A new analysis method towards highly sensitive plasmonic fiber sensors

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I. Introduction

A gold-coated tilted fiber Bragg grating (TFBG) can detect the surrounding refractive index (SRI) change by surface plasmon resonance (SPR) shift. Following a similar principle as in the Kretschmann prism, the theoretical sensitivity of this device would be as large as the grating period projected along the fiber axis. However, the most commonly used demodulation methods achieve only 5% of this objective. We have developed a new demodulation method whose sensitivity rivals the theoretical predictions of the SPR.

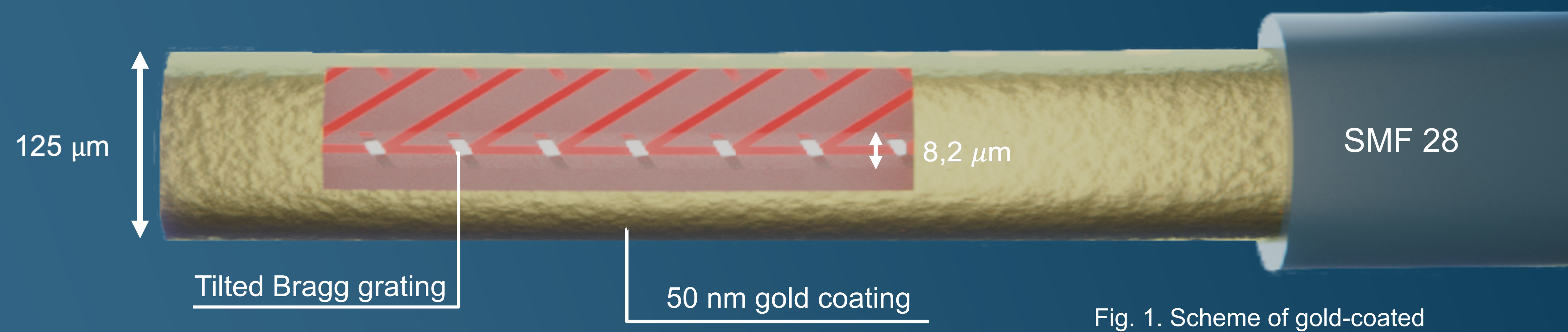

Fig. 1. Scheme of gold-coated tilted fiber Bragg grating (TFBG)

II. Theoretical concepts

Phase matching condition

$$\lambda_{cl}^{i} = \left(n_{eff}^{co}(\lambda_{cl}^{i}) + n_{eff}^{cl}(\lambda_{cl}^{i})\right)\Lambda.$$

Effective refractive index of surface plasmon is expressed by

$$n_{eff}^{sp} = \sqrt{\frac{\epsilon_m \epsilon_d}{\epsilon_m + \epsilon_d}}.$$

Sensitivity of the SPR shift

$$\frac{d\lambda^{sp}}{dn_{SM}} = \Lambda R\left\{\left(\frac{\epsilon_m}{\epsilon_m + n_{SM}^2}\right)^{\frac{3}{2}}\right\}.$$

