Fraunhofer HHI: Video, AI, Networks, and Photonics

100 Mio € Budget, 600+ people, 80% self-financed

Video Compression



H.265 / HEVC: 4th Emmy received ~5B devices

Photonic and 5/6G Networks



LiFi for high speed data in EMI environments

Quantum networks

InP and Hybrid PICs



Up to 145 GHz Terahertz sensing QKD components



Quantum Technologies @ Fraunhofer HHI

Components for Quantum Communication

Systems for Quantum Communication

Enabling Technologies for Quantum Communication / Sensing / Computing



Quantum Communication – (over)simplified

Only showing Discrete Variable technologies, no quantum repeater

Alice



Channel







Single Photon Emitter Deterministic, e.g. Quantum Dot Non-deterministic, attenuated laser

Entangled photon pair emitter

Fiber / Free Space Optics

1300 / 1550 / 1060 nm Copropagation with datachannels Single Photon Detector Superconducting Nanowires < 10 K°

Avalanche Photodetectors ~ -20 C°







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Channel

Bob



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DV-QKD BB84 Transmitter PIC Hybrid integration for polarization encoding





4 polarization states from thin-film elements



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HHI

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Beyond state of the art performance InGaAs SPAD Chips

Only European 1550 nm SPAD chip source

Yasio

Under Development:

- Vertical integration of SPAD chips into module package
- Co-integration with quenching ASIC



GEEGENERT VON

für Bildung und Forschung

Bundesministerium

🖉 Fraunhofer

HHI

High Quantum Efficiency InGaAs Photodiodes

Customized Designs Available

- Low noise and up to 99% quantum efficiency between 1064 and 1550 nm
- Coherent detection of quantum signals, e.g. optical quantum computing
- Fundamental science like gravitational wave detection in LIGO







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Quantum Communication Systems @ Fraunhofer HHI

Concepts, architectures and testbeds

- Transparent and scalable integration of QKD into existing IT infrastructures
- Testbeds and OpenLabs for quantumenhanced NextGen networks



Building blocks and sub-systems

- QKD-Synchronization methods
- Time-tagging modules
- Detection modules
- FPGA and DSP modules for QKD



Channel and network technologies

- Quantum channel technologies for multiplexing and routing networks
- All-optical ad-hoc free-space quantum-secure links



Certifiable QKD systems

- Continuous, autonomous operation over telecom fibers and FSO links
- Remote control and monitoring
- Use-case-specific and ready to deploy





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OpenQKDLab – Part of BMBF SQuaD Project

Testbed, Proof of Concept, use case exploration













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Automatic startup and continuous operation under varying

Demonstrated in complicated environment

- Interoperability with central key management system and industrial encryptors
- Operation over telecom fiber and FSO-links
- Demonstrated between two German federal government offices for QKD-secured video-conferencing

conditions

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625 MHz Time-Bin encoded BB84 QKD System

QKD Sender Quantum LB1 MHz Clock OUT

QuNET



Post-Processing

DWDM Multiplexer



Encryptor



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Hybrid Tunable Lasers ...

... with the option to cointegrate optical functions

- Single photons via weak coherent pulses
- Integrated pump for non-linear optics
- Laser concept can be transferred into VIS → gain chip material







785 nm → GaAs gain chip





Integration of Micro-Optical Elements

Enabling quantum technologies with...

... low-loss on-chip free-space sections ...



... for NLO crystal integration. \rightarrow SHG, SPDC, ...







Example: Spontaneous Parametric Down Conversion ...

... 532 nm => 810 nm / 1550 nm entangled photon pair



PolyBoard w/ **NLO waveguide** (ppLN/ppKTP) for SPDC, **long pass TFF** (LP) to filter out pump light and **dichroitic mirror** (DM) to separate signal and idler photons





Switching Quantum Bits (or control light) at GHz-Speed

Thin-film LiNbO₃ MZ-modulator PICs for e.g. optical quantum computing

- 1st generation with 0.3 dB/cm waveguide loss
- Simple concept for fibre edge coupler (patent pending)









Quantum Technologies @ Fraunhofer HHI Summary

SPADs and high efficiency detectors

Quantum PICs (InP, Polymer, SiNx, TFLN) for a wide range of applications

QKD testbed and systems

