

SMART LIGHTING SMART LIGHTING ENGINEERING RESEARCH CENTER
Lighting Innovation for a Smarter Tomorrow

Smart Lighting
Lighting Innovation for a Smarter Tomorrow

Kenneth A. Connor
Education Director
Smart Lighting ERC


Rensselaer BOSTON UNM HOWARD ROSE-HULMAN

SMART LIGHTING Goals

- Intro to Our Center
- Solid State Lighting
- Overall Vision
- Light
- Demos

SMART LIGHTING The History of Lighting

THE CASE FOR A NATIONAL RESEARCH PROGRAM ON SEMICONDUCTOR LIGHTING
Roland Haitz and Fred Kish, Hewlett-Packard Company, Palo Alto, CA 94304
Jeff Tsao and Jeff Nelson, Sandia National Laboratories, Albuquerque, NM 87185-0601



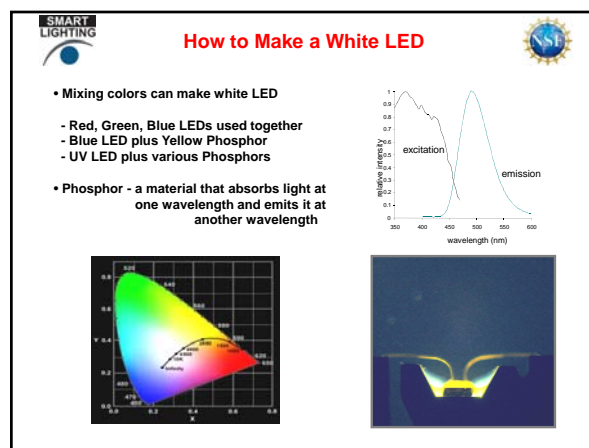
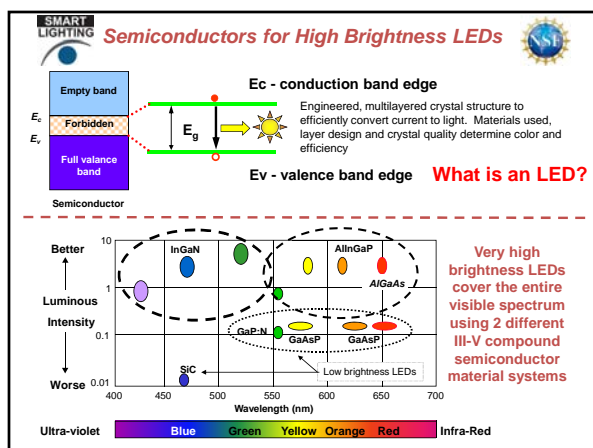
Fire Candles and Lamps Bulbs and Tubes Semiconductors

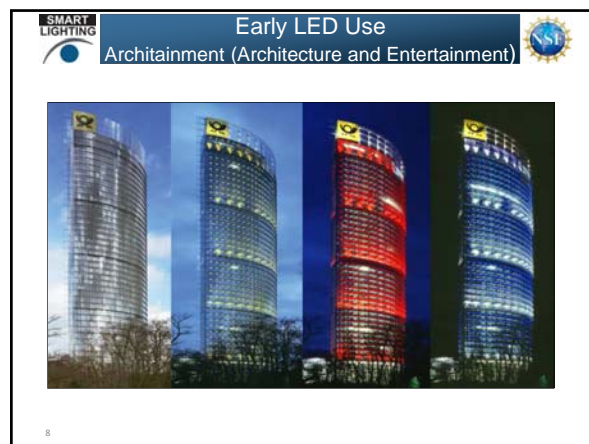
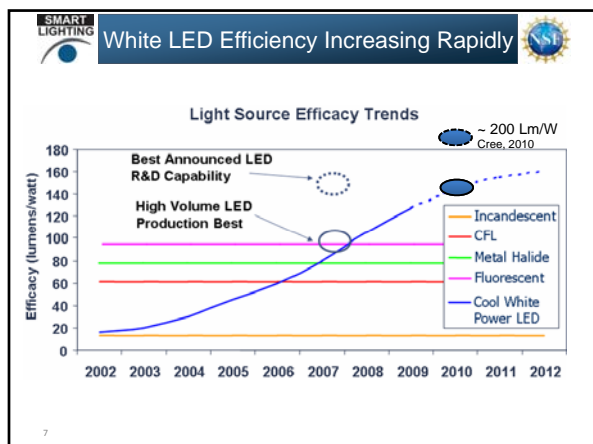
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SMART LIGHTING Overview

