

# Tunable 2.5Gb/s Receiver for Wavelength-Agile DWDM-PON

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**Abstract:** We demonstrate a low-cost, tunable receiver based on semiconductor thin film filters. A bit-error ratio of  $10^{-10}$  is demonstrated at a received optical power of -18 dBm in a three-channel, 2.488 Gb/s, DWDM test system.

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## 1. Introduction

We have demonstrated a low-cost, reliable and manufacturable, tunable receiver component based on semiconductor thin-film filters. The new functionality made available by this device adds a fundamental building block to the toolkit of systems engineers for upgrading existing GPON and WDM-PON systems and for enabling next-generation, wavelength-agile systems.

Even with the substantial data rates that single-wavelength, fiber-optic systems can support, services such as HDTV, on-demand programming and telepresence are leading data-service providers and system manufacturers to roll-out PON architectures using DWDM to keep pace with demand in FTTP applications. In order to fully realize the operational benefits of such DWDM-PON systems, the ability to dynamically provision wavelengths at both the ONU and ONT is needed. Presently available wavelength-agile technologies used in DWDM backbone networks are not able to meet the severe cost constraints of an end-user market. Therefore, migration to multi-wavelength systems in FTTP has until now focused on WDM-PON systems in which all wavelengths are broadcast to all receivers and a static filter used to select the appropriate channel [1]. Tunable filters at the receiver have been identified as a possible solution to this challenge [2]. Here we report the first demonstration of a dynamically reconfigurable receiver based on a tunable filter. An example of the ONU configuration in a possible future network which would use this technology is shown in Fig. 1.

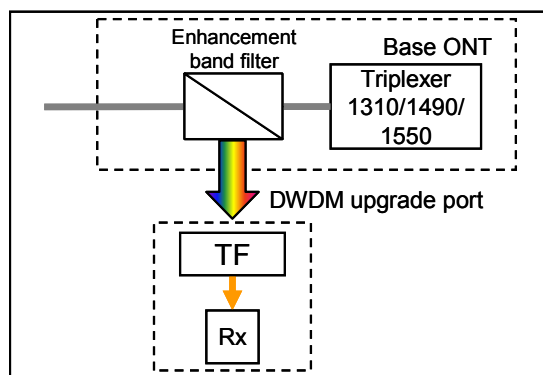


Fig. 1. GPON compatible ONU implementation with enhancement band filter and tunable receiver

## 2. Component design

The tunable receiver component consists of a proprietary, tunable optical filter chip and a high-speed InGaAs PIN photodiode assembled in a TO46 package with the photodiode connected to an external amplifier and control circuit, as shown in Fig. 2. The tunable thin-film filter is composed of amorphous silicon and silicon nitride layers. Similar filter structures have been previously demonstrated to meet the exacting reliability standards of telecommunications systems [3]. This thermo-optic filter is tuned by applying a current to an integrated heater film as shown in Fig. 2(b). The filter transmission frequency is locked to a data signal using a dither algorithm that monitors the Received Signal Strength Indicator (RSSI) level output from the amplifier and optimizes it by adjusting the drive current amplitude.

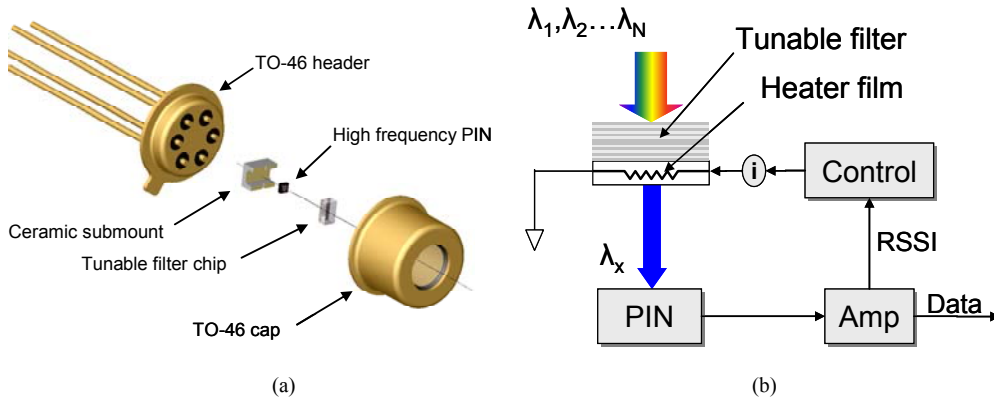


Fig. 2. Exploded view and functional block diagram of tunable receiver component. RSSI: Received Signal Strength Indicator.

### 3. Experimental Results

A four-channel transmission spectrum of the tunable optical filter is shown in Fig 3 with drive power required to tune to each channel shown in the legend (inset). The channel spacing is 200 GHz. This spacing and frequency region was used to demonstrate functionality within a frequency range proposed for NGA PON services [4].

