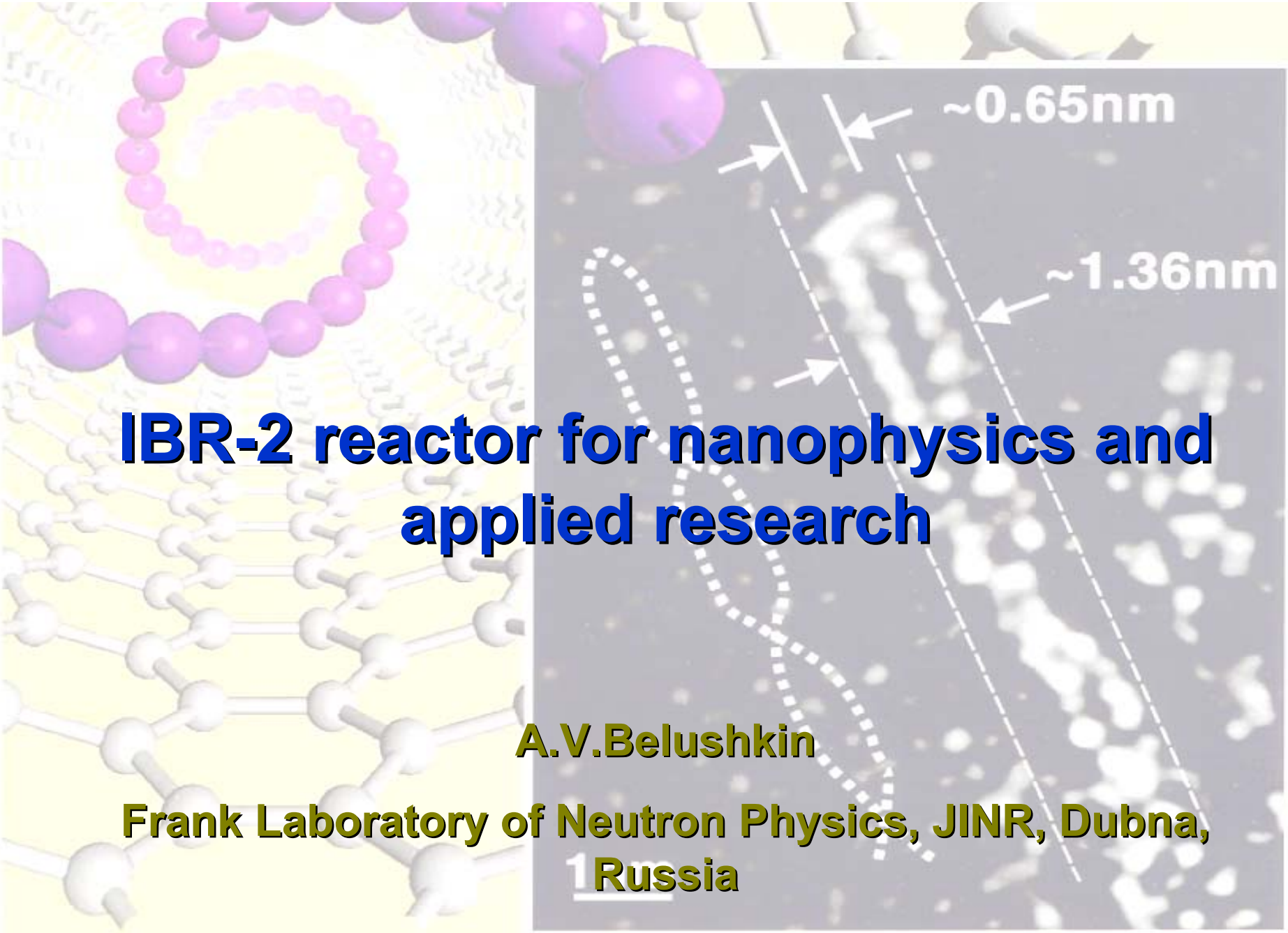


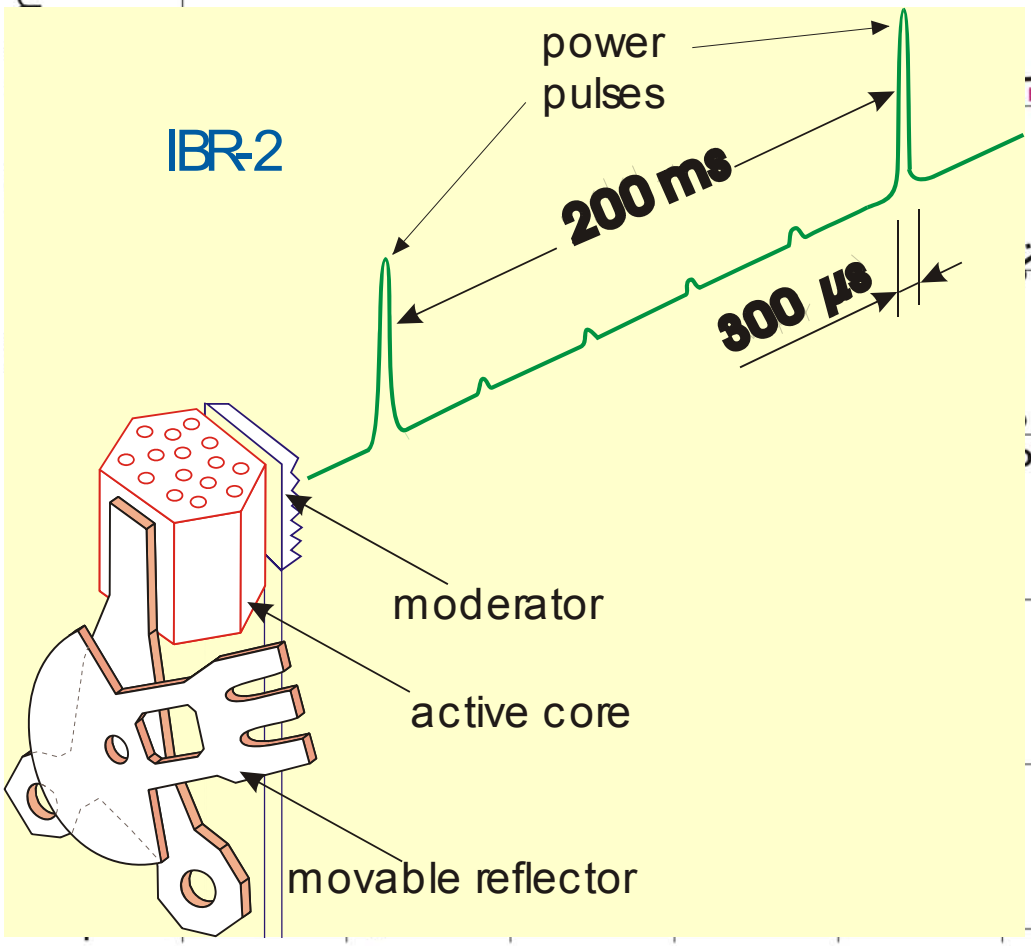
IBR-2 reactor for nanophysics and applied research

A.V.Belushkin

Frank Laboratory of Neutron Physics, JINR, Dubna, Russia

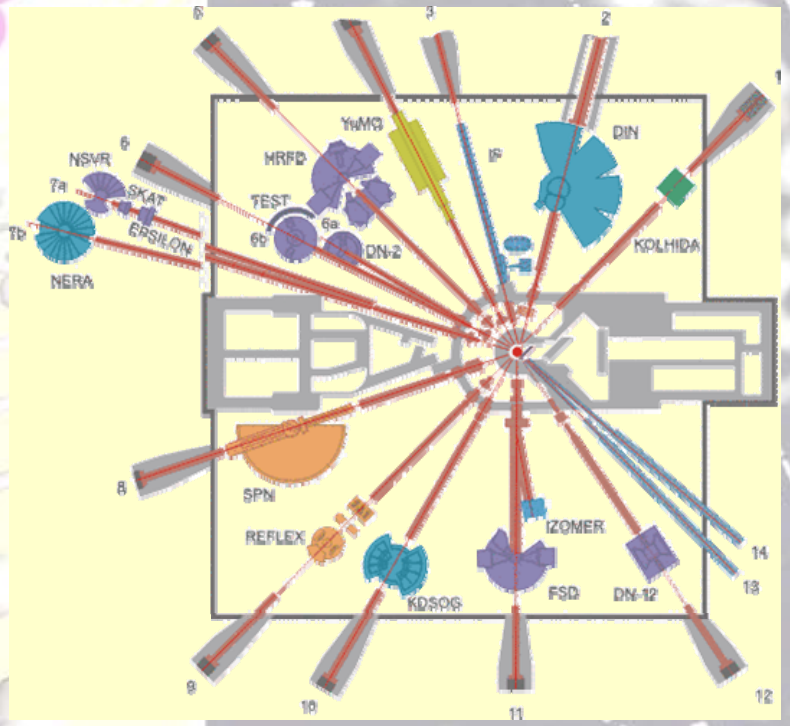
IBR-2 – fast pulsing reactor.

Included in 20-years strategic research program with neutrons in Europe



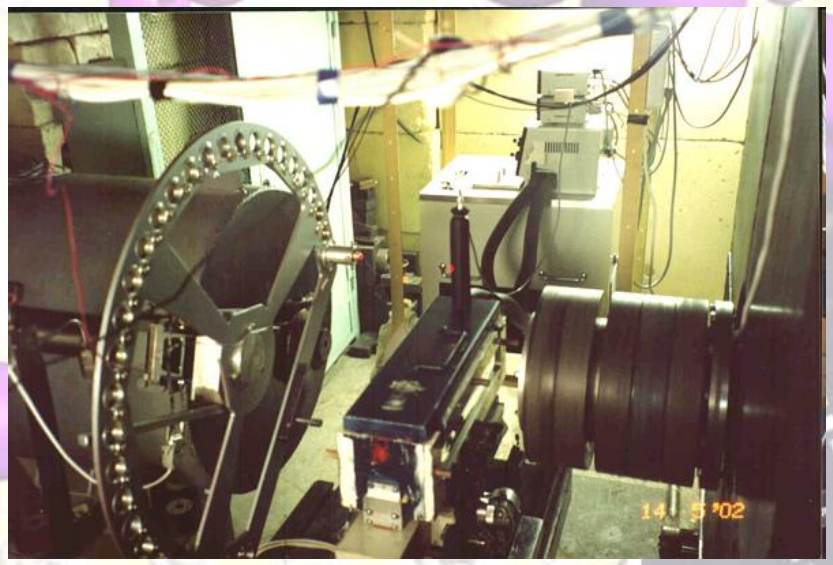
Source: IAEA-TECDOC-1439, February 2005

IBR-2 Reactor Spectrometers Complex – the main JINR basic facility for condensed matter physics research with neutrons



10 available neutron spectrometers - DN-2, HRFD, DN-12, YuMO, REMUR, REFLEX, SKAT, EPSILON, NERA-PR, DIN-2PI

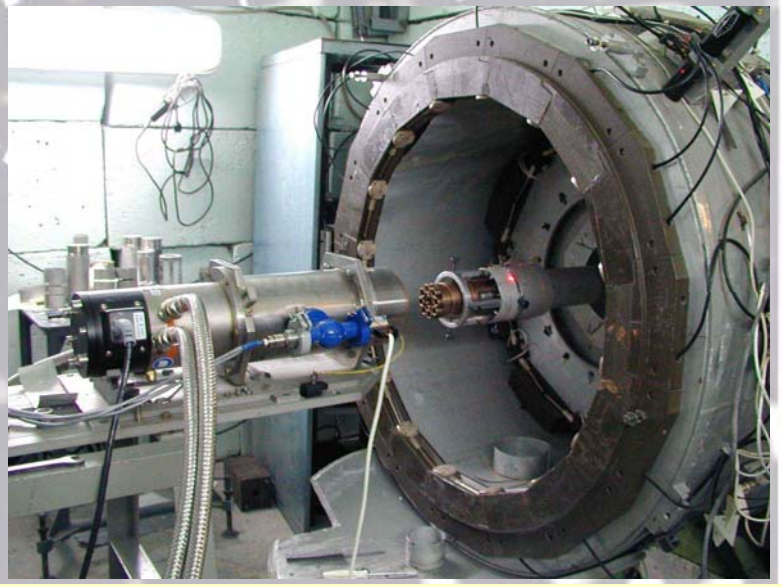
3 new spectrometers projects under realization – DN-6, GRAINS, FSD



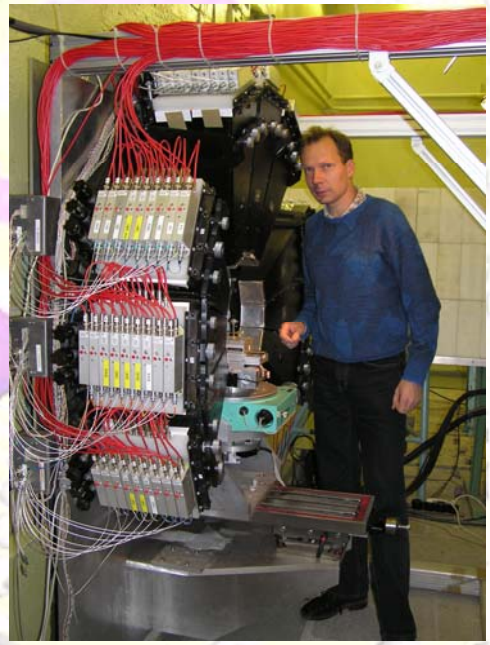
YuMO – small angle scattering spectrometer

