Lighting technology

Automotive light sources

The most important light sources for the lighting systems on the vehicle front and rear are halogen lamps, bulbs, gas-discharge lamps and LEDs.

Thermal radiators

Thermal radiators generate light from heat energy. The major liability of the thermal radiator is its low working efficiency (below 10 %) which, relative to the gas-discharge lamp, leads to very low potential for luminous efficiency.

Incandescent (vacuum) bulb

Among the thermal radiators is the bulb (Fig. 1) whose tungsten filament (2) is enclosed by glass (1). A vacuum is created inside the glass, which is why the incandescent bulb is also known as a vacuum bulb.

At 10 to 18 lm/W (lumen/Watt), the luminous efficiency of an incandescent bulb is comparatively low. During bulb operation, the tungsten particles of the filament vaporize. The glass consequently darkens over the course of the bulb's service life. The vaporization of the particles ultimately leads to the filament breaking and thus failure of the lamp. For this reason, incandescent bulbs as light sources for the headlamps have been replaced by halogen lamps. For cost reasons, however, incandescent bulbs continue to be used for other lights and as light sources in the passenger compartment. Even the lighting of passive display elements (e.g. fan, heating and air-conditioning controllers, LCD displays) is generally performed by incandescent bulbs, the color of which is changed by means of color filters for the application and design concerned.

Halogen lamp

There are two types of halogen lamp: with one or two tungsten filaments. The halogen lamps H1, H3, H7, HB3 and HB4 (see table at the end of the chapter) only have one filament. They are used as light sources for the low-beam, high-beam and fog lights.

The bulb is made of quartz glass. The quartz glass filters out the low UV content of the beam that halogen lamps emit. Unlike an incandescent bulb, the glass of a halogen lamp contains a halogen charge (iodine or bromine). This makes it possible for the filament to heat up to temperatures approaching tungsten's melting point (around 3,400 °C), thereby achieving commensurately high levels of luminous power.

1 Incandescent bulb

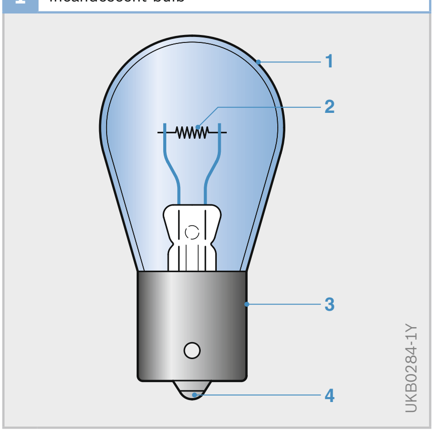

Fig. 1
1 Glass bulb
2 Filament
3 Lamp socket base
4 Electrical connection

2 H4 halogen lamp (detail from Fig. 3)

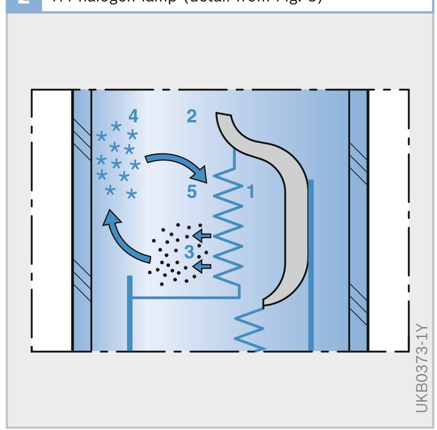

Fig. 2
1 Tungsten filament
2 Halogen charge (iodine or bromine)
3 Evaporated tungsten
4 Halogenated tungsten
5 Tungsten deposits

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Close to the hot bulb wall, vaporized tungsten particles combine with the filler gas to form a transparent gas (tungsten halide). This is stable within a temperature range of approximately 200 to 1,400 °C. Tungsten particles re-approaching the filament respond to the high temperatures at the filament by dispersing to form a consistent tungsten layer. This cycle (Fig. 2) limits the wear rate of the filament. In order to maintain this cycle, an external bulb temperature of approx. 300 °C is necessary. The glass therefore encloses the filament tightly. It remains clear throughout the entire service life of the lamp.

The rate of filament wear is also limited by the high pressure that is generated in the bulb, limiting the vaporization rate of the tungsten.

The H4 halogen lamp generates the light beam in the same way but has two filaments (Fig. 3, Items 2 and 3). This means that only one lamp is required for each low-beam and high-beam headlamp.

The lower part of the low-beam filament is masked by a screen integrated in the headlamp. As a result, the light is only emitted into the upper part of the reflector (Fig. 8) and thereby prevents dazzling other road users.

Switching from low beam to high beam activates the second filament. Halogen lamps with an output of 60/55 W[1] emit around twice as much light as incandescent bulbs with an output of 45/40 W. The high luminous efficiency of around 22 to 26 lm/W is primarily the result of the high filament temperature.

[1] High beam/low beam

3 H4 halogen lamp

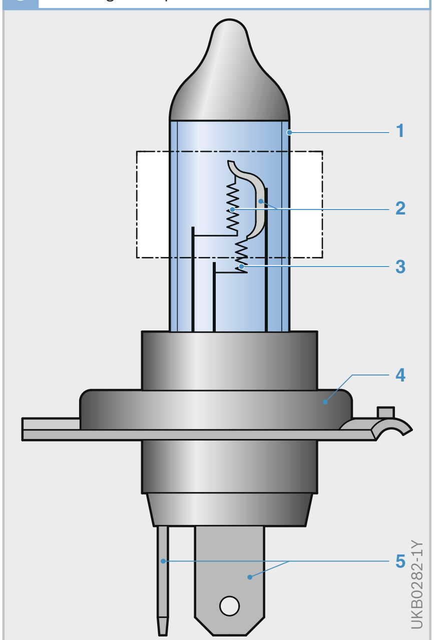


Fig. 3
1 Glass bulb
2 Low-beam filament with cap
3 High-beam filament
4 Lamp base
5 Electrical connection

Gas-discharge lamps

Gas discharge describes the electrical discharge that occurs when an electrical current flows through a gas and causes it to emit radiation (examples: sodium-vapor lamps for street lighting and fluorescent lamps for interior lighting).

