

OPTICAL FIBER TAP

This invention relates to a non-destructive tap for an optical fiber, and especially to a tap used to provide a node in a ring topology data processing local area network.

In the past few years, as large scale integration of semiconductor circuitry has made microprocessors and microcomputers available, there has arisen an increased interest in methods of efficient interconnection into what are usually referred to as local area networks. The aim of the local area network is the connection of data processing nodes (terminals, computers, etc.) in such a manner that they may communicate with each other, sharing resources and exchanging information. Such networks are now commercially available from such manufacturers as Xerox Corporation (Ethernet™) and Wang Laboratories (Wangnet™).

Three general classes of physical link topologies are employed for these networks: bus, star, and ring. The bus topology provides a bus which operates as a bidirectional transmission facility to which all the nodes are attached. Signals from one node enter the bus and propagate down it in both directions to its ends, where they are terminated. Such a topology provides a passive attachment mechanism: nodes may be added to or deleted from the network without disruption. In the star topology, all signals from the nodes pass through a central point (the "hub"). The hub may be active, and act as a controller: a typical example of this is a telephone switchboard or PBX; or may be passive, and simply provide a junction for transmission facilities to and from each node.

24

In the ring topology, however, the nodes are connected by unidirectional transmission facilities to form a structure with a single closed path. Signals placed on the ring pass from node to node and are regenerated as they pass through each node. The attachment node has been referred to as active attachment, enabling all attached nodes to maintain synchronization. A disadvantage of the ring topology is, however, that the addition or deletion of nodes disrupts the network.

Approximately contemporaneously with the increase in networks has been interest in optical fibers as a data communications medium. Optical fibers offer substantial advantages over electrical conductors, particularly in bandwidth (enabling higher data transmission rates) and in immunity to electrical noise (requiring less shielding). Two principal disadvantages are fragility and difficulty of connection. Adequate techniques are now available for jacketing and strengthening optical fiber cables so that they can be used virtually as easily as conventional communications cable, and certainly as easily as high-bandwidth coaxial cable, and techniques for connection continue to improve.

It is when an optical fiber is proposed to be used as the communications medium in a ring network that a real disadvantage of optical fibers appears. When a node is removed from a ring network, the break in the ring occupied by the detector-data processor-transmitter of that node must be filled to establish connection between the nodes on either side of the removed node. For electrical circuitry, this is comparatively easy: a switch can be used to break the line and connect it to the node. The deterioration of signal quality when the

node is switched out of the ring is minimal. However, when an optical fiber is used, connections cannot be as easily made and broken.

5 What is desired is an optical fiber tap which, when it is not actuated, causes essentially no loss in the optical fiber and which, when actuated, switches as much as desired of the optical signal into/out of the node.

10 We have discovered that it is possible to produce a tap for an optical fiber, the tap having an open position in which it does not operate on the fiber and a closed position in which it does operate on the fiber, which enables the non-destructive tapping of an optical fiber. Such a tap may be used, for example, in a node in a local area network, particularly a ring topology local area
15 network. The tap operates, when in its closed position, by bending the fiber to permit the detection of an optical signal passing down the fiber and the injection of an optical signal into the fiber.

20 The invention is illustrated in the accompanying drawing, in which Figure 1 shows the tap in its closed position, Figure 2 shows it in its open position; and Figure 3 shows a second embodiment of the tap.

In a first aspect, this invention provides a tap for a buffered optical fiber, the tap having an open position in which it does not operate on the fiber and a closed position in which it does operate on the fiber, comprising:

- (a) a first bending means through which the fiber passes and which has an open position in which the fiber is not bent and a closed position in which the fiber is bent sufficiently to cause at least a portion of an optical signal passing down the fiber to escape and be tapped from the fiber;
- (b) a detecting means for detecting the tapped optical signal which has escaped from the fiber when it is maintained in a bent configuration by the first bending means;
- (c) signal attenuation means, located downstream of the first bending means, through which the fiber passes, which has an open position in which an untapped portion of the optical signal passing through the fiber is not attenuated and a closed position in which the untapped portion of the optical signal passing through the fiber is attenuated, and an attenuator actuating means for moving the attenuation means between its open and closed positions,
- (d) a second bending means, located downstream of the signal attenuation means, through which the fiber passes and which has a position in which the fiber is bent (and preferably has an open position in which the fiber is not bent and a closed position in which the fiber is bent) sufficiently to permit the injection of an optical signal into the fiber;
- (e) injecting means for injecting an optical signal into the bent position of the fiber when it is maintained in a bent configuration by the second bending means; and
- (f) bender actuating means for moving the first, and optionally the second, bending means between their open and closed positions.

