How to do transmission measurements of the DVCS crystals.

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This document describes the core apparatus available to do the transmission measurements through the DVCS PbF_2 crystals, how to setup the commercial software to take the data and the simple pieces of code we wrote to do the analysis.

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When a flux light (F) is incident on a medium, a part R of this flux is reflected by the medium surface, an other part A is absorbed by the medium and the remaining part T is transmitted through the medium such that:

$$T + A + R = F \tag{1}$$

This document describes how to measure the transmission coefficient τ defined as

$$\tau = \frac{T}{F} = \frac{L - A - R}{F} \tag{2}$$

even though the actual quantity of interest (for the radiation damage point of view) is the absorption A. Curing is not supposed to affect the reflectivity of the surfaces, and with this hypothesis measuring the effect of the curing on τ is a good indication of the variation of the absorption A. Nevertheless, this means that even with no absorption τ would not be 100 %. Actually, a rought calculation of the reflection fraction using the Fresnel equation gives a reflection fraction of 8.5% (air index of reflection =1, PbF2=1.82 at 400 nm). Such that τ measured at 400 nm, should not exceed 91.5%.

1 Apparatus and setup

1.1 Hardware

Figure 1 is an exert of the Ocean Optics catalog [1] describing the core apparatus we are using. It consist of a Deuterium-Tungsten (DT) halogen lamp and a High-resolution (HR) Spectrometer analyzing the spectra of the lamp. The apparatus is provided with a system of fibers, collimating lenses and lenses fixture for sampling. Figure 3 shows the wave length analyzer of the photo-spectrometer and figure 2 gives the specifications of the DT lamp. Figure 4 shows the spectrum measured by the combination of the DT lamp and the HR. Finally, to do the transmission measurements through the DVCS crystal, a 2 pieces wood support is provided. The goal of the support is double: level the crystal with the fibers, and insure that the fibers stay perpendicular to the crystal.

Tips and recommendation

- The DT lamp takes 1/2 hour to warm up and reach its stated stability (see figure 2). But the bubles inside the lamp have a "short" life time. The Deuterium lamp last 800h∼1 month. So it is just better to turn off the lamp when not in use.
- The intensity and even shape of the DT spectrum measured by the HR is very sensitive on how well the fibers are attached to the two devices and the fiber holder. For reliable results make sure the fibers are screwed all way in.
- Remember that the ADC counting the intensity of the spectra does saturates at 2.10^{16}=65536.
- The fiber holder is less sturdy than it looks at first. Make sure while taking the data that its legs do not brush the side of the wood support. This would distort the spectrum you are measuring. Actually it was what was giving us transmission greater then 100% at first.

1.2 Data acquisition

The HR is read by a commercial software called SpectraSuite. SpectraSuite is a modular, Java-based spectroscopy software platform that operates on Windows, Macintosh and Linux operating systems. We have been using it under Linux only. The CD of the software contains the executables as well as a copy of operating manual.

The software can control any Ocean Optics USB spectrometer and device. So far, we have been using it only for setting up the integration time of the ADC (usually 500μs) and to save the data when prompted with a Crtl-S signal. Figure 5 shows the configuration we have chosen for saving the data as well as how to access this configuration window.

Tips and recommendation

- The HR needs to be plugged to the USB port of the computer before starting the software.

- We were unable to check that the memory of the ADC was cleared out after each reading but it seems to us that it is not. Make sure to let the software cycle through a bunch of acquisition before saving data if you go to a new configuration.

- SpectraSuite doesn't keep track of the number of files it already has saved. That is if you close SpectraSuite, then re-open in the configuration shown on figure 5, the first file number it will save is 00000. There is therefore a risk of overwriting previous data. To avoid that, we have been changing the directory in which the data are saved daily. There migth be a smarter way to do that.

2 Taking data

In practice, to measure the transmission τ of the light through the block, one computes the following ratio:

$$\tau(\lambda) = \frac{S(\lambda) - B(\lambda)}{L(\lambda) - B(\lambda)} \tag{3}$$

where λ is the wave length, $L(\lambda)$ is the intensity of the light source at a given wavelength, $B(\lambda)$ is the intensity of the background and $S(\lambda)$ is the intensity of the lamp after going through the block. This means that one need to provide three measurements to evaluate the transmission: one with the lamp obstructed (B), one with the lamp on but no block (L) and finally one with the block in the path of the light (S).

Tips and recommendation

- When measuring the background B, one should be careful to block the light coming out the DT lamp which is not the same as blocking the light getting into the HR: the background B has a contribution from the HR ADC pedestal but also potentially from the ambient light of the room where the data are taken. For the lab we have been working in (brightly illuminated by a white fluorescent light), we have evaluated the contribution of the ambient light to be $\tilde{0}.5$ % of $L - B$.

- In order to check that the direct light spectra L is stable through out the data taking, we have taken the habit to measure L both at the beginning and at the end of the exercise. Only one measurement of B is needed.

- For the data we have taken, we used the sticker on the crystal as a reference. We put the sticker up and use it to signal the end of the crystal marked as location 0 cm.

