Chapter 17

Opto-Electronic Packaging

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Additional information is available at the end of the chapter

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1. Introduction

Future optical communication systems will use the high bandwidth of optical fiber in the optical frequency domain. Fast transmitter and receiver modules are basic elements of these systems, which are able now to transmit terabits/s of information via the fiber. Experiments with opto-electronic integrated circuits (OEICs) in laboratory test beds and field tests require a special packaging that respects system requirements such as high environmental stability and low optical insertion loss. Several concepts for fiber-chip coupling schemes had been proposed in the past. One of these is laser micro welding shown by[1], [2], [3], [4], [5], [6], [7]. This scheme is referring to the standard for high volume industrial manufacture. The investment costs for this laser welding equipment are considerably high. There are numerous proven techniques for aligning OEICs effectively. For laboratory use and rapid prototyping a flexible design is needed which is able to adapt different OEICs with changing dimensions to an existing module type.

In this chapter you will get general information what does opto-electronic packaging mean. Here fiber-chip coupling with basic coupling concepts will be illustrated. The different types of active adjusting and passive techniques are explained. Optical connectors play a very important role to interconnect different transmission systems. In passage 7 an overview of existing fiber connectors is shown. Afterwards, different optical module types for active and passive opto-electronic devices are described in details. Finally, the long-term stability of the modules must be tested and all reliability requirements for international test procedures are specified.

In its simplest arrangement, the packaging of OEICs involves the alignment and attachment of the light guiding areas of the OEIC and the optical fiber. At the beginning of this section, the basics of optical coupling theory with an introduction to optical mode fields and their matching by lenses is presented. Afterwards, a description of active and passive waveguide to waveguide coupling techniques will follow. Finally, optical connectors and the outline of different kinds of start of the art optical modules will be depicted followed by a short overview of long-term stability tests.

At this point I would like to define the opto-electronic packaging which was given by [8]:

„Opto-electronic packaging means working on the connection of opto-electronic integrated circuits to optical and electrical transmission lines and bias supply combined in a environmental stable housing."

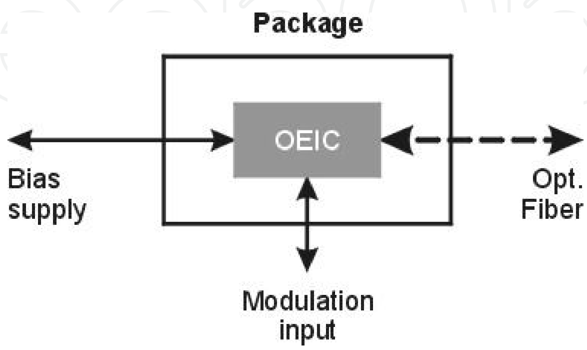

Figure 1. Basic package design for opto-electronic modules.

In the following several different technologies are listed which are essential to develop a new package:

1. RF-technique
2. Classical ray tracing optics & wave optics
3. Mechanical construction / CAD-design
4. Wire bond technique
5. Heat dissipating management / cooling
6. Communications engineering
7. Solid state physics
8. Micro systems design
9. Thick film circuits
10. Gluing, welding, soldering

2. Fiber-chip coupling

The behavior of the optical beam can normally be described by classical ray optical functions for lenses with focus length and focus point. If the dimensions of the optical beam come close to 1.5μm, which is the wavelength used in optical networks, the behavior of the beam must be described by wave optical functions.

$$p(\mathrm{r}) = p(0) \times \exp\left\{-2\left[\frac{\mathrm{r}}{w_0}\right]^2\right\} \tag{1}$$

$$2w_0 = \text{Mode field diameter(MFD)}$$

$$w\ (z) = \sqrt{\left[w_0^2 + \left(\frac{z\lambda}{2n\pi w_0{}^2}\right)^2\right]} \tag{2}$$

Here, the optical field within a wave-guide can be described nearly perfectly by a Gaussian intensity distribution, called p(r), which can be expressed with equation (1). If the wave travels within the waveguide, the mode field diameter is constant due to the combining function of the waveguide itself. At the end of the waveguide, the optical field is not guided and the field expands with increasing distance to the output facet. The expansion of the field can be calculated by equation (2). The point at which the intensity has fallen down to $1/e^2$ or 13.5% of the maximum intensity in radial direction, which is shown in figure 2, defines the mode field diameter.

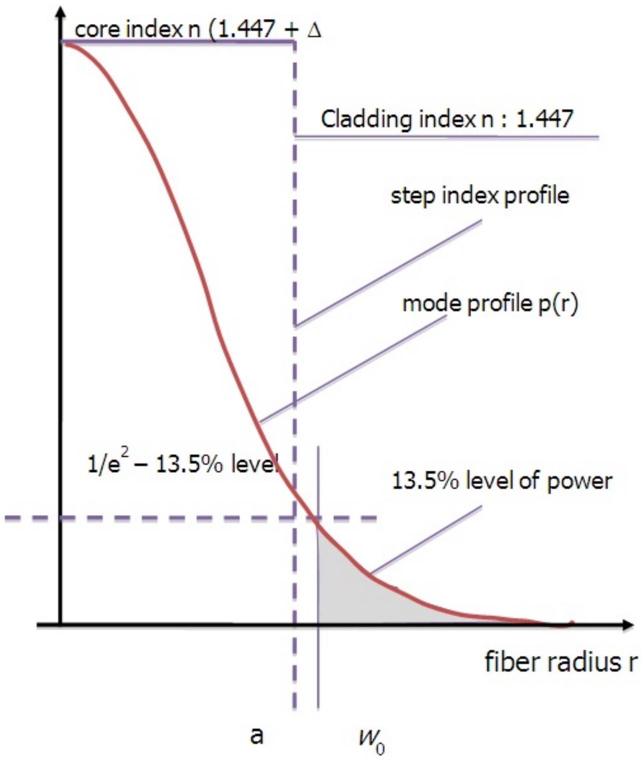

Figure 2. Intensity distribution of the optical mode field.

After leaving the waveguide, the optical mode field radius, which is half of the spot-size, expands with increasing distance to the facet. For distances of less than 200 μm the field distribution is called ”near-field” and for larger distances ”far-field”. The angle where the intensity is fallen to $1/e^2$ or 13.5% of the maximum intensity is called ”far-field angle” which corresponds to the near-field radius. These parameters are normally shown in the data sheets of laser diodes or LEDs.

For an efficient transfer of optical energy from the SMF and a laser diode wave guide, the mode profiles should ”overlap” as much as possible which is described by [9]and is depicted in equation (3). The coupling efficiency ◎ between two Gaussian beams can be expressed by means of the mode fields of laser diode w_{ld}, and fiber w_{SMF} and also as a function of lateral, angular and longitudinal misalignment between the two wave guides:

$$\eta = \kappa \cdot \exp\left[-\kappa \left\{ \frac{x_0^2}{2}(1/w_{LD}^2 + 1/w_{SMF}^2) + \pi^2\theta^2 \left[w_{LD}^2(z) + w_{SMF}^2 \right] / 2\lambda^2 - x_0\theta z / w_{AWG}^2 \right\} \right] \quad (3)$$

Where

$$\kappa = 4w_{LD}^2 w_{SMF}^2 / \left[(w_{LD}^2 + w_{SMF}^2)^2 + \lambda^2 z^2 / \pi^2 n_{gap}^2 \right] \quad (4)$$

With

λ- wavelength

N_{gap} – referactive index of medium between the waveguide and fiber

X_0 – lateral misalignment

θ- angular misalignment

Z – longitudinal misalignment

To measure the loss in decibel, the efficiency ◎ must be multiplied 10 times by the logarithm$_{10}$ which is designated here as L:

$$L(\eta) = 10\log(\eta) \quad [\text{dB}] \quad (5)$$

3. Basic coupling concepts

A comparison of the optical mode fields of the optical standard monomode fiber called SMF with a typical laser diode is shown in figure 3, where also the mode field diameter of a standard single mode fiber is depicted, respectively The properties of the SMF are standardized through the International Telecommunication Union [10].

