Supercontinuum based mid-IR imaging

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MINERVA improved medical diagnostics

workshop, Munich, 30 June 2017

Gooch & Housego
ENABLING OPTICAL TECHNOLOGIES

Outline

1. **Imaging system (Minerva "Lite") – wavelength range: 3 - 5 µm,**

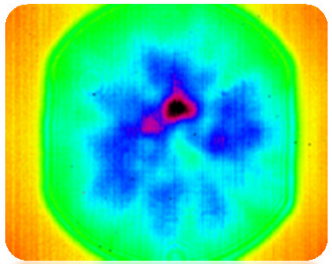
2. **Scanning system – wavelength range: 2 – 9 µm,**

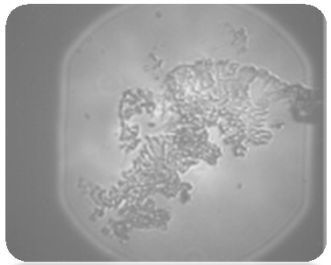
   b) **Short wavelength system: 2 - 5 µm,**

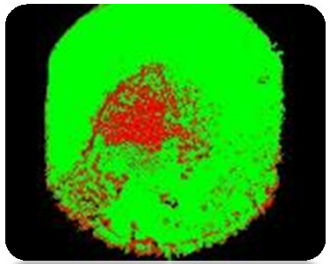
   c) **Long wavelength system: 6 – 9 µm.**

