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School of Electrical Engineering
Lighting Unit
Finland

Led and Other Relevant Light Source Technologies for Street and Other Public Outdoor Lighting

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Energy Efficient Street Lighting
May 20, 2014

Outline

- Light source options
- Energy saving potential
- Scenarios for LED lighting
- Barriers and challenges for LEDs
- Mesopic photometry

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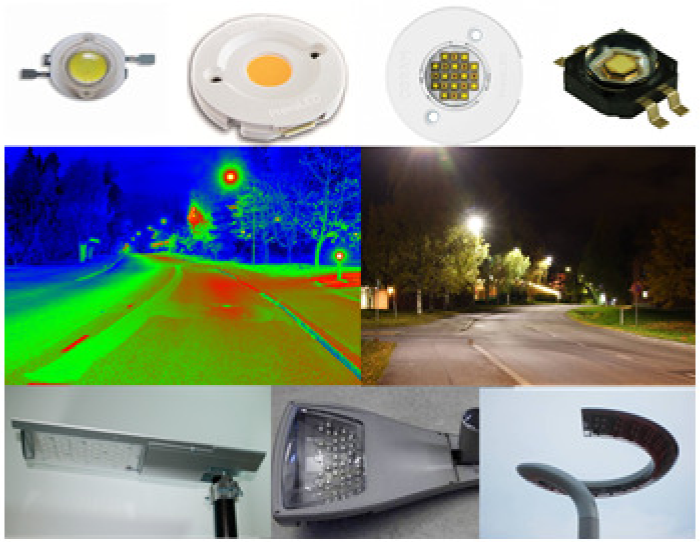
Road lighting in transition

Sub study 1 - LEDs and other light source technologies

1-2013



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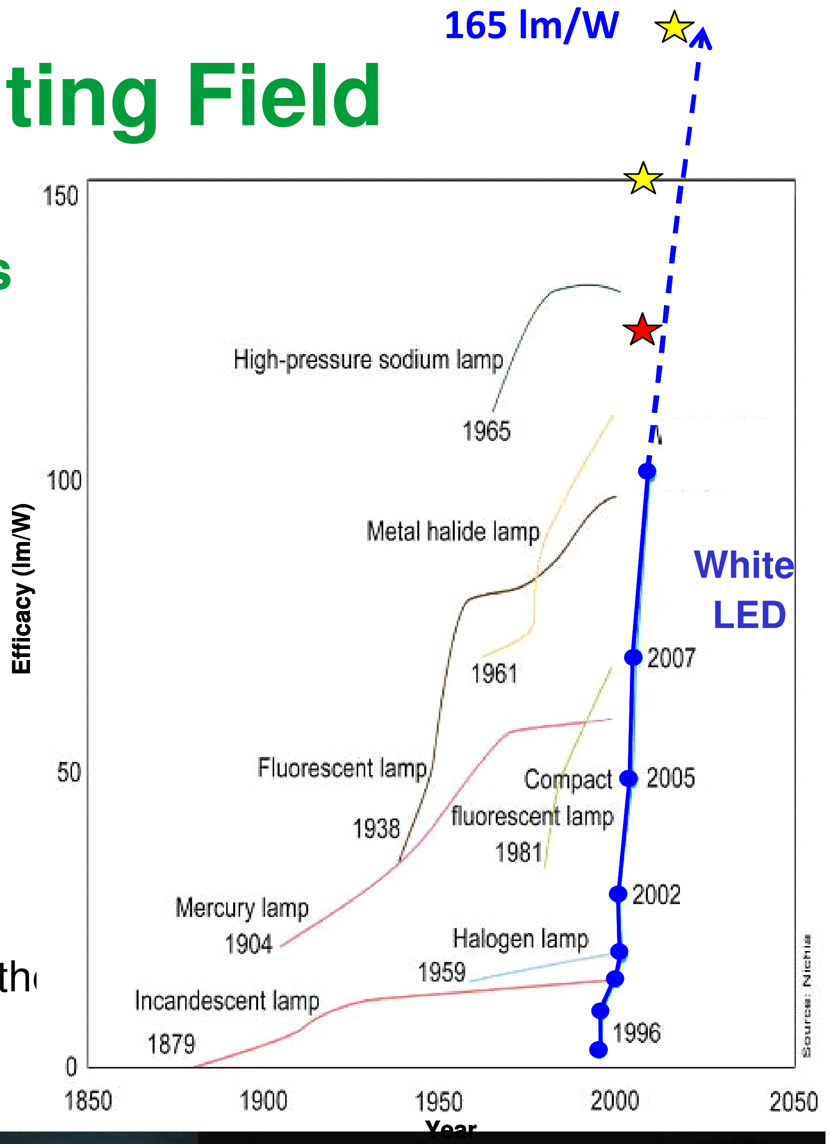
Huge Changes in the Lighting Field

