Near-infrared product moisture sensors: Cost-effective and ultra-compact technology for inline monitoring

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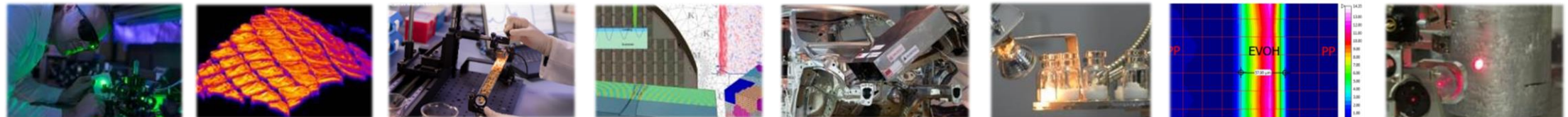
- ## Research project: **EDDY – Enhanced Drying**
  - Cost-effective sensors for inline process analysis combined with advanced numerical models to enable energy efficient drying processes
  - Use of renewable energy sources (e.g. heat pumps)

- ## Drying process
  - Most **wide-spread process** in industry
  - **12-25%** of industrial energy consumption
  - Predominantly relying on **fossil fuels**
  - Processes are carried out without actual knowledge about moisture
  - Fluctuation of the drying process due to weather conditions

- ## Benefits of (inline) product moisture measurements:
  - **Save energy** by optimizing drying processes and avoiding over-drying
  - **Aovid mold** induced spoilage due to increased moisture
  - **Strong economic factor** due to the trading according to **product weight**
  - **Ensure high product purity and quality**
  - **No errors during sample collection** (samples stay in process instead of transferring them to laboratory)

- Moisture is mostly determined **offline using gravimetric measurements** (moisture balance)

    - → **No possibility for real-time measurement**
    - → **No process control possible**

moisture balances

- Inline-capable alternatives are often based on **measurement of dielectric properties**

