TT 28: Poster Session: Topological Topics

Time: Monday 15:00–19:00 Location: Poster B

TT 28.1 Mon 15:00 Poster B

Emergent Weyl fermion bulk excitations in TaP and NbP evidenced from solid state NMR and NQR — H. Yasuoka[1], K.M. Ranjith[1], T. Kubo[1,2], Y. Kishimoto[1,2], D. Kasinathan[1], M. Schmidt[1], B. Yan[1], H. Tou[2], C. Felser[1], A.P. Mackenzie[1], and •M. Baenitz[1] — [1]MPI for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Department of Physics, Graduate school of Science, Kobe University, Kobe, 657-8501 Japan

The monophosphides TaP and NbP belong the class of Weyl semi metals and exhibit a non centrosymmetric structure and sizable spin orbit coupling. A crossing of linearly dispersive topologically protected polarized bands at a single point in reciprocal space defines the Weyl node where the fermion mass vanishes theoretically and a giant orbital hyperfine coupling is expected [1]. ^{181}Ta quadrupole resonance(NQR) resolves three NQR lines associated with the split level transitions for the $I = 7/2$ Ta nuclear spin. The spin lattice relaxation violates the Korringa law and shows a pronounced $(1/T_1T) \propto T^2$ behaviour [2] which is assigned to the magnetic excitations of the Weyl fermions, in agreement with theoretical predictions [1]. In addition we present first ^{93}Nb NMR results from NbP single crystals. Here we investigated the anisotropic hyperfine interaction and the excitations of the $I = 9/2$ Nb nuclear spin.

[1] Z. Okvatovity et al., PRB 94 (2016)
[2] Y. Yasuoka et al., PRL 118 (2017)

TT 28.2 Mon 15:00 Poster B

Structure-Property Investigation of Superconductivity in Nb-doped Bi_2Se_3 — •Simone Munkholm Kevy[1], Laura Wollesen[1], Henriette Elisabeth Lund[2], Philip Hofmann[2], and Martin Bremholm[1] — [1]Department of Chemistry and iNano, Aarhus University, 8000 Aarhus C, Denmark — [2]Department of Physics and Astronomy, Interdisciplinary Nanoscience Center, Aarhus University, 8000 Aarhuc C, Denmark

Topological insulators (TI) have over the past decade been studied extensively due to their interesting electronic properties that make them excellent candidates for applications in quantum computing. Bi_2Se_3 is a highly studied TI and a large number of studies have investigated the effects of doping. Of particular interest, doping of Bi_2Se_3 with Cu, Sr or Nb, leads to bulk superconductivity while the topological surface states remain intact [1-3]. In the present study, high quality crystals grown by a melt growth quench technique were investigated to reveal structure-property relations of doped Bi_2Se_3. The crystal growth conditions were explored to determine optimal growth conditions. The crystal $Nb_xBi_2Se_3$ growth by slow cooling produces compositional gradients and the as-grown crystal boules contains secondary phases that affects the elemental composition and thus the physical properties. Crystallographic studies are combined with property measurements to provide a detailed structural understanding of superconductivity in doped Bi_2Se_3.

[1] Y. S. Hor, Phys. Rev. Lett., 104, 057001, 2010.
[2] Z. Liu, J. Am. Chem. Soc., 137, 10512, 2015.
[3] Y. Qiu, arXiv:1512.03519, 2015.

TT 28.3 Mon 15:00 Poster B

Local moment spin dynamics as a probe for topological properties — •Guilherme G. Lesseux[1,2], Martin Dressel[1], Marc Scheffler[1], Jean C. Souza[2], Ricardo R. Urbano[2], Pascoal J. G. Pagliuso[2], and Carlos Rettori[2,3] — [1]1. Physikalisches Institut - Universität Stuttgart, Stuttgart, Germany — [2]"Gleb Wataghin" Institute of Physics - University of Campinas, Campinas, Brazil — [3]CCNH, Universidade Federal do ABC, Santo André, Brazil

Electron spin resonance (ESR) of diluted magnetic impurities is a powerful local technique that can directly probe the nature of the interactions between localized magnetic moments and the electronic environment as well as the local, dynamic and static, crystalline site symmetry. Therefore, ESR may be an appropriate tool to investigate metallic surface states and other related relevant features for the physics of topologically nontrivial materials. Here, we present experimental strategies to probe topological properties by means of local moment spin dynamics. Unusual ESR results in half-Heusler YPt(Pd)Bi and SmB_6 compounds are presented and discussed in terms of their topological properties.

