



BROMEDIR: **Development** and **evaluation** of a miniaturized FT-MIR instrument for in-farm milk analysis

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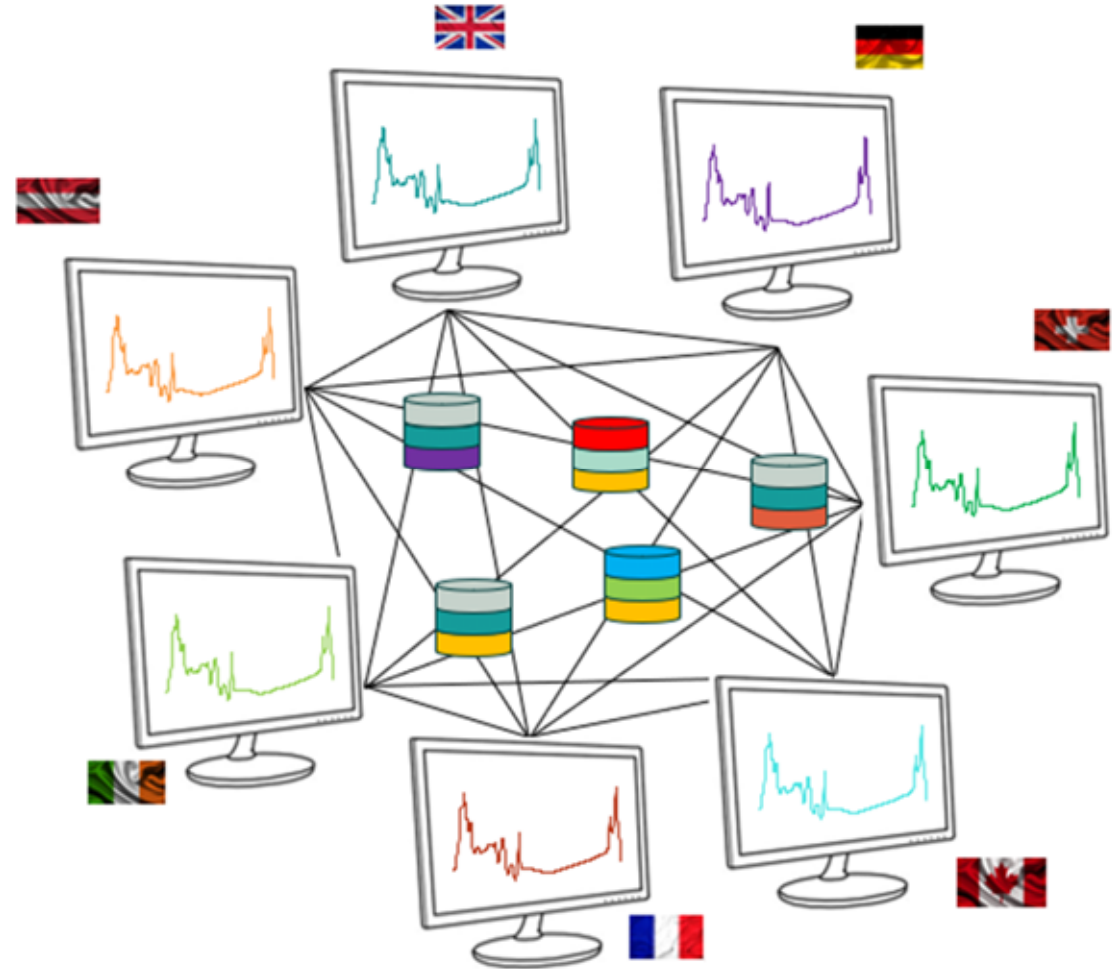
Standardization : possibility to transfer FT-MIR models from instruments to instruments since 2015



Technical (sample creation, sending) & Scientific



IT, database, servers and admin



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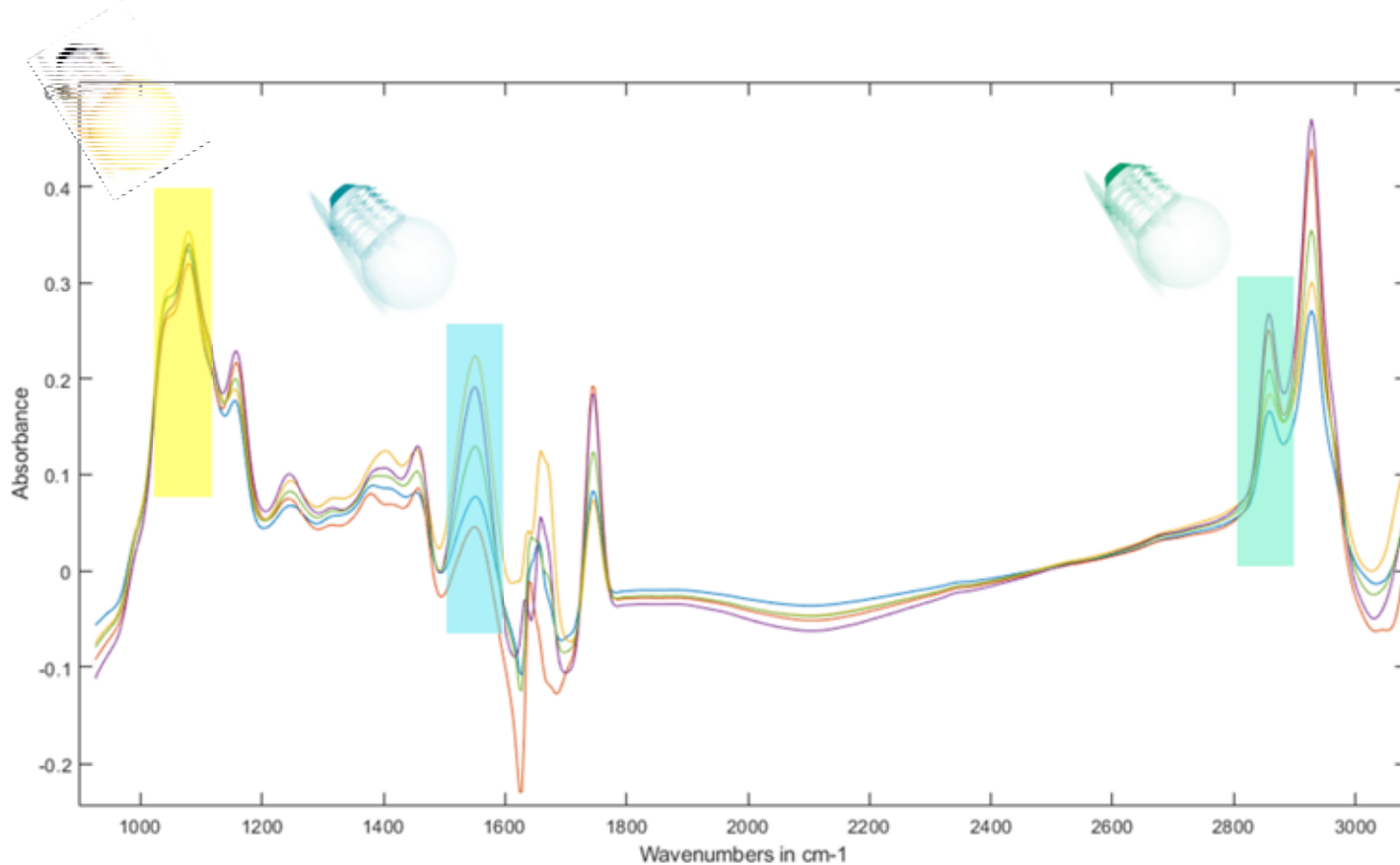
Standardization of milk mid-infrared spectrometers for the transfer and use of multiple models

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Daily in-farm milk analysis

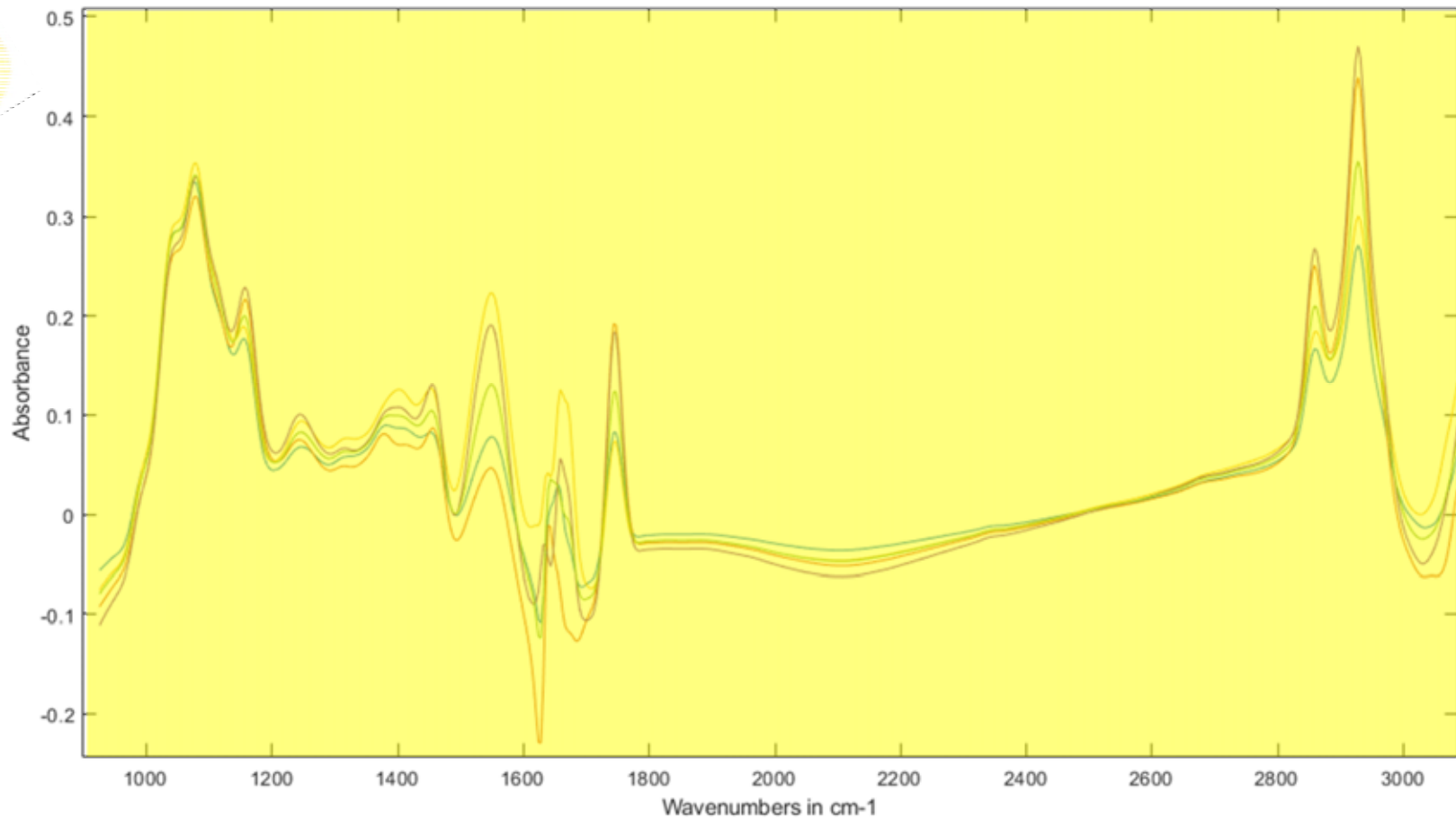
High frequency of measurement (daily) * Individual cow level

