Different types of Optical Filters and their Realistic Application
Vijay Laxmi Kalyani, Varsha Sharma

Vijay Laxmi Kalyani, Government Women Engineering College, Ajmer, India
vijaylaxmikalyani@yahoo.com
Varsha Sharma, Government Women Engineering College Ajmer, India
12varshasharma@gmail.com

Abstract—Filter is a device which is allows some signal to pass and stop others. In electronics, many types of filters are used such as passive or active, analog or digital, high pass, low pass, band pass, band stop, all pass, linear or non-linear, IIR, FIR filter. Filter are use in communication system, audio system, filter are also use in test equipments - spectrum analyser, signal generators. In optical communication optical filter are used to selectively transmit or reject a wavelength or range of wavelengths. Optical filter is a device which is pass a light particular range or wavelength and remaining light is block. Optical Filters are used in many applications such as fluorescence microscopy, photography, optical instrument, spectroscopy, clinical chemistry, or machine vision inspection. Optical Filters are ideal for life science, imaging, industrial, or defence industries. Optical filter are include a “crystalline material” for UV band pass filter. Photonics based filters are RF photonics filter, Microwave filter, Si RF filters. In this paper first we introduce the optical filters, and then we explain the different types of optical filters and realistic applications of filters.

Keywords—Photonic based optical filter, Filter application.

I. INTRODUCTION
Optical communication is a communication which transfers an information using light from transmitter to receiver. Generally optical communication system use a transmitter and receiver, and channel .Transmitter encodes information into an optical signal, a channel is transmitting a signal, and receiver is receiving the signal. In transmitters generally use light emitting diode (LED’s) or laser diodes. In optical communication, different types of optical filters are used are used to selectively transmit or block certain wavelengths within optical systems. The two main categories of optical filters are Absorptive and Dichroic Filters. In an absorptive filter, light is blocked based on the absorption properties of the glass substrate used. In ideal some applications where noise in a system from unwanted light is an issue. In Absorptive filters light can be incident upon the filter from a wide range of angles and the filter will maintain its transmission and absorption properties. Whereas, a dichroic filter is block an unwanted light and transmit desire spectrum. It uses the principle of interference. Separate channel are use in dichroic filter in telecommunication network that use WDM to long optic fiber.

II. DIFFERENT TYPES OF OPTICAL FILTER
Optical filter are transmit light different wavelength and eliminate unwanted light. Optical filters are commonly used in photography, optical instruments, colour stage lighting and fluorescence applications such as fluorescence microscopy and fluorescence spectroscopy.

A - Fabry-perot Filter
It is also known as a “Thin-film filter” a fabry -perot filter optical filter consists a two flat highly reflective mirror spaced some distance apart facing each other [1]. A light signal is incident left part of fabry-perot interferometer. Some light pass through a cavity, some light leave the remaining light is reflected [2].

\[ T = \frac{1}{(1-R)^2 + 4R} \sin^2 \left( \frac{\beta}{2} \right) \]

\[ \Phi = \frac{2\pi}{\lambda} 2nD \cos \phi. \]

\[ n = \text{Refractive Index} \]

\[ D = \text{Distance between mirrors} \]

Figure 1: Deposition of Multiple Layers of alternating High and Low Index Materials onto a Glass Substrate
Source: www.edmundoptics.com
Figure 2: Fabry-Perot Filter
Source: https://www.google.co.in/search?q=fabry+perot+filter

Figure 3: The behavior of wavelength in a fabry-perot filter

B- Fiber-Bragg Grating filter
Fiber Bragg Grating is element of WDM system. This is performing Multiplexing, Demultiplexing function [3]. When a light pass through a grating some wavelength interfere effectively and other is destructively.

Figure 4: Fiber Bragg Grating

A fiber Bragg grating is a narrow band reflection filter [2]. FBG work with isolator and circulator component.

Figure 5: Optical Circulator
Source: https://www.google.co.in/search?q=fibre+bragg+grating+circulator&espv=2&biw=1

Fig. 5 shows that circulator with grating. Many wavelengths are entering a port 1 of the circulator first & all wavelengths are transmitted and λ2 wavelength reflects & exists from port 3. Add signal λ2 enter a port 1 in circulator second and emerge from port 2 and enter grating it’s reflect from grating and transmit. it has been multiplexing and demultiplexing WDM signal.

\[
\lambda_B = 2\Lambda n_{\text{eff}}
\]

Where \(\lambda_B\) = Bragg wavelength
\(n = \) Refractive Index
\(\Lambda = \) grating period

\[
R_{\text{max}} = \tan h^2 (kl)
\]

\[
\Lambda\lambda = \lambda_B^2 \frac{n_{\text{eff}}}{n} \left( (kl)^2 + \pi^2 \right)^{1/2}
\]

\[
k = \omega n_B \frac{\Lambda}{\lambda_B}
\]

C - Tunable Filter
Two main technologies are making tunable filter MEMS & Bragg grating [2]. Tunable Filter technologies-Liquid-crystal tunable filter, Acousto-optics tunable filter, linear variable filter. Tunable filter are use in Drug discovery, micro plate readers, Gemology etc.

D - Absorptive Filter
Absorptive filter generally build from glass to which different inorganic or organic compound added. These compounds consume some wavelength of lights and transmit others. The compound also added plastic to produce a gel filter, which is lighter and low cost than glass based filter.

Figure 6: Absorptive Filter
Source: http://www.globalspec.com/learnmore/optical_components_optics/optical_components/optical_filters

E - Band pass Filter
Band pass filter allow certain wavelength and block other wavelengths. The width of band pass filter exists in wavelengths range is less than an angstrom and few hundred nanometers. Band pass filter is combination of LP & SP filter. In single optical channel, band pass filter is block and reject noise and pass the optical channel wavelength [4]. A band pass filter also optimizes the sensitivity of a receiver [5].
Figure 7: Wide band pass filter, narrow band pass filter, Short pass and long pass filter.

