ON THE MANIFESTATION OF TWO-PHOTON RESONANCES UNDER THREE-PHOTON IONIZATION OF SAMARIUM ATOM

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Possible reasons for a change of the resonance structure of the two-photon resonantly enhanced three-photon ionization spectra of a Sm atom in relatively weak fields ($\varepsilon < 6 \times 10^5$ V cm^{-1}) are considered. With a variation in the laser field strength, a considerable redistribution of the amplitudes of resonance maxima is observed. The main reason for this phenomenon is shown to be related to the different conditions of the ionization process saturation for the transitions differing in their probabilities and the initial level populations.

1. Introduction

The present paper is a continuation of our investigation of the multiphoton ionization of a Sm atom [1, 2] and is devoted to the studies of the influence of the laser field strength on two-photon resonances under the three-photon ionization of this element.

It has been shown earlier [1] that the three-photon ionization spectra of Sm measured at various laser field strengths are different. This concerns both the amplitudes and shapes of the resonance maxima and their location and the total number. In this case, a distinct change of the resonance structure, which is mainly due to the two-photon excitation of intermediate bound states, is observed in fields not exceeding 6×10^5 V cm^{-1}. Note for comparison that, for most atoms, a considerable change in the resonance structure under the two-photon resonantly enhanced three-photon ionization is observed, as a rule, at strengths $\varepsilon > 10^6$ V cm^{-1} (see, for example, [3—5]).

The detailed analysis of the three-photon ionization spectra for samarium atom measured at different field strengths [1] shows that the change in the resonance structure with a variation in ε is mainly due to a change of the resonance maxima amplitude ratio. In many cases even a drastic redistribution of the amplitudes is observed: with increase in the field strength, the maxima with initially lower amplitudes begin to dominate over those being initially more intense. In addition, a variation in ε can also result in the appearance and the vanishing of resonance maxima.

This paper deals with the explanation of the reason for the observed difference in the behavior of the resonance maxima due to the two-photon excitation of intermediate bound states with a field strength variation under the three-photon ionization of a Sm atom.

Note that spectra measured in relatively weak fields, when resonance maxima are clearly distinguished, are of the most interest for spectroscopic investigations. Therefore, we have restricted ourselves to the strengths $\varepsilon < 10^6$ V cm^{-1}.

2. Experiment

A detailed description of the experimental apparatus has been given elsewhere [2]. Briefly, the linearly polarized radiation of a pulsed tunable laser was focused into a vacuum chamber and crossed by a Sm effusive atomic beam produced in a resistively heated oven. The percentage populations of the ground $^7F_{0-6}$ term levels at the atomic source operation temperature ~ 650 °C are 18, 35, 26, 13, 5, 2, and 0.5, respectively. The ions produced in the collision region were extracted by a constant electric field and, after passing through a home-made time-of-flight mass-spectrometer, detected by a tandem multichannel plate detector.

A tunable FL-2001 (Lambda Physik) laser with a linewidth of ~ 0.2 cm^{-1}, pulse duration of ~ 12 ns and maximal output energy of ~ 1 mJ pumped by the Nd:YAG-laser second harmonic served as a laser radiation source. The wavenumber ω was varied within the range $17000 \div 18450$ cm^{-1}. The maximal electric field strength in the collision region was about 6×10^5 V cm^{-1}.

The wavenumber was absolutely calibrated with the accuracy not worse than 0.2 cm^{-1} with respect to the reference optogalvanic spectrum of a commercial Cu—Ne hollow-cathode lamp and to the transmission spectrum of a Fabry—Perot interferometer (FSR = 1 cm^{-1}) measured simultaneously with the Sm three-photon ionization spectrum.

In the course of the experiment, the Sm$^+$ ion yield was measured as a function of the wavenumber $A^+(\omega)$ at different field strengths in the interaction region. First, we have measured the $A^+(\omega)$ dependence within the $\omega = 17000 \div 18450\,\text{cm}^{-1}$ range at two field strengths: $\varepsilon \approx 5 \times 10^5$ V cm^{-1} and $\varepsilon \approx 1.8 \times 10^5$ V cm^{-1}. Then, in the resonance maxima region where a considerable change of the ratio of amplitudes was observed, the $A^+(\omega)$ dependence was measured at several ε values, allowing one to analyze the behavior of the above maxima with a variation in the field strength in detail.

