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State of art in the science and Technology of Electrical Discharge Light Sources

G. Zissis

C.P.A.T. - U. Toulouse III
http://cpat.ups-tlse.fr

Light Sources Workshop
September 13-14th, 2005
Matsuyama, Japan

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Producing Artificial Light before electricity

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HOT

Incandescence

- ✓ Fire
- ✓ Torches
- ✓ Candles
- ✓ Oil lamps
- ✓ Gas lamps

COLD

Luminescence

- ✓ Fluorescence
- ✓ Phosphorescence
- ✓ Triboluminescence & thermoluminescence
- ✓ Lightning

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Producing Artificial Light using electricity

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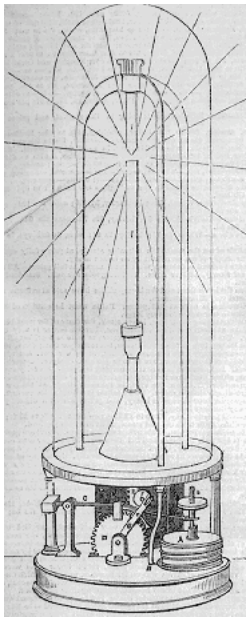
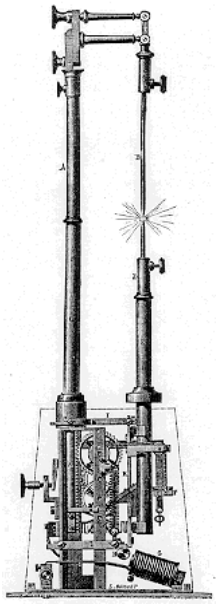
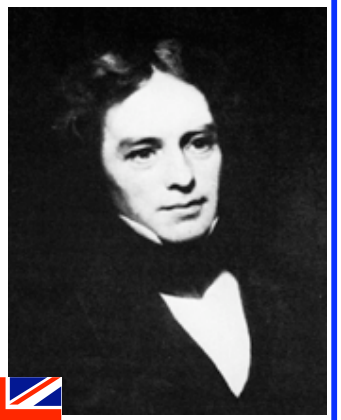
Electric Arc

Carbon arc





Humphry Davy & Michael Faraday

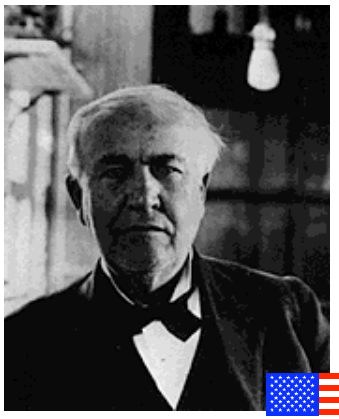


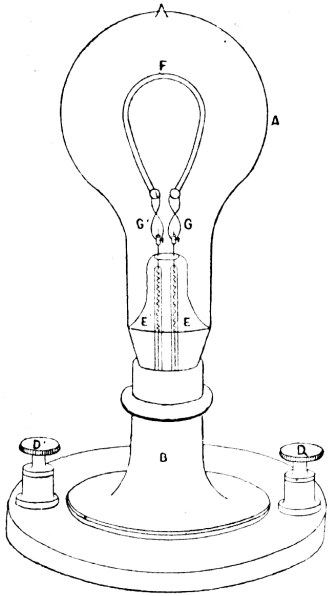
1812

Incandescence

Carbon filament

Thomas Edison





1878

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The Family of Electric Light Sources

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Clusters

Selective Filter

Halogen

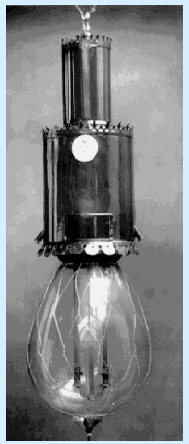
Classic W-wire

Incandescence

Operating Pressure

Type of Spectrum

Power supply mode



Electrical Discharge

Luminescence

L.E.D & O-LED

Field emission

Solid State

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Light sources are everywhere

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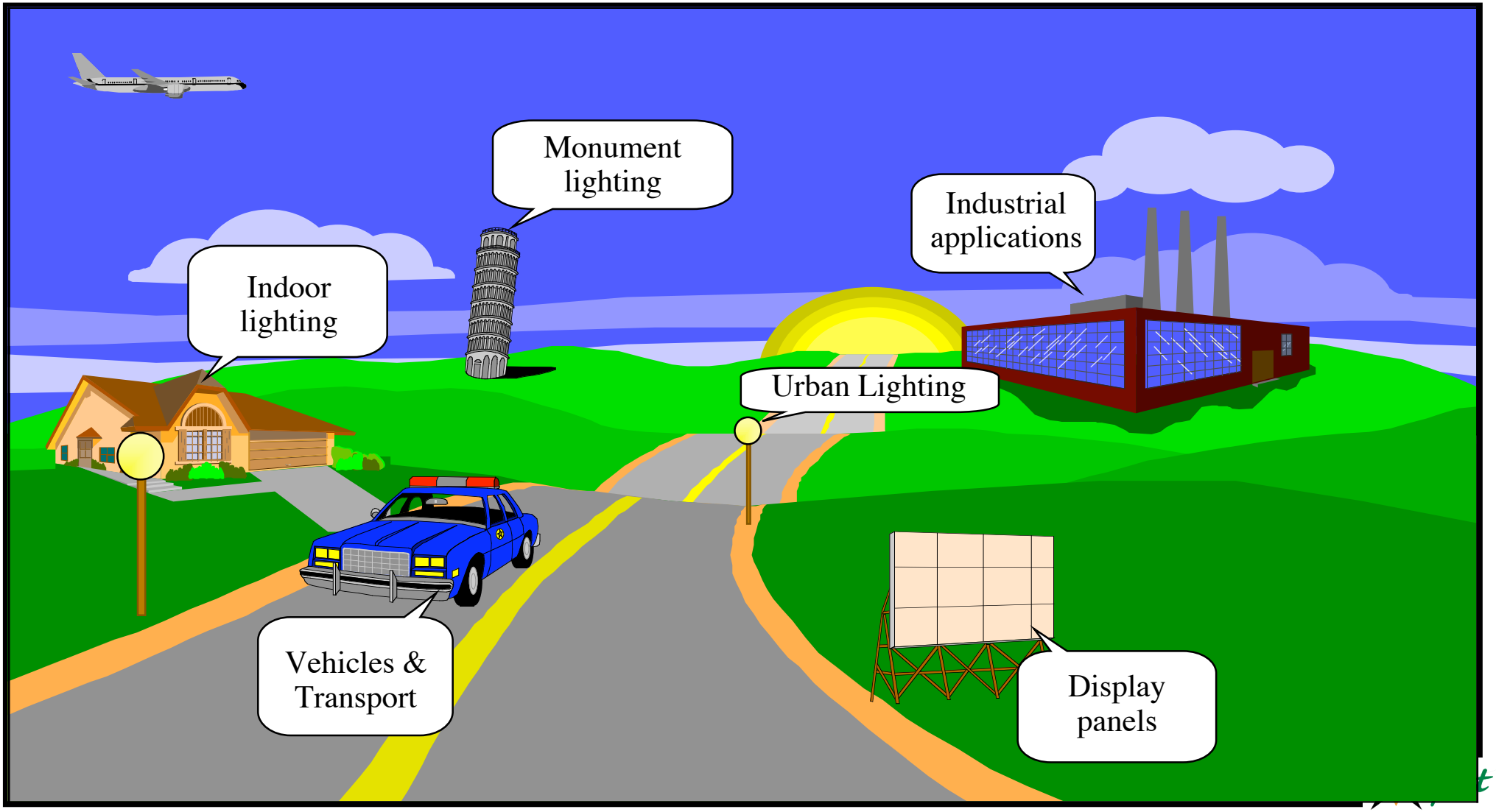
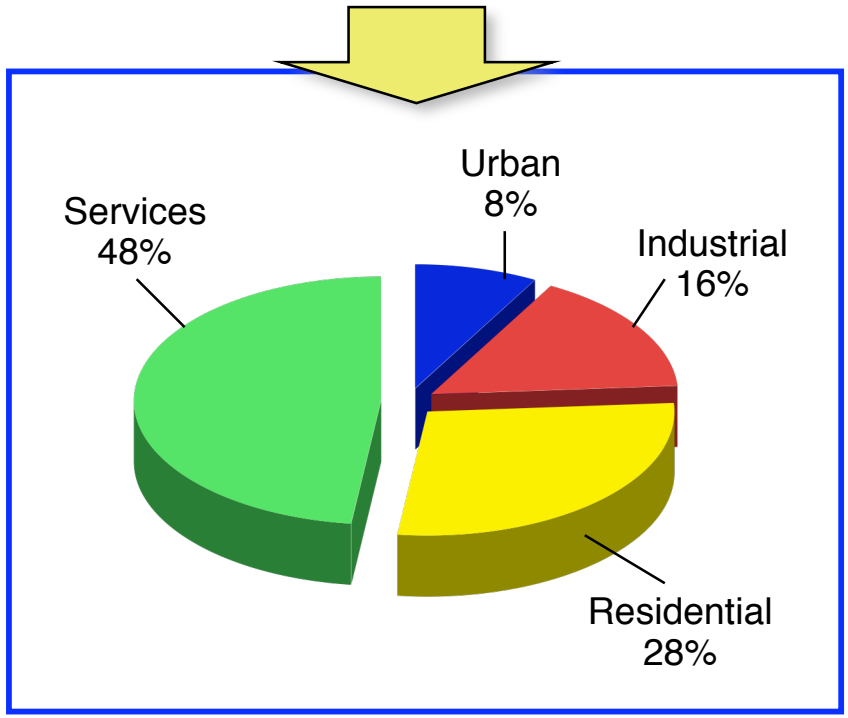


