Effect of Dopant Diffusion on the Long-Term Stability of Fabry-Pérot Optical Fibre Sensors

Dimitrios Polyzos, Jinesh Mathew, William N. MacPherson and Robert R. J. Maier

Abstract — We present a research to determine the long-term stability of intrinsic Fabry-Pérot (F-P) optical fibre sensors in high temperature environments. In-fibre sensors were created in 125μm diameter single mode fibre (Corning SMF28 Ultra) and a 125μm diameter PCF ESM-12B pure SiO2 fibre spliced to a SMF28 fibre with a low reflectivity Cr layer at the interface. The outcome is a low finesse optical cavity either formed by a short length of Ge doped SMF fibre, or a short length of pure and undoped SiO2 core PCF fibre. We demonstrate the manufacturing technique required for these intrinsic FP sensors as well as the stability of their optical characteristics at temperatures up to the range of 850°C to 1050°C. We report on the effect of annealing on stability after exposing sensors to temperatures of 1000°C above nominal working temperatures. In the temperature range above 900°C we observe increasing levels of non-reproducible drift characteristics. Stability is demonstrated up to 1000°C. After extended exposure of sensors to high temperatures we observe deviations from the initial smooth second order response of phase versus temperature which has been attributed to a change in core diameter in the fibre leading to the sensor at the distal end due to Ge diffusion at the high temperatures. The down lead is exposed to over a length of 17cm. The dopant diffusion of an SMF28 ultra fibre has been studied using Energy Dispersive X-rays analysis (SEM/EDX), to measure the radial distribution of Ge concentration before and after being heated for a period of 100 days.

Index Terms—dopant diffusion, high temperature, intrinsic Fabry-Pérot, optical fibre sensors, PCF, SMF28 ultra

I. INTRODUCTION

Optical fibre sensors have been used by industry in replacement of conventional electric sensors, as they are lightweight, highly sensitive, immune to electromagnetic radiation and they can be embedded in metallic components. Liquid level [1], refractive index [2], strain [3], pressure [4], temperature [5, 6] and a series of other measurands can be measured by optical fibre sensors. The optical fibre sensors are used in military services, biometric companies, civil engineering structural health monitoring, aircraft health monitoring and the oil industry [3]. Intrinsic Fabry-Pérot sensors have been extensively examined in our research to investigate stability at high temperatures. In our previous studies, we investigated a series of FP sensors with different sensing elements, such as a Ge-doped sensor, undoped pure SiO2 sensor, and F-doped sensor [7-9]. Germanium doping is the most common used method to create a refractive index contrast between core and cladding by raising the refractive index of the core material. However, the same effect can be achieved by depressed the cladding refractive index as in F-doped (F-SM1500SC-9/125-P). Ge and F dopants in optical fibres are known to have enhanced diffusing constants at high temperatures [10, 11]. The critical difference in the light of our research is that in the case of a Ge doped fibre we expect a reduction in Ge concentration by out diffusion of Ge into the surrounding SiO2 cladding and in the case of a F-doped cladding the in-diffusion of F into the core region.

Fused silica exhibits a strain point temperature in the region of 900°C to 1100 °C [12]. Exact values for this parameter in SMF-28 and SMF-28 ultra were not available, hence operation of fibre sensors in the region above 900°C will experience some level of interference from this parameter. This happens because of the single or multiple fusion splicing process carried out to join up the distal fibre sensor end to the interrogation fibre and indeed, throughout our previous experiments reported in [8, 9], we observed a drift in the sensor phase responses at temperatures above 900°C up to 1050°C.

Also, it has been noticed that the phase response of the FP sensor, started to exhibit modulations and deviations from a near ideal 2nd order polynomial as expected from theory, with the depth of modulations increasing over time when kept at high temperature. We postulate that the dopant diffusion affects sensor response, from the core to the cladding of the fibre and vice versa, which normally takes place after the sensor have been exposed to high temperatures for long periods of time. To address this characteristic, a new type of sensor whose sensing element (cavity length of the sensor) would be undoped. For that reason, we manufactured a pure SiO2 cavity FP sensor from a PCF fibre (ESM-12B) and tested it at high temperatures. This sensor’s cavity has no dopant neither to its cladding nor to its core. The results of these tests are presented in this paper.

