

Chapter 4 Sensor Test and Performance Analysis

For a pressure sensor head, there are two main parameters that need to be tested:

- Static Pressure;
- Temperature effects;
- Dynamic pressure.

As we mentioned in Chapter 2, the SCIIB system has advantages over other systems. So we chose to use the SCIIB system already developed at the Center for Photonics Technology (CPT) for sensor testing. Though we cannot read the air-gap change directly, by using other data processing software, we can still get information about the air-gap change information easily.

4.1 Construction of the Pressure Testing System

The sensor testing system was constructed based on a computer-controlled pressure generator/controller manufactured by Pressure Systems, Inc. (PSI). The system configuration is shown in Figure 4-1. The pressure controller/generator can supply a static pressure up to 200psi, and the accuracy of the pressure output is 0.1% of the full scale. The construction of this system allowed us to evaluate the SCIIB system. The system also allows us to test many performance characteristics of the pressure sensor, such as the linearity, repeatability and dynamic range.

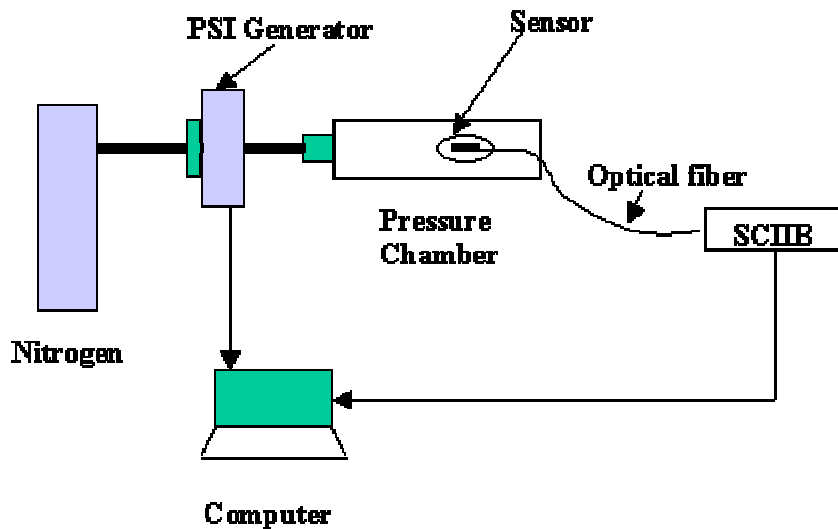


Figure 4-1 Schematic of PSI pressure sensor test system

4.2 SCIIB System Evaluation

In a normal interferometric and intensity-based fiber sensor system, the source power fluctuation and other optical components losses often affect the performance of a well-designed sensor.

In order to measure the light source fluctuation, the sensor is disconnected from the SCIIB system. The fiber connected to the SCIIB system is cleaved and the light reflected from the fiber end face goes back to the SCIIB system for testing. The SCIIB narrow-band output signal after six-hour testing is plotted in Figure 4-2.

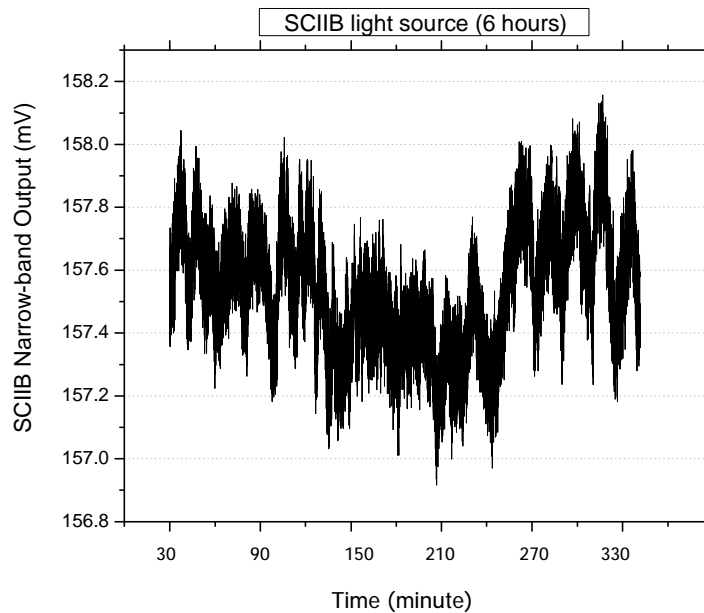


Figure 4-2 Light source fluctuation monitored by SCIIB narrow-band channel

As we mentioned in Chapter 2, the SCIIB technology can self-compensate for source power fluctuations by self-referencing the two channels output. Figure 4-3 plots the ratio of narrow-band signal to wide-band signal. This result reveals that the SCIIB system signal processing has a good self-compensation capability.

