PRESS RELEASE

Ultra-compact light source for quantum encryption

Photonics West 2025: Fraunhofer IOF presents VCSEL-based photon source for quantum-encrypted communication

Jena (Germany) / San Francisco (USA)

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF is presenting a new photon source at SPIE Photonics West in San Francisco (January 28 to 30, 2025) that has been specially developed for the "Prepare-and-Measure" protocol of quantum communication. The components of the source are optimized for use in space.

The concept of using strongly attenuated, randomly polarized light pulses for secure quantum communication has been around since the mid-1980s. Most commercial light sources for quantum communication are still based on this idea today. The biggest challenge here is to generate indistinguishable and randomly polarized photons at a high rate in a source that is as compact and energy-efficient as possible.

The Fraunhofer IOF in Jena has now developed a photon source based on a linear array of eight vertically emitting semiconductor lasers (VCSELs). It has a ultra-compact design, high spectral and temporal precision and good polarization quality. The system has been specially developed for secure connections from satellites to the ground station.

Indistinguishable photons and decoy states

The new photon source uses a gallium arsenide (GaAs) substrate for eight VCSELs at 850 nm with lithographically structured polarizers developed at the University of Stuttgart. With these integrated components, the source can deliver four polarization states (H/V/D/A) for signals according to the BB84 protocol from an ultra-compact box.

The temperature deviations of the individual VCSELs are significantly smaller than 0.5 K. As a result, the wavelength differences of the polarized photon packets < 40 pm be maintained. Preliminary data show that the on-chip polarizers achieve an extinction ratio of at least 12 dB in the diagonal direction and at least 20 dB in the horizontal or vertical direction.

Four of the eight VCSEL channels provide decoy states by using an attenuator (~4 dB). This increases the overall security of the quantum communication link, as both signal and decoy pulses are generated in the system in a spectrally and temporally indistinguishable manner.

Press Contact
Desiree Haak | Fraunhofer Institute for Applied Optics and Precision Engineering IOF | Phone +49 3641 807-803 |
Albert-Einstein-Straße 7 | 07745 Jena | Germany | www.iof.fraunhofer.de | desiree.haak@iof.fraunhofer.de

The integrated digital-to-analog conversion, developed in collaboration with Technical University of Ilmenau, allows pulse rates of up to 5 GHz. This signal is expected to originate from an additional quantum random number generator. The optical system of the source is housed in a KOVAR box with a low expansion coefficient.

The VCSEL source for BB84-based quantum key distribution with decoy states fits into a volume of 40 × 40 × 43 mm³ thanks to the integrated components. The signals of the eight separate channels differ spectrally by less than 50 pm and indicate differences of time delays of <1ps. This makes the source a promising candidate for a space mission on a microsatellite (Cubesat). All technologies have been selected to be ready for future qualification in space.

Presentation at Photonics West 2025

The Fraunhofer IOF team will present a prototype of the photon source for secure quantum communication at this year's SPIE Photonics West in San Francisco (USA) from January 28 to 30 at the Fraunhofer booth in the German Pavilion (4205 North Hall).

Erik Beckert, head of the "Opto-mechatronic Components and Systems" department at Fraunhofer IOF, will present the technology on January 26 at 1:50 p.m. (Room 158, Moscone South) in his lecture "Ultracompact, VCSEL-based photon source for prepare-and-measure QKD".

About Fraunhofer IOF

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena conducts application-oriented research in the field of photonics and develops innovative optical systems for controlling light - from its generation and manipulation to its application. The institute's range of services covers the entire photonic process chain from opto-mechanical and opto-electronic system design to the production of customer-specific solutions and prototypes. At Fraunhofer IOF, about 500 employees work on the annual research volume of 40 million euros.

For more information about Fraunhofer IOF, please visit:
www.iof.fraunhofer.de

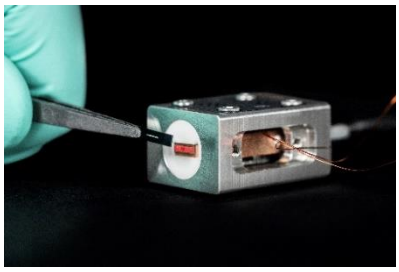
Scientific contact

Dr. Erik Beckert
Fraunhofer IOF
Department Opto-mechatronic
Components and Systems

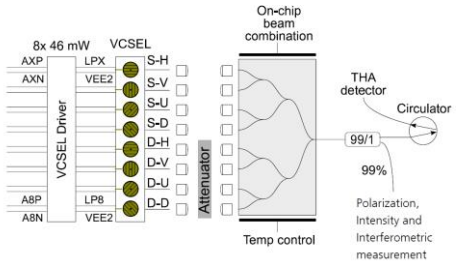
Phone: +49 (0) 3641 807 - 338
eMail erik.beckert@iof.fraunhofer.de

Press images

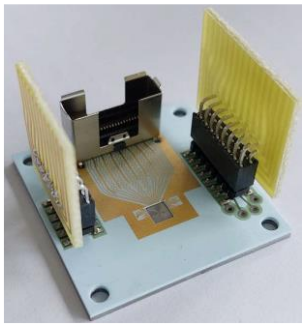
The following images are available in the Fraunhofer IOF press section at https://www.iof.fraunhofer.de/en/pressrelease.html for download.



The housing of VCSEL laser diodes with integrated temperature control is extremely compact. © Fraunhofer IOF



Schematic representation of the eight-channel VCSEL source for polarization encrypted photons. © Fraunhofer IOF



A ceramic printed circuit board (PCB) is bonded to a molybdenum heatsink. The PCB carries the VCSEL and driver chip (center). The wings are plugs for thermal management components.
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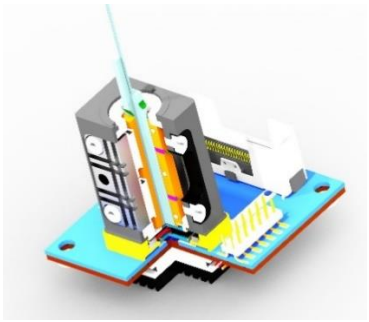

The VCSEL source on the ceramic printed circuit board (PCB) is shown with the KOVAR frame housing. The tiny glass tip on top of the housing is the waveguide combiner, where the polarization signal comes to exit.
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