Characterization of camera spectral sensitivity

Location:

NERC Field Spectroscopy Facility, University of Edinburgh
(http://fsf.nerc.ac.uk)

Dates:

May 5-9, 2015

Cameras:

- Stereo cameras: 2 DSLR cameras Nikon D5200 with AF Nikkor 35mm f/2D lenses.
- Spheron camera with a Nikkor fish-eye lens.

Equipment/laboratory configuration:

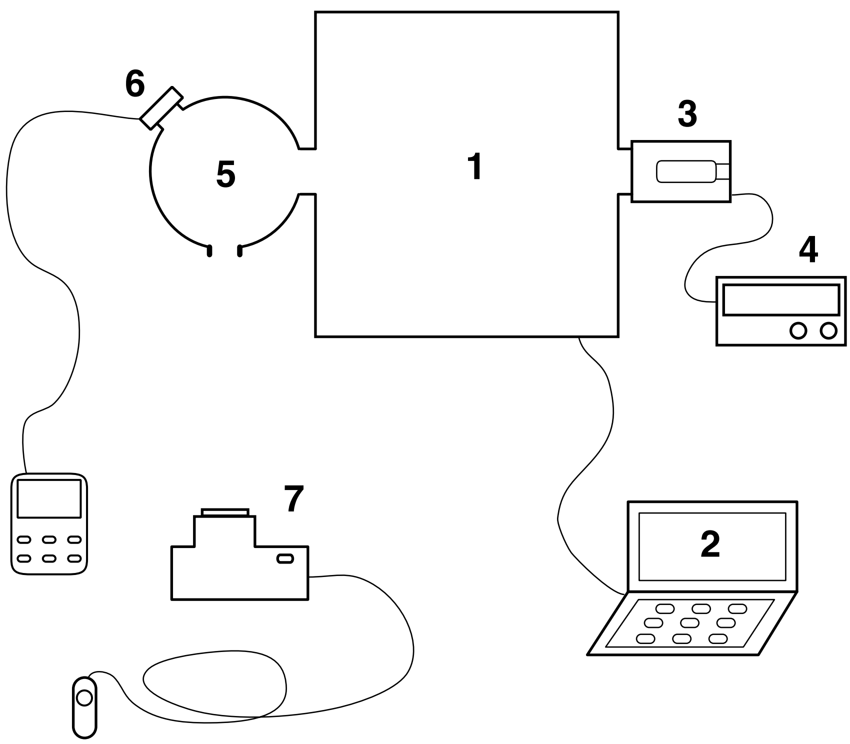

Figure 1: schematic of the set-up.

1) Double grating monochromator
2) Laptop (to control the monochromator)
3) Tungsten light source
4) Power control for the light source
5) Integrating sphere, diameter d=10cm
6) Light meter
7) Camera

Details and Procedure:

Figure 1 depicts the physical setup used in the laboratory. A tungsten light source was powered in constant current mode (I = 5.6A for Nikon D5200 camera measurements and I = 6.3A for the Spheron HDR SpheroCam). The monochromator (an Optronic Laboratories (USA) OL 750-M-D) generated narrowband wavelength stimuli (half bandwidth (HBW) = 4nm) in 5nm steps across the measurement range (390 – 745nm).

The monochromator uses a number of internal filters to filter out stray light. We used two filters for our measurements; Monochromator Filter 2 is optimized for presenting stimuli <599nm; we used this filter for presenting stimuli between 390 and 620nm. Monochromator Filter 3 is optimized for presenting stimuli >599nm, and we used this filter for stimuli between 580 and 745nm, ensuring overlap between filter measurements.

The output of the monochromator was directed to an integrating sphere (D = 10cm) and presented to the sensor device (camera, or silicon diode) through an aperture (D = 2.5cm). We measured the light intensity from the monochromator and its integrating sphere using a reference silicon photodiode (OL DH-330C S/N: 12101253, Optronic Laboratories, USA). The diode has a linear response output over the visible spectrum (see Figure 2), which allowed us to characterize the relative intensity of our narrowband stimuli.

