

AUSTRALIAN ANTARCTIC DIVISION OPTICAL CALIBRATIONS

This document describes the Low Brightness Source (LBS) and procedures used for calibrating a Czerny-Turner grating spectrometer near 840nm (OH(6-2) band) and a Bomem Fourier-transform spectrometer near 1500 nm (OH(3-1) and (4-2) bands) located at Davis station, Antarctica.

LBS units

At present we use several Tungsten filament LBS units to determine instrument response functions for a Czerny-Turner spectrometer (CTS) and a Fourier Transform Spectrometer (FTS), both measuring OH rotational temperatures over Davis, Antarctica. Some pictures of the LBS are shown below. We have 3 the same so that we can rotate units between Davis and Australia for calibration.

They consist of a metal box (525 x 162 x 162 mm) divided into 3 sections. The first, containing the bulb, is anodized black and allows air circulation (by natural convection) around the lamp through side vents.

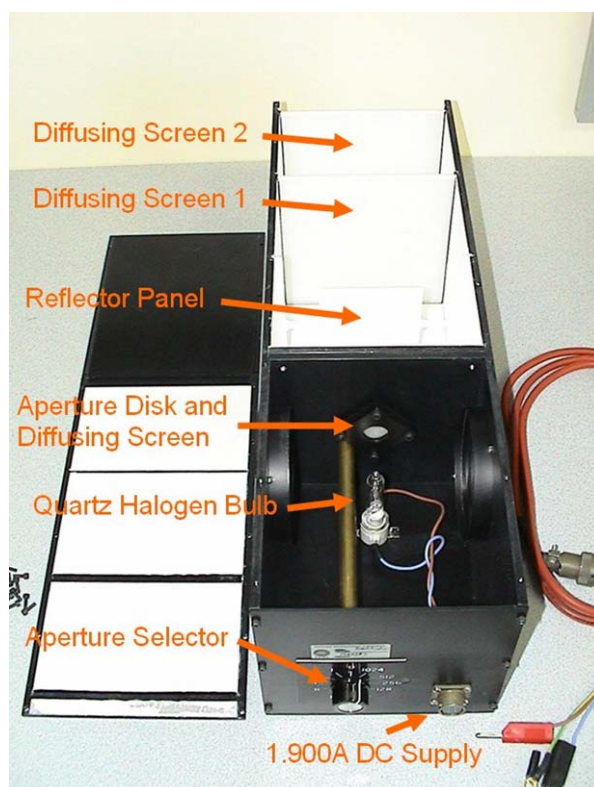
Light passes through to the second section via a small diffusing screen and an aperture disk. A rotary switch on the rear panel selects the aperture size.

