ROLE OF BOUND STATES IN THE PROCESS OF MULTIPHOTON IONIZATION OF ATOMS

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Multiphoton ionization of xenon and krypton atoms by the second harmonic of a neodymium laser was observed. The results of the experiments show that an important role is played in the multiphoton ionization process by the bound states of the electron in the atom.

IN experiments on multiphoton ionization of xenon atoms ($I = 12.13$ eV) and krypton atoms ($I = 13.996$ eV) by radiation with quantum energy 1.18 and 1.78 eV, it was observed that the ionization probabilities proportional to the radiation intensity raised to the power $K < K_0$, where $K_0 = \langle I/\hbar\omega + 1 \rangle$ is the number of quanta absorbed during the ionization [1]. We have assumed earlier [1] that this phenomenon can be the result of the effect of a strong field of an electromagnetic wave on the bound states of the electron in the atom. For example, this action can become manifest in the fact that the upper levels in the atom overlap as a result of broadening and a shift in a strong radiation field [2]. An electron entering into the region of such levels goes off with probability ~ 1 into the continuous spectrum. In this connection, the probability of the ionization process is determined by the probability of adsorption of a smaller number of quanta than K_0. Another manifestation of the action of the field on the atom is the change in the width and the detuning of the quasiresonance, as a result of which $K < K_0$ may also be observed [3]. It was difficult to draw any conclusions concerning the role of these effects from the results of the earlier experiment [1], since the magnitude of the quantum was smaller than the distance from the first excited level to the boundary of the continuous spectrum. Observation of $K < K_0$ in each concrete case could be the summary result of simultaneous action of both the overlap effect of the upper levels and the effect of quasiresonance.

A new experiment, performed with the same atoms at a quantum energy $\hbar\omega = 2.36$ eV of the second harmonic of a neodymium laser ($K_0 = 6$ for both atoms) gave more distinct results. In this case the magnitude of the quantum is comparable with the distance from the first excited level to the boundary of the continuous spectrum. Unlike the earlier experiments, only one penultimate quantum falls into the region close to the boundary of the continuous spectrum ($I - 5\hbar\omega = 0.3$ eV), and in the krypton atom–far from the boundary ($I - 5\hbar\omega = 2.2$ eV), i.e., the effect of the overlap of the upper levels can be decisive only for xenon. The experiment yielded for xenon $K = 4.4 \pm 0.2$, $\Delta K = K_0 - K = 1.6 \pm 0.2$. The strong decrease of the value of K compared with K_0, observed in this case, was interpreted by us as the result of the overlap of the upper level. The experimental data for krypton are less accurate, and the obtained value $K = 5.5 \pm 0.5$ does not make it possible to state whether K differs from K_0. Further refinement of this quantity will clarify this question. The result of this experiment shows that if a difference between K_0 and K does indeed exist for krypton, this difference is small. From our point of view, this result is in good agreement with the absence, in the present case, an influence of the overlap of the upper level and the quasiresonances (the quantity $5\hbar\omega$ differs from the energy of the nearest level to which the transition is allowed by an amount ~ 0.5 eV).

At an electric field intensity $E_a = 3 \times 10^7$ V/cm, the probability of ionization of xenon is equal to $W(Xe) = 10^{7.8 \pm 1.8}$ sec^{-1}, while for krypton $W(Kr) = 10^{5.6 \pm 1.8}$ sec^{-1} (the measurement accuracy is discussed in [1]).

Results of the measurement of the ratio of the probabilities of the ionization of xenon and krypton at $\hbar\omega = 2.36$ eV also point to an appreciable role played by the concrete spectrum of the atom. In this experiment, $K_0 = 6$ for both atoms. From the point of view of the theories which do not take into account the concrete spectrum of the atom [4], the ionization-probability ratio is determined by the following relation:

$$W(\mathrm{Xe})/W(\mathrm{Kr}) \cong (I(\mathrm{Kr})/I(\mathrm{Xe}))^{K_0} \approx 2.$$

The experimentally observed value (N_i–number of ions)

$$W(\mathrm{Xe})/W(\mathrm{Kr}) \cong N_i(\mathrm{Xe})/N_i(\mathrm{Kr}) = 10^{1.7\pm0.3},$$

differs greatly from the theoretical one.

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