to the low degree of optical orientation of the 2^3S_1 metastable state of the He^3 atoms which is due to rapid exchange of the "metastability" with the 1^1S_0 ground state and the presence of a nonzero spin and magnetic nuclear moment in the case of He^3. The optical pumping of the He^3 atoms in the 2^3S_1 state was performed at liquid nitrogen temperature in order to reduce the metastable exchange cross section (which decreased when the temperature was lowered[6]) and increase the degree of spin orientation of the metastable atoms. The influence of the orientation of the He^3 atoms in the 2^3S_1 state on the emission of helium and the electron density in a helium plasma was discovered and investigated in these experiments. Pump lamps filled with He^3 and He^4 were employed. The results obtained were compared with the hypotheses discussed above.

1. EXPERIMENTAL METHOD

The experimental investigation was carried out using the apparatus shown schematically in Fig. 1. A cell filled with helium at a pressure of 0.1–0.3 torr was placed in a weak static magnetic field ($H_0 = 1-2$ G). generated by Helmholtz coils. A high-frequency gas discharge was excited in the cell. The exciting voltage was produced by a 60 MHz oscillator, denoted by OSC in Fig. 1. The resonance radiation sources ($\lambda = 10\,830$ Å) were capillary lamps filled with He^3 or He^4 at 3–5 Torr. High-frequency discharges were excited in these lamps by a separate oscillator (OSC). The use of separate oscillators for the lamps and the cell allowed us to vary the strength of the discharge within a wide range without affecting the intensity of emission from the lamps. The circular polarization was imparted to the pumping radiation by a polaroid P and a quarter-wave plate $\lambda/4$ made of a polyethylene film.

The optical orientation of the helium atoms was destroyed by exciting magnetic resonance transitions between the Zeeman sublevels of the 2^3S_1 state. This was done using an oscillating magnetic field H_1 generated by a coil connected to an oscillatory circuit tuned to 5 MHz and supplied by a GZ-7A oscillator. The resonance value of the magnetic field H_0 was deduced from the relationships $f_{1/2} = 3.8H_0$ and $f_{3/2} = 1.9H_0$ (the units of f and H_0 were MHz and G, respectively), corresponding to resonances of two hyperfine structure states of the 2^3S_1 term of the He^3 atoms characterized by total momenta $F = 1/2$ and $F = 3/2$.[4]

The resonance change in the intensity of emission from the cell was recorded with an F-1 antimony-cesium photocell which was sensitive between 3000 and 6000 Å. Therefore, the resonance change in the absorption of the 10 830 Å line, responsible for the orientation, was not measured. The signal/noise ratio was increased by modulating weakly the static magnetic field H_0 at a frequency of 400 Hz (a GZ-18 af oscillator was used for this purpose), amplifying the photocell signal by a V6-4 selective amplifier, detecting the signal synchronously (K3-2), and recording the derivative of the signal on the chart of a PS1-02 automatic plotter. The bandwidth of the recording channel was 0.25 Hz.

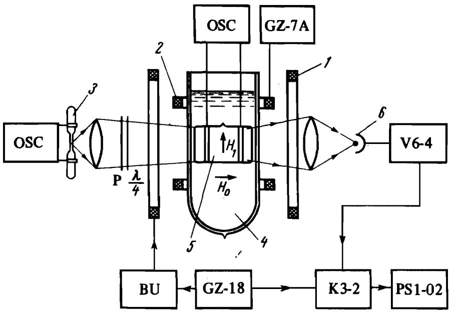

FIG. 1. Schematic diagram of the apparatus: 1–Helmholtz coils; 2–rf coil; 3–capillary pump lamp; 4)Dewar flask with liquid nitrogen; 5–cell with the investigated helium isotope; 6–F-1 photocell.

The change in the electron density in the discharge plasma was deduced from the change in the conductivity which altered the amplitude of the hf voltage across the discharge-exciting electrodes. This was done by connecting a bridge based on 6Kh2P diodes to these electrodes. The signal from the load resistance of this bridge was applied to the input of the V6-4 amplifier shown in Fig. 1. During these measurements the F-1 photocell was disconnected. The strength of the discharge was deduced from the current passing through an FD-7K silicon photodiode which recorded the intensity of the $\lambda = 10\,830$ Å light scattered by the cell at right-angles to the beam provided by the pump lamp. The investigations were carried out at T = 77°K. The discharge cell, filled with He^3 at 0.3 Torr, was placed inside a glass Dewar flask containing liquid nitrogen.

