EDITORIAL

Progress in quantum technology: one photon at a time

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Progress in quantum technology: one photon at a time

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Technological developments sparked by quantum mechanics and wave–particle duality are still gaining ground over a hundred years after the theories were devised. While the impact of the theories in fundamental research, philosophy and even art and literature is widely appreciated, the implications in device innovations continue to breed potential. Applications inspired by these concepts include quantum computation and quantum cryptography protocols based on single photons, among many others. In this issue, researchers in Germany and the US report a step towards precisely triggered single-photon sources driven by surface acoustic waves (SAWs) [1]. The work brings technology based on quantum mechanics yet another step closer to practical device reality.

Generation of single ‘antibunched’ photons has been one of the key challenges to progress in quantum information processing and communication. Researchers from Toshiba and Cambridge University in the UK recently reported what they described as ‘the first electrically driven single-photon source capable of emitting indistinguishable photons’ [2]. Single-photon sources have been reported previously [3]. However the approach demonstrated by Shields and colleagues allows electrical control, which is particularly useful for implementing in compact devices. The researchers used a layer of InAs quantum dots embedded in the intrinsic region of a p–i–n diode to demonstrate interference between single photons. They also present a complete theory based on the interference of photons with a Lorentzian spectrum, which they compare with both continuous-wave and pulsed experiments.

The application of SAWs in achieving precisely triggered single-photon sources develops the work of researchers in Germany in the late 1990s [4]. Surface acoustic waves travel like sound waves, but are characterized by an amplitude that typically decays exponentially with depth into the substrate. As Rocke and colleagues demonstrated, they can be used to dissociate an optically excited exciton and spatially separate the electron and hole, thereby increasing the radiative lifetime by orders of magnitude. The interesting behaviour of SAWs has led to studies towards a number of other applications including sensing [5–7], synthesis and nanoassembly [8]. For applications in single-photon sources, the electron–hole pairs are transported by the SAW to a quantum dot where they recombine emitting a single photon. However, so far various limiting factors in the system, such as the low quality of the quantum dots used leading to multiple-exciton recombinations, have hindered potential applications of the system as a single-photon source.

Control over high-quality quantum-dot self-assembly is constantly improving. Researchers at the University of California at Berkeley and Harvard University in the US report the ability to successfully position a small number of colloidal quantum dots to within less than 100 nm accuracy on metallic surfaces [9]. They use single-stranded DNA both to act as an anchor to the gold or silver substrates and to selectively bind to the quantum dots, allowing programmed assembly of quantum dots on plasmonic structures. More recently still, researchers in Germany have reported how they can controllably reduce the density of self-assembled InP quantum dots by cyclic deposition with growth...
interruptions [10]. The impressive control has great potential for quantum emitter use.

In this issue, Völk, Krenner and colleagues use an alternative approach to demonstrate how they can improve the performance of single-photon sources using SAWs. They use an optimized system of isolated self-assembled quantum posts in a quantum-well structure and inject the carriers at a distance from the posts where recombination and emission take place [3]. The SAW dissociates the electron–hole pairs and transports them to the quantum posts, so the two carrier types arrive at the quantum post with a set time delay. Other approaches, such as Coulomb blockade ones, have struggled to achieve the sequential injection of the carriers that results from this approach. As the authors explain, the result is a highly efficient process with greater stability at high acoustic powers compared with direct optical pumping at the position of the post: ‘Our findings demonstrate that quantum posts with their surrounding wide matrix quantum well are an ideal system for the realization of a precisely triggered SAW-controlled single-photon source’.

The work of Völk, Krenner and their co-authors draws on a vast range of developments in fundamental physics and nanotechnology. As is so often the case, how developments in one direction facilitate work in another is only really apparent in hindsight. In his Nobel Prize acceptance speech, Max Planck remarked: ‘The whole strenuous intellectual work of an industrious research worker would appear, after all, in vain and hopeless, if he were not occasionally through some striking facts to find that he had, at the end of all his criss-cross journeys, at last accomplished at least one step which was conclusively nearer the truth’ [11]. Whether the cumulative efforts of all the researchers in theoretical physics and technology mentioned here bring us closer to the truth, time will tell. But it seems quite likely that they will bring us closer to turning the quantum capabilities of science-fiction to reality.

References

[7] Sheng L, Dajing C and Yuquan C 2011 A surface acoustic wave humidity sensor with high sensitivity based on electrospun MWCNT/Nafion nanofiber films Nanotechnology 22 265504