“Solid-state lighting”

Lighting – prerequisite
of human civilization

500,000 years ago- first torch

70,000 years ago – first lamp (wick)

1,000 BC – the first candle

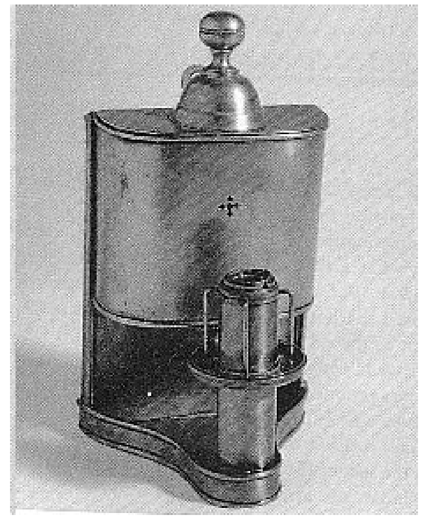
1772 - gas lighting

1784 Agrand lamp - the first lamp relied on research (Lavoisier)

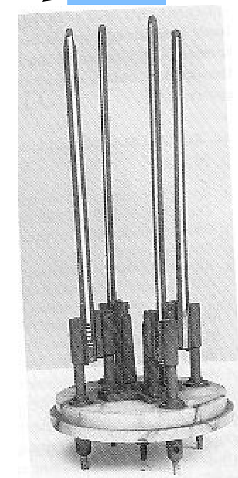
1826 -Limelight - solid-state lighting device

1876 – Yablochkov candle

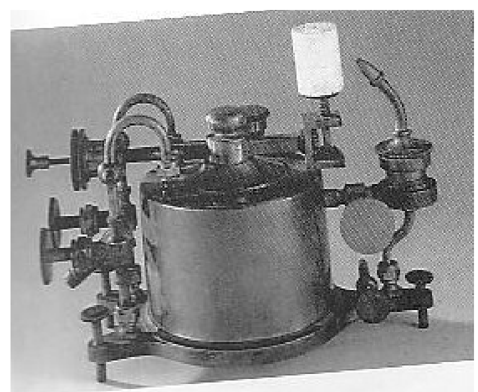
1879 – Edison bulb



Agrand lamp



Yablochkov candle (1876)

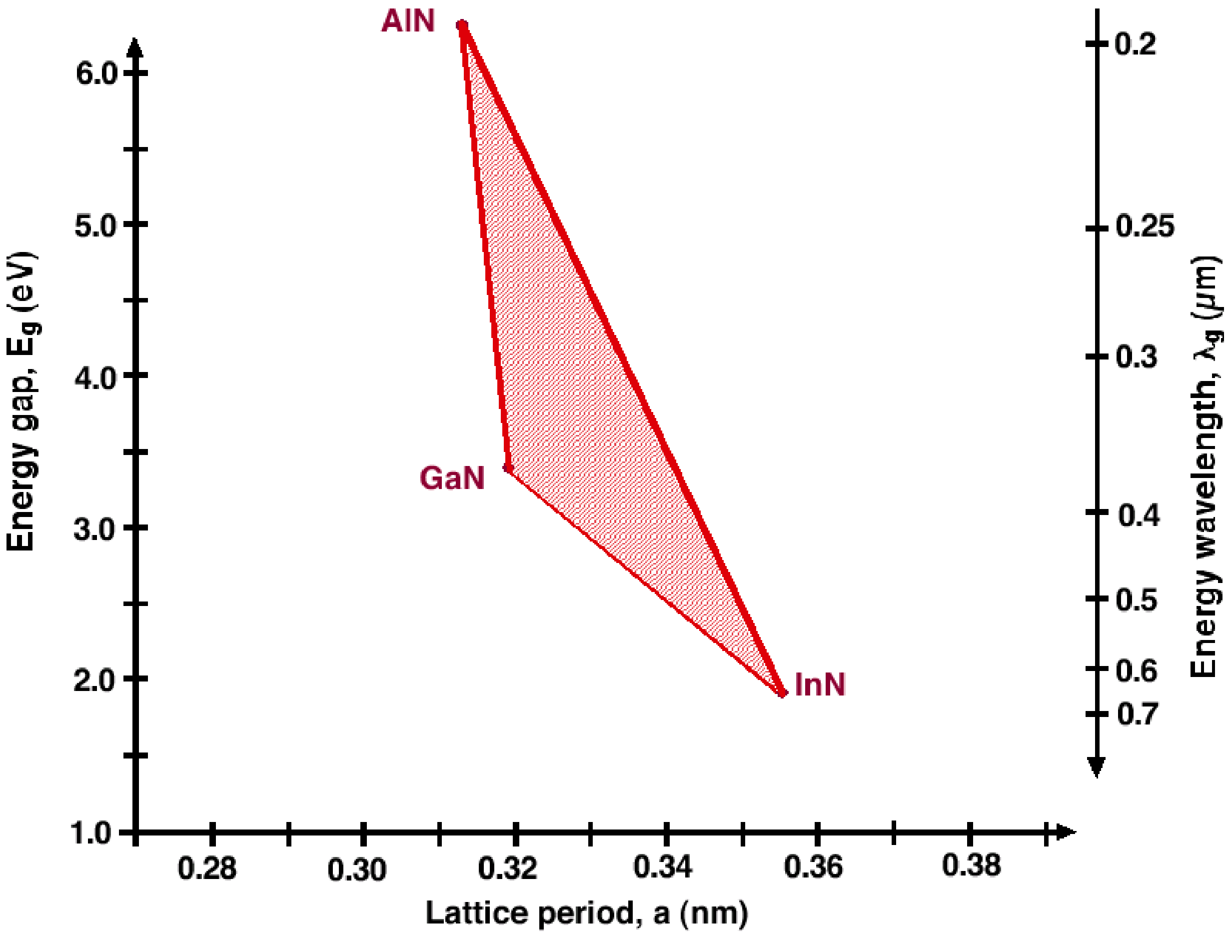


Limelight

Edison bulb (1879)

The III-V wurtzite quarternary:

GaInAlN



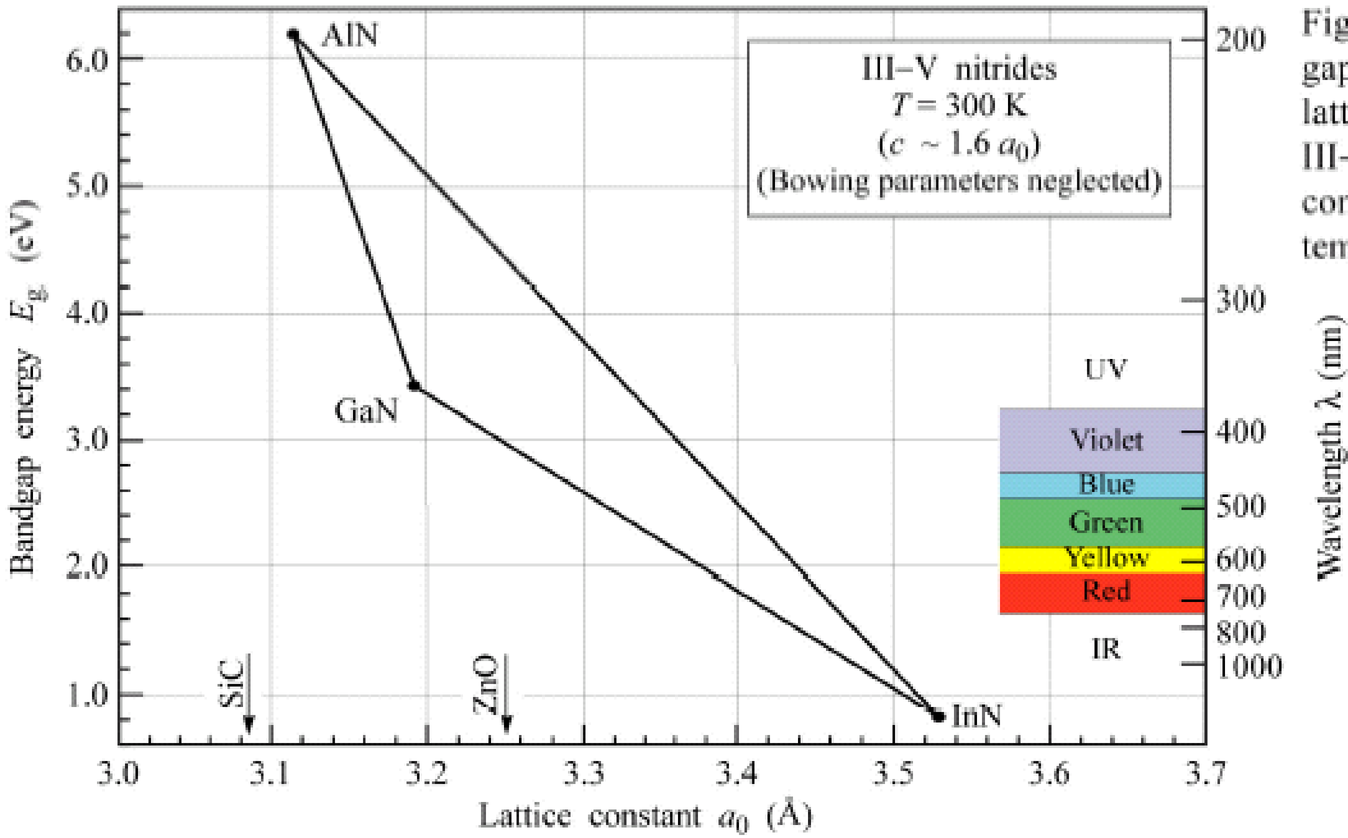
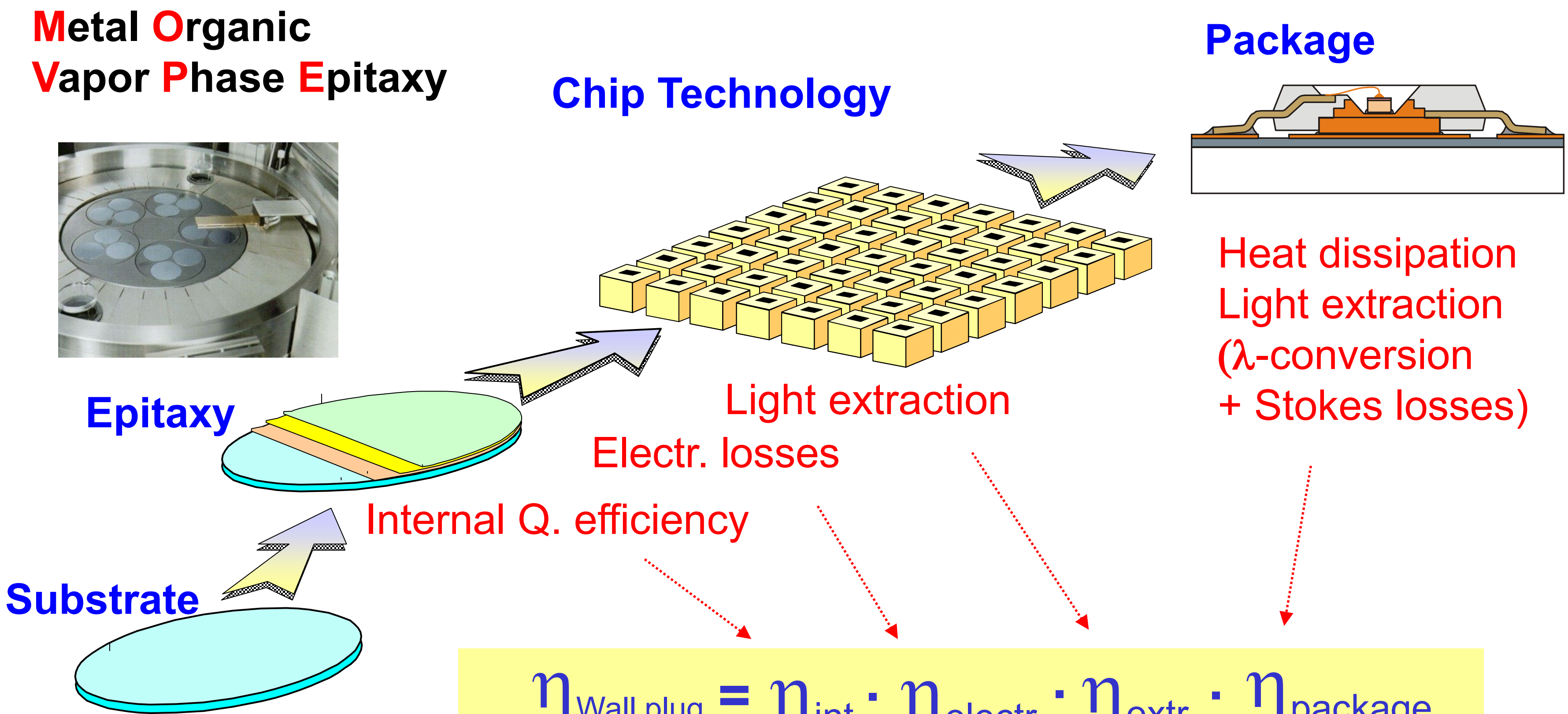