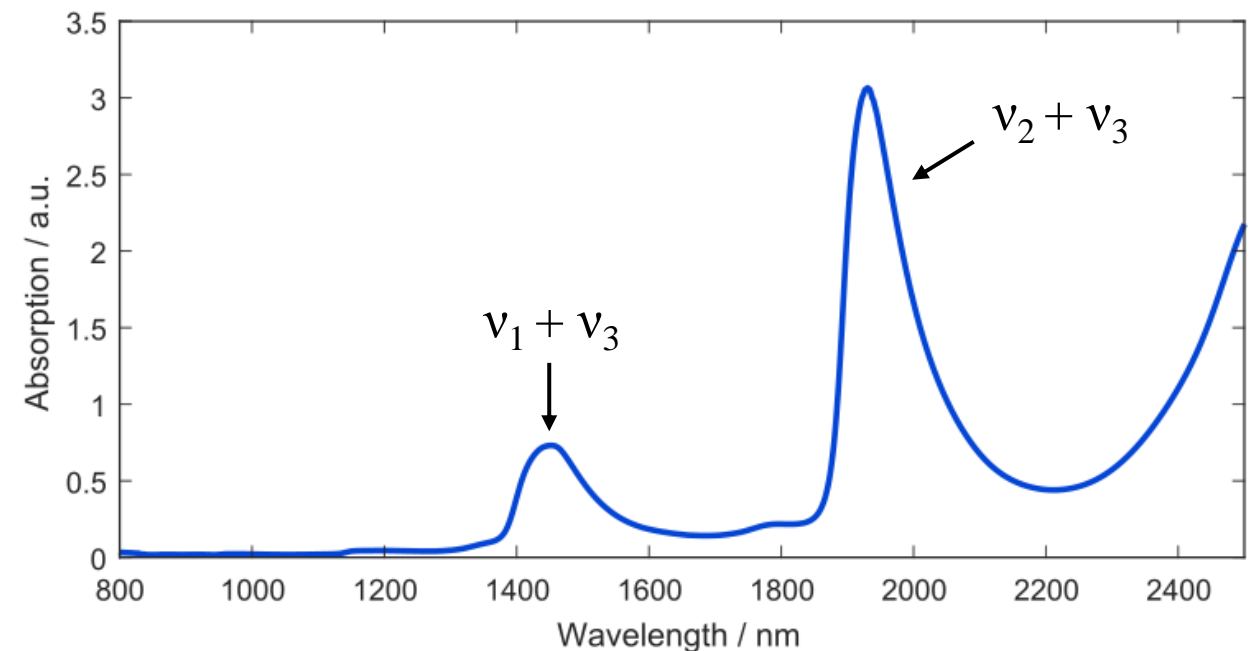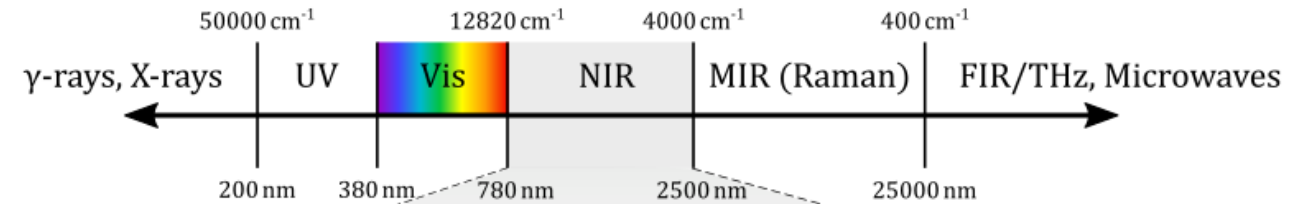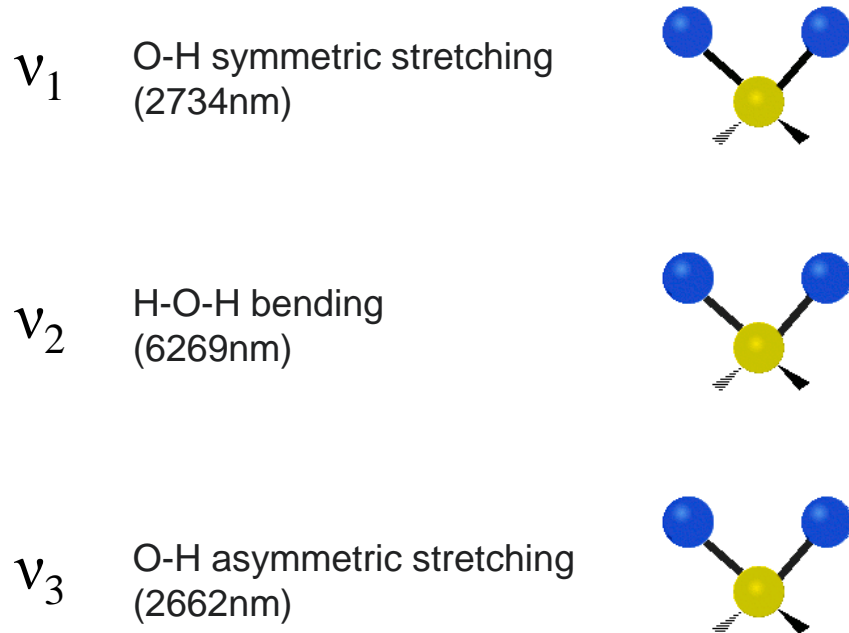   - **Sensor needs to be in close vicinity of the sample**

    → **often not possible or desirable**

FDR moisture sensor

radar-based moisture sensor

capacitive moisture sensor

- Moisture can also be measured using **near-infrared (NIR) spectroscopy**

→ Strong **absorption of water in NIR** is exploited to measure water content

Fundamental vibrations of the H_2O-Molecule:

ν_1 O-H symmetric stretching (2734nm)

ν_2 H-O-H bending (6269nm)

ν_3 O-H asymmetric stretching (2662nm)

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RESEARCH CENTER NON DESTRUCTIVE TESTING

▪ Moisture can also be measured using **near-infrared (NIR) spectroscopy**

- Light source (halogen) is used to **illuminate sample**

- **Reflected light is collected** and spectrally resolved

- Collected **spectrum is analyzed** to get moisture value (machine learning)

→ **Large measurement distances are possible**

→ **Real-time capable**

→ **Automated measurements**

→ **Additional information can also be extracted** from spectra (protein content, fat content, ash content, …)

