CHARACTERISTICS OF LIGHT EMITTING MODULES FOR FIBRE OPTIC COMMUNICATION AND SENSORS

Emission sources directly connected with fibre cables are very attractive for research and many industrial applications. Direct connection has rather simple joint design, high mechanical and thermal stability and lower level of optical noise compared with connection method using miniature lens with antireflection coatings used by many manufacturers.

Multi Mode Fibre Optic Coupled Emitting Modules

A series of laser pigtailed emitting modules has been developed in a proprietary flat packages ILPN-109M-(3-200) type with CW mode, optical output power from 3 to 100 with wavelength range *mW* 800 ÷ 860 *nm*, FWHM: 2 ÷ 4 *nm* and a temperature range from -60 to +55 °*C*. These devices are very stable to thermal cycling. They have low noise levels and broad modulation band (250 *MHz*). The fibre core diameter is 50 or 62.5 *microns*.

The edge-emitting LED (ELED) module ILPN-110M with optical output power of 1 *mW* is very resistant to high temperature (over 70 °*C*). Typical coupling efficiencies into the fibre with core diameter of 50 *microns* is high at 70 ÷ 80 % for laser diodes (LD) and 25 ÷ 35 % for ELEDs.

Emitting laser modules have also been developed at wavelength of 1300 *nm*, particularly LM3-1300, an uncooled module analogous to ILPN-109M, and LM3-1300-BT ("Butterfly") and -DT (DIL package) cooled modules. They include LD, photodiode (PD) based on InGaAsP/lnP compounds, built-in thermoelectric microcooler for keeping the required temperature, and thermistor. Analogous packages are used for superluminescent MM fibre optic coupled modules LM4-1300 and LM4-1300-BT and -DT with output power over 0.3 *mW*.

Single Mode Fibre Optic Coupled Emitting Modules

Advantages of laser diode direct connection to optical fibre are manifested in case of single mode fibre (SMF) connection. High sensitivity to misalignment of the fibre with laser diode (over 3 *dB* at each *0.2 ÷ 0.3 microns* of misalignment) does not allow to create reliable and rather cheap dismountable connection. High requirements to precise alignment and SMF fixing essentially complicate the matching joint and raise the cost of device. For stabilization of the emission input into the fibre a thermoelectric cooler is used. The devices designed at our company comprise matching joints providing long-term stable characteristics in the wide range of mechanical and temperature exposures.

Mechanical and thermal stabilization has been achieved in single-mode pigtailed LDs (LM1-850) and SLDs (LM2-850) by means of matching joints.

These diodes are widely applied in fibre optic sensors, gyros, communication links and low coherent optical tomography (see Table 1) and other systems.

Table 1

Module	P_{out}	I_d	T_{op}	Spectral FWHM
type	*mW*	*mA*	° *C*	*nm*
LM1-850	1	120	-60 /+55	4
LM2-850	0.3	200	-60 /+70	>15

These devices are uncooled transmitting modules. LM1-850 comprises a laser diode and photodiode. Typical output power vs driving current characteristic is shown on Fig. 12.

LM2-850 is a SLD with wide FWHM -over 15 *nm*. Active elements of these modules are made on the base of double heterostructure GaAlAs/GaAs, which has a stripe geometry formed by Zn diffusion to reverse shift of *p-n* junction with V-groove. Emission input to the fibre with 5 *microns* core diameter was performed with microlens with 5 ÷ 7 *microns* radius, formed by stretching the fibre end in the electrical arc. Typical coupling efficiency for SM optical fibre makes up 36 ÷ 40 % for LD's and 15 - 20 % for SLDs. At output power of 0.3 *mW* (at the end of the pigtail with 5 *microns* core diameter), ripples amplitude did not exceed 1*%.*

After optimization of SLDs emission spot and microlens on the fibre end, the maximum output power reached 1 ÷ 2 *mW*, which is very important for fibre systems with many branches. Modules LM2-850 type find wide application in fibre optic gyros, sensors and modern optical tomographic systems, used now in ophthalmology and dermatology.

