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Toward Optical Determination of Calcium Isotope Ratios: Spectroscopy of CaF Isotopologues

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Isotope ratio measurements play a central role in understanding processes across the biological, environmental, and physical sciences. Calcium isotope ratios have gained increasing attention as sensitive indicators of bone metabolism in biomedical research [1-5]. Despite their importance, high-accuracy calcium isotope analyses are traditionally performed using multi-collector inductively coupled plasma mass spectrometry, which provides high precision but requires extensive chemical sample preparation and specialized laboratory infrastructure.

Here we present an optical approach to calcium isotope analysis based on high-resolution laser spectroscopy of calcium monofluoride (CaF). Fluorine is monoisotopic, allowing isotope-dependent frequency shifts in the CaF optical spectrum to directly reflect Ca isotope differences. Using a supersonic molecular beam and laser-induced fluorescence spectroscopy, we resolve isotope-dependent spectral features in the $A^2\Pi$–$X^2\Sigma^+$ band system for ^{40}CaF, ^{42}CaF, and ^{44}CaF [6]. Ongoing work focuses on improving signal-to-noise ratios and constraining systematic effects to establish a spectroscopic framework for isotope ratio determination.

We present initial measurements demonstrating spectroscopic sensitivity to the ^{44}Ca/^{40}Ca ratio under controlled laboratory conditions and evaluate factors limiting precision. This work establishes a foundation for optical isotope ratio measurements and provides an alternative or complementary analytical technique for biomedical and environmental isotope applications.

[1] Skulan & DePaolo (1999), *PNAS* 96, 13709–13713.
[2] Skulan et al. (2007), *Clin. Chem.* 53, 1155–1158.
[3] Morgan et al. (2012), *PNAS* 109, 9989–9994.
[4] Eisenhauer et al. (2019), *Bone Rep.* 10, 100200.
[5] Tissot et al. (2024), *Metallomics* 16, mfae050.
[6] Bashiri et al. (2025), *J. Mol. Spectrosc.* 410, 112023.