



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

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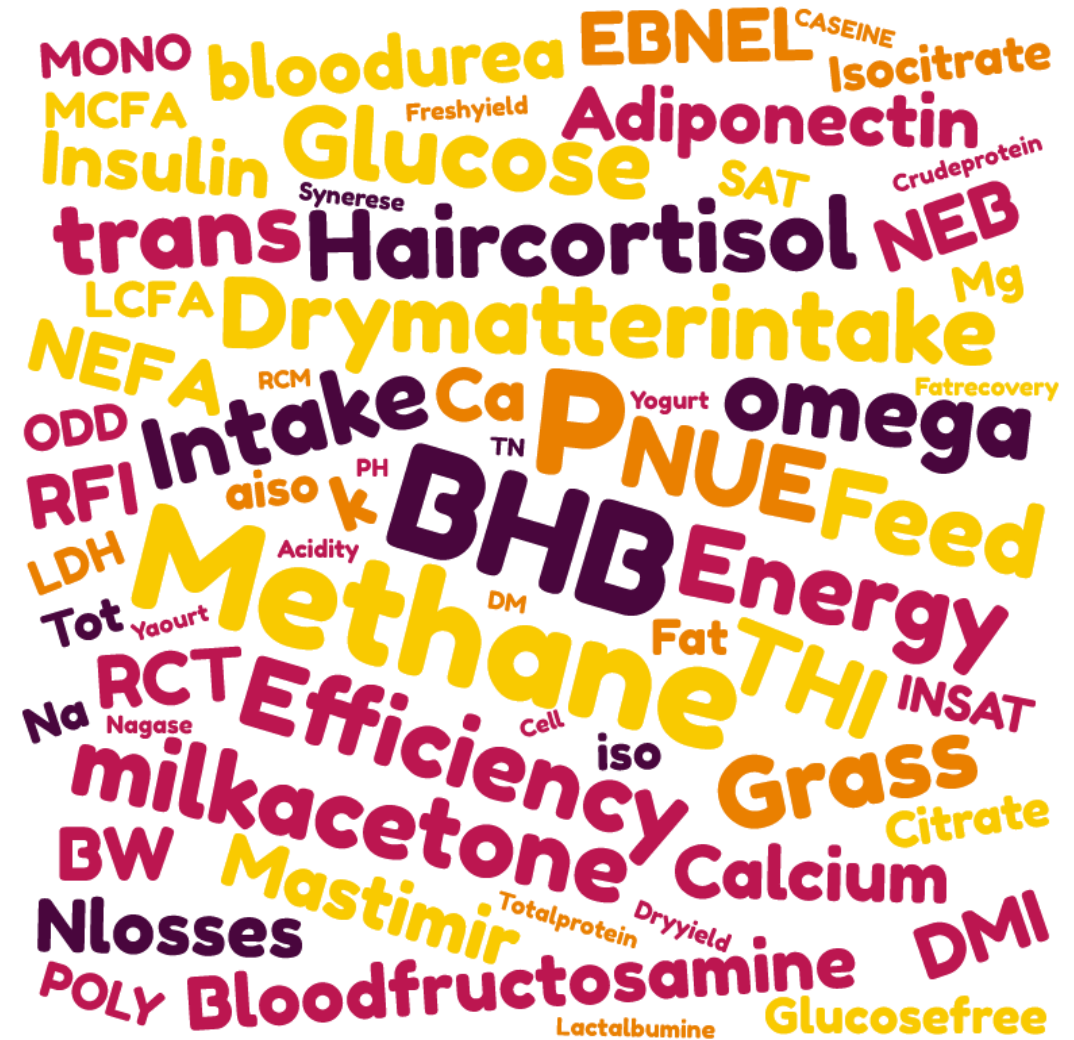
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FT-MIR use in dairy farms

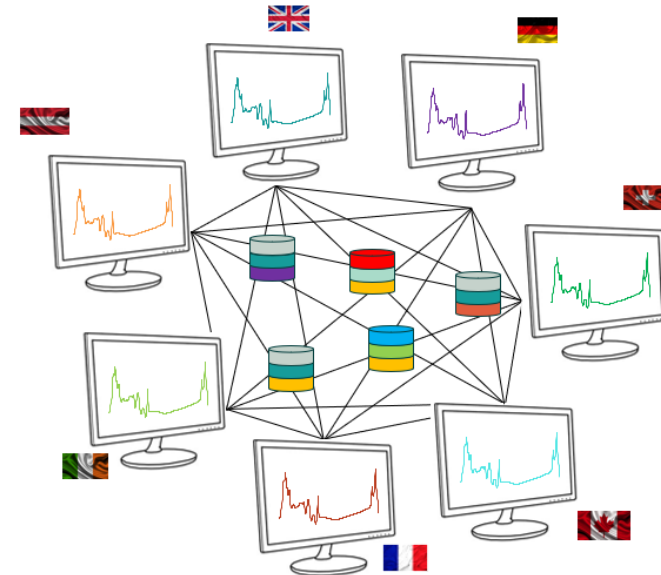
- > 20 years research
- High number of phenotypes (+200 models)
 - Milk fine quality (Fatty acids, Minerals, Proteins fractions, Process...)
 - Environment (methane, N losses, N efficiency)
 - Health (mastitis, NEB, metabolic troubles...)
 - Diet intake and efficiency
 - Grazing
 - Chronic stress
 - Lipolysis
 - Heat stress
 - ...
- Milk recording
- Genetics



FT-MIR use in dairy farms

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Standardization : possibility to transfer FT-MIR models from instruments to instruments since 2012

