Clerkenwell hosts inaugural Daniels Lecture

by Justin Koullapis

The inaugural George Daniels Lecture (to be presented annually), a function of the bequest left by George Daniels to City University, London, was delivered at the Oliver Thompson Lecture Theatre on 18 September to an audience of about 200. Professor Patrick Gill from the National Physical Laboratory presented a talk entitled *Optical Atomic Clocks – Light Years Ahead?*

The talk was extremely recondite, illustrating just how far the science of time measurement has moved from the days when the BHI occupied the building just next door to the lecture hall, a few metres away in Northampton Square.

Currently, the world's 'master clock' is an agglomeration of national time standards, employing caesium clocks in one form or another. The uncertainty of the best of such clocks is presently about 2 or 3 x 10^{-16}. For readers unfamiliar with the operation of these clocks, a vapour of caesium metal is 'charged' or excited by microwaves, during which some of the atoms in the sample jump to an abnormally high energy state. Upon later dropping back to their normal state, they emit that excess energy, which can be measured. Due to the 'quantum' behaviour of atomic energy, this measured frequency is always extremely precise: 9,192,631,770 Hz.

Thanks to various uncertainties, this method is no longer the most precise. The latest family of atomic clocks employs a different system, whereby a single atom is 'trapped' by progressively cooling it down to a few millikelvins above absolute zero, and holding it captive in an electromagnetic 'egg-box'. This alone was the subject of much contention in physics because it could appear to violate the 'uncertainty principle'. Still, a high-precision pulsed laser then 'strokes' the atom, exciting it, and causing it to emit frequencies as before. The outputs are subsequently used to refine the phase of the combing laser.

The precision of the best such devices, employing aluminium anions, is about 9 x 10^{-18}, roughly two orders of magnitude better than the best caesium clocks. However, problems exist with respect to co-ordinating the time/frequency data between different locations (as is currently used to establish UTC) and, indeed, in the distribution of the data to the wider world. The best communication networks can currently transmit such data with a precision of only about 10^{-16} per day, ie only as good as caesium clocks!

Practical uses for clocks this accurate (one second over the lifetime of the universe...) are many. Investigations into relativity become easy. The professor pointed out that the precision is such that a change in the height of the clock off the floor as little as 40cm produces measurable relativistic changes in timekeeping.

Geodesy, the measurement of the exact shape of the earth, requires ever more precise clocks, giving subsequent increases in precision in earthquake prediction, gravitational measurements, etc.

GPS and navigation are also obvious benefactors of increasingly good clocks.

An unexpected demand for high precision clocks came from the banking industry, where the ability to make and time-stamp trades with minute precision gives enormous commercial advantage – imagine being able to place a position picoseconds before your competitor!

It was notable that there were some interesting, although not immediately obvious, parallels between these exotic clocks and the history of mechanical horology. For example, the drive to produce ever smaller 'optical lattice clocks' has resulted in them now being reduced to 'almost portable', ie, they can be built on a lab bench as opposed to consuming a whole room. Temperature changes can affect them badly: the laser tubes need to be kept at a very stable temperature so that their reflecting surfaces stay a precise distance apart, otherwise the light frequency is altered. Finally, the laser 'servant' occasionally and lightly probing the single-atom 'master' to determine its behaviour immediately resonated with me (if you please); after all, this is exactly how Hamilton-Shortt's pendulum clocks got to be the world's most accurate!

George Daniels would no doubt have approved.