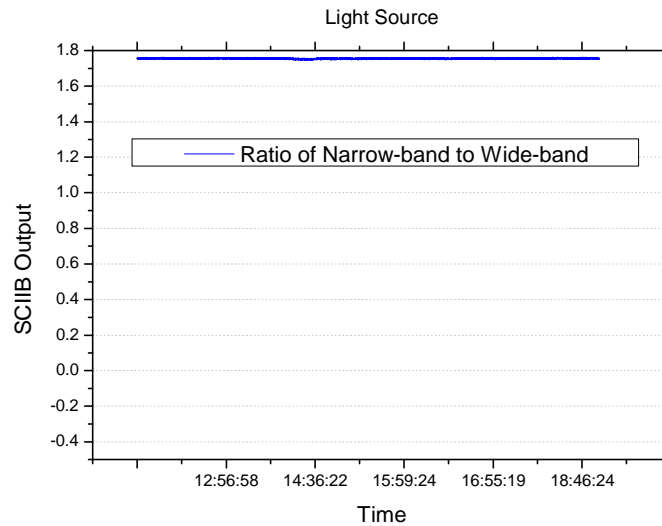


Figure 4-3 Light source fluctuation self-compensated by SCIIB system

4.3 Static Pressure Measurement

The sensor used in this test was a single-mode fiber sensor with 95 μ m thickness (after etching) diaphragm and 1mm diameter etched pit. Due to the sinusoidal nature of the interference signal, the direct output from the SCIIB system is a nonlinear function of the applied pressure as shown in Figure 4-4. We use the narrow-band output instead of the ratio of narrow-band output to wide-band output of SCIIB system here in order to use the absolute values to make some calculations.

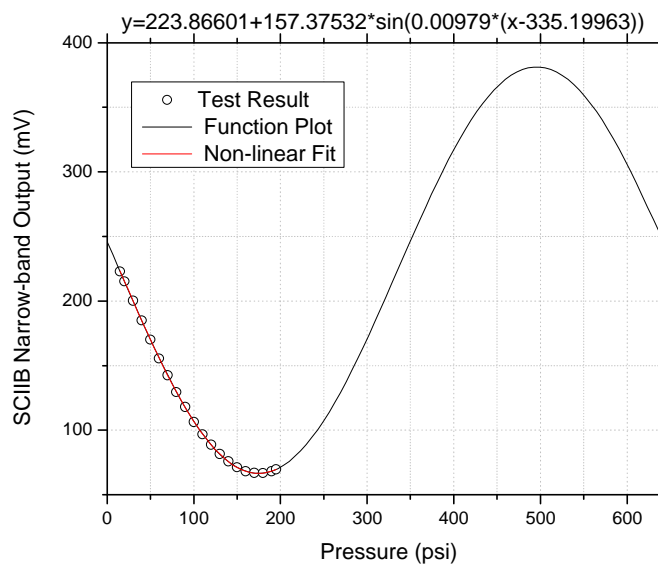


Figure 4-4 Static pressure measurement

Comparison of the sensitivity between experimental results and theoretical calculations

From the sensitivity formula $d_{diap} = \frac{y_0}{p} = \frac{3(1-m^2)}{16Eh^3} \times r^4 = 1.71 \times 10^{-8} \frac{r^4}{h^3}$

mentioned in Chapter 2, we got the calculated sensitivity of this sensor. It is 1.246nm/psi.

From the plot in Figure 4-4, when the pressure changed from 0~630psi, we can get the full cycle of the interference signal. So the actual sensitivity of the sensor would be $\lambda/2=775\text{nm}/630\text{psi}=1.23\text{nm}/\text{psi}$. This value is very close to the theoretical calculation.

4.4 Hysteresis of Pressure Measurement

The difference between outputs for a given pressure value under rising and falling heads is termed hysteresis.^[24] The sensor probe is made of silica glass material and the operating range of the sensor in terms of pressure induced strain is very small. Therefore, the hysteresis of the sensor is expected to be small. Hysteresis of the pressure sensor was measured by cycling the applied pressure between 14psi and 200psi. The measurement results are shown in Figure 4-5. The experimental results confirm our expectation. There was no noticeable hysteresis found within the operation range.