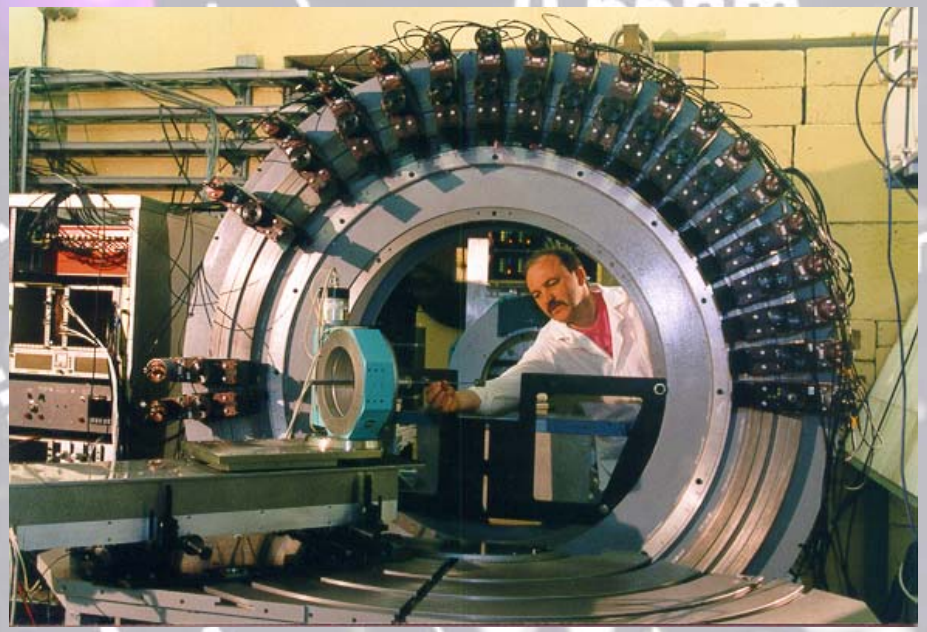
HRFD – high resolution Fourier diffractometer

REMUR – reflectometer with polarized neutrons



DN-12 – diffractometer for studies of microsamples under extreme conditions

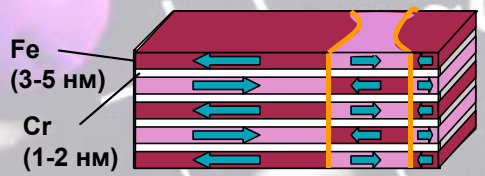


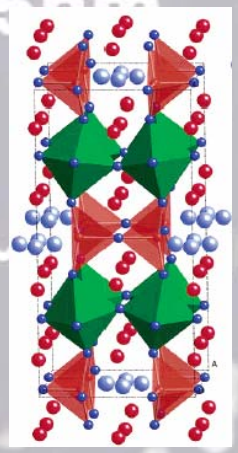


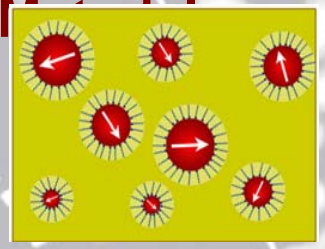
Epsilon-MDS and SKAT diffractometers complex for studies of geological materials

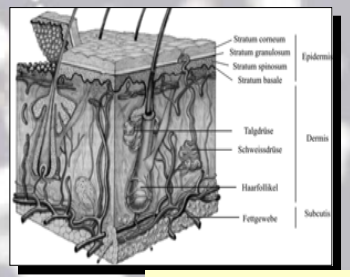
PRIORITY DIRECTIONS OF RESEARCH

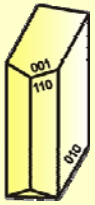
- Physics of Nanosystems
- Structure and Dynamics of Functional [illegible]
- Complex Liquids and Polymers
- Molecular Biology and Pharmacology
- Structure of rocks and minerals
- Neutron Nanodiagnostics

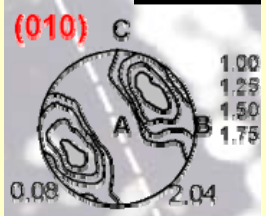


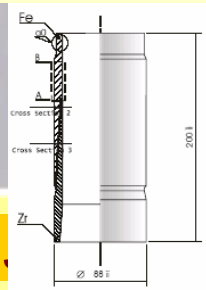


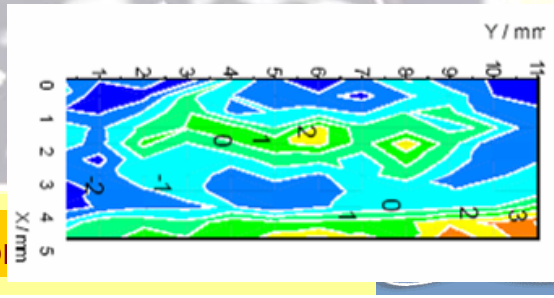




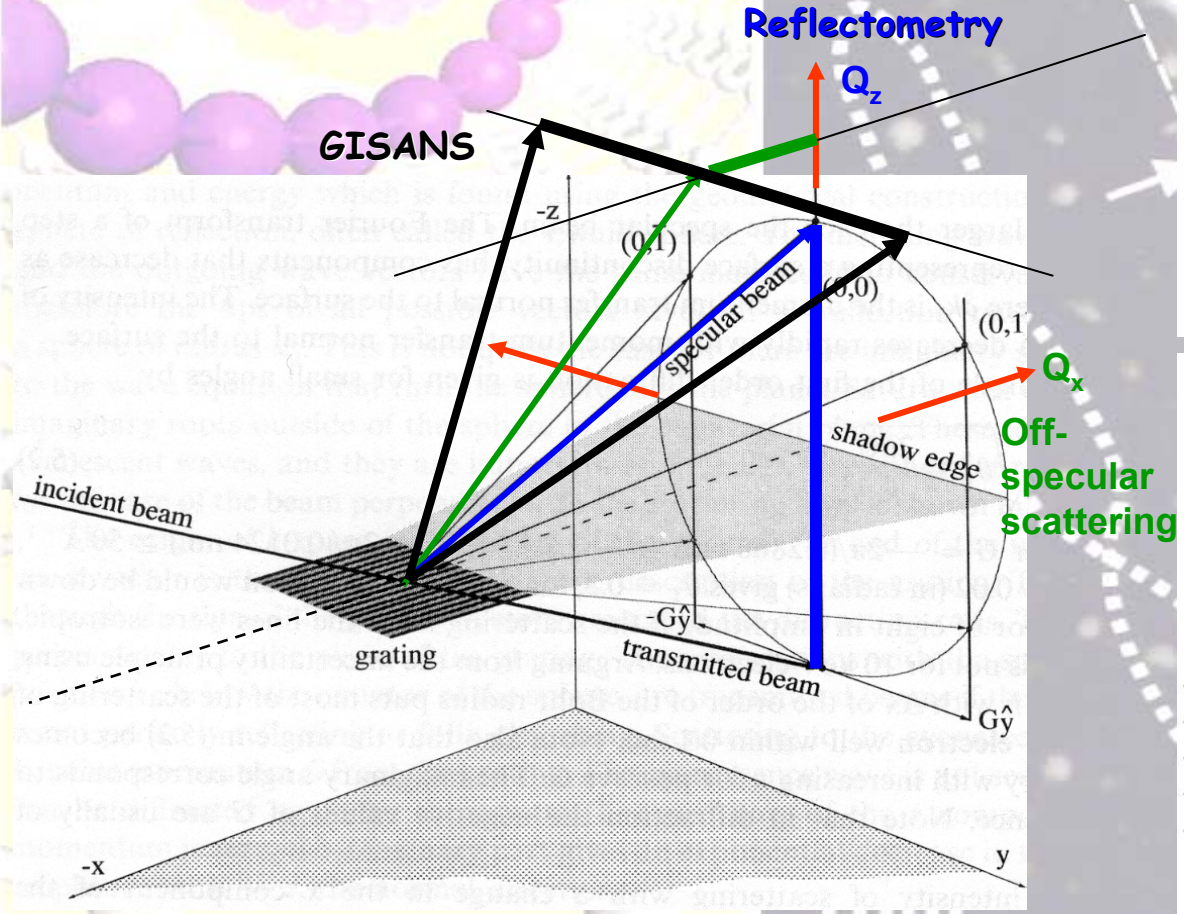




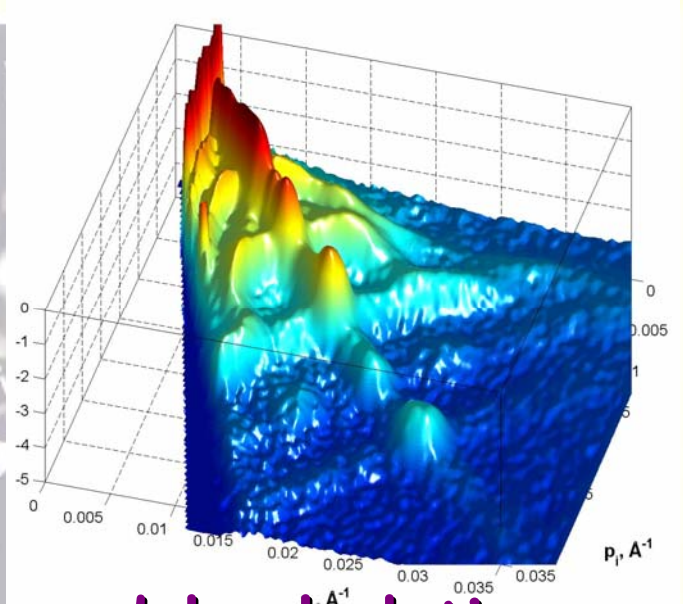




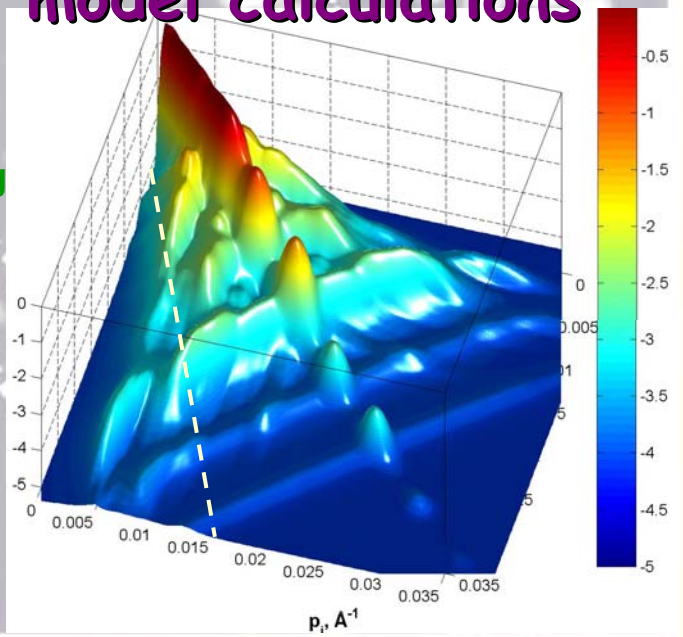
Principle scheme of the experiment using neutron reflection



experiment

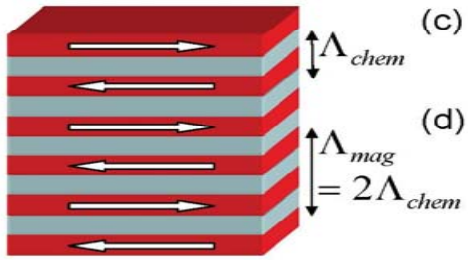


model calculations

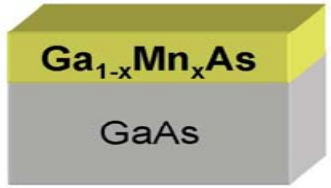


Studies of magnetic nanostructures by polarized neutron reflectometry

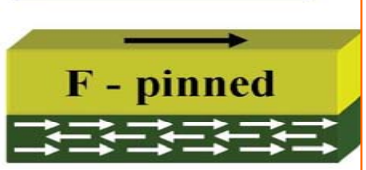
a) Exchange coupled superlattice with anti-ferromagnetic ordering (e.g. GMR and TMR systems)



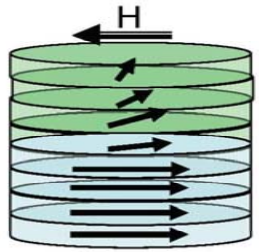
b) Dilute magnetic semi-conductors as spin-injectors in semiconductor heterostructures



c) Laterally patterned magnetic films

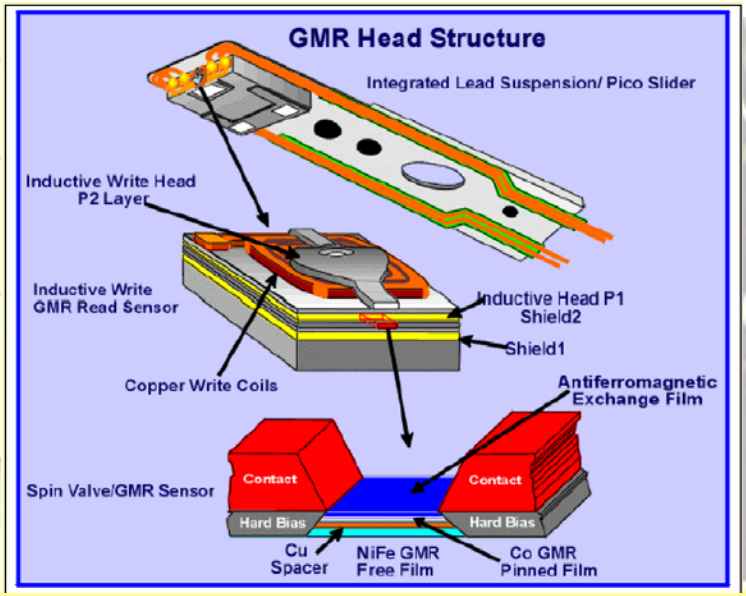


d) Ferromagnetic films on antiferro-magnetic substrates with exchange bias through common



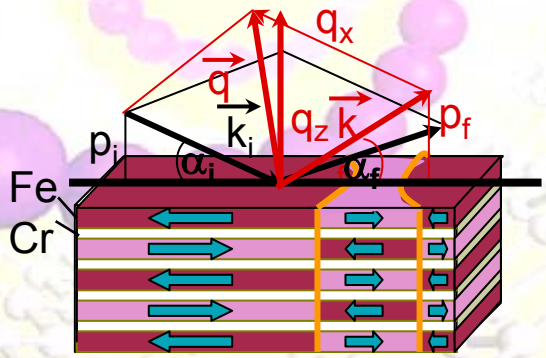
e) Spring magnets consisting of a top soft magnetic layer exchange coupled to a magnetically hard layer.

