Standoff detection and classification procedure for bioorganic compounds by hyperspectral laser-induced fluorescence

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Outline

- Laser based standoff detection
  - Scenarios
  - Detection schemes
- Laser induced fluorescence (LIF)
  - Principle and capabilities
  - Experimental setup / measurement procedure
  - Measured substances
  - Data analysis / online classification results
- Summary and outlook
- Acknowledgements

Scenarios

intended output

infrastructure targets

public / crowded targets

accidental output

industrial accidents


natural events


Fast detection and early identification of hazardous substances with low false alarm rates and low risk for people are essential!

Detection schemes

local / classification information

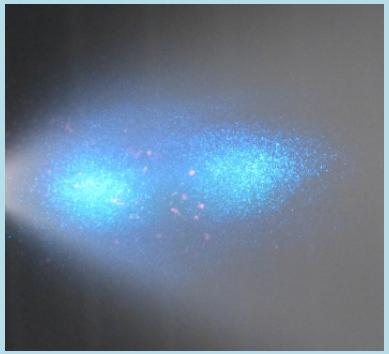
laser based detection

+ fast localization / time-dependent mapping

+ classification

- limited identification

free transmission range,
DLR Lampoldshausen



fluorescent aerosol,
DLR Lampoldshausen

particle samplers

+ identification ability

- „right“ positioning?

- origin / movement / distribution of cloud?

gas chromatograph - mass spectrometer,
Wikimedia Commons*

UAV,
Wikimedia Commons*

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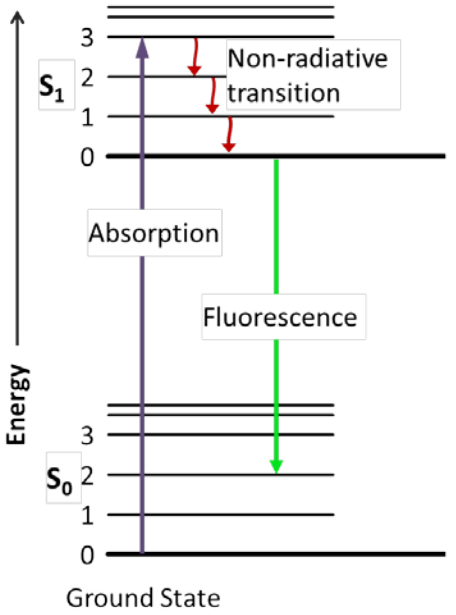
LIF: Principle and Capabilities (1)

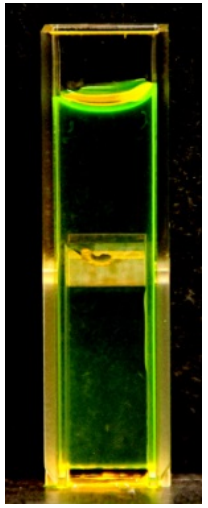
LIF:
- excitation by laser light (non-resonant)
- fluorescence may occur as the molecules relax to the ground state
- emitted fluorescence light shows characteristics of the molecules

advantages:
- discrimination of chemical and biological material
- high signal strength
- no highly sophisticated requirements to excitation wavelength
- eye safe excitation wavelength (UV, < 400 nm)

disadvantage:
- broad band fluorescence emission → limited potential for identification



Jablonski diagram of absorbance, on-radiative decay, and fluorescence, Wikimedia Commons*



