

# Multi-row Headlamp System in the Mercedes-Benz E-Class

Until now, LED headlamps consist of mechanical actuators and a single, controllable LED row, which simply allows the dynamics of the high beam. For the development of the new Multibeam LED headlamp, Daimler and Hella rely on three-row technology with 84 individually controllable pixels. Thereby, a variable kind of light distribution in the range of low beam and high beam becomes possible which delivers for every traffic situation the right road illumination from town light to glare-free high beam.



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### ACTUATOR-FREE PIXEL HEADLAMPS

As opposed to older generations of headlamps, which could only offer a straight low beam or high beam, modern headlamp systems are able to optimise illumination by tailoring it to suit each individual driving situation. During this process such systems read and make use of signals received from the vehicle's environment in order to recognise various road traffic scenarios. Today cameras are increasingly being used to detect the movements of other road users (those driving ahead and oncoming traffic) so that light distribution can be appropriately adjusted. As a result of details on current road conditions becoming more and more precise and because information density on dynamic traffic situations is constantly increasing, lighting systems, which can adjust illumination to suit any one given situation, are now most definitely required.

Up to now this has been achieved by using mechanical actuators, which, how-

ever, involved all the attendant restrictions as regards response time and flexibility. Also pixel headlamps without any actuators are in use for the first time, but their functional scope is however limited to the high beam function.

World premiere as an automotive application: The new Mercedes-Benz E-Class (model range W213) now boasts a multi-row headlamp technology. It enables the complete flexibility and variability of light distribution throughout the entire range to be illuminated by the high and low beam, and all this without using any mechanical actuator units.

### STRUCTURE OF THE HEADLAMP

The second generation Multibeam LED headlamps in the Mercedes-Benz E-Class have come up with a veritable high-end lighting technology in a completely new guise; the first generation was presented in [1] with the model upgrading of the CLS-Class. For the new headlamps, **FIGURE 1**, two light guides generate the lighting functions of daytime running lights (DRL), position lights, direction indicators and so-called coming home light in blue appearance, which welcomes the driver and creates surprising, optical highlights.

The cornering light is located on the inner side of the vehicle. The road surface low beam makes up the section of the headlamp towards the outside edge of the vehicle.

The striking heart of the headlamp is the precision LED grid module which is arranged between the two light guide arms. At the same time it also serves as an equally striking part of the headlamp's styling thanks to its fascinating blue appearance. The result is the absolutely unmistakable lighting character of the new E-Class.

### PRECISION LED GRID MODULE WITH 84 PIXELS

Headlamp systems with a glare-free, segmented high beam have been on the market for about two years (since 2013). Up until recently they have consisted of a single, controllable LED row, which only generated the high beam. But now the newly developed precision LED grid module produces lighting using a grid made up of three rows and a maximum amount of 30 columns. The 84 individu-

ally controllable LED pixels thus enable the activation of a variable kind of light distribution, bespoke for every road traffic situation. The entire light output is obtained from just the one optical system with all the permitted light functions, **TABLE 1**, being controlled by switching on or dimming individual LED light sources. The use of mechanical components, such as actuator units, has therefore become redundant.

### VARIABLY CONFIGURABLE LIGHT DISTRIBUTIONS IN LOW BEAM AND HIGH BEAM

The new, more precisely diffused light distribution gives the high beam a longer useful life and, consequently, leads to a considerably increased safety factor. Unlike static high beam systems, the Multibeam LED headlamp assists and supports the driver even then when other vehicles are located in the field illuminated by the headlamps. Because this system specifically, and indeed within a fraction of a second, masks these vehicles out of its light distribution, the driver is able to proceed with the high beam switched on at all times. This also applies even if several vehicles are to be found in the sensing area of the headlamps all at the same time.

This results in the vehicles themselves being darkened but the areas between them and next to them remain illuminated by the high beam. The bottom line is that drivers are always assured of the best possible lighting technology in out-of-town locations, without other road users being dazzled, **FIGURE 2**.

Two different kinds of optical systems – so-called modules – see to the light distribution of the headlamp. First, the road surface light module (or basic module) enables not only the field of vision directly in front of the vehicle but also its broad peripheral areas to be uniformly and homogeneously illuminated.