MINERVA “Lite”
λ= 3 – 5 µm

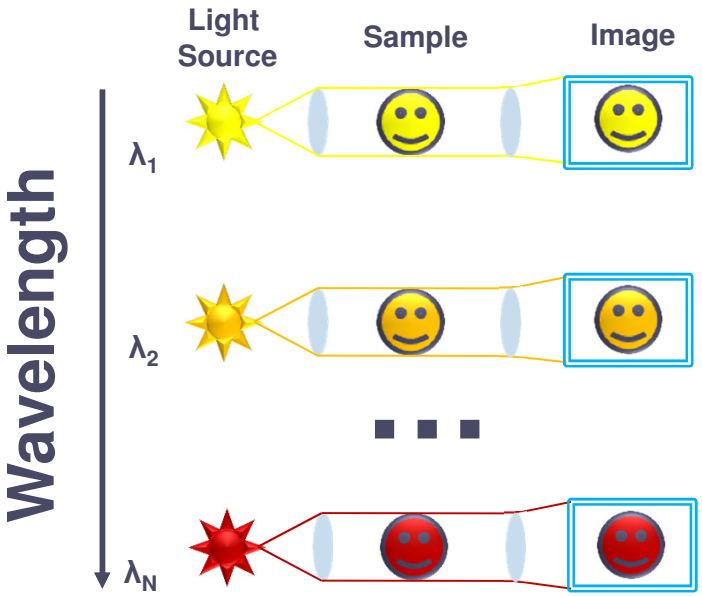
Imaging system

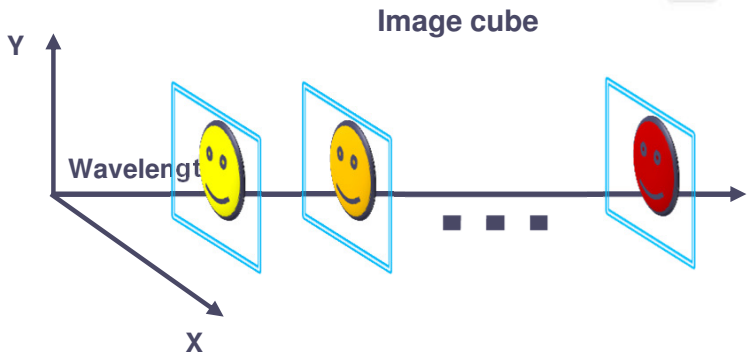






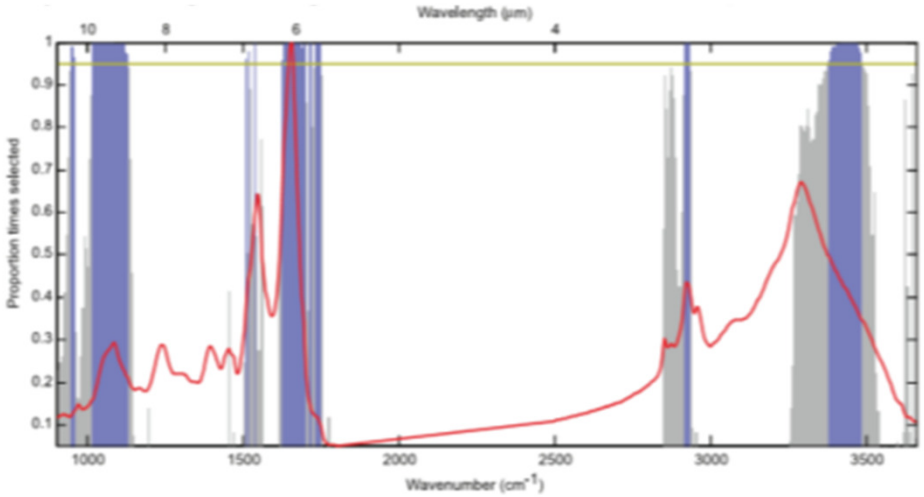
Imaging system – basic concept





Spectroscopic features of interest

(well defined in broad spectral region)



Requirements:

- **Narrow and fast wavelength selection**
- **Fast and high definition imaging**

G.Lloyd, N. Stone, Appl. Spect. 69, 1066-1073 (2015)

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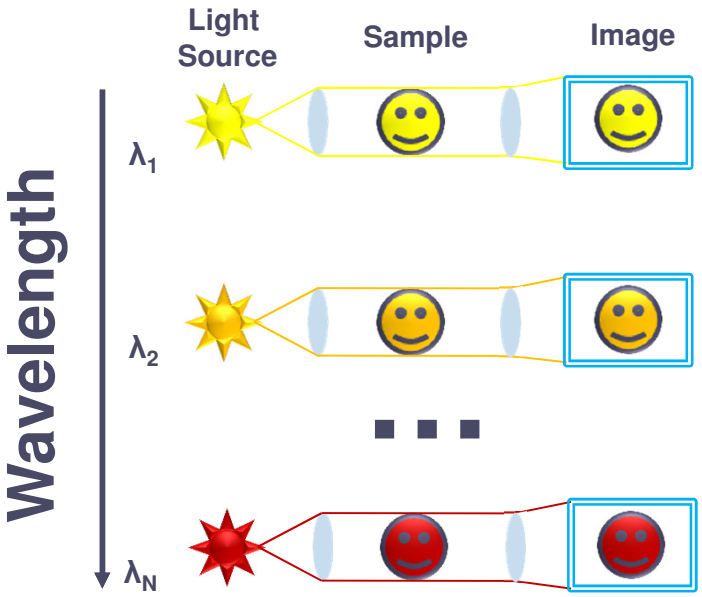
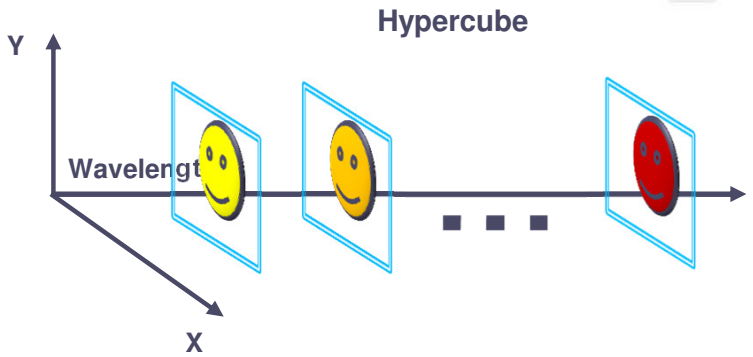
Imaging system – basic concept





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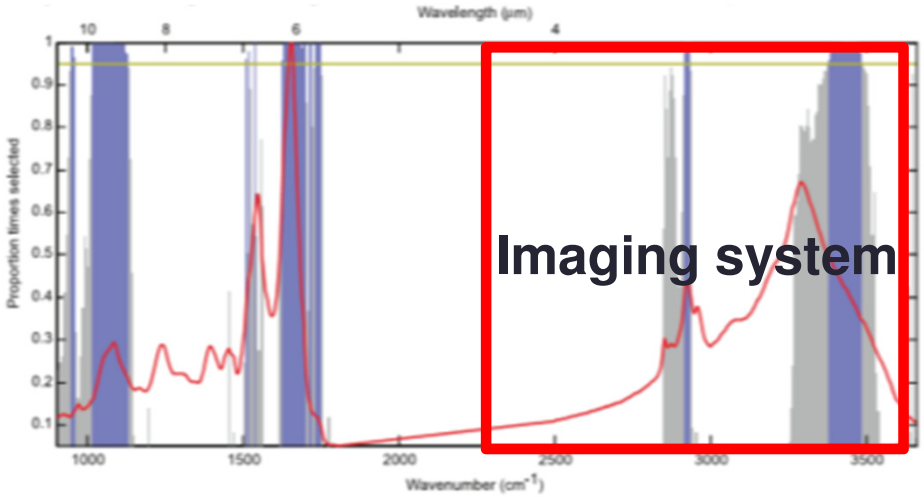

