SEAVISION

Unconventional machine vision techniques for industrial applications

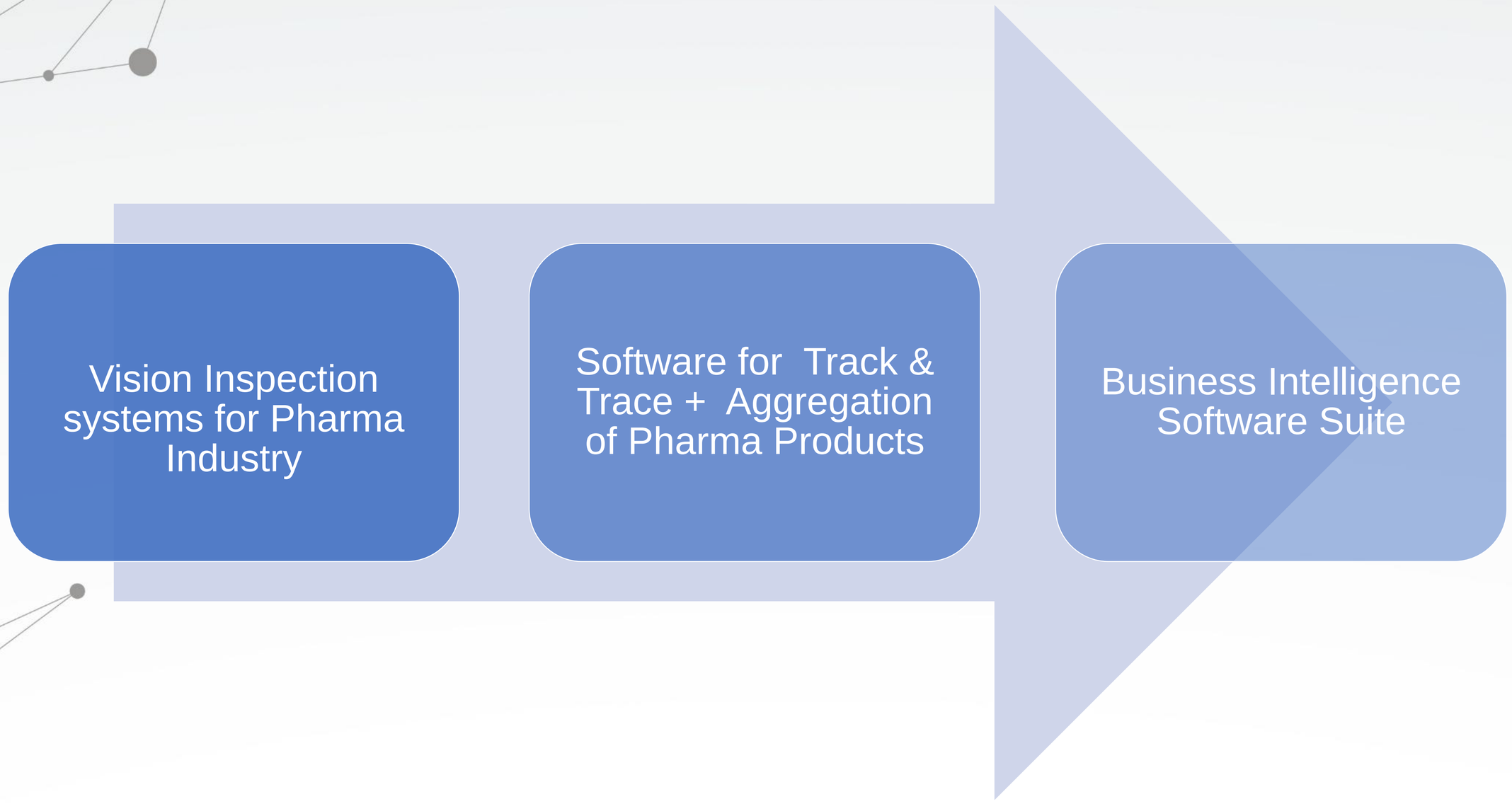
Study:
Physics Degree – Physics of Matter @Physic department of Milan
PhD – Physics of matter (Molecular Physic) @ Polytechnic University of Marche, Materials engineering department

Activities (from the past up to now)

- Interferometric systems at VIRGO (EGO) gravitational waves detector
- Non destructive inspection and materials characterisation with Neutrons/X-ray diffraction, tomography, small angle scattering
- Optical imaging and laser profilometry for industrial applications
- Spectroscopic methods for materials characterisation
- Hyperspectral methods for materials and pharmaceutical products analysis

