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Cascade-corrected lifetimes of the $3p\,^4D_{3/2,5/2,7/2}$ energy levels in N III

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A detailed cascade-corrected energy-level lifetime analysis of the $3p\,^4D_{3/2,5/2,7/2}$ energy levels in N III was undertaken by studying the $3p\,^4D_J-3s\,^4P^{\circ}_J$ transitions, as well as incorporating cascading from the higher-lying $3d\,^4P^{\circ}_J$, $3d\,^4D^{\circ}_J$, and $3d\,^4F^{\circ}_J$ energy levels. The present paper therefore describes beam-foil measurements of the decay times of a number of $2s^12p^1(^3P^{\circ})3p$ and $3d$ levels in N III. These $3d$ levels were found to have a very marked influence of approximately 15% on the lifetimes of the $3p\,^4D_J$ energy levels. This influence was studied using a multiexponential curve-fitting technique, as well as the now well-proved (arbitrarily normalized decay curve) technique. The beam-foil method using these techniques is expected to provide a reliable and consistent experimental check on lifetime calculations.

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I. INTRODUCTION

During the past decade the beam-foil group at the University of Stellenbosch concentrated mainly on the lifetimes of energy levels of ionized oxygen [1–8], nitrogen [9], krypton [10–13], neon [14], argon [15,16], xenon [17,18], aluminum [19], and phosphorus atoms [20]. Having completed a very detailed study of the energy-level lifetimes in the oxygen atom in the wavelength range 200–500 nm[1], we are now conducting a similar study of the energy levels in the nitrogen atom, not only to eventually make isoelectronic sequence predictions, but also because there is a need for reliable transition probabilities in nitrogen. It has already been proved that strong configuration interaction leads to inaccurate theoretical values [21,22] in N I. In N III we found the $3p\,^4D_J$ energy levels and the energy levels cascading to these levels are well excited in the beam-foil source at the Van de Graaff of the National Accelerator Centre of the Council for Scientific and Industrial Research at Faure.

These energy levels in nitrogen have been studied very extensively in the past [9,24–29]. In many cases the agreement between different experimental results and between theory and experiment is reasonable, but there are nevertheless a significant number of cases where the situation is unsatisfactory. Often, there is either poor agreement between different experimenters, or only a few experimental results are available for comparison with the theory. We have concentrated mainly on transitions where experimental agreement has been relatively poor, or where very few experimental data are available. To obtain reliable radiative lifetimes, some of the most powerful tools available today for studying atomic energy-level lifetimes using the beam-foil technique were used to overcome traditional beam-foil complicating factors such as lines being blended with neighboring transitions. Inadequate compensation for cascade repopulation of the primary excited level by higher-lying levels was avoided by utilizing the computer programs DISCRETE [30] and CANDY [31] in careful analyses of the data.

II. EXPERIMENT

The experiments were performed at the 5.5-MV HVEC Van de Graaff accelerator (model CN) of the National Accelerator Centre at Faure. The basic experimental setup has been described previously [9]. A mass-analyzed N^{2+} ion beam was accelerated to energies of 0.5, 1.0, and 2.0 MeV and sent through a thin carbon foil prepared by the hydrocarbon cracking technique [32]. The thin carbon foil provides a well-defined time of excitation for the ions in the fast beam and the subsequent decay in time, or distance along the beam, of excited states of the multiply charged ions provides a simple lifetime measurement technique. Decay data were obtained using photon-counting techniques. The lifetimes of the levels are related to the decrease in intensity of a specific line observed along the axis of the beam. These curves are continuously recorded during the displacement of the target relative to the entrance slit of the spectrometer. The distance between the target and the observation point varies from 0 to 20 cm. The spectra were recorded at a fixed distance of 0 cm downstream from the foil, i.e., a foil position to obtain maximum intensity. Beam currents of up to 5 μA were obtained. Spectrometer slit widths of 100 μm resulted in high intensities, as well as good spatial resolution of 0.3 nm full width at half maximum (FWHM). The spectrometer was refocused during the spectral scans using a formula derived for a 0.3-m plane grating crossed Czerny-Turner monochromator [1]. This was also done during the lifetime measurements. Improvement in the resolution might have been possible by reducing the slit widths to perhaps 50 μm, but for the present purpose the advantages did not compensate for the reduction in the signal. The subsequent intensities of the emitted light were studied as a function of energy in order to identify to some degree the charge state of the excited levels.