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The far field angle of the fiber is defined to a small value of 11.5°. A typical laser diode shows different values for lateral and vertical axis of 20° to 30° and 30° to 40°, respectively.

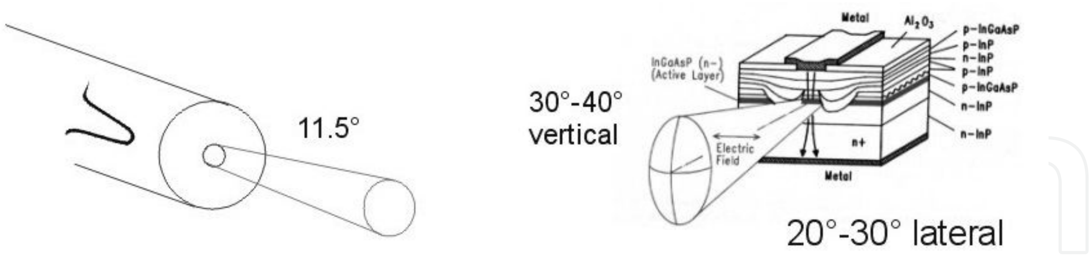

Figure 3. Far field of an optical fiber in comparison to the field of a laser diode.

If one compares the field parameters of fiber and laser diode a great mismatch can be found. Consequently, the optical coupling efficiency between these two devices is very low. The coupling loss between the two fields without additional mechanical misalignments can be calculated in decibel with Saruwatari's formula from equ. (3), which can be simplified into the formula (7):

$$Loss(R) \approx -10\log(R)\left[dB\right] \tag{6}$$

$$R = \frac{4}{\left\{ {w_1}/{w_2} + {w_2}/{w_1} \right\}^2} \tag{7}$$

With this formula the mode field mismatches between the single mode components and the corresponding mismatch loss can be calculated to equ. (6), all lateral and angular misalignments of the fiber axis relative to the incident beam of the laser waveguide are set to zero.

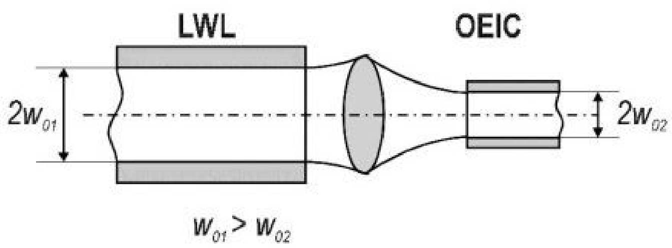

Figure 4. Mode field adaptation by an optical lens or lens system.

Different mode fields can be adapted by so called "mode field transformers". These devices are, for example, lenses or lens systems, which are shown in figure 4. With these devices, a nearly perfect coupling between the two wave-guides is possible. Due to limitations in costs, several lens configurations have been proposed for the optical coupling of laser diodes to single mode fibers. As shown in figure 5, simple ball lenses can be used to adapt the two mode fields. Coupling efficiencies of up to 30% are possible. A better approach is the use of graded index lenses or Selfoc-lenses. For a focusing lens, so-called half-pitch devices are used. Whereas quarter-pitch lenses are used to form parallel beams. These can reach efficiencies of 70%. Another approach is to form a lens at the end of the fiber, which is called fiber taper. With this device, efficiencies up to 90% have been achieved.

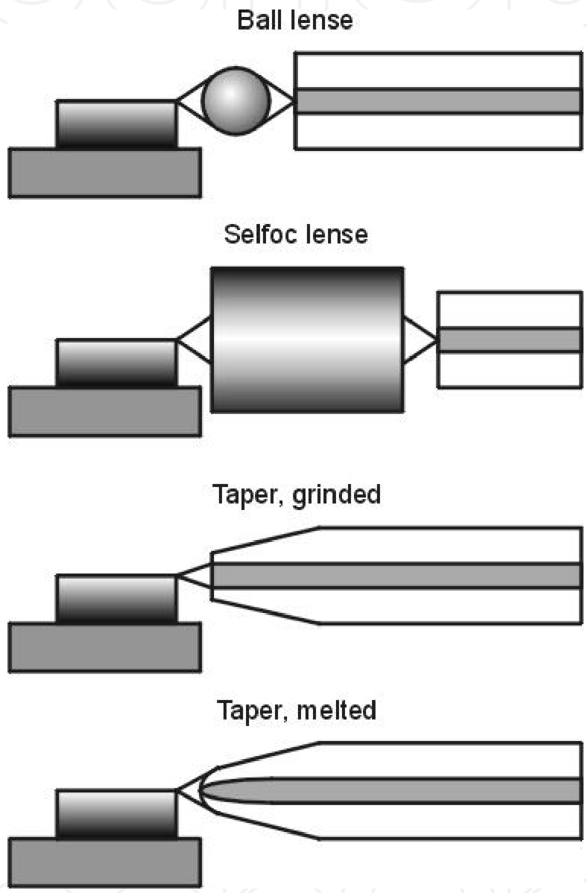

Figure 5. Mode field adaptation by several micro-optic solutions.

4. Adaptation of mode fields

As depicted in chapter 3, comparison of the optical fields of a butt ended standard single-mode fiber (SMF)and of edge emitting laser diodes shows a great mismatch. This mismatch is the reason for the very low coupling efficiency of approx. 15% for a butt ended fiber

This low efficiency can be overcome by a better adoption of the two optical mode fields with lenses. A coupling efficiency of more than 90% has been shown. Disadvantages occur at the

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handling of the parts because there are several parts including one ore two lenses, the fiber and the chip, which must be handled for optical alignment. The consequence is a rather costly of opto-electronic packaging.

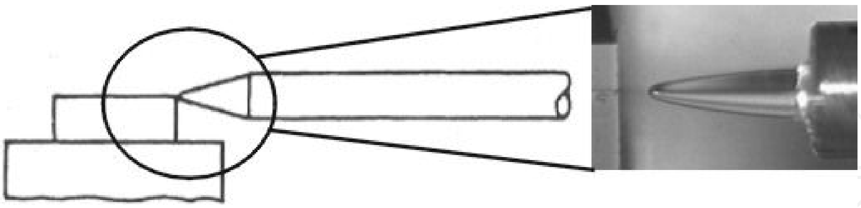

Figure 6. left side: Sketch of a melted fiber taper in front of an OEIC, right side: photograph.

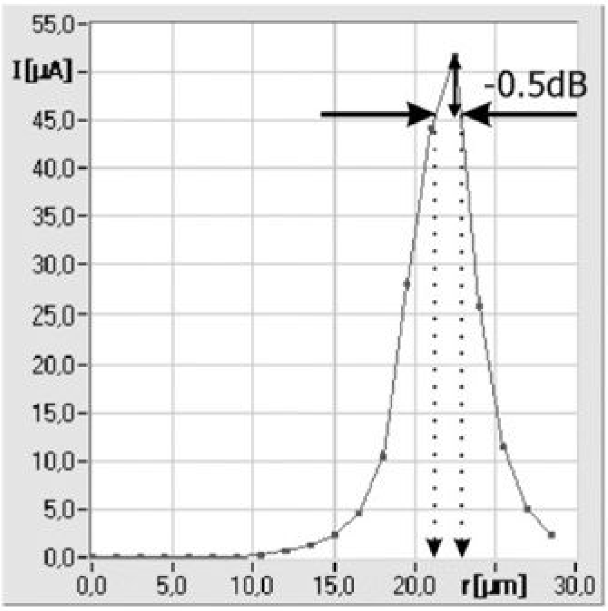

Figure 7. X and Y-axis: 2µm tolerance for 0.5 dB additional coupling loss.