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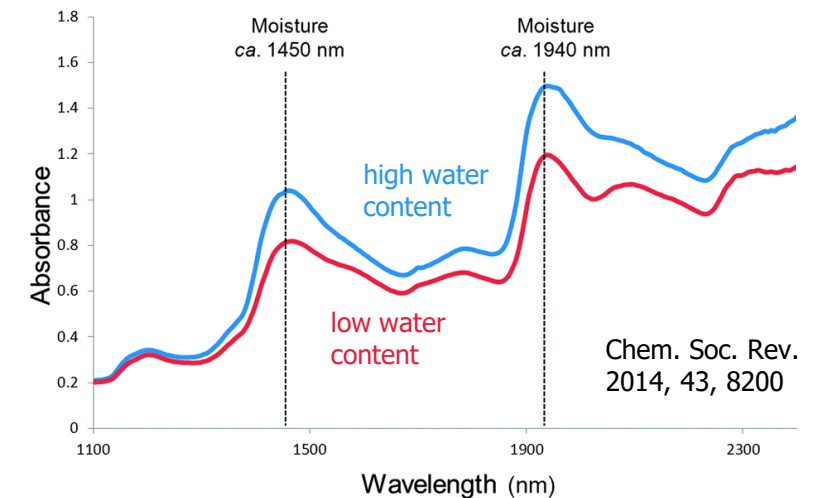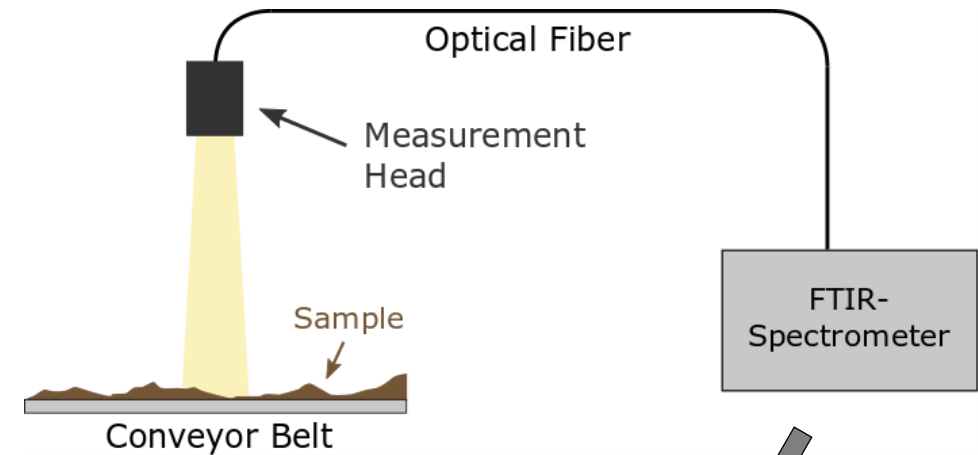
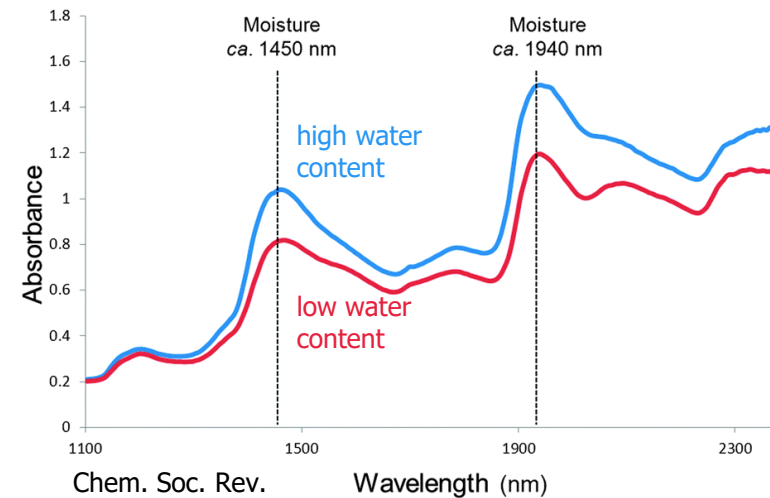# Conventional NIR-Spectrometers vs. MOEMS-based

■ **Conventional NIR-Spectrometers**

- Sensitive and broadband

- Rather expensive (typically >40 k€)

- Sensitivity to vibrations due to moving parts

micro spectrometer

19" rack process spectrometer
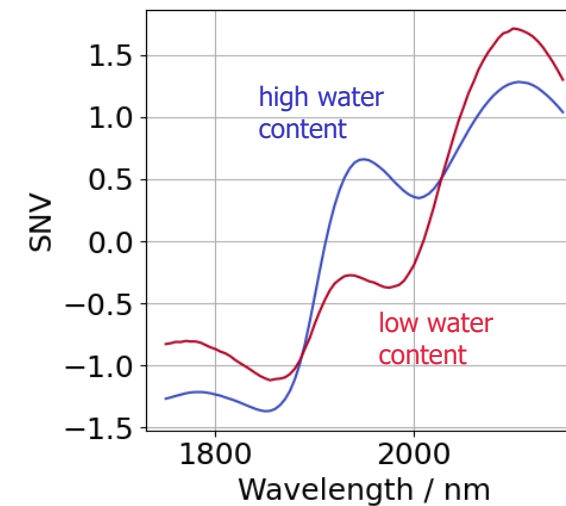
fibre optics

