Fraunhofer
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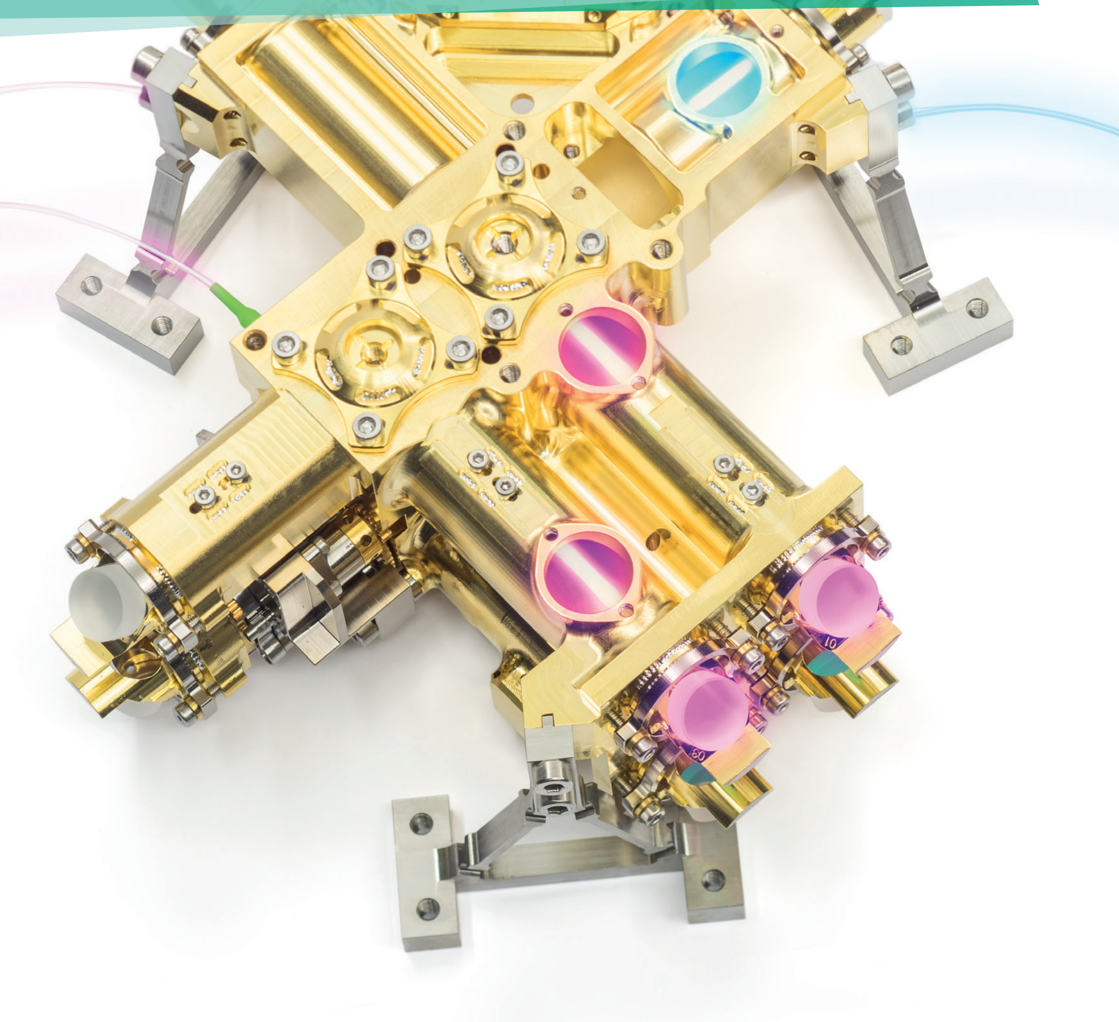
RESEARCH TOPICS IN
APPLIED QUANTUM OPTICS AND QUANTUM INFORMATION PROCESSING



Joined research teams: For the PhD education programm Fraunhofer IOF and Friedrich Schiller University Jena cooperate closely together: Groupleaders from left to right: Dr. Markus Gräfe, Dr. Falk Eilenberger, Dr. Frank Setzpfandt, Dr Erik Beckert and Dr. Fabian Steinlechner.

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The Fraunhofer Institute for Applied Optics and Precision Engineering in Jena conducts applied optics research on behalf of the industry and as part of publicly funded research projects. The range of services includes system solutions, starting with new design concepts, through technology development, manufacturing, and measurement methods to the construction of prototypes and pilot series for applications. The Fraunhofer IOF is also pioneering applied optical quantum technology, providing innovative solutions for science and industry wherever quantum-enhancement may lead to revolutionary applications.

