UNIVERSITÀ DEGLI STUDI DI CAGLIARI

AFFIDABILITÀ DI LASER SINTONIZZABILI DI TIPO INNOVATIVO PER APPLICAZIONI IN SISTEMI DI TELECOMUNICAZIONE

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PREFACE

The demand for Broad Band services for private as well as for commercial users is expected to increase worldwide at an accelerated pace in the next future. To allow the mass introduction of the broadband access services, however, a number of technological barriers still need to be overcome. In particular, research is presently very active in the field of photonics, aimed at the development of a new generation of photonic devices based on nanotechnology. These should allow to solve in a cost-effective way the so called "metro bottleneck", that is the congestion in the metropolitan access infrastructure, expected to arise from the increased traffic flowing from the access network to the telecommunications "backbone", and viceversa, due to the increase of capacity demand from the customers.

In order to be successful, innovative photonic products must of course satisfy a number of performance requirements, either economical and technical, and in particular they must be designed and manufactured in such a way as to guarantee that they will operate reliably for as long a period as possible.

The study reported in the present thesis consists in the full reliability assessment of a new product designed and manufactured by Pirelli, that is a tunable laser of new conception, based on photonic nanotechnologies.

In the first chapter of this work the current opportunities and ideas in component reliability assurance are discussed. The reliability proactive approach, implementing reliability assurance at the front end of the production line, is described. The next group of chapters introduces the device. In chapter 2, a structural design overview of the device is given, to point out contingent problems in a reliability point of view. The stress tests appropriate in the reliability assurance process for the optoelectronic devices are briefly described in chapter 3. Chapter 4 includes a comprehensive discussion on the functional aspects of the device, the identification of suitable performance parameters and characterization procedure. The qualification exercise, with its plan, the tests carried out, and the results, are then detailed in chapter 5.

CHAPTER 1

RELIABILITY APPROACH & QUALIFICATION STANDARD

RELIABILITY APPROACH

Reliability has always been considered as an extremely important factor of merit for any element of telecommunication networks.

Today the demand for high reliability is becoming even more stringent as long as more and more applications, beside the traditional voice communication, depend upon it. Let us remind the definition, given by IEEE, for reliability as a property of a product: "… the ability of a system or component to perform its required functions under stated conditions for a specified period of time".

You also define reliability in terms of the methodological tools that are needed to assess such property, which means that reliability is also “a design engineering discipline which applies scientific knowledge to assure a product will perform its intended function for the required duration within a given environment. This includes designing in the ability to maintain, test, and support the product throughout its total life cycle. Reliability is best described as product performance over time. This is accomplished concurrently with other design disciplines by contributing to the selection of the system architecture, materials, processes, and components - both software and hardware; followed by verifying the selections made by thorough analysis and test” [1].

Reliability engineering is, in general, performed throughout the entire life cycle of a product, including development, test, production and operation.

A sound reliability approach generally includes three fundamental activities: design for reliability, reliability verification and analytical physics. Design for reliability means applying reliability criteria at the early stage of the product: this starts with the idea phase of the product development cycle and is necessary to affect the design for a positive product reliability improvement.

To this aim it is necessary to understand the physical mechanisms involved in working in the different conditions the product is specified for, so as to anticipate potential problems.

Reliability verification ensures meeting customer’s reliability objectives. This reliability engineering activity takes place either as process reliability assessment or as design maturity testing. In the first case it focuses on the development of a fundamental understanding of a platform’s inherent reliability and provides the basis to develop a realistic accelerated design maturity test. Design maturity testing demonstrates that product customer’s needs will be met when it is exposed to demanding conditions.

Analytical physics is designed to collect knowledge about a product’s physics of failure, understanding how and why a failure may occur.

If we analyse, more specifically, Historically, the development of electronic and optoelectronic products quality and reliability assurance over the last thirty years, we can observe that there has sbeen a shift from end of life testing to assurance techniques that move to the front end of the process, up to the design itself. Steps in this direction were taken from the end of the seventies [2]. During the eighties the idea of "wafer level reliability" for microelectronic devices was introduced.

In those years the reliability community started to deal with the limitations of applying traditional accelerated product life tests and the wafer level reliability measurement techniques, to resolving very low failure rates [3]. It was clear that the reliability engineering and manufacturing community would have to take over with the challenge of continuously decreasing failure rate for complex systems. In this direction, different contributions were published, auspicating the use of a new building-in approach to reliability. To achieve this objective it was necessary to review the essential features of this new approach and contrast them with those of the traditional approaches, identifying obstacles in accepting the building in reliability approach and suggesting ways to overcome them, so as to propose a way to facilitate the implementation of this approach [4].

Meanwhile, technological innovations were providing integrated circuits of increased functionality and complexity. Design tools aided a new multiplicity of products.

Traditional qualification procedures could not keep pace with this evolution with respect to requirements of product reliability, ability of qualifying the multiplicity of future products, and market demands for saving cost and time.

Market and manufacturers were asking for the development of a new reliability assurance concept. It had to take into account design tools, basic product elements, materials, manufacturing process and controls, as a whole system, to be qualified with respect to the consistency and efficiency of all of the implemented reliability assurance measures. The main part of this concept was the qualification of the manufacturing technology [5].

Terms as built-in reliability and proactive process control were coined at that time.

The reliability assurance activities were moving directly into the production lines and their inputs.

The term "proactive" was taken in its literal meaning, as “(of a policy or person or action) controlling a situation by causing something to happen rather than waiting to respond to it after it happens” [6], as opposed to the traditional approach, which was focussed on "reactive" policies (with reference to the literal meaning of "reactive", “(of a policy or person or action) tending to react to a stimulus”) [7].

The differences in the two approaches, for reliability assurance, are relevant. The traditional, reactive approach, is in fact essentially based on measuring reliability of the ultimate product indicating, with lifetests, the values for mean time to failure (MTTF) or mean time between failures (MTBF), and using burn-in techniques to screen production from infant mortalities.

The high level of built-in reliability associated with the majority of the electronic and optoelectronic devices, modules and systems today make the traditional reliability assurance techniques practically unaffordable.

Demonstrating reliability levels of few FITs would need impracticably large sample sizes and testing periods, contrasting with market demands for saving costs and time.

The proactive approach to reliability assurance opened a new set of issues to the manufacturing industry such as the identification, control and elimination of the causes for component failure. The idea is to assess the reliability, in general of a product, in the very product line, by controlling all the input parameters implementing a proactive manufacturing. The approach is one of "total" reliability management, in which the efforts of devices manufacturers, suppliers and customers are coordinated in an effective partnership.

At the present time, as already anticipated during the last decades of the past century, the strength of the global competition for the development of new products in a short time, the shortening of products life cycle, and customers that are more and more demanding, have motivated leading companies to renovate their new product procedures in the form of a stage gate new product process. The aim is to obtain built-in reliable products capable of meeting customer’s expectations.

A stage gate system is a conceptual and operational road map for moving a new product project from idea to launch.

This method divides the effort into distinct stages separated by management decision gates.

Reliability, with all its three upper mentioned activities, fully supports a stage gate product development cycle starting with the product conception, continuing trough final product obsolescence. It is then essential in designing a reliable product capable of meeting, when expressed, customer’s expectations.

Understanding the requirements of new technologies or new products is a very basic issue.

Different than in the past, today customers, in many cases, no longer set requirements in detail. They actually rely on manufacturers to understand their needs. Consequently, for leading companies transferrring customers requests into reliable products is a great challenge.

Customers’ expectations for reliability prediction can vary quite significantly, especially when dealing with worldwide market and a wide range of applications. This said, it’s clear that customer’s requirements can be either quantitative or qualitative.

Quantitative reliability requirements are the ones clearly expressed in terms of device or system specifications, determining targets concerning the function to be performed, the operating conditions and the criteria for approval testing.

Qualitative requirements are the ones expressed in standards generally dealing with quality and reliability assurance. Depending on the application field, aerospace, defence, automotive, telecommunication, etc., those requirements may be more or less stringent.

The main objectives of standards are [8]:

- the standardization of configuration, operating conditions, test procedures, selection and qualification of components, materials and production process, logistical support, etc.;
- the harmonization of quality and reliability assurance/management systems;
- the agreement on terms and definitions.

As written before, a company providing devices has a list of industry standards specified and marketing specifications very well defined.

Previous to the release of a new device for mass manufacturing, it must undergo a full qualification exercise according to the industrial standards that are current in the market geographic area foreseen for the business.

TELCORDIA TECHNOLOGIES GENERIC REQUIREMENTS

This work deals with the standard procedure for generic reliability assurance of optoelectronic devices used in telecommunications equipments expressed in Telcordia GR-468-CORE, Issue 2, Sept. 2004.

This standard presents the Telcordia view of proposed generic reliability assurance practices for most optoelectronic devices used in telecommunications equipments. The expressed generic requirements establish uniform methods, controls, and procedures for testing optoelectronic devices.

The Telcordia standard process implements Telecommunications Act 1996 directives relative to the development of industry wide generic requirements relating to communications equipments.

Generic requirements represent high-quality, vendor neutral technical specifications. These provide the Telcordia view of proposed generic criteria for telecommunications equipment, systems, or services considering factors such as interoperability, network integrity, funding-client expressed needs, and other inputs.

Telcordia General Requirements are widely utilized, referenced, and accepted worldwide especially in assuring reliability on optoelectronic devices for telecommunication applications.

Telcordia Technologies is a leading global provider of telecommunications software and services for IP, wire lines, wireless and cable networks. It represents the former research and development division of the Bell telephone companies. Telcordia Technologies changed its name from Bellcore in 1999 to mark its new focus on combined voice and data networks and independence from the Bells. In 1997 appeared the Bellcore Methods because the application of the Military Standard Handbook was not satisfying on commercial products. At present, pursuant to the previously mentioned act, Telcordia invites all interested parties to participate in the ongoing evolution of generic requirements for the telecom industry.

Open standards such as Telcordia General Requirements benefit consumers, enterprises, service and network providers, equipment suppliers, and even countries by promoting interoperability, interconnection, and innovation, stimulating competition among service providers and suppliers. At the conclusion of the generic requirements development, Telcordia publishes them and they are available for license.

The Telcordia standard GR-468-CORE calls for successful completion of stringent benchmark tests to demonstrate required reliability for optoelectronic devices used in telecommunications equipment.

These requirements must be passed prior to field installation by telecommunication equipment suppliers to ensure long devices lifetime even in very harsh operating conditions.

The general requirements expressed in Telcordia GR-486-CORE provide the test programs, sequences and sample sizes for the qualification testing exercise. Considering that those stated in this document are just general requirements, qualification programs may be accepted in part or in whole depending on the device or system design peculiarities and on expressed requests by customers.

This standard, with the purpose of qualification effort cost reduction, allows [9] the use of non conforming devices for minor reasons. This may be, for example, the case of devices, outside a specification for optical wavelength, because of a different temperature setting involving in a peak frequency shift respect to the ITU grid. In this case the choice of employing non conforming devices in the qualification exercise should be clearly documented by the device manufacturer or supplier.

This work deals with the reliability assurance for the Pirelli Tunable Laser. In particular it will be demonstrated how the Pirelli dynamically tunable laser has successfully completed all Telcordia standard GR-468-CORE testing.

CHAPTER 2

DEVICE BRIEF DESCRIPTION

When dealing with the planning of the reliability activities to perform on a product, at any stage of its life cycle, an exhaustive structural and functional knowledge is requested.

A detailed comprehension of the product is the sole tool in identifying its critical states. When recognized, the reliability engineers need to identify the proper tests and loads as to stress the foresaid product critical aspects in a proactive logic aimed to define a built in reliable product.

Scope of this chapter is to give a general overview of structural design of the device and to point out contingent problems in a reliability point of view.

Functional aspects will be widely discussed in chapter 4 when dealing with optical and electrical characterization.

PIRELLI DTL C-13 050

Dynamically Tunable Laser DTL C13 Series is a high power full C-Band tunable laser source. It is a continuous wave external cavity laser for advanced optical network systems.

DTL C13 has been designed to tune over the entire C-band on the ITU-T 50 GHz channel grid with high spectral purity and frequency stability. It has been also designed to meet Telcordia GR-468-CORE qualification requirements.

Externally appears as a hermetically sealed 26-pin butterfly packaging.

Primary addressable application for Pirelli tunable laser is its exploitations in wavelength and dense wavelength division multiplexing systems.

Tunable lasers offer the potential to significantly reduce the required number of inventory lasers and costs. With fixed wavelength lasers, as a matter of fact, service providers need great stocks in trades for each wavelength in operation, entailing enormous costs.

Tunable lasers are the key in the evolution to reconfigurable networks in wavelength division multiplexing systems. For these reasons it is necessary that those sources should have the same characteristics over the whole tuning range. Moreover the device should be only marginally expensive than its fixed counterpart.

All the previously mentioned information point out that:

- the device is provided with an hermetic package, consequently mechanical and environmental tests need to be performed to assess reliability for sealed devices;
- the device addressable market is the one of the WDM and DWDM networks. Consequently tests must be carried out to demonstrate at least a stable carrier optical power and channel frequency.

WHY AN EXTERNAL CAVITY LASER

A Fabry-Perot laser comprises an active gain medium and two external mirrors providing feedback for oscillation. All the lasing modes are determined by the half-wave resonance condition, and the mode spacing depends on the cavity length. Cavity length and gain bandwidth are such that many modes may oscillate simultaneously. Multimode behaviour tends to limit the applications for which Fabry-Perot devices are suitable. Such a fact has led to the development of more complex geometries providing single mode operation with high spectral purity. Most common among these are the distributed feedback and the distributed Bragg reflector lasers, which both rely on scattering from periodic structures to provide frequency selective feedback.

Broadband tuning especially for distributed feedback lasers over ranges comparable to external cavity lasers has been obtained [10], but line widths of these lasers are two or three orders of magnitude broader than that obtainable with external cavity devices.

The easiest way to obtain a widely tunable laser is to make a DFB array by integrating great number of different single frequency DFB lasers on a single chip. DFB array imposes a trade-off between the tuning range and the output power [11] because of the increasing losses in the coupler as the number of DFB lasers is improved.

Other monolithic solutions have been proposed and full band tuning has been demonstrated, but they suffer from complicated tuning mechanisms requiring the control of three or more currents [12], [13]. Moreover, they need an additional optical amplifier to boost the output power.

Simple wavelength tuning can be achieved using an external cavity wavelength tunable laser, with a widely tunable filter in the free space part. Different kind of external tunable cavity lasers have been proposed with the tuning mechanism based for example on micromechanical systems [14] or on acousto-optic filters [15].

Simple scheme and tuning mechanism could be achieved integrating a grid generator into the laser cavity combined with a tunable filter to select a specific channel [16]. Compact configurations has been proposed consisting of a gain chip, a phase section and a free space with a collimating lens, a fixed etalon, used as a grid generator and a liquid crystal based tunable mirror [17].

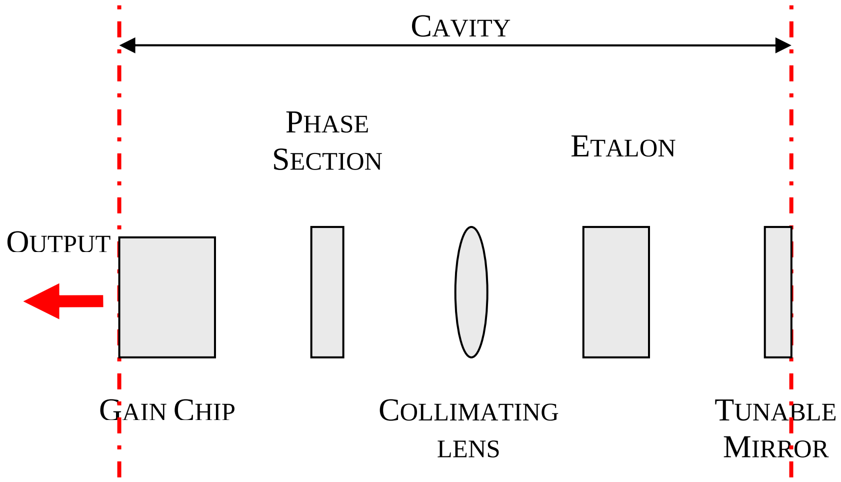

Figure 1: Layout of an external cavity wavelength tunable laser.

DEVICE CAVITY

The DTL is an external cavity laser consisting of a few intra cavity components with no moving parts needed to achieve tunability.

Cavity incorporates:

- a single angled facet high power gain chip with broadband low modal reflectance at the angled facet and an optimum reflectance at the normal facet;
- a collimating cavity lens;
- a phase controller avoiding the need for a mechanical tuning of the cavity length;
- an etalon providing a tight selectivity of a cavity mode aligned with the ITU frequency comb;
- a liquid crystal based mirror for which the tunability is obtained by means of the voltage applied to its two leads.

The integration of the phase control avoids the need for mechanical tuning of the cavity length.

Key element in reaching the full C band tunability is a liquid crystal based tunable mirror fully developed in Pirelli.

The frontal part of the device, included inside the butterfly package, incorporates two collimating lenses, a beam splitter and a monitor photodiode.

The device requires two parameters to tune the wavelength over the whole band, namely the phase current and the voltage over the tunable mirror.

Pirelli developed a proprietary assembling process that under the reduced number of the constitutive elements reduces the assembly time, increasing the manufacturing yield thus minimizing the overall device cost. All the optical components are mounted using an in house developed laser welding technique. A full customized apparatus, integrating the previous mentioned laser welding station, performs, with extremely high precision, a fully complex routine controlled automatic alignment of the parts by means of high automated stages.

The block descriptive provided explanation emphasizes other critical issues related to the device:

- all the parts included in the device must meet the needs for Pirelli DTL. A supplier approval procedure and its furnished part qualification are requested;
- optical alignment of the parts is a critical issue in assuring the cavity stability. Tests must be performed to ensure the cavity robustness;
- gain chip, etalon and tunable mirror fine thermalization is requested;
- welding and fixing resins robustness must be ensured.

Telcordia reliability assurance criteria recognizes five different levels of optoelectronic devices assembly, that from the lower to the higher level of complexity are: wafer level, diode level, sub module level, module level and integrated level. In particular, depending on the level assembly testing procedures may change.

Pirelli dynamically tunable laser, according to Telcordia definition is placed at a module level, in fact it is a relatively small hermetically sealed assembly containing a chip laser, a monitor photodiode, an optical bed as carrier structure mounted on a thermoelectric cooler, two different thermistors as temperature sensors, a package with leads and a fiber optic pigtail.

TUNING MECHANISM

Pirelli dynamically tunable laser tuning action does not include any mechanical or thermal action. This peculiarity assures a great repeatability of the tuning action accomplishing excellent characteristics of speed and reliability.

The etalon is suitably designed to ensure a tight selectivity of a cavity mode aligned with the ITU grid frequency comb. This laser can operate on a 100 or 50GHz spacing grid depending on the etalon spectral characteristics. Fundamental parameter for the alignment to the ITU grid is a fine control of the temperature of optical bed by means of thermoelectric cooler.

The stability of the selected operating grid frequency at the operating case temperature is guaranteed by means of an active control algorithm which provides for an effective wavelength locking functionality without the introduction of an external or packaging integrated wavelength locker device.

The tuning action, in general, is realized by applying different driving voltages to the Pirelli liquid crystal mirror selecting only one peak from the etalon comb. The mirror design includes a diffractive optical pattern that provides for a wavelength independent reflectivity, modulating with the voltage the refractive index of its whole structure.

ACTIVE CONTROL ALGORITHM

A control algorithm ensures stability and repeatability of Pirelli DTL, allowing the laser to be effectively locked to the selected ITU grid frequency.

The control loop adjusts both the current of the phase control element and the voltage over the tunable mirror to achieve output power and frequency stability. Furthermore setting the injection current of the gain chip is possible to fix the power at the desired level value.

Pirelli DTL is intrinsically stable; the role of the control algorithm is just to prevent degradations of the cavity phase occurring due to aging or strong temperature changes as will be extensively explained in the chapter relating to the optical characterization, after the description of the power output and frequency dynamics.

