Nanophotonics for single particle sensing and quantitative analysis

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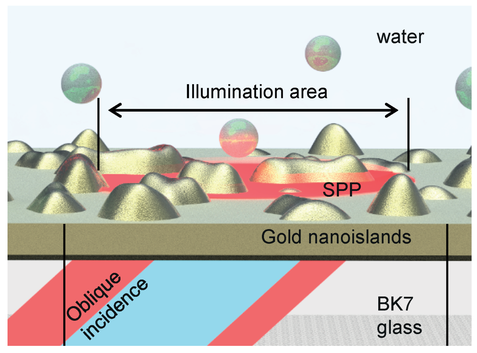
RESEARCH OVERVIEW

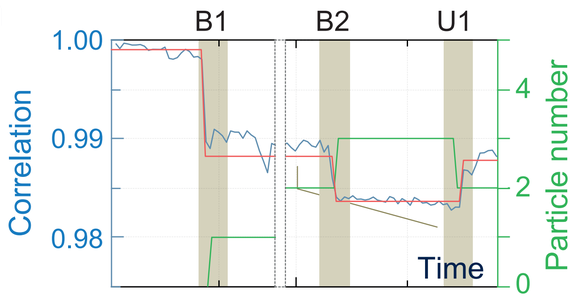
Our research covers topics including:

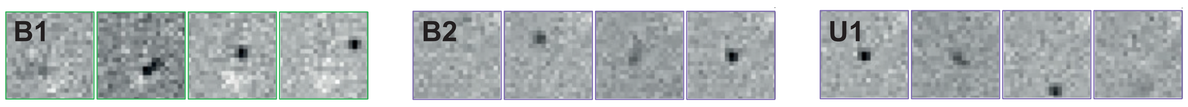
- **Modelling novel single particle optical and plasmonic sensing platforms**
- **Optimising detection limits and quantifying information theoretic limits in single molecule sensing**
- **Quantitative measurement techniques e.g. for tracking and particle sizing**
- **Enhancing light-matter interactions for improved sensitivity**

Single particle detection with plasmonic speckle

- **SPP leakage radiation:** provides interferometric SPR sensor output.
- **Disordered nanoisland substrate:** random interference of surface plasmons produces speckle.
- **Correlation-based detection:** individual (un-)binding of 50 nm Au polystyrene nanoparticles observed.
- **Independent validation:** by means of bright-field and fluorescence microscopy.

