The spectrum analysis of light emitted by LED using a CMOS RGB-based image sensor and feasibility study for its application

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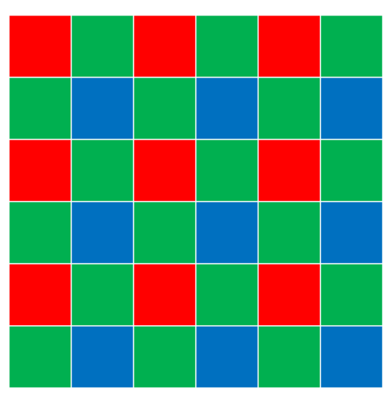
Introduction & Motivation

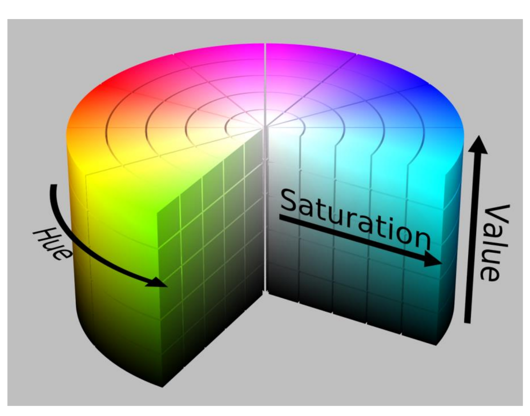
- ✓ Liquid Scintillator (LS) is used for detecting charged or neutral particles in particle physics experiments.
- ✓ Spectrophotometer is usually used for measuring emission spectrum of LS. Instead, we try to use a digital image with complementary metal oxide semiconductor (CMOS) sensor camera.
- ✓ As a prior research, we study the spectrum analysis of LED source using camera. (Canon EOS 450D)

Camera Response & Hue

- ✓ Camera could reconstruct the color using color filter.
- ✓ Each R, G, B color filter has transmittance spectrum.
- ✓ Generally, these color filter is combined with certain pattern called Bayer filter. (RG/GB)
- ✓ We assume that each Color filter intensity is on the RGB color space and convert it with HSV color space.
- ✓ HSV color space is consist with Hue(H), Saturation(S) and Value(V). And it is linear with RGB color space.
- ✓ In HSV color space H is chromatic property that could be relate with wavelength.



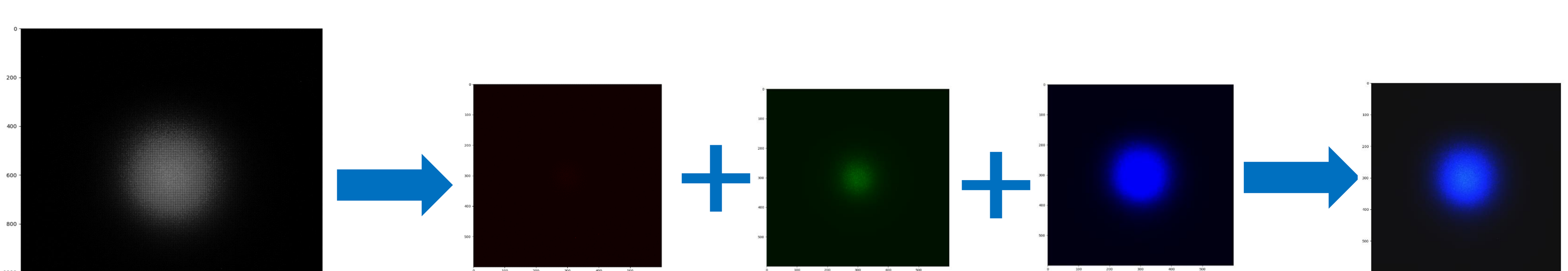
Bayer filter



HSV color space

Raw Image

- ✓ When light passes the Bayer filter, it is injected into photodiode on the CMOS sensor and saved as a voltage.
- ✓ This voltage is digitalized and saved in raw image.
- ✓ In raw image, each pixel shows one of light intensity about the R, G or B filter.
- ✓ Normally image is interpolated but in this analysis we used down sampling to mimic R, G, B to RGB color space.



