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IMPROVED OSL EXCITATION WITH FIBEROPTICS AND FOCUSED LAMPS

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ABTRACT --- A fiberoptic illuminator for OSL excitation is described which uses a new geometry for improved uniformity and efficiency, together with two focused lamp light sources for use with it.

1. INTRODUCTION

Multiple bundle fiberoptic ring illuminators have frequently been used for OSL excitation (for example, at Oxford [Spooner 1989] and OSU [Pierson et al. 1994]). Their advantages over focused single source illumination (whether fixed optical trains, as in some laser- and Xe arc-excited systems [Huntley et al. 1985, Hütt et al. 1988], or detector-mounted, as in the Risø system [Bøtter-Jensen and Duller 1992]) include improved uniformity and non-directionality of illumination, flexible and remote placement of large or hot light sources, and closer sample-detector geometry. In practice, using a ring of discrete light sources, it is difficult to avoid an undesirable central 'hot spot' of increased excitation while achieving good coupling efficiency of light source power to the sample. A related problem is efficiently coupling power from a lamp to the fiber bundle entrance aperture, which has hitherto necessitated high lamp powers (>1 KW) for adequate OSL excitation, especially when narrow bandwidth of excitation is required for the experiment. We have used a new illuminator geometry, two opposed rectangular 'light bars', to improve uniformity and efficiency, together with focused lamps to obtain high power levels at the sample with relatively modest lamp power. Compared to an earlier ring configured 8-ended fiberoptic assembly of similar construction (Daybreak 1992), the light bar assembly gives a 25 per cent increase in power over a 1 cm diameter sample area while halving the non-uniformity. This paper will describe a combined fiberoptic/IRLED illuminator and two light sources, halogen and xenon arc, developed for use with it.

2. FIBEROPTIC ILLUMINATOR

In ring illumination using non-collimated sources (of approximately gaussian beam profile) tilted significantly away from nomal incidence, it is very difficult to achieve flat illumination over an extended sample without having the beam's central spot hit the sample plane outside the sample diameter. This puts only a small fraction of the total beam power within the sample area, and means that in a practical application where the light must be used efficiently, there is a trade-off between excitation power and uniformity. Bøtter-Jensen et al. 1991 have used two concentric rings of IRLEDs to address this problem, but this is not so practical an approach for fiberoptics. While mapping intensity profiles from small fiber bundles as a prelude to modeling prospective configurations, we noticed that two opposed f/1.5-f/2 beams, inclined at 45 degrees to the sample plane, yielded a nearly constant intensity on that plane along the line connecting them, and it was apparent that the superposition of multiple pairs of discrete beams in a line (as optical fibers arranged in a ribbon or bar form, or a linear array of LEDs, where the linear dimension is at least twice the sample diameter) would give a uniform intensity on the sample plane. For efficiency in a practical device, the linear dimension must be reduced, and 12 mm wide, 2.5 mm high 'light bars' inclined at 45 degrees were found to give satisfactory uniformity (figure 1). All points within the sample area fall within 10 per cent of the average intensity. The aspect ratio could be increased, or the bar divided with a central gap, to 'stretch' the bar and improve the uniformity further (at the expense of somewhat decreased power to the sample). It is important to note that the output of an optical fiber preserves much of the angular distribution of the input beam, so that the angular character of the light source beam has an effect on the uniformity. For this reason the light bars are mounted on movable blocks, so that uniformity can be optimized for a particular light source by altering the spacing. Note also that this type of light bar is unsuitable for collimated beams unless they are modified with a converging element (or diverging, in the case of small diameter laser beams).

Figure 2 shows the illuminator construction. A custom-built glass fiberoptic assembly of 9 mm entrance aperture, with output divided into two ends with epoxy molded 12 mm by 2.5 mm light bars and a 1 mm diameter monitor bundle (all thoroughly randomized to minimize any effect of intensity variation across the input) is incorporated into a 16 mm high housing that mounts between the top lid and PMT housing of a Daybreak 1100 TL system. The optical glass detector filter stack (6.5 mm of Hoya U-340 for green OSL) is mounted mostly within the illuminator housing in order to minimize the sample to detector distance. A four filter changer under computer control (now under development), would make available an optimal detector spectrum for each different excitation wavelength, while adding only 10 mm to this distance.

