8 PhD / Postdoctoral Positions in Nano & Quantum Optics

The laboratory for Nano & Quantum Optics of the Abbe Center of Photonics has a number of open positions for PhD candidates and postdoctoral researchers, which provide ideal career opportunities for suitable candidates within the graduate school of the Abbe School of Photonics (www.asp.uni-jena.de):

- PhD: Controlling light emission by dielectric nanoantennas
- PhD: Machine learning-based design of metamaterials & Metamaterial-based machine learning systems
- PhD: Strong coupling to quantum emitters by plasmonic superfocusing
- PhD: Spatiotemporal dynamics of nano-scale light-matter interactions in metasurfaces & atomic membranes
- PhD/Postdoc: Nanoscale integrated quantum photonics
- PhD/Postdoc: Quantum imaging and sensing
- PhD/Postdoc: Quantum communication and single photon sources
- Postdoc: Quantum photonics

The laboratory for Nano & Quantum Optics is part of the Max Planck School of Photonics (www.maxplanckschools.de). Therefore, exceptional PhD applicants might also be offered to enter the Max Planck School's elite program, providing truly superior support to future academic careers.

The lab's research targets the control of light at the single photon level and at the nanoscale using nanostructured materials and ultrafast nonlinear optical effects. The lab, which is a part of the Institute of Applied Physics and the Institute of Solid State Physics at the Faculty of Physics and Astronomy of the Friedrich Schiller University Jena (Germany), covers a broad range of research fields in experiment, technology, and theory to study interaction of light with microstructured and nanostructured matter, employing advanced methods for nanofabrication, experimental characterization, and numerical modelling.

We are constantly looking for talented young scientists, who would like to contribute to cutting edge research projects on quantum photonics at the nano scale. Currently there are openings for PhD projects and postdoctoral projects on the above topics, but other topics motivated by the interest of potential candidates can be discussed as well.

Details about the laboratory for Nano & Quantum Optics and on the open positions can be found at www.iap.uni-jena.de/nano+quantum+career. If you have specific questions about joining our lab, please contact either of us:

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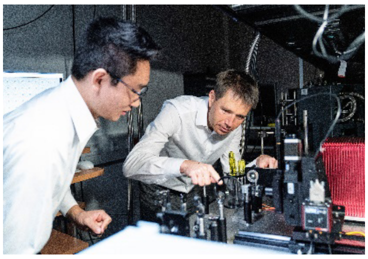
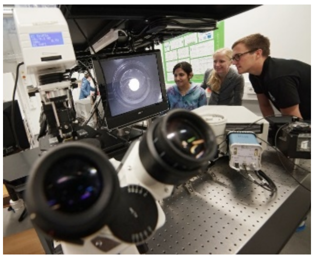
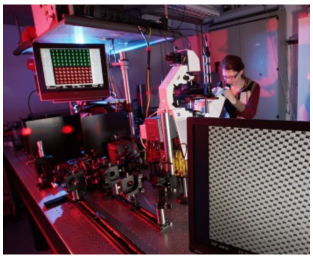
Please direct your applications to our central online application system at https://apply.asp.uni-jena.de and make sure to indicate that you are applying to the "Nano and Quantum Optics Lab". Applicants for postdoctoral positions should also use the PhD application window of the online system. All applications will be evaluated continuously until all open positions are filled.

The offered full-time positions are initially limited to 3 or 2 years (PhD/Posdoc), an extension is possible. Severely handicapped people are given preference in case of equal qualifications, aptitude and professional qualifications.


