OSIRIS

Original Systems for Image Rendition via Innovative Screens

Funded by the European IST Program (FP6)
http://www.osiris-project.eu/

Novel light sources for projection

White Paper

OSRAM
Opto Semiconductors

Stefan Groetsch, Roland Schulz
OSRAM Opto Semiconductors GmbH
Leibnizstraße 4,
93055 Regensburg, Germany

September 2009

Table of

Contents

Introduction

High luminance projectors use discharge lamps as light sources. Solid state light sources like LEDs or lasers are up to now only used in pocket or pico projectors. Due to their longer lifetime solid state light sources are a significant benefit to projectors. The reliability of the projectors is increased and the costs can be reduced, because no lamp replacements are necessary. Furthermore solid state light sources will lead to a widely increased color gamut. LEDs have a very high purity and lasers are even on the rim of the color space.
Within the EU-funded project OSIRIS (Original System for Image Rendition via Innovative Screens) OSRAM OS is developing laser and LED based light sources for high luminance projectors.

Laser light sources

The lasers developed within OSIRIS will be used for a 300lm front projector. The projector will use LCoS images. LCoS imagers require polarized light and therefore lasers are the best suitable light sources for these type of imagers. The optical engine has a efficiency of approximately 25% per colour. OSRAM OS will provide red and green lasers. With a wavelength of 640nm for the red laser and 532nm for the green laser respectively 2.4W and 1.2W of laser power are required for a D65 color balance.
For blue about 1 Watt is required depending on the wavelengths of the lasers. Best suitable for this application are GaN laser diodes at 445nm. Another possibility is a frequency doubled solid state lasers as well as a combination of these different laser technologies.

Red Laser

The red laser consists of an InGaAlP laser diode array. The laser diode array is soldered on a innovative expansion matched heat spreader in a compact, small footprint copper package for high heat dissipation. The module design and assembly process is tailored to enable low cost high volume manufacturing. To facilitate an ease assembly in the module a fast-axis collimation lens close to the laser facet is included in order to achieve a low divergent beam in the fast axis. The slow axis is not influenced by this lens. With this optical element a beam divergence (full angle, $1/e^2$) of $\Theta_{fast} \leq 1°$ and $\Theta_{slow} \approx 10° - 20°$ is achieved.
Figure 1 shows the typical optical output power of the red laser array as well as a picture of the compact package. Seven emitters are included in this package.

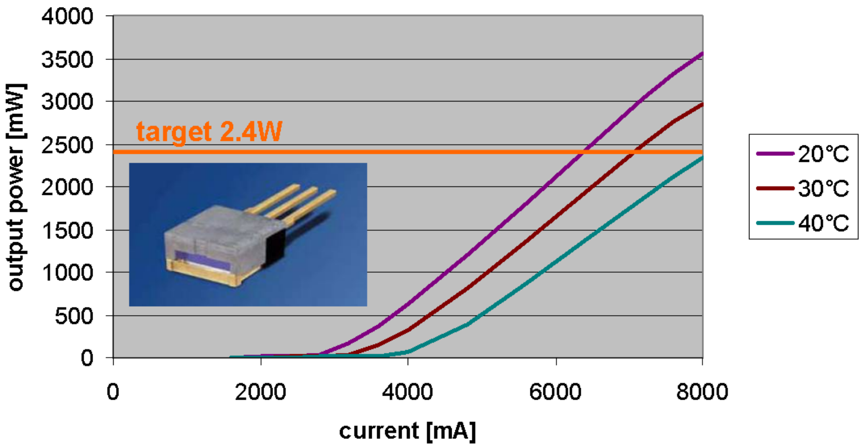
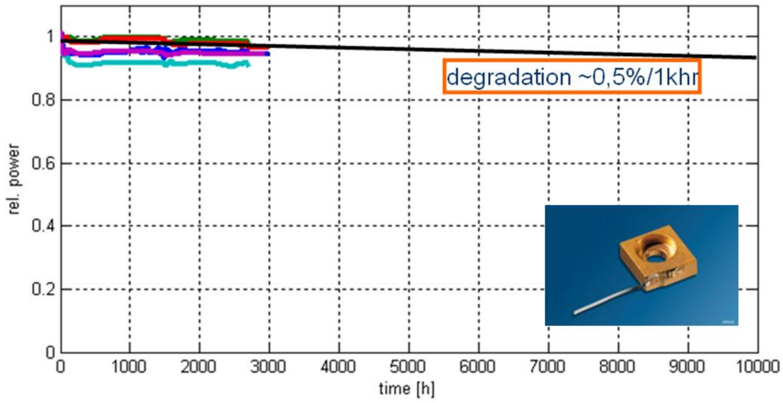


