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D. C. ELECTRIC FIELD BEHAVIOR OF HIGH LYING STATES IN ATOMIC URANIUM

J. A. Paisner, L. R. Carlson, E. F. Worden,
S. A. Johnson, C. A. May, and R. W. Solarz

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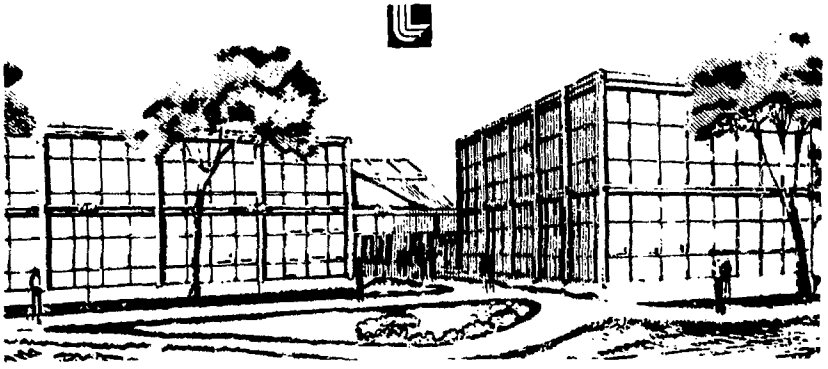

We have studied the effects of D. C. electric fields on high lying Rydberg and valence states in atomic uranium. Investigations of D. C. electric field effects in simple atoms by other authors have been confined to the study of Rydberg states.[1,2] These works have included measurements of Stark shifts, lifetime lengthening via ℓ-mixing, critical fields for ionization, barrier tunneling, and the appearance of zero-field parity forbidden transitions. In this paper we report parallel results for atomic uranium, as well as the observation of field induced autoionization of valence states.

The uranium atoms are stepwise excited to levels within a few hundred cm^{-1} of the continuum by the output of three N_2 pumped pulsed dye lasers each operated near 6000 Å. Using excitation wavelengths that we have previously identified, the uranium atom can be prepared in a Rydberg or valence state beneath the ionization limit. These Rydberg states have been determined to belong to the $5f^37s^2$ np, nf and $5f^36d7s$ np configurations. An external electric field is then applied. By measuring the number of ions produced as a function of impressed field, a critical field for ionization E_c was determined. For Rydberg progressions having the ground state of the ion as their limit we have found $E_c = k\,(n^*)^{-4}$ with the critical field of 168 V/cm for $n^* = 39.18$. This dependence of the critical field on n^* has been consistently reported in studies of simpler atomic systems by other investigators.

We have also observed electric field induced ionization of valence states. At field strengths of approximately 1 kV/cm some states of the atom which were previously bound and beneath the ionization limit become

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autoionizing states. However, dependence of ionization rate is a more slowly varying function of field then in the case of the Rydberg states. When the ionizing electric field is above the critical value and overlaps the exciting pulse in time, the optical transitions to these levels broadens considerably, to 1 to 5 cm^{-1}.

In addition, Stark shifts and splittings have been studied. In very low fields, < 20 V/cm the Rydberg levels with $n^* > 38$ display large splittings and shifts, on the order of several cm^{-1}, as well as lifetime lengthening due to mixing in of states of higher angular momentum. For example, the $n^* = 39.18$ levels have a lifetime of 5(2) μsec in zero field, and 11(2) μsec in a 6 V/cm field. The appearance of new resonances as a function of field is also evident and arises from transitions to levels that are normally parity forbidden in zero field.

A detailed description of the experimental techniques and results will be presented and the application of these methods to laser isotope separation will be discussed.

References

1. T. W. Ducas, M. G. Littman, R. B. Freeman, and D. Kleppner, Phys. Rev. Letters 35, 366 (1975) and references therein.

2. R. F. Stebbings, C. J. Latimer, W. P. West, F. B. Dunning and T. B. Cook, Phys. Rev. A 12, 1453 (1975) and references therein.

