Solid-State Lighting: The III-V Epi “Killer App”

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HP calculator.
http://www.hpmuseum.org/32.jpg

Center high-mount stop light (CHMSL).
http://www.honda-tech.com/showthread.php?t=2413558

Traffic light.
http://mksurf8.blogspot.com/2009/11/relasyon.html

NASDAQ’s Giant Video Display in Times Square, New York (Jeff Tsao)

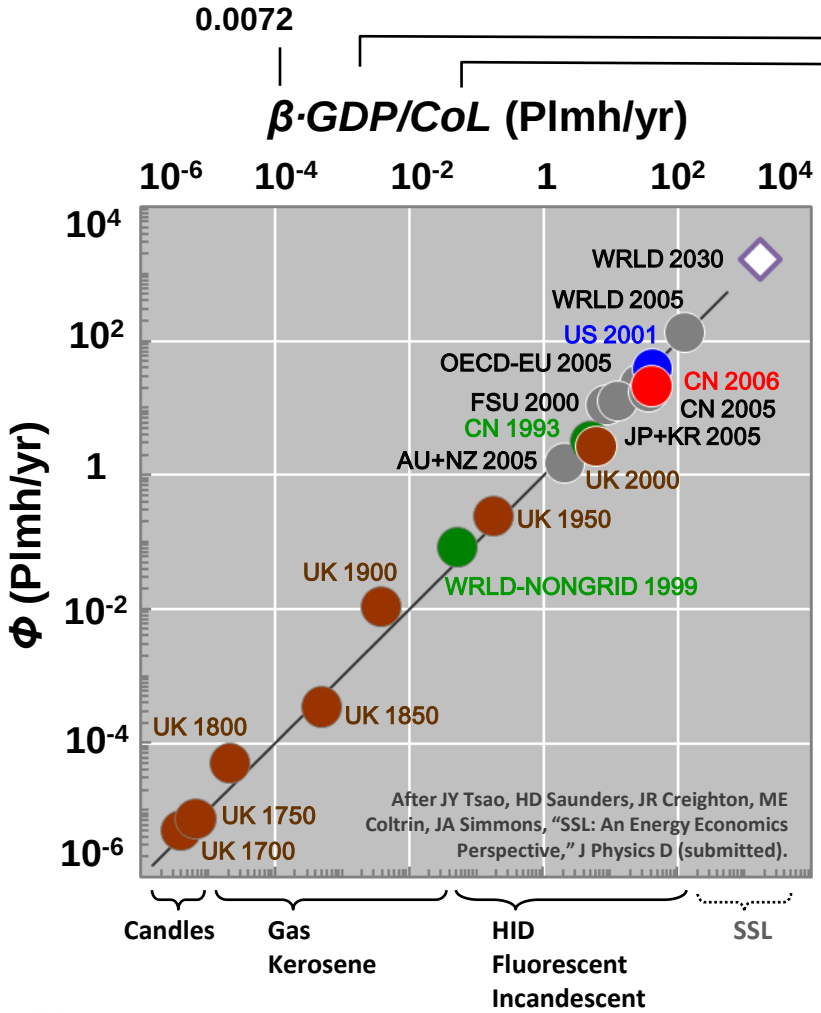
Surefire U2 flashlight.
http://en.wikipedia.org/wiki/File:SurefireU2JPG.jpg

Nokia camera phone with LED flash.
http://www.itechnews.net/wp-content/uploads/2009/07/Nokia-3720-Classic-the-most-rugged-mobile-phone.jpg