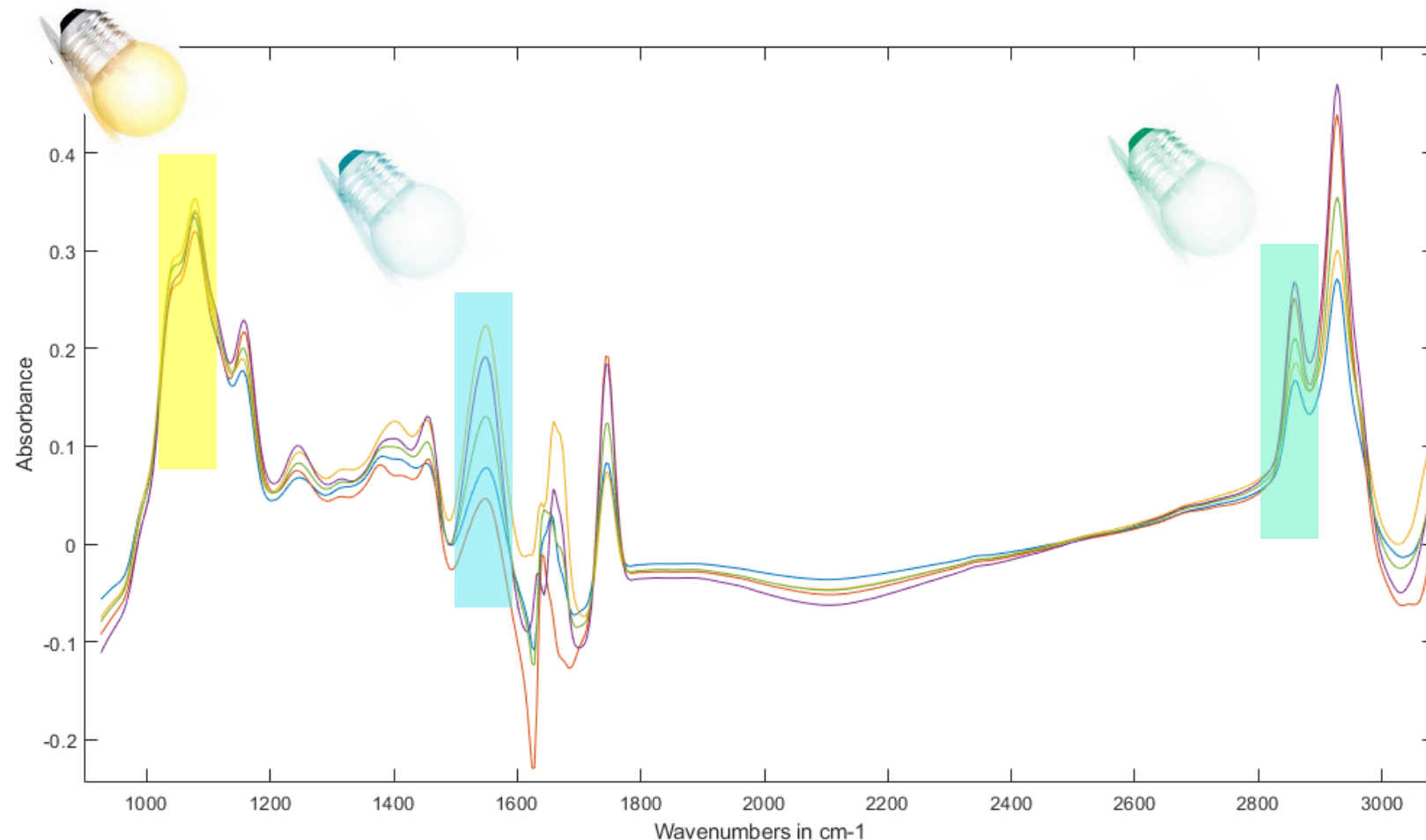


**BUT low frequency,
every 4 to 6 weeks with DHI**

Daily in-farm milk analysis

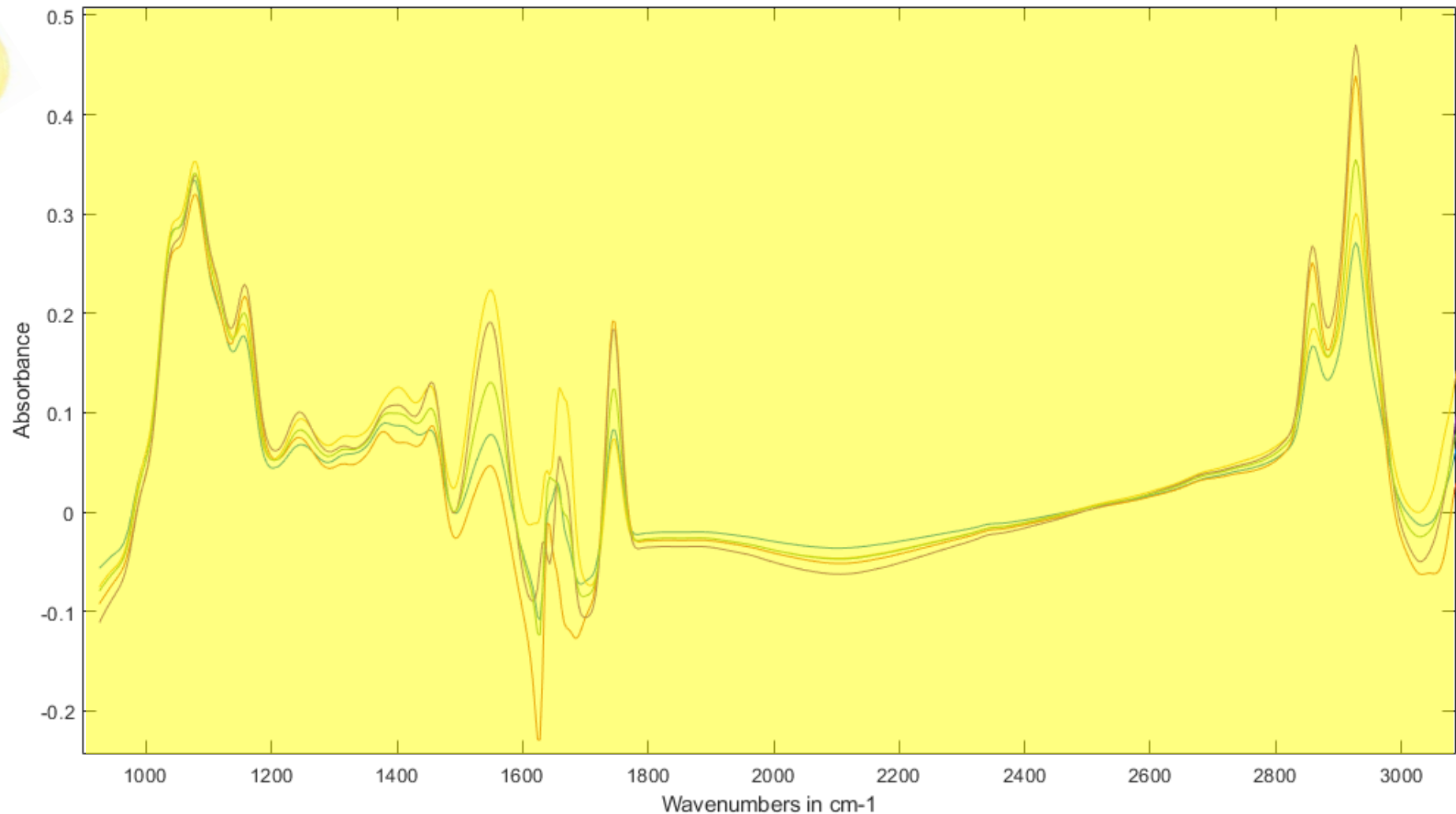
High frequency of measurement (daily) * Individual cow level

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



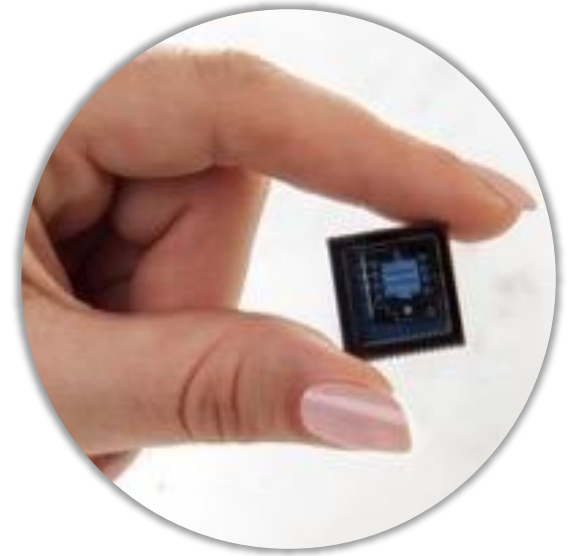
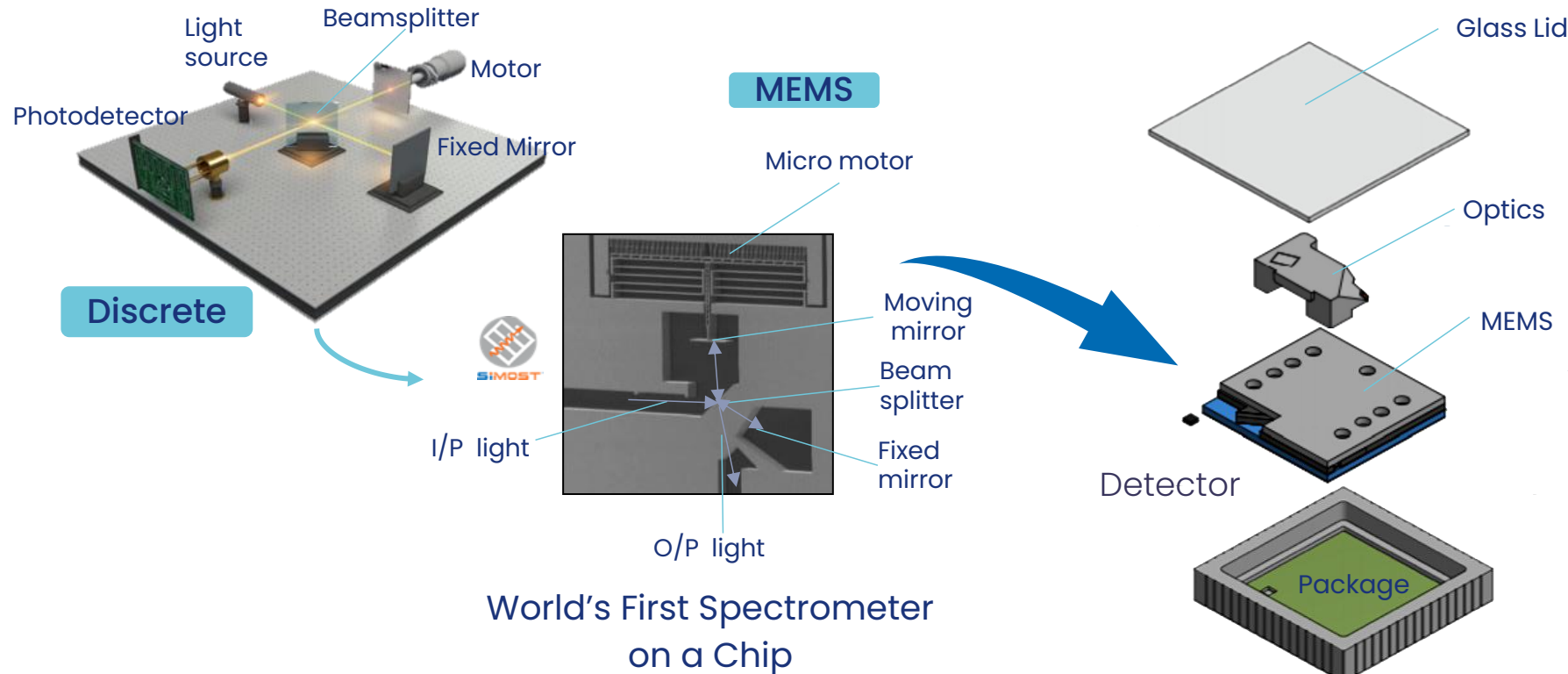
Objective of Bromedir: develop a miniaturized FT-MIR spectrometer for in-farm milk analysis covering the full FT-MIR range

