LUXIM®

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Introduction to LIFI Solid-State Plasma Lighting

Lawrence Berkeley National Lab

www.LUXIM.com

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Outline

- Introduction to LUXIM
- Solid State Plasma Lighting Technology
- Application Benefits
- LIFI Roadmap
- Summary
- Demonstration

LUXIM Corporation: LIFI Lighting

- LUXIM Corporation
  - Lighting Component Company
    - High volume production
  - Diverse markets
  - Investors:

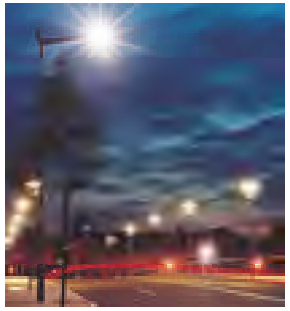
LUXIM Headquarters

- LIFI®
  - Long stable lifetime
  - Energy efficient
  - Full color spectrum
  - Fast turn-on, re-strike and dimmable

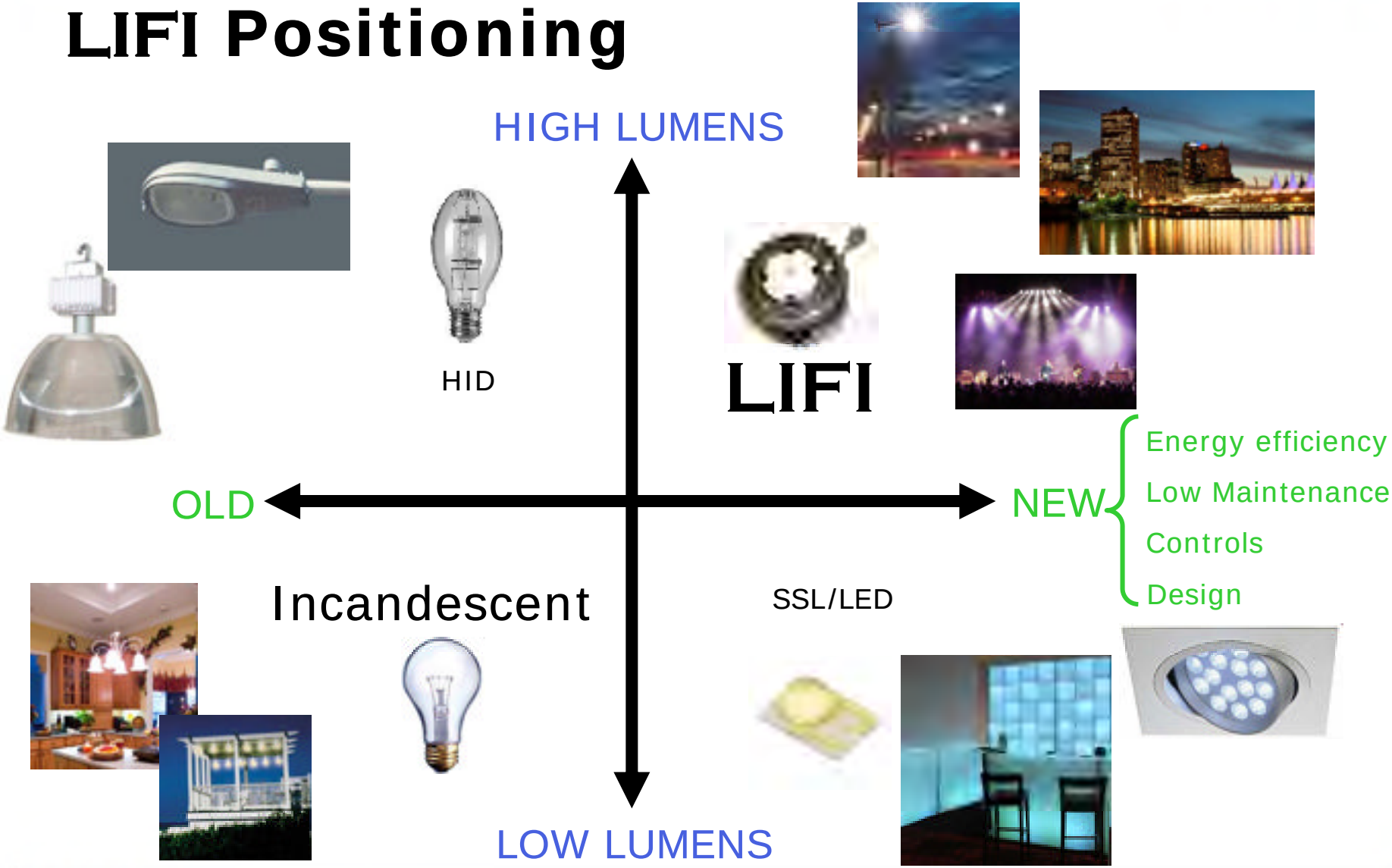
LIFI STA-40 Series Light Source

LIFI Lighting Markets

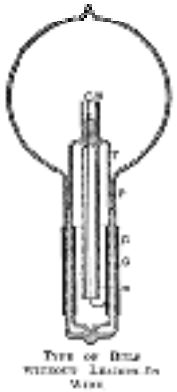
High Output, Efficiency, Intensity, Spectrum

	High End Projection Display	Instrument & Medical	Entertainment	Architectural, Street & Area
				
Benefits	•Long life •Full spectrum •High contrast •Fast start	•Low Maintenance •Stable output •Full spectrum	•Energy efficient •Low Maintenance •High CRI •Small source	•Energy efficient •Low Maintenance •High CRI •Small source

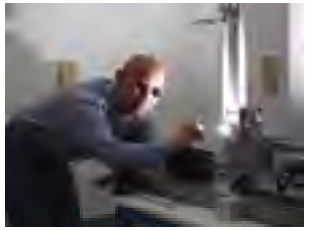
LIFI Positioning



History of Solid State Plasma Lighting



1890s Nikola Tesla demonstrates electrode-less coupling of power to lamps



1990s Fusion Lighting and DOE develop a High Intensity sulphur lamp

2000s LUXIM Corporation develops a compact Solid State High Intensity light source

