Integrated Optics refractometry: Sensitivity in relation to spectral shifts

H.J.W.M. Hoekstra

MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

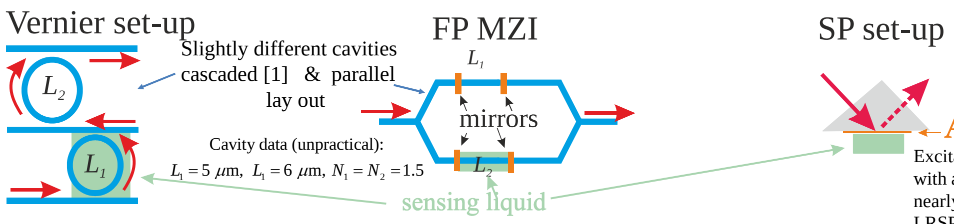
Tel.+31 53 489 2816, Fax. +31 53 489 3343, Email: h.j.w.m.hoekstra@utwente.nl

Abstract

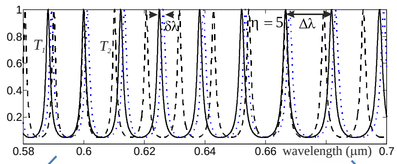
The poster

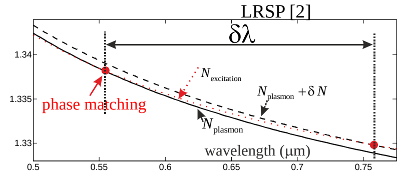
- Introduces a new variant to the Vernier-effect based sensor published by reference [1], both showing huge spectral shifts $\delta\lambda$
- Discusses a few sensors showing huge spectral dependence on the modal index, N, and on the index of the sensing material, n_s
- And the relevance of such devices for device sensitivity, S

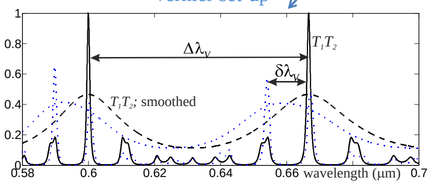
Sensing devices with principally a huge spectral shift

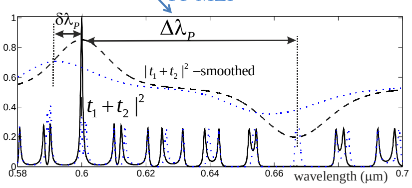


Transmittance of the separate cavities, T_1, T_2 and T_1 after shift $\delta\lambda$ (dotted blue)









$$\underbrace{\left|\frac{\partial\lambda}{\partial n_s}\right|_{N_{exc}-N_p}}_{\text{huge}} = \underbrace{\left|\frac{\partial\lambda}{\partial(N_{exc}-N_p)}\right|_{n_s}}_{\text{huge}} \left(\frac{\partial N_{pl}}{\partial n_s}\right)$$

- Huge spectral shifts in all three devices owing to similarity of sensing part and 'analyser' part
- Huge shifts go together with a broad spectral response
- What does the introduced huge spectral shift mean for the sensitivity? (nothing!)

Sensitivity

- Definition of Sensitivity: $S_n \equiv \left|\frac{\partial \ln T}{\partial n_s}\right|_\lambda$ (assuming that noise $\propto T$)
- Huge spectral shift in above devices goes together with broad response:

$$\left|\frac{\partial \ln T}{\partial n_s}\right|_\lambda = \underbrace{\left|\frac{\partial \ln T}{\partial \lambda}\right|_{n_s}}_{\text{small}} \underbrace{\left|\frac{\partial \lambda}{\partial n_s}\right|_T}_{\text{huge}},$$

e.g. $S_{n,\text{Vernier}} = \left|\frac{\partial \ln T_1 T_2}{\partial n_s}\right|_\lambda = \left|\frac{\partial \ln T_1}{\partial n_s}\right|_\lambda = S_{n,\text{single cavity}}$ No effect of huge shift!

Sensitivity, what is relevant?

What is important for a high sensitivity in an interferometric set-up with a (PhC) sensing Waveguide?

reformulation of S_n: $S_n = \underbrace{\left|\frac{\partial \ln T}{\partial \beta}\right|_n}_{\text{interferometry}} \underbrace{\left|\frac{\partial \beta}{\partial \lambda}\right|_n}_{\propto 1/v_g} \underbrace{\left|\frac{\partial \lambda}{\partial n}\right|_T}_{\propto D_{\text{relative}}}$

- low group velocity (like in PhC and plasmonic waveguides)
- large spectral shift for the response of the waveguide [3]:

$$(\partial\lambda/\partial n_s)_T \propto \int_{\text{unit cell}}^{\text{sensed material}} |\boldsymbol{E}|^2\, d\tau \Big/ \int_{\text{unit cell}} \varepsilon\, |\boldsymbol{E}|^2\, d\tau$$

corresponding to strong light-matter interaction.

- Interferometry to transform modal phase shifts into power changes (MZI, FP) and to increase light-matter interaction (FP).

Conclusions

- Huge spectral shifts in devices as shown above do not increase the sensitivity, but
- relax demands on the resolution of the scanning laser or spectrometer
- The crucial point of large sensitivity in interferometric sensing seems to be the light-matter interaction

References

1. T. Claes et al., *Experimental characterization of a Si photonic biosensor consisting of two cascaded ring resonators based on the Vernier effect etc.*, Opt. Expr. 18, 2010, 22747-22761
2. G.G. Nenninger et., *Long-range surface plasmons for high resolution surface plasmon resonance sensors*, Sensors and Actuators B 74, 2001, 145-151
3. J.D. Joannopoulos at. al., *Photonic Crystals: Molding the flow of light*, Princeton University, 2008

MESA+ INSTITUTE FOR NANOTECHNOLOGY

UNIVERSITY OF TWENTE.