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Test of local Lorentz invariance in the phonon sector using quartz BAW oscillators

In this work, we will present the test of local Lorentz invariance using the precision measurements of oscillation masses of particles (phonons). The experiment utilizes two ultra-stable Bulk Acoustic Wave (BAW) quartz oscillators placed orthogonally to each other on a turntable and search for LIV by comparing their relative frequency shift. The resonant frequency of mechanical resonators including BAW oscillators depends on the mode effective mass, which not only depend on the external load-ings but also on the intrinsic mass, i.e. inertial masses of composing particles of the device. Thus, the modulations of inertial masses can be converted to the modulations of phonon resonant frequencies and can be detected precisely with frequency measurement techniques. In SME theory, the modulations of the inertial masses depend on the direction and boost velocity in space. In this case, the LIV test is reduced to the measurements of frequency stabilities of mechanical resonators as a function of direction and boost velocity in space. The overall sensitivity of such an experimental scheme is limited by the frequency stabilities of resonators or oscillators at time periods twice of the rotation period rather than the long-term performance of the oscillators. The best sensitivity is achieved by limiting the integration time low and in this experiment the rotating period of the turntable is optimized at 1 second. Quartz BAW oscillators provide the best frequency stability below 10-13 between 1 and 10 seconds in integration time and low sensitivity to other effects such as temperature, vibration, acceleration and aging. The stability of the oscillators has an order of magnitude improvement than the one used in the previous version of the experiment. Data analysis is done by using the two-stage demodulated least square (DLS) method. The fractional frequency difference is demodulated into DLS parameters and linked to SME neutron c coefficients to obtain the sensitivity.

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