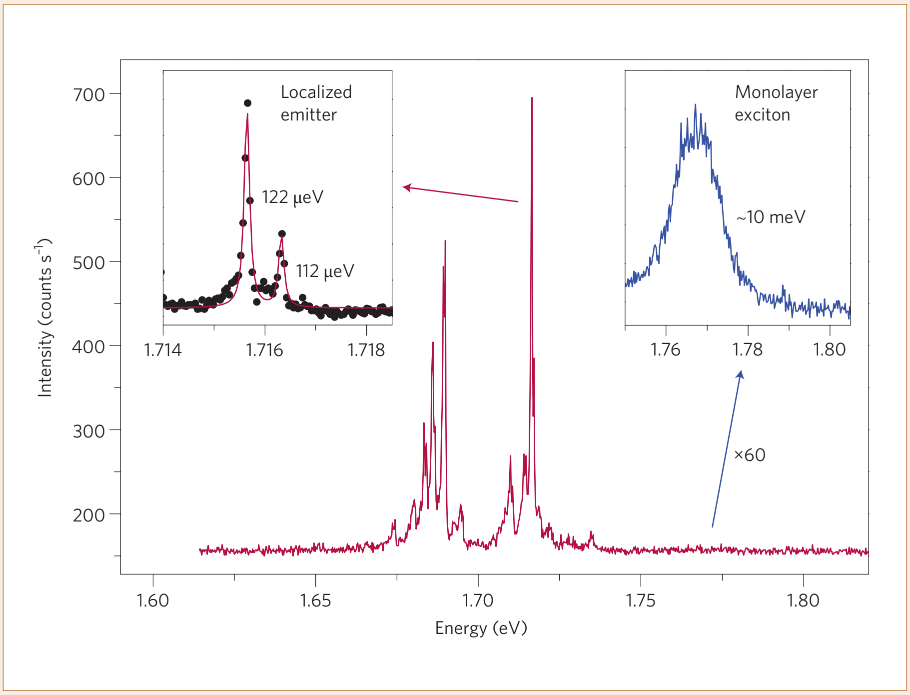
2D SEMICONDUCTORS

One at a time



NATURE PUBLISHING GROUP

The isolation of the graphene monolayer in 2010 inspired attempts for the isolation of atomic-thick sheets of semiconductors. The existence of a bandgap in transition metal dichalcogenide monolayers makes them extremely attractive for optoelectronics applications, with their potential still under investigation. Now, writing in *Nature Nanotechnology*, four groups of researchers — Ajit Srivastava, Atac Imamoğlu and co-workers (http://doi.org/4cq), Chao-Yang Lu, Jian-Wei Pan and collaborators (http://doi.org/4cr), Nick Vamivakas and colleagues (http://doi.org/4cs), and Marek Potemski and co-workers (http://doi.org/4ct) — report independently the potential of these materials as single-photon emitters, while Rudolf Bratschitsch and colleagues report similar findings in *Optica* (**2,** 347–352; 2015).

Single photons have great potential as qubits (the unit for encoding quantum information), not only because of their high speed but also because of their ease of manipulation using linear optics. Various degrees of freedom have been used for encoding information, such as polarization and spin. Whereas any light source can, in principle, be attenuated enough to emit on average one photon at a time, the interest lies in deterministic (or triggered) sources that can emit only one photon at user-specified time intervals.

All of the groups use tungsten diselenide (WSe$_2$) encapsulated between a Si substrate and a SiO$_2$ layer. Under continuous-wave excitation at temperatures below 10 K, they all identify in the photoluminescence spectrum (pictured; from Lu, Pan and colleagues) bright, sharp lines with linewidth around 100 μeV (left inset), distinct from the neutral (right inset) or charged monolayer excitonic emission. As the excitation power increases, these peaks exhibit the typical behaviour of a two-level system: peak intensity increases until it reaches saturation. The emission saturates for relatively low power, and the five teams attribute this behaviour to defects and impurities. Bratschitsch and co-workers as well as Potemski and colleagues observe these narrow-line emitting centres at the edge of the WSe$_2$ flake, whereas Vamivakas and co-workers observe them at the interface between a mono- and a multilayer.

All groups performed Hanbury Brown–Twiss measurements under continuous-wave excitation (Lu, Pan and colleagues also performed experiments under pulsed excitation), to confirm the two-level nature of these emitters. Their emission was split in two using a 50:50 beamsplitter, and the two output ports were connected to two single-photon detectors, which 'clicked' every time a photon arrived. A counter recorded the time interval between these two events and produced a histogram. The probability of two photons to arrive simultaneously with zero time delay must be below 0.5 for a single-photon source and in the ideal case, reach zero. All five pieces of work showed values around 0.2.

Further polarization-resolved measurements revealed that the emission is split into a doublet of two cross-circularly-polarized branches. On application of an external magnetic field perpendicular to the sample plane, the splitting between the two branches increases proportionally to the magnetic field value, an effect called Zeeman splitting, which is well known in semiconductor quantum dots. The fact that the charged exciton from the WSe$_2$ also exhibits this behaviour indicates strongly that the emitters are WSe$_2$ excitons trapped in defects in the monolayer. The lifetime of these emitters, however, was much longer compared with the exciton lifetime; it varied from 600 ps (Potemski *et al.*) to 2 ns (Srivastava, Imamoğlu *et al.*). Additionally, Vamivakas and colleagues showed that, by applying an external voltage, the emission properties (such as lifetime) could be modified; this further indicates the presence of local anisotropic potential from the defects that trap the excitons.

Although further work is needed to clarify the exact nature of these emitters, these results open a new line of investigation regarding the potential of these semiconductor monolayers for quantum technology.

MARIA MARAGKOU