QUANDELA

PRODUCT
CATALOGUE
2024

Since our inception, Quandela has been committed to harnessing the power of quantum mechanics to develop cutting-edge solutions that address some of the most pressing challenges faced by businesses today. From single photon sources to quantum computing, our diverse portfolio of products and services embodies our dedication to pushing the limits of quantum technology.

In this brochure, you will discover how Quandela's expertise and innovation can propel your organization forward, enabling you to unlock new possibilities and stay ahead in today's fast-paced digital landscape. From enhancing data security and optimizing computational capabilities to revolutionizing medical imaging and environmental monitoring, the potential applications of quantum technology are limitless, and Quandela is here to lead the way.

As we continue to pioneer quantum solutions, we invite you to join us on this journey of exploration and discovery. Together, let us shape the future of technology and usher in a new era of innovation.

Thank you for choosing Quandela as your partner in quantum excellence.

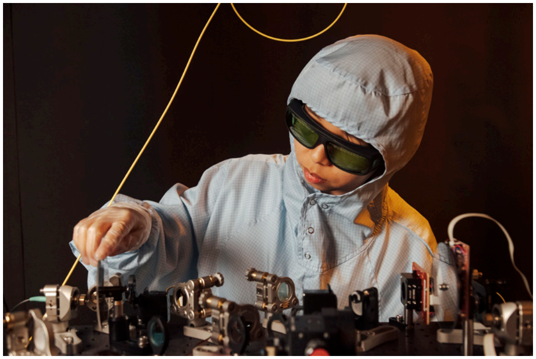
Niccolo Somaschi
CEO, Quandela

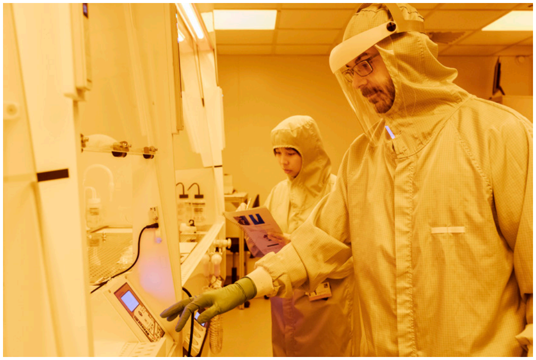
Established in 2017 by Prof. Pascale Senellart, Niccolo Somaschi, and Valérian Giesz, Quandela pioneers a groundbreaking synergy between photonics and quantum technologies. Our innovative work centers around the development of eDelight, a cutting-edge solid-state singlephoton source that effectively eliminates all remaining barriers to the scalable manipulation of single photons.

Over the past years, we have harnessed our collective expertise to craft highly performant modules tailored for the emission, manipulation, and detection of single photons. These modules serve the research community and contribute to the advancement of quantum computing.

At Quandela, we firmly believe in the transformative potential of photonics at the quantum level. Our commitment to pushing the boundaries of technology underscores our mission to propel the development of quantum technologies into new realms of possibility.

Pascale, Niccolo and Valérian
Founders of Quandela





MosaiQ

The first datacenter-ready quantum computer

Prometheus

The leading standalone quantum-dot based single-photon source

eDelight

Efficient generation of pure single photons

Q-DMX

Transparent & active time-to-space demultiplexing

Quandela Cloud

A cutting-edge platform tailored to your needs

MosaiQ

The first datacenter-ready
quantum computer

Rack system

The Mosaiq system, from a MosaiQ-6 to MosaiQ-12 is composed of the following components

Fully modular

Fully Upgradable

Low Energy Usage (from 2.3kW)

Short lead-time (8 to 10 months)

- Laser & controls included
- Active time-to-space demultiplexer
- Opto electronic modules
- Natively ready for Quantum Networks
- Photonic integrated module circuit
- Cryostat chamber including the pigtailed single photon source
- Pump
- Air-cooled helium compressor module

The setup of the proposed photonic quantum computer is based on the schematic of Ascella (Figure 1) Quandela's 6-qubit quantum computer.

This 6-qubit platform is fully described in Nature Photonics (https://www.nature.com/articles/s41566-024-01403-4).

Ascella operates in Quandela's facilities, and it is accessible via Quandela's proprietary cloud since November 2022 (cloud.quandela.com).

