Technical description and instruction manual of the extended cavity diode laser ECDL-4810RM (S/N 061096).

The extended cavity diode laser ECDL-4810RM is a tunable source of high-coherent radiation in near infrared. The central wavelength of the working range is 487 nm. However, the detuning of 1 nm to short and long wavelengths is possible. The laser can be used in metrology, spectroscopy and interferometry.

ECDL-4810RM consists of an optical head and an electronic unit connected by a cable via connectors DHS-15. The standard length of the cable is 1.8 m. The plug of the electronic unit must be inserted into the **earthed socket**. The optical head is grounded. However, it is necessary to remember that there is a high voltage (200V) supplying piezo-element under the lid of the optical unit. The piezo-element is accessible when the lid is taken off.

The optical head.

The optical head (Fig.1) consists of a laser diode heat-sink (pos.1), an antireflection coated laser diode (LD) with an aspheric objective C230TME-A (N_A=0.55; f=4.5 mm; output aperture – 4.9 mm), thermoelectric microcoolers (Peltier elements), thermosensors mounted into the laser diode heat-sink and into the case of the optical head (two 10 kOhm thermistors). The laser diode is rigidly integrated with the collimating objective in a common module. The common module with the attached mirror (pos.2) is inserted into the heat-sink. The mirror (R=15%) extracts part of laser radiation out of the optical cavity keeping the laser beam unmoved during the wavelength tuning.

Two loops of thermostabilization keep the temperatures of both the heat-sink and the case (pos.7) constant regardless of each other, such that the case of the optical head serves as a radiator of an internal loop of thermostabilization and the base of the optical head serves as a radiator of an external one. The base of the optical head has longitudinal side slots to mount the head onto an optical table. The mounting of the optical head has to provide efficient heat removal from its base.

The optical cavity of the tunable laser is formed by the rear high-reflective facet of the laser diode (SAL-0488-010) and the Littrow diffraction grating (1200 grooves/mm) operating in a second order (pos.3). The grating is attached to a horizontal shaft, which defines the proper direction of the laser beam diffraction. A piezo-element (pos.6) varies simultaneously the incidence angle of the laser beam and the cavity length. This allows extending the range of continuos tuning. The adjustment screw (pos.5) rotating the grating realizes the coarse tuning of the laser wavelength.

The precise matching of the wave reflected from a grating and the incident one is crucial for an extended cavity diode laser to obtain high coherence and significant output power at the same time. The ECDL-4810RM does not have control knobs to adjust the position of the collimating objective in respect to the laser diode and to align the laser beam in vertical direction. All these important settings require serious skills, and they are made on an assembling stand in advance. In the case of laser diode degradation the common module of a laser diode and a collimating objective must be replaced as a unit.

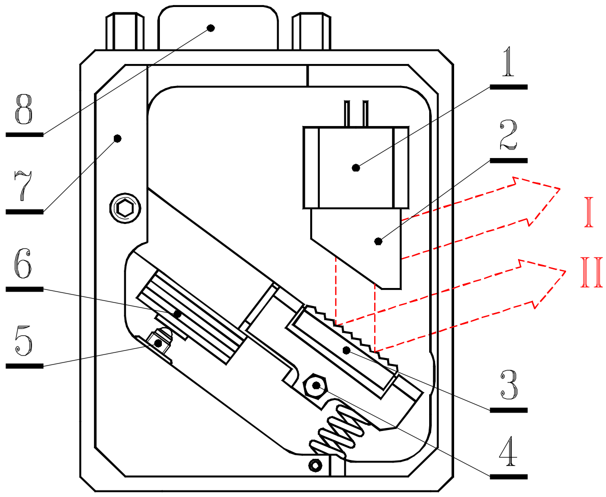


Fig.1. The optical head (top view, a lid is off). 1 – the laser diode heat-sink; 2 – the mounted semitransparent mirror; 3 – the diffraction grating attached to the horizontal shaft; 4 – the vertical M2 lock-screw; 5 – the horizontal M3x0.25 tuning screw; 6 – the piezo-element; 7 – the case of the optical head; 8 – the connector DHS-15F; **I** – auxiliary (unmoved) output; **II** – main output (zero order of the diffraction grating).

Contrary to the collimating objective the vertical alignment of the laser beam still remains possible even after demounting of the ECDL from the assembling stand. The horizontal axle (horizontal shaft) of the diffraction grating is gripped by a collet. The collet closes or opens when the vertical lock-screw (pos.4) is turned clockwise or counter-clockwise respectively. The slightly asymmetrical grip of the horizontal axle in the collet rotates the axle when the screw locks the collet. Typically clockwise rotation of the lock-screw moves the laser beam up; counter-clockwise rotation moves the beam down. **Do not rotate the lock-screw more than a quarter of a turn!** Otherwise it might be broken or the horizontal axle might be completely released. If more beam shift is necessary, then the Γ-shaped lever from the maintenance kit must be used. It can be inserted into the slot of the shaft butt-end and fixed by M2 screw. The horizontal shaft rotates freely when the lock-screw is loosened. One can tight the lock-screw after alignment taking into account the above mentioned axle rotation during tightening.

Typically the output beam of a laser diode is astigmatic. Therefore, sometimes the most effective optical feedback is achieved at the slightly convergent output beam, that is to say the inessential convergence ($\sim 2\times10^{-3}$) of a laser beam does not demonstrate the wrong alignment of the ECDL.

The electronic unit.

The electronic unit (ULDC112 – the universal laser diode controller) controls the laser diode current and temperature, the temperature of the laser case, and the length of an external part of the laser cavity with accuracy sufficient to get the required output characteristics of the ECDL-4810RM. An analog power supply provides all voltages essential for control circuits: stabilized ±15V, +200V, ±5V and unstabilized ±6V. There are three fuse sockets under the unit lid close to the line connector. One socket corresponds to the line voltage of 240V AC, another one – to the voltage of 220V AC and third one – to 117V AC. **Only one fuse of 2A must be inserted into the relevant socket!** One more fuse of 100 mA (F1 from Fig. 6) protects the output of the high-voltage power supply from the abridgement. To open the unit lid unscrew four screws from the unit bottom.