2. EXPERIMENTAL RESULTS

Our investigation revealed that the optical orientation of the He^3 atoms in the 2^3S_1 metastable state affected the emission of helium in the visible part of the spectrum and the electron density in the helium discharge plasma.

Figure 2 shows the derivatives of the signals representing the resonance changes in the electron density (a) and in the intensity of the visible emission from the He^3 atoms excited in weak (b) and strong (c) discharges. We observed signals during magnetic resonance of two hyperfine structure states of the 2^3S_1 term with $F = 1/2$ and $F = 3/2$. The atoms were oriented by circularly polarized light produced by a lamp filled with He^3. It is evident from Fig. 2 that the resonance change in the emission intensity was positive in a weak discharge (Fig. 2b) but negative in a strong discharge (Fig. 2c).

The positive change in the emission intensity increased strongly when the strength of the discharge was reduced. The signal representing this change was observed on the screen of an oscillograph and it was characterized by a signal/noise ratio of the order of 5 in the case of very weak discharges. The resonance change in the electron density was also largest in the

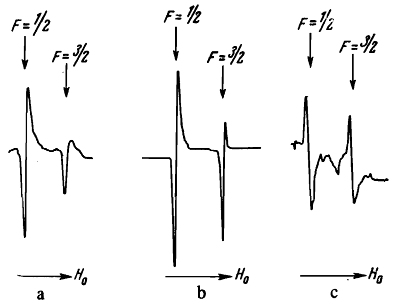

FIG. 2. a–Derivatives of the resonance signals representing the change in the electron density in an He^3 discharge plasma. b–Derivatives of the resonance signals representing the change in the density of emission from He^3 atoms in a weak discharge. c–Derivatives of the resonance signals representing the change in the density of emission from He^3 atoms in a strong discharge. The pumping radiation was circularly polarized and generated by a lamp filled with He^3.

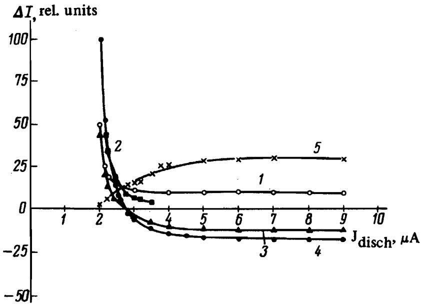

FIG. 3. Dependences of the resonance changes in the emission from He^3 atoms (ΔI) on the discharge current. Curves 1 and 2 were obtained by pumping a discharge cell with circularly polarized light produced by a lamp filled with He^4; curves 3 and 4 were obtained by pumping with circularly polarized light produced by a lamp filled with He^3. Curves 1 and 3 correspond to resonance in the state with $F = 3/2$, whereas curves 2 and 4 correspond to resonance in the state with $F = 1/2$. Curve 5 represents the resonance change in the intensity of the 3889Å line of He^3 atoms pumped with unpolarized light from a lamp filled with He^4. All the curves are reduced to the same scale.

weakest discharge and decreased strongly with increasing strength of the discharge. However, in all cases, the change in the electron density was positive irrespective of whether the pumping was provided by an He^3 lamp or by an He^4 lamp. Figure 2a shows the resonance change in the electron density obtained when the discharge in the He^3 cell was very weak.

Figure 3 gives the dependences of the resonance change in the emission intensity (ΔI) on the strength of the discharge in a cell pumped with light from lamps filled with He^4 or He^3. Curves 3 and 4 in Fig. 3 were basically similar to the experimental curves for He^4 reported in[1], i.e., in the case of pumping of the He^3 atoms with the He^3 lamp, the sign of the resonance change in the emission intensity was reversed when the strength of the discharge was increased. In the case of pumping of the He^3 atoms with light from the He^4 lamp (curves 1 and 2 in Fig. 3), the emission intensity always increased under resonance conditions irrespective of the strength of the discharge. In the latter case, the signal corresponding to the resonance of the $F = 3/2$ state decreased with increasing strength of the discharge, reached a certain level, and then remained constant (curve 1 in Fig. 3). The signal for the $F = 1/2$ state decreased quite rapidly to the noise level but remained positive (curve 2 in Fig. 3). It should be noted that the noise recorded by the photocell increased strongly with increasing strength of the discharge.

No resonance change in the electron density was observed when the He^3 atoms were pumped with unpolarized light.

The change in the emission intensity of the He^3 atoms as a result of pumping with unpolarized light produced by the He^4 lamp was only observed for the λ = 3889 Å line in resonance with the $F = 3/2$ state (curve 5 in Fig. 3). The corresponding signal increased with increasing strength of the discharge. In the case of pumping with unpolarized light from the He^3 lamp, the intensity of the 3889 Å line exhibited only a very small negative change under weak discharge conditions.