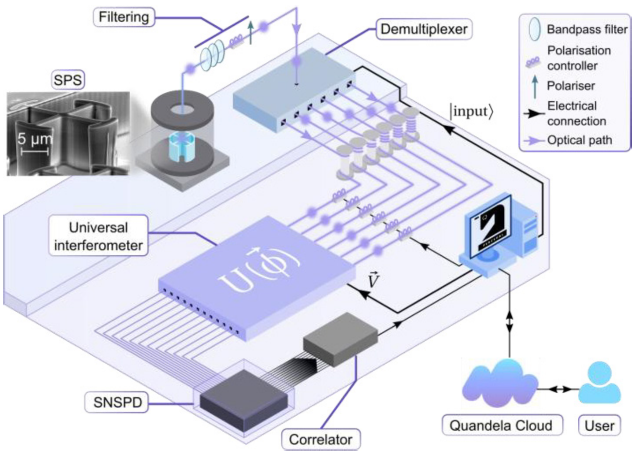


Figure 1 Schematic of the "Ascella" 6-qubit photonic quantum computer launched in Nov 2022 on Quandela Cloud (cloud.quandela.com).

Architecture of Ascella presented in Nature Photonics paper as supplementary pdf document.

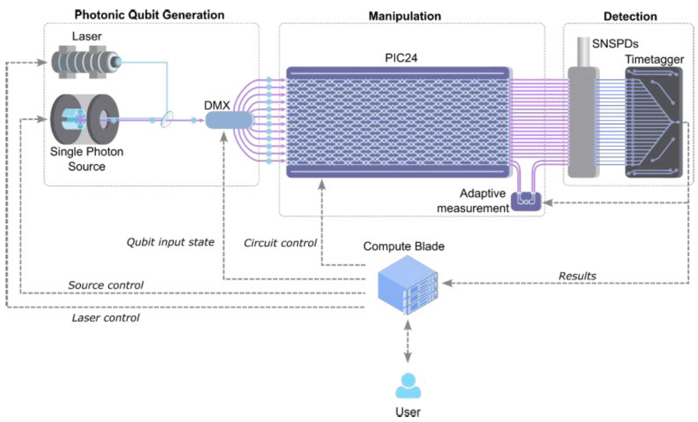


Figure 2 Schematic of MOSAIQ-12, based on the general architecture of AscellaQPU, and adapted for 12-qubits by modifying and adding:

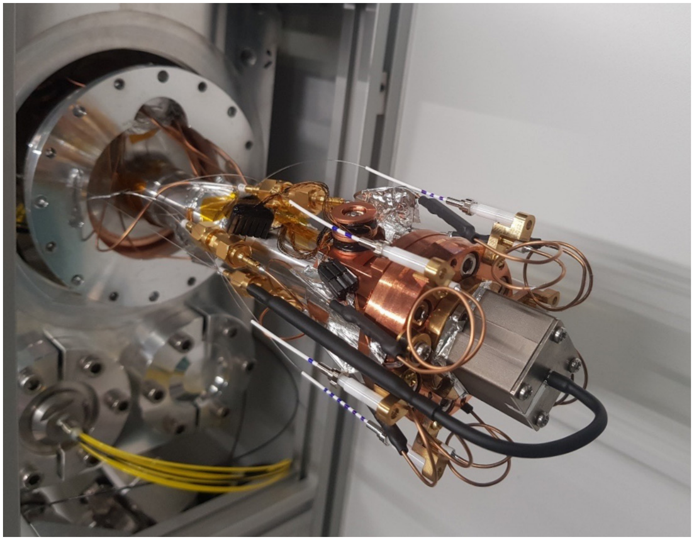
- The universal chip has 24 modes to allow the manipulation of 12 photonic qubits
- Photon detection will integrate Pseudo-PNR detectors (see Photon detection below)
- An adaptative measurement module is integrated to allow proof of concept MBQC implementation

Cryogenic system, pigtail eDelight device & SNSPDs

The eDelight (or single-photon source) device is installed in a compact cryostat. Both the cryostat chamber and the compressor are integrated in MosaiQ systems.

The cryostat is a standard which reaches 3K via a closed cycle of compression and expansion of helium gas. The air-cooled compressor is now compact and fit in a rack self. To ensure the mandatory temperature cycle after each 3 months at cryogenic temperature, the system also includes a vacuum pump.

The single-photons detectors are SNSPDs. In a MosaiQ-6 system they are all integrated in the same cryostat chamber as the eDelight device, while they are dispatched in two cryostat chambers in a MosaiQ-12. The eDelight device is cover by a shield so that the excitation laser does not saturate the single-photon detectors.



