output/input ports as a second pass input back into the output/input ports. The second pass input passes through the Mach-Zehnder interferometer and is filtered a second time. It will be appreciated that multiple Mach-Zehnder stages can be provided to perform various filter functions.

[0016] The Mach-Zehnder interferometer can have a fixed path length mismatch or it can be tunable depending upon the particular application for the filter. For example, various tuning methods, such as temperature, strain, electric and magnetic fields, etc., can be used to maintain, change, and/or otherwise control the filter function.

[0017] The device of the present invention can be used in various components and subsystems within a system. For example, the device can be used to perform filtering functions in various components, subsystems, and network elements, including transmitters, receivers, multiplexers, demultiplexers, switches, add/drop multiplexers, etc. In all-optical network or subnetwork embodiments, the device can be used to perform tunable or fixed wavelength filtering. As such, networks employing the tunable filter **40** in combination with various optical components, such as transmitters, receivers, and optical switching devices, can support reconfigurable transmission paths for the signal wavelengths through the network.

[0018] The present invention addresses the limitations of the prior art by providing filtering devices and methods that can provide increased control and flexibility necessary for higher performance, lower cost optical transmission systems. These advantages and others will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying schematic drawings for the purpose of illustrating embodiments only and not for purposes of limiting the same, wherein:

[0020] **FIGS. 1 and 2** illustrate optical system embodiments;

[0021] **FIG. 3-4** illustrates double pass Mach-Zehnder filter embodiments;

[0022] **FIG. 5** illustrates single and double pass Mach-Zehnder filter spectral response profiles;

[0023] FIGS. **6-11** illustrate double pass Mach-Zehnder filter embodiments; and,

[0024] **FIG. 12** illustrates an optical receiver double pass Mach-Zehnder filter application.

DESCRIPTION OF THE INVENTION

[0025] **FIG. 1** illustrates an optical system **10**, which includes a plurality of nodes **12** connected by optical communication paths **14**. Advantages of the present invention can be realized with many system **10** configurations, topologies, and architectures. For example, an all optical network, one or more interconnected point to point optical links (**FIG. 2**), and combinations thereof can be configured in various topologies, i.e., rings, mesh, etc. to provide a desired network connectivity.

[0026] The system **10** can support one or more transmission schemes, such as space, time, polarization, code, wavelength and frequency division multiplexing, etc., singly or in combination within a network to provide communication between the nodes **12**. The system **10** can include various types of transmission media **16** and be controlled by a network management system **18**.

[0027] As shown in **FIG. 1**, optical processing nodes **12** generally can include one or more optical components, such as transmitters **20**, receivers **22**, amplifiers **24**, optical switches **26**, optical add/drop multiplexers **28**, and interfacial devices **30**. For example, in WDM embodiments, the node **12** can include optical switches **26** and interfacial devices **30** along with multiple transmitters **20**, receivers **22**, and associated equipment, such as monitors, power supplies, system supervisory equipment, etc.

[0028] The optical processing nodes **12** can be configured via the network management system **18** in various topologies. The deployment of integrated transport optical switches **26**, and optical add/drop multiplexers **28** as integrated switching devices in intermediate nodes $\mathbf{12}_i$ can provide all-optical interconnections between the transmitters **20** and receivers **22** located in non-adjacent origination and destination nodes, $\mathbf{12}_o$ and $_d$, respectively. The use of integrated transport switching devices in the system **10** in this manner provides for distance independent all-optical networks, sub-networks, and/or nodal connections.

[0029] In various network embodiments, multiple paths, e.g., $\mathbf{14}_1$, and $\mathbf{14}_2$, can be provided between nodes **12**. The optical path **14** between adjacent nodes **12** is referred to generally as an optical link. The optical communication path **14** between adjacent optical components along the link is referred to generally as a span.

[0030] Various guided and unguided transmission media **16**, such as fiber, planar, and free space media, can be used to form the optical communication paths **14**. The media **16** supports the transmission of information between originating nodes $\mathbf{12}_o$ and destination nodes $\mathbf{12}_d$ in the system **10**. As used herein, the term "information" should be broadly construed to include any type of audio, video, data, instructions, or other signals that can be transmitted.

[0031] The transmission media **16** can include one or more optical fibers interconnecting the nodes **12** in the system **10**. Various types of fiber, such as dispersion shifted ("DSF"), non-dispersion shifted ("NDSF"), non-zero dispersion shifted ("NZDSF"), dispersion compensating("DCF"), and polarization maintaining ("PMF") fibers, doped, e.g. Er, Ge, as well as others, can be deployed as transmission fiber to interconnect nodes **12** or for other purposes in the system **10**. The fiber typically can support either unidirectional or bi-directional transmission of optical signals in the form of one or more information carrying optical signal wavelengths λ_{si}, or "channels". The optical signal channels in a particular path **14** can be processed by the optical components as individual channels or as one or more wavebands, each containing one or more optical signal channels.

[0032] Network management systems ("NMS") **18** can be provided to manage, configure, and control optical components in the system **10**. The NMS **18** generally can include multiple management layers, which can reside at one or more centralized locations and/or be distributed among the