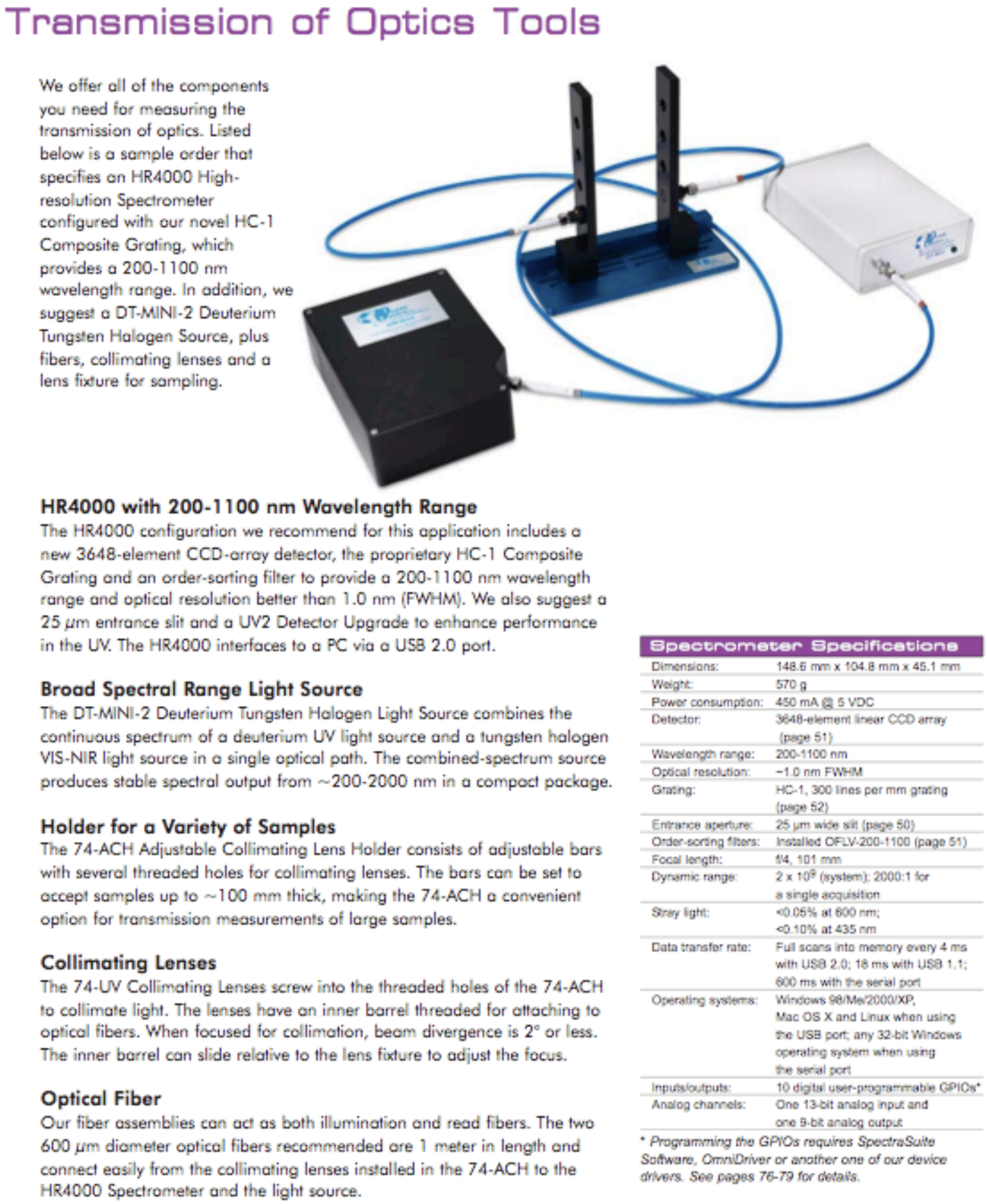
3 Analyzing the data

We have written two simple codes to analyze the data produced by SpectraSuite. Both code use the class onedatafile.h (.C) that reads and manipulate the data from one data file from SpectraSuite.
The code check.C compares an arbitrary number of spectra (from different files) together.

Figure 6 shows both the text and graphic output of the program check.C.
The code analysis.C computes the transmission of the light through the crystal measured at different location along the crystal. Figure 7 shows both the text and graphic output of the program. This figure also shows the input file necessary to run this code.

References

[1] Ocean Optics, Inc, http://www.oceanoptics.com



Transmission of Optics Tools

We offer all of the components you need for measuring the transmission of optics. Listed below is a sample order that specifies an HR4000 High-resolution Spectrometer configured with our novel HC-1 Composite Grating, which provides a 200-1100 nm wavelength range. In addition, we suggest a DT-MINI-2 Deuterium Tungsten Halogen Source, plus fibers, collimating lenses and a lens fixture for sampling.

