Nigerian Journal of Theoretical and Environmental Physics (NJTEP)
ISSN Online: 1597-9849
ISSN Print: 3026-9601
DOI: https://doi.org/10.62292/njtep.v3i1.2025.68
Volume 3(1), March 2025

# Dependence of Luminescence Lifetimes on Radiation Absorbed Dose from Quartz using a Time-Resolved Based Pulsing System

***[1]Uriri, S. A., [2]Nwakaji, K. N., [3]Abeukuta, O. J. and [4]Okoh, F. N.**

[1]Department of Physics, Delta State University of Science and Technology, Ozoro, Nigeria
[2]Department of Geology, Delta State University of Science and Technology, Ozoro, Nigeria
[3]Department of Chemistry, Delta State University of Science and Technology, Ozoro, Nigeria
[4]Department of Science Laboratory Technology, Delta State University, Ozoro, Nigeria

*Corresponding author's email: uriris@dsust.edu.ng

**Keywords**:
Absorbed dose,
Time-resolved luminescence,
Quartz,
Pulsing system,
Lifetime.

**ABSTRACT**

Time-resolved optical stimulation of luminescence is an important technique that is well established for the study of dosimetric materials including quartz, carbon doped aluminium oxide, feldspar, etc. These materials, particularly quartz, Is a material of interest in dosimetry. Time resolved optical stimulation separate in time the stimulation and emission of luminescence. The luminescence is obtained from the quartz sample using a brief light pulse and the emission of the luminescence is monitored. The aim is to investigate the influence of radiation dose on luminescence lifetimes in quartz using a more cost effective and easy to design light emitting diode pulsing system. Here, a new pulsing system based on light emitting diode is designed and is used to study the dependence of luminescence lifetimes on radiation dose in quartz. The Luminescence lifetimes measured between 5 and 200 Gy beta dose were constant at about 42.0 ± 1.3 µs. The luminescence lifetime is independent of dose because most of the luminescence is emitted from LH centres which would not have been sufficiently emptied by annealing at 500 $^0$C prior to irradiation.

## INTRODUCTION

Luminescence is a process whereby light of a certain wavelength is emitted from previously irradiated materials, mostly semiconductors and insulators when under exposure to light at a different wavelength or heated. There are different forms of luminescence including optically stimulated luminescence (OSL), thermoluminescence, photoluminescence, etc. OSL is the luminescence emitted at one wavelength from an irradiated insulator or semiconductor when exposed to light at a different wavelength. OSL measurements are carried out by the stimulation of an irradiated sample with a light source emitting visible, ultra-violet or infrared light at a certain wavelength.

Time-resolved optical stimulation (TR-OSL) is an important technique for measurement of OSL whereby light pulses of constant intensity are used to separate in time the stimulation and emission of luminescence (Uriri, 2016). The luminescence is stimulated using a short light pulse emitting visible, infrared light or ultra-violet at a certain wavelength which is detected by a photomultiplier tube. The measured signal consists of linearly increasing luminescence component and scattered stimulating light. After the pulse, the luminescence and the scattered stimulation light are separated by the careful use of band pass filters and transmission filter. The band pass filters are used to transmit the luminescence and the transmission filters to attenuate the intensity of the scattered stimulation light (Botter-Jensen, 1997; Galloway et al., 1997). The measured intensity of the luminescence decreases exponentially in time to produce a decay curve. In time-resolved luminescence, the decay curves can be respectively deconvoluted by non-linear regression into three principal components; the fast, medium and slow component (Bailey et al., 1997; Chithambo and Galloway, 2001; Smith and Rhodes, 1994). Time-resolved luminescence technique gives high signal-to-noise ratio over extended measurement times (Galloway et al., 1997). The spectra obtained from time-resolved luminescence have the potential to provide information concerning the dynamics of radiative recombination processes associated with specific bands and the nature

of the defect where recombination occurs (Bailiff, 2000).

