Quantum-limited single molecule sensing: probing nanoscale biological machinery in its native state

N. P. Mauranyapin, L. S. Madsen, M. A. Taylor, M. Waleed and W. P. Bowen

Australian Centre for Engineered Quantum Systems, University of Queensland, Australia
E-mail: w.bowen@uq.edu.au

Sensors that are able to detect and track single unlabelled biomolecules are an important tool both to understand biomolecular dynamics and interactions, and for medical diagnostics operating at their ultimate detection limits. Recently, exceptional sensitivity has been achieved using the strongly enhanced evanescent fields provided by optical microcavities and plasmonic resonators [1,2]. However, at high field intensities photodamage to the biological specimen becomes increasingly problematic [3]. Here, we introduce a new approach to evanescent biosensing that combines dark field illumination and heterodyne detection in an optical nanofibre-based platform [4] (see Fig. 1). This allows operation at the fundamental precision limit introduced by quantisation of light. We achieve state-of-the-art sensitivity with a four order-of-magnitude reduction in optical intensity, for the first time reaching beneath known photoinduced biological damage thresholds. We demonstrate quantum noise limited tracking of single biomolecules as small as 3.5 nm, allowing surface-molecule interactions to be monitored over extended periods (inset, Fig. 1).

This research provides a pathway to probe the dynamics of the nanoscale biological machinery of living systems in their native state, without either labels or photoinduced changes in their behavior. By achieving quantum noise limited precision, our approach also presents a step towards quantum-enhanced single-molecule biosensors.

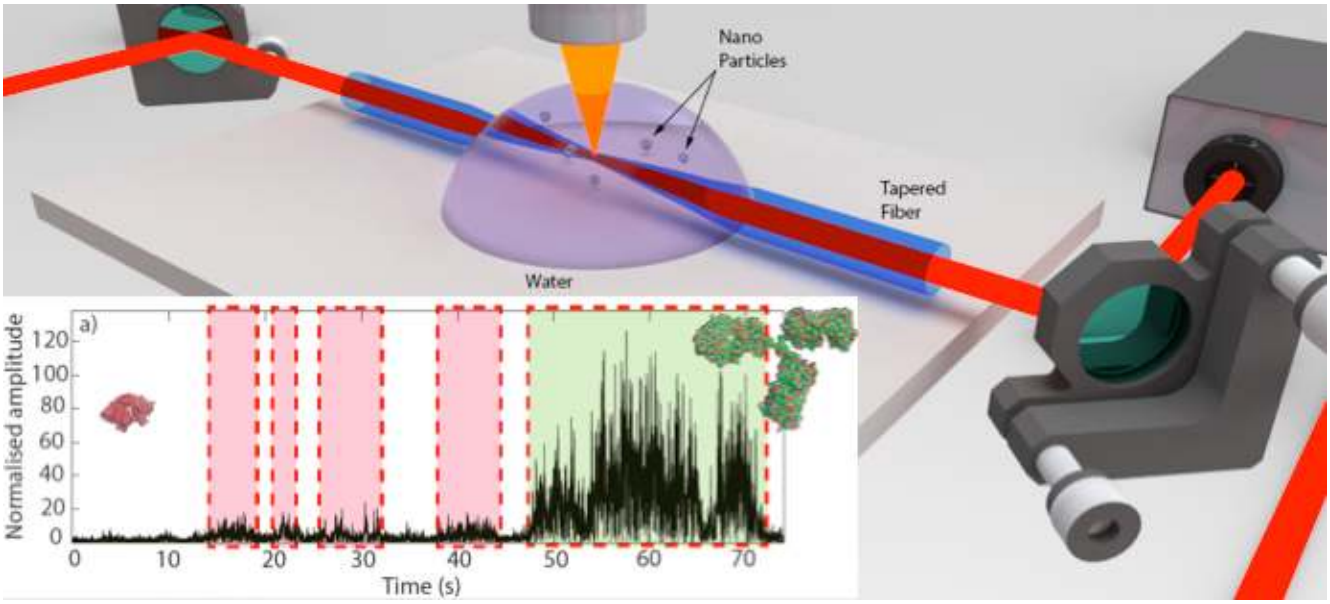

Fig. 1: Diagram of experiment. Inset: Real-time detection of BSA (left) and anti-*e. coli* antibody (right).

[1] M. D. Baaske, M. R. Foreman and F. Vollmer, Nature Nanotechnology **9** 933-939 (2014); [2] Y. Pang and R. Gordon, Nano Letters **12** 402-406 (2012); [3] See e.g. U. Mirsaidov, W. Timp, K. Timp, M. Mir, P. Matsudaira and G. Timp, Phys. Rev. E. **78** 021910 (2008); [4] N.P. Mauranyapin et al. arxiv:1609.05979 (2016).