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High-Efficiency Light Generators For Sodium Plasma Bulbs and RF Power Drivers

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Application Support, Product Marketing

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Agenda

- History of Basic Lighting
  - Incandescent Lamps
  - Fluorescent Lamps
  - Light Emitting Diode Lamps
  - Light Emitting Plasma Lamps
- Comparisons of Various Lighting Performance Metrics
- How Light Emitting Plasma Lamps Work
- Light Emitting Plasma Lamp Examples
- Existing Light Emitting Plasma Lamp Vendors
- Freescale Plasma Driver Solutions
- Conclusions

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History of the Incandescent Lamp

- First light emission as a result of heating: 1802, platinum filament, Humphrey Davy, battery powered.
- 75 years later Thomas Edison perfects the carbonized bamboo filament in a partial vacuum, creating the first light bulb in 1880
- GE added tungsten filaments in 1906
- Frosted bulbs developed in 1924

History of the Compact Fluorescent Lamp

- First fluorescent light: 1856, German glass blower Heinrich Geissler creates the Geissler tube
- Former Edison employee Daniel McFarlan Moore perfects the 2 and 3 meter tubes in 1904
- GE develops commercially successful fluorescent tubes in 1934
- CFLs designed at GE in response to the 1973 oil crises, become widespread with Philips in 1980s

History of the Light Emitting Diode Lamp

- 1907 discovery of electroluminescence (when a material emits light in response to an electrical current): H. J. Round working at Marconi Labs, using a silicon carbide “cat’s whisker” radio detector
- First practical red LEDs were developed at GE in 1962 by Nick Holonyak, Jr.
- LED lamps first developed in 2008 to compete with CFLs
- White light is made by adding phosphor to a blue or ultraviolet LED

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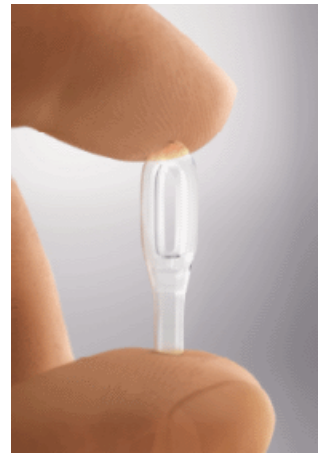
History of the Light Emitting Plasma Lamp

- Sulfur electroluminescence discovered by Michael Ury and Charles Wood in 1990
- Fusion Lighting was created in 1992 to market the invention under the support of the U.S. Department of Energy

