FOUR CHANNEL FIBRE OPTIC TRANSMITTER AND RECEIVER MODULES FOR CMS DETECTOR TRACKER READOUT LINKS

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Abstract

We report on the realisation of compact four channel optical transmitter (Tx) and receiver (Rx) modules which have been developed in collaboration with CERN's EP/CME division.
Custom modules with pigtailed Fabry-Perot laser diodes and PIN photodiodes have been designed and fabricated using the Silicon Optical Bench (SiOB) technology. Both Tx and Rx modules are assembled in a compact 14 pin DIL ceramic package.
The four optical fibre pigtails are bundled in a common jacket, terminated in a ribbon and connectorised with an MPO4-T angle polished connector.
The Tx modules are hermetic and epoxy free. Both Tx and Rx modules exhibit good linearity, low noise and good temperature stability.

1. INTRODUCTION

Four channel optical transmitter (Tx) and receiver (Rx) modules have been developed for the CMS detector tracker readout link.
The CMS central tracker consists of approximately 12 million detector channels from which data will be transferred over an analogue optical link at 40 Msamples/s. Each link transmits 256 time multiplexed analogue samples. Therefore, approximately 50000 links will be required.
The link will be composed of Tx modules inside the LHC transmitting data over optical fibres to Rx modules in the data-logging room at a distance of about 100m. Furthermore, there will be a few thousand digital links to and from the tracker for transmission of clock and control signals [1].
This paper outlines the assembly of custom four channel modules in part 2. Part 3 covers the electro-optical characterisation of these modules while part 4 reports some initial results of reliability testing.

2. MODULE DESIGN AND ASSEMBLY

Due to the nature of the application and severe operating environment (analogue link, a 4T magnetic field, the presence of nuclear radiation, limited space) a number of requirements must be fulfilled [2] :

1. Low noise, high linearity transmitter and receiver
2. Compact package
3. Low mass , non magnetic packaging materials
4. Hermetic and epoxy free Tx modules for high reliability
5. Radiation hardness
6. Temperature range of -20 to +70 °C

A solution has been developed based on the Silicon Optical Bench (SiOB) technology available in Italtel to meet these requirements.
A 1300 nm Fabry-Perot laser diode is aligned to a singlemode (SM) optical fibre using a custom silicon submount in the case of the Tx; while in the Rx a PIN photodiode is aligned to a SM optical fibre using another custom submount. The resulting pigtailed optical sub-assemblies (OSAs) are then packaged in groups of four.
The laser OSA is shown in Fig.1. The laser chip is die-attached to the submount by means of evaporated Au/Sn eutectic solder. The die-attach is a batch process and takes place in a reducing atmosphere. The solder is confined during the die-attach process by means of an evaporated Ti solder dam. The laser's p contact is accessed by means of a gold wire-bond. At the front of the laser submount is another bond pad where the metallised angle cleaved fibre is actively aligned and attached using a Au/Sn solder preform. The preform is melted by driving current through a Cr resistor running under this bond pad. This resistor is thermally isolated from the rest of the submount by means of a thick oxide layer and is electrically isolated from the fibre bond site by another thinner oxide layer.
Fig. 2 shows the PIN submount. The die attach and wire bonding processes are similar to those of the laser. The optical fibre is placed in an etched v-groove and actively aligned to the back-illuminated PIN by means of a 54° turning mirror at the end of the v-groove. Once coupling efficiency has been maximised the fibre is fixed in place using thermally cured epoxy.

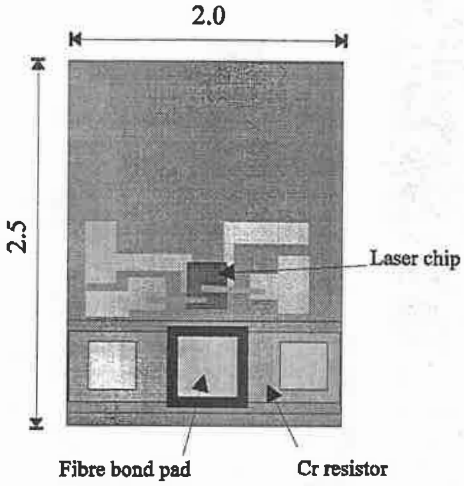

Fig. 1 : Laser optical sub-assembly

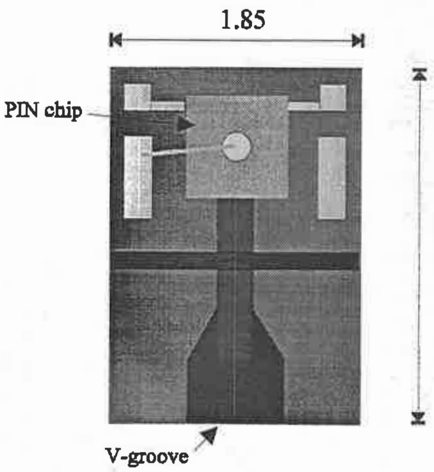

Fig. 2 : PIN optical sub-assembly

The 14 pin DIL package, which is common to both Tx and Rx, has been designed in collaboration with Kyocera Finceramics. It is made up of a ceramic body, lid and ferrule and a metal leadframe.

