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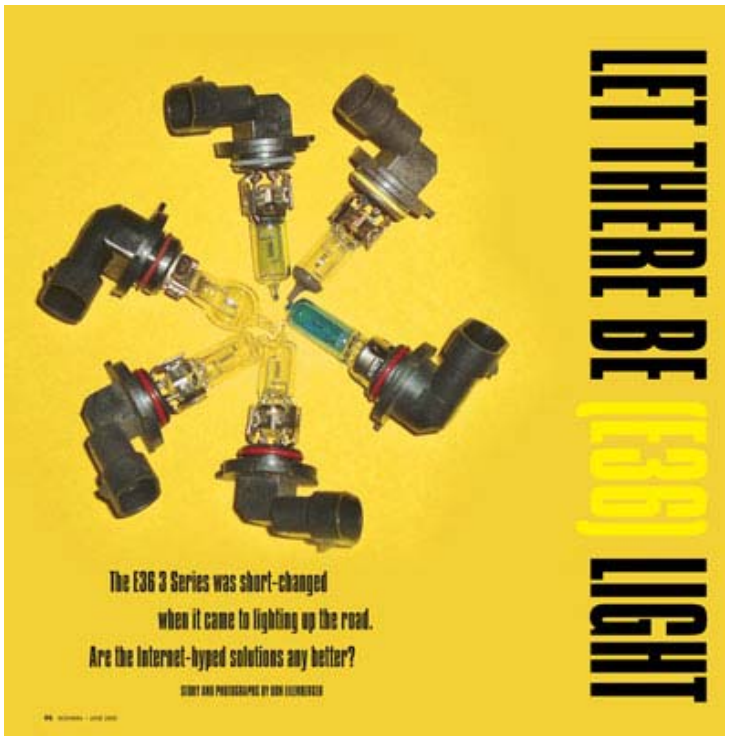
Let There Be (E36) Light

By Don Eilenberger

June 2005

The E36 3 Series was short-changed when it came to lighting up the road. Are the Internet-hyped solutions any better?



I recently purchased a slightly (well) used ’98 M3 convertible, and found to my dismay that it was barely drivable at night due to the abysmal light the stock headlights provided. I have owned a number of BMWs and currently also own a 2003 525iT with the factory HID light option. Other BMWs I’ve owned where the lighting seemed fine were an ’87 535i, a ’92 525i, a ’99 M coupe, and a ’98 528i; all of these had stock factory lighting, and while not at HID levels, the light available was adequate.

The lack of light set me off on a search for better lighting for the E36 series. What I’ve found out might be of interest to other E36 owners, but it’s quite extensive; so this is the first of two articles. Our first goal is improving the stock headlights and using alternative bulbs in them; the second will examine the process of replacing the stock U.S. headlights with Euro-pattern ones, available from a number of vendors in the USA.

U.S. E36 headlight design, or how’d we get these awful lights? There have been claims that the primary pattern difference between U.S. and Euro headlight standards is due to the extensive use of non-illuminated overhead signs in North America and the widespread use of self-illuminated signs in Europe. This claim actually is not true, since self-lit overhead signs are almost as rare abroad as in North America. Both U.S. and European standards have identical minimum requirements for upward light from low beams to illuminate overhead reflective signs; there is also a maximum value, which for the U.S. specifications is much higher than the Euro ECE headlight standard. U.S. headlamp designs generally greatly exceed the minimum overhead standard, while European headlamp designs stay closer to the minimum values.

The headlights used on the U.S. E36 series BMW were designed to meet the specifications of Federal Motor Vehicle Safety Standard 108 *at the time the lights were designed.* The U.S. design remained unchanged for U.S.-bound vehicles for the entire E36 production run. The design was marginal when new due to the construction and design of the optics, and the potential loss of power to the bulbs due to BMW’s “just adequate” electrical wiring.

The problems with the E36/U.S. headlights are compounded as the vehicle ages due to the physical construction of the U.S. headlights; instead of using glass for the front cover, they use a somewhat fragile polycarbonate (plastic) front cover, which is easily pitted and easily scratched. It also deteriorates due to UV exposure from the sun, causing it to become a milky color—the effect is comparable to cataracts in human eyes. The deterioration of this plastic cover will cause a reduction from the meager light the headlight gives when new. Due to the U.S. laws regulating this type of headlamp, it could not be fitted with a replaceable cover. All of our E36s are at least six years old at this time—and time has not been kind to the majority of the headlight covers.

