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Design Thin Film Narrow Band-pass Filters For Dense Wavelength Division Multiplexing

Dr.Gaillan H.Abdullah *, Dr.Bushra.R.Mhdi **, Nahla.A.Al.Jabar
*,**, **Laser and Optoelectronics Centor,The Minsitry of Scinces and technology**

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ABSTRACT

We present tow different design thin film multi-cavity narrow band-pass filter. These filters are most widely used filtration technologies that made possible technical advancement of modern optical communication system. This paper is concerned with a theoretical study on optoelectronics physics to design and analyze this type of filter. A brief introduction to the thin film multi-cavity filter technology will be presented. The recent progress in design thin film multi-cavity technology will be reviewed. These designs consist of two material TiO_2 / SiO_2 as high / low index. The wavelength range from 600 to 900nm and detecting light at three and four wavelengths' 620,700 and 805 also 625,685,760 and 885nm. The filter is to be coated on Fused Silica having index 1.55 and operates at normal incidence.

Corresponding Author:

Nahla.A.Al.Jabar
Laser and Optoelectronic Center,
The Ministry of Science and Technology,
Serious Material Building, 5th Level,
Al-Jadery, Baghdad - Iraq
email: boshera65m@yahoo.com

1. INTRODUCTION

Thin film multi-cavity narrow band-pass filters are widely used in wavelength division multiplexing (WDM) applications in fiber optic communication systems. These filters must have sharp cut-on and cut- off on either side of the passband and practically zero transmittance outside the bandpass, over the wavelength range of the applications. Wavelength division multiplexing (WDM) is an integral component of fiber optic communication systems and enables several channels of information to be encoded on light signals of different wavelengths and transmitted simultaneously over the same optical fiber, to separated and decoded at the receiving end [1]. The Fabery Perot multicavity narrow band-pass interference filter is still the most weidly used device for multiplexing and demultiplexing of the different wavelengths transmitted over the optical fiber [2- 4]. The narrow band-pass filters must have very steep cut-on and cut-off transmittance characteristics as well as very low transmittance at wavelengths other than the transmission wavelength, to avoid crosstalk between the different channels. For Dence WDM (DWDM) applications, the separation between neighboring wavelength channels is less than 1nm and so the width of the passband of an individual filter must be less than 0.5nm, which makes the fabrication of these ultra-narrowband filters an extremely challenging and difficult task. But for coarse WDM (CWDM) the adjacent wavelength channels are separated by 20nm or more and so the width of a filter bandpass can be 12-20nm, making the fabrication of these filters are more feasible task. The design techniques for the multilayer stacks used in the fabrication of narrowband filters for WDM applications are described extensively by Thelen [5] and Baumeister [6]. These thin film filters are fabricated by plasma and ion-assisted electron beam evaporation [7], by reactive magnetron sputtering (e.g. the microplasma method [8]) or by plasma impulse chemical vapour deposition [9]. These are several manufacturers of thin film band-pass filter for WDM (CWDM as well as DWDM).

Method" to describe the step of research and used in the chapter "Results and Discussion" to support the analysis of the results [2]. If the manuscript was written really have high originality, which proposed a new method or algorithm, the additional chapter after the "Introduction" chapter and before the "Research Method" chapter can be added to explain briefly the theory and/or the proposed method/algorithm [4].

2. THEORY

The basic design of narrow band-pass filter is constructed on the Fabry-Perot multi-cavity interferometer. Their basic structure is a multilayer stack of alternately high index and low index thin film, most of which are one-quarterwave thick at the design wavelength, deposited on an opthalmic glass or silica substrate [10]. The technology of DWDM is one of the most recent and important technique in the development of fiber optic communication technology. In the following section we briefly describe the stages of fiber optic technology and the place of DWDM in the development. The reality of fiber optic communication had been proven in the nineteenth century, but the technology began to advance rapidly in the late of the twentieth century. After the probability of transmitting light in fiber had been established, it was known that light has an information-carrying capacity of 10,000 times greater than the highest radio frequencies. Besides, the additional advantages of fiber optic communication over copper wire include the ability to carry signals over long distances, low error rates, immunity to electrical interference, security, and light weight. Multiplexing and demultiplexing functions both employ narrow bandpass filters, cascaded and combined in other ways to achieve the desired result. Particular techniques that have been used including prisms, diffraction gratings, fiber Bragg Grating, arrayed waveguide gratings (AWG) or thin-film filters. A simple multiplexer or demultiplexer can be done by using a prism. Figure (1) demonstrates the demultiplexing case. A parallel beam of polychromatic light impinges on a prism surface; each component wavelength is refracted differently. This is the "rainbow" effect. In the output light, each wavelength is separated from the next by an angle. A lens then focuses each wavelength to the point where it needs to enter a fiber [11].