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



Innovative core technology

Miniaturizing spectrometer to unprecedented scale



Advantages

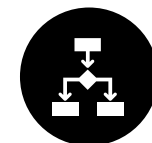
- Low cost scalable technology
- Portable
- Robust
- Lab-grade performance
- Cloud Connectivity
- Online Analytics

SiP System in Package

- MEMS (micro-electromechanical systems)
- Photo-detector
- Optics



Identification

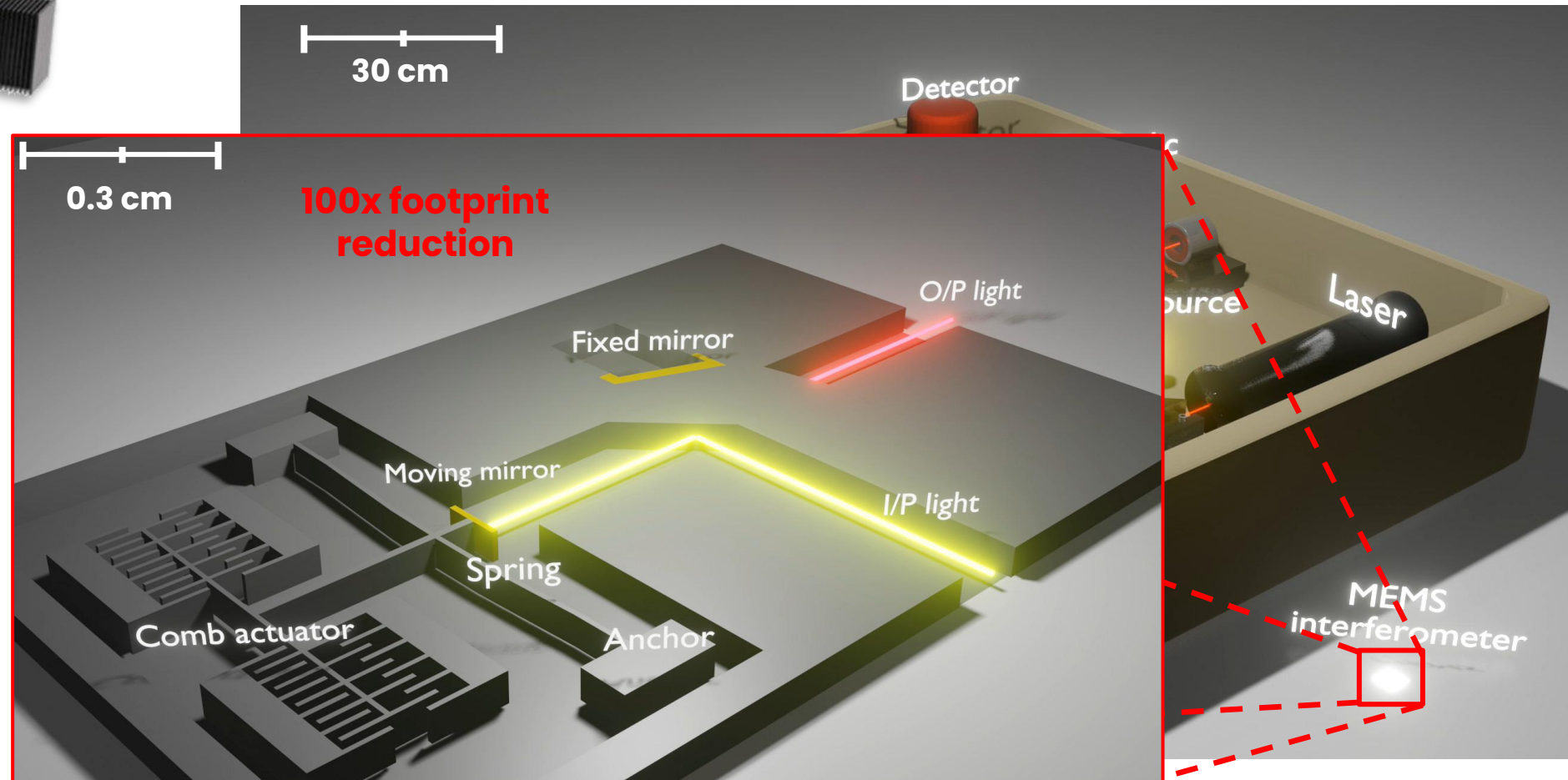
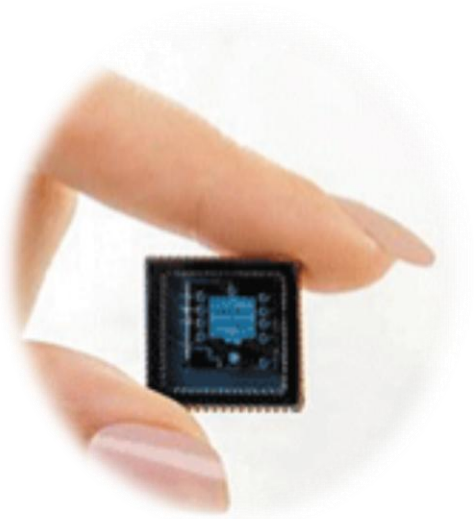


Classification



Quantification

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



WideRange FTIR Spectrometer

Available portable miniaturized spectrometers in market limited to NIR ($< 2.6 \mu\text{m}$)

- ✓ Broadband MEMS FTIR spectrometer
- ✓ **Wide Spectral Range:** 6000 to 1000 cm^{-1} range (Fingerprint Region)
- ✓ Portable platform
- ✓ **Resolution:** 42 / 66 cm^{-1}
- ✓ **SNR** > 5000



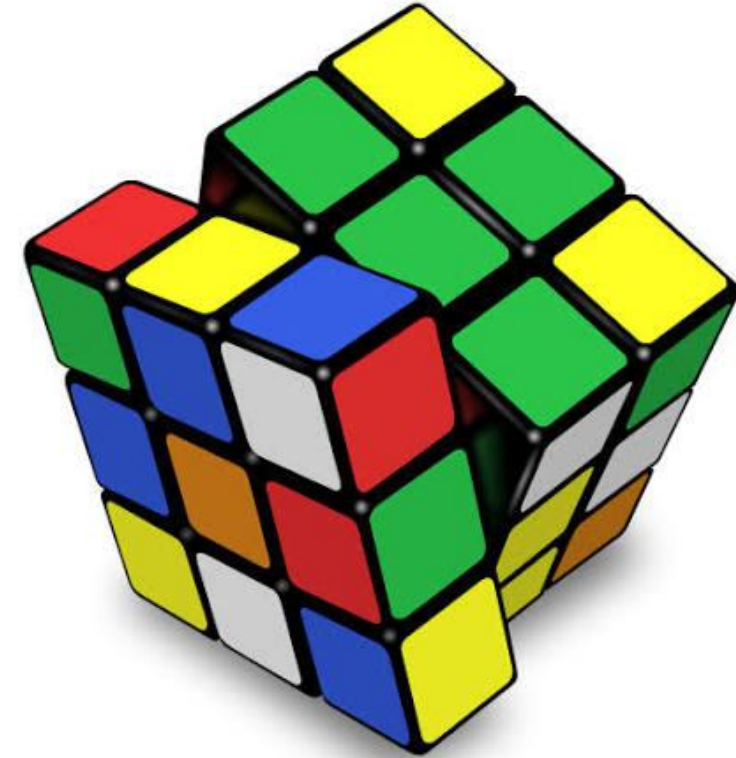
BROMEDIR interferometer & photodetector

- **Size:** 11.6 X 11.8 X 11.5 cm
- **Weight:** ~ 1 kg

After 2 years of development

- Optimization of the detector (cooled vs uncooled)
- Optimization of the interferometer
- Test of several
 - thermal light sources
 - LEDs (cheaper light sources)
 - cell materials
- Optimizing the combination of elements
- Optimization of settings (resolution, apodization...)