Figure 1: PI-curve of multi emitter array at 640nm; layout of laser package, size 10x10x5 mm^3

The required output power can be reached over a wide temperature range up to 40°C. This reduces the effort for cooling the device.

Besides performance lifetime is an important attribute of the light sources to show that they are capable to replace the lamp. Figure 2 shows the data of a life time experiment of a red single emitter.



[2]

Figure 2: life time experiment of a red single emitter laser on C-mount package; I_{op}=900mA, P_{op}=300mW

After 3000h one can hardly reckon a degradation of the device. We extrapolate a degradation of about 5% in 10.000h. This best in class life time is much larger than that of discharge lamps which are in the order of a few thousand hours.

Green Laser

For the green laser an array of diode pumped frequency doubled solid state lasers is used. The laser crystal is a highly efficient compound crystal consisting of a Nd:YVO_4 as active medium and a KTP crystal for frequency doubling pumped by one of our high power GaAs laser diodes. We think this approach is best for the application to get high output powers with a small form factor.
Figure 3 shows the typical optical output power of the green laser array as well as a picture of the compact package. Five emitters are included in this package.

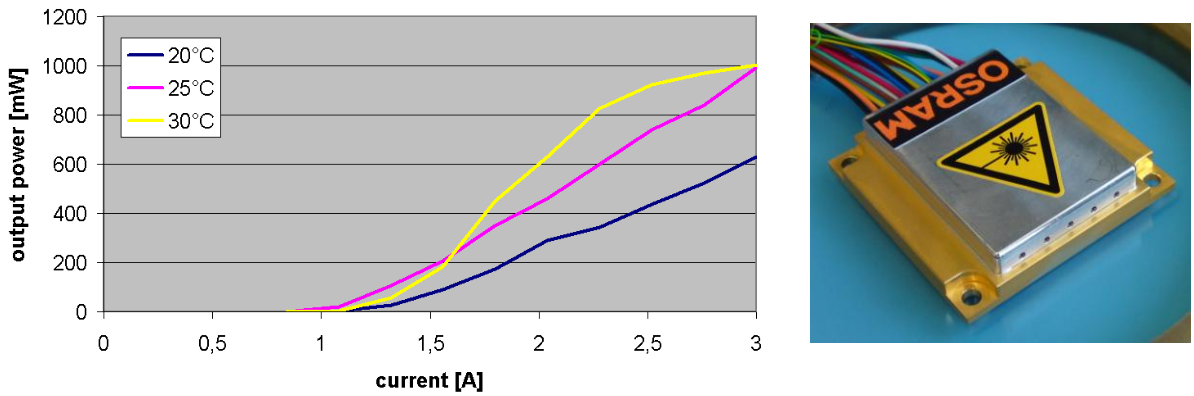


Figure 3: PI-curve of multi emitter array at 532nm in pulsed mode; layout of laser package, size 45x45x10 mm^3

The temperature dependency of the output power is connected to the wavelength shift of the laser diode of about $\Delta\lambda \approx 0.3$nm/K. If the wavelength of the laser diode does not match the absorption wavelength of the Nd:YVO_4 the output power is reduced.
An important feature of light sources for display applications is the stability of the light sources. With red lasers this is no issue since they are direct emitting diodes. With green lasers this might be a problem because they are frequency doubled lasers. Here the well

known green problem can lead to unwanted instabilities. Figure 4 shows the output power of a green laser over several hours operation. The laser was stabilised at more than 1.5W with fluctuations with a standard deviation of 1.5%. The target output power was well exceeded.