2008 Next stage of adoption

LIFI Lighting Mechanism

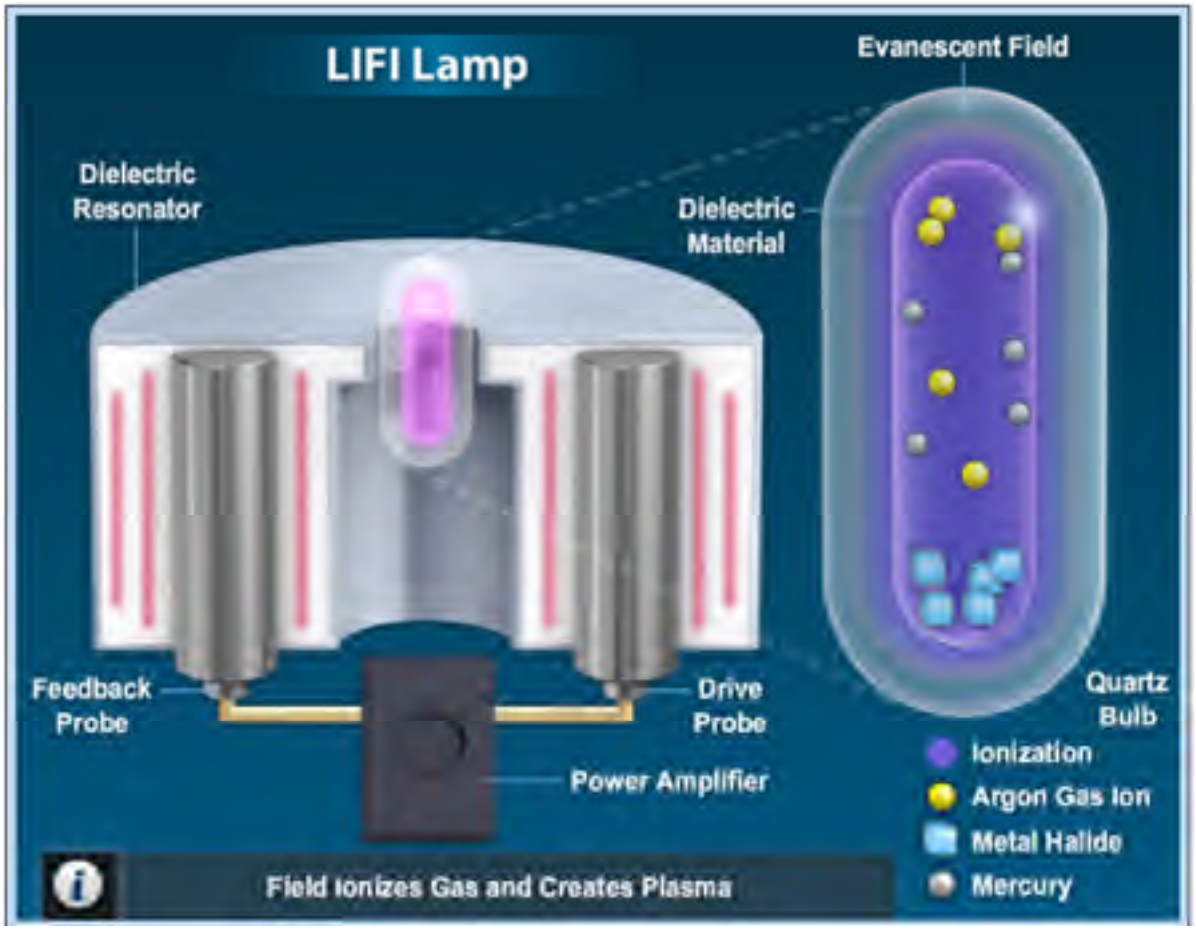


Image credit: Michael W. Davidson, Florida State University

RF Device Technology Comparison

- Luxim is device technology agnostic

Technology	Mode	DC to RF Efficiency (%)	Power in Single Pkg (W)	Cost ($/W)	Reliability	Ruggedness	In Volume Production	Voltage (V)
GaAs	Depletion	60	240	$0.42	Fair	Fair	Y	12 & 28
LDMOS	Enhancement	90	1000	$0.12	Good	Excellent	Y	28 & 48
GaN	Depletion	>90	180	$2.00	Unknown	Unknown	Maybe	28 &48
VDMOS	Enhancement	>90*	5000	$0.10	Good	Good	Y	>100V

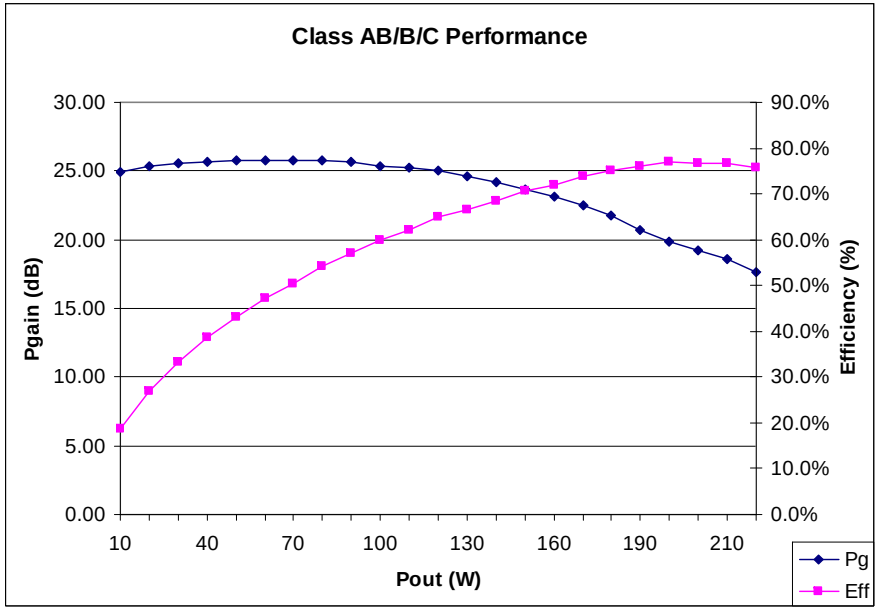
- Luxim has experimented with several different device technologies and is currently using LDMOS

RF Amplifier Topologies

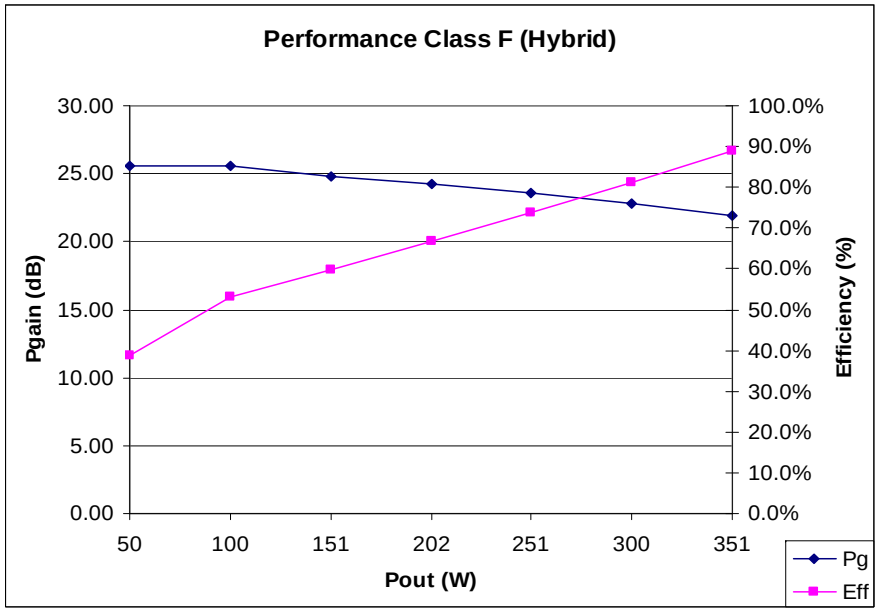
- Efficiency and Power are the key performance attributes that determine amplifier topology
- There are several topologies that have been widely used in various amplifier applications
  - Class AB/B/C saturated
  - Class F
  - Class D/E (switch mode)