The ε value was reduced by changing the location of the focusing lens ($f = 16$ cm) with respect to the position of an “exact focus”. In this case, due to the increase of the effective volume, the number of Sm atoms in the interaction region is also increased. This favored the resonance structure to be clearly revealed at low ε. A decrease of the strength by neutral density filters at the constant location of a focusing lens “exactly at the focus” experimentally resulted in a much less distinct resonance structure. The field strength was calculated based on the laser beam energy, pulse duration, and beam cross section. The latter was determined for different locations of the focusing lens by solving the caustic equation [6].

3. Results and Discussion

The studies of the $A^+(\omega)$ dependences and the analysis of the ratio of the resonance maxima amplitudes related to the two-photon excitation of intermediate bound states at different laser field strengths have shown several typical features. First, the field strength variation results in a change of the resonance maxima amplitude ratio which is very pronounced in many cases. Secondly, a drastic redistribution of the amplitudes of resonance maxima is observed in the case where they result from the transitions from differently populated levels. In this case, the $A^+(\omega)$ dependences in the vicinity of the above maxima behave similarly with a variation in the field strength. Namely, at low ε, the maxima related to the transitions from less populated levels, as a rule, are more intense than those corresponding to the transitions from more populated levels. With increase in the field strength, the maxima due to the transitions from more populated levels outstrip those related to the transitions from less populated levels. Thirdly, the increase of the field strength up to 6×10^5 V cm^{-1} does not lead to a visible change in the resonance maxima positions. However, the variation of ε can result in the disappearance of certain maxima and the appearance of other maxima. In the case where the resonance maxima are closely located, this makes impression of their shift.

A quite small value of the field strength ($< 6 \times 10^5$ V cm^{-1}) allows one to suggest the observed change of the resonance structure not to be related to the disturbance of the electron state spectra of samarium atom, e.g. owing to the dynamic Stark effect or the resonance mixing of levels. The change of the maxima amplitude ratio with a variation in the field strength testifies to the fact that the ion signal rise rate changes. This is peculiar for the ionization process saturation effect related to the 100% ionization of atoms in the interaction region during the laser pulse duration.

A specific feature of the electron state spectrum of a Sm atom that distinguishes it from other atoms is that its ground term is $^7F_{0-6}$ septet, all the levels of which are populated even at relatively low temperatures. Therefore, the resonance structure in the three-photon ionization spectra for a Sm atom has form of the array of maxima due to the transitions (mainly two-photon ones) from all seven ground-term levels. The different transition probabilities and populations of their initial levels stipulate different conditions of the ionization process saturation for the above transitions. This is revealed, in its turn, in the different behavior of the corresponding resonance maxima with a variation in the field strength, resulting eventually in a change of the resonance structure.

We explain this pattern in more details by the example of the $A^+(\omega)$ dependence measured in the vicinity of the two-photon transitions $^7F_2 \to E_1$ and $^7F_4 \to E_2$ ($E_1 = 36644.6$ cm^{-1}, $J_1 = 1$ and $E_2 = 38105.1$ cm^{-1}, $J_2 = 3 - 5$ [2, 7]) at different field strengths (see Fig. 1). It is clearly seen that, at low ε, the amplitude of the maximum due to the two-photon transition from the $^7F_4$ level ($\omega = 17916.0$ cm^{-1}) exceeds that of the maximum corresponding to the two-photon transition from the $^7F_2$ level ($\omega = 17916.4$ cm^{-1}). With increase in the field strength, the amplitudes of the maxima are redistributed: at first, they become equal (Fig. 1, curve *3*), and then the amplitude of the maximum due to the two-photon transition from the $^7F_2$ level becomes dominant. At the maximal value of ε, the maximum corresponding to the transition from the $^7F_2$ level is clearly revealed in the $A^+(\omega)$ dependence, whereas the maximum due to the transition from the $^7F_4$ level is considerably lower in amplitude and is weakly resolved against its background (Fig. 1, curve *6*).

