

Call 2021
Final Evaluation



QD-E-QKD

Quantum Dots for Entanglement-based Quantum
Key Distribution

Rinaldo Trotta

<https://www.qd-e-qkd.eu/>



COLLABORATION

7 partners, 4 countries,
1 widening country, 2 SMEs

Rinaldo Trotta (Coordinator)



SAPIENZA
UNIVERSITÀ DI ROMA

Italy

Vladyslav Usenko



Palacký University
Olomouc

Czech Republic (widening country)

Thomas Scheidl

qtlabs

Quantum Technology Laboratories

Austria (SME)

Henning Weier

qssys
Quantum Space Systems

Germany (SME)

Stefano Bonora

CNR IFN
Istituto di Fotonica e Nanotecnologie

Italy

Armando Rastelli

JKU
JOHANNES KEPLER
UNIVERSITÄT LINZ

Austria

Tobias Huber-Loyola

Julius-Maximilians-
**UNIVERSITÄT
WÜRZBURG**

Germany

Interdisciplinary nature

Nanotechnology
Quantum photonics
Optical and electronics
engineering
Quantum information
theory



16 online meetings + 3 in-person meetings (in Rome, Wuerzburg, and Olomouc).

Exchange of 5 researchers (across Austria, Germany, Italy)



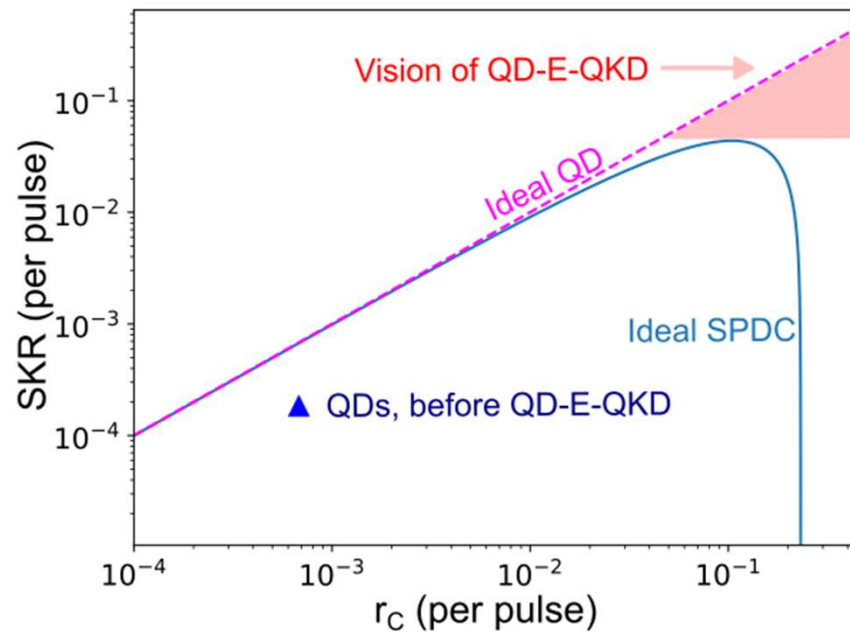
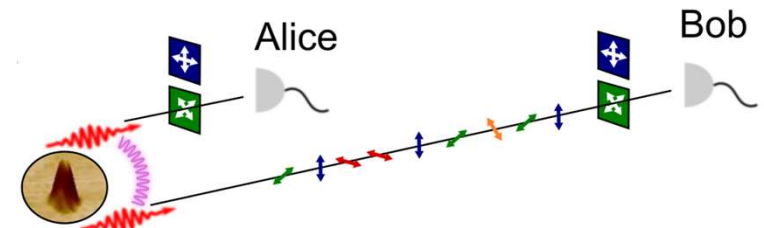
2 prototypes shared (between Italy and Austria)