III. SPECTRUM ANALYSES

Line identification was accomplished using the tables of Striganov and Sventitskii [33]. Studying the emitted

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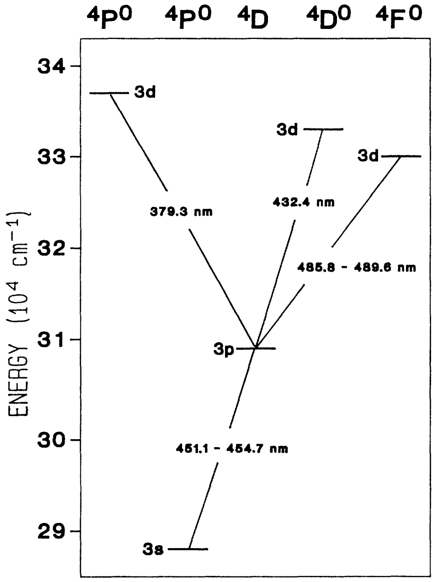

FIG. 1. Partial Grotrian diagram of observed $2s^12p^1(^3P^\circ)nl$ energy levels in N III.

spectra originating from transitions from the $3p\,^4D_J$ upper levels, it was found that the intensity decreased from 6000 counts/s at 0.5 MeV to about 400 counts/s at 2-MeV beam energy. This method of determining the charge states, based on the variation of the intensities of the lines, gives good results for medium or strong lines, but for weak transitions the identification of the charge state is still dubious. However, our charge state as well as line identification of the observed lines are in excellent agreement with other observations [23–29].

A Grotrian diagram of the relevant observed energy levels in doubly ionized nitrogen is shown in Fig. 1. The wavelengths are based on the tables of Striganov and Sventitskii [33], as well as the tables of Bashkin and Stoner [34]. The extensive report by Bashkin *et al.* [35] has also been used in the identification of the observed lines. In this report, Bashkin *et al.* [35] listed the relative intensities of nitrogen and oxygen lines in the wavelength region of 270–660 nm at various beam energies and also classified the radiative lifetimes as being very short, short, medium, or long. These estimates assisted us in distinguishing between the various assignments possible for some of the lines that have been observed, although they were not intended as quantitative measurements. This criterion alone was therefore deemed insufficient to assign the observed lines, since the excitation produced by the foil may be very different from excitation in other sources.

IV. DATA ANALYSES FROM CURVE FITTING

A. Primary decays

1. The $3p\,^4D_J$ energy levels in N III

Transitions from these levels were identified as having the highest intensity at 0.5-MeV beam energy and the results of Sec. III convinced us that there can be no uncertainty as to the charge state of the particles associated with these spectral lines. A spectral scan at 0.5 MeV between 450 and 455 nm, showing the transitions from the $3p\,^4D_J$ energy levels, is shown in Fig. 2. The shoulder observed at 451.1 nm was resolved at 50-μm slit widths. However, care had to be taken regarding the influences of transitions from the different excited levels as observed at the various wavelengths. Transitions between 451.1 and 454.7 nm were studied, and the lifetime results obtained from the multiexponential curve-fitting program, DISCRETE [30], are presented in Table I, along with other theoretical [36] and experimental values available. These lifetime measurements merit further discussion. Measurements were performed at 451.1 nm (the $3p\,^4D_{3/2}-3s\,^4P^\circ_{3/2}$ and $3p\,^4D_{5/2}-3s\,^4P^\circ_{3/2}$ transitions), 451.5 nm ($3p\,^4D_{7/2}-3s\,^4P^\circ_{5/2}$), 452.4 nm ($3p\,^4D_{3/2}-3s\,^4P^\circ_{3/2}$, 453.5 nm ($3p\,^4D_{5/2}-3s\,^4P^\circ_{5/2}$), 453.1 nm ($3p\,^4D_{1/2}-3s\,^4P^\circ_{3/2}$), and at 454.7 nm ($3p\,^4D_{3/2}-3s\,^4P^\circ_{5/2}$). Examples of some decay curves associated with the $3p\,^4D_J$ energy levels are shown in Fig. 3. The reason for the apparent fall in the intensity at the end of decay curve is because these are logarithmic plots and near 180 mm the background region is entered. In these plots the background has been subtracted but as explained later this subtraction was a free parameter in the curve-fitting procedure.

