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25.04.2024

OPTIMIZING SPECTRAL SYSTEMS: PRACTICAL DESIGNS FOR AGRITECH APPLICATIONS

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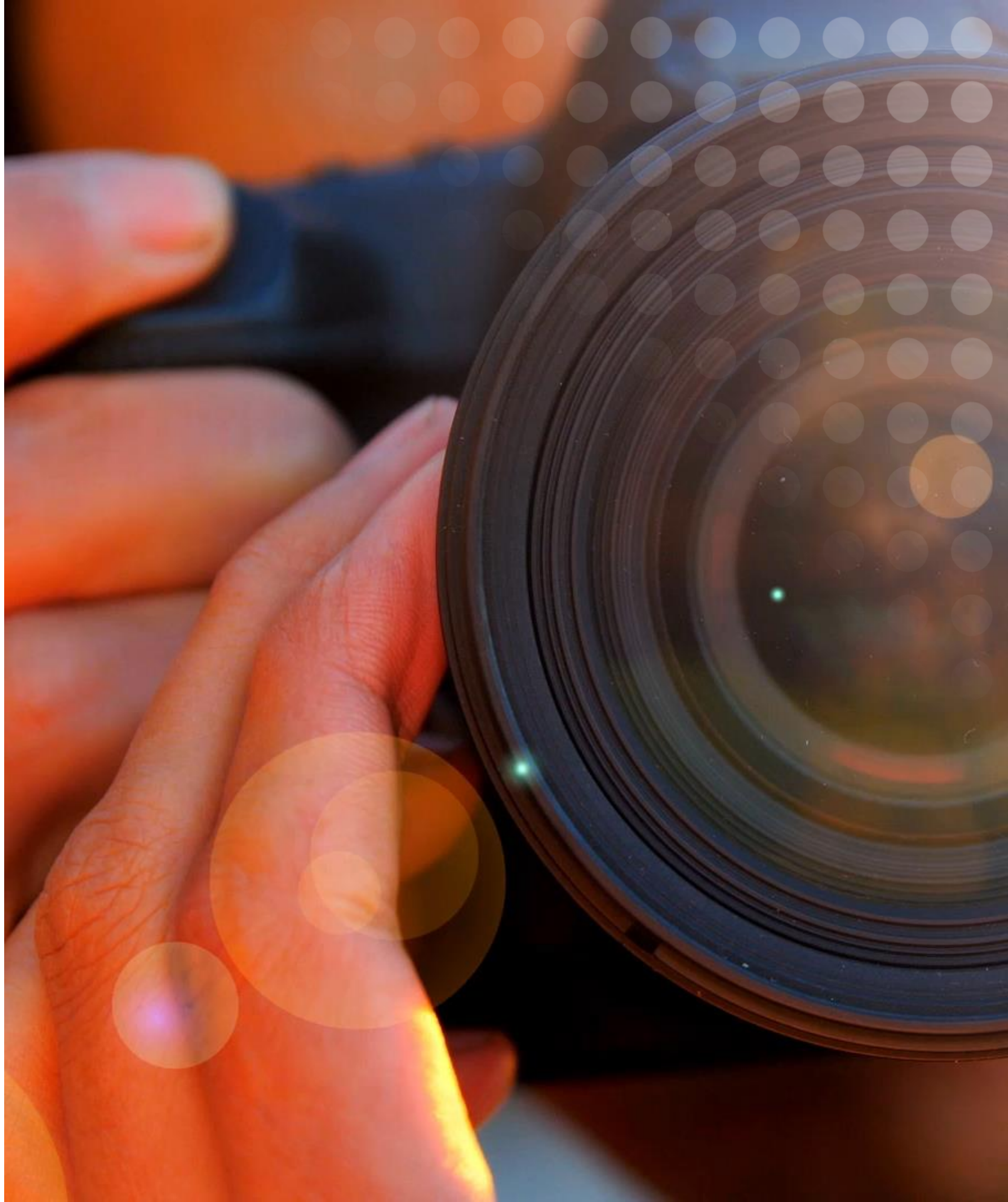

CSEM AT A GLANCE

We are a public-private, non-profit, Swiss **technology innovation center**.

We enable competitiveness through innovation by developing and transferring world-class technologies to industry.