Some Figures

- 2 100 TWh electrical power consumed every year for lighting → *1 000 large electric power plants*
- 10%-15% worldwide energy production
- 200 billion Euros spent for energy per annum



(Mils, RL-5, 2003)

- ✓ 5% Luxemburg
- ✓ 12% France → *More than 41 TWh*
- ✓ 21% USA → *Global Production FR + IT*
- ✓ 34% Tunisia
- ✓ 86% Tanzania → *Lighting is an important factor for sustainable development*

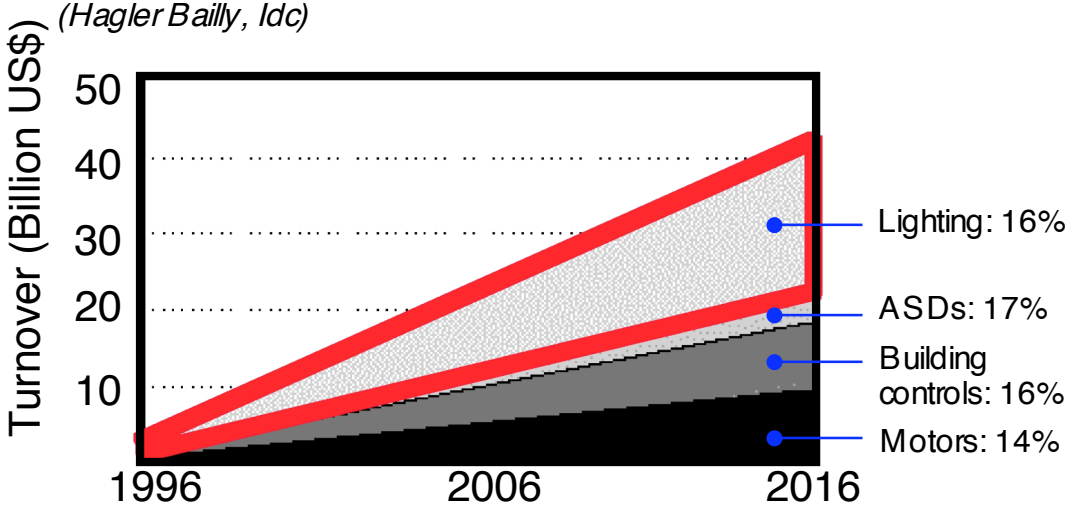
- 30 billion lamps operate every day worldwide
- 10 billion new lamps are produced per annum

- 1 800 millions of tons of CO_2 per annum
- 80 tons of Hg-contaminating wastes are collected in France per annum
- Light pollution of the skies

Lighting is a rapid growing sector worldwide

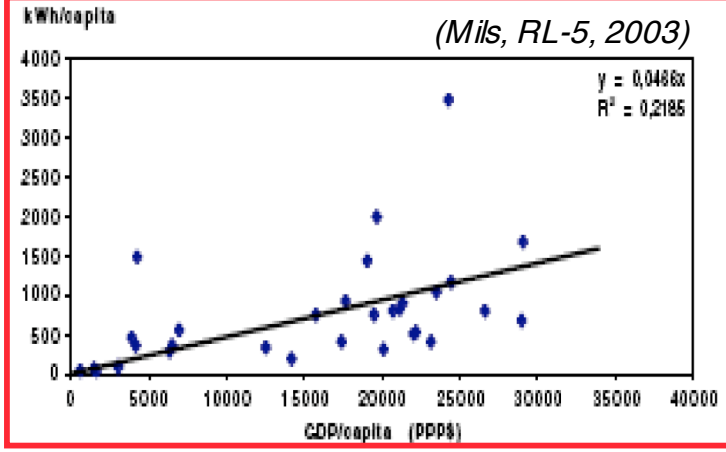
Fastest growing technology markets

(Hagler Bailly, Idc)



This figure don't includes "periphery" Industry and non-lighting applications

(Mils, RL-5, 2003)



Needs are also increasing:

OECD predicts that needs will be multiplied by a factor of 2 within next decade

Problem:
Many major products are in Matutity & Saturation

Lifecycle of Next Generation Technology/Product

Technical Systems exist in a lifecycle characterized by 4 distinct phases:

- Childhood: New Invention or new technology is becoming ready for market
- Growth: Product or Technology is improved and increases market share
- Maturity: Product/technology is highly Optimized and all potentials activated
- Saturation: Cost structure becomes ineffective, products begin to disappear

To be successful it is crucial to know the status of each product and the transition to new generations

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Question:

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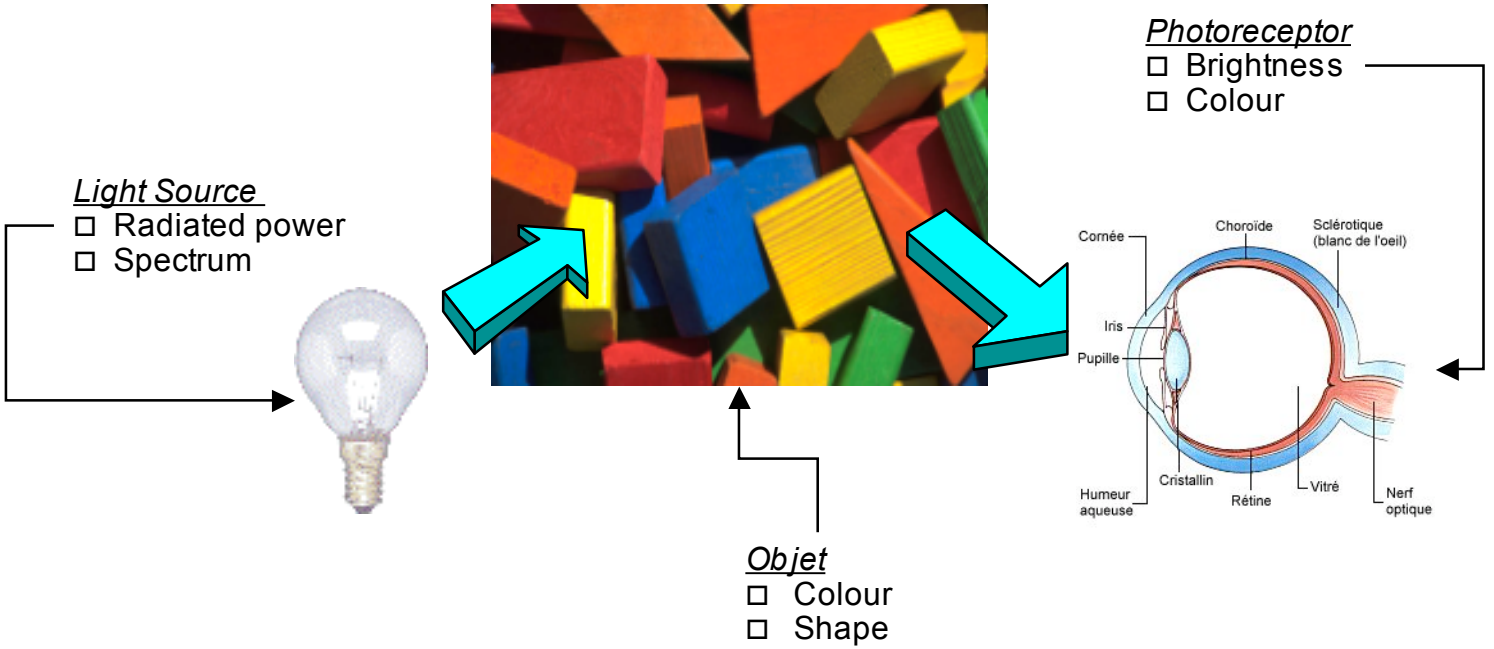
What does it means "to see"

To see: Using a photoreceptor in order to detect, to locate and to identify an object illuminated by a light source



Some definitions
(the photoreceptor)

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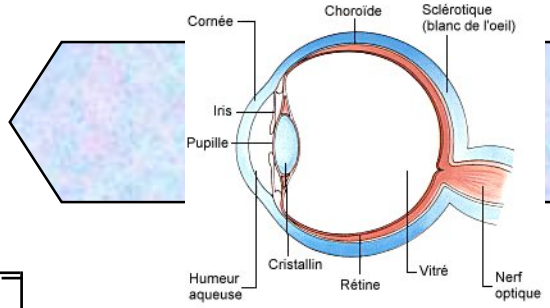
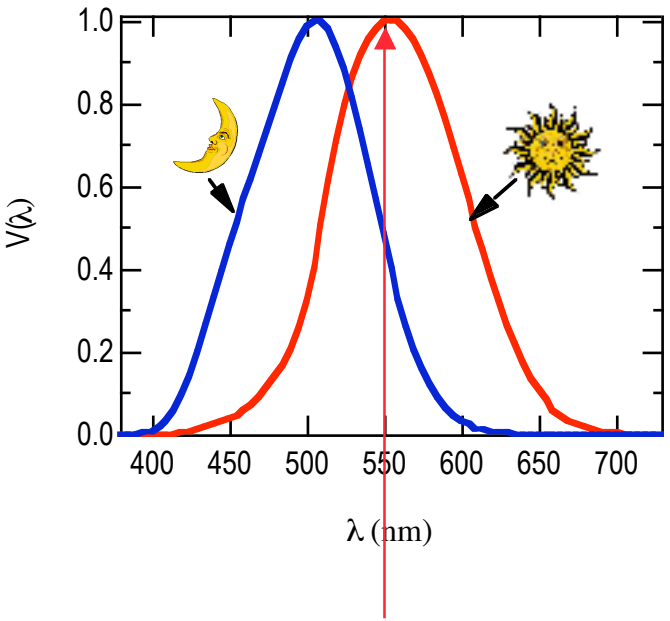
Brightness



