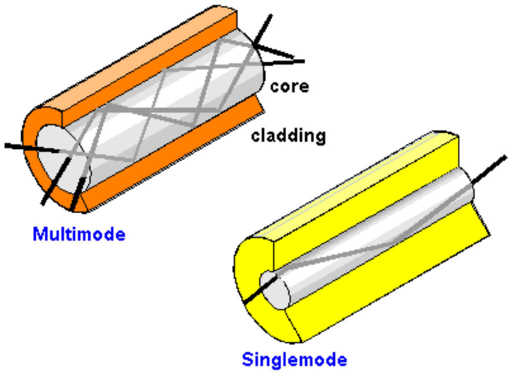
Sensores em fibra ótica

Escola de verão de física 2021 - Grupo 14

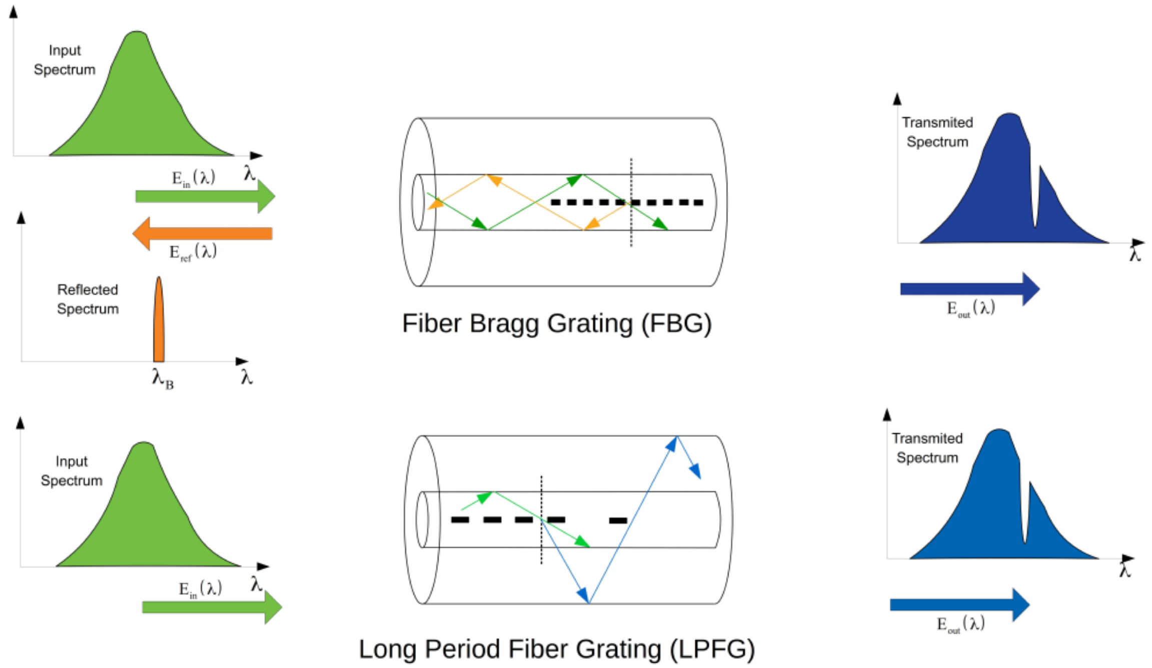
Introduction

Firstly information travelled in the form of electrical signals on electric cables
Nowadays, although electric cables are still used for data communication for high frequencies, optical fibers present lower attenuations.
This allows information to be transmitted to higher distances without significant signal losses

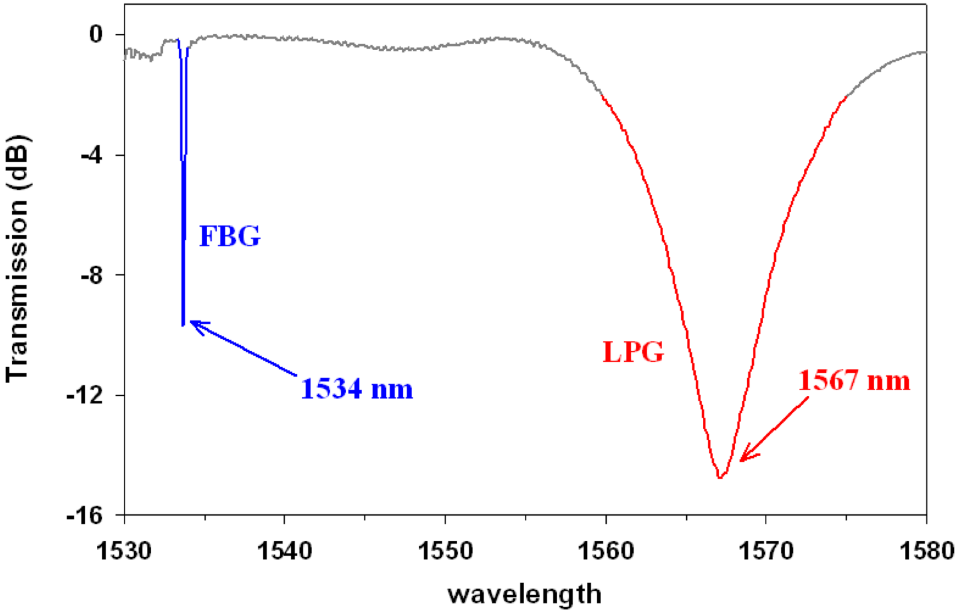


Attenuation losses
Coax. cable = 54dB/Km
Optical fiber = 0.02 dB/Km

LPFG and FBG: Principle of operation



LPFG and FBG : Principle of operation



LPFG

Length: 2.46 cm
Period: 615 µm
λ_{res}: 1567 nm
FWHM: 6.5 nm
transmission loss: 15 dB

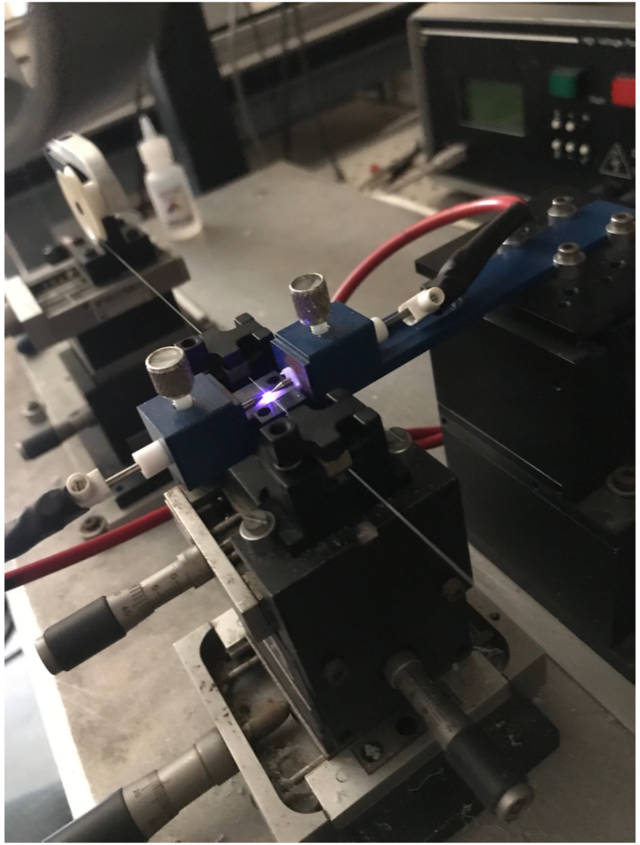
FBG

Length: 1 cm
Period: 530 nm
λ_{res}: 1534 nm
FWHM: 0.26 nm
transmission loss: 10 dB

