Dlaczego dioda świeci i jak zamienić ładunek elektryczny na foton?

Jacek.Szczytko@fuw.edu.pl Wydział Fizyki UW

Przerwa energetyczna

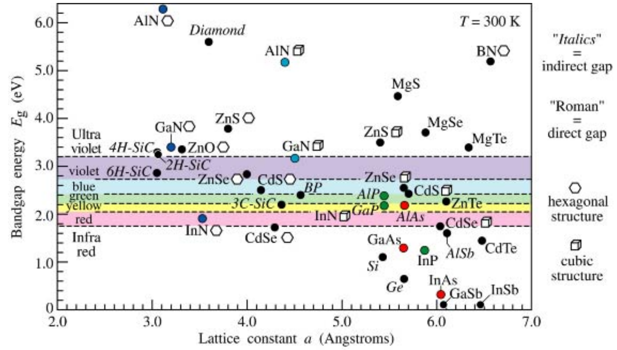
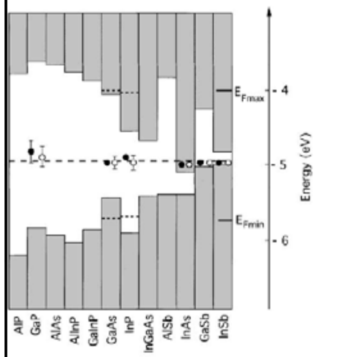


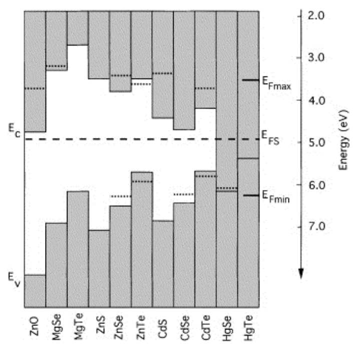
Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

Bandgap engineering

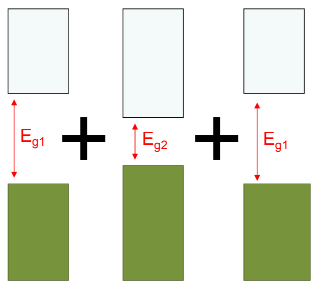
Valence band offset



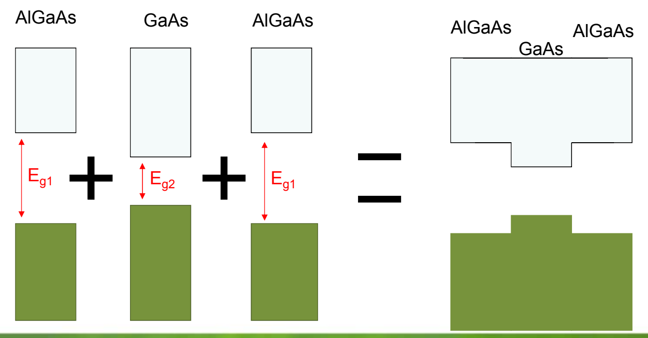


Band offsets and the Fermi level stabilization energy III–V compounds. The energy is measured relative to ...um level. The filled circles represent stabilized Fermi ...in heavily damaged materials, exposed to high energy

Studnia Kwantowa



Studnia Kwantowa



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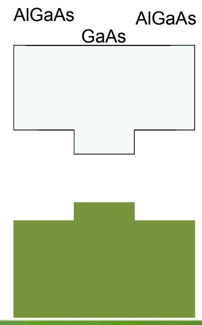

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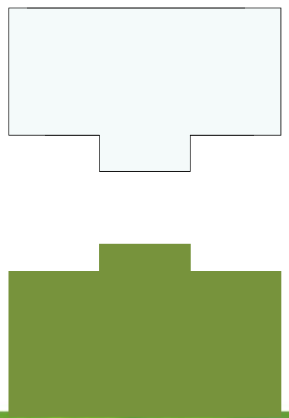

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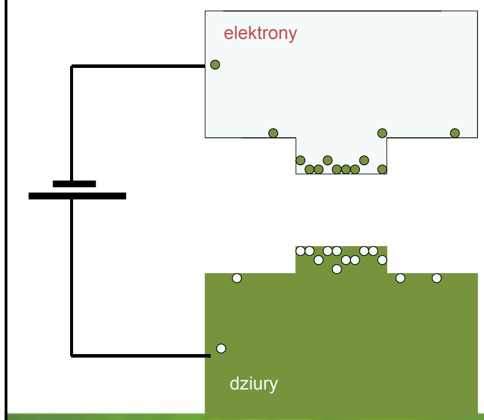
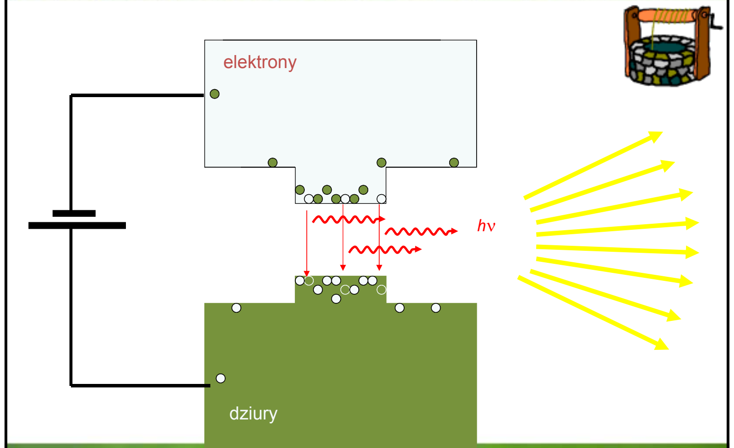
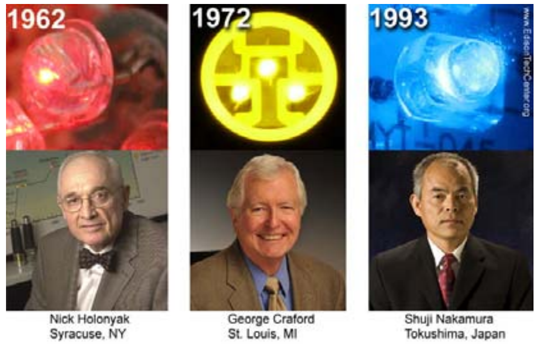


Studnia Kwantowa

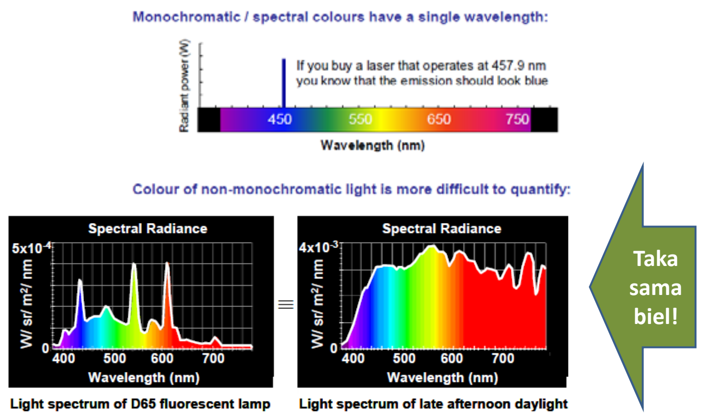


Trzy kolory



http://www.edisontechcenter.org/LED.html

Trzy kolory



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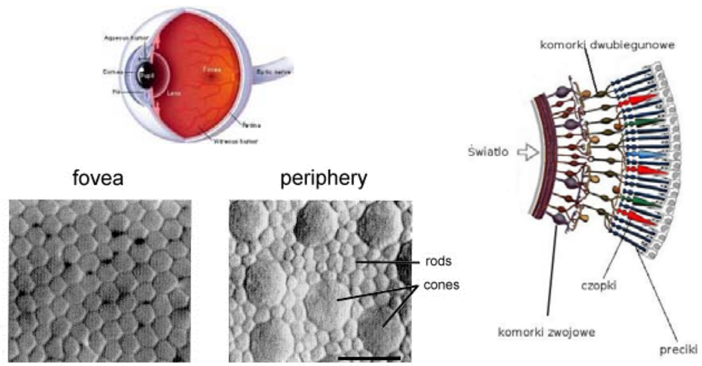
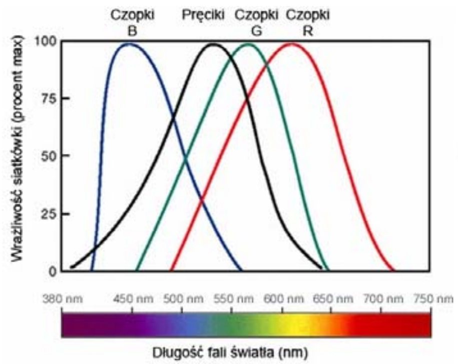
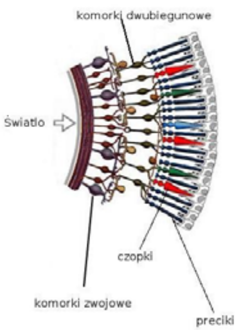
Trzy kolory



http://195.117.188.199/rozdzial_1_12.htm

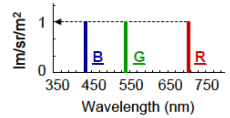
Trzy kolory





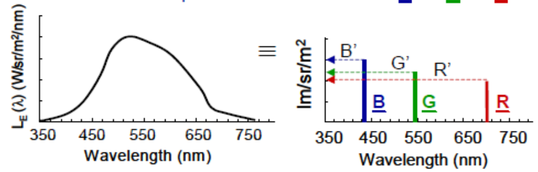
Trzy kolory

- Early experiments used B (435.8 nm), G (546.1 nm) and R (700 nm) as "unit amounts" of blue, green and red primary colours in luminance (lm/sr/m²)



- Note that B, G and R are of different size in radiometric power units (W/sr/m²) because the sensitivity of the eye will be different for different colours

Colour of emission spectrum ≡ Colour of: B'B + G'G + R'R



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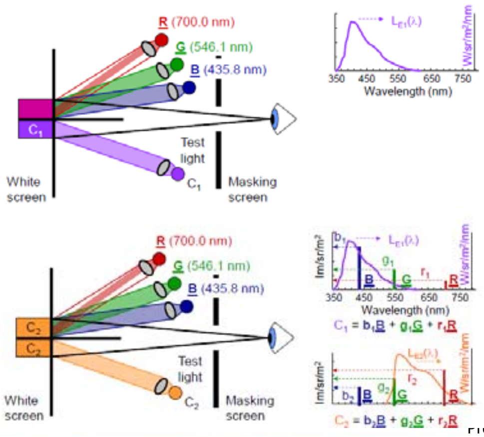

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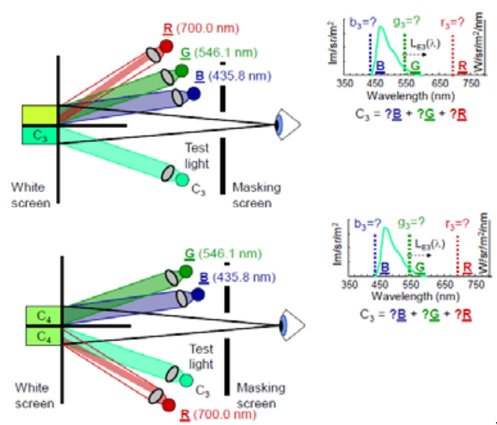
Trzy kolory



Niektórych kolorów NIE DA się otrzymać!