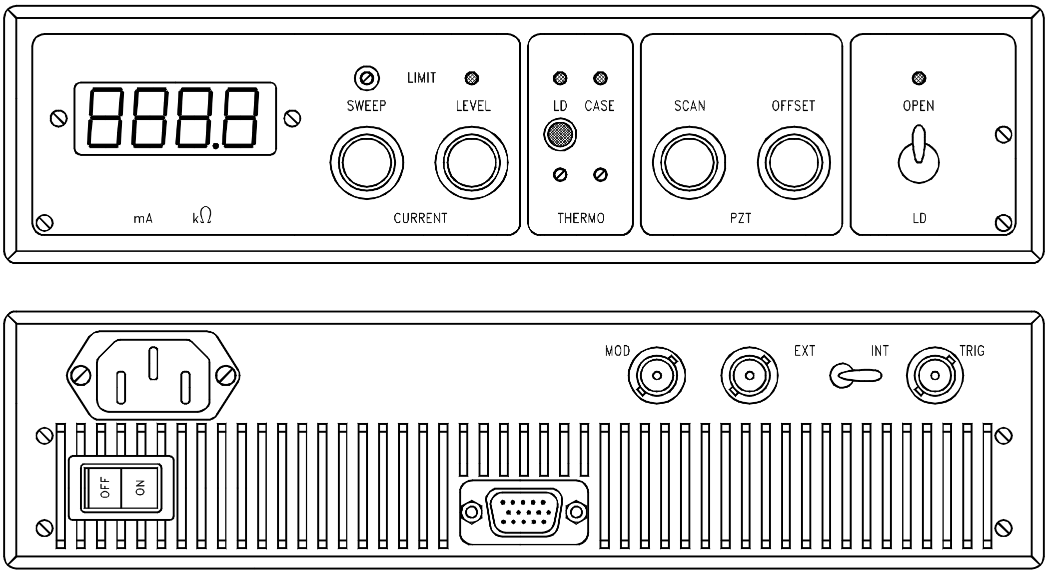


Fig.2. The front and rear panels of the electronic unit.

There are few functional zones on the front panel of the electronic unit reflecting operation of a current source (CURRENT), a temperature controller (THERMO), a high-voltage amplifier (PZT), and a laser diode shunt (LD) (Fig.2).

The CURRENT zone includes a digital monitor, control knobs of LD current level (LEVEL), scan amplitude (SWEEP), and current cut-off (LIMIT). A red light emitting diode (LED) is on in the case of current limitation. The maximum current value of the electronic unit (ULDC112) is 150 mA. The full scan amplitude of the current is about 40 mA.

The internal triangular-wave generator can modulate the LD current at line frequency and its sub-harmonics **f**, **f/2**, **f/4**, **f/8**. To set frequency of modulation, only one corresponding jumper of the DIP-8 switch on the printing board (SW5) must be set in position ON. Taking into account the low-frequency mechanical resonance of the laser cavity, the frequency **f/2** (that is 30 Hz for USA and 25 Hz for Europe) is preset in ECDL-4810RM. The higher frequencies might be used, if the high sweep rate is important and the excess amplitude ripple in the vicinity of the extremum of the modulation signal can be neglected. The trimmer of current cut-off (LIMIT) is located above the SWEEP knob. Such a current limitation might be necessary to prevent degradation of a laser diode due to accidental current overload. The current overload indicator is located to the right from the corresponding trimmer.

The THERMO zone includes two trimmers of temperature adjustment for internal (LD) and external (CASE) loops of thermostabilization. Clockwise rotation of the trimmers results in increase of the object temperature. Two double-color LEDs are above the corresponding trimmers. They reflect the state of the thermoloops. The absence of any light in THERMO zone indicates the regular temperature regime of a laser diode and a laser case. The green color of a LED informs on active cooling of the corresponding object, that is the outer temperature is higher than the pre-set object temperature. The red color of a LED displays heating (the outer temperature is below the pre-set temperature). The LEDs in the THERMO zone lights red too when the optical head and the electronic unit are both disconnected.

The pushbutton in the THERMO zone is required to indicate the value of the reference resistor, which sets the temperature of a laser diode. The display of the ULDC112 reads its resistance in kiloohms at the pressed pushbutton.

The PZT zone includes the knobs of alternative (SCAN) and constant (OFFSET) voltages applied to piezo-elements. The control signal of a high-voltage amplifier is similar to the one of a current source, and the relative phase of two signals allows realizing the synchronous change of the LD current and the laser cavity length. This expands the continuos tuning range of the output laser frequency. To scan piezo the full resource of the high-voltage amplifier can be used providing ±200V. The maximum PZT tuning is obtained at neutral position of the OFFSET knob. The constant phase difference between the signal of an internal oscillator and a line frequency allows minimizing the influence of line pickup under optical data recording.

The LD zone includes a switch of a laser diode shunt and an indicator of the shunt state. It is recommended to keep a laser diode shorten (the LED does not light) at the moment of electronics switching on and then till the changeover of the LD and case temperature to a steady state. When the LD switch is on (position OPEN, the LED lights green) the shunt changes its value from about 4 Ohm to tens MOhm during a few seconds removing a short circuit and protecting the LD from the transients. Also the shunt protects a laser diode from a current overload when one of the ±15V voltages breaks down.

The line connector, the input connector for high-frequency (up to 50 kHz) current modulation (MOD), the input connector of an external control signal, the switch of a control signal (EXT-INT), and the output connector of the built-in generator (TRIG) are placed in the upper row of the rear panel. There are the power switch and the optical head connector (DHR-15M) in the lower row. The triangular signal of about $5V_{p-p}$ from the TRIG output can be used to control or to synchronize external devices. In order to control the output frequency of the ECDL-4810RM by an external signal the EXT-INT switch must be set into the EXT position. In this case the output of the built-in sweep generator is disconnected from the inputs of the current source and the high-voltage amplifier, and the TRIG output duplicate the external signal. The signal from the MOD connector is directly coupled to the current source regardless of position of the EXT-INT switch.

Activation of the ECDL-4810RM.

1. Connect the cable between the optical and electronic units.
2. Check up the settings of the SWEEP and LEVEL knobs. They have to be in the extreme left position.
3. Turn on the power supply switch on the rear panel of the electronic unit and wait until the LEDs in the THERMO zone stop flashing.
4. Turn on the laser by the LD switch and set the recommended current.

