INNOVATIVE SUBMARINE AMPLIFIER DESIGN FOR HIGH CAPACITY OPTICAL SYSTEMS

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Abstract: The recent introduction on the market of a new generation high capacity coherent photonic transmission systems has opened new opportunities in the telecom submarine business both for the capacity upgrade of existing links and for the cost effective realization of Multi Terabits submarine new connections. In this paper we show the use of an integrated optics Passive Integrated Component (PIC) for realize a small, compact and easy to mount optical amplifier with very high reliability to be used in very high capacity (high fiber count) small size submarine amplifiers.

1 INTRODUCTION

As for the terrestrial link also in submarine system the increase in cable fibre count can allow more complex network architecture and higher link availability using better path protection solutions.

Repeated submarine optical links are limited in fibre count by the number of optical amplifiers that can be accommodated inside the pressurised vessel. This limit is due to problems of space occupancy and power consumption. Particularly critical is the situation of the space occupancy due to the repeater handling problems. In particular, the requirements imposed to the repeater to be laid using standard linear traction machine and 3 meters wheel limit severely length, diameter and weight of the repeater itself. On the other hand, the specifications on pressure resistance of the repeater (800 bar) increase dramatically the weight of the repeater housing and reduce the inner available space

In order to avoid this problems the only way to increase the number of amplifiers, and then the number of fibres and systems, is to reduce the amplifier dimensions.

Up to now the submarine amplifiers, that present a typical schematics as show in figure 1, are made by splicing a large number of discrete optical components

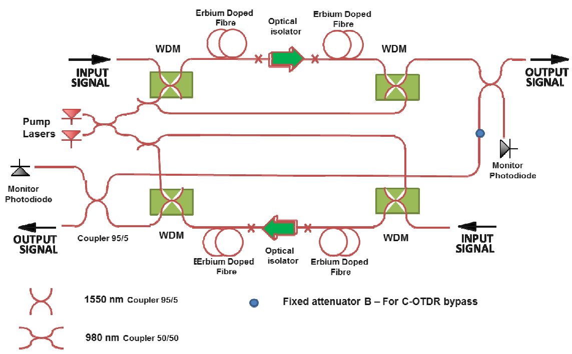

Figure 1 – Submarine optical amplifier schematic

(WDM, couplers, splitters, isolators, active fibres, etc.) in a small organizer where the curvature radius of the fibres and the position of the splice are carefully controlled for reliability purpose. This optical assembly is a complex and critical process optimized during a long history and can’t be further reduced in dimensions without creating functionality and reliability problems.

To solve this problem we propose the use of a Passive Integrated Component (PIC) containing all the passive optical components except isolator and active fibre that can't be integrated as shown in figure 2.

In this way we drastically reduce the number of components and of the fibre pigtail to be spliced allowing a significant dimensions reduction for the optics and a large reduction in assembly complexity therefore increasing the optical assembly reliability.

Regarding the PIC reliability we have used a well-established and reliable technology both for the chip and the package. A qualification program to assess the device reliability is in progress.

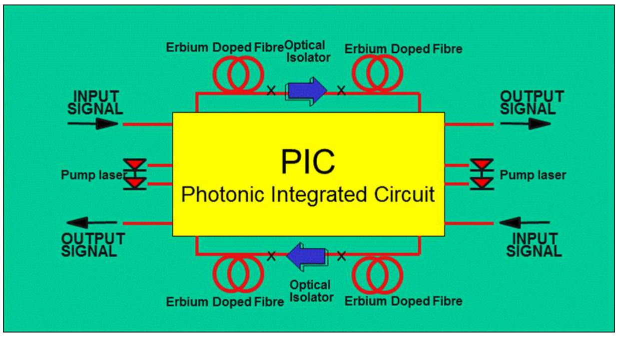

Figure 2 – Submarine amplifier schematic using PIC

2 PIC TECHNOLOGY AND DESIGN

The choice of the PIC technology must take into account a various aspects such as a small chip footprint, the capability to manage in the same waveguides both signals and pump wavelengths (1550nm and 980nm), low reflections at the chip facets, negligible nonlinear effects, high optical power handling capability, reliability and yield, good coupling with the optical fibers, availability of the foundries and low costs, etc. We found that the best compromise is achieved with glass on silicon technologies with refractive index contrast equal to 1.5%. Such a technology is well consolidated, reliable and available on the market through a number of foundries in US, Europe and far East. It allows a bending radius down to only few millimetres for both wavelengths and a coupling efficiency with fibers better than 90%. The relative high index contrast, moreover, is necessary to realize the WDM couplers that must be short and polarization independent.

A schematic of the layout is shown in fig. 3. WDM couplers, pump combiners, tap couplers for monitoring, calibrated attenuators for a bidirectional amplifier (two systems with loopback for control) are all placed in a chip 8 by 2 mm large. Suitable mode converters are placed at the chip edge to improve the fiber coupling and reduce the facet reflectivity. The layout has been replicated four times to serve four bidirectional systems (8 EDFA) in less than 1 cm^2. The chip is fully passive and no heaters for functionality control are required, resulting in a simple and low cost package. The four systems version requires two compact standard fiber-blocks of 32 fibers each, giving a substantial aid to the assembling of the whole module.