Those of us with the original lighting on their U.S. E36 are stuck with a design that was marginal when it was first designed. The question is, can it be improved on?

Maximize the available lighting: The first thing to do with the stock headlights on an E36 is to make sure you’re getting as much available light as possible to the road. Most E36s have considerable mileage— they are the

Ultimate *Driving* Machine, right?—and the polycarbonate headlight covers are often badly pitted and scratched. Some headlight covers also have turned a semi-translucent white color caused by the plastic deteriorating due to environmental conditions (or the use of excessively harsh car-wash detergents.)

Good news: in many cases the plastic covers can be made nearly as new with a bit of work by the owner (see sidebar). Unfortunately, due to the non-replaceable front lens design of the U.S. E36 headlight assembly, it isn't possible to remove the internal lenses and clean them. Over a period of years these can have a film form on them that not only reduces the light output, but also increases glare from the headlight. I know of no good answer to this problem— but getting the headlight cover clear again, and keeping it that way, is a big step forward in making the best use of the light available from the stock system.

Owners may also consider adding headlight relays to the wiring on an E36. The wiring of the headlight circuits was barely adequate for the current drawn when the electrical system was new. The use of higher-wattage bulbs will certainly overload these circuits, and the circuit performance deteriorates with age, dropping the voltage to the lamps. The light available from a bulb is greatly affected by a voltage drop of only 10-20%. This sort of drop (1.2-2V) can result in a 40-70% reduction in available light. The use of relays located near the bulbs and powered with adequate feeds can reduce the voltage drop to less than a few percent when constructed and installed correctly. On my '98 M3, I measured a 0.75V drop between the jump-start post under the hood and the positive feed on the high-beam bulb. This resulted in a measured 15% loss of light output from the bulb—which was a standard-wattage bulb.

Consider other sources of light: Polishing the headlights did help somewhat, but the lighting was still marginal. My next try at improving the lights on my M3 was to try alternative bulbs in the stock headlight housings. There is a wide variety of alternative bulbs available in the E36 stock light types— some good, some not so good. I gathered a sample of each of what I thought might be useful improvements over stock, or heavily marketed lamps, and tested them.

I tested the alternative bulbs both on a test-bench and on the road. I purposely concentrated on the low beam, since that was the beam that needed the most improvement. The high beam on the stock headlight with a stock bulb was acceptable to me, although there is no doubt it might be improved.

There were certain bulbs I didn't concern myself with, since all reference material I could find on them presented them as not providing useable light; these were the *dichroic coated* bulbs, which produce light of changing color depending on your viewing angle to them.

I wouldn't suggest using higher-wattage bulbs for several reasons: They have the potential do damage the headlight housing due to the additional heat they produce; they have the potential to damage the headlight wiring due to the additional current they consume; and even if properly fed, they produce too much glare for use in traffic.

Stock halogen bulbs: The stock bulbs used in the E36/U.S. headlights are a 9006 low beam and a 9005 high beam. This series of bulbs was developed in response to the 1983 decision by NHTSA to allow replaceable- bulb headlights in addition to the sealedbeam lights that had been mandatory since 1940. The requirements for the replaceablebulb headlight required the replaceable bulb to have an integral seal: on these bulbs, the O ring around the base. These halogen bulbs also featured an extended life compared to other available bulbs, making them attractive to U.S. auto marketers, who tend to include even such consumables as bulbs in the new-vehicle warranty.

The stock bulbs are a 9006 (HB4) 55-watt low-beam bulb and a 9005 (HB3) 65-watt high-beam bulb. They are available in any auto-parts store and are produced by almost every bulb manufacturer. These identical bulbs are referenced in the ECE regulations as HB4 and HB3. They are low-cost, being easily found for $6.00 with a bit of shopping. But used in the stock BMW E36 U.S. headlight housings, they do not produce a lot of useful light. The pattern is a diffuse one with a bright central spot. Poor quality and dirty optics, and voltage drop to the bulb due to marginal wiring, reduce even more the minimally useful light produced.