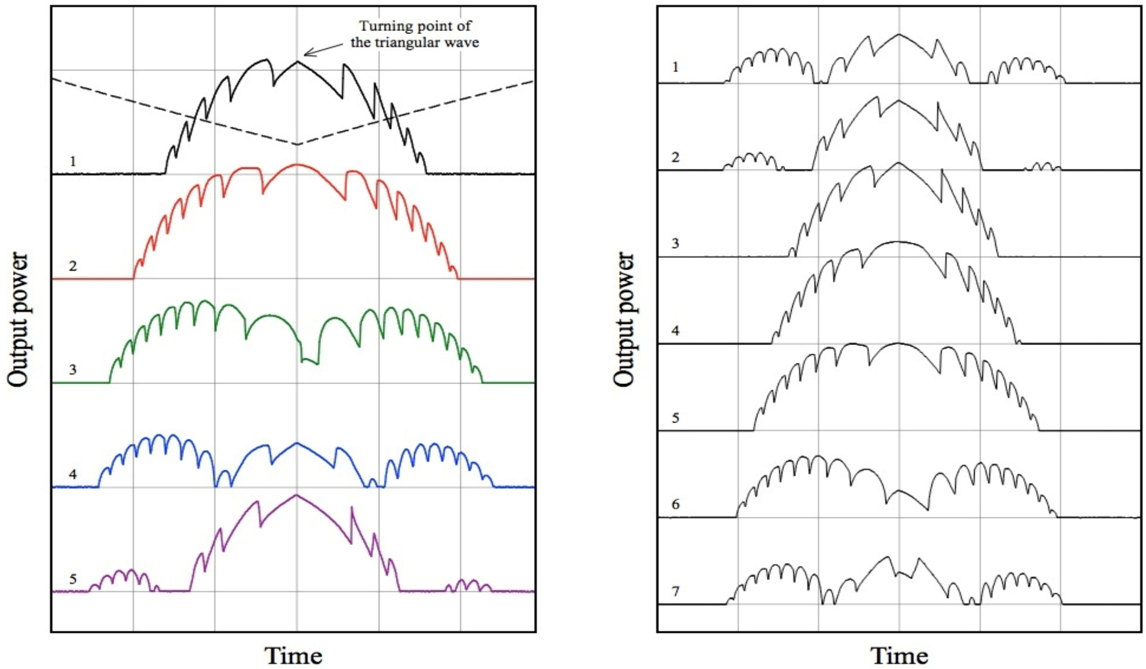
Disabling the ECDL-4810RM.

1. Set both the AC and the DC to zero (the SWEEP and LEVEL knobs are in the extreme left position).
2. Turn off the laser current by the LD switch.
3. Switch off the power supply.

Frequency tuning and alignment of the ECDL-4810RM.

The mechanical stability of the ECDL-4810RM is high enough to keep the laser output in close vicinity of the particular wavelength (say atomic transition) for weeks, so that the LD current and the PZT voltage remain the only means to tune the laser precisely to this desirable wavelength. However, the degraded characteristics of the ECDL (increasing of the threshold current, output power reducing, tuning range reducing, poor side-mode suppression ratio, amplitude noise increasing) might indicate that realignment of the extended cavity is necessary.

The following experimental data specify the operation of the ECDL-4810RM and might serve as references for its alignment.



a) b)

Fig.3. The dependencies of the output power on the LD current at different positions of the diffraction grating. The LD current is changed by the symmetrical triangular wave (shown by dashed line). **a)** The position of the diffraction grating changes monotonously in one direction from curve 1 to curve 5 by tuning screw. **b)** The position of the diffraction grating changes monotonously from curve 1 to curve 7 by the knob OFFSET. The curves are shifted vertically in respect to each other to make the picture more readable.

Fig.3 shows a family of oscillograms which correspond to dependencies of the ECDL output power on the LD current at different positions of the diffraction grating in the diffraction plane. The signal of the built-in triangular wave generator is used to synchronize oscilloscope and to control the laser current. The LD current linearly changes in time and a photodetector registers the corresponding change of ECDL power.

The practically flat regions at the bottom of the oscillograms correspond to subthreshold regime of the ECDL. The LD current change causes variations of the temperature and the index of refraction of the LD gain medium and hence the change of the optical length of the LD and of the whole ECDL cavity. The frequent steps on the power-on-current dependencies are resulted from the extended cavity mode hops.

The residual reflection coefficient of the LD front (output) facet is small enough to prevent LD lasing. However the LD eigen modes are not entirely suppressed. This explains the nonmonotonous behavior of the output power with the linear change of the current, clearly observable on the curves 3, 4, 5 of Fig.3a and 1, 2, 6, 7 of Fig.3b. The power increases when the LD mode gets closer to the wavelength of the maximum grating reflection and reduces when it gets farther. The lasing may even stop when two neighboring modes are equally far from the peak of grating reflection (curves 5 of Fig.3a and 1, 2 of Fig.3b).

The monotonously increasing numbers of the curves 1 – 5 of Fig.3a and the curves 1 – 7 of Fig.3b comply with the diffraction grating shift in one direction. Thus, the curves 1 and 5 of Fig.3a and the curves 1 and 7 of Fig.3b practically close the cycle of relative frequency detuning of the LD eigen mode and the peak of grating reflection.

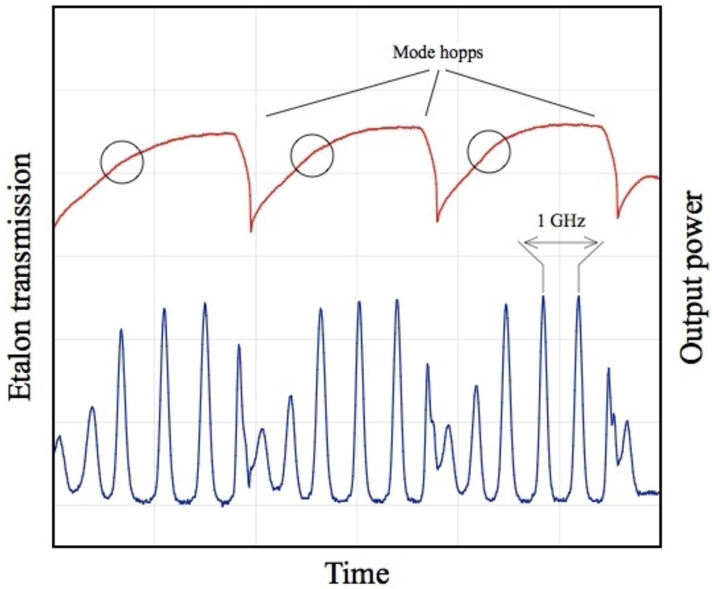


Fig.4. The output power (red curve) **and the transmission of the Fabry-Perot etalon** (blue curve) **on the PZT voltage sweeping.** The LD current is constant.