Cooled analogues of the said devices are the modules LM1-850-BT and -DT, comprising a thermoelectric microcooler with maximum consumption current of 1 *A* and thermistor with resistance of 10 *kOhm*.
For the wavelength of 1300 *nm* several types of fibre coupled odules with 7 ÷ 9 *microns* fibre core diameter were designed. Their parameters are shown in Table 2.

Table 2

Module	P_{out}	I_d	T_{op}	Spectral FWHM
type	*mW*	*mA*	*° C*	*nm*
LM1-1300-DT	1	< 100	-40 /+70	< 4
LM2-1300-DT	0.3	< 150	-40 /+70	> 20
LM1-1300-1	1	< 100	-40 /+70	0.1

Typical output power vs driving current characteristic is shown on Fig. 13, 15.

Modulation vs Frequency dependence of LM1-1300 laser modules is shown on Fig. 14.

The first two types of modules are manufactured in DIL or "Butterfly" packages. Active element in these modules is based on double hetero-structure InGaAsP/lnP with overgrown stripe geometry. In LM2-1300-DT/BT the resonator mirror surfaces are covered with antireflection coating. Active element emission power control is performed with InGaAsP/lnP photodiode. At 3 ÷ 4 *microns* active area width and 6 ÷ 10 *microns* microlens radius, coupling efficiency made up 50 ÷ 60 *%* for LD's and 8 ÷ 12 *%* for SLDs. P_{out} vs I_d characteristics for unpackaged and SM fibre-optic coupled modules are shown on Fig.7,8, respectfully.

Ten samples of LM1-1300-DT modules were exposed to 20 thermocycles from - 40 to +70 *°C* in the system with two cells, the time of samples transfer from one cell to the other was 20 *sec*. As a criterion of validity there was taken the change of emission power at the end of the fibre, at fixed volumes of pumping current and active element temperature, not exceeding 1 *dB*. After the test all samples showed this change in the range of 0 ÷ 0.6 *dB*. From these 10 samples 5ones were chosen at random, and then exposed to temperatures from -60 to +70 *°C*. Four devices showed the emission power change less than 0.8 *dB* relatively to the initial value, in one module this value changed to 0.9 ÷ 1 *dB*.

All samples successfully passed the vibration test at 20 *g* acceleration in 20 ÷ 2000 *Hz* frequency range. There was also developed a single-frequency coupled cavity resonator LD module

LM1-1300-1 with a narrow spectrum band (< 0.1 *nm*), comprising a built-in LD, TE cooler, photodiode and thermistor. The external resonator provides generation at single longitudinal mode. It is formed by on of the mirror surfaces of active element and semitransparent end of fibre piece. On the side opposite to the mirror surface the active element is aligned with the optical fibre of fibre optic communication link. Single-frequency tuning and side-mode suppression (up to -20 ÷ 23 *dB*) could be made in active mode by changing of coupled cavity length and TE cooler current, and thus it is possible to select lasing wavelength. This method enables to manufacture a set of modules with fixed emission frequencies in the range 1240 ÷ 1320 *nm* at each 5 or 10 *nm*.

850 and 1300 nm Superluminescent Diodes on Submounts.

For application in fibre-optic gyros and customer designed sensors, there was developed a set of unpackaged SLDs on submounts. Their parameters and characteristics are shown in Table 3 and at Figures 1 - 11.

The presented R&D results and characteristics show the range of optical modules, which could find wide application in fibre optic sensor and systems. These superluminescent diodes may be supplied also on the following heatsinks: 206, 207, 208, 211, 212.

