LED laboratory lighting

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Introduction

Over the last three decades there have been various recommendations about laboratory lighting. These have changed with changing understanding of the luminescence responses of quartz and feldspars, as well as with changes in the availability of affordable lighting technology (e.g., Sutton and Zimmerman, 1978; Jensen and Barbetti, 1979; Spooner and Prescott, 1986; Smith, 1988; Galloway and Napier, 1991; Lamothe, 1995; Spooner et al., 2000; Huntley and Baril, 2002).

In reviewing the excitation spectrum of feldspar by Ditlefsen (1991) and their own tests on loess, Huntley and Baril (2002) summarize that when one is preparing quartz, the reddest visually comfortable illumination is preferred, whereas when preparing feldspars, wavelengths in the region ca. 530-630 nm would be preferable. With advances in LED lighting technology, affordable and adjustable LED lamps of different colors have become available.

Here, we summarize our own adoption of such lighting by presenting some high-resolution spectra from representative LED lighting that we employ, and a spectrum from our filtered compact-fluorescent ceiling lamps. Since 1984 the first author has used Lee (www.leefilters.com) number 158 (deep orange) plastic filter to cover fluorescent ceiling lamps and other laboratory lights (see also Spooner and Prescott, 1986; Smith, 1988). The DRI laboratory uses discrete-switchable, ceiling mounted, compact-fluorescent bulbs masked by 4-6 layers of Lee #158.

The transmission curve for # 158 in our 24-year-old LEE sample pack indicates <1% transmission below the cut-on wavelength of ca. 550 nm, but we note that the Lee website presently provides a transmission curve for #158 that shows 1-5% transmission below 550 nm. To ensure that such possible transmission (in different batches?) is reduced to insignificance, we always use 4-6 layers of filter, depending on the application.

Instrumentation

We measured optical fluxes ($\mu W/cm^2$) from our various light sources using a NIST-traceable calibrated radiometer (Model IL-1400a, International Light, www.intl-lighttech.com). Filter F-15957 and a cosine diffuser are mounted over the UV stabilized silicon photodiode detector (SEL033). We measured spectra over the range 350-2500 nm, using an Analytical Spectral Devices (ASD) Inc. Fieldspec® Pro spectroradiometer (www.asdi.com). This spectroradiometer consists of 3 detector arrays (and diffraction gratings), with response boundaries at ~980 nm and ~1800 nm. The response function has a 10-20% variation over the interval 520-800 nm, and the response falls off by a factor of 4 between ~800 nm and 950 nm. The response increases again above 1000 nm and becomes essentially flat in the range 1400-2400 nm. We have applied no response corrections to the spectra presented below, primarily because the spectroradiometer response is essentially flat in the main region of interest (520-800 nm) and because we detected no emissions from our laboratory lights in the region 800-1200 nm.

Laboratory lights

The use of 4 to 6 layers of Lee #158 filter on the ceiling lamps ensures that the intensity at our laboratory bench surfaces ranges spatially from ~30 nW/cm^2 to ~100 nW/cm^2. Under some working conditions we raise this general illumination to a localized maximum of ~230 nW/cm^2. A typical spectrum from our ceiling lamps is shown in Fig. 1. The step response at ~990 nm manifests a detector boundary offset between separate detectors within the Fieldspec® that cover different portions of the spectrum. This offset is unimportant here because we are interested only in the relative signals within each portion. It is clear that: 1) a few layers of Lee #158 adequately blocks light below the cut-on wavelength; and 2) the compact fluorescent lamps emit nothing significant in the range 720-1000 nm, the range encompassing the feldspar near IR resonance (~880 nm, e.g., Hütt et al., 1988; Aitken, 1998).