3. DISCUSSION OF RESULTS

The resonance increase in the electron density in the He^4[1] and He^3 (Fig. 2a) discharge plasmas is due to a reduction in the spin orientation of the helium atoms in the 2^3S_1 state, which occurs under magnetic resonance conditions. The dependence of the electron density in a plasma on the orientation of metastable helium atoms and the increase in this density under resonance conditions can be explained as follows.

The main source of electrons in a helium plasma—under the pressures considered here—is the ionization of metastable atoms resulting from their collisions with one another:[3]

$$\begin{aligned} &He(2^3S_1) + He(2^3S_1) \rightarrow He(1^1S_0) + He^+ + e^-,\\ &He(2^3S_1) + He(2^1S_0) \rightarrow He(1^1S_0) + He^+ + e^-,\\ &He(2^1S_0) + He(2^1S_0) \rightarrow He(1^1S_0) + He^+ + e^-. \end{aligned} \tag{1}$$

It is shown in[3,7] that the yield of electrons in such processes depends on the relative spin orientations of the colliding metastable atoms. This is due to the fact that in type (1) collisions the total projections of the spins of all particles should be conserved.[3] If this condition is satisfied, the probability of ionization in collisions of metastable atoms is practically equal to unity[8] [the cross sections for all collisions in Eq. (1) are the same and equal to 10^{-14} cm^2].

We shall first consider the phenomena which appear as a result of optical pumping of metastable He^4 atoms.[1]

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The collision of two He^4 metastable atoms in the 2^3S_1 state in the case of identical values of the spin projections $m_S = +1$ or -1 does not give rise to ionization in accordance with Eq. (1) because such ionization would not conserve the total projection of the spins of all the particles. Bearing this point in mind, we find that the number of electrons dn_e/dt formed in a plasma per unit time because of type (1) reactions is

$$dn_e/dt \sim (N_+N_- + N_0N_+ + N_0N_- + N_1N_+ + N_1N_- + N_1N_0 + {}^1/_2N_0^2 + {}^1/_2N_1^2). \tag{2}$$

Here, N_+, N_0, and N_- are, respectively, the populations of the Zeeman sublevels of the 2^3S_1 state of He^4 characterized by values of $m_S = 1$, 0, and −1. The populations under optical pumping conditions are calculated theoretically in[9,10]. The quantity N_1 is the population of the 2^1S_0 metastable level.

If we separate in Eq. (2) the sum of the squares of the numbers of all the metastable atoms, we obtain

$$dn_e/dt \sim [(N_1 + N_+ + N_0 + N_-)^2 - (N_+^2 + N_-^2)]. \tag{3}$$

Magnetic resonance in the 2^3S_1 state of optically oriented atoms equalizes the populations N_+, N_0, and N_- and this alters the electron yield:

$$\begin{aligned} \Delta(dn_e/dt) &\sim (N_+^2 + N_-^2) - (\overline{N}_+^2 + \overline{N}_-^2)\\ &= 2\overline{N}_+\Delta N_+ + 2\overline{N}_-\Delta N_- + (\Delta N_+)^2 + (\Delta N_-)^2, \end{aligned} \tag{4}$$

where $\overline{N}_+$ and $\overline{N}_-$ are the populations under magnetic resonance conditions subject to saturation, i.e., $\overline{N}_+ = \overline{N}_- = N/3$, and $N = N_+ + N_0 + N_-$; $\Delta N_+ = N_+ - \overline{N}_+$; $\Delta N_- = N_- - \overline{N}_-$. Equation (4) follows from Eq. (3) if we bear in mind that ΔN_+ and ΔN_- are finite differences. It is assumed that the total number of metastable atoms ($N_1 + N_+ + N_0 + N_-$) is not affected by optical pumping and magnetic resonance.

In the case of pumping with unpolarized light (alignment of atoms), the values of N_+ and N_- increase by the same amount at the expense of N_0. Therefore, it follows from Eqs. (3) and (4) that the resonance change in the electron density should be positive.

