COMPONENTS FOR ADVANCED WDM NETWORKS

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Abstract: As WDM transmission capacity increases, flexibility in WDM networks is becoming crucial. This calls for components with high bit rate potential, wide optical bandwidth, regeneration capabilities, ... In this context, the paper will review advances in semiconductor-based components for routing and switching.

Introduction

With the fast evolution of traffic demand and the variety of services, advanced WDM networks will have to be extensible and upgradable both in terms of capacity and geographical distances. Flexibility regarding reconfiguration, management, bit rates, formats and traffic is another key feature required for these advanced WDM networks. Intensive research and development is now directed towards reconfigurable nodes with enhanced functionalities as provided by wavelength routing (WR) or wavelength translating (WT) optical cross-connects (OXC). Another step further, which is also matter of advanced research today could be the introduction of optical packet switching (OPS) [1]. In that context, wavelength -translating broadcast-and-select architectures have been proposed for OXC and OPS nodes. The key functions which are required include space switching, wavelength conversion and wavelength filtering. In addition, 3R-regeneration was also found necessary to ensure good signal quality after several cascades and provide extensibility of the network [2].

Key component requirements

For all these functions, polarisation independence, bit rate transparency (at least up to 10Gb/s, 40Gb/s in the future), low insertion loss, large input power dynamic range, flat wavelength optical response, high extinction ratio, low crosstalk, etc are key component requirements for OXC and OPS nodes. High speed gating is also a key feature for OPS. Last but not least, manufacturability and reliability issues are of great importance. It appears therefore very attractive to develop generic components for both applications. The semiconductor optical amplifier (SOA) constitutes a key building block for space switching matrices by exploiting optical gating, for all-optical wavelength conversion by cross-phase modulation in SOAs placed in interferometric structures, for wavelength selectors by optical gating of demultiplexed signals and for 3R regenerators as illustrated in Figure 1.

Experimental results

A versatile polarisation independent SOA structure that can be optimized for linear operation as in optical gating or for enhanced non linearities as in wavelength converters has been developed and applied for realizing several kinds of devices [3].

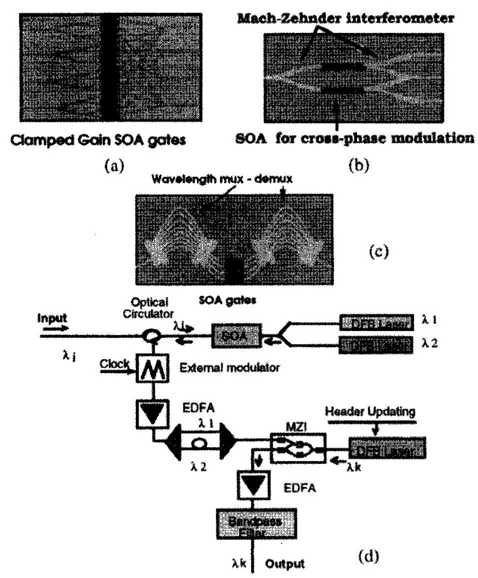

Figure 1: Schematic of space switch (a), all-optical wavelength converter (b), wavelength selector © and 3R-regenerator [12] (d).

Space switch

The space switch stage which usually works in WDM regime is built with clamped gain SOAs (CG-SOAs) in which the signal induced gain fluctuations that occur in conventional SOAs are suppressed by clamping the gain by a lasing oscillation. CG-SOAs have been demonstrated for OXC [4] and OPS [5] applications. Low penalty operation with 16 channels at 10Gb/s has in particular been achieved. Arrays of 4 CG-SOAs, which have been implemented in a WT-OXC within the European OPEN project have demonstrated successfull operation in two field trials, showing the reliability and the maturity of this technology [6]. Similar arrays exhibited low penalty under fast switching of optical packets with only 3.2ns guardbands between packets (Figure 2 left) [7]. More recently, arrays of 8 CG-SOAs with high performance and uniform characteristics were demonstrated [8], further increasing the integration level. Wide optical bandwidth of 35nm @-1dB and up to 60nm @-3dB were also obtained.

