Magnetic and chemical correlations in itinerant magnets

Supervisor: Prof. Laszlo Szunyogh
szunyogh@phy.bme.hu
http://www.phy.bme.hu/~szunyogh/

Short description of work:
A deep-rooted understanding of the mechanisms at atomistic level lends further support to the rapid development in ultrahigh density magnetic recording, magnetic sensor technology or even medical applications of magnetic nanoparticles. Short-range order (SRO) magnetic correlations seem to play an important role in local magnetic formation in Ni, while the ordering of different chemical elements in alloys on a short-range can also remarkably influence the magnetic interactions in magnetic alloys. First principles based theoretical methods are highly useful to study such phenomena. In the proposed work we intend to apply the Embedded Cluster Green's Function method within the Korringa-Kohn-Rostoker formalism to investigate the formation of local magnetic moments and the interactions between them in small ordered clusters embedded in disordered magnetically and/or chemically disordered system. The latter ones are described in terms of the Coherent Potential Approximation (CPA) and the Relativistic Disordered Local Moment (RDLM) scheme, also available in the program package developed at the Department of Theoretical Physics BME. In particular, we aim to study the magnetism of Ni and of the FeCo alloy, as well as some of disordered Heusler-compounds. Beyond the bulk state, we will extend our studies to surfaces and in multilayer systems that might display new features related to SRO due to their reduced dimensionality.

Topology and dynamics in interacting quantum systems

Supervisor: Prof. Balazs Dora
dora@eik.bme.hu

Short description of work:
Topology plays a prominent role in many areas of physics, es exemplified by the 2016 Nobel prize in physics and the discovery of topological insulators. The PhD project focuses on strongly interacting topological insulators and other systems both in equilibrium and under non-equilibrium circumstances, such as a quantum quench. Quantum light-matter interactions, Fock-space entanglement as well as quantum chaotic behaviour will be addressed in a variety of settings.

Non-equilibrium dynamics of integrable models

Supervisor: Dr. Balázs Pozsgay
pozsgay.balazs@gmail.com
http://sft.phy.bme.hu/

Short description of work:
In theoretical physics most problems can be solved only using certain approximations or numerical methods, and this motivated the study of the so-called integrable models where complete exact solutions can be found despite the models being truly interacting. Examples include statistical physical models, spin chains, and integrable quantum field theories. One model that has been investigated is the famous Heisenberg spin chain. A central topic in the last few years has been the non-equilibrium dynamics, in particular equlibration and thermalization in this model. Whereas a lot is known about the physical properties in equilibrium, there are very few results available about real time evolution. An interesting property is that in the long time limit the model does not equilibrate towards a Gibbs ensemble (as it would in the case of a generic quantum system), instead it forms steady states that are described by the so-called Generalized Gibbs Ensemble. In this respect the model is an exception to the general principles of statistical physics, and this raises many important questions.
The research project aims to study a number of inter-connected open problems in relation with time evolution in the XXZ chain and related models. We intend to use the Bethe Ansatz and closely related methods, with a certain degree of numerical work involved. The research project can be considered pure mathematical physics, but the models describe real world experimental situations, and there is a possibility that the calculations will later be confirmed by experiments. The PhD student will work together with the supervisor and other members of the MTA-BME ,,Momentum'' Statistical Field Theory group.

Quantum effects in InAs nanowire based nanocircuits

Supervisor: Dr. Szabolcs Csonka
csonka@mono.eik.bme.hu

Short description of work:
In this project the applicant will develop and investigate nanocircuits based on InAs nanowires. When such nanowires are combined with superconductors very interesting circuits can be created, like Cooper pair splitters or circuits which host Majorana Fermions or Prafermions, which are key ingredients of novel quantum computational schemes.
More details: http://nanoelectronics.physics.bme.hu/quantum_electronics

High quality two dimensional nanocircuits

Supervisor: Dr. Peter Makk
peter.makk@gmail.com

Short description of work:
Recently a new class of material was discovered, which are only one or a few atomic thin. These two dimensional (2D) materials (like graphene, hBN etc.) have opened a new horizon in material science. Combining these layers novel heterostrucutres can be created with exciting properties. In this project the applicant will develop and investigate nanocircuits built from 2D materials.
More details: http://nanoelectronics.physics.bme.hu/quantum_electronics

Matrix-product state approach for correlated quantum systems

Supervisor: Prof. Gergely Zarand
http://exotic.phy.bme.hu/
zarand@eik.bme.hu

In case of interest, please, contact the supervisor!

Quantum-computer prototypes in superconducting nanostructures

Supervisor: Dr. Andras Palyi
palyi@mail.bme.hu
http://eik.bme.hu/~palyi/

Short description of work:
Superconducting nanoscale electronic circuits play an important role in realizing elementary schemes of quantum information processing. It is possible to use these circuits to realize few-bit protopype quantum computers, to spatially separate spin-entangled Cooper pairs, or to create exotic quasiparticles possessing non-fermionic and non-bosonic exchange statistics. The PhD student joins the corresponding theoretical research. Possible subjects: (1) Topological quantum computing with superconducting nanostructures: description of the dynamics of topologically protected, superconductor-based quantum bits (initialization, control, readout, information-loss mechanisms). (2) Analysis of electronic transport of spatially separation of Cooper pairs emitted by a superconducting contact. Within these topics, there is an opportunity to collaborate with the local research group of Szabolcs Csonka, where such nanostructures are investigated experimentally.

Quantum bits in solids

Supervisor: Dr. Andras Palyi
palyi@mail.bme.hu
http://eik.bme.hu/~palyi/

Short description of work:
Quantum information processing is expected to provide efficient solutions for certain computational tasks. In the past decade, many experiments have demonstrated the functionality of the physical mechanisms required for operating quantum bits based on the spin of a single electron. For such qubits, single-qubit logical operations can be realized, e.g., using ac electromagnetic fields, whereas two-qubit operations can be performed using the exchange interaction. The student will carry out theoretical research within this field. The task is to study and analyze simple, universal models, as well as concrete experimental setups, in order to characterize the dynamics and functionality of spin-based quantum bits. The relevant mechanisms include spin-orbit, hyperfine, and electron-phonon interactions, disorder effects, electromagnetic noise, etc. The goal is to understand the role of these mechanisms in coherent control and information loss of the qubits, and thereby to help optimizing the experimental setups for quantum information processing. Within this subject, there is an opportunity to collaborate with the local research group of Szabolcs Csonka, where such nanostructures are investigated experimentally.

A microwave instrumentation based approach toward quantum technology

Supervisor: Prof. Ferenc Simon
f.simon@eik.bme.hu
http://goliat.eik.bme.hu/~f.simon/

Quantum technology (QT) is an emerging new paradigm which intends to exploit the accumulated fundamental knowledge in the field of quantum mechanics for practical applications in e.g. sensing, computing, or communications. Our experimental group is active at present in three areas related to QT: i) the magnetic resonance spectroscopy in light induced excitations in solids, ii) improving the ultimate sensitivity of microwave impedance measurements, and iii) studying the spin-dynamics of non-equilibrium magnetization in solids (a field called spintronics). Common in these approaches is the extensive use of high sensitivity microwave (1-100 GHz) instrumentation combined with modelling and theoretical description. We are seeking a canditate who has firm knowledge in electrodynamics, quantum mechanincs, and elementary condensed matter physics. A devotion toward experimental research including microwave electronics, cryogenics, computer interfacing of instruments is an advantage.
Representative papers are found at:
https://arxiv.org/find/all/1/all:+EXACT+ferenc_simon/0/1/0/all/0/1