EFFECT OF OPTICAL ORIENTATION OF He^4 ATOMS IN THE 2^3S_1 STATE ON THE ELECTRON DENSITY AND RADIATION OF HELIUM ATOMS IN A PLASMA

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The effect of optical orientation of He^4 atoms in the 2^3S_1 state on the radiation of ortho- and parahelium atoms in a gas discharge absorbing cell is observed. The phenomenon is studied under various experimental conditions. It is found that on destruction of orientation of the helium atoms in the 2^3S_1 state the electron density in the plasma of the gas discharge cell increases. Some suggestions concerning the nature of the phenomena are presented.

OPTICAL pumping of paramagnetic atoms, including helium atoms in the metastable 2^3S_1 state, has been revealed so far by the changes in the absorption or scattering of the resonant radiation[1-3] used for the pumping. In the present investigation we observed that the optical orientation of He^4 in the 2^3S_1 state influences the radiation of the gas-discharge absorbing cell at a variety of transitions of the atoms of parahelium and orthohelium. It was also established that when the orientation in the 2^3S_1 state is disturbed, the electron density in the plasma of the gas-discharge absorbing cell is increased somewhat, and this occurs simultaneously with the change of the emission of the helium atoms in the cell. We describe here these investigations.

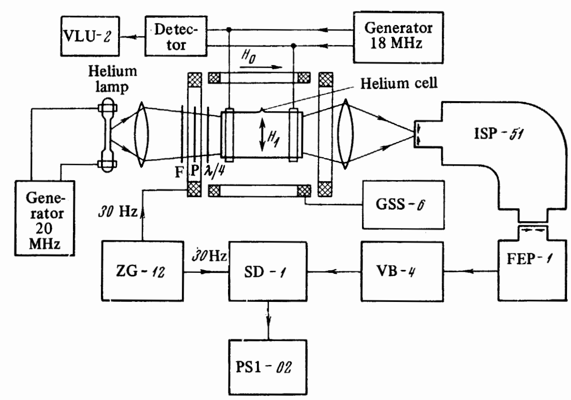

FIG. 1. Diagram of experimental setup.

1. EXPERIMENTAL PROCEDURE

Unlike the customary procedure of investigating optical pumping[1-3], consisting in observing only the absorption or the scattering of the pumping resonant radiation, we investigated the behavior of the radiation emitted by a gas-discharge absorbing cell at an optical orientation of the He^4 atoms in the 2^3S_1 state. To this end, the radiation of the helium cell was analyzed with a spectrograph. The influence of the optical pumping, as usual, was determined by destroying it with radiofrequency magnetic resonance.

The experimental setup is shown in Fig. 1. The pumping lamp was a Pyrex capillary of 4 mm diameter, filled with helium at a pressure 4–5 torr, in which an electrode-less high-frequency discharge was excited. The absorbing cell was a glass cylinder of 60 mm diameter and 100 mm length, and was filled with helium at a pressure 0.1 torr. Another generator also excited a high-frequency electrodeless discharge in the cell; the intensity of this discharge could be varied during the course of the experiment by varying the coupling with the generator. The pump lamps and the absorbing cells were filled with helium by diffusion through heated quartz, using a procedure described in[4].

The light incident on the cell was usually passed through a light filter F, which separated from the emission of the helium line the line $\lambda = 1.083\ \mu$ (transition 2^3S-2^3P), with the aid of which the pumping was effected. This light either remained unpolarized, or was circularly polarized with the aid of a polaroid P of type PPI-1 and a $\lambda/4$ plate of mica. The light emitted by the gas-discharge absorbing cell was directed to the input slit of a glass prism spectrograph ISP-51, which operated in conjunction with a photoelectric attachment FET-1 in the wavelength band 3600–6000 Å. Our setup has made it possible to investigate the radiation emitted from the cell both along a constant magnetic field H_0 (Z axis) (this is shown in Fig. 1) and in a direction perpendicular to this field (X axis). In the investigation of the radiation from the cell along the X axis, a polarizer was placed ahead of the spectrograph in order to separate from this radiation the π and σ components. In all our investigations, the light from the pump lamp was directed along the Z axis.