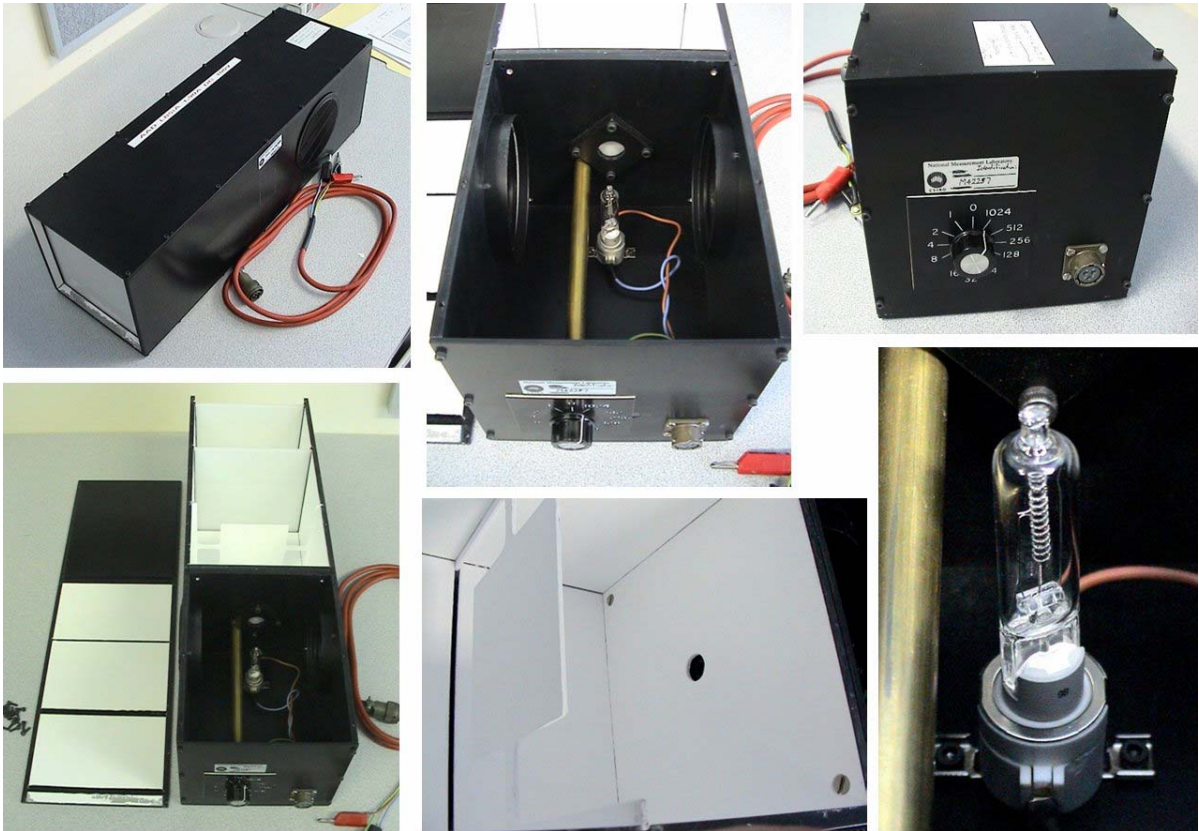
Second and third sections are painted with Labsphere WRC-680 Diffuse White Reflectance coating (barium sulphate based paint) and are divided by an opal glass diffusing screen. A reflector panel (also coated with WRC-680) inside the second section prevents light from directly irradiating the first diffusing screen.

The third section is sealed by another diffusing screen, which is viewed from the front for calibration.

We use a coiled-coil filament tungsten-halogen bulb (Philips 250Q/CL 120V). The filament is chosen for its robustness since the units are transported annually (by ship, road and air) but we pay for this in the power requirements. It is operated at 1.900A (current limited) DC (~100V, 190W) using an Optronics OL83A precision current source (23 kg worth).

An original unit operated on AC power (120V) and the power supply was much smaller but unfortunately (out of our control) it got changed to DC in 1996 and we decided to stick with it. The spectral emission is quite different between AC and DC power.





The aperture disk contains 12 settings from shut to a 14 mm diameter hole in roughly equal increments.

It is normally set to the 512 setting for calibration on our instruments. The radiance on this setting is approximately $2.07\text{E-}05 \text{ W}/(\text{m}^2\cdot\text{nm}\cdot\text{sr}) = 0.0021 \text{ uW}/(\text{cm}^2\cdot\text{nm}\cdot\text{sr})$ at 840nm.

The aperture disk may also be used on the 1024 setting which increases the radiance by a factor of 3. The radiance on this setting is approximately $6.02\text{E-}05 \text{ W}/(\text{m}^2\cdot\text{nm}\cdot\text{sr}) = 0.006 \text{ uW}/(\text{cm}^2\cdot\text{nm}\cdot\text{sr})$ at 840nm.

Calibrations at Davis

On each instrument the LBS is set up to completely fill the field of view, powered up and left for ~30 minutes to stabilize. Routinely we do calibrations each month with a minimum of 4 consecutive scans so that we can get a measure of the repeatability uncertainty.

On the CTS we scan 700-900nm (0.05nm step, 0.5sec dwell, 0.16nm instrument function FWHM). This covers the ranges of both the OH(8-3) and (6-2) bands.

Lab and photomultiplier temperatures are monitored for each scan as there is a detectable change in spectral response with temperature.

The response curve is normalised and fit with a quadratic across each band (eg 835.0 - 855.5nm for the OH(6-2) band, normalised at 840nm).

Uncertainty in the response function for the P12/P15 ratio (the largest wavelength separation we use for rotational temperature measurements) is typically less than 0.3% each year (which equates to about 0.3K temperature error)

For the FTS, the detector is sensitive from about 1200 to 1700 nm (5700-8300/cm), but the region of principal interest is the OH(4-2) and (3-1) bands at 1500-1600 nm. Uncertainty in the response function was 0.5-0.8% in 2003.

Calibrations of the LBS at NML

The LBS is calibrated annually by source substitution with a transfer standard at the Australian National Measurement Laboratories.

