

EAgLE

European Action towards Leading Centre
for Innovative Materials

FP7-REGPOT-2012-2013



EAgLE

European Action towards Leading Centre
for Innovative Materials



Research and nanotechnology in the Institute of Physics PAS



IF PAN



On October 17, 2013 the Institute of Physics of the Polish Academy of Sciences celebrated of the 60th anniversary of its foundation



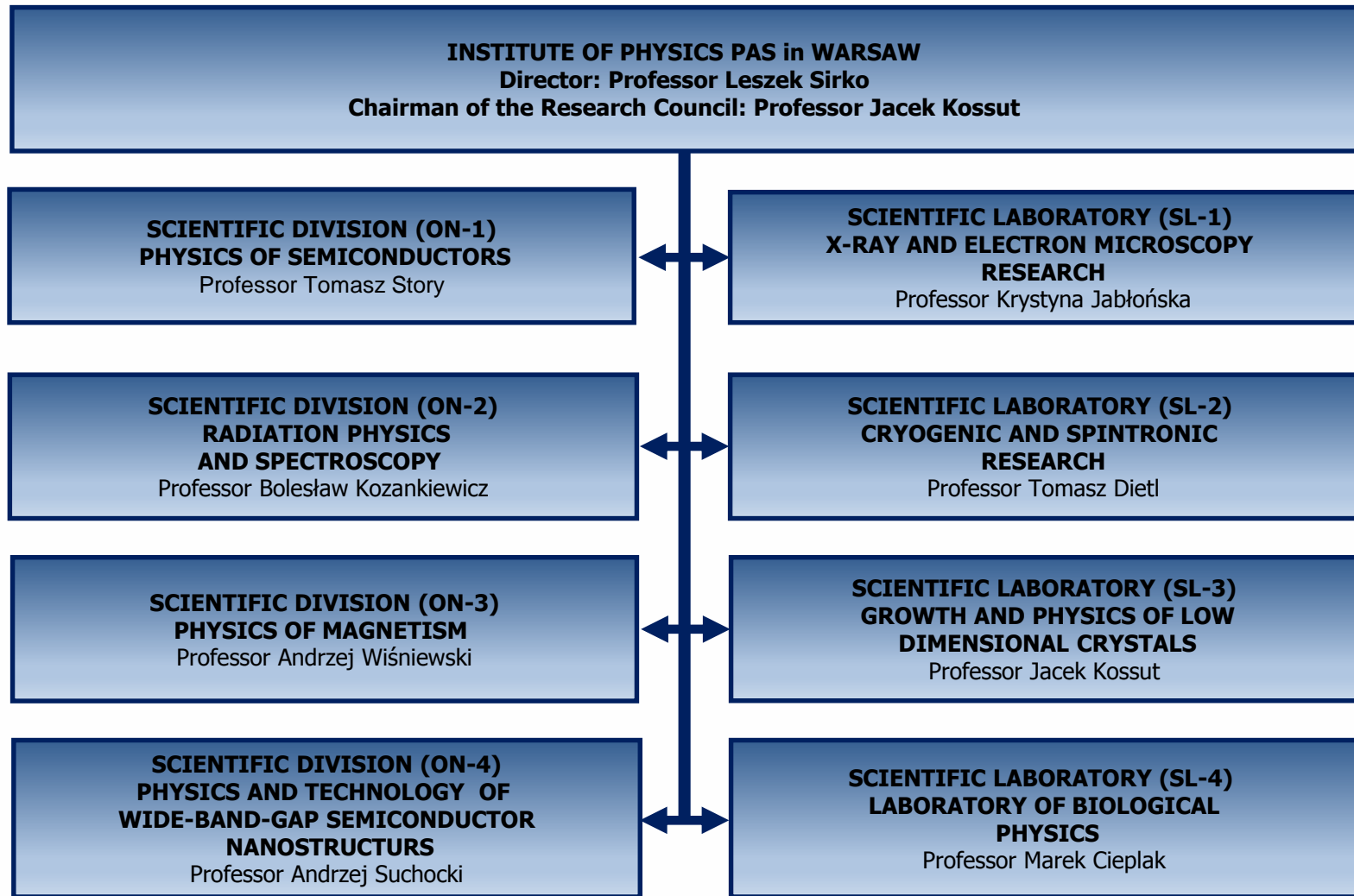
President's Minister Henryk Wujec



The celebration was organized under honorary patronage of the President of the Republic of Poland Bronisław Komorowski



Structure of IF PAN



Employment in 2014

Number of employees of IP PAS (31.12. 2014):

Number of employees: **385**

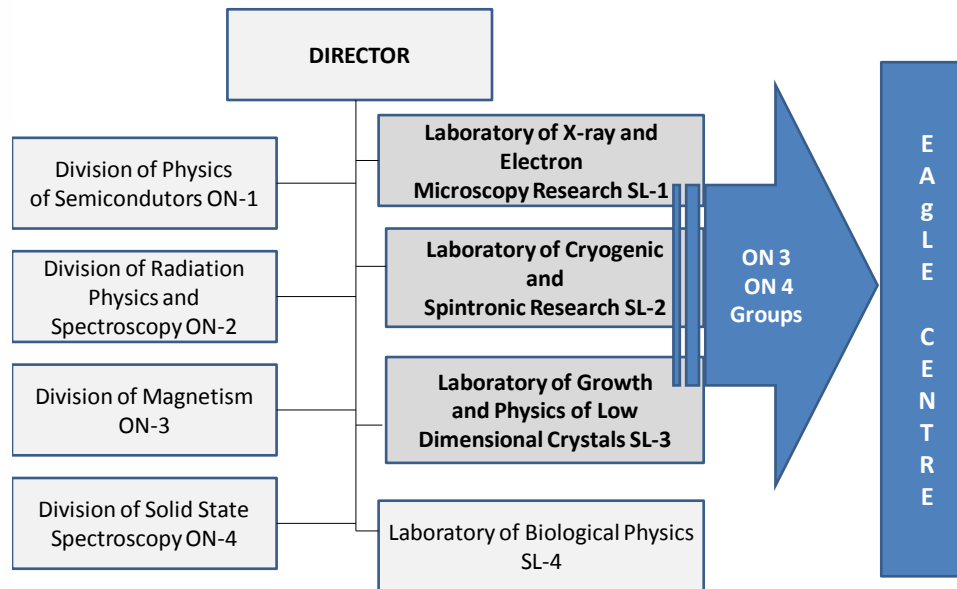
- **Professors:** **46**
- **Associate Professors:** **26**
- **Assistant Professors:** **71**
- **Visiting Professors:** **1**

Number of Ph.D. students in the International Post-Graduate Studies of the Polish Academy of Sciences: 68



The EAgle staff

The EAgle staff includes **94 members with 11 Professors, 13 Associate Professors and 37 PhD holders** selected from research groups located in 3 Laboratories and 2 Divisions within the organisational scheme of IF PAN.