flourescein in cuvette, DLR Lampoldshausen

*) creativecommons.org/publicdomain/zero/1.0

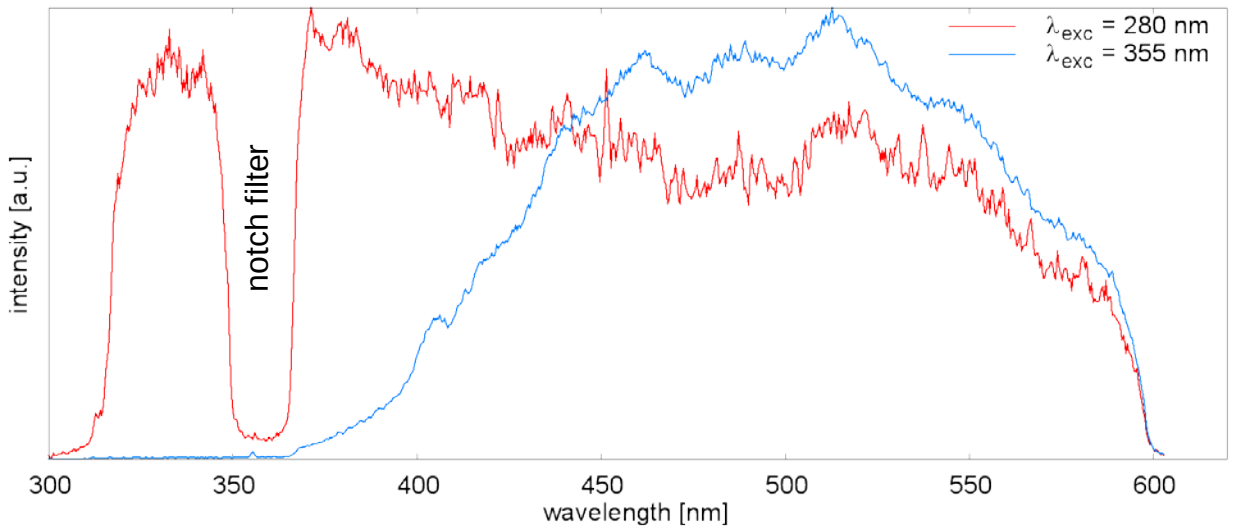
LIF: Principle and Capabilities (2)

discrimination capabilities:

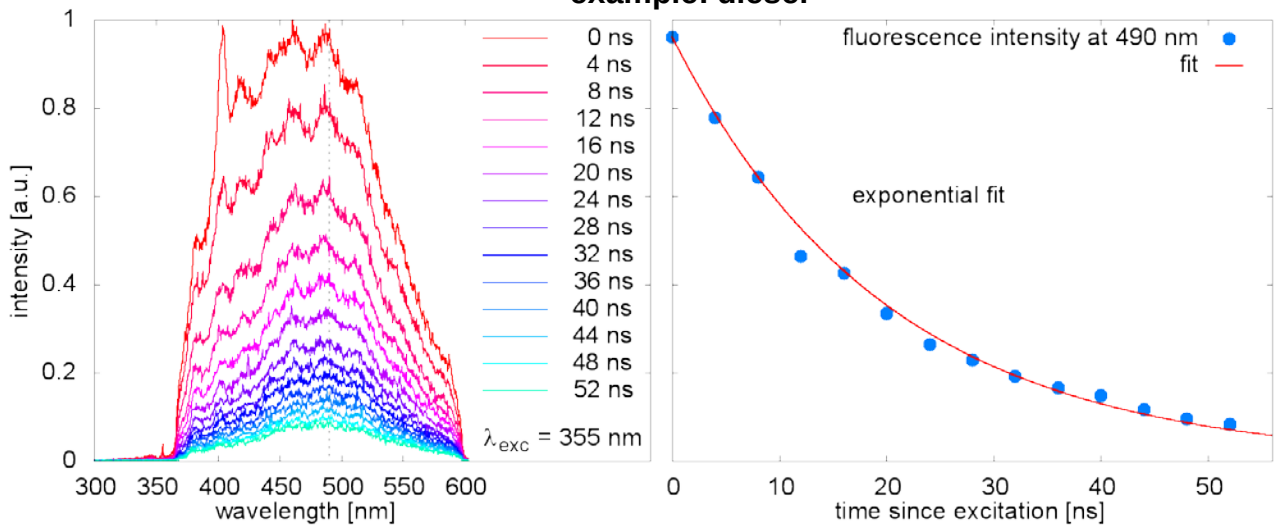
1) the use of **different excitation wavelengths** provides multiple fluorescence spectra for one substance