HR4000 with 200-1100 nm Wavelength Range

The HR4000 configuration we recommend for this application includes a new 3648-element CCD-array detector, the proprietary HC-1 Composite Grating and an order-sorting filter to provide a 200-1100 nm wavelength range and optical resolution better than 1.0 nm (FWHM). We also suggest a 25 μm entrance slit and a UV2 Detector Upgrade to enhance performance in the UV. The HR4000 interfaces to a PC via a USB 2.0 port.

Broad Spectral Range Light Source

The DT-MINI-2 Deuterium Tungsten Halogen Light Source combines the continuous spectrum of a deuterium UV light source and a tungsten halogen VIS-NIR light source in a single optical path. The combined-spectrum source produces stable spectral output from ~200-2000 nm in a compact package.

Holder for a Variety of Samples

The 74-ACH Adjustable Collimating Lens Holder consists of adjustable bars with several threaded holes for collimating lenses. The bars can be set to accept samples up to ~100 mm thick, making the 74-ACH a convenient option for transmission measurements of large samples.

Collimating Lenses

The 74-UV Collimating Lenses screw into the threaded holes of the 74-ACH to collimate light. The lenses have an inner barrel threaded for attaching to optical fibers. When focused for collimation, beam divergence is 2° or less. The inner barrel can slide relative to the lens fixture to adjust the focus.

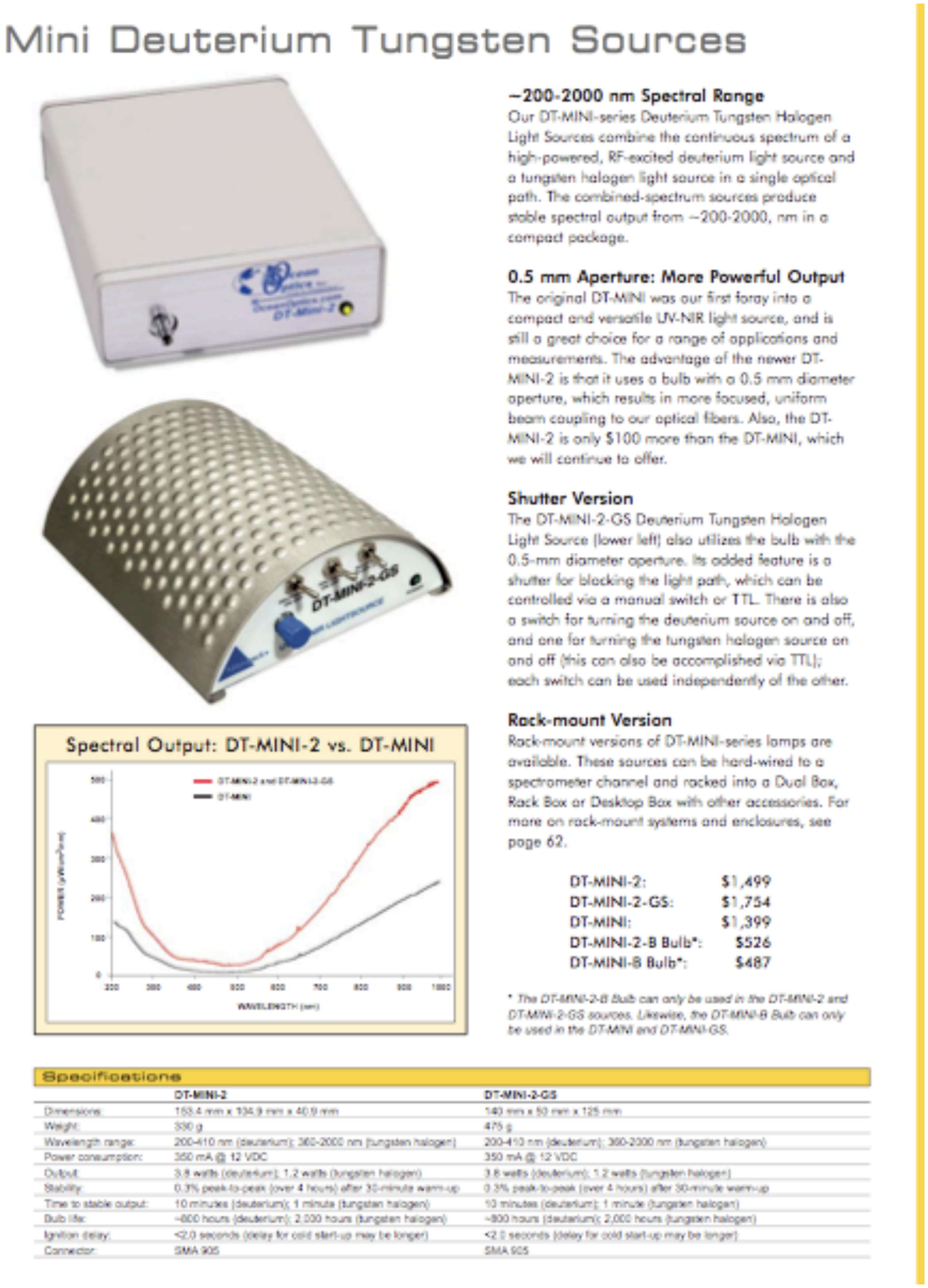
Optical Fiber

Our fiber assemblies can act as both illumination and read fibers. The two 600 μm diameter optical fibers recommended are 1 meter in length and connect easily from the collimating lenses installed in the 74-ACH to the HR4000 Spectrometer and the light source.

