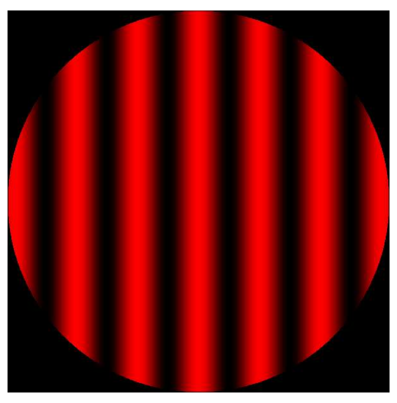
Spectral interferometric fiber optic temperature sensor with enhanced sensitivity



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Abstract

Spectral interferometric techniques utilizing the interference of polarization modes in a highly birefringent (HB) elliptical-core fiber to measure temperature are analyzed experimentally and theoretically. First, an experimental setup comprising a white-light source, a polarizer, a sensing birefringent fiber, an analyzer and a spectrometer is considered. Temperature sensing by this method is based on the wavelength interrogation. Second, a setup with a birefringent quartz crystal to increase the sensitivity of the temperature sensing is considered. Third, we consider a setup with another interferometer (represented by a polarizer, a birefringent quartz crystal and an analyzer) to increase the sensitivity of the temperature sensing with utilizing of the Vernier effect and in this case resultant spectrum has got an envelope.

