Fitting of stimulated luminescence dose response curves using the Lambert-W function; implementation with Python

G. Kioselaki[1], K. Prevezanou[1], P. Konstantinidis[1], E. Tsoutsoumanos[2], G. S. Polymeris[3], V. Pagonis[4] and G. Kitis[1]

[1] Nuclear and Elementary Particle Physics Laboratory, Physics Department, Aristotle University of Thessaloniki, GR-54214, Thessaloniki, Greece
[2] Department of Physics, University of Thessaly, GR-35100, Lamia, Greece
[3] Institute of Nanoscience and Nanotechnology, NCSR "Demokritos", GR-15310, Ag. Paraskevi, Greece
[4] McDaniel College, Physics Department, MD-21157, Westminster, USA

Abstract

Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) dating can determine, by means of measuring the accumulated radiation dose, the time elapsed since material was either heated or exposed to light. Nowadays, both TL and OSL are widely used in archaeometry, mainly for the age determination of different samples and artifacts. An important characteristic in these experimental procedures is the dose response, which describes the magnitude of the response of a studied artefact, as a function of dose after a certain exposure time. The lower and upper age limits of TL and OSL methods are set by the TL and OSL response to natural or artificial dose. Dose response has great importance in the luminescence community, for its archaeological and dosimetric aspects. Luminescence dating specifically (a) provides a means of determining burial ages for sediments and associated archaeological artifacts and fossils as old as roughly 1Ma, (b) is a key dating technique for the reconstruction of past environment and climate, (c) stands as the unique dating method for pottery and burnt flint being capable of identifying two sequential occupational phases using the same sample. In TL and OSL is highly desirable their dependence to be linear, on the contrary there are various cases of non-linear such response. The possibility of using the entire TL/OSL dose response curve and not only the linear part, is expected to result in a significant extension of the age limit achievable using luminescence. Besides some rare cases, all the aforementioned dose response fitting expressions fail to provide trustworthy ages for the samples that either approach or even reach saturation; the errors at this dose response region might exceed 50%. Recently, Pagonis et al., (2020) have reported an effective way to deconvolve all the dose response curves, being in the linear, but mostly supralinear or saturation regions by using the Lambert W function. The results showed that the newly proposed expressions fit excellently experimental TL/OSL dose response curves, allowing thus to estimate much larger, than usual, equivalent doses and significantly extending the upper limits of TL and OSL dating techniques. From a geo-archaeological point of view, this task could possibly result in an extension of the upper limit of the detectable age in archaeological but mostly in geological findings. Such analytical expressions could move our knowledge some further steps forward, as it will improve the precision of ages within the saturation region for quartz. In the aforementioned study, these new analytical expressions were tested on a variety of experimental curves from scientific literature using the programming language Python, which is under an open-source license and it can run on Mac OS X, Windows, Linux, and Unix and has become very popular among researchers and students due to the vast number of open libraries used for mathematical analysis and data processing.

References

[1] G. Kitis, G. S. Polymeris and V. Pagonis, "Stimulated luminescence emission: From phenomenological models to master analytical equations", Applied Radiation and Isotopes, Vol. 153 (2019), pp. 108797
[2] V. Pagonis, G. Kitis and R. Chen, "Superlinearity revisited: a new analytical equation for the dose response of defects in solids, using the Lambert W function", Journal of Luminescense, Vol. 227 (2020), pp. 117553
[3] V. Pagonis, G. Kitis and R. Chen, "A new analytical equation for the dose response of dosimetric materials, based on the Lambert W function.", Journal of Luminescence Vol. 225 (2020), pp. 117333