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Low-cost external cavity diode laser for cold atom experiments

W Temnuch[1,3,4], S Buathong[2,4], P Phearivan[2,4] and S Deachapunya[2,3,4,*]

[1]Department of Physics, Faculty of Science, Kasetsart University, Bangkok Province, 10900, Thailand
[2]Department of Physics, Faculty of Science, Burapha University, ChonBuri Province, 20131, Thailand
[3]Thailand Center of Excellence in Physics, Ministry of Higher Education, Science, Research and Innovation, 328 Si Ayutthaya Road, Bangkok 10400, Thailand
[4]Quantum and Nano Optics Research Unit, Burapha University, ChonBuri Province, 20131, Thailand

*E-mail: sarayut@buu.ac.th

Abstract. In this article, the construction of an external cavity diode laser (ECDL) with the wavelength selection and stabilization given by an interference filter in a cateye reflector mirror type instead of using a common grating Littrow configuration is described. We show that our ECDL can be locked for several hours to a given frequency with the broad temperature variation of about 0.2-0.4 ºC. A rubidium saturated absorption spectroscopy was used to check our ECDL with the D2 hyperfine transitions. Our low-cost and stabilized ECDL can be used for cold atom experiments as well as in quantum and atom optics applications.

1. Introduction

External cavity diode laser (ECDL) is a tunable diode laser and this laser can be tuned to an atomic transition. This property is very essential to conduct atomic experiments and applications such as highly precise grating period measurement [1], the microfabricated atomic clock [2], and investigating two-photon transition in rubidium [3]. Common ECDL designs are the Littrow [4] and Littman-Metcalf [5] configurations employing a diffraction grating for wavelength selection. ECDLs have been developed in order to provide lasers having easier alignment and being less sensitive to acoustic and mechanical disturbances. An alternative method for development of ECDLs is to use narrow bandpass interference filters in cateye reflector mirrors [6,7] for wavelength selection.

In this article, we demonstrate a home-made ECDL in a cateye configuration. The laser frequency is checked by a saturated absorption spectroscopy with the D2 hyperfine transitions of ^{85}Rb as well as ^{87}Rb.

2. Principle and method

The ECDL in a cateye reflection design is a robust and stabilized alignment to mechanical vibration noises. Its basic setup is illustrated in figure 1. The light from a laser diode (LD) is collimated by an aspheric collimating lens (CL). A polarizing beam splitter (PBS) cube acts as an output coupler because rotating the laser diode can modulate the ratio between output and feedback light power. Wavelength selection in cateye reflector configuration is provided from rotating a narrow passband interference filter (IF Semrock, LL01-780-12.5) instead of using the diffraction grating in Littrow configuration. Moreover, this method can ensure that laser operation on a single external cavity mode [6] and the filter rotation does not impact on the sensitivity [7]. The feedback beam is reflected back by a cateye reflector, consisting of lens (L) and a mirror (M) and it is the most efficiency when the lens focuses light onto the cateye mirror. The mirror determines the total external cavity length which can be slightly modified by a piezo-electric transducer (PZT) attached behind the mirror. The cateye reflector leads to narrow linewidths of the laser. Furthermore, increasing the feedback light from the external cavity [8] and the cavity length [7] can help to reduce the linewidth. In order to provide the stabilized frequency, the laser temperature is necessary to be controlled consistently.

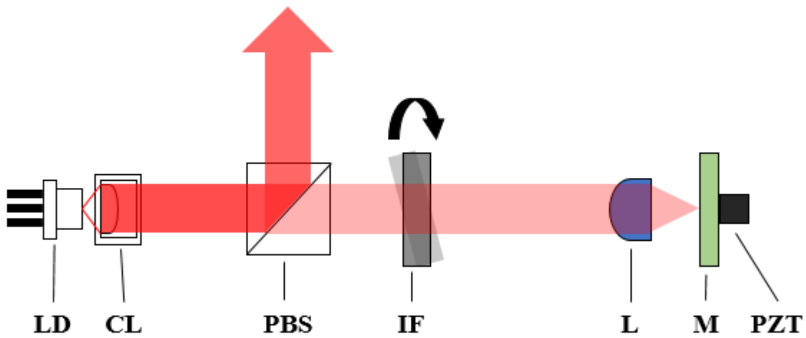

Figure 1. (Top view) Schematic diagram of an external cavity diode laser (ECDL) by using an interference filter (IF) in a cateye reflector mirror type [7]. The output beam is reflected from polarizing beam splitter (PBS) cube (details see text).