A commercial IBM giant magnetoresistance read head

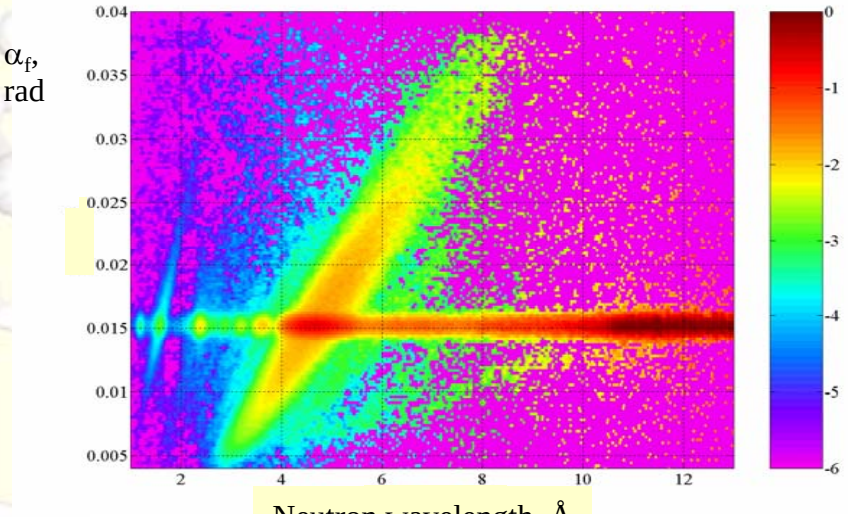


Magnetic off-specular reflection of polarized neutrons from multilayers Cr/Fe

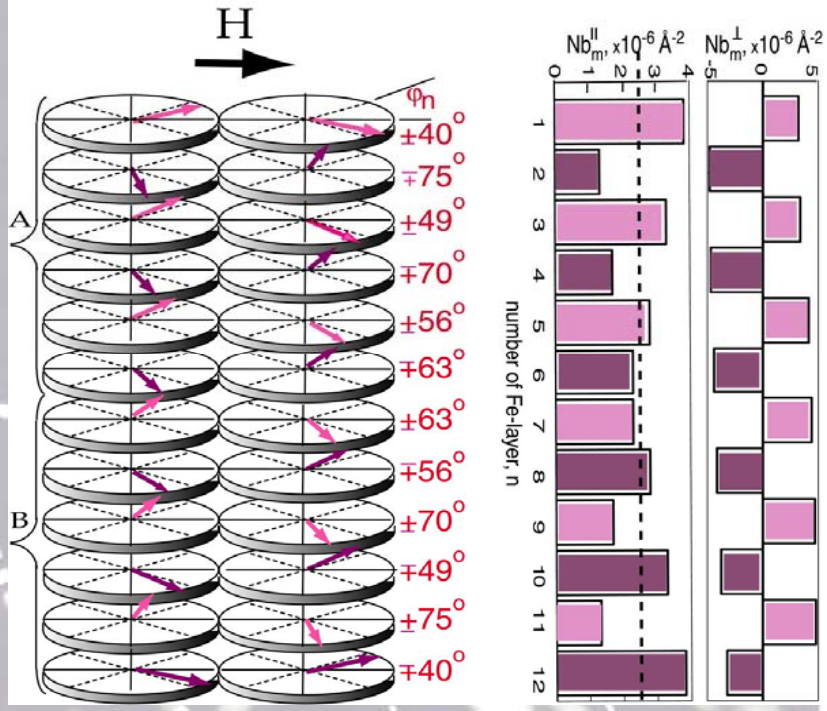
TU Muenchen (Germany), ILL (France), PNPI RAS (Russia), FLNP-JINR



Scheme of experiment

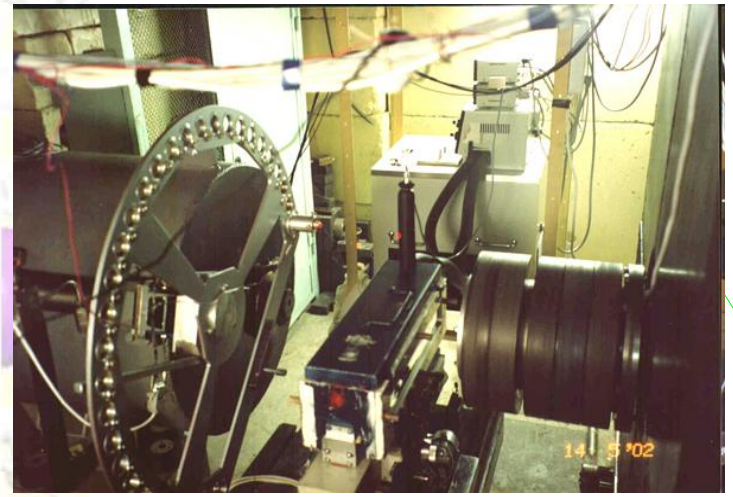


Scattering pattern from sample
$[^{57}Fe(67Å)/Cr(9Å)]_{12}/Al_2O_3$, H=200 Oe



Found magnetic structure as a function of depth. Twisted canted states in exchange-coupled multilayers are induced by a magnetic field applied.

YuMO – small-angle scattering spectrometer at IBR-2



The study of structure aspects of optical properties in the nanosystem GeO_2-Eu_2O_3-Ag

OPTICAL PROPERTIES

Effect of the Chemical State of Silver on the Luminescence Properties of GeO_2–Eu_2O_3–Ag Films

G. E. Malashkevich[a], G. P. Shevchenko[b], S. V. Serezhkina[a], P. P. Pershukevich[a], G. I. Semkova[a], and G. K. Glushonok[b]

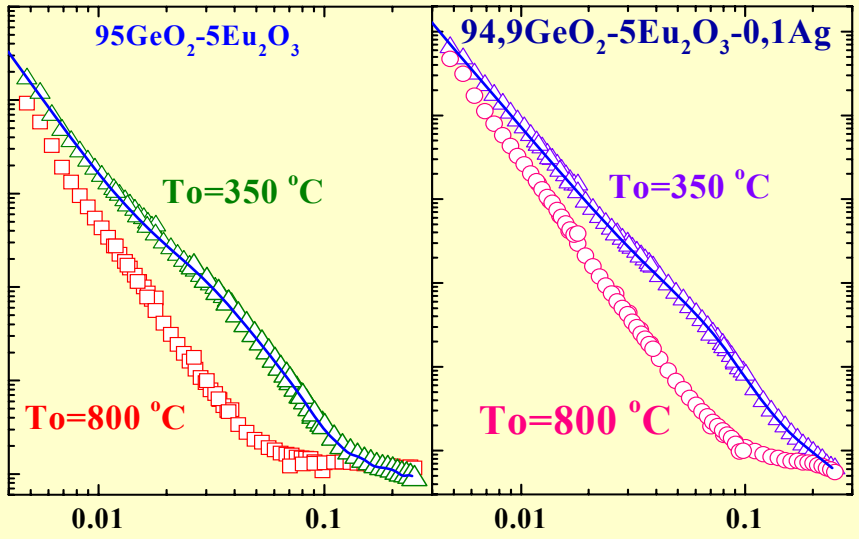
Silver doping effect

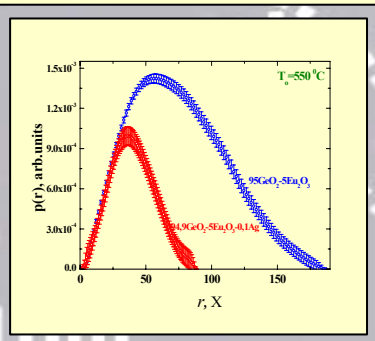
Increasing of luminescence intensity

~1000 times

Experimental methods

Crystal structure	Nanostructure
X-Ray diffraction	Small angle neutron scattering





The breakage of clusters because of the formation of Eu-O-Ag bonds

An increase in the intensity of luminescence excitation lines $^7F_0 \rightarrow {}^5L_6$ and $^7F_0 \rightarrow {}^5H_6$ of Eu^{3+}

Magnetic fluids for brain cancer treatment:

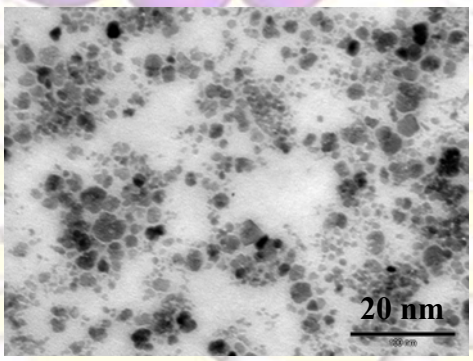
magnetite in water with double layers of myristic (MA) and lauric (LA) acids

