SINGLE-COLOR THREE-PHOTON SPECTROSCOPY OF EXCITED STATES OF A SAMARIUM ATOM

O.I. GOMONAI

Institute of Electron Physics, Nat. Acad. Sci. of Ukraine
(21, Universytets'ka Str., Uzhgorod 88000, Ukraine; e-mail: vkel@mail.uzhgorod.ua)

UDC 539.18

A technique of single-color three-photon resonance-ionization spectroscopy of highly excited even-parity states of a samarium atom is developed. It provides the use of only one source of laser radiation and is based on the detection in three-photon ionization spectra measured at different strengths of the laser field of groups of maxima due to the excitation of the same upper levels from different initial levels of the ground term. The spectrum of even-parity states of a samarium atom located in the energy range 34298–40527 cm^{-1} is investigated. The energies and total momenta of 272 states are determined. Sixteen new even-parity states, data on which are absent in the literature, are discovered.

1. Introduction

Samarium belongs to the group of rare earth elements (REE), for which the originality of the spectra of energy levels is conditioned by the presence of the inner $4f$ unfilled shell. The investigation of this group of atoms is of a purely scientific interest associated with studying the peculiarities of the completion of the inner shell after the outer shell is already filled and of a practical interest caused, in particular, by the possibility to create REE vapor lasers, the solution of important astrophysical problems related to the determination of the REE concentrations in the atmosphere of the Sun and other stars, etc.

The $4f^6$-shell of a samarium atom is less than half filled, which defines the extremely dense and complicated spectrum of its electronic states [1]. A close arrangement of levels causes a considerable configuration interaction conditioned by intershell correlations of s- and f-electrons, which essentially complicates the interpretation and theoretical calculations of the samarium spectrum [2]. In spite of a rather large number of experimental papers devoted to the spectroscopy of samarium (see, for example, [3–13]), the spectrum of its energy levels is insufficiently investigated up to now. First of all, this concerns highly excited bound states located in the energy region higher than 30000 cm^{-1} that are of maximal interest with regard for the possibility of their practical use.

The overwhelming majority of the data on highly excited levels of a samarium atom available in the literature is obtained with the help of the method of stepwise multicolor laser spectroscopy [3–11] that represents the most precise and widely used method of investigation of the energy structure of complicated atoms and molecules for today [14]. However, its application requires the use of at least two sources of laser radiation, which represents a rather complicated technical problem. In the case of a samarium atom, with regard for the peculiarity of its electronic structure, one can successfully apply the single-color laser spectroscopy using only one radiation source. The given paper is devoted to the single-color three-photon resonance-ionization spectroscopy of even-parity highly excited states of a samarium atom. It is the states that are very prospective for the use in schemes of multicolor photoionization while solving the various problems concerning selective population, namely isotope separation, production of superpure substances, ultrasensitive spectral analysis, etc. [15].

2. Experiment

A linearly polarized radiation of a pulsed dye laser FL2001 (Lambda Physik) pumped with the second harmonics of a Nd:YAG-laser was focused with the help of a lens with a focal distance of 16 cm into a vacuum chamber, where it intersected a beam of samarium atoms formed by an effusive source at right angle. Samarium ions formed in the region of interaction of the atomic and laser beams were extracted by a constant electric field and, after passing through a time-of-flight mass spectrometer, were detected by a microchannel detector of the VEU-7 type.

In the course of experiments, we measured the dependences of the yield of single-charged samarium ions on the frequency of laser radiation $N^+(\omega)$ at various values of the strength of the laser radiation field in the interaction region.

The frequency of the laser radiation ω was varied in the range 16700–18450 cm^{-1}. In this case, the width of the radiation line amounted to $\sim$ 0.2 cm^{-1}. The determination of the absolute value of the frequency to within ± 0.2 cm^1 was performed by both the optogalvanic spectrum of a hollow-cathode Cu-Ne lamp and the transmission spectrum of a Fabry–Perot interferometer which were measured simultaneously with the dependence $N^+(\omega)$. The maximal value of the strength of the laser radiation field in the interaction region didn't exceed 7×10^5 V/cm. The concentration of samarium atoms was approximately equal to 10^{10} cm^{-3}.

