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A New Modular High Capacity OSL Reader System

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ABSTRACT--A new modular OSL system built on a 60-sample automation platform is described, upon which are installed a compatible family of sample elevator/heater mechanisms, OSL exciters, photon counting detectors, and irradiators. All components may be changed out, including the control electronics, firmware, and status display. The excitation family includes modules for both large area and arrays of single grains. The detector family has both single and quad (multispectral) capabilities. Both irradiation and detection stations are temperature controlled.

1. INTRODUCTION

Most OSL measurements have been made on TL readers adapted to OSL, but now that OSL has become the preferred mode of dosimetry for geochronology at many laboratories, it makes sense to develop a reader system for OSL only. Such a reader can be optimized for OSL, and avoid any compromise and expense imposed by TL requirements. We have attempted to do so with a high-capacity mechanical sample changer base unit (60 samples on a single 38 cm diameter platter) with a variety of bolt-on modules for sample temperature control and elevation, several types of OSL excitation and detection, and irradiation. Many of these attachments are mechanically and electrically compatible with the Daybreak 1100-series TL readers as well. An especially useful feature is inclusion of two temperature controllers, so that the sample temperature at the detector may be precisely controlled using a thermoelectrically (TEM) cooled/heated stage (0-200C), while the sample preheating after irradiation is performed at another location by means of a nichrome resistance heater (ambient-300C). This is located under the irradiator so that irradiation may be done at elevated temperatures. OSL excitation is accomplished either by the fiberoptic and IR LED device described at the Canberra meeting (Bortolot 1997), by a new all solid state light source, or by a green laser scanner now under development for multiple single grain measurements and OSL imaging. Photon counting detector options include the standard single PMT and a new four PMT filter-based multiband detector. All the new devices are described below. Earlier Daybreak OSL xenon arc and halogen light sources with the fiberoptic/IROSL illuminator are compatible with the new reader.

2. MECHANICAL PLATFORM

The mechanical base unit (figure 1) of the new reader has a plan similar to that of the Risø TL reader (Bøtter-Jensen 1988), being mechanically simple and economical to construct. A single large removable platter containing 60 samples mounts on a rotating hub. Temperature controlled sample and irradiation stages push the sample disks 10 mm up from the platter to the excitation/detection plane and 20 mm into the beta irradiator. This elevation of the sample disk minimizes effects on adjacent samples. The unit has a 'pizza box' geometry slightly larger than the platter and 9 cm high including the lid. The lid is fairly light in weight since the system is not evacuated, but is constructed of 6 mm aluminum jig plate for dimensional stability. There is a simple offset hinge arrangement so that when the lid is raised to 45 degrees, there is adequate room to mount the platter easily. A side strut holds the lid open. The same mounting hole pattern is present for compatibilty at both excitation and irradiation positions, so that one could conceivably mount two separate exciter/detector assemblies or irradiators. The platter motion components and sample stages are mounted on jig plate as well.

The detector is protected from ambient light by a slide shutter when the lid is opened. The shutter actuator has a catch to lock the lid down when the shutter is not entirely closed, and there is a mechanical interlock to prevent the shutter from opening when the lid is up. Two microswitches sense lid down and shutter open conditions for electronic interlock use, and their state is displayed on the front status panel. The beta irradiator has no additional safety shutter since its own shutter is adequate. A mercury tilt switch interrupts the irradiator power when the lid is raised more than 5 degrees, so that the shutter closes.

The platter is rotated using a worm gear arrangement, and the same simple turns counting scheme is used as in the Daybreak 1100-series TL readers, one turn per sample position. Sample position reproducibility is within 0.25 mm (total excursion), and since the motor has variable speed drive, this may be improved by lowering motor speed as the sample position is approached. The long axis of the temperature controlled stages is along the circumference of the platter, rather than radially (as in the Risø reader), so that there is much greater tolerance of position misalignment. The sample elevators are pulled up by springs (and forced down by the mechanism) so that radical misalignment will not cause any damage.