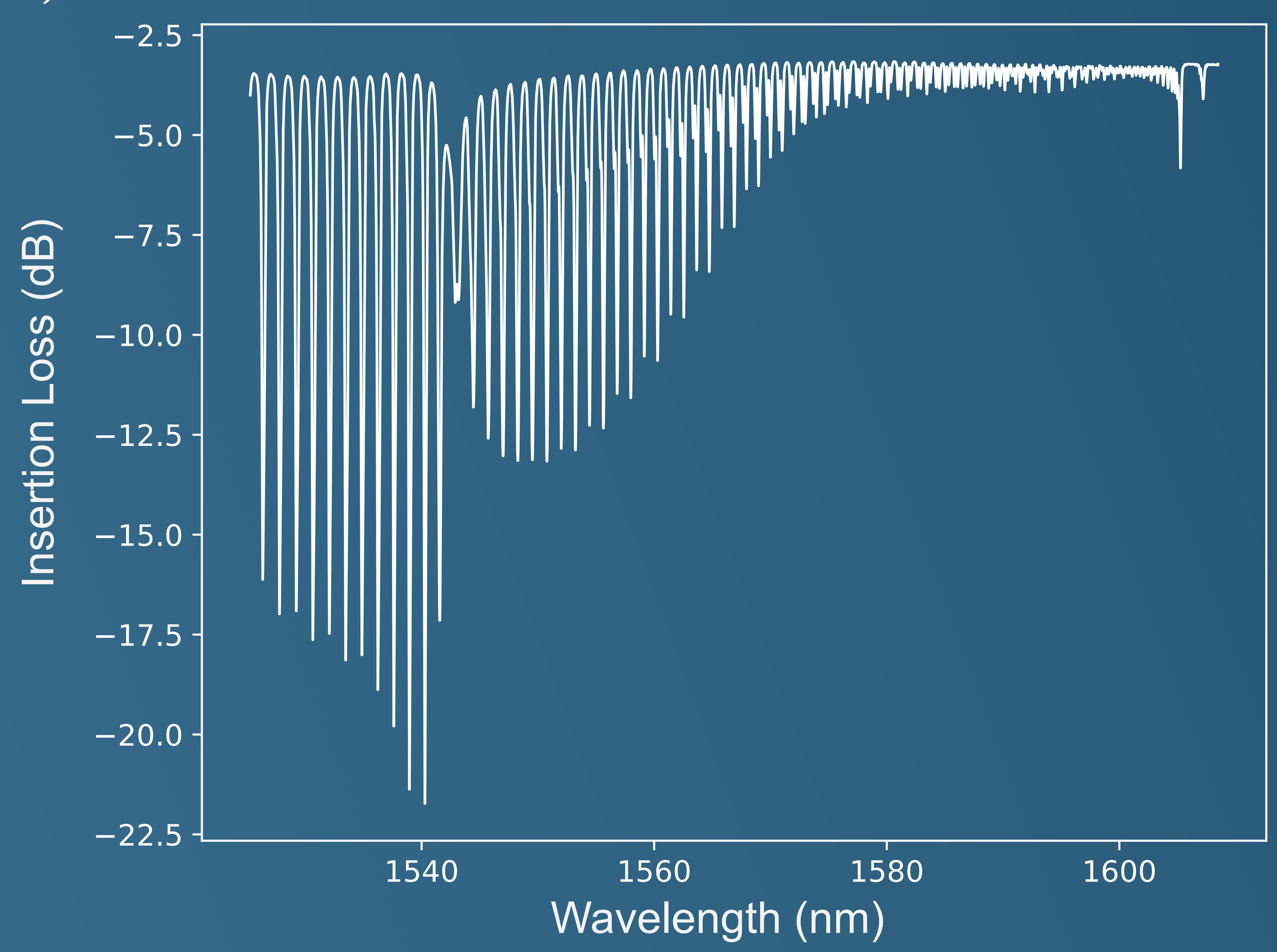

Fig. 2. P-polarized mode of the gold-coated TFBG insertion loss spectra

III. Experimental data

- Grating period projected along the fiber axis : Λ = 555.40516 nm
- Metal permittivity $\epsilon_m = (0.58 - 11i)^2$
- n_{eff}^{co} = 1.4447

IV. The most common method

- ❑ Determination of the most sensitive modes
- ❑ Tracking their evolution with SRI