Measurement systems for time-resolved luminescence based on LED systems and lasers have been reported (Chithambo and Galloway, 2003; Chithambo, 2011; Sanderson and Clark, 1994; Markey et al., 1995). Sanderson and Clark (Sanderso and Clark, 1994) make use of a 470 nm light from an N2 dye laser to pulse optically stimulated luminescence from alkali feldspar with a pulse width of the order of 10 ns. Chithambo and Galloway (Chithambo and Galloway, 2003) used a pulsed 525 nm green light-emitting-diode system to measure luminescence from feldspar and quartz. Markey et al. (Markey et al., 1995) carried-out time-resolved luminescence to study features of luminescence from α-Al2O3 in which the light from an Ar-ion laser was used to stimulate luminescence. The aim of this study is to develop an easy-to-use pulsing system using blue light emitting diodes for measurements of time-resolved luminescence and use the system to investigate the influence of radiation dose on luminescence lifetimes in quartz

## MATERIALS AND METHODS

### The New Pulsing System

Figure 1 shows a schematic diagram of the pulsing system. Figure 1(a) shows the schematic arrangement for detection and measurement of time-resolved luminescence spectra. Figure 1(b) is a schematic diagram showing the designed circuitry used to generates the brief pulse. The detecting system shown in Figure 1(a) was reported previously by Galloway (Galloway, 2002), Chithambo and Galloway (Chithambo and Galloway, 2003), and Chithambo (Chithambo, 2011). The pulsing circuit shown in Figure 1(b) is new and is discussed in detail. A monostable mul tivibrator based on the NE555N timer integrated circuit was used to generates pulses of various duration and the generated pulses are sent into a MOSFET transistor (2N700 MOSFET transistor). A set of 16 LEDs that are arranged in a dural holder were used to stimulate the luminescence, with a Schott GG-420 long-pass filter placed in front of each LED to prevent scattered stimulation light from entering the photomultiplier tube. A transmission filter (Schott BG39), with a transmission peak at 340 nm was placed in front of the photomultiplier tube to transmit the emitted luminescence to the photomultiplier tube. The detected luminescence from several scans is combined giving rise to a time-resolved luminescence spectrum. The spectrum is generated by timing the duration between a START and a STOP signal. A multichannel scaler produces a START signal that triggers the pulsing system to turn ON 16 LEDs for stimulation. The emitted luminescence is detected by a photomultiplier tube (EMI 9635QA) and the signal fed into the combination of a timing filter amplifier (Ortec 474) and a constant-fraction discriminator (Ortec 584). A valid STOP signal is provided by the first photon signal detected from the quartz sample under stimulation. The multichannel scaler then records the luminescence-photon counting rate until a STOP signal arrives. To prevent scattered stimulation light from reaching the photomultiplier tube, a long pass filter (Shott GG-420) was placed in front of the 16 LEDs. A transmission filter (Schott BG39) was then placed in front of the photomultiplier tube to transmit the emitted luminescence.

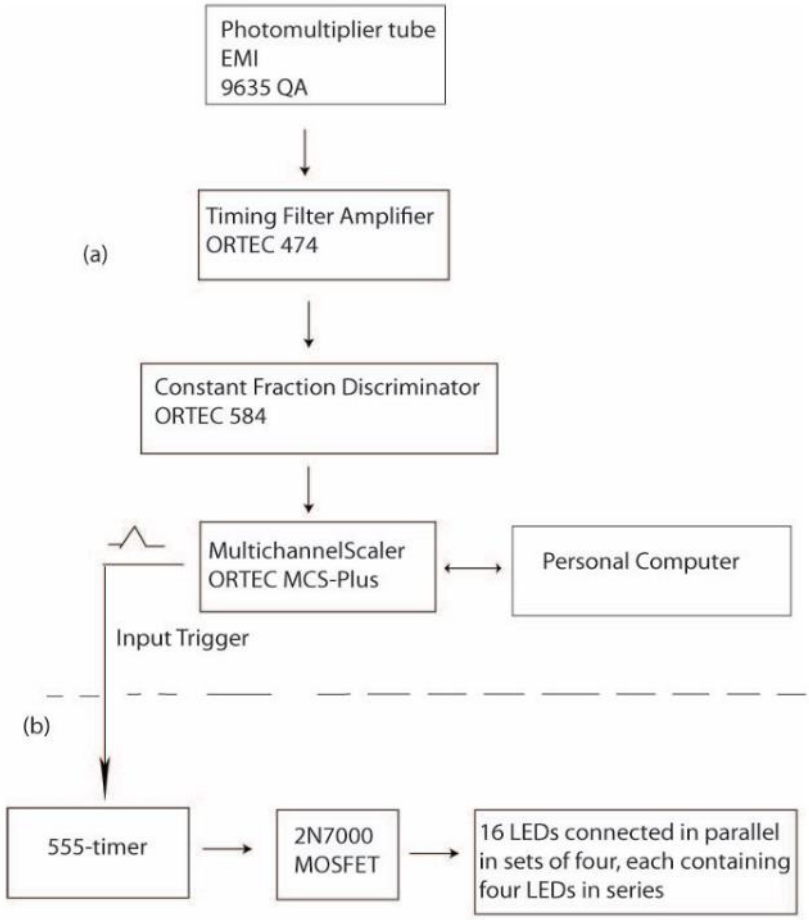


Figure 1: The pulsing system showing the arrangement for detecting and recording time-resolved luminescence spectra (a) and the pulsing circuitry used to pulse the light emitting-diodes (b)