The control electronics is that used in the Daybreak 1100-series readers with only some minor changes in firmware to reflect the differences in mechanical configuration and the addition of some detector-related functions. This, together with the TEM and heater plate controllers and motor drivers, is mounted on a tray that slides out from the side of the instrument for easy service access. The input and output connectors and bus expansion are likewise grouped together on a demountable rear panel. Thus, all parts of the system may be changed out or upgraded easily. The display on the front of the lid gives a fairly complete picture of the status of the instrument, with a sample position display and 16 red LED backlights. A replacable negative overlay is used for legending. Error conditions are flagged by blinking the appropriate LED. Pertinent details are also displayed on the host computer screen while taking data using the Daybreak TLAPPLIC software, and complete information with diagnostics and instrument control can be displayed at any time by clicking the righthand mouse button.

3. TEMPERATURE CONTROLLED STAGES

Unlike TL, OSL generally requires sample temperature to be held stable. This is especially true for IROSL of feldspars since the signal is strongly affected by temperature, but this is true of quartz as well, though to a lesser extent (Spooner 1994). When a single stage is used both for preheating after irradiation and measurement, the time to cool and stabilize the sample after a preheat can exceed several minutes. This becomes an annoyance when doing single aliquot measurements on recent sediments. We decided to use two temperature-controlled stages in order to take advantage of the precise temperature setting and cooling possible with TEMs, but be able to preheat quickly and flexibly using a nichrome resistance heater. It is possible to use nichrome heaters in both positions and this is probably a necessity for the single aliquot regenerative method where sample temperatures routinely exceed 100C, and where a TL measurement of the 125C quartz peak may be required for normalization.

The nichrome heater is of conventional design with a chromel/alumel thermocouple welded to the underside. A pulsewidth modulated switching controller provides up to 50W power to the heater. While the maximum heater temperature is specified to be 300C, it can go up to 700C briefly (to allow TL measurements where a purge gas is sufficient).

The TEM sample stage uses a high temperature 31 couple module (Melcor, Trenton NJ USA). Unlike older types of TEM, this can tolerate temperatures beyond 200C. The TEM pumps 3.1W from (or into) the copper block that pushes the sample disk up from the platter. There is a 0.25 mm teflon cladding on the sides of the block to inhibit heat transfer between block and platter. The temperature is monitored by a thin film platinum resistance thermometer embedded in the block. The stage can be cooled below 0C, but condensation presents a practical limit of about 10C in many climates. While the maximum temperature differential possible with the Peltier effect is 64C for this device, heating beyond this differential is possible, as the TEM becomes a resistance heater. The only disadvantage of a TEM is slow response time. Normally this is not a problem since a stabilized temperature near ambient is used for the majority of measurements.

4. SOLIDSTATE OSL EXCITER

The recent availability of high power green and blue single quantum well (SQW) LEDs from Nichia Chemical Industries Ltd. (Tokyo, Japan) has made practical solidstate visible OSL exciters possible (see, for example, Galloway 1997). There are many advantages to an all solid state light source. These include virtually infinite life compared with 10-2000 hours for incandescent and arc lamps, vastly lower power and cooling requirements, linear output control from zero to maximum power, and absence of light escaping into the laboratory. We have adapted the 'light bar' configuration described earlier (Bortolot 1997) for use with these LEDs. Figure 2 shows the form of the diode arrays. Two rows of five LEDs each are mounted in a copper block for good thermal transfer (each row of diodes is first soldered to a 0.5 mm thick BeO substrate with co-fired silver solder pads, for insulation and thermal transfer). Two such assemblies mounted at 45 degrees from vertical are used to illuminate the sample disk. Filter glass (4 mm of Schott GG475 and 2.5 mm of BG39) removes the out-of-band emission 'tails' that could pass through the detector filters. The resulting emission peak at 515 nm has a full width at half maximum of 40 nm. Some individual bialkali photocathodes may have sufficient residual sensitivity at 700-730 nm that the BG39 filter by itself might be insufficient to remove fully the long wavelength tail, so the background detected with a 6 mm thickness UG11 filter may exceed acceptable limits. Use of a metal oxide band rejection coating to remove the UG11 transmission peak centered at 720 nm (Omega Optical 330BW80 or Schott DUG11; coating on 2.5 mm of UG11 glass) lowers the background feedthrough to undetectability, at the cost of lowering sensitivity.