The circuitry for amplification, synchronous detection, and recording the output signal is shown in Fig. 1. It consists of a narrow-band amplifier V6-4, a synchronous detector SD-1, and an automatic recorder PS1-02.

The radio-frequency magnetic field H_1, which excited the resonant transitions between the Zeeman sublevels of the 2^3S_1 state of the He^4 atoms, was produced by coils fed from a standard signal generator GSS-6. The generator frequency was 3.5 MHz, and the magnetic field H_0 was varied linearly near a value 1.25 G.

The usual methods of determining the electron densities in the plasma (probe, microwaves, etc.) are rather complicated. Under our conditions it was possible to register the change of the electron density in the cell by determining the change of the plasma conductivity. This change of conductivity was determined from the change of the discharge-exciting high-frequency voltage on the cell. To this end, a special detector, shown in Fig. 1, was connected to the electrodes of the cell. The detector current produced on its load a voltage whose dc component was measured with a vacuum-tube voltmeter VLU-2. The low-frequency ac component of this voltage was fed either through a broad-band amplifier to the oscilloscope, or to a second synchronous-detection channel (not shown in Fig. 1). A reference voltage of 30 Hz frequency was applied to the synchronous detector SD-1 of this channel from the generator ZG-12, shown in Fig. 1.

In an appreciable part of the experiments we used for the investigation of the radiation from the cell not a spectrograph with FEP-1 attachment, but a vacuum antimony-cesium photocell Ph-1, which was sensitive to the visible region of the spectrum. This greatly increased the sensitivity of the entire registration channel, owing to the appreciably larger transmission of such a system compared with a spectrograph. The signals from the photocell were sufficiently intense, so that they could be registered on the oscilloscope screen directly after amplification, whereas the use of a spectrograph was possible only in conjunction with a system of synchronous detection with a band width 0.03 Hz.

The investigations were performed in the following manner. The spectrograph was tuned to the maximum of the spectral line emitted by the gas-discharge cell. The magnetic field H_0 was then linearly scanned in the band in which radio-frequency resonance was observed on the scattered light $\lambda = 1.083\ \mu$. The automatic recorder PS1-02, shown in Fig. 1, then registered (in the form of the derivative of the resonant signal) the changes occurring in the radiation of the investigated line when the optical orientation of the helium atoms in the 2^3S_1 state was destroyed. When the photocell Ph-1 was used in place of the spectrograph, the investigation procedure was similar. In this case we registered either the total effect on all the helium-atom lines lying in the sensitivity region of the photocell, or else we installed in front of the photocell light filters that separated from the radiation of the cell the individual lines or groups of lines of helium.

2. EXPERIMENTAL RESULTS

The first experiments were performed without a spectrograph, with a Ph-1 photocell, the signal from which was fed to the oscilloscope through a broad-band amplifier. We registered in this case the changes occurring in the radiation of the gas-discharge cell in the spectral region from 3600 to 6000 Å (the line $\lambda = 1.083\ \mu$ was automatically excluded). It was observed that upon pumping with circularly polarized light of $\lambda = 1.083\ \mu$, under conditions of a weak discharge, the intensity of the radiation from the cell increased at resonance in the 2^3S_1 state of the He^4 atoms. The signal noise ratio at minimum discharge intensity exceeded 100. Under the conditions of a sufficiently strong discharge, a decrease of the intensity of the radiation from the cell was observed at the resonance. The signal/noise ratio was 10. When pumped with unpolarized light of $\lambda = 1.083\ \mu$, the picture was qualitatively duplicated, but the intensity of the signals was much lower. Subsequently, the derivatives of these signals were registered with an automatic recorder of the synchronous-detection method (see Fig. 2).

To study the influence of the optical pumping in the 2^3S_1 state on the individual emission lines of the gas-discharge helium cell, the investigations were carried out with the aid of the setup shown in Fig. 1. Figure 3 shows the derivatives of the resonant signals recorded for different lines emitted from the cell. We see that the signals from all the lines have a similar (positive) sign, corresponding to an increase of the intensity of the radiation when the orientation in the 2^3S_1 state is destroyed. The intensities of the signals shown in Fig. 3 turned out to be approximately proportional to the total intensities of the corresponding lines emitted by the helium cell. Signals of this type were obtained for strong and weak discharges when pumped with light of circular polarization for 20 spectral lines of HeI in the range from 5876 to 3705 Å. (The level scheme of helium is given, for example, in[5], and its spectral lines are given in[6].) The signals for all the lines were positive in the case of a weak discharge and negative for a strong one. The signals for the same lines were obtained for a strong discharge in the cell when pumped with unpolarized light. All turned out to have the same negative sign. All the signals were registered using radiation along the Z axis.