We are looking for research candidates to join the »Quantum Communication Technologies« team, led by Dr. Fabian Steinlechner. The research in the group focuses on the development of photonic quantum technology - from novel quantum light sources and scalable high-dimensional quantum information processing methods, to long-distance transmission of quantum states. A central goal is to transfer these approaches to practical quantum hardware for quantum cryptography and quantum sensing in fiber networks and free-space links.

What you can expect from us

Photonics is a sophisticated quantum technology that combines a range of skills ranging from optical engineering to applications in quantum communication and sensing. The Fraunhofer IOF provides access to the entire photonic process chain, starting at basic research in nonlinear optics and integrated photonics and ultrafast electro-optic modulation and including optical engineering and micro-assembly technologies. This integration into the research site and ongoing international research collaborations will shorten development paths and provide more time for practical implementations. Students will thus have research opportunities in quantum information science, technology development, applied photonics, and the industry.

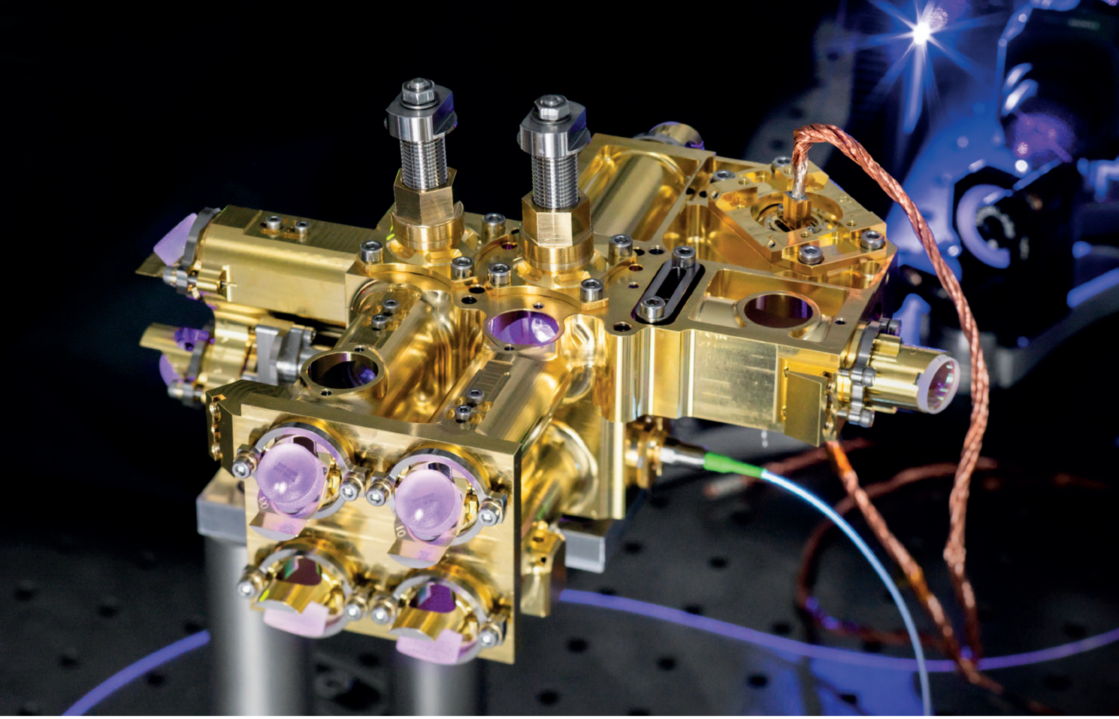
The following research projects are available:

- High-Dimensional Quantum Communication
- Quantum Information processing with hyperentanglement
- Ultra-bright entangled photon sources
- Quantum Key Distribution Systems for fiber networks
- Space-suitable hardware for satellite-based quantum communication

For more information see also:
www.iof.fraunhofer.de/qtech
www.acp.uni-jena.de/steinlechner.html

Ultra-bright entangled photon sources for Quantum Communication and Quantum Sensing

Entangled photons are a vital resource in quantum technology applications, acting as low-noise probes in quantum imaging and sensing, as versatile information carriers in quantum information processing and quantum networks, or as tamper-proof padlocks in quantum cryptography.