- What's an LED
- Lighting Class LEDs?
- The Future of Solid State Lighting

4

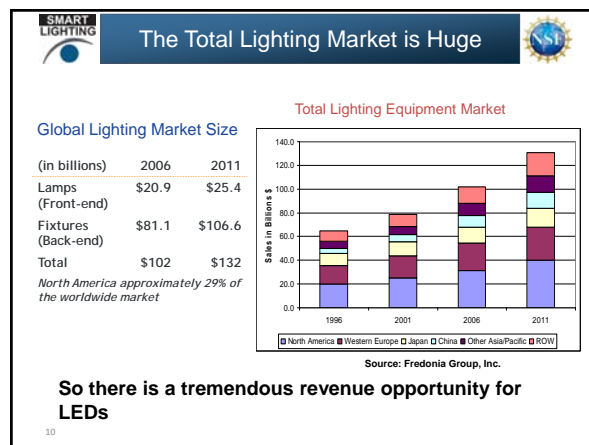




Solid State Lighting – Coming fast

Courtesy of SolarOne

- Many street lighting programs
- 100% SSL buildings are starting to appear (mostly in Asia)
- Many hundreds of start-up companies in Solid State Lighting
- Generally still not ready for prime time
 - Lack of good standards
 - Very high prices
 - Lots of "junk LED bulbs"



This is where research is published, not peer reviewed literature

United States Patent
Erchak et al.

(10) Patent No.: **US 7,196,354 B1**
(45) Date of Patent: **Mar. 27, 2007**

(54) WAVELENGTH-CONVERTING LIGHT-EMITTING DEVICES

(75) Inventors: **Abdul A. Erchak**, Cambridge, MA (US); **Michael Lin**, Cambridge, MA (US); **Edoardo Liberato**, Newton, MA (US); **Je A. Venzon**, Boston, MA (US); **Michael G. Brown**, Tyngsboro, MA (US); **Robert F. Karlick, Jr.**, Chelmsford, MA (US)

(73) Assignee: **Luminus Devices, Inc.**, Woburn, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 25 days.

