At one point, there was debate about whether the polaritons maintain their bosonic character (known as 'strong coupling' between the photon part and the electronic part) at densities high enough to condense, but it is now standard to show that the polaritons remain good bosons in the strong-coupling regime when the above-mentioned effects occur, including the spatial condensation. When the strong coupling breaks down, the system becomes a standard laser. Recent experiments[9,10] demonstrate that polariton BEC and standard lasing can occur as two quite separate transitions at the same place in the same sample, at different densities.

The lifetime of the polaritons in these experiments may seem dauntingly short: a few picoseconds. But the absolute time, of course, is irrelevant; what matters is the ratio of the lifetime to the equilibration time, which is of the order of the particle scattering time. If the lifetime is long compared with the equilibration time, it is proper to treat the system as being in equilibrium[11]. In the case of polaritons, at low density the picosecond lifetime is short compared with the time of equilibration via phonon emission and absorption. As the polariton density is increased, however, polariton–polariton scattering becomes more important, and can become short compared with the lifetime. It never seems to become less than a factor of five or so below the lifetime, however. When the polaritons condense, a new radiative channel of coherent, laser-like photon emission is opened up. Raising the polariton density just increases this coherent emission, and eventually destroys the condensate by an effect known as phase-space filling.

As a result, the momentum distribution measured in the experiments never fits an equilibrium Bose–Einstein distribution. Instead there are three regions of momentum space: a higher-energy 'reservoir' of excitons (which are similar to polaritons, but with much longer lifetime and much heavier mass, on the order of the electron mass); the low-energy polariton states; and a 'bottleneck' region in between. Each of the three regions has a different characteristic temperature. Numerical models[12–14] show that Bose statistics of the particles have an important role in the build-up of the condensate, but the constant inflow of hot polaritons prevents equilibration of the low-energy polaritons with particles in higher energy states.

Is the polariton system therefore uninteresting, because it has incomplete equilibrium? As the classic sales phrase has it, "it's not a bug, it's a feature". Weakly interacting condensates in equilibrium are now thoroughly understood. Much atom-trapping work has turned to non-condensates and fermionic systems. In excitonic and polaritonic condensates, a new knob can be turned, which is the lifetime of the particles. The surprising thing is that despite the incomplete equilibrium, so many of the canonical telltales of condensation can still be observed in polaritonic condensates. But what, exactly, determines the point of breakdown, when we can no longer speak of a condensate because the lifetime is too short? Which properties of a condensate are robust against non-equilibrium perturbations? These questions can be asked very generally in regard to any system of bosons, but polaritons provide a test bed for experimental investigations.

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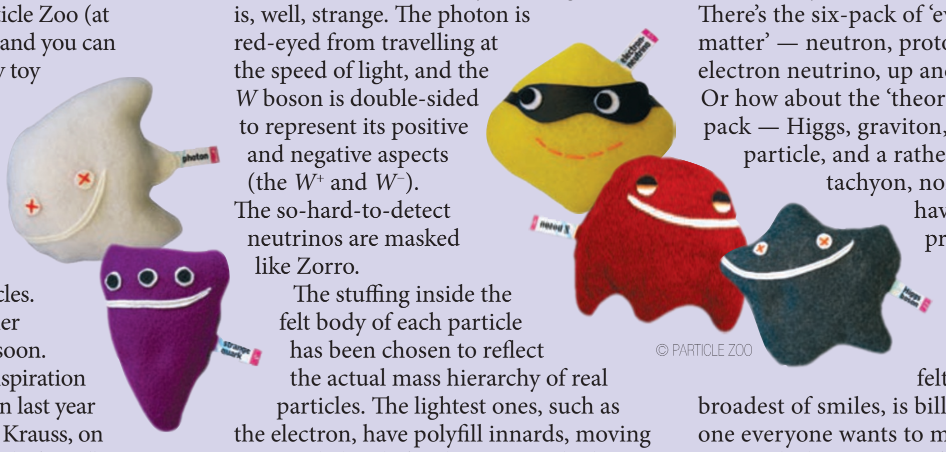
PARTICLE PHYSICS

Going to the zoo

The standard model of particle physics includes a veritable 'zoo' of subatomic particles. Visit the Particle Zoo (at www.particlezoo.net), and you can order your own cuddly toy version of your favourite particle.

Created — and sewn individually — by Julie Peasley, the zoo currently comprises 33 toys of particles and antiparticles. Supersymmetric partner particles are to follow soon.

Peasley cites her inspiration as a public lecture given last year at UCLA by Lawrence Krauss, on "The beginning and end of time". With advice from physicist Derek van Westrum, she devised her toy zoo, in which each of the particles and antiparticles has a distinct, and appropriate, appearance.



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The charm quark, for instance, bears a red rose, and the three-eyed strange quark is, well, strange. The photon is red-eyed from travelling at the speed of light, and the *W* boson is double-sided to represent its positive and negative aspects (the W^+ and W^-). The so-hard-to-detect neutrinos are masked like Zorro.

The stuffing inside the felt body of each particle has been chosen to reflect the actual mass hierarchy of real particles. The lightest ones, such as the electron, have polyfill innards, moving up to poly beads for the muon, which is described on the website as a heavy electron that "lives fast and dies young". Monster particles such as the top quark are stuffed with polished gravel.

Each particle is available individually, or in a series of collections. There's the six-pack of 'everyday matter' — neutron, proton, electron, electron neutrino, up and down quarks. Or how about the 'theoreticals' four-pack — Higgs, graviton, dark-matter particle, and a rather evil-looking tachyon, none of which have yet been proved to exist.

The Higgs boson, rendered in grey wool felt and with the broadest of smiles, is billed as "the one everyone wants to meet". Indeed it is: with the start-up of the Large Hadron Collider now confirmed for 10 September, we could soon be making its acquaintance.

Alison Wright

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