The discharge chamber of the gas-discharge lamp (Fig. 4, Item 3) is filled with the inert gas xenon and a mixture of metal halides. The electrical voltage is applied between two electrodes (4) protruding into the bulb. An electronic ballast unit is required for switching on and operation. Application of an ignition voltage in the 10 to 20 kV range ionizes the gas between the electrodes, producing an electrically conductive path in the form of a luminous arc. With the alternating current (400 Hz) applied, the metallic charge is vaporized due to the temperature increase inside the bulb and light is radiated.

Under normal circumstances the lamp requires several seconds to ionize all of the particles and generate full illumination. To accelerate this process, an increased starting current flows until this point.

When maximum luminous power is achieved, limitation of lamp current commences. A sustained operating voltage of only 85 V is sufficient to maintain the arc.

Light sources relying on the gas-discharge concept acquired new significance for automotive applications with the advent of the "Litronic" electronic lighting system. This concept features several crucial benefits compared with conventional bulbs:

- Greater range of the headlamp beam
- Brighter and more even carriageway illumination
- Longer service life, as there is no mechanical wear
- High luminous efficiency (approximately 85 lm/W) due to the emission spectrum being predominately in the visible spectral range
- Improved efficiency thanks to lower thermal losses
- Compact headlamp designs for smooth front-end styling

The D2/D4-series automotive gas-discharge lamps feature high-voltage-proof sockets and UV glass shielding elements. On the D1/D3-series models, the high-voltage electronics necessary for operation are also integrated in the lamp socket. All series can be broken down into two subcategories:

- Standard lamp (S lamp) for projection headlamps (Fig. 4) and
- Reflection lamp (R lamp) for reflection headlamps (Fig. 5). They have an integrated shutter (3) to create the light-dark cutoff, comparable with the shutter in the H4 lamp.

Until now, gas-discharge lamps with the type designations D1x and D2x were used. From 2007, the D3/D4-series will also be fitted as standard. These have a lower operating voltage, a different charge gas composition, and different arc geometries.

4 D2S gas-discharge lamp

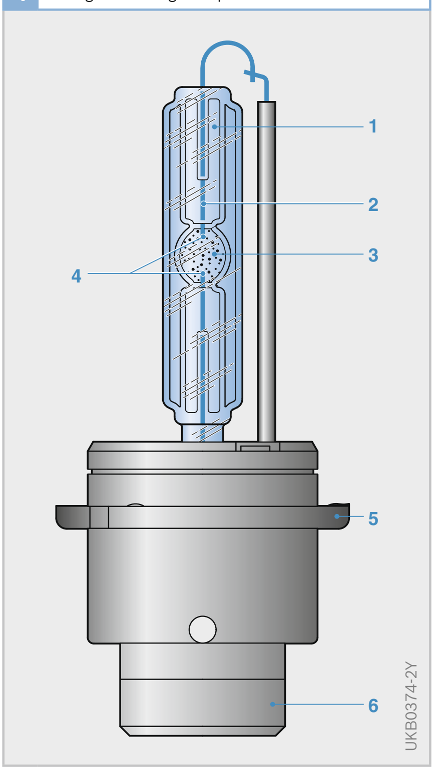


Fig. 4
Gas-discharge lamp for projection headlamps
1 Glass capsule with UV shield
2 Electrical lead
3 Discharge chamber
4 Electrodes
5 Lamp base
6 Electrical connection

5 D2R gas-discharge lamp

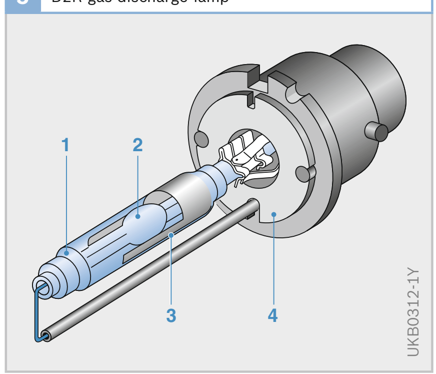


Fig. 5
Gas-discharge lamp for reflection headlamps
1 UV inert-gas bulb
2 Discharge chamber
3 Shutter
4 Lamp base

Light emitting diodes

The light emitting diode (LED) is an active light element. If an electrical voltage is applied, current flows through the chip. The electrons of the atoms of the LED chip are highly energized by the voltage. As light is emitted, they return to their initial state of low energy charge.

The 0.1 to 1 mm small semiconductor crystal is seated on a reflector that directs the light with pin-point precision.

LEDs are commonly used as light sources for lights on the rear of the vehicle, especially the additional stop lamps located in the center. They make it possible for a narrow, linear beam to be emitted.

By comparison with incandescent bulbs, LEDs are beneficial in that they emit maximum output in less than a millisecond. An incandescent bulb takes approximately 200 ms. LEDs, for example, are therefore able to emit the brake signal sooner and thus shorten the response time to the brake signal (brake pedal depressed) for drivers behind.