1. Experimental setup a results I

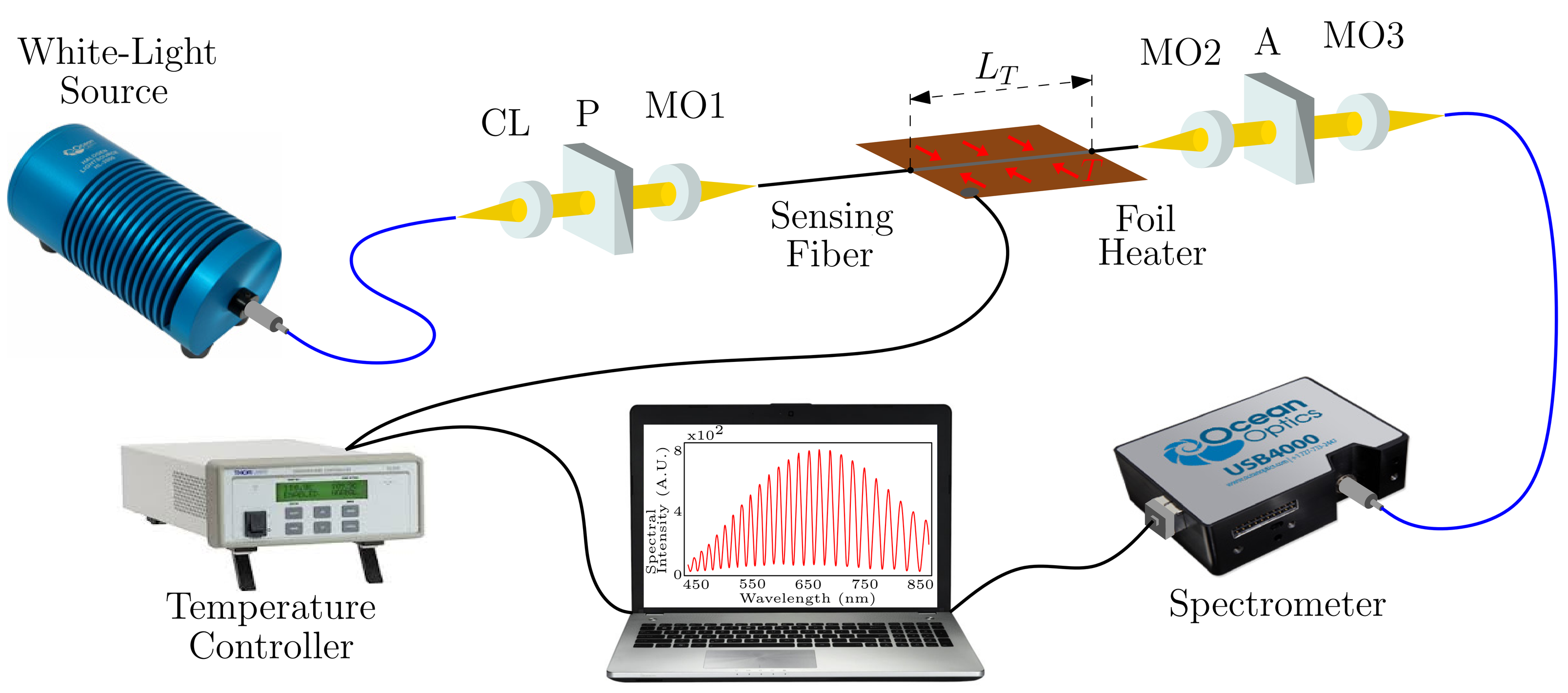

Figure 1: *Experimental setup with HB sensing fiber to measure temperature; collimating lens (CL), polarizer (P), analyzer (A), microscope objectives (MO1 - MO3).*

First, a standard method of the temperature sensing with a fiber interferometer employing a polarizer, the HB fiber and an analyzer is considered (see Fig. 1). Using the method, a channeled spectrum is generated, which shifts with the temperature change of the sensing part of the HB fiber (see Fig. 2). We revealed that the temperature sensing based on the wavelength interrogation can reach a sensitivity of -0.12 nm/K at shorter wavelengths (Fig. 3).

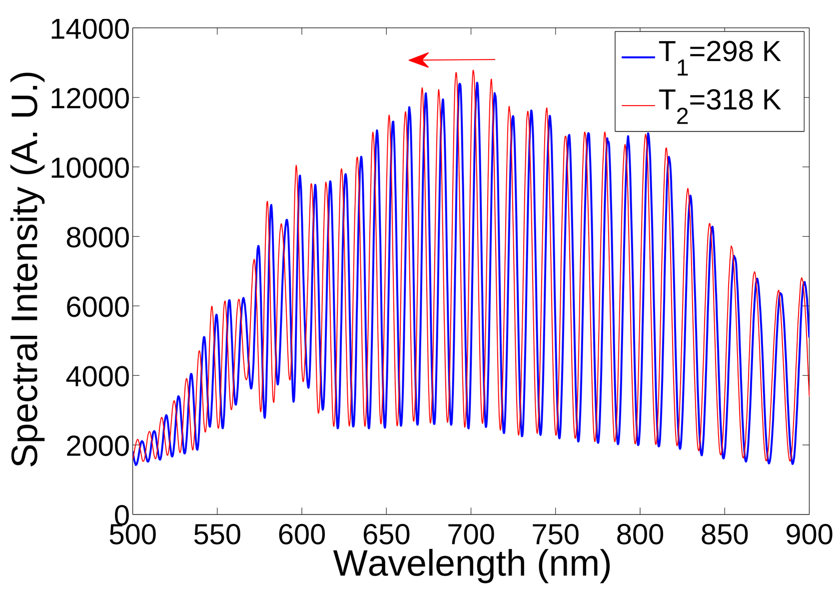

Figure 2: *Recorded spectra for temperatures T_1 and T_2.*

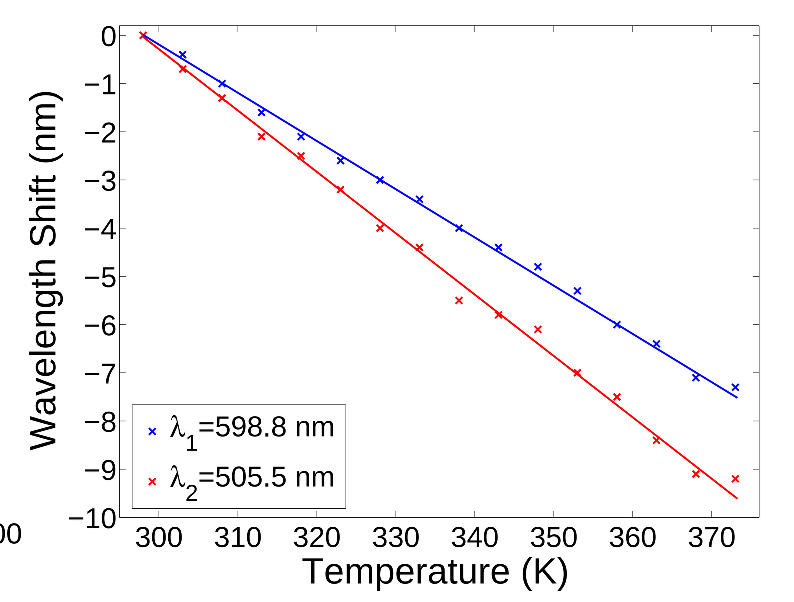

Figure 3: *The wavelength shift of an extreme for initial positions λ_1, λ_2 (solid lines are fits).*