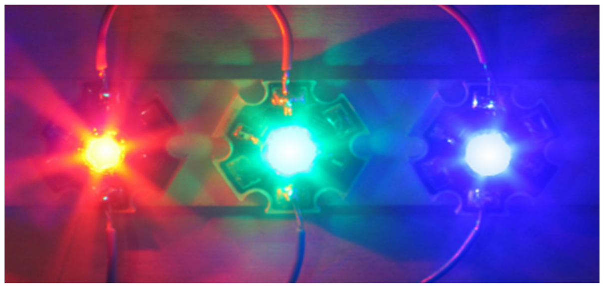
LEDs revolution in the lighting markets

- Constant development of LED light sources, e.g. luminous efficacy of white LED
  2004: 30 lm/W
  2014: 165 lm/W
- LED lighting markets
  2007: 4.6 billion US$
  2012: 11.4 billion US$

European EcoDesign directive

- Phasing out of several inefficient lamp types (e.g. mercury, incandescent, T12)
- Mercury vapour lamps will be phased out from th European markets by 2015
- Restrictions also on HPS and MH lamps






Outdoor Lighting

- Long installation operating times and annual operating hours
- High maintenance and lamp replacement costs

- Life cycle cost analysis
- Light source options: HID lamps and LEDs

HID Lamps

Low pressure sodium lamp, LPS

- Monochromatic yellow light
- No colour rendering
- High luminous efficacy, up to 200 lm/W
- Life-time 16 – 18 000 h
- Being replaced by high pressure sodium lamps

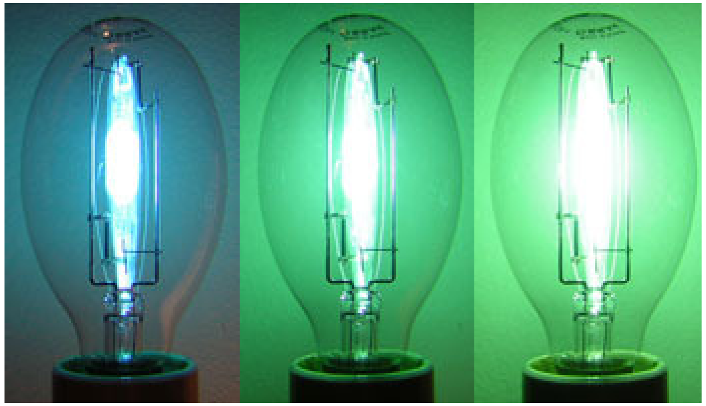
High pressure sodium lamp, HPS

- Luminous efficacy 80 – 150 lm/W
- Life-time 20 000 - 24 000 h
- Colour rendering index CIE CRI = 20-25
- Yellowish light, CCT 1900-2200 K

HID Lamps

Mercury vapour lamp, MV

- Luminous efficacy 45-55 lm/W
- Life-time 20 000 h
- Colour rendering index R_a ~ 45-60
- Colour temperature 3 000 – 4 000 K
- Being phased out in Europe



