Development and Construction of a Low-cost Colorimeter

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Abstract

The colorimetric characterization of computer-controlled CRT displays require radiometric measurements with high precision and accuracy. Most of the available color-measuring-instruments (either photometers, colorimeters and especially spectroradiometers) use expensive optical and electronic devices which make them nearly unaffordable in many applications. The aim of this paper is to present a low-cost design of a colorimeter with regard to the maximum achievable accuracy.

Introduction

There are two different kinds of color-measuring-methods. The Wideband Measurement Devices mainly use three sensors with responsivities matching as closely as possible a CIE standard observer. They directly measure CIE tristimulus values while integrating the spectral radiance distribution (SRD) of the incident light. The most common way to achieve the correct responsivity is to select a set of specially designed optical filters, which fit most perfectly in conjunction with the sensor sensitivity to the colour-matching functions (CMFs). The Spectral Measurement Devices measure the radiometric property of an optical radiation source as a function of wavelength.[1,2]

The Measurement Concept

The requirements regarding the system are:

- total costs below 650,- US$
- resolution: $\Delta\lambda = 5nm$
- error in chromaticity values: $x,y < \pm 0.005$
- error in Luminance: $Y < 5\%$

The idea in developing a new colorimeter was not only the monetary budget but also the task to use new principles for acquiring the optical information. The first rough idea to start this study was to use a PSD element. This is a photo sensitive diode, a linear element with three connectors. When a spotlight is falling on this element, one can decide on the exact locus of the spot by calculating the relation of the two voltages. Further investigations showed, that this construction would not be suitable because the integration over the CMFs could not be controlled.

The described construction takes advantage of the spectral measurement method using a prism as the dispersing element and three lenses for the entrance optics (Figure 1). The resulting spectrum is scanned by a CCD Linear-Image-Sensor with 2048 elements, so that the non-linear characteristic of the prism dispersion (Figure 2) can partly be compensated by the high resolution of the sensor. Linear wavelength steps would demand for at least 80 samples. Because of the non-linear dispersion of the prism material *Schott-F2* the number of samples have to be raised by the factor of ten in the red area of the spectrum.

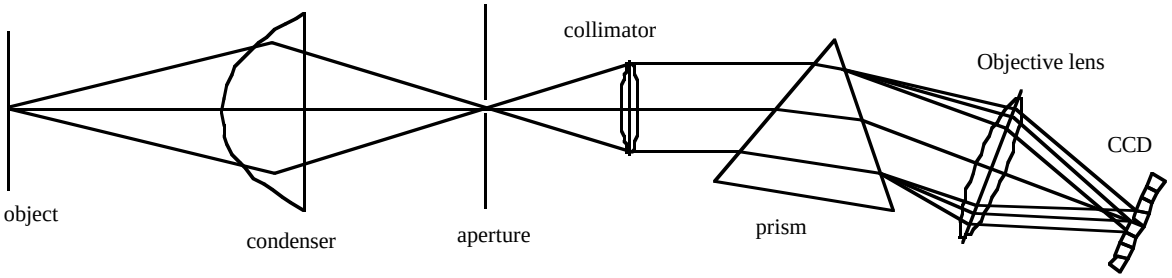

Figure 1. The optical construction

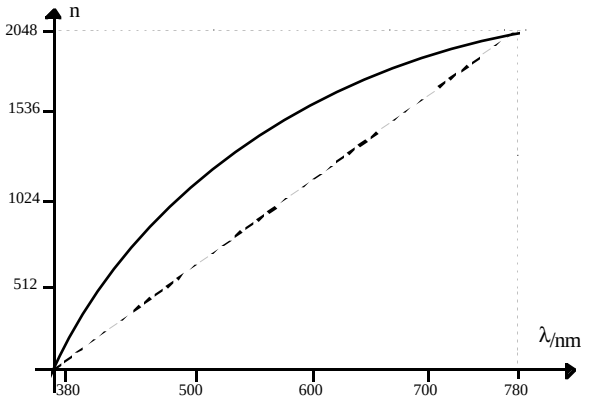

Figure 2. Distribution of wavelengths on the linear array

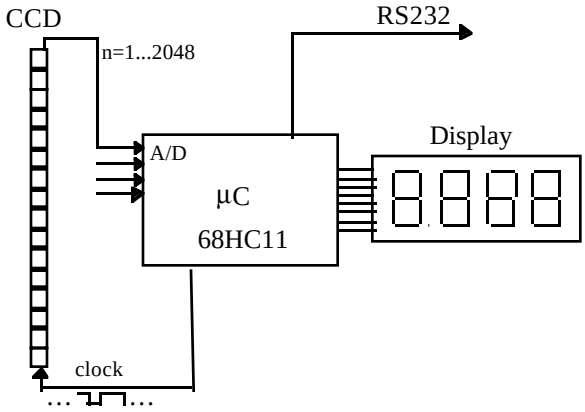

Figure 3. Data acquisition and signal processing

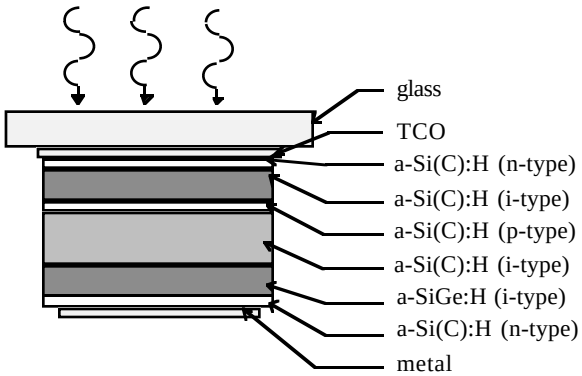

Figure 4. Schematic cross section of a nipin three color detector

Signal Processing

The output signal of the CCD attains to a microcontroller unit Motorola 68HC11. The sampling is performed from 380 to 780nm in wavelength steps of 5nm in order to minimize the data acquisition and necessary software based filtering. This is a feature of the linear-image-sensor, which supports any clustering of pixels when initialized with a certain clock-signal. The clock-signal can be provided via one serial port of the microcontroller. The sampling depth is 8 Bits and by means of a software LUT the spectral sensitivity of the sensor and the varying number of elements per wavelength step must be corrected. The calculation of the tristimulus values from the CIE color matching functions which are realized in a table can be implemented just by summing the 80 weighted packages. Any useful chromaticity coordinates can easily be derived from the tristimulus values. For this implementation CIE xyY and L*u*v* have been chosen to be calculated alternatively. On the output side the microcontroller drives a LC seven-segment-display, but for automatized measurements the coordinates can also be transmitted via RS232 interface.

Conclusion

This paper describes a current development, so by the time of the conference first results will be presented. For future projects it will be possible to use just one NIPIN three color detector. These are multilayered diodes of amorphous hydrogenated silicon (a-Si:H) which can be designed with different relative spectral responses at certain bias voltages.[3] The photosensitivity of a-Si:H is rather high compared to crystalline silicon and the fabrication process is easy to handle.

References

1. H. Widdel and D. Post, “Color in electronic displays”, Plenum Press, New York, 1992.
2. R. W. G. Hunt, “Measuring Colour”, John Wiley & Sons, New York, 1987.
3. H. Stiebig et.al., “Novel Multi Spectral Detectors based on a-Si:H Thin Film Technology” *OPTO96 2nd Congress and Exhibition for Optical Sensor Technology.*