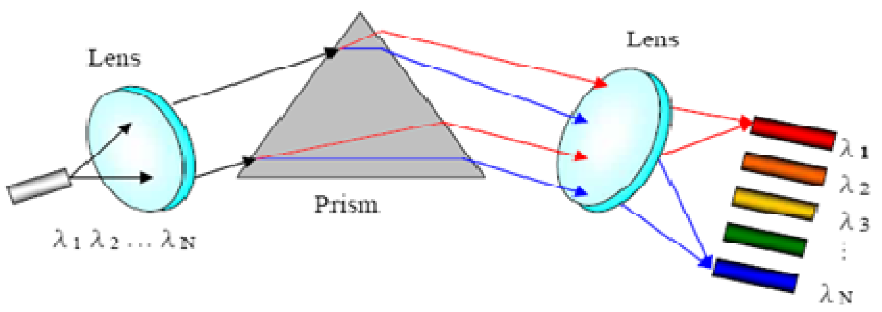

Fig. (1) Prism type of Demultiplexer [12].

Another technology is based on the principles of diffraction and of optical interference. When a polychromatic light source impinges on a diffraction grating (see Figure 2), each wavelength is diffracted at a different angle and therefore to a different point in space. Using a lens, these wavelengths can be focused onto Individual fibers.

A different technology uses interference filters in devices called thin-film filtersor multilayer interference filters. Thin-film filters consist of a number of alternatelayers of transparent dielectric materials of high and low refractive indices deposited sequentially on an optical substrate. The stack of thin films can be made using one of the coating technologies, such as plasma-assisted deposition, ion beam sputtering deposition, and ion assisted deposition (IAD). Thin-film filters exhibit a very low temperature coefficient, long stability, and small losses of chromatic dispersion and polarization-related dispersion. In DWDM system, a thin-film filter would only transmit the wavelength of the optical channel which was designed for the filter and would reflect all others in the DWDM signal. Figure (3) shows a thin-film filter type of demultiplexer in diagrammatic form. The detail properties will be described in the follow chapters.

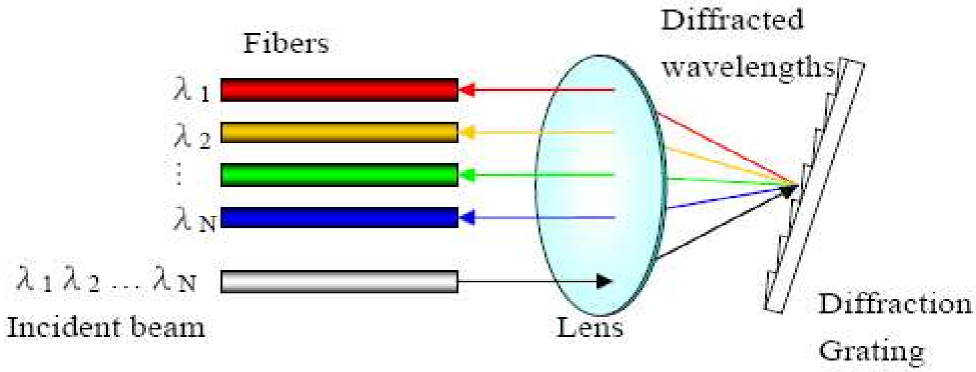

Fig. (2) Diffraction Grating type of Demultiplexer [12].