- Precision livestock farming
 - Powerful to detect deviations
 - Heat
 - Unknown disturbances (r
- BUT current miniaturized systems
 - NIR
 - A few MIR wavenumbers



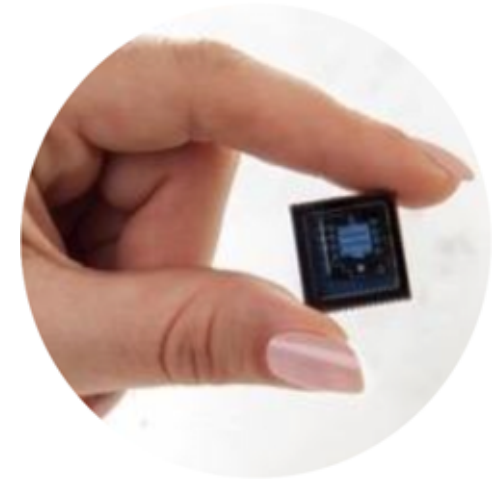
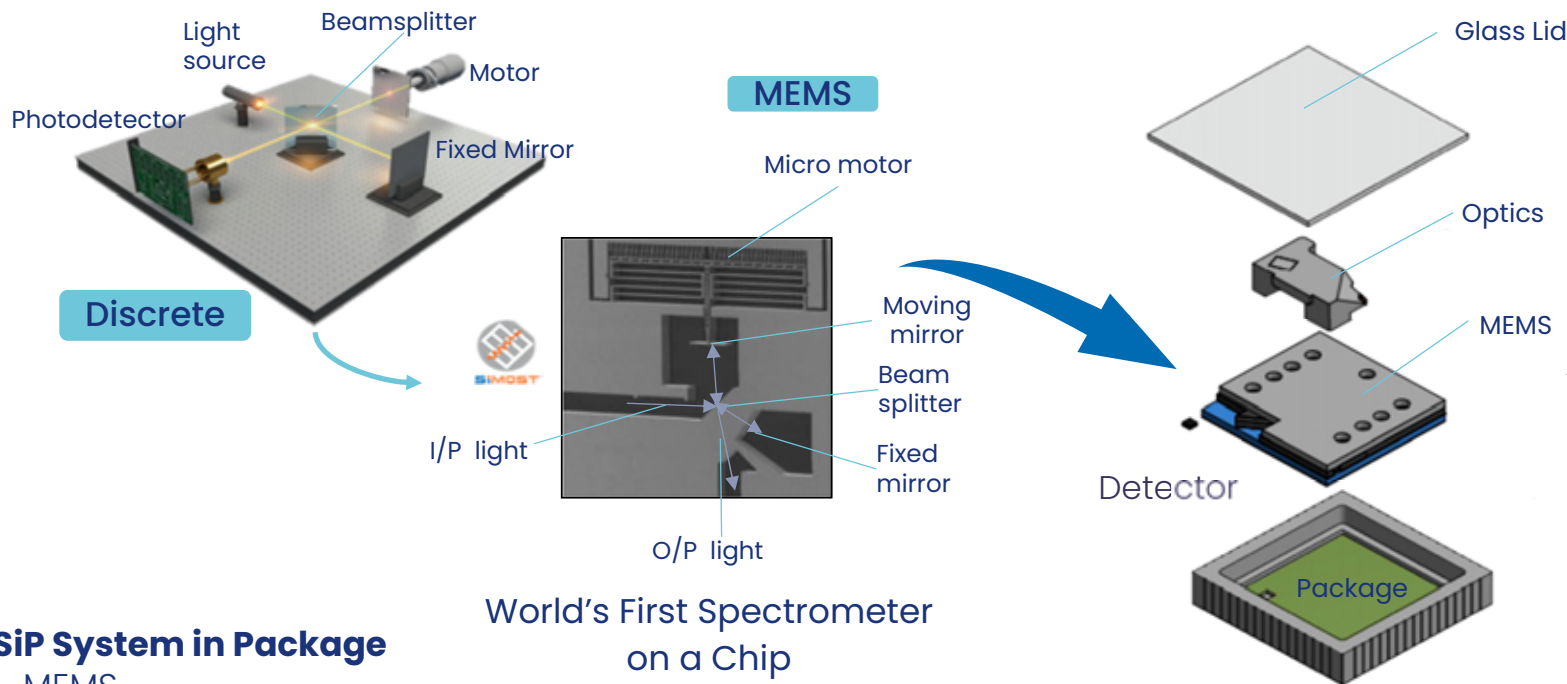
Objective of Bromedir: develop a miniaturized FT-MIR spectrometer for in-farm milk analysis covering the full FT-MIR range

→ Transfer of existing (+200) FT-MIR models for daily monitoring



Innovative core technology

Miniaturizing spectrometer to unprecedented scale



SiP System in Package

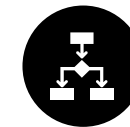
- MEMS
- Photo-detector
- Optics

Advantages

- Low cost scalable technology
- Portable
- Robust
- Lab-grade performance
- Cloud Connectivity
- Online Analytics



Identification

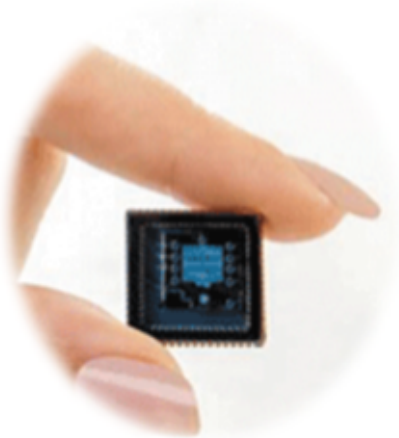
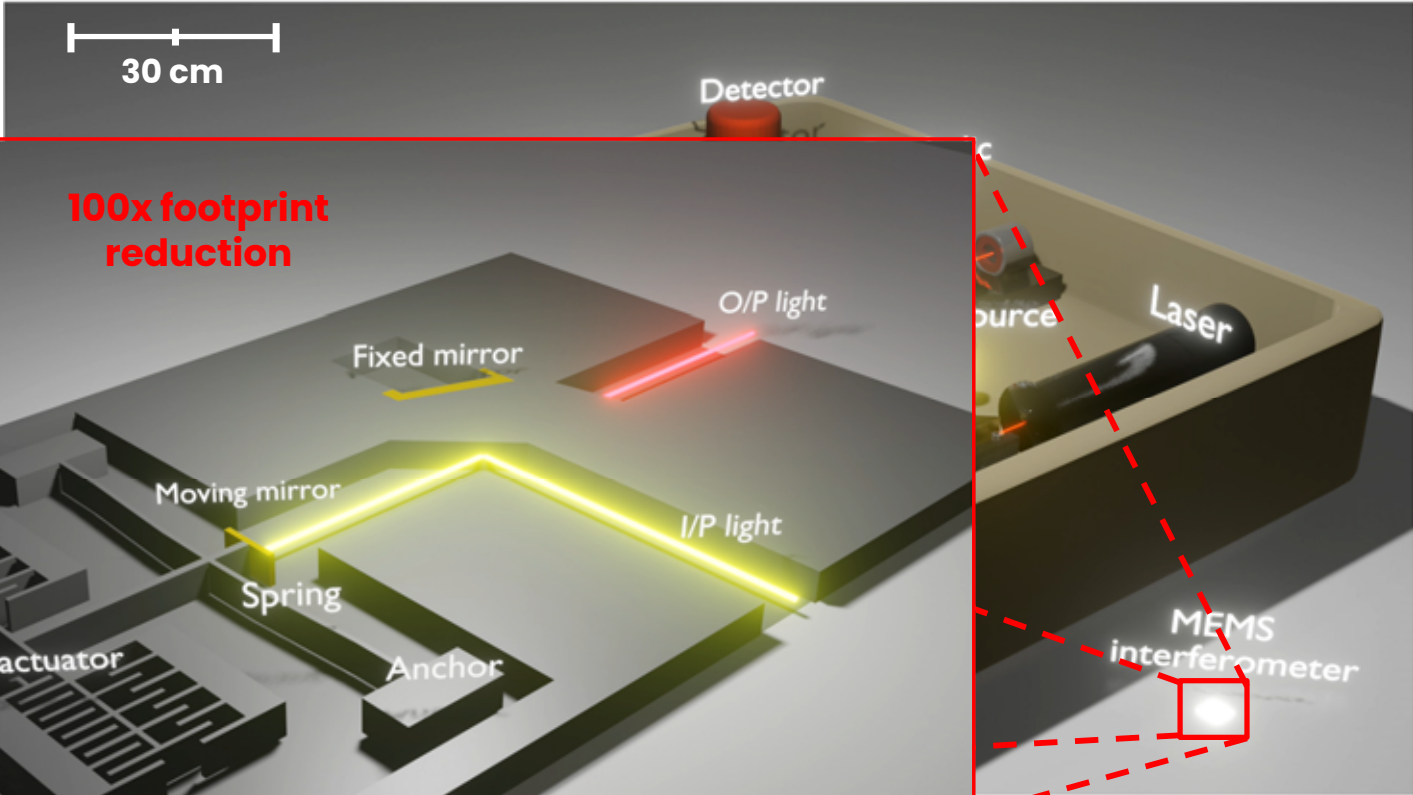


