Autonomous Frequency Stabilization in Cold Atom Experiments

M. Zarei [1,2*], I. Knottnerus[2], A. Urech[2], F. Schreck[2], M. Zawada[1], P. Morzyński[1]
[1]Institute of Physics, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University, Toruń, Poland
[2]Institute of Physics, University of Amsterdam, Amsterdam, The Netherlands
*e-mail: mzarei@umk.pl

We present an autonomous frequency stabilization algorithm implemented in two software packages: a python program for NI-DAQ cards and a web application dedicated to Redpitaya boards. The system is capable of automatic and real-time control of the frequency of external-cavity diode lasers (ECDLs), enabling fast relocking of the ECDL. The algorithm can use cavity transmission and/or wavemeter signals as input parameters.

Keywords—cold atom; autonomous; frequency stabilization; ECDL; real-time; relock;

I. Introduction

One of the key technologies in cold atom experiments such as optical atomic clocks, quantum computers and simulators, as well as in optical communication and time keeping, is taking advantage of external-cavity diode lasers (ECDLs). ECDLs are tuneable diode lasers with a very narrow bandwidth. Because of the high sophistication of cold atom experiments, it is very important to have full control over frequency and single mode operation of the laser.

Fully automatic control in cold atom experiments, including relocking lasers' stabilization, frequency control of repumping lasers, control over currents in magnetic field coils [1] is a big challenge. On the other hand, it is crucial in high-TRL cold atom applications, such as transportable optical clocks [2–4], quantum computers [5], future satellite missions [6], and space missions [7,8].

Here we present two developed software packages, a python program for NI-DAQ cards and a web application dedicated for Redpitaya boards, for automatic frequency stabilisation and relocking of ECDLs to signals from cavity transmission and/or a wavemeter. The algorithm is capable of monitoring and compensating frequency drifts of the laser. Keeping track of the laser drift allows the algorithm to find the target lock frequency as fast as possible.

II. Methods/Results

A schematic diagram of the autonomous frequency stabilization in the experiments is shown in Fig. 1. The algorithm operates in two modes: Either in manual mode, when the operator can manually control the piezo transducers (PZT) voltage and current of the laser diode or in automatic mode, when the laser is kept on the lock frequency.

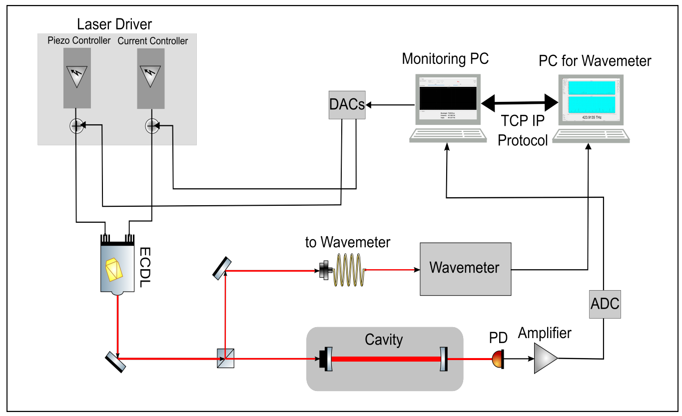

Fig. 1. Schematic diagram of the autonomous frequency stabilization in the experiments.

In automatic mode, there are two different types of input signals which are selectable: cavity transmission and/or wavemeter signal. After processing the signals by the software, appropriate feedback is sent to the PZT and/or current controller of the laser driver.

The picture of the software for relocking ECDLs is shown in Fig. 2. The upper picture presents the python program where the NI-DAQ card is used for signal acquisition from cavity transmission and for sending feedback to the laser driver. The lower picture presents a web application dedicated for Redpitaya boards.

The relocking algorithms verify the lock by comparing the value of the cavity transmission signal and/or by comparing the frequency difference between preset frequency and frequency measured by the wavemeter. If one of those values is below a predefined threshold, the algorithm starts scanning the PZT to find the target frequency. If the laser is not operating on the single mode, which can be deduced from the wavemeter signal, the algorithm starts scanning the current controller of the laser driver to find the fringe pattern similar to a reference pattern set by the operator.

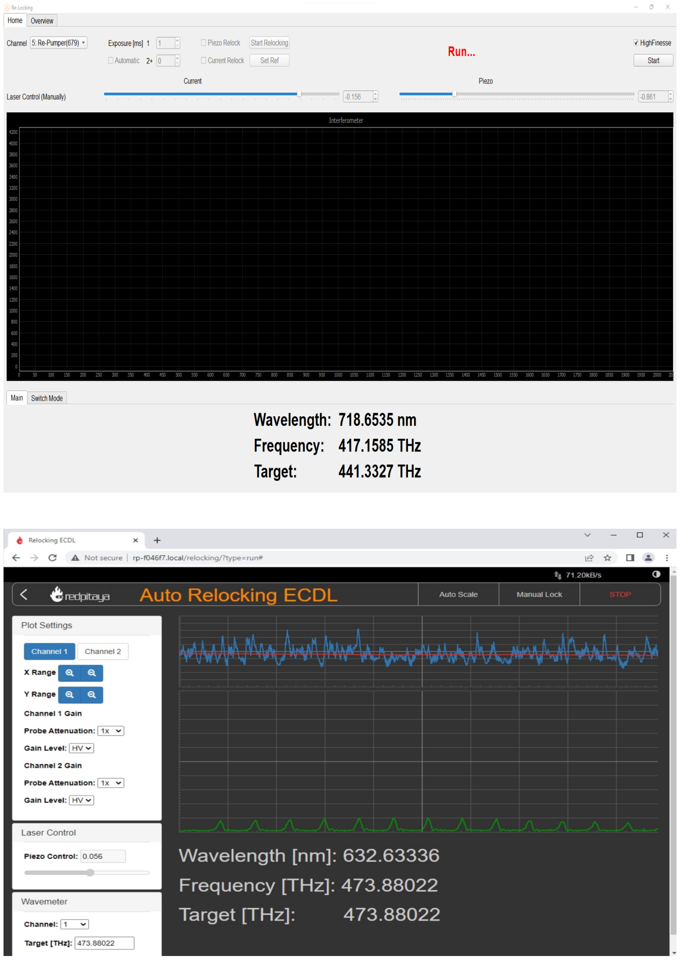

Fig. 2. Software for relocking ECDLs, (upper) Python program for NI-DAQ cards, (lower) web application dedicated for Redpitaya board.

III. Conclusions

We present software packages for frequency stabilization and automatic relocking of ECDLs taking advantage of a cavity transmission and/or wavemeter signals.

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