Many papers have been published on dopant diffusion in optical fibres [13-15]. Preliminary results of germanium dopant diffusion have been published in our previous work [9]. We used an Energy Dispersive X-ray (EDX) Spectroscopy technique to measure the percentage of the dopant’s diffusion. We applied that to both of our sensors, Ge-doped and F-doped, however as fluorine is a low-z material it proved to be
problematic to be measured by EDX. So, after the first diffusion results we extended our analysis of Ge thermal diffusion tapering phenomena of the core along the heated optical fibre, which have been proposed in the literature [16, 17].

In this study, we demonstrate the manufacturing process for our FP sensors, as well as presenting an extensive long-term stability analysis (100 days) for a Ge-doped and an un-doped (pure SiO₂) sensor. Through this analysis, we aim to determine and understand the mechanisms of the limitations and benefits in of intrinsic FP sensors which make them suitable for temperature monitoring above 850°C. Moreover, we present a more detailed investigation on the dopant diffusion of an SMF28 ultra fibre using SEM and EDX techniques.

II. THEORETICAL BACKGROUND AND EXPERIMENTAL SET-UP

A. Intrinsic Fabry-Pérot (F-P) optical fibre sensor manufacturing

An FP sensor consists of two reflective parallel mirrors, with a well-defined spacing. For our fibre based FP sensors, one mirror is a ~3nm (15% reflectivity) [8] thin film of chromium sandwiched between two optical fibres which are spliced together, whereas the second mirror is formed from a bare fibre end (3.6% Fresnel reflectivity). The result, presented in Figure 1, is an integrated Ge-doped SMF28-Cr-SMF28 (Figure 1) with a cavity of 60μm.

The process for manufacturing the pure SiO₂ sensor follows the same sequence as above with small differences. A short piece of PCF fibre was spliced to a SMF28 as it can be seen in Figure 2. The reason of choosing PCF fibre was to collapse the air holes through the splicing process and form a short piece of pure SiO₂ fibre. This results in a short length 170μm (Figure 2) of pure SiO₂ spliced to a SMF28 fibre. The PCF-SMF28 formation was cleaved at a position close to the air holes (~150μm from the splicing joint). The collapsed PCF was then spliced to a cleaved, chromium coated SMF28 fibre which eventually formed a pure SiO₂-Cr-SMF28 sensor. Finally, cleaving the pure SiO₂ region at 55μm distance from the splice joint, results in a pure SiO₂ intrinsic F-P sensor (SiO₂-Cr-SMF28) with a cavity length of 55μm (Figure 3).

Figure 2. PCF optical fibre with a 170μm length of pure SiO₂ spliced to a SMF28 ultra fibre. On the left, we can see the still intact air holes which haven’t collapsed from the splicing process. The dashed line is the position we cleaved in order to extract the pure SiO₂ piece. The red straight line is the position of the PCF-SMF28 splice.

Figure 3 depicts an illustration of the half-length temperature profile of the furnace (Nabertherm RD 30/200/11) measured by an N-type thermocouple. Black data represent the experimental data, blue line is the theoretical exponential fitting function and the red dots are the position of each fibre’s piece measured with EDX technique.

Figure 4. Temperature longitudinal profile of the tube furnace (Nabertherm RD 30/200/11) measured by an N-type thermocouple. Black data represent the experimental data, blue line is the theoretical exponential fitting function and the red dots are the position of each fibre’s piece measured with EDX technique.

The splice intensity that was used for the SMF28 ultra fibre to the PCF fibre splice was 18.5W. The optimal splice intensity at the SMF28-Cr-PCF set-up is important, as the aim is to collapse the PCF’s air holes whereas in the same time maximum breaking splice strength is achieved.

B. Temperature profile of Nabertherm RD 30/200/11 tube furnace
III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Phase response during sensor’s cycling

Figure 5 illustrates the annealing process and testing cycles of the pure SiO$_2$ sensor for three different dates during the stability test. Figure 5(a) portrays the annealing process phase response of the sensor before starting the stability test. Figure 5(b) portrays a testing cycle phase response of the sensor two months into the stability test.

Figure 5. Annealing cycling and test cycles, phase response of pure SiO$_2$ sensor for three time periods during stability test. Graph (a) corresponds at the start of stability test annealing cycle, Graph (b) corresponds to the test cycle after two months have passed, Graph (c) corresponds to the test cycle after the end of the stability test and Graph (d) presents these three graphs together co-plotted.

