Terahertz Based Automated Food Analysis

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THz spectroscopy: basic facts

- Terahertz spectral range: usually defined form 0.1 THz up to 10 THz
- Crystalline phonon vibrations, hydrogen bonding stretches and torsions, and low-frequency bond vibrations within this range
- Non-ionising radiation: THz photon energy ~0.41÷41 meV: 100-10000 times below the ionising level

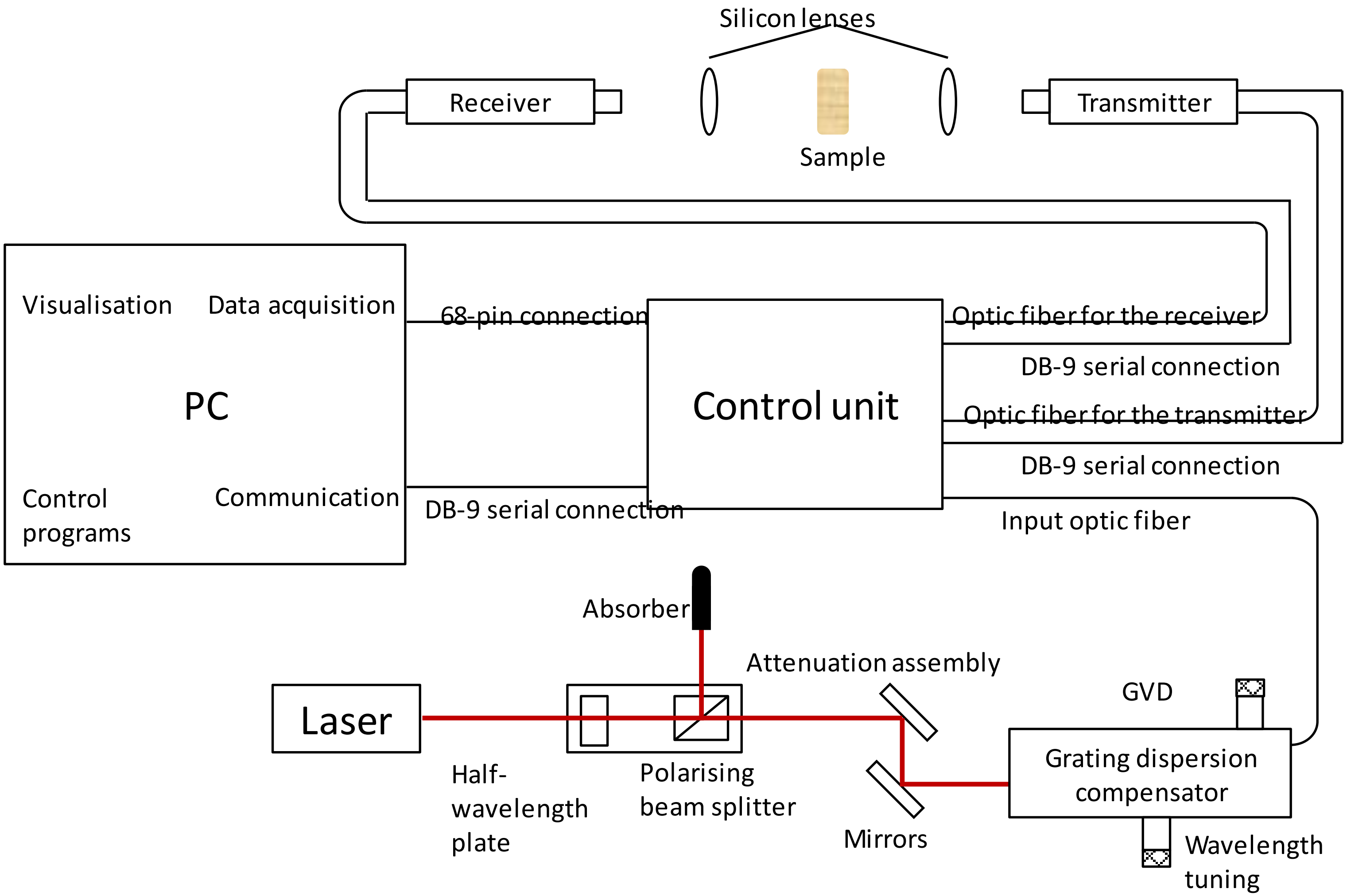
THz spectroscopy modes

- Time-domain spectroscopy (THz-TDS)
- Frequency-domain spectroscopy (THz-FDS)

Investigated foods

- Edible oils
- Sugars, proteins and salts

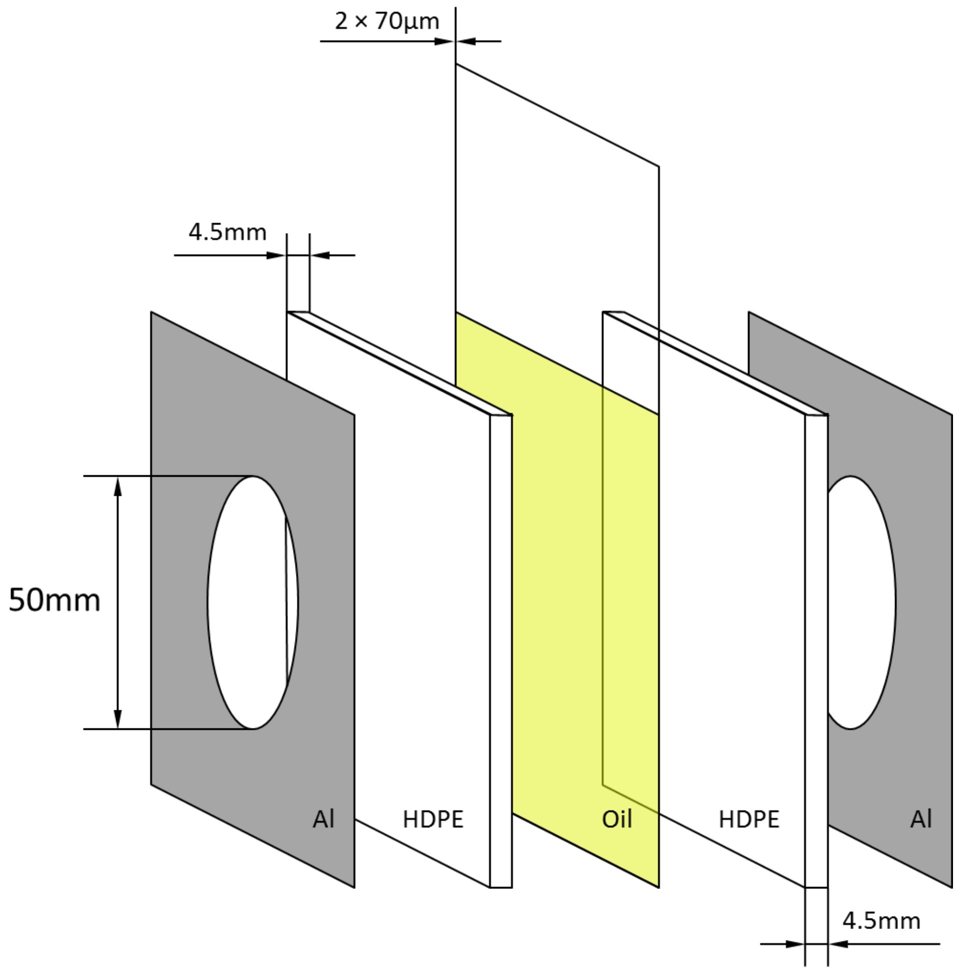
THz TDS experimental setup

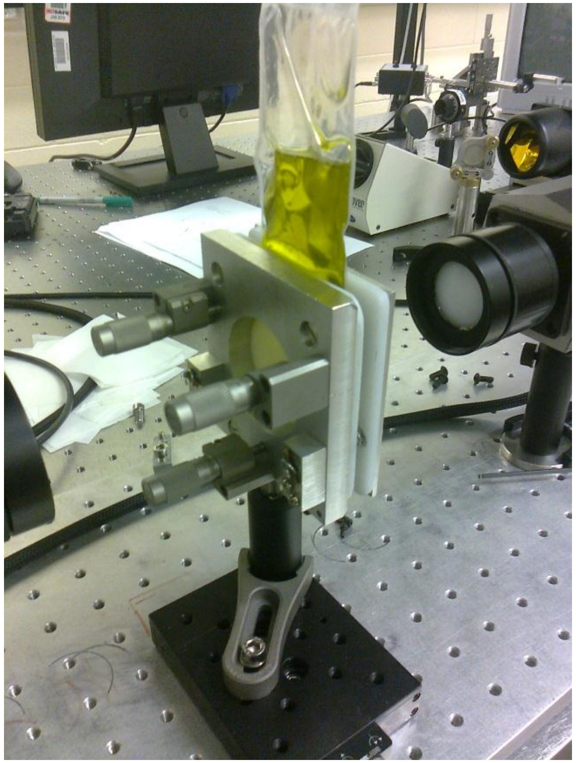


Hardware for oil investigation

- Picometrix system with Mai Tai laser
- Collimated THz beam
- HDPE-based sample holder
- LDPE bags for the oil
- Room temperature with humid atmosphere
- Room temperature with nitrogen atmosphere

