Unveiling the potential of a novel hyperspectral camera for medical imaging

Fabrizio Preda, CEO at NIREOS

EPIC Meeting on Photonics assisted Cancer Pathology and Surgery – 29/30.11. 23 – University Hospital Antwerp

Digital Pathology and Hyperspectral Imaging

Up to 39% patients who undergo surgery leave the operating room **without a complete tumor resection** due to positive or close margins.*

A **complete resection** is associated with **3-5 times improvement in the patient survival ***

The current standard → Analysis of the frozen section of biopsies.

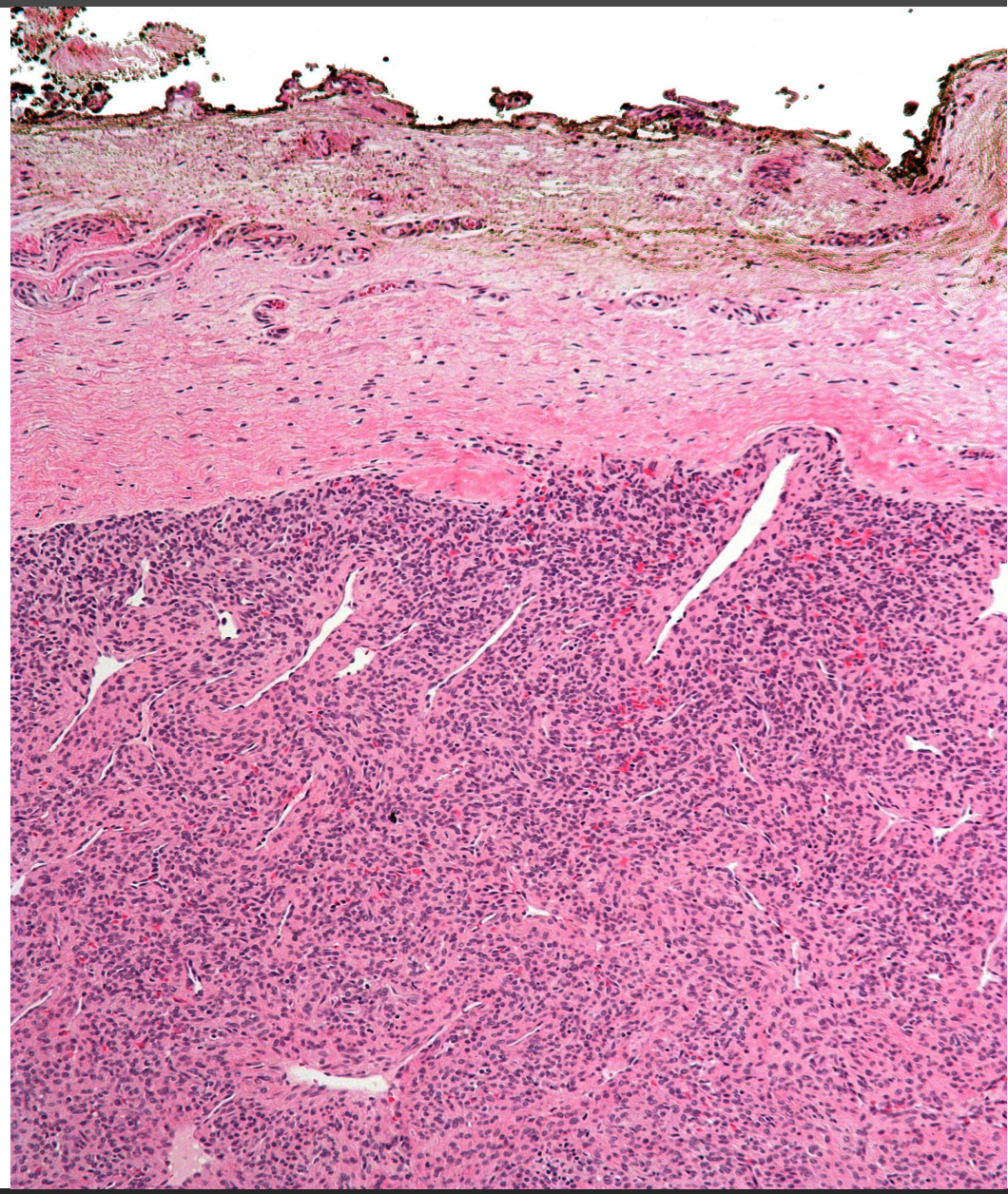
Visual inspection of the H&E-stained tissue by the pathologist

Time-consuming, Subjective

Need for Fast and Objective method → DIGITAL PATHOLOGY

Optical Methods (RGB, Multispectral or Hyperspectral, Raman,…) + **Machine Learning**

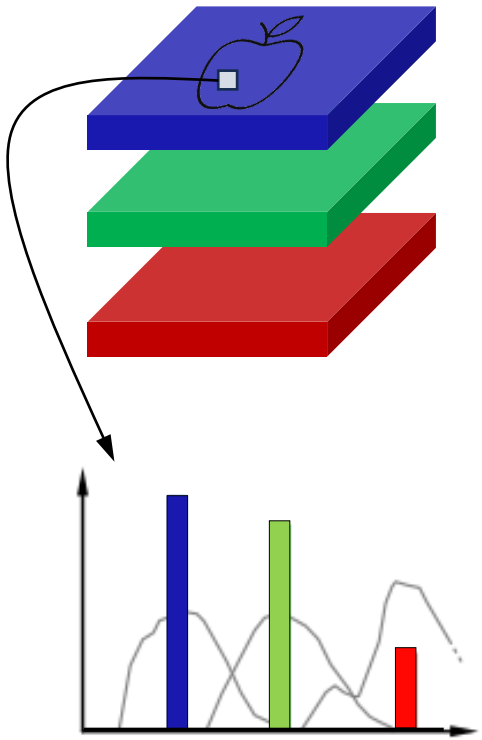
- *First objective classification step in tumor margin assessment*
- *Improve the following histopathological evaluation by highlighting potential areas of interest.*



** Fei B, et al., J Biomed Opt. 2017 Aug;22(8):1-7*

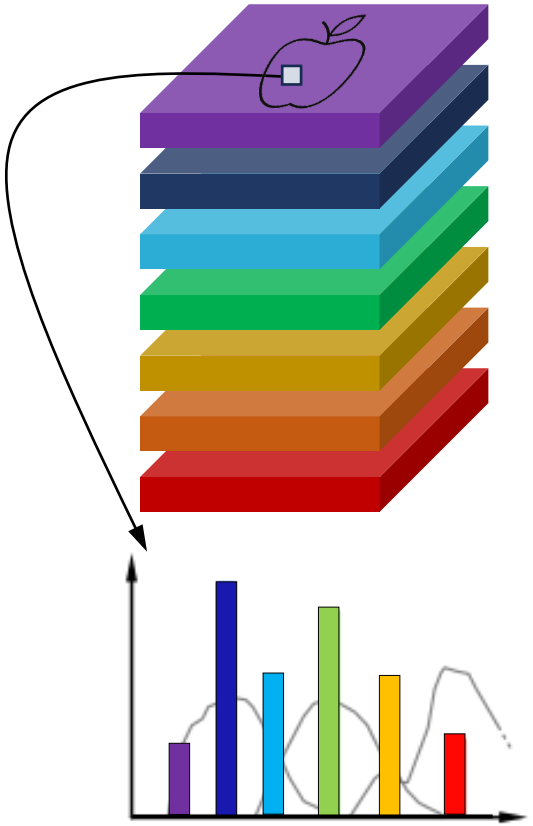
Digital Pathology and Hyperspectral Imaging

RGB



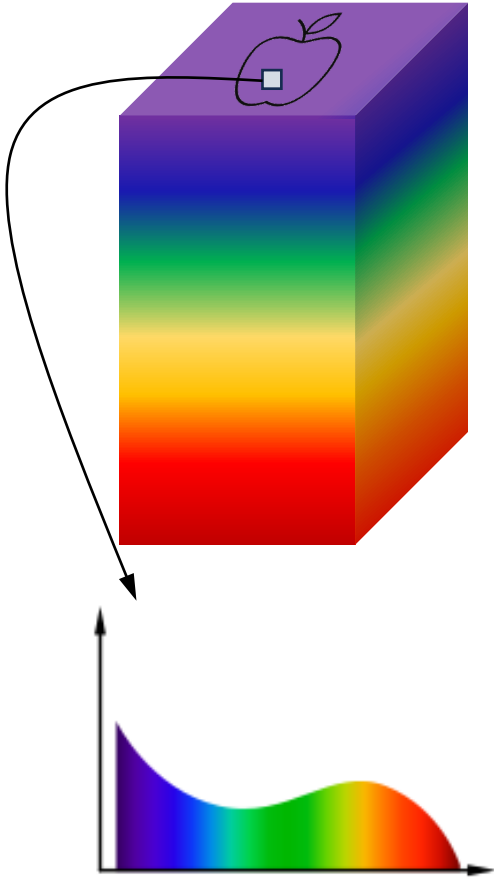
Wavelength

MULTISPECTRAL (MSI)