MECHANICAL DIMENSIONS

Pirelli DTL mechanical is contained in a standard hermetically sealed butterfly package (30mm X 12.7mm X 10.5mm) with 26 pins with a pin-distance is 1.27 mm.

PIN	Function	PIN	Function
1	TEC Anode	26	TEC Cathode
2	Monitor PD Cathode	25	LD Cathode
3	Monitor PD Anode	24	LD Anode
4	Environmental Thermistor	23	NC
5	Environmental Thermistor	22	Phase element
6	Optical Bed Thermistor	21	Phase element
7	Optical Bed Thermistor	20	NC
8	Tunable Mirror	19	Tunable Mirror
9	NC	18	NC
10	NC	17	NC
11	NC	16	NC

12	NC	15	NC
13	GND	14	GND

Table 1: DTL C13 Pin-Out

ELECTRICAL AND OPTICAL SPECIFICATIONS

Qualitative reliability can be performed by a precise knowledge of the device in terms of materials, parts and assembly procedures which directly point at the final product.

Quantitative reliability instead, relates to the clearly expressed requirements in terms of device or system specifications, determining targets concerning the function to be performed, the operating conditions and the criteria for approval testing. It is thus that, in assessing quantitative reliability, all the product features must be clear in the mind of the reliability engineer.

Some of the optical and electrical specifications of the Pirelli DTL C13 050 are subsequently briefly summarized in the tables below listed. All the expressed parameters are specified over lifetime within a -5÷+70 ° C operating environmental temperature ranges.

Symbol	Spec.	Unit	Symbol	Spec.	Unit
λ_{RANGE}	>35	nm	SMSR	>45	dB
ν_{STEP}	50	GHz	ΔF_S	±1	GHz
P_{OUT}	13	dBm	T_{warm_up}	20	S
ΔP_{OUT_EOL}	<±1	dB	P_{OFF}	<-35	dBm

Table 2: Pirelli DTL C13 Optical Specifications

Symbol	Spec.	Unit
ILD	<400	mA
P_{PHASE_EL}	<500	mW
P	3	W

Table 3: Pirelli DTL C13 Electrical Specifications

CHAPTER 3

RELIABILITY ASSESSMENT

Reliability assurance main issue is to verify the suitability of a given item, whether it is a material, or a component, or an assembly, or a system, for a stated application and amount of time. The reliability assessment process involves many actors and the product itself in different phases of its lifecycle. It includes the prior qualification and lot to lot controls of the parts, implicating a supplier effort, commonly known as supplier or vendor approval, in as suring that the specific supplied devices meet the needs of the manufacturer, feedback and corrective action procedures and device final qualification.

Typically final qualification is the last effort in a built in reliability approach, ahead of the release of a product, arising from the design assessment to the production phase, passing through a transitory phase by means of prequalification exercises directed to define the proper screening to prevent infant mortality failures from escaping to the customer.

The prequalification process is characterized by the lack of a universally accepted system [18]. This has led to the development of a number of proprietary prequalification systems together with an over reliance on human judgment for assessment in practice. To improve the reliability and objectiveness of decisions being made, prequalification needs to be carried out on a more rational basis.

In general a good prequalification exercise directed, by means of test vehicles and subassemblies, to assure the process and the product choices moves from a reliable admission of the critical states.

QUALIFICATION

This activity, actually completely supported by international standards, needs a careful planning, in particular it is important to allocate the correct number of devices to the selected tests among the ones required to assure that the product is able to successfully satisfy the requirements expressed in the reference standard.

Devices qualification has two primary segments [19]:

- characterization of the qualification process intended to confirm the ability of the device to meet the equipment manufacturer’s performance requirements;
- the mechanical and environmental stress testing of the qualification process intended to verify that the basic device design and fabrication materials and processes are sound, and can be expected to provide adequate long term reliability.

Below are listed the different pass/fail mechanical and environmental tests, requested by Telcordia GR-468-CORE Issue2, Sept.2004 for qualification of optoelectronic devices.

After each test is requested an exhaustive optical and electrical characterization to establish the pass/fail result of the performed test on the selected number of devices.

Next chapters provide a detailed description of the electro/optical device characterization procedure, the qualification test plan and pass/fail criteria.

ACCELERATED TESTS

The reliability tests employed are chosen based on the failure mechanisms of interest to the reliability engineers, as different stress tests accelerate different failure mechanisms.

Reliability tests in general utilize temperature, moisture or humidity, current, voltage, and pressure as stress factors to accelerate failure.

Performing reliability under normal operating conditions requires a very long time and the use of an extensive number of units under test, so it is usually costly and impractical. This has led to the development of accelerated life testing, where the devices under test are subjected to more severe environment conditions, increased or decreased stress levels, than the normal operating environment so that failures can be induced in a short period of test time.

Information obtained under accelerated conditions is then used in conjunction with a reliability prediction in assessing the reliability of components and products under normal operating conditions.

The idea of accelerated testing is then to reduce time, accelerating the failure mechanism in a compressed testing period. To perform this activity is necessary an extensive capability to simulate all the environmental life hazards conditions placed on product in a reasonable short time period. Accelerated testing, means aging by stressing the failure modes improving the chances for failure occurring in a reasonable short time.

Accelerated testing must be carefully designed: loads can not exceed the product design capability, avoiding the occurrence of inconsistent testing failures.

The stress tests suitable for optoelectronic devices, modules and systems include mechanical integrity tests and both powered and non-powered environmental stress tests.

MECHANICAL TESTS

These tests are planned to demonstrate the capability of the device to endure to mechanical shocks and vibration as might occur due to roughly handling, transportation[1] or operation in the field. Thus all the devices under test are not working during the tests but each of them must be appropriately measured before and after each test.

VIBRATION

In vibration test, the devices under test, secured on a proper bearing with leads and fiber adequately protected are fixed on a dynamic shaker bench and subject along a direction to a previous selected vibration profile. This can be either sinusoidal or random. Telcordia GR-468-CORE Issue2 refers to the procedure appearing in MIL-STD-883E, Method 2007.3, Vibration Variable Frequency. This is a destructive test and is performed for the purpose of determining the effect on component parts of vibration in the specified frequency range.

This method requires the devices under test to be vibrated with simple harmonic motion having either peak to peak amplitude of 0.15cm±10% or a peak acceleration of the specified test condition A, B, or C. The vibration frequency shall be varied approximately logarithmically between 20 and 2,000Hz and must return to 20Hz in not less than 4 minutes. This cycle shall be performed 4 times in each of the orientations X, Y, and Z, for a total of twelve times. This method specifies the different test condition peak accelerations

Condition	Peak acceleration
A	20g
B	50g
C	70g

Table 4: MIL-STD-883E, Method 2007.3, test conditions

In particular for all the devices covered in GR-468-CORE the applicable condition is A. After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

MECHANICAL SHOCK

In mechanical shock test, the devices under test, secured on a proper bearing, are fixed on a dynamic shaker bench and subject in each of the six spatial orientations, for a fixed number of times, to an acceleration pulse. Telcordia GR-468-CORE Issue2 refers to the procedure appearing in MIL-STD-883E, Method 2002.4, Mechanical Shock. This test is intended to determine the suitability of the devices when subjected to fairly severe shocks as a result of suddenly applied stresses or abrupt changes in motion produced by rough handling, transportation, or field operation. The testing equipment shall be capable of providing shock pulses of 500 to 30,000 g with pulse duration between 0.1 and 1.0ms to the body of the device. The acceleration pulse shall be a half-sine waveform with an allowable distortion not greater than ±20 percent of

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[1] Transportation is defined as when the product is in transit from the warehouse to the customer.

the specified peak acceleration, and shall be measured as clearly expressed in the method, by a proper accelerometer [20]. Unless otherwise specified, the device shall be subjected to five repetitions of a shock pulse of the peak acceleration level specified in the selected test condition and for the duration specified in each of the orientations ±X, ±Y and ±Z. This method specifies the different test conditions

Condition	Peak acceleration	Pulse Duration
A	500g	1.0ms
B	1500g	0.5ms
C	3000g	0.3ms
D	5000g	0.3ms
E	10000g	0.2ms
F	20000g	0.2ms
G	30000g	0.12ms

Table 5:MIL-STD-883E, Method 2002.4, test conditions

In particular for all the devices covered in GR-468-CORE the applicable condition is A for components and modules. In the case of integrated modules, the applicable test conditions depend strictly on the mass of the device. In particular GR-486-CORE identifies two different requirements in terms of peak acceleration and pulse duration depending on the mass of the device.

Mass	Peak acceleration	Pulse Duration
≤0.255Kg	300g	3.0ms
>0.255Kg & ≤1.0Kg	50g	11.0ms

Table 6: Test conditions depending on the mass of the device

After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

THERMAL SHOCKS

Thermal shocks are planned to test the package hermetic integrity of a module. Telcordia Gr-468-CORE Issue2 refers to condition A of the procedure appearing in MIL-STD-883E, Method 1011.9, Thermal Shock. Thermal Shock is performed to determine the resistance of the part to sudden changes in temperature. The parts undergo a specified number of cycles, which start at ambient temperature. The parts are then exposed to an extremely low temperature and, within a short period of time, exposed to an extremely high temperature, before going back to ambient temperature. The procedure lists three sets of test conditions, for example using hot and cold bath temperatures. In the actual case of this qualification exercise, specimens are tested by means of a two zone vertical shock chamber, capable to complete the selected number of cycles moving from the cold to the hot chamber.

Mil-Std-883, Method 1011 specifies:

- total transfer time lower than 10 seconds;
- total dwell time greater than two 2 minutes;
- specified temperature reached in lower than 5 minutes;
- a minimum of 15 cycles.

The test conditions are below listed

Condition	Low Temp.(°C)	High Temp.(°C)
A	-0 (+2/-10)	100 (+10,-2)
B	-55 (+0/-10)	125 (+10,-0)
C	-65 (+0/-10)	150 (+10,-0)

Table 7: Mil-Std-883E, Method 1011, Thermal Shock test conditions

In particular Telcordia GR-468-CORE suggests for all hermetic optoelectronic devices condition A.

Failures due to thermal shock depend on:

- the difference between the high and low temperatures used;
- the transfer time between the two temperatures;
- the dwell times at the extreme temperatures.

After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

NON POWERED ENVIRONMENTAL STRESS TESTS

These tests are planned to demonstrate the capability of the device to withstand the high and low temperatures encountered during storage[2] and transportation. All the tested devices are not powered during the tests but each of them must be appropriately measured before and after each test.

HIGH TEMPERATURE STORAGE

The high temperature storage test is performed to determine the effect on devices of long-term storage at elevated temperatures without any electrical stresses applied. High temperature storage consists of storing the devices under test at the specified ambient temperature for a specified amount of time. Long term high temperature storage tests are required by Telcordia reliability assurance test procedures [21]. High temperature storage is effective for the

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[2] Storage is defined as any time the product is packaged but not in transit, such as sitting on a dock or in a warehouse.

reliability testing and literature is reach of examples showing that this test stimulate failure modes as oxidation, bond and lead finish intermetallic growths, etc., in much the same manner as high temperature operating tests. Any oven or thermal chamber capable of providing controlled elevated temperature may be used for this environmental test. After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

LOW TEMPERATURE STORAGE

Low temperature storage test consists of storing the devices under test at the specified ambient temperature for a specified amount of time.

Long term low temperature storage tests pointed out just few failure mechanisms [22] and therefore according to Telcordia GR-63-CORE, a three days low temperature storage test is required by reliability assurance test procedures. Any freezer or thermal chamber capable of providing controlled low temperature may be used for this environmental test. After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

TEMPERATURE CYCLING

Temperature cycle testing, or simply temperature cycling, determines the ability of devices under test to resist extremely low and extremely high temperatures, as well as their ability to withstand cyclical exposures to these temperature extremes. This test accelerates fatigue failures and is preformed by means of a thermal chamber according to the requirements test conditions.

The purpose of this test depends on the level of the optoelectronic device being tested. In the case of a module the intent is to ensure the long term mechanical stability of the optical alignment within the module package. In particular the failure mechanisms that are accelerated by thermal cycling are those related to mechanical stresses caused by a difference in the thermal coefficients of expansion in the used materials. Telcordia GR-486-CORE, Issue2 refers to the procedure appearing in MIL-STD-883E, Method 1010.7, Temperature Cycling. This method specifies the different test conditions

Condition	Low Temp.(°C)	High Temp.(°C)
A	-55	85
B	-55	125
C	-65	150
D	-65	200
E	-65	300
F	-65	175

Table 8: Mil-Std-883E, Method 1010.7, Thermal Cycling test conditions

with a total transfer time from hot to cold or from cold to hot not greater than one minute, a dwell time shall greater than ten minutes with load reaching the specified temperature within fifteen minutes. The Telcordia general requirements arrange, for optoelectronic devices, less harsh test conditions in terms of low and high temperatures, dwell time and ramp rate. Dwell time in this test is particularly important issue. It must be long enough for the device, module or subsystem to reach dwell temperatures. After completion of the test, an external visual examination of package, boot and leads is performed. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

DAMP HEAT

The simultaneous application of temperature and humidity is an extremely important test to assess reliability of hermetically and non hermetically sealed devices. Telcordia GR-486-CORE, Issue2 refers to the procedure appearing in MIL-STD-202G, Method 103B, and IEC 60068-2-3 Temperature Cycling. This method specifies the different test conditions. All the procedure can be performed in any climatic chamber avoiding condensation dripping upon the devices under test. At conclusion of the whole sequence each device is subject to electro optical characterization. Failure of any specified measurement or examination evidence of defects to the package, boot and leads or illegible markings, not caused by fixturing, shall be considered a failure.

FIBER INTEGRITY TESTING

With the issuance of Telcordia GR-468-CORE, Issue 2, reliability assurance for optoelectronics devices qualification of optoelectronic devices, in September 2004, the requirement to perform fiber testing has been expanded to beyond what had been previously known as fiber pull testing.

The listing of Mechanical Integrity Tests in Table 4-3 of Issue 2 references three tests which are required for all optoelectronic modules and integrated modules with fiber pigtails. While the test conditions vary in consideration of the fiber pigtails being coated, tight-buffered versus loose-buffered or reinforced, the modules are to be subjected to the following:

- fiber integrity cable retention test;
- fiber integrity side pull test.

CABLE RETENTION TEST

The intent of this test is to mechanically stress the interconnecting device to fiber optic cable joint in tension.

The results of this test provide an indication as to the relative strength of the cable to interconnecting device joint and it may also indicate degradation resulting from prior environmental exposure. The procedure for this test appears in TIA[3], TIA-455-6-B, FOTP-6, Cable Retention Test Procedure for Fiber Optic Cable Interconnecting Devices.

For the pigtails covered in this document a weight of 0.5Kg, is applied to the secured cable at a minimum of ten centimetres from the loose end of the fiber, and is maintained for one minute.

At conclusion of the whole sequence each device is subject to an optical characterization in determining whether the device passes or fails the test.

SIDE PULL TEST

The intent of this test is to mechanically stress the interconnecting device to fiber optic cable joint in tension.

The results of this test provide an indication as to the relative strength of the cable to interconnecting device joint and it may also indicate degradation resulting from prior environmental exposure. The procedure for this test appears in Telcordia GR-326-CORE, Transmission with Applied Tensile Load.

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[3] Telecommunication Industry Association (TIA) is accredited by the American National Standards Institute (ANSI) to develop voluntary industry standards for a wide variety of telecommunications products. TIA's Standards and Technology Department is composed of five divisions which sponsor more than 70 standards formulating groups. The committees and subcommittees sponsored by the five divisions (fiber optics, user premises equipment, wireless communications, communications research and satellite communications) formulate standards to serve the industry and.

For the pigtails covered in this document a weight of 0.25Kg, is applied to the secured cable at a distance between twenty two and twenty eight centimetres from the device housing at an angle of ninety degrees.

At conclusion of the whole sequence each device is subject to an optical characterization in determining whether the device passes or fails the test.

OPERATING LIFE TEST

In addiction to the accelerated above explained operating life test could be performed for the purpose of demonstrating the quality and reliability of devices subjected to the specified conditions over an extended time period.

Either a static or a dynamic condition may be used, depending on the device type.

The devices in use for this test are supplied at the maximum rated injection current, phase element current and voltage values expressed in the product specifications sheet. Moreover they are maintained at the highest working environmental temperature. The devices are consequently tuned on highest channel at their higher optical power out value.

Sometimes this testing method is addressed as an accelerated testing under worst case operating conditions for a given device.

The extrapolation of data for FIT rate does not include any electrical or thermal acceleration.

Life test studies, collecting lifetime data under carefully controlled operating conditions can help a manufacturer to develop statistical models to predict devices lifetime under intended operating conditions.

To obtain statistically meaningful data, life test studies normally involve a great number of devices examined for long periods, of at least 5000 hours and often extending beyond a year. This methodology is obviously cost effective owing to the cost of the devices and for the resources involved.

A detailed description of the life test bench and device operation conditions are given in appendix A and in chapter 5.

CHAPTER 4

CHARACTERIZATION PROCEDURE

All the mechanical and environmental tests requested by Telcordia GR-468-CORE Issue2, Sept.2004 for reliability assurance and qualification of optoelectronic devices are pass/fail tests. Before and after each test is necessary an exhaustive focused characterization to establish the performed pass/fail test result.

In chapter 2, a subset of the device optical and electrical features has been considered as relevant in driving the identification of the pass/fail criteria. The tests' outcomes depend, at each characterization check point, on those criteria.

The mentioned reasons call for a careful design, development with final characterization/evaluation for the suitable bench marks. Measurement bench must be also time invariant and repeatability must be ensured.

Characterization process must perform the appropriate measurements to highlight the proper parameter deviations within their boundary ranges. Boundary ranges generally depend on the quantitative requirements expressed in terms of device specifications.

The measurement type and the observed parameters strictly depend on the functional features of the device under test. It is therefore needed an appropriate understanding of the device functional mechanisms by means of an intensive measurement campaign fully supported with scientific literature.

HOW DOES IT WORK?

The main issue, dealing with this work, was the understanding of the Pirelli DTL wavelength selection due to the interaction of all the intra cavity parts.

An intensive measurement campaign was carried out onto different tunable lasers, involving all the electrical “adjustable” parameters. Temperature too, either internal, or external (environmental or case temperature), played a key role in this learning process. In particular the internal temperature can be varied by changing the packaged thermo electric cooler set point, the external one, by conditioning the device under test in a thermal chamber or on a proper mount.

To give an idea on the complexity of the problem a few graphs of the performed measurements on a device are listed below. They refer to a subset of measurements performed at a set 25°C value for the TEC and the environmental temperatures.

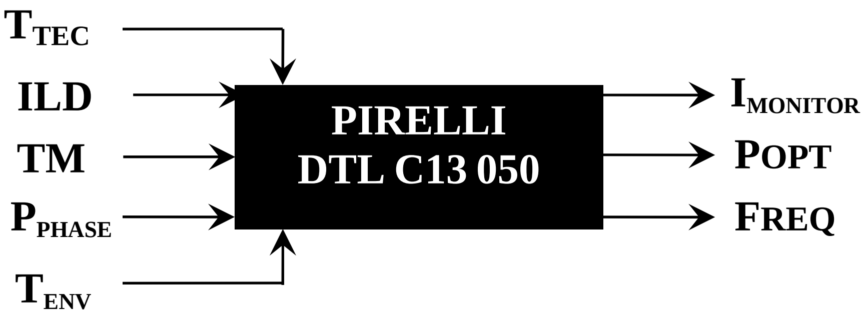


Figure 2: DTL Black Box Learning Process Approach

The idea was to approach the device as a black box with a series of input and output parameters. On one side, gain chip current, tunable mirror voltage, phase current and the two temperatures, on the other photodiode monitor current, optical power output and frequency respectively representing the inputs and the outputs.

As a consequence clearly results:

- the tuning action is principally realized by applying different driving voltages to the liquid crystal mirror, see figures 3 and 10.
- Central part of the tuning range is critical respect to the channel selection. Figures 3 and 10 clearly demonstrate in this range, the greater density of channels per unitary voltage variation.