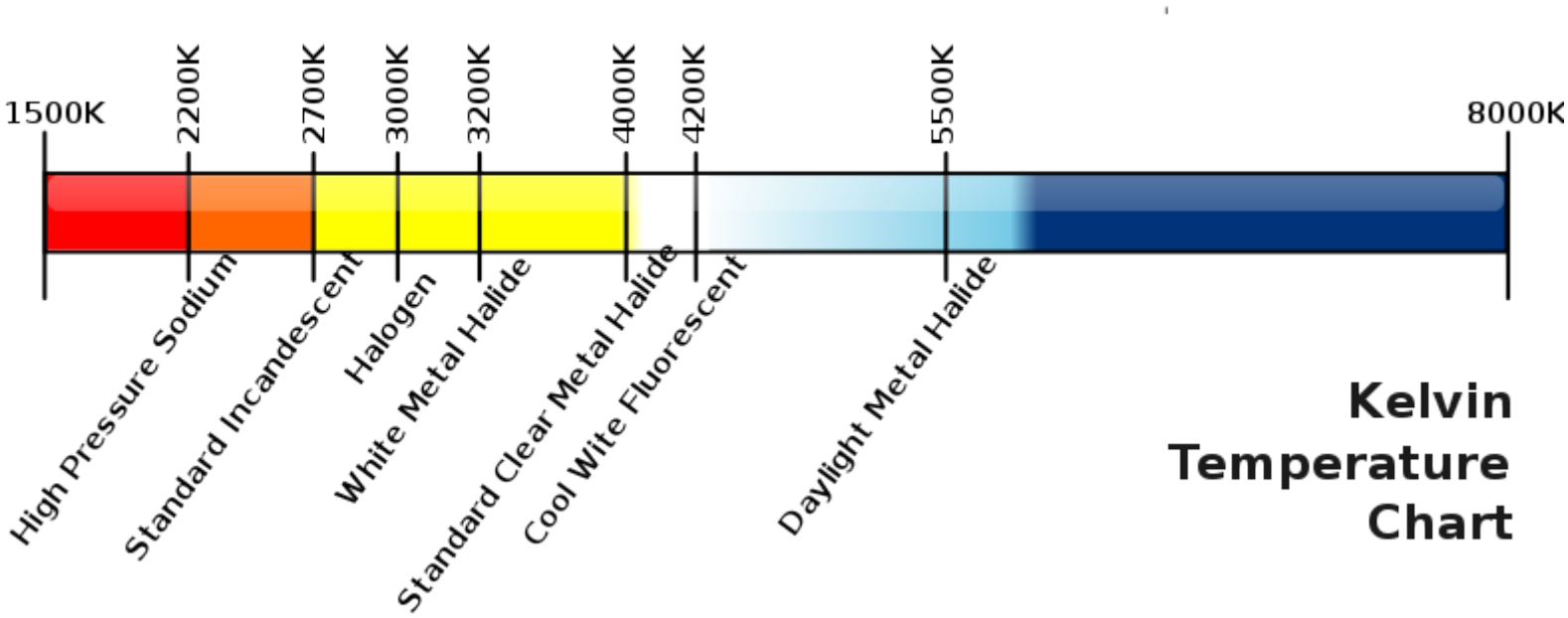


- Fusion Lighting closed in 2002, LG licensed all patents
- Future bulb refinements are ongoing

Lamp Performance Comparison

Characteristic	Incandescent	CFL	LEDL	LEPL	Units
MTTF	**0.1**	**1.2**	**3.5**	**6**	**years**
Lumens per Watt	**15**	**65**	**60**	**140**	**lm/W**
Luminous Efficiency	**2**	**12**	**4**	**15**	**%**
Color Rendering Index	**100**	**89**	**27**	**80**	**---**
Start Time	**0.1**	**0.3**	**0.1**	**30**	**Sec**
Re-strike Time	**0.1**	**0.1**	**0.1**	**60**	**Sec**
Color Temperature	**2700**	**4100**	**6000**	**5500**	**CCT**
Average Lumens	**1**	**3**	**0.8**	**5-25**	**Klm**
Average Lamp Cost	**0.35**	**0.75**	**15**	**500**	**$**

What is Correlated Color Temperature?



- Color temperature is a quanitiave measure of how white a light source is compared to others. The higher numbers are associated with the “cooler”, “bluer” shades of white, lower numbers are associated with the “warmer” or “soft white” shades of white.

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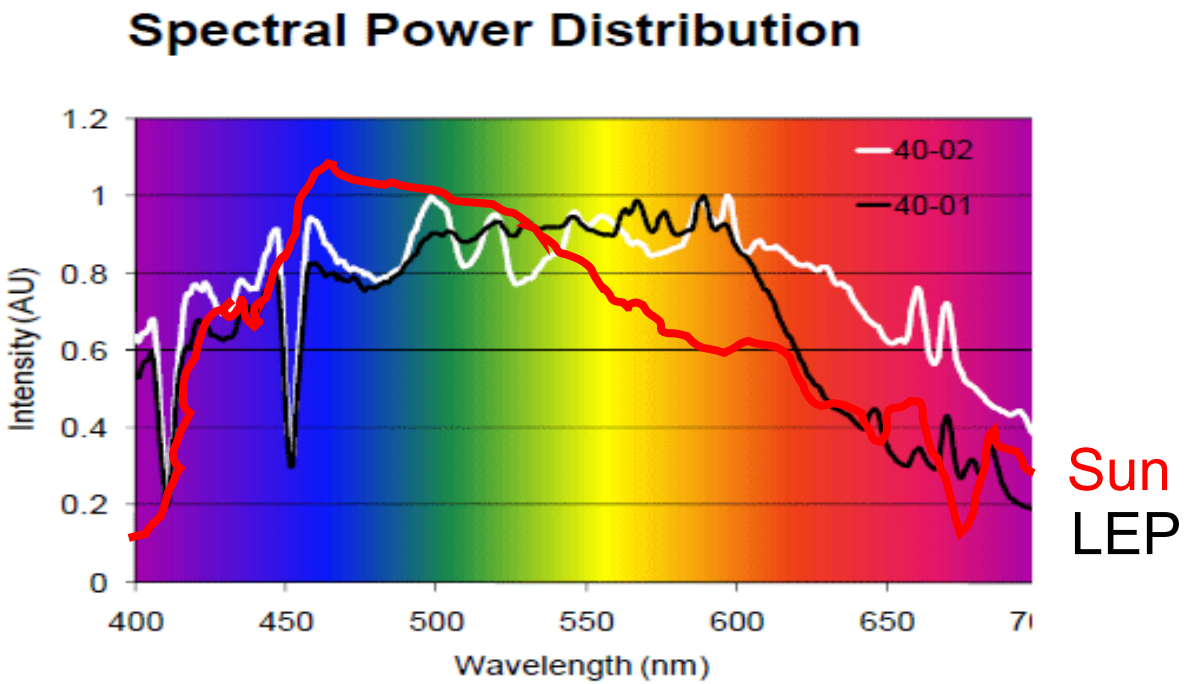
What is Spectral Power Distribution?