17.5 mm

25 mm 25 mm
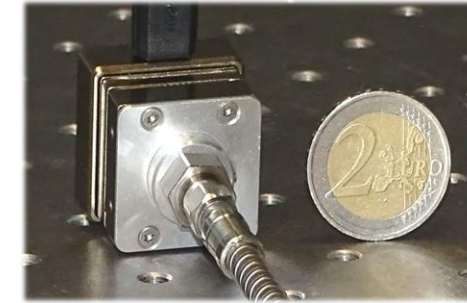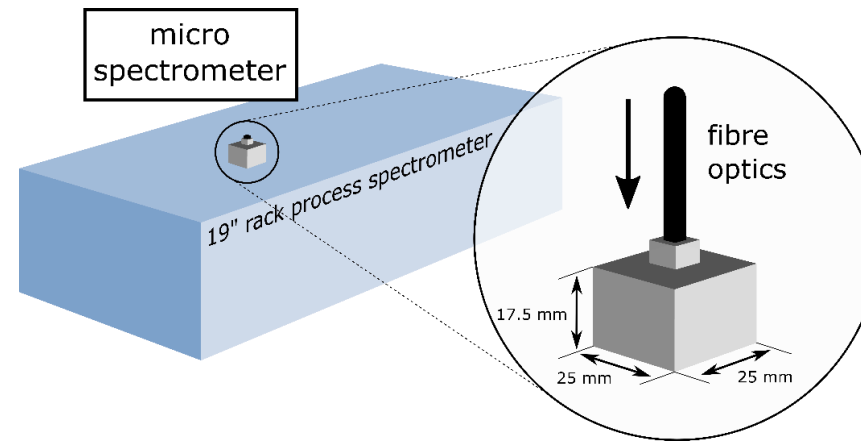
■ **MOEMS-based NIR-Spectrometers**

- Higher **cost efficiency** / lower price (>3 k€)

- More **compact** hardware

- Higher ruggedness / **less maintenance**

- **Narrowband** (Different modules available)

MOEMS ... Micro-Opto-Electro-Mechanical Systems

Conventional NIR-Spectrum

Moisture *ca.* 1450 nm

Moisture *ca.* 1940 nm

high water content

low water content

Absorbance

Wavelength (nm)

Chem. Soc. Rev. 2014, 43, 8200

MOEMS NIR-Spectrum

high water content

low water content

SNV

Wavelength / nm

- Austria's only potato starch factory
  - Gmünd, Lower Austria

- Starch is processed into:
  - **Maltodextrin**
  - **Glucose syrups**

- Used in:
  - Mashed potatoes
  - Pudding
  - Carrier in pharma industry
  - Bio-based polymers
  - Adhesives and construction additives
  - Etc.

- Spray drying
  - Gentle drying process

- Product is sampled by an automated plate sampler

- Dropped into sample chamber for subsequent analysis
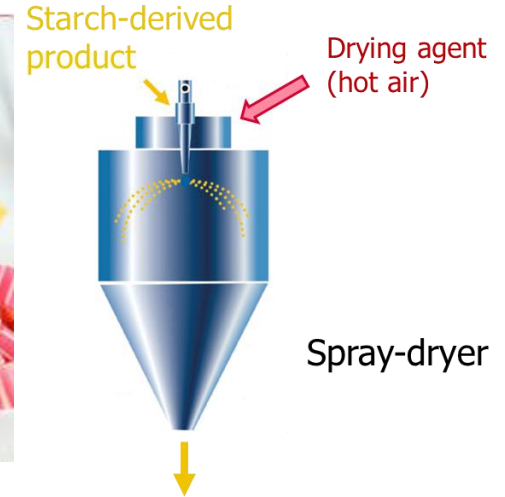
Automated plate sampler (side view)
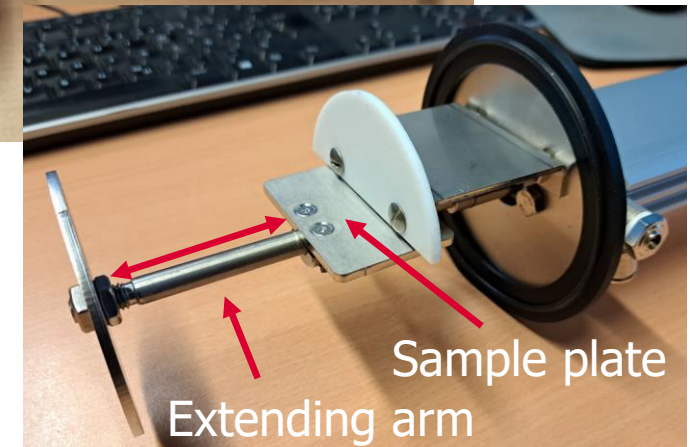
Inside of the automated plate sampler

