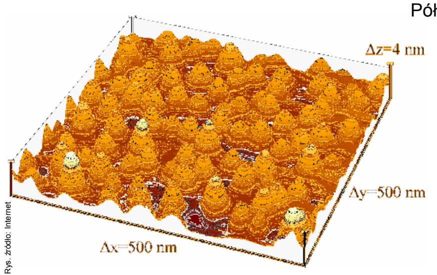
Nanotechnologie (II)

Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko



Rys. źródło: Internet

Półprzewodniki
- a.Studnie
  - i.Studnie i ekscytony
  - ii.Lasery
  - iii.Dwuwymiarowe gazy
- b.Druty
  - i.Półprzewodniki
  - ii.Organika
  - iii.Laser z drutów
- c.Kropki
  - i.Kropki planowane i nie
  - ii.Tranzystor na pojedynczym elektronie

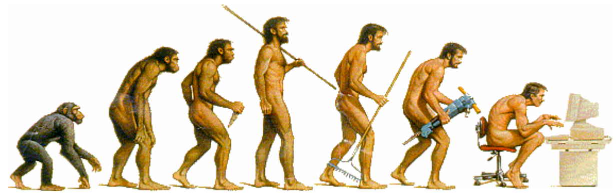
Jeszcze o teoriach (nie tylko fizycznych)

Odpowiedzialność za słowo – pojęcia mają znaczenie (energia, fale, polaryzacja, moderator pola, stężenie w roztworze) i dają się przekazać drugiej osobie bez uciekania się do przenośni.

Uczciwość – doświadczenie jest arbitrem.

Teoria naukowa jest naukowa gdy:
- Jest testowalna
- Jest falsyfikowalna
- Przewiduje wyniki

[**Karl Popper** + dyskusje (e.g. Thomas Kuhn)]



Jeszcze o teoriach (nie tylko fizycznych)

POPPER, Karl, 1980. Evolution. New Scientist **87**(1215):611.

In the 17 July issue of ***New Scientist*** (p. 215) you published an article under the title „Popper: good philosophy, bad science?" by Dr Beverly Halstead. This article, it appears had two purposes:

1. To defend the scientific character of the theory of evolution, and of palaeontology. I fully support this purpose, and this letter will be almost exclusively devoted to the defence of the theory of evolution.
2. To attack me.

As to (2), I find this uninteresting and I shall not waste your space and my time in defending myself against what are in my opinion hardly excusable misunderstandings and wild speculations about my motives and their alleged history.

Returning to (1), it does appear from your article (provided its quotation from Colin Patterson's book – which I do not know – is not as misleading as your quotations from my book) that some people think that I have denied scientific character to the historical sciences, such as palaeontology, or the history of the evolution of life on Earth; or to say, the history of literature, or of technology, or of science.

This is a mistake, and I here wish to affirm that these and other historical sciences have in my opinion scientific character: their hypotheses can in many cases be ***tested***.

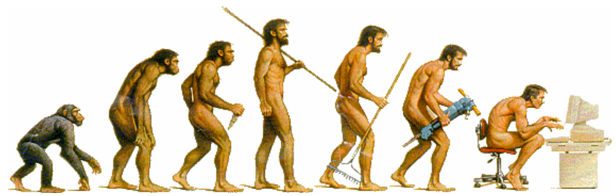
It appears as if some people would think that the historical sciences are untestable because they describe unique events. However, **the description of unique events can very often be tested by deriving from them testable predictions or retrodictions**.

Jeszcze o teoriach (nie tylko fizycznych)

Pytać!

Jeżeli jakaś teoria filozoficzna nie daje się przetłumaczyć na góralski, to jest to teoria fałszywa.

Józef Tischner



Nanotechnologie (II)

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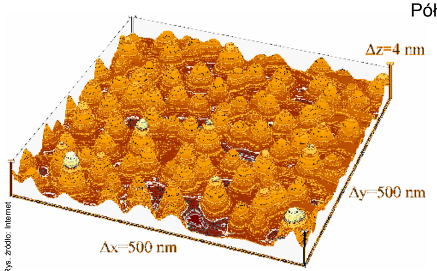

Rys. źródło: Internet

Półprzewodniki
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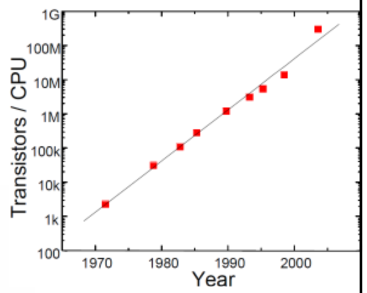
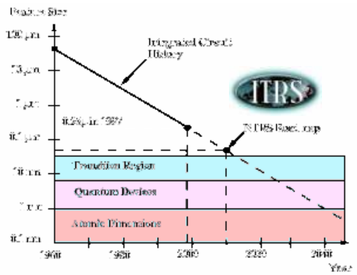
- c. Kropki
  - i. Kropki planowane i nie
  - ii. Tranzystor na pojedynczym elektronie

TRENDY: Pierwsze Prawo Moore'a

Ilość komponentów (tranzystory, połączenia, izolacje itd.) w IC podwaja się co około 18 miesięcy.



Rozmiar liniowy komponentów również zmniejsza się wykładniczo w czasie.



Te trendy nie mogą być kontynuowane w nieskończoność.

- Co zastąpi technologię Si?
- Z czego będzie wynikała ta zmiana technologii?

EKONOMIA

Źródło: Intel

Nanotechnologie

JAK?

- Top-down, czyli (nano)technologia
- Bottom-up, czyli samoorganizacja

CO?

- Studnie, druty, kropki
- Nanorurki i nanomaszyny

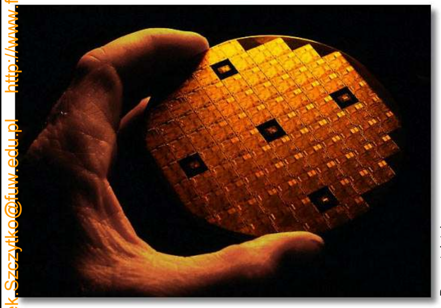
Top-down


Vincent Laforet/The New York Times

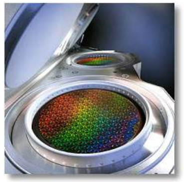
Top-down, czyli małe jest piękne!

Jacek Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Nanotechnologia
Litografia
Udoskonalenia
Galeria
Fizyka na Hożej



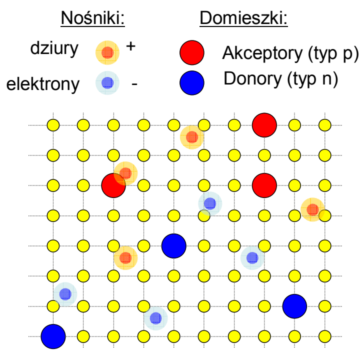
Prescot, Intel



Bottom-up

Półprzewodniki

II	III	IV	V	VI
Be	B	C	N	O
Mg	Al	Si	P	S
Zn	Ga	Ge	As	Se
Cd	In	Sn	Sb	Te

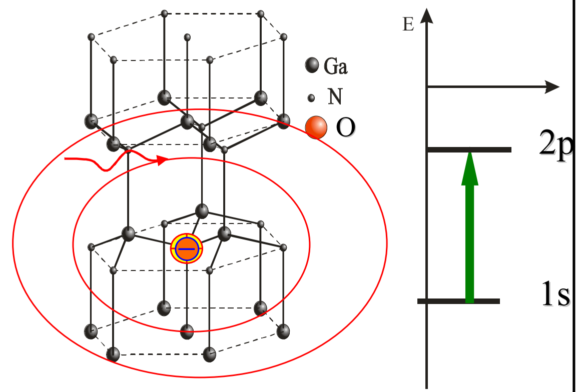


Grupa IV: diament, Si, Ge
Grupy III-V: GaAs, AlAs, InSb, InAs...
Grupy II-VI: ZnSe, CdTe, ZnO, SdS...

Neutralny donor

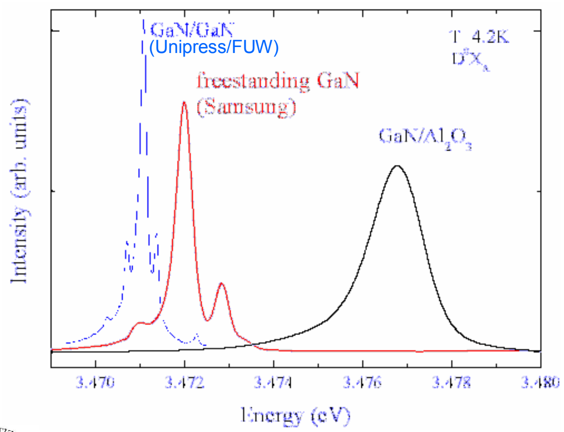
Magneto-spektroskopia w silnych polach magnetycznych

m*



Andrzej Wysmołek

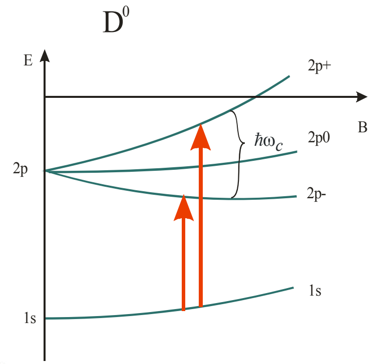
Próbki GaN



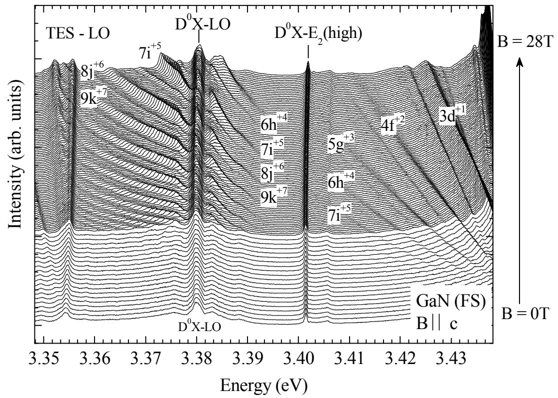
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