PhD on Controlling light emission by dielectric nanoantennas

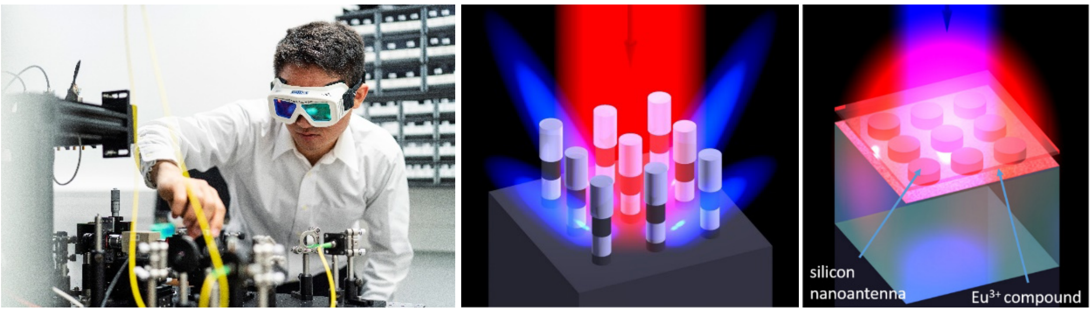
Nanoantennas provide an efficient link between optical near- and far-fields. They have the ability to strongly enhance the interaction of light with nanoscale matter and, in particular, they provide a tool for controlling the emission of light and its properties from localized sources. Most nanoantennas to date are composed of metallic nanoparticles. Metal nanoparticles can support localized surface plasmons, namely collective oscillations of the free electrons of a small metal particle, which can be harnessed to achieve the antenna functionality. However, unlike at radio frequencies, at optical frequencies metals exhibit strong intrinsic absorption losses, which reduces their radiation efficiency, which can be a problem for basic research as well as real-world applications. A new route to overcome this problem is offered by nanoantennas composed of dielectric nanoparticles instead of metallic nanoparticles. Dielectric nanoparticles support strong Mie-type resonances and can have very low losses at optical frequencies. In the last few years several dielectric nanoantenna design proposals have been presented, showing their potential for spontaneous emission control with high radiation efficiency. However, low losses are not the only motivation to investigate dielectric nanoantennas: in addition, high index dielectric nanoparticles support not only the commonly used electric dipolar resonances, but also higher multipolar resonances, such as magnetic dipole and electric quadrupole resonances. These multipolar resonances have a vast potential to control the emission from exotic emitters supporting electromagnetic transitions of higher order, and they offer a natural platform, which can be well defined by modern nanotechnology, to study new, unexplored multipolar interactions at optical frequencies.

The objective of this doctoral project is the experimental realization of coupled photonic systems consisting of nanoscale emitters and dielectric nanoantennas.

In this doctoral project the following techniques will be applied and developed further:

- Photoluminescence spectroscopy and time-resolved photoluminescence
- Back focal plane imaging of emission
- Characterization of exotic emitters
- Numerical simulations for dielectric nanoantenna design and optimization
- Precise positioning of nanoscale light emitters

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable



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PhD on Machine learning-based design of metamaterials & Metamaterial-based machine learning systems

The focus of the project will be on the implementation of neural networks (NN) to improve and simplify our physical models of metamaterials and nano-optical interaction. Specifically, the task will be to develop models and suitable neural networks for so called stacked metasurfaces. These are a subclass of metamaterials that consists of multiple layers of nano-structured surfaces. They allow to achieve complex optical behavior while being intuitive to model and to realize experimentally.

In addition, it will be studied to what extend machine learning algorithms for image recognition can be implemented directly into the optical system instead of the currently used entirely computational approaches. Due to the nature of passive parallel processing of optical information, this has the potential to dramatically speed up such algorithms and to the same extend also to reduce the necessary power consumption. If successful this would therefore open up entirely new application perspectives for real time image recognition in power limited environments.

Besides the implementation and use of machine learning algorithms the research project will be centered in the rapidly evolving field of nano-optics and metamaterials. Therefore, it will involve also the use of Maxwell's theory in order to describe the interaction between light and various arrangements of nano-particles on physical models. Due to the complexity of the underlying physics, numerical methods and simulations on high-performance computers will be employed. In combination with an intuitive analytical framework the PhD candidate will learn to develop semi-analytic models to both understand the physical processes of metamaterials and engineer application driven solutions.