Second, there is the long-range module (precision LED grid module). This newly developed module is extremely bright and generates light distribution that can be found at a distance between 20 to approximately 435 m in front of the vehicle. The light distribution of this module is divided up into 84 separate controllable segments (pixels) arranged in three rows, **FIGURE 2**. Each one of these pixels can be controlled to generate between

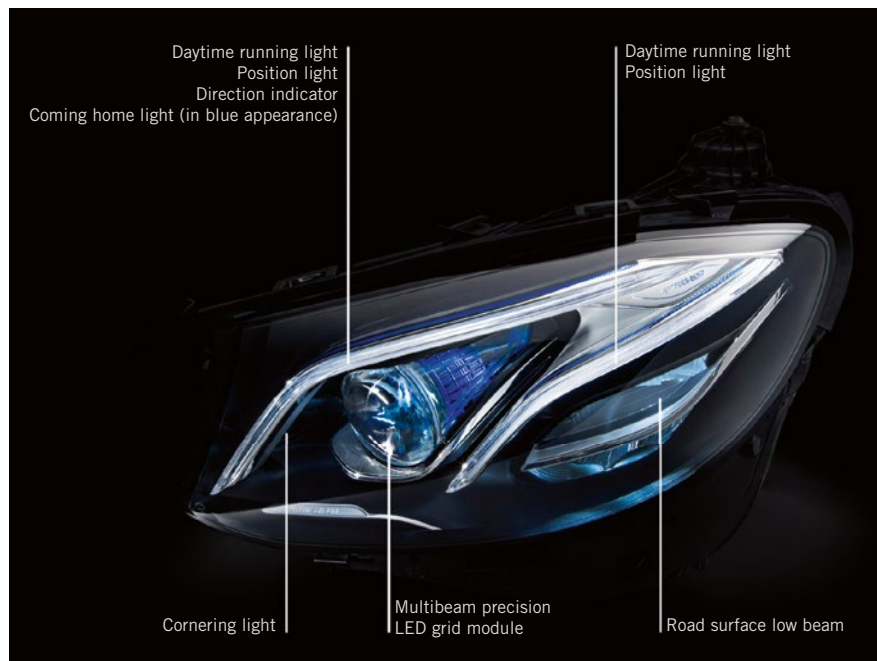


**FIGURE 1** Multibeam LED headlamp in the Mercedes-Benz E-Class with its different light modules (© Daimler)

| Lighting function     |                                   | Conventional matrix (single row) | New precision LED grid module (three rows) |
|-----------------------|-----------------------------------|----------------------------------|--------------------------------------------|
| Town light            | Adaptive lighting functions (AFS) | –                                | ×                                          |
| Country light         |                                   | –                                | ×                                          |
| Motorway light        |                                   | –                                | ×                                          |
| Adverse weather light |                                   | –                                | ×                                          |
| Dynamic bend light    |                                   | –                                | ×                                          |
| High beam             | High beam                         | ×                                | ×                                          |
| Glare-free high beam  |                                   | ×                                | ×                                          |

**TABLE 1** Seven lighting functions in comparison – the precision LED grid module enables functions for low and high beam to be freely configured for the first time ever (© Hella)