The invention also provides a fibre optic network, preferably a local area network, especially having a ring topology, having the tap of the invention.

The invention further provides a method of tapping an optical fiber carrying an optical signal which comprises;

(a) bending the fiber at a first position and detecting a signal which escapes from the fiber;

(b) attenuating the signal in the fiber at a second position that is downstream of said first position and upstream of a third position; and

(c) bending the fiber at the third position that is downstream of the second position at which attenuation takes place and injecting another optical signal at said third position.

The attenuation means may be physically linked to the first bending means and detecting means so that the signal which is removed from the optical fiber by the attenuation means is collected by the detecting means.

Particular advantages of the tap of this invention include that (a) it is non-destructive, i.e. the fiber remains a continuous length and need not be broken and terminated to enable use of the tap, (b) even when the fiber is placed within the tap, passing through the bending means, the tap does not operate on the fiber when in its open position and there is substantially no attenuation induced by the tap, (c) the tap is readily movable between its open and closed positions, enabling tapping of the fiber only when desired, and (d) because the optical signals may be passed through the buffer of the fiber into and out of the fiber, the fiber need not be completely stripped and is thus less subjected to breakage or environmental damage.

Optical fibers for telecommunications and data processing applications are generally of the glass-on-glass type, comprising a glass core (through which the optical signals travel), a glass cladding of a lower

29

refractive index surrounding the core to enable it to act as a waveguide, and a relatively soft polymeric buffer, generally of a refractive index greater than the cladding, which surrounds the cladding. A fiber with the buffer removed, i.e. a fiber comprising only core and cladding, is much weaker than the same fiber with a buffer. This weakness manifests itself both as a much greater tendency to break when bent (a buffered fiber can stand much tighter bends and repeated bends better than an unbuffered one) and a tendency to stress-cracking (because the hydrolytic attack on the unbuffered fiber is particularly prone to occur at bends where micro-cracks may be formed). Both of these factors limit the usefulness of any technique which operates on unbuffered fibers, especially when it is desired to be able to repeatedly connect and disconnect an optical coupler or tap. In the case of plastic-clad silica (PCS) fibers, which are contemplated especially for military use, and all-plastic fibers, the buffer and cladding may be the same. The buffer may be surrounded by a jacket. It is possible, by the use of the tap of this invention, to withdraw signals from or inject signals into, an optical fiber through the buffer.

Figure 1 shows the tap of this invention in its closed, or operating position. The tap comprises two matching blocks 10 and 12, designed to come together about an optical fiber 14, along which an optical signal may travel in the direction of the arrow. The receiver section of the tap comprises a first bending means 16, a first coupling means 18, and a detecting means 20,

which may be connected by a signal line 22 (optical or electrical) to a data processor, etc. (not shown). The transmitter section comprises a second bending means 24, a second coupling means 26, and an injecting means 28, which may be connected by a signal line 30 to a signal source, e.g. the data processor. Located between the first and second bending means is a signal attenuation means 32, shown here as a means for inducing a series of bends in the fiber.

When the tap is in the closed position, so that the fiber 14 is held between blocks 10 and 12, at least a portion of a signal passing down the fiber in the direction of the arrow is caused to escape from the fiber by the bend maintained in the fiber by the first bending means 16. That signal is coupled into the detecting means 20 by coupling means 18, and is then available to an external device. The signal remaining in the fiber 14 beyond the first bending means may then be attenuated by signal attenuation means 32, to prevent confusion between the original signal and a signal to be injected into the fiber by the transmitter. That signal, originating in some device external to the tap, passes into the injecting means 28, and is then injected, via second coupling means 26, into fiber 14 where it is held bent by the second bending means 24. The signal then passes down fiber 14 in the direction indicated by the arrow.

