Technical note:

A stable reference light source

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Introduction

In the course of luminescence experiments, it can sometimes be useful to check the long term stability of the system which measures the emitted light. This means that, for a given luminescent sample, the counting must be the same whatever the amount of time that has elapsed between two successive measurements. The problem arise, for example, in fading tests or in day light bleaching studies, which involve repeated measurements of a given sample, day after day or month after month.

For that purpose, we have been using for several years a stable light source that can be simply measured at any time for checking a possible shift in the light detection system, and correcting for such a shift in the case it is significant. It is presented below.

Basically, the light source is a scintillating screen that is irradiated by beta particles from ^{14}C nuclei. The design that is given on Fig.1 is only schematic, since the geometry and size will depend on the luminescence set that is used.

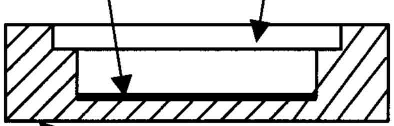

Figure 1.
Schematic cross section of the light source

The ideal reference light must have the same features as the samples to be measured : same order of magnitude of counting rate and same colour, so that all possible causes of shift in the measuring system are taken into account, including, e.g., slight variation of the response of the PM tube (due to electronic shift) or variation of the transparency of the front filter (due to scratching, or darkening during TL experiments).

In this view, two different screens are used in our laboratory for routine TL dating of quartz in the red or in the blue region of its spectrum.

The blue one is a *general purpose* polyvinyl toluene plastic sheet (Nuclear Enterprise NE 102), 1 mm thick, with luminescence emission at around 420 nm.

The red one is a europium doped LuAg ($Lu_3Al_5O_{12}:Eu^{3+}$), 1 mm thick, which has a luminescence at around 620 nm. This is the wavelength of the main red emission of quartz (see, e.g., Hashimoto et al., 1987). It should be noted that this material is not commercially available, however it can be processed quite easily by a specialized laboratory since it has the same features as the famous YAG: Nd^{3+} used in lasers. However, authors can help providing a few of them.

Both screens are stable. Particularly, LuAg is chemically and mechanically very resistant and not hygroscopic. It can possibly shift a little with temperature, but not significantly around room temperature. When compared with YAG, substitution of Y by Lu is intended to enhance the absorption of ionising radiation, thus to increase efficiency.

Choice of the beta source

When the current delivered by the photo-multiplier tube is used for luminescence measurements, no special specification has to be followed in the design of the reference light-source. But, when the photo-multiplier tube is routinely used in the photon counting mode, special care must be given to the choice of the beta source, for both activity and beta energy considerations: typically, less than one photo-electron should be emitted by the photo-cathode per beta particle incident to the scintillating screen, at a rate lower than the routine counting frequency. This requires not too high an energy – ^{14}C fits this condition - and a limited activity. The reason why is qualitatively explained below.

Suppose 10 photons reach the photo-cathode for one incident beta particle. Since they all arrive at the same time, this will result in a single pulse initiated by the simultaneous production of 2 photo-electrons (assuming a 20% quantum efficiency). If less than 10 photons reach the cathode, due to variation of the filter transparency, or if the efficiency of the photo-multiplier shifts and becomes lower say by a factor of 2, the bunch of 10 photons still will result in one pulse, initiated by 1 photo-electron only. The pulse will have twice a lower intensity, but the counting rate with a given beta source will remain unchanged, leaving the operator unaware of the shift. However, with a TL or OSL source, which gives randomly time-distributed photons, the counting rate will have been reduced by 2.

Alternatively, if no more than one photon attains the photo-cathode per beta particle, the number of pulses per second for a given beta source is proportional to the global efficiency of the light measuring system. This allows detection and correction for possible shift.

Theoretical prediction is not straightforward. Roughly, the calculation for the blue screen is as follows.

The mean energy value for beta particles from ^{14}C is 49 KeV. The efficiency of the blue emitting plastic being around 2%, we get, for one beta particle of 49 KeV, 980 eV transmitted to photons in the screen. The maximum emission wavelength is ≈ 420 nm, corresponding to an energy of 3 eV. This leads to 327 photons that are emitted in 4Π. As far as the photo-cathode is seen trough a solid angle of 0.1, 2.6 photons reach this cathode. The quantum efficiency of the cathode is around 0.2, thus we finally get 0.5 photo-electron produced at the cathode for one beta particle. At a first glance, this means that we get a proportionality (factor 0.5) between beta activity and counting rate.

Since the efficiency of the PM tube is significantly less for the red light than for the blue one, one can assume that, when the proportionality is verified for the blue emission, it is also for the red one.

Fulfilling the above conditions can be checked experimentally. One technique consists in observing the pulses using an oscilloscope: they must have the same height whatever the visible surface of the scintillating screen. This surface can be modified by use of a mask. Another technique consists in verifying the linearity of the counting by use of well-known attenuation filters. The counting-rate should match exactly the attenuation factor of the filters

In the present work, the radiocarbon source was obtained by evaporating a commercial solution doped with radiocarbon mixed to cellulose-acetate dissolved in acetone onto the bottom of the disk supporting the screen. However, it can be better to use a commercially available "planchet source". This avoids manipulation of radiocarbon and guarantees a better homogeneity of the surface activity. The total activity of the radiocarbon source was around 200 kBq.

Counting results

Table 1 shows the counting results that were obtained, using a bi-alkali 9635 QA EMI PM-tube, fitted with a "blue" band-pass filter Shott BG12 (maximum transmission at around 400nm) and a "red" high-pass sharp-cut filter Shott 610FG (50% transmission at around 600 nm).

Light source	Filter	
	BG 12 (blue)	610FG (red)
red	1200	255
blue	2800	28
none (= dark counts)	22	22

Table 1.
Counting results in counts/s.

It can be observed that the "red" source has a significant blue component. With these figures, a counting time of 100s allows a standard deviation of less than 1% with the red source. This is enough for most luminescence experiments.

Aknowledgements

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References

Hashimoto, T., Yokosaka K. and Habuki H., (1987) Emission properties of thermoluminescence from natural quartz : blue and red response to absorbed dose. Nucl. Tracks Radiat. Meas. **13**, 57-66.