# Feasibility study on the spectrum of light emitted by LED using a CMOS RGB-based image sensor and its application

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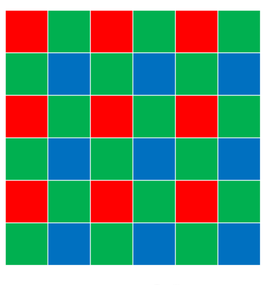
## Introduction & Motivation

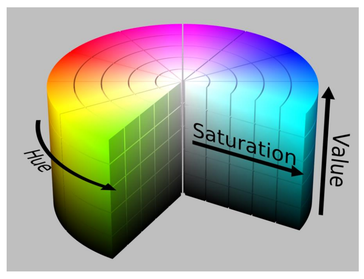
- ✓ Liquid Scintillator (LS) is used for detecting charged or neutral particles in many particle physics experiments.
- ✓ LS emits photons and it's energy is detected on photo multiplier tube (PMT) which required an appropriate wavelength according to quantum efficiency.
- ✓ Spectrophotometer is usually used for measuring emission spectrum of LS. However, we used a digital image based on complementary metal oxide semiconductor (CMOS) sensor camera.

## Camera Response & Hue

- ✓ Camera based on CMOS sensor with Bayer filter is used. (ie, Canon EOS 450D)
- ✓ Wavelength has a direct relationship with color of light in the visible range.
- ✓ We can get light intensity through the Bayer color filter with 3 types of raw red (R), green (G), blue (B).
- ✓ HSV color space consists of hue (H), saturation (S), value (V).
- ✓ RGB and HSV color space has linear relation and H is related with wavelength.



Bayer filter




HSV color space

## Experiment Setup

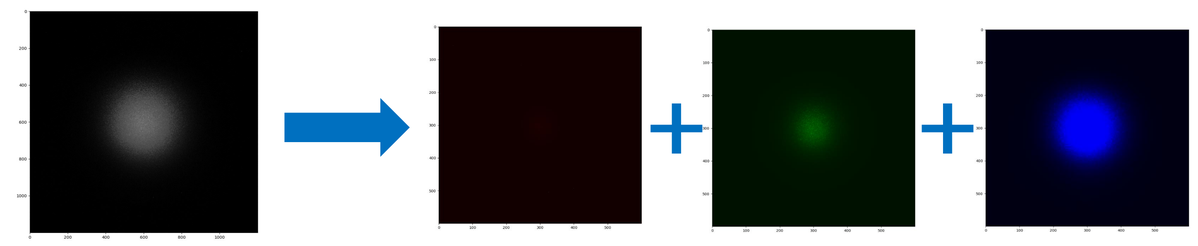
- ✓ As a light source we used laser module with 3 wavelength (405, 440 and 473 nm) ranges.
- ✓ LED source is also used for light source through the diffraction grating.
- ✓ Transmission blazed grating is used for the experiment.
- ✓ In grating image, we calculate wavelength with distance; between $0^{th}$ order diffraction fringe and $1^{st}$ order.

Experiment setup

Diffraction grating image

## Raw Image Process

- ✓ Sensor intensity can be combined with a certain patterns of Bayer filter.
- ✓ So each pixel has only 1 color information with R, G, B.
- ✓ In general interpolation named demosaicing algorithm is used.
- ✓ We assumed 4 pixels to 1 unit basis of RGB.

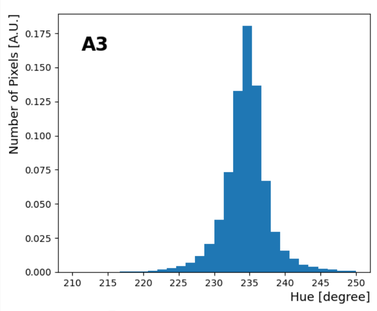


Raw image sample ($2N \times 2N \times 1$)

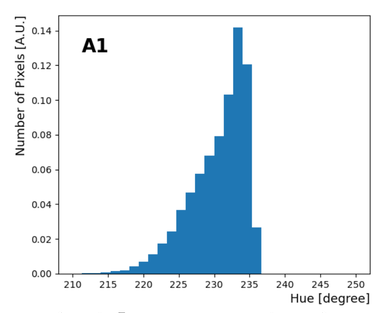
Raw data for each red, green, blue pixels ($N \times N \times 3$)

## Image Analysis Process & Result

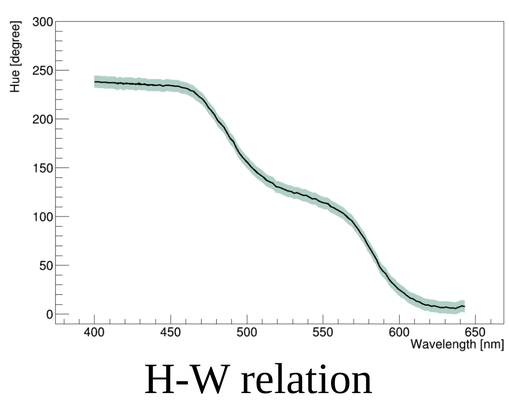
- ✓ In each 1 unit basis, we convert RGB to H.
- ✓ In laser images, each H distribution per wavelength has a certain peak.
- ✓ Because, pixel distribution has a bias in the saturated image, and so samples without it was used.
- ✓ In grating image, we apply same process and get H value and calculated wavelength for each distance.
- ✓ Finally hue and wavelength (H-W) relation can be obtained.




(without saturation)




(with saturation)




H-W relation

## Summary & Future Plan

- ✓ As a result, we get relation between H-W relation with Canon EOS 450D camera.
- ✓ In the future, measuring emission spectrum using LS fluorescence images based on CMOS camera can be performed instead of spectrophotometer.
- ✓ And get H-W relation with another color filter system based on Foveon X3 image sensing technology.

## 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.