Higher-wattage bulbs: Higher wattage 9006/9005 bulbs are available from several sources. The higher current draw produces more light—but also more heat—from the bulbs. While the increase in light output might seem desirable, there are several disadvantages to using high-wattage bulbs in the BMW E36. First, the factory headlight wiring on an E36 isn't capable of supporting the additional current draw of a higherwattage bulb. The bulb will run at less than the designed voltage, which in turn causes it to produce less light and have a shorter lifetime. It also presents the very real possibility of damage to the stock wiring harness, and dangerous glare to other road users. Use of an over-wattage bulb without the use of headlight relays on your BMW is literally playing with fire.


High-wattage bulbs

A secondary concern is the possibility of headlight damage caused by the additional heat of a higher-wattage bulb. And there are also concerns that these bulbs may be produced by off-brand companies using obsolete manufacturing equipment, producing products of low quality. If the manufacturing process doesn't assure very accurate placement of the filament, it can have a large effect on the beam performance and glare produced.

In all cases, when increasing light output, the glare perceived by oncoming traffic will also increase. The question is then if the glare presents a danger or is excessive. Apoorly-manufactured bulb—or one that produces too much light for the optics—may increase the possibility of dangerous levels of glare.

Higher-wattage bulbs typically sell at a premium price, $15-30 per bulb. They're available at some major auto-parts stores, or through mail-order and web sales.

continued »

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Higher output "same wattage" halogen bulbs: There are bulbs available that claim to produce more light while drawing the same current as the stock 55-watt and 65-watt bulbs. Their ads frequently make claims like "55watts = 90watts." This sort of claim is a hint that the advertising/marketing staff has gotten ahead of the engineering staff; use of this sort of equivalency rating has no basis in fact, since wattage is not a measure of light output.

Xtravision 9005 bulb

These bulbs are available from various sources, from large reputable manufacturers to smaller marketers; the quality varies greatly, depending on the manufacturing source. The actual amount of light produced frequently does not match the manufacturer's claims, and some of them alter the beam pattern, making the increased light less useful. However, some of these bulbs do produce more light than a standard halogen bulb design. Brands from major manufacturers include bulbs such as the Sylvania "Xtra- Vision," GE "High Output" and "Night- Hawk," Philips "High Visibility" and "VisionPlus," and Narva "Rangepower."

These bulbs also tend to have shorter lifespans than a standard halogen bulb of the same wattage. The changes made to the bulb filament to produce more light with the same current draw also may adversely change the pattern of the light produced when mounted in the headlight reflector.

Typically selling at a premium price—$15 to $20 per bulb—"higher output same wattage" bulbs are available at any major auto-parts store, or by mail-order and web sales.

"Blue" or "whiter" bulbs: These are bulbs that the manufacturer claims make "whiter," or sometimes "blue" light. There are bulbs available from reputable manufacturers claiming to make "whiter" light; this is really a marketing term, 2 and advertisers rarely claim any increase in actual light output. The claim may be made that the user can see better with these bulbs due to the whiter color of the light produced, and often a big deal is made of the bulbs' "color temperature," which, like wattage, is not a measure of light output or effectiveness.

There are bulbs available from other sources that claim that they produce not only bluer light but also *more* light. In testing, the claim of "more light" is frequently found to be inaccurate, because to achieve the bluer appearance of the light, a blue filter coating is put on the bulb. The blue filter absorbs visible light with the result that the actual light output is less than another lamp of the same wattage. Moving the spectral output of the lamp toward the blue end of the spectrum also moves it toward the end where the human eye has problems processing it; this, too, lessens the effectiveness of the bulb.

Sylvania SilverVision Bulb

These bulbs are frequently advertised as "xenon" bulbs. This is only partly accurate. HID bulbs do use xenon gas in their envelope. Standard halogen bulbs also may use some percentage of xenon gas to improve thermal efficiency, but the amount is relatively low—in the single-digit percentages. Too much xenon in a tungstenhalogen bulb will lessen the lifetime of the bulb. The claim of "xenon bulb" is intended to imply that the bulbs are HID bulbs— which they are not. Claims of 50%, 100% xenon are simply bogus—and a hint to avoid the vendor who makes such claims.