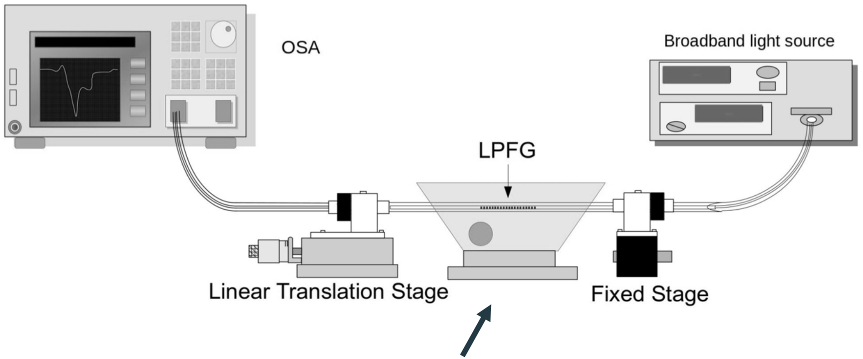
Fabrication Methods

LPFG fabricated by electric-arc discharge

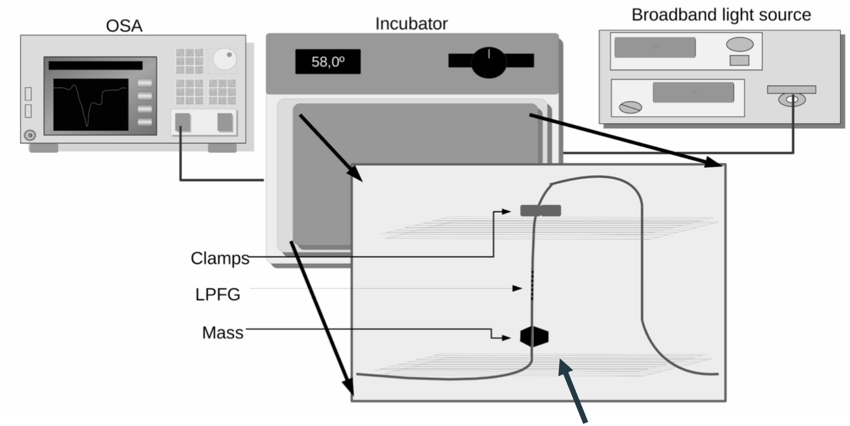
FBG produced by femtosecond laser



Experimental setup for LPFG measurements



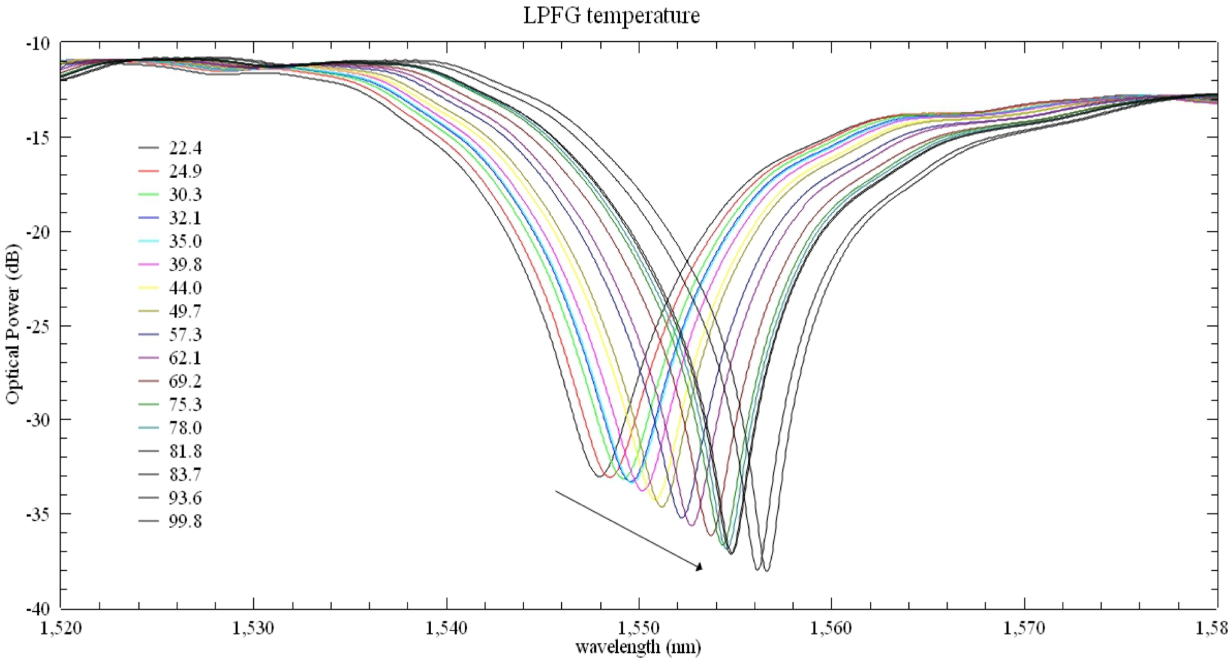
LPFG immersed on different liquid samples



LPFG inside chamber under constant strain

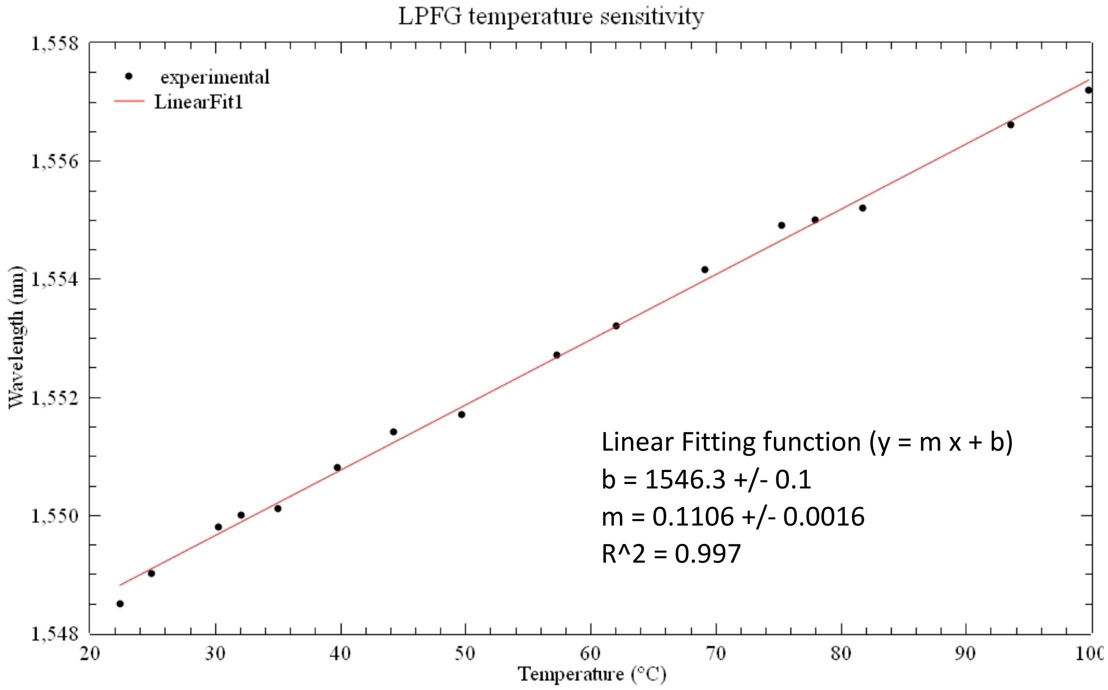
Experimental setup for refractive index (RI) and temperature measurements