1984
FOUNDED

> 600
SPECIALISTS

>100
MIO TURNOVER

225
CLIENTS

> 50
VENTURES
since 1984

> 200
PATENTS
maintained

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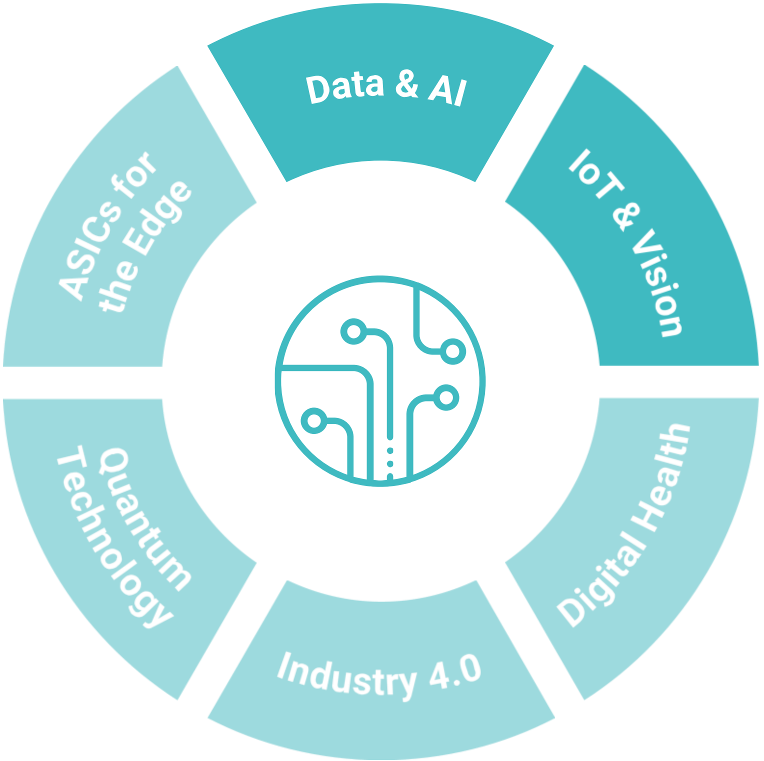
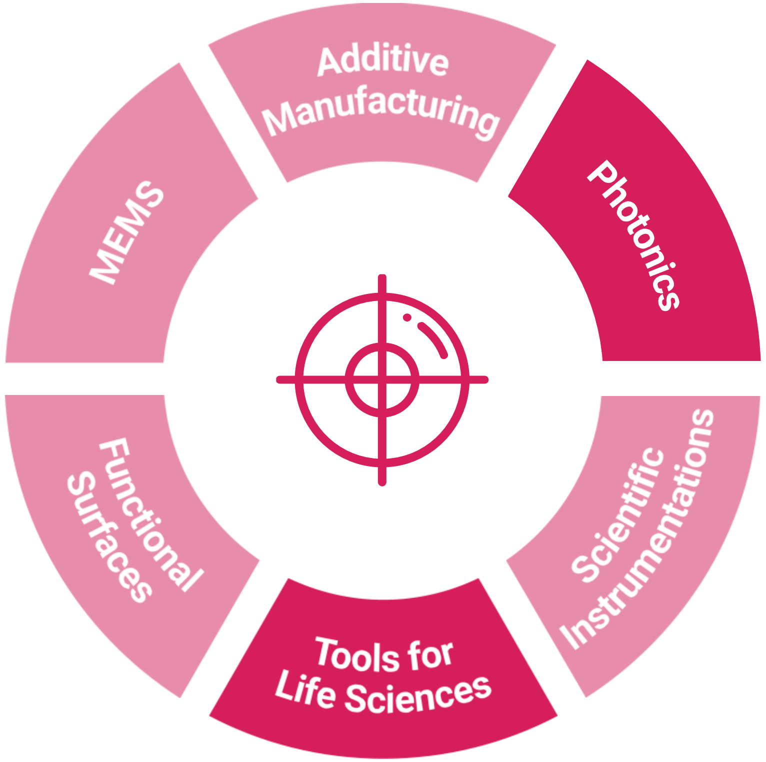
DYNAMIC RESEARCH FOR DYNAMIC INDUSTRIES: EVOLVING TO MEET THE NEEDS