As an example for integrated lens design, lenses can be made at the end of the fiber by melting the glass fiber and pulling it. This kind of fiber end is called fiber taper and works like a lens with typical diameters from 20 µm to 50 µm. In figure 6 you can see at the left side the chip facet and its wave guide and at the right side the melted fiber taper in front of the wave-guide. The fiber is additionally fixed into a metal cannula. With these tapered fibers a coupling efficiency of more than 50% can be realized. Unfortunately, a high precision fixation of better than 0.5 µm is necessary to mount the tapered fiber in front of the OEIC without additional losses. Therefore, the mechanical resolution of the coupling mechanism must be better than this value. The fixing procedure after coupling should not introduce additional displacements and must be stable enough to fix the coupling mechanism, which is important for a good long-term stability. The short working distance of 10 µm between fiber taper and laser which can be seen in the photograph is also dangerous for the life of the laser diode if it comes into contact with the with the fiber end. But there is only one low-priced device on the market, which makes this device very comfortable for use in small and very reasonably priced modules.

The tolerances for lateral and longitudinal fixing of the fiber taper in front of the opto-electronic circuit or OEIC are shown in figure 7 and figure 8. Both graphs show the distance in micrometers at the x-axis and a relative intensity of the coupling efficiency between the tapered fiber and the OEIC. You can see in figure 7 that within 2 micrometers the intensity will not be lower than 0.5 dB of the maximum intensity. For the longitudinal direction the tolerance is much greater: in this case 8µm, which can be seen in figure 8.

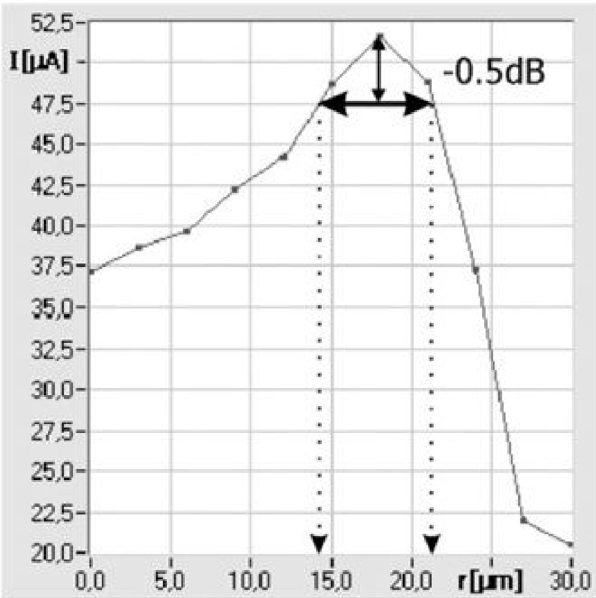

Figure 8. Z-axis with higher tolerance of 8µm.

Please remember: it is easier by a factor of four to perform the optical coupling in longitudinal direction in comparison to the lateral direction.

5. Active adjusting techniques

In optical packaging laboratories, fiber-chip coupling is performed within sub-micrometer precision in order to get a high coupling efficiency between the optical devices. Precision optical experiments depend upon reliable position stability. Vibration sources in and around the work are depicted in figure 9. Floors carry vertical vibrations in the range of 10 Hz to 30 Hz caused by people, traffic, seismic activity, and construction work. Tall buildings sway up to a meter in the wind, at frequencies from 1 Hz to 10 Hz. Machinery generates vibrations up to 200 Hz. Optical benches and their associated vibration isolating support systems provide a rigid and virtually vibration-free working surface that holds the components of an ex-

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periment in a fixed relative position. The legs support the tabletop: Air suspension mechanisms reduce practically all vibrations by two orders of magnitude.

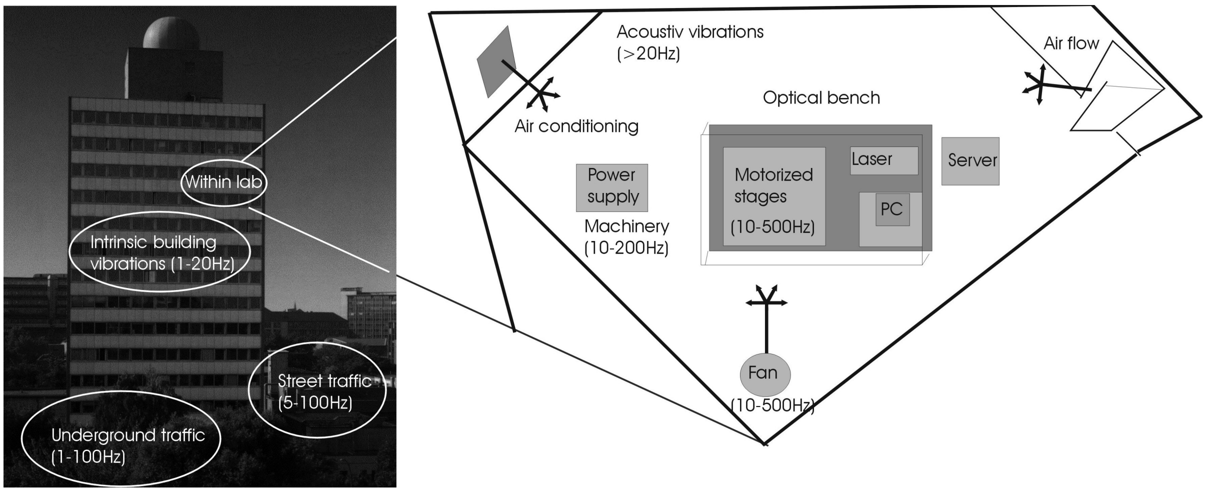

Figure 9. Influence of vibrations for micro positioning.

In order to align a fiber optically to another component, one has to move either the fiber, the component or both. Three linear and three angular motions are necessary to describe fully the motion and position of a solid body in space. The figure below identifies the six degrees of freedom using the common Cartesian frame of reference. When each of these degrees of freedom is singularly constrained by a hardware device, the device is labelled kinematic.

The device used to move a component in the linear x, y, or z direction is a translation stage. The device used to move a component in the angular θx, θy, or θz direction is a rotation stage.

Actuators are used to move the component on a translation stage to its desired position. There are three basic types of actuators used with precision stages: manual drives, stepper motor drives, and piezoelectric transducers. Manual drives and stepper-motor drives can move components over long distances, constrained only by the size of the manual drive or, in the case of stepper motors, the length of the lead screw. Piezoelectric transducers can move components over very short distances with nanometre precision. The range and resolution of the various drives and stage technologies is shown in figure 10 below.

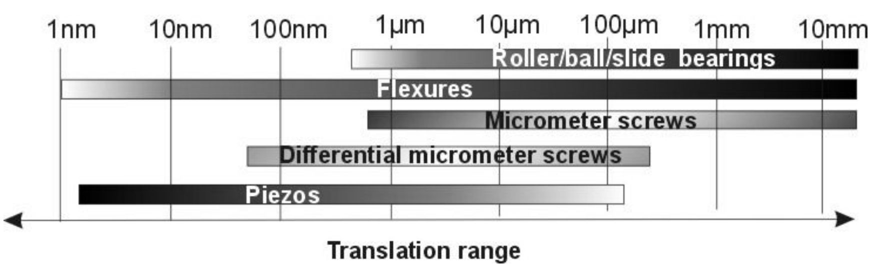

Figure 10. Translation ranges of available micro mechanical stages and screw systems.

