Developing a Photon Counting System for Thermoluminescence Dating Analysis Using NI LabWindows/CVI Software

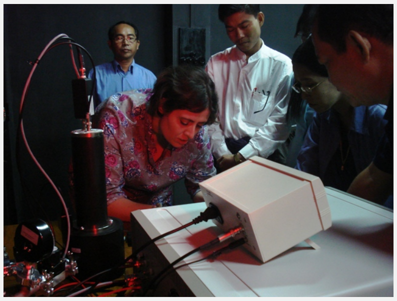

Figure 1: Performing TL analysis: (Left) The vacuum oven with the photon detection unit and the low-noise, high-speed preamplifier attached.

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- Gianluca Pizzocolo, CLD, LabWindows/CVI and NI TestStand Certified Developer, IPSES

The Challenge:
Implementing an integrated hardware and software system that can date archaeological or historical materials by analyzing emitted luminescence from heated samples.

The Solution:
Using NI LabWindows™/CVI software to manage an embedded system that controls the heating process, acquires signals from a photomultiplier in real time, and transfers data to a PC using an NI-488.2 GPIB interface for analysis.

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About IPSES

IPSES is an Italian company that specializes in designing hardware, firmware, and software solutions for scientific instrumentation and customized electronics for both academic research and industrial use. IPSES designs and develops advanced systems closely with their customers who determine the requirements for these targeted and reliable solutions. This approach is particularly important when developing projects for rapidly evolving scientific research applications that require effective, flexible, and easy-to-modify device designs.

Using NI products, IPSES developed this thermoluminescence (TL) analysis system for material science and physics departments, specifically for dating ceramic archaeological materials.

Defining Thermoluminescence and How It Is Used for Dating Archaeological Findings

When radiation is incident on a material, some of the energy may be absorbed and re-emitted as light with a longer wavelength. The wavelength of the emitted light is characteristic of the luminescent substance and not of the incident radiation. TL is the process by which a mineral emits light when it is heated. The thermally excited light emission follows the previous absorption of energy from radiation. Energy absorbed from ionizing radiation that is naturally present in the environment (for example, alpha, beta, gamma, and cosmic rays) frees electrons to move through the crystal lattice, but some electrons are trapped at imperfections in the lattice. Subsequent heating of the crystal releases some of these trapped electrons with an associated light emission. If the heating rate is linear and the probability of a second trapping is negligible with respect to the probability of a recombination, the TL intensity is related to the activation energy of the trap level by a known expression.

Measured TL depends on three main factors:

- Radiation exposure time
- Radiation intensity
- Material structure of the sample

Materials of archaeological or historical interest that can be dated by TL analysis include ceramics, brick, hearths, fire pits, and kiln and smelter walls because a non-negligible part of these materials, such as quartz and feldspars, is thermoluminescent. Heating ceramic in a furnace during the production process resets TL accumulated by these materials; from this point on, TL begins growing again as time passes. The accuracy of TL dating techniques is ±5 to 10 percent for items that are 50 to 20,000 years old, if the sample is correctly picked up.

The Developed System

The system consists of the following components:

- Vacuum-tight oven that recirculates nitrogen and is equipped with a strip heater directly connected to an isolated thermocouple.
- Vacuum pump and valves to regulate flow.
- Photon detection unit composed of a sensitive photomultiplier with an acquisition spectrum centered on 400 nm, an enclosure with a magnetic shield, a diaphragm with infrared filters, and an interlock switch for the high-voltage output.
- Low-dimension, low-noise signal preamplifier directly installed on the detector unit that makes sure a weak signal is not dispersed along the cable.
- High-voltage power supply that can be adjusted from -320 V to -1,995 V.
- Integrated TL control unit to manage heating ramps and analyze photon emissions.
- PC equipped with data acquisition and control software and a high-performance, parallel NI PCI-GPIB interface to manage photon acquisition.

The system's most important features are accurately controlling and stabilizing heating ramps up to 550 °C with a rise rate between 0.5 °C and 15 °C per second. It is fundamental to have a high degree of control in the photon emission process and to perform measurements under the same conditions. This feature allows to compare data from different measures and to have a quick and accurate photon counting, associating it exactly to the temperature of the specimen at that moment.

To meet these requirements, a control system with closed-loop, proportional–integral–derivative (PID) control was implemented. To meet these requirements, we implemented a closed-loop, proportional–integral–derivative (PID) control system that has a high-precision heating process and intelligently manages the photon counting process using autoranging to concentrate on the actual count and maintain appropriate full-scale resolution.

To ensure the system is fast and responsive and can transfer data to a PC in real time, we selected the NI-488.2 GPIB bus as the communication interface. The NI PCI-GPIB DMA controller helped us achieve reliable, fast communication, and we avoided any possible interruption during data transfer. This is crucial because the sample can only be analyzed once and any interruption in data communication or defect in controlling the ramp affects the whole analysis. The archaeological samples are usually limited in number and require a long, complex preparation, so the system must be reliable.

The software, developed in LabWindows/CVI, acts as the operator interface for the entire system. Having one operator interface on the PC helps us supervise the entire process and coherently and consistently view the data that could not otherwise be grouped together, since it is related to different devices.

When a new test starts, heating ramp parameters such as rate of ascent and final temperature desired, must be set. Then, the analysis begins and the system displays the data in real time as it is acquired by the photomultiplier. After the test, a graph of the glow-curves is shown that represents the change in counted photons that occured when the temperature increased. It is then possible to analyze and modify the glow-curves by applying various algorithms and comparing the curves with previously saved curves. It is essential to make detailed comparisons of the spectra since the dating procedure is based on a comparison of glow-curves: the natural TL emitted by a sample is compared with the TL emitted by a sample collected from the same object after an exposure to a known radioactive source (β and α) for a due time.