The next oscillograms (Fig.4) are recorded at the constant LD current and the linear sweep of the PZT voltage. They show, how three consecutive mode hops are reflected in the output power (upper red curve) and in the transmission of a Fabry-Perot etalon (lower blue curve). The zero power level is far below outside of the screen. The transmission peaks of the etalon demonstrate the continuous tuning range of 5 GHz, though the contrast of the peaks reveals that the extended-cavity laser operates in a high-coherent regime only half of this range. The switch-over from the low-coherent regime to the high-coherent one might be diagnosed using just a power dependence on the tuning parameter (PZT voltage, current, etc.): the smooth power change indicates high-coherent regime, while the kinks and fractures inform about some instabilities (mode competition, parasitic optical feedback and so on) degrading the laser linewidth. Such a switch-over in our case is marked by black circles on the red curve.

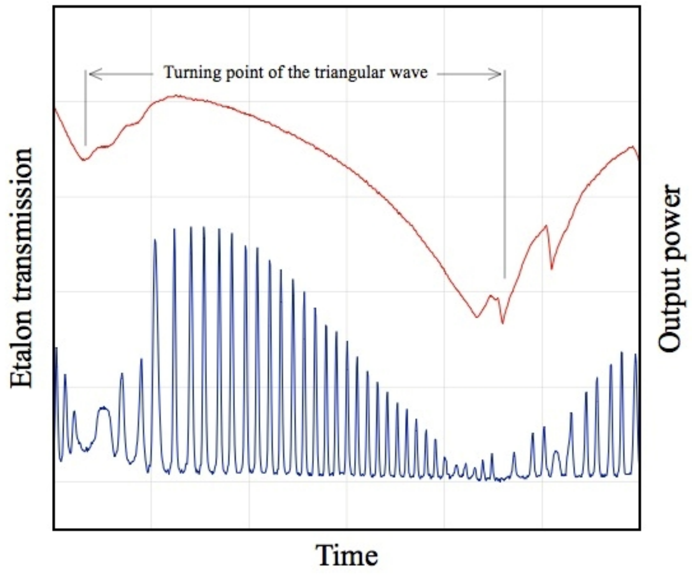


Fig.5. The output power (red curve) **and the transmission of the Fabry-Perot etalon** (blue curve) **at the synchronous scan of the piezo and the LD current**

It is possible to expand continuous tuning range of the ECDL using united tuning of the LD mode, the extended-cavity mode, and the peak of the grating reflection. This is achieved by the synchronous sweeping of the piezo voltage and the LD current. The Fig.5 demonstrates such full-scale tuning of the ECDL-4810RM. The PZT scan is set close to the maximum, while the current scan and the DC levels of the LD current and the PZT voltage are found experimentally to avoid mode-hops inside the full tuning range.

Follow the way below if the laser realignment is necessary.

1) Insert the Γ-shaped lever into the slot of the horizontal axle of the grating.

2) Find the direction in which the lever decreases the LD threshold. Gently press the lever up and down for this.

3) The clockwise rotation of the lock screw (Fig.1, pos.4) is applied if the motion of the lever down (i.e. the laser beam reflected from the grating goes up) reduces the threshold. The counter clockwise rotation is needed at the up-level position. Use a wrench number 4 to rotate the lock screw. Typically few degree rotation of the screw is enough to restore the operation of ECDL-4810RM.

4) When the minimum of the threshold current is achieved, set if necessary the operation wavelength by tuning the horizontal screw (Fig.1, pos.5) which is accessible even in fully assembled optical unit.

Appendix I. The circuits and the layout of the ULDC112.

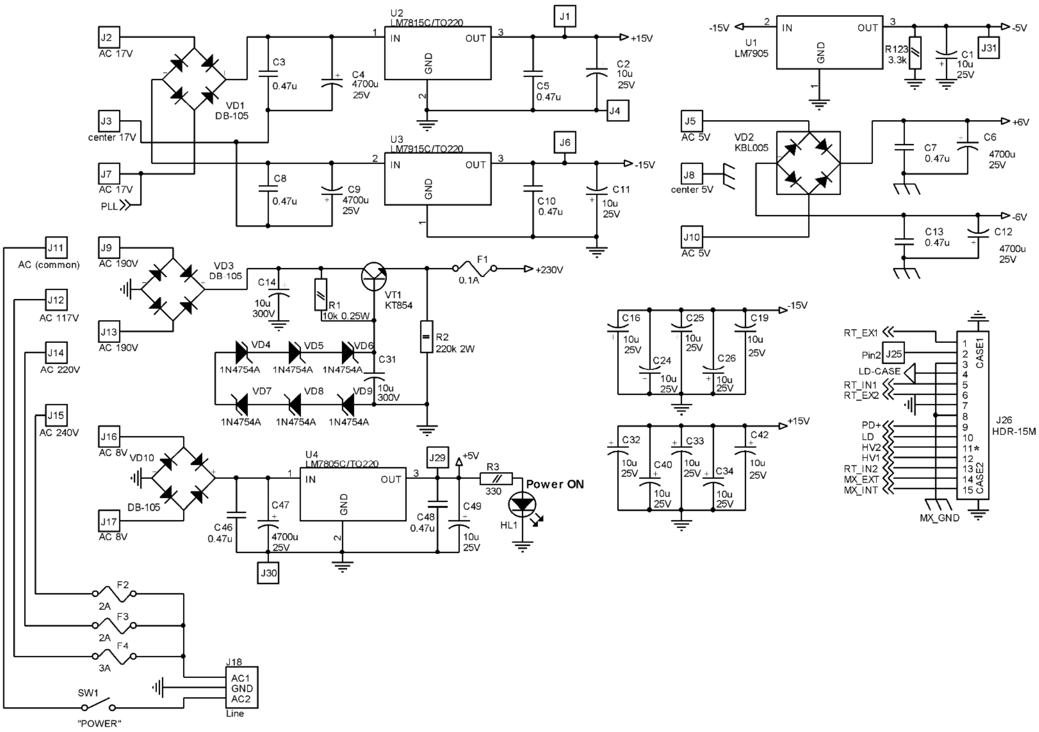


Fig.6. The circuit of the power supply.