The ionization of samarium atoms took place due to the absorption of three photons, i.e. the three-photon ionization occurred. In this case, the two-photon excitation of even-parity states manifested itself in the dependence $N^+(\omega)$ in the form of resonance maxima. For example, Fig. 1 presents a fragment of the dependence $N^+(\omega)$ measured in the frequency range 17940–18150 cm^{-1} at a laser radiation field strength of $\varepsilon \approx 1.9 \times 10^5$ V/cm, which gives a full idea of the whole investigated region. It's worth marking out a high density of the resonance structure that reaches two maxima per 1 cm^{-1} in some spectral regions.

The field strength was decreased by means of a variation of the position of a focusing lens with respect to that of the "exact" focus performed with the help of a micrometer screw. In this case, an increase of the focal volume resulted in a corresponding rise of the number of samarium atoms in the interaction region. This fact allowed one to properly register the resonance structure at low values of the field strength. The magnitude of the field strength in the interaction region was calculated by using the values of radiation energy, the pulse duration (~12 ns), and the cross section of the laser beam that was determined for different positions of the focusing lens by means of the solution of the equation of caustic [16].

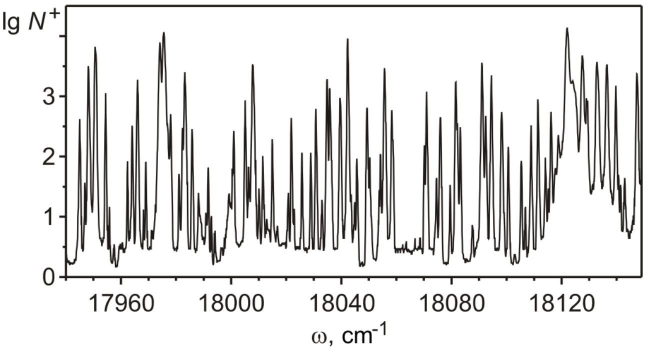

Fig. 1. Fragment of the three-photon ionization spectrum of a samarium atom

3. Technique of Single-Color Three-Photon Resonance-Ionization Spectroscopy

A distinctive feature of the spectrum of electronic states of a samarium atom lies in the fact that its ground term represents a septet ^7F [1], all of whose levels are populated even at relatively low temperatures. For example, at a working temperature of the atom source of $\sim$ 900 K, the levels are populated according to the Boltzmann distribution in the following way: 18 ($^7F_0$), 35 ($^7F_1$), 26 ($^7F_2$), 13 ($^7F_3$), 5 ($^7F_4$), 2 ($^7F_5$), and 0.5% ($^7F_6$). With regard for this fact, the excitation of a certain level according to the selection rules can occur due to the transitions from several different levels of the ground term ^7F. In the case of even-parity excited states of a samarium atom, they are presented by the two-photon transitions determined by the selection rules $P_o = P_n$ and $\Delta J = 0, \pm 1, \pm 2$, where P_o and P_n are the parities of the ground and excited states, J is the total angular momentum. Additionally forbidden transitions are the two-photon $J = 0 \rightarrow J = 1$ and $J = 1 \rightarrow J = 0$ ones [17]. As for the selection rules concerning the S and L quantum numbers, one can expect their essential violation taking into account the deviation from the „pure" LS-coupling taking place for heavy atoms, to which samarium belongs. This fact is confirmed by the presence of intense lines caused by the transitions, for which $\Delta S \neq 0$ and $\Delta L \geq 2$, in the absorption and emission spectra of samarium [18].

