



LEDs in the spotlight

A highly efficient LED module integrates plastic optics

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With new designs, LEDs enter the illumination market. A new design that combines a metal reflector with a plastic reflector achieves a particularly narrow beam angle and high efficiency. Such LEDs are suitable for spotlights, LED arrays and fibre couplings.

In recent years we have witnessed great improvements in LED performance, making LEDs suitable for a range of applications for which they were either not suitable or only of limited usefulness. In addition, LEDs have well-known characteristics such as long lifetime, small dimensions and low energy requirements. Traditionally LEDs were used primarily as displays, for example in vehicle dashboards. More recently they are being used as a light source for general illumination applications. Examples of new products based on LED technology include torches, desk lamps and powerful illumination modules for inspection systems.

An example of the new LED generation is a module which is excellently suited for a variety of illumination applications and

which utilises the small size of the actual luminous body, the LED chip itself. The compact dimensions of the LED light sources give light designers a great deal of freedom as regards shaping, a feature already used in new illumination units. In addition, the small dimensions of the actual luminous surfaces of the LEDs allow a high level of flexibility in beam guiding in optical systems.

LED chip in the metal reflector

The LED module in our example (Figure 1) consists of an LED chip mounted in the base of a solid metal reflector (copper coloured in the illustration). The reflector has been designed to provide a suitable

outlet for the bonding wires. This principle was developed by the company Die-Mount in Erfurt, Germany. In this configuration it is used with a directly coupled optical fibre primarily for data transfer. In contrast to previous simple designs (LED injected in a plastic housing), this principle enables considerable gains in efficiency in coupling light into the fibres.

The principle also allows a different optical module to replace the fibre coupling above the metal reflector for general illumination applications. In this example, a parabolic plastic reflector from Leica Projektion is fitted above the metal reflector. The plastic reflector guides the light from this point. It is approximately 10 mm in length and shown in Figure 1 as a transparent blue part.

All other parts, such as the grey element, are simply holders or bases, and are only indirectly important for the assembly. The holder influences the mechanical precision and thus the angle error of the optical assembly. The printed circuit board (PCB) shown in green with one of the two electrical connection pins can be seen below the copper coloured reflector. The base area corresponds to the PCB surface area of 5 mm x 5 mm and can be used to construct an illumination matrix with this grid size.

Two reflectors for optimal beam guiding

The parabolic reflector is a continuation of the contour of the metal reflector and thus takes over beam guiding. At this distance from the LED, the beam angles are narrowed to such an extent that the reflector surface of the plastic reflector provides total reflection. The advantages are clear: firstly, coating is not necessary, and secondly, the geometry of the component is very simple. This means that it can be manufactured cheaply in high volumes. For this reason, plastic was the obvious choice of material for the reflector.

In this context it should be mentioned that plastic optical components are excellent for use in lighting applications with LED light sources. Their density of light power is not too high and the light

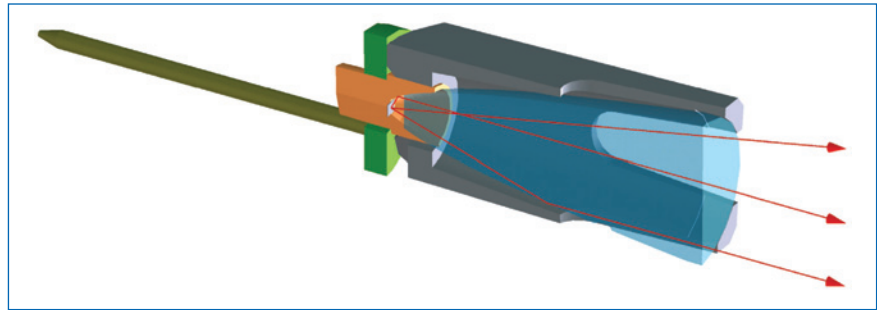


Figure 1. The new LED is not injected in a plastic housing, but mounted in the base of a metal reflector

is emitted from the LED in a relatively narrow wavelength range. In the case of LEDs with wavelengths in the visible range, the emitted light does not contain an infrared portion which could cause a temperature rise in following plastic optical components.

Plastic optical components have several advantages over conventional optical

specifications in illumination applications. There is no need to combine LED illumination with glass optical components unless an unusually high level of precision is needed.

