JINR Institute

Small Angle Scattering Spectrometer

YuMO

Report of the first Year

2023 / 2024

Postdoc Research Fellow

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Candidate of science condensed matter Physics (SPBU) 21 June 2021

Title of PhD Dissertation 2021:

(Magnetic properties of iron nanowire arrays: the impact of geometrical parameters)

Current position:

Researcher Postdoc Fellowship [20 Nov. 2023 – Present] – **FLNP** / **YuMO**

Field of work:

- Magnetic nanowire materials
- nanowires and nanomaterials
- FORC analysis
- Small Angle Scattering

Publications:

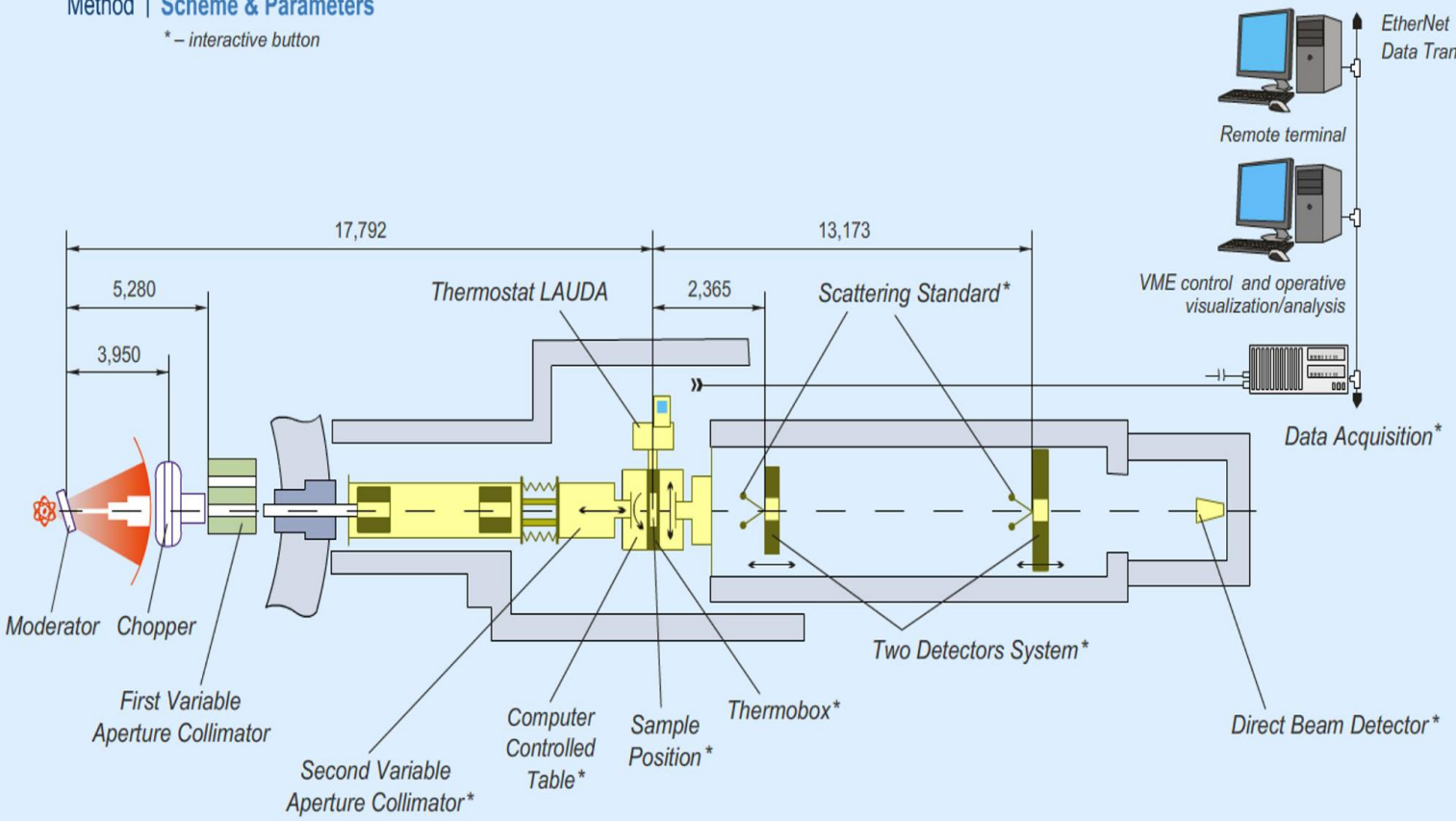
- El-Din, IMA Tag; Hassan, SSA; El-Din, MSM Nour; **Almekawy**, AH. (2015) Treatment of total reaction cross section for proton and antiproton scattering from 3He.Journal of Nuclear Science and Applications„48,4,219-236,**2015**,
- **Elmekawy A. H. A.,** Iashina E. G., Dubitskiy I. S., et al. (**2020**) Magnetic properties and FORC analysis of iron nanowire arrays.Materials Today Communications. doi: https://doi.org/10.1016/j.mtcomm.2020.101609.
- Dubitskiy I. S., **Elmekawy A. H. A**., et al. (**2021**) Effect of Interactions and Non-uniform Magnetic States on the Magnetization Reversal of Iron Nanowire Arrays.Journal of Superconductivity and Novel Magnetism. doi: https://doi.org/10.1007/s10948-020-05711-y.
- **AHA Elmekawy**, E Iashina, I Dubitskiy, et al. (**2021**) Magnetic properties of ordered arrays of iron nanowires: The impact of the length.Journal of Magnetism and Magnetic Materials. doi: https://doi.org/10.1016/j.jmmm.2021.167951.
- AA Mistonov, IS Dubitskiy, **AHA Elmekawy,** et al. (**2021**) Change in the Direction of the Easy Magnetization Axis of Arrays of Segmented Ni/Cu Nanowires with Increasing Ni Segment Length.Physics of the Solid State. doi: https://doi.org/10.1134/S1063783421070179.

