Comparison of the Arcoptix's ARCSpectro HT with a standard grating spectrometer

In this document we present a comparison of our high throughput ARCSpectro HT Fourier Transform Spectrometer and a standard grating spectrometer with similar resolution and spectral range when measuring diffusing light sources. It is impossible to find a grating spectrometer with exactly the same performances than the ARCSpectroHT (because of the difference of its working principle). However we decided to choose for the comparison the popular grating spectrometer USB2000 produced by Ocean optics. It has comparable detector (and read out electronic) quality (dark noise and saturation level), a little weaker resolution (slit of 25 μm), a little smaller spectral range, similar size, both USB read out electronic. Despite of the inherent trade-offs between resolution and spectral range of the grating spectrometers, we estimate the USB2000 (600 grooves) is the closest to the our ARCSpectro HT.
Of course the big difference between both spectrometers (which explains the measurements shown in the figures below) is the entrance aperture of 4mm of the ARCSpectro HT which permits to collect 100 times more light than its grating homologue!

The following table summarizes the main performances of both spectrometers:

Performances	OO USB 2000	ArcSpectro HT
Resolution	1.5 nm	0.5 nm
Spectral range	300 nm – 850 nm	380nm- 1050nm
Entrance aperture	25 μm entrance slit	4mm circular aperture
Detector pixels	2048 (Sony silicium CCD)	3648 (Toshiba silicium CCD)

Optical setup

As shown in figure 1, we build a very simple setup constituted of a collimated halogen light followed by a filter (interference filter at 630nm or a broadband green filter). The light traverse a 1 cm thick cuvette containing water with a few drops of cream diluted in it. This mixture can be considered optically as a strong volume scatterer. The light is then focalized at his best with two lenses (but this does not help much because we are in the case of a extended diffusing source) on a measuring spot. In the measuring spot we put:

1) A 1 meter long 600μm core fiber (with minimal light losses) connected to the USB.
2) Directly the entrance of the ARCSpectro HT.

In both case we tried to optimize fiber position (or entrance position) and lens position for optimal coupling intensity.
Notice that is possible (if necessary because lack of space) to use a 4mm light guide to bring the light to the entrance of the ARCSpectro HT, this would deteriorate the measurement shown in this document by about 40%.

We made three series of measurements:

1) with a interference filter at 630nm placed after the halogen lamp

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2) with a broadband filter placed after the halogen lamp.
3) We replaced the halogen lamp with HgAr lamp (supplied with a 9V battery) HQ-1 from Ocean Optics.