Wavelength

HYPERSPECTRAL (HSI)



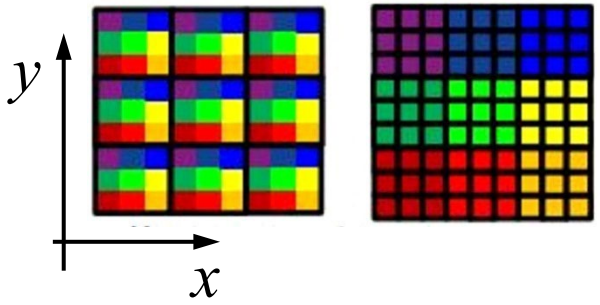
Wavelength

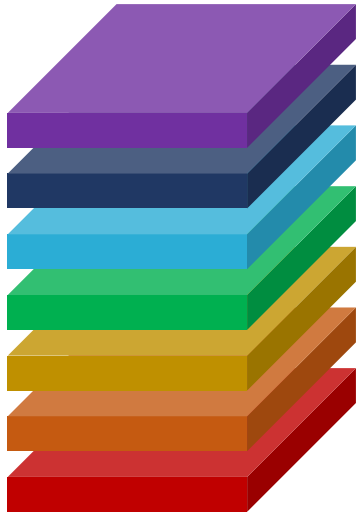
HSI provide a combination of SPECTRAL and SPATIAL information, paving the way to the creation of computer-aided diagnostic tools for both stained and unstained histological specimens.

Improvement in the detection of tumors compared to traditional RGB.

Other Spectral Imaging Techniques

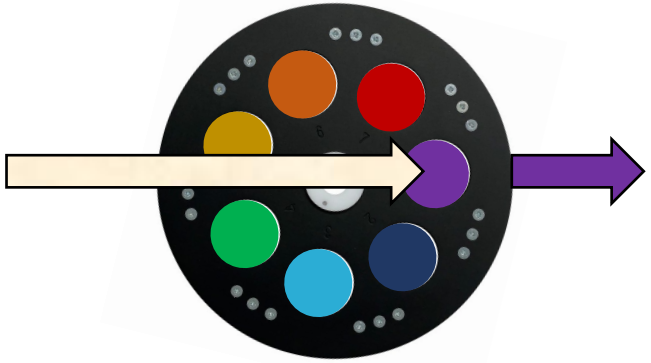
SNAPSHOT IMAGING

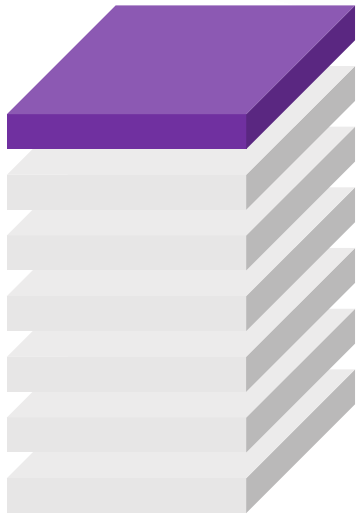




- Fast
- Compromise Spatial & Spectral res.

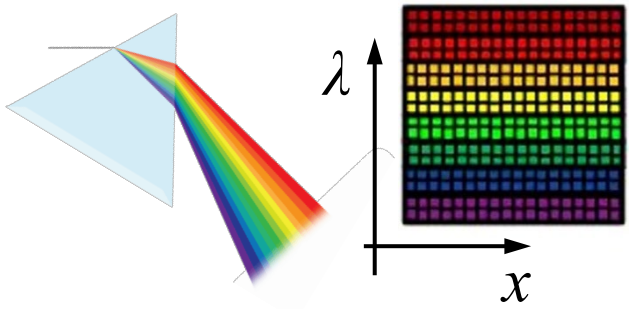
STARING IMAGING





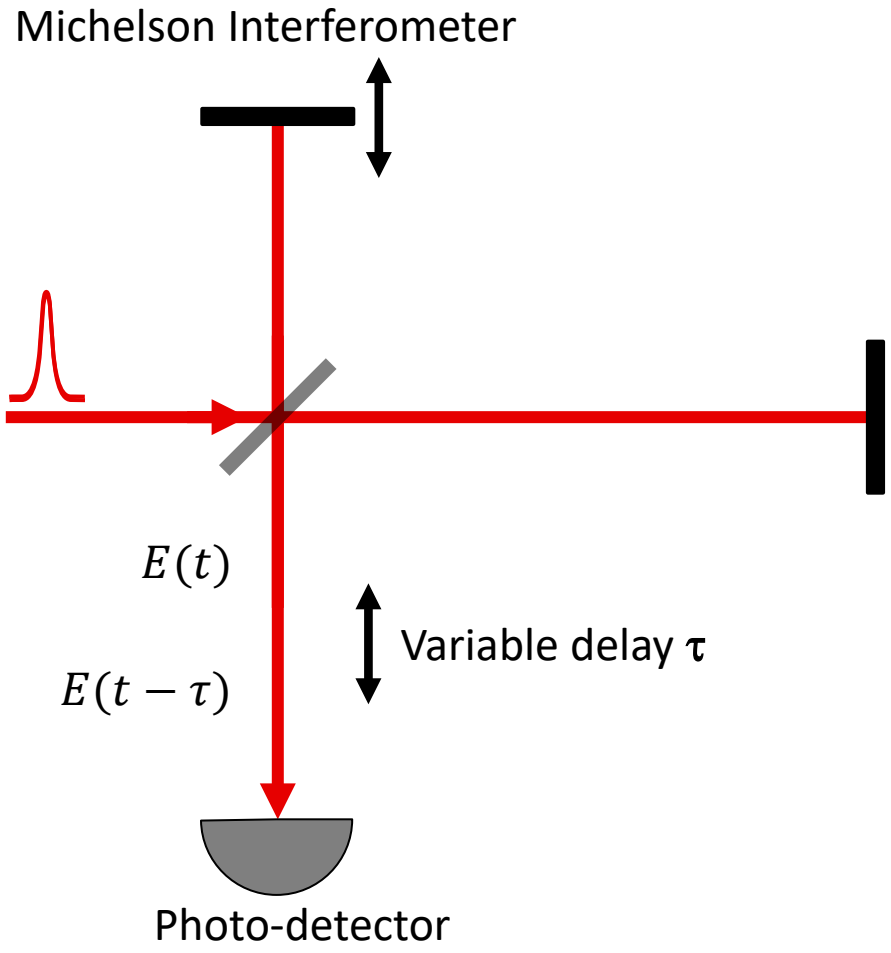
- Good Spatial Resolution
- Low number of bands