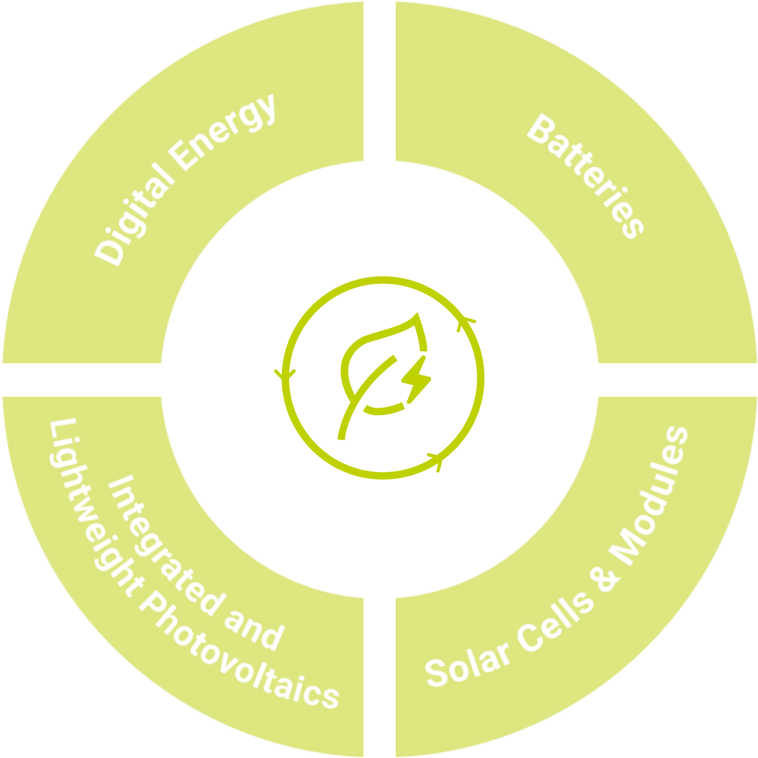
Digital Technologies



Precision Manufacturing

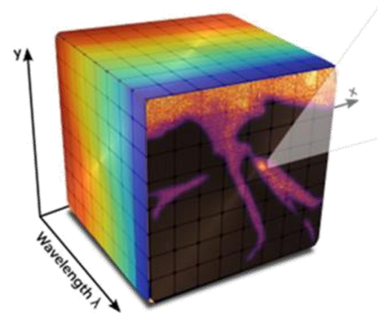


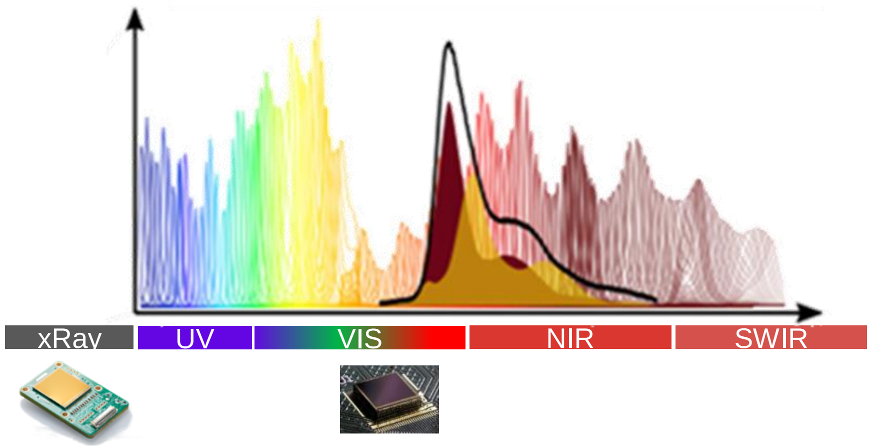
Sustainable Energy



SPECTRAL IMAGING

- Beyond what is visible through spectral decomposition





Chemical imaging

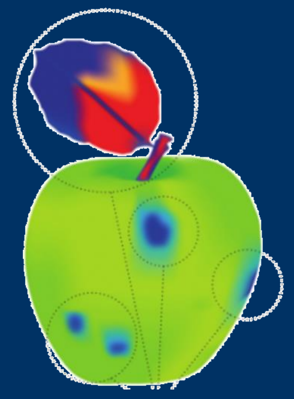
Plant phenotyping

Medical Imaging

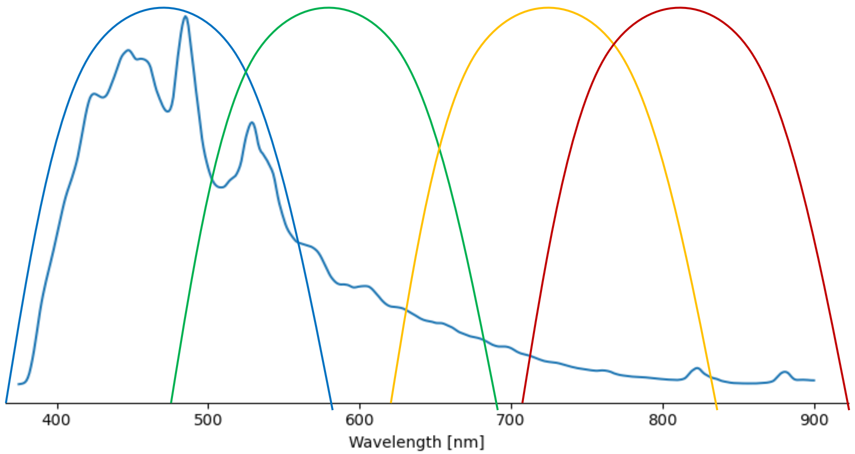
Food Processing

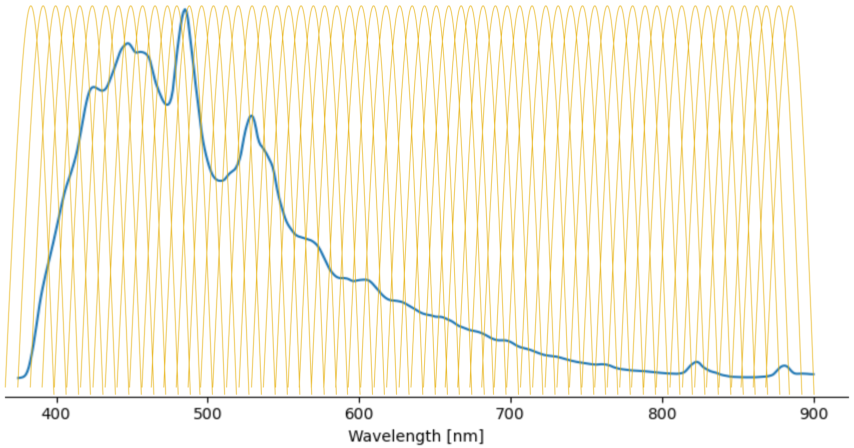
Gas imaging*

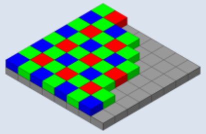
Water Pollution



SPECTRAL IMAGING TECHNOLOGIES





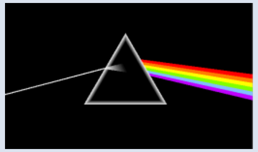


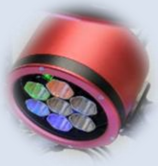
Pixel filters

Vignette filters

Structured light

FTIR





Illumination

Filter wheel

Push-broom

