Imaging with undetected photons in the mid-Infrared

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Abstract

Mid-infrared (mid-IR) light is highly relevant for both technology and basic research. Currently, detection in the mid-IR is greatly compromised due to the poor temporal and spatial resolution of detection technologies. Here, we present a quantum imaging concept that allows imaging in the mid-IR while detecting in the visible. This allows sensing in the mid-IR while detecting in the visible with a standard CMOS camera, enabling low noise, low cost and fast data acquisition.

The functionality to image samples in the mid to far infrared holds the promise of new perspective on problems of tremendous biological and industrial relevance, opening the door to exploiting the highly specific vibrational and rotational 'fingerprints' of molecules as contrast mechanisms [1]. The principle limitation, however, remains one of detection, with mid-IR imaging technology being prohibitively expensive, technically demanding and suffering from poor sensitivity and resolution. The absence of a good detection option has lead to numerous approaches that exploit wavelength conversion to the visible regime, where one can enjoy the comparable maturity of CCD and CMOS technology driven by the life sciences. Here, we demonstrate how quantum non-linear interferometry [2] can provide a powerful tool for imaging in the mid-IR, facilitating detection in the near-infrared with a standard CMOS camera.

Our implementation concerns a non-linear interferometer (see Figure 1. a) formed between two identical

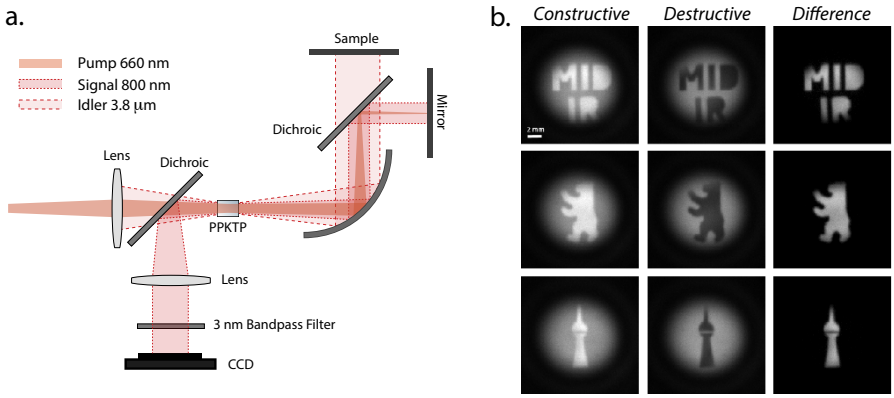

Figure 1: **a.** *Experimental Setup:* Continuous wave pump light at 660 nm stimulates a highly non-degenerate, collinear SPDC process in a Michelson-style interferometer. The signal and idler fields generated on first pass are split, allowing the idler to probe a sample, before being recombined and travelling back into the non-linear crystal with the coherent pump field. The resulting signal field is imaged on a CCD, bearing the spatial information obtained by the idler when probing the sample. **b.** *Results:* Constructive, destructive and difference interference images of the signal mode for cardboard cutouts probed by the idler.

spontaneous parametric down-conversion (SPDC) processes coherently pumped in series. The highly non-degenerate signal and idler fields emerging from the first crystal are subsequently aligned into the second crystal, erasing any *welcher weg* information. The strong spatial correlations shared between the signal and idler modes ensure any distiguishing spatial information obtained by the idler is transferred to the signal. Accordingly, a sample illuminated with the mid-IR idler is imaged via the signal with a off-the-shelf CMOS camera, absent any requirement to image the idler. Our technique enables low noise, low cost and fast imaging in the mid-IR - a problem of central relevance for both industry and the life sciences.

[1] M. J. Baker *et al. Using Fourier transform IR spectroscopy to analyze biological materials.* Nature Protocols, **9** 1771–1791, 2014.

[2] G. Barreto-Lemos *et al. Quantum imaging with undetected photons.* Nature, **512** 409–412, 2014.