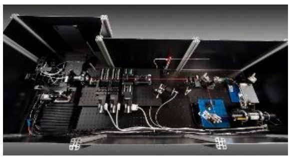
PTB's Calibration and Measurement Capabilities for QKD

In our lab we characterize the detection efficiency of single-photon detectors in an absolute and traceable manner with measurement uncertainty of less than 1%, as well as in terms of dead time and polarization dependence. As part of third-party funded projects, we characterize new types of detectors, for example at 589 nm for free-space QKD in daylight. For single-photon sources, we characterize them in terms of their photon flux, photon statistics, wavelength, polarization and temporal stability. We can also provide a tomographic reconstruction of non-degenerate entangled photons and obtain a fidelity value. We are building up expertise and the capabilities for testing various protocols for QKD, quantum entanglement distribution, and multiple-user clock synchronization with our available infrastructure.

A: Brief Information

Testbed Title	PTB's Calibration and Measurement Capabilities for QKD
Institution/ Organization	Physikalisch-Technische Bundesanstalt (PTB), Braunschweig
Contact	Prof. Dr. Stefan Kück: stefan.kueck@ptb.de
	Dr. Nicolas Spethmann: nicolas.spethmann@ptb.de
Status	active
Type	component calibration and characterization

B: Technical Information

Component	Parameter/Measurement	Wavelength
any fiber component	optical transmission	1480 nm – 1640 nm
	attenuation	
	polarization extinction ratio (PER)	
beamsplitter	splitting ratio	1480 nm – 1640 nm
SPAD detector photo: SPAD_Calibration 	detection efficiency	589 nm 633 nm 780 nm 850 nm 927 nm 1280 nm - 1350 nm 1450 nm - 1600 nm more on request
	detector dead time	589 nm 633 nm 780 nm 850 nm 927 nm 1280 nm - 1350 nm

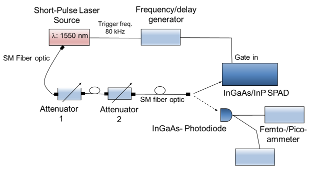
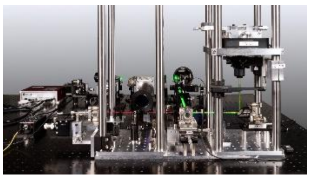
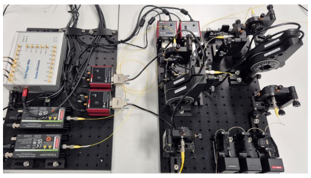
		1450 nm - 1640 nm more on request
	dark count rate	-
	after pulsing probability	1480 nm - 1640 nm more on request
	timing jitter	1550 nm more on request
	optical backflash probability	1480 nm - 1640 nm
SNSPD detector 	detection efficiency	1480 nm - 1600 nm
	detector dead time	1480 nm - 1640 nm
	dark count rate	-
	timing jitter	1550 nm more on request
attenuated laser 	photon number distribution	1550 nm more on request
	spectral distribution	1527 nm - 1565 nm @ 10 pm accuracy 800 nm - 1700 nm @ 130 pm accuracy
	photon rate, mean photon number	visible light 930 nm 1400 nm - 1700 nm more on request
single-photon-source 	single-photon purity	visible light 930 nm 1400 nm - 1700 nm more on request
	photon number distribution	visible light 930 nm 1400 nm - 1700 nm more on request
	spectral distribution	1527 nm - 1565 nm @ 10 pm accuracy 800 nm - 1700 nm @ 130 pm accuracy
	photon flux	1480 nm - 1600 nm
	source efficiency	1480 nm - 1600 nm
entangled-photon source	quantum state tomography	790 nm - 890 nm 1400 nm - 1600 nm
	visibility (HOM)	
	photon statistics	

photo: quantum state tomography 	bandwidth	
photodiode 	external quantum efficiency	1450 nm - 1600 nm more on request

C: Additional information

Linked Projects	- QuNET+BlueCert: https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/qunet-bluecert - Qu-TEST & Qu-PILOT: https://qu-test.eu/ - QR.N: Quantenrepeater.Net - Vernetzte Quantenrepeater für die künftige Ende-zu-Ende-Sicherheit, https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/quantenrepeater-net-qr.n - QuAtuLo-Sicheres lokales Kommunikationsnetzwerk für den mobilen Einsatz: https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/quatulo
Press Release and Publications	- *Detection efficiency calibration of single-photon silicon avalanche photodiodes traceable using double attenuator technique*, 2015, (calibration of single photon detectors) - *Experimental realization of an absolute single-photon source based on a single nitrogen vacancy center in a nanodiamond*, 2017, (NV-center SPS) - *Metrological characterization of a commercial single-photon source with high photon flux emission*, 2024, (commercial QD-SPS)

