EXALOS
The bright light source company

High power blue lasers for white light generation

Marco Rossetti

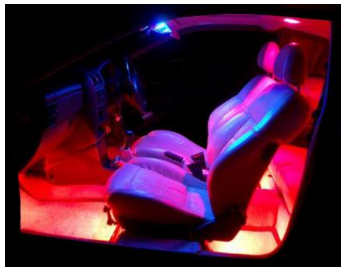
SWISS PHOTONICS

Workshop: Smart Lighting

Friday, 30.10.2015, EPFL

Solid state lighting

LEDs have conquered most of the lighting empire.



But lasers may strike back!

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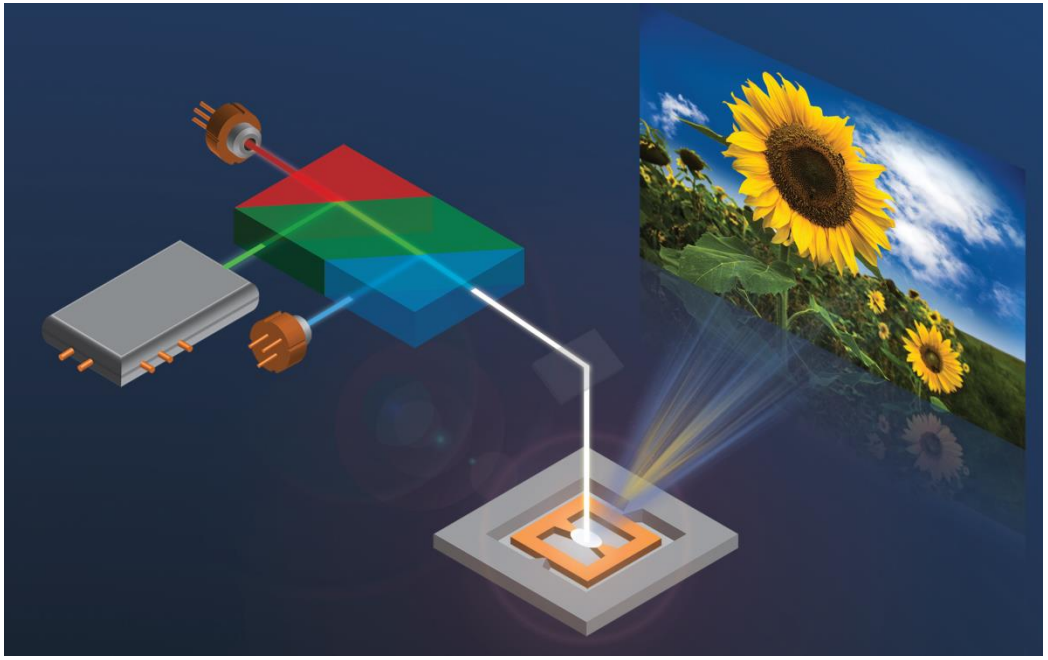
Some examples

MicroVision

RGB laser projectors



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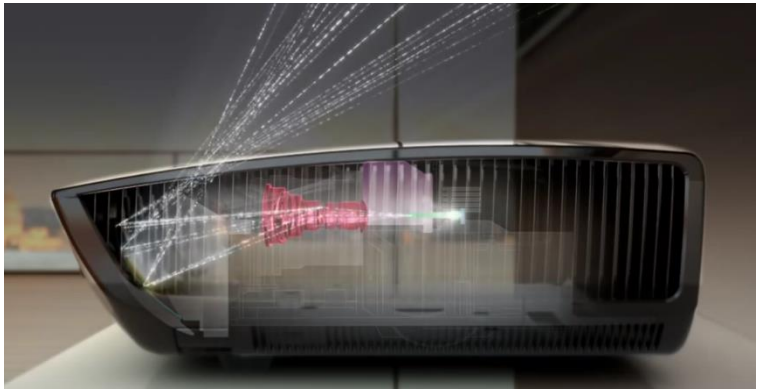
Some examples

LG
Life's Good



LG 100 Inch LASER Display Hecto

BRING THE REAL CINEMA IN YOUR HOME

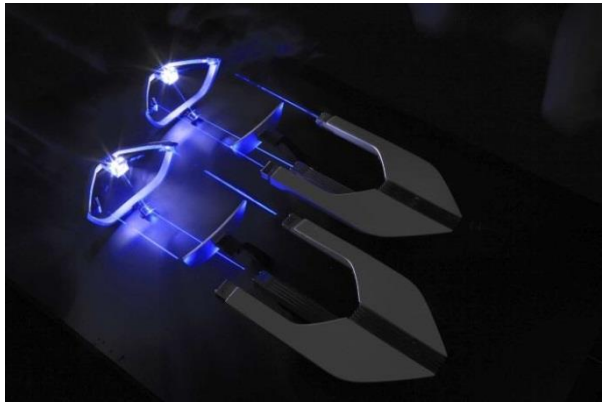
HECTO

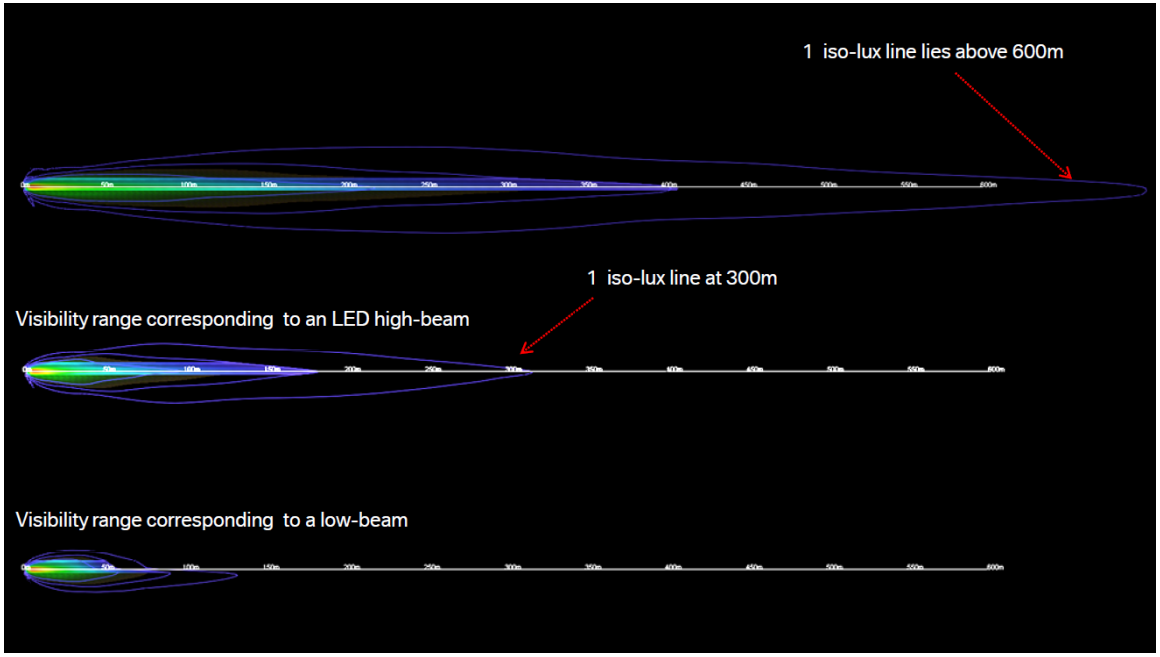
- LG LASER DISPLAY
- 100'' GIGANTIC SCREEN
- WIFI BUILT-IN
- HD DIVX

EXALOS

Some examples

BMW i8 laser-based headlights

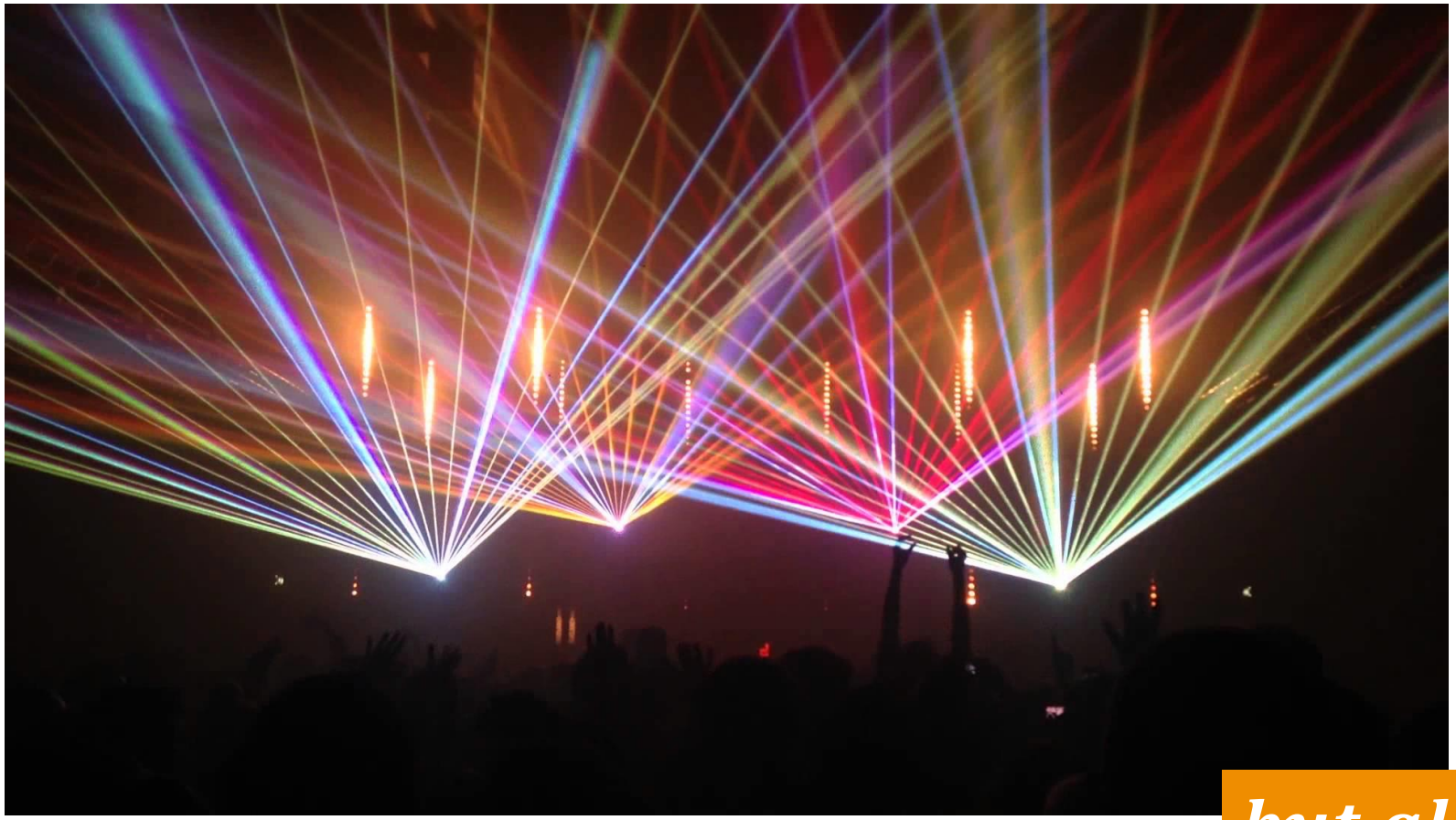




Hanafi et Erdl., Laser light, BMW ek-711, 21.05.2015

Why lasers?