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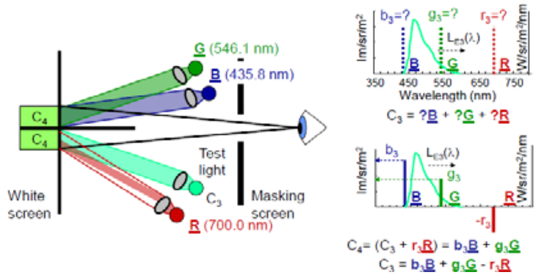
Trzy kolory



Niektórych kolorów NIE DA się otrzymać!

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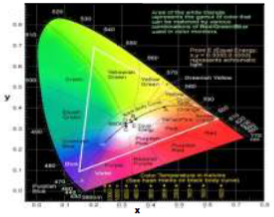
Trzy kolory

International Commission on Illumination CIE (1931) chromaticity diagram

Simplify presentation of colourimetric data by using CIE (1931) chromaticity diagram with coordinates x, y and z that are normalisations of the tristimulus values:



Colour of $L_E(\lambda)$: $C = Z'\underline{Z} + Y'\underline{Y} + X'\underline{X}$

$x = X' / (X'+Y'+Z')$

$y = Y' / (X'+Y'+Z')$

$z = Z' / (X'+Y'+Z') = 1 - x - y$

There are only two independent values (z offers no additional information) so a 2D plot of x and y can be used to represent the tristimulus information

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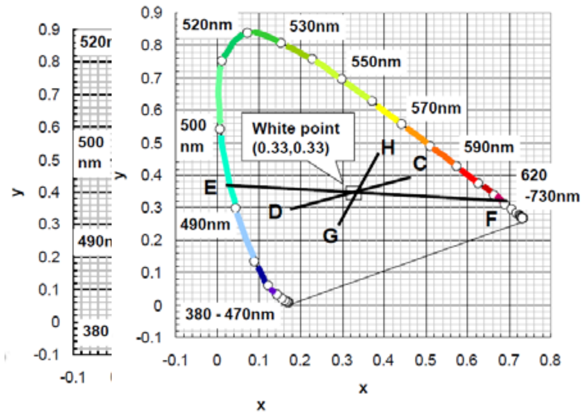
Trzy kolory



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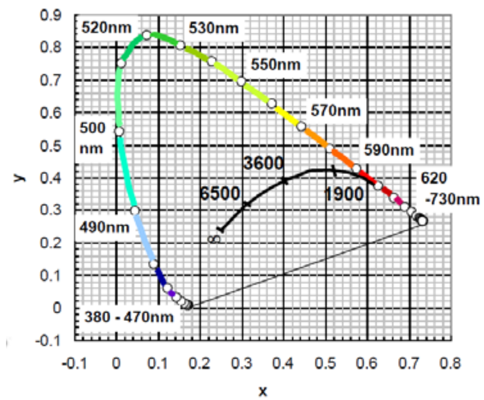
Trzy kolory



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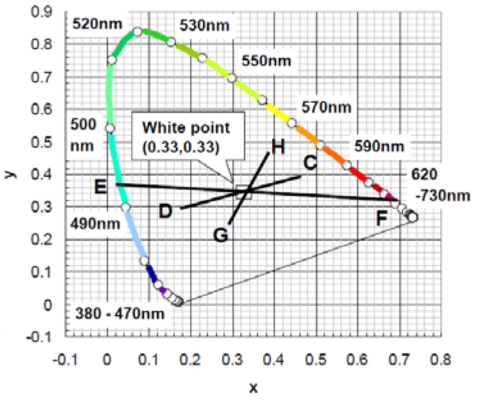

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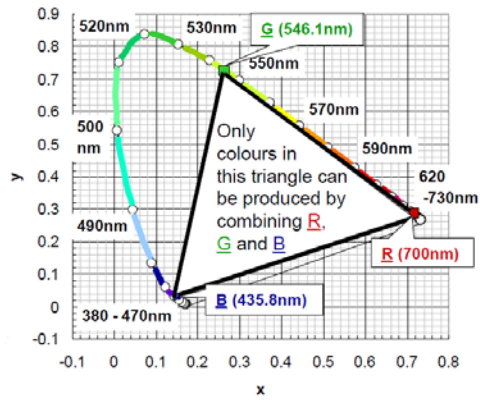
Trzy kolory



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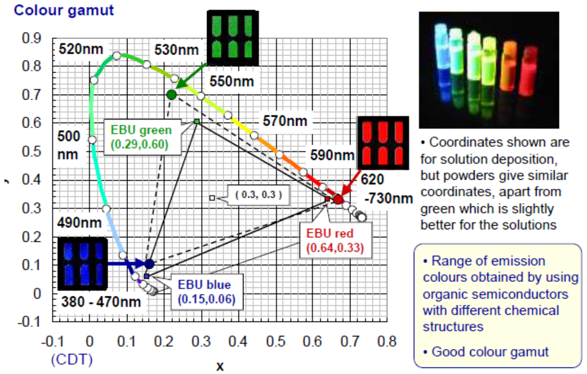
Trzy kolory

Why use organic LEDs for displays?



- Coordinates shown are for solution deposition, but powders give similar coordinates, apart from green which is slightly better for the solutions

- Range of emission colours obtained by using organic semiconductors with different chemical structures
- Good colour gamut

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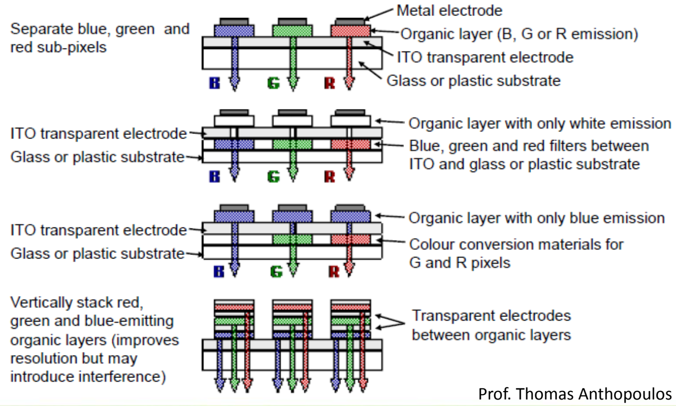
Trzy kolory

Different approaches for colour generation



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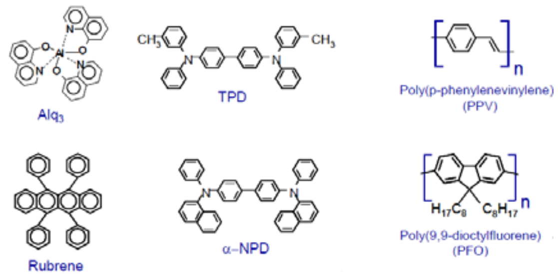
Trzy kolory



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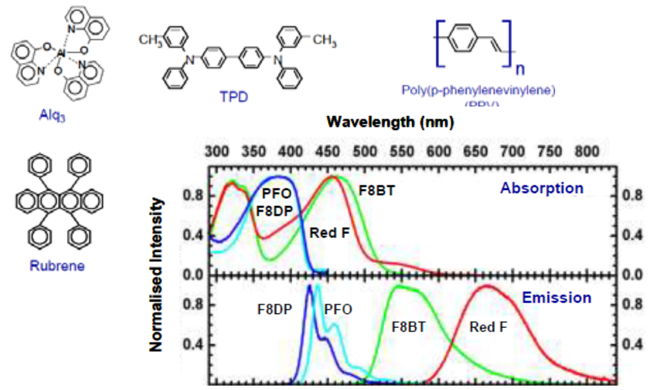

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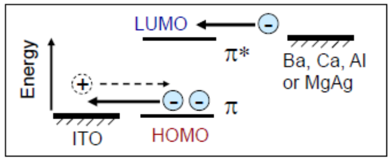
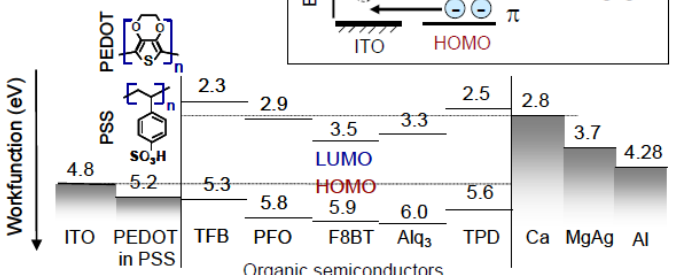
- Need to match workfunctions of electrodes to HOMO and LUMO energies of organic semiconductor





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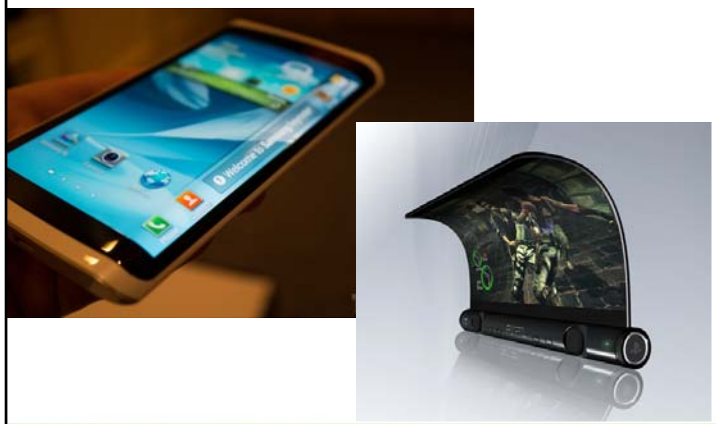