Sample plate

Extending arm

- Sample is dropped into the chamber

- Multi-mode optical fiber
  - Illumination and collection of reflected light

- Ex protection zone
  - Mechanical parts are pneumatic
  - Spectrometer and light source are placed outside

- Sample is sticky
 - Chamber is flushed with pressured air

H_2O

$R^2 = 0,986$
4 Latente Variablen
RMSECV = 0,223
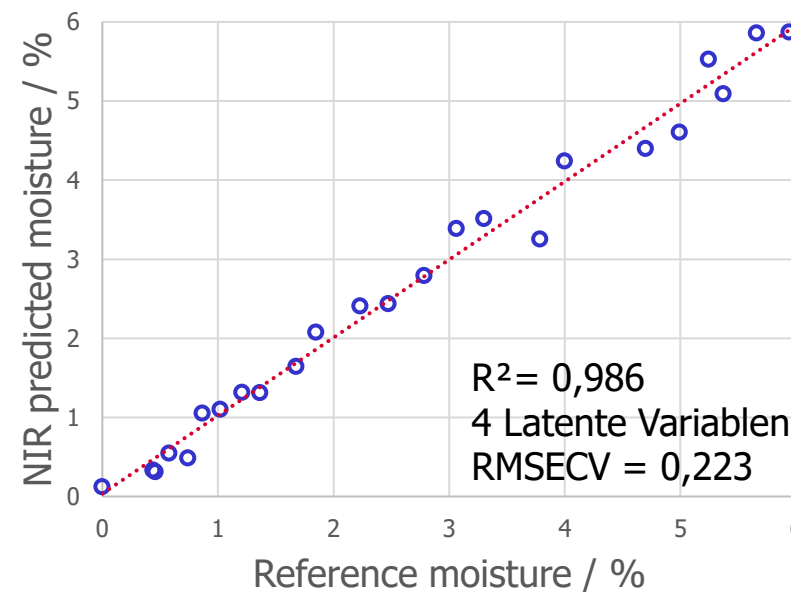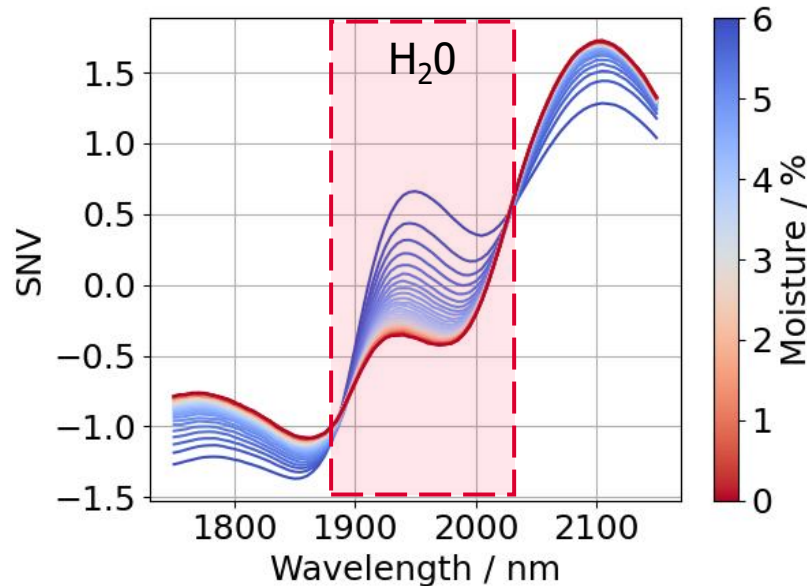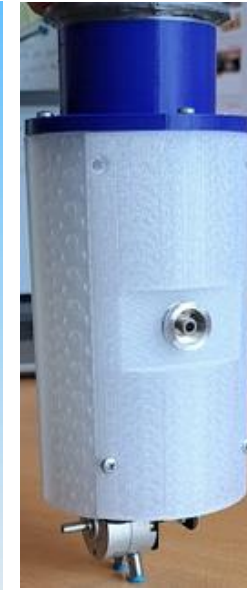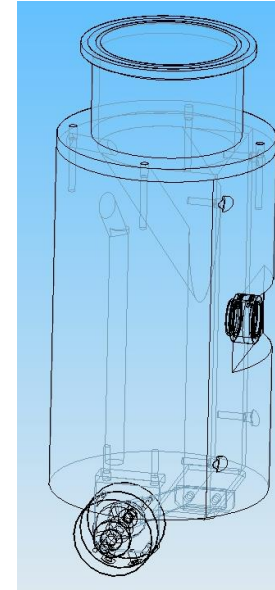
RMSECV…Root Mean Square Error Cross-Validation

