DESIGN AND REALIZATION OF LASER DIODE POWER SUPPLY

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Summary Under the terms of development of specialized system for transmissions of analogue high frequency signals by means of optical fibres, the source of coherent infrared radiation has been designed and manufactured. The source has to excite Mach–Zehnder type external intensity electro-optical modulator. That is why the generated radiation has to meet certain requirements. Rigorously constant optical power and wavelength as well as linear polarisation of the radiation have to be reached. The parameters must be time stable and independent on external influences – especially temperature changes. The article is focused on structure of the realized appliance and submits achieved results.

1. INTRODUCTION

In general, there are two possibilities to modulate intensity of light source. The first one is direct modulated excitation of light source, and the second one is indirect external modulation of steady light beam. The second way is inherent in use of external intensity modulator and has certain advantages in comparison with direct modulation. Firstly, it is clear and explicit division of system components on biasing part and modulating part. Secondly, it is wider bandwidth, which can be reached. Especially the bandwidth is one of desired features of the system under development. As a core component of the system serves an electro-optical modulator FA-20 operating up to 20 GHz. To let the modulator work properly, the incoming radiation has to meet following requirements:

* The only possible source of radiation is laser diode. A diode must operate in continuous (CW) regime and must be mode hopping free.
* Generated optical power should have sufficient value and must be strictly constant.
* Wavelength of the radiation must meet the wavelength range of the modulator i.e. between 1525 up to 1615 nm and must be strictly constant as well.
* The radiation has to be coupled to optical fibre pigtail and should be linearly polarised. The end of the pigtail should be equipped with SC connector.

Generally, there is not any strict demand regarding to exact value of optical power or wavelength. A stability of the parameters seems to be far more important than absolutely exact values. The parameters must be time stable and temperature invariant as much as possible. This should ensure repeatability of measurements during the system use.

2. MAIN IDEA

As a source of radiation has been chosen PL15M001 (PD-LD, Inc.) laser diode. A package contains ML925B11F (Mitsubishi, Inc.) chip [1] and an optoisolator. The diode is pigtailed with 9/125 PM Panda fibre (Fujikura, Inc.). The pigtail ends with SC connector. The laser generates nominal wavelength of 1550 nm, which is in the middle of the desired wavelength range of FA-20. Thanks to the type of the diode (DFB) a very narrow spectral line should be expected with side bands enormously suppressed (more than 40 dB). Mode hopping is ruled out as well.

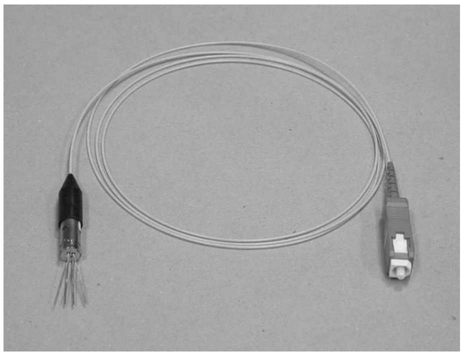

Fig. 1. PL15M001 laser diode

At the end of the pigtail the laser gives nominal value of 1 mW of optical power. This value seems to be sufficient. Nevertheless, a real power value depends on many factors. First of all, it is almost liner function of injected current (above threshold level of course). Secondly, the temperature of laser diode active layer and package temperature play important role. An influence of the both factors can be seen in Fig. 2.

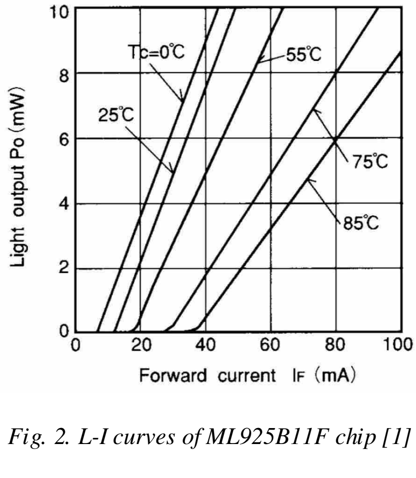

Fig. 2. L-I curves of ML925B11F chip [1]

The Final Data Test protocol of the laser shows that nominal power of 1000 μW has been reached in case the diode was injected with 26 mA of forward current and the package was kept at 22 °C. Near by this working point a temperature drift of output power of -25 μW/°C can be expected. The diode also demonstrates wavelength drift of +0,1 nm/°C. These are typical values for most of DFB lasers.