Metal halide lamp, MH

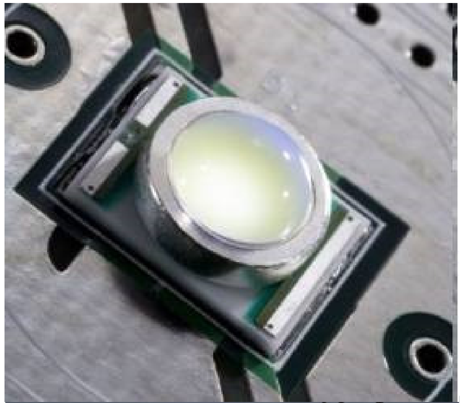
- Luminous efficacy 60 – 110 lm/W
- Life-time 6 000 – 20 000 h
- Colour temperature 2 700 – 5 000 K
- CIE CRI = 65-95
- Ceramic and quartz arc tubes

LEDs in sustainable lighting solutions

- High (increasing) luminous efficacy
- Long life-time (50 000 h) compared to discharge lamps (HPS < 24 000 h, MH < 20 000 h)
- White light with good colour quality
- Contain no mercury

Why LEDs?

- High (increasing) luminous efficacy
- Small unit size, freedom to luminaire design
- Long life-time
- Versatile colour characteristics
- Durable
- No mercury
- Easy to control colour and intensity
- Quick starting



Light source development

Discharge lamps

	Baseline technology in 2010				Percent improvement by 2030	
Lamp types	Mean system power (W)	Lamp life (1000 h)	Mean system efficacy (lm/W)	Luminaire efficiency (%)	Mean system efficacy	Lamp life
Mercury vapour	219	20	30	65%	0%	0%
Metal halide	247	18	60	65%	15%	15%
High pressure sodium	241	28	84	65%	5%	5%
Low pressure sodium	107	25	89	65%	5%	5%

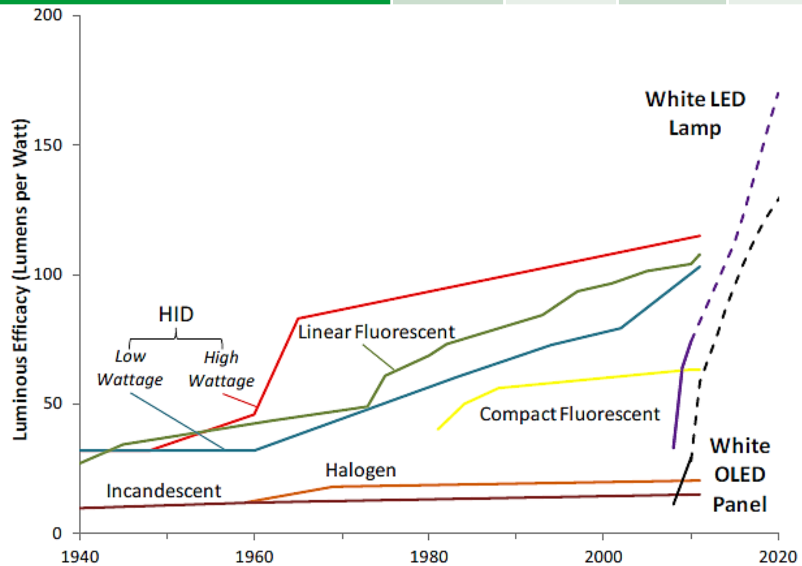
Source: DOE 2012

Light source development

Metric	2011	2013	2015	2020	Goal
Package luminous efficacy (lm/W)	97	129	162	224	266
Thermal efficiency	86%	87%	88%	90%	90%
Efficiency of driver	85%	87%	89%	92%	92%
Efficiency of fixture	86%	87%	89%	82%	92%
Resultant luminaire efficiency	63%	66%	69%	76%	76%
Luminaire luminous efficacy (lm/W)	61	85	112	170	202