Spectrometer Specifications	
Dimensions:	148.6 mm x 104.8 mm x 45.1 mm
Weight:	570 g
Power consumption:	450 mA @ 5 VDC
Detector:	3648-element linear CCD array (page 51)
Wavelength range:	200-1100 nm
Optical resolution:	~1.0 nm FWHM
Grating:	HC-1, 300 lines per mm grating (page 52)
Entrance aperture:	25 μm wide slit (page 50)
Order-sorting filters:	Installed OFLV-200-1100 (page 51)
Focal length:	f/4, 101 mm
Dynamic range:	2 x 10^9 (system); 2000:1 for a single acquisition
Stray light:	<0.05% at 600 nm; <0.10% at 435 nm
Data transfer rate:	Full scans into memory every 4 ms with USB 2.0; 18 ms with USB 1.1; 600 ms with the serial port
Operating systems:	Windows 98/Me/2000/XP, Mac OS X and Linux when using the USB port; any 32-bit Windows operating system when using the serial port
Inputs/outputs:	10 digital user-programmable GPIOs*
Analog channels:	One 13-bit analog input and one 9-bit analog output

** Programming the GPIOs requires SpectraSuite Software, OmniDriver or another one of our device drivers. See pages 76-79 for details.*

Figure 1: *Typical transmission tools proposed Ocean optics. This picture is extracted from the 2006 Ocean Optics catalog.*



Mini Deuterium Tungsten Sources

~200-2000 nm Spectral Range

Our DT-MINI-series Deuterium Tungsten Halogen Light Sources combine the continuous spectrum of a high-powered, RF-excited deuterium light source and a tungsten halogen light source in a single optical path. The combined-spectrum sources produce stable spectral output from ~200-2000, nm in a compact package.

0.5 mm Aperture: More Powerful Output

The original DT-MINI was our first foray into a compact and versatile UV-NIR light source, and is still a great choice for a range of applications and measurements. The advantage of the newer DT-MINI-2 is that it uses a bulb with a 0.5 mm diameter aperture, which results in more focused, uniform beam coupling to our optical fibers. Also, the DT-MINI-2 is only $100 more than the DT-MINI, which we will continue to offer.

Shutter Version

The DT-MINI-2-GS Deuterium Tungsten Halogen Light Source (lower left) also utilizes the bulb with the 0.5-mm diameter aperture. Its added feature is a shutter for blocking the light path, which can be controlled via a manual switch or TTL. There is also a switch for turning the deuterium source on and off, and one for turning the tungsten halogen source on and off (this can also be accomplished via TTL); each switch can be used independently of the other.

Rack-mount Version

Rack-mount versions of DT-MINI-series lamps are available. These sources can be hard-wired to a spectrometer channel and racked into a Dual Box, Rack Box or Desktop Box with other accessories. For more on rack-mount systems and enclosures, see page 62.

DT-MINI-2:	$1,499
DT-MINI-2-GS:	$1,754
DT-MINI:	$1,399
DT-MINI-2-B Bulb*:	$526
DT-MINI-B Bulb*:	$487

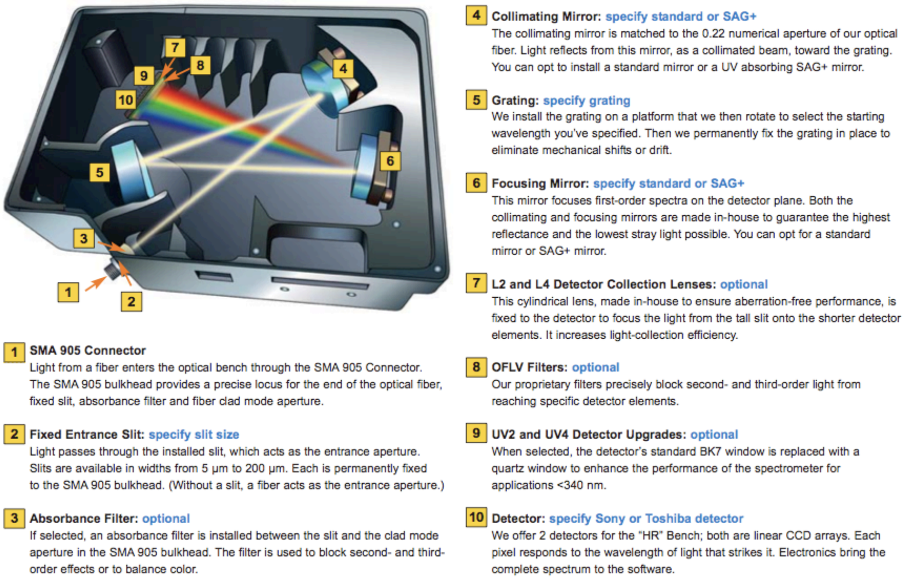
* *The DT-MINI-2-B Bulb can only be used in the DT-MINI-2 and DT-MINI-2-GS sources. Likewise, the DT-MINI-B Bulb can only be used in the DT-MINI and DT-MINI-GS.*