LPFG temperature results (spectra)



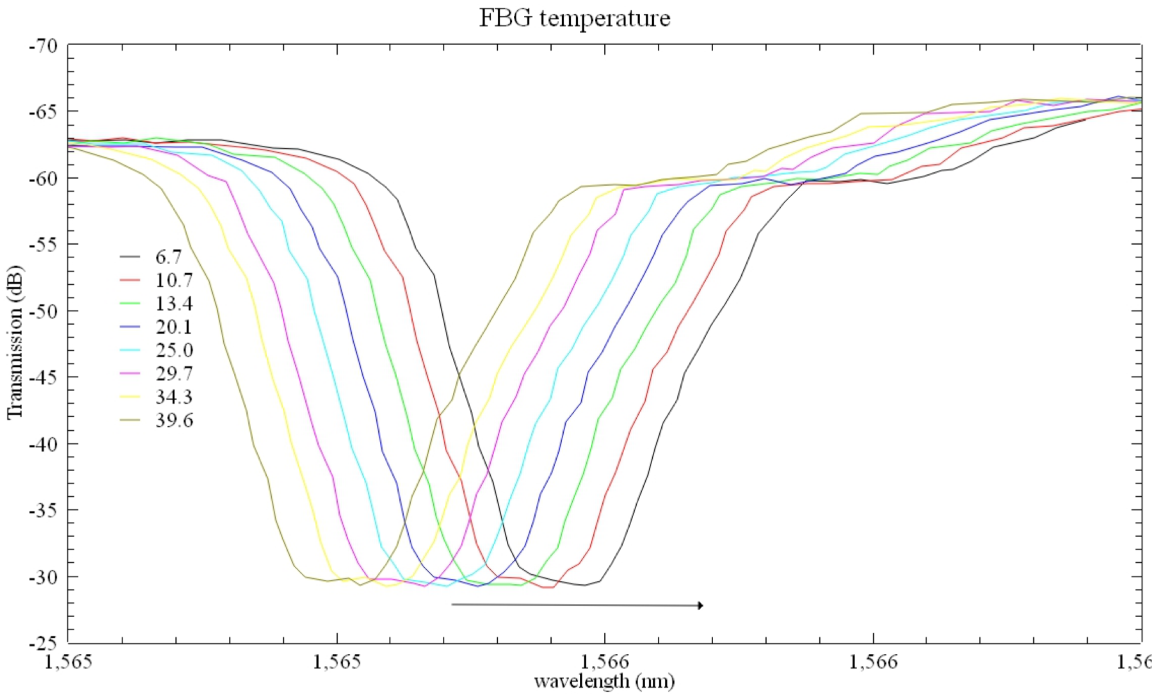
visible red-shift and amplitude increase

LPFG temperature sensitivity



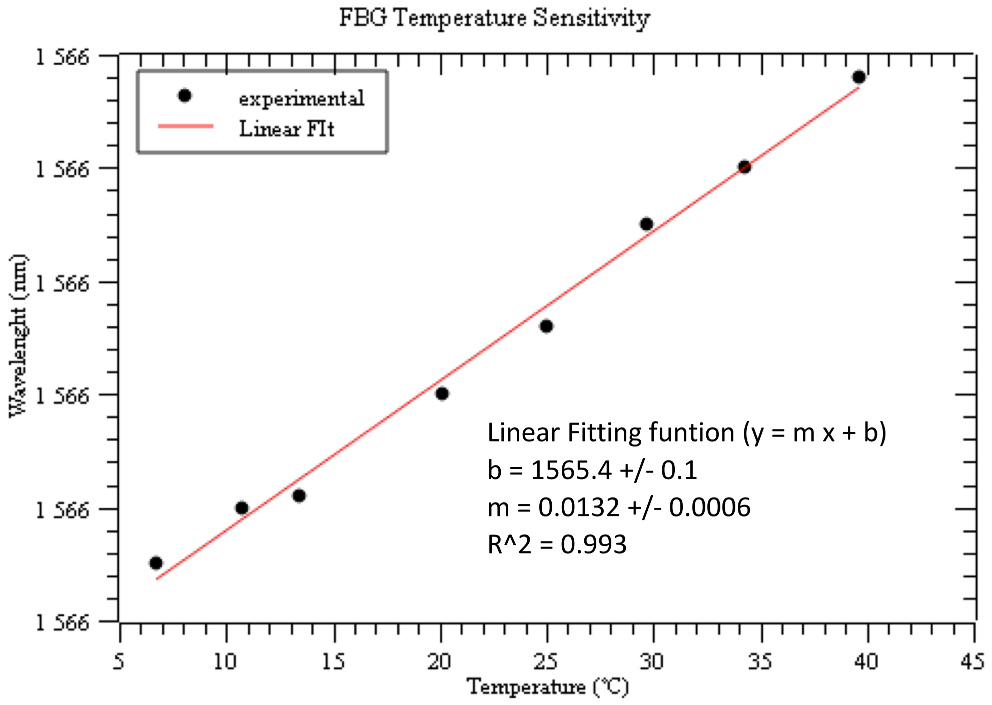
$S_{temperature}$ = 110.6 pm/ºC

FBG temperature results (spectra)