Vittorio Calbucci
SEA Vision R&D Engineer

Area of business



Our History

SEAVISION

Company is founded — 1995

New Headquarter — 2004

Acquisition of Electronica (Spain) — 2006

RC

SEA Vision France is founded — 2007

Training Lab opening — 2013

2nd site is open in Pavia — 2015

New partnership in USA — 2015

HQ opening in Brasil — 2017

New partnerships in Russia, India, Korea, Taiwan, Pakistan — 2017

Marchesini Group acquires 48% of SEA Vision — 2018

Acquisition of 8% of the minority shareholding of cmp — 2018

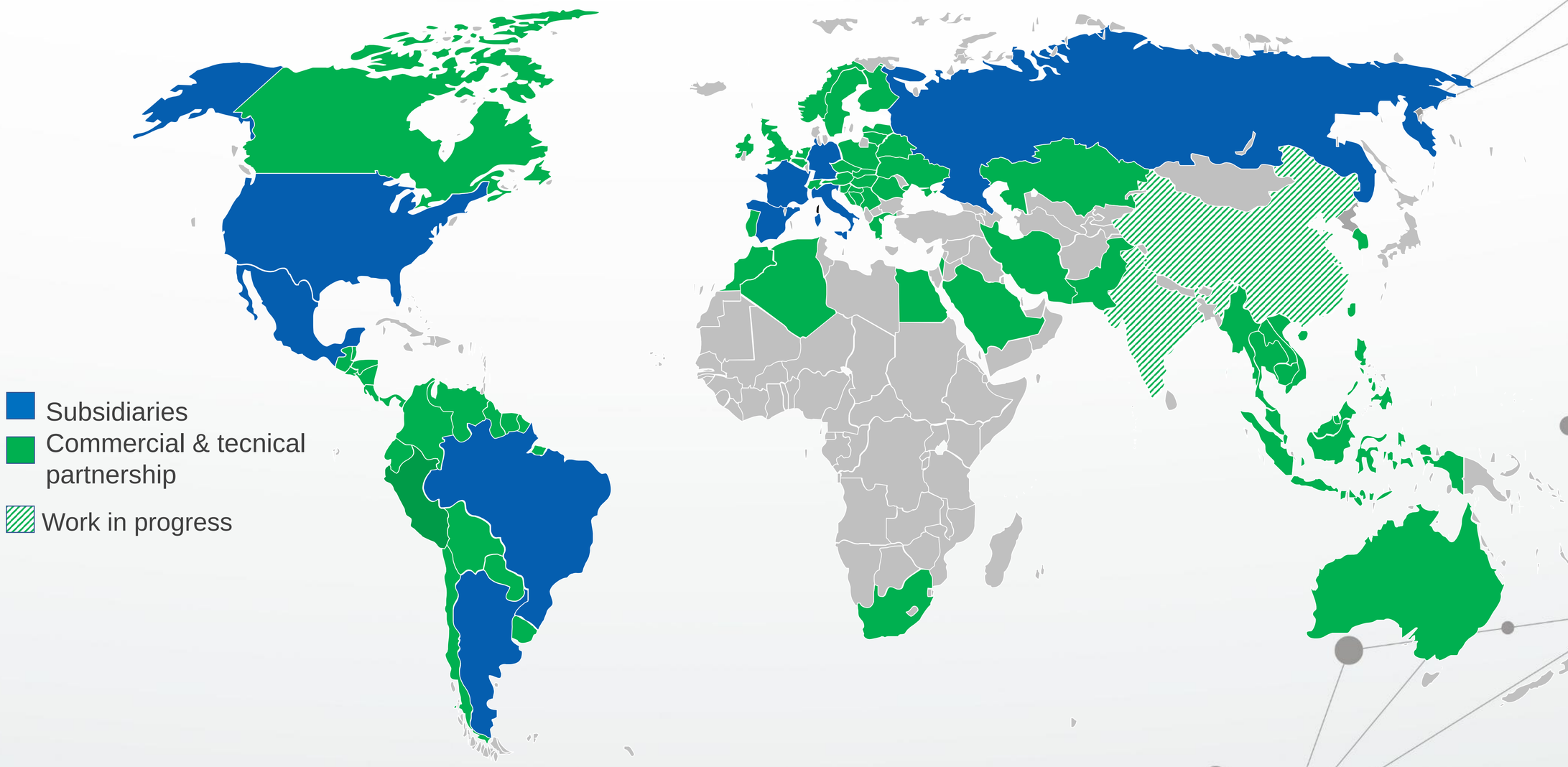
New Subsidiaries in Germany, Russia and USA — 2018

3rd site is open in Pavia (Warehouse) — 2018

Acquisition of 100% of LIXIS **(LATAM)** — 2019

First stone of the new HEADQUARTER in Pavia — 2019

Today global reach



Employees and Sales results

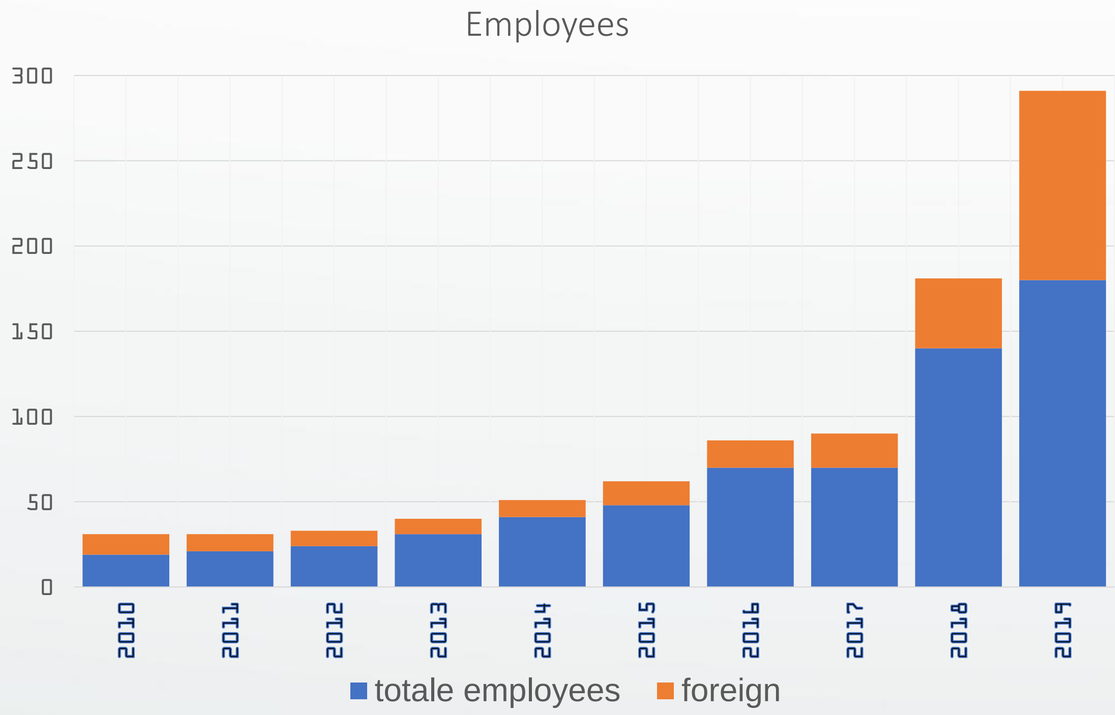
Our staff expertise combined with a proportional staff growth rate ensure customers the highest level of service.