Spectral Output: DT-MINI-2 vs. DT-MINI

Specifications

	DT-MINI-2	DT-MINI-2-GS
Dimensions:	153.4 mm x 104.9 mm x 40.9 mm	140 mm x 50 mm x 125 mm
Weight:	330 g	475 g
Wavelength range:	200-410 nm (deuterium); 360-2000 nm (tungsten halogen)	200-410 nm (deuterium); 360-2000 nm (tungsten halogen)
Power consumption:	350 mA @ 12 VDC	350 mA @ 12 VDC
Output:	3.8 watts (deuterium); 1.2 watts (tungsten halogen)	3.8 watts (deuterium); 1.2 watts (tungsten halogen)
Stability:	0.3% peak-to-peak (over 4 hours) after 30-minute warm-up	0.3% peak-to-peak (over 4 hours) after 30-minute warm-up
Time to stable output:	10 minutes (deuterium); 1 minute (tungsten halogen)	10 minutes (deuterium); 1 minute (tungsten halogen)
Bulb life:	~800 hours (deuterium); 2,000 hours (tungsten halogen)	~800 hours (deuterium); 2,000 hours (tungsten halogen)
Ignition delay:	<2.0 seconds (delay for cold start-up may be longer)	<2.0 seconds (delay for cold start-up may be longer)
Connector:	SMA 905	SMA 905

Figure 2: *Deuterium-Tungsten lamp specification. Note that we own two lamps a DT-MINI and a DT-MINI-GS. The DT-MINI is the version preceeding the DT-MINI-2 This picture is extracted from the 2006 Ocean Optics catalog.*



1 SMA 905 Connector
Light from a fiber enters the optical bench through the SMA 905 Connector. The SMA 905 bulkhead provides a precise locus for the end of the optical fiber, fixed slit, absorbance filter and fiber clad mode aperture.

2 Fixed Entrance Slit: specify slit size
Light passes through the installed slit, which acts as the entrance aperture. Slits are available in widths from 5 μm to 200 μm. Each is permanently fixed to the SMA 905 bulkhead. (Without a slit, a fiber acts as the entrance aperture.)

3 Absorbance Filter: optional
If selected, an absorbance filter is installed between the slit and the clad mode aperture in the SMA 905 bulkhead. The filter is used to block second- and third-order effects or to balance color.

4 Collimating Mirror: specify standard or SAG+
The collimating mirror is matched to the 0.22 numerical aperture of our optical fiber. Light reflects from this mirror, as a collimated beam, toward the grating. You can opt to install a standard mirror or a UV absorbing SAG+ mirror.

5 Grating: specify grating
We install the grating on a platform that we then rotate to select the starting wavelength you've specified. Then we permanently fix the grating in place to eliminate mechanical shifts or drift.

6 Focusing Mirror: specify standard or SAG+
This mirror focuses first-order spectra on the detector plane. Both the collimating and focusing mirrors are made in-house to guarantee the highest reflectance and the lowest stray light possible. You can opt for a standard mirror or SAG+ mirror.

7 L2 and L4 Detector Collection Lenses: optional
This cylindrical lens, made in-house to ensure aberration-free performance, is fixed to the detector to focus the light from the tall slit onto the shorter detector elements. It increases light-collection efficiency.

8 OFLV Filters: optional
Our proprietary filters precisely block second- and third-order light from reaching specific detector elements.

9 UV2 and UV4 Detector Upgrades: optional
When selected, the detector's standard BK7 window is replaced with a quartz window to enhance the performance of the spectrometer for applications <340 nm.

10 Detector: specify Sony or Toshiba detector
We offer 2 detectors for the "HR" Bench; both are linear CCD arrays. Each pixel responds to the wavelength of light that strikes it. Electronics bring the complete spectrum to the software.

Figure 3: *Diagram of the "HR" optical bench used in the HR4000 high-resolution Spectrometer. It shows how light moves through the symmetrical crossed Czerny-Turner design of the bench. This picture is extracted from the 2006 Ocean Optics catalog.*