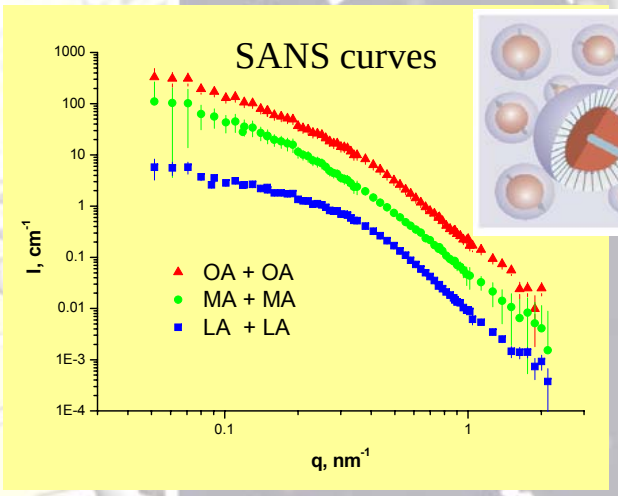
Electron microscopy

Small-angle neutron scattering

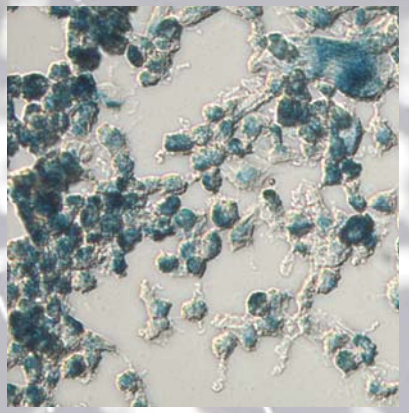
Penetration into cells

MA+MA

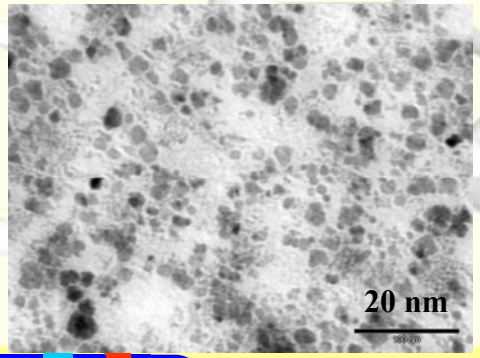


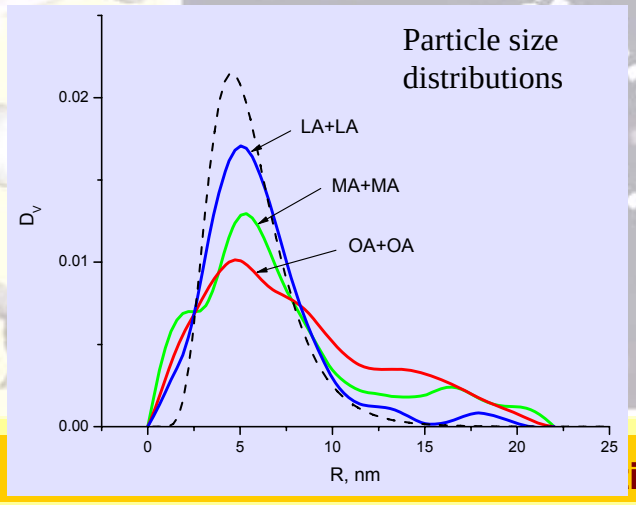


MA+MA

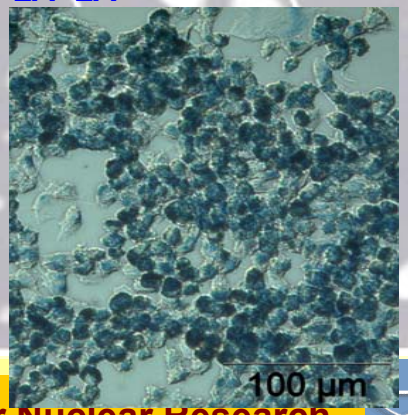


LA+LA

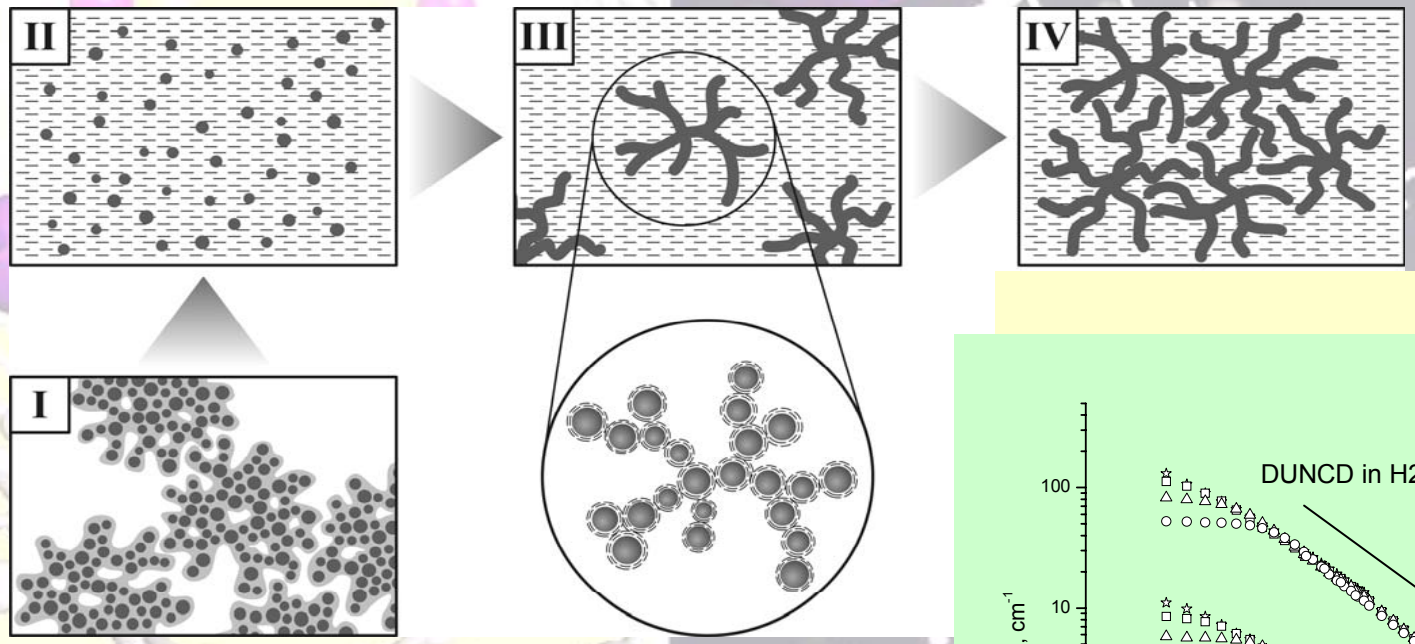




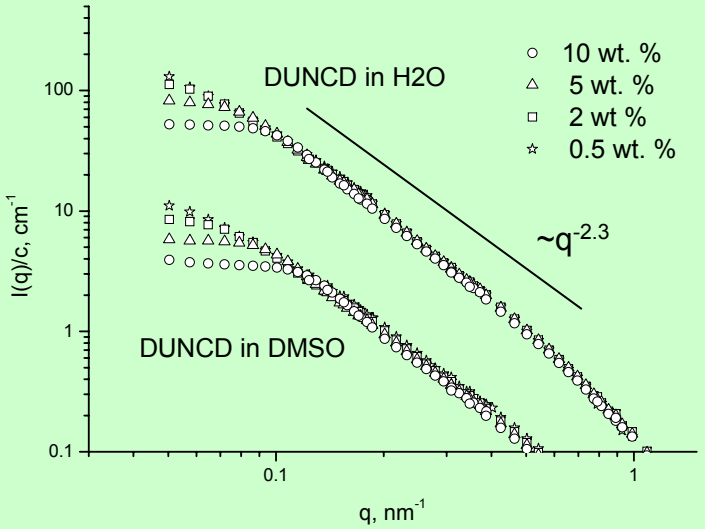
LA+LA



Aggregate structure in liquid dispersions of detonation ultrananocrystalline diamond (DUNCD)

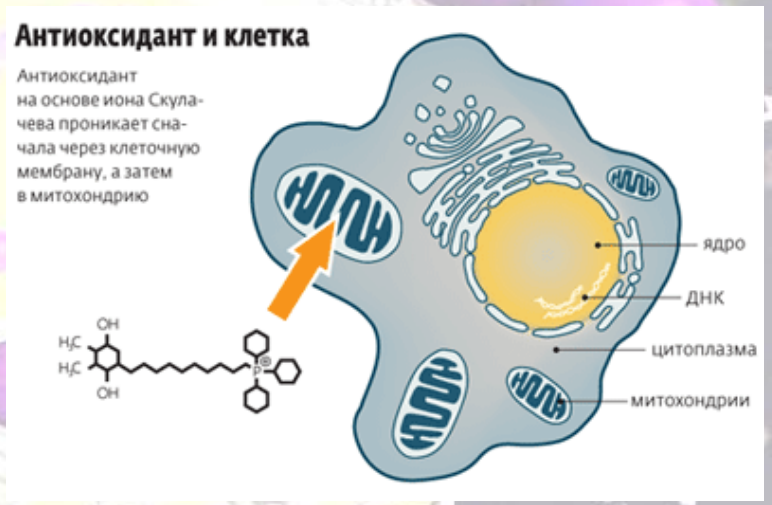


I – initial powder, diamond crystallites (size ~6 nm) in non-diamond porous matrix
II – liquid (water) dispersion of diamond crystallittes after wet milling procedure (*C* ~ 1 wt. %)
III – growth of the new branched clusters (size > 40 nm, *D* ~ 2.3)
IV – dispersion after concentrating (*C* ~ 10 wt. %) with interpenetrating aggregates



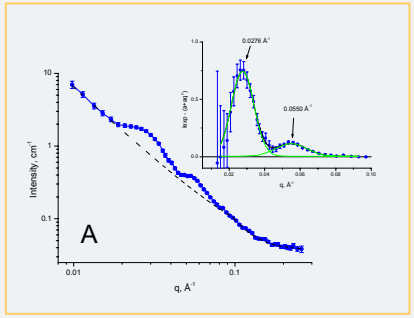
SANS curves for different nanodiamond dispersions showing that the correlation length becomes less than the cluster size when concentrating the systems (cluster interpenetration).

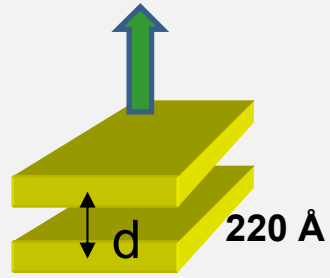
3D structures inside mitochondria



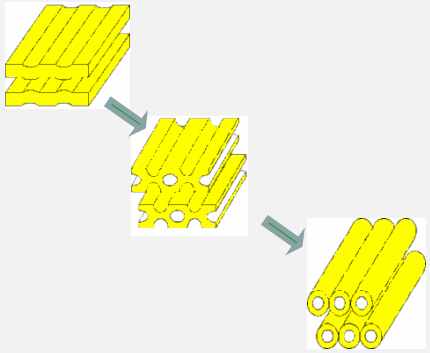
Heart mitochondria

Modification of the mitochondria packing under osmotic pressure

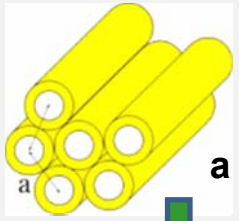




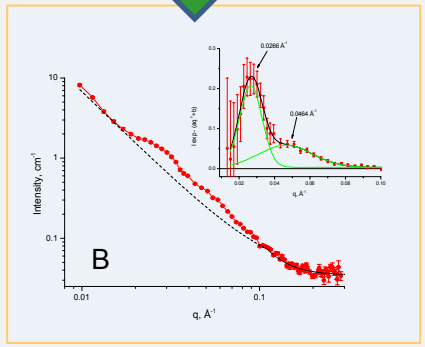
Lamellar packing

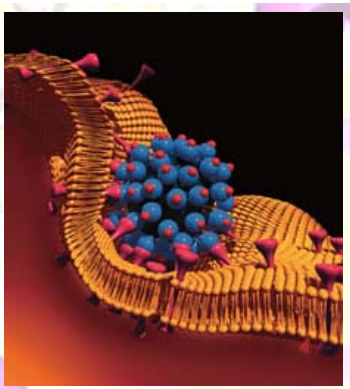


Hexagonal packing

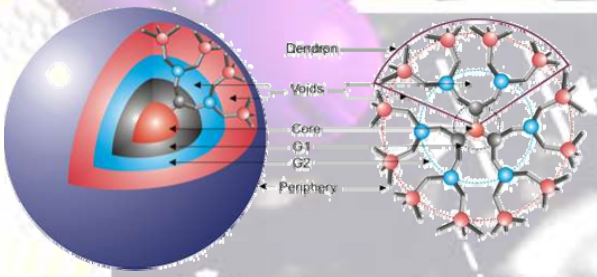


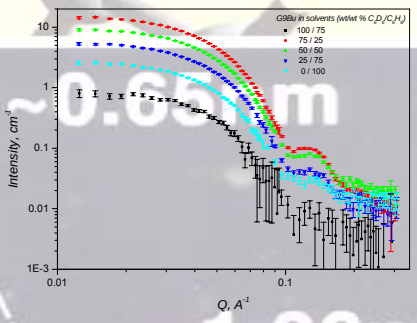
a = 250 Å



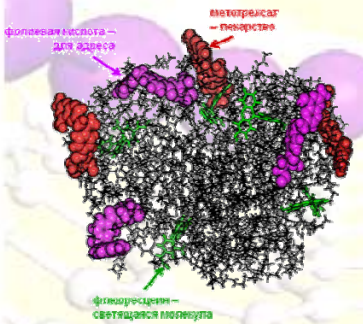


FARMACOLOGY

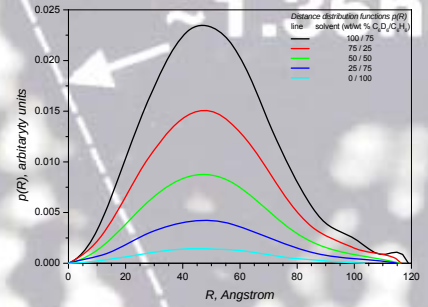


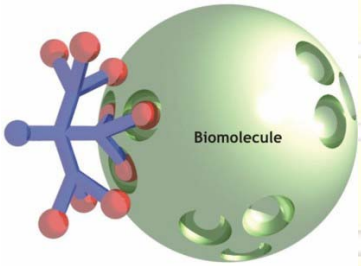


DENDRIMERS

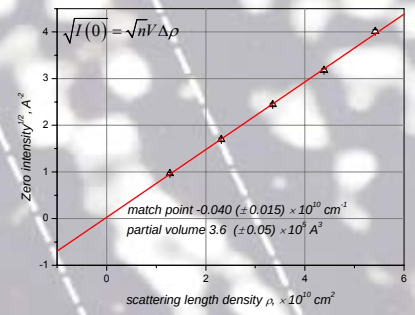


MEDICINE

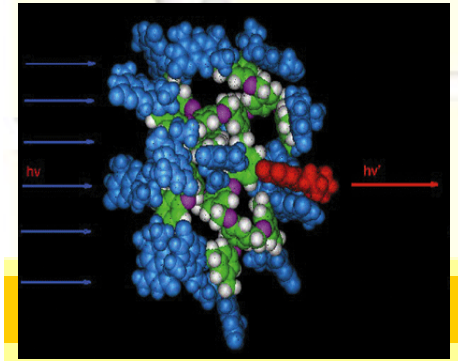




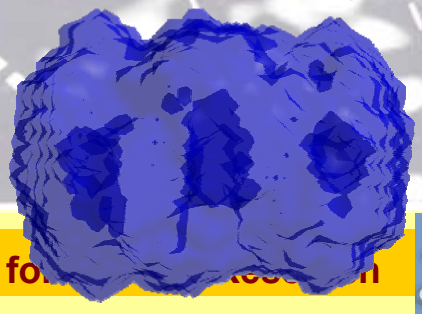
BIOLOGY



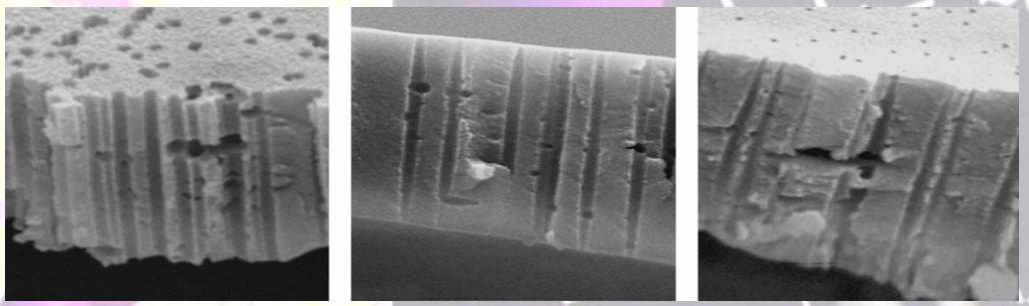
Found of new structural features of dendrimers



