High Power Connectors

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Abstract: The recent tendency to increase the power in optical transmission systems requires the development of connectors with a higher damage threshold power. A singlemode connector designed to lower the power density to a harmless value using an expanded beam technology is presented in this work.

1 Introduction

As the traffic in the communication networks is getting denser every day, the power used in optical fibers is increasing constantly. Three years ago the maximum power used in a singlemode fiber was 10 mW, but now it has raised to 500 mW or even more.

This fast raise has mainly been caused by the demand of higher bitrates and longer transmission distances, which led to the development of new technologies that contributed to increase the power level. The introduction of Dense Wavelength Division Multiplexing has played an important role in this regard: allowing the transmission of several low-power channels at different wavelenghts over a single fiber, DWDM multiplies the power of every channel by the amount of channels up to a total power of several hundreds of mW.

New EDFA's and Ramam amplifiers also contribute to the power raise, beeing able to deliver more than 1 W of signal power over a singlemode fiber.

At the present time the only limitation that hinders the use of higher power in singlemode fiber communication systems is the physical limit of the fiber itself, namely nonlinear effects that cause signal distorsion, depletion and crosstalk between different channels.

2 The High Power issue

The transmission of high power signal through singlemode fibers raises new challenges not only for the fiber manufacturers, but for the in-line components manufacturers as well. Within the core of the fibers and in the areas where the light beam is focussed, the power density can reach more than 10 GW/m2 (as a reference, this is more than hundred times the power density dissipated on the surface of the sun). This can have catastrophical consequences for the materials that cannot withstand such a high power density.

One very critical component is the singlemode connector. Good connectors provide only a very reduced hindrance to the transmitted signal (the best connectors guarantee a maximum attenuation as low as 0.1 dB). This small losses are mostly induced by a mismatch of the fiber core parameters (numerical aperture, diameter) or a lateral and angular misalignment, and the energy that gets lost this way is not a threat to the connector reliability, as it is dissipated through the fiber cladding.

Problems begin when the connectors are not perfectly clean. Contamination particles that are located at the connector interface can absorb part of the transmitted energy and convert it to heat. When the heat produced this way is high enough, the temperature of the fiber can raise over the melting point of silica, causing the collapse of the connection. Fig. 1 shows a standard singlemode fiber that has burnt as a result of the presence of a contamination particle.

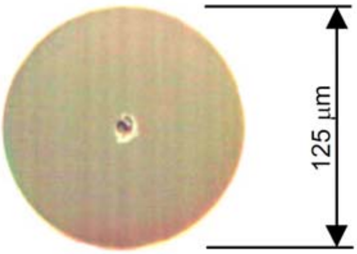

fig. 1 Burnt singlemode fiber

2.1 Contamination particles

The most dangerous contaminants are solid specks that are produced by wear of the alignement sleeves when ceramic ferrules are insterted, particularly in case of metal or plastic sleeves. Other dangerous contaminants are dust and other particles that are introduced from the external environment when the connectors are disjoined.

Calculations based on heat conduction formulas show that even extremely small contamination particles have a destructive potential, as displayed in Fig. 2.

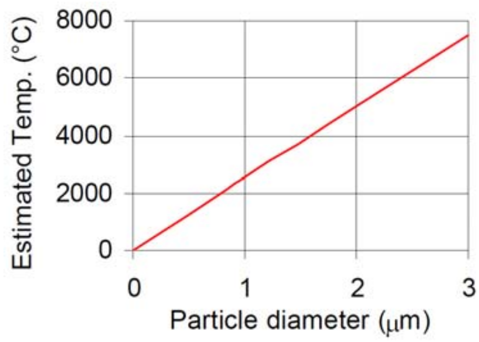

fig. 2 Temperature in a SM fiber core with 1W signal assuming a 100% light absorbing particle

This calculations have been confirmed by field experience, where many connectors have been reported to fail even when used in a clean and controlled environment.

To avoid these problems, a connector that has to bear high power signals must ensure perfect cleanliness conditions. A visual inspection of the ferrule's endfaces before every mating is essential. There shouldn't be any metallic wear parts; metal sleeves and threads are to be avoided. When the connectors are unmated, there must be a protection cap for the ferrules, in order to avoid any contamination on the fiber. The mating adapter must also have a protection cap to prevent dust particles to enter the sleeve. At present Diamond's **E-2000™** connector is the only connector that offers all these features (Fig.3)

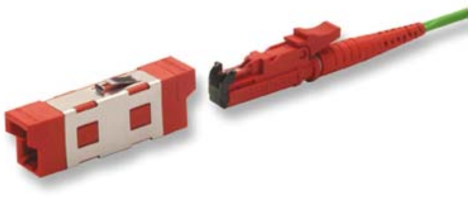

fig. 3 E-2000™

3 High Power Expanded Beam Connector

Cleanliness the above mentioned features are still not sufficient to guarantee a flawless functioning of the connectors, as small particles that may be overlooked with a field inspection microscope could still cause the connector to fail. The only way to eliminate this risk is to reduce the power density at the connector interface, i.e. to enlarge the beam diameter. For this reason we propose a new connector design based on expanded beam technology.