In the motor vehicle, LEDs are used as illuminators or in displays, in the interior they are used for lighting, in displays or display backlighting. In the lighting system, they find use as auxiliary stop lamps and tail lamps, and, increasingly in future, as daytime running lamps and in headlamps.

Technical lighting variables

Luminous intensity

The brightness of light sources can vary. Luminous intensity serves as an index for comparing them. It is the visible light radiation that a light source projects in a specific direction.

The unit for defining levels of luminous intensity is the candela (cd), roughly equivalent to the illumination emitted by one candle. The brightness of an illuminated surface varies according to its reflective properties, the luminous intensity and the distance separating it from the light source.

Examples of permissible values

Stop lamp (individual): 60 to 185 cd
Tail lamp (individual): 4 to 12 cd
Rear fog lamp (individual): 150 to 300 cd
High beam (total, maximum): 225,000 cd

Luminous flux

Luminous flux is that light emitted by a light source that falls within the visible wavelength range.
Values are expressed in lumen (lm).

Illuminance

The illuminance is the luminous flux arriving at a given surface. It increases proportionally along with the light intensity, and decreases with the square of the distance.

Illuminance is expressed in lux (lx):
$1\ lx = 1\ lm/m^2$

Range

The range is defined as the distance at which the illuminance in the light beam still has a given value (e.g. 1 lx). The geometric range is the distance at which the horizontal part of the light-dark cutoff is shown on the road surface with the headlamps on low beam.

Main headlamps (Europe)

Function

On the one hand, the main headlamps must provide maximum visual range while at the same time ensuring that the glare effect for oncoming traffic is kept to a minimum and that light distribution immediately in front of the vehicle remains in line with the requirements of safe operation. It is vital to provide the lateral illumination needed to safely negotiate bends, i.e. the light must extend outward to embrace the verge of the road. Although it is impossible to achieve absolutely consistent luminance across the entire road surface, it is possible to avoid sharp contrasts in light density.

High beam

The high beam is usually generated by a light source located at the reflector's focal point, causing the light to be reflected outward along a plane extending along the reflector's axis (Fig. 7). The maximum luminous intensity which is available during high-beam operation is largely a function of the reflector's mirrored surface area.

In four and six-headlamp systems, in particular, purely parabolic high-beam reflectors can be replaced by units with complex geometrical configurations for simultaneous use of high and low beams.

In these systems the high-beam component is designed to join with the low beam (simultaneous operation) to produce a harmonious overall high-beam distribution pattern. This strategy abolishes the annoying overlapping sector that would otherwise be present at the front of the light pattern.

Low beam (dipped beam)

The high traffic density on modern roads severely restricts the use of high-beam headlamps. The low beams serve as the primary source of light under normal conditions. Basic design modifications implemented within recent years are behind the substantial improvements in low-beam performance. Developments have included:

- Introduction of the asymmetrical low-beam pattern, characterized (RHD traffic) by an extended visual range along the right side of the road.
- Introduction of new headlamp systems featuring complex geometrical configurations (PES[1], free-form surfaces[2], facetted reflectors[3]) offering efficiency-level improvements of up to 50 %.
- Headlamp leveling control (also known as vertical aim control) devices adapt the attitude of the headlamps to avoid dazzling oncoming traffic when the rear

[1]) The PES (Poly-Ellipsoid System) headlamp system works with an imaging optical lens. Unlike with conventional headlamps, the light pattern generated by the reflector is reproduced on the roadway by the lens together with a screen for creating the light-dark cutoff.

[2]) Reflectors with small short focal length whose shape is calculated using special programs (CAL: Computer Aided Lighting). In this way, three separate reflectors for low beam, high beam and fog lamp can be accommodated within the same space needed by a conventional parabolic reflector, while luminous efficiency is increased at the same time.

[3]) With facetted reflectors, the surface is divided into individually optimized segments. This results in reflector surfaces with high levels of homogeneity and sideways beam spread.

7 High beam (beam projection)

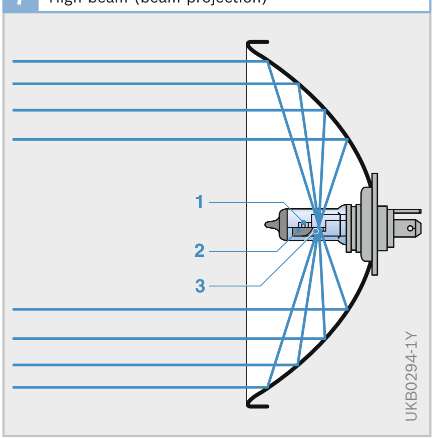


Fig. 7
1 Low-beam filament
2 Cap
3 High-beam filament at focal point

8 Low beam (beam projection)

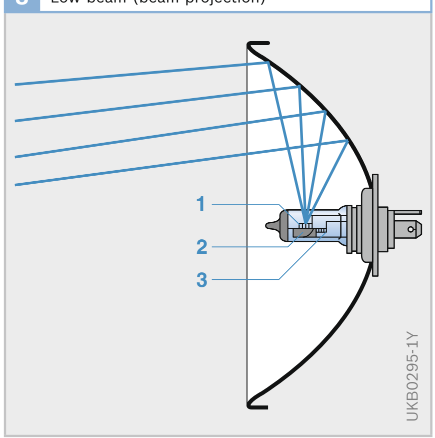


Fig. 8
1 Low-beam filament
2 Cap
3 High-beam filament

of the vehicle is heavily laden. Vehicles must also be equipped with headlamp washer systems.

- "Litronic" gas-discharge lamps supply more than twice as much light as conventional halogen lamps.