RF Amplifier Topologies

Performance of Class AB/B/C and Class F Luxim Amplifiers



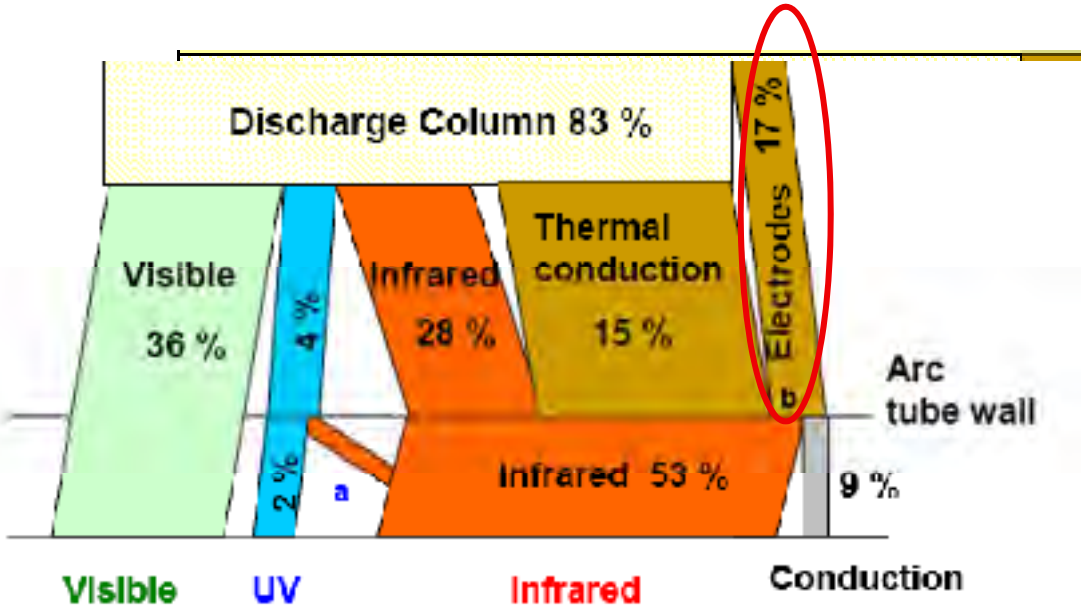
Current Generation Product



Next Generation Product

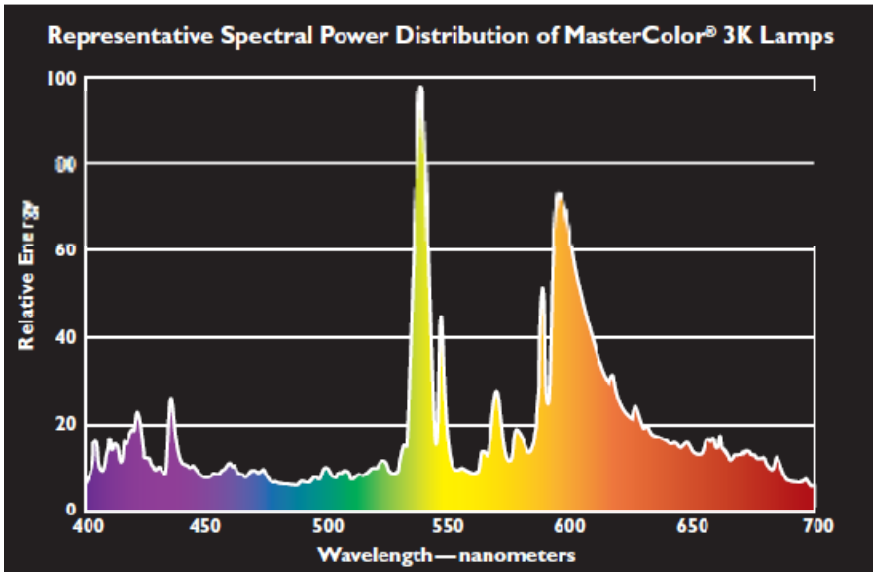
LIFI Intrinsic Advantage: Efficiency

20% (1/.83) Efficiency Gain

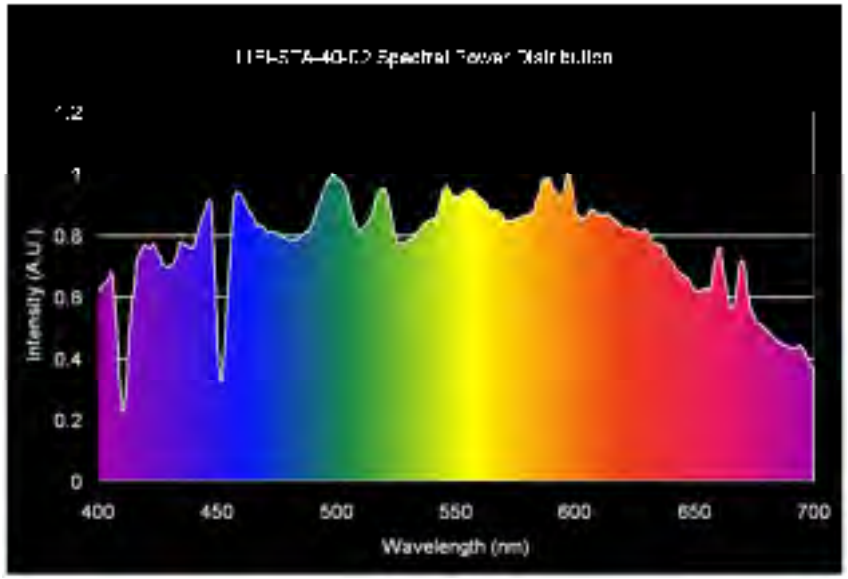


LIFI Intrinsic Advantage: Spectrum

CMH



LIFI



- LIFI technology allows for full color spectrums and tailoring spectrums for specific applications including:
  - Street and Area (5000-6000)
  - Projection/Instrumentation (6500-9000K)
  - Warm Color (3200K)

LIFI Intrinsic Advantage: Electrode Free

A. Dimming/Reduced Power Operation

- No arc flicker electrode tips
- No tungsten sputter (wall darkening)
- Dimming extends life of LIFI source & electronics

