Circuit switched optical networks

Some of the most important components required for enabling optical networking are investigated through both experiments and modelling. These all-optical components are the wavelength converter, the regenerator and the space switch. When these devices become "off-the-shelf" products, optical cross-connects can substitute the electrical nodes that today connect the installed optical fibres. This substitution will enable a massive increase in capacity since the bandwidth of the individual wavelength channels can be increased drastically when the electronic bit processing can be omitted. Furthermore, it is expected that the optical solution will offer an economical benefit for high bit rate networks. This thesis begins with a discussion of the expected impact on communications systems from the rapidly growing IP traffic, which is expected to become the dominant source for traffic. IP traffic has some characteristics, which are best supported by an optical network. The interest for such an optical network is exemplified by the formation of the ACTS OPEN project which aim was to investigate the feasibility of an optical network covering Europe. Part of the work presented in this thesis is carried out within the OPEN project and consequently a short description of the project is given, which reveals that the all-optical wavelength converter is a key element in the cross-connect design that was studied in the project. Techniques for all-optical wavelength conversion is the topic of the following chapter, where two techniques are accentuated as the most promising candidates for implementation. The first technique is based on cross-gain modulation in semiconductor optical amplifiers (SOAs) and 40 Gbit/s conversion is demonstrated with this scheme. Furthermore, the ability to cascade these devices is assessed through modelling. The obtained results predict that a high signal quality is still attainable after 20 converters. The second technique relies on cross-phase modulation in an SOA based interferometer and also with the technique 40 Gbit/s conversion is demonstrated. Again the cascaddability is investigated this time by concatenating two interferometric wavelength converters at 20 Gbit/s causing a negligible penalty. The interferometric converters are not only attractive owing to their conversion capabilities. The technique inherently also provide regeneration in terms of pulse reshaping, which is demonstrated experimentally at both 20 and 40 Gbit/s. The scheme is extended to also offer retiming and demultiplexing, which also is demonstrated at 40 Gbit/s. The interferometric devices is also used for regeneration without performing wavelength conversion at 40 Gbit/s resulting in a 2.5 dB improvement. The converters are often considered as a part of the optical cross-connect, where also optical space switching is performed. Therefore, space switching based on both optical gates and interferometric switches is investigated. Moreover, an experiment including both space switching and wavelength conversion is carried out, hereby simulating a path through a cross-connect. For this experiment the troublesome conversion to the same wavelength is demonstrated, where a penalty of 2.5 dB is obtained. Concerning conversion to the same wavelength also a relatively new interferometric structure exploiting separation of waveguide modes and thereby capable of conversion is investigated thoroughly at 10 Gbit/s. A new device for all-optical wavelength conversion based on coupling of power between waveguides is proposed. The device exhibits a quasi-digital transfer function that allows for improved performance in terms of both regeneration and input power dynamic range compared to the interferometric wavelength converter. Detailed modelling gives an understanding of the coupling mechanisms and how it can be controlled. Static modelling demonstrates the capability of wavelength conversion and a 2.5 Gbit/s eye diagram with an extinction ratio of 23 dB is obtained through dynamic simulations.