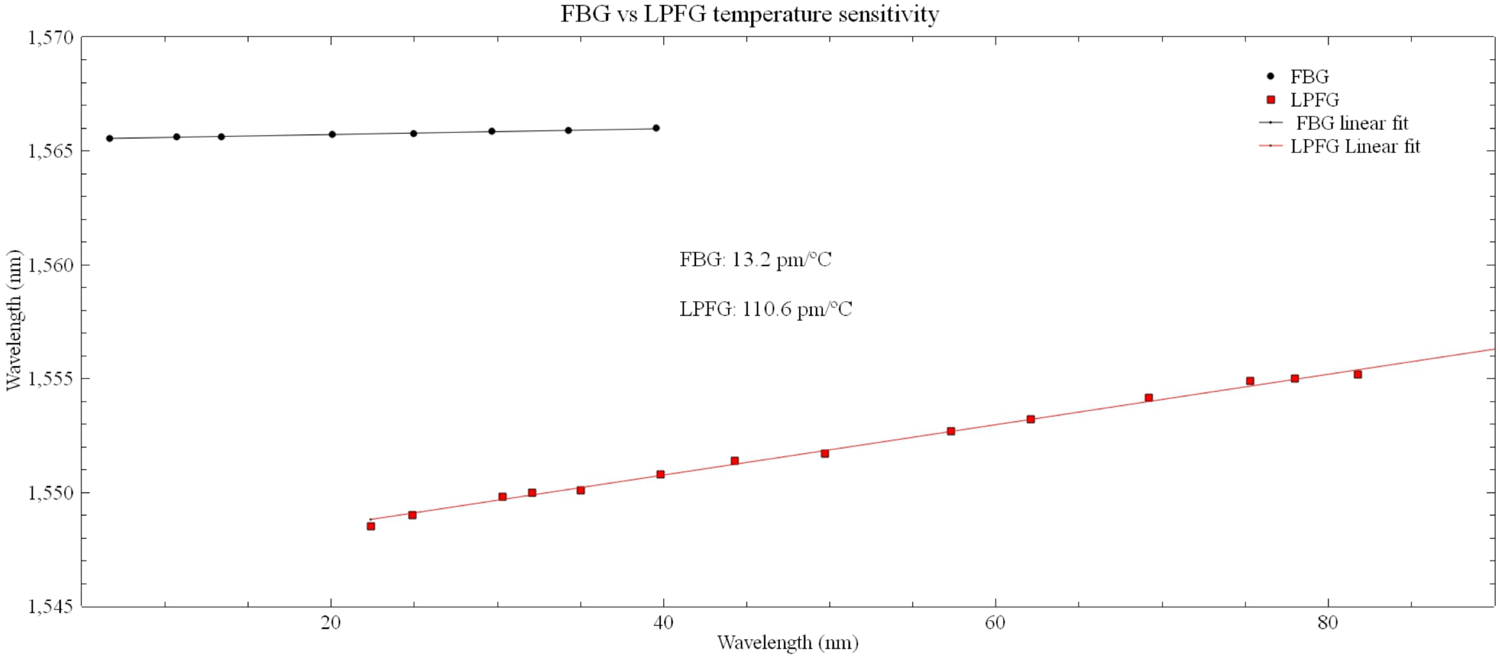
visible red-shift and negligible amplitude change

FBG temperature sensitivity



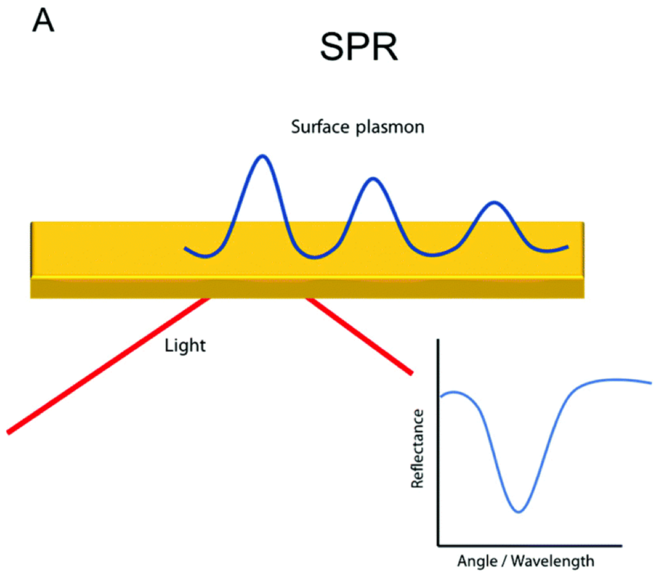
$S_{temperature}$ = 13.2 pm/ºC

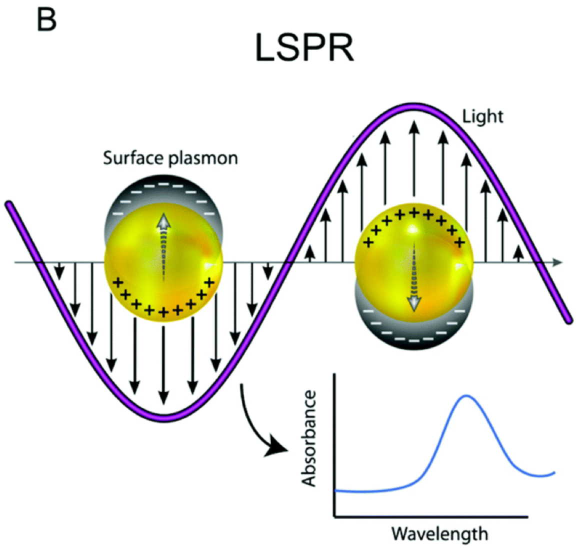
Temperature sensitivity comparison



LPFG presented a near 10x increase on temperature sensitivity over FBG

Plasmonic sensors

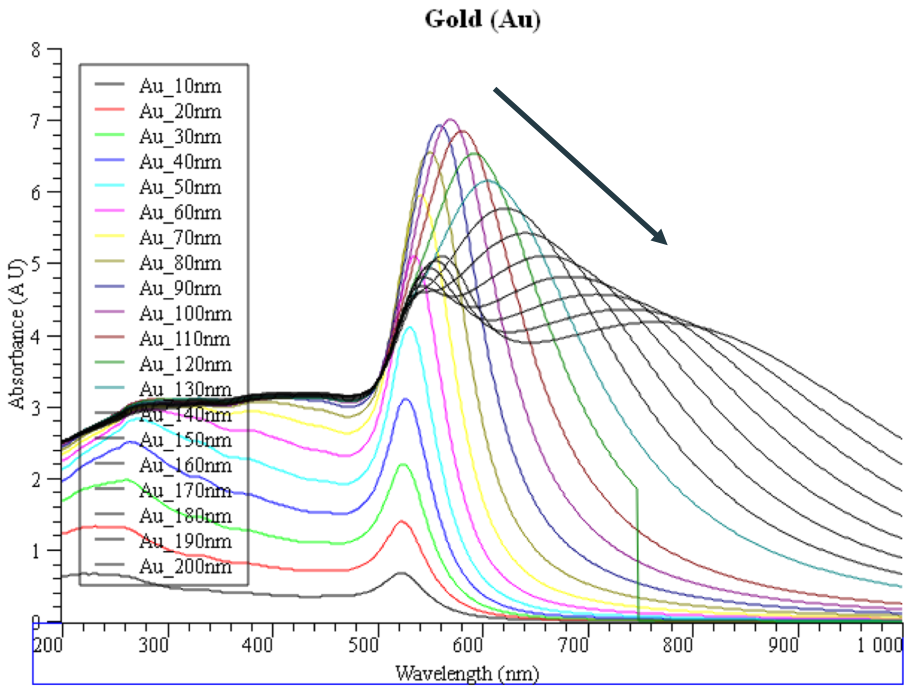




plasmonic excitation on metallic thin film by incident light
Surface plasmon resonance (SPR)

plasmonic excitation on nanoparticle by incident light
Localized surface plasmon resonance (LSPR)

LSPR material and size dependency (gold)