- Spectral power distribution is a quantitative measure of how closely the frequency spectrum of the light source compares to that produced by the sun. Spectral distribution helps with color rendering and is required by plant life in aquariums and artificial growing environments.

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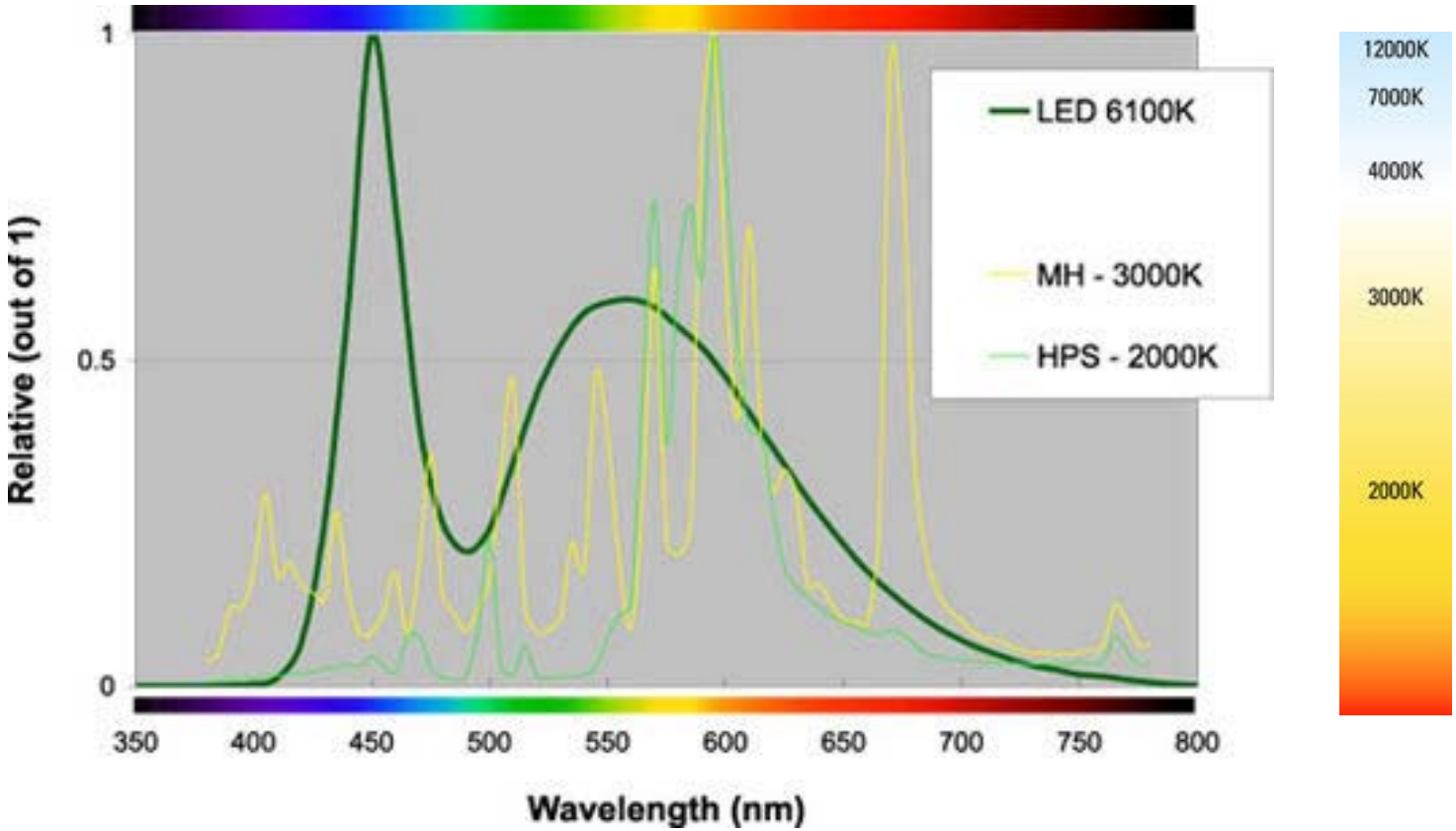
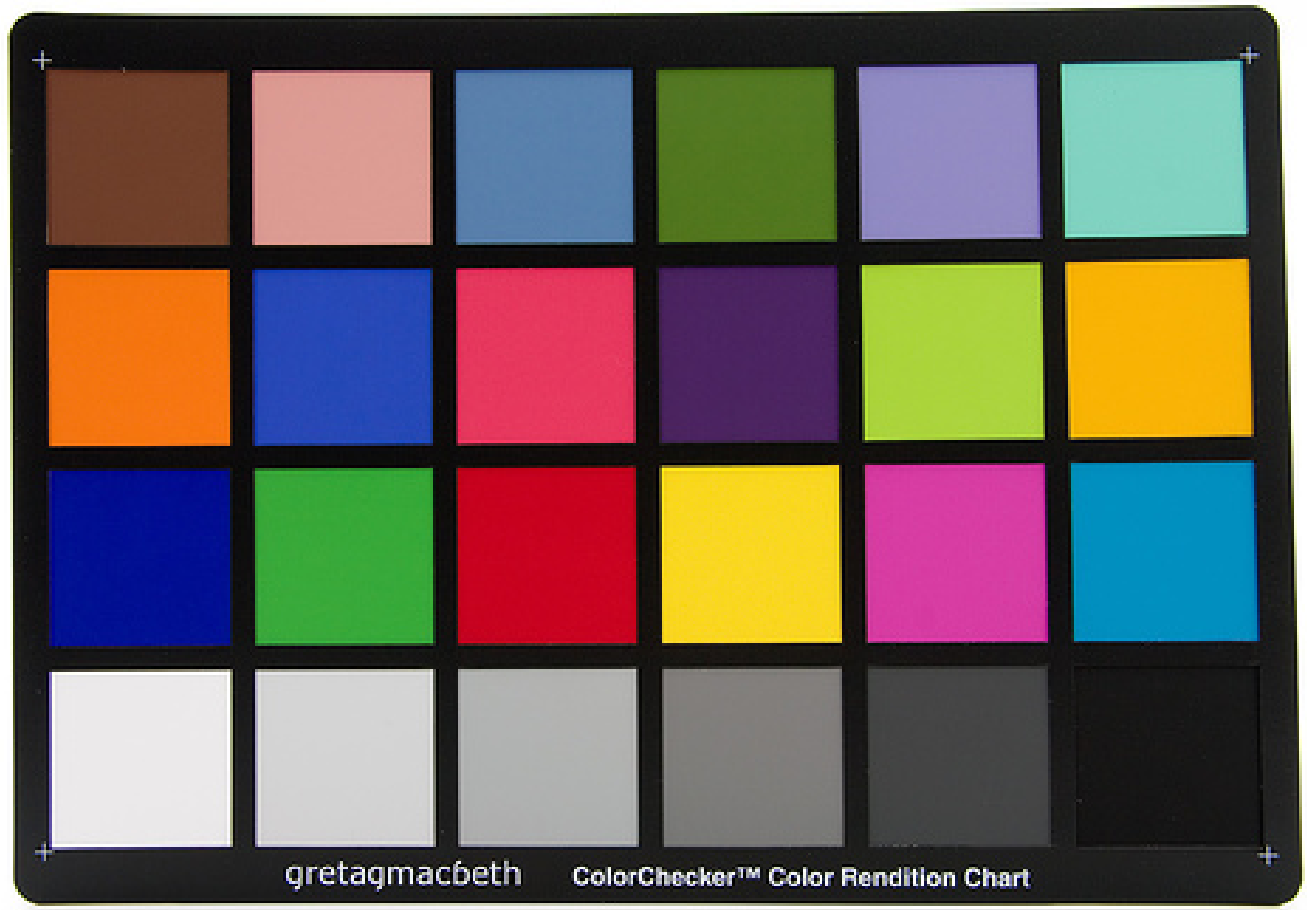
LEDL Light is Very “Bluish Cool” with Very Poor Spectral Distribution