Its overall dimensions are 10x17x4 mm (width x length x height). Its features include alignment markers on the package floor for repeatable submount die-attach and a spacer at the back so that the pigtails of the two OSAs to the rear don't interfere with the two OSAs at the front.

In the Tx the laser OSAs and fibres are soldered respectively to the package floor and ferrule, whereas in the Rx, epoxy is used.

The internal configuration of the Rx module is seen in Figs.3 and 4.

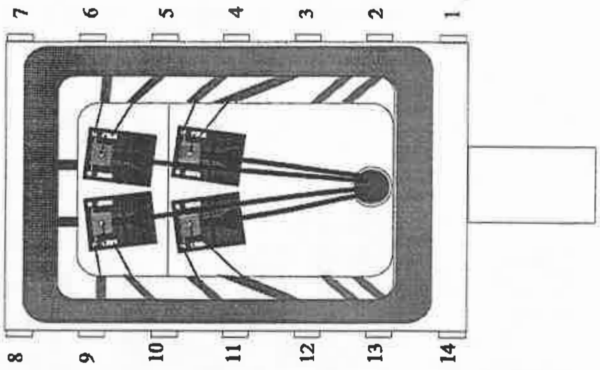

Fig 3. : Internal package configuration of Rx module

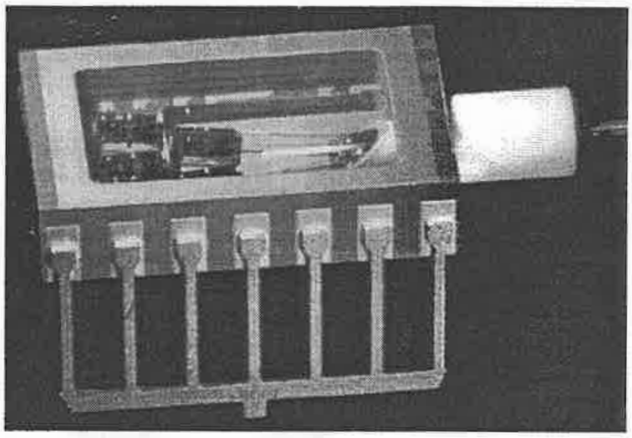

Fig 4 : Rx module in detail

The ceramic lid which is supplied with a Sn/Pb solder preform is soldered to the package in a reducing atmosphere, using a customised process.

During the development of this process trials were carried out on test modules which were then subject to gross and fine leak hermeticity tests according to MIL STD 883D Method 1014. As a result, optimised process conditions were identified which allow the realisation of hermetic modules.

It was therefore possible to assemble completely epoxy free hermetic Tx modules as required.

Fig.5 shows in detail the lid soldered to the package. The solder meniscus is continuous and shiny in appearance indicating a good seal.

Finally, a bend limiter is fixed to the ceramic ferrule and the fibres which are colour coded according to channel number are bundled in a common jacket and terminated with a MPO4-T angle polished connector. Fig. 6 shows the finished module complete with connector.