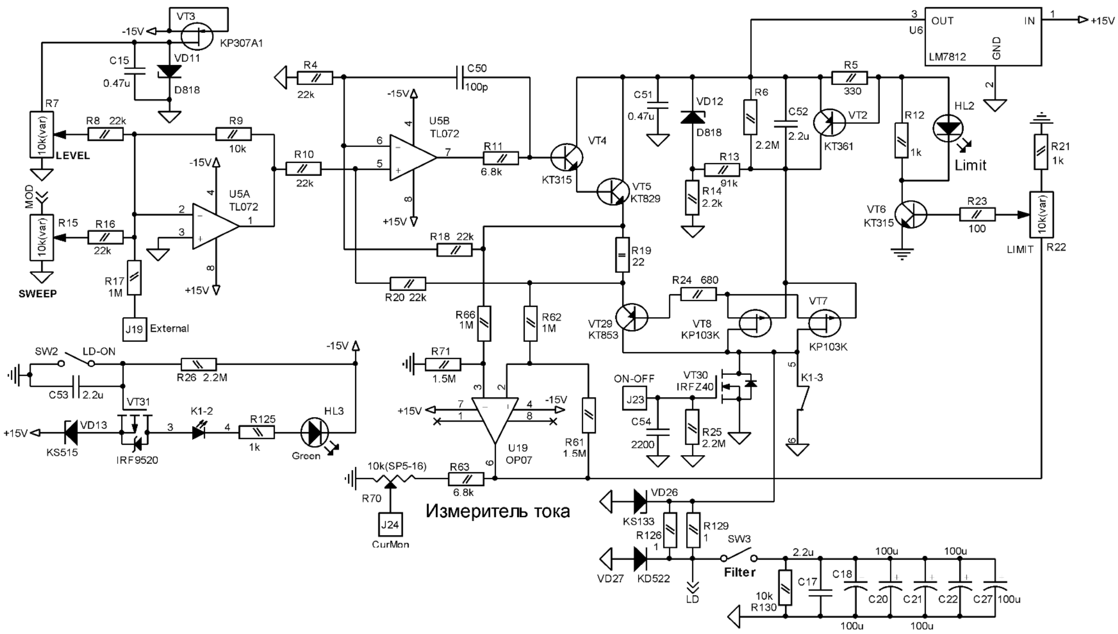


Fig.7. The circuit of the current source.

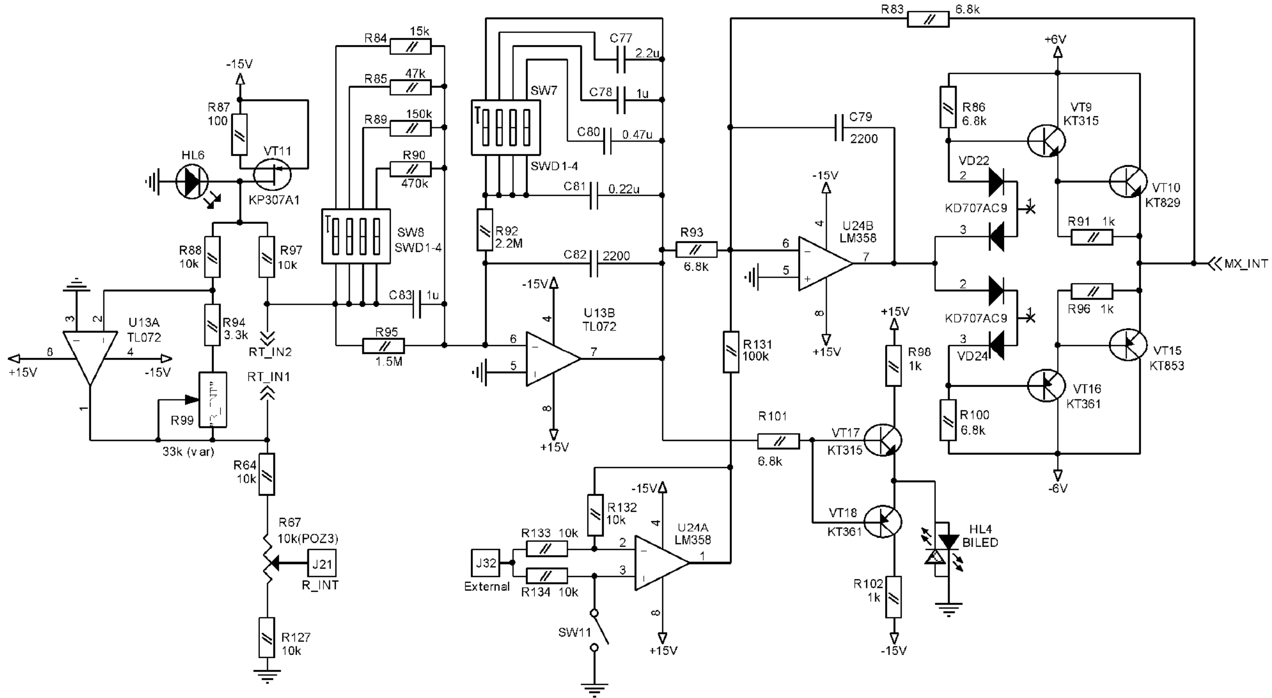


Fig.8. The circuit of the internal temperature controller.

