захвата. В докладе обсуждается природа радиационно-индуцированных дефектов кристаллической структуры.

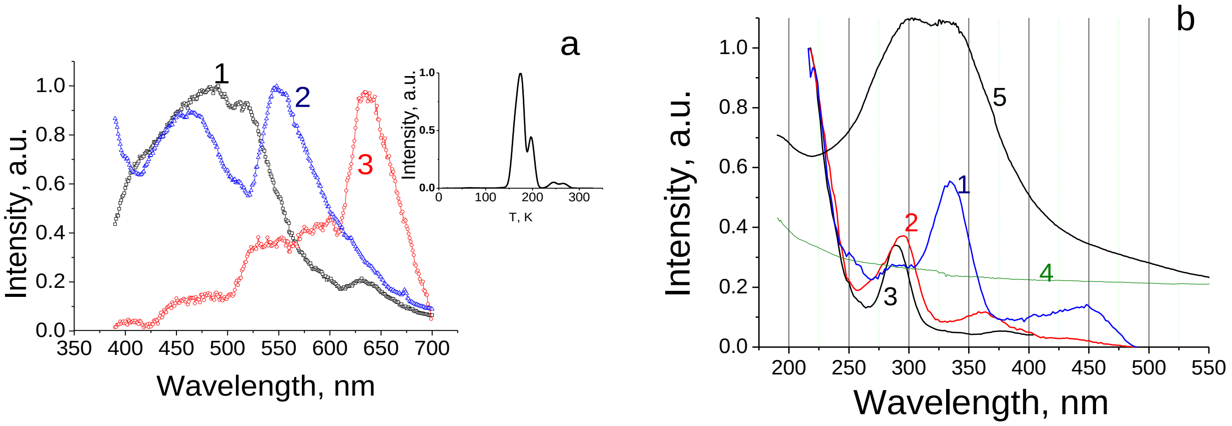

Рис. 1. a – спектры ФЛ облученного D= 120 kGy кристалла $SrMgF_4$: λ_{exc}= 290 (1), 440 (2), 340 нм (3), T= 8 K; на вставке - кривая термовысвечивания в полосе 360 нм; b – спектры возбуждения ФЛ для полосы 630 (1), 530 (2), 450 нм (3) и спектры поглощения кристалла $SrMgF_4$ до (4) и после облучения (5).

1. Пустоваров В.А., Огородников И.Н., Omelkov S.I. и др., Физика твердого тела 56, 448 (2014).

QUANTUM NANOSKYRMIONS

Sotnikov O.M.[1*], Mazurenko V.V. [1], Colbois J. [2], Mila F. [2],
Katsnelson M.I. [3,1], Stepanov E.A. [3,1]

[1] Ural Federal University, Yekaterinburg, Russia
[2] Institute of Physics, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland
[3] Radboud University, Institute for Molecules and Materials, Nijmegen, The Netherlands
*E-mail: oleg.sotn@gmail.com

Recent progress in experimental techniques made observation of skyrmions with the size of a few nanometers [1] possible. On such small characteristic length scale compared to the lattice constant, quantum effects cannot be neglected. In particular, it concerns low-dimensional systems with small spin (e.g. $S = 1/2$), where quantum fluctuations play a crucial role.

Here, we report on the first attempt to introduce the concept of purely quantum skyrmions based on the exact numerical solution of the quantum problem, described by Heisenberg-exchange free Hamiltonian [2]:

$$\hat{H} = \sum_{i<j} \boldsymbol{D}_{ij}[\hat{\boldsymbol{S}}_i \times \hat{\boldsymbol{S}}_j] - B\sum_{i} \hat{S}_i^z , \qquad (1)$$

where $\boldsymbol{D}_{ij}$ is Dzyaloshinskii-Moriya interaction, $\hat{\boldsymbol{S}}_i$ denotes spin operator and B represents z-oriented magnetic field. The definition of quantum skyrmion is complicated due the fact that calculation of skyrmion charge [3] requires to know all three components of spin at the same time which is impossible in quantum case due to uncertainty principle. On the other hand, the classical skyrmion can be presented as the superposition of enclosed spin spirals, and its structure factor should reveal intensities at the momenta that are related to period of these spirals. Therefore, the quantum skyrmion can be identified as a multiple-q state of a quantum system with a special distribution of intensities in the spin structure factor comparable to the classical skyrmionic case.