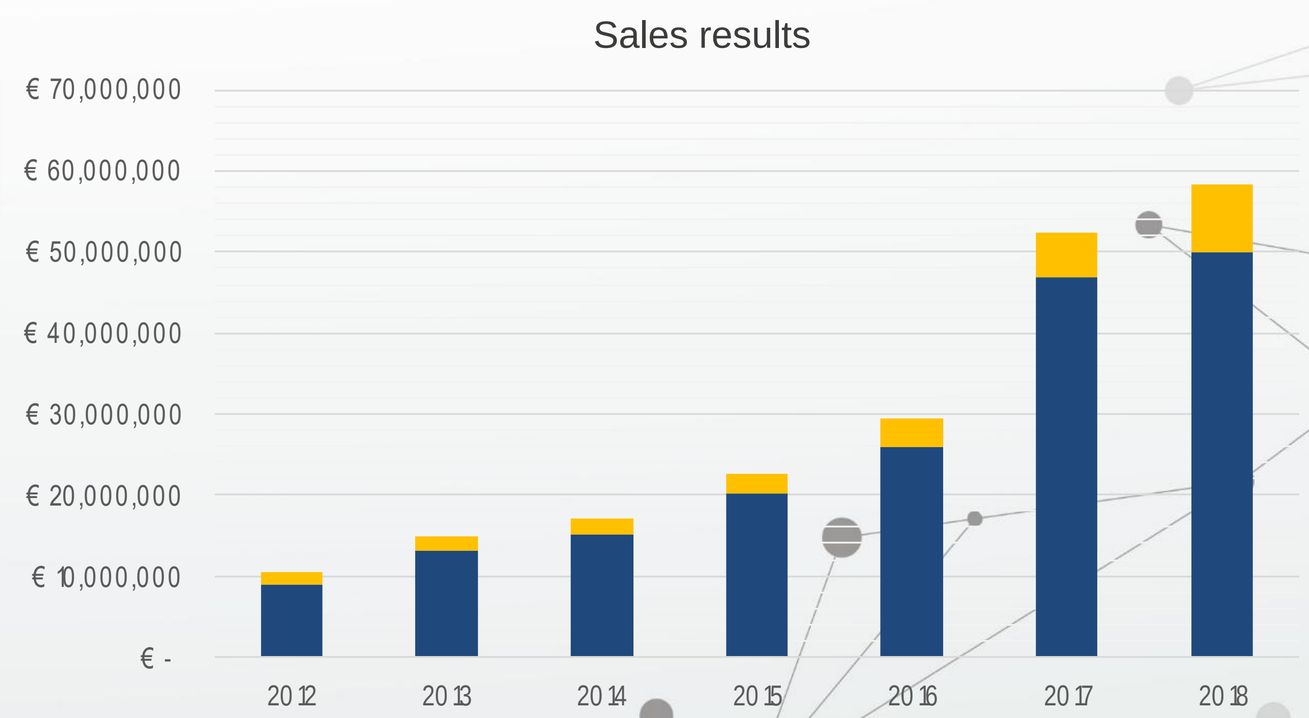
175
Italy

60
Abroad

70
LIXIS

295
Total





SEA Vision Products

HARLEQUIN

vision software
for the qualitative and
quantitative control of
pharmaceutical products

HARLENIR

vision software
for the chemical
composition inspection
of pharma products

OCV

solutions for the
traceability of the drug
along the distribution chain
and vision qualitative
control

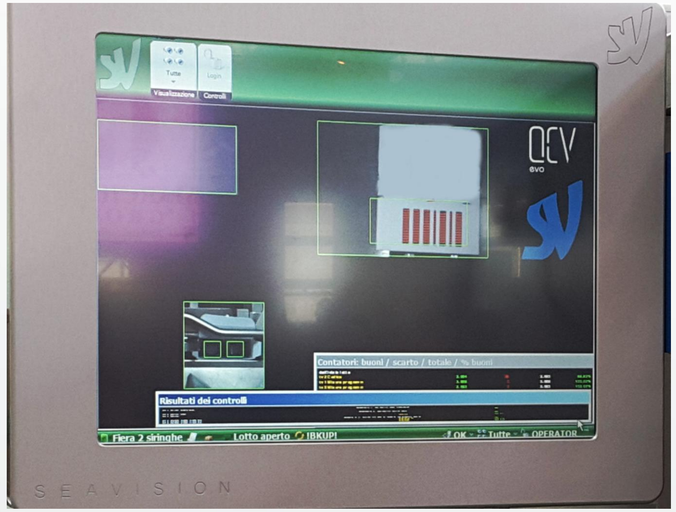
YUDOO

modular suite software for the
management of optical drug
production lines 4.0 including
data collection, data analytics
and business intelligence

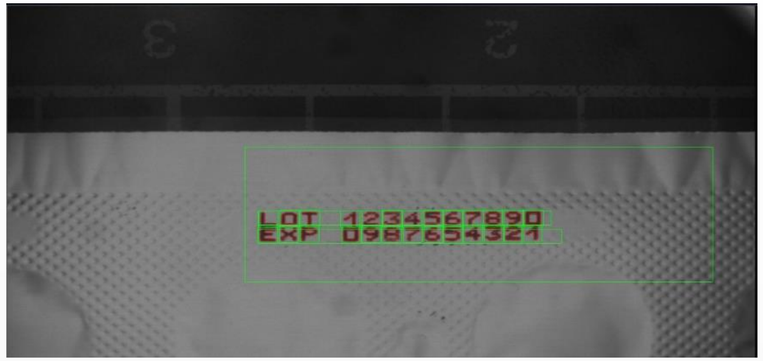
OCV

OCV is our vision system that can be adapted to basically any kind of control requested in the primary and secondary packaging process.

On of the most powerful tools of the OCV are **serialization / aggregation** and the **programmable measure**.