Colour



1 radiant watt (W) emitted at 555 nm
equals to 683 lumens (lm)

Efficacacy (η)
lm/W

The eye perceives different wavelengths and the brain "see" colours

An object appears coloured by selectively reflecting or absorbing various wavelengths of incident light

Colour rendering index (CRI)
& Colour Temperature

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An example of "Colour"…

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Original

Sodium Low pressure

Sodium High Pressure

Mercury High Pressure

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…and of ambiance

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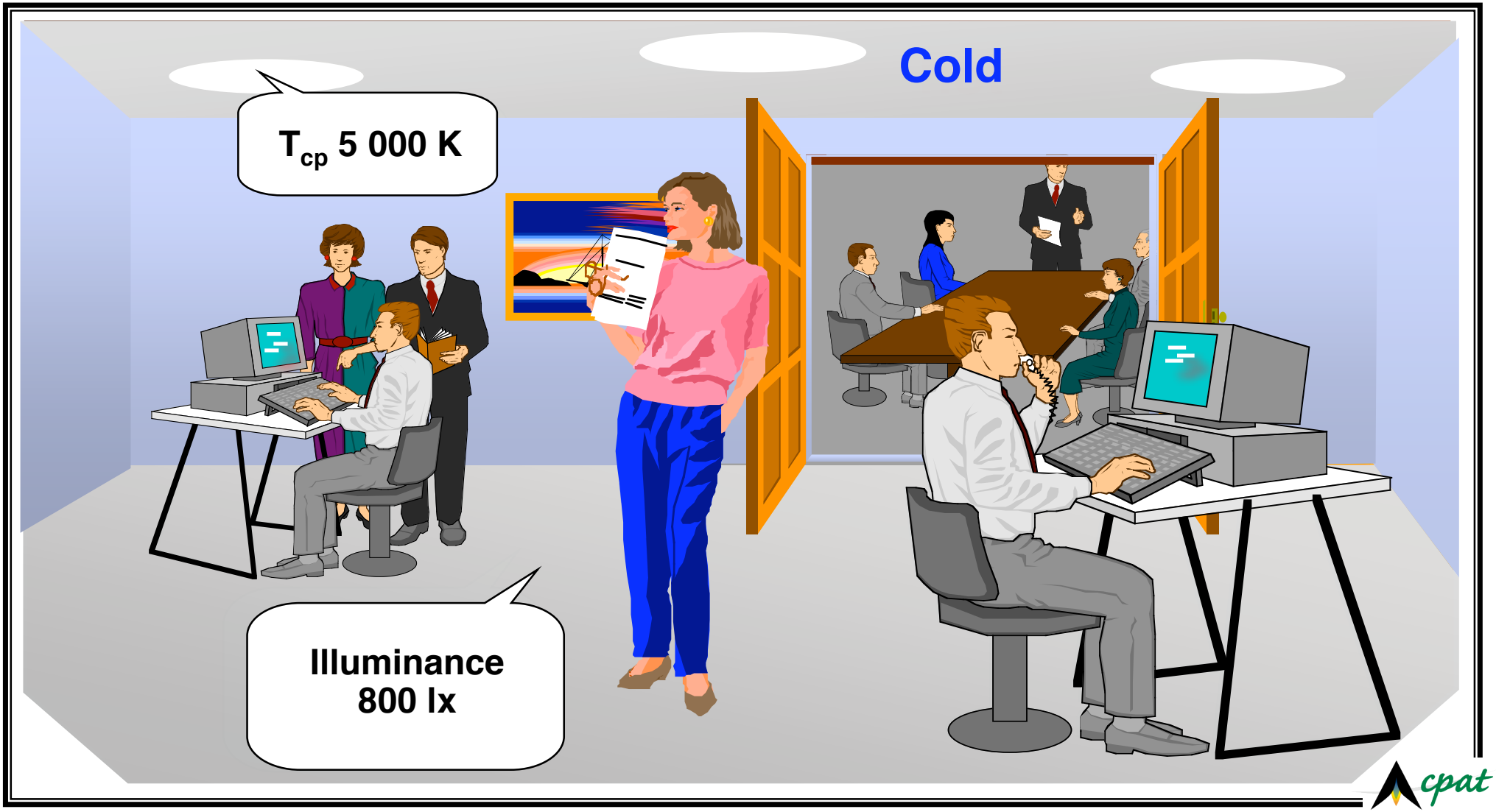

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A first answer…

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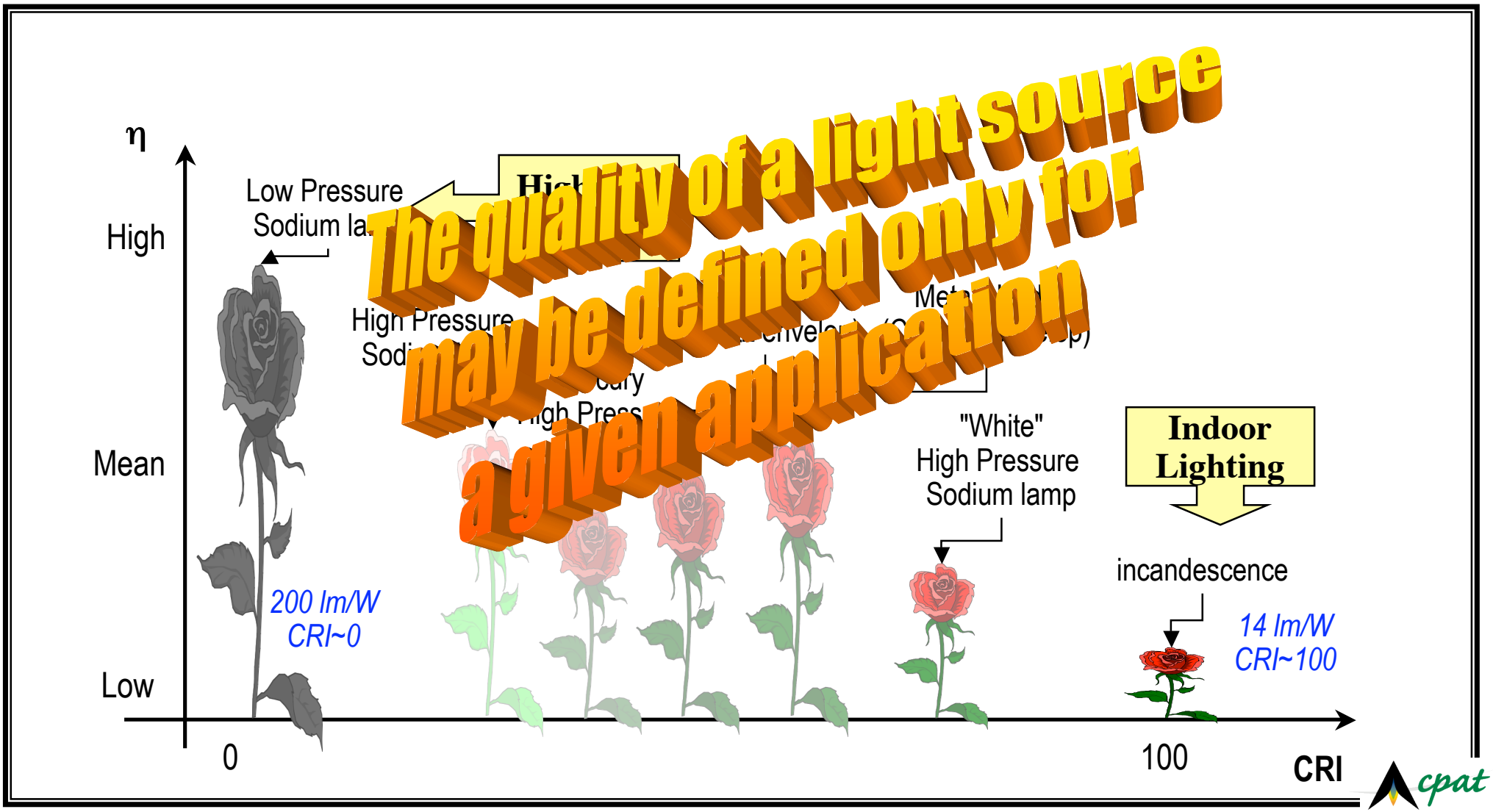

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The "10 commandments" for a good lamp

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- Produce light by using a minimum input power
- Produce "good light"
  - Spectrum
  - CRI
  - Colour Temperature
- Produce stable light
  - Fluctuations
  - Maintenance
- Produce instantaneous light
- Be interchangeable with other lamps
- Have a minimum cost
- Have a long lifetime
- Be light and compact
- Be recyclable
- Avoid any pollution
  - Heat
  - UV
  - EMI
  - Toxic Materials

This is utopic...