Because they are cool!



but also … …

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Outline

LD vs LED: handbook of semiconductor physics

GaN-based LDs: technology and performance

White light generation

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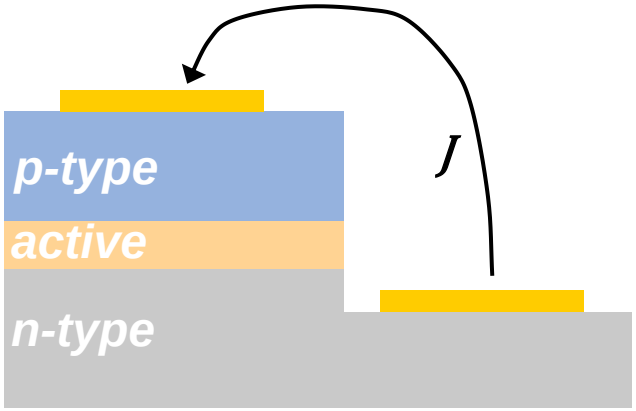
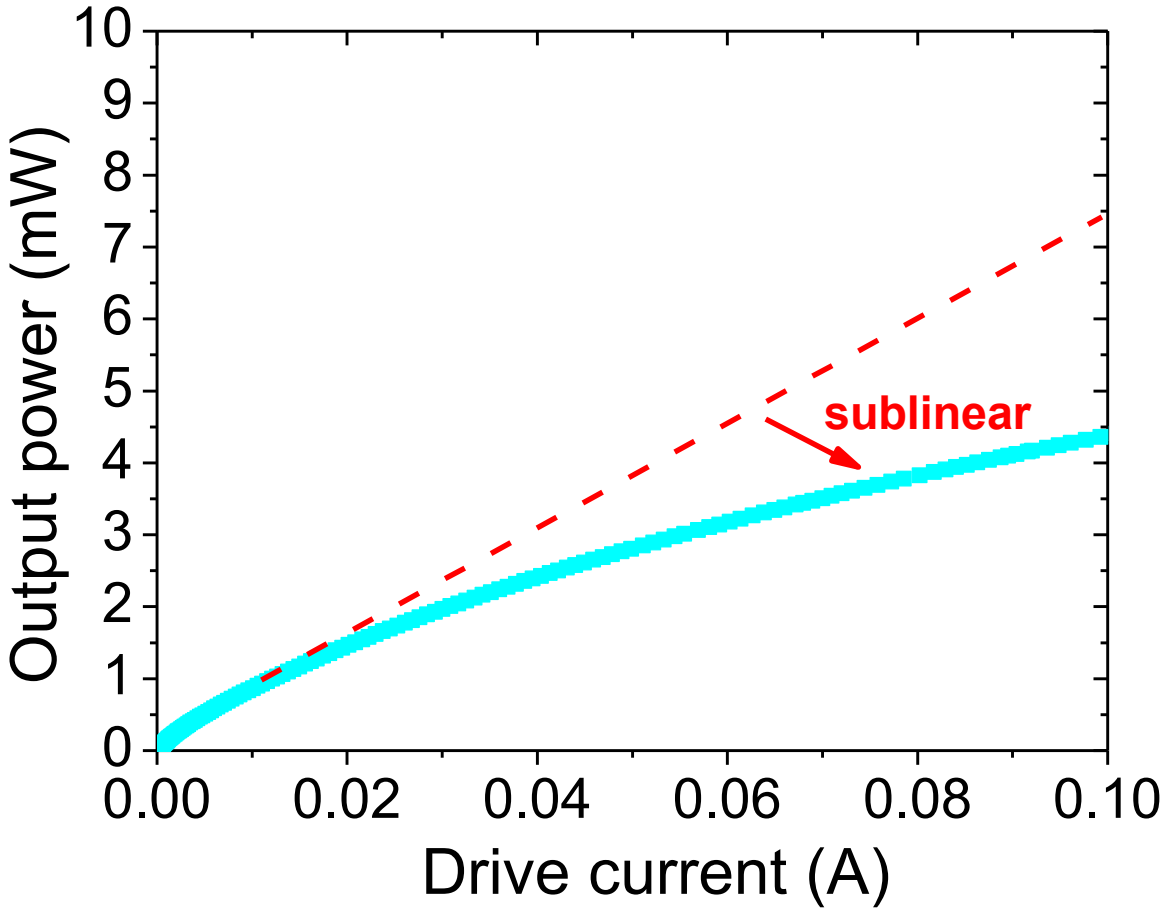
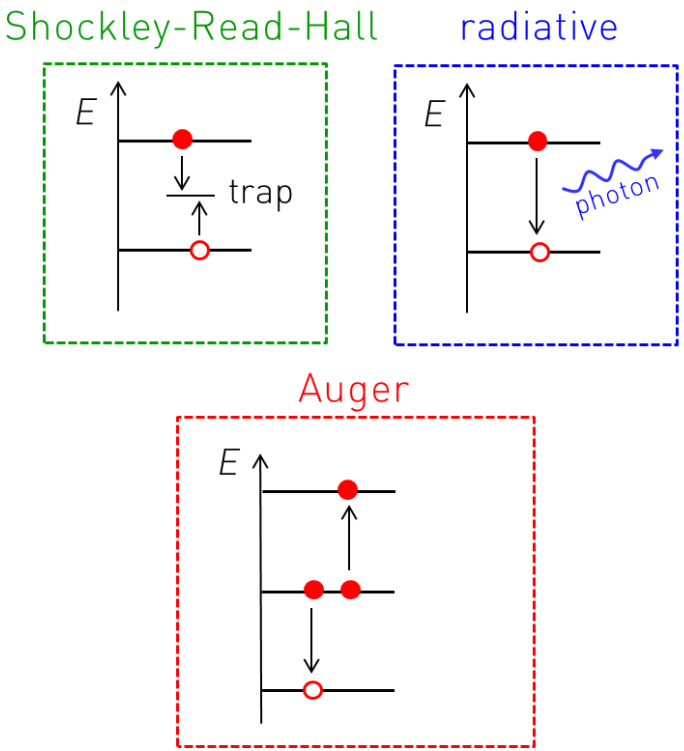
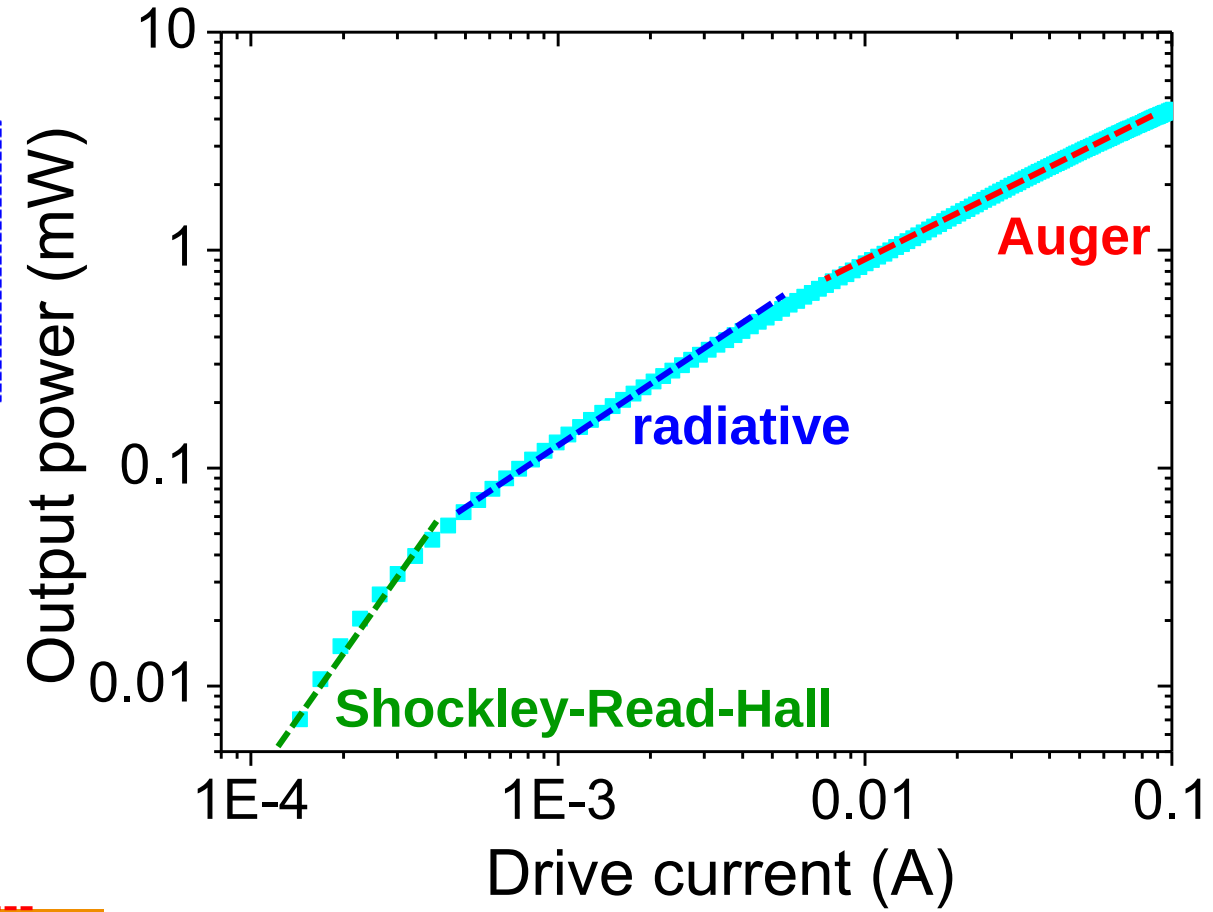
LED guide for dummies





