Characterization and Comparison of the Relative Humidity Response of Hydromorphic Polymers in Long-Period Fiber Grating Structures

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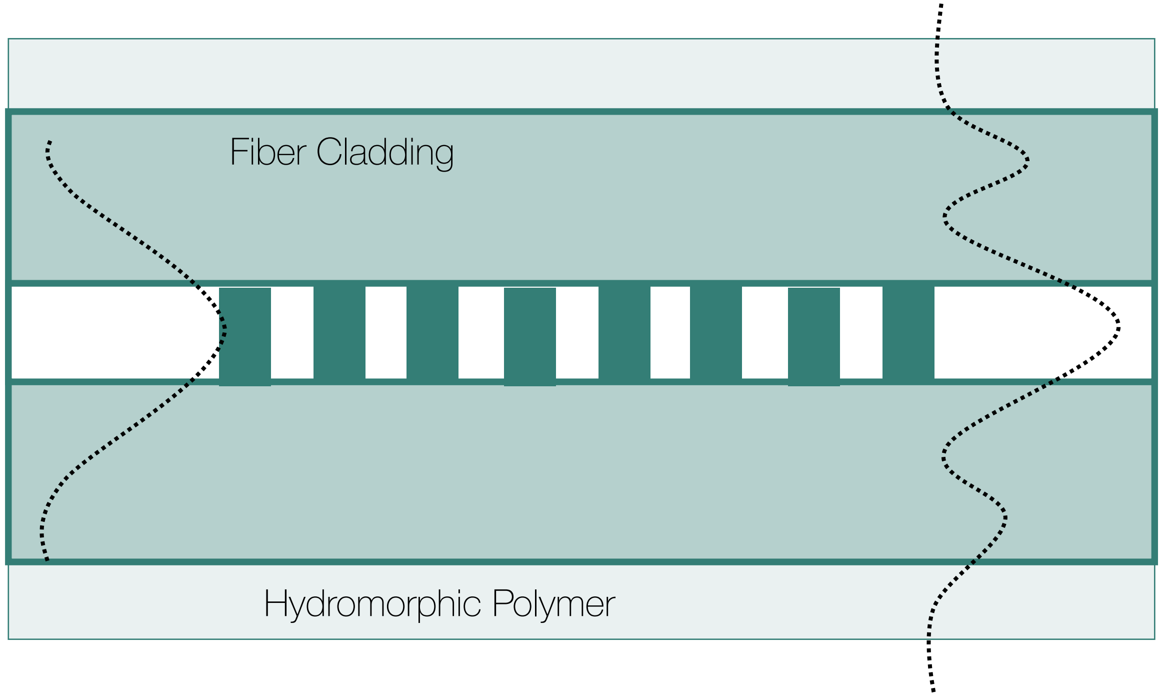
Long-Period Fiber Grating Structures as Optical Sensors