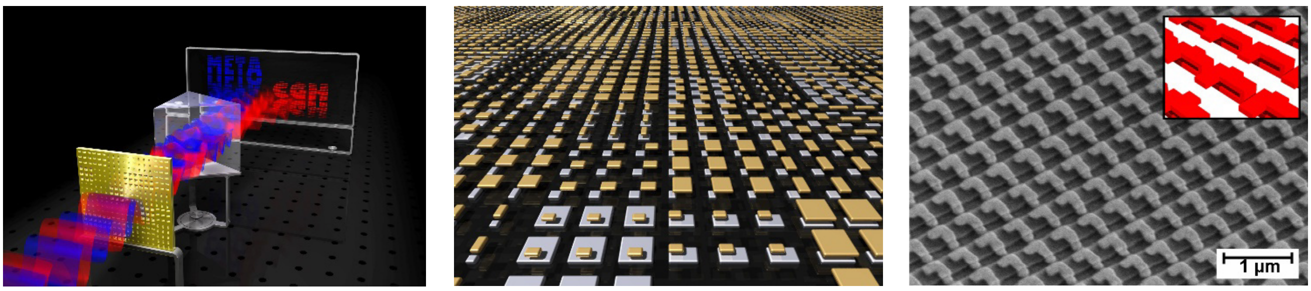
The project will be based on existing tools for the rigorous solution of Maxwell's equations as well as on Python and MatLab code. This can be used as a starting point for future work as well as to learn the basics of nano-optical modelling in combination with neural networks.

The results of the work will directly impact the scientific community as the application of neural networks to stacked metasurfaces is just at the beginning.

Depending on the abilities and preferences of the PhD candidate the following subjects would be covered

- Machine learning algorithms and neural networks for inverse system design
- Rigorous numerical simulations of nanostructured surfaces on high-performance computing systems
- Analytical modelling of complex physical systems

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable



Typical inverse design process for metasurface construction: Left: A desired macroscopic optical functionality is the usual starting point. Center: This functionality needs to be integrated conceptually in a flat arrangement of nanostructures. Right: The desired functionality of specific nanogeometries has to be verified by rigorous simulation methods and technological implementations.

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PhD on Strong coupling to quantum emitters by plasmonic superfocusing

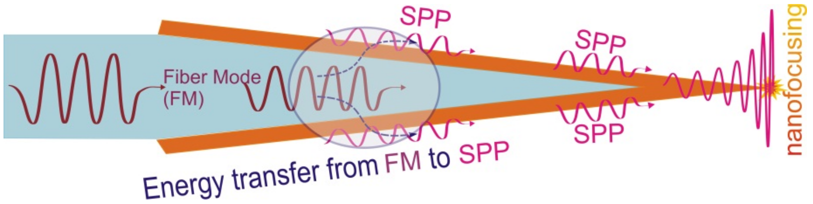
Nanosized quantum emitters are the basis of many quantum photonic circuits. However due to the size mismatch between the nanosized emitters and the micron scale radiation fields, their coupling to propagating electro-magnetic waves is weak and difficult to control. Therefore, exploiting strongly localized nearfields of nano-resonators or plasmonic elements is considered to be a key element for the realization of strong coupling.

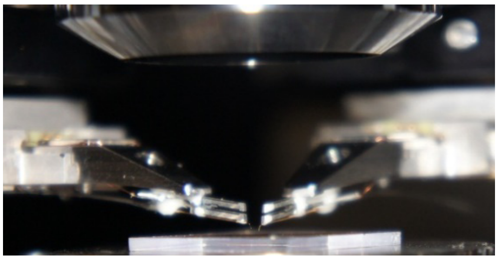
Scanning near-field optical microscopy (SNOM) is a powerful technique to measure and study simultaneously the architecture of nanostructures and their electromagnetic near fields. Among the different types of SNOMs, the scattering pseudo-heterodyne SNOM (ps-het SNOM) offers two main advantages: high resolution in topographical and optical images by employing sharp cantilever tips and simultaneous detection of field intensity and phase by exploiting lock-in detection methods and interferometry.

