Laser noise reduction with additional filtering resonator

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Abstract— We study quantum computing technology based on neutral rubidium atoms. Effect of Rydberg blockade is use in order to achieve entanglement of two qubits. Rydberg states are obtained by shining on the array of cold atoms with two lasers. Stability of the driving lasers and noise reduction are required for high fidelity of quantum gates. Theoretical analysis and experimental setup of PDH-locking scheme with additional filtering resonator will be presented.

Keywords— filtering resonator, laser noise, PDH-locking, rybderg states, rubidium atoms, quantum computing.

I. Introduction

Nowadays there are many physical platforms for quantum computing. Neutral atoms are prospecting technology due to their ability to provide the way to implement one-qubit gates using levels of hyperfine structure of atom (for example 5S sublevels of rubidium-87) and two-qubit gates using effect of Rydberg blockade by driving electrons of two atoms to Rydberg states with high main quantum numbers simultaneously. Error sources for these systems are the following: finite lifetime of atomic states, Stark effect, thermal motion of atoms and noises in laser radiation. In this work we studied laser frequency noise measurement [1,2], numerical simulation of Raman oscillations driven by electric field and attempt to suppress noise of the laser by combining PDH locking with filtering resonator that is kept in resonance with the laser by piezo controller and suppresses frequency noise at frequencies more than linewidth of the resonator.

II. Theoretical analysis

We model Raman oscillations by solving Schrodinger's equation [3,4]. We consider electric field experienced by atoms in the vacuum chamber as sum of spectral components that can be recreated from laser's spectrum. Average of density matrix allows to estimate the probability of excitations to Rydberg state that is used as further metric of noise influence.

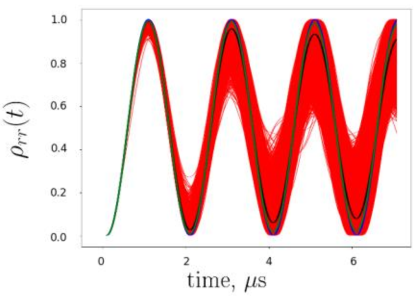

Fig. 1. Evolution of exited state population in the three-level system simulated using red laser's spectra.

III. Experimental results

Using the three-level system we modeled excitation of the atom when a spectrum of one laser is put as a noise source. We also considered adding Fabri-Perot resonator before the vacuum chamber in order to reduce noise, in that case spectra are multiplied by Airy function:

$$\mathrm{H}(\omega) = \frac{1}{1 + F\sin(\omega/\Delta\omega)^2}$$

Simulations show that error in excitation of the atom after applying π-impulse is decreased from 0.2% to 0.1%.

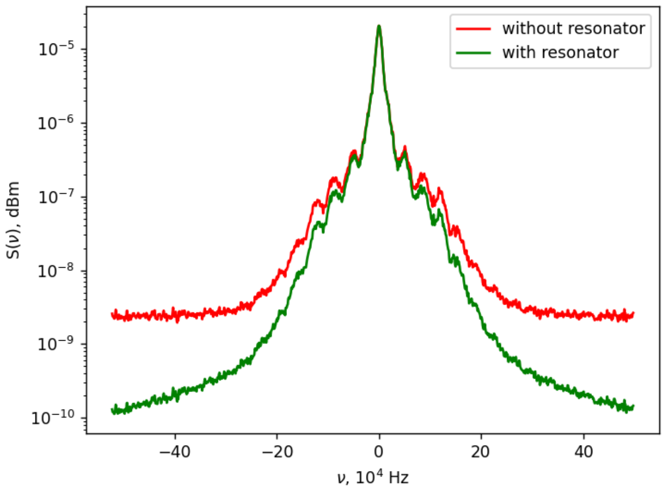

Fig. 2. Measured spectra of the laser via heterodyne method (blue) and spectra after multiplication by Airy function of the resonator (orange).

Our main goal is to present scheme of laser stabilization that includes filtering resonator locked with piezo controller to the laser and show measurements of laser noise suppression.

References

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