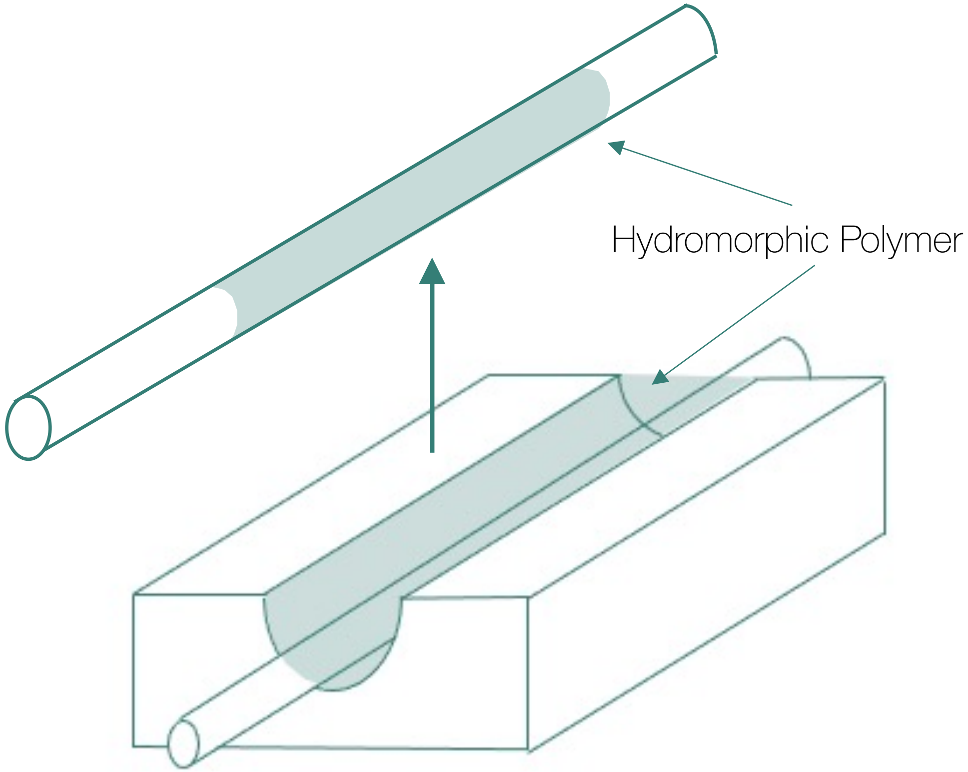
Working principle and functionalization for Relative Humidity sensing



Section drawing of a LPFG, showing its working principle and the hydromorphic polymer coating used for RH sensing

- Long Period Fiber Gratings consist of a periodic modulation to the refractive index of the core of the fiber;
- This creates a rejection band in the spectral window, which is highly sensitive to environmental variations;
- By coating LPFGs with a humidity responding polymer, an optical sensor is created, due to the its response to RH variations.

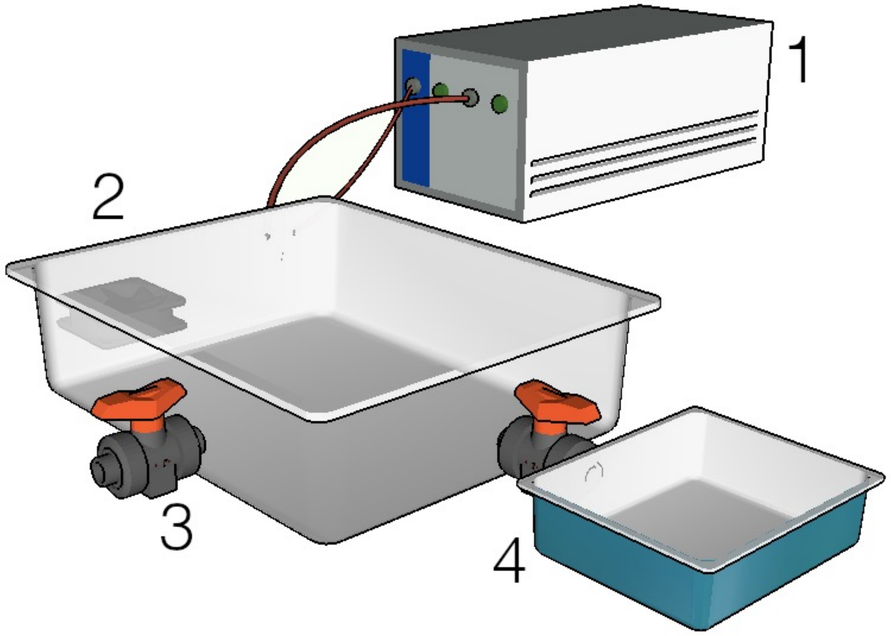
Coating Procedure and Humidity Responsive Polymers



Coating procedure of an LPFG with a hydromorphic polymer, consisting of dipping the fiber horizontally in a U-groove filled with the polymer and slowly pulling it upwards.

- Poly(vinyl alcohol)
  - Common polymer in humidity sensing;
  - RI varies from 1.49 to 1.34 at (1310 nm);
  - Concentrations: 5, 7.5 and 10% wt/wt.
- Poly(ethylene glycol)
  - Not as common as PVA in LPFG sensing;
  - RI varies from 1.455 to 1.413 (n_D);
  - Concentrations: 50, 75 and 100% wt/wt.
- Hydromed™ D4 (Hydrogel)
  - Never reported in humidity sensing;
  - Fabricated by AdvanSource Biomaterials ;
  - Concentrations: 5, 7.5 and 10% wt/wt.