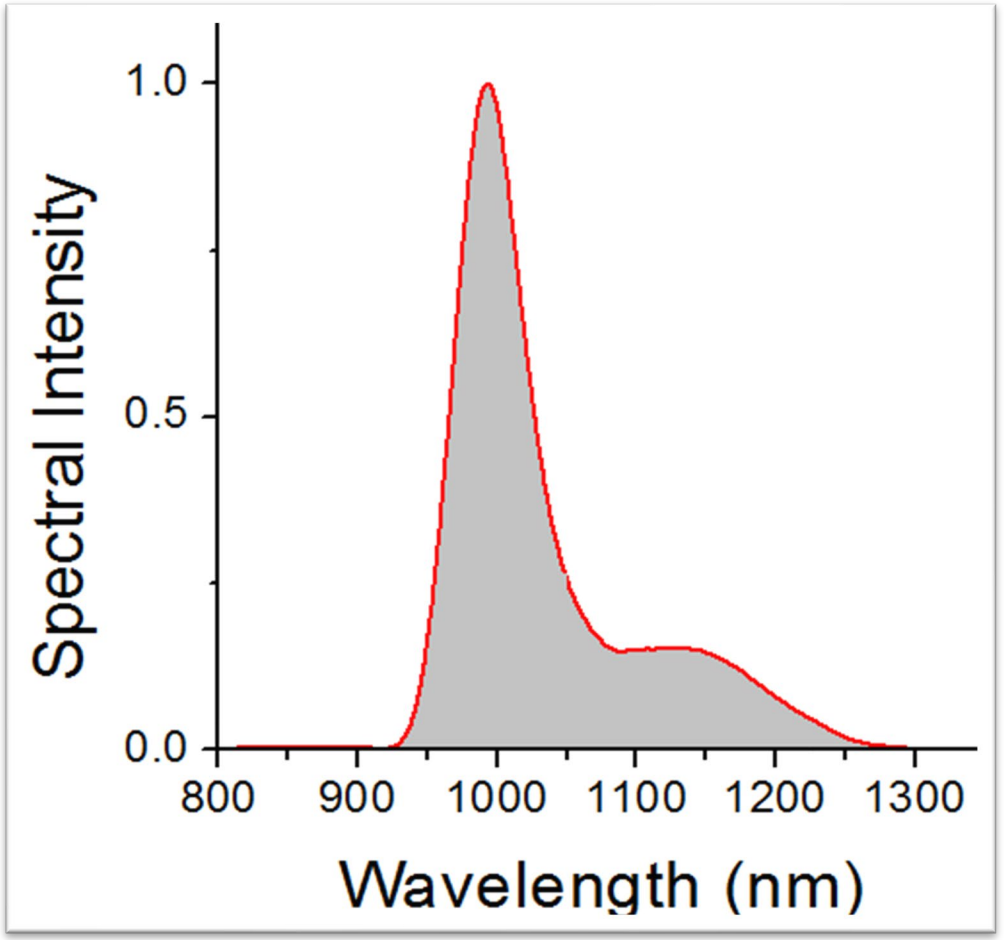
PUSHBROOM IMAGING



- Good Spatial & Spectral res.
- Line Scan: movement required

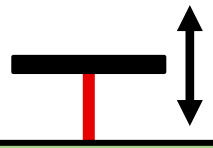
NIREOS approach: Fourier Transform





NIREOS approach: Fourier Transform

Michelson Interferometer



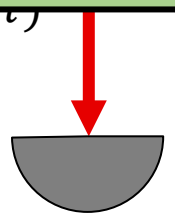
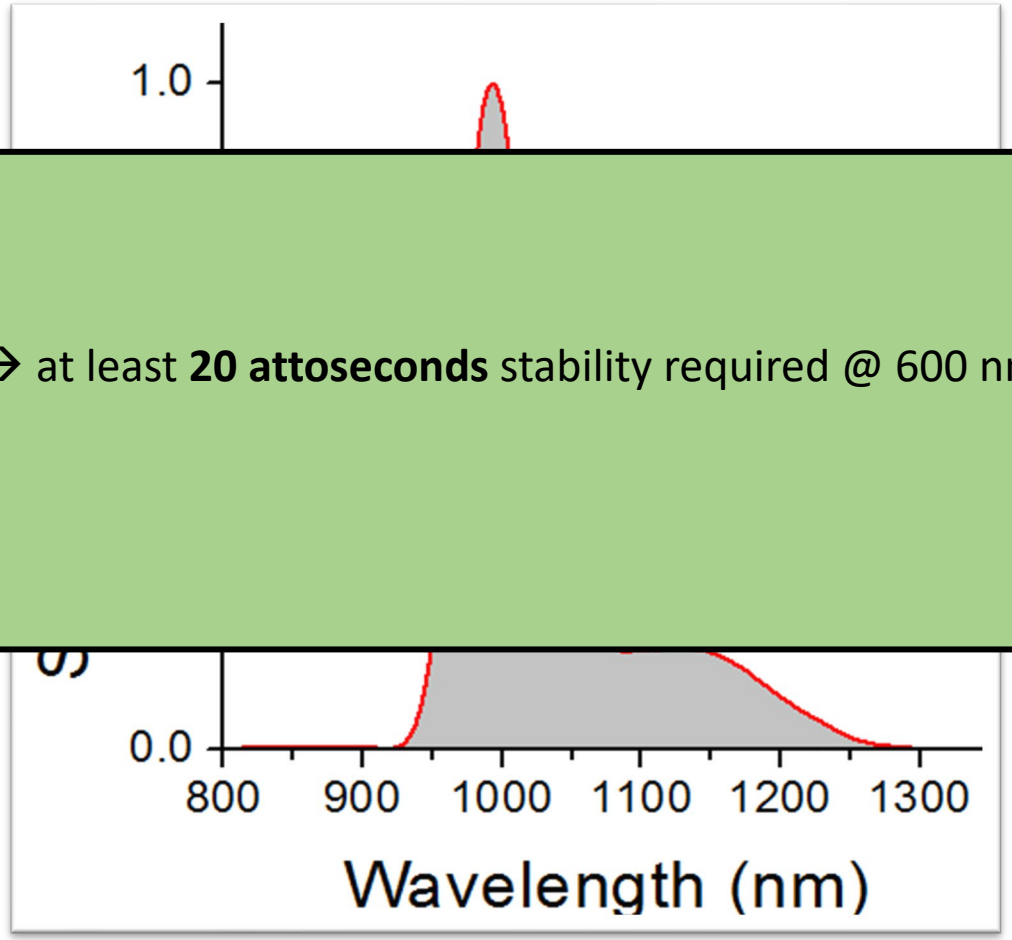


Photo-detector



REQUIREMENTS FOR A PORTABLE IMAGING SYSTEM:

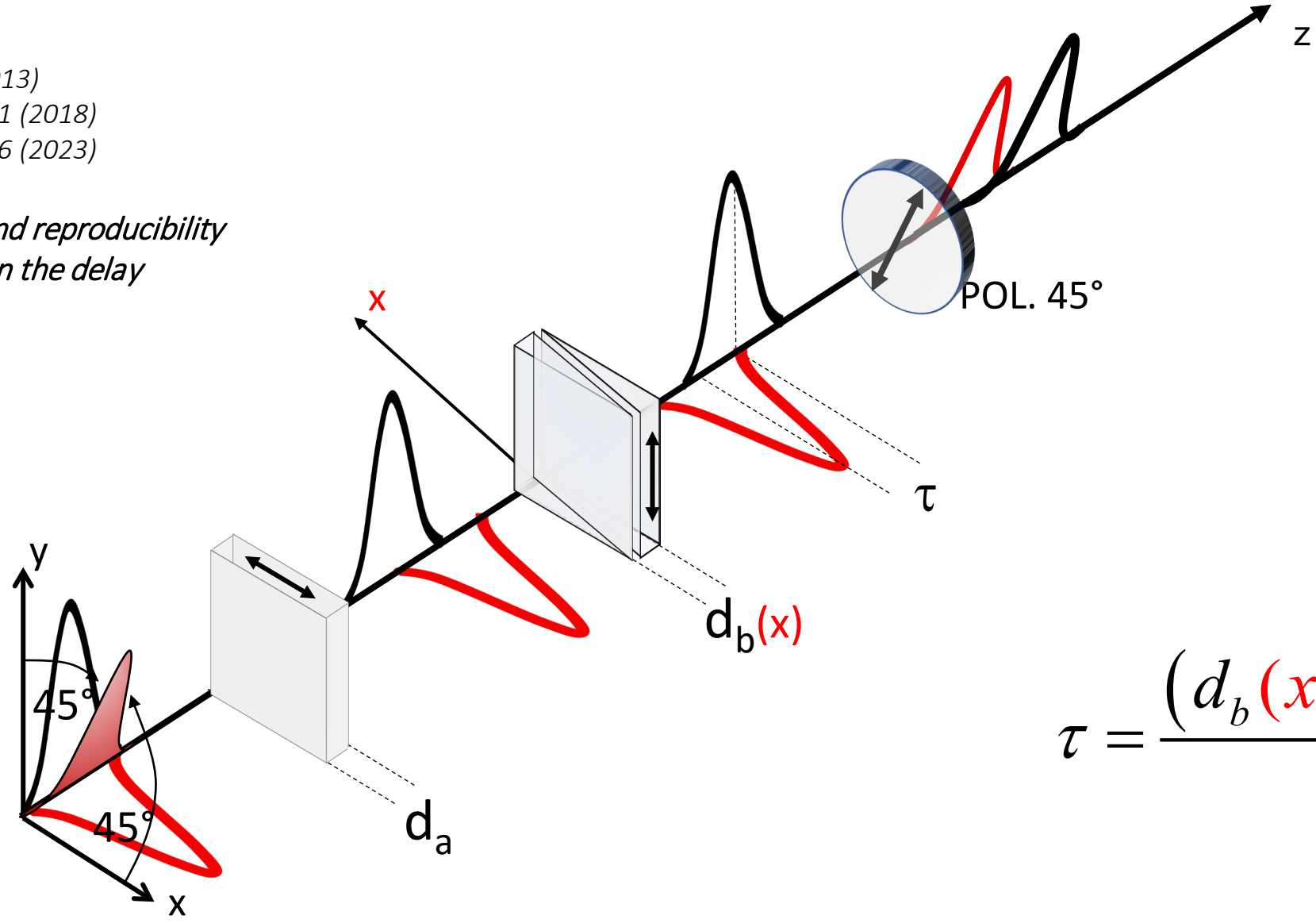
- Accuracy of delay **< 1/100** of the optical cycle (→ at least **20 attoseconds** stability required @ 600 nm)