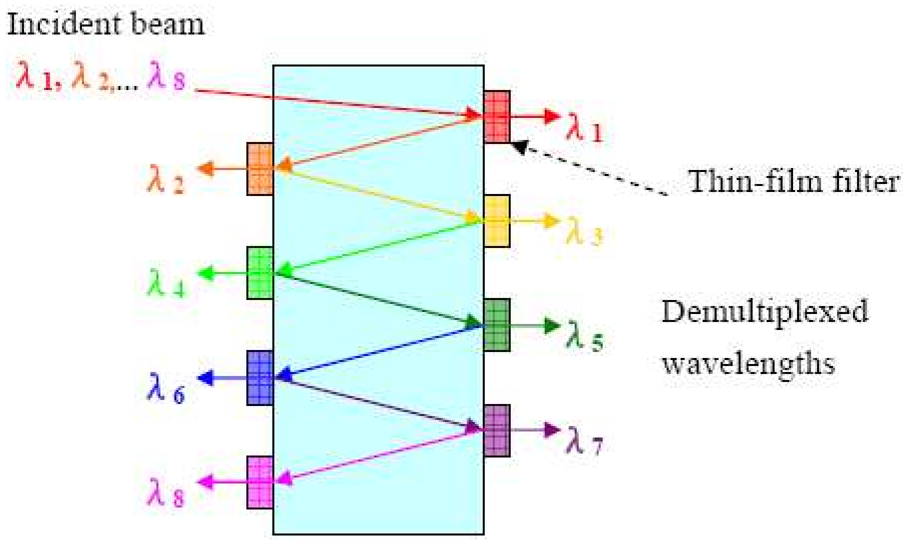

Fig. (3) Thin-film filter type of Demultiplexer [12].

Of these designs, the AWG and thin-film filters are gaining prominence. Their big advantage is that they can be designed to perform multiplexing and demultiplexing operations simultaneously. AWGs are polarization-dependent, and they exhibit a flat spectral response and low insertion loss. Thin-film filters exhibit a very low temperature coefficient, long stability, good isolation between channels, and small losses of chromatic dispersion and polarization-related dispersion. Besides, the cost of a multiplexer/demultiplexers based on the thin-film filters technology is much cheaper than the AWG technology [13].

3. RESULTS AND DISCUSSION

In the present work, these theoretical designs have been suggested and their profiles have been fully studied for the visible region and near IR region using open filter software [14]. The technology of DWDM is one of the most recent and important technique in the development of fiber optic communication technology. The band-pass filter used for detecting light at three and four wavelengths' 620,700 and 805 also 625,685,760 and 885nm as in design below. Between these wavelengths the filter is allowed to transmit nearly 0.1 as in figure (1) and nearly zero as in figure (2). The filter is to be coated on Fused Silica having index 1.55. The filter operates at normal incidence. The most common structure for narrow band-pass filters (multi-cavity band-pass filters) is an all-dielectric filter consisting of a quarter-wave optical thick layers for the mirrors and half-wave optical thick, or multiple half-wave optical thick layers for the spacers. So that the open filter program can be used to design this filter, we use TiO2 and SiO2 as the tow coating materials. The layers structures of narrow band pass filter for tow designs can be see below. The characteristics transmission vs. wavelength clearly seen from figure (1) and (2) which shows the center to center spacing of the channels in wavelength units. As you can see, the dencer spacing allows many more channels. The figure (2) also shows that these filters must have an extremely narrow bandwidth compared with figure (1).

Table.1 layer structure of multi-cavity narrow band pass filter

No	materials	Thicknesses (nm)
1	TiO2	75.130
2	SiO2	126.590
3	TiO2	78.970
4	SiO2	128.100
5	TiO2	79.510
6	SiO2	200.030
7	TiO2	113.530
8	SiO2	153.010
9	TiO2	43.450
10	SiO2	20.850
11	TiO2	84.080
12	SiO2	140.530
13	TiO2	19.370
14	SiO2	59.240
15	TiO2	84.740
16	SiO2	194.550
17	TiO2	122.320
18	SiO2	128.320
19	TiO2	79.150
20	SiO2	127.490
21	TiO2	77.770

