E²TPA: Exploiting Entangled Two-Photon Absorption

What is Entangled Two-Photon Absorption?
Entangled two photon absorption (ETPA) is analogous to classical two photon absorption (TPA), except in the case of ETPA, the two photons act as a single quantum object – always correlated and arriving at the molecule at the same time – behaving like the much more efficient single photon absorption. This effect represents one of the most significant quantum advantages with real application potential in the near-term.

Motivation
Nonlinear spectroscopy and microscopy techniques are ubiquitous in a wide range of applications across physics and biology. However, these usually rely on high-powered pulsed laser systems. A promising alternative is to exploit entangled two-photon absorption (ETPA), which can lead to tens of orders of magnitude lower incident fluxes than in conventional two-photon absorption schemes.

ETPA's Goals
- Develop cohesive theoretical & experimental guidelines for application design.
- Fabrication & development of quantum light sources optimised for ETPA systems.
- Design & exploitation of plasmonic nanoarrays for enhanced ETPA performance.
- Demonstrate ETPA providing a baseline for quantum-enhanced system design.

Theory
We take an holistic approach to better understand the complete light-matter system to determine and exploit the quantum advantage afforded by ETPA. In particular, a relationship between classical and entangled two photon absorption cross-sections has been identified:

\[ \sigma_{\text{ETPA}} = \int \frac{d\sigma}{d\Omega} \]

where \( \sigma \) represents the entangled and classical cross-sections respectively, and A and T are the entanglement area and time. The factor \( f \) has been introduced as an ad-hoc pre-factor to compare the quantum enhancement.

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Fluorescence Schemes
Fluorescence detection schemes are closest to existing microscopy & spectroscopy approaches. We aim to improve the SNR and test theoretical proposals to better understand temporal and spatial characteristics and the light-matter interaction itself.

Transmission Schemes
This method is based on broadband correlation functions \( g(\nu,\mu) \). These are robust against linear loss but highly sensitive to correlated loss. We can also introduce a time delay between the two photons, reducing uncertainties from switching samples.

PPLN Waveguide Technology
We will develop PPLN waveguide technologies for the relevant wavelength regimes, improving efficiencies - photon pair rates – for simpler/cheaper lasers and evaluating their performance for commercial fluorescence spectrometers.