Stimuli were presented sequentially in 5nm steps over the visible spectrum (range of 390nm – 745nm for the Spheron; 390-715nm for Nikon cameras). At each stimulus setting we took camera images of the output aperture of the integrating sphere. A number of scans were completed for each stimulus (3 scans for Spheron, 10 images for the Nikon cameras). In post-processing, a central patch from each image was selected and RGB intensity measure, and the results at each stimulus value were then averaged across the three scans.

Thus, for each presented wavelength we have a measure of stimulus intensity (measured with the silicon diode) and the camera response (raw RGB image files). Here we describe the process used to characterize the spectral profiles of our cameras.

1) Silicon photodiode response

Figure 2 depicts the response of the calibrated silicon photodiode, with measurements covering a large wavelength range (left panel), and just the visible spectrum region (right panel). As seen in the right-hand panel, the diode response is nearly linear over the visible spectrum.

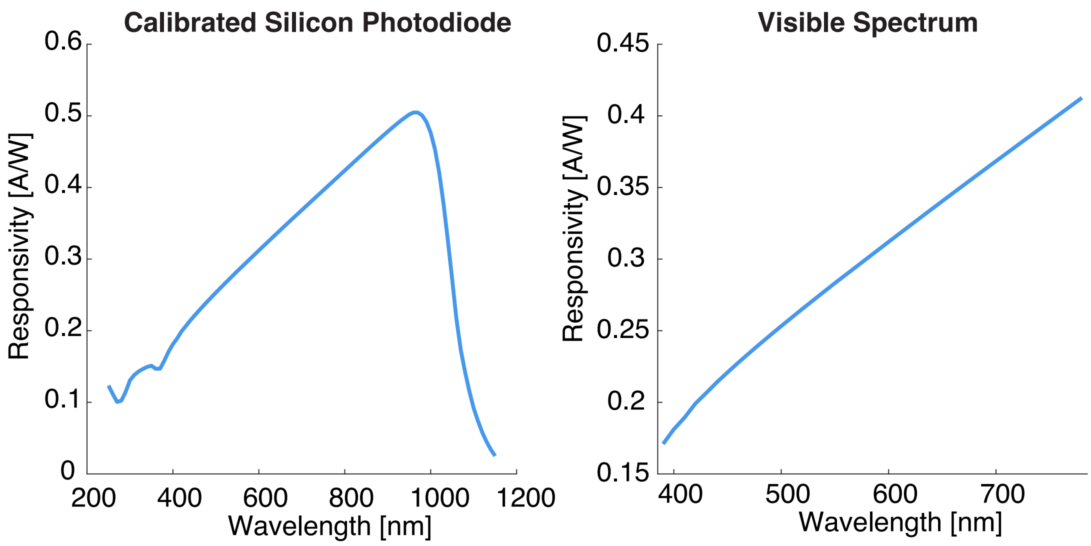

Figure 2: Response of the calibrated silicon photo-diode.

Figure 3 depicts the response of the silicon diode for the full range of our stimuli (left panel). The right panel depicts response data, normalized by the responsivity values shown in Figure 2.