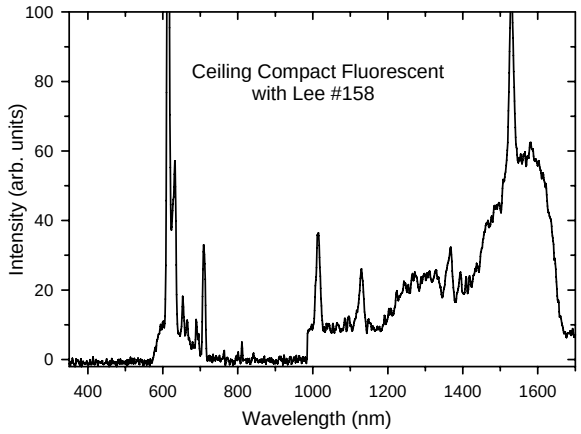

Figure 1: *Spectrum from a filtered (Lee #158) compact fluorescent ceiling lamp, mounted in a reflector-floodlamp configuration (Lumatech Lighting, Model 1051x for 5W compact fluorescent bulbs, www.lumatechlighting.com), showing the typical Hg emission lines superimposed on a fluorescent-lamp emission continuum.*

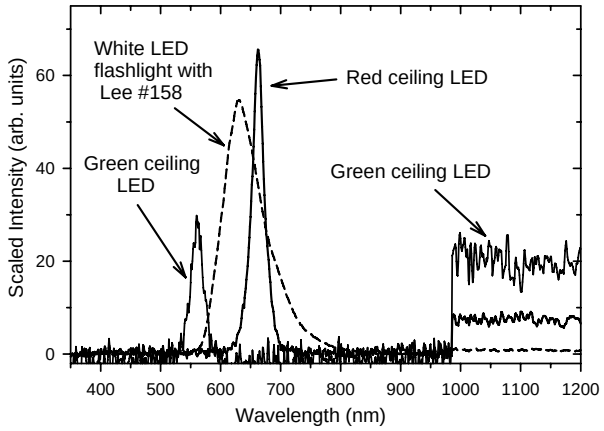

Figure 2: *Spectra for three types of LED lamps. The relative noise in the green-lamp spectrum reflects our use of a relatively short signal-integration time for this lamp.*

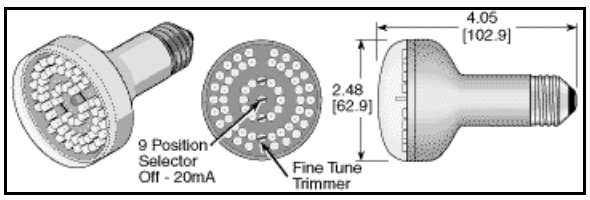

Figure 3: *Format of the adjustable screw-base, colored LEDtronics darkroom safelight bulbs. The dimensions are in inches and mm (parentheses) (image from www.ledtronics.com).*

For close-in work around the laboratory when samples are not exposed, or to momentarily read beaker labels, we employ LED flashlights ('Long Life LED Light', Item 809-1050-0, The Brinkmann Corporation, www.brinkmann.net) covered with 3-4 layers of Lee #158. These also emit nothing significant in the range above 800 nm (Fig. 2). However, these LED flashlights and our filtered ceiling lamps are probably unsuitable for direct or long exposures of feldspars because of their relatively broad emissions (Figs. 1 and 2).

Adjustable LED bulbs

For feldspar preparations, either of two recently available LED lamps with adjustable-intensity could be used. The LED darkroom safelights that we employ are available from LEDtronics, Inc. (www.ledtronics.com). In the adjustable-intensity category with standard screw bases for 120V AC operations, only two from LEDtronics are suitable for luminescence dating laboratories: a green and a red lamp (LEDtronics R20 darkroom bulbs, BSD-1293 series). Yellow (peak emission ~590 nm) non-screw-base LED miniature bulbs are available from LEDtronics, but not in the favorable format that is available for red and green lamps. This format is shown in Fig. 3. The attraction of this format lies not only in the convenient screw-in base, but also in the availability of a position-selector switch and of a fine-tune trimmer. We use only the trimmer to reduce the intensity. The spectra from our installed LED bulbs are shown in Fig. 2. These red and green LED lamps have narrower emissions than those outlined by Mauz et al. (2002) and thus do not require additional filtering. They are rated at having $> 10^5$ hours operating life, very low power consumption, and vibration resistance.