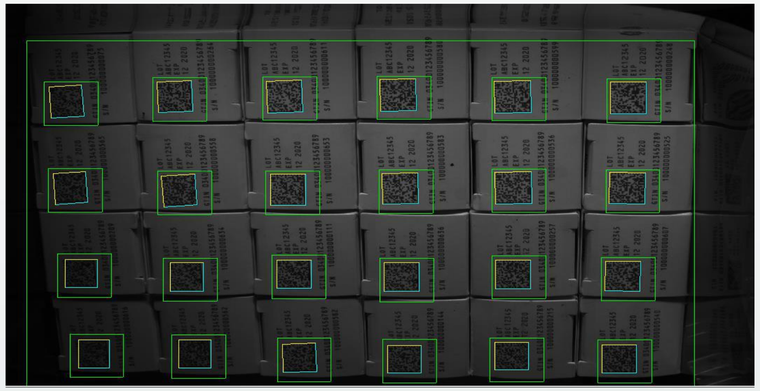


OCV - Serialization and Aggregation

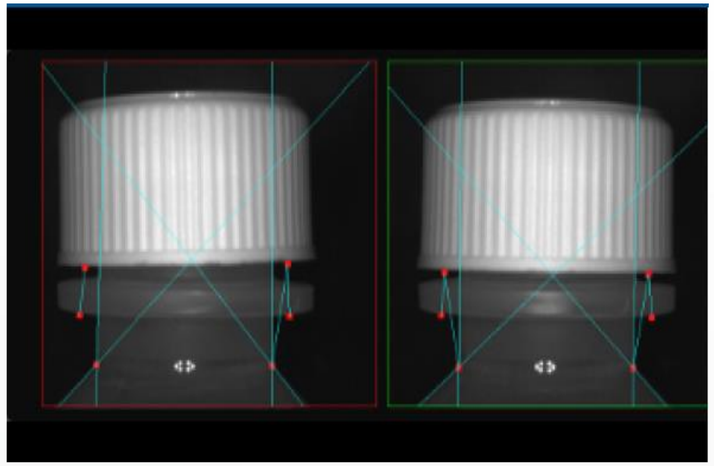


OCV is the platform that we use for **serialization and aggregation application.**
In addition can operate:

- Real time printer management
- Real time operations
- Remote Batch connector (Start,Stop,Hold,etc…)
- In Batch Rework operation
- Adaptable configuration for manufacturing process

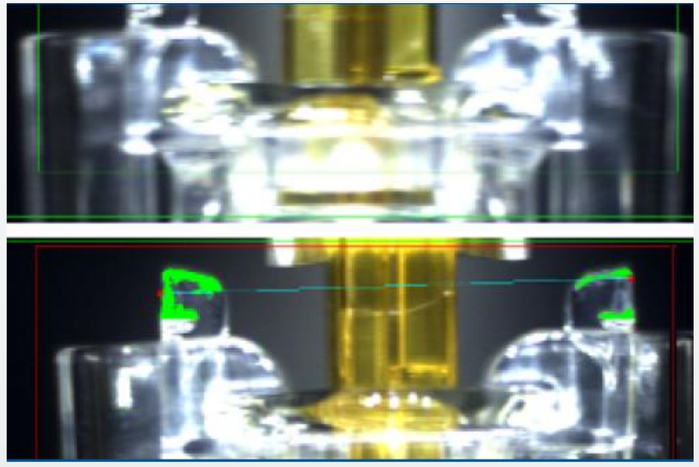


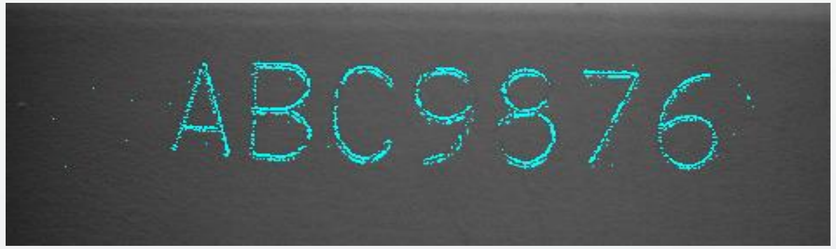
OCV - Programmable Measures



Programmable Measures are a library of simple image processing tools (edge detection, blob detection, extraction of pixels, distance calculation…), allowing the operator to create a customized application for image analysis with specific acceptance conditions.

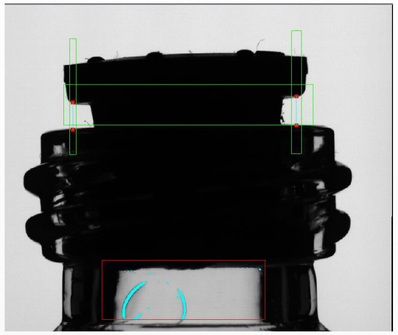
This tool is very powerful because allow us to create for a standard library of algorithm a step-by-step control that may have multiple check build inside.





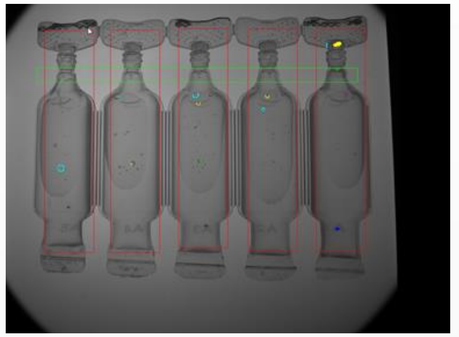
OCV - Integrity Checks

OCV was developed back in the days for code reading and OCV/OCR controls.

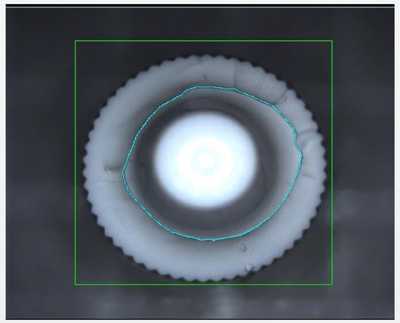


Cap Position and glass scratch

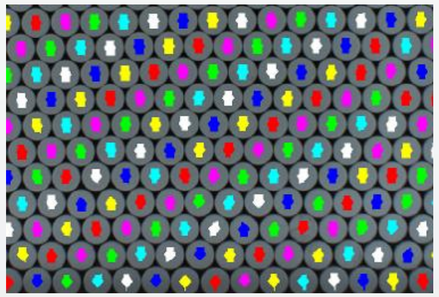
Liquid presence, label presence and ampoules ring check



