DEVICE FOR EDUCATION OF FREQUENCY STABILIZATION OF SEMICONDUCTOR LASER BY LINEAR ABSORPTION

Bohdan RŮŽIČKA, Doctoral Degree Programme (3)
Dept. of Radio Electronics, FEEC, BUT
E-mail: ruzicka@isibrno.cz

Supervised by: Dr. Otakar Wilfert

ABSTRACT

In this contribution we describe a device which was developed to demonstrate frequency stabilisation of semiconductor laser by linear absorption. The usage of absorbents for frequency stabilization in metrology and telecommunications is very progressive. This is original solution and it is intended for practical teaching students of optoelectronic courses.

1 INTRODUCTION

In near future, most of commercial optical communication systems will operate on the principles of wavelength division (WDM) multiplex. Sources of coherent light with standardized wavelength are used in these systems. The coherent light is modulated by carried signal. It is necessary to ensure the wavelengths were accurately tuned on wavelengths which are determined by the standard.

Current optical standards are realized as one-frequency lasers which use optical non-linearities caused by transitions in absorption medias. These systems are able to achieve high stability of frequency (till 10^{-11}). The stability of frequency of semiconductor lasers is considerably dependent on operational supply current and on chip temperature. That is why it is useful to minimalize fluctuations of the main operational parameters. A laser diode is very sensitive to static electricity and EM interference. Its quality shielding and galvanic separation of signal wires from supply wires is not useless complication.

This branch is taught in the Technical University of Brno only on the theoretical level. This appliance brings practice into classwork and enables education more efficient. We used linear absorption instead of saturated absorption. Linear absorption provides worse results than saturated absorption but it is more suitable for demonstrating purposes thanks to its simplicity.

2 THE CONFIGURATION

Our design respects these aspects:

High mechanical endurance. Seeing that this device will be used as the educational one is necessary to protect it against rough handling. The optical components are fragile.

Simplicity and lucidity. This makes easier understanding of difficult subject matter.

Safety factors. The device uses max. 5 mW laser diode, emitting in the visible region of spectra (635 nm), to protect user's eyes.

We would like to describe our technical solution in the next paragraph. It is divided into two parts, mechanical and electrical configuration.

2.1 MECHANICAL ARRANGEMENT

We used a massive duralumin frame. That was essential in the face of considerable proportions. A covering, made of clear plexiglass, was also made. It protects delicate optical components and preserves users against laser light. The schematic diagram is shown in Fig. 1.

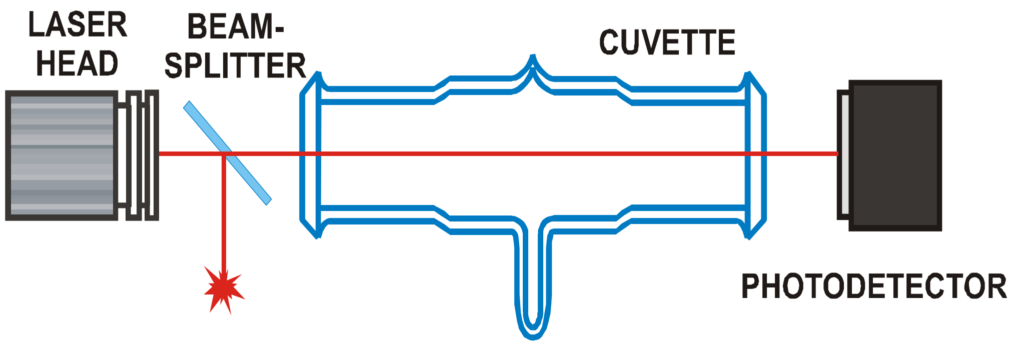

Figure. 1: The schematic diagram.

We chose iodine vapour as the absorption medium. Absorption lines of iodine are placed in the visible region of spectra. The burette with iodine vapour is operated at ambient temperature. It becomes less precise but it is technically simpler.

The laser head with a semiconductor laser diode generates laser-beam, which is devided into two directions by the beam splitter. One part is used for laser frequency stabilization while another one is intended for spectral profile analysis. Analogue signals from photodetectors are converted to digital and processed in a personal computer. The personal computer generates frequency regulation action signal for lock-loop according to level of absorbed laser light power in the iodine cuvette. The next task for the computer is to tune resonator over the laser-beam peak. Received signal from the photodetector is adequate to laser spectral profile. The view of the whole device is shown in Fig. 2.