→ objective: improve the signal to noise ratio



Milk is injected using
automated syringe pump

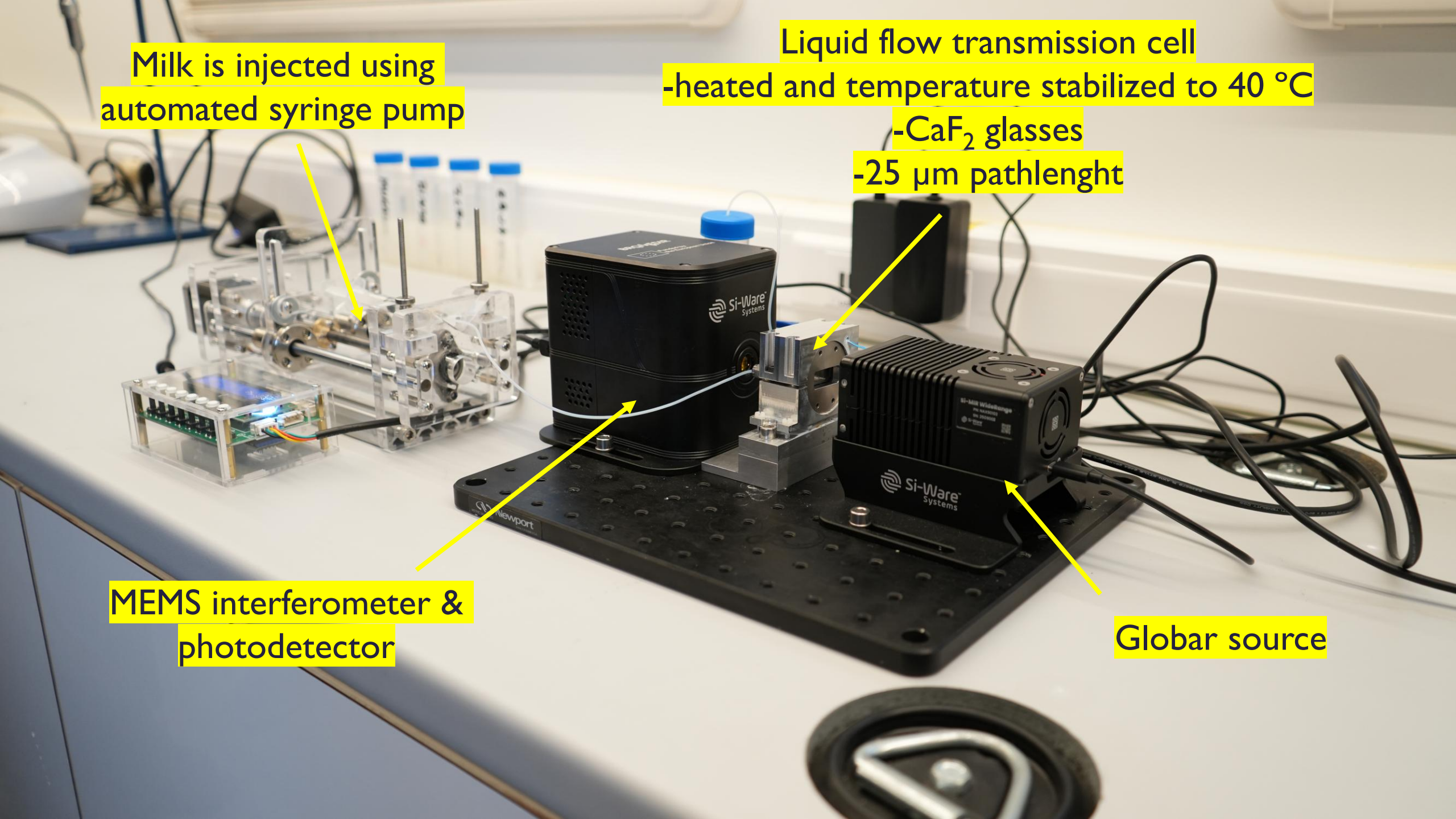
Liquid flow transmission cell
-heated and temperature stabilized to 40 °C