The greatest advantage in the development of the LED spotlight with the plastic parabolic reflector made jointly by Leica Projektion and DieMount is that al-

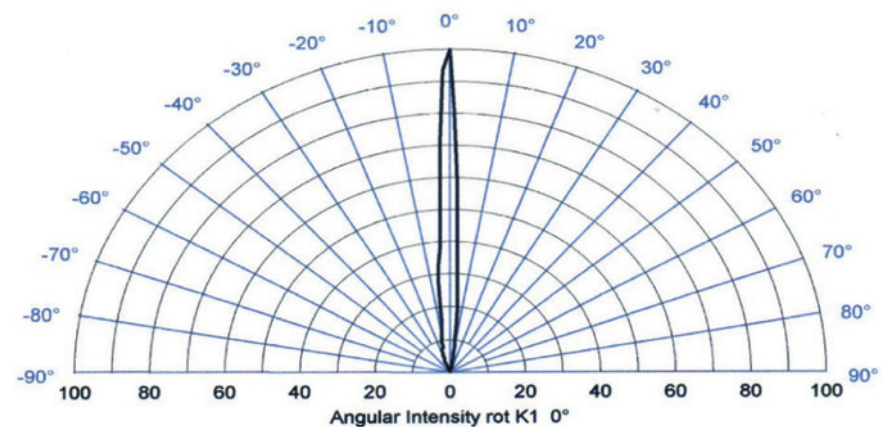


Figure 3. The measurement of the angular intensity distribution shows the very narrow beam angle

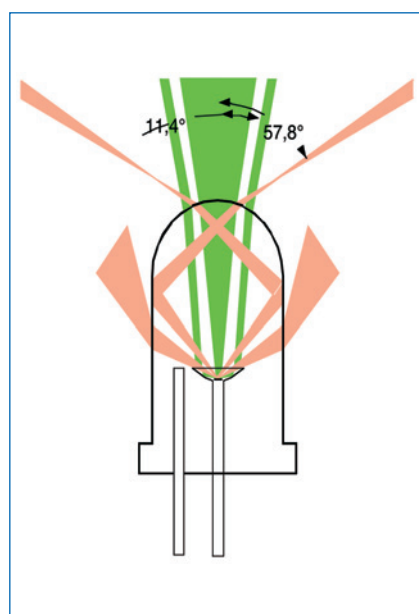


Figure 2. The new LED has a much narrower beam angle than the conventional LED shown here

components made of glass. For example, they allow a greater degree of flexibility as regards shaping, particularly for light guiding elements (for example bent light guides with an exit lens). The only restriction is that the component must be capable of manufacture using the primary shaping method. This means that expensive machining is not required. Holder elements and optical components can be integrated in one element, separate holder elements are therefore not required.

Simple, cost-effective mass production

Today's manufacturing methods for plastic optical components achieve levels of precision which are satisfactory for normal

most all coupled light is emitted from the module in a very narrow beam angle of approx. $\pm 4^\circ$. This good collimation of the light can be used for true spotlighting with small illuminated surfaces, even over large distances. The beam angle is determined to a certain degree by the length of the reflector. Very good collimation results are achieved with a reflector length of just 10 mm. Shorter reflectors would result in a wider beam angle.

In contrast to a conventional assembly with an LED chip positioned in a plastic housing with an exit lens, considerably more light is emitted towards the optical axis of the system (Figure 2).

The angle distribution shown in Figure 2 of a conventional LED system shows >>>

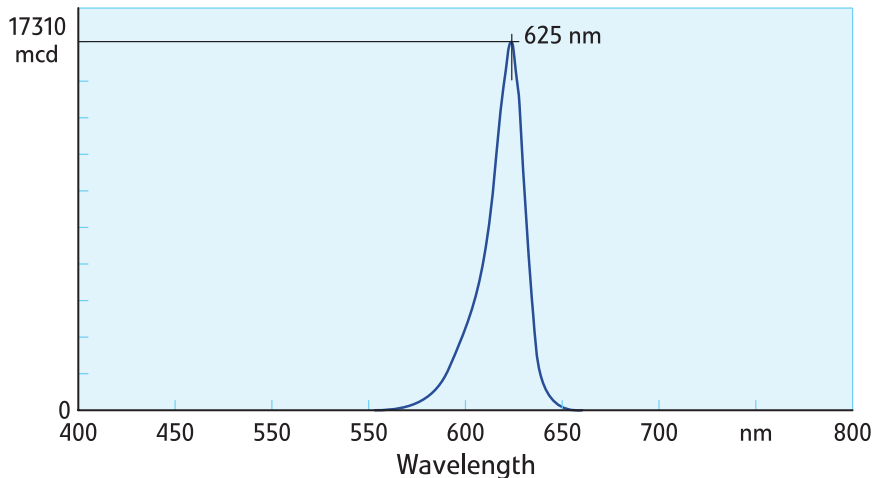


Figure 4. Measurement of the peak wavelength, i.e. the maximum beam intensity, of a red LED

clearly that the light is emitted in various directions. This type of angle distribution is difficult to control in a following optical illumination system and can generally be optimised only for a specific distance. In the module developed by Leica Projektion, however, the light emitted by the system does not diverge as strongly and the aperture angle is small. For this reason, the following optical system can often have a less complex design.