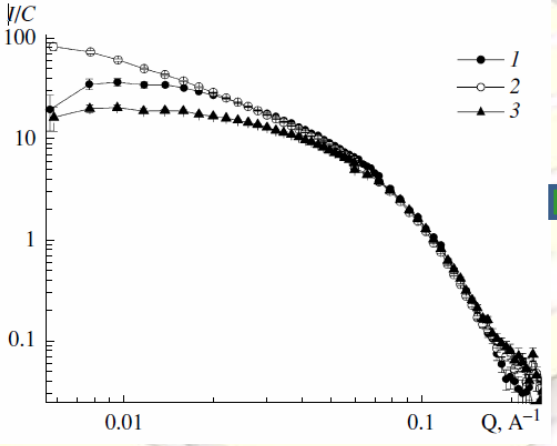
PHOTOCHEMISTRY



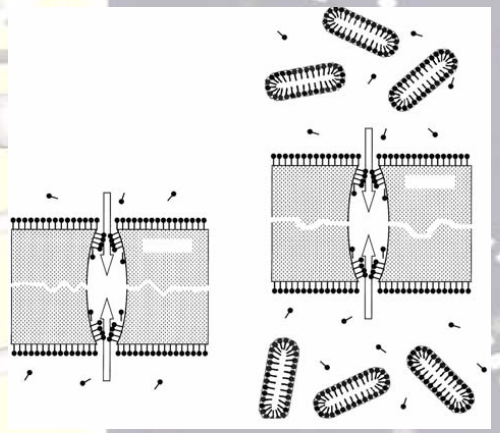
Surfactant Aggregation in Solutions Applied for Track Etching and Its Possible Effect on the Pore Shape in Track Membranes



Exemplification of the pore shapes in TMs obtained by the etching under different conditions of poly(ethylene terephthalate) films irradiated by a parallel beam of accelerated krypton ions : (a) etching with 2M NaOH at 80°C in the absence of surfactants, (b) 6 M NaOH, 70°C, DBA-Na, and (c) 3 M NaOH, 80°C, DSBS-Na; film thickness is 5μm.



Small-angle neutron scattering curves normalized with respect to surfactant concentration for (*1*) NBDEO +1 M KCl, (*2*) NBDEO + 1 M NaOH, and (*3*) NBDEO samples.

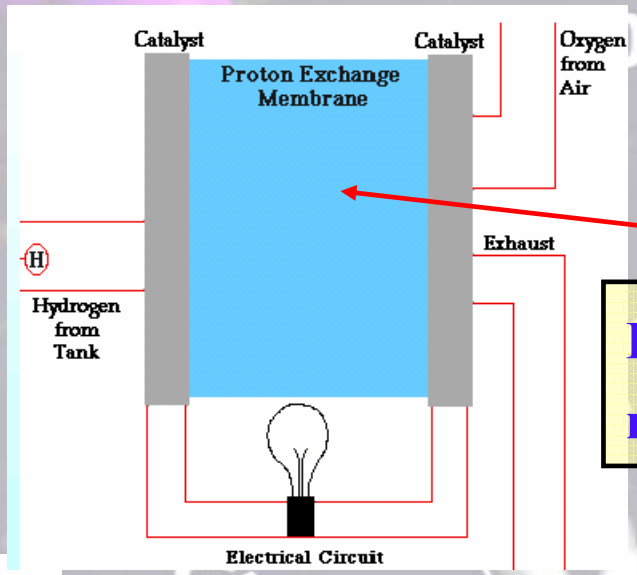


Layout of pore formation in an ion-irradiated polymer film etched with a surfactant-containing etching solution: (a) with no regard to micelles and (b) with regard to the size and shape of micelles. Both sides of the film are in contact with the solution.

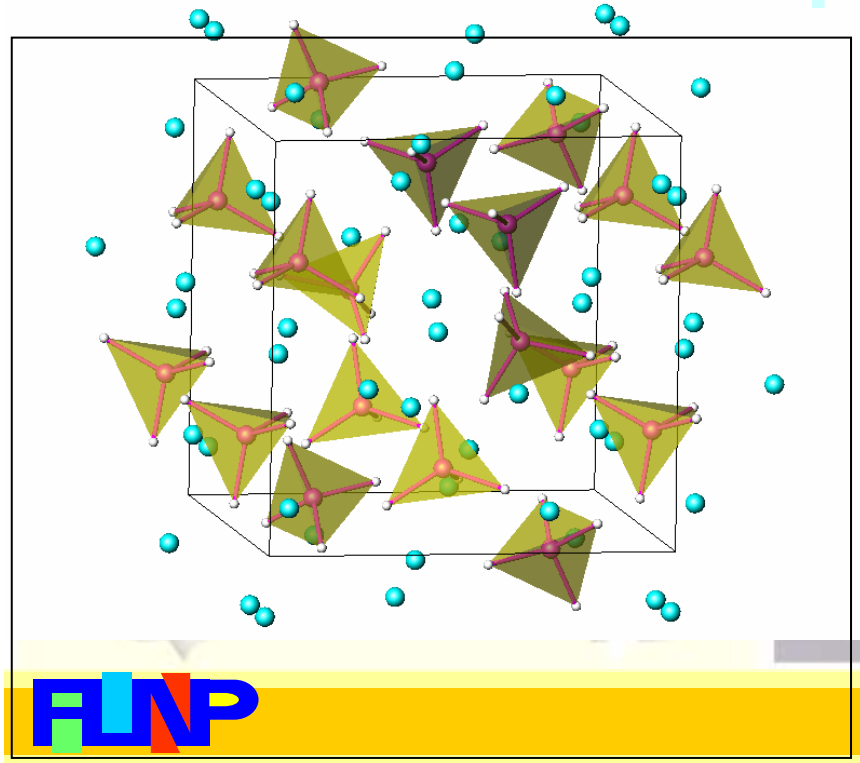
Concentration NBDEO, %	Concentration KCl, M	Micelle parameters	
		Cylinder radius, nm	Cylinder length, nm
0.4	0	2.3	15.2
0.8		2.3	18.0
0.9		2.3	18.0
1.0		2.2	17.2
0.1	1	2.1	25.6
0.3		2.4	24.4
0.9		2.3	28.5
1.2	3	2.4	163.2

Geometric parameters of NBDEO micelles in the presence of KCl as determined by fitting the experimental data to model cylinders

Hydrogen storage and fuel cell materials

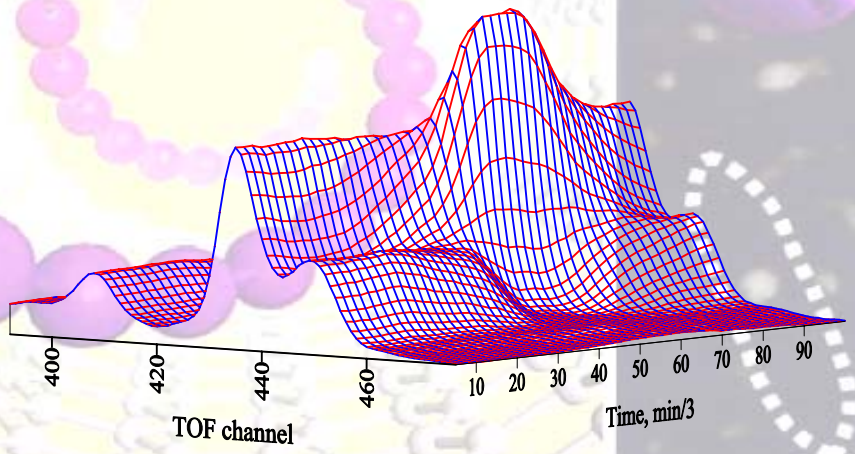


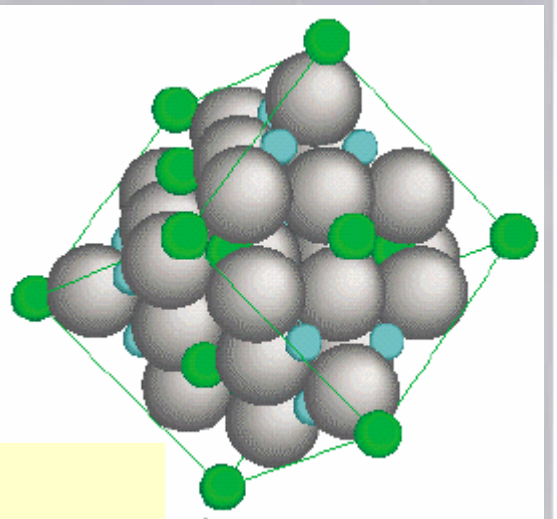
Proton exchange membrane



Atomic structure of the hydrogen storage material Li_2BeD_4, determined by neutron diffraction at IBR-2 reactor (HRFD diffractometer

Solid state chemistry





Time scale / temperature scale: T = 400 K→ 800 K → 400 K.

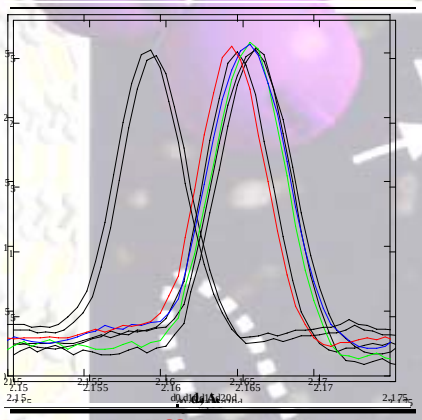
Heating/cooling with ≈1 grad/min.

Cubic structural phase (Fd3m) transforms into tetragonal phase ($I4_1/adm$) and back.

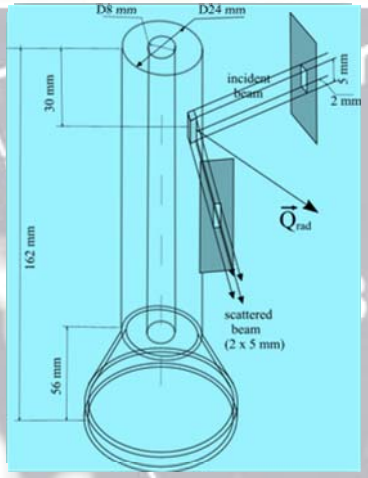
Cubic phase of $CuLi_{0.1}V_{0.1}Fe_{1.8}O_4$

Solid state transformation on heating in complex ferrite $CuLi_{0.1}V_{0.1}Fe_{1.8}O_4$, visualized by real time neutron diffraction at IBR-2 reactor

Engineering diagnostics



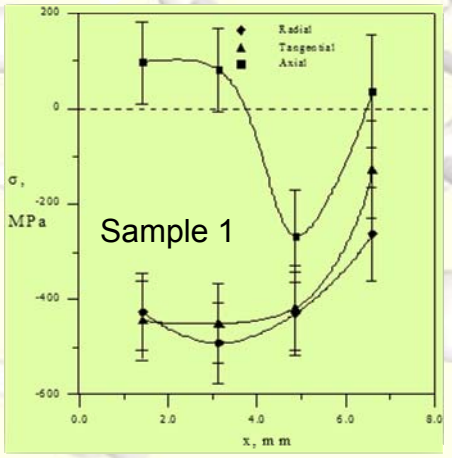
Neutron diffraction peak shift due to residual stress

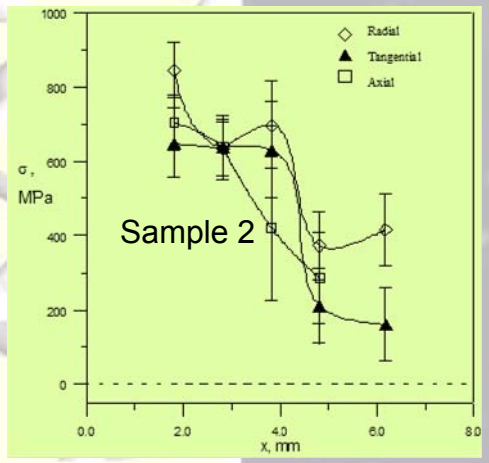


The layout of experiment

Equipment for mining industry

"…On basis of these results ПП80НВ.00.006 type striker made of 20X2H4A steel with surface cementation treatment was implemented in ПП80НВ perforator's production.
Application of this steel provide 2.5 times gain in mean time to failure: for 65C2BA steel mean time to failure is about 40 hours while for 20X2H4A steel this value was increased up to 100 hours."





The measured residual stress distribution in the sample along radial coordinate *x*.

