Electroabsorption-modulated DFB laser ready to attack 10Gbit/s market

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Electroabsorption-modulated DFB-laser ready to attack 10 Gbit/s market

Introduction

Electroabsorption Modulator integrated with a DFB-Laser diode (EA-ILM) is now a well-established technology for 2.5Gbit/s telecommunications on fiber optics where it tends to gradually replace the traditional lithium niobate modulator fed with a DFB-laser. Compared to lithium niobate, the EA-ILM approach offers significant size reduction, requires low driving voltage and has virtually the potential to offer the same cost, on the medium term, as those of a single DFB laser source. In addition, performances of EA-ILM are similar to lithium niobate for practical applications. However, to date a large number of systems suppliers are still reluctant to get use of EA-ILM despite their intrinsic advantages over lithium niobate. First of all it seems that performances of EA-ILM are not yet fully recognized by the systems makers. In addition systems makers still have little confidence in the capability of EA-IML manufacturers to supply EA-ILM devices in volume on all wavelengths of the I.T.U WDM grid. This situation can be explained by the fact that EA-ILM products were not really ready when the demand literally exploded under the pressure of the 2.5Gbit/s WDM market. Most of EA-ILM manufacturers had not yet completed their development program at that time, and were not able to face the demand in a context where the capability to deliver in a short time is a necessary condition to be qualified by systems manufacturers. The story is turning differently for the 10Gbit/s case since EA-ILM manufacturers have taken advantage of the experience they acquired for the development of their 2.5Gbit/s product. Moreover, some manufacturers chose, at the very start of their development program, to design their EA-ILM chip with both 2.5 and 10Gbit/s capabilities. In this later case, only the package module and the submount had to be made compatible with 10Gbit/s standards in order to move from the 2.5Gbit/s product to the 10Gbit/s version. The choice of having developed a single EA-ILM chip for both 2.5 and 10Gbit/s not only allowed a reduction of the development costs but also leads now to an immediate availability of the I.T.U wavelengths grid since the WDM coverage is already done for the 2,5Gbit/s market. Alcatel had early developed its EA-ILM component with 2.5 and 10Gbit/s capabilities and is ready now to face the 10Gbit/s challenge in both single-wavelength and WDM applications up to 1700ps/nm dispersion.

Main applications

Three main10Gb/s applications are covered by existing standards :

- Short reach transmission (< 50ps/nm)
- Intermediate reach transmission (800ps/nm) : ITU-T S64.2
- Long reach transmission (1600ps/nm):ITU-T L64.2

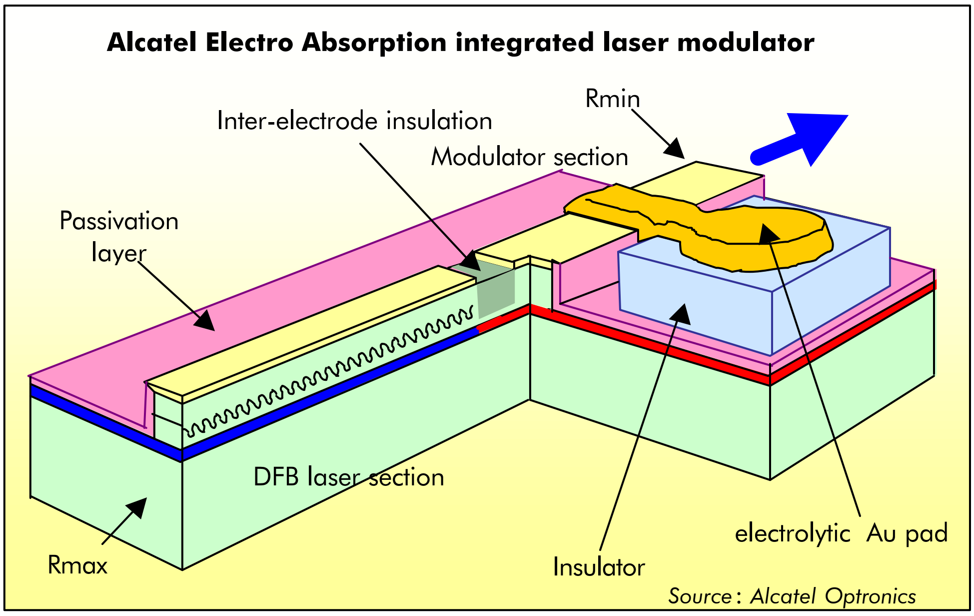
The short reach product is designed to allow connection between WDM transmission equipment and routers or terminals. The EA-ILM technology is being proposed as a standard for short reach interfaces by certain equipment manufacturers in the Optical Interconnection Forum (OIF)