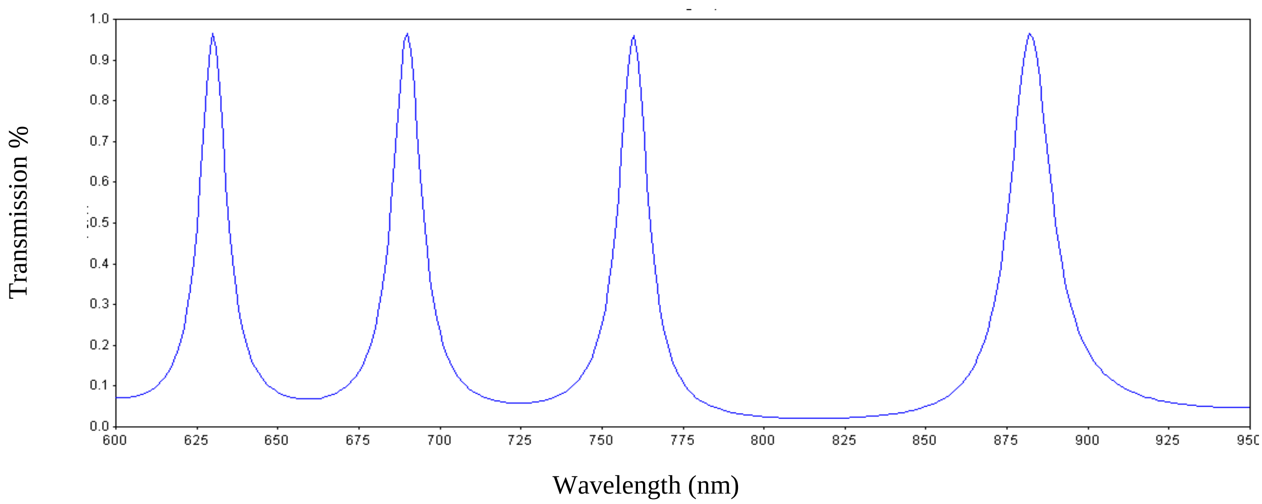

Fig. (4) Transmission vs. wavelength for design narrow bandpass filter with four multi-cavity

Table.2 layers structure of multi-cavity narrow band pass filter

No	materials	Thicknesses (nm)
1	TiO2	76.987
2	SiO2	118.632
3	TiO2	76.987
4	SiO2	118.632
5	TiO2	76.987
6	SiO2	118.632

7	TiO2	76.987
8	SiO2	118.632
9	TiO2	76.987
10	SiO2	118.632
11	TiO2	76.987
12	SiO2	593.158
13	TiO2	76.987
14	SiO2	118.632
15	TiO2	153.975
16	SiO2	118.632
17	TiO2	76.987
18	SiO2	118.632
19	TiO2	76.987
20	SiO2	118.632
21	TiO2	76.987
22	SiO2	118.632
23	TiO2	76.987
24	SiO2	118.632
25	TiO2	76.987

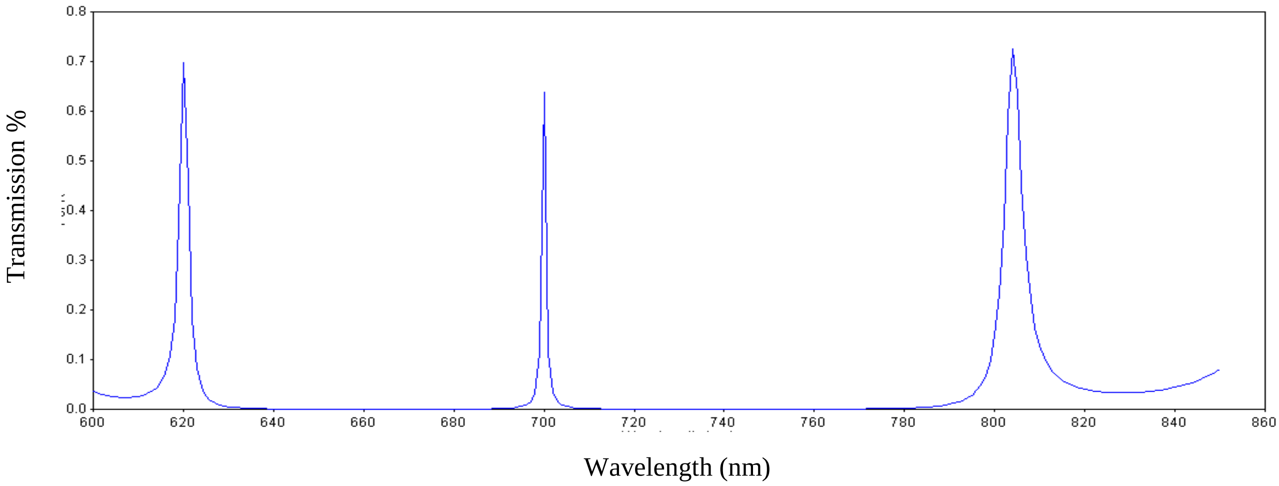

Fig. (5) Transmission vs. wavelength for design narrow bandpass filter with multi-cavity