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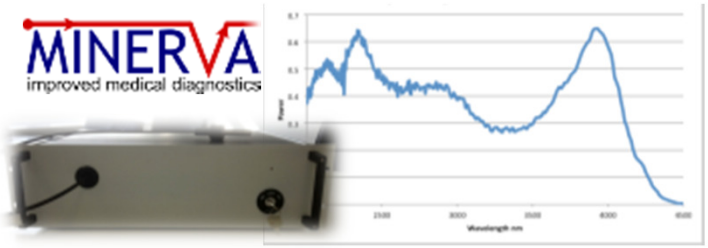
Imaging system - details

NKT supercontinuum source



Xenics camera

Imaging system - details

Supercontinuum source

Spectral range: 1.8 – 4.5 µm
Repetition rate: 2.5 MHz

AOTF

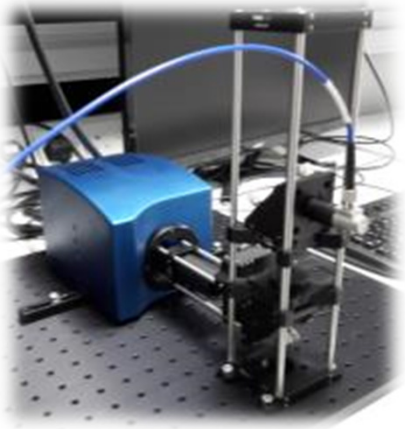
Spectral range: 2 – 4.5 µm
Spectral resolution: 1- 4 nm

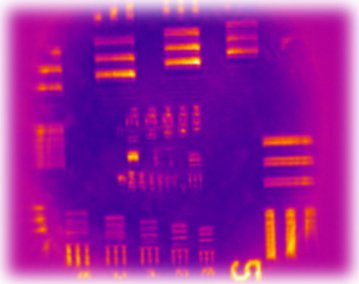
Camera

Spectral range: 3 (1) – 5 µm
Resolution: 640 x 512
Pixel pitch: 20 µm
Frame rate: 90 fps

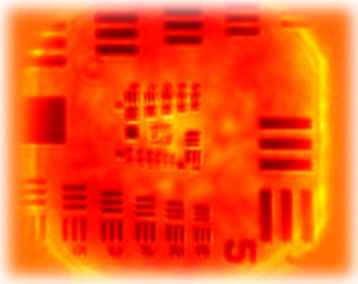
Equipment

Optical head





Reflection



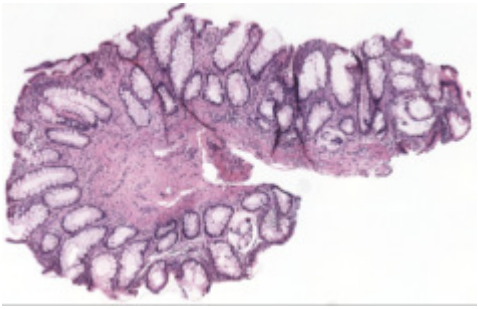
Transmission

System

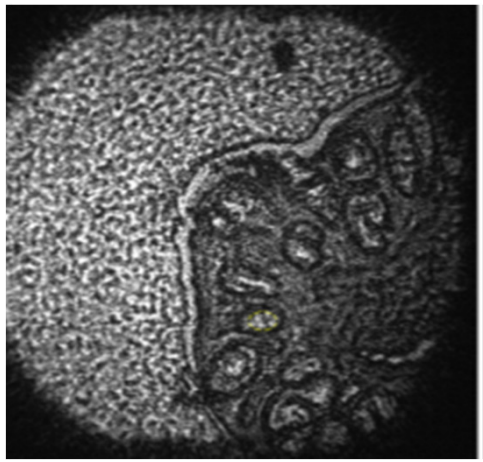
Acquisition speed: 50 fps (limited by frame grabber)
Field of view: 3 mm
Pixel resolution: 5 µm
Actual resolution: 30 µm (limited by optics – simple refractive optics)