For fiber-chip-alignment mostly all six degrees of freedom must be moved. Several commercial six axes motion systems have been developed with translatoric resolution of better then 0.02μm and angular resolution of better then one arc second. As an example, a mechanical/piezoelectric driven system with six degrees of freedom is shown in figure 11. Software tools are also included for automated coupling for one fiber and fiber arrays. Most of the software applications are available as a Labview virtual Instrument (VI).

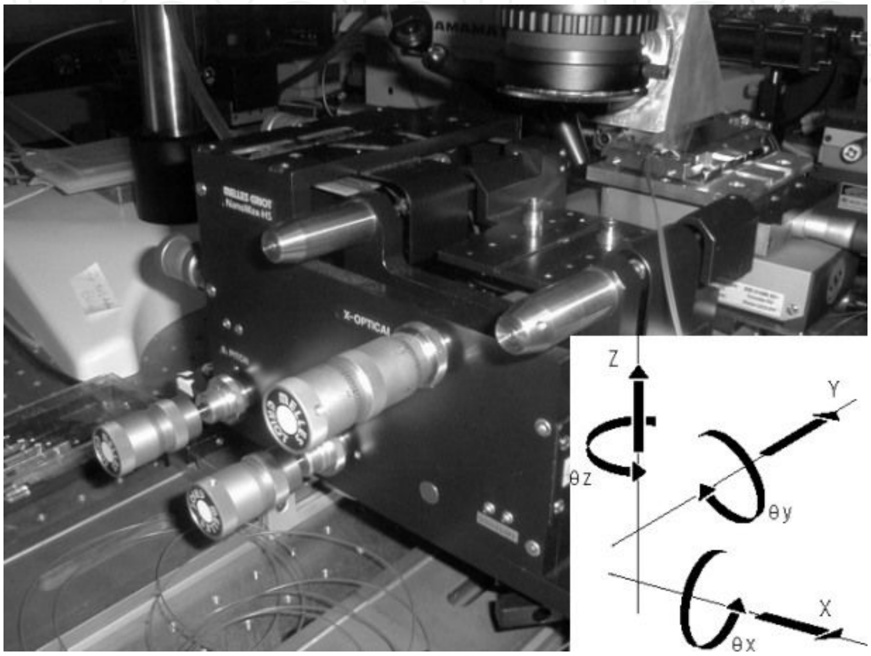

Figure 11. Six axes Nano-positioning system.

6. Passive adjusting techniques

6.1. Flip-chip-technique

The flip-chip (FC) bond technology was developed in 1964 by IBM for high dense packages for hybrid modules. At that time it was called C4-technology or Controlled Collapse Chip Connection [11]. Its main goal was to replace the uneconomical wire bonds. The FC-technique allows the highest density of connections on the chip scale. For this reason this technique is a possible candidate for high volume production in the micro electronic industry.[1, 12] and [13] have shown that the FC-technique could meet the precision needed for optical fiber-chip coupling (± 3μm). Figure 12 shows the working principle of the optical FC-connection. The OEIC is connected bottom up to the substrate. Bonding is performed by a thermal reflow process which isdepicted in figure 13. The surface forces of the melted solder trek the OEIC into a preferred position, that differs very little from connection to connection. This is called "self-alignment". [14], [15]and [16] had developed a fluxless FC-bonding technique which allows a self-alignment of better than 1μm. Additionally, the short bond-dis-

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tances promise very good RF-features up to 100GHz bandwidth. Today this progress allows the introduction of batch processing for the optical and electrical part of the optoelectronic packaging of OEICs. This benefit opens the market for high volume production of devices for optical communications systems that allows cost effective production of low budget products for the consumer market.

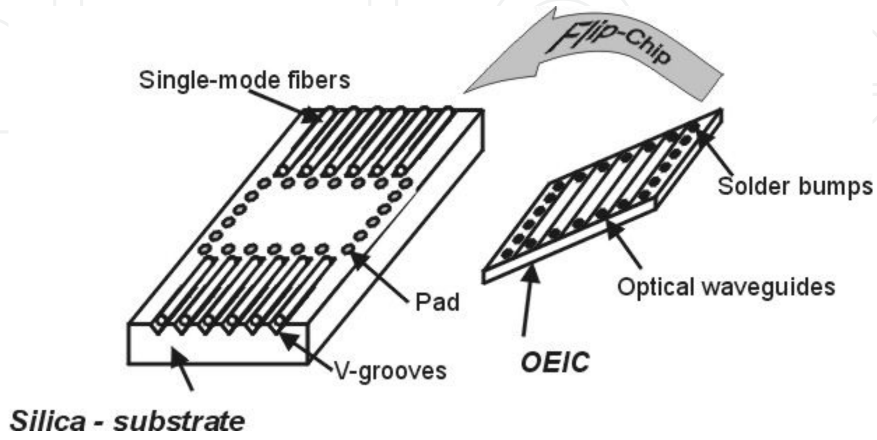

Figure 12. Flip-chip set-up.

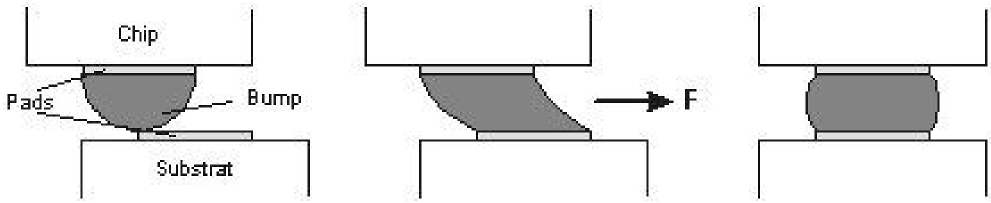

Figure 13. Flip-chip self-alignment.

6.2. Optical board technology

The progress in mechanical precision of the FC-bonds makes it possible to align one or multiple optical fibers direct to OEICs. Firstly, the OEIC will be FC-bonded as shown in figure 14. In the next step the fibers are inserted into V-grooves, fabricated by an anisotropic wet etching of the silica substrate. After insertion, the fiber must be fixed mostly by UV-hardened glue. Here more than 100 fibers can be arranged passively in one single fabrication step to the OEIC. An example of the connection of four lasers to an array of single mode fibers is shown in photograph 15.

In the next development step additional electrical amplifiers, multiplexers, modulators etc. can also be located on the substrate. This kind of hybrid integration is called optical motherboard or photonic lightwave circuit (PLC) depicted in figure 16. This type of integration is the most promising technique today for reaching an adequate price level of optical communications products for the consumer market.

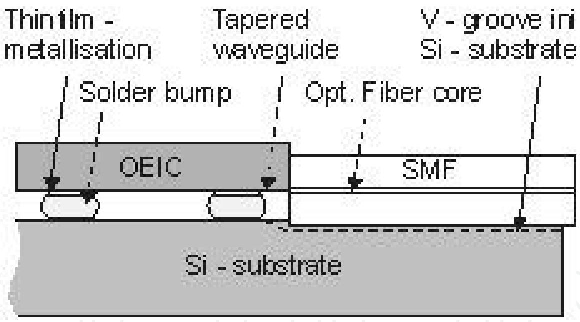

Figure 14. Fiber-chip connection with flip-chip.