Three major advantages of the reflector module

The reflector module thus has three major advantages. The narrow beam angle allows the transmission of a narrow light bundle over large distances, i.e. enables spotlight illumination over large distances. The principle of LED beam coupling developed by DieMount is very efficient – fewer LEDs are therefore needed than in conventional assemblies. The reduction in the required number of LEDs lowers the energy consumption and, in turn, the thermal loading which is advantageous

for the assembly of an LED illumination matrix consisting of Leica Projektion / DieMount LEDs suitable for matrix applications.

The advantages of the LED spotlights already described can be substantiated by photometric measuring results. The dependency of the light intensity on the

strength of the forward current is of greatest interest. The beam angle (goniophotometer measurement, Figure 3), the dominant wavelength and peak wavelength (Figure 4) were measured in test samples exemplarily. The dominant wavelength is a measure of the colour impression made on the human eye. The peak wavelength is determined by the maximum intensity of the spectrum in dependence on λ . A photometer / radiometer with an LED measuring configuration in accordance with CIE 127 (/CIE 127-1997) (>Averaged LED Intensity< I LED B) was used to measure the luminous intensity.

Figure 5 shows the results for the red Leica / DieMount spotlight LED. In the measurements, the readings for several LEDs were recorded for a specific value I_f and then averaged for the LED type. The red LED achieves an averaged value of approx. 19.3 cd at 20 mA. The aperture angle reaches only approx. $\pm 3^\circ$ (Figure 3). The peak wavelength is 625 nm (Figure 4), the dominant wavelength is 615.9 nm. Key technical data for the red Leica / DieMount LED are listed in Table 1.

In addition, the photometric values of the new blue Leica / DieMount LEDs, the

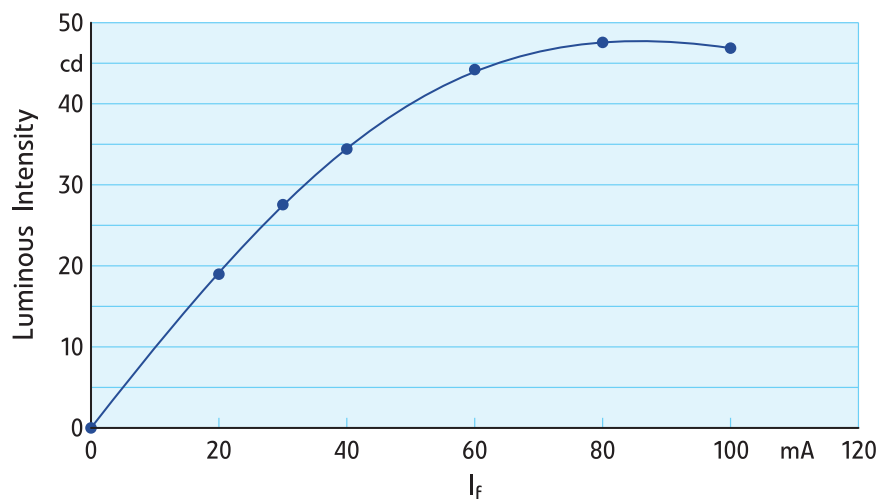


Figure 5. Luminous intensity of the LEDs in dependence on the forward current

Typical operating current	20 mA
Peak wavelength	625.0 nm
Dominant wavelength	615.9 nm
Luminous intensity at 20 mA (average)	19.3 cd
Half aperture angle (at full width at half-maximum)	$\pm 3^\circ$

Table 1. Technical Data for the red Leica/DieMount LED

	Red	Blue	Green	Amber
Typical operating current I_f [mA]	20	20	20	20
Peak wavelength [nm]	625.0	454.0	516.0	592.0
Dominant wavelength [nm]	615.9	457.9	521.2	589.8
Luminous intensity [cd] at 20 mA (average)	19.3	9.0	12.3	6.9
Half aperture angle [°] (at full width at half-maximum)	+3	+3	+5.5	+5.8

Table 2. Technical Data for Leica/DieMount LEDs of different colours

green LEDs and the new amber LEDs were also measured using the same set up. The results are summarised in Table 2.

