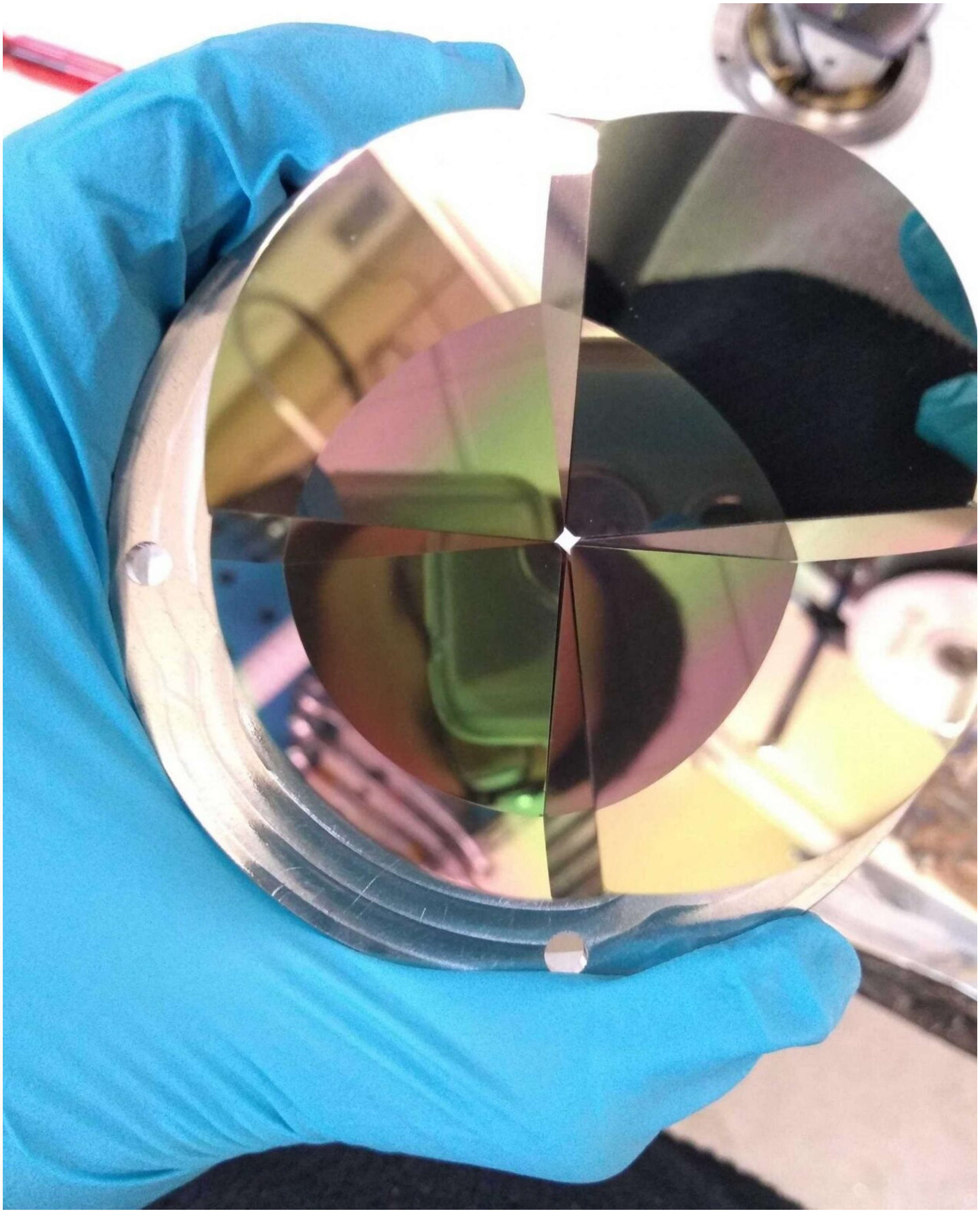
New cold atom source lays groundwork for portable quantum devices

June 21 2021



Researchers designed a cold atom source that uses four mirrors arranged like a pyramid and placed in a way that allows them to slide past each other like the petals of a flower. This creates an adjustable hole at the top of the pyramid through which the cold atoms are pushed out. This image depicts the device. Credit: Christopher Foot, Oxford University

Although quantum technology has proven valuable for highly precise timekeeping, making these technologies practical for use in a variety of environments is still a key challenge. In an important step toward portable quantum devices, researchers have developed a new high-flux and compact cold-atom source with low power consumption that can be a key component of many quantum technologies.

