Investigation of superconductivity and magnetism in layered nanostructures by polarized neutron reflectometry with secondary radiation registration

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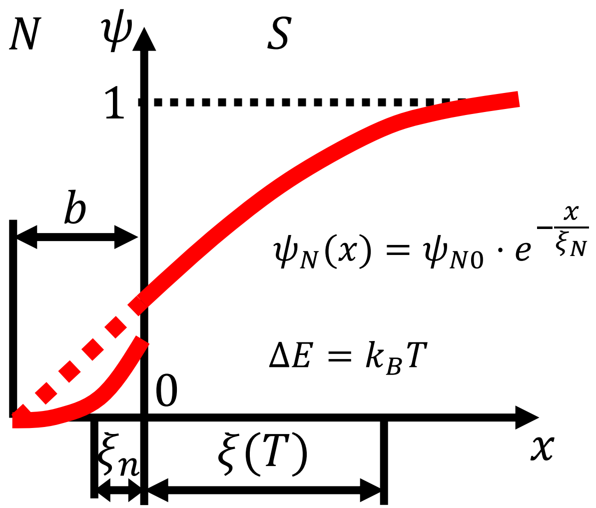
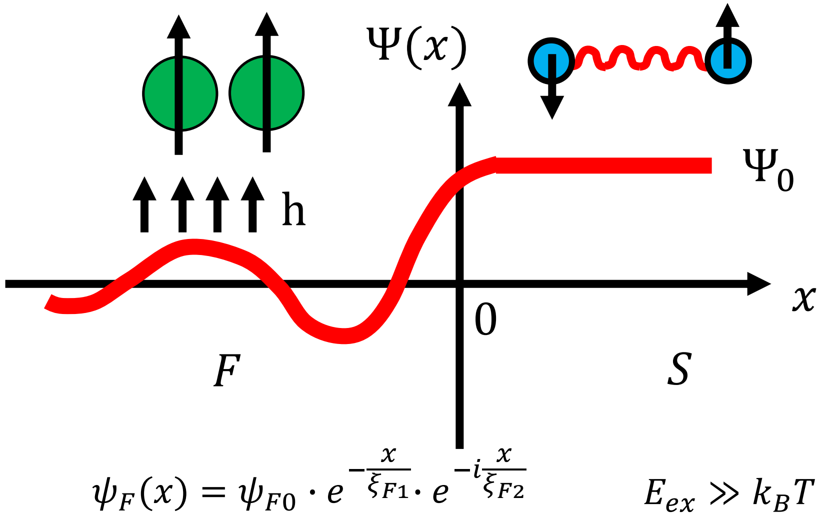
Magnetic and superconducting heterostructures

Normal metal / superconductor



Ferromagnet / superconductor

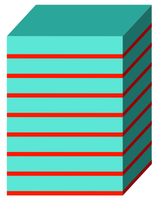


Magnetic states of S-F systems under influence of proximity effects

Low-dimensional heterostructures $d \sim \xi$

Influence of magnetism on superconducting properties of the system $\frac{I_F}{I_S} \sim 10^2$ $I \sim T_c$

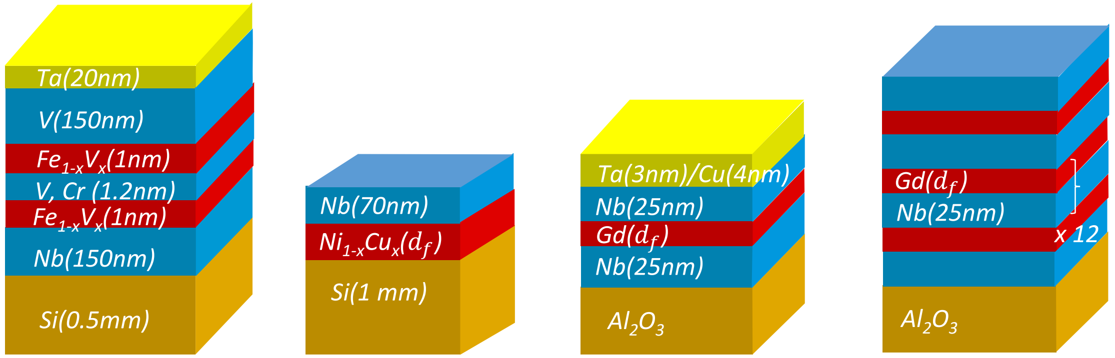
Influence of superconductivity on magnetic properties of the system $d_F \sim \xi_F$ $d_F \ll d_S$