Though the tap has been shown as being bilaterally symmetric in construction, such is not a requisite of the invention, and the receiver and transmitter may be independently designed for optimum performance.

Figure 2 shows the tap in its open position. Because the fiber 14 is not bent by the bending means or signal attenuation means, an optical signal may pass down it in the direction of the arrow substantially without attenuation, as if the tap were not present.

The bend radius of the fibers when maintained in its bent position by the first or second bending means will preferably be 1.5 to 15mm, particularly 2 to 10mm, especially 3 to 8mm.

The angle between the signal entering or leaving the fiber at the bending means and the tangent to the fiber core at the point of impact of the signal will preferably be less than the acceptance angle of the fiber, for example less than 20° , particularly not more than 10° , especially substantially 0° . The point of impact of the signal is preferably at the point at which the bend maintained in the fiber by the bending means straightens out, so that the signal is preferably directed along an essentially straight piece of fiber. This is particularly important for the transmitter.

The coupling members should (a) conform to the surface of the fiber, (b) lie in the path of the optical signal, and (c) increase the proportion of the signal coupled into or out of the optical fiber. Each will preferably comprise a block of a resiliently deformable polymeric material, such as a polysiloxane, which is transparent to the optical signal and has a refractive index which is preferably approximately equal to the refractive index of the buffer of the fiber, for example within ± 0.3 , e.g. ± 0.2 , especially ± 0.1 , of the buffer refractive index. The material of the block preferably has a Young's modulus less than that of the buffer, for example less than 10^7 N/m^2 .

The signal attenuation means may comprise means for inducing a series of bends in the fiber, as it is well-known that bending a fiber leads to signal loss therefrom. It is desirable, however, that the attenuation means
5 should not damage the fiber, so that a signal may pass down the fiber with essentially no attenuation when the tap is in its open position.

The tap should be easily movable between its open and closed positions by an actuating means. This motion
10 may, for example, be performed by a solenoid. The solenoid may be biased such that the tap is normally open, and is closed when power is applied to the solenoid. In this way, if power to the tap is lost, the optical fiber is released and a signal may pass down the fiber
15 unattenuated.

A further advantage of the tap of this invention is that it may be installed in an optical fiber loop which forms the basis of a ring network (for example, built
20 into a socket box in a wall in a building within which the optical fiber loop is located) and only put into use when it is desired to add a node to the ring at that point. Because the tap may be connected to the data processor of the node by separate signal lines (e.g. electrical signal
25 lines), additional slack in the ring optical fiber is not required, and rewiring of a building for a network is rendered facile.

32

Figure 3 shows an alternative embodiment for the tap of this invention in which the first bending means forms a part of the signal attenuation means.

5 The body 110 of the tap has a slot 112 in which slides (in the direction of the arrows A) a key 138 having microbend-inducing protrusions 140. The key 138 is preferably of metal or rigid polymer and, if polymeric, is preferably of a lower refractive index than the buffer. It will generally be movable by a solenoid or similar
10 actuating means (not shown) so that when it is not urged against the fiber to cause optical coupling the fiber will be unbent and will show no attenuation. The optimum shape and spacing of the protrusions 140 may be determined either by experiment and/or by reference to e.g. U.S. Patent
15 No. 4,253,727 (Jeunhomme et al.). The spacing is preferably 0.5 to 5mm, especially 1 to 2.5mm.

A rigid backing means 114 supported by the body 110 of the tap, supports a polymeric rod 116. The backing means may be metal or, preferably, polymeric. The backing
20 means and rod may each be flat or the backing means and rod may be so shaped that they form a waveguide in which rod 116 acts as the "core" of the waveguide and backing means 114 as the "cladding". Of course, a part of the "cladding" 114 is then cut away to form a slot into which
25 the fiber 122 may be laid to allow it to contact rod 116.