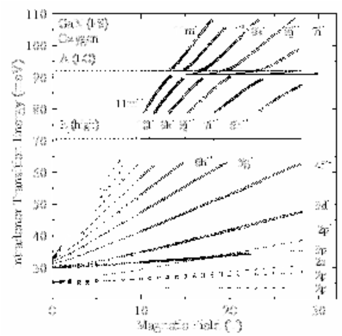
Andrzej Wysmołek

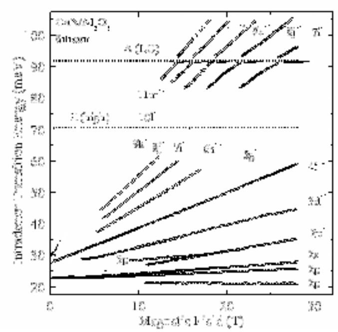
Spektroskopia w dalekiej podczerwieni



Highly excited oxygen states



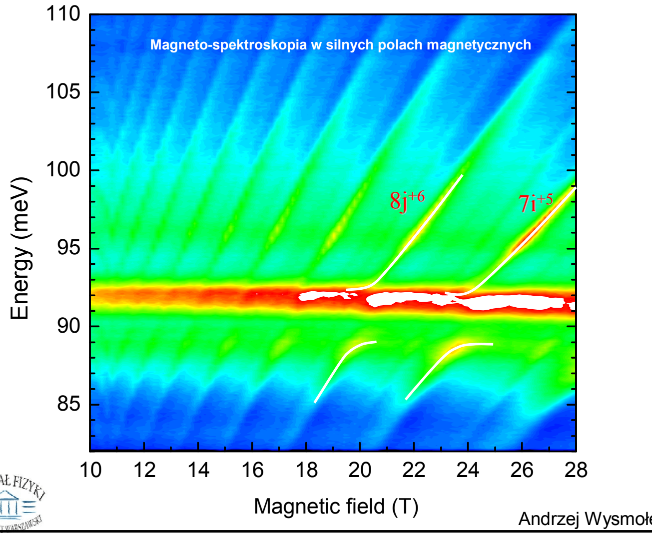




Oxygen
R_y=30.28(5) meV
Δ_{1s}=2 .9meV
E_B=33.18meV
ΔE_p=1.3(1) meV,
Δg=0.4(1)
p=2.2(1)

Silicon
R_y=30.28(5) meV
Δ_{1s}=0
E_B=30.28meV
ΔE_p=1.3(1) meV
Δg=0.3(1)
p=2.3(1)

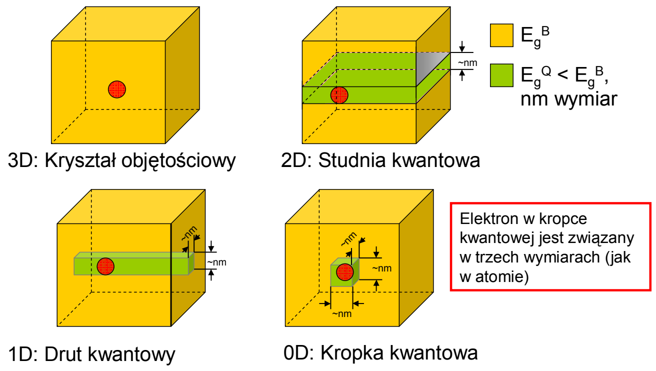
Andrzej Wysmołek



Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Andrzej Wysmołek

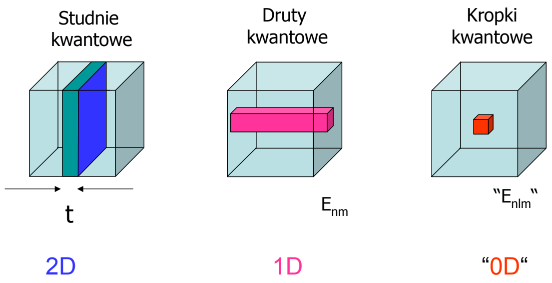
Wymiary świata



Elektron w kropce kwantowej jest związany w trzech wymiarach (jak w atomie)

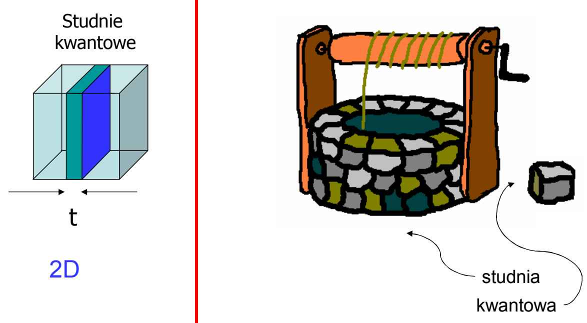
Turid Worren NTNU Norway

Struktury niskowymiarowe
Low-dimensional Semiconductor Systems



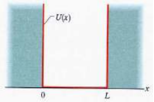
Hubert J. Krenner

Struktury niskowymiarowe
Low-dimensional Semiconductor Systems



Prof. Andrzej Twardowski

Cząstka w studni potencjału

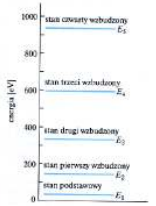


Warunek $kL = n\pi \quad \Rightarrow \quad k = n\frac{\pi}{L} \qquad n = 1,2,3...$

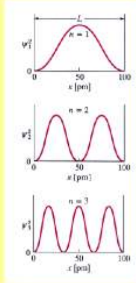
oznacza, że wektor falowy może przyjmować tylko niektóre wartości, czyli że jest skwantowany

Podobnie energie są skwantowane:

$$E = \frac{\hbar^2 k^2}{2m} = \left(\frac{\hbar^2 \pi^2}{2mL^2}\right) n^2$$



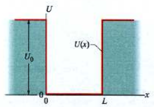
Prawdopodobieństwo (kwadrat funkcji falowej)



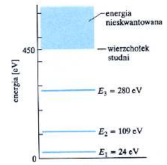
* „klasyczna" cząstka w studni mogłaby mieć dowolne energie i przebywać w dowolnym miejscu studni.

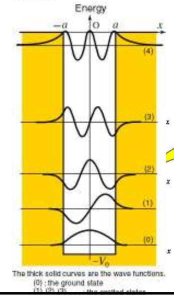
Prof. Andrzej Twardowski

Cząstka w studni skończonej



W przypadku studni skończonej też jest kwantyzacja energii (ale są też energie nieskwantowane).



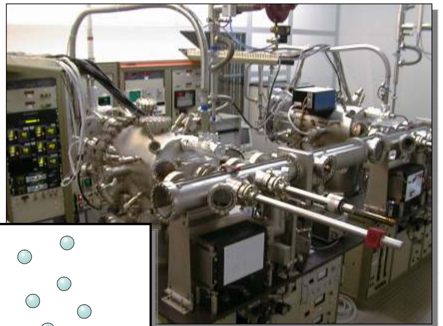


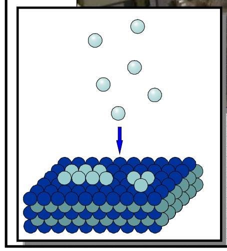
Funkcja falowa rozciąga się poza barierę!

Cząstka może wnikać w barierę!

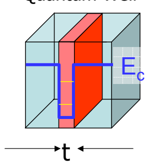
Zasadnicza różnica: Klasyczna cząstka nie może wnikać w barierę.

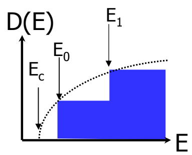
MBE





Quantum Well

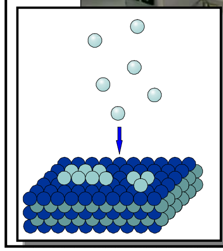




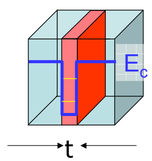
MBE→ Osadzanie z atomową precyzją warstw o różnym składzie lub domieszkowaniu

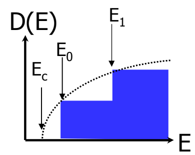
Hubert J. Krenner

MOCVD



Studnia kwantowa



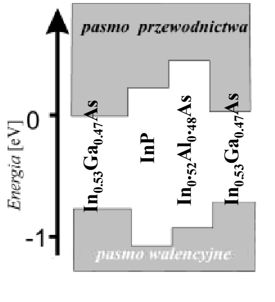


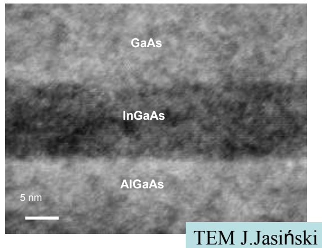
MOCVD→ Osadzanie z atomową precyzją warstw o różnym składzie lub domieszkowaniu

Studnia Kwantowa

Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Inżynieria przerwy energetycznej

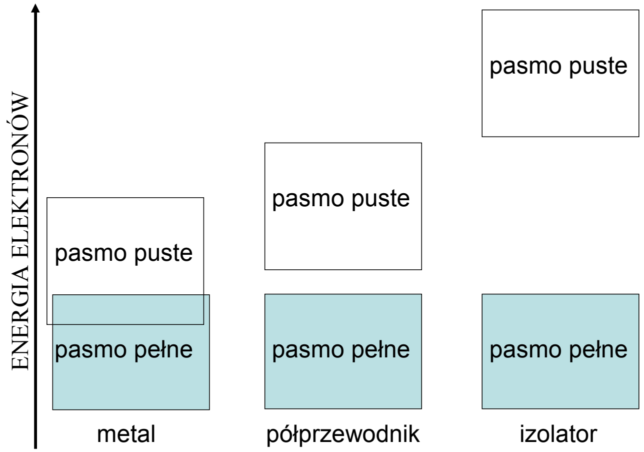




TEM J.Jasiński

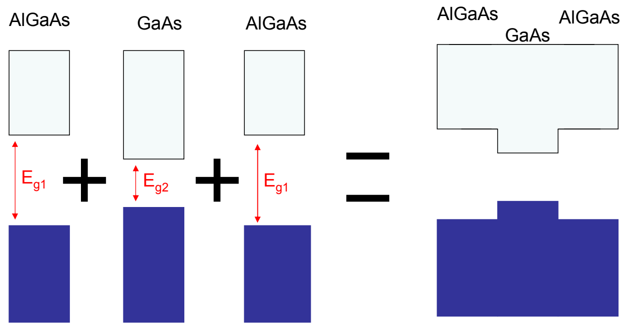
A. Babiński

Teoria pasmowa ciał stałych.