What is Color Rendering?



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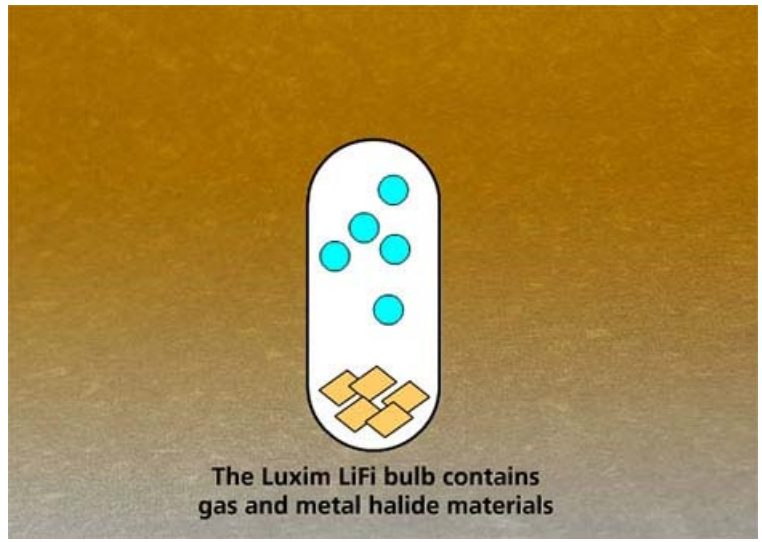
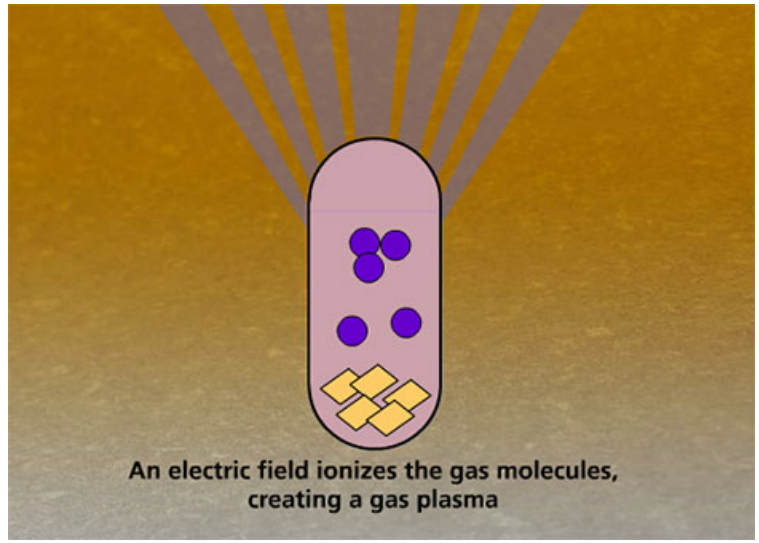
How a LEPL Works

- Under cold start conditions, LEPL bulbs contain solid metal halide salts and some noble gas matter
- RF amplifier feedback is adjusted to provide a low level RF electrical field in the resonator puck
- No light is created during this stage of the warm up process
- Load VSWR conditions in the puck are very poor, which creates a very high stress condition in the RF amplifier



How a LEPL Works

- 5 seconds into the warm up process, the electrical field ionizes the noble gases and creates plasma
- Bulb starts to emit a slight purple glow
- RF amplifier is turned up to a higher level as load VSWR conditions start to improve in the resonator puck



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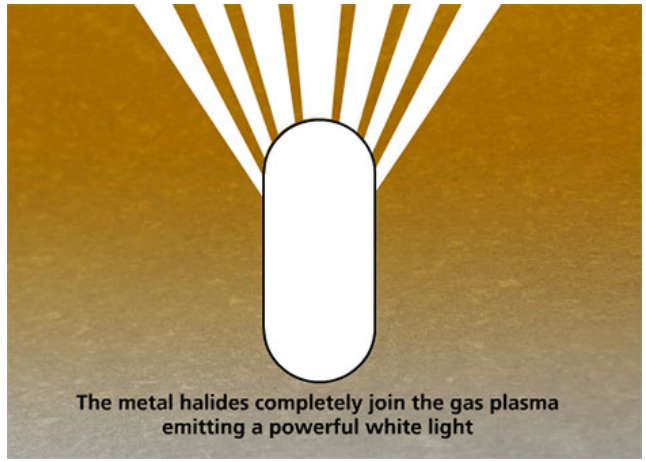
How a LEPL Works

- As the plasma warms up further, it vaporizes the halide salts and the bulb produces a stronger blue emission
- As the salts warm further, they join into the molten plasma and produce a very powerful white light emission
- Gas is excited to 5 atmospheres of pressure; total start up time is 30 seconds
- The RF amplifier is turned up to full power and the puck's VSWR stabilizes into a very good impedance match