TYPICAL OUTPUT POWER EMITTED
FROM SM FIBER OPTIC COUPLED
SLD MODULE of LM2-850 TYPE
vs
OPERATING CURRENT at VARIOUS VALUES of
AMBIENT TEMPERATURE

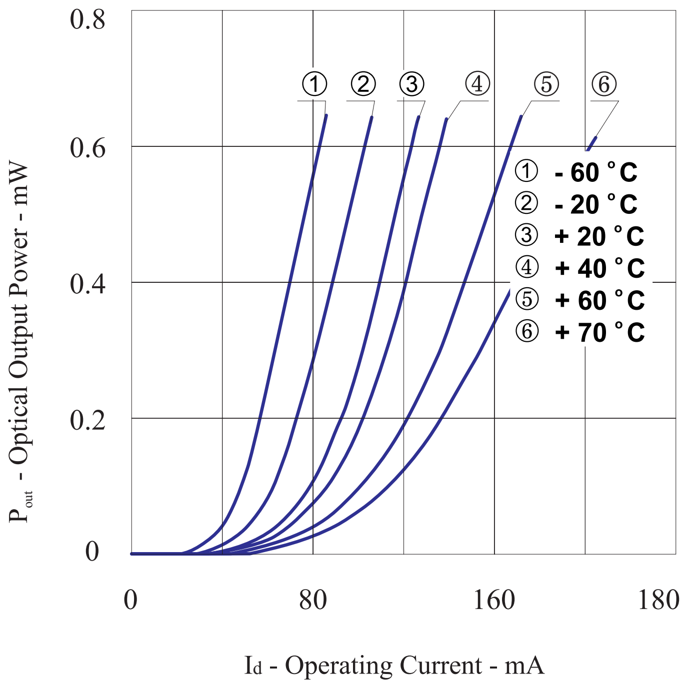

Figure 1

TYPICAL OUTPUT POWER EMITTED
vs
OPERATING CURRENT at THREE VALUES of
AMBIENT TEMPERATURE for SLD-2-4

