Tunable GPON Receivers Enable Phased Migration to 1Gb/s per Subscriber

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Abstract: We demonstrate a tunable receiver with -30dBm sensitivity at 10^{-10} BER on any of seven 100GHz spaced channels, and propose deployment strategies for low-cost migration to up to 1Gb/s per subscriber downstream Wavelength-Agile PON.

OCIS codes: (060.2330) Fiber optics communications; (060.2340) Fiber optics components

1. Introduction

We demonstrate a tunable receiver operating at 2.488Gb/s with sensitivity of -30 dBm at a bit-error ratio (BER) of 10^{-10} when tuned to one of up to seven 100GHz-spaced ITU DWDM channels at ambient temperatures from 0C to 50C. Sensitivity degradation due to crosstalk was found to be less than 0.4dB with adjacent channel spacing reduced to 50GHz. This is the first demonstration of a low-cost tunable receiver with performance sufficient to meet sensitivity specifications for GPON receivers [1].

Devices such as this tunable receiver [2] enable wavelength-agile PON as a cost-effective alternative to more expensive Next-Generation PON (NG-PON) solutions based on 10Gb/s technologies that are presently under consideration. Migration strategies for these NG-PON deployments have largely focused on 10Gb/s solutions or WDM-PON using fixed wavelength receivers to achieve up to 1Gb/s per subscriber. Alternatively, a 7 x 100GHz tunable receiver operating at 2.5Gb/s provides aggregate bandwidth nearly two times greater than that of a single channel 10Gb/s PON receiver. In addition to compatibility with existing GPON Optical Distribution Networks (ODN), the use of tunable receivers enables phased rollout of multi-wavelength services, thus reducing expenses and making targeted bandwidth upgrades possible. Diagrams showing this migration strategy are presented in Fig. 1.

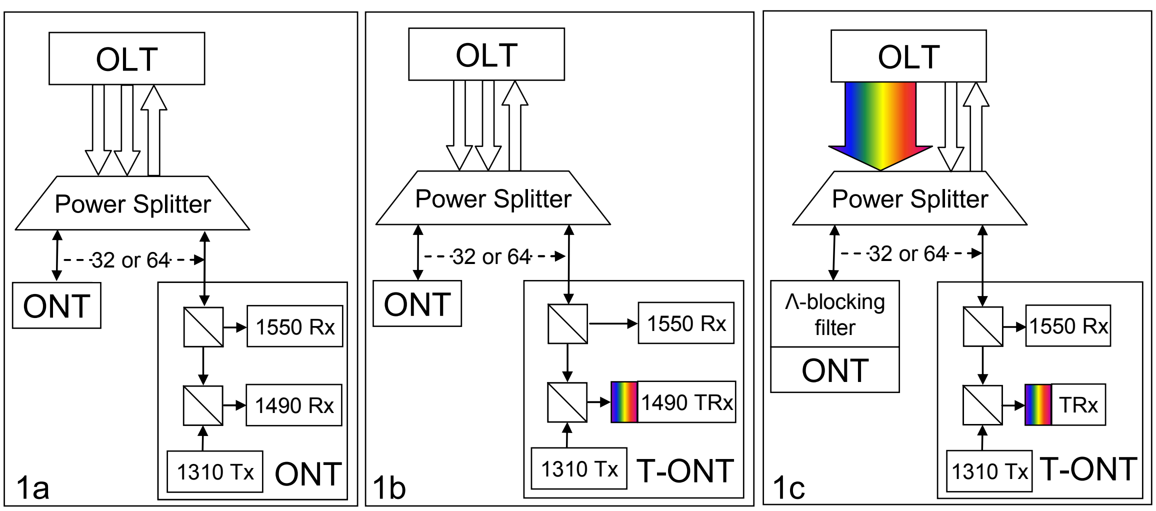

Fig. 1a, 1b & 1c. A potential migration strategy from GPON to wavelength-agile PON providing up to 1Gb/s per subscriber.