Objectives of the EAgLE Project

The EAgLE Project is implemented by pursuing five objectives which are in line with the requirements of the RegPot-2012-2013 -1 call:

Objective 1

Enhancement of human capacity through twinning activities with leading European research centres, also in the emerging now R&D areas, the recruitment of experienced researchers, organization of and participation in workshops, and topical conferences.

Objective 2

Enhancement of technical capacity via the purchasing of new equipment and upgrading the existing facilities in the EAgLE laboratories, by exploiting the capabilities of European large facilities, and by developing appropriate theoretical and computational tools.

Objectives of the EAgLE Project, cnt.

Objective 3

Fostering of the innovation and promoting cooperation with industry by identifying the market needs, evoking entrepreneur spirit, and developing IPR strategy within the IF PAN as well as by adapting laboratories, characterization protocols, and computational methods in order to deliver world-top expertise for industrial users.

Objective 4

Better integration in ERA by twinning activities with leading European research centres, organisation of focussed events, participation in international and European events, particularly foreseeing pan-European needs and project calls.

Objective 5

Increasing the visibility of the EAgLE capabilities and accomplishments through dissemination and promotion activities among following stakeholders: industry, academia, regional and national authorities as well as public at large.

Budget and resources of the project

	Direct costs (Personnel; Other direct)	Subcontracting	Indirect costs 7% (reimbursed by EC)	Requestes EU contribution	Total Indirect costs	Total costs
WP 1	205 850,00 €	12 870,00 €	14 409,50 €	233 129,50 €	41 170,00 €	259 890,00 €
WP 2	929 800,00 €	0,00 €	65 086,00 €	994 886,00 €	185 960,00 €	1 115 760,00 €
WP 3	1 091 400,00 €	17 208,00 €	76 398,00 €	1 185 006,00 €	218 280,00 €	1 326 888,00 €
WP 4	1 380 000,00 €	99 000,00 €	96 600,00 €	1 575 600,00 €	276 000,00 €	1 755 000,00 €
WP 5	472 640,00 €	17 488,00 €	33 084,80 €	523 212,80 €	94 528,00 €	584 656,00 €
WP 6	260 550,00 €	70 257,00 €	18 238,50 €	349 045,50 €	52 110,00 €	382 917,00 €
WP 7	84 150,00 €	3 000,00 €	5 890,50 €	93 040,50 €	16 830,00 €	103 980,00 €
Total:	<u>4 424 390,00 €</u>	<u>219 823,00 €</u>	<u>309 707,30 €</u>	<u>4 953 920,30 €</u>	<u>884 878,00 €</u>	<u>5 529 091,00 €</u>



Scientific activity in 2014

Published papers: 811, including:

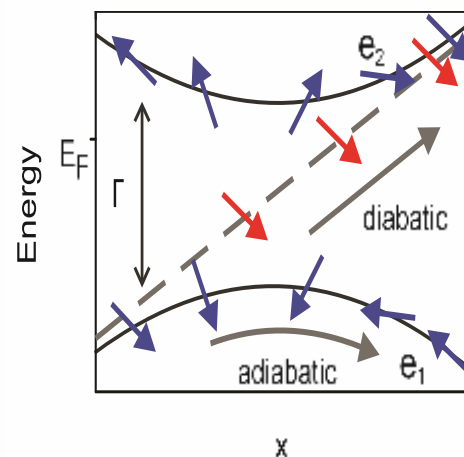
- Papers published in journals with “Impact Factors” > 0: 264
- Papers published in other journals: 52
- Monographs: 4
- Conference papers: 491



Spin-Transistor Action via Tunable Landau-Zener Transitions

C. Betthausen,¹T. Dollinger,²H. Saarikoski,²V. Kolkovsky,³G. Karczewski,³
T. Wojtowicz,³K. Richter,²D. Weiss^{1*}

Spin-transistor designs relying on spin-orbit interaction suffer from low signal levels resulting from low spin-injection efficiency and fast spin decay. Here, we present an alternative approach in which spin information is protected by propagating this information adiabatically. We demonstrate the validity of our approach in a cadmium manganese telluride diluted magnetic semiconductor quantum well structure in which efficient spin transport is observed over device distances of 50 micrometers. The device is tuned "off" by introducing diabatic Landau-Zener transitions that lead to a backscattering of spins, which are controlled by a combination of a helical and a homogeneous magnetic field. In contrast to other spin-transistor designs, we find that our concept is tolerant against disorder.

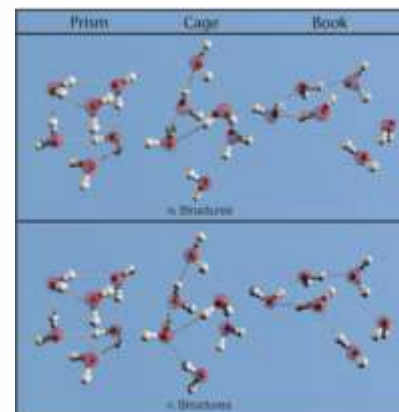


Structures of Cage, Prism, and Book

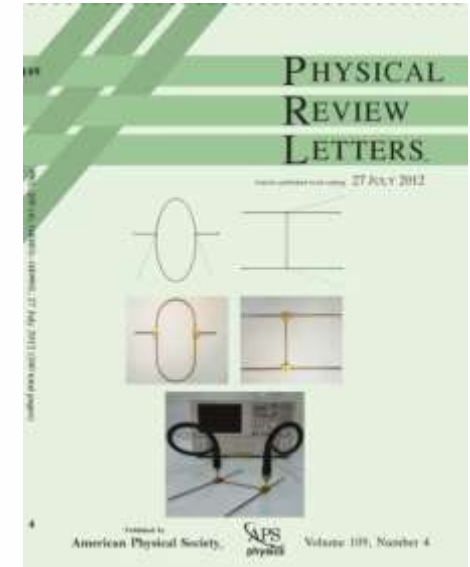
Isomers of Water Hexamer from Broadband Rotational Spectroscopy

Cristóbal Pérez,¹Man T. Muckle,¹Daniel P. Zaleski,¹Nathan A. Seifert,¹Berhane Temelso,²
George C. Shields,^{2*}Zbigniew Kisiel,^{2*}Brooks H. Pate^{2*}

Theory predicts the water hexamer to be the smallest water cluster with a three-dimensional hydrogen-bonding network as its minimum energy structure. There are several possible low-energy isomers, and calculations with different methods and basis sets assign them different relative stabilities. Previous experimental work has provided evidence for the cage, book, and cyclic isomers, but no experiment has identified multiple coexisting structures. Here, we report that broadband rotational spectroscopy in a pulsed supersonic expansion unambiguously identifies all three isomers; we determined their oxygen framework structures by means of oxygen-18-substituted water (H_2^{18}O). Relative isomer populations at different expansion conditions establish that the cage isomer is the minimum energy structure. Rotational spectra consistent with predicted heptamer and nonamer structures have also been identified.