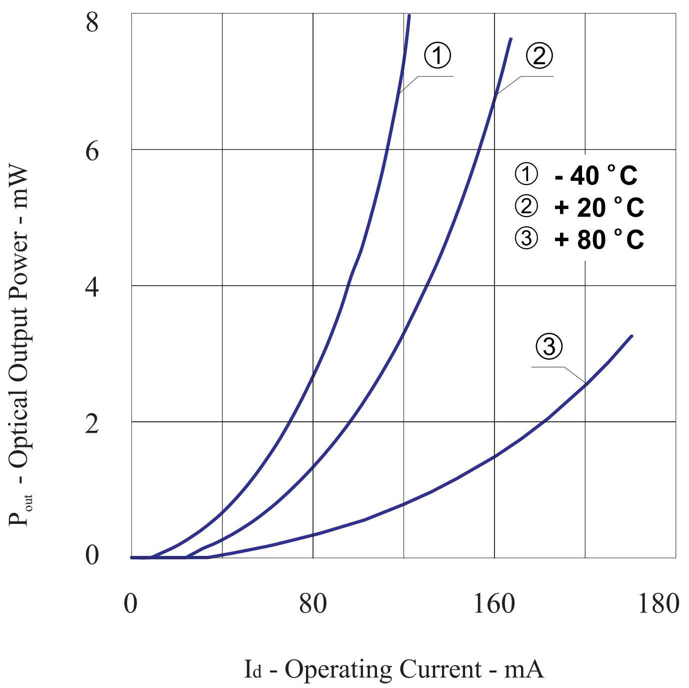

Figure 2

TYPICAL NEAR FIELD PATTERN
of SLD-2-4 EMISSION
@
THREE VALUES of OPERATING CURRENT

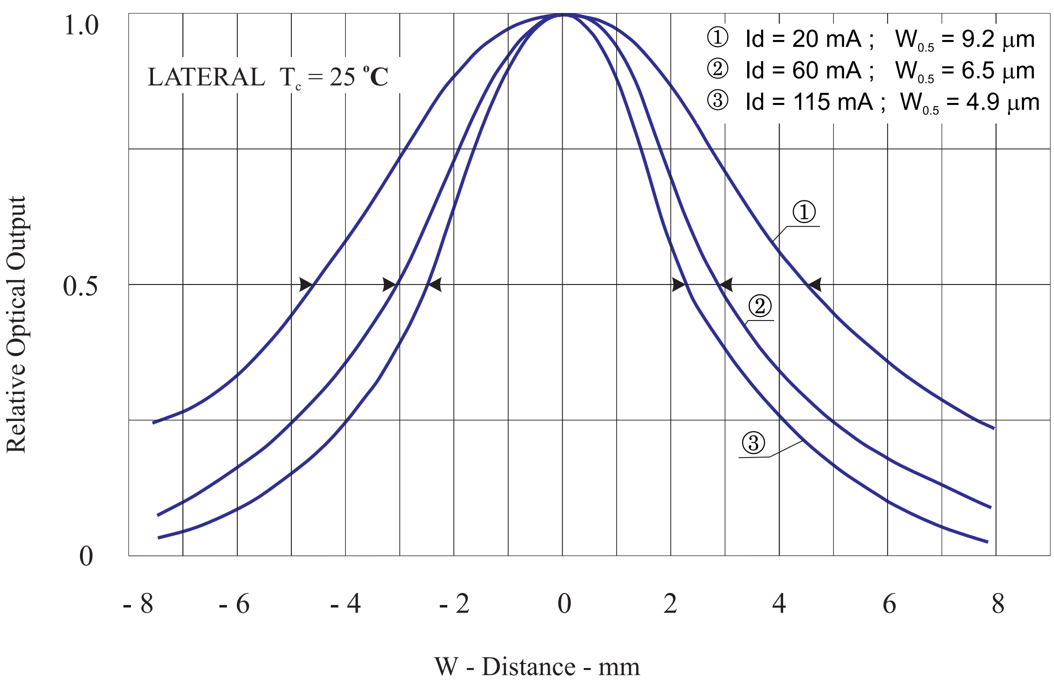

Figure 3

TYPICAL FAR FIELD PATTERN
of SLD-2-4 EMISSION
@
OUTPUT POWER of 5 mW

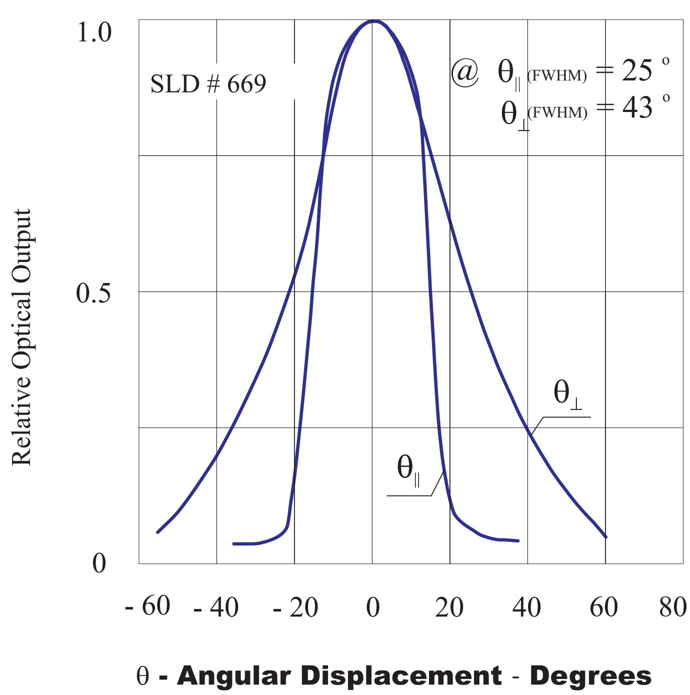

Figure 4

