Physical Sciences

Suppressing Loss of Ions in an Atomic Clock

Ion traps are excited at two different frequencies.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improvement has been made in the design of a compact, highly stable mercury-ion clock to suppress a loss of ions as they are transferred between the quadrupole and higher multipole ion traps. Such clocks are being developed for use aboard spacecraft for navigation and planetary radio science. The modification is also applicable to ion clocks operating on Earth: indeed, the success of the modification has been demonstrated in construction and operation of a terrestrial breadboard prototype of the compact, highly stable mercury-ion clock.

Selected aspects of the breadboard prototype at different stages of development were described in previous *NASA Tech Briefs* articles. The following background information is reviewed from previous articles: In this clock as in some prior ion clocks, mercury ions are shuttled between two ion traps, one a 16-pole linear radio-frequency trap, while the other is a quadrupole radio-frequency trap. In the quadrupole trap, ions are tightly confined and optical state selection from a ^{202}Hg lamp is carried out. In the 16-pole trap, the ions are more loosely confined and atomic transitions are interrogated by use of a microwave beam at approximately 40.507 GHz. The trapping of ions effectively eliminates the frequency pulling that would otherwise be caused by collisions between clock atoms and the wall of a gas cell. The shuttling of the ions between the two traps enables separation of the state-selection process from the clock microwave-resonance process, so that each of these processes can be optimized independently of the other. This is similar to the operation of an atomic beam clock, except that with ions the "beam" can be halted and reversed as ions are shuttled back and forth between the two traps.

When the two traps are driven at the same radio frequency, the strength of confinement can be reduced near the junction between the two traps, depending upon the relative phase of the RF voltage used to operate each of the two traps, and can cause loss of ions during each transit between the traps and thereby cause loss of the 40.507-GHz ion-clock resonance signal.

The essence of the modification is to drive the two traps at different frequencies — typically between 1.5 and 2 MHz for the quadrupole trap and a frequency a few hundred kHz higher for the 16-pole trap. A frequency difference of a few hundred kHz ensures that the ion motion caused by the trapping electric fields is small relative to the diameter of the traps. Unlike in the case in which both traps are driven at the same frequency, the trapping electric fields near the junction are not zero at all times; instead, the regions of low electric field near the junction open and close at the difference frequency. An additional benefit of making the 16-pole trap operate at higher frequency is that the strength or depth of the multipole trap can be increased independent of the quadrupole ion trap.

This work was done by John Prestage and Sang Chung of Caltech for NASA's Jet Propulsion Laboratory.

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Simplified Vicarious Radiometric Calibration

At-sensor radiance is estimated more directly than in prior methods.

Stennis Space Center, Mississippi

A measurement-based radiance estimation approach for vicarious radiometric calibration of spaceborne multispectral remote sensing systems has been developed. This simplified process eliminates the use of radiative transfer codes and reduces the number of atmospheric assumptions required to perform sensor calibrations. Like prior approaches, the simplified method involves the collection of ground truth data coincident with the overpass of the remote sensing system being calibrated, but this approach differs from the prior techniques in both the nature of the data collected and the manner in which the data are processed.

In traditional vicarious radiometric calibration, ground truth data are gathered using ground-viewing spectroradiometers and one or more sun photometer(s), among other instruments, located at a ground target area. The measured data from the ground-based instruments are used in radiative transfer models to estimate the top-of-atmosphere (TOA) target radiances at the time of satellite overpass. These TOA radiances are compared with the satellite sensor readings to radiometrically calibrate the sensor.

Traditional vicarious radiometric calibration methods require that an atmospheric model be defined such that the ground-based observations of solar transmission and diffuse-to-global ratios are in close agreement with the radiative transfer code estimation of these parameters. This process is labor-intensive and