Defect Grating Simulations: Perturbations by AFM-like Tips

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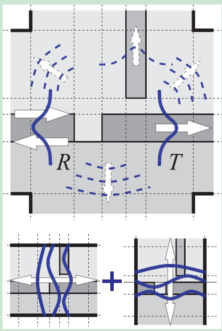
A defect grating in a silicon on insulator waveguide is simulated. We consider spectral changes in the optical transmission when a thin silicon nitride or silicon tip is scanned across the defect. The tip perturbs the resonance field, moving its peak wavelength and possibly changing its shape and quality factor. For the nitride tip, the influence is mostly a spectral shift; for silicon, the change of the resonance shape is pronounced. In particular for the nitride tip we observe a close correspondence between the wavelength shift as a function of tip position, and the local intensity in the unperturbed structure.

Calculation Method: QUEP

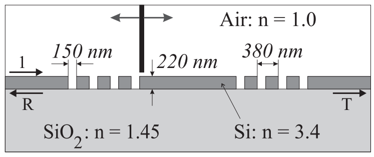


Subdivide the calculation window into layers and slices with constant refractive index along the vertical / horizontal axis.

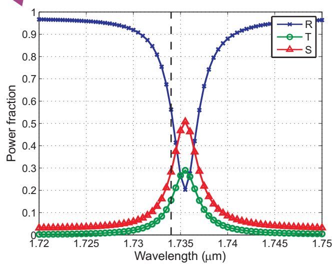
Expansion into bidirectional mode sets on layers and slices enables quasi-analytical simulations with transparent boundaries.

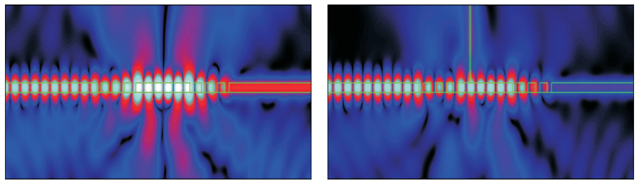
The defect grating with a 4-hole-long defect in the middle shows a pronounced resonance near λ = 1.735 μm. Slightly off-resonance, at the dashed line in the spectrum plot, the field is strongly influenced by a tip - and the transmission, reflection and scattering change.

Question: How do these changes relate to the unperturbed local intensity - i.e. do we measure this intensity by monitoring the transmission while probing?



Silicon (n=3.4) or Silicon Nitride (n=2.0) Tip: 40 nm wide, 10 nm above surface. T = modal transmission, R = modal reflection S = scattering





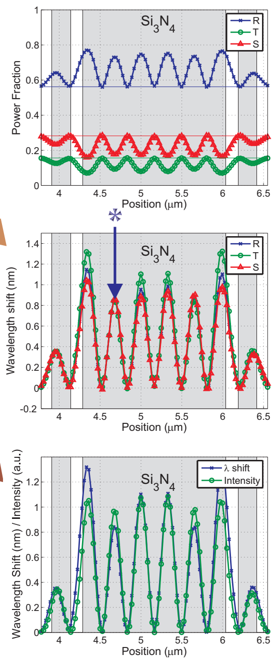
Silicon Nitride Tip

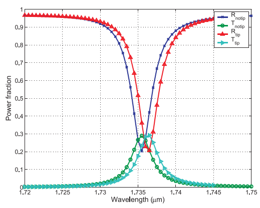
Scan of silicon nitride tip over surface - *R*, *T* and *S* vary.

Look-up in spectrum: What wavelength shift of the resonance is needed for this change in *R*, *T*, or *S*?

The predictions are nearly equal for R, T and S, thus the tip causes almost exclusively a shift of the resonance position; the form of the spectrum is largely unaffected.

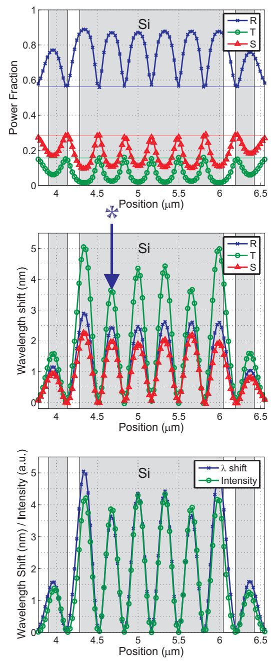
Predicted shift (from T) and local field intensity correlate quite well.





Spectrum with tip at location 4.6664 μm (*)

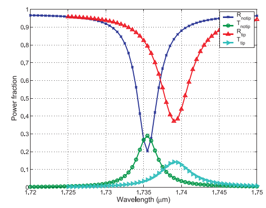
Silicon Tip



With a silicon tip, *R*, *T* and *S* vary much more strongly.

The predicted shift of the resonance is is also greater, and not nearly equal for *R*, *T*, and *S*. Thus, the spectrum deforms and shifts.

Still, the predicted wavelength shift (from T) and the local field intensity correlate very well!



Spectrum with tip at location 4.6664 μm (*)

Conclusions

Despite possibly strong deformations of the resonance spectrum, the local unperturbed field intensity can still be related to the changes in the transmission due to the presence of a dielectric tip. Though this relation is nonlinear, the unperturbed spectrum can be used to re-linearize the response. These results confirm the experiments in [1].

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References

[1] W.C.L. Hopman et al., *Nano-mechanical tuning and imaging of a photonic crystal micro-cavity resonance*, Optics Express, vol **14**, issue 19, pp. 8745-8752, 2006.

[2] M. Hammer, *Quadridirectional eigenmode expansion scheme for 2-D modeling of wave propagation in integrated optics*, Optics Communications, vol **235** (4-6), pp. 285-303, 2004.