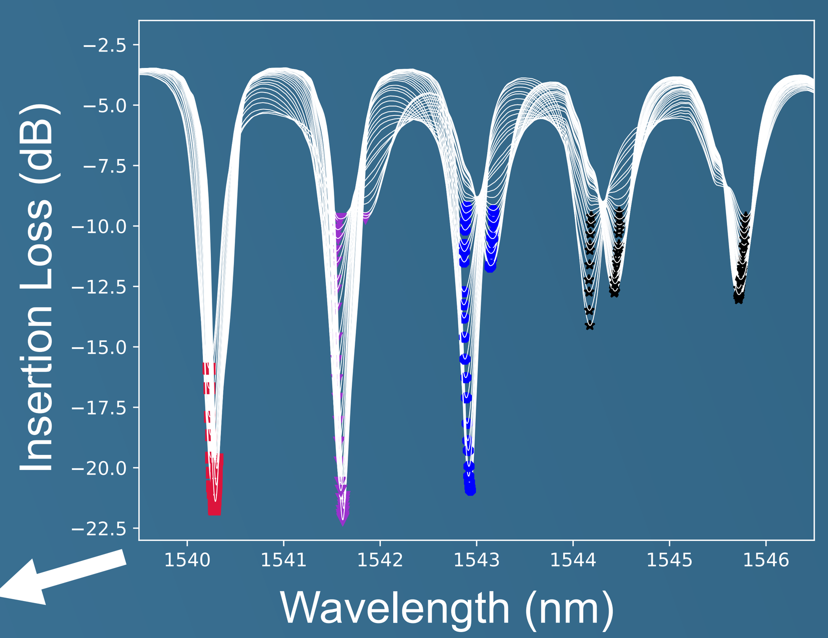

Fig. 3. Focus on the most sensitive modes (+1, +2, +3)

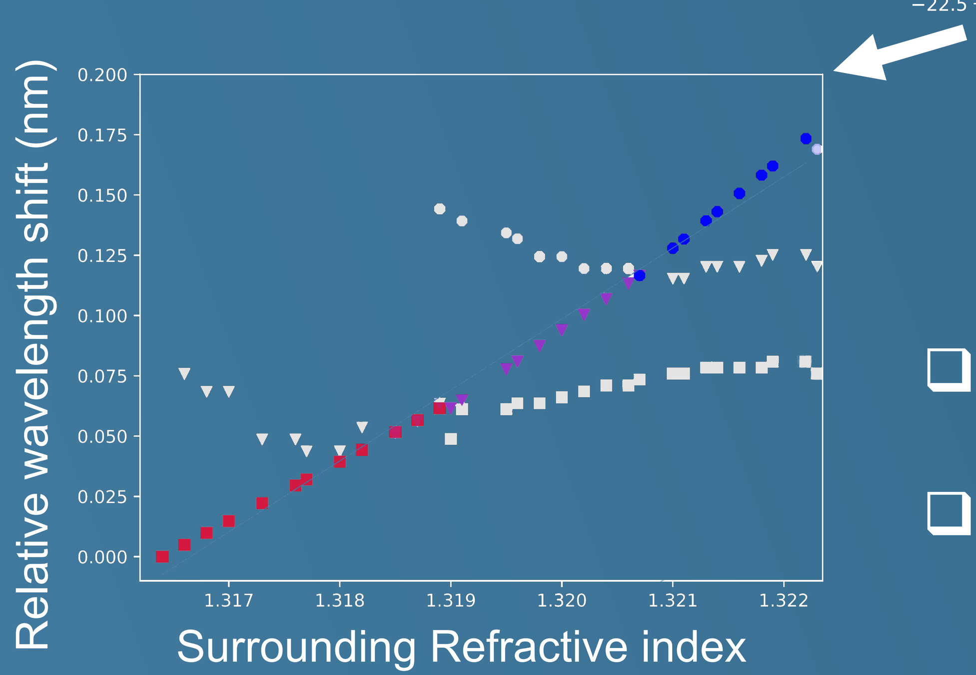

Fig. 4. Sensitivity determination using current method (29.441 nm/RIU)

- ❑ Selecting the RI range sensitivity for all mode
- ❑ Extracting the sensitivity by linear fit