Patented Technology: Patent n° US11867957 delivered on January, 9th 2024, PCT/FR2022/050805

Opto-electronic systems

Laser shaping

To efficiently excite the eDelight device and emit the single-photons, MosaiQ systems integrate a pulsed laser and a laser shaper. The laser parameters, such as the central wavelength or the pulse duration, are perfectly controlled and monitored by the system.

QFDMX-n module

MosaiQ systems also include an opto-electronic system which allows for both filtering out the reflected laser and efficiently collecting the emitted single photons. These systems also allow to send the stream of single-photon into n-channels. Quandela proposes up to 12 channels. The fibre delays ensure a synchronisation of the single photons from each channel.

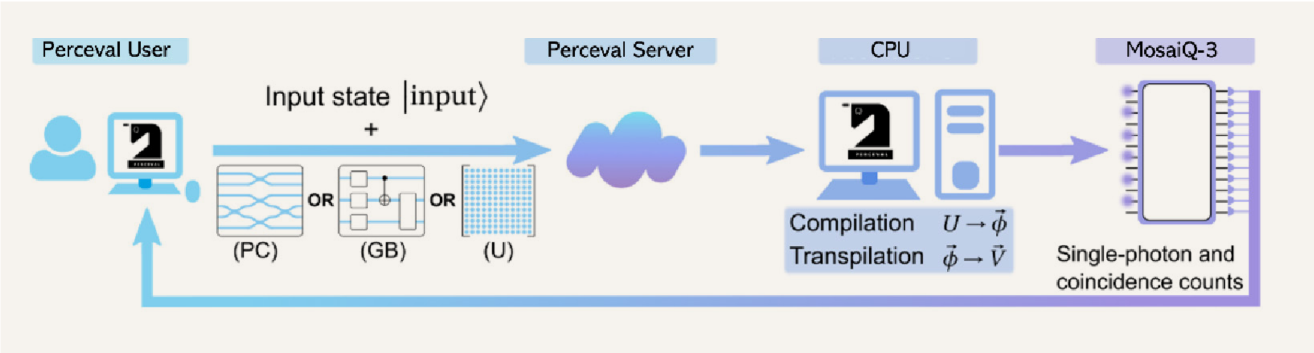
Photonic chip with m modes

MosaiQ systems integrate a photonic chip with m modes. Directly placed after the QFDMXs and before the SNSPDs, this is the quantum processor of the QPU. Composed of waveguides, the single-photon paths are modifiable by changing phase shifters linked to local resistors. These changes depend on the implemented job/ calculation.

Software

The MosaiQ system* is fully automatised and is a stand alone product. A blade controls all the devices. Measurement points enable to stabilised or maximised some metrics so that the system is always optimised.

The user has access to the QPU via a personal version of the Quandela Cloud. Thanks to Perceval, they can implement any job compatible with their n-qubits m-modes QPU:



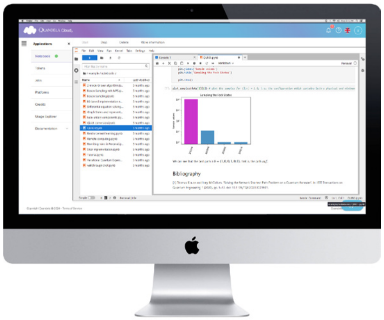
Access to Quandela Cloud

Build hybrid architecture and get access to high-availability QPU and GPU-accelerated simulators. Benefit from packaged quantum primitives through Quandela Quantum Toolbox.

Implement shot-based billing though different offering for small experiments up to mission-critical enterprise access.

Integrate Token-Based REST API with multi-language SDK for integration in Business applications.

Register at cloud.quandela.com



*from a MosaiQ-6 to MosaiQ-12

SPECIFICATIONS / REQUIREMENTS

Space for a rack cabinet	80 (w) x 100 (d) x 180 (h) cm3
Weight	>300kg on four wheels per unit
Electrical connection	230V ±10V compatible with CEE 7/3, CEE 7/4 or CEE 7/5
Temperature	between 10°C and 30°C, with a daily peak-to-peak fluctuations amplitude of less than ±5°C
Relative humidity	below 55%, with a daily peak-to-peak fluctuations amplitude of less than ±15%