Imaging system

Visible image

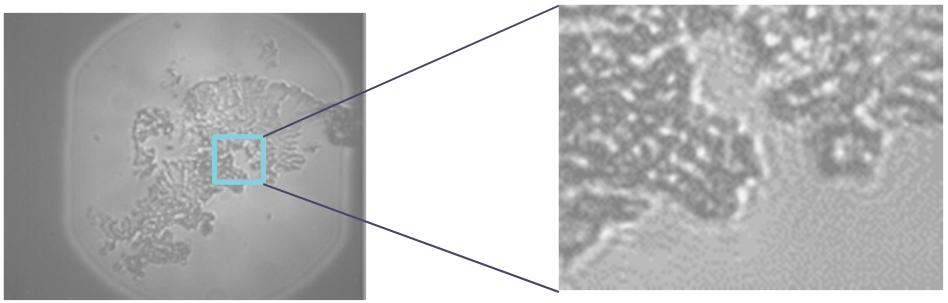


Mid-IR image



- **Supercontinuum light is coherent.**
- **Coherence is largely preserved in the single mode fiber.**
- **Speckle occurrence in biological issues**

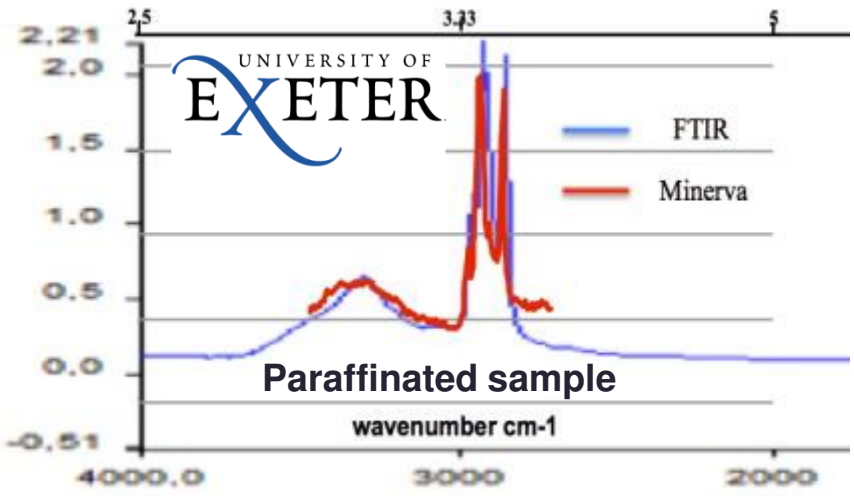
Multimode input : **Speckle suppressed (Residual ~ 10 %)**

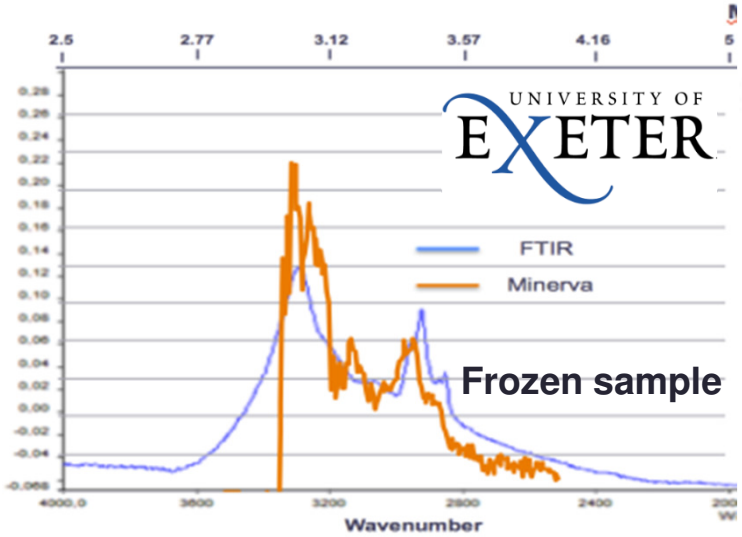


Zoom in

Imaging system

Comparison with commercial system



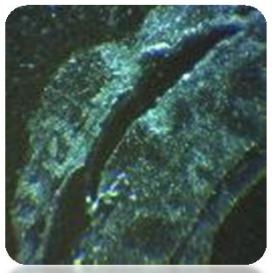


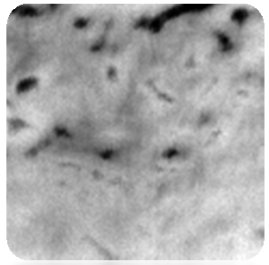
Spatially averaged to reduce the speckle.

