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High-performance and scalable semiconductor single-photon sources for quantum secure communication

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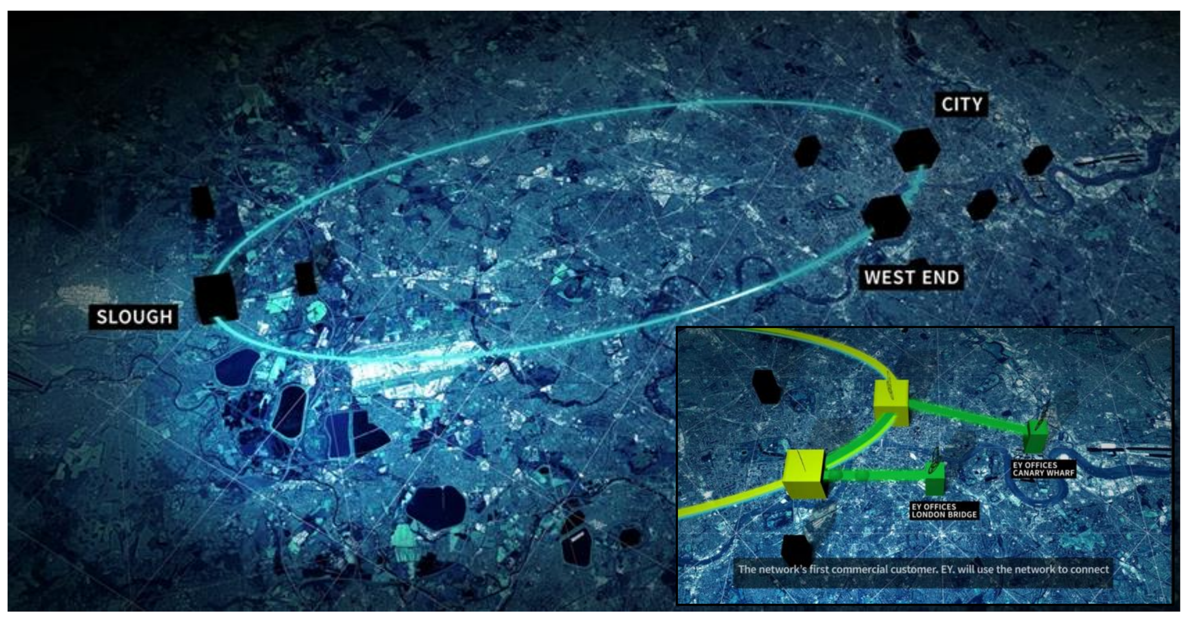
1. Quantum networks

- Information encoded in photonic qubits and transmitted over optical fibres.
- **Secure communication** between nodes using Quantum Key Distribution (QKD) for long-term data security.
- Connect remote quantum processors and enable **distributed quantum computing**.

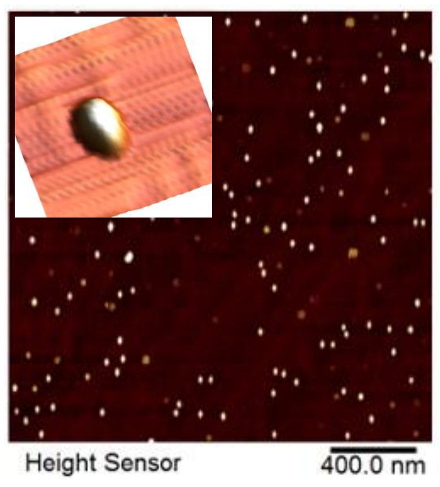
Scalable sources of single and entangled photons are the keystone for building photonic quantum networks.



London quantum-secure metro network: 3 core nodes and customer access tails are connected using QKD.

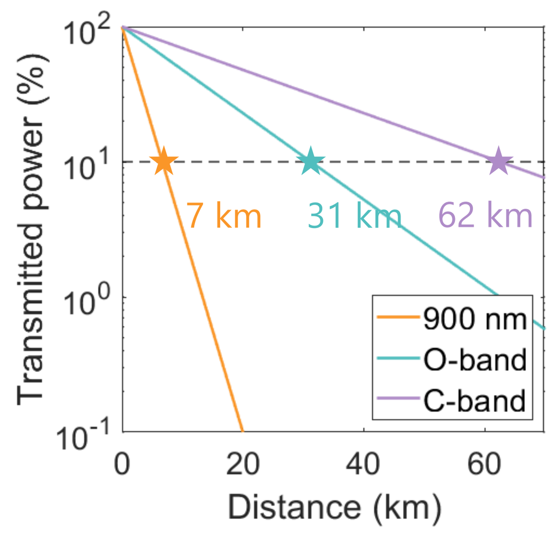
2. Semiconductor quantum dots (QDs)

- Nanostructures that confine electrons and holes within a small volume.
- Robust, stable, compatible with standard semiconductor processing techniques.
- On-demand emission of **single** and **entangled photons** at telecom wavelengths.