LEDs

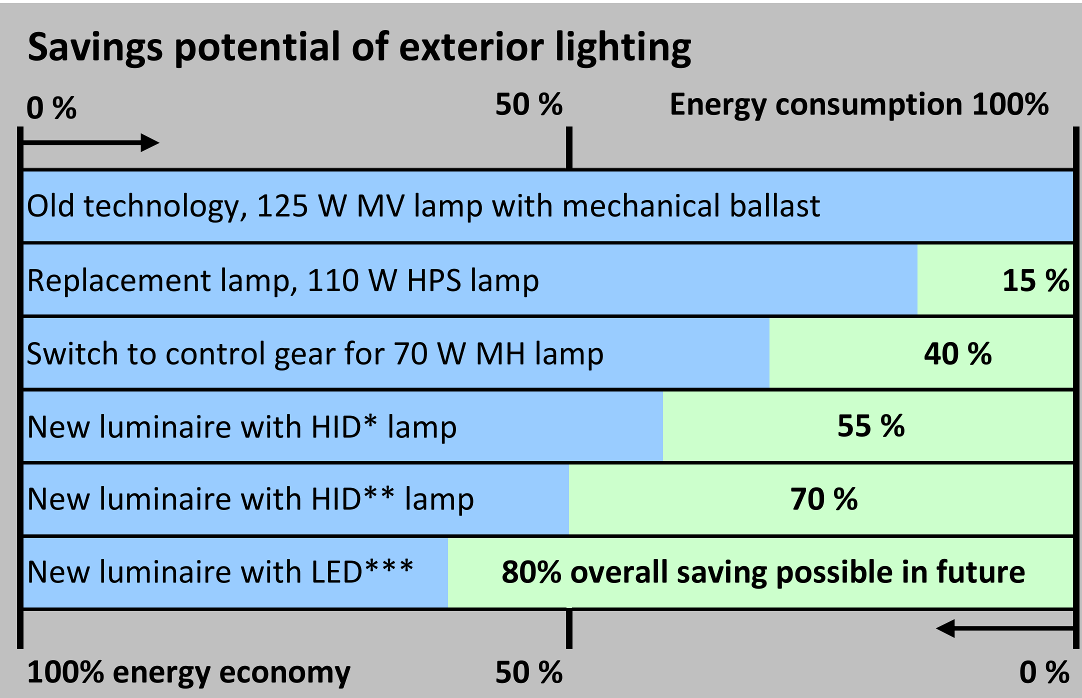
Source: DOE 2012



Lighting Quality: Colour of light

- White light renders object and environmental colours as natural
- Coloured light (i.e. yellow HPS lamps): poor colour rendering