The lifetime measurements performed at 451.1, 451.5, 452.4, and 543.5 nm yielded decay curve characteristics belonging to the $3p\,^4D_J$ energy levels. Growing-in cascades, due to decays of higher terms, were present in all these decay curves. The effect of these cascades on the primary lifetime was investigated by varying the start channel of the fit. The end point was also varied to test

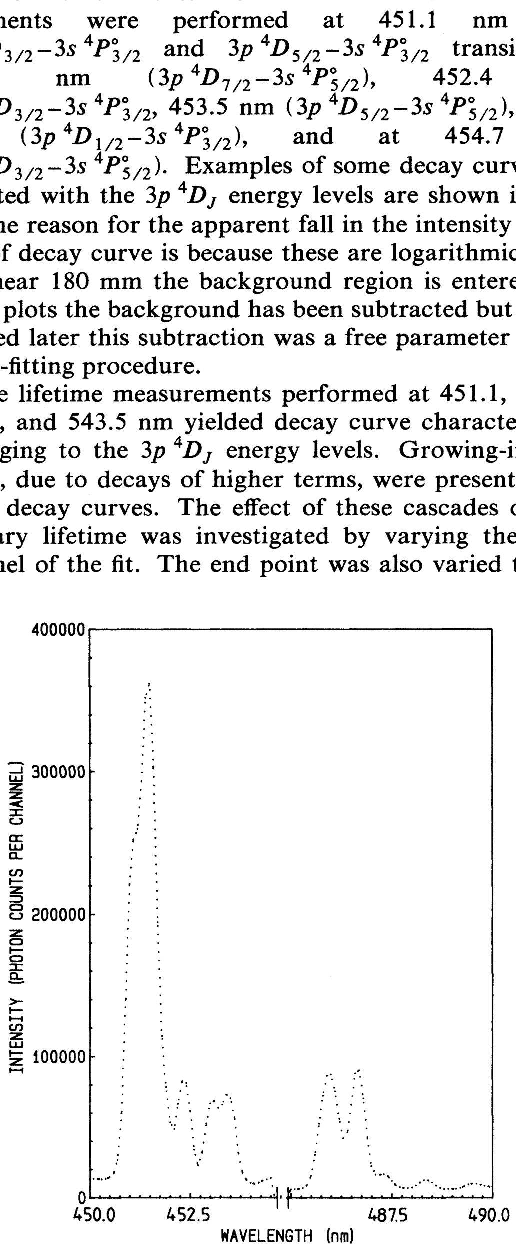

FIG. 2. Part of the nitrogen spectrum between 450 and 490 nm obtained with a beam energy of 0.5-MeV and 100-μm slit widths.

TABLE I. Results obtained from curve fitting for some $2s^12p^1(^3P^\circ)3p$ and $2s^12p^1(^3P^\circ)3d$ levels in N III.

Observed wavelength (nm)	Observed level	Lifetimes (ns)		
		This work[a]	Other experiments	Theory
379.3	$3d\,^4P^\circ_{5/2}$	2.77±0.19 (18.4±0.36)	2.9;[b]3.03;[c]1.46[d]	10.1[e]
432.4	$3d\,^4D^\circ_{5/2}$	2.48±0.01		
451.1	$3p\,^4D_{3/2}$	18.2±0.36 (−9.92±0.40)	31.0[g]	14.3[e]
451.5	$3p\,^4D_{7/2}$	18.0±0.36 (−10.5±0.42)	24.0;[b]24.0;[f]31.7[g]	14.3[e]
452.4	$3p\,^4D_{3/2}$	17.7±0.35 (−9.79±0.78)		
453.5	$3p\,^4D_{5/2}$	17.5±0.88 (−11.2±1.0)	21.3[i]	
485.8	$3d\,^4F^\circ_{3/2}$	16.2±0.06 (−2.3±0.25)	19.1[g]	15.9[e]
486.1	$3d\,^4F^\circ_{7/2}$	15.5±0.15 (−1.93±0.40)	16.9;[b]16.9;[f]21.8;[g]17.4[i]	15.9[e]
486.7	$3d\,^4F^\circ_{9/2}$	16.3±0.16 (−2.46±0.29)	16.7;[c]16.7;[b]16.9;[b]16.7;[c]16.7;[f]15.7;[g]17.5;[h]17.4[i]	15.9[e]
487.4	$3d\,^4F^\circ_{5/2}$	16.3±0.33 (−2.65±0.86)		
488.4	$3d\,^4F^\circ_{7/2}$	16.7±0.17 (−2.69±0.62)		