The sample holder





Experiments with oils

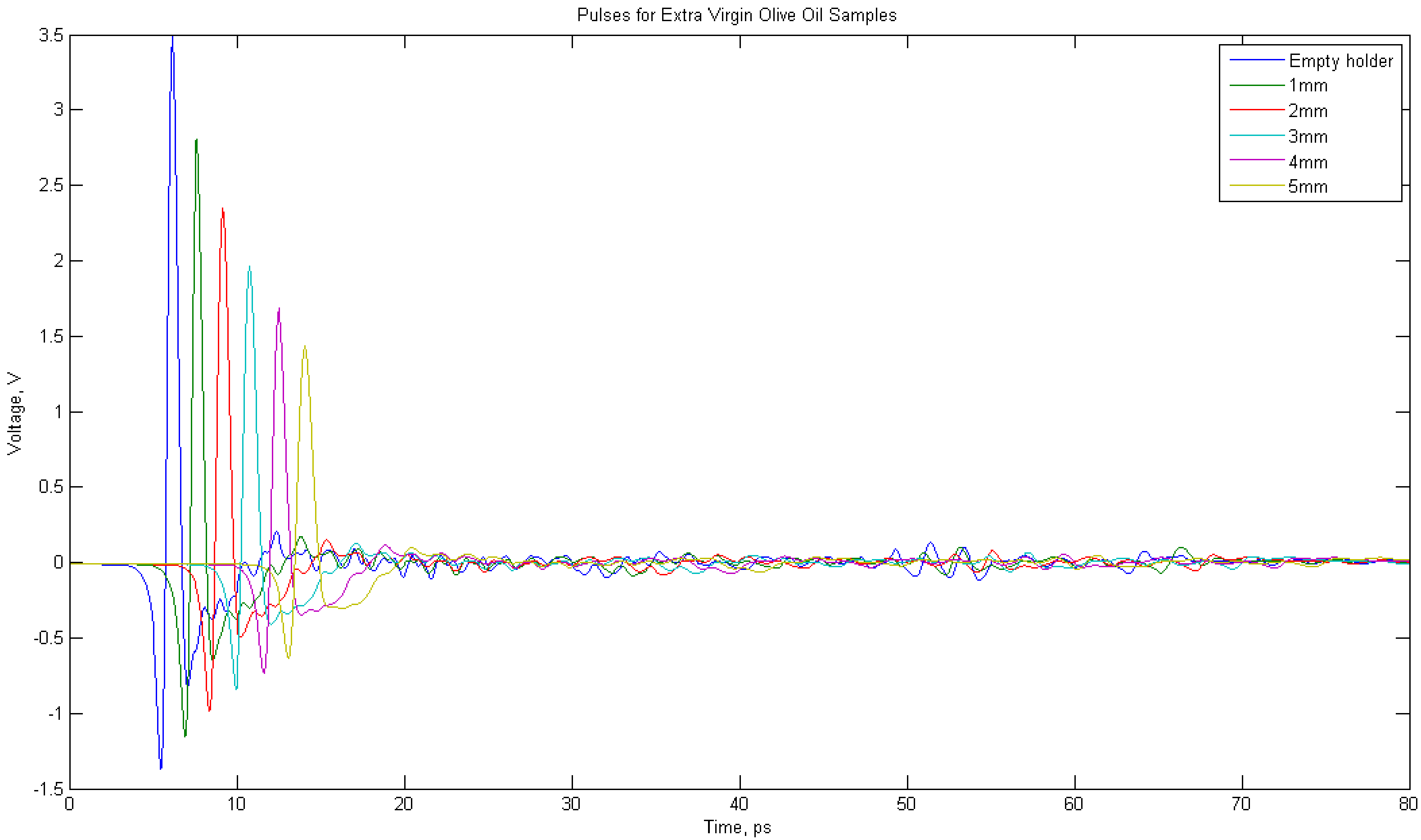
- Prolonged heating (1 hour) up to 180^{o}C
- Repeated cooking above the smoke point
- Cooling down to room temperature
- Averaging over 1000 scans
- Sample thickness of 1, 2, 3, 4 and 5 mm
- Reference signal with sample holder at 0mm
- Reference signals with nitrogen filled bags

Results

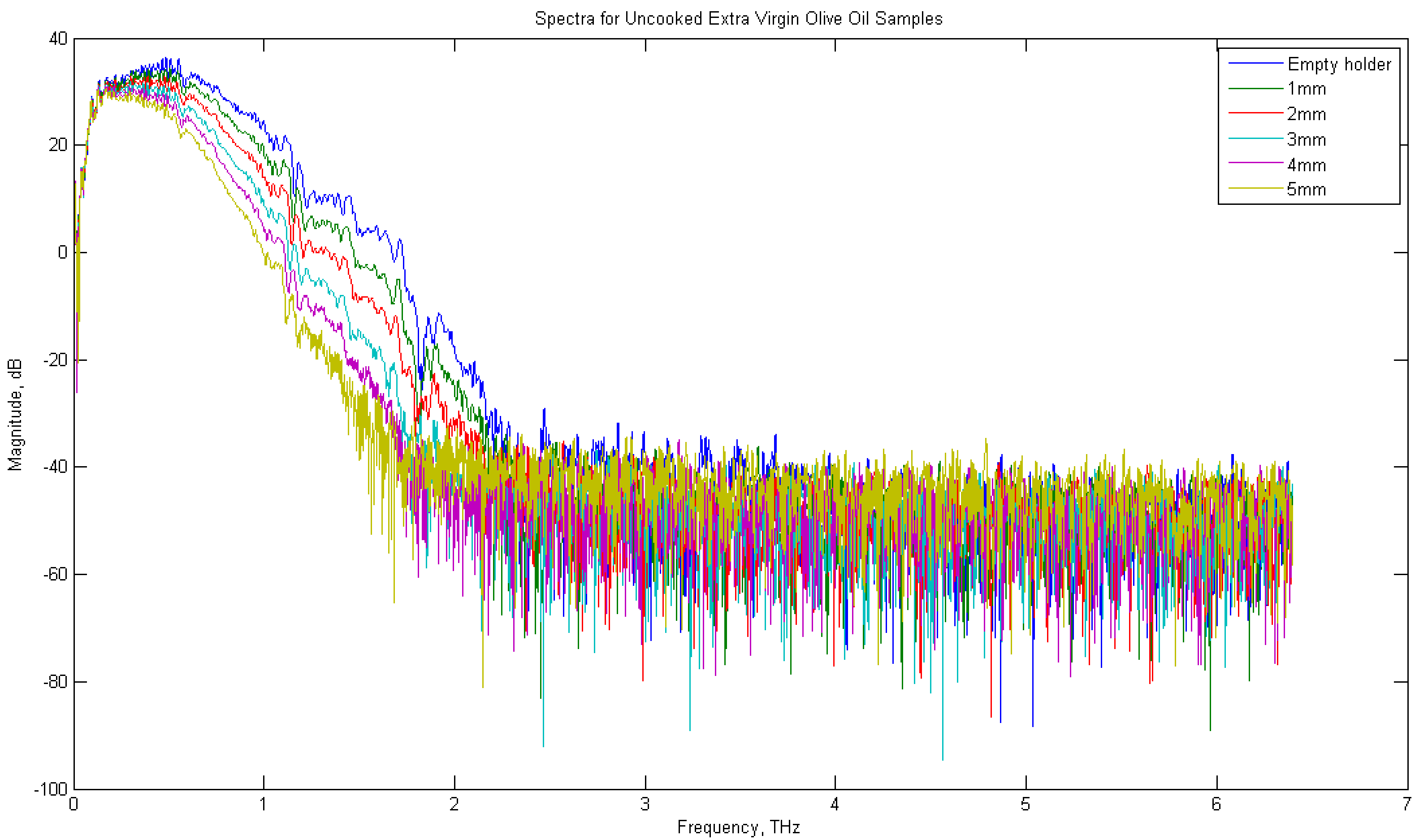
- In the 0-2 THz spectrum, the different edible oils are practically indistinguishable as reported in other literature sources