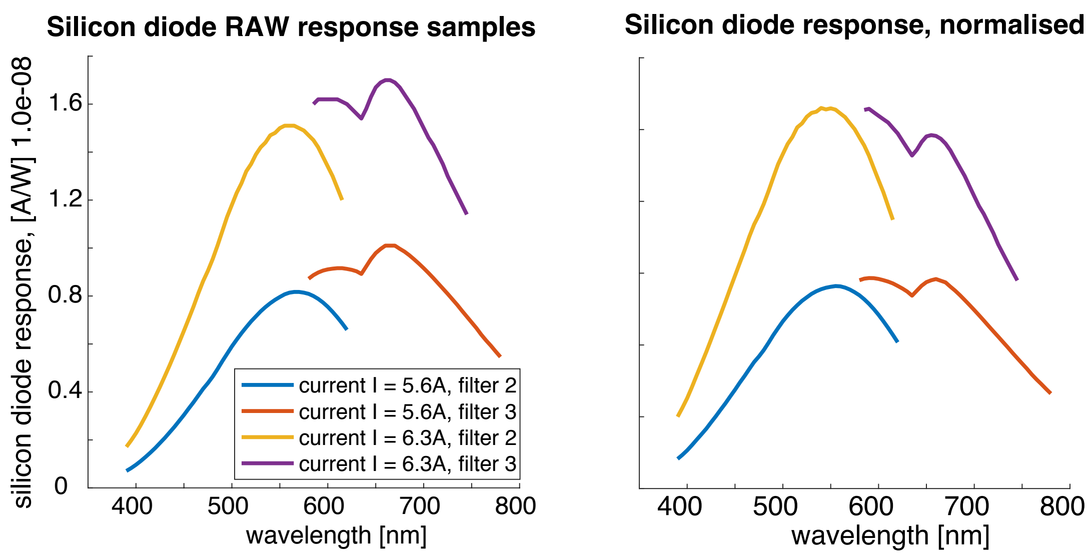

Figure 3. Left – Raw response of silicon diode, Right – diode response normalized by responsivity (see Figure 2), yielding relative radiance per stimulus.

2) Camera response and normalized spectral sensitivity

A. Spheron SpheroCam

Light source: Tungsten lamp in constant current mode, I=6.3A, U~23.5V

The Spheron generates HDR image as it rotates around its vertical axis. The azimuthal width of each Spheron scan was 1deg. Three Spheron scans were completed with each stimulus.

Spheron's parameters:

- aperture f = 2.8
- ISO = 200
- HDR 26 f-stops
- Central exposure 1/2 sec.
- White balance "cloudy sky Q4" (same as we used for SYNS dataset)
- Horizontal field of view 1 deg.

Spheron images were converted to Radiance HDR format Figure 4 shows the raw data from the Spheron SpheroCam (left panel). The right panel depicts the Spheron data after normalization. These data reflect the relative spectral sensitivity of the RGB channels of the Spheron, and can be downloaded in the accompanying text file, which includes data for the three channels (R, G & B) at 5nm steps between 390 and 745nm.

