Single Mode Graded Index Expanded Beam Connectors For Optical Sensor Applications In Harsh Environment

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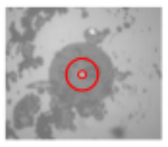
Abstract :

- Single-mode standard connector with expanded beam micro lens. Simple to integrate.
- Low insertion loss and low reflectance in C and O bands. Less sensitive to contaminants.
- Relaxed alignment tolerances compared with standard SMF.
- Validated solution for Fiber Bragg Grating (FBG) optical sensors arrays.
- Applications: harsh environment, optical fiber sensor applications.

1. Introduction

— Context —

- Single mode fiber optic connectors (SMF)
- FBGs sensors arrays
- Harsh environments



Wind turbine equipped with FBG sensors

— Issues —

- Very small beams diameters (10µm)
- Low fluid resistance
- Significant losses in the presence of contaminants
- Very critical axial and lateral positioning tolerances

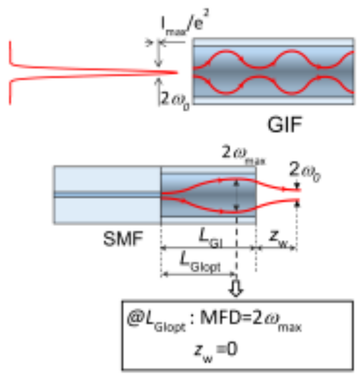
— Objectives —

- Robust connections in harsh environment
- Low coupling losses
- Low reflections
- Relaxed alignment tolerances
- Very competitive cost

2. Theorical concepts and principle of the solution

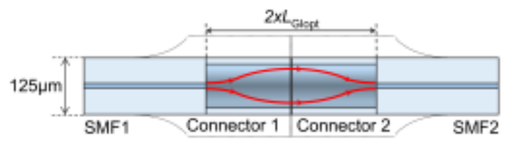
— Expanded beam micro lenses —

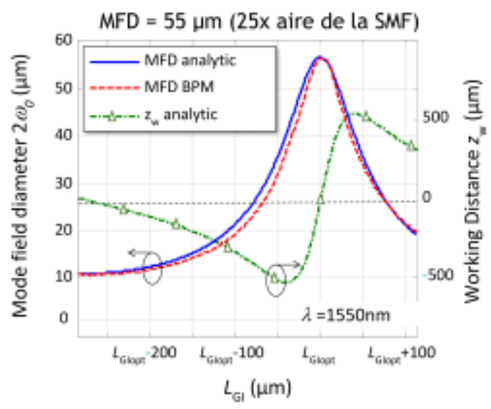
- Gaussian beam: periodic variation of the Mode Field Diameter (MFD=2ω0) and working distance zω in the Gradient Index Fiber (GIF)
- Analytical simulations and BPM (Beam Propagation Method)
- Maximum MFD for LGI = LGIopt and zω = 0
- LGIopt depends on the GIF profile
- SMF-GIF clived at LGIopt of the splice
- Alignment tolerances at 1dB: anglular θ, lateral Δx, axial Δz



Connector Type	θ (°)	Δx (µm)	Δz (µm)
Connector SMF	2,6	2,5	57
Connector 55 µm	0,5	13	1560
Connector 110 µm	0,25	26	6250