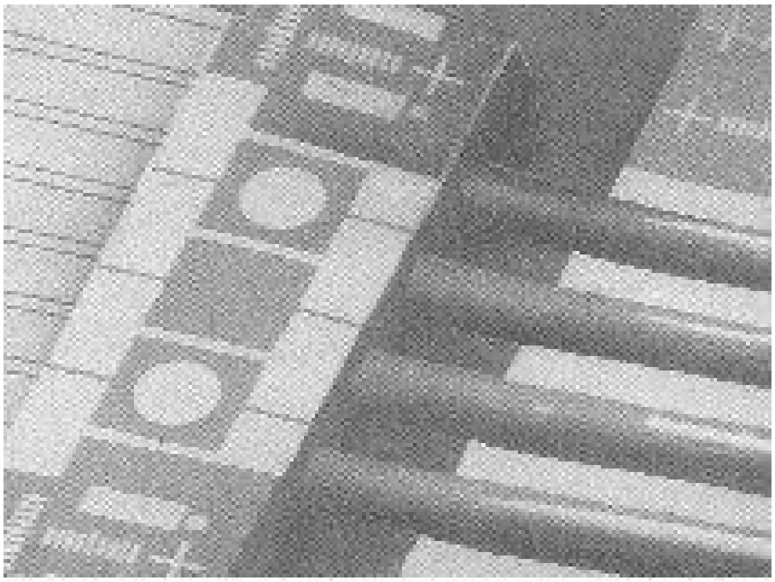

Figure 15. Photograph of flip-chip bonded laser array(Heinrich-Hertz-Institute, Berlin).

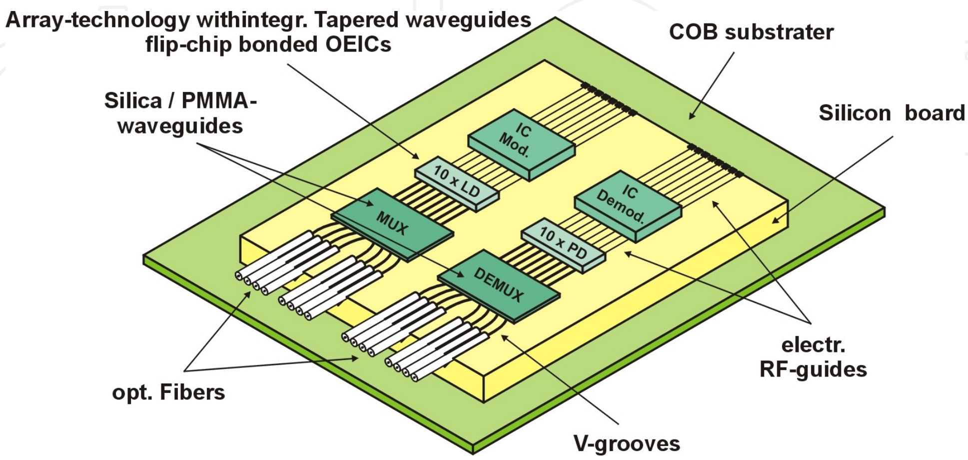

Figure 16. Concept for a complete optical motherboard [1], [17].

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7. Optical connectors

7.1. Single fiber connectors

This chapter will give a summary of the optical connectors used today. There are several different types of connectors used for single mode and for multimode operation. Additionally, there are straight polished types and slant polished ones, which are used in high speed optical communication systems because of their high reflection loss characteristics. Further on, connectors are used in various applications including:

11. Polarization maintaining fibers

12. Matching gel/coating

13. Physical contact

14. Air gap

15. Automated light shutter function

16. Duplex connectors

Name	losses	Straight cut	Slant cut	Single (SM) Multi (MM) mode	Polarization maintaining	Durability (insertions)	Price
Mini BNC	0.21dB	-20dB		MM		"/500	low
ST	0.28dB	-20dB		SM,MM		"/500	med
FC/PC	0.35dB	-30dB		SM,MM		"/500	low
FC/APC	0.4dB		-55dB	SM		"/500	med
SMA	0.38dB	-20dB		MM		"/500	low
Radiall VFO	0.4dB	-30dB		SM	yes	"/250	high
	0.7dB		-55dB	SM		"/250	high
Radiall EC	0.2dB		-50dB	MM		"/250	med
	0.5dB		-60dB	SM	yes	"/250	med
Diamond E2000	0.18dB	-30dB		SM		"/1000	low
	0.18dB		-55dB	SM	yes	"/1000	low
SC	0.5dB	-30dB		SM		"/1000	low
	0.5dB		-60dB	SM	yes	"/1000	low
HRL-10	0.3dB		-60dB	SM		"/1000	High
LC-Duplex	0.2dB	-30dB		SM/MM		"/10.000	low

Table 1. Optical connectors summary.

All loss failure mechanisms that can be acknowledged at the fiber to fiber coupling are also detectable at connector-connector coupling. All possible losses are depicted in figure 17. Only highly precise mechanical feed and exact surface polishing can avoid high loss at the connection. Intrinsic losses can be avoided by using matching fibers, while extrinsic losses can be overcome by strong mechanical feed. Today feeder elements with better than 2 μm lateral deviation are commercially available. Polishing and cleaning the connector surface can avoid absorption and the scattering of the optical power. With the help of anti reflection coatings or angled surfaces, reflections can be (7°-8° degrees) overcome. All connectors are very similar in their mechanical structure. The fiber is fed through a ferrule made of ceramics, which centers the fiber. Than the ferrule is filled with UV-curing glue. After hardening, the end of the fiber is cut and polished. The outer diameter of the normally used ferrule is 2.5mm or 1.25mm. In figure 18 a cross section of a connector is depicted.

In the following, typical connectors used today are listed in table 1.

The most popular connector today is the FC/PC one direct followed by the Diamond E2000 and the very small SC connector. FC/PC-connectors (see figure 19) are mostly used in optical equipment but have the disadvantage to be easily soiled with dust and dirt. The E2000 is used by several Telecoms because of the integrated dust cover and beam shutter.

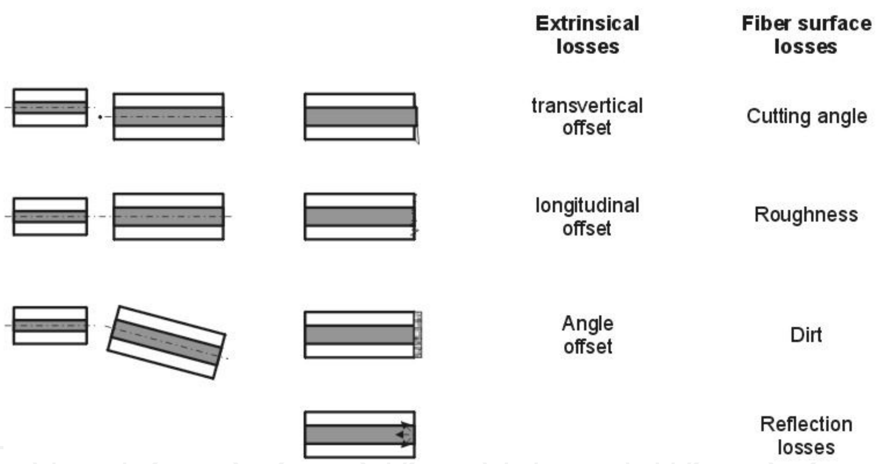

Figure 17. Loss mechanisms at connector end surface.

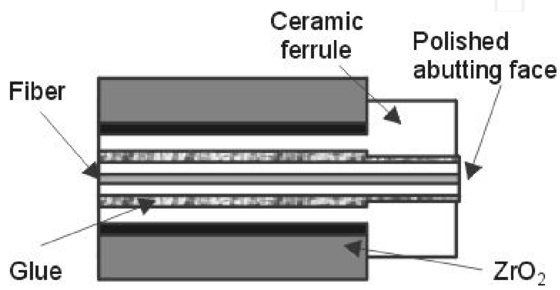

Figure 18. Cross section of an optical connector.