- Thickness considerations

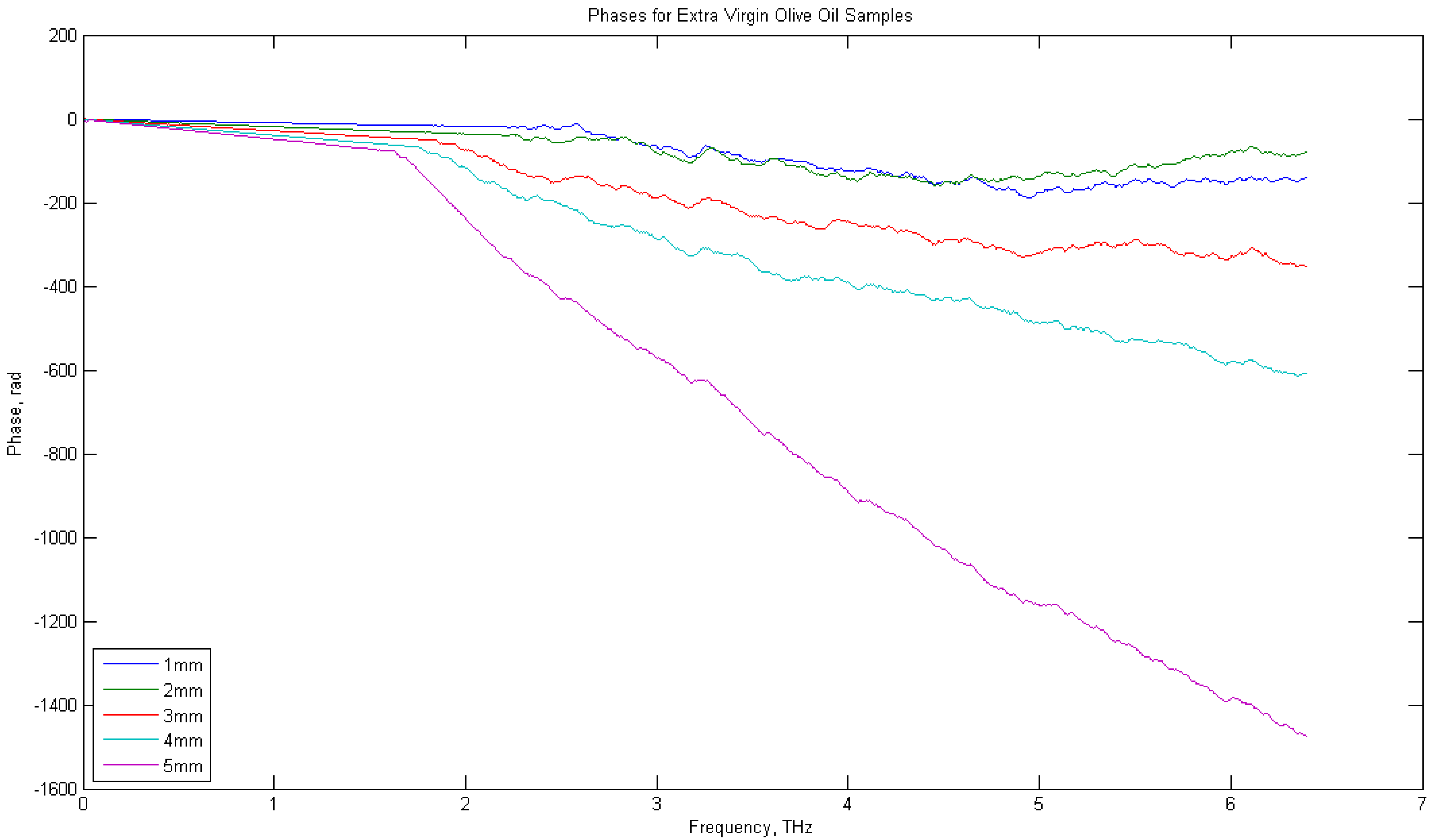
Extra Virgin Olive Oil, humid air



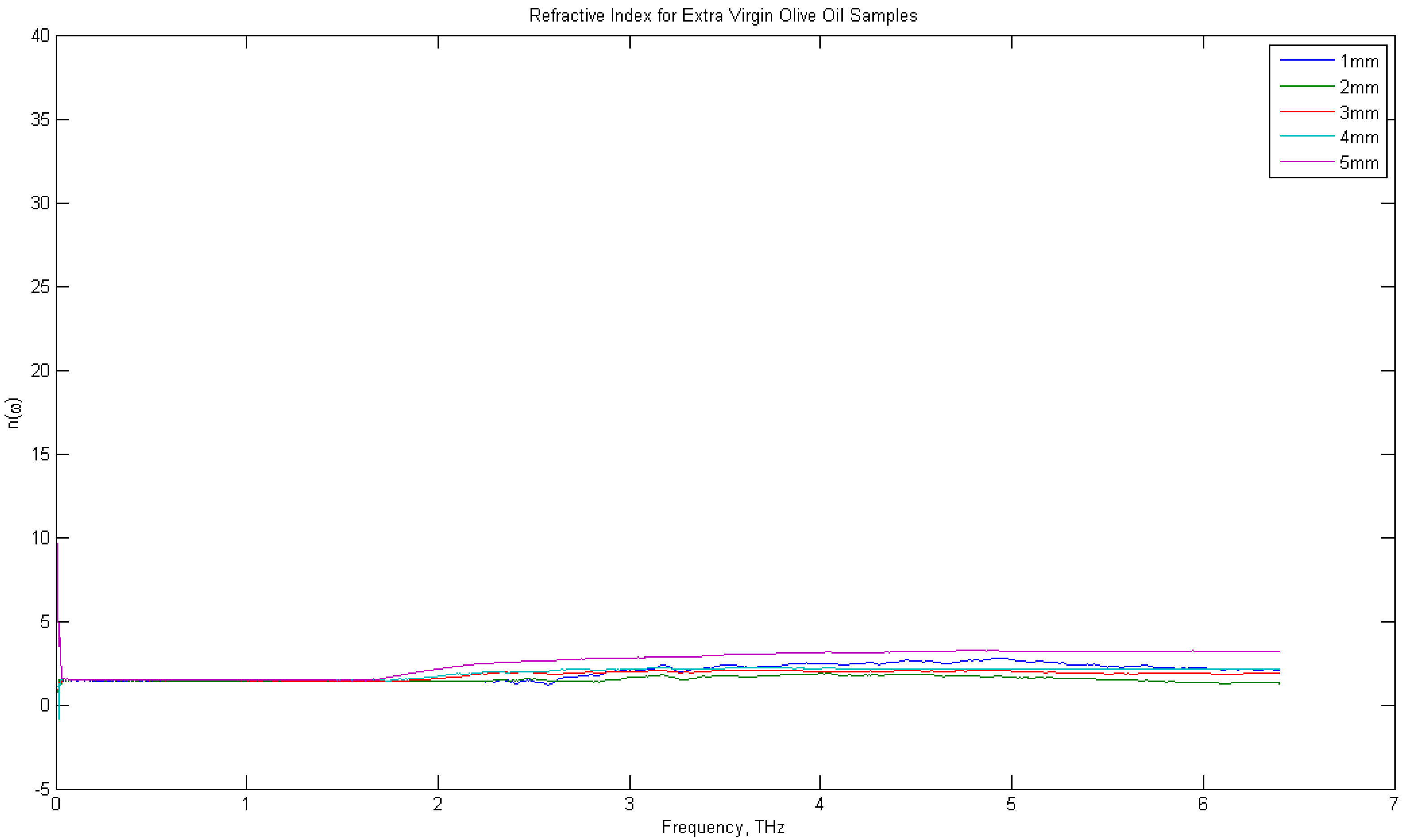
Extra Virgin Olive Oil, humid air



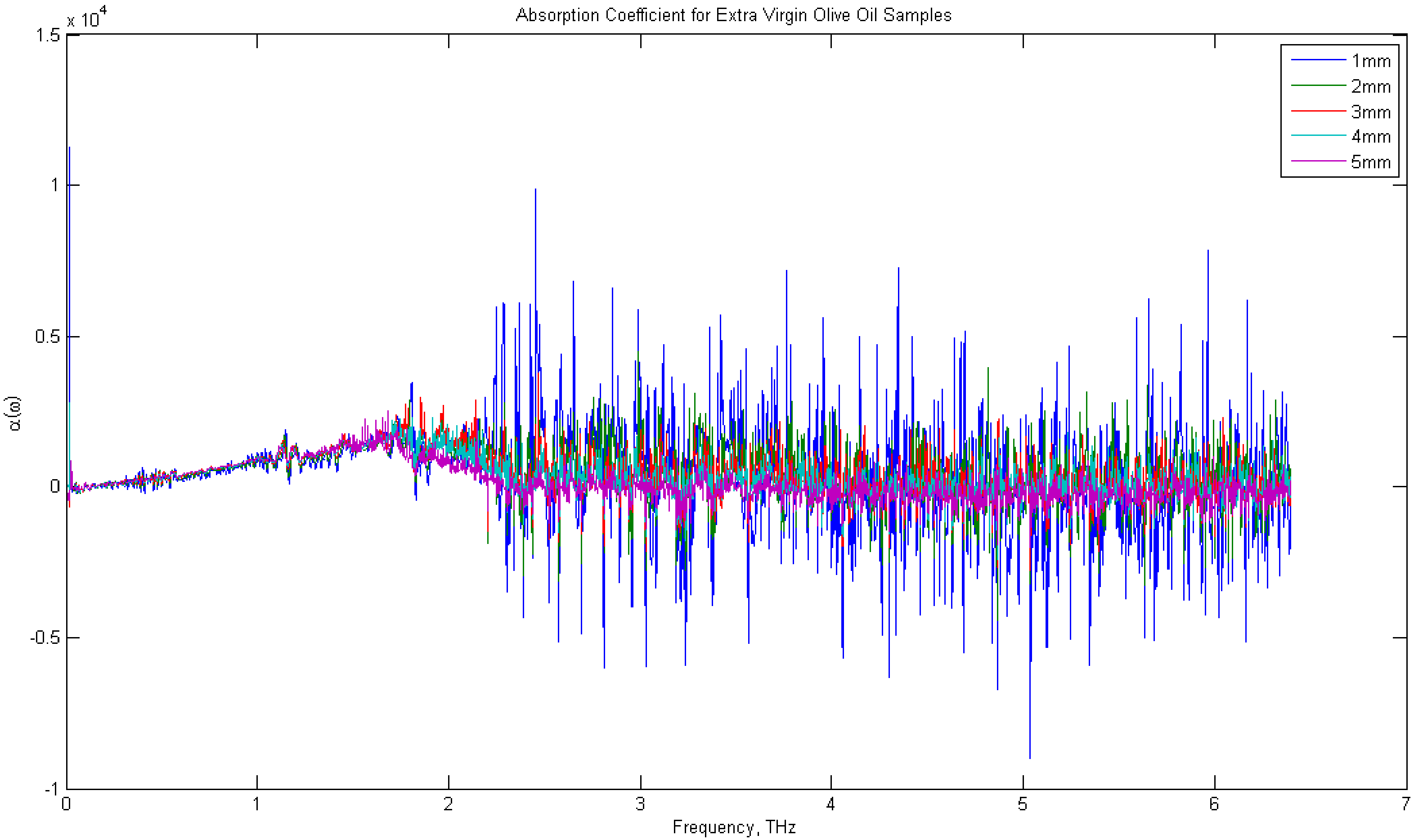
Extra Virgin Olive Oil, humid air



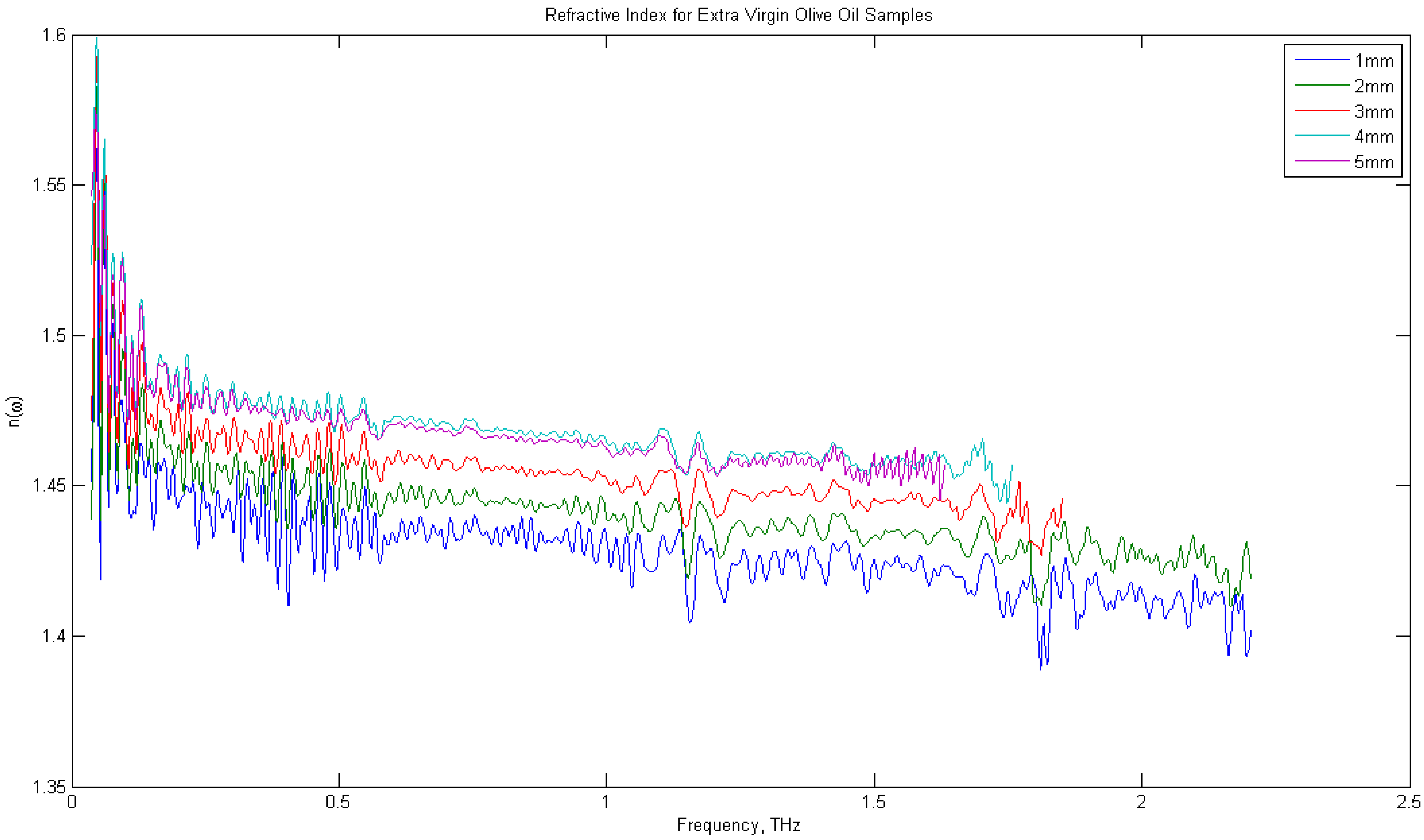
Extra Virgin Olive Oil, humid air