QuantERA Call 2021 Final Evaluation



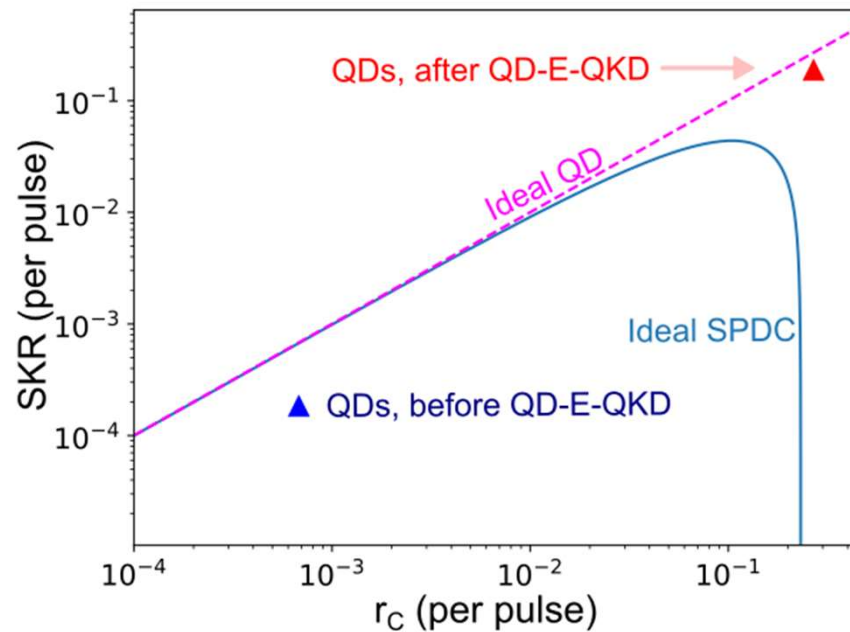
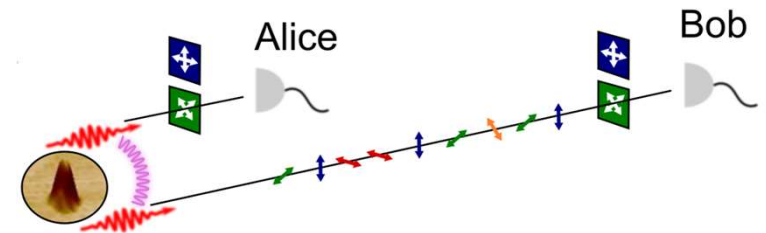
SUCCESS STORY

The overall vision of QD-E-QKD is to develop a **full-fledged quantum technology that overcomes fundamental limitations of entanglement-based QKD systems**



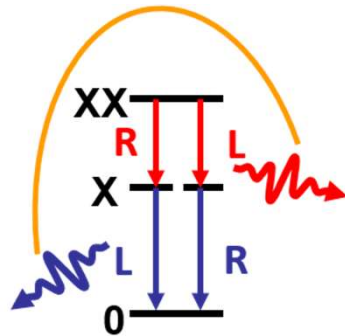
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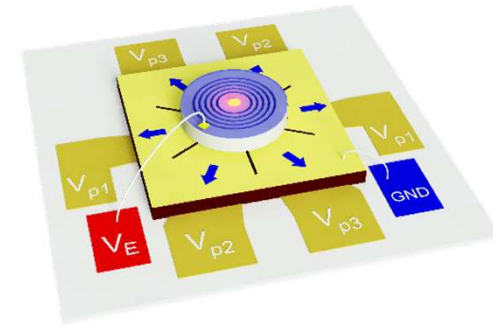
A novel technology for entanglement-based QKD!

A NOVEL SOURCE OF ENTANGLED PHOTONS

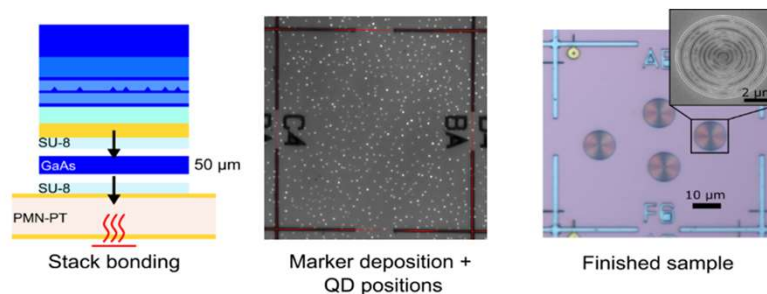


Polarization-entangled photon pairs generated via the radiative biexciton (XX) – exciton (X)- ground state (0) cascade in a QD.