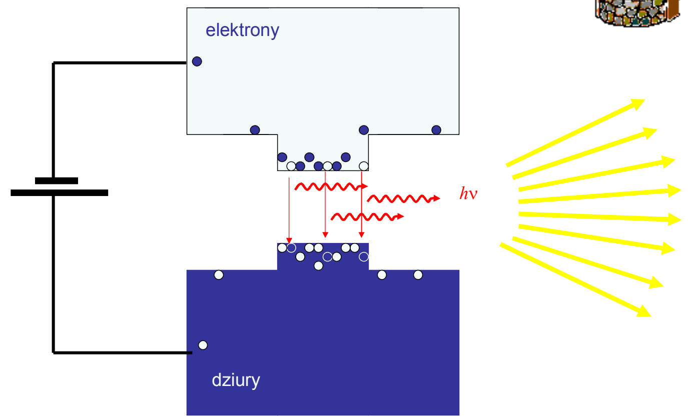


Jak zobaczyć przerwę?

Studnia Kwantowa

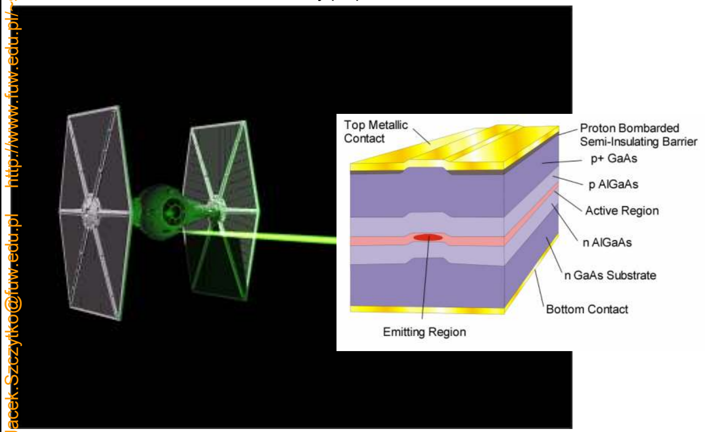


Studnia Kwantowa



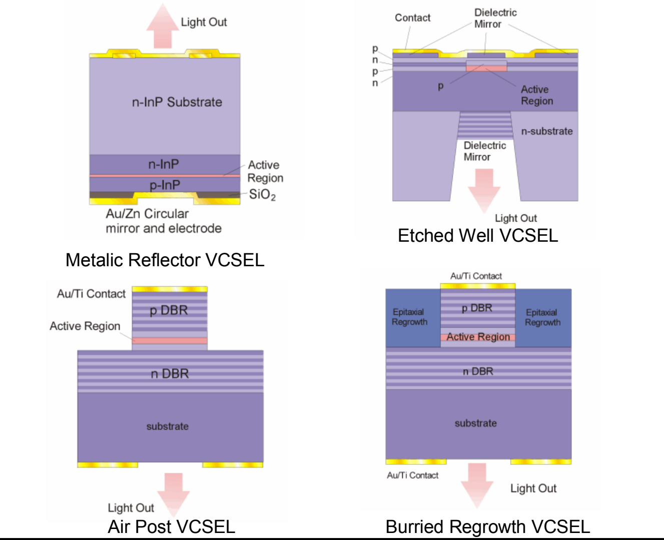
Studnie Kwantowe

Lasery półprzewodnikowe



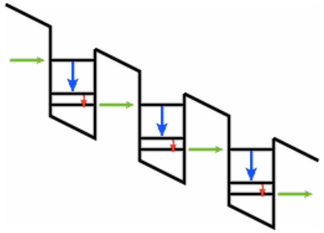
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Vertical Cavity Surface Emitting Laser

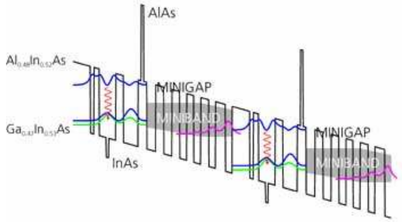


http://britneyspears.ac/physics/vcsels/vcsels.htm

QCL - Quantum Cascade Laser



QCL - Quantum Cascade Laser

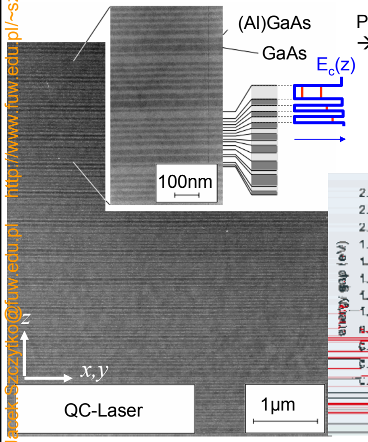


The QUANTA® OEM module (LASER COMPONENTS)

http://www.sacher-laser.com/QCL_LaserHead.php

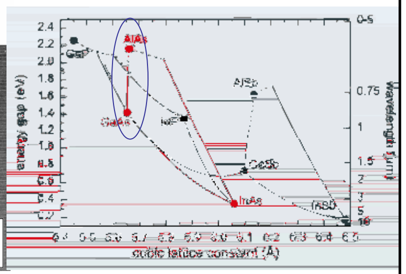
Band structure engineering

Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko



Przestrzenne zmiany przerwy energetycznej
→ Inżynieria przerwy energetycznej

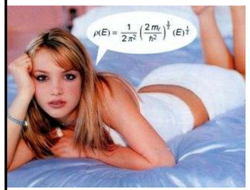
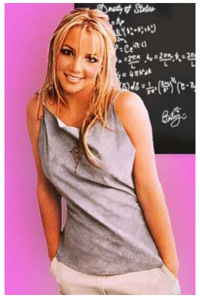
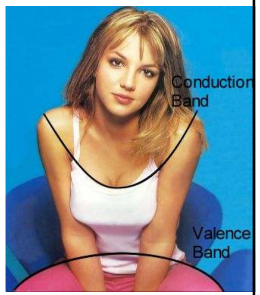
→ Możliwe ponieważ GaAs i AlAs mają tę samą strukturę krystaliczną i stałą sieci



Hubert J. Krenner

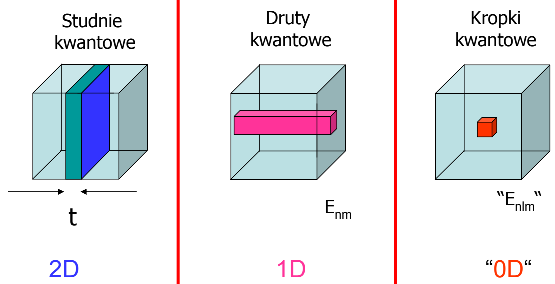
Studnie Kwantowe

Więcej: **http://britneyspears.ac/lasers.htm**

Struktury niskowymiarowe

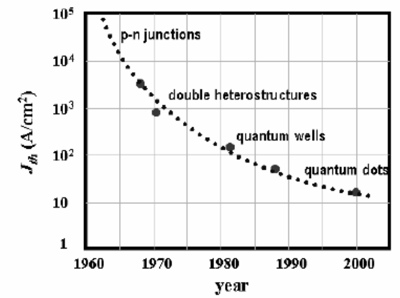
Low-dimensional Semiconductor Systems



Hubert J. Krenner

Druty

Figure 8 The trend of the reduction of semiconductor laser threshold



Druty

PHYSICAL REVIEW B VOLUME 52, NUMBER 15 15 OCTOBER 1995-I

Dimensionality effects on strain and quantum confinement in lattice-mismatched $InAs_xP_{1-x}$/InP quantum wires

M. Notomi*
NTT Opto-electronics Laboratories, 3-1 Morinosato-Wakamiya, Atsugi, Kanagawa 243-01, Japan
J. Hammersberg and H. Weman
Department of Physics and Measurement Technology, Linköping University, S-581 83 Linköping, Sweden
S. Nojima, H. Sugiura, M. Okamoto, and T. Tamamura
NTT Opto-electronics Laboratories, 3-1 Morinosato-Wakamiya, Atsugi, Ka
M. Potemski
Grenoble High Magnetic Field Laboratory, Max-Planck Institute für F
and Centre National de la Recherche Scientifique, 38042 Greno
(Received 29 March 1995)

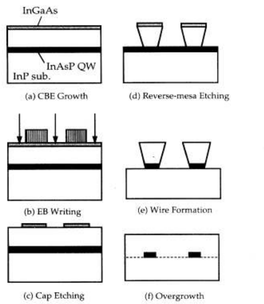


FIG. 1. Fabrication process of strained InAsP/InP quantum wires.