2) additional **time-dependent measurements** provide an extra feature depending on the fluorescence life time

example: yeast

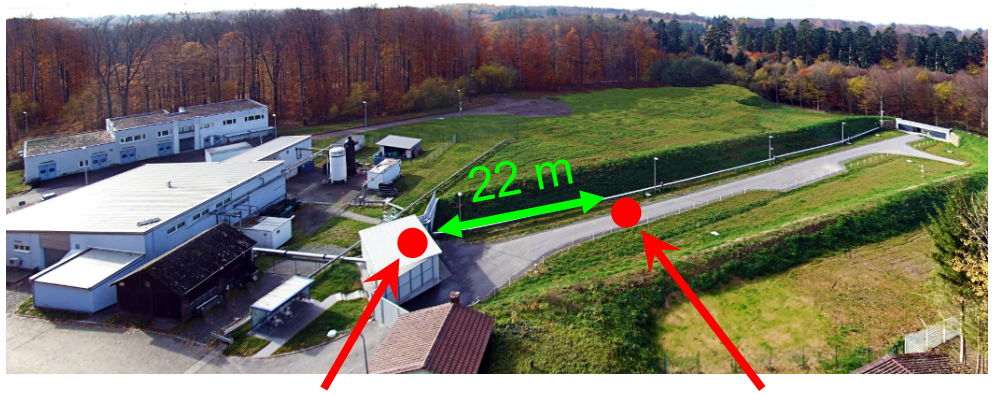


example: diesel

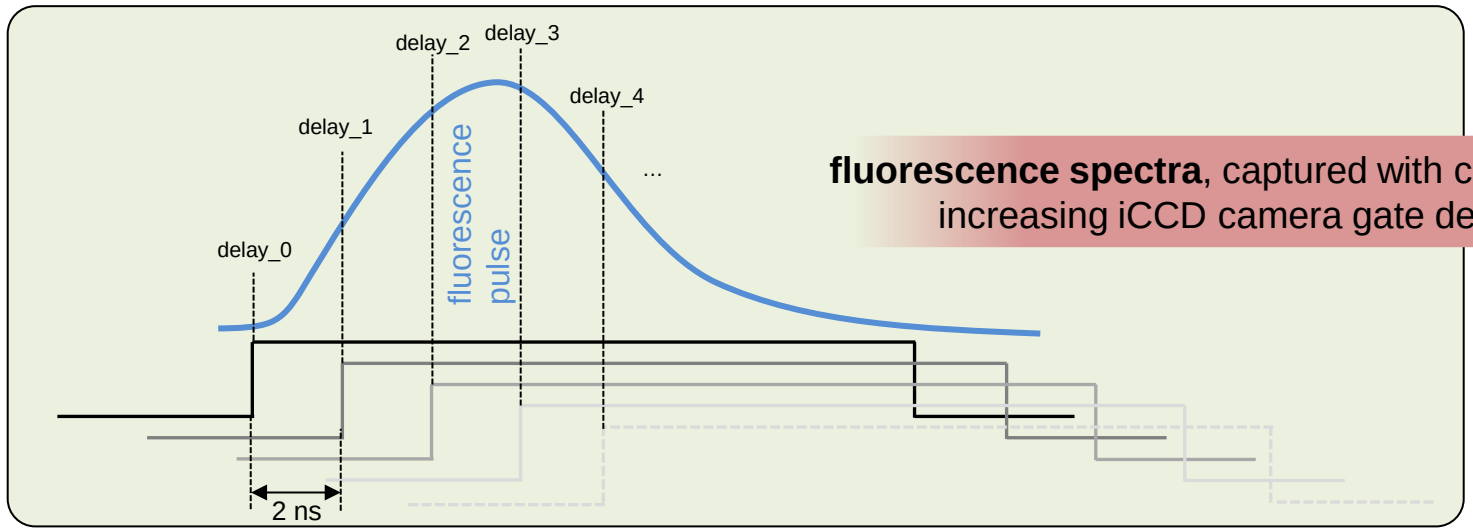


LIF: Experimental setup

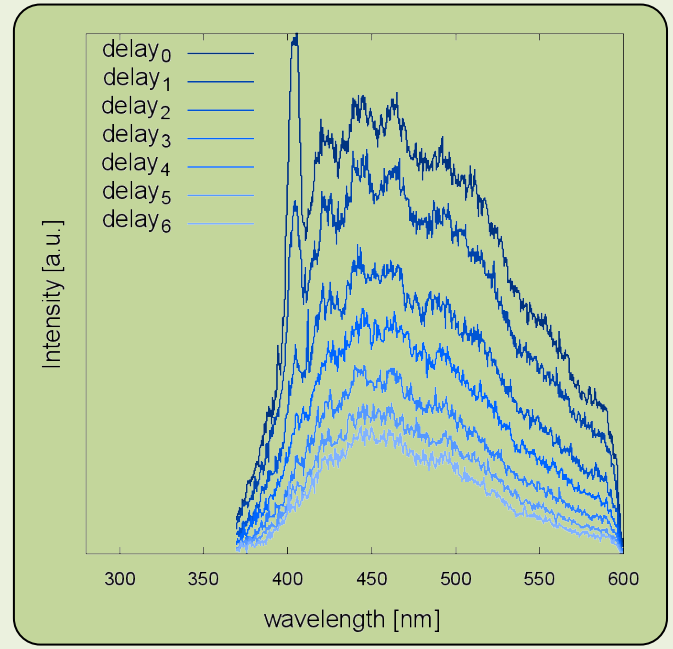
- distance to target: 20 – 135 m (currently 22 m)