V. The new demodulation method

- ➢ Finding upper and lower envelopes
- ➢ Minimum amplitude determination

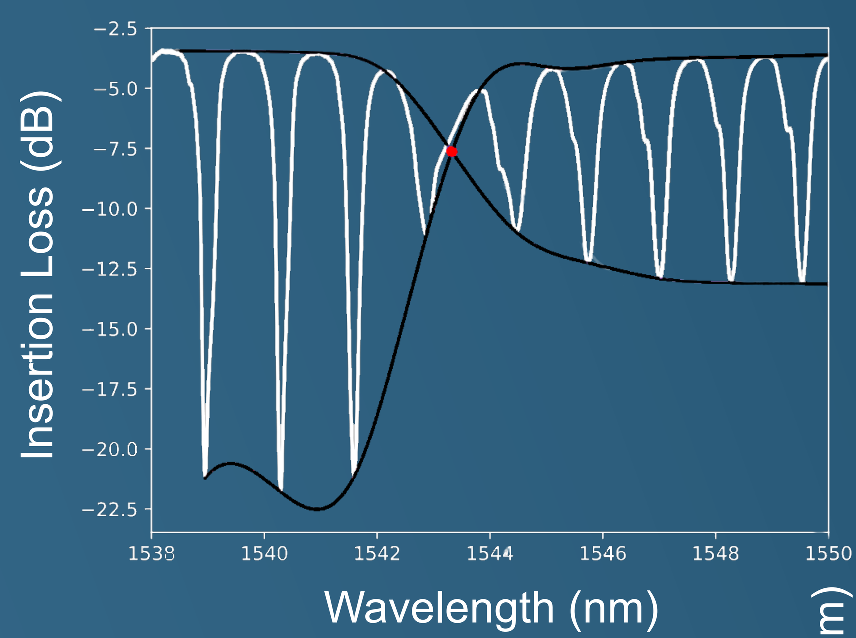

Fig. 5. Crossing point (red) determination using upper and lower envelopes (black)

- ➢ Cubic spline interpolation
- ➢ Crossing point determination
- ➢ Extracting the sensitivity by linear fit

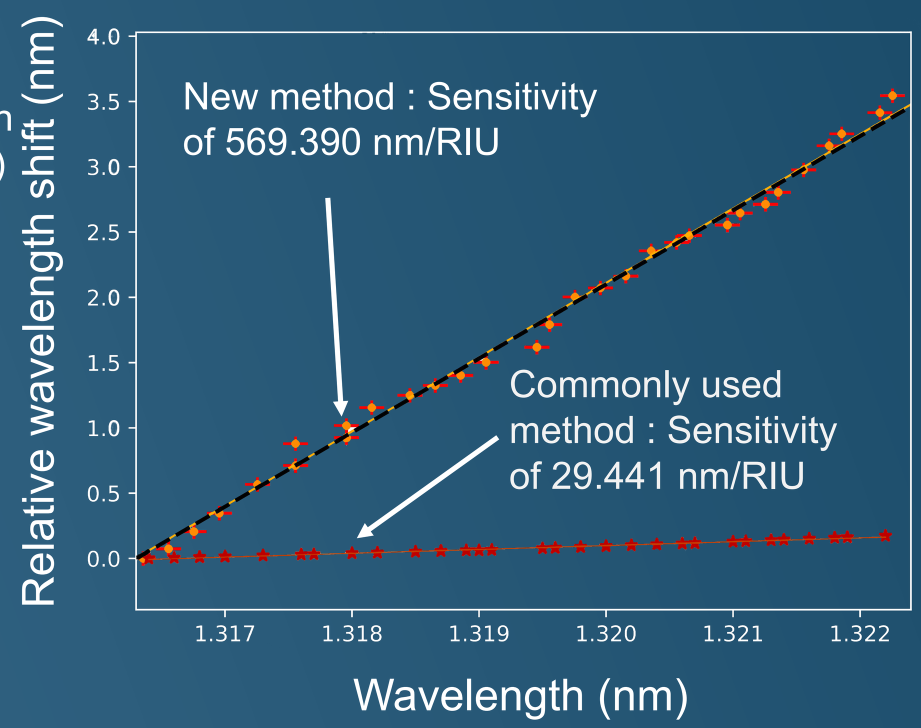

Fig. 6. Comparison of the sensitivities obtained by both methods. The black dashed line is the theoretical prediction (567.503 nm/RIU).

VI. Conclusion

Gold-coated TFBGs are promising platforms for the development of highly sensitive biosensors. The demodulation technique based on the tracking of the crossing point between the two spectral envelopes has shown a sensitivity of 569.390 nm/RIU, which is more than twenty times higher than the single peak tracking demodulation. The simplicity of the method also allows automatization of the demodulation process. Furthermore, similarities between the crossing point sensitivity and the theoretical prediction of the SPR shift were shown. The Automation of the process could lead to real-time analysis of chemical binding effects in the case of TFBG-based biosensors in future work.

For more information:

Acknowledgments

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