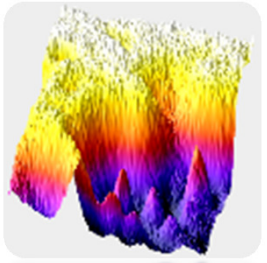
- **Scanning system introduced to solve speckle issue and extend the spectral range.**
- **There is a penalty in acquisition speed (imaging system acquires full spatial and spectroscopic information in matter of seconds).**

MINERVA
λ= 2 – 9 µm

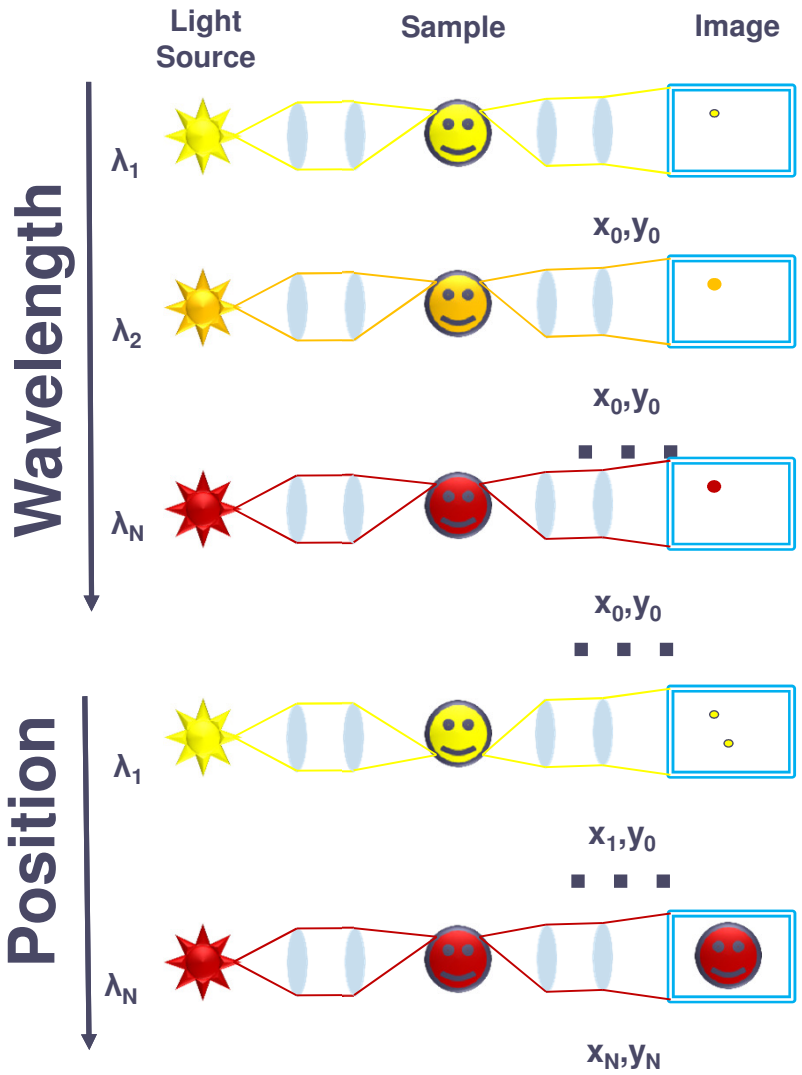
Scanning system

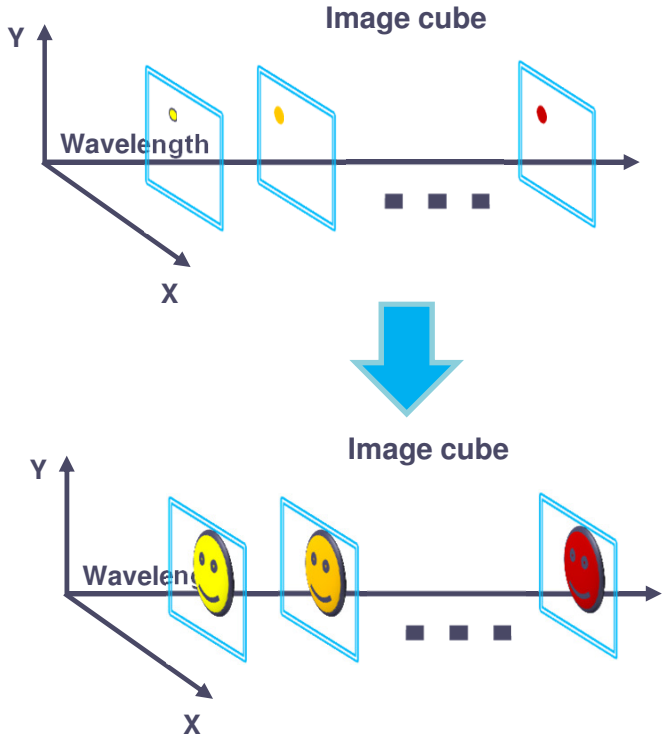






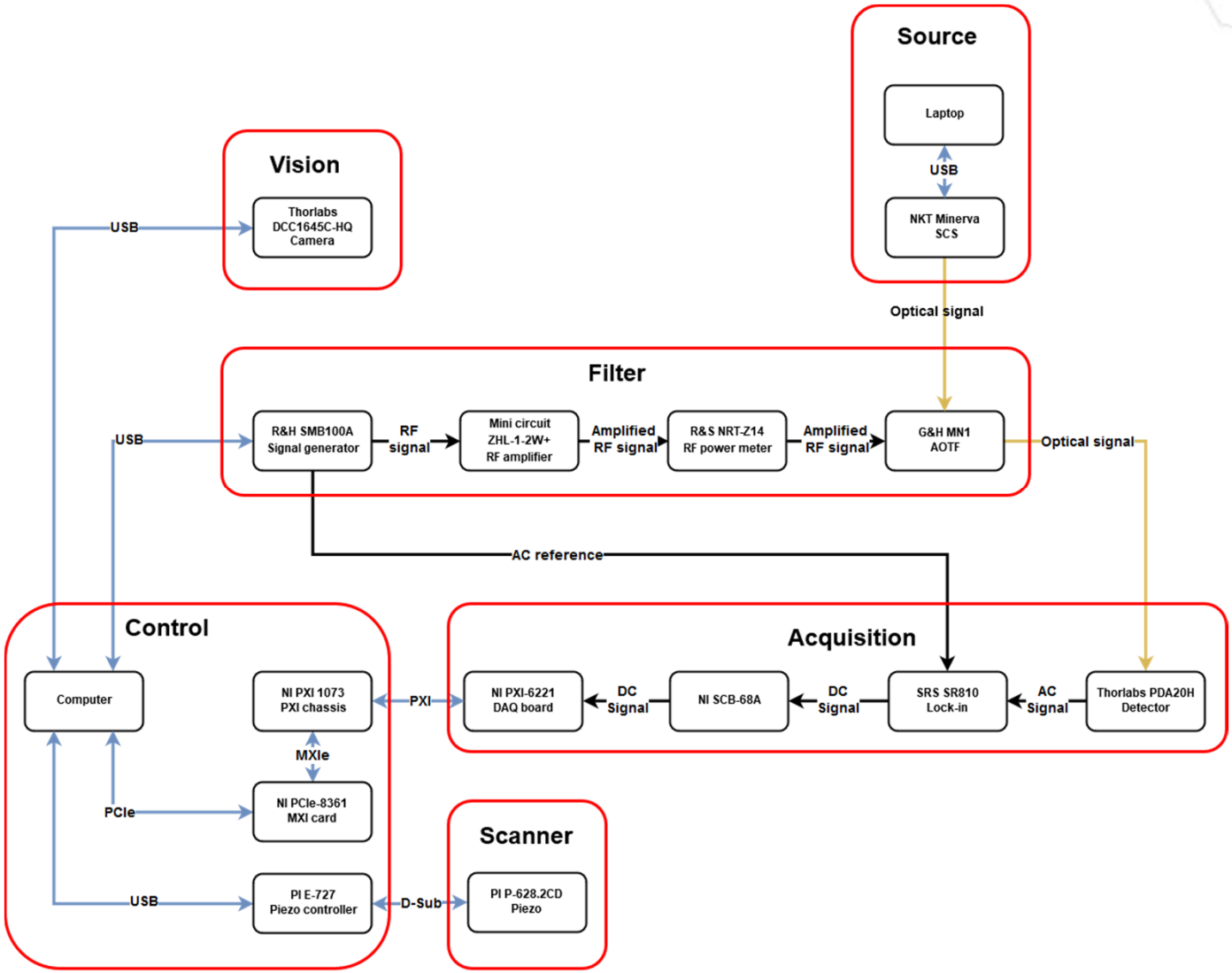
Scanning system – basic concept





Significantly slower than imaging.