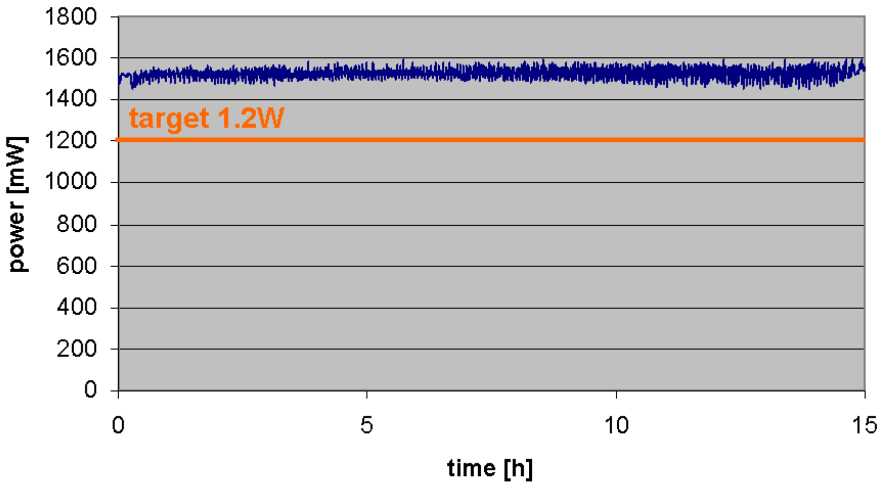


Figure 4: stability of a green laser array in pulsed mode

LED light sources

With the demand from the OSIRIS project for high brightness sources for slim RPTVs with 500 lm on screen or multi projection views, OSRAM Opto Semiconductors developed a new set of high current capable LED chips and packages. The slim projection TV based on 0.65" DLP lead to a peak white flux requirement of roughly 7000 to 8000 lm from three discrete LED sources. The size of the micro display implicates a light emitting area of about 4.8 mm x 2.6 mm per colour. More chip area will not contribute to the usable flux in the system. This is valid for surface emitting diodes with lambertian radiation characteristics like OSRAM OS is producing since some years.

High Current LED Chips

The whole 4.8 mm x 2.6 mm emitting area is split into 6 individual dies, which are operating simultaneously. The design of each single chip is optimized for high luminance by keeping the current entry area separated from the light emitting area. The epitaxial layout and the electrical contact layout of the chip allows running high current densities of $3A/mm^2$ compared to around $0.35A/mm^2$ related to standard current densities in the LED industry. Also the chip substrate behaviour was optimized to allow better heat extraction from the junction area.

Figure 5 and Figure 6 show the outstanding achievements of the development. Figure 5 is the optical flux over driving current (short pulses measurement) and figure 6 a test picture of the luminous pattern at 3A driving current. 500 lm optical output at $3A/mm^2$ with an uniformity better than 80% could be reached for a green emitting diode. Both values, optical output and uniformity over the emitting surface, are crucial factors to enable a high brightness in the projection systems.