Examples of the "whiter" type of bulbs are Sylvania SilverStar, PIAA Star White, Wagner Tru-View, and Philips BlueVision. Examples of the "blue" type of bulbs are numerous ones from small sources and some from PIAA ("Xtreme White Plus").

There are no advantages to "whiter" or "blue" bulbs, in my opinion, unless you're an HID pretender. There has been a lot of debate over whether humans can "see better if the light is whiter." Studies done by the University of Michigan indicate that as the lighting color moves from white toward blue, the effect of glare becomes more of a problem, especially as eyes age. Manufacturers of the blue bulbs claim otherwise.

Blue also being a shorter wavelength of light causes more "scatter"—i.e., diffuse reflections within the human eye—than longer-wavelength light. Scatter is undesirable. The use of yellow bulbs/lights for fog lights is directly related to this; the yellow effectively eliminates almost all the blue components of light, greatly lessening apparent backscatter in foggy conditions. There is an excellent discussion on the effect of blue bulbs and human vision by Daniel Stern of Daniel Stern Lighting: see www.danielsternlighting.com/tech/ bulbs/blue/bad/bad.html.

Besides frequently having less useable light output and a shorter life, the blue-color bulbs can cause additional glare to oncoming drivers; they typically sell at a premium price, $19-50 per bulb.

HIR bulbs: HIR bulbs are the result of research done at General Electric to develop a bulb with 80% of the light output of an HID bulb at 20% of the cost. They represent a different design for a halogen bulb that maintains the filament positioning and dimensions of the 9005/9006 series bulbs. Where they differ from standard 9006/9005 bulbs is in the shape of the bulb "envelope" (the outer quartz covering of the bulb.) HIR bulbs have a spherical portion of the envelope designed in concert with an internal reflective coating to reflect heat from the filament that is normally wasted back on the filament to make it burn brighter. This reuse of normally wasted heat allows the bulb to produce more light without drawing more current. They also have a very slightly different base to prevent their use in 9005/9006 headlight housings.

These bulbs are used on vehicles such as Nissan Maxima, Infinity I30, the Dodge Viper, and the BMW Z8. People have used these in 9005/9006 headlight housings by trimming one tab on the base of the bulb. Advantages: More light with the same current draw (doesn't overload the wiring). Produces less heat than even a stock bulb of the same wattage. Reasonable cost vs. performance. Normal tungsten-halogen bulb lifetime. Same filament positioning as 9006/9005 bulbs, maintaining the standard pattern of the stock headlight.

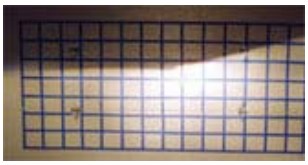

HIR 9011 Bulb

However, HIR bulbs are relatively difficult to find—and expensive. Available by mail order and web sales only, they also have the potential for increased glare with the increase in light output. Though they must be modified (tab reduced in size) to fit in a 9006/9005 housing, directions for doing this are easily found on the Internet.

I have recently found several web sites that are selling a Polarg version of the HIR light that looks *exactly* like the original GE bulb design. I would be cautious in purchasing these bulbs, since supposedly the reason GE got out of the HIR bulb business was that their design had problems leading to inadequate reliability and bulb life in real-world use. Polarg appears to be manufacturing these in China; they also list them as direct replacements for the 9005/9006 series bulbs, so they may have modified the base to make them usable in 9005/9006 headlight housings.

The bulbs I tested are made by Toshiba, and while they use the GE-patented technique of a high-reflective IR coating inside the capsule, they have also been redesigned to make the design more reliable. The Toshiba bulbs I tested were $29.95 each plus shipping. They require a minor modification to one locating tab to fit in the U.S. housings. The Polarg bulbs which apparently have 9005/9006 bases are priced at $75-130 per set.

Testing: To test some of the claims made for various bulb designs, I decided to set up a test station in my garage that would use standard parameters for the testing, and equipment that would allow for repeatable measurements.



The photo shows a grid I created on the inside of my garage door (with a Europrojector light under test). The grid is seven feet wide by 3.5 feet high, with cross-points/measurement locations at six-inch intervals. I then set up a test stand for the headlight assembly that is located sixteen feet from the grid. The test stand allows me to align the headlight assembly for each bulb, and locate the brightest spot on the headlight output at the same position for each test allowing for repeatable measurements.

