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Cold Atom Clocks and Fundamental Tests

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We will describe the present status for the realization of the SI unit of time, the second. Microwave frequency standards operating with laser cooled cesium and rubidium atoms have advanced by two orders of magnitude in the last two decades. Cesium fountains currently operate at the fundamental quantum noise limit with 107 detected atoms and display a relative frequency stability of 1.5x10ˆ-16 after 50 000 seconds of averaging time.
The SI second is realized with an accuracy of 3x10ˆ-16 implying an error of less than a second over 100 million years.
In a second part, we will describe tests of fundamental physical laws using ultra-stable clocks. By comparing clocks of different nature new limits are obtained for the time variation of the fundamental constants of physics such as the fine structure constant alpha. The ability to compare microwave and optical clocks using the newly developed frequency comb technique opens a wide range of possibilities in clock comparisons.
By installing in space ultra-stable cold atom clocks (PHARAO/ACES project for flight in 2013), improved tests of general relativity will be performed, such as a measurement of Einstein's gravitational red-shift at the one part per million level. A new kind of relativistic geodesy based on the Einstein effect will provide information on the Earth geoid. Finally prospects for laser cooled atomic clocks operating in the optical domain with frequency stability in the 10ˆ-18 range will be outlined.

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