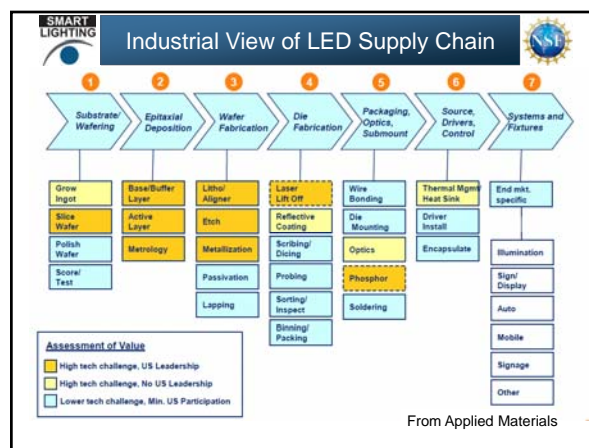
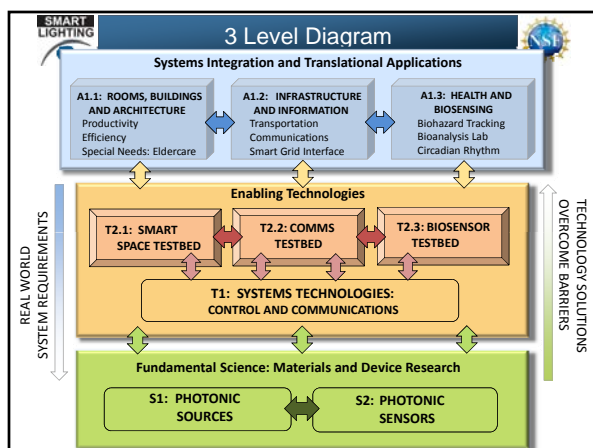
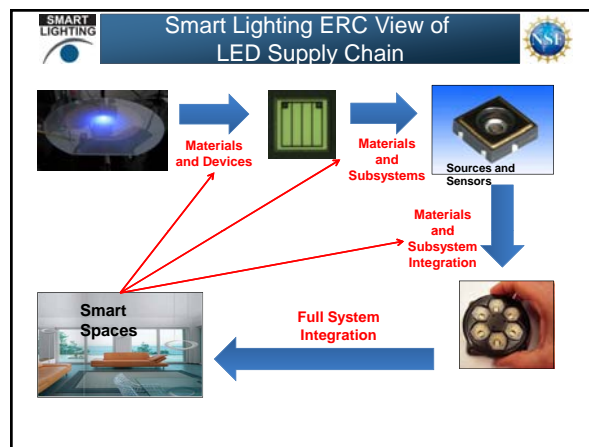
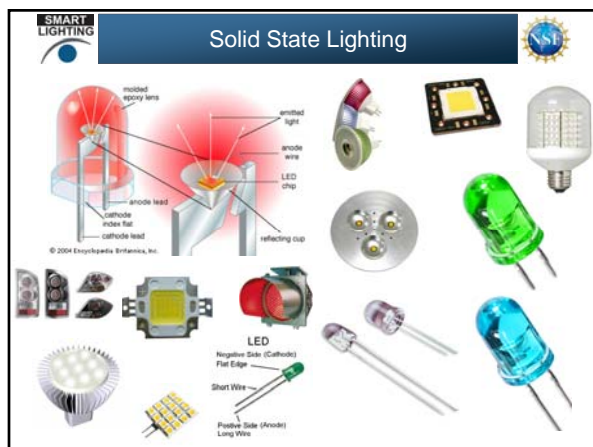
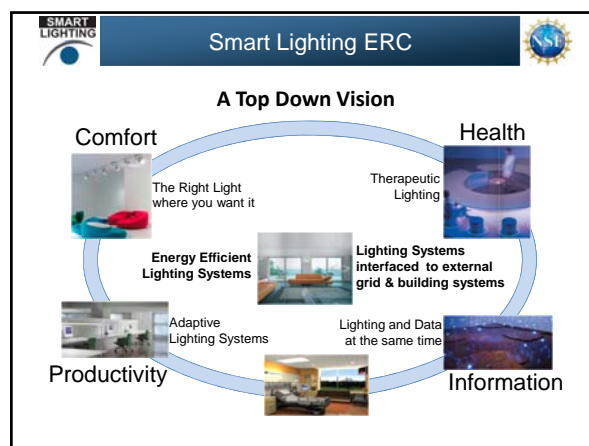
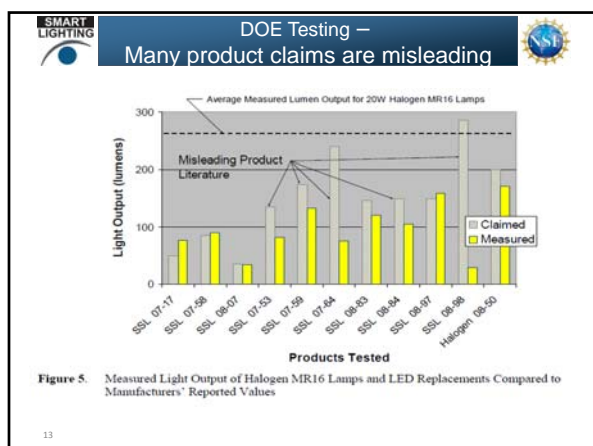
(21) Appl. No.: **11/238,667**

(22) Filed: **Sep. 29, 2006**

OTHER PUBLICATIONS

"NewPac sets new standard with 500 lumens (LED) lighting", LEDs Magazine, <http://www.ledmagazine.com/press/1616/>, Times announced Jul. 5, 2005, Date of website printout Jan. 23, 2006.





Novel Uses of SSL

- LEDs and Lighting
- Key System Level Aspects
 - Chips and Packaging
 - Electronics and Optics
 - Bulbs and Sockets
- Other LED Applications
- Smart Lighting

19

Square Source in a Round Lighting Hole?

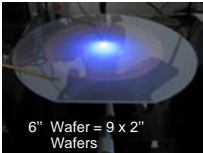


- DC device in an AC Powered World
- Cool light source with thermal management challenges
- Great LED Efficacy – High Lm/W
...But low Lumens per part
- Cost still way too high (\$100 per 1000 Lm)
- Can Semiconductor "Thinking" do the job?