Classification

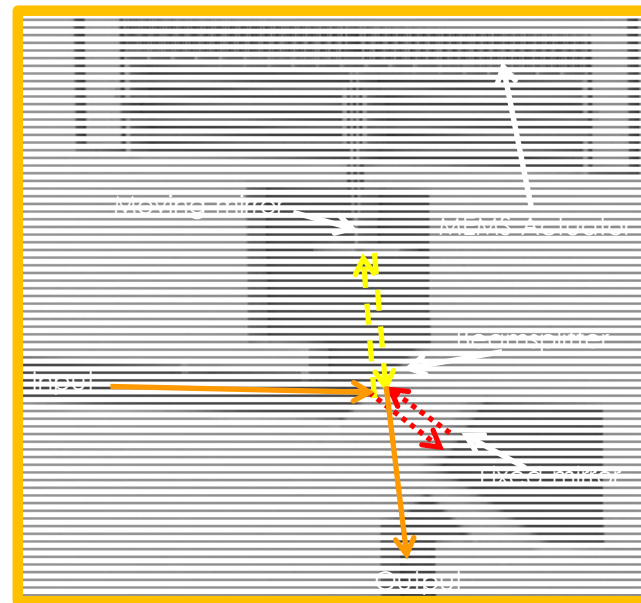
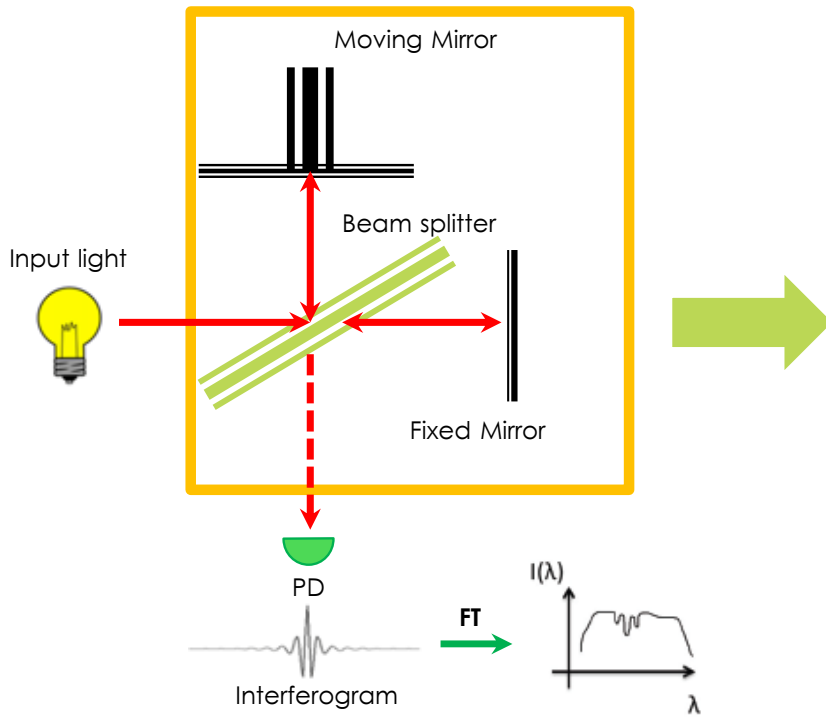


Quantification

From Benchtop Macroscopic Instrument to MEMS Photonic Integrated Circuit (PIC)

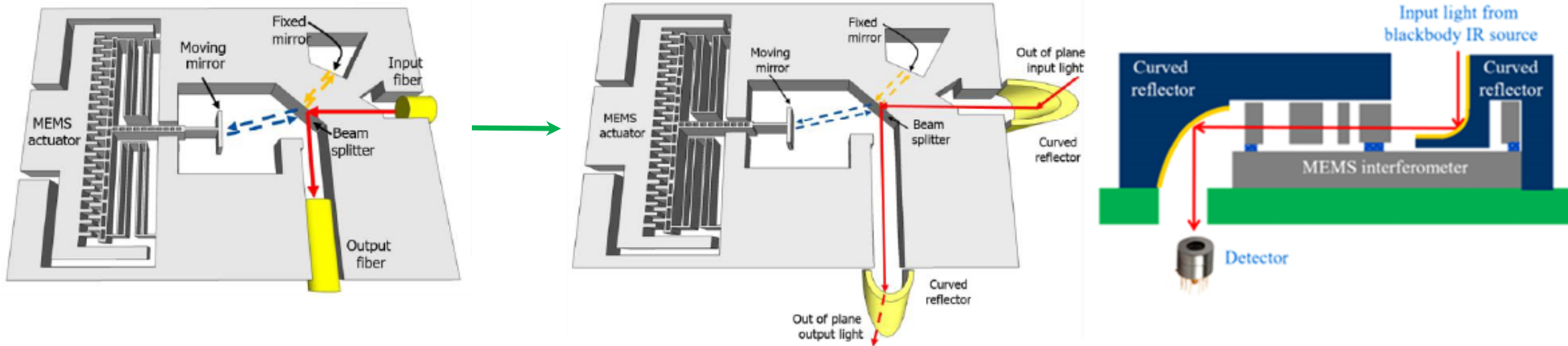


Monolithic Michelson Interferometer



WideRange wavelength operation

- Unlike available portable miniaturized spectrometers in market limited to NIR ($< 2.6 \mu\text{m}$), **our technology allows operation in a very WideRange spectral range ($> 10 \mu\text{m}$)**
 - MEMS PICs allow **free-space propagation of light** (contrary to most of PICs which are based on guided light propagation in waveguides)
 - Additionally, we use free space optics instead of optical fibers interfacing between outside world and PIC chip

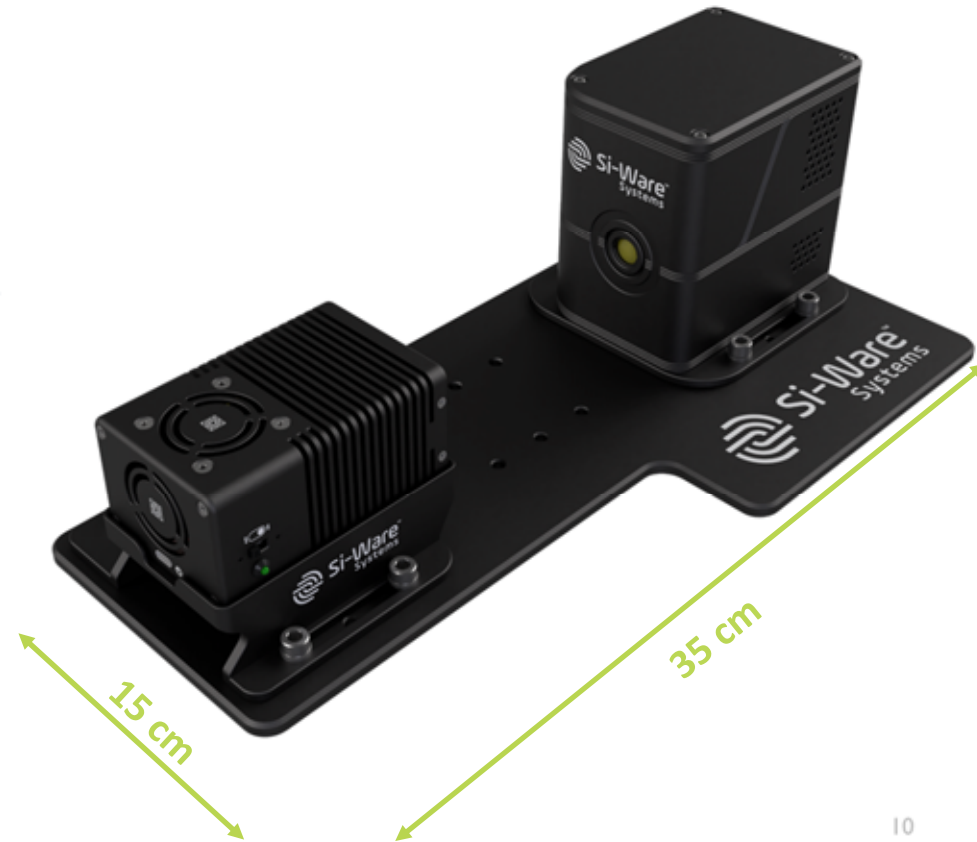
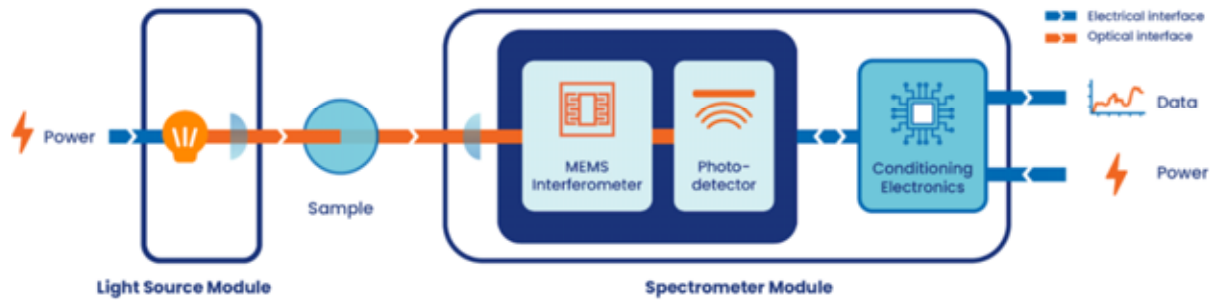


WideRange FTIR Spectrometer


- ✓ Broadband MEMS FTIR spectrometer
- ✓ Extends beyond 1000 cm^{-1} ($10\text{ }\mu\text{m}$)
- ✓ Portable platform

