TATP gas phase detection for security applications based on mid-infrared absorption spectroscopy

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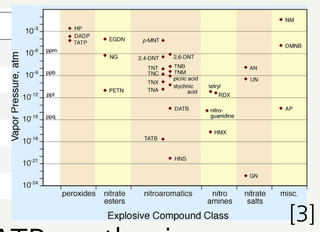
Motivation

- TATP has been used in IEDs as the explosive of choice in several terrorist bomb attacks[1,2]

Attack	Date of Attack
2015 Paris Attack	11/13/2015
2016 Brussels Airport Attack	3/22/2016
2017 Manchester Concert Bombing	5/22/2017
2017 Brussels Central Station Attack	6/20/2017
2017 Barcelona Car-Ramming Attack and Cambrils Stabbing	8/17/2017
2017 Parsons Green, London Underground Attempted Bombing	9/15/2017



[3]

- Precursor materials for TATP synthesis are readily available and inexpensive
- TATP's sensitivity makes it extremely dangerous, and even small quantities (1g) can cause injury and damage if detonated

→ persistent threat to public safety and first responders

→ MIR absorption spectroscopy offers a unique combination of sensitivity, specificity, non-destructive nature, and real-time detection capabilities for detecting TATP

Aim of this work

RQ 1

- Is a fast and reliable detection of volatile explosives possible?
- What are the key-figures compared with published (non-optical) systems?

RQ 2

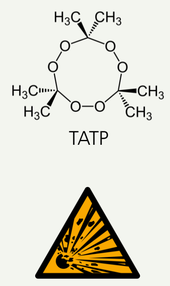
- How large is the impact of saturation effects and how can cross-contamination be suppressed?
- Which system performance can be achieved with different multipass cells and what are the (dis-) advantages?

RQ 3

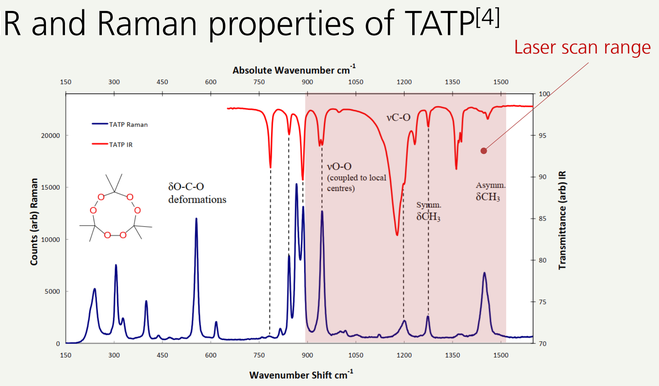
- How can the lab setup be transferred to a field applicable system, i.e. for security checks or drone-based detection?
- What are the requirements for in-field operation?

Sample preparation & properties

- Synthesis of solid TATP powder at DLR Lampoldshausen (129 mg used in experiment)



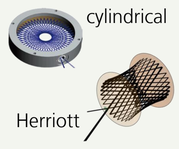
- IR and Raman properties of TATP[4]



Measurement principle

- MIR absorption spectroscopy testing different multipass cells:

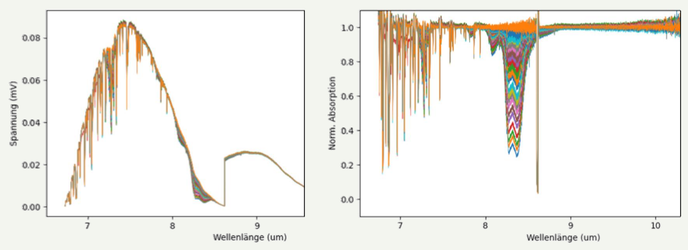
	Herriott	Cylindrical
Optical path length	31.2 m	4.03 m
Number of reflections	80	
Sample volume	850 ml	31 ml



- Broadband tunable external cavity quantum cascade laser (EC-QCL):

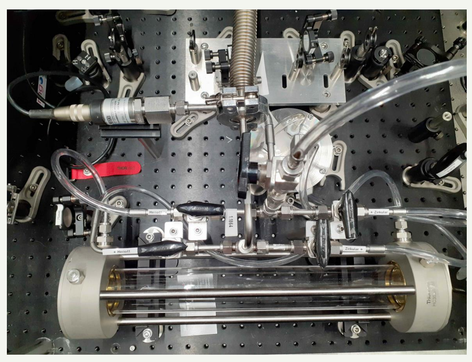
Scan range	6.7 µm (1490 cm^{-1}) – 11.1 µm (910 cm^{-1})
Scan rate	1000 cm^{-1}/s
Repetition rate	1 MHz
Pulse width	100 ns

