Hyperfine Structure of Xe by Frequency Comb Calibrated Saturation and Collinear Fast Beam Spectroscopies

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The measurements of hyperfine structure (HFS) in atomic spectra provides information on the interaction of the nuclear magnetic moment with the magnetic field produced by electrons and also on the coupling of the nuclear electric quadrupole with the gradient of the electric field at the position of the nucleus. Hyperfine structure and isotope shifts of Xe were investigated with Doppler-free saturated absorption spectroscopy for all transitions in the 820-841 nm spectral interval. The absorption lines were observed in an inductively coupled Xe discharge. A widely tunable narrow line Ti:sapphire laser was employed for the excitation of the HFS transitions between 6s and 6p levels. For improving the accuracy of spectroscopic measurements a broadband frequency comb (FC) was used with 8fs laser pulses at a repetition rate 80MHz that covered the whole 820-841nm spectral interval. In the frequency domain the beat notes of the Ti:sapphire and the FC laser provided a precision frequency ruler. For stabilization of this FC, it was referenced to a CW laser, which in turn was disciplined to a Rb frequency standard.

The hyperfine structures for ^{129}Xe and ^{131}Xe were well resolved. For the transitions with the wavelengths in vacuum near 820.860 and 841.150 nm also isotope shifts of the even isotopes were clearly observed. The hyperfine structure and isotope shifts of Xe isotopes were observed for several transitions in the near-IR range 820-841 nm by using the Doppler-free saturated absorption spectroscopy approach. We were able to identify wavelength regions (around 820.860 and 841.150 nm) where transitions from seven different Xe isotopes could be clearly identified. Furthermore, the position of the HFS lines is in good agreement with previous measurements by other groups, and the shapes of these lines have been simulated with numerical models, which qualitatively well reproduces the experimental spectral profiles.

Another experimental setup scheme that we use for measurements of atomic HFS employs a fast ion beam, where ions (Xe II) are produced in an ion source and accelerated to $/sim10$ keV. The following scheme is being investigated: the laser excitation at a wavelength $/sim834.777$ nm from a metastable 5d2[4]7/2 level to the excited 6p2[3]o5/3 level leads to the transition to the 6s2[2]3/2 state and fluorescence at $/sim541.915$nm. Calculations show that the HFS of ^{129}Xe with 3 transitions and that of ^{131}Xe with 9 transitions can be expected.

Performing quantitative spectroscopic analysis shows promise for the determination of isotopic abundances, including measurement of different isomers of the same isotope. Further development of these approaches can lead to designing a compact apparatus of Xe isotope analysis.

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