Figure 5(c) portrays a test cycle phase response of the sensor at the end of its stability test, having been exposed to temperatures above 850°C for three months. Figure 5(d) displays these three phase responses co-plotted all together. The phase response with respect to temperature is not linear for either sensor, instead it follows a 2nd order polynomial behaviour, as the phase is directly correlated with the thermo-optic coefficient. Some of the working temperatures during the stability tests were close to the strain point of fused silica. Before the stability tests, the sensors are subjected to an annealing cycle at temperatures close to the strain point eliminating any thermal stress at the core/cladding interface. According to our previous work [8], any residual thermal stress at the optical fibre sensor’s response can cause a phase drift of less than 0.2 radians, which is translated to a temperature drift of less than 10°C, at temperatures close to fused silica’s strain point.

Table I displays the sensitivities of both sensors at 400°C, 700°C and 900°C. The Ge-doped sensor is 5μm longer than the pure SiO$_2$ one, which explains the slightly higher sensitivity of the Ge-doped sensor [7]. Through phase sensitivity a conversion of the phase units (radians) of the sensor to temperature units (Celsius degrees) can be achieved, which leads to an estimation of the sensor’s temperature drift in units of Celsius degrees.

All graphs represent a single cooling down process from 1000°C to 25°C at a rate of 1°C min$^{-1}$. As can be seen in Figure 5(d), the phase response of the sensor is stable over the three months of stability tests, confirmed by the fact that the three phase responses overlap each other. Nevertheless, within Figure 5(b) and Figure 5(c) modulations make an appearance, especially for temperatures above 200°C. We believe that these modulations come from a second order cavity that interferes with the signal of our fundamental cavity. This second order cavity is presumably correlated with expanding tapering phenomena of the core radius, caused by the germanium diffusion from the core to the cladding at elevated temperatures. These modulations make their appearance at all times during the annealing cycling up to 1000°C.

B. Long-term stability tests at high temperatures

After annealing, the sensors are ready for long-term stability tests. The maximum temperature that was reached at these experiments was 1050°C. In previous experiments the sensors were pushed further than 1100°C but the sensors showed large drifting due to exceeding of phase transition point of SiO$_2$ [8, 18].

Figure 6. Long term stability test of Ge-doped SMF28 ultra FP sensor (60μm). Each letter is referred to the stability test of Figure 7. The red dashed horizontal line indicates the phase at 900°C of the third stability cycle, whereas the red vertical dashed lines indicate the phase difference at 900°C, between the stability cycles.

Figure 6 and Figure 8 portray the 100 days long-term stability test of Ge-doped and pure SiO$_2$ FP sensor (60μm). Each letter is referred to the stability test of Figure 7. The red dashed horizontal line indicates the phase at 900°C of the third stability cycle, whereas the red vertical dashed lines indicate the phase difference at 900°C, between the stability cycles.

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Table I SENSITIVITIES OF SENSORS

<table>
<thead>
<tr>
<th>Type of sensor</th>
<th>Temperature 400°C</th>
<th>Temperature 700°C</th>
<th>Temperature 900°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure fused silica – PCF (55μm cavity)</td>
<td>5.87 mrad/°C</td>
<td>6.59 mrad/°C</td>
<td>7.32 mrad/°C</td>
</tr>
<tr>
<td>Ge-doped SMF28 ultra (60μm cavity)</td>
<td>6.69 mrad/°C</td>
<td>7.36 mrad/°C</td>
<td>8.4 mrad/°C</td>
</tr>
</tbody>
</table>

Table I displays the sensitivities of both sensors at 400°C, 700°C and 900°C. The Ge-doped sensor is 5μm longer than the pure SiO$_2$ one, which explains the slightly higher sensitivity of the Ge-doped sensor [7]. Through phase sensitivity a conversion of the phase units (radians) of the sensor to temperature units (Celsius degrees) can be achieved, which leads to an estimation of the sensor’s temperature drift in units of Celsius degrees.
Figure 7. Expanded stability test views of the Ge-doped FP sensor at 1000°C (a), 950°C (b), 1050°C (c) and 900°C (d). Each letter corresponds to the same letter in Figure 6. The red lines represent a 30-floating point averaging.

Figure 6 and Figure 8 present some indicative phase responses for various temperatures, such as at 1000°C (a), at 950°C (b), at 1050°C (c) and at 900°C (d). We normally categorize the long-term stability test in cycles, for example Graph (a) belongs to the cooling process of the 1st cycle, whereas Graph (b) belongs to the heating process of the 2nd cycle and Graph (d) to the cooling process of 3rd cycle.