TECHNICAL SPECIFICATIONS

Number of Qubits		6, 10 or 12 and more to come
Physical circuit depth		up to 12 Qubit, 12
T-gate (1-Qubit gate)	Corrected fidelity	99,6 ± 0,1%
	End-to-end fidelity	99,6 ± 0,1%
CNOT gate (2-Qubit gate)	Corrected fidelity	99,0 ± 0,8%
	End-to-end fidelity	93,8 ± 0,6%
Toffoli gate (3-Qubit gate)	Corrected fidelity	90,0 ± 1,4%
	End-to-end fidelity	86 ± 1,2%
Heralded GHZ state	Fidelity	82 ± 4%
Q-score		6
Average service level agreement for hardware support		1 week

MosaiQ	2	6	10	12	24 (in 2025)
Q-Score			6		
QOPS		144	400	576	2328
Size		1 rack	2 racks	2 racks	2 racks

PROMETHEUS

The leading standalone quantum-dot based single-photon source

Cryostat, pulsed laser, solid-state single photon sources and active demultiplexer

ALL IN ONE SYSTEM

Optical Quantum technologies require long streams of identical single photons produced in a stable and robust manner.

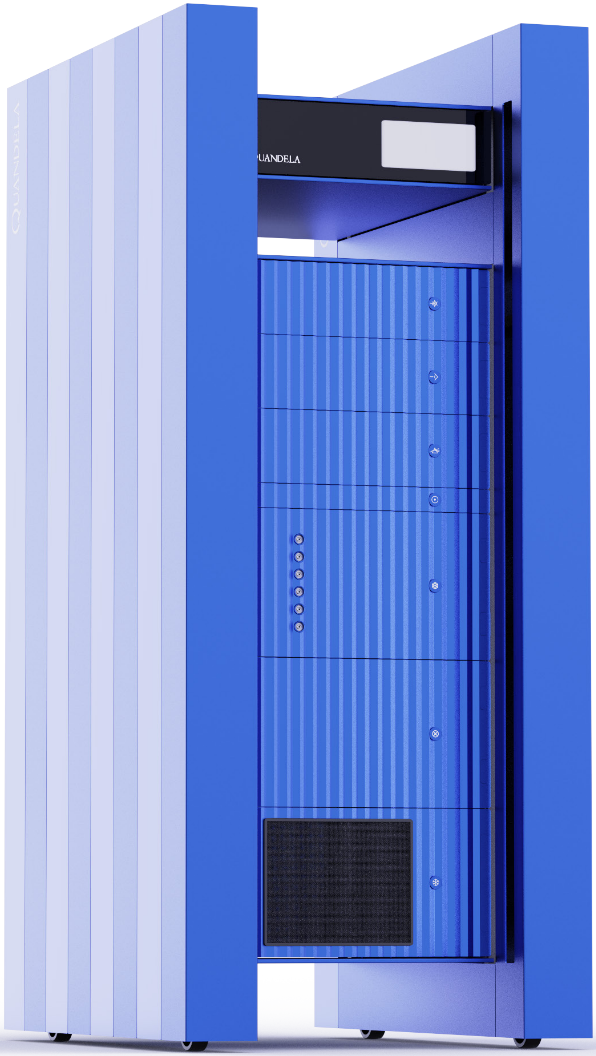
The revolutionary concept and design of Prometheus' stand-alone single-photon source makes it the optimal solution for providing a high rate of single and indistinguishable photons for demanding quantum applications.

It consists of an all-in-one device that provides a stable stream of photons with a record brightness thanks to our proprietary technology.

Hence, with Prometheus, engineers and researchers can now focus their efforts on their ideas for the design of new experiments based on the manipulation of a large number of optical quantum bits.

Modular Design

Ready for large-photon number applications



An optical laboratory in one reliable and vertical device

After years of research and innovation, Prometheus is the only standalone device for the emission and the detection of single photons at record rates.

Inside Prometheus:

- A Helium closed cycle cryostat with air-cooled compressor (water cooling possible) integrating eDelight single photon sources and SNSPDs detectors (optional);
- A 80-MHz pulsed laser used for the optical excitation of the source
- Optical and electronical modules for the use of the source and detectors
- Optional Active Demultiplexer Q-DMX (from 6 to 12 outputs)
- Vacuum Turbo Pump
- Main Computer with user-friendly control software

All the modules are interconnected via optical fibers, which provides a modularity and upgradability.

Thus, the performance of the device can be upgraded, which will never be obsolete.

Applications:

Use of multiple single photons at the input of programmable interferometers. Photonic Integrated Circuits can be provided.