Scanning system – short λ



Scanning system – short λ

Piezo scanner

Step time: 30 ms
Range: 800 x 800 µm

Visible camera

Field of view: 800 x 640 µm
Pixel resolution: 0.6 µm
Actual resolution: 4 µm

Detector

Spectral range: 1.5 – 4.8 µm
Bandwidth: 10kHz

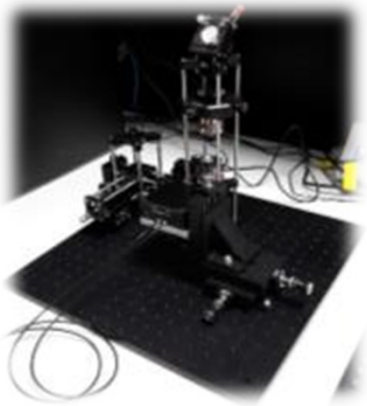
Cassegrain objectives

Magnification: 15x
NA: 0.3

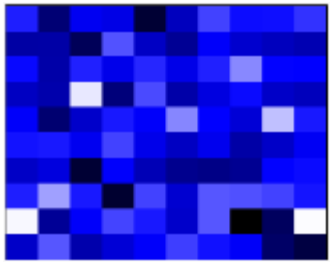
Software

LabVIEW on Windows

Optical head



GUI



Data saved as .png image
1 step = 1 pixel

System

16 ms per point acquisition time

(non-deterministic OS)

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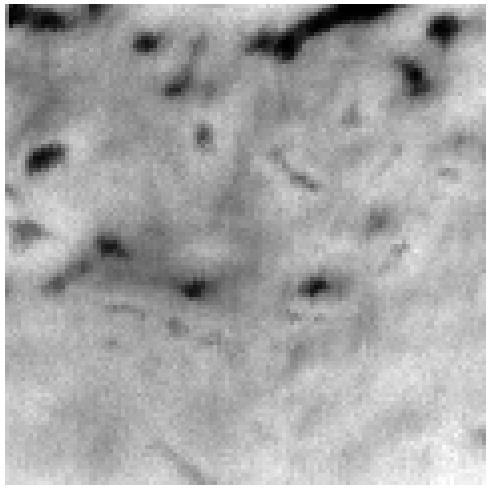
Scanning system – short λ