We also investigated the behavior at resonance of the cell radiation along the X axis, for both the π^- and

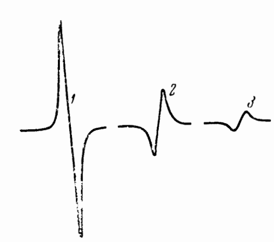

FIG. 2. Signals showing the change of intensity of the total radiation of helium atoms in the visible region under radio-frequency resonance in the 2^3S_1 state: 1—pumping with circularly polarized light, weak discharge; 2—the same, strong discharge; 3—pump with unpolarized light, strong discharge.

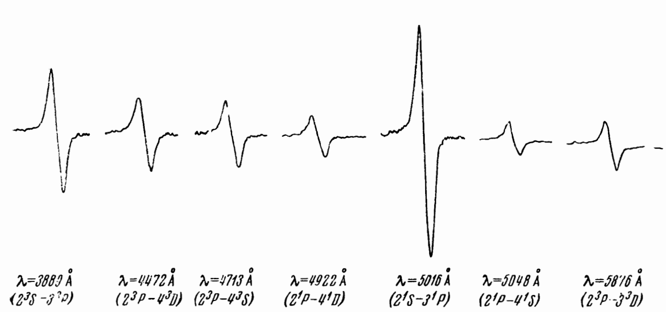

FIG. 3. Signals showing variation of the intensities of certain spectral lines of helium atoms emitted by the cell under radio-frequency resonance in the 2^3S_1 state. Pumping with circularly polarized light, weak discharge.

σ components of the helium lines lying in the same region of the spectrum. These investigations have shown that for a weak discharge and in the case of pumping by circularly polarized light, the signals of the π^- and σ components of all the lines were positive, i.e., they coincided with the signs of the signals observed for radiation in the Z direction.

For a strong discharge and for pumping with either unpolarized or circularly-polarized light, the signals of the π^- and σ components were negative, i.e., they also coincided with the signs of the signals for the Z axis, in the case of all but two of the spectral lines of helium. The anomaly was observed only for the lines 5876 Å (2^3P-3^3D) and 3889 Å (2^3S-3^3P). For these lines, the signs of the signals for the π components turned out to be positive, whereas for the σ components they were negative, and the intensities of the π-component signals were approximately half those of the σ components for each of these two lines. For all the other lines, the signals were approximately equal for the π and σ components.

Under the conditions of our experiment, we observed no spectral lines of HeII in the visible part of the radiation from the cell.

Owing to the small transmission of the spectrograph, we were unable to trace the behavior of the resonant signals for each spectral line as a function of the intensity of the discharge in the cell and of the state of the polarization of the pumping $\lambda = 1.083\ \mu$ light. This dependence was therefore investigated with the aid of the photocell Ph-1, with registration of the total radiation from the helium cell in the visible region. The measure of the discharge intensity was taken to be the high-frequency voltage exciting this discharge, and measured across the cell electrodes.

Figure 4 shows the results of these investigations. The ordinates for curves 1 and 2 (in arbitrary units) represent the absolute changes of the intensities ΔI of the total radiation of the cell in the visible region at resonance in the 2^3S_1 state, i.e., the intensity of signals similar to those shown in Fig. 2. An idea of the values of the considered effects can be obtained from the following figures: the relative change of the radiation intensity of the cell at resonance, at a minimum discharge intensity (~80 V on Fig. 4) amounts to 2×10^{-3} for curve 1 and 6×10^{-5} for curve 2. At maximum discharge intensity (147 V on Fig. 4), the respective values are 4×10^{-5} and 10^{-5}.