TT 28.4 Mon 15:00 Poster B

Flat Optical Conductivity due to the Dirac nodal line in ZrSiS — •Micha Schilling[1], Artem Pronin[1], Martin Dressel[1], Bettina Lotsch[2], and Leslie Schoop[2,3] — [1]1. Physikalisches Institut, Universität Stuttgart, 70569 Stuttgart, Germany — [2]Max-Planck-Institute for Solid State Research, 70569 Stuttgart, Germany — [3]Department of Chemistry, Princeton University, Princeton, USA

In graphene, the isolated two-dimensional Dirac cones cause a universal (i.e. material-independent) interband optical conductivity: the conductivity is frequency independent and the value is set by the quantum conductance. In ZrSiS, linear dispersing bands are quasi-two-dimensional and the Dirac points form nodal lines of two types. Spin-orbit coupling (SOC) opens a small gap along one of them. It was theoretically proposed, that the interband conductivity of such a nodal-line semimetal would also exhibit a frequency-independent behavior [1]. The absolute value, however, be material dependent, related to the length of the nodal line. We investigated the optical response of ZrSiS by the means of Fourier-transform infrared spectroscopy. We measured the reflectivity over a frequency range from 6 to 3000 meV at different temperatures down to 10 K and determined the optical conductivity. Our results confirm the theoretical expectations, revealing flat optical conductivity between 30 and 300 meV. From the measurements we could estimate the length of the nodal line in the reciprocal space and the size of the SOC-induced gap [2].

[1] J. P. Carbotte, J. Phys. Condens. Matter **29**, 045301 (2017).
[2] M. B. Schilling *et al.*, Phys. Rev. Lett. **119**, 187401 (2017).

TT 28.5 Mon 15:00 Poster B

One-dimensional physics in the edge states of the high-temperature Quantum Spin Hall system bismuthene on SiC(0001) — •Raul Stühler, Felix Reis, Jörg Schäfer, and Ralph Claessen — Physikalisches Institut and Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany

Bismuthene (a mono-atomic honeycomb lattice of Bi-atoms) chemisorbed on a SiC(0001) substrate has recently been synthesized and shown to be a promising candidate for the realization of a room-temperature Quantum Spin Hall (QSH) effect which is based on a novel QSH mechanism [1]. Experiments with angle-resolved photoelectron spectroscopy (ARPES) and scanning tunneling spectroscopy (STS) found excellent agreement with the calculated topological band structure. In particular, while the bismuthene film displays a large bulk band gap of ∼0.8eV, conducting edge states are observed at the boundaries of the honeycomb layer, e.g. at terrace steps of the substrate, as expected for a two-dimensional topological insulator (2D-TI). Here we demonstrate, by a detailed analysis of tunneling spectra, that these edge states are indeed one-dimensional (1D) and correlated in nature. The STS spectra display power law behavior with energy and temperature as well as universal scaling, consistent with the expectations for a (helical) Tomonaga-Luttinger liquid (TLL).

[1] F. Reis, G. Li, L. Dudy et al., *Science* **357**, 287 (2017).

TT 28.6 Mon 15:00 Poster B

Giant microwave magneto-conductivity in topological Insulators — •Lea Pitz-Paal, Mahasweta Bagchi, Christoph Grams, Zhiwei Wang, Yoichi Ando, and Joachim Hemberger — Universität zu Köln

Recently, locally conducting puddles were identified in the bulk-insulating topological insulator $BiSbTeSe_2$ at temperatures below 50K [1]. These puddles are the result of imperfect compensation of charged donors and acceptors in the bulk. Additionally, it was shown that these puddles in a nearly bulk-insulating topological insulator $TlBi_{0.15}Sb_{0.85}Te_2$ grow in an increasing magnetic field [2]. This was detected when observing the resulting enhancement of the DC-conductivity. The puddles are growing due to the magnetic field and therefore form a percolating current paths. In the case of $BiSbTeSe_2$ the puddles are not connected because of much better compensation. Therefore, an enhancement of the puddles size is not observable with DC-measurements in this case. Hence, to examine the puddles in $BiSbTeSe_2$, an alternative approach based on AC-measurements in magnetic field is presented here. Our measurement also show an considerably enhanced AC-conductivity with increasing magnetic field and, therefore, a growth of the puddles.