Sample 1

Multimode input

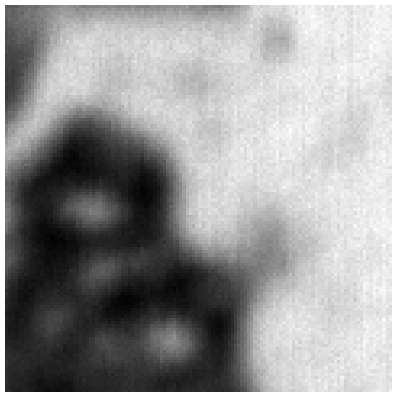
Sample 2

Mid-IR image @ 3µm

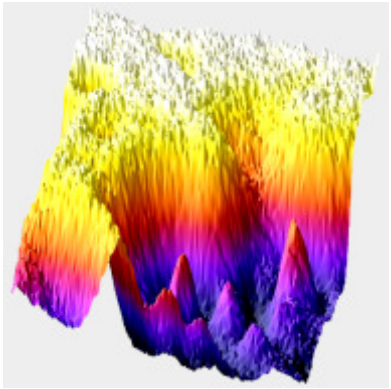


Area size: 600µm x 600µm
Pixel resolution: 5µm
Time averaging: 10ms

Mid-IR image @ 3µm



3D representation

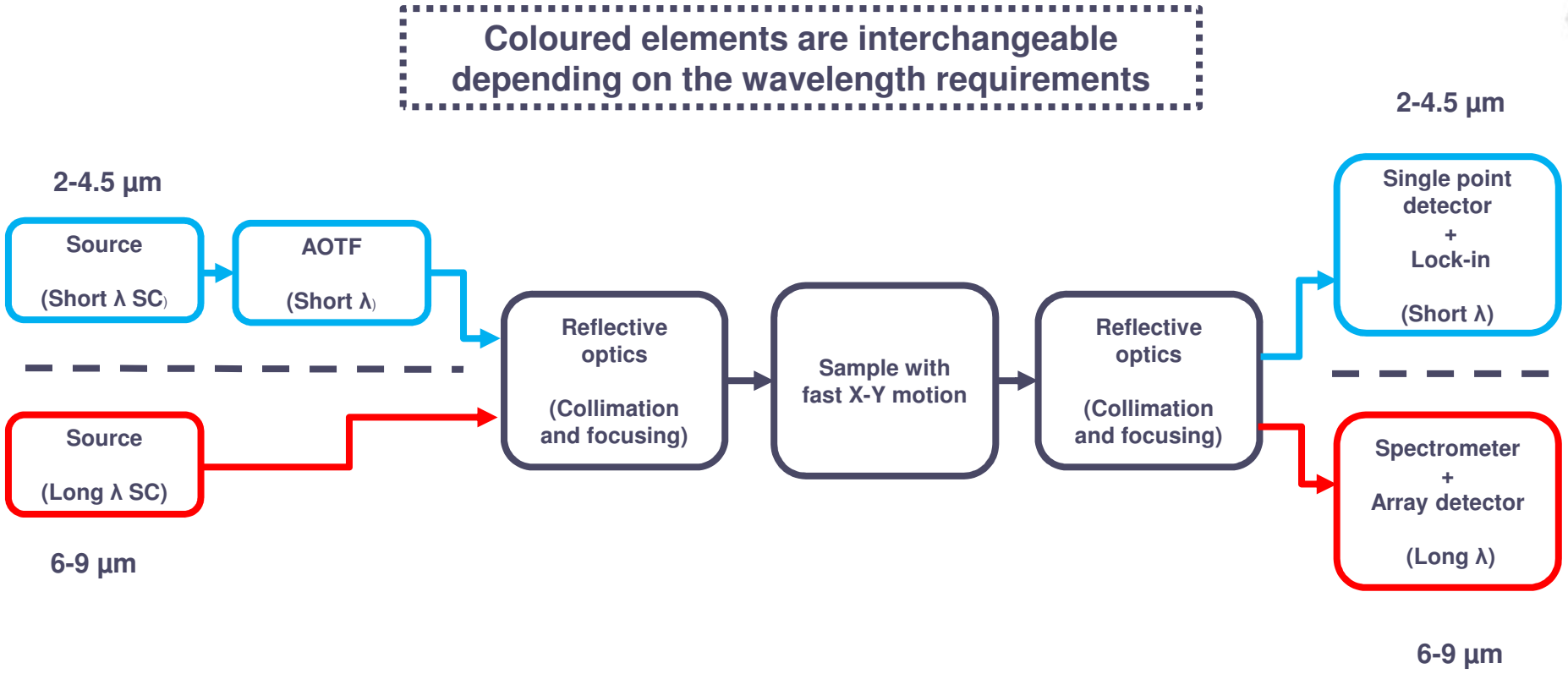


No speckle – spatial averaging

Current work:

- **Testing**
- **Building larger data set.**

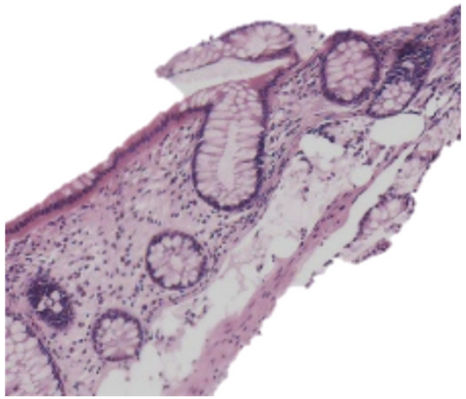
Broadband system scheme



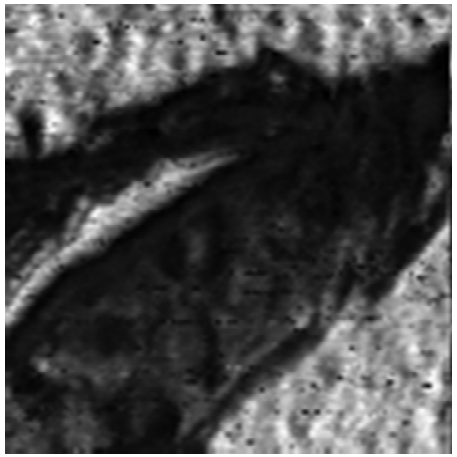
Scanning system – long λ

Experiment conducted at DTU

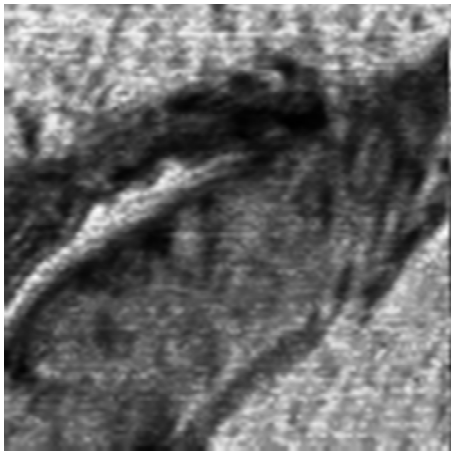
Visible image



λ = 6030 nm



λ = 6450 nm



Technical difficulties
lead to limited data set

Area size: 600µm x 600µm
Pixel resolution: 5µm
Time averaging: 100ms

Demonstrated supercontinuum imaging above 5µm.

Conclusions

- Supercontinuum source is a viable option for imaging in Mid-IR.
- In combination with the AOTF and the camera, it allows for very fast data acquisition (~s).
- Speckle is an issue when used system is used in the imaging mode.
- Spatial averaging solves the speckle issues.
- Further development needed for operation above 5 µm.

Thank you for your attention.