The frequency measurement of the ECDL employs a saturated absorption spectroscopy [9]. The emitted beam from the ECDL passes through a vapor cell as a pump beam and then transmits a quarter-wave plate before being reflected back by a mirror in the same path. The probe beam, travelling through the cell again, is detected by a fast photodiode. Signals from the photodiode give spectra of the D2 transition $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ in ^{85}Rb [10] and ^{87}Rb [11]. In addition, the given spectrum is used to lock the frequency on its side of peaks.

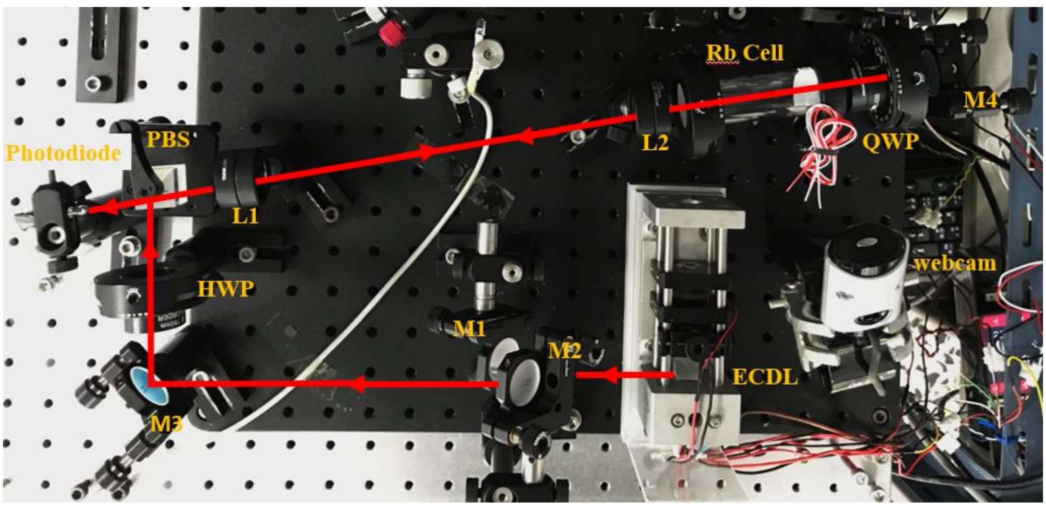

Figure 2. Experimental setup for a home-made ECDL and rubidium saturated absorption spectroscopy (details see text).

3. Experimental setup

The experimental setup is shown in figure 2. We constructed a low-cost ECDL (about 2,000 USD) in a cateye configuration with a laser diode (Thorlabs, L785H1) as a light source with the laser power of about 150 mW. Firstly, the laser temperature had to be controlled by a commercial temperature control circuit (Thorlabs, TCM1000T) to cool down at 20.6 ºC and then a commercial current control circuit (Wavelength Electronics, LDTC0520) injected a current into the laser. A vertically polarized beam from the ECDL was adjusted to a normal height according to other elements by mirrors M1 and M2 (Thorlabs, BB1-E03). Next, it was reflected by a mirror M3 (Thorlabs, BB1-E03) passed through a half-wave plate (HWP) (Thorlabs, WPH10M-780) in order to change the polarization. We used a polarizing beam splitter (PBS) (Thorlabs, PBS202) to select the vertically polarized light for our saturated absorption spectroscopy, while the horizontal polarization was employed for any optical experiments. The light reflected by PBS was expanded by two lenses L1 (Thorlabs, LB1761-A-ML) and L2 (Thorlabs, LB1945-B-ML) to cover with a rubidium vapor cell (Precision Glassblowing, TG-ABRB). After it was transmitted through a quarter-wave plate (QWP) (Thorlabs, WPQ10M-780), reflected by a mirror M4 (Thorlabs, BB1-E03) and traversed through the QWP again to change the laser polarization from vertical to horizontal polarization. The reflected beam traveled to a photodiode (Osram, SFH213) with the same path to detect rubidium saturated absorption signals shown on an oscilloscope screen. The method of tilting the surface of elements was used to prevent the light from reflecting back to the laser diode. We increased the laser current continuously until we observed the fluorescence in the Rb cell by using a webcam as an IR camera. Meanwhile, we used a home-made servo-lock circuit to scan the external cavity length to find the saturated absorption spectra related to the D2 hyperfine transitions by changing the voltage for the piezo scanning.