Oleh Hul, Michał Ławniczak, Szymon Bauch, Adam Sawicki, Marek Kuś,
and Leszek Sirko,
Are scattering properties of graphs uniquely connected to their shapes?
Phys. Rev. Lett. 109, 040402 (2012) .



PRL 109, 208101 (2012)

PHYSICAL REVIEW LETTERS

week ending
16 NOVEMBER 2012

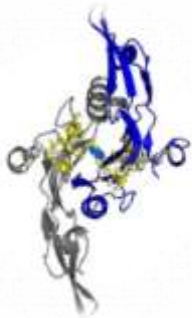
Cystine Plug and Other Novel Mechanisms of Large Mechanical Stability in Dimeric Proteins

Mateusz Sikora and Marek Cieplak[§]

Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland

(Received 3 April 2012; published 13 November 2012)

We identify three dimeric proteins whose mechanostability is anisotropic and should exceed 1 nN along some direction. They consist with distinct mechanical classes: either chain-based, or involving a cystine



nature
materials

LETTERS

PUBLISHED ONLINE 30 SEPTEMBER 2012 | DOI:10.1038/NMAT1740

Topological crystalline insulator states in $Pb_{1-x}Sn_xSe$

P. Dziawa¹, B. J. Kowalski¹, K. Dybko¹, R. Buczko¹, A. Szczerbakow¹, M. Szot¹, E. Łusakowska¹,
T. Balasubramanian², B. M. Wojek³, M. H. Berntsen³, O. Tjernberg^{3*} and T. Story^{1*}



Access to long-term optical memories using photon echoes retrieved from semiconductor spins

L. Langer¹, S. V. Polkaev^{1,2}, I. A. Yegorov¹, M. Salewski³, D. R. Yakovlev¹, G. Karczewski⁴, T. Wojtowicz¹, I. A. Akimov^{1,5} and M. Bayer¹

The ability to store optical information is important for both classical and quantum communications. Achieving this in a comprehensive manner (converting the optical field into material excitation, storing this excitation, and releasing it after a controllable time delay) is greatly complicated by the many, often conflicting, properties of the material. More specifically, optical memories in semiconductor quantum structures with high oscillator strength are inevitably characterized by short excitations (lifetime limit, therefore, short optical memory). Here, we present a new experimental approach to stimulated photon echoes by transferring the information contained in the optical field into a spin system, where it is decoupled from the optical vacuum field and may persist much longer. We demonstrate this for an *n*-doped GaTe/CdMgTe quantum well, the storage time of which could be increased by more than three orders of magnitude, from the picosecond range up to tens of nanoseconds.

Photon echoes are amazing optical phenomena, in which resonant excitation of a medium by short optical pulses results in a delayed response in the form of a coherent optical flash. Since their first observation in ruby in 1964, photon echoes have been reported for many vapours¹, rare earth crystals² and semiconductors^{3–7}. Spontaneous (two-pulse) and stimulated (three-pulse) photon echoes have been demonstrated and used for studying the energy levels and coherent evolution of optical excitations^{8,9}. Although there is great interest in the application of photon echoes for quantum memories^{10,11}, photon echoes occur in an ensemble of oscillators with an inhomogeneous distribution of optical transitions, which are essential to provide high efficiency and large bandwidth, allowing for storage of multiple photons with high capacity. Current research efforts regarding photon echoes have mainly concentrated on rare earth crystals and atomic vapours with long storage times, which are crucial for the implementation of robust light-storage memories.

In the early stages of photon echo experiments, the spin level structure of ground and excited states was recognized to contribute to the formation of spontaneous and stimulated photon echo signals^{12–15}. If optically addressed states have orbital and/or spin angular momenta, then the splitting of these states by a magnetic field (the Zeeman effect) provides an additional degree of freedom for the control of photon echoes through optical selection rules^{16–17}. Moreover, coherent transfer from optical to spin excitations^{18,19} has been suggested to considerably extend storage times, as demonstrated for quasistatic systems with comparable optical and spin coherence times²⁰. However, coherent operations in spin systems cannot be performed faster than on nanosecond or even longer timescales due to the low oscillator strength of the optical transitions. Here, we demonstrate for a semiconductor that the shortest picosecond optical pulses and the weak transverse magnetic field applied in our experimental protocol are used to transfer of a slow-level optical excitation into a long-lived electron spin state. This allows stimulated photon echoes to be induced with high bandwidth on subpicosecond

timescales, exceeding the lifetime lifetime of the optical excitations by more than three orders of magnitude. We reveal two mechanisms leading to the extension of stimulated echo revival—coherent transfer and spin transfer—and show that, depending on the polarization configuration of the three resonant laser pulses, we are able to shuttle the optical field into a spin component that is decoupled either along or perpendicular to the magnetic field. The possibility of addressing of these spin components and, in particular also for one along the magnetic field, enables an approach highly appealing for future applications in memory devices.

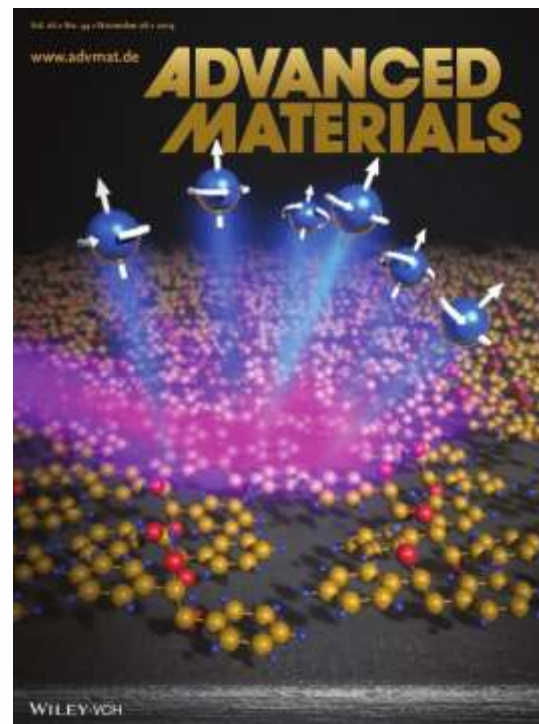
Photon echoes from trions in atom magnetic field

To demonstrate magnetic field-induced stimulated photon echoes we studied a semiconductor GaTe/CdMgTe quantum well, a model system that can be tailored for targeted applications at a atomic level by means of nanotechnology. The fundamental optical excitations in semiconductors—excitons—have large oscillator strength, so resonant absorption may be achieved with close to unity efficiency, even for structure thicknesses smaller than the light wavelength. Accordingly, propagation effects are not as important as in atomic vapours and rare earth crystals.