Two IRLED light bars each consisting of six T-1 GaAlAs diodes (880 nm,) 20 degree half angle, equivalent approximately to an f/1.4 beam) are mounted on adjustable blocks perpendicular to the fiberoptic bars. The uniformity of IR illumination is similar to that shown in figure 1, but there is less fall off at the edges. Maximum IR power at the sample is 45 mW /cm^2 . Because the LED leads are very well heat sunk, junction temperature rise is much reduced, and warm up effects are small at maximum power even without intensity servoing. A 1 mm jacketed plastic optical fiber is affixed to one of the IRLEDs for servo control feedback. This fiber and the monitor bundle from the fiberoptic assembly together go to a single temperature compensated PIN diode detector. The IRLED current controller has a dual-gain photodiode amplifier, so that whichever light source is active can be monitored. This signal is digitized in the TL system and sent to the host computer as part of the data stream, where it is used to verify that the light source actually is on (lamp failure detect).

A similar illuminator has been built for the Daybreak 1150 TL system. In this case mechanical constraints make it necessary to stack the light bars and LEDs together, with the LEDs inclined at 55 degrees from vertical.

3. HALOGEN LAMP SOURCE

The requirement of a low f-number input beam for the fiberoptic illuminator described above suggested that a reflector halogen spotlamp would efficiently couple into the bundle without any additional condenser lenses. A widely available 150 W lamp, Phillips EKE, has many characteristics that recommend it for the present application. It has an ellipsoidal dichroic reflector that reflects 400-700 nm while transmitting the IR, a spot size compatible with the fiberoptic input, and a focal distance sufficient to allow interposing several filters. It also has a high color temperature (3250K) and long life (200 hours). Figure 3 shows the light source.

The lamp output spectrum is tailored for green OSL excitation primarily by use of a sharpcut longpass optical glass filter (Hoya Y-44), and a shortpass interference filter (T=50 per cent at 575 nm). We follow Bøtter-Jensen and Duller 1992 in the general choice of excitation and detection spectra. Additional filters are needed to further reduce the residual IR component transmitted by the shortpass filter: an extended hot mirror reflects away the 750-1600 nm band, reducing the thermal load on the IR absorption glass (Hoya LP-15) which removes all residual long wavelength IR. Because there is a small transmission at 700-740 nm in the U-340 detector filter, where the EMI 9235Q PMT detector still has a (very) small sensitivity, this wavelength region is further suppressed by a Schott BG39 filter, to reduce background well below 100 counts per second at full power (with a narrowband interference filter added to the filter stack as described below, the background is below detection limits). Alternatively, an interference notch filter coating, available from several optical coating companies, could be applied to the U-340, attenuating the background by a factor of more than 1000. Figure 4 shows the excitation and detection spectra for the OSL system. Special attention has been paid to suppression of IR between 1000 and 2000 nm, to avoid spurious response from impurity feldspars in quartz samples. For this the LP-15 is required, as the hot mirrors, BG39 glass, and the glass fiber bundle (fiber transmission drops to zero only beyond about 1900 nm) all have significant transmission in this region.

The power delivered to the sample is more than adequate for OSL excitation. Using a 10 mm square photodiode (Hamamatsu S1337-1010BQ, calibration 200-1150 nm traceable to NIST), the measured intensity is 72 mW/cm^2 at the sample position. By way of comparison, Bøtter-Jensen and Duller 1992 report a sample intensity of 16 mW/cm^2 for a direct illuminator using a 75 W halogen lamp and similar excitation filtration. The intensity is altered in our light source by neutral density filters (inconel on glass) instead of an iris diaphragm to ensure reproducibilty of setting and also to avoid vignetting effects on uniformity of illumination. A filter slide makes filter changing convenient. An electronic shutter completes the optical path. The lamp and optical train are completely enclosed, with air to the cooling fan and the exhaust ducted. There is no direct lightpath to the exterior, and stray light in the laboratory is avoided.