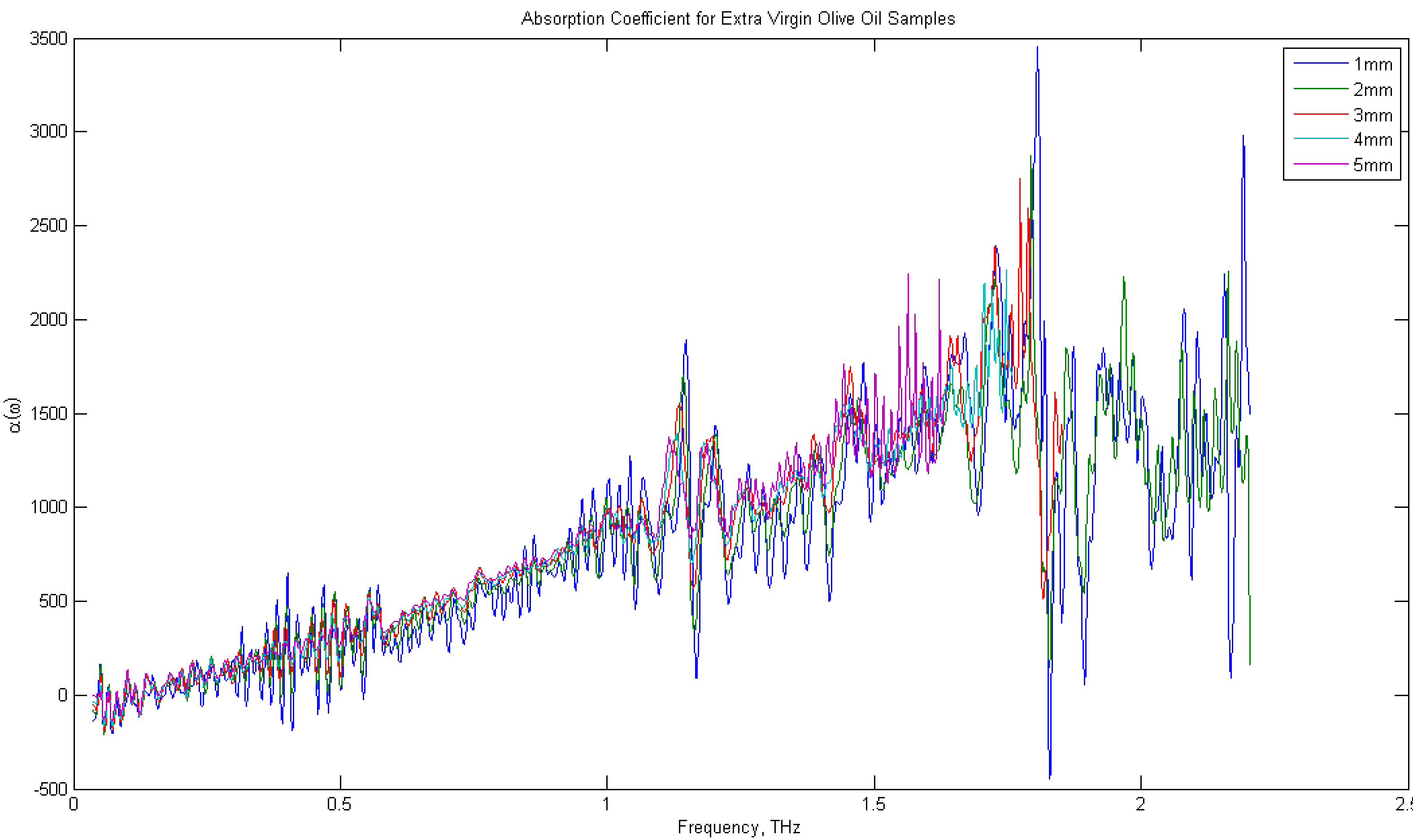
Extra Virgin Olive Oil, humid air



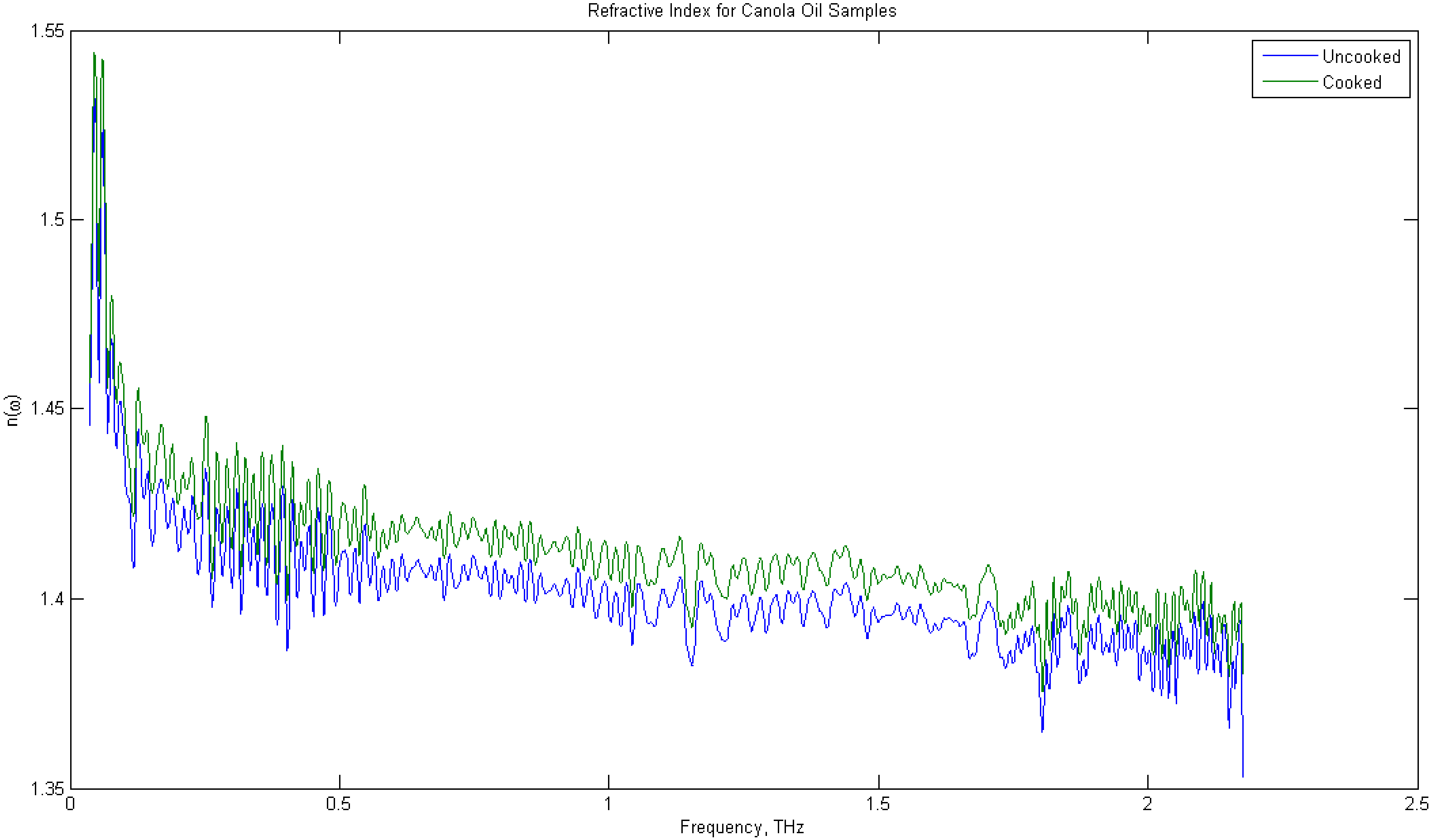
Extra Virgin Olive Oil, humid air



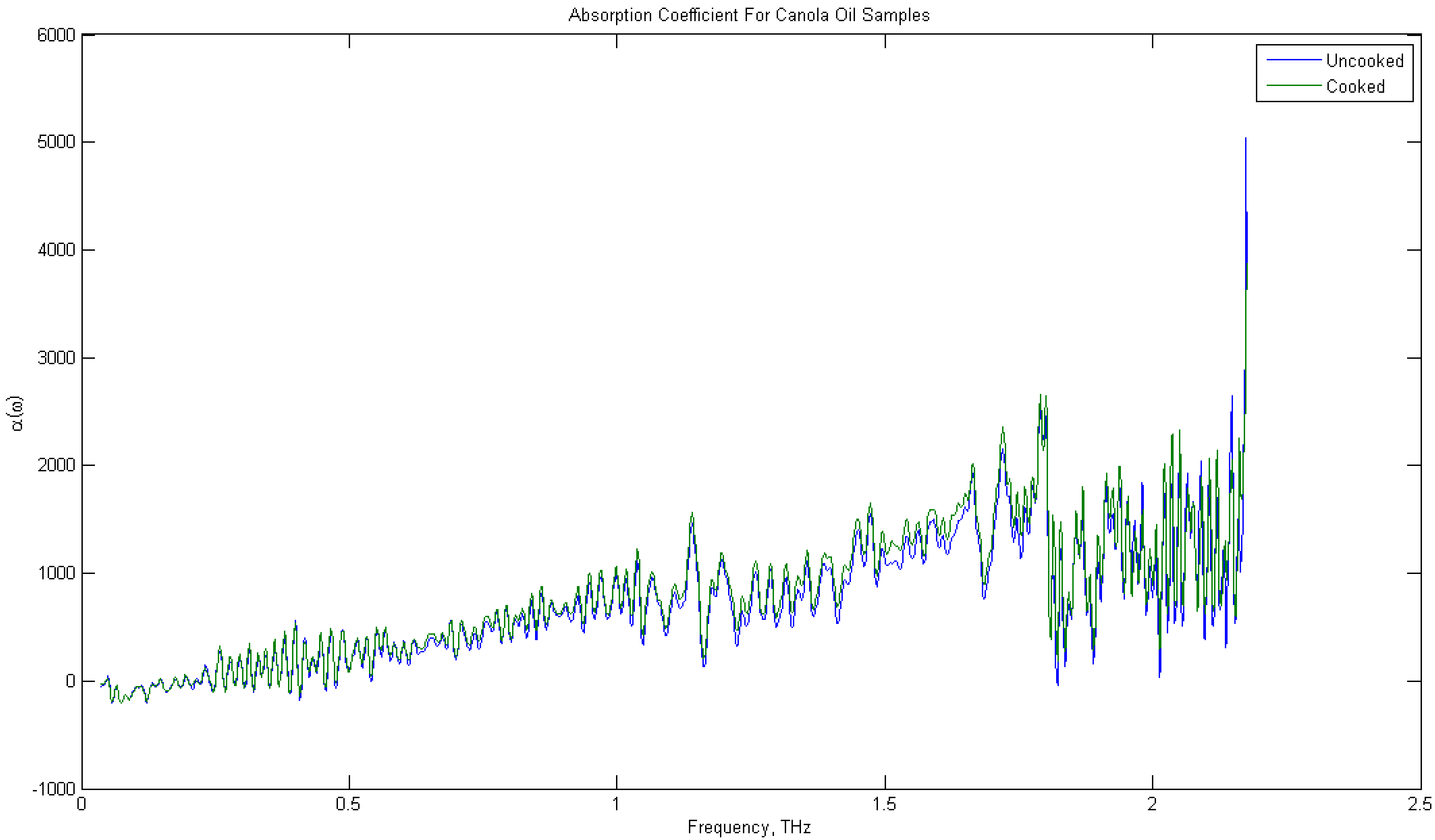
Extra Virgin Olive Oil, humid air



Rapeseed oil, smoke point



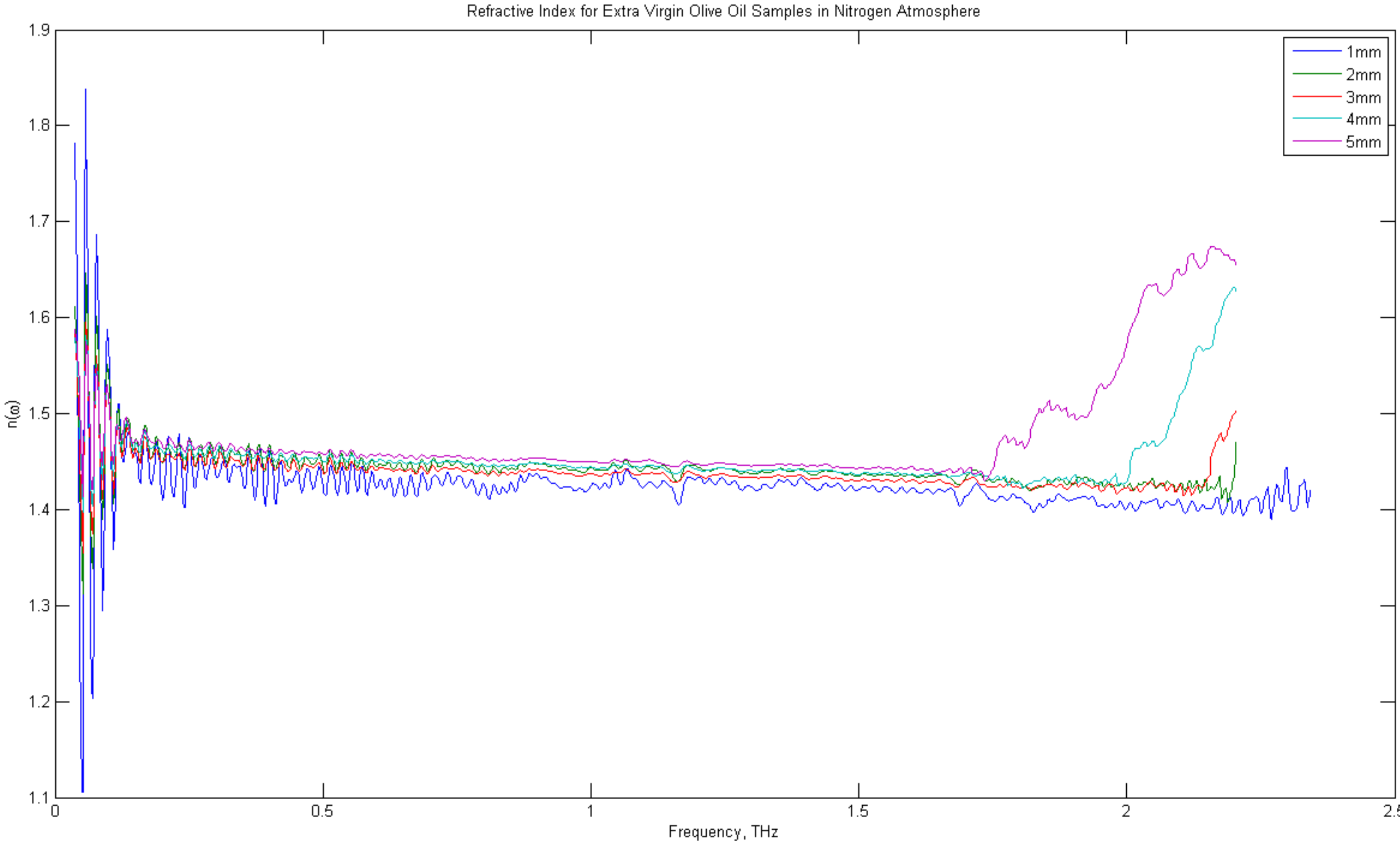
Rapeseed oil, smoke point