2.2 ELECTRICAL ARRANGEMENT

THE CURRENT CONTROLLER

The current controller regulates the laser current by comparing a reset voltage with feedback voltage proportional to the laser current (Fig.3). It is a traditional design based on a single operation amplifier described in [1,2,3]. The controller uses a sense resistor in series with the laser diode to produce a voltage which is compared to a stable reference voltage.

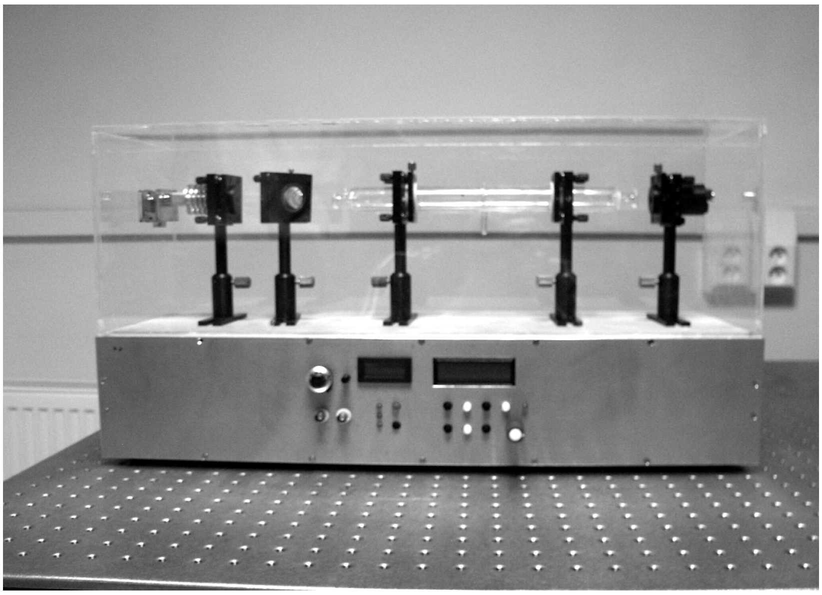

Figure 2: *The photo of the whole arrangement.*

The laser diodes emitting on short wavelengths are well known for their sensitivity to electric transients [5]. That is why the great care was taken to ensure safe switching of the laser diode even in case of power drop-out. The supporting circuitry generates smooth rising and falling current ramps. The laser diode is also switched off by relay Re1 which short-circuits the output of the voltage reference. The resulting sharp voltage edge is filtered by the following low-pass filter with the cut-off frequency 1 Hz to a smooth ramps. The manual setting of the current zero level before switching off is not necessary. When the current source is not in operation, the pins of the laser diode are short-circuited by a relay Re2 placed in the small box attached directly to the laser diode mount.

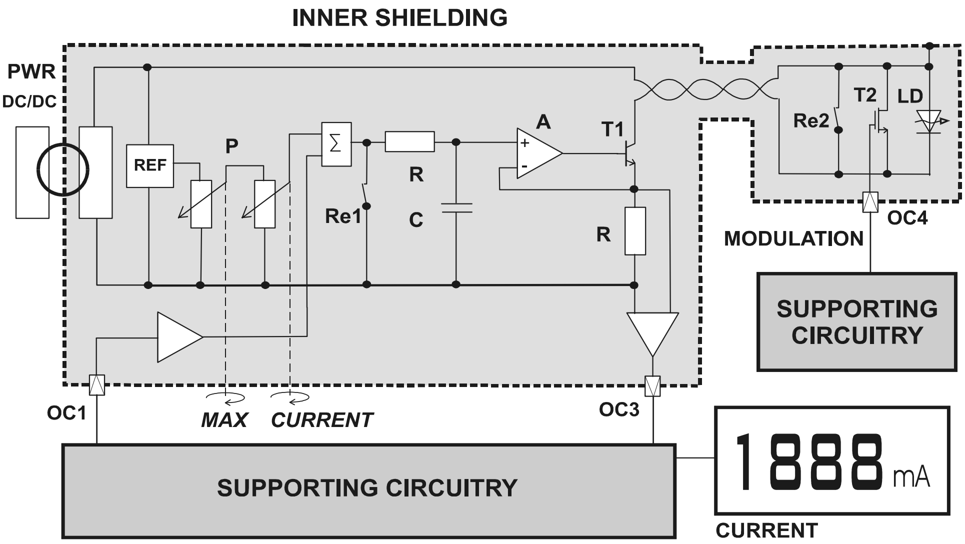

Figure 3: *Simplified block diagram of the current controller.*

The correct turn-off is secured also in case of power drop-out. The current-controlling core is supplied by a large capacitor for a duration needed to go down with the current smoothly. The controlling relay Re1 turns off the reference voltage immediately after the drop-out and stays off even if the power supply is restored. Then it must be switched on manually.