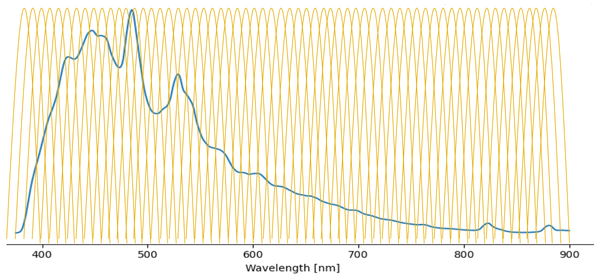
SYSTEM DESIGN: TRADEOFFS

Spectral discrimination power

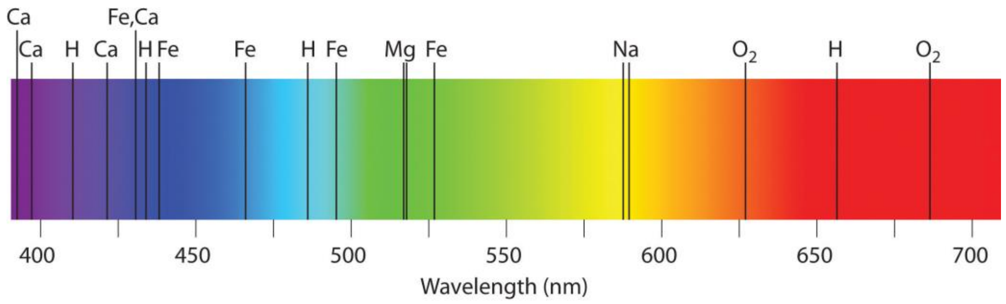
- Spectral resolution
- Spatial resolution
- Acquisition time
- Cost
- Size
- Complexity
- Versatility

DESIGN CHOICES

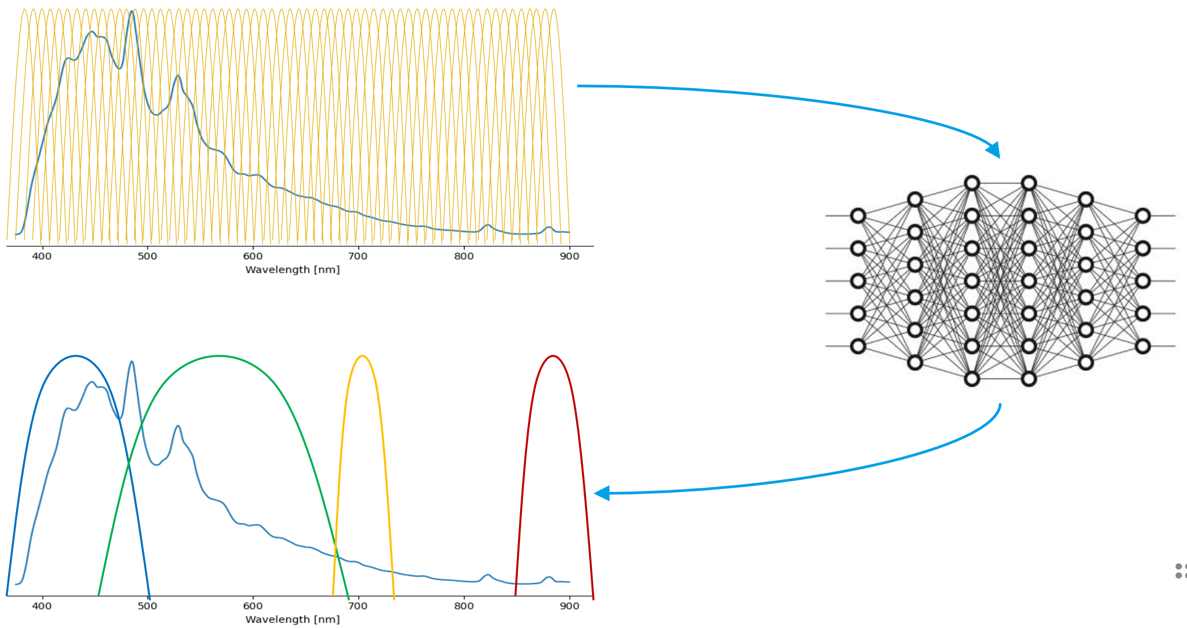
- Maximize coverage and sampling
  - Snapshot impossible



- Target specific wavelengths
  - Needs physical modeling
  - SNR issues



- Iterate for best cost/performance ratio
  - Leverage AI for optimal design
  - Adopt alternative designs



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ILLUMINATION VS SENSING

- Hyperspectral illumination:
  - Usually cheaper
  - Subject to light contamination
- Hyperspectral sensing:
  - Can do snapshot imaging
  - More complex

Why not both?