Green and IR LED light bars are mounted together in an aluminum housing block, 97 mm X 150 mm X 23 mm high, that also incorporates the drive electronics.

The green diodes used here (Nichia NSPG310) are matched both in intensity and wavelength. [These single quantum well devices have process-dependent emission wavelength, so that the unselected LEDs have peak wavelengths ranging from 510 to 545 nm.] The OSL sensitivity of quartz, for example, is quite dependent on excitation wavelength: a 13 nm difference in wavelength (at 520 nm) corresponds to as much as 30 per cent difference in signal (Spooner 1994; estimate made from his Figure 5). Therefore, in order to achieve reasonable uniformity of illumination, both wavelength and intensity of the LEDs must be matched. The 20 LEDs used in the green excitation source are selected for high output power and matched +/- 3 per cent in output and +/- 5 nm, centered on 515 nm. Because the LEDs are well heatsunk, temperature rise is small, and even at a forward current of 30 mA temperature effect on output power and wavelength is minimal. Power delivered to the sample at 30 mA is 30 mW/cm^2 (as measured by a calibrated 10 mm square silicon photodiode), equivalent to or better than achievable with halogen or arc lamp sources with narrowband filtration. Nichia has recently (spring 1999) been able to double LED output, and power levels up to about 60 mW/cm^2 should easily be obtainable, making it possible to use interference filter spectrum shaping if desired. Certainly the advantages the solid state devices now have render incandescent and arc lamps virtually obsolete, except when variable wavelength excitation is necessary.

One of the LED mounting blocks has a photodiode for output power servo control. The excitation power is electrically adjustable from 0-100 per cent of maximum power, unlike incandescent light sources, and makes possible the intriguing power ramping (linear modulation) scheme proposed by Bulur (1996).

Since the LED mounting blocks are removable, other LED wavelengths may be used in the same excitation device. The Nichia blue LED NSPB-series have even a higher output power than the green, but greater attention to filtration must be paid to reduce feedthrough. The blue SQW LEDs have a smaller shift of wavelength with forward current, so are more suitable than the green devices for linear modulation.

IRLED excitation at 880 nm uses five LEDs per side in similar mounting blocks, with RG830 glass filters for suppression of light detectable by the PMT. The use of filtration at the source reduces the dependence on BG39 filters at the PMT, and allows a wider spectrum of OSL to be detected.

5. MULTIBAND DETECTOR

It is now well known that the various TL and OSL emission bands of mineral materials have varying suitability for geochronology due to their bleaching and saturation characteristics (see, for example, Krbetschek, et al., 1997). It should be useful to take simultaneous multiband data, and choose the best behaved emission band for dosimetry.

Grating spectrometer instruments give high resolution (Luff and Townsend 1992) but are quite expensive and/or insufficiently sensitive for measurements of natural materials at the radiation doses found in quaternary and holocene sediments. For the small number of bands needed (3-5), the simple approach of non-multiplexed detectors is attractive both from cost and efficiency considerations. A rotating filter wheel (Fleming 1968) system uses only a single detector, but the recent availability of inexpensive small integrated photon counters from Hamamatsu Corp. and Electron Tubes Ltd. makes it feasible to avoid any moving parts. We have developed a four PMT filter detector that uses an efficient solid quartz lightguide array and four Electron Tubes P30CWAD-5 detectors. These use 30 mm UV glass window bialkali PMTs, have a built-in HV supply and amplifier/discriminator, and measure only 35 mm diameter by 182 mm long. They are usable from 250-620 nm. Four 21 mm diameter lightguides 70 mm long fabricated of UV grade fused quartz form a shallow dome over the sample. The sides of the bottom end of the guides are faceted where they join in order to pack them closely. Figure 3 shows the device in two views, and a view of the lightguide assembly alone. The four lightguides are each at a 15 degree angle to the vertical to permit mounting of four detectors with filter stacks in a square. The detectors have threaded mounts for height adjustment to accomodate variable filter thickness up to 12 mm and provide a snug light tight o-ring seal against the filters, preventing light leakage around them. The filters are changed by removal of four thumbscrews that hold the detector and filter mounting blocks together. The entire detector array and lightguide assembly is housed in a deepdrawn aluminum can 97 mm square and 250 mm high, approximately the size of the barrel of a 50 mm PMT housing. Four 32-bit counter channels and HV control (the four PMT HV supplies are separately enabled) are mounted in a small pod in the cable between the detector and the OSL reader's expansion bus connector. Data transfer is bit parallel byte serial with expansion to allow a greater number of detector channels. The expansion bus of the reader system is buffered and permits several devices to be connected at one time. The multiband detector occupies 16 bytes of the 64-byte expansion address space. It is compatible with the 1100-series readers.

