Fiber Conservation and Reclamation
Utilizing Single Fiber Technology
Champion ONE
23400 Mercantile Road, Ste 2,
Beachwood, OH 44122
P: 800-860-7466/F: 216-831-2541
sales@championone.net

Introduction
The historical methodology for creating a fiber optic link between transceivers employs a pair of fibers. One fiber was meant for transmission 'east-west' and the other fiber was for receiving the opposite transmitted signal 'east-west'.
However, due to fiber limitations originating from a variety of causes (fiber duct exhaust, leased fiber cost constraints, etc.) methodologies now exist to utilize a single strand of fiber, and allow for operational and capital expenditure savings. These savings, coupled with the ability to deploy a variety of services in both single point-to-point circuits that can be grown into multi-service, multi-protocol WDM links make single fiber based WDM solutions a viable, if not essential tool for the design engineer looking to improve fiber utilization.

Overview
Champion ONE provides optical transceivers and passive filters in a variety of form factors, data rates, protocols, and distance (power) options. A further 'variety' is the option to have many of these optical transceivers and filter modules (which are typically DUAL fiber solutions) in corresponding single fiber (bi-directional or 'bi-di') versions. This paper seeks to describe the single fiber solutions, for both a single circuit as well as multi-circuit or WDM solutions, and the considerations that should be taken when choosing one method over another, as well as testing concepts to be considered.

Single Fiber, Dual Wavelength, Single Service
This variety of single fiber solution has the greatest number of options available for single service designs. Transceivers are utlized that have 'paired' wavelengths which allow for transmission and reception of a full duplex signal over a single strand of fiber.

Wavelengths are utilized that will provide both the reach (power) requirements as well as required isolation necessary to support the circuit by virtue of their separation.

Typically, the following pairs are used:

- 1310nm and 1490nm
  - 10-20km rated parts
  - 1000Mbps or lower
- 1310nm and 1550nm
  - 20-60km rated parts
  - 100Mbps through 2Gbps

Approaching the 2500Mbps (OC-48) data rate, typically WDM-series wavelengths are used:

- 1490nm and 1590nm)
  - 40km and 80km runs

1000Mbps data rates on runs exceeding 60km:

- 1470nm, 1490nm, and/or 1590nm

This chromatic separation allows for isolation as well as rejection of any potential back reflections to the transmitter/receiver subassembly in these transceivers without any considerable cost impact due to specialized subcompoents - the 'same' wavelength to either 'side' of the link is simply outside of the detection window of the receiver. This is why the majority of technical/operational issues with this form of single fiber solution arise from facing 'same to same' rather than properly paired sets. It is left to the deployment/design engineers to decide and implement best practices for which wavelength will be 'upstream' and/or 'downstream' in a link.

A limitation that also arises from this type of optic comes from the fact that a physical loopback cannot be implemented for testing, as the rejection of the 'same' wavelength the optic launched prevents this capability, as mentioned above.

However, despite the operational wavelength consideration and the physical loopback issue, this product offering is the simplest to implement, and available in transceivers that supposrt Fast Ethernet, OC-3/12/48, and Gigabit Ethernet data rates and protocols in SFPs, Gigabit Ethernet in GBIC form factors, and now 10G Ethernet/OC-192 in XFP and 10G Ethernet in SFP+ form factor.

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Single Fiber WDM
Single fiber WDM solutions are a natural extension of the 'paired wavelength' concept detailed above, but with the addition of the appropriate CWDM or DWDM filter(s) to accomplish the combining and separating of the wavelengths on the fiber as they reach the port to complete the service circuit. The benefit of single fiber WDM is that it utilizes standard dual-fiber WDM transceivers with standard filters in a different configuration. However, two wavelengths must be used for EACH circuit, so the fiber reclamation-to-wavelength ratio is always halved versus other approaches to single fiber WDM.

This need for pairs of wavelengths also leads to the need for increased sparing (one of each wavelength) as well as the operational issue of deployment – jumpering to and from the filters is done in a 'cross-over' manner:

Side "A":
1470 SFP Tx to 1470 Mux port
1470 SFP Rx from 1490 Demux port
1510 SFP Tx to 1510 Mux port
1510 SFP Rx from 1530 Demux port
…and so on

Side "B":
1490 SFP Tx to 1490 Mux port
1490 SFP Rx from 1470 Demux port
1530 SFP Tx to 1530 Mux port
1530 SFP Rx from 1510 Demux port

These issues aside, the flexibility allowed by utilizing standard dual-fiber WDM optics translates into the deployment of the widest variety of form factor, data rate, and protocol support – equal to what is supported in standard dual-fiber WDM filter designs.

Single Fiber Single Wavelength (single service)
Single fiber deployments are beneficial to a number of 'service provider' type businesses, especially wavelength-delivery based business ethernet services and cell tower backhaul. Utilizing a pair of fibers for every service can become costly as well as unwieldy in certain areas where ducts or conduit is almost as capacity, and dark fiber is near exhaust.

Single Fiber Single wavelength (SF/SL) transceivers allow for the benefits of standard 'bi-dis' but no pairing of wavelengths is needed. The same wavelength is deployed at both ends of the connection, and isolation is achieved in two ways:

1. An APC (angle polished) connector should be used INTO the receptacle of the SFP transceiver, and it is preferred at the first interface (patch panel or filter).
    a. This APC connector will reject initial interface back reflection, preventing DAMAGE to the laser/receiver assembly as well as BER issues that may result from a mixture of back-reflected and incoming light.
2. The transmitter/receiver subassembly utilizes a 'comparator' that is able to isolate and absorb any signal that results from back-reflection.
    a. As a consequence of using this additonal, specialized receiver, current limitations on this solution are as follows:
        i. Data Rate: 1250Mbps
        ii. Protocol: Gigabit Ethernet
        iii. Rated distance: ~40km

The transceiver uses the same amount of power and is recognized by the switch or router port just as any other SFP transceiver would be. However, one strand without pairing of wavelengths can provide full duplex Gigabit Ethernet service between locations up to 40km apart.

Single Fiber Single Wavlength (WDM)
The same considerations of fiber plant and protocol/data rate/distance are still applicable when multiple services are to be deployed over a strand of fiber. However, now the fiber can support up to 8 services over a single strand, providing a fiber count savings on the long-haul portion of the fiber plant, as well as a single strand from the filter module to the port.

Sparing is minimized, as is the need to plan too far ahead. A single channel 1470nm, for example) can be deployed day ONE and lit as a standard point to point, delaying predeployment of additional passives until the business case requires more circuits, thus reducing intial deployment costs. At a later date, with minimal service interuption, a WDM filter can be placed in front of one side of the transceiver, then the other, and 7 additional channels can be added to that link.