Operating concept

Low-beam headlamps need a light-dark cutoff in the light pattern. In the case of H4 halogen headlamps and Litronic headlamps with D2R bulbs, this is achieved by the image from the shield (H4) or the shutter (D2R). On headlamps for all-round use (H1-, H7-, HB11 bulbs), the light-dark cutoff is achieved by the special imaging of the filament.

Headlamp systems

Dual-headlamp systems rely on a single shared reflector for low- and high-beam operation, e.g. in combination with a dual-filament H4 bulb (Fig. 9 a).

In quad headlamp systems one pair of headlamps may be switched on in both modes or during low-beam operation only, while the other pair is operated exclusively for high-beam use (Fig. 9 b).

9 Headlamp systems

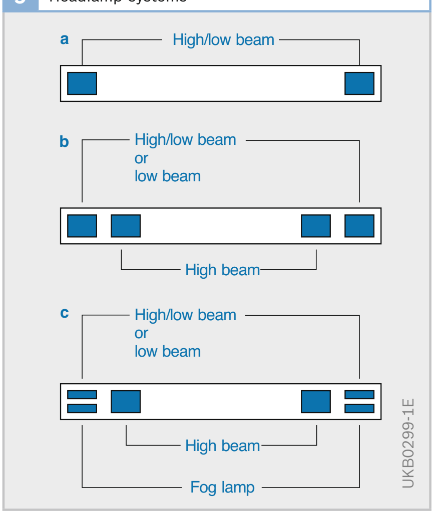


Fig. 9
a Dual-headlamp system
b Quad-headlamp system
c Six-headlamp system

Six-headlamp systems differ from the quad configuration by incorporating a supplementary fog lamp within the main headlamp assembly (Fig. 9 c).

Main headlamps (North America)

High beam

The designs for high-beam headlamps are the same as in Europe. Facetted reflectors with, for example, HB5 or H7 lamps are used.

Low beam (dipped beam)

Headlamps with a light-dark cutoff that rely on visual/optical adjustment procedures have been approved in the USA since 1 May, 1997. This has made it possible to equip vehicles for Europe and the USA with headlamps of the same type and, in some cases, even the same reflectors.

Regulations

The regulations for the attachment and wiring of main headlamps are comparable with the European regulations (Federal Motor Vehicle Safety Standard [FMVSS] No. 108 and SAE Ground Vehicle Lighting Standards Manual).

An amendment to FMVSS 108 that entered effect in 1983 made it possible to start using headlamp units of various shapes and sizes with replaceable bulbs. These were known as the RBH, or Replaceable Bulb Headlamps.

Headlamp systems

North America mirrors European practice in employing dual, quad and six-headlamp systems.

Litronic

Overview

The “Litronic” (Light-Electronics) headlamp system uses xenon gas-discharge lamps that produce a powerful lighting effect despite the low front-end surface area requirement. The illumination of the carriageway represents a substantial improvement over that provided by conventional halogen units (Fig. 10).

The light generated contains a higher proportion of green and blue and is thus more similar to the spectral distribution of sunlight. Night-time driving is therefore less exacting for the driver.

Design

The components of the Litronic headlamp system are:

- Optical unit with xenon gas-discharge lamp (S lamp, R lamp; see “Gas-discharge lamps” section)
- Electronic ballast unit with igniter and ECU

10 Light pattern on the road (comparison)

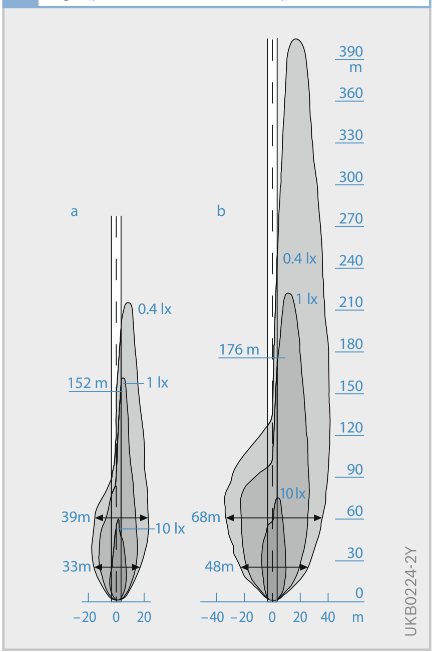


Fig. 10
a H4 lamp
b Litronic PES D2S lamp

For low beam, the headlamps with xenon gas-discharge lamps are installed in a quad system that is combined with the high-beam headlamps of the conventional design.

With the Bi-Litronic system, however, the low and high beams are generated by only one gas-discharge lamp from a dual-headlamp system.

An integral part of the headlamp is the electronic ballast unit responsible for activating and monitoring the lamp.
Its functions include:

- Ignition of the gas discharge (voltage 10 to 20 kV)
- Regulated power supply during the warm-up phase when the lamp is cold
- Demand-oriented supply in continuous operation

The control units for the individual lamp types are generally developed for a specific design type and are not universally interchangeable.