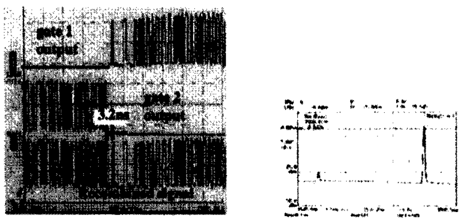

Figure 2: Optical packet switching by CG-SOAs with 3.2ns guard band between packets (Left); Eye diagramme at 10Gb/s and output spectrum of an all-active MZI all-optical wavelength converter (Right).

Wavelength conversion

Wavelength translation in the nodes offer link-by-link allocation, simpler resource management, easier network expansion and partial regeneration by the wavelength converter. This regeneration is required for compensation of signal impairments during transmission and routing. Wavelength conversion can also be used for contention resolution in OPS. All-optical wavelength conversion allows to remain in the optical domain without OE conversion; the power consumption is almost constant versus bit rate and it has the potential for very high speed (40Gb/s or above). The interferometric wavelength converter has been demonstrated up to 10Gb/s (Figure 2 right) [9] with high OSNR (35dB in 0.1nm), high output extinction ratio (>10dB), 0dB insertion loss or even gain. 2R regeneration provided by these devices allowed also for the cascade of four WT-OXC nodes with low penalty and 334km long transmission in between [4]. Recently, a new architecture which allows filter-free co-propagation operation in a MZI wavelength converter has been demonstrated which has the potential for ultra-high speed wavelength conversion (thanks to co-propagation in long SOAs), while preserving the conversion to « same wavelength » [10]. All-optical wavelength converters showed also excellent operation in the WT-OXC of the OPEN project [6].

Wavelength selection

Wavelength filtering can be obtained by wavelength selectors built with phased array demultiplexers and SOA gates. The digital control of this device and its fast selection speed provided by the SOAs are key features for future WDM networks. Monolithic integration is attractive with respect to stability, reliability and manufacturability. Such monolithic wavelength selectors on InP with very low insertion loss (2.5±1dB) (figure 3 left) and high extinction ratio (50dB) have been demonstrated recently on 4-channel devices with 200GHz spacing [11] with wide input dynamic range and low penalty at 2.5Gb/s. Thanks to the compact design and the self-aligned integration process, this technology is extensible to a much larger number of channels with smaller channel spacing as anticipated to be needed in future WDM networks.

3R-regeneration

2R-regeneration provided by all-optical wavelength converters allows to cascade a few nodes. However, jitter accumulation prevent from unlimited number of cascades. In a flexible and easy upgradable network, it appears therefore necessary to introduce 3R-regeneration (ie with time processing). Figure 3 right shows the penalty evolution at 10Gb/s vs number of cascaded spans with and without 3R-regeneration [12]. With the output regenerative architecture shown in figure 1, it was in particular possible to cascade more than 40 OPS nodes (16x16 Broadcast-and-Select Switch) operating with data signals at 10Gb/s with penalty below 1dB vs back-to-back configuration [2].

Conclusion

Flexibility and upgradability will necessarily be requested for advanced WDM networks. This implies high reconfigurability, as provided for example by broadcast-and-select WT-nodes, high output signal quality for transmission as achieved with 2R or 3R regeneration and compatibility with further upgrades in number of channels, bit rate, format, etc. A large range of key functions required in that context can be achieved with SOA-based devices which already proved their suitability for OXC and OPS applications.

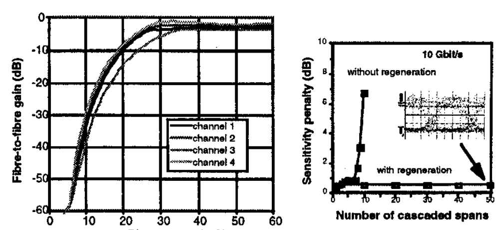

Figure 3: Transmission characteristic of a monolithic 4-channel wavelength selector on InP (Left); Sensitivity penalty at 10Gb/s vs number of cascaded spans including one interface and 55km of DSF (Right)

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