- excitation wavelengths: 280 nm, 355 nm
- repetition rate: 10 Hz (5 Hz per wavelength)
- laser pulse: ~10 mJ with ~7 ns width
- telescope aperture: 400 mm
- spectrometer:
  - resolution: 1 nm
  - bandwidth: 300 – 600 nm

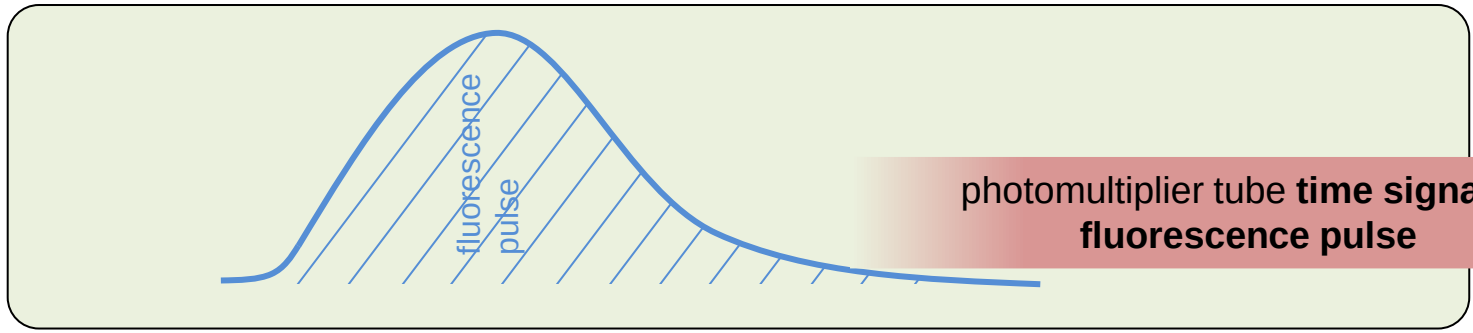


LIF: Acquired data



fluorescence spectra, captured with consecutive increasing iCCD camera gate delays