Thus, observing a group of maxima corresponding to two-photon transitions from different initial levels to the same excited level and determining their position, one can find the energy E of this excited level:

$$E = \sum_i (E_i + 2\omega_i)/i,$$

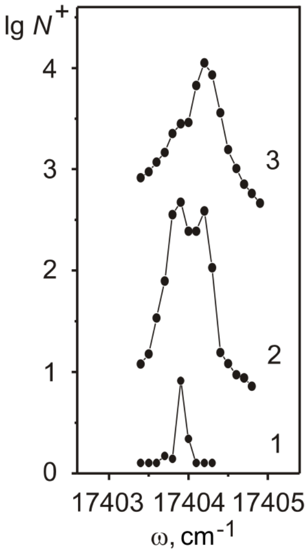

Fig. 2. Dependence of the yield of Sm$^+$ ions on the frequency of laser radiation measured in the neighborhood of two-photon transitions from the levels $^7F_5$ (ω = 17403.9 cm^{-1}) and $^7F_1$ (ω = 17404.2 cm^{-1}) at various values of the fielf strength: $\varepsilon_1 \approx 5.6\times10^4$ V/cm, $\varepsilon_2 \approx 1.9\times10^5$ V/cm, and $\varepsilon_3 \approx 4.5\times10^5$ V/cm

where E_i stands for the energy of the initial level [1], from which the transition takes place, ω_i is the frequency at which the maximum corresponding to the transition from the given initial level is observed, and i is the number of the observed maxima ($i \leq 5$). The total angular momentum J of the excited level is determined according to the selection rules based on the values of the total angular momentum of the initial levels from which the transitions are observed. We developed a program that analyzed all possible combinations of the observed maxima and, on the basis of the comparison with experimental data, determined the energies and total angular momenta of excited levels. In this case, the maxima were combined into groups in such a way that the difference between the calculated value of the frequency and its experimentally observed magnitude didn't exceed 0.2 cm^{-1}. This fact allowed one to essentially decrease the probability of the appearance of a "strange" maximum in the group, which was high in view of a large density of the resonance structure (see Fig. 1).

It's worth noting that not all possible two-photon transitions allowed by the selection rules can clearly manifest themselves in the form of resonance maxima in the dependence $N^+(\omega)$ measured at a certain value of the strength of the laser radiation field in the interaction region. This is related to the fact that the form of a resonance structure essentially depends on the field strength [19]. The resonance structure of spectra of three-photon ionization of a samarium atom represents a collection of maxima caused by transitions from all the seven levels of the ground term. Different probabilities of the transitions as well as unequal populations of lower levels, from which the transitions take place, result in different conditions of saturation of the ionization process for various transitions. This fact causes the unequal behaviors of the corresponding resonance maxima following the variation of the field strength. It's also worth adding that, with regard for the high density of the resonance structure, the maxima can overlap. That's why it's difficult to discover less intense maxima against the background of more intense ones.

Investigations [19] have demonstrated that, with increase in the strength ε of the laser radiation field, the relation between the amplitudes of resonance maxima changes in the favor of those conditioned by less probable two-photon transitions, which is explained by a faster saturation of the ion signal at frequencies corresponding to more probable transitions. In the case where less probable transitions take place from more populated initial states, an increase of the field strength can result in a cardinal redistribution of the amplitudes of the resonance maxima: with increase in the field strength, maxima with initially lower amplitudes start to exceed those with initially higher amplitudes. In addition, with a variation of ε value, one can observe the vanishing of some maxima and the appearance of other ones.

In the case of multiplet transitions, the most probable of them are usually those taking place from levels with a high value of J [17]. At the same time, in accordance with the Boltzmann distribution, levels with large J are the least populated. This results in the fact that maxima caused by two-photon transitions from the least populated levels $^7F_5$ and $^7F_6$ are very weak or don't appear at all in the dependence $N^+(\omega)$ at high values of the field strength. At the same time, at low values of ε, they clearly manifest themselves and can even exceed, by the amplitude, the maxima caused by transitions from more populated levels.