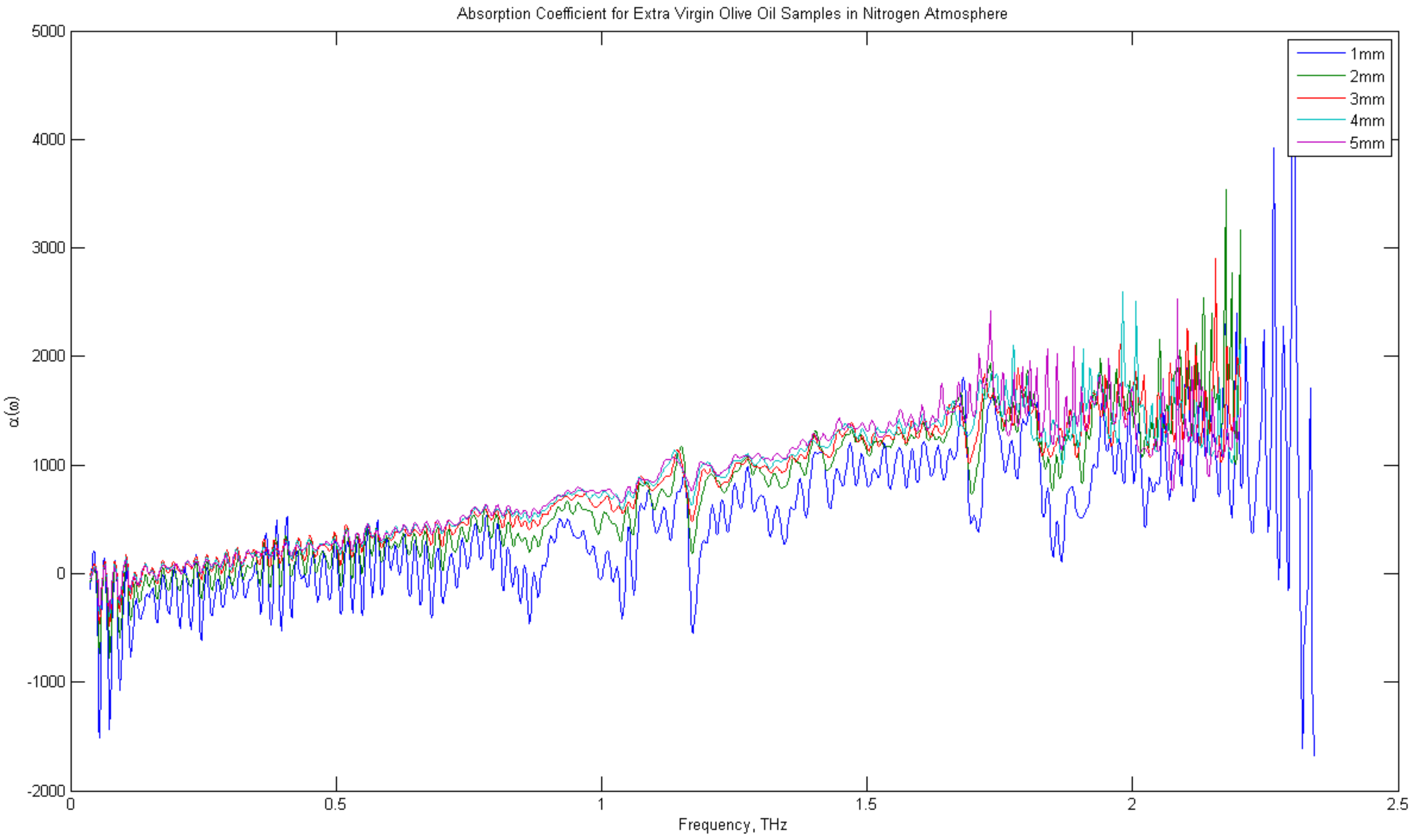
Observations

- The absorption and refraction slightly increase after cooking (experimentally repeatable)
- The are many artifacts caused by Fabry-Perót reflections and water molecules in the air
- Additional signal processing and a “clean air” needed, e.g. nitrogen saturated air