Ultrafast coherent spectroscopy of excitons employing laser pulses is well established for semiconductor nanostructures²¹. However, for storage applications, excitons have rarely been considered because of their limited optical coherence time T_2 due to their complex many-body interactions and their short radiative lifetime ($\tau \leq 1$ ns) (a downside of the large oscillator strength). In nanostructures such as quantum dots, the optical absorption is weak but still limited by radiative decay. Recently, theoretical approaches involving the long-living spin coherence of resident electrons have been pursued. Most such studies have focused on optical control of the spin, which tangles spin manipulations and requires an optical field²². The storage of trions in an optical field by encoding it in an ensemble of electron spins has not yet been addressed.

¹Supertechnische Physik 2, Technische Universität Darmstadt, 4602 Darmstadt, Germany; ²Saint-Petersburg State University, 191026 St. Petersburg, Russia; ³A.J. Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia; ⁴Institute of Physics, Polish Academy of Sciences, PL-02095 Warsaw, Poland; ⁵in email: i.a.akimov@tuebingen.de

Miguel Niño, Iwona Kowalik, Francisco Luque, Dimitri Arvanitis, Rodolfo Miranda and Juan de Miguel, *Enantiospecific Spin Polarization of Electrons Photoemitted Through Layers of Homochiral Organic Molecules*, *Advanced Materials* 26, 7474 (2014).



Division of Molecular and Condensed Matter Physics,
Uppsala University, Sweden



Physics Faculty, TU Dortmund University, Germany

Research projects in 2014

<u>All together:</u>	140
- Statute projects:	24
- Individual grants from the Ministry of Science and Higher Education:	76
- Projects from the Programme Innovative Economy (POIG):	6
- Foundation for Polish Science:	5
- Supplementary grants from MSHE:	4
- International research projects:	4
- Other projects:	18



International collaboration in 2013 – 2014

(WP2,WP6)

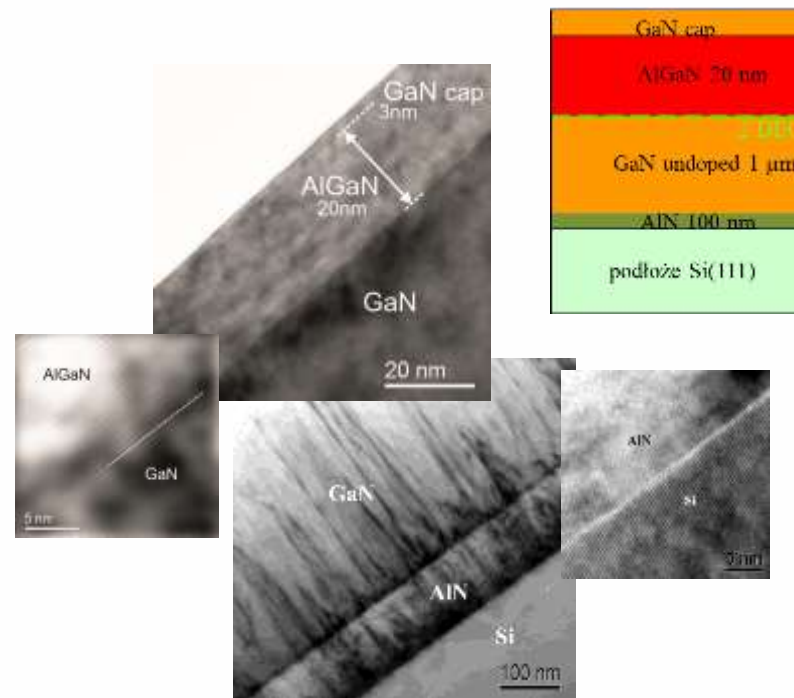
	2013		2014	
	all	EAgLE	all	EAgLE
Scientific visits to IF PAN	81	29	146	94
Visits to other Institutions	348	14	448	69

Fabrication of new materials



Double reactor MBE machine for the growth of ZnO and GaN heterostructures

HEMT AlGaN/GaN structures for application in microelectronics and biological sensors



Grown in the group of Prof. Z. Żytkiewicz

Atomic Layer Deposition reactors



Coating specifications:

- max. substrate size: \varnothing 10 cm
- max. substrate height: **0.6 cm \rightarrow 6 cm**
- growth speed: \sim **0.01 nm/s**

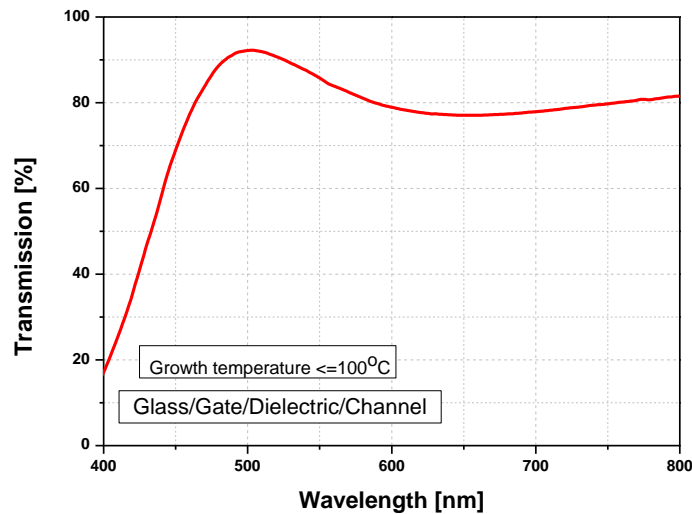
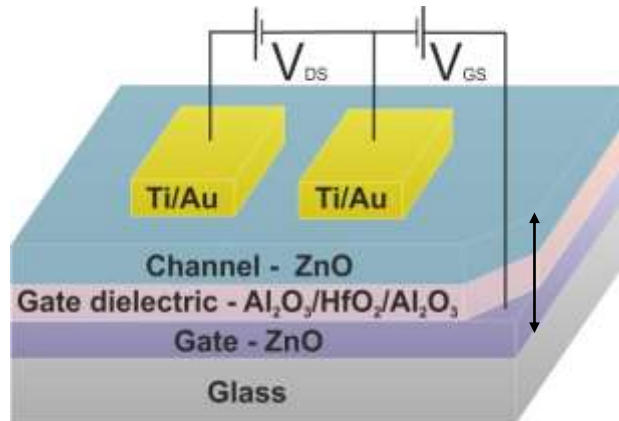


Coating specifications:

- max. substrate size: \varnothing 20 cm
- max. substrate height: **0.3 cm**
- growth speed: **0.04-0.08 nm/s**

Thin Film structures grown by ALD

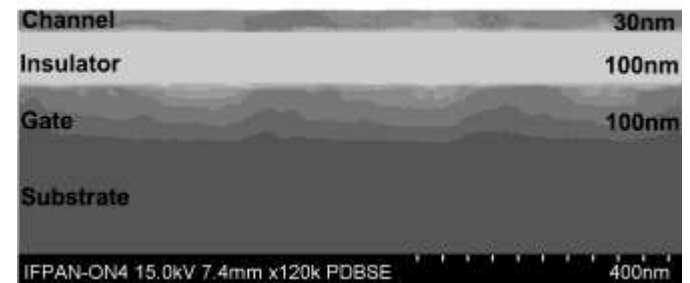
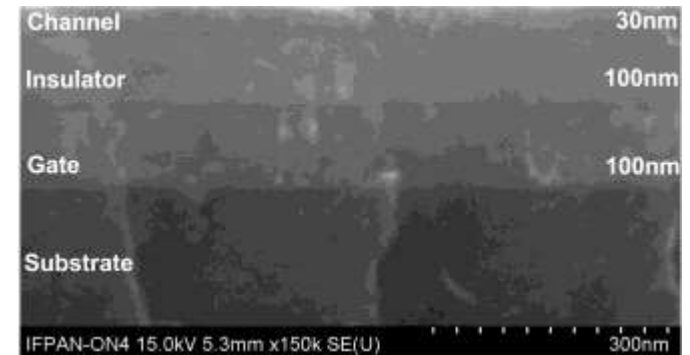
Thin Film Transistor deposited on transparent substrate



Optical transmission spectra

Atomic Layer Deposition

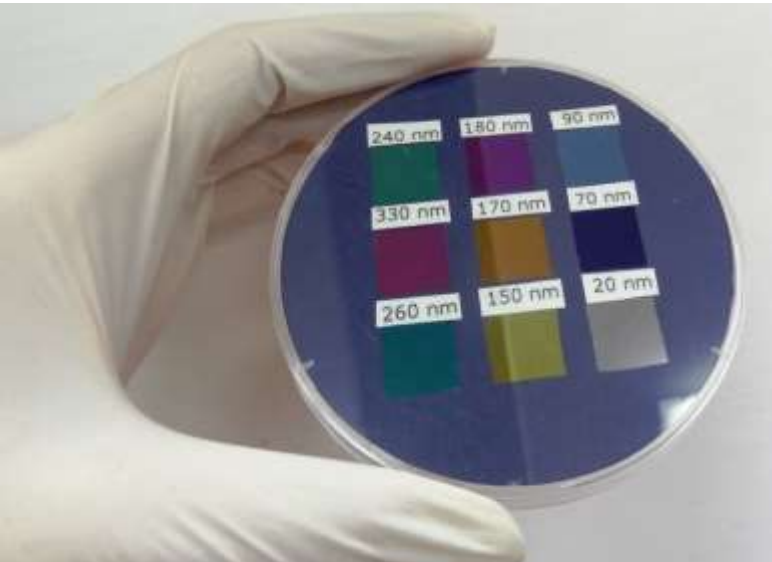
Growth temperature: $\leq 100^\circ\text{C}$



Cross-section SEM image of ZnO-TFT with high-k gate dielectric

Transmission average: $\sim 85\%$

Properties of oxide layers grown by ALD

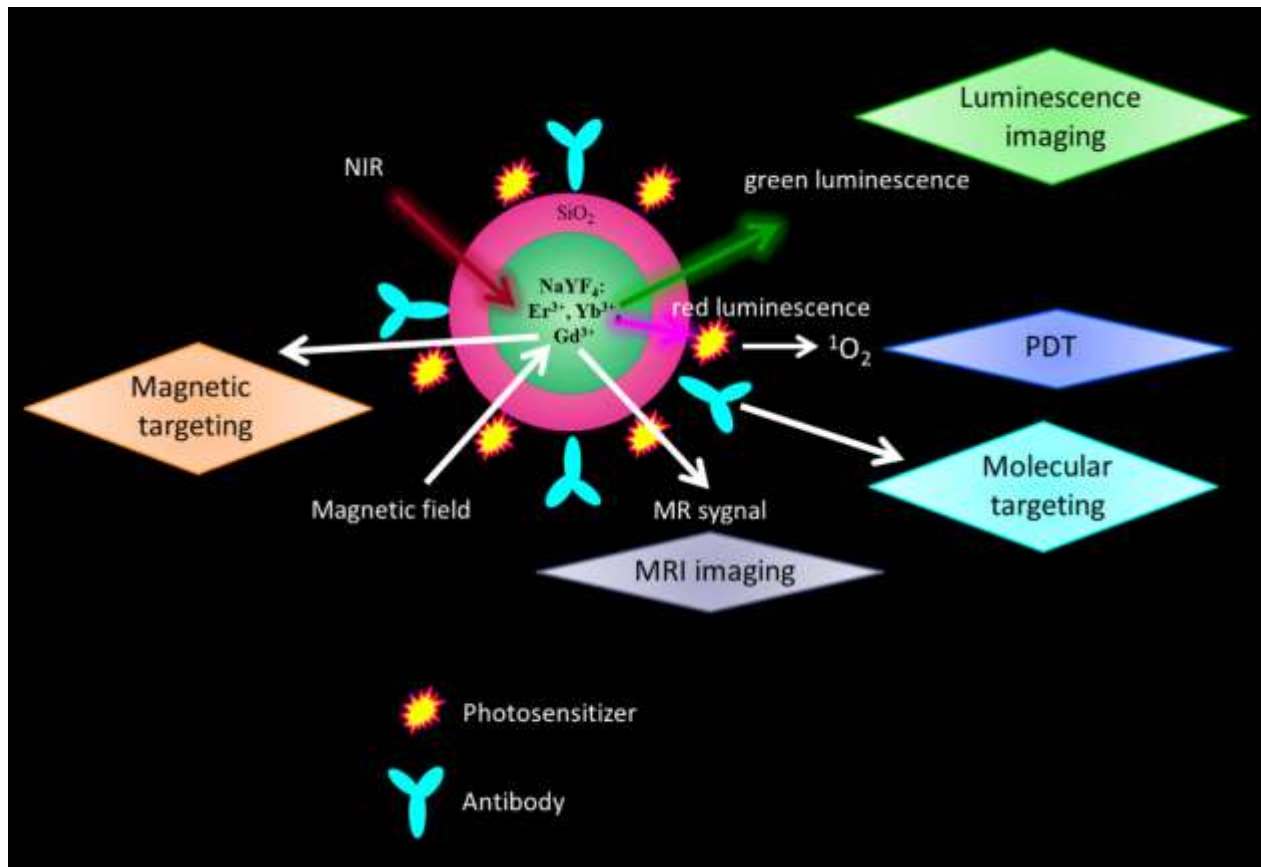


Oxide films with different thickness on Si

Properties of our oxide thin films:

- Uniformity of coatings
- Color (aesthetic properties)
- Antibacterial properties
- Average transmission in visible spectra: > 80%
- Hydrophobic properties
- Protective coatings (external factors, corrosion, oxidation)

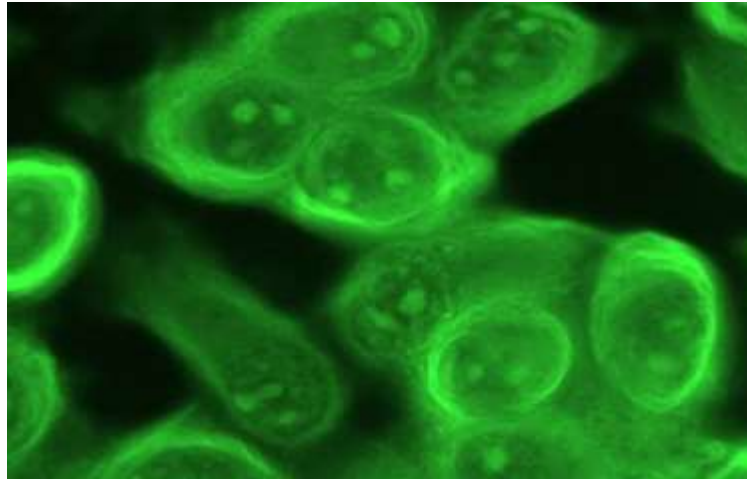
Multifunctional upconverting nanoparticles



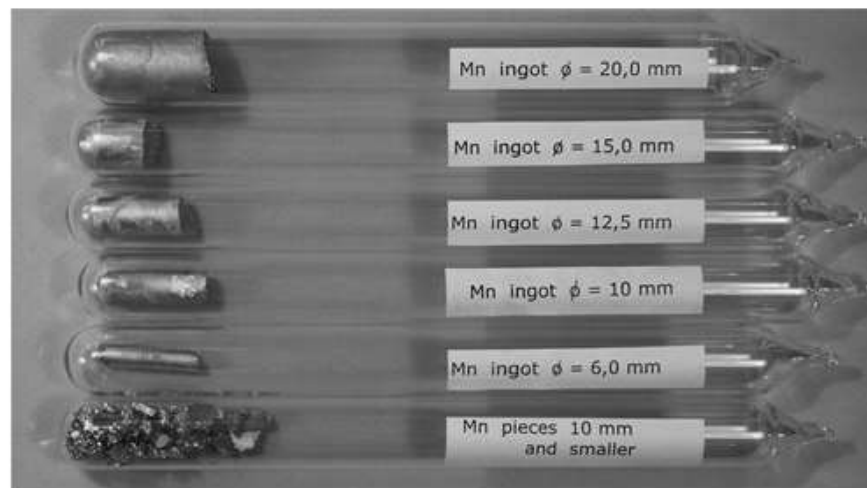
Upconverting nanoparticles synthesised in the group of prof. Danek Elbaum

Core-shell ZnO/MgO quantum dots

synthesis by sol-gel method



HeLa Cells labelled with ZnO/MgO quantum dots (biosensors)
Fluorescence Microscopy: Ext- 340 nm, Em-540 nm.



ULTRAPURE MANGANESE ${}_{25}\text{Mn}^{54.996}$ (m5N8; t5N7)*

FOR MBE AND OTHER SEMICONDUCTOR TECHNOLOGIES

NEW METHOD OF PURIFICATION** - particularly effective for removal of oxygen, carbon and sulfur contaminants

RESULTS OF ANALYSES by the atomic absorption spectroscopy and the spark source mass spectrometry (in ppm):

Li < 0.05	Na < 0.03	P < 0.1	Ca < 0.08	Cu < 0.2
B < 0.01	Mg < 0.06	S < 0.07	Cr < 0.08	Zn < 0.2
C < 0.1	Al ≈ 0.5	Cl < 0.1	Fe < 0.5	
F < 0.1	Si ≈ 0.8	K < 0.08	Ni < 0.1	

Available Products:

- Pieces 10 mm and smaller (see photograph)
- Ingots $\Phi = 6$, $\Phi = 10$, $\Phi = 12.5$, $\Phi = 15$, $\Phi = 17$ and $\Phi = 20$ mm and $20 \div 30 \pm 3$ mm length (see photograph)

Note: density of Mn is $\approx 7.4 \text{ g/cm}^3$

ALL PRODUCTS are vacuum packed in glass ampoules to prevent oxidation

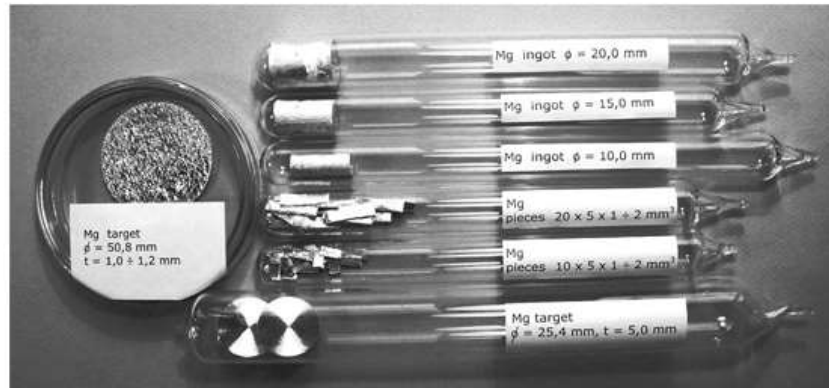
DELIVERY TIME for all products: 2-3 weeks. Note: a number of pieces ($\approx 50 \div 100$ g) are always in store, ready to dispatch immediately.

CONTACT: Prof. Andrzej MYCIELSKI
 Institute of Physics
 Polish Academy of Sciences
 Al. Lotników 32/46, 02-668 Warsaw, POLAND
 Fax: (+48 22) 843 09 26; Tel. (+48 22) 843 56 26
 e-mail: mycie@ifpan.edu.pl
<http://www.ifpan.edu.pl/ultrapure/>

* The prefix "m" indicates purity with respect to the metallic content only; the prefix "t" indicates purity with respect to all contaminants. "N" signifies a number of "9s".

** The author (A.M.) was nominated in 2000 to the Economic Prize of the President of the Republic of Poland.

The construction of the technological equipment for the purification processes has been financed in part by the Foundation For Polish Science.



