All-optical signal processing and regeneration

The trend in the industry today is that more and more complex functionalities are moving from the electrical domain and into the optical domain, demonstrating that all-optical networks are coming closer to realisation. In order for this progress to continue, there is a need for advanced optical components. The objective of this thesis is therefore to present an investigation and evaluation of key components that will be important enablers for future optical networks, namely optical space switches, wavelength converters and regenerators. The focus in the present work is on semiconductor optical amplifier (SOA)-based devices. The thesis starts out by giving a description of the motivations and driving forces for the current evolution of optical networks from point-to-point systems to all-optical network topologies. The use of SOA-based devices for all-optical gating is investigated with the use of a detailed large-signal model. An important parameter for SOA-based gates is the input power dynamic range (IPDR) as it determines the cascadability of the devices. Guidelines on how to maximise the IPDR are therefore established. Important trends are that short SOAs with low confinement factors and a low applied bias current should be used. These guidelines are verified by an investigation of the cascadability of the SOAs. Another type of SOA-based gate, namely the gain-clamped SOA (GC-SOA), is investigated. GC-SOAs have a higher saturation input power than conventional SOAs, making them attractive for multi-channel operation. It is shown that the cascadability of GC-SOAs is superior at 2.5 Gbit/s compared to conventional SOAs for up to at least 16 wavelength channels, whereas the benefit is reduced at higher bit rates due to influence from relaxation oscillations in the GC-SOA. Furthermore, all-optical wavelength converters are treated. Initially, cross-gain modulation (XGM) in SOAs is described and guidelines as to how to achieve a high modulation bandwidth are outlined. It is demonstrated that using long SOAs with high confinement factors and high bias currents together with high optical powers is beneficial to improve the performance. Moreover, issues concerning counter-directional coupling are discussed and advantages and disadvantages of the scheme are highlighted. A scheme, that can be used as a part of all-optical re-timing, is also investigated. The scheme has some advantages compared to conventional wavelength conversion since conversion of an optical clock signal is used instead of CW light. An investigation of these advantages is carried out and the feasibility of the scheme is demonstrated at 20 Gbit/s. A description of interferometric wavelength converters (IWCs) is also given. The high-speed capabilities are investigated and conversion at 20 Gbit/s is demonstrated in a single Mach-Zehnder interferometer (MZI) and a cascade of two Michelson interferometers (MIs). Furthermore, wavelength conversion at 40 Gbit/s is achieved with a penalty of -0.6 dB. The challenge of conversion to the same wavelength is discussed and two approaches are described and demonstrated experimentally. The first solution is based on a dual-stage converter employing an XGM-converter in the first stage and an IWC in the second stage. An assessment of the dual-stage converter at 20 Gbit/s shows an insertion penalty of -1.5 dB. The second approach is based on a dual-order mode (DOMO) MZI and a detailed investigation at 10 Gbit/s is presented. In addition, a conversion scheme that exhibits excellent transmission and speed performance will be described and evaluated at 10 Gbit/s. Besides wavelength conversion, IWCs are also attractive for all-optical regeneration. Experiments carried out at 40 Gbit/s demonstrate excellent performance for 2R regeneration, which is emphasised by a clear improvement of the optical signal-to-noise ratio and a noise suppression capability. 3R regeneration is also illustrated at 40 Gbit/s, where insertion of the regenerator results in a penalty of -0.5 dB. The scheme for 3R regeneration is extended to also include demultiplexing and demonstrated experimentally for demultiplexing from 40 to 10 Gbit/s. Finally, a scheme for 2R regeneration in IWCs, without the normally accompanying wavelength conversion, is presented. The high-speed capabilities are also demonstrated in an experiment carried out at 40 Gbit/s, where clear noise suppression is achieved in an MZI.