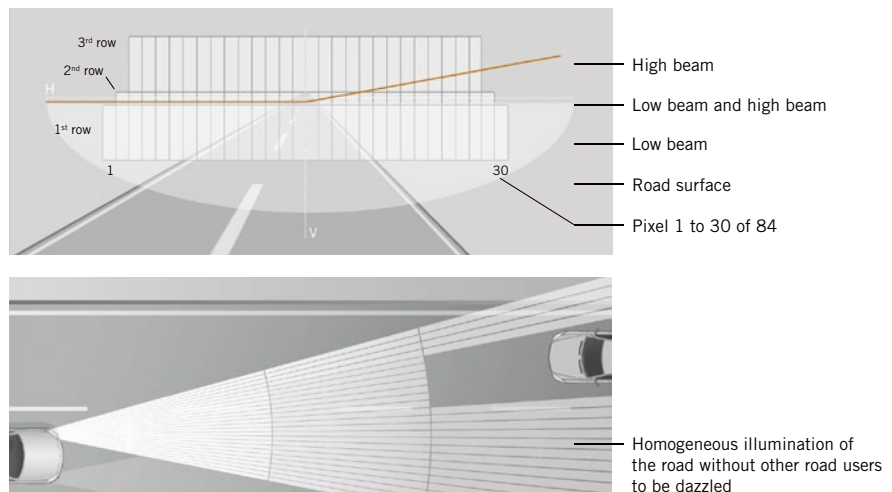


**FIGURE 2** Schematic of light distribution in horizontal and vertical perspective (© Hella/Daimler)

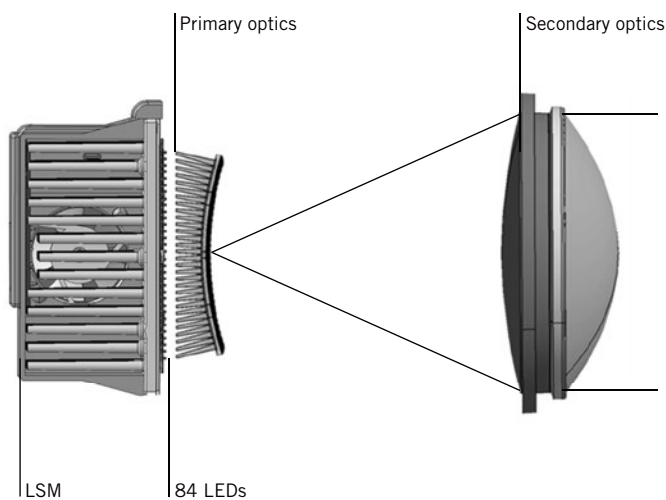
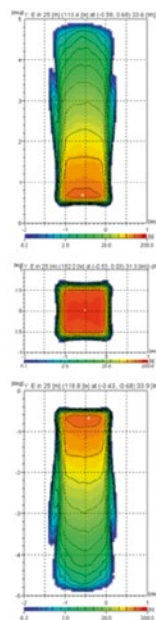


**FIGURE 3** Optical design of the precision LED grid module with Light Source Module (LSM) as well as primary and secondary optics (© Hella)



0 and 100 % of its luminous intensity, depending on the light distribution required at any one given time.

The long-range module is optically split up in such a way that the lower row generates the low beam and the upper one a part of the high beam, **FIGURE 2**. The middle row fulfils functions required for areas covered by both the high and low beam. When dimmed, the middle row brings about the asymmetry of the low beam. When all LEDs are powered to their full capacity, this row sets up the main part of the high beam and provides very high illuminance in the central area of light distribution.

When the camera system recognises either oncoming traffic or road users driving ahead, the appropriate pixels are automatically deactivated, with the result that a dark tunnel is formed in the pattern of light distribution. The entire scope of light distribution is recalculated by the headlamp control units every 10 ms. In this way other road users are not dazzled but the driver can continue on his journey still using the high beam. Back-glare can also be effectively avoided. One example of this is the way road signs are clearly recognised and specifically darkened.

## OPTICAL DESIGN OF THE PRECISION LED GRID MODULE

The Light Source Module (LSM) includes the light sources (84 LEDs), the necessary control electronics and its thermal

management system including the fan, **FIGURE 3**. The primary optics create an image at an intermediate level, which is then displayed into the traffic area by the secondary optics. The distance, necessarily conditional of manufacturing, between the LEDs on the circuit board causes gaps in the illuminance on the input side. The challenge facing us is to fill these gaps in the optical system in such a way that, when adjacent segments are switched on, the image produces a homogeneous light pattern without any masking or blanks. At the same time, however, there can be no overlap to the adjacent segments to create a sharp contrast from light to dark.

A further challenge is the vertical brightness curve in the bottommost row 1, **FIGURE 2**. Here it is important that this row's output flows out smoothly and radiates into the light distribution shining on the road surface without the driver noticing any transition (inhomogeneity).

The primary optics take the form of Total Internal Reflection (TIR) optics. So as to achieve a high degree of lighting efficiency, the primary optics have to be positioned as close as possible to the LEDs. The result is then the creating of extremely high illuminance at the points of coupling with the TIR optics. Conventional types of plastics are not suitable for this kind of illuminance. Glass, which would be the preferred material, cannot be used for production and tolerance reasons. Therefore, transparent silicone

material (liquid silicone rubber), specially developed for this purpose, is used.

The secondary optics are designed as an achromatic PMMA double lens system. This ensures that an optimal imaging quality of the light module is achieved throughout all functions.