Druty

42 Int. J. of Nanotechnology, Vol. 1, Nos. 1/2, 2004
Nanolasers: Lasing from nanoscale quantum wires
Samuel S. Mao

Figure 9 Quantum wire fabrication based on nanoscale etching and re-growth

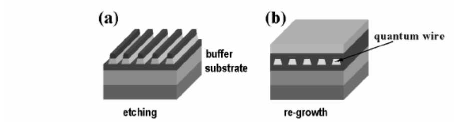
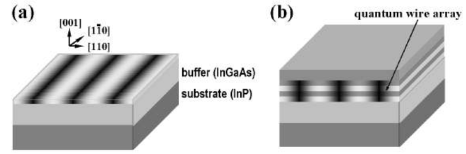


Figure 10 Formation of one-dimensional nanoscale quantum wires by strain-induced lateral ordering



Druty

42 Int. J. of Nanotechnology, Vol. 1, Nos. 1/2, 2004
Nanolasers: Lasing from nanoscale quantum wires
Samuel S. Mao

Figure 11 Growth of quantum wires on a vicinal surface with multiatomic steps

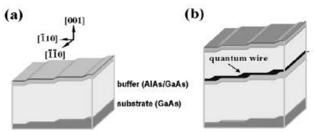
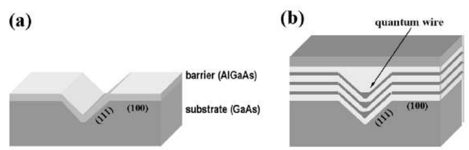


Figure 12 Selective growth of quantum wires on a pre-patterned V-groove substrate



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Nanolasers: Lasing from nanoscale quantum wires
Samuel S. Mao

Figure 13 Selective growth of quantum wires on a pre-patterned Λ-ridge substrate

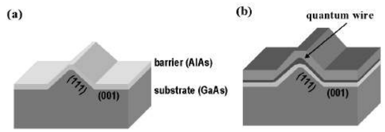
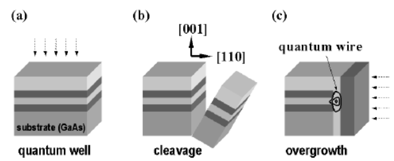


Figure 14 Formation of one-dimensional T-intersection quantum wire structure by cleaved-edge overgrowth



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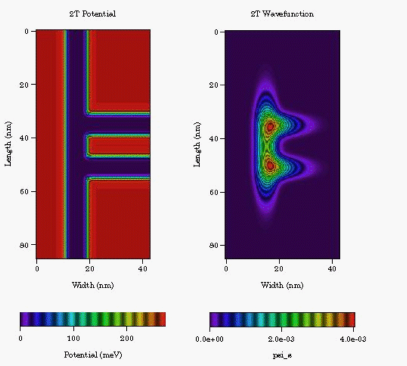
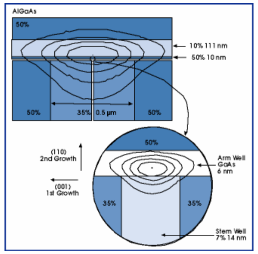
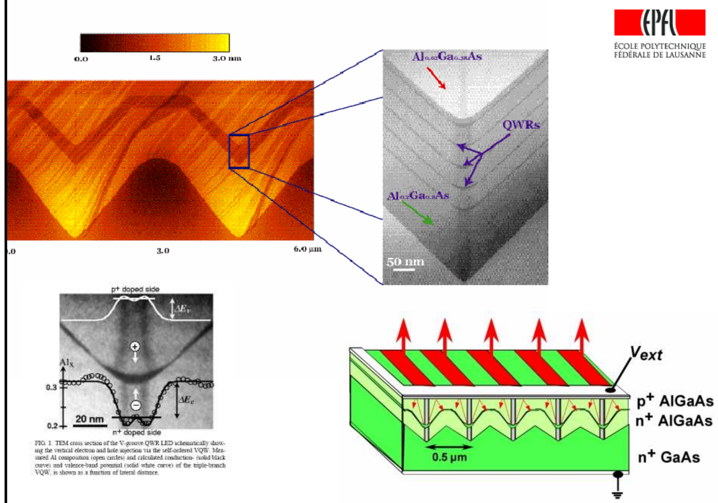
Jacek.Szczytko@fuw.edu.pl   http://www.fuw.edu.pl/~szczytko





http://gams.cam.nist.gov/hpcc/physics/nano.html

http://www.photonics.com/spectra/research/XQ/ASP/preaid.82/QX/read.htm



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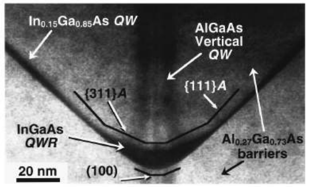


FIG. 1. Dark field TEM micrograph showing a cross-sectional view of a $In_yGa_{1-y}As/Al_xGa_{1-x}As$ QWR (sample $In_{0.15}$).

APPLIED PHYSICS LETTERS VOLUME 72, NUMBER 6 9 FEBRUARY 1998

Self-ordering and confinement in strained InGaAs/AlGaAs V-groove quantum wires grown by low-pressure organometallic chemical vapor deposition

E. Martinet, F. Reinhardt, A. Gustafsson, G. Biasiol, and E. Kapon
Department of Physics, Swiss Federal Institute of Technology (EPFL), 1015 Lausanne, Switzerland

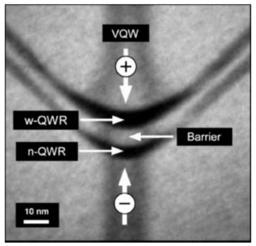
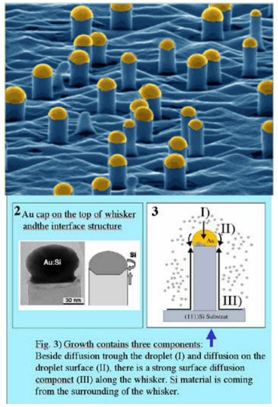
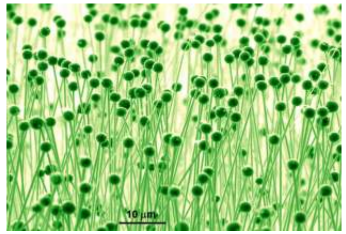


FIG. 1. Cross-sectional TEM micrograph of the QWR region in sample A with a schematic illustration of the electron and hole injection via the VQW's.

Druty



http://www.mpi-halle.mpg.de/~mbe/



www.ece.odu.edu/g_seminar.htm

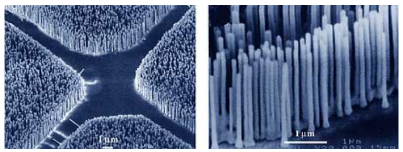


Photo by Peidong Yang/UC Berkeley, courtesy of *Science*

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P.X. Gao et al. / Chemical Physics Letters 408 (2005) 174–178 175

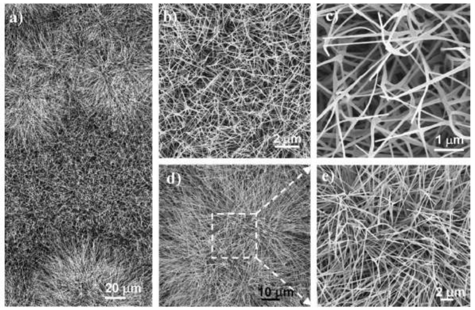

Fig. 1. (a) A typical low magnification SEM image of the as-grown networks of ZnO nanowires and nanorods consisting two types of morphologies, as indicated by area b (b,c) and c (d,e). (b,c) Enlarged SEM images of uniform networks of ZnO nanowires and nanorods. (d,e) Enlarged SEM images of clumps of nanowires showing the interconnected nanowires and nanorods.

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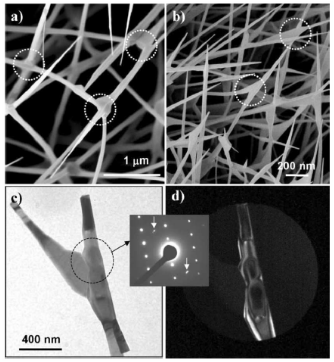

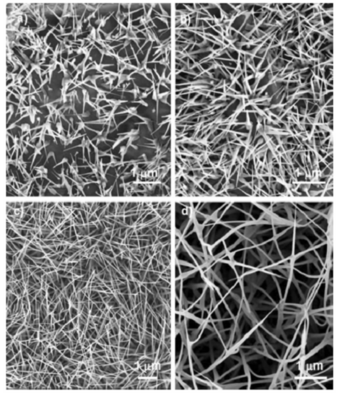

Fig. 4. (a,b) Interconnection types of ZnO nanowires in the nano-network. (c,d) Bright-field and dark-field TEM images of two nanowires interconnected with each other, indicating that the two nanowires are single crystals but they have no orientation relationship. The circle area is used for recording the selected area electron diffraction pattern (inset).

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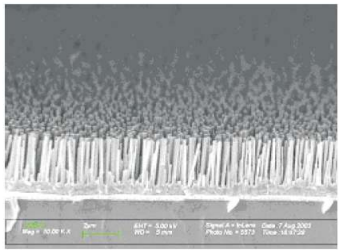


Figure 3. $Si/SiO_2/Ti/Pt/ZnO$/Nanowire.

Tamkang Journal of Science and Engineering, Vol. 7, No 3, pp. 135–138 (2004) 135

Growth and Patterning of ZnO Nanowires on Silicon and $LiNbO_3$ Substrates

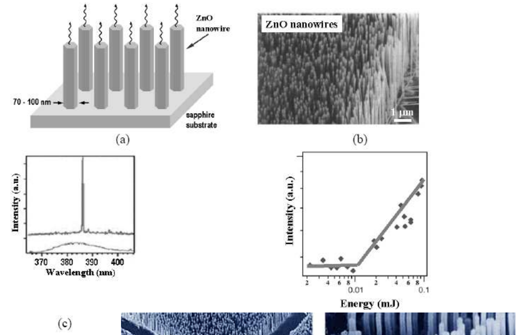
T. K. Shing*, H. H. Pan, I.-C Chen and C. I. Kuo

Druty

42 Int. J. of Nanotechnology, Vol. 1, Nos. 1/2, 2004

Nanolasers: Lasing from nanoscale quantum wires

Samuel S. Mao



Laserowanie bez wnęki (t.j. sam nanodrut jest dla siebie wnęką!)