Using a laboratory power supply, I powered each test bulb with regulated 12.6 volts. The lab supply also allowed me to measure the current draw from the bulb, which allows an accurate calculation of actual wattage for each bulb. These wattage figures will not exactly match those given by the manufacturer since the manufacturer tests are done at 12.8V, giving a slightly higher number. The wattage figures are provided for comparison of the relative power consumption of each bulb.

Measurements were taken for each bulb at each cross-point on the grid; 120 measurements were taken for each bulb. The measurements were taken with a professional "foot-candle" meter. This meter is particularly suitable for this testing since it is an "incident" design (it measures the light falling on the meter, not light reflected from a surface.)

It was possible to get very accurate and repeatable measurements using this test setup. The measurements were then entered into an Excel spreadsheet, where analysis was performed and graphs generated. All data was "normalized," which means I subtracted the background light (from a single small light I used at the other end of the garage). The background light was one footcandle over the entire measurement area.

I decided to test the most commonly used bulbs, ones I considered may have valid claims and the one making the claim to the best performance:

- Sylvania standard 9006 low-beam bulb
- Sylvania standard 9005 high-beam bulb
- Sylvania XtraVision (claimed + 20% light output) low-beam bulb
- Sylvania SilverStar high-beam bulb
- Toshiba HIR low-beam bulb
- Toshiba HIR high-beam bulb

- Generic Bling Blue Bulb high-beam bulb

« previous continue »

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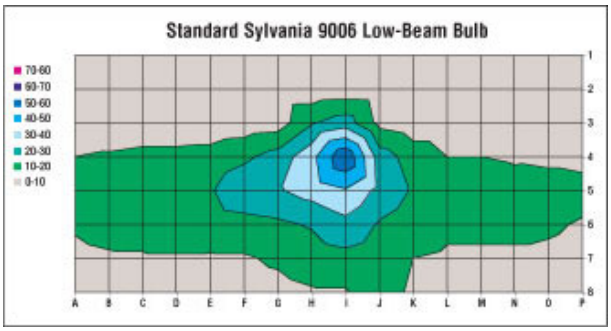
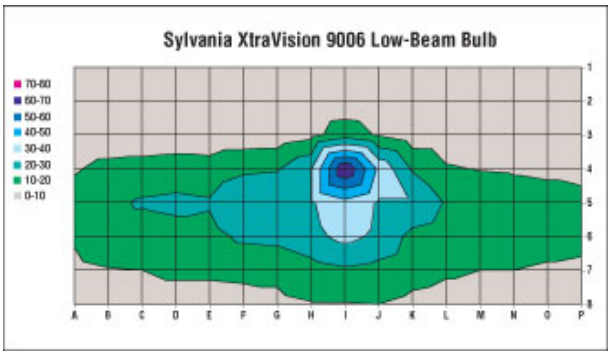


Standard Sylvania 9006 low-beam bulb in an E36 U.S. housing

The plot above represents the actual lowbeam light output in foot-candles of a standard Sylvania tungsten-halogen 9006 bulb in the BMW U.S. E36 headlight assembly. The scale is purposely set from 0-80 footcandles since later plots will be of bulbs that are capable of producing 80 foot-candles and this allows easy comparison of the plots.

The bump upwards in the U.S. pattern can be easily seen here. The brightest spot in the output is at I-4 (as it will be for other plots). This spot would be below the horizon at Horizontal Line 4, and to the right of the driver at Vertical Line I.

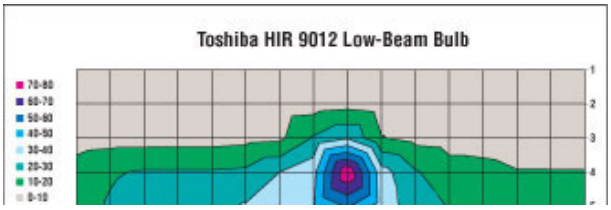
Measured current draw at 12.6V was 4.1 amps, which equates to 51.7 watts.