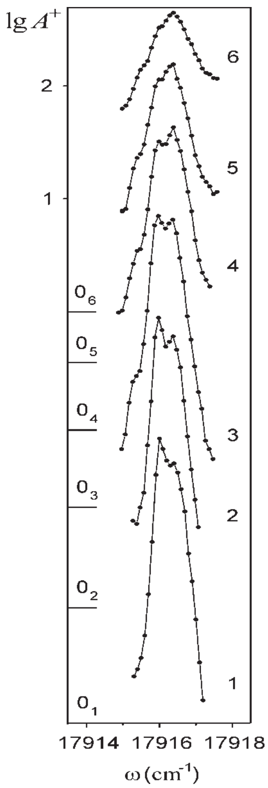

Fig. 1. Wavenumber dependences of the Sm$^+$ ion yield (on the log scale) measured in the vicinity of the two-photon transitions from the levels $^7F_4(\omega = 17916.0$ cm^{-1}) and $^7F_2\omega = 17916.4$ cm^{-1}) at different field strengths, V/cm: 1.7×10^5 (*1*), 2.1×10^5 (*2*), 2.5×10^5 (*3*), 3.4×10^5 (*4*), 4.7×10^5 (*5*), 5.4×10^5 (*6*)

Such a behavior of the maxima under consideration can be explained as follows. The probability of the two-photon $^7F_4 \rightarrow E_2$ transition, taking into account the ratio of the amplitudes of the maxima at low ε and the population of the $^7F_4$ level lesser approximately by a factor of 5, exceeds more than by one order of magnitude that of the two-photon $^7F_2 \rightarrow E_1$ transition. The different transition probabilities result in different values of the threshold saturation intensities I_1 and I_2, i.e. the laser intensities, at which the ionization process saturation begins. Hence, the condition $W \sim 1$ (W is the ionization probability) begins to hold true. For illustration, Fig. 2,*a* shows a schematic dependence of the ionization probability W on the laser intensity I [3]. Note that the field strength and radiation intensity are related as $I \sim \varepsilon^2$. It is seen that the most probable transition [in this case, from the $^7F_4$ level (curve *1*)] is characterized by a lower value of the saturation intensity $I_1 (I_1 < I_2)$. That is, the ionization saturation is achieved with increase in the laser intensity earlier in the case of the more probable transition.

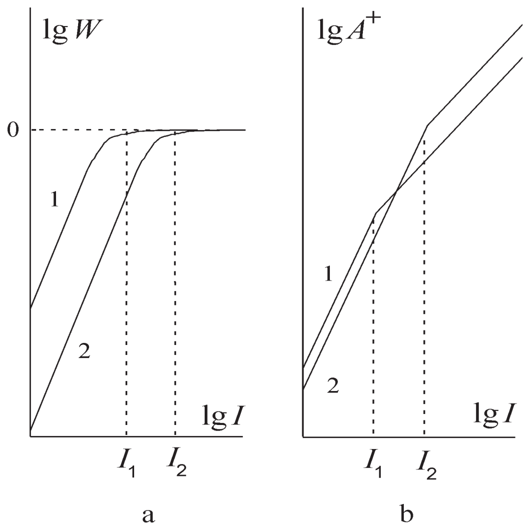

Fig. 2. Ionization probability (*a*) and ion signal (*b*) as functions of the laser intensity on the double log scale

The amplitude of the maximum A^+ is determined by the transition probability W and the initial level population N ($A^+ \sim WN$). The dependences of the ion signal on the laser intensity at maxima are shown in Fig. 2,*b*. Here, curve *1* corresponds to a more probable transition but from a less populated level (in this case, $^7F_4 \rightarrow E_2$), while curve 2 corresponds to a less probable transition but from a more populated level (in this case, $^7F_2 \rightarrow E_1$). Note that the curves in Fig. 2,*b* are a result of the simulation. It appeared impossible to measure directly the dependence $A^+(I)$ in our experiment since the change in the laser intensity was accompanied by the variation of the number of target atoms. We performed the simulation by basing on the maxima amplitude ratio A_1^+/A_2^+ at minimal ε and on the ratio of the populations of the corresponding levels N_1/N_2 used to estimate the transition probability ratio $W_1/W_2 = A_1^+N_2/A_2^+N_1$ and the saturation intensity ratio $I_1/I_2 = \sqrt[3]{W_2/W_1}$. The dependence of the ion yield on the laser intensity in the case of the absence of saturation was described by the relation $A^+ \sim I^3$ while the ion signal saturation region ($I > I_1$ for curve *1* and $I > I_2$ for curve *2*) by the relation $A^+ \sim I^{1.5}$ [8]. Note that we deal here with the ion signal exactly at the resonance.

