Modeling and Simulating the Effects of Parabolic Ring Cavity Geometry on Atom Interferometer and Quantum Accelerometers

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Quantum accelerometers, valued for their high sensitivity and potential use in space technology, measure acceleration with matter-light interferometry, outperforming conventional models. To overcome challenges like transverse mode degeneration, this project simulated quantum accelerometer and atom interferometry using parabolic cavities, hypothesizing it enlarges beamwaist while controlling transverse mode. The atom interferometer inside the optical cavity is affected by the strong laser intensities and high-quality wave fronts in the cavity. However, interference between the frequency components of light inside the cavity leads to spatial variation in the Raman Pulse and Transitions. This causes AC Stark Shifts between Raman pulses, which can significantly impact the performance of interferometry. By using a parabolic cavity, the AC Stark Shift was investigated. Optimum values of parabolic cavity properties were obtained to achieve the largest beamwaist. The simulation program was developed for testing and collecting data. According to simulation, parabolic cavity achieved enlarged beamwaist, stable cavity, and non-degenerate transverse modes. The focal length and depth of the mirrors affect the performance. We observed that the parabolic cavity has boundary conditions that align with theoretical expectations. This project showed that using a parabolic cavity instead of linear cavity can achieve enlarged beamwaist while controlling transverse mode. As a result of simulation, parabolic cavity achieved "0,00083m" beamwaist, which is nearly two times of linear cavity’s beamwaist. Future studies will adjust the different cavity geometries which provide more superior properties and improve the performance of the Quantum Accelerometer.