4. CONCLUSION

This type of band-pass coating is used in telecommunications industry to control the transmission of multiple laser lines (i.e., channels) through fiberoptic cables. The spacing between laser wavelengths is denser, allowing the fiber to transmit more information. A popular component for adding a channel (multiplexing) or removing it (demultiplexing), is a thin-film narrowband filter that transmits one channel and reflects all others. The production of such filters in sufficient volume is the most demanding task ever undertaken by the optical thin-film industry. The goal of this talk is to give an overview of how a DWDM system works, where optical thin film filters fit in, and what it takes to make them.Clearly see from design (2) the bandwidth is narrow compare with design (1) this is because using optimization. There are many other applications of multi-cavity filters such as spectral radiometry, medical diagnostics, chemical analysis, colorimetry, environmental monitoring, security systems, avionics, space-based laser communication systems, space and ground base telescopes, and others.

REFERENCES

[1] A Baus, KMK Srivatsa, T K Chakraborty&T K Bhattacharya,"Fabrication of narrow bandpass filter for wavelength division multiplexing applications- A feasibility study", Indian Journal of Engineering & Materials Sciences, Vol.14, April 2007, pp.125-132.
[2] Baumeister P W, "Laser Focus World", July (2001) 145-146
[3] Morton D. Soc vacuum coating Technology, conf.proc, (2003) 1-6

[4] BaumeisterPW,"Optical Coating Technology", 1st (SPIE press, Washington), (2004), ch1 and ch7.
[5] ThelenA,"Design of optical interference coatings" 1st ED (MaGraw Hill Book Company, New York), ch10 (1989).
[6] Baumeister P W, App opt, 42 (2003) 2407- 2414.
[7] Zoller A, Gotzolmann R, Mats K &Cuhing D, App. Opt.,35 (1996) 5609-5612.
[8] Scobey MA, Spock DE, Grasis ME & Beattie JA, proc opt Fiber comm conf.(USA), (1996), 242- 243
[9] Bauer S, Klipper L, Rothaan U, &Kuhr,"Thin solid films" 442,189-193(2003).
[10] Macleod H A," Thin film optical filter"2nd Ed (Adam HilgerLtd,Bristol), ch7(1989)
[11] J. Minowa and Y. Fuji, "Subnanometer bandwidth interference filter for optical filter communication system," Appl. Opt. Vol. 27, pp. 1385-1396, (1988).
[12] Chanies thesis "Research of Dependence of the Uniformity on the design and Fabrication of Sub-Nanometer Narrow band-pass Filters" 91246004pdf (1995).
[13] R. R. Willey, "Achieving narrow bandpass filters which meet the requirements for DWDM," Thin Solid Films Vol. 398, pp. 1-9, 2001.
[14] S. Lauouche, L. Martinu,"Open-Filters: open-source software for the design, optimization, and synthesis of optical filters" *Appl. Opt*., 47, C219-C230 (2008).

BIOGRAPHIES OF AUTHORS

Gaillan H. Abdullah was born in Bagdad ,Iraq in 1963,she received B.S degree in physical scince from Baghdad University,in1986,M.S degree in Laser and optoelectronics (Alrasheed College / university of Technology-Baghdad) in 2002and he Ph.D degree in laser and optoelectronics Technology from Technology University /Iraq-Bagdad in 2010. She joined to the Laser and Optoelectronic center in Ministry of Science and Technology in 2009,and carried out research in Thin films design system and optical design .

Bushra.R.Mhdi was born in Bagdad ,Iraq in 1966,she received B.S degree in electrical Engineering from Technology University,in1987,M.S degree in Laser Application in Electrical Engineering(Institute of Laser and Plasma)from Bagdad University in 2001 and he Ph.D degree in laser Engineering from Technology University /Iraq-Bagdad in 2009. She joined to the Laser and Optoelectronic center in Ministry of Science and Technology in 2009,and carried out research in laser a design system and laser application .In 2010 she formed fiber communication section and began program in optical fiber sensor. She has numerous publication in the areas of fiber laser ,laser system design and fiber sensor technology.

Nahla.A.Aljaber was born in Bagdad, Iraq in 1969,she received B.S degree in Physics Science from Technology University,in1992,M.S degree in Laser Application in Physics Science (Institute of Laser and Plasma) in 2003. She joined to the Laser and Optoelectronic center in Ministry of Science and Technology in 2009,and carried out research in laser a design system and laser application .In 2010 she formed fiber communication section and began program in optical fiber sensor.