The signal detected by the photomultiplier tube is fed into the combination of a timing filter amplifier and a constant-fraction discriminator. The timing filter amplifier shape the pulses and optimize the signal-to-noise ratio for timing measurements. These are then furnished to a constant-fraction discriminator where they are counted. The multichannel scaler simultaneously triggers the pulsing circuitry and records the counting rate of events as a function of time.

**RESULTS AND DISCUSSION**

Figure 2 shows an example of a TR-OSL spectrum obtained from a sample of quartz annealed at 500 $^0$C and irradiated to 5 Gy. The luminescence was stimulated at a pulse width of 11 s. The open circles represent the TR-OSL spectrum while the solid squares show background counts. The inset shows the portion of the TR-OSL spectrum after the light-pulse. All measurements were undertaken using the new pulsing system as described above. Each measurement was repeated five times and the mean lifetime obtained. The portion of each TR-OSL spectrum after the light-pulse was fitted with the equation,

$$I(t) = A\,exp\left(-\frac{t}{\tau}\right) + \beta\,, \qquad (1)$$

where A is a scaling parameter, $\tau$ is the luminescence lifetime, l(t) is the time dependence of luminescence after the light-pulse, t is time and B a constant added to account for the background signal. The luminescence lifetime extracted from the fit is 40.2 ± 2.0 s. This value is consistent with ones reported for quartz annealed at 500 $^0$C. For example, Galloway (Galloway, 2002) reported a lifetime of 39.9 ± 0.4 s for a sample of quartz annealed at 500 $^0$C, Chithambo and Galloway (Galloway and Chithambo, 2000) reported a lifetime of 40.0 ± 0.3 s for quartz annealed at 500 $^0$C and Chithambo (Chithambo, 2006) reported a lifetime of 41.8 ± 0.3 s for quartz annealed at 500 $^0$C. The luminescence lifetimes obtained using the new system are in good agreement with those reported in the literature as explained.

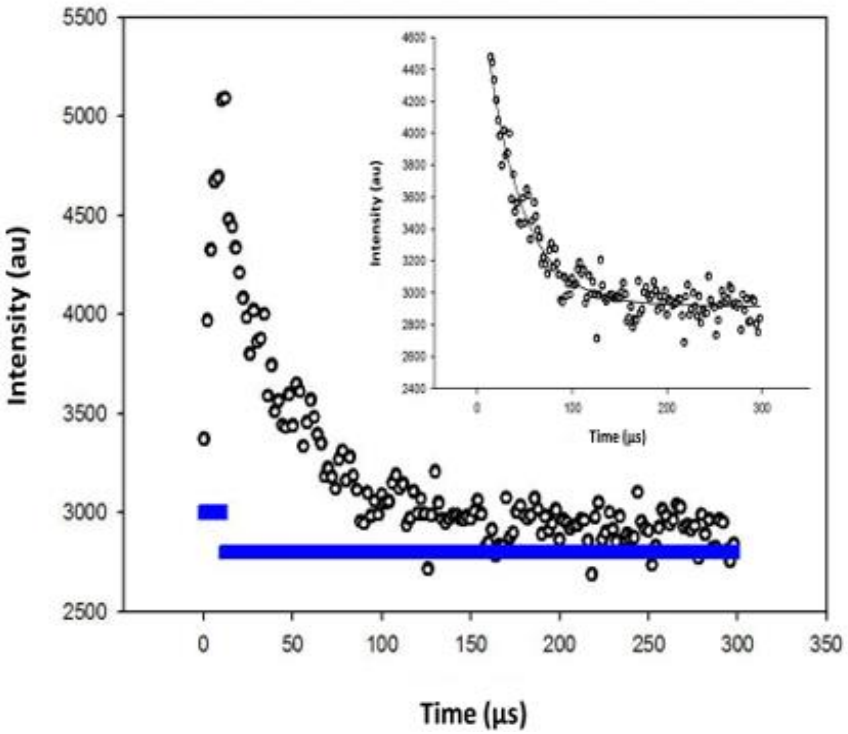


Figure 2: A TR-OSL spectrum from a sample of quartz annealed at 500 $^0$C and irradiated to 5 Gy before 470 nm pulsed stimulation. Background counts (solid squares) are shown for comparison. The inset shows the luminescence after the light-pulse

