Using OSRAM OS PLPM4 450 Multi-Die Package (MDP)

Application Note

1. Introduction

This application note provides a guideline for proper use of Osram Opto Semiconductors multi-die package (PLPM4 450) containing blue multi-mode InGaN laser diodes.

The PLPM4 450 is designed for applications which require high blue laser power in combination with remote phosphor, e.g. high brightness projection.

Features of the product:

- Butterfly package with typical 50 W optical output power in continuous wave operation (cw) at T_{case} = 65 °C. (Please note that case temperature is not equivalent to any heatsink temperature; details in chapter 6)
- 18 - 20 multimode laser chips in one package
- One package contains 4 copper bars (channels). Per channel up to 5 multimode laser chips are bonded in series connection
- Wavelength 450 nm ±10 nm at T_{case} = 65 °C and 50 W optical output power (cw-operation)
- Typ. wall plug efficiency of 31% at T_{case} = 65 °C
- ESD protection diode for each laser chip

For more detailed information and the latest product update please visit www.osram-os.com or contact your local sales office to get technical assistance during design-in phase.

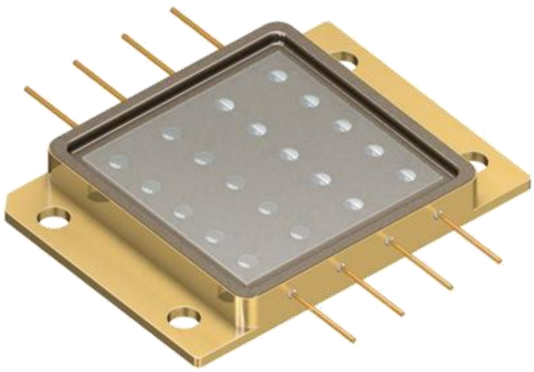

Figure 1: Product picture of multi-die package (MDP) PLPM4 450

2. Safety Instructions

Depending on the mode of operation, the MDP emits highly concentrated visible light which can be hazardous to the human eye. Products which incorporate these devices have to follow the safety precautions found in IEC 60825-1 “Safety of laser products”.

Testing and maintenance of these products shall be performed only by personnel trained in laser safety. For details please refer to relevant local safety regulations and to the manufacturer’s requirements according to IEC 60825-1.

The laser class is determined by the driving conditions and optical design, such as focusing lenses and needs to be determined by the manufacturer of the final product.

3. Storage and Shipping

Storage and shipping of MDP should be done in a clean and dry atmosphere in a temperature range of -20 °C up to 85 °C

4. Unpacking and Handling

The multi-die packages are shipped in a conductive plastic shipping container that is packed in a sealed conductive plastic bag.

Before opening the plastic bag, diode lasers should be kept at least 4 hours in the room where the bag will be opened to achieve thermal equilibrium. The protective bag may be opened only in a clean environment and non-humid atmosphere.

Solvents, non-conductive plastics and glues are not allowed near the diode lasers as solvents could emerge and deposit onto the window. Especially, the blue multi mode power laser light can bake the contamination on the window, reducing the transparency of window.

Dust on the window can be removed by clean oil-free compressed air. Mechanical stress to the window should be avoided to prevent the breaking of the hermetic seal.

Please also avoid scratches at the bottom surface of the MDP. They can increase the thermal resistance of the device in case of mounting to heatsink and therefore might result in reduced optical output power, wall-plug efficiency and long term stability.

The devices are shipped in conductive plastic trays which are stacked by 2 layers with 12 pieces each. (see figure 2 and 3).