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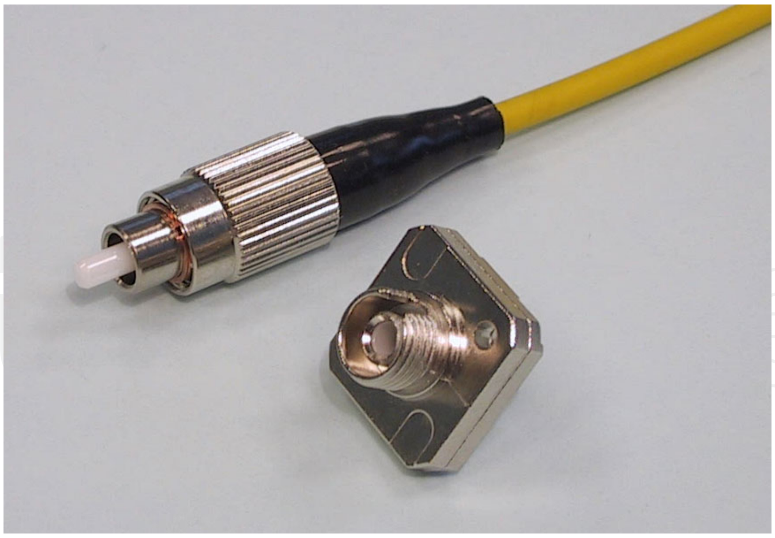

Figure 19. Optical FC/PC connector.

7.2. Multi-fiber connectors

These types of connectors are often used for the connections of mainframes or servers and at Fiber Distributed Data Interface (FDDI) links. Here the data were transmitted via several optical data links between the server stations with up to 10 Gbit/s per link. Also multi-sensor systems are using these kinds of connectors. Commercial available types are listed in table 2. The most commonly used connector is the MT one which is depicted in figure 20.

Figure 20. Multi-fiber MT-connector.

Name	Losses	Straight polished	Single (SM) Multi (MM) mode	durability (insertions)	User	Price
ESCON	0.5dB	-20dB	MM	"/500	LAN,Comp. Network	low
FDDI M	0.5dB 0,5dB	-20dB -20dB	MMSM	"/500"/500	WDM	med
MTConnect	0.3dB 0,5dB	-25dB -25dB	MMSM	"/200"/200	WDM	high

Table 2. Optical multi-fiber connectors.

8. Modules

This chapter will summarize several types of modules, which are used in commercial standard opto-electronic packages. These can be divided into four basic categories:

1. Transmitter (laser) -modules w/o cooling
2. Receiver (photodiode) -modules
3. Transceiver modules (Transmitter/Receiver)
4. Passive devices (sensor) -modules

Each category will be demonstrated by an example, but first some words about the required coupling method.

8.1. Fiber-chip coupling in modules

The performance of an optical coupling and the affordable operating expense are strongly dependent on the coupling device and the fiber used. The performance is directly correlated to the coupling efficiency. All commercial implementations are a trade off between cost and efficiency. To reach a very good efficiency you have to invest much manpower, which must be reflected in the price of the product. On the mass market only very low cost modules are available. That's the reason why here only modules with very low coupling efficiency can be found. The coupling of devices to multi mode fibers is less expensive than to single mode fibers, which are also priced lower than fiber-taper couplers. These are on the other hand are cheaper than lens-couplers, because of the time effort required to adjust additional coupling devices.

8.2. Multimode fiber coupling

The multimode fiber has an diameter of 50μm and a numerical aperture of 0.25 (15° aperture). Usually this type of coupling is used in photodiode modules where the fiber is directly connected to the photo-absorbing surface of the diode, which is depicted in figure 21.

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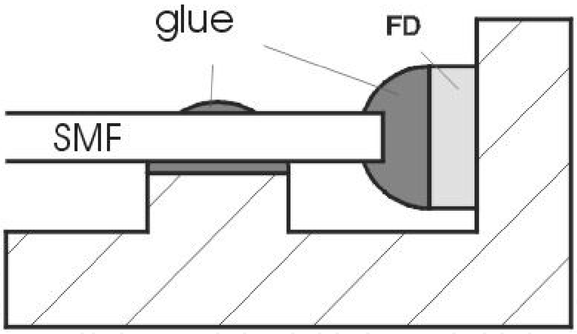

Figure 21. Direct attach of an optical fiber to a photo diode.

8.3. Singlemode-fiber coupling

In section 3 it has been demonstrated that a single mode butt fiber coupling to a Laser diode can have only 10 % efficiency. But with a lens system, which adapts the different optical mode fields, 50 % to 90 % coupling efficiency can be achieved (see figure 22). Table 4 gives a view of the mechanical aspects for coupling efficiencies with several coupling designs.

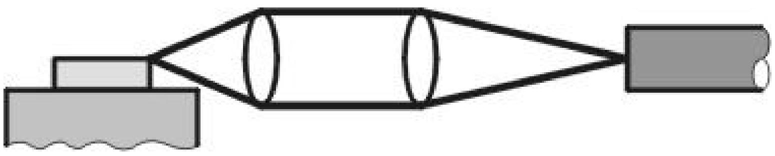

Figure 22. Fiber-chip coupling by a two-lens system.

Coupling technique (Laser-fiber)	Alignment precision (µm) for 1 dB add. loss at lateral/ longitudinaldisplacement	Coupling loss (dB)
Butt fiber (50µm)	15/50	7-10
Butt fiber (9µm)	2/20	7-10
System with one lens	0,5/5	3
Double lens system	0,5/5	1-3
Fiber taper	0,3/3	3-5

Table 3. Alignment precision for one dB additional coupling loss.

8.4. Transmitter and receiver modules

Transmitter modules for low cost applications are normally designed for simple butt fiber to chip coupling without temperature control of the emitting OEIC. Today more lensed coupling arrangements fixed by laser welding are often introduced. In figure 23, a coaxial coupled receiver module for high data rates of 40Gbit/s is depicted. This set-up is also used in low-priced transmitter modules for single mode operation.

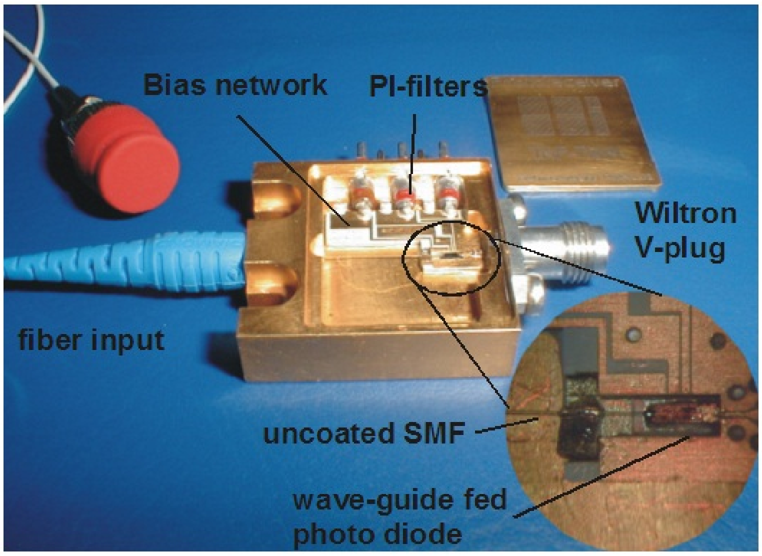

Figure 23. Receiver module.