2. Experimental setup a results II

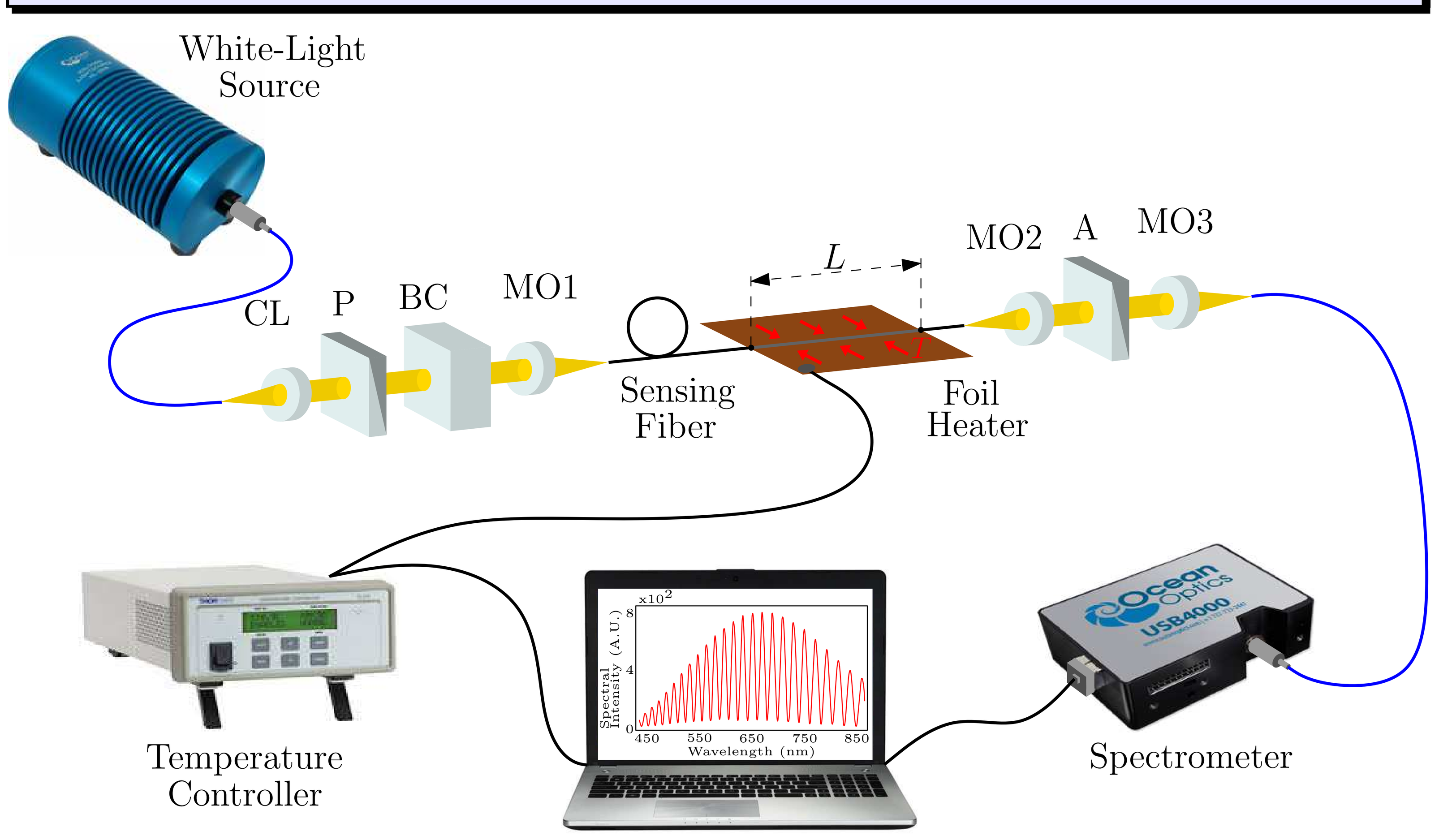

Figure 4: *Experimental setup with HB sensing fiber to measure temperature with higher sensitivity; collimating lens (CL), polarizer (P), birefringent crystal (BC), analyzer (A), microscope objectives (MO1 - MO3).*