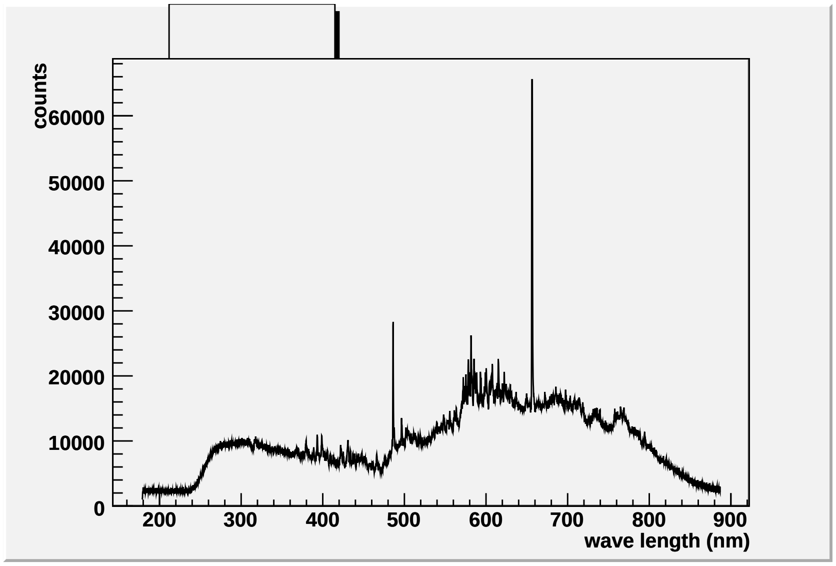
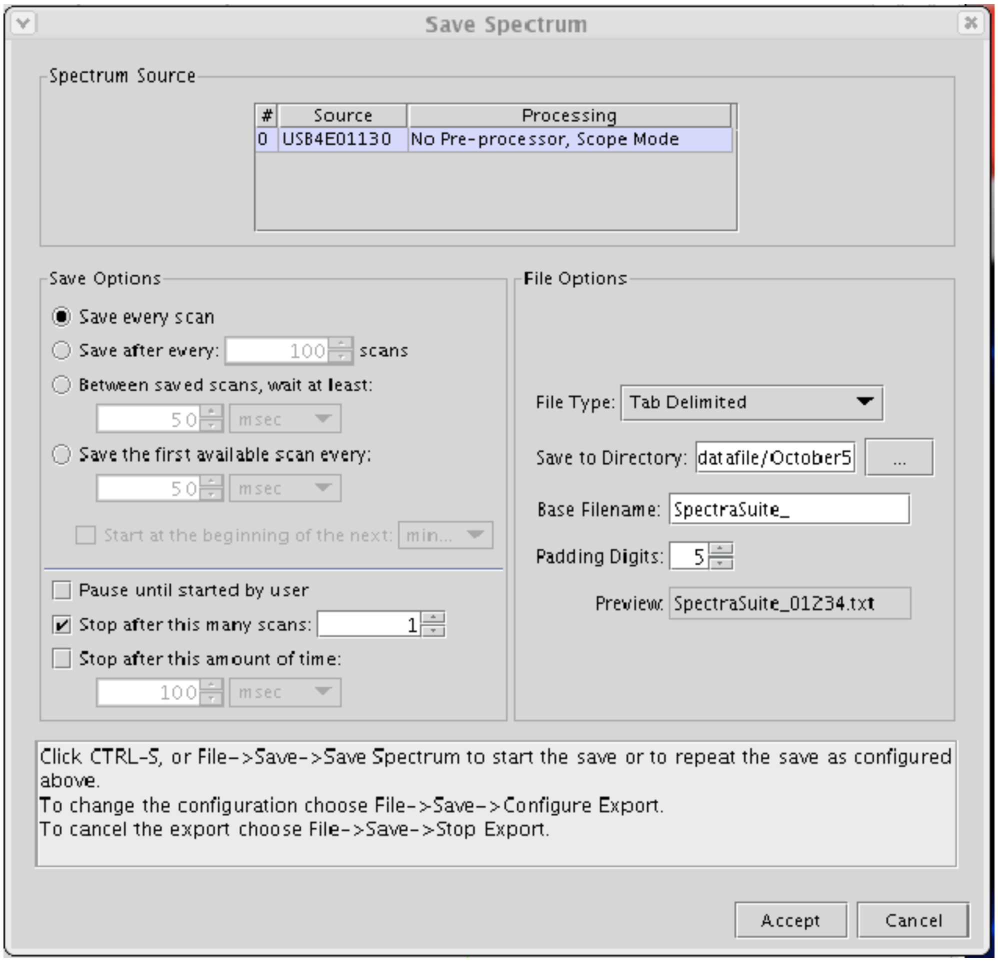


Figure 4: *Deuterium-Tungsten lamp spectrum measured by the HR spectrometer. This spectra is obtained with the thiner binning delivered by the HR spectrometer (∼ 0.3 nm/bin).*