The lamp intensity is servo-controlled using an optical fiber to convey light to the cooler environment of the controller electronics. A compact high efficiency switching supply powers the lamp. After a short warmup, the intensity stability was better than) 0.5 per cent over an extended period. Because of the long lamp life, the lamp is not turned off between shinedowns.

Since the OSL sensitivity of many minerals may show a wavelength dependence, it may be undesirable to excite with such a wideband spectrum as described above. Pierson et al. 1994 have developed a variable narrowband source to explore this dependence in the visible, to complement the work of Hütt et al. 1988 on feldspars in the infrared. The high power available from the focused halogen source makes it practical to use narrowband interference filters to restrict the excitation wavelength passband. Using an unblocked 514 nm filter (34 nm FWHM, 90 per cent peak transmission) in the filter slide, we obtain 20 mW/cm^2 at the sample. Neither highside nor lowside blocking is needed since the wideband filtration serves the purpose. Using a standard dielectric and dye blocked filter (500 nm, 10 nm FWHM, T=50 per cent), we measure 3.0 mW/cm^2. By replacing the 575 nm shortpass filter with one whose edge is at 650 nm, and omitting the BG39, narrowband filters within the range 460-640 nm can be used. The 650 nm shortpass filter has its minimum transmision at 720 nm (about one-quarter that of the 575 nm filter), where the transmission of U-340 is troublesome, but further attention would probably need to be paid for reduction of background signal.

Rees-Jones et al. 1996, in an laboratory intercomparison, have found that the the growth curve and ED (at least in the materials they studied) was the same for OSL data using this light source (with 514 nm filter) as that taken with an argon ion laser, while preliminary work with the wideband excitation gave significantly different EDs that varied along the shinedown . This suggests that the wideband stimulation may be interacting with deeper traps.

4. XENON ARC OSL SOURCE

Because of the interest in wavelength dependence of OSL sensitivity evident at recent Specialist Seminars, we have developed a xenon arc OSL source suitable for narrowband excitation over a wide range of wavelengths. Having a spectrum nearly flat from 330-800 nm and emitting relatively little in the far infrared, these lamps are ideal for such investigations. While previously reported work (Spooner 1989, Hütt et al. 1988, Pierson et al. 1994) used highpower (À1 KW) standard short arc lamps with condensing lenses, this present work makes use of a compact 300W ceramic collimated lamp from ILC Technology. An integral silver parabolic reflector yields a well-collimated beam 25 mm diameter. Total beam power over the flat portion of the spectrum is 50-60 mW/nm. The light source we have developed using this lamp is shown in figure 5. An extended hot mirror reflects the 750-1600 nm region up to a heatsink to reduce thermal load on the interference bandpass filter. Hoya Y-44 sharpcut glass is again used to further block the short wavelength side. This glass has a particularly steep transition, and less of a transmission tail at short wavelengths than other shortcut glass in this wavelength region, and is highly recommended. The electronic shutter is reflective (silicon oxide over aluminum) and diverts the beam up to the heatsink when closed. The output passband is completely determined by the narrowband interference filter. The high power in the beam (about 20 W) places great demands on the filter. Metal blocked filters are used here because of their tolerance of heat, although their transmission is less than with dielectric and dye blocking. Typical peak filter transmission in the 450-600 nm range is 45-55 per cent. These metal blocked filters are at least 99.99 per cent reflective out-of-band, and keep well below their 200C temperature limit. The filters and shutter are fan cooled. An f/1.5 lens is used to couple the beam into the fiberoptic bundle of the illuminator. Here, again, neutral density filters are used to set the power level at the sample. In the case of the xenon lamp, there is a 3:1 range of electronic control of intensity. However, at low current the arc tends to wander, causing instability, and there is no increase in lamp life, as there is with incandescent lamps. With 20 nm wide filters, the power delivered to the sample is approximately 50 mW/cm^2. With wider filters, the sample would require cooling at maximum excitation power. No great effort was expended to optimize efficiency, and similar powers at narrower passbands should ultimately be attainable.