$$|\Phi\rangle = (|R_{XX}L_X\rangle + |L_{XX}R_X\rangle)/\sqrt{2}$$



Development of ultra-bright sources of highly entangled photons based on QDs in microcavities integrated onto piezoelectric actuators



- Entanglement fidelity up to 96%
- Photon-pair extraction up to 50%
- Purcell Factor up to 10
- **Coincidence rates as high as 16 MHz!**

M. B. Rota *et al.*, *Elight* **4**, 13 (2024)

T. M. Krieger *et al.*, *ACS photonics* **11**, 596 (2024)

G. Peniakov *et al.*, *Laser & Photonics Reviews* **18**, 2300835 (2024)

I Brytavskiy *et al.*, *arXiv:2607.11494* (2026)

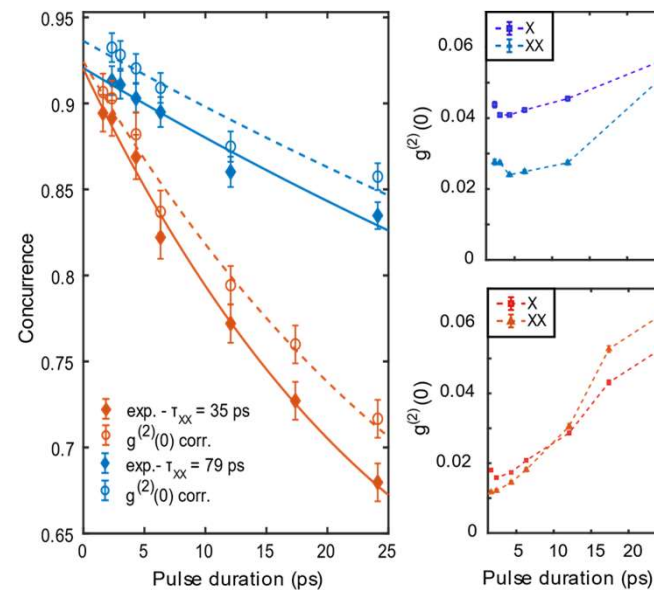
M. B. Rota, E. Schoell *et al.*, in preparation (2026)



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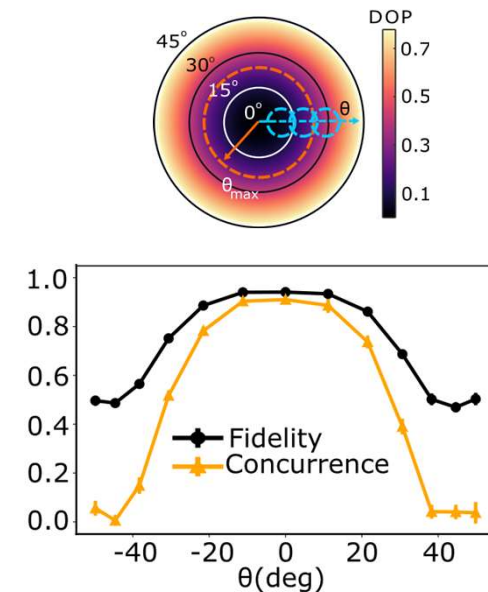
NEW PHYSICS