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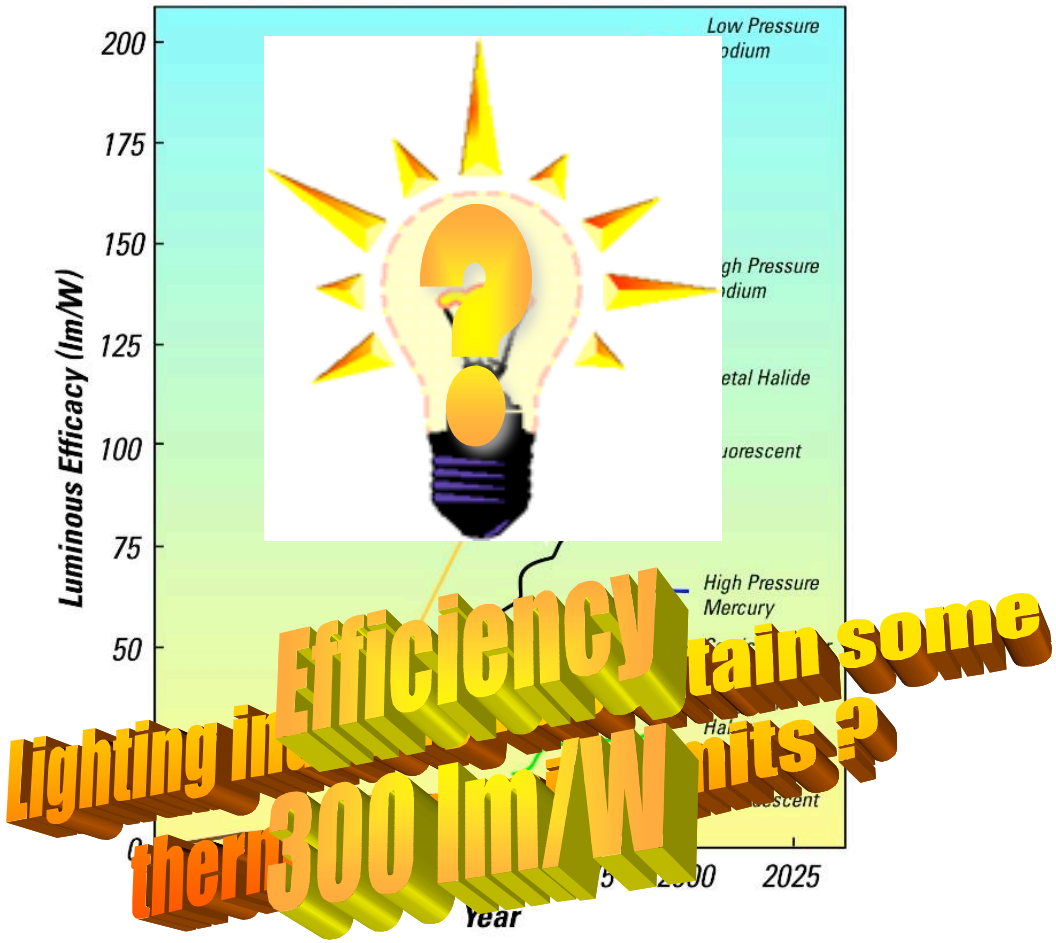
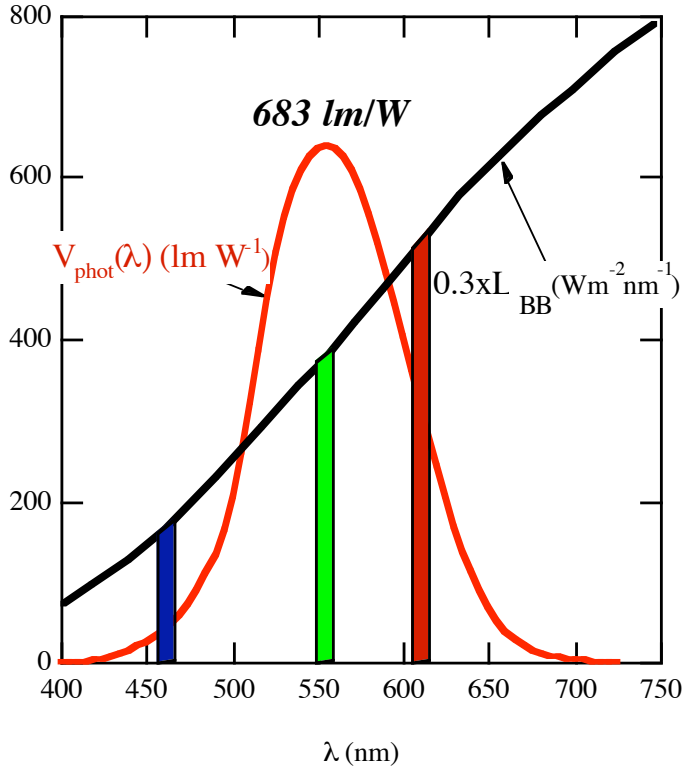
OK!
What is the next challenge for the lamps ??

Progress of luminous efficiency



(J. Waymouth, ALITE-95)

Theoretical limit



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Research and development are “key” issues

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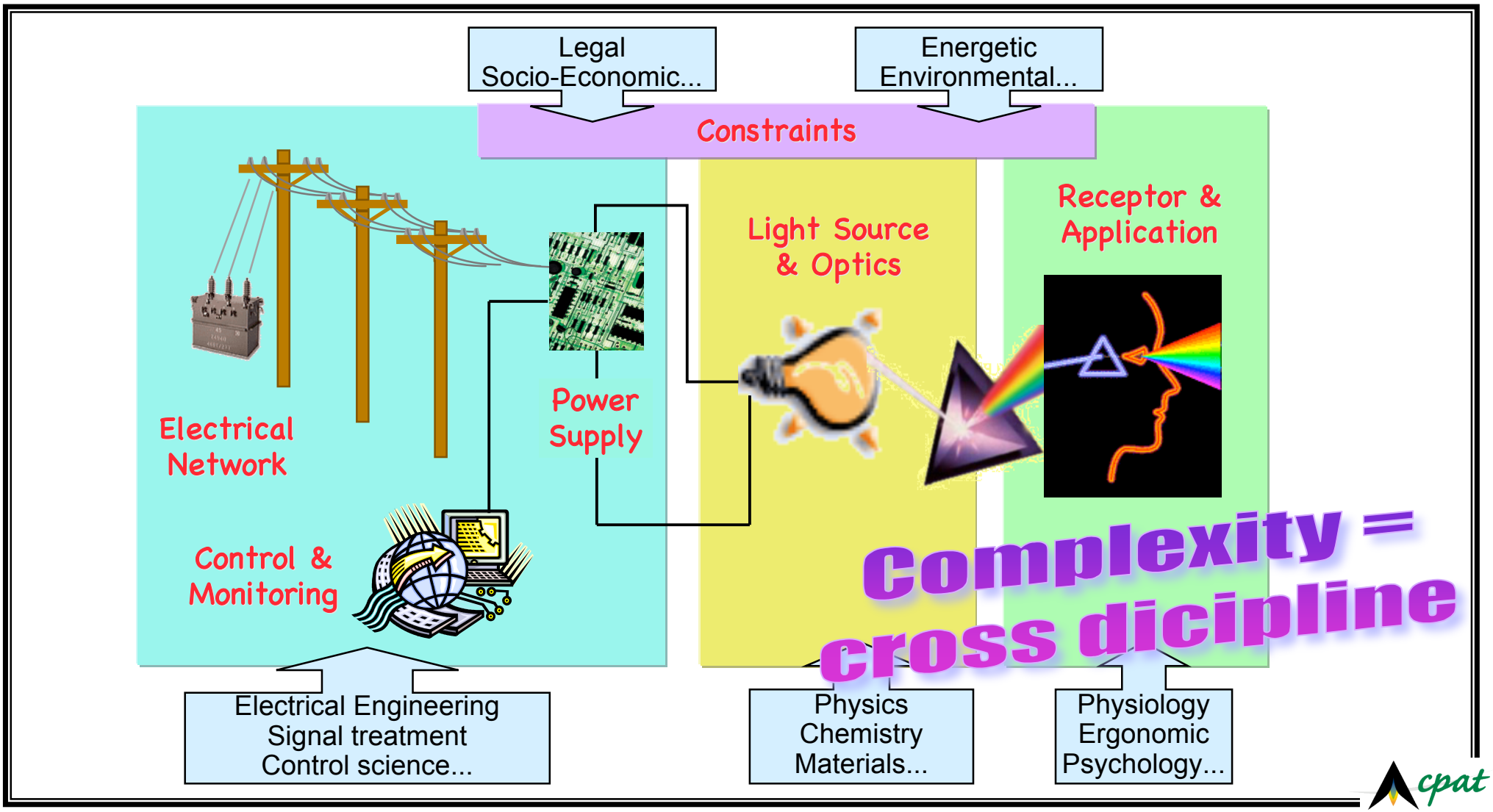

