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OC 2.2

Technologies and Architectures for Multiwavelength Optical Cross-connects

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Summary

Wavelength-selective optical cross-connects are expected to be key enabling elements for multiwavelength optical networking. In designing such cross-connects, there are significant interactions and tradeoffs between the internal architectures of the cross-connects and the hardware technologies used to implement them. With some switch and multiplexer technologies, it is necessary to use dilated architectures, which increase the complexity of the cross-connect, in order to meet system requirements for crosstalk rejection. In cross-connects requiring wavelength translation, different internal architectures require different types of wavelength translation elements.

A critical requirement for multiwavelength cross-connects is high crosstalk rejection. In simple point-to-point multiwavelength systems, wavelength-selective components with a crosstalk rejection of ~15 dB are sufficient (provided that all the signals have similar intensities). In multiwavelength optical networks, involving wavelength reuse, it is possible to have crosstalk between two channels at the *same* wavelength. In this case the signals can interfere coherently, and to eliminate the effects of this coherent crosstalk, multiwavelength cross-connects with crosstalk rejections of 35 dB or more are required.

Another key requirement for wavelength-selective components for multiwavelength optical networking is that the useable channel bandwidth (over which the loss and crosstalk rejection requirements are met) be as wide as possible. The useable bandwidth of such components has a major impact on the requirements for the wavelength stability of laser sources. It also effects the number of wavelength-selective components that can be concatenated in a network, which impacts the optimum network architecture and the maximum network size. In most components the characteristic that limits the useable bandwidth is crosstalk rejection, not insertion loss.

The basic functionality of a multiwavelength optical cross-connect is to take signals from N input fibers, each of which carries up to M different signals on different wavelength channels, and to route those NxM signals to N output fibers. The probability of blocking in such cross-connects can be reduced by including the capability to translate an input signal on one wavelength channel to a different wavelength channel, but the need for this capability a controversial issue.

Many of the cross-connect architectures currently being studied make use of wavelength demultiplexers on each of the N input fibers, a set of M (one for each wavelength) NxN space-division (non wavelength selective) switches, followed by a wavelength multiplexer for each of the N output fibers. Since the wavelength de/multiplexers are used in series, a crosstalk rejection of ~18-20 dB per component is sufficient, and can be achieved by most available technologies. Multiplexers using multilayer dielectric filters generally provide the largest useable bandwidths, but it is difficult to achieve channel spacings of <2 nm with this technology.

For the space-division switches, micro-optic devices using mechanical motion of prisms or other beam deflectors provide excellent crosstalk rejection and low insertion loss, but do not scale gracefully to larger-dimension switches. Multiple electro-optic switch elements can be integrated on a single substrate (e.g. lithium niobate), but the required crosstalk rejection can only be achieved by using dilated switch architectures, which require many more switch elements. Semiconductor switch elements, with switchable optical amplifiers, may be able to provide sufficient crosstalk rejection, but the technology needs further development to establish its capabilities. A recently-described technology, using liquid-crystal switch elements, appears to provide the required crosstalk rejection, but in a bulk-optics configuration.

Using acousto-optic effects (in lithium niobate waveguides) it is possible to make a 2x2 switch element that can simultaneously provide "independent" switching of multiple wavelength channels. In principle, a cross-connect using this technology would require many fewer switch elements than the approached described above. However, with the best devices reported to date it is necessary to use dilated architectures to achieve sufficient crosstalk rejection, and interactions between channels may require additional dilation.

Technologies for wavelength translation are at a much earlier state than switch technologies, although there have been some impressive demonstrations of prototype devices. Devices that accept an input at any arbitrary wavelength, and translate it to a fixed output wavelength, would be used at the output of a cross-connect. Most of the experimentally-demonstrated devices are of this type. Devices with a fixed input wavelength and a variable output wavelength would be used at the input to a cross-connect. Devices that could accept an arbitrary input wavelength, and translate it to an arbitrary output wavelength could be located in the middle of a space-division switch fabric, and would simplify that fabric, but such devices currently appear to be the most difficult to realize.

In summary, there is no clear winner for cross-connect technology, and there are many opportunities for further research and development.

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