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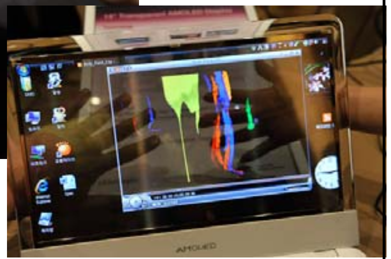
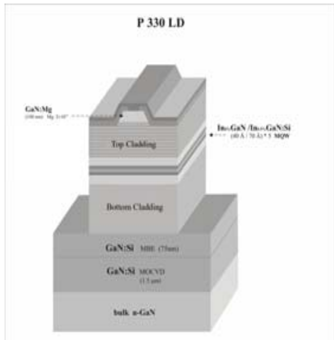
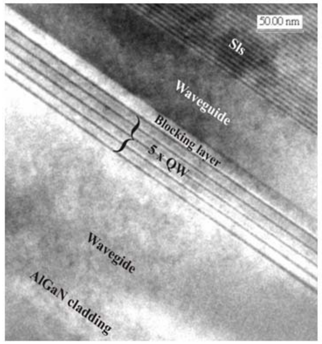


CES 2013

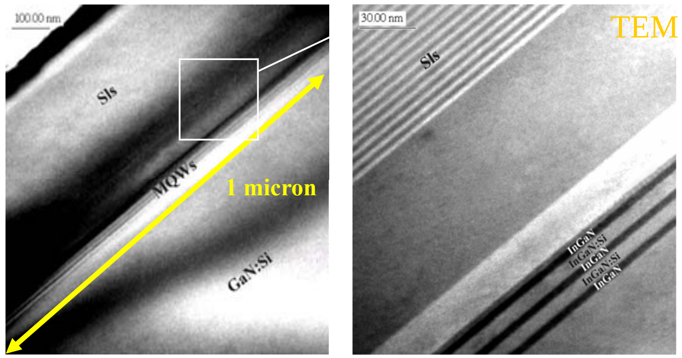
S a

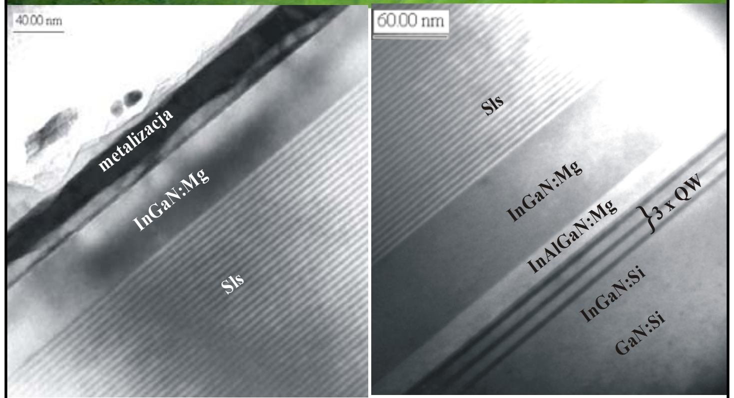
Dioda laserowa wykonana metodą MBE



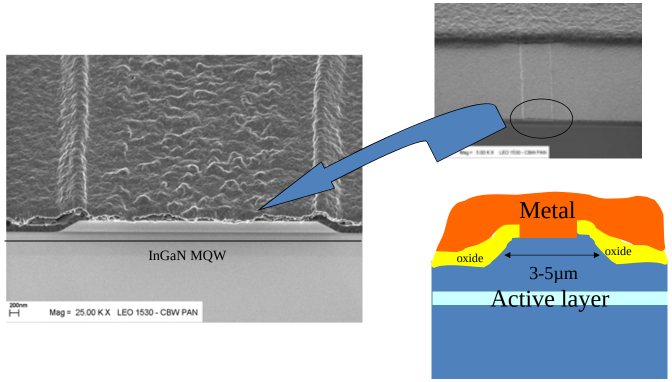


TEM



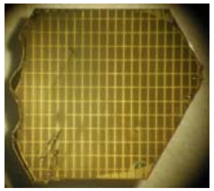


Processing laserów na azotku galu

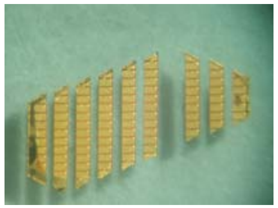


Processing laserów na azotku galu

Struktura laserowa po processingu



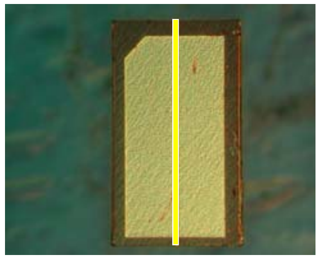
Łupanie na linijki laserowe



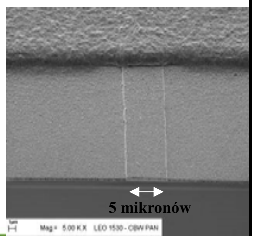
Pojedynczy przyrząd

Lasery półprzewodnikowe są bardzo małe

Szerokość kostki = 0.3 mm

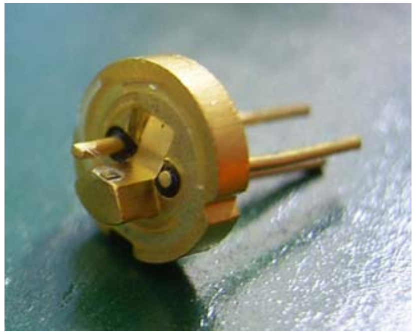


Długość lasera = 0.5 - 1 mm



Szerokość lasera = 0.001 – 0.02 mm !! (1 μm - 20μm)

Montaż laserów – wersja impulsowa



www.topgan.fr.pl

Czesław Skierbiszewski *UNIPRESS*

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Żarówka 15-20 lumenów/watt (standardowa 100W – 17 lumenów/watt)
Halogen 20 lumenów/watt
Świetlówka 60-110 lumenów/watt
Świetlówki kompaktowe 45-60 lumenów/watt

Biała dioda: typowo 20-50 lumenów/watt, rekord z 2005r. 130 lumenów/watt!

http://www.otherpower.com/otherpower_lighting.html
http://www.theinquirer.net/?article=27731

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Trochę historii

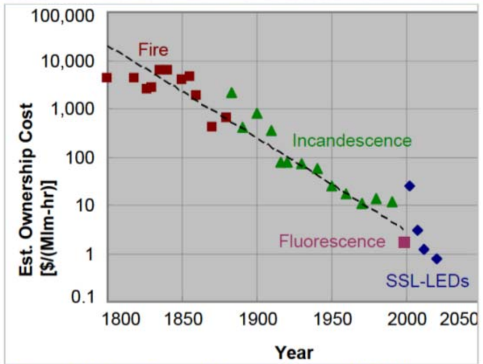

Figure 6. Estimated ownership costs of light, in 1992 dollars. Data for Fire and Incandescence for operating cost are from the work of W. Nordhaus,[15] to which estimates of capital cost have been added. Data for Fluorescence are from our estimates. Data for SSL-LEDs are the targets of this Roadmap.

http://lighting.sandia.gov/lightingdocs/OIDA_SSL_Roadmap_Tutorial.pdf

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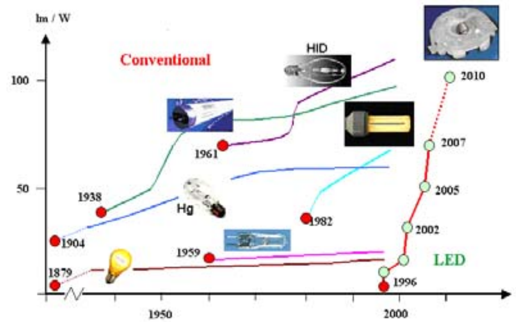
Trochę historii



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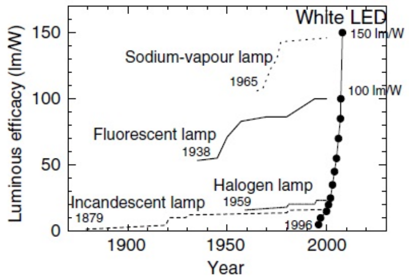
Trochę historii

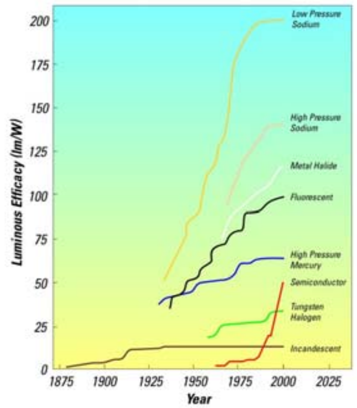


The history of luminous efficacy in different types of lighting shows the rapid improvements in white LEDs. The years in which the white light sources were developed are also shown. Credit: Yukio Narukawa, et al.