SPECIFICATIONS / REQUIREMENTS

Technology	Proprietary fabrication process and design, fully deterministic: a selected quantum dot coupled to the optical cavity mode.
Single-photon emission wavelengths	925nm (+/- 5nm) 780nm (+/- 5nm) Telecom wavelengths (1550nm) single photons available via a Frequency Conversion Module (optional)
Photon Polarization	All the photons have the same polarization
Minimal Guaranteed Fibered Brightness(photon presence per pulse probability)	From 17% to 26%[1]
Typical Single-photon generation rate	> 20 M photons per second
Single-photon purity : g(2)(0)	Typically 2%, < 3% guaranteed[1]
Indistinguishability	Typically 94%, > 92% guaranteed[2]
Single-photon bandwidth – emitter lifetime	1.2 (+/- 0.4) GHz , < 150 (+/- 50) picoseconds Fourier-transform-limited’’ emission
Cooling Time About 12	hours for the pumping and cooling to 4K
User Interface	All-in-one fully automated software on the integrated computer
Required Electrical Supply & Power Consumption	220V ; < 3kW For Air-cooled compressor
Physical dimensions (cm)	185 (h) x 108 (w) x 76 (d)

1 Depending on the chosen performance by the customer, typical brightness is higher than the minimal guaranteed brightness
2 Second order correlation measured” via Hanbury Brown-Twiss interferometer

Please note that these specifications are subject to change without any prior notice.

eDelight

Photonic Qubit generator
efficient and deterministic

About semiconductor quantum dots

eDelight utilizes semiconductor InAs Quantum dots as its primary sourcing elements, demonstrating near-ideal quantum emitter behavior. The precision and efficacy of our quantum dot system are enhanced through a deterministic coupling mechanism, where selected quantum dots are deterministically coupled with an optical cavity in the form of a micropillar.

The micropillar's structure is crafted from doped semiconductors, enabling the application of a DC-voltage for fine-tuning the quantum dot transition. This meticulous adjustment results in a precise spectral matching of the emitted photon, achieved by orchestrating the recombination of charges within the quantum dot with the optical mode of the cavity. The integration of these advanced technologies ensures optimal control over individual quantum dots and enhances the collection of emitted photons, establishing eDelight as a pioneering solution in quantum emitter technology.

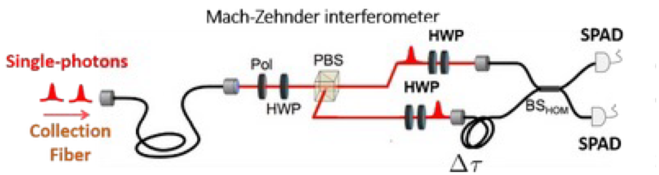
READ MORE:

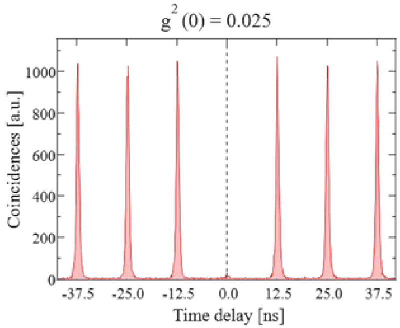
P. Senellart et al., High-Performance Semiconductor Quantum-Dot Single-Photon Sources, Nature

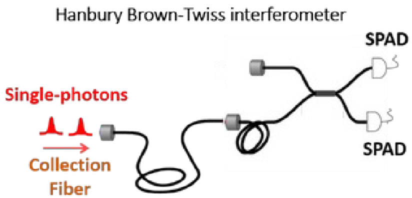
Nanotechnology 12 (2017)

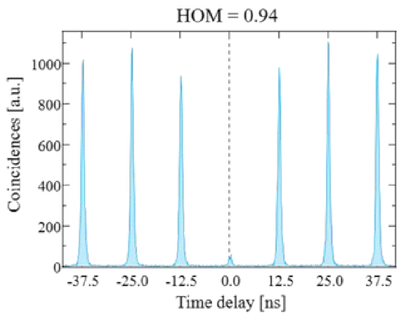
N. Somaschi et al. Near-Optimal Single-Photon Sources in the Solid State, Nature Photonics 10 (2016)

High brightness with low multiple photon emission and high photon indistinguishability