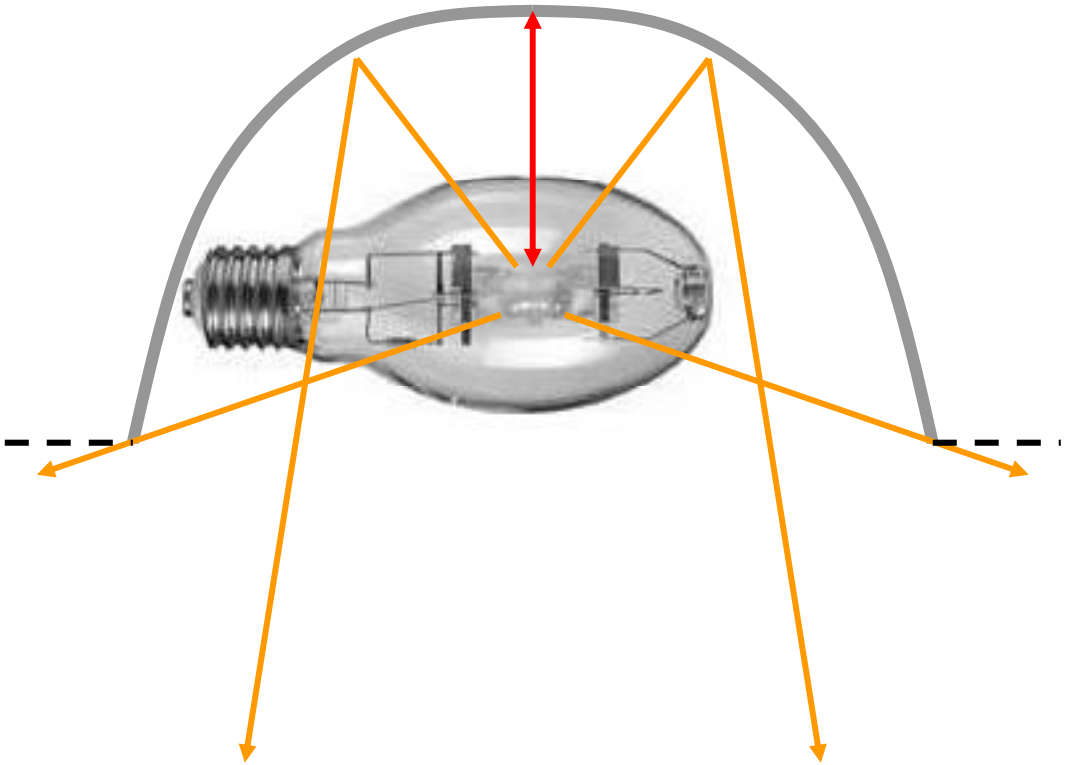
B. Eliminate Mechanical Failures

- No glass to metal seal
- No reaction of fill to tungsten electrodes

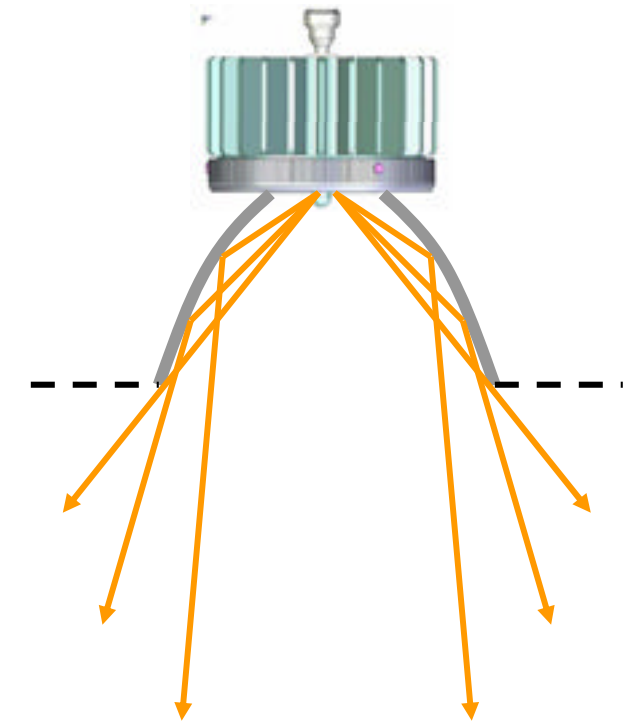
C. Rapid Start and Re-Strike

LIFI Intrinsic Advantage: Directional

CMH



LIFI

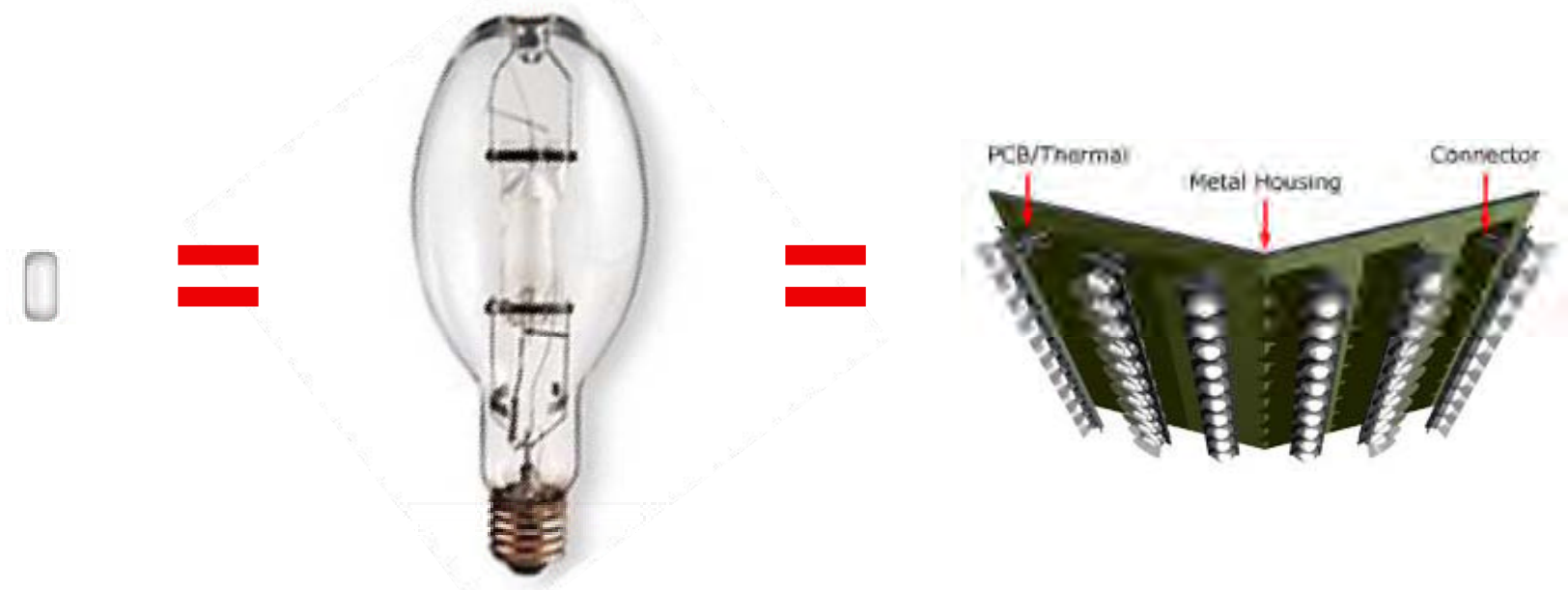


Better Uniformity and Fixture Efficiency

LIFI Technology Features

- Efficiency
  - 120 LPW
- Reliability
  - 30,000 hr lifetime
- Color
  - 95 CRI, 5600 Kelvins
- Compact
  - 800 lumens/mm^2
- Intelligent
  - Digital control
  - Dimmable

Comparative Analysis vs. LED



To generate 25,000 Lumens you need:

