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LED-based Solar Ring Light Simulator on a Measurescope

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Abstract: Luminance and irradiance uniform ring-light is essential for image processing and machine vision for measure scopes. A curved lens is designed for irradiance uniformity and five types of wavelengths of LEDs are used to fulfill luminance uniformity.

Summary

Many commercial ring lights, such as Mitutoyo, Nikon, and Keyence lights have not achieved luminance uniformity in the ring lights of their measure-microscope series. This project is aimed at the potential and feasibility of design rationales with cost concerns to achieve luminance and irradiance uniformity with a feed-back control feature to further optimize irradiance uniformity of the ring light prototype made at the University of Massachusetts Amherst Intelligent Sensing lab. The luminance uniformity is achieved by including five types of wavelengths LEDs. Irradiance uniformity is fulfilled by the lens that has a curvature with the relationship to the distance from the ring light to the stage. Feed-back control is essential as well since the ring light can adapt to the more various ambient lighting environments. The performance of the luminance and irradiance uniformity was tested by a light intensity measurer and light wavelength measurer (Hioki FT3424 Light Meter). The light hood (the lens) design includes the justification in material (transparency and refraction factor) and curvature(with relation to the distance from the camera to the stage) (Figures 1 and 2).

Figure 1: Printed light frame in ABS material with LEDs and plastic circuit board.

Figure 2: Manufactured lens with light frame.

In literature [1], Jing-Tao Don and his fellows tried to include various wavelengths of LEDs (RGB), however this paper with focused more on lens design and cost rationale/justification for ring-light doing better work in machine vision [1].

To fabricate the lens, the market usually uses acrylic, glass or high transparency plastics. Hereby we use polarizing polycarbonate (PC) because this material is more cost-effective than glass and acrylic. Since different focal lengths of cameras would be used for different curvatures of the lens, it is important to make the lens replaceable from the ring light. Polarizing polycarbonate is not as brittle as glass. The transparency of this material is as high as glass and acrylic.

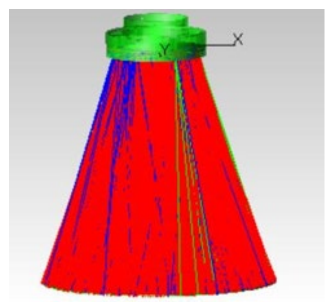

Figure 3: TracePro light simulation setup.

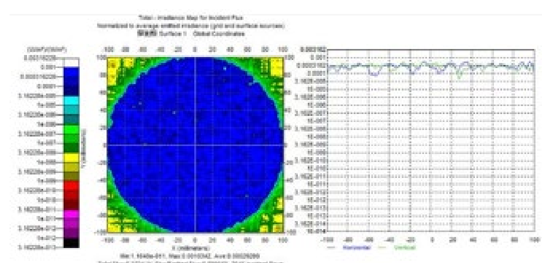

Figure 4: Simulation result for 0.4m distance with curvature.

The whole light is optimally designed by simulating the setup of multi-layer and various wavelength

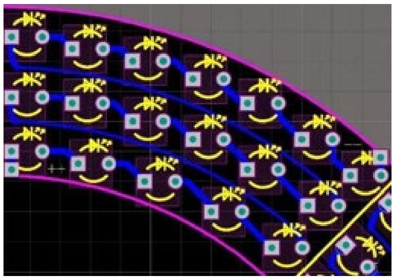

Figure 5: Altium Designer LEDs packaging.

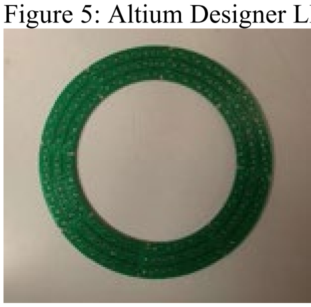

Figure 6: Manufactured plastic circuit board.

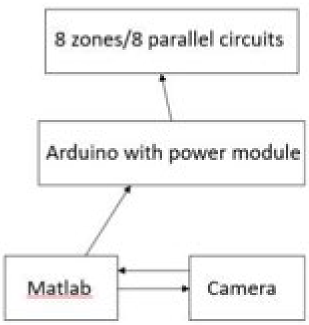

Figure 7: Feed-back control design.

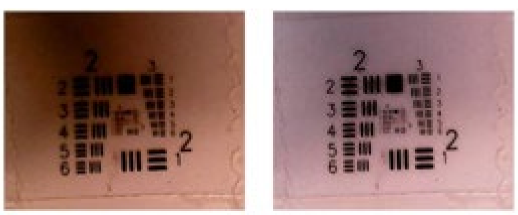

Figure 8: Hue adjustment.

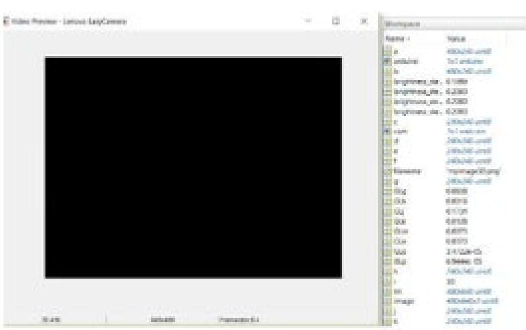

Figure 9: Grey-level calibration.

LEDs in a TracePro. The whole light design allows customers to easily change lens (for different camera magnification) (Figures 3 and 4). For cameras with higher magnifications, the cameras need to be closer to the stage, in which the ring light's lens' curvature would be higher. Hereby an ergonomic mechanism is used to replace the lens. There are total of 144 LEDs in the ring light, with eight individually controlled sections being controlled independently. The plastic circuit board is designed by Altium Designer (Figures 5 and 6). The LEDs are distributed on the board in three layers. The layer on the opposite side of the LEDs is the place for welding. In those eight sections, there are 48 white (VAOL-10GWY4) LEDs, 24 red (VAOL-10GAT4), green (VAOL-10GDE4), blue (VAOL-10GSBY4) and yellow (VAOL-10GCE4) LEDs. The inner-circle has 42 LEDs, which are all white. All the LEDs are 5mm and the power consumption at a normal ambient environment is about 20.2W (all 144 LEDs). A feed-back control (MATLAB PID) can be implemented in that the ring light would adapt to a more variable ambient environment. Eight individual sections of LEDs would be supplied with different voltage values to achieve even better light intensity uniformity. At the prototyping stage, we use Arduino PWM ports and voltage amplifier circuits (Op-Amps) to fulfill the electricity supply. Since this ring light is intended for better machine vision purposes, basic image processing algorithms were implemented for the camera (grey-level calibration, hue adjustment) (Figures 7, 8 and 9). Simulations have been performed before fabricated and the optimization process has been implemented (comparing real performance results against simulation results). The performances can achieve the same level of CA-DR Series made by Keyence Corporation. This prototype will be used to renovate a 1979 Nikon measure scope.

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References

1. Dong, J.-T. (2011). Optical design of color light-emitting diode ring light for machine vision inspection. Optical Engineering, 50(4), 043001. doi: 10.1117/1.3567053