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FIELD IONIZATION APPARATUS – FIGURE ONE

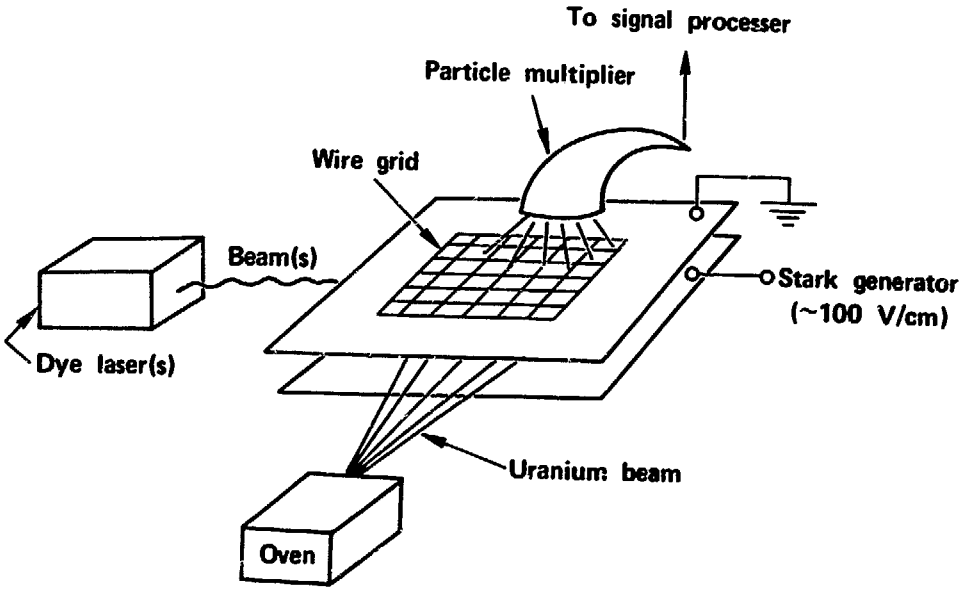

Figure Two

IONIZATION SIGNAL AS A FUNCTION OF PULSED IONIZING ELECTRIC FIELD

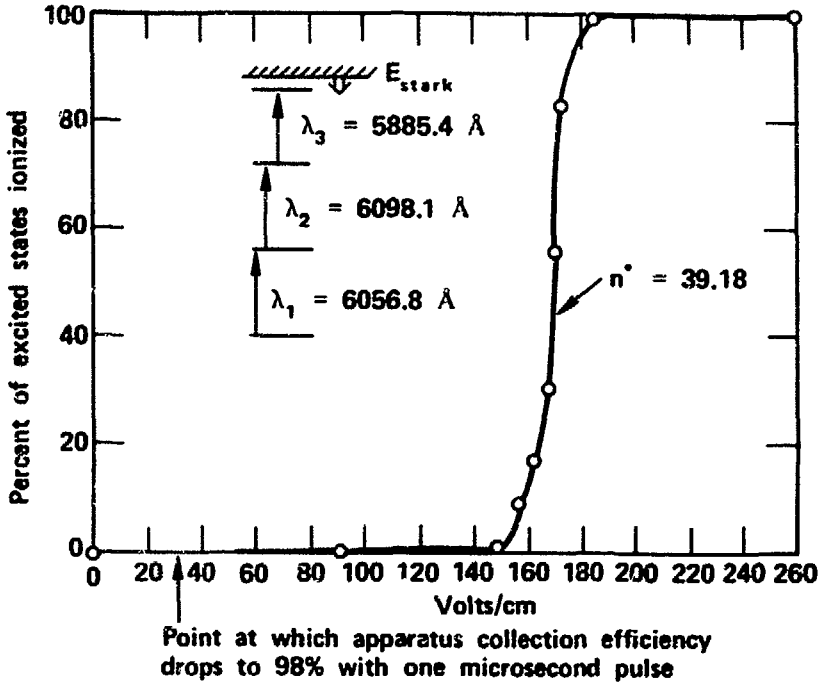

Figure Three

LOG-LOG PLOT OF CRITICAL IONIZATION FIELD VERSUS n^* FOR HIGH RYDBERG STATES