One tic tac sized Solid-State High Intensity bulb OR

One grapefruit sized conventional bulb OR

An array of 200 high power LEDs

Comparative Analysis vs. HID

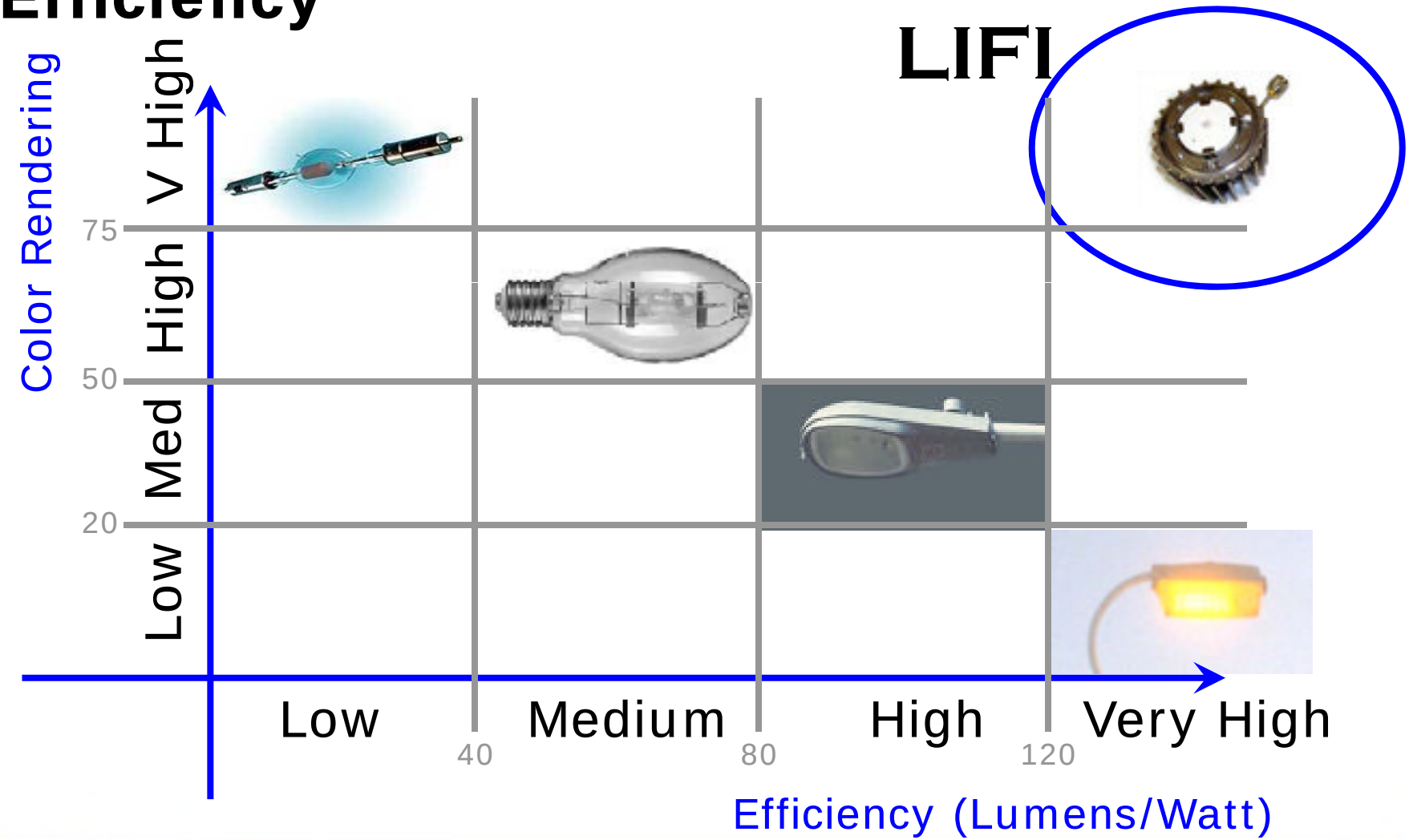
250W

1 Ton of CO_2/Year

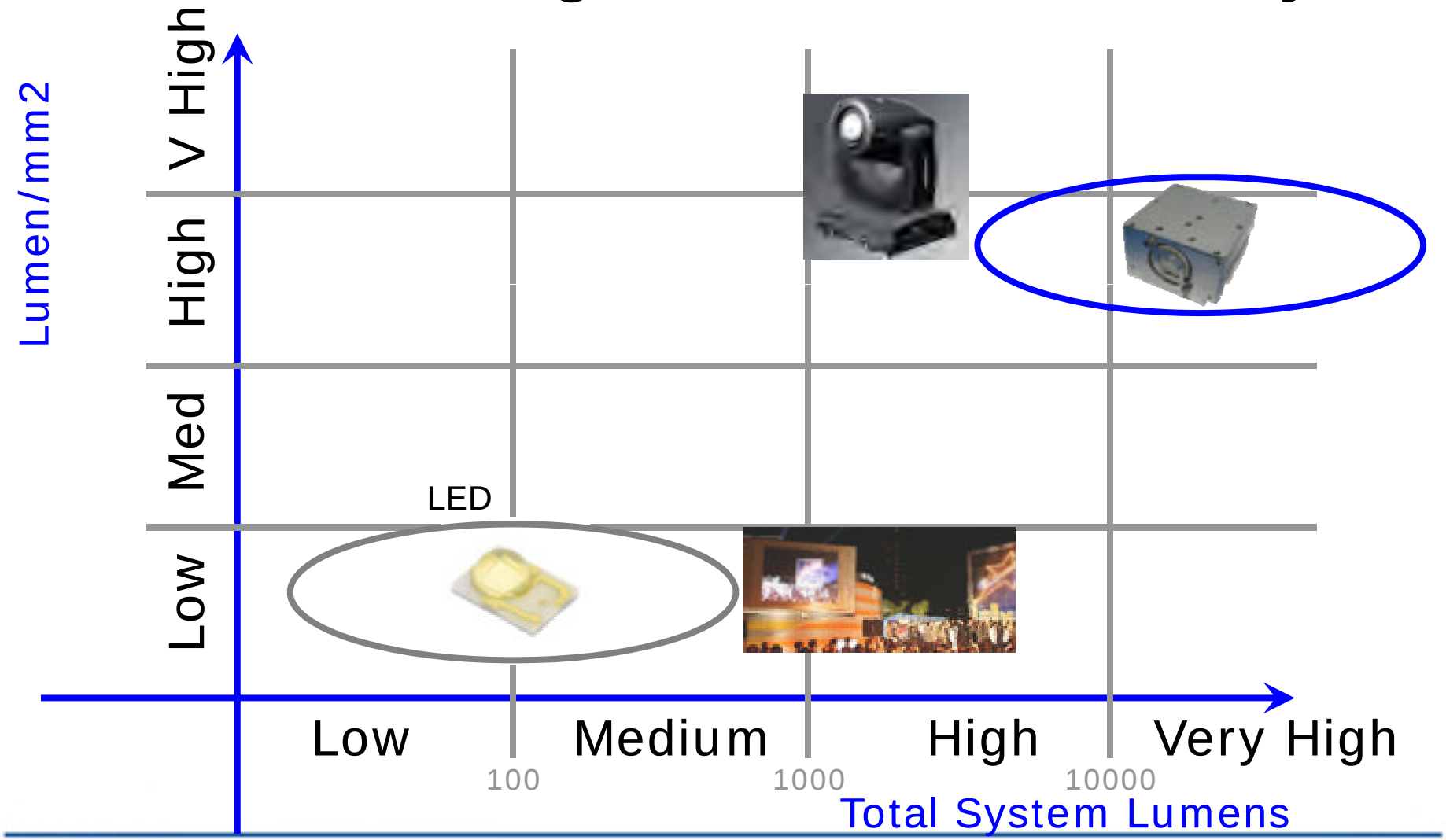
450W

2 Tons of CO_2/Year

LIFI Provides Excellent Color AND Efficiency



LIFI Advantage in Lumen Density

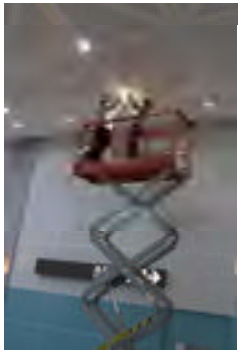


Applications Highlights

Compact/Beam

Low Glare - Indirect

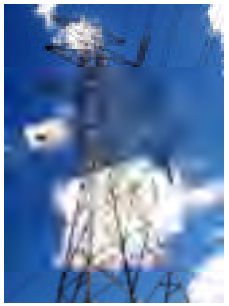
Daylighting/Low Occupancy



Low Maintenance

Solid State High Intensity

High Color Quality



Energy Savings

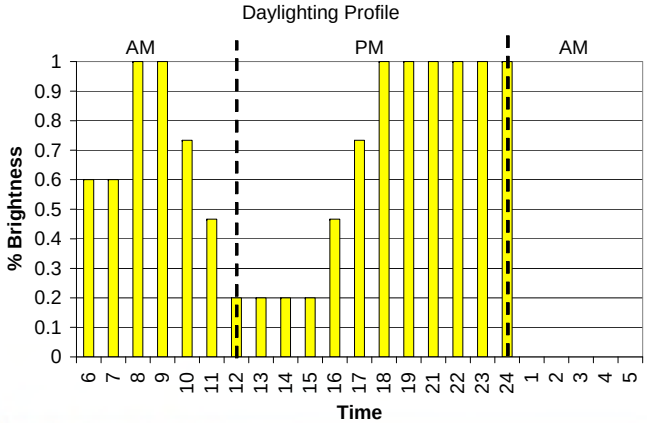
Full Cutoff – Dark Sky

Continuous Operation

Photo credit: Spaulding Lighting

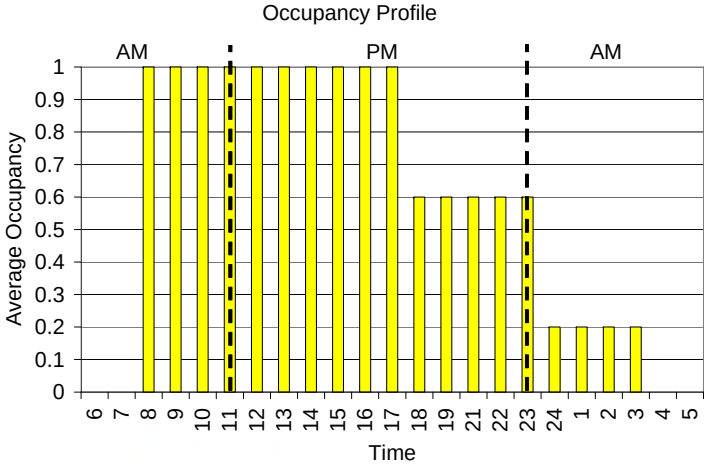
Fixture	Walkway Direct	Walkway Direct
Technology	PS Metal Halide	SSHI
Lamp Model	MH-400-HOR-PS	LIFI-STA-40-01
Lamp Power (W)	400	180
Ballast/Driver Eff. (%)	93%	75%
AC/DC Eff. (%)	100%	90%
Tot. Power (W)	430	267
Source Lumens/Watt	92	120
Initial Source Lumens	36800	21600
Mean Source Lumens	25760	18360
Fixture Eff. (%)	65%	90%
Mean Fixture Lumens	16744	16524
Daily Usage (hrs)	12	12
Dimming Level	1	1
Dimming (hrs)	0	0
Annual KW-Hr (Full Power)	1884	1168
Annual KW-Hr (Dim)	0	0
$/KW-Hr	0.12	0.12
Annual Operating Cost ($)	$ 226	$ 140
Lifetime (Hrs)	15000	30000
Replacement Lumen Level	70%	70%
Replacement Cycle (Hrs)	10500	30000
#Lamps/Yr	0.42	0.15
Replacement Cost/Lamp ($)	250	250
Annual Maint Cost ($)	$ 104	$ 37
Total Annual Cost ($)	**$ 330**	**$ 177**
Savings/Fixture ($)		**$ 154**
Savings/Installation ($)	**20,000 units**	**$ 3,073,805**

Daylighting



Fixture	Indoor Industrial	Indoor Industrial
Technology	PS Metal Halide	SSHI