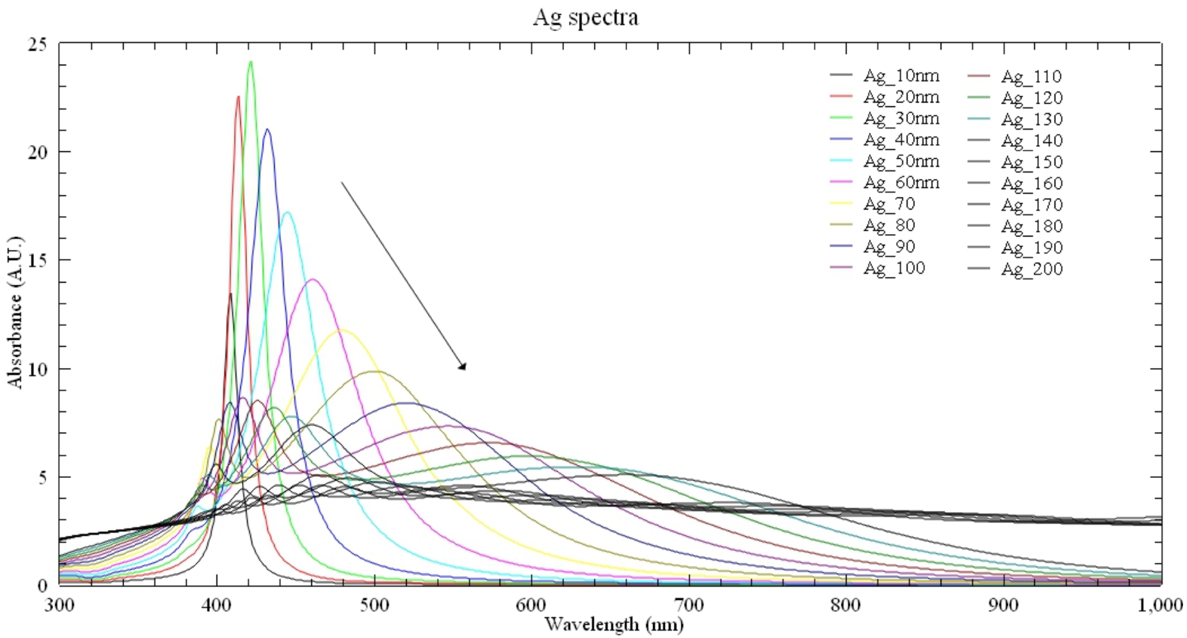
LSPR wavelength increases along the nanosphere diameter

For a gold nanosphere of 60 nm diameter the LSPR band is located at 525 nm

gold is the most stable nanomaterial for RI sensing in water

Simulation results

LSPR material and size dependency (silver)



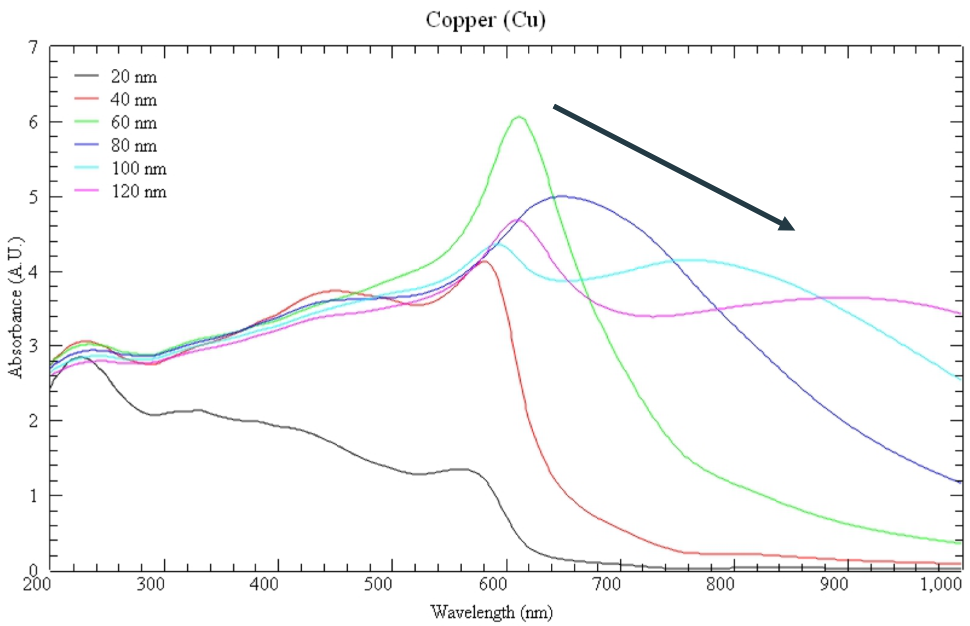
LSPR wavelength increases along the nanosphere diameter

For a silver nanosphere of 60 nm diameter the LSPR band is located at 470 nm

Silver oxidates when in contact with water so is not as good as gold for measurements in liquids

Simulation results

LSPR material and size dependency (copper)



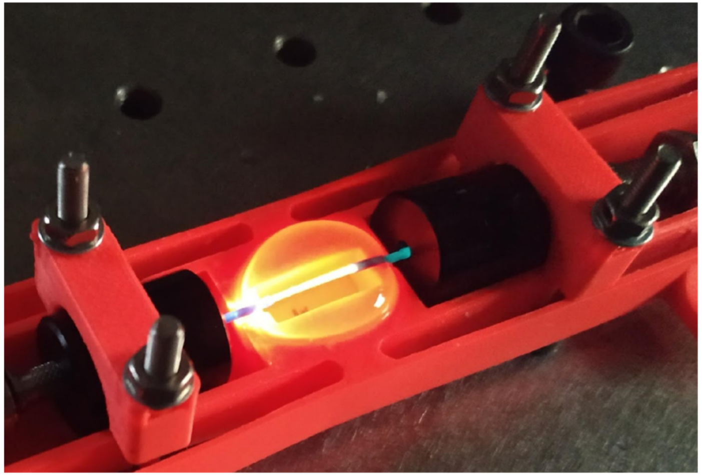
LSPR wavelength increases along the nanosphere diameter

For a copper nanosphere of 60 nm diameter the LSPR band is located at 610 nm

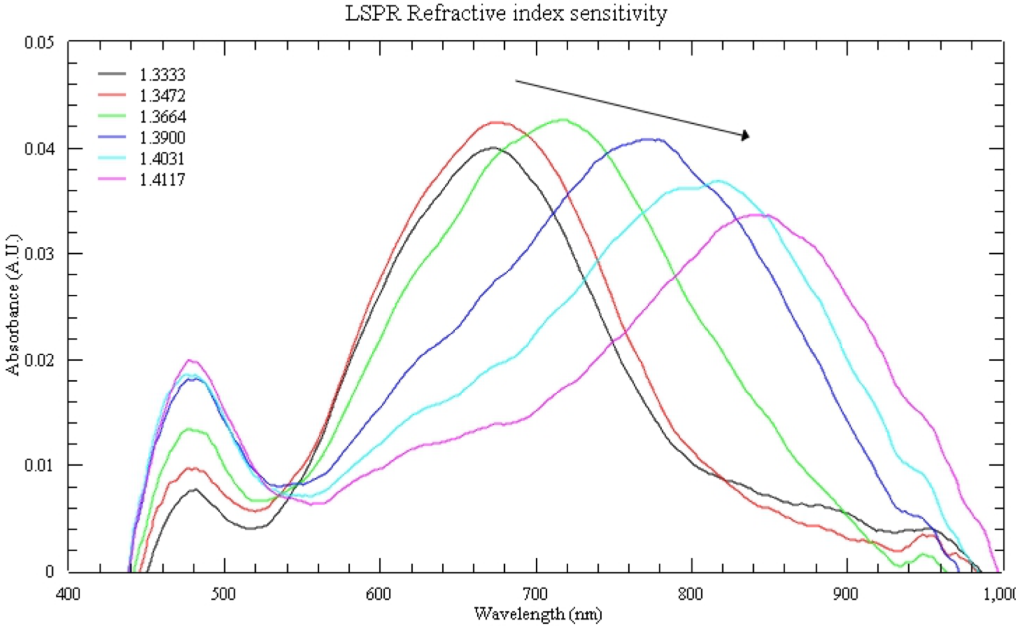
Copper oxidates fast when in contact with water