-CaF₂ glasses

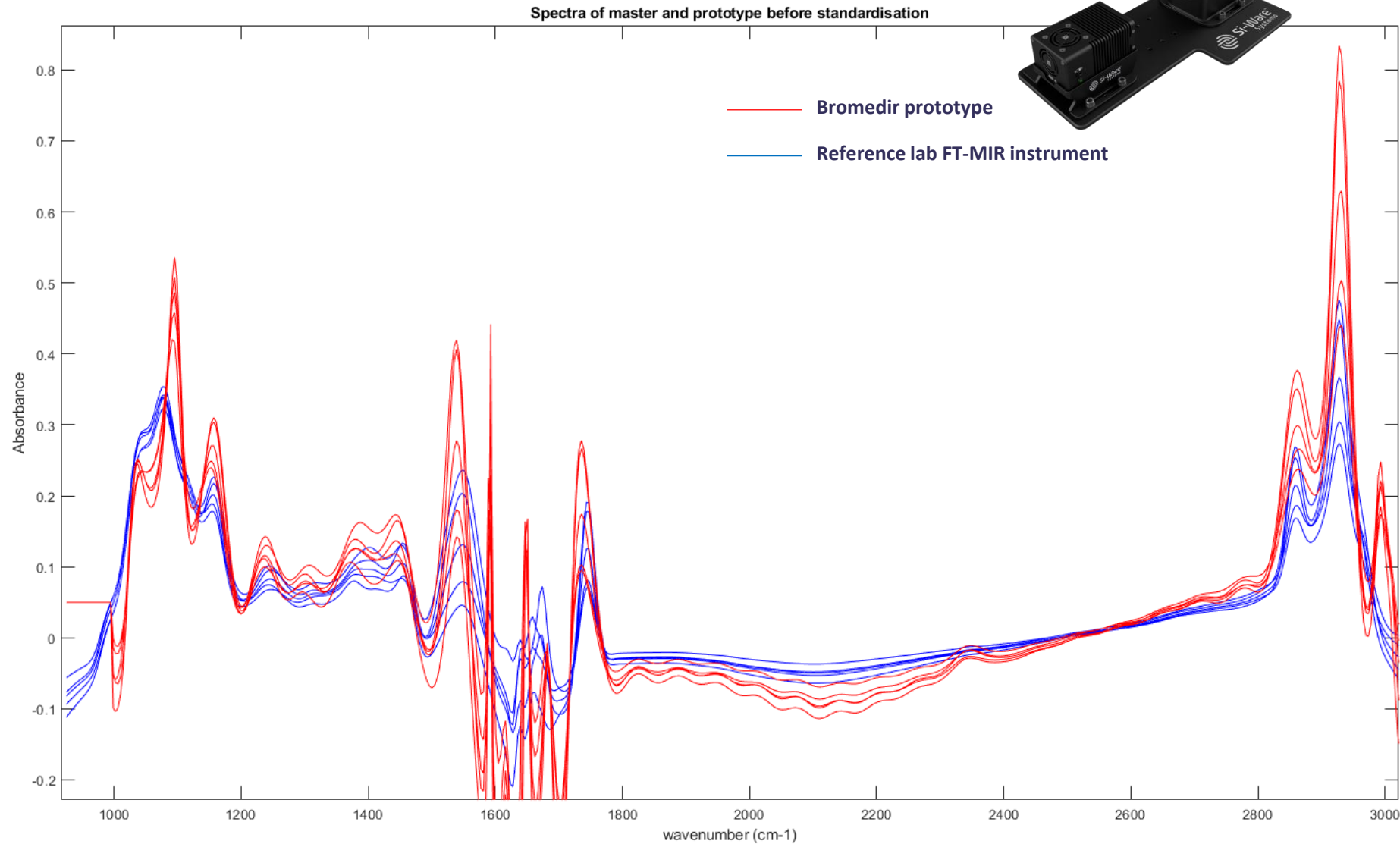
-25 μm pathlength

MEMS interferometer &
photodetector

Globar source

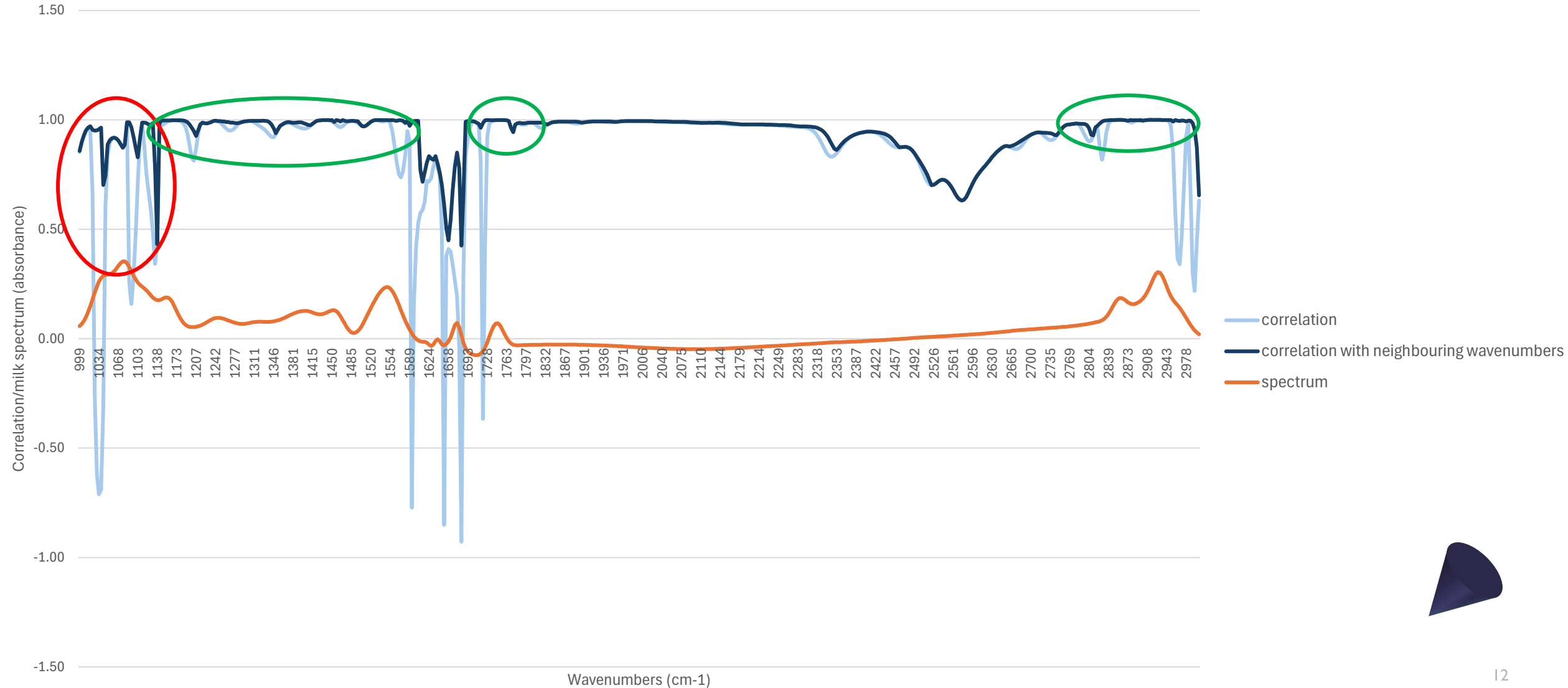


After 2 years of development

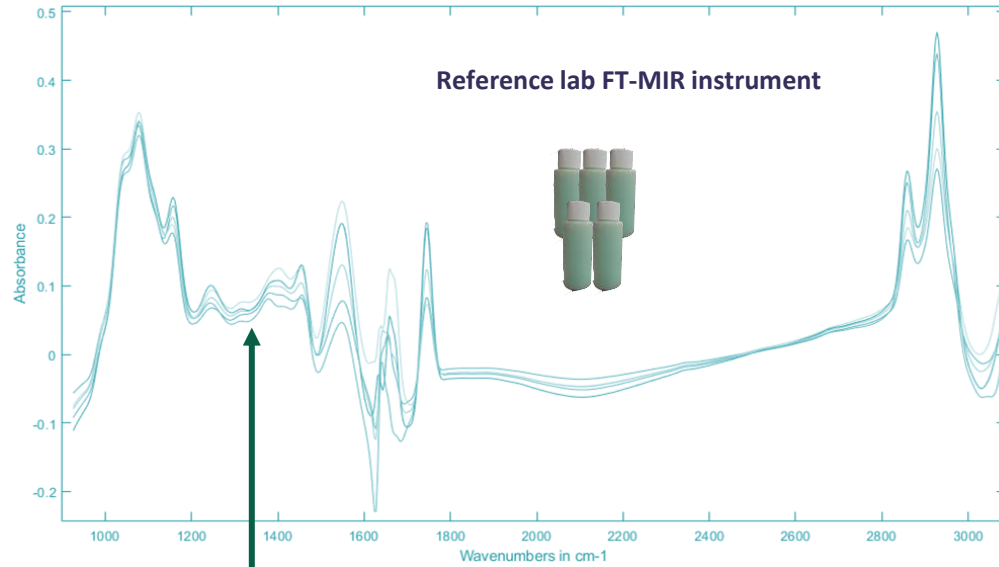


Similar information to reference lab instrument?

