Random Plasmon Scattering for Single Particle Sensing

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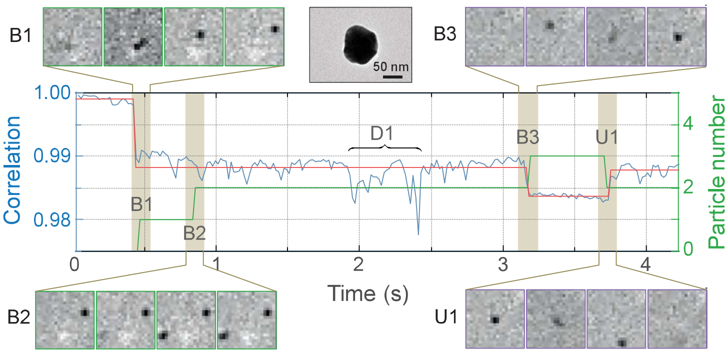
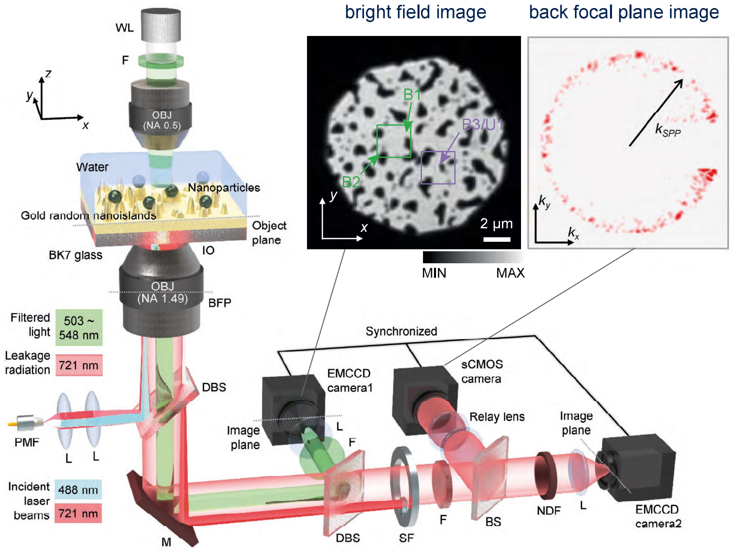
Introduction

- **Single particle sensing:** is an important tool in healthcare, environmental monitoring and fundamental biological research, to enable early diagnostics, non-equilibrium measurements and study of molecular function.
- **Surface plasmon resonance (SPR) sensors:** are low cost, robust and benefit from aqueous operation, on-chip integrability and a wealth of existing biological protocols. Nevertheless, SPR sensors lack the desired single particle sensitivity due to losses.
- **Random plasmon scattering:** we have experimentally demonstrated how random nanoisland substrates can enable single particle sensing on an SPR platform, by virtue of strongly confined fields and speckle based detection.
- **Multiple scattering enhancements:** theoretical modelling shows multiple scattering can enhance sensitivity further.

Single particle detection with plasmonic speckle

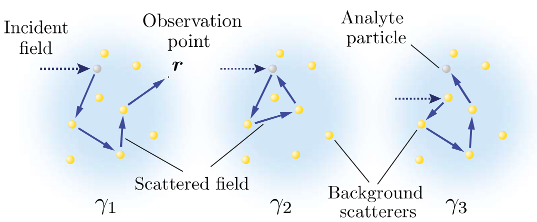
- **Leakage radiation from plasmon scattering:** strongly confined to ring in back focal plane due to conservation of momentum.
- **Disordered nanoisland substrate:** produces random interference of surface plasmons whereby leakage ring exhibits a speckle pattern. Surface topography analysis indicates operation in single scattering regime.
- **Correlation based detection:** changes in speckle pattern monitored over time. Individual binding and unbinding observed for 50nm gold nanoparticles and polystyrene nanobeads.



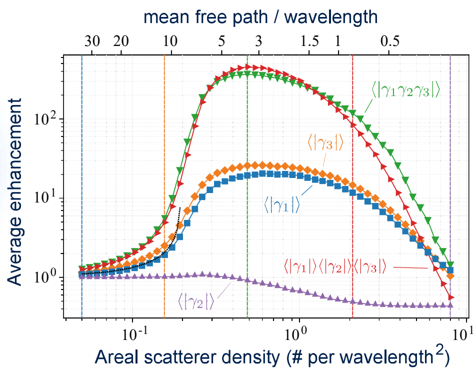


- **Validation measurements:** bright field and fluorescence microscopy used to independently verify particle binding.

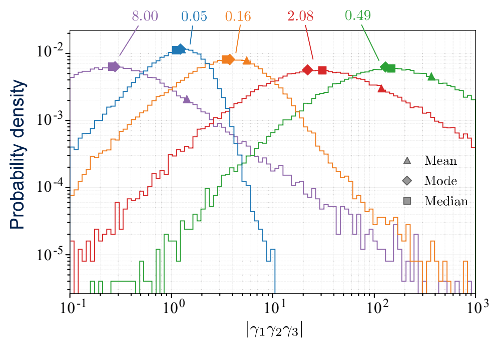
Multiple scattering enhancements



- Coupled dipole model describes multiple scattering between nanoislands.
- Three families of scattering trajectories define enhancement factors for scattered field perturbation: $\delta\mathbf{E}_{ms} = \gamma_1\gamma_2\gamma_3\delta\mathbf{E}_{ss}$



- Optimal enhancement of field perturbation set by competing effects of nanoisland coupling and plasmon localisation.



- Sensitivity enhancements of over two orders of magnitude predicted. Distributions are long-tailed.

References

- H. Lee et. al, Nanotech. 33, 165502 (2022).
- J. Berk and M.R. Foreman, Phys. Rev. Research 3, 033111 (2021).
- J. Berk and M.R. Foreman, ACS Photon. 8, 2227-2233 (2021).
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Conclusions

- **Single particle detection on an SPR platform:** enabled by scattering of surface plasmons and random interference.
- **Multiple scattering enhancements:** analytically analysed and three distinct contributing scattering processes identified.
- **Substrate design:** enhancement dependence on substrate properties investigated. Sensitivity gains > 100 achievable.