Patented fiber coupled integration of eDelight in cryostats

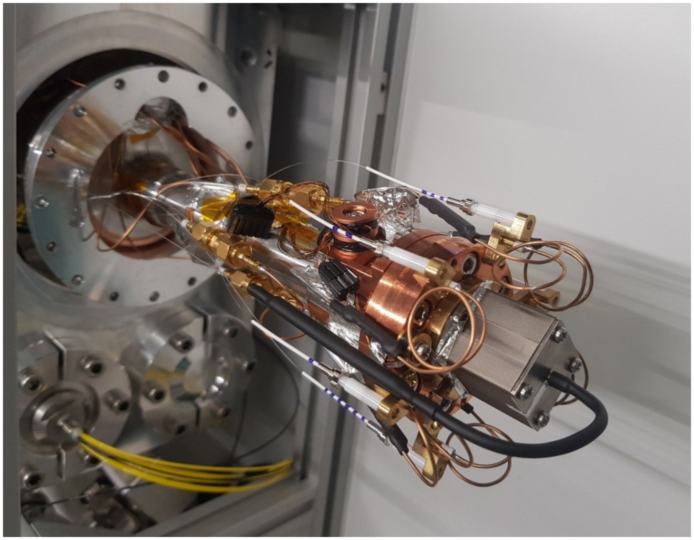
Since eDelight sources must be cooled down at a temperature below 6 Kelvin (K) to emit highly indistinguishable photons, Quandela has developed a unique method for the pigtail of one source with one single-mode fiber in order to facilitate the integration in standard Helium closed cycle cryocoolers.

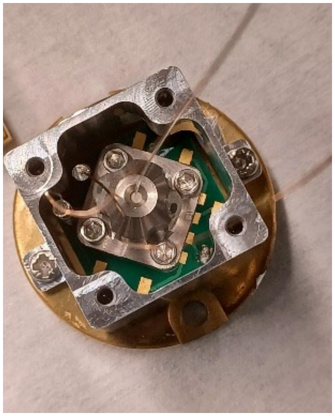
In one fabricated chip, around twenty (20) pillars (all of them integrating one quantum dot) are fabricated and the brightest source is then selected to be coupled to a single-mode fiber (whose core diameter is around 2 micrometers). The same fiber is used for the optical excitation and for the collection of generated photons.

One source is coupled to one fiber.

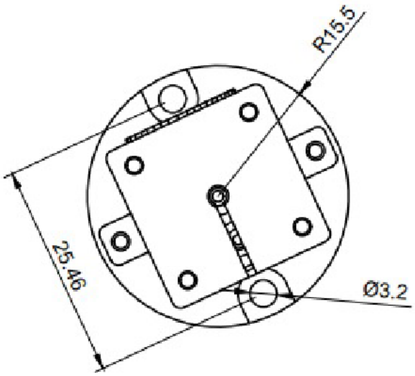
The pigtailed source can then be integrated with other devices as Superconducting Nanowire Single-Photon Detectors (SNSPDs) in the same cryostat chamber.

Contact us to check the compatibility of your existing system





Patented Technology : Patent n° US11867957 delivered on January 9th2024, PCT/FR2022/050805



SPECIFICATIONS / REQUIREMENTS

Technology	Proprietary fabrication process and design, fully deterministic: a selected quantum dot coupled to the optical cavity mode.
Single-photon emission wavelengths	925nm (+/- 5nm) 780nm (+/- 5nm) Telecom wavelengths (1550nm) single photons available via a Frequency Conversion Module (optional)
Photon Polarization	All the photons have the same polarization
Minimal Guaranteed Fibered Brightness (photon presence per pulse probability)	From 17% to 26%[1]
Typical Single-photon generation rate at an excitation clock rate of 80MHz	> 20 M photons per second
Single-photon purity : $g^{(2)}(0)$	Typically 2%, < 3% guaranteed [2]
Indistinguishability	Typically 94%, > 92% guaranteed[3]
Single-photon bandwidth – emitter lifetime	1.2 (+/- 0.4) GHz , < 150 (+/- 50) picoseconds ''Fourier-transform-limited'' emission
Required laser pulse energy	about 10-13 J (per excitation pulse) – See Prometheus pages to see the laser options
Required operating temperature	< 6 Kelvin
Required Temperature stability	T. stability: < 50 mK
Pigtailed Device Dimensions	Height: 5cm – Diameter of the round plate: 3.1cm

1 Depending on the chosen performance by the customer, typical brightness is higher than the minimal guaranteed brightness
2 Second order correlation measured" via Hanbury Brown-Twiss interferometer
3 Photon indistinguishability between successively emitted photons measured by ''Hong-Ou-Mandel" interference measurements

Please note that these specifications are subject to change without any prior notice.