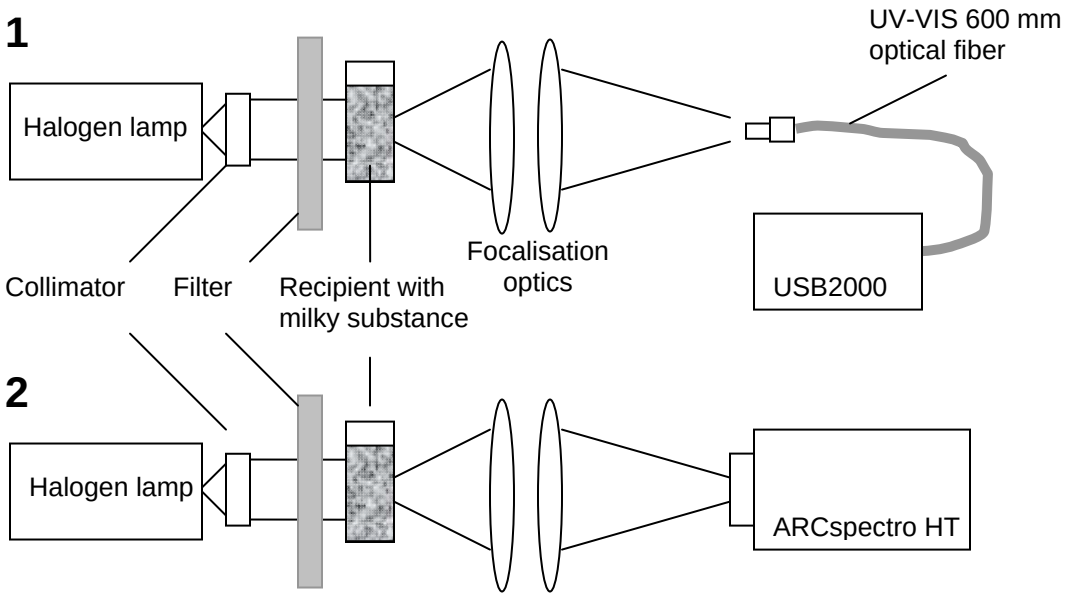

Figure 1: Filtered collimated Halogen lamp shines on a volume scatterer (milky water) the scattered light is collected on a measurement spot. 1) the light is collected via a 600mm optical fiber to the USB 2000. 2) The ARCSpectro HT is directly placed on the measurement spot.

Results

The figures below compares the spectra measured with the ARCSpectro HT and with the USB 2000 in strictly similar measurement conditions described in figure 1. We treated here the case of the spectral analysis of a highly scattering sources. This of course a particular (but important) case where the ARCSepctro is clearly superior to a grating spectrometer (as one can see in the figures below). This is simply explained by its higher so called “étendue” (or throughput) that is about 100x larger than for a comparable grating spectrometer. **In the case where only very few lights enters the grating spectrometer, it is limited by its dark noise (signal is weaker than dark noise) and no useful spectrum can be obtained even if increasing the integration time** (as we can see in figure 4). Indeed (in the low light case) increasing the integration increases the dark noise as much as the signal so the SNR stays below 1 and nothing can be measured.
On the other hand the **ARCSpectro HT collects 100X more light and is not necessarily (for the same setup) dark noise limited and has a much better SNR**.

The measurements in the figures below demonstrate very clearly (with completely different types of light sources) how useful it can be to have high throughput spectrometer if dealing with extended diffusing light sources.

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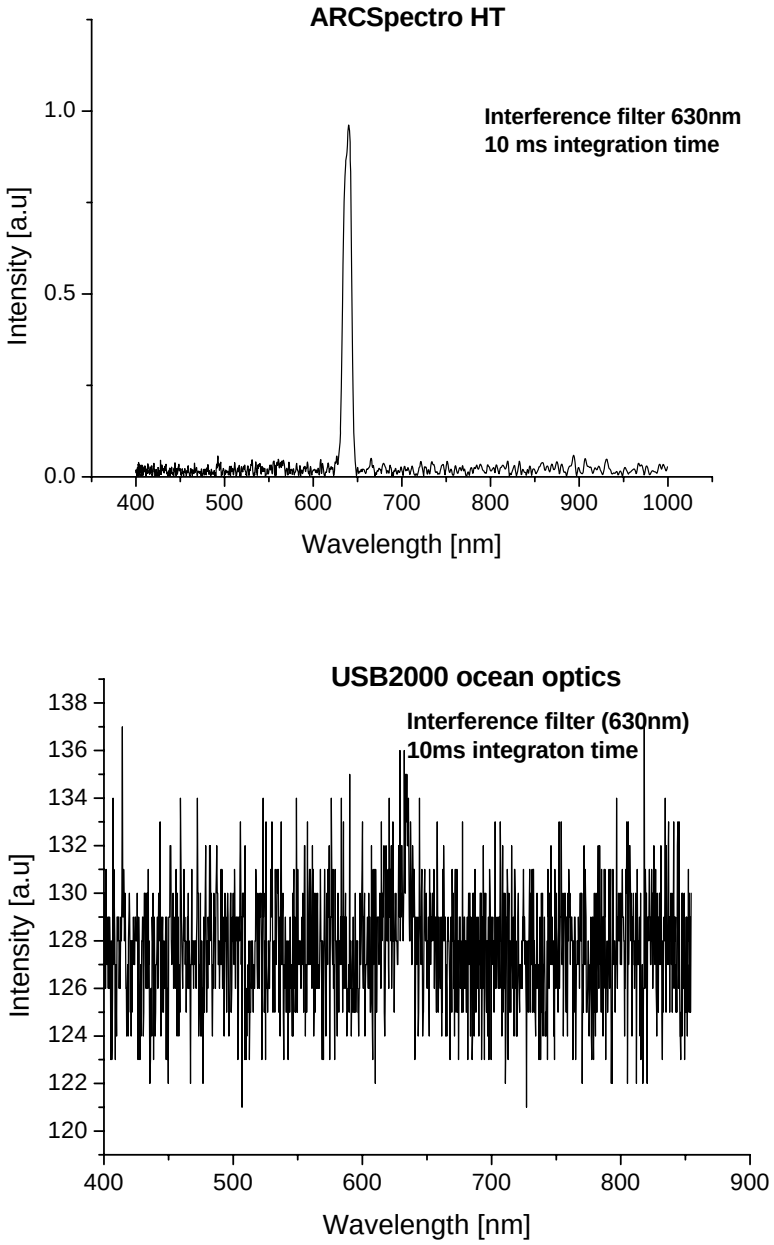

