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Enhanced Surface-to-Bulk Sensitivity Ratio of a Waveguide Grating Biosensor by Angular Interrogation at Short Wavelengths

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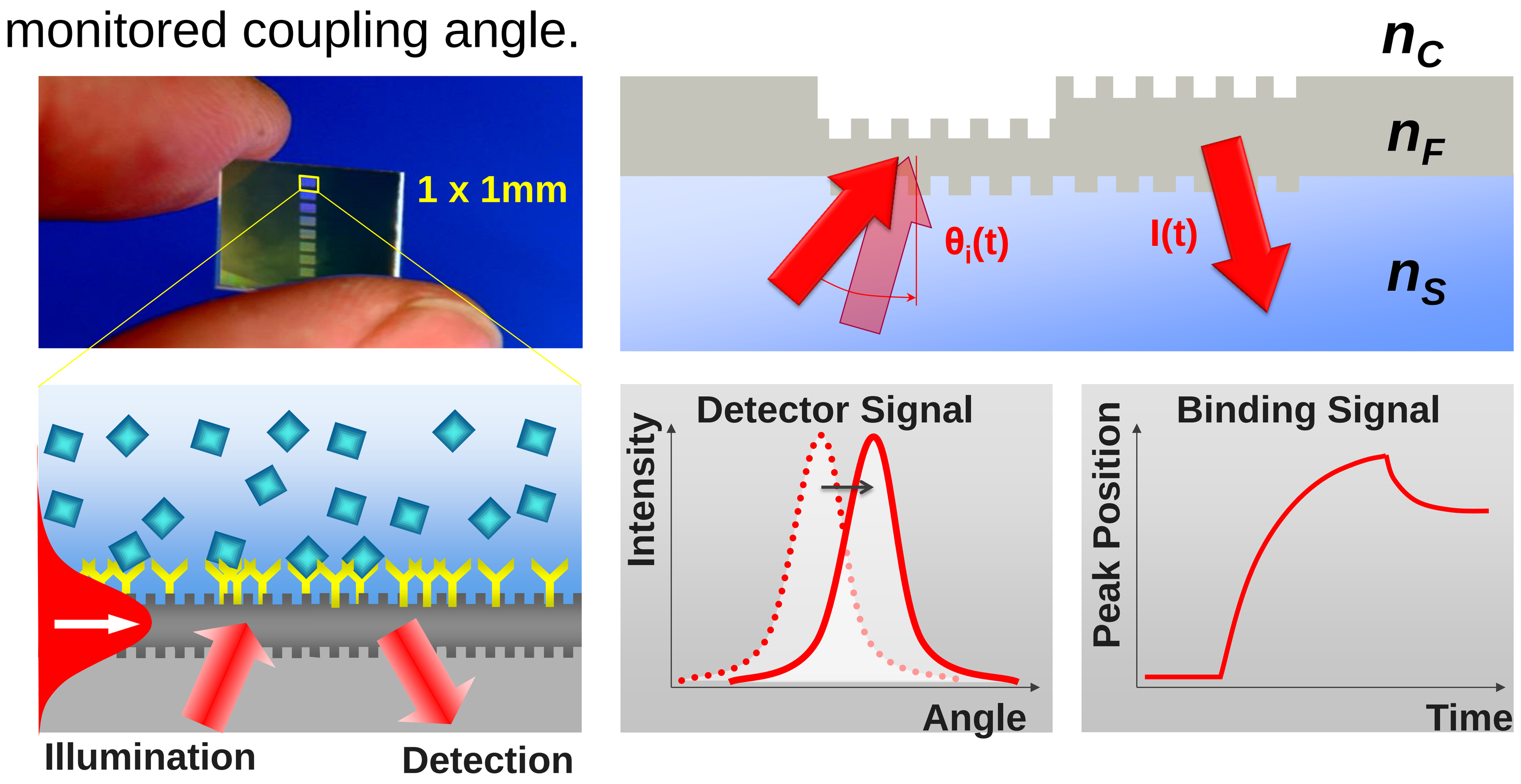
Label-free, waveguide grating based biosensors are sensitive to effective refractive index changes caused by the adsorption of biomolecules onto the sensor surface or due to refractive index changes of the bulk solution [1]. As these changes can only be sensed within the penetration depth of the evanescent field of the propagating mode, the so-called surface-to-bulk sensitivity ratio can be optimized by changing the wavelength of the interrogating light source. Since short wavelengths lead to a shallower penetration into the bulk solution but higher field densities in close proximity to the sensor, molecular binding events to the surface can be measured with enhanced sensitivity, whereas adverse refractive index changes of the bulk solution are suppressed [2, 3]. Additionally, the higher refractive index contrast at shorter wavelengths leads to an increased sensitivity. Besides numerical simulations and comparative measurements at different interrogation wavelengths ranging from the near-ultraviolet to the infrared, an integrated angle interrogated sensor system working at shorter wavelengths and higher repetition rates than common commercial systems is presented.