**Dependence of luminescence lifetimes on dose**

The aim of this experiment was to investigate the dependence of luminescence lifetimes on dose in quartz annealed at 500 $^0$C. The sample was irradiated with beta doses between 5 and 200 Gy before 470 nm stimulation using an 11 s pulse. Measurements were repeated five times and the mean lifetime evaluated. Luminescence lifetimes were evaluated for each TR-OSL spectrum by fitting Equation 5.1 to the signal after the light-pulse. Figure 3 shows the dependence of luminescence lifetimes on beta dose. For all doses used in this experiment, that is, between 5 and 200 Gy, the luminescence lifetimes obtained were unaffected by beta dose. The mean lifetimes were constant at about 42 ± 1.3 s. Thus, our results show that luminescence lifetimes in quartz are independent of radiation dose for a sample annealed at 500 $^0$C. This value is consisted with ones reported for quartz annealed at 500 $^0$C. For example, Galloway (Galloway, 2002) reported a lifetime of 41.5 ± 0.5 s for quartz annealed at 500 $^0$C and Chithambo (Chithambo, 2006) reported a lifetime of 41.8 ± 0.3 s for quartz annealed at 500 $^0$C. The influence of irradiation on luminescence lifetimes can be described with reference to an energy band model proposed by Galloway (Galloway, 2002). Figure 3 shows this energy band model consisting of a non-radiative recombination centre R and three radiative centres labelled as LH, LL and LS. The electron traps are shallow traps (ST), optically sensitive traps (LST) and deep traps which are not optically stimulated, represented as DT. In this model, annealing causes the transfer of holes from a non-radiative centre R to and between radiative centres LH, LL and LS with corresponding lifetimes H and L (Galloway, 2002). All luminescence centre contributes to the stimulated luminescence but the value of the luminescence lifetime depends on the luminescence centre that is dominant (Galloway, 2002). The luminescence lifetime is independent of dose because most of the luminescence is emitted from LH centres which would not have been sufficiently emptied by annealing at 500 $^0$C prior to irradiation (Chithambo and Ogundare, 2009, Galloway, 2002).

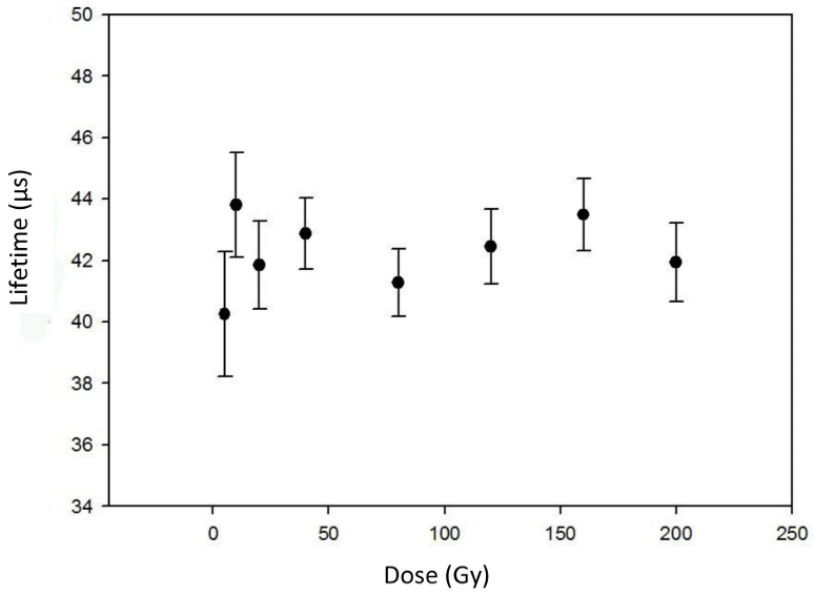


Figure 3: Dependence of luminescence lifetimes on beta dose in quartz annealed at 500 $^{0}$C