Figure 8. Long term stability test of pure SiO2 FP sensor (55μm). Each letter is referred to the stability test of Figure 9.

Sensors don’t exhibit large drifts after they have been subjected to a stability test throughout the cooling process. This is happening due to thermal relaxation of the optical fibre at temperatures above 1000°C. Stability tests of Ge-doped and pure SiO2 are presented in Figure 7 and Figure 9, respectively. Each sensor exhibited a variety of phase drifts at different temperatures. For instance, Ge-doped FP sensor exhibited a drift of 2.5°C after 5 days at 950°C (b), whereas after 8 days at 900°C (d) the drift is 4°C. In comparison, the SiO2 FP sensor exhibited a temperature drift of less than 1°C, after being exposed to 1000°C for 3.5 days (a) and 8 days at 900°C (d). In addition, the SiO2 sensor showed a temperature drift of only 2°C after a period of 5 days at 950°C. At 1050°C both sensors showed a large temperature drift more than 10°C for a period of 5.5 days. At this temperature, it is difficult to predict the phase behaviour of the sensors, as it sometimes follows a periodic modulation and other times it is constantly drifting. The SiO2 FP sensor thus presents a better stability response compared to the Ge-doped FP sensor whereas operating below the softening point of SiO2. We attribute this to its lack of dopant in the sensing element.

Table II displays both sensors’ temperature drift during the stability tests at these four representative temperatures. The noise level of each sensor is peak to peak <4°C, whilst after a 30-point averaging the noise is reduced to one third of the original noise <1.5°C. The 30-point averaged plot is the narrow red line that can be found in Figure 7 and Figure 9.

The phase value of the Ge-doped FP sensor in Figure 6 (red dotted horizontal line) shows that the phase value of the sensor at 900°C, has a distinctive difference compared with the phase at the same temperature of the previous cycle. To illustrate this example, it was added red vertical dotted lines in Figure 6 which show the phase differences of Ge-doped FP sensor at 900°C, at the end of the 1st cycle, the 2nd cycle and the 3rd cycle. The red horizontal dotted baseline corresponds to the 3rd cycle’s phase value at 900°C. Δθ2 is approximately 0.25 radians and is the phase difference of the 3rd and 2nd cycle whereas Δθ1 is approximately 0.85 radians and represents the phase difference between the 3rd and 1st cycle. The same analysis can be applied at other temperatures such as 950°C and 1000°C.

Table II

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Type of sensor</th>
<th>1000°C (over 3 days)</th>
<th>950°C (over 5 days)</th>
<th>1050°C (over 5 days)</th>
<th>900°C (over 8 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ge-doped SMF28 ultra (60μm cavity)</td>
<td>9°C</td>
<td>2.5°C</td>
<td>18.1°C</td>
<td>4°C</td>
<td></td>
</tr>
<tr>
<td>Pure fused silica – PCF (55μm cavity)</td>
<td>&lt;1°C</td>
<td>2°C</td>
<td>11.4°C</td>
<td>&lt;1°C</td>
<td></td>
</tr>
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</table>

However, Figure 8 presents the long-term stability test of SiO2 sensor where is not detected any significant phase difference for the same temperatures between the cycles. This suggests that the lack of dopant diffusion in the pure SiO2 sensing element leads to higher stability whereas the sensing
element of the Ge-doped FP sensor experiences an effective refractive index shift as a result of dopant diffusion. This then influences the effective cavity length of the fibre, giving an absolute change to the recovered phase.

C. Experimental diffusion results

Based on the diffusion effect it is clear that dopant diffusion has the capability to cause an unpredictable change on the phase stability response of our sensor. To demonstrate that this effect is indeed occurring within these sensors it was necessary to measure the diffusion in the heated fibre. One of the FP fibre sensors was removed from the furnace and was cut in three pieces of approximately 9cm each, preparing them for polishing. Each piece of the fibre represents a specific position in the furnace. Thus, position 1 is the tip of the sensor which suffered from the maximum heating, position 2 is the middle of the fibre and position 3 was kept at room temperature throughout the stability tests. Figure 4 displays the positions of each fibre.

The polished fibre tips were used for SEM photos and EDX measurements. Multiple line scans for germanium detection along the full area of the fibre’s core, were applied. In that way, is presented a complete estimation of the germanium across the full core area and the adjacent cladding. Figure 10 (Graphs (a), (b) and (c)) portray the germanium percentage concentration for each line scan. Each graph represents a different longitudinal position of the heated fibre (Figure 4).