Experimental Setup for Relative Humidity Measurements

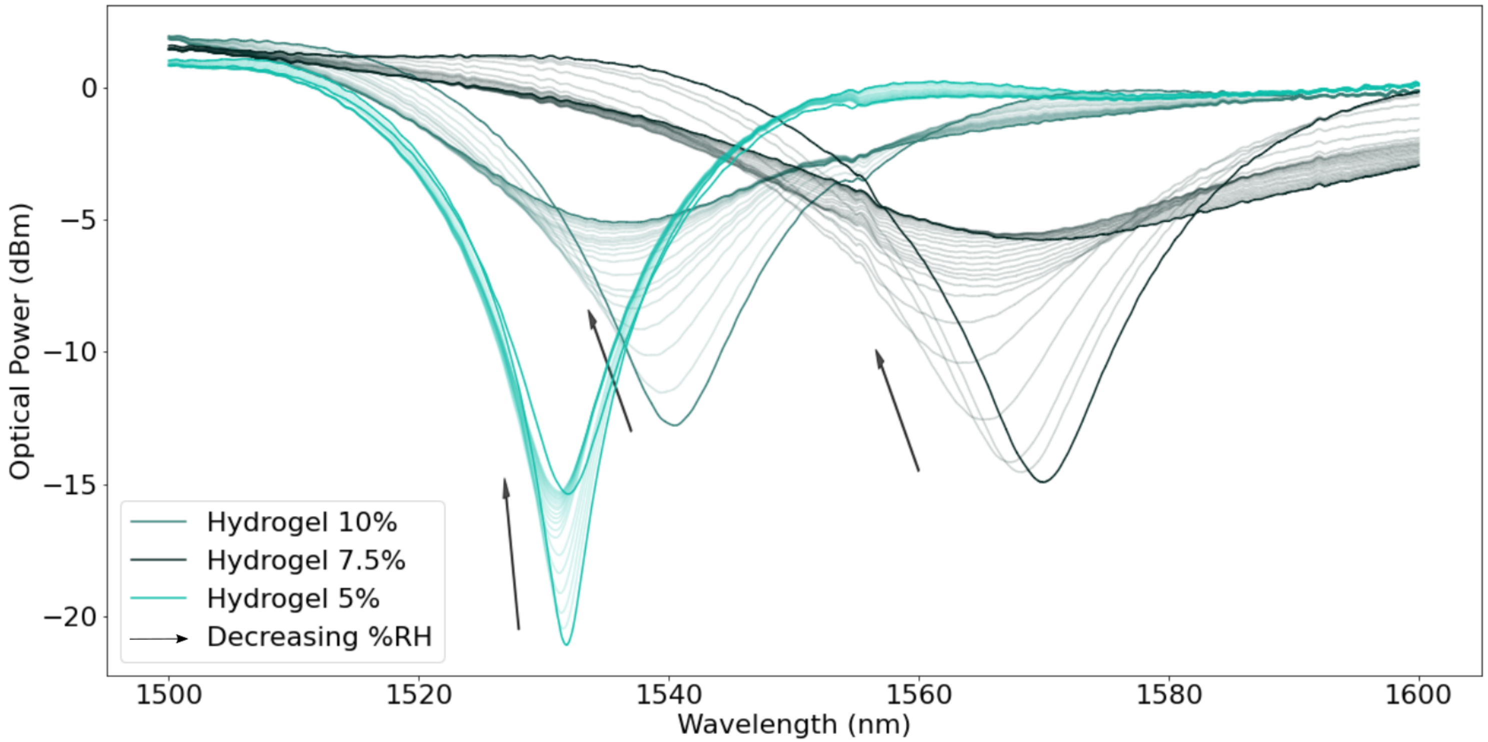


Experimental setup created to measure changes in LPFG spectra in varying values of relative humidity.