LED guide for dummies





$$J \propto An + Bn^2 + Cn^3$$

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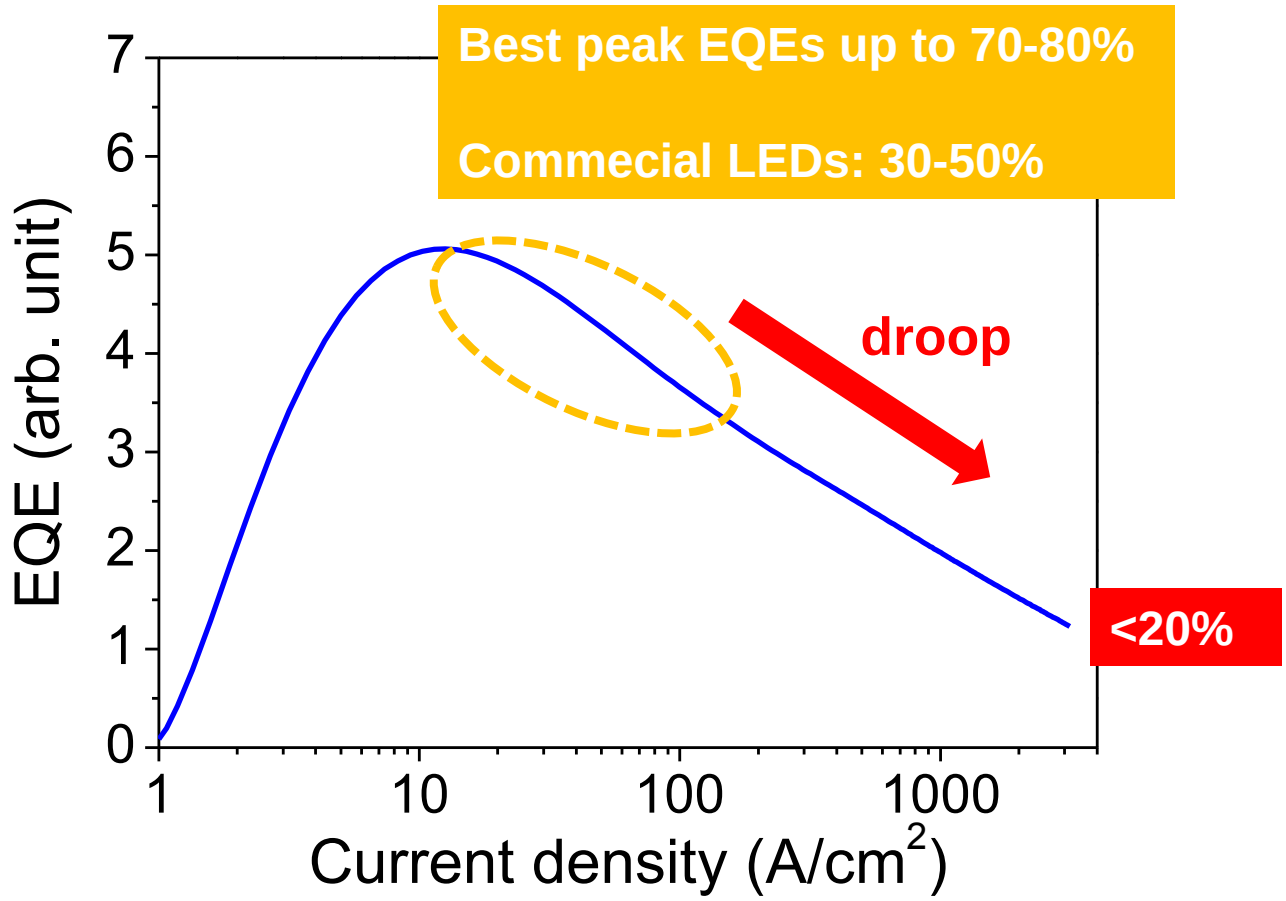
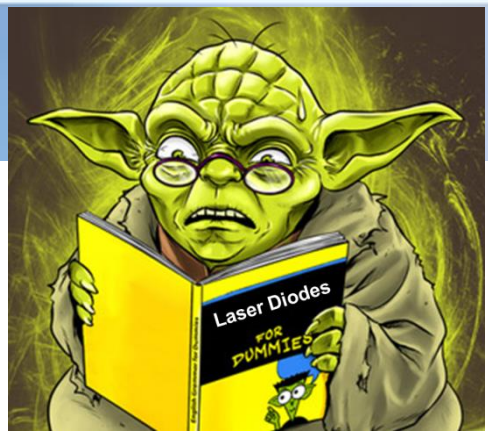
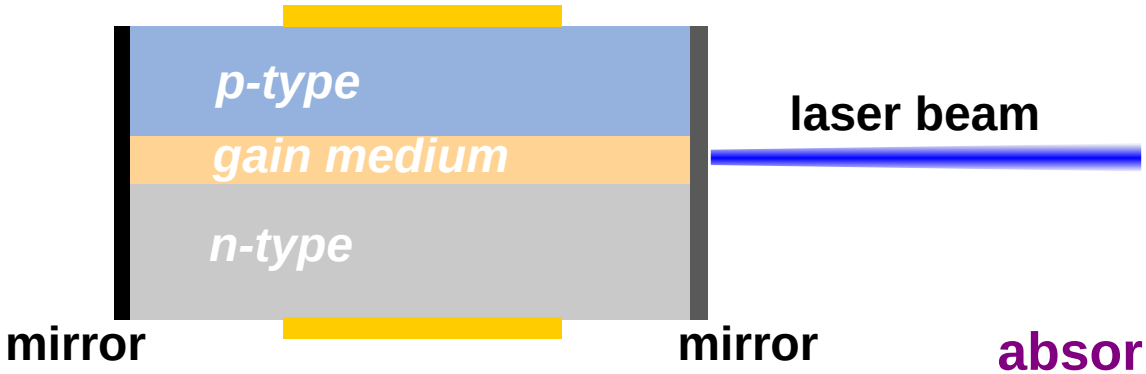
Efficiency droop in a LED



In a laser





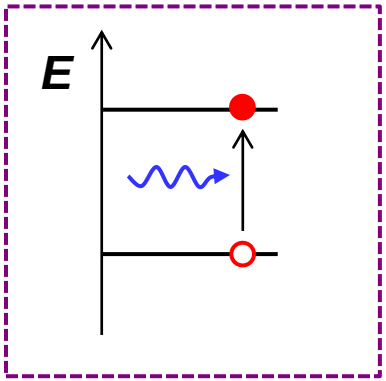
$$\frac{dn}{dt} = \frac{J}{qd} - An - Bn^2 - Cn^3 - Gs$$

$$\frac{ds}{dt} = (G - \alpha)s + \beta Bn^2$$

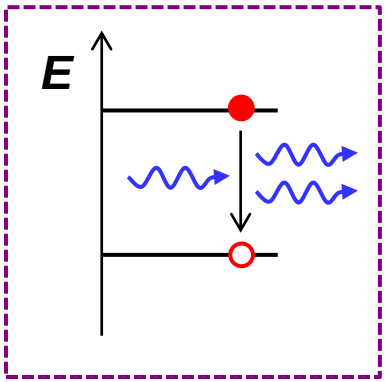
$$G \propto (n - n_0)$$

$$\alpha = \alpha_m + \alpha_i$$

absorption



stimulated emission



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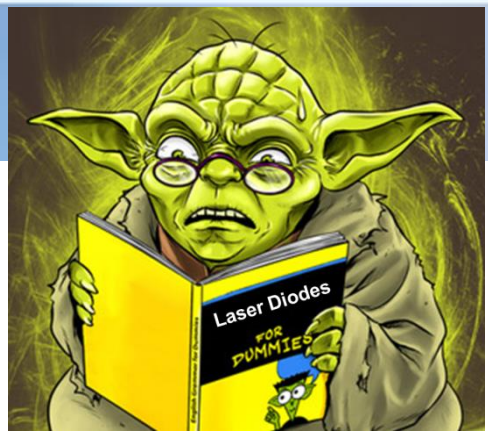
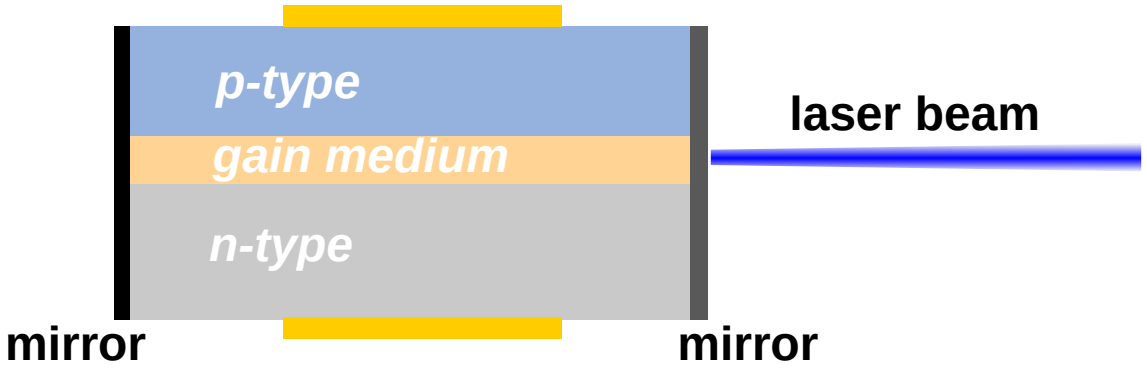
In a laser