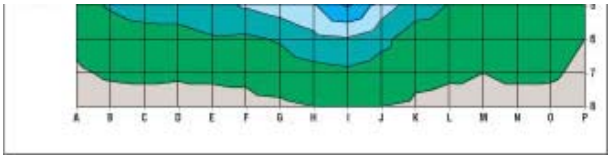


Sylvania XtraVision low-beam bulb in an E36 U.S. housing

Comparing the XtraVision bulb with the standard tungsten-halogen bulb does show that the XtraVision bulb produced more light than the standard bulb, but it did not produce a great amount more. At the brightest point on each pattern (I-4) the standard bulb produced ~60 foot-candles and the XtraVision bulb produced ~70 foot-candles. This is an increase of 16.6%, not the claimed 20%. As can be seen, the patterns are very similar. (On the road, the additional 16.6% was not very impressive. I could see a small improvement in lighting—a subjective result, to be sure.)

Measured current draw at 12.6V was 4.0 amps, which equates to 50.4 watts.



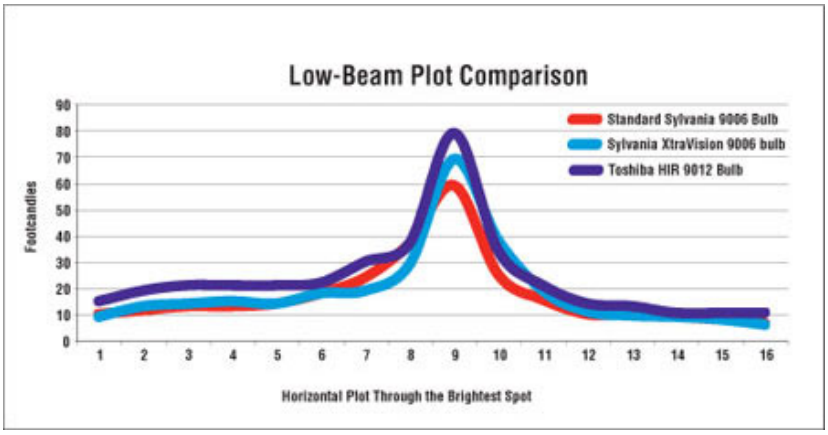


Toshiba HIR low-beam bulb in an E36 U.S. housing

The results of the Toshiba HIR lowbeam bulb reveal an increase in light in the U.S. housing. The peak light measured at I-4 was ~80 foot-candles. This is ~33% more light than a standard halogen bulb in the same housing. There is more light to the left side of the pattern in the yellow (20-30 fc) and light blue (30-40 fc) zones. On the road, the additional 33% is noticeable. Visibility was improved. Use of these bulbs in a 9005/9006 housing *must* be accompanied by careful and correct lamp aim, with clear and clean headlight lenses to minimize the negative effect of the increased glare.

Not measured in this test is upward stray light, which is visible up the walls and across the ceiling as you pull into the garage or drive into a tunnel. More intense light in the beam means more upward stray light, which has the potential to cause glare-back to the driver in rain, fog and snow.

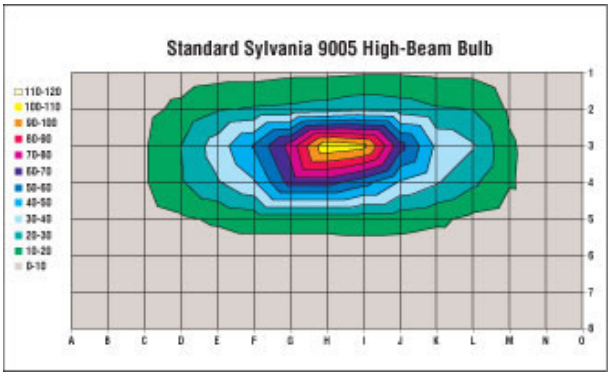
Measured current draw at 12.6V was 4.5 amps, which equates to 56.7 watts.



Linear horizontal plot of all the previous low-beam results

To make it a bit simpler to understand, I did a plot of the light intensities of each bulb across the horizontal line #4:

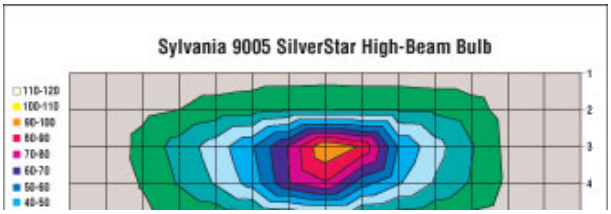
The relative brightness of each bulb is simple to compare. The Sylvania Xtra- Vision bulb actually produced less light than a standard Sylvania bulb just to the left of the bright spot in the U.S. pattern.

