SOA-Based Power Equalisation for 100 Gb/s Passive Optical Network

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In Passive Optical Networks (PONs), upstream packets arriving at an Optical Line Terminal (OLT) receiver could have up to ~20 dB dynamic range (DR) due to customer-to-OLT differential loss. The conventional approach to equalise upstream packet power variation is to use a burst-mode trans-impedance amplifier (BM-TIA) that resets its electrical gain for every packet. Research attention is currently focusing on spectrally efficient 4-level pulse amplitude modulation (PAM4) as a cost-effective approach to realise 100 Gb/s PON. However, it is challenging to implement BM-TIAs with sufficient linearity, bandwidth and dynamic range to support 50 Gbaud PAM4 transmission, the current state-of-the-art achieving a DR of 15.4 dB [1], for example. Furthermore, such links must meet the 29 dB optical power budget of legacy PON systems, which can be addressed with the use of Semiconductor Optical Amplifiers (SOAs) as a preamplifier in the OLT to increase receiver sensitivity. However, operating the SOA with a constant bias degrades high-power packets due to the gain saturation induced patterning effect. The distortions are nonlinear and hence require Digital Signal Processing (DSP) far more complex than the conventional feed-forward equaliser (FFE) to recover symbols with bit error rates (BERs) below the forward error correction (FEC) limit [2,3]. This work demonstrates the benefits and performance of SOA-based power equalisation in an emulated 100 Gb/s PON upstream (Fig. 1(a)) in a continuous operation mode. We compare two techniques [4,5] to vary the SOA gain according to its input power: (A) variable bias current, and (B) control light injection at a wavelength different from the signal. To the best of our knowledge, this is the first time such techniques have been applied to 100 Gb/s PAM4 for the PON application.

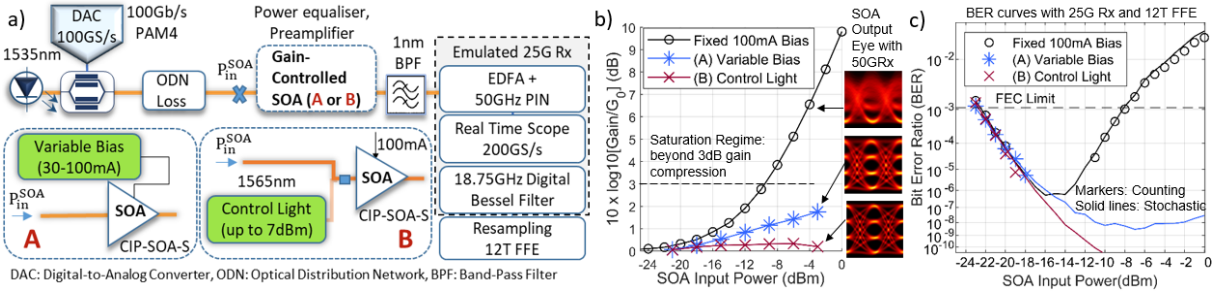

Fig. 1 (a) Experimental setup emulating PAM4 PON upstream back to back transmission using ideal transmitter and receiver to study the two SOA gain control schemes A and B. The extent of gain saturation (actual gain divided by small-signal gain) for each operating point (b) and BER performance (c) versus SOA input power for the three modes of SOA operation: fixed SOA bias with no power equalisation and the two SOA gain control schemes to maintain a constant output power of -2dBm.

Based on the ITU-T G.9804.3 PON standard, a bandwidth limiting 25G Rx is emulated with an 18.75 GHz digital Bessel filter. Fig.1(c) shows that the SOA nonlinearity results in a V-shaped performance curve supporting only 15 dB DR. The SOA output power is kept constant at −2 dBm using the two gain control schemes (A and B), which show a BER performance below 1×10^{-3} over a 23 dB range of input power; exceeding the PON DR target. The stochastic BER is estimated assuming Gaussian distribution to compare the two techniques at low error rates. Fig.1(b) shows for scheme A as we lower the bias for high input packet powers to reduce gain, we avoid operating the SOA in the saturation regime which is defined as the region where the gain has dropped by more than 3 dB from the small signal gain. In scheme B, the injected control light used to reduce the gain is always of higher power compared to the input signal packet powers, keeping the SOA in the linear regime and free from patterning effect. Additionally, measurements (not shown here) indicated the signal-to-noise ratio (SNR) at high input powers was lower for scheme A due to degradation in noise figure at low bias currents. While both techniques provide a large DR, control light injection outperforms variable bias at high input powers, making scheme B better suited for higher order modulation formats that require high SNR. Equalising the packet powers in the optical domain instead of electrical, as in the BM-TIA case, provides two advantages – (1) high dynamic range operation without any bandwidth limitation from the SOA and (2) the signal does not experience SOA gain saturation effects and is free from non-linear distortions avoiding the need for complex DSP.

References

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