Energy Saving Potential in Outdoor Lighting



* HPS or MH lamp

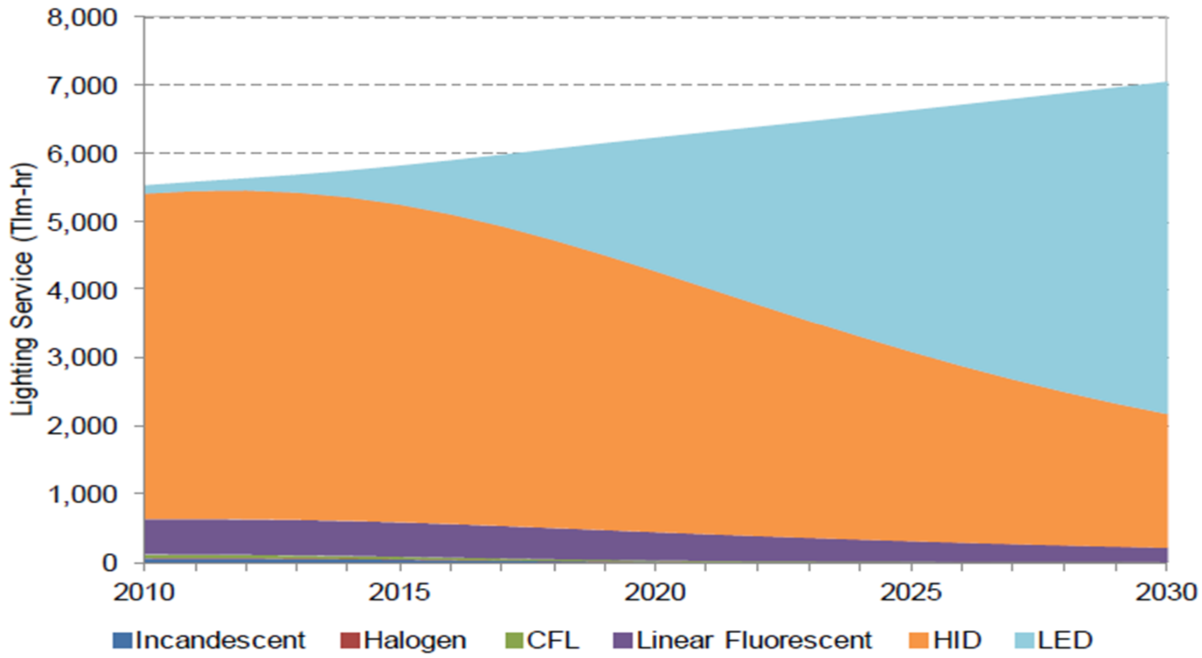
** HPS or MH lamp, with control system and 50% output for 2000 h

*** With control system and 50% output for 2000 h

Source: CELMA

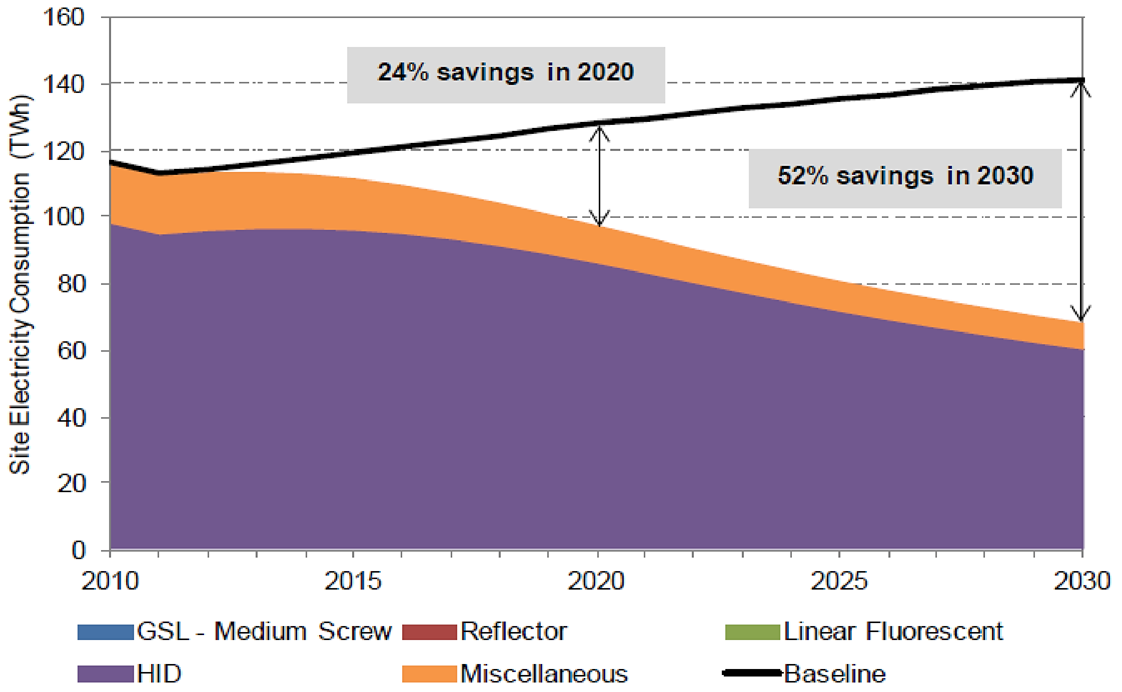
Lighting Service Forecast

US DOE: share of LEDs in outdoor lighting luminaire sales 87% in 2030



Source: DOE 2012

Outdoor lighting energy consumption forecast



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Source: Navigant Consulting 2012