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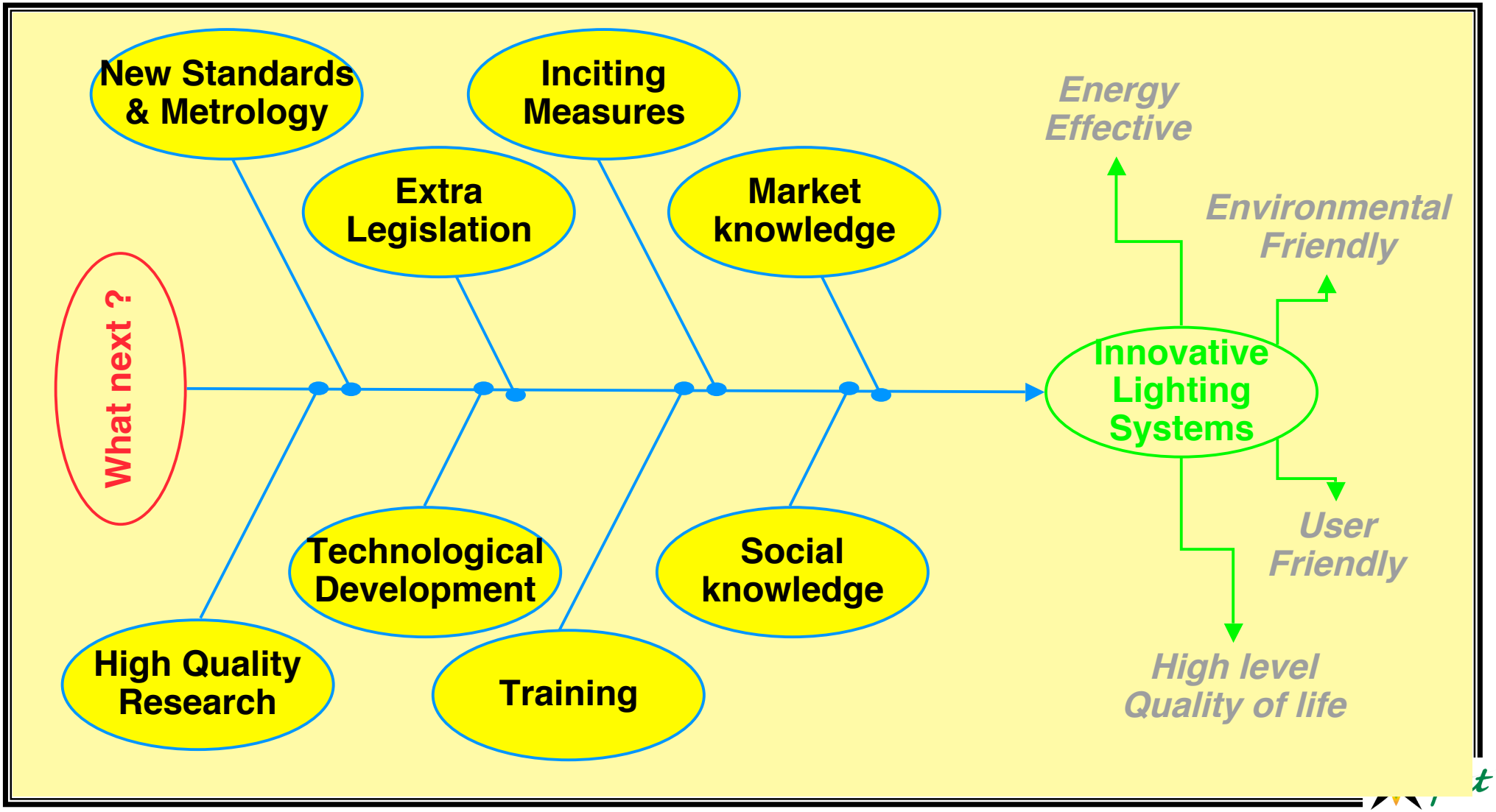
But many other issues are also crucial…



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OK!
Where are the challenges ?

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Low pressure lamps

Phosphors (this is a major challenge)

How to avoid ~50% phosphor conversion loss?

- Quantum splitting phosphors – 2 visible photons for each UV photon – some progress
- Generate white light directly in visible region by using high volatility molecules

Power El nics

- Enhanci erating conditions
- Deep di
- Permane

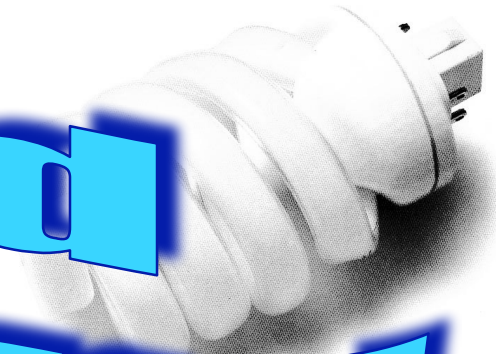
UNDER CONSTRUCTION

Avoid Mercury!

Shape and Quality

Some mileage left here for innovation

Heliax CFL (GE)



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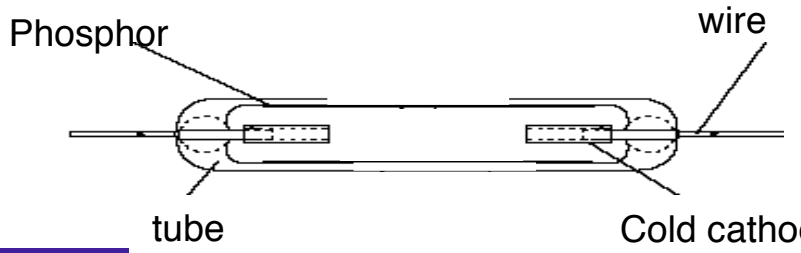
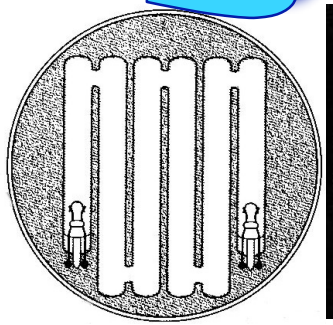
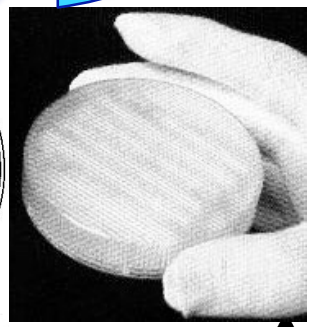
Lamps for special applications (backlighting)







HARISON

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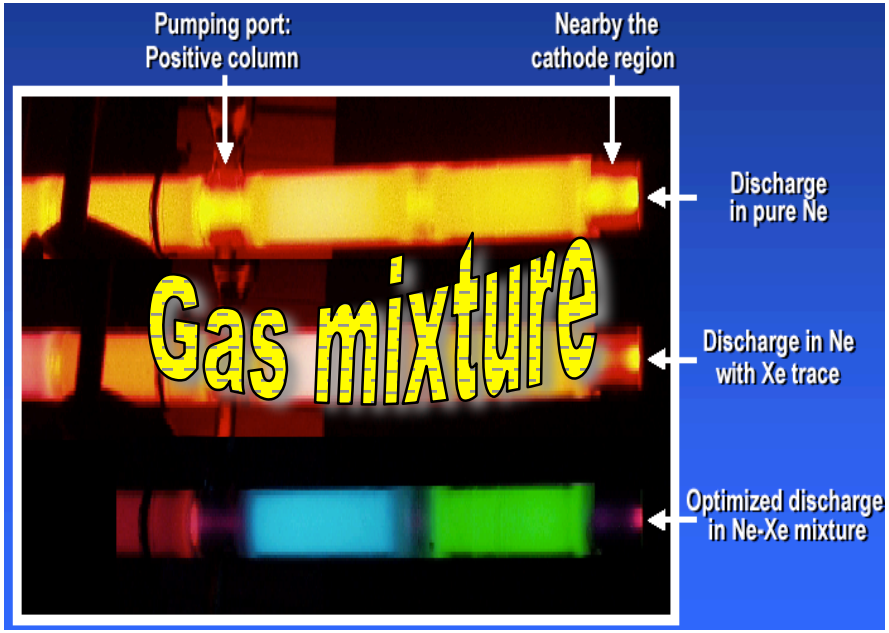
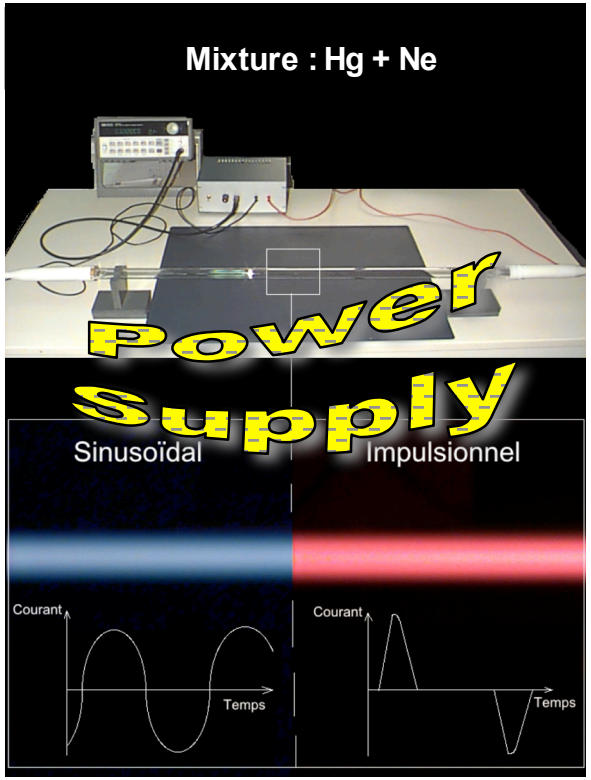
Colour control



- ✓ Publicity Lighting
- ✓ Automotive



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High Pressure lamps

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Ceramic MHLs

- **Power range: 20 - 400 W**
- **Efficacy: 70 -100 lm/W**
- **CRI: 86 - 95**
- **T : 3000 - 4500 K**
- **: 7000-16000 h**

White colour required with less Hg…

- Shape & [illegible]ness
- Colo[illegible]
- [illegible]time an[illegible]
- [illegible]tronic gears
- Dimming with adaptation to vision requirements
- Rapid [illegible]w