In this PhD project, we aim to take the performance of ps-het SNOM-based near-field detection and control to the next level with the vision to realize strong coupling to quantum emitters, as e.g. vacancy centers, quantum dots, quantum dots, lanthanide nanoparticles, and emission centers in atomically thin membranes of MoS_2. To achieve this goal we study a new generation of high-performance plasmonic tips, which promise to provide unprecedented performance parameters. As a first step, the SNOM tips' performance parameters are to be evaluated by exploring the tip's interaction with different quantum systems. To explore the spectral and temporal characteristics of the quantum systems, a superfocusing SNOM setup will be combined with a time correlated single photon counting system and a single photon sensitive optical spectrometer. After establishing stable measurement methods and skills, we want to apply this tool to the in depths investigation of the interaction of the nano-sized quantum systems with plasmonic and dielectric nano-antennas. Besides experimental characterization, analytical and computational modeling shall be carried out to understand the complex behavior of the quantum emitters and their interaction with the tips.

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable

Applicants should have experimental experience as well as the motivation to develop and run complex laboratories. Basic knowledge and experience in programming, nanotechnology, electromagnetic simulation software, and process control software (e.g. LabView) are helpful.





Left: Schematic for the excitation of a superfocusing surface plasmon-polariton at a metalized fiber tip by resonant coupling to a propagating fiber mode. Right: Two-tip nearfield scanning optical microscope for direct measurement of the optical near-field Green's function of photonic nanostructures.

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PhD on Spatiotemporal dynamics of nano-scale light-matter interactions in metasurfaces and atomic membranes

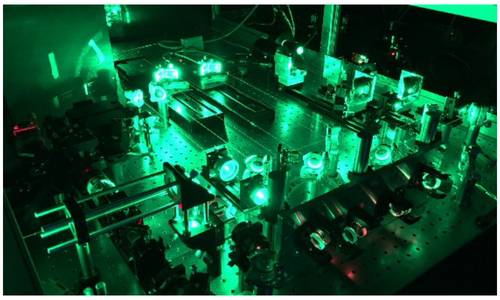
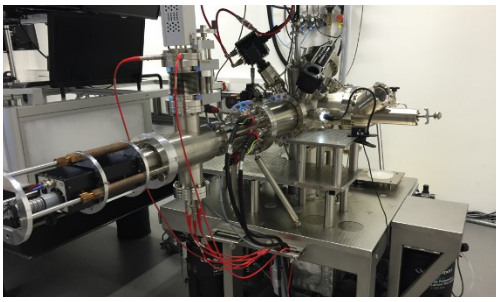
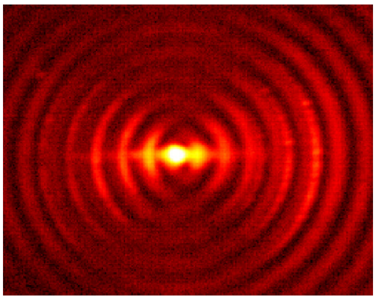
The control and characterization of light on length scales shorter than the diffraction limit (~0.5 λ) requires shaping or probing of the photonic states by nano-scale matter. Therefore, basically all nanooptical effects are coupled states of light and excited matter. Hence, the exploration of optics down to the nanoscale requires detailed knowledge about strong light-matter interaction at these ultrashort length scales. This interaction typically concerns the electronic states and happens on ultrashort time scales of a few femtoseconds. The experimental observation of such effects hence requires tools probing simultaneously the electronic matter states and the photonic states with nanometer spatial and femtosecond temporal resolution.