SLD-2-4 POLARIZATION RATIO
vs
OPERATING CURRENT for THREE DEVICES
MANUFACTURED
of VARIOUS HETEROSTRUCTURES

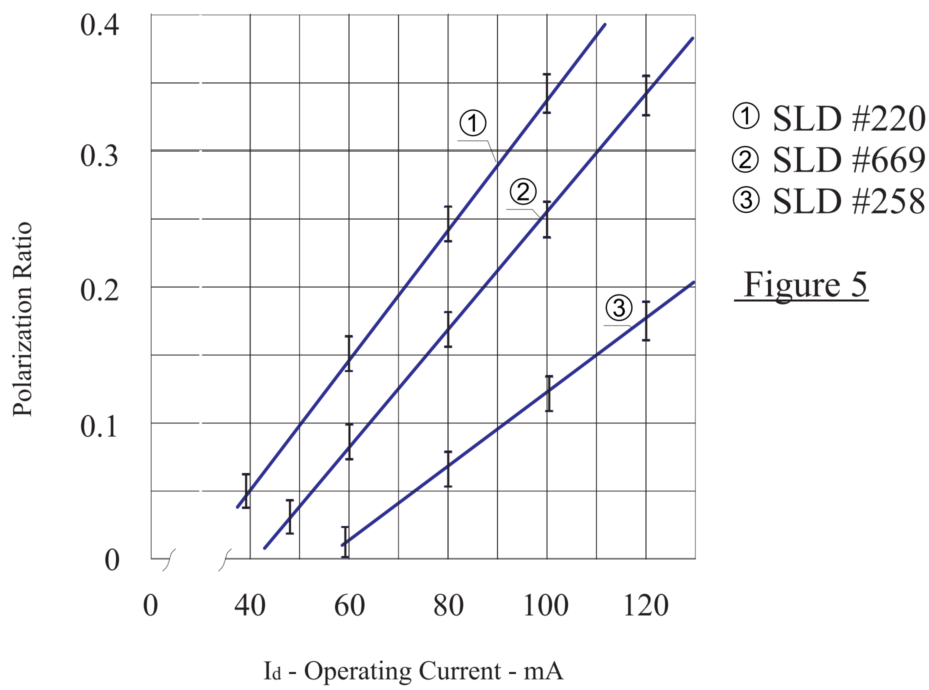

Figure 5

TYPICAL SPECTRUM
of SLD-2-4 EMISSION
@
OUTPUT POWER of 5 mW

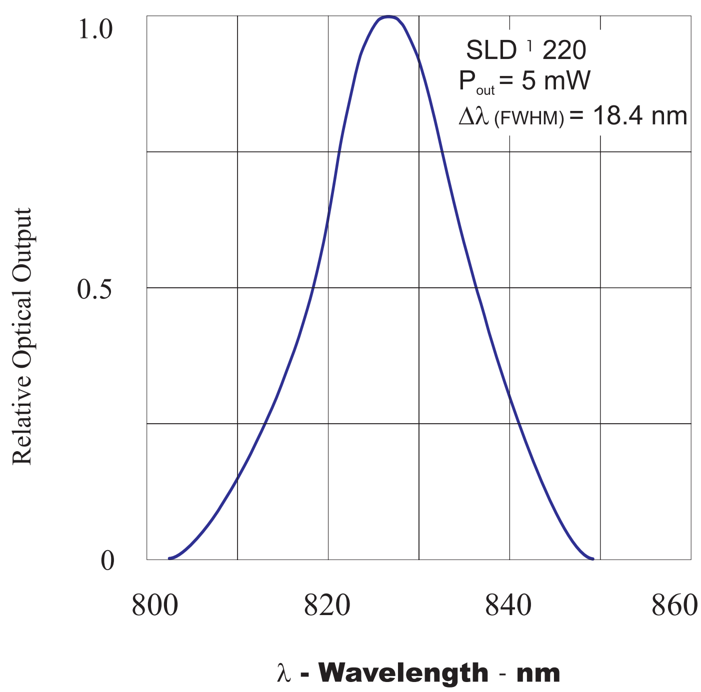

Figure 6

TYPICAL OUTPUT POWER
of 1300 nm SUPERLUMINESCENT DIODE