For example, Fig. 2 shows the dependence $N^+(\omega)$ measured at three values of the field strength in the neighborhood of the two-photon transitions $^7F_5 \rightarrow E_1$ and $^7F_1 \rightarrow E_2$ (E_1 = 37933.0 cm^{-1}, J_1=3, 4, and E_2 = 35101.0 cm^{-1}, J_2=3 [9, 11]). One can see that, at the extreme ε values, only one of the two maxima is observed; in particular, at low ε_1 – the one corresponding to the transition from the less populated level $^7F_5$, whereas at high ε_3 – that corresponding to the transition from the level $^7F_1$, which is the most populated one.

At $\varepsilon_2 \approx 1.9 \times 10^5$ V/cm, both maxima clearly manifest themselves in the dependence $N^+(\omega)$.

It's worth noting that the magnitudes of the field strength indicated in Fig. 2 were fitted experimentally rather than chosen at random. For example, ε_2 represents the value, at which (as was shown by detailed investigations) there appears the maximal number of possible maxima in the dependence $N^+(\omega)$. The value ε_1 is the least possible, at which the recording apparatus still reliably registers the ion signal. The value ε_3 is the highest possible, at which the ion signal isn't yet distorted by the effect of 100% ionization of samarium atoms in the region where the laser radiation is focused. Measurements performed at the field intensities ε_1 and ε_3 allow one to discover additional maxima that already manifest themselves or still don't in the dependence $N^+(\omega)$ at the strength ε_2, taking into account the regularity of a redistribution of the amplitudes of maxima with variation of ε, what was discussed above.

Thus, the investigation of the spectrum of excited even-parity states of a samarium atom includes the following steps:

– Measurements of the dependence $N^+(\omega)$ at three above-mentioned values of the strength of the laser radiation field in the interaction region, which allows one to discover the overwhelming majority of resonance maxima. Moreover, in all the three cases, a specific value of ε must be maintained constant in the whole spectral region, which gives a possibility to correctly compare separate regions of the dependences $N^+(\omega)$.

– Determination of the energies and total angular momenta of even-parity excited states on the basis of the registration of the positions of maxima associated with the two-photon excitation of the same upper levels from different initial levels of the ground term.

It's worth noting that, in addition to the maxima associated with the two-photon excitation of even-parity states, one also observes those caused by the one-photon excitation of odd-parity states in the dependence $N^+(\omega)$. However, their identification doesn't present any difficulties taking into account their small number and the well-known energies of these states [1].

4. Results

Applying the proposed technique of single-color three-photon resonance-ionization spectroscopy, we investigated the spectrum of highly excited even-parity states of a samarium atom. The energies and total angular momenta of 272 states located in the energy region 34298–40527 cm^{-1} were determined. These data are presented in the Table. The comparison of our values of the energies with those obtained by other authors has demonstrated that they are in good agreement.

In many cases, the comparison of the amplitudes of maxima in the groups corresponding to the excitation of the same upper level from different initial levels of the ground term testifies to their essentially nonuniform relationship. Even the maxima conditioned by transitions from two neighbor levels to a certain excited one can have amplitudes that differ from one another by several times. With regard for the population of levels, the performed analysis has demonstrated that the probabilities of two-photon transitions from different initial levels to the same upper one can differ by more than an order of magnitude. In some cases, this fact makes it impossible to discover the corresponding maxima and, consequently, to unambiguously establish the total moment of some excited levels.