It is clearly seen from Fig. 2,*b* that the ratio of ion signals in the maxima at different laser intensities is determined by the mutual position of curves *1* and *2*. At low intensities ($I < I_1$), the amplitude of the maximum due to the transition from the $^7F_4$ level is larger (curve *1* lies above curve *2*). With increase in the laser intensity,

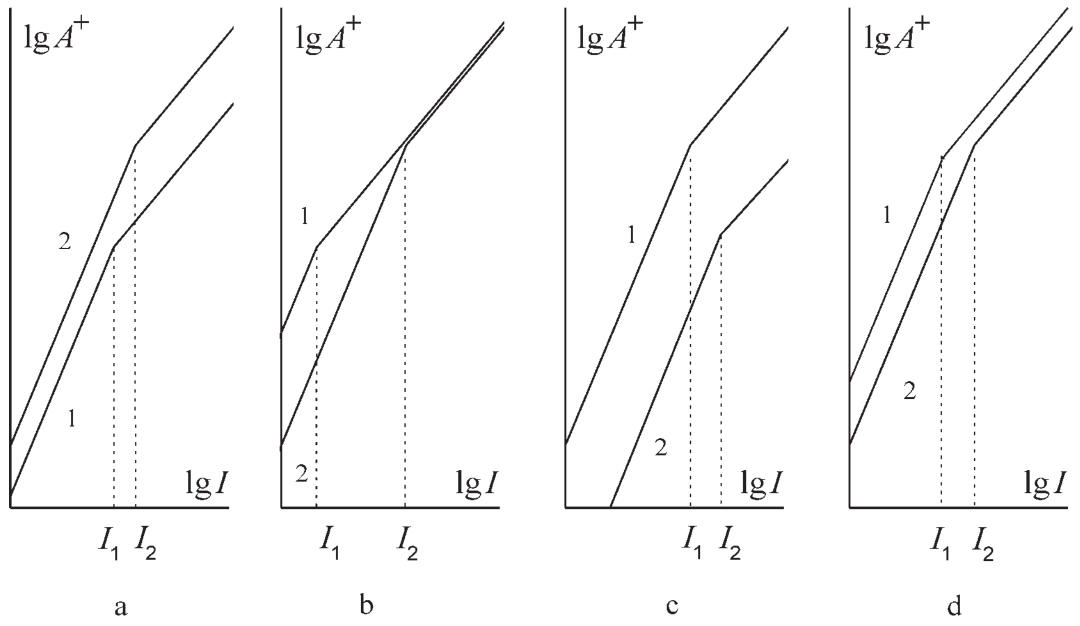

Fig. 3. Ion signal as a function of the laser intensity on the double log scale. Curve *1* corresponds to a more probable transition, curve *2* — to a less probable one

the ion signal saturation for the $^7F_4 \rightarrow E_2$ transition is reached earlier. In this case within the $I_1 < I < I_2$ intensity range, the ion signal rise for the $^7F_4 \rightarrow E_2$ transition is slowed down ($A^+ \sim I^{\,1.5}$), while that for the $^7F_2 \rightarrow E_1$ transition does not change ($A^+ \sim I^{\,3}$). Thus, the amplitudes of the maxima under consideration become equal first (curves *1* and *2* meet), and then the amplitude of the maximum corresponding to the $^7F_2 \rightarrow E_1$ transition becomes larger (now curve *2* lies above curve *1*). Hence, the observed redistribution of the amplitudes of the maxima with a variation in the field strength (Fig. 1) is explained by different conditions of ion signal saturation for the $^7F_2 \rightarrow E_1$ and $^7F_4 \rightarrow E_2$ transitions (Fig. 2,*b*).

It is obvious that the maxima amplitude redistribution will be observed only in the case if the condition $W_1N_1 > W_2N_2$ in the absence of saturation holds true (i.e. curve *1* lies above curve *2*). Otherwise, the dependence $A^+(I)$ will have form shown in Fig. 3,*a*. That is, at any value of the laser intensity, the amplitude of the maximum due to the less probable transition but from the more populated level (curve *2*) will exceed that for the more probable transition but from the less populated level (curve *1*). In this case, with increase in the laser intensity, the amplitude A_1^+ will "fall behind" the amplitude A_2^+.