Second, a new fiber optic temperature sensor employing a tandem configuration of a birefringent quartz crystal and HB fiber placed between an analyzer and a polarizer is considered (see Fig. 4). For the sensor, a modified channeled spectrum is generated, which contains equalization wavelength and shifts with the temperature change of the sensing part of the HB fiber (see Fig. 5). We analyze the new fiber optic temperature sensor theoretically and show that the sensitivity of the temperature sensing based on the wavelength interrogation is enhanced in comparison to a standard fiber optic temperature sensor. Experimental results for the sensor with the HB fiber under test show that the temperature sensing can reach a sensitivity of -0.30 nm/K (see Fig. 6).

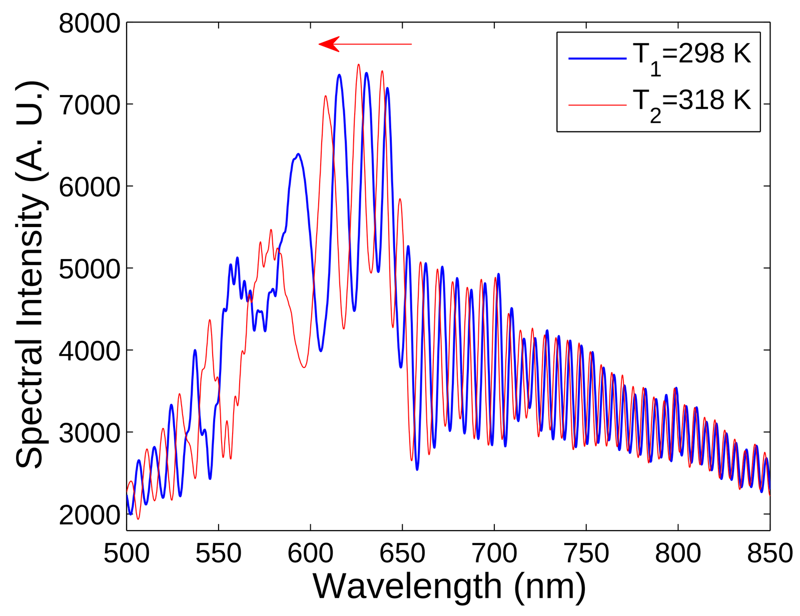

Figure 5: *Recorded spectra with equalization wavelengths for temperatures T_1 and T_2.*

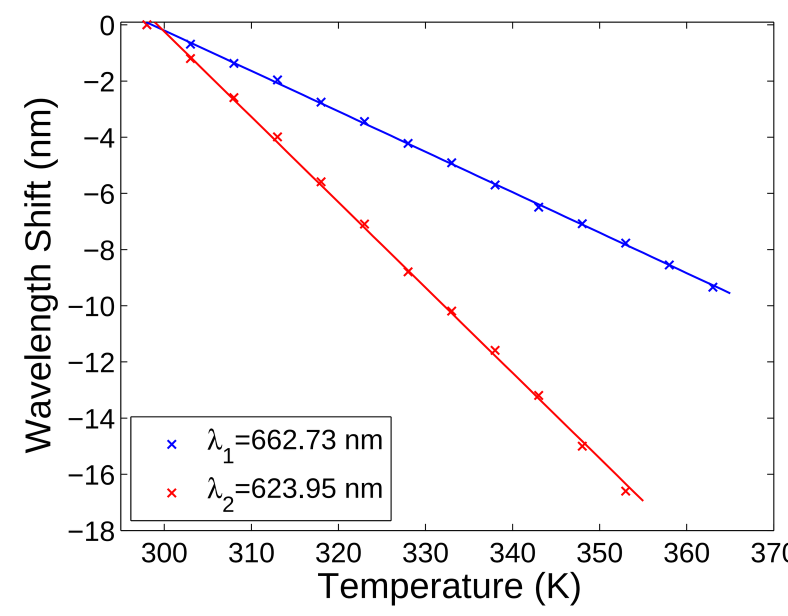

Figure 6: *The wavelength shift of an extreme for initial positions λ_1, λ_2 (solid lines are fits).*