The lamp is powered by an efficient switching power supply, servo-controlled to stabilize the beam intensity. An unsilvered glass mirror (R=0.04) reflects part of the beam onto an opal glass diffuser to integrate over the beam area. An optical fiber conveys part of this to a photodiode (conditioned further by a hot mirror and Hoya LB-120 light balancing filter to approximate a radiometric filter) on the servocontroller board. By itself, the lamp is somewhat noisy: about 3 per cent peak-to-peak fluctuation in intensity. The low frequency of this noise indicates that arc wander rather than current ripple is the cause. With servo control, this is reduced to under 1 per cent, as is the stability over an extended period. Lamp life is approximately 1000-1500 hours depending on the number of lamp starts, which degrade the electrodes.

We have developed an 8-filter wheel for this light source, controlled by computer, for automated wavelength change. This is a step on the way to coupling with a grating monochromator. Since this source is intended to be a basis module for future instruments, the control electronics includes drivers for two DC motors, two stepper motors, and two solenoids.

5. CONCLUSION

A new geometry for fiberoptics in OSL, opposed light bars, has been used in the development of a sample illuminator for OSL excitation, together with two light sources, halogen and xenon arc, for use with it. The illuminator is compact, permitting decreased sample-detector distance, and has improved uniformity of excitation over the sample area over a previous ring configuration illuminator. It also contains an IRLED source of similar geometry. The two new light sources both have sufficient output power to make the use of narrowband interference filters practical for routine OSL measurements. Special effort was made to ensure exclusion of any residual IR, to avoid spurious responses.

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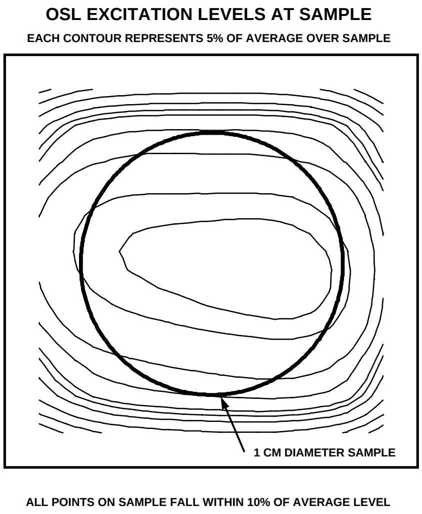

Figure 1. Constant intensity contours for illumination with two rectangular light bars inclined 45 degrees from normal incidence. All points within the sample area fall within 10 per cent of the average intensity. A photodiode of 1 mm^2 active area was used for the measurements.