Why telecom wavelength?

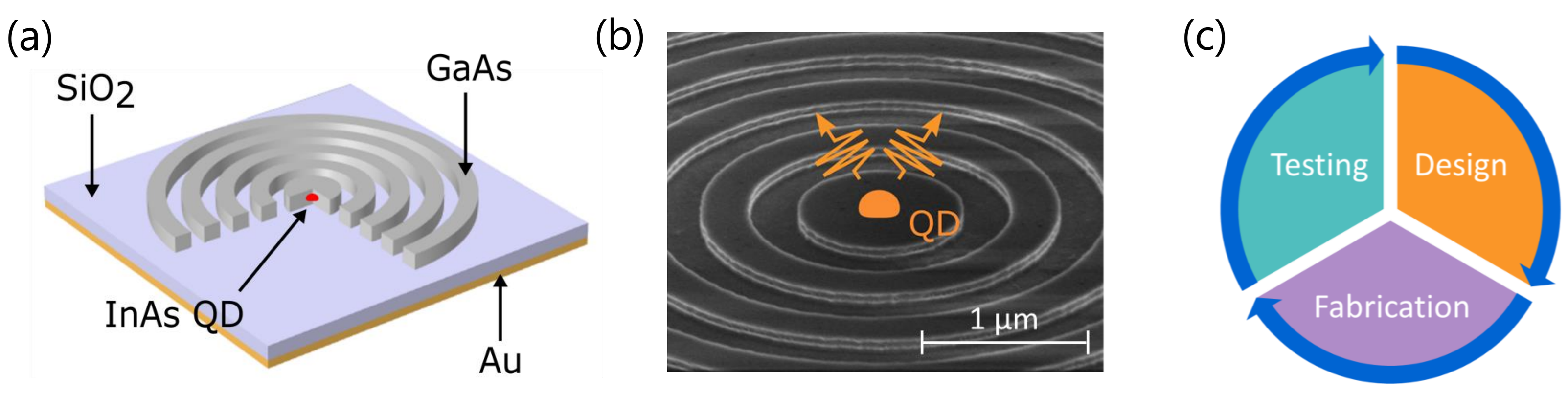
- Compatibility with standard components and existing optical fibre infrastructure.
- Transmission gains: $>10^2$ times better than shorter wavelength over 20 km of fibre.



Engineering the photonic environment for efficient collection of the emitted photons.

3. Our approach

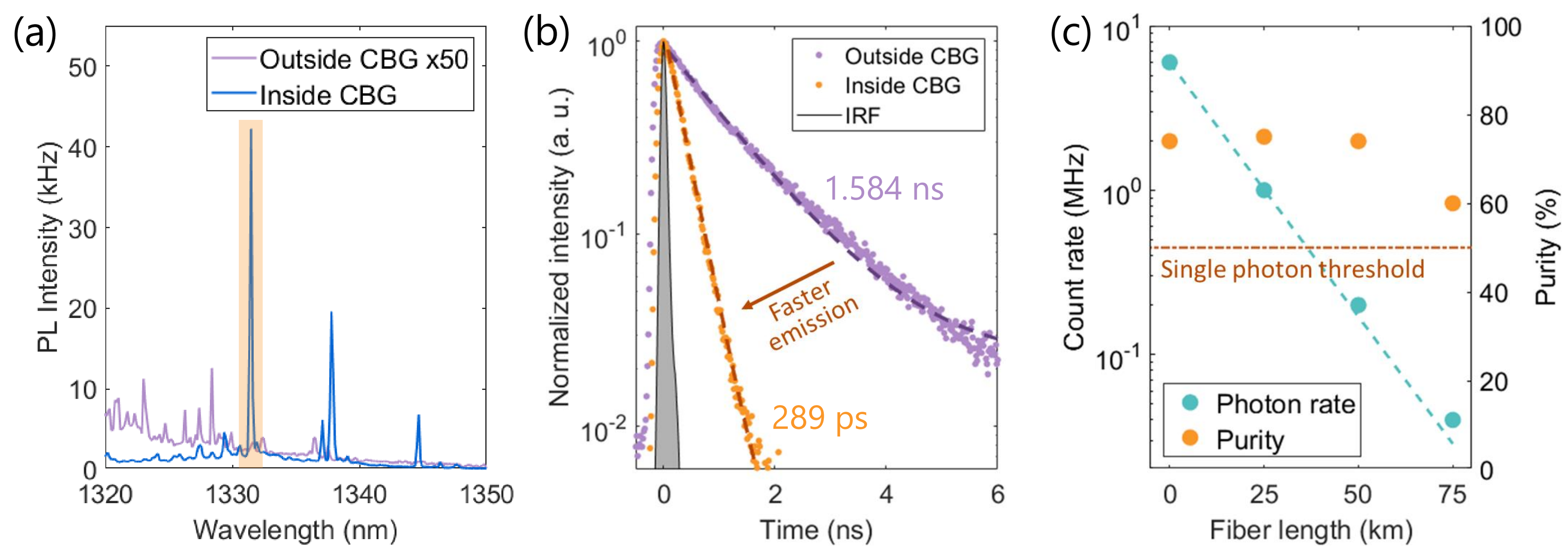
- Integration of telecom QDs into **circular Bragg grating** (CBG) resonators.
- Purcell effect and directivity cause the emission of a bright and steady flow of indistinguishable telecom photons.
- Performance optimised through a continuous feedback loop.