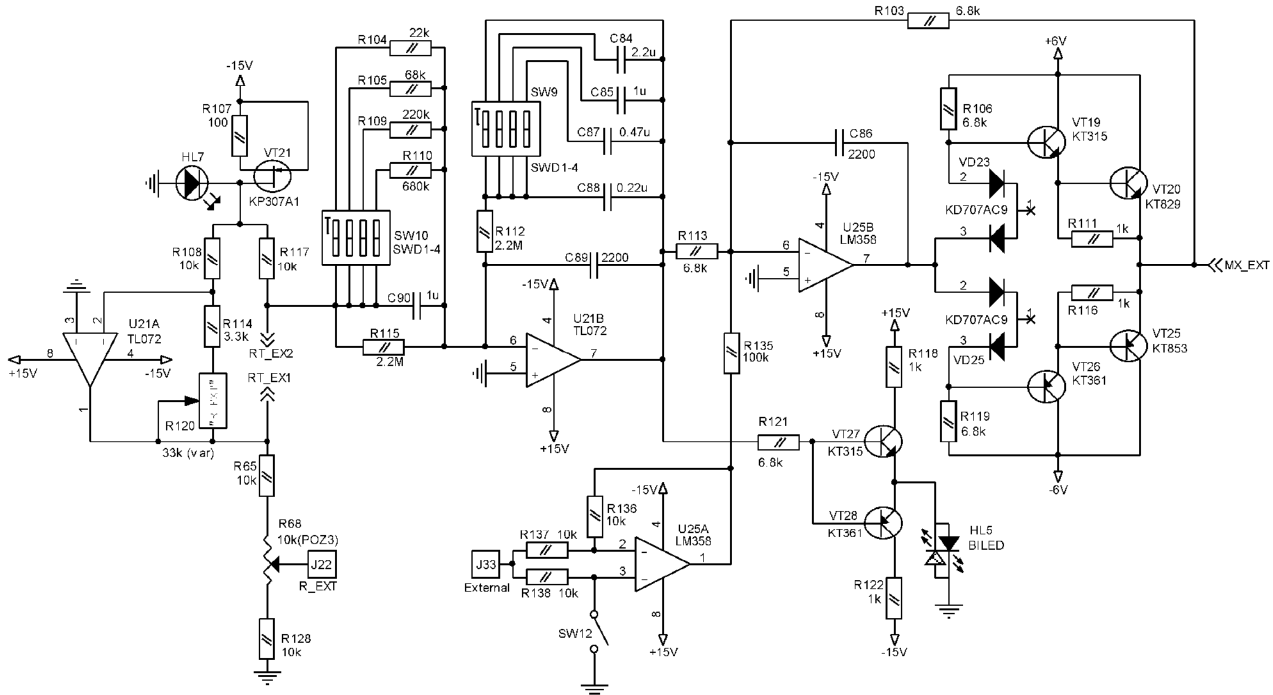


Fig.9. The circuit of the external temperature controller.

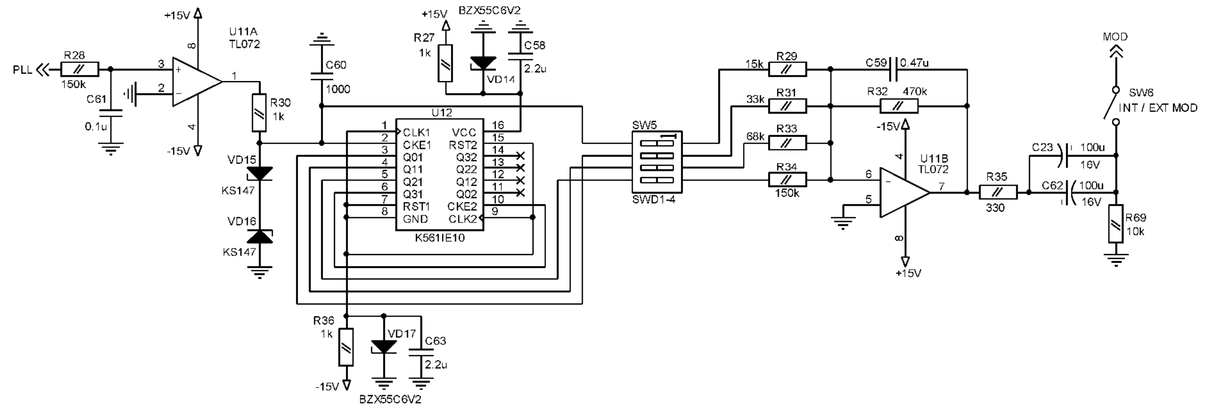


Fig.10. The circuit of the triangular-wave generator.

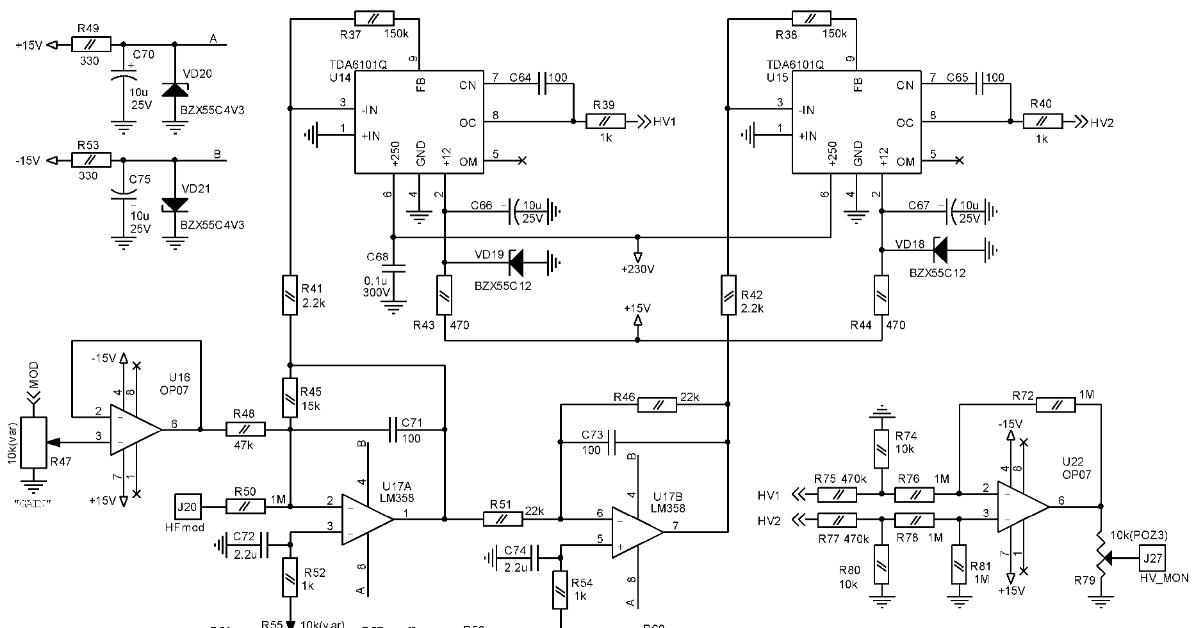


Fig.11. The circuit of the high-voltage amplifier.