## DESIGN IMPLEMENTATION OF THE PRECISION LED GRID MODULE

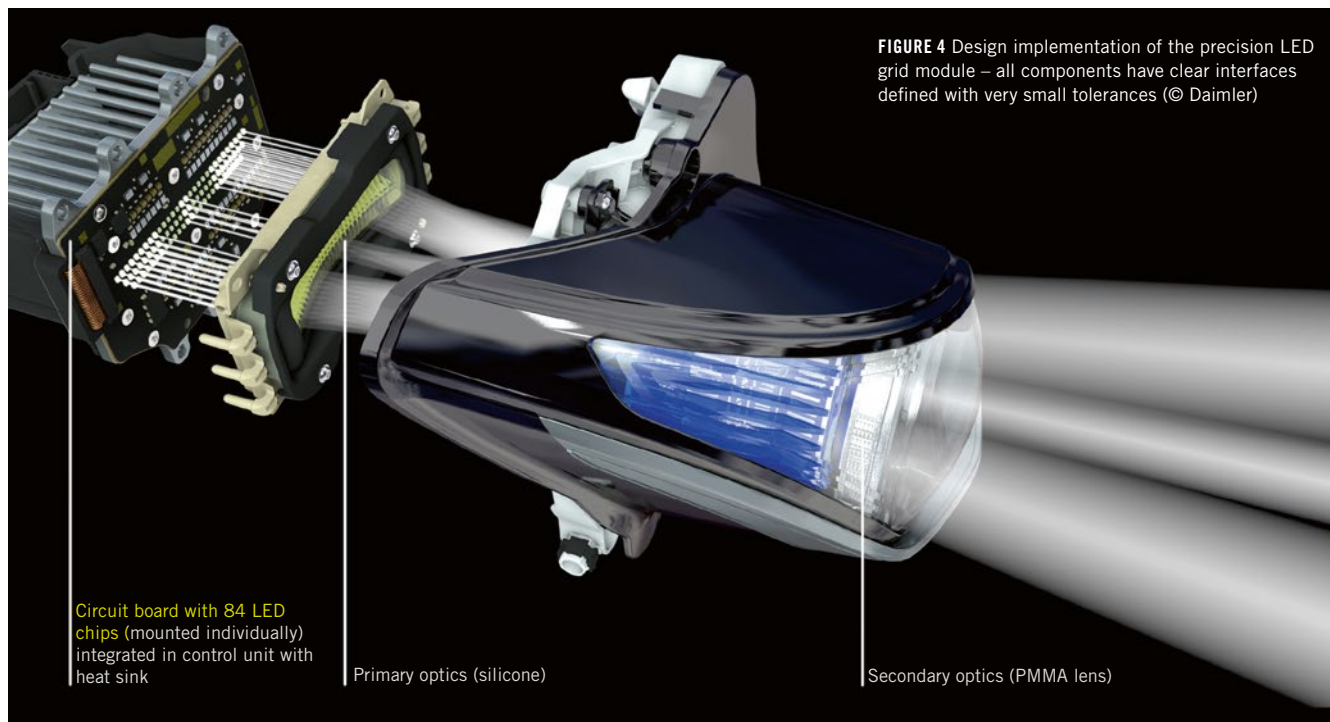
The newly developed precision LED grid module is made up of the following components: the LSM including the circuit board with 84 LEDs, the silicone primary optics and the lens holder with the secondary optics, **FIGURE 4**. In order to guarantee optimal lighting function, all these components have clear interfaces defined with very small tolerances. Or they are designed in such a way that adjustment, calibration as well as focusing and qualification can all be carried out during ongoing production processes.

The aim of adjustment is to achieve an optimal degree of efficiency between the LEDs and the primary optics. The decisive step in the adjustment process is the high precision connection of the printed circuit board with the LEDs relative to the silicone primary optics. In the production process one sees an automated adjustment process taking place for the first time. Using image processing data and a topology scan, this automated process finds the optimal alignment for the two components concerned. Fixation is then carried out by means of a UV hardening glue.

After alignment the assembly is automatically put to a calibration in a special test setup. Here the individual LEDs/pixels are in turn powered one after the other and assigned the default set point of their brightness level. In this way it is guaranteed that adjacent pixels achieve the customised light output and that the resulting light pattern therefore is homogeneous.

