let light be there

Brighter automotive beams, though they pierce the dark, can rob other drivers of night vision. Lighting experts see the problem from both sides.

By Paul Sharke, Associate Editor

If today's lighting designers get their way, engineers will one day expand their sight deeper down black roads. But doctors, lawyers, and other high rollers may see farther first. For the rest of us, the price of sophisticated auto lighting for now may be too big a cost to bear.

According to Ford's Mario Campos, a project manager at the company's Dearborn, Mich., safety office, HID, or high energy discharge, lighting debuted in the automotive world with its 1991 installation into high-end BMWs. Mercedes, Lincoln, and Lexus followed. Recently, automotive lighting supplier Hella of Lippstadt, Germany, said it would furnish bi-xenon headlighting for the Volkswagen Passat W8. It is a system similar to that found aboard Porsche 911 Turbos.

Along with xenon HID systems come leveling systems and lamp washers to keep the bright lights from blinding approaching motorists. From there, it's mere steps to the so-called adaptive front lighting systems now being developed. These systems propose shutters and lamp combinations to put light where and when it's needed most.

Lights out in front: Hella developed prototype headlamps for the Volvo SCC, Safety Concept Car. Glass fiber bundles guide light from a central xenon source out to three Fresnel lenses.

To any driver who has longed to see more than just a barrage of snowflakes rushing up from the night, the new luminaires could bring blessed relief. Yet, for those who've had to stare spellbound into the bright white of onrushing autos, fancy lamps might seem mere highway weaponry that will land in the quivers of a few dim bulbs. How then to give to some without taking from others—that is the engineering question.

The advantage of, and trouble with, high intensity discharge lighting is that it more than triples the output of halogen bulbs while consuming fewer watts. According to Campos, feeding 33 watts into an HID headlamp yields nearly 5,200 lumens; putting 60 watts into a halogen bulb gives off a mere 1,600. The light from an HID lamp, said to be closer to the hue of natural light and thus thought to be better at illuminating a rain-wrapped road, comes from an electrode-ignited xenon atmosphere.

It takes a big jolt to start that ignition, Campos said, about 20,000 volts. A ballast is needed. But the bulb itself is no bigger than a halogen lamp; the ballast can be located beyond the shell of the headlamp assembly. So the HID bulb adapts well to existing headlamp structures.

Structures today have moved completely away from sealed beam assemblies, relying instead on aerodynamic housings whose shapes are designed to flow with the contours of car bodies. Even before automotive HID lighting arrived, halogen bulbs had sought independence from their housings, Campos said, not only to free up lens shapes to the whimsy of stylists but to reduce drag as well. Aero headlamps first appeared in the 1984 Lincoln Mark VII, Campos said.

Then, in the late 1980s, Honda introduced complex reflector lamps, which moved the responsibility for beam focusing back to a reflective surface and away from a lens. Still another kind of aero headlamp combined bulb, lens, and reflector in a compact assembly. Called projector lamps because of their similarity to the assemblies used in slide projectors, the units focus light through fish-eye lenses held near the bulbs. In either case, the housing lens could be simplified optically. It no longer needed to bear the burden of directing illumination.

Campos pointed out that the price of vehicle lighting rose with the coming of halogen bulbs, then again with aero lamps, and still again with HID lighting. The Lincoln Mark VIII, Ford's current offering with HID lighting, doubled the cost of the already expensive halogen lamp that it replaced, said Campos. Yet the systems look identical on their outsides. And the HID lamps incorporate no dynamic leveling control, as mandated for European markets. According to Campos, those systems cost even more.

Eureka study

Brussels-based Eureka, a European program for the promotion of research and development, began defining requirements for advanced headlamp systems through an industrial group in 1993. According to Manfred Gaugel, secretary to the directorate of the project, the group submitted the resulting draft regulation to the various governing boards just last year. Thus, the process of advanced headlamps becoming a European standard, which Gaugel said takes four to five years and involves several steps, is under way.

Funded by Eureka Project EU 1403, member countries Austria, France, Germany, Italy, the Netherlands, and Sweden, and by a lengthy list of manufacturers (BMW, Bosch, Daimler-Benz, Fiat, Ford, Hella, Magneti-Marelli, Opel, Osram, Philips, PSA, Renault, Valeo, Volkswagen, Volvo, and ZKW), the Advanced Front Lighting System study, or AFS, went beyond current European regulations governing discharge lighting. At least one existing regulation, ECE No. 98, already calls for auto-leveling and cleaning systems for discharge lights, Gaugel said.