For the intermediate reach application, a booster-free 800ps/nm transmission on standard single mode fiber must be achieved. The EA-ILM technology has proven a great ability to fulfill this application thanks to its high output power. For the moment single wavelength is being used but WDM requirements are now emerging

The long reach application is certainly the most promising market for the WDM EA-ILM product since it offers an unbeatable cost-performance trade-off compared to competing approaches.

From Short to long reach applications, the EA-ILM technology is the ideal candidate to constitute a cross-application standard.

Moreover, some equipment manufacturers have already demonstrated 10Gbit/s transmission over 150kms span (ITU-T V 64.2) with the Alcatel EA-ILM product (A 1915 LMM), using Dispersion Shifted Fiber. Compensation technologies should increase the transmission span to longer distances making thus the EA-ILM technology compatible with all the market demand.

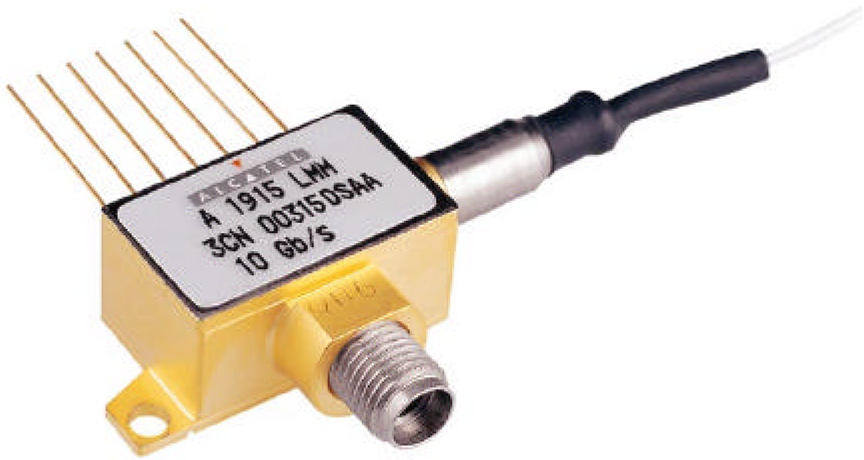


Schematic view of EA-ILM Alcatel

Figure 1

Chip design

The design of the Alcatel EML chip is based on the ridge stripe laser structure. The butt-joint technique is used to couple the modulator and the laser section. The butt-joint technique makes independent optimization, of the laser and the modulator sections, possible and yields a high coupling efficiency between the two sections as well. The design of the ELM chip is greatly simplified thanks to the ridge structure, which reduces the number of epitaxial growths to only 3 steps resulting in a high wafer yield. In addition, the modulator ridge structure has a low capacitance which gives an electrical bandwidth in excess of 12GHz and a rise time as low as 35ps. Last but not least, the electrical isolation between the laser and the modulator sections is greater than 1 MΩ. This isolation is obtained by using a high-reliability proton implantation step. A high reflectivity coating is deposited on the rear facet to increase the output power on the front side whereas an antireflection coating is deposited on the front facet so as to prevent any optical reflections back into the laser section.