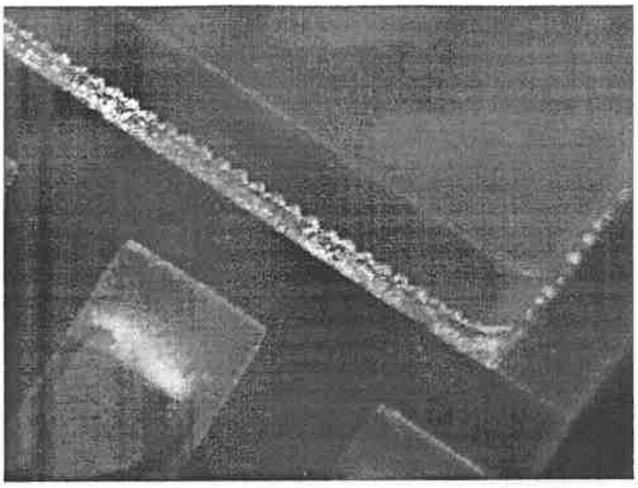

Fig.5 : Lid to package hermetic seal

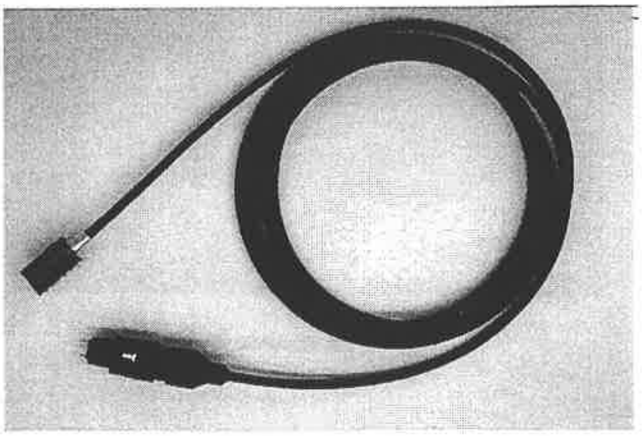

Fig 6 : Module with MPO connector

3. MODULE TESTING

Two automatic test stations, which can measure up to 5 Tx and Rx modules at a time, are used to perform the measurements. All modules are tested at 25°C and then burned-in to stabilise behaviour and to identify weak devices. Following burn-in the functionality of the Tx modules is verified from -20 to +75°C and that of the Rx modules from -40 to +85 °C. Fig. 7 shows the Tx module test station.

As these modules will be used in an analog link, the modules should have high linearity and low noise. Fig.8 shows a typical laser P/I curve at 25°C while Fig.9 shows the laser RIN (Relative Intensity Noise) vs. frequency. Table 1 shows some typical receiver characteristics. Results for the full analog link are reported elsewhere at this conference [3].

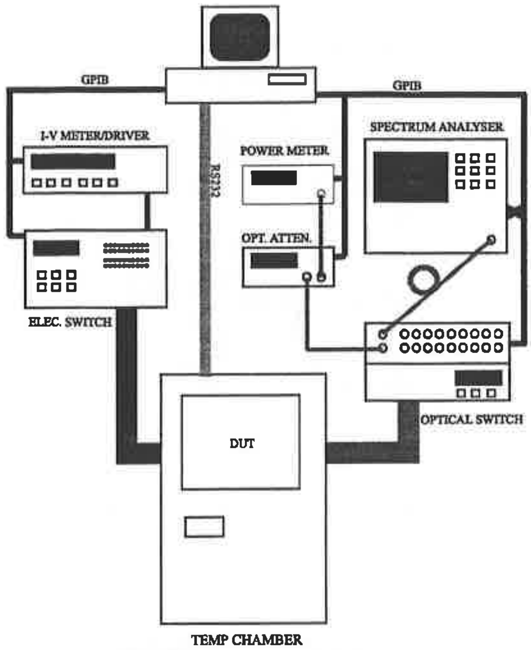

Fig.7 : Measurement system for Tx modules

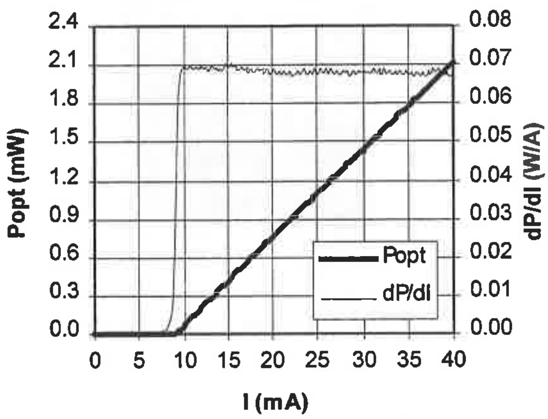

Fig.8 : typical laser P/I curve at 25°C

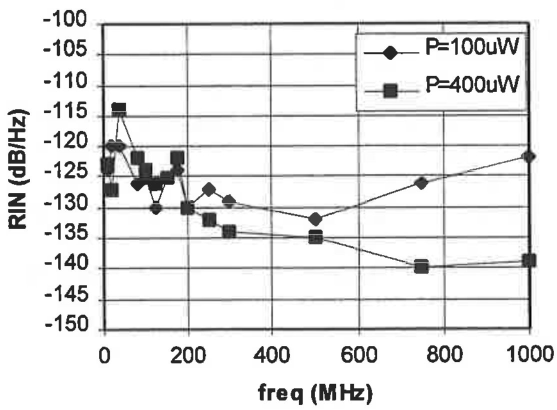

Fig.9 : laser RIN measurement

Responsivity (1310nm)	0.85	A/W
Dark current (-5V)	0.1	nA
Breakdown voltage	> 30	V
Linearity	< 1	%
Capacitance (-5V)	1.5	pF
Optical back reflection	-55	dB