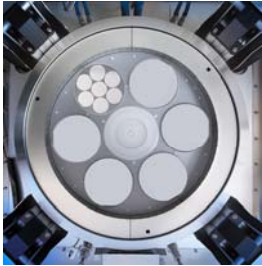




LEDs – the Chips will be Free (almost)



6" Wafer = 9 x 2" Wafers



Aixtron 42x2 or 6x6 Production Tool

- Low cost, large diameter substrates
- New LED Growth Platforms (faster, lower cost)
- Automated Production
- Are radically different approaches to LED chip manufacturing required?

Packaging: Thousands of Styles

Standard Types (< 1/8 W) – low cost, low light




Medium Power Types (< 1/2 W)



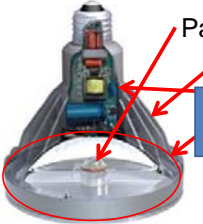

High Power Types (1 to 100 W)





- No Standard Package – though some more popular than others
- Lighting Trends: (1) Lots of small LEDs spread out (diffuse)
(2) Biggest Chip in Smallest Package (spot)

System – Putting it all together



Packaged

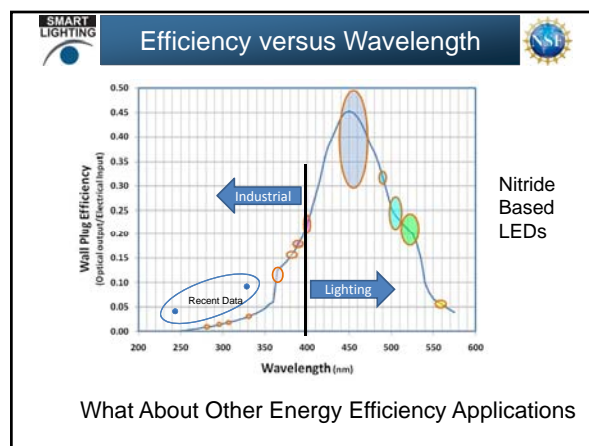
INSIDE

- AC LED at 200 Lm/W
- Thermal Glass Heat Sink
- Remote Phosphor
- Non-Yellow Phosphor
- Internal Smart Grid Interface
- Etc.

FUTURE ??????

Cree LRP-38™ @ 55 Lm/W
(Efficiency of system parts are approximate)

Will we still need a socket?



SMART LIGHTING **UV Curing**

- Cuts drying energy consumption by ~70%
- No solvent emission – “dries” by polymerization

SELECT YOUR INDUSTRY

Only ~20% of manufacturing processes that could be UV cured are using UV curing today

SolidUV Proprietary Information

SMART LIGHTING **Replace Hg Bulbs with UV LEDs**

Hg Arc Lamp (300 W/in)
65% of energy in IR

UV LED Array (150 W/in)
No IR

Water or solvent based coating using 1.2MBTU/H gas fired forced air oven	UV Arc Lamps 2 300W/in, 60" wide bulb 1,080,000 lbs/yr	Projected High Power UVLED system 540,000 lbs/yr
--	--	---

Hg Lamps – about \$700M/year in Replacement Lamps

Green House Gas Emissions Reductions for a single product (3 production lines @ 24x5)

SMART LIGHTING **Today's Lighting**

- Do we really need sockets? (when LEDs outlast buildings)
- Semiconductor paradigm the right model? (Can we get the costs we need?)
- Lighting Design – What we want or a cover up for poor light sources

SMART LIGHTING **Look Up**
Right Above the Smart Lighting ERC Door

NEXXUS LIGHTING

Lamp Facts	
Chip Supplier	Nichia
Packager	Citizen
LED Count	108
Watts	7.8
Lumens	550
CCT	3000K
Cost	\$90

Compared to a 75W PAR 30 Incandescent Lamp:

- Electrical savings offsets higher cost in one to two years, depending on usage (on-time) – for 24 hr. operation at \$0.12/kWhr, payback is < 1 year
- Lifetime of over 50,000 hours, or about 20x better than an incandescent bulb

The Smart Lighting ERC would like to thank Nexus for providing the lamp

SMART LIGHTING **Summer Undergrad Students**

- Irene Benny- RPI
- Rachel Romines – Rose-Hulman
- Dennis Deensie – Morgan State
- Daniele Manikeu – Morgan State
- Adrianna Anderson – St. Rose
- Tiffany Knapp – St. Rose

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SMART LIGHTING **LIGHT**

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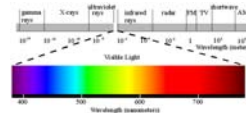



SMART LIGHTING LIGHT – How Do We Use It?