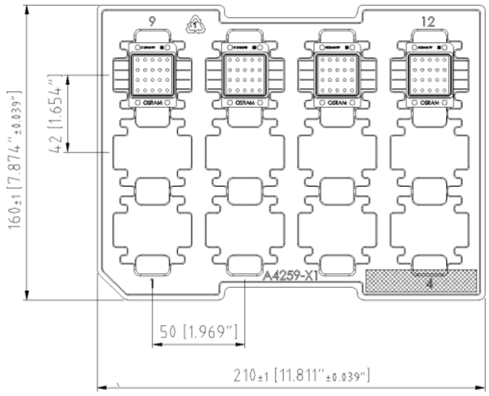

Figure 2: Tray outline in 4x3 matrix

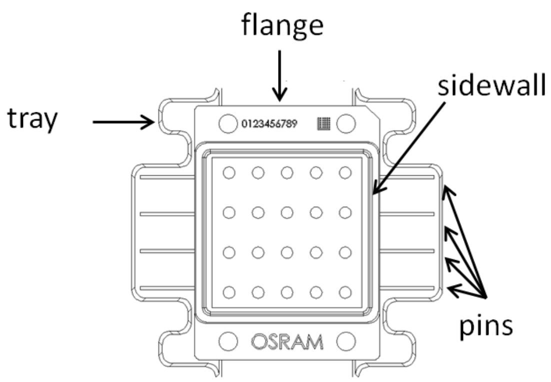

Figure 3: Single package in tray.

For handling of the device it is strongly recommended to use sidewalls or flange of MDP as schematically shown in figure 4. Mechanical stress on pins or bending of pins can lead to damage of hermetic sealing and has a negative effect on long term stability.

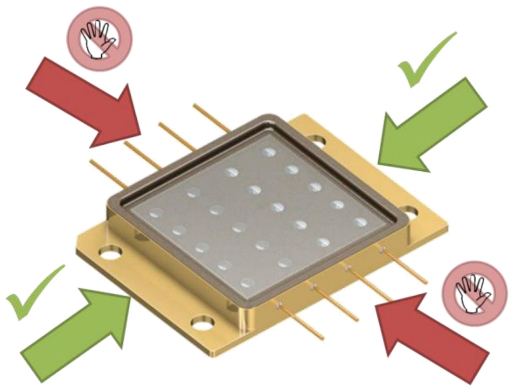

Figure 4: Schematic handling instruction for multi-die package.

ESD Handling

InGaN diode lasers are electrostatic sensitive devices. Thus, their handling requires strict precautions against electrostatic charges. Every person and each tool that might get into contact with the diode laser must be continuously ESD protected. Therefore, the devices should only be handled in ESD protected areas (EN 100 015 former CECC 000 15).

The MDP has ESD protection diodes inside the package and is protected to voltages of up to 2 kV (HBM model). For polarity please refer to the datasheet.

Basics for protection against statics

Grounding

Grounding systems shall be used to ensure that devices, personnel and any other conductors are at the same electrical potential.

Protection

To avoid exposure to static charges, keep components and modules separated during storage and transit. By protecting against exposure to statically charged objects and electric fields, potential damage to laser components is minimized. As statically charged insulators cannot be discharged by grounding. It is advisable to eliminate non-conductive plastic material and other type of insulator from the working place, transit and storage areas.

Neutralization

Neutralization is the process to discharge insulators. This happens naturally through the process of ionization. Ions are charged particles that are always present in the atmosphere in form of atoms, molecules or groups of molecules like water drops. The use of an ionizer generates billions of ions into the air and enables the static charge on insulator to leak away.

Prevention

Prevention can be the most effective and important personal contribution to eliminate damage caused by ESD. Please find below

a set of guidelines:

- Always keep work areas clean and tidy. Remove unwanted objects, especially those made of non-conductive plastic materials.
- When transferring components from one person to another, both should be grounded or at the same voltage potential.
- Avoid that the laser components or modules come into contact with any insulating material.
- Never enter a static-proof work area without taking the appropriate precautions.
- Always be aware of these rules when working with devices that can be damaged by electrostatic discharges.