SOME PUBLICATIONS FROM OUR CUSTOMERS IN 2023

B. Polacchi et al., Quantum teleportation of a genuine vacuum-one-photon qubit generated via a quantum dot source, arxiv:2310,20521 (2023)

M. Valeri et al. , Generation and characterization of polarization-entangled states using quantum dot single-photon sources, arxiv:2308,02422 (2023)

H. Cao et al., A Photonic Source of Heralded GHZ states, arxiv:2308.05709 (2023)

Q-DMX

The first active time-to-space demultiplexer for multiphoton applications.

It combines optics and electronics in a compact module. Now available for 6 photons and up to 12 photons adapted to interface eDelight & Prometheus with integrated circuits.

- Compact, fast and highly transmittive for single photon demultiplexing
- One fibered input
- Up to 12 fibered outputs
- Controlled by a software

SPECIFICATIONS / REQUIREMENTS

Number of Fibered Outputs	From 6 to 12
Operation Wavelength	920-930 nm (identical as eDelight & Prometheus) 780 nm
Guaranteed Channel Transmission (measured in a single-mode 780HP fiber)	70%, typical transmission: 75%
Rise Time	T switch ~ 50 ns
Tunability of the plateau Time	Yes, via the software
Activation/Deactivation of outputs	Yes, via the software
Physical dimensions (cm)	15 (h) x 49 (w), 47 (d)
Weight	Optics: ~ 17 kg Electronics: ~4kg
Electrical connections	100V/120V/230 V, 50 Hz

PLEASE NOTE:

For the installation of the fiber delay loops necessary to synchronize the outputs, please contact us.

From the reported metrics it's possible to calculate the *N* (no of outputs) -photon coincidence rate at the output of the Q-DMX.

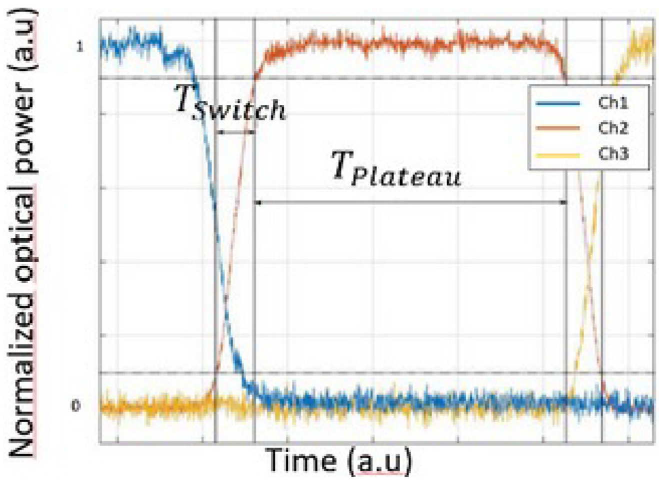
From the values we can extract at first the "Filling factor":

$$FF = T_{plateau} / (T_{switch} + T_{plateau})$$

From which one can calculate the final rate of *N* coincidences at the output

$$C_N = rep.rate * FF * \frac{(\eta * Brightness)^N}{N}$$

(rep. rate represents the clock rate of the driving excitation laser and brightness identifies the eDelight device efficiency – previous pages).



Quandela cloud 2.0

Fulfill your quantum ambitions with a cutting-edge platform tailored to your needs.

Register for free:
cloud.quandela.com

Quandela Cloud is a comprehensive platform to discover, learn, test, and develop quantum solutions. It gives access to the most advanced quantum servers available at Quandela, easy to use software for generating and manipulating quantum circuits, as well as middleware for executing hybrid quantum-classical workflows in heterogeneous computing environments.

Available quantum computers on Quandela cloud

Since 2022
Ascella 6 photons / 12 modes

Q2 24
Altair 10 photons / 20 modes

Q4 24
Belenos 12 photons / 24 modes

Exqalibur – GPU-enhanced emulation:
Introducing a new emulator for photonic qubits that leverages the capabilities of the most powerful GPU and enables computations at an unprecedented scale. With this advancement, users can now explore up to 150 billion parameter spaces across 20 photonic qubits at kilohertz rates, facilitating faster prototyping and optimization of quantum algorithms.

Exclusive QPU reservation service:
In addition to standard on-demand access, the new system offers premium users an intuitive reservation platform to secure QPU time on designated dates and times. This tailored reservation model enhances the user experience by facilitating seamless coordination among development teams.

