Cascadability of broadcast and select switch blocks with interferometric wavelength converters at 10 Gbit/s

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the OPA input, the amplified signal at the OPA output, and the wavelength-converted idler at the OPA output. We see that signal amplification and wavelength conversion lead to negligible power penalty. This indicates that this type of cw amplifier could potentially be used in practical IMDD communication systems.

The idler is broadened more than the pump, which implies FM broadening of several GHz for the idler. While we have shown that this is tolerable for IMDD signals, the same is not true for FSK signals, because there is considerable distortion of the frequency spectrum. To verify this, we modified the system as shown in Fig. 1(b). Figure 3 shows BER versus received power for the signal at the OPA input, the amplified signal at the OPA output, and the wavelength-converted idler at the OPA output. We see that there is a power penalty of 4 dB attributable to signal amplification by the OPA. Power penalty for the idler is high, as expected because of spectral broadening, and seem to create a BER floor near 10^{-6}.

These measurements indicate that efficient one-pump fiber OPAs perform well for all modulation formats when used as signal amplifiers, but only for IMDD (and possible ASK) signals when used for wavelength conversion. This problem can in principle be solved by going to two-pump OPAs, for which idler spectrum broadening can be avoided by synchronously modulating the two pumps.

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WH5 2:30pm

Cascadability of broadcast and select switch blocks with interferometric wavelength converters at 10 Gbit/s

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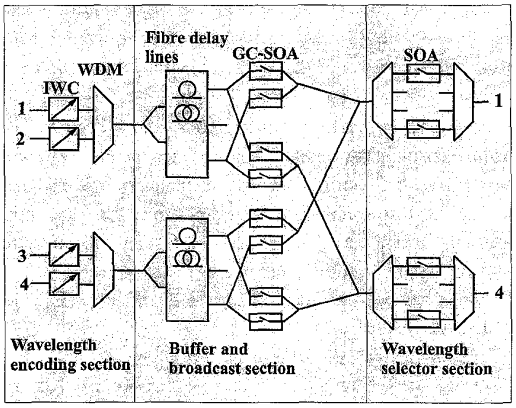
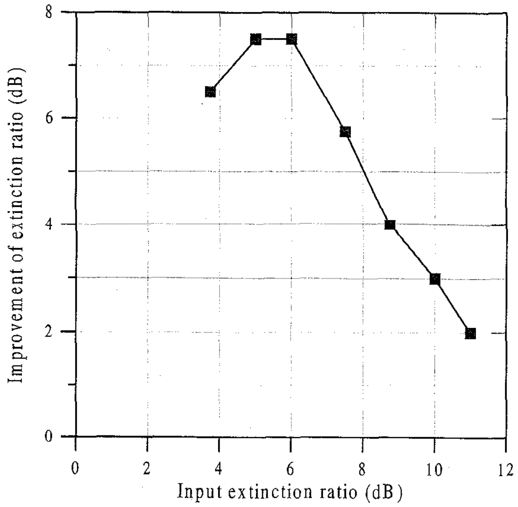
An optical packet layer is considered a way to increase the flexibility and switching granularity of the overall network.[1] In such a layer the signals will pass several switch blocks and therefore the cascadability of all-optical switch blocks is essential. Based on experiments, we perform a detailed investigation of the cascadability of an all-optical packet switch block (which is based on the switch block of the ACTS project KEOPS.[2] The switch block deploys wavelength converters and semiconductor optical amplifiers as key elements. We experimentally show that interferometric wavelength converters (IWCs) improve the signal extinction ratio and thereby the cascadability of the switch blocks. Furthermore, the cascadability for different switch sizes is assessed both with and without the regenerative effect of the IWCs.

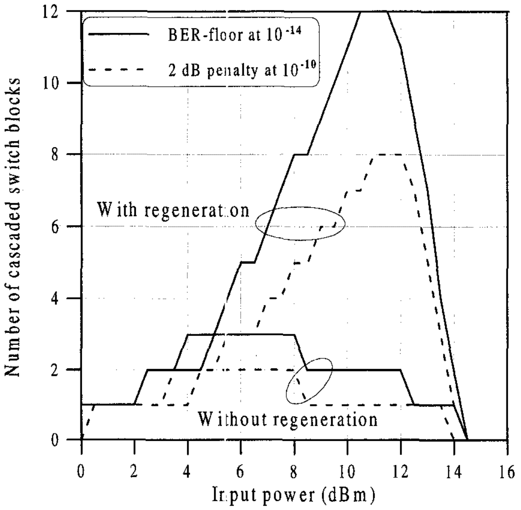


WH5 **Fig. 1.** The broadcast and select packet switch block comprising a wavelength encoding section, a buffer section and a wavelength selection section.