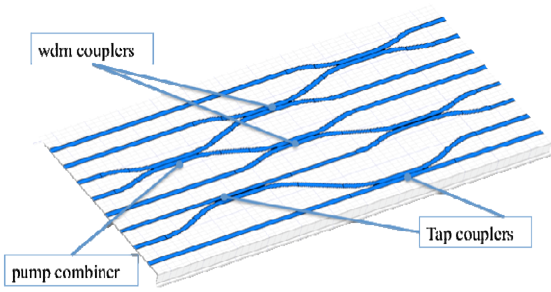

Figure 3 – Layout of the PIC for the bidirectional amplifier with loopback

3 PACKAGE AND RELIABILITY

Most of the optical functions inside the amplifier are realized with fused fiber technology based components. This technology is extremely controlled, assessed and reliable, though the complexity of the optical design and the necessity to reduce space make the assembly procedures extremely critical and this can affect reliability in an unpredictable way.

Considering a reliability block diagram approach to evaluate amplifier reliability, we can group the optical components into three blocks: the active devices (laser and photodiode), the isolator that has a specific technology and all passive components, usualy fused fibers based.

The repeater Failure rate (FiT in the following) is the sum of the three blocks FiT figures. The contribution of the fused fibers block to the repeater FiT figure is approx 0.5FiT per amplifier but considering a repeater with more than 2 amplifiers an additional multiplication factor must be considered in order to evaluate handling due to assembly complexity. This can be 'heavy' in the part count compromising the whole reliability result. The formula describing the Failure rate of the repeater is the following:

FiT repeater= FiT amplifier. *n.amplifier= (FiT active components + FiT isolator + FiT fused fiber* C complexity) *n. Amplifier

where C is the complexity factor that increase with the number of amplifier. The correct evaluation of C is difficult and indicates a reliability risk.

The PIC solution allows to cancel the C factor because the assembly becomes easy and safe, and to substitute the FiT of fused fiber components with the FiT of PIC device. The above formula becomes:

FiT repeater= FiT amplifier. *n.amplifier= (FiT active component + FiT isolator) *n. Amplifier + FiT PIC

The Failure rate of PIC device is not dependent on the number of amplifier, in fact the integration complexity do affect the chip process but it does not affect its reliability. Actually no failure mechanisms are related to chip technology itself but only to the packaging process.

Package failure rate can be addressed with an appropriate and exhaustive qualification program that can be widely completed with field data from similar PIC devices used for other applications and sharing same manufacturing process. The qualification exercise will considered not only environmental stress but even stress due to high power exposure as from active fiber outputs. The main issue is of course alignment stability, that must be deeply analyzed. Anyway it must be considered that the operating conditions for submarine systems are extremely mild concerning temperature variation and humidity, the stress mainly affecting alignment stability. This indicates that qualification exercise is not a critical issue. At present the exercise is in progress and results will be available soon. The qualification exercise is mainly a Telcordia gr_1221_core test plan extended over 10000hrs with additional tests for high power density related failures both at 980nm and at 1550nm.

4 REPEATER DESIGN

In addition to the adoption of integrated optic technology in order to reduce the space occupancy of the amplifier optical components also the electronic hardware has been minimized by designing an electronic circuit with only the amplifier output power stabilization circuit and the control for redundancy management but without any supervision functionality. The amplifier monitoring function is performed by a C-OTDR operating on line at a wavelength outside the transmission bandwidth The COTDR operate out of band and at low power even on very long links therefore avoiding any impairments on the transmission channels.

By using those optical and electrical solutions it is possible to increase significantly (up to 2 X) the number of amplifiers in an industry standard repeater. Higher fiber count (up to 32) submarine cables can be adopted and therefore the capacity of the submarine link can increase substantially together with its commercial attractiveness

An alternative option is to keep the number of amplifier constant and use a smaller vessel reducing therefore the complexity and cost of the mechanic and facilitating the handling of the repeater during the laying and recovery process.

As an example Padtec has designed a small repeater that can house up to 8 systems (16 amplifiers) which is shown in fig 4. Thanls to its reduced dimensions the repeater does not need gimbals for passing over the laying sheave.

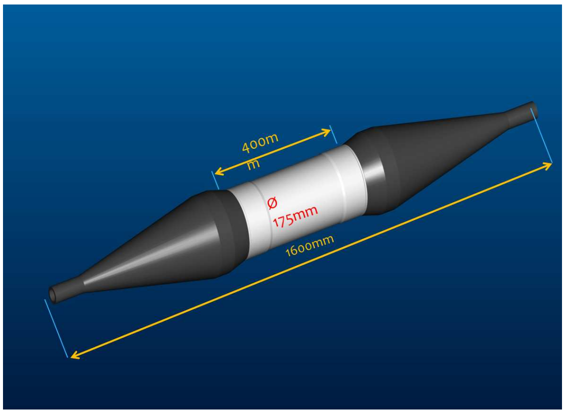

Figure 4 – Small repeater design that can house up to 16 amplifiers using PIC

5 CONCLUSION

In conclusion we have presented an innovative design solution for submarine repeaters that, using a silicon based PIC and an all optical in line supervision system, allow the possibility to increase the number of system in a submarine optical link improving the capability and the flexibility in traffic management.

The use of PIC also reduce the complexity of the assembly increasing the reliability and reducing the cost.