ADVANCES IN WIDELY-TUNABLE OPTICAL TRANSMITTERS

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Abstract *Widely-tunable lasers have been integrated with semiconductor optical amplifiers and either electroabsorption or Mach-Zehender modulators to create high-performance optical transmitters. High yield and reliability have been demonstrated on these single-chip devices*

Introduction

Within the past couple of years there has been some renewed interest in photonic integration. Although photonic or optoelectronic integrated circuits, (PICs) or (OEICs), have been researched for many years, the drivers to develop products with these technologies have been largely absent. Perhaps, this was because the end users of telecommunications equipment were not very sensitive to the cost and size metrics involved with having discrete components in their optical transmitters and receivers, perhaps this was because the performance of these PICs and OEICs fell short of the requirements, or perhaps this was because the volume of such ICs was simply too small to justify the investment to develop them. No doubt, all of these issues have been involved to some extent, but there seems to be a growing recognition that there needs to be a change in the cost, size and power metrics associated with optical transmitters and receivers for them to meet the specifications of future systems.

Advances in the art have largely removed most of the performance shortcomings, but the need for volume production and capital investment still remain at issue. Work at UCSB and Agility Communications has aimed to address these issues by developing a low-cost 'platform technology' that is capable of providing a wide variety of PICs without changing the basic manufacturing process. This limits the required capital investment and enables higher volume by sharing the technology across a number of components. In this paper, we will review some of the progress in producing widely-tunable transmitters, which can function as universal WDM transmitters, because a single part can be used for any optical wavelength across the entire fiber-optic C-band (or other band).

Single-chip transmitter

Figure 1 shows a schematic of the InP-based transmitter chip. It includes the four-section sampled-grating DBR (SGDBR) laser[1], an integrated SOA, and an electro-absorption modulator (EAM)[2]. A common quaternary waveguide extends throughout the entire device and quantum well gain layers are included at the laser gain and SOA sections. The modulator bias is varied across the 40 nm tuning range to enable efficient modulation across this entire range.

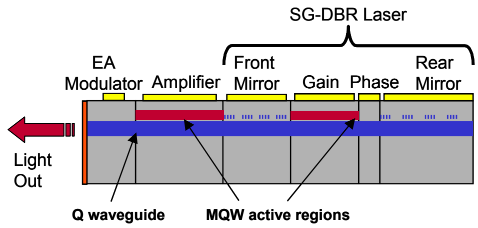


Figure 1. Single-chip widely-tunable transmitter using a SGDBR laser integrated with an SOA and EAM.

Figure 2 shows the bit-error rate after transmission through 350 km of standard single-mode fiber for two different wavelengths. The data is applied directly to the EAM of the chip. The average modulated output power is about 3dBm in this case. Error-free operation was observed.

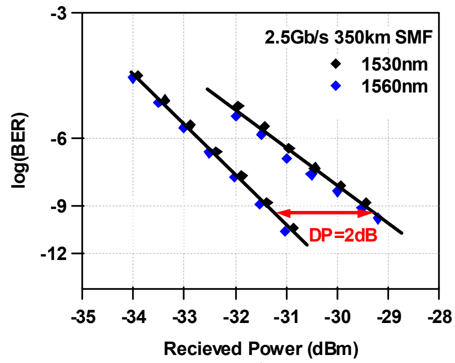


Figure 2. Bit-error-rate results after tranmission through 350 km of standard fiber at 2.5 Gb/s.

These same chips can be operated as cw sources by keeping the EAM in the on-state. Another Agility product uses this approach by calibrating the output to be 10 mW at each of the 100 channels spaced by 50 GHz across the C-band. Other cw products leave the EAM off for more power out.

Relatively high output power has recently been obtained by a slight redesign. Figure 3 shows the cw characteristics of a device that was calibrated for 40 mW into fiber across the entire C-band. Also included are the linewidth, $\Delta\nu$, the relative intensity noise, RIN, and the side-mode suppression ratio, SMSR for all C-band channels.