The aim of this PhD project is to study such ultrafast nanoscale dynamics in semiconductor metasurfaces, which are hybridized with plasmonic antennas, nanowires, and atomic membranes like graphene or MoS_2. To achieve this goal new experimental techniques with unprecedented temporal and spatial have to developed. Besides scanning nearfield optical microscopy (SNOM), laser driven photoemission electron microscopy (PEEM) is such a technique, which probes directly the electronic excitation of matter with the spatial resolution of an electron microscope. Temporal resolution is obtained by triggering the photoemission by few-cycle laser pulses (~6 fs). These ultra-short laser pulses give access to dynamical processes, inaccessible to electronic measurement systems. Laser driven PEEM is thus an ideal probe to study the photo-induced electron dynamics in the building blocks of photonic nanosystems. A typical PhD project will combine advanced instrumentation of fs lasers and ultra-high vacuum systems for electron microscopy with the physics of several novel quantum systems and metasurfaces.

Depending on the abilities and preferences of the PhD candidate the following subjects would be covered

- Experimental investigation of the ultrafast dynamics of laser-excited solid state nanosystems
- Nanotechnologies for the realization of hybrid nonlinear photonic nanosystems and metasurfaces
- Theoretical modeling and numerical simulation of the spatio-temporal dynamics of light and electrons on the nano-scale below the diffraction limit based on rigorous solutions of Maxwell's equations coupled to material models

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable

Left: Dual channel OPCPA system for the generation of ultrashort laser pulses in a pump-probe configuration. Center: PhotoEmission Electron Microscope - PEEM. Right: Electron-photon wavepackets on a ring-type nanoantenna.

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F. J. F. Löchner, R. Mupparapu, M. Steinert, A. George, Z. Tang, A. Turchanin, T. Pertsch, I. Staude, and F. Setzpfandt, "Controlling second-harmonic diffraction by nano-patterning MoS_2 monolayers," Opt. Express 27, 35475-35484 (2019).

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PhD or Postdoc on Nanoscale integrated quantum photonics

Nanoscale waveguides in lithium niobate on insulator systems are an emerging platform for integrated optics that offers unrivalled properties like small absorption losses in a wide spectral range, high optical nonlinearities, and the ability for ultrafast modulation of material properties. Based on these exceptional properties, a number of basic elements for integrated optics, e.g. low-loss waveguides, fast modulators, and nonlinear frequency converters have been demonstrated. All these demonstrations used waveguides with cross-sections in the range of a few hundred nm, showing the large potential of this platform for high-performance integrated optics that can realize complex photonic functionalities in very small devices.

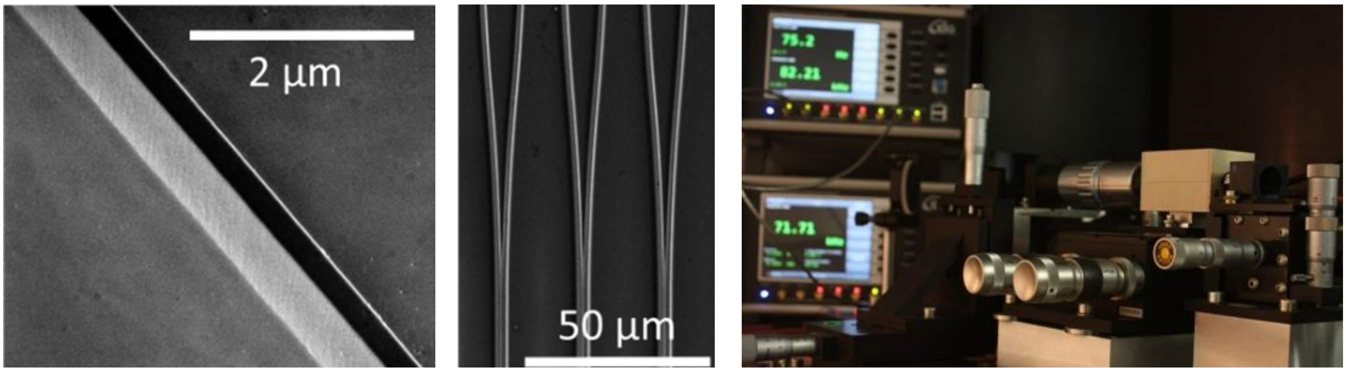
We aim to use this platform to move quantum optics to the nanoscale by implementing sources for photonic quantum states, optical elements to modify and control these quantum states as well as single-photon detectors in a single optical chip. This will enable to realize different quantum functionalities in lithium niobate nanowaveguides, e.g. quantum-enhanced sensing devices, sources, and receivers for quantum communication, or circuits that implement optical quantum computing.

