



A low cost TL–OSL reader dedicated to high temperature studies



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ABSTRACT

In some applications, luminescence dating needs performing studies above 550 °C and conventional or commercial instruments are not always perfectly adapted to this temperature range. We describe here an automated instrument capable of thermoluminescence and optically stimulated luminescence measurements. Main mechanical and digital design is reported showing the technical options leading to both a low cost of fabrication and good high temperature performances. The mechanical design favors simply shaped parts and uses a 3D-CAD software that can drive a numerically controlled milling machine. Besides, electronics is limited to elementary signal conditioning (for photomultiplier and thermocouple) and the more complex functions (as thermal regulation) are performed with softwares running on a standard PC. A fully automated prototype instrument was built using these options. This confirmed the low cost of fabrication and the possibility of measurements up to 800 °C and of withstanding temperatures higher than 600 °C for several minutes.

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1. Introduction

Luminescence is used in many applications where there is a need to reconstruct the radiation dose to which a sample has been exposed. In dating archaeological and geological materials, measurements are often made on groups of grains extracted from the sample under study [1,2]. Typically 2–4 mg of grains in the range of size 90–300 µm are mounted on a metal plate and the luminescence emitted from all these grains is measured simultaneously. Use of conventional luminescence instrumentation has led to different methods of measuring a radiation dose. Multi-aliquot (MAAD) or single aliquot (known as SAR for instance) have been used either in optically stimulated luminescence (OSL) or thermoluminescence (TL) studies [3,4].

One of the challenges in luminescence dating is to date feldspars, some of which being affected by anomalous fading. This phenomenon is well documented in the

conventional temperature range (300–500 °C). However, some feldspar species such as plagioclases from volcanic rocks may display a strong luminescence above 600 °C and this high temperature TL emission (HTTL) had been claimed to be devoid of anomalous fading [5]. This point of high relevance for TL dating has nevertheless not been actually revisited since then. Only a few laboratories have explored luminescence properties at temperatures higher than 550 °C [6–8]. In practice, a few apparatus dedicated to high temperature studies have been built in the mid 70s or 80s generally enabling the measurement of one single sample aliquot only at each run [9]. Recent studies on Neolithic ceramics renewed interest for HTTL using a specially constructed instrument [10]. Indeed, above 550 °C, there are some special needs such as an improved temperature control and a sufficient heating power to insure thermal regulation, a good management of high light flux (to preserve the photomultiplier sensitivity) and a mechanical design that can withstand rapid and repeated large temperature variations. On the other hand, commercial systems such as the OSL–TL reader developed at Risø Laboratory, enabling the measurement of several aliquots in a

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single run, were mostly designed for OSL studies and has not been frequently used for TL measurements in the high temperature domain [11–13].

In order to resume studies of high temperature luminescence, a prototype of TL reader that enables the routine measurements up to very high temperature (780 °C) has been devised. This system includes an OSL extension and also comprises a 1.85 GBq $^{90}\text{Sr}/^{90}\text{Y}$ β -source that delivers a dose rate of around 3.7 Gy/min to materials such as feldspars or quartz. Achieving a TL–OSL instrument is nothing new in itself as there are not many ways to measure low light levels or to create a linear temperature ramp. However, we present here the solutions we chose so as to lower fabrication costs (mechanics and thermics) and take advantage of the present available data acquisition modules that simplify the instrument. Our mechanical design privileges simply shaped parts and, as we used a CAD software (solidworks), a direct drive of a milling machine can be performed easily. On the other hand, electronics is limited to elementary signal conditioning (mainly photomultiplier and thermocouple). All complex functions (such as thermal regulation) are performed via Labview virtual instruments (national instruments) that run on a standard PC. The graphical approach of this software allows building new functions or adapting existing ones even for non-programmer users.

