LIFETIME MEASUREMENT OF THE Sc II 3d4p $z^3F^o_2$ LEVEL USING ULTRAVIOLET LASER EXCITATION OF A FAST ION BEAM

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Fast Sc^+ ions from an isotope separator are excited selectively by Doppler tuned radiation from a high power ultraviolet extension of the beam-laser technique. The cascade-free determination of the lifetime of the Sc II 3d4p $z^3F^o_2$ level yielded the value 6.2 ± 0.2 ns.

The most accurate measurements of atomic meanlives which have been made to date have involved the study of in-flight de-excitation of a fast monoenergetic ion beam after excitation by tuned resonance radiation from a laser [1–4]. Both Doppler shift and dye laser tuning techniques have been used to provide selective excitation, which avoids the problems of cascade repopulation with no degradation of the high precision time resolution provided by the sharp ion velocity, and under favourable circumstances uncertainties can be reduced to less than 1%. However, until recently the application of this method was restricted to levels which can be reached through resonance absorption from the visible wavelength region. The availability of high power lasers with ultraviolet capabilities now extends this applicability. We report herein the first meanlife measurement utilizing excitation of a fast ion beam by laser radiation of wavelength shorter than 400 nm, applied to the $z^3F^o_2$ level in Sc II.

The experimental arrangement is shown in fig. 1. A 45 keV monoenergetic Sc^+ beam was obtained from an isotope separator and directed into the measuring chamber through beam defining slits D1 and D2, after which it was collected in a current monitoring Faraday cup. The intensity stabilized laser beam from the UV argon ion laser (Coherent Radiation, CR-18) was directed perpendicularly toward the ion beam by a mirror M1. One of the four UV laser wavelengths, 363.8 nm, was selected by a dispersing prism. The 1W laser beam was defined by an aperture D3 and entered the vacuum chamber through a Brewster's angle window, where it was reflected by a mirror M2 mounted on a precision rotation table, enabling the angle between the ion beam and the laser beam to be set accurately and reproducibly for Doppler tuning of the laser beam. After intersection with the ion beam the

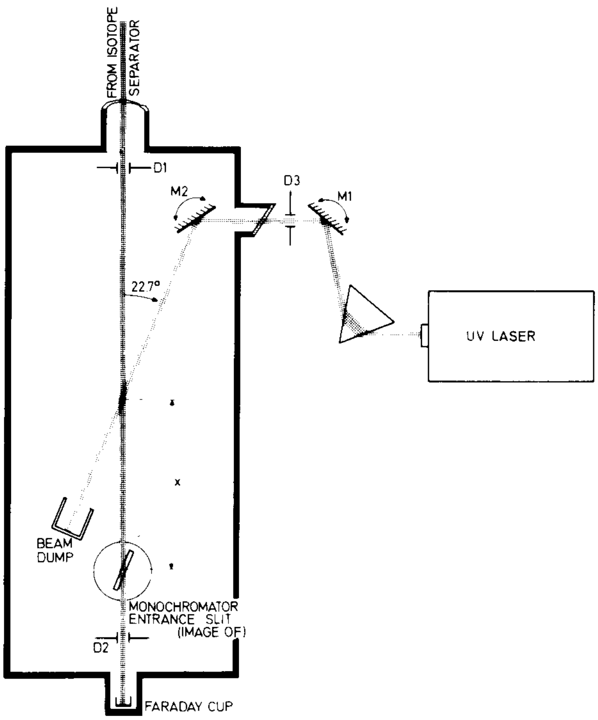

Fig. 1. Schematic diagram of apparatus.

