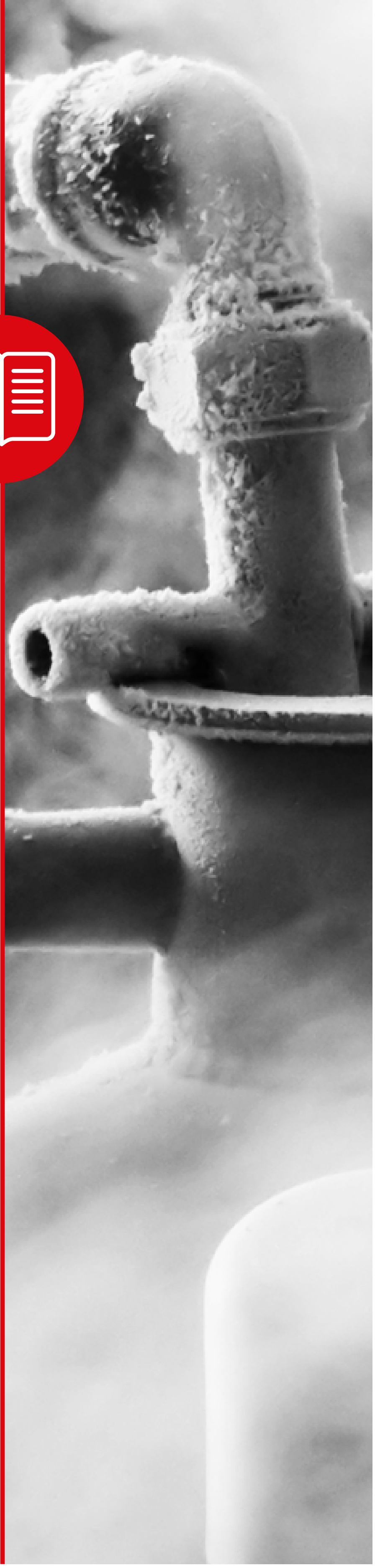
WHITE PAPER



FISCHER FIBEROPTIC AT CRYOGENIC TEMPERATURES

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REIMAGINING CONNECTIVITY TOGETHER

FISCHER FIBEROPTIC AT CRYOGENIC TEMPERATURES

THIS PAPER DISCUSSES THE PERFORMANCES OF A FISCHER FIBEROPTIC SERIES CONNECTOR WHEN TESTED AT 1.9 KELVIN.

The test was performed at CERN's cryogenic facility (SM18) under the EuCARD-2 Transnational Access program. It was co-funded by the partners and the EC-Capacities-FP7 under Grant Agreement 312453.

The objective was to measure the robustness of the connector in the cryogenic environment. The connector is the interface between the data acquisition system and the fiber optic sensors used for measuring strain and temperature during the powering tests on the superconducting magnets. The Fischer FiberOptic connector linked the inside sealed cryostat with the outside environment. The temperature in the cryostat was slowly reduced, cooling the helium inside to superfluid helium phase at 1.9 K.

The results in terms of precision optical performances of the Fischer FiberOptic connector were conclusive.

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Jean Baptiste Gay is involved in the development of new products at Fischer Connectors. His main motivation is to provide the best technical expertise and solutions to respond to customers' needs.

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INTRODUCTION

CERN is developing tests for cryogenic instrumentation based on fiber optic sensors for temperature and strain monitoring for the new generation of superconducting magnets. These tests are carried out at temperatures of near absolute zero. This paper discusses the performances of a Fischer FiberOptic Series connector transmitting the signal from the sensor placed inside the cryostat to the outside environment.

Cool-down measurements were taken to quantify insertion and return losses. The optical performances described in this paper were conclusive. Some degradation in terms of sealing was observed and is also described in this report.

The use of fiber optic sensors in cryogenic conditions remains very rare. Nevertheless, the performances observed during these tests allow us to guarantee the use of our FiberOptic Series connector in other applications in extreme environments. One example is described at the end of this report.

TEST FACILITY

The SM18 facility at CERN is a world-leading magnet test facility for testing magnets and instrumentation at low temperatures (1.9 K up to 80 K) and up to high currents (20 kA).
Due to its extensive infrastructure and long-standing expertise, it has unique capabilities to carry out tests for instrumentation and superconducting magnets in vertical or horizontal test benches, and magnetic measurements of all types of accelerator magnets.

FIG.1

A real magnet test was conducted inside one of the large cryostats, one of CERN's vertical test stations.

TEST SET-UP

A cryostat consists of several mechanical layers in a big Dewar used to slowly cool helium to superfluid liquid helium phase at 1.9 K.

The lambda plate is the last mechanical layer within the cryostat. The temperature below the lambda plate is below 1.9 K and rises to 4.2 K above the lambda plate.

The Fischer FiberOptic Series connector was mounted through the lambda plate and the plug was immersed in the 1.9 K superfluid helium.