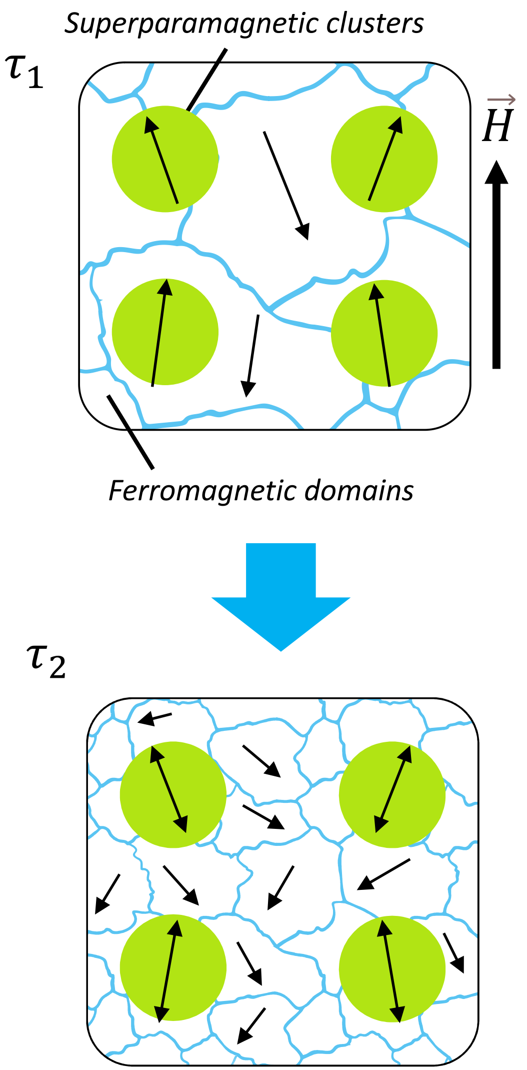
S-F structure
$d \sim 1 \div 10^3\ nm$

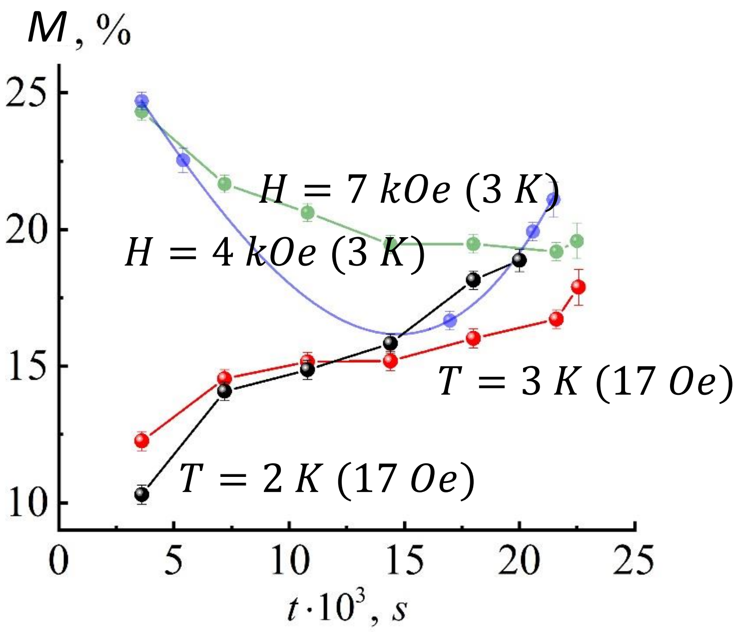
Proximity effects at S-F structures. Results

- $d_F \sim \xi_F$
- $d_F / d_S = 10^{-3} \div 10^{-2}$
- *Alloys: FeV, CuNi*
- *Systems S/Fe/S - type*
- *Different metalls (V, Nb, Fe, Ni, Gd)*