Adjustable-intensity LED bulbs with screw bases are also available from Kurtzon (www.kurtzon.com), and perhaps other firms, at similar peak wavelengths to those of the red and green LEDs in Fig. 2. These Kurzton bulbs, however, have significant emissions at the long-wavelength side of the peak, that are not present in the spectra from the LEDtronics bulbs. For example, the Kurtzon red (660 nm) LED has undesirable emissions (12% of the peak intensity) in the range ca. 850-950 nm, and again above 1000 nm. Thus, caveat emptor, not all LED bulbs are alike. In a 2001 brochure, Kurtzon stated that 585 nm ('yellow') and 610 nm ('orange') LED screw-base bulbs were available, but they do not appear to be presently available. Kodak (via distributors) provides a LED screw-base darkroom safelight, but no spectral emission information is readily attainable, and it is likely that this is a bulb manufactured by LEDtronics (which supplies Kodak, among other firms).

For aid in loading single grains of quartz into Risø single-grain discs we use the LEDtronics red LED bulb inserted into a standard goose-neck desk lamp, and trimmed to reduce the intensity 20 cm below the bulb center to a level of 5 μW/cm^2. This seems to be near a minimum comfortable-viewing level with this bulb. While being loaded, the discs are exposed to typically 2-3 μW/cm^2 of this red LED at their off-axis positions. This red illumination provides a surprisingly more comfortable viewing experience of contrasts and textures than the normal broadband red safelight of typical photographic darkrooms.

Sample signal-loss tests

We have tested the effects of a 15 hr exposure to the red and green LED bulbs on 'natural' polymineral 4-11 μm grains of a 11.5 ka loess from South Island New Zealand (Berger et al., 1996). Four sample discs were centered 20 cm below the desk-lamp red LED (5 μW/cm^2, trimmed intensity as stated above) and 4 discs were centered 131 cm below the ceiling mounted green LED (74 nW/cm^2, untrimmed intensity). The red LED exposure reduced the first 5 s of IRSL (readout at 30°C) by 13±4% and the green, by 4.3±4.7%. Assuming a linear reduction, these changes correspond to 0.9%/h loss of IRSL for this red exposure and ~0.3%/h for this green exposure. Clearly, feldspar IRSL would be negligibly affected by either bulb if exposures under these irradiance conditions are short enough (e.g., 15-20 min. red, and 30-40 min. green). These unequal effects on IRSL partly reflect the different irradiances of these particular exposures and partly the different spectral sensitivities of feldspar discussed by Huntley and Baril (2002).

We also exposed Risø calibration quartz (150-250 μm, previously drained in a SAR run, re-irradiated to ~6 Gy) under the same irradiance geometries as above, but for 19.5 hours. With a preheating of 250°C (10s) and a cut heating at 180°C, the red LED reduced the SAR L_0/T_0 by 2.5±2.8% and the green LED, by 1.4±2.1%, statistically barely detectable. Assuming a linear reduction, these changes correspond to a negligible ~0.1%/h reduction in quartz L_0/T_0 from the red and a negligible ~0.07%/h from the green. We deduce that exposures of quartz to these configurations of these LEDs for up to a few hours (red or green) would have no significant effect.

In summary, these adjustable-intensity LEDtronics lamps are long-lived, cool running, affordable (ca. $180 each), provide precisely defined and wavelength-stable emissions, and have little or no effect on feldspar IRSL and quartz PSL (photon-stimulated luminescence) under convenient configurations.

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Reviewer

A.K. Singhvi

Reviewer comments: It is useful to be reminded of an important part of luminescence dating. LED illuminations are the future, as besides giving a controlled spectrum they also reduce scattered light in the laboratory.