Tutorial
Fiberoptic Rotary Joint

The Fiberoptic Rotary Joint (FORJ) is the optical equivalent of the electrical slip ring. It allows uninterrupted transmission of an optical signal while rotating along the fiber axis. The FORJ is widely used in missile guidance systems, robotic systems, remotely operated vehicles (ROVs), oil drilling systems, sensing systems, and many other field applications where a twist-free fiber cable is essential.

Technology
A quick search in the patent data base produces hundreds of inventions around two-channel or multiple-channel fiberoptic rotary joints. Commercially, however, there have been very limited choices for technologies. At Princetel, we use our proprietary technologies to facilitate both the dual-port and multiport FORJs. We offer our customers an exciting new alternative for significantly better performance.

Key parameters
A FORJ's only function is to provide connection between two or multiple fiber cables. Therefore, it is critically important to ensure that the device has low insertion loss, small insertion loss variation, and high return loss (a measure that characterizes the amount of reflection a FORJ generates).

Insertion Loss: 3-dB insertion loss is equivalent to 50% transmission. As one can imagine, it can cut into the overall optical budget significantly if the insertion loss is not maintained below this level. At Princetel, we have set ourselves a tough target – less than 3-dB insertion loss for most of our FORJ products. In fact, we have far exceeded our goal by maintaining a typical 0.5 dB insertion loss in our single channel FORJs.

Insertion Loss Variation: It is natural to experience some loss variation as the FORJ rotates due to changing coupling conditions. However, if this variation reaches a certain level, signal-to-noise ratio degrades. 0.5 dB maximum is the best performance commercially available.

Return Loss: All laser sources especially DFB (distributed feedback) lasers are sensitive to optical reflection, which causes spectral fluctuation and subsequently, power jitter. Return loss is a measure of the amount of reflection accruing in an optical system. A -45 dB reflection is equivalent to 45 dB return loss. While a singlemode FORJ can reach as high as 65 dB return loss even for multi-channel FORJs, the typical figure for multimode is around 30-40 dB.

A minimum of 40-50 dB return loss is the industry standard for passive components to ensure normal system operation in single mode fiber systems. Princetel guarantees a minimum of 40 dB return loss on all single-channel and multi-channel FORJs. Some models, such as MicroJ series FORJs, have return loss spec as high as 50 dB. In fact their typical return loss figure is 60 dB.

Single channel vs. multiple channels

The single channel FORJ has a very simple mechanical structure which allows the device to be compact, high speed, and highly reliable. More and more system designers are considering single channel fiber as the practical bandwidth of singlemode fiber increases and the cost of WDM devices continue to decline. As a result, the cost of an n-channel WDM and a single channel FORJ combined can be lower that of an n-channel FORJ. With the help of high-performance DWDM devices one can multiply the capacity of a single fiber by 40-100 fold without compromising the performance.

For those who definitely need two channels in their FORJs Princetel offers a coaxial design to maintain a compact package and good performance at a reasonable cost. And there is no “dead spot” at any rotation angle.

A much more complex mechanical structure is necessary to facilitate the multi-pass (multi-channel) FORJs. The device also requires careful optical system design to maintain good performance in all three key areas mentioned above. Poor optical structure will not only jeopardize the critical performance of the device, but also create new problems such as high wavelength dependent loss, high PDL (polarization dependent loss), high PMD (polarization mode dispersion), and high crosstalk. Princetel’s proprietary multi-channel design allows channel count as high as 10.

Wavelength dependent loss is a measure of uniformity of the insertion loss vs. wavelength since multiple wavelengths, such as 1310 and 1550 nm, are common. If the optical system contains a highly dispersive element such as a prism with non-normal incidence angle, wavelength dependent loss can be an issue. 0.5-dB insertion loss difference between 1310 nm and 1550 nm is generally acceptable.

Polarization dependent loss, similar to wavelength dependent loss, is a measure of uniformity of insertion vs. polarization as the input polarization randomly changes at all times in a typical fiber optic system. Less than 0.1 dB is considered the industry standard for passive components. Again, a prism with a non-normal incidence angle is known to create PDL at a level higher than acceptable in high-performance systems.

Polarization mode dispersion is a measure of pulse stretching due to the travel speed difference of the two orthogonal polarization modes. Any natural or induced birefringence will cause PMD in the system. 0.1 pico-second (ps) or less is a common requirement for passive components.

Crosstalk measures the amount of signal crossing between channels. The requirement is very different between singlemode, 50 dB, and multimode, 20-40 dB. Poor optical component quality is the main cause of high crosstalk.

Singlemode vs. multimode
Singlemode fibers carry optical beams in their purest form, a mathematically perfect Gaussian profile. They provide a bandwidth far wider than multimode with much lower loss over distance. With the advancement of WDM technology and the increasing availability of components at lower cost singlemode fiber has become more and more popular. Singlemode systems offer far superior upgradability to higher bandwidth. Overall, multimode systems still offer the cost advantage over singlemode system with similar performance.

Size
The history of passive fiber optic components has proved that size does matter. In fact, size reduction has long been one of the driving forces for innovation. Princetel has successfully created the smallest single channel FORJ, the MicroJx series of FORJs, with overall dimensions at a fraction of their competing counterparts. Our dual-channel and multiple-channel FORJs are also competitive in their overall dimensions.

Pigtails vs. receptacles
Like fiber optic attenuators, a FORJ can be packaged with either pigtails or receptacles on both ends of the device. The pigtailed version typically has better optical performance since it eliminates the variations in connectors and contamination of the connector joints.

We recommend the pigtailed version to most of our customer for those reasons. However, for applications that do not allow fixed pigtails on the device, we do offer both FC and ST format receptacles in our R series FORJs. One can even mix and match pigtail and receptacle in one device to create his own configuration.

Oil filling
FORJs have been used widely in undersea applications where water tightness and pressure equalization are important. Oil filling can be a good solution. Some users even find oil filling useful in land-based applications where moisture and dust are to be avoided. At Princetel we employ oils that can operate at extreme temperature range.

Applications
FORJs are widely used in robotic systems, remotely operated vehicles (ROVs), oil drilling systems, sensing systems, medical instruments, broadcasting, and many other field applications where a twist-free fiber cable is essential. Combined with electrical slip rings or fluid rotary joints, FORJs add a new dimension to traditional rotary joints. As fiber optic technology advances, more and more traditional slip ring users will benefit from FORJs in their new fiber systems.

Custom designs
All our FORJ products can be custom made to meet specific requirements. Call us if you do not see an immediate solution on our website. You may be surprised on how much we can make your job easier.