Fig. 1a shows a current GPON node, including RF overlay. Tunable ONTs can coexist in a standard GPON node with fixed ONTs by initially tuning the receiver to the current downstream channel, as shown in Fig. 1b. The addition of wavelengths at the OLT is only required when additional downstream bandwidth is needed. Once a new channel is populated at the OLT, all targeted tunable ONTs can be reconfigured remotely to make use of the new bandwidth, as shown in Fig. 1c. In this scenario, legacy fixed wavelength ONTs may require a blocking filter to prevent crosstalk. A similar approach can be used in long-reach multi-wavelength hybrid PON applications to enable wavelength stacking and remote management [3].

2. Component design

The tunable receiver utilizes amorphous silicon and silicon nitride-based thin film Fabry-Perot bandpass filters. These filters are thermo-optically tuned using a resistive heater layer incorporated in the filter stack [4]. The center frequency of the filter is tuned by driving a current through the resistive heater layer in the filter stack. As the temperature of the stack changes, the resonance frequency of the bandpass also changes. The filter is packaged in a standard TO46 can above an APD on a submount with a TIA, thermistor, and decoupling capacitors for the APD bias and TIA supply lines. The assembly (shown in Fig. 2) is hermetically sealed by resistive welding of either a flat window or lensed TO cap. The manufacturing process uses equipment identical to that used to build standard GPON receivers in TO packages, and shares many of the same procedures.

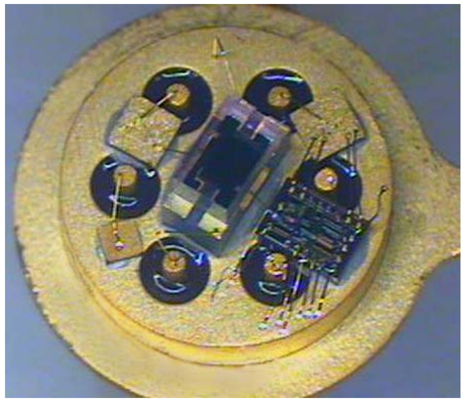

Fig. 2. Tunable receiver on a TO46 header prior to cap welding.

The component is mounted on a PCBA which routes the high frequency signal to outputs and the low frequency (DC level) signal to a filter control circuit. An EEPROM mounted on the PCBA stores a simple calibration of drive current vs. temperature and channel which is also utilized by the filter control circuit. To tune the filter to a specified channel, the controller first reads and sets the calibrated current value, which tunes to the approximate location of the channel. The DC signal level is then used to lock the filter to the channel and actively track it. An additional function possible with this device is remote monitoring of wavelength and power at each tunable ONT in a node. This is accomplished by tuning the filter over the entire channel band while monitoring the DC signal level.

3. Experimental Results

The sensitivity of a tunable receiver capable of tuning over 7 x 100GHz channels was characterized with and without the presence of adjacent channels. Measurements of the bit error rate (BER) were made with adjacent channels at 50GHz and 100GHz from the channel of interest, and at ambient temperatures of 0C, 25C, and 50C. A block diagram of the apparatus used to perform BER testing of the tunable receiver is shown in Fig. 3.

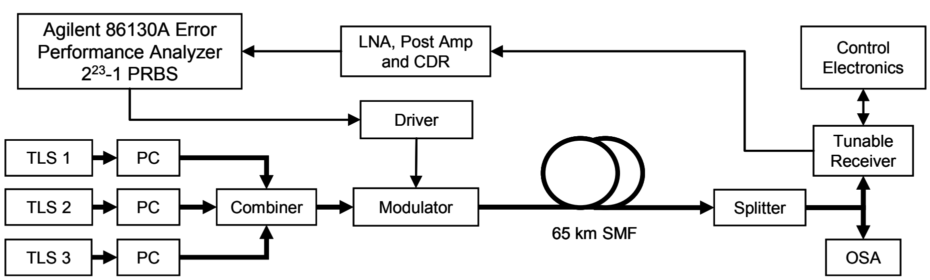

Fig. 3. Block diagram of system for testing a tunable receiver with three 2.5Gb/s modulated signals.