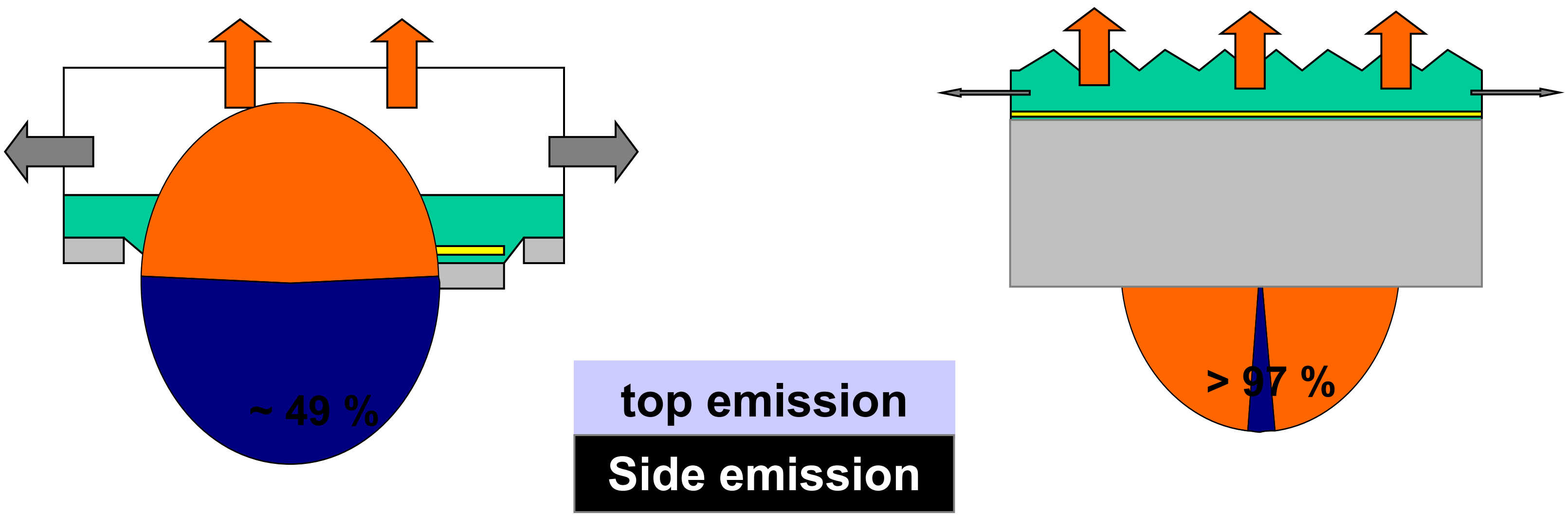
Fig. 12.12. Bandgap energy versus lattice constant of III–V nitride semiconductors at room temperature.



$$\eta_{\text{Wall plug}} = \eta_{\text{int}} \cdot \eta_{\text{electr}} \cdot \eta_{\text{extr}} \cdot \eta_{\text{package}}$$

Sapphire-PowerLED
(generic)
volume emitter
top or bottom contacts

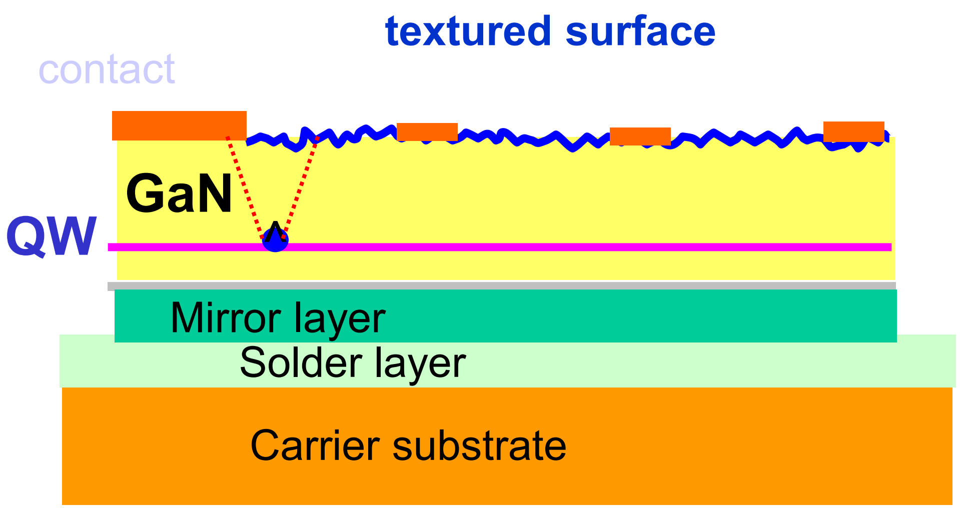
Thinfilm Technology
surface emitter
top and bottom contacts



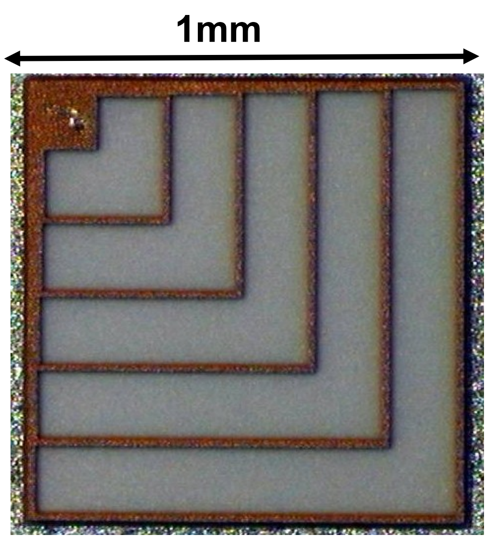
Thinfilm technology has the best front emission, higher luminance and best scalability.

ThinGaN: The Way to Improve Light Extraction

Thinfilm principle:		Present actions:
• prevent absorption in substr.	⇒	highly reflecting mirror
• low internal absorption	⇒	thin epi layers
• prevent waveguiding	⇒	optimize surface roughness

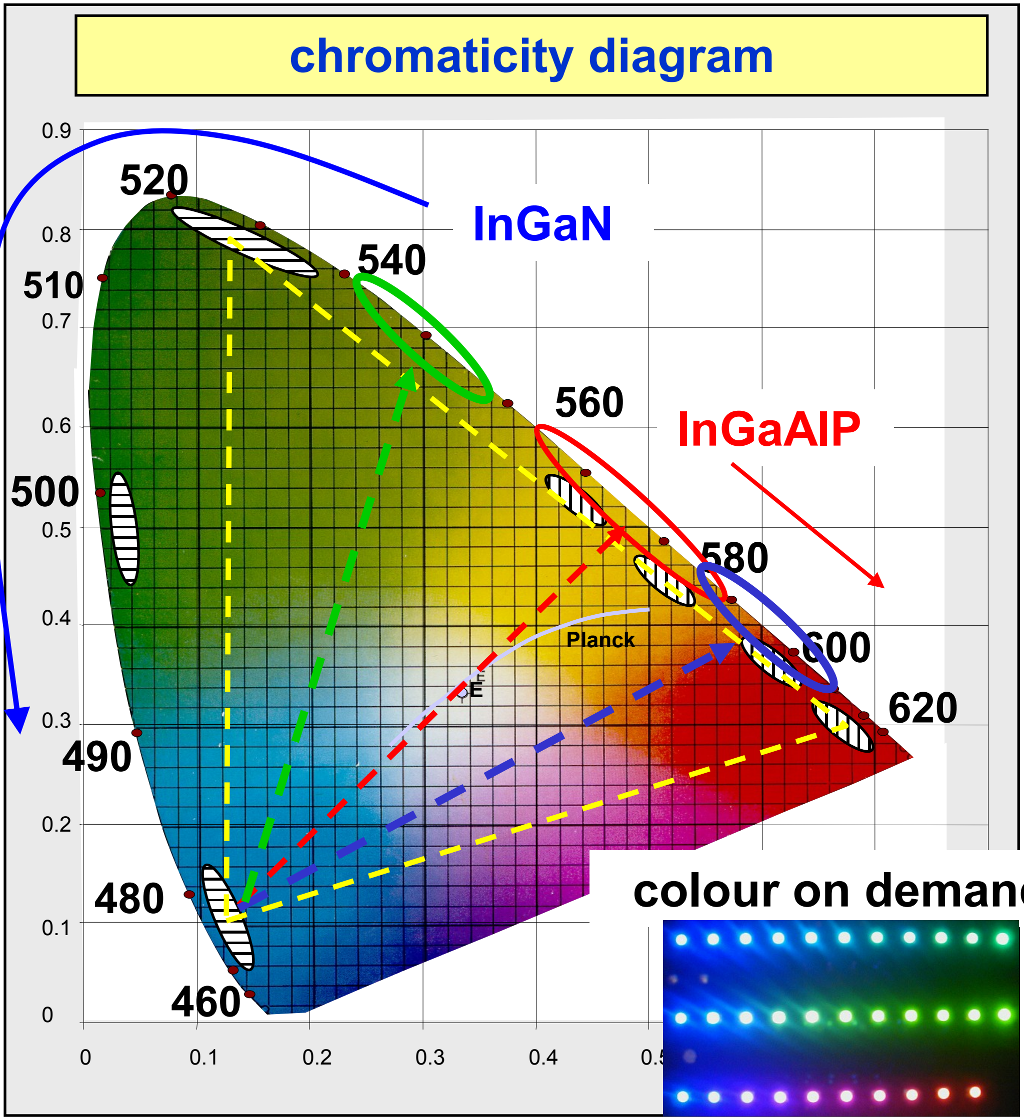


PowerThinGaN; scematic side view



PowerThinGaN top view

⇒ **Light extraction of 75% is reached**



1st approach: Muli-colour-LEDs:

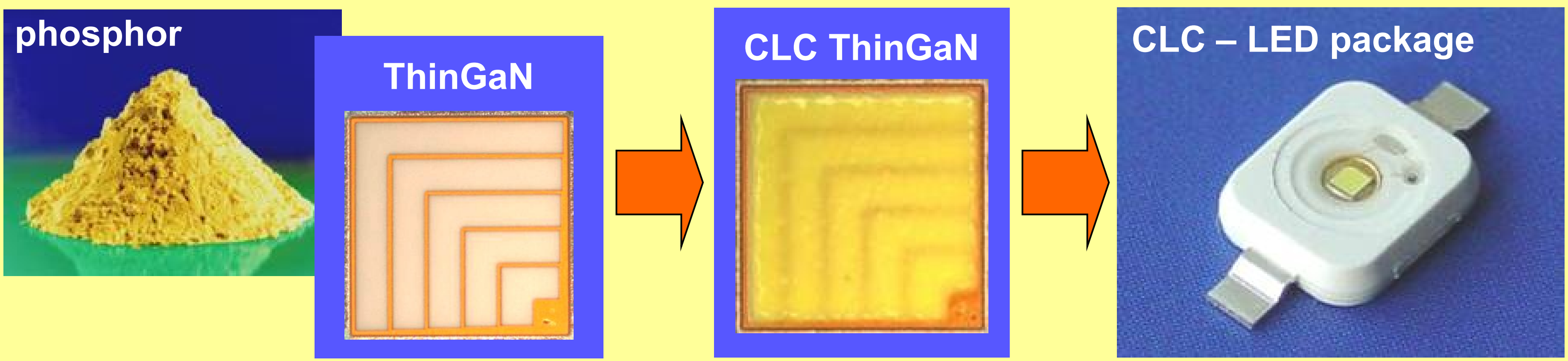
turnable colours within
the yellow triangle & white

2nd approach: conversion:

 +  = 

blue LED	„yellow„ phosphorous	„white“ light

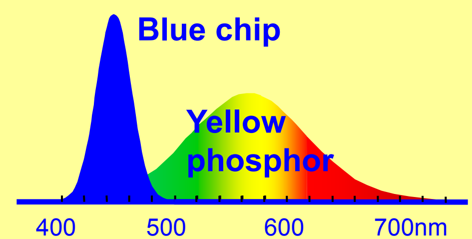
improved light conversion ⇨ chip level conversion (CLC) layer



⇨ **excellent color homogeneity**

⇨ **die sorted “white” chips**

⇨ **high luminance**



⇨ **perfectly suitable for optical systems**

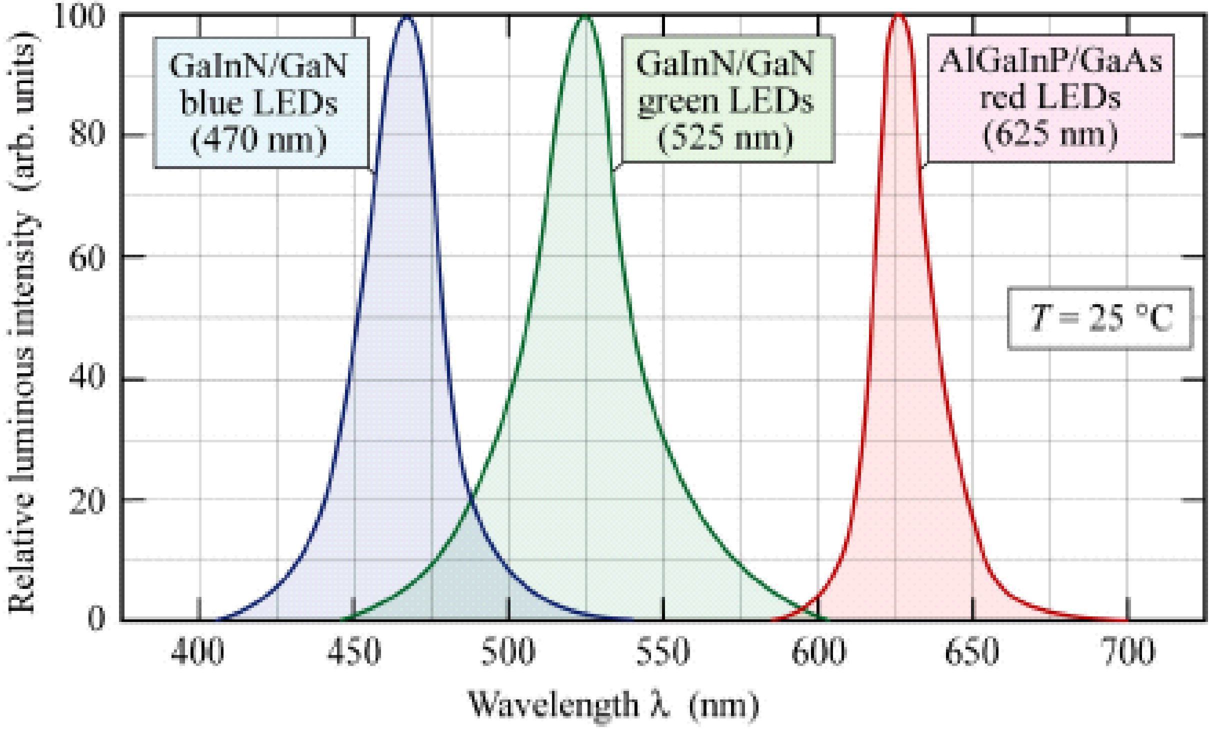


Fig. 12.16. Typical emission spectrum of GaInN/GaN blue, GaInN/GaN green, and AlGaInP/GaAs red LEDs at room temperature (after Toyoda Gosei Corp., 2000).

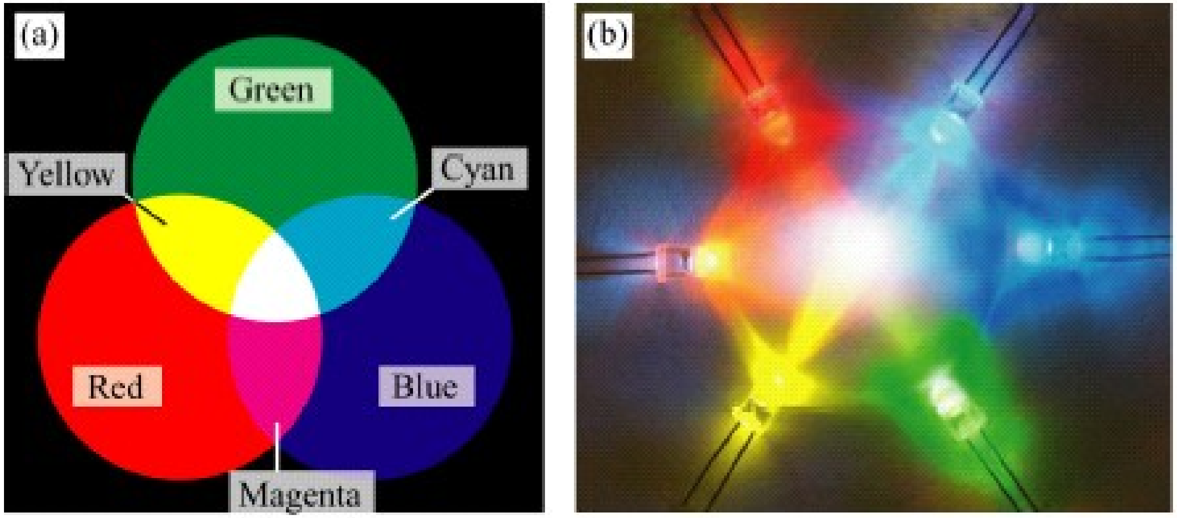


Fig. 19.1. (a) Schematic of additive color mixing of three primary colors. (b) Additive color mixing using LEDs.

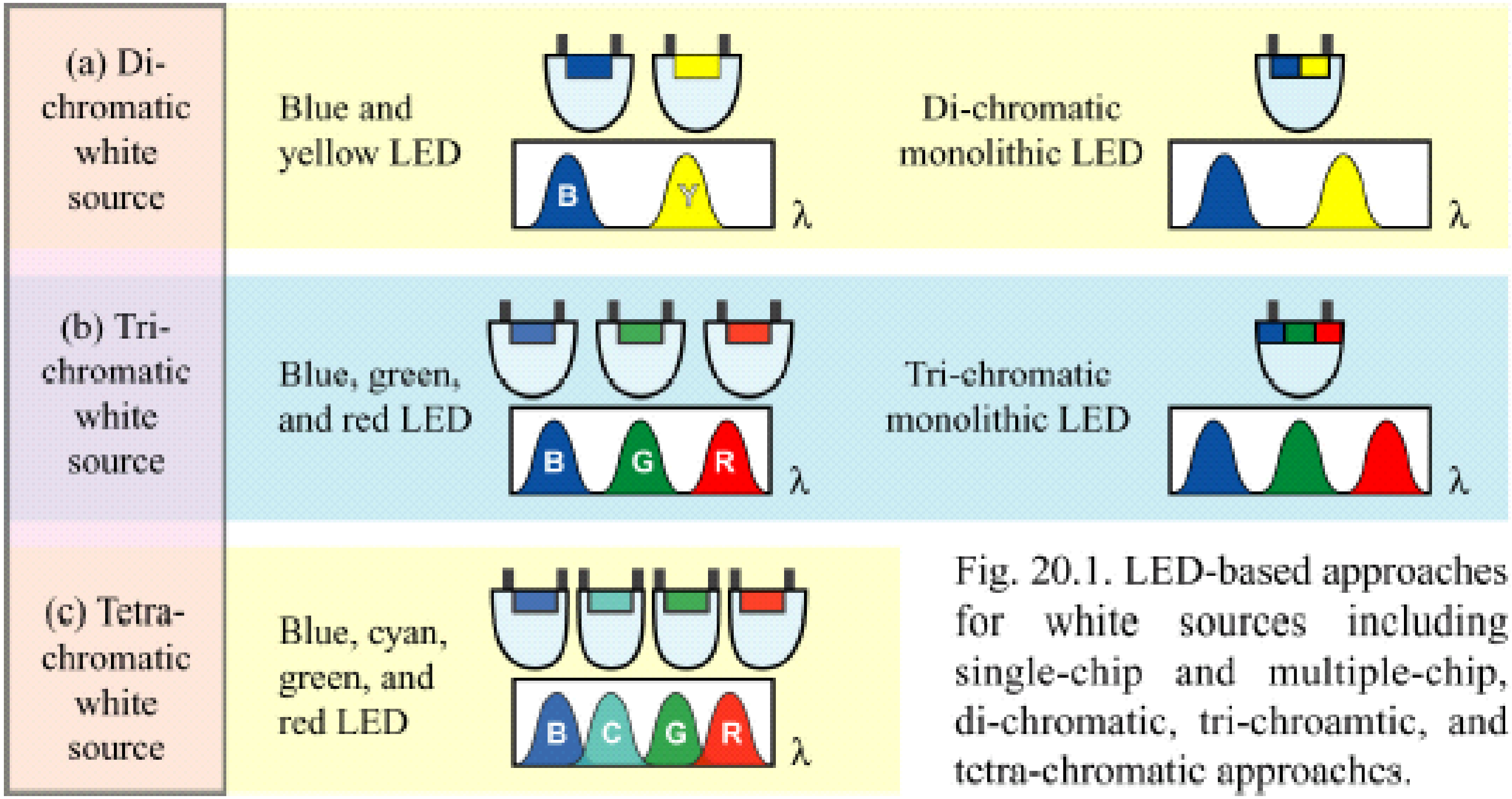


Fig. 20.1. LED-based approaches for white sources including single-chip and multiple-chip, di-chromatic, tri-chroamtic, and tetra-chromatic approaches.