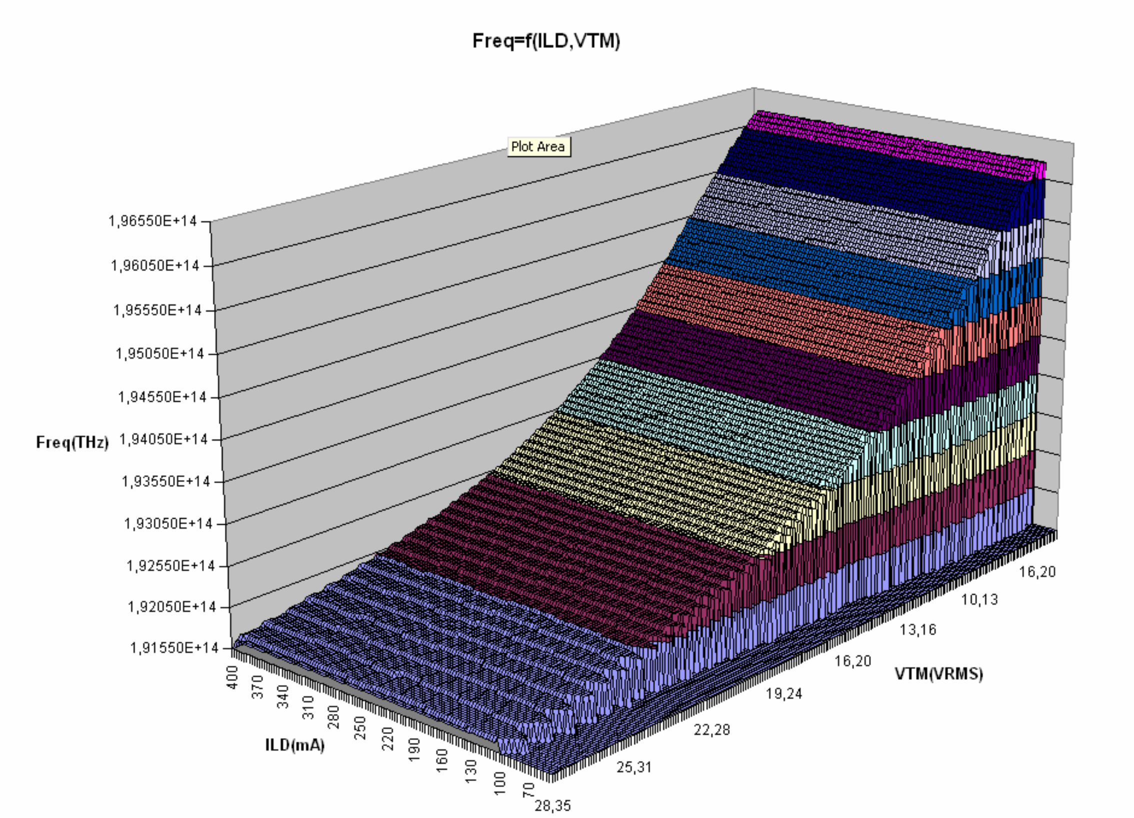


Figure 3: Frequency Map with Pphase=0mW

- The tuning action is secondly realized, as depicted in figure 4 and 11, respectively either by applying a different driving injection current for a fixed phase controller current, or by applying a different phase current for a fixed gain chip. This effect, properly known as mode hopping, in both cases is the result of the induced thermal effects.

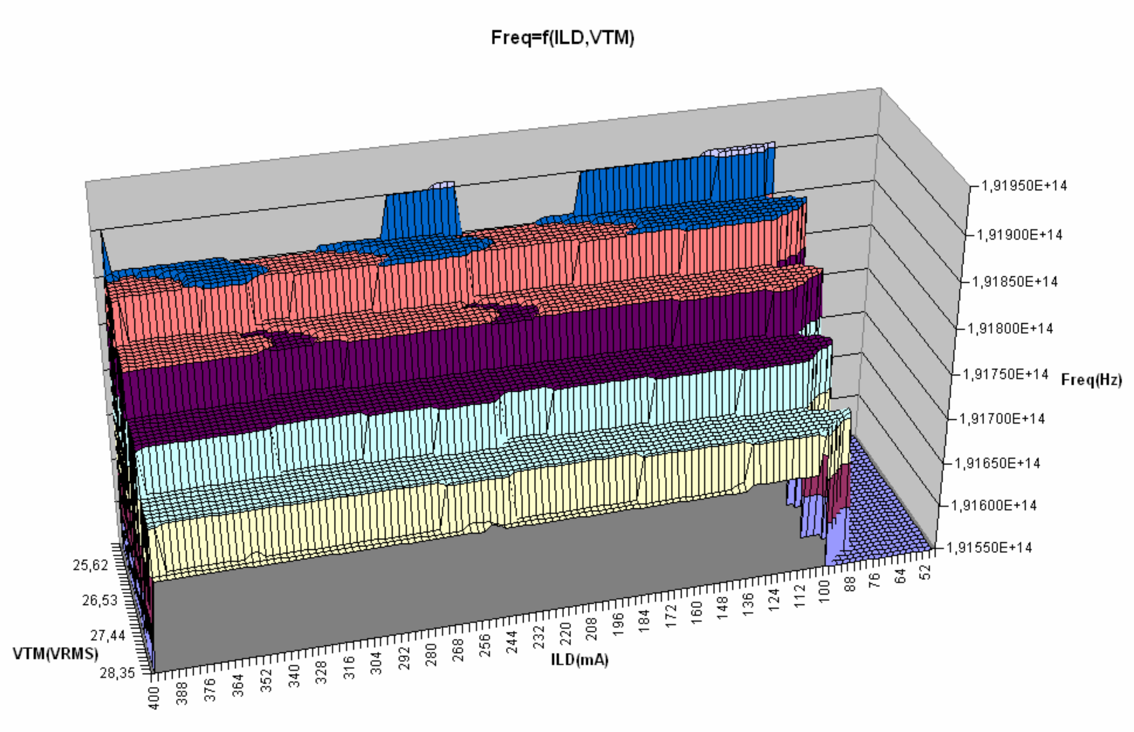


Figure 4: Frequency Map with Pphase=0mW Detail

Figures 5, 6, 8 and 9 describe the amplitude photodiode current and optical power output variations versus two simultaneous sweeps for chip injected current and tunable mirror applied voltage at a fixed phase current.

Figures 12 and 13 illustrate the optical power output variation versus two simultaneous sweeps for phase current and tunable mirror applied voltage at a fixed chip injected current.

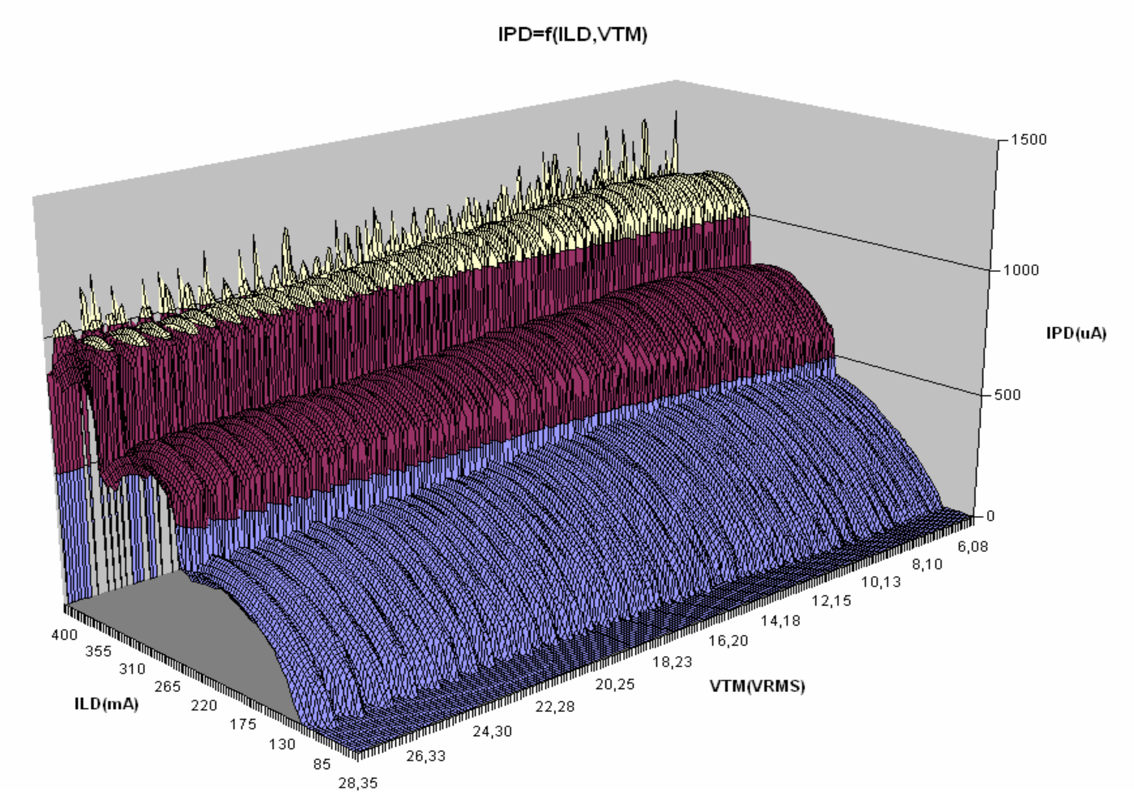


Figure 5: Monitor Current Map with Pphase=0mW

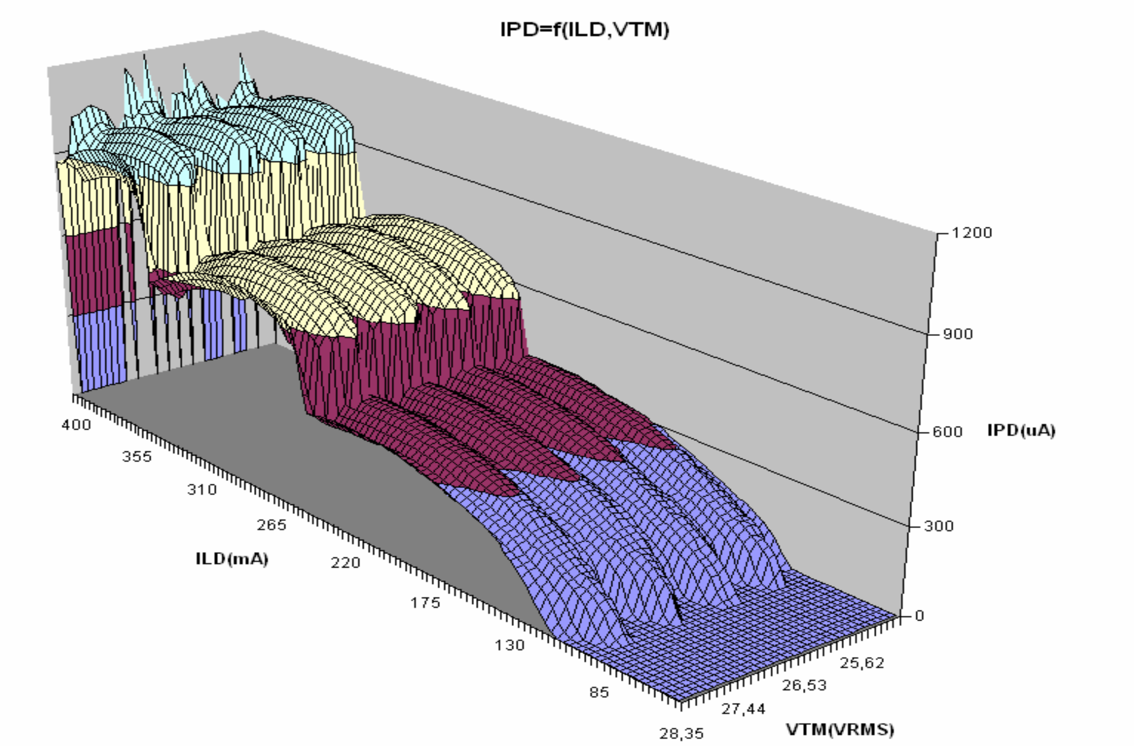


Figure 6: Monitor Current Map with Pphase=0 Detail 1

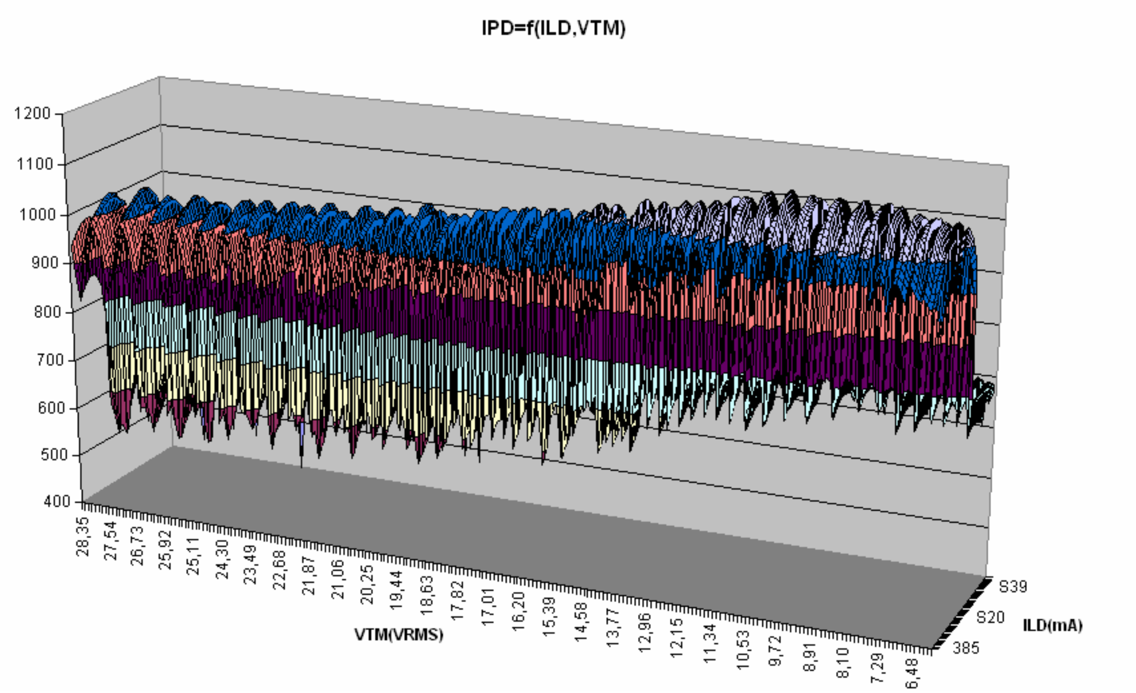


Figure 7: Monitor Current Map with Pphase=0 Detail 2

From a careful analysis of the surfaces illustrated in figures 5, 6, 7, 8, 9, 12 and 13 it results:

- the structure is discrete in amplitude, either for the photodiode current or the optical power out. This effect is induced by the etalon action on the gain chip mode hopping. In both the measurement setups, indeed, an increase of the temperature is achieved increasing the gain chip injection current in a case, or the phase current in the other. Both refractive index and band gap temperature dependence imply cavity modes pattern and gain curve variation [23]. The gain chip curve shifts to higher wavelengths modes or conversely to lower frequencies, as clearly illustrated in figures 4 and 11. Because of it, when a mode does not exhibit sufficient gain, the lasing wavelength jumps to another one with sufficient gain for lasing.

- Optical power output and photodiode current levels, in both the measurement conditions, are not constant overall the tuning range. Figure 7 clearly depicts this effect. It is the cumulative consequence of the gain chip variation in band and the dependence of the mirror reflectance on the applied voltage.
- The optical power output and photodiode current peak levels are not constant overall the gain chip current variation. Differently, the same parameters are uniformly aligned to the same value overall the dissipated power phase element variation.

This functional difference is the key element in the evaluation of the parameters for the tuning action. Appropriately adjusting both the current of the phase control element and the voltage over the tunable mirror, good output power and frequency stability is achieved. Moreover the gain chip injection current can be set to fix the output power level at the desired value. It is than possible to obtain isofrequential LI curves no more discontinuous in amplitude, where the output power depend quasi linearly on the gain chip injected current.