- Compact Size

NIREOS technology: CPI, a common-path interferometer

Based on the patents
N°: US9182284B2 (2013)
N°: 102018000008171 (2018)
N°: 102023000005346 (2023)

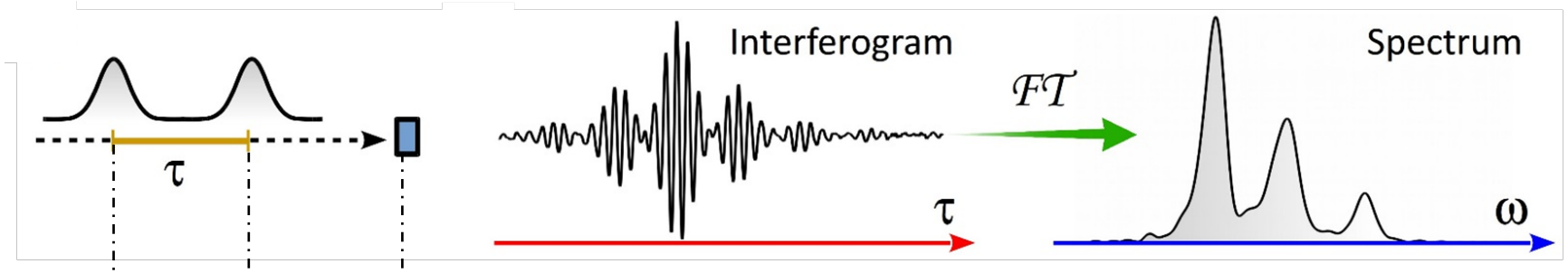
- *High stability and reproducibility*
- *High accuracy in the delay*
- *Compact*



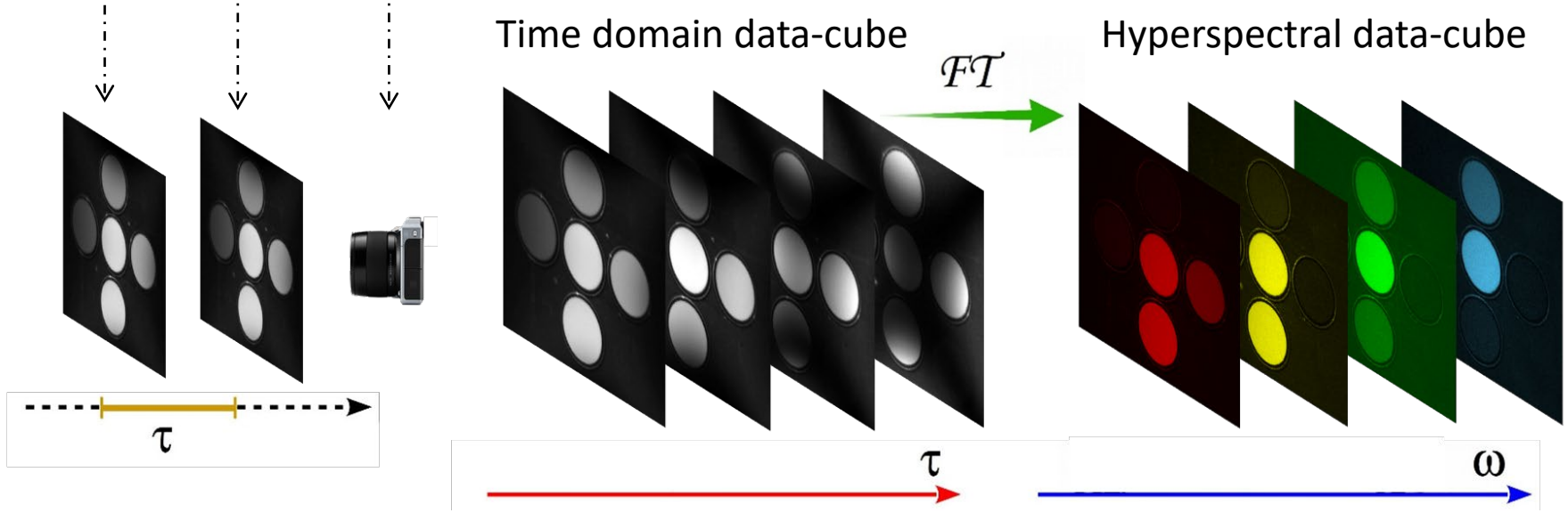
$$\tau = \frac{\left(d_b(x) - d_a\right)\Delta n}{c}$$

Fourier Transform Hyperspectral Imaging

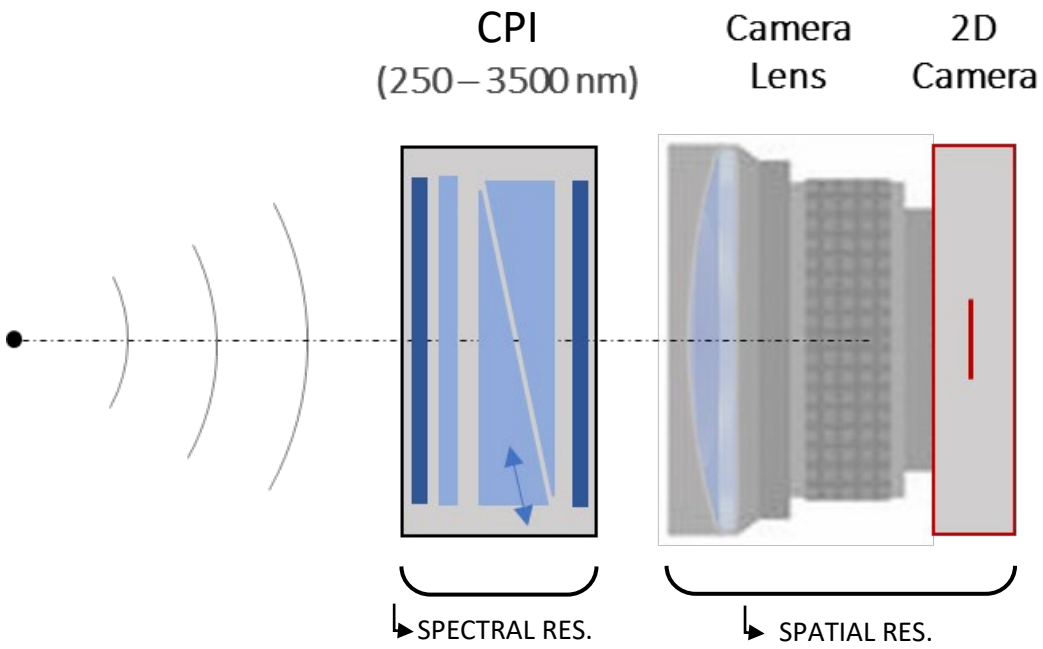
FTIR spectrometer
(single pixel detector)



FTIR Hyperspectral camera
(2D detector)



Scheme of the Hyperspectral Camera



Spectral range (limited by the sensor):