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ILLUMINATION VS SENSING

- Hyperspectral illumination:
  - Usually cheaper
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- Hyperspectral sensing:
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Why not both?

➔ Spectral mixing-unmixing:

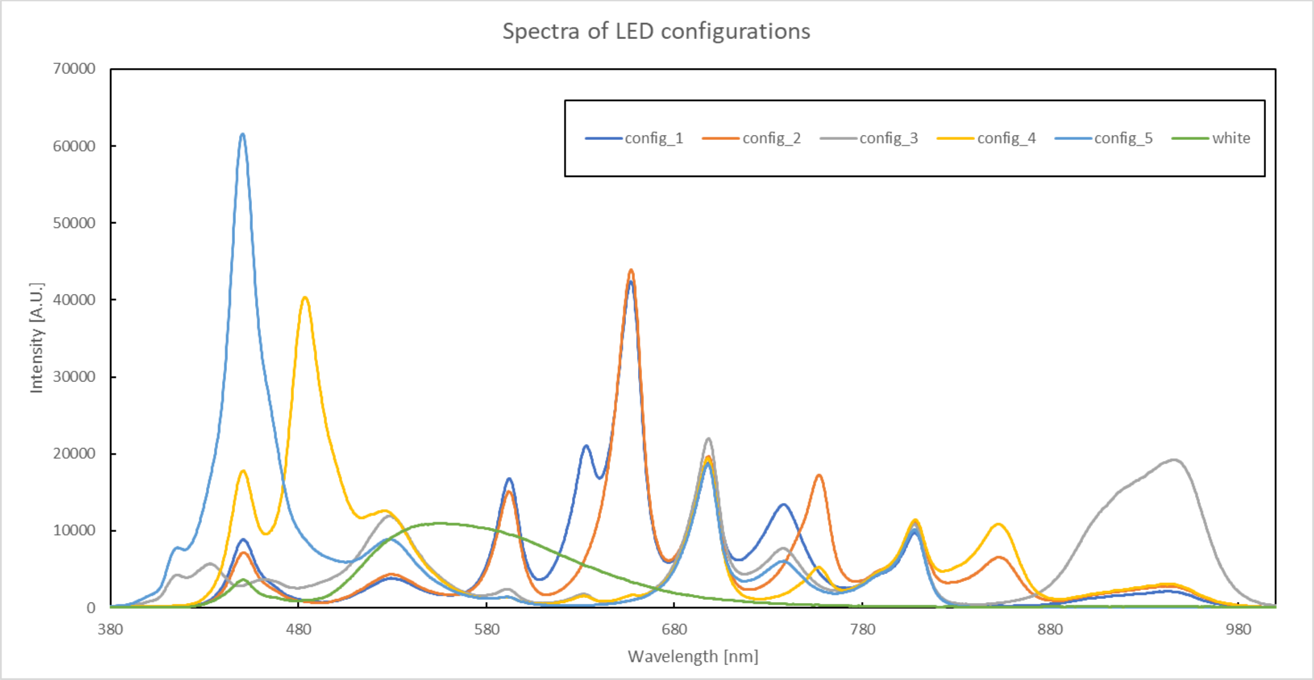
$$r = R(\lambda_1)L(\lambda_1) + R(\lambda_2)L(\lambda_2) + R(\lambda_3)L(\lambda_3)$$
$$g = G(\lambda_1)L(\lambda_1) + G(\lambda_2)L(\lambda_2) + G(\lambda_3)L(\lambda_3)$$
$$b = B(\lambda_1)L(\lambda_1) + B(\lambda_2)L(\lambda_2) + B(\lambda_3)L(\lambda_3)$$

