University of Regina

Fiber Quality Test Plans

To: Hall D Collaboration
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Subject: Optical Instrumentation for Fiber Testing

We are planning to acquire an optical system from Ocean Optics Inc. (OOI). This system will be very effective and efficient in the testing of light transmission, attenuation length measure−ments and quality control of scintillating fibers (SciFi), as part of our BCAL R&D effort. A very similar system may also be used by ODU, for the Vertex Counter. Measurements obtained with this system will be cross−checked with cosmic ray and in−beam results.

INTRODUCTION

This proposal is laid out in seven sections: Spectrometers, Light Sources, Accessories, Compo−nent Stability and Reliability, Configuration Options, Pricing and Acknowledgments. Addi−tional component specifications are provided in an Appendix.

A. Spectrometers

A.1 USB2000 Spectrometer

The USB2000, displayed in the adjacent image, seems to be suitable for our measurement needs, and has the advantage of being the most compact and straightforward platform.

The USB2000 miniature fiber optic spectrometer is a small−footprint, plug−and−play version of Ocean Optics' S2000 spectrometer. The USB2000 is in−tended for single−channel operation: the software controls and displays one spectral input per software window. Its key features are:

- Simplified spectrometer−computer interface: Plugs directly into Universal Serial Bus port of any desktop or notebook PC.
- Small footprint.

- Miniature modular design: there is a choice from 2 detectors, 14 gratings, 6 slits and hundreds of accessories to optimize a system for any application.
- Streamlined start−up: Automatically reads the wavelength calibration coefficients of the spectrometer and configures spectrometer operating software.
- No external power requirements: Spectrometer draws its power from the computer.

Setting up the USB2000 Spectrometer is easy. The user simply installs the latest version of OOIBase32 Spectrometer Operating Software onto any laptop PC with Windows 98 or 2000 op−erating system and then connects the USB cable from the spectrometer to the PC, eliminating the need for installing external A/D converters and searching for available IRQs and input/output ranges. Wavelength calibration coefficients unique to each spectrometer are programmed into a memory chip directly on the USB2000; OOIBase32 software simply reads these values from the spectrometer. The USB2000 requires no external power supply; it draws its power from the computer. In fact, the USB port can be used to power light sources that connect to the spec−trometer. Connections to the fibers are straightforward with SMA connectors. Finally, with spe−cial interface cabling, the USB2000 can be connected to a handheld PC.

A.2 S2000 Spectrometer

The S2000 miniature fiber optic spectrometer from Ocean Optics is a low−cost, high−performance system easily configured for thousands of UV−VIS−Short−wave NIR applications from 200−1100 nm. The S2000, shown in the adjacent image, features a high−sensitiv−ity linear CCD array that provides unusually high re−sponse and excellent optical resolution in a miniature package −− for a fraction of the cost of larger, less−flexible systems.

The S2000, however, must communicate with a PC via an external A/D converter, which can be problematic if a PC is connected to several devices. This is not a problem if, say, a dedicated laptop is used to read out the S2000. The user needs to install the latest version of OOIBase32 Spectrometer Operating Software onto any laptop PC with Windows 98 or 2000 operating system.

The S2000 features the following innovations:

- Flexible fiber optic spectroscopy: Bring the instrument to the sample.
- Small footprint.
- Miniature modular design: Choose from 3 detectors, 14 gratings, 6 slits and hundreds of accessories to optimize the system for your application.
- Stackable: Connect up to 8 synchronous spectrometers for multi−point sampling.

The S2000 has been reconfigured for an optical bench small enough to fit into the palm of a hand. This compact optical bench −− with no moving parts −− has a high−sensitivity 2048−ele−ment linear CCD−array detector that accepts light energy transmitted through single−strand op−tical fiber and disperses it via a fixed grating across the array. Finally, operating performance will vary according to a number of factors, including spectrometer configuration −− especially the groove density of the grating and the size of the entrance optics −− as well as the application itself (for example, low vs. high light level applications).

