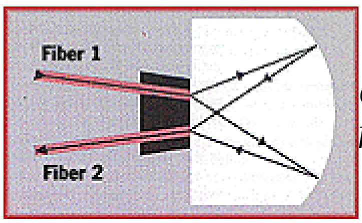
CSR Technology: Flexible Options for Fiber Optics

Centro-symmetrical reflective (CSR) optics is a flexible techonology for making a variety of devices for controlling the path of light in a fiber-optic network. Going beyond simple point-to-point links requires multiplexers, splitters, and switches to allow the application flexibility needed to construct practical networks and to bring fiber to the home.

The basis of CSR technology is a concave mirror. Consider two fibers placed at positions equidistant from the center of curvature of a spherical mirror. When light emerges from one fiber, it spreads out as it reaches the mirror and reflects. The reflected cone is a 1:1 image of the incident cone, a mirror image on the opposite side of the mirror's centerpoint. Thus derives the term *centro-symmetric reflection* -- the incident and reflected light are symmetrical to the center of curvature.



CSR optics provides the 1:1 imaging needed for low-cost fiber-optic couplers.

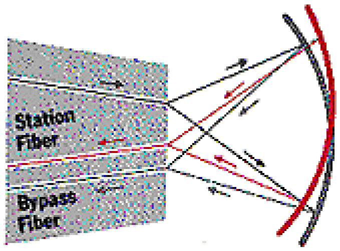
Several factors influence the performance of a CSR-based device:

- Radius of the mirror
- Refractive index of the medium between the fiber and mirror
- Fiber core diameter and NA
- Fiber angle with respect to mirror axis
- Fiber axis separation

CSR technology allows a variety of devices necessary for flexible fiber-optic applications.

Bypass Switch
A CSR-based bypass switch uses fibers cemented into a precision-etched fiber holder for highly accurate positioning. These mirror mounts on a bearing that permits it to pivot on an axis perpendicular to the plane containing the fibers. When the mirror is in one position, light from the network is reflected off the mirror into the fiber to the station.

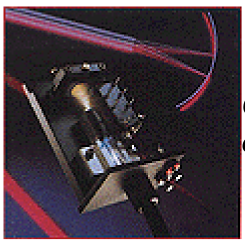
When the mirror is pivoted by an electromagnetic actuator to its other position, incoming light is reflected back onto the network output line directly, bypassing the node completely.



A bypass switch uses a pivoting mirror to achieve optical switching

This CSR approach is highly stable, since the mirror can be pivoted to one of two highly stable positions. The fibers themselves, precisely placed during manufacture and coated with an antireflective coating to reduce back reflections, do not have to be moved.

Insertion loss is typically 0.6 dB and crosstalk is less than 50 dB. The switches are quite compact -- a bypass switch is less than 0.5 inch high -- and reliable. They exhibit environmental stability and a life in excess of 1 million switching cycles.

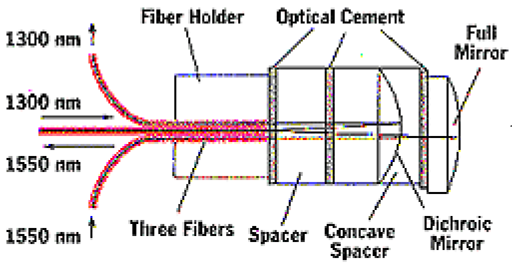

CSR technology is easily adapted to many applications, such as the optical bypass switch shown.

Multiplexer/Demultiplexer

Interest in bringing fiber to the home and in higher performance networks makes low-cost, high-volume optical wavelength-division multiplexer (WDM) ever more desirable. An optical multiplexer combines two or more signals of different wavelengths onto a single optical fiber, while the demultiplexer separates the signal onto individual fibers at the other end. A two-wavelength multiplexer -- say one working at 1300 and 1550 nm -- can effectively double the information-carrying capacity of a link, since each wavelength can exploit the full bandwidth available. Conversely, a user can cut fiber requirements in half by using a WDM to provide full-duplex bidirectional transmission over a single fiber.

A two-wavelength CSR WDM uses two mirrors in a stacked, monolithic assembly. This assembly is packed in an aluminum tube, with the fibers all extending from one end. The fibers are mounted in a closely packed formation in the fiber holder.

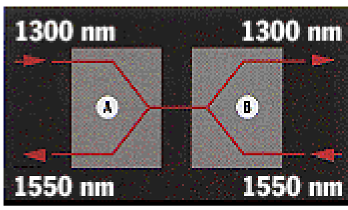
The first mirror consists of a plano-convex lens with a dichroic mirror coating. It is aligned with the fiber holder and fixed in a precise position to create a 1:1 imaging between the 1300-nm short-wavelength fiber and the bidirectional transmission fiber. The dichroic coating on the lens serves a longwave-pass filter, reflecting the short wavelength and passing the longer 1550-nm light.



A WDM uses two mirrors to direct two different wavelengths.

The longer wavelength strikes the second mirror, and is reflected a second time through the dichroic long-pass coating. This provides very high isolation between the two wavelengths.

A bidirectional application uses two different WDMs. One end uses a Type A WDM -- equivalent to the one described above with a long-pass dichroic mirror on the first lens. The other end uses a Type B WDM, which is oppositely configured: a short-pass dichroic mirror reflects the 1550-nm light and passes the 1300-nm light.



Bidirectional application of a WDM.

CSR technology offers great flexibility in devising fiber-optic couplers. The concave mirror approach is conceptually simple, yet highly adapable to a great many applications. In addition, CSR devices combine ruggedness and manufacturing advantages that make them an attractive alternative to other coupling methods in both price and fitness for application.