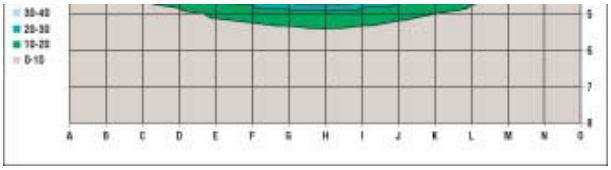


Standard Sylvania high-beam bulb in an E36 U.S. housing

The generic Sylvania 9005 low-beam bulb in the E36 housing makes what could be considered a typical high-beam pattern. The peak at H-3 is 109 foot-candles. H-3 represents the horizon (line 3) straight ahead of the driver (vertical line H.) On the road these provide adequate and uniform lighting.

Measured current draw at 12.6V was 4.9 amps, which equates to 61.7 watts.

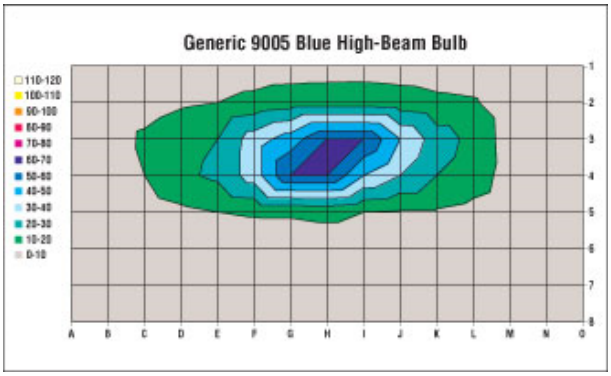




Standard Sylvania Silver-Star bulb in an E36 U.S. housing

The Sylvania 9005 “SilverStar” highbeam bulb is advertised as making “whiter and 20% brighter” light, and this is supposed to improve the driver’s ability to use the light. I can’t comment on that claim, although the bulb does have a blue coating on the quartz envelope. What is obvious in comparing the “SilverStar” to the standard Sylvania high-beam bulb is that the SilverStar makes *less* light than a standard bulb. The difference at the brightest point in the beam is 77 foot-candles from the SilverStar, and 109 footcandles from the normal high-beam bulb. This equates to ~23% less light. The pattern is basically maintained with perhaps a bit more light going towards the left side. The loss of light is fairly uniform across the entire pattern compared to the standard clear halogen bulb. I didn’t try these on the road, so I have no comment on how well they work.

Measured current draw at 12.6V was 5 amps, which equates to 63 watts.



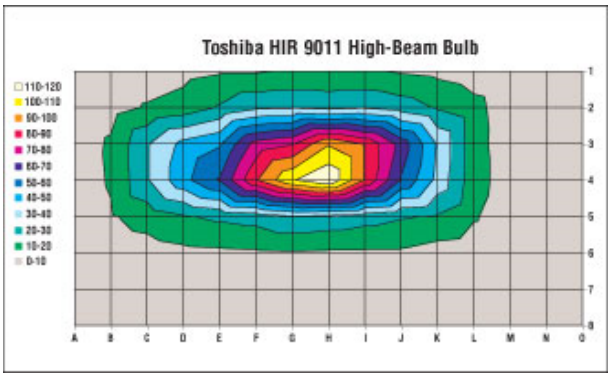
Generic 9005 blue-bulb, claimed 100W, in an E36 U.S. housing

This bulb came to me with no manufacturer’s markings; indeed, the only marking on it was 9005, HR3. It has a fairly dark blue coating on the quartz envelope.

My initial impression on testing it was that the light appeared to be a blue color when compared to all the other bulbs I’d tested. In looking at the headlight assembly from a distance, the blue color is quite noticeable, and glare seems increased or more irritating (a subjective measurement). It’s obvious here that not only has the pattern changed with a strange-looking center spot, but also the intensity compared to a normal halogen high-beam is considerably less. This appears to be a lose-lose proposition.