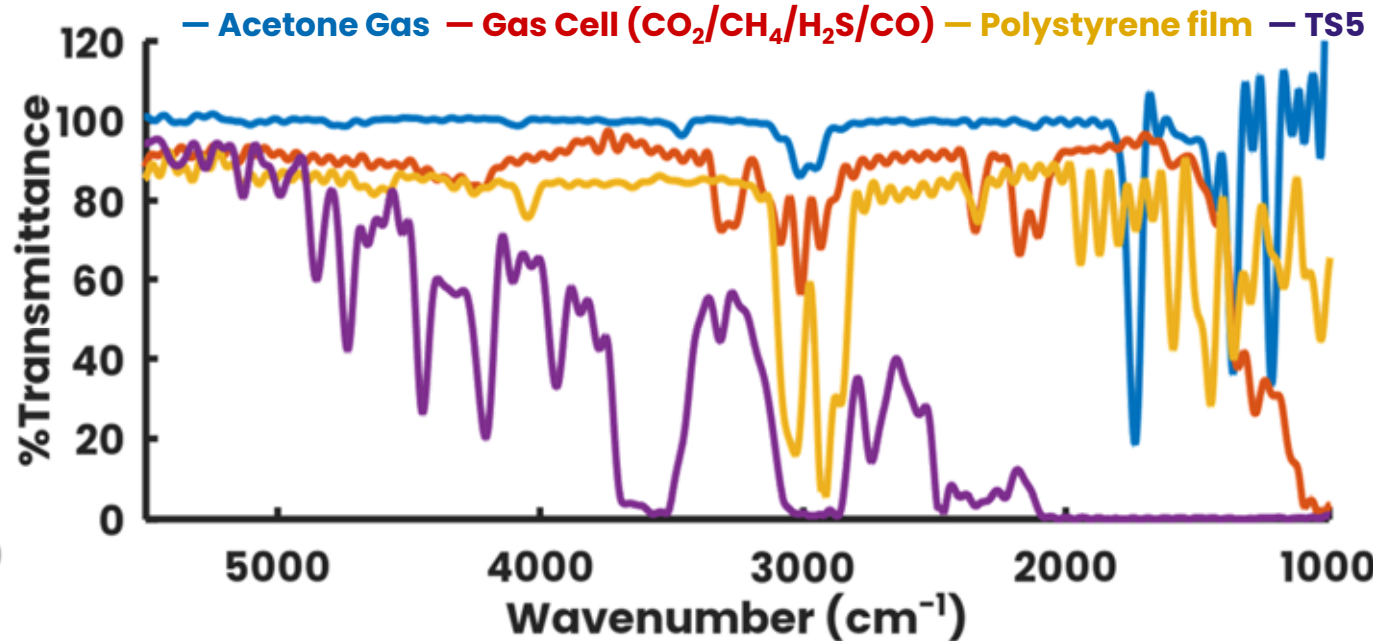
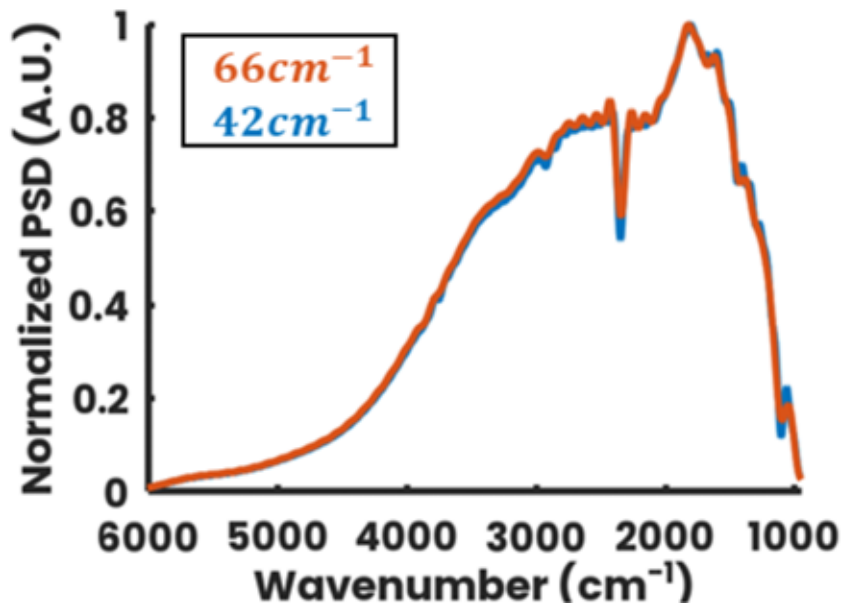
BROMEDIR Spectrometer

- Size: $11.6 \times 11.8 \times 11.5\text{ cm}^3$
- Weight: ~ 1 kg



Performance

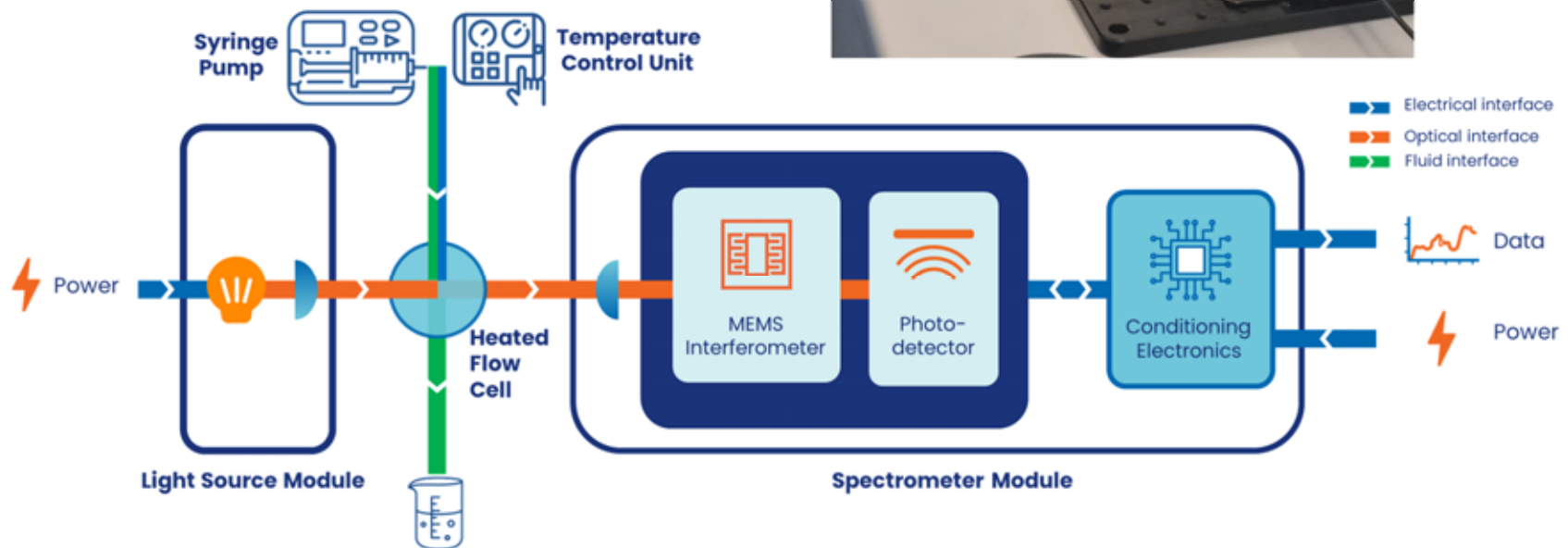
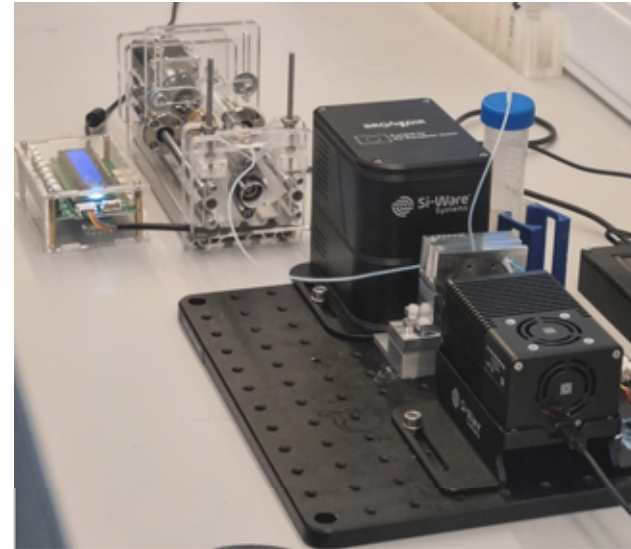
- ✓ **Spectral Range:** 6000 to 1000 cm^{-1} range (Fingerprint Region) 
- ✓ **Resolution:** 42 / 66 cm^{-1}
- ✓ **SNR** > 5000