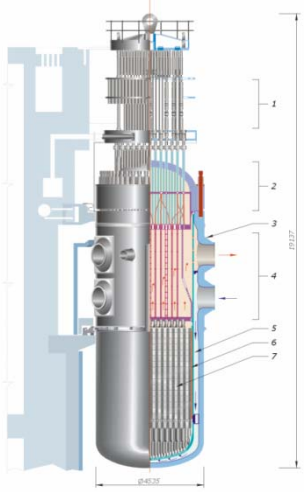
УТВЕРЖДАЮ
И.О. Технического директора
ОАО «Тулламашзавод»
В.И. Соловьев
10. 12 2002г

АКТ
по внедрению в производство ударника ПП80НВ.00.006 из стали 20Х2Н4А

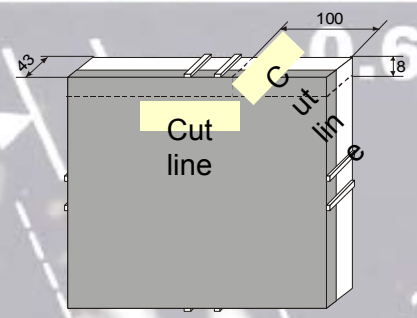
Commissioning certificate

Residual stress study in VVER-1000 reactor vessel

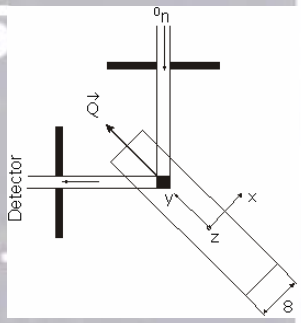
Novovoronezh Nuclear Power Plant with VVER-1000 type reactor.



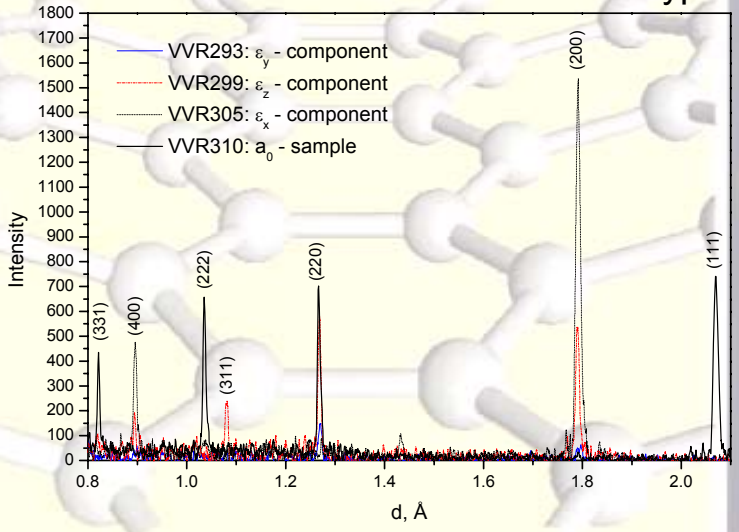
VVER-1000 is a 1000 MW Russian nuclear power reactor of PWR type.



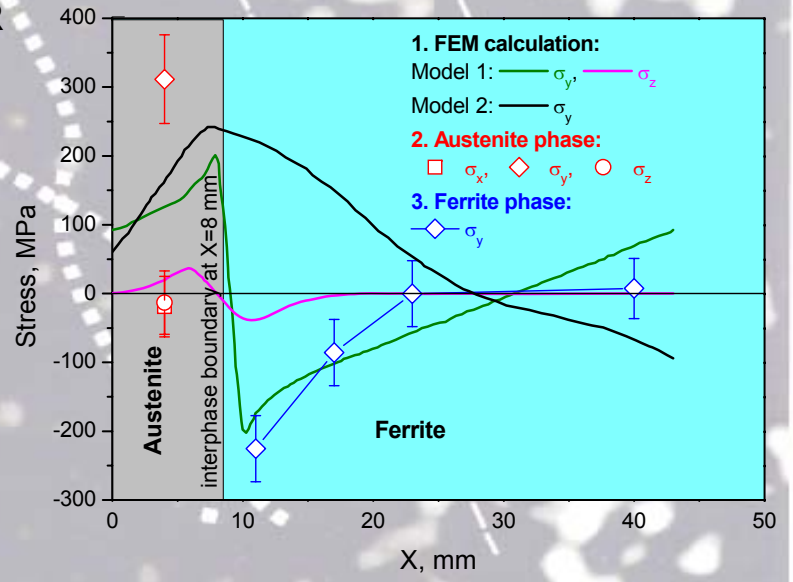
Virgin sample - part of the VVER-1000 reactor vessel.



Residual strain measurement layout.

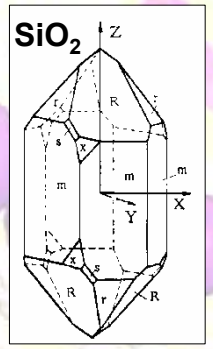


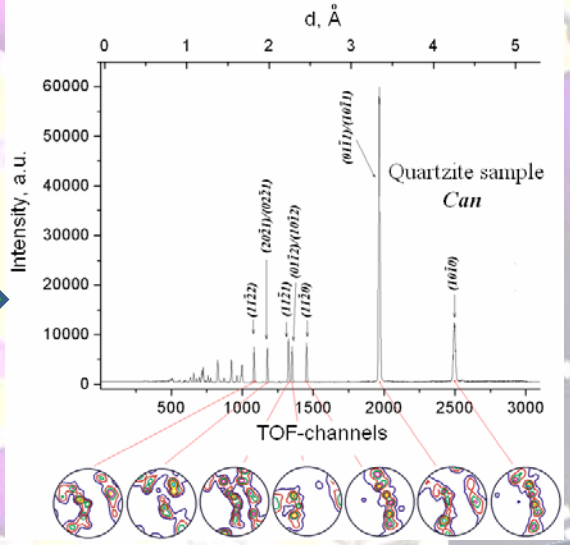
Typical neutron diffraction spectra.

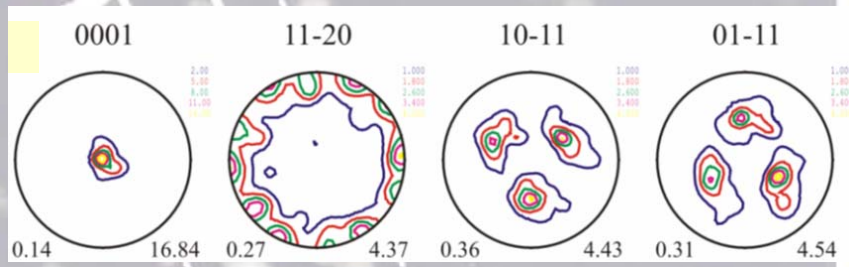


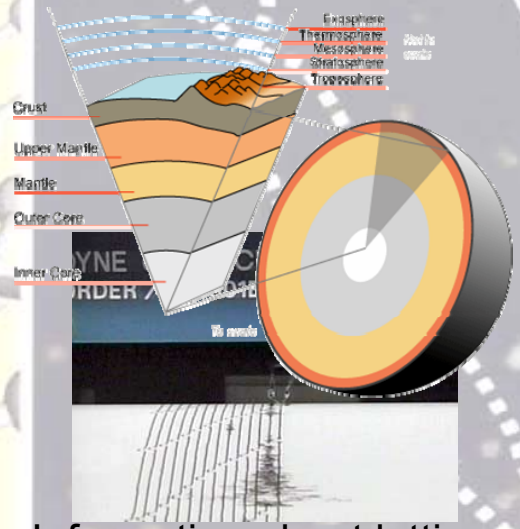
Residual stress vs. X coordinate: FEM calculations in comparison with neutron data.

Quantitative texture analysis of minerals using neutron diffraction







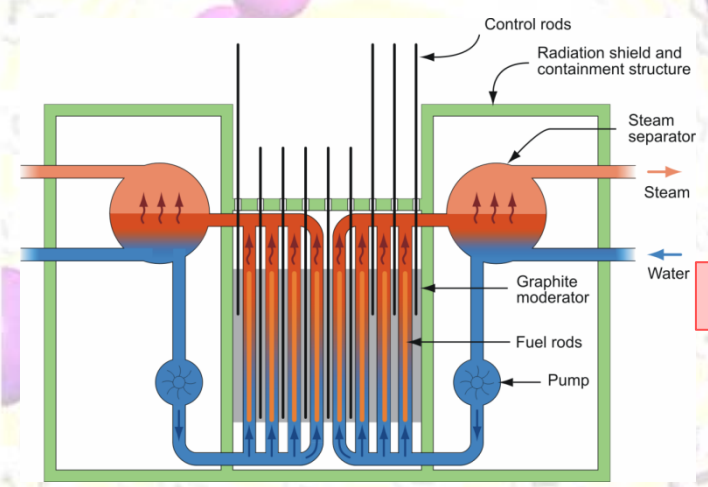


Piezoelectric textures of polycrystalline quartz allow to use the electrical methods of geophysical prospecting of quartz reef, containing gold, non-ferrous metals, single-crystalline piezo-optical raw

Information about lattice preferred orientation allows to calculate the elastic anisotropy of rocks for interpretation of seismic data.

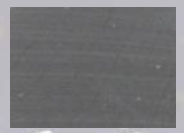
To ensure the ecological safety of nuclear waste deposits it is necessary to take into account the anisotropy of physical properties of host rock.

Texture and elastic properties of reactor graphite GR-280

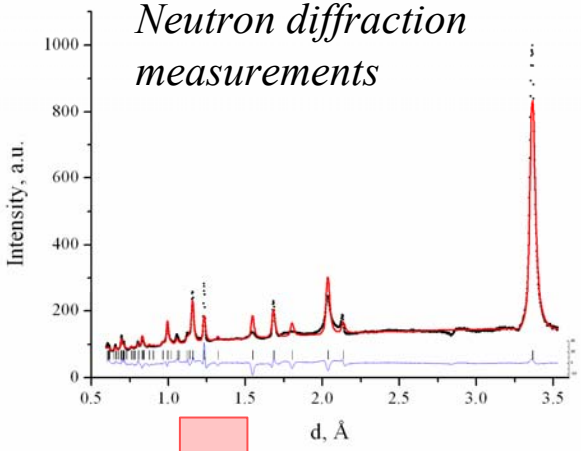


RBMK reactor scheme(Wiki)

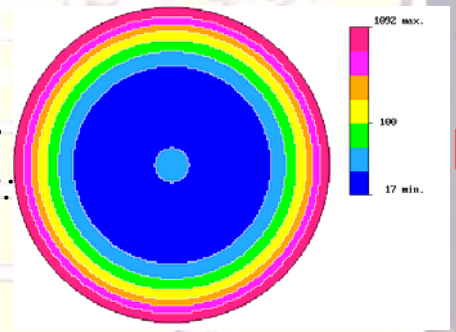
GR-280 (moderator blocks)



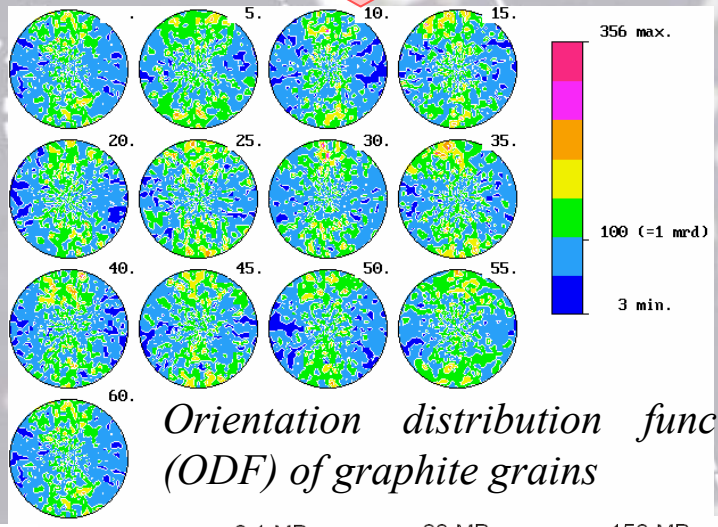
Neutron diffraction measurements



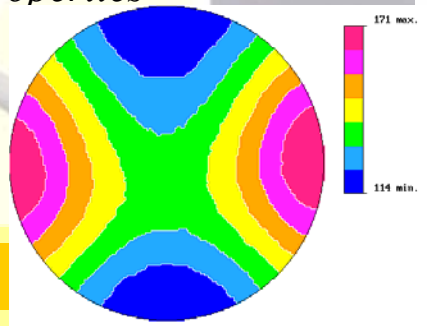
Single crystalline elastic properties:



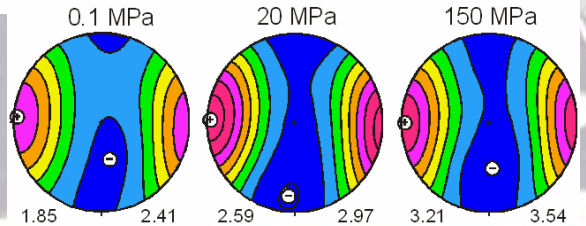
Calculation of polycrystalline properties



Orientation distribution function (ODF) of graphite grains



Extrusion direction of the graphite block



Influence of pores and cracks (via ultrasonic experiments at different pressures)