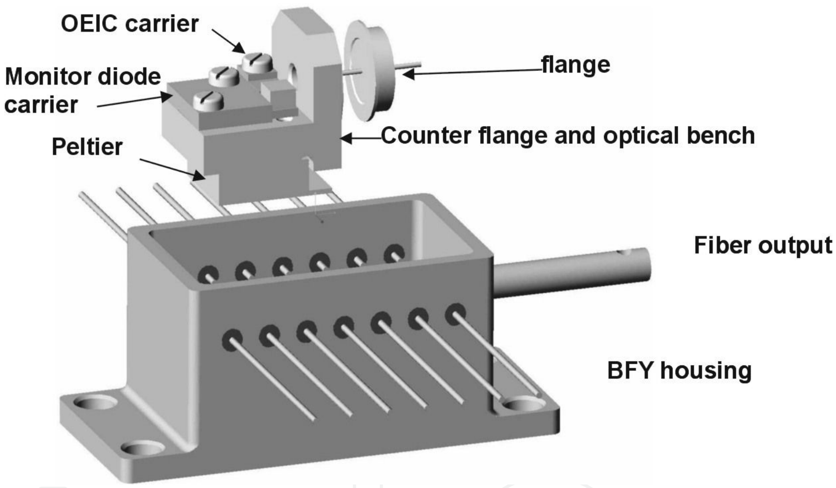

Figure 24. Temperature controlled laser module with fiber-taper coupling.

For high bit rate optical communications systems, cooled laser devices are needed. These modules are much more complicated in their mechanical set-up which is shown in figure 24. Here a tapered fiber was adjusted in front of the OEIC which is temperature stabilized by a Peltier cooler and a temperature sensor (thermistor) shown by [18].

8.5. Transceiver modules

These kind of modules are used in optical transmission systems where both terminals of the communications line can talk at the same time, which is called bi-directional communication. Transmitter and receiver functions must be integrated in these modules, which are shown in figure 25.

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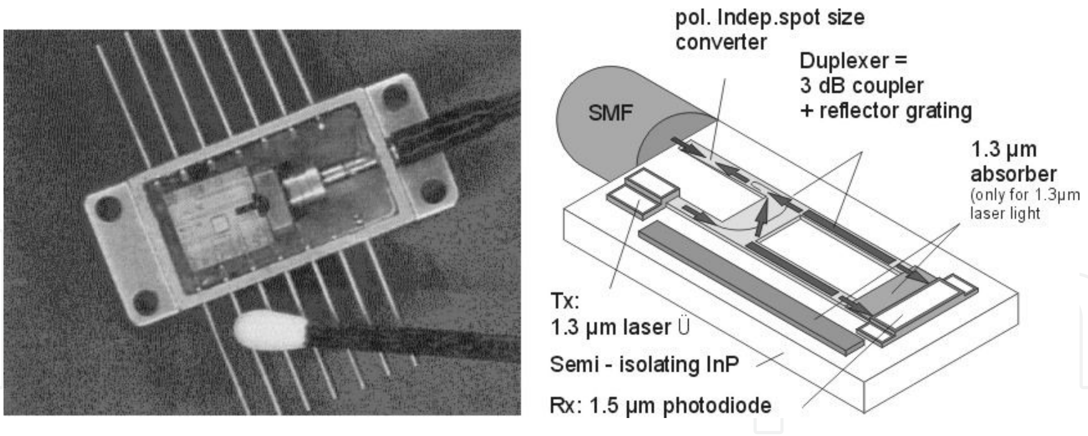

Figure 25. Monolithically integrated transceiver module.

8.6. Sensor and passive devices modules

These kind of modules are normally very easy to fabricate. Bragg sensors are used in a very wide spectrum of applications such as temperature sensors and strain gauge. The grating is centered into a metal or plastic tube and fixed with special glue.

Other passive devices use multiple fiber ports which can be combined in an array. Typical array devices are arrayed waveguide gratings (AWG)for multi wavelength optical transmission systems. These OEICs must be connected to up to 64 IO-ports at both chip sides as presented by [2], which can be seen in figure 27.

Typical housings are shown in figure 26.

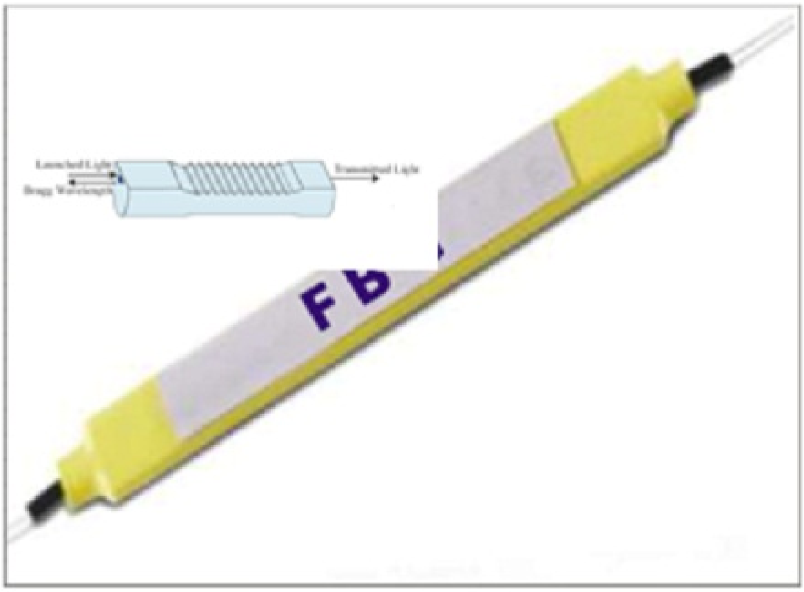

Figure 26. Fiber Bragg grating module.

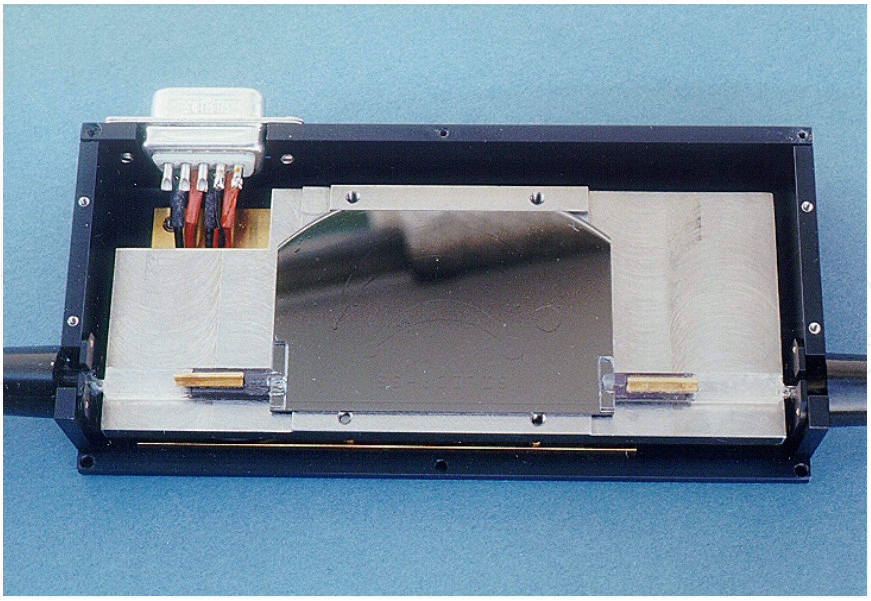

Figure 27. Arrayed waveguide grating module [19].