1- Interrogation unit; 2 – Humidity Chamber;
3 – Exterior valve; 4—Humidity valve.

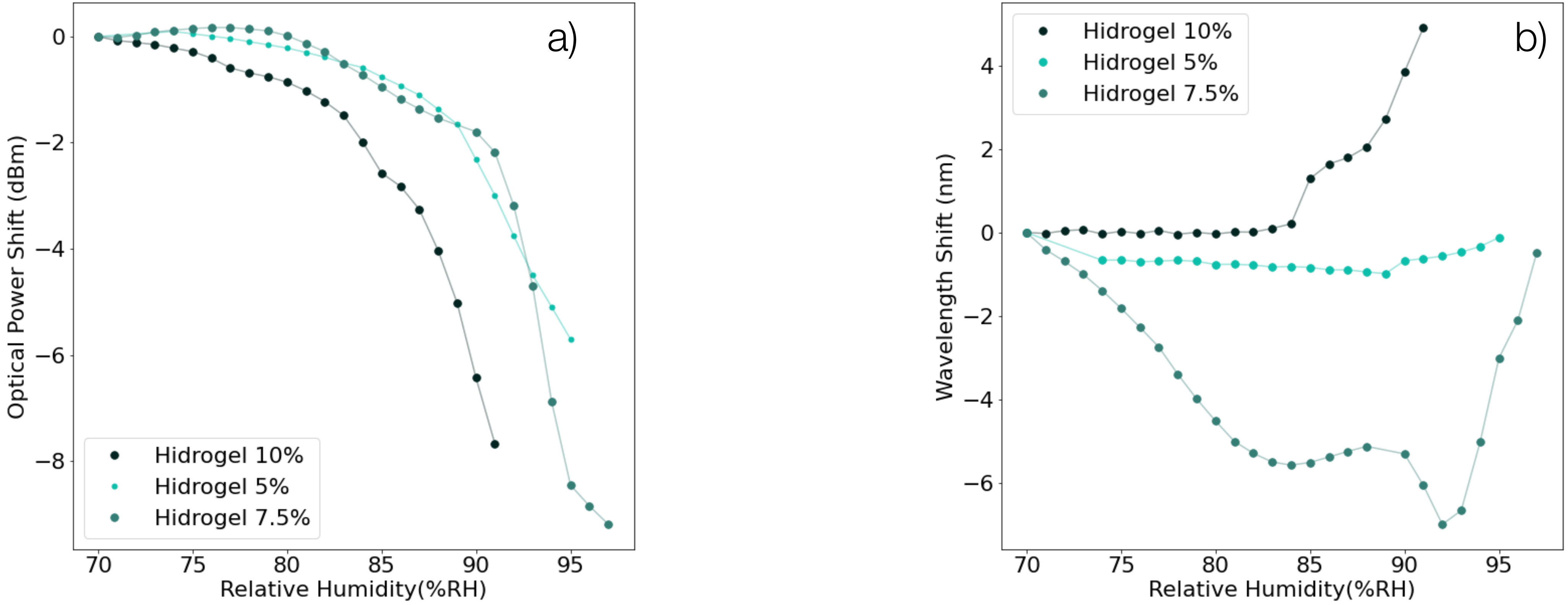
- Measurements were made in an environments that allows for slow variations of relative humidity;
- The valves allow for a controlled increase or decrease in RH values inside the humidity chamber;
- A DHT22 humidity and temperature sensor is also placed inside;
- The interrogation unit is connected to the stretched LPFGs inside, recording spectra every 1%RH variation.