View of 1915 LMM Alcatel module

Figure 2

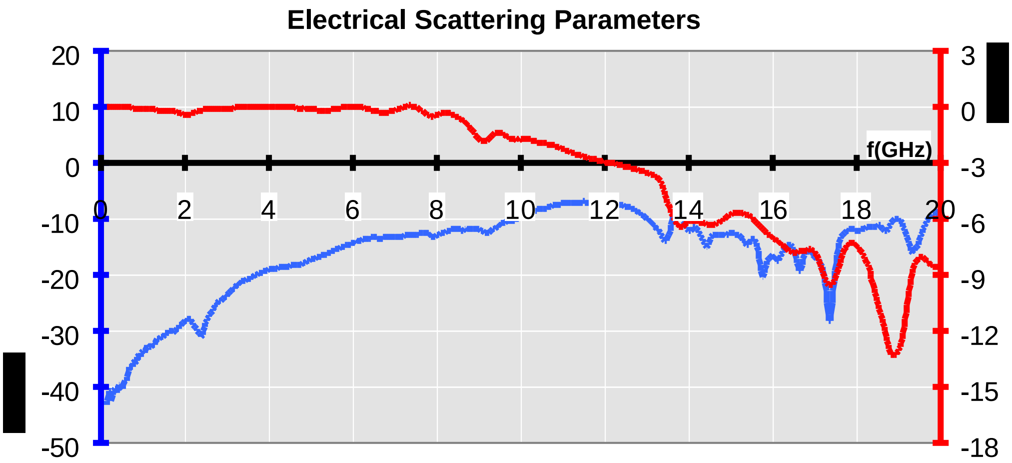
Module characteristics

The chip is pigtailed in an hermetic package including a thermoelectric cooler and an optical isolator. A RF coaxial connector (K or GPO type) is used for the modulation input since butterfly connections have not yet proven their compatibility with 10Gbit/s applications. Mechanical design is compatible with industry standards so that second sourcing is possible.

Static characteristics

Static characteristics shows typically 20mA threshold current and 4mW fiber output power at an 80mA drive current and a bias voltage of 0V. A maximum extinction of 15dB is achieved for – 2.5V. The chirp with respect to the modulator voltage shows a zero value around –1.3 volts.

S-parameters



S21 and S11 curves of EA-ILM Alcatel 1915 LMM module for 80mA drive and –1V modulator bias

Figure 4

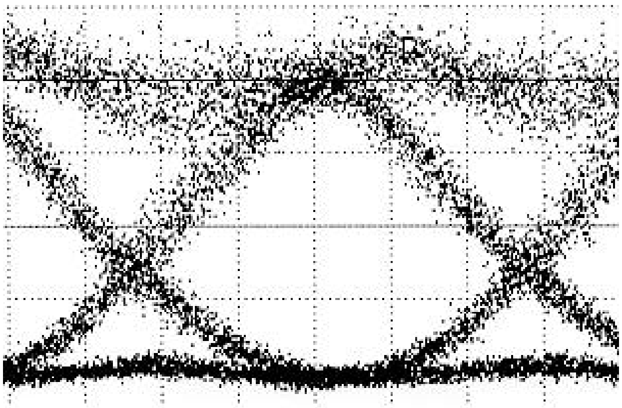
Dynamic and fiber transmission characteristics

Alcatel 1915 LMM module shows a typical 3 dB bandwidth (S21) of approximately 12GHz, which exceeds the required bandwidth for 10Gbit/s transmission but, as an advantage, offers the possibility to add errors correcting codes. The return loss (S11) curve which, is the amount of reflected power , is displayed in figure 4 and stay as low as –10 dB up to 8GHz. This is compliant with the more stringent requirements in the field of telecommunications. Extensive work was undertaken to optimize the product's system performance.

In particular the Alcatel 1915 LMM simultaneously provides a high optical power, a dynamic extinction ration greater than 10 dB, and a low fiber dispersion penalty. An extinction ratio greater than 10dB is obtained for a modulation voltage of typically 1.5 volts, which is compatible with most of the commercially available drivers. The average power obtained under modulation is greater than 0dBm for 700ps/nm transmission (see figure 7) which, gives a large margin for most of applications. Figure 5 shows typical eye diagram after 40kms propagation on standard non-dispersion shifted single-mode fiber. A clear open eye is obtained allowing a path penalty lower than 2 dB (see figure 6) without optimizing the modulation and bias voltages. In practice, a path penalty lower than 1 dB is always achieved by adjusting the bias and modulation voltages to the optimum values for each module. Similar performances are achieved for 80Kms transmission but with less margin for the adjustment of the bias and the modulation voltages since the chirp is the most limiting factor in this case. Lowering the chirp requires to increase the bias voltage according to the chirp response of the material, with respect to the electric field. Unfortunately, the bias voltage can no longer be increased without reducing the extinction ratio.

In addition, the average output power is also reduced when increasing the bias voltage since the chirp parameter and the absorption increase simultaneously as they are intrinsically linked by physical laws of electro-absorption process.