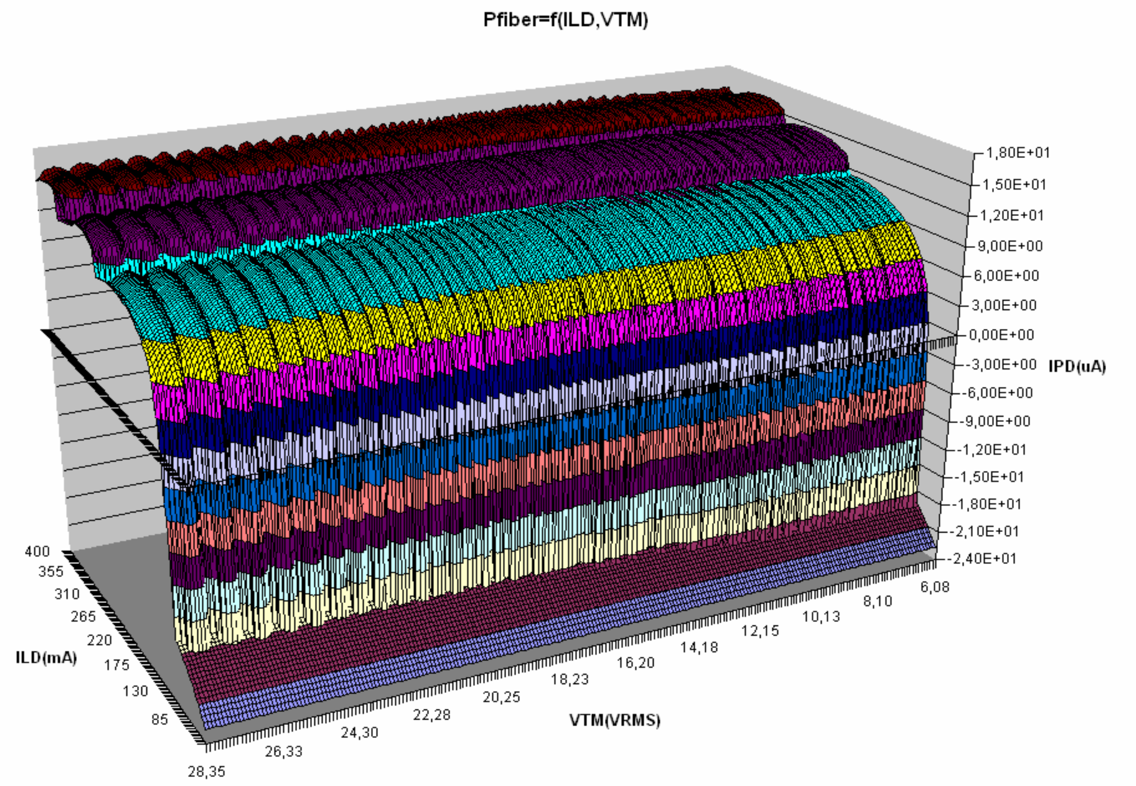


Figure 8: Pout Map with Pphase=0

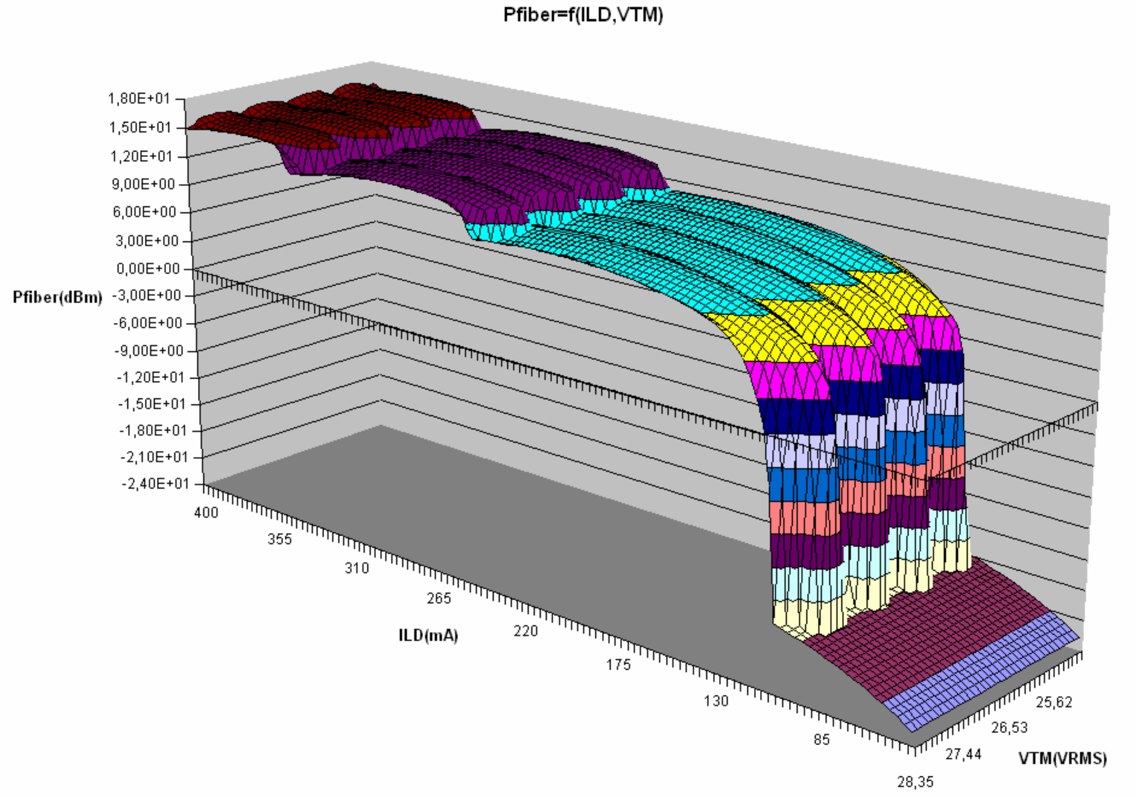


Figure 9: Pout Map with Pphase=0 Detail

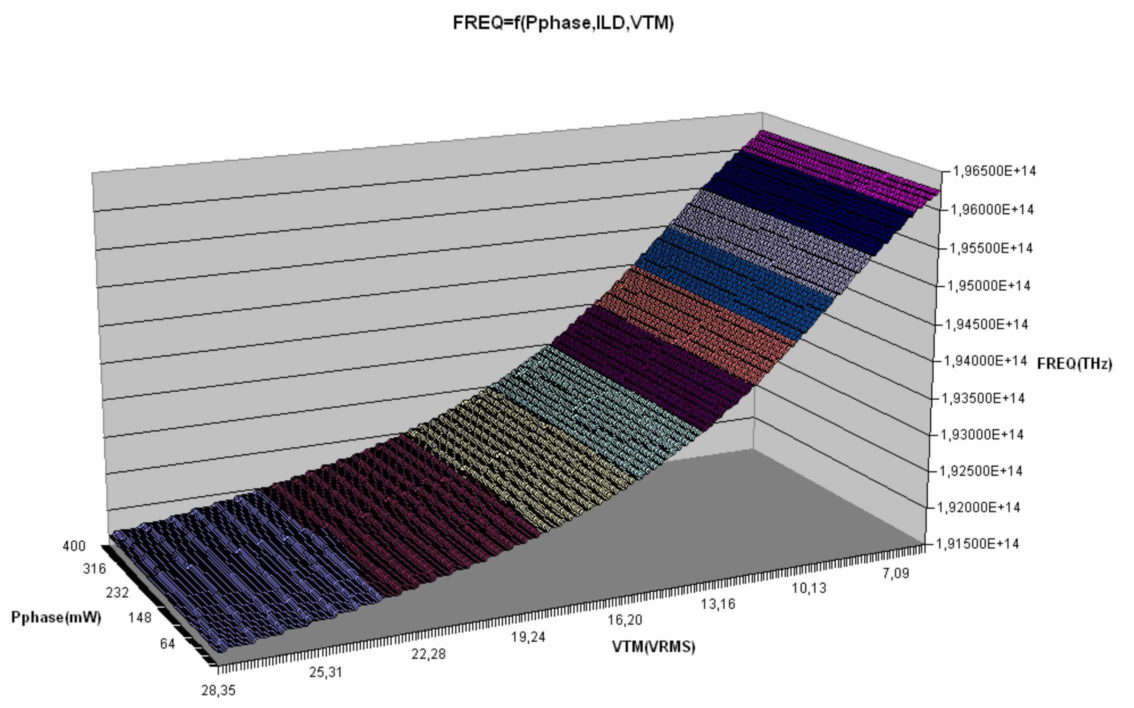


Figure 10: Frequency Map with ILD=I*

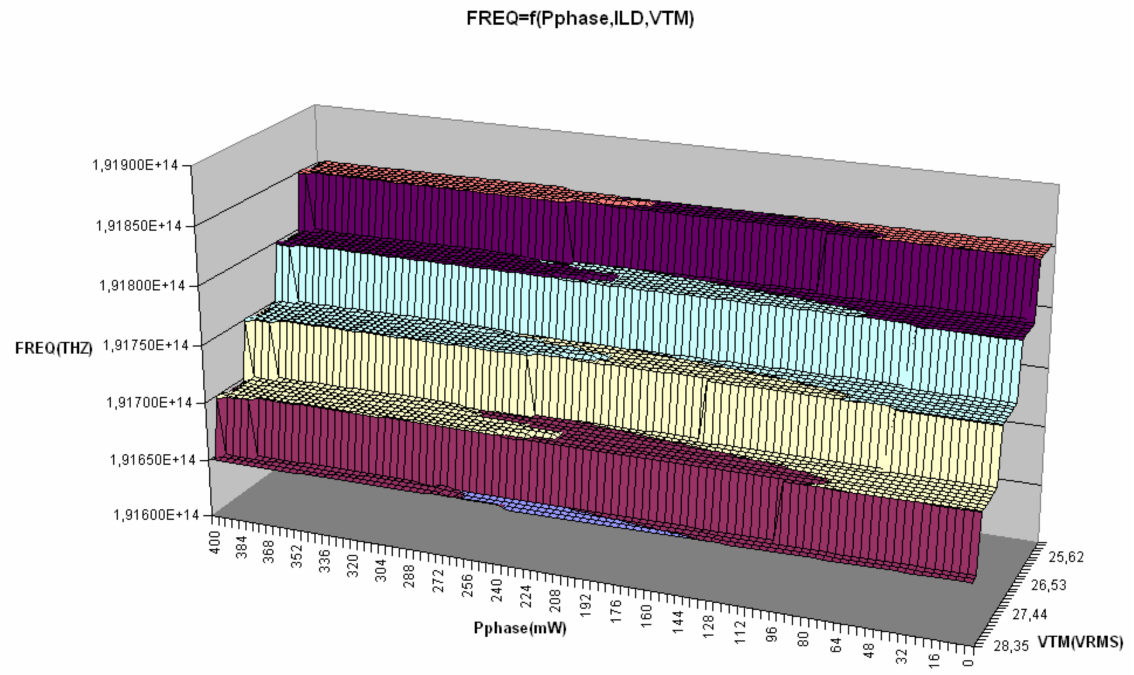


Figure 11: Frequency Map with with ILD=I* Detail

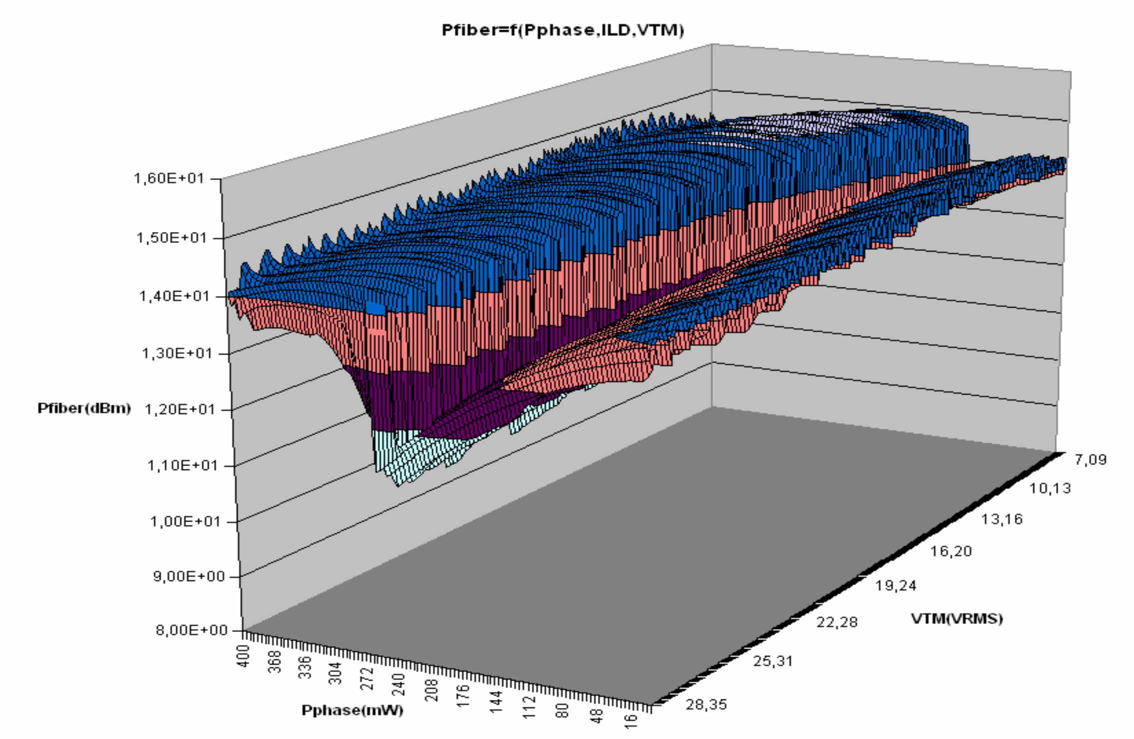


Figure 12: Pout Map with ILD=I*

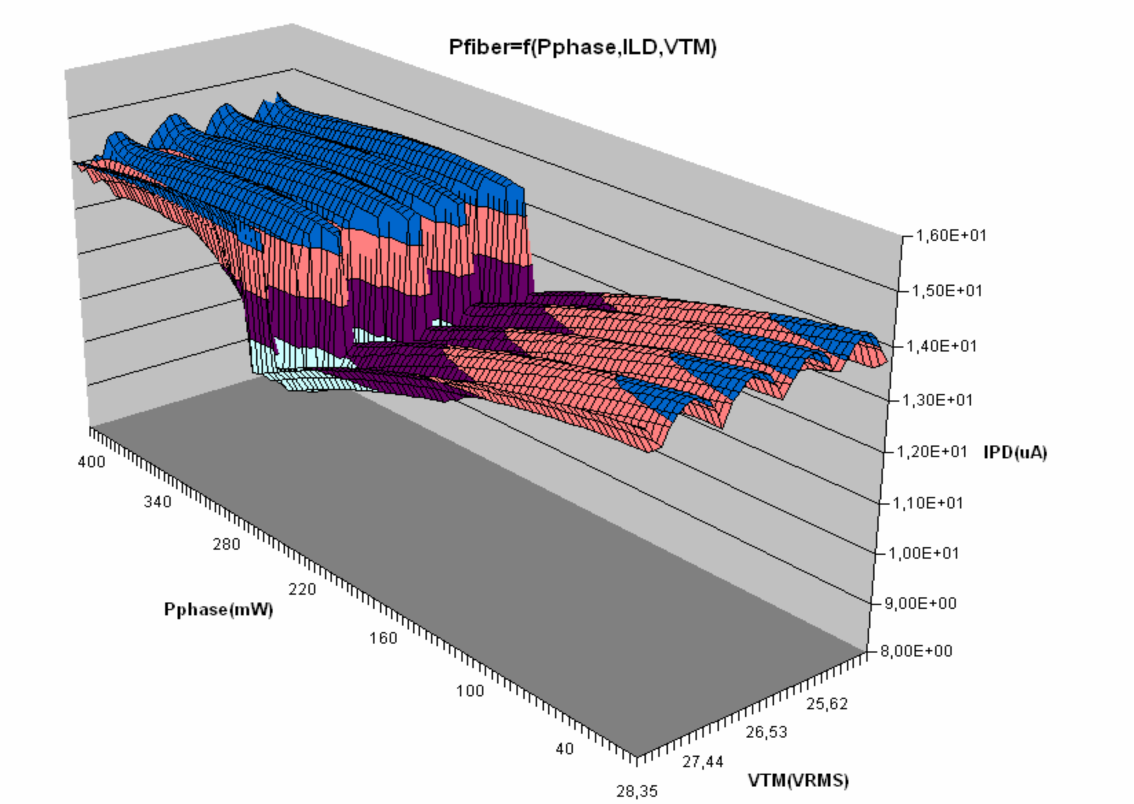


Figure 13: Pout Map with ILD=I* Detail

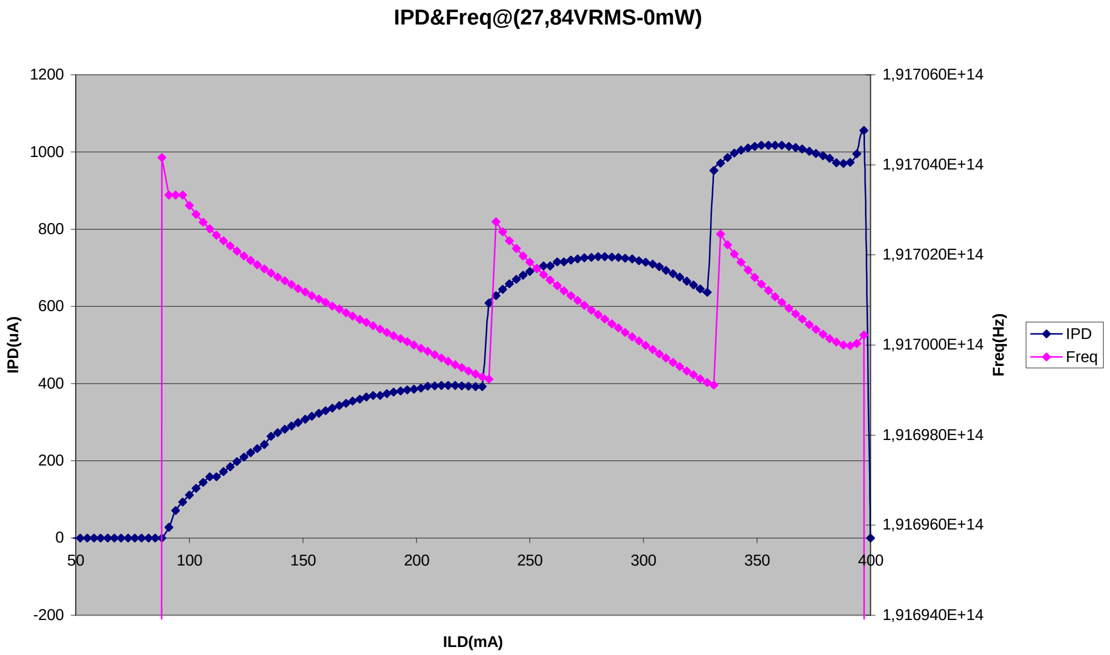


Figure 14: Figures 6 and 8 Merged Cross Section at VTM=27.84VRMS

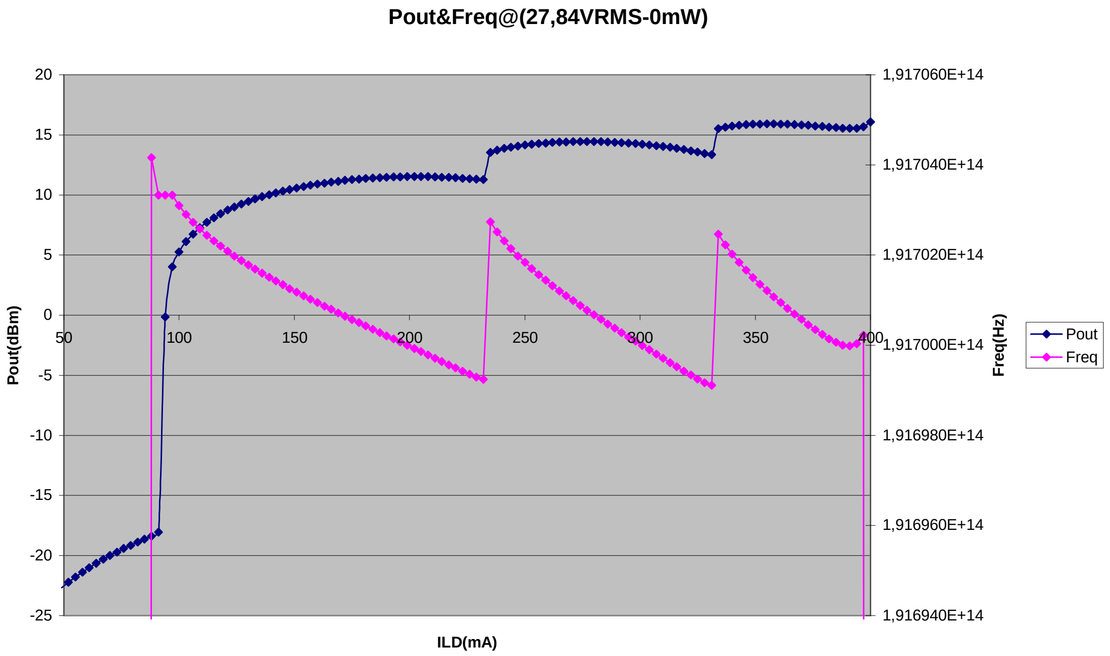


Figure 15: Figures 6 and 9 Merged Cross Section at VTM=27.84VRMS

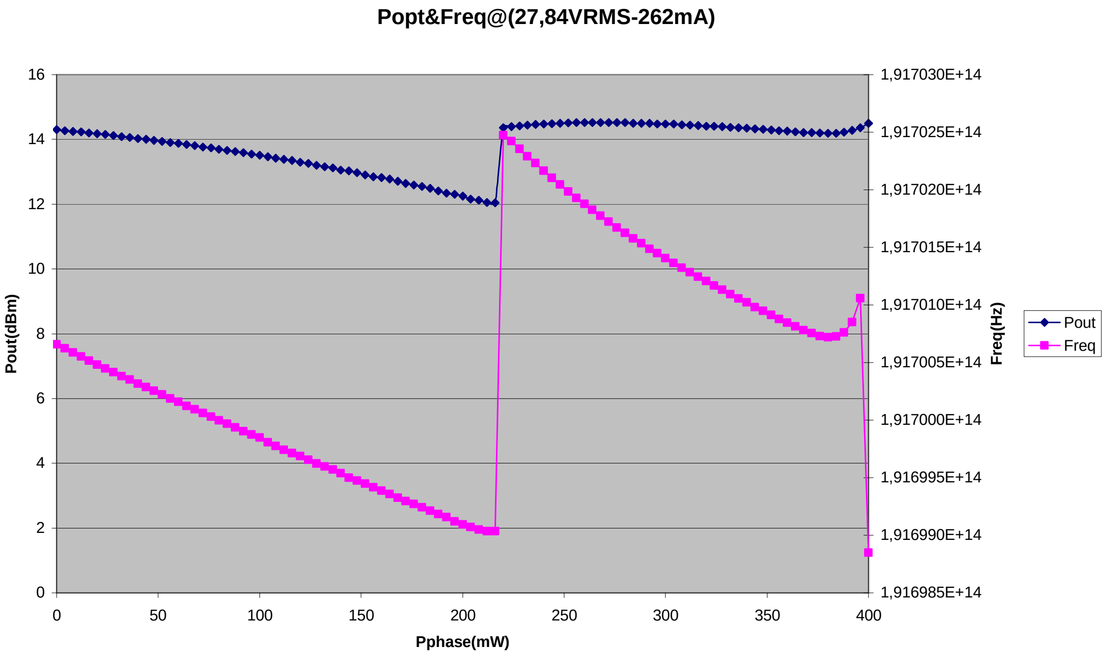


Figure 16: Figures 11 and 13 Merged Cross Section at VTM=27.84VRMS

Figures 14 and 15 are two bi-dimensional cross sectional views of the previously described 3D maps. They describe the dependences of the photodiode monitor current, the optical power out and frequency versus an injection gain chip current variation in a range from 50mA to 400mA. Tunable mirror voltage is set to a fixed value and no power is dissipated in the phase element.