Experimental Results – Hydrogel Coatings



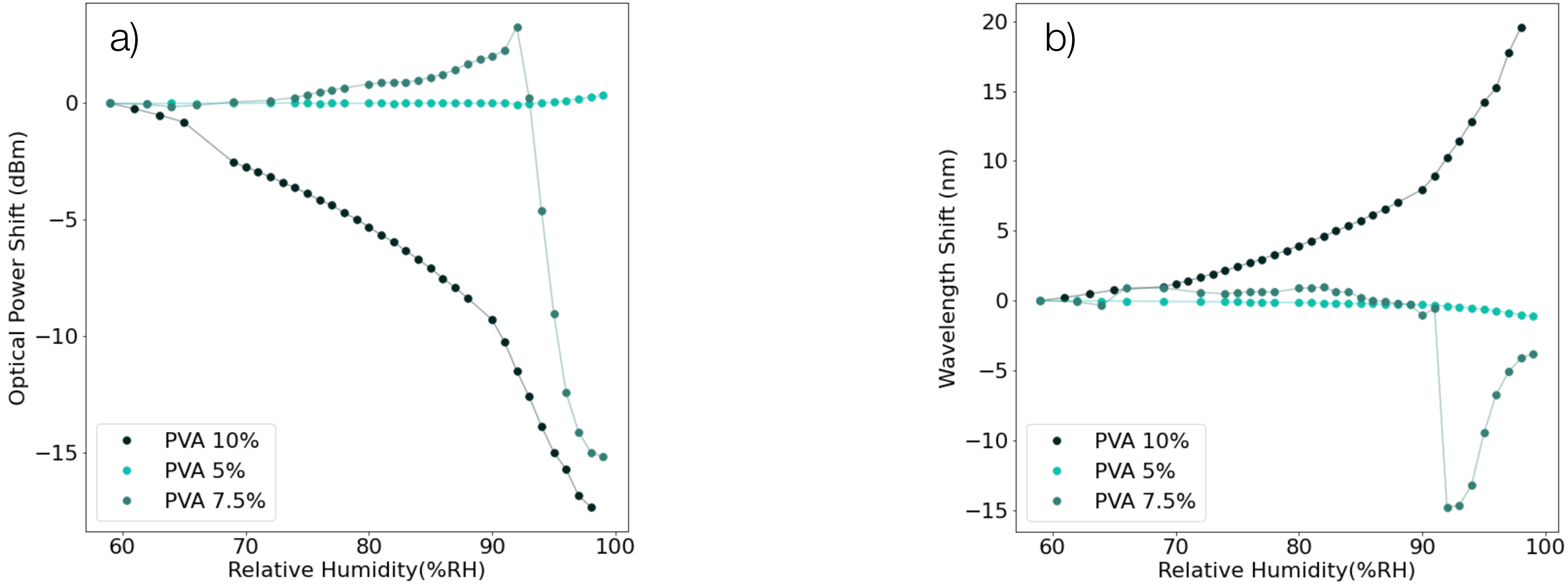
Spectral variation of Hydrogel coated LPFGs with varying relative humidity conditions.

Experimental Results – Hydrogel Coatings



Spectral variation of the three Hydrogel coated LPFG sensors and their measured response:
(a) Optical Power Shift response; (b) Wavelength Shift Response.