150-400 W : direct concurrence for SHP for urban lighting

20W-70 W : direct concurrence for inc. lamps for given applications

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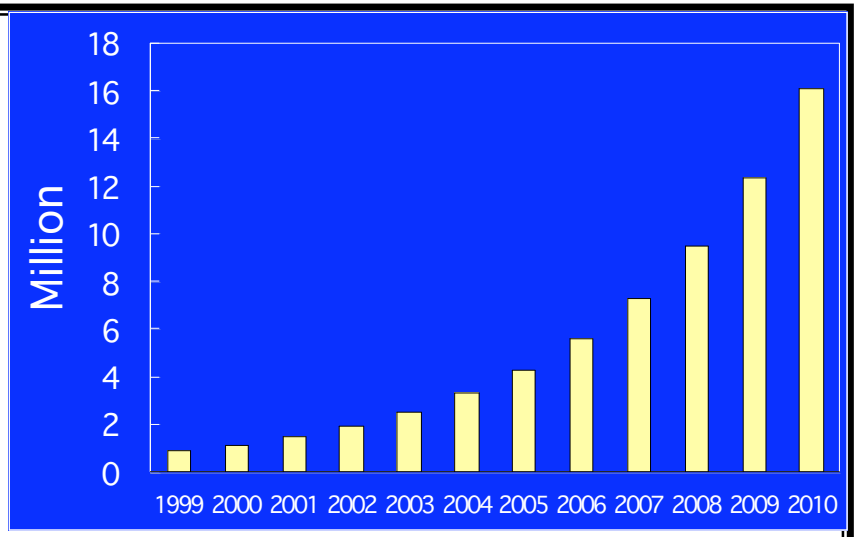
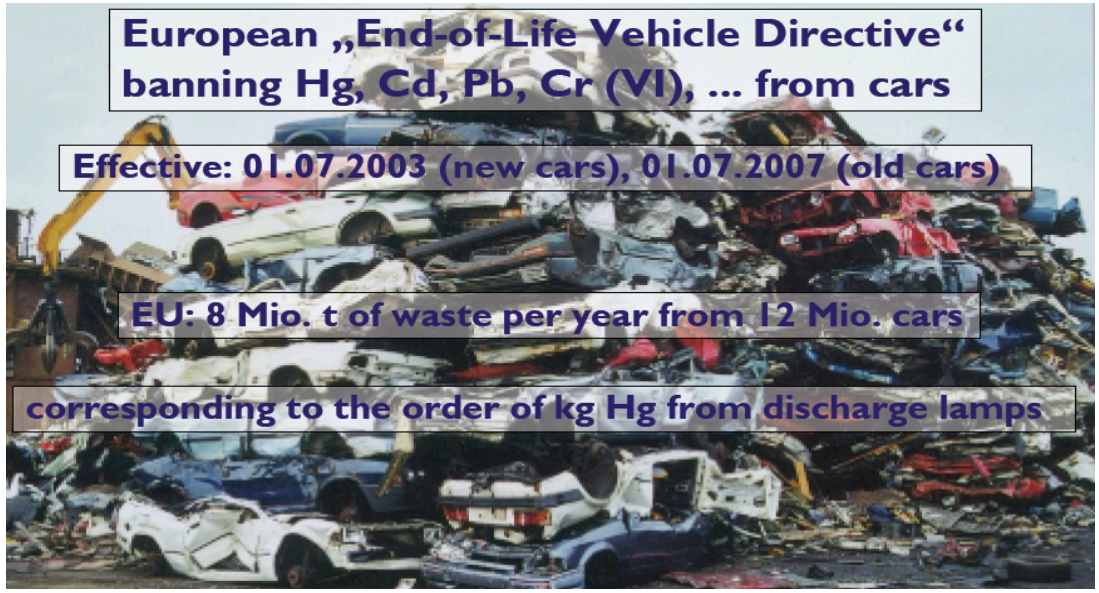
And more especially automotive…

Market issues

Environmental issues





D2S

Hg-free

Electrodeless lamps

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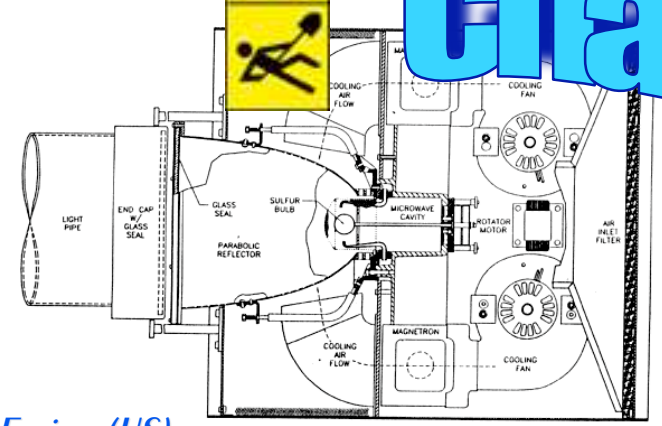
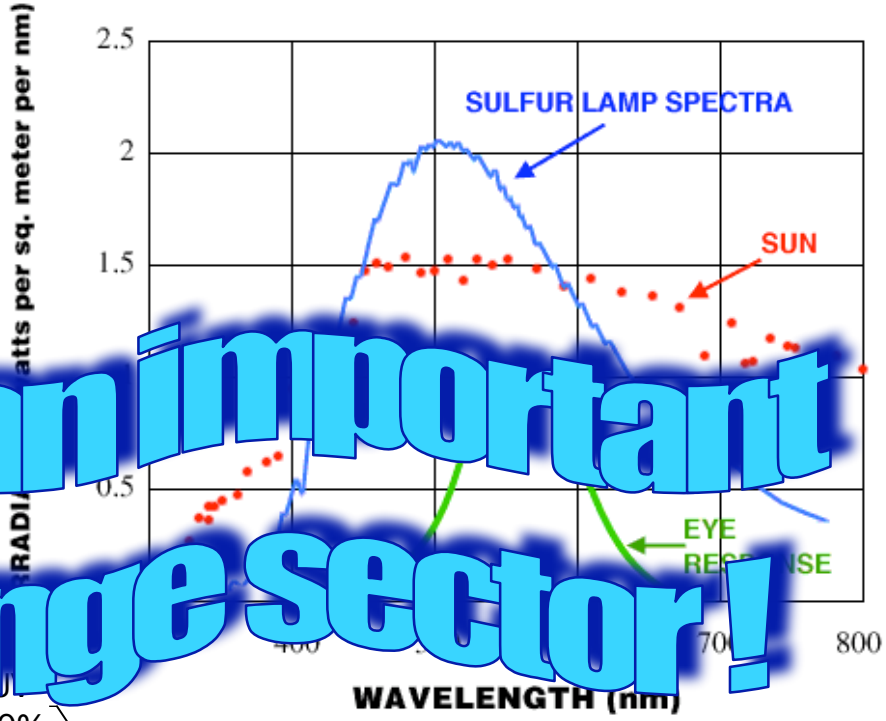
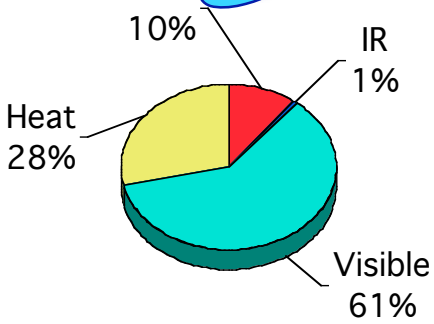
Sulphur lamp



Fusion (US)



This is an important Challenge sector!



Power (W)	1385	3400
Intensity (lm)	134000	410000
Efficacy (lm/W)	97	120
T_{col} (K)	5400	6500
CRI	79	86

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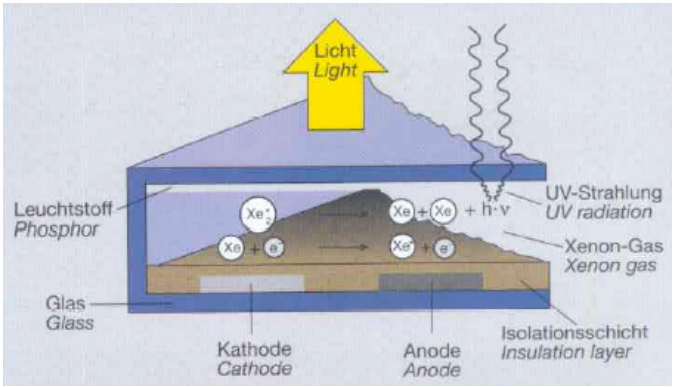
Excimer & DBD lamps (General lighting & signs)

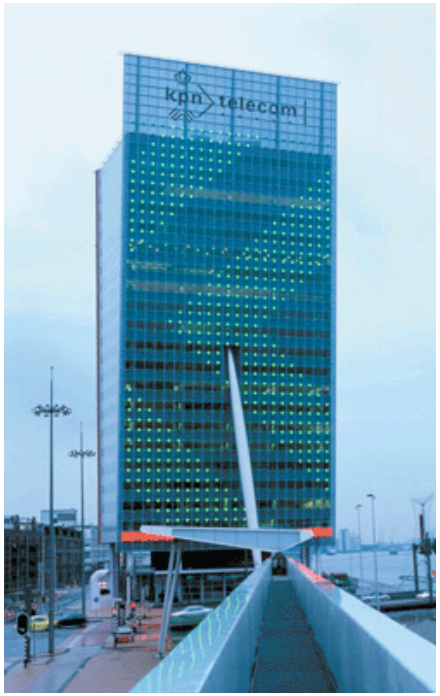
- ✓ **General lighting**
- ✓ **Advertisement**
- ✓ **Backlighting**

The biggest worldwide advertisement display (3 000 m², 900 PLANON™)
Dutch telecommunications company, KPN, (Rotterdam).