It should be noted that the condition $W_1N_1 > W_2N_2$ is a necessary but not a sufficient condition in order to observe the redistribution of maxima. At a certain ratio of probabilities W and populations N, the dependence $A^+(I)$ may have form shown in Fig. 3,*b*. That is, with increase in the laser intensity, the maximum due to the less probable transition but from the more populated level (curve *2*) will "overtake" the maximum corresponding to the more probable transition but from the less populated level (curve *1*) by amplitude though will not "outride" it. A similar behavior is also seen for the $A^+(I)$ dependences in the case where the less probable transition occurs from the less populated level (Fig. 3,*c*), as well as where the initial levels are equally populated (Fig. 3,*d*). Note that, for definiteness, the curves in Fig. 3 are simulated for the pairs of transitions from the $^7F_2$, $^7F_4$ levels (*a*—*c*) and $^7F_2$, $^7F_2$ levels (*d*). The ratios of the transition probabilities in this case are as follows: $W_1/W_2 = 2.6 (N_1 < N_2)$ (*a*), $W_1/W_2 = 52 (N_1 < N_2)$ (*b*), $W_1/W_2 = 3.8 (N_1 > N_2)$ (*c*) and $W_1/W_2 = 4 (N_1 = N_2)$ (*d*).

From the dependences shown in Figs. 2,*b*, 3,*a*—*d*, one may conclude that, with increase in the laser intensity, the ratio of the amplitudes of maxima is changed in favor of those resulting from less probable two-photon transitions. This is due to the fact that, for more probable transitions, the ion signal saturation takes place earlier ($I_1 < I_2$). In the case where less probable transitions occur from more populated levels, a drastic redistribution of the amplitudes of maxima can be observed: the maxima due to the above transitions not only "overtake", but in many cases even "outride" the maxima corresponding to more probable transitions but from less populated levels by amplitude. One may add that the above dependences $A^+(I)$cover almost all qualitatively possible cases: $W_1 > W_2$, $N_1 < N_2$ (Figs. 2,*b*, 3,*a*,*b*), $W_1 > W_2$, $N_1 > N_2$ (Fig. 3,*c*), $W_1 > W_2$, $N_1 = N_2$ (Fig. 3,*d*).

The analysis of the three-photon ionization spectra measured within the $\omega = 17000 \div 18450$ cm^{-1} range at different laser field strengths has shown that, in most cases, the behavior of the resonance maxima with a variation in ε is explained quite well by the dependences shown in Figs. 2,*b*, 3,*a*—*d*. It should be noted, however, that a detailed analysis of the behavior of the maxima is complicated in many cases since a lot of resonance maxima corresponds not to one but to two and more different transitions [2]. The behavior of such maxima is now determined by the sum of all the transitions contributing to a maximum.

The above mechanism of the redistribution of the amplitudes of resonance maxima explains well the fact that, with increase in the laser field strength, the maxima due to the two-photon transitions from poorly populated levels ($^7F_{5,\ 6}$) are, as a rule, weakly revealed or even not revealed at all in the three-photon ionization spectra [2]. Meanwhile, they are not only clearly revealed at low ε, but can even exceed the maxima due to the transitions from the most populated levels ($^7F_{1,\ 2}$) by amplitude.

As an example, consider a fragment of the three-photon ionization spectrum for a Sm atom (see Fig. 4) measured at different ε in the vicinity of the two-photon transitions $^7F_1 \to E_1$ and $^7F_5 \to E_2$ ($E_1 = 35101.0$ cm^{-1}, $J_1 = 3$ and $E_2 = 37933.0$ cm^{-1}, $J_2 = 3$, 4 [2, 7, 9]). It is clearly seen that, at a low field strength, only a single maximum is observed ($\omega = 17403.85$ cm^{-1}) being due to the two-photon transition from the $^7F_5$ level. This testifies, taking into account that the $^7F_1$ level population is larger by more than 17 times, to a considerably higher probability of the transition from the $^7F_5$ level ($W \sim A^+/N$). With increase in ε, the maximum corresponding to the two-photon transition from the $^7F_1$ level appears at the wavenumber $\omega = 17404.2$ cm^{-1}. The further rise of the field strength leads to the redistribution of the amplitudes of the observed maxima: the amplitude of the maximum corresponding to the transition from the $^7F_1$ level gradually exceeds the amplitudes of the maximum due to the transition from the $^7F_5$ level which is not almost revealed in the dependence $A^+(\omega)$ at the maximal ε.

