Abstract

In this thesis, I present my contribution to optical atomic clocks and tweezers machines to make these complicated experiments more robust and easy to operate in clock and Rydberg spectroscopy, respectively. Therefore, I am presenting two sets of results for the performance of the automatic system and real measurement while the experiments are automatic.

In the first part of this thesis, I describe the development of an automatic system for stabilizing lasers and auto relocking them after the introduction and theory. Alongside building an autonomous and robust optical atomic clock, an automatic control system has been developed for compensation coils to control magnetic fields during the clock cycle and for direct digital synthesis (DDS). These systems have been built and tested successfully in optical atomic clock and tweezer machines at Nicolaus Copernicus University and the University of Amsterdam, respectively.

In the second part, after implementing these automation systems in the experiments, I performed clock spectroscopy to measure the temperature of the strontium (Sr) atoms in the ground state in the lattice, linewidth of the clock line, and Rabi oscillation. Zeeman shift and probe light shift have been measured as well. In the end, the stability of the atom-cavity was measured during campaign 2022 and has been compared with campaign 2015.

Additionally, the temperature of atoms in the lattice has been measured while they are excited on $^3P_0$ state. This measurement is to study the temperature changes of the trapped Sr atoms in the lattice after interacting with a magic-zero wavelength at 390 nm. Unfortunately, as the 390 nm laser was broken, there was no possibility of studying the effect of magic-zero on the trapped Sr atoms.

The auto relocking system has also been tested successfully in an optical tweezers machine project for the Rydberg laser. Additionally, I have characterized the Rydberg laser locked to the cavity. In the end, a Rydberg spectroscopy was performed while the Rydberg laser was locked by this system.