Graph (a) shows the germanium percentage (wt.%) of the fibre at position 1, associated with 1021°C. Graph (b) represents the germanium percentage (wt.%) of the fibre at position 2 which corresponds to 985°C and Graph (c) corresponds to the unheated fibre, position 3, of temperature 25°C. In addition, Graph (d) is a SEM image displaying the EDX series of line scans that were applied on the core area. The spacing between the line scans is roughly 2μm. The germanium concentration wt.% of the optical fibre is constant, meaning that it cannot escape from optical fibre’s design due to diffusion. The low step spacing resolution (~2μm) of germanium concentration linescans, justifies the lack of germanium profile spread out to the cladding presented in Figure 13. In addition, the experimental data were fitted with an exponential function which provides a suitable metric germanium distribution based on roughly 9 data points. More linescans, especially on the core/cladding interface, would increase the data points of germanium concentration and would show more accurately the spread out of germanium into the cladding.

According to optical fibre core expanded tapering theory the relationship of each fibre’s position in the furnace with the dopant diffusion is directly connected via the temperature gradient of the furnace illustrated in Figure 4. It is expected the fibres that have been exposed to high temperatures to exhibit a wide germanium distribution along the core and show low peak germanium concentration in the centre of the core. On the other hand, fibres that have not been heated at all, they will keep a steep germanium distribution with the highest peak sitting at the centre of their core.

The full width half maximum (FWHM) of each germanium concentration line scan of Figure 10 was calculated. The FWHMs are plotted with respect to the position of each scan. An illustration of position 3’s calculated FWHMs of the germanium concentration profile, can be seen in Figure 11. Additionally, a Gaussian fit to the FWHM profile of Figure 11 is applied, which simulates the overall FWHM of the germanium distribution profile for each fibre position. Although a Gaussian fit in Figure 11 is not very accurate it does provide a suitable metric to compare the diffusion of germanium at each position.

![Figure 11. Gaussian fit of each line scan FWHM of position 3 with respect to fibre radius.](image)

The Arrhenius equation [11, 15] has been used to estimate the diffusion coefficient of germanium diffusion towards cladding. Using the initial and final Ge concentration of the cladding presented in Figure 13.
sensor, our calculations showed a diffusion coefficient of \( D = 1.92 \times 10^{-19} \) m²/sec for an average temperature of 955°C extracted from the stability tests, which is highly divergent by the reported values found in literature [15]. This divergence can be explained by the long period of time (~100 days) and the large temperature range (850°C to 1050°C) of the stability tests, as priority of this work was the long-term phase stability investigation of the sensors at high temperatures.

Figure 12 shows the calculated FWHM of each position of the same fibre, corresponding to dopant diffusion plotted against maximum temperature. Position 1 of the fibre has been exposed to the highest temperature, and it is characterized by the highest FWHM value (FWHM=9.32μm) among the three positions. On the other hand, position 3, which has been unheated, should have the minimum FWHM value (FWHM=7.7μm).

Figure 13 displays the germanium concentration with respect to fibre radius for the three positions of the same fibre. In the same figure, the blue (triangle) data correspond to position 3 which hasn’t been heated at all, red (circle) data and black (square) data correspond to position 2 and position 1, respectively. As it is expected, position 1 has the minimum germanium dopant concentration (4.86 wt.%) whereas position 3 shows the highest germanium dopant concentration (8.1 wt.%). A Gaussian fitting function was applied to the experimental data of Ge wt.% concentration giving a rough estimated metric of the Ge distribution of each fibre’s position. Thus, germanium diffusion affects the core radius by making it larger, which can lead to expanding tapering phenomena and transformation of the single mode core to a multimode core, for specific wavelengths [17, 19].

![Figure 13. Germanium concentration of position 1 (black square data), position 2 (red circle data) and position 3 (blue triangle data) of the fibre with respect to fibre's radius.](image)

Through the combination of Figure 12 and Figure 13 results, it can be estimated the final radius of the position’s 1 fibre core. The radius of the core at position 3 is \( \alpha = 4.1 \mu m \) (Corning SMF28 Ultra) which corresponds to our experimentally measured values of 7.7μm and 8.1 for FWHM and germanium wt.%, respectively. For the fibre exposed to the maximum temperature (position 1) FWHM and germanium wt.% are 9.32μm and 4.86, respectively. By comparing the increase of the FWHM, from 7.7μm to 9.32μm, a rough estimation gives core’s size increase from \( \alpha = 4.1 \mu m \) to \( \alpha = 5 \mu m \). This then corresponds to the final radius of the fibre after being heated for 100 days.

