PHOTONICS INSIGHTS

Quantum dots light up ahead

Igor Aharonovich[a,b,*]
[a]School of Mathematical and Physical Sciences, Faculty of Science, University of Technology Sydney, Ultimo, Australia
[b]ARC Centre of Excellence for Transformative Meta-Optical Systems, University of Technology Sydney, Ultimo, Australia

Epitaxial quantum dots (QDs) are high-quality semiconductor nanostructures that mimic atoms for their discrete energy levels. Developments of QDs date back to the early 1990s in quest of temperature-insensitive lasers. Since then, much effort has been devoted to studying the fundamental physical phenomena observed in those quantum-confined structures. Recently, the QD community has shifted its focus onto quantum photonics applications, motivated by the rapidly developing quantum science. The most prominent application for QDs is their use as a deterministic single-photon source—a non-classical emission of light that underpins quantum computation, communication, and sensing. The field has grown substantially within the last decade, shifting from controlled growth of isolated QDs to a full integration of ultra-pure QD single photon sources with photonic nanostructures[1–6].

Writing in *Photonics Insights*, Zhou *et al.*[7] have reviewed the most recent advances in the field of epitaxial QDs. The review starts with basics of QDs, including fabrication techniques, level structures, and methods for noise suppression. A comprehensive discussion about non-classical light generation by QDs is then provided. Here, they highlight the current optical excitation methods of QDs and the role of optical nanostructures in boosting photon extracting efficiency, both internally (coupling photons to a single photonic mode) and externally (collecting photons to a single-mode fiber). The dipole–photon interface in QD devices has been reviewed, which enables chiral photon emission or mediates photon–photon interaction at the single-photon level. In particular, the authors put an emphasis on the single spins trapped in QDs, allowing for optical manipulation of qubits in the solid state (one-qubit gate). Impressive improvements of qubit coherence have been recently achieved: $T_2^* \sim 125\,\mathrm{ns}$[8] and $T_2 \sim 0.113\,\mathrm{ms}$ (using a Carr–Purcell–Meiboom–Gill pulse sequence)[9]. Such an interface between the spin and photons offers a promising route to the entanglement between remote spin qubits and the creation of one-dimensional cluster states with high fidelity.

Zhou *et al.* also focus on the prominent platforms of QDs in integrated quantum circuitry. They review recent development on the reconfigurability of quantum photonic devices, which is a key feature required by quantum information. They further summarize tunable devices across various material platforms that have been or can potentially be combined with QDs. The authors then provide a prospective about implementing QD devices for real world quantum applications. Both existing results in quantum computation and communication, and challenges in the foreseeable future are covered.

This perspective is timely, and will be an excellent guide for both newcomers to the field, as well as experienced quantum scientists who are on the cusp of their next breakthrough.

References

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*Address all correspondence to Igor Aharonovich, Igor.Aharonovich@uts.edu.au