# Electric-field-resolved spectroscopy of molecular vibrations

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## I. Abstract

An immediate consequence of light interacting with matter is electric-field-induced charge separation in the material system. Attosecond metrology [1] and THz time-domain spectroscopy [2] have provided experimental tools enabling access to the (consequences of the) resulting dynamic polarization with sub-cycle temporal resolution for wavelengths in the near-infrared and far-infrared, respectively.

Here, we explore the application of field-resolving metrology to molecular vibrations in the mid-infrared spectral region. Waveform-stable, ultrashort mid-infrared pulses [3] are used to excite molecular vibrations. Field-resolved spectroscopy (FRS) measures coherent electric fields as the most direct macroscopically observable consequence of microscopic molecular dipoles oscillating in unison after this ultrashort, impulsive excitation. By employing electro-optical sampling (EOS) for detection [3], in FRS the mid-IR signal is mapped to the near-infrared spectral region, where detectors with significantly superior noise figures are available and where thermal background is negligible. Furthermore, the resonant molecular response can be efficiently separated from the non-resonant response (Fig.1) which introduces an undesired background in traditional spectroscopy techniques like Fourier-transform infrared spectrometry (FTIR).

The talk will address the latest progress in FRS technology for molecular spectroscopy, in particular the development of waveform-stable, high-power laser systems covering the entire molecular fingerprint region and broadband, efficient EOS. Furthermore, benchmarking measurements demonstrating the sensitivity and specificity advantages of this novel technology over the state of the art in broadband molecular fingerprinting will be presented. These advances are expected to strongly benefit applications in fields as diverse as analytical chemistry, environmental monitoring or the life sciences.

## II. Figure

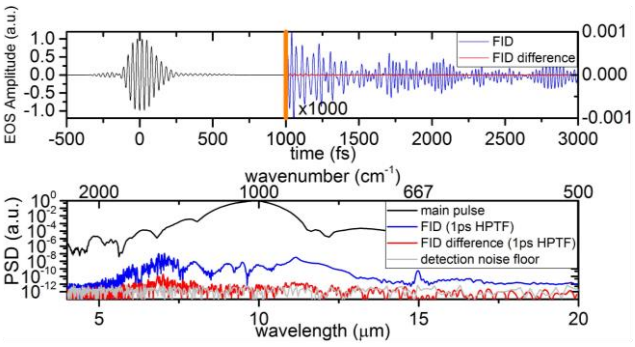



Figure 1. Upper panel: electric field of a mid-infrared pulse after propagation through 1 m of ambient air. The free-induction decay (FID) of the air molecules follows the impulsive excitation in time and is detected in a background-free manner by EOS. Lower panel: power spectral density of the signals in the upper panel. The detection dynamic range exceeds that of state-of-the-art FTIR by several orders of magnitude.

## III. References

1. Sommer A. et al. 2016. Attosecond nonlinear polarization and light-matter energy transfer in solids. Nature 534: 86

2. Tonouchi, M. 2007. Cutting-edge terahertz technology. Nature Photon. 1: 97

3. Pupeza, I. et al. 2015. High-power sub-two-cycle mid-infrared pulses at 100 MHz repetition rate. Nature Photon., 9: 721

## IV. Biography

Ioachim Pupeza has completed his PhD in laser physics in 2011 at the Max Planck Institute of Quantum Optics (MPQ) and the Ludwig Maximilians University of Munich, Germany, after receiving diploma degrees in electrical engineering and pure mathematics from the Technical University Braunschweig, Germany in 2006 and 2007, respectively. In 2013/2014 he worked as a postdoctoral researcher at the Institute of Photonic Sciences in Barcelona, Spain, and since 2014 he has been leading the research group *Field-Resolved Metrology* at the MPQ. He has published more than 35 papers in reputed peer-reviewed journals.

## V. Presenting author details



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