Correlation between Prototype and Reference lab instrument absorbances

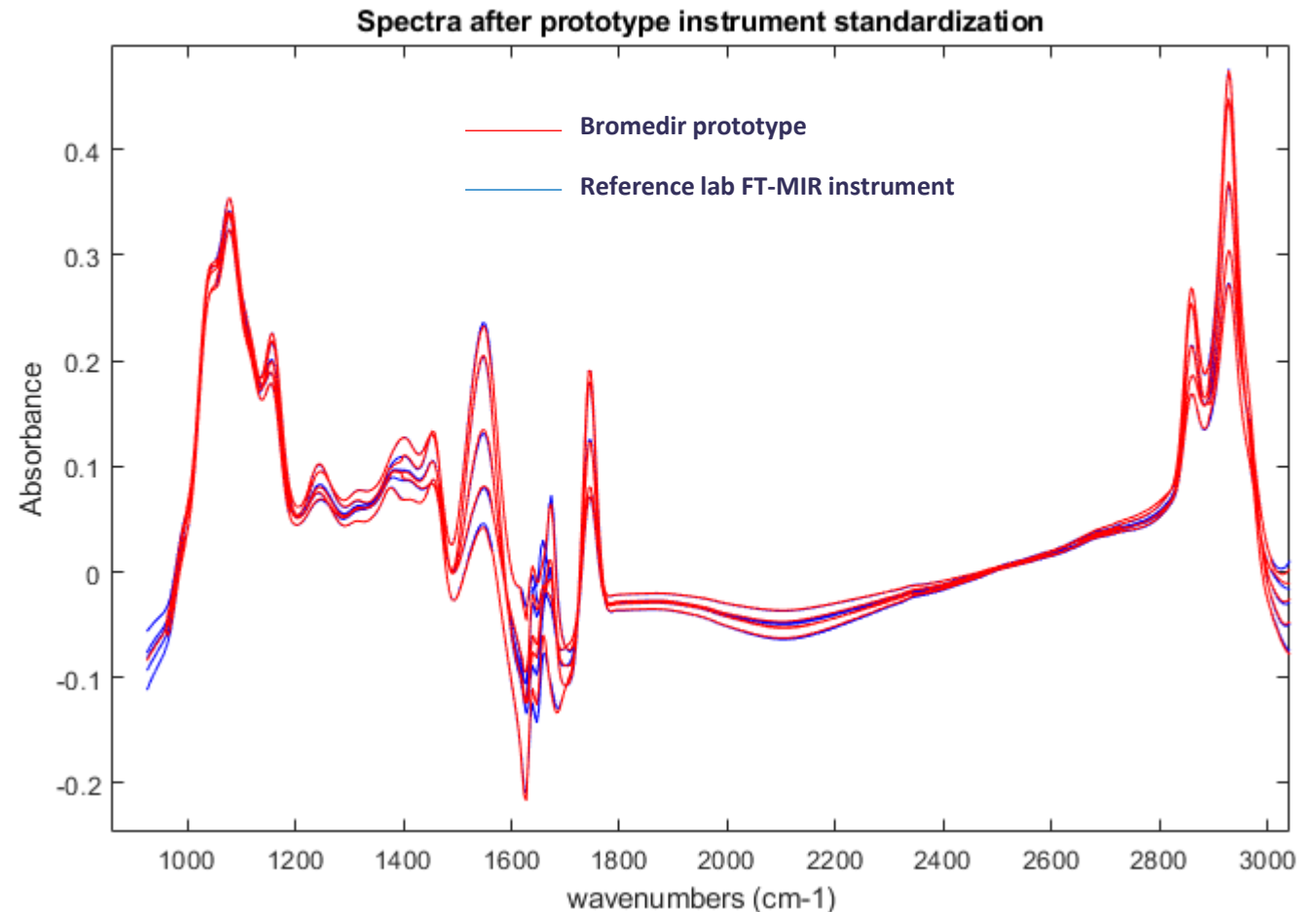
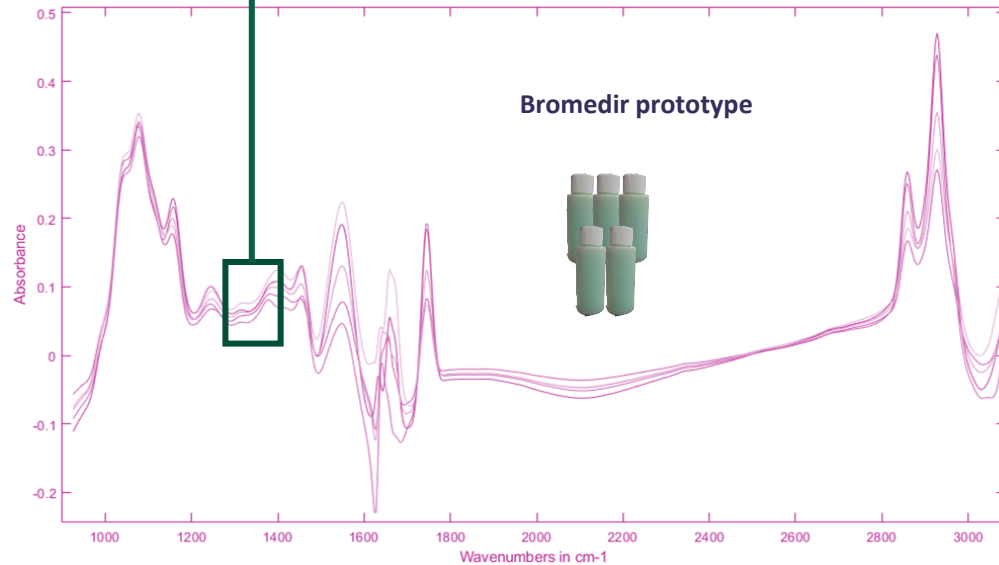


Transfer of existing models on the prototype?



Standardisation of the prototype to a reference lab instrument

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

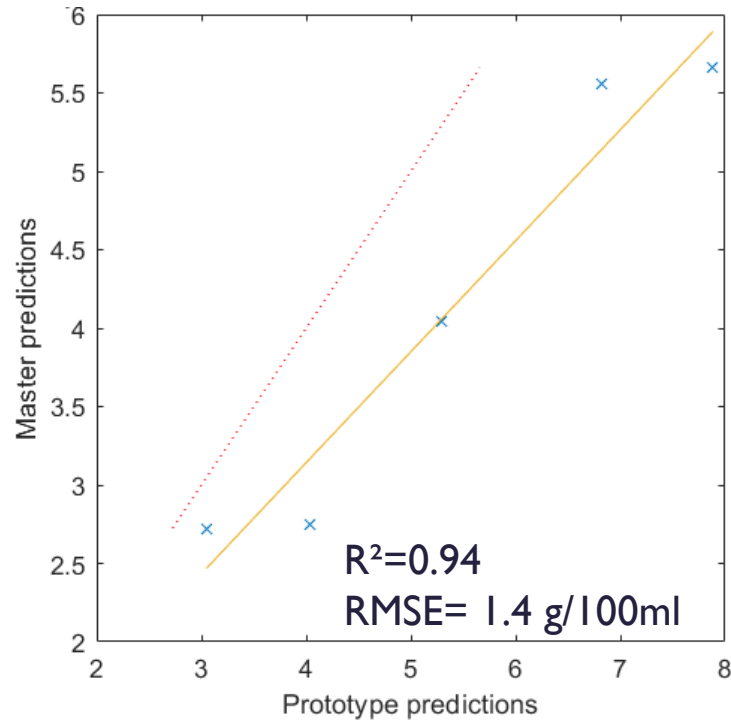


Transfer of a 'own made' **Fat** model

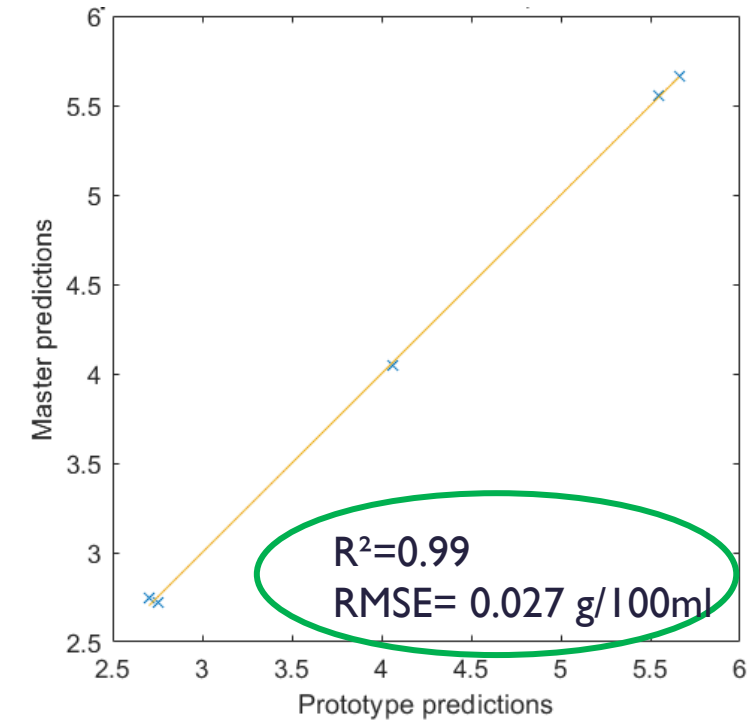


Standardization of Prototype to a Reference Lab instrument (Master)

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



Fat (without standardization)



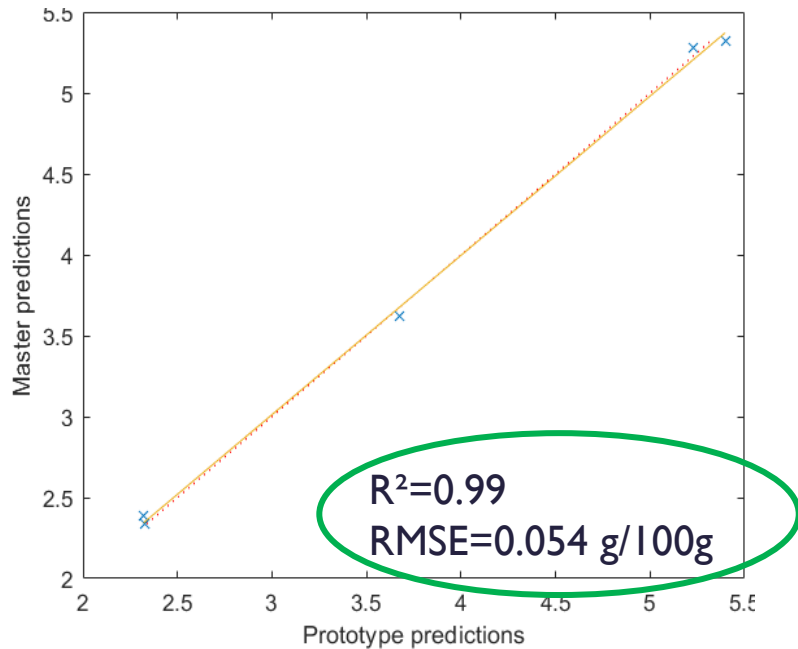
Fat (with standardization)