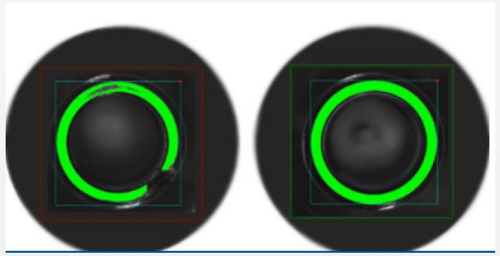
Impurities on plastic



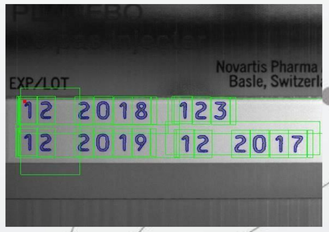
Sleeve Presence



Product quantity check



Bottle Neck Integrity



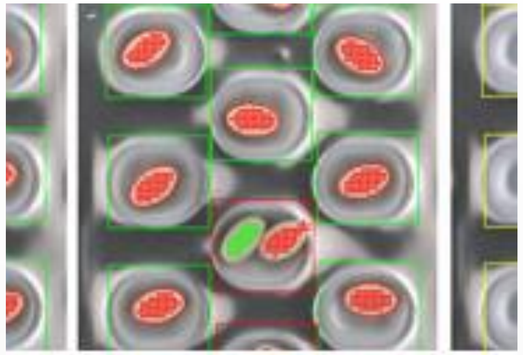
OCV / OCR

Harlequin

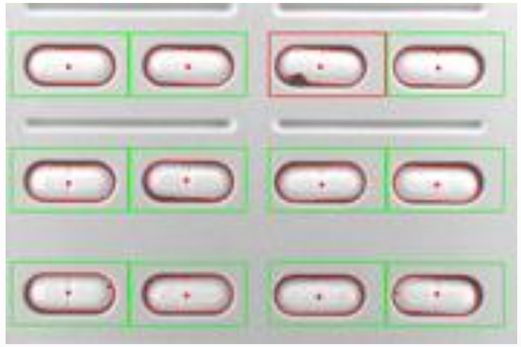
Harlequin is the vision system for the inspection of oral solids forms and pharmaceutical kits on blistering and thermoforming machines

- Components presence/integrity in white PVC, transparent and paper-made tray
- Mainly vials, syringes, ampoules
- Barcodes, 2D codes and online-printed variable data

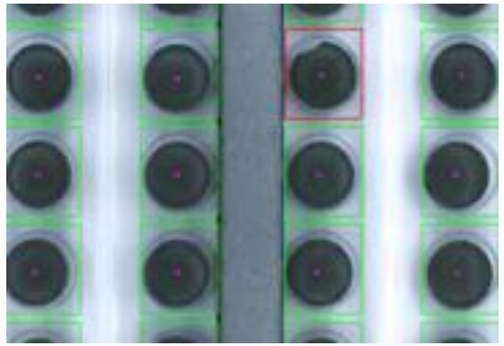
Harlequin - Components presence/integrity



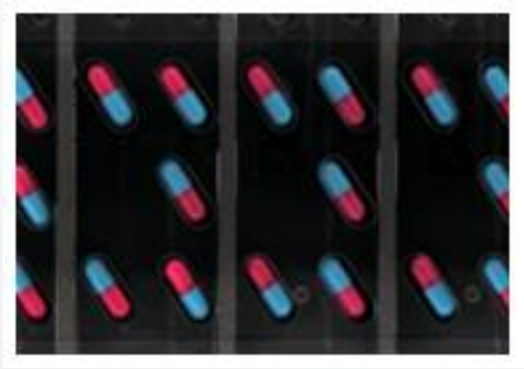
Tablets and capsules inspection on ALU-ALU:
- **Presence, Color, Integrity**
- **Multi-product on the same cavity**



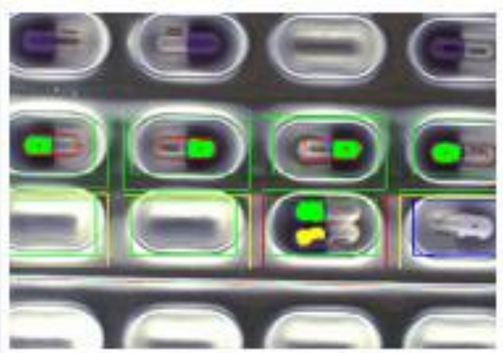
White Tablets on White Blister:
- **Presence of defects: Cracks, Dents, Black Dots**
- **Chromatic inspection**



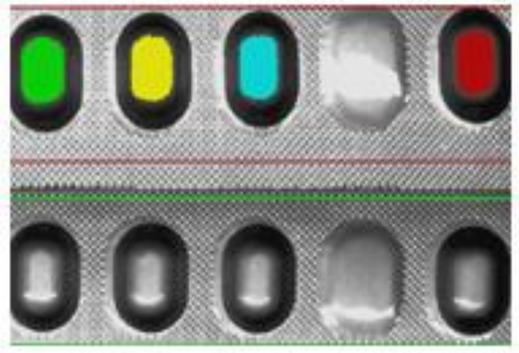
Tablets Inspection on transparent PVC: Presence, Color, defects



Capsules Inspection on PVC
- **Presence, Color, Integrity, Dimensions**
- **Double Chromatic Check for color inspection**



Capsules in Blue/Transparent Blister
- **Presence, Color**
- **Double products in the same cavity**

