Hands-on-Tutorials

1. AG Reinhard

Title: Quantum control and magnetometry with NV centers in diamond

Teaser: Measuring and imaging magnetic fields at the nanoscale is important, for example for the study of spin and charge currents. There are many ways to investigate and measure nanoscale magnetic fields, such as MRFM and scanning SQUIDS. These techniques have a high sensitivity but require advanced expertise and equipment such as cryogenic cooling.

Here, in this hands-on tutorial, you will be introduced to a simpler and cheaper platform to perform high-resolution magnetometry measurements under ambient conditions. Nitrogen vacancy (NV) color centers in diamonds [1] are spin defects that have very high ($\mathrm{nT}/\sqrt{\mathrm{Hz}}$ [2]) sensitivity that can be used not only to perform magnetometry measurements but also imaging the spin environments in the area surrounding this atom like sensor with nanometer scale resolution [3].

In this tutorial you learn about the basics of controlling qubits, perform single gate operation on qubits, measure Rabi oscillations and the coherence time T2 using a dynamical decoupling sequence. And at the end you will have chance to write and measure your own sequence of single qubit gates.

[1] Taylor, Jacob M., et al. "High-sensitivity diamond magnetometer with nanoscale resolution." *Nature Physics* 4.10 (2008)

[2] Barry, John F., et al. "Sensitivity optimization for NV-diamond magnetometry." *Reviews of Modern Physics* 92.1 (2020)

[3] Arai, Keigo, et al. "Fourier magnetic imaging with nanoscale resolution and compressed sensing speed-up using electronic spins in diamond." *Nature nanotechnology* 10.10 (2015)

Remarks: Number of participants per session: 4, Duration of the session: 60 min

Supervised by: Mohammad Amawi, Laser safety instruction: needed
- session over 1 day
- location: U32 or U04, presumably U32.

2. AG Korn

a. Exfoliation and transfer of 2D materials

Bedingungen/Remarks:

- Max Teilnehmerzahl: 3 Personen

- Training geht über beide Tage

Teaser: 2D materials are fascinating novel solid-state systems that are surprisingly easy to produce and readily integrated with other systems. We will show you how to exfoliate 2D materials such as Molybdenite from bulk crystals and identify individual flakes using optical microscopy. You will also learn how to transfer these materials onto a pre-determined spot on a substrate.

Supervised by: vermutlich Michael Kempf

- duration of the session [min]: volle verfügbare Zeit in den Slots Dienstag und Mittwoch (geht für die Teilnehmer über beide Tage)
- safety instruction needed: nein
- location: Raum 036

b. Micro-Spectroscopy of 2D materials

Bedingungen/Remarks:

- Max. Teilnehmerzahl: 3 Personen
- Training kann an einem einzelnen Tag durchgeführt werden, bei Bedarf können also 2x 3 Personen teilnehmen

Teaser: Photoluminescence and Raman spectroscopy are powerful tools to analyze the properties of solid-state systems. In combination with microscopy, they provide a means to map structures on micron length scales. You will learn how these techniques work, using various 2D materials as test samples. Potentially, other samples provided by participants may be studied as well.

- supervised by: vermutlich Tobias Korn
- duration of the session [min]: volle verfügbare Zeit der jeweiligen Slots
- safety instruction needed: ja (Nutzung Laser)
- location: Raum U15 und/oder 039

3. Ö – project – AG Reinholz/Tiggesbäumker

In this tutorial we will explore possibilities to highlight LiMatI research to the public. Based on results of a given PhD obtained in one of the LiMatI projects (yet to find) we will discuss possibilities to distribute the science to an audience being present at e.g. Lange Nacht der Wissenschaften.

Remarks: no restriction/aiming for 6(-10) people
- seminar room
- 2 Days
- no safety instruction needed
- with regard to the advised target group the tutorial will be held in german

Supervised by: Roman Gruchow, Norman Iwe, Josef Tiggesbäumker

4. AG Lochbrunner/F. Fennel

Topic: **generation and compression of tunable fs-light pulses with NOPAs (noncollinear optical parametric amplification)**

Teaser: students learn how to operate and align a tunable light source (NOPAs), which allow to generate femtosecond pulses in the visible (440nm-750nm). After generation the pulses are temporally compressed by a prism compressor resulting in pulse durations of app 30 fs, which is proven by an autocorrelation measurement.