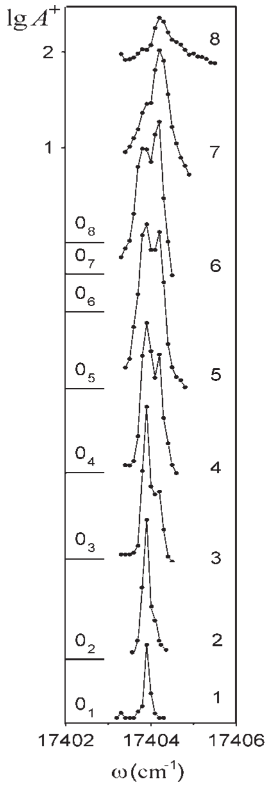

Fig. 4. Wavenumber dependences of the Sm$^+$ ion yield (on the log scale) measured in the vicinity of two-photon transitions from the levels $^7F_5$(ω = 17403.85 cm^{-1}) and $^7F_1$(ω = 17404.2 cm^{-1}) at different field strengths, V/cm: 2.4×10^4 (*1*), 5.4×10^4 (*2*), 7.7×10^4 (*3*), 1.6×10^5 (*4*), 2.1×10^5 (*5*), 3.1×10^5 (*6*), 4.7×10^5 (*7*), 5.4×10^5 (*8*)

The redistribution of the amplitudes of maxima is caused, similarly to the previous case (see Fig. 1), by the faster saturation of the ion signal at the wavenumber of the more probable transition but from the less populated level $^7F_5 \to E_2$. The cause for the lack of the maximum corresponding to the transition from the $^7F_5$ level is related to the considerable difference between the number of atoms ionized owing to the resonance three-photon ionization from this level (2%) and the number of atoms ionized due to the direct three-photon ionization from all other levels (98%). With increase in the field strength, the saturation of the ion signal owing to the resonance ionization is reached earlier than that of the signal due to the direct ionization because of the considerably higher probability of the former process. Therefore, the rate of increase of the total ion signal, against the background of which the resonance maximum is revealed, exceeds that for the amplitude of this maximum, thus resulting in a drastic reduction of the amplitude of the maximum and its considerable broadening.

It should also be noted that, owing to the extremely dense resonance structure of the three-photon ionization spectra for a Sm atom (in some intervals up to two maxima per 1 cm^{-1} [1, 2]), the proximity of adjacent, more intense maxima affects the manifestation of small-amplitude maxima. The latter are weakly revealed and even nor revealed at all against the background of more intense maxima, as occurs, for instance, in the cases under consideration (see Fig. 1, curves *5, 6*; Fig. 4, curves *7, 8*). We add that the level of the ion signal against which the resonance maxima are revealed is determined in the case of a Sm atom not only by the direct three-photon ionization but, to a great extent, by the resonance ionization owing to the overlapping of closely located resonance maxima. This makes the conditions of the clear manifestation of resonance maxima due to the transitions from weakly populated levels ($^7F_{5,\ 6}$) at larger ε to be more severe.

While comparing only curves *1* and *8* in Fig. 4 measured at minimal and maximal ε, respectively, without regard for curves *2—7* obtained at intermediate ε, we meet the illusion that the resonance maximum (ω = 17403.85 cm^{-1}) is shifted with increase in the field strength toward larger wavenumbers (ω = 17404.2 cm^{-1}). In fact, as shown above, these are two completely different maxima, one of which is clearly revealed at low ε, while the second one — at higher ε. Secondly, the dependences $A^+(\omega)$ measured at different field strengths differ by the number of maxima. Curves *4—6* show two clear maxima each, while all other curves only one.

Hence, one may conclude that it is correct to compare separate intervals of the dependence $A^+(\omega)$ only provided they are measured at the same field strength.