These normally cover the 600-900nm range and the following procedure has been adopted:

1. Two scans of the transfer standard (this is a 500W tungsten filament lamp positioned 10 metres from the spectrometer input)
2. Four scans of the LBS (on the 1024 aperture setting positioned at the spectrometer input)
3. Repeat scan of the transfer standard.

Where each scan is comprised of:

- Two samples at a reference wavelength (750nm)
- Two darks samples
- Scan 600-745 nm, Sampled in 5 nm steps
- Two darks samples
- Scan 750-900 nm, Sampled in 5 nm steps
- Two darks samples
- Two samples at a reference wavelength (750nm)

Each sample is the average and SD of 200 measurements.

Supply current and voltage and lab and detector temperature are monitored at the start and end of each scan.

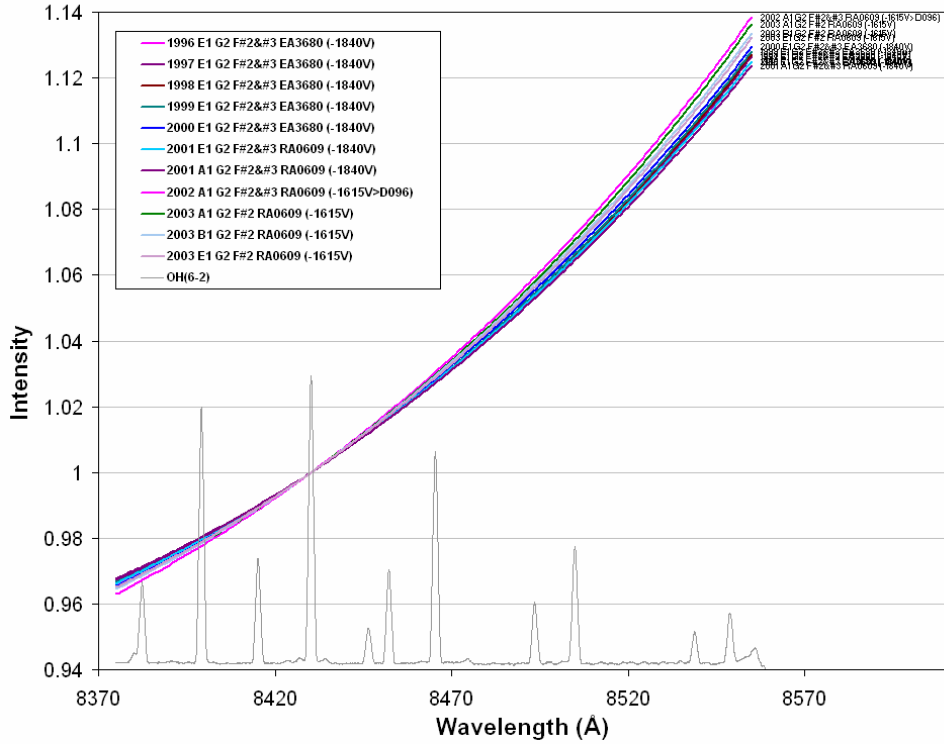
Dark and Reference wavelength scans allow drift in the instrument or source to be assessed and the scan data are corrected for this (by linear interpolation).

The uncertainty in the derived 'source function' for the P12/P15 ratio is typically of the order of 0.3% (or 0.3K).