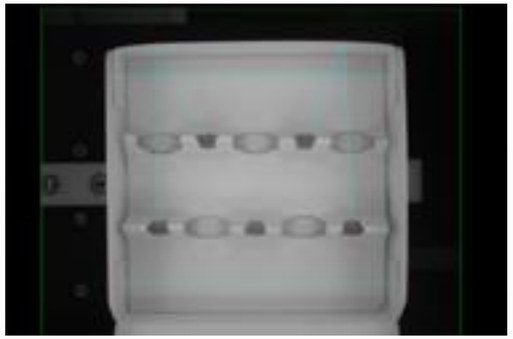


Control in the cavity of the shape and tablet position

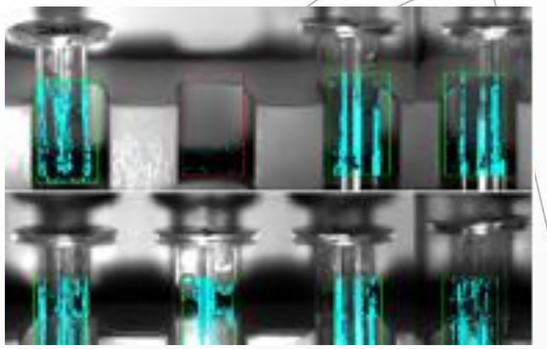
Harlequin - Packaging integrity

Presence of impurity and defect on the blister surface

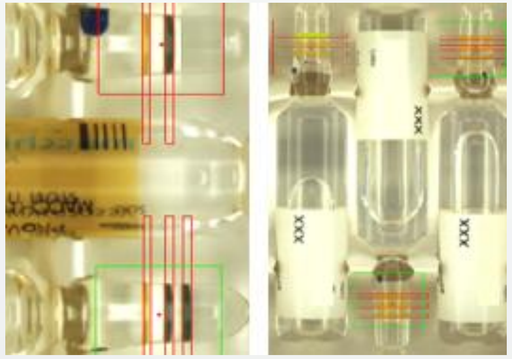
Control of components in tray



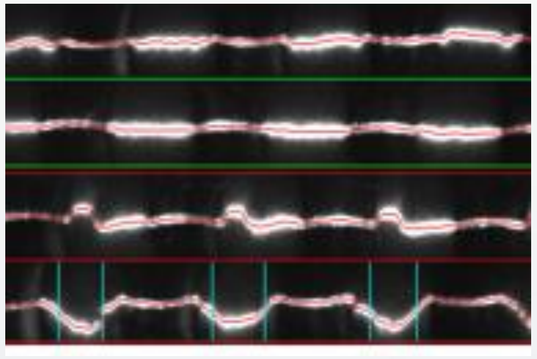
Control of tray formation



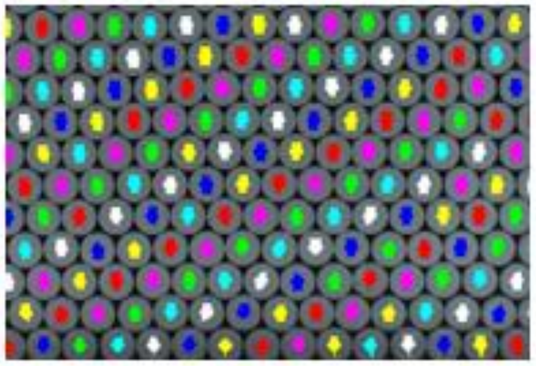
Syringes inspection: Integrity, completeness



Control of Color rings in vials



Powder level inside the vials: 3D inspection

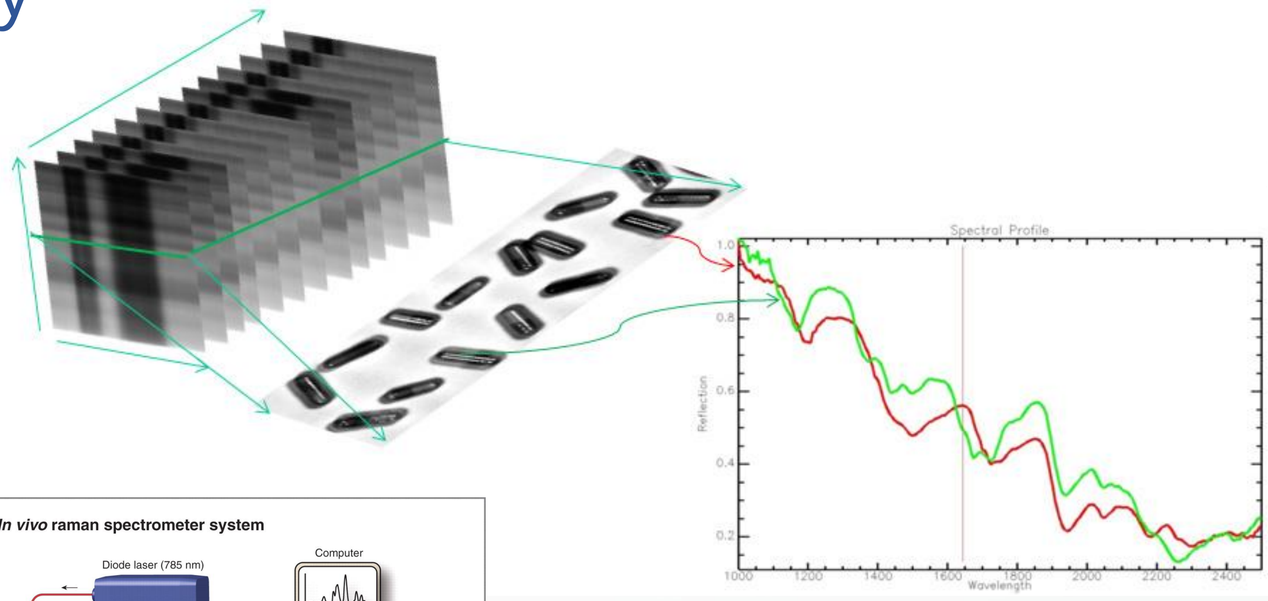


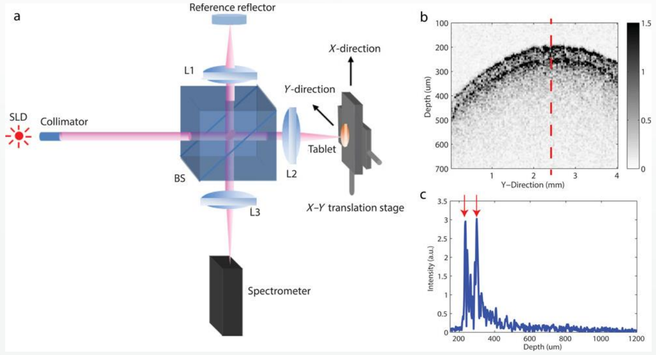
Counts vials in a tray

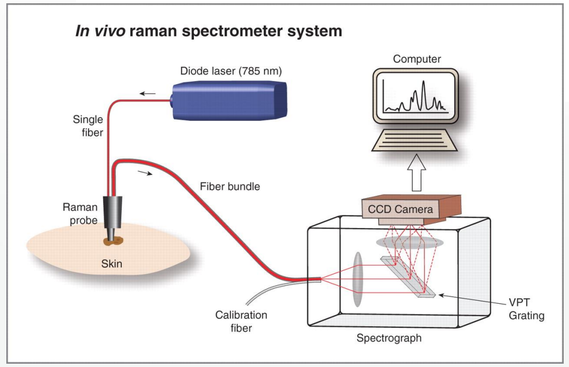
Control of forming cartons for inserting components

