Microvision Application Notes: Luminance Measurements

2/17/98 Rev. 1

Calibration Conditions

The SS210/220 optical systems are calibrated and the calibration data verified using an integrating sphere light standard set to a color temperature of 2856° Kelvin (Luminance A). This source produces a black-body curve with a well-characterized distribution of spectral energy that does not have any discrete spectral "peaks". The calibration data supplied with the system provides information about the accuracy of spectrometer measurements of a Luminance A standard from 0.1 Cd/m^2 to 1000 Cd/m^2.

The spectrometer system is spectrally calibrated using a mercury-argon light source, which provides a series of accurate spectral peaks over the visible range of 380 to 780 nm.

The CCD camera system with the supplied photopic filter is calibrated with the same light standard and calibration data supplied. The calibration is performed at multiple points over a range of 5 to 1000 Cd/m^2 to linearize the detector response in this range.

All calibrations are performed with NIST traceable equipment.

Both the CCD camera and spectrometer are **thermally regulated**. The temperature is displayed in the upper right corner of the plug-in, and will change color from **red** when **out of regulation range** to **blue** when **within regulation range**.

System measurement range

Because CRT's and other display devices emit light with the energy concentrated in narrow spectral regions, the dynamic range of the measurement system will not be as great when making measurements of the luminance of these sources. Calibrated neutral density filters are supplied to provide a range of measurement capability that should exceed the requirements of most applications. Other calibrated filters can be supplied if requested.

The spectrometer system has a maximum range at 1 frame of 1000 Cd/m^2 at 2856° K. This corresponds to a luminance value of about 500 Cd/m^2 for a typical CRT white field. This range can be extended by 2, 4, or 10 times with the supplied filters.

The CCD camera system with the provided F5.6 lens and photopic filter has a maximum range of 800 Cd/m^2 at 2856° K. This corresponds to a peak luminance value of about 600 Cd/m^2 and a mean luminance value of about 200 Cd/m^2 for a typical CRT white field. This range can be extended by 2 or 10 times with the supplied filters.

Area luminance measurements made with the spectrometer

The spectrometer system is inherently much more accurate than the CCD camera system for making area luminance measurements. At the normal working distance the spectrometer lens collects light from a 12.5 mm. diameter circle. This spot size has been chosen because it encompasses an area of about 500 pixels on a typical display. The lens system has a 1.5° aperture angle, permitting area luminance measurements to be made with a larger spot size by moving further away from the display under test. At a distance of 500 mm. the spot size will be increased from 12.5 to about 25.5 mm.

The spectrometer measures luminance by focusing the collected light on a diffraction grating which creates a "rainbow" that is projected onto a 2K element linear CCD array. The amount of energy at each wavelength is then calculated, and the luminance value is calculated by weighting the resulting energy using the CIE photopic response curve, which attempts to normalize to the human eye's response. Since the eye is most sensitive in the 580 nm. (green) region, a given amount of energy in this region will have a higher luminance value than the same amount of energy in the red or blue region of the spectrum.

Spectrometer measurement parameters

The software provides the capability to set the number of samples averaged together, the number of frames integrated, and the frame rate.

The **frame rate** is normally set automatically when the timing file for the pattern generator is selected, but it can be manually changed by selecting the **rate** button.

The number of **samples** averaged together is nominally set to the default value of 3, but may be set from 1 to 999.

The number of **frames** of data collected for a given measurement controls the length of time that the light from the UUT is integrated by the spectrometer. The optimum accuracy is obtained when the maximum data point of the spectrum collected is close to 50% of the full-scale reading. The number of frames can be adjusted from 1 to 50. There are two different ways the number of frames may be set, automatically or manually. An operating mode which provides an upper limit of <50 frames is available. The main reason for using a mode other than fully automated with a range from 1 to 50 frames is to speed up the measurement process with some trade-off in accuracy.

In **automatic adjustment mode**, the number of frames is adjusted by the system dynamically for each measurement to keep the full-scale value in the middle of the system dynamic range. This is the default mode when the system is started, and is selected by setting the **frames** variable to a **negative number**. Setting this variable to -50 will cause the system to automatically adjust the number of frames collected between 1 and 50 for each measurement point. Setting the variable to a negative number <50 will result in automatic adjustment with a maximum number of frames equal to the negative number.
(Setting the number of frames to -10 will cause the system to adjust for the optimum number between 1 and 10 for each measurement point).