It will be realized that it is desirable that backing means 114 be either highly reflective or relatively transparent and of lower refractive index than rod 116 to improve its properties as an optical cladding, and be rigid enough that it should not deform when the fiber is pressed against rod 116 (or light will be lost). A suitable material for backing means 114 is e.g. polyvinylidene fluoride. Rod 116 should be transparent, since it is, in effect the "core" of a waveguide, and should be resiliently deformable and softer than the buffer of the fiber desired to be used. A preferable hardness range is about 30 to 90 Shore A. Below about 30 an anomalous coupling effect occurs - the coupling (as measured by light emerging from the end of the rod) increases with increasing force to a certain point and then decreases. It is believed that this is due to loss of light from the rod as it is deformed. Above about 90 coupling increases with increasing force, but the fiber tends to break before very high coupling is achieved as the fiber is simply being compressed between two relatively rigid objects.

For optimum detection, it is expected that the rod refractive index should be greater than that of the buffer at the fiber. Suitable materials for the rod include, for example, silicones of the type already used conventionally in fiber optics. An example of a suitable material is Shinetsu KE106, which is a two-part RTV silicone. Many other materials are, of course, also suitable within the constraints described above.

The end of rod 116 which carries the coupled light, i.e. the end furthest away from the source of the light, abuts against a detector 152, which may be connected to data processing means, etc. by a signal line (not shown).

34

The buffered fiber 122, after passing through the coupler as described above, then passes through a transmitter section comprising a macrobend inducing means shown as rod 154 and a signal injecting means shown as a light source 156 and coupling means 158 analogous to 28 and 26 of Figures 1 and 2. Although it is believed that the single macrobend of the transmitter section causes no substantial attenuation of the light which may be passing down the fiber 122, it is possible to have the transmitter section open and close (such as by movement of source 156 and coupling means 158 in the direction of the arrows B) to minimize the extent of the bending when the transmitter section is not being used.

A signal passing down optical fiber 122 from end 160 may be not only coupled into rod 116, but may also be so attenuated by the coupler that essentially no signal is being carried by the fiber by the time it reaches the transmitter section. This may be desirable when the tap is used as a node in a ring network, in which each mode receives and regenerates the signal when it is actively connected into the circuit.

Thus this second embodiment parallels the first embodiment in function, and differs in the fact that while in the first embodiment the detecting means and attenuation means are separate in the second embodiment the attenuation means and detecting means are physically combined. In this way, the first bending means corresponds to the first key protrusion (although each protrusion causes a coupling of

light out of the fiber); and the attenuation means to the key and rod assembly as a whole. The key and rod assembly shown in Figure 3 is, of course, suitable as an attenuation means for the tap of Figure 1, and the rod then may be opaque if desired.

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10 By the use of either embodiment, or indeed any other embodiment within the scope of this invention as limited by the claims, it is possible to provide a tap for a buffered optical fiber capable of acting as a node for a local area network, especially a ring topology local area network, that will require minimum rewiring and provide portability for the nodes.



CLAIMS:

1. A tap for a buffered optical fiber, the tap having an open position in which it does not operate on the fiber and a closed position in which it does operate on the fiber, comprising:

- (a) a first bending means through which the fiber passes and which has an open position in which the fiber is not bent and a closed position in which the fiber is bent sufficiently to cause at least a portion of an optical signal passing down the fiber to escape and be tapped from the fiber;
- (b) a detecting means for detecting the tapped optical signal which has escaped from the fiber when it is maintained in a bent configuration by the first bending means;
- (c) signal attenuation means, located downstream of the first bending means, through which the fiber passes, which has an open position in which an untapped portion of the optical signal passing through the fiber is not attenuated and a closed position in which the untapped portion of the optical signal passing through the fiber is attenuated, and an attenuator actuating means for moving the attenuation means between its open and closed positions,
- (d) a second bending means, located downstream of the signal attenuation means, through which the fiber passes and which has a position in which the fiber is bent (and preferably has an open position in which the fiber is not bent and a closed position in which the fiber is bent) sufficiently to permit the injection of an optical signal into the fiber;
- (e) injecting means for injecting an optical signal into the bent position of the fiber when it is maintained in a bent configuration by the second bending means; and
- (f) bender actuating means for moving the first, and optionally the second, bending means between their open and closed positions.



- 15 -

2. The tap of claim 1 which further comprises a first coupling means comprising a resiliently deformable material which, when the first bending means is in its closed position, will (a) conform to the surface of the fiber, (b) lie in the path of an optical signal escaping from the fiber, and (c) increase the proportion of an optical signal escaping from the fiber which is received by the detecting means.