The 4 × 4 packet switch architecture in Fig. 1 comprises three sections: 1) Wavelength encoding, realized by interferometric wavelength converters followed by wavelength-division multiplexers. 2) Buffer and broadcasting, consisting of fiber delay lines followed by gain-clamped semiconductor optical amplifier (GC-SOA) gates.[3] 3) Wavelength selection, composed of two WDMs with SOA gates between them. For each output an open GC-SOA gate identifies the fiber delay line to be tapped and the wavelength selector then determines which packets are selected. Besides wavelength routing the IWCs at the input of the switch block are capable of enhancing the extinction ratio of an incoming signal. This is shown by the experimental results in Fig. 2 giving the improvement of the extinction ratio for an integrated Mach-Zehnder interferometer.[3] This regeneration is included in a detailed simulation model by which we asses the performance of the packet switch block. Our model takes into account spontaneous emission noise, interference noise, gain saturation in the gates, signal distortion as well as regeneration in the IWCs. As shown in Fig. 3 the regenerative effect yields a better cascadability. The figure predicts the cascadability of a 4 × 4 switch block at 10 Gbit/s as a function of the switch input power. Two sets of curves are shown: one representing a bit error rate (BER) floor of 10^{-14} and one for a 2-dB power penalty at BER = 10^{-10}. These curves show that only three switch blocks can be cascaded at a BER floor at 10^{-14} without regeneration in the IWCs while up to 12 switch blocks in cascade are possible with regeneration included. Figure 3 also shows that with regeneration the optimum input power is higher than without regeneration. This is due to a higher input power allowed before the extinction ratio degradation due to gain saturation in the gates becomes dominant compared to the noise accumulation. When



WH5 **Fig. 2.** Experimental results illustrating the regenerative effect of an IWC by showing the improvement in extinction ratio as a function of the input extinction ratio.



WH5 Fig. 3. The maximum number of cascaded switch blocks as a function of the switch input power at 10 Gbit/s; both with and without regeneration in the IWCs.

increasing the switch size the beneficial effect from the IWCs is still significant. The overall maximum number of cascaded switch blocks is assessed to eight at a BER floor of 10^{-14} for an 8 × 8 switch block while only two switch blocks in cascade are possible without the regeneration. Finally, the corresponding numbers for a 16 × 16 switch block is four with regeneration and two without.

In conclusion, it is demonstrated that the use of IWCs in the broadcast and select packet switch block results in an improved cascadability. Furthermore, it is predicted that successful concatenation of eight 8 × 8 and four 16 × 16 switch blocks is possible.

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WH6 2:45pm

Cascaded wavelength conversions using four-wave mixing in semiconductor optical amplifiers

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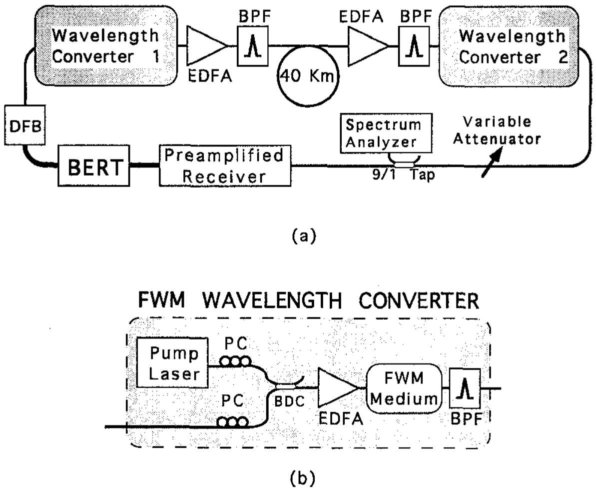
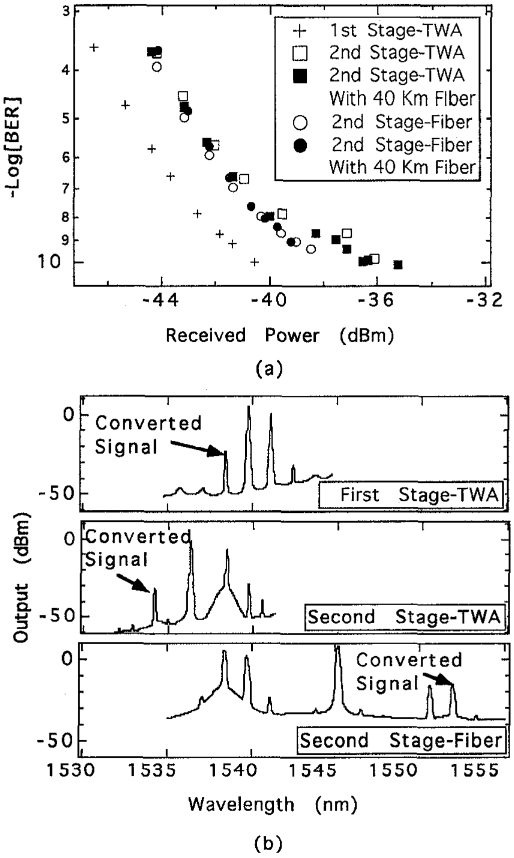
Wavelength conversion in wavelength-division multiplexed (WDM) communication systems would provide significant network performance improvement.[1] Optoelectronic, cross-gain saturation, and cross-phase saturation wavelength converters are candidate technologies that have been well characterized,[2] however, they are not "transparent" to either bit-rate or modulation format. Complete transparency is offered only by ultrafast wave mixing techniques—in the present case four-wave mixing (FWM) in semiconductor optical amplifiers (SOAs). To date, demonstrations of noncascaded, SOA FWM wavelength conversion have shown negligible degradation to the system performance for bit rates up



WH6 Fig. 1. (a) System diagram. (b) Details of the wavelength converter. FWM medium is an SOA in Converter 1 and either an SOA or a 4.4-km segment of dispersion-shifted fiber in Converter 2.



WH6 Fig. 2. (a) BER vs. received power data for the various systems demonstrated. (b) Output spectra (0.1-nm resolution bandwidth) of the FWM element for the various wavelength converters.