- Illumination – Lighting in our homes and work, for our cars, etc.
- Imaging – Microscopes, telescopes, photography, etc
- Displays – Television and Computer Monitors (CRT, Plasma, LCD, etc.)
- Signaling – Traffic lights (cars, trucks, trains, boats, etc.), laser pointer, etc.
- Information – Optical fibers, read-write for storage (CD, DVD, Blu-Ray, etc), barcode, etc.
- Cutting, etching, etc.

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SMART LIGHTING Characteristics of Light



- Spectrum (Color)
- Polarization
- Time Variation (Blinking)
- Direction

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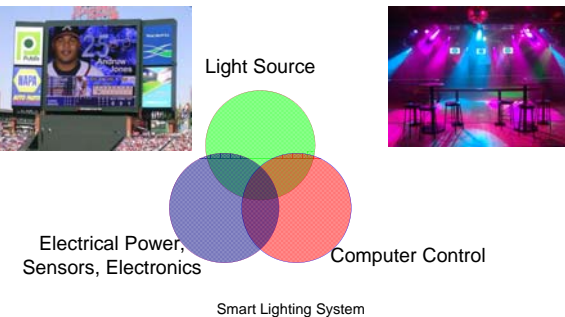


SMART LIGHTING Making Light Smart

- Light Source
 - LED
- Power for Light Source
 - Battery (DC Voltage)
- Control
 - Computer (Processor)

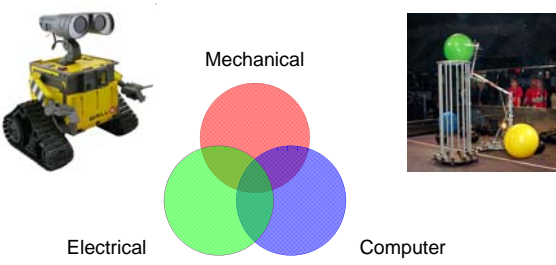

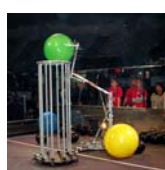
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SMART LIGHTING Smart Lighting

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SMART LIGHTING Similar to Robotics

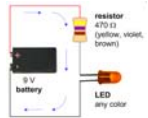
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SMART LIGHTING Making Light Through Electronics

