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Using a Standard Light Source

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UNITED STATES DEPARTMENT OF ENERGY

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Thermoluminescence Dating Apparatus "Efficiency" Measurement using a Standard Light Source

Gary W. Cariveau

The thermoluminescence (TL) apparatus used for the MMA-BNL dating project has been especially designed to improve upon light collection and transmission properties, when compared to most currently used dating systems. Two methods of light collection have been developed: one employing aspheric reflectors and the other using a reflector and lens system.

In order to compare the relative effectiveness of these two systems, and to compare their performance against theoretical predictions or future improvements, a "standard" lamp and housing has been developed and calibrated. Two types of miniature lamps were evaluated for this purpose. They are both available from Edmond Scientific Company and their characteristics are shown in Table 1.

Light distributions were measured to see how closely the lamps approximated an isotropically radiating source. The intensity distribution of each lamp was measured using a light meter having an angular acceptance of 1° (Honeywell Pentax Model $1^\circ/21^\circ$ spot meter) and a lamp to detector separation of 115 cm. While keeping the separation constant, the detector was rotated over a range of 180 degrees. The relative intensity results are shown in polar plots in figures 1 and 2. These data are for three different orientations of the lamp filament plane, 0, 45, and 90 degrees with respect to the lamp to detector plane of reference.

The flux distribution from the 1.5 volt lamp is more uniform than the 5 volt lamp with respect to rotation and orientation. Because it is also the smallest in size and light output, it was decided to use the 1.5 volt lamp for

calibration.

The lamp was placed in a base that is of the same physical dimensions as the TL dating apparatus oven. Mounting the lamp at an equivalent sample position ensures reproducible placement, closely simulating a ceramic sample to be measured for dating.

The assembled lamp and housing were used with an EM1 9635QA photo-multiplier (PM) tube (serial numbers 23064 and 21084) mounted in a Products for Research Model TE 102 PM cooler. Measurements were made to determine the PM tube response as a function of distance from the light source. These results could then be used to calculate the PM tube current per unit of solid angle subtended by the PM. The operating conditions and results of the measurements for tube #23064 are shown in figure 3. Three PM tube voltages (250, 270, and 300 volts) were used to check for PM tube saturation effects and reproducibility. In all cases a Power Designs, Inc. Model 2005, serial no. 67310 voltage supply was used. Note that as the light is moved to a distance bringing it inside of the PM cooler, there are departures from a "point-source" condition which causes a variation from the expected inverse square response.

A synopsis of the data in figure 3 is listed in table 2. Using these results, when the source is outside of the housing (inverse square response), it is possible to calculate an average current per steradian of flux accepted. This value is 2.8 microamps/steradian for tube #23064 (HV = 270 V, lamp = 1.3 V) and 33.0 microamps/steradian for the tube #21084 (HV = 250 V, lamp = 1.3 V).

The design objective for the current optical system in the TL apparatus is for an acceptance angle of 140 degrees. This corresponds to a solid angle of 4.9 steradians, which predicts for 100% optical efficiency, a measured current of 13.7 microamps when using the standard lamp at 1.3 volts and #23064 PM tube at 270 volts.

When the standard lamp and holder was placed in the normal operating position, using the same conditions as above, on 24 September 1976, the measured current was 85 nanoamps. Note that these measurements were made without any filters or windows, i.e. integrating all radiation from the "standard" incandescent source reflected by the two aspheric mirrors. Dividing the measured value by the predicted response indicates an "efficiency" of about 6.2%. The measurement was repeated on 25 April 1978 (using tube #21084). Using the same geometry as on 24 September 1976, a current of 3.7 microamps was measured with the "standard" lamp at the sample position (HV = 250 V, lamp = 1.3 V). This response indicates an "efficiency" of about 2.3% for the system using two reflecting surfaces.

It should be remembered that the two optical elements in this system are not over-coated and have been oxidizing since April 1976, when they were last aluminized. Realuminizing would certainly improve the reflectivity and subsequent "efficiency" of the system.

Further improvements of the existing mirrors, and evaluation of the new mirror-lens system, or even optical alignment of either system, can be checked using this technique.

Table 1
 Characteristics of Miniature Lamps
 from Edmonds Scientific Co., Barrington, NJ 08007

	microminiature	subminiature
	Lamp number 40690	Lamp number 40691
Volts	1.5	5
current, ma	30	55-120
diameter, mm	0.76	3.15
length, mm	2.03	6.35
light output, millilumens	160	300-1800
life expectancy, hours	1,000	4000-16,000
lead diameter, mm	0.1	0.18-0.25
lead length, mm (min)	9.5	1.25
lead material	platinum	copper

Table 2

Tube #23064, HV = 270 V, Lamp = 1.3 V

Distance from detector to lamp	Current
(cm)	(nA)
20	150
30	78
40	38
50	22
70	10.6
90	6.4
100	5.4
120	3.9
140	2.9

Fig. 1. Relative intensity of a microminiature lamp, number 40690,
1.5 volts.

Fig. 2. Relative intensity of a subminiature lamp, number 40691,
5.0 volts.

Fig. 3. Photomultiplier tube current vs. lamp to detector distance.
Broken line indicates expected inverse square response.