- **14,000 tonnes of bakery products annually**

- **100 different products**
  - Bread
  - Pastry
  - **Dumplings and breadcrumbs**

- **Freshly baked buns are aged and cut into dumplings**

- **Conveyor belt dryer**
  - Energy Source: Natural Gas

- **Development of reflection measurement head**

Drying agent (hot air)

dumpling bread →

Conveyor belt dryer
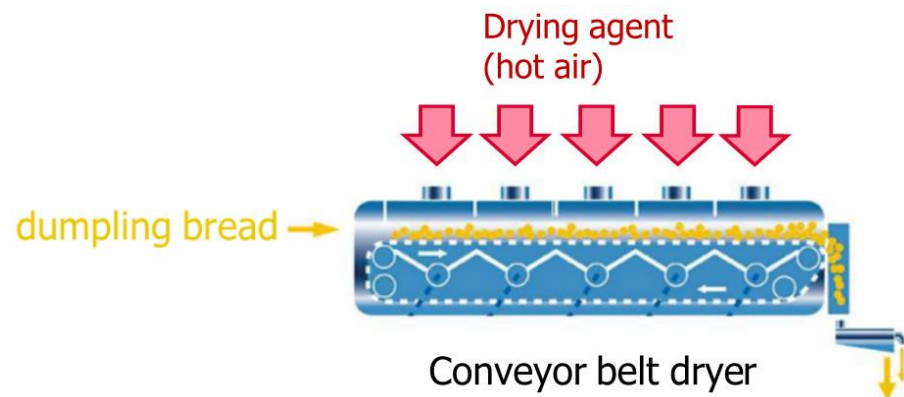
Reflection measurement head

- Conveyor belt is enclosed
  - High temperatures and dust inside the dryer

- Limited Space
  - Several conveyor belts stacked on top of each other
  - Product runs through the dryer in a snake route

- Optical parts out of glas have to be enclosed
  - Reflection measurement head is placed in a stainless steel box
 - Polycarbonate protective window