The SD2000 and the various external A/D converter options are for multi−channel operation: the software controls and displays both channels in open software window against one common wavelength axis vs. one common time base.

B. Light Sources

B.1 LS−1 Tungsten Halogen Light Source

In order to test the scintillating fibers, a white light source is required, which is usually served by the LS−1 tungsten halogen lamp, shown in the adjacent image. This light source, is a versatile white−light source optimized for the VIS−NIR (360 nm−2 mm). The lamp offers high color temperature, highly efficient output and long life in a compact, economical package. It is available with a 900−hour, 3100 K bulb or a 10,000−hour, 2800 K bulb. More details on the LS−1 are provided in the Appendix.

B.2 USB−LS−450 Light Source

However, OOI has built a very nice compact LED source that can either be a stand alone light source or can take its power and control from the USB2000 to which it is plugged into. The LS−450 is an example providing the general idea of the standalone product and USB−LS−450 for the plug−on source. The USB−LS−450 is an inte−grated, multi−purpose LED drive module designed for use with the USB2000 Spectrometer (as displayed in the adjacent image). It has a small−footprint and is plug−and−play spectrometer that plugs into the USB port of any desktop or notebook PC.

These units are available in their standard configuration with a bright blue LED used for fluorescence excitation. For the SciFi test, we propose to replace the blue LED and put in a new white LED (spectral emission from about 410 to 720 nm). The fiber coupling is worked out so this is very convenient. If the geometry of the test measurements can be set up in such a way that both the measured and source ends are together then the plug on source is very convenient. More details on the LS−450 are provided in the Appendix.

C. Accessories

There is a large line of spectroscopic accessories to use with both the USB2000 and the SD2000 spectrometers. For our application, Greg Gamble (see acknowledgment) recommends a #3 grat−ing (350−850 nm), an OFLV−300−1000 order sorting filter (removes 2nd order signals), and a 50µm slit. This set−up provides good sensitivity with approximately 2 nm resolution across a range from about 330 nm to just over 1000 nm. The best signal response is in the 350−850 nm range.

Most accessories have SMA connectors for application flexibility. Changing the sampling sys−tem is as easy as unscrewing a connector and adding new components or accessories, such as light sources, sampling holders, filter holders, attenuators, diffuse reflectance standards, inte−grating spheres and an extensive line of optical fibers. A standard SMA 905 connector can be adapted in our set−up with the scintillating fibers. What is also need is a convenient mount to mount and hold the fibers in a mount that efficiently couples to a standard SMA 905 connector

which OOI uses in all their products for fiber coupling. Moreover, such an operation must be *repeatable*. For this, a Dremel tool chuck holder might be convenient, but most likely a plastic holder must be custom−designed and built at Regina. The key to the mounting is repeatabil−ity. Although the required measurements are conceptually simple, because of the geometry de−pendence the set−up and repeatability issues might become a challenge.

D. Component Stability and Reliability

Observations and remarks from Greg Gamble:

- The USB2000 is wavelength calibrated as part of its manufacturing process. If there is a change (other than the minor variation we may see if temperature is varying more than 5C in 10 minute periods) then the USB2000 is broken. Greg's experience of this happening is zero. So this should not be an issue.
- White LED's have excellent long term stability of 50K ++ hours.
- The SMA connectors OOI uses are simple robust connectors with reasonable repeat−ability. The only issue that needs to be addressed is to come up with a design having a bare fiber mounting chuck that will allow simple and repeatable connections to be made into the OOI SMA connectors.

E. Configuration Options

Option A: USB2000−based System

The source light is sent down a standard fiber (or a gold standard). The light is measured in the USB2000 and that spectrum becomes the reference. The light is then blocked and a second measurement is taken. This renders the light source, the connector to the gold standard fiber, the connector from the fiber to the Spectrometer and the Spectrometer normalized. An absorption of this should be "0" across the full range of the reference lamp. Transmission, conversely, is 100%. And the relative irradiance is the black body curve with a value of 1.000.