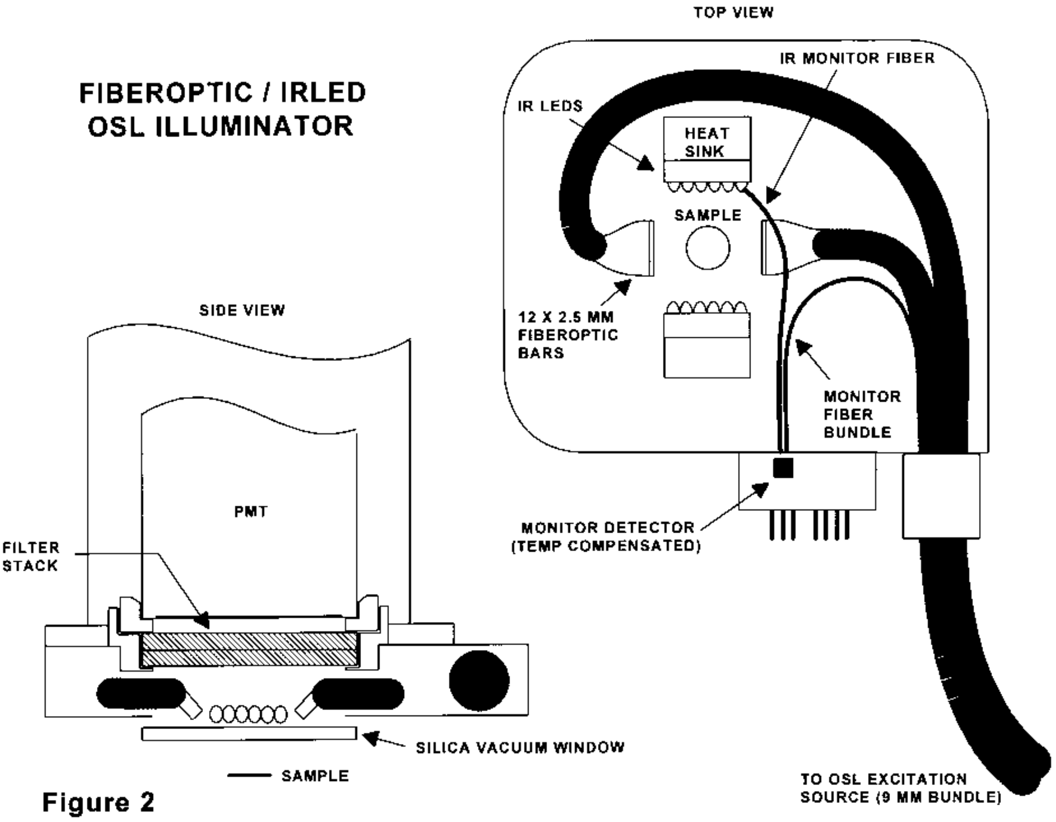

Figure 2

Figure 2. The combination fiberoptic/IRLED OSL illuminator. Both fiberoptic and IRLED light bar spacing is adjustable to optimize uniformity

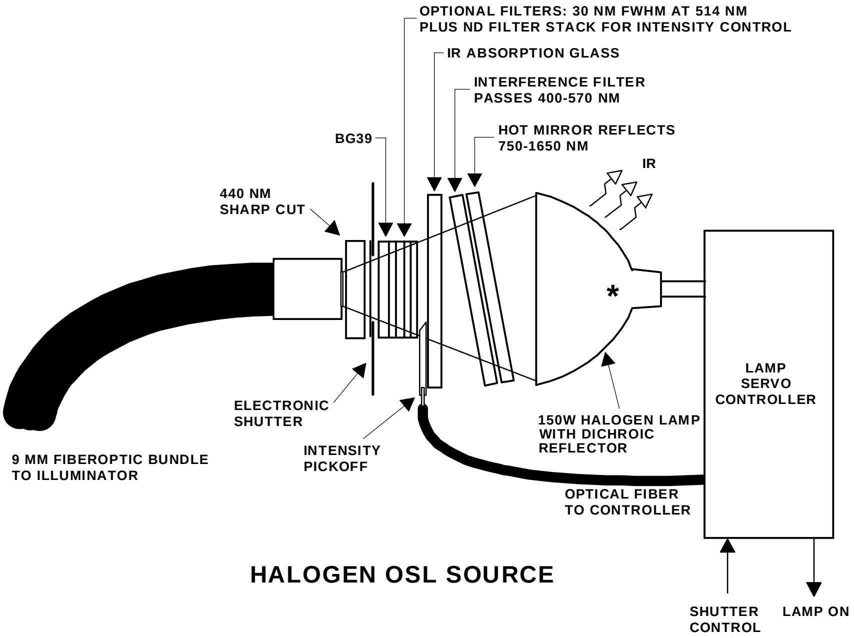

Figure 3

Figure 3. Schematic view of halogen OSL excitation source.