[a] Cascade lifetimes are given in parenthesis. A negative value indicates a growing-in cascade. Errors are only an indication of the accuracy of the fit.

[b] Denis *et al.* (Ref. [26]).

[c] Pinnington and Lin (Ref. [27]).

[d] Lewis *et al.* (Ref. [23]).

[e] Wiese, Smith, and Glennon (Ref. [36]).

[f] Denis *et al.* (Ref. [24]).

[g] E. H. Pinnington (Ref. [28]).

[h] Ceyzeriat *et al.* (Ref. [29]).

[i] J. Desesquelles (Ref. [37]).

the influence of the decay tail on the lifetimes. In all cases the lifetime values remained stable. Since the uncertainty in the background may also be responsible for a fraction of the lifetime uncertainties, the fits were made leaving the average background as a free parameter [38]. The decay curves were therefore analyzed by using the raw data, whereby the DISCRETE [30] program determines the background to be subtracted.

Denis *et al.* [24,26] reported a 24.0-ns lifetime measured at 451.5 nm, which they assigned to the $3p\,^4D$ multiplet. They reasoned that the disagreements between their experimental transition probabilities and those reported by Wiese [36] are not too excessive, for the following reasons: "The theoretical values, obtained in the Coulomb approximation or with the self-consistent-field method, are given with uncertainties within 25%. The deviations from experiment are sometimes too great, but the measurements may be disturbed for some lines by blending with other weak multiplets, and for others by the possibility of intercombination transitions." Pinnington [28] also ascribed reasonably long lifetimes to the $3p\,^4D$ multiplet, measured at 451.0 and 451.5 nm, which he ascribed to cascading. A cascade-corrected lifetime analysis will therefore give the most reliable lifetime result.

In spite of the fact that the lifetime measurements at 453.1 and 454.7 nm also yielded the lifetimes of the $3p\,^4D_{1/2}$ and $3p\,^4D_{3/2}$ energy levels, the shapes of these two decay curves were not only markedly different from the first four, but the decay curve compositions from the curve-fitting analyses were also quite different from those of the other four measurements. For the first four measurements the curve-fitting analyses yielded a two-component decay composition with a primary lifetime of approximately 18 ns and a growing-in component of approximately 10 ns.

For the measurement at 453.1 nm a three-component decay curve was obtained with lifetimes of 19.3 and 4.05 ns as well as a growing-in component of 0.65 ns. Several reasons can be put forward for the different results obtained at this wavelength. This decay curve is undoubtedly influenced by transitions from the $4fG(\frac{9}{2})_4$ level in N II and/or the $2p3p\,^3S_1$ energy level in N IV. Transitions from the $4fG(\frac{9}{2})_4$ level in N II are also tabulated at 223.5, 223.9, and 455.3 nm. No spectral lines were observed in the spectral scan at the first two wavelengths. A lifetime measurement was carried out at 455.254 nm by Fink *et al.* [25] and they ascribed a lifetime of 11.7 ns to the $4f\,^3G$ multiplet in N II, compared with the calculated theoretical mean lifetime of 2.9 ns [36]. At 455.0 nm Bashkin *et al.* [35] observed weak spectral lines at 0.5- and 1.0-MeV energies, and no spectral line at 2.0 MeV. The 0.5-MeV observation was ascribed to the $4f\,^3G$ multiplet in N III, while they ascribed their measurement at 1.0 MeV to the $3p\,^4D$ multiplet in N III. They also classified the lifetimes as being short, which may favor the N II assignment. Their measurements at 453.1 and 453.3 nm are assigned to the $4f\,^1G$ multiplet in N II, the $3p\,^4D$ and $3d\,^4P^\circ$ multiplets in N III and the $3p\,^3S$ multiplet in N IV, depending on the energy; the lifetimes were all classified in the long lifetime region.