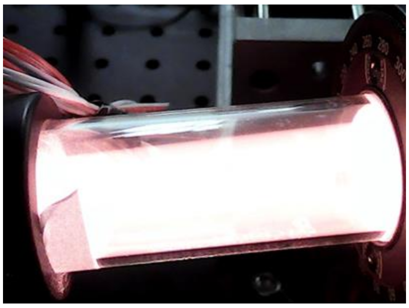

Figure 3. Fluorescence of the rubidium cell.

4. Results and discussion

Here, we show the experimental results with the laser temperature at about 20.6 ºC. To test the laser frequency with the saturated absorption spectroscopy, the laser current was adjusted until the fluorescence appeared in the Rb cell as shown in figure 3. Meanwhile, the piezo actuator was scanned by the voltage ramp (blue lines in figure 4) with the scanning frequency at 15 Hz to find the spectra of rubidium D2 hyperfine transitions (red lines in figure 4). In figure 4, each spectrum is related to excitation of the transition $5^2S_{1/2} \rightarrow 5^2P_{3/2}$ in two rubidium isotopes from different hyperfine ground states (F) : ^{85}Rb $F = 3 \rightarrow F'$ (a), ^{85}Rb $F = 2 \rightarrow F'$ (b), ^{87}Rb $F = 2 \rightarrow F'$ (c) and ^{87}Rb $F = 1 \rightarrow F'$ (d). Each of the spectra was found at the variation of laser currents. For locking the frequency, we used the servo-lock circuit to lock the frequency at one side of the spectrum. The given one was locked for up to 10 hours with the broad temperature (20.2 - 21.0 ºC) within the frequency stability in the range of 30 MHz and the laser linewidth of below 9 MHz was measured by a scanning Fabry-Perot interferometer (Thorlabs, SA210-5B) and confirmed with the appearance of the ^{85}Rb $F = 3 \rightarrow F' = 4$ transition.

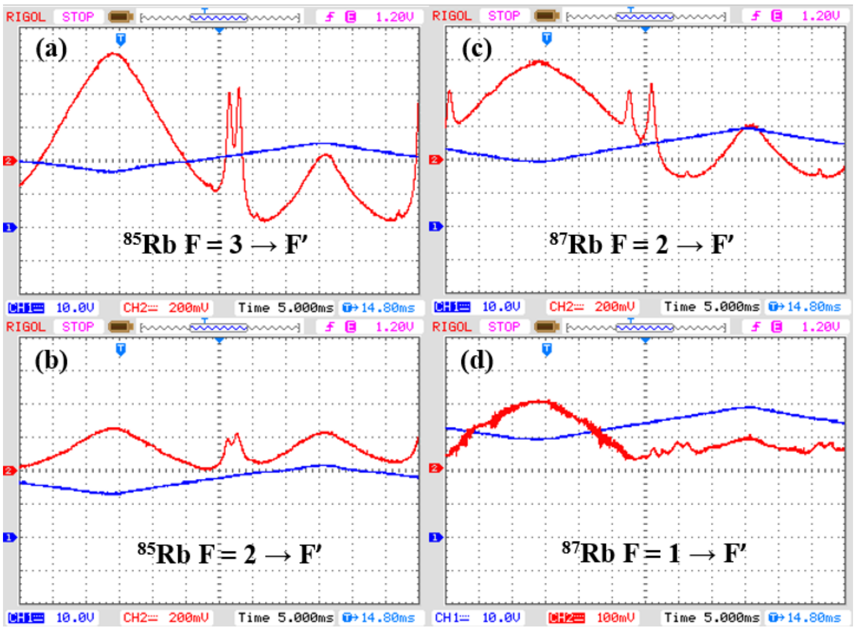

Figure 4. Oscilloscope screens showing the supply voltage of piezo actuator (blue lines) and saturated absorption spectroscopy signals from different hyperfine ground states (F) (red lines) of (a) ^{85}Rb $F = 3 \rightarrow F'$, (b) ^{85}Rb $F = 2 \rightarrow F'$, (c) ^{87}Rb $F = 2 \rightarrow F'$, and (d) ^{87}Rb $F = 1 \rightarrow F'$.

5. Conclusions

We show that the home-made external cavity diode laser (ECDL) in the cateye configuration without the box cover can be frequency-locked for up to 10 hours even though the temperature always changes about 0.2-0.4 °C. Moreover, we still demonstrate the clear spectra of all D2 hyperfine transitions in both ^{85}Rb and ^{87}Rb by using the rubidium saturated absorption spectroscopy to check the frequency of our ECDL. Our low-cost and frequency stabilized ECDL can be applied for cold atom experiments.

Acknowledgments

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