For further information on ESD handling we refer to the application note „ESD Protection while Handling LEDs“, which is also valid for InGaN laser diodes http://catalog.osram-os.com/catalogue/catalogue.do;jsessionid=4E1480F2ABAF39F230EF1A39DD7FA210?act=downloadFile&favOid=020000000023697000200b6

5. Mounting

Mounting of MDP should be done at base plate of package as shown in figure 3 using 4 screws (M2.5). The screws should be fixed cross-wise with a defined torque of 38 cN each. During mounting, the package should not be exposed to mechanical stress. Any deformation of the MDP has to be prevented. To maintain the hermetic sealing of the package, no stress must be applied at the pins. The global coordinate origin is at the center on baseplate of the package.

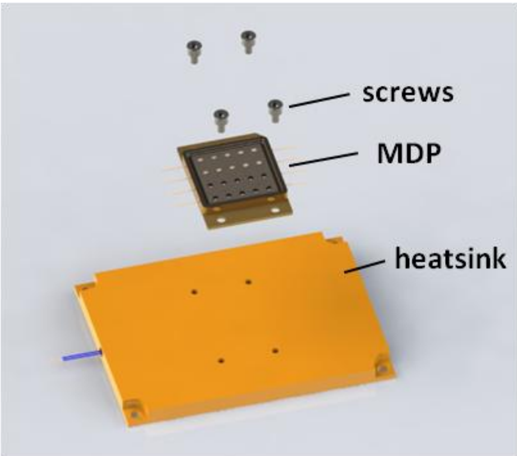

Figure 5: Schematic drawing of MDP mounting- process on heatsink under usage of 4 screws.

The heatsink should provide appropriate thermal properties, e.g. for passive cooling heatsink with heatpipes or for lab set-up Cu heatsink + Peltier-element + watercooling are suggested. The heatsink should be able to keep the case temperature below defined maximum value. Furthermore the heatsink has to provide planar surface, any warpage or roughness can affect the thermal connection and therefore decrease the optical output power, wall-plug efficiency or influence the long-term stability of the device.

For cw-operation of MDP, sufficient thermal connection of package to heatsink must be ensured. One possibility to improve the interface is the usage of a thin film of thermally conductive paste.

The thermally conductive paste must not contain silicon and must not show any outgasing even in long term-operation.

6. Thermal Management

To obtain the best performance of the multi-die package (MDP) in cw-operation in combination with long lifetime, an appropriate cooling and mounting is required. The mounting is described in chapter 5.
For the discussion of thermal properties of MDP, active cooling is considered separately from passive cooling.

- Active cooling is understood in a way that the temperature of the heatsink is kept constant during operation. This can be realized for example by using water-cooling or water-cooling in combination with Peltier-elements.

- Passive cooling is for example realized by the usage of appropriate designed heatsinks (e.g. heatsink with heat-pipes + fan). In this case the MDP temperature depends on the operation condition and the ambient temperature.

6.1 Active cooling

In case of active cooling, the package is for example mounted on a thin piece of copper as shown schematically in figure 5.

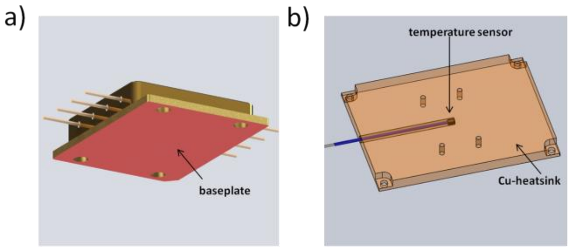

Figure 6 a) T_{case} is defined as the maximum temperature at the backside of the baseplate of MDP, marked in red. b) $T_{heatsink}$ is defined as the temperature measured within the heatsink centered underneath the mounted MDP.

For further discussion a clear definition of case temperature T_{case} and heatsink temperature $T_{heatsink}$ is necessary. T_{case} is the highest temperature at the backside of the package (see figure 6a).
The heatsink temperature is measured within the heatsink, directly underneath the center of the mounted MDP (see figure 6b). During operation the heatsink temperature is kept constant, e.g. by the usage of water-cooling + Peltier elements.

