Application Note

Fiber Optic Temperature Array Sensors for Cryogenic Processes and Storage

THE CHALLENGE

The demand to effectively measure temperature fields or multiple temperature locations down to minus 253°C (20K) will increase with the increase in production, handling and storage of liquefied gases based on natural gas, biogas, green hydrogen etc. As example, it is foreseen that compressors, pumps, valves, heat exchangers, pipelines and storage tanks may need to be monitored in real time in order to:

- **Enable efficient process control**
- **Monitor levels of stored liquid gases**
- **Detect stratification of stored liquid gases**
- **Alarm in the event of a leakage**

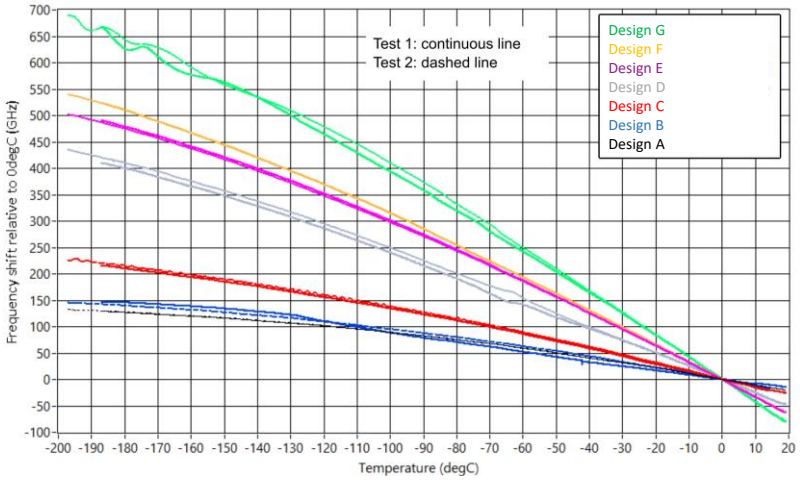
THE SOLUTION

Optical Fiber Bragg grating (FBG) sensors, in which measurements are made inside miniature (<=250µm) glass fibers, have a very small form-factor, support a large number of measurement points with a single sensing cable, are zero power so intrinsically safe, and work over an extraordinarily large temperature range. So, they are ideally suited to meet this cryogenic measurement challenge.

Fiber optic sensing experts Proximion has, therefore, decided to prioritize sensor research in this area combined with the development of customized solutions for cryogenic array sensors.

As an example, Proximion has screened the behaviour of various FBG, coating and encapsulation designs down to minus 196°C (77K) as seen in the figure to the right.

The aim is to have the in-house capability to quickly develop and deliver robust, customized FBG based sensors for measuring temperatures down to minus 253°C (20K).



Proximion screening test of the wavelength responses vs. temperature down to minus 196°C (77K) for various bare, coated and encapsulated fiber combinations.

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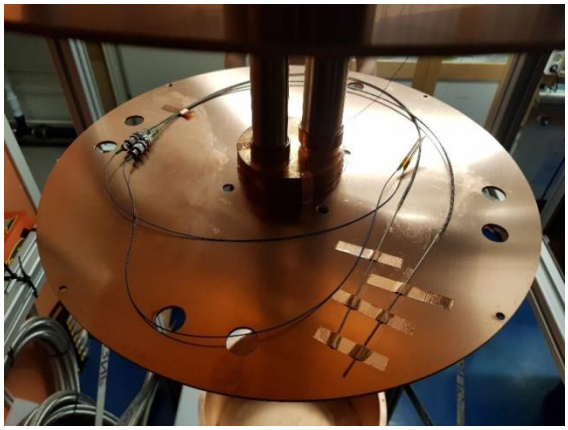
It is well known that the change in the refractive index of glass vs. temperature (the thermo-optic coefficient on which FBG temperature sensing relies) starts to flatten out below minus 173ºC (100K). Therefore, temperature measurement below this level needs to rely on changes in the FBG period caused by strain changes vs. temperature coming from the fiber itself (α_Λ), which are much less than the thermo-optic effect at higher temperatures. An accurate, low temperature sensor design, therefore, needs to combine this fiber effect with the strain effects coming from the combination of attached coating, substrate and encapsulation as generalized in the below equation:

$$[\frac{\Delta\lambda_B}{\lambda_B}] = (1 - p_e) \in + (\alpha_\Lambda + \alpha_n)\Delta T \; + \; coating \; + \; substrate \; + adhesive \; + \; encapsulation$$

$\frac{\Delta\lambda_B}{\lambda_B}$ – the relative shift in the Bragg wavelength; p_e – strain optic coefficient; $\in$ – applied strain; α_Λ – the thermal expansion coefficient of the optical fiber; α_n – the thermo-optic coefficient of the fiber; and ΔT – change in temperature.

This complex strain situation can to some extent be simulated but, in the end, needs to be accurate measured down to the working temperature of the sensor since internal strains from the manufacturing processes are also present. A cryogenic sensor should possess limited hysteresis effects, so these also need to be considered and tested in the development. Proximion has gained access to a cryostat that work down minus 253ºC (20K), or even below if required, for evaluation of sensor designs for various measurement setups and applications. Consequently, Proximion can be regarded as ideal partner for the development of customized cryogenic sensors.

It is expected that the first customized cryogenic temperature array designs from Proximion, working down to minus 20K, will have an accuracy of a few K with a resolution below 0.1K. The sensor designs for various applications and conditions will accordingly see different accuracy and resolution vs. design and cost requirements. This is something Proximion is in a good position to optimize according to customer demands based on its in-house written, customized and encapsulated FBGs combined with access to a state-of-the art cryostat testing facility.



Customized Proximion cryogenic sensor designs in a cryostat for testing of wavelength responses and hysteresis effects for an application working down to minus 253ºC (20K).

THE COMPANY

Part of the huge Hexatronic Group, Proximion AB designs and manufactures customized, high performance fiber optic sensor systems for use in numerous harsh environment applications proximion.com

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