ANALYTICAL INVESTIGATIONS AT IBR-2M REACTOR

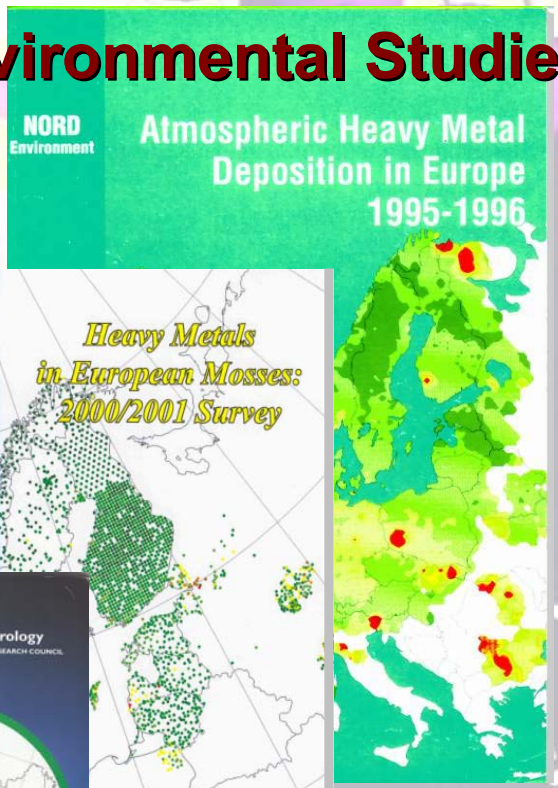
Instrumental neutron activation analysis INAA	*Epithermal neutron activation analysis ENAA*	*Cyclic neutron activation analysis CNAA*

Life Sciences	Material Science

- **Biomonitoring** of atmospheric deposition of heavy metals and other elements (Project **REGATA**)
- Control of quality and safety of **foodstuffs**, grown in industrially contaminated areas of RF and South Africa (**grant of SA**)
- Assessment of different ecosystems and their impact on **human health**

- **Biotechnologies:** development of new pharmaceuticals and cleaning the environemnt from toxic elements (biosorption)
- NAA for the technological process of synthesis **of diamonds and NB (boron nitride)**
- Analysis of **archeological and museum objects** from Russian and other countries
- NAA for **decommissioning of Nuclear Power Plants** and **utulization of industrial wastes**

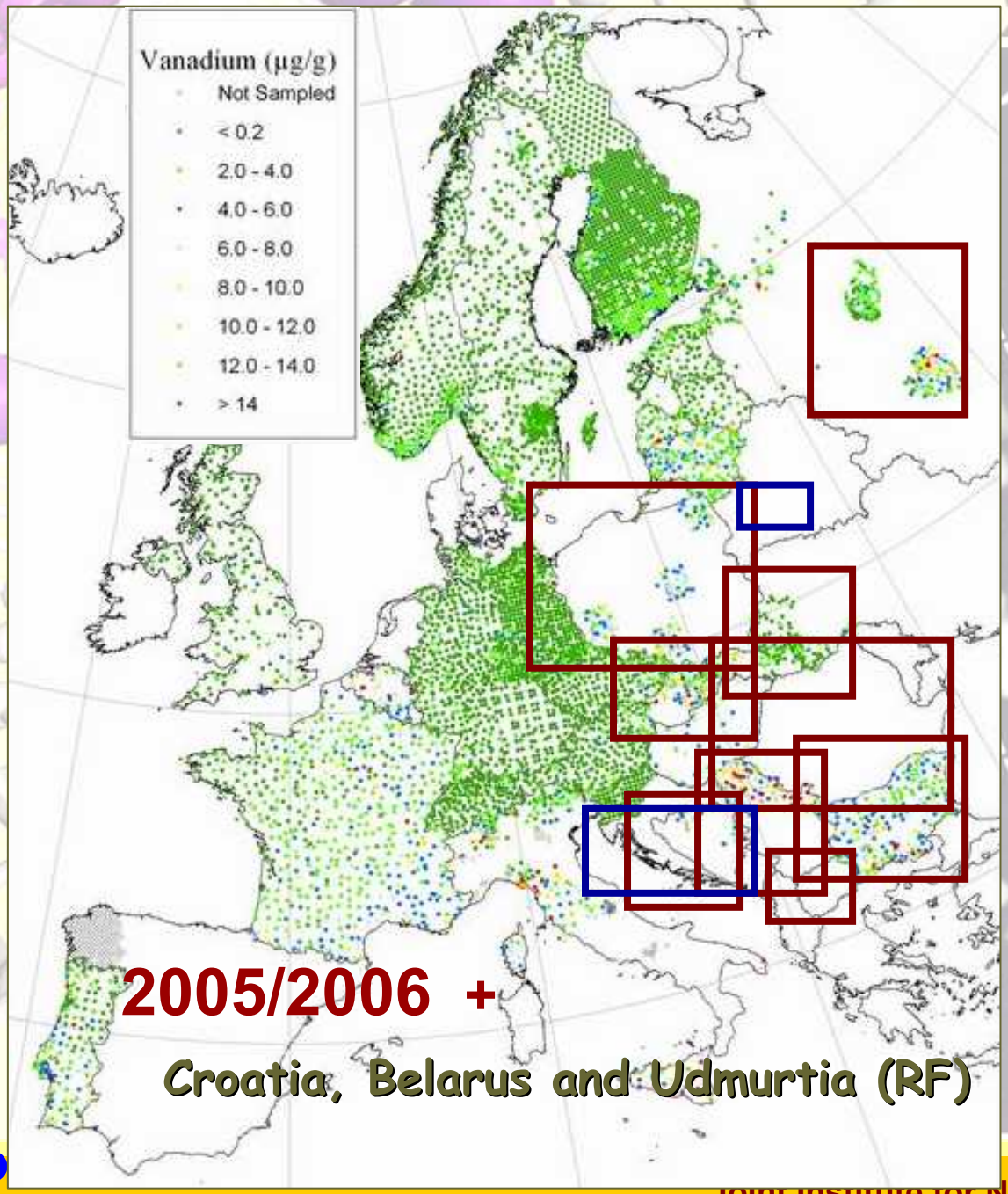
NAA for Environmental Studies



UNECE

Atlas of Heavy Metal Atmospheric Deposition in Europe – assessment based

Countries collaborating with FLNP in the field of biomonitoring



2000/2001

Russia

Poland

Slovakia

Ukraine

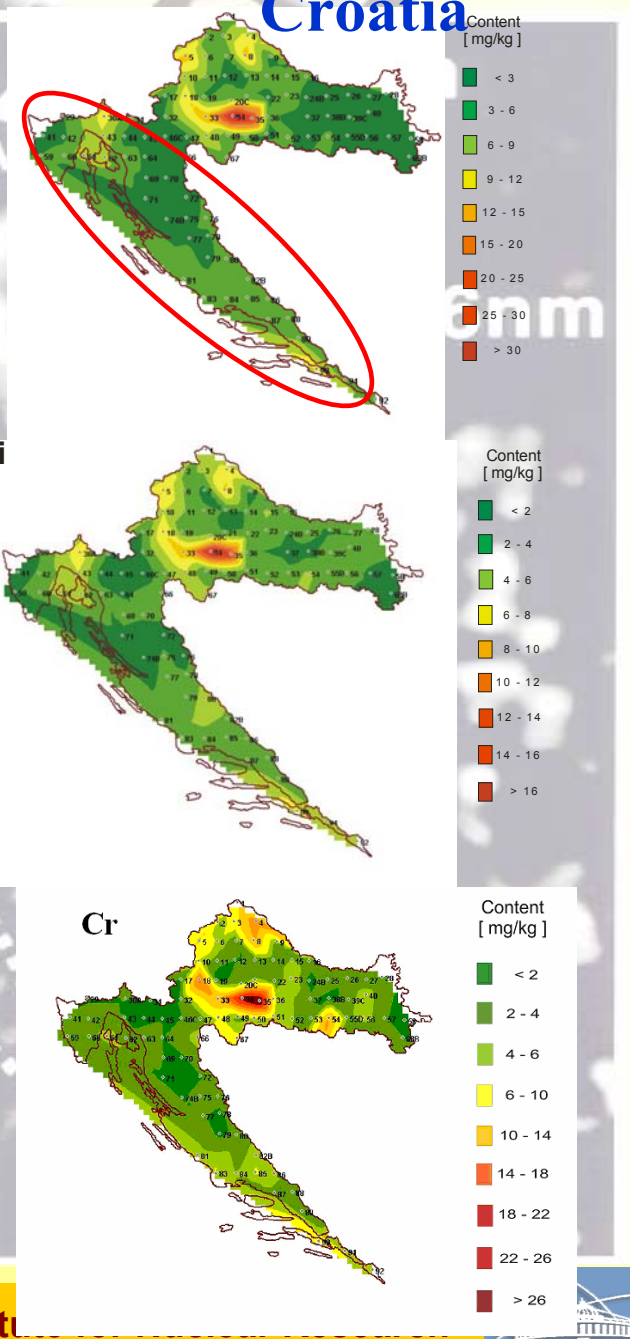
Romania

Serbia

Bosnia

Bulgaria

Macedonia



Dr. **Stefano Loppi**
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Fax +39 0577 232896
Email loppi@unisi.it

NAA for Archaeology

2nd International School on the Characterization of Organic Residues in Archaeological Materials (2nd ISCORAM)
Certosa di Pontignano (Siena, Italy, June 14-18, 2010.)
http://www.unisi.it/servizi/certosa/

NAA FOR IDENTIFICATION OF ORGANIC RESIDUES IN CERAMICS DATED FROM NEOLITHIC AGE

Mazurkevich A.N.[1], Frontasyeva M. V.[2],
Kul'kova M.A.[1], Dolbunova Ye.B. [1] , Strelkova L.P.[2]

[1]The State Hermitage Museum, St.-Petersburg, Russian Federation
[2]Joint Institute for Nuclear Research, Dubna, Russian Federation

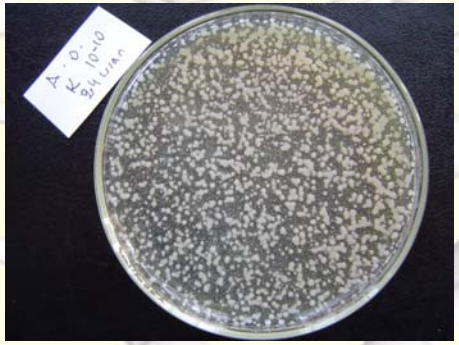
Determined: Na, Mg, Al, S, K, Ca, Sc, Ti, Mn, Fe, Co, Ni, Zn, As, Se, Br, Rb, Sr, Zr, Mo, Sb, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Dy, Tm, Yb, Hf, Ta, W, Au, Th, U

NAA for Biotechnology

Development of new Se-, I- и Cr-containing pharmaceuticals based on blue-green micro-alga *Spirulina Platensis* (2 patents of Russian Federation)

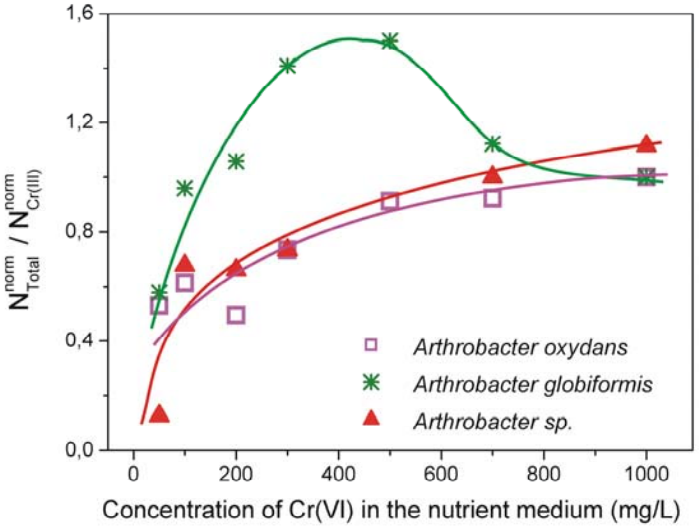
Cleaning of the environemnt from toxic elements (Cr, Hg, U etc.) by means of microorganisms (*Spirulina Platensis, Arthrobacter oxidans etc.*)

Development of methods for bacterial leaching of metals from low-grade ores and waste



A. oxydans: control

A. oxidans under impact of 1000 mg/l of Cr(VI)



Georgia – JINR Member state
Prof. Nelly Tsibakhashvili
Institute of Physics,
Tbilisi, Georgia
Nelly_tsibakhashvili@yahoo.com

Potential collaborator in Italy:
Prof. L. Campanella
Dipartimento di Chimica, Università di Roma La Sapienza, Piazzale Aldo Moro 5, 00185, Rome, Italy.
luigi.campanella@uniormal.it