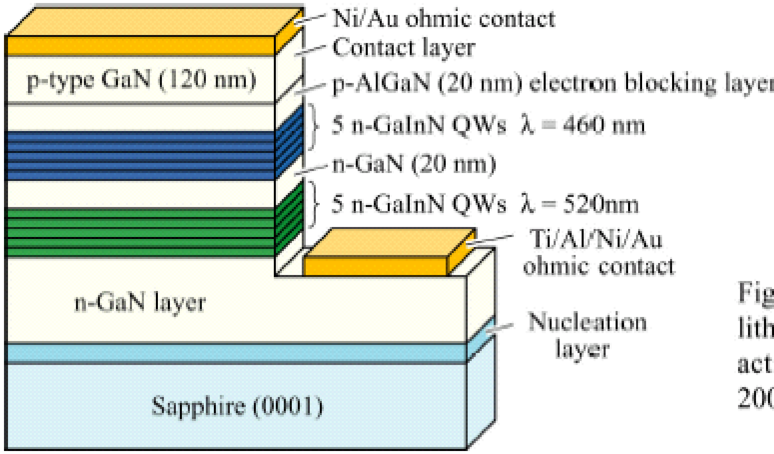


Fig. 20.4. Structure of a monolithic dichromatic LED with two active regions (after Li *et al.*, 2003).

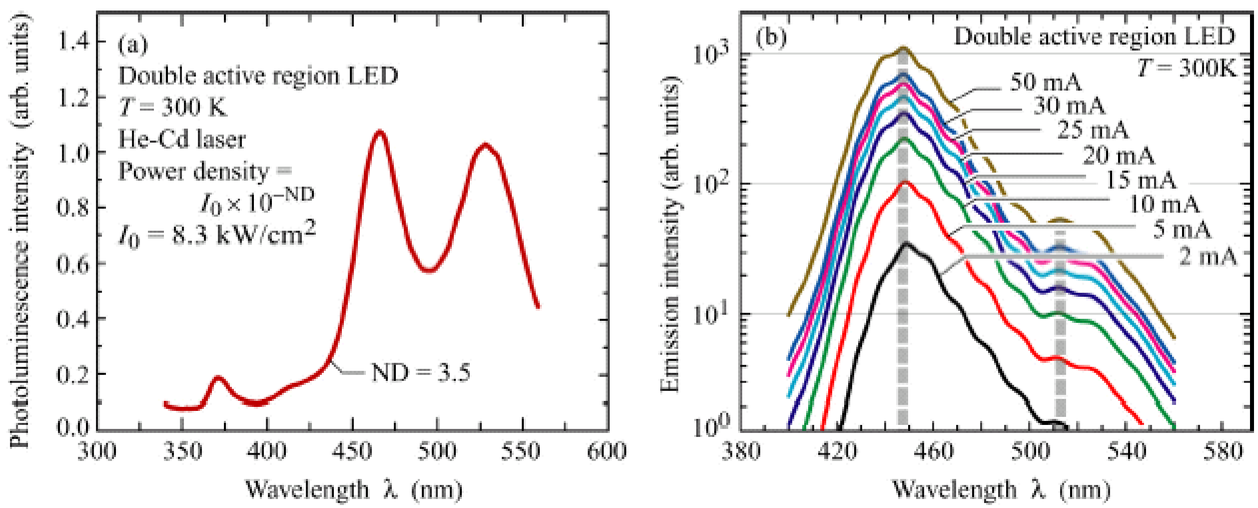


Fig. 20.5. Room temperature (a) photoluminescence and (b) electroluminescence spectra of monolithic dichromatic LED with two active regions (after Li *et al.*, 2003).

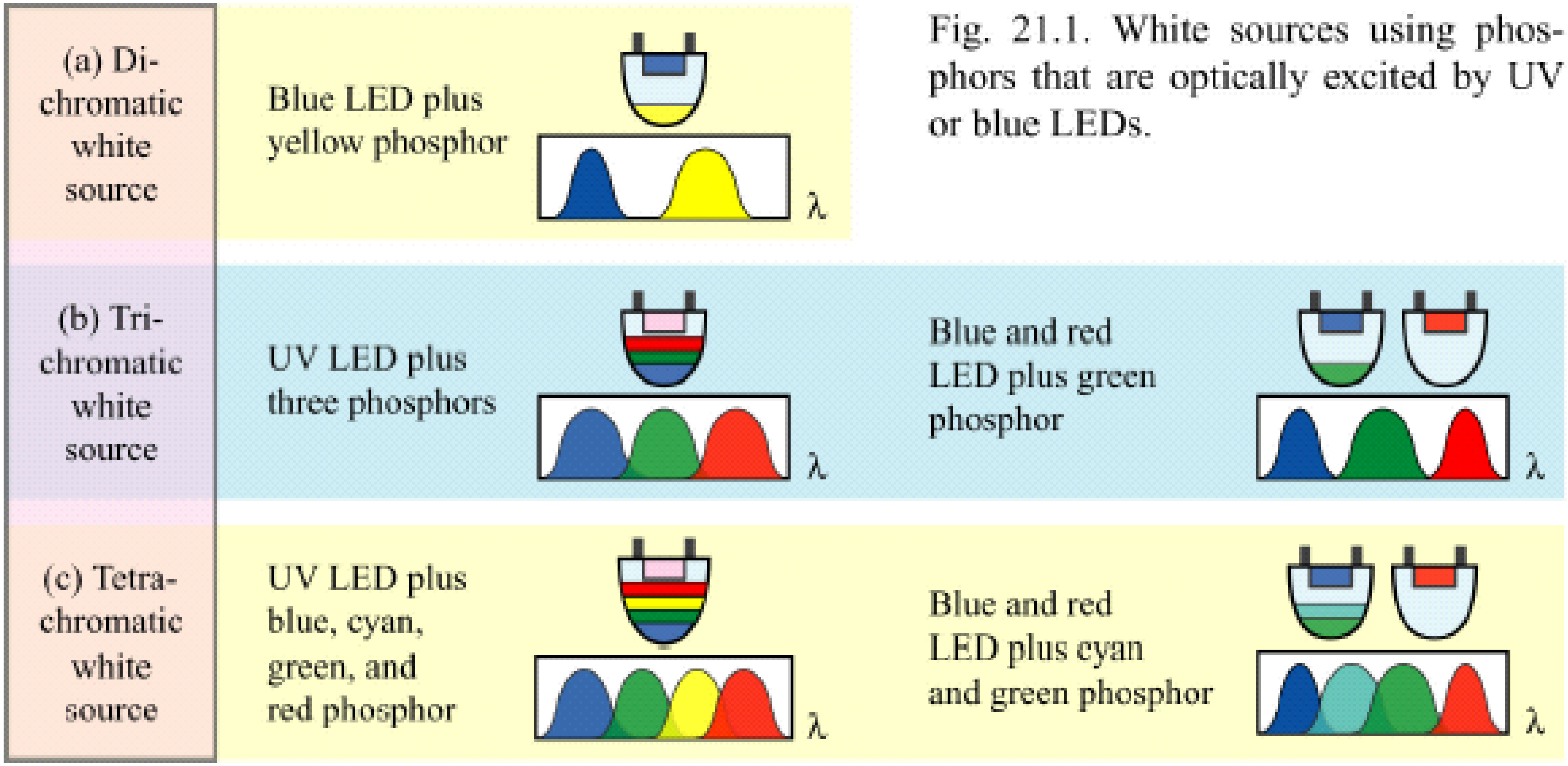


Fig. 21.1. White sources using phosphors that are optically excited by UV or blue LEDs.

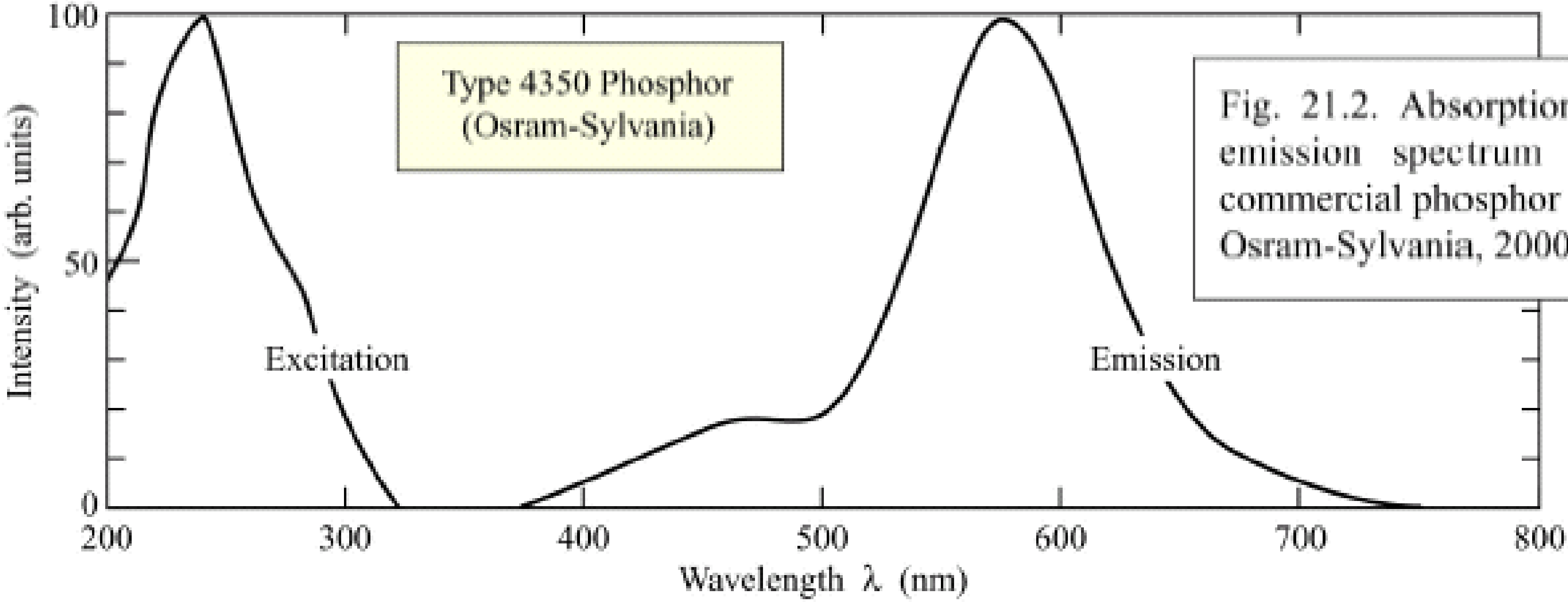


Fig. 21.2. Absorption and emission spectrum of a commercial phosphor (after Osram-Sylvania, 2000).