Read more at: http://phys.org/news202453100.html#jCp

http://phys.org/news202453100.html

Trochę historii



http://phys.org/news202453100.html

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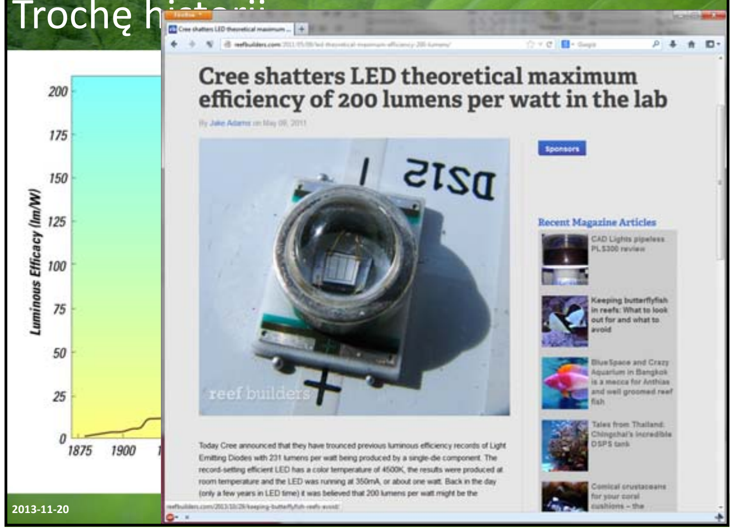

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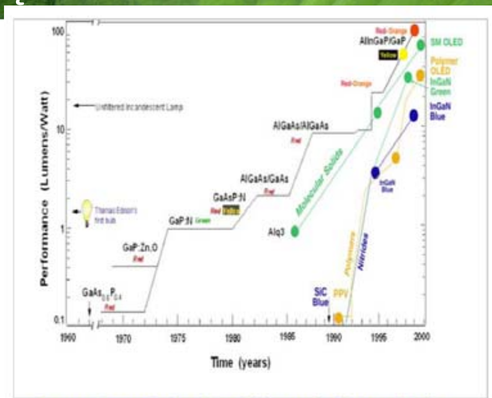


Figure 3. The evolution of total efficacy of solid-state lighting technologies. Also shown are typical efficacies for traditional incandescent and fluorescent technologies. [Courtesy of George Craford, LumiLeds Lighting.]

http://lighting.sandia.gov/lightingdocs/OIDA_SSL_Roadmap_Tutorial.pdf

„Biała dioda”

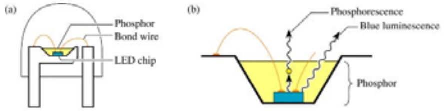
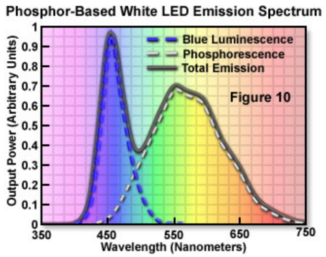


Fig. 11.5. (a) Structure of white LED consisting of a GaInN blue LED chip and a phosphor-containing epoxy encapsulating the semiconductor die. (b) Wavelength-converting phosphorescence and blue luminescence (after Nakamura and Fasol, 1997).



http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

Photon Recycling

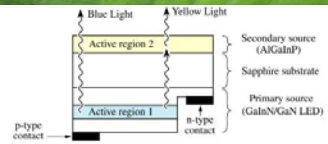


Fig. 11.8. Schematic structure of a photon-recycling semiconductor LED with one current-injected active region (Active region 1) and one optically excited active region (Active region 2) (after Guo *et al.*, 1999).

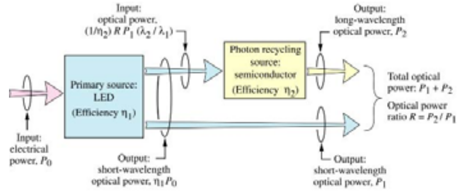


Fig. 11.9. Photon-recycling semiconductor LED power budget with electrical input power P_0 and optical output power P_1 and P_2.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

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Forever Flashlights.
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http://www.lc-led.com/
http://www.albeotech.com/
http://www.albeotech.com/
http://www.hollysolar.com/
http://www.whiteled.net/
Edison Screw Based Lamps
S11 DecorLED
S14L DecorLED
A19 DecorLED
G30 DecorLED
R20 Fixed-Intensity
PAR20 Spotlight LED Light Bulb
MR16 TrackLED Light Bulb
Hi-Power FlashLED Flashlights
51


OLED
Cathode Layer
Organic Active Layers
TFT array
Substrate
Art. Lebedev Studio
http://www.universaldisplay.com/foled.htm
Courtesy of Sony Corporation.
Courtesy of Samsung SDI.
2013-11-20
http://www.universaldisplay.com/active.htm
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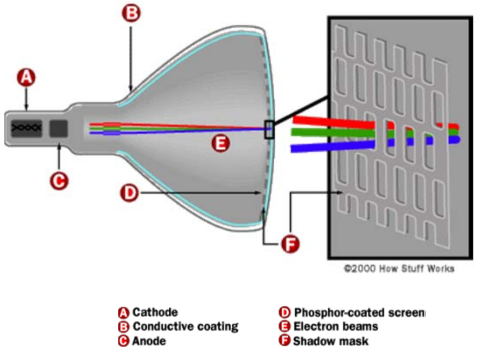
Projektory



http://electronics.howstuffworks.com/projection-tv1.htm

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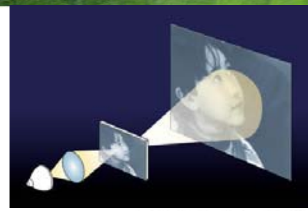
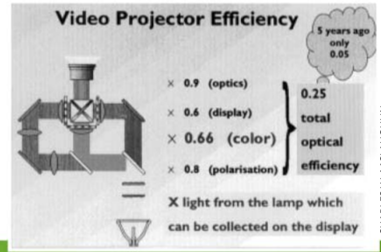
Projektory

- LCD





CHARLES W. MCLAUGHLIN

http://electronics.howstuffworks.com/projection-tv1.htm

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Projektory

- LCD
- Liquid Crystal on Silicon

http://electronics.howstuffworks.com/projection-tv1.htm

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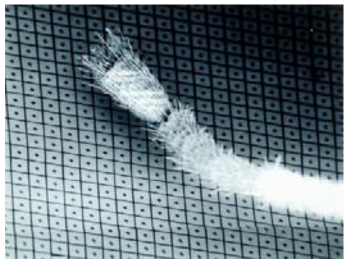
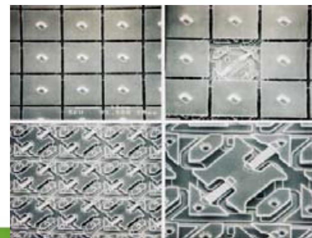
Projektory

- LCD
- Liquid Crystal on Silicon
- Microelectromechanical Systems (MEMS)
  - Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (1000:1, BENQ 10000:1)

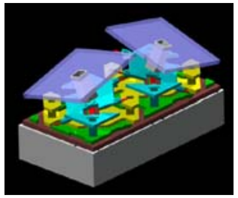


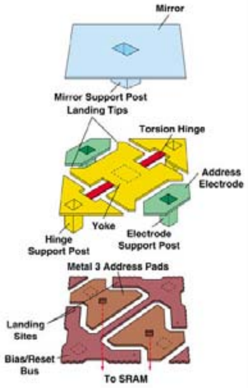


http://electronics.howstuffworks.com/projection-tv1.htm

Projektory

- LCD
- Liquid Crystal on Silicon
- Microelectromechanical Systems (MEMS)
  - Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (1000:1, BENQ 10000:1)

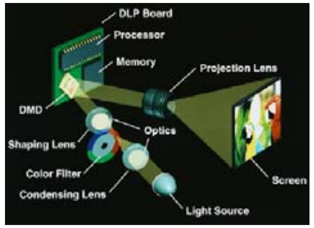


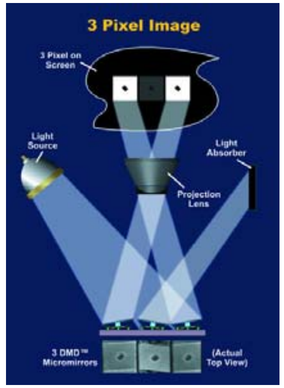


http://electronics.howstuffworks.com/projection-tv1.htm

Projektory

- LCD
- Liquid Crystal on Silicon
- Microelectromechanical Systems (MEMS)
  - Digital Micromirror Devices (DMD) = Digital L Processing (DLP), (1000:1, BENQ 10000:1)





http://electronics.howstuffworks.com/projection-tv1.htm

Lasery

http://www.laser...ics.com/

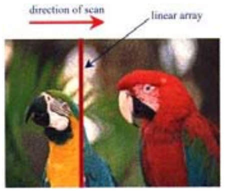
http://www.spacelaser.com/laser/

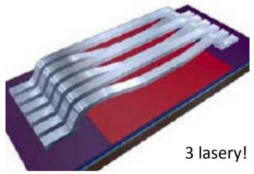
Figure 16: Symbol Laser Projection Display Demo

http://www.symbol.com/

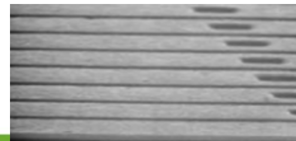
Projektory

- LCD (1000:1)
- Liquid Crystal on Silicon
- Microelectromechanical Systems (MEMS)
  - Digital Micromirror Devices (DMD) = Digital Light Processing (DLP), (3000:1, BenQ 10000:1)
- Grating Light Valves (GLV) (Sony 4000:1)



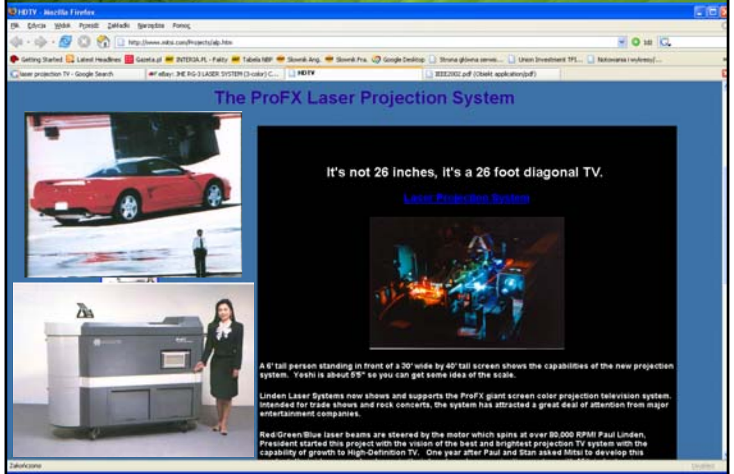


3 lasery!