Transfer of a 'own made' models

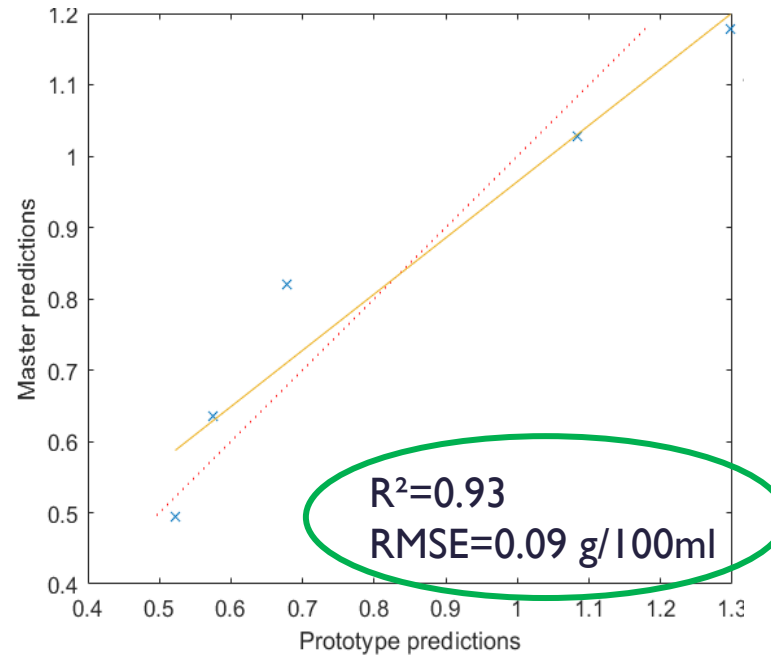


Successful transfer of **Fat**, **Protein** & **Oleic Acid (C18:1c9)**

✓ Achieving high R^2 and low RMSE error

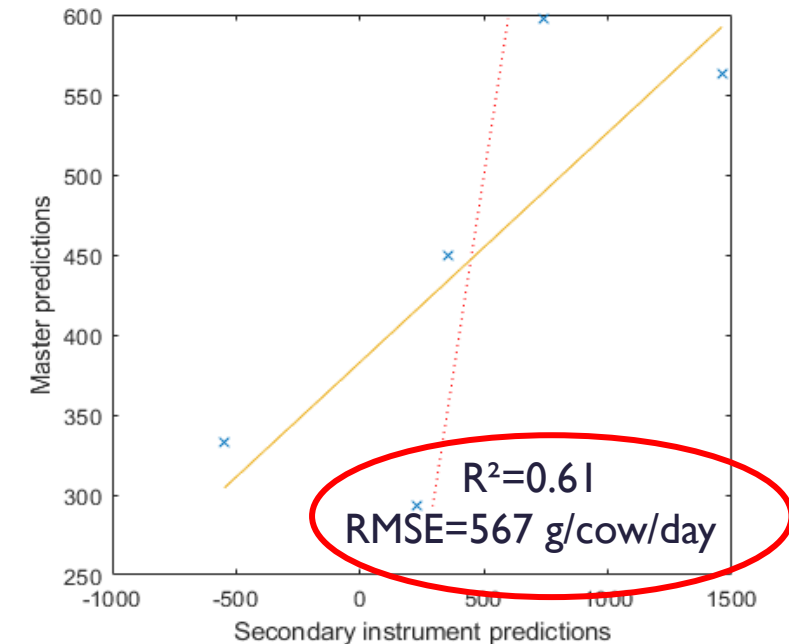


Crude proteins (g/100g)
with standardization



Oleic Acid (g/100ml)
with standardization

Failing for **Methane emissions**



Methane emissions
(g/cow/day)
with standardization

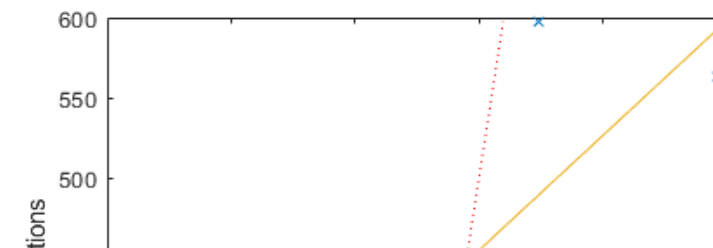
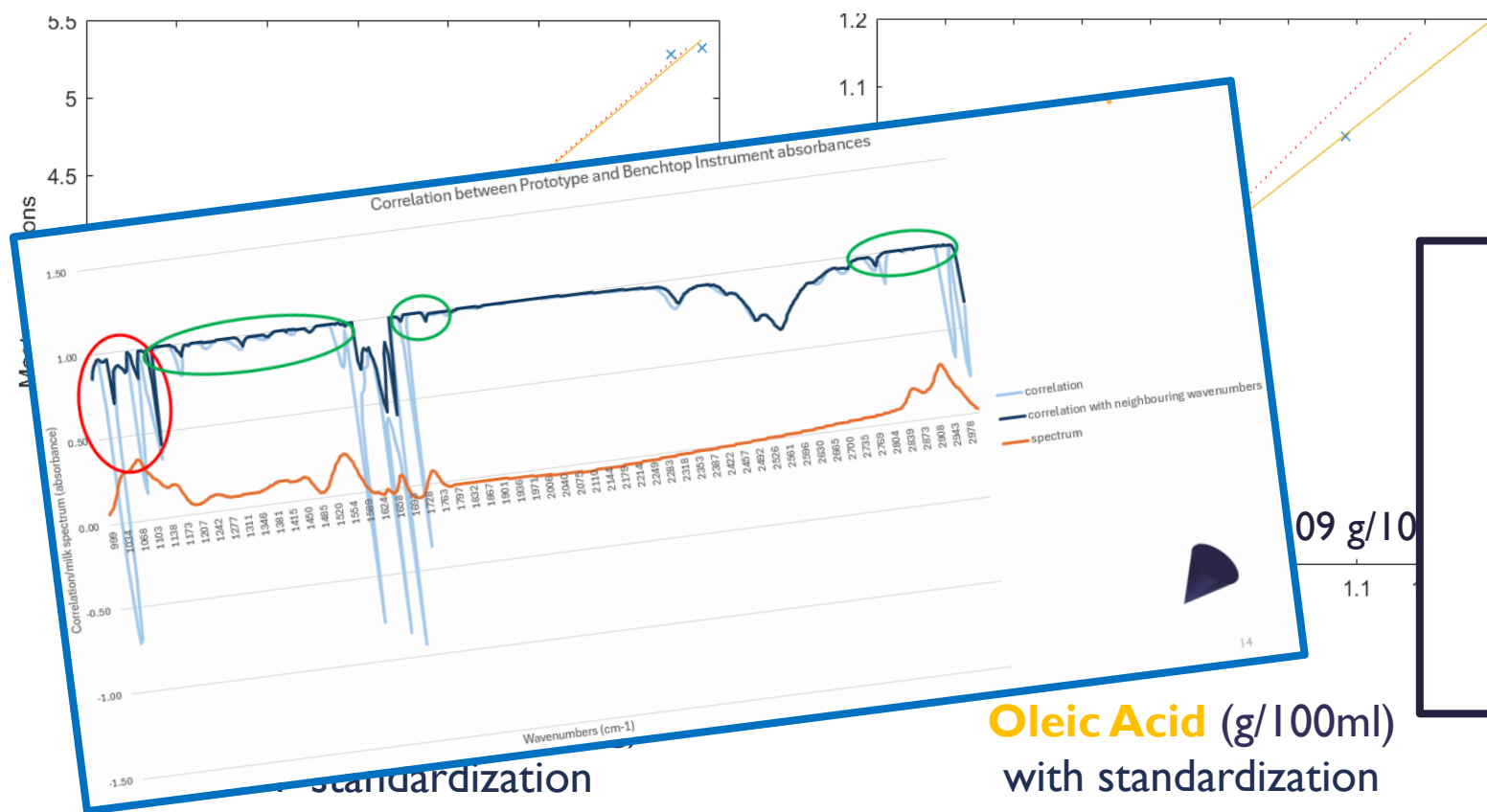
Transfer of a 'own made' models



Successful transfer of **Fat**, **Protein** & **Oleic Acid (C18:1c9)**

✓ Achieving high R^2 and low RMSE error

Failing for **Methane emissions**



Still work to do on the hardware → improving the signal

To 'shorten' the models with less wavenumbers?