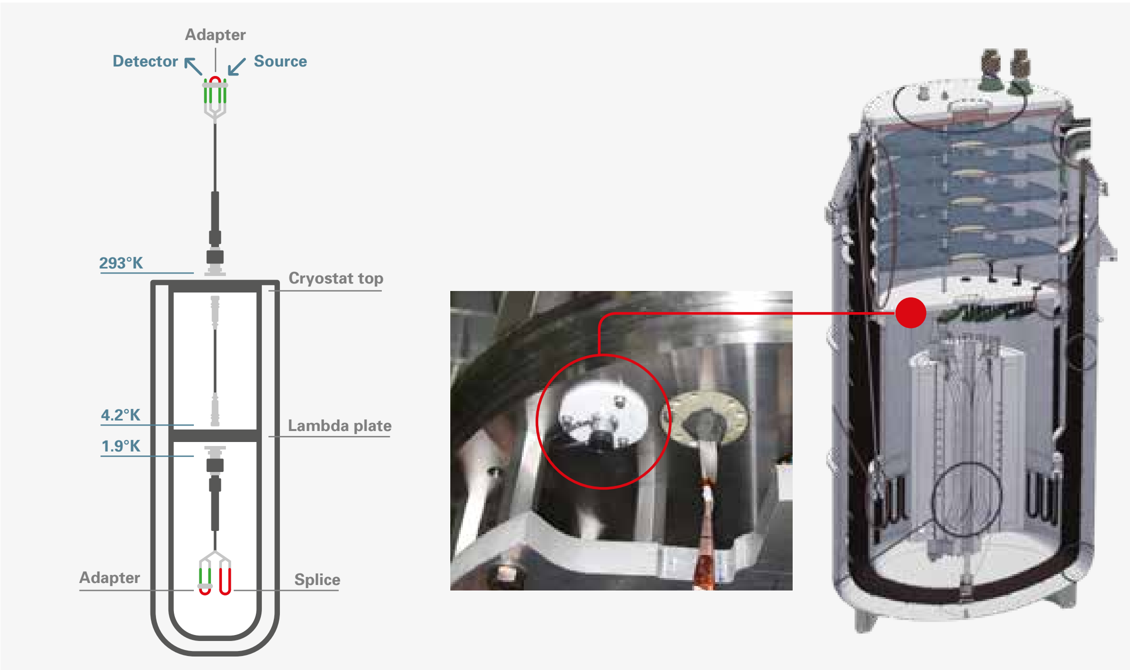


FIG.2

Optical Path of the test set up

The Device Under Test (DUT) is the sum of connections from 1 to 11.

For the purpose of this test, the connections numbered 2, 4, 8, and 10 refer to Fischer FiberOptic Series connections.

The connections numbered 3 and 9, that are a splice (3) and FC/APC (9), are also included in the 1.9 K measurements.

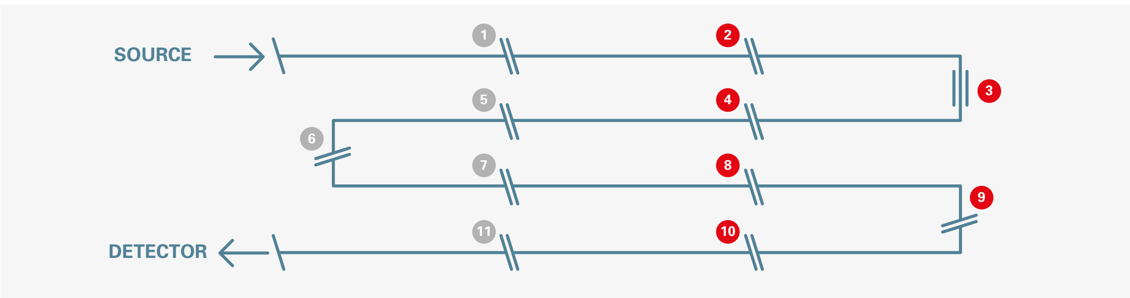


FIG.3

Since the measured insertion loss is the sum of **all 11 connections**, we should expect something around ≅ 2.2 dB (0.2 dB per contact x 11).

The BR5 Backreflection Meter by JGR Optics was used to measure and monitor the insertion loss change during the cool down.

The BR5 was programmed to record the following measurements every 10 seconds:

- Insertion losses at 1310 nm and 1550 nm wavelengths;
- Return losses at 1310 nm and 1550 nm wavelengths.

COOL-DOWN MEASUREMENTS

The cool-down took place over several days in phases. While it is impossible to achieve a perfect match between the temperature inside the cryostat and the measured insertion loss, what is known is the measurements that were taken at precise temperatures:

- Initial measure : 293 K
- Intermediate step: 68 K
- Intermediate step: 4 K
- Low temperature : 1.9 K
- After test: 293 K ➔ **reversible!**

The cool-down values in the intervals have been linearized, as a precise cool-down curve was not available.

Optical results

The change in temperature has very little effect on the insertion loss between ambient temperature (293 K) and 60 K. The observed drift is within the instrument's measurement accuracy. However, between 60 K and 1.9 K the insertion loss increases slightly.