- LED (Light emitting diode)
- Resistor
- Wires
- Battery

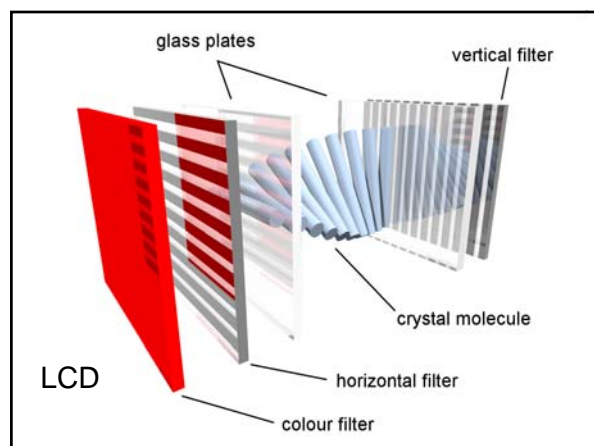
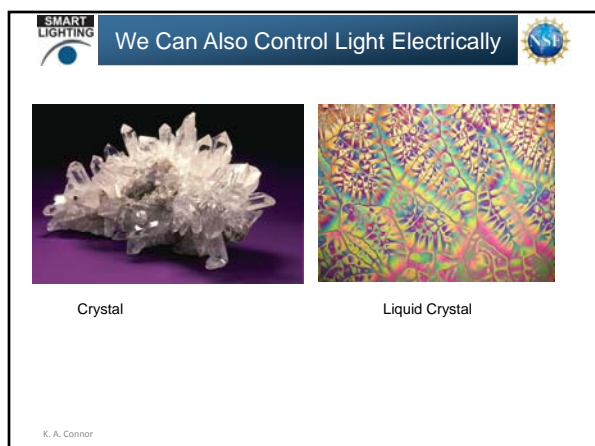
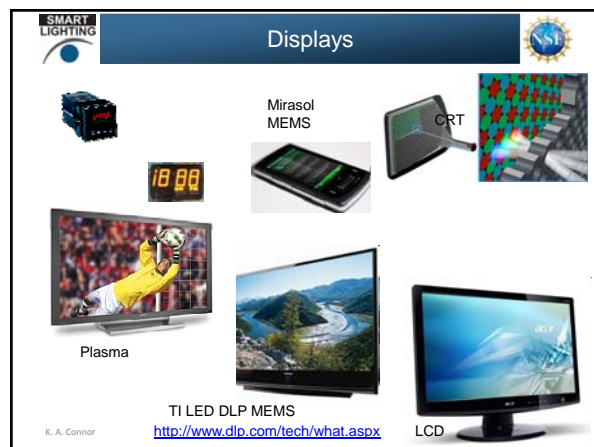
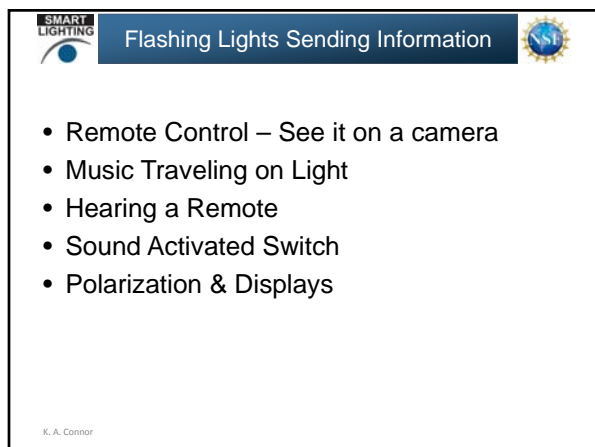
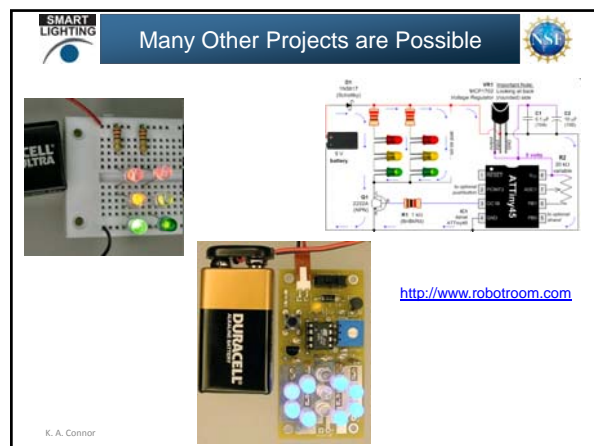
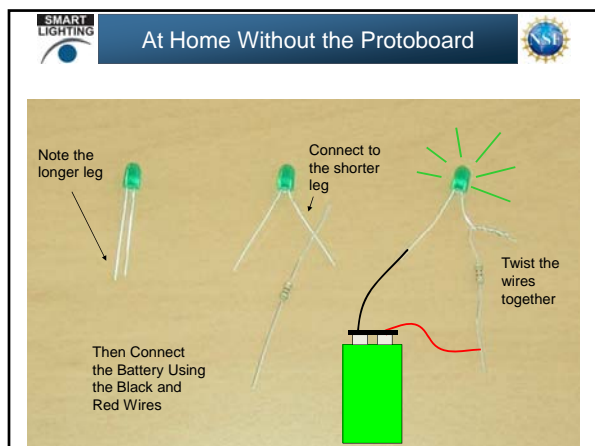
We have made a solid state light
Such a light could be used to send flashing signals

