

Physics World

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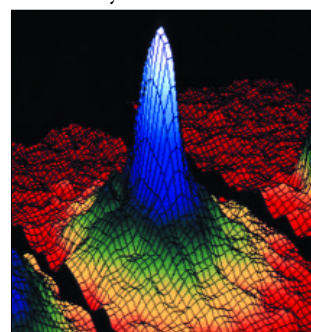


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Ten of the best for BEC

The rate of progress in the field of ultracold atomic gases over the past decade has been remarkable. Ever since the first Bose–Einstein condensate was produced in rubidium-87 exactly 10 years ago this month, a string of ground-breaking results has flowed from laboratories around the world. Indeed, since the *Physics World* website started publishing its highlights of the year in 1997, ultracold gases have only failed to make the list once (in 2000). In recent years attention has switched to degenerate Fermi gases, which are shaping up to be just as exciting (see pages 8–9).

Ultracold atomic gases can also serve as textbook examples of many basic physical phenomena. To create a Bose condensate or a degenerate Fermi gases it is necessary to cool the atoms until their de Broglie wavelength, which is inversely proportional to their temperature, becomes comparable with the average distance between them. However, if the atoms get too close together, they might form a solid, so the gas has to be dilute, which calls for even lower temperatures.



As of mid-2005 five alkali metals have been condensed – lithium-7, sodium-23, potassium-41, two isotopes of rubidium (⁸⁵Rb and ⁸⁷Rb) and caesium-133. For many years hydrogen was the front-runner in the race, but unexpected problems meant that it was not condensed until 1998. Helium, which succumbed in 2000, was also difficult to condense because it exists in a metastable state that contains some 20 eV of energy, which can be a problem if you are working at thermal energies of 10⁻¹⁰ eV (see *Physics World* May 2001 pp21–22).

The first condensates were produced with a combination of optical and magnetic cooling techniques (which themselves are also splendid textbook examples of basic physics), with all-optical traps arriving a few years later. The advantage of the all-optical approach is that magnetic fields can then be used to control the interactions between the atoms – making attractive interactions repulsive, for example – with the powerful Feshbach-resonance technique. Optical traps have allowed ytterbium and chromium to be condensed in recent years. Ytterbium is notable because it is the only atom with two valence electrons to be condensed so far, while chromium has a very large magnetic dipole moment. Both elements are important in industrial applications as well.

Ultracold gases are also textbook examples of quantum statistics: the fact that we can see a cloud of bosonic ⁷Li atoms get smaller as it is cooled, while a gas of fermionic ⁶Li atoms remains the same size, is a striking example of the exclusion principle in action. Of course, the most salient aspect of condensates and Fermi gases is that they are quantum gases – macroscopic objects that exhibit purely quantum phenomena such as superfluidity. The next frontier will be performing what were previously thought to be “thought experiments” in condensed-matter physics by trapping Fermi gases on optical lattices – “crystals of light” created by laser beams. These experiments will give physicists the chance to explore many-body phenomena such as superfluidity and superconductivity in systems that are much cleaner than the samples used in most condensed-matter experiments. A decade from now there will be even more to celebrate.

Waiting games

The gap between Bose and Einstein’s papers on quantum statistics and the production of the first atomic condensate was 71 years. Compared with this, it is remarkable that a mere 23 years passed between Pauli proposing the neutrino and Reines and Cowan detecting it. But patience is also necessary when working with neutrinos, as Dave Wark’s epic feature on page 29 makes clear.

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