Simulation results

LSPR refractive index results (spectra)

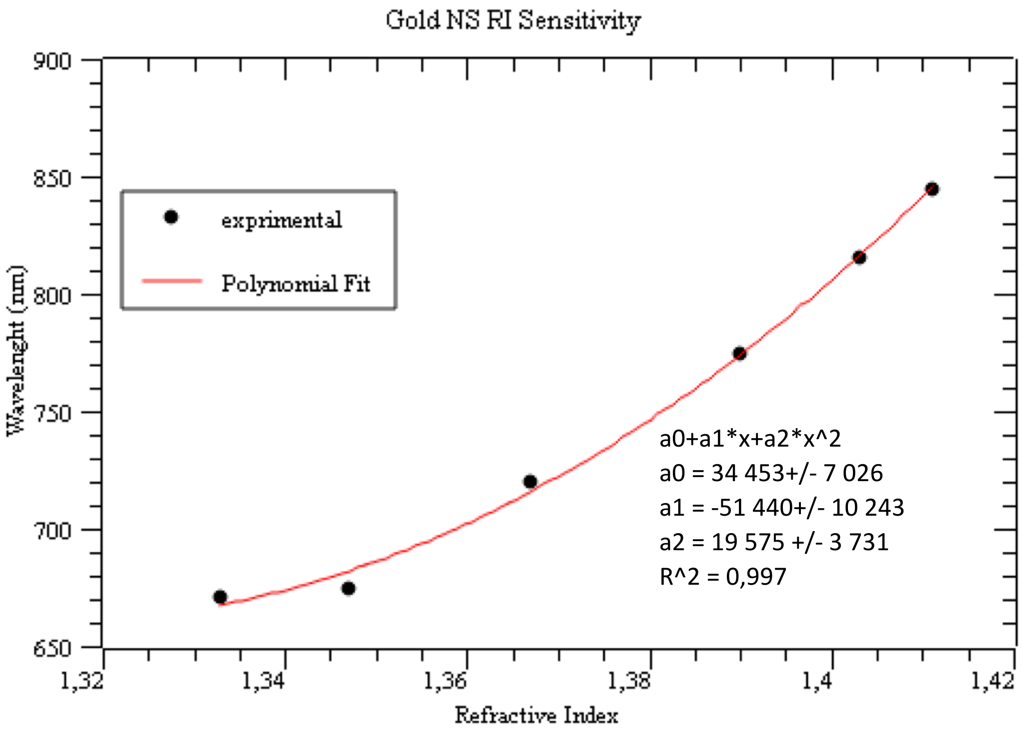


LSPR with Au nanospheres on multimode optical fiber



RI dependence on LSPR band

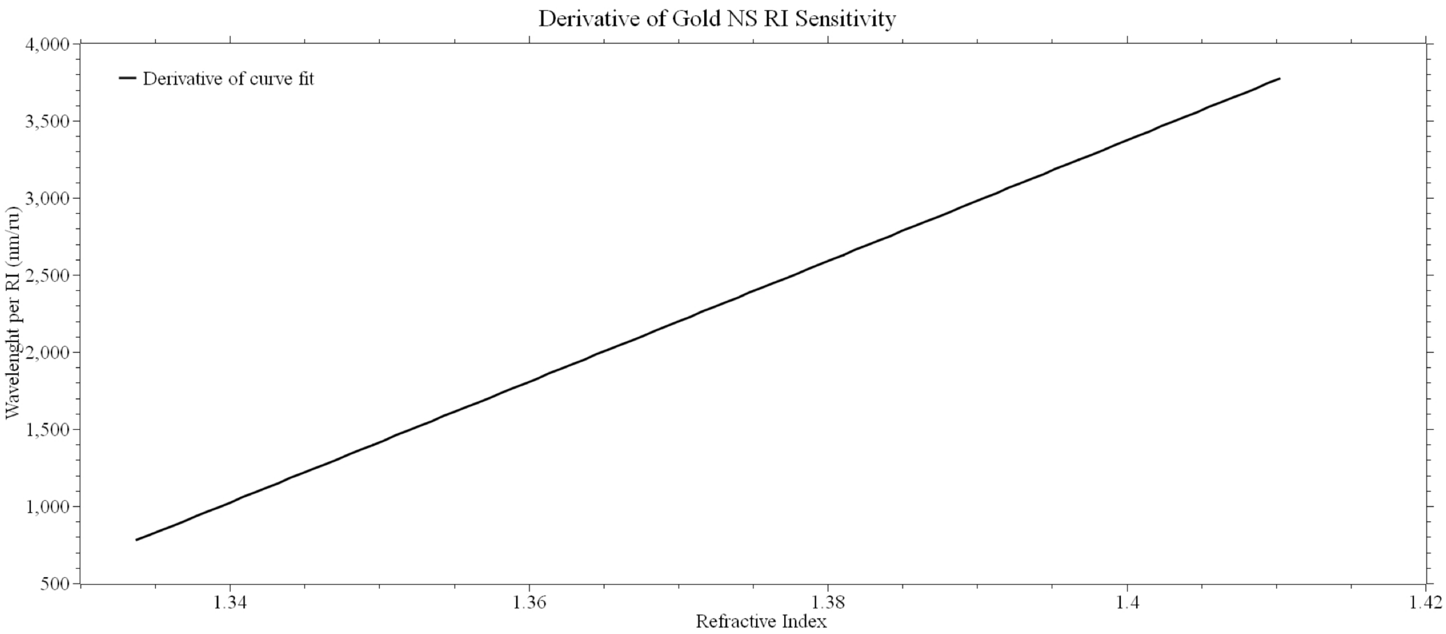
LSPR refractive index results (polyfit)



RI sensitivity increases for higher external RI values

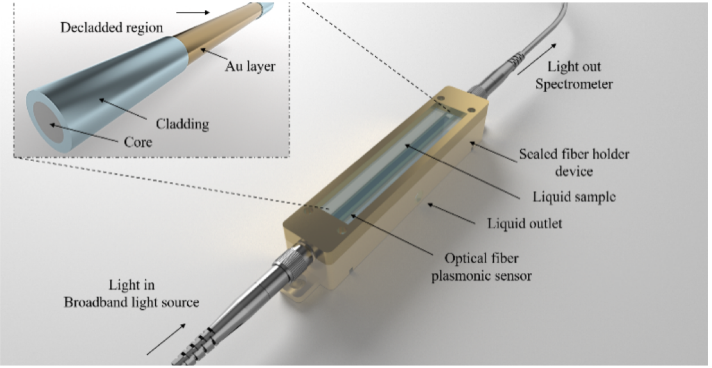
Non-linear behavior

LSPR RI results (Sensitivity derivative)

