Wavelength-Tracking High-Speed Photodetector

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Abstract: We report on a 1550 nm tunable high-speed photodetector configured to exhibit wavelength-tracking behavior. This enables a low-cost WDM system showing resilience to wavelength drift.

OCIS codes: (230.5160) Photodetectors; (250.0040) Detectors; (140.7260) Vertical cavity surface emitting lasers;

1. Introduction

Tunable photodetectors are promising receivers for wavelength-division multiplexed (WDM) optical communications, enabling simple and highly reconfigurable WDM networks. They are particularly important to the next generation passive optical network (PON), primarily time- and wavelength-division multiplexed (TWDM) PON [1]. Recently, MEMS-tunable vertical-cavity surface emitting lasers (VCSELs) have been demonstrated as effective tunable, resonance-enhanced photodetectors for high-speed communications at 1550 nm, opening the door to low-cost bidirectional communication between identical transmitter and receiver devices [2]. The narrow wavelength pass band of tunable photodetectors necessitates precise control of the transmitter wavelengths and subjects the system to performance degradation resulting from drifting laser wavelength or photodetector resonant frequency due to thermal fluctuations. While such problems are well addressed in large-scale WDM systems using thermally stabilized laser sources, a WDM network comprising tunable VCSELs and photodetectors would require a lower-cost solution to wavelength drift. Here, we demonstrate the use of high-speed tunable photodetectors configured with wavelength tracking as a solution to laser wavelength drift.

2. Device and Configuration

The bifunctional photodetector-VCSEL device in this work uses a high-contrast grating (HCG) as the top mirror in place of the conventional distributed Bragg reflector (DBR), providing a lighter mirror for faster MEMS tuning [3]. As shown in the device diagram, Figure 1(a), tuning of the resonant cavity is accomplished by electrostatic force on the MEMS HCG mirror. Since VCSELs require a high-Q cavity mode with an electromagnetic wave intensity peak spatially aligned with the multiple quantum well active region, this same optical mode provides significant enhancement of photocurrent when pumped with on-resonance light.

Wavelength tracking can be implemented in photodetectors with integrated electrostatic tuning mechanisms by connecting a resistor to the shared detector/tuning contact [4]. Since negligible current flows through the electrostatic tuning mechanism, as it is a reverse-biased diode, this creates a linear relationship between photocurrent and the voltage applied across the tuning contact. Thus, the detector uses its own photocurrent to apply a tuning bias onto itself according to \( V_{\text{tune}} = I_{\text{PD}} \cdot R - V_T \), depicted as the load line in Fig. 1(c). Stable operation occurs where the load line and photodetector responsivity curve cross, but only on the blue (high \( V_{\text{tune}} \)) side of the responsivity peak. The wavelength tracking range can be selected independent parameters \( V_T \) and \( R \).

![Fig. 1](SM4G.6.pdf) (a) Diagram of the device. (b) Electrical schematic of the device in tracking configurations. (c) Photocurrent vs. tuning voltage in non-tracking configuration with -11 dBm input power. Superimposed load line shows the tracking condition.
3. Communication System

We demonstrated the photodetector's tracking ability to receive high-speed data in the presence of adjacent WDM channels with a bit-error rate (BER) testing setup operating at 1 Gbps. Two externally modulated tunable lasers provided the channel of desired data, CH1, driven by the pulse-pattern generator (PPG) of an Anritsu MP1800A BERT, and CH2, driven by an uncorrelated PPG. A bias tee routed the DC component of the photocurrent through the tracking bias system and the RF component back to the BERT through a +26 dB electrical amplifier.

![Schematic of 1 Gbps data transmission experiment](image)

We characterized the 1 Gbps BER performance of the link versus the wavelength of CH1 in four configurations: non-tracking (R=0 Ω) with CH1 only; tracking with CH1 only; tracking with CH2 detuned 4 nm blue at 1575 nm; and tracking with CH2 detuned 4 nm red at 1575 nm. As shown in Fig. 3, each configuration produced an error-free (1e-9) BER at the nominal CH1 wavelength of 1571 nm with a received power of -11 dBm. While the narrow passband limited the error-free operation of the non-tracking configuration to within a bandwidth of 0.5 nm, wavelength tracking enhanced that bandwidth to 1.1 nm. The flat-bottomed shape of the BER vs. CH1 wavelength curve illustrates that tracking effectively protects the link's performance from wavelength fluctuations.

![Fig. 3. BER vs. CH1 wavelength at -11 dBm received power for: (a) tracking vs. non-tracking configurations with only CH1 (b) tracking configuration with the adjacent CH2 off, 4 nm red, and 4 nm blue. Tracking bias values were V_T = -2 V and R=68 kΩ](image)

4. Conclusion

We have demonstrated 1 Gbps operation of a wavelength-tracking tunable photodetector to enable WDM networks insensitive to the drift of the lasers' wavelength. This proof-of-concept experiment can be extended to other tunable laserdetector devices to make a robust and configurable WDM system.

The authors acknowledge the support of NSF CIAN ERC under EEC-08120702, DARPA MEPHI HR0011-11-2-0021, and a Department of Defense National Security Science and Engineering Faculty Fellowship.

5. References