Bidirectional dynamic data transmission through a rotary interface

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Abstract. A multichannel bidirectional dynamic data transmission system (DDTS) through a rotary interface with one fiber is designed based on a fabricated single pass fiber optic rotary joint. The feasibility of transmission system is tested at both 1310- and 1550-nm wavelength bands. The performance of this DDTS was measured using optical spectrum analyzer and lightwave multimeter. The insertion losses of DDTS were 1.55 and 1.20 dB at 1310- and 1550-nm wavelength bands, respectively. The total bandwidth of the DDTS is more than 170 nm. © *2005 Society of Photo-Optical Instrumentation Engineers.* [DOI: 10.1117/1.1906235]

With the rapid development of communication, a high-speed, rotating-to-fixed dynamic data transmission system (DDTS) is needed in some fields. Usually, a fiber optic rotary joint (FORJ) can be used to transmit both analog and digital signals through a rotating interface. Compared with electrical slip rings, FORJ is immune to electromagnetic interferences,[1] but has the disadvantage of high manufacturing and assembly cost.

To ensure that the optical signal is efficiently transmitted, both ends of the single-mode fiber are required to be held very closely and in proximity so that a minimal amount of light is lost in the gap.[2] In this letter, a single-channel FORJ was designed using C-lenses, the working principle and structure of which are similar to those of graded-refracted-index (GRIN) lenses.[3] Compared with GRIN lenses, the insertion loss of C-lenses is better when the working distance is longer than 50 mm.[4] Through precise mechanical design, the insertion loss of single channel FORJ is less than 2 dB at either the 1310- or 1550-nm wavelength. To enhance the capability of the FORJ, a
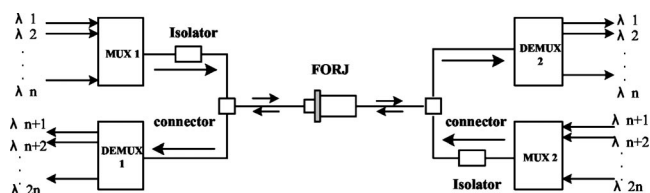

Fig. 1 Principle of dynamic data transmission system.

wavelength division multiplexing (WDM) technique was adopted to increase the signal transmission capacity.[5]

The working principle of DDTS is shown in Fig. 1. The wavelengths λ_1, λ_2,...,λ_n are first sent to WDM multiplexer 1 (MUX 1) where the input signals are combined into an optical single-mode (SM) fiber. Then they are sent to an isolator where the input signals are isolated from the output signals from the FORJ to reduce the noise of the dynamic transmission system. The optical signals arrive at the FORJ through the connector and are transferred across a rotating interface. Finally the received light is demultiplexed and sent into the output channels. In this way, multichannel signals from a rotary platform can be transferred to the stationary platform. At the same time, the wavelengths λ_{n+1}, λ_{n+2},...,λ_{2n} at the other end of DDTS are transmitted to MUX 2 and the input optical signals arrive at the FORJ. Then the input optical signals pass the rotating interface through the optical isolator and connector. Finally the λ_{n+1}, λ_{n+2},...,λ_{2n} are transmitted into the output channels by DEMUX 1. Because the optical components including the FORJ are all bidirectionally operable and passive components, the DDTS supports bidirectional optical transmission as well as a data transfer rate of hundreds of Gbps.

To test the feasibility of the multichannel bidirectional DDTS, an optical signal transmission system on both 1310- and 1550-nm wavelengths was designed and fabricated. A 1310/1550-nm WDM is used as the wavelength MUX and DEMUX. A 1550- and 1310-nm laser diode (LD) serve as the input light source. The 1310- and 1550-nm operating wavelengths are sent into the DEMUX/MUX in two oppo-
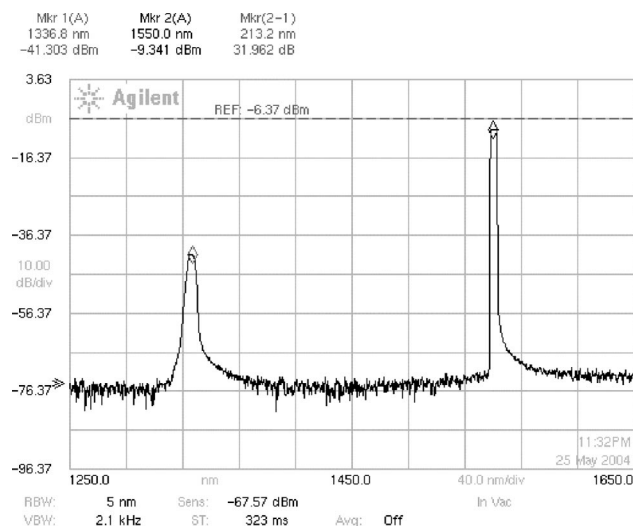