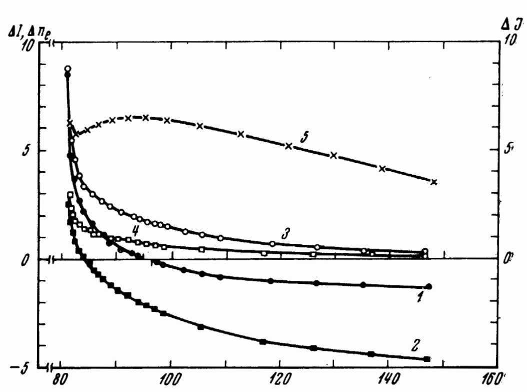

FIG. 4. Dependences of the resonant changes of the radiation intensity of helium atoms in the visible region ΔI (curves 1 and 2), of the electron density Δn_e (curves 3 and 4), and of the ordinary optical-pumping signal ΔJ (curve 5) on the high-frequency voltage on the cell electrodes. 1, 3, and 5—pumping with circularly polarized light, 2 and 4—pumping with unpolarized light. The units of ΔI, Δn_e, and ΔJ are arbitrary. The scale on curves 2 and 4 is 10 times larger than on 1 and 3 respectively.

As seen from Fig. 4, the resonance signals for the emission of the helium atoms in the visible region of the spectrum first decrease in magnitude with increasing discharge intensity, vanish, and then reverse sign and increase again. It should be noted that both the total intensity and the intensities of each individual spectral line of the emission of the helium gas-discharge cell increase monotonically with increasing discharge intensity. The density of the metastable atoms in the 2^3S_1 state increases with increasing high-frequency voltage exciting the discharge in approximately the same manner as the intensity of the emission from the cell. This density of the metastable atoms is determined from the total magnitude of the $\lambda = 1.083\ \mu$ resonant radiation scattered by the cell. The behavior of the optical-pumping signal ΔJ at the wavelength $1.083\ \mu$ as a function of the discharge intensity is represented by curve 5 of Fig. 4.

It is seen from Fig. 4 that in the cases of pumping by unpolarized and circularly-polarized light, the change of the sign of the resonant signal occurs at different intensities of the gas discharge in the cell. It should be noted that the very process of the reversal of the sign of the signal in these two cases is essentially different. In the case of pumping with unpolarized light, the resonant signal in the visible region gradually decreases with increasing discharge intensity, vanishes, and then appears with the sign reversed. On the other hand, when circularly-polarized light is used for the pumping, the reversal of the sign of the resonant signal is a more complicated process.

The signal does not vanish completely for any value of the discharge-exciting cell voltage, and the character of the process of sign reversal can be understood in this case by referring to Fig. 5. This process is reflected by a discontinuity on curve 1 of Fig. 4. The signals that could be observed in this region on the individual lines emitted by the cell (for example 5876, 3839 Å) behaved in similar fashion when pumped by circularly-polarized light. Thus, the effect represented in Fig. 5 cannot be ascribed to a superposition of signals from different spectral lines emitted by the cell. The change of the sign of the resonant signals at dif-

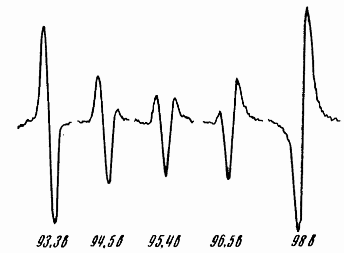

FIG. 5. Reversal of sign of the resonant signal of the visible radiation of the helium atoms with increasing discharge intensity when pumped with circularly polarized light. The numbers represent the high-frequency voltage on the cell.

ferent lines occurs at somewhat different but rather close values of the high-frequency voltage exciting the discharge in the cell.

