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PHASAR-based integrated WDM devices

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Phased-Array demultiplexers (PHASARs, AWGs or WGRs) are key components in WDM networks. They can be realised in almost any waveguide technology and are, therefore, very suitable for integration with other devices. A review will be given of the operation principles and applications in advanced integrated WDM devices.

Introduction

Phased-array wavelength demultiplexers [/1/-/4/] (called PHASAR's, AWG's or WGR's) have become key components in modern WDM systems. PHASAR's have can be realised in a single-mask planar waveguide technology, which makes them robust and fabrication tolerant and potentially low-cost. Their main potential lies in applications with moderate crosstalk requirements and in integration in more complex devices like multiwavelength receivers and transmitters, add-drop filters and optical crossconnects, and signal processing applications like dynamic gain equalizers and dispersion compensators.

Silica on silicon technology

The best performing PHASAR's are presently realised in silica-on-silicon technology. Crosstalk figures for than –30 dB nowadays in commercial devices. and below –40 dB using trimming techniques. Devices with up to 80 channels and down to 25 GHz channel spacing are commercially available. Insertion losses are typically around 5 dB.

Devices with much larger channel counts and smaller channel spacings have been demonstrated in the laboratory. NTT recently reported a two-stage tandem demultiplexer with 4200 channels and a wavelength spacing of 5 GHz /5/. Further, insertion loss below 1 dB has been reported using a special technology /6/.

Commercial applications are still restricted to rather simple devices. There is a clear trend towards more complex applications, using thermo-optic phase shifters to introduce dynamic functions, such as in active PMD compensation /7/, dynamic gain equalisation /8/, add-drop multiplexers and crossconnects (/9/, see Figure 1)

InP-based technology

Silica-on-silicon technology is closer to maturity than Indium-Phosphide (InP)-based semiconductor technology, but its applications are restricted to passive and low-speed dynamic functions based on thermo-optic phase shifters. InP is better suited to more complex functions involving light generation, amplification, detection and a range of non-linear signal operations. InP can integrate all these functions on a single chip. Further, InP-based devices are smaller by one or two orders than silica-based devices /10/, which makes them very suitable for application in complex integrated circuits. Their performance is lagging behind silica-on-silicon devices, but it is steadily improving. Due to their small waveguide core coupling to fibres is more difficult, and hence more costly, than for silica-based devices. This makes them less competitive for circuits with a restricted functionality. For more complex circuits InP will become a dominant material, however.

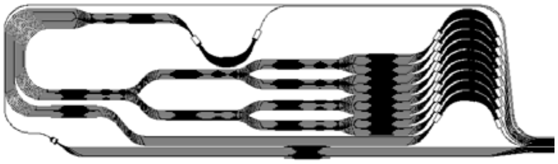


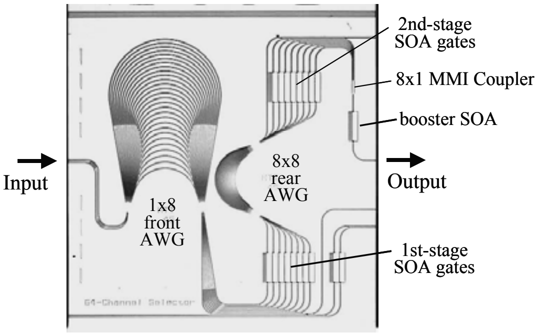
Figure 1 *Mask layout of a silica-based 8-channel 1x9 wavelength selective crossconnect. Chip length is 8.6 mm.*

WDM receivers

An application that is close to the market is an integrated multiwavelength receiver /10/. Monolithic integration has the potential to bring down the cost and increase the reliability of MW-receiver modules. Further it leads to a drastic volume reduction. Receiver bandwidths (for single detectors) in excess of 40 GHz have been reported /12/. Main problem to be solved is the electrical crosstalk between the closely spaced detectors.

Channel selectors

An example of an application that is based on integration of passive waveguide devices and semiconductor optical amplifiers is a channel selector consisting of a demultiplexer for separating the wavelengths, an array of SOA's for selecting one of them, and a multiplexer to couple the selected signal to the output fibre. Wavelength selectors have been reported both in hybrid and monolithic form /13/,/14/. Monolithic integrated devices combine a small device size with on-chip loss-compensation (zero-loss-between-fibres) at a potentially lower cost. Kikuchi et al. /13/ recently reported a device in which 1-out-of-64 channels can be selected using 16 SOA's that are operated as optical gates.