Sharp QuadPixel RGBY LED-backlit LCD Display.
http://www.macworld.com/article/145541/2010/01/sharp_quadpixel.html

http://tan-moneyonline.com/wp-content/uploads/2008/03/earthatnight-asia1.jpg

Historical and projected consumption of light



		CoL ~ CoE / η			GDP = N · gdp			Φ	ϕ
Nation or Nations	Year	Cost of Light	Cost of Energy	Lumi-nous Efficacy	Gross Domestic Product	Popu-lation	per capita gross domestic product	Consump-tion of Light	per capita consump-tion of light
		$ / Mlmh	$ / MWh	lm / W	G$ / yr	Gper	$ / per-yr	Plmh / yr	Mlmh / per-yr
Wrld	2030	0.6	119	268.0	139,091	8.3	16,704	1,688.00	202.68
Wrld	2005	3.3	119	47.5	60,670	6.4	9,445	129.52	20.05
US	2001	2.0	76	49.7	12,039	0.3	42,237	41.99	136.11
Wrld Non-Grid	1999	600.2	183	0.3	4,404	2.0	2,202	0.05	0.04

Chip area needed to light the world

http://tan-moneyonline.com/wp-content/uploads/2008/03/earthatnight-asia1.jpg

$$\Phi_{Demand} \cong \frac{\beta \cdot GDP}{CoE / \eta} = p \cdot A \cdot \eta \cdot D = \Phi_{Supply}$$

0.0072

Cost of energy

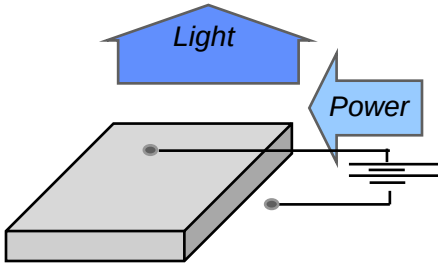
Luminous efficacy

Input power density

Luminous efficacy lm/W

Area

Duty cycle



Area

~1.3 km²

240 football fields

137 T$/yr

$$A = \frac{\beta \cdot GDP}{CoE \cdot p \cdot D}$$

1/4

119 $/MWh

300 W/cm²

Area Turnover

~0.15 km²/yr

28 football fields/yr

Yield 3/4

$$\frac{dA}{dt} = \frac{A / Y}{\tau / D}$$

1/4

Life 25 khr

MOVPE Reactors

~ 800

$$\# \cong \frac{dA / dt}{a \cdot w \cdot r \cdot u}$$

Area of 4" wafer

Wafers per run 12

Runs per day 3

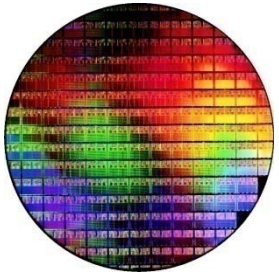
Uptime 330 days/yr

The other electronics “killer apps”

Sharp QuadPixel RGBY LED-backlit LCD Display. http://www.macworld.com/article/145541/2010/01/sharp_quadpixel.html

http://en.wikipedia.org/wiki/File:Solar_cell.png

http://blog.elisehuard.be/wp-content/uploads/2007/12/wafer_200mm_90nm_1024k_dc.jpg