Other manufacturers also claim that their LEDs generate a high luminous intensity at relatively low energy consumption, in particular in comparison with conventional LEDs. We evaluated a similar commercially available product at the

Outlook

The advantages of the LED module described here open up a range of interesting applications, for example in the automotive industry, in medical technology, sensor technology and signalling technology. The good collimation of the emitted light beam makes the module su-

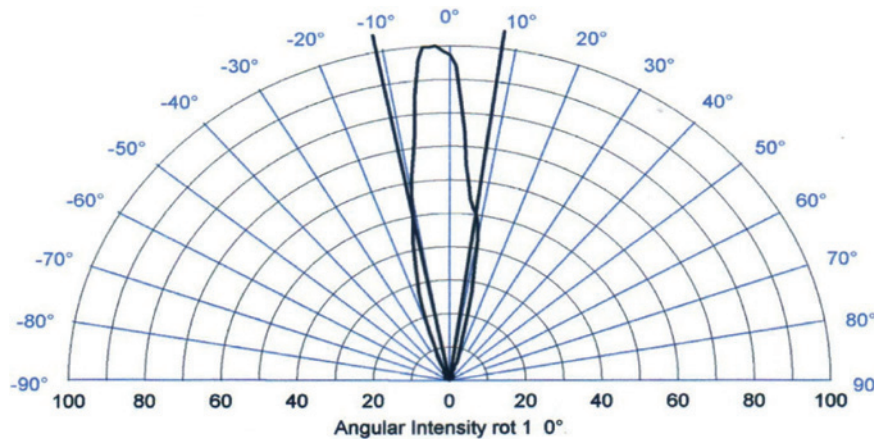


Figure 6. A reference LED, available commercially, has a wider angular intensity distribution

same forward current (20 mA). Figure 6 shows the aperture angle of a similar red LED. The beam angle is considerably wider than that of the Leica / DieMount LED. With reference to luminous intensity, a considerable difference, of almost factor 5, could be observed.

These results clearly show that the combination of a metal reflector and a plastic reflector is particularly advantageous for light guiding as the luminous intensity is optimised by maximised efficiency.

itable for effect illumination as a spotlight. This is particularly beneficial in combination with an off-axis Mangin mirror. Concepts have already been drawn up for this system.

With minor modifications to the LED module discussed here, light can be coupled with very good results into smaller fibre bundles. The good collimation of the light is also advantageous here. By mixing the fibres from several bundles with different LED wavelengths, white light can be generated at a certain distance

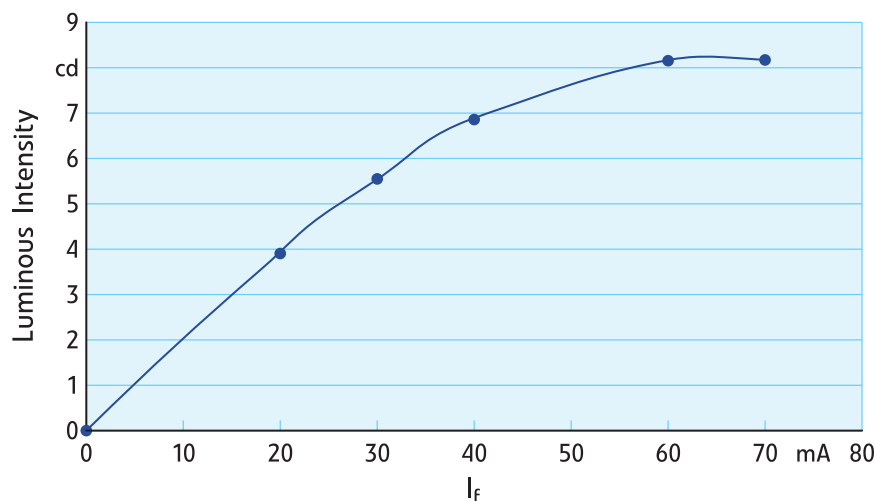


Figure 7. In the reference LED, the luminous intensity in dependence on the forward current is also lower

behind the light guide aperture. If several wavelengths are used, for example four or five, a spectrum can be generated that results in good colour rendering.

Conclusion: the performance of LED illumination can be improved for a range of applications in conjunction with optimised additional optical components, thus making the use of LEDs an attractive option. LED illumination sources can be combined very well with plastic optical components. The small size of the LED light sources and chips facilitate excellent beam guidance design. Particularly in conjunction with plastic optical elements, this results in a high level of freedom in the design of optical illumination systems. <<

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The Braunschweig specialist for lighting and plastics technology Leica Projektion GmbH Zett Geräte has a joint venture with DieMount GmbH concerning the development and manufacture of LED spotlights and LED illumination systems. DieMount GmbH, Erfurt is a manufacturer of electro-optical components. Leica is responsible for optical system development, including optical calculations, manufacturing and sales of the lighting technology application according to customer specifications.