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Precision measurement of atomic isotope shift for new physics searches.

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Atomic isotope shift (IS) is the isotope-dependent energy difference in the atomic electron energy levels. These shifts serve an important role in atomic and nuclear physics. Recently, precision spectroscopy of IS was suggested for the search of new forces beyond the standard model. The idea relies on nonlinearity of King plots for narrow optical transitions. To date, the best King plot was measured with precision on the order of 100 Hz and only very few IS were measured at the Hz level. We present a simple scheme to measure the IS with mHz precision. Instead of measuring the absolute transition frequency for each of the isotopes separately, we extract only the shift by measuring the parity oscillations of two isotopes that were prepared in an entangled state. In a recent experiment we demonstrated this method on the quadrupole transition $S_{1/2}$ - $D_{5/2}$ in Sr^+ isotopes. The IS shift between $^{86}Sr^+$ and $^{88}Sr^+$ was measured to be 570,264,063.435(5)(8) (statistical)(systematic) Hz. Furthermore, we were able to detect a relative difference of 3.46(23) 10^{-8} between the orbital g-factors of the electrons in the $D_{5/2}$ level of the two isotopes. Interestingly, uncorrelated states can be used as well with a penalty of reducing the signal to noise ratio by a factor of two. Thus, making this method applicable to existing setups of trapped ions as well as neutral atoms in optical tweezers. Testing King linearity at the sub-Hz level may be able to improve bounds on new physics and have interesting prospects for testing quantum many-body calculations and the study of nuclear structure.