While trying to achieve QBER < 1 % **we discovered new physics...**



Optical Stark effect limits entanglement

F. Basso Basset *et al.*, Phys. Rev. Lett. **131**, 166901 (2023)

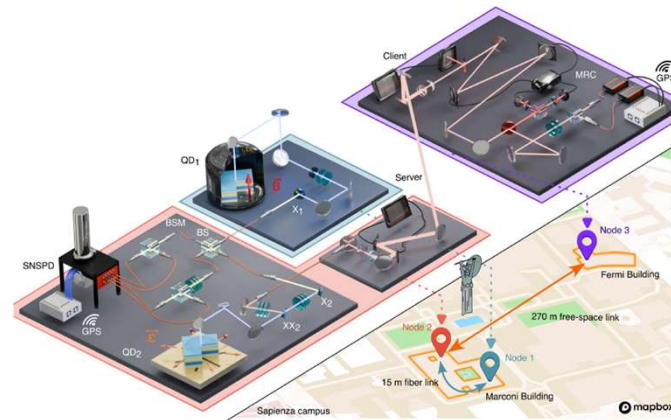


Wavector-polarization correlation limits entanglement

A. Laneve *et al.*, Nature Commun. **16**, 6209 (2026)

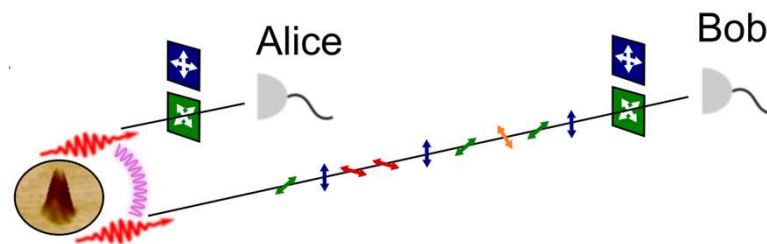
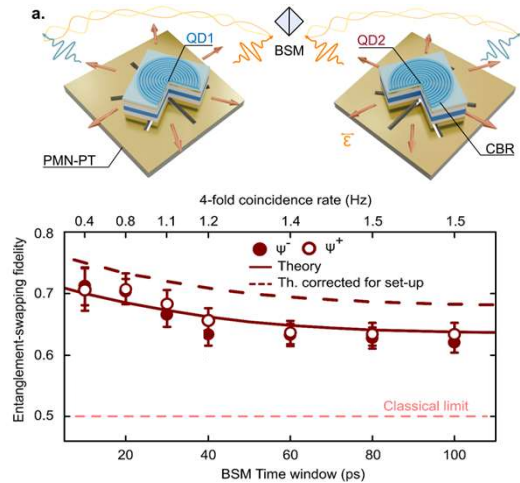
... max achievable QBER ~ 1.9 %, **enough for applications!**

ADVANCED QUANTUM COMMUNICATION



QUANTUM TELEPORTATION

A. Laneve *et al.*, Nature Comm. **16**, 10028 (2025)



ENTANGLEMENT SWAPPING

M. Beccaceci *et al.*, Science Advances, in press (2026)

ENTANGLEMENT-BASED QKD

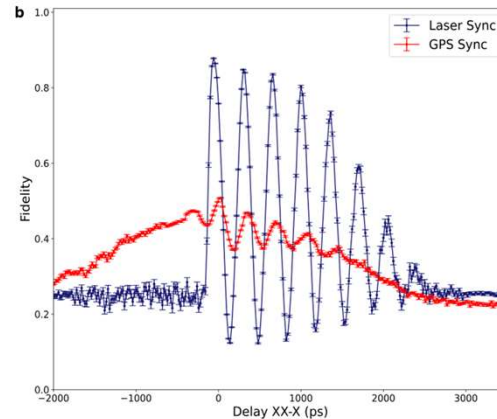
Secure Key Rates as high as 270 kbit/s

M. B. Rota, E. Schoell *et al.*, in preparation (2026)

2 NEW PROTOTYPES REALIZED

Remote synchronization

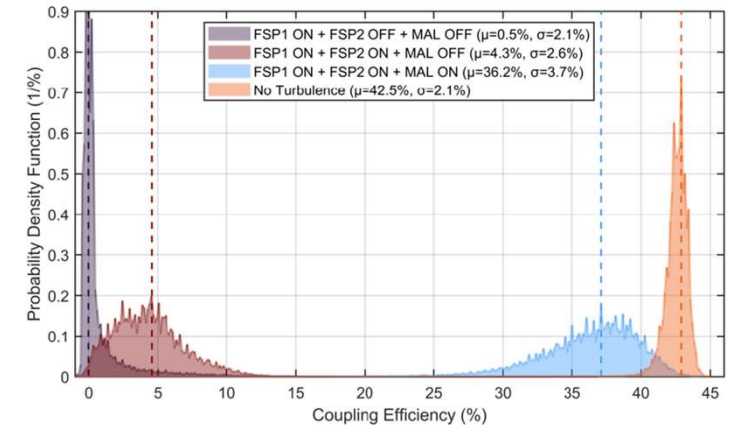
- Fiber and free-space solutions integrated in one device
- 850nm SMF-coupled laser integrated into sender device
- PPS jitter about 10 ps!