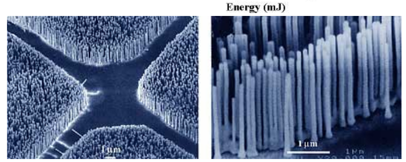
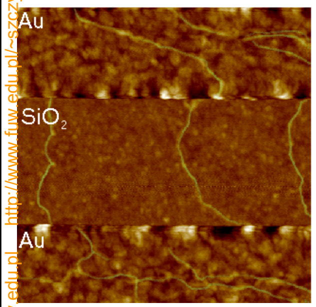
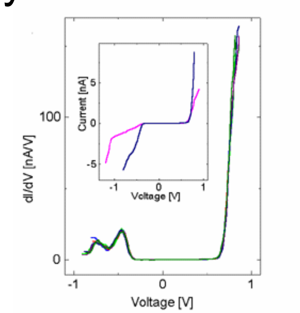


Photo by Peidong Yang/UC Berkeley, courtesy of *Science*

Druty

Jacek Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko



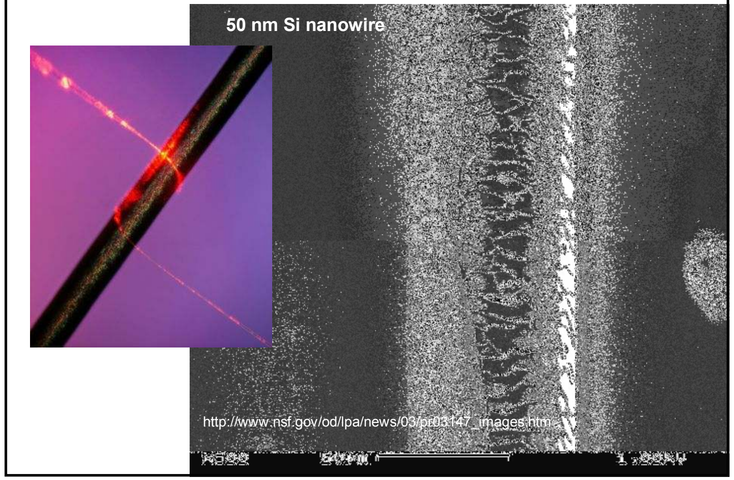


Conductance measurements on lambda DNA fragements

Fragments of lambda DNA with a length of 1.5 micron (4500 base pairs) were deposited on gold electrodes spaced by about 250 nm. By AFM imaging single DNA molecules were found between the electrodes. The measured resistance between the electrodes was found to be larger than 200 GOhm. Below is an AFM image of DNA over gold electrodes.

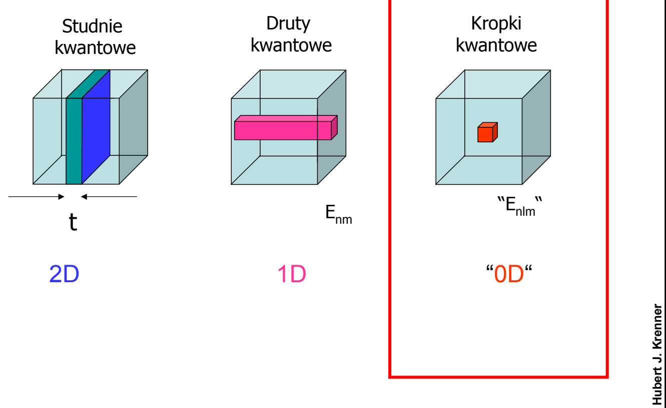
D. Porath, A. Bezryadin, S. de Vries, and C. Dekker *Direct measurement of electrical transport through DNA molecules* Nature 403, 635 (2000)

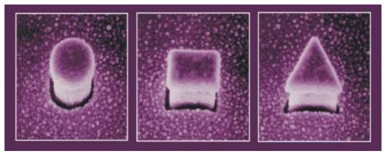
Druty



Struktury niskowymiarowe

Low-dimensional Semiconductor Systems





http://qt.tn.tudelft.nl/research/qdots/

Kropki

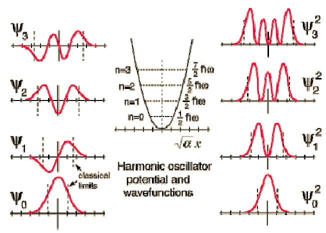
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

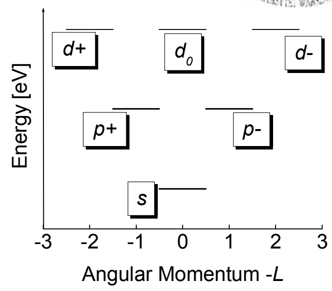
- Co to są Kropki Kwantowe - Quantum Dots (QD)
- W jaki sposób je się wytwarza
  - Nanotechnologia
  - Samoorganizujące się Kropki Kwantowe (Self-assembled Quantum Dots)

Textbook:
"Mesoscopic region in a semiconductor surrounded by higher band gap material"

- Pełna kwantyzacja stanów
- gęstość stanów funkcji δ Diraca
- Wąskie widma spektralne w emisji i absorpcji
- „Sztuczne atomy" - "Artificial Atoms"

Kropki kwantowe - lokalizacja w płaszczyźnie wzrostu





$$V_\beta(x,y)=\frac{1}{2}m_\beta^*\omega_\beta^2(x^2+y^2)$$

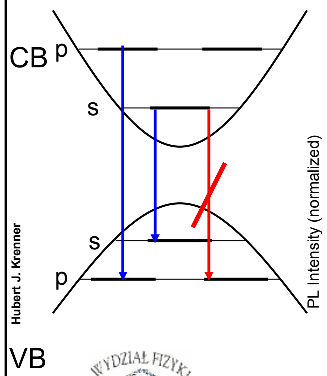
gdzie, β = *e*, *h*

$$E_{\beta,n,m}=\hbar\varpi_\beta(n+\frac{1}{2})+\hbar\varpi_\beta(m+\frac{1}{2})$$

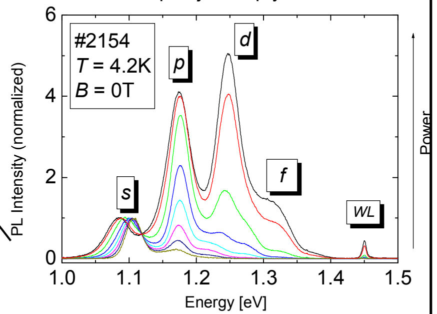
$n, m = 0,1,2...$
$L = n - m$ (elektron)

Adam Babiński

Kropki kwantowe – sztuczne atomy

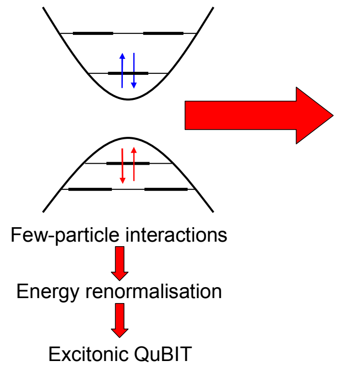


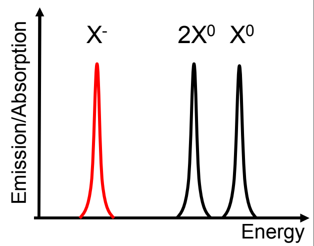
Model oscylatora harmonicznego:
- powłoki s-, p-, d-,…
- Dozwolone przejścia optyczne

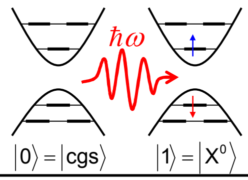


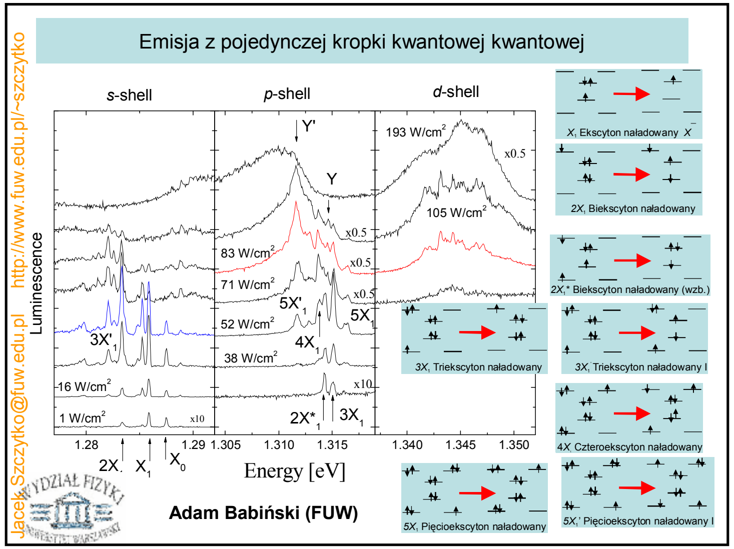
Luminescencja z dużego zbioru QDs
w funkcji mocy pobudzania (l_{exc}=514.5 nm)