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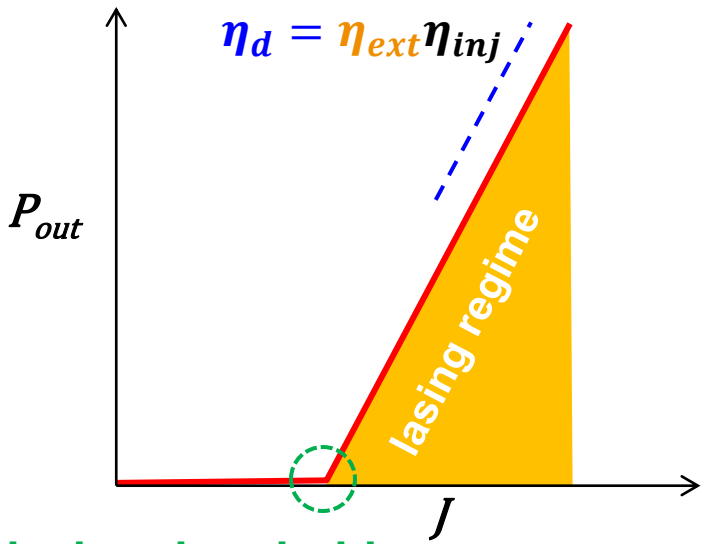
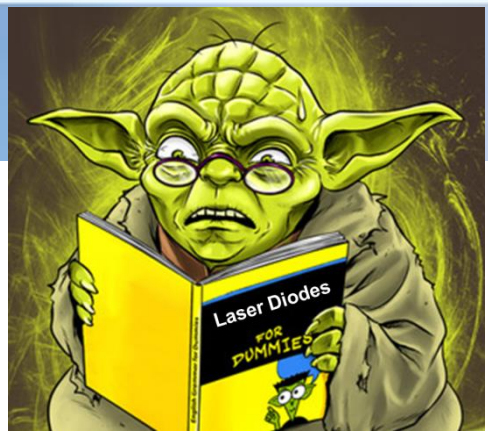


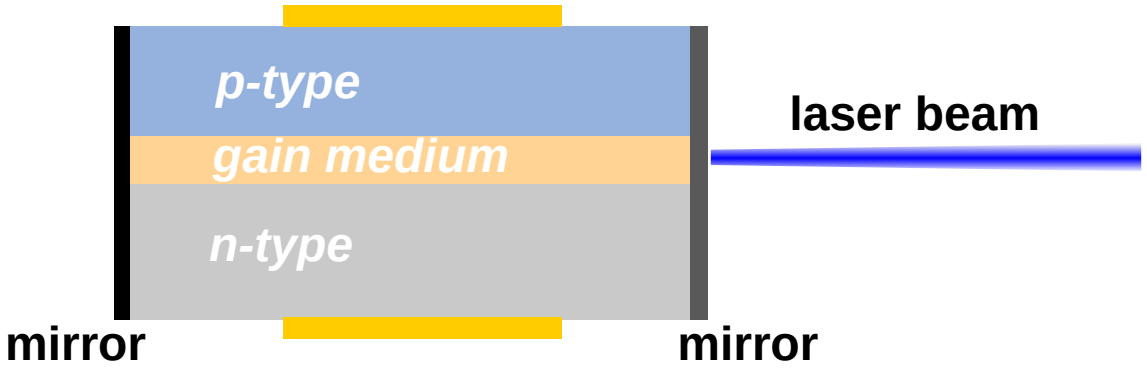
lasing threshold

$$G = \alpha$$

EXALOS

In a laser





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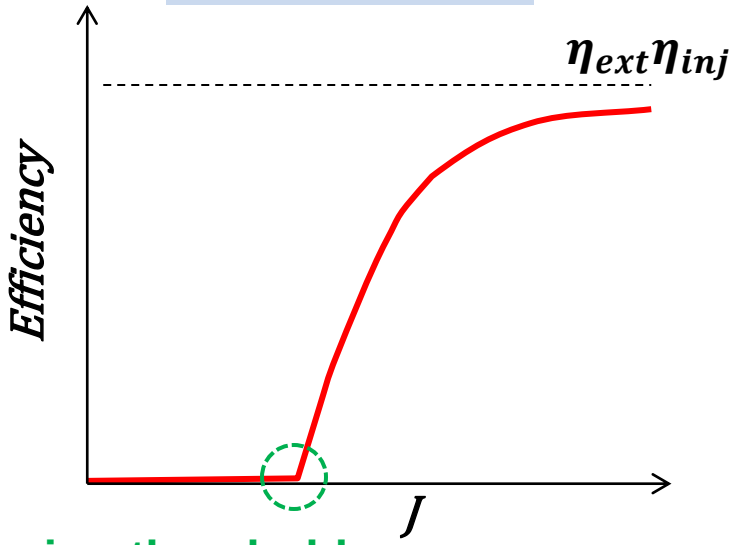
$$G \propto (n - n_0)$$

$$\alpha = \alpha_m + \alpha_i$$

droop free!



lasing threshold

$$G = \alpha$$

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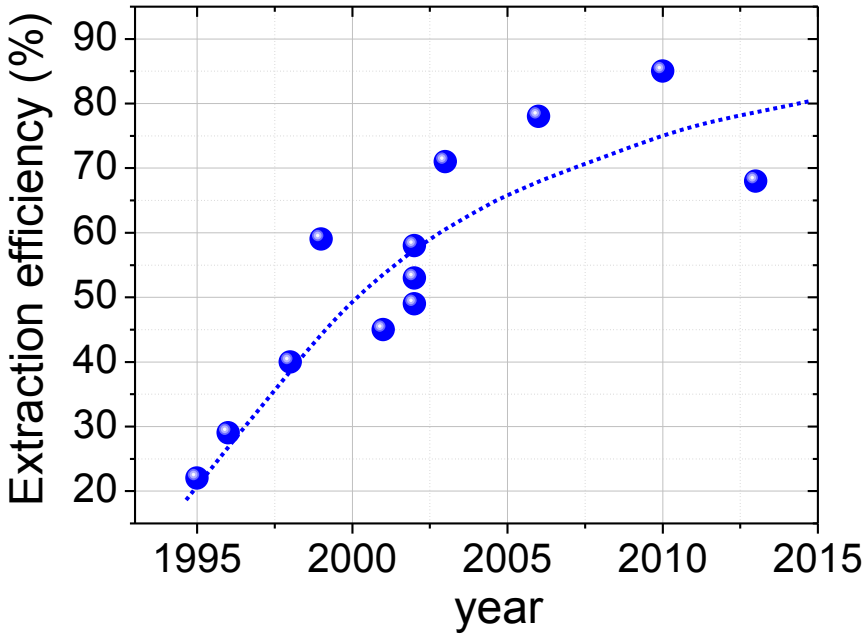
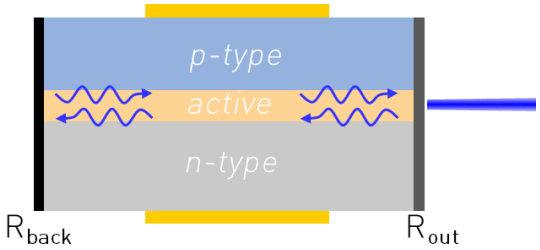
Extraction efficiency

LED trend



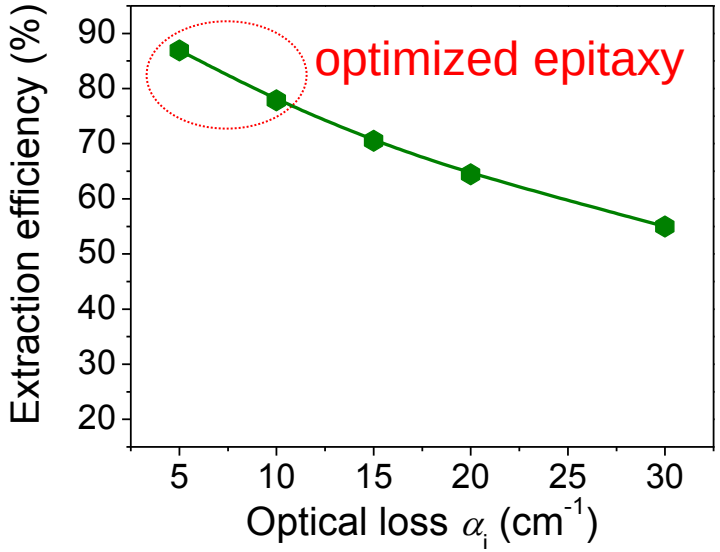
- ***NiAu semitransparent contact***
- ***Flip chip***
- ***Thin film flip chip***
- ***Patterned sapphire substrate***

Laser



$$\eta_{ext} = \frac{\alpha_m}{\alpha_m + \alpha_i}$$

resonator length
mirror reflectivity
optical loss



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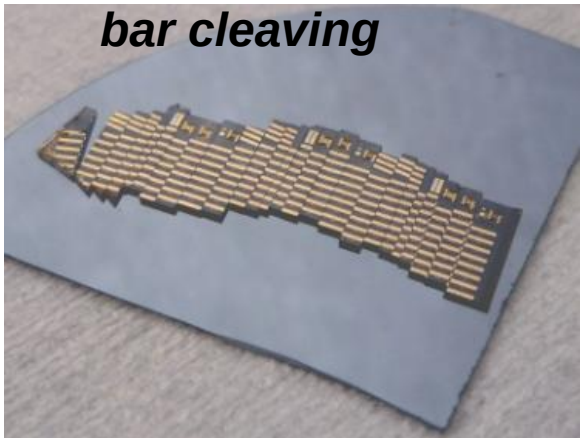
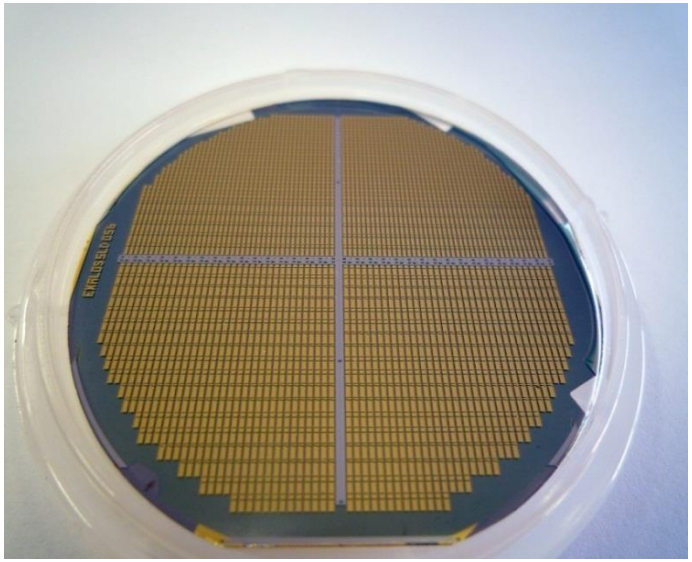
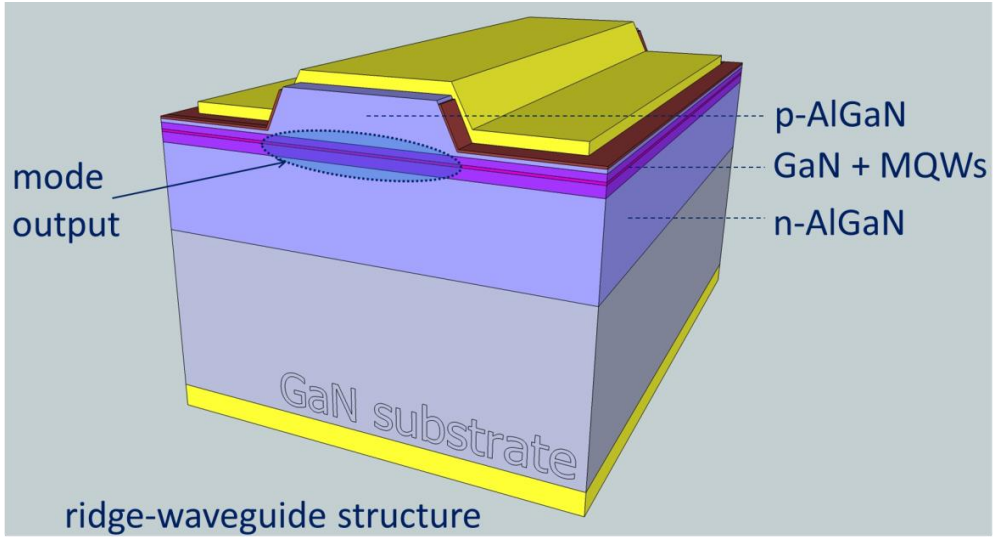
GaN-based laser diodes