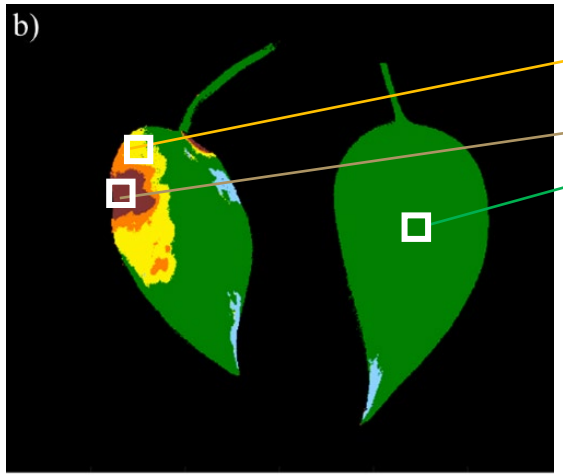
- 400 – 1000 nm (Si detector)
- 900 – 1700 nm (InGaAs detector)
- 1200 – 2300 nm (T2SL detector)
- <u>400 – 1700 nm (Si + InGaAs)</u> NEW

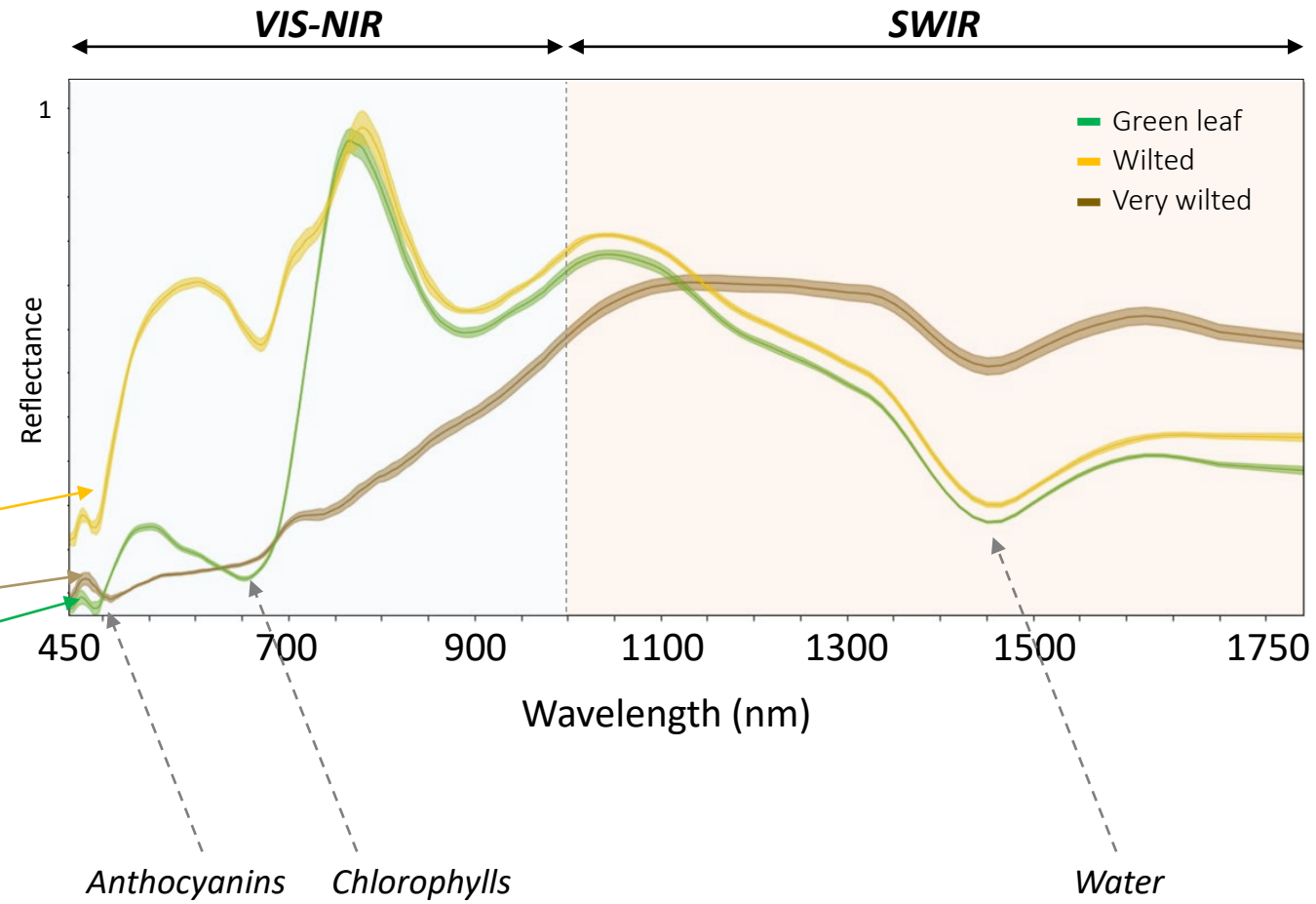
- **High Spatial & Spectral Resolution** (e.g. 1.3 Mpixel // <1.5 nm @400 nm)
- **Staring technique** → Ease of use & **Integration with commercial microscopes**
- No slit, no gratings → **High optical throughput** → **Fluorescence Hyperspectral Imaging**
- **Variable Spectral Resolution** (selectable via software) → Flexibility and versatility

VIS-SWIR Spectral Coverage

RGB projection

Spectral Angle Mapper (SAM)



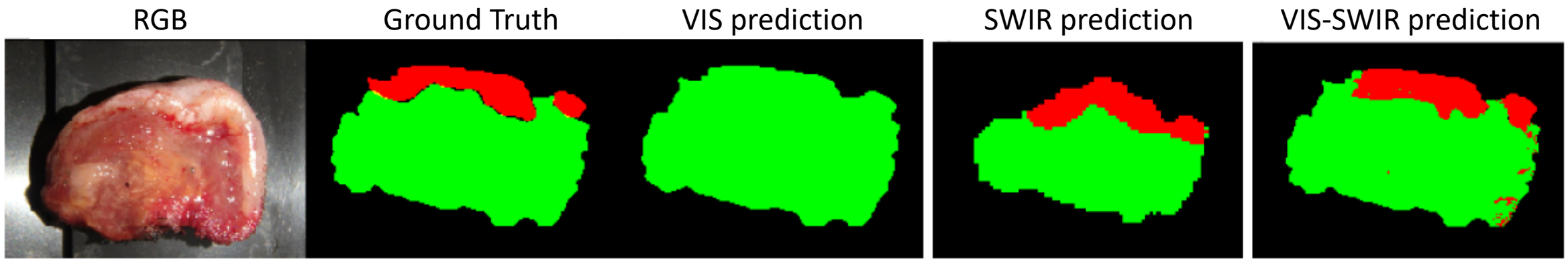


Importance of VIS-SWIR range in digital pathology

« VIS channels are generally more significant than *SWIR* for tumor segmentation.

However, there are cases where the *SWIR* channels are the most crucial and decisive for tumor segmentation,

while the tumor is not spotted by VIS channels »



S. Trajanovski, et al., "Tongue Tumor Detection in Hyperspectral Images Using Deep Learning Semantic Segmentation," in IEEE Transactions on Biomedical Engineering, vol. 68, no. 4, pp. 1330-1340, April 2021

Hyperspectral Imaging in Microscopy – Transmission

Hyperspectral Camera (400-1000 nm) coupled with an Olympus CX43 microscope

Sample: **unstained fresh-frozen oral squamous cell carcinoma** tissue *

Modality: transmission geometry

Illumination: white LED (430 – 760 nm)