3. The tap of claim 2 wherein the bend radius of a fiber maintained by the first bending means is 1.5 to 15mm.

4. The tap of any preceding claim, which further comprises a second coupling means comprising a resiliently deformable material which, will (a) conform to the surface of the fiber, (b) lie in the path of an optical signal from the injecting means, and (c) increase the proportion of an optical signal from the injecting means which is injected into the fiber.

5. The tap of claim 4 wherein the bend radius of a fiber maintained by the second bending means is 1.5 to 15mm.

6. The tap of any preceding claim, constructed such that the fiber can pass from the first bending means to the attenuation means and from the attenuation means to the second bending means.

7. The tap of any preceding claim wherein the attenuator actuating means is operationally connected to the bender actuating means such that the first bending means, second bending means, and signal attenuation means are simultaneously movable between their open and closed positions.

8. The tap of any preceding claim wherein at least one of the actuating means comprises a solenoid which is biased



such that the means moved by the actuating means is in its open position unless power is applied to the solenoid.

9. The tap of any preceding claim wherein the attenuation means comprises means for bending the fiber, at a plurality of points, sufficiently to cause a substantial portion of an optical signal passing down the fiber to escape from the fiber.

10. The tap of claim 9 wherein the attenuation means comprises:

- (1) a resiliently deformable polymeric rod of cross-section at least as great as the buffered fiber;
- (2) rigid backing means for the polymeric rod; and
- (3) a rigid key having regularly spaced protrusions on a surface thereof;

and the actuating means comprises means for urging that surface of the key having the protrusions against the fiber to force it into contact with the polymeric rod at at least a plurality of bends induced in the fiber by the protrusions to cause an optical signal passing down the fiber to pass into the polymeric rod, thereby attenuating an optical signal passing down the fiber.

11. The tap of claim 10 wherein the first bending means and attenuation means are physically combined such that the first bending means comprises the first protrusion of the key and the bend actuating means and attenuator actuating means comprise the means for urging the key against the fiber.

12. The tap of claims 10 and 11 wherein the spacing between the protrusions of the key surface is between 0.5 and 5mm.

13. The tap of claim 12 wherein the spacing is between 1.0 and 2.5mm.

14. The tap of any preceding claim wherein the second



- 17 -

bending means has an open position in which the fibre is not bent and a closed position in which the fiber is bent.

15. A tap according to any preceding claim, where the bender actuating means is also capable of moving the second bending means between its open and closed portion.

16. A fibre optic network having a tap according to any preceding claim.

17. A network according to claim 16, being a local area network and/or a network having a ring topology.

18. A network according to claim 16 or 17, in which the attenuation means is upstream of the second bending means and the first bending means forms a part of or is upstream of the attenuation means.

19. A network according to claim 16, 17 or 18, wherein the fiber subjected to the bending means is buffered such that when the first and second bending means are closed an optical signal escapes through a buffer and an optical signal is injected through a buffer.

20. A method of tapping an optical fiber carrying an optical signal which comprises;

(a) bending the fiber at a first position and detecting a signal which escapes from the fiber;

(b) attenuating the signal in the fiber at a second position that is downstream of said first position and upstream of a third position; and



- 18 -

(c) bending the fiber at the third position that is downstream of the second position at which attenuation takes place and injecting another optical signal at said third position.

21. A method according to claim 20, wherein the detected signal escapes from the fiber and/or the injected signal is injected into the fiber through a coupling means.

22. A method according to claim 20 or 21, wherein the detected signal escapes from the fiber and/or the injected signal is injected into the fiber through a buffer of the fiber.

23. A method according to any of claims 20, 21 and 22, wherein steps (a), (b) and (c) are readily reversible and when reversed the optical signal is transmitted along the fiber at the position of the tapping with substantially no loss.

24. A method according to any of claims 20 to 23, wherein the fiber comprises a glass core surrounded by a glass cladding.

25. A method according to any of claims 20 to 24, wherein the fiber forms part of a ring network.

26. A method according to any of claims 20 to 25, wherein the fiber is bent about a radius of between 1.5 and 15 mm.
