dip wavelength shift can be expressed as ε = ΔL/L = Δλ/λ. The applied gas pressure of 1 MPa will result in a very small dip movement of 14 pm, which could be ignored.

Assuming that the length of micro-channel is a constant, the pressure sensitivity can be derived from Eq. (2) as

$$\frac{d\lambda}{dP} = \frac{\lambda}{\Delta n}\frac{d(\Delta n)}{dP}, \tag{4}$$

where d(Δn)/dP illustrates the RI change of air in micro-channel varying with pressure. At room temperature (15~25 °C), the RI of air is a function of the pressure and temperature [18]:

$$\mathrm{n} = 1 + \frac{2.8793\times10^{-9}\times P}{1+0.003671\times t}, \tag{5}$$

where n, P, t are the RI of air, the pressure (Pa), and the temperature (°C). If the temperature remains unchanged, there is a linear relationship between the air RI and the pressure. d(Δn)/dP can be calculated to be 2.63×10^{-3} when the temperature is 25 °C and the pressure is increased to 2 MPa. From Eq. (4) the pressure sensitivity of the TCF-based MZI can be calculated to be ~9.52 nm/MPa at 1610 nm for Δn = 1.445-1.0 = 0.445, which is very close to the experimental result. Therefore, the RI variation of the air in the micro-channel induced by the increased pressure plays a leading role on its pressure response. Comparing with the previously reported fiber pressure sensors, such as π-phase-shifted FBG (6.9 pm/Mpa) [7], side-hole dual-core photonic crystal fiber (32 pm/Mpa) [8], fiber tip micro-cavity (315 pm/Mpa) [11], our TCF-based MZI shows a much higher sensitivity of −9.6 nm/Mpa and more compact structure.

Temperature response of the fiber sensor was also investigated, where the TCF-based MZI is placed into an electrical oven and gradually increasing the temperature from room temperature to 100 °C with a step of 10°C. A red shift is clearly observed when the temperature is increased. Wavelength shift of the interference dip at ~1623 nm with temperature variation is displayed in Fig. 5(d), where a good linear response with a temperature sensitivity of 43 pm/°C was obtained. The temperature response of the TCF-based MZI is mainly determined by the thermo-optical effect of the fiber core. In case no temperature compensation is employed in practical measurements, the gas pressure measurement error resulting from temperature is 4.4 KPa/°C, which is lower than the minimum detectable gas pressure change (5.2 KPa) of this MZI sensor. Hence the pressure-temperature crosstalk can be ignored.

4. Conclusions

In summary, we reported a micro-channel based TCF in-line MZI for gas pressure measurement. This device is fabricated by combining fusion splicing with fs laser micromachining technique. The two cores of the TCF perform as two interference arms and a micro-channel was drilled through one core by means of FS laser micromachining and the micro-channel worked as the precise sensing region. The proposed TCF-based MZI exhibits an ultra-high gas pressure sensitivity of −9.6 nm/MPa from 0 to 2 Mpa and a low temperature cross-sensitivity of 4.4 KPa/°C. It is suitable for gas pressure detection, biomedical sensing, environmental monitoring and other industrial applications.

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