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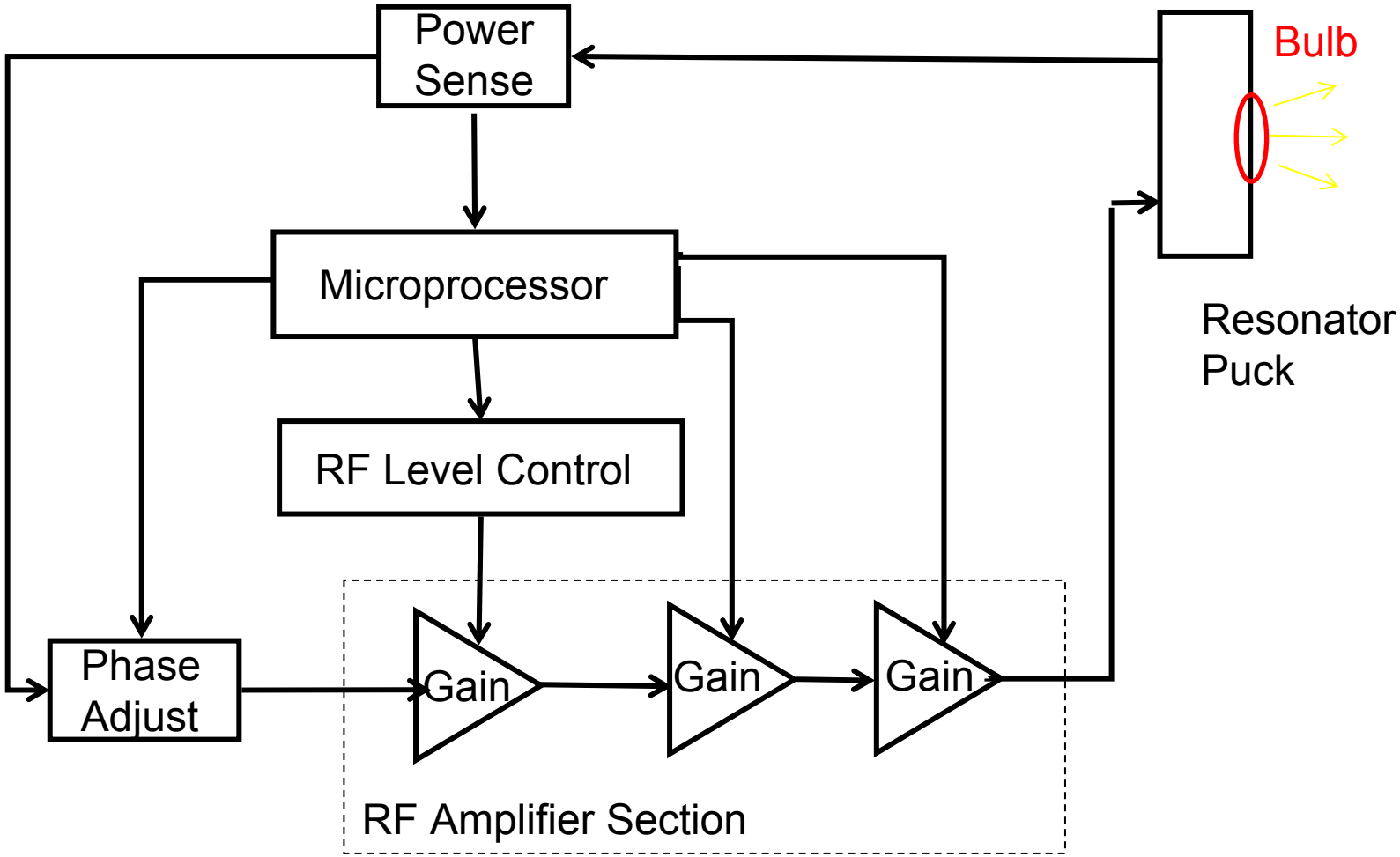

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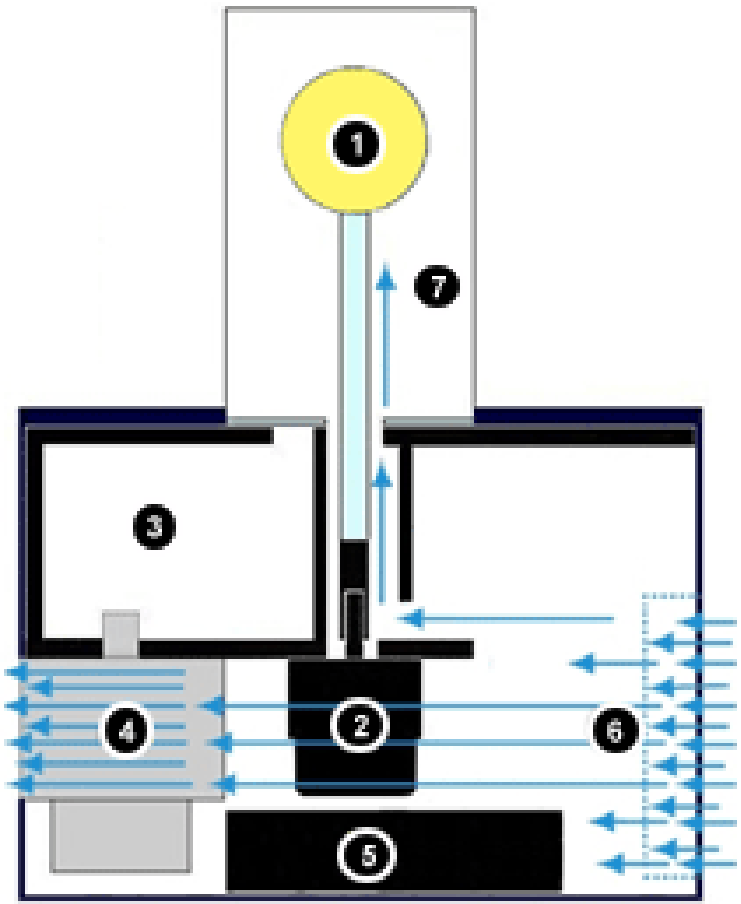
How a Magnetron Based LEPL Works

