WAVELENGTH DIVISION DEMULTIPLEXERS

AND DEMULTIPLEXERS FIBER OPTIC NETWORKS

Wavelength division multiplexing (WDM) and demultiplexing (WDDM) devices are considered to be two of the key elements for enhancing the transmission bandwidth of optical communications and sensor systems. During past 20 years, various types of WDMs and WDDMs have been proposed and demonstrated. Wavelength-division multiplexing (WDM) technology allows multiple optical channels to be simultaneously transmitted at different wavelengths through a single optical fiber, and is a useful means of making full use of the low-loss characteristics of optical fibers over a wide-wavelength region. Besides its capability to efficiently exploit the huge bandwidth of single mode optical fibers, WDM is promising for constructing different levels of transparency to optical transmissions (i.e., independent of data bit-rate, modulation format, or protocol), which permits excellent upgrading and backward compatibility of the current networks. This makes WDM the key technology for tomorrow's developments in data, voice, imaging, and video communications. The table below compares various WDM technologies available at present.

A COMPARISON AMONG COMPETING DWDM TECHNOLOGIES

Technologies	Advantages	Disadvantages
Thin-film dielectric interference	Mature technology Good temperature stability Good wavelength selectivity Very good PDL Flat passband	Difficult to product narrow channel spaced filters (<100GHz) Insertion loss is not uniform for high channel counts Filters can only be manufactured for a fixed wavelength Not scalable
Planar array Waveguide	Uses IC fabrication processes. Scalable to high channel counts Multiple functions on a single chip	Difficult fiber interface Capital-intensive Requires large infrastructure Need temperature controller
Fiber Bragg Gratings	Mature technology	Mechanical stability problem High back reflection; must use isolator.
Fused, cascaded Mach-Zehnder Interferometers	Low insertion loss and polarization effects Very narrow channel spacing devices possible Easy coupling to fiber Filter “comb” vs. wavelength-specific filter	High channel count devices require cascaded devices resulting in a larger form factor device.
Diffraction Gratings	Low & uniform insertion Loss Best crosstalk, less than –40dB Good temperature stability Scalable	Devices can be bulky Typically used in a free space mode requiring careful assembly techniques.

OMEGA’S DIFFRACTION GRATING BASED WDDM

Omega Optics’ DWDM development uses diffraction-grating devices featuring a finely ruled grating that diffracts the incident beam into different angles and positions. As shown in Figure 1, each wavelength channel corresponds to a unique diffraction angle, and that can be collected by individual fibers. This technology has several major advantages, including low and uniform insertion loss across the entire passband, superior crosstalk, accurate wavelength, athermal performance and scalability. The low channel count devices can be easily upgraded to high-count devices simply by installing more fibers. The operating principle of the Omega’s Littrow structured grating-based WDM multiplexers/demultiplexers is illustrated in Figure 1 below. An input fiber and multiple output fibers are arranged on the focal plane of the lens. Wavelength-multiplexed light signals from the input fiber are collimated by the lens, and reach the diffraction grating. The light is angularly dispersed, according to different wavelengths, and simultaneously reflected. Then the different wavelengths pass through the same lens and are focused to their corresponding output fibers. Each wavelength is fed to one individual output fiber. This functions as a demultiplexer. When working in the reverse direction, the device serves as a multiplexer. Since Littrow WDM multiplexers/demultiplexers use fewer components, they are very cost-effective.

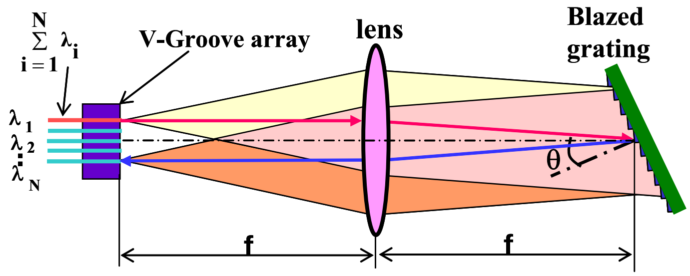

Figure 1. The basic structure of the Littrow type WDM.