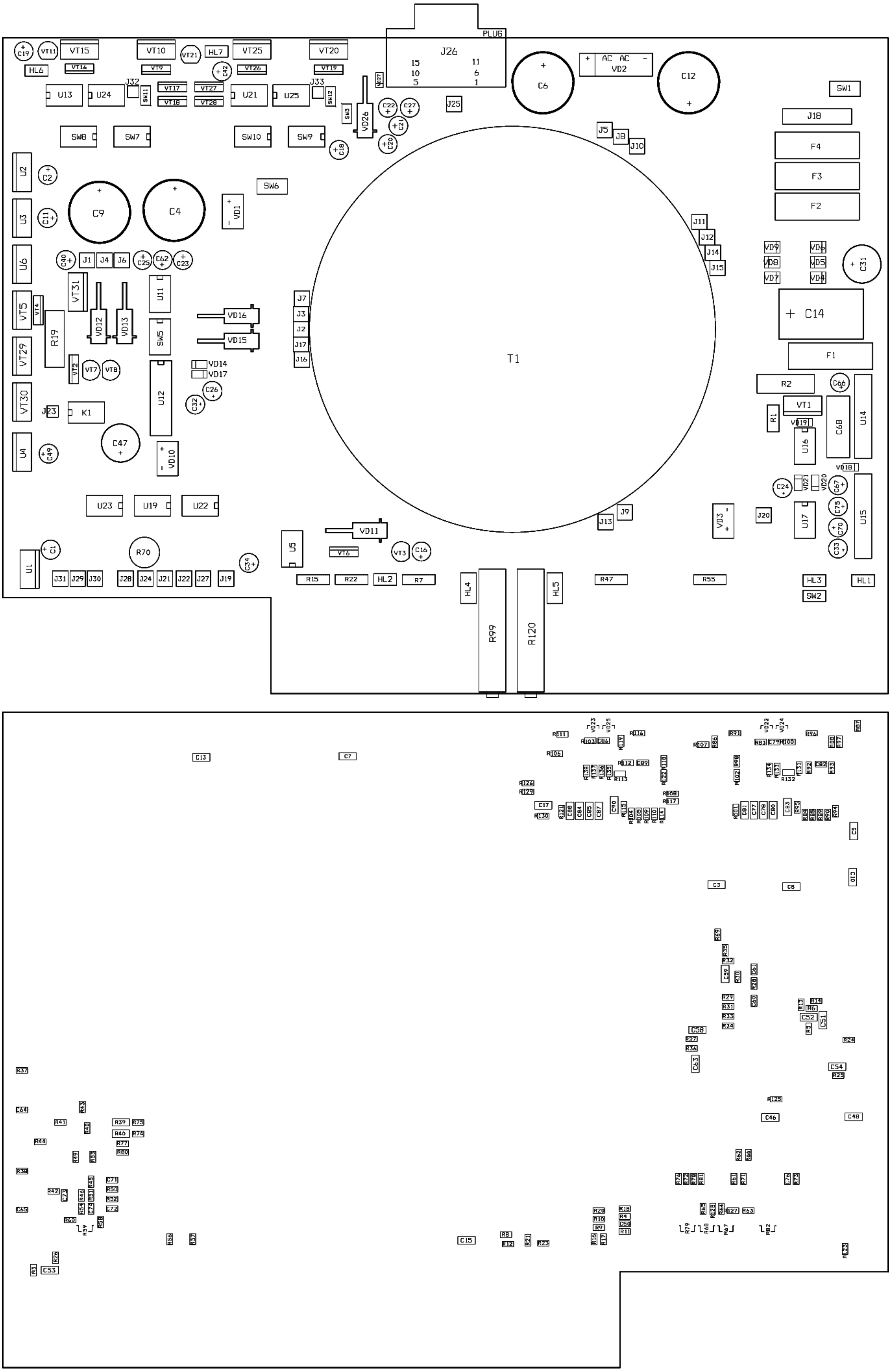


Fig.12. The layout of the ULDC112.

Appendix II. Diode Laser Data Sheet: SAL-0488-010.

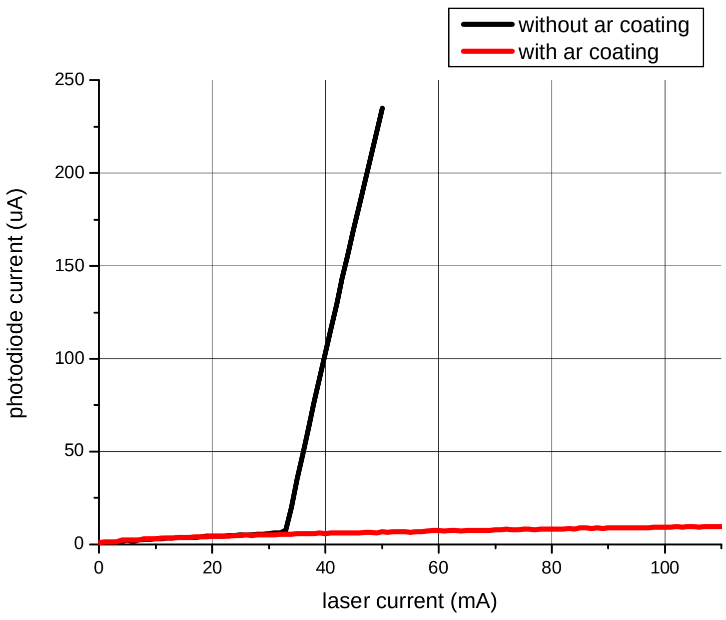
Description of the Laser Type:

Ridge Waveguide Laser Diode for 488 nm

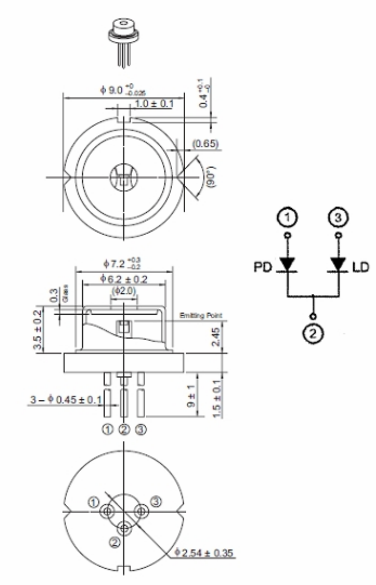
Specific Data of the Diode Laser:

Serial-No.:	AL218-01
Header:	TO5,6 (Adapter TO9)
I–max:	130 mA
Polarity:	positive
Temperature:	25° C

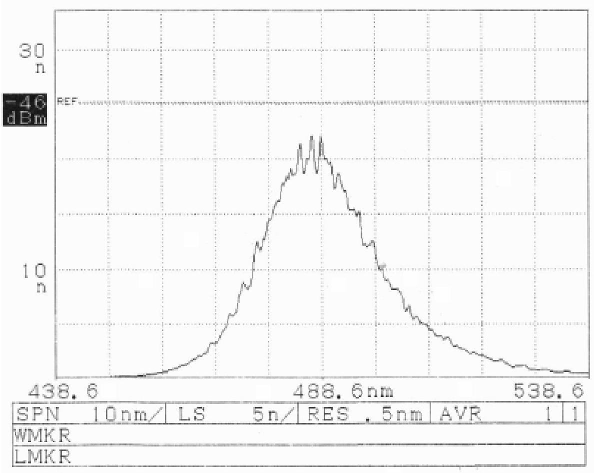
Laser current

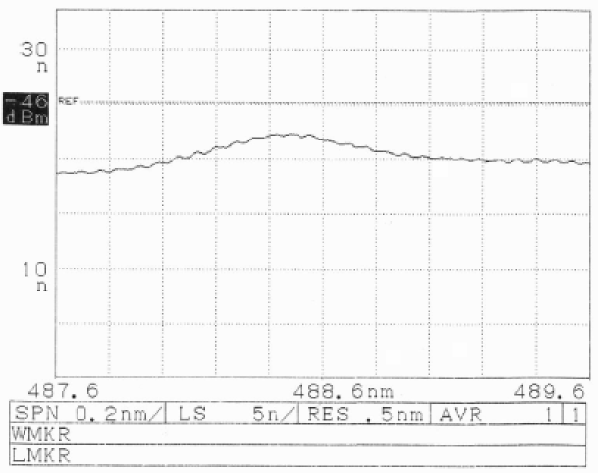


Pin connection



Spectrum:

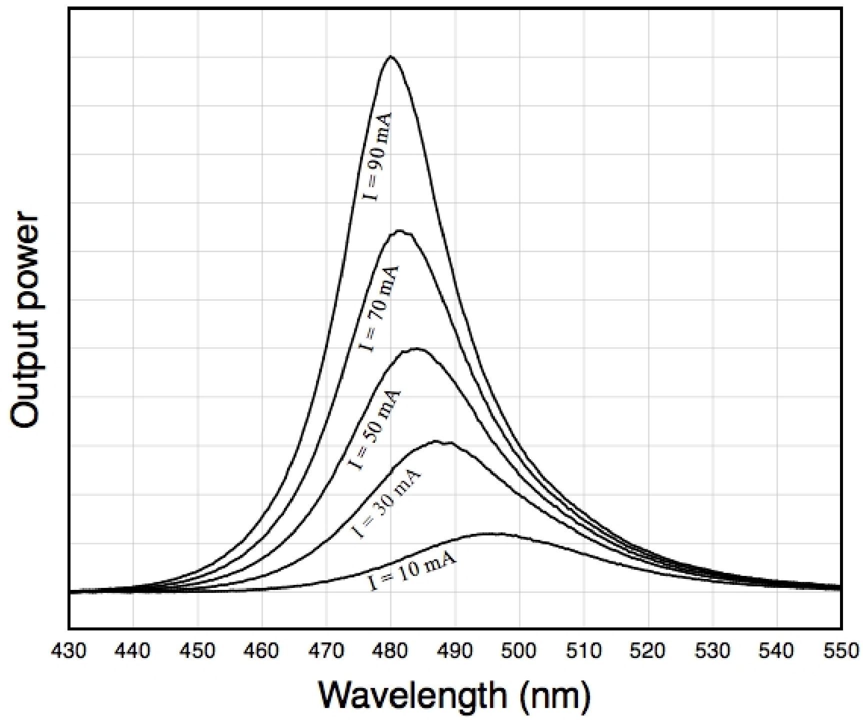




R<5.0E-5

Date: 27.04.2012 Signature:

Appendix III. The spectra of SAL-0488-010 #AL218-01 at different currents and temperatures.



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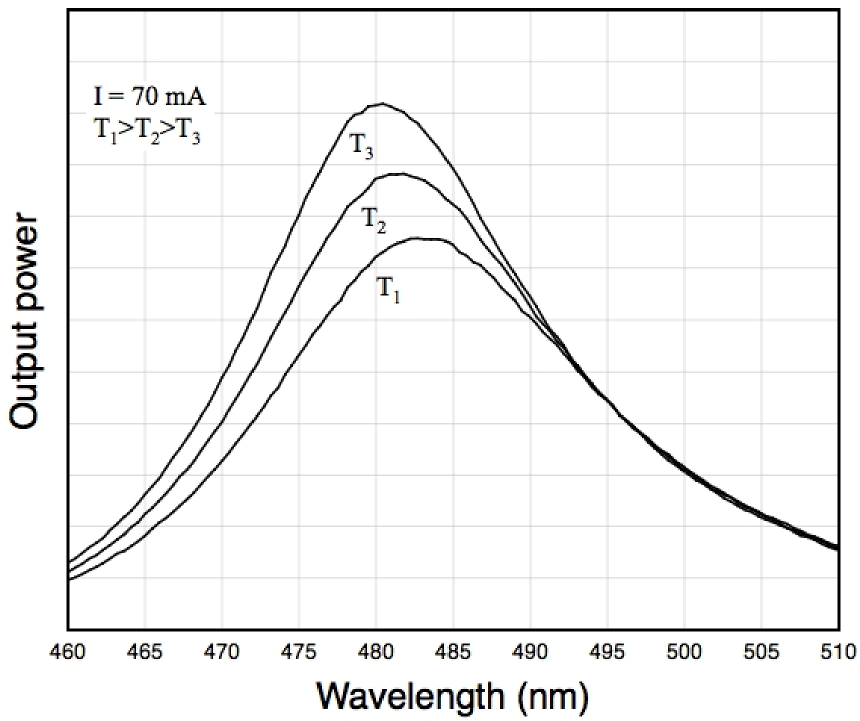

Common recommendations of the ECDL-4810RM maintenance.

1. Do not try to change the laser beam collimation. In the case of laser diode degradation the module has to be replaced as a whole by a manufacturer.

2. Do not violate the procedures of the laser activation and disabling.

3. Do not reduce the LD temperature below the dew point. The LD temperature can be estimated using the TCR (temperature coefficient of resistance) of the thermistor: TCR = - 4 %/°C.

4. Use an optical isolator to avoid unwanted reflections back into the laser.

5. Follow **the golden rule:** an ECDL as a part of an experimental setup must be switched on the last and switched off the first.

Specifications.

1. Wavelength		**486.9 nm**
2. Output power	at the main output	at the auxiliary output
@ 60 mA	**1.7 mW**	**3.7 mW**
@ 75 mA	4.0 mW	8.6 mW
3. Continuos tuning range		
by PZT only		5 GHz
by PZT+LD current		25 GHz
4. Coarse tuning range		± 1 nm
5. Polarization		linear vertical
6. Beam shape		elliptical 5×1.5 mm^2
7. Threshold current		41 mA
8. Operating current		**60 mA**
9. Thermistor		**11.0 kOhm**
10. Optical head dimensions		66×50×44 mm^3
11. Optical head weight		170 g
12. Electronic unit dimensions		260×210×70 mm^3
13. Electronic unit weight		2.7 kg