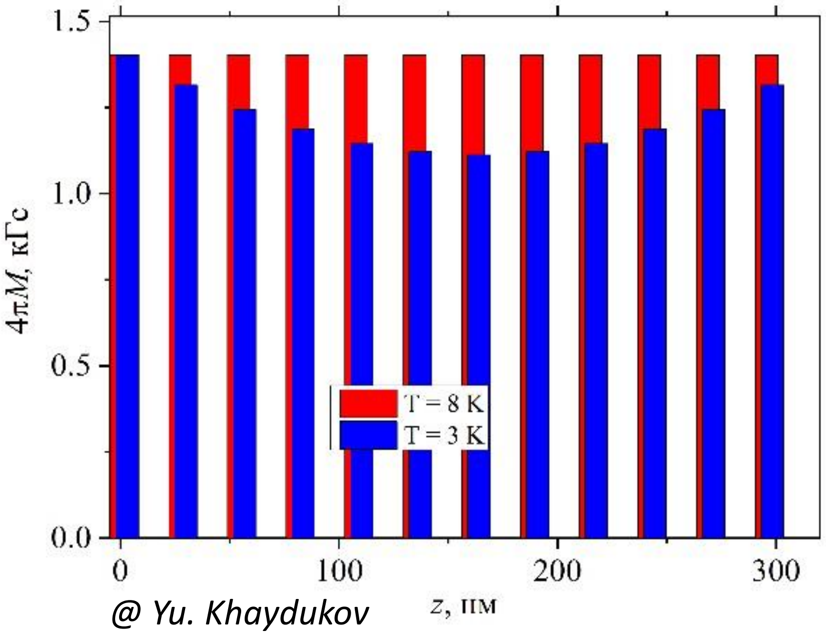


Nominal structures





Magnetic moment relaxation of the structure with ferromagnet FeV



Magnetic field displacement by Nb/Gd superlattice

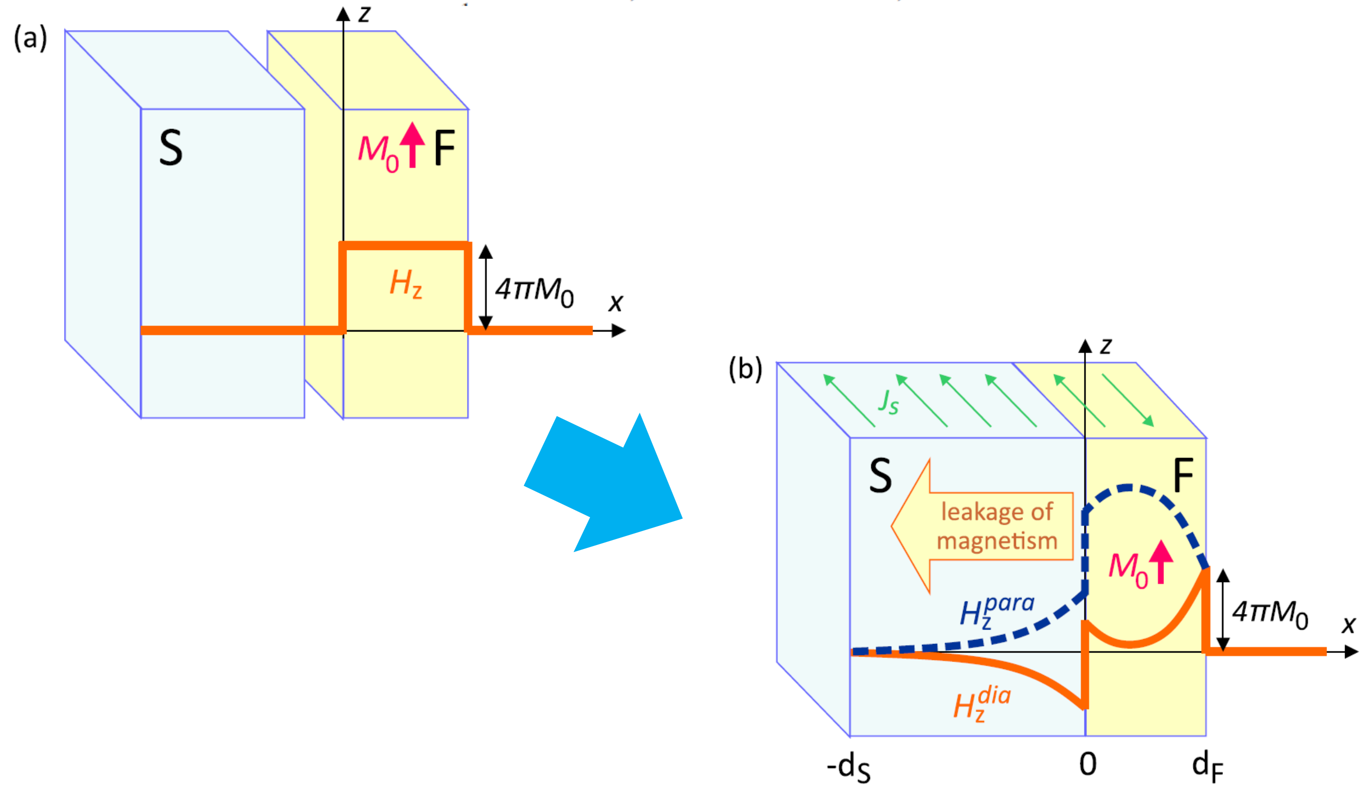
Inverse proximity effect

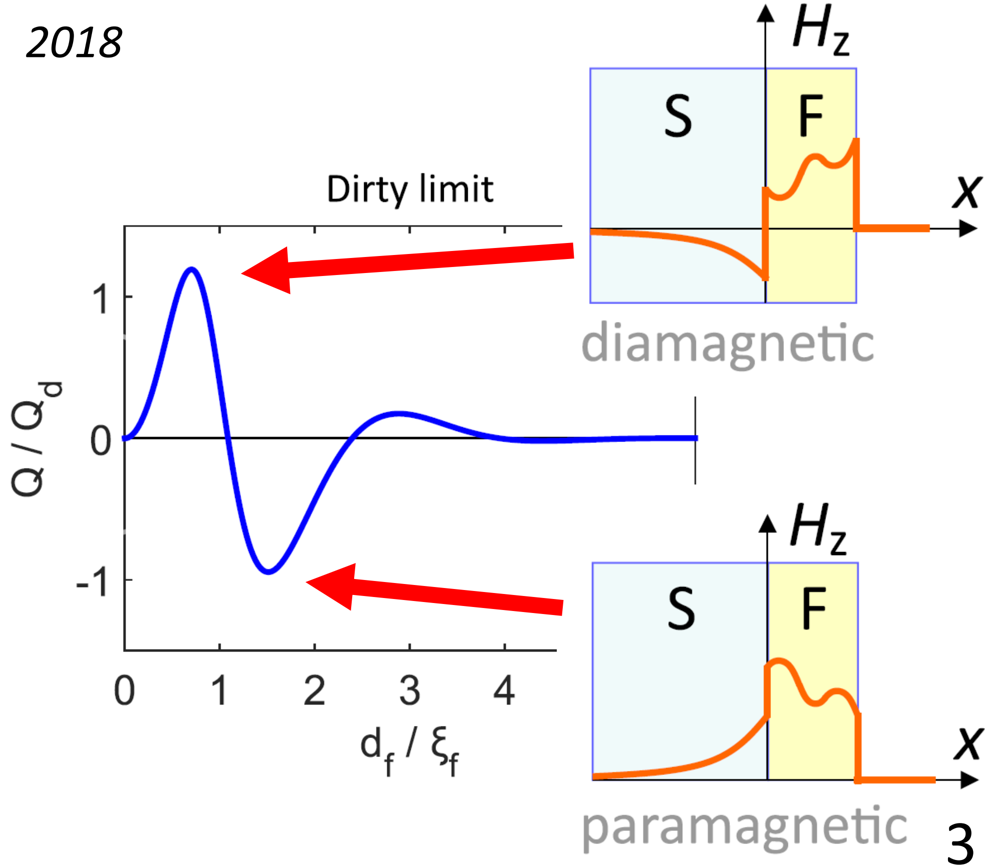
Recently, a new proximity effect has been described in ferromagnetic-superconducting layered nanostructures, which is characterized by a large scale (10 nm) of the interaction of superconductivity and magnetism, and which takes place for any ferromagnets.