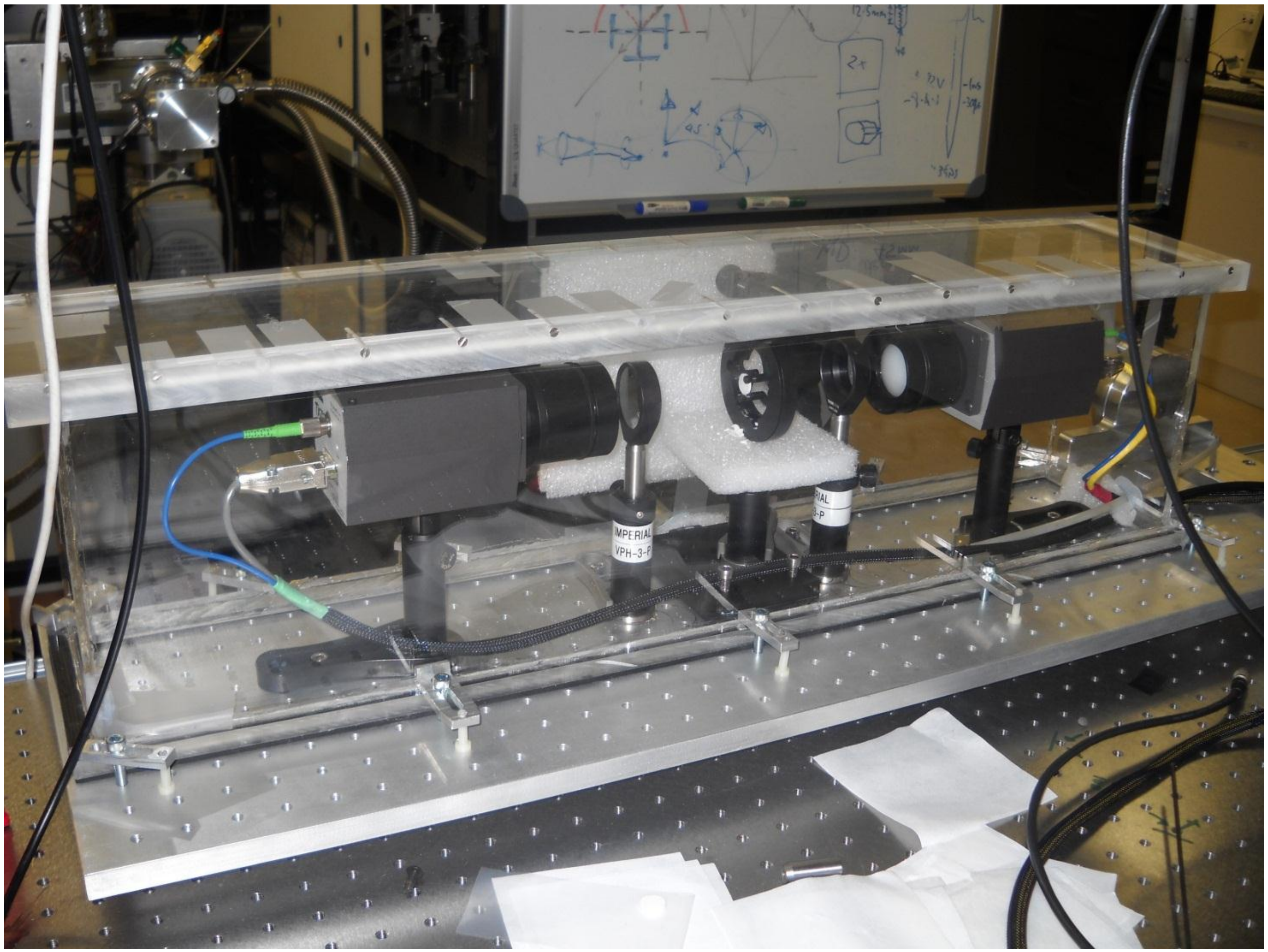
Extra Virgin Olive Oil, Nitrogen air



Extra Virgin Olive Oil, Nitrogen air



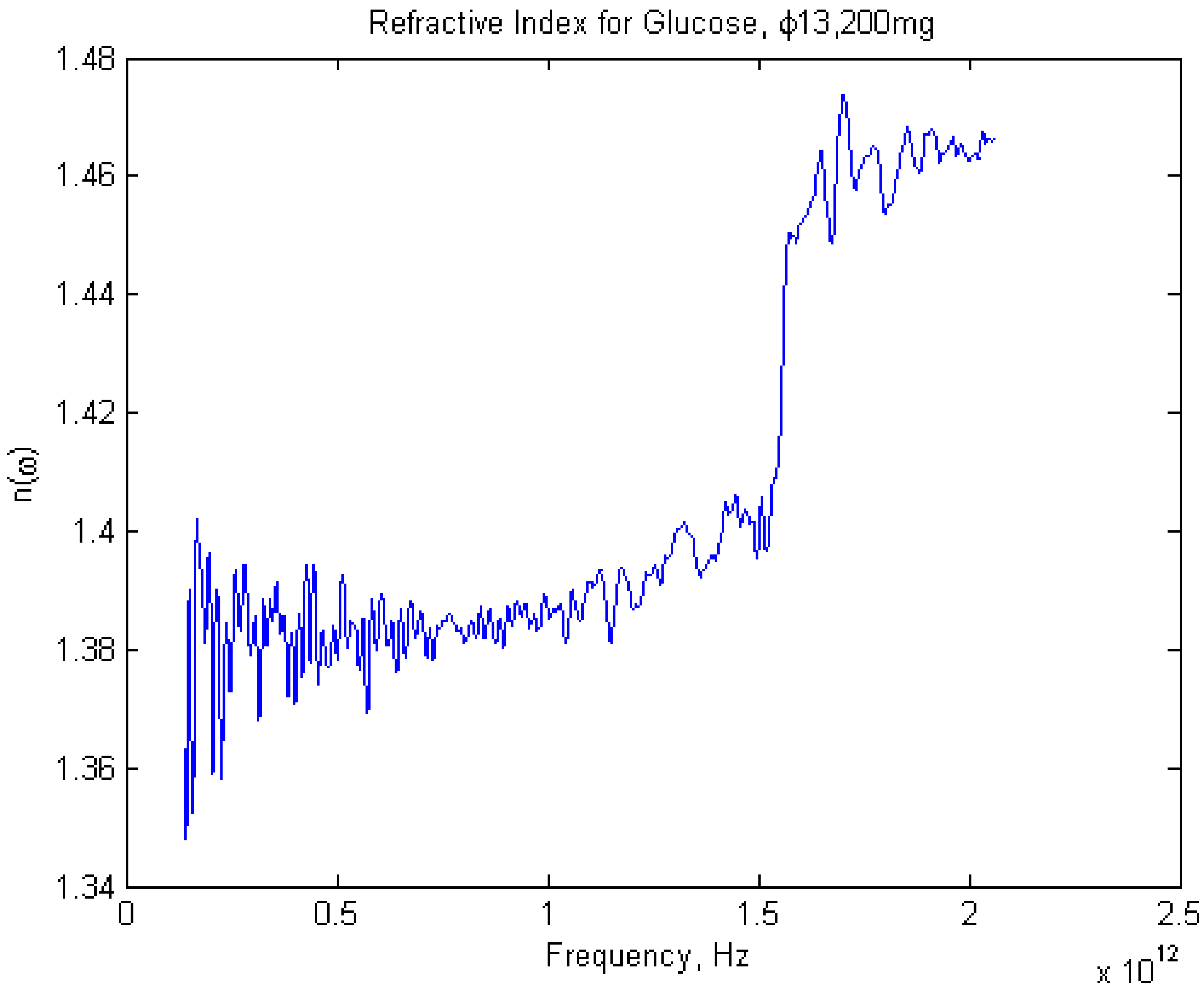
Setup for investigating sugars and salts



Experimental setup

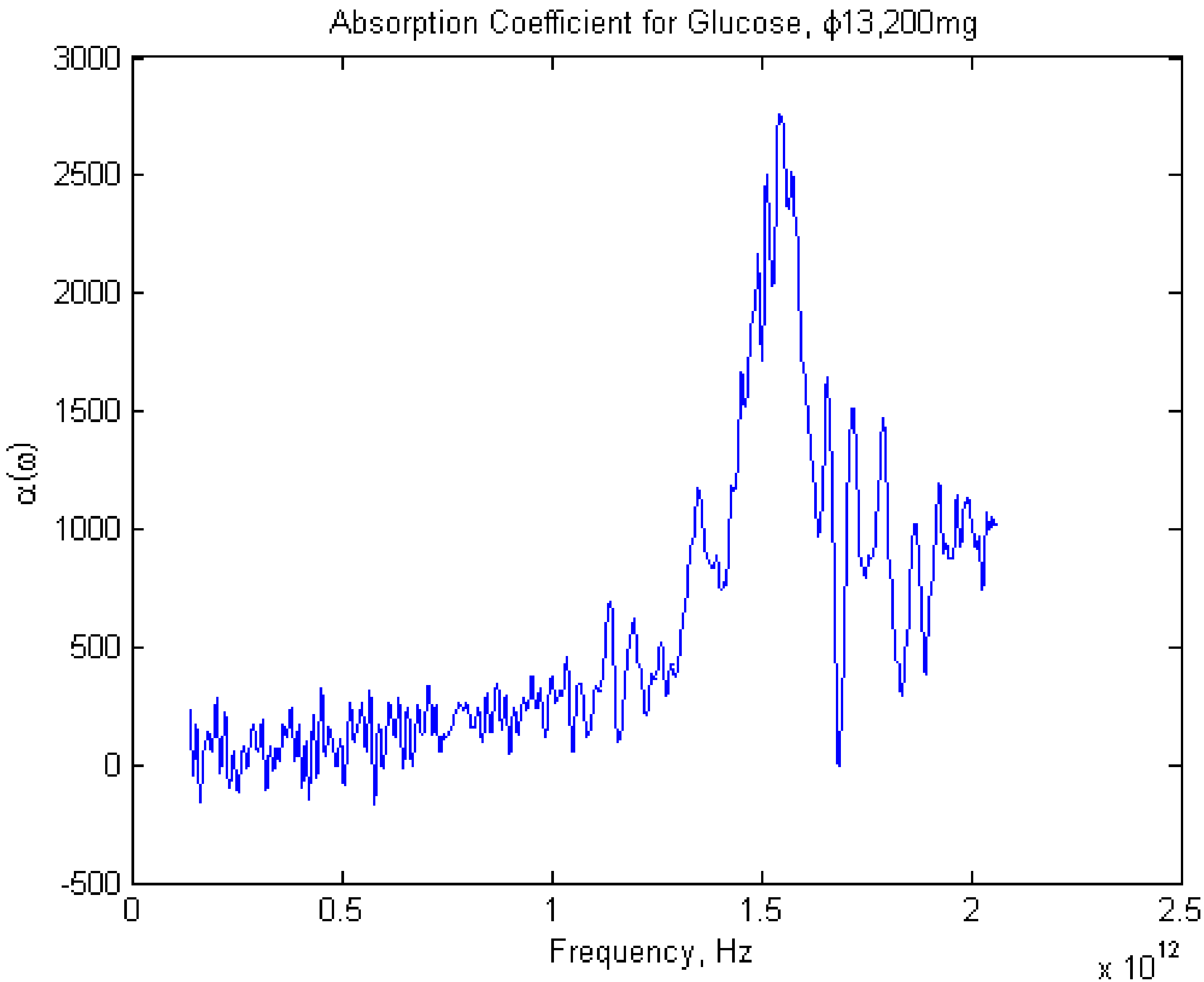
- The powder is pressed under 10 tons to form a pellet
- The Plexiglas chamber is filled with Nitrogen
- The THz beam is focused with silicon lenses

