Chirality Amplification and Detection Using Cavity Optical Rotation Enhancement

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ABSTRACT

A molecule is "chiral" when it is - geometrically - non-superimposable on its mirror image. Chirality manifests as optical activity, *i.e.* as optical rotation (OR) of the polarization plane of light traversing the sample, with the two "enantiomers" (mirror images) producing opposite polarization rotations. Systems not possessing this geometric non-superimposability, but which cause OR with the same symmetry as chiral rotation, are also referred to as chiral systems, the prime example being the parity non-conserving (PNC) optical transitions in certain atomic and molecular systems.

Chirality is ubiquitous in nature, and, thus, of great importance to a wide range of fields, from the fundamental research in biology, chemistry, physics and medicine, to the high-market-value pharmaceutical, chemical, cosmetic, and food industries, which collectively comprise a multi-billion € market. However, chiral signals are typically very weak, on the order of 10 μrad for organic gas samples, down to 1 nrad (or less) for PNC transitions. This is the main impeding factor limiting the practical applications of chiral sensing, despite its apparent tremendous importance.

Recently, our group demonstrated a new optical-cavity-enhanced polarimetry apparatus (*Nature* **514**, 76; 2014), which offers important advantages in chiral sensing: weak OR signals are enhanced by the number of cavity round-trips, sensitivity-limiting spurious birefringence is suppressed, rapid signal reversals yield absolute measurements of optical activity without the need to remove the sample, while the scalability of the design ensures that the same apparatus can be used to perform measurements on any weakly-absorbing chiral sample.

HANDCORE, an HFRI/GSRT-funded project led by Dr. G. E. Katsoprinakis, aims to take this technique to the next level, using high-finesse optical cavities and state-of-the-art continuous-wave (CW) lasers, to reach ultra-sensitive, shot-noise-limited results, while also improving on the robust and proven pulsed-laser variations. Functioning prototype apparatuses (CW and pulsed) are already in operation, and improvements are being implemented daily. The CW setup in particular, will yield the first ever chiral measurements in its spectrum region (mid-IR; ~1315nm), with a primary focus on the optical activity of terpenes, especially interesting in the fields of forest ecology and chemistry, and of thin chiral films. However, the ultimate goal of the project is the measurement of the PNC-induced OR in atomic iodine (*PRA* **87**, 040101R; 2013), which constitutes a low-energy test of the standard model of particle physics. Measuring PNC in atomic iodine will, on one hand, lift a long-standing discrepancy between the two finest measurements of atomic PNC to date (cesium: *Science* **275**, 1759; 1997 | thallium: *PRL* **74**, 2658; 1995 and *PRL* **74**, 2654; 1995), and on the other hand, pave the road for measuring PNC in various other atomic and molecular systems, by adapting our low-cost, table-top setup to the relevant spectral regions.

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