In the energy range $E = 35768.9 \div 38855.7$ cm^{-1}, we also discovered new even-parity states of a samarium atom, data on which were absent in the literature. In the Table, they are marked by the index #. According to the selection rules with respect to J, all these states could be excited in experiments performed in [11], and the lowest of them – in [8,9]. However, their excitation wasn't observed in the indicated papers. A possible reason for this fact lies in a small probability of the two-color stepwise excitation of these states. In addition, we didn't manage to unambiguously determine the total angular momentum for the seven uppermost levels ($E = 37712.3 \div 38855.7$ cm^{-1}) (see the Table). This is caused by the fact that a part of the transitions caused by the excitation of these levels didn't fall into our spectral region. If we suppose that the total angular momentum of the considered levels $J \geq 5$, the absence of data on them in work [11] can be explained by the fact that, in this paper, only states with $J = 0 \div 4$ could be excited.

5. Conclusions

We have developed a technique of single-color three-photon resonance-ionization spectroscopy of highly excited even-parity states of a samarium atom based on the detection of the groups of maxima, which are caused by the excitation of the same upper levels from different initial levels of the ground term, in spectra of three-photon ionization measured at various values of the strength of the laser radiation field.

Energies and total angular momenta of even-parity states of a samarium atom

№	E, cm^{-1}	J	№	E, cm^{-1}	J	№	E, cm^{-1}	J	№	E, cm^{-1}	J	№	E, cm^{-1}	J
1	34298.7^{ac}	2	56	35544.9^{ae}	1	111	36362.3^{e}	2	166	37164.8^{e}	2	221	38258.9^{e}	3.4
2	34312.1^{ac}	1.3	57	35547.6^{ae}	2	112	36364.1^{e}	3	167	37171.2^{e}	1	222	38292.6^{e}	1
3	34346.2^{c}	2	58	35569.4^{ae}	2	113	36377.2^{e}	1	168	$37175.0^{\#}$	2	223	38316.7^{e}	2
4	34395.3^{a}	1.3	59	35580.0^{c}	4	114	36391.4^{e}	2	169	37214.3^{e}	2	224	38360.3^{e}	3.4
5	$.34399.1^{ac}$	1	60	35582.0^{e}	3	115	36395.7^{e}	4	170	$37244.5^{\#}$	3	225	38381.5^{e}	2
6	34438.2^{ac}	2	61	35589.2^{c}	4	116	36404.0^{e}	1	171	37270.4^{e}	1.2	226	38406.4^{e}	3.4