- The sulfur lamp consists of a golf ball-sized fused-quartz bulb **(1)** containing several milligrams of sulfur powder and argon gas at the end of a thin glass spindle. The bulb is enclosed in a microwave-resonant wire-mesh cage **(7)**. A magnetron **(4)**, variably powered by a digital electronic PSU **(5)**, bombards the bulb, via a waveguide **(3)**, with 2.45 GHz microwaves. The microwave energy excites the gas to several atmospheres of pressure, which in turn heats the sulfur to an extreme degree, forming a brightly glowing plasma capable of illuminating a large area. Because the bulb heats up considerably, it is necessary for an electric motor **(2)** to spin the bulb while a fan **(6)** cools it to prevent it from melting.



Different Plasma Lighting Applications

- Big box, warehouse lighting
  - Adjustable intensity
  - Need correct spectral purity
  - Long service life

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Different Plasma Lighting Applications

- Theater and stage lighting
  - Adjustable intensity
  - Need correct spectral purity
  - Long service life
  - Need active computer controlled spot heads

Robe Robin 300 Plasma Spot Light Head Specs

- Luxim LifiENT 31-02 plasma lamp source, 266W, Luminous Flux 18,000 Lm, CCT 6,000K, CRI=94, lamp life 10,000 hrs
- Linear motorized zoom 10°– 40°
- RNS2: Innovated robe navigation system with LCD touch screen and battery backup, gravitation sensor for auto screen positioning and operation memory service log with RTC
- CMY + CTO diachronic color flag system in combination with light homogenization system provides smooth and fast color mixing
- Color wheel with 7 + 1 user-replaceable magnetic "SLOT&LOCK" trapezoid shaped positions
- Rotating gobo wheel with 7 + 1 user-replaceable magnetic "SLOT&LOCK" gobos

Robe Robin 300 Plasma Spot Light Head Specs

- Static gobo wheel with 9 + 1 user-replaceable "SLOT&LOCK" gobos
- 3-facet 11° rotating index able prism
- Extremely fast motorized iris
- Variable frost effect
- Electronic dimming 20 – 100% and strobing possibilities
- Pan and tilt movement in 16/8 bit resolution 540°/280° with locking mechanism
- Communication protocols USITT DMX-512, ArtNet, MA Net, MA Net2, RDM

Different Plasma Lighting Applications

- Street lighting
  - Very high volume
  - Efficiency/payback time
  - Long service life
  - Low maintenance

Different Plasma Lighting Applications

▶Street lighting

- The LEPL Streetlight from Century ANA operates at 266 watts and produces as much usable light asa 400 watt metal halide system. In addition, the LEPL Streetlight is rated at 50,000 hours — almost three times more than traditional metal halide systems. The fixture is relatively compact, and has thermal management built into its exterior. For further energy savings, the LEPL Streetlight supports continuous dimming to 20%, and can be coupled with a standard photocell or motion detector.

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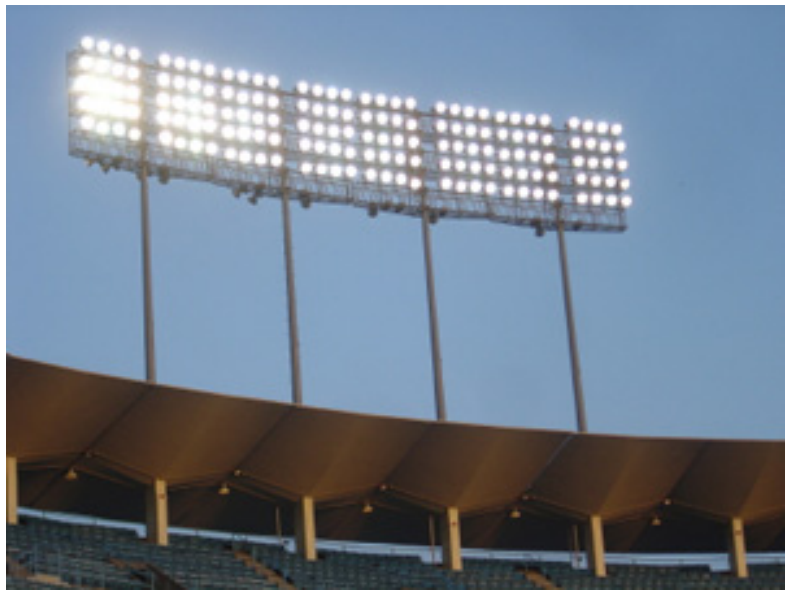
Different Plasma Lighting Applications

- Stadium lighting
  - Low volume
  - Long service life requirement



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Different Plasma Lighting Applications

- Architectural lighting
  - Low volume
  - Need long MTTF

Current Market Leaders

- Luxim Corporation
- Topanga Technology
- Ceravision Limited
- Plasma International
- LG
- Others?