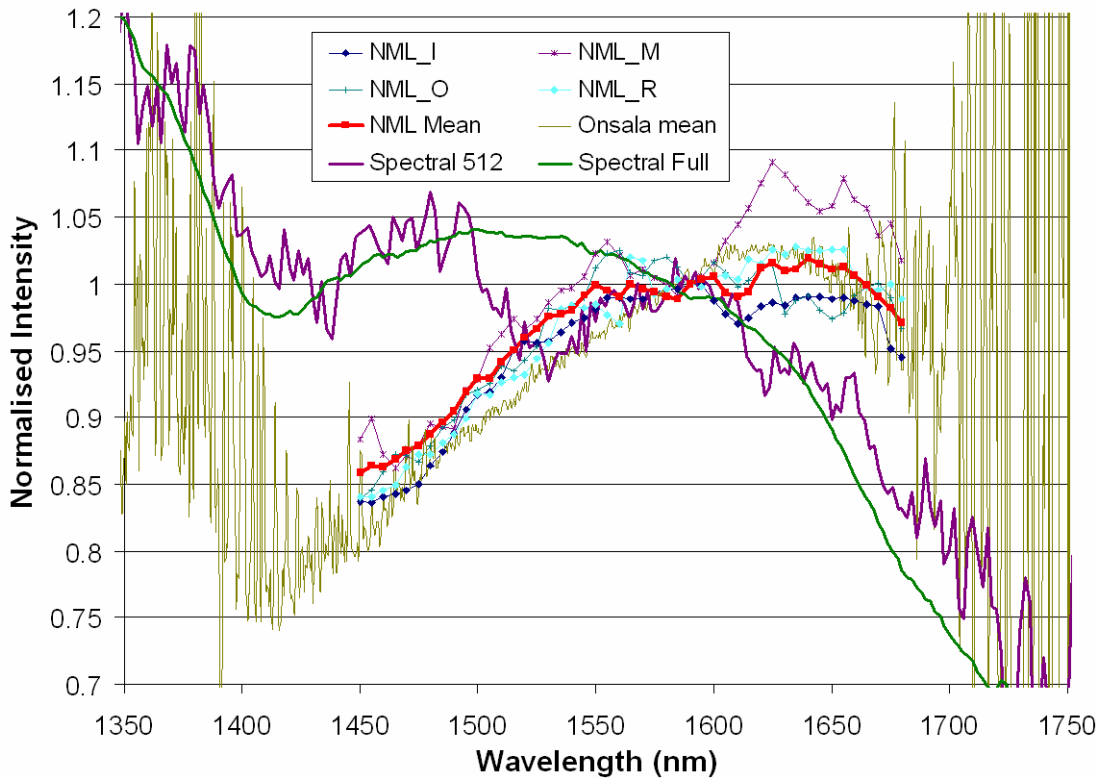
We started these calibrations in 1996 but were not able to get consistent results until 1999, due to IR scatter in the blackout curtains that shielded the transfer standard over the 10 metres between it and the spectrometer. It turned out that the fire retardant used in the black cloth is 'white' in the IR.

In calculating the instrument response corrections shown below we assumed that the LBS 'source function' did not change between 1996 and 1999. The SPX instrument response has been very consistent over the 8 years. These curves include a change in the order separation filter and change in the GaAs detector.

Response Correction Functions



As yet we have not been able to obtain an accurate calibration of the LBS over the 1500-1600 nm range (for the FTS) at NML due to a lack of suitable detector on their system. I have made source substitution calibrations on Pat Espy's system in Onsala, Sweden and with the Spectral group in Toronto for this region, but the agreement between them is not good .. see below. This has yet to be resolved.



Red curve is the mean of NML scans
 Brown curve is the Pat Espy (Onsala) measurement
 Purple and green curves are the Spectral measurements on two aperture settings.

We perhaps should be using a black body radiator to calibrate at the higher wavelength but a temperature of ~2000K is required. NIST are currently attempting a calibration over this wavelength range (June 2006).

I visited NIST in June 2006 to deliver the LBS and discuss the calibration procedures (with Bob Saunders, Jim Gardner and Howard Yoon). Some points of note from those discussions include:

We discussed using IR LED's as a low brightness source (low power, extremely long life). I have in fact modified one of the LBS units and fitted it with an IR LED panel. The disadvantage of LED's is that they have a large temperature gradient (or spectral shift with temperature) so you have to monitor and regulate the temperature very accurately.

Our LBS units operated at 1.900 A are significantly underrated (~190W instead of their rated 250W) and this is likely to effect the halogen cycle (deposition of tungsten back onto the filament) and this will have serious consequences for the bulb life and stability.

Their recommendations for replacement bulb would be a 12V car headlamp. These have robust filaments, long life and can be powered by small, lightweight DC power supplies with precision current control.

The orientation of our LBS from the vertical (at Davis) to the horizontal (at NML) may result in a measurable spectral change due to the 'sagging' of the filament. According to Howard this has been measured in the UV spectrum and there is likely to be an effect in the IR. This needs to be investigated for our LBS.

I have also been sourcing black body radiators (discussed these with Irfan Azeem) at Embry Riddle who use these to calibrate the South Pole Michelson. Some are provided by www.opticalenergy.com/infrared-ir-blackbody-sources/ or at <http://www.mikroninfrared.com/products/products.shtml#Blackbody> but the cost (and size) becomes large for the higher temperatures required for the 1500 nm region.

John French
June 2006