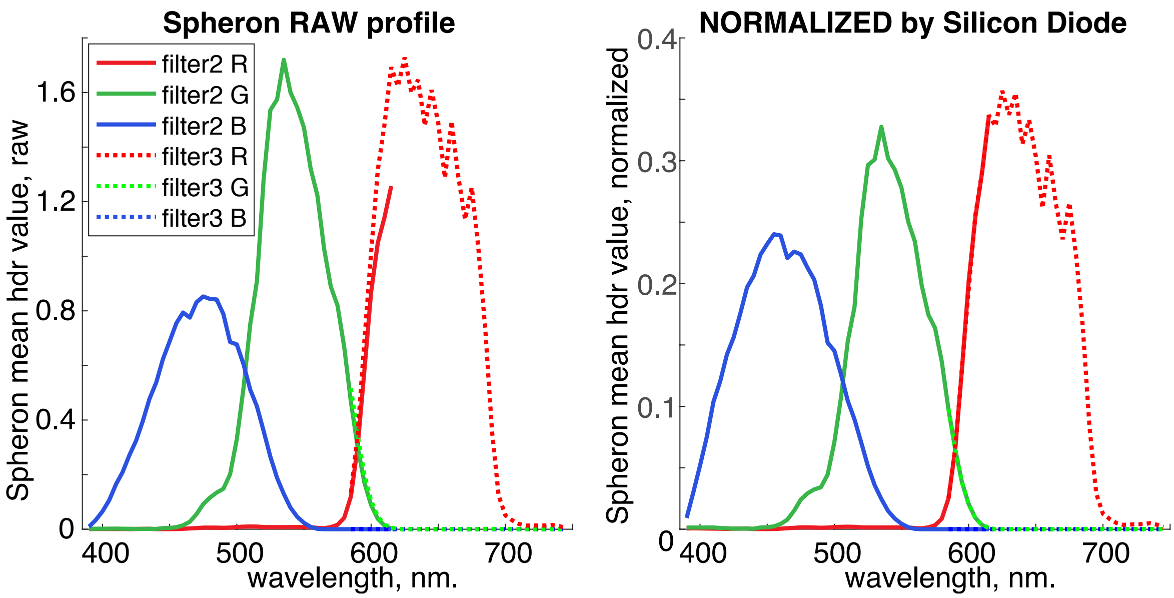

Figure 4. Left - shows Spheron's raw responses (mean value per HDR patch), Right - normalized by relative radiance of the samples (see Figure 3, Right)

B. Nikon D5200 DSLR cameras, labeled LEFT and RIGHT

Light source: Tungsten lamp in constant current mode, I=5.6A, U~X

Procedure: 10 photos per stimulus; results were averaged.

Camera lens: AF Nikkor 35mm f/2D
Camera settings:

ISO: 100
Exposure: 1/2sec,
Aperture: f2.5

Focus: 0.25 (closest possible)
Output: RAW file format

Figure 5 shows the raw data from the two Nikon DSLR cameras. Figure 6 shows the linearization curve of the cameras (Left and Right cameras had identical linearization functions). The linearization data were obtained from the EXIF data in the RAW camera output files. These data were used to normalize the output of the cameras; the final output of the process is depicted in Figure 7. These data reflect the relative spectral sensitivity of the RGB channels of the two cameras, and can be downloaded in the accompanying text file, which includes data for the three channels (R, G & B) at 5nm steps between 390 and 715nm.

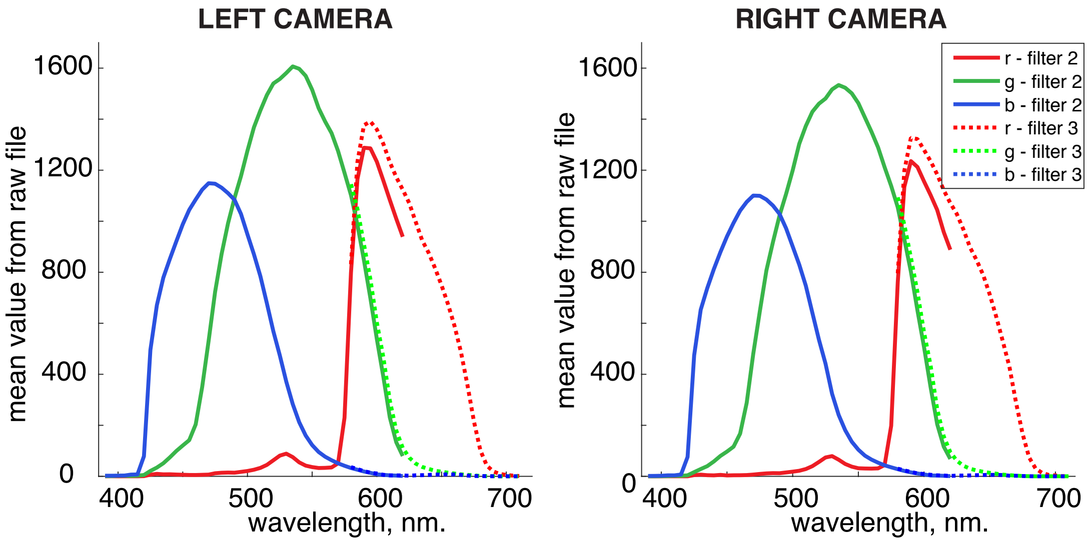

Figure 5. Raw responses from Nikon cameras.

