PHOTOELECTRON SPECTROSCOPY OF LASER EXCITED Ca ATOMS

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Abstract: Ca I atoms were excited by pumping the Ca I $3p^64s^2\ 1S_o \rightarrow Ca I \ 3p^64s4p \ 1P_1$ transition using a cw ring-dye-laser. In a second step the atoms were excited by synchrotron radiation to core resonances $3p^5dnl\ell$' which mainly decay by autoionization. Varying the photon energy of the synchrotron radiation the partial cross-section $3p^64s4p \ 1P_1 \rightarrow 3p^64s\ell\ell$ were studied.

INTRODUCTION

Core excitations of atomic Ca induce dramatic changes of the outer shell configuration leading to complicated absorption and ion spectra and to prominent satellite structures in the photoelectron spectra /1,2,3/. Therefore, Ca is ideally suited to test predictions based on atomic-many-body theory. The rearrangement of the outer electrons upon core excitation is expected to strongly depend on the initial configuration. The study of core excitations of excited Ca I atoms promises detailed insight in the many electron effects. 3p-absorption spectra of excited Ca I atoms and of Ca II ions have been determined by Sonntag et al /4/ using a flashlight pumped dye
laser to induce the $3p^64s^2 \, ^1S_0 + 3p^64s4p \, ^3P_1$ ($\lambda = 657.2$ nm) intercombination transition and the VUV radiation of a ruby laser produced plasma. The photoionization cross section of Ca II ions has been obtained by Lyon et al./5/. In all spectra strong autoionizing resonances have been detected. The intense radiation of a laser can be used to achieve a considerable fraction of atoms in well prepared excited states./6,7/. Combining a cw ring-dye-laser with synchrotron radiation we have studied the Ca I $3p^64s4p \, ^1P_1 + 3p^5n\ell\ell'\ell''\ell''$ autoionization resonances.

**EXPERIMENTAL**

The Ca atomic beam was produced from an oven heated by electron impact. The oven was operated at temperatures of about 800 K to produce a density of about $10^{11}$ Ca atoms/cm$^3$ in the interaction region. The excitation of the Ca atoms was achieved by pumping the resonance transition Ca I $3p^64s^2 \, ^1S_0 +$ Ca I $3p^64s4p \, ^3P_1$ with a cw ring-dye-laser at $\lambda = 422.7$ nm. An output power of about 90 mW with Stilbene 3 in single mode operation was obtained by 3W UV pump power of an Ar-ion-laser. The fraction of the excited atoms was estimated to 5%. In order to lock the cw ring-dye-laser to the resonance transition the resonance fluorescence emitted perpendicular to the atomic and the laser beam was monitored by a photomultiplier. The Ca I $3p^64s4p \, ^1P_1 +$ Ca I $3p^5n\ell\ell'\ell''\ell''$ excitations were obtained by synchrotron radiation emitted from the electron storage ring BESSY. The synchrotron radiation was monochromatized with a toroidal grating monochromator./8/. The bandwidth of 0.06 eV of the monochromator was achieved with a slit width of 0.5 mm. Both beams were focussed in the interaction region with a focal spot $\phi < 1$ mm. A good illumination of the interaction region by both radiation sources was obtained when the laser beam, propagating towards the storage ring, coincided with the beam of the synchrotron radiation.

The kinetic energy of the photoelectrons was determined by a cylindrical mirror analyzer (CMA). The CMA had an angular acceptance of 0.8% of 4$\pi$ and an energy resolution of $\Delta E = 0.8$% of the pass energy of the electrons. Only electrons emitted at angles close to the magic angle of 54°44' relative to the polarization vector of the synchrotron light were accepted by the CMA.
RESULTS

Fig. 1 shows a part of the photoelectron spectrum of Ca atoms at the energy \( h\nu = 33.03 \text{ eV} \) of the dominant Ca I \((1p_1)3p \rightarrow 3d\) resonance. In the absence of laser radiation, one observes photolines 4s, 3d, 4p corresponding to the final ionic states of Ca II. When the laser is on, new photoelectron lines appear. They are shifted by the laser excitation energy of 2.93 eV. The relative strengths of these photoelectron lines markedly differ for the ground state and the excited state spectrum. Fig. 2 shows the Ca I \(3p^64s4p \rightarrow 1p_1 + 3p^64s\ell\) partial cross section. There is a strong resonance at 33.03 eV. The
shoulders at both sides are located at 32.89 eV and 33.17 eV. The experimental points were best fitted with three Gaussian profiles at 32.89 eV, 33.03 eV and 33.17 eV photon energy with halfwidths of 0.12 eV, 0.13 eV and 0.18 eV. The 3p-absorption spectra of Ca I 4s2 1S0 and Ca I 4s4p 3P are dominated by similar maxima positioned at 31.4 eV and 32.29 eV respectively. Going to Ca II the corresponding 3p64s2s - 3p53d4s2p resonance shifts to 33.2 eV.

**Fig. 2:** Partial cross section of the transition

Ca I 3p64s4p 1P1 → Ca II 3p64s^2s 

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