Lamp Model	MH-400-HOR-PS	LIFI-STA-40-01
Lamp Power (W)	400	180
Ballast/Driver Eff. (%)	93%	75%
AC/DC Eff. (%)	100%	90%
Tot. Power (W)	430	267
Source Lumens/Watt	92	120
Initial Source Lumens	36800	21600
Mean Source Lumens	25760	18360
Fixture Eff. (%)	67%	90%
Mean Fixture Lumens	17259.2	16524
Daily Usage (hrs)	18	18
Dimming Level	1	see profile
Dimming (hrs)	0	see profile
Annual KW-Hr (Full Power)	2826	1509
Annual KW-Hr (Dim)	0	see profile
$/KW-Hr	0.12	0.12
Annual Operating Cost ($)	$ 339	$ 181
Lifetime (Hrs)	15000	30000
Replacement Lumen Level	70%	70%
Replacement Cycle (Hrs)	10500	30000 +
#Lamps/Yr	0.63	0.22
Replacement Cost/Lamp ($)	250	250
Annual Maint Cost ($)	$ 156	$ 55
Total Annual Cost ($)	$ 496	$ 236
Savings/Fixture ($)		**$ 260**
Savings/Installation ($)	**2000 units**	**$ 519,471**

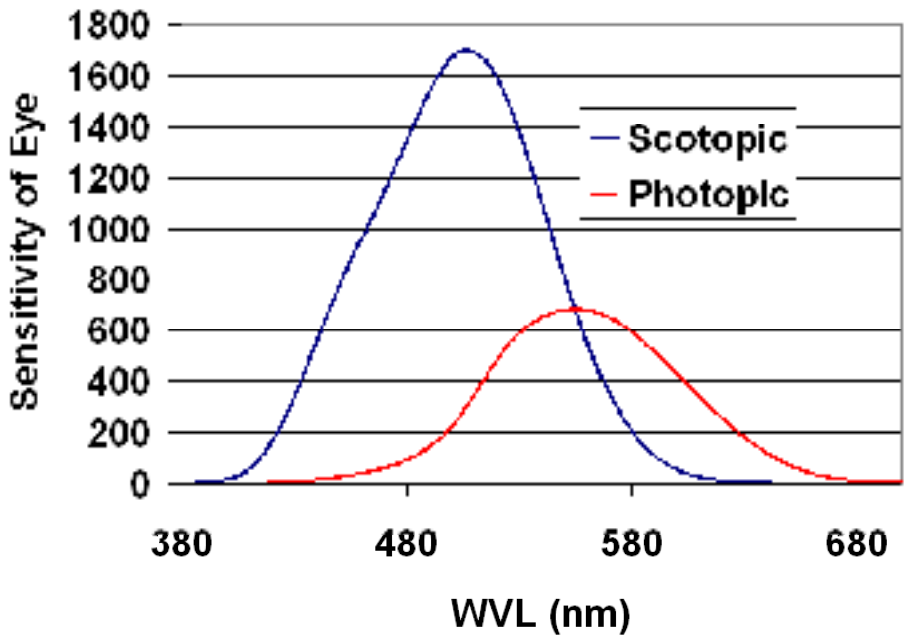
Low Occupancy



Fixture	Parking Lot	Parking Lot
Technology	PS Metal Halide	SSHI
Lamp Model	MH-400-HOR-PS	LIFI-STA-40-01
Lamp Power (W)	400	180
Ballast/Driver Eff. (%)	93%	75%
AC/DC Eff. (%)	100%	90%
Tot. Power (W)	430	267
Source Lumens/Watt	92	120
Initial Source Lumens	36800	21600
Mean Source Lumens	25760	18360
Fixture Eff. (%)	67%	90%
Mean Fixture Lumens	17259.2	16524
Daily Usage (hrs)	20	20
Dimming Level	1	see profile
Dimming (hrs)	0	see profile
Annual KW-Hr (Full Power)	3140	1606
Annual KW-Hr (Dim)	0	see profile
$/KW-Hr	0.12	0.12
Annual Operating Cost ($)	$ 377	$ 193
Lifetime (hrs)	15000	30000
Replacement Lumen Level	70%	70%
Replacement Cycle (Hrs)	10500	30000 +
#Lamps/Yr	0.70	0.24
Replacement Cost/Lamp ($)	250	250
Annual Maint Cost ($)	$ 174	$ 61
Total Annual Cost ($)	$ 551	$ 254
Savings/Fixture ($)		**$ 297**
Savings/Installation ($)	**2000 Units**	**$ 594,061**