The project was split into three phases. First, to determine the feasibility of adaptive, flexible lighting, AFS used a rack-mounted cluster of 16 different light fixtures to track how well someone outside a car could tell from its lighting that it was, in fact, a vehicle. Another area of concern was how well a pedestrian could gauge the speed of an approaching car from the assortment of lighting arrangements. Then, using the same rack of lamps and, in some cases, controlling them manually, the group made preliminary judgments of lighting schemes for adverse weather driving, cornering, highway running, and sign reading.

For the second phase of the project, the headlamp and car makers outfitted a half-dozen automobiles with special lights. They dedicated each car to at least two specific, optional illumination settings, whether rounding a bend, rolling along a country lane, or poking about town.

Carrier bars hold a range of lamps for studying adaptive front lighting systems. Early into the Eureka study, test bars helped researchers answer initial questions.

Among the notable results, lighting that reduced glare on wet roads helped both the operators of AFS-equipped cars and the drivers of opposing vehicles. A second find was that the more intense a glare, the more it disturbed oncoming drivers. No surprise there. But the size of the light source affected the level of discomfort. After sources were normalized to the same luminous intensity, the researchers discovered that small areas of glare were more disturbing than large ones.

Another phenomenon, called dynamic glare, occurred as vehicles changed attitude—during braking or acceleration, for example, or when traversing rough roads. Momentary flashes disturbed opposing drivers more as their duration increased. Light pulses lasting less than a half-second were generally tolerated. Those lasting longer than eight to 10 seconds degraded visual performance because of the longer time for eyes to readapt to lower light levels once the pulse ceased. One practical application of this knowledge will be in smoothing the transitions between adaptive lighting modes, Gaugel said.

In many of these studies, AFS received support from leading European research institutes (funded by the project members).

To promote a global acceptance of the AFS ideas, Eureka invited Japanese and U.S. companies to cooperate in phase three of the project, including the final preparation and submission of the proposal for a draft regulation.

Among the reasons that European standards mandate self-leveling HID systems while U.S. standards don't may be the different philosophies that guide lighting system design. According to Michael Flannagan, a senior scientist at the University of Michigan's Transportation Research Institute, European regulators' concern over glare contrasts with U.S. regulators' emphasis on maximizing vision. For many decades, low beam patterns have been different between the two regions, he said.

To explain the difference, Flannagan referred to an isocandela diagram, a chart of concentric rings used to plot equal areas of lighting intensities. A simple picture, really, of what you see from a lamp beam projecting on a wall, isocandela diagrams are produced by analyzing light beams with instruments called goniometers, he said.

Imagine a line that runs straight out from lamp to wall. The point where it hits the wall Flannagan designated HV.

European patterns exhibit a sharp line at HV between the bright lower part of the beam and the dark upper part. U.S. patterns diffuse. U.S. beams point down and to the right. U.S. patterns resemble "more of a blob," he said, and cast light farther up the road.

The sharp line on the European pattern—what Flannagan called the vertical cutoff—translates to a similarly distinct separation between light and dark at the road surface. "European patterns go out to 60 meters, then stop," he said. You can see a fairly sharp line, he added.

U.S. lamps direct more light at distant objects, Flannagan said. But, they also direct more light into the eyes of passing motorists.

"It's a tradeoff," he said. "U.S. and European designs are simply two points on that tradeoff." Both sides will argue that theirs is the right way, "but they're just different," he said.

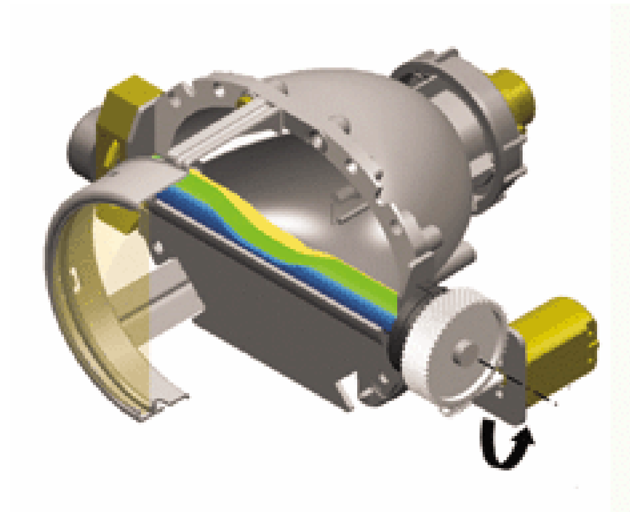
A change may be on the way, though. The U.S. federal standard governing auto lighting safety, FMVSS 108, has begun permitting headlamp aiming by visual as well as mechanical means, Flannagan said. Most U.S. lamps have three pips that provide reference points for a spirit level, according to Flannagan. That is the mechanical method for aiming lamps. Yet, very few car owners pay any attention to headlamp aim, he said. Those who do (ME readers, anyone?) are not likely to use a level, but instead will simply shine them on a wall and start turning screws. Aiming the diffuse beam of a typical U.S. lantern in that manner sometimes yields haphazard results, though Flannagan stressed that checking the headlamps that way was better than neglecting their maintenance altogether.

