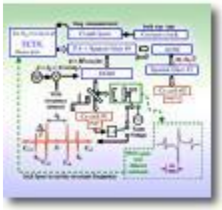

Absolute frequency of cesium 6S-8S 822 nm two-photon transition by a high-resolution scheme

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Spotlight

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Spotlight summary: Optical frequency measurements made a giant step forward 13 years ago when Ted Haensch and Jan Hall and their colleagues showed how to use a mode-locked laser to count optical frequencies. This Nobel-prize winning research made it possible to measure laser frequencies with mind-boggling precision. Scientists were suddenly able to spend less time babysitting lasers and to spend more time on atomic physics -- perfecting the science of stabilizing lasers to atomic transitions. The world record in this game is held by NIST, where a fractional frequency instability of only 1.6 x 10^{-18} has been demonstrated.

Ultra-stable lasers have applications in geodesy, interferometry, metrology, time-keeping, and communication. They are also used to challenge scientific ideas on a very fundamental level, in areas ranging from testing QED calculations in simple atoms, looking for parity non-conservation, and searching for possible variations in the values of fundamental constants.

For some of these applications, it is not enough to have a stable laser. Its absolute frequency must also be known. As of right now, the amazing stability of NIST-class lasers is not routinely available. The clockwork required for absolute frequency measurements, while available commercially, is not always convenient to have on hand. So it is important to have well-known "secondary" frequency standards that can be conveniently and inexpensively reproduced in nearly any laser lab where an absolute frequency needs to be measured.

The paper by Wu et al. is an impressive example of one such secondary standard. They measured the absolute frequency of the Cs 6S-8S transition at 822 nm. Their approach is a variation of modulation transfer spectroscopy using cw lasers. They use a semiconductor laser at 822 nm to excite the two-photon transition and measure the fluorescence cascade photons in the blue. The cw laser frequency is measured using a self-referenced fs-laser-based frequency comb.

While the methods are somewhat routine, their result is astonishing. Finding that their measurements disagreed with high accuracy results in the literature, Wu et al. measured the 6S-8S transition frequency in 10 different Cs vapor cells. In former times, research groups made their own cells, repeatedly distilling and purifying Rb or other elements before sealing them off. But nowadays it is simply more convenient to buy cells from one of many different vendors. It has long been believed that commercial vapor cells were clean enough to allow accurate spectroscopy at the 10 kHz level, corresponding to a fractional frequency uncertainty of 3 x 10^{-11}. The surprising result from Wu's work is that the 6S-8S transition varies by hundreds of kHz in their cells. Cells with the largest shifts correlated with broader line widths, up to nearly a factor of 2. This is not pressure broadening due to Cs in the cell--that has been taken out in their work. The shift and width are due, evidently, to impurities in the cell. Without a reasonable theory to guide them, they chose to quote their measured transition frequency from the cell with the narrowest line width -- the transition width that was closest to the natural linewidth.

This work has significant implications. Not only is every commercial vapor cell suddenly suspicious, but measurements that used a Rb or Cs or I2 or other vapor cell as a secondary frequency reference are called into some doubt, Wu's work included. Cell-based spectroscopy, when used as a secondary frequency standard, is in the uncomfortable situation of having potentially large and unknown uncertainties. A high-accuracy measurement in an ultrapure and collision-free environment is certainly warranted. Atomic theory also has a near-term opportunity to explain what Wu et al. have measured, and to guide future measurements in this field.

The need for reliable secondary frequency standards is not going away. Wu's results are a challenge to the field of spectroscopy. Cell manufacturers may need to develop some way of testing and validating their products. But until this is resolved, it looks like spectroscopists have a little more work to do.

--Scott Bergeson