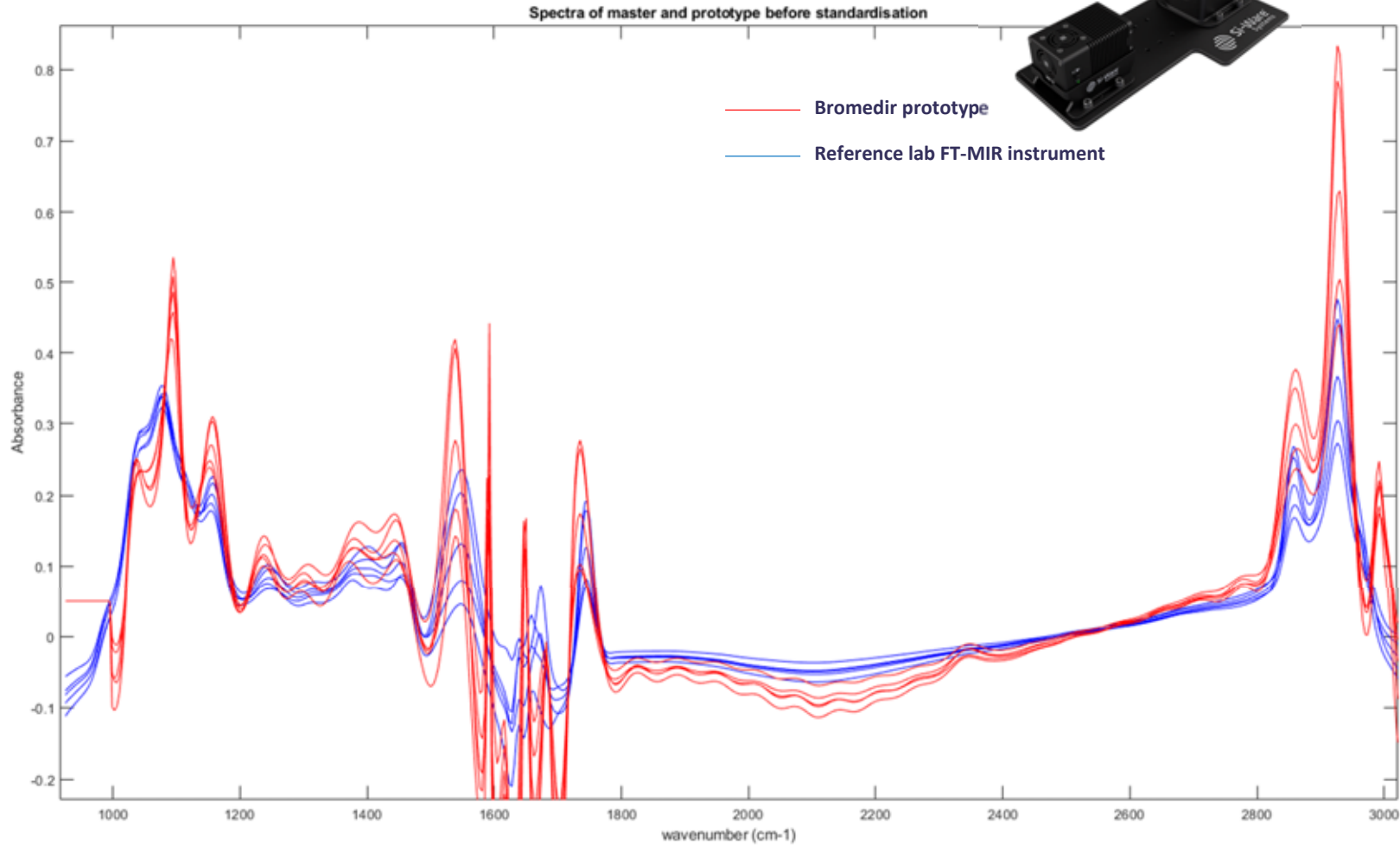
Example Measurements Overlay – transmission spectra of Acetone and $\text{CO}_2/\text{CH}_4/\text{H}_2\text{S}/\text{CO}$ gas cells, polystyrene film and TS5 reference material at 42 cm^{-1} resolution

BROMEDIR Milk analyzer

- Spectrometer integrated with liquid flow cell
- Flow cell is heated and temperature stabilized to 40 °C
- Milk is injected using automated syringe pump

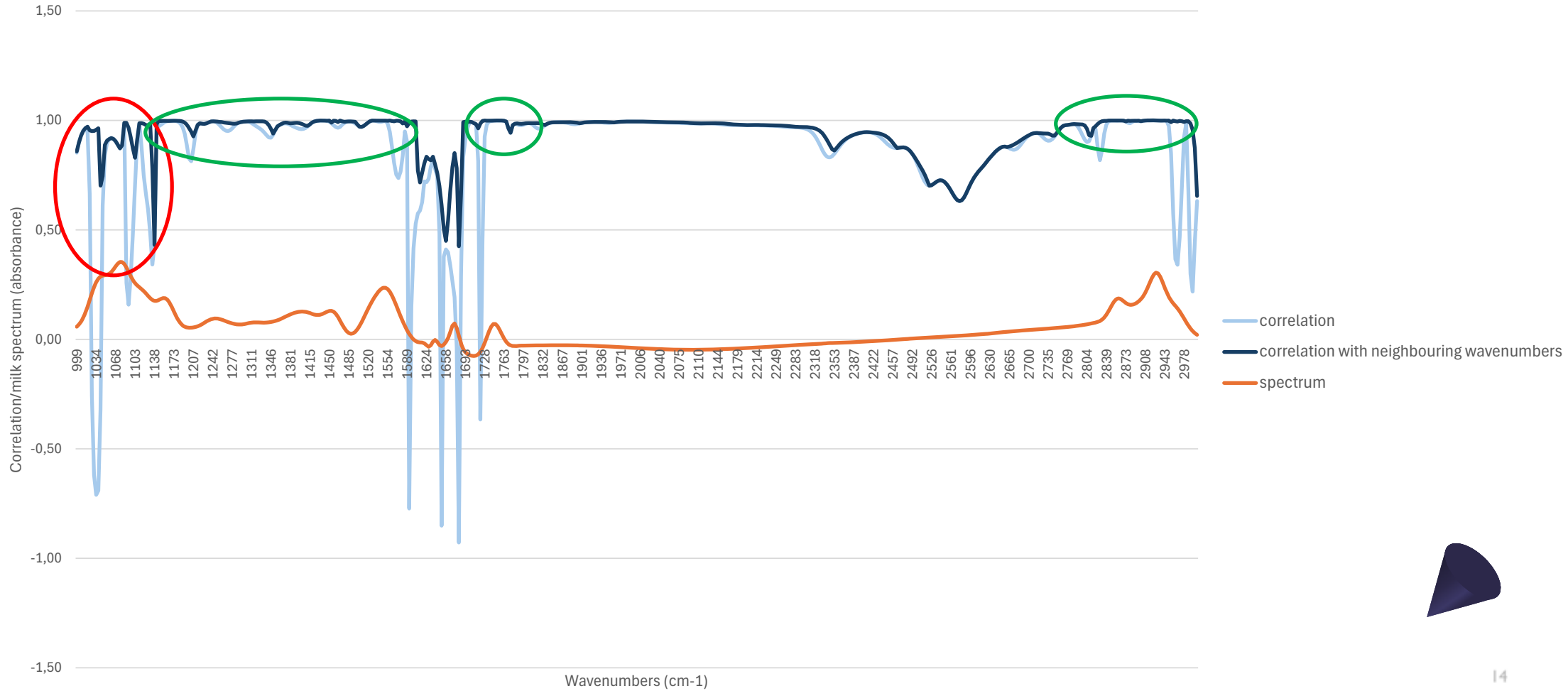


After 2 years of development

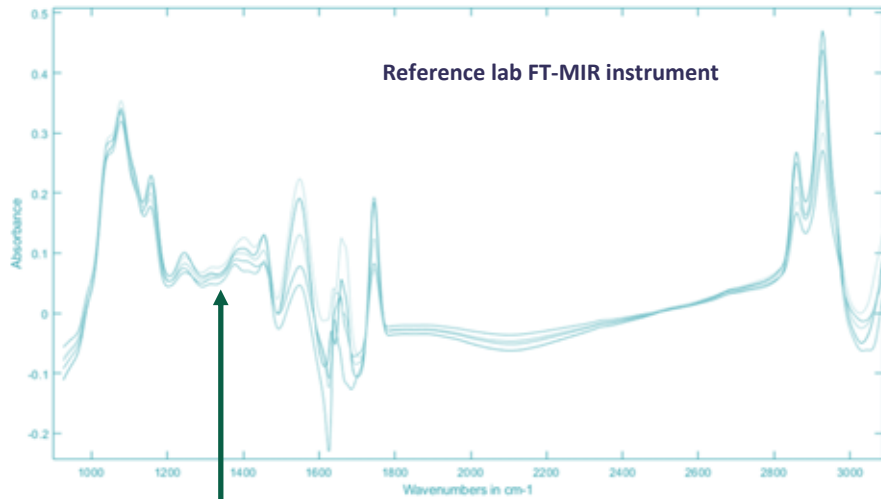


Similar information to reference lab instrument?

Correlation between Prototype and Reference lab instrument absorbances

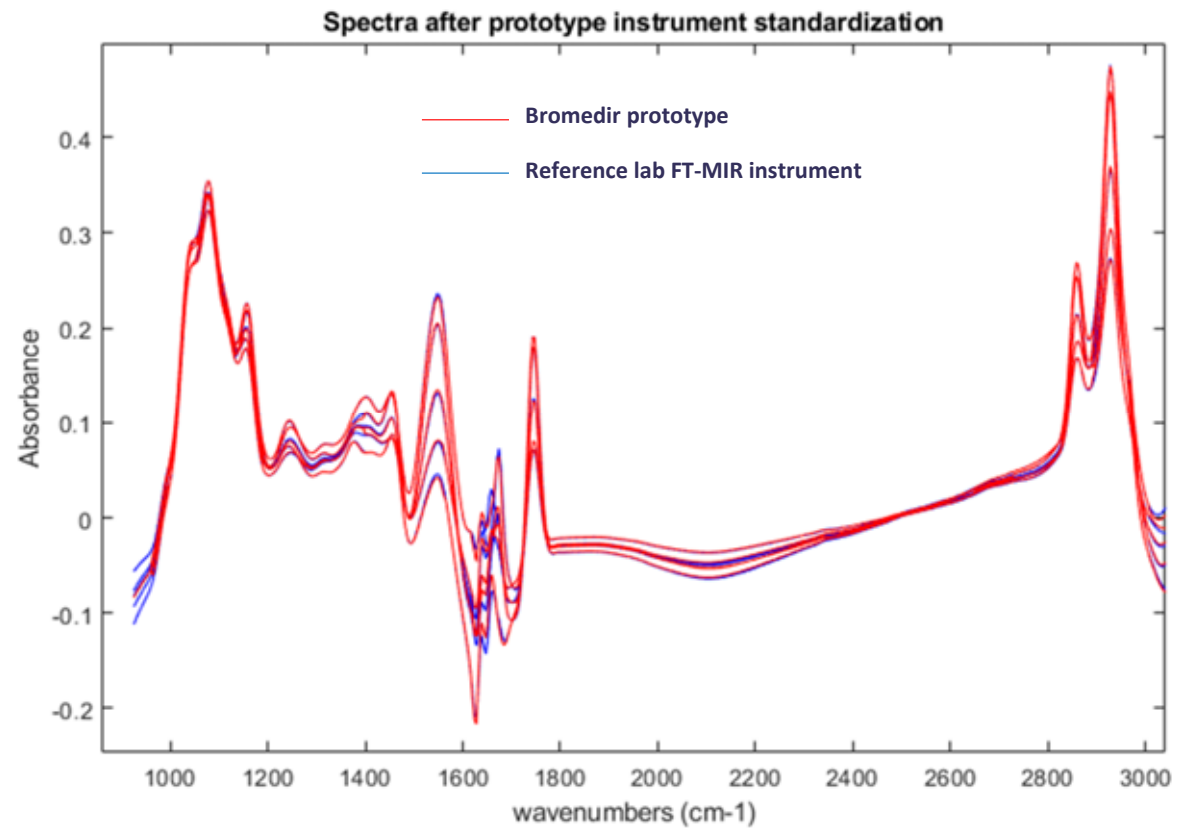
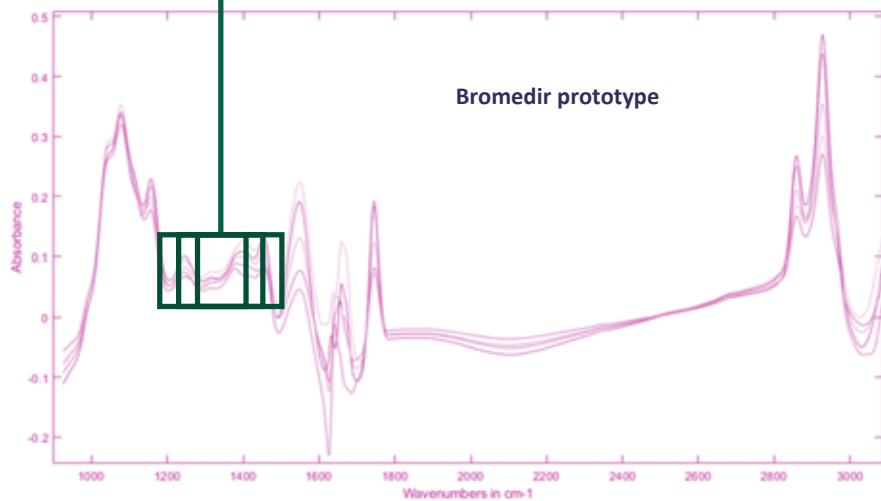