Sample size: 3 x 3.5 mm

Final datacube: 32 hyperspectral images

Spatial resolution: 0.6 μm/pixel; 1.3 Mpixel; 20x objective

Avg. Spectral resolution: 3 nm

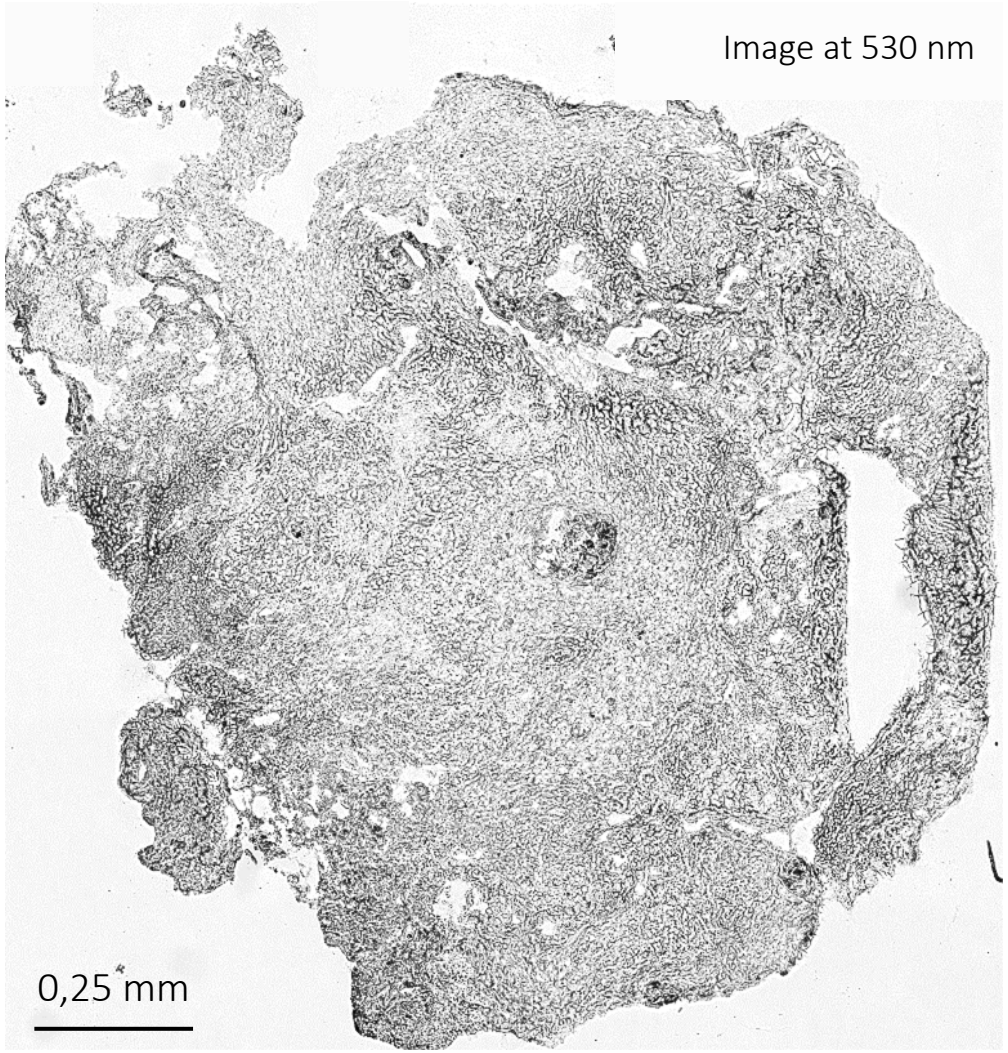
Integration time: 3 ms

Measurement time: 10 sec/image → ~5 minutes

**In collaboration with David Pertzborn and Franziska Hoffmann, Jena University Hospital and Matteo Negro and Benedetta Talone, Cambridge Raman Imaging*

Hyperspectral Imaging in Microscopy – Transmission

Hyperspectral, Unstained (**32 images, 18 GB data**)



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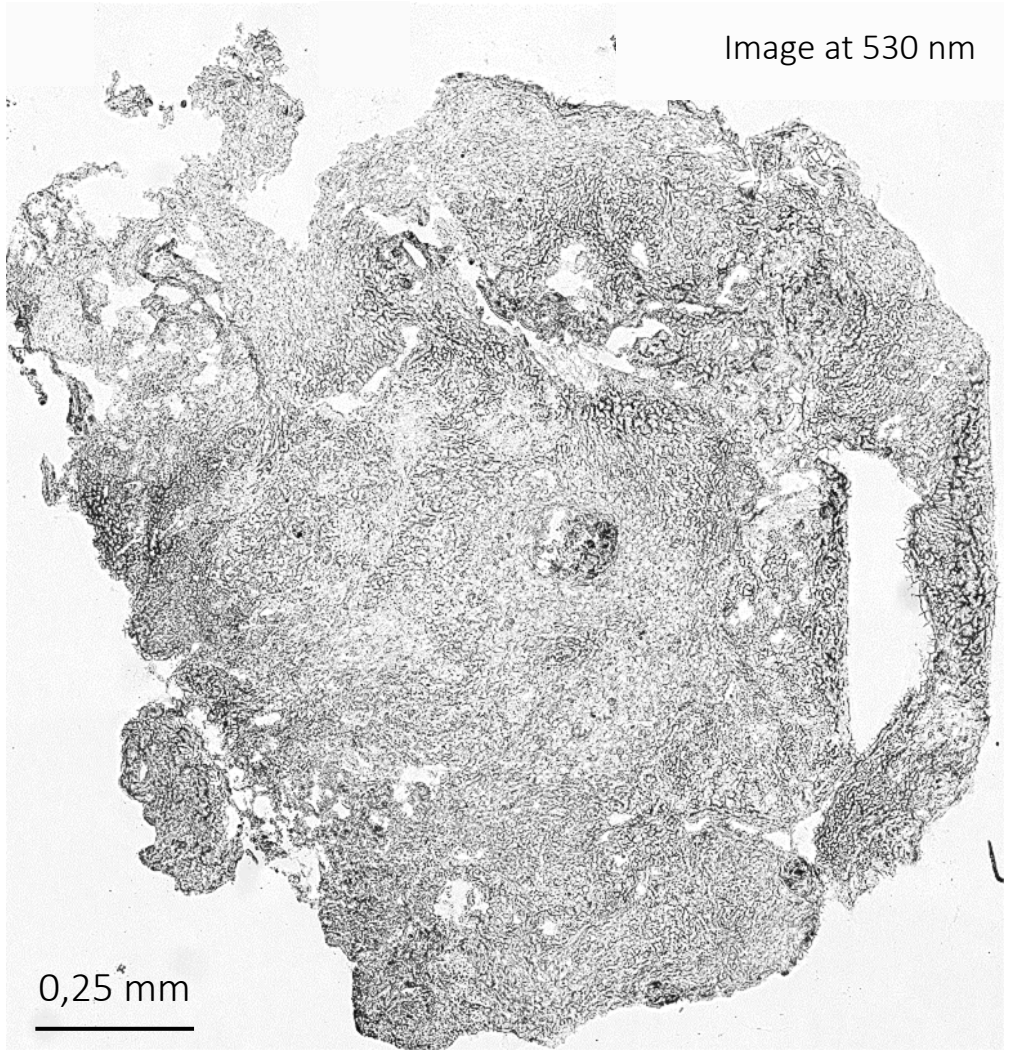
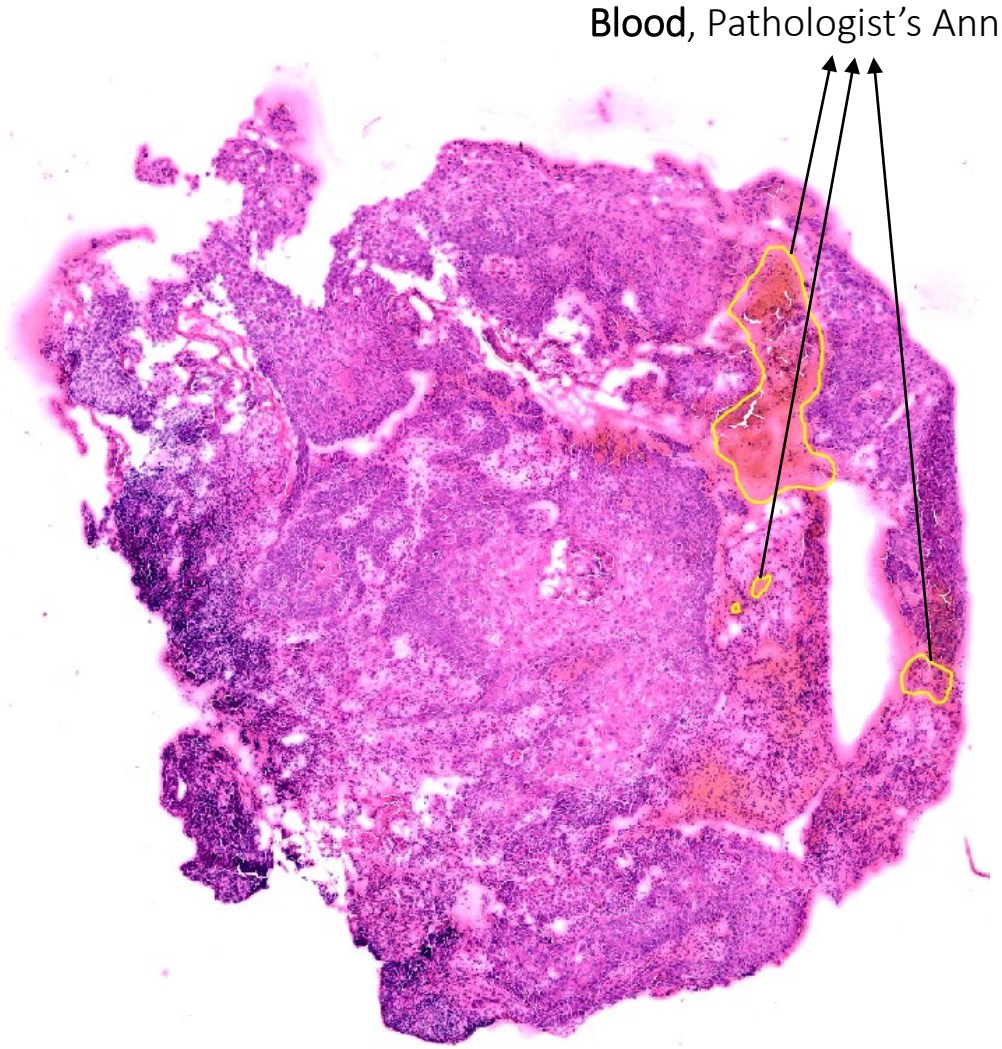


