

Analytical and numerical estimations of blackbody radiation shift uncertainty in optical atomic clocks

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Blackbody radiation shift uncertainty gives one of the most significant contribution to accuracy budgets of modern optical atomic clocks [1, 2]. Known approaches to reduction of this contribution assumes shielding atoms from the hot environment by storing them in cryogenically cooled cold-fingers [3], covering the internal parts of vacuum chamber with ultra-low emissivity coatings [4] or directly measuring the temperature visible for atoms [2,5].

Our approach is to combine direct temperature measurements of the vacuum parts used in construction of optical atomic clock's setup with calculations of the conductive and radiative heat transfer in whole system, resulting in the information about the temperature visible for atoms stored in optical lattice. With the knowledge of the emissivity coefficients of the materials used in the construction of optical clocks' setups [6] we are able to and calculate the radiative heat transfer from the clock's vacuum chamber surfaces to the atoms. This heat transfer induces frequency shift of clock transition at the relative level of 10^{15} - 10^{16} in room temperatures. The shift has to be known with the lowest possible uncertainty. Calculation of the heat transfer can be performed in two complementary ways: using finite element method (FEM) numerical simulation or analytically. Analytical solutions are much more complicated and can be performed only for limited number of geometries, but in case of possibility of high accuracy uncertainty estimations they are much more desirable than the numerical ones. We present recent results of calculations of blackbody radiation shift in strontium optical lattice clock based on solution of conductive and radiative heat transfer performed analytically and numerically, supported by precise measurements of emissivity coefficients of vacuum compatible materials in range from 0 to 30 °C.

References:

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