3. Experimental setup a results III

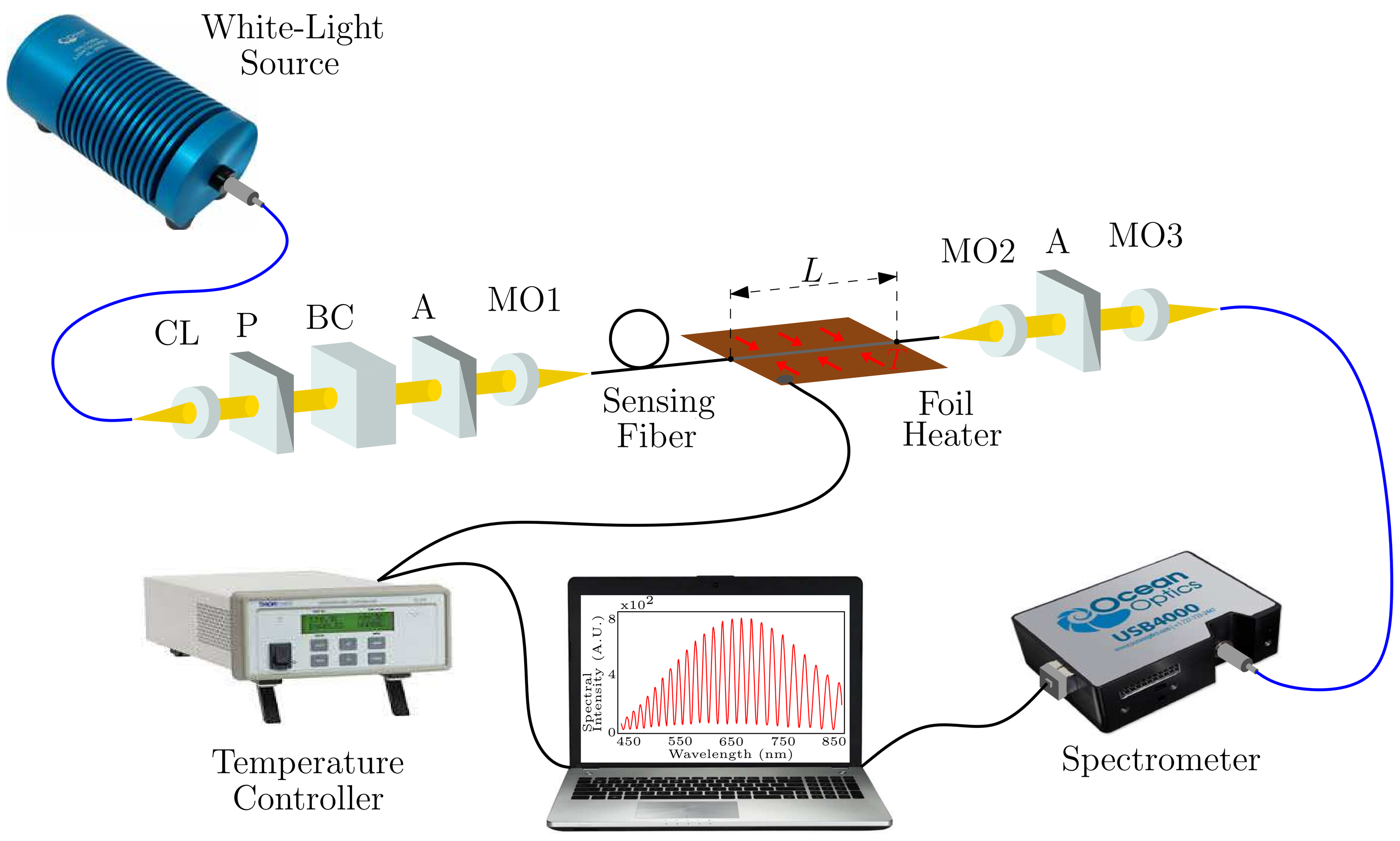

Figure 7: *Experimental setup with HB sensing fiber to measure temperature with utilizing of the Vernier effect; collimating lens (CL), polarizer (P), birefringent crystal (BC), analyzer (A), microscope objectives (MO1 - MO3).*

Finally, we propose a new sensor configuration in which the Vernier effect is generated [1] and the resultant channeled spectrum is with the envelope which shifts with the temperature change of the sensing part of the HB fiber. We analyze the new fiber optic temperature sensor theoretically and show that its temperature sensitivity is substantially enhanced in comparison to a standard fiber optic temperature sensor. We also demonstrate experimentally the temperature sensitivity enhancement for the fiber optic sensor with the HB fiber under test.