Barriers and challenges for LEDs

EC Green Paper

Barriers for wide deployment of SSL technology:

- risk of buying products of unproven or insufficient quality
- lack of information for consumers and professional end users
- high initial purchase costs

Reasons why cities are reluctant to use SSL widely in outdoor lighting :

- relatively high investment costs together with tight annual city budgets (even if this is generally offset by significantly lower lifetime costs)
- lack of trust quality certification schemes
- lack of standards to develop proper specifications

Street Lighting Life Cycle Calculations

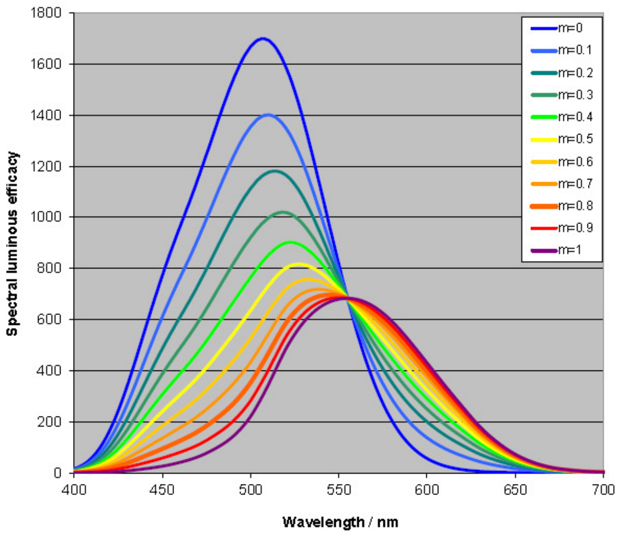
- Long annual operating hours
- High maintenance and replacment costs
- Long performance period (25-30 years)
- Investment and operating costs (energy + maintenance)

Life cycle calculations => overall economic benefit

Mesopic Photometry

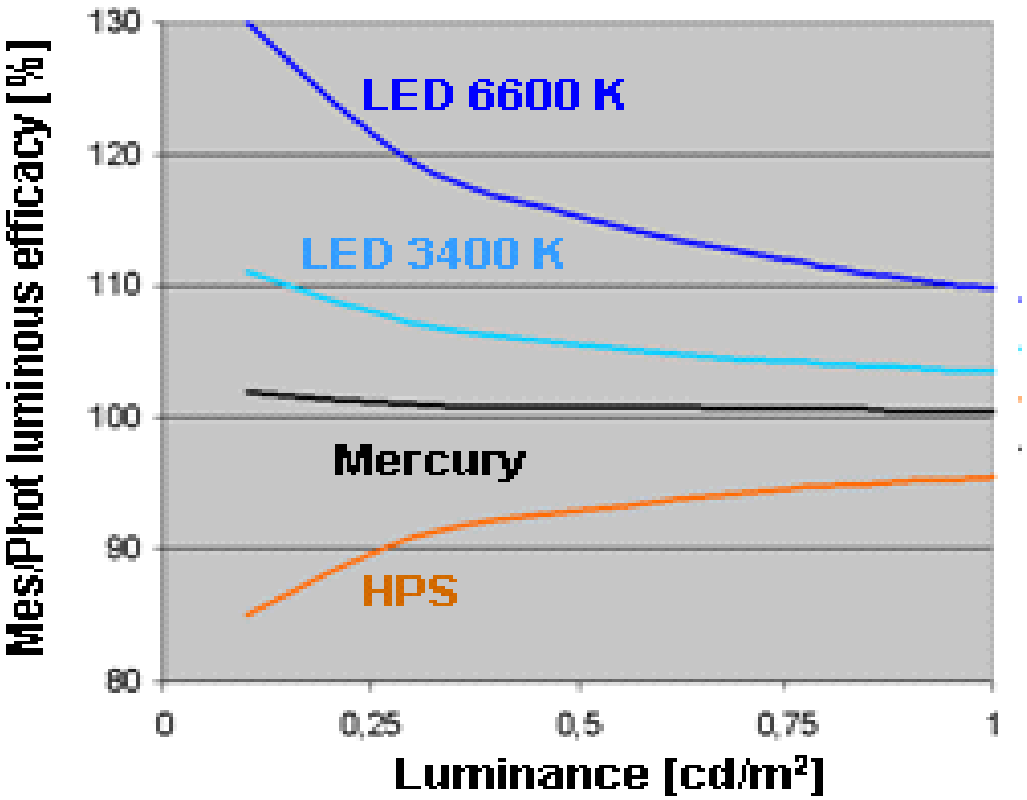
- CIE 191:2010 Recommended System for Mesopic Photometry Based on Visual Performance