A. Laneve *et al.*, arXiv:2607.21093 (2026)

Compensating for turbulences

- Novel approaches to improve efficiency
- Tunable angle prism (TAP) for beam wandering corrections
- Multi-actuator lens (MAL) for correction of high order aberrations

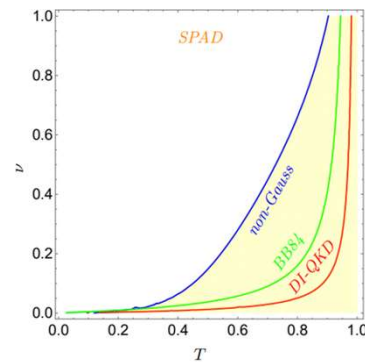


A. Vanzo *et al.*, Optics Express **34**, 18318 (2026)

Comparing DV and CV

entanglement-based QKD and their
robustness against noise

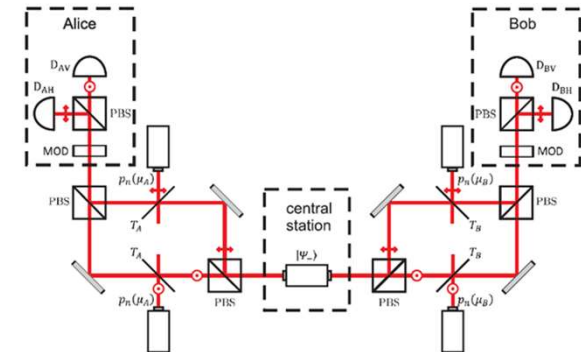
M. Lasota *et al.*, New Journal of Physis **25**, 123003 (2023)



Comparing SPDC and QD performances

in entanglement-based QKD

M. Gumberidze *et al.*, Optics Express **34**, 27264 (2026)



Analysing the relation between non-Gaussianity and security in entanglement-based QKD

M. Gumberidze *et al.*, arXiv:2511.01761 (2025)

Work	Source	Source model	S	QBER	Key rate
Vivoli <i>et al.</i> [32]	SPDC	EPR	~ 2.35	–	–
Tsujimoto <i>et al.</i> [33]	SPDC	EPR	~ 2.31	–	–
Kołodyński <i>et al.</i> [23]	SPS (+ SPDC in SH)	H-BSM	–	–	0.82 (SH) 0.95 (CH)
González-Ruiz <i>et al.</i> [22]	SPS (QD)	H-BSM	–	–	~ 0.77
This work	SPDC	EPR	~ 2.3	~ 0.5	insecure
	QD	EPR	~ 2.5	~ 0.05	~ 0.21

SCIENTIFIC OUTPUTS



- **28 peer review publications**

2 Phys Rev. Lett – 1 Elight – 1 Laser and Phot. Review – 3 Nano Lett – 3 Phys. Rev. B – 1 Appl. Phys. Lett. – 1 ACS Photon. – 1 New J. of Phys. – 4 Nature Communic. – 1 Nano Converg. – 1 Phys. Rev. A – 2 npj Quantum Inf. – 2 Science Adv. (1 in press) – 2 Optics Express – 1 Sensor and Actuators A – 1 Appl. Phys. Rev. – 1 Phys. Rev. Research (in press)

- + **3 manuscripts currently on Arxiv**

- **> 25 participation to international conferences and workshops**

- **38 jobs created + 57 researchers involved**

- **10 master AND 9 PhD theses related to QD-E-QKD**

- **8 activities related to education and public engagement**

- **1 Summer school organized under the umbrella of QD-E-QKD**



<https://sites.google.com/view/quantumtechnologyschoolerice/home>

IMPACT

- **2 Prototypes fabricated by the two SMEs**



- **1 Spin-off fellowship (500 k€ for 1.5 years)**
for the application of the innovative
entangled-photon source within the industry.



- **1 StartCup 2025 prize**
to provide expert support for innovative start-up projects
towards the actual foundation of a company



WHAT'S NEXT

- **Improve the QD-E-QKD technology and test it in **real-life** communication scenarios**





Thank you for your attention



Co-funded by
the European Union