The rhenium dichalcogenides: van der Waals layered semiconductors that break all the rules

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Rhenium disulphide and rhenium diselenide are two of the less familiar members of the family of forty or so layered transition metal dichalcogenides (TMDs). The TMD family contains metals, superconductors, and direct and indirect bandgap semiconductors and these can in principle be combined layer by layer to build up new device concepts. The compounds ReSe$_2$ and ReS$_2$ are conventional semiconductors but are unusual within the TMD family in that they have a particularly low strength of interaction between layers – lower even than more familiar van der Waals materials such as MoS$_2$ – and they do not possess the typical hexagonal structure, but are triclinic with a relatively large number of atoms per unit cell. In multi-layer devices, these materials offer a controlled in-plane anisotropy of most physical properties, including a sensitivity to light polarization. Due to this anisotropy, their Raman spectra demonstrate a large number of zone-centre modes which allow one to measure the orientation of the in-plane crystallographic axes down to a monolayer. We have carried out both experimental and first-principles computational studies of ReX$_2$ in order to understand the observed Raman spectra; we establish some common features of the lattice dynamics of this family of materials and we investigate also the more exotic (and radioactive) technetium analogue, TcS$_2$, for which we have calculated the zone-centre phonon modes in order to predict its Raman spectra.