vs
DRIVING CURRENT
@
CASE OPERATING TEMPERATURE T = 20 ^{0}C

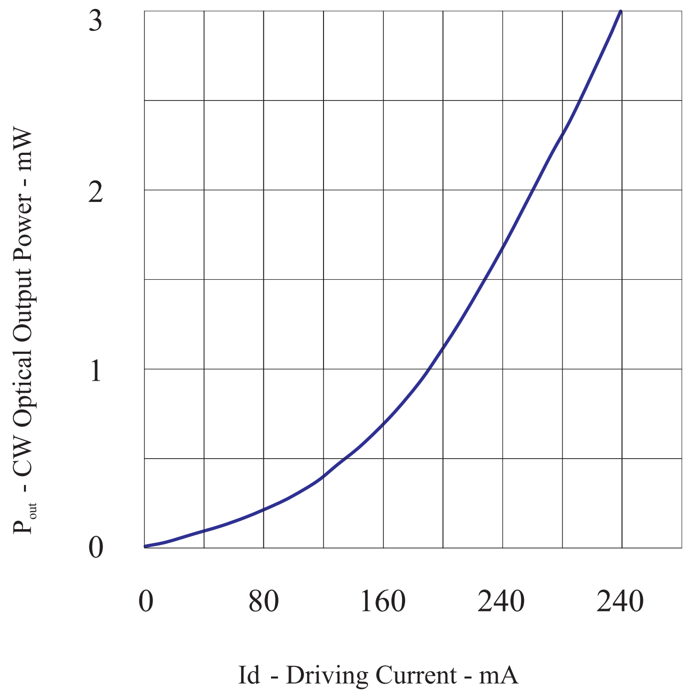

Figure 7

TYPICAL OUTPUT POWER
of 1300 nm SUPERLUMINESCENT
FIBER OPTIC COUPLED MODULES
vs
OPERATING CURRENT
@
CASE OPERATING TEMPERATURE T = 27.5 ^{0}C

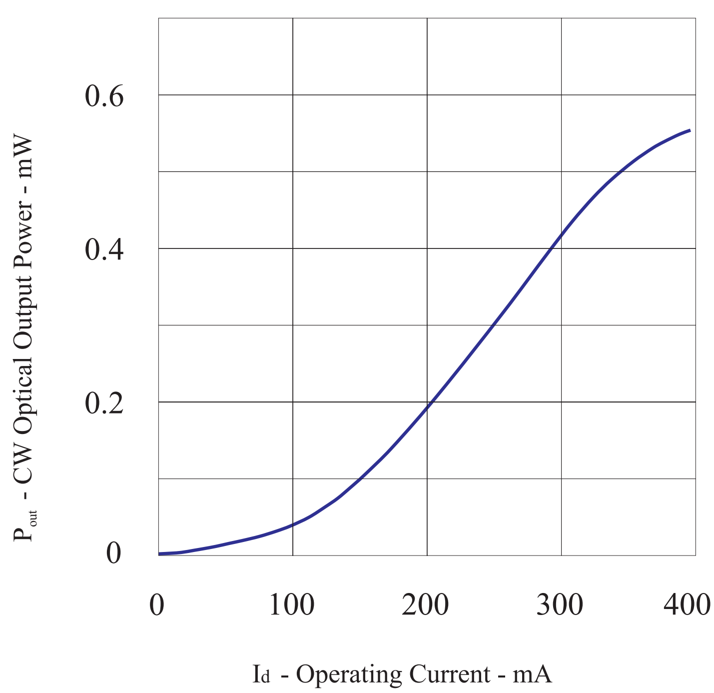

Figure 8