

Integrated Optics Modules for Handheld Quantum Key Distribution

Peter Freiwang Lukas Grimmeißen Jacob Birkmann Rengaraj Govindaraj

Jannik Luhn Clemens Sonnleitner Thomas Schwarzwälder

Wenjamin Rosenfeld





TU Munich ANU qutools GmbH

Giacomo Corrielli Andrea Crespi Roberto Osellame



BMBF-HQS, BMBF-QUBE , ENB-ExQM, EU-QWAD











- QKD sender
 - test
 - QKD receiver
 - handheld key exchange
 - next steps





• get small!









simple device use integrated optics more complex tasks by the receiver

- integrated optics: SiO on Si, Si, InP,
- hand held

Univ. Oxford (H. Chun et al. Opt. Expr. **25**, 6784, (2017)) Univ. Bristol







- 4 diodes + integrated optics
 - 4 VCSEL, 250 µm pitch
 - fs-laser-written waveguides (G. Corrielli, R. Osellame)
 - micro lenses
 - polarizers: nano-wire, FIB etching



evaluation of components

- VCSEL
 - control electronics with programmable delays
 - → short pulses
 - ~250 ps pulse width
 - → excellent overlap





Wavelength (nm)

- wavelength due to production
 - \rightarrow selection necessary

evaluation of components

- fs-written waveguide
 - overlap light from 4 VCSELs into one single output mode
 - circular cross section
 - 3D-writing
 - → couplers pol. independent
 - very low birefringence
 → output modes "equal"







O evaluation of components

- polarizer
 - gold nano-wire
 - FIB etching
 → orientation
 - optimisation for trapezoids
 - → very high extinction ratio > 1000:1 low transmission (~7%)

	H′	+45′	-45′	V ′
Experiment	30.6	30.8	32.1	32.5
Simulation	31.1	31.7	34.6	36







evaluation of components

- output states
 - quantum process tomography
 - pre-compensate birefringence partly
 - final compensation in receiver!

 \rightarrow QBER = 1.5%







- complete module
 - add beacon (680 nm) for pointing
 - mount on optical bench, integrate with electronics







- QKD-Receiver
 - passive basis choice, 4 SPADs, polarization compensation
 - spatial filter to avoid side-channel attacks (0.08°)
 - mobile phone tilt sensor for reference frame alignment
 - beacon for beam tracking (±3°) and synchronisation





- static test
 - GLLP evaluation: $\mu \sim 0.15$ / pulse, T ~ 41% $\rightarrow R_{sec} = 148.8$ kbit/s









- hand-held test
 - 4 user, η~18%, QBER~2.3%,

 $R_{sec} \sim 5.5 kbit/s$ (including alignment parameter)

User	η (%)	T (kbit/s)	QBER (%)	R _{raw} (kbit/s)	R _{sec} (kbit/s)
1	31.9	336.9	2.3	144.6	13.6
2	12.8	307.8	2.6	47.5	3.4
3	19.0	324.9	2.2	76.4	6.5
4	17.5	295.8	2.6	69.3	4.4
1	18.6	277.0	2.3	80.3	6.3
2	18.9	424.1	2.3	39.1	4.4
3	16.8	425.8	2.4	46.3	5.4
4	21.6	263.3	2.6	96.1	5.7
Average	19.6	333.0	2.4	75.0	6.2





- Evaluation of components for QKD with cube sats
- integrated optics
 for quantum payload
- optical ground station





- hand-held operation
 - integrated optics
 - automatized alignment and synch.
 - η~18%, R_{sec}~5.5 kbit/s
- improvements:
 - better (basis) alignment x4
 - decoyx20
- integrate in more free-space systems
 - more sturdy for urban areas, airplanes and satellites







