Molecular internal state quantum interferometry for precision tests of fundamental physics

A. Wicht (1), C. Lämmerzahl (2)

(1) Institute for Experimental Physics, University of Düsseldorf, Germany, (2) ZARM, University of Bremen, Germany, (andreas.wicht@uni-duesseldorf.de , clammer@zarm.uni-bremen.de)

Atom interferometers have proven to be the most accurate and most sensitive tool of optical metrology if not of physics in general. With the advent of fs-optical frequency combs and with the recent progress in the generation of ultra-cold molecules now the application of quantum interferometric methods to molecules seems to come into reach.

(Diatomic) molecules differ from atoms in that the existence of an internuclear axis allows them to distinguish per se between (i) the direction along their axis and (ii) the two directions orthogonal to it. This makes them ideal probes especially for those kinds of experiments which aim at the analysis of anistropic effects: we can prepare molecules in a specific vibrational state and orient them in space by creating an appropriate superposition of angular momentum states. We then transfer the molecule into a coherent superposition of (i) a state corresponding to an orientation along one specific axis and (ii) a state corresponding to an orientation along an orthogonal direction. An anisotropy between these two directions will cause a differential shift of the (vibrational) energy associated with the two orientations, which in turn will cause an accumulation of a quantum mechanical phase shift between these two states. This quantum mechanical phase shift can be controlled and read out by means of the techniques which are now well established in atom interferometry. Similarly to future atom interferometers this type of quantum interferometers would significantly benefit from space based operation.

We give a first simplified analysis of whether and how molecular internal state quantum interferometers could be used for precisions tests of fundamental physics, like tests of standard model extensions or gravitational wave detection. We outline how a molecular internal state quantum interferometer could in principle be based on the coherent manipulation of individual rovibronic states by means of phase coherent optical fields.