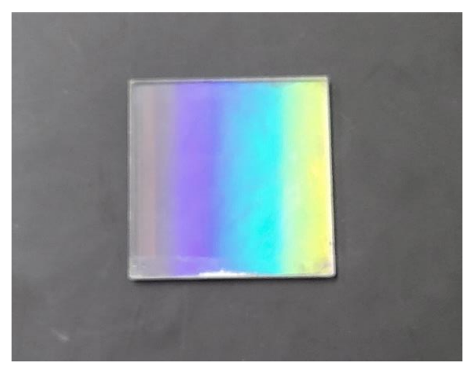
Raw image sample ($2N \times 2N \times 1$)

Raw data for each red, green, blue pixels (From Bayer filter)

After down sampling ($N \times N \times 3$)

LED Source Image

- ✓ For the light spectrum we used 2 kinds of light source.
- ✓ One is white LED that diffracted through the transmission blazed grating.
- ✓ We took the picture of 0~1st order of diffraction fringe on the screen.
- ✓ From diffraction fringe, the distance between the 0 order and 1st could convert with wavelength of each point via Bragg's law. ($2d \sin\theta = m\lambda$)



Transmission blazed grating

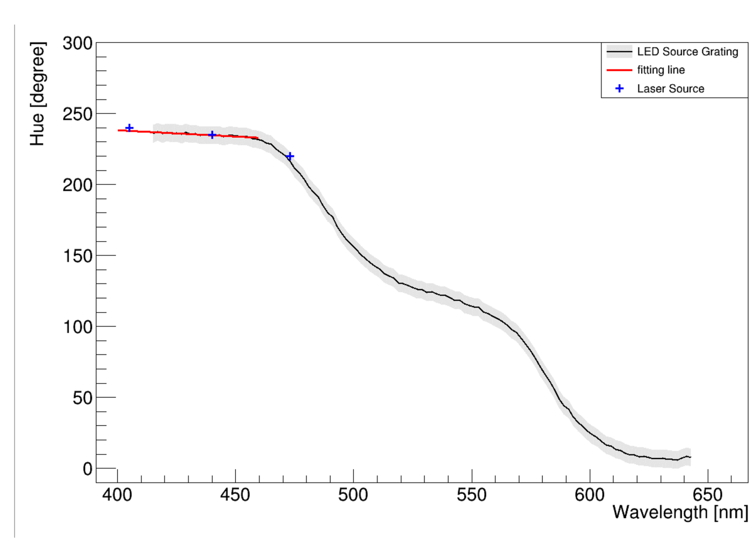
Diffraction grating image

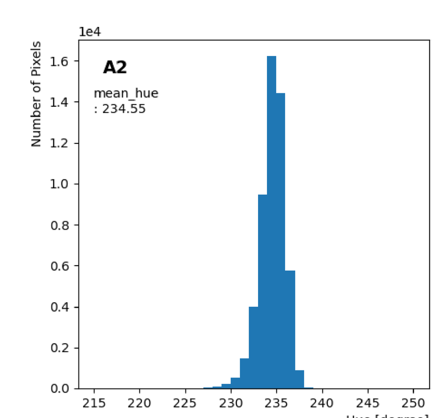
Laser Source Image

- ✓ Second light source is laser using 3 range of laser module with 405, 440 and 473 nm.
- ✓ Laser image is used to cross check the result from LED source.

Result & H-W curve

- ✓ With LED image, we produce the H-W curve range of 420~650 nm.
- ✓ Laser image shows the narrow distribution of Hue and it was close to LED H-W curve.





Example of Hue distribution (Laser)

Summary & Future Plan

- ✓ We got the H-W relation of the Canon EOS 450D camera.
- ✓ With this relation, we can reconstruct the wavelength from narrow spectral light using the digital image
- ✓ In the future, measuring emission spectrum using LS fluorescence images based on the CMOS camera can be performed instead of spectrophotometer.

Reference

- ✓ McGregor, T.J.; Spence, D.J.; Coutts, D.W. Laser-based volumetric colour-coded three-dimensional particle velocimetry. Opt. Lasers Eng. 2007, 45, 882–889.
- ✓ De Oliveira, H.J.S de Almeida,L.F. A handheld smartphone-controlled pectrophotometer based on hue to wavelength conversion for molecular absorption and emission measurements. Sens. Actuators B 2017, 238, 1084–1091.