



**FAU Erlangen-Nürnberg**

<b>Title</b>	<b>Course leader</b>	<b>Date</b>
1. Advanced Machine Learning	Florian Marquardt	Mo 18-19.30 Thu 18-19.30
2. Paradigmatic models in quantum optics and condensed matter Physics	Kai Schmidt Claudiu Genes	Mo 14-16
3. Theoretical Quantum Optics	Adriana Pálffy-Buss	Tue 14-16
4. Wave guide and photonic crystals	Nicolas Joly Bernhard Schmauss	Tue 14.15-15.45 Fr 12.15-13.45

**JGU Mainz**

<b>Title</b>	<b>Course leader</b>	<b>Date</b>
5. Precision measurements	Dmitry Budker Ferdinand Schmidt- Kaler	Tue 10.15-11.45 Thu 10.15-11.45

**UdS, Saarbrücken**

<b>Title</b>	<b>Course leader</b>	<b>Date</b>
6. Control of Quantum Systems (Ctrl-Q)	Jürgen Eschner	Wed 9-10
7. Introduction to quantum information	Frank Wilhelm- Mauch	Mo 12-14 Fr 15-17

Please register for courses you are interested in via email. You can find the contact information and short abstracts on the following pages. All courses will take place via an online video solution like zoom or MS Teams and can be attended from any location. For successful attendance active participation is required. Details will be defined by the lecturer at the beginning of the course.

**1. Advanced Machine Learning**  
**by Florian Marquardt**

**Abstract:**

We will describe advanced modern methods of artificial intelligence and their potential application to artificial scientific discovery, in physics and other fields. This includes: representation learning (including deep variational autoencoders etc.).

- active learning (how a neural network can choose suitable training samples on its own)
- reinforcement learning and optimization methods
- graph neural networks
- generative neural networks (learning to sample from an observed statistical distribution)
- transformers and other attention-based methods
- advanced concepts from information science and statistics (e.g. mutual information)
- automated program discovery
- applications in quantum physics, statistical physics, dynamical systems

**Monday 18.00-19.30, Thursday 18.00-19.30**

**Registration:**

Please send an email to [florian.marquardt@mpl.mpg.de](mailto:florian.marquardt@mpl.mpg.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

**2. Paradigmatic models in quantum optics and condensed matter Physics**  
by Kai Schmidt and Claudiu Genes

**Abstract:**

Welcome to the seminar on paradigmatic models in condensed matter physics and quantum optics. The main idea is to dive in most important concepts and physical phenomena from paradigmatic, often exactly solvable, models in the fields of condensed matter physics as well as quantum optics which are relevant for the theoretical description of systems with light and matter. This includes, amongst others, light-matter interactions, quantum phase transitions and criticality, non-trivial topological properties, superconductivity, and superradiance.

**Monday 14-16**

**Registration:**

Please send an email to [kai.phillip.schmidt@fau.de](mailto:kai.phillip.schmidt@fau.de), [claudiu.genes@mpl.mpg.de](mailto:claudiu.genes@mpl.mpg.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

**3. Theoretical Quantum Optics**  
by Adrianna Pálffy-Buss

**Abstract:**

The course provides an introduction to quantum optics from theoretical perspective. Modern concepts and proof of principle experiments that address the quantum properties of light are discussed. The material is intended to bridge the gap between standard quantum mechanics, electrodynamics and statistical mechanics and the theory needed to explain quantum optics experiments.

**Tuesday 14-16**

**Registration:**

Please send an email to [adriana.palffy-buss@fau.de](mailto:adriana.palffy-buss@fau.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

**4. Wave guide and photonic crystals**  
by **Nicolas Joly and Bernhard Schmaus**

**Abstract:**

The goal of this lecture is to give basics knowledge of optical waveguides and their applications. This will cover the following topics:

- Guidance mechanism (geometric and EM approaches)
- Photonic crystal fibres (solid-core, hollow-core, bandgap and anti-resonance fibres)
- Nonlinear optics effect in optical fibres
- Applications

**Tuesday 14.15-15.45, Friday 12.15-13.45**

**Registration:**

Please send an email to [nicolas.joly@fau.de](mailto:nicolas.joly@fau.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

**5. Precision measurements**  
by **Dmitry Budker and Ferdinand Schmidt-Kaler**

**Abstract:**

The series of lectures will cover modern precision experiments to test fundamental laws of nature. We address atomic clock transitions and clock comparisons, Penning mass spectroscopy, tests of the equivalence principle, e.g. by torsion balance measurements, but also in cold atoms in free fall using (interferometric) devices. We address tests of the special relativity by measurements of relativistic Doppler shift in accelerator rings. The discussion of current tests for parity violation, for the search for a permanent electric dipole moment (EDM) are completed by a discussion of searches for dark matter and the discussion of current limits, already set by precision experiments today. In the lecture we will explain several important techniques, which are used to obtain the breath-taking accuracy, including cooling, trapping atoms or ions, spectroscopic and interferometric techniques.

**Tuesday 10.15-11.45, Thursday 10.15-11.45**

**Registration:**

Please send an email to [budker@uni-mainz.de](mailto:budker@uni-mainz.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

## **6. Control of Quantum Systems (Ctrl-Q)**

**by Jürgen Eschner, Christoph Becher, Giovanna Morigi, Frank Wilhelm-Mauch**

### **Abstract:**

The Ctrl-Q Seminar is a regular activity of the topical PhD Program "Control of quantum systems for the development of quantum technologies" at the UoS. Seminar speakers, who may be either guests or regular participants, present recent papers from the field of quantum science and quantum technologies. The Ctrl-Q Seminar is organized through Teams and is held digitally, about bi-weekly, on Wednesdays at 9:00 am. You have to sign up to attend. You find all further information on Wiki pages in the Team, including papers that are suggested for presentation. Suggested papers shall be approved by the coordinating professors, Prof. Morigi, Prof. Becher, Prof. Eschner, or Prof. Wilhelm-Mauch. Everybody in QuCoLiMa is welcome to attend the Ctrl-Q Seminar as regular or occasional listener. In order to pass it as an RTG course, you will have to participate for one semester (i.e., for 6 months that can begin any time) and to present one paper in a seminar talk.

### **Wednesday 9-10**

#### **Registration:**

Please send an email to [juergen.eschner@physik.uni-saarland.de](mailto:juergen.eschner@physik.uni-saarland.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).

## **7. Introduction to quantum information**

**by Frank Wilhelm-Mauch**

### **Abstract:**

It's a relatively new idea to exploit the laws of quantum mechanics to target hard computational problems. It has impact on physics, chemistry, computer science, math and many more disciplines because quantum computers, in principle, can outperform classical computers. Furthermore, quantum information represents a post-Moore paradigm, because Moore's scaling law will saturate during the next few years limited by fundamental laws of physics. Although useful quantum computers are still far outside reach, small toy versions are already demonstrated in experiment. Actually, IBM offers some of their chips as open access in the cloud. This lecture's goal is to give a broad overview on the main concepts and applications on the field of quantum information.

### **Monday 12-14, Friday 15-17**

#### **Registration:**

Please send an email to [fwm@physik.uni-saarland.de](mailto:fwm@physik.uni-saarland.de) and [trr306-rtg@fau.de](mailto:trr306-rtg@fau.de).