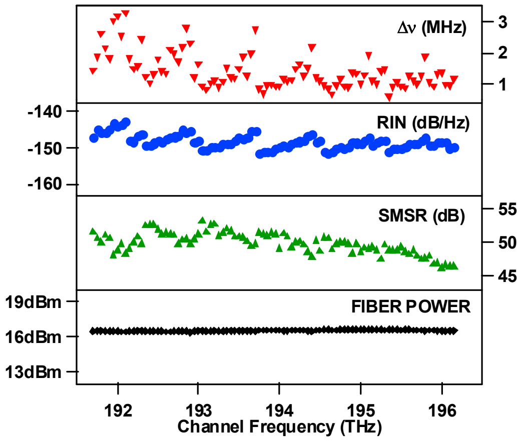
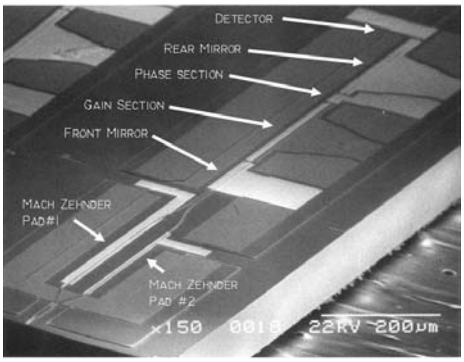
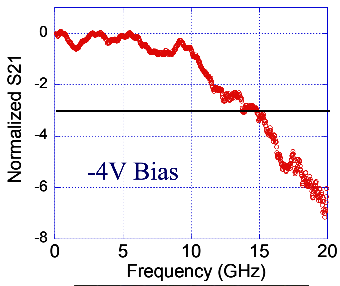


Figure 3. CW characteristics of SGCBR-SOA device for 100 channels--calibrated for 40 mW of fiber power.

Recent work both at UCSB[4] and Agility includes some effort on replacing the EAM with a Mach-Zehender modulator (MZM). This is being done to improve the chirp characteristics for long-haul applications.





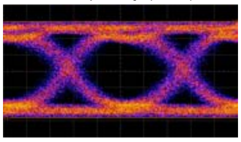


Figure 4. (Top) SEM photo of SGDBR integrated with a Mach-Zehender modulator. (Middle) Small signal bandwidth of SGDBR-MZM device; (bottom) eye-diagram at 10 Gb/s.

By monolithically integrating the MZM a much smaller footprint and low power dissipation is possible. In addition, the chirp can be tailored for each channel across the wavelength band by adjusting the biases to the two legs of the MZM as has been done for the EAM case. Figure 4 gives an SEM photo and initial results of the UCSB device. Using a similar device developed at Agility, error free transmission over 80 km of standard fiber was demonstrated for all channels at 10Gb/s.

Reliability

Figure 5 summarizes some of the reliability data taken on the 10 mW cw product by Agility. Both the integrated EAM transmitter and the 10 mW cw version have undergone complete Telcordia qualification. Because of the InP single-chip architecture, these PICs can be qualified in much the same way as simple laser chips. Such is not the case with other types of widely-tunable transmitters in which separated optical parts are involved in some sort of hybrid package.

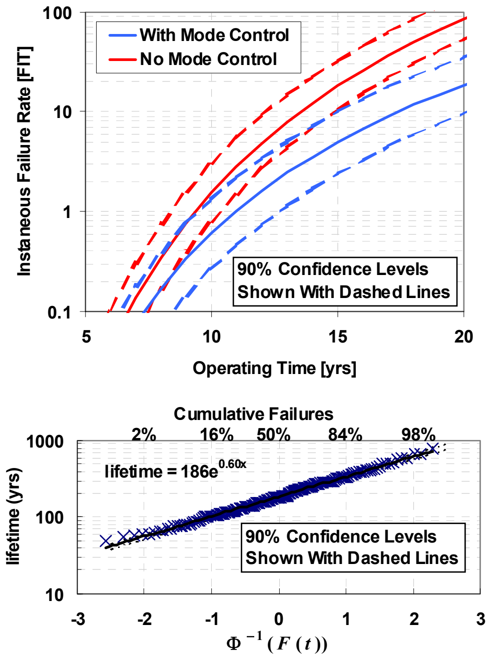


Figure 5. (Top) FIT rate vs. time, assuming both original mirror biases as well as with bias updating. (Bottom) Lifetime distribution of 200 parts tested. Maximum channel currents assumed.

Conclusions

Single-chip widely-tunable optical transmitters have been demonstrated that have performance and manufacturing aspects that are attractive for system insertion.

References

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