When the current source is properly designed, dangerous transient pulses can get to the laser diode only by induction from the outside. To suppress this effect, it is necessary to use a proper shielding. The laser diode is connected via a double shielded twisted cable. Circuits of current controller are galvanically isolated from the outside and also enclosed in a double shielding. The outer shielding is connected to the common ground. The ground current as well as the current induced to the ground-loop closed by the outer shielding may flow through it. Strongly suppressed interference generated inside is further shielded by the inner shielding which is floating including the LD housing. The inner shielding is not a signal-carrying conductor. The current controller is equipped with an input for slow current tuning of the laser frequency and an output from the built-in photodetector. Both are galvanic isolated using linear optocouplers (HCPL 7800). Our current driver can provide up to 150 mA of the current.

THE TEMPERATURE CONTROLLER

The laser diode is housed in the copper mounting block. There is placed a temperature sensor AD22100 as close as possible to the laser diode package with respect to maintenance of the shortest time delay of the heat transfer between the laser diode and the sensor. Data from the temperature sensor are digitalized and processed by a programme in microcomputer, MCU (DSP56F805), where an action value for the Peltiér's element is calculated [6]. The Block diagram of the digital temperature controller is in Figure 4.

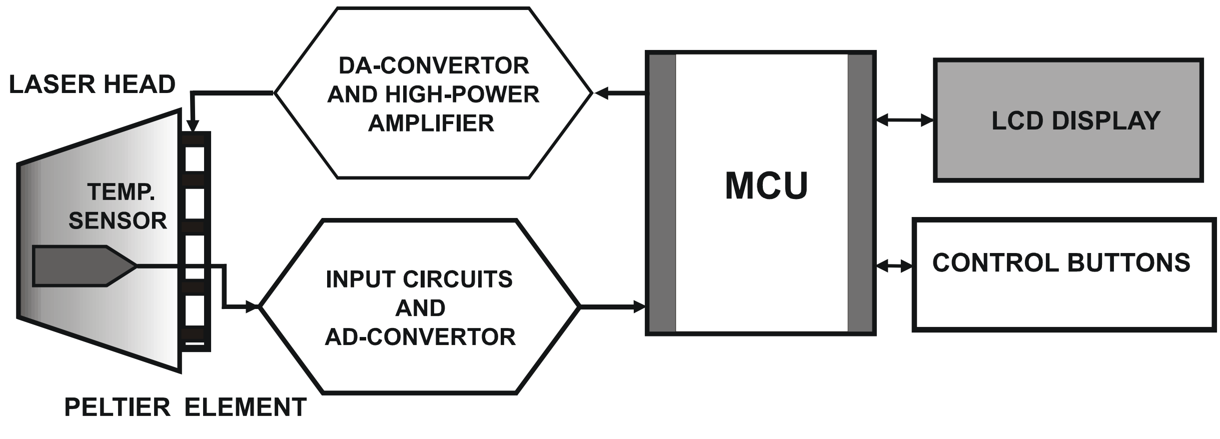

Figure 4: *Block diagram of the digital temperature controller.*

The copper block is mounted through Peltiér's element on a large aluminium cooler. The Peltiér's element driven by DC current works as a thermal pump. Direction of the flow and amount of the pumped heat is determined by a polarity and an intensity of instantaneous value of the DC current. This value is driven by MCU on the basis of data from the temperature sensor. This forms a servo-loop. When the servo-loop is closed, the programme in the MCU performs the PID regulation algorithm. The MCU can operate in several regimes where the main of them is the continuous temperature stabilization of the controlled laser diode. It can measure also the instantaneous value of the laser diode temperature during open servo-loop. The MCU also provides the self-learning process of particular component of the PID regulation.

3 CONCLUSION

We have made a record of frequency spectrum noise of emitting laser light. It showed the presence of a quantum white noise and 1/f noise which are typical for all lasers. No other significant spectral components can be seen. The long-term measurement was performed as well. The current produced by the instrument was measured for ten hours at a stable ambient temperature. The current drift is inconsiderable.

We would like to target at a development of the controlling locking-loop by means of personal computer. The programme LabVIEW (fi. National Instruments) is in consideration. The usage of computer technique will lead to a modern solution.

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