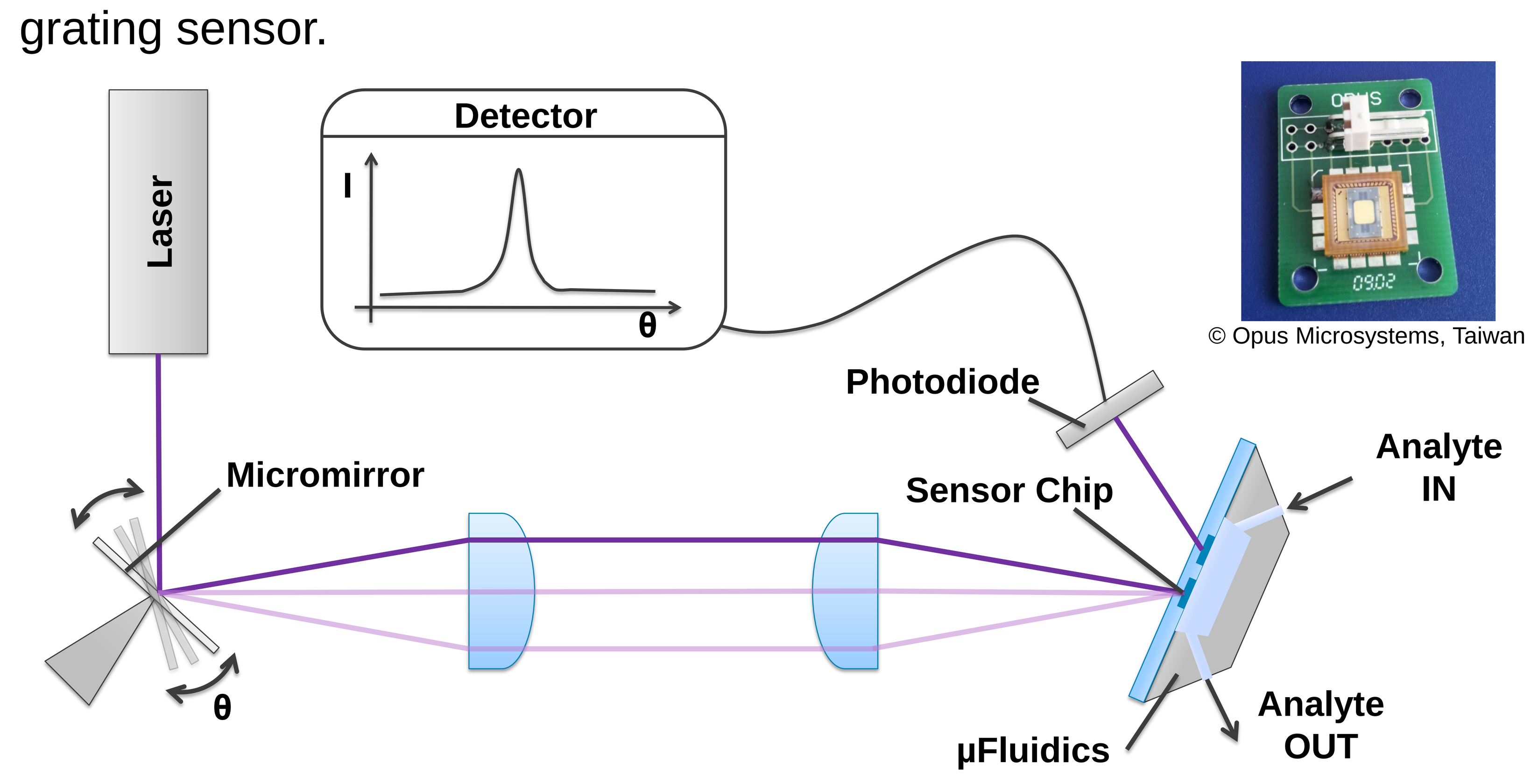
Sensing Principle

The adsorption of target molecules onto the Ta_2O_5 waveguide grating as well as the variation of the cover refractive index n_C cause a change of the effective refractive index and therefore a shift of the monitored coupling angle.



Reader System Schematics

MEMS scanning mirror for fast angular interrogation of the waveguide grating sensor.