Glucose



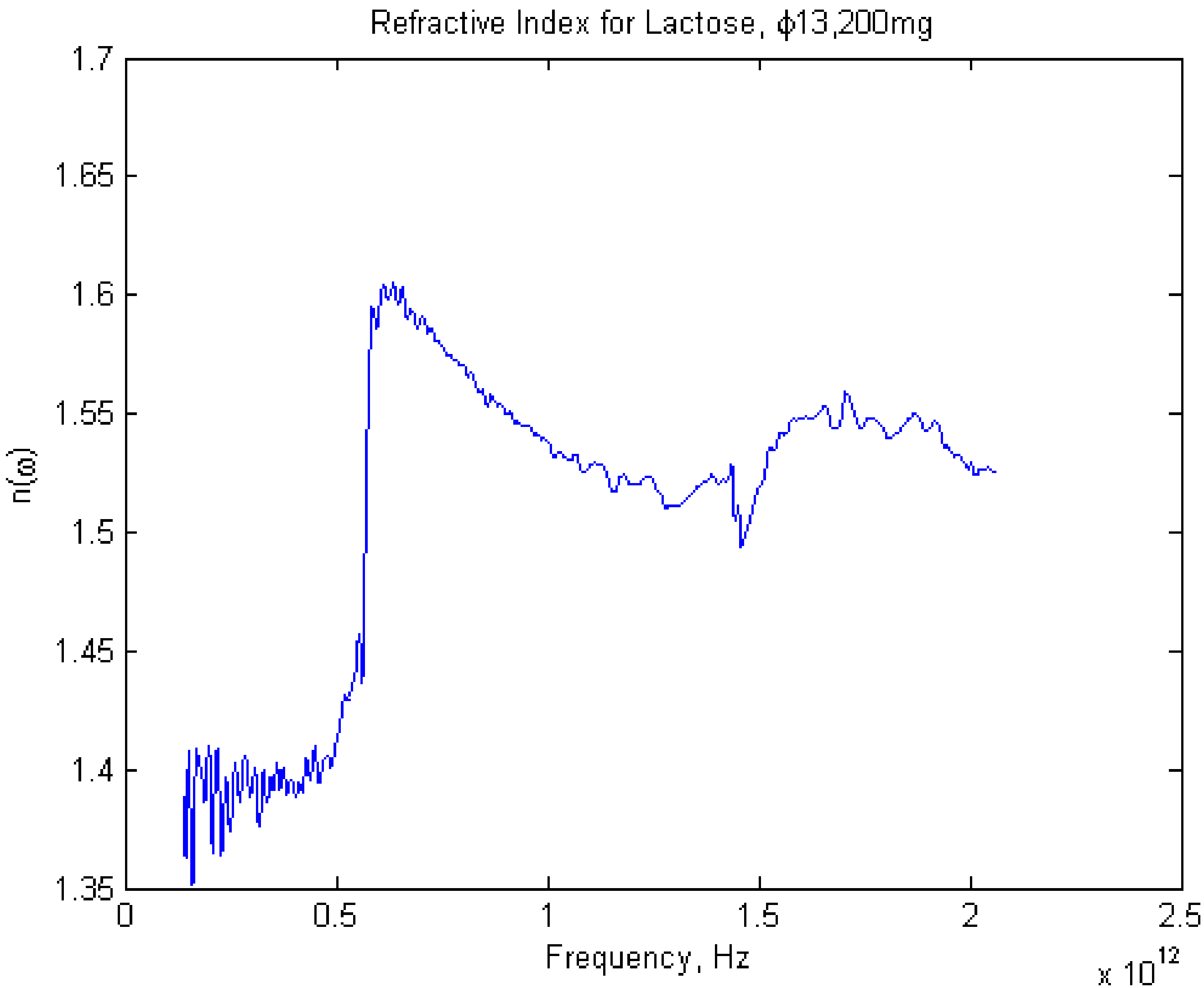
Refractive Index for Glucose, ϕ13,200mg
1.48
1.46
1.44
1.42
1.4
1.38
1.36
1.34
n(ω)
0
0.5
1
1.5
2
2.5
Frequency, Hz
x 10^12

Glucose



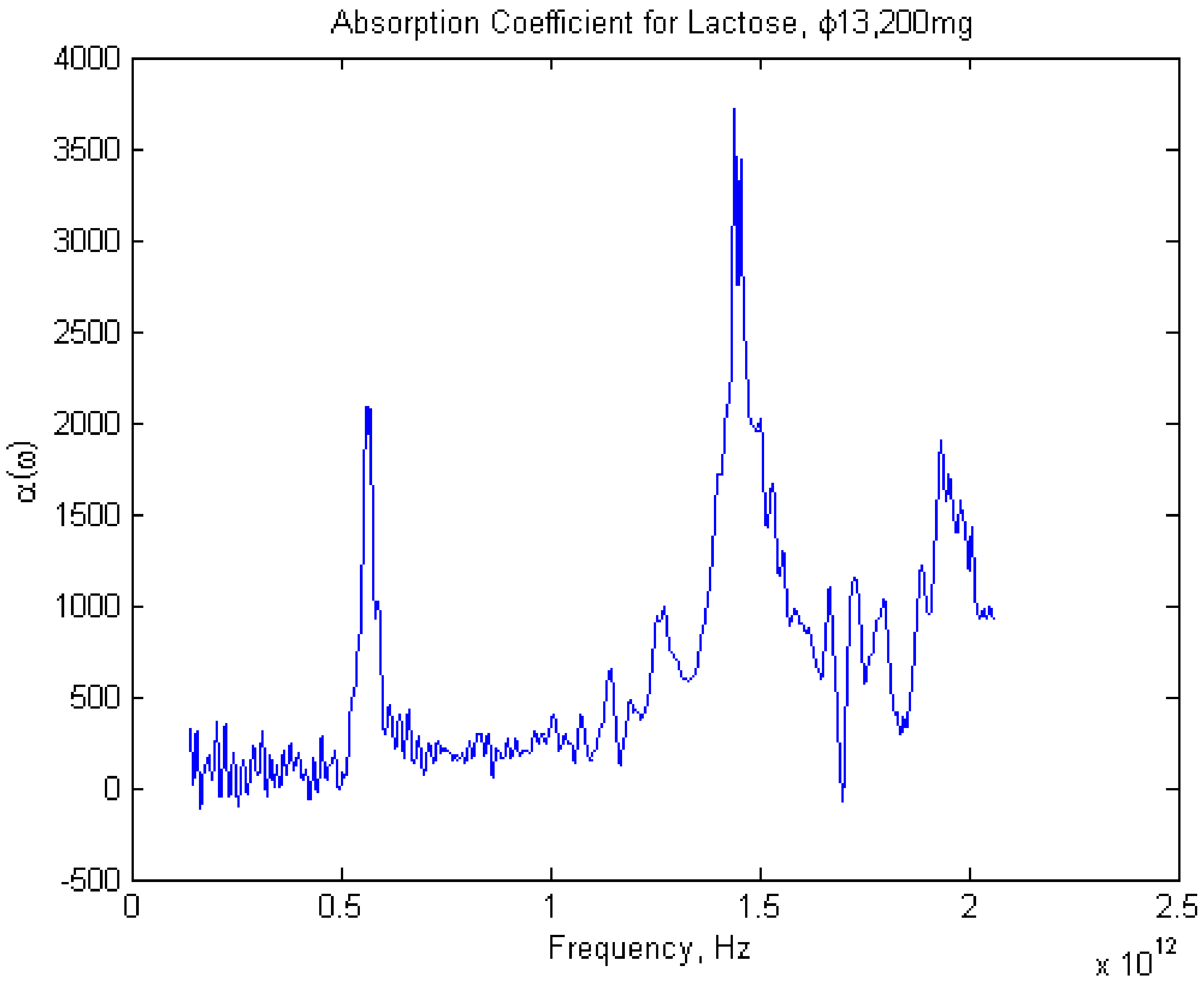
Absorption Coefficient for Glucose, ϕ13,200mg
3000
2500
2000
1500
1000
500
0
-500
α(ω)
0
0.5
1
1.5
2
2.5
Frequency, Hz
x 10^12

Lactose



Refractive Index for Lactose, ϕ13,200mg
n(ω)
1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
0
0.5
1
1.5
2
2.5
Frequency, Hz
x 10^12

Lactose



Absorption Coefficient for Lactose, ϕ13,200mg
4000
3500
3000
2500
2000
1500
1000
500
0
-500
α(ω)
0
0.5
1
1.5
2
2.5
Frequency, Hz
x 10^12