D. Theoretical explanation of phase modulations

The number of guided modes in a simple step index fibre can be defined via the V number (Eqn. 1). Single-mode propagation is achieved, for a given wavelength, when \( V < 2.405 \),

\[
V = \frac{2\pi \cdot NA \cdot \alpha}{\lambda}
\]

where \( \lambda \) is the wavelength, NA is the numerical aperture and \( \alpha \) is the core radius of the fibre [20].

Based on our model’s theoretical calculations, it was found out that a small increase of the core radius, approximately 1μm, can lead to a second mode (LP_{11}) support, and through the difference in the propagation constants, a second cavity. The RIs of the core and the cladding were calculated through the Sellmeier equation (Eqn. 2).

\[
n(\lambda) = \sqrt{1 + \sum_{i=1}^{3} \frac{A_i \lambda^2}{\lambda^2 - B_i^2}}
\]

where \( \lambda \) is the wavelength, \( A_i \) and \( B_i \) are Sellmeier coefficients. The Sellmeier coefficients \( (A_1, A_2, A_3, B_1, B_2, B_3) \) that were used, can be found in literature [21, 22]. Combining Eqn. (1) and Eqn. (2) it can be calculated the V normalized frequency with respect to the spectrum’s wavelength.

![Figure 14. Theoretical calculation of V-number with respect to wavelength for the initial and final core fibre radii, before (black data \( \alpha = 4.1 \mu m \)) and after (blue data \( \alpha = 5 \mu m \)) diffusion. The red dashed line shows where the V-number is 2.405.](image)

Black data in Figure 14 correspond to the initial radius of the core before the optical fibre is heated, \( \alpha = 4.1 \mu m \), whereas the blue data correspond to the final radius of the core after being heated, which is \( \alpha = 5 \mu m \). The red dashed line in the same figure represents the threshold for which a fibre terminates to function as single mode. Considering that for a radius of \( \alpha = 5 \mu m \), each wavelength of the spectrum can support a second order mode (LP_{11}) in the fibre, it can be concluded that the appearance of a second cavity in our sensor is feasible.

We postulate that the second order cavity comes from the partial coupling of intensity from the fundamental to the second order mode. The diffusion of the Ge dopant towards the cladding modifies the step index profile of the core to graded index profile. If we assume that the taper is axisymmetric, as is usually the case with a single fibre taper, then the fundamental LP_{01} local mode can partially couple to LP_{11} mode which its different propagation constant causes the phase modulations at high temperatures [19]. The experimental results of the second order mode establishment
with the modification of the graded index profile is on progress for further investigation.

IV. Conclusions

In this paper, we have reviewed two intrinsic Fabry-Pérot optical fibre sensors with different types of sensing elements. One of them has a germanium doped cavity whereas the second one is consisted by an undoped pure SiO$_2$ cavity. A detailed description of pure SiO$_2$ sensor’s manufacturing has been presented. Also, we have demonstrated their phase stability responses after they have been subjected to temperatures between 850°C and 1050°C for 100 days. A thorough investigation based on multiple EDX line scanning and FWHM determination of heated and unheated pieces of the same fibre has been presented. Dopant diffusion and tapering due to exposure of the optical fibre to high temperatures, can lead to an introduction of a second order mode cavity in the optical fibre.

The results showed that by moving from a germanium doped Fabry-Pérot sensor to an undoped pure SiO$_2$ Fabry-Pérot sensor, we managed to constrain the phase drift to its minimum at higher temperatures. This, clearly has an impact on improving the functionality of the Fabry-Pérot sensor. The pure SiO$_2$ Fabry-Pérot sensor showed the most encouraging phase stability results up to 1000°C, whereas Ge-doped Fabry-Pérot sensor showed large drifts due to diffusion in its doped sensing element.

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V. References


Dimitrios Polyzos received his undergraduate diploma from the Department of Physics, School of Applied Mathematical and Physical Sciences, National Technical University of Athens, in 2010. In 2012, he obtained his MSc degree in “Photonics and Lasers”, from the Department of Physics, University of Patras, Greece. His current project as a PhD candidate at Applied Optics and Photonics research group in School of Engineering and Physical Sciences at Heriot-Watt University focuses on the applications of Fabry-Pérot optical fibre sensors at harsh environments and their stability response at high temperatures.