QPU advancement – introducing Altair:
With the release of Quandela Cloud 2.0, significant enhancements have been made to the quantum computing hardware. Altair, the latest 10-qubit quantum processor takes central stage and is now accessible to developers worldwide. This upgraded quantum processing unit builds upon the success of its predecessor, Ascella, which was launched in January 2023 and operated for over 12,900 hours. Ascella achieved a remarkable availability rate of 92% over a 6-month operation.

Flexible pricing options for small experiments up to mission-critical enterprise access

Built-in error mitigations:

Two powerful patented error mitigation techniques have been introduced for the control of Altair, allowing us to push further the fidelity and quantum gates speed:

AI-driven quantum fidelity enhancement:
This technique harnesses the power of machine learning's 'clear-box' methodology to significantly mitigate hardware imperfections. This innovative approach boosts qubit fidelity by several percentage points, ensuring even greater reliability and performance in quantum computing applications. Further details are provided below.

Photon recycling:
This unprecedented technique exploits lossy output photon states to consolidate statistics of non-lossy states, allowing for a more precise estimation of the probability distribution with fewer numbers of shots.

QUANTUM TOOLBOX

This comprehensive suite includes pre-optimized primitives tailored for specific applications such as Variational Quantum Eigensolver (VQE) and graph analysis.

It expedites the time to production of quantum algorithms for industry-specific use cases, by providing a native optimization of these algorithms with Quandela QPUs and selected GPUs.

Backed by the expertise of Quandela's application team, users will receive direct support to maximize the utility and efficacy of these tools.

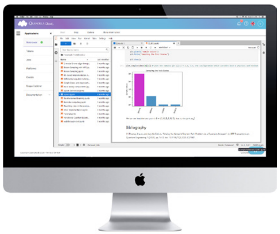
VQE chemistry
VQE to compute ground state of molecules on QPU BeH, LiH, H2O, H2 on QPU

$H = \Sigma h_\alpha P_\alpha$ VQE custom
To compute ground state of user-chosen Hamiltonian

CVar-VQE
VQE variant to solve combinatorial optimization problems

Graph isomorphism
Boson salmpling based algorithm to check whether two graphs are isomorphic

Dense subgraph identification
Boson sampling based algorithm to identify dense subgraphs



Watch our tutorial videos on YouTube:
www.youtube/@quandela2110

RELEVANT SCIENTIFIC PUBLICATIONS:

Quantum-dot-based single photon Sources

P. Senellart et al., High-Performance Semiconductor Quantum-Dot Single-Photon Sources, Nature Nanotechnology 12 (2017)

N. Somaschi et al. 'Near-optimal single-photon sources in the solid state', Nature Photonics 10, 340 (2016)

S. Thomas et al. 'Bright Polarized Single-Photon Source Based on a Linear Dipole' Phys. Rev. Lett. 126, 233601 (2021)

Photonic cluster state generation

S. Wein et al. Photon-number entanglement generated by sequential excitation of a two-level atom, Nature Photonics 16, 374 (2022)

N. Coste et al. High-rate entanglement between a semiconductor spin and indistinguishable photons, Nature Photonics 17, 582-587 (2023)

Compatibility and interfacing with an active demultiplexer and other modules for quantum computing applications

Anton et al., 'Interfacing scalable photonic platforms: solid-state based multi-photon interference in a reconfigurable glass chip', Optica6 (2019)

D. Istrati et al. 'Sequential generation of linear cluster states from a single photon emitter', Nature Comm. 11, 5501 (2020)

M. Pont et al. Quantifying n-Photon Indistinguishability with a Cyclic Integrated Interferometer, Phys Rev X12.031033 (2022)

M. Pont et al. 'High-fidelity generation of four-photon GHZ states on-chip', arXiv:2211.15626 (2022)

Single-photon based quantum computing

N. Maring et al. A General-Purpose single-photon based Quantum Computing Platform, arXiv:2306,00874 (2023) – Accepted for publication in Nature Photonics

N. Maring et al. One nine availability of a Photonic Quantum Computer on the Cloud toward HPC Integration, arXiv:2308,14582 (2023)

N. Heurtel et al. Perceval: A Software Platform for Discrete Variable Photonic Quantum Computing, Quantum 7, 931 (2023)

Xavier Pereira
Chief Growth Officer

Mobile
+33 (0) 7 44 81 43 40

Email
xavier.pereira@quandela.com

Website
quandela.com

Quandela

Campus Eiffel
— Bâtiment Pascal

7 rue Léonard de Vinci
91300 Massy

France

www.quandela.com

Quantum Technologies proudly fabricated in France