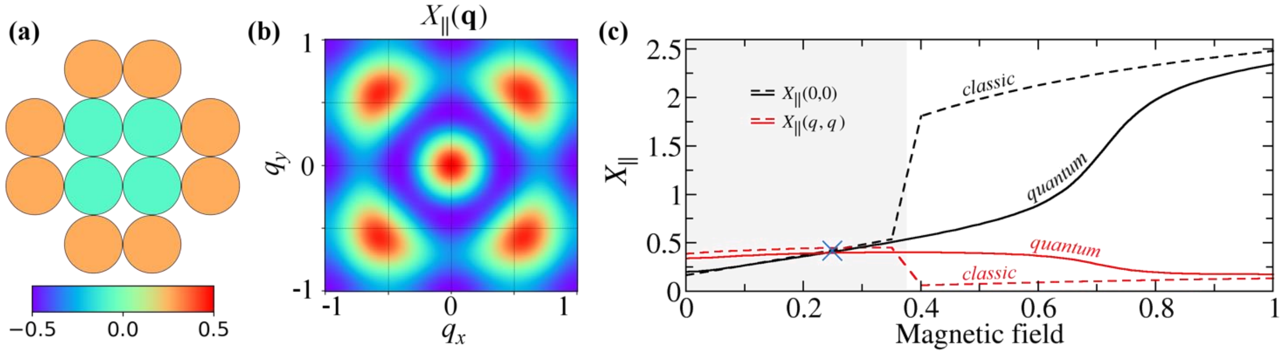

Fig. 1 (a) Schematic representation of 12-site cluster considered in this work. Color denotes z component of spin $\langle \hat{S}_i^z \rangle$ calculated for quantum solution of Hamiltonian (1) at field $B = 0.25\,|\boldsymbol{D}_{ij}|$ and $T = 0$. (b) Spin structure factor $X_{||}$ calculated for the solution. (c) Magnetic field dependence of $X_{||}(0,0)$ and $X_{||}(q,q)$, $q = 0.56\pi$. Blue cross denotes the solution presented at (b).

Solving model (1) for 12-site spin cluster at field B $= 0.25|\mathbf{D}_{ij}|$ by means of ED we calculated z components of spin and structure factor $X_{||}$ (Fig. 1 (a) and (b)) which demonstrate typical skyrmionic behavior in comparison with classic solution. Figure 1 (c) shows dependence of $X_{||}$ on magnetic field for classic and quantum solutions. One can see that in quantum case skyrmion state appears even at field values for which classic one becomes polarized. Such a behavior was corroborated by analysis of skyrmion ground state structure. We also shown that quantum skyrmion is stable against temperature fluctuations since structure factor remains distinguishable up to T $\approx 0.6|\mathbf{D}_{ij}|$.

The work of M.V.V., S.O.M., and S.E.A. was supported by the Russian Science Foundation Grant 18-12-00185. The work of K.M.I. was supported by NWO via Spinoza Prize. The work of C.J. and M.F. is supported by the Swiss National Science Foundation. Details of this research were published and available at Ref. [4].

1. Heinze S., *et al.*, Nature Physics **7**, 713 (2011).
2. Stepanov E.A., *et al.*, arXiv:1710.03044.
3. Berg B., and Lüscher M., Nuclear Physics B **190**, 412 – 424 (1981).
4. Sotnikov O.M., Mazurenko V.V., Colbois J., Mila F., Katsnelson M.I., Stepanov E.A., arXiv:1811.10823.