7	34517.3^{a}	1.3	62	35594.1^{ae}	2	117	36409.3^{e}	3	172	37340.0^{e}	1	227	38413.4^{e}	2
8	34522.4^{ac}	3	63	35605.3^{ae}	3	118	36457.1^{e}	4	173	37343.1^{e}	3	228	38439.6^{e}	3.4
9	34561.9^{a}	2	64	35612.7^{e}	4	119	36463.3^{e}	4	174	37356.5^{e}	1.2	229	38443.6^{e}	3.4
10	34571.0^{c}	2	65	35652.0^{ae}	1	120	36474.6^{e}	2	175	37357.3^{e}	3	230	38528.4^{e}	3.4
11	34590.4^{acd}	2	66	35679.7^{ae}	3	121	36483.1^{e}	4	176	37387.2^{e}	1, 2	231	38591.2^{e}	3
12	34630.8^{cd}	1	67	35700.0^{e}	1	122	36515.4^{e}	2	177	37416.5^{e}	1	232	38596.0^{e}	3
13	34657.5^{acd}	1	68	35730.7^{ae}	3	123	36535.3^{e}	3	178	37430.3^{e}	1	233	$38605.6^{\#}$	4–6
14	34660.1^{acd}	3	69	35742.2^{e}	1	124	$36536.7^{\#}$	1.3	179	37445.6^{e}	4	234	38608.9^{e}	2
15	34670.0^{c}	3	70	35747.0^{ae}	2	125	36543.8^{e}	4	180	37449.6^{e}	2	235	38700.6^{e}	2
16	$.34713.1^{acd}$	1	71	35748.8^{ae}	3	126	36553.4^{e}	4	181	$37477.4^{\#}$	5	236	38709.0^{e}	4
17	34723.4^{ac}	2	72	$35768.9^{\#}$	2	127	36565.5^{e}	1	182	37494.0^{e}	1	237	$38713.5^{\#}$	4–6
18	34736.5^{acd}	3	73	35776.6^{c}	4	128	36572.0^{e}	3	183	37568.7^{e}	3	238	38720.4^{e}	3
19	34774.8^{acd}	3	74	35779.3^{abe}	3	129	36576.9^{e}	4	184	37576.8^{e}	2	239	38734.0^{e}	3
20	34796.0^{acd}	2	75	35785.7^{e}	1	130	36587.4^{e}	3	185	37588.3^{e}	4	240	38760.5^{e}	3
21	34812.0^{acd}	3	76	35821.3^{e}	2	131	36592.8^{e}	2	186	37616.5^{e}	3	241	38764.2^{e}	3
22	34865.6^{ac}	2	77	35839.1^{e}	2	132	36618.1^{e}	2	187	37629.9^{e}	2	242	38773.5^{e}	3
23	34921.6^{acde}	2	78	35846.2^{e}	3	133	36625.9^{e}	4	188	37656.2^{e}	3.4	243	38793.3^{e}	3
24	34932.7^{acd}	1	79	35874.3^{e}	3	134	36628.4^{e}	1	189	37678.6^{e}	1	244	38803.7^{e}	4
25	34969.8^{acde}	3	80	35879.8^{e}	4	135	36637.8^{e}	4	190	37707.5^{e}	1	245	38817.7^{e}	2
26	35020.2^{c}	3	81	35906.0^{c}	5	136	36644.6^{e}	1	191	$37712.3^{\#}$	3–5	246	38848.2^{e}	2
27	35045.6^{ace}	3	82	35920.6^{e}	4	137	36682.5^{e}	3	192	37717.8^{e}	3.4	247	$38855.7^{\#}$	4–6
28	35047.2^{acde}	1	83	35931.9^{e}	2	138	36701.8^{e}	2	193	37762.5^{e}	3.4	248	38883.3^{e}	3
29	35069.9^{acde}	1	84	35959.3^{e}	1.2	139	36732.4^{e}	4	194	37812.6^{e}	1	249	38891.5^{e}	2
30	35072.8^{a}	2	85	36003.8^{ce}	4	140	36748.3^{e}	4	195	$37814.9^{\#}$	3–5	250	38909.9^{e}	2