Aspects of SANS At YuMO

Small-angle neutron scattering spectrometer YuMO

Method | Scheme & Parameters

* – interactive button



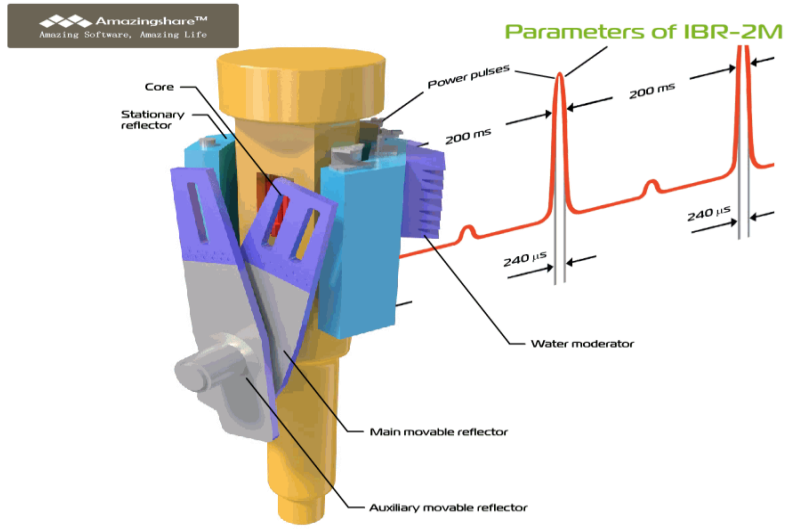
Frequency of pulse repetition – 5 Hz

Used wavelength – 0.5 Å to 8 Å

Q-range – 7×10^{-3} – 0.5 $Å^{-1}$

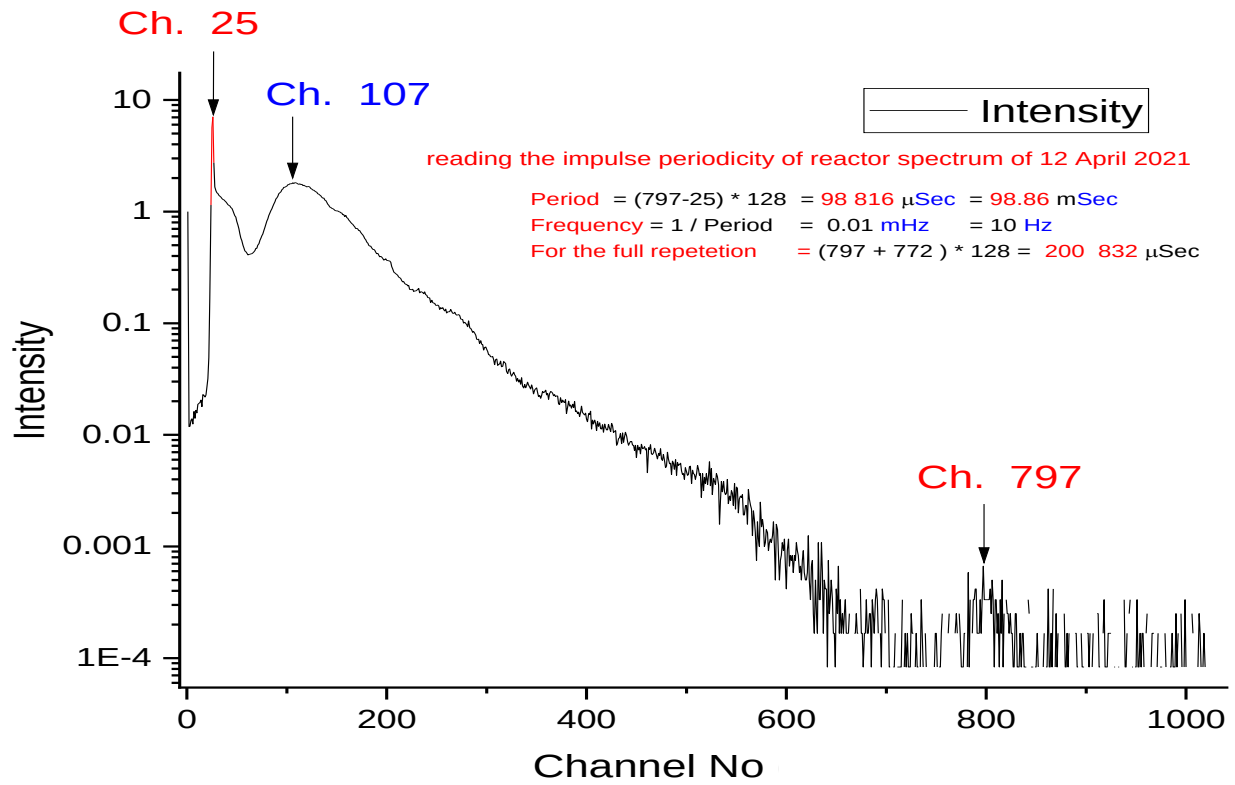
Neutron Source IBR2

Pulse Periodicity & Spectrum



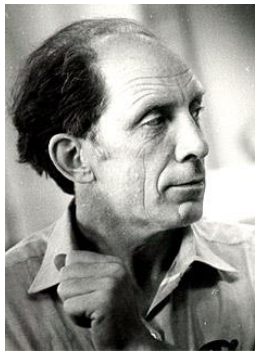
Average power, MW	2
Burst power, MW	1850
Fuel	PuO_2
Number of fuel assemblies	69
Maximum burnup, %	9
Pulse repetition rate, Hz	5; 10
Pulse half-width, μs: fast neutrons thermal neutrons	 240 320
Rotation rate, rev/min: main reflector auxiliary reflector	 600 300
MMR and AMR material	nickel + steel
MR service life, hours	55000
Background, %	7.5
Thermal neutron flux density from the surface of the moderator*: - time average - burst maximum	 ~10^{13} n/cm²·s ~10^{16} n/cm²·s

* More precise data on the thermal neutron flux density after the modernization will be available when the reactor operates at full power.