It is obvious that there is not possible to use usual stabilized laboratory power supply to drive laser diode. Apart from demands mentioned above, there are problems of protection of laser against prospective transients, overcurrent and ESD. There are two ways to drive laser diodes: APC (Automatic Power Control) or ACC (Automatic Current Control). Thanks to higher achievable power stability the ACC method have been chosen. In case of ACC control the forward current of laser is stabilized by negative feedback. The current is sensed by means of small precise resistor, which is connected in serial with laser diode. A voltage drop across the resistor serves as feedback signal for regulator. The feedback signal is compared with steady reference value, which produces error signal for regulator. The negative feedback keeps the current at constant value. In case of constant temperature of laser the optical power and wavelength are kept steady as well.

3. STRUCTURE OF THE APPLIANCE

The ACC method combined with precise temperature control has been chosen to drive the laser diode. To achieve desired parameters of the output light it was necessary to design and build several electronic circuits. Due to necessity of temperature control the diode has been placed in specially designed thermally insulated housing – laser module. A basis of electronics part is created by two standalone circuits: ACC driver for current control and TEC driver for temperature control. Next circuits (Control unit and Display/Keyboard unit) are necessary to coordinate the functions, permanent monitor and test the parameters of the device. A supply voltage to particular blocks is obtained from linear power line supply (PWR block). As the gadget is supplied from power line, the power line filter is necessary. This precaution has to minimize penetration of possible voltage peaks from power line, which can be very dangerous to expensive and sensitive laser diode. Overall arrangement can be seen in Fig. 3. The key blocks (Laser Module, ACC Driver, TEC Driver and Control Unit) have been realized as follows:

The Laser Module ensures thermal bond among thermoelectric cooler (TEC), laser diode and temperature sensor. Simultaneously, a minimum thermal couple has to be kept between the thermal bond and surrounding area of the module. A precise and extremely small NTC thermistor (B5740G0103 Epcos AG.) was used as a temperature sensor. The thermistor is embedded in thermal bond as close to the laser as possible. Apart from thermal separation, the housing makes electromagnetic shield and protects the laser against mechanical damage. The thermal bond has been made of shaped aluminium piece and has been tightly connected to TEC. A large shaped cooler with a fan has been mounted on the opposite side of the TEC. The laser module also contains simple filter circuit as the last protection stage of laser against prospective transients.

The ACC Driver supplies the laser diode with constant current regardless the changes of load impedance and protects the laser against overcurrents. A hybrid integrated circuit WLD3343 (Wavelength Electronics, Inc.) [2] has been chosen as a key component for realization of the driver. The circuit serves as a linear regulator with supply voltage of 5 V. A working point of driver has been set to 26 mA in accordance to Final Data Test protocol supplied by manufacturer of the LD. Maximum output current of the driver is 30 mA, which is safely below absolute maximum ratings found in the laser data sheet. The reference value of the regulator is derived from low noise reference ADR441. The soft start function is one of the WLD3343 advantages. By means of the function the laser is switched on in two steps. In the first step the laser is introduced to the state of spontaneous emission only (I_F<I_{th}, approximately 1 mA). This state is kept about 370 ms. The second step brings a gradual transition to the state of stimulated emission (I_F>I_{th}, i.e. 26 mA of desired value). This procedure allows laser to warm up gradually and avoid thermal