Figure 2: Measurement of the spectrum of the light emitted by a diffusing milky diffusing mixture illuminated with a halogen lamp filtered with 630nm interference filter. Above the spectrum is measured with Arcoptix's Arcspectro HT and below the spectrum measured with the USB2000 from Ocean optics. Both spectra have been measured in strictly identical conditions as described in figure 1 and with an identical integration time of 10ms (no averaging or boxcar averaging).

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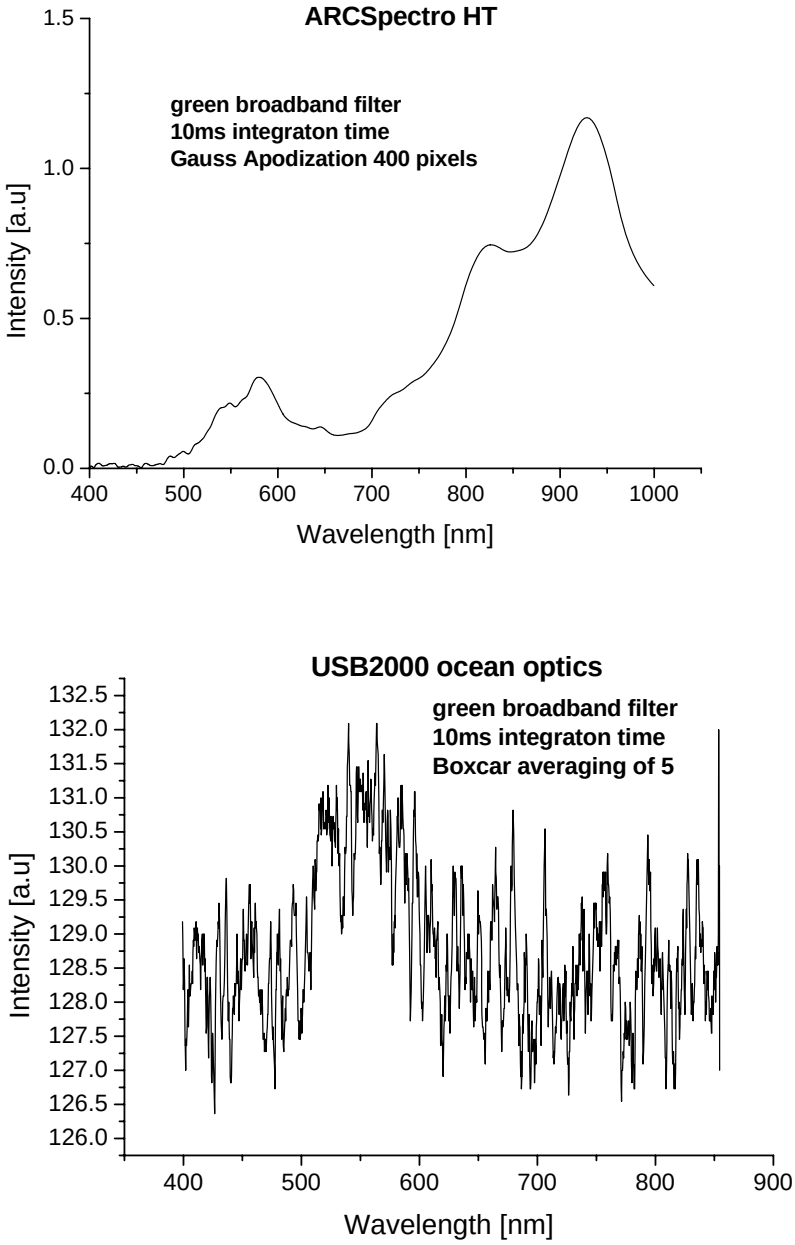