Next, the fiber to be tested is mounted in the same way as the reference fiber. Its measurement will have some variation from the standard. We must decide a priori on the amount of variation that will be acceptable for the quality control tests, based either on tolerances supplied by the manufacturer, or as referenced in the literature by the KLOE, JetSet and CMS calorimetry groups. The spectral response of each fiber can be saved in a file, for future analysis or refer−

ence. In a setup such as this a periodic normalization to the gold standard is required. **If the USB2000 spectrometer can be re−normalized frequently in a convenient and reproducible manner, then this option would provide an acceptable solution for our measurement needs.**

Option A −− Equipment List

1. One USB2000 spectrometer with appropriate configuration.
2. Light source: depending on the wavelengths being used this could be a single LED packaged in a direct enclosure.
3. 2 x fibers, probably P200−UV/VIS, one coupled to the spectrometer input and the other to the LED.
4. SMA coupled holders to accommodate the fibers. These will be custom−chucks, designed and built in Regina. One end of these will have a common SMA connector to couple to the OOI fibers.
5. A laptop PC running Windows 98 or 2000.
6. The standard OOIBase32 software. This is available from the OOI web site at no charge.

Option B: SD2000−based System

There is a second option worth consideration. It may be ad−vantageous in terms of time to use a dual beam measurement system with one channel always measuring the gold standard, so that normalization occurs during each measurement. More importantly, in this way we avoid a repeatability issue in terms of connecting to the gold standard and periodically re−peating the calibration of the spectrometer.

This option requires a different spectrometer platform, the S2000 configured as a dual channel spectrometer (SD2000) and coupled to an ADC1000−USB (shown in the adjacent image). Each SD2000 channel is as per the USB2000 chan−nel. The light source is split through a bifurcated fiber with the LS−450 standalone LED source as preferable. The fix−ture is now cabled into by the split fiber so that equal amounts of light can run down both the gold standard (refer−ence) and the measurement channel. At the other end, the

fixture allows for the coupling of the light into the two channels. The ADC1000−USB is a separate component, as opposed to being built in as per the USB2000, and is powered from the USB interface.

This package supports a convenient normalization mode, whereby the reference signal is measured, any desired adjustments are made to the optical system and to the integration time in order to maximize the signal, and then this measurement is saved as a reference. The light is blocked and the dark is measured and subtracted. Now the spectrometer is normalized for optical geometry and the reference light source. The software display can be set up to display Absorbance, percent Transmission, or relative Irradiance in the quantitative display of the data. All the spectral (measurement) files can be saved to disk, in a delimited text format, thus readable by any software display package. **This option allows for a real time normalization between the two channels so that there is always a reference to the standard, and is the optimal solution for our measurements.**

Option B −− Equipment List

1. One SD2000 spectrometer, with each channel configured appropriately, and positioned as closely to each other as possible.
2. Light source: since this is a standalone setup, the LS−1 fiber coupled tungsten halogen lamp is the most convenient and versatile unit. However, the LS−450 can also be configured with one of several LED's.
3. Bifurcated fiber, to couple each optical path to the same light source.
4. 2 x fibers, probably P200−UV/VIS, one coupled to the spectrometer input and the other to the LED.
5. SMA coupled holders to accommodate the fibers. These will be custom−chucks, designed and built in Regina. One end of these will have a common SMA connector to couple to the OOI fibers.
7. The standard OOIBase32 software. This is available from the OOI web site at no charge.

F. Pricing

Measurement Option	*Key*	*Estimated Price*
Option A USB2000 spectrometer, built−in spectrometer accessories, light source, fiber cable and adaptors	*Advantage*: simple, easy to configure, lowest cost *Disadvantage*: requires periodic re−calibra−tion of the reference spectrum	USB2000: US$3,500 Laptop: US$1,700 Software: 0 **Total: US$5,200**
Option B SD2000 spectrometer, built−in spectrometer accessories, light source, ADC1000−USB, fiber cables and adaptors	*Advantage*: normalization and calibration are done in every measurement *Disadvantage*: requires an external ADC, and thus is more expensive	SD2000: US$4,800 Laptop: US$1,700 Software: 0 **Total: US$6,500**

For the BCAL fiber tests at Regina Option B has been selected, since this will avoid repeatability issues in re−coupling the gold fiber periodically for a normali−zation check, and will render the task far less time−consuming than Option A. Option A is simpler and can also do the job when a smaller number of fibers are being tested, such as for the Start/Vertex counter being built by ODU.