We implemented sophisticated, intuitive zoom functions for all the graphs. These functions help the user accurately analyze the curve and precisely relate the photon emissions with the heating temperatures. Functions to modify the curves such as smoothing, average, subtraction, and integral were also developed. All data can be exported in ASCII code to compare data acquired with other systems.

Advantages of Using LabWindows/CVI Software

Using LabWindows/CVI helped us immediately implement complex analysis algorithms because we could use algorithms already developed in ANSI C by research institutes. Compared to other ANSI C development environments, the library functions and numerous manageable, customizable graphics features offered in LabWindows/CVI help easily interface the system to the NI PCI-GPIB board.

There were also historical advantages to using LabWindows/CVI. We developed the first photon counting system several years ago for laboratories at the University of Milan in Italy, and although the system was more rudimentary and less automated, it was the direct precursor to the actual laboratory both for the hardware and software. The first analysis software was developed about 15 years ago for the MS-DOS OS using version 3.1 of LabWindows/CVI. As technology advanced in the subsequent years and we developed the current system, managing and upgrading the software was never a problem. The continuous improvement of LabWindows/CVI has certainly contributed to our system evolution.

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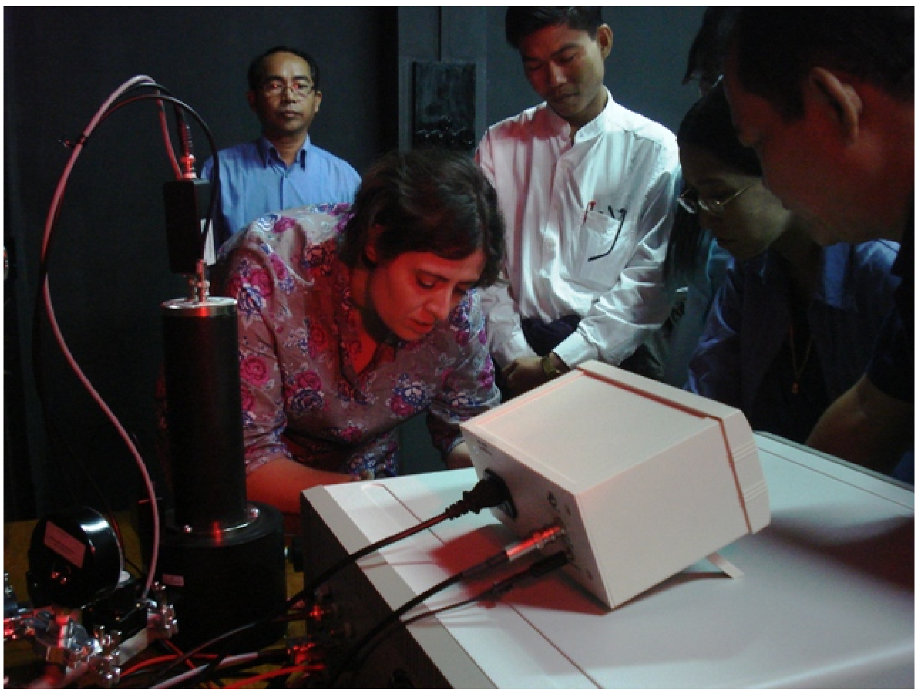

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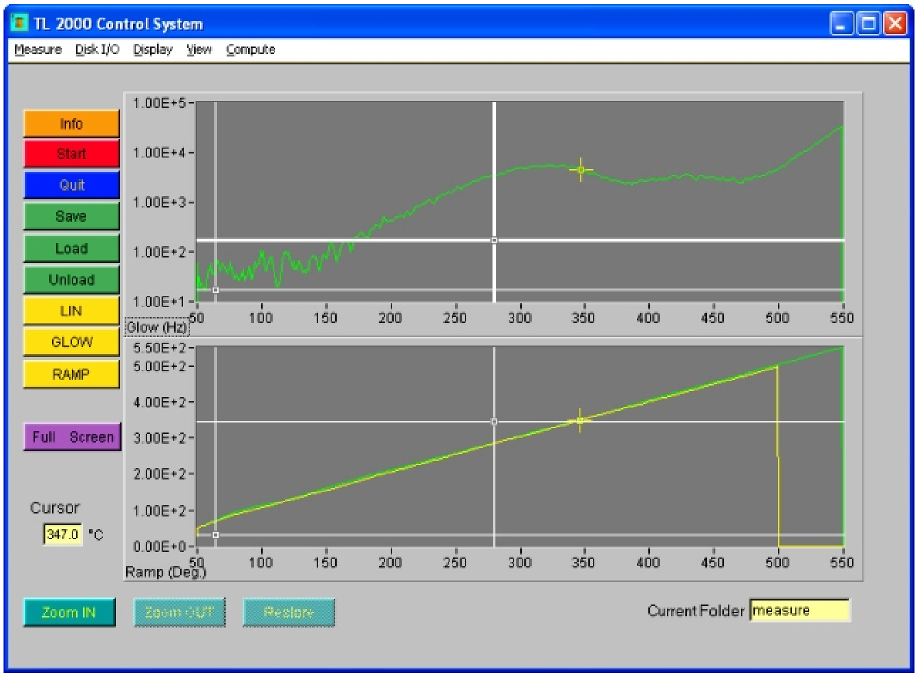

Figure 2: This software interface shows a heating ramp and the relevant photon emission glow-curve.

Figure 3: IPSES TL Laboratory for National Material Science Department of the Tubitak Marmara Research Institute – CNRS – Turkey

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