# Integrated Plasmo-Photonic Bimodal Interferometer for Temperature Sensing

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**Abstract:** This work reports on an integrated plasmo-photonic bimodal interferometer with 1.233 nm/℃ sensitivity.

Photonic temperature sensors compared to other techniques relying on different physical mechanisms, exhibit superior performance demonstrating high sensitivity to temperature variations, wide temperature range, stability, and immunity to electromagnetic interference [1-3]. While early prototypes were based on fiber solutions [4], photonic integration enabled the miniaturization of these sensors without compromising their performance. Meanwhile, the field of plasmonics has attracted attention for its ability to offer compactness and extreme light confinement, enabling a diverse range of applications [5]. In this work, we propose an integrated plasmo-photonic bimodal interferometric sensing platform that leverages the advantages of both technologies, achieving an experimental temperature sensitivity of 0.563 nm/℃ with an air-cladded sensing area. This value increases to 1.233 nm/℃ by utilizing water instead of air, taking advantage of the higher thermo-optic coefficient (TOC). In principle, the proposed sensor can operate at different temperature ranges by using materials with different thermal properties on top of the sensing area.

Figure 1(a) shows a 3D conceptual schematic of the plasmo-photonic bimodal interferometric device that serves as a temperature measurement platform. The photonic part consists of cladded polymeric SU8 waveguides with dimensions of 1.8 (H) x 1.5 (W) $\mu m^2$. The SU8 waveguide is thinned to 0.9 μm for a 75 μm long distance, and an Aluminum (Al) metal stripe with dimensions of 80 nm (H) x 7 μm (W) is deposited to form a cavity that can be left empty or host thermo-optically sensitive materials in gas or liquid state. Two metal/insulator interfaces are formed at the top and bottom surfaces of the metal stripe, capable to support surface plasmon polariton (SPP) modes. These modes propagate along the two metal surfaces and interfere at the output photonic waveguide,

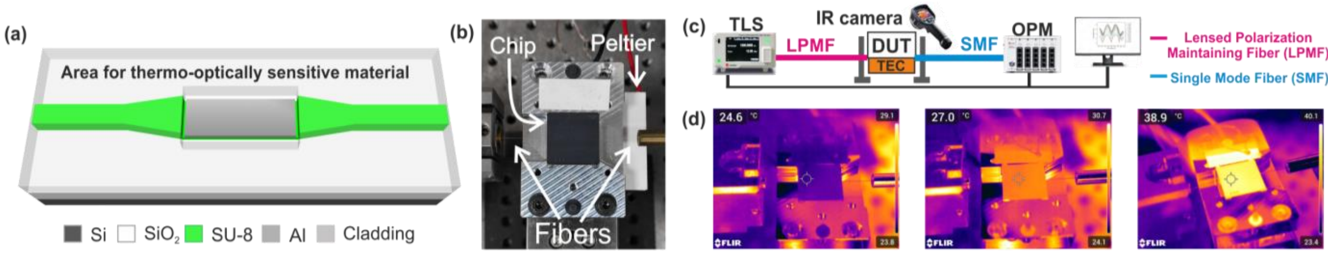


*Figure 1: (a) 3D conceptual design of the plasmo-photonic bimodal interferometric temperature sensing platform. (b) Image of the DUT and TEC configuration. (c) Schematic of the experimental setup. (d) Thermal images at three different temperatures, 24.6 ℃, 27℃, 38.9 ℃, demonstrating the thermal change during this heating scheme.*

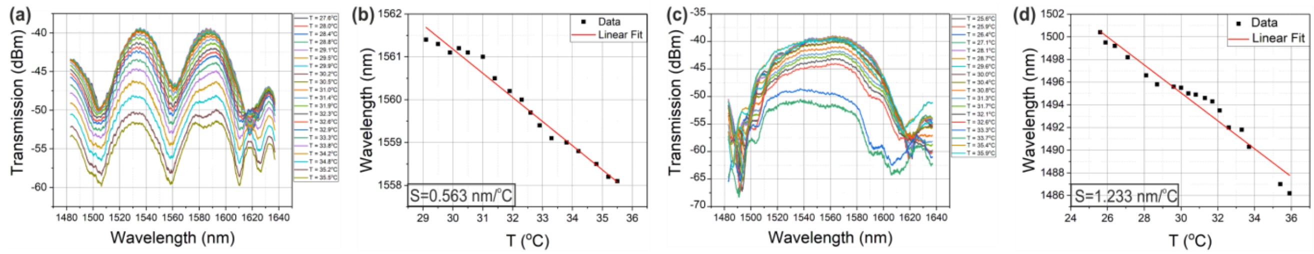


*Figure 2: (a) Experimental spectral response of the temperature sensing platform under air conditions. (b) Least squares linear fit of the wavelength dip shift vs. temperature change, revealing an experimental sensitivity of 0.563 nm/℃. (c) Experimental spectral response of the temperature sensing platform filled with water. (d) Least squares linear fit of the wavelength dip shift with the temperature change, in the presence of water, showing an experimental sensitivity of 1.233 nm/℃.*

realizing a single-arm interferometer. A more detailed description of the sensor and its operation as a refractive index sensor is given in [6,7]. Any temperature variation on the sensor chip will lead to changes of the refractive indices of the materials, that will alter the effective indices of both SPP modes. Therefore, an intense wavelength shift of the interference dips at the sensor output will be recorded.

The sensor chip was heated by a Peltier module located directly under the chip holder as shown in Figure 1(b), while the temperature was measured at the chip surface with an IR thermal camera. Figure 1(c) shows the experimental setup employed to perform the measurements consisted of a tunable laser source (TLS) and an optical power meter (OPM). The response of the sensor was first investigated with air acting as the medium on top of the plasmonic waveguide, in a temperature range from 27.6℃ to 35.5℃. By analyzing the recorded spectral response of Figure 2(a), an experimental sensitivity of 0.563 nm/℃ was calculated, as can be seen in Figure 2(b). Subsequently, a drop of water was injected into the thermo-optically sensitive material region exploiting the relatively higher TOC of water compared to air and the experiment was repeated for a temperature range from 25.6℃ to 35.9℃, as presented in Figure 2(c). The linear fitting of the data in Figure 2(d), revealed an experimental sensitivity of 1.233 nm/℃ confirming the sensitivity improvement of the sensor versus the TOC.

In summary, an integrated plasmo-photonic interferometer is experimentally evaluated for temperature sensing with high precision. The sensitivity of the device is directly related to the TOC of the material on the sensing area as confirmed by air and water measurements. The proposed temperature sensor is capable to support operation at different temperature ranges by placing liquids with diverse thermal properties on the plasmonic surface.

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