Devices for quantum communication – entangled photon pair source for satellite based communication

In this project, you will develop novel entangled photon sources with record brightness and with ultra-narrow spectral bandwidths, as required for quantum networks and interfacing with memories. The work will involve the optimization of cavity-enhanced nonlinear optical devices and optical waveguides, theoretical model calculations, and proof-of-concept applications. In order to facilitate field deployment and modular integration with a variety of ongoing project collaborations, the sources will feature a compact foot-print and address practical issues such as improved stability and autonomous long-term operation.

High-dimensional Quantum Communication using spatial Modes

State-of-the-art quantum communication protocols mostly use binary state encoding (e.g. polarization qubits). Encoding quantum information in the transverse spatial mode of photons provides access to a much larger – in principle an unbounded – state space. Recent technological advances in spatial light modulation and detection have made spatial mode encoding, in particular in orbital angular momentum modes, an intriguing option for quantum communication channels with significantly increased information capacity.

In this project, you will assemble a compact source of high-dimensional orbital angular momentum (OAM) entanglement and develop efficient measurement techniques based on diffractive optical elements. Building on successful laboratory trials, you will study the transmission of high-dimensional quantum states in free-space and fiber link scenarios. Basic scientific programming skills are required to optimize the spatial mode structure of quantum states, as well as experimental control and data acquisition. Prior experience with spatial light modulation or holography is beneficial, although not strictly required.

Hyperentangled Quantum Information Processing

Photons have several degrees of freedom (DOF) which can be used to encode information. The majority of quantum applications demonstrated to date, however, focus on a single photonic degree of freedom (polarization), so that large portions of the state space go unused. Encoding quantum information in several DOF simultaneously is one of the ways to increase the dimensionality of the quantum state space, and with it the information capacity of an individual photon.

In this PhD project, you aim to harness hyperentanglement, that is, simultaneous entanglement in the time-frequency and polarization DOF for applications in quantum information processing. You will aim for a massive parallelization of quantum communications, allowing for implementations of next-generation quantum protocols with unrivalled performance. This improvement will be achieved through advanced technology, such as dense wavelength-division (WDM) multiplexing and state-of-the-art superconducting photon detectors. The work will involve quantum information science for protocol optimization, quantum nonlinear optics to engineer quantum sources, and high-speed electro-optic modulation for quantum state analysis and switching. Basic scientific programming skills are required for protocol optimization, experimental control and data acquisition. Prior experience with electro-optic modulation, fast optical switching technologies, or wave shapers is beneficial, although not strictly required.

High-bit-rate Quantum Key Distribution Systems

While the realization of quantum communication schemes is routine work in the laboratory, non-trivial engineering challenges emerge in the pursuit of practical implementations in existing fiber infrastructure or long-distance free-space links.

In this PhD project, you will develop advanced quantum key distribution (QKD) systems for collaborative field trials in real communication infrastructure. The work will be at the intersection of quantum communication and optical engineering, with a focus on ultra-fast optoelectronics to meet the exceptional time-bandwidth requirements and high-speed analog and digital signal processing. Quantum expertise is not a prerequisite, as the project aims to adapt methods from conventional high-speed optical communications to the quantum operational regime. Programming skills will be required for data handling, basic feasibility studies and model calculations.

Photonic Devices for Quantum Communication in Space

The transmission of quantum states of light via optical satellite links could extend the range of quantum communication to global distances. In what has been termed a "quantum space race", free-space quantum communication has advanced to a level of maturity that is now markedly reflected in several successful satellite experiments around the globe. With the basic principle now established, the next required step towards practical satellite-based quantum key distribution (QKD) services, is to boost the data rates in free-space quantum links. Through collaborative projects with the European Space Agency (ESA) and international partners in academia and industry, the Fraunhofer IOF is currently developing space-suitable quantum hardware and adaptive optics systems for quantum communication with space platforms and long-distance free-space links.

In this project, you will be involved in the development of space-suitable quantum hardware, such as ultra-stable and compact entangled photon sources, high-repetition-rate single photon pulse sources, and high-speed quantum random number generators. The successful candidate will acquire a comprehensive skill set spanning state-of-the-art quantum state engineering, optical system design, as well as optical integration and micro assembly. Previous programming experience will be beneficial for protocol design, autonomous control loops, and basic feasibility calculations.

What we expect from you

With a background in physics, laser technology, electronics, engineering or a similar photonic study program, successful candidates will be enthusiastic to work in a multi-disciplinary team with collaborators from local research groups as well as international partners in academia and industry.