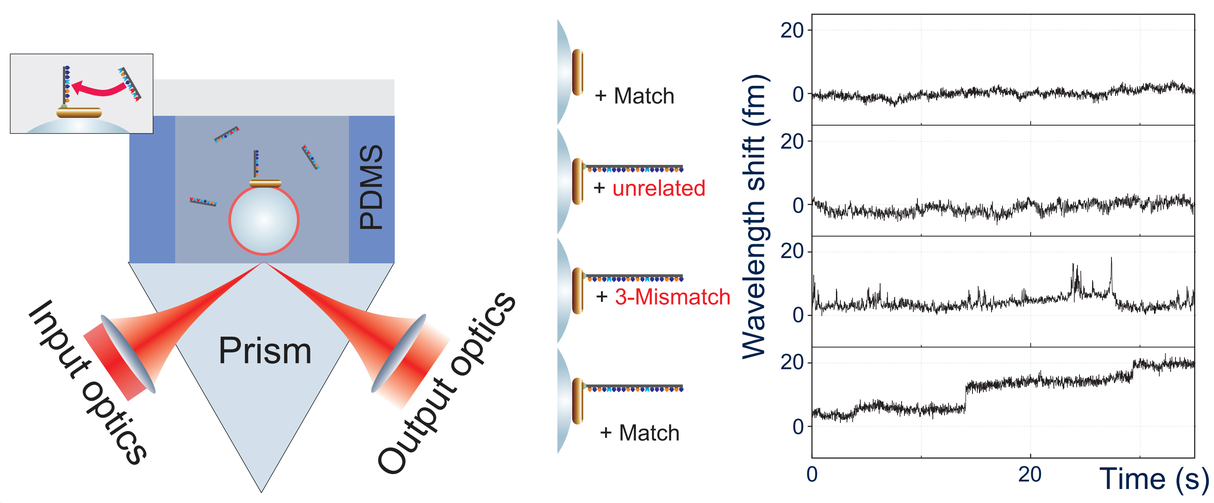






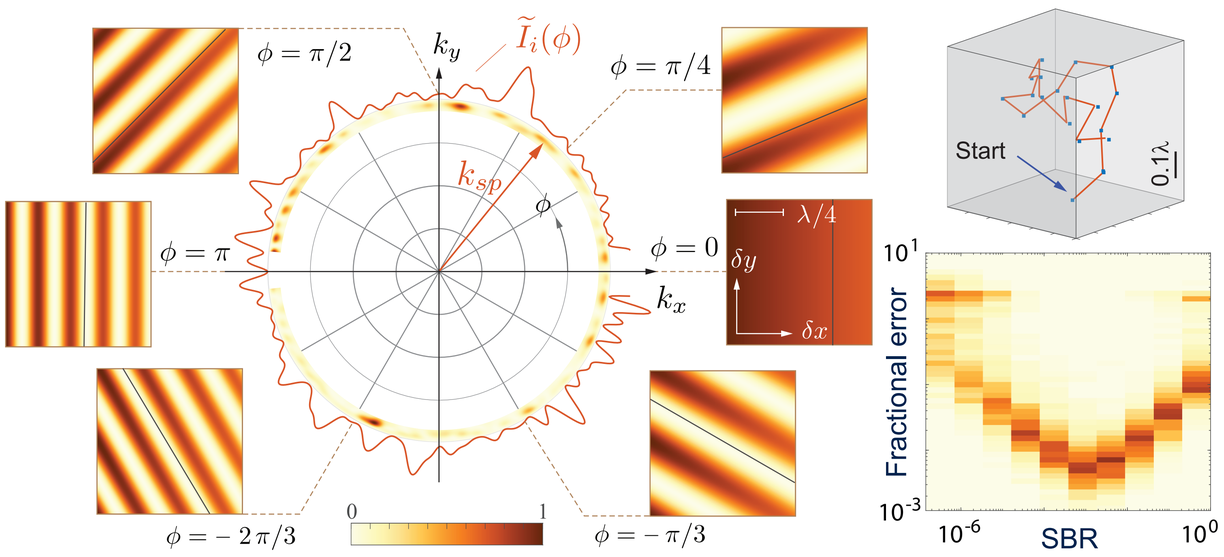
Hybrid plasmonic-photonic WGM sensors

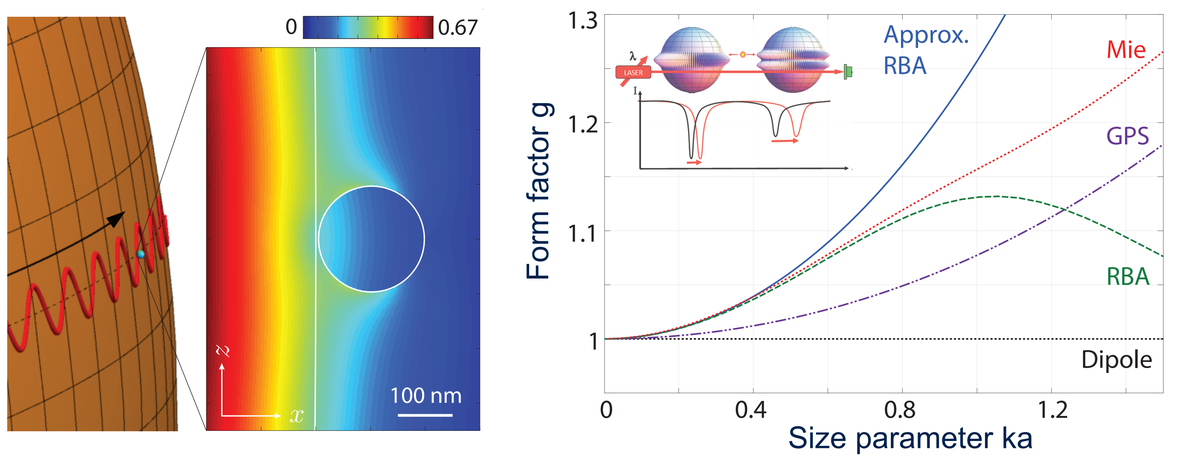
- **High Q whispering gallery mode resonator:** functionalised with Au nanorod based DNA receptor enhances light-matter interactions.
- **Specific detection of DNA hybridisation:** 8 base complimentary strands generate individual binding steps.