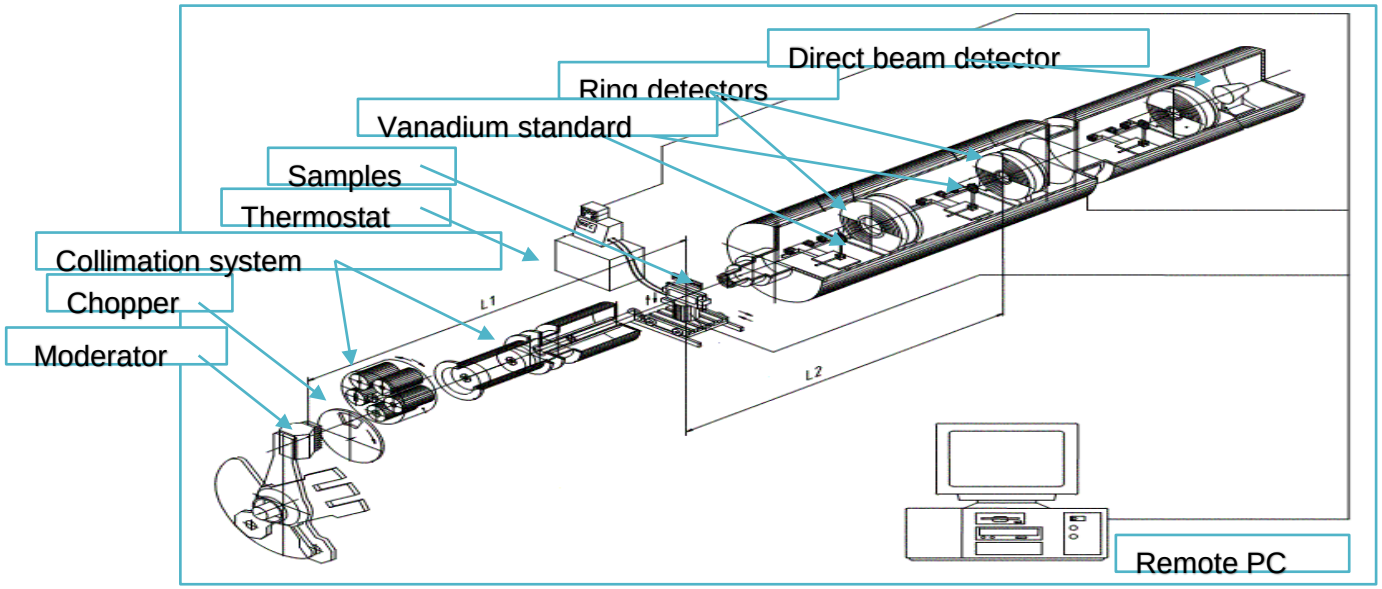


Small Angle Scattering Technique

Parameters Of SANS At YuMO



Юрий Мечиславович Останевич



- Simply, this method is used to investigate material with unknown periodicity - unlike normal diffraction - as constituents of the material have mystery structure.
- Dimensions of the investigated material determined by the characteristics of probing particle you are going to use (mainly the wavelength) even you are using x-rays, neutron or photons.
- For YuMO line, neutrons have wavelength between 0.7 – 8 A, which allow to investigate materials in size range (10 – 100 A).
- This technique is a non-destructive elastic scattering, so biological samples could be easily studied even with applied condition of thermo-living organism.

Point of Interest

Applicability of small angle neutron scattering and FORC Method for studying magnetic behavior for arrays of 3D Magnetic nanowires materials

Outlines

- Investigate the impact of geometrical parameters (impact of length) on the magnetic behaviour of our samples.
- Results by First order reversal curve (FORC) between two different samples (short / long length) was significant, such analysis help to reveal internal interactions during magnetization process.
- Using Small Angle Neutron Scattering (SANS) analysis with and without applying external magnetic field parallel to nanowire axis, seeing Impact of geometrical parameter on scattering curve on both situations.
- Testifying SANS possibility to investigate internal interactions and compatibility with the results of FORC analysis.

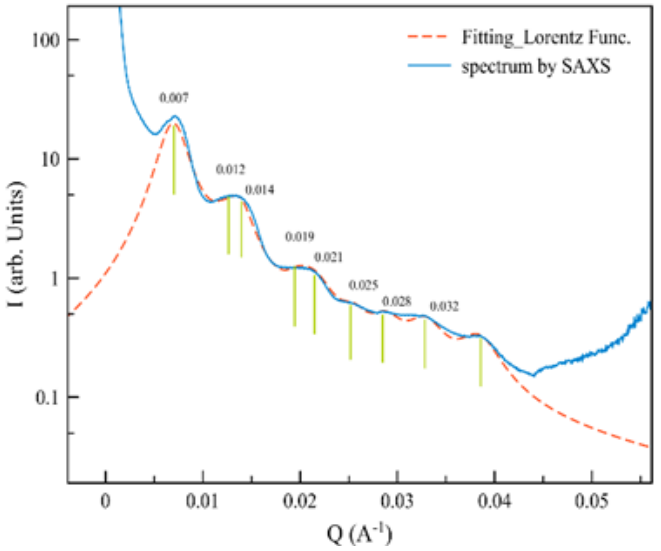
Expectations

small angle neutron scattering should add more understanding to the magnetic behaviour which should be realized by using the 2D new detecting system on YuMO. With both methods, a good characterization for the magnetic behaviour- which is of great importance for different applications- could be satisfied.