9. Reliability requirements

For application in optical networks, modules must be stable with respect to temperature changes and mechanical stresses. At present, there are several definite environmental and mechanical criteria for optical devices such as sensor and transmitter modules., which are investigated with reference to the [20] requirements. In the tests, insertion losses were measured online for each sample.

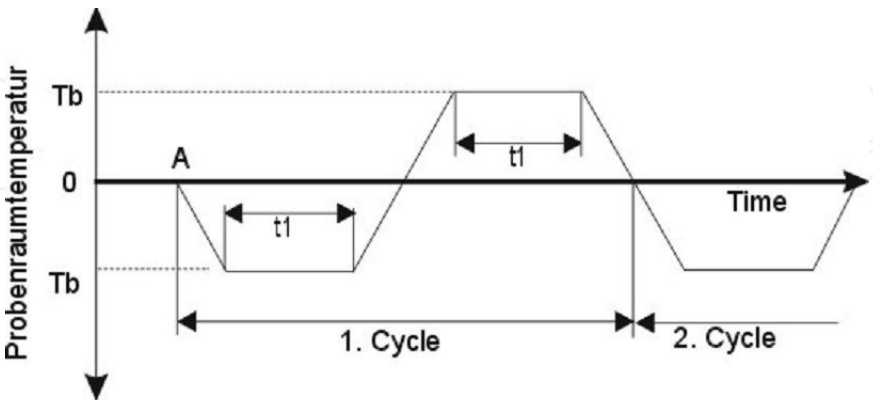

Figure 28. Temperature cycle test structure.

Temperature stress can be invoked into the modules by cycling the environmental temperature between a high temperature called TA and a low temperature TB that is depicted in

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figure 28. Additionally, relative air humidity can be increased up to 80 % or 95. The following institutions have developed the commonly used testing standards:

5. DIN (Deutsche Industrie Norm, German Industrial Standard Organization) 40046

6. MIL-STD (Military Standard/USA) 810/202

7. IEC (International Engineering Committee) 60068-X

8. Telcordia 6R-78, -326, -357, -468

Stress parameters	Tests
Climate	Cold, dry heat, dust and sand Low pressure Wheat heat at constant temperature Dry heat at cycling temperatures Solar radiation
Mechanical	Dropping, acceleration, vibrations
Chemical and biological	Corrosive atmosphere, growths of mold
Packaging and manufacturing	Welding, ultrasonic cleaning, mechanical strength of connector pins
div.	Sealing

Table 4. Environmental test parameters.

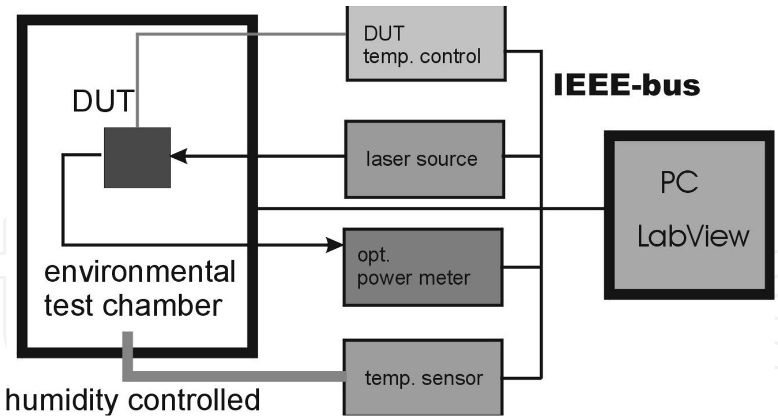

Figure 29. Environmental test set-up.

A typical set-up used for temperature testing is depicted in figure 29. Further, the device under test (DUT) is placed into a humidity controlled environmental test chamber. The temperature behavior of the opto-electronic module is mostly characterized by measuring the variation of optical output power. A plot of a typical temperature test between +15°C and +40°C is shown in figure 30. The temperature behavior of a laser module shows a maximum output variation of ±0.15 dB with temperature which is a real good result. Three cycles within 4 hours of measuring time were performed with temperature controlling of the OEIC shown in figure 30.

After thermal cycling, the test for mechanical shock and vibration stress was completed. Mechanical shock tests must be performed in all three Cartesian directions. The measured accelerations amounted to more than 200 g within 3 ms. The vibration tests where performed by a so called “shaker machine”. The excitation of the module was measured with an acceleration sensor and a digital oscilloscope. The acceleration was controlled to be stronger than 16 g within a broad spectral bandwidth of 50-5000 Hz. Several tests figures can be run with the so called “shaker machine”:

5. Sinusoidal acceleration1-1.000g
6. Noisy acceleration 1-10.000 Hz
7. Resonance test and -strain
8. Shock excitation 10 – 10.000g

To reach a certified test label for opto-electronic modules according to the Telcordia specifications, eleven modules must undergo the environmental and mechanical stress test. None of the tested specimens is allowed to show a failure. The strong requirements for the test procedures are only achieved by substantial preliminary testing of the modules.

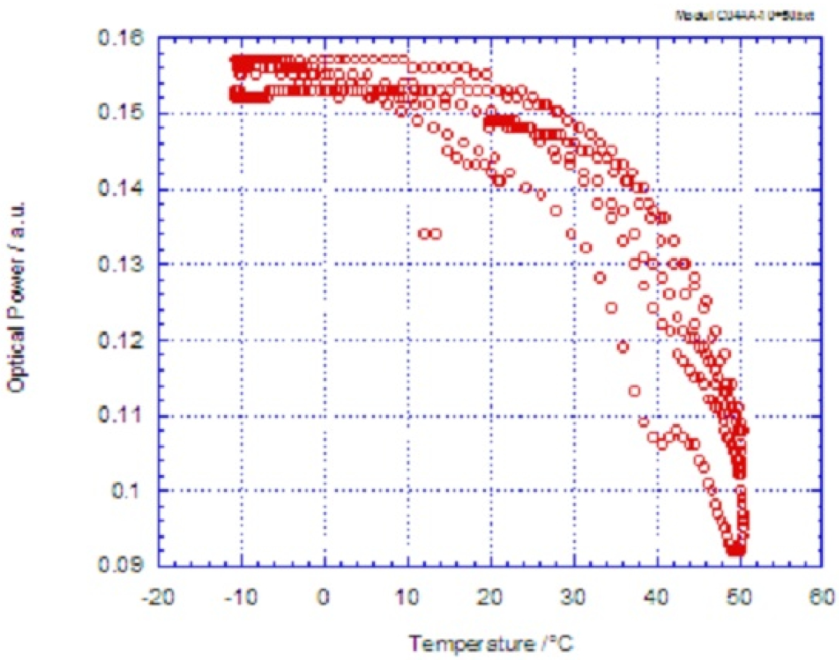

Figure 30. Temperature test of the laser module between -15°C and 50°C.

Sources of supply for environmental standard tests-

VDE-Verlag http://www.vde-verlag.de

DIN http://www.din.de

http://dx.doi.org/10.5772/51626

IEC-standards-shop http://www.iec-normen.de

Telcordiahttp://www.telecom-info.telcordia.com

10. Conclusion

We designed and fabricated a series of modules for one-sided and double-sided fiber-chip coupling for single mode and multimode fibers with simultaneous coupling of both chip sides by a new-patented set-up. Additional, we created passive and active modules with temperature control and multi fiber connections up to 16 fibers via fiber arrays. The modules have been tested in a reliability stress program between -40° C and +80°C and by a vibration shaker. Electrical modulation signals up to 50 GHz can be fed via RF connectors to the OEIC. The packages show good long-term stability and are well suited for rapid prototyping in laboratory environmentand high volume production.

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