Figure 16 illustrates the dependences of the optical power out and frequency versus a phase element power variation in a range from 0mW to 400mW. Chip laser injected current and tunable mirror voltage are set to a fixed value.

These two groups of images enclose all the described observable evidences obvious in the three dimensional maps.

CHARACTERIZATION PROCEDURE

The Telcordia standard GR-468-CORE calls for successful completion of stringent benchmark tests to demonstrate required reliability for optoelectronic devices used in telecommunications equipment. At each check point the devices shall then be tested for performance and physical characteristics, as appropriate.

Telcordia requirement R4-5 recommends for tunable lasers to measure the performance parameters with the wavelength set to the minimum specified operating wavelength, the maximum specified operating wavelength, and a wavelength near the middle of the specified tuning range.

The device characterization programmes two different steps.

The first step, according to Telcordia R4-5, schedules three different channel measurements: the first, the last, and another near the middle of the tuning range. This “middle channel” is chosen at a voltage value within the range where the voltage/frequency curve slope is greater. On the assumptions at the previous paragraph, set the channel by optimizing the applied voltage over the mirror, the device under test is then characterized involving with two consecutive sweeps in laser diode chip current and phase element current. The first current sweep is particularly important to state, among the other effects, the cavity stability. Pirelli DTL is intrinsically stable. The role of the second sweep is to verify the capability of a control algorithm to prevent cavity phase variations may occur, for instance, at strong temperature aging. This characterization is assisted by means of a properly designed and developed benchmark monitoring the gain chip current, the tunable mirror voltage, the phase element power, the optical bed temperature, the case temperature, the photodiode monitor current, the optical power output and the peak frequency. The characterization bench is described in the appendix at this chapter.

The second check point characterization step schedules the electrical characterization of all the parts embedded within the device. For example, by means of a semiconductor parameter analyzer, I-V curves are acquired for the gain chip, the photodiode, the phase element, the thermistors and the thermoelectric cooler. All these analyses are conducted taking into account the boundary ranges expressed in the devices' specifications.

The output for each device under test optoelectrical characterization is a formatted file text set ready to be processed.

All the devices involved in the qualification effort are then fully characterized at their incoming and at each subsequent programmed check point. Qualification plan, carried forward to the next chapter, in fact schedules a test point characterization set. The interval between characterizations depends strictly on the test, in the case of thermal cycle environmental test, for instance, check points are fixed after 20, 50, 100, 500 cycles.

After each test check point, all the files relating to the involved devices are processed and a report comes out. This report lists for each test and for each characterization point, the DUTs parameters variations referred to their incoming values. All the changes in the parameters account the bench introduced measurement errors. These values are then plotted on charts reporting along the horizontal axis the characterization test time and along the vertical axis the specific performance value variation.

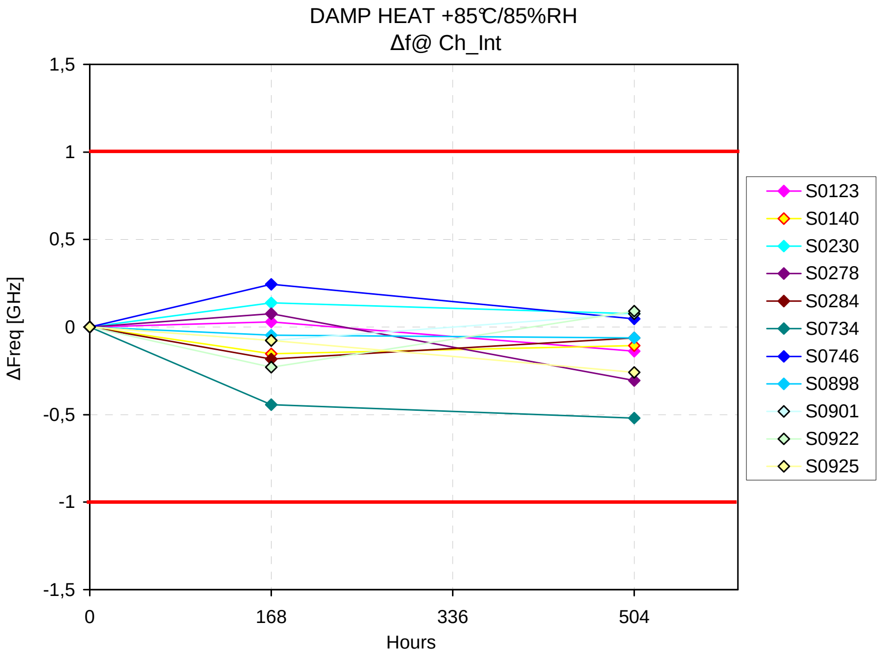


Figure 17: Output Frequency Variation Chart

An example for such outputs returned by the dataset evaluation application is showed in figure 19.

This chart reports for each device involved in the damp heat test the frequency variations referred to the incoming value related to the middle tuning band channel. Each device under test is identified, in the legend, by means of its serial number. The two horizontal red lines represent the pass fail criteria.

APPENDIX TO CHAPTER 4

CHARACTERIZATION BENCH

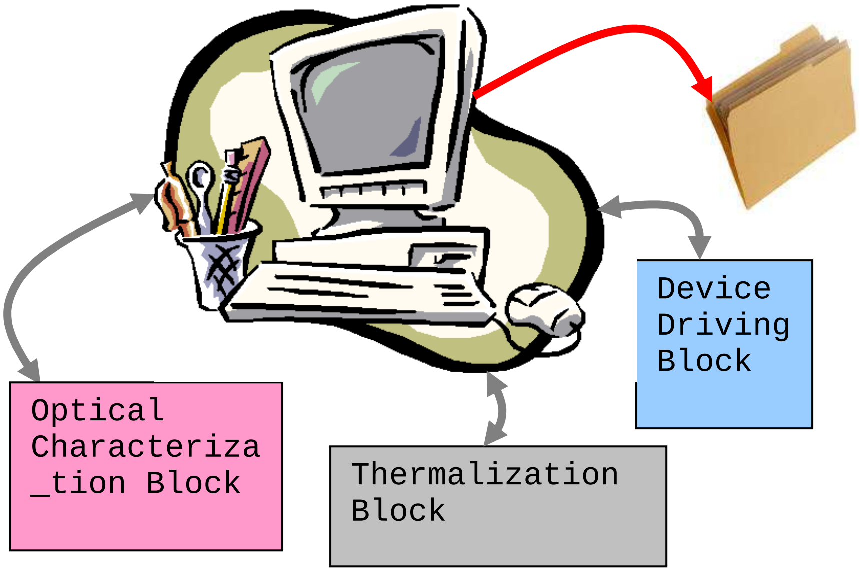


Figure 18: Optical Characterization Bench Scheme

The optical characterization bench setup can be subdivided in three different functional blocks. The first performs all the optical measurements. The second drives the device under test and the last one provides the internal and external thermalization of the device.

The optical measurement block consists of a power meter and a wavelength meter, connected to the optical fiber connector of the device by means of a beam splitter.

Figure 19: Wavelength Meter

Lasing peak frequency is monitored with an Agilent 86122A Multi-Wavelength Meter capable to measure the wavelength and optical power of laser light in the 1270÷1650 nm wavelength range with an absolute wavelength accuracy of ±0.3 pm at 1550nm.

The maximum displayed power level is 10 dBm; for this reason a fixed 5 dBm optical attenuator is used to reduce the power level of the input optical signal. Because the 86122A simultaneously measures multiple laser lines, it is a suitable instrument in characterizing dense wavelength division multiplexed systems and the multiple lines of Fabry-Perot lasers.

Figure 20: Power Meter and Optical Head

Tunable laser optical power output, reduced by the insertion loss of a beam splitter, is measured by means of an Agilent Technologies 81622B optical head connected to an Agilent Technologies 81618A interface module placed inside an Agilent 8163A mainframe. This optical head is designed for low polarization dependant loss, low spectral ripple and high return loss. It is provided of a large area Germanium sensor for power measurements in the optical range of 850 to 1650 nm suitable for a power range of +27 dBm to -55 dBm.

The driving function of the DUT is implemented controlling the injection current of the chip laser, the voltage over the tunable mirror and the current of the phase element.

Figure 21: Laser Driver and Internal TEC Temperature Controller

The injection current of the chip laser is provided by means of an ILX Lightwave LDC-3724B Laser Diode Controller. This is a high performance, microprocessor based instruments that offer a high stability, low noise current source with an integrated 32W temperature controller specifically designed for controlling the current and temperature of laser diodes. These controllers are known throughout the industry for their reliability, precision, and ease-of-use.

Independent power supplies for laser and TEC current provide clean, isolated power for laser protection and stability, moreover is provides laser diode protection including slow start, adjustable current limit and compliance voltage, intermittent contact protection, and output shorting relays are incorporated into each model.

This controller is used in delivering bipolar current to the thermoelectric cooler assuring a steady optical bed temperature with a typical temperature stability of 0.01°C.

Figure 22: Arbitrary Waveform Generator

Voltage generation for the tunable mirror is supplied by an Agilent Technologies 33220A Function Arbitrary Waveform Generator.

It uses direct digital synthesis techniques to create a stable, accurate output signal for clean, low distortion sine waves. It also gives square waves with fast rise and fall times up to 20 MHz and linear ramp waves up to 200 kHz. The 33220A can also be used to generate complex custom waveforms with 14-bit resolution, and a sampling rate of 50 MSa/s permitting the storage up to four waveforms in non-volatile memory.

In particular during the characterization procedure it provides a sine waveform with a frequency of 100 kHz, with VRMS voltage amplitude depending on the selected characterization channel.

Figure 23: 10X Voltage Amplifier

The output waveform is then driven through a FLC Electronics AB F10A Voltage Amplifier. It is a general purpose linear amplifier designed for laboratory use. It is based on a fast high-voltage operational amplifier with a feedback network chosen to give a voltage amplification of 10 times. Any function or arbitrary waveform generator with low output impedance and output voltage up to ±10 V can be used as an input device. The input protection network cuts accidental spikes and overshoots. Its output drives the mirror allowing the full range device tuning and is also monitored with an oscilloscope.

Figure 24: Phase Element Controller

A fine phase control is reached with an Agilent N6762A precision DC power module providing precise control and measurements in the microampere region with low output noise and fast output speed.

Figure 25: Case Temperature Controller

The case temperature is set by means of an ILX Lightwave LDT-5412 4W thermoelectric temperature controller optimized for controlling the temperature of laser diodes and photo detectors. The instrument controls and displays thermistor resistance while delivering bipolar current to a thermoelectric module. The unit’s hybrid proportional-integral control loop offers fast settling times with a typical temperature stability of 0.01°C. This module, allowing temperature values overall the entire operative range of the device, offers the possibility to perform temperature device characterizations.

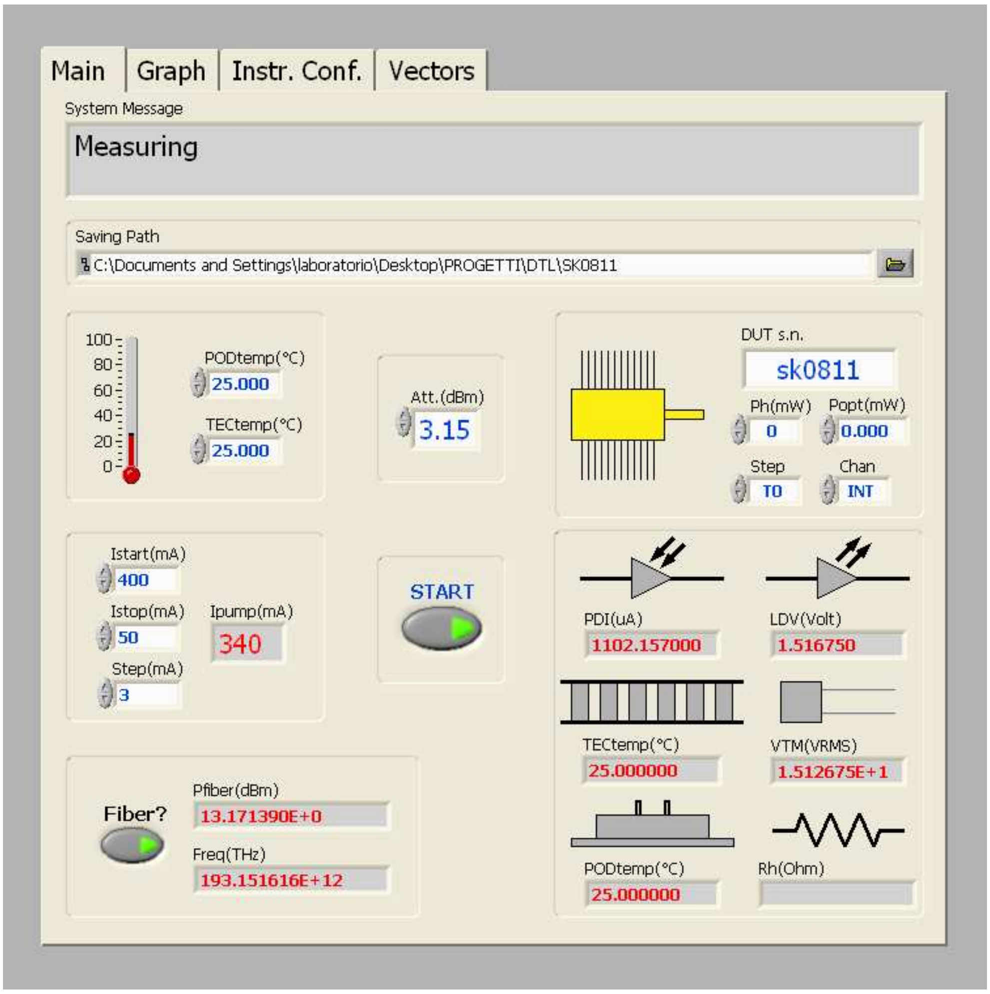
Figure 26: Laser Diode Mount

The device under test is placed on the ILX Lightwave LDM-4980 Single channel Telecom Laser Diode Mount providing a compact, easy-to-use solution for laser diode fixturing. These mount is available for butterfly 26-pin packages. This series of mounts accommodates most telecom laser module types including CW, direct modulated (Bias-T), 2.5Gbits/s, 10Gbits/s, and tunable DFB laser modules. This mount features ILX Lightwave’s standard 9-pin D-sub input connectors with configurable pin designations to accommodate virtually any laser diode pin configuration. Zero insertion force (ZIF) sockets and spring-loaded clamps facilitate ease of mounting.

All the described instruments are remote controlled with a dedicated Labview 7.1 programmed virtual instrument.

This virtual instrument by means of a user friendly and easy to use interface, implements all the requested functions for the instruments connected to the computer by means of 488.1-1987 IEEE Standard Digital Interface for Programmable Instrumentation.

This virtual instrument needs a few functional inputs in its “main” folder such as the extremes for a laser diode injection current sweep and the correspondent step, the case temperature working value, the optical bed temperature the channel of interest and the current to drive the phase element.



System Message: Measuring

Saving Path: C:\Documents and Settings\laboratorio\Desktop\PROGETTI\DTL\SK0811

PODtemp(°C): 25.000

TECtemp(°C): 25.000

Att.(dBm): 3.15

DUT s.n.: sk0811

Ph(mW): 0

Popt(mW): 0.000

Step: T0

Chan: INT

Istart(mA): 400

Istop(mA): 50

Step(mA): 3

Ipump(mA): 340

PDI(uA): 1102.157000

LDV(Volt): 1.516750

TECtemp(°C): 25.000000

VTM(VRMS): 1.512675E+1

Pfiber(dBm): 13.171390E+0

Freq(THz): 193.151616E+12

PODtemp(°C): 25.000000

Rh(Ohm):

Figure 27: Main Folder of the DTL Characterization VI

When the device is provided of a fiber optic pigtail with an optical connector, the optical attenuation due to the insertion loss of the beam splitter must be expressed in the dedicated field.

Some parameters regarding the serial number of the device under test, the saving path folder and the testing time must also be furnished.

When running the program outputs a set of optical and electrical parameters of interest. For each testing run the virtual instrument outputs a formatted file. This file reports a matrix containing, for each step of the laser diode current sweep, all the monitored parameters' values.

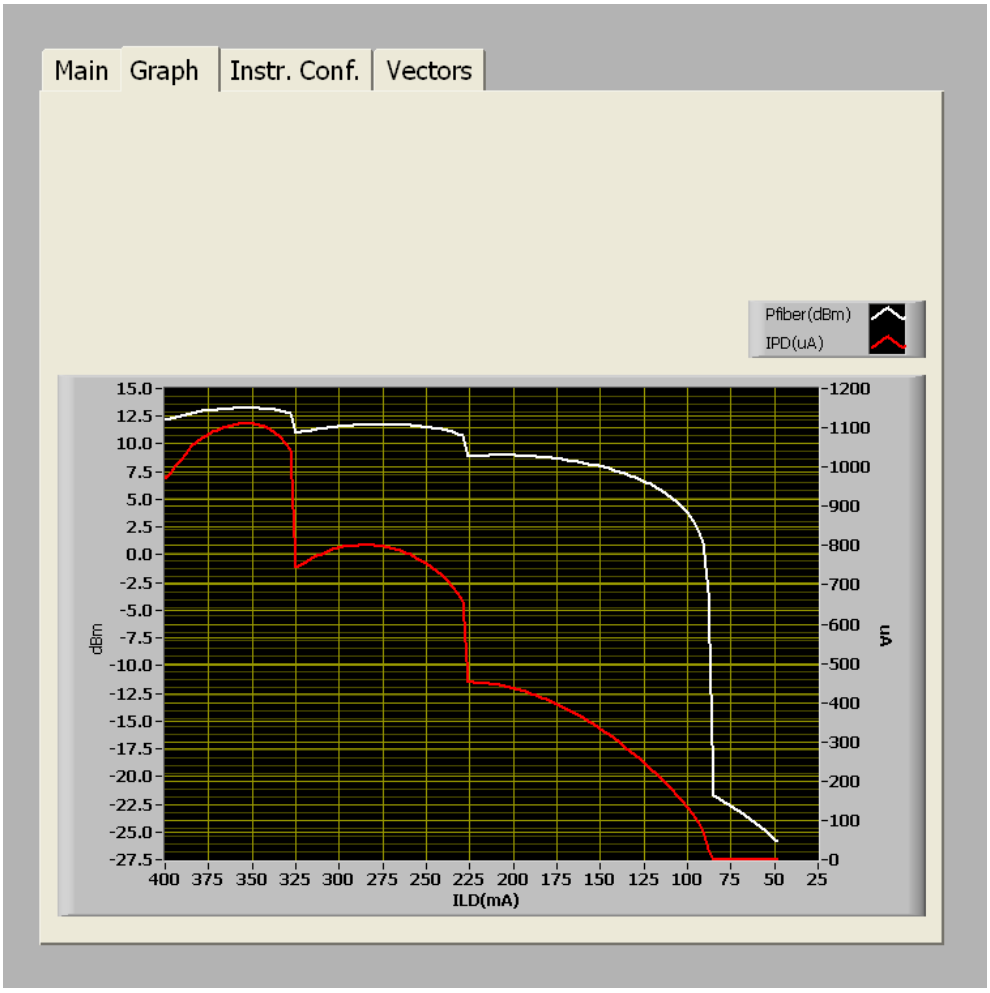


Figure 28: Graph Folder of the DTL Characterization VI

CHAPTER 5

TEST PLAN & RESULTS

Scope of this chapter is to give, starting with the qualification plan, the results of the tests performed on 85 devices belonging to the Pirelli Dynamically Tunable laser family DTL C13 050.

