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Expanded Beam Connectors for Single Mode Optical Fiber Sensor Applications in Aerospace

Sébastien Claudot¹ Xavier Insou^{1,2} Lionel Quélet³ and Monique Thual²

¹Souriau, ITD, Eaton, Champagné, France

²Institut Foton, CNRS UMR6082, University of Rennes 1, Lannion, France

³IDIL Fibres Optiques, Lannion, France

sclaudot@souriau.com, lionel.quetel@idil.fr, monique.thual@univ-rennes1.fr

Abstract

We propose an expanded beam micro lens in standard single mode connectors, compliant with aerospace connections. Low Insertion loss, high return loss and relaxed alignment tolerances compared with Single Mode Fiber (SMF) are demonstrated in C and O band. We give some sensing application cases in aerospace domain.

1. Introduction

Connections in harsh environment are key elements in the composition of the measurement line in single mode optical fiber sensors. For example, in the ASHLEY European project (Avionics Systems Hosted on a distributed modular electronics Large scale dEmonstrator for multiple tYpes of aircraft), different optical sensors are implanted in multiple types of aircrafts. One of the biggest challenges is often to couple light through the sensor device [1].

A solution to realize harsh single mode connectors is to increase the mode field diameter at the fiber output. This extension is generally obtained by using ball or hemispherical lenses at the end of the fibers [2]. This technique is interesting but not optimized in terms of insertion loss and return loss, it also needs a specific connector housing. In this article, we propose an innovative solution to increase the beam diameter with low insertion loss, low reflectance and good repeatability by using standard connectors.

First, we give the concepts and principle of this solution, then we integrate it in standard connectors. Finally, some optical fiber sensor applications pointing out the interest of these expanded beam connectors are given.

2. Theoretical concepts and principle of expanded beam connectors

Due to their very small Mode Field Diameters (MFD), SMF are very sensitive to contaminants, laser power and alignment defaults when injecting signal from one fiber to one another whatever the application as illustrated in Fig.1.

Expanded beam micro-lenses are very useful to relax lateral and axial positioning tolerances as can be seen in Fig. 1, where defaults that lead to 1 dB excess loss are calculated with equations extracted from ref [3] for different kinds of expanded Gaussian beams whose MFD are 55 and 113 μm , compared with SMF of 10.5 μm MFD at a wavelength of 1550 nm. The lateral positioning tolerances are relaxed from 2.5 to 26 μm , the axial one from 57 to 6250 μm with a 113 μm MFD expanded beam compared with SMF. But the angular alignment decreases with expanded beam from 2.6 to 0.25°.

Then a MFD around 55 μm is a good tradeoff to relax lateral and axial positioning tolerances without decreasing the angular ones compared with SMF. For the same reasons, expanded beams are less sensitive to high power and contaminants such as dust which is a major issue in aerospace applications.

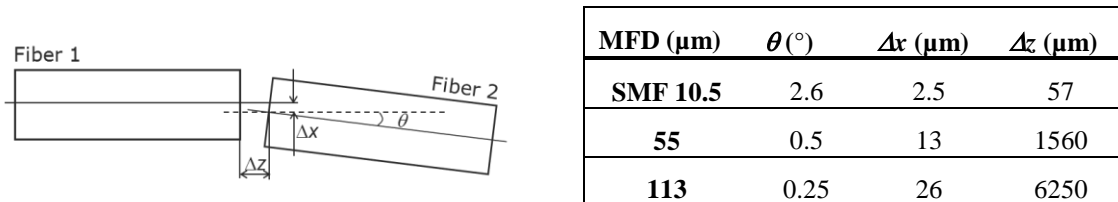


Fig. 1: Positioning defaults between two fibers (left side, lateral Δx , axial Δz or angular $\Delta\theta$) and tolerances for 1dB excess loss @ $\lambda=1550\text{nm}$ (right side)

A solution to achieve such an expanded beam at a SMF fiber output consists in splicing a parabolic lateral Graded Index Fiber (GIF) to a SMF and to cut the GIF, at a length from the splicing, where the wave front is plane at the fiber output and the working distance is null.

3. Integration of expanded beam fibers in aerospace sensor system

Expanded beam fibers can easily be integrated as standard single mode connectors such as LC or even a multipoint one, as can be seen in Fig. 2 showing a picture of a aerospace grade connector with two expanded beam fibers. The fibers are glued and polished in connector ferrules with a standard procedure and conventional optic fiber polishing machines compatible with mass production. This operating mode authorizes repeatability in terms of optical coupling loss as low as 0.5 dB from O to C band and optical return loss as high as 65 dB [4].

More, only one microlens fiber can be used as a simple collimator allowing better interaction of the light with any gaseous, liquid or solid medium [5]. In the same way, sensitive functions can be added in between the fibers thanks to the relaxed axial and lateral positioning tolerances. In the future, multimode fiber spliced between two single mode fibers could be a way for low-cost and simple interrogation technique as studied in [6].



Fig. 2: Example of multipoint aerospace grade connectors with expanded beam fiber

Temperature sensing is a major application case in aircrafts : fire alarm in the turbofan engine, bleed-air overheat detection inside the cabin or health monitoring of high power distribution lines through the wing. Distributive Temperature Sensing using Rayleigh technology (DTS) or multipoints heat probe as Fiber Bragg Grating technology (FBG) can overcome existing systems but request to limit optical reflections from its several cable sections connected all together. The GIF-lens expanded beam connector is a ideal solution to preserve the system performance over all its lifetime.

5. Conclusion and Discussions

We have theoretically analyzed and experimentally demonstrated the use of innovative expanded beam fibers integrated in standard connectors for SM optical sensor applications with low insertion loss and low reflectance. The connectors authorize transmissions in a broad range of wavelengths (>200 nm) and should also support higher power than SMF (for electrical sensors powered by light). Due to its specifications, such connectors can be used in a large range of applications including thermal monitoring of power link for future more-electrical-aircrafts.

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