

Miniature and Low Wattage HID Lamps?

I know that some of us want a more energy efficient flashlight or a more energy efficient bicycle headlight or the like. And some of us wonder why commercial products to satisfy those desires aren't out there?

As for flashing a xenon strobe rapidly with low energy flashes - there is a bit of a problem. Performance of xenon flashtubes largely gets better with higher flash energy and worse with lower flash energy. If the energy is high enough to give satisfactory improvement of energy efficiency over halogen lamps, any economical flashtube including all made of glass as opposed to quartz will not survive such flashing repeated rapidly enough to appear to glow continuously.

NOTE - It takes 50-60 flashes per second to avoid flicker! Movies avoid flicker at 24 frames/second by having the "on" fraction of each cycle being about 80 percent of the cycle as opposed to the fraction of 1 percent that a fast xenon strobe would have. (NOTE - someone tells me that movie projectors "blink" twice per frame for 48 "blinks" per second, and this may well be true for just some projectors.) You need the off time to be under 20 or preferably under about 16 milliseconds to make the light appear continuous.

Further discussion of this is in a [separate file on making xenon glow continuously](#).

Now back to miniature HID lamps:

One obstacle is the thermal conduction loss from the arc. This is surprisingly proportional to the overall length of the arc and surprisingly independent of the width of the arc or the gas/vapor pressure or the power.

For the really technical explanations why, look in the book "The High Pressure Mercury Vapor Discharge" by W. Elenbaas published by the North Holland Publishing Co. in Amsterdam. The principles are relevant to gases/vapors other than mercury.

One thing that happens is that if the arc diameter is reduced, the temperature gradient around the arc steepens and this makes the loss largely independent of the arc diameter.

This loss is largely independent of gas/vapor pressure since increasing the concentration of gas molecules also reduces their mobility by having more in each other's way.

Increasing power delivered to the arc increases the arc temperature by a surprisingly small amount. In the most oversimplified case radiated power is proportional to temperature to the fourth power. In addition, the emissivity of the gas/vapor increases (usually drastically) with temperature, making the radiated power proportional to arc temperature raised to a power much higher than 4. So the arc temperature is substantially more constant than proportional to the fourth root of radiated power!

For an arc in mercury vapor or xenon with the arc length much greater than the diameter of the arc, this loss is roughly 10 watts per centimeter of arc length. For short arcs, thermal conduction from the ends of the arc is also significant which makes this loss substantially more than 10 watts per centimeter of arc length for short arcs.

Now, one would wonder why then it would not be simple to have an arc only a fraction of a millimeter long so that the thermal conduction loss would be a watt or less?

The reason is that the voltage drop across the extremely short arc would be low compared to the voltage drop in the processes of electrons entering and exiting the arc. Ordinarily, the "cathode fall", or the process of getting electrons from metal into the arc is about 10 volts. In

the very intense heat of the cathode region of a short arc lamp, this can be a little less but is certainly over 6 and probably at least 8 volts. This figure normally varies slightly inversely with power and intensity of heating of the electrodes!

If the voltage drop across the short arc is low, it will be mostly electrode drop. If the voltage across the arc is only about 15 volts (common in lower wattage short arc lamps like 150 watts or less), a majority of this voltage drop is in electrode losses. Multiply the current (amps) by something like 9 volts to get the wattage dissipated into the electrode drops and multiply the current by something like 6 volts to get the wattage dumped into the body of the arc. And subtract from that maybe 2-3 watts per millimeter of arc length for the thermal conduction loss! It is easy to increase the voltage drop of a short arc by increasing the gas/vapor pressure. But there are limits! Hot quartz bulbs can reliably at most contain a pressure of a couple hundred atmospheres! Even at such a high pressure, the voltage across the main body of an arc one millimeter long will only be several to maybe a couple dozen volts. Figure on the low side since the intense power level in such arcs makes them a bit hotter than usual and makes them more conductive than usual.

So now we have the situation for a 1 millimeter arc that about half or more of the lamp wattage is wasted in electrode losses and about 2-3 watts of what's left goes to the thermal conduction loss.

One other problem - remember that thermal conduction from the arc is proportional to the length of the arc. But if you miniaturize any given existing lamp design, the area of the bulb varies with the square of the length! Miniaturization increases conducted heat per unit bulb area! Miniaturize the bulb and you may need forced air cooling. How energy efficient is a 3 watt mercury vapor lamp that needs a 2 watt fan to keep it adequately cool?

Still another problem: If you scale the size of a lamp, life expectancy is roughly proportional to the linear dimensions of the lamp. So if you scale some existing lamp design in half and keep the temperature of all the various parts the same (despite doubling conducted heat per unit area), you cut the life expectancy in half. This is because (in part) the thickness of whatever regions of the electrodes is halved. And with half heating (remember the thermal conduction loss varies linearly with length) on 1/4 bulb area, expect double condensation of electrode vapors per unit area of the bulb. This is a bit oversimplified but you will find it to be true!

And there is another problem to short arcs: The electrodes are close to all parts of the bulb and evaporated electrode material condenses onto all parts of the bulb. Because of this, short arc lamps mostly have life expectancy around 500 hours or so, and that is in the available wattages - mostly 100 watts to kilowatts!