	- *Absolute calibration of a single-photon avalanche detector using a bright triggered single-photon source based on an InGaAs quantum dot*, 2021, (detector calibration using SPS) - *A study to develop a robust method for measuring the detection efficiency of free-running InGaAs/InP single-photon detectors*, 2020, (InGaAs SPAD calibration) - *Photon number dependent afterpulsing in superconducting nanostrip single-photon detectors*, 2020, (afterpulsing in SNSPDs) - *Bright single-photon emission from a GeV center in diamond under a microfabricated solid immersion lens at room temperature*, 2023, (GeV-center SPS) - *Detection of ultra-weak laser pulses by free-running single-photon detectors: Modeling dead time and dark counts effects*, 2021, (SPADs: dead time & DCR)
Demonstrated Milestone	- absolute, traceable detection efficiency at a measurement uncertainty of < 1% as well as in terms of dead time and polarization dependence. - characterization of new single-photon detectors - characterization of key parameters such as single-photon purity, spectral distribution and photon flux for various single photon sources at cryogenic and room temperature. - provide a tomographic reconstruction of non-degenerate entangled photons and obtain a fidelity value.
Outlook	- metrology for entangled photon pair sources
Suggested Use Cases	- component characterization for QKD - device characterization at QKD-testbeds

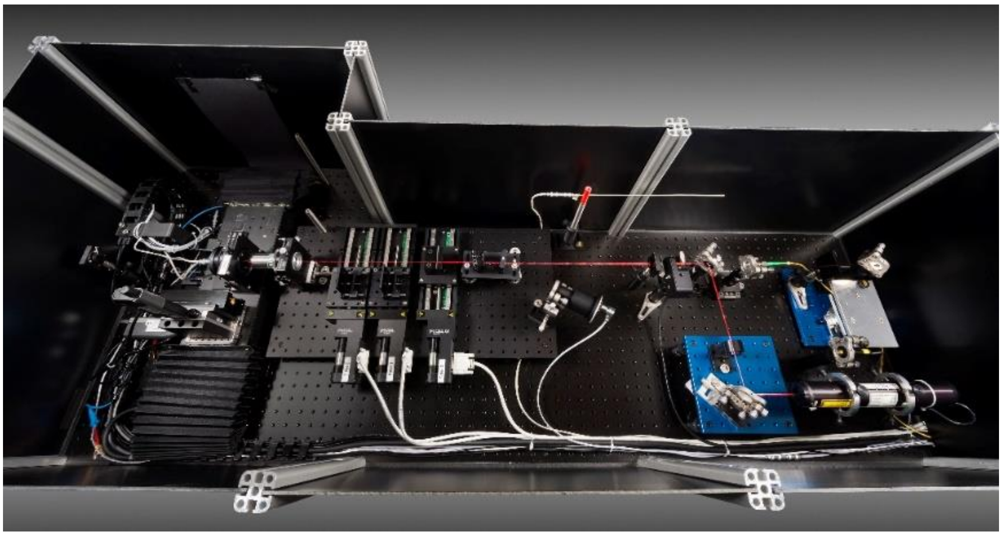


Figure 1: SPAD Calibration

Figure 2: SNSPD

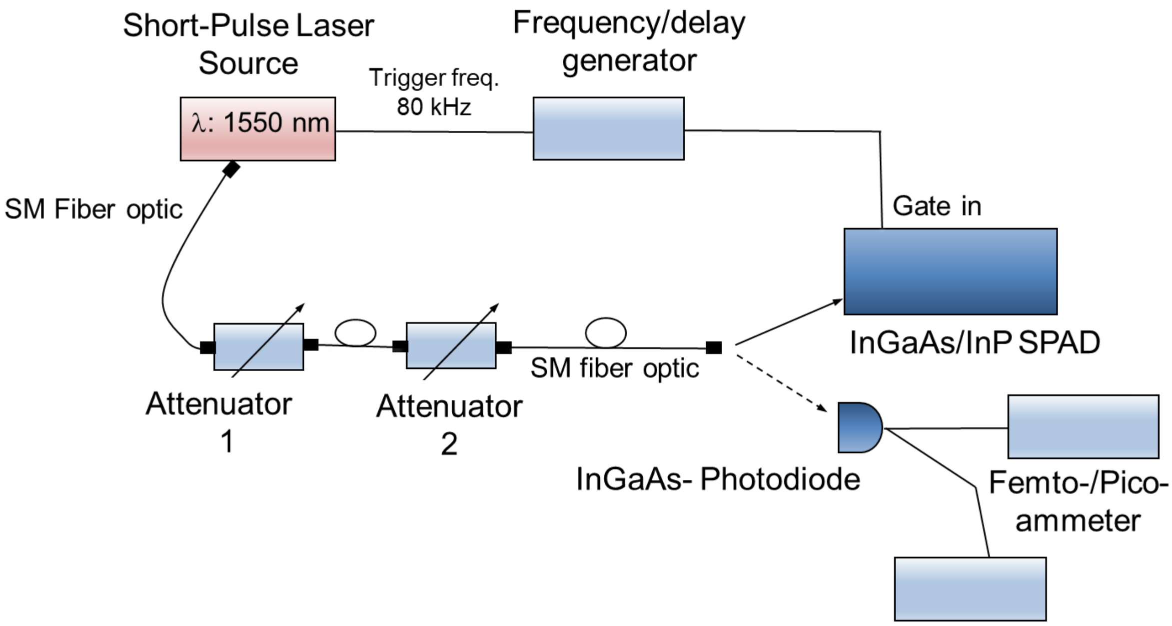


Figure 3: Attenuated Laser

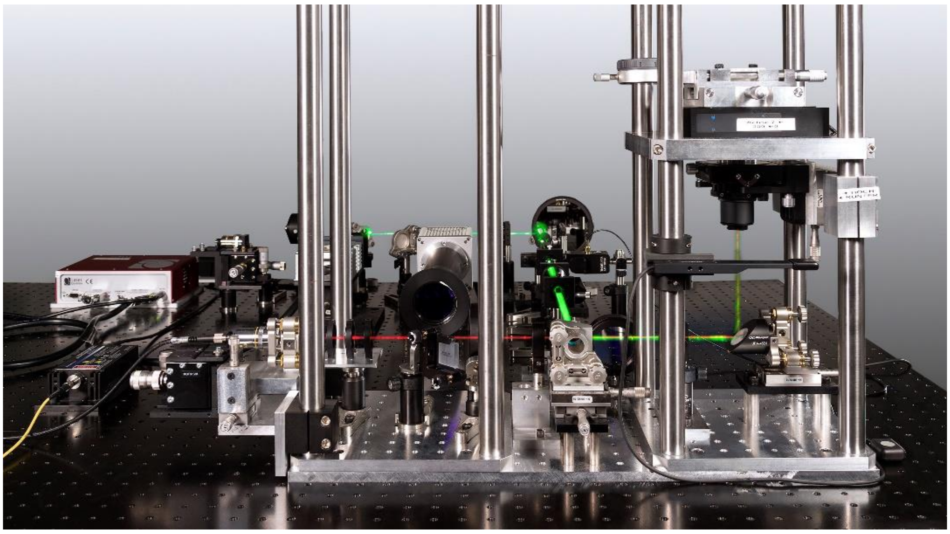


Figure 4: Single-Photon-Source

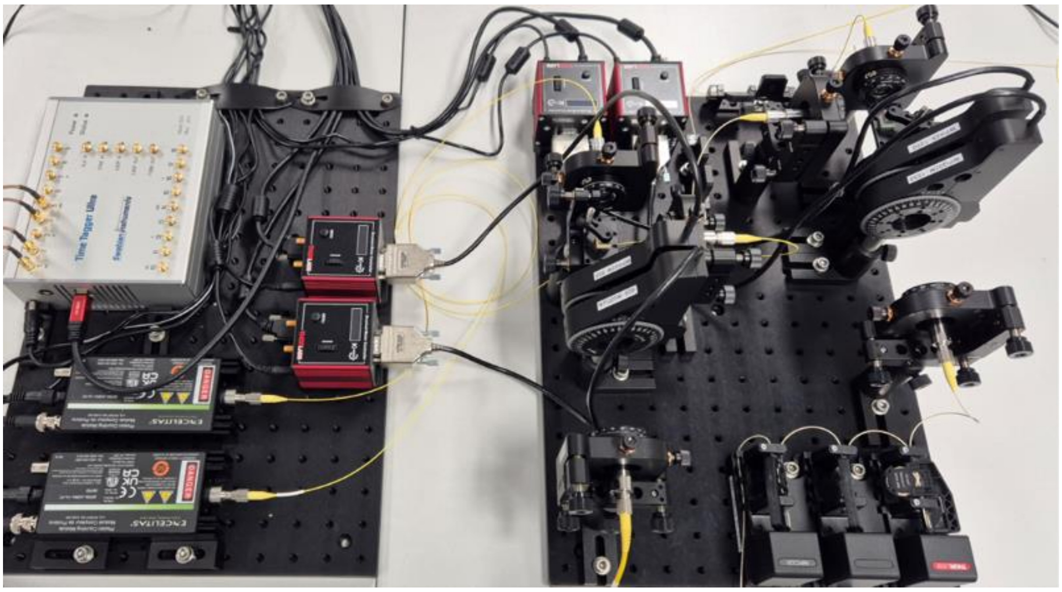


Figure 5: Quantum State Tomography

Figure 6: Photodiode