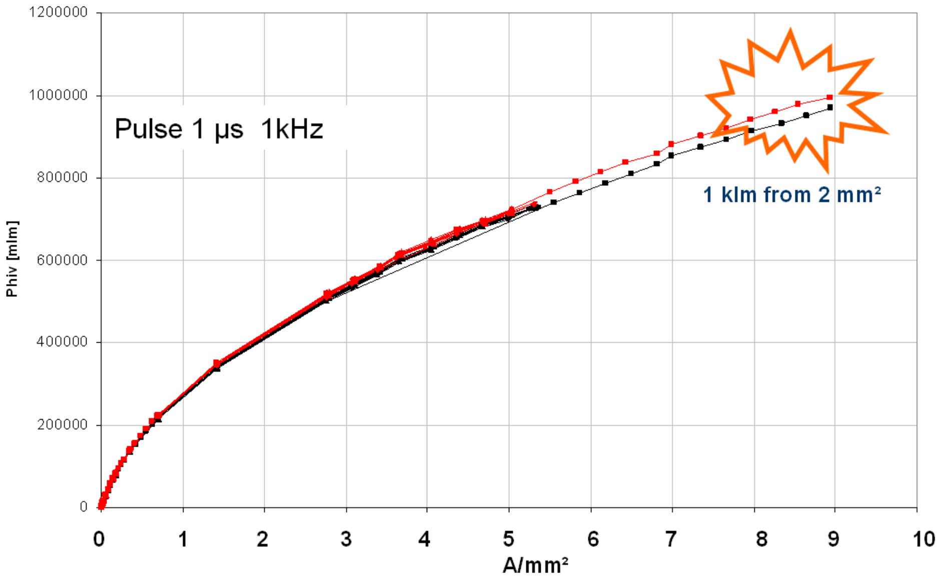


Figure 5: Short pulse measurement of a green emitting 2 mm² die

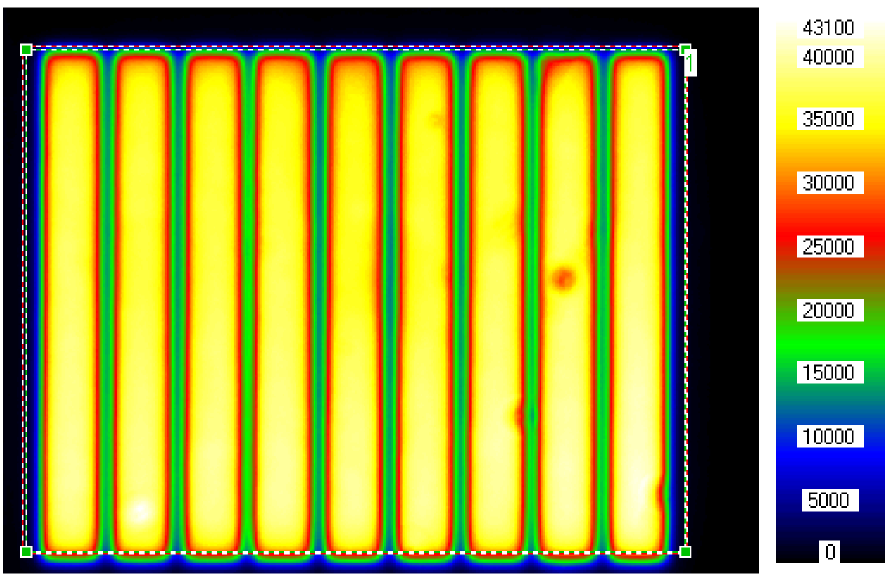


Figure 6: High luminance uniformity over the emitting surface of the die also at 3A driving current

High power package

A novel package approach as shown in Figure 7 brings six of these high power led chips on one copper heat sink substrate. The direct solder attach reduces the thermal resistance of this LED device to only 0.5 K/W and allows a peak power load densities of 15 W/mm² in pulse mode or 10 W/mm² in average. The almost gapless configuration minimizes the uniformity irregularities between the individual LED chips. An antireflection coated window is protecting the dies and the assembly. The demonstrated values from figure 8 show a total white peak flux of 8000 lm to 9000 lm. Assuming an efficiency of 20% for the whole projection system a white flux of more than 1500 lm on screen can be expected. First lifetime verifications in Figure show also stable operation at those high driving conditions.