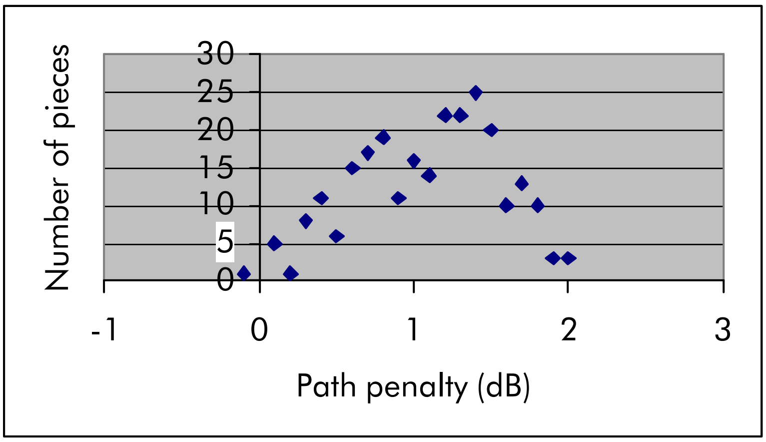
As a result, a trade-off between the path penalty and the extinction ratio has to be found playing with the bias and the modulation voltages. It is clear that a higher chromatic dispersion requires less chirp to maintain the penalty at a low value and consequently makes the adjustment more precise.



80ps / div

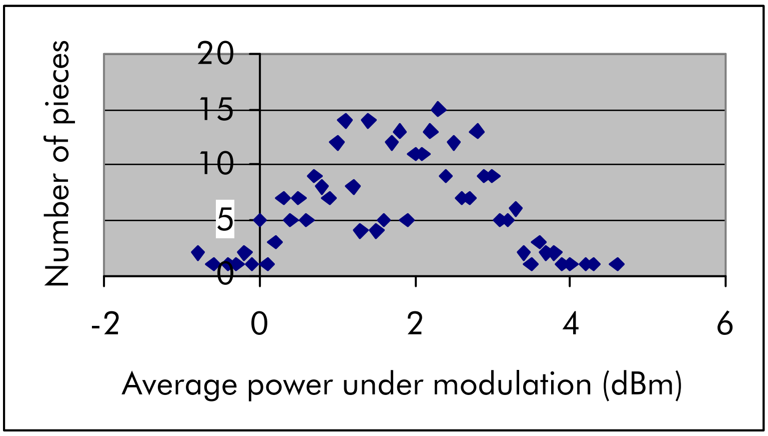
Typical eye diagram after 40Kms of non-dispersion shifted fiber

Figure 5



Path penalty measured on 300 EA-ILM for fixed modulation voltage conditions
(bias voltage = -1,25 V; modulation voltage = 1,5 V) and 40Kms 10Gbit/s transmission

Figure 6



Average output power under modulation measured on 300 EA-ILM for fixed modulation voltage conditions (bias voltage = -1,25 V; modulation voltage = 1,5 V) and 40Kms 10Gbit/s transmission.
Figure 7

Deployment status

Since January 1999, the Alcatel 1915LMM has been massively deployed on the international market. Most of the deliveries have been done to support the Intermediate and Short Reach applications. The 10Gb/s EA-ILM technology has been adopted by some of the major worldwide telecommunication equipment manufacturers, in the US, in Europe and in Asia.
The long reach product is being tested by several customers and should be validated by the end of this year.

Future extensions

The next step is to extend the WDM coverage to the L-band up to 1605nm by mid-2000. Systems manufacturers seem to agree that first L-band applications will be on Dispersion Shifted Fiber (DSF). Because of the zero dispersion, the Four Wave Mixing (FWM) nonlinear process seriously limits the number of channels that can be transmitted in the C-band on DSF fiber. Moving to L-band gives a slight amount of dispersion that fits better to WDM transmission. In addition, the low dispersion of DSF fiber is well suited to 10Gbit/s since it authorizes hundreds of kilometers span without compensation. Considering that thousands kilometers of DSF fiber are already deployed around the world a demand for 10Gbit/S EA-ILM in L-band should soon emerge.

Considering the package, the main on-going development is to release for year 2000 a product with built-in wavelength monitoring, designed to be compatible with 50GHz channel spacing in WDM applications (Alcatel 1945LMM). Despites this new functionality, the package and the pin out of the new product will stay compatible with the previous series without the integrated wavelength monitoring function, in order to avoid a complete redesign of existing boards. The choice of an analog outpout for the control signal will leave the freedom for the user to drive the wavelength either with a digital or an analog circuit.
Besides, others on going Alcatel developments include releasing bias-free version, full 14-pin butterfly package configuration and an extending temperature range thanks to multi-element cooler, for a greater tunability in WDM applications.