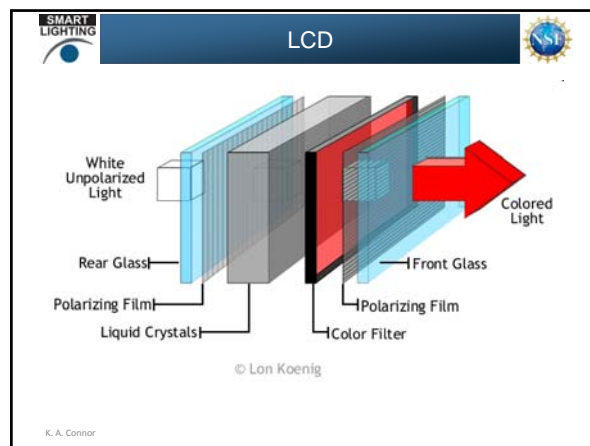
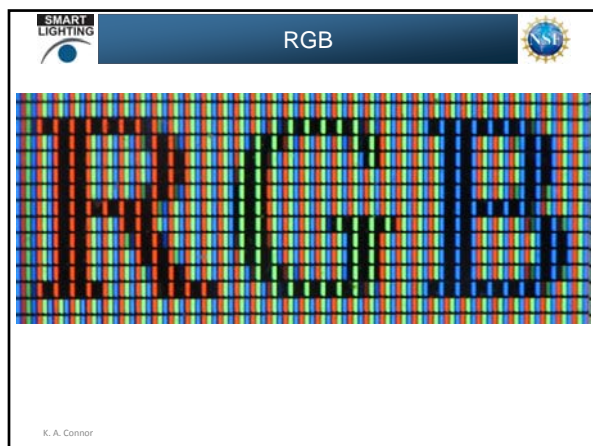
This is what the stop and go lights (red, yellow, green) are made from these days



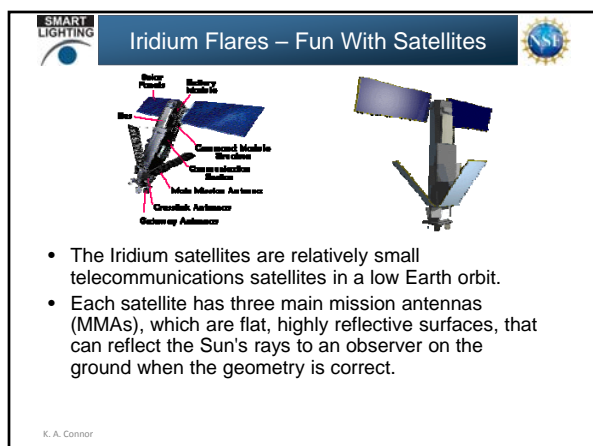
<http://www.robotroom.com>

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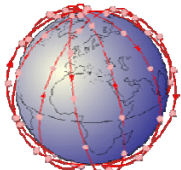

-
- 1987: Two Motorola engineers envision a constellation of low orbiting satellites.
 - 1990: The Iridium System is announced.
 - 1995: FCC License granted
 - 1998: Constellation of 66 satellites successfully launched.
 - 1999: Chapter 11
 - 2002: Licenses, etc. assigned to New Iridium
- Note: Financing was several billion dollars



-
- The satellite's attitude is controlled so that the long axis remains vertical, with one MMA always pointing forwards. Given this knowledge of the attitude, together with the orbital position of the satellite and the Sun and observer's location, it is possible to calculate the angle between the direction to the observer from the satellite and the line of a perfect reflection of the Sun. This is the so-called "mirror angle" and determines the magnitude of the flare.

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Iridium Flares

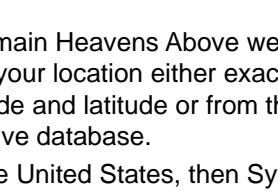



- [Heavens Above](#) is an extensive website with information on tracking objects in space, notably including Iridium Satellites.

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Iridium Flares



- In the main Heavens Above webpage, select your location either exactly by longitude and latitude or from their extensive database.
- Choose United States, then Sycaway (where I live) Latitude: 42.742, Longitude: 73.653, Elevation: 121 m
- Select Iridium Flares for the Next 7 Days.

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Heavens Above

Buy Binoculars Online

Binoculars.com

Iridium Flares

Clicking on the time of the flare will load another page with more details, including a map showing the track of the flare along the ground, and the location of the nearest point of maximum intensity.

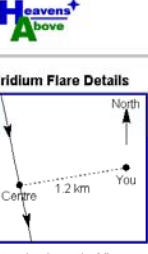
Search Period Start: 21:24, Sunday, 10 November, 2002
Search Period End: 22:24, Sunday, 17 November, 2002
Observer's Location: Sycaway (42.742°N, 73.653°W)
Local Time: Eastern Standard Time (GMT - 5:00)