Scotopic vs. Photopic Lumens

Photo Credit: LED Workplace



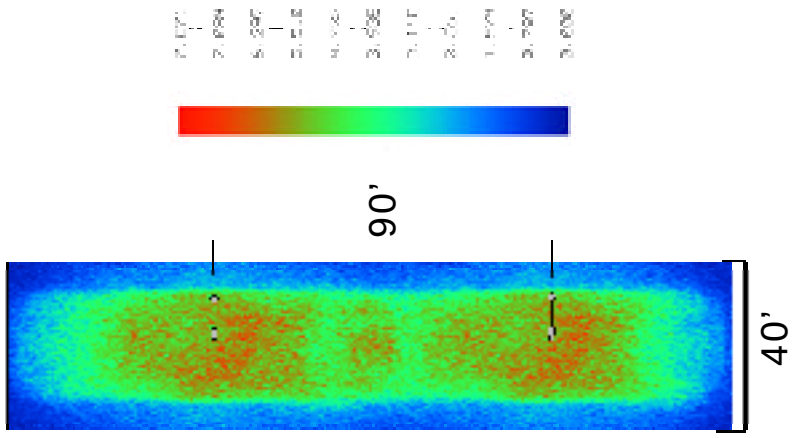
- S-P ratio
  - HPS = 0.64
  - Metal Halide = 1.4
  - Solid State Plasma = 2.4

180W LIFI	100%
400W MH	60%
400W HPS	50%

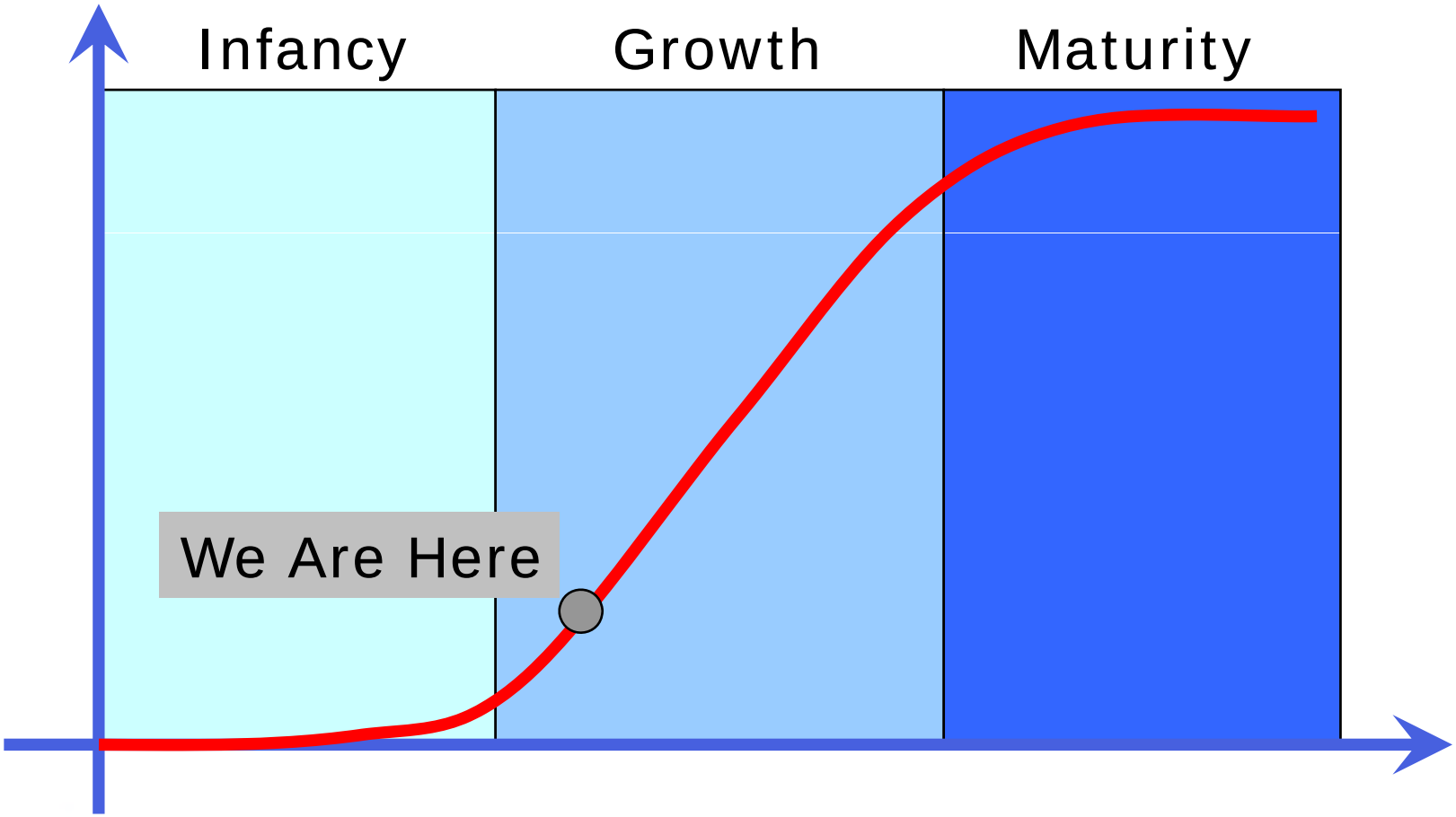
Glare Free, Walkway

Fixture	Walkway Indirect	Walkway Indirect
Technology	CMH	SSHI
Lamp Model	HCI E 250W	LIFI-STA-40-01
Lamp Power (W)	250	110
Ballast/Driver Eff. (%)	93%	56%
AC/DC Eff. (%)	100%	90%
Tot. Power (W)	269	217
Source Lumens/Watt	100	120
Initial Source Lumens	25000	13200
Mean Source Lumens	17500	11220
Fixture Eff. (%)	50%	80%
Mean Fixture Lumens	8750	8976
Daily Usage (hrs)	12	12
Dimming Level	1	1
Dimming (hrs)	0	0
Annual KW-Hr (Full Power)	1177	952
Annual KW-Hr (Dim)	0	0
$/KW-Hr	0.12	0.12
Annual Operating Cost ($)	$ 141	$ 114
Lifetime (Hrs)	13000	30000
Replacement Lumen Level	70%	70%
Replacement Cycle (Hrs)	9100	30000 +
#Lamps/Yr	0.48	0.15
Replacement Cost/Lamp ($)	250	250
Annual Maint Cost ($)	$ 120	$ 37
Total Annual Cost ($)	$ 262	$ 151
Savings/Fixture ($)		**$ 111**
Savings/Installation ($)	**20,000 Units**	**$ 2,218,311**