6. SCANNED LASER EXCITER

Among the many problems faced in dosimetry of natural mineral materials is the often large grain-to-grain variation of TL/OSL properties, including the presence of poorly-bleached grains all of which affects dosimetry when an assemblage of grains is measured together (see for example, Roberts, et al., 1999) . Duller, et al. (1998) have described a laser scanning OSL detector system for the Risø reader that permits irradiation and heating of many grains at once, and individual readout for characterization of grains and dosimetry. We are developing a simple scanner of this sort (figure 4) for our OSL reader system, using new subminiature galvanometer servos from Cambridge Technology (Cambridge MA) in an x-y scanner mount. The field of scan is 13 mm square. The beam from a 10 mW green diode pumped solidstate laser with optics to focus it down to a 10-200 micron diameter spot (galilean 3X beam expander plus appropriate biconvex focusing lens), power stabilization and thermoelectric cooler is directed into the galvo scanner, then reflected down onto the sample disk by a 6 mm by 9 mm turning mirror at 45 degrees. A segmented octagonal cone reflector, made of thin glass sheet with magnesium fluoride protected aluminum coating, collects light from the sample and efficiently couples it to the PMT. The 10 mm black anodized sample disk contains an array of 52 0.5 mm diameter sample wells on 1 mm centers to contain the grains, together with reflective orientation marks. A bright interrupted outside rim on the periphery of the disk reflects laser light up to a ring of eight photodiodes for establishment of the disk's position and orientation. A series of radial scans is made from outside the disk inward till the edge is detected, in order to establish the center position and scale of the sample disk (without exposing the samples to the laser). Once that is determined, the beam is scanned in a circle to find the postion of the interrupting slots in the edge. With this information the positions of individual grains may be calculated. Since these galvanometers require no holding current, and the position-finding scans are fairly slow (compared to the 500 Hz raster scans possible with these devices), there is very little temperature rise to cause drift of the built-in position sensors (0.05%of scan/C). 12-bit x-y position information is applied to the servo controllers for a 3 micron position resolution. We expect the thermal drift over the course of measurements of grains on a sample disk to be under 25 microns. This device is designed to be compatible with the 1100-series readers.

7. CONCLUSION

A new modular OSL reader, consisting of a base mechanical unit and a set of bolt-on sample stages, irradiator, exciters and detectors has been developed. The aim has been to produce a versatile basis for a measurement system that may easily be updated as new techniques are devised.

8. ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

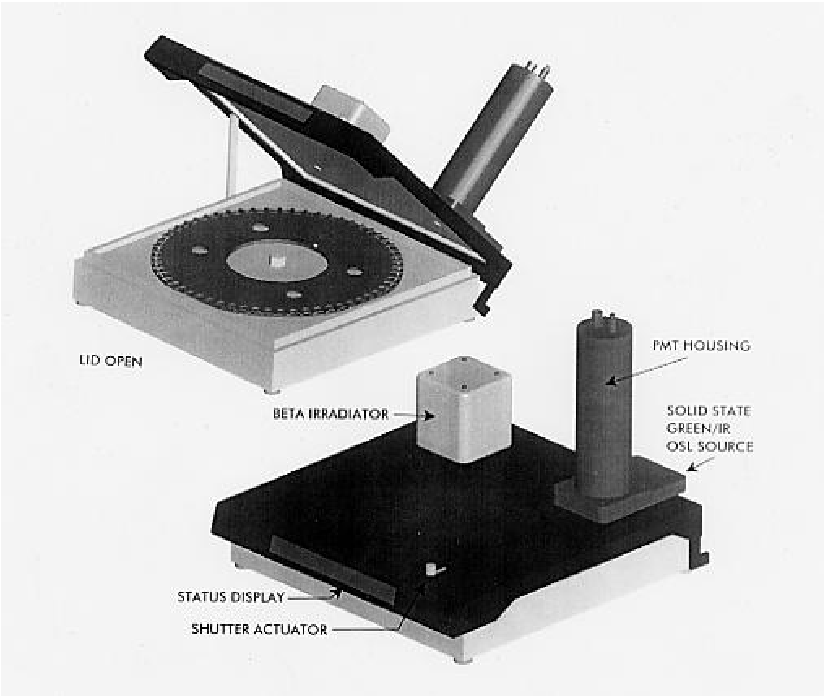

Figure 1. The mechanical platform of the modular OSL reader is of conventional design with a tilt-up cover lid. Interchangeable sample elevator/temperature control stages, OSL exciters, detectors, irradiators bolt on to this base, and the control electronics is a slide out module, for flexible reconfiguration and updating.

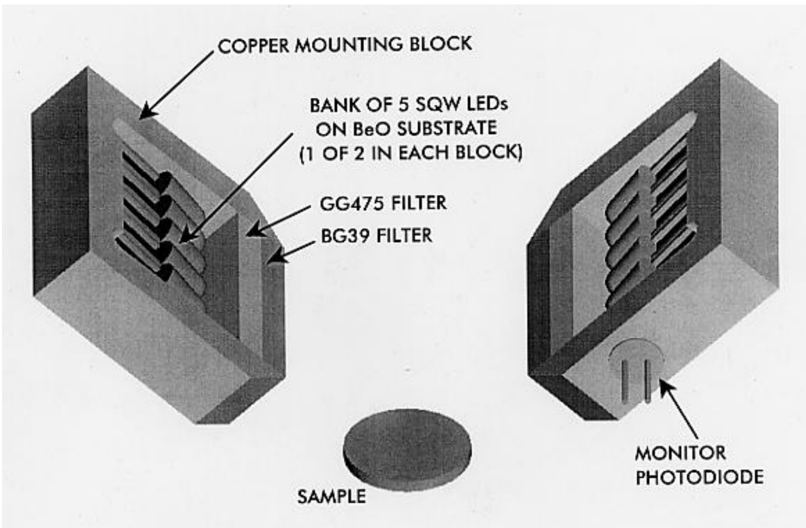

Figure 2. The green LED excitation source. Two rows of five LEDs and out-of-band blocking filter glass are contained in each copper block. For blue LEDs, the longpass filter is Hoya Y-44. The IROSL exciter is of similar construction, and oriented at 90 degrees to the visible source. The exciter module houses these two light sources together with their control electronics.