- ***Epitaxy on GaN substrate***
- ***Standard fabrication***
  - ***Optical lithography***
  - ***Wet and dry etchings***
  - ***Thin film deposition***

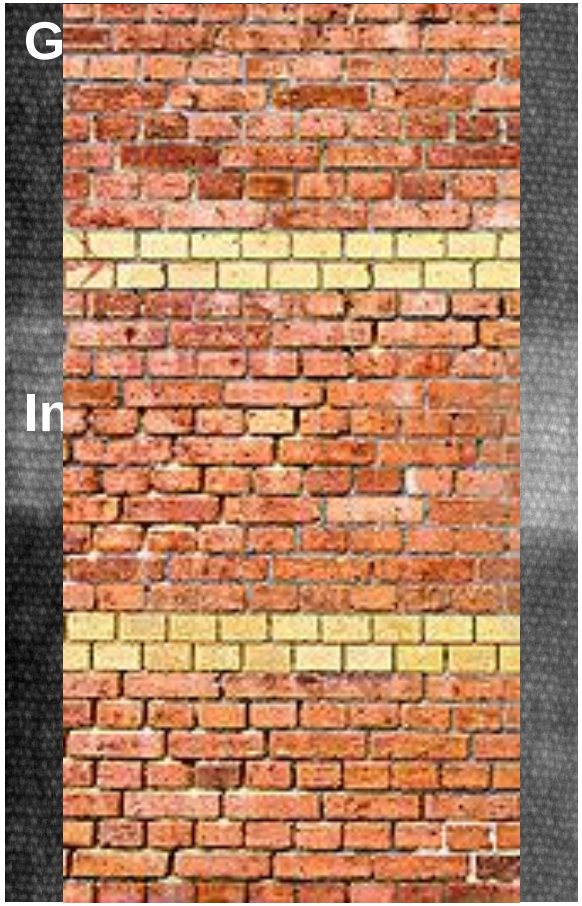


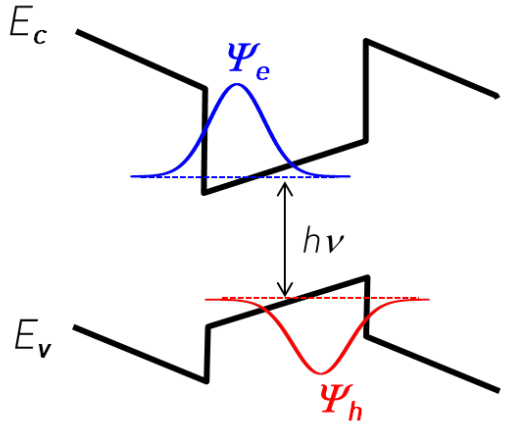




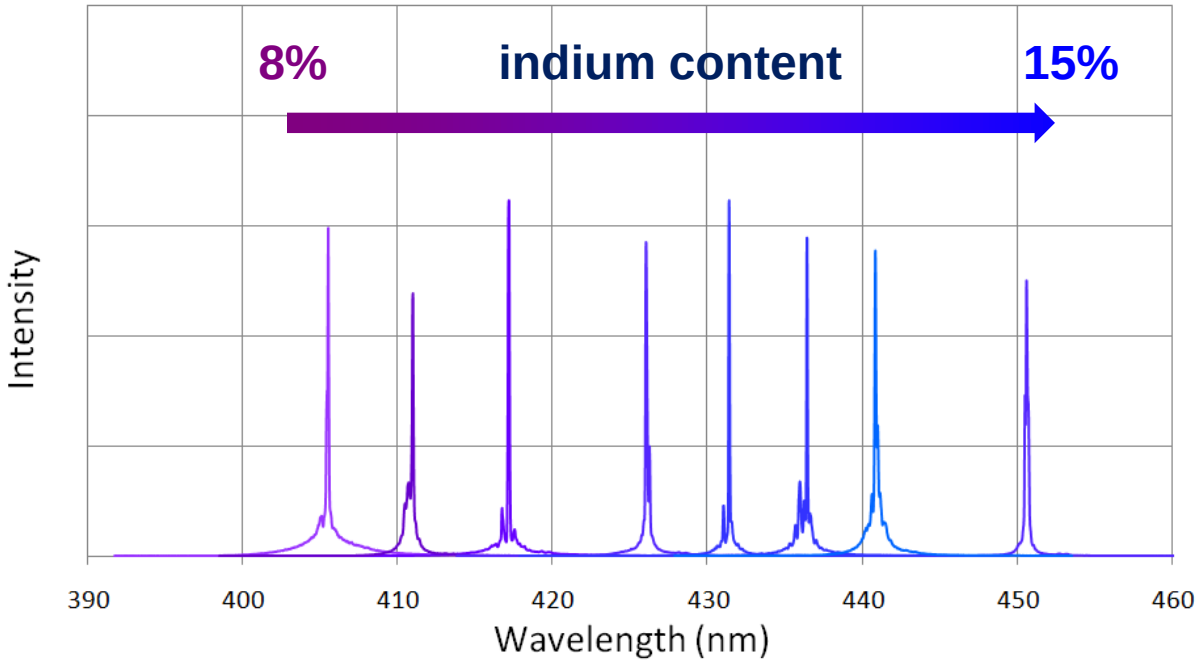
Tailoring the emission wavelength

QW structure

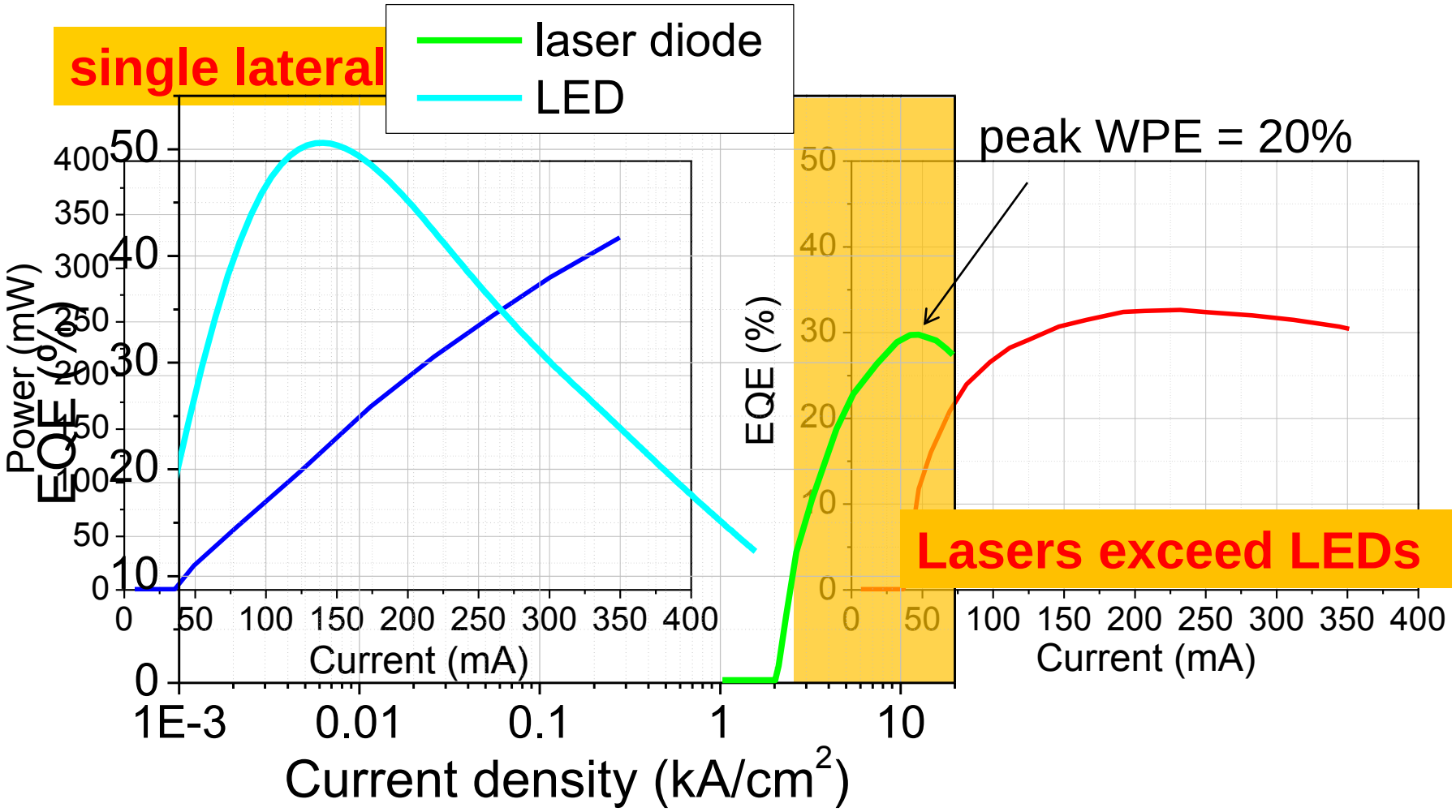




engineering of band diagrams



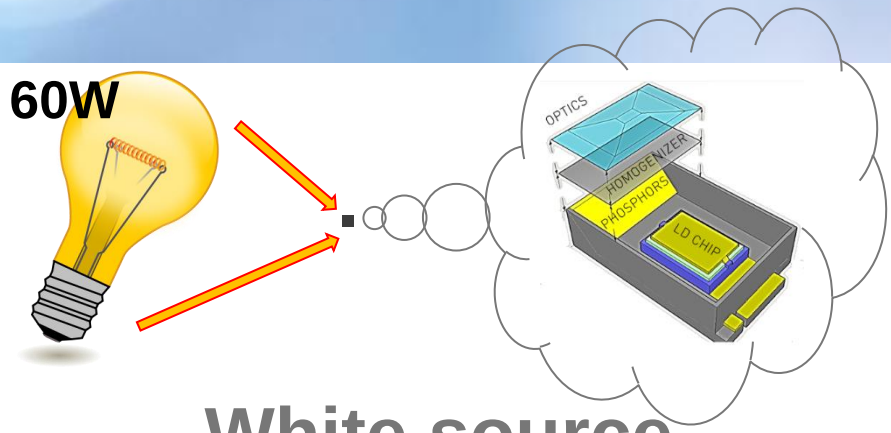
Violet laser performance



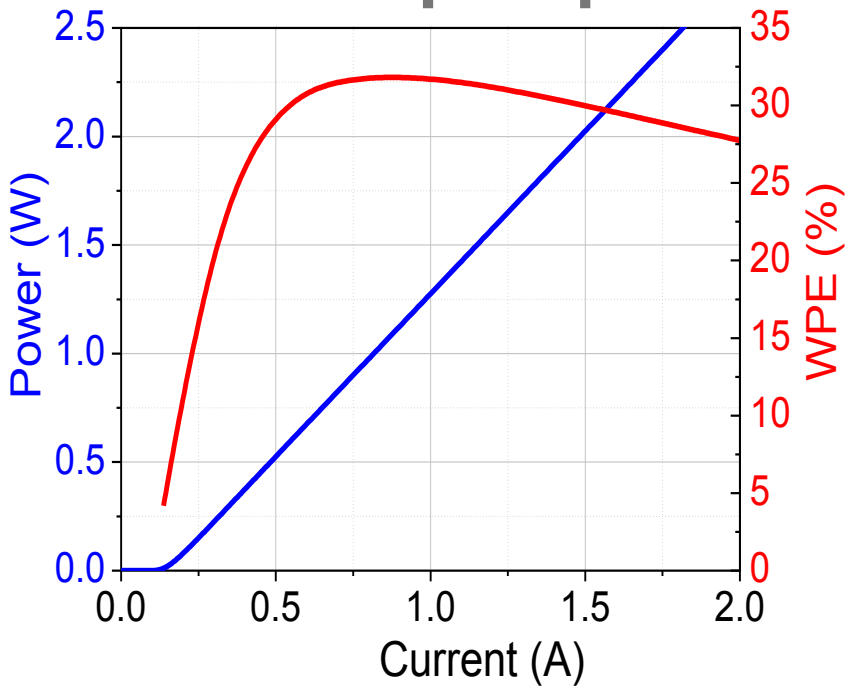
Great expectations

Going multimode……

