Design of an Optically Stimulated Luminescent Dosimeter (OSLD) Reader for Temporal Dosimetry

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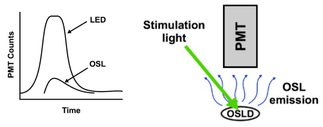
Abstract

Optically stimulated luminescence forms the basis for dating techniques, while optically simulated luminescent (OSL) materials are commonly used for dosimetry. When properly stimulated with light, these materials emit light in proportion to the integrated ionizing radiation dose. The optimal light stimulation wavelength varies with the material, as does the wavelength of the emitted light. To investigate potentially new dosimetric materials, and to explore potential improvements to dating techniques, it is desirable to use a wide variety of stimulation wavelengths. However, affordable OSL readers capable of easily switching among stimulation wavelengths are not widely available. An OSL reader was therefore designed and built to utilize light emitting diodes (LEDs) that could be easily exchanged to stimulate with a variety of wavelengths. Unfortunately, the persistence of light from LEDs following their deactivation can cause substantial interference with detection of the emitted light, despite careful attention to both filtering and system geometry. In an attempt to overcome that limitation, a new design was explored that uses a laser diode system. The price of laser diodes has dropped substantially in the past few years because of technical advances, thus making them far more affordable than when earlier OSL systems were designed. The choice of various components in this design, including laser diodes, aspheric lenses, and a temperature-controlled laser diode mount will be discussed in this work.

Background

OSL measurement techniques:
- Continuous wave (CW-OSL): collect signal during stimulation
- Pulsed (POSL): collect signal between quick pulses of light

Previous Design Limitations:
- Unable to do fast pulses
- LED on/off time ~10 ms



Importance of wavelength:
- The higher the frequency of excitation light, the deeper the traps that are accessed
- Traps have different half-lives
- Ultimately can extract temporal information from passive, integrating OSL dosimetric materials!

Mission relevance:
- This OSLD reader is necessary for the development of OSL technology for use as chain-of-custody detectors for SNM

Design Criteria

- Quick timing (i.e. faster pulses of light)
- Multiple stimulation lights over a broad range of wavelengths
- Easy to switch between wavelengths
- Discrimination capabilities (stimulation light vs. OSL)
- Inexpensive

Reader Design

Fig. 1 (right): Reader components (PMT, laser diode and mount, sample holder, sheet of OSL material) inside of light-tight housing.

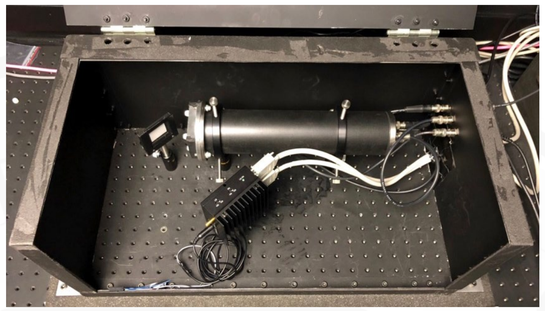
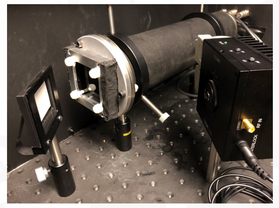


Fig. 2 (below): Close up view of diode mount, sample holder, and PMT. Front of PMT has filter holder that can hold up to 4 filters (i.e. Hoya U-340).



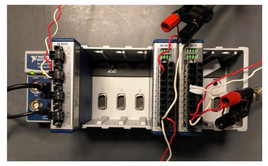
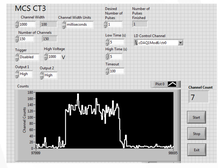
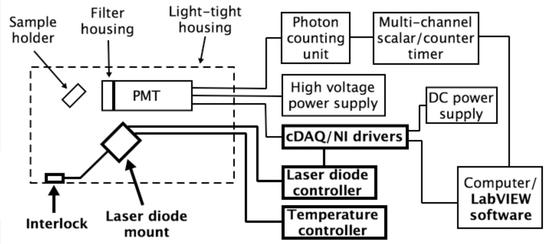


Fig. 3 (above): National Instruments cDAQ and drivers used to control the reader.