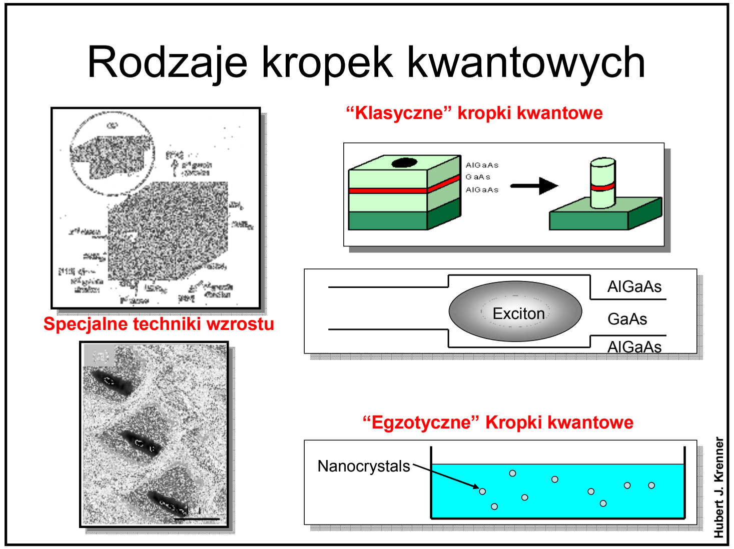
Oddziaływania wielociałowe

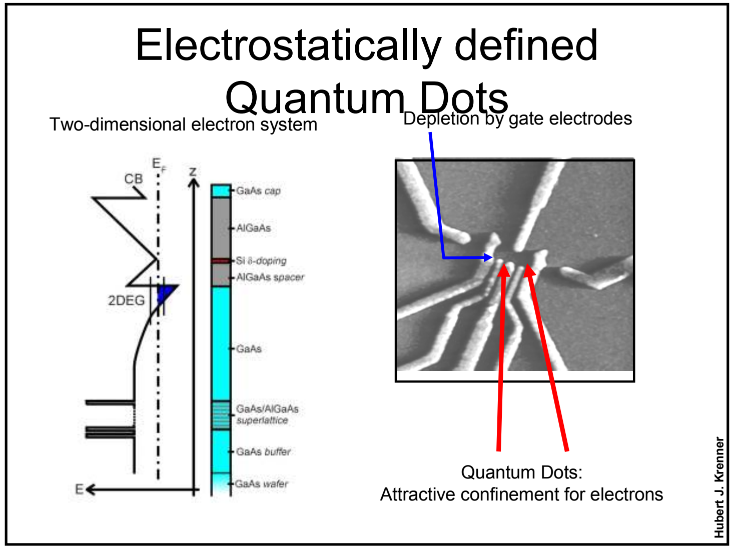


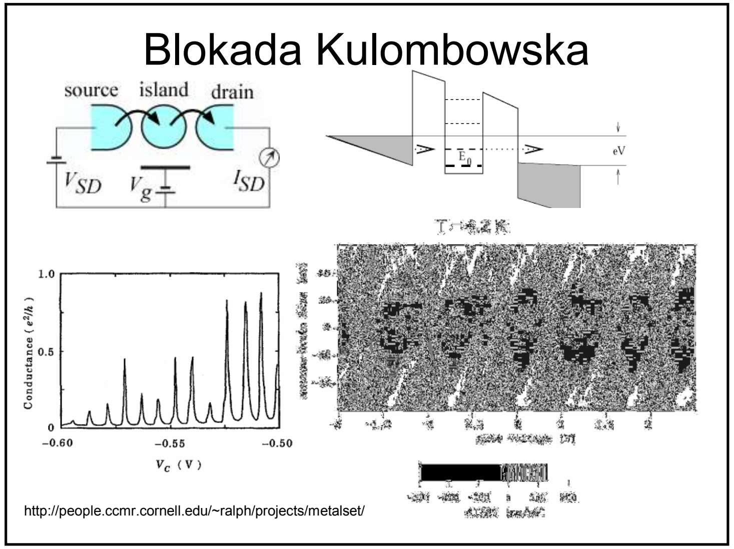





Emisja z pojedynczej kropki kwantowej kwantowej
s-shell
p-shell
d-shell
Luminescence
Energy [eV]
193 W/cm2
105 W/cm2
83 W/cm2
71 W/cm2
52 W/cm2
38 W/cm2
16 W/cm2
1 W/cm2
X, Ekscyton naładowany
2X, Biekscyton naładowany
2X,* Biekscyton naładowany (wzb.)
3X, Trieksyton naładowany
4X Czteroekscyton naładowany
5X, Pięcioeksyton naładowany
Adam Babiński (FUW)
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko


Rodzaje kropek kwantowych
"Klasyczne" kropki kwantowe
Specjalne techniki wzrostu
AlGaAs
GaAs
AlGaAs
Exciton
"Egzotyczne" Kropki kwantowe
Nanocrystals
Hubert J. Krenner

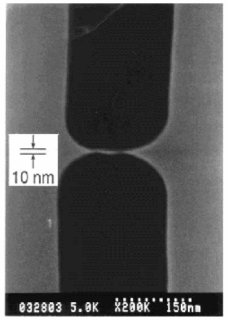

Electrostatically defined Quantum Dots
Two-dimensional electron system
Depletion by gate electrodes
CB
E_F
z
2DEG
E
GaAs cap
AlGaAs
Si δ-doping
AlGaAs spacer
GaAs
GaAs/AlGaAs superlattice
GaAs buffer
GaAs wafer
Quantum Dots:
Attractive confinement for electrons
Hubert J. Krenner


Blokada Kulombowska
source
island
drain
V_SD
V_g
I_SD
eV
Conductance (e²/h)
V_G (V)
http://people.ccmr.cornell.edu/~ralph/projects/metalset/

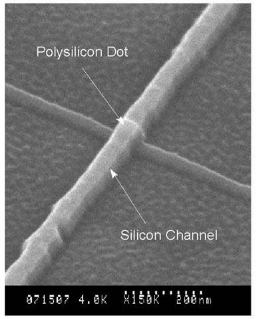
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Kropki

Silicon Single Electron Transistor
(After Gate Oxidation)

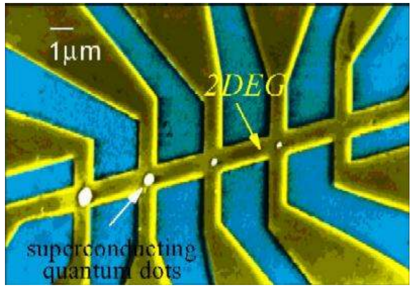


Silicon Single Electron MOS Memory
(Before Oxidation)



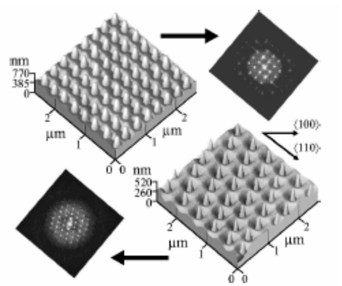
NanoStructure Lab
UNIVERSITY OF MINNESOTA

Kropki



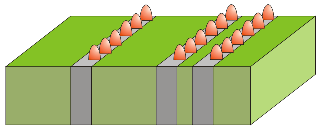
A series of superconducting aluminum disks (0.1 to 2 microns in size) sit on top of a semiconducting structure. Buried beneath the spots where the strips cross are tiny realms in which electrons, constituting 2-dimensional electron gases (2DEG), are sensitive to the magnetization of the disks above. In this way the size-dependent properties of superconductors no bigger than a Cooper pair (the electron doublets that form inside superconductors) can be studied.

Positioning Quantum Dots – Patterned Substrate

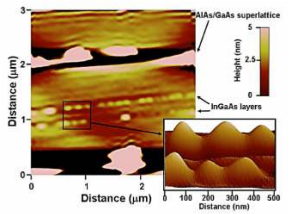


Zhong *et al.*, APL **84**, 1922 (2004)

Lithographycally defined Diffusion

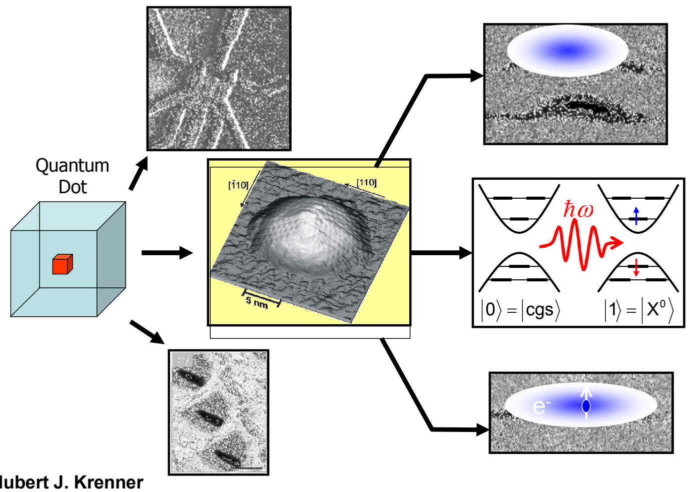


MBE defined
Diffusion or Strain
Jochen Bauer



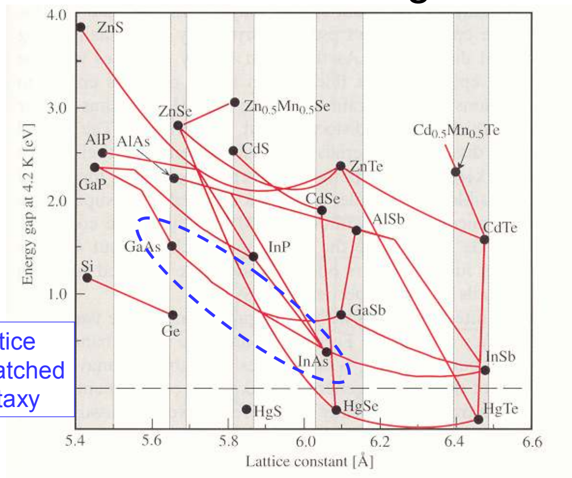
Wasserman *et al.*, APL **85**, 5352 (2004)

Hubert J. Krenner



Hubert J. Krenner
Walter Schottky Institut and Physik Department E24, TU München

Lattice mismatched growth

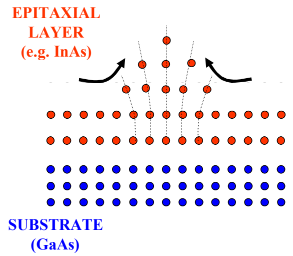


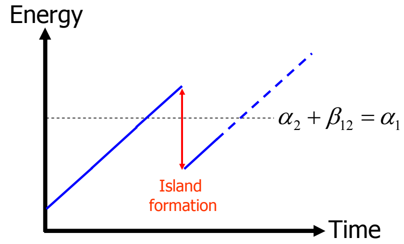
Lattice Mismatched Epitaxy

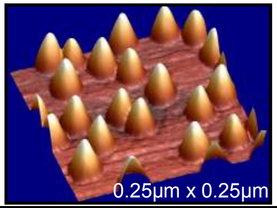
Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