Operating principle

In the gas-discharge lamp, the arc is ignited when the light is switched on. A high voltage of 18 to 20 kV is required for this to be possible. 85 V are required to maintain the arc after ignition. The voltage is generated and regulated by an electronic

11 Electronic ballast unit

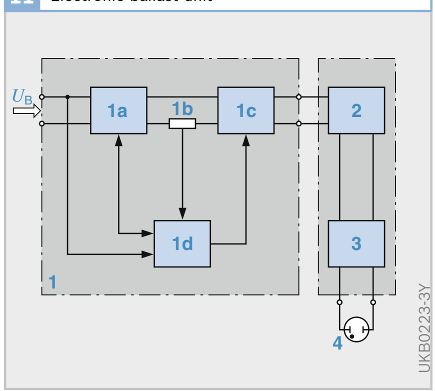


Fig. 11
Electronic ballast unit for 400 Hz alternating current supply and pulse ignition of the lamp

1 Control unit
1a DC/DC converter
1b Shunt
1c DC/AC converter
1d Microprocessor
2 Igniter
3 Lamp socket
4 D2S lamp
U_B Battery voltage

ballast unit (igniter, Fig. 11). After ignition, the gas-discharge lamp is operated for approximately 3 secs with an elevated starting current (approximately 2.6 A) so that it achieves maximum luminosity with minimal delay. The bulb's output in this period is anywhere up to 75 W. During continuous-running operation, it is 35 W.

The maximum luminous efficiency of approximately 90 lm/W is achieved once the plasma has heated the quartz glass to approximately 900 °C. Once the gas-discharge lamp has achieved maximum luminosity, the ballast unit reduces the current output to the bulb to approximately 0.4 A for continuous-running operation.

Fluctuations in the vehicle system voltage are for the most part compensated for by the ballast unit to prevent luminous flux variations. If the bulb goes out, e.g. due to an extreme voltage drop (below 9 V) or increase (above 16.5 V) in the vehicle electrical system, it is automatically reignited without delay. The reignition is limited to five attempts for safety reasons. The power supply is then interrupted by the ballast unit.

Bi-Litronic "Reflection"
The "Reflection" Bi-Litronic system makes it possible to generate the low and high beams using only one gas-discharge lamp (DR2 lamp) from a dual-headlamp system. The concept relies on an electromechanical positioner that responds to the high/low-beam switch by varying the attitude of the gas-discharge lamp within the reflector. It alternates between two different positions to generate separate projection patterns for low and high beam (Fig. 12).

This layout gives Bi-Litronic the following major advantages:

- Xenon light for high-beam operation
- Visual guidance provided by the continuous shift in light distribution from close to extended range

12 Bi-Litronic "Reflection"

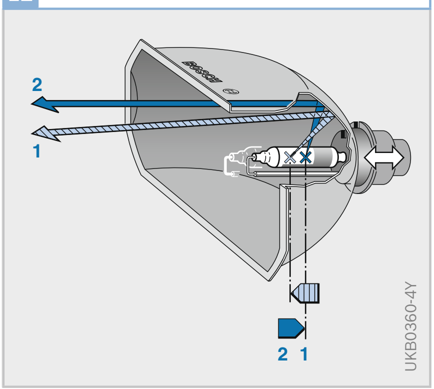


Fig. 12
1 Low beam
2 High beam

13 Litronic 4 system in reflection headlamp with integral dynamic headlamp leveling control (example)

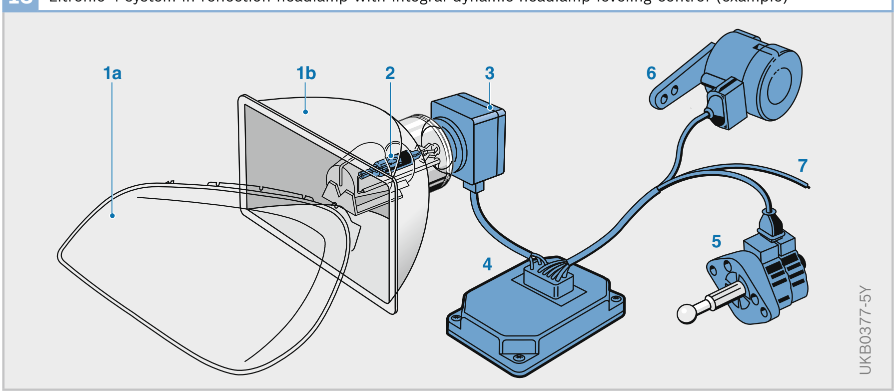


Fig. 13
1a Lens with or without scatter optics
1b Reflector
2 Gas-discharge lamp
3 Igniter
4 Control unit
5 Stepper motor
6 Axle sensor
7 To the vehicle electrical system

- Substantial reduction in space requirements as compared to a conventional quad headlamp system
- Lower costs through the use of just one gas-discharge bulb and one ballast unit per headlamp
- Greater freedom in headlamp design due to the individual reflector shape.

Special design variants of the Bi-Litronic "Reflection" lamp involve solutions in which the entire reflector is moved or individual components of the bulb cover are opened.

14 Bi-Litronic "Projection"

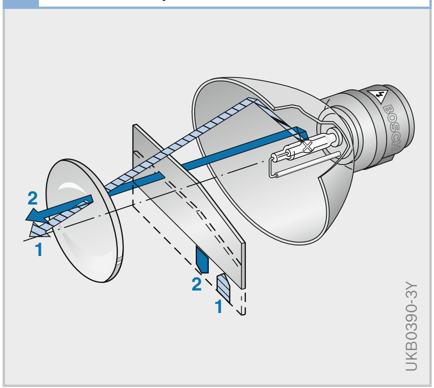


Fig. 14
1 Low beam
2 High beam

Bi-Litronic "Projection"
The Bi-Litronic "Projection" system is based on a PES Litronic headlamp. It shifts the position of the shutter for the light-dark cutoff to provide xenon light for high-beam operation.

With lens diameters of 60 and 70 mm, the Bi-Litronic "Projection" is the most compact combined low- and high-beam headlamp on the market, yet it still provides superb illumination.

