A $^{201}Hg^{+}$ Comagnetometer for $^{199}Hg^{+}$ Trapped Ion Space Atomic Clocks

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A method has been developed for unambiguously measuring the exact magnetic field experienced by trapped mercury ions contained within an atomic clock intended for space applications. In general, atomic clocks are insensitive to external perturbations that would change the frequency at which the clocks operate. On a space platform, these perturbative effects can be much larger than they would be on the ground, especially in dealing with the magnetic field environment. The solution is to use a different isotope of mercury held within the same trap as the clock isotope. The magnetic field can be very accurately measured with a magnetic-field-sensitive atomic transition in the added isotope. Further, this measurement can be made simultaneously with normal clock operation, thereby not degrading clock performance.

Instead of using a conventional magnetometer to measure ambient fields, which would necessarily be placed some distance away from the clock atoms, first-order field-sensitive atomic transition frequency changes in the atoms themselves determine the variations in the magnetic field. As a result, all ambiguity over the exact field value experienced by the atoms is removed. Atoms used in atomic clocks always have an atomic transition (often referred to as the "clock transition") that is sensitive to magnetic fields only in second order, and usually have one or more transitions that are first-order field sensitive. For operating parameters used in the $^{199}Hg^{+}$ clock, the latter can be five orders of magnitude or more sensitive to field fluctuations than the clock transition, thereby providing an unambiguous probe of the magnetic field strength.

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