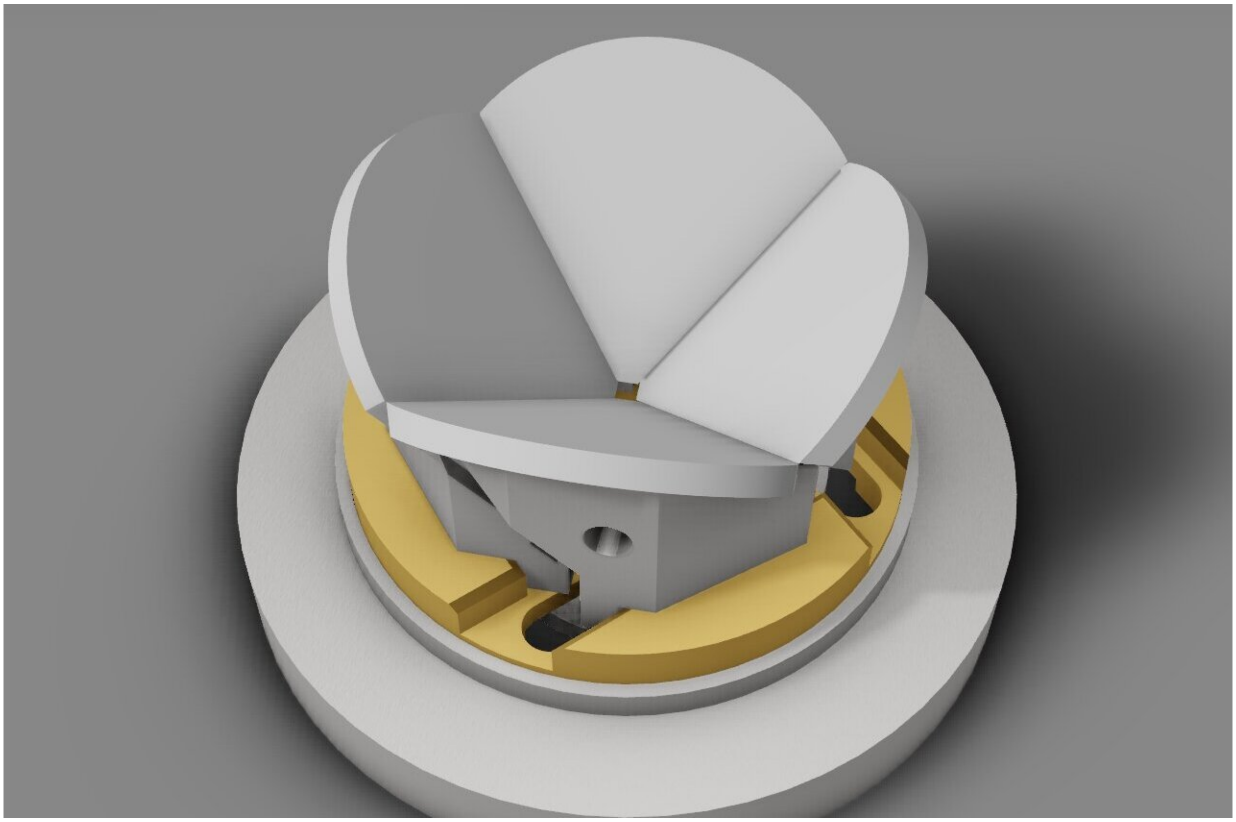
"The use of quantum technologies based on laser-cooled atoms has already led to the development of atomic clocks that are used for timekeeping on a national level," said research team leader Christopher Foot from Oxford University in the U.K. "Precise clocks have many applications in the synchronization of electronic communications and navigation systems such as GPS. Compact atomic clocks that can be deployed more widely, including in space, provide resilience in communications networks because local clocks can maintain accurate timekeeping even if there is a network disruption."

In The Optical Society (OSA) journal *Optics Express*, S. Ravenhall, B. Yuen and Foot describe work carried out in Oxford, U.K. to demonstrate a completely new design for a cold atom source. The new device is suitable for a wide range of cold-atom technologies.

"In this project we took a design we made for research purposes and developed it into a compact device," said Foot. "In addition to timekeeping applications, compact cold-atom devices can also be used for instruments for gravity mapping, inertial navigation and communications and to study physical phenomena in research applications such as dark matter and gravitational waves."

Cooling atoms with light

Although it may seem counterintuitive, laser light can be used to cool atoms to extremely low temperatures by exerting a force that slows the atoms down. This process can be used to create a cold-atom source that generates a beam of laser-cooled atoms directed toward a region where precision measurements for timekeeping or detecting gravitational waves, for example, are carried out.



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Credit: Christopher Foot, Oxford University

Laser cooling usually requires a complicated arrangement of mirrors to shine light onto atoms in a vacuum from all directions. In the new work, the researchers created a completely different design that uses just four mirrors. These mirrors are arranged like a pyramid and placed in a way that allows them to slide past each other like the petals of a flower to create a hole at the top of the pyramid through which the cold atoms are pushed out. The size of this hole can be adjusted to optimize the flow of cold atoms for various applications. The pyramid arrangement reflects the light from a single incoming laser beam that enters the vacuum chamber through a single viewport, thus greatly simplifying the optics.

The mirrors, which are located inside the vacuum region of the cold-atom source, were created by polishing metal and applying a dielectric coating. "The adjustability of this design is an entirely new feature," said Foot. "Creating a pyramid from four identical polished metal blocks simplifies the assembly, and it can be used without the adjustment mechanism."

Better measurements with more atoms

To test their new cold-atom source design, the researchers constructed laboratory equipment to fully characterize the flux of atoms emitted through a hole at the apex of the pyramid.

"We demonstrated an exceptionally high flux of rubidium atoms," said Foot. "Most cold-atom devices take measurements that improve with the number of atoms used. Sources with a higher flux can thus be used to improve measurement accuracy, boost the signal-to-noise ratio or help achieve larger measurement bandwidths."

The researchers say that the new source is suitable for commercial application. Because it features a small number of components and few assembly steps, scaling up production to produce multiple copies would be straightforward.

More information: Sean Ravenhall et al, High-flux, adjustable, compact cold-atom source, *Optics Express* (2021). DOI: 10.1364/OE.423662

Provided by The Optical Society

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