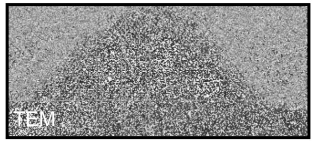
Hubert J. Krenner

Wzrost kropek kwantowych





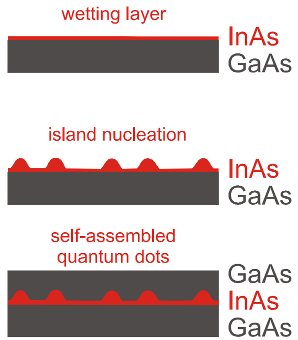


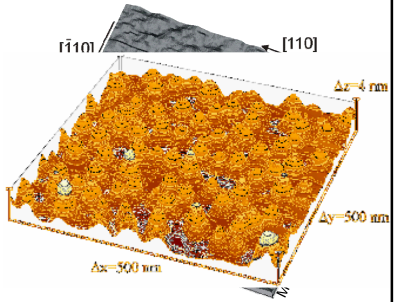


- Defect-free semiconductor "clusters" on a 2D quantum well wetting layer

Hubert J. Krenner

Self-Assembled Quantum Dots





In(Ga)As on GaAs: ~7% lattice mismatch

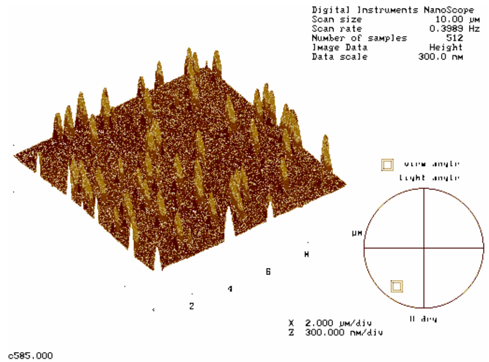
Stranski-Krastanov growth mode

Inhomogeneity

Goldstein et al., APL **47**, 1099 (1985)

Hubert J. Krenner

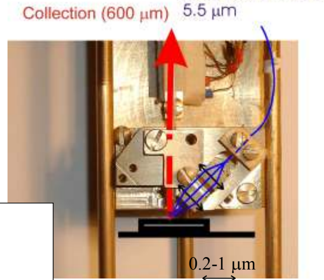
GaN/AlGaN QD's



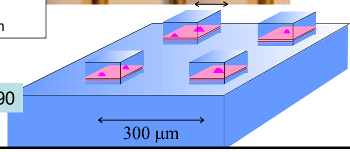
Wzrost – K. Pakuła, AFM - Rafał Bożek

Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko

Doświadczenie



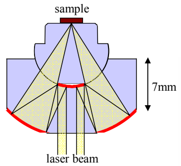
T=300K
Minimum step~50 nm
Maximum step ~1 μm
T=4.2K
Minimum step~5 nm
Maximum step ~100 nm

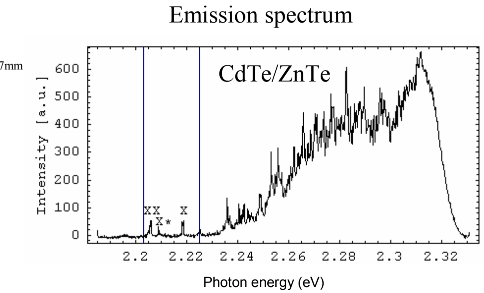


A.Babinski, et al. Physica E 26 (2005) 190

FUW Hoża 69

Access to individual QDs





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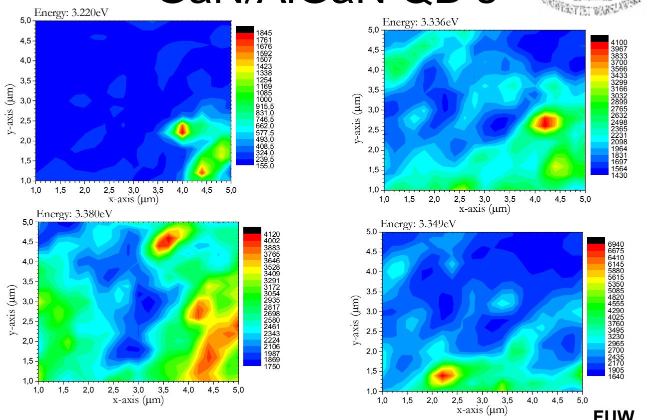
Hoża 69

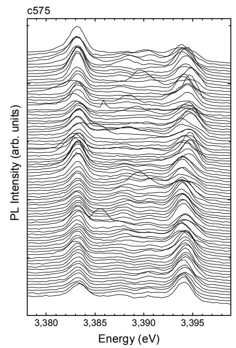
GaN/AlGaN QD's

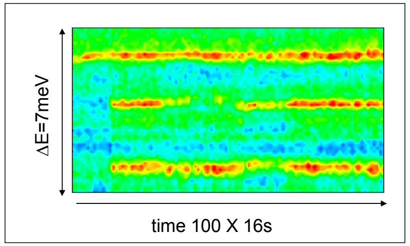


μPL- Barbara Chwalisz et al.

FUW
Hoża 69

GaN/AlGaN QD's





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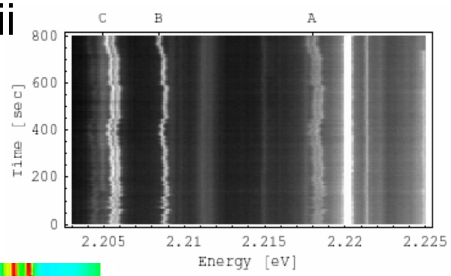
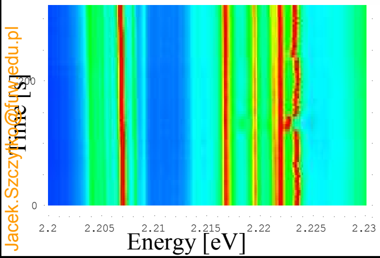
Hoża 69

μPL- Katarzyna Surowiecka et al.

Skoki energii

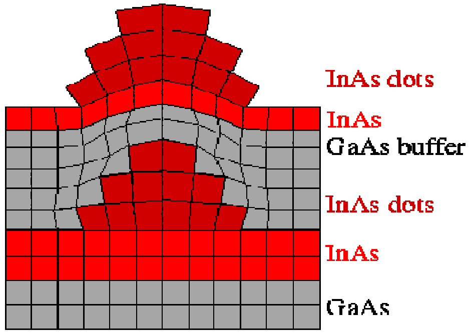
Pomagają znaleźć przejścia z tej samej kropki





prof. J. Gaj
A. Kudelski *et al.*, 2005

Sztuczne molekuły

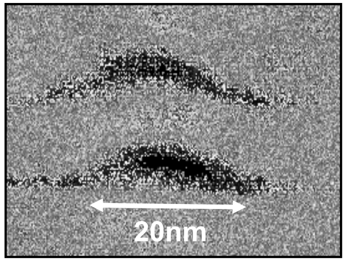


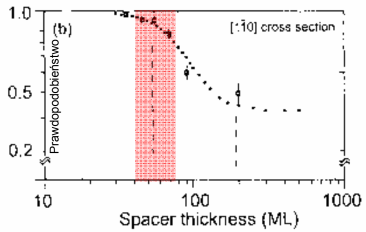
Hubert J. Krenner

Strain-driven self-alignment

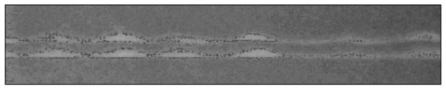
Nominal 10nm barriers

High pairing probability





Xie *et al.*, PRL **75**, 2542 (1995)



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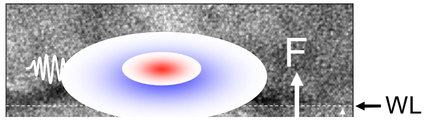
Excitonic quantum BITs



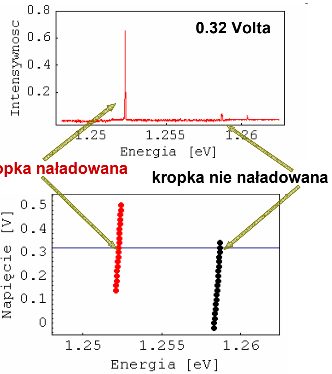
- Excitons represent QuBITs
- Optical generation by optical pulses
- Electric field tunes QuBIT interactions

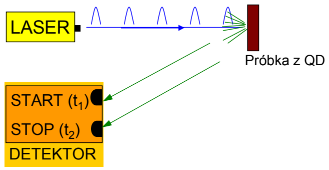
A. Barenco *et al.*, PRL **74**, 4083 (1995), E. Biolatti *et al.*, PRL **85**, 5647 (2000), F. Troiani *et al.* PRB **62**, (R)2263 (2000), Zrenner *et al.*, Nature **418**, 612 (2002), M. Bayer *et al.*, Science **291**, 451 (2001), X. Li *et al.*, Science **301**, 809 (2003)

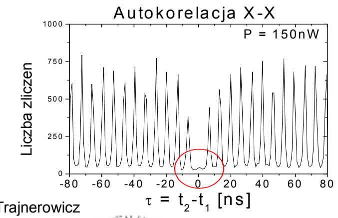
Hubert J. Krenner

Kropki kwantowe

- „elektron na żądanie”
- „foton na żądanie”







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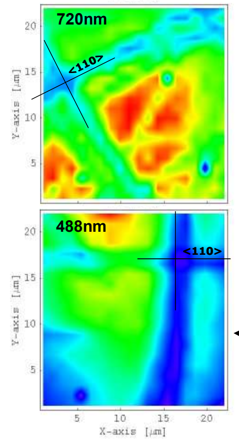
mgr B. Piechal
M. Goryca
T. Kazimierczuk