2. Instrument main features

The general architecture of a multiple aliquot TL–OSL instruments is made up of simple units. The main functional components (Fig. 1) are: a positioning system, a heating module, a photomultiplier, a light guide system associated with an external light source (for OSL), a shielded beta source, electronic systems and a computer interface. Simplified functional organization of the reader (Fig. 2) shows the direct interfacing of computer and instrument controls (on/off, radioactive source position, etc.) or physical signal acquisitions (PMT pulses, temperature, light source driving, etc.). This choice of organization avoids the use of an external micro-controller and gives the user an easy access and a strong control to the instrument via a “user-friendly” interface. As shown in Fig. 2, a PMT high tension divider and five electronic modules are necessary: a TTL relay interface, a PMT preamplifier with a TTL compatible output, a voltage controlled current source to drive the OSL light source, a thermocouple conditioner (cold junction compensation and amplifier), a voltage controlled pulse width modulation (PWM) to drive the sample heater. These electronic modules are simple and some of them are directly derived from the electronic part application notes and all are costless and easy to build (see supplementary Figs. 1–6).

These choices were validated by building a prototype with an electronic interfacing based on a data acquisition PCI-card (PCI-MIO 16XE 50) from National Instruments. This card has analog and digital ports (TTL), counting TTL scales and permits to control the inputs and monitor the outputs of each subsystem: general on–off relay, solenoid valves for water and nitrogen flows, heating module

power, photomultiplier TTL counting, thermocouple voltage (one analog port is dedicated to thermocouple acquisition and can compensate for cold junction), light stimulation, irradiation durations. We also checked that electronic interfacing can be made with two low cost USB data acquisition modules (NI-DAQ 68xx series) joined to a laboratory-made electronic conditioning thermocouple compensation module.

The user interface was created using Labview software from national instruments. Elementary procedures such as thermoluminescence reading, sample preheating, phosphorescence reading, OSL stimulation at a fixed temperature (from 30 °C to 800 °C), irradiation of a sample, etc. are driven by sub-routines (named “Labview virtual instruments”). Different more or less complex protocols as MAAD or SAR, TL reading, etc. are entirely automated and can be quickly configured by the user.

However, some parts of the TL–OSL reader prototype deserve a more detailed presentation because they depart from previous readers and at first when they were designed, it was not sure they could accurately achieve their functions. Four functions were likely to be problematic: the size of the positioning system, the thermal conception of the instrument and the heating regulation, the efficiency of light collection, the OSL stimulation performed via light guides. The designs that resulted in fulfilling these functions are presented hereafter.

2.1. Positioning system

The sample positioning system (Fig. 3) consists of two superposed brass disks 250 mm in diameter. The lower disk (supporting platform) is fixed and a polished track was created along the circumference on which sample holders can slide. The overhanging disk (turntable) is 0.5 mm apart from the supporting platform. This disk is perforated with 36 circular 11 mm in diameter holes. Cup shaped sample holders (10 mm in diameter) sit in these holes. Holders are stainless steel disks SS 316 L (0.5 mm thickness) with a small edge (0.5 mm) in periphery that prevents sample grains from escaping. As the turntable rotate it pushes the holders along a circular path. This rotation allows to position one of the 36 holders at any requested place. Once an holder is its position the turntable reverses direction breaking its physical contact. For luminescence measurements the holder is placed on top of a resistive heating strip. This strip is inserted within the supporting platform perpendicularly to the polished track leaving a 0.5 mm empty space at both lateral edges of the strip preventing direct thermal and electrical contact with the platform. The upper surface of the strip is precisely at the level of the polished track. This insures a smooth shifting when an holder is pushed onto the strip. Thus, the holder rests directly on the heater strip and high temperatures (800 °C) can be achieved. In this case, the turntable which is just 0.5 mm above the strip although not in direct contact is heating slightly but no deformation is observed. This principle involving a turntable and a supporting platform has been used in previous systems [14]. However the diameter of our prototype is large. To achieve its fabrication, the 1 mm thick upper brass disc was

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