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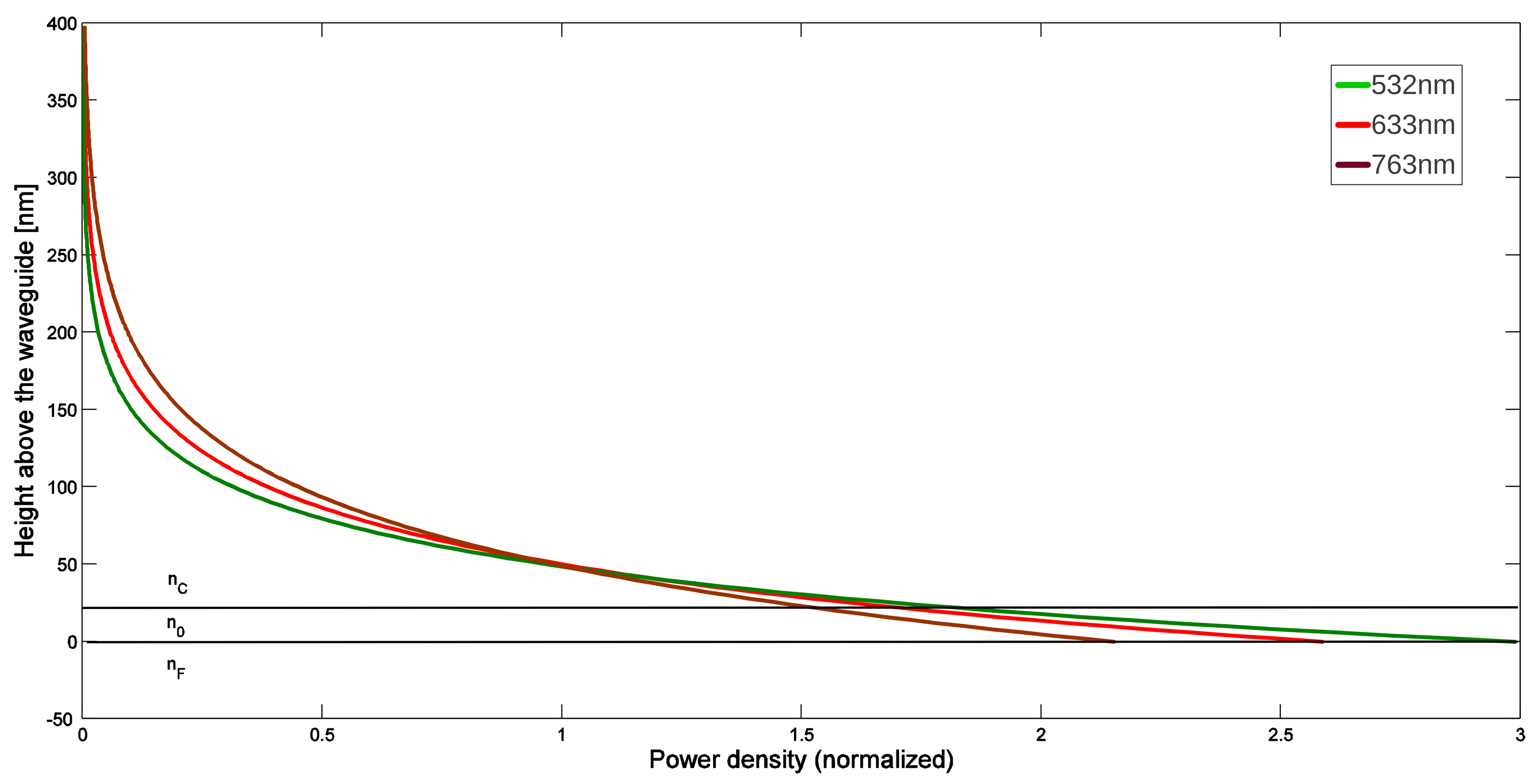