Spectrum Source

#	Source	Processing
0	USB4E01130	No Pre-processor, Scope Mode

Save Options

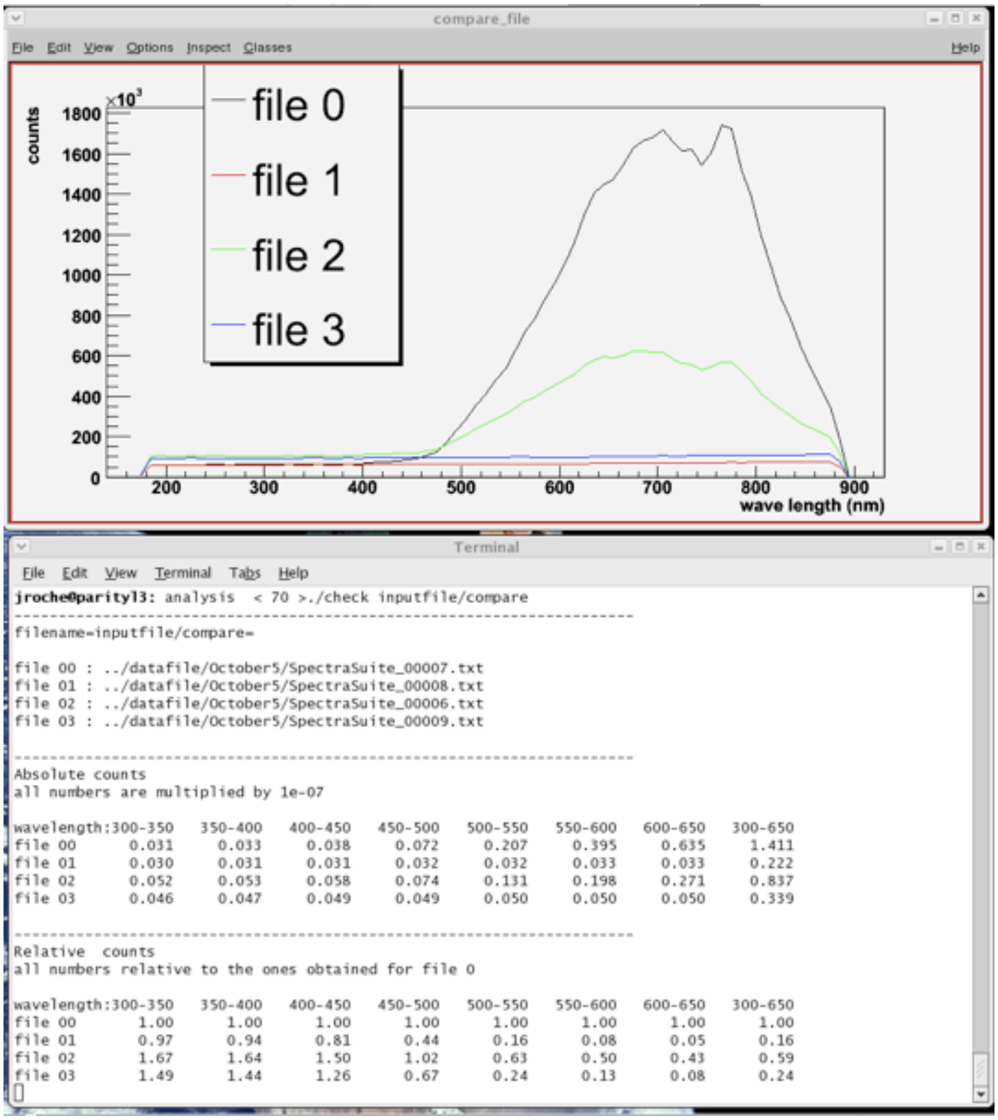
● Save every scan
○ Save after every: 100 scans
○ Between saved scans, wait at least: 50 msec
○ Save the first available scan every: 50 msec
☐ Start at the beginning of the next: min...
☐ Pause until started by user
☑ Stop after this many scans: 1
☐ Stop after this amount of time: 100 msec

File Options

File Type: Tab Delimited
Save to Directory: datafile/October5
Base Filename: SpectraSuite_
Padding Digits: 5
Preview: SpectraSuite_01234.txt

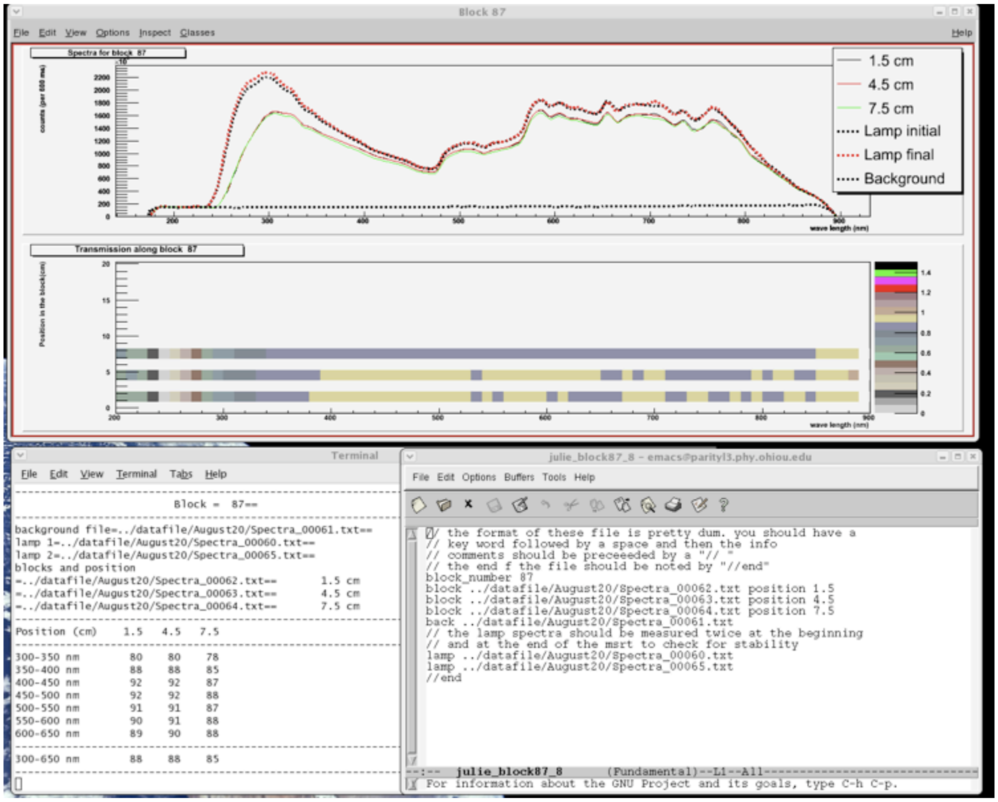
Click CTRL-S, or File->Save->Save Spectrum to start the save or to repeat the save as configured above.
To change the configuration choose File->Save->Configure Export.
To cancel the export choose File->Save->Stop Export.