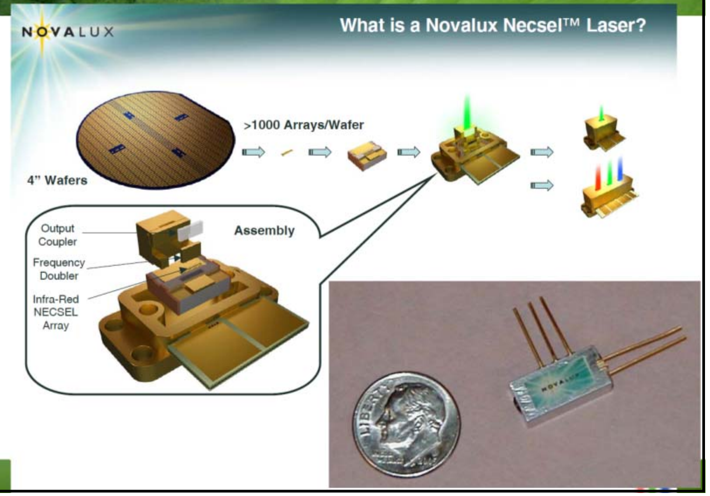


http://electronics.howstuffworks.com/projection-tv1.htm

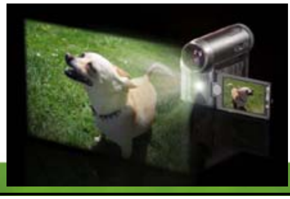
HDTV



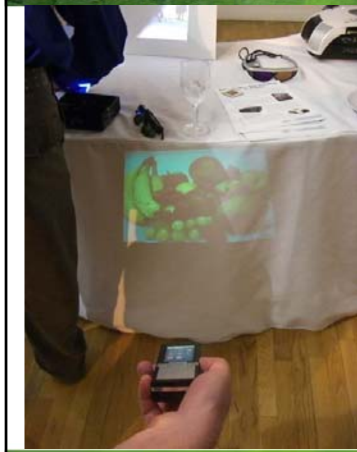
Laser TV



Laser TV



Laser TV



Hands-on with Texas Instruments' cellphone projector

Posted Sep 20th 2007 12:15PM by Evan Blass

Filed under: Cellphones, Displays, Features

Now that we have email, internet, TV, GPS, cameras, and satellite radio on our cellphones, our next wish is for bigger, higher resolution screens -- which seems paradoxical, because larger displays almost always mean bulkier devices. Well Texas Instruments thinks it'll soon be able to nullify this trade-off with an in-handset projector that we've heard about several times before, but last night's Pepcom event in New York was the first time we've been able to peep the technology up close. Not that the TI reps made it easy to do so: the prototype unit was in a locked metal case underneath the table, and we had to swear up and down that we saw Walt Mossberg getting a demo before they'd cough it up. As you can see, the reason they want to keep this under wraps for the time being is that the quality and brightness are certainly not ready for prime time yet; while the unit we saw used lasers as the light source, we're told that an LED-based model still in the lab offers significant improvements. Keep reading for more shots of this rare prototype -- along with a video courtesy of Popular Science -- and give yourself a few moments to bask in the future before returning to the stark reality of your own phone and its dim little QQVGA action...

http://www.engadget.com/tag/TexasInstruments/

Lasery w akcji

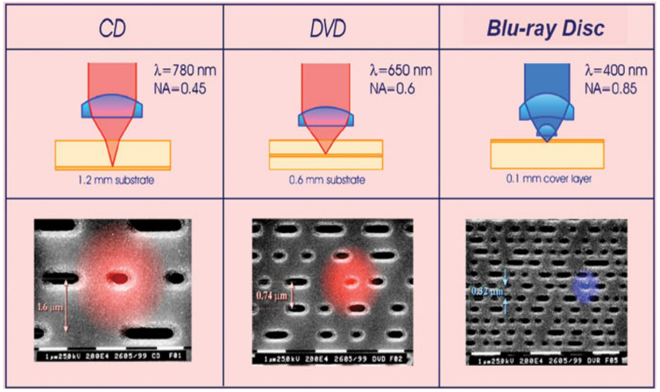
Niebieskość 405 nm

Lasery czerwone nie dają możliwości zapisu filmu w standardzie wysokiej rozdzielczości HDTV

Płyta DVD nagrana przy pomocy lasera 640 nm może pomieścić 4.7 GB

To za mało aby pomieścić film zapisany w standardzie wysokiej rozdzielczości – potrzeba około 15 GB

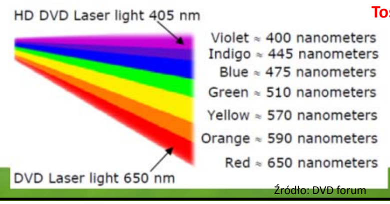
Zapis o dużej gęstości: CD, DVD, Blu-ray



0.8 GB **4.7 - 9 GB** **24 - 50 GB**

Niebieskość 405 nm

- Blue DVD 23 GB (Sony Pro-Data $2500-3000)
- Blue-ray 27 GB (50 GB dwustronnie) (Dell, **Sony**, Koninklijke **Philips** Electronics, Hitachi, Hewlett-Packard Co, LG Electronics, Matsushita Electric Industrial, (Panasonic), Pioneer, Samsung, Sharp, Thomson Multimedia, Walt Disney Company, Buena Vista Entertainment) **Philips ~$700**
- HD-DVD 15-20 GB (Hewlett-Packard Co, Hitachi, **IBM**, Industrial Technology Research Institute (Taiwan), Intel, LG Electronics, Matsushita Electric Industrial (Panasonic), **Microsoft**, Mitsubishi Electric, NEC, Pioneer, Koninklijke Philips Electronics, Samsung Electronics, Sanyo Electric, Sharp, Sony, Thomson, Time Warner, **Toshiba**, Victor of Japan (JVC), Walt Disney Pictures and Television, Paramount, Universal Studios and Warner Bros) **Toshiba ~$450**



Źródło: DVD forum

Niebieskość 405 nm

- Blue-ray 27 GB (50 GB dwustronnie) (Sony, Philips Electronics, Sony, Hitachi, Hewlett-Packard Co, LG Electronics, Matsushita Electric Industrial, (Panasonic), Pioneer, Samsung, Sharp, Thomson Multimedia)
- „The licensing agreements, which are 10-year renewable contracts, will include the right to use the Blu-ray format and logo as well as the content protection specifications. Licenses for the format and logo will range from $20,000 to $60,000 depending on which products--discs, players or components--manufacturers want to develop. The same is true for the protection specifications, which range in price annually from $4,000 to $12,000".

Blu-ray Disc

HD DVD

Niebieskość 405 nm

Potrzebny laser: 5-100 mW, 405 nm, jednomodowy, dobra wiązka, wysoka niezawodność niska cena