Optimization of standardization 'windows size' and complexity



Standardization of Prototype to a Reference Lab instrument (Master)

Mathematical transfer based on analysis of identical sets of 5 reconstituted raw milks

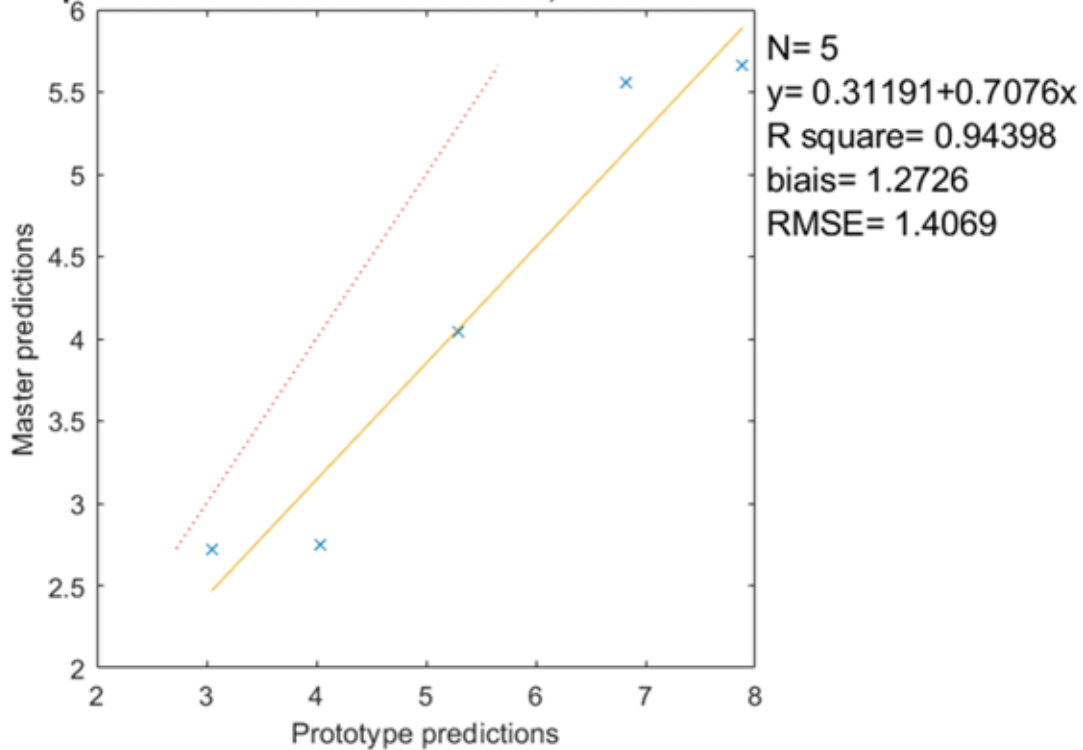


Transfer of a 'own made' Fat model

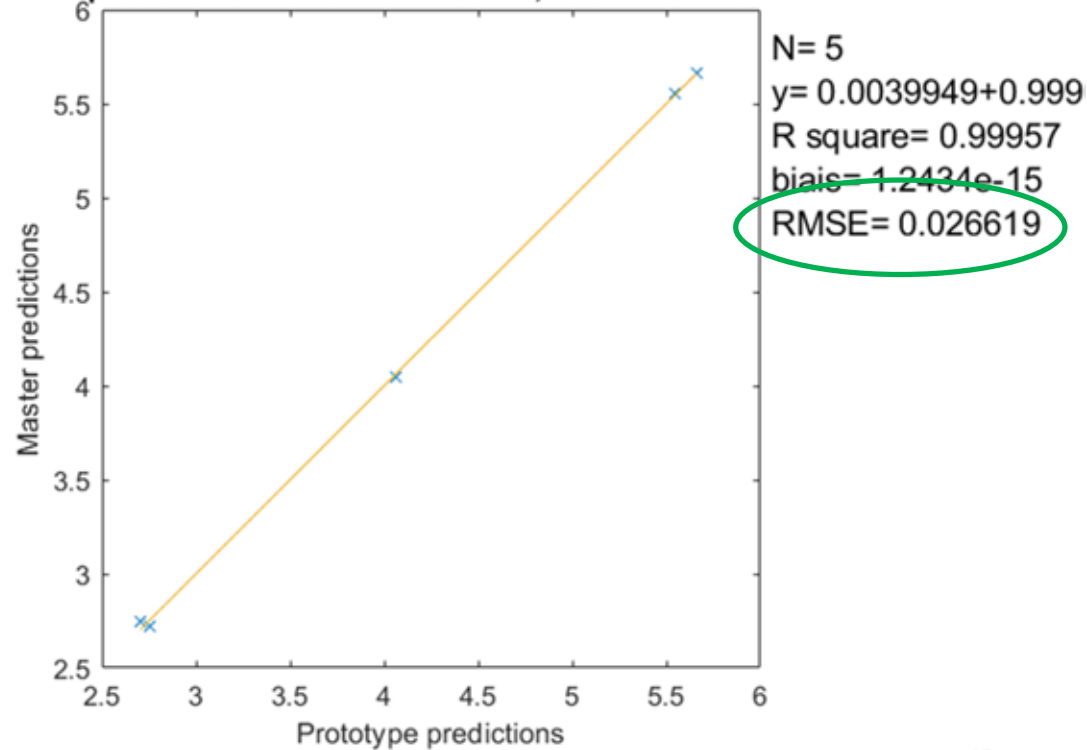
Standardization of Prototype to a Reference Lab instrument (Master)

Mathematical transfer based on analysis of identical sets of 5 reconstituted raw milks

Fat predictions without standardisation, Master vs PROTO13



Fat predictions after standardisation, Master vs PROTO13

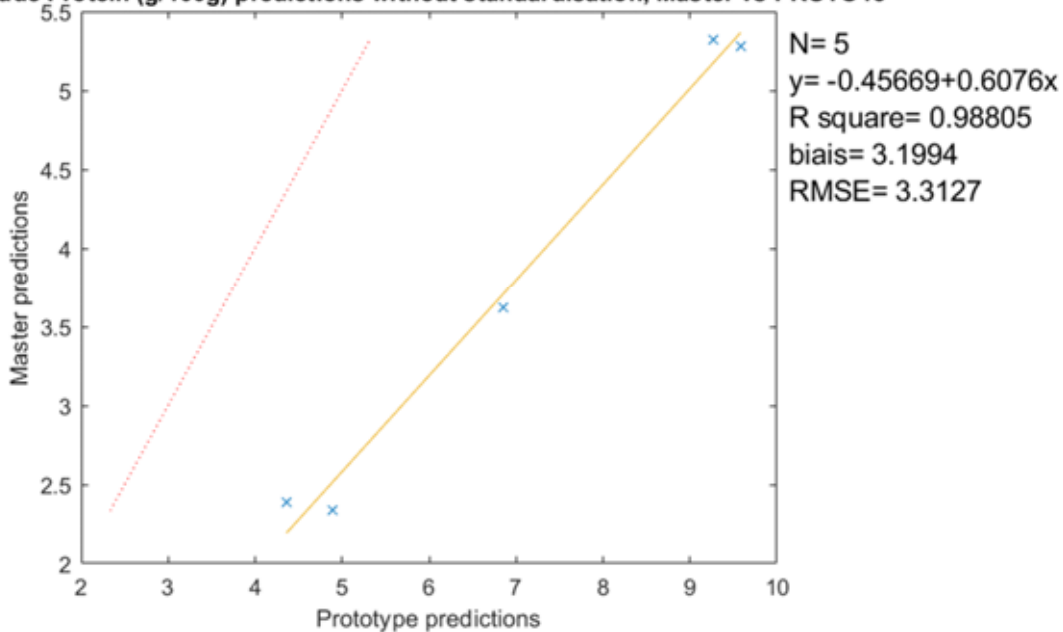


Transfer of a 'own made' Protein model

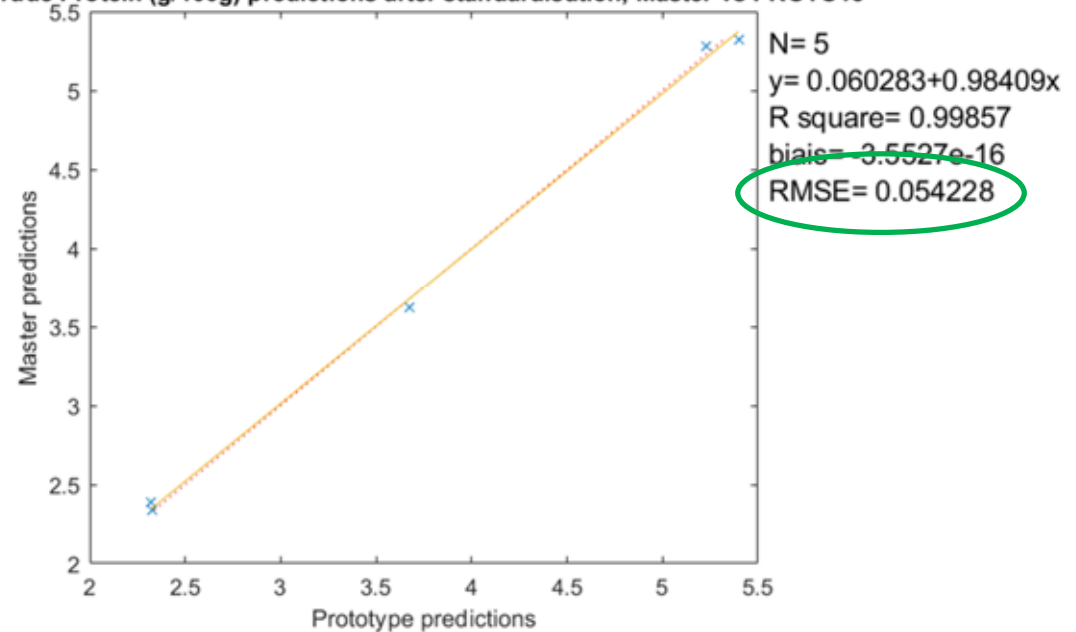
Standardization of Prototype to a Reference Lab instrument (Master)