photomultiplier tube **time signal of fluorescence pulse**

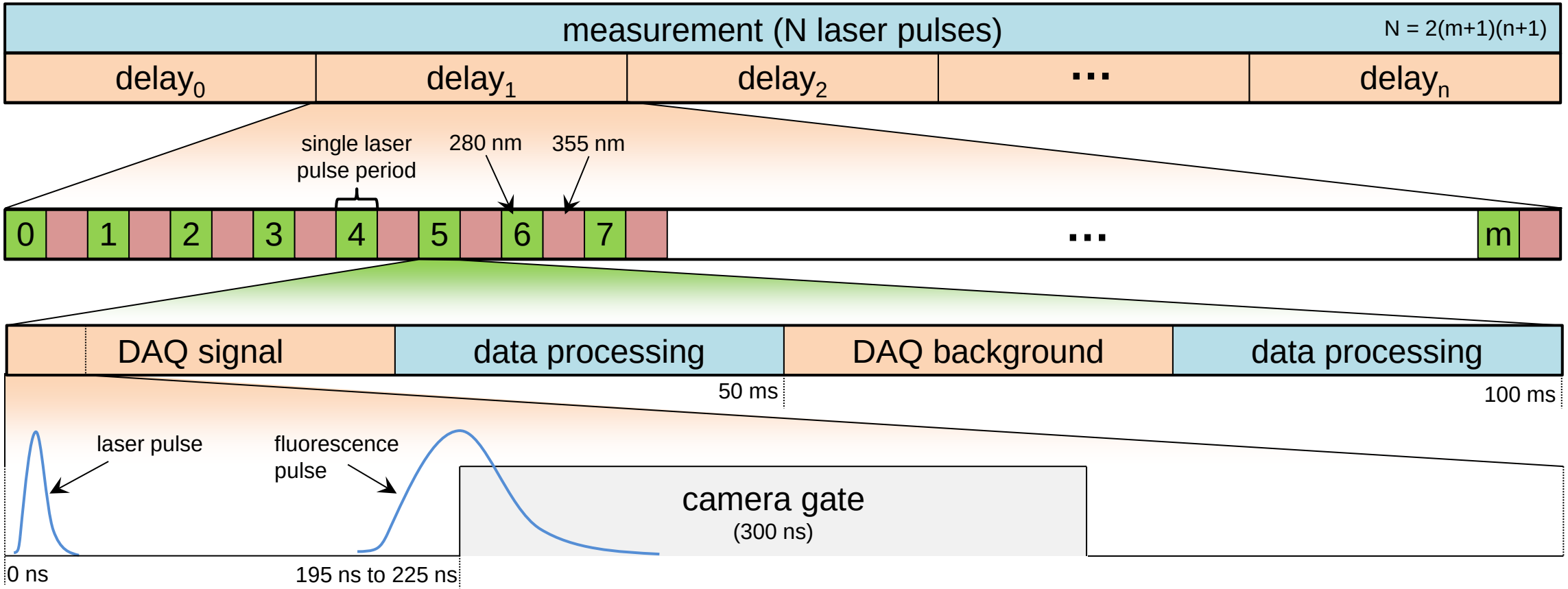
time integral of fluorescence pulse for **normalization of spectra**

data preparation

network (proprietary protocol via TCP/IP)

analysis / classification software

Measurement timing

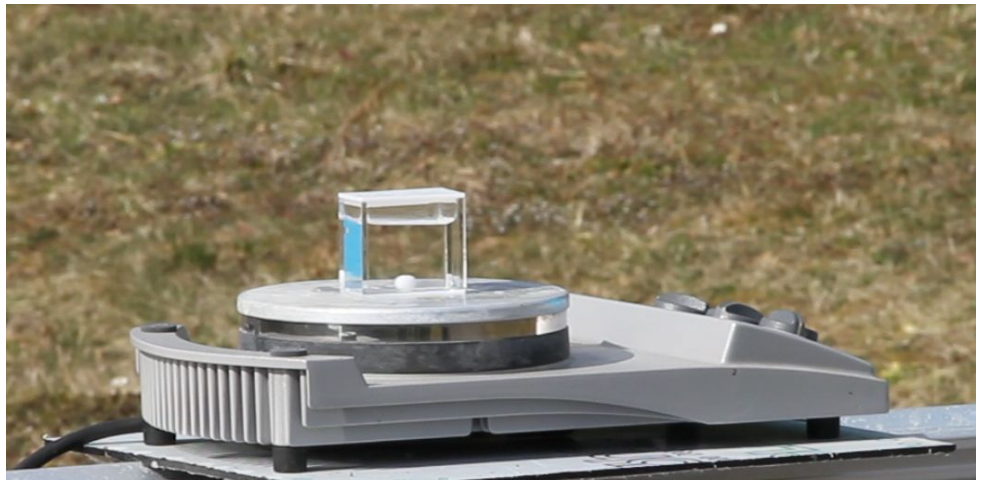


Example for 10 Hz: A measurement with 4 delays and 10 accumulated spectra takes approximately 8 s.