The essential advantages of the Bi-Litronic "Projection" are:
- Xenon light for high-beam operation
- Most compact solution for high and low beams
- Modular system

Headlamp leveling control

Function

Without headlamp leveling control, the range of the headlamps would alter with a change in load or operating condition of the vehicle (constant-speed travel, stationary, acceleration, braking). The headlamp leveling control adjusts the tilt angle of the low beam to the tilt angle of the vehicle body. This results in a permanently good visual range with no dazzling of oncoming traffic under all load conditions.

15 Litronic 2 system in projection headlamp (example)

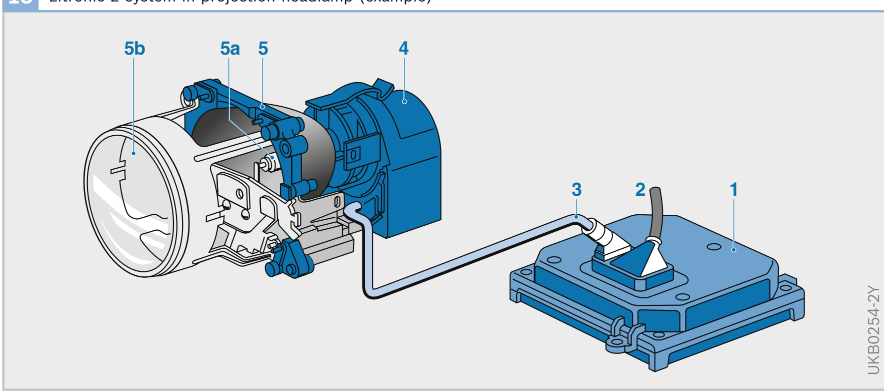


Fig. 15
1 Control unit
2 To the vehicle electrical system
3 Shielded cable
4 Igniter
5 Projection module
5a D2S lamp
5b Lens

Designs

All headlamp leveling controls feature actuators that move the headlamp reflector (housing-type design) or headlamp unit up and down. Automatic systems rely on sensors that monitor suspension travel as the basis for generating proportional signals for transmission to the aiming actuators. Manually operated units employ a switch near the driver's seat to control the setting.

Automatic headlamp leveling control

Automatic headlamp-leveling control systems fall into two categories: static and dynamic. While static systems compensate for load variations in the luggage and passenger compartments, dynamic systems also correct headlamp aim during acceleration – both from standing starts and when underway – and when braking.

The components of a typical headlamp-leveling control system include (Fig. 16):

- Sensors on the vehicle axles (Items 3 and 6) to measure the body's inclination or tilt angle.
- An ECU (5) that uses the sensor signals as the basis for calculating the vehicle's pitch angle. The ECU compares this data with the specified values and responds to deviations by transmitting appropriate triggering signals to the headlamps' servomotors.
- Servomotors (2) to adjust the headlamps to the correct angle.

Static system

In addition to the signals from the suspension sensors, the static system's control unit also receives a speed signal from the electronic speedometer. The controller relies on this signal to decide whether the vehicle is stationary, undergoing a dynamic change in speed, or proceeding at a constant speed. Automatic systems based on the static concept always feature substantial response inertia, so the system corrects only those vehicle inclinations that are consistently registered over relatively long periods.

Each time the vehicle has pulled away, it corrects the headlamp adjustment as a function of the vehicle's load. This adjustment is checked again when the vehicle steadies into constant-speed travel and is then corrected if necessary. Deviations between the target and actual position are evened out by the system.

The static system only generally requires a sensor on the rear axle of the vehicle. A DC motor is used as each headlamp's actuator.

16 Principle of an automatic headlamp-leveling control system (dynamic system)

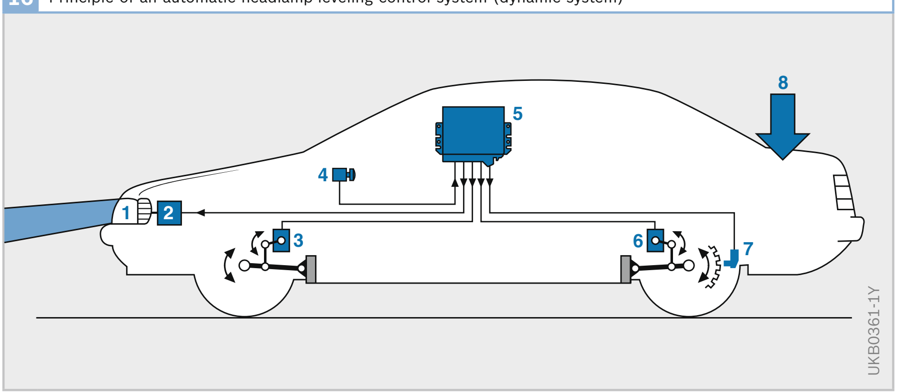


Fig. 16
1 Headlamp
2 Actuator
3 Front-suspension travel sensor
4 Light switch
5 Electronic control unit
6 Rear-suspension travel sensor
7 Speed sensor
8 Load

Dynamic system

The dynamic automatic system relies on two distinct operating modes to ensure optimal headlamp orientation under all driving conditions. Supplementary capabilities in speed-signal analysis over the static headlamp leveling control endow the system with the ability to differentiate between acceleration and braking.

With the vehicle driving at constant speed, the dynamic system, like the static system, remains in the range that features a high level of damping but as soon as the controller registers acceleration or braking, the system immediately switches to its dynamic mode. Faster signal processing and the higher servomotor adjustment speed allow the headlamp range to be re-adjusted within fractions of a second. Following acceleration or braking, the system automatically reverts to operation in its delayed-response mode.

Due to the greater dynamics requirements, the dynamic system needs one sensor per vehicle axle and rapid stepping motors to adjust the headlamps.