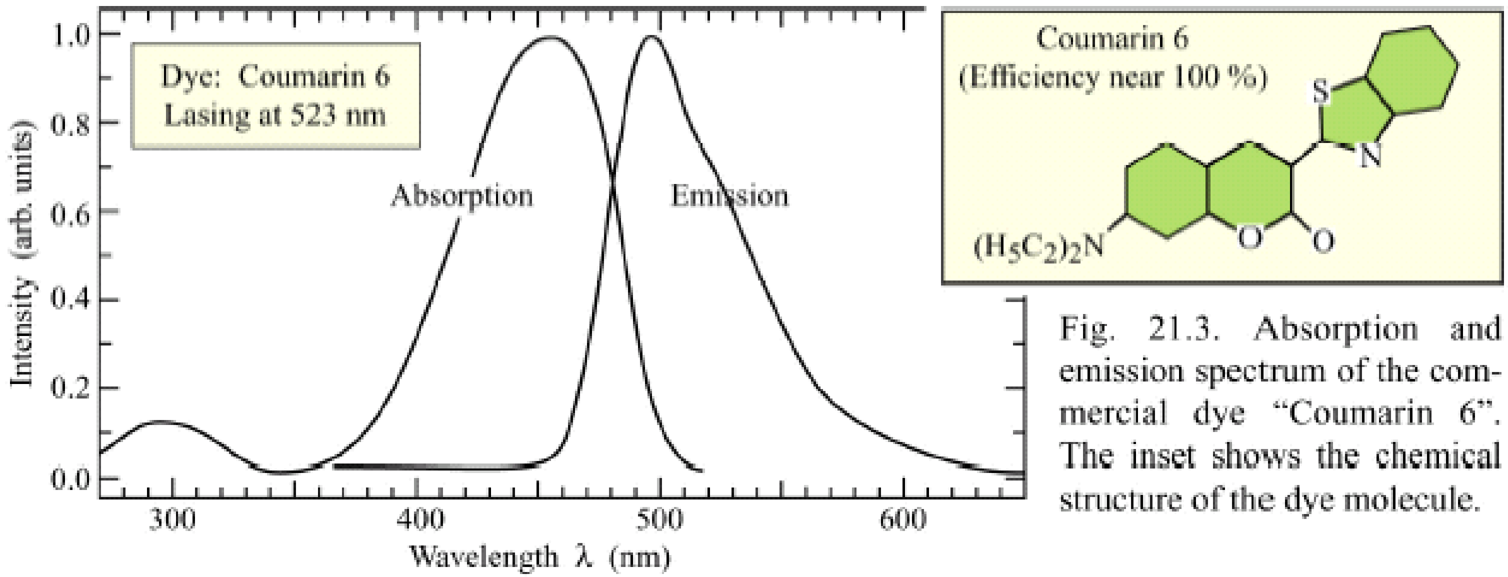


Fig. 21.3. Absorption and emission spectrum of the commercial dye "Coumarin 6". The inset shows the chemical structure of the dye molecule.

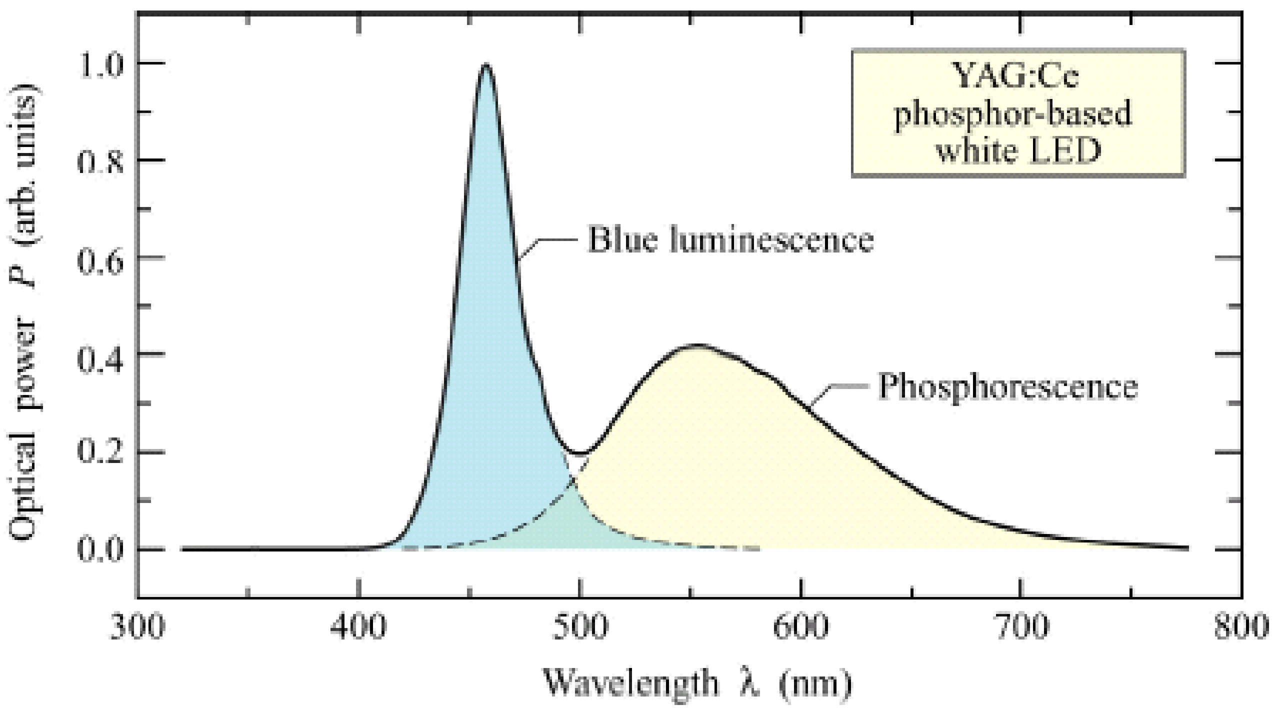


Fig. 21.8. Emission spectrum of a phophor-based white LED manufactured by Nichia Corporation (Anan, Tokushima, Japan).

Lumen (lm)

Unità di misura del flusso luminoso.
Equivale al flusso luminoso emesso da una sorgente isotropica di intensità luminosa di 1 candela su un angolo solido di 1 steradiante

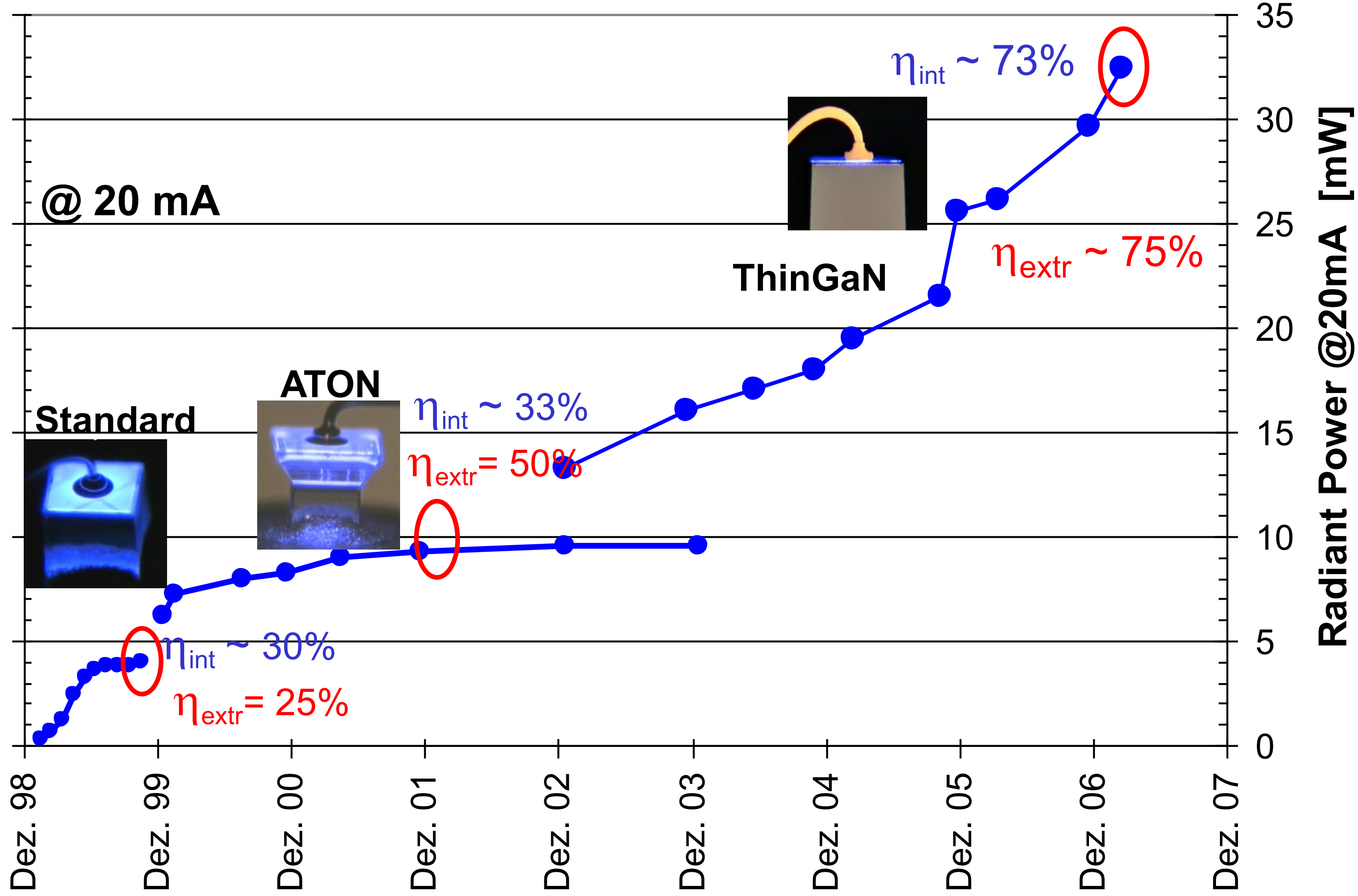
Una sorgente isotropica con intensità luminosa di 1 candela emette un flusso luminoso totale di 4π lumen

Candela (cd)