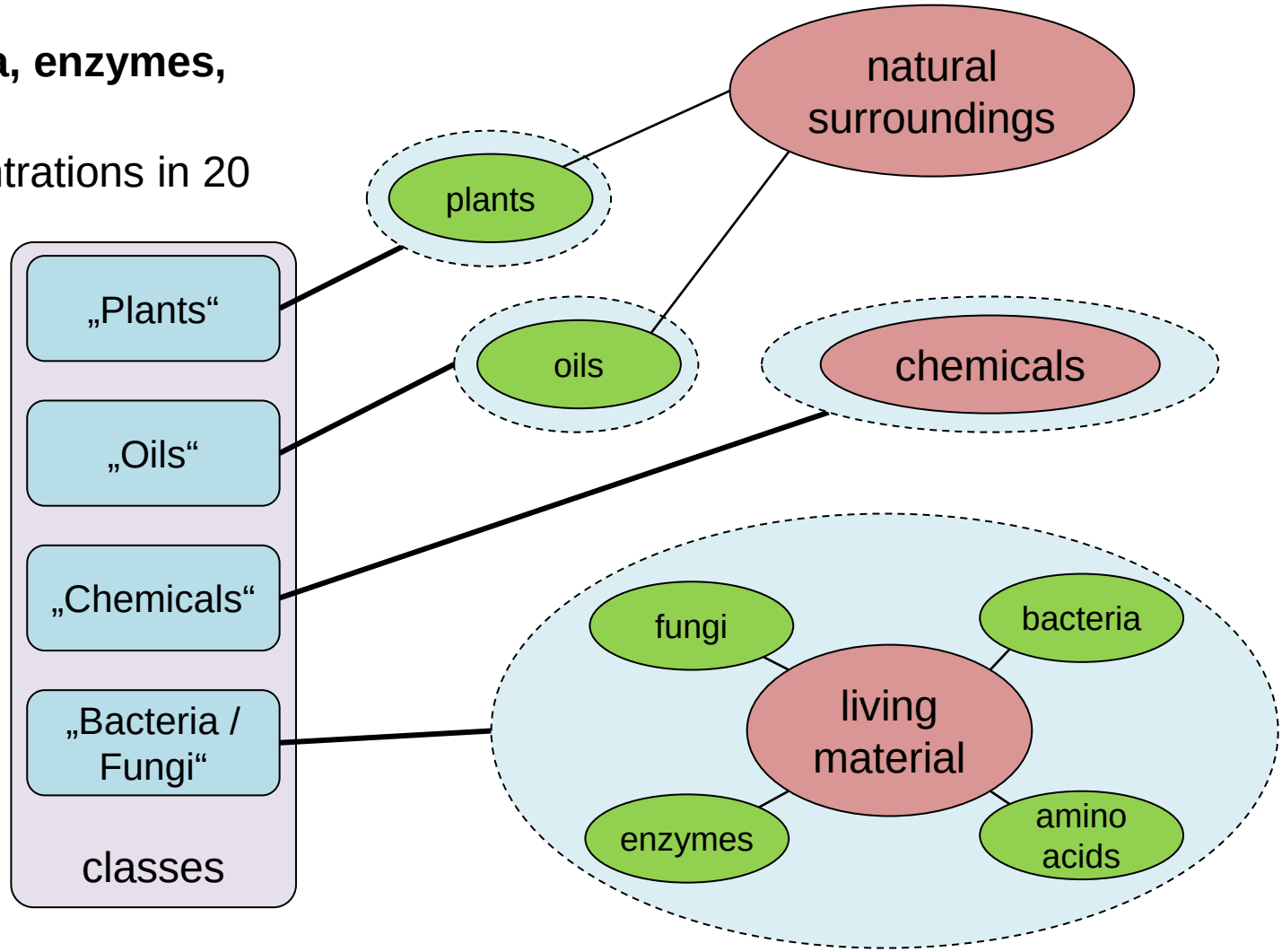
2 x 4 x 10 x 100 ms = 8 s

Measured substances

- investigated substance groups: **fungi, bacteria, enzymes, amino acids, chemicals, plants, oils**
- solutions in deionized water at different concentrations in 20 ml cuvette
- solutions are stirred during the measurement
- **standoff distance: 22 m**