Points had been covered

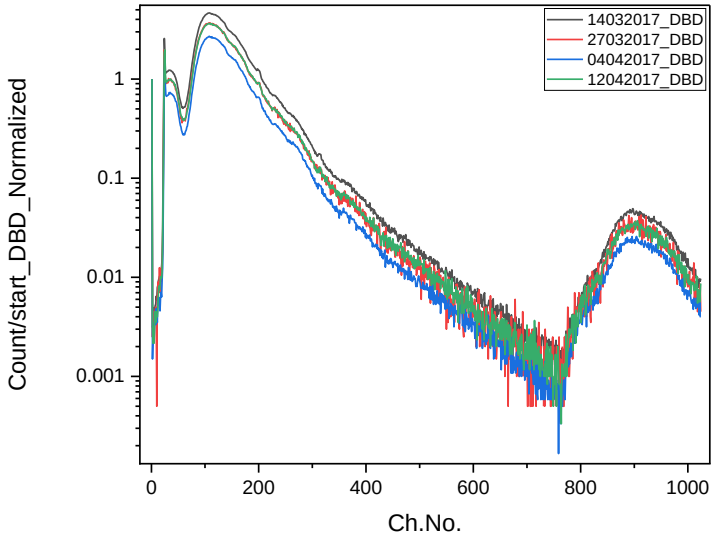
- Training and studying basics of both SANS and SAXS techniques, processing previous experimental data using SAS, Sasview, and ATSAS package.

- Conducting one experiment onto SAXS (XENOCS) investigating periodicity of magnetic nanowire samples (CuNi – Fe).
- samples represent a set of 2D hexagonally arranged pores of randomly oriented domains.



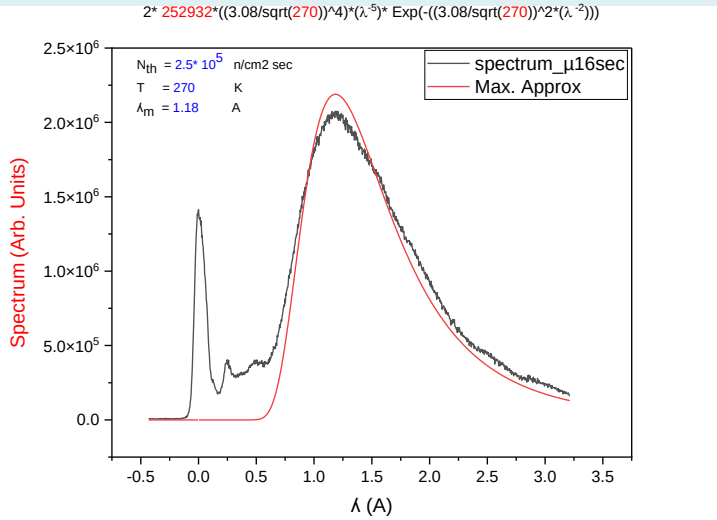
- Participating through the setting of the 2D PSD detector, electronical setup and testifying.

- Studying and analyzing the change of neutron spectrum within several cycles of the reactor since 2015, by processing the count obtained onto the direct beam detector DBD of the YUMO facility.
- Change of spectrum with years since 2015 indicating how neutrons with higher wavelength could be noticed on first two years with reasonable dynamic factor also the effect of the chopper frequency alignment with the reflector periodicity.

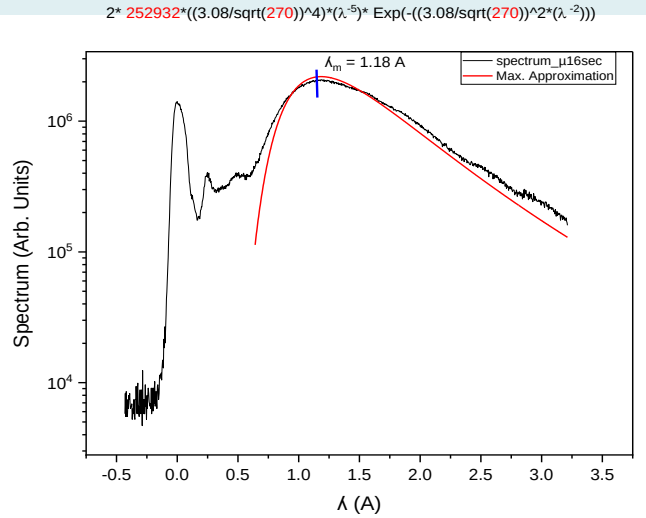


Points had been covered

- Studying and analyzing the neutron spectrum with channel time width of 16 μsec compared to other spectrum with standard 128 μsec channel width.

