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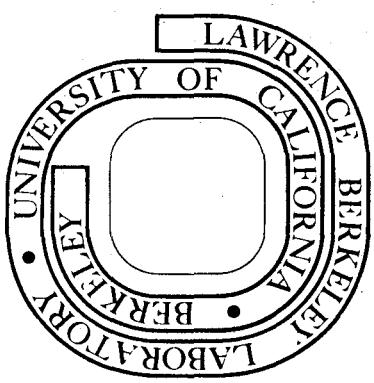

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Abstract

When compared with carbon foil data, reduced beam-tilted-foil orientation and alignment magnitudes are observed as a function of foil tilt angle and amount of evaporated surface gold.

The coherent orientation and alignment of excited atom[1-3] and ion[2-4] levels produced by the beam-tilted-foil collision promises to be useful in the measurement of fine- and hyperfine-structures[5] of excited levels by means of rf and level-crossing spectroscopy and quantum-beat techniques[2,3]. The possibility of creating foil surfaces which enhance particular excited level tensor components[6] appears highly desirable, and may further provide novel information about surface interactions and parameters. Recently we briefly reported a dependence on foil material of the magnitude of the orientation produced by an asymmetric undirectional ion-foil collision[2]. A reduction in the orientation was observed when gold was deposited on the (usual) carbon foil final surface, while at a single energy a thin layer of aluminum produced results essentially identical to those of carbon. The lack of any dramatic changes in orientation magnitude produced by an aluminum surface was subsequently demonstrated by others[7] over a 300 keV incident ion energy range.

We describe here the results of measurements which show that (1) all the coherent orientation and alignment components of the 4d ^{1}D level of fast He atoms generated by a beam-tilted-foil collision are reduced in magnitude by a gold layer deposited on the final (downstream) foil surface, (2) the reduction depends on the amount of deposited gold, (3) only material deposited on the downstream surface of the foil is effective, (4) the magnitude of the reduction varies differently with foil tilt angle for each alignment or orientation component, (5) a similar reduction is found for P levels in Li, and (6) the magnitude of the effects depends on the quantum state of the transmitted particle.

The experimental arrangement was identical to that described earlier[2,8]. 60 keV ions were incident on foils tilted at angles β of 30, 45, or 60 degrees. Light emitted by excited levels was collected at a fixed distance d = 3.7 cm downstream from the foil, from a narrow spatial region kept parallel to the foil surface. A uniform magnetic field applied parallel to the beam was swept uniformly in time to produce quantum beats in the emitted light intensity. The amplitudes of these beats, in linearly and circularly polarized light, were measured both as a function of foil tilt angle β and of the amount of gold evaporated onto the surface of the carbon foils before mounting. The gold was simultaneously evaporated onto a clean microscope slide, and the transmission T of the slide plus evaporated gold was measured on a Jarrall-Ash densitometer to calibrate the amount of evaporated material. The transmission varies non-linearly with thickness for relatively thick ($\gtrsim$100 Å) layers[9], but fairly linearly for thin layers. From calibration curves[9], the thickest deposited layer was $\lesssim$90 Å. However, the apparent energy loss of the transmitted ions indicated even thinner gold layers.

The initial measurements were performed on the 4922 Å transition from the 4d $^1D_2$ level of He at a foil tilt angle $\beta = 45°$. The amplitude of the quantum beat varying at the Larmor frequency ω, proportional to the orientation parameter O_{-1}^{col}, was measured with the gold layer on first the downstream, and then the upstream, surface of the foil. With the gold layer upstream (and a carbon surface downstream), the results were identical to those produced by slightly thicker uncoated carbon foils; i.e., increased scattering of the beam particles from the forward direction

produces only small changes in the relative signal. A significant reduction in the orientation, related to the amount of evaporated gold, was found when the gold layer was downstream, as Table I shows.

Using one thickness of evaporated gold, denoted #4 in Table I, the orientation and alignment were measured as a function of foil tilt angle with the gold layer alternately upstream and downstream. The results are tabulated as ratios in Table II. Previously we had shown on a phenomenological basis that each orientation and alignment parameter of the 4d ^{1}D level varied, within the experimental accuracy, as a power of sin β when the foil was tilted. Within the current statistics, the decreased signals produced by the gold layer, and the ratios in Table II, vary in the same characteristic ways.

The microscopic texture of the foil surface, as well as the physical or chemical properties of the surface material itself, can be expected to influence the amount of orientation or alignment produced in a tilted foil collision. In these measurements the vacuum was not better than 10^{-6} Torr, so the surfaces can be presumed to be contaminated[10,11], and the chemical properties not representative of the underlying material. The evaporated gold of the coating may well not be deposited uniformly[12], tending to increase the surface roughness and consequently reduce the tilt-angle dependent tensor components in quantum states with relatively large principal quantum number n, which sample a relatively large surface area as they leave the foil. On the other hand, atoms in low n states may be expected to interact with a much smaller surface area and be less sensitive to roughness. To partially test this hypothesis, we measured the orientation of the 2p and 3p $^2P_{3/2,1/2}$ levels of ^{7}Li via the 6708 Å

and 3233 Å transitions respectively. Evaporated gold layers which produced relatively large reductions in orientation at a 45° tilt angle for the n = 4 ^1D level of He produced only minute reductions for the n = 2 ^2P level of Li, even though the initial orientation produced by a tilted carbon surface was comparable. Intermediate results were found for the n = 3 level of Li. Although these results confirm the initial expectations, a more systematic investigation must be pursued before definite conclusions can be drawn.

On the same hypothetical basis, one might expect that low n states of highly charged ions will interact with only a few surface atoms, and hence be insensitive to the macroscopic tilt of even a carbon foil. Little orientation would then be expected in this limit. Further measurements to test these speculations are planned.

The results presented above demonstrate that the physical properties of the downstream surface of the foil play a significant role in the production of the coherent tensor components of excited levels of fast foil excited particles. The unidirectional passage of the fast particle through the final surface provides both a unique collision geometry to study and elucidate the ion-foil interaction, and useful parameters for the study of the structure of excited ions.

TABLE I

Ratios of orientation magnitudes observed in transitions from the 4d $^1D_2$ level of 60 keV He atoms excited by gold coated foils tilted 45 degrees. The orientation ratio R is constructed from orientation signals measured with the gold layer downstream and upstream respectively.

Foil Coating I.D.#	Optical Transmission (%)	Orientation Ratio R (±0.012)
#1	0.8	1.04
#4	0.63	0.81
#5	0.62	0.69
#0	----	0.65
#6	0.54	0.58

TABLE II

Ratios of tensor component magnitudes observed in transitions from the 4d $^1D_2$ level of 60 keV He atoms excited by gold coated foils at several tilt angles. The tensor component ratio is constructed from signals measured with the gold layer downstream and upstream respectively. Gold layer #4 was used.

Tensor Component	Tensor Component Ratio	Foil Tilt Angle (Degrees)
O^{col}_{-1}	0.85	30
	0.75	45
	0.57	60
A^{col}_{+1}	0.62	45
	0.61	60
A^{col}_{+2}	0.70	45
	0.39	60

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