Summary
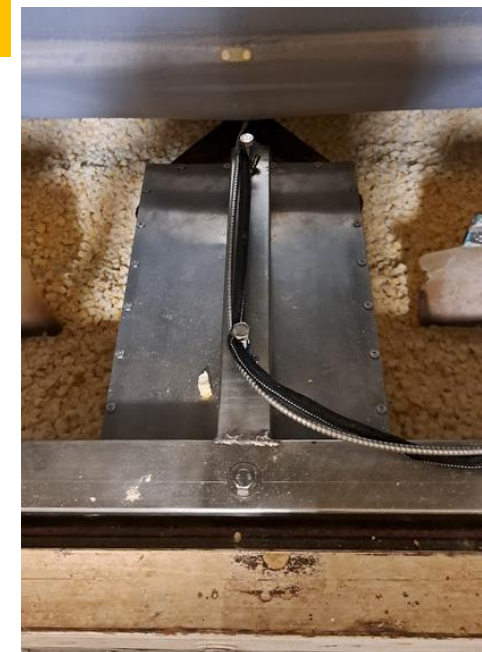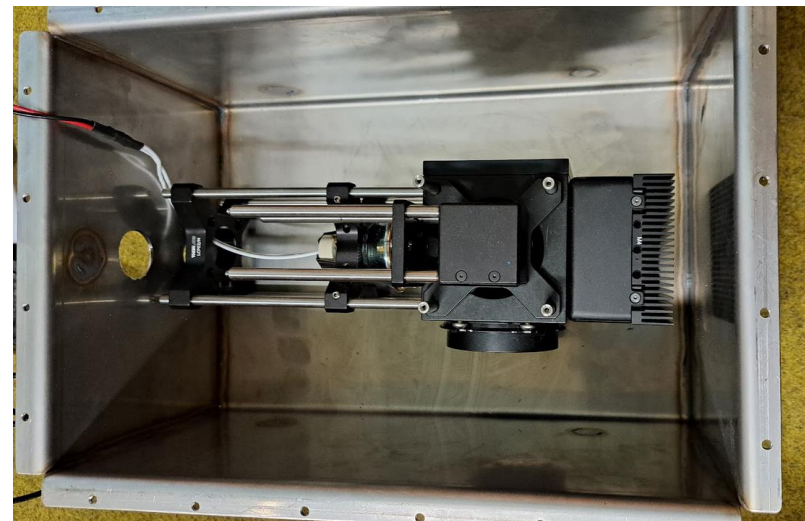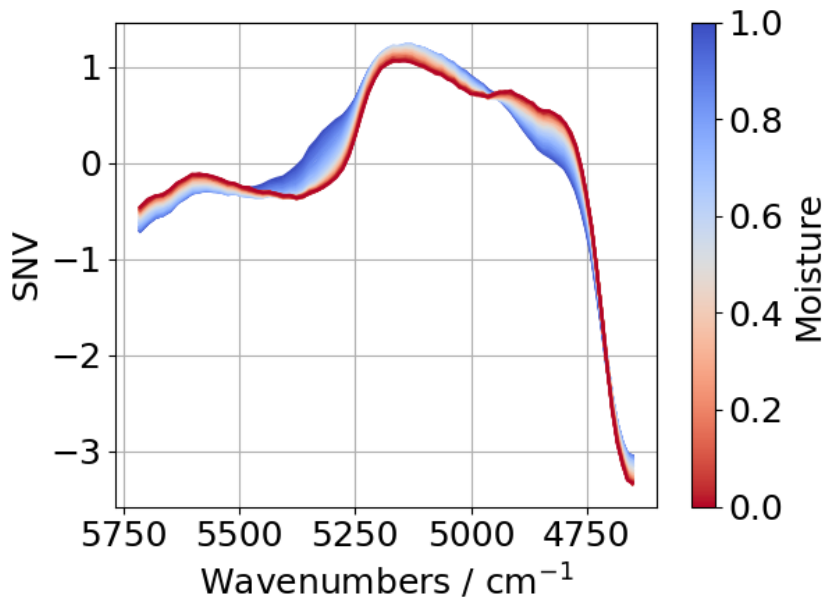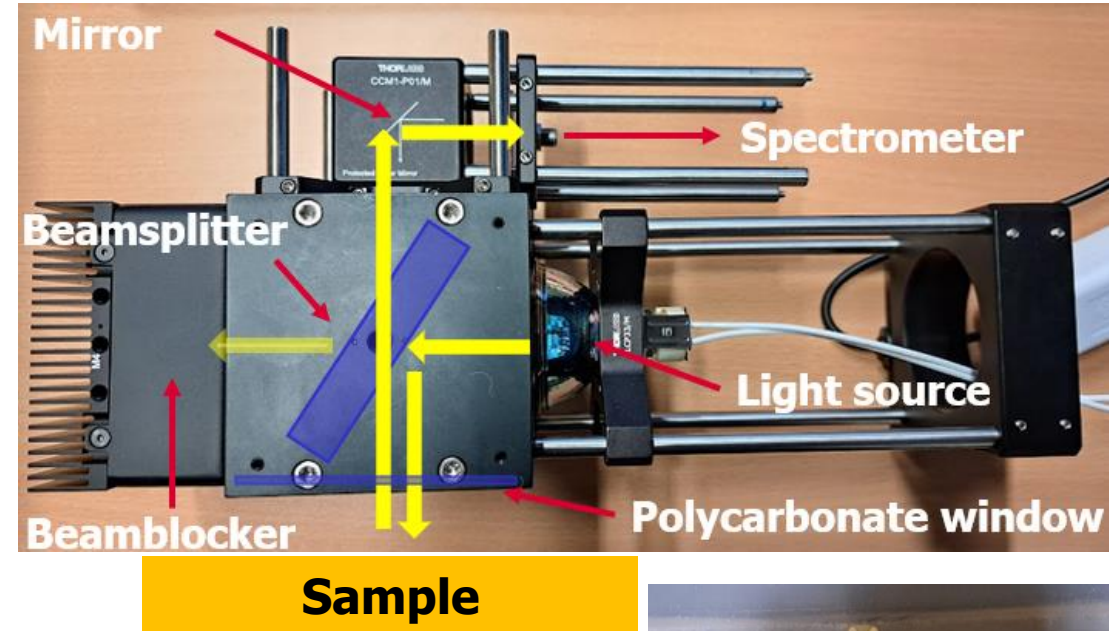
- NIR spectroscopy is a **powerful measurement technique** for moisture measurement