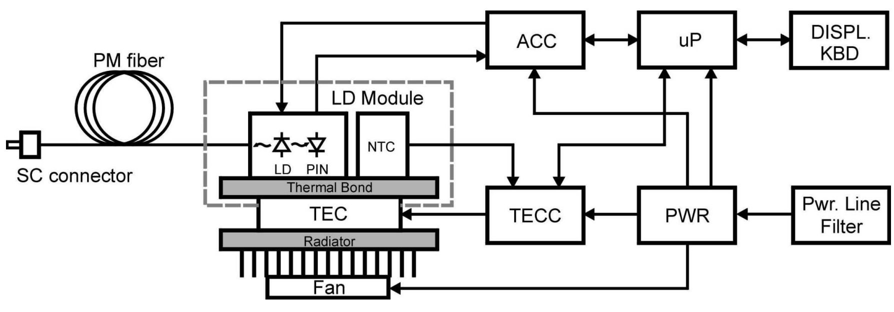

Fig. 3. Block diagram of the laser power supply

shock as well as reduce prospective transient phenomenon. The circuit is equipped with output for laser current monitoring as well as with transimpedance amplifier for monitoring of output optical power by means of integrated photodiode inside the laser chip. Both outputs are connected to the Control Unit. The operation of ACC Driver was tested on model of real laser arranged from combination of usual diodes. The measurements of short term stability of generated current revealed fluctuations lower than ±0,02% in relation to set value. The short term stability was measured in a 5-minute-period.

The TEC Driver has to thermally stabilize the laser diode. The temperature set point is kept by means of TEC block, which is an integral part of laser module as well as temperature sensor. A value of current flowing through TEC determines volume of heat pumped through the TEC. Direction of the heat flow is determined by direction of the TEC current. This phenomenon allows precise control of laser diode temperature by means of alternative heating and cooling. Nevertheless, to achieve sufficient temperature stability an efficient current controller use is necessary. A LTC1923 integrated circuit (Linear Technology, Inc.) [3] has been chosen as a key component of the TEC Driver. The LTC1923 represents high frequency PWM modulator for direct driving of external H-bridge. The H-bridge serves as DC-DC converter or source of the current for TEC block. Apart from PWM stage, the LTC1923 include analogue controller, which is able to track fluctuations of temperature by means of external temperature sensor. A desired temperature is determined by means of reference voltage set at the second input of the controller. The PWM modulator works at 150 kHz. The power stage of the circuit uses IRF7389 transistors (H-bridge) and LTC1693 ICs (drivers of the H-bridge). An additional LTC2053 instrumentation amplifier was used as a front stage of the PI controller. This precaution gives the circuit ability to achieve 10 times higher temperature stability in comparison to the version with internal PI controller only. The TEC controller is equipped with several mechanisms protecting the TEC against ovecurrent, overvoltage and thermal run-away. The measurements revealed short term stability better than ±0,003 °C and factor of stability of 350 [4], [5].

The Control Unit coordinates operation of the whole appliance. A main task is to safe proper switching on and off the laser. Apart from that the unit provides continual check of observed parameters. The unit is based on 8-bit AT89S53 microcontroller. The digital system is not able to protect laser against accidental transients in order of µs. On the other hand it can secure switching off the laser in case of gradual degradation of any of observed parameters. A change of optical power as a result of TEC driver failure is a good example. Generally, the unit checks following parameters: temperature of laser diode, temperature of environment, laser diode current, monitor photodiode current, TEC current, TEC voltage. Optical power is derived from monitor photodiode current. In case of cross of any limit of any of the parameter, the instantaneous switching off of the ACC driver and TEC driver is ensured by the unit. Any of the measured parameters can be observed at LCD front panel.

4. EXPERIMENTAL VERIFICATION

Regarding the application the most important parameters are short term stability of optical power and wavelength of the radiation. An optical multimeter OMM6810B (ILX Lightwave, Inc.) with InGaAs sense power/wavehead OMH6727B was used for verification. The sensing head is able to measure optical power in the range from -40 dBm up to +30 dBm. The wavelength range is 950 nm – 1650 nm [6].