Adaptive lighting systems

Adaptive frontlighting system (AFS)

From 2007, function enhancements for headlamp systems based on a new EC control are permitted. The vehicle may then also have motorway lights, adverse weather lights and city lights. The optimum light pattern for each of the functions is identified and automatically selected by the vehicle electronics in response to evaluation of various vehicle sensors.

The first vehicles with AFS systems were registered back in mid-2006 thanks to an EU waiver for road traffic.

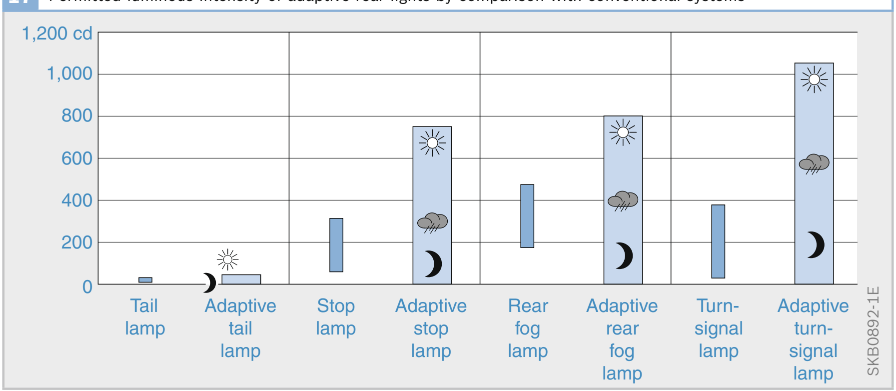
Adaptive rearlighting system (ARS)

Until now, the rear lights for vehicle perimeter lighting were equipped with single level switching. Depending on the type and design, these produced an invariable luminous intensity within the legal limit values.

Today, a multitude of sensors are used to determine environmental parameters and light conditions (brightness, dirt, visual range, wet conditions, etc.). To achieve optimum visibility (sufficient luminous intensity without excessive glare), the rear lights may in future vary luminous intensity to suit the vehicle surrounding (Fig. 17).

A stop lamp, for example, would be lit with high luminous intensity in sunlight and with low luminous intensity at night to ensure that other road users are able to recognize and draw the correct conclusion from the action of the vehicle.

17 Permitted luminous intensity of adaptive rear lights by comparison with conventional systems



Cornering lights (Europe)

The cornering lights function that has been approved for use in Germany since 2003 improves visual range on corners and in turning situations. This is made possible by a variation of the horizontal illumination of the area in front of the vehicle. With static cornering lights, this is achieved by supplementary reflectors being switched; with dynamic cornering lights, the headlamp module is pivoted laterally (Fig. 18).

During the control process, the light module or the reflector elements are pivoted by a stepping motor. The pivot angle and pivot speed are calculated by the cornering lights ECU as a function of vehicle speed and the steering angle. Sensors detect the adjustment angle of the headlamps and use failsafe algorithms to prevent dazzling of oncoming traffic in the event of a system malfunction.

18 Aiming strategy of the basic and turning modules of a static/dynamic cornering headlamp (left side)

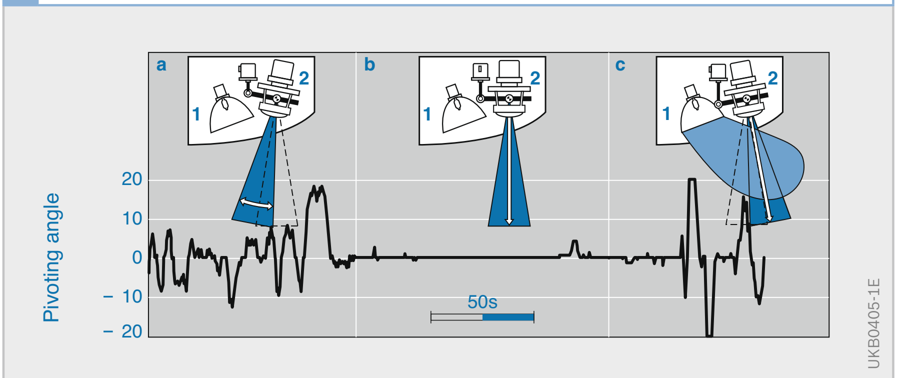


Fig. 18
a “Country road/ bends” position
b “Motorway” position
c “Town/turning” position
1 Turning module
2 Basic module