G. Acknowledgments

Much of the information provided in this report came courtesy of Greg Gamble, of Gamble Technologies Limited (greg@gtl.ca, Vancouver Office: +1.604.929.3881, Mississauga Distribu−tion Facility: +1.800.268.2735 or +1.905.812.9200). The remaining information was assembled from the the web site for Ocean Optics Inc.: http://www.oceanoptics.com/, where additional specifications may be found.

Appendix

There are useful information links on the OOI web site that provide information in addition to that presented in this Appendix. For example, links off the Spectrometers page reference grat−ing and slit selection vs. sensitivity and resolution.

USB2000 Features

Computer interface	Universal Serial Bus (RS−232 available on side connector)
Spectrometer channel	Master spectrometer channel only
Integration time	3 milliseconds−65 seconds
Data transfer rate	Full scans (2048 wavelengths) into memory every 13 milliseconds; OOIBase32 time acquisition approximately every 25 milliseconds
Dimensions	4" x 2.5" x 1.3" LWH
Portability	A pair of Lithium Ion cells makes the USB2000 Spectrometer field−portable. The USB−BP Battery Pack delivers 225 mA at 5 Volts −− sufficient to power a light source and the USB2000 for 8hours con−tinuously, or a USB−LS−450 LED module and the USB2000 for 12hours continuously. Included is a battery charger for replenishing spent batteries.

S2000 Features

CCD elements	2048 elements @ 12.5 mm x 200 mm per element
Integration time	3 milliseconds−60 seconds (with 1 MHz A/D card)
Effective range	200−1100 nm
Sensitivity (estimated)	86 photons/count
Signal to noise	250:1 (at full signal)
Dimensions	6" x 4.5" x 4" LWH (SD2000)
Dimensions	5" x 4.5" x 1" LWH (ADC1000−USB)
Dimensions	11" x 4.5" LW (Combined package)

LS−1 Tungsten Halogen Light Source

Included with the LS−1 are a 1/2" OD BG−34 filter for color correction and Teflon diffusing disks for attenuation of light source output. The LS−1 comes with a 12VDC power supply and a power cord, and has the following key features:

- VIS−NIR spectral range: Useful for chemical analysis, reflectivity of solid objects and color measurement.
- Compact size: Just 3.5" x 2.0" x 1.25" (LWH)and less than 1/2 lb.
- Long life: Available with 900−hour or 10,000−hour bulbs.

The LS−1 features an SMA 905 connector for easy coupling to OOI fiber optic spectrometers and accessories, including optical fibers and probes. A built−in slot accepts loose optical filters up to 3 mm in thickness. Either LS−1 version can be installed with spectrometers and other de−vices into a multi−device rack unit or desktop box.

USB−LS−450 Light Source

The USB−LS−450 has the following key features:

- Simplified LED−spectrometer interface: LED connects to spectrometer, which plugs directly into Universal Serial Bus port of any desktop or notebook PC.
- Small footprint.

The USB−LS−450 module connects to the USB2000 Spectrometer via a 10−pin connector on the front of the spectrometer. The spectrometer provides power to the LED and also enables synchronization functions and I2C communications. Finally, the USB−LS−450 board allows for software−controlled switching between pulsed and CW operation of the LED.

Criteria	Specification
Power output	no less than 60 mW into a 60 m m optical fiber
LED drive current	20 mA +/−150 mA
Maximum modulation frequency	1 kHz
0.5% stability time	less than 1 minute
Temperature−dependent drift	+0.1%/degree C