Double-resonance studies on compact, high-performance rubidium cell frequency standards

This thesis presents experimental studies on continuous-wave (CW) laser-microwave double-resonance (DR) spectroscopy and metrology in rubidium (87Rb) vapor cells in view of new high-performance, compact Rb-cell atomic clocks. The Rb vapor cell is confined inside a magnetron-type cavity microwave resonator (MWR). The CW DR spectroscopy involves two resonant electromagnetic fields that are operated simultaneously to interrogate the atoms - the <i>optical field</i> to polarize the atoms by optical pumping, and the <i>microwave field</i> to drive the ground-state hyperfine clock transition that serves as an atomic frequency reference. Details on characterization of compact laser heads and microwave synthesizers used in this work are presented. The vapor cell standards are useful in our everyday lives for applications ranging from telecommunications, navigation, metrology etc.
 In view of improving the performances of the Rb cell standards, two different clock approaches were studied in detail:
 The first one is on use of vapor cells (1.4 cm³) whose inner walls are coated with anti-relaxation material. A first ever wall-coated cell clock was demonstrated with good short-term frequency stability. The medium- to long-term stability was found to be limited by the temperature coefficient (TC) of the coating material itself. This work gave the insight to important features to be considered in future anti-relaxation coating materials for atomic standards.
 The second novel approach involves using a bigger cell (12 cm³) within a newly developed, improved MWR towards a high-performance atomic standard. Adopting a larger cell gives a higher atomic Q-factor signal that improves the short-term clock stability. In this approach, the cell was filled with ⁸⁷Rb and buffer gases. With this clock, we demonstrate the state-of-the-art short-term stability of <1.4×10^{−13} <i>τ</i>^{−1/2}. Metrological quantitative measurements on parameters influencing the medium- to long-term stability were studied in view of next generation satellite navigation systems that demand a stability level of <1×10^{−14} at 10⁴ s (equivalent to <1 ns/day). The potential of short-term stability and understanding of the limiting factors on medium- to long-term time scales demonstrated in this study pave the way for future work towards the commercialization of high-performance Rb atomic clocks for a variety of applications.

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