50 GB ☺

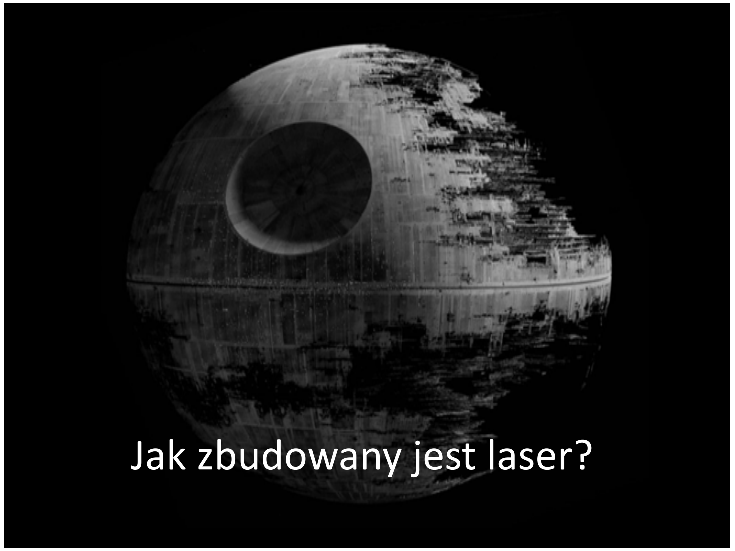
3300 $ ☹

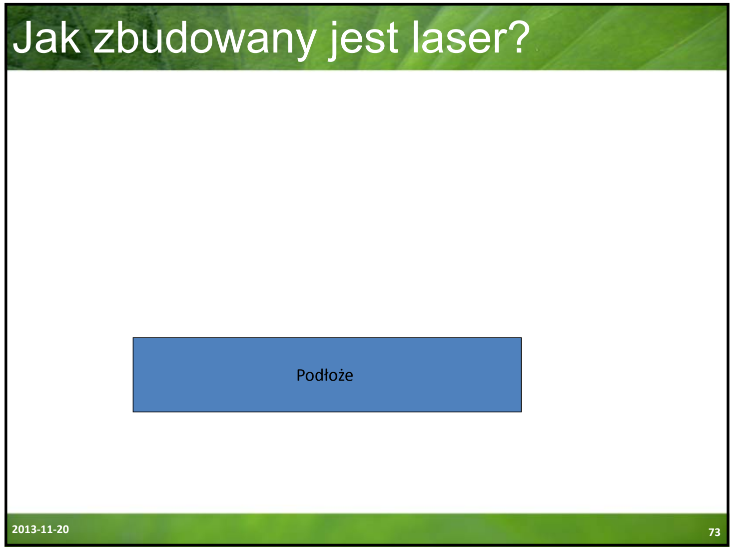
14 kg ☹

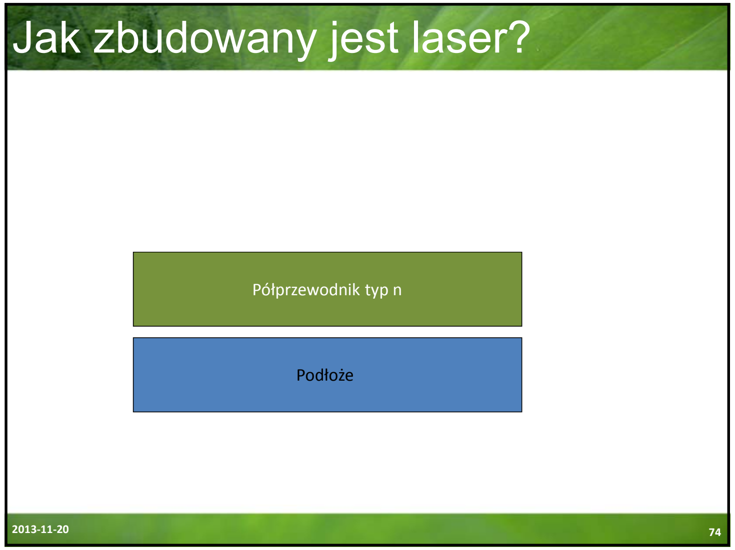
Czesław Skierbiszewski *UNIPRESS*

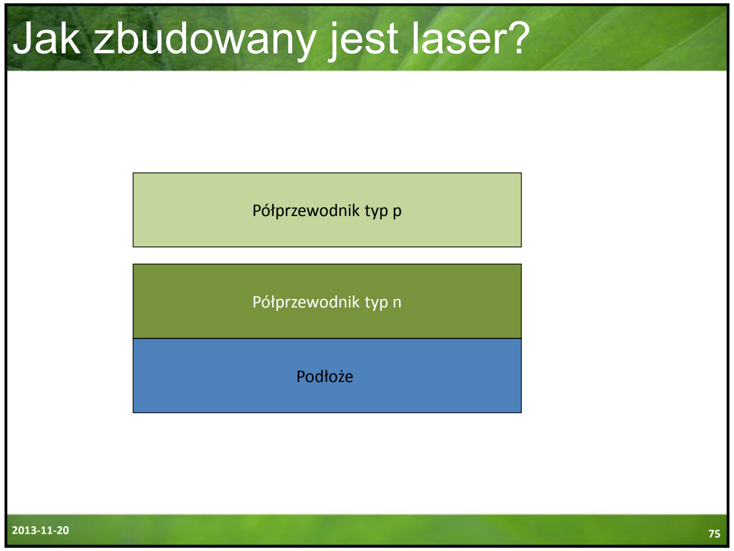
Niebieskość 405 nm

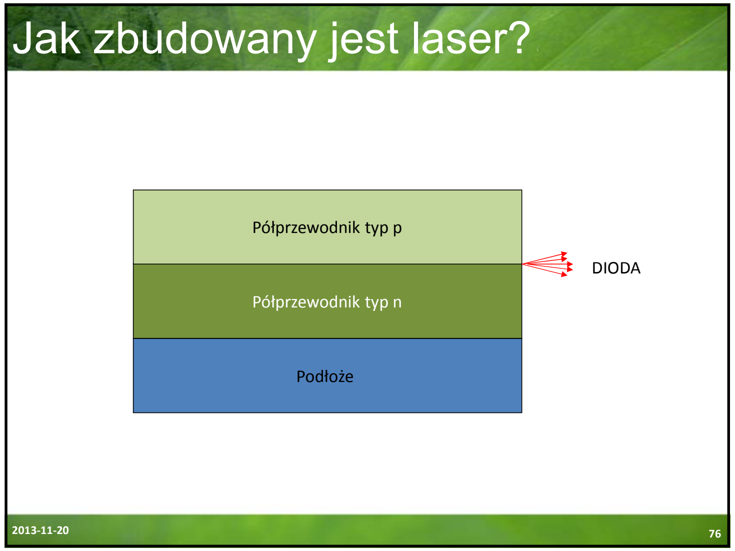
- **Drukowanie**: drukarka laserowa 600 dpi drukująca 60 stron na minute (60 ppm) korzysta obecnie z lasera 760 nm i systemu optycznego o aperturze 6mm by uzyskać 35 µm FWHM. Dla wydruku 1200 dpi (17 µm FWHM) czerwony laser potrzebuje droższego i większego systemu optycznego o aperturze 12 mm i głębi ostrości jedynie 0.5mm (z taką precyzją względem papieru laser musi być ogniskowany). Laser GaN 390 nm może dać wydruk 1200 dpi za pomocą systemu optyki 6mm i głębi ostrości 1mm.
- Do wydruku 60 ppm potrzeba laserów GaN 6 mW CW (większa moc umożliwia większe prędkości wydruku).
- Długośc fali powinna być >430 nm, żeby nie dopuścić do uszkodzenia (rozkładu) materiałów organicznych (plastików) używanych w budowe .



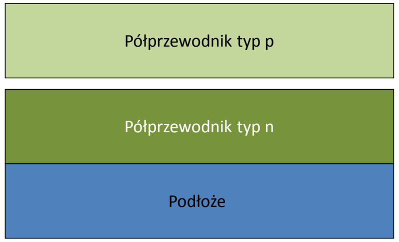

Jak zbudowany jest laser?
Podłoże
2013-11-20
73


Jak zbudowany jest laser?
Półprzewodnik typ n
Podłoże
2013-11-20
74

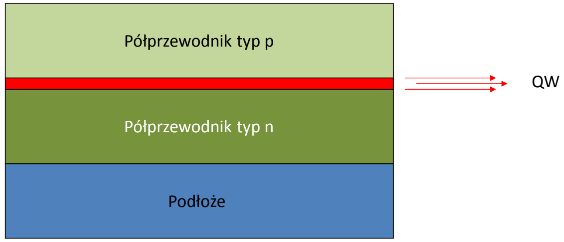

Jak zbudowany jest laser?
Półprzewodnik typ p
Półprzewodnik typ n
Podłoże
2013-11-20
75


Jak zbudowany jest laser?
Półprzewodnik typ p
DIODA
Półprzewodnik typ n
Podłoże
2013-11-20
76

Jak zbudowany jest laser?



Jak zbudowany jest laser?



Trochę historii

- 1907 – żółta elektroluminescencja SiC (Henry Joseph Round)
- 1936 – elektroluminescencja ZnS, George Destriau
- Lata '50 pierwsze diody świecące (w podczerwieni) z GaAs – akronim Light Emitting Diode (LED),
- **MASER** (Microwave Amplification by the Stimulated Emission of Radiation) Charles H. Townes in 1954.
- 1960 **LASER** (rubin, Theodore Maiman) 1961 He-Ne (Ali Javan, William Bennet, and Donald Herriot)

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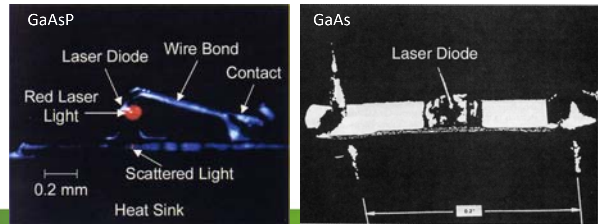
- 1962 Pierwsze diody laserowe GaAsP (Holonyak & Bevacqua) i GaAs (Robert Hall, Lincoln Laboratories) (pulsed,LN)
- Lata '60 pierwsze diody świecące na czerwono z GaAsP/GaAs, a później GaAsP/GaP



http://www.rpi.edu/~schubert/

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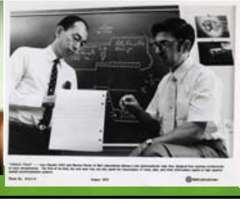

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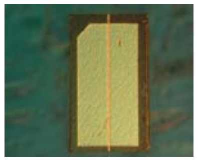
- Lata '60 pierwsze diody świecące na czerwono z GaAsP/GaAs, a później GaAsP/GaP
- 1970 pierwszy laser cw RT (Zhores Alferov ZSRR, Hayashi and Panish, Bell Labs)
- Połowa lat '70 diody z GaP (zielone). **Czerwone** + **Zielone** = **Żółte**
- Połowa lat '80 diody z GaAlAsP (bardzo wydajne).
- Połowa lat '90 diody z InGaAlP (jeszcze bardziej wydajne) czerwone, pomarańczowe, zielone i żółte.

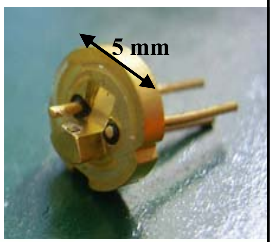
Trochę historii

1977 – pierwsza rozmowa telefoniczna transmitowana światłowodem
1982 – Phillips and Sony rozpoczynają produkcje odtwarzaczy CD
1996-97 – technologia DVD

Left: first CD-player (1982)

Obecnie ponad 60% rynku laserów półprzewodnikowych to :
Lasery telekomunikacyjne: 1.55 µm
Lasery CD, DVD 790, 640 nm





Czesław Skierbiszewski *UNIPRESS*

Przerwa energetyczna

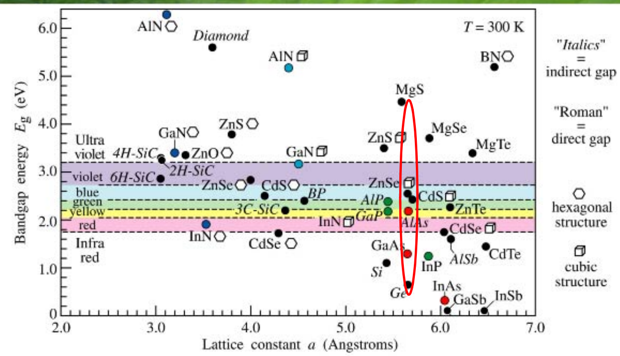


Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

Obiecujący materiał

1272 Appl. Phys. Lett. 59 (11), 9 September 1991 0003-6951/91/361272-03$02.00 © 1991 American Institute of Physics 1272

Blue-green laser diodes

M. A. Haase, J. Qiu, J. M. DePuydt, and H. Cheng
3M Company, 201-1N-35 3M Center, St. Paul, Minnesota 55144

Lifetime 100h

(Received 17 May 1991; accepted for publication 13 June 1991)

The first laser diodes fabricated from wide-band-gap II-VI semiconductors are demonstrated. These devices emit coherent light at a wavelength of 490 nm from a ZnSe-based single-quantum-well structure under pulsed current injection at 77 K. This is the shortest wavelength ever generated by a semiconductor laser diode.

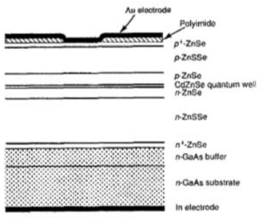


FIG. 1. A cross section of a blue-green laser diode.

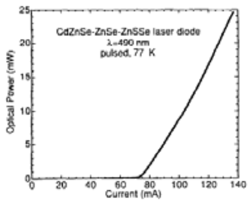


FIG. 2. The *L-I* characteristic of a blue-green laser diode. This gain-guided device is 20 μm wide and 1160 μm long.

Obiecujący materiał

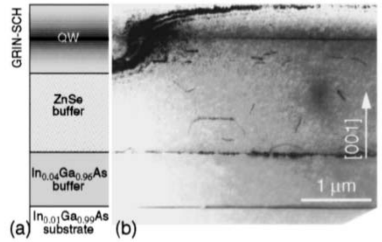


FIG. 1. (a) Schema of the structure; (b) bright field TEM image in the cross section of No. 372 near the [110] zone axis.