To quantify the impact of the thermal connection of MDP to heatsink, specially prepared test packages with temperature sensors (NTC) were used. The NTC's were connected to the baseplates of the packages with thermally conductive glue (Ag) as shown in figure 7a. The evaluation showed that using the recommended mounting technique, e.g. usage of 4 screws with defined torque, thermally conductive paste and planar heatsink, the thermal resistance of the interface is in the order of 2 K/W per chip. This value is directly influenced by the quality of the heatsink with regard to planarity and the usage of thermal interconnects, e.g. thermally conductive paste and the applied mounting technique.

In case of appropriate mounting of the package, the thermal resistance of the system (MDP + interface to heatsink) increases from 8 to 10 K/W per chip as shown in Figure 7b). The case temperature can be calculated with following equation

$$T_{\text{case}} = R_{\text{th, interface}} \cdot P_{\text{diss}} + T_{\text{heatsink}} \quad , \qquad (1)$$

where P_{diss} is the dissipated power and $R_{th,interface}$ is the thermal resistance of the interface connection.

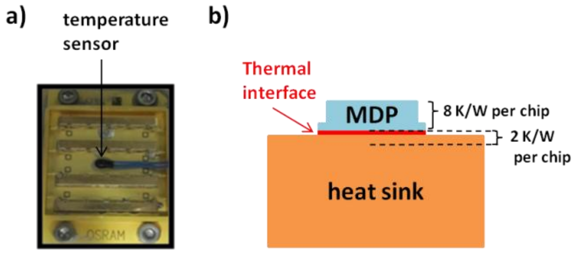

Figure 7a) Test package with temperature sensor. b) Overview of R_{th}-contribution of MDP mounted on heatsink

The dissipated power per laser chip can be derived by

$$P_{\text{diss}} = U \cdot I - P_{\text{opt}} = \frac{P_{\text{opt}}}{WPE}(1 - WPE) \;, \qquad (2)$$

where *I* is the operation current, *U* the operation voltage per chip, P_{opt} the optical output power per chip (50 W divided by number of chips) and *WPE* is the wall-plug efficiency.

Assuming a wall-plug efficiency of 31% and P_{opt} = 2,5 W per chip (20 laser chips in MDP, Bin 1), one gets a dissipated power of ~5,6 W per chip.

According to formula 1), the difference between T_{case} and $T_{heatsink}$ can be derived by multiplying P_{diss} with $R_{th,\ interface}$.
Taking an $R_{th,\ interface}$ of 2 K/W per chip, the offset between T_{case} and $T_{heatsink}$ is roughly 11 °C. This means that under the assumption of proper mounting, the specification in datasheet for T_{case} = 60 °C

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and 50 W optical output power correlates to a heatsink temperature of ~ 50 °C.
The maximum rating for the junction temperature of GaN-lasers is 135 °C. Operation above this value will reduce the lifetime of the MDP.

The junction temperature $T_{junction}$ can be calculated with following equation

$$T_{\text{junction}} = R_{\text{th, system}} \cdot P_{\text{diss}} + T_{\text{heatsink}} \quad , \quad (3)$$

where $R_{th,\ system}$ is the sum of $R_{th,\ MDP}$ = 8 K/W and $R_{th,\ interface}$ = 2 K/W per chip. This assumption is valid as long as the heatsink temperature is constant, e.g. in case of lab set-up using water-cooling and temperature stabilization by Peltier-elements.
Insufficient cooling not only affects the long-term stability but also influences the optical output power. In figure 8 is the effect of insufficient cooling on the light vs. current (*LI*)- characteristics of MDP displayed. In worst case the optical power can even drop to zero at high operation currents. If a MDP does not reach the specified optical output power at specified maximum operation current, please review your mounting technique and cooling system.