- CIE JTC-1:
  Implementation of CIE 191 Mesopic Photometry in Outdoor Lighting (2012 -)



COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

Mesopic/Photopic Luminous Efficacy



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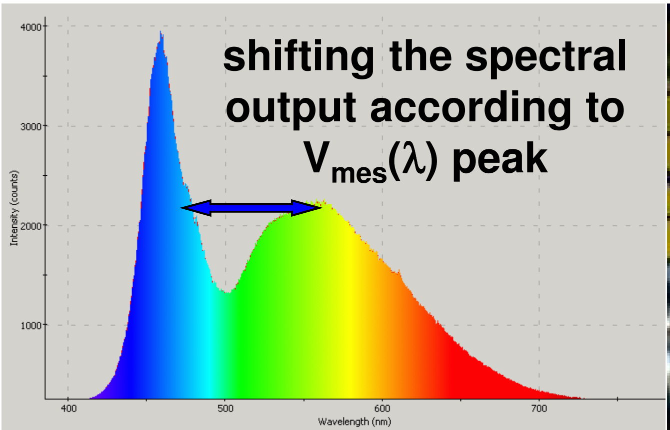
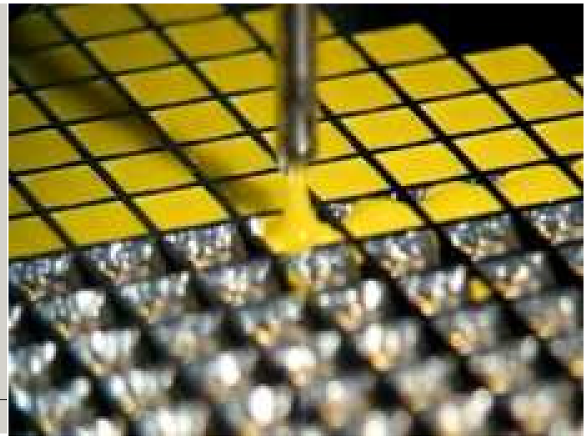
LED Development for Mesopic Efficiency

- CIE System of mesopic photometry: new international technical basis for light source (LED) development
- Optimisation of LED spectral output for increased luminous efficacy and visibility at low light levels





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Impacts of Mesopic Photometry – Outdoor Lighting

- **choice of light sources** - *optimised lamp spectrum*
- **lighting design** - *dimensioning values, energy etc.*
- **energy efficiency** - *improved lighting system efficacy*
- **visibility** - *optimal spectrum for vision*
- **road safety** - *enhanced visibility conditions*
- **lighting quality** - *increased use of white light*

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Conclusions

- Outdoor lighting is under major changes
- LEDs are taking over
- Huge potential for energy savings in outdoor lighting
- Barriers and challenges for LEDs exist
- Mesopic photometry favours white light


Thank you!