JOURNAL OF APPLIED PHYSICS VOLUME 83, NUMBER 4 15 FEBRUARY 1998

Transmission electron microscopy and cathodoluminescence studies of extended defects in electron-beam-pumped $Zn_{1-x}Cd_xSe/ZnSe$ blue-green lasers

Jean-Marc Bonard[a,b] and Jean-Daniel Ganière
Département de Physique, Institut de Micro-et Optoélectronique, Ecole Polytechnique Fédérale, CH-1015 Lausanne, Switzerland
Lia Vanzetti,[c] Jens J. Paggel,[c] Lucia Sorba,[c] and Alfonso Franciosi[c]
Laboratorio Nazionale TASC-INFM, Area di Ricerca, Padriciano 99, I-34012 Trieste, Italy
Denis Hervé[d] and Engin Molva
Département Optronique, LETI (CEA-Technologies Avancées) 17 rue des Martyrs, F-38054 Grenoble Cedex 9, France

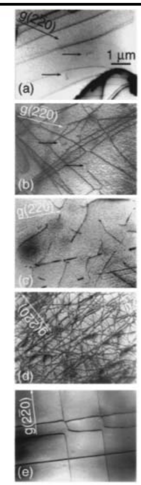


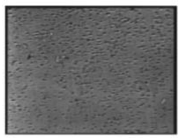
FIG. 3. Bright field TEM images of No. 372 in plan view taken with g =(220) two beam diffraction conditions near the [001] zone axis: (a) top GRIN layer (thickness of the foil: ~400 nm); (b) whole GRINSCH (~800 nm); (c) ZnSe buffer (GRINSCH removed); (d) ZnSe buffer with III-V/II-VI interface (GRINSCH removed); (e) InGaAs buffer and substrate-buffer interface (GRINSCH and ZnSe buffer removed).

Obiecujący materiał

JOURNAL OF APPLIED PHYSICS VOLUME 91, NUMBER 6 15 MARCH 2002

Patterned heteroepitaxial processing applied to ZnSe and $ZnS_{0.02}Se_{0.98}$ on GaAs (001)

X. G. Zhang, A. Rodriguez, P. Li, F. C. Jain, and J. E. Ayers[a]
Electrical and Computer Engineering Department, University of Connecticut, 260 Glenbrook Road, Storrs, Connecticut 06269-2157


(a)

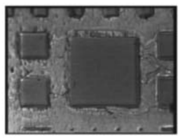

(b)

FIG. 1. The etch pit morphology of: (a) a 6000 Å thick as-grown ZnSe layer on GaAs and (b) a PHP prepared layer consisting of 6000 Å thick ZnSe mesas on GaAs. Both pieces were from the same ZnSe/GaAs wafer.

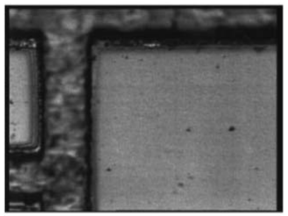

(d)

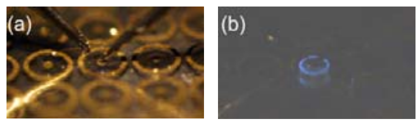
FIG. 5. The etch pit morphology of $ZnS_{0.02}Se_{0.98}$ on GaAs: (a) a 2900 Å thick as-grown and (b) a 2900 Å thick PHP prepared (both pieces were from the same wafer); (c) a 6000 Å thick as-grown and (d) a 6000 Å thick PHP prepared layer [both (c) and (d) were from the same wafer].

Obiecujący materiał

May 19, 2005

World's First Blue LED Made with Zinc Oxide

A Japanese team led by Professor Masashi Kawasaki of the Tohoku University Institute for Materials Research announced it had successfully developed the world's first blue light-emitting diode (LED) made with low-cost zinc oxide in December 2004.



http://www.jetro.go.jp/en/market/trend/topic/2005_05_led.html

Przerwa energetyczna

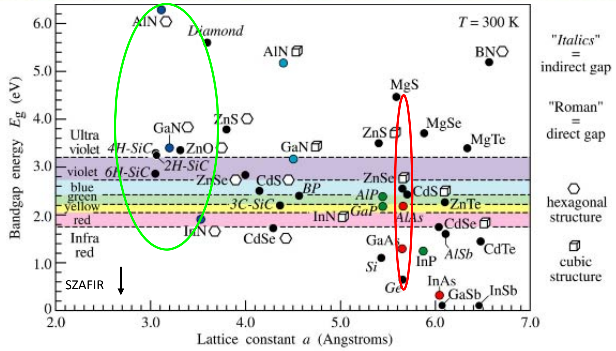


Fig. 11.4. Room-temperature bandgap energy versus lattice constant of common elemental and binary compound semiconductors.

http://www.rpi.edu/~schubert/Light-Emitting-Diodes-dot-org/chap11/F11-04-R.jpg

2013-11-20 89

Trochę historii

★ 1970 - J. Pankove (RCA labs) odkrył, że GaN może eimitować niebieskie światło.

★ 1989 - I. Akasaki & H. Amano (Matsushita, Nagoya University)
- domieszkowanie na typ p GaN (z Mg),
- nieskotemperaturowa warstwa buforowa

★ 1992-1996 - S. Nakamura (Nichia) LEDs oraz LD z MOVPE
- „two-flow MOVPE process" do wzrostu warstw GaN
- wygrzewanie termiczne GaN:Mg

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Trochę historii

- Połowa lat '90 diody z InGaAlP (jeszcze bardziej wydajne) czerwone, pomarańczowe, zielone i żółte.
- 1993 Niebieskie diody Nichia (Nakamura)
- 1996 Niebieski laser Nichia (Nakamura) RT, pulsed 215 mW

Nichia Chemical Industries

http://nsr.mij.mrs.org/news/flash.html

2013-11-20 91

Trochę historii

ScienceWatch

Why did you decide to use gallium nitride?

Nakamura: At that time, in 1989, there were two materials for making blue LEDs: zinc selenide (ZnSe) and gallium nitride (GaN). These had the right band gap energy for blue lasers. But everybody was working on zinc selenide because that was supposed to be much better. I thought about my past experience: **if there's a lot of competition, I cannot win.** Only a small number of people at a few universities were working with gallium nitride so I figured I'd better work with that. **Even if I succeeded in a making a blue LED using zinc selenide, I would lose out to the competition when it came to selling it.**

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Troche historii

SCIENCEWATCH

You still weren't doing laser research?

Nakamura. Not yet. In 1985, I went to work on a gallium aluminum arsenide epitaxial wafer. This is also used for LEDs. It's called an epitaxial wafer because you use very thin layers to make the LEDs. So I spent the next three years on that and came out with these gallium aluminum wafers for red and infrared LEDs, but the same thing happened: Our sales were not good because the bigger companies were already selling the same product by the time I was. The quality of our LEDs and epitaxial wafers was just as good and the prices were the same, but our company was small and local and couldn't compete. So once again my company was not happy.

By this time the R&D department was down to just me-the other two people left because the results were so terrrible. I kept at it, but I was dispirited. For ten years I had worked very hard to make these products. I worked twelve hours a day, seven days a week, except holidays. I had a very, very small budget and had to make everything I needed myself. I even made my own reactors- the furnaces needed to do the crystal work. The commercial reactors were too expensive. I made three products all by myself, and still my salary and position were not good at the company. My bosses always complained that my results were terrible, because I spent a lot of money, as far as they were concerned, and nothing sold. But for ten years I had been working to make these LED materials and I knew at the time there were no high-brightness blue LEDs. For LED researchers, this was a dream. But my bosses said it would be impossible to create a blue LED at Nichia, because many big companies and many research teams in big universities were trying to do it and were failing. So I went to went to my company's chairman, Nobuo Ogawa, who was my professor's friend, and the president Eji Ogawa, who was his son-in-law. **I asked them if they would let me do research on blue LEDs and they said "Sure. No problem. Go ahead."** I was very surprised. I asked them to give me a large budget so I could do it. **"Please give me three million U.S. dollars," and they said "Sure. No problem."** They had faith in me because, despite the dismal sales, I had developed three new products for this company and I was the only one at Nichia who had succeeded in making new products.

GaP, GaAs

http://www.sciencewatch.com/jan-feb2000/

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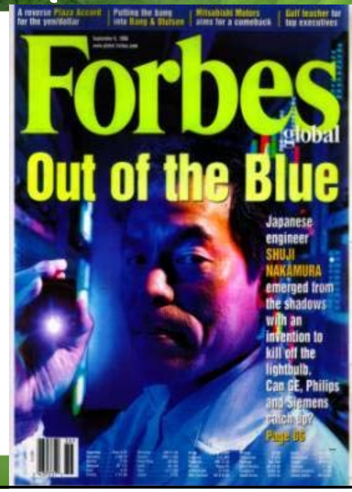
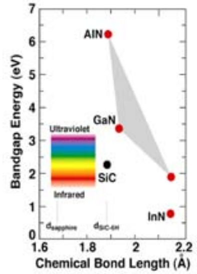
Trochę historii



1992-1996



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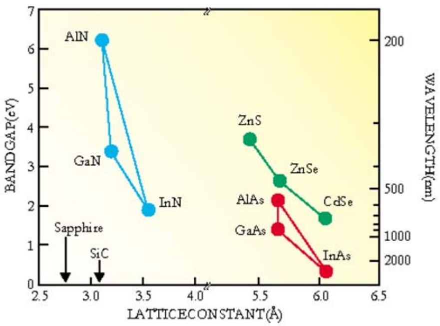
Jak zbudowany jest laser?



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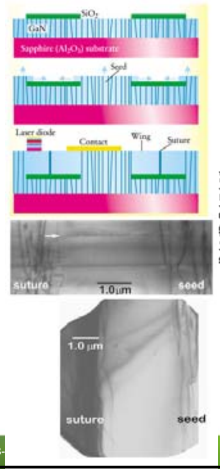
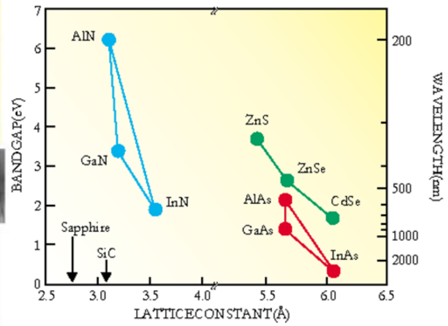
Jak zbudowany jest laser?



Lateral epitaxial overgrowth (LEO)
ELO



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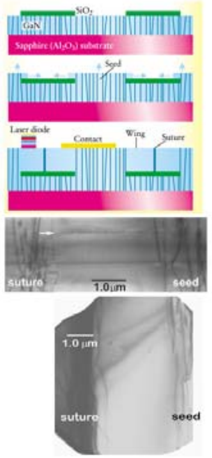
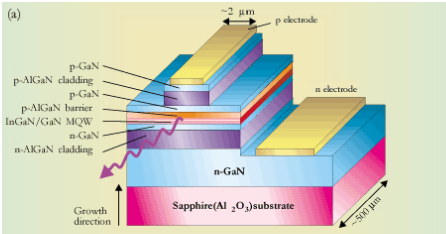
Jak zbudowany jest laser?