Mathematical transfer based on analysis of identical sets of 5 reconstituted raw milks

Crude Protein (g/100g) predictions without standardisation, Master vs PROTO13



Crude Protein (g/100g) predictions after standardisation, Master vs PROTO13

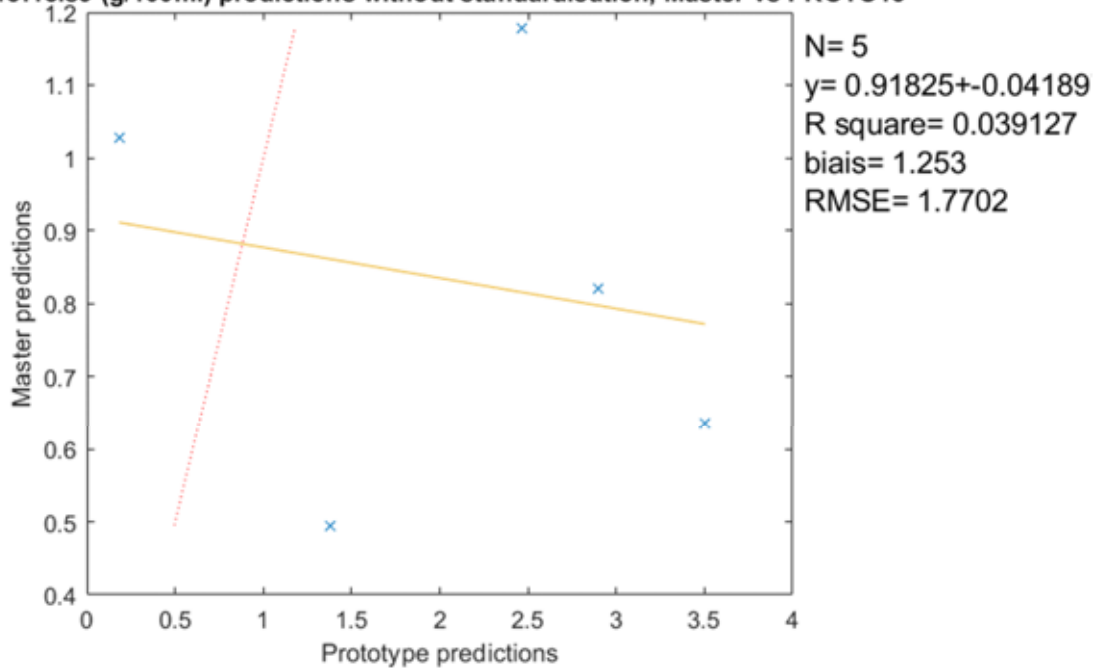


Transfer of a 'own made' C18:1c9 model

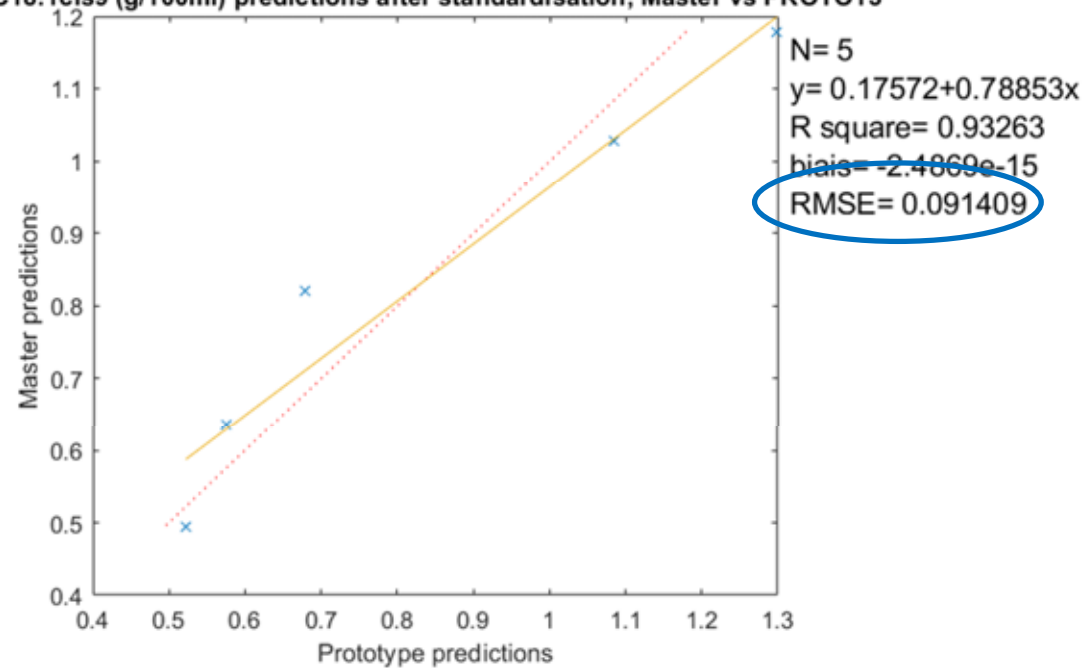
Standardization of Prototype to a Reference Lab instrument (Master)

Mathematical transfer based on analysis of identical sets of 5 reconstituted raw milks

C18:1cis9 (g/100ml) predictions without standardisation, Master vs PROTO13

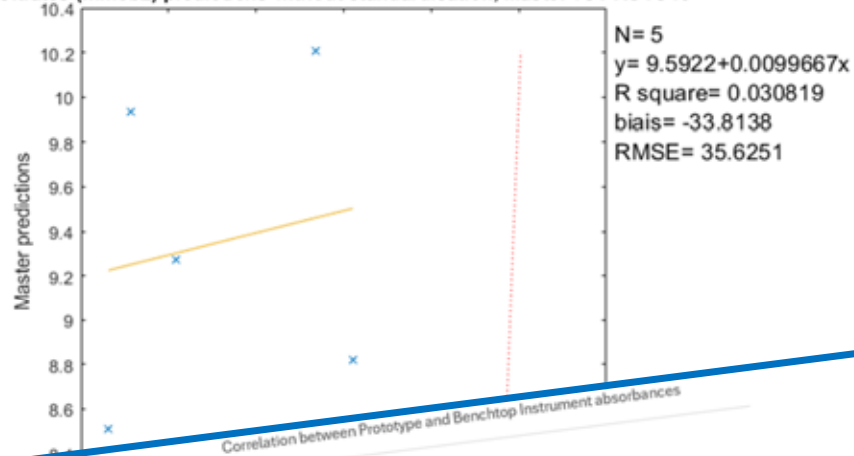


C18:1cis9 (g/100ml) predictions after standardisation, Master vs PROTO13

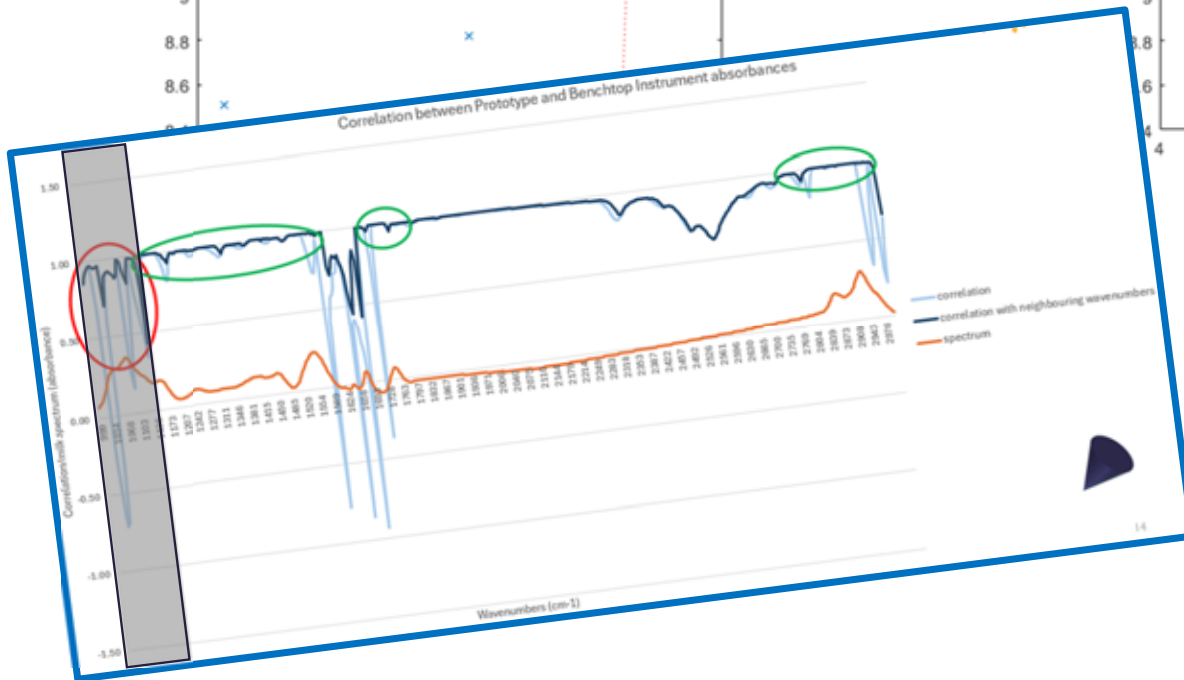
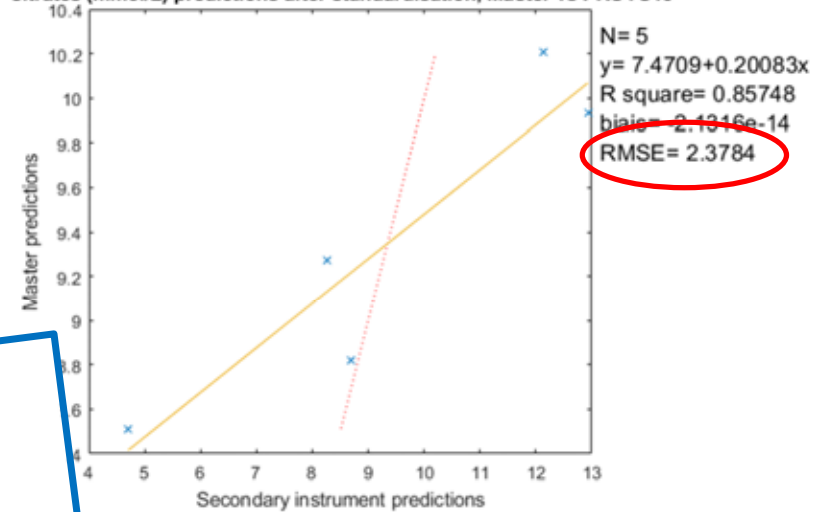