HID lamps of long life expectancy have longer arc tubes with most of the tubing safely far from the electrodes by having the tubing length great compared to the tubing diameter. Since you need some significant tubing diameter to not overheat from 10 watts per centimeter of conducted heat, you need an arc tube length of a few centimeters for good efficiency and long life. Now, with a few centimeters of arc length and 10 watts per centimeter of losses, you need lots of watts for good efficiency. This does not work for good efficiency at low wattage!

One possible solution for cleaning the arc tube or bulb is adding iodine or another halogen to take advantage of the halogen cycle. You hope for the halogen to attack any condensed electrode material vapors on the inner surface of the bulb or arc tube. But remember that there will be parts of the electrode structure at the same temperature as the inner surface of the bulb and these parts of the electrode structure will also be attacked by the halogen. Also note that traces of halogen vapor impair ionization of the gas in the bulb, necessitating higher starting

voltages.

But the halogen cycle has been utilized with limited success in lower wattage metal halide lamps. The automotive headlight HID lamps are 35 watt metal halide lamps that supposedly have an average life expectancy of 2700 hours. How practical is it to you to spend about \$100 (or more) on a lightbulb that lasts 2700 hours just to get the light of a 100 to 150 watt halogen lamp for 35 watts (42 watts and maybe more including ballast losses)?

The Philips 50 watt standard metal halide lamp lasts longer than that and is available at Home Depot for maybe around \$35. But 50 watts is not some really low wattage good for bicycle lights and flashlights.

Believe me, there is a lot of money to be made from low wattage HID lamps suitable for bike lights and flashlights. So how low in wattage have practical HID lamps been made?

As for standard type general purpose metal halide lamps - there is the 50 watt Philips one available at Home Depot for maybe around \$35. General Electric and Philips make a 39 watt general purpose metal halide lamp sometimes referred to as a "35 watt" lamp, but to get these you probably have to go to an electric/lighting supply shop and order them, probably by the case.

Automotive headlight HID lamps are specialized 35 watt metal halide lamps. There is xenon in them at high pressure to enable some useful light output while they are warming up. They require multikilovolt starting pulses and cost around \$100 or more. More info on these is [Here](#).

High pressure sodium lamps are available in a 35 watt version. You can get them at many home centers for around \$25 or in some hardware stores for a little more.

The lowest wattage standard mercury lamp is the 40 watt one, or more common the 40/50 watt one. This thing, after ballast losses, is only a little more efficient than the more efficient halogen lamps.

Now for available lower wattage HID lamps, but these are expensive specialty lamps probably costing over \$150:

[Welch Allyn](#) makes, among their other specialty lamps, the "Solarc" or "Hi Lux" miniature metal halide arc lamps. Their 21 watt one is used in the Cat Eye "Stadium Light", which is a high-end bicycle headlight costing a good \$400-500 or so.

UPDATE 8/27/2000 - Welch Allyn now has a 10 watt lamp in production. They have minimum order requirements apparently designed to discourage casual users. I have heard of them developing working laboratory prototypes as small as 2 watts, but they have no plans to put any under 10 watts into production due to cost and general unworkability.

UPDATE 10/1/2000 - the 10W lamp has an initial luminous efficacy of 45 lumens/watt and a life expectancy of 1,000 hours according to the PDF datasheet available from their [10 Watt Lamp Datasheet](#).

[Advanced Radiation Corporation](#) makes a 20 watt xenon short arc lamp. Expect efficiency less than the 13-14 lumens per watt typical of 75 watt xenon short arc lamps. This lamp is only practical where a hundred or two lumens must be emitted by a light source much more compact than a 10 or 20 watt halogen lamp filament.

As for why specialty HID lamps cost so much? One reason is that they are made of fused

quartz. Quartz is as hard as a rock at the melting point of iron (1535 degrees C). Steel tools melt before quartz gets workable. And you need torches using oxygen to get hot enough - a regular Bunsen burner or even a "MAPP" gas blowtorch from a hardware store is not hot enough.

And if you have the heat and the tools, there is still another problem - quartz has a narrow plastic range of temperature. The temperature needed to get quartz barely as soft as taffy or frozen chewing gum is only a few dozen degrees short of making quartz liquid enough to pour. Quartz is trickier to work than glass and glassblowers that can work quartz will not be working for minimum wage! Specialty quartz lamps are hand-made by adequately compensated skilled craftsmen and will cost many times the cost of a mass-produced HID lamp.

Production machinery that can mass-produce quartz lamps is so expensive that only lamps that will sell in huge quantities (hundreds of thousands) can be made economically by such machinery. Otherwise it would cost even more to get the machines made and set up than it would be to hire those highly skilled glassblowers. If you have a specialty HID lamp design that would use the same bulb and the same leads as a halogen lamp that is in production, then maybe you could make a deal with an existing lamp manufacturer. (Expect a minimum production run of thousands - perhaps many thousands - of lamps at a price at least a few times that of a halogen lamp in order to make it worthwhile to the manufacturer.)

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