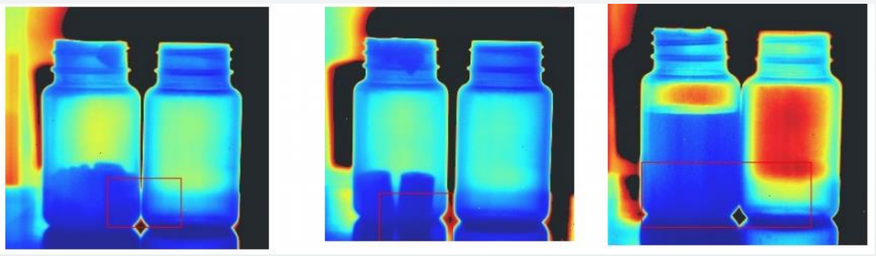
Non-Destructive technology

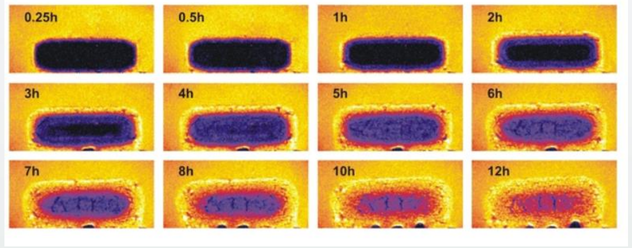
- Hyperspectral Imaging
- Optical Coherence tomography
- Thermography
- Optical Spectroscopy
- Terahertz Imaging
- Nuclear Magnetic Resonance



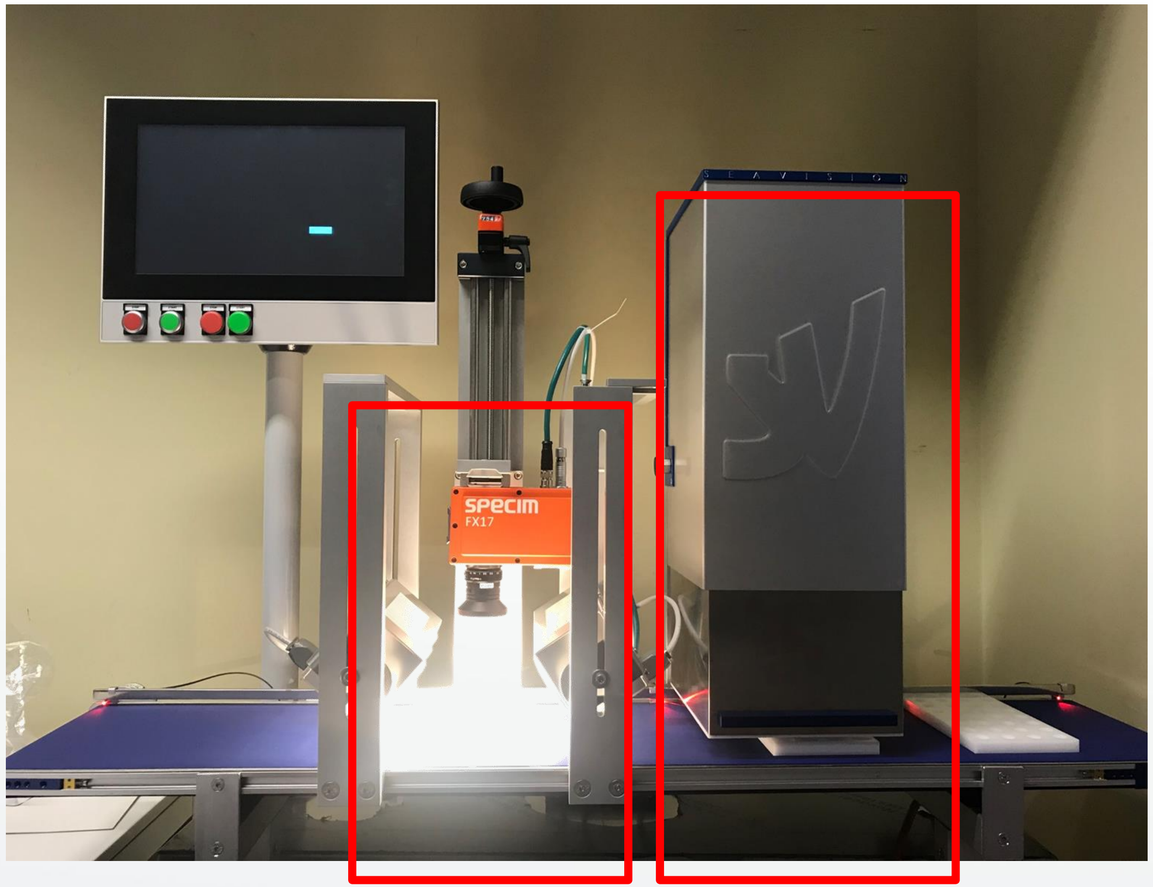








HarleNIR - Chemical imaging

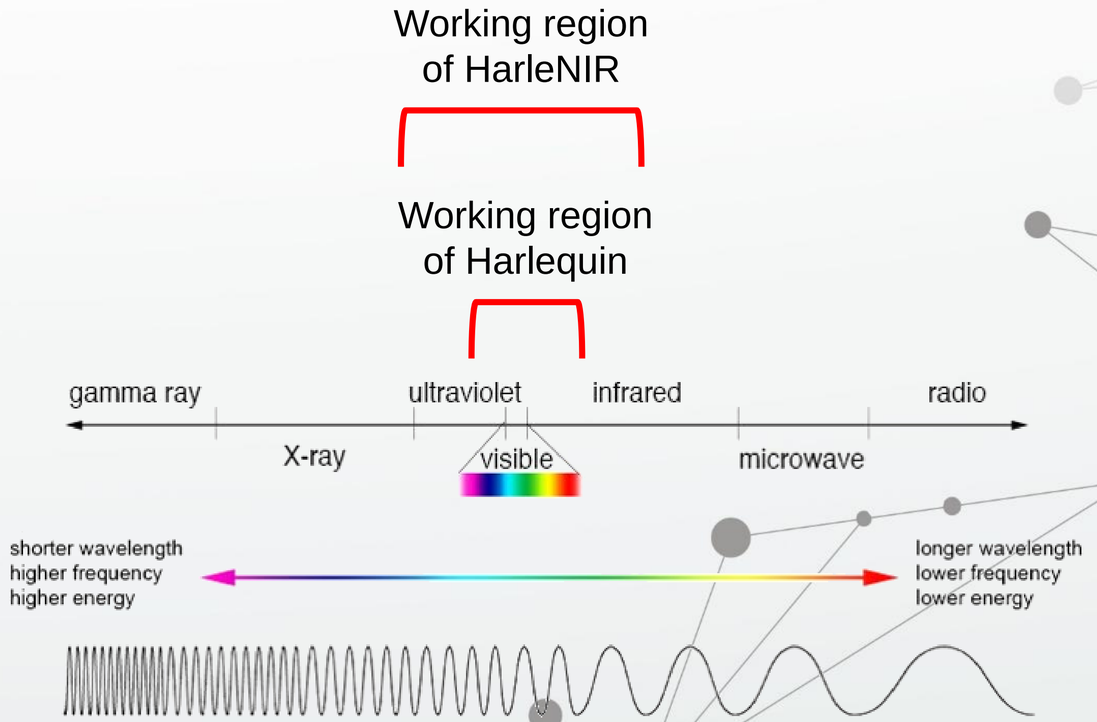


Hyperspectral camera system

B&W or RGB camera system Harlequin

With the introduction of the hyperspectral camera as inspection system for the pharmaceutical products Harlequin is becoming HarleNIR.