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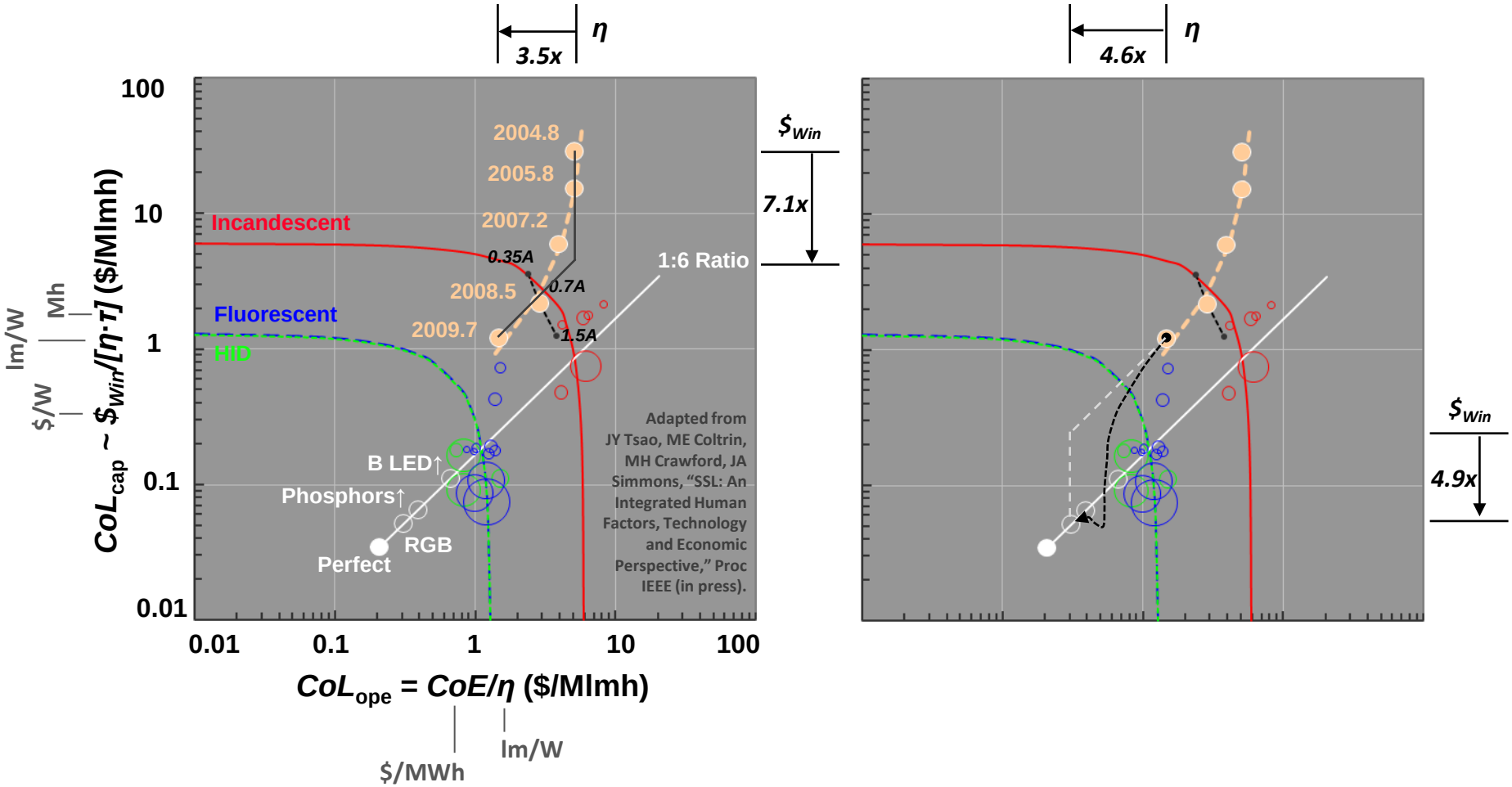
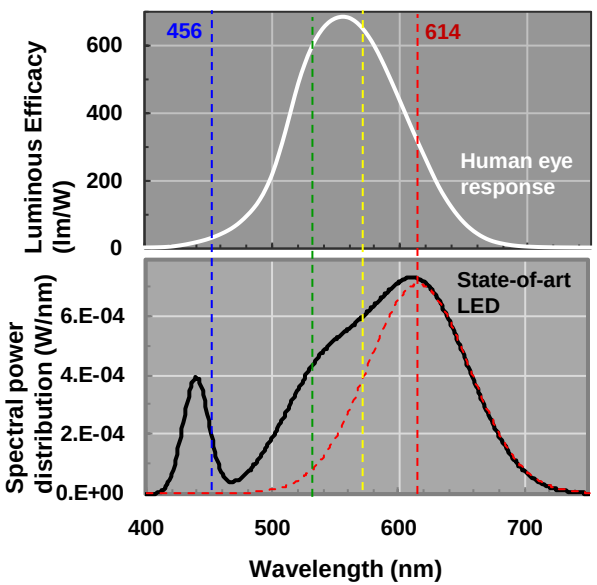
Market	Liquid crystal displays (2009)	Solar cells (2009)	Si electronics (2009)	GaN solid-state lighting (2030)	GaAs electronics (2009)
Approximate area turnover (km^2/year)	230	64	4.4	0.15	0.026
# football fields / year	43,000 (Lake Tahoe / 2)	11,800 (Manhattan)	800 (2 x Monaco)	28 (Vatican City / 4)	5
	Estimate from Steven S Rosenblum, Corning, Inc	Assuming 9.6 GW_p (http://www.displaybank.com/eng/info/sread.php?id=5730) at 15% efficiency	Estimate from Gartner (http://www.fabtech.org/news/_a/gartner_revises_silicon_wafer_demand_forecast/)		Estimate from A Anwar, Strategy Analytics