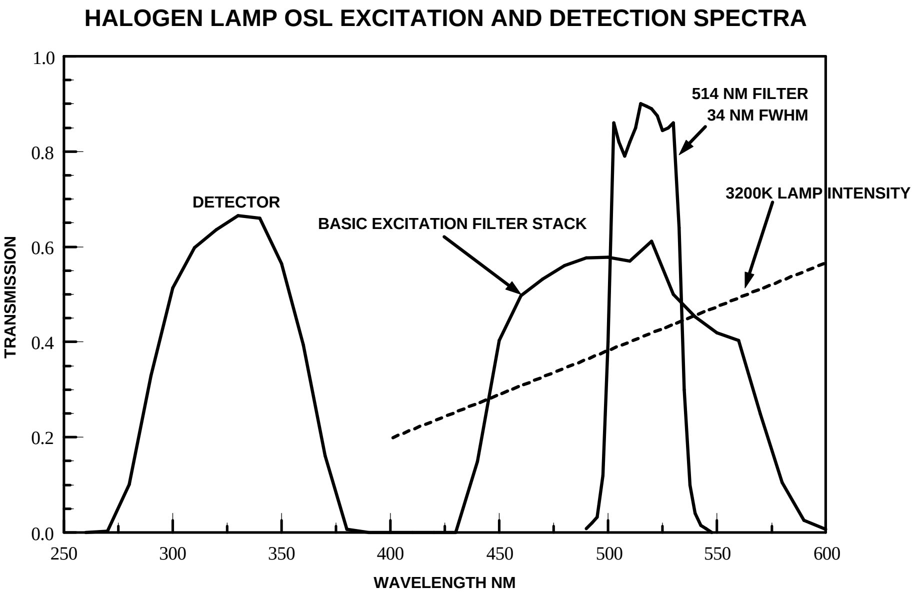

Figure 4

Figure 4. Excitation and detection spectra for halogen light source. Additional narrowband filters may be used. An example is shown superimposed on the wideband excitation spectrum. The excitation power delivered to a 1 cm diameter sample is 72 mW/cm^2 wideband and 20 mW/cm^2 for a 34 nm wide (FWHM) bandpass filter at 514 nm. By replacing some of the filters that define the wideband spectrum, narrow bandpass filters in the 460-630 nm range can make the halogen lamp source into a useful variable wavelength OSL exciter.

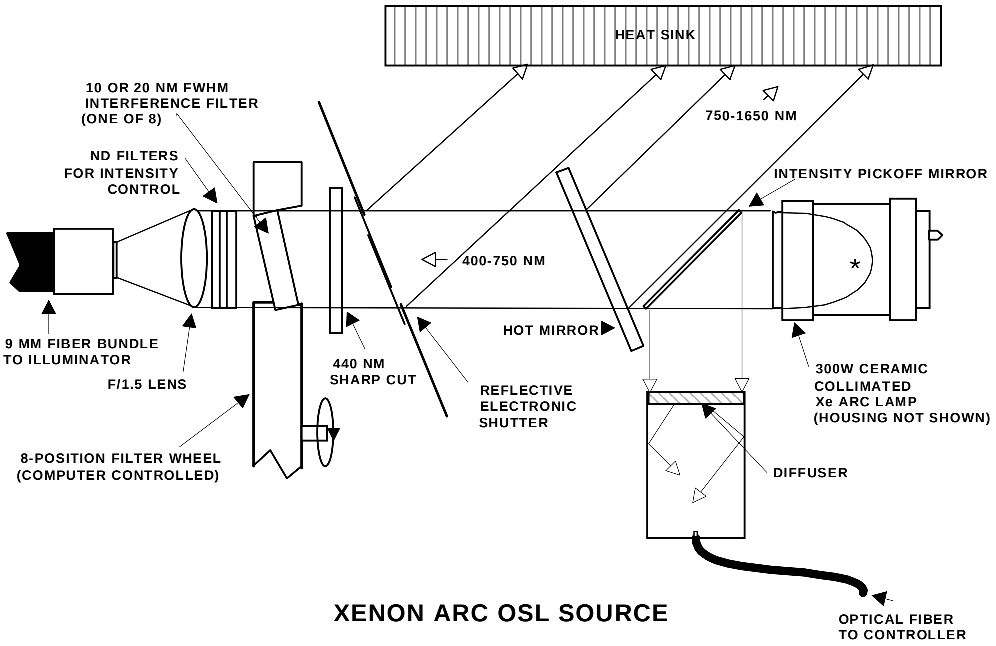

Figure 5

Figure 5. Schematic view of the xenon arc OSL excitation source.