31	35089.5^{acde}	3	86	36007.5^{e}	3	141	36760.1^{e}	2	196	37825.4^{e}	1.2	251	38916.6^{e}	3
32	35101.0^{ac}	3	87	36024.5^{e}	1	142	36763.2^{e}	3	197	37878.3^{e}	3.4	252	38926.6^{e}	4
33	35135.6^{ac}	1	88	36031.8^{e}	3	143	36776.5^{e}	3	198	37879.7^{e}	3.4	253	38946.3^{e}	3
34	35138.1^{ace}	2	89	36057.8^{e}	2	144	36778.2^{e}	2	199	37904.5^{e}	3.4	254	38966.3^{e}	2
35	35155.1^{ace}	2	90	36084.8^{e}	3	145	36812.8^{e}	3	200	37933.0^{e}	3.4	255	38990.1^{e}	4
36	35163.9^{acde}	1	91	36087.5^{e}	3	146	36834.9^{e}	1	201	37943.8^{e}	1	256	39014.0^{e}	4
37	35169.5^{ace}	3	92	36095.6^{e}	4	147	36841.6^{e}	4	202	37967.8^{e}	1	257	39066.3^{e}	4
38	35222.2^{ae}	2	93	36134.0^{e}	3	148	36855.6^{be}	3	203	37971.3^{e}	2	258	39087.6^{e}	4
39	35226.0^{ac}	1.3	94	36138.8^{e}	4	149	36863.3^{e}	4	204	38034.1^{e}	3.4	259	39114.2^{e}	4
40	35235.9^{c}	4	95	$36145.9^{\#}$	1	150	36873.5^{e}	2	205	38035.8^{e}	3.4	260	39154.6^{e}	3
41	35237.2^{ade}	3	96	36162.3^{e}	3	151	36890.7^{e}	3	206	38044.1^{e}	3.4	261	39191.5^{e}	4
42	35242.9^{ae}	2	97	36188.9^{e}	2	152	36912.4^{be}	3	207	38083.9^{e}	2	262	39233.1^{e}	4
43	35259.5^{a}	2	98	36193.9^{e}	1	153	36920.2^{e}	4	208	38089.9^{e}	3.4	263	39273.2^{e}	3
44	35262.5^{c}	4	99	36201.3^{e}	2	154	36929.4^{e}	2	209	$38105.1^{\#}$	3–5	264	39408.3^{e}	4
45	35311.0^{ce}	4	100	36217.2^{e}	3	155	36953.9^{e}	4	210	38109.4^{e}	2	265	39537.1^{e}	3
46	35327.9^{c}	4	101	36223.6^{e}	3	156	36964.2^{be}	2	211	38115.1^{e}	3.4	266	39567.2^{e}	4
47	35342.5^{a}	1.3	102	36238.9^{e}	3	157	36976.2^{e}	2	212	38122.4^{e}	3.4	267	39609.5^{e}	4
48	35348.7^{a}	1.3	103	36248.3^{e}	2	158	36996.6^{e}	3	213	38128.6^{e}	2	268	39723.7^{e}	3
49	35371.0^{ae}	1	104	36257.7^{be}	3	159	37022.5^{be}	3	214	38147.6^{e}	2	269	39931.3^{e}	3.4
50	35414.0^{ae}	3	105	36269.8^{e}	4	160	37029.9^{e}	1	215	38166.6^{e}	3.4	270	39987.2^{e}	3.4
51	35444.4^{ae}	1	106	36290.4^{e}	4	161	37054.4^{be}	3	216	38184.7^{e}	3.4	271	40070.5^{e}	3.4
52	35461.2^{ae}	2	107	36302.7^{e}	3	162	$37067.0^{\#}$	2.3	217	38198.1^{e}	2	272	40526.7^{e}	3.4
53	35487.4^{ae}	2	108	36308.2^{e}	1	163	37070.9^{e}	1	218	38210.4^{e}	3.4			
54	35491.4^{ae}	3	109	36324.6^{e}	4	164	$37077.6^{\#}$	2.3	219	38246.4^{e}	2			
55	35512.9^{e}	4	110	36340.9^{e}	4	165	$37130.1^{\#}$	2.3	220	$38254.7^{\#}$	3–5			