Studnie kwantowe

μ-fotoluminescencja

pobudzanie „w” studni



pobudzanie „powyżej” studni

nieostry obraz dyfuzja nośników

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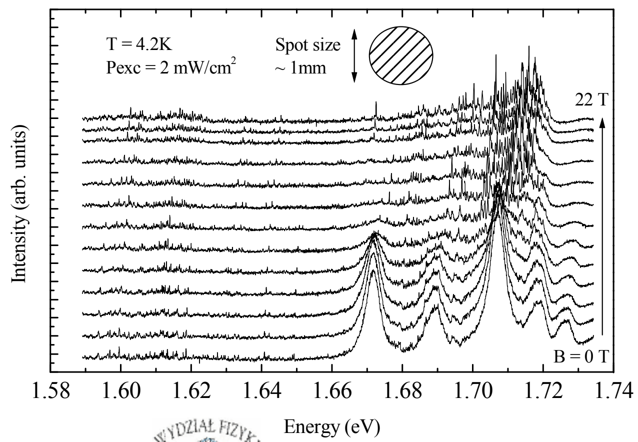
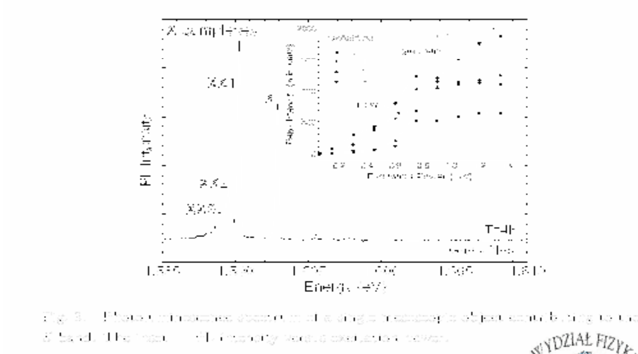
mgr K. Kowalik
mgr W. Pacuski
mgr A. Trajnerowicz
mgr B. Piechal
M. Goryca
T. Kazimierczuk



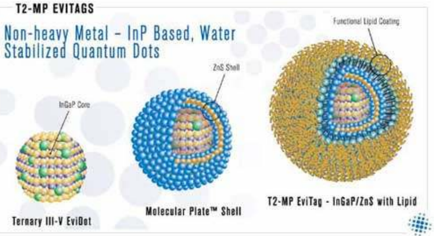
Andrzej Wysmołek et al.

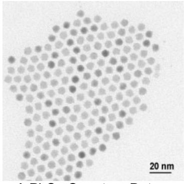
GaAs/AlAs „lakes”



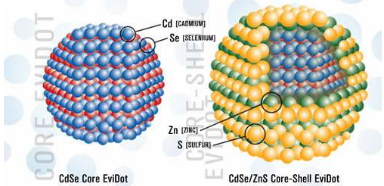
μPL- Barbara Chwalisz et al.

Kropki kwantowe + bio



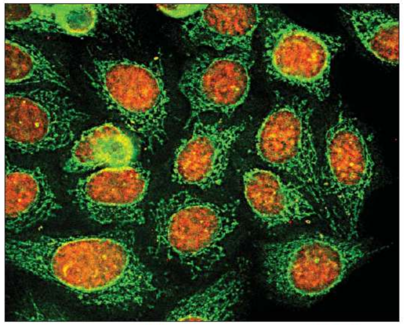


A PbSe Quantum Dot as seen through a transmission electon microscope (TEM).



http://www.evidenttech.com/

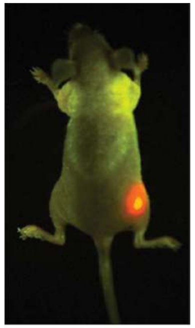
Kropki kwantowe + bio



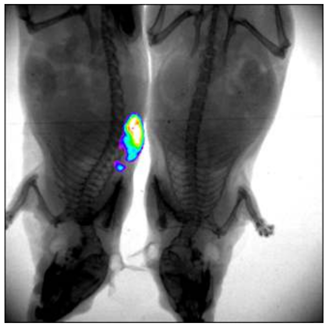
Double duty. Green quantum dots cling to mitochondria in the cytoplasm; orange ones label proteins in the same cells' nuclei.

Science, Vol 300, Issue 5616, 80-81 , 4 April 2003

Kropki kwantowe + bio

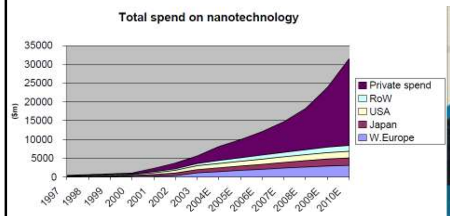


Bull's-eye. Red quantum dots injected into a live mouse mark the location of a tumor.

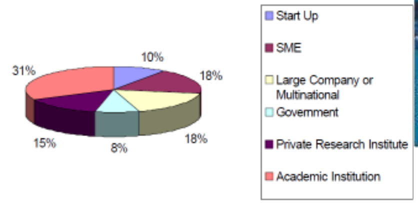


Science, Vol 300, Issue 5616, 80-81 , 4 April 2003

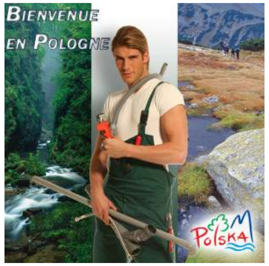
Nanotechnologie



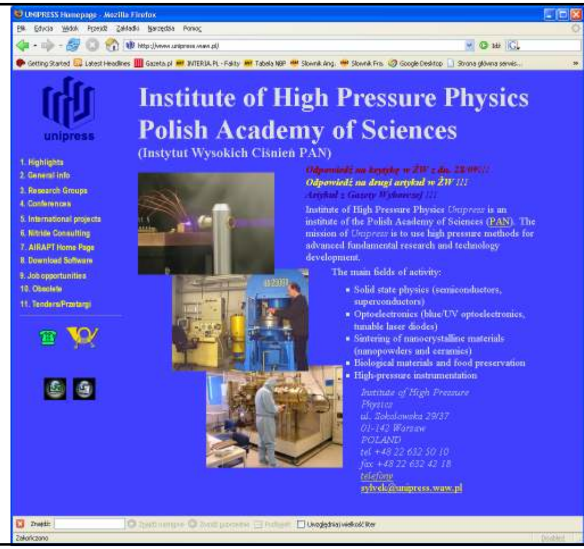
Type of company or institution



Jacek.Szczytko@fuw.edu.pl http://www.fuw.edu.pl/~szczytko



TERAZ POLSKA



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Niebieskie lasery są ciągle bardzo drogie – 2000 USD/sztukę !

4.1 Manufacturers of Laser Diode Chips

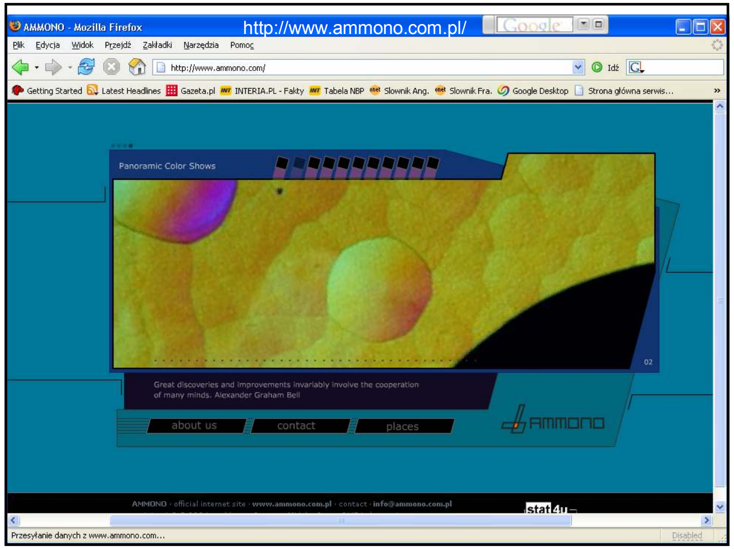
4.1.1 Cree, USA
4.1.2 Matsushita, Japan
4.1.3 NEC, Japan
4.1.4 Nichia, Japan
4.1.5 Osram Opto Semiconductors, Germany
4.1.6 Pioneer, Japan
4.1.7 Rohm, Japan
4.1.8 Samsung, Korea
4.1.9 Sanyo Electric, Japan
4.1.10 Sharp, Japan
4.1.11 Sony, Japan
4.1.12 TopGaN, Poland
4.1.13 Toshiba, Japan
4.1.14 Toyoda Gosei, Japan

Strategy Analytics

March 2004

http://www.strategyanalytics.com/

Czesław Skierbiszewski *UNIPRESS*



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Podziękowania

Zakład Fizyki Ciała Stałego http://www.fuw.edu.pl/~zfcs/
prof. dr hab. M. Baj

WYDZIAŁ FIZYKI UNIWERSYTET WARSZAWSKI

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dr M. Potemski (GHMFL)
prof. R. Stępniewski
Prof. M. Baj
dr hab. D. Wasik
dr J. Siwiec

Spektroskopia ultraszybka

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dr hab. A. Golnik,
M. Goryca,
T. Kazimierczuk,
dr P. Kossacki,
K. Kowalik,
W. Maślana,
W. Pacuski,
B. Piechal,
J. Suffczyński,
A. Trajnerowicz

Kropki Kwantowe: $GaN/Al_xGa_{1-x}N$

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mgr K. Pakuła
mgr R. Bożek
mgr K. Surowiecka
dr A. Wysmołek
mgr B. Chwalisz
prof. J. Baranowski
dr K. Kossacki
dr K. Korona
dr hab. A. Golnik

Promieniowanie THz

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dr Krzysztof Karpierz,
mgr Maciej Sakowicz,
prof. dr hab Marian Grynberg

Spintronika

prof. dr hab Maria Kamińska
prof. dr hab Andrzej Twardowski
dr Jacek Gosk
dr Jacek Szczytko,
mgr Konrad Dziatkowski,
mgr Marcin Zając

W następnym tygodniu:

Nanotechnologia III i IV

1. Miniaturyzujemy III.
   a. Nanorurki
      i. Wegiel i nie tylko
      ii. Pokręcone zasady
2. Nanomaszyny