It will be demonstrated how the Pirelli DTL has successfully completed all Telcordia GR-468-CORE Issue2, Sept. 2004 testing, resulting fully compliant to the requirements requested for reliability assurance and qualification of optoelectronic devices for telecommunication applications.

TEST PLAN

All the qualification exercise has been fully designed according to Telcordia GR-468-CORE, Issue 2, Sept. 2004. In the table below are listed all the scheduled tests.

			Sampling			
	Tests	**Reference**	**LTPD**	**SS**	**Fail**	**Status**
Mechanical	Thermal Shock	3.3.1.2	20	11	0	**Passed**
	Vibration - Seq. A	3.3.1.1.1	20	11	0	**Passed**
	Mechanical Shock - Seq. A	3.3.1.1.2				**Passed**
	Vibration - Seq. B	3.3.1.1.1	20	11	0	**Passed**
	Mechanical Shock - Seq. B	3.3.1.1.2				**Passed**

Environmental	Low Temperature Storage	3.3.2.1	20	11	0	**Passed** (168hrs); on going for info
	High Temperature Storage	3.3.2.1	20	11	0	**Passed**(1000hrs); on going for info
	Temperature Cycling	3.3.2.2	20	11	0	**Passed**(100cycles); on going for info
	Damp Heat	3.3.2.3	20	11	0	**Passed**(500hrs); on going for info
Fiber Integrity	Cable Retention	3.3.1.3.3	20	11	0	**Passed**
	Side Pull	3.3.1.3.2				**Passed**
	Accelerated Aging	3.3.3.1	-	8	0	**Passed**(1000hrs); on going for info

Table 9: Qualification Test Plan

For each scheduled test is provided the name, the standard reference, the lot tolerance percent defective value, the sample size, the maximum number of failures allowed and the status of the test. Sample size, LTPD and the acceptance number of rejects are correlated according to the MIL-S-19500 and MIL-M-38510.

PASS/FAIL CRITERIA

Prior to any other consideration pass/fail criteria on the performance parameters. In general they depend on the specific application the device is provided to. In particular for this qualification exercise these limits are imposed to optical power out and frequency. Optical power and frequency stability are, for the DTL, the two preliminary features to its addressable market of WDM and DWDM application.

Test	Pass/fail criteria
Mechanical Integrity	ΔPout<+/-0.5 dB (@ 25°C) Δf<+/- 1 GHz (@ 25°C)
Endurance	
Reliability	ΔPout EOL <+/-1 dB ΔfEOL<+/- 1.5 GHz

Table 10: Pass/Fail Criteria

TEST RESULTS

All the planned tests had been fully described in chapter 3, with details on the purpose they are planned to, the description of the apparatus requirements they are performed with and the procedures.

Along this chapter, test objectives and test results will be listed. For each scheduled test is reported the sample size and the DUTs serial number, the test conditions and duration, the scheduled characterization check points. Graphs representing the results, according to the previously described characterization procedure and pass fail criteria, will also be shown.

HIGH TEMPERATURE STORAGE

The high temperature storage test is performed to demonstrate the capability of the devices under test to withstand the effects of long-term high temperature storage.

Sample size	**11**
Serial number	SK0022, SK0033, SK0044, SK0074, SK0079, SK0122, SK0147, SK0178, SK0211, SK0250, SK0285
Test conditions	(+85± 2)°C
Test duration	1000hrs for qualification; 5000hrs for info
Monitoring schedule	check points at t=0, 168hrs, 504hrs and 1004hrs ; other check points at t=2000 and 5000hrs

Table 11: High Temperature Storage Test Conditions

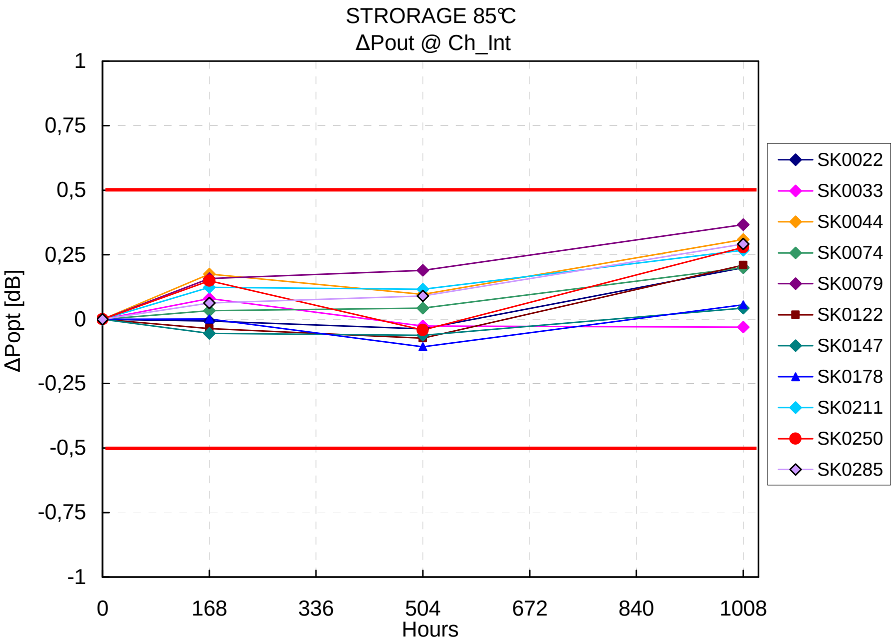


Figure 29: Storage +85°C Optical Power Variations

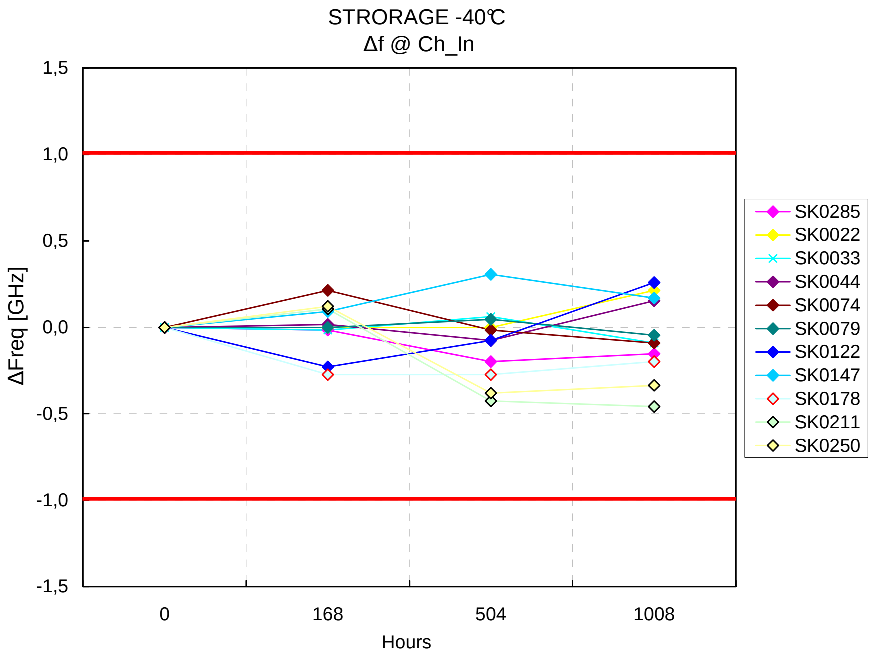


Figure 30: Storage +85°C Frequency Variations

Figure 29 and 30 show the output power and frequency variation overall the test duration, for the 11 devices involved in the test. Pass criteria are satisfied, therefore the test is passed. Actually it is on going to get reliability information.

LOW TEMPERATURE STORAGE

The low temperature storage test is performed to demonstrate the capability of the devices under test to withstand the effects of long-term high temperature storage.

Sample size	**11**
Serial numbers	SK0063, SK0154, SK0731, SK0787, SK0803, SK0807, SK0880, SK0891, SK0899, SK0915, SK0937
Test conditions	-40°C± 2°C;
Test duration	168hrs for qualification; 2000hrs for info
Monitoring schedule	check points at t=0, 168hrs, 504hrs and 1008hrs; other check points after every other 1000hrs

Table 12: Low Temperature Storage Test Conditions

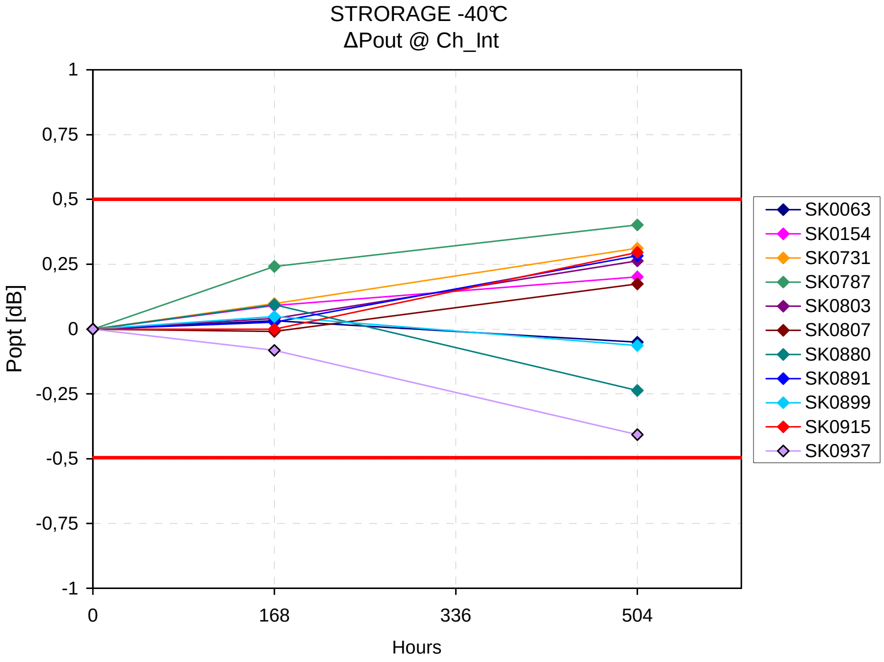


Figure 31: Storage -40°C Optical Power Variations

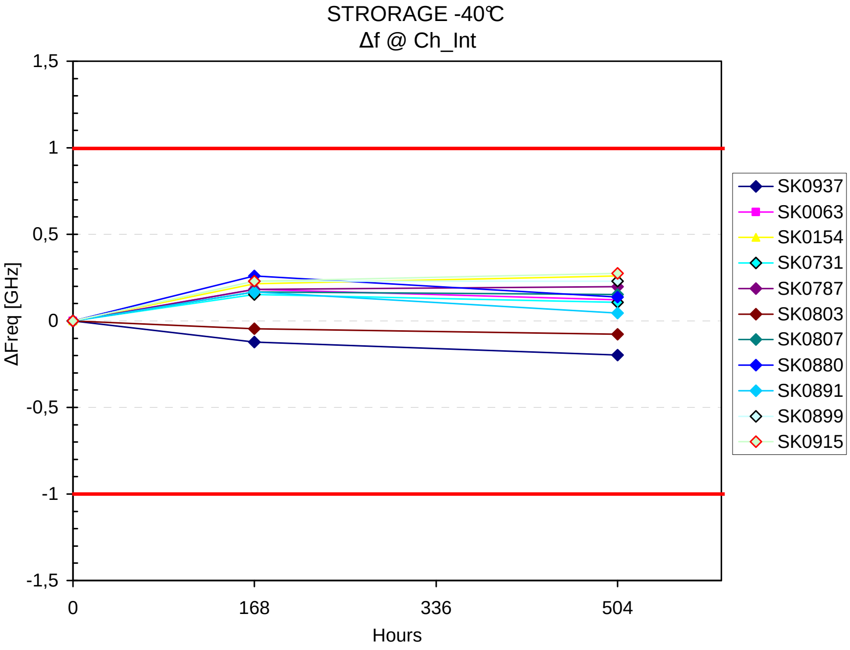


Figure 32: Storage -40°C Frequency Variations

Figure 31 and 32 show the output power and frequency variation overall the test duration, for the 11 devices involved in the test. Pass criteria are satisfied, therefore the test is passed. Actually it is on going to get reliability information.

THERMAL CYCLES

Temperature cycle testing, states the ability of devices under test to resist extremely low and extremely high temperatures, as well as their ability to withstand cyclical exposures to these temperature extremes. The purpose of this test is to ensure the long term mechanical stability of the optical alignment within the module package.

Sample size	**11**
Serial numbers	SK0039, SK0087, SK0088, SK0142, SK0222, SK0231, SK0238, SK0241, SK0276, SK0263, SK0284
Test conditions	(-40/85°)C± 2°C; 30min dwell, 90min transition
Test duration	100cycles for qualification; 500cycles for info
Monitoring schedule	check points at 20, 50 and 100 cycles; other check points after 200 and 500 cycles

Table 13: Temperature Cycling Test Conditions

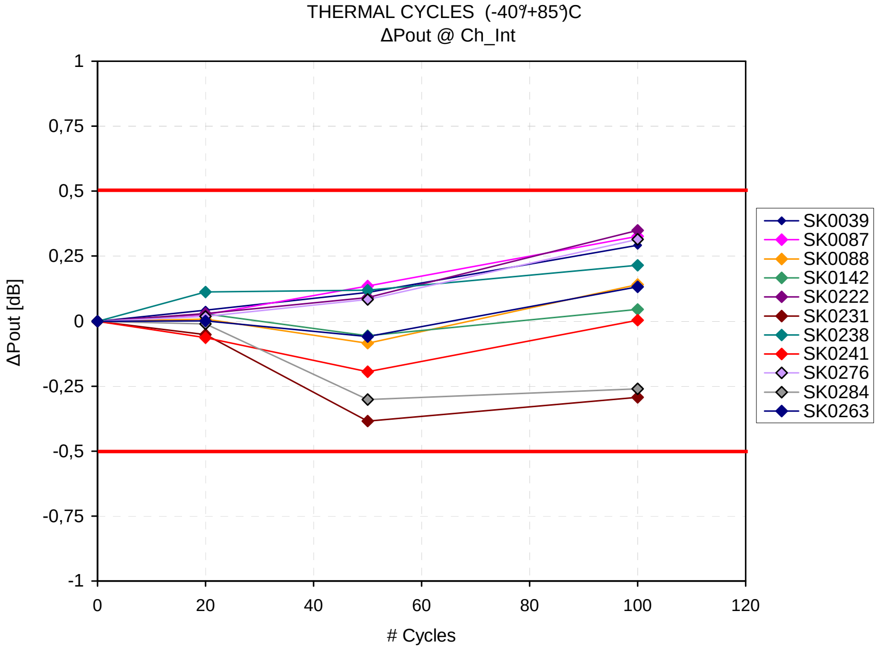


Figure 33: Thermal Cycling -40/+85°C Optical Power Variations

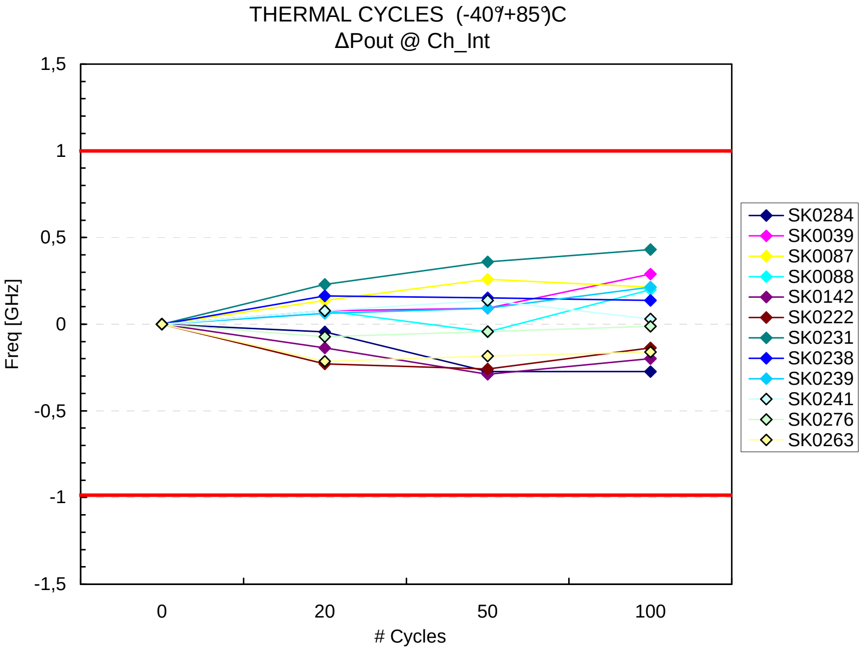


Figure 34: Thermal Cycling -40/+85°C Frequency Variations

Figure 33 and 34 show the output power and frequency variation overall the test duration, for the 11 devices involved in the test. Pass criteria are satisfied, therefore the test is passed. Actually it is on going to get reliability information.

DAMP HEAT TEST

The simultaneous application of temperature and humidity is an extremely important test to assess the hermeticity of the device hermetic package and the humidity resistance of the pigtail performances. Note that the pigtail is not hermetic itself and non-hermetically welded to the devices package.

Sample size	**11**
Serial number	SK0278, SK0922, SK0898, SK0734, SK0230, SK0284, SK0901, SK0140, SK0925, SK07460, SK0123
Test conditions	+85°C/+85%RH
Test duration	500hrs for qualification; 1000hrs for info
Monitoring schedule	check points at t=0, 168hrs, 504hrs and 1008hrs.

Table 14: Damp Heat Test Conditions

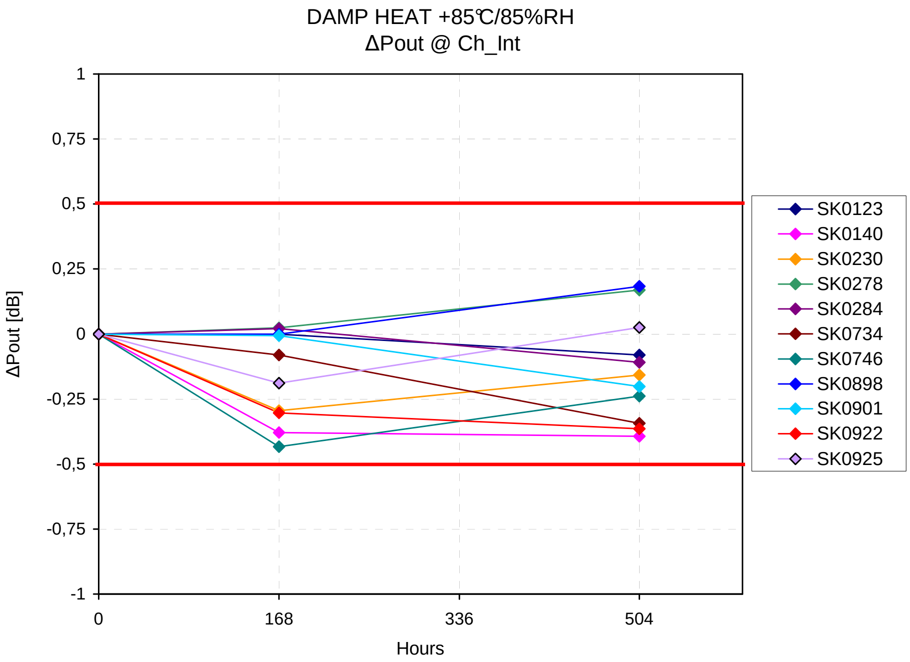


Figure 35: Damp Heat +85°C/85%RH Optical Power Variations

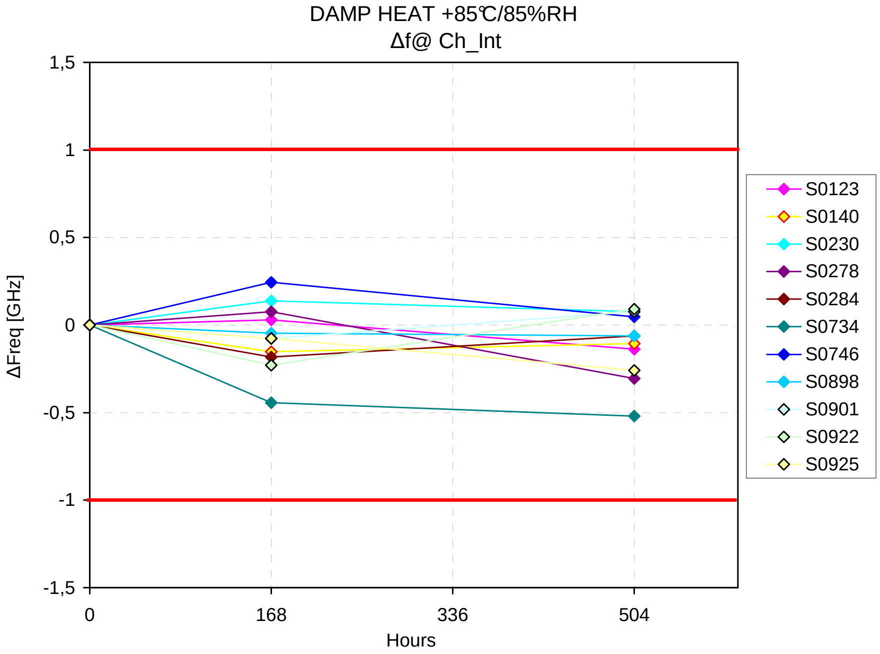


Figure 36: Damp Heat +85°C/85%RH Frequency Variations

Figure 35 and 36 show the output power and frequency variation overall the test duration, for the 11 devices involved in the test. Pass criteria are satisfied, therefore the test is passed. Actually it is on going to get reliability information.

