

# A nonlinear interferometer for mid-infrared spectroscopy with undetected photons

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## Abstract

Mid-infrared (mid-IR) spectroscopy is a powerful technique to identify and monitor a vast range of materials by their strong molecular transitions in this wavelength regime. Applicability, however, is technologically hampered by poor detector performance and cost, and complexity of suitable light sources. Our approach circumvents these limitations by using a nonlinear interferometer with non-degenerate broadband downconversion photon pairs to probe our samples with the idler photons in the mid-IR, while only requiring detection of the signal photons around 800 nm with a standard spectrometer. We present first results for our mid-IR spectroscopy with undetected photons, which potentially offers a fast and cost effective alternative to Fourier transform infrared spectroscopy.

Identification and analysis of materials like polymers, gases or biological tissues by mid-IR spectroscopy in environmental and biomedical studies often relies on Fourier transform infrared spectroscopy (FTIR). However, working in this wavelength range is challenging due to the high cost of bright and broadband light sources, and the large noise and poor efficiency of IR detectors. Circumventing these difficulties, a different approach using correlated light in nonlinear interferometers [1] was recently demonstrated with correlated, non-degenerate photon pairs for the spectroscopy of CO<sub>2</sub> [2,3].

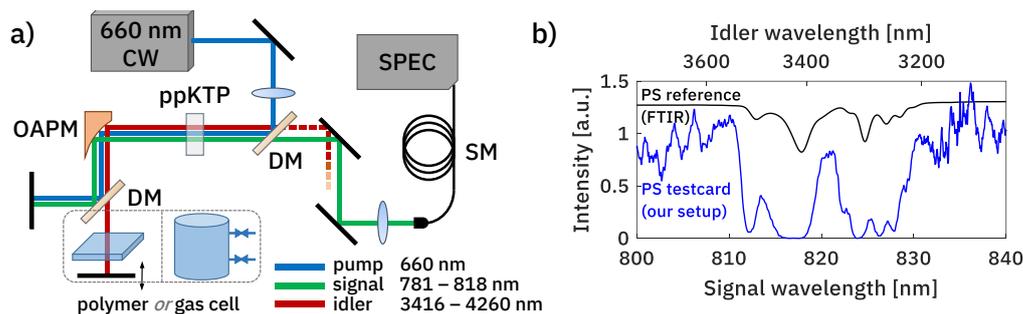


Figure 1: **a)** current setup, see text for details; **b)** first results for spectroscopy of a polystyrene (PS) testcard in our setup and comparison to a FTIR reference spectrum of PS, shifted for clarity.

Here, we modify the approach of [2,3], implementing mid-IR spectroscopy with a standard NIR-Spectrometer and a bespoke broadband photon source, improving spectral resolution and acquisition speed. In our setup (Fig. 1a) a 660 nm continuous wave laser pumps a periodically poled Potassium Titanyl Phosphate (ppKTP) crystal creating photon pairs with an estimated rate over the whole bandwidth (3.4 to 4.3  $\mu\text{m}$  for idler) of  $10^8$  pairs/s. An off-axis parabolic mirror (OAPM) collimates the pump, idler and the signal without chromatic aberration. Pump and signal are separated by a dichroic mirror (DM) from the idler photons, which probe the sample. On the way back, the OAPM images all light back into the crystal. Thus photon pairs generated in the first pass cannot be distinguished from pairs generated in the second pass and there is interference. Spectrally dependant absorption in the idler leads to increased distinguishability and thus diminished visibility, from which we can infer the absorption spectrum by measuring the spectrum of the signal photons (Fig. 1b). For this the signal photons are measured with a standard spectrometer (SPEC), while the idler light is never detected. We aim to further develop this scheme and demonstrate its usefulness for polymer analysis and gas spectroscopy, with the goal to identify real-world applications, for which it may prove a fast and cost effective alternative to established methods such as FTIR.

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[2] A. Barh, C. Pedersen, and P. Tidemand-Lichtenberg, *Opt. Lett.* **42**, 1504 (2017)

[3] A. Paterova, H. Yang, C. An, D. Kalashnikov and L. Krivitsky, *New J. Phys.* **20** (2018) 043015