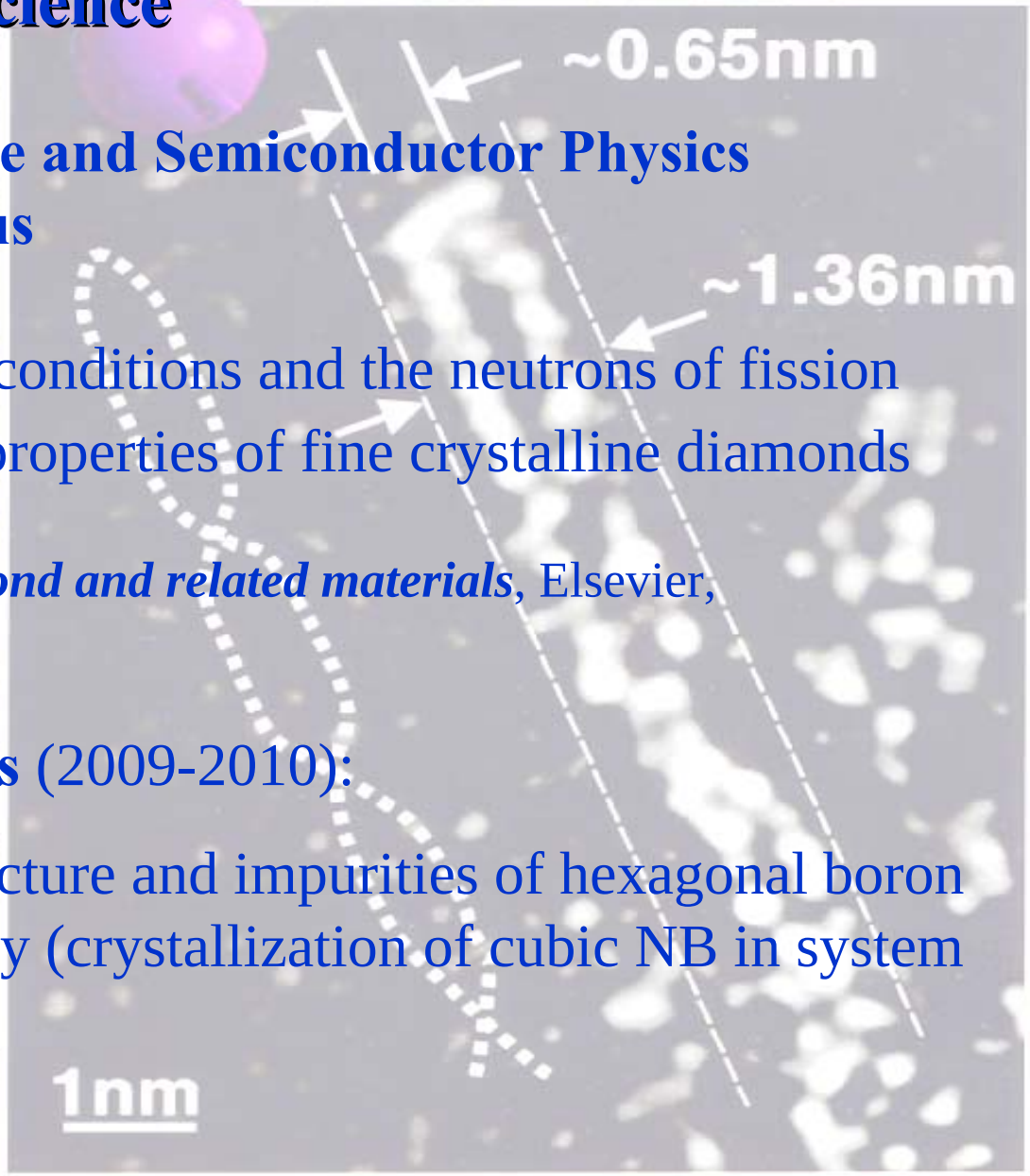
Development of metallic nanoparticles using biotechnology based on extremophilic microorganisms

An overall objective is to develop the scientific and technological base for utilizing microorganisms to synthesize nanoparticles with the desired characteristics, in particular, to study biosynthesis of metallic (Ag, Au) and metal oxide (TiO2) and other semiconductor nanoparticles (CdS, CdSe) by a variety of microbes, and to ultimately use this knowledge to develop new methods of large-scale nanoparticle production.

Specific objectives are:

- Intensive screening of microbes to evaluate their ability to produce metallic, metal oxide and also semiconductor nanoparticles;
- Develop a detailed procedure of nanoparticle synthesis for selected microbial strain;
- Characterization of physical and chemical properties of biosynthesized nanoparticles;
- Understanding of biochemical and genetic mechanisms of nanoparticle production by selected microbial strain.

NAA for Material Science



Institute of Solid State and Semiconductor Physics
NASB, Minsk, Belarus

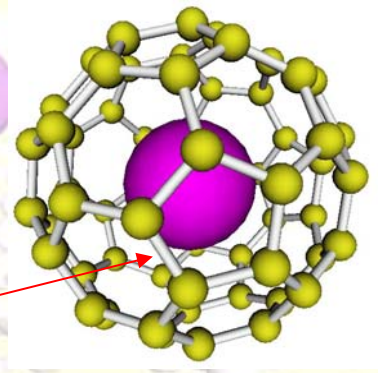
Influence of synthesis conditions and the neutrons of fission spectrum on physical properties of fine crystalline diamonds

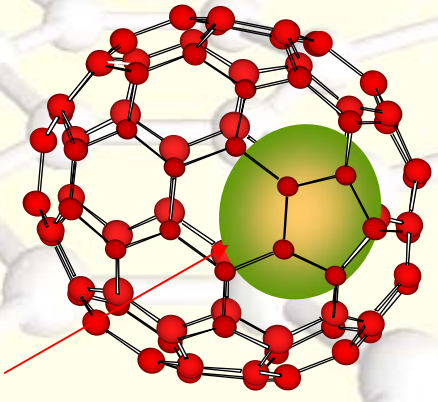
International Journal ***Diamond and related materials***, Elsevier, Vol. 14, 2005, p. 1678-1682

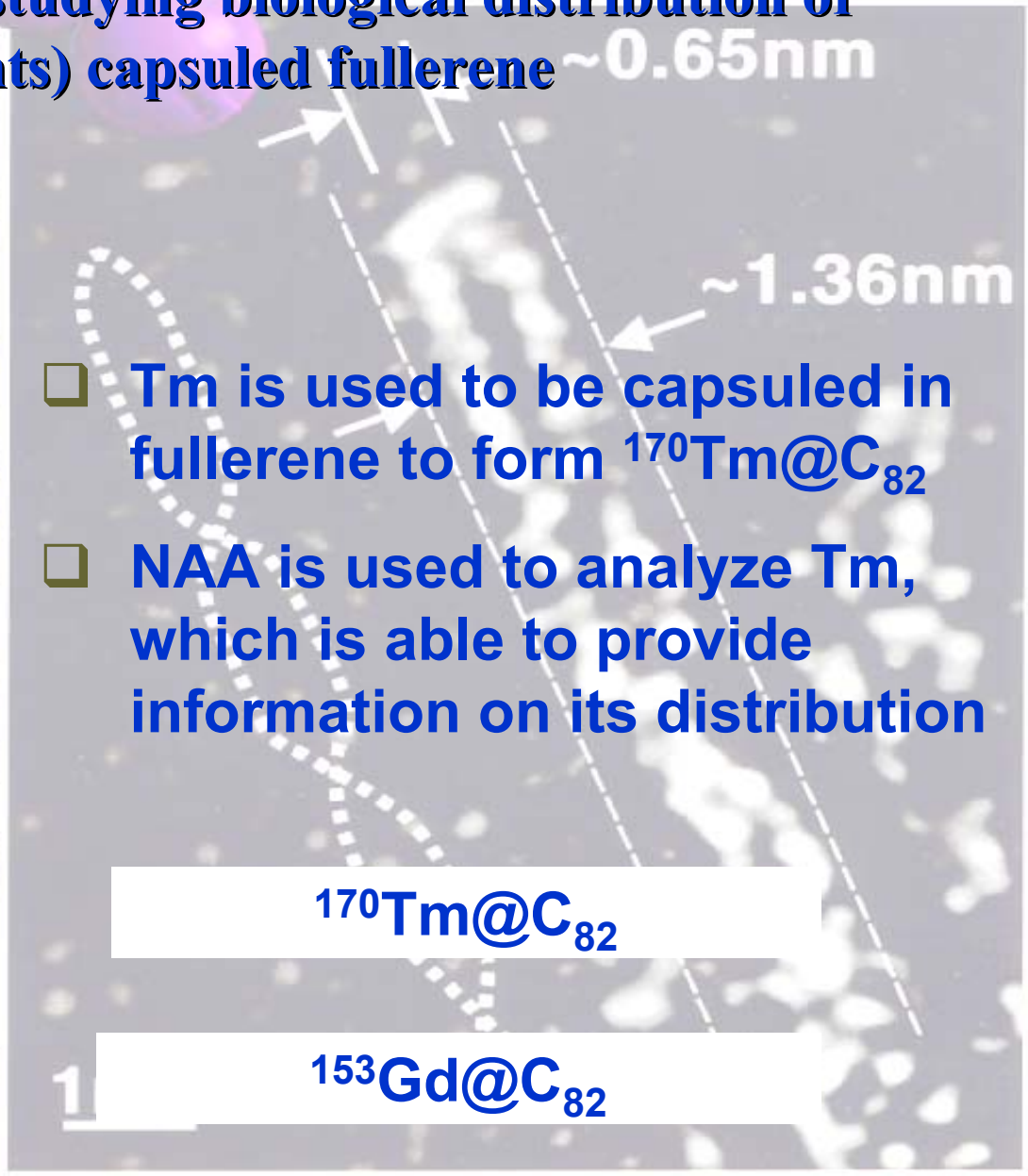
Grant RFBR- Belarus (2009-2010):

NAA for studying structure and impurities of hexagonal boron nitride (BN) technology (crystallization of cubic NB in system Li_3N-BN)

Perspectives of NAA for studying biological distribution of REE (Rare Earth Elements) capsuled fullerene





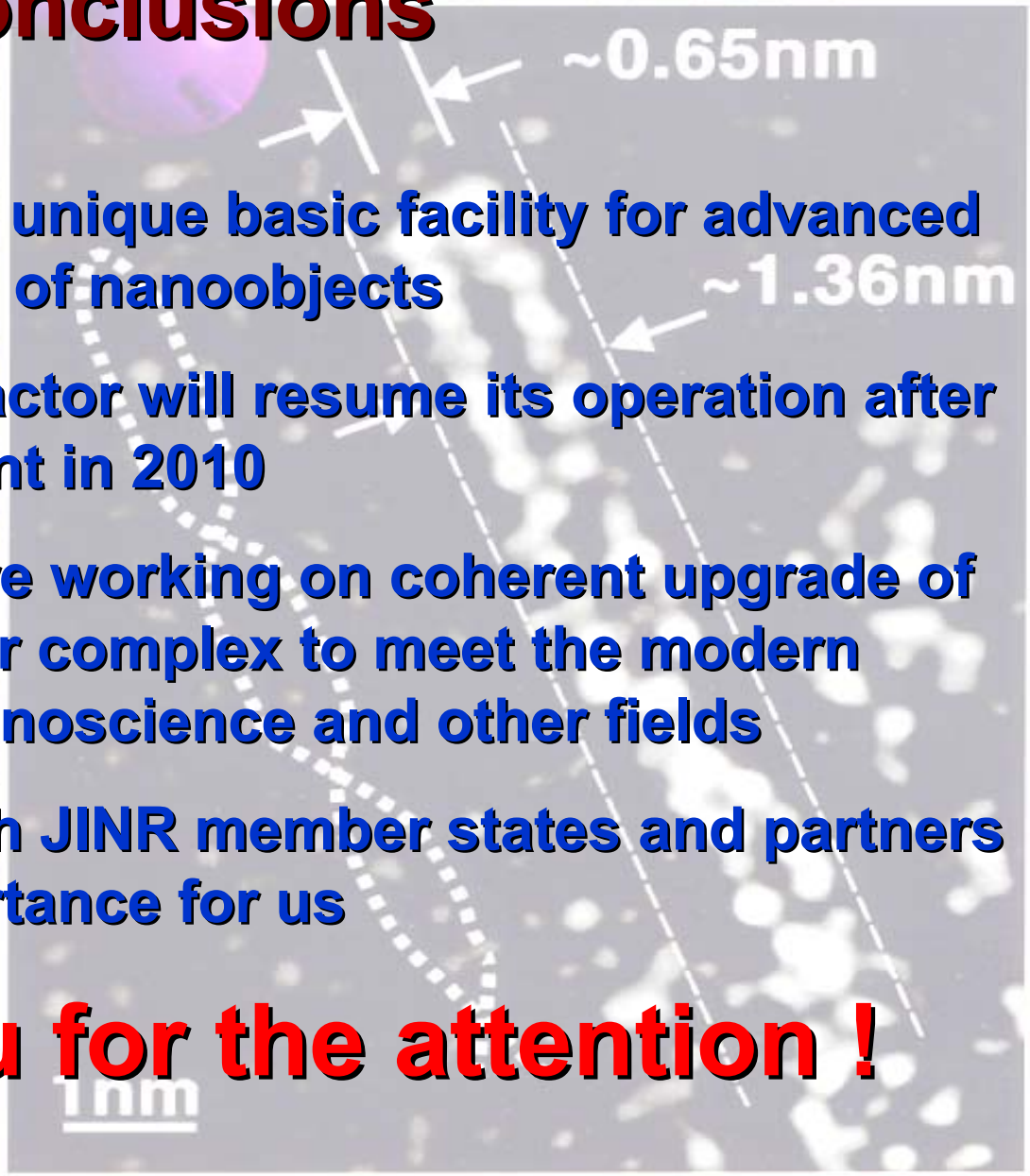


- Tm is used to be capsuled in fullerene to form $^{170}Tm@C_{82}$
- NAA is used to analyze Tm, which is able to provide information on its distribution

$^{170}Tm@C_{82}$

$^{153}Gd@C_{82}$

Conclusions



- ✓ JINR possesses unique basic facility for advanced characterisation of nanoobjects
- ✓ IBR-2 pulsed reactor will resume its operation after the refurbishment in 2010
- ✓ At present we are working on coherent upgrade of the spectrometer complex to meet the modern challenges in nanoscience and other fields
- ✓ Cooperation with JINR member states and partners is of great importance for us

Thank you for the attention !