Electromagnetic proximity effect in planar superconductor-ferromagnet structures

S. Mironov,[1] A. S. Mel'nikov,[1,2] and A. Buzdin[3,4,5]

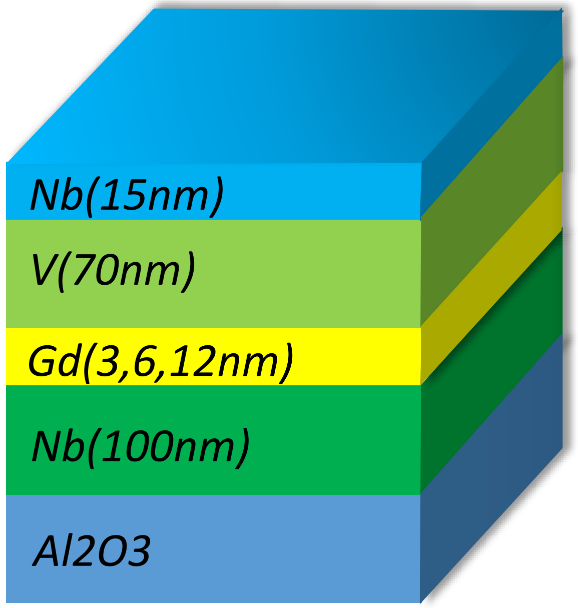
2018





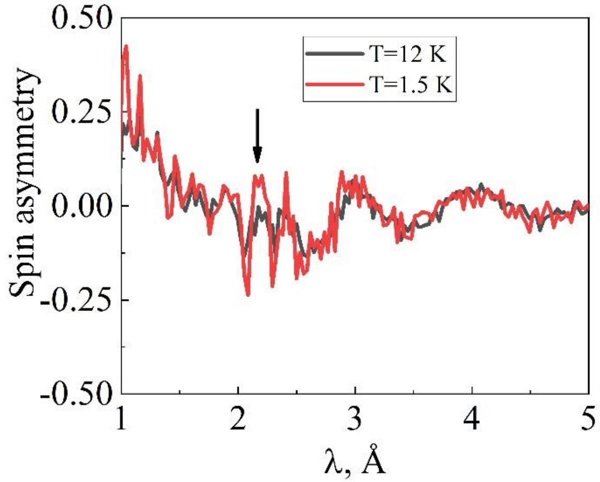
Inverse proximity effect. Results and plans.

At present, the Al2O3//Nb(100nm)/Gd(3nm)/V(70nm)/Nb(15nm) structure, where Gd is a ferromagnet and Nb and V are superconductors, has been studied. A change in the magnetization in superconducting layers (at area 10 nm close to F-layer) under the influence of superconductivity at a level of 4-10% was found, which corresponds to the implementation of the inverse proximity effect. Further plans are in detailed processing of experimental data and new experiments.



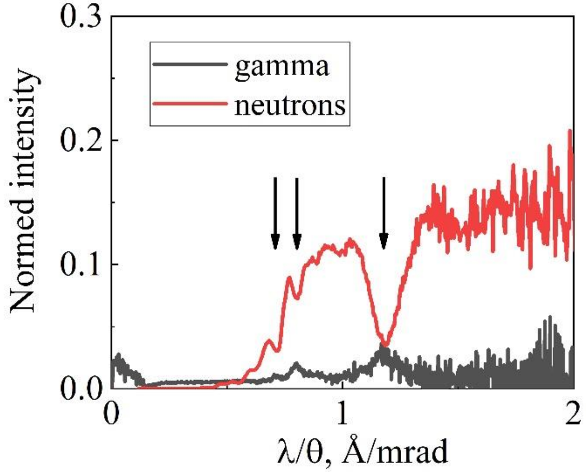
Polarized neutrons

determination of the magnetic profile of the Gd layer
and superconducting layers;
nuclear profile for sum of elements



Secondary radiation channel (gamma-quanta)