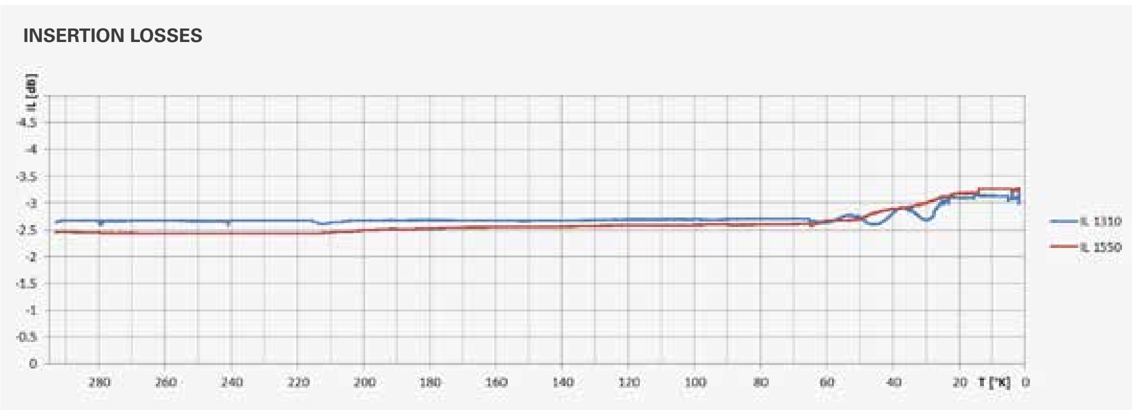
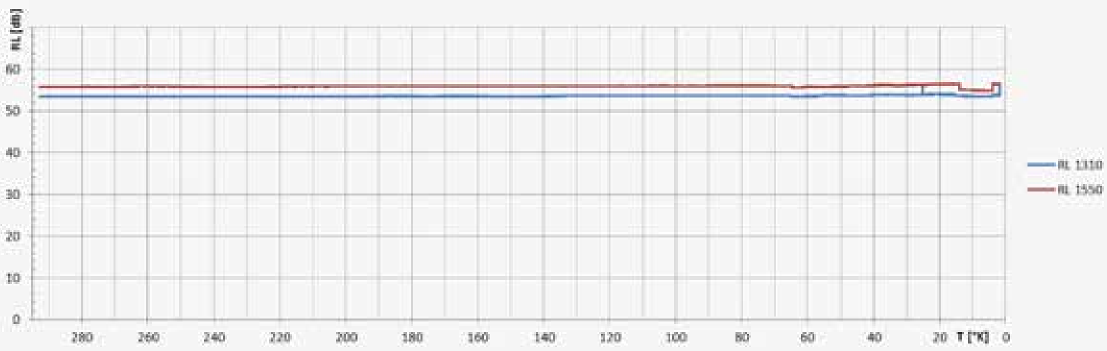


FIG.4

FIG.5

RETURN LOSSES



This increase has to be considered when using the sum of just six connections (2, 3, 4, 8, 9 and 10 in Fig. 3). Therefore, the average 0.6 dB increase can be divided by 6 ➔ reducing it to 0.1 dB per connection of IL increase. This is within commonly specified IEC norms: the loss increase has to stay within less than 0.2 dB during a test. Notably this test is not as described by the IEC Committee, as only 6 of the available 11 connections were measured, but the 0.2 dB increase can be extended.

The temperature has no measurable effect on the return loss performances. This means that the Hertzian contact conditions of the Butt Joint (technology used in the Fischer FiberOptic connector) physical contact remain preserved throughout the temperature range.

Sealing results

When a parts analysis was undertaken on the plug to assess for material degradation, it was noted that the only permanent effect had occurred on the sealing, which had slightly decreased. This can be attributed to thermal expansion stress on the epoxy that is used on the cable strain relief. The leak increase recorded is, however, very small and, therefore, most likely still acceptable for many cryogenic applications. (Increasing from 1*10-6 to 2*10-5 mBar*l/s on the DUT)

CONCLUSION

In conclusion, the test proved that the Fischer FiberOptic Series connector can operate at cryogenic temperatures.

Optical performances were only marginally affected, increasing the IL by 0.1 dB per contact. It is also noteworthy that the increased insertion loss only occurred at cryogenic temperatures (1.9 K) and reverted back once the temperature had returned to ambient temperature (the measured IL was exactly the same before and after the test).

This test serves as an excellent baseline measurement for further testing and gives us a good starting point for investigating fiber optic interconnect solutions for other cryogenic applications.

One such application could be LNG pipelines, where temperatures can drop to approximately -180°C. In this situation, as demonstrated in the CERN tests, optical fiber can be used to monitor temperatures along the pipeline even in extreme cold.

FISCHER **FIBEROPTIC** SERIES

ABOUT FISCHER CONNECTORS

Fischer Connectors has been designing, manufacturing and distributing high-performance connectors and cable assembly solutions for more than 60 years. Known for their reliability, precision and resistance to demanding and harsh environments.

Fischer Connectors' products are commonly used in fields requiring faultless quality, such as medical equipment, industrial instrumentation, measuring and testing devices, broadcast, telecommunication and military forces worldwide.

Primary design and manufacturing facilities are located in Saint-Prex, Switzerland, with subsidiaries and distributors located worldwide.

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