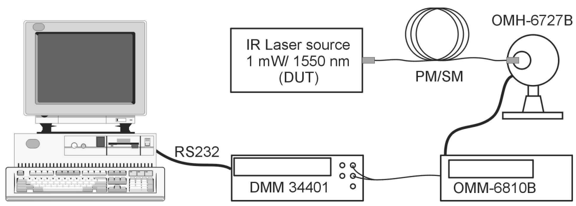

Fig. 4. The measuring system arrangement: the evaluation of power fluctuations

The Power Analog Out at the rear panel of the OMM6810B was used to measure fluctuations of the optical power. By reason that a signal at the Power Analog Out simply tracks the measured optical power delivered to the sense head, the fluctuations can be measured by usual digital multimeter. An Agilent 34401 DMM was used to digitize the value. The DMM was controlled by PC under the LabVIEW application. The arrangement of the measuring system can be seen in Fig. 4. The measured data are presented in the Fig. 5.

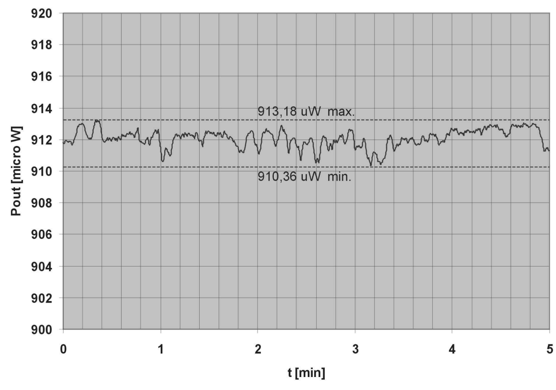

Fig. 5. Short term stability

The data were measured in a 5-minute-period with 2 Sa/s sampling rate. Next, it was found out that generated wavelength fluctuations are under resolution of OMM6810B i.e. better than ±0,1 nm.

5. CONCLUSION

Technically challenging and relatively expensive appliance was designed, manufactured and tested. The values of the wavelength and average optical power established by the measurements are suitable for the needs of the application. The short term stability of the optical power (±0,16%) seems to be satisfactory too.

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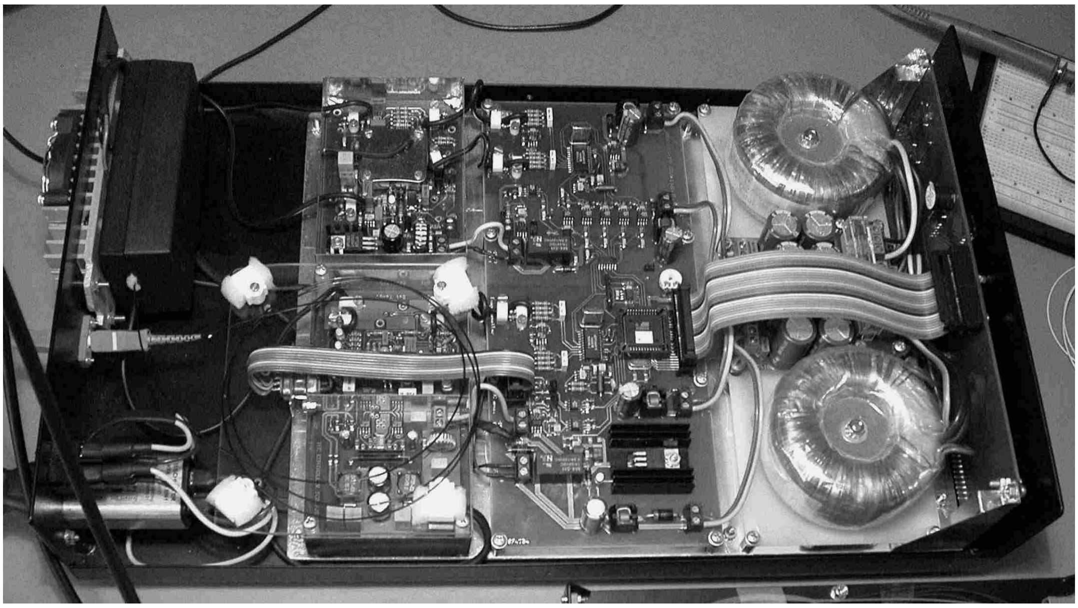

Fig. 6. The realized laser power supply

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