Hands on techniques for optical system development

A well respected machine vision company wanted to upgrade the illumination system it uses with its high productivity bar code readers. The goal of this system was to create a band-like light beam that illuminates items marked with bar codes. Each system is comprised of 6 lighting modules.

In this project the main task was to develop an optical system for a single module that allowed a new more efficient and lower cost CREE LED be used in replacement of the previously used Lumiled LED. However, since the new CREE based module would be used in the field as a replacement for modules that already contained the older LEDs, the requirement was the match the performance of the older module so it would be seamless to the end user and completely interchangeable.

Given these requirements, limitations in design freedom and the desire to if possible continue using the same or similar lenses for both modules, the approach we took was a 'hands on' one.

To study and model both Cree and Lumiled modules, we assembled an optical board according to the optical layouts provided by the customer. The LED board was fixed while Fresnel lens array and cylindrical lens could move along optical axis. Power density and line width were measured with the help of NOVA optical power meter fixed on a 2-coordinate metric stage. To measure distances, we used calipers, clock type indicators, and nonius (vernier) rulers. Spot width was measured by shifting sensors of optical power meter with an attached stop 2mm in diameters.

Spot width was measured as the distance between points where the light power was 0.1 of P maximum ($D_{0.1}$). After measuring spot width, optical power meter sensor was put in the position where power density was maximum and the small round stop was replaced with the one having square aperture with area of 1 cm^2. Then longitudinal positions of both Fresnel lenses were changed so that power density would reach maximum. After this step the line width was checked again. These iterations were repeated for a number of times so we could reach required power density at required distance. During iterations we controlled decentering and co-planarity of LED board and Fresnel lenses with the help of additional low power helium-neon laser.

Our experiments established that the quality of focusing depends on how accurately the lens array is positioned relative to LED. Based on measurement of LED on-board positions, we determine that this tolerance should be 0.008 mm. The distance between LED and lens array is affected by thickness of thermo conductive compound between the LED bottom side and base board that it is soldered to. We recommended that heat path electrode should be soldered to PCB with the help of conventional solder.

This will improve thermal resistance and reduce LED positioning tolerance along optical axis. Another factor is the tolerance on LED height indicated in the data sheet (4.3+-0.2mm). From the optical viewpoint, this tolerance is rather wide and brings some uncertainty to the remaining optics in the system.

Another factor to consider was the installation of lens array plastic sheet. Assuming that lens array holder has proper height, the error of lens array positioning will depend on quality of pressing the plastic sheet against the holder and skew of the plastic sheet due to heat. We suggested that it would be helpful to use a thin flexible interlayer between the pressing bar and plastic sheet.

This will help to disseminate force across the plastic sheet. In the original construction, the cavity between the plastic sheet and base board is closed. As temperature rises, the air inside does not leave the enclosure and can deform plastic. This risk factor can be reduced if vent holes in the lens holder are used. The holes will allow free air convection inside the cavity.

We also found that not all geometrical data given in LED data sheet was true. In fact, actual distance from LED die to its focusing lens does not match what is indicated on the sheet. This parameter was key for accurate calculation of focus optics for Cree device.