A Taxonomical Consideration of Optical Add/Drop Multiplexers

Cedric F. Lam,* Nicholas J. Frigo
AT&T Labs—Research, Room A5-1E31, 200 S. Laurel Ave., Middletown, NJ 07748, USA
E-mail: cflam@ieee.org, nff@research.att.com

Mark D. Feuer
JDS Uniphase, 625 Industrial Way West, Eatontown, NJ 07724, USA
E-mail: mark.feuer@us.jdsuniphase.com

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Abstract. The use of optical add/drop multiplexers (OADM s) is considered as a possible way to save the number of transponders required at a network node by optically bypassing wavelengths that do not need to be dropped. There are many different flavors of OADM s offered by vendors. In this paper, we give a taxonomy of OADM s from the perspectives of both technology considerations and possible implications on network performance. The purpose of the taxonomy is to serve as a frame work for cost and performance studies on dense wavelength division multiplexing (DWDM) optical transmission systems.

Keywords: optical add/drop multiplexer, taxonomy, wavelength division multiplexing

1 Introduction

We first give a brief presentation of optical add/drop multiplexers (OADM s) from the physical technology point of view. Basically, three contending technologies, multi-layer thin-film interferometric filters, fiber Bragg gratings and arrayed waveguide routers (AWG; also called waveguide grating routers or Dragone routers after inventor C. Dragone) are viewed as having promising market potentials.

In the next section, we summarize the properties of the above major technologies as general background knowledge to facilitate understanding the limitations and design considerations in OADM systems. However, the main purpose of this document is to serve as a taxonomy of OADM s from a functional point of view, and provide a general framework for further network system design and performance evaluation analysis.

2 Technology Background

Among the three major contending options, thin film filters [1] can be made relatively cheaply. It is also commonly used to achieve bandpass filters, which cover the spectrum occupied by a few wavelengths in a dense WDM system having ITU wavelength separations from 25 GHz to 200 GHz. Thin film filters have the advantages of low loss, low polarization dependence, and most importantly, very good thermal stability, which makes them ideal for field applications in low cost systems in which temperature control is undesirable for cost reasons.

Technology advancement in the recent years has made it possible to produce low loss, narrow-band thin film filters with very sharp roll off and relatively flat passband (e.g., ±0.11 nm BW with 20–30 dB suppression at 0.5 nm from the passband center) which meets the 100 GHz ITU DWDM requirements.

* Corresponding author.
The loss of a single-wavelength thin film filter is usually between 0.5 dB to 1 dB. To use as a wavelength add/drop filter or WDM demultiplexer, thin film filters with different passband wavelengths are cascaded, for example, in a zigzag fashion as shown in Fig. 1. Therefore, wavelength demultiplexing is achieved in a linear fashion. Despite the fact that wavelength spacing and arrangement of the cascaded filters are quite flexible, cascading leads to increasing loss as the wavelength count increases. Therefore, these filters are usually used when the wavelength count is small, to keep the loss within a reasonable budget.

Fiber Bragg grating (FBG) [2] is another commonly used technology for wavelength add/drop and demultiplexing. It is an all-fiber filter technology in which the refractive index of a hydrogen loaded fiber is permanently patterned by exposing the fiber to short wavelength light. The short-wavelength writing light has a periodically modulated intensity generated by two interfering laser beams or a laser beam and a phase mask. The resulting grating reflects optical signals whose wavelengths match the Bragg reflection condition, which is determined by the period of the index modulation.

Gratings are by nature narrow band devices which are ideal for DWDM channel filtering. To separate the input signal from the counter propagating reflected signal, an optical circulator which is non-reciprocal is used. A wavelength add/drop multiplexer using FBG is shown in Fig. 2. With proper designs, gratings can be designed with better than 99% percent reflectivity, very flat reflection band and a sharp roll-off. A circulator usually has 0.5 to 1.0 dB insertion loss. As a result, most of the loss of an OADM using gratings and circulators (1.0 to 2.0 dB) comes from the optical circulator. Like thin film filters, the insertion loss increases as more and more (grating + circulator) filters are cascaded. Temperature stable FBGs can be made by mounting gratings on a substrate having precisely controlled thermal expansion.

The third type of commonly used wavelength demultiplexer is arrayed waveguide router (AWG), also called waveguide grating router (WGR) or Dragon router [3]. It consists of two star couplers and an array of waveguide arms of increasing lengths in between, forming an integrated diffraction grating (Fig. 3). The whole device is fabricated as a planar waveguide device on a semiconductor substrate using micro-fabrication technology. Unlike thin film and FBG demultiplexers, which separate individual wavelengths one by one in a serial fashion, an AWG demultiplexes individual wavelengths at different output ports of the second star coupler in a parallel fashion. Fig. 3 also shows the wavelength routing table of an AWG. Besides being able to function as a