KEY PARAMETERS

Some of the key parameters are independent of the multiplexing/demultiplexing structure. An optimal design must take into account the following constraints: (a) nominal wavelengths or frequencies of each channel; (b) number of channels; (c) channel separation, in wavelengths or frequency; (d) passing bandwidth of each channel, or channel capacity; (e) insertion loss; (f) the transmission spectrum over the passing bandwidth of each channel; (g) isolation among channels, or the power level due to crosstalk; (h) polarization-dependent loss (PDL); (i) for passive devices, sensitivities due to ambient temperature, pressure, humidity variation, etc.; (j) return loss (RL); (k) the power damage threshold, or the maximum optical power for each channel; and (l) pulse-broadening of the device. Such other issues as physical geometry, weight, input/output interfaces, and greater or lesser cost depending on applications also directly affect the choice of design spaces.

WDM systems for telecommunication tend to use a 100*GHz* frequency grid centered at 193.1*THz* optical frequency, aiming at a 10*Gbs* capacity per channel, as recommended by ITU-T. This constrains the choice of (a)-(c) even though devices with channel spacing less than 50*GHz* have been developed. Much wider channel spacing for shorter-distance data communication may be a good compromise for operational and economic reasons. For grating-based WDM multiplexers/demultiplexers these parameters are mostly determined by the dispersion ability of the grating, subject to the constraints of the physical size of the device. The loss spectrum of a passive device is generally sufficient to characterize the requirements (d)-(h) above, when appropriate out-coupling interfaces are taken into consideration. In the remaining part of this section we discuss these terms in detail with experimental data obtained in our efforts to optimize the design for grating based WDM multiplexers/demultiplexers. Material selection and engineering are also important elements by means of which the performance of the device is optimized. In practice, packaging issues should be considered along with the other criteria.

Such other issues as return loss, pulse broadening or bit rate, power damage threshold, physical size and weight, and cost affect the design of devices. As a rule of thumb in fiber optics, a polished end angle of 8 degrees will reduce the return loss to better than 40 dB for a single-mode devices. Since the grating-based WDM multiplexer/demultiplexer works on the principle of grating dispersion, when a light pulse passes through the device, the pulse will be broadened. The pulse broadening can be reduced by contracting the device. The physical size and weight can be reduced by increasing the angular dispersion ability of the device. A good WDM multiplexer/demultiplexer must optimize all these key parameters.

DEVICE PACKAGING AND PERFORMANCE

Team Omega has developed a 40-channel single-mode-in and single-mode-out demultiplexer. Figure 2 shows the solid mode mechanical drawing and a packaged module of DEMUX. The entire package size is

10.5×3.0×0.9 inch. The DWDM is a stand-alone unit employing a stainless steel housing to provide a thermal expansion coefficient compatible with the lens material. The entire assembling and packaging process is passive and epoxy-free, which avoids the possible wavelength and insertion loss shifting caused by the UV curing of epoxy. Through improving the mechanical design, careful choices of optical materials, employing the epoxy-free packaging and sealed package housing, one expects to obtain excellent thermal behavior for this DEMUX.

The spectral passband of the 40-channel WDDM is shown in Figure 3. The average insertion loss is 3 dB (0.3dB STD). The wavelength accuracy is within 0.078 nm. The 1dB passband is about 0.15, and the 3dB passband is 0.25 nm. The average crosstalk is below -30 dB, which is the best channel isolation so far achieved by any WDM technology. The average PDL is 0.16 dB.

Today's DWDM system deployments require a premium on performance, cost, flexibility and reliability. No single technology appears to provide the optimal solution for all applications. A careful technology selection or the application of a hybrid approach such as the pairing of interleavers and diffraction grating components can be a very attractive solution.