Fig. 4 (below): Front panel of LabView VI designed to control laser pulses and collect signal from PMT.





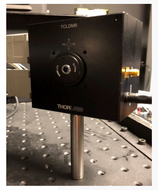


Fig. 5 (left): The temperature controlled laser diode mount.

Fig. 6 (above): Overall reader design schematic. Bolded are either new or modified components

Fig. 7 (right): Laser diode and aspheric lens (for collimation)

Table 1 (right): Specifications of laser inventory

Center Wavelength (nm)	Color	Beam Diameters (mm)	Output Power (mW)	Laser Class
404	Violet	3.5	400	3B
450	Blue	1.8	1600	4
462	Blue	3.6	1400	4
520	Green	1.8	120	3B
638	Red	2.8	700	4
808	Infrared	2.4	1000	4

Preliminary Testing

Fig. 8 (below): CW-OSL measurement performed on an Al_2O_3:C OSLD with 450 nm (blue) laser. Exponentials describe decay of OSL due to readout process. Sum of exponentials fitted curve had $R^2 = 0.98$.

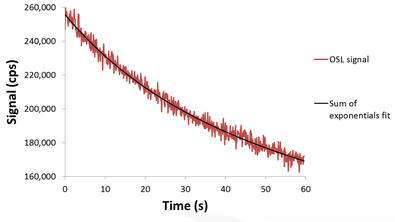


Fig. 9 (below): CW-OSL measurements using 638 nm (red) laser for 4 Al_2O_3:C OSLDs with doses ranging from 0 to 1 Gy.

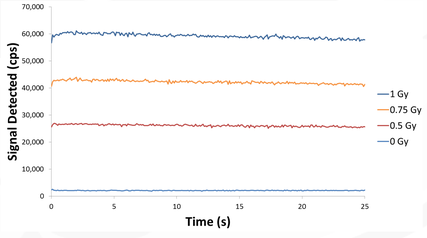
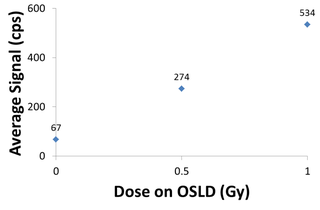


Fig. 10 (below): Average signal for 3 Al_2O_3:C OSLDs stimulated with the 638 nm (red) laser in POSL mode (1 ms pulses, 30 pulses/s). Errors bars smaller than markers.



CVT Impact

Impact of the CVT on development:
- Workshop participation
- 6 full-length publications, 9 conference abstracts/presentations, 8 poster presentations
- CVT summer undergraduate fellow & hourly student researcher
- Naval research enterprise internship
- Now pursuing graduate degree

Impact on other students:
- Sam Frank: graduate student at MIT
- Elizabeth Rubenson: undergrad continuing in BME
- Jack Thiesen: undergrad continuing in engineering physics, music theory, and minor in EECS

Technology transitions:
- Rexon TLD Systems and Components, Inc (Beachwood OH) has expressed interested in developing an OSL system in collaboration with UM, based upon this preliminary work
- Patents existing prior to CVT may be licensed
- Potential IP

Future Work

- Test quality of reader rigorously
- Implement more components (new PMT for POSL, more filtering)
- Optimize setup for different lasers and OSL materials
- Identify reader's sensitivity to low doses
- Expand laser collection
- Investigate mechanisms of OSL (i.e. traps and wavelengths)
- Perform temporal dosimetry measurements
- Test uncommon OSL materials or find new materials

Conclusion

- OSL reader capable of different stimulation wavelengths was designed & built
- Preliminary results shows reader is capable of performing OSL measurements
- Now able to develop temporal dosimetry techniques which will enable use of OSLDs as chain-of-custody detectors

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National Nuclear Security Administration