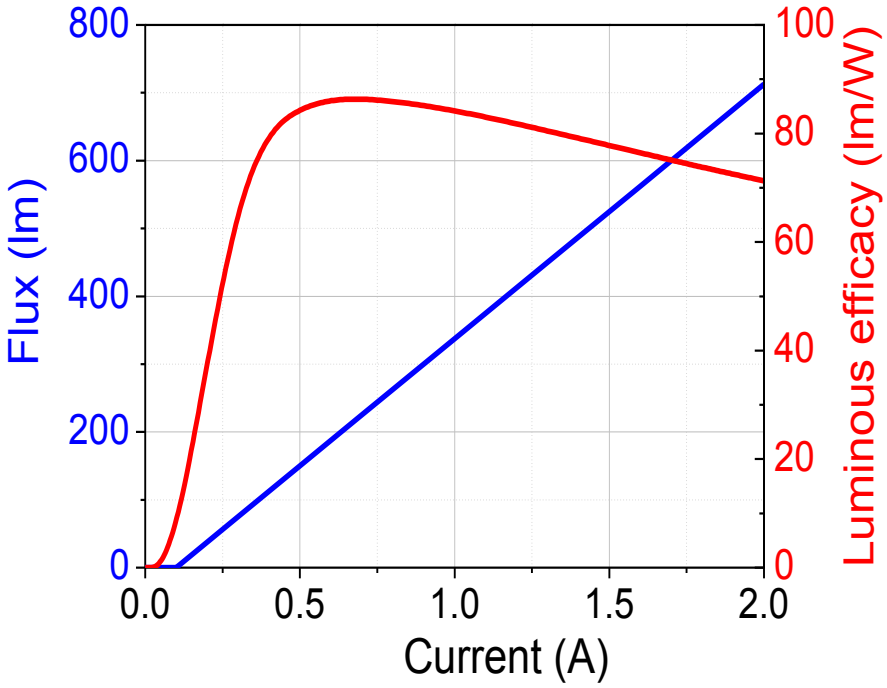
estimate of power and flux



Laser pump



White source



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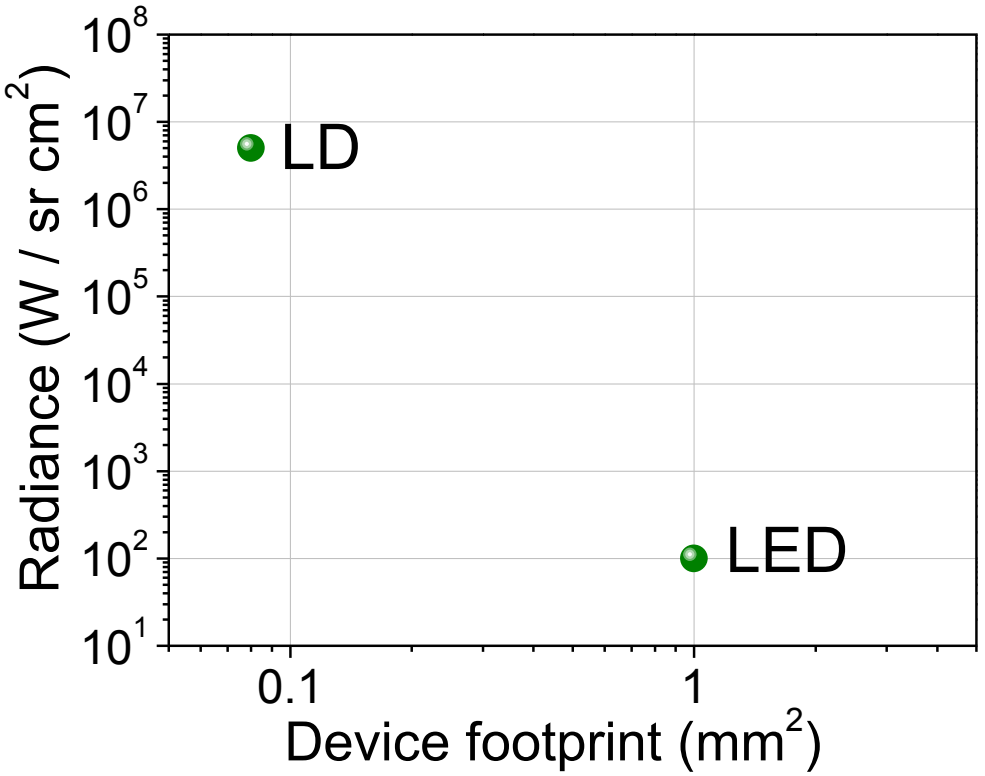
When dimension counts

More LDs per unit surface

Radiance several orders of magnitude higher for LDs

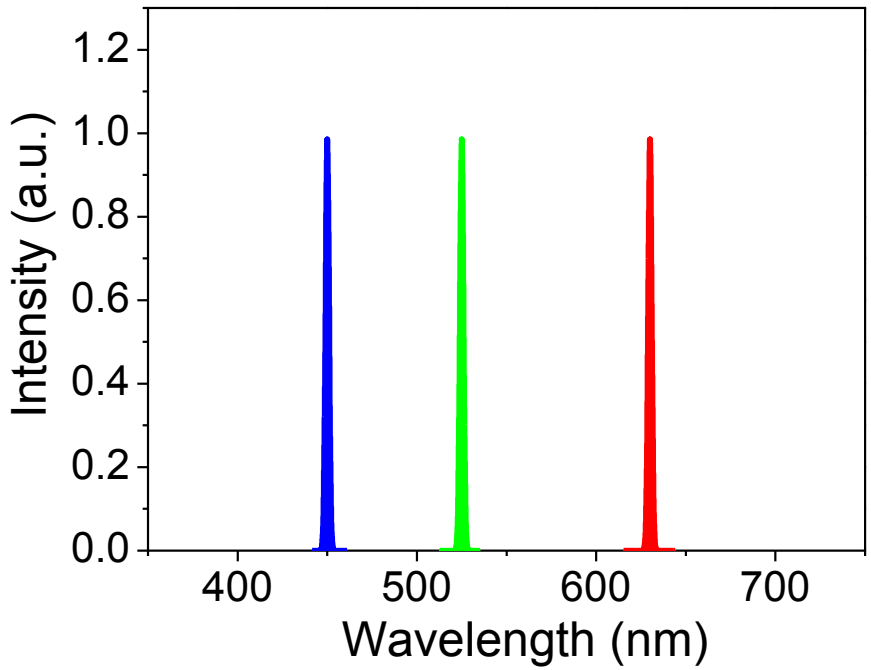


LD very attractive for specialty applications needing compact and high radiance light sources

EXALOS

White light generation with LDs

Pure Play RGB laser

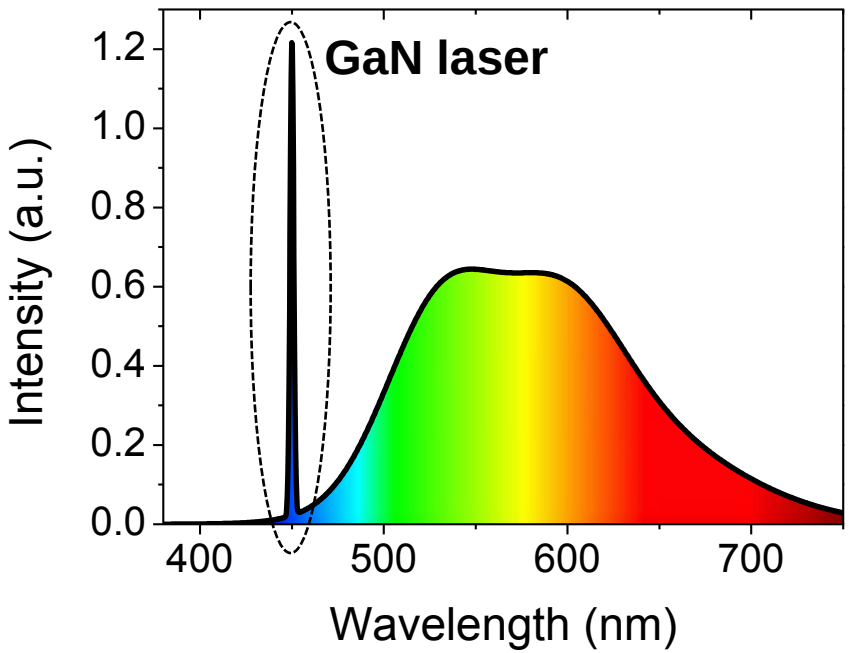


Not suited for compact emitters!