Expanded beam connectors that use collimating lenses have been on the market for many years. They are constructed to be used in harsh environments, so they usually have rugged bodies and provide high insertion loss values. The purpose of this project was therefore to construct an expanded beam connector that has the same dimensions, optical characteristics and ease of use as a standard SM connector.

The solution is to use a piece of gradient index fiber instead of an external lens to collimate the light beam. This way the expanded beam system can be integrated in a standard 2.5 mm or even in a 1.25 mm ferrule, as displayed in Fig. 4.

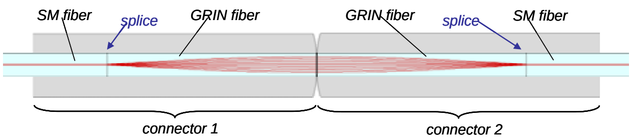

fig. 4 Expanded beam connectors based on gradient index fibers

The GRIN fiber is spliced to a standard SM fiber and cut at the right length in order to achieve the desired focal length. At the connector interface, the beam is collimated and has a large mode field diameter, dependent on the magnification of the GRIN fiber. In the other connector, the second GRIN fiber focusses the beam back to the SM fiber.

In order to achieve low IL values, as with every collimating lens system, the focal length and the direction of the output beam must have very tight tolerances. While the focal length can be easily adjusted through polishing of the ferrule endfaces, to straighten the beam direction is a more difficult operation. However this problem can be solved with style basing on Diamond's proprietary second crimping technology. The fiber is glued into a sleeve made of a soft nickel alloy, which can then be deformed in a determined direction to adjust the fiber position. Usually this technology is used to reduce the core excentricity in standard SM connectors, but in this case it can as well be employed to reduce the deviation angle of the output beam. Fig.5 shows an example of the effects of this technology on a GRIN fiber Expanded Beam connector.

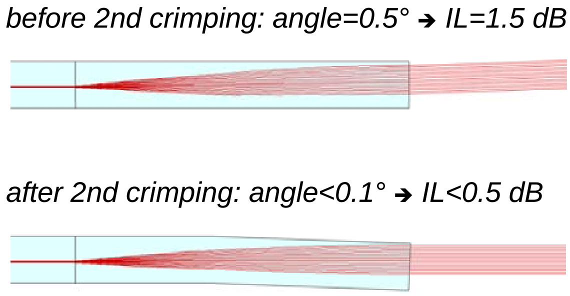

fig. 5 Attenuation of a GRIN Expanded Beam connector before and after 2nd crimping of the ferrule

As displayed in Fig.5, the high signal attenuation due to the deviation angle can be lowered to a very low value by tilting the fiber. As long as the collimation is right and the angle can be kept below 0.1°, the IL is lower than 0.1 dB.

3.1 First results

Tests have been done with different kind of GRIN fibers, that offered spot enlargements from 30 to 110 mm. The connectors with the largest magnification produced a lower power density, while the ones with the lowest magnification offered better transmission efficiency because of lower optical aberrations. The optimum solution was somewhere in the middle, and we choosed a 40 µm enlargement. Fig.6 displays the effects of contamination particles on a High Power Connectors with a 40 µm spot diameter (compare with Fig.2).

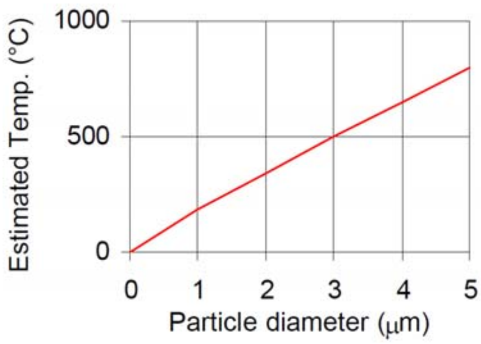

fig. 6 Temperature in a 40um GRIN fiber with 1W signal assuming a 100% light absorbing particle

4 Conclusion

We presented a connector that can withstand high power signals (up to 1 W) and show low insertion loss value (similar to standard SM connectors). This connector is based on expanded beam technology. A piece of gradient index fiber is used as collimating lens. The connector body is a E-2000™ connector that offers a good protection of the ferrule from the environment thanks to its protection cap.