Date	Local Time	Intensity (Mag.)	Alt.	Altitude	Distance to flare centre	Intensity of flare centre (Mag.)	Satellite
13 Nov	05:11:13	-2	26°	162° (SSE)	27.0 km (W)	-7	Iridium 11
14 Nov	05:25:17	-2	25°	162° (SSE)	21.5 km (E)	-7	Iridium 3
15 Nov	06:42:50	-1	29°	76° (ENE)	39.7 km (E)	-7	Iridium 28
16 Nov	06:36:44	-7	28°	74° (ENE)	1.2 km (W)	-7	Iridium 30
17 Nov	05:16:14	-1	26°	170° (S)	35.0 km (W)	-7	Iridium 26
17 Nov	06:30:35	-1	28°	73° (ENE)	45.9 km (W)	-6	Iridium 57
17 Nov	17:34:52	-1	60°	34° (NE)	30.1 km (W)	-8	Iridium 46

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Iridium Flares



Buy Binoculars Online

Binoculars.com

Iridium Flare Details

Date: Saturday, 16 November, 2002
Your Location: Sycaway (42.742°N, 73.653°W)
Time Zone: Eastern Standard Time (GMT - 5:00)
Satellite: Iridium 30
Antenna (MMA): Front
Flare centre is at: 42.740°N, 73.668°W
Distance to centre: 1.2 km (0.8 miles)

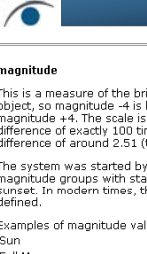
Map showing path of flare centre over Earth's surface

At your location		At flare centre	
Time:	06:36:44	06:36:44	
Magnitude:	-7	-7	
Altitude:	28°	28°	
Azimuth:	74° (ENE)	74° (ENE)	
Mirror angle:	0.0°	0.0°	

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Iridium Flares



magnitude

This is a measure of the brightness of a celestial object. The lower the value, the brighter the object, so magnitude -4 is brighter than magnitude 0, which is in turn brighter than magnitude +4. The scale is logarithmic, and a difference of 5 magnitudes means a brightness difference of exactly 100 times. A difference of one magnitude corresponds to a brightness difference of around 2.51 (the fifth root of 100).

The system was started by the ancient Greeks, who divided the stars into one of six magnitude groups with stars of the first magnitude being the first ones to be visible after sunset. In modern times, the scale has been extended in both directions and more strictly defined.


Examples of magnitude values for well-known objects are;

Sun	-26.7 (about 400 000 times brighter than full Moon!)
Full Moon	-12.7
Brightest Iridium flares	-8
Venus (at brightest)	-4.4
International Space Station	-2
Sirius (brightest star)	-1.44
Limit of human eye	+6 to +7
Limit of 10x50 binoculars	+9
Pluto	+14
Limit of Hubble Space Telescope	+30

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Iridium Flares



- What will you see?
- Look at <http://homepage.mac.com/kevision/video/iMovieTheater25.html> and <http://www.youtube.com/watch?v=1PFUP5LPyuA>

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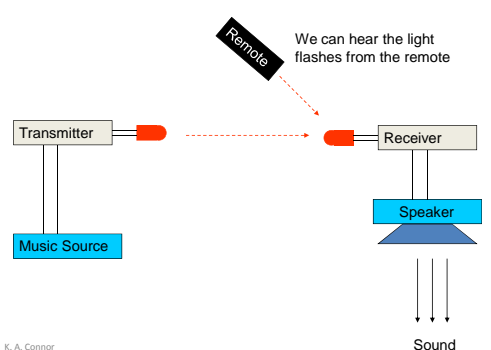
Remote Controls



- Infrared Light
- Cannot be seen by humans
- Can be seen by digital camera
- Remote control sends light flashes to TV or any other device it is to control

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Music Traveling on Light Flashes



We can hear the light flashes from the remote

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Butterfly and Bee Vision



what butterflies see

what humans see

Image made with light visible to humans

Image made with only UV light

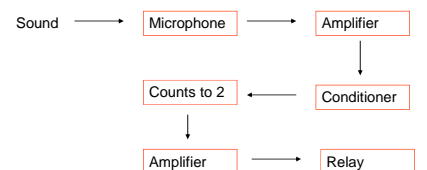
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The Clapper



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The Clapper



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graph LR
    Sound --> Microphone
    Microphone --> Amplifier1[Amplifier]
    Amplifier1 --> Conditioner
    Conditioner --> Counts[Counts to 2]
    Counts --> Amplifier2[Amplifier]
    Amplifier2 --> Relay
  
```

This is a good example of a system that makes a decision based on some kind of input

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Questions?



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