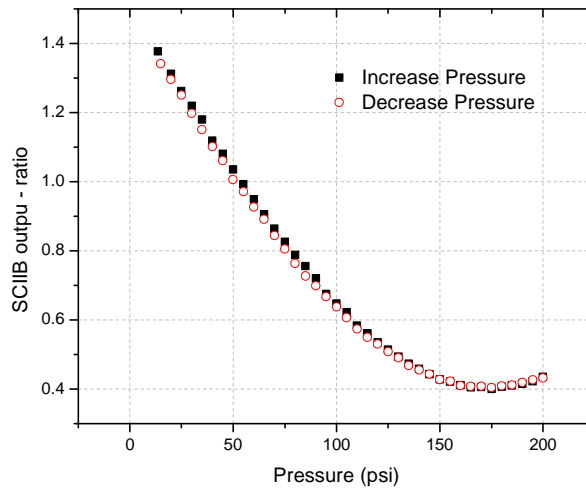


Figure 4-5 Hysteresis of the pressure sensor

4.5 Dynamic Pressure Measurement

To demonstrate the sensor's dynamic response, the pressure signal provided from PSI system was programmed to pressurize the chamber at even steps, as shown in Figure 4-6.

See Figure 4-7

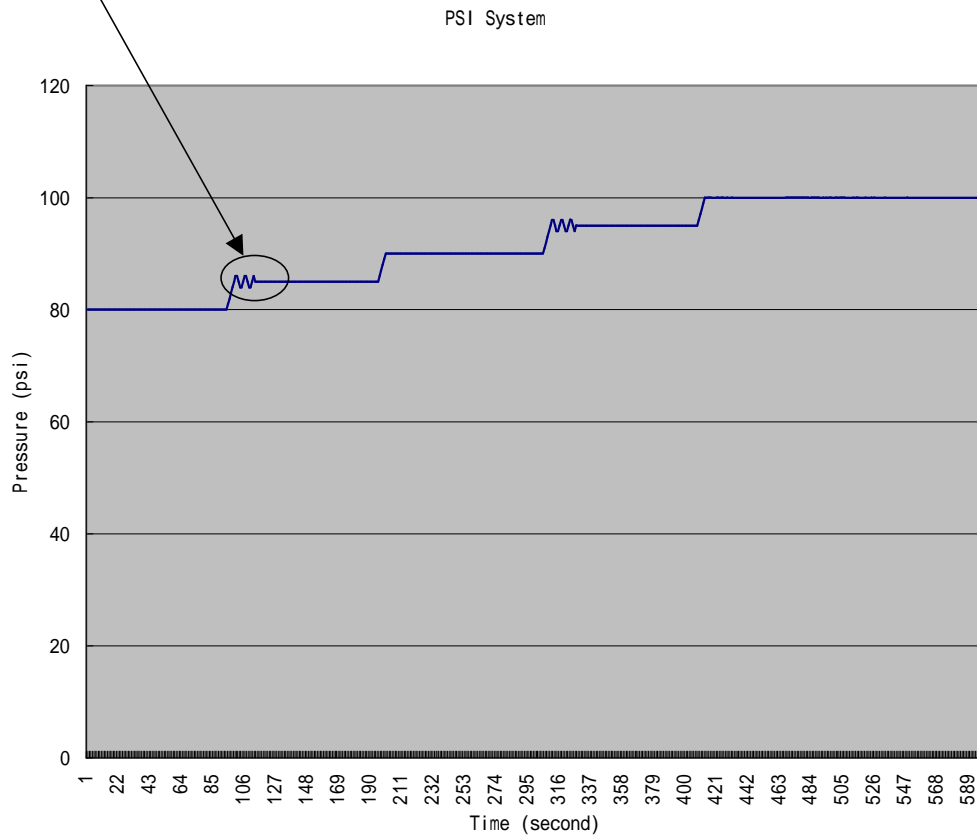


Figure 4-6 Pressure provided by the PSI system

There are fluctuations when the pressure was increased by the PSI system from 80psi to 85psi. These fluctuations helped us to know the dynamic response of the sensor. In Figure 4-7, the fluctuations are illustrated more clearly. The pressure was increased from 81psi to 85psi and kept stable at 85psi. The total time for the fluctuations was 19 seconds. And the peak-to-peak value of the fluctuations was 2psi.

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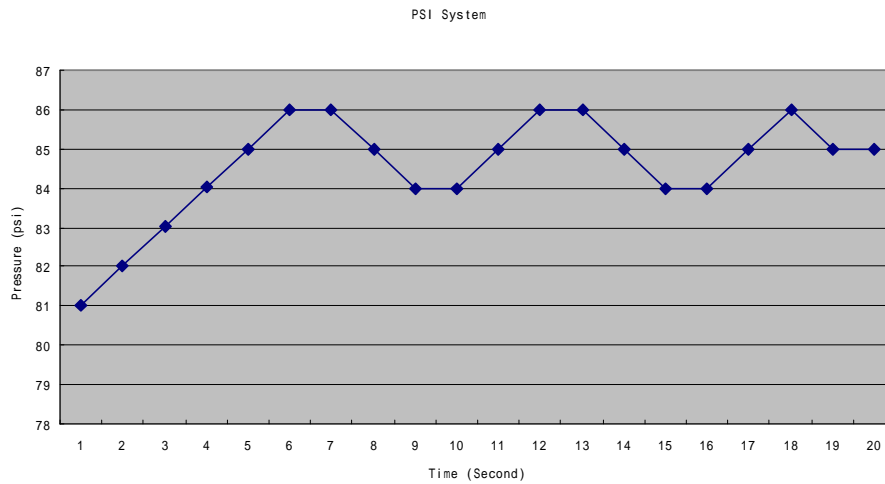