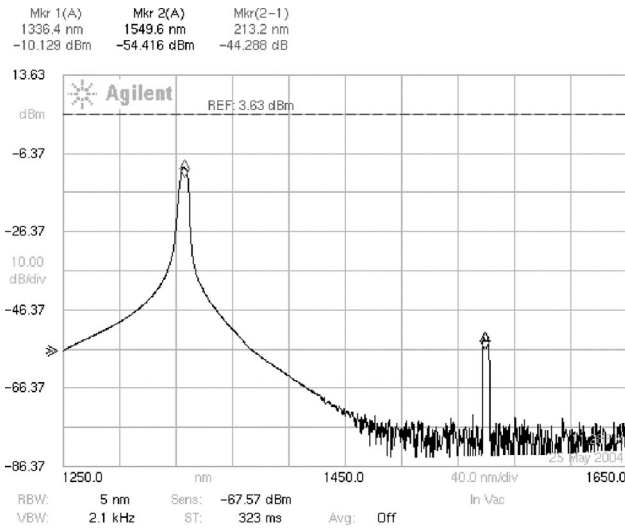**Fig. 2** Output 1 spectrum of DDTS.

Fig. 3 Output 2 spectrum of FORJ.

Fig. 4 Relationship between the insertion loss of DDTS and its rotation angle.

site directions. We use optical spectrum analyzer (OSA) and lightwave multimeter (LM) to measure the insertion loss of each output channels and inspect the output spectrum. When the FORJ is rotating, λ_1 and λ_2 are sent to the FORJ simultaneously. The spectrum of output 1 is shown in Fig. 2. There are two peaks in the optical spectrum of output 1, with center wavelengths of 1310 and 1550 nm, respectively. The power of optical signal centered at 1550 nm is 32 dB higher than that at 1310 nm in output 1. Similarly, there are also two peaks in the optical spectrum of output 2 (shown in Fig. 3) and the tested isolation between the 1310- and 1550-nm optical signals of output 2 is more than 44 dB.

The insertion loss of the output channel of the system is measured at different rotation angles. The measurement results are shown in Fig. 4. The maximum insertion loss of output 1 is 1.2 dB and the insertion loss of output 2 is less than 1.55 dB. The main reason for larger insertion loss of output 2 compared to output 1 is the better isolation of the 1550-nm channel than the 1310-nm one. Compared to the FORJs reported in Refs. 6 and 7, this design is cost-effective and has a low insertion loss.

The effective bandwidth of DDTS is defined as the difference of the maximum wavelength and minimum wavelength where the insertion loss is 3 dB larger than its minimum value. Since the tested insertion loss of this DDTS is less than 2 dB at both wavelength bands, the bandwidth of the DDTS is more than 130 nm at the 1550-nm wavelength window and more than 40 nm at the 1310-nm wavelength window. Therefore, the effective bandwidth of DDTS is more than 170 nm, which allows hundreds of channels to be used to transmit dynamic data.
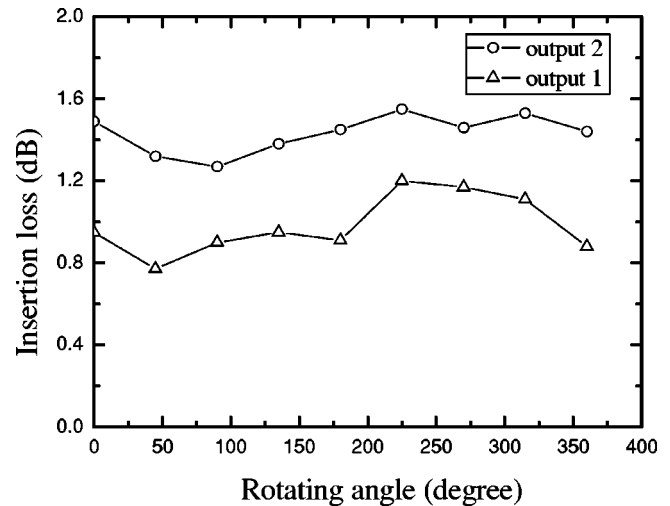
To summarize, a multichannel bidirectional DDTS using WDM technique is designed based on a single-channel FORJ. The feasibility of this DDTS was tested at both the 1310- and 1550-nm wavelength bands. The performance of this DDTS was monitored using OSA and LM. Across the rotating interface, it can bidirectionally transmit a large number of dynamic optical signals with insertion loss around 1.55 dB at the 1310-nm wavelength band and 1.20 dB at the 1550-nm wavelength band. The performances of this DDTS using WDM technique meet the bandwidth requirements of optical fiber communication systems.

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