Curves 3 and 4 of Fig. 4 show the dependence of the changes of the electron density Δn_e, occurring in the plasma of the absorbing cell when the optical orientation in the 2^3S_1 state is destroyed by radio-frequency resonance, on the intensity of the discharge. An idea of the changes in the electron density can be obtained from the following figures: at the minimum discharge intensity (high-frequency voltage about 80 V), the relative change of the electron density at resonance $\Delta n_e/n_e$ amounts to 2×10^{-3} for curve 3 and 3×10^{-5} for curve 4 (Fig. 4). For the maximum discharge intensity (147 V) these changes are equal to 5×10^{-6} for curve 3 and are of the order of 10^{-7} for curve 4. The value of n_e was assumed to be the difference between the readings of the voltmeter VLU-2 (Fig. 1) in the presence and in the absence of a discharge in the cell. The value of Δn_e was assumed to be the low-frequency ac component of the voltage produced across the detector load by passes through resonance in the 2^3S_1 state. It has been established that both the electron density and the radiation intensity vary in synchronism in the case of resonant destruction of the optical orientation in the 2^3S_1 state. The form of the resonant signals Δn_e is similar to the signals shown in Fig. 2 (curve 1) and Fig. 3.

For an additional confirmation of the influence of the optical orientation of the helium atoms in the 2^3S_1 state on the electron density and on the emission of the helium atoms in the plasma, a number of control experiments were performed. Thus, when the light from the pump lamp was covered, the resonant changes of the electron density and of the cell radiation practically vanished. However, precise investigations have shown that there are very weak resonant signals indicating also a change of the radiation from the cell in the visible region in the absence of light from the pump lamp. These signals were weaker in magnitude by a factor of 10^3 than those obtained in the presence of the pumping light. This effect can be attributed to the fact that unpolarized radiation of certain parts of the cell at the wavelength 1.083 μ produces optical pumping of the helium atoms in the 2^3S_1 state[1,3] in other parts of the cell.

A subsequent experiment has shown that the presence of radiation with $\lambda > 1.083\ \mu$ in the light incident on the cell does not influence the effects considered above.

The new experiment consisted in applying a low-frequency (50 Hz) magnetic field of large amplitude, perpendicular to $\mathbf{H}_0$, in the absence of a radio-frequency magnetic field H_1 and in the absence of longitudinal modulation of the field $\mathbf{H}_0$. This led to a periodic variation of the angle between the light beam producing the pumping and the direction of the magnetic field. If the relaxation times are small compared with the period of modulation of the magnetic field, then the degree of optical orientation of the helium atoms depends on this angle[1]. If the described effects of variation of the electron density in the cell and of the intensity of its radiation depend on the optical orientation of the helium atoms in the 2^3S_1 state, then these effects should be observed at double the field modulation frequency in such a resonant experiment. Indeed, when pumping with circularly polarized light at a wavelength 1.083 μ, we observed in these experiments a periodic variation of both the electron density and of the emission produced by the helium atoms in the visible region. When pumping with unpolarized light of the same wavelength, we observed periodic variations of the radiation of the helium atoms. We were unable to observe a change in the electron density. All this apparently signifies also that the effects considered above are not connected with absorption of the power of the resonant radio-frequency emission by the gas-discharge helium plasma.

Attempts were made to observe the phenomena described above in the case of optical orientation of He^3 atoms in the 2^3S_1 state. In these experiments, such phenomena could not be observed, this being apparently connected with the small degree of orientation of the He^3 atoms in the 2^3S_1 state.

3. DISCUSSION OF RESULTS

The experimental results described in the preceding sections offer undisputed evidence of the influence of optical orientation of the He^4 atoms in the 2^3S_1 state both on the emission of the helium atoms in a gas-discharge absorbing cell in various transitions of these atoms, and on the electron density in the helium plasma. This influence consists in the following:

1. In a weak discharge, with pumping by either unpolarized or circularly polarized light with $\lambda = 1.083\ \mu$, the emission of the helium atoms increases both in the Z direction and in the X direction when the optical orientation in the 2^3S_1 state is destroyed (Figs. 2–4).

2. In a strong discharge, under the indicated conditions, the emission of the helium atoms for all the investigated spectral lines decreases at resonance (Figs. 2 and 4).

Thus, for each given value of the discharge there is observed at resonance a simultaneous increase (or decrease) of the intensities of all the investigated lines, and not a growth (or decrease) of the intensity of certain lines at the expense of the others.

3. There exists a definite value of the discharge intensity, at which the resonant change of the radiation intensity of the helium atoms in the cell reverses sign. The value depends on the state of polarization of the pumping radiation (Fig. 4).