Transfer of a 'own made' citrate model

Citrates (mmol/L) predictions without standardisation, Master vs PROTO13



Citrates (mmol/L) predictions after standardisation, Master vs PROTO13



Still work to do on the hardware →
improving the signal

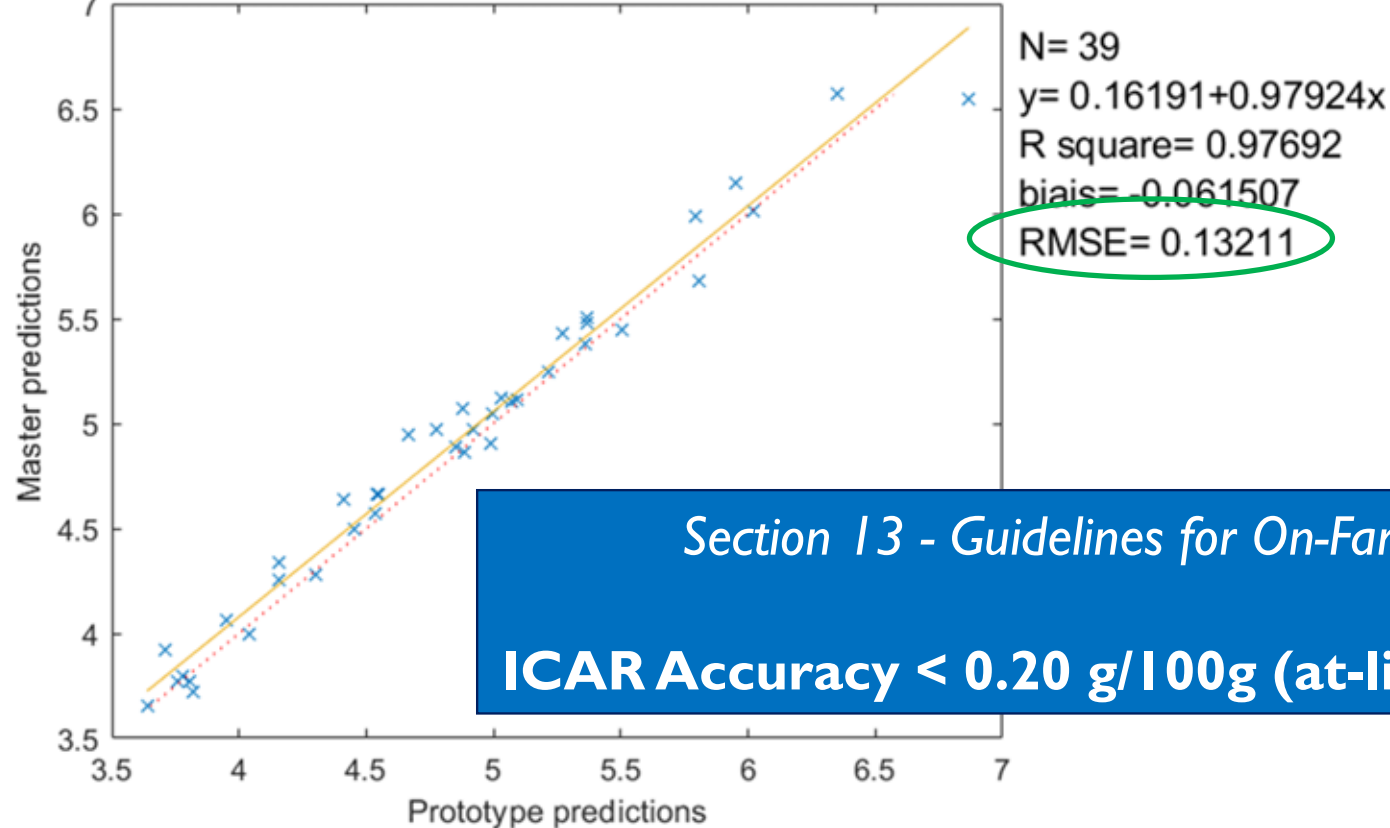
To 'shorten' the models with less
wavenumbers?

Validation

Analysis of individual raw milk from 39 CRA-W Holstein cows

Both on reference lab instrument and on the prototype (after standardization)

Fat (g/100ml) of 39 validation cows after standardisation, Master vs PROTO13



Section 13 - Guidelines for On-Farm Milk Analysis

ICAR Accuracy < 0.20 g/100g (at-line) or 0.25 (in-line)

Conclusions – Halfway through a long journey

Great potential

First miniaturized FT-MIR prototype covering the full MIR range (1000-3000 cm^{-1})

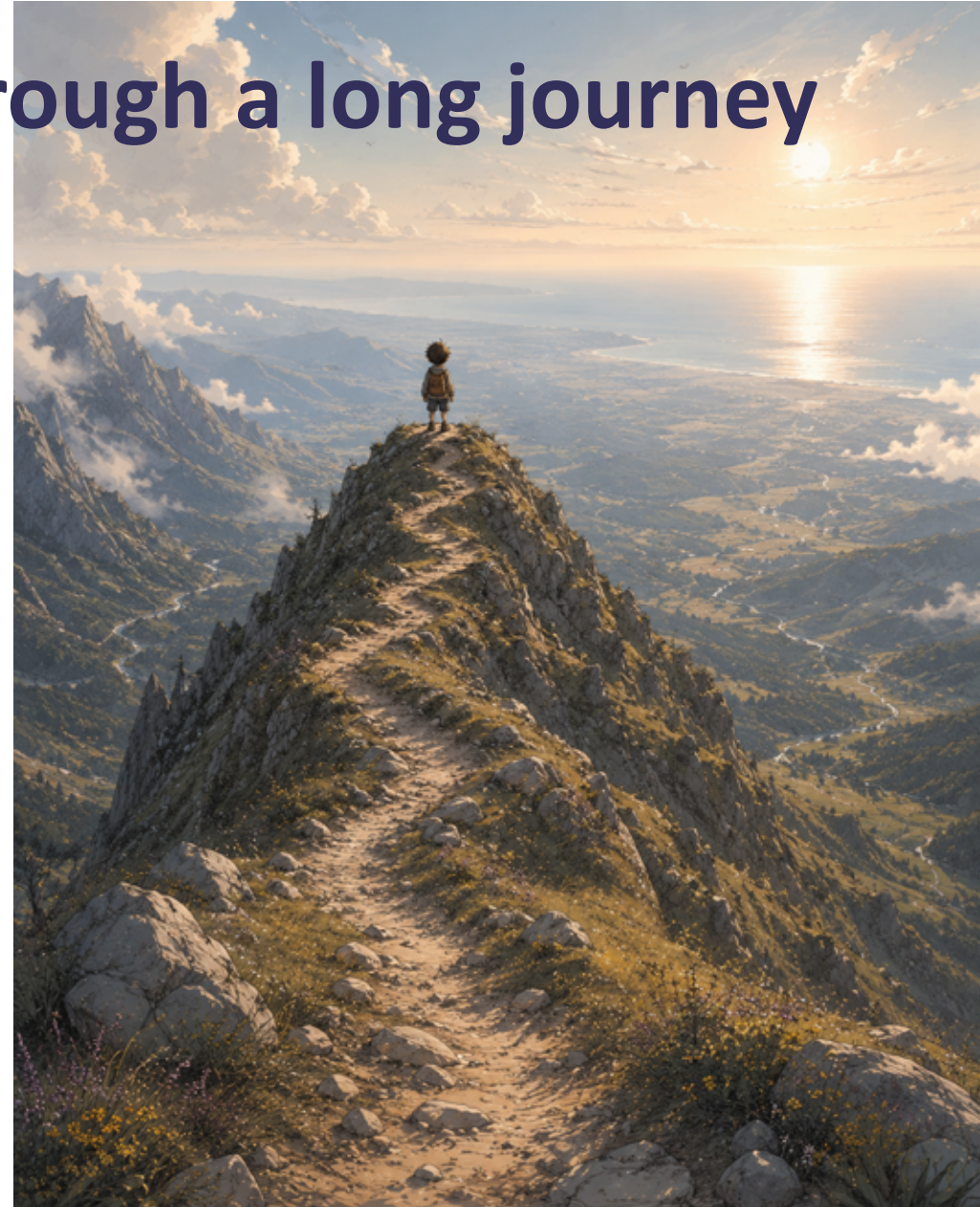
Transfer of existing model is possible

Accuracy of prototype & transferred models can reach ICAR thresholds

Still work to do

Signal and stability to be optimized

Models to be adapted ('shortened') with less wavenumbers?





Thank You!

For more information, please contact:

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Come visit us for
a live demo at **Booth 4**

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