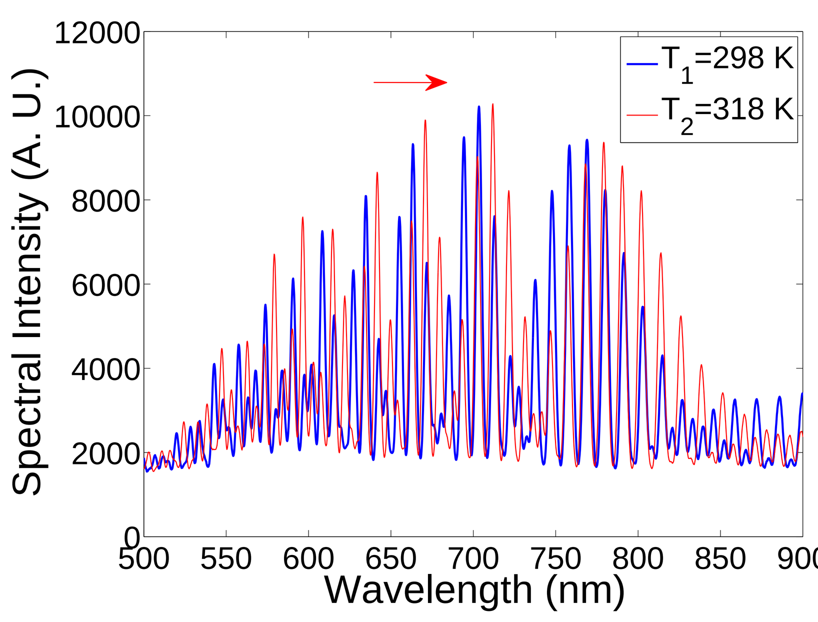

Figure 8: *Recorded spectra with envelopes for temperatures T_1 and T_2.*

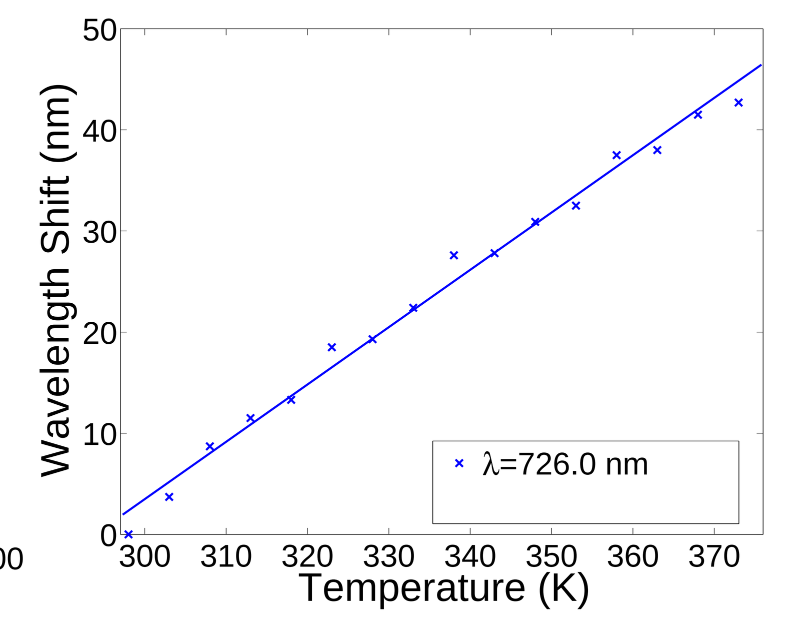

Figure 9: *The wavelength shift of an extreme for initial wavelength λ (solid line is a fit).*

4. Conclusions

Spectral interferometric methods utilizing the interference of polarization modes in a HB fiber have been analyzed experimentally and theoretically. For the first and for the second setup, the temperature sensitivity reaches -0.12 nm/K and -0.30 nm/K, respectively. Finally, we used the setup generating the Vernier effect and reached the temperature sensitivity 0.56 nm/K.

References

[1] Militky, J. *et al*, *Opt. Commun.* **366**, 335-339 (2016).