Plasmon interferometric scattering for tracking

- **Weak scattering regime:** analytically known shift dependence.
- **Consistent trajectory:** from multi-frame tracking algorithm.
- **Sub-nanometer precision:** simulated for optimal noise regime.





Quantitative particle sizing with WGM multiplexing

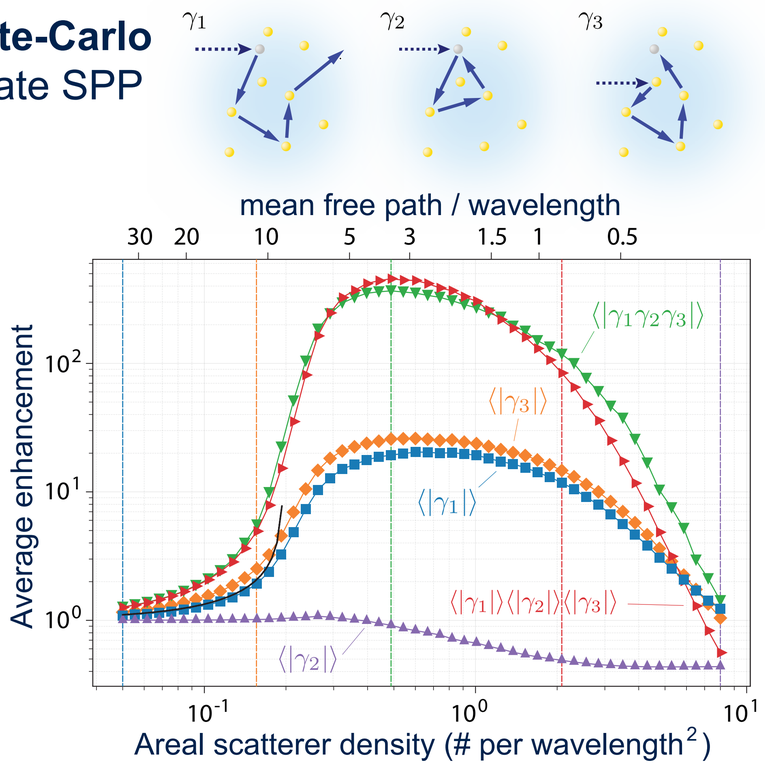
- **Multiplexed WGMs:** particle binding shifts higher order whispering gallery modes differently.
- **Ratiometric analysis:** allows binding latitude to be found.
- **Evanescent mode field gradient:** necessitates accurate model of fields within particle for subsequent sizing.

Multiple scattering sensitivity enhancements

- **Coupled dipole Monte-Carlo model:** used to simulate SPP multiple scattering.
- **Scattered field perturbation:** enhancement given by three classes of scattering trajectory.

$$\delta \mathbf{E}_{ms} = \gamma_1 \gamma_2 \gamma_3 \delta \mathbf{E}_{ss}$$

- **Optimal sensitivity enhancement:** balances nanoisland coupling and strong plasmon localisation.



Optimising detection limits in WGM biosensing

- **Reactive sensing principle:** perturbative approach to WGM shifts and broadening
- **Measurement acuity:** analytically found under differing noise regimes from Cramer-Rao bounds

$$N = \Delta\omega / \delta\omega$$

λ (nm)	InfA viron Q_0	R_{opt} (μm)	d_{opt} (μm)	$\log_{10} N_{opt}$
1550	1.30×10^5	60.64	0.972	1.23
1300	1.79×10^5	53.07	0.866	0.92
780	1.51×10^8	46.80	1.169	-2.23
633	1.52×10^9	41.18	1.127	-3.41
410	7.95×10^9	26.63	0.799	-4.65