THREE-PHOTON SPECTROSCOPY OF NEUTRAL SAMARIUM

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The process of three-photon ionization of samarium atoms has been studied within the 17200-18400 cm^{-1} spectral range. The three-photon ionization efficiency dependence on the laser emission frequency reveals a large number of resonance maxima resulting from the two-photon excitation of bound Sm atom states, the data on which are not available in literature.

The experimental material gained up to date on the multi-photon ionization testifies that the principal regularities and peculiarities of this process are mainly due to the originality of the energy-state spectra for objects under study. However, among the whole variety, only two groups of atoms, i.e. alkali and alkaline-earth atoms, have been studied quite completely and systematically [1,2]. As regards other groups of atoms, no systematic studies were performed. This does not allow one to generalize the peculiarities and regularities of multiphoton ionization for these atoms. Therefore, such studies are of indisputable scientific interest.

In the present work, the process of three-photon ionization of samarium atom as one of the representatives of rare-earth elements, has been investigated. This element is the sixth in a series of lantanoides, it has less than half-filled f-subshell and is characterized by a quite complicated spectrum typical for the rare-earth elements [3].

The general schematic of the experimental setup is shown in Fig.1. A linearly polarized radiation of pulsed due laser was focused into the vacuum chamber, where it was crossed by a samarium atom beam. The ions produced as a result of multi-photon ionization were extracted from the collision region by electric field, analyzed by a time-of-flight mass-spectrometer and detected using a microchannel plate. After amplifying by mens of a fast amplifier with varied gain ratio, the ion signal entered the input of the detection system that allowed the signals to be selected and accumulated in a digital form within a certain preset number of laser pulses.

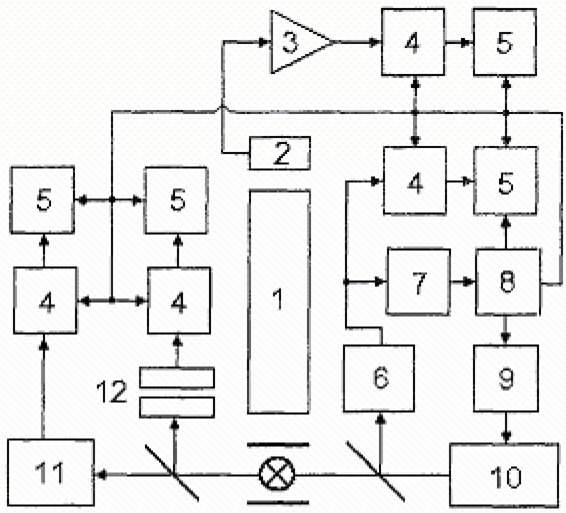

Fig 1. Scheme of the experimental apparatus

1. time-of-flight mass spectrometer
2. microchannel plate
3. amplifier
4. A/D converter
5. pulse counter
6. photodiode
7. two-level comparator
8. synchronization unit
9. laser control unit
10. dye laser FL-2001
11. hollow cathode lamp
12. Fabry-Perot interferometer