## CONCLUSION

A new light-emitting-diode pulsing system for measurement of time-resolved optical stimulation of luminescence is developed. The pulsing system was used to study the dependence of luminescence lifetime on dose and measurement temperature. Results obtained using the pulsing system to measure the dependence of luminescence lifetime on dose and measurement temperature were presented and discussed. The LEDs in the system are pulsed at various durations by a 555-timer integrated circuit operated as a monostable multivibrator. The output signal from the pulsing system was detected by a photomultiplier tube and send to a computer screen for recording. The time-resolved optical stimulation spectra from quartz were measured to demonstrate the system performance. The time-resolved luminescence was measured at beta doses between 5 and 200 Gy from a sample of quartz to investigates the dependence of luminescence lifetime on dose and temperature. The measured luminescence lifetimes were independent of beta dose between 5 and 200 Gy. The luminescence lifetime is not dependent on dose because most of the luminescence is emitted from LH centres which would not have been sufficiently emptied by annealing at 500 0C prior to irradiation. In summary, the performance of the new pulsing system had shown to be consistent with the results of the dependence of luminescence lifetimes on absorbed dose in quartz obtained with others measurement systems.

## ACKNOWLEDGEMENT

Special thanks to Prof Chithambo, Head, Luminescence Research Laboratory, Rhodes University, South Africa for allowing this work to be conducted in his laboratory.

## REFERENCES

Botter-Jensen, L. (1997). Luminescence techniques: instrumentation and methods. Radiat. Meas. 27, 749–768. https://doi.org/10.1016/S1350-4487(97)00206-0

Galloway, R.B., Hong, D.G., Napier, H.J. (1997). A substantially improved green-light-emitting diode system for luminescence stimulation. Meas. Sci. Technol. 8, 267–271. https://doi.org/10.1088/0957-0233/8/3/008

Bailey, R.M., Smith, B.W., Rhodes, E.J. (1997). Partial bleaching and the decay form characteristics of quartz OSL. Radiat. Meas. 27, 123–136. https://doi.org/10.1016/S1350-4487(96)00157-6

Smith, B.W., Rhodes, E.J. (1994). Charge movements and their relevance to optical dating. Radiat. Meas. 23, 329–333. https://doi.org/10.1016/1350-4487(94)90060-4

Bailiff, I. K. (2000). Characteristics of time-resolved luminescence in quartz. Radiat. Meas. 32, 401 – 405. https://doi.org/10.1016/S1350-4487(00)00126-8

Chithambo, M. L., Galloway, R. B. (2003). A pulsed-emitting-diode system for stimulation of luminescence" Meas. Sci. Tech. 11, 418 – 424. http://dx.doi.org/10.1088/0957-0233/11/4/312

Chithambo, M. L. (2011). A time-correlated photon counting system for measurement of pulsed optically stimulated luminescence, J. Lumin vol 131, 92 – 98 https://doi.org/10.1016/j.jlumin.2010.09.005

Sanderson, D. C. W., Clark, R. J. (1994). Pulsed photostimulated luminescence of alkali feldspar. Radiat. Meas. 23, 633 – 639. https://dx.doi.org/10.1016/1350-4487(94)90112-0

Markey, B. G., Colyott, L. E., Mckeever, S. W. S. (1995). Time-resolved optically stimulated luminescence from α-Al2O3:C, Radiat. Meas. vol 24, 457 – 463. https://doi.org/10.1016/1350-4487(94)00119-L

Chithambo, M. L (2006). On the correlation between annealing and variabilities in pulsed-luminescence from quartz, Radiat. Meas. 41, 862 – 865. https://doi.org/10.1016/j.radmeas.2006.05.010

Galloway, R. B. (2002). Luminescence lifetimes in quartz: dependence on annealing temperature prior to beta irradiation, Radiat. Meas. 35, 67 – 77. https://doi.org/10.1016/S1350-4487(01)00258-X

Chithambo M. L., Ogundare F. O. (2009). Luminescence lifetime components in quartz: Influence of irradiation and annealing, Radiat. Meas. 44, 453 – 457. https://doi.org/10.1016/j.radmeas.2009.03.005

Chithambo, M. L., Galloway, R. B. (2001). On the slow component of luminescence stimulated from quartz by pulsed blue light-emitting-diode, Nucl. Instrum. Meth. B. 183, 358 – 368. http://dx.doi.org/10.1016/S0168-583X(01)00694-2

Uriri, S. A. (2016). A light-emitting-diode based pulsing system for measurement of time resolved luminescence, International Journal of Luminescence and applications. 6 (1), 5-13 https://ijlaindia.org/wp-content/uploads/2015/07/Volume6/Issue1/2.pdf

Chithambo, M. L., Galloway, R. B. (2000). A pulsed light-emitting-diode system for stimulation of luminescence. Meas. Sci. Technol. 11, 418 – 424 http://dx.doi.org/10.1088/0957-0233/11/4/312