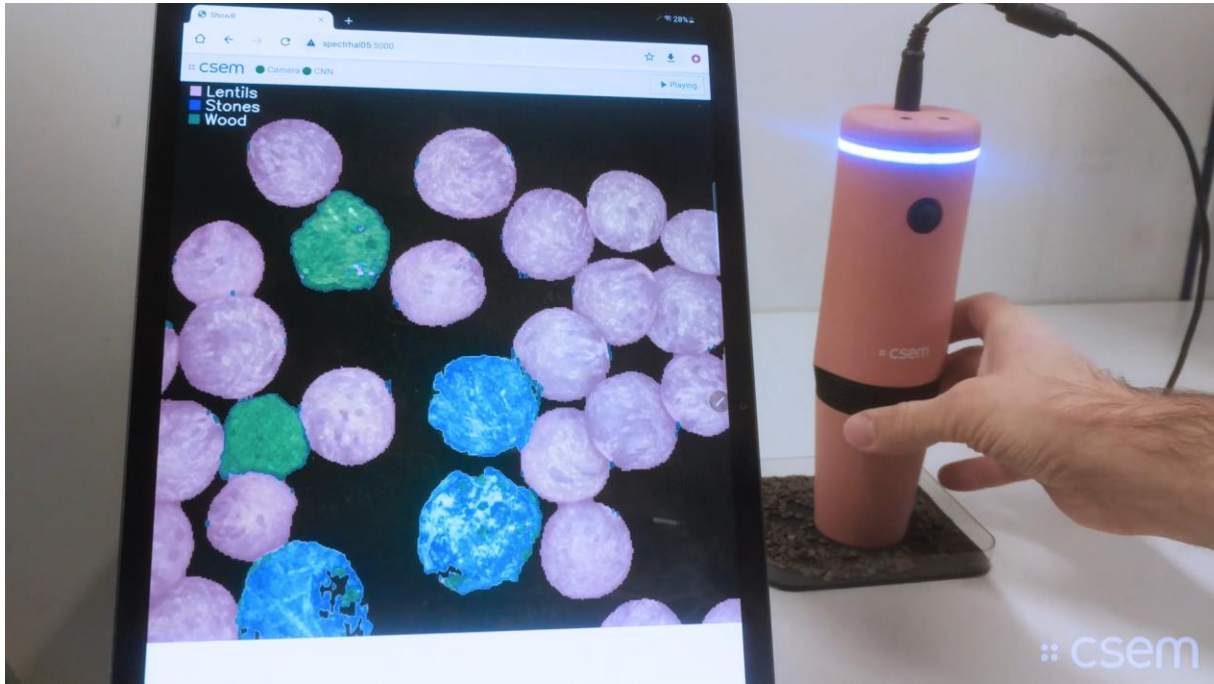
$$\begin{pmatrix} r \\ g \\ b \end{pmatrix} = \begin{pmatrix} R(\lambda_1) & R(\lambda_2) & R(\lambda_3) \\ G(\lambda_1) & G(\lambda_2) & G(\lambda_3) \\ B(\lambda_1) & B(\lambda_2) & B(\lambda_3) \end{pmatrix} \begin{pmatrix} L(\lambda_1) \\ L(\lambda_2) \\ L(\lambda_3) \end{pmatrix}$$

$$\begin{pmatrix} L(\lambda_1) \\ L(\lambda_2) \\ L(\lambda_3) \end{pmatrix} = \begin{pmatrix} R(\lambda_1) & R(\lambda_2) & R(\lambda_3) \\ G(\lambda_1) & G(\lambda_2) & G(\lambda_3) \\ B(\lambda_1) & B(\lambda_2) & B(\lambda_3) \end{pmatrix}^{-1} \begin{pmatrix} r \\ g \\ b \end{pmatrix}$$

MIXING – UNMIXING: COMPRESSIVE SENSING EXAMPLE

- *Use case:* Foreign matter in lentils
- *System type*: Multispectral
- *Technology*: Multispectral illumination
- *Sensor type*: RGB
- *Number of acquisitions (**mixed**):* **5**
- *Number of bands (**unmixed**):* **15**



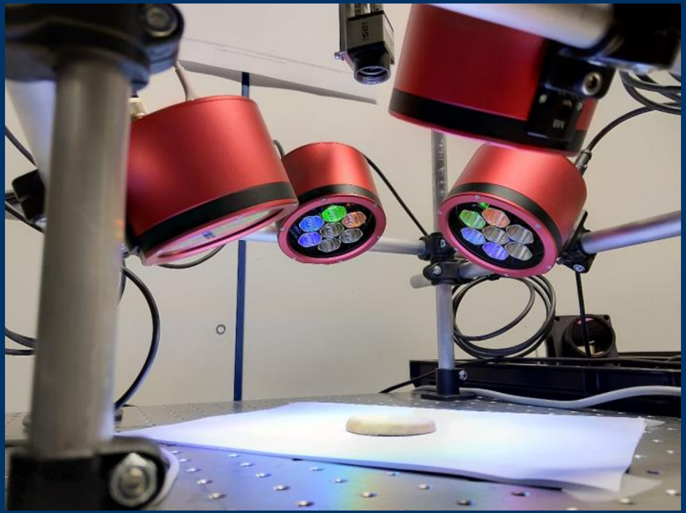


HYPERCOOK

Snapshot multispectral camera

In conjunction with custom high-power multispectral illumination system to suppress ambient parasitic light effect