Much like their European counterparts, new U.S. lamps that are capable of being aimed visually—so-called visual optical aim headlights—have sharp vertical cutoffs, Flannagan said. Because the line between light and dark is distinguished easily, aiming them by throwing their beams upon a wall is exactly the method prescribed.

"A sharp vertical cutoff makes it easier to aim visually; it also makes aim more critical," Flannagan said.

Vertical aim happens to be very important for headlamp performance. In a study at the University of Michigan's Transportation Research Institute, which compared vertical and horizontal aim of headlight performance as well as mounting height, lateral separation, lens dirt, voltage, number of working lamps, beam pattern, and light source, vertical aim was found to be "overwhelmingly the most important factor in influencing the performance of low-beam headlamps," according to the report.

"The message for car owners," Flannagan added, "is you really ought to aim your headlamps."



A collection of free-form surfaces in front of the bulb could dial in the appropriate lighting to match the situation, said Hella, the manufacturer.

Above the vertical cutoff, European headlamps project virtually no light, so they would be less capable of illuminating overhead signs. As such, signs practically pop out from the darkness only as a car passes beneath them. A sharp vertical cutoff and downward aim are due in part to a desire by European governments to minimize glare.

The U.S. National Highway Traffic Safety Administration is fielding more complaints about glare as lighting systems evolve. Many complaints of glare pepper NHTSA's public docket. Complaints identify high intensity discharge headlamps and sport utility vehicle headlamps, claiming that both are too bright and the latter are too high. While low-glare European headlamps could solve the problem, they would shorten a driver's view down the road. Even so, there are efforts underway to blend the best of both systems.

European and American standards for automotive lighting may never converge. The philosophies behind each standard and the ways that they apply are very different. U.S. standards say, in effect, here are things you must have on a motor vehicle. European standards instead say here are the only things you can have.

Take an adaptive front lighting element such as a swiveling lens, for example. A manufacturer might design the lights to turn left or right with the turn of the wheel. Another might make them swivel only when the car is moving above a certain speed. In the second case, the speed restriction prevents a stopped car, with wheels turned, from blinding a passing motorist.

Because a U.S. standard does not restrict design, it would not necessarily prohibit either part-time or full-time swiveling lamps. It wouldn't even mention them. So long as the standard doesn't ban a system's use, any manufacturer building cars for the United States could use one of the swiveling lamp setups, or none, or any alternative, as it saw fit. But a manufacturer building for Europe would be unable to supply either kind of swiveling lamp unless the standard specifically permitted it.

Intelligent lamps

European lighting manufacturers, such as Hella, work in conjunction with automakers, other lighting manufacturers, and research groups in demonstrating for regulators the technology that might one day be required on cars there. Looking ahead to 2005, when the Eureka standard could be law, Hella is designing intelligent lighting systems capable of producing as many as five different beams from a single bulb. At the system's heart lies a projection lamp and something the company describes as a free-form cylinder.

Hella engineers developed free-form reflectors during the late 1980s, as a step up from parabolic reflectors, which dominated the automotive industry for nearly a century. Rather than casting a parabolic cone of light and then having to shield half of it to comply with European requirements, every point on the free-form reflector is calculated so it reflects light rays out to specific parts of the road.

When adaptive front lighting standards take effect in Europe, fixed beam patterns (top) will be able to change automatically (bottom) to meet road and lighting conditions. Pictured here, swiveling lamps illuminate bends in the road.

Intelligent lighting uses similar free-form technique to produce a cylinder with several contours that can rotate in front of the light source. As a vehicle's sensors detect changes in lighting requirements, the appropriate surface comes around to cast the right pattern.

Hella's bi-xenon lamp, mentioned earlier, brings intelligent lighting systems closer to realization. A two-stop shutter provides the necessary cutoff for a dipped beam. In this way, two beams are made to share a single source.

Ford's Campos considered the day when the entire front and rear lighting ensemble would be illuminated through one or two high intensity discharge sources and piped out to projection points via fiber optics. This was one way in which the cost of advanced lights could be brought closer to the reach of the average car buyer, he said. But for now, Campos said he thought pricey HID lighting would remain an option on only the most luxurious cars.

In a technical paper Campos presented at the 2000 SAE World Congress, he compared replacement costs between HID and halogen headlights for several luxury cars that offered the option. Replacing an HID lamp and self-leveling system cost about $500 more than replacing a halogen lamp, which alone cost hundreds more dollars to replace than the old sealed beams that could be bought for a dozen bucks at the local mart.