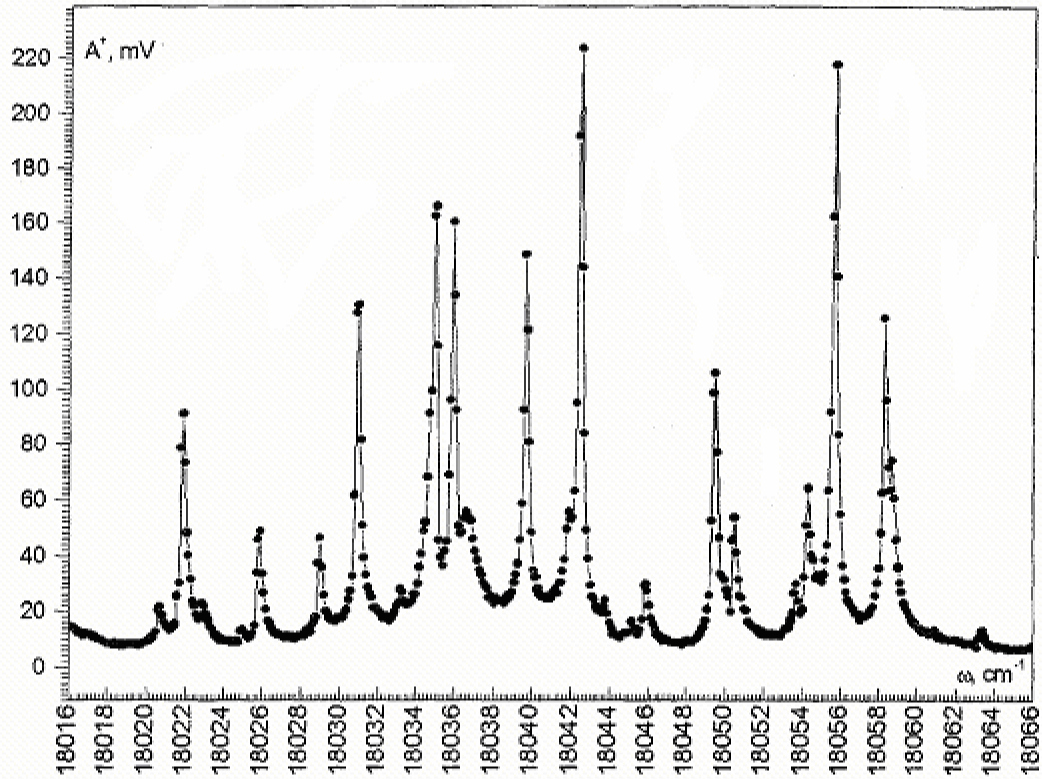

Fig.2. Laser emission frequency dependence of the three-photon ionization efficiency of Sm atom.

A test hollow-cathode lamp and the Fabry-Perot interferometer (FPI) with a photodiode were used to determine accurately the frequency of a scanned laser and form a reference opto-galvanic neon spectrum and the frequency equ-distant marks – the FPI transition maxima. Such an experimental scheme allowed the absolute measurements of transition frequencies to be carried out with the 0.05 cm^{-1} accuracy. The experimental procedure was controlled by an "Olivetti-M10" PC. During experiment the dependences of the efficiency of three-photon ionization on the laser emission frequency were measured.

Figure 2 shows one of the $A^{+}(\omega)$ dependences measured in the $\omega = 18016 \div 18066$ cm^{-1} frequency range at the pulse capacity in the collision region being $P_i \approx 28.5$ kW.The dependence is characterized by a presence of a large number of distinct resonance maxima of different amplitude and shape, the overwhelming majority of which is due to the two-photon excitation of unknown highly-excited even states of the samarium atom.

The relevant classification of the maxima is presented in Table 1.

Table 1. The proposed classification of maxima..

ω, cm^{-1}	Transition	J
18020.80	not identified	—
18021.85	$^7F_2 \to (36855.5)$	3
18022.80	$^7F_4 \to (38318.9)$	2-5
18024.95	not identified	—
18025.80	$^7F_2 \to (36863.5)$	4
18028.90	$^7F_0 \to (36057.8)$	0
18030.80	$^7F_2 \to (36873.5)$	0
18033.00	not identified	—
18034.80	$^7F_1 \to (36362.3)$ $^7F_2 \to (36881.4)$	0 0
18035.75	$^7F_0 \to (36071.5)$	0
18036.45	not identified	—
18039.55	$^7F_3 \to (37568.7)$	3,4
18041.65	$^7F_3 \to (37572.9)$	2-4
18042.30	$^7F_1 \to (36377.2)$	1,3
18043.60	not identified	—
18044.90	not identified	—
18045.55	not identified	—
18049.35	$^7F_1 \to (36391.4)$	1,3
18050.35	$^7F_2 \to (36912.6)$	2,4
18053.65	$^7F_3 \to (37596.8)$	2-4
18054.25	$^7F_2 \to (36920.4)$	4
18055.70	$^7F_1 \to (36404.1)$	1,3
18058.25	$^7F_2 \to (36928.4)$	0
18058.65	$^7F_2 \to (36929.3)$	1
18063.45	not identified	—

In conclusion, note that not identified maxima may result, first, from the resonance transitions between two excited bound states. In this case the population of the lower excited state may occur due to the Raman or hyper-Raman scattering. Second, these maxima may result from the three-photon excitation of narrow autoionizing Sm atom states lying above 54000 cm^{-1}. No data on these states are available now in literature.

References

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ТРИФОТОННА СПЕКТРОСКОПІЯ АТОМА САМАРІЮ

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Досліджено процес трифотонної іонізації атомів самарію у спектральній області 17200÷18400 $см^{-1}$. У залежності ефективності трифотонної іонізації від частоти лазерного випромінювання виявлено велику кількість резонансних максимумів, зумовлених двохфотонним збудженням зв`язаних станів атома Sm, дані про які відсутні в літературі.