  → **Inline-capable** → **Automatic and real-time**

  → **Flexible optical interfaces** → **Non-destructive**

- **Novel MOEMS technology** allows the realization of **cost-efficient** and compact NIR spectrometers

- **Spectral measurement** also allows for **simultaneous determination of additional parameters**

  – Protein, fat, ash content,…

<3 k€
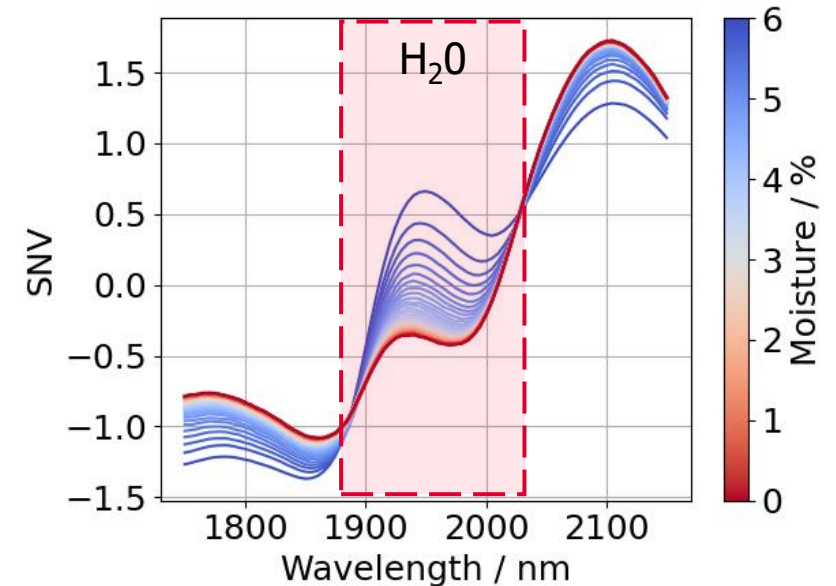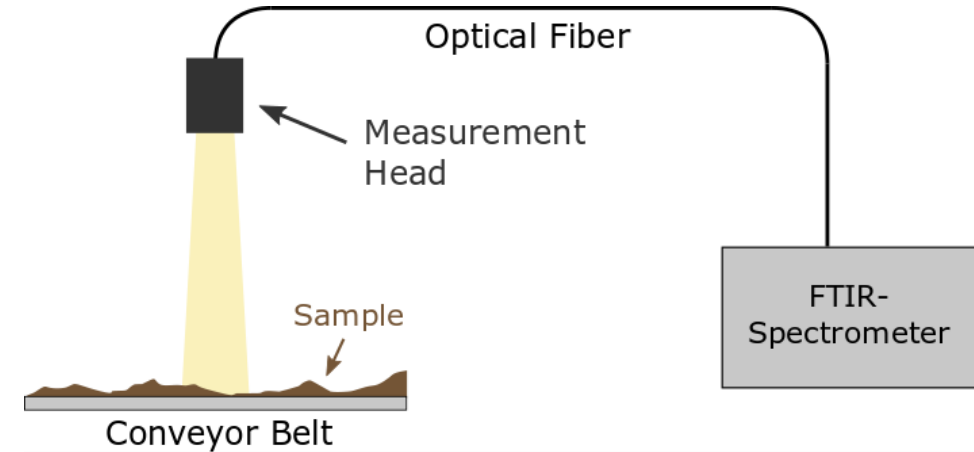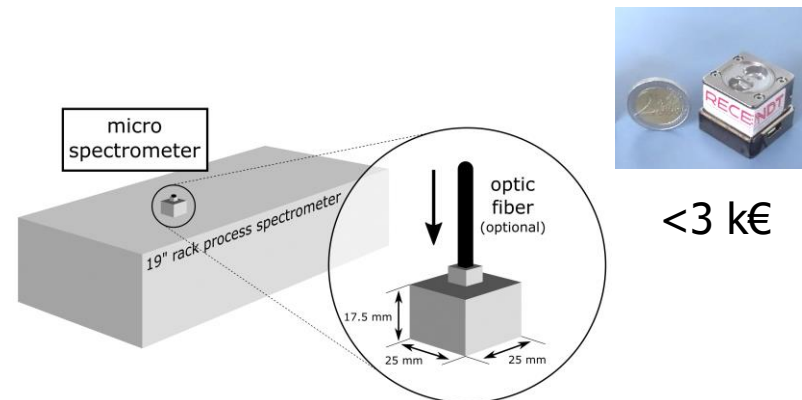
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