Figure 5: *Suggested configuration for saving data within SpectraSuite. Choose: "Save every scan" and "Stop after 1 scan". To be analyzed using the software we wrote, choose to save under the format "Tab Delimited". Note also on the lower portion of this window, how to open the window and save the files.*



```
jroche@parity13: analysis  < 70 >./check inputfile/compare
-----------------------------------------------------------------------
filename=inputfile/compare=

file 00 : ../datafile/October5/SpectraSuite_00007.txt
file 01 : ../datafile/October5/SpectraSuite_00008.txt
file 02 : ../datafile/October5/SpectraSuite_00006.txt
file 03 : ../datafile/October5/SpectraSuite_00009.txt

-----------------------------------------------------------------------
Absolute counts
all numbers are multiplied by 1e-07

wavelength:300-350   350-400   400-450   450-500   500-550   550-600   600-650   300-650
file 00       0.031     0.033     0.038     0.072     0.207     0.395     0.635     1.411
file 01       0.030     0.031     0.031     0.032     0.032     0.033     0.033     0.222
file 02       0.052     0.053     0.058     0.074     0.131     0.198     0.271     0.837
file 03       0.046     0.047     0.049     0.049     0.050     0.050     0.050     0.339

-----------------------------------------------------------------------
Relative  counts
all numbers relative to the ones obtained for file 0

wavelength:300-350   350-400   400-450   450-500   500-550   550-600   600-650   300-650
file 00        1.00      1.00      1.00      1.00      1.00      1.00      1.00      1.00
file 01        0.97      0.94      0.81      0.44      0.16      0.08      0.05      0.16
file 02        1.67      1.64      1.50      1.02      0.63      0.50      0.43      0.59
file 03        1.49      1.44      1.26      0.67      0.24      0.13      0.08      0.24
```

Figure 6: *Text and graphic outputs of the software check.C. This code lets you compare the spectra (from different SpectraSuite files). Note these outputs are produced for data taken with the broken lamp which explains the lack of counts below 500 nm*



```
------------------------------------------------------------------
                         Block =  87==
------------------------------------------------------------------
background file=../datafile/August20/Spectra_00061.txt==
lamp 1=../datafile/August20/Spectra_00060.txt==
lamp 2=../datafile/August20/Spectra_00065.txt==
blocks and position
=../datafile/August20/Spectra_00062.txt==       1.5 cm
=../datafile/August20/Spectra_00063.txt==       4.5 cm
=../datafile/August20/Spectra_00064.txt==       7.5 cm
------------------------------------------------------------------
Position (cm)    1.5   4.5   7.5
------------------------------------------------------------------
300-350 nm        80    80    78
350-400 nm        88    88    85
400-450 nm        92    92    87
450-500 nm        92    92    88
500-550 nm        91    91    87
550-600 nm        90    91    88
600-650 nm        89    90    88
------------------------------------------------------------------
300-650 nm        88    88    85
------------------------------------------------------------------
```

```
// the format of these file is pretty dum. you should have a
// key word followed by a space and then the info
// comments should be preceeeded by a "// "
// the end f the file should be noted by "//end"
block_number 87
block ../datafile/August20/Spectra_00062.txt position 1.5
block ../datafile/August20/Spectra_00063.txt position 4.5
block ../datafile/August20/Spectra_00064.txt position 7.5
back ../datafile/August20/Spectra_00061.txt
// the lamp spectra should be measured twice at the beginning
// and at the end of the msrt to check for stability
lamp ../datafile/August20/Spectra_00060.txt
lamp ../datafile/August20/Spectra_00065.txt
//end
--:--  julie_block87_8      (Fundamental)--L1--All---------------------
For information about the GNU Project and its goals, type C-h C-p.
```

Figure 7: *Text and graphic outputs of analysis.C. This code computes the transmission coefficient of the crystal along the crystal position. The lower right window shows the input file use to produce these outputs.*