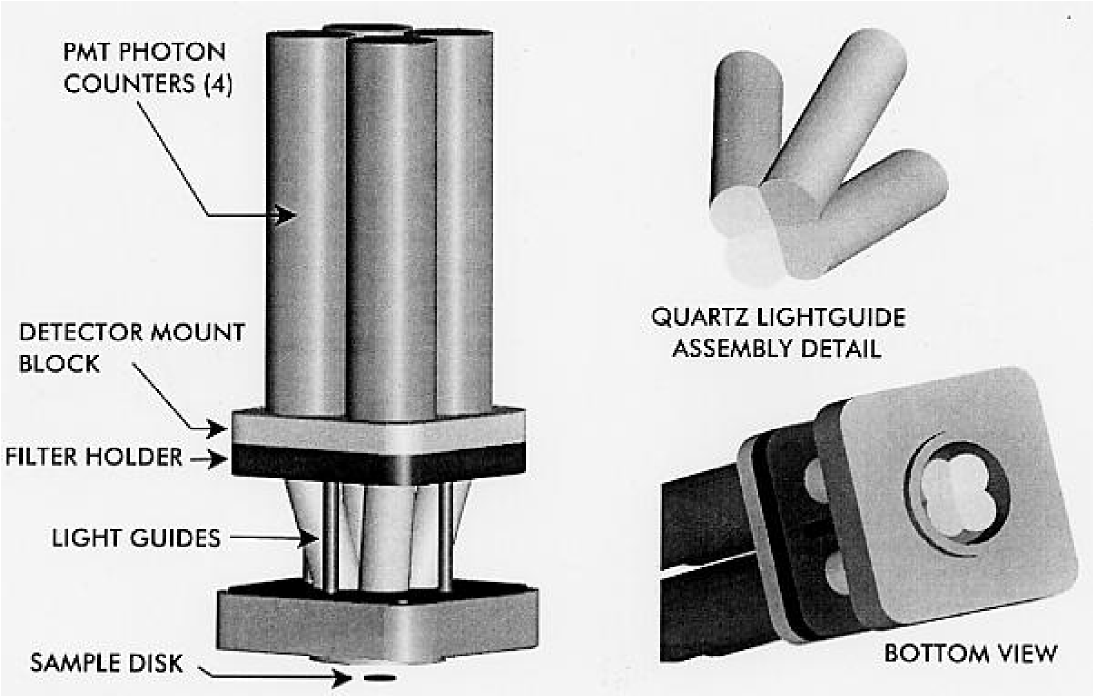

Figure 3. The multiband filter detector has four photon counting PMT modules looking through filter stacks and solid quartz light guides at the sample. Total detection efficiency is approximately equal to that of a 50 mm PMT, but is divided among the four detectors. While the multiplex advantage of a grating instrument is lost, the actual per channel efficiency in this instrument is greater due to the small number of channels and the absence of an input slit.

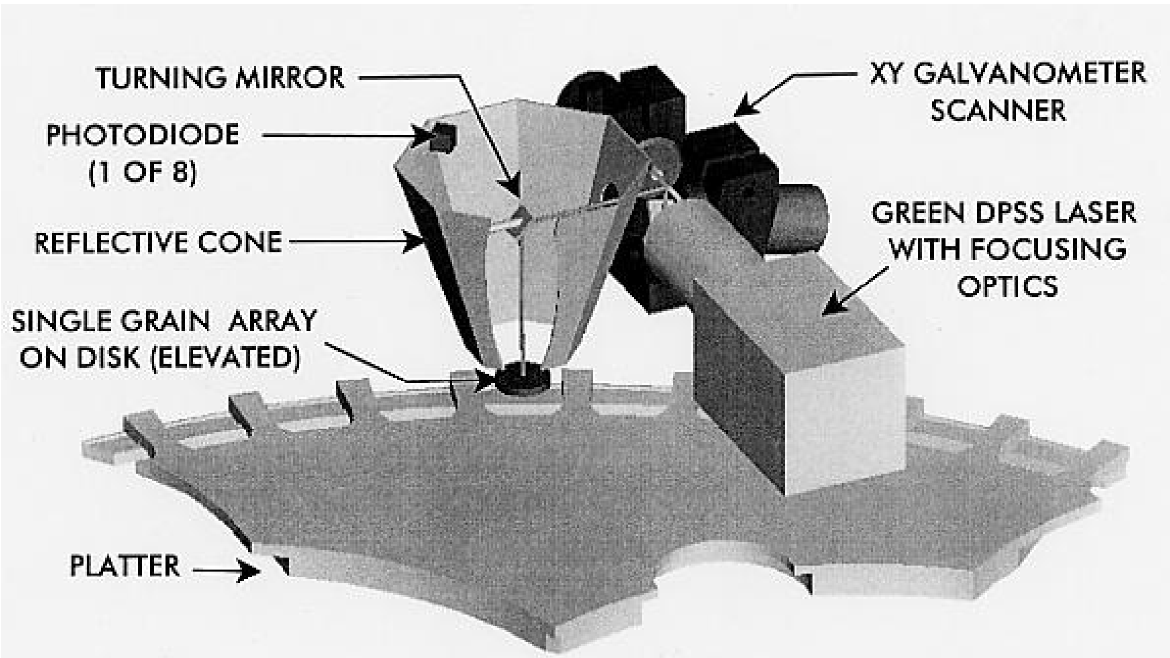

Figure 4. The galvanometer-scanned laser OSL exciter for arrays of single grains.