19 Improvement in the adaptive light pattern of the cornering headlamps

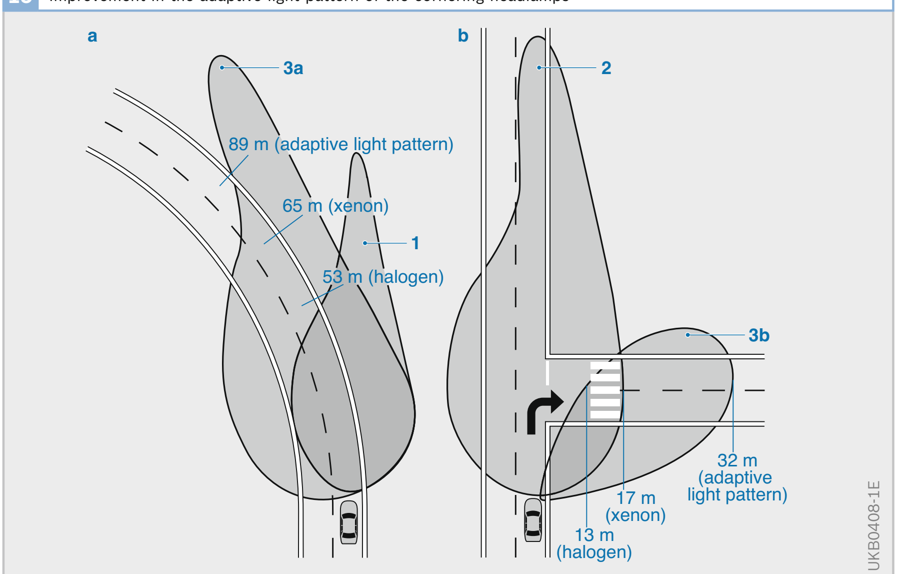


Fig. 19
a Dynamic cornering lights, cornering to the left
b Static cornering light, turning to the right
1 Light pattern of halogen headlamps
2 Light pattern of xenon headlamps
3a Adaptive light pattern: dynamic cornering lights
3b Adaptive light pattern: static cornering lights

1 Specifications for motor-vehicle bulbs (2-wheeled vehicles not included)

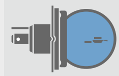
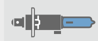
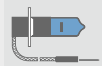
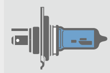
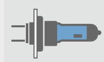
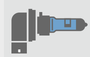
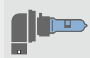
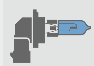
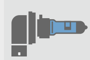
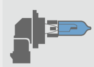
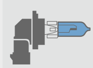
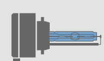
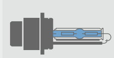
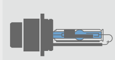
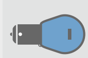
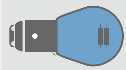
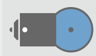
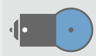
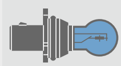
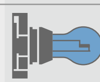
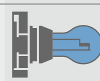
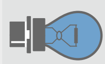
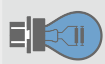
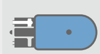
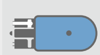
Application	Category	Voltage rated value V	Power rated value W	Luminous flux setpoint value Lumen	IEC base type	Illustration
High beam, low beam	R2	6 12 24	45/40[1] 45/40 55/50	600 min/ 400–550[1]	P 45 t-41	
Fog lamp, high beam, low beam in 4-headlamps	H1	6 12 24	55 55 70	1,350[2] 1,550, 1,900	P14.5 e	
Fog lamp, high beam	H3	6 12 24	55 55 70	1,050[2] 1,450 1,750	PK 22 s	
High beam, low beam	H4	12 24	60/55 75/70	1,650/ 1,000[1], [2] 1,900/1,200	P 43 t-38	
High beam, low beam in 4-headlamps, fog lamp	H7	12 24	55 70	1,500[2] 1,750	PX 26 d	
Fog lamp, static cornering light	H8	12	35	800	PGJ 19-1	
High beam	H9	12	65	2,100	PGJ 19-5	
Fog lamp	H10	12	42	850	PY 20 d	
Low beam, fog lamp	H11	12 24	55 70	1,350 1,600	PGJ 19-2	
Low beam in 4-headlamps	HB4	12	55	1,100	P 22 d	
High beam in 4-headlamp	HB3	12	60	1,900	P 20 d	
Low beam, high beam	D1S	85 12[5]	35 approx. 40[5]	3,200	PK 32 d-2	
Low beam, high beam	D2S	85 12[5]	35 approx. 40[5]	3,200	P 32 d-2	
Low beam, high beam	D2R	85 12[5]	35 approx. 40[5]	2,800	P 32 d-3	
Stop, turn-signal, rear fog, reversing lamp	P 21 W PY 21 W[6]	6 12 24	21	460[3]	BA 15 s	

Table 1

1 Specifications for motor-vehicle bulbs (continued)

Application	Category	Voltage rated value V	Power rated value W	Luminous flux setpoint value Lumen	IEC base type	Illustration
Stop lamp/ tail lamp	P 21/5 W	6 12 24	21/5[4]) 21/5 21/5	440/35[3]), [4]) 440/35[3]), [4]) 440/40[3])	BAY 15 d	
Side-marker lamp, tail lamp	R 5 W	6 12 24	5	50[3])	BA 15 s	
Tail lamp	R 10 W	6 12 24	10	125[3])	BA 15 s	
Daytime running light	P 13 W	12	13	250[3])	PG 18.5 d	
Stop lamp, turn signal	P 19 W PY 19 W	12 12	19 19	350[3]) 215[3])	PGU 20/1 PGU 20/2	
Rear fog lamp, reversing lamp, front turn signal	P 24 W PY 24 W	12 12	24 24	500[3]) 300[3])	PGU 20/3 PGU 20/4	
Stop, turn-signal, rear fog, revers-ing lamp	P 27 W	12	27	475[3])	W 2.5 x 16 d	
Stop lamp/ tail lamp	P 27/7 W	12	27/7	475/36[3])	W 2.5 x 16 q	
License-plate lamp, tail lamp	C 5 W	6 12 24	5	45[3])	SV 8.5	
Reversing lamp	C 21 W	12	21	460[3])	SV 8.5	
Side-marker lamp	T 4 W	6 12 24	4	35[3])	BA 9 s	
Side-marker lamp, license-plate lamp	W 5 W	6 12 24	5	50[3])	W 2.1 x 9.5 d	
Side-marker lamp, license-plate lamp	W 3 W	6 12 24	3	22[3])	W 2.1 x 9.5 d	

1) High/low beam. 2) Setpoint values at test voltage of 6.3; 13.2 or 28.0 V.
3) Setpoint values at test voltage of 6.75; 13.5 or 28.0 V. 4) Main/secondary filament.
5) With ballast unit. 6) Yellow-light version.