4. The radiation of the helium atoms in the plasma is influenced both by the optical polarization (pumping with circularly polarized light) and the optical alignment (pumping with unpolarized light) of the helium atoms in the 2^3S_1 state. The influence of polarization is qualitatively similar to that of alignment (Fig. 4), although the magnitudes of these effects are different.

5. Changes in the intensities of the individual lines of the helium atoms in resonant destruction of the optical pumping, at a fixed discharge intensity, are approximately proportional to the total intensities of these lines emitted by the cell.

6. In the case of pumping with circularly polarized light, the reversal of the sign of the resonant signal, which is observed in the emission of the helium atoms

in the visible region, has a rather complicated character (Fig. 5).

7. In the case of pumping with either circularly-polarized or unpolarized light, in a strong discharge in the cell, the resonant signals for the π components in the X direction, on the lines 5876 Å (2^3P-3^3D) and 3889 Å (2^3S-3^3P) turn out to be of opposite sign to the signals for the σ components of these lines as well as the signals for the π and σ components of all the other lines. This anomaly seems all the more strange since it is not observed for the lines of similar nature 4472 Å (2^3P-4^3D) and 4026 Å (2^3P-5^3D).

8. Upon destruction of the optical orientation of the helium atoms in the 2^3S_1 state, an increase is observed of the electron density in the helium plasma (Fig. 4). The absolute value of this increase, and particularly its relative value, decrease with increasing discharge intensity. This effect appears in the case of pumping with either circularly polarized or unpolarized light, but it is much smaller in the latter case (Fig. 4).

9. Resonant changes of the electron density and radiation intensity of the cell in the visible region reach maximum values at minimum discharge intensities (Fig. 4), whereas the optical-pumping signal at the wavelength 1.083 μ is maximal at a certain intermediate discharge intensity (curve 5, Fig. 4).

10. The centers of the resonant signals indicating the change of the electron density and radiation of the cell in the visible region coincide with the centers of the ordinary resonant signals of optical pumping at the 1.083 μ wavelength. The width and shapes of the lines of all these resonant signals also coincide, with the exception of signals of the type shown in Fig. 5.

The dependences of the resonant variation of the electron density and of the radiation intensity of the helium atoms on the discharge intensity (at least in the region of positive values of the signals in Fig. 4) are qualitatively similar. This makes it possible to assume that the second of the considered effects (ΔI) is connected with the first (Δn_e) and is possibly caused by it. Further, with increasing intensity of the discharge, the resonant signal of the helium-atom radiation reverses sign, whereas the change of the electron density always retains the same sign at resonance. Starting from this, it can be assumed that the resonant change of the radiation intensity of the helium atoms is due to competing processes that make contributions of opposite signs to this change and depend differently on the discharge intensity.

We advance below certain preliminary considerations concerning the causes of these experimentally observed effects.

It can be assumed that the indicated effects are due to the following: when the optical orientation of the helium atoms in the 2^3S_1 state is destroyed by the radio-frequency resonance, the absorption of the pumping radiation with wavelength 1.083 μ at the 2^3S-2^3P transition increases. This can change the populations of the levels 2^3S and 2^3P, and, owing to the stepwise excitation of the helium atoms from these levels by electron impact, it can change the intensities of the other values emitted by the atoms. A similar effect is observed upon change of the populations of the different levels of the neon atoms in a helium-neon laser at the instant of appearance of generation[7]. In addition, the change of populations of the levels 2^3S and 2^3P with increasing absorption of light at the instant of resonance can change the number of ionizing helium atoms and consequently the density of the electrons in the plasma.

To verify this assumption, we undertook experiments on 100-% modulation of the intensity of the light of the pump lamp with a frequency of 30 Hz at a wavelength 1.083 μ without modulation of the magnetic field H_0, and at a radio-frequency magnetic field $H_1 = 0$. Since the absorption of the pumping light by the helium atoms changes by 1–2% in the ordinary radio-frequency resonance, it follows that if the change of the electron density and of the emission of the atom are due to this change of the absorption, then 100% modulation of light with wavelength $\lambda = 1.083$ μ should lead to similar effects, but much larger in magnitude. This statement is based on the fact that in the case of 100% modulation of the light from the pump lamp the ac component in the radiation scattered by the cell at 1.083 μ is larger by 100 times than the optical-pumping signal, which is also observed in the scattered resonant radiation. This means that the change of the absorption of the $\lambda = 1.083$ μ radiation increases by 100 times when the light is modulated, compared with the case of optical pumping. In these experiments, account was taken of the errors connected with the scattering of the light by the structural elements of the instrument.