solution on a stirrer, DLR Lampoldshausen

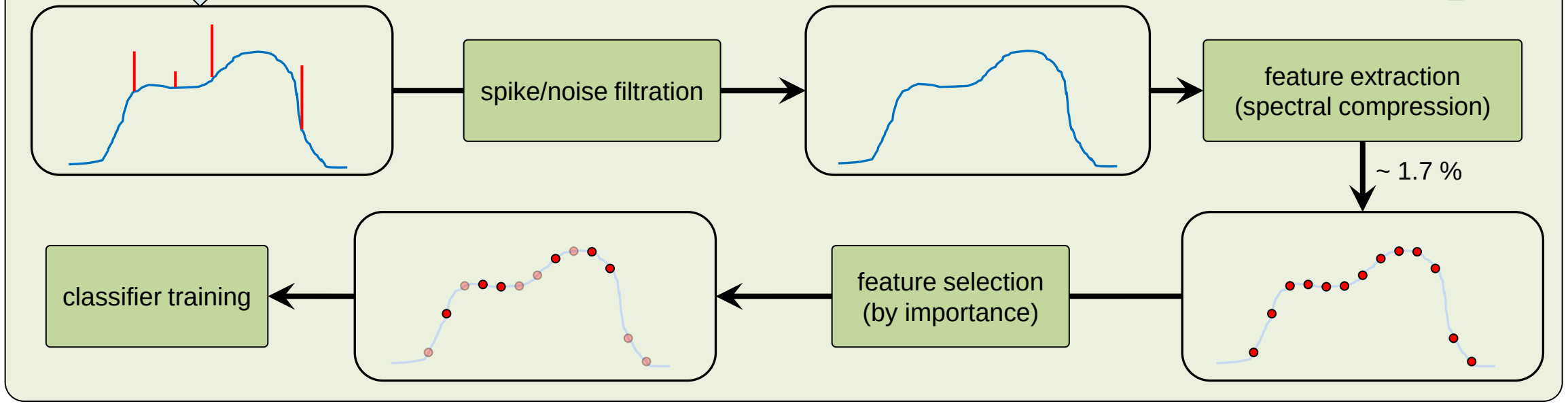


Data analysis (classifier training by LDI Innovation)

training data sampling

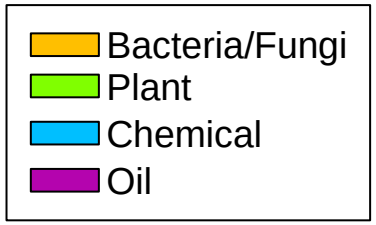
- substances of different concentrations (more than 200 samples)
- training data: 16 camera gate delays, 100 accumulations per delay
- background correction, normalization
- 720 spectral data points per captured spectrum

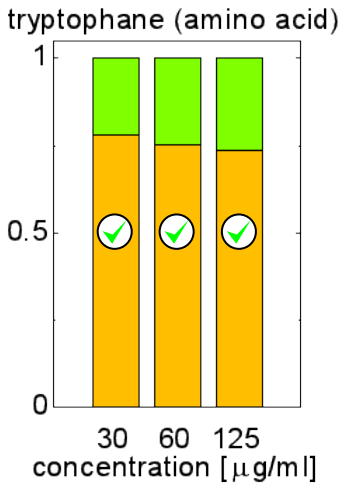
data analysis

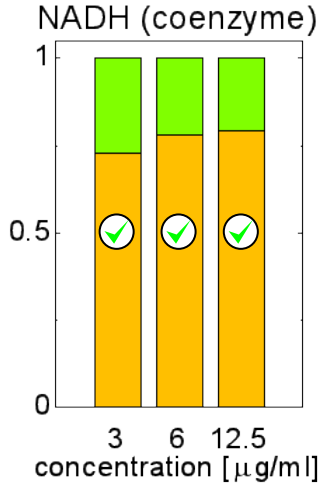


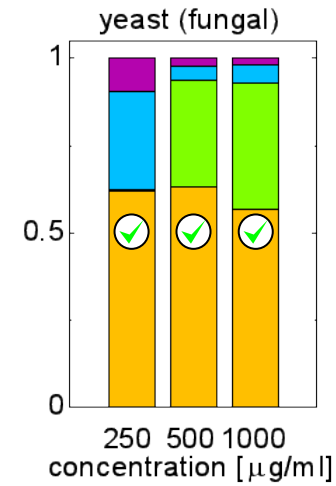
Online classification results

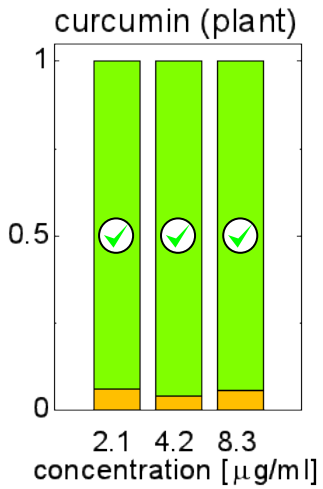
- plots show classification propabilities for each class
- 10 independent measurements per substance and concentration
- only 2 of the 28 tested samples are classified falsely