Supervised by: Steffen Wolter
- maximum number of participants per session: 4 people (can be extended to 6 people if necessary)
- duration of the session [min]: 120 min but we can offer both days the same tutorial
- safety instruction needed: yes: laser safety
- location: lab U21 in Forschungsbau
- special conditions / restrictions: none

5. AG Szameit / Heinrich

topic: *DiscO on a chip – Discrete optics in laser-written waveguide arrays*
Teaser: *This tutorial serves as a hands-on introduction to laser-written systems of photonic waveguides. After a brief primer on waveguides and the fundamentals of discrete diffraction, we will experimentally characterize the propagation dynamics of light in a number of one- and two-dimensional waveguide arrangements including directional couplers, homogeneous chains, "photonic graphene" and topological Kagome lattices.*

Supervised by: *Julius Beck, Matthias Heinrich*
Maximum number of participants per session: *5*
Duration of the session [min] and over 1 or 2 days: *1 day, 2 sessions:*
nicht genügend Interessenten: Mittwoch Ausfall
Safety instruction needed: *Laser safety*
Location: *SR 183, mit Beamer/Smartboard – das Setup ist portabel*
Special conditions / restrictions: *N/A*

6. AG Klinke

Topic: Synthesis and characterization of fluorescent halide perovskite nanomaterials
Teaser: Halide perovskites are among the most promising nanomaterials for applications in photovoltaics and light-emitting devices. We will demonstrate their (easy) synthesis, ion exchange, purification procedure for the samples, crystal phase identification by XRD, absorption and (time-resolved) fluorescence spectroscopy. These are the first steps to
investigate their intriguing optical and electronic properties. Research questions relate to the ruling optoelectronic mechanisms and their stability.

Supervised by: Dr. Sushant Ghimire
Maximum number of participants per session: 6
Duration of the session [min] and over 1 or 2 days:
The synthesis will be performed during the first day (2 hours) and the characterization during the second day (2 hours).
Safety instruction needed: Keep calm, don't touch anything if not advised and carry lab coat and safty goggles.

7. AG Speller/Barke:

Topic: **a. Scanning force microscopy of nanostructures**
Teaser: Force microscopy increasingly is an indispensable tool for the characterization (often quality control) of your samples. Structure and heights can be assessed with nanometric resolution. The method is very versatile and offers a number of functional information channels such as material contrast, stability, electric charge/surface potential, manipulation, a.m.m. The training shall serve to provide an access to the method, and discuss its possible benefits with regard to your LiMatI research question.

Supervised by: Lukas Böttcher, Physics of Surfaces and Interfaces
- Maximum number of participants per session: 4
- Duration of the session [min] and over 1 or 2 days: e.g. 1 x 4h
- Safety instruction needed: not necessarily
- Location: U035
- Special conditions / restrictions: cannot take place in parallel with "Scanning electron microscopy of nanostructures" (same lab)

Topic: **b. Scanning electron microscopy of nanostructures (SEM)**
Teaser: Scanning electron microscopy is increasingly is an indispensable tool for the characterization (often quality control) of your samples. Structure and material composition can be assessed with nanometric resolution. The method operates in vacuum, according to the specimen the primary energy and the angle is to be adjusted. The training gives insight in how to prepare a sample, focus the beam and understand the images. The training shall serve to provide an access to the method, and discuss its possible benefit with regard to your LiMatI research question.

Supervised by: Mirco Wendt, Physics of Surfaces and Interfaces
- Maximum number of participants per session: 3
- Duration of the session [min] and over 1 or 2 days: for instance 1 x 4h
- Safety instruction needed: not necessarily
- Location: U035
- Special conditions / restrictions: cannot take place in parallel with "Scanning force microscopy of nanostructures" (same lab)

8. AG Bauer:

Topic: **Solving the time-dependent Schrödinger equation**
Teaser: The simulation of non-perturbative quantum dynamics in laser fields requires the solution of the time-dependent Schrödinger equation (TDSE) in one way or another. We will solve the one-dimensional TDSE directly in position space using the Crank-Nicolson method. We will use Python to implement our TDSE solver. As an example, we apply our TDSE solver to the simulation of high-harmonic generation.

Supervised by: Dieter Bauer
- Maximum number of participants: Flexible
- Duration of the session [min] and over 1 or 2 days: Only on Tuesday, 2h
-safety instruction needed: No
- location: Seminar room 1 (or lecture hall 1 in case of too many participants)
- special conditions / restrictions: Bring your own laptop with Python installed (we recommend the free Anaconda distribution, which includes many useful applications such as the Spyder development environment for Python and Jupyter Notebooks)

9. AG Fennel:

Topic: **Solving Maxwell's equations numerically**
Teaser: Modeling the time-dependent linear or nonlinear response of materials to electromagnetic radiation requires the solution of Maxwell's equations. Here, we will implement the Finite-Differences-Time-Domain (FDTD) Method to solve these equations in one dimension and apply our knowledge to simulate the impact of a short laser pulse on a multilayered dielectric mirror (aka Bragg mirror).

Supervised by: Christian Peltz
- Maximum number of participants: Flexible
- Duration of the session [min] and over 1 or 2 days: Only on Wednesday, 2h
- safety instruction needed: No
- location: Seminar room 1 (or lecture hall 1 in case of too many participants)
- special conditions / restrictions: Bring your own laptop with Python installed (we recommend the free Anaconda distribution, which includes many useful applications such as the Spyder development environment for Python and Jupyter Notebooks)