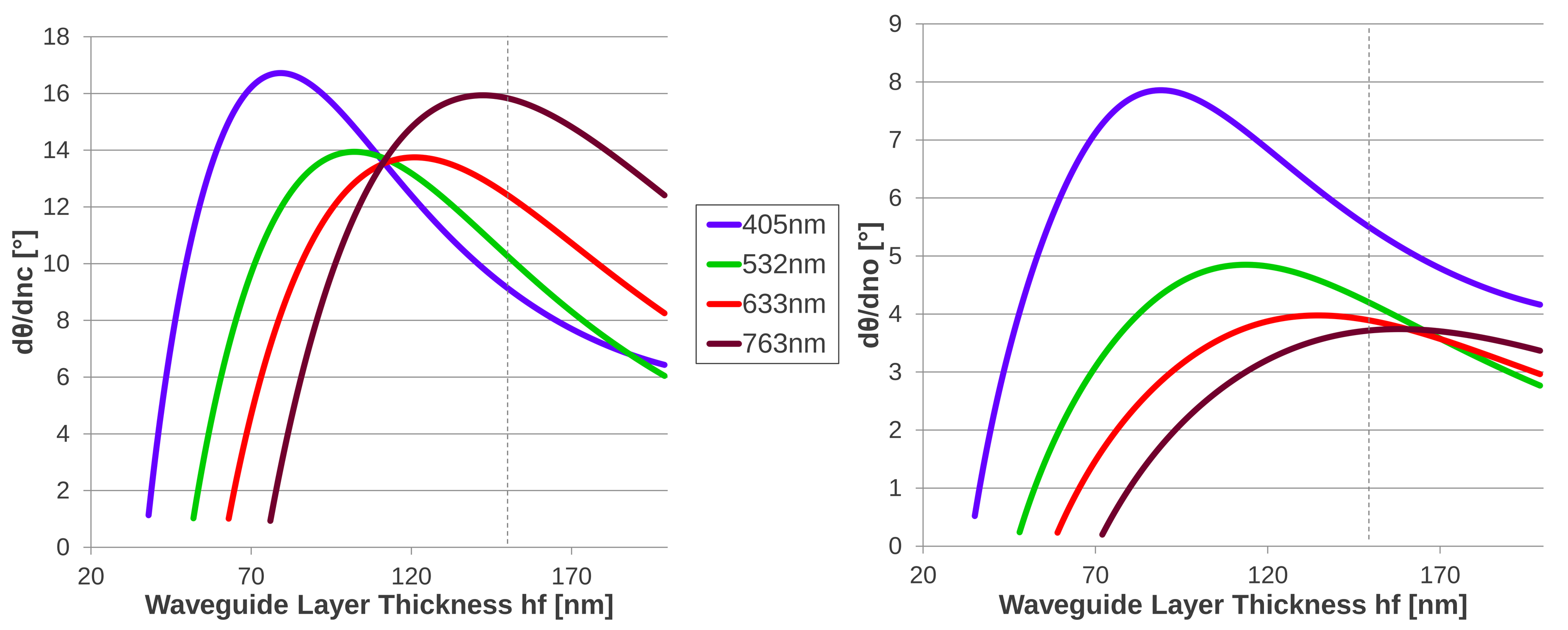
Evanescent Field Considerations