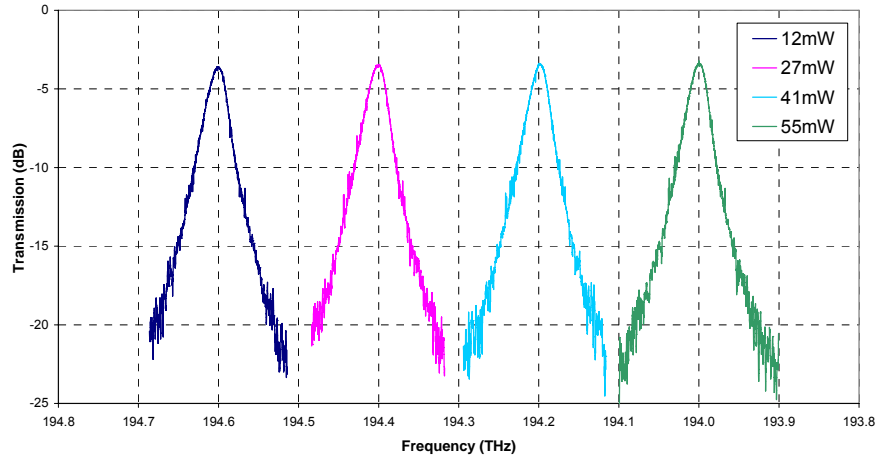


Fig. 3. Frequency vs. transmission by drive power for a 2.5Gb/s tunable receiver tuned across four 200GHz spaced channels

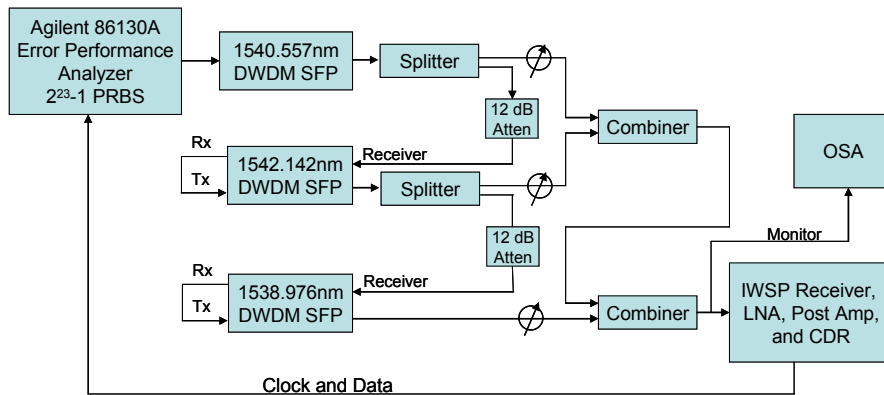


Fig. 4. Block diagram of BER test system. Testing was performed both with and without modulated adjacent channels present

A block diagram of the apparatus used to perform BER testing of the tunable receiver is shown in Fig. 4. A single small-form pluggable (SFP) WDM transmitter (ch #2) was driven by an Agilent bit-error rate test-set (BERT) that generated a 223 1 pseudo-random bit sequence (PRBS) at a data rate of 2.488 Gb/s. Two additional SFP transmitters were daisy-chained to generate optical signals spaced 200 GHz either side of the first transmitter (ch #1, #3). Each transmitter had an extinction ratio (ER) of approximately 9.5 dB. The data delay between transmitter

outputs was set to two bit-periods in order to de-synchronize the data between adjacent channels. Individual attenuators were used to adjust the optical power of each channel to ensure equal powers at the receiver. The channels were passively combined at the attenuator outputs and a 10% tap was inserted before the receiver to monitor the optical spectrum using an OSA. 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. 5. The BER performance of channel #2 only is plotted with solid points and the performance of channel #2 in the presence of adjacent channels #1 and #3 is plotted with hollow points. A BER of  $<10^{-10}$  [5], is measured at received optical powers of -18.0 dBm and -17.7 dBm in the single channel and three-channel cases respectively. Comparison of the two curves demonstrates the effective isolation of the center channel by the tunable optical filter. The received eye diagram at the LNA output for channel #2 without adjacent signals is shown inset for input power of -10 dBm.

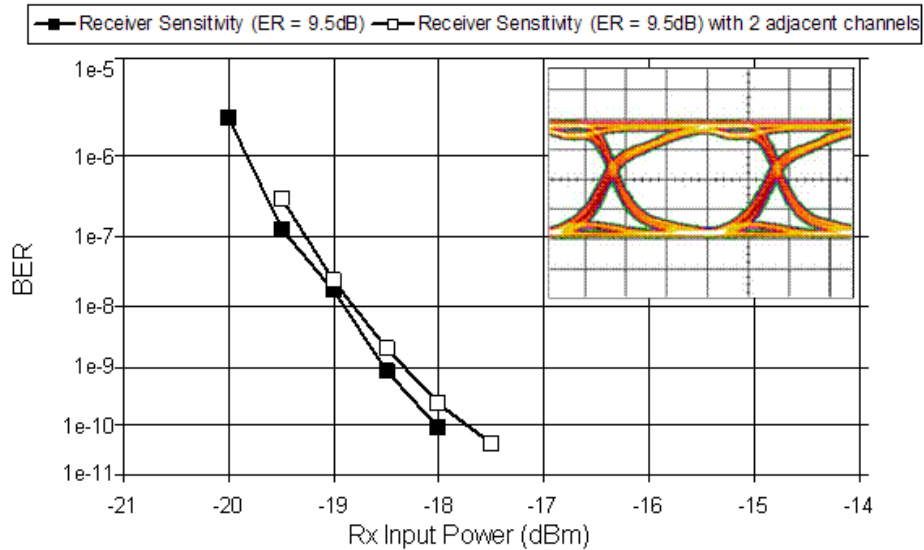


Fig. 5. Plot of BER vs. receiver input power showing performance with and without adjacent channels present. Inset: Eye diagram showing receiver performance at -10dBm receiver input power.

#### 4. Conclusion

We have demonstrated an inexpensive tunable receiver that achieves 2.5Gb/s operation with sufficient channel isolation to allow DWDM operation at 200GHz channel spacing and BER less than  $10^{-10}$  at input powers within ITU specifications for NGA PON networks. The device can be operated across at least four 200GHz spaced channels. We also describe a network implementation that is compatible with existing GPON fiber deployments and can minimize plant expenditures while offering substantially increased bandwidth to targeted subscribers.

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#### 6. References

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