The project comprises the development, optimization, and test of individual quantum elements in such circuits, the implementation of basic quantum interference experiments to gauge the performance of complex lithium niobate quantum circuits and the design and realization of large-scale circuits that perform applicable functionalities.

Depending on the abilities and preferences of the candidate the following subjects would be covered

- Theoretical quantum optics and numerical simulations
- Experimental characterization and nanostructuring technology
- Development and demonstration of quantum applications

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable



Left: Lithium niobate rib waveguide. Center: Y waveguide splitters. Right: Setup for characterization of integrated quantum circuits.

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PhD or Postdoc on Quantum imaging and sensing

The strong correlations and entanglement present in quantum states of light, e.g. photon pairs generated by spontaneous parametric down-conversion, allow for novel sensing, spectroscopy, and imaging modalities. These can operate at lower intensities, with better signal-to-noise-ratio, and in extended spectral ranges compared to traditional approaches.

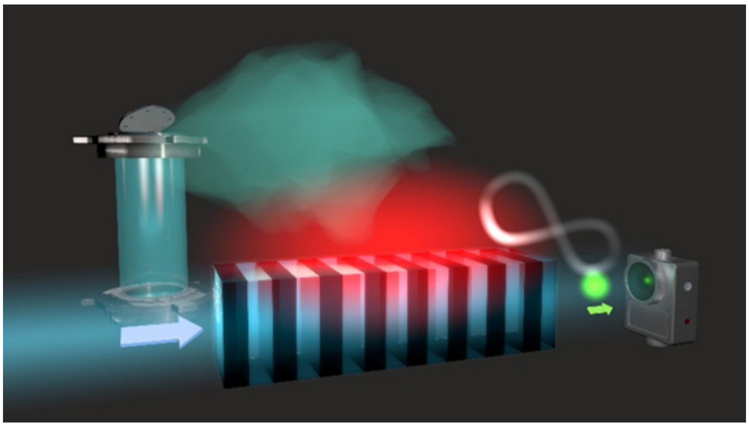
We are developing such imaging and sensing methods based on different measurement approaches. In Ghost Imaging, images are created based on the spatial correlations between the two photons of a pair, which enables to image objects without looking at them with a camera. Instead, a single-pixel detector observes the object illuminated by one photon of a pairs and the image is formed by correlating the detector measurements with the measurements of a camera that interrogates the paired photons that do not interact with the object. On the other hand, induced coherence by quantum interference of several photon-pair sources enables imaging and spectroscopy without detecting any of the photons the saw the object.

The task of the scientist is the development and optimization of such quantum sensing and imaging schemes, e.g. by implementing and testing dedicated photon state sources, specific measurement geometries, or improved data processing. Furthermore, the application prospects of the optimized methods shall be evaluated in realistic sensing scenarios.

Depending on the abilities and preferences of the PhD candidate the following subjects would be covered

– Implementation and characterization of Ghost Image microscopy
– Realization of integrated spectroscopy based on induced coherence
– Conceptual development of quantum sensing modalities

Required qualification: Master or Diploma in physics, photonics, electrical engineering, or comparable



Artistic sketch of an integrated sensing scheme for gas sensing with photon pairs, where the red photons interact with the substance under test but only their green partner photons are detected.