HarleNIR working range 300 – 1700nm



Customized light source depending on the application

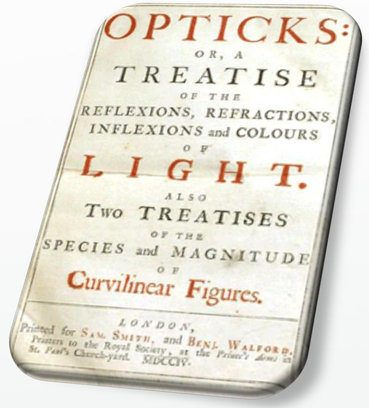
HarleNIR - Possible applications on a pharmaceutical products

	PHARMACEUTICAL PRODUCTS		
	TABLETS	CAPSULES	POWDERS
VIBRATING PLATE			
Mix-up avoidance	●	●	
Foreign object identification	●	●	
Presence of cracks	●	●	
Absence of coating		●	
Overlapping defects		●	
Identification of empty blister	●		
Moisture content determination	●	●	
BLISTERING MACHINE			
Mix-up avoidance	●	●	
Foreign object identification	●	●	
Presence of cracks	●	●	
Absence of coating		●	
Overlapping defects		●	
Identification of empty blister	●		
Measure of the active principle distribution	●		
Moisture content determination	●	●	
GRANULATOR			
Moisture content determination			●
Homogeneity of blend			●

Origin of the spectroscopy

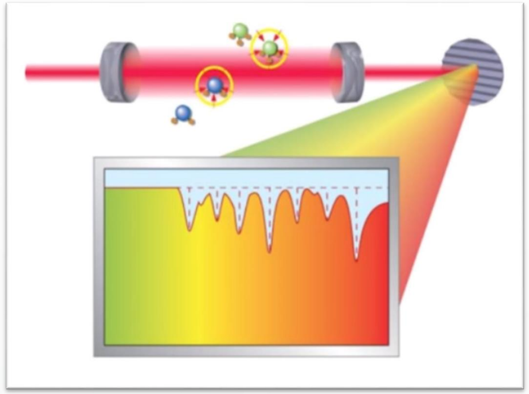
In the year 1704 **Sir Isaac Newton** build the first Spectrometer described on it’s book.

In the year 1800, **Sir William Herschel** discovered the existence of infrared radiation.

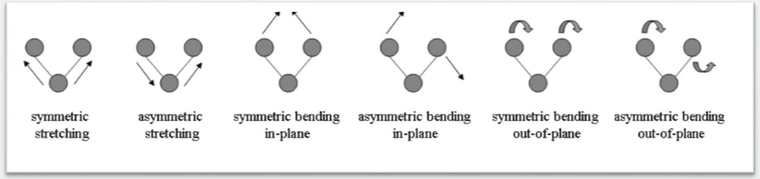


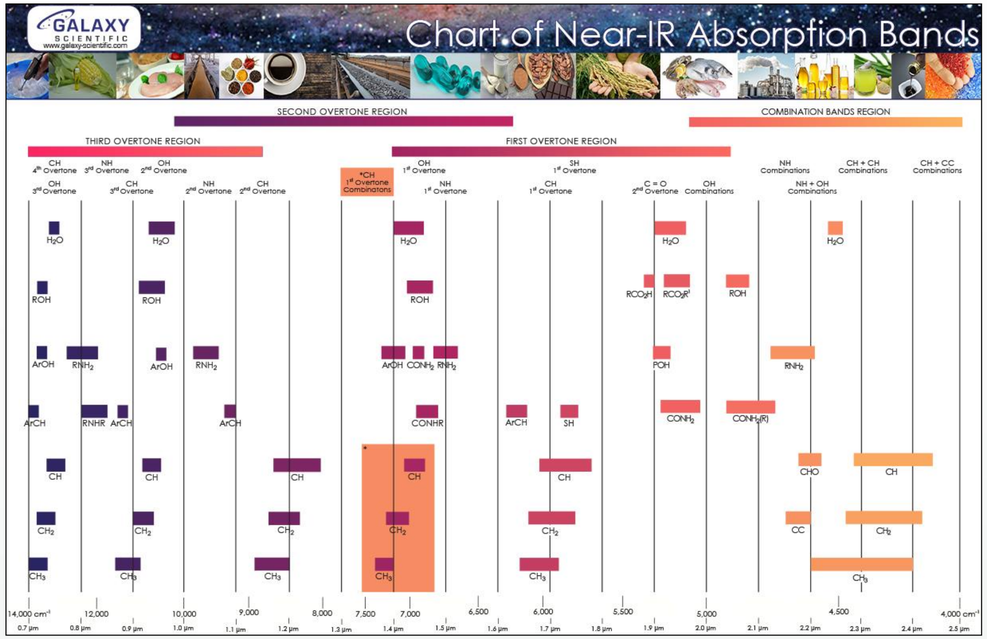
Where and what we are looking for?

Spectroscopy is the study of light interacting with matter.



Dipole Moment	Relationship between IR intensity and dipole moment
$\mu = \alpha d$	$I_{IR} \propto \left(\frac{d\mu}{dQ}\right)^2$
	Q is the vibrational coordinate



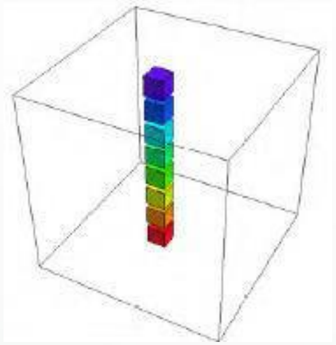


