UTILIZATION OF SYNCHROTRON RADIATION FOR THE MEASUREMENT OF FAST FLUORESCENCE LIFETIMES OF IONS IN SOLIDS☆

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Synchrotron radiation from an electron storage ring has been used to measure the lifetime of the very short lived uv fluorescence of LaF_3:Ce^{3+}.The value obtained was 20 nsec. Several considerations which could improve and extend the experimental method are discussed.

Many of the traditional difficulties facing the spectroscopist working in the ultraviolet have been circumvented in recent years with the advent of electron storage ring synchrotron radiation sources. The synchrotron spectrum is continuous with much of its output in regions previously accessible to only a few line sources. Synchrotron radiation originates in vacuum-permitting direct exposure of the sample to the radiation with no intervening absorbing material. The radiation is polarized and well collimated.

We have recently made use of another property of the radiation from a storage ring source – that it consists of very short, regularly spaced pulses. The University of Wisconsin Physical Science Laboratory 240 MeV storage ring provided the excitation for a fluorescence lifetime measurement on LaF_3:Ce^{3+} recently conducted here [1]. The ring operates at a frequency of approximately 32 MHz and generates light pulses approximately 4 nsec long. Undispersed light from the ring was incident upon the sample, which was mounted within a vacuum chamber communicating directly with the storage ring beam tube. Flurescent radiation from the sample passed through a sapphire window, located at a right angle to the incident beam, and was focussed by a suprasil lens on the entrance slit of a Jarrell–Ash 1/4 meter spectrometer. Light at 3050 Å was detected with a 1P28 photomultiplier operated at 1250 V. The PM output was directed to a Tektronix 1S1 sampling unit operated in the manual scan mode, in which the trigger to sampling time is held constant. Triggering for the 1S1 was provided by a signal from the storage ring RF supply. The 1S1 output went to a discriminator and from there to a Hewlett–Packard 5245L counter (see fig. 1). The 1S1 was calibrated with respect to

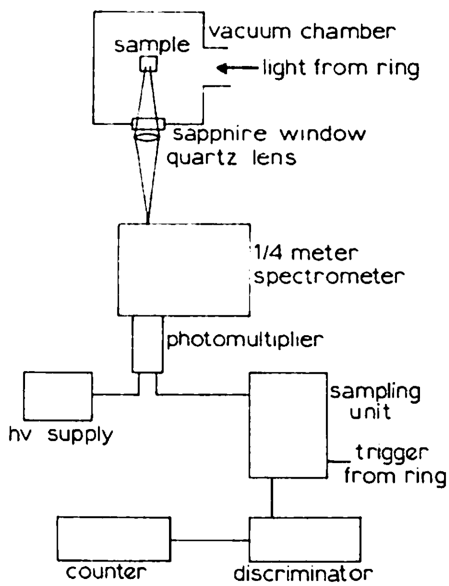

Fig. 1. Experimental apparatus used for the measurement of the LaF_3:Ce^{3+} fluorescence lifetime.

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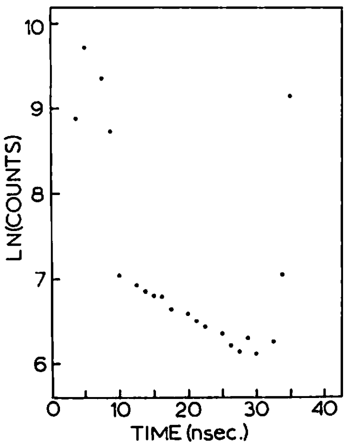

Fig. 2. Logarithm of counts versus delay. The large peaks are scattered light during the excitation period.

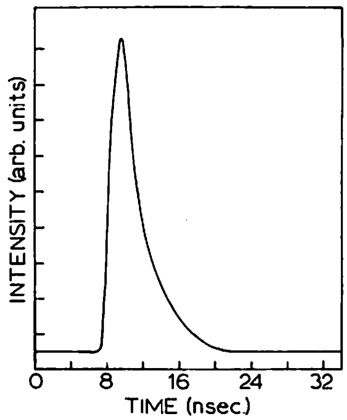

Fig. 3. The response of the photomultiplier to a single photon.

the storage ring RF and counts were taken with various delays set on the 1S1. The counting period was ten minutes. The storage ring beam current was noted at the start and end of a count. The beam current decay was approximately linear over a ten-minute counting period.

A plot of the logarithm of the number of counts, normalized to 1 mA average beam current, versus delay is shown in fig. 2. The peak at ~ 5 nsec is light scattered from the incident beam during the excitation period. The second peak at ~ 36 nsec is scattered light from the following light pulse 31.25 nsec later. Between the two scattered light peaks is a linear region with a slope corresponding to $\tau = 20$ nsec, the fluorescent lifetime.

The method can be extended to shorter or longer lifetimes. For measuring shorter lifetimes the length of the exciting pulse can be shortened to ~ 1 nsec by "bunching" the electrons in the storage ring although the beam current decay rate increases dramatically when this is done [2]. The electronics resolution may be shortened also by using a faster PM tube or by setting the discriminator at a higher level on the PM response (see fig. 3). The 1S1 gate width is ~ 350 psec. For measuring longer lifetimes the storage ring beam may be "wobbled" so that only a subharmonic of the synchrotron beam frequency strikes the sample – permitting a longer observation of the fluorescence decay before the sample is re-excited.

The counting rate could be improved by building a delay gate with less dead time than the 1S1, which has a maximum operating frequency of 80 kHz. The 1S1 does have the advantage of a scanning mode in which the trigger to gate interval is varied by an internal or external signal. In this manner it may be used with a multichannel analyzer to give a very complete picture of the input waveform. Also, in this mode it is not necessary to measure the ring beam current for normalizing the counts in each interval. The single photon response function was measured using the 1S1 in this manner. For the Ce^{3+} lifetime measurement, however, our multichannel averager's 1024 channels required an impractically long measuring period. At the very low count rate we observed the sampling unit can be more efficiently utilized by using a photon for triggering and measuring the time interval to the next RF pulse. We expect to improve the count rate by a factor of 300 using this technique which we hope to implement shortly.

References

[1] L.R. Elias, Wm.S. Heaps and W.M. Yen, to be published.
[2] E. Rowe, private communication.