Figure 4-7 Pressure provided by PSI system

In Figure 4-8, the output of SCIIB system for the pressure from 80psi to 85psi is shown. The fluctuations of the pressure were tested out by the SCIIB system. The SCIIB output for pressure from 80psi to 100psi is shown in Figure 4-9. Compared with the pressure input and the SCIIB output, the input and the output can agree with each other.

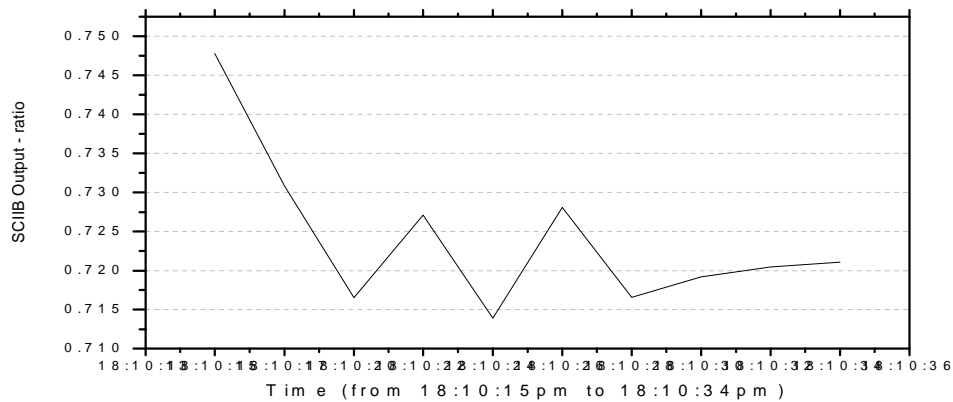


Figure 4-8 SCIIB system output for pressure from 81psi to 85psi

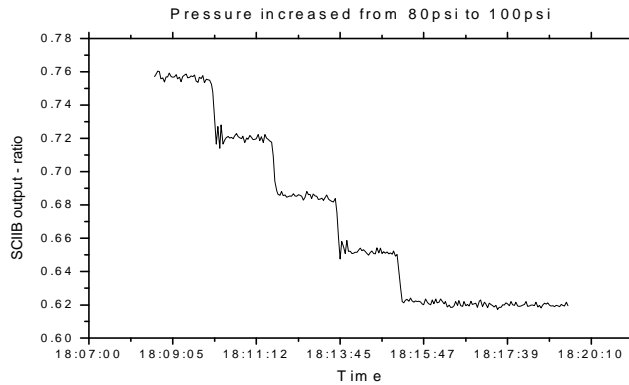


Figure 4-9 SCIIB system output for pressure from 80psi to 100psi

4.6 Temperature Dependence of the Pressure Sensor

For the pressure sensor, the temperature effect should be as small as possible. Because this type of sensor is expected to work at high temperature, the temperature dependence becomes more important issue. During the sensor design, special materials: fused silica, sol-gel with similar coefficients of thermal expansion, are chosen to reduce the temperature effect.

The sensor is tested by placing it in a furnace. It was heated up from room temperature to 600°C and stayed at 600°C for a few minutes. Then it was cooled down from 600°C. The SCIIB output is shown as Figure 4-10. We compared this SCIIB output with the result from the pressure measurement. We found that 1 °C temperature change has the same effect with 0.06psi pressure change (35psi / (600-25) degree C) and causes the air-gap changes by about 0.15nm.

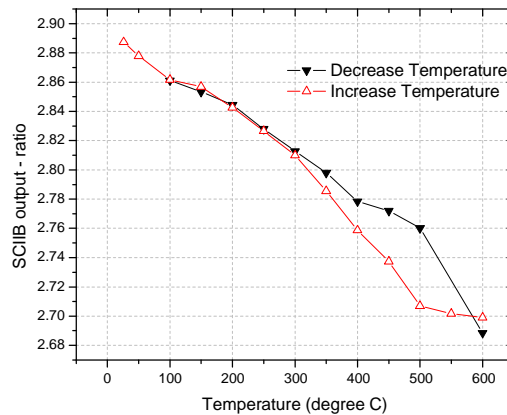


Figure 4-10 Temperature dependence of the pressure sensor