Unità di misura dell’intensità luminosa

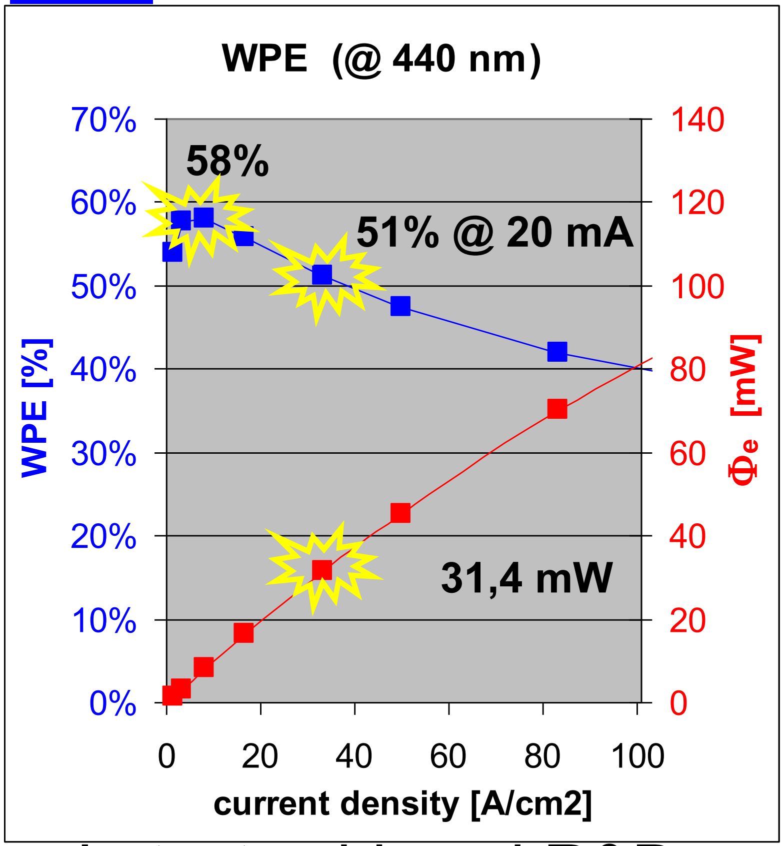
Una candela è pari all'intensità luminosa, in una data direzione, di una sorgente che emette una radiazione monocromatica di frequenza pari a 540×10^{12} hertz e di intensità radiante in quella direzione di 1/683 di watt per steradiante

InGaN (Blue) Improvement Over Last 6 Years

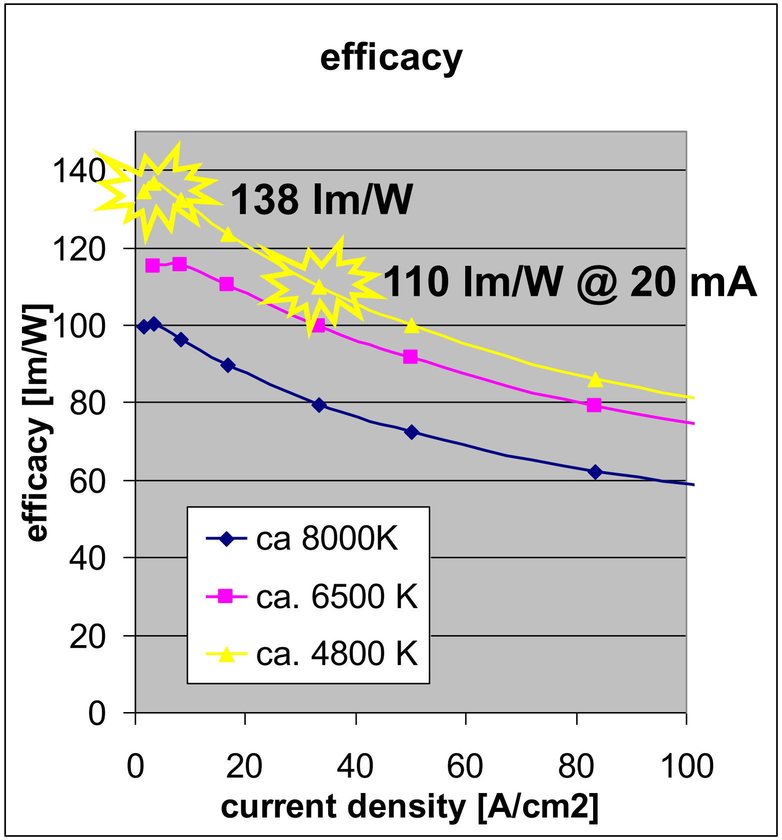


300 µm – class ThinGaN in 5mm radial package

Blue



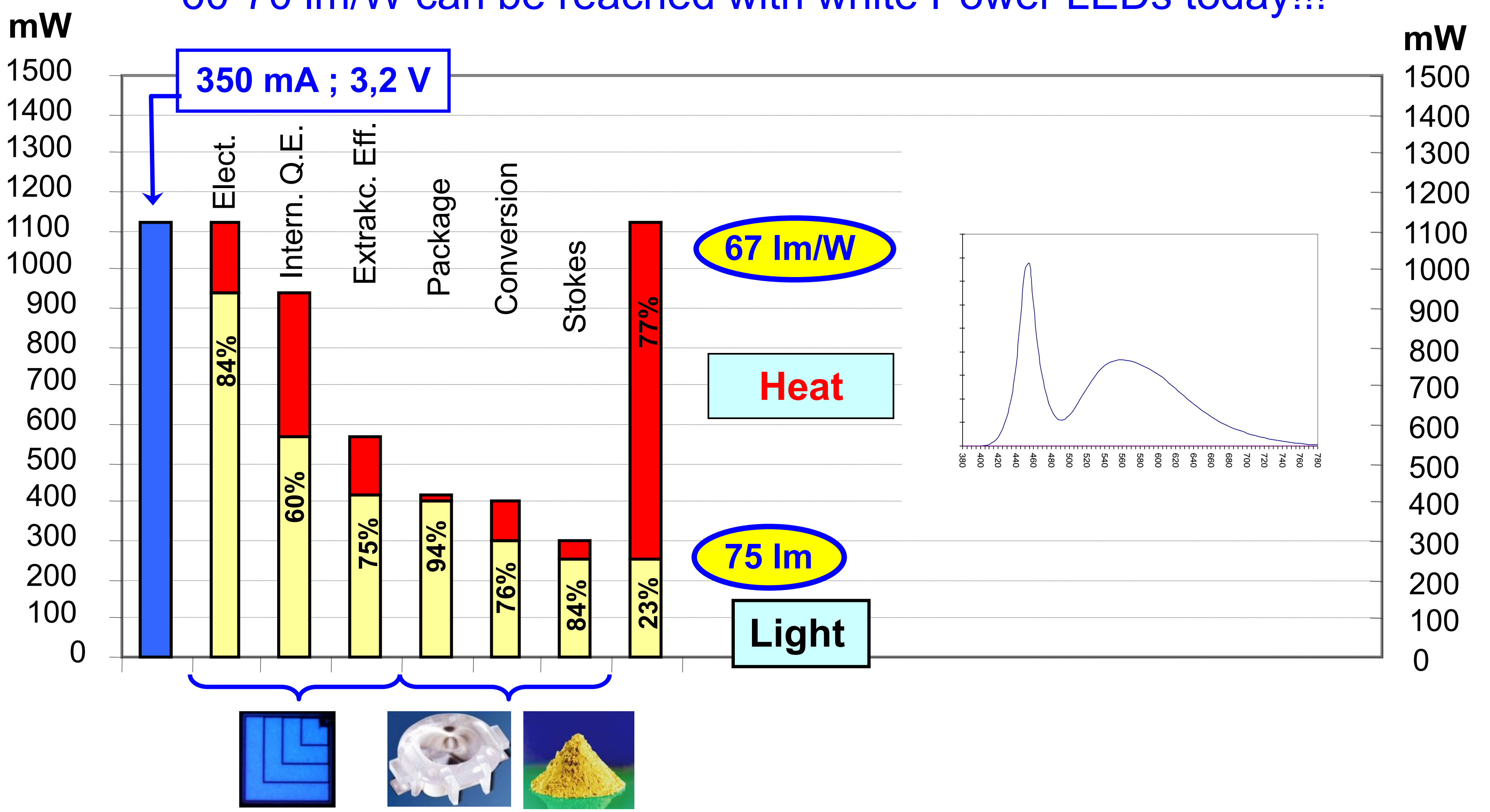
White



Latest achieved R&D record values

Power Balance of a White Power LED (1W Dragon) with 1mm² InGaN-Chip (today)

60-70 lm/W can be reached with white Power LEDs today!!!



Further brightness improvement: approaches

Increase current ⇒ more lumens

1st approach: **Constant chip size**

- increase current density

⇒ more lumens but less efficiency

2nd approach: **Constant current density**

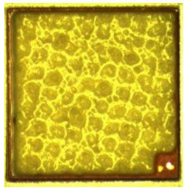
- increase chip size

⇒ more lumens but more costs

Further brightness improvement: increase current density

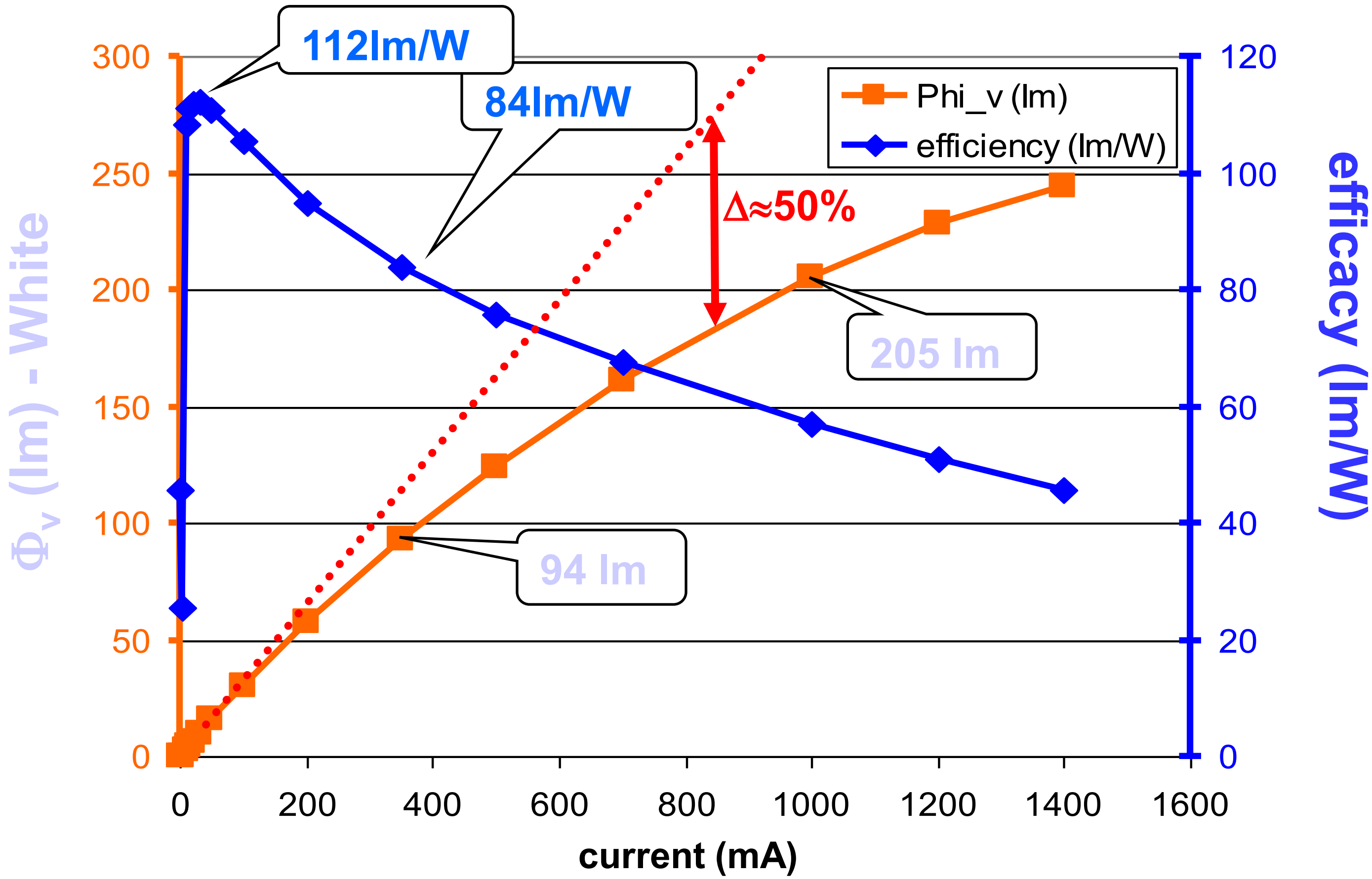
1mm x 1mm:

with CLC



Dragon

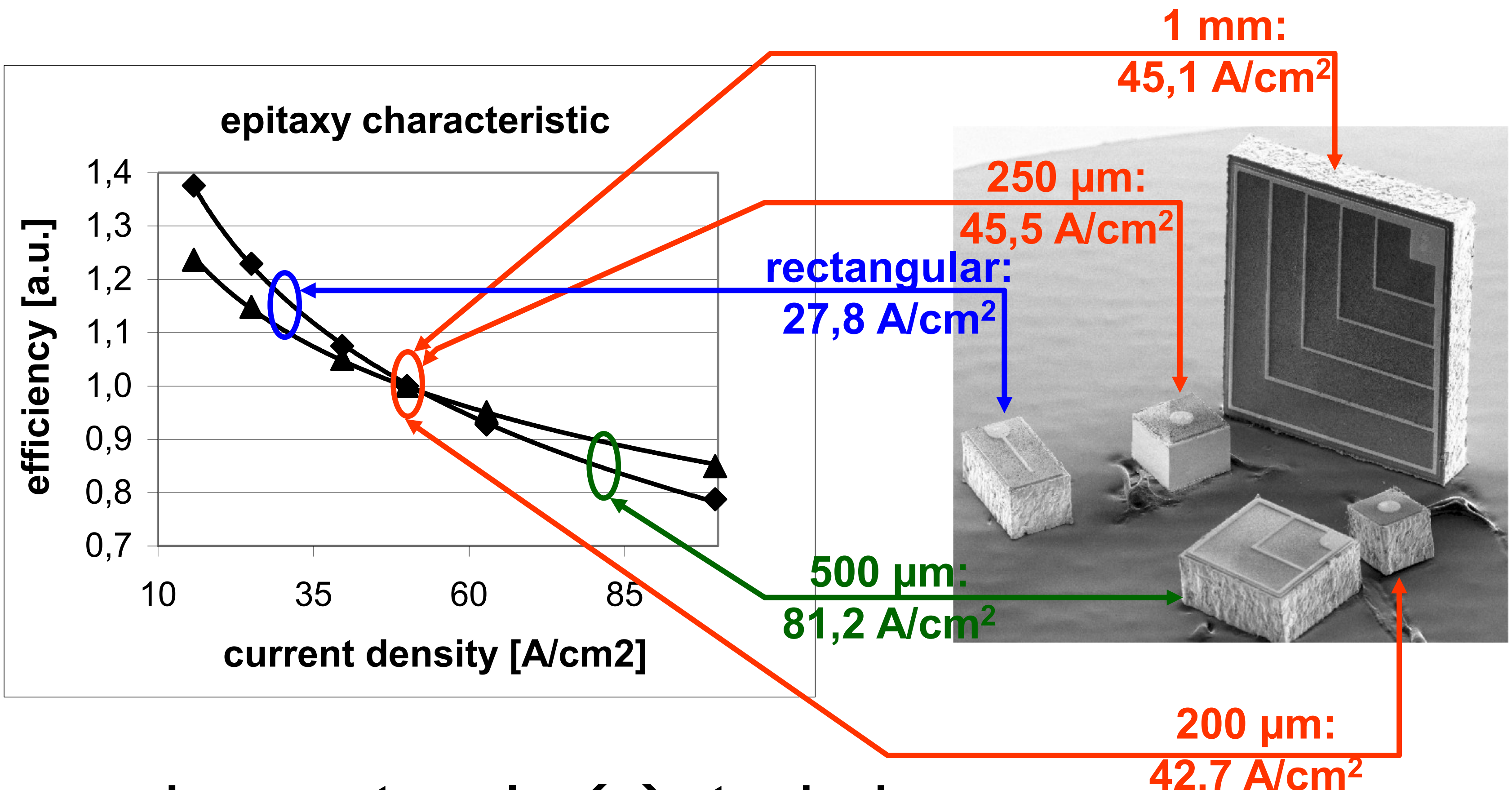
with lens



lumen output saturates & efficacy drops with increased current

reasons: non-linearity of IQE by 1) current density and 2) heating

efficiency of light generation dependent on current density:

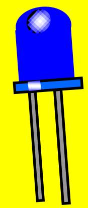


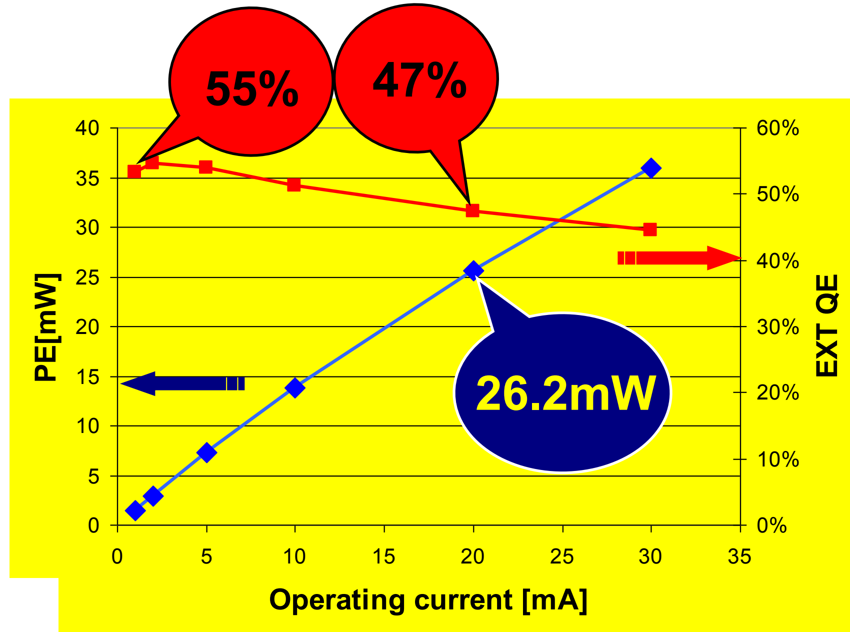
comparison rectangular ←→ standard :

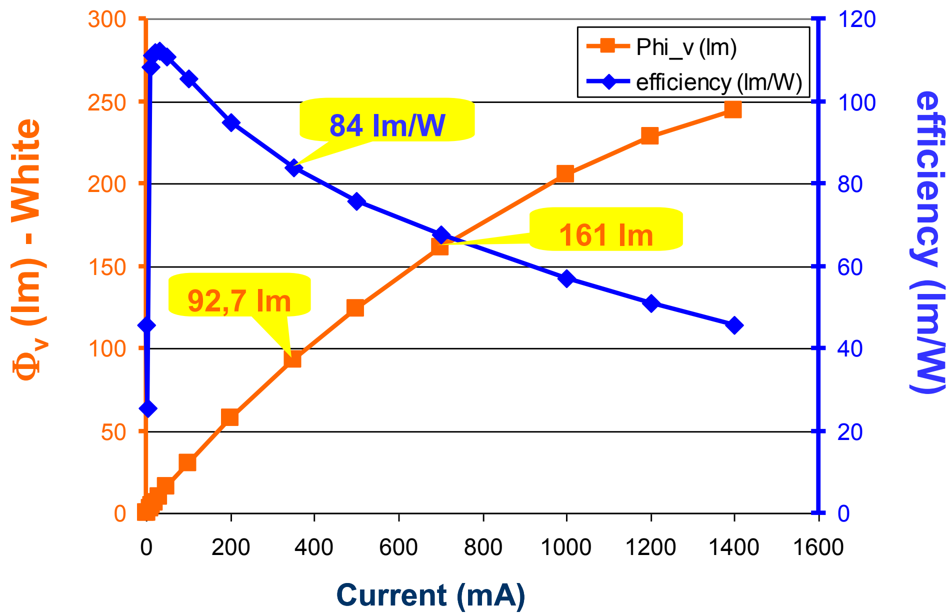
Up to 15 % brightness increase by reduced current density

standard chip size

V_f = 3,1V @ 20mA







power chip 1x1mm²

V_f=3,1V @ 350mA
Lowest V_f reported
For power devices

Further brightness imrovement: approaches

Increase current ⇒ more lumens

1st approach: **increase current @ constant chip area**

challenges:

- **improve heat management (decrease R_{th} of entire device)**
- **improve linearity of IQE regarding current density**

2nd approach: **increase current @ constant current density**

⇒ increase chip area

challenges:

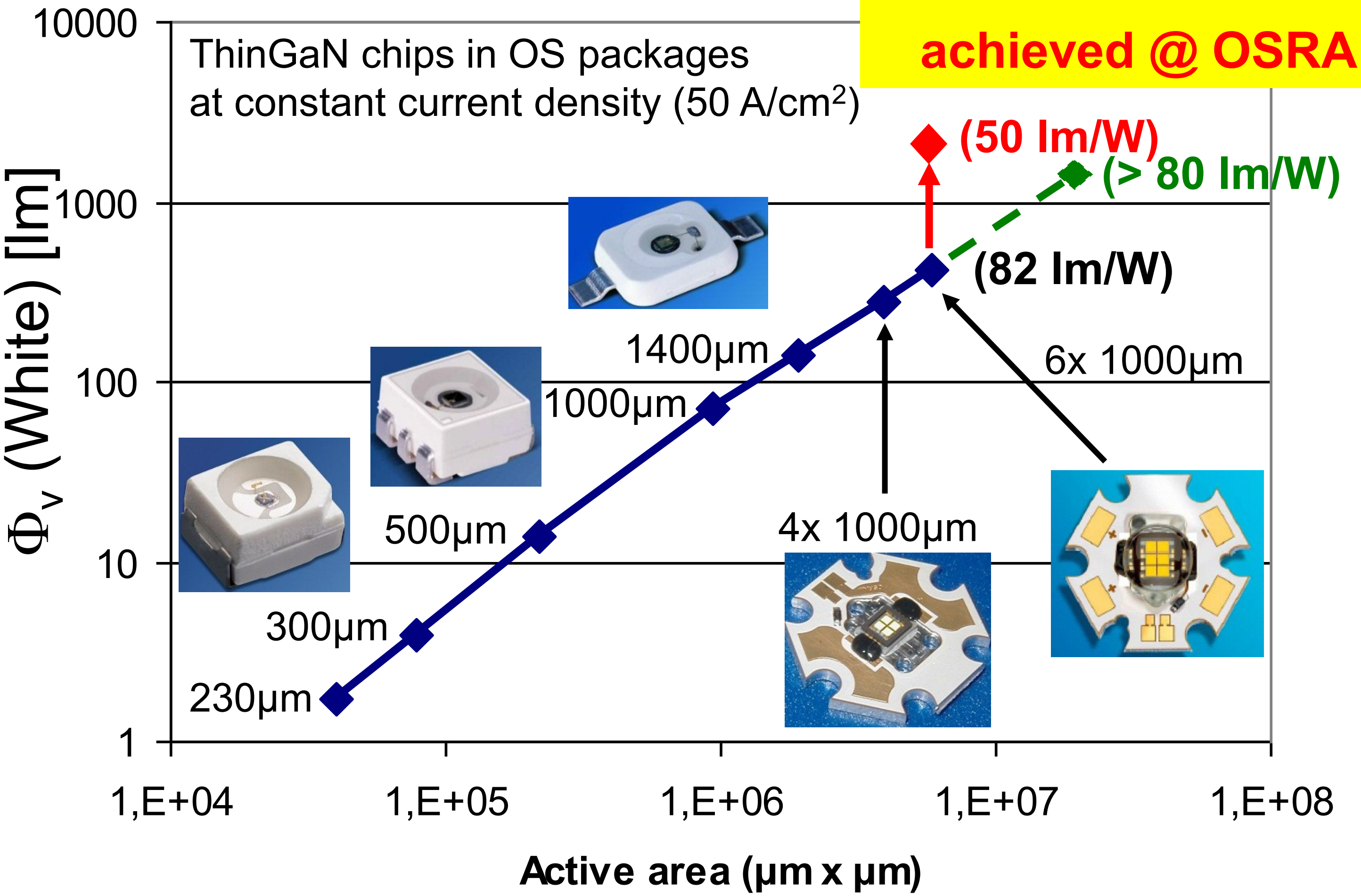
- **decrease costs per chip area and package**

Further brightness imrovement: increase

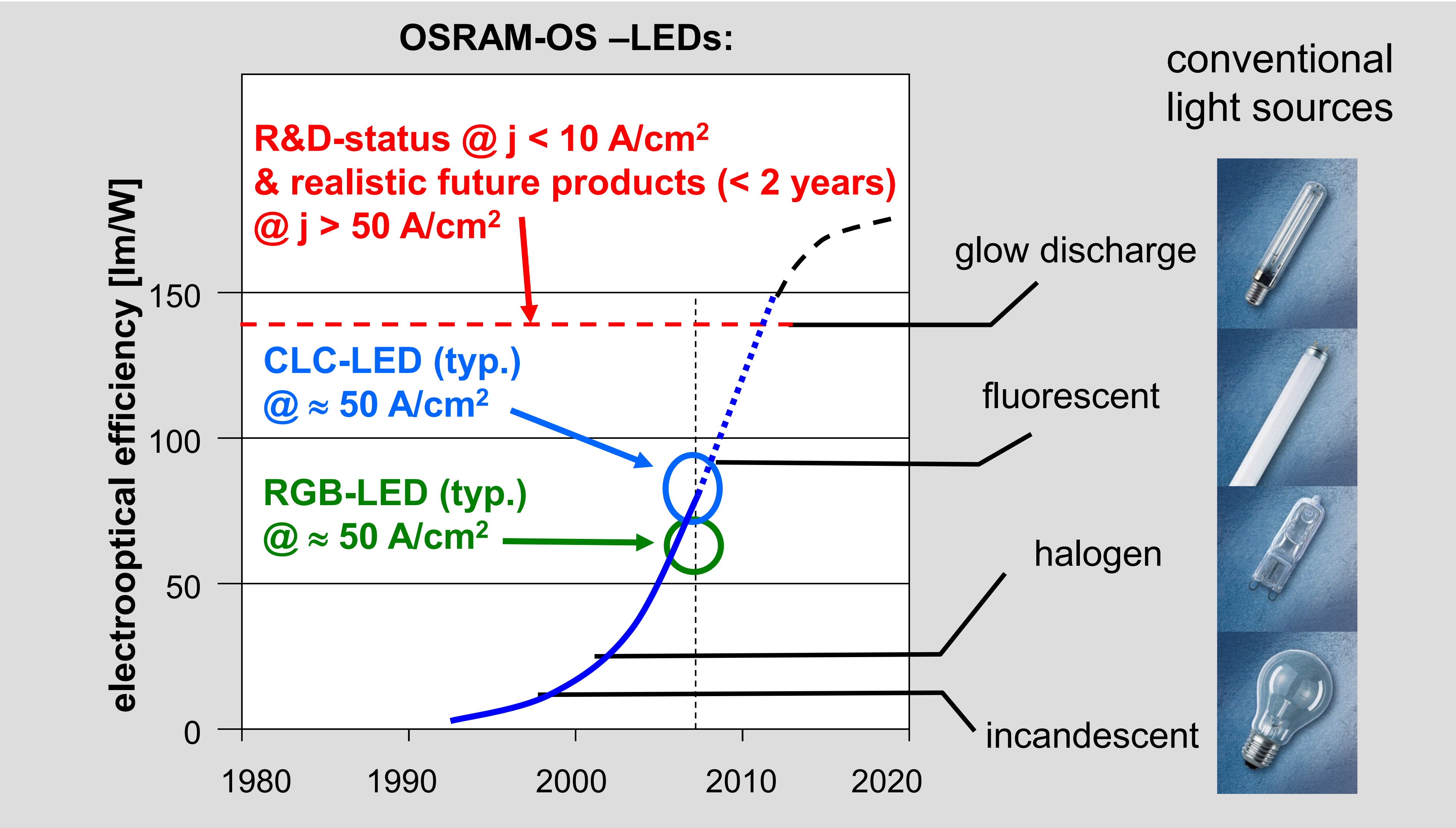
Single emitter with

1170lm

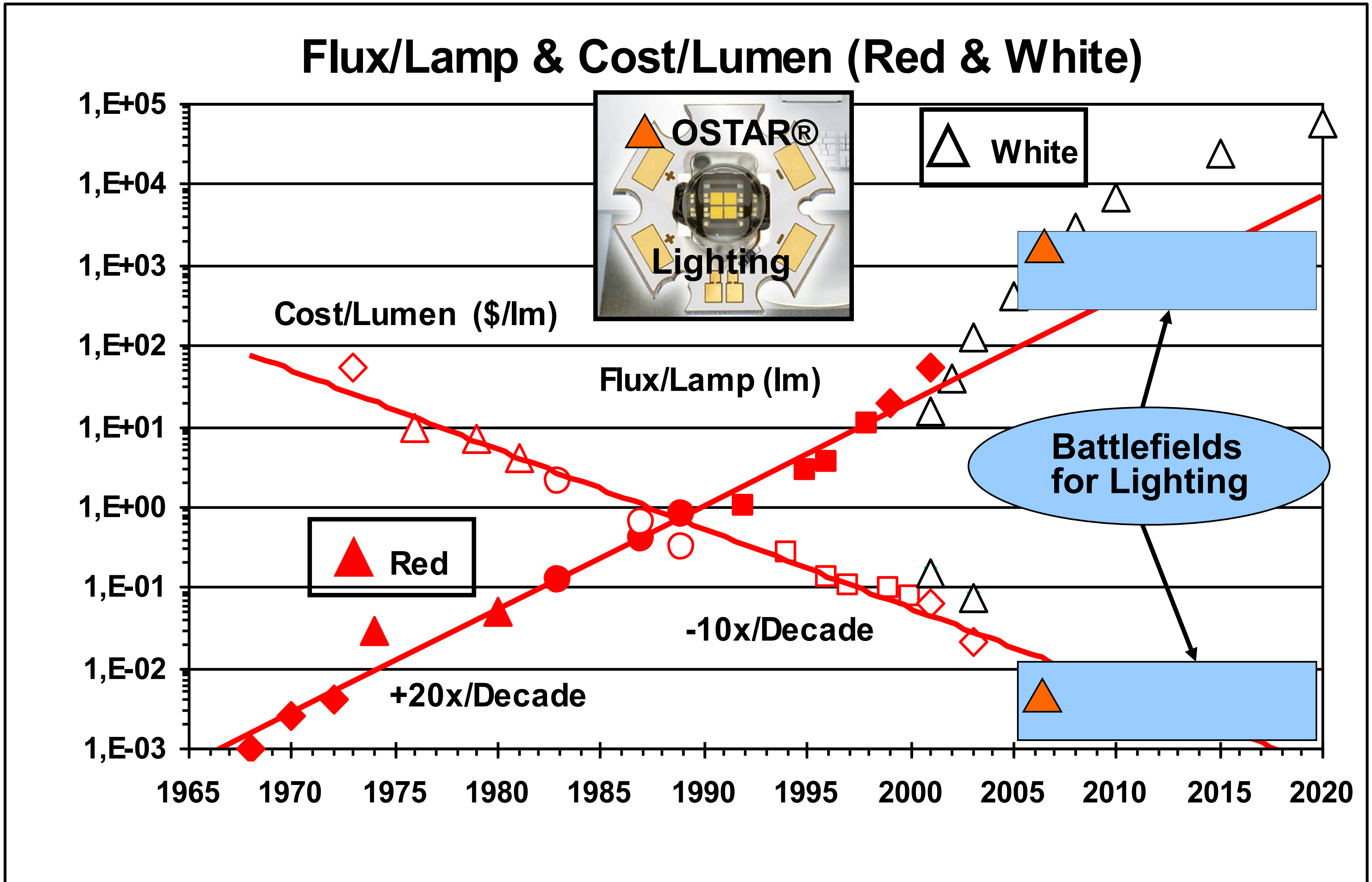
achieved @ OSRAM



Coming soon: typ. 1000lm white light product


OSRAM-OS –LEDs:
conventional light sources
R&D-status @ j < 10 A/cm²
& realistic future products (< 2 years)
@ j > 50 A/cm²
CLC-LED (typ.)
@ ≈ 50 A/cm²
RGB-LED (typ.)
@ ≈ 50 A/cm²
electrooptical efficiency [lm/W]
0
50
100
150
1980
1990
2000
2010
2020
glow discharge
fluorescent
halogen
incandescent

Roland Haitz's Battlefields for LED Lighting – and Our OSTAR Position



HV signal head **LV signal head (Super pressure lamp)** **LV signal head (Halogen lamp)** **LED signalhead**

Lamp power:	135 W	50 W	50 W	15 W (signal monitor)
Life cycle:	6 Months	8 Months	12 Month	120 Month
Energy saving:	0 %	63 %	63 %	89 %
Maintenance rate:	100 %	75 %	50 %	5 %