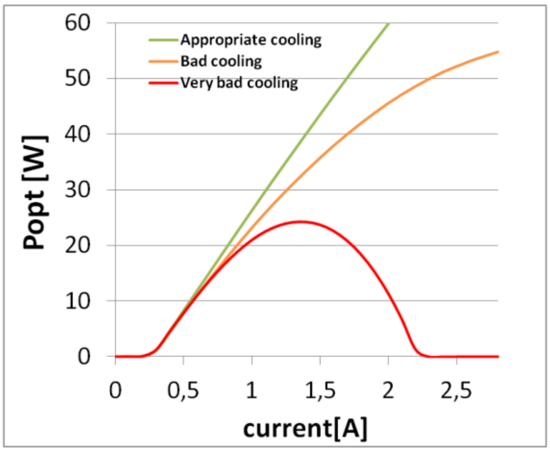

Figure 8: Influence of cooling on optical output power of MDP (PLPM4 450)

6.2 Passive cooling

In case of passive cooling, the multi-die package has to be mounted on appropriate designed heatsinks. One possibility is the usage of heatsinks containing heatpipes in combination with fans as schematically shown in figure 9. The orientation of the fan has to ensure an airstream through the fins of the heatsink. Therefore the usage of an appropriate ducting is also recommended (not shown in figure 9).

In case of passive cooling the heatsink definition is not useful anymore, as the MDP is directly mounted on heatpipes. Therefore, the ambient temperature is defined as reference temperature. The system R_{th} consists of three contributions, the R_{th} of the heatsink, the R_{th} of thermal interface and the thermal resistance of MDP.

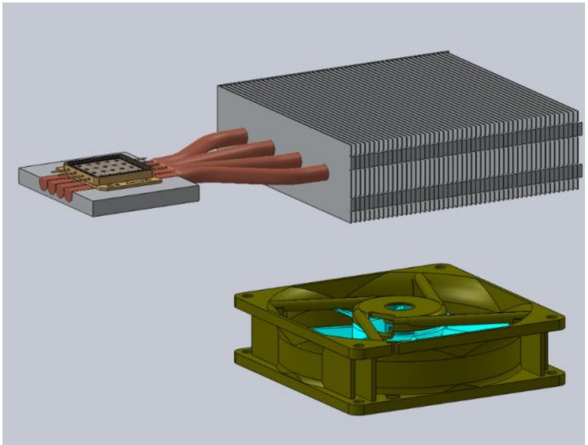

Figure 9: Schematic drawing of MDP on reference heatsink with heatpipes.

The thermal resistance of the whole system can be calculated by

$$R_{th,system} = R_{th,heatsink} + R_{th,interface} + R_{th,MDP} \quad (4)$$

The junction temperature $T_{junction}$ can be calculated with following equation

$$T_{junction} = R_{th,\ system} \cdot P_{diss} + T_{ambient} \qquad (5)$$

where $T_{ambient}$ is the temperature of the air that is used for cooling the heatsink. The junction temperature therefore depends on operation conditions of MDP and ambient temperature.

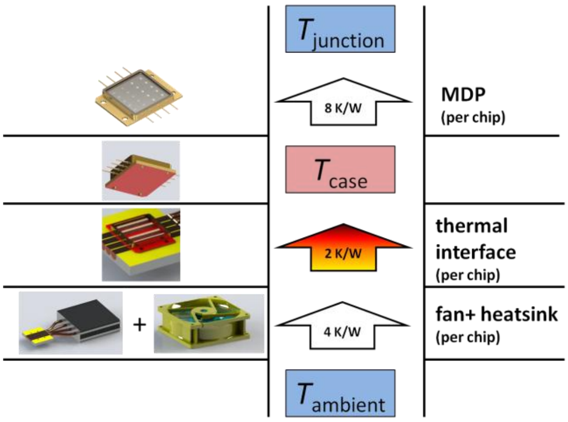

Figure10: Overview of example R_{th}-contribution for MDP mounted on reference heatsink.