Later calibration, the next step is the focussing. This involves the secondary optics being optimally focused and fixed in the module on the basis of lighting data extracted from image processing.

In the last step, the qualification, the module, now complete, is checked by means of lighting image processing to ensure that it adheres to the set values of the lighting requirements.



### PIXEL-CONTROLLED LIGHT DISTRIBUTIONS FOR SAFETY BONUS

The new Multibeam LED headlamp allows a virtually infinite number of light distribution combinations, **FIGURE 5**. The following information describes scenarios for driving straight ahead and driving in a 300-m bend which can only be brought about by variable control of the individual LEDs. The implementation of mechanically operated parts like actuator units is not necessary:

- The town light function allows a very wide light distribution to be generated, thus bringing about optimal illumination of the roadside in built-up areas while at the same time preventing glare for other road users.
- In the country road situation, it is possible for a one-sided, far-reaching light distribution to be generated in order to direct the driver's attention to the medium and long-range distances of his own lane.
- In the high beam operation mode, all the pixels of the precision LED grid module are activated so as to provide the driver with the maximum amount of light output if no other road users are located in the area ahead of his vehicle.

- In the partial high beam mode, the switching off of individual pixels leads to the generating of a dark tunnel which masks out oncoming road users or those driving ahead.

The newly developed adverse weather light reduces reflections on the oncoming lane when it is raining by specifically dimming individual LEDs in the low beam range and it actively helps to prevent indirect dazzling of oncoming traffic.

In addition to its use in the already familiar roundabout light function, data from the navigation system can also be used in the new headlamps of the E-Class in order to detect junctions and motorways in advance. And, consequently, light distribution is automatically adapted to suit such situations as they arise.

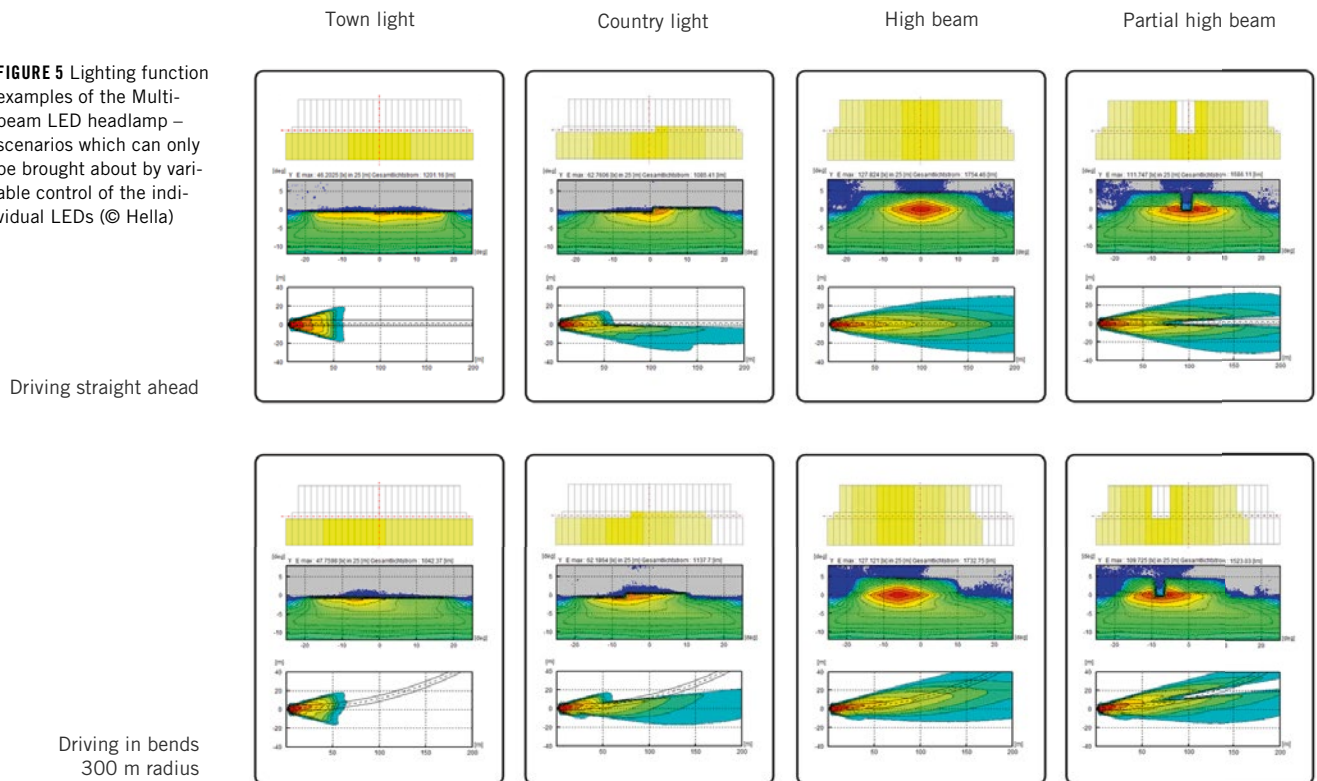
The newly developed precision LED grid module enables all the various light distributions described before to be swivelled into position virtually (without actuator units), also those in the low beam range. Here, by means of variable dimming of individual pixels adapted to suit each situation, the light focus in the particular setting is shifted so that the driver's attention is directed towards the bend. Such dynamic bend lighting that is implemented purely by electronics is a world premiere.

