The ultimate accuracy machine

October 4 2013

A clock being developed by a physicist at The University of Western Australia is the first of its kind in Australia - and will be the only southern hemisphere-based clock in the international Atomic Clock Ensemble in Space (ACES) project if Associate Professor John McFerran can accomplish his goal of building the clock in time for the ACES launch in 2016.

Dr John McFerran, from UWA's School of Physics, is working on the nation's only cold atom optical clock. The device, which he and students are building with Australian Research Council funds in the University's Frequency and Quantum Metrology lab, will be part of a consortium of the world's most accurate clocks. It may help redefine time and add to our understanding of the laws that govern the universe.

Atomic clocks, or as Dr McFerran likes to think of them, humankind's ultimate accuracy machines, are used as primary standards for international time distribution services, to control the frequency of television broadcasts, in global navigation satellite systems such as GPS, and testing the laws of physics.

The UWA clock uses atoms of the rare earth element ytterbium (Yb). A Yb sample is heated in an effusion cell to 400° Celsius and then several billion atoms per second are guided into a vacuum chamber. The atoms are first slowed down to below one tenth of their initial speed before they are trapped, cooled, trapped again in a "lattice" and then probed with a laser that represents the closest thing to a pure sine wave.

"Think of the purest musical note you have ever heard then 'multiply the clarity' by more than a billion times - this is how pure the sine wave must be," Dr Mc Ferran said.

"So far at UWA the slowing part has been achieved with lots still to do, but having been only six months in the lab, this is good going."

Unlike standard atomic clocks which use microwaves, the next-generation atomic clocks such as at UWA operate at optical frequencies which are much higher than microwaves and enable time to be divided into shorter intervals for more precise measurement (about one hundred thousand times smaller).

"Atoms are driven by the fundamentals of the universe," Dr McFerran said. "This is why we use the properties of atoms to define time to an accuracy of 16 or more decimal places.

"Yb is a good element to use because it has electronic transitions that are intrinsically very pure and at the same time heavily immune to external perturbations. Aluminum ion, Yb ion, mercury and strontium clocks are also being worked on internationally and there will be debate around the world for years to come about which, or what combination of atomic clocks is most suitable for a future definition of the SI second."

Since gaining a PhD at UWA in 2003, Dr McFerran has held post-doctoral research positions at the National Institute of Standards and Technology in Boulder, Colorado, at LNE-SYRTE, Paris Observatory and at XLIM, Limoges, France. NIST and SYRTE are also setting up a ground station as part of the Atomic Clock Ensemble in Space. While these institutes already have several atomic clocks in operation, the ground stations are still setting up their microwave links to the International Space Station (ISS), on board which ACES will place its atomic clock ensemble.

The UWA clock will hopefully be completed in time for the ACES launch in 2016 and then be linked to the atomic clocks on ISS and to atomic clocks in Boulder and Paris. Over three years, the frequency ratios of the clocks will be compared to help physicists evaluate whether one of the bedrock parameters that describe the properties of the universe - the fine structure constant (alpha) is very slowly changing or not. Some physics theories suggest it could.

"Physicist are desperate to find more evidence beyond the Standard Model of particle physics to help pin down their theories. Quantifying rates of change (including zero) of fundamental constants provides such evidence," Dr McFerran said.

"To understand who we are, we need to understand the world we live in. This is why I do physics."

Provided by University of Western Australia