CBG resonator: (a) Schematic 3D illustration of a CBG. (b) SEM image of a device fabricated on GaAs. (c) Feedback loop for performance optimisation.

4. A bright and fast telecom single-photon source

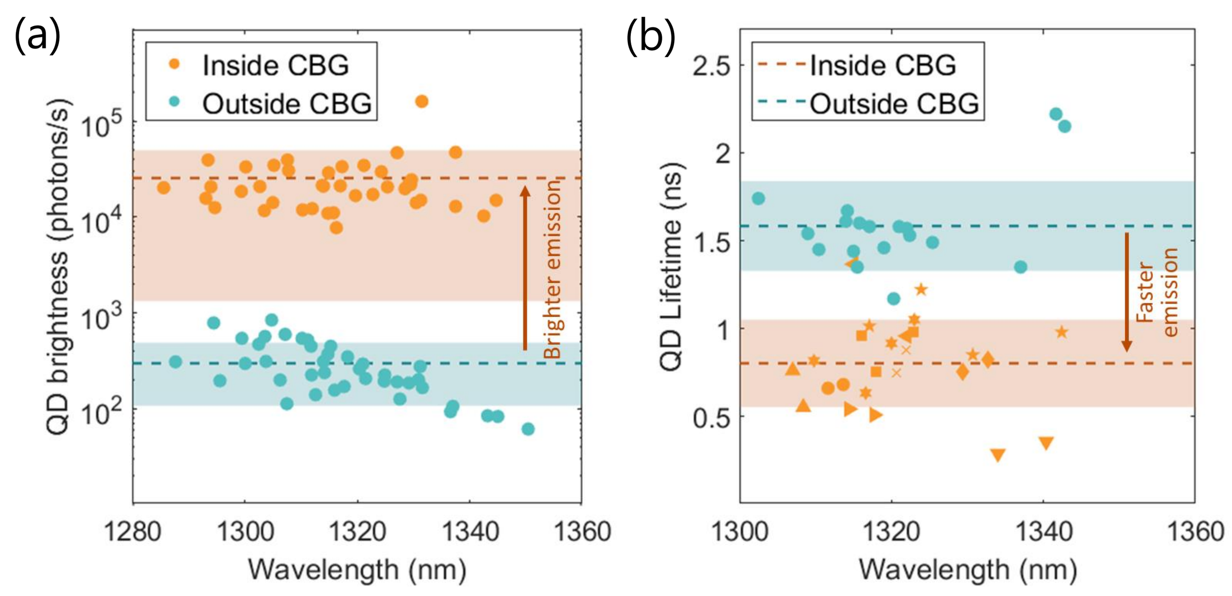
- 100× **improved brightness** compared to QDs on the same chip without CBG resonators.
- 5× **faster photon emission** enabled by the Purcell effect.
- High rates and single-photon purity preserved after propagation over >50 km of optical fibre



Characterisation of a CBG single-photon source: (a) Enhanced photon emission from a telecom QD in a CBG resonator. (b) Radiative lifetimes with evidence of Purcell enhancement. (c) Rates and single-photon purity after propagation in a commercial telecom fibre.

5. Reproducibility and scalability

- A compact 5×5 mm semiconductor chip has the potential to host hundreds of CBG sources.
- Ensuring reproducible performance is key for **cost-effective** fabrication and large-scale adoption of this technology.
- We present the performance of 10 devices selected from a matrix of 40 (**25% yield**).



Reproducible performance of 10 different CBG sources: (a) QD integrated PL intensity measured at saturation. (b) Corresponding radiative lifetimes.

6. Conclusions

- **100× brighter** and **5× faster emission** of telecom single photons from a quantum dot in a CBG resonator.
- Reproducible performance supports **large-scale, cost-effective fabrication** of the sources.
- High-rate transmission of pure single photons over >50 km of commercial optical fibre, proving readiness for **distribution of quantum light over long distances** using the existing fibre infrastructure.

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