Three Case Studies

Example 1: Design and Control of Optical Media System

We spent a year and had 2 ½ people working to control the chip sets used in off the shelf CD and DVD drives. Additional generations of the chips sets took less time (2-3 months)

Using a multi channel oscilloscope the data we are able to see and control includes:
Input signals: laser, track and focus servo photo diode, data optical signal, tilt detector, spherical aberration corrector signals. We can track command signals of front end processor which control the devices listed above.

Additional signals that we are able to control are signals that control disk rotation, optical head radial movement, track-to-track jump of objective, sequence of control signal generated by front end processor at optical read errors (track lost, dust, scratch, etc.)

Output signals from the processor: laser status, error status, data signal (eye pattern when analogue), control signals for system components, laser on off, disc present, decoded signal about whether disc is CD or DVD, motor rotation signal ie speed of spinning, ROM vs WORM disc for signal for changing laser power, and head position signal

Based on complex analysis of these signals, we can back engineer algorithms of entire device operation. These are algorithms of media type analysis (CD, DVD, DVD-R, etc.), algorithms of device tuning for specific data medium used at a certain moment, algorithms of primary data processing and digitalization, algorithms of processing read errors and algorithms of drive turn off.

In other words, this is a full system of drive and media interaction. This data was used so that we can manually control entire device with the help of algorithms that we need. For example, parameters of most feedback systems are located in firmware memory in the form of tables.

Numerical values of these table are specific to the type of media. So developing such tables and inserting our values, we can adjust the drive (front-end processor) for non-standard (custom) media. This was the main goal of this activity.

Using non-standard media suggests modification of optical head layout too. We can modify, replace, and custom design most elements of a standard optical head. The only element we cannot modify is read objective suspension (electromagnetic actuator) but we still can replace objective in actuator.

We can design a custom read objectives including single-element plastic aspheric ones.. Also we have lots of experience in assembly, adjustment, fine tuning, quality control of different optical pick-up heads (from CD to recent models of DVD heads).

It is usual that drive-media system design includes feedback from drive to medium. Our activity included development of custom measurement equipment to measure such medium parameters as modulation ability, reflectivity, absorption, robustness to dirt, quality of write elements (pits) which affect output signal jitter, S/N ratio in servos and data optical paths. Based on these measurements, we recommended how to optimize media manufacturing.

Example 2: 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.

Example 2: Non sequential modeling

A small firm providing lighting system to the automotive repair market was building a new system based on LEDs. The firm has mechanical and industrial design expertise but needed design assistance to model the uniform illumination pattern they hoped to achieve. During this project we worked exclusively with software design tools. The customer delivered their mechanical designs and the constraints on the reflector and we built a Zemax model using the non sequential tools in that program. The model we built was later outputted as an IGES file and prototyped.

Using their requirements we provided, design ray tracing and tolerancing for an elliptical reflector, and made determinations on:

- Shape of reflector,
- Optimized surface texture of reflector,
- Tolerance regions of LED position relative to reflector,
- Recommended mechanic dimensions of reflector optical (reflective)surface
- A calculation of light distribution to verify final results

The actual deliverables were: AutoCad drawings to show the mechanical features, image files based on Zemax output to show the expected illumination pattern, MathCAD files to give a mathematical representation and an IGES file for use by the customers rapid prototyping vendor

We also provided design suggestions and gave design trade offs. For example we found reflector height was critical for this construction (17mm). This height allowed to capture entire main wing of directional diagram. However, it was possible to reduce this height to 14mm if acceptable losses of total LED light power are 12% versus the current calculated yield of 92%.