- Normalization of measured spectrum by reference channel



Experimental setup

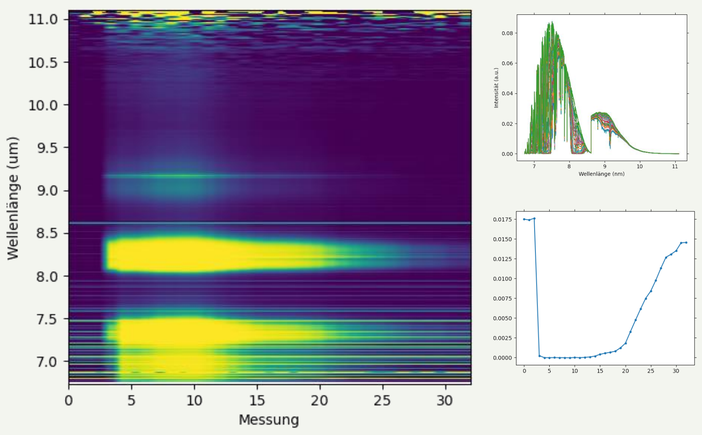
- Optical setup with gas tube system



- Developed doormat with ventilation extraction system underneath

1. Proof of concept study by applying liquid acetone solution onto shoe surface

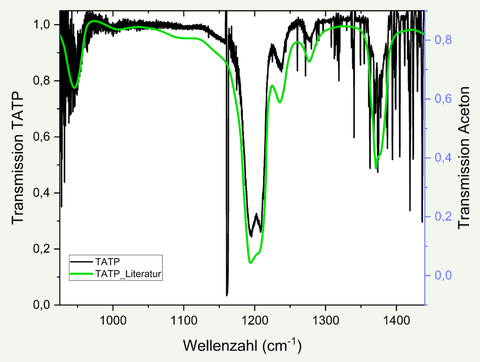
   Temporal development of MIR signal plotted in a waterfall representation



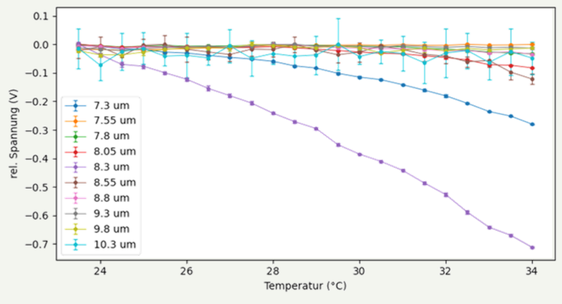
2. Controlled sublimation of TATP for determining the temperature and pressure dependency on a heated plate in a pressure chamber

Results – TATP absorption spectrum

- Detection of TATP absorption verified (RQ1)

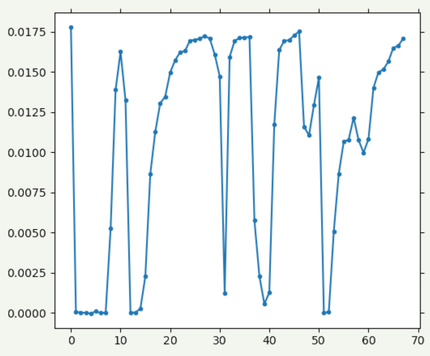


- Reliability of detection increases with temperature due to increasing vapor pressure



Results – System performance

- Fast signal recovery after measuring explosive precursors (RQ2)



- Optical path length of cylindrical cell is too short for measuring TATP at room temperature and standard pressure
- Sucking volume of doormat has to be improved further to avoid cross-contaminations by adhesions
- Improved gas cells are needed with a better optical path length to sampling volume ratio

Outlook

- Completely optical fiber based detection system for a reliable and robust operation
- Performing drone based measurements
- System extension for double path measurements of released gas clouds

References

[1] https://www.newamerica.org/future-security/reports/jihadist-terrorism-17-years-after-911/key-trends-in-terrorism/
[2] https://www.dni.gov/files/NCTC/documents/jcat/firstresponderstoolbox/78--NCTC-DHS-FBI---Triacetone-Triperoxide-(TATP)-.pdf
[3] Ewing et al.: The vapor pressures of explosives, TrAC Trends in Analytical Chemistry, 42, 2013, 35-48
[4] Stokes et al.: The fusion of MIR absorbance and NIR Raman spectroscopic techniques for identification of improvised explosive materials in multiple scenarios; Proceedings of SPIE; 2009

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