These experiments were performed both with circularly polarized and with unpolarized light of wavelength 1.083 μ, with both strong and weak discharge in the cell. In such a 100% modulation of the light, changes of the intensity of the helium atom emission were observed in the visible region. These changes had the same phases as under the analogous conditions with resonant disturbance of the optical pumping. The magnitudes of these changes were approximately the same as in the case of radio-frequency resonance, whereas they were expected to be 10–100 times larger. The same took place also for changes of the electron density and with the light modulated. The impression was gained that the observed effects might be connected with modulation of the degree of optical orientation of the helium in the 2^3S_1 state upon modulation of the light. To exclude the influence of optical orientation in the case of such a modulation of the light, a resonant radio-frequency magnetic field H_1 was introduced to destroy the optical orientation of the helium in the 2^3S_1 state. This did not eliminate the effects of the changes of the electron density and the radiation of the helium atoms at the light-modulation frequency, but only decreased their magnitude by a factor 1.5–2.

It can be concluded from these experiments, in any case, that the change of the populations of the levels 2^3S and 2^3P due to changes in the absorption of the $\lambda = 1.083$ μ light under radio-frequency resonance is not the main cause of the effects observed in the present study. In favor of this conclusion is also the equality of signs of the resonant change of the radiation intensity in all the investigated lines of the helium atom (Fig. 3). If these effects were to be caused by the change of the populations of the levels 2^3S and 2^3P, then signals of opposite signs would be observed apparently for different lines, depending on the levels with which the excitation of the line under consideration is connected[7], since the changes of the populations of the levels 2^3S and 2^3P are opposite at resonance.

It is interesting that if in the case of 100% modulation the cell is illuminated with light from a helium lamp at wavelengths larger than 1.1 μ, i.e., without the resonant radiation at $\lambda = 1.083\ \mu$, then changes of the electron density and of the radiation intensity of the helium atoms at the modulation frequency are likewise observed. These changes are larger by one order of magnitude than the signals described in the preceding section, and are probably connected with the modulation of the absorption of light at the transition 2^1S-2^1P ($\lambda = 2.058\ \mu$) of the helium atoms and the corresponding modulation of the populations of these levels.

It is possible that when the helium atoms in the 2^3S_1 state are polarized with circularly polarized light, the plasma electrons also turn out to be polarized as a result of spin exchange with these atoms. Then, if the cross sections of the stepwise excitation depend on the mutual orientations of the spins of the free electron and the helium atom in the 2^3S_1 state, in analogy with the situation with sodium atoms[8], then the destruction of these polarizations by the radio-frequency resonance in our experiments would apparently lead to the observed effects. But in the case of pumping with unpolarized light there is only the alignment of the helium atoms in the 2^3S_1 state, i.e., there is no polarization of either the electrons or the atoms. The foregoing explanation is then inconsistent.

It is possible that the cross sections for stepwise excitation of the helium atoms by electrons from the 2^3S_1 state depend on the direction of free-electron motion relative to the direction of the spin of the atom. This would mean that the effects considered above should depend both on the degree of polarization or alignment of the metastable helium atoms, and on the direction of the oscillations of the electrons in the case of high-frequency discharge in the cell. Experiments with a change of the direction of the electron current in the discharge relative to the orienting beam are being carried out at the present time.

An analysis of a number of other interaction mechanisms in a plasma, capable of giving rise to the orientation of the helium atoms in the 2^3S_1 state, particularly those investigated in[9], has not yet yielded an explanation of the discussed phenomena.

Thus, at present there is no satisfactory explanation of the effects, observed in this paper, of the influence of optical orientation of the He^4 atoms in the 2^3S_1 state on the electron density and on the emission of the helium atoms in a plasma.

A further study and a satisfactory explanation of these phenomena will probably result in a new method of investigating subtle processes occurring in a gas-discharge plasma.

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