

INFLUENCE OF MULTIPHOTON RESONANCE ON THE MULTIPHOTON IONIZATION PROCESS

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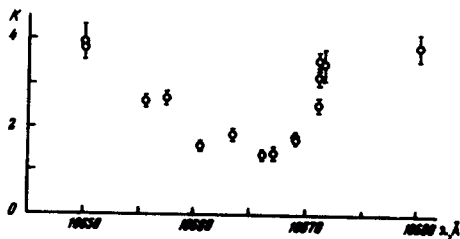
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An experimental study of multiphoton ionization of atoms [1, 2] has revealed that the functional dependence of the multiphoton-ionization probability on the radiation intensity depends on the relation between the energies corresponding to integer numbers of quanta and the energies of the stationary states of the electron in the atom. On the basis of the entire aggregate of experimental results, it was concluded in [3] that the ionization probability is described by the law $W = A F^{K_0}$ only in the case when the difference between the energies corresponding to integer numbers of the quanta and the energies of the stationary states of the atoms is large and remains essentially unchanged when the field is turned on. Here $K_0 = \langle l/\hbar\omega + 1 \rangle$ is the number of quanta needed, in accordance with the energy conservation law, to extract an electron from the atom. In all other cases [1, 2], the foregoing law does not hold, owing to the proximity of the energies of the integer number of quanta to the energies of the stationary states.

One of the reasons for the change in the functional dependence may be ionization due to a two-step transition, i.e., a process in which the electron goes over into the continuous spectrum via a resonant level [4 - 8]. If the probability of one of the transitions from the ground state to the resonant level, or of the transition from the resonant level to the continuous spectrum, becomes so large that saturation of this transition sets in, then the functional dependence of the ionization probability on the field will be determined only by the functional dependence of the unsaturated transition on the field. It is shown in the theoretical papers [4, 6, 7] that the change of K_0 can occur also in a two-step transition if the quasis resonant level shifts and broadens in a strong field by an amount comparable with the deviation from resonance and larger than the natural width of the level.

To investigate the influence of the resonance effect on the multiphoton ionization process, the following experiment was set up: A potassium atom ($I = 4.34$ eV) was ionized by radiation from a neodymium laser ($\hbar\omega = 1.17$ eV) operating in the giant-pulse mode. The energy of the 4f level of potassium is close to the energy of three neodymium-radiation quanta. To produce three-photon resonance, the wavelength of the neodymium laser was tuned in the range from 10590 to 10680 Å. The tuning was with a dispersion resonator consisting of a rotating prism, an output mirror, and two Fabry-Perot interferometers with $d \sim 250$ μ, operating in the transmission mode. By varying the inclination of the interferometer to the resonator axis it was possible to vary the generation wavelength smoothly in the indicated range. The generation line half-width measured with a diffraction grating was 4 Å. The grating had 200 lines/mm and the dispersion in the 10600 Å region was 3.7 Å/mm. The focused neodymium-laser radiation (lens with focal length 120 mm) was aligned with the atomic-



Exponent of power-law dependence of multiphoton ionization on the radiation intensity vs. the radiation wavelength.

1.5×10^6 V/cm.

potassium beam. The measurement setup was similar to that described earlier (cf., e.g., [3]).

We measured in the experiment, at fixed radiation frequencies, the probability of 4-photon ionization (in relative units) as a function of the radiation intensity (in absolute units). The frequency, the line half-width, and the space-time distribution of the neodymium-laser radiation were kept constant and verified during the entire experiment. The measurements were made in a field

The measurement results are shown in the figure. The abscissas represent the neodymium laser wavelengths. The radiation wavelength corresponding to 3-photon resonance with the 4f level of potassium is 10665 Å. The ordinates are the experimental values of K. The rms error of K in one series of measurements is indicated. The generation frequency was made absolute within ± 2.5 Å. It must be borne in mind that in the figure the experimental points are referred to the centers of the generation lines (the half-width of the generation line is 4 Å). It is clearly seen from the figure that the functional dependence of the 4-photon ionization probability on the radiation intensity changes noticeably when the energy difference between the three neodymium-radiation quanta and the 4f level of potassium decreases. The exponent K at exact resonance equals $K_{\text{res}} = 1.5 \pm 0.1$ whereas far from resonance, at a detuning larger than 20 Å, we have $K = 4 \pm 0.1$, i.e., $K = K_0$.

An approximate estimate of the ionization probability shows that when the centers of the generation line and of the 4f line coincide the ionization probability increases by two orders of magnitude compared with the probability at wavelengths far from resonance.

The presently available results make it difficult to determine a definite cause of the change in the functional dependence of the ionization probability on the field intensity on going through the resonance level. This is connected, for example, with the fact that, owing to the large width of the generation line, only a fraction of the neodymium-laser quanta are at resonance with the 4f line of potassium.

We can thus conclude qualitatively that multiphoton resonance with the excited state of an electron in an atom may be one of the reasons why the exponent of the power-law dependence of the multiphoton-ionization probability on the radiation intensity decreases.

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