Transitions from the $2p3p\,^3S_1$ energy level in N IV are also tabulated at 448.0 and 449.6 nm. The fact that the intensity of the spectrum increases by a factor of 3 from 0.5 to 1.0 MeV at these two wavelengths, is considered to be indicative of an energy level belonging to a higher charge state, in this case the $2p3p\,^3S_1$ energy level in N IV. The influence of the $3d\,^4P^\circ_J$ energy levels in N II is

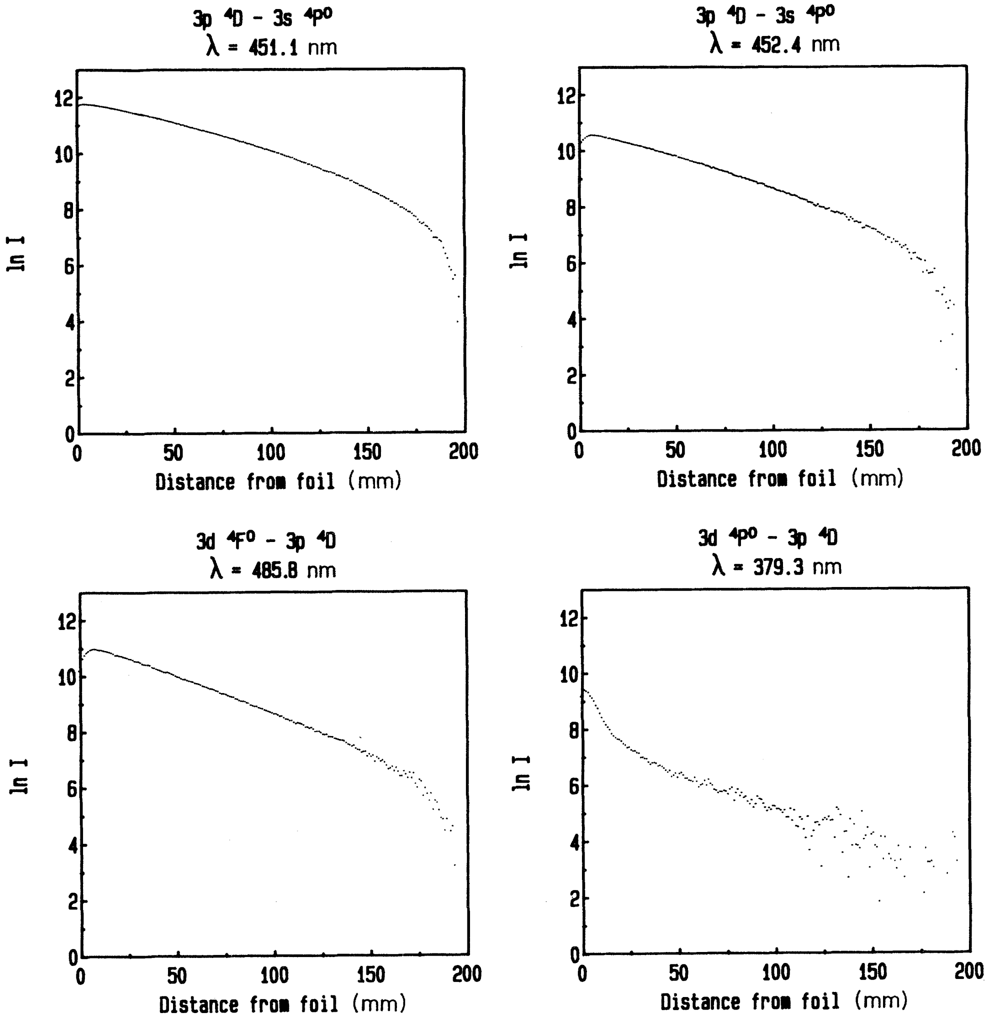

FIG. 3. Background-corrected decay curves, of ln intensity vs distance from foil, measured for the $3p\,^4D$, $3d\,^4D^\circ$, and $3d\,^4F^\circ$ levels.

somewhat difficult to ascertain at this wavelength as it does not influence the decays at other wavelengths. However, the presence of the third component (a short lifetime) may be indicative of the decay of the $3d\,^4P_J^\circ$ energy levels, as it was found that these levels do influence the $3p\,^4D_J$ energy-level lifetimes.

