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Hyperfine Physics in Alkali-Metal Vapors[1]

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Although alkali-metals were all discovered by the mid-19th century, vapors of these Column I elements have been studied with particular intensity in the last 75 years, initially as pseudo-one-electron systems with easily accessed optical or near-infrared P→S transitions to the ground state having strong oscillator strengths. Currently, they are widely used in precision magnetometry, atomic clocks, and in gyroscopes; they are also of fundamental importance in the study of cold atoms, Bose-Einstein condensates, and atom interferometry—even some table-top searches for physics beyond the standard model. All stable alkali-metal isotopes have half-integer nuclear spin, and the ground-state hyperfine coupling to the valence electron generates a rich spin physics that is crucial to all of these areas of study. Our laboratory focuses on optical pumping: the use of circularly polarized resonance light to produce large non-equilibrium ground-state spin polarization in alkali-metal vapors. We also work on the technique of spin-exchange transfer of this polarization to the nuclei of certain noble gases (^{3}He and ^{129}Xe), which finds application to magnetic resonance imaging of the lung, among many others. We have worked most recently on characterizing electron-paramagnetic-resonance (EPR) frequency shifts in hyperfine transitions that result from interactions between the polarized alkali-metal vapor and the polarized noble-gas nuclei. These are studied optically with much higher sensitivity than inductive techniques; indeed, such shifts can be used as a sensitive probe of the noble-gas magnetization.

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