Note: Indices $a-e$ indicate the energies of even-parity states that were also observed in the following works: a—[8], b—[12], c—[9], d—[10], e—[11]. Index # indicates the states, data on which were absent in the literature.

The energies and total angular momenta of 272 even-parity states of a samarium atom located in the energy range 34298–40527 cm^{-1} are determined. Sixteen new states, data on which are absent in the literature, are discovered.

The obtained results have testified to high potentialities of the proposed technique for the investigation of highly excited states of a samarium atom. In addition to the use of the only source of laser radiation, its advantages also lie in the possibility of obtaining information on the ratio of the probabilities of the two-photon excitation of the same upper levels from different initial levels of the ground term, as well as on the influence of the laser radiation field on the appearance of such multiplet transitions in spectra of three-photon ionization.

The author thanks to O.I. Plekan for the help in performing the experiments.

1. N.C. Martin, R. Zalubas, and L. Hagan, *Atomic Energy Levels: The Rare-Earth Elements, NSRDS-NBS-60* (US Gov. Print. Office, Washington, DC, 1978).
2. P. Carlier, J. Blaise, and M. Schweighofer, J. de Physique **29**, 729 (1968).
3. V.E. Dobryshin, N.A. Karpov, S.A. Kotochigova, B.B. Krynetskii, V.A. Mishin, O.M. Stelmakh, and V.M. Shustryakov, Opt. Spektr. **54**, 415 (1983).
4. Hu Sufen, Znang Sen, Mei Shimin, Qiu Jizhen, and Chen Xing, J. Quant. Spectrosc. Radiat. Transfer **43**, 75 (1990).
5. Hu Sufen, Znang Sen, Qiu Jizhen, Liang Yi, Wang Gang, and Chen Xing, Chinese Physics, **10**, 731 (1990).
6. Hyunmin Park, Hyun-Chae. Kim, Jonghoon Yi, Jaemin Han, Yong-joo Rhee, and Jongmin Lee, J. Korean Phys. Soc. **33**, 288 (1998).
7. T. Jayasekharan, M.A.N. Razvi, and G.L. Bhale, J. Phys. B: At. Mol. Opt. Phys. **33**, 3123 (2000).
8. A.D. Zyuzikov, *Laser Resonance Photoionization Spectroscopy of Excited and Autoionization States of a Samarium Atom* (Prepr. ISAN SSSR; No. 21, Troitsk, 1988) (in Russian).
9. T. Jayasekharan, M.A.N. Razvi, and G.L. Bhale, J. Opt .Soc. Am. B **13**, 641 (1996).
10. Hyunmin Park, Hyun-chae Kim, Jonghoon Yi, Jaemin Han, and Jongmin Lee, J. Korean Phys. Soc. **30**, 453 (1997).
11. T. Jayasekharan, M.A.N. Razvi, and G.L. Bhale, J. Opt .Soc. Am. B **17**, 1607 (2000).
12. Liejuan Jia, Chunyang Jing, Zhiyao Zhou, and Fucheng Lin, J. Opt. Soc. Am. B **10**, 1317 (1993).
13. A.K. Pulhani, M.I. Shah, Vas Dev, B.M. Suri, J. Opt .Soc. Am. B **22**, 1117 (2005).
14. V.S. Letokhov and V.P. Chebotaev, *Nonlinear Laser Ultrahigh-Resolution Spectroscopy* (Nauka, Moscow, 1990) (in Russian).
15. V.S. Letokhov, *Nonlinear Selective Photoprocesses in Atoms and Molecules* (Nauka, Moscow, 1983) (in Russian).
16. G. Baravian and G. Sultan, Physica B+C **128**, 343 (1985).
17. I.I. Sobel'man, *Introduction to the Theory of Atomic Spectra* (Nauka, Moscow, 1977) (in Russian).
18. W. Albertson, Phys. Rev. **52**, 644 (1937).
19. A.I. Gomonai and O.I. Plekan, Ukr. J. Phys. **50**, 1117 (2005).

Received 25.06.07.
Translated from Ukrainian by H.G. Kalyuzhna

ОДНОЦВЕТНАЯ ТРЕХФОТОННАЯ СПЕКТРОСКОПИЯ ВОЗБУЖДЕННЫХ СОСТОЯНИЙ АТОМА САМАРИЯ

А.И. Гомонай

Резюме

Разработана методика одноцветной трехфотонной резонансно-ионизационной спектроскопии высоковозбужденных четных состояний атома самария, которая предусматривает использование только одного источника лазерного излучения и основана на обнаружении в спектрах трехфотонной ионизации, измеренных при разных значениях напряженности поля лазерного излучения, групп максимумов, связанных с возбуждением одних и тех же верхних уровней с разных начальных уровней основного терма. Исследован спектр четных состояний атома самария, расположенных в области энергий 34298—40527 см$^{-1}$. Определены энергии и полные моменты 272 состояний. Обнаружены 16 новых четных состояний, данные о которых отсутствуют в литературе.