ULTRAPURE MAGNESIUM ${}_{12}\text{Mg}^{24,312}$ (m6N; 15N8)*

FOR MBE AND OTHER SEMICONDUCTOR TECHNOLOGIES

NEW METHOD OF PURIFICATION AND PREPARATION**

particularly effective for removal of oxygen and metallic contaminants

RESULTS OF ANALYSES by the spark source mass spectrometry (in ppm):

Li < 0.02	Na ≈ 0.1 ± 0.05	P < 0.03	K ≈ 0.1 ± 0.05	Fe ≈ 0.1 ± 0.05
B < 0.02	Al ≈ 0.25 ± 0.05	S ≈ 0.07 ± 0.03	Ca ≈ 0.1 ± 0.05	Cu < 0.05
F < 0.03	Si ≈ 0.2 ± 0.1	Cl < 0.05	Mn < 0.05	Zn ≈ 0.2 ± 0.8

Available Products:

- Pieces ≈(10 x 20, 10 x 10, 10 x 5, ...) mm² plates, about 1-2 mm thick cut into pieces from bigger plates (see photograph)
- Ingots φ10 10±25 mm length (see photograph)
φ15, φ20 mm, and φ 25mm 20±30 mm length (see photograph)
- Targets φ = 25,4mm (1 inch) 3±10 mm thickness (see photograph)
φ = 50,8mm (2 inches) 1,0±1,6 mm thickness (see photograph)

Note that the density of Mg is 1.7 g/cm³

DELIVERY TIME for all products: 2-3 weeks.

Note: a number of pieces (≈ 10±20 g) are always in store, ready to dispatch immediately

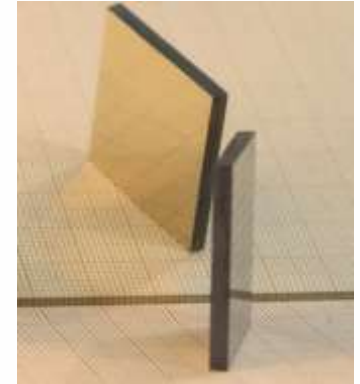
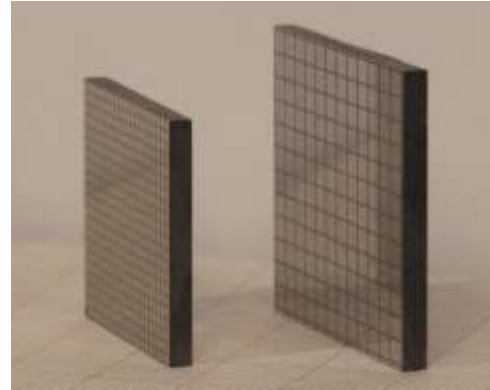
ALL PRODUCTS are vacuum packed in glass ampoules to prevent oxidation

CONTACT: Prof. Andrzej MYCIELSKI
Institute of Physics
Polish Academy of Sciences
Al.Lotników 32/46, 02-668 Warsaw, POLAND
Fax: (+48 22) 843 09 26; Tel. (+48 22) 843 56 26
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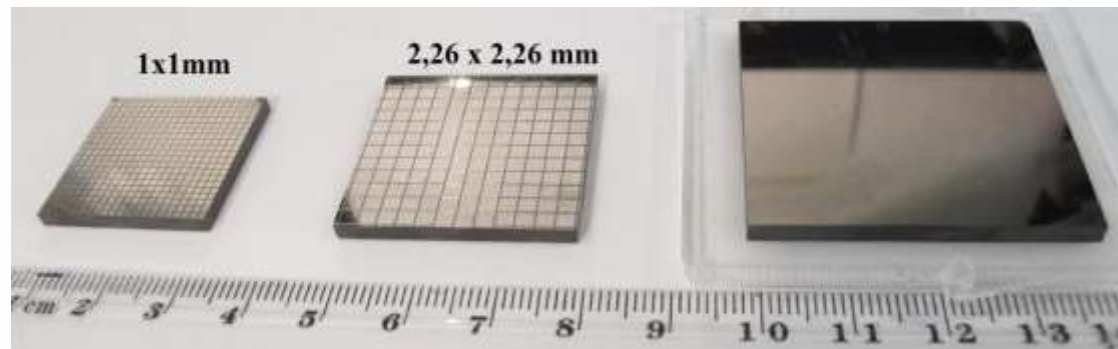
(Cd,Mn)Te crystals for X-ray and gamma-ray detectors



Pixels $2,46 \times 2,46 \text{ mm}^2$ for nuclear medicine.

Pixels $1,1 \times 1,5 \text{ mm}^2$ for measuring of density of osteoporotic bones.

Pixels $1,0 \times 1,0 \text{ mm}^2$ for computer tomography.



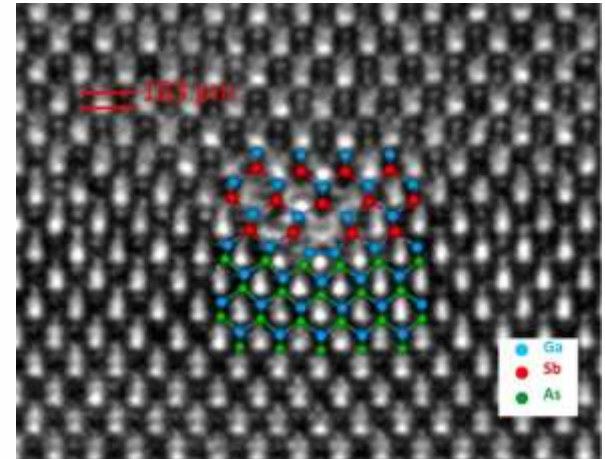
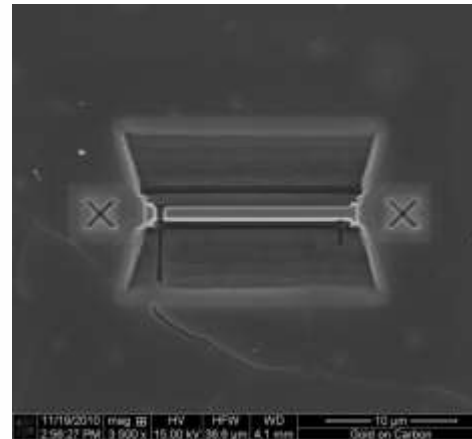
Characterization of new materials



- *Determination of crystal structure and crystallographic defects by high resolution X-ray diffraction systems*

Transmission Electron Microscope Titan 80-300, Helios – NanoLab 600

- *Determination of crystal structure in nanoscale*
- *Investigation of crystallographic defects*