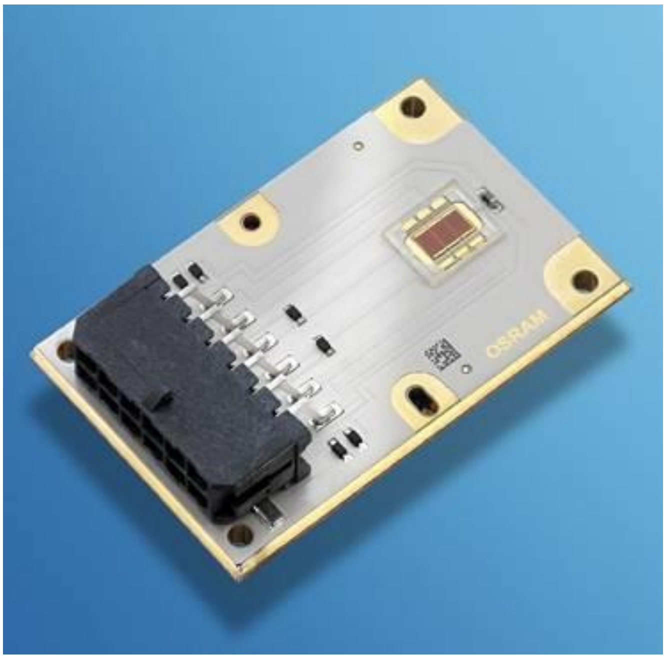


Figure 7: High Power OSTAR: LED configuration with 6 high current dies directly soldered to the core of the copper heatsink .

Colors	Red, Green, Blue
Pulse Current	36 A
Best Brightness: Red True-Green Blue	 3800 lm 3800 lm >22 W

Figure 8: Brightness values demonstrated within the OSIRIS project

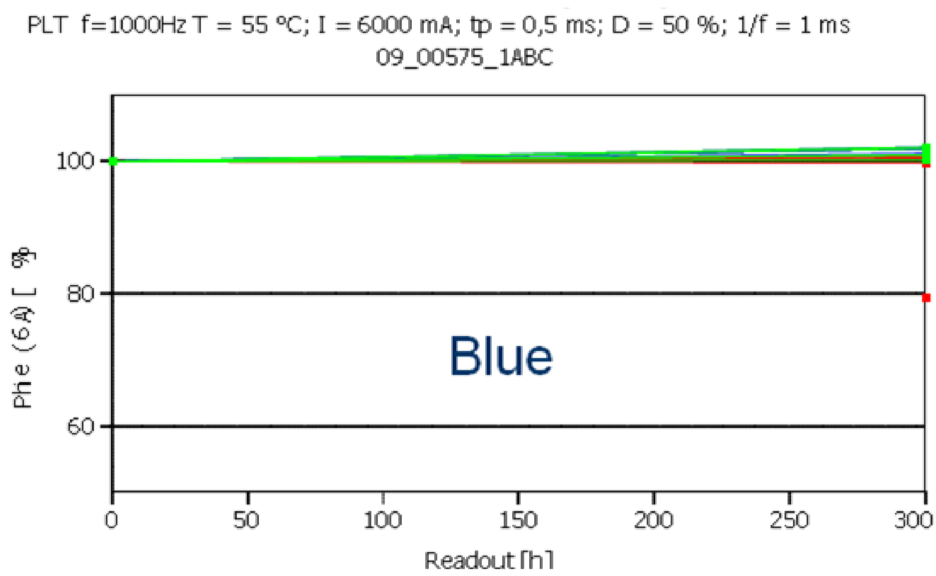


Figure 9: Life test results of a blue high power OSTAR operating at 6 A/Chip or 36 A total

Summary

Within the OSIRIS project OSRAM succeeded to demonstrate best in class laser as well as LED light sources for high luminance projection systems. OSRAM’s proven track of records for innovative package solution as well latest emitter chip developments allowed to exceed the required brightness levels and life time requirements. Projectors in the kilolumen range are now feasible with this outstanding progress.