Determination of the nuclear profile of the Gd layer



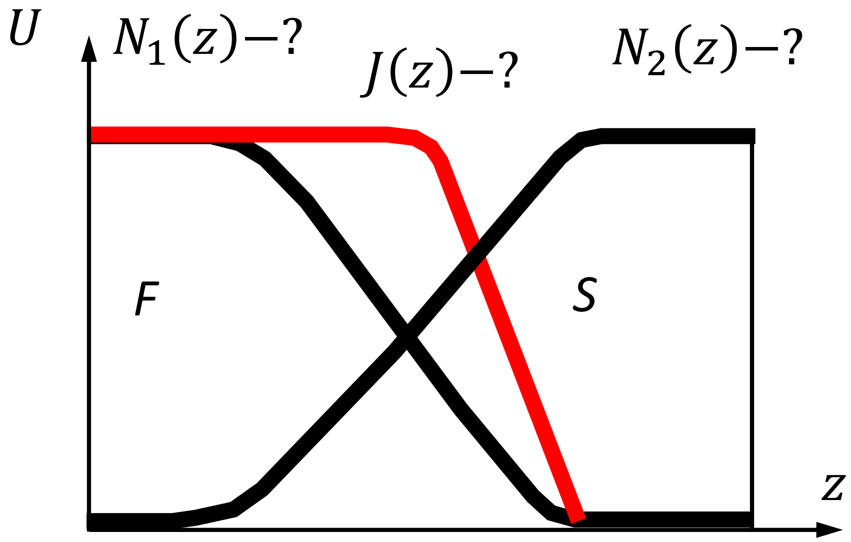
Secondary radiation registration

Secondary radiation registration at neutron reflectometry

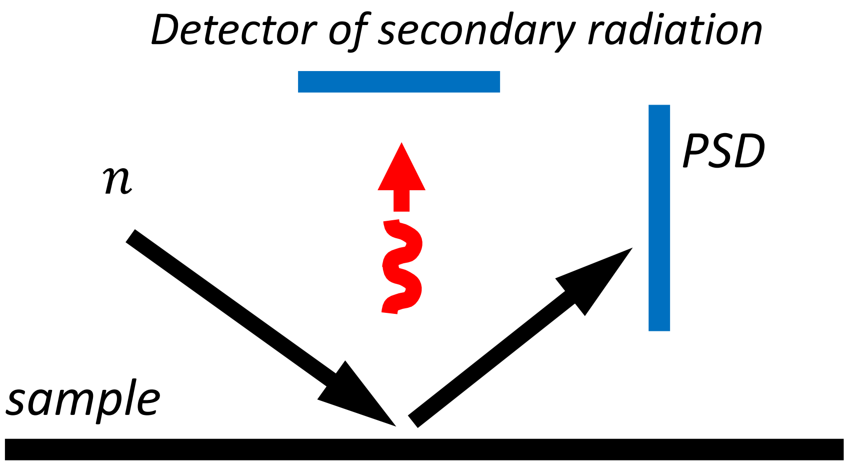
Channel of secondary radiation registration at REMUR-spectrometer:

- *charged particles:* $\sigma_{min} = 0.025\ barn$ *(~ 22 isotopes)*
- *gamma-quanta:* $\sigma_{min} = 0.3\ barn$ *(> 100 isotopes)*
- *spin-flip neutrons:* $B_{min} = 1\ Gs$ *(9 elements: Fe, Co, Ni, Gd, Dy, Tb, Ho, Er, Tm)*

Data for layer with thickness 5 nm



$$W = \sum W_{ij} \propto \sum N_i \sigma_{ij}$$



$$J_{i,j}(k_{z0}) \sim \int \frac{|\psi(z,k_{z0})|^2 \cdot Im(u)}{|\psi_0(k_{z0})|^2 \cdot k_0} N_i(z) dz$$

Zhaketov V.D. et al. // Surface investigations, vol. 6, pp. 1-15 (2021)
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Conclusion

1. Proximity effects in superconducting-ferromagnetic structures were studied. A nonequilibrium magnetic state in the structures with ferromagnets of the transition group of metals, such as FeV and NiCu, has been discovered and investigated.

2. At the structure Al2O3//Nb(100nm)/Gd(3nm)/V(70nm)/Nb(15nm) change in the magnetization in superconducting layers (at area 10 nm close to F-layer) under the influence of superconductivity at a level of 4-10% was found, which corresponds to the implementation of the inverse proximity effect.

3. At the REMUR reflectometer realized mode for detecting secondary radiation: charged particles, gamma quanta, and neutrons with spin flip, what makes it possible to determine the spatial profile of individual isotopes.

Thank you for your attention!