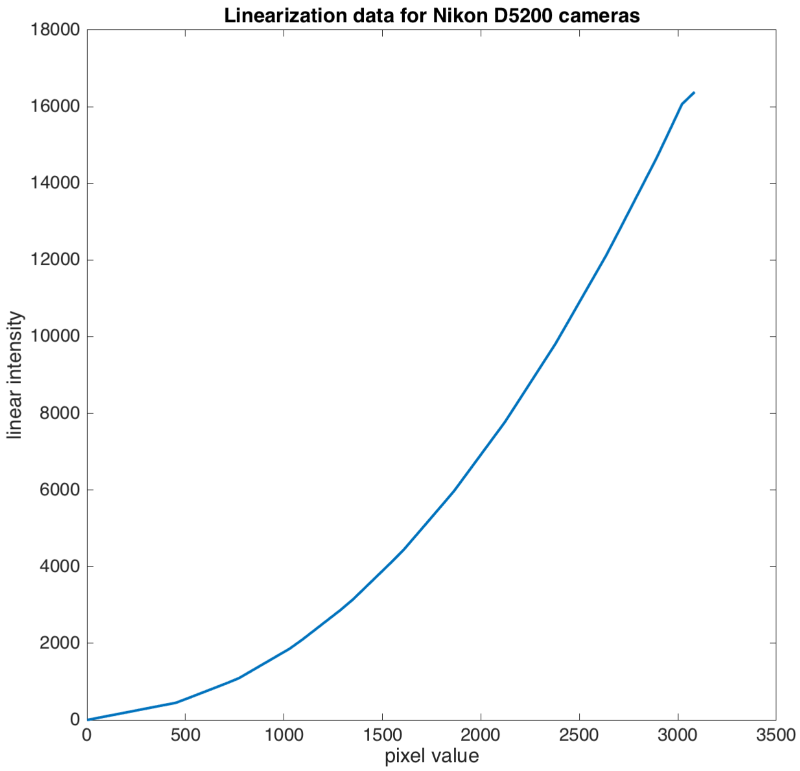

Figure 6. Linearization curve for Nikon D5200 cameras.

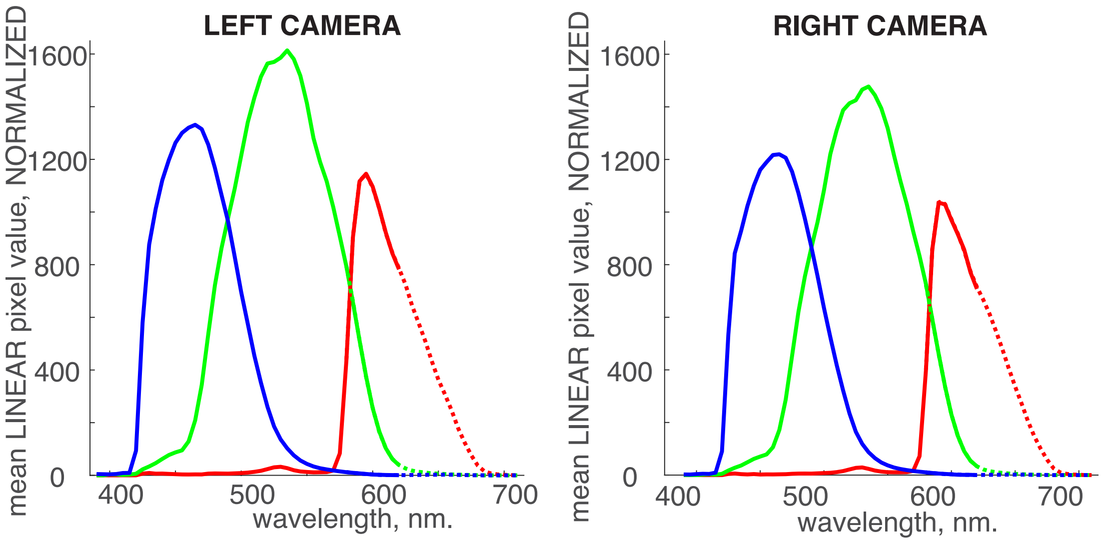

Figure 7. Responses from Nikon cameras linearized and normalized