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Toward a continuous atom laser

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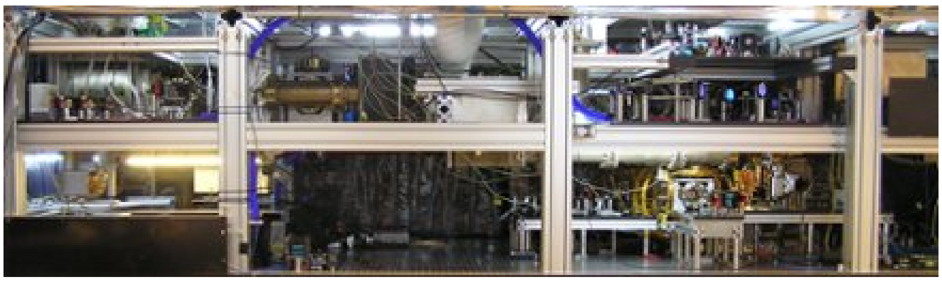

The experiment used to create the permanently existing cold gas cloud. Credit: F. Schreck et al

Ever since its invention, the laser has been an invaluable tool in physics. It is expected that an atom laser - with the light waves replaced by the quantum waves of atoms - could have similarly important applications, for example in constructing ultra-precise clocks. A research team led by UvA researcher Florian Schreck has now made important progress towards the creation of the first continuous atom laser. The team's results were published in *Physical Review Letters* earlier this week.

In an ordinary laser, light waves form a so-called coherent state: when these waves come out of the laser, they all oscillate in exactly the same way, with the same frequency and the same phase. Quantum mechanics tells us that the particles that we are made of, quarks, electrons and even whole atoms, also have wave-like properties. But can atoms also be put in a coherent state? Or can a laser be built where instead of light we shine with atoms?

That the theoretical answer to this question is 'yes' is a fact that any physics student can easily prove. In fact, having such a device would be extremely useful: the collective vibrations of the atoms could be used for example to gauge ultra-precise atomic clocks. However, turning the theory into an actual functioning device is not as easy as it sounds. So far, atom lasers have been created by extracting a beam of atoms from a so-called Bose-Einstein condensate, a gas cloud at very low temperature in which all atoms are in the same quantum wave state. However, putting the atoms in the same state only solves part of the problem. For most applications of an atom laser, they need to work continuously. The real challenge is therefore to bring the atoms into the same wave state quickly enough, so that the atom laser has access to a continuous supply of these coherent particles.

Creating a Bose-Einstein condensate typically involves cooling a gas in several stages over tens of seconds. However, the extracted atom laser beam lasts only as long as atoms remain in the condensate, typically a much shorter time of only fractions of a second. After that split second, a new supply must be made, which again takes tens of seconds - and so on.

Schreck and his team, postdoc Benjamin Pasquiou and PhD-students Shayne Bennetts and Chun-Chia Chen, now propose to achieve a continuous supply by separating the different cooling stages in space instead of time. Each stage takes place at a different location: the atoms are cooled down by ordinary lasers while they are on the way to the place where the final atom laser beam will be created. The team manages to do this by making clever use of the special properties of strontium, an element with just the right electronic structure to be cooled down slowly, step by step, while it is "on the move".

Using their methods, Schreck and collaborators have now succeeded in implementing the first stages of the continuous cooling, leading to the permanent existence of a gas cloud that is much colder and much denser than in any previous attempt. They further showed that their scheme provides enough cold atoms to be compatible with the creation of a continuously existing Bose Einstein condensate. The final step is of course to make an atom laser using this permanent condensate - a step which according to Schreck should take place within the next year. That would fulfill his dream: creating an atom laser that never needs to stop to recharge.

More information: Steady-State Magneto-Optical Trap with 100-Fold Improved Phase-Space Density, S. Bennetts, C.-C. Chen, B. Pasquiou and F. Schreck. *Phys. Rev. Lett*. 119 (2017), 223202

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