Table 1 : Typical Rx electro-optic characteristics at 25 °C

4. RELIABILITY

Due to the nature of the application, module reliability is of utmost importance particularly in the case of the modules which will be inside the LHC and to which there will be limited access during the lifetime of the experiment . Three Tx/Rx pairs were subject to thermal cycles from -20 to +70 °C with a ramp time of 1 minute and dwell times of 15 minutes. This test should provide information about the module mechanical integrity i.e. if there are any residual stresses on the fibres this is likely to show up in a variation in chip to fibre coupling efficiency. Laser threshold current and slope efficiency and PIN responsivity and dark current were tested before and after each of the aforementioned tests. The results are shown in Figs. 10 and 11. If we use the Bellcore standards [4] as a guidline then the pass/fail criteria are variations of ± 10% in PIN responsivity and laser slope efficiency, no obvious change in laser threshold current (Ith) while the accepatable change in dark current (Idark) is not specified. Considering these guidlines the results shown below are quite satisfactory with no variations above the 10% limit, while variations in Idark and Ith are below the measurement error.
Mechanical shock and fibre pull tests which should give an indication as to the robustness of the modules when subject to handling during installation are currently underway.

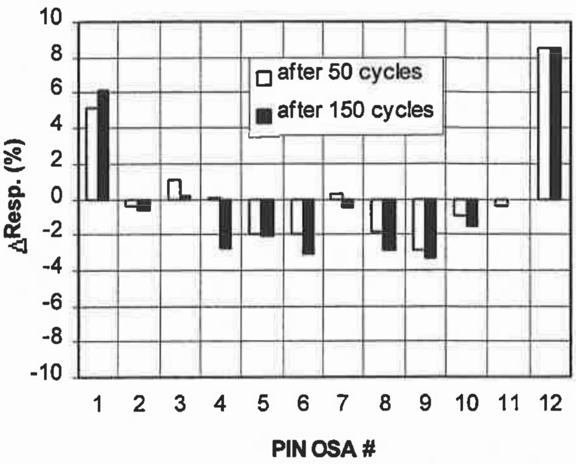

Fig 10 : Cumulative change in PIN responsivity after temperature cycling

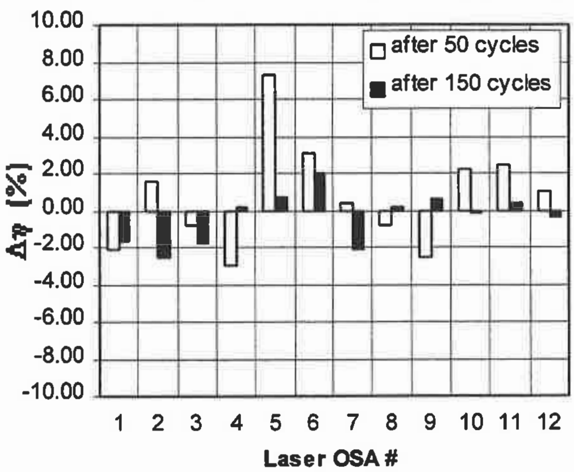

Fig 11 : Cumulative change in laser slope efficiency after temperature cycling

5. CONCLUSIONS

Four channel optical transmitter (Tx) and receiver (Rx) modules have been sucessfully developed and realised. These devices are assembled in a mainly ceramic package which has been developed in collaboration with Kyocera Fineceramics. The Tx modules are hermetic and epoxy free.
Both the active components (laser or PIN chips) and optical fibres are aligned on silicon submounts which have been specifically designed and fabricated for this project.
The dimensions of the 4 channel module of 10x17x4 mm compare favourably with those of the industry standard single channel mini-DIL package of 7.6x13.2x3 mm.

Several new packaging processes were developed to fulfill CERN's requirements. These include :

- assembly of four devices in a single package, including the development of custom mechanical fixtures for placement of the four OSAs and fibres.
- soldering of the ceramic lid to the package (the standard process consists of a metal lid seam sealed to the package) .

The modules have been extensively tested and shown to meet the electro-optical specifications. Results obtained after temperature cycling of the modules are encouraging and further reliability tests are planned.

ACKNOWLEDGEMENTS

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