This work is supported by the DFG via SFB1238 (Cologne).

[1] N. Borgwardt *et al.*, Phys. Rev. B **93**, 245149(2016)
[2] O. Breunig *et al.*, Nat. Commun. **8**, 15545(2017)

TT 28.7 Mon 15:00 Poster B

Length scale of puddle formation in 3D topological insulators

— Thomas Bömerich, Jonathan Lux, •Qingyufei Terenz Feng, and Achim Rosch — Institut für Theoretische Physik, Univeristät zu Köln, Germany

In most semiconductors and insulators the presence of a small density of charged impurities cannot be avoided, but their effect can be reduced by compensation doping, i.e. by introducing defects of opposite charge. Screening in such a system leads to the formation of electron-hole puddles, which dominate bulk transport, as first recognized by Efros and Shklovskii. Metallic surface states of topological insulators (TI) contribute extra screening channels, suppressing puddles. We investigate the typical length l_p, which determines the distance between puddles and the suppression of puddle formation close to metallic surfaces in the limit where the gap Δ is much larger than the typical Coulomb energy E_c of neighboring dopants, $\Delta \gg E_c$. In particular, this is relevant for three dimensional Bi-based topological insulators, where $\Delta/E_c \sim 100$. Scaling arguments predict $l_p \sim (\Delta/E_c)^2$. In contrast, we find numerically that l_p is much smaller and grows in an extended crossover regime approximately linearly with Δ/E_c for numerically accessible values, $\Delta/E_c \sim 35$. We show how a quantitative scaling argument can be used to extrapolate to larger Δ/E_c, where $l_p \sim (\Delta/E_c)^2/\ln(\Delta/E_c)$. Our results can be used to predict a characteristic thickness of TI thin films, below which the sample quality is strongly enhanced.

TT 28.8 Mon 15:00 Poster B

In-plane H_{c2} anisotropy of $Cu_{1.5}(PbSe)_5(Bi_2Se_3)_6$

— •Lionel Andersen, Zhiwei Wang, Thomas Lorenz, and Yoichi Ando — II. Physikalisches Institut - Universität zu Köln, Germany

The material series $(PbSe)_{5n}(Bi_2Se_3)_{3m}$ can be understood as a natural layered heterostructure. Since the end-member PbSe is topologically trivial and the other end-member Bi_2Se_3 is a well-known topological insulator, the series provides an interesting playground for the study of topological phenomena [1]. The member of this series with $n = 1$ and $m = 2$ shows strong evidence for unconventional superconductivity after Cu doping [2]. Recently the related material $Cu_xBi_2Se_3$ was proved to be a topological superconductor through the observations of a spontaneous rotational symmetry breaking [3,4]. In this contribution we present a study of the H_{c2} anisotropy observed in $Cu_{1.5}(PbSe)_5(Bi_2Se_3)_6$ obtained by resistance measurements. In addition to an out-of-plane anisotropy a clear in-plane anisotropy was found, which is difficult to be explained by a crystallographic or the associated Fermi surface anisotropy. This suggests a symmetry breaking similar to the case of $Cu_xBi_2Se_3$.

[1] K. Nakayama et al., Phys. Rev. Lett. **109**, 236804 (2012)
[2] S. Sasaki et al., Phys. Rev. B **90**, 220504 (2014)
[3] K. Matano et al., Nat. Phys. **12**, 852 (2016)
[4] S. Yonezawa et al., Nat. Phys. **13**, 123 (2017)

TT 28.9 Mon 15:00 Poster B

Electrical transport studies on the type-II Weyl semimetal candidate $W_{1-x}Mo_xTe_2$

— •Matthias Gillig[1,2], Federico Caglieris[1], Boy Roman Piening[1], Igor Morozov[1,4], Saicharan Aswartham[1], Joseph Dufouleur[1], Bernd Büchner[1,2,3], and Christian Hess[1,2,3] — [1]Leibniz-Institute for Solid State and Materials Research, IFW Dresden, 01069 Dresden, Germany — [2]Institute of Solid State Physics, TU Dresden, 01069 Dresden, Germany — [3]Center for Transport and Devices of Emergent Materials, TU Dresden, 01069 Dresden, Germany — [4]Moscow State University, 119991 Moscow, Russia

The semimetals WTe_2 and Td-$MoTe_2$ have been the first compounds proposed as a type-II Weyl semimetals. While for these parent compounds the Weyl points are far above the Fermi level, it is presumed that mixing the two phases brings them to relevant energies.