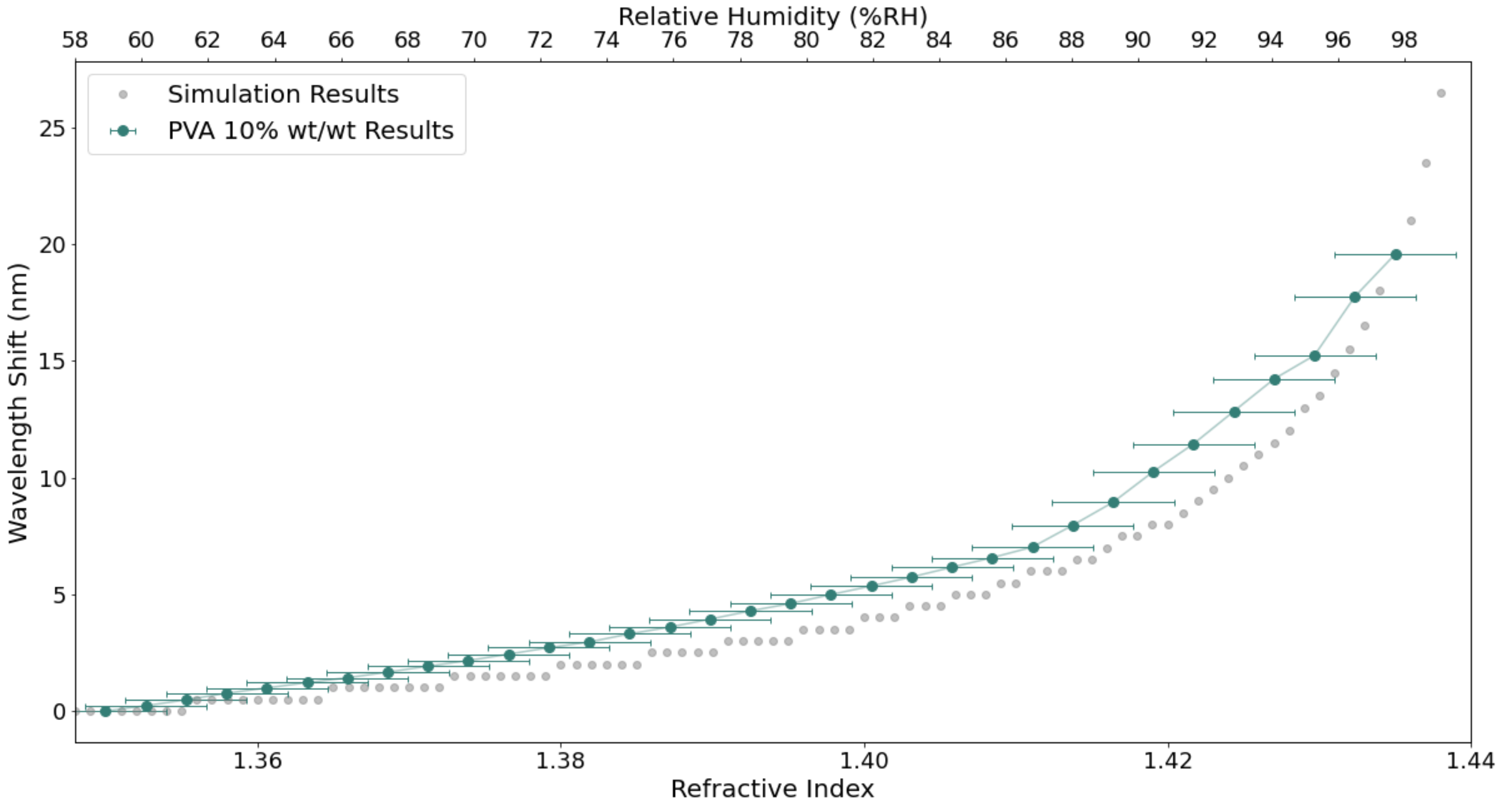
Experimental Results – PVA Coatings



Variation of the spectra of the three PVA coated LPFG sensors and their measured response:

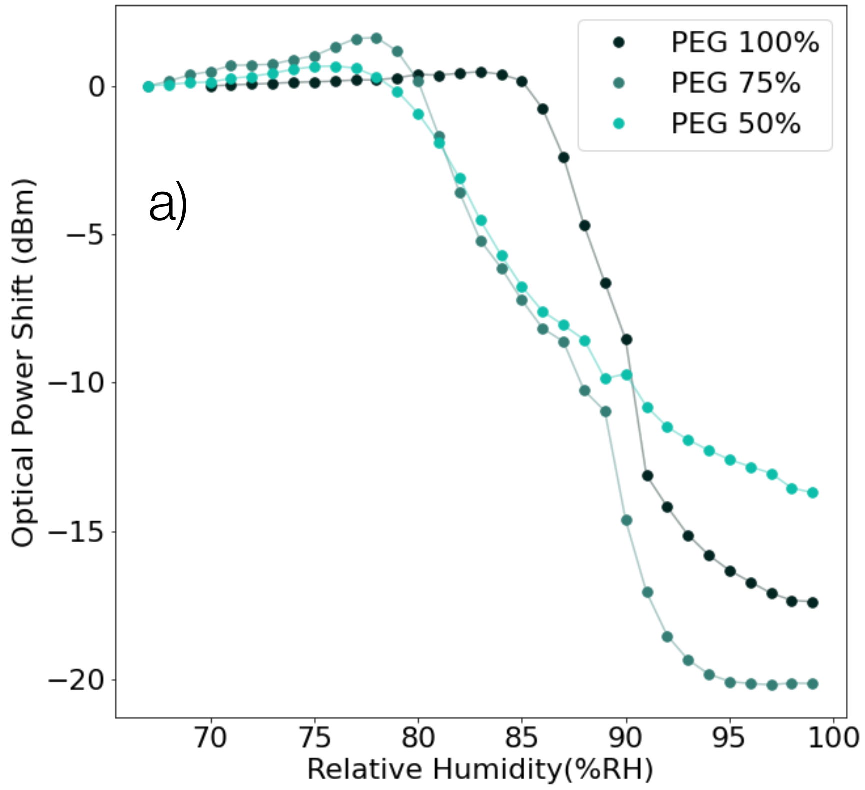
(a) Optical Power Shift response; (b) Wavelength Shift Response.