In the case of pumping with circularly polarized light (polarization of atoms), either N_+ or N_- increases and the other quantity decreases. The values of ΔN_+ and ΔN_- can then be obtained from the results given in[9]. For example, in the case of light with the right-handed polarization (σ^+), we obtain the following expressions which are valid in the absence of mixing in the $2^3P_{0,1,2}$ states (this was true of our experiments) if allowance is made for the relaxation in the 2^3S_1 state:

$$\Delta N_+ = \frac{Na}{3B}[(24k+42)a+2k+14], \tag{5}$$

$$\Delta N_- = -\frac{Na}{3B}[(12k+21)a+4k+7]. \tag{6}$$

Here, $k = I_0/I_3$, where I_0 and I_3 are the intensities of the D_0 and D_3 lines under pumping conditions; $a = \tau F$ where τ is the magnetic relaxation time of the 2^3S_1 state and F is the total intensity of the pumping radiation incident on the discharge cell; $B = (12K + 21)a^2 + (4k + 16)a + 3$. Under the conditions which produce optical orientation of the helium atoms in the 2^3S_1 state the value of k is quite small, whereas the value of a is fairly large so that, in accordance with Eqs. (5) and (6), we have $|\Delta N_+| > |\Delta N_-|$. Since, in this case, $\Delta N_+ > 0$ and $\Delta N_- < 0$, it follows from Eq. (4) that $\Delta(dn_e/dt) > 0$. Obviously, in the case of pumping light with the left-handed polarization (σ^-), the value of ΔN_+ is given by Eq. (6) and the value of ΔN_- is given by Eq. (5), so that $|\Delta N_+| < |\Delta N_-|$ with $\Delta N_+ < 0$ and $\Delta N_- > 0$, which—according to Eq. (4)—again gives $\Delta(dn_e/dt) > 0$. Thus, under resonance conditions the electron density should increase if the pumping light is circularly polarized.

The experiments reported in[1] have indicated that the resonance change in the electron density is positive irrespective of the strength of the discharge and this is true of unpolarized and circularly polarized pumping light. It has been established for He^4 [1] and for He^3 (present investigation) that the resonance change in the electron density decreases with increasing strength of the discharge. This is in agreement with Eqs. (3) and (4) and with the analysis given above since the degree of optical orientation of helium atoms decreases (i.e., the values of $|\Delta N_+|$ and $|\Delta N_-|$ decrease) with increasing strength of the discharge.

We shall now analyze type (1) collisions of He^3 atoms on the assumption that the sum of the projections of the total spin Σm_F of all the particles is conserved in every collision. The electron yield is then given by a relationship analogous to Eq. (3):

$$\frac{dn_e}{dt} \sim \left(\sum_{m_F} N_{m_F}\right)^2 - (N^2_{3/2} + N^2_{-3/2}), \tag{7}$$

where N_{m_F} is the population of that sublevel of the metastable 2^3S_1 or 2^1S_0 state of He^3 whose magnetic quantum number is m_F. It is evident from the above relationship that the change in the electron density $\Delta(dn_e/dt)$ should occur only if the radiofrequency resonance is excited in the $F = 3/2$ state when the populations $N_{3/2}$ and $N_{-3/2}$ are affected. The resonance signal of the state with $F = 3/2$ should not be observed. However, it is evident from Fig. 2a that both signals of the change in the electron density are present and the signal corresponding to the resonance in the state with $F = 1/2$ is even greater than the signal for $F = 3/2$.

Since the collision time of metastable atoms is much smaller than the reciprocal of the energy of the hyperfine interaction between electrons and nuclei, it is more likely (from the theoretical point of view) that type (1) collisions conserve independently the total electron spin Σm_S and the total nuclear spin Σm_I of all the particles. The total projection of the sum of the spins $\Sigma m_F = \Sigma m_S + \Sigma m_I$ is conserved automatically. In this case, the expression for dn_e/dt yields a finite change $\Delta(dn_e/dt)$ also when the resonance is excited in the $F = 1/2$ state. However, the calculated amplitude of the resonance signal representing the change in the electron density in the $F = 1/2$ case is over an order of magnitude smaller than the amplitude of the corresponding $F = 3/2$ signal. If, moreover, we assume that because of the resonance destruction of the orientation in the $F = 1/2$ state and the associated metastable exchange[4] the orientation is destroyed also in the $F = 3/2$ state, we find that these two signals can only become equal. Thus, there is no satisfactory explanation why the resonance signal representing the change in the electron density should be stronger for $F = 1/2$ than for $F = 3/2$.

The experimentally observed resonance increase in the intensity of the emission from He^3 atoms in a weak discharge (Fig. 2b) is a consequence of the resonance increase in the electron density (Fig. 2a). A comparison of Figs. 2a and 2b shows that the ratio of the amplitudes of the signals representing the change in the emission intensity for $F = 1/2$ and $F = 3/2$ behaves exactly as the ratio of the amplitudes of the signals representing the change in the electron density.

