

Development of a molecular Hg₂ clock to investigate fundamental physics

M. Witkowski¹, A. Linek¹, M. Zawada¹, R. Ciuryło¹

1. Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Toruń
email: rciurylo@umk.pl

We introduce a novel molecular sensor designed for the study of fundamental interactions, focusing on clock transitions within a Hg-Hg system. Our project implements optical Feshbach resonances in systems involving Hg₂ or Hg-alkali systems [1, 2], with the ultimate goal of constructing a Hg₂ optical molecular clock [3, 4]. This tool has the potential to push limits for fundamental research by achieving unprecedented advancements in terms of precision and accuracy.

To experimentally investigate new hadron-hadron interactions, we will employ Hg₂, one of the heaviest two-atom molecule. The interatomic potential of Hg-Hg is relatively well-characterized [5], especially compared to other heavy molecules like Yb₂. Nonetheless, to mitigate the impact of theoretical imperfections, we will leverage quantum defect theory [6] and measure rovibronic bound states near the dissociation threshold within the ground electronic configuration [7]. This approach has recently emerged as a promising method for probing new interactions [8].

The spectroscopy of Hg₂ will be conducted in gas samples cooled to microkelvin temperatures within a dipole trap. Experimental results from one- and two-color photoassociations involving various isotopologues of Hg₂ will provide essential insights into quantum defects that describe near-threshold bound states, with and without electron excitation. Mapping these bound states within the Hg₂ system will allow us to select the appropriate isotopologue for realization of the optical molecular clock [8]. To achieve the electronic ground state of Hg₂, a two-stage experiment will be employed. Firstly, a weakly bound state of Hg₂* (near the molecule dissociation limit) will be created through photoassociation. Subsequently, the electronic ground-state molecule will be formed via stimulated Raman adiabatic passage (STIRAP). The realization of an optical molecular clock will be pursued based on proposed scenarios outlined in Ref. [3]. The photoassociation spectra will be referenced to optical atomic frequency standards, aiming for sub-kHz level accuracy. The formation of ultra-cold Hg₂ molecules through photoassociation represents a significant advancement in our understanding of fundamental physics.

References

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