Fixed adjustment mode is selected by entering a positive number from 1 to 50 as the **frames** variable. This will cause the system to make all measurements at the specified number of frames.

In order to make accurate luminance measurements, **it is critical that the peak value not be permitted to exceed 100% of full scale**. The value displayed in the upper left corner of the spectrometer plug-in is the % of full scale of the maximum point in the current data set. If this value exceeds 100%, the number of frames must be reduced, or if the system is still clipping at 1 frame, a neutral density filter installed in front of the lens.

Calibrated Neutral density filters of 10, 25, and 50% transmission ratio are supplied with the system. These filters may be installed on either the SS210 or SS220 lens system, and the appropriate **calibration configuration** must be selected for the filter in use under the **init - spectrometer - change calibration configuration** menu.

User supplied Neutral density filters of other values may be installed, and the **auxiliary transmission factor** variable may be set to scale the system readings accordingly, but these will not be as accurate as the supplied filters, which are individually spectrally calibrated for each system.

Luminance Units and **Color Units** may be selected under the **init - spectrometer** menu. These settings do not affect system calibration, merely change the form of the displayed data.

The **Spectral, Illuminant, and Photopic** functions under **init - spectrometer** are used to **calibrate or recalibrate** the system, and should **not** be used unless the user has access to a mercury-argon spectral calibration source and an integrating sphere luminance standard, and has the appropriate experience in the use of these standards.

Peak and area luminance measurements made with the CCD camera (SS210 only)

The CCD camera provides the capability to make luminance measurements by installing the provided photopic correction filter in front of the lens system. This filter attempts to provide a transmission response curve that matches the response of the silicon detector to the CIE curve. The photopic filter appears green, because it passes green light through with little attenuation, since that part of the spectrum is the most heavily weighted in the photopic response curve. The silicon CCD detector is very sensitive in the near-infrared portion of the spectrum, so the photopic filter greatly attenuates the light in this portion of the spectrum.

The CCD camera system is calibrated with the same Luminance A light standard that is used for spectrometer calibration, and is most accurate at a color temperature of 2856° K.

Luminance Calibration of the CCD Camera

The camera is calibrated at F5.6 (the unmarked lens setting between F4 and F8), and the **luminance calibration is only valid at this F stop and with the photopic filter installed in front of the lens, the focus ring set at the infinite position, and the original shipping configuration element size**.

For optimum luminance measurement accuracy, the F-stop and focus settings should not ever be changed from the factory settings. For purposes of spatial and geometry measurements, it is sometimes useful to change these parameters, as well as change the element size by installing or removing extender rings and recalibrating the new element size using the supplied **Ronchi ruling calibrator box**.

If the element size, F-stop, or focus setting is changed, the photopic calibration is invalid. If the F-stop is changed, the best repeatability is obtained by rotating the ring first to the 1.6 end, then setting it back to 5.6. This will typically result in less than 5% uncertainty in addition to the error reported in the calibration data sheet.

Lens options

As an option, the SS210 system may be supplied with two interchangeable lens systems; one with the focus and aperture **locked** and the photopic filter **permanently** installed, and a second adjustable lens for geometry and spatial measurements.

Measurement Dynamic Range

Because it is a **focused** system, the CCD is capable of measuring both **peak** and **mean** luminance values. The factory calibration is performed at 2 frames, and provides a range up to peak luminance values of about 600-700 Cd/m^2 for a typical CRT. This range may be extended by installing the supplied **neutral density filters** in front of the photopic filter, and entering the filter value

A provision is made to increase the accuracy of luminance measurements made with the CCD camera by performing a "spot calibration" under the "init-camera" menu.

Spot calibration of the SS210

To perform a spot calibration of the CCD camera, the UUT (unit under test) must either be driven by the pattern generator of the SS210 system, or be running the MV remote program and controlled via the serial port. When the spot calibration function is selected, the system will make measurements of red, green, blue, white, and dark screens with the spectrometer, then move the stage to position the CCD camera in the same location, and make the same measurements again. A correction factor is then generated which is applied to subsequent measurements to improve the accuracy of the CCD camera values.