EXALOS

White light generation with LDs

blue laser & yellow phosphor

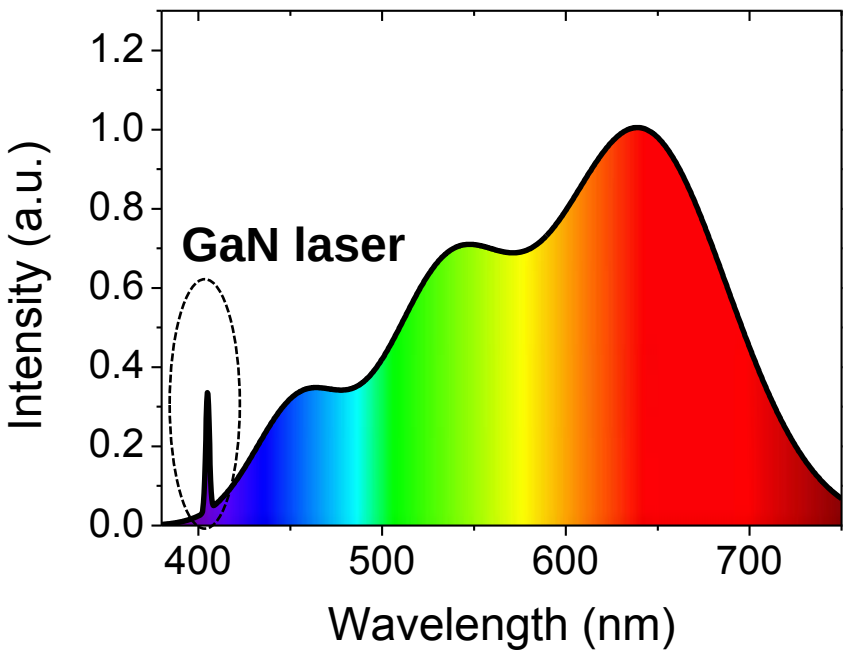


Lower conversion loss ☺

LD more challenging ☹

Light diffusers needed ☹

violet laser & RGB phosphor



Highest laser efficiency ☺

Best CRI ☺

Downconversion loss ☹

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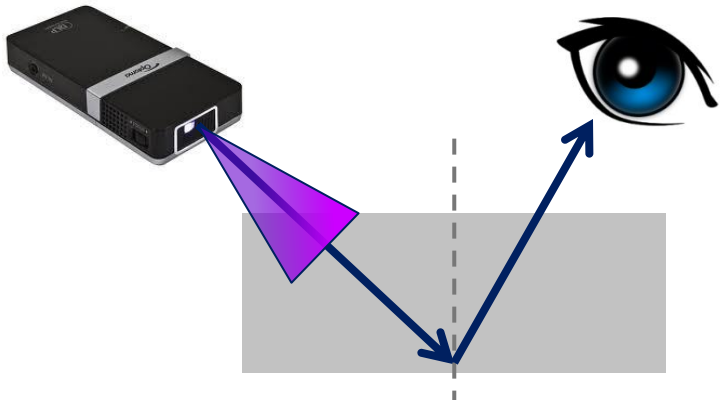
Laser diode speckle noise



- **light dephasers**
- **violet + RGB**

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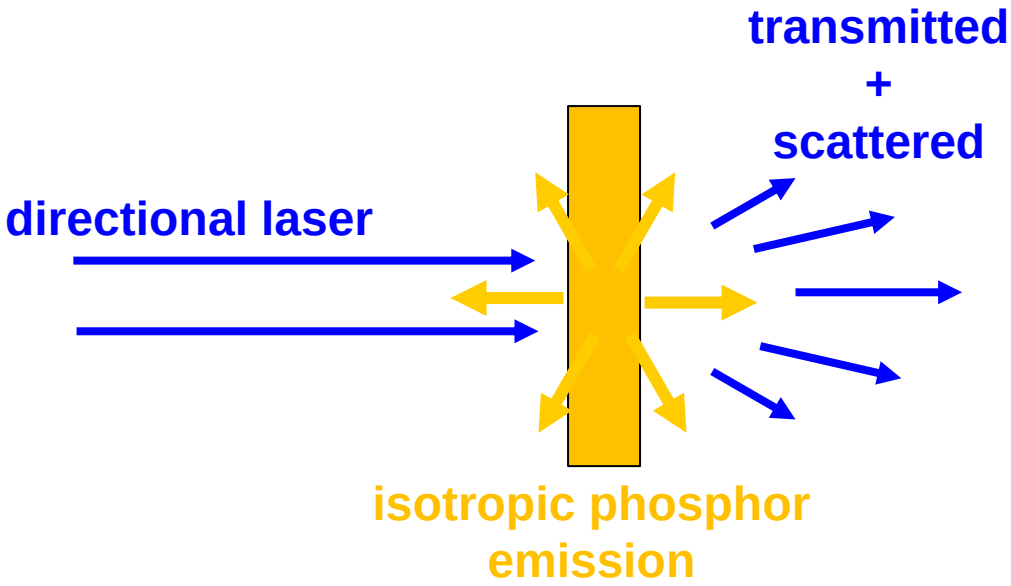
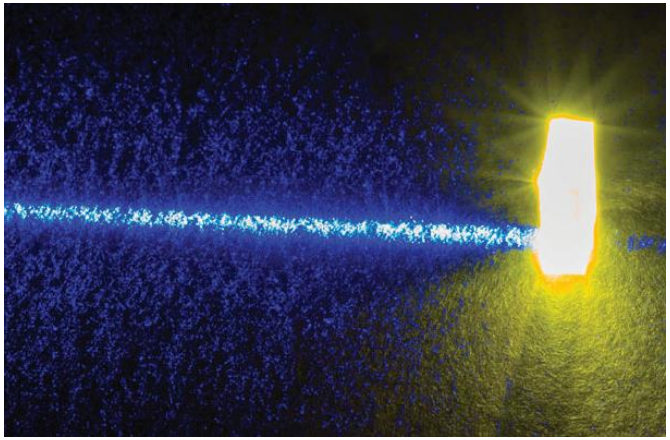
Color anisotropy (pure blue LD)



S. P. DenBaars, UCSB, Santa Barbara



Sandia & Corning

- light mixers required
- violet + RGB

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Conclusion

cool

compact

efficient

low droop

high radiance

KTI/CTI
DIE FÖRDERAGENTUR FÜR INNOVATION
L'AGENCE POUR LA PROMOTION DE L'INNOVATION
L'AGENZIA PER LA PROMOZIONE DELL'INNOVAZIONE
THE INNOVATION PROMOTION AGENCY

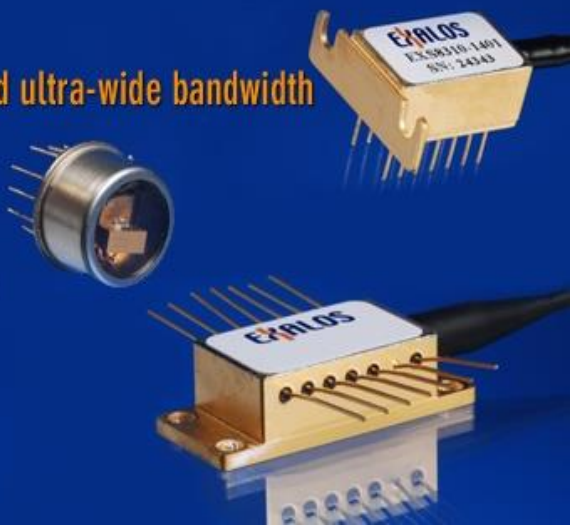
EPFL

EXALOS broad-band modules

SLED Modules

Solutions for ultra-high output power and ultra-wide bandwidth

- High-power ultra-broadband SLEDs
- Wavelengths from 650 to 1700 nm
- Cooled packages for fiber-based or free-space applications
- Uncooled low-cost packages



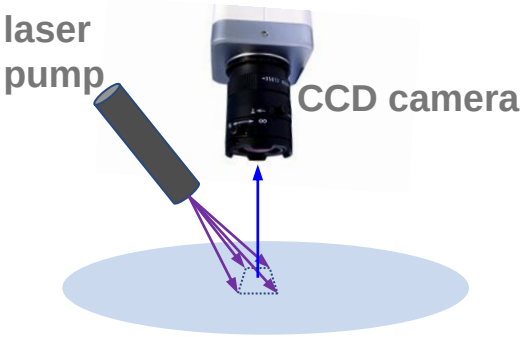
Wavelength Swept Source

High-performance external-cavity wavelength sweeping laser

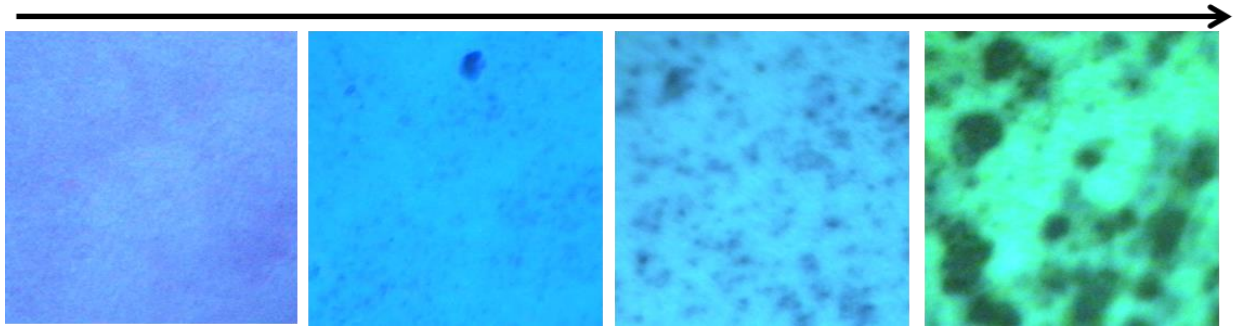
- High sweep frequency (up to 150 kHz)
- Multiple Spectra (840,1060,1220,1310,1550nm)
- Wide sweep range (up to 150 nm)
- High output power (up to 40 mW)
- Long ranging depth
- High phase stability