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laser light was absorbed in a blackened cavity dump. Not shown in fig. 1 is a box of black material placed around the interaction and deexcitation region in order to decrease the stray light. The positions of the ion and laser beams were held fixed in space, and the time dependence of the deexcitation process was studied by a movable monochromator mounted on a lathe bed, which travelled parallel to the ion beam and was driven by a step motor. The monochromator viewed perpendicularly from above the plane shown in fig. 1, and was tilted so that its slit was parallel to the laser beam so as to permit viewing as close as possible to the intersection of the beams. The $z\,^3F_2^o$ level was excited by resonance absorption in the 364.2 nm transition and its decay was measured by the branch at 441.5 nm. Resonance excitation with light from the 363.8 nm laser radiation occurred at an intersection angle of 22.7° ± 1.0°, indicating an ion beam velocity of 0.441 ± 0.004 mm/ns, which was also verified by the accelerator voltage calibration.

To record a decay curve, the detection system was moved upstream or downstream to collect data at about 60 equally spaced points. The same procedure was used to search for positional variations in laser background, beam background from beam-gas collisions and detection efficiency. Variation in detection efficiency along the ion beam was determined in the same way as the beam background, but with the monochromator set at the direct image to provide a higher counting rate. We found the detection efficiency and the backgrounds to be practically constant.

A total of 30 decay curves were recorded. They were all least-squares fitted to a function of the form $A + B\exp(-t/\tau)$ to account for background from scattered light. Care was taken that the fit started at a point well beyond the excitation region. Comparison between the fitted background A and the separately determined sum backgrounds showed that background from scattered fluorescence light was close to zero. Four of the original 30 curves were omitted on basis of a χ^2 concordance test. The remaining 26 curves gave a weighted average meanlife $\tau = 6.18 \pm 0.11$ ns. This 1.8% error includes statistical variations as well as variations in ion current and laser power. The step length was determined to within 0.2%. The ion velocity was calculated within an estimated uncertainty of 0.8% from the wavelength difference and the intersection angle. Detection efficiency and background along the ion beam were found to be constant to within 0.1%. These errors together with the standard deviation of the 26 fits add in quadrature to a total relative error of 2.0%. Fig. 2 shows a measured decay curve obtained after addition of nine scans with the same ion velocity.

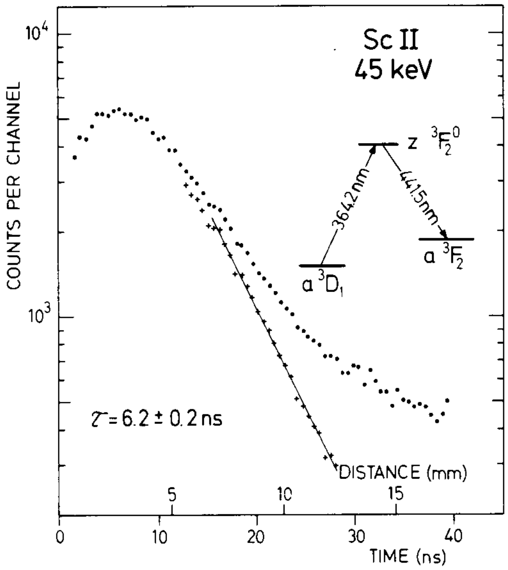

Fig. 2. Semilog plot of the intensity decay curve of $3d4p\,z\,^3F_2^o$ in Sc II (• raw data, + measured background subtracted).

The final result is presented in table 1 along with other measurements and theoretical estimates. It should be pointed out that the beam-foil measurement includes the lifetime of the entire term $z\,^3F_{2,3,4}^o$ as the resolution is rather low due to Doppler broadening in a beam-foil experiment. With the laser excita-

Table 1
Experimental and theoretical values for the lifetime, τ (ns), of the $3d4p\,z\,^3F_2^o$ level in Sc II.

This work	Other experiments	Theory
6.2 ± 0.2	5.5 ± 0.6 [5] [a]	5.2 [6] [c] [7] [d]
	5.8 [9] [b]	5.0 [6] [c] [8] [d]
	6.5 [10] [b]	5.7 [9] [e]

[a] beam foil
[b] emisson
[c] SOC
[d] semi-empirical
[e] Coulomb approximation

tion in this work the $z^3F_2^o$ level is selectively excited. With tunable coumarin dye lasers, pumped with powerful UV lasers, the beam-laser method could be extended considerably.

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