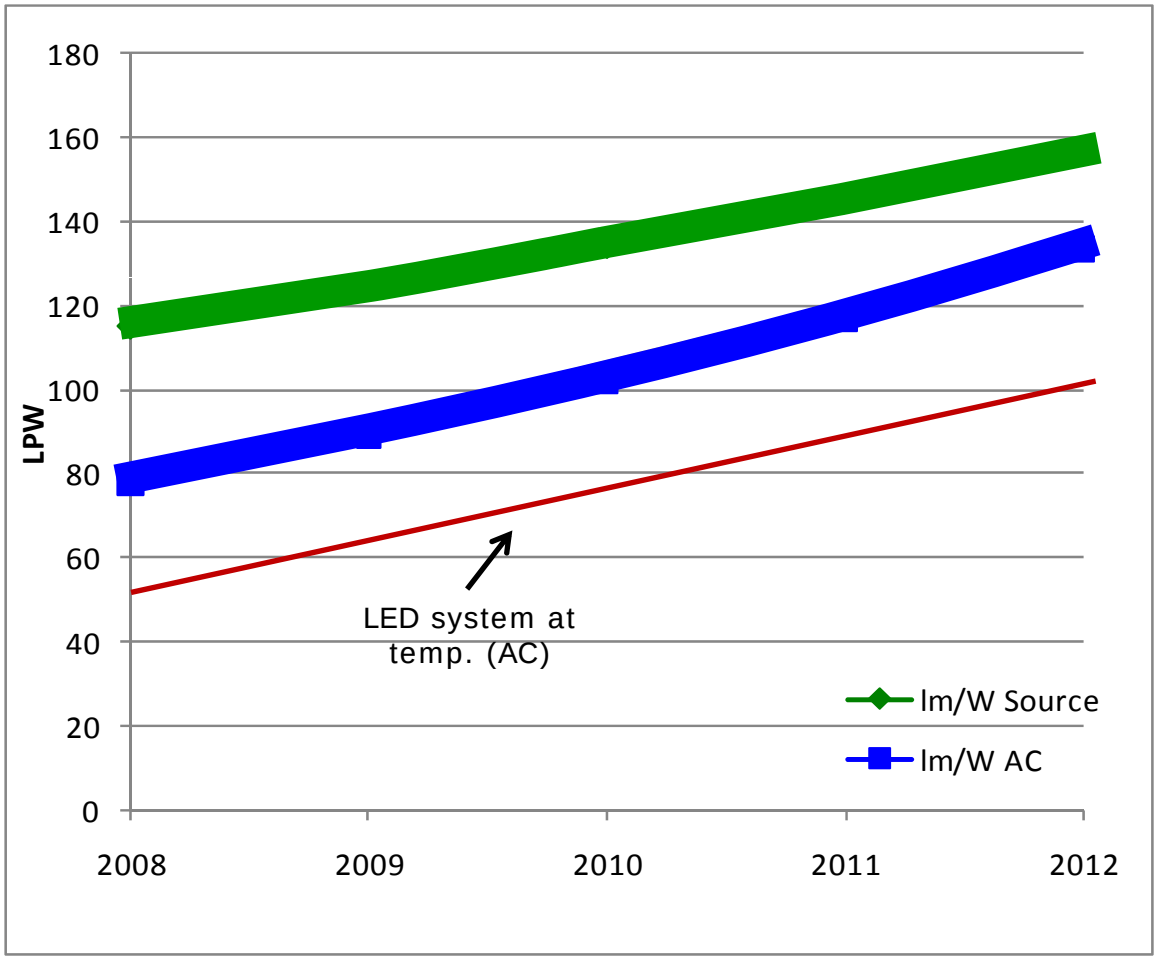
Compact Fixture Examples



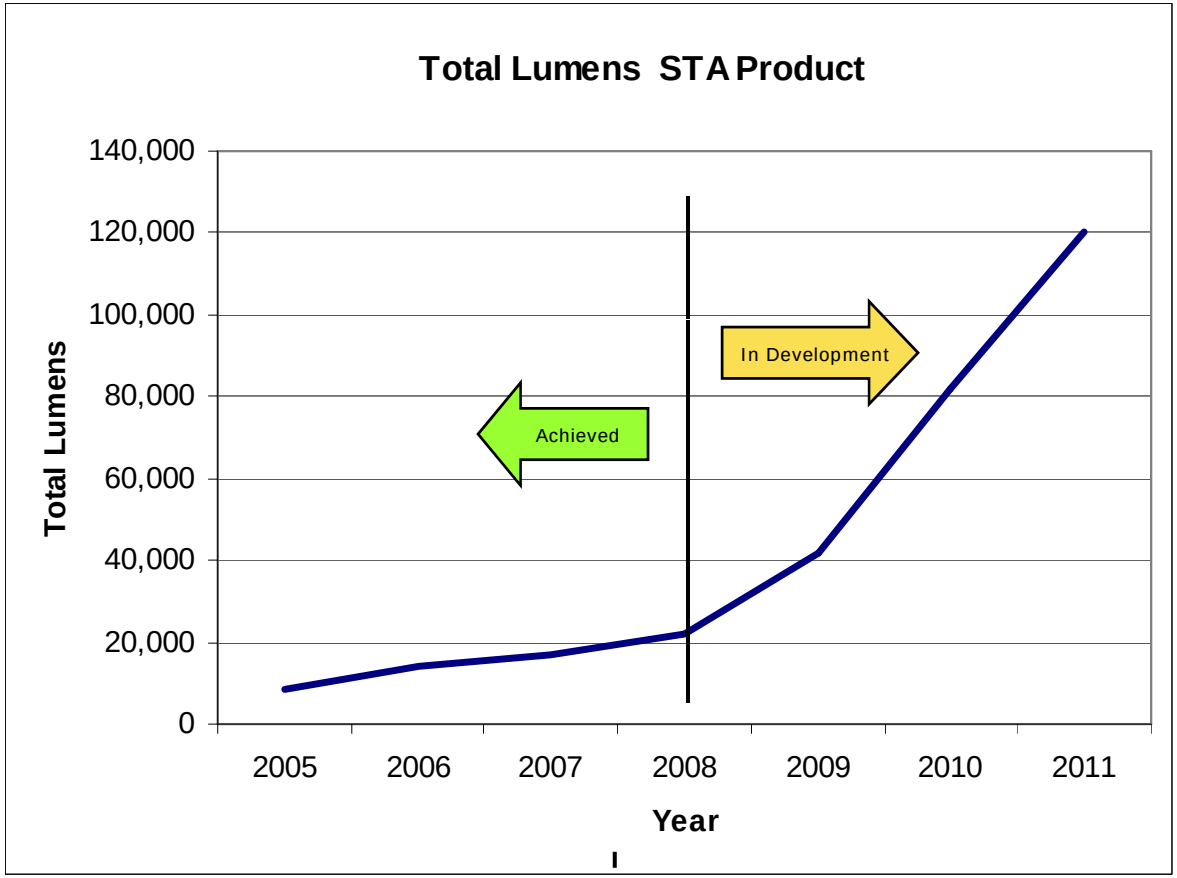
Solid-State Plasma Lighting S-Curve



Driving Efficiency to Lead Solid State Lighting



Lumens Roadmap



Focus on high collection efficiency

Focus on total lumens and system efficiency

LIFI for General Lighting Summary

- LIFI provides highest available efficacy from full spectrum, long life source
- Technology implemented in commercial products in 2009
- Fixture design support available