A 0.3 NM-ACCURATE OPTICAL DISTANCE RULER BASED ON FLUORESCENCE QUENCHING BY TRANSPARENT CONDUCTORS

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Transparent conductive oxides (TCOs), such as the well-known indium-tin oxide (ITO), find widespread use in modern (nano)technological applications because of their unique combination of negligible optical absorption and good electric conductivity. In microscopy ITO-coated glass slides are used, e.g., in correlated light and electron microscopy [1] where conductivity is needed to prevent charging artefacts during electron microscopy. We, however, show that despite the near-zero imaginary part of the refractive index that is responsible for the material's transparency, TCOs drastically quench optical emitters when the emitter is within 10 nm from the TCO (see Fig. 1). We measure fluorescence lifetimes as a function of distance to the ITO-surface. Our results reveal a strong dependency of emission efficiency and fluorescence lifetime on ITO-emitter separation, in good correspondence with theory. This shows that the main channel for quenching is through strong near-field dissipation. Our results also reveal that this makes for an exquisite short-range optical ruler. Previous quenching-based optical rulers, based on interactions with plasmonic or graphene materials [2, 3], have allowed measuring distances in the 20–100 nm range. Distances below 20 nm have, however, been hard to assess due to poor photon yields or weak absolute variations. We show that TCO-based rulers close this gap, allowing distance measurements with far-field optics in the 1–10 nm distance range with deep subnanometer sensitivity [4].

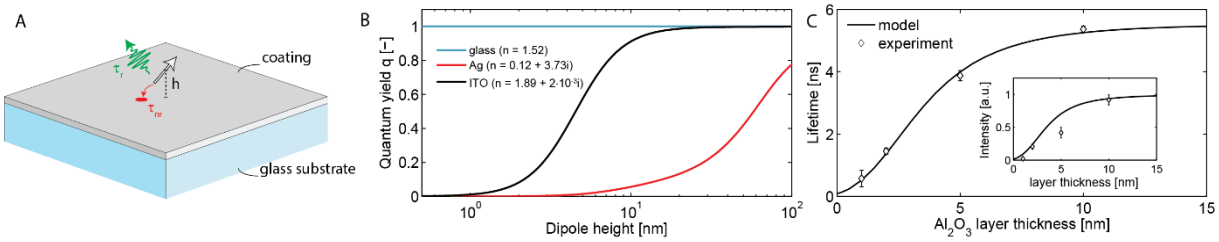

Figure 1: (A) When a light source, such as a molecule (arrow), is positioned close to a thin layer of ITO, the intensity of the emitted light can decrease strongly depending on the distance *h*. (B) For metals emission quenching is well known: below 100 nm molecules start to transfer energy to the metal instead of fluorescing (red curve). For glass, the emission intensity is constant (blue curve). For ITO, molecules can emit photons as if close to glass for distances over 10 nm. However, for smaller distances the intensity decreases strongly as a consequence of a sudden rise in absorption in the ITO. (C) The intensity decrease can be measured and vice versa, it can be used to determine the distance between the light source and the ITO (inset). Not only does the intensity drop, also the lifetime of the molecule is drastically reduced which allows for a robust distance measurement based on lifetime.

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