Enroute to the end game: luminous efficacy, cost, functionality

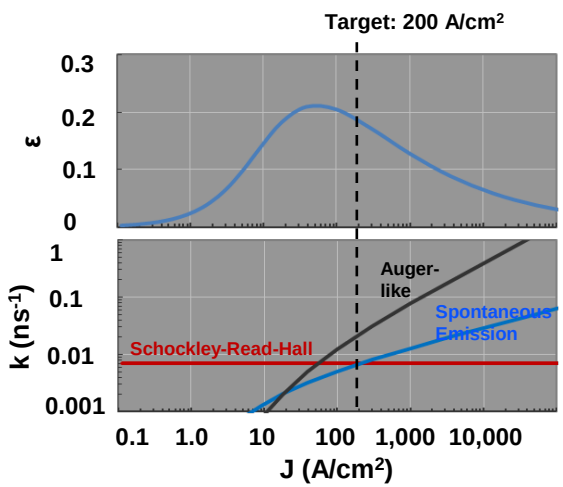


Technology Grand Challenges

① ***Luminous Efficacy:*** ***Narrow-linewidth shallow-red color conversion***



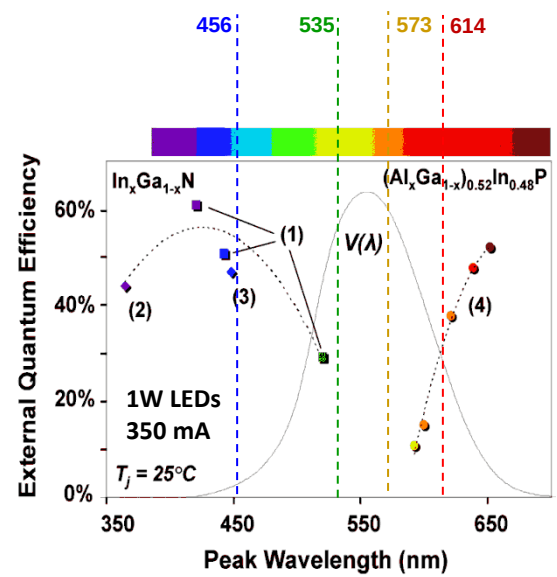
② ***Cost:*** ***Eliminate blue LED efficiency droop***



$$\varepsilon = \underbrace{\left(\frac{V_{ph}}{V_{ph} + IR}\right)}_{\varepsilon_{Joule}} \cdot \varepsilon_{inj} \cdot \underbrace{\frac{BN^2}{AN + BN^2 + CN^3 + \ldots}}_{\varepsilon_{IQE}} \cdot \varepsilon_{ext}$$

2.8V 0.6Ω

③ ***Luminous Efficacy and Functionality:*** ***Fill in the red-yellow-green gap and add control loops***



Courtesy of M. Krames, Philips-Lumileds

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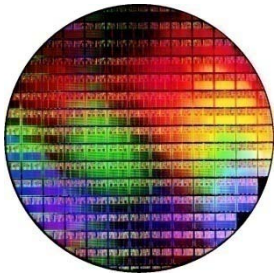

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<u>Acknowledgements</u>:
Randy Creighton · Mike Coltrin · Roland Haitz · Harry Saunders · Eric Shaner · Jerry Simmons · Paul Waide

Work at Sandia National Laboratories was supported by Sandia's Solid-State-Lighting Science Energy Frontier Research Center, funded by the U.S. Department of Energy, Office of Basic Energy Sciences. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy's National Security Administration under Contract DE-AC04-94AL85000.