Osram Planon DBD and gear

Gas : Xe (Hg-free)
Pressure > 100 Torr
Thickness< 10mm
Lifetime > 10 000 h





OSRAM GMBH

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Excimer lamps (special applications)

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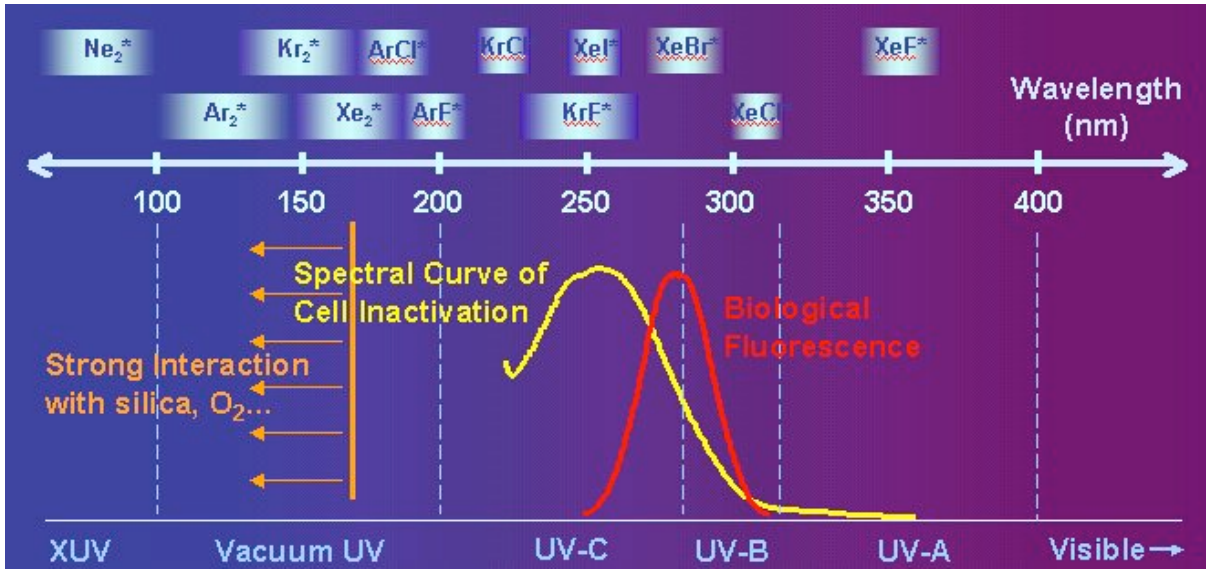
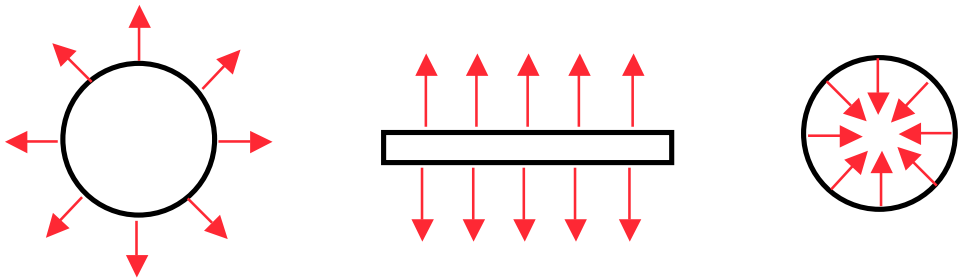
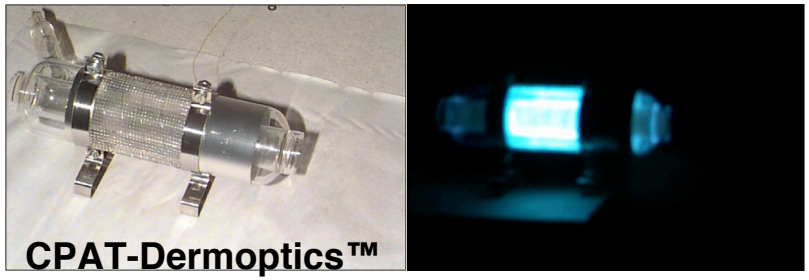


Industrial Applications

- ✓ Photochemistry/Polymerization
- ✓ Surface Traitement
- ✓ Water Purification
- ✓ Dermatologie & Medecine
- ✓ Photo-catalysis

Flexible Geometry





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Light Emitting Diodes

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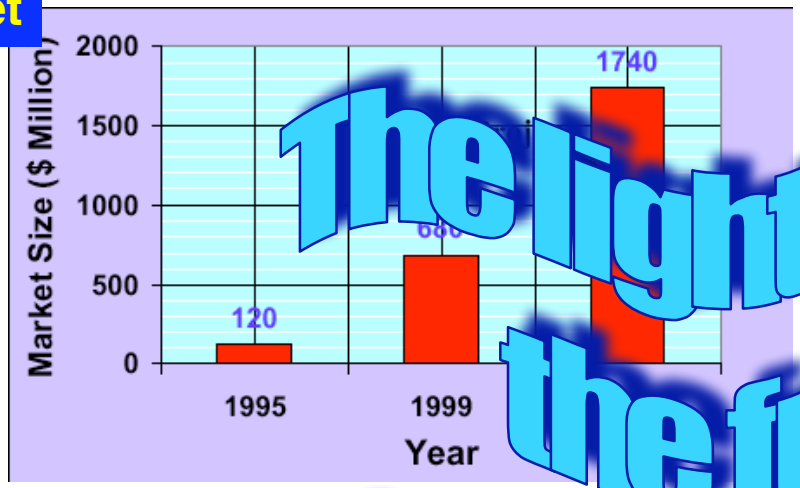
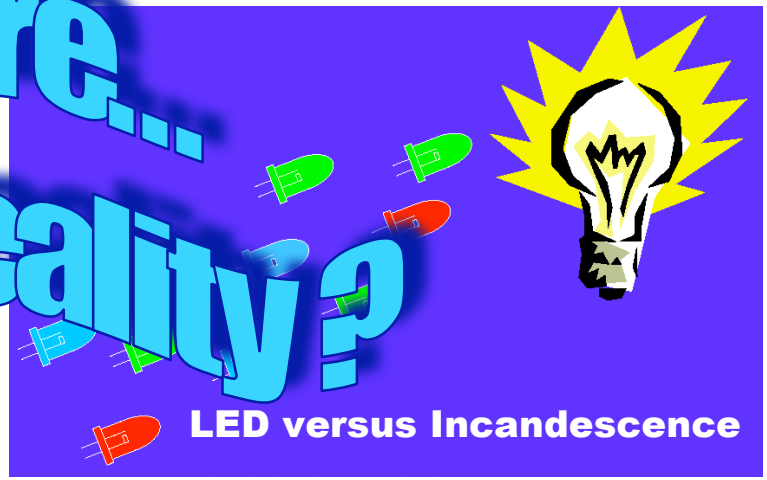
Market



The light source of the future... Dream or reality ?



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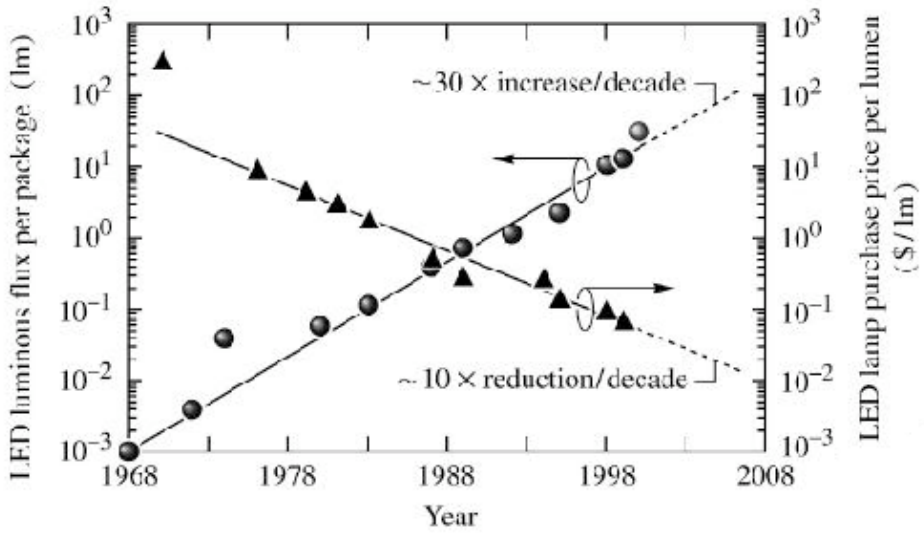
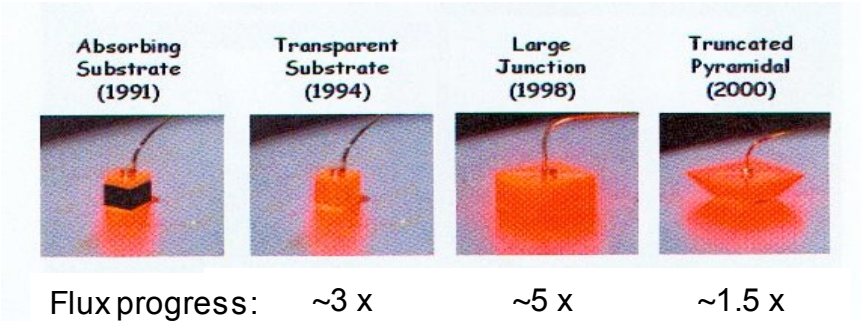
Some Positive points