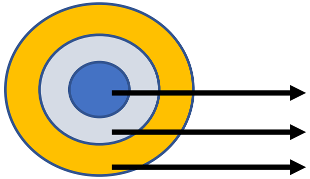


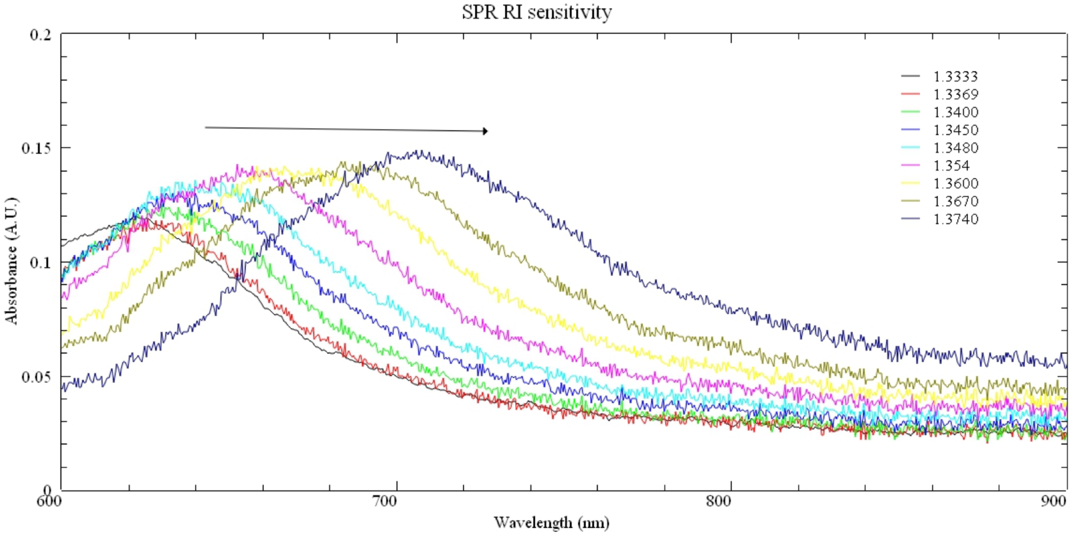
RI sensitivity much higher than the diffraction type of sensors

SPR refractive index results (spectra)



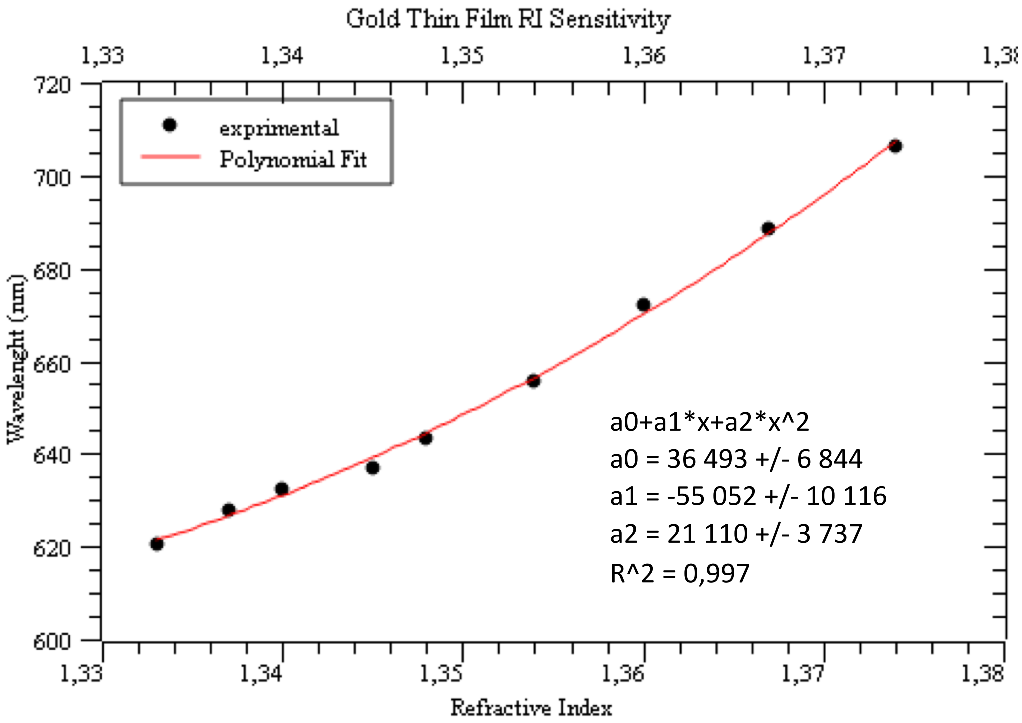
Multimode fiber covered by a gold thin film (50 nm)



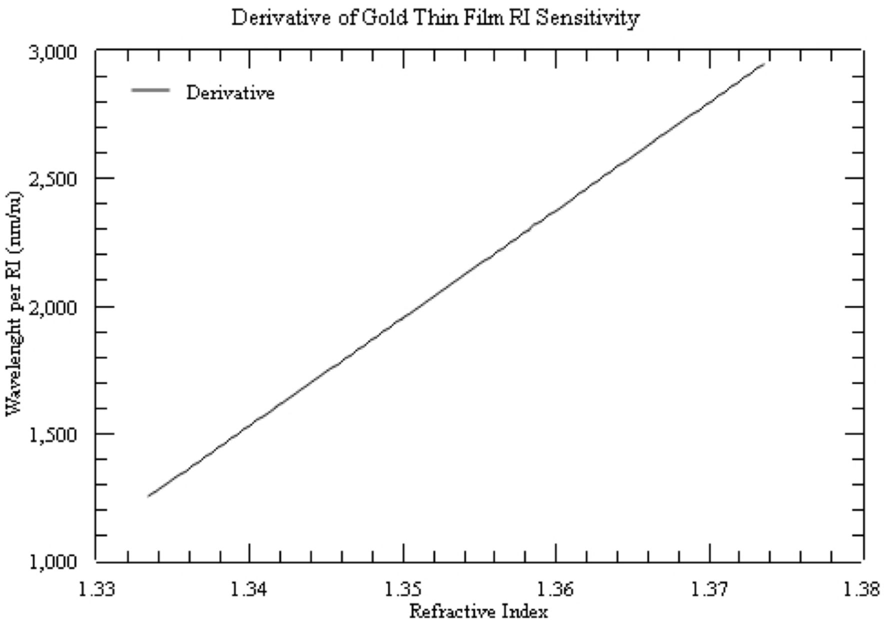


visible red-shift and small amplitude increase

SPR refractive index results (polynomial fit)