THERMAL SHOCK TEST

Thermal shocks are planned to assess the package hermetic integrity of the module. Moreover it is performed to determine the resistance of the part to sudden changes in temperature.

Sample size	**11**
Serial number	SK0199, SK0254, SK0714, SK07234, SK0808, SK0811, SK0834, SK0846, SK0889, SK0890, SK0904
Test conditions	ΔT=120°C -40 °C ÷ +85°C 30min dwell, <10sec transition
Test duration	20 shocks for qualification, 1day
Monitoring schedule	check before and after test

Table 15: Thermal Shock Test Conditions

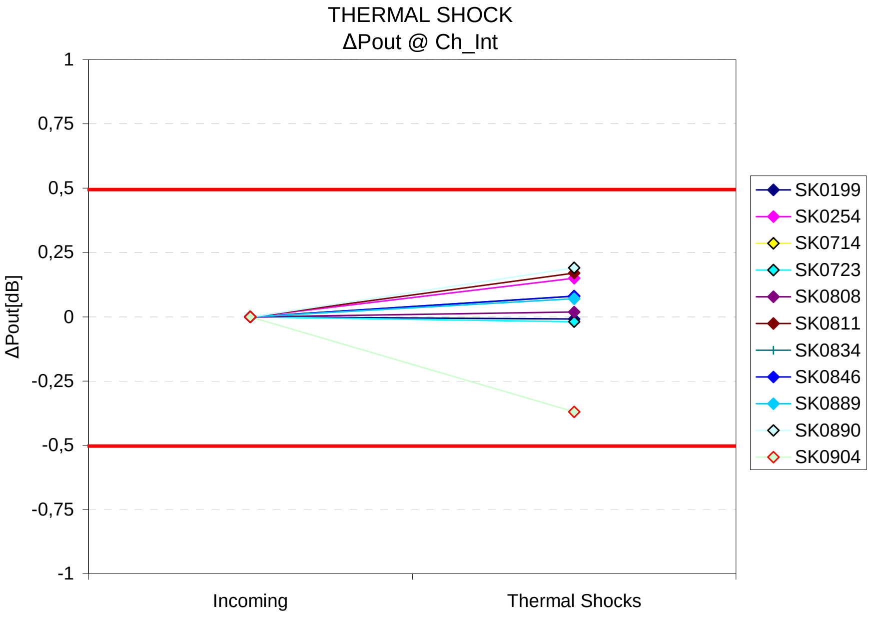


Figure 37: Thermal Shock Test Optical Power Variations

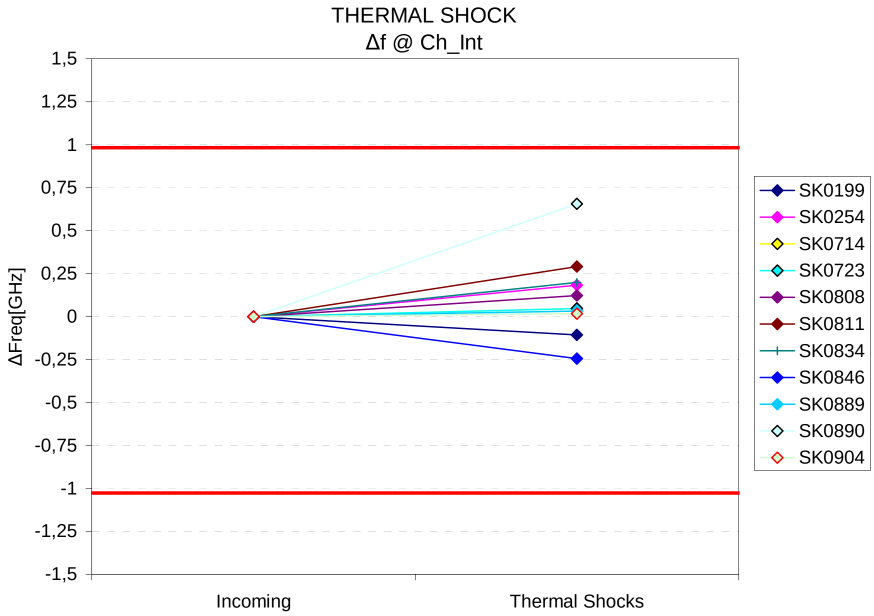


Figure 38: Thermal Shock Test Frequency Variations

Figure 37 and 38 show, for the 11 devices, the output power and frequency variation between before and after the test. Pass criteria are satisfied, therefore the test is passed.

VIBRATION AND MECHANICAL SHOCK

Two different sequences where applied to two groups of 11 devices.

The first scheduled, for the planned DUTs, a sequence of vibrations and mechanical shocks at 300G.

The second scheduled, for the planned DUTs, a sequence of vibration and mechanical shocks at 500G.

SEQUENCE A

In this case the DTL was approached as and integrated module thus the mechanical shock test conditions depend on the mass of the module.

The objective of this sequence was to assure the components robustness towards shocks as might occur due to roughly handling, transportation or operation in the field.

Sample size	**11**
Serial number	SK0199, SK0254, SK0714, SK07234, SK0808, SK0811, SK0834, SK0846, SK0889, SK0890, SK0904
Test conditions	Vibration: 20G, 20-2000Hz 4min/cy, 4cy/axis
	Mechanical shock: 5 times/axis 300G, 3.0ms
Test duration	1 day
Monitoring schedule	check before and after test

Table 16: Sequence A Test Conditions

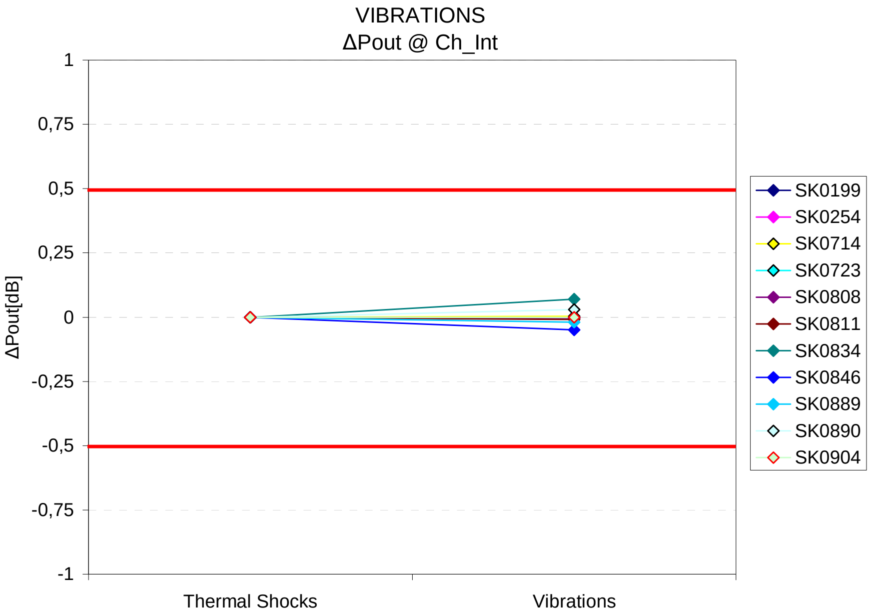


Figure 39: Vibrations Optical Power Variations

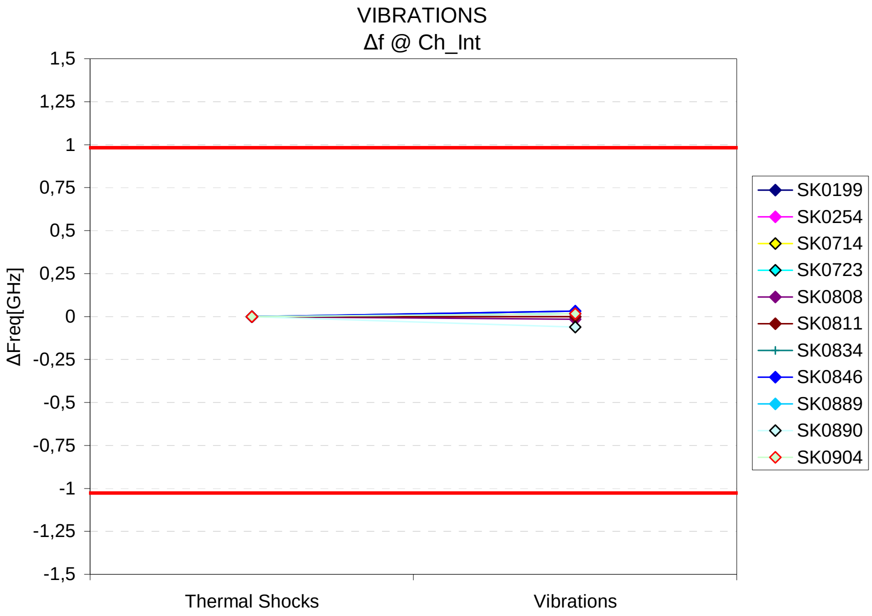


Figure 40: Vibrations Frequency Variations

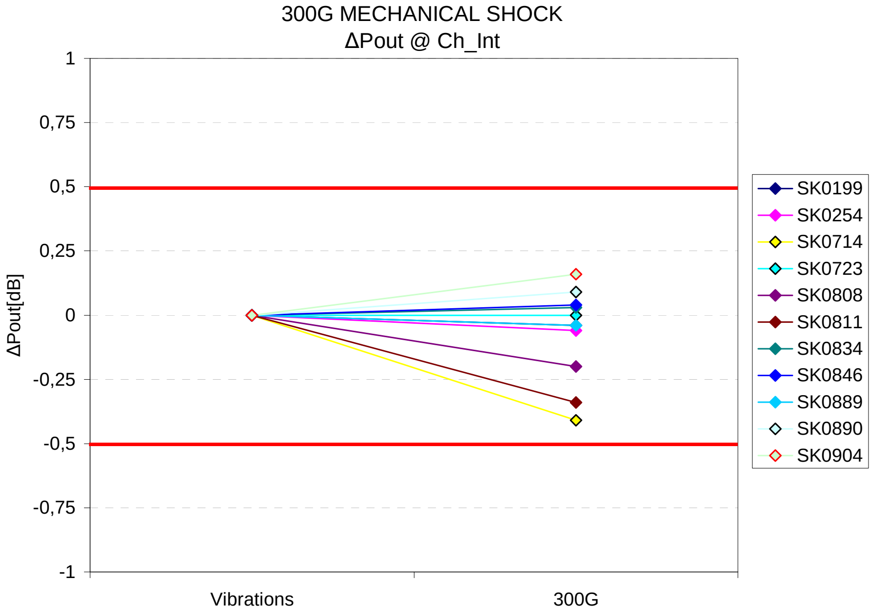


Figure 41: 300G Mechanical Shocks Optical Power Variations

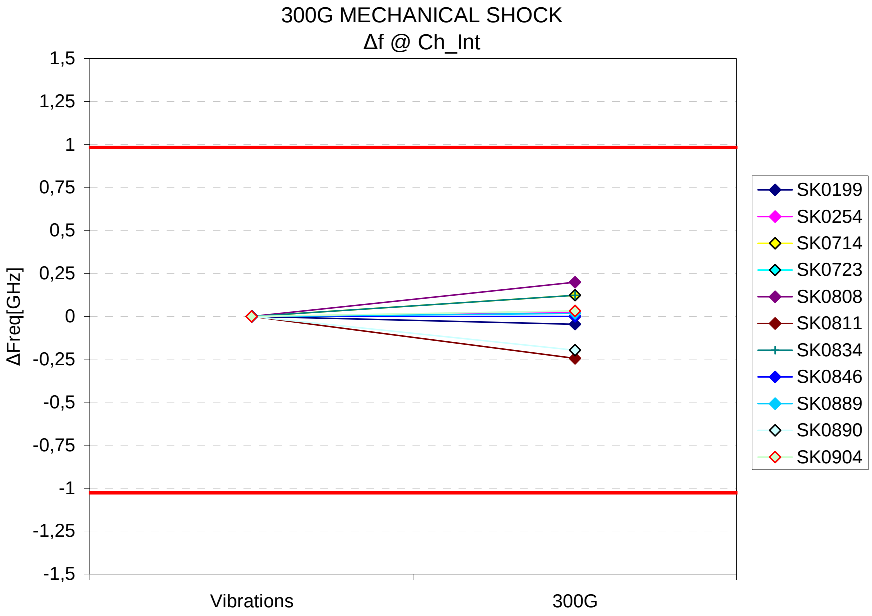


Figure 42: 300G Mechanical Shocks Frequency Variations

The group of the last three figures, from 39 to 42, show the output power and frequency variation, between before and after the performed tests. Pass criteria are satisfied, therefore the test is passed.

The 11 devices involved in sequence A had been previously scheduled for thermal shocks.

It’s interesting to observe, as showed in figures 43 and 44, how the device results extremely robust to the performed sequence of mechanical tests. The sum of the total effects, in terms of the optical power output variation and frequency variation, is still within the range expected to successfully pass a qualification test.

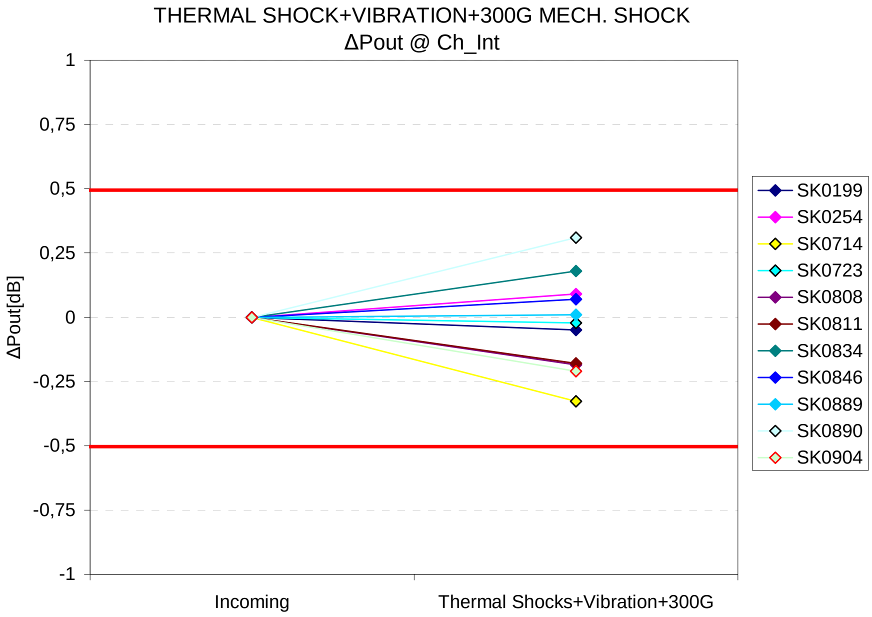


Figure 43: Thermal Shocks + Sequence A Total Power Variations

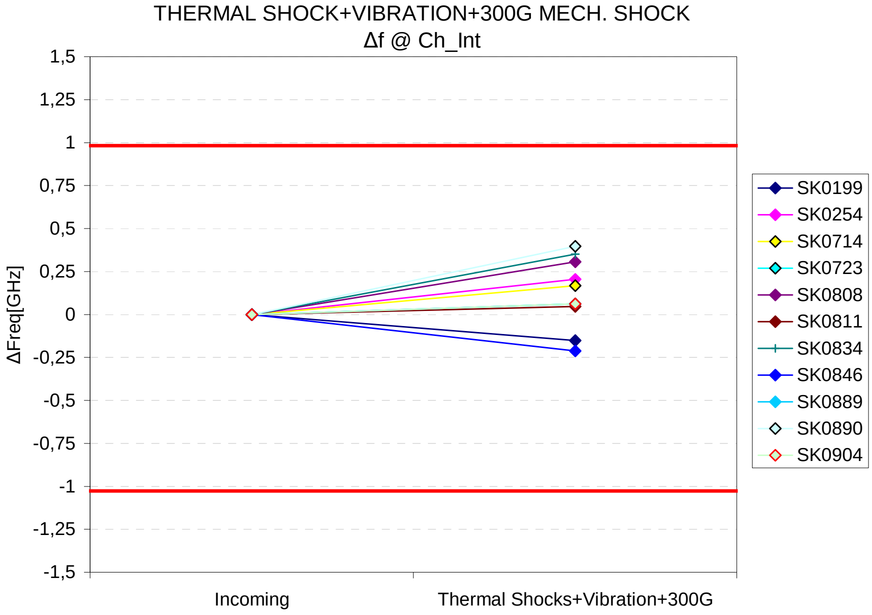


Figure 44: Thermal Shocks + Sequence A Total Frequency Variation

SEQUENCE B

In this case the DTL was approached as a device at the diode level or module level, thus the mechanical shock test applicable condition is Condition A.