Craford's law



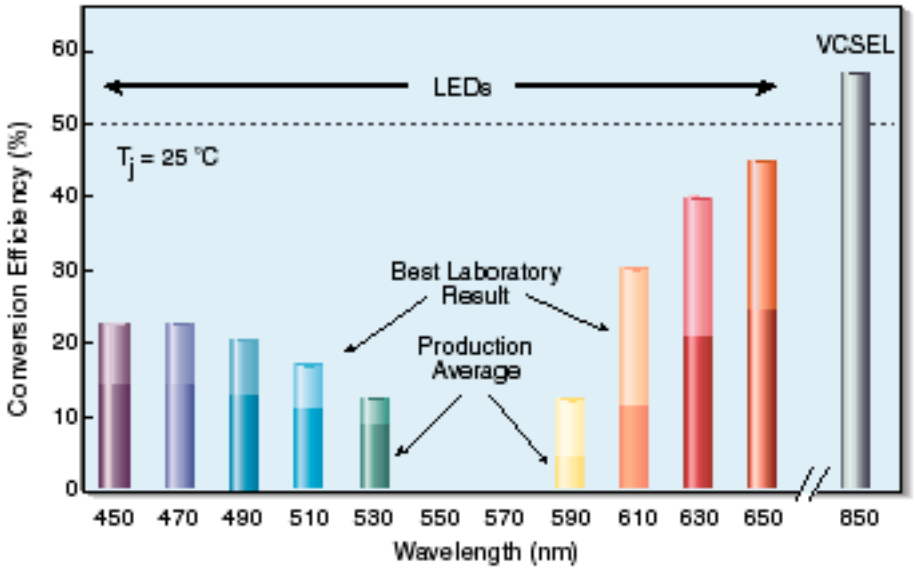
- High brightness
- Excellent colours
- High efficacy (for some colours)
- Low dimensions & weight
- High lifetime (>25 000 h)
- No theoretical limit for efficacy

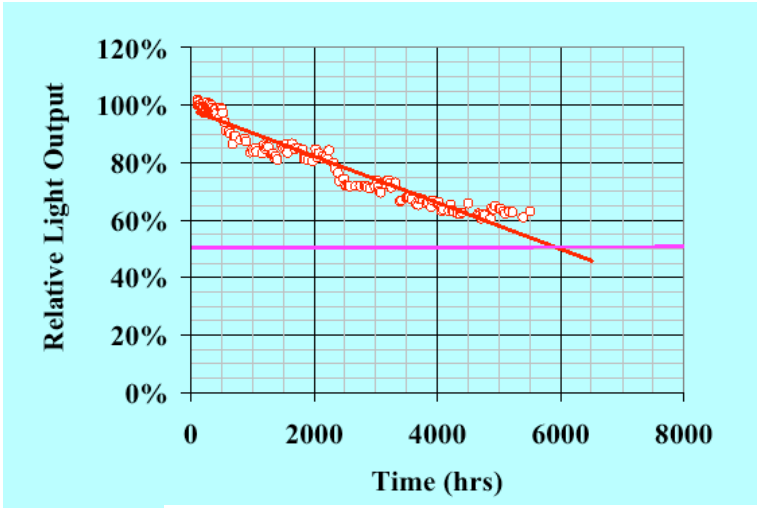
Progress in light extraction



Progress in systems

Problems & Challenges





Flux Maintenance (1W white LED)

- **Low power (W)**
- **Directional lighting**
- **High cost for a global system**
- **Severe colour changes with Voltage & Current**
- **Sensible in temperature/humidity**
- **High complexity system control**
- **Poor production reliability in line**

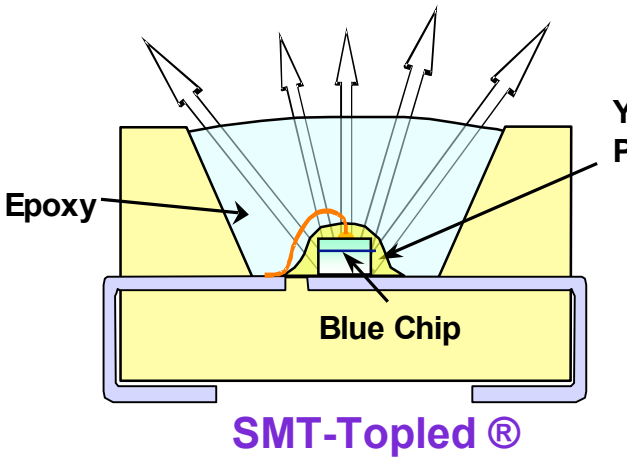
Challenges:

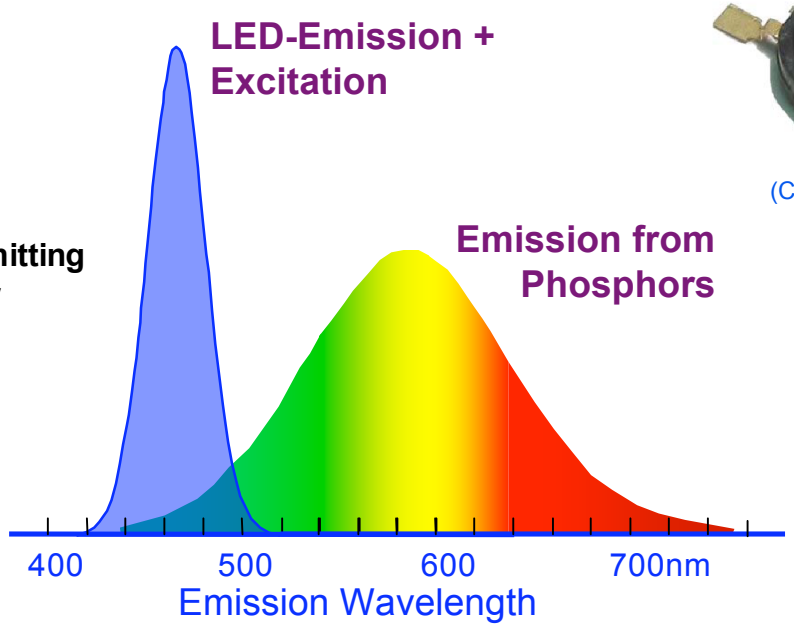
1: Enhance flux maintenance
2: Close the gap from green to yellow
3: Enhance efficacy by 50% @ every λ
4: Enhance line production reliability
5: Increase emitting surface
6: Enhance system control

White LEDs the Challenge !

LED are compact, mechanically stable, need only low voltage operation, can be dimmed, and have long life time.

White LED





(Copyright LumiLeds)

Courtesy of Osram GmbH

US congress voted in 2002, $470 million program for white LEDs for general lighting

Today: 25-30 lm/W

Objective: 200 lm/W white LED by 2011 !

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O-LEDs

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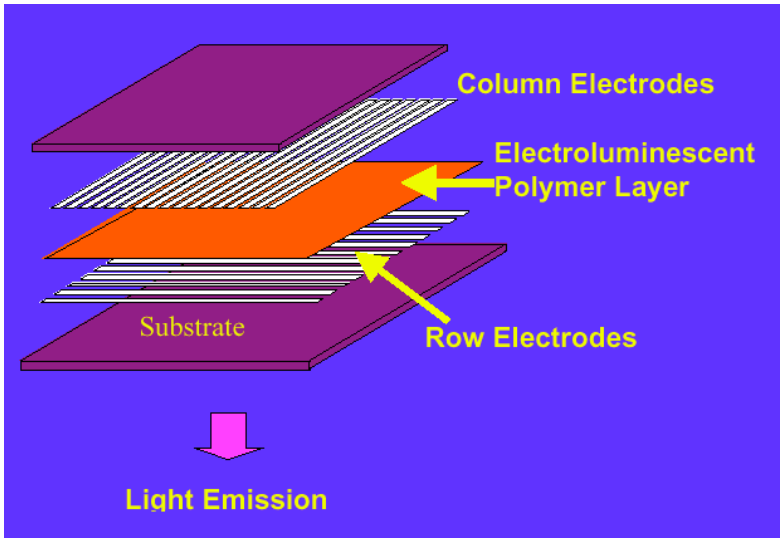

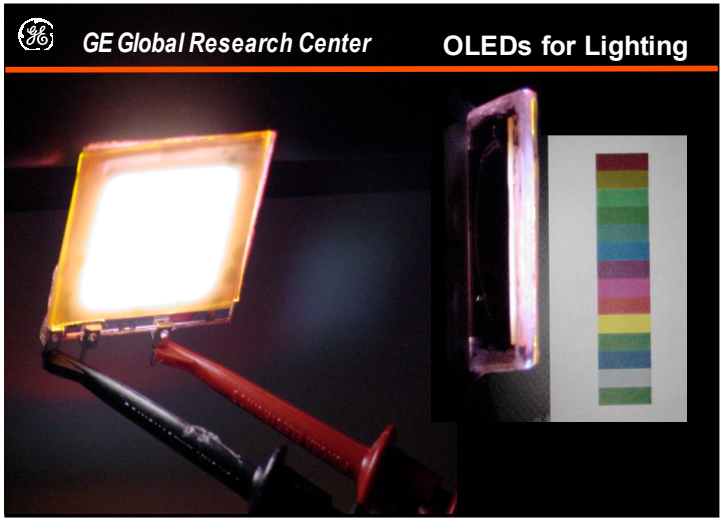

- High resolution
- High Colour Quality
- Flexible, bendable…
- Excellent mechanical properties
- Low weight
- Small dimensions

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In conclusion

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