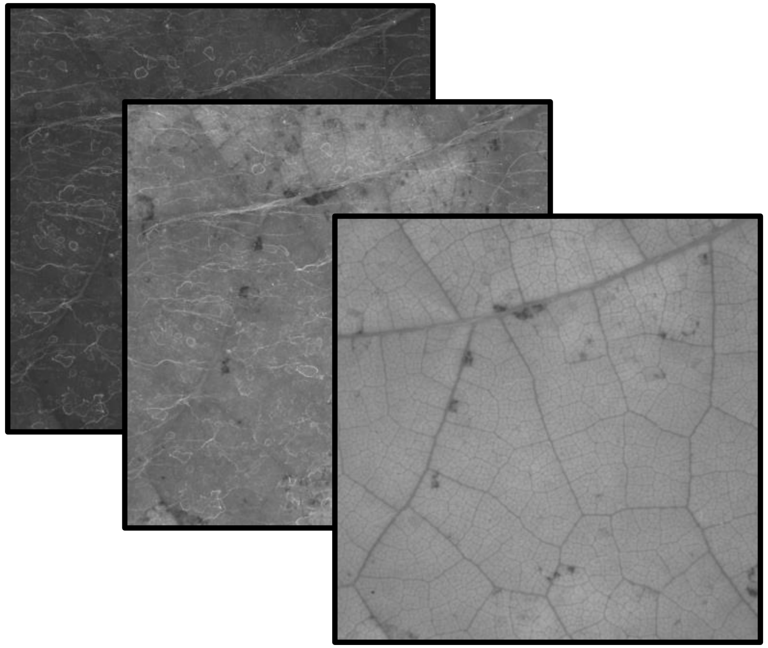
• Compact spectral camera	3^{cm} x 3^{cm} x 3^{cm}
• Multiple wavelengths	20 bands
• Spectral range	VIS+NIR
• Fast cube acquisition	60 fps
• Image resolution	350 x 350

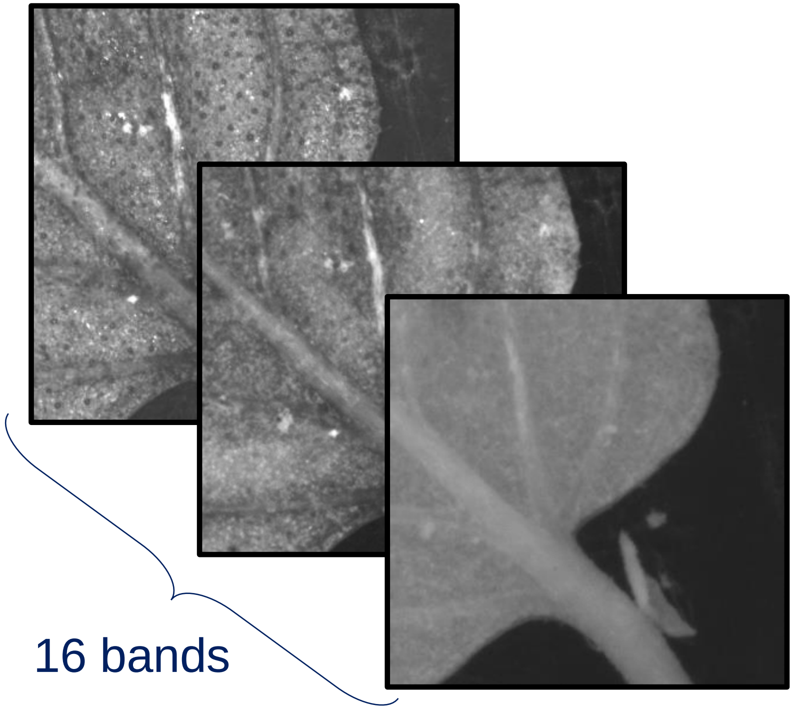


Optional multispectral illuminators

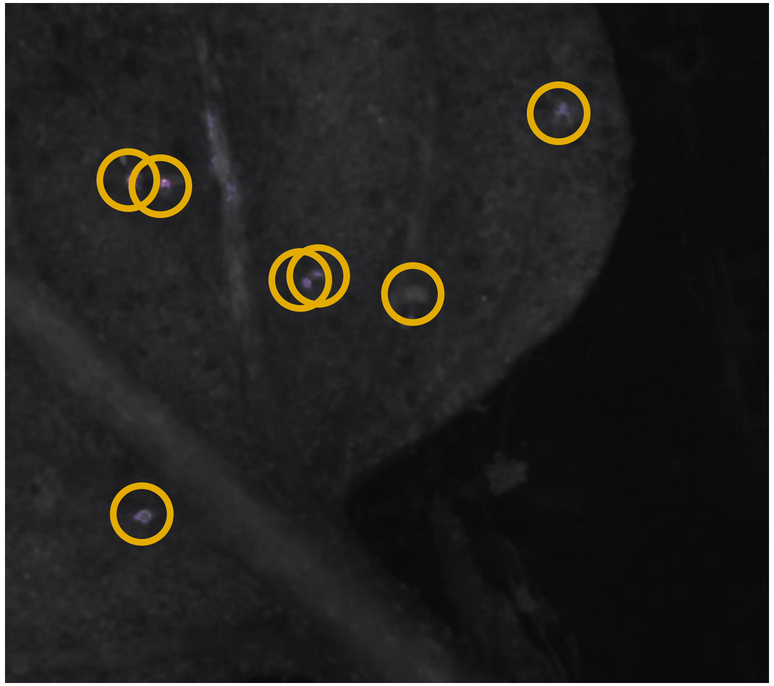
AGRARSENSE

- Downy mildew detection
- Pest detection
  - Aphids
  - Spider mites
  - Thrips
  - …
- Water stress detection
- Plant parts segmentation
  - Vine clusters
  - Vine grapes