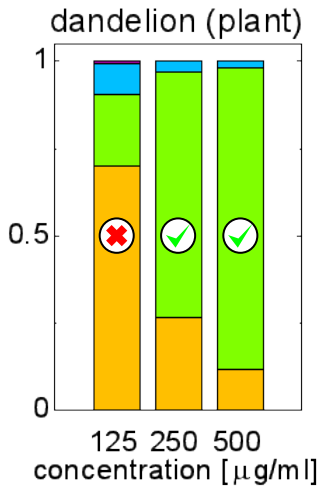


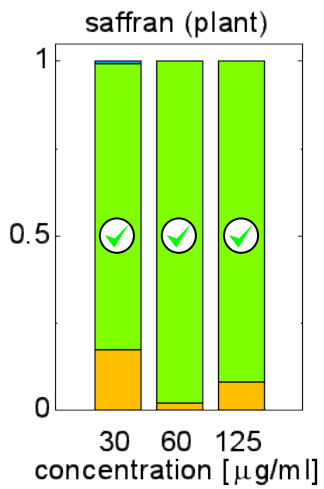


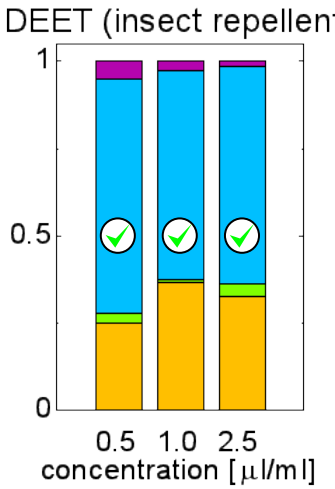


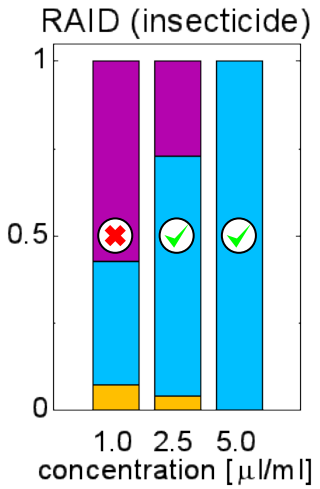


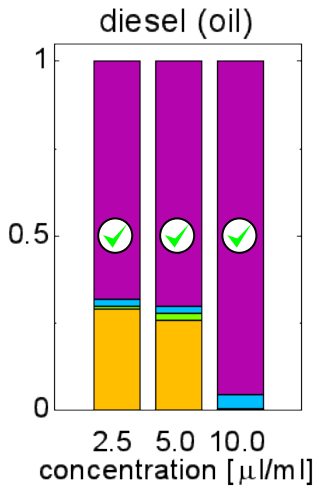


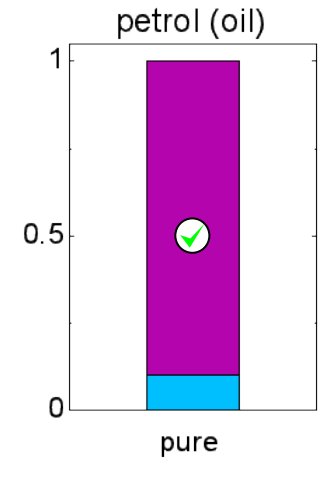












Summary and Outlook

Summary

- set up a standoff LIF system for detecting bioorganic and chemical substances
- discrimination features: two different excitation wavelengths, time-dependent spectra
- classifier training with various substance groups (living material, chemicals, natural surroundings)
- successful automatic online classification within a few seconds (< 10 s)

Outlook

- increase repetition rate (up to 100 Hz)
- increase discrimination ability (e.g. 3rd and 4th excitation wavelength)
- differentiate classes (e.g. discriminate specific living material)
- extension of standoff distance

Contributing People

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Thank you for your attention!