Figure 3: Measurement of the spectrum of the light emitted by a diffusing milky diffusing mixture illuminated with a halogen lamp filtered with a broad band green filter which transmits the green light and the NIR spectral region. Above the spectrum is measured with the Arcspectro HT and below the spectrum is measured with the USB2000 from Ocean optics. Both spectra have been measured in strictly identical conditions as described in figure 1 and with an identical integration time of 10ms. A Boxcar of 5 pixels averaging (5 neighbor pixel averaging) is performed on the USB2000 spectrum and a Gaussian apodization of 400 pixels (in the interferogram) has been performed in the first measured spectrum (Fourier transform equivalent of boxcar averaging) .

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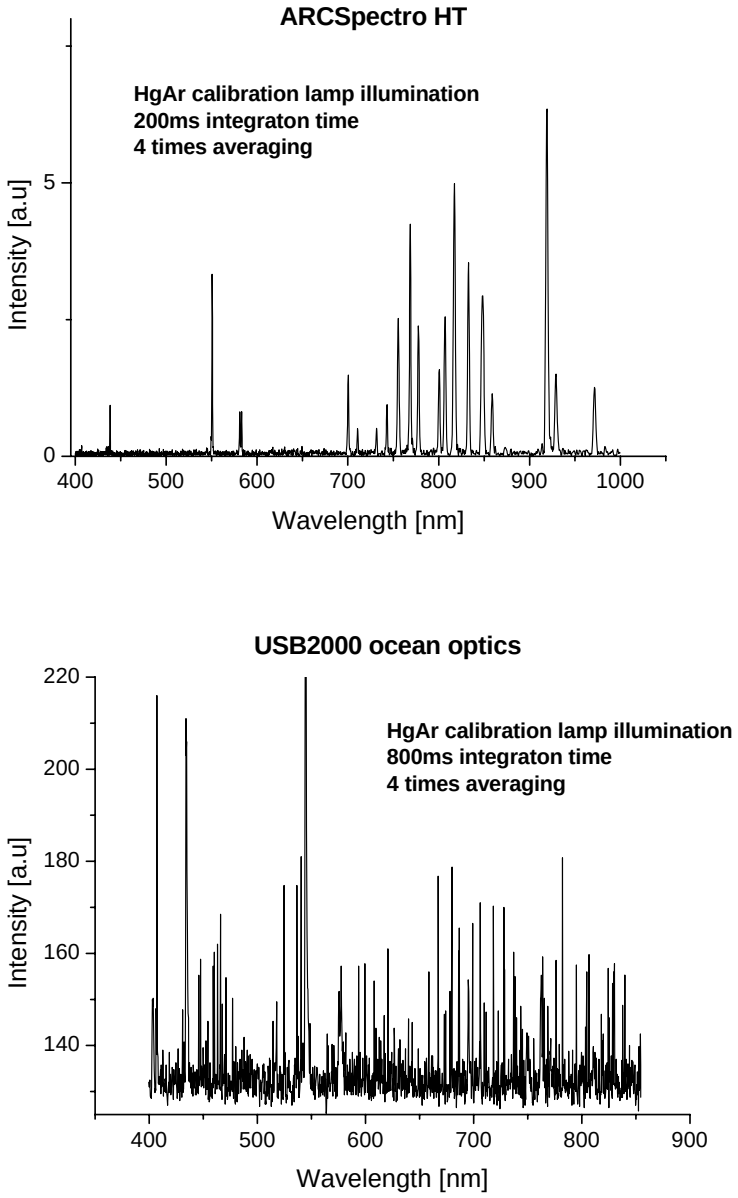

Figure 4: Measurement of the spectrum of the light emitted by a diffusing milky diffusing mixture illuminated with a HgAr calibration HG-1 from ocean optics. Above the spectrum is measured with the ARCSpectro HT and below the spectrum is measured with the USB2000 from Ocean optics. Both spectrum have been measured in strictly identical conditions as described in figure 1 **but with different integration times** (200ms for the ARCSpectro HT and 800ms for the USB2000). The plotted spectra is the results of 4 averaged spectra (measured consecutively in time). Notice that the USB2000 gives a useless spectrum even for a higher integration time.

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