When atoms collide

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Scientists at the UK's National Physical Laboratory (NPL) have proposed a new way to determine accurate time faster.

Very precise time keeps the Internet and e-mail functioning, ensures television broadcasts arrive at our TVs and is integral to a network of global navigation satellites (such as the Global Positioning System) used for precision mapping and surveying, environmental monitoring and personal location-based services.

But time can only be useful if it is the same for everyone. And that requires a single source against which we can all check our clocks.

The caesium fountain that NPL operates is one of only a handful of highly precise measurement devices around the world that inform the global primary time standard – the definition of accurate time. NPL's atomic fountain measures the accuracy of existing time standards and feedback readings to inform any adjustments to Coordinated Universal Time – the basis for the worldwide system of timekeeping.

NPL's instruments do not simply measure time. They measure the absorption of electromagnetic waves by caesium atoms and detect the resultant changes in the internal state of those atoms. The absorption peaks at a specific electromagnetic frequency. They can then lock this frequency and use the number of oscillations of that frequency, during a given period of time, to define a second, like the ticks of a conventional clock.

One second, for example, corresponds to just over nine billion oscillations of an electromagnetic signal locked to the peak change in caesium atoms.

But an atomic clock is never perfect. One of the challenges when identifying the accurate frequency reference is that it tends to fluctuate very slightly and its average value is only known within a certain error range. In atomic fountains, these tiny errors are largely due to atoms colliding with each other inside the fountain. This is known as a collisional frequency shift.

There have been several theories about what affects the collision shift and how to compensate for it but existing methods can take days or even weeks. The team at NPL has discovered a potential new approach, reducing the time it takes to confirm the accuracy of a frequency reading to a matter of hours – ten times faster than it can currently be done. It is based around the state of the atoms during their flight in the fountain. They can be in one of two states – upper or lower, or in a combination of the two.

The NPL team in collaboration with NIST (USA) and PTB (Germany) discovered that the effect the collisions have on the frequency signal depends on which state the atoms are most in. Upper results in a negative shift, lower in a positive shift. This suggests the existence of a split between upper and lower state atoms that cancels the shift out and results in no affect to the frequency signal.

Operating a caesium fountain at this ‘zero-shift’ point is an attractive proposition as it removes the need to compensate for collision shifts and accelerates the process of confirming the accuracy of frequency standards. This means laboratories providing the primary time standard can feed back more readings in any given period of time, increasing the accuracy of recommended adjustments to UTC, potentially improving the overall accuracy of the world's time.

Source: National Physical Laboratory

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