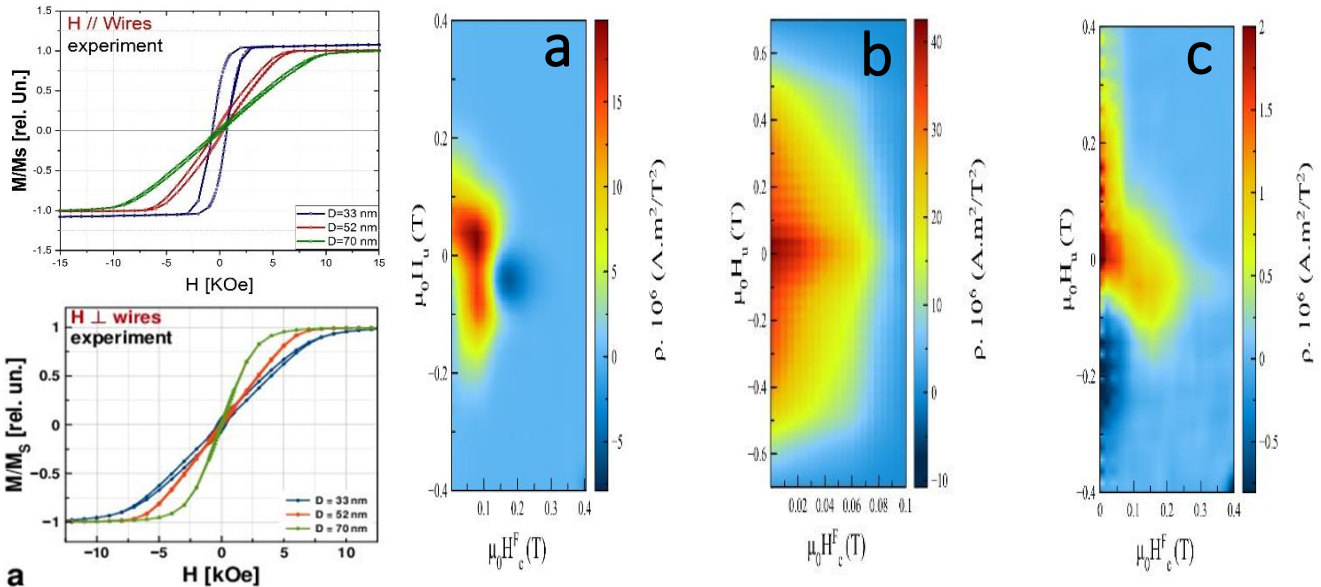


Maxwell Approximation to experimental spectrum with channel width 16 μsec (Linear scale)



Maxwell Approximation to experimental spectrum with channel width 16 μsec (Log. scale)

- Participated in Scientific Forum (Physics 2024 – Samarkand) with Poster titled **“Magnetic characteristics of arrays of iron-based nanowires investigated by FORC Analysis”**.



FORC diagrams of Fe nanowire arrays with the following parameters (H ll NW)

(**a**) (d=33 ± 2 nm, L = 30.1 ± 0.7μm)
(**b**) (d=55 ± 4 nm, L = 18.8 ± 0 .6μm)
(**c**) (d=69 ± 7 nm, L = 26.9 ± 0.7μm)

Present

- Currently conducting SAXS analysis on Rigaku instrument (MIPT) for Powder samples of magnetic composite (Magnetite / Yttrium oxide) with different concertation (unfinished analysis).
- Preparing results related to Stability of DBD and its modernization to be published.

Work to be conducted

- Solving technical issues related to magnetic field system, applying suitable conditions to conduct SANS experiments with external magnetic parallel to nanowire axis for our samples and take a part in work upgrading position sensitive detector (PSD).
- Preparing new samples with new geometrical parameters (smaller diameters of 30 nm and Different length).
- Writing algorithm suitable for processing anisotropic pattern expected with our samples.
- Investigating possibility of enrolling used templates for Neutron focusing application.
- Preparing paper discussing the DBD efficiency.
- Preparing results of Magnetic Material (Nanowires / Powder) concerning size effect for publication.

Thank you
for
your attention

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for
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An example of scattering pattern by SANS for a system of iron nanowires with diameter of 50 nm.
The pattern is like that observed in measurements at the synchrotron. However, close peaks are practically indistinguishable, and the observed number of orders is much lower than in the synchrotron experiment.
This is due to;
. larger size of the neutron beam,
. The fact that in this case scattering occurs the nuclear and magnetic structures of the sample not on the electron density.

The positions of the Bragg reflections are in good agreement with the synchrotron scattering indicates a high correlation between the distribution of electron density and the positions of nuclei.

In addition, the positions of the magnetic peaks coincide with the positions of the nuclear ones.