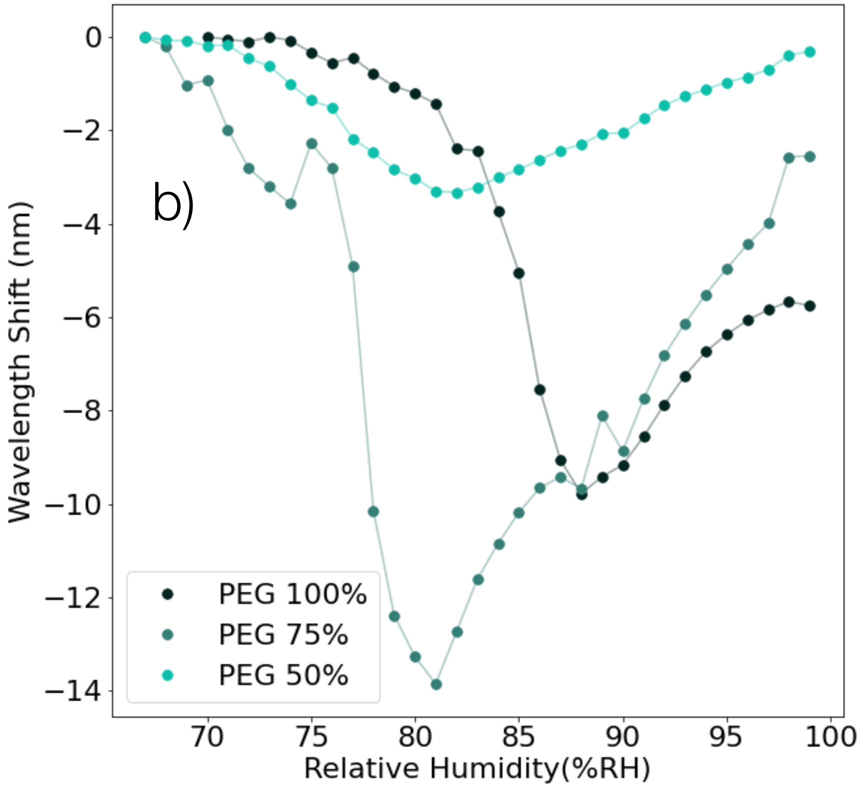
Experimental and Simulation Results – PVA Coatings



Comparison between the wavelength shift of experimental 10% wt/wt PVA LPFG and the simulations of as function the external refractive index.

Experimental Results – PEG Coatings





Variation of the spectra of the three PEG coated LPFG sensors and their measured response:
(a) Optical Power Shift response; (b) Wavelength Shift Response.

Conclusions

- The 10% wt/wt PVA sensor displays excellent performance in both wavelength and optical power shift;
- Good agreement with the numerical simulations is seen;
- In the case of Hydrogel and PEG coated LPFGs, the transition from guided to leaky modes makes them less suitable for humidity sensing due to discontinuities in the wavelength shift curve;
- More research is needed in order to understand how to optimize the sensors performance and its working range.