Prior knowledge in any of the following fields is preferable:

- Optics & metrology, nonlinear optics, electronics, electro-optics, optical communications, laser technology, quantum optics, integrated optics
- Basic scientific programming skills (e.g. MatLab, Python)
- Experimental skills and familiarity in handling basic laboratory equipment

Application and Contact

If you are interested in one of our research topics please contact Fabian Steinlechner (including a CV and a short motivation letter), or use the form for unsolicited applications at our webpage: www.**iof.fraunhofer.de/en/jobs**

For further questions
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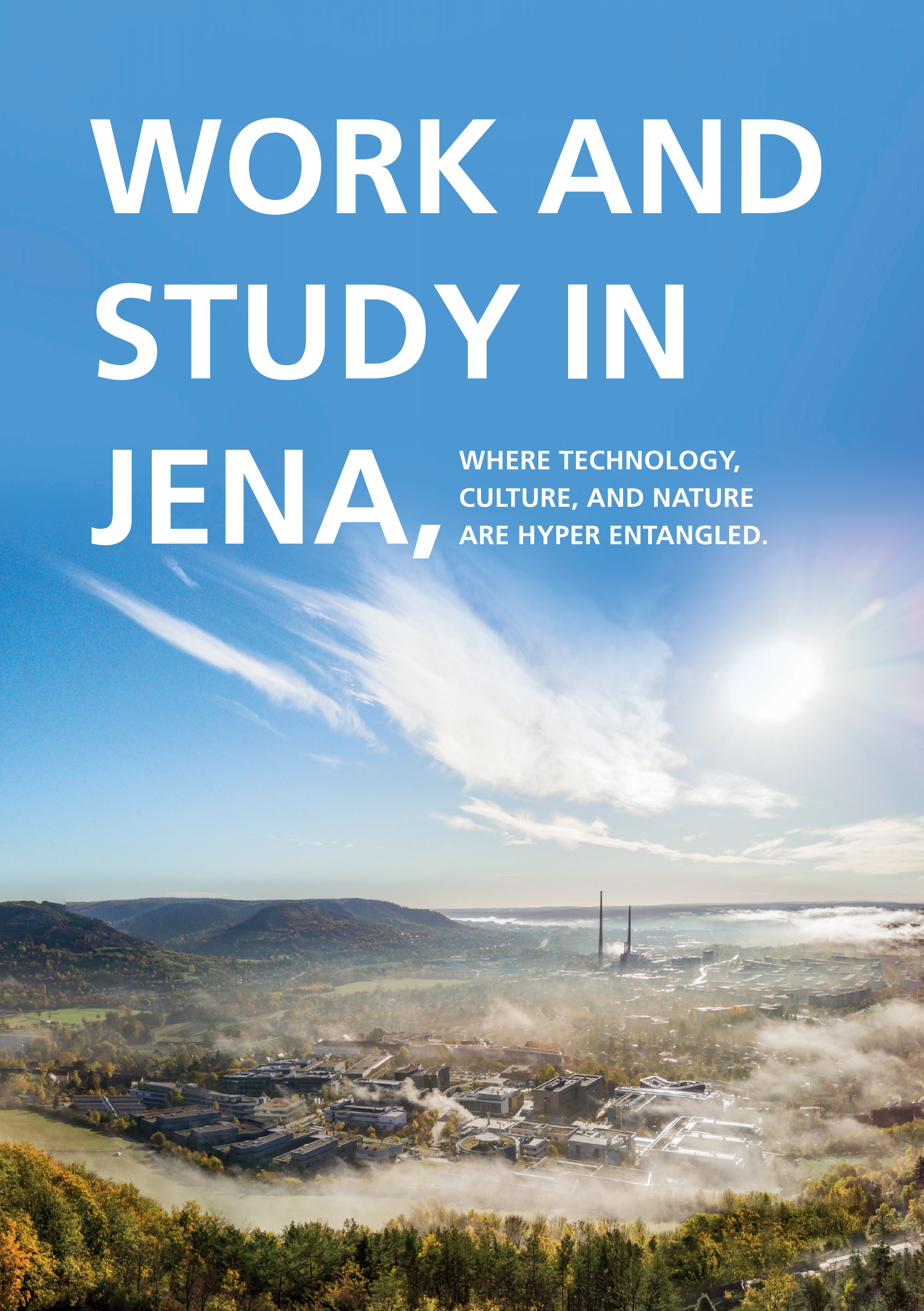
WORK AND STUDY IN JENA,
WHERE TECHNOLOGY, CULTURE, AND NATURE ARE HYPER ENTANGLED.