Source: http://www.olympusmicro.com/primer/techniques/fluorescence/filters.html

F - Infrared Filter
Infrared lights much more wavelengths than visible lights. Frequencies from 300 GHz to 430 THz [6]. Use of infrared filter in infrared photography, metrology, thermograph, heating. Infrared divided in near- infrared or far- infrared.

Figure 8: Infrared filter
Source: http://www.maxmax.com/aXNiteFilters.htm

G - Ultraviolet Filter
Ultraviolet wavelengths is 400 nm to 100 nm, and sub divided into Ultraviolet A (400-315 nm), B (315-280 nm), and C (280-100 nm) designations [6]. Ultra violet light is electromagnetic radiation which is shorter than visible light but longer than X-rays. Ultra violet filters having three layers RED, GREEN, BLUE. UV filters use in diverse application.

H - Dichroic Filter
A Dichroic Filter is used to transmit the light, depending on the wavelength; it transmitted the light of a specific wavelength range, while light of a different range is blocked. These filters are used for long pass and short pass applications.

III.PHOTONICS BASED OPTICAL FILTER
Photonics is smallest unit of light. This is associated with the generation, transmission, manipulation, detection of light. Photonics use a laser, fiber optics and electro optical device. This is use in medical field, military, and telecommunication. Many photonic based filters are use in communication, optical interconnection network, and ultra high speed information processing.

1. MICROWAVE PHOTONICS FILTER- Microwave photonics is study of the microwave and optical signals, for an application of a Broadband, wireless network, sensor network, radar, satellite communication. Microwave photonics filter are same of the ordinary microwave filter. Advantage of microwave photonics based filter is low loss, high bandwidth, tunability. This microwave photonics based filter is use in radar and phase array antennas [7]. In general photonics microwave filter are use an optical coupler, FBGs, array waveguide, mach-zehender, length of a dispersive fibre [8].

2. SILICON RF-PHOTONICS FILTER & DOWN CONVERTER- RF photonics filter is filter a 1.25 GHz wide signal with 20 db filter rejection and 20 GHz centre tuning range. RF photonics filter is based On CMOS optical filter [9].

3. PHOTONICS –BASED INTERFERENCE MITIGATION FILTER- To avoid interference in signal a photonics based filter are use. This filter have a parallel topology , and grating based photonics band pass filter , or a dual offset cavity structure based on new noncommensurate delay line. This topologies are reduce a problem in both narrow stop band & very wide pass band minimum interference over a wide microwave range [10].

IV REALISTIC APPLICATIONS OF OPTICAL FILTER
Optical filter are widely used in instrument & technology system, scientific equipment, computers, optical communication network, data storage units and display interfaces.

1. Colour Imaging Filter - Colour imaging filter are optical filter which is use the control the spectral properties of light & departure the colour. HORIBA Scientific UK supplies a variety of colour imaging system.
2. Blue band pass filter are use in low contrast between yellow background and white letters [11]. A blue band pass filter blocks a yellow light and dark the background.

3. Infrared band pass filter are use in remove interference in barcode’s background. Ink is use in beverage label reflects IR [11].

4. Short pass filter are use in remove IR emitted heat in the production process. Short pass filter block IR light obtained from heat [11].

5. Band pass filter are use in Fluorescence microscopes for eliminate pump light from Fluorescence signal light, Eye Protection from laser radiation eliminate
infrared laser light and pass a visible light, sun glasses pass a visible light and block a UV light [12].

6. Thin-film optical filters: Thin-film optical filters are used to provide the highest standards such as improvements in transmission, blocking, and both transmitted and reflected wave front properties, which translates into bright, high-contrast images, and accurate detection of target molecules in fluorescence imaging and detection system applications.

Figure 14: Hard coated thin film optical filter

7. Multispectral Optical Filter Assembly: This technology combines individually-coated multispectral filter substrates into an array assembly. The new assemblies range from two-filter stacks to eight-filter stacks, or more. For added flexibility, these filter assemblies can employ a variety of adhesives including space-qualified adhesives [13]. These are used in linear and planar-array CMOS detectors, medical instrumentation, commercial, government, and aerospace applications.

Figure 15: Multispectral Optical Filter Assembly

8. Long wave Infrared (LWIR) Optical Filters: The "thermal imaging" region, in which sensors can obtain a completely passive image of objects only slightly higher in temperature than room temperature - for example, the human body - based on thermal emissions only and requiring no illumination such as the sun, moon, or infrared illuminator. This region is also called the "thermal infrared" [14]. This is ideal for a variety of applications, such as gas sensing and thermal imaging.

Figure 16: Long wave Infrared Optical Filters

V. FUTURE SCOPE

Future scope of optical filter is we require a high performance filter need for high transmission, deeper blocking, and larger angle. Now days multiple single band optical filter are use, future demand is become multiband version of optical filter. In medical field filter device is merge with "infrared light" source to achieve diagnostic test.

VI. CONCLUSION

The objective of this paper provides an overview of optical filter and use in area in communication. This paper is summarized basics optical filter characteristics.

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Author’s Details

Vijay Laxmi Kalyani is currently working as Assistant Professor in the department of ECE in GWECA, Ajmer. She has attended various workshops, conferences, FDP, STC etc. and also published many research papers in various International Journals, National Journals and Conferences, she is also a member of IAENG.

Varsha Sharma is pursuing M.Tech (II -Sem) in Digital Communication in GWECA, Ajmer.