— SMF-GIF Connector —

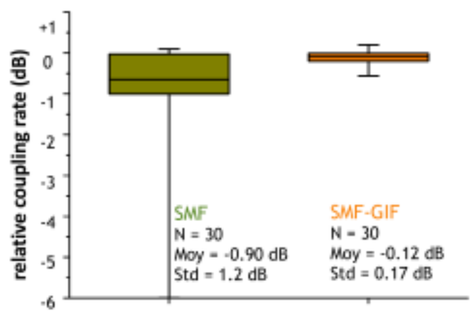




3. Tests results in harsh environment - Tests have been realized with the MFD 55 µm design

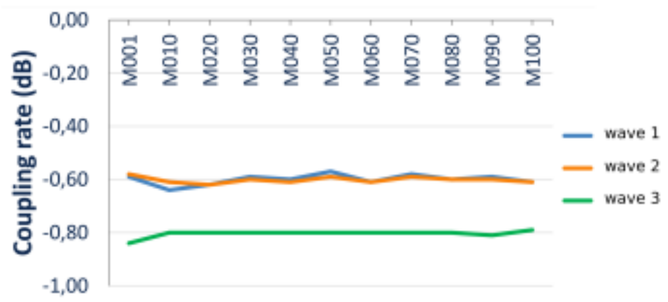
CODEF Connector with two expanded beam fibers (hardened fiber connectors by expanded beams) for harsh environments, integrating SMF -GIFcontacts

— Coupling losses variation in contact with contaminants —



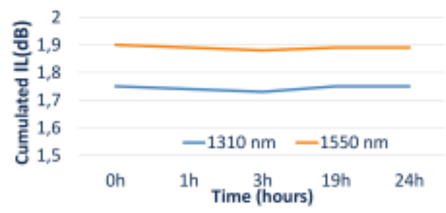
- Oil, water and dust on 1 channel @1550 nm
- SMF-GIF better than SMF in the presence of contaminants

— Endurance during operations —



- 3 waves connector CODEF undergoing 100 matings without cleaning
- Stable coupling rate @1550 nm

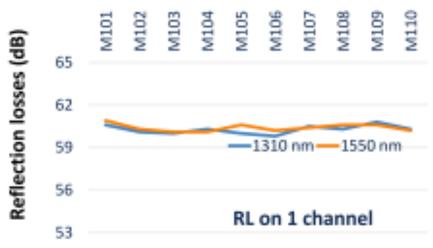
— 90% humidity at 40°C —



- 3 waves connector cascaded during 24h
- Insertion loss measurement (IL)
- No deviation of the optical link budget in moist heat atmosphere

— Reflectance stability during operations —

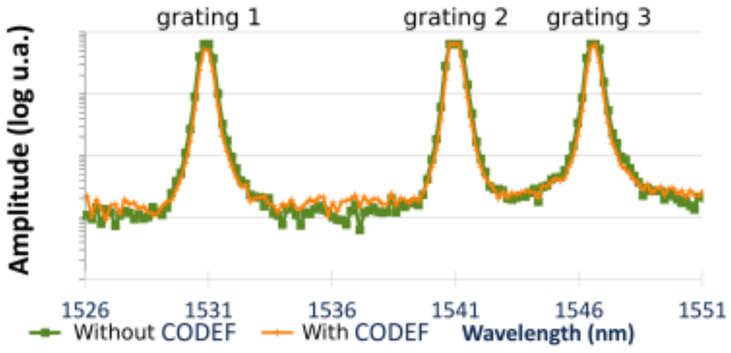
- 10 matings realized, return losses measurement (RL)



OCWR measurement. Dynamic 65 dB
Precision ± 1 dB. Resolution 0.1 dB
Standard "IEC 61300-3-6 Method 1"
Repeatable RL at ± 0.5 dB

— Optical sensor test —

- No spectral deviation of the sensor with 3 FBGs array and the use of expanded beam connectors (CODEF)



— Schematic view (below) & picture (down) of the tested system —

Dynamic 30 dB
Precision ±30 pm
Resolution <1 pm

4. Conclusion & expectations

- Single-mode connector with fiber-to-fiber contact: graded-index expanded beam micro lens.
- Large mode diameter: robust to contaminants (oil, water, dust). Low insertion loss (<1dB) and low return losses (~60dB), without anti-reflective coating, conserved properties from band C to band O.
- Relaxed lateral and axial positioning tolerances. Connectors easy to manufacture and reproducible.
- Very good behaviour in harsh environment: robustness to contaminants and aggressive environments. Strong performance stability during and after exposure.
- Applications: FBG optical sensors arrays in harsh environment; temperature, pressure, elongation sensors.
- Expectations: power transmission on SMF up to few tens of watts, integration on moving pieces such as rotating connectors.