(chip size : 7.0 x 7.0 mm^2)

Figure 2 *InP-based WDM 64-channel selector.*

WDM sources.

PHASAR-based multiwavelength lasers consists of an array of SOA's connected to a multiplexer that is integrated in the Fabry-Perot cavity. In this device the wavelength channels are automatically tuned to the passbands of the multiplexer and coupled to a single output port with low loss. Integrated devices have been reported operating at 16 and 40 wavelengths /16/. Multiwavelength (MW) lasers reported so far are from the Fabry-Perot cavity type. Recently we realised an MW ring laser (Figure 3). The device measures only 1.5 mm^2 and shows lasing at 7 different wavelengths /17/. Ring lasers do not need mirrors, which is convenient for integration in larger circuits.

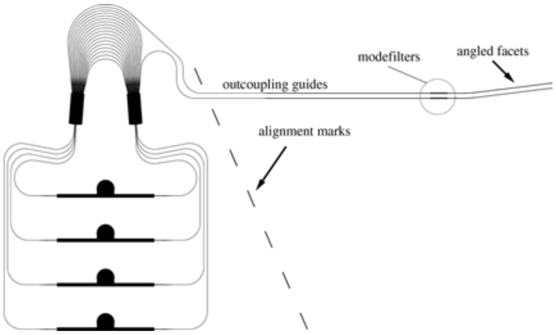


Figure 3 *Multiwavelength ring laser (1 x 1.5 mm)*

Recently we integrated 4-channel chirped FP-type multiwavelength laser with an interferometric wavelength converter as depicted in Figure 4 /18/ using a three-step MOVPE epitaxy process for integration of SOA's with passive components /19/. The devices shows a static extinction ratio over 20 dB. Main challenge in this approach is to improve the stability of the laser against feedback of modulated power.

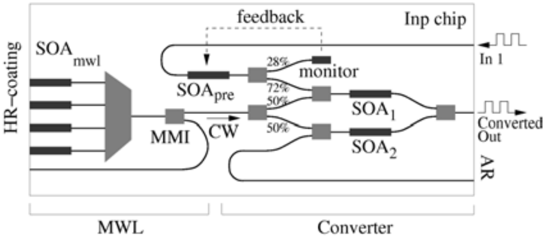


Figure 4 *Schematic of a wavelength converter that has been integrated with a 4-channel PHASAR multi-wavelength laser.*

WDM switching devices

PHASAR-based WDM switching devices have been reported both in silica-on-silicon and in InP-technology. A recent example of a silica-based device is a 2x2 wavelength selective cross connect capable of switching 128 channels in sets of 8 /20/. Silica-based devices look promising for slow (circuit-) switching purposes. InP-based devices have the advantage of a smaller device-size, much higher switching speed (suitable for packet-switching) and the potential to integrate functions like on-chip signal monitoring and level control. An example is the 2x2 WDM-crossconnect shown in *Figure 5. /21/)*

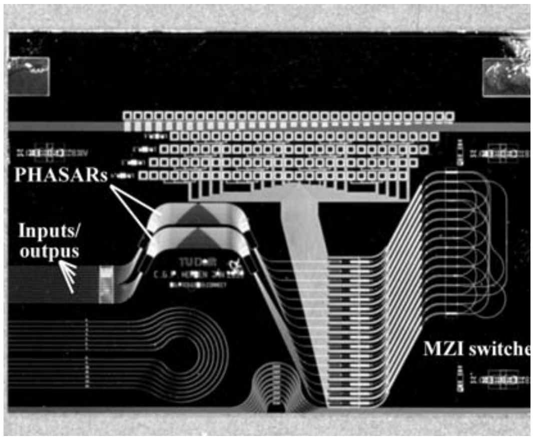


Figure 5 *Photograph of InP-based WDM cross-connect with dilated switches*

Conclusions

PHASAR-based devices play an increasingly important role in providing the functionality required in advanced WDM-networks in a compact form and at steadily decreasing costs. Dominant technology so far is silica-on-silicon. Performance and fabrication costs of InP-based devices show steady improvement.

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