We have performed magneto-electrical transport measurements on a series of $W_{1-x}Mo_xTe_2$ single crystals. Zero-field resistivity increases upon substituting Mo for W but keeps metallic properties. The large non-saturating magnetoresistance is reduced in between the two phases, while the Hall resistivity decreases continuously from WTe_2 to $MoTe_2$. A simple two-band analysis ascribes this behavior to suppressed charge carrier compensation and declining mobilities. Observed Shubnikov-de-Haas oscillations show no drastic changes of the electronic structure.

TT 28.10 Mon 15:00 Poster B

Quasiparticle interference pattern in superconducting quantum wells

— •Mehdi Biderang[1] and Alireza Akbari[1,2] — [1]Asia Pacific Center for Theoretical Physics, POSTECH, Pohang, Korea — [2]Department of Physics, POSTECH, Pohang, Korea

Spin-orbit interaction (SOI) plays an important role in the electronic properties of solids. Particularly, when it is originating from the bulk inversion symmetry breaking combining to the asymmetry of confining potential, it moves to Dresselhaus or Rashba types of SOIs. In superconducting state, these types of SOIs may cause the parity mixing and occurrence of the accidental node in the superconducting gap. We study the symmetry of superconducting gap and its trace on the quasiparticle interference pattern for a two-dimensional superconducting quantum well grown in (110) direction, by considering the effect of the interplay of Rashba and Dresselhaus SOIs. Our theoretical results show that changing the relative strength of Dresselhaus to Rashba, from 0 to 1, leads to fix the spin quantization axis at fully mixed Dresselhaus-Rashba. Moreover, a C4 symmetry of superconducting pairing changes to C2, which is consistent with the variation of the Fermi surface topology.

TT 28.11 Mon 15:00 Poster B

Majorana bound states in monoatomic Fe-nanowires on superconducting Pb

— •Carl Drechsel, Rémy Pawlak, Marcin Kisiel, Jelena Klinowaja, Tobias Meier, Shigeki Kawai, Thilo Glatzel, Daniel Loss, and Ernst Meyer — Department of Physics, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

Motivated by their potential use as topological qubits, Majorana bound states (MBS) have attracted an utmost interest. Theoretical calculations predict their occurrence in the combination of quasi-one-dimensional nanowire systems onto s-wave superconductors.

Here, we measure the spatial and electronic characteristics of topological, superconducting chains of iron atoms on Pb(110) to investigate the wave function and the localization length as fingerprint for MBSs [1]. After first observations by scanning tunneling microscopy (STM) [2,3], we demonstrate by combining STM and atomic force microscopy (AFM) at low temperature (< 5 K) that the Fe chains are mono-atomic, structured in a linear fashion, and exhibit zero-bias conductance peaks at their ends [4]. This can be interpreted as signature for a Majorana bound state [5]. From these observations, we strongly support the idea of using MBSs in Fe chains on superconducting Pb as qubits for quantum computing devices.

[1] J. Klinovaja, D. Loss, Phys. Rev. B 86, 085408 (2012)
[2] S. Nadj-Perge et al., Science 346, 602 (2014)
[3] M. Ruby et al., Phys. Rev. Lett. 115, 197 (2015)
[4] R. Pawlak et al., npj Quantum Information, 16035 (2016)
[5] V.Mourik et al., Science 336, 1003 (2012)

TT 28.12 Mon 15:00 Poster B

Stability of Majorana edge modes in an interacting Kitaev chain in presence of non-Markovian electron-phonon interaction

— •Julian Schleibner, Florian Katsch, and Alexander Carmele — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik von Halbleitern, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany

We study a generic example of a system that fails to thermalize, namely a Kitaev chain with a bulk and topological edge-edge states [1, 2]. It is of interest to study the resilience of such Majorana modes in the presence of nearest-neighbor interaction and non-Markovian dissipation. The nearest-neighbor interaction couples the Majorana edge modes to the bulk leading to decay of the edge correlation due to dissipation into the phonon reservoir. The systems' time evolution is described and evaluated by means of Heisenberg equation of motion for small system sizes, taking into account the full hierarchy. The contributions originating from the phonon bath are calculated in second order Born factorization. The results are compared to previous studies, where the dissipation into a Markovian reservoir was described within a master equation framework, implying violation of the parity symmetry. In this case the edge correlation shows an exponential decay in homogeneous chains and a stretched exponential decay in disordered chains [3].

[1] Pal *et al.*, Phys. Rev. B **82**, 174411 (2010).
[2] Kitaev, Phys. Usp. **44**, 131 (2001).
[3] Carmele *et al.*, Phys. Rev. B **92**, 195107 (2015).

TT 28.13 Mon 15:00 Poster B

Measuring the spin structure of Majorana bound states using optical quantum dots — •Lena Bittermann[1] and Patrik Recher[1,2] — [1]Institut für Mathematische Physik, TU Braunschweig — [2]Laboratory for Emerging Nanometrology Braunschweig

Since signatures of Majorana bound states have been found, a lot of research in this field was initiated. Despite of this, their spin structure [1] is still not well understood.

In a one dimensional semiconducting wire on top of a superconductor with an applied Zeeman field, Majorana bound states can arise at the ends of the wire to which quantum dots can be coupled [2]. Here we propose such a setup where two optical quantum dots are also connected to hole reservoirs so that photons can be created via recombination. We first perform a Schrieffer-Wolff transformation to receive the effective low energy model of the electronic system with weak coupling between the dots and the Majorana bound states. Furthermore, we use a master equation formalism to obtain the steady state solution. By analyzing the resulting photon emission spectrum, we investigate the corresponding processes of recombination to draw conclusions on the spin polarization of the Majorana bound states.

[1] D. Sticlet, C. Bena and P. Simon, PRL 108, 096802 (2012)
[2] M. T. Deng et al., Science 354, 1557 (2016)

TT 28.14 Mon 15:00 Poster B

Tunable quasiparticle poisoning in Josephson Junctions — •Daniel Frombach[1] and Patrik Recher[1,2] — [1]Institut für Mathematische Physik, TU Braunschweig — [2]Laboratory for Emerging Nanometrology Braunschweig

The fractional Josephson effect is one of the unique features of Majorana bound states (MBS) forming in Josephson junctions [1]. However, its experimental realization still remains challenging partially due to quasiparticle poisoning potentially spoiling the 4π periodic effect. Despite first signatures of the 4π periodicity having been reported [2][3], the effect of such quasiparticle poisoning is still not well understood.

Here we propose a setup based on silicene, in which an experimental handle in the form of a perpendicular electric field exists, with which it can be possible to introduce an artificial poisoning experienced by the MBS. We analyze the poisoning effect on the current voltage characteristic of the junction and discuss the critical current as a possible indicator for the topology of the junction.

[1] L. Fu and C.L. Kane, Phys. Rev. B 79, 161408 (2009)
[2] L. P. Rokhinson et al., Nat. Phys. 8, 795 (2012)
[3] J. Wiedenmann et al., Nat. Commun. 7, 10303 (2016)

TT 28.15 Mon 15:00 Poster B

Multifractality of wavefunctions at the spin quantum Hall transition — •Daniel Hernangómez-Pérez[1], Soumya Bera[2], Ilya Gruzberg[3], and Ferdinand Evers[1] — [1]Institute of Theoretical Physics, University of Regensburg, D-93050 Regensburg, Germany — [2]Department of Physics, Indian Institute of Technology Bombay, Mumbai 400076, India — [3]Ohio State University, Department of Physics, 191 W. Woodruff Avenue, Columbus Ohio, 43210, USA

At the spin quantum Hall transition (class C) the Hall conductance for spin is quantized while charge is not conserved. Corrections to scaling are found to be small near the transition that connects two neighboring plateau states. Therefore, it lends itself as a natural testbed for analytical predictions. We here present a numerical study of the wavefunction statistics. Our results: (i) In a recent theoretical investigation [1], Bondensan et al. argue in favor of exact parabolicity of multifractal spectra near integer quantum Hall transitions. Thus motivated we investigate the class C spectrum and find that it is far from parabolic. (ii) Analytical arguments [2,3] predict a symmetry of the multifractal spectrum that we can confirm with a very high accuracy.