In figure 10 an example overview of the system R_{th} is shown. Based on simulations and measurements, a thermal resistance of heatsink and fan of 0.2 K/W is assumed in this example which gives then 4K/W per chip (for PLPM4 450B1). According to formula 4, the system Rth in this example case is 14 K/W per chip.

Depending on the device performance, the mounting quality (thermal connection of MDP to heatsink) and the thermal resistance of heatsink + fan, the customer must ensure that the junction temperature does not exceed 135 °C.

Typical dissipated power at heat sink is 115W. For heat sink design, OS recommendation is to consider a maximum dissipated power of 130W. A reference heatsink- design is available at Osram OS (also available collimation lense array).

6.3 Thermal rollover

A so called thermal rollover in cw-operation is mainly observed for the visible multi-mode lasers which have the highest thermal load at the operating point. The same statement is valid for the multi-die package. In figure 11 the *LI*-characteristics of a MDP for varying case temperatures is shown. For high operation currents and elevated case temperatures the *LI*- curves show a slight nonlinear behavior. This effect is caused by a self-heating of the package. For increasing case temperatures the bending of the curves starts at lower currents due to lower efficiencies at higher temperatures.

If an MDP is operated in overstress, which means at too high power levels or temperatures above specification and therefore, driven nearby or at this thermal rollover the lifetime of the laser diode will be reduced. However, at specified conditions and appropriate cooling no rollover occurs.

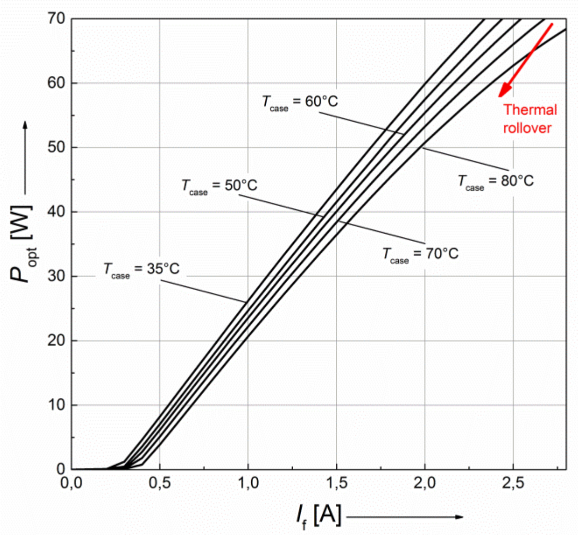

Figure 11: Temperature dependence of the thermal rollover for a MDP (Bin1) with typical performance.

7. Operation conditions

OSRAM OS multi-die package (MDP) is developed for cw-operation. To obtain the target lifetime it is mandatory not to exceed the nominal output power and the nominal operation conditions (operating current, optical output power, junction temperature & case temperature) for a longer period of time. Operation above nominal operation conditions may reduce the lifetime of the MDP and operation above the maximum ratings specified in the data sheet even for a short time may irreversible damage the device.

OSRAM OS multi-die package may also be operated in pulsed mode at any pulse widths between a few ns and dc and at any duty cycle. However, the maximum ratings specified for cw-operation apply to the pulsed operation as well. This is also valid with regard to operation currents.

8. Electrical Driving

A laser diode is a current-driven device. Therefore it is not recommended to use a voltage source to drive the MDP. In this case electrical overstress may occur to the laser diodes as the operation voltage varies from device to device and additionally depends on the case temperature.

Special care has to be taken, when switching the electrical power on and off, as transient currents beyond the maximum ratings can occur damaging the laser diodes inside the package.

To operate MDP correctly, a suitable laser driver is recommended. A reliable laser driver must act as an accurate constant current source with good transient protection and very low noise.

Furthermore, please note that at different temperatures the output power of the MDP will change. Thus, for applications that require a constant output power over a broad range of temperatures an automated power control (APC) is necessary. A photodiode (PD) is usually adopted to optically monitor the output power of laser diode. OSRAM Opto Semiconductors provides a series of photo detectors with compact size and high sensitivity which are suitable for implementing an APC.