As noted above, at low ε, the maxima due to the two-photon transitions from less populated levels exceed, as a rule, those corresponding to the transitions from more populated levels. This indicates that the two-photon transitions from the less populated levels are more probable than those from the more populated levels. This seems quite consistent, since the less populated levels have larger total momenta J. In the case of multiplet transitions, the highest probability is seen, as a rule, for the transitions from the levels with larger J. For example, in the case of one-photon multiplet transitions, their probability is by 1–3 orders of magnitude higher than that for the transitions between the levels with small J [10]. A similar ratio of probabilities will be observed, probably, for two-photon transitions as well. Note that no data on the two-photon transition probabilities in the Sm spectrum are available.

The fact that the maxima due to various transitions behave differently with a variation in the field strength can be used to identify the resonance structure of the three-photon ionization spectra of a Sm atom. Consider, for example, the dependences $A^+(\omega)$ shown in Fig. 5. The observed maxima, according to [2, 7, 9], are due to the two-photon transitions $^7F_2 \rightarrow E_1$ (A), $^7F_3 \rightarrow E_2$ (B), and $^7F_1 \rightarrow E_3$ (C) (E_1 = 35327.9 cm^{-1}, $J_1 = 4$; E_2 = 36007.5 cm^{-1}, $J_2 = 3$; E_3 = 34812.0 cm^{-1}, $J_3 = 3$). It is seen well that, at minimal ε, the largest amplitude is observed for maximum B, whereas maximum C corresponding to the transition from the most populated level $^7F_1$ has the lowest amplitude. With increase in the field strength, maximum C outstrips maximum A by amplitude and its amplitude at maximal ε is nearly equal to that of maximum B.

The observed change in the ratio of the amplitudes of maxima B and C, similarly to the previous cases (see Figs. 1, 4), is easily explained by the faster ion signal saturation at the wavenumber of the more probable transition but from the less populated level $^7F_3 \rightarrow E_2$. The probability of ionization from the $^7F_3$ level, taking into account the ratio of the amplitudes of the maxima ($A_B/A_C \approx 5.7$) at minimal ε (Fig. 5, curve *1*) and that of the populations of levels ($N_1/N_3 \approx 2.7$), is approximately 15 times larger than the probability of ionization from the $^7F_1$ level.

As for maximum A, though the wavenumber ω = 17258.0 cm^{-1} corresponds formally to the two-photon transition $^7F_2 \rightarrow E_1$ [2, 7], it is not this transition which dominates here and determines the behavior of maximum A. The simulation of the dependences $A^+(I)$ shows that, in the case if maximum A were due to the transition from the $^7F_2$ level, an increase of the field strength would result in an enlargement of the relative amplitude of this maximum (see Fig. 6,*a*, curve A). At the maximal ε, maximum A should have the largest amplitude. However, it is not observed. The fact that, with increase in the field strength, a distinct reduction of the amplitude growth rate for maximum A is observed as compared to that of maxima B and C clearly indicates that maximum A is due to the transition which (i) is more probable than the transitions from the $^7F_1$ and $^7F_3$ levels and (ii) originates from the level with the population less than that of the $^7F_3$ level. The simulation of the $A^+(I)$ dependences with the inclusion of the ratio of the amplitudes of maxima A, B, and C at different ε allows us to conclude that maximum A is probably related to the two-photon transition $^7F_4 \rightarrow E = 36789.1$

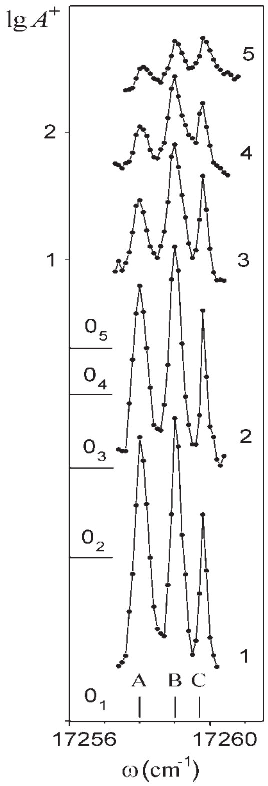

Fig. 5. Wavenumber dependences of the Sm$^+$ ion yield (on the log scale) measured in the vicinity of maxima $A(\omega = 17258.0 \text{ cm}^{-1})$, $B(\omega = 17259.0 \text{ cm}^{-1})$, and $C(\omega = 17259.7 \text{ cm}^{-1})$ at different field strengths, V/cm: 1.6×10^5 (*1*), 2.5×10^5 (*2*), 3.4×10^5 (*3*), 4.9×10^5 (*4*), 5.4×10^5 (*5*)