It is mentioned in the Introduction that, apart from the resonance increase in the electron density, there should be some additional process which alters the sign of the resonance change in the emission intensity with increasing strength of the discharge (curves 3 and 4 in Fig. 3). This process is evidently the resonance reduction in the number of the metastable helium atoms in the 2^3S_1 state, which is the starting point for a major fraction of the electron excitations to higher levels. This reduction in the number of the metastable atoms may result from the $2^3S_1 \rightarrow 2^3P_1$ optical transition followed by the $2^3P_1 \rightarrow 1^1S_0$ intercombination transition.[2] The number of the $2^3S_1 \rightarrow 2^3P_1$ optical transitions increases in the case of magnetic resonance in the 2^3S_1 state because of an increase in the absorption of the pumping light of λ = 10 830 Å. It is likely that this resonance reduction in the total number of the metastable helium atoms, which reduces the first sum in Eq. (3), is always less than the resonance reduction in the second sum $(N_+^2 + N_-^2)$ in the same formula. Therefore, the resonance change in the electron density caused by increasing strength of the discharge remains positive but it becomes much smaller. However, in a strong discharge the resonance increase in the electron density is relatively small and the reduction in the total number of the metastable atoms during resonance makes a large contribution to the change in the emission intensity of the helium atoms and can reverse the sign of this intensity change. It is also likely that the probability of the $2^3P_1 \rightarrow 1^1S_0$ intercombination transitions becomes higher in a strong discharge, which would increase the importance of this process in the phenomena considered here.

It should be pointed out that because of the overlap of the $2^3S_1 \rightarrow 2^3P_1$ and $2^3S_1 \rightarrow 2^3P_2$ optical transitions, which combine to give the D_3 line,[4,5] the second of these transitions should also make a considerable contribution to the reduction in the total number of the metastable atoms during resonance.

The assumption of the influence of the $2^3S_1 \rightarrow 2^3P_1 \rightarrow 1^1S_0$ transitions can be checked experimentally by pumping He^3 atoms with light produced by lamps filled with He^3 and He^4. The results of such experiments (Fig. 3) confirm the influence of the $2^3S_1 \rightarrow 2^3P_1$ transition on the resonance change in the emission intensity of He^3 atoms in a strong discharge. Light produced by a lamp filled with He^4 excites only the $2^3S_1 \rightarrow 2^3P_0$ transition in He^3 atoms and, in this case, the resonance reduction in the intensity of the emission from these atoms is not observed, irrespective of the discharge strength (curves 1 and 2 in Fig. 3). However, if the same He^3 atoms are pumped with light from a lamp filled with He^3, all three $2^3S_1 \rightarrow 2^3P_{0,1,2}$ transitions are excited, the resonance signal changes its sign and becomes negative when the discharge strength is increased (curves 3 and 4 in Fig. 3). This is in agreement with our hypothesis of the influence of the $2^3S_1 \rightarrow 2^3P_1 \rightarrow 1^1S_0$ transitions on the change in the intensity of the emission from helium atoms under resonance conditions.

The resonance change in the intensity of the 3889 Å emission line, resulting from pumping of He^3 atoms with unpolarized light (curve 5 in Fig. 3), is not related to the processes discussed above. This change is caused by the change in the absorption in the outer regions of the discharge cell of the radiation emitted from the inner regions due to the $2^3S_1 \rightarrow 3^3P_{0,1,2}$ transitions (λ = 3889 Å) and is a consequence of the alignment of helium atoms in the 2^3S_1 state by unpolarized pumping light of λ = 10 830 Å. The influence of the optical pumping of metastable He^3 atoms with unpolarized light on the emission due to other transitions in helium atoms and on the electron density in a plasma is too weak to be observed.

Thus, the results reported above demonstrate that the influence of the optical orientation in the 2^3S_1 state on the emission from helium atoms and on the electron density in a plasma is governed by two competing processes.

1) At the moment of resonance the optical orientation of the metastable helium atoms in the 2^3S_1 state is destroyed so that their collisions increase the electron yield. This increases the frequency of electron-impact excitations of the metastable atoms and, therefore, raises the intensity of the emission from the helium atoms due to various atomic transitions.

2) During resonance the number of the metastable atoms decreases because of an increase in the absorption of the pumping light involving the $2^3S_1 \rightarrow 2^3P_1$ transition and the $2^3P_1 \rightarrow 1^1S_0$ transition of helium to the ground state. This process reduces the intensity of the emission from helium atoms at the moment of destruction of the optical orientation.

In weak discharges the first process predominates. In stronger discharges the relative importance of the first process decreases and that of the second increases.

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