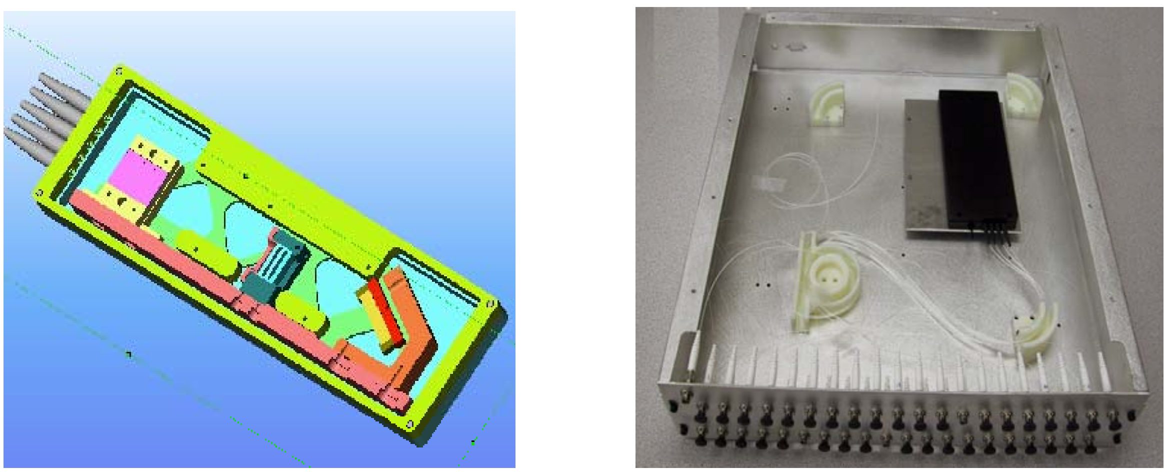

Figure 2. Solid model assembly drawing(left) and a packaged WDDM module (right).

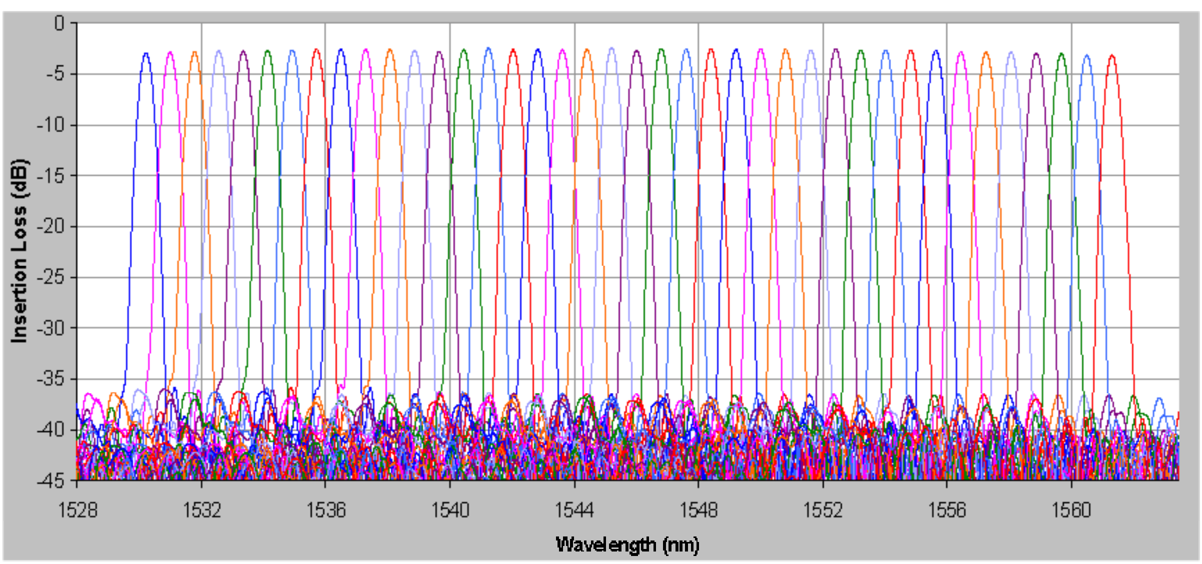

Figure 3. Output spectrum of the DEMUX.