A two-component decay curve was obtained at 454.7 nm, yielding a primary lifetime of 17.9 ns, which is in good agreement with the other lifetimes obtained from curve fitting for the $3p\,^4D_J$ energy levels, as well as a second component of 2.03 ns; this was not a growing-in component. This component may arise from the decay of the $5s\,^2S_{1/2}$ energy level in N III, but as this level is also tabulated at 453.9 nm, where no transition was observed, it seems more likely that this lifetime arises from the $3d\,^4D_J^\circ$ and $3d\,^4F_J^\circ$ energy levels that cascade to the $3p\,^4D_J$ levels.

B. Cascading levels

Several factors, such as lifetime ratios, level populations, branching ratios, and higher-order cascades, determine whether a particular cascading level can significantly influence the analysis of the primary decay curve. It is possible to predict the importance of a cascade using theoretical and/or empirical methods. However, the most detailed information can be obtained by looking experimentally at intensity ratios and decay curves for as many cascade levels as possible. Three cascading levels were identified in the spectrum analyses, the influence of which on the primary level has to be further investigated. The same procedures as for the primary decays were followed to obtain the curve-fitted lifetimes of all the cascading levels.

1. The 3d $^4P_J^\circ$ energy levels in N III

The $3d\,^4P_J^\circ$ levels decay to the $3p\,^4L_J$ $(L=S,P,D)$ levels at 379.3 nm $(3d\,^4P_{5/2}^\circ\text{–}3p\,^4D_{7/2})$, the decay curve of which, measured at 0.5-MeV beam energy, is also shown in Fig. 3, 452.8 nm $(3d\,^4P_{1/2}^\circ\text{–}3p\,^4S_{3/2})$, 454.6 nm $(3d\,^4P_{5/2}^\circ\text{–}3p\,^4S_{3/2})$, and at 529.8 nm $(3d\,^4P_{5/2}^\circ\text{–}3p\,^4P_{3/2})$. The transition at 529.8 nm lies outside the detection range of our spectrometer and could therefore not be observed. The decay at 452.8 nm yielded a three-component best fit, the primary lifetime of 4.47 ns corresponded to a blend between the $3p\,^4D_{1/2}$ and the $3d\,^4P^\circ_{1/2}$ energy levels, while the other component of 19.3 ns was indicative of the decay of the $3p\,^4D_{1/2}$ level. Another component of 0.64 ns was also obtained, which may be due to cascading to $3d\,^4P^\circ_{1/2}$ from a higher-lying level with a short lifetime. A cascade-corrected lifetime analysis has shown that the lifetimes of the $3d\,^4P^\circ_J$ levels are indeed influenced by higher-lying energy levels [39]. The decay components obtained for the measurement at 464.6 nm could not be used in any further analyses as it has already been shown in Sec. IV B 1 that this transition was blended with the $3p\,^4D_{3/2}-3d\,^4P^\circ_{5/2}$ transition at 454.7 nm. The decay constants measured at 379.3 nm can be unanimously ascribed to the decay of the $3d\,^4P^\circ_{5/2}$ level, as there are no nearby transitions in the nitrogen spectrum that can influence the decay curve measured at this wavelength.