9. Wavelength shift and spec limits

The shift of the emission wavelength with temperature for GaN laser diodes is in the range of 0.04 to 0.06 nm/K. In figure 11 the wavelength shift from pulsed operation at T_{case} = 25 °C to cw-operation at I_{op} = 2 A and different case temperatures displayed. The wavelength in pulsed mode is measured within a current pulse of 3ms and an amplitude of 2 A.

The emission wavelength of GaN-laser diodes is temperature dependent. Therefore the spectral distribution in cw-operation depends on the quality of thermal connection, the efficiency of MDP and the operation condition.

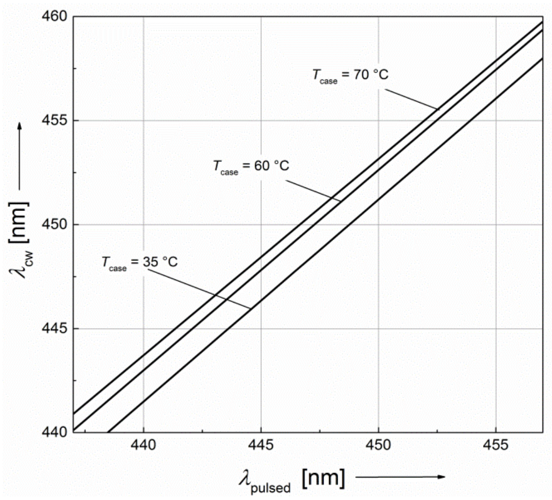

Figure 11: Correlation curve of wavelength from pulsed operation to cw-operation for

different case temperatures under the assumption of good thermal connection.
As the MDP contains up to 20 multimode laser chips, the emission spectrum consists of multiple laser peaks.

In figure 12 an example spectrum of MDP is shown. According to datasheet, the spectrum limits in pulsed operation of 437-457 nm correspond to a range of 440-460 nm in cw-operation at T_{case} = 60 °C under the assumption of good thermal connection.

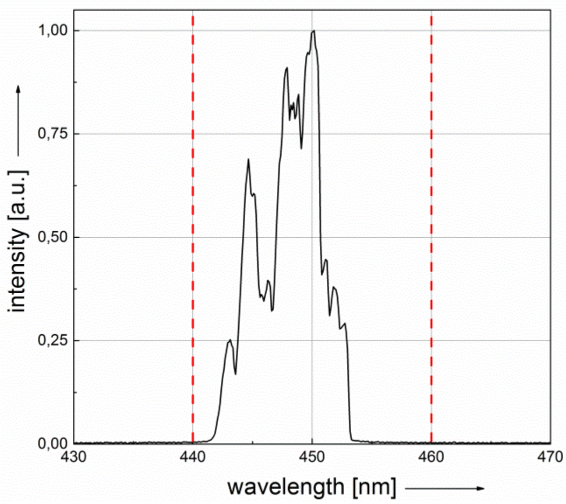

Figure 12: Example spectrum of MDP with 95% optical power between 440 - 460 nm in cw-operation at T_{case} = 65 °C and P_{opt} = 50 W.

10. Optical

In case of optic design or simulation needs, ray files of laser diodes for various software versions (e.g. Lighttools, Zemax, ASAP, Tracepro, Speos) can be downloaded from OS website (Application Support): www.osram-os.com

For latest updates regarding multi-lense arrays, please contact the local OS sales office.

Appendix

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About Osram Opto Semiconductors

Osram Opto Semiconductors GmbH, Regensburg, is a wholly owned subsidiary of Osram GmbH, one of the world's three largest lamp manufacturers, and offers its customers a range of solutions based on semiconductor technology for lighting, sensor and visualisation applications. The company operates facilities in Regensburg (Germany), Sunnyvale (USA) and Penang (Malaysia). Further information is available at www.osram-os.com.
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