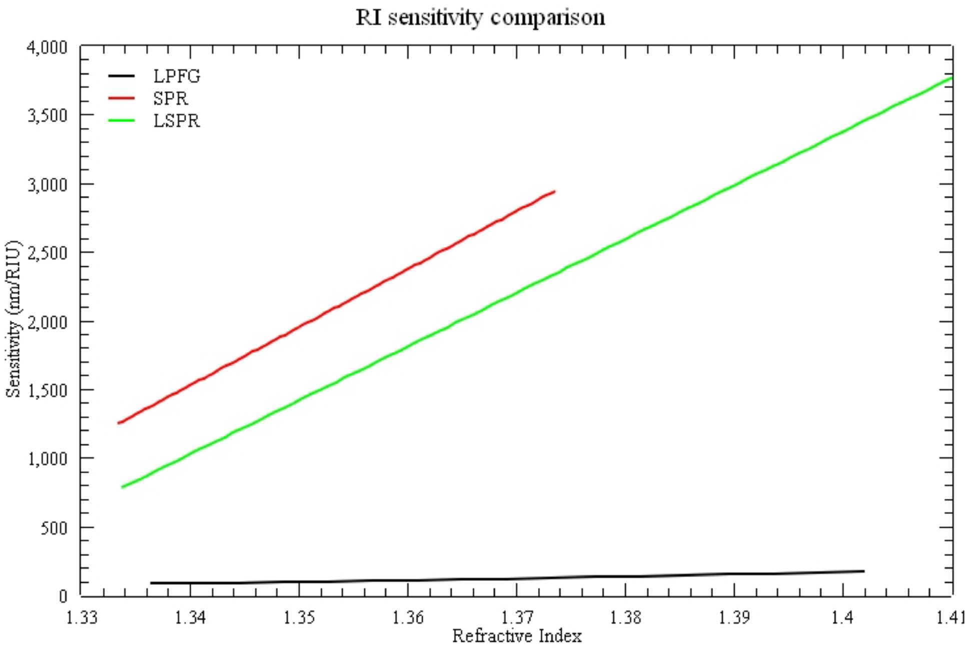


SPR refractive index results (polyfit derivative)



RI sensitivity much higher than the diffraction type of sensors

Discussion



The plasmonic sensors present the overall higher RI sensitivity

The thin film SPR is the most sensitive to external RI changes

The LPFG is the lowest performant sensor for RI but is able to sense temperature

The FBG sensor presents null RI sensitivity

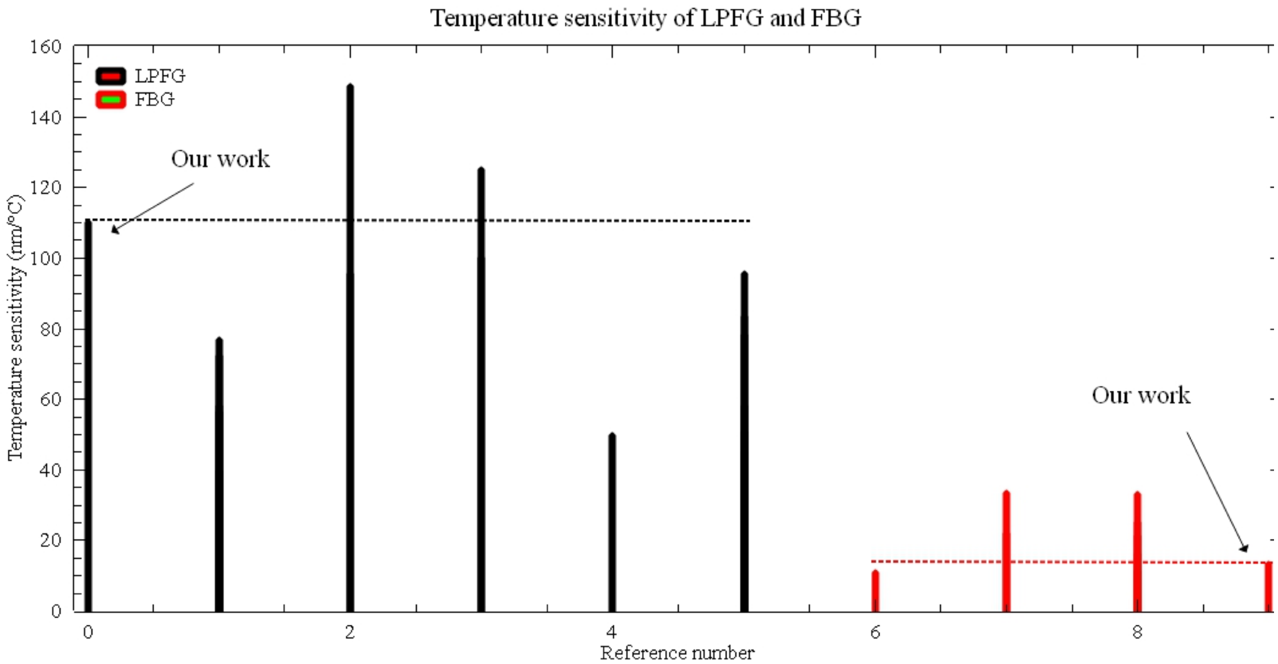
Discussion

The plasmonic sensors presents higher RI sensitivity with optical fibers with negligible temperature cross-sensitivity

To sense temperature LPFG presents the higher sensitivity, but FBG with a smaller band width presents a more favourable approach when multiple sensors are needed, since they occupy a smaller spectral bandwidth

The FBG sensor can compensate for the thermal sensitivity of the LPFG when the latter is used as a refractive index sensor

Discussion



1: Arc-Induced Long-Period Fibre Gratings. Fabrication and Their Applications in Optical Communications and Sensing, PhD thesis, FCUP, 2006, Gaspar Rego

2: Xinran Dong, Zheng Xie, Yuxin Song, Kai Yin, Dongkai Chu, Ji'an Duan. High temperature-sensitivity sensor based on long period fiber grating inscribed with femtosecond laser transversal-scanning method[J]. Chinese Optics Letters, 2017, 15(9): 090602

3: Viveiros, D.; de Almeida, J.M.M.M.; Coelho, L.; Vasconcelos, H.; Maia, J.M.; Amorim, V.A.; Jorge, P.A.S.; Marques, P.V.S. Temperature Stability and Spectral Tuning of Long Period Fiber Gratings Fabricated by Femtosecond Laser Direct Writing. *Sensors* **2020**, *20*, 3898. https://doi.org/10.3390/s20143898

4: Esposito F, Ranjan R, Stăncălie A, et al. Real-time analysis of arc-induced Long Period Gratings under gamma irradiation. *Sci Rep*. 2017;7:43389. Published 2017 Mar 6. doi:10.1038/srep43389

5: Esposito, Flavio & Srivastava, Anubhav & Campopiano, Stefania & Iadicicco, Agostino. (2019). Sensing Features of Arc-induced Long Period Gratings. Proceedings. 15. 10.3390/proceedings2019015029

6. Lai, Jinxing & Qiu, Junling & Fan, Haobo & Zhang, Qian & Hu, Zhinan & Wang, Junbao & Chen, Jianxun. (2016). Fiber Bragg Grating Sensors-Based In Situ Monitoring and Safety Assessment of Loess Tunnel. Journal of Sensors. 2016. 1-10. 10.1155/2016/8658290.

7. Ruiya Li, Yuegang Tan, Yiyang Chen, Liu Hong, Zude Zhou, Investigation of sensitivity enhancing and temperature compensation for fiber Bragg grating (FBG)-based strain sensor, Optical Fiber Technology, Volume 48, 2019, Pages 199-206, ISSN 1068-5200, https://doi.org/10.1016/j.yofte.2019.01.009.

8. Jaehoon Jung, Hui Nam, Byoungho Lee, Jae Oh Byun, and Nam Seong Kim, "Fiber Bragg grating temperature sensor with controllable sensitivity," Appl. Opt. 38, 2752-2754 (1999)

Discussion

Any questions :) ?