RGB, H&E stained



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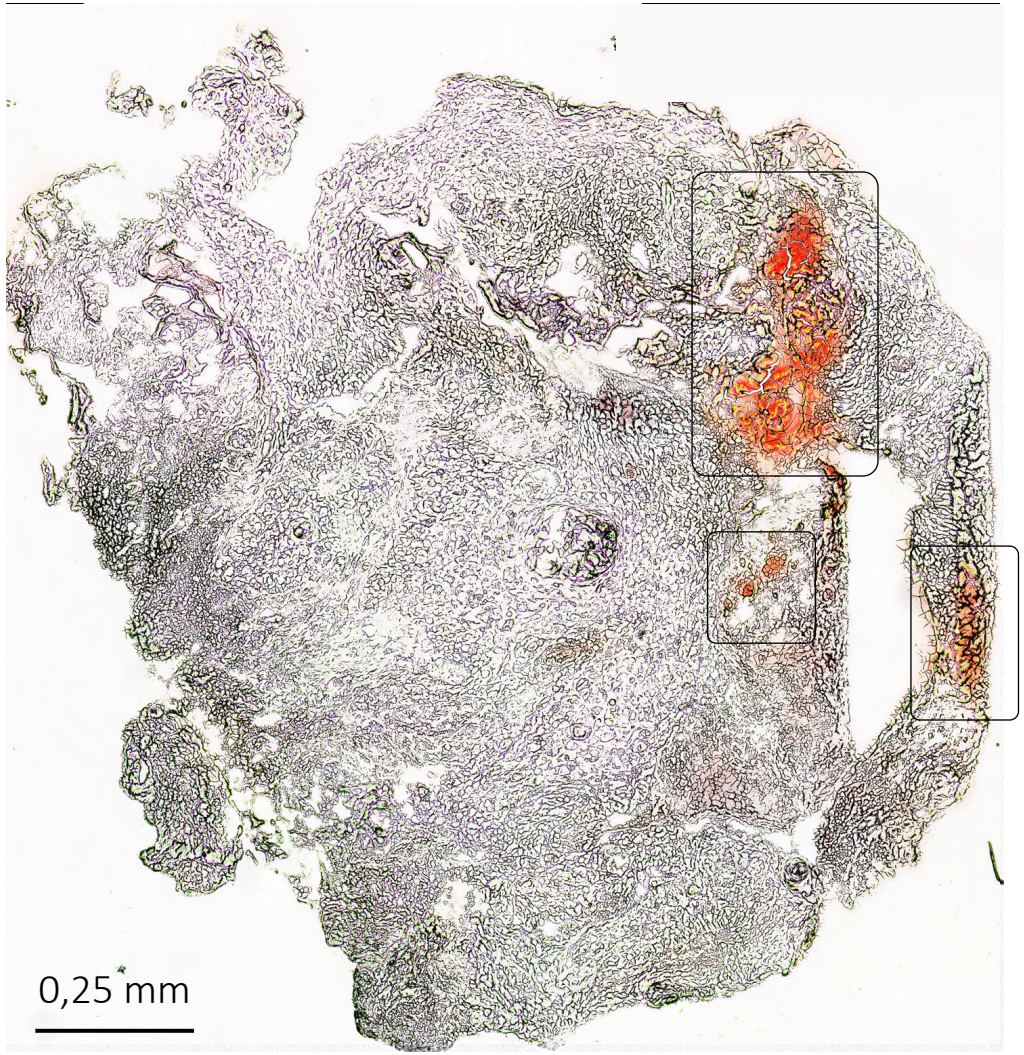
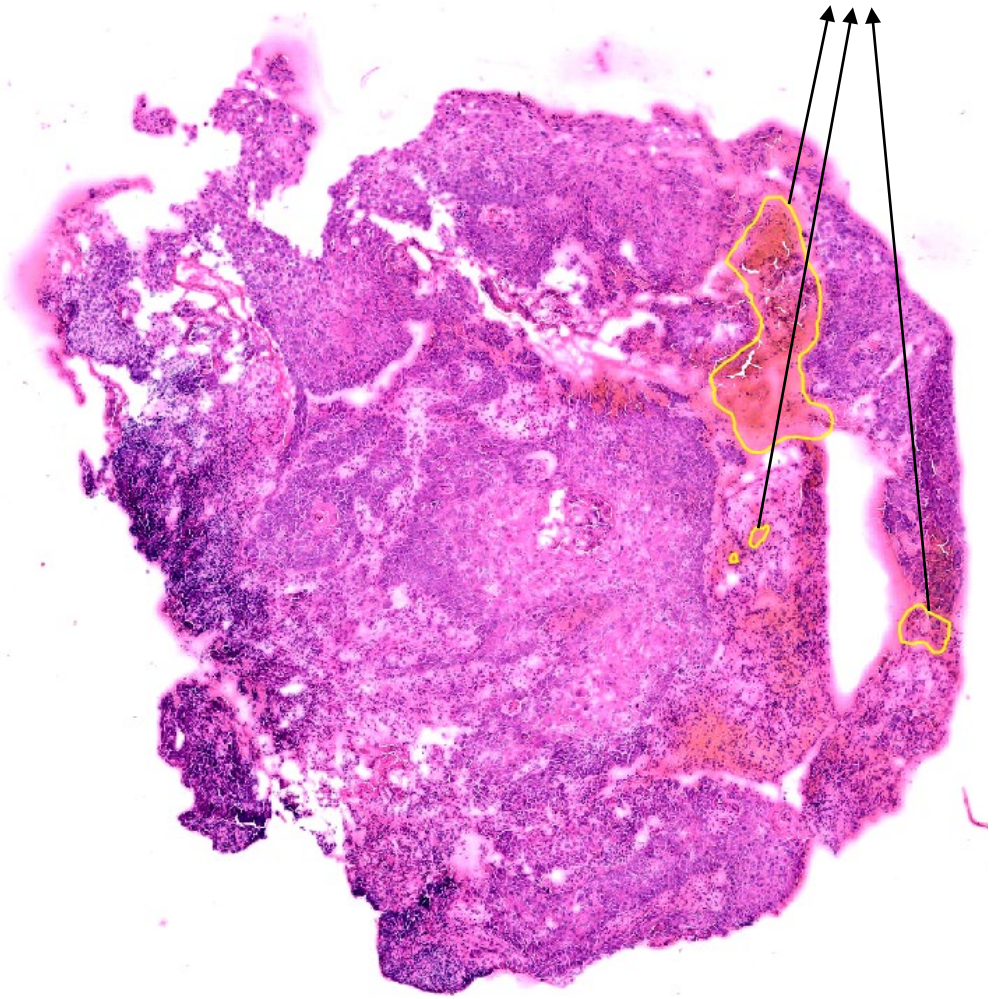