I didn’t try these on the road, so I have no comment on how well they work.

Measured current draw at 12.6V was 5.4 amps, which equates to 68 watts, despite the claim of 100W.



Toshiba HIR 9011 high-beam bulb in a E36 U.S. housing

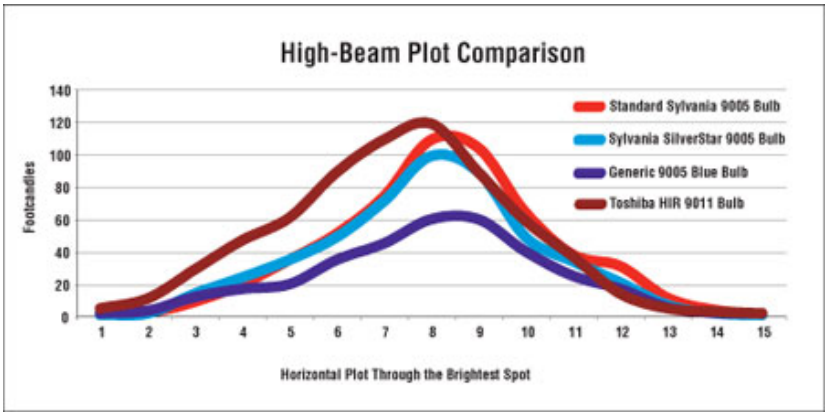
The Toshiba 9011 is an impressive bulb. Since glare to oncoming traffic is normally not a concern with high-beam use (since they should *only* be used with no oncoming traffic, or traffic in front of you within the fall of the beam), it is of interest to us. The pattern also seems shifted with the most intense spot moved downwards (to line 4). The peak output at H-4 was 119 foot-candles, compared to 99 foot-candles in a normal halogen bulb. This is an increase of 17% at the brightest spot. What is useful with this bulb is the overall increase in brightness compared to a standard halogen bulb. The pattern also seems to favor the left side a bit.

I have used these on the road, and they are impressive. Brightness is more than adequate, and the overall pattern provides not only good central illumination, but in combination with the low beam, good side and overhead illumination.

These bulbs should *never* be on when there is oncoming traffic, and I would strongly suggest only using them in

clean and well-polished headlight housings.

Measured current draw at 12.6V was 5.1 amps, which equates to 64.2 watts.



Linear horizontal plot of all the previous high-beam results

To make it a bit simpler to understand, I did a plot of the light intensities of each bulb across the horizontal line #3—which represents the horizon, with the exception of the Toshiba HIR 9011 bulb; this was plotted with line #4 (where it was most intense.)

The most apparent conclusion from the following chart is the clear inferiority of the blue-bulb in producing useful light. All the other bulbs were useable in the vehicle; but use of a blue bulb such as was tested would be a step backwards in illumination. If the user is vigilant about not using the high beam when in any traffic conditions, the Toshiba bulb makes an impressive and useful amount of light.

Conclusions: My tests led me to conclude that it is possible to increase the usefulness of the stock E36 U.S. headlights. But while the bulb used will make a large difference, it is equally important that the headlight cover be in good condition, for two reasons:

More effective: Light gets to the road if the cover is clear, and isn't scattered or absorbed by scratches and pitting.

Glare is greatly reduced; a pitted and scratched cover creates a great deal of glare for oncoming and leading drivers.

The M3 is now drivable at night.

Suggested Reading

NHTSA report on HID glare. SAE/Government/Industry Meeting 2003:
http://www-nrd.nhsta.dot.gov/pdf/nrd-01/SAE2003/Perel.pdf

SEMA (Specialty Equipment Market Association--aftermarker equipmeNT) Responds to NHTSA's Request for Comments on Perceived Glare from Front-Mounted Lamps:
http://www.sema.org/main/semaorghome.aspx?ID=50855

NHTSA's ruling on glare:
http://www.nhtsa.dot.gov/cars/rules/ruling/glare.html

SEMA responses to various NHTSA rulings including specific rulings on headlight replacement issues:
http://www.enjoythedrive.com/content/?ID=25405

Highly Recommended: Daniel Stern's comments to NHTSA on headlight glare:
http://dsl.torque.net/images/DSL_8885.pdf

« previous