Marvel in terms of miniaturization and packaging

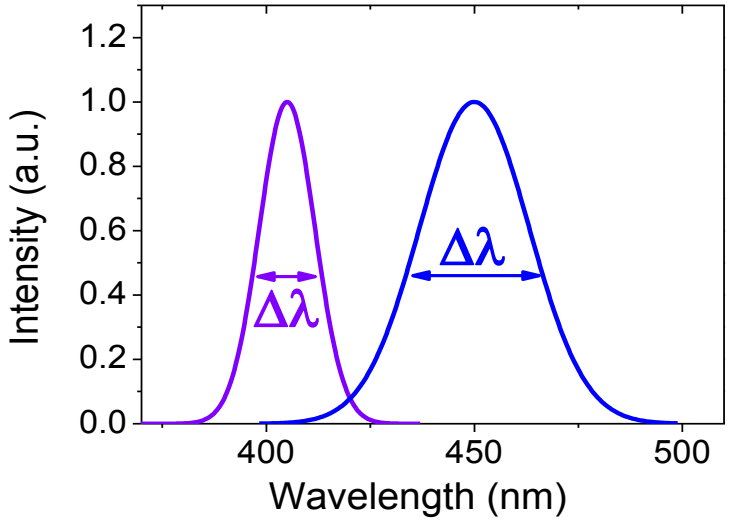
Increasing the emission wavelength



Increasing the indium content or QW thickness



→ High indium content: lower composition uniformity/higher disorder



broadening

↓

dispersed gain

↓

lower efficiency

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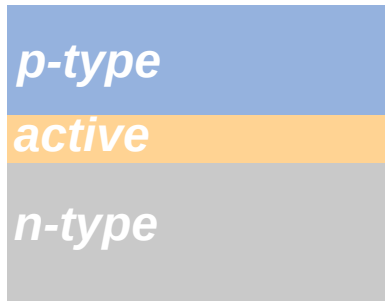
Increasing the emission wavelength

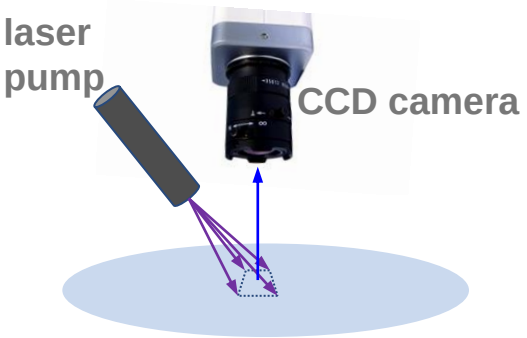
Impact of p-type growth on active region

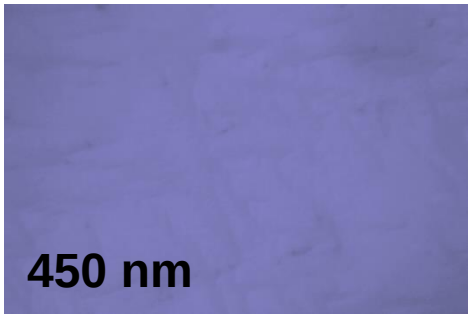
p-type: Tg ~ 1000C

active region: Tg ~ 700C

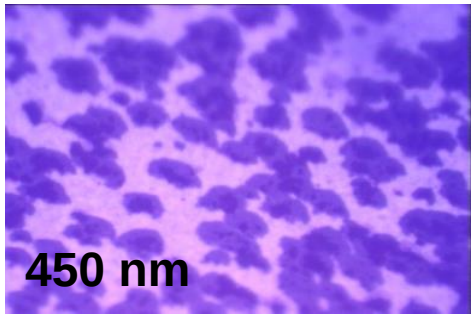


requires low temperture p-type layers!





p-type growth



In-rich region may get «burned» during *p*-GaN growth

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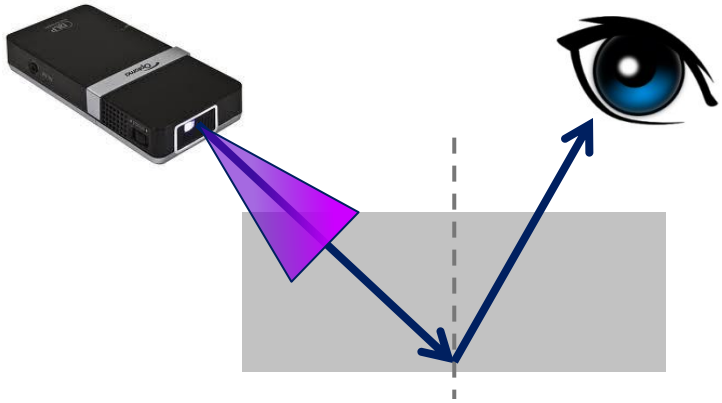
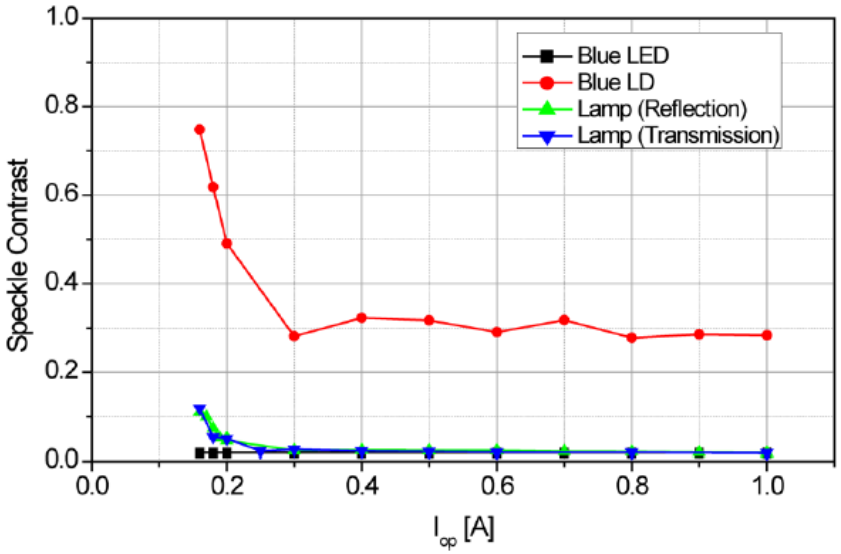
Laser diode speckle noise





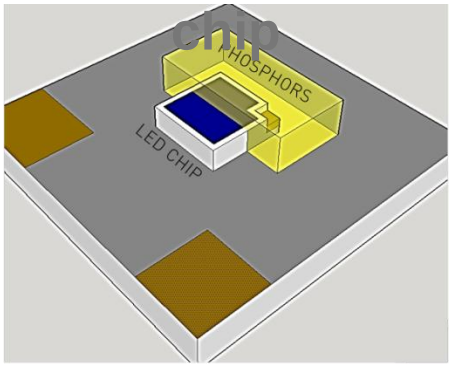
Toshiba Lighting & Technology Corporation,
J. Light & Vis. Env. Vol.37, No.2 & 3, 2013

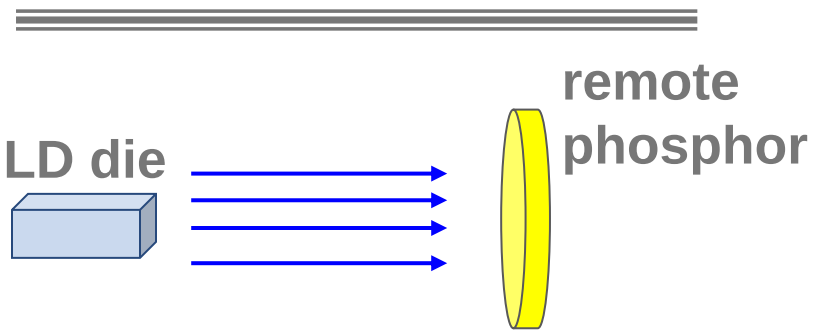
- **light dephasers**
- **violet + RGB**

EXALOS

Design flexibility & remote phosphors

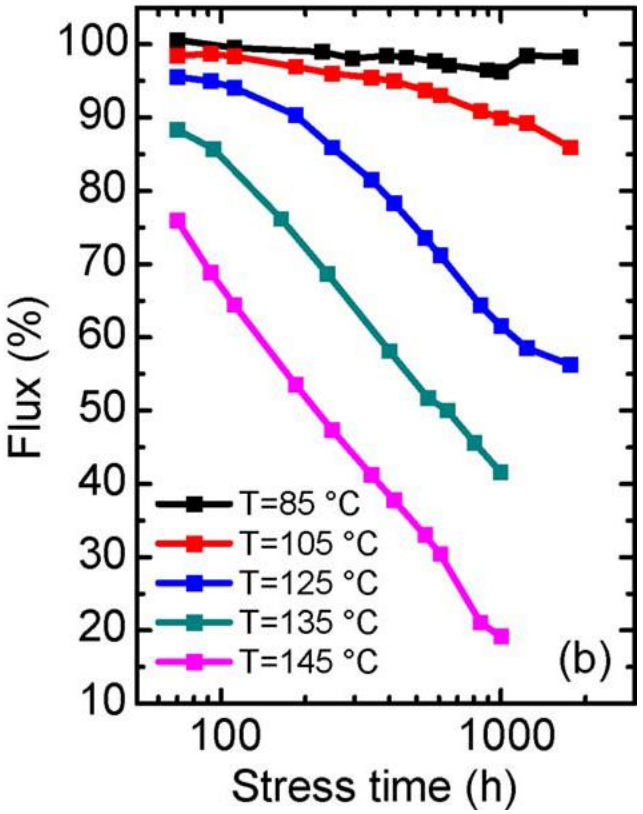
phosphors in contact with LED





LD specially suited for remote phosphor configurations!

Temperature degradation



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