To improve transfer methodology

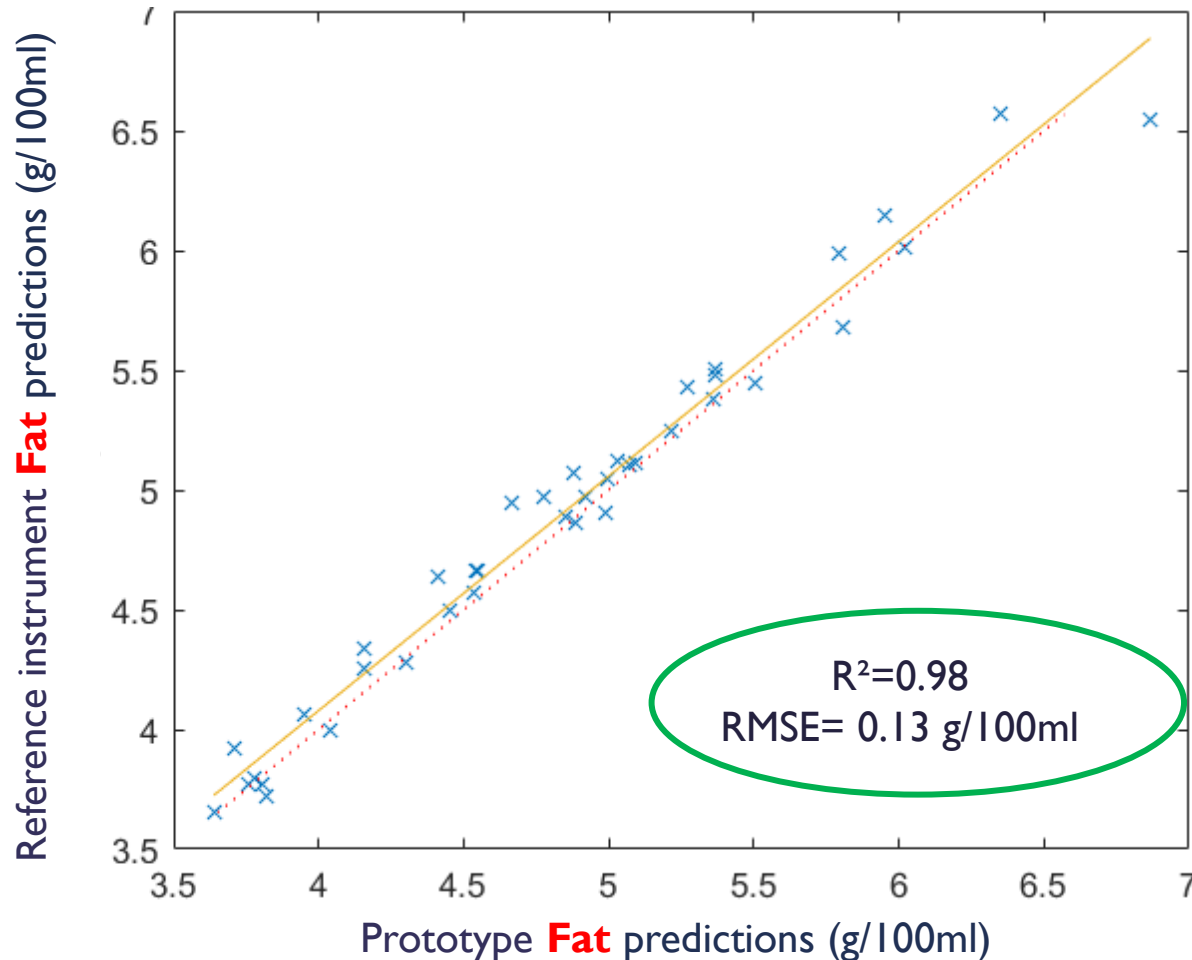
(g/cow/day)
with standardization

Validation



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

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



*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

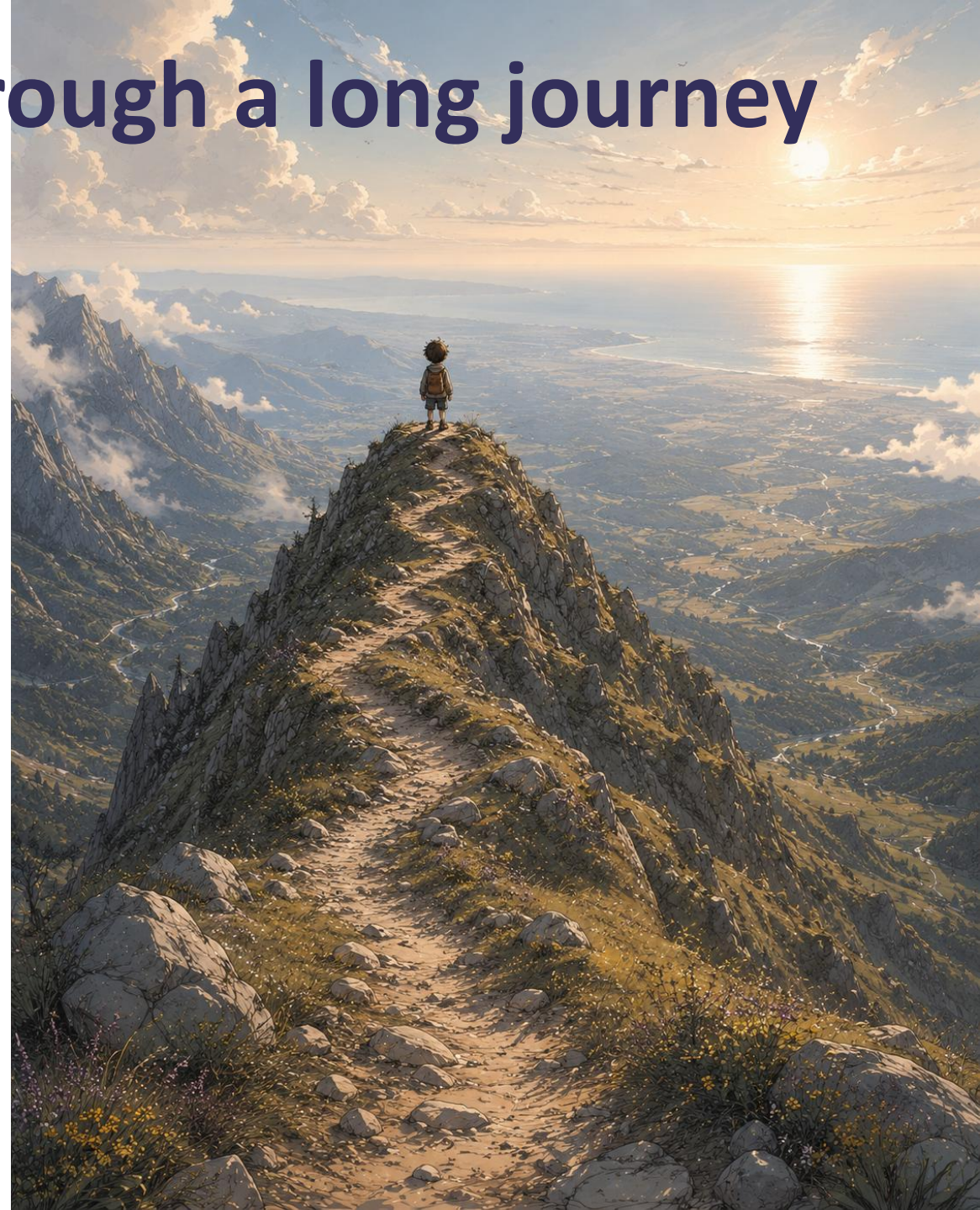
Accuracy of prototype & transferred models can reach ICAR thresholds

Still work to do

Signal and stability to be optimized

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

Transfer of model to be improved





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Thank You!

For more information, please contact:

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Website: <https://bromedir.eu/>

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