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PhD or Postdoc on Quantum communication and single photon sources

Solid-state single photon sources on the basis of defect centers in 2D-materials have matured to the point that they have demonstrated their application potential for quantum communication systems. They are small, lightweight, robust and produce a large number of single photons at very high quality. They can be integrated with optical systems and packaged into devices for usage in quantum communication systems.

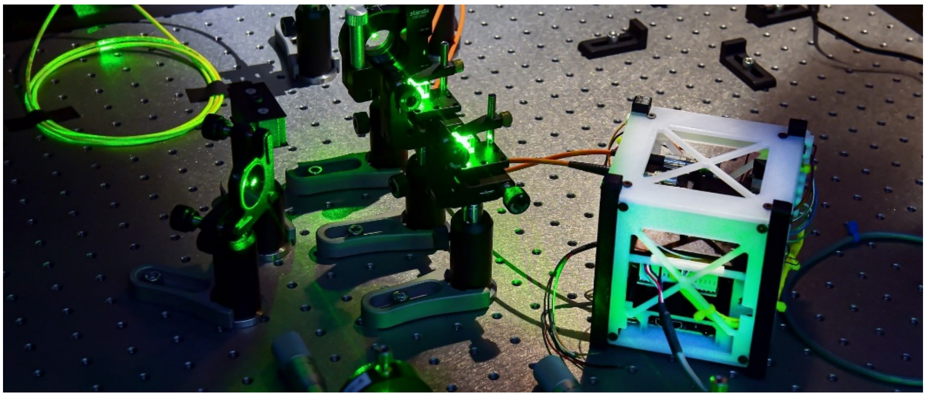
In a next step we plan to use hBN-based (hexagonal boron nitride) single photons sources in a payload for a small satellite, demonstrating their feasibility for space-based QKD-systems (quantum key distribution). The payload will also be used to interface with a vapor-based quantum memory unit, the interaction of which must be simulated and characterized in multiple ground-based proof-of-principle experiments. Moreover, we will also integrate the source with on-board interferometric experiments, to demonstrate the quantum advantage in optical sensing and to test fundamental concepts on quantum mechanics in micro-gravity.

The task of the scientist is the development and optimization of single-photons sources, based on single photon emitters in hBN and the conduction of experiments in QKD and quantum sensing in the lab and on a local free-space communication test facility. The scientist will also work in the development and integration of quantum photonic payload for a demonstrator and/or a flight-model for a quantum-optical satellite mission.

Depending on the abilities and preferences of the candidate the following subjects would be covered

- Development of single photon sources and their integration with plasmonic pump schemes as well as their integration with guided wave systems
- Demonstration of experiments in QKD and quantum sensing based on single photon sources
- Development and characterization of a quantum payload for a satellite mission and/or a demonstrator thereof

Required qualification: PhD, Master or Diploma in physics, photonics, electrical engineering, or comparable



Demonstrator for a single-photon source in a 1U-cubesat package together with an experiment in quantum sensing.

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Postdoc on Quantum photonics

We are looking to fill the position of a research associate for the newly established Thuringian Innovation Center for Quantum Optics and Sensor Technology (InQuoSens). The Innovation Center InQuoSens at the locations of the Abbe Center of Photonics in Jena pursues the conceptual goal to increase the innovative power of the Thuringian economy by excellent science in the fields of quantum optics coordinated with the economy. The tasks of the new research associate are the implementation and coordination of scientific projects in the field of quantum photonics, the development of the scientific infrastructure of the Innovation Center InQuoSens, the networking of the center's scientists with the emerging Thuringian quantum photonics industry, the representation of the Innovation Center to the outside, and, if suitable, to engage in the management of the Center.

Desired qualifications

- Excellent university degree in physics or a related field
- Experience with independent scientific work, proven by the award of a doctorate
- Deep knowledge in quantum optics and photonics
- Knowledge of numerical simulation methods and high-performance computing technology is advantageous
- Experience in applying for scientific projects and their coordination
- Excellent communication skills (oral and written) in German and English
- The ability to work effectively both independently and as part of a larger team

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