Three tunable lasers (TLS 1-3) were passively combined, then passed through a single $LiNbO_3$ modulator that was driven by an Agilent bit-error rate test-set (BERT). The modulator had an extinction ratio of approximately 10dB. The polarization of each laser output was adjusted using a polarization controller (PC) to maximize transmission through the modulator. The optical power of each channel was adjusted to ensure equal powers at the receiver. A 65km spool of single-mode fiber (SMF) was used to decorrelate the data between adjacent channels by more than one bit period. A 10% tap was inserted before the receiver to monitor the optical spectrum using an optical spectrum analyzer (OSA). The tunable receiver was actively locked and tracked the channel of interest throughout the test period. For BER testing of the receiver, a low noise amplifier (LNA) was used to amplify the photodiode output.

The BER sensitivity to the per-channel received power is plotted in Fig. 4. The BER performance of a channel in the presence of adjacent channels is plotted for channel spacing of 50GHz (hollow) and 100GHz (solid). Measurements are shown with ambient conditions of 0C (triangle) and 50C (square). A BER of less than 10^{-10} is measured at a received optical power less than -30dBm for all cases. There is a channel crosstalk penalty of approximately 0.4dB as the channel spacing is reduced from 100GHz to 50GHz and the sensitivity variation over the temperature range is approximately 1 dB due to coupling between the drive and high frequency circuits. The received eye diagram at the LNA output is shown in the inset for a single 2.488Gb/s input channel with extinction ratio of -10dB, input power of -28dBm and at ambient temperature of 25C.

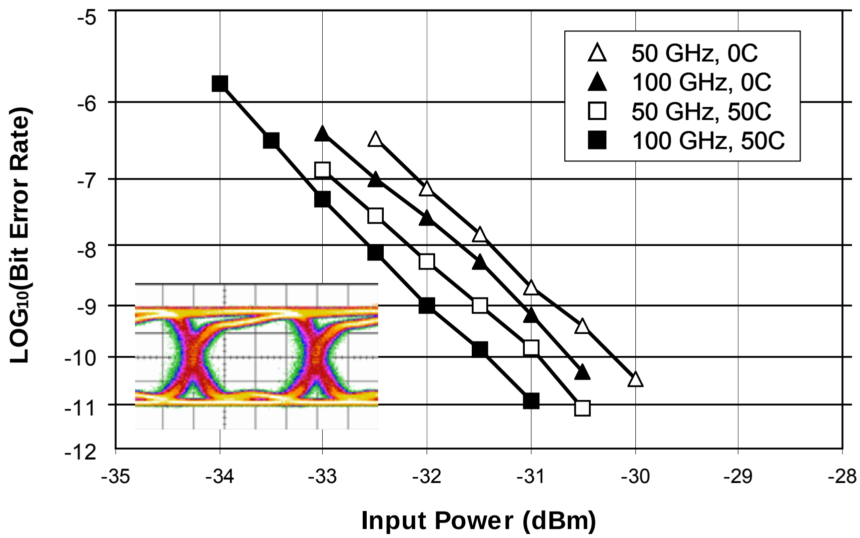

Fig. 4. BER of the channel of interest versus input power with decorrelated adjacent channels spaced 50GHz and 100GHz at 0C and 50C. Inset: Received eye diagram, 2.488Gb/s, -28dBm input power, extinction ratio of 10dB, 25C ambient, no adjacent channels present.

4. Conclusion

We have demonstrated an inexpensive tunable receiver which enables Wavelength-Agile PON (WA-PON), as a bandwidth solution that can cost-effectively bridge the gap between current and next-generation PON systems without requiring changes to the ODN or deployment of 10Gb/s electronics. Sensitivity of -30dBm at 2.488Gb/s was demonstrated with decorrelated adjacent channels present 50GHz from the channel of interest and across an ambient temperature range of 0C to 50C. In a 32 subscriber node with a 7 x 100GHz channel plan, such devices make possible 17.5Gb/s aggregate BW PON nodes, providing >500Mb/s per subscriber, while operating on a 13 x 50GHz channel plan can reach 32.5Gb/s aggregate, or >1Gb/s per subscriber.

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6. References

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