Patent Applications in 2013

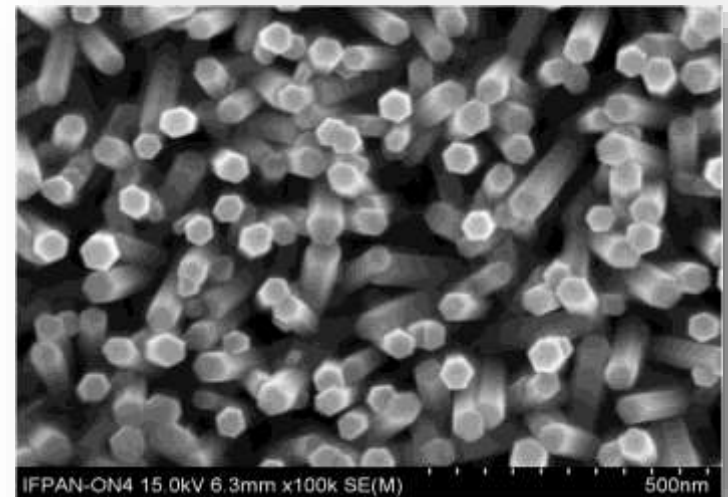
Lp.	Title	Date	No	Country
1	Hydrothermal method of production of ZnO nanorods	13.02.2013 r.	P.402753	Poland
2	Hydrothermal method of production of oriented ZnO nanorods	13.02.2013 r.	P.402754	Poland
3	P-i-n structure of UV detector and way of its production	12.04.2013 r.	P.403520	Poland
4	Way of production of substrates with nanocoatings with a developed surface	15.05.2013 r.	P.403897	Poland
5	Way of production of antireflection coating on a transparent substrate and multilayer antireflection film	11.06.2013 r.	P.404291	Poland
6	Structure of UV detector and way of its production	11.07.2013	P.404645	Poland
7	Method of preparation and a device for obtaining semiconductors with homogeneous hydrogen concentration	08.11.2013 r.	P.405990	Poland

Patents in 2013

Lp.	Title	Date	No	Country
1	Method of preparation of undoped n-type lead sulfide	06.11.2013 r.	P.392848	Poland
2	Method and a device for preparation of polycrystalline semiconductor compounds	05.11.2013 r.	P.389480	Poland
3	Method of preparation of layered nanocomposite thermoelectric material	19.06.2013 r.	P.391233	Poland
4	Detector of X-rays and gamma-rays	31.07.2013 r.	P.381438	Poland
5	Method of preparation of semiconductor n-(Eu,Gd)Te/p-PbTe heterostructures and a heterostructure for generation of random numbers	15.04.2013 r.	P.383757	Poland
6	Method of fabrication of semiconducting zinc oxide layers	06.07.2013 r.	P.384127	Poland
7	Thermoluminescence Detector	01.09.2013 r.	P.388778	Poland

Patents in 2012 – 2014 (WP5)

	2012	2013	2014
Patents	4	7	12



Nanowires ZnO obtained in the Group of prof. Marek Godlewski

Scientific Prizes in 2005 – 2013

- Agilent Technologies Europhysics Prize

Professor Tomasz Dietl – 2005

- Prize of the Foundation for Polish Science

Professor Tomasz Dietl – 2005

Professor Andrzej Sobolewski – 2007

- Copernicus - 2008

Prize of the Foundation for Polish Science and Deutsche
Forschungsgemeinschaft (DFG)

Professor Andrzej Sobolewski

Professor Wolfgang Domcke

- Smoluchowski - Warburg Prize

Prize of the Polish and German Physical Societies

Professor Andrzej Sobolewski – 2009



Scientific Prizes in 2005 – 2013, CNT.

- Siemens Research Prize 2008

Professor Andrzej Mycielski

For the achievements in: „Development of a method of purification and production of ultrapure (6N) elements: Manganese (Mn), Magnesium (Mg), and other selected semiconducting compounds for advanced technologies and applications”.

- Stefan Pieńkowski Prize of the Polish Academy of Sciences

Dr Piotr Deuar - 2010

Dr Michał Matuszewski - 2011

Dr Łukasz Cywiński - 2013

-The Prize of the Minister of Science and Higher Education

Professor Tomasz Wojtowicz - 2013



Professor Maciej Kolwas
President of the European Physical Society
2009-2011



Professor Tomasz Dietl
was elected a member
of the Steering Committee
of the European Research Council - 2012



Technological Prizes in 2014 (WP5)

The Belgian and International Trade Fair for Technological Innovation
Innova 2014, Brussels



Gold Medal with mention for the innovation: *Innovative antibacterial coating*

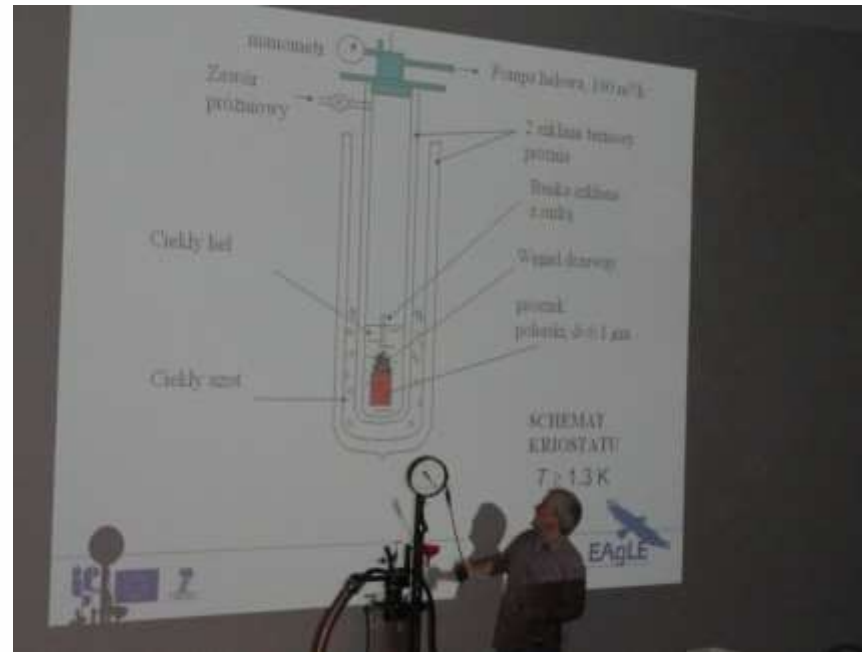
Silver Medals for the innovation:

Ultra-sensitive UV radiation detector

Innovative photovoltaic cell based on nanorods and ZnO layers

Promotion via mass media, popularization of science (WP6)

18th Warsaw Science Festival (in 2014)



Prof. Grzegorz Grabecki explains the “fountain effect”
in superfluid helium

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European Action towards Leading Centre
for Innovative Materials

FP7-REGPOT-2012-2013



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