Simulated power density distribution of the evanescent sensing fields for different wavelengths: Short wavelengths exhibit a higher surface to bulk power density ratio compared to longer wavelengths with a bigger penetration depth. (n_C, n_0, n_F: cover-, sensing layer- and waveguide refractive index, respectively)



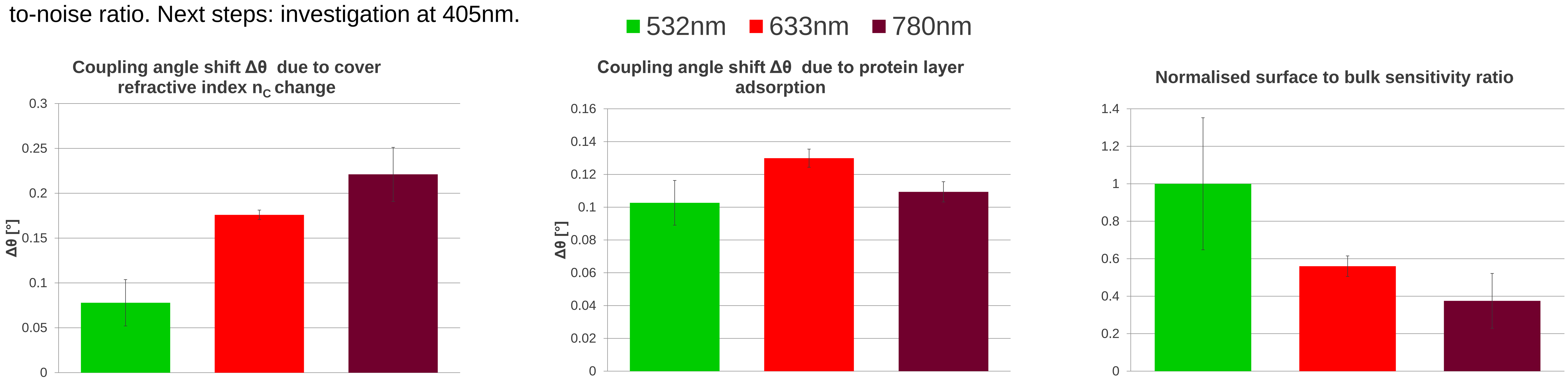
Simulated Sensor Sensitivities

Calculated sensor sensitivities for different interrogation wavelengths upon refractive index changes of the bulk cover medium (left) and within the sensing layer (right) with a thickness of 20nm, simulating the adsorption of molecules to the surface: The simulations suggest that the sensitivity regarding bulk refractive index changes remains approximately constant for different wavelengths considered, while short wavelengths are favoured for the detection of adsorbed species.



Measurements / Results

To investigate the abovementioned simulations, the coupling angle shift Δθ upon the change of the cover refractive index n_C (H_20 → 10%wt Glycerol in H_2O) and upon the adsorption of a protein layer (10% FBS in PBS) for a waveguide grating coupler type (h_f = 150nm) has been measured for three different wavelengths. In agreement with the simulations, the measured shift induced by the cover refractive index change decreased for shorter wavelengths, whereas the shift due to the absorption of a protein layer was similar for all investigated wavelengths at the given waveguide layer thickness h_f. Thus, we conclude that short wavelengths exhibit an increased surface-to-bulk sensitivity ratio and therefore a potentially higher signal-to-noise ratio. Next steps: investigation at 405nm.



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