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Example Freescale RF Power Solutions

MWE6IC9100N

140W Rated Power

Performance

Peak Power	*180W*
Gain	*33.5 dB*
PAE	*65%*

Key Features

Lowest cost plastic TO package
High-gain 2 stage device
Dual path configuration

MRF8S9200N

225 W Rated Power

Performance

Peak Power	*250 W*
Gain	*19 dB*
Drain Efficiency	*70%*

Key Features

High-performance HV8 technology
Low-cost overmolded package
Highest level of ruggedness

MRF6V4300N

350 W Rated Power

Performance

Peak Power	*330 W*
Gain	*22 dB*
Drain Efficiency	*60 %*

Key Features

High-performance VHV6 technology
Low-cost overmolded package
50V operation for improved power density

"In the very near future, there will only be two lighting sources, LED and LEP™. The only question is at which lumens level will the choice be made."

Geoff Brown, VP of Sales, Luxim Corp

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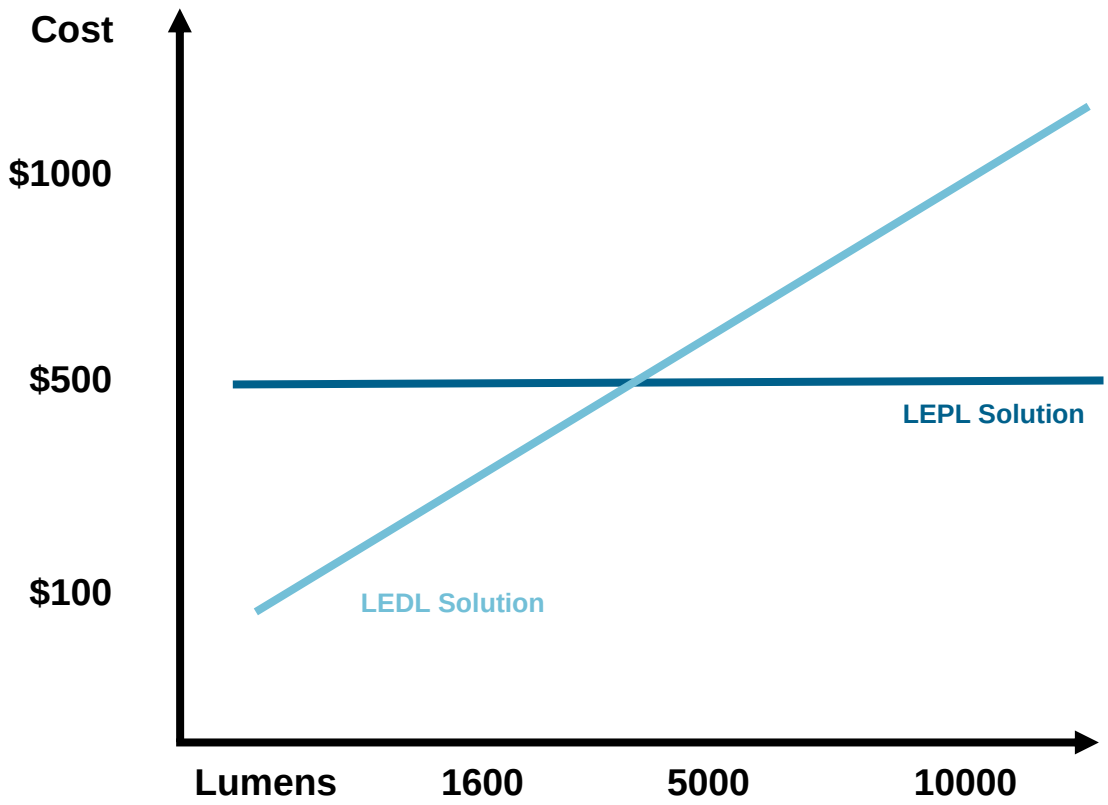
Cost per Lumen Trade-off



- With the current technology, the price trade off level is right at $500 and 5000 Lumens. These will only drop in the near future.

Conclusions

- 20% to 40% of a building's energy cost is spent on lighting
- All lighting solutions are becoming energy efficient, and LEPL are a big part of the very high lumens solutions
- Freescale RF Power Division is investing in this new, disruptive technology

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North America's Lights from Space

Stop by the RF Division's table in the Technology Lab to participate in an interactive RF power demonstration of our latest amplifier devices.

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