radius[10], whereas strong light–matter coupling in such 2D atomic layers is readily achievable[11].

In this context, the work of Imamoğlu and colleagues[2] clearly suggests that multilayer structures based on transition metal dichalcogenide monolayers are among the most promising candidates for the observation of exciton-mediated superconductivity. The schematic structure that they propose[2] is a microcavity with an embedded n-doped layer containing a two-dimensional electron system (2DES) placed in close proximity to the double quantum layer (Fig. 1), where the generation of spatially indirect excitons is controlled by pumping of the external laser. The structure design is crucial: excitons and free electrons must be placed as close as possible to each other in order to maximize the scattering probability, but tunnelling between 2DES and the excitonic layer must be excluded to prevent exciton dissociations.

The proposed light–matter hybridization of transition metal dichalcogenide monolayers in the vicinity of two-dimensional electron systems demonstrates new pathways in the quest for exciton-mediated superconductivity. All-optical control of superconductivity in semiconductor heterostructures goes beyond the excitement of replacing phonons with excitons to couple electrons in Cooper pairs. It could bridge superconductivity, lasing and exciton condensates, and unleash a plethora of previously inconceivable devices. ❐

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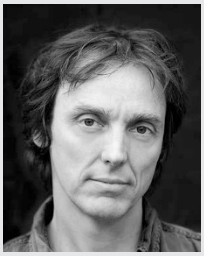
MATERIAL WITNESS

ENGINES OF IMAGINATION



PHILIP BALL

When does analogy become ontology? Or to put it in a less grandiose fashion, what's the difference between saying a physical system is 'like' X and saying that it 'is' X? That question is surely prompted by the report from Roßnagel *et al.* of a 'single-atom heat engine'[1]. By moving a single calcium ion through a cyclic process within an asymmetric electrical trap, the researchers can get it to absorb heat from a hot reservoir (where it consists of electrical noise) and do mechanical work while dissipating some of the heat into a cold reservoir (a beam of laser photons, which cool the ion). This work can be stored and used to drive an oscillator. Thus the device satisfies all the reasonable criteria for a heat engine, with the single ion acting as a kind of piston.

Any practical applications are unclear — the engine produces a power output of just 3.5×10^{-22} W, although its near 0.3% efficiency is respectable enough for such a minuscule system. The point is more fundamental: to show that thermodynamics, although arguably not really operating here at a 'single-atom' level (the input and output are many-particle quantities), can be applied even with atomic-scale components.

All the same, to cast this system as an engine is to tell a particular story about it. That's not a criticism, but rather recognition of how science is done. This account of manipulations of an atom via its interactions with electromagnetic fields would have little meaning without the analogy with the machines of the Industrial Revolution.

And this is no more than we do for pretty much any complex system: we must 'chunk' it, as cognitive scientists would say, into elements from which we can build a story. Consider quasiparticles such as holes, phonons, plasmons and heavy electrons, which are so indispensible to condensed-matter physics. Apply too much reductionism and there's nothing to see. Does this mean that the quasiparticles are somehow illusory, or do they have some more profound ontological status? Some physicists, such as Brian Greene, have argued that emergent structures are just a convenience imposed by our inability to calculate everything from first principles[2] (although that inability, given the combinatorial possibilities, is not just a matter of principle). With reference to the concepts of condensed matter, Stephen Blundell argues in contrast that emergent narratives are a valid and efficient way to describe complex reality, with a "non-trivial relationship to the underlying microphysics"[3].

For one thing, not every emergent narrative will correctly describe reality. Thermodynamics is one that does, but how this essentially classical theory tallies with the quantum aspects of microscopic physics is an area of active study[4]. And that, perhaps, is one of the best justifications for casting energy exchanges between a trapped ion and its environment within the narrative of the classical functions of a heat engine — because the system then looks very promising for examining the connections between these two topics. Or to put it another way: there's a big difference between giving a prosaic result some canny packaging to help it sell, and (as here) finding a story that offers fruitful purchase for the mind. ❐

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