RGB, H&E stained

Blood, Pathologist's Annotation



Hyperspectral Imaging in Microscopy – Transmission

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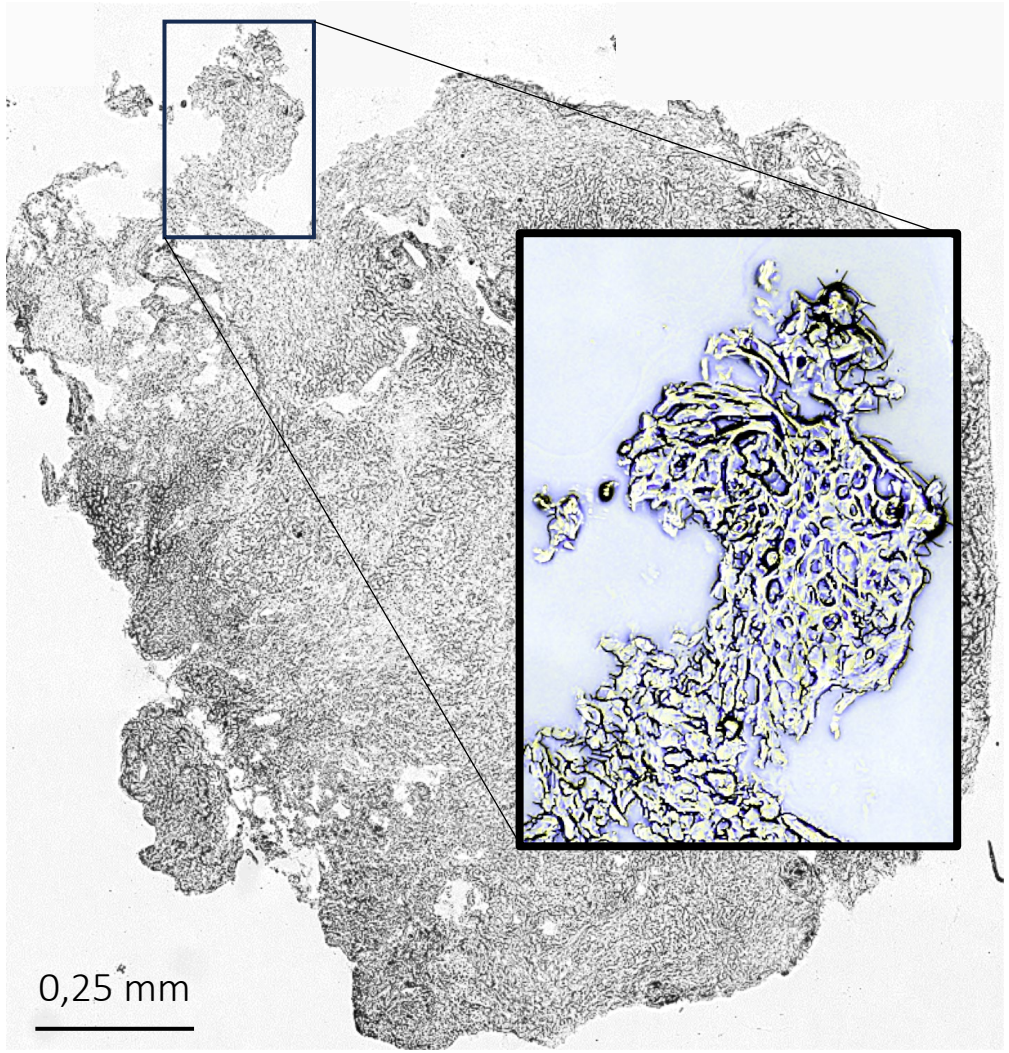
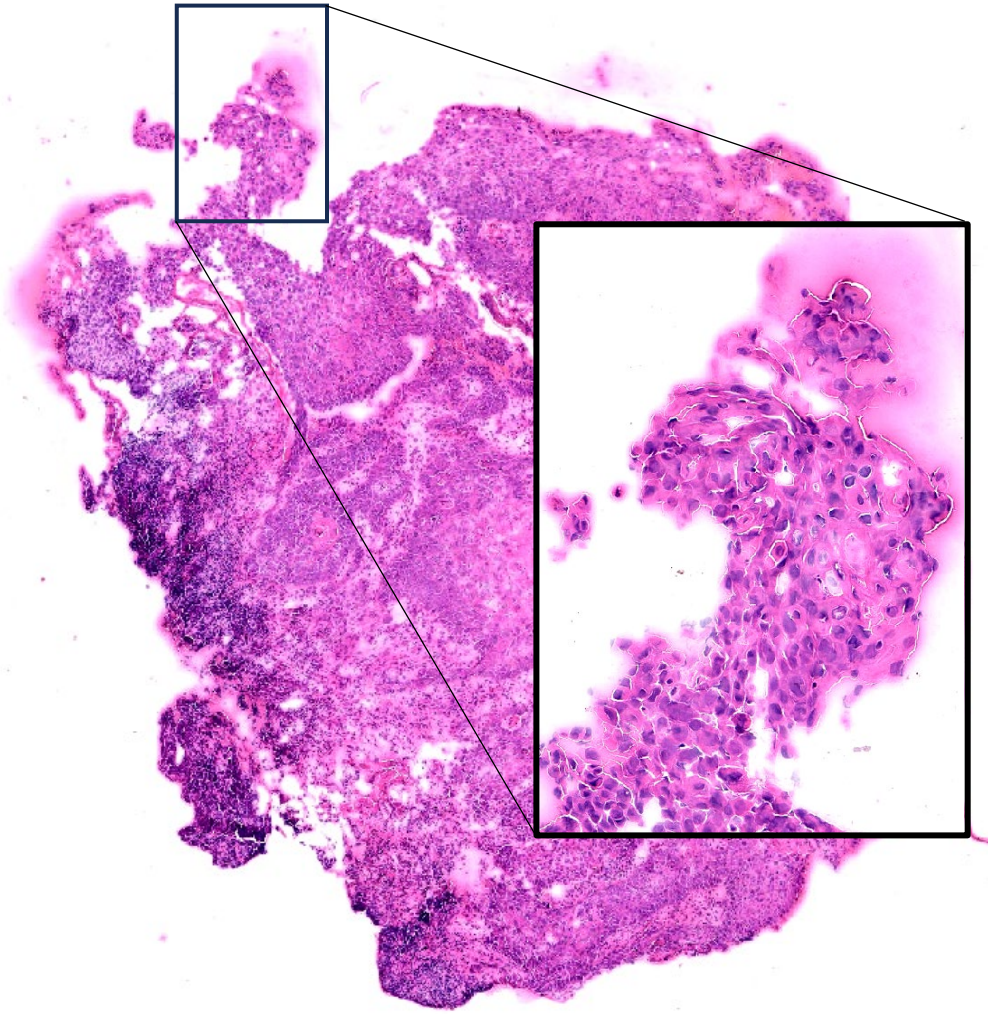


RGB, H&E stained



Outlook

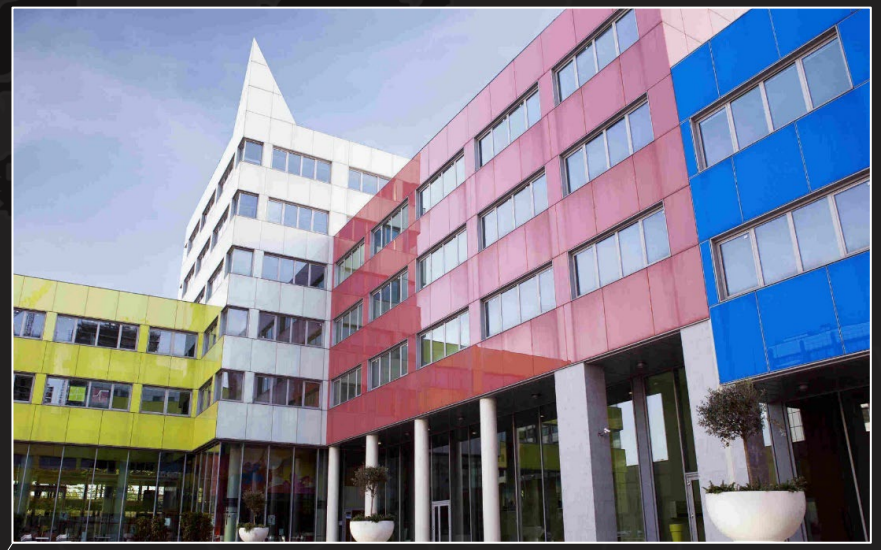
- **Novel Hyperspectral Technology**
  - Great Spatial & Spectral Resolution
  - High Light Throughput → Fast measurements and auto-fluorescence
  - Easy coupling with commercial microscopes

- Next step: extensively exploit the **VIS-SWIR range (400-1700 nm)**

- **Integration in DIGITAL PATHOLOGY**, as an additional tool for intraoperative tumour margin detection on **unstained** specimens.

- Could be combined with other optical techniques, such as Raman Spectroscopy (point-like but more accurate)

Thanks for the attention



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