[1] R. Bondesan, D. Wieczorek, M. R. Zirnbauer, Nucl. Phys. B 918, 52 (2017).
[2] A. D. Mirlin, Y. V. Fyodorov, A. Mildenberger, F. Evers, Phys. Rev. Lett. 97, 046803 (2006).
[3] I. Gruzberg, A. D. Mirlin, M. Zirnbauer, Phys. Rev. B 87, 125114 (2013).

TT 28.16 Mon 15:00 Poster B

Fractional quantum Hall phenomenology in mosaic-like conductors — Ferdinand Kisslinger[1], •Dennis Rienmüller[1], Erik Kampert[2], and Heiko B. Weber[1] — [1]FAU Erlangen-Nürnberg, Lehrstuhl für angewandte Physik — [2]High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf

In the early days of graphene research, fractional values of e^2/h in the two-terminal conductance were interpreted as heralding FQHE in graphene [1],[2]. Since then, a variety of detailed investigations of FQHE states in monolayer [3]-[5] were reported.

In this work, another approach was made by utilizing a simple route to generate magnetotransport data that share essential signatures with fractional quantum Hall effect. Ingredients to the generating model are, on the one hand, conducting tiles with integer quantum Hall effect as well as metallic linkers, and, on the other hand, Kirchhoff's laws. When connecting few identical tiles in a mosaic, fractional steps occur in the conductance values. Richer spectra representing several fractions occur when the tiles are parametrically varied. Parts of the simulation data are supported with purposefully designed graphene mosaics in high magnetic fields. The model can, however, not explain substructure within the last Landau level. The findings emphasize that the occurrence of FQH phenomena does not necessarily indicate interaction-driven physics.

[1] X. Du et al., Nature 462, 192(2009).
[2] K. I. Bolotin et al., Nature 462, 196(2009).
[3] C. R. Dean et al., Nat. Phys. 7, 693(2011).
[4] F. Ghahari et al., Phys. Rev. Lett. 106(2011).
[5] B. E. Feldman et al., Phys. Rev. Lett. 111(2013)

TT 28.17 Mon 15:00 Poster B

Low temperaturate properties of B20 compounds — •Timur Yasko, Georg Benka, Andreas Bauer, Christian Oberleitner, Alexander Engelhardt, and Christian Pfleiderer — Lehrstuhl für Topologie korrelierter Systeme, Technische Universität München, Garching, Germany

Transition-metal mono-silicides crystallizing in the non-centrosymmetric space group $P2_13$ have been studied for decades due to a wide range of complex magnetic and electronic properties. Recently, the diamagnetic metal CoSi was proposed as a potential candidate material for hosting Weyl-type excitations [1]. We report on the growth of large high-quality single crystals by means of the optical floating-zone technique. Following a thorough metallurgical characterization, we present a comprehensive study of the intriguing low-temperature magnetic and transport properties of CoSi.

[1] Peizhe Tang et al., arXiv:1706.03817, 2017

TT 28.18 Mon 15:00 Poster B

Topological phase characterization of SSHH model — Daniel Duarte, Marta Prada, and •Daniela Pfannkuche — Universität Hamburg, I. Institut für Theoretische Physik, Jungiusstrasse 9, 20355 Hamburg

We study a one-dimensional interacting fermionic chain by means of density matrix renormalization group. The different spin correlation functions are studied and a phase diagram is obtained as a function of dimerization and on site interaction parameters. We find a striking phase showing finite spin edge correlations. Next we characterise the topology of the phase in terms its Zak phase and the existence of edge states. We discuss the connection between the appearance of edge-spin correlations and the Zak phase, and provide an extended phase diagram, complementing existing ones [1,2] These results could be experimentally realised in a cold atom experiment with a one-dimensional optical trap.

[1] B.-T. Ye, L.-Z. Mu, H. Fan, Phys. Rev. B 94, 165167 (2016).
[2] Da Wang, S. Xu, Yu Wang, C. Wu, Phys. Rev B 91, 115118 (2015).