Synchrotrons

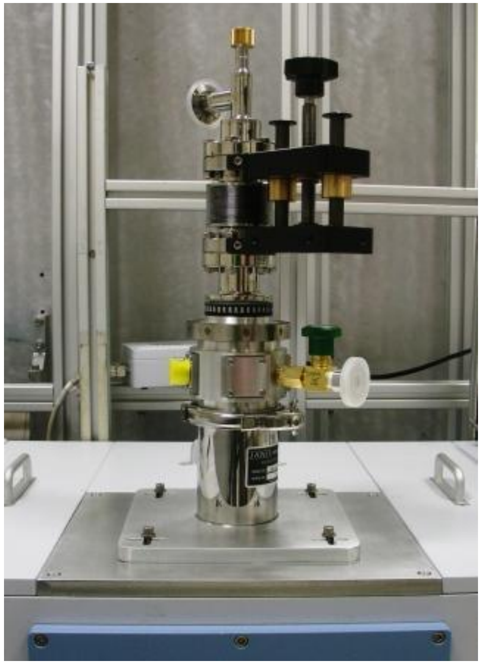
- Large machines for accelerating electrons
- Intense wideband tunable polarised light
- Some typical applications: biosciences, medical research, environmental sciences, agriculture, minerals exploration, material science and engineering
- Not so typical (yet) applications: food safety and quality

THz/FIR synchrotron beamline

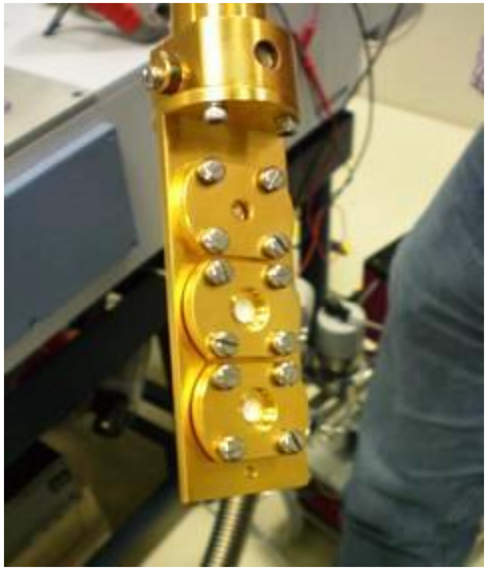
- Brüker IFS 125/HR interferometer
- Cooling down to –193°C with liquid Nitrogen
- Janis Research cryostat sample holder
- Vacuum conditions
- Bolometer detection at –269°C (liquid Helium)
- Nitrocellulose matrix for the samples

Experimental setup for FDS

The interferometer

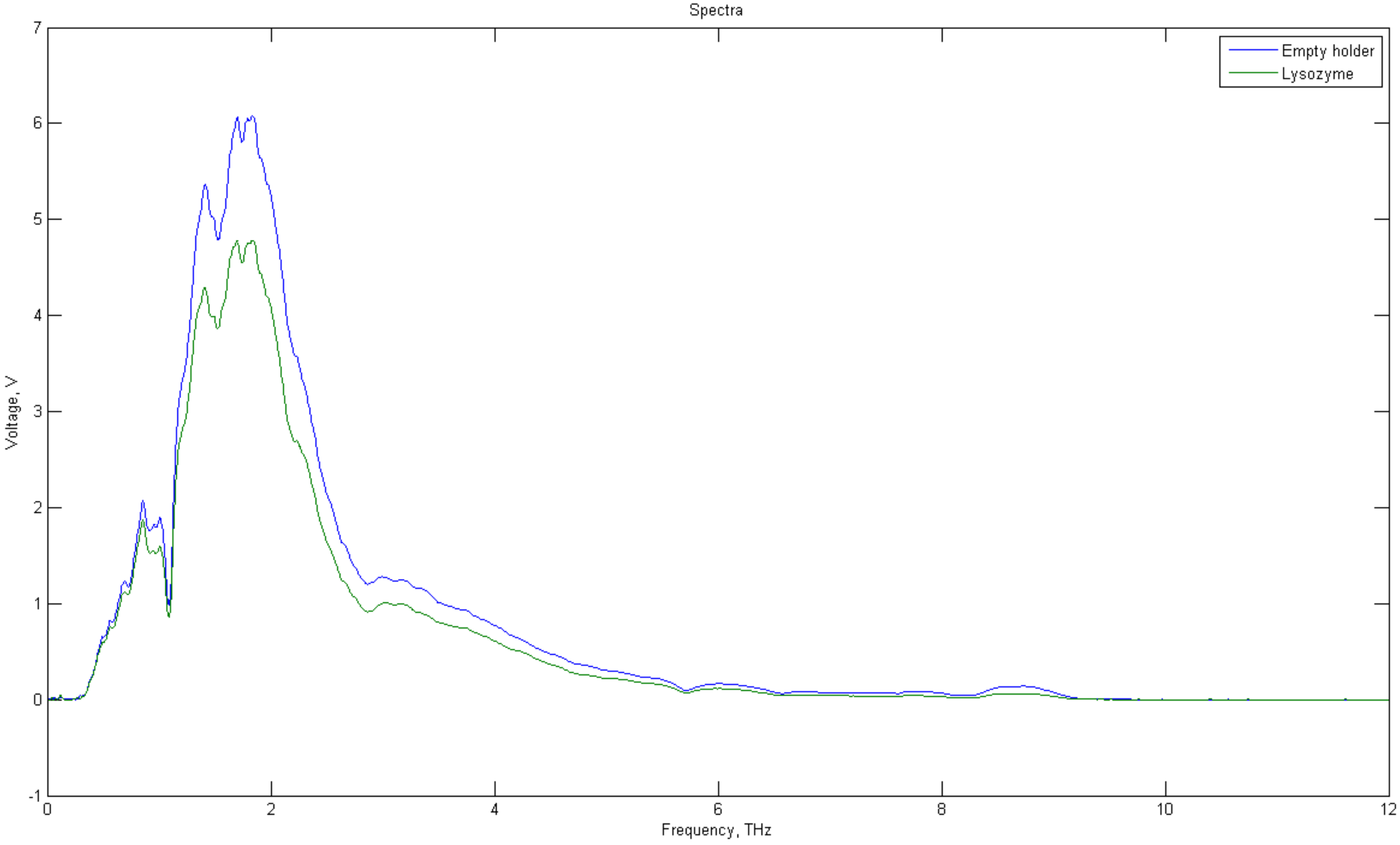


The cryostat

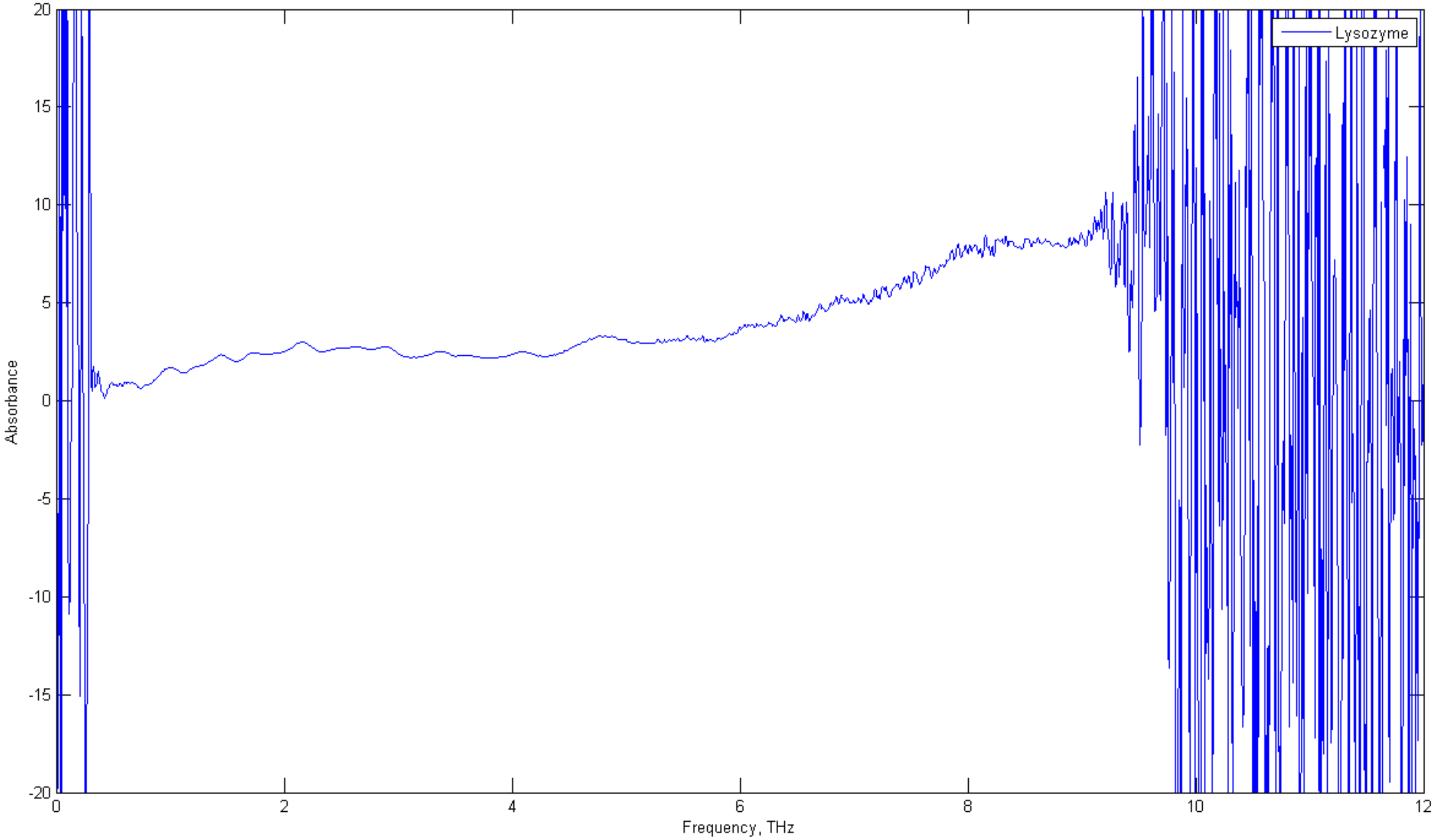


The sample holder

Lysozyme, 600UI



Lysozyme, 600UI



In conclusion…

- THz TDS is a promising mode for investigating food related substances
- Synchrotron-based THz FDS investigation is highly precise but prohibitively expensive to be used only in food industry
- THz TDS and FDS are a valuable complement to other spectroscopic modes for food analysis

Thanks for your attention