Sample size	**11**
Serial number	SK0490, SK0710, SK0755, SK01008, SK1018, SK1040, SK1467, SK1475, SK1035, SK1041, SK1461
Test conditions	Vibration: 20G, 20-2000Hz 4min/cy, 4cy/axis
	Mechanical shock: 5 times/axis 500G, 3.0ms
Test duration	1 day
Monitoring schedule	check before and after test

Table 17: Sequence B Test Conditions

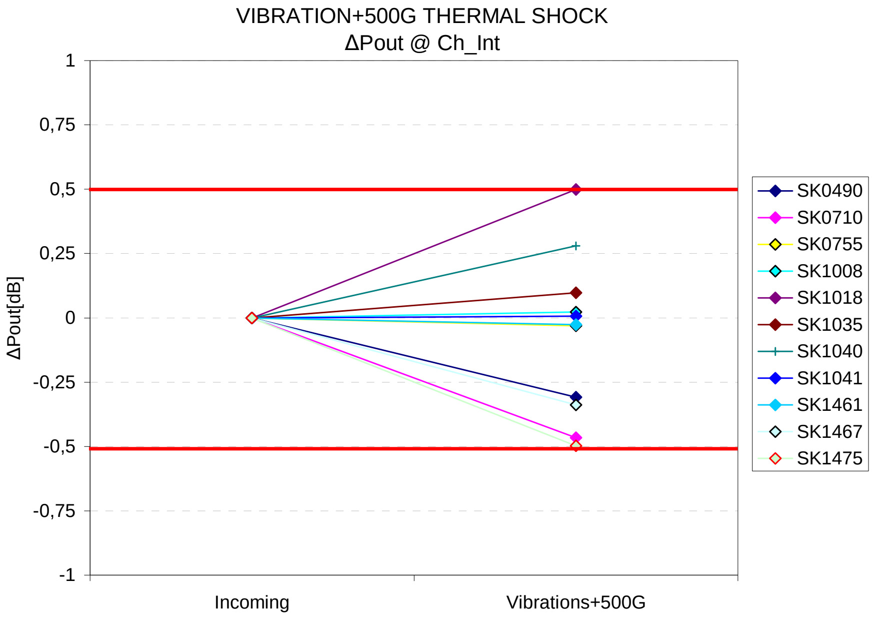


Figure 45: Sequence B Optical Power Variations

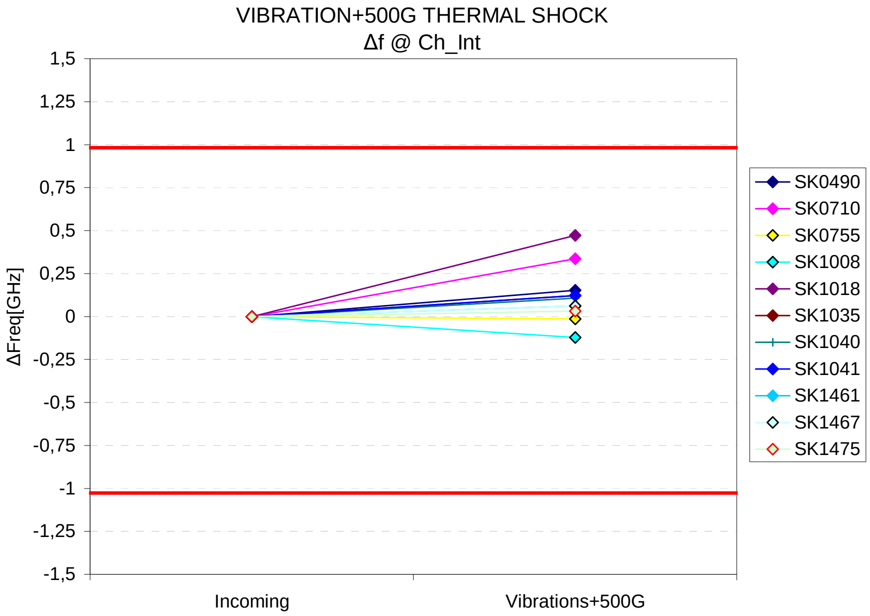


Figure 46: Sequence B Frequency Variations

Figures 45 and 46 show the output power and frequency variation between before and after the tests scheduled for sequence B. Pass criteria are satisfied, therefore the test is passed.

CABLE RETENTION AND SIDE PULL TESTS

The objective of this test is to mechanically stress the interconnecting device to fiber optic cable joint in tension. These two tests were scheduled upon the same set of devices.

Sample size	**11**
Serial number	SK0278, SK0922, SK0898, SK0734, SK0230, SK0284, SK0901, SK0140, SK0925, SK07460, SK0123
Test conditions	0.5 Kg 1min
Test duration	1/2 day
Monitoring schedule	check before and after test

Table 18: Cable Retention Test Conditions

Sample size	**11**
Serial number	SK0278, SK0922, SK0898, SK0734, SK0230, SK0284, SK0901, SK0140, SK0925, SK07460, SK0123
Test conditions	0.25 Kg 90 degrees, 22-28cm from device housing
Test duration	1/ 2day
Monitoring schedule	check before and after test

Table 19: Side Pull Test Conditions

After each performed test, any difference was observed so the tests were successfully passed.

OPERATING LIFE TEST

Operating life test is performed for the purpose of demonstrating the quality and reliability of devices subjected to the specified conditions over an extended time period.

Sample size	**8**
Serial number	SK0023, SK0017, SK0042, SK0109, SK0220, SK0252, SK0277, SK0281
Test conditions	MAX ILD
	MAX VTM
	MAX Pphase
	70°C Tcase
	Continuous Monitoring
Test duration	1000hrs for qualification; other 4000hrs for info
Monitoring schedule	Check before and after test

Table 20: Operating Life Test Conditions

The devices in use for this test are supplied at the maximum rated injection current, phase element current and voltage values expressed in the product specifications sheet. Moreover they are maintained at the highest working environmental temperature. The devices are consequently tuned on highest channel at their higher optical power out value.

Devices are continuously monitored, with a sampling time of five minutes. This is an accelerated test under worst case operating conditions for the devices under test.

The devices under test, as detailed in appendix A, are driven by means of a hybrid algorithm which implements a dynamic control in terms of optimizing the lasing point, suitably adjusting the voltage over the tunable mirror and the current injected in the gain chip. The phase element power is fixed at its maximum power rating value.

This condition was intentionally conceived to assure the cavity stability in time during operation to demonstrate no degradation occurring.

The extrapolation of data for FIT rate will not include any acceleration factor, hence greater is the aging test device hours, better will be the calculations of the wear out and random failure rates.

RELIABILITY CALCULATIONS AND RESULTS

Reliability tests are designed to stress the proper mechanisms forcing devices failures. Typically reliability accelerated tests use stressful conditions than the ones used during the device qualification process.

Telcordia Technologies recognizes as desirable, setting it as an objective, to include to the tests performed for qualification, a set of reliability tests depending upon the device typology. According to that, all the environmental tests are actually running for reliability information, at least for 5000 hours or 500 cycles as requested for central office applications. Telcordia stated in GR-

468-CORE, Issue 1, that those tests are useful as a staring point for a reliability program.

Actually, the upper mentioned tests are running, but market and marketing issues call for a reliability quantitative evaluation in despite of the reliability longer times. For this reason and according to the generally accepted statement that the basic reliability of optoelectronic systems can be no better than the reliability of the components contained in the equipment, a first evaluation on DTL reliability has been completed according to Telcordia SR-332, “Reliability Prediction Procedure for Electronic Equipment”.

Telcordia SR-332 documents the recommended methods for predicting devices and units hardware reliability and defines four different device quality levels. As an agreement on terms, device refers to a basic component or part, and unit to an assembly.

The procedures related in the selected reference document are recommended for prediction serial system hardware reliability.

The Pirelli Dynamically Tunable Laser can be assimilated to a system for which the failure of a single part could cause a failure for the whole system.

According to the tuning operation device critical parameters and to the control algorithm, the parts involved in the equivalent serial system can be recognized.

Thermo electric cooler and the related thermistor are the fundamental parts assuring the device thermalization and the consequent alignment to the ITU grid. The liquid crystal mirror is critically associated to the tuning mechanism. Gain chip may affect the overall performances and the photodiode monitor is vital for the control algorithm.

Such a quantification process has been approached according to the part count method with the following combination for burn-in treatment and device application conditions expressed in:

- no device burn-in;
- device operating condition at 40°C and 50% rated electrical stress.

With this parameter combination, selecting a quality level II, the part steady state failure rate is given by

$$\lambda_{SS} = \pi_Q \lambda_G$$

where λ_G is the steady state failure rate for the ith part and π_Q its quality factor.

All the failure rates for the parts within the DTL package are fully identified by mean of the supplier approval process.

The assembly steady state failure rate is then computed as the sum of the failure rate prediction for all the parts in the unit, multiplied by an environmental factor

$$\lambda_{SS}^{*} = \pi_E \sum_{i=1}^{m} N_i \lambda_{SSi}$$

where m is the number of different parts in the assembly, N_i the quantity of the ith part and π_E the environmental factor.

According to table H, in the Telcordia SR-332 document, the environmental factor is unitary for central office applications.

Quality level II matches the DTL parts specifications therefore the quality factor is unitary.

Any part within the dynamically tunable laser is greater in number than one. The steady state failure rate of its assembly is therefore equal to the sum of the steady state failure rates of its parts.

According to the provided parts failure rates the total steady state failure rate for the Pirelli DTL actually is less than 1000FIT. An intense activity with the suppliers is actually on going relatively to long term parts reliability calculations. According to this the suggested value for the DTL failure rate must be considered as an upper value doomed to be reduced in the immediate future.

CONCLUSIONS

In order to be successful, innovative photonic products must a number of performance requirements, either economical and technical, and in particular they must be designed and manufactured in such a way as to guarantee that they will operate reliably for as long a period as possible. According to this statement, this work dealt with the full reliability assurance of a new product designed and manufactured by Pirelli: the Pirelli Dynamically Tunable Laser DTL C13 Series.

It is a high power full C-Band tunable laser source consisting in a continuous wave external cavity laser for advanced optical network systems designed to tune over the entire C-band on the ITU-T 50 GHz channel grid with high spectral purity and frequency stability.

A proper design and a set of reliability involving feedback and corrective actions, accomplishing all the product lifecycle from it's conceived to its qualification, achieved a built in reliable product with high power and frequency stability. In particular it has been demonstrated how the Pirelli dynamically tunable laser has successfully completed all Telcordia standard GR-468-CORE testing required for the reliability assurance process for the optoelectronic devices used in telecommunication systems.

Actually long term reliability tests are still running for information. These activities involve directly the DTL but also some of its internal parts, with the aim of improve the indications on the device failure rate.

APPENDIX A

LIFE TEST BENCH

This bench mark is designed to manage the operative lifetest, planned for the Pirelli Dynamically Tunable Laser qualification.

Scope of this appendix is to describe the building blocks constituting the life test bench, their implemented functionalities and specific features.

BENCH BLOCK DESCRIPTION

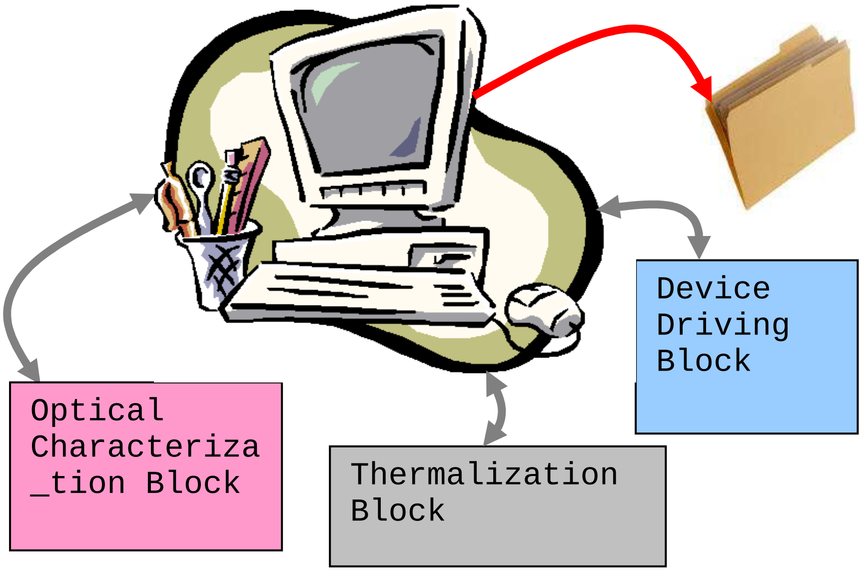


Figure 47: Lifetest Bench Block Scheme

The lifetest bench setup can be subdivided in three different functional blocks. The first performs all the optical measurements. The second drives the devices under test and the last one provides the external thermalization of the devices.

The optical measurement block consists of a power meter, a wavelength meter, a tunable laser source, an optical switch and a beam splitter.

All the output fibers of the devices under test are plugged in an equal number of inputs of an optical switch. A reference tunable laser output is also plugged in to a port of the same switch.

The output of the optical switch is connected to the input of a 50/50 beam splitter. The beam splitter outputs are then connected to a power meter and a wavelength meter.

The driving function of the DUTs is committed to the Pirelli DTL Evaluation boards connected to each device under test.

Each of the evaluation boards, implements the DUT driving function by means of a firmware running in its onboard logic. Under expressed request for the lifetest planned objectives, this logic implements a control algorithm, setting the best lasing point, controlling the gain chip injected current and the voltage over the mirror.

The phase element is set to a working point equal to its maximum power rating value.

The thermalization block provides the case temperature for the devices under test.

EXPLOITED INSTRUMENTATION

The wavelength meter is a Burleigh WA 1100, capable to measure laser light in the 700÷1650 nm wavelength range with an absolute wavelength absolute accuracy of ±1.5 pm at 1550nm.

The optical switch is a JDS Uniphase 1x16 switch suitable for remote fiber optic component testing and measurement systems. It is stepper motor-based with queriable switch position. Its typical insertion loss is 0.5 dBm.

Figure 48: Tunable Laser Reference

The bench reference Agilent Technologies 8168E is a tunable laser source with a wavelength range of 1475 to 1575nm with a resolution of 0.001nm. It has a Fabry Perot-Laser InGaAsP, a permissible output power in continuous wave <1.6mW and a beam diameter of 9um.

Figure 49: Power Meter Sensor

Tunable lasers and reference optical power output, lowered by the insertion loss of the cascaded optical switch and beam splitter, is measured by means of an Agilent Technologies 8163B power sensor inside an Agilent 8163B mainframe. This optical sensor is designed for low polarization dependant loss, low spectral ripple and high return loss. It is provided of a large area Germanium sensor for power measurements in the optical range of 800 to 1700 nm suitable for a power range of +10 dBm to -110 dBm an is thermally stabilized.

The phase power supply is provided by a DC power module, with low output noise and fast output speed, for each device under test.

Figure 50: Case Temperature Controller

The case temperature is set by means of an ILX Lightwave LDC-3916 16-Channel Laser Diode Controller. It is designed for simultaneous control of both laser current and temperature in a single mainframe for R&D or production test of optical devices. It is geared with eight 3916558 modules. The module contains a single three ampere independent temperature controller that drives a thermoelectric cooler (TEC). The temperature controller features a bi-polar current driver that works with TEC modules to deliver precise temperature control over a wide range of temperatures. Each module offers fast settling times with a typical temperature stability of 0.01°C.

Figure 51: Laser Diode Mount

The device under test are placed on the ILX Lightwave LDM-4980 Single channel Telecom Laser Diode Mount providing a compact, easy-to-use solution for laser diode fixturing. These mount is available for butterfly 26-pin packages. This series of mounts accommodates most telecom laser module types including CW, direct modulated (Bias-T), 2.5Gbits/s, 10Gbits/s, and tunable DFB laser modules. This mount features ILX Lightwave's standard 9-pin D-sub input connectors with configurable pin designations to accommodate virtually any laser diode pin configuration. Zero insertion force (ZIF) sockets and spring-loaded clamps facilitate ease of mounting.

Figure 52: Thermocouple Module

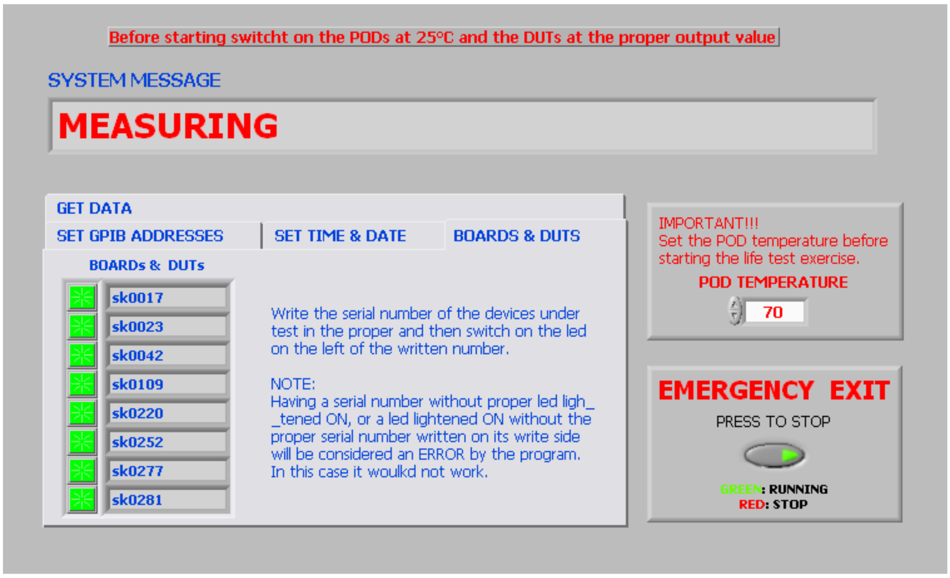
Laboratory temperature is monitored by means of a Fluke digital multimeter connected to a Fluke 80TK thermocouple module standard banana plugs. It uses Type-K thermocouple probe. It's accuracy in the range -20°C to 350°C is 0.5% ± 2°C.

DTL LIFETEST VI

All the described instruments and functionalities are remote controlled with a dedicated Labview 7.1 programmed virtual instrument.

This virtual instrument by means of a user friendly and easy to use interface, implements all the requested functions for the instruments connected to the computer by means of 488.1-1987 IEEE Standard Digital Interface for Programmable Instrumentation.

This virtual instrument needs a few inputs in its “Boards & DUTs” folder such as the serial numbers of the devices under test and the working case temperature.



Before starting switcht on the PODs at 25°C and the DUTs at the proper output value

SYSTEM MESSAGE
MEASURING

BOARDs & DUTs
sk0017
sk0023
sk0042
sk0109
sk0220
sk0252
sk0277
sk0281

Write the serial number of the devices under test in the proper and then switch on the led on the left of the written number.

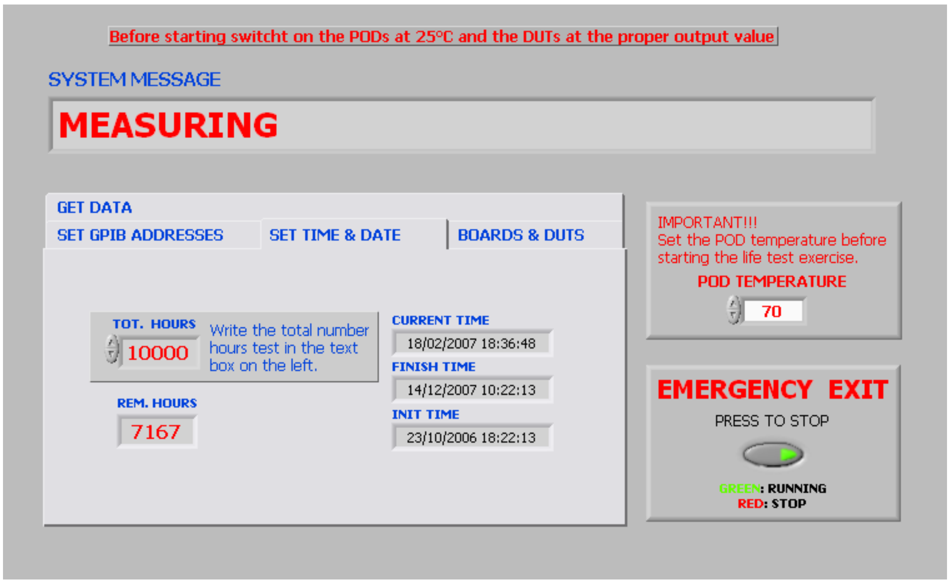
NOTE:
Having a serial number without proper led ligh_ _tened ON, or a led lightened ON without the proper serial number written on its write side will be considered an ERROR by the program. In this case it woulkd not work.

IMPORTANT!!! Set the POD temperature before starting the life test exercise.

POD TEMPERATURE
70

Figure 53: “Boards & DUTs” Folder of the DTL Lifetest VI

The test endurance, expressed in hours must be inserted in the proper control in the “Set Time and Date” Folder.



Before starting switcht on the PODs at 25°C and the DUTs at the proper output value

SYSTEM MESSAGE

MEASURING

TOT. HOURS: 10000

Write the total number hours test in the text box on the left.

REM. HOURS: 7167

CURRENT TIME: 18/02/2007 18:36:48

FINISH TIME: 14/12/2007 10:22:13

INIT TIME: 23/10/2006 18:22:13

IMPORTANT!!! Set the POD temperature before starting the life test exercise.

POD TEMPERATURE: 70

Figure 54: “Set Time & Date” Folder of the DTL Lifetest VI

When running, this virtual instrument after enabling the output of the devices under test at the highest channel, provides a continuous monitoring of the devices under test with a user defined sampling time.

The output, for each device under test, is a formatted text file ready to be processed. Per each row it contains a tab spaced string reporting all the DUT electro-optical parameters’ values, the reference power output, the case temperature and laboratory temperature, in order to get information on possible test bench drifts and the sampling time.

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