cm^{-1}. In this case, the shape of curve A (see Fig. 6,*b*) describes well the behavior of maximum A with a variation in the field strength (see Fig. 5). The probability of this transition is twice larger than that from the $^7F_3$ level and 28 times larger than that from the $^7F_1$ level. As for the two-photon transition $^7F_2 \to E_1$, it is weak in this case and has no considerable effect on the behavior of maximum A. Note that no data on the level with $E = 36789.1$ cm^{-1} have been found in the literature.

4. Conclusions

The change in the resonance structure of the two-photon resonantly enhanced three-photon ionization spectra for a Sm atom with a variation in the field strength is due to the different conditions of the ionization saturation for different transitions. The ratio of the amplitudes of resonance maxima depends on the field strength, probability of the corresponding transitions, and the population of levels, from which the above transitions originate.

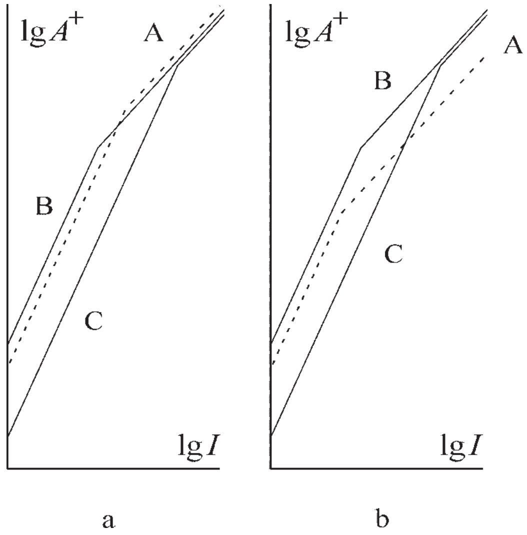

Fig. 6. Ion signal in the maxima A, B, and C as a function of the laser intensity on the double log scale: *a* — maximum A corresponds to the transition from the $^7F_2$ level; *b* — maximum A corresponds to the transition from the $^7F_4$ level

With increase in the laser field strength, the ratio of the amplitudes of resonance maxima changes in favor of the maxima which result from less probable two-photon transitions. This is explained by the more rapid ion signal saturation at the wavenumbers of more probable transitions. In the case where less probable transitions occur from more populated levels, a drastic redistribution of the amplitudes of resonance maxima may be observed: with increase in ε, the maxima due to the above transitions not only “overtake” but in many cases even “outride” the maxima corresponding to more probable transitions but from less populated levels by amplitude.

With increase in the field strength, the maxima due to the two-photon transitions from poorly populated levels ($^7F_{5,\ 6}$) are, as a rule, weakly revealed or even not revealed at all in the three-photon ionization spectra. At the same time at low ε, they are not only clearly revealed, but even exceed the maxima corresponding to the transitions from the most populated levels ($^7F_{1,\ 2}$).

The change of ε can result in the vanishing of certain resonance maxima and in the appearance of other resonance maxima. To observe clearly a certain maximum, one has to choose corresponding experimental conditions.

Thus, it is possible to correctly compare separate intervals of the dependence $A^{+}(\omega)$ only provided they are measured at the same field strength.

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ПРО ПРОЯВ ДВОФОТОННИХ РЕЗОНАНСІВ ПРИ ТРИФОТОННІЙ ІОНІЗАЦІЇ АТОМА САМАРІЮ

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Резюме

Розглянуто причини зміни резонансної структури спектрів двофотонно резонансно-підсиленної трифотонної іонізації атома самарію у відносно слабких полях ($\varepsilon < 6 \cdot 10^5$ В/см). Із зміною величини напруженості поля лазерного випромінювання спостерігається значний перерозподіл амплітуд резонансних максимумів. Показано, що основною причиною цього є неоднакові умови насичення процесу іонізції для переходів, що різняться між собою ймовірностями та заселеностями початкових рівнів.