Between 526.1 and 529.9 nm (the $3d\,^4P^\circ_J-3p\,^4P_J$ transitions) we did not observe any spectral lines. Only three other authors [23,24,27] have already investigated the decay of the $3d\,^4P^\circ_{5/2}$ energy level, all of them using the beam-foil technique. The results obtained in this investigation are in fair agreement with the work of Denis *et al.* [24], who reported a lifetime of 2.9 ns, as well as a second component of 38.2 ns, which they either ascribed to the decay of cascades from levels corresponding to high quantum numbers ($n>4$), or to the effect of the residual gas. They concluded that complementary experiments are necessary to verify either of their two hypotheses. The identification of the spectral lines in the work of Pinnington and Lin [27] is complicated by the fact that they had three elements—nitrogen, carbon, and oxygen—present in their beam. Therefore, they considered three possible identifications for their measurement at 379.4 nm, namely multiplet 34 in O II, multiplet 2 in O III, and a transition from the $3d\,^4P^\circ_{5/2}$ energy level in N III. However, they did not observe the other members of the O II multiplet, of which the line at 379.4 nm would be the weakest transition. Neither did they observe the strong spectral line at 376.0 nm, corresponding to multiplet 2 in the O III spectrum. Transitions in oxygen were therefore not considered to be responsible for the observed line at 379.4 nm. Their lifetime of 3.03 ns is in fair agreement with that of this investigation. Lewis *et al.* [23] considered their transition at 379.3 nm to be probably the strongest of the allowed $3d\,^4P^\circ_J$ transitions, due to the fact that of the eight tabulated transitions from the $3d\,^4P^\circ_{5/2}$ energy levels, they observed only one. They also neglected cascading to this level as they did not observe any of the nine allowed transitions to the $3d\,^4P^\circ_{5/2}$ level. The reason for their low value of 1.46 ns, measured at 379.3 nm, cannot be explained.

2. The $3d\,^4D^\circ_J$ energy levels in N III

The spectral range where this level can be observed is between 644.5 and 648.8 nm (the $3d\,^4D^\circ_J-3p\,^4P_J$ transitions) and between 432.1 and 435.4 nm (the $3d\,^4D^\circ_J-3p\,^4D_J$ transitions). The $3d\,^4D^\circ_J-3p\,^4P_J$ transitions lie outside the detection range of our spectrometer system and could therefore not be observed. The only observed spectral line in the 432.1–435.4-nm wavelength region was at 432.4 nm, the decay curve of which, measured at 0.5-MeV beam energy, is also shown in Fig. 3. The intensity of this spectral line varied from 10 000 photon counts per channel at 0.5-MeV beam energy to 5000 photon counts per channel at 1.0- and 2.0-MeV beam energies. Only two other authors have already observed the $3d\,^4D^\circ_J-3p\,^4D_J$ transitions, namely Bashkin and Stoner [34] and Fink, McIntyre, and Bashkin [25], although no one reported any lifetimes. The spectral line at 432.3 nm in the spectrum of Fink, McIntyre, and Bashkin [25] first appeared at 1.0 MeV (N_2^{28}) and got stronger at 1.5 and 2.0 MeV (N^{14}). It is well known that any branch can be used in the arbitrarily normalized decay curve treatment of cascading [31]. We also considered the possibility that the totality of the transitions might have an effect on the population of the $3p\,^4D_J$ transitions to the extent that the data, although representing many exponentials, only appeared to contain one.

3. The $3d\,^4F^\circ_J$ energy levels in N III

The $3d\,^4F^\circ_J$ energy levels were observed at 485.8 nm ($3d\,^4F^\circ_{3/2}-3p\,^4D_{1/2}$) (the decay curve of this transition, measured at 0.5-MeV beam energy is also shown in Fig. 3), 486.1 nm ($3d\,^4F^\circ_{7/2}-3p\,^4D_{5/2}$), 486.7 nm ($3d\,^4F^\circ_{9/2}-3p\,^4D_{7/2}$), 487.4 nm ($3d\,^4F^\circ_{5/2}-3p\,^4D_{5/2}$), and 488.4 nm ($3d\,^4F^\circ_{7/2}-3p\,^4D_{7/2}$). The intensities of these spectral lines varied from 90 000 photon counts per channel at 0.5 MeV to 40 000 photon counts per channel at 1.0 MeV and 2500 photon counts per channel at 2.0-MeV beam energy, respectively. A spectrum scan at 0.5 MeV showing the $3d\,^4F^\circ_J$ energy levels between 485 and 490 nm is also shown in Fig. 2. All the results obtained from curve fitting showed a primary decay constant of approximately 16 ns, as well as a growing-in component of about 2.3 ns. The primary lifetime is assigned to the decay of the $3d\,^4F^\circ_J$ energy levels, while the presence of the growing-in component is ascribed to cascading from higher-lying ^4P levels. The only measurement with different decay constants was obtained at 489.6 nm, where a blend between the $3d\,^4F^\circ_{5/2}$ energy level in N III and the $3p\,^1P_1$ energy level in N II was measured. We obtained a 26.1-ns primary decay component, as well as a second component of 2.68 ns. Fink, McIntyre, and Bashkin [25] measured a decay time of 10.0 ns at this wavelength and ascribed this value to the decay of the $3p\,^1P_1$ energy level in N II. Unfortunately, this is the only wavelength within our detection range where transitions from the $3p\,^1P_2$ energy level are tabulated, the other being at 648.2 nm.