16 bands



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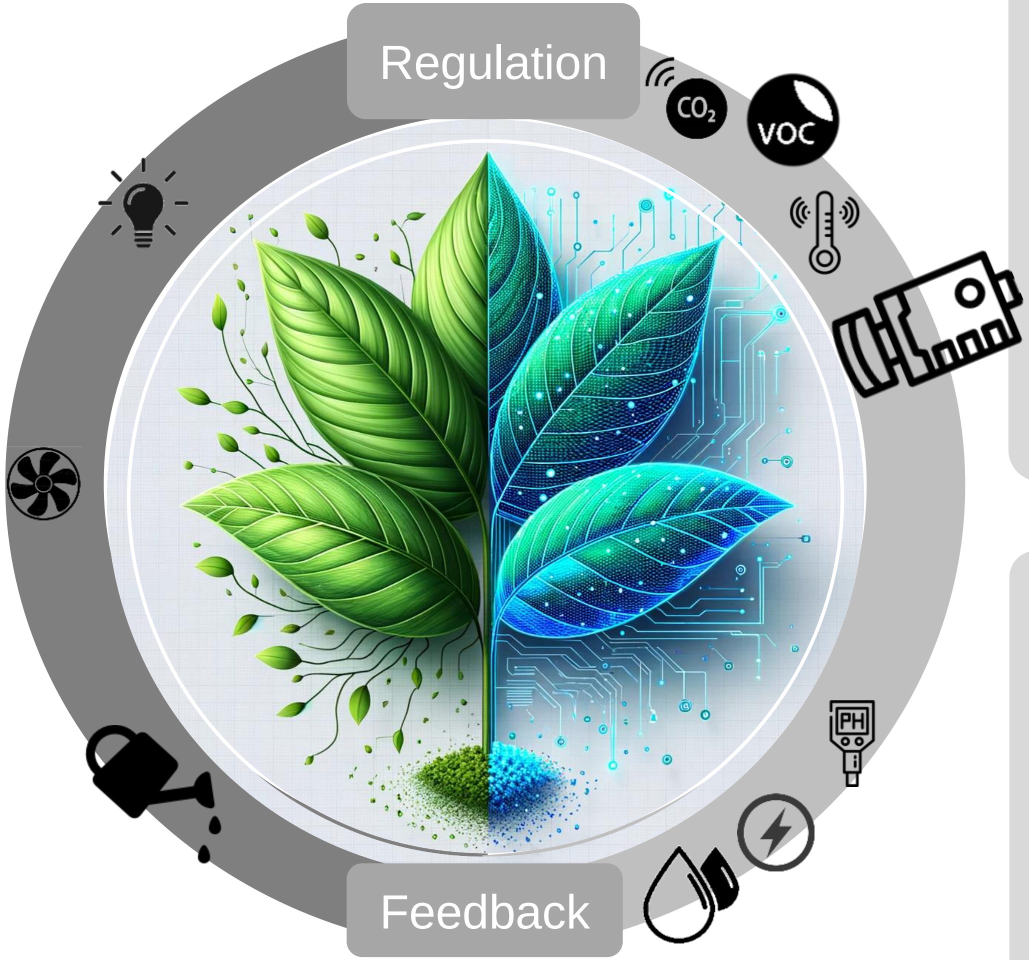
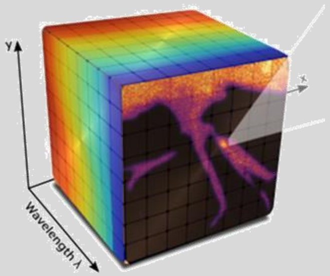
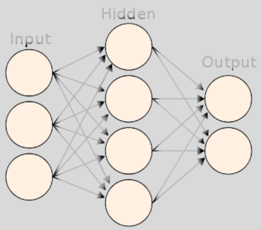
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

TOWARDS THE PLANT’S DIGITAL TWIN



Spectral imaging

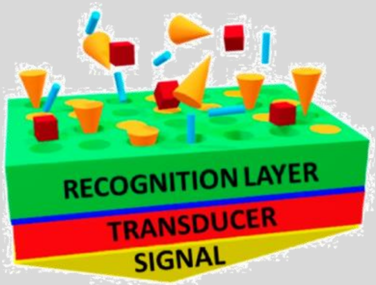


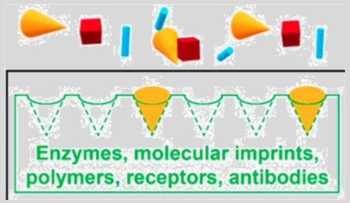


Plant Insight:

Physiological
Chemical
Stress levels

Electro-Chemical sensing





Water Insight:

Herbicide content
Antibiotic levels
Pesticide content

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FUTURE DIRECTIONS

- New optical designs coming soon
- Access to the low SWIR region (400 to 1700 nm) is now possible
- Open to collaboration on new use cases
- Looking out for implementation partners