Sharp breaks the blue laser duopoly

By Leo Lewis in Tokyo

Published: December 20 2006 00:43 | Last updated: December 20 2006 00:43

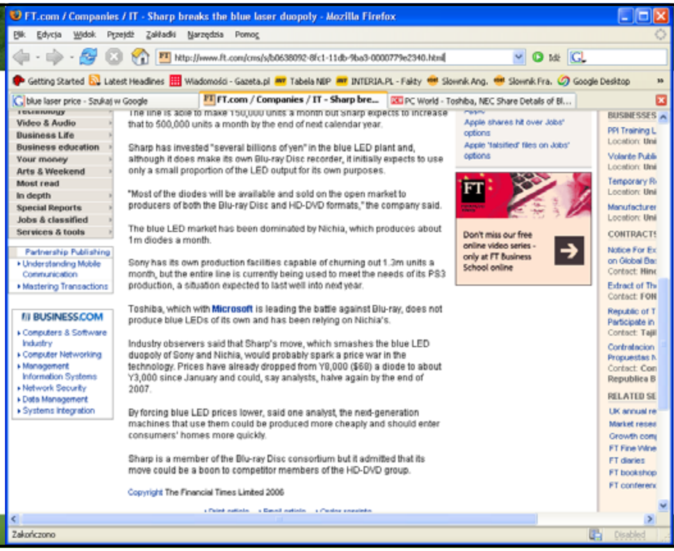
Sharp has begun mass production of blue laser diodes – the critical component in rival next-generation DVD systems – in a move that is expected to escalate the "format war" between Blu-ray Disc and HD-DVD players.

The LEDs are used by both competing formats to read and write data on to discs, but production has been dogged by bottlenecks, seriously delaying the availability of the players.

The new standards are expected to generate billions in revenue for the technologies' backers – led by Sony in the case of Blu-ray and Toshiba for HD-DVD – as well as Hollywood studios, the consumer electronics industry and retailers.

Early manufacturing problems with blue LEDs were blamed for the acute pre-Christmas shortages in the US and Japan and delays in the European launch of Sony's PlayStation3 games console, which incorporates a Blu-ray Disc player.

Sharp began production of blue LEDs at its electronic components factory in Hiroshima in late November.



The line is able to make 150,000 units a month but Sharp expects to increase that to 500,000 units a month by the end of next calendar year.

Sharp has invested "several billions of yen" in the blue LED plant and, although it does make its own Blu-ray Disc recorder, it initially expects to use only a small proportion of the LED output for its own purposes.

"Most of the diodes will be available and sold on the open market to producers of both the Blu-ray Disc and HD-DVD formats," the company said.

The blue LED market has been dominated by Nichia, which produces about 1m diodes a month.

Sony has its own production facilities capable of churning out 1.3m units a month, but the entire line is currently being used to meet the needs of its PS3 production, a situation expected to last well into next year.

Toshiba, which with Microsoft is leading the battle against Blu-ray, does not produce blue LEDs of its own and has been relying on Nichia's.

Industry observers said that Sharp's move, which smashes the blue LED duopoly of Sony and Nichia, would probably spark a price war in the technology. Prices have already dropped from Y8,000 ($60) a diode to about Y3,000 since January and could, say analysts, halve again by the end of 2007.

By forcing blue LED prices lower, said one analyst, the next-generation machines that use them could be produced more cheaply and should enter consumers' homes more quickly.

Sharp is a member of the Blu-ray Disc consortium but it admitted that its move could be a boon to competitor members of the HD-DVD group.

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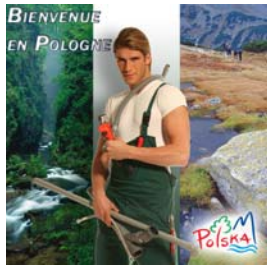
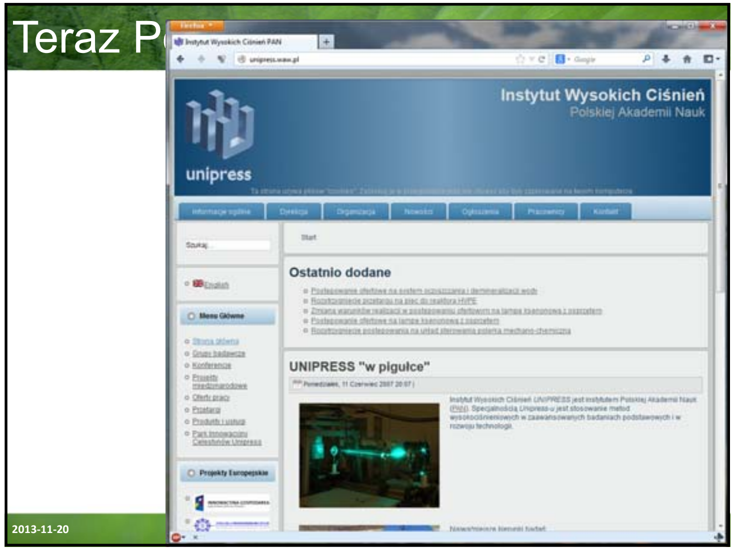
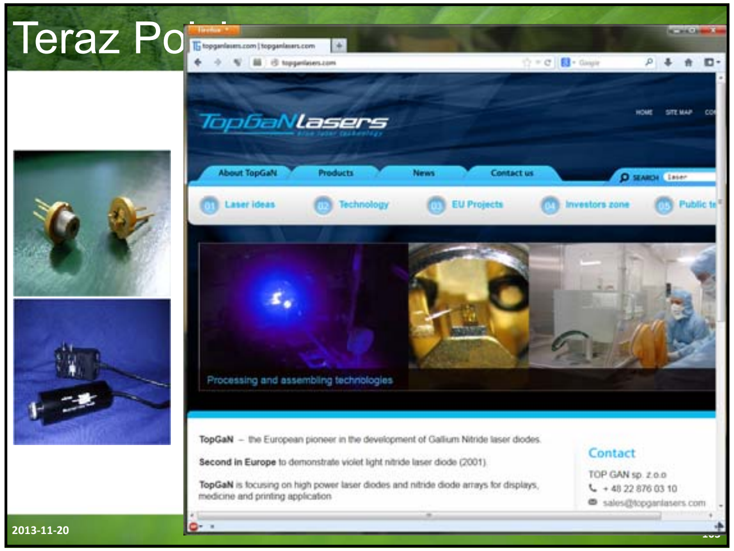
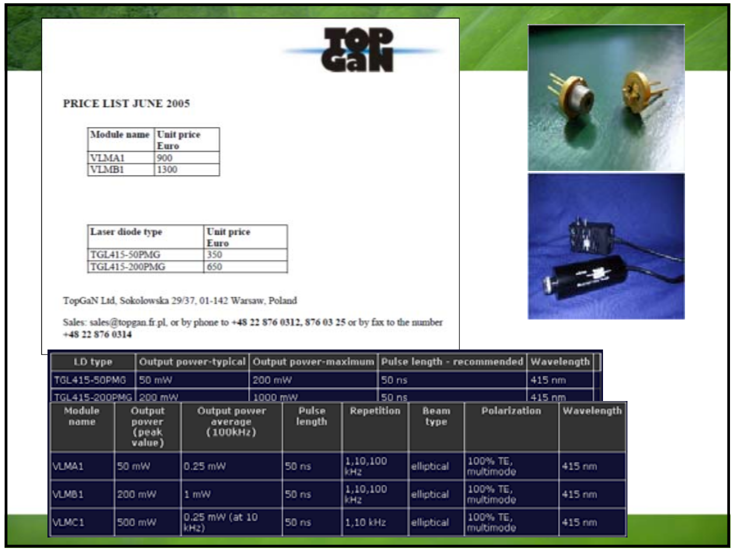


TERAZ POLSKA







TOP GaN

PRICE LIST JUNE 2005

Module name	Unit price Euro
VLMA1	900
VLMB1	1300

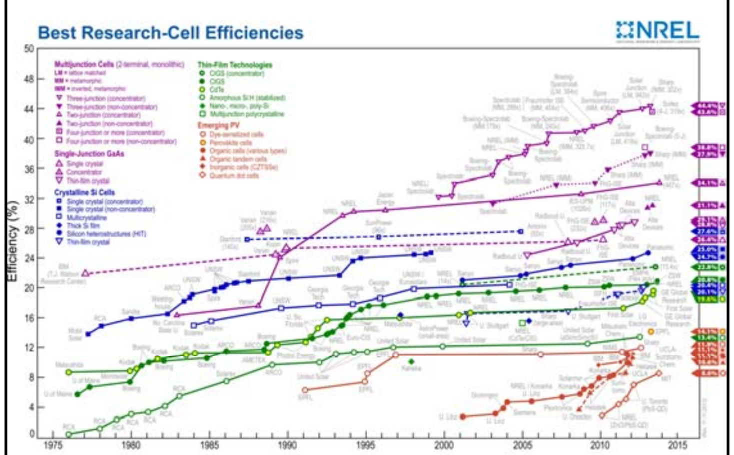
Laser diode type	Unit price Euro
TGL415-50PMG	350
TGL415-200PMG	650

TopGaN Ltd, Sokolowska 29/37, 01-142 Warsaw, Poland

Sales: sales@topgan.fr.pl, or by phone to **+48 22 876 0312, 876 03 25** or by fax to the number **+48 22 876 0314**

LD type	Output power-typical	Output power-maximum	Pulse length - recommended	Wavelength
TGL415-50PMG	50 mW	200 mW	50 ns	415 nm
TGL415-200PMG	200 mW	1000 mW	50 ns	415 nm

Module name	Output power (peak value)	Output power average (100kHz)	Pulse length	Repetition	Beam type	Polarization	Wavelength
VLMA1	50 mW	0.25 mW	50 ns	1,10,100 kHz	elliptical	100% TE, multimode	415 nm
VLMB1	200 mW	1 mW	50 ns	1,10,100 kHz	elliptical	100% TE, multimode	415 nm
VLMC1	500 mW	0.25 mW (at 10 kHz)	50 ns	1,10 kHz	elliptical	100% TE, multimode	415 nm



http://www.nrel.gov/ncpv/images/efficiency_chart.jpg