

DOE/ER/14214-4

COHERENT EXCITATION OF AUTOIONIZING RESONANCES
BY ELECTRON IMPACT

Progress Report

March 1995 – April 1996

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December 1995

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
UNDER GRANT NUMBER DE-FG05-91ER14214

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Coherent Excitation of Autoionizing Resonances

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Introduction

Experimental investigations are being carried out into interference effects caused by the coherent population, by electron impact, of autoionizing levels and continua of differing total angular momentum and parity. The work provides information on the atomic excitation and ionization mechanisms by charged particle impact.

The experimental technique being used is electron-electron coincidence [or $(e, 2e)$] spectrometry. Differing binary (I^+) and recoil (I^-) lobe intensities in coplanar $(e, 2e)$ ejected-electron angular distributions may be modeled by interference cross-terms, between opposite parity final-state continua, that change sign when $\theta_{ej} \rightarrow \theta_{ej} + 180^\circ$ in the angular distributions. The magnitude of these cross-terms varies rapidly with ejected-electron energy across overlapping autoionizing resonances. The energy variation in the interference terms may be examined by obtaining the *sum* ($I^+ + I^-$) and *difference* ($I^+ - I^-$) between $(e, 2e)$ energy spectra measured at ejected-electron angles 180° apart [1-4].

Experimental Work

Cadmium

The coplanar $(e, 2e)$ spectrometer consists of four principal components: an electron gun, a metal vapor atomic beam oven, a scattered electron spectrometer and an ejected electron spectrometer. The ejected-electron channel incorporates a resistive anode type position sensitive detector. The spectrometers are mounted on two horizontal concentric turntables; the ejected electron is therefore always detected in the scattering plane. The angular range of the scattered spectrometer is $\pm 45^\circ$ with respect to the electron beam direction. Because the electron gun is recessed in a side arm, the ejected spectrometer has a useful range of $-30^\circ \rightarrow -160^\circ$ and $-200^\circ \rightarrow -270^\circ$, when the scattered spectrometer is at 0° . This range is sufficient to investigate the binary and recoil directions in a single experiment, without recourse to the more usual method of normalizing separate experiments at $\pm \theta_{sc}$.

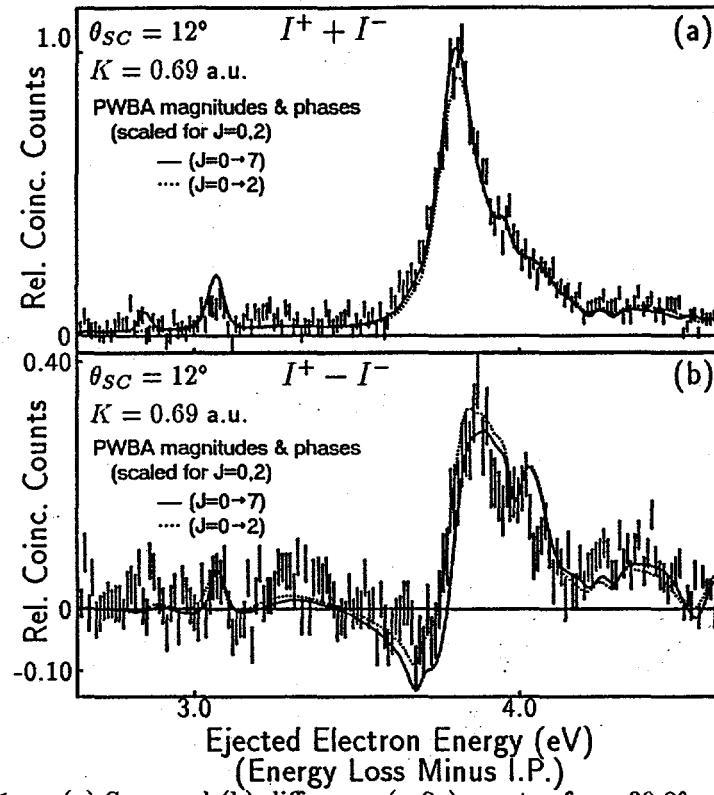


Figure 1. (a) Sum and (b) difference $(e, 2e)$ spectra from 39.2° magic angle experiment for $\theta_{sc} = 12^\circ$

A recent major experimental advance has been the development of a novel type of high-voltage trap for the collection of cadmium vapor [5]. The trap makes use of the empirical observation that the deposition of cadmium on surfaces occurs mainly close to high voltage electrodes. This effect seems to have its origins in an attractive force acting on neutral cadmium atoms due to an induced electric-dipole moment in the presence of large electric-field gradients. The trap consists of a central aluminum disc maintained at $+1000$ V with respect to ground potential and mounted at the top of a vertical aluminum cylinder terminated at its bottom end by a triple mesh assembly to provide adequate electrostatic shielding of the interaction region. This device is extremely efficient at the collection of cadmium, resulting in much longer microchannel plate lifetimes.

Measurements are currently being made for a range of scattering angles up to 20° . At each scattering angle pairs of spectra for ejected-electron directions 180° apart are taken for three angles with respect to the momentum transfer axis: 0° , 39.2° , and 54.7° . These three angles probe different ejected-electron partial waves. At 0° all partial waves are present, whereas at the other two "magic angles", the $m = 0$ components of $\ell = 3, 2$ are absent respectively since $Y_{\ell 0}(\theta_{MAG}) = 0$. Because of the angular momentum of ground state Cd and Cd $^+$ (1S_0 and $^2S_{\frac{1}{2}}$) each partial wave corresponds to the ionization amplitude of multipolarity $J = \ell$, where J is the

total angular momentum of the Cd $5sE\ell$ continuum.

Earlier experiments [4] found that at small scattering angles the ionization process is well described by restricting the multipole series to $J = 0, 1, 2$. The measured relative multipole magnitudes (monopole/dipole and quadrupole/dipole) disagreed with PWBA calculated quantities by about a factor of two. The measured relative phases disagreed with the PWBA results by about $\pm\pi/4$.

At the larger scattering angles of the present experiments, the inclusion of several higher multipoles is required for a description of the ionization process. However, for an intermediate scattering angle where $J = 3$ becomes important, but higher terms are still small, the experiments at 39.2° magic angle experiment "removes" the $J = 3$ amplitude and enables a test of the relative $J = 0, 1, 2$ magnitudes and phases. This is shown in Fig 1 for a scattering angle of 12°. In the figure, the theoretical PWBA monopole/dipole and quadrupole/dipole amplitudes have been scaled and phase adjusted by the amounts found from the small angle experiments. It is being investigated whether these corrections are valid for all scattering angles up to 20°.

Helium

A second ($e, 2e$) spectrometer has recently been acquired and is at present being reconfigured. The original spectrometer will continue the experiments in cadmium, while it is intended to devote the new spectrometer to similar types of experiments in helium.

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