Various other experimenters [24,26–29] have observed the $3d\,^4F^\circ_J$ energy levels. These lifetime results are shown in Table I. The values vary between 15.7 and 21.8 ns, all of which were assigned to the decay of the $3d\,^4F^\circ_J$ energy levels. A comparison of our lifetimes (Table I) with the results of earlier beam-foil studies shows that there is generally good agreement with previous work, but it has to be pointed out that cascading does influence the lifetimes of the $3d\,^4F^\circ_J$ energy levels, illustrating the necessity of applying the more rigorous cascade-correction method before a final comparison can be made. These analyses are at the moment being carried out. Fink, McIntyre, and Bashkin [25], as well as Bashkin [34], have also observed the $3d\,^4F^\circ-3p\,^4D$ multiplet, but they did not report any measured lifetimes.

V. ANDC ANALYSES

In performing the ANDC analyses for the $3p\,^4D_J$ energy levels, only cascading from the more heavily populated $3d\,^4F^\circ$ and $3d\,^4D^\circ$ levels were initially included. However, the fits showed some instabilities and a closer inspection showed that cascading from the $3d\,^4P^\circ$ level had to be included. Although the intensity of the line associated with a transition from the $3d\,^4P^\circ$ level was weak, it was found to be important in the analyses. When carefully considering cascading from all three levels, the final results of 12.7 and 12.8 ns were obtained, the analyses of which was found to be stable according to the test criteria introduced by Engström [31]. The final result satisfying the test criteria thus confirmed the importance of all three cascades in the analysis. The N III lifetimes obtained in this work are given in Table II, together with the results from previous studies. Only one set of theoretical data, based on the work of Wiese, Smith, and Glennon [36], is included in the table. Applying the ANDC correction technique, lifetimes were obtained that were around 30% shorter than those extracted from multiexponential fitting. The reason for this large difference is ascribed to the fact that cascading to the $3p\,^4D_J$ levels was found to be quite severe.

TABLE II. ANDC results for the $3p\,^4D_J$ levels in N III.

Identified level	Lifetimes (ns) This work	Other experiments	Theory
$3p\,^4D_{7/2}$	12.7±0.9	31.7;[a]24.0;[c]24.0[d]	14.3[b]
$3p\,^4D_{5/2}$	12.7±0.9	21.3[e]	14.3[b]
$3p\,^4D_{3/2}$	12.8±0.9	31.0[a]	14.3[b]

[a] E. H. Pinnington (Ref. [28]).

[b] Wiese, Smith, and Glennon (Ref. [36]).

[c] Denis *et al.* (Ref. [26]).

[d] Denis *et al.* (Ref. [24]).

[e] J. Desesquelles (Ref. [37]).

VI. CONCLUSIONS

We have obtained accurate cascade-corrected beam-foil lifetimes for the $3p\,^4D_J$ levels in N III. These data are in better agreement with available theoretical lifetimes. The three dominant $3d\,(^4P_J^\circ,\ ^4D_J^\circ,\ ^4F_J^\circ)$ cascading energy levels were identified and the importance of incorporating all three in the ANDC analyses was shown. This experiment was largely motivated by previously observed discrepancies between experimental results and between theory and experiment. The present results indicate that the agreement between theory and experiment is more satisfactory and we believe that these results are of sufficient accuracy to serve as useful and meaningful checks for further calculations.

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