### INTERACTION OF THE HEADLAMP WITH THE VEHICLE

In order to generate light distribution entirely electronically and to suit a constantly changing traffic situation, it is imperative to have a complete system which is "intelligent". The electronic components present in a vehicle have to harmonise so that an optimal light distribution can be achieved. The multi-function camera placed on the windscreen, which is also used for other driver assistance systems, records the surroundings and the traffic situation. The camera then sends this information to four electronic control units, which calculate the ideal light pattern 100 times per second. Consequently ultra-rapid and precise adjustments to the light required for any driving situation are possible.

As well as the visual information provided by the camera, data from the navigation system is also used for these calculations. Thus particular driving scenarios, such as those created by roundabouts, junctions or motorways, can be recognised in advance and the relevant light distribution then automatically adapted to suit. The four control units refer to already available information on the weather

**FIGURE 5** Lighting function examples of the Multi-beam LED headlamp – scenarios which can only be brought about by variable control of the individual LEDs (© Hella)



situation and activate, if necessary, the adverse weather light or the enhanced fog light function.

A central head unit allows various light settings to be made. Switching on or off of the Intelligent Light system functions is therefore possible. So is the switching over from a left-hand to a right-hand drive traffic system (tourist mode). Furthermore, time parameters of the coming home light function can be adjusted.

## OUTLOOK

The optical system showcased here is the first of a new generation. The multi-row LED headlamp system makes it possible to bring about for the first time ever adaptive high beam and low beam settings without using any mechatronic components.

In the ensuing vehicle generations the trend towards the use of dynamic systems will continue. With the help of all

the technology presented here, solutions are currently being worked on, which will increase even more the number of controllable pixels used.

In conjunction with such an aim, it is fitting to mention here the publicly sponsored project  $\mu$ AFS [2]. This research project, under the auspices of a consortium led by Daimler, is set to develop a light source which will have more than 1024 individually controllable segments. Research work will be concluded in the year 2016. All findings and results will then be used for the development of the next generation of systems.

In the long term, modules will be developed which will have a resolution of many thousands of pixels. As well as making use of the  $\mu$ AFS technology, in research projects of the future we will see approaches to solutions using technologies such as liquid crystal display (LCD), digital mirror device (DMD) or laser scanning.

Hand in hand with these developments, the question of how to ramp up and enhance the functions already available is very real indeed, perfecting extra functions that are necessary and which make sense in assisting the driver of a vehicle. In future, high-resolution modules will, for example, make it possible to set the headlamp beam without the use of any mechanical components – it will mark the final disappearance of the last mechanically moving part of a headlamp.

## REFERENCES

- [1] Maier, M.; Moisel, J.; Herold, F.: Multibeam Headlights in the Mercedes-Benz CLS-Class. In: ATZworldwide 117 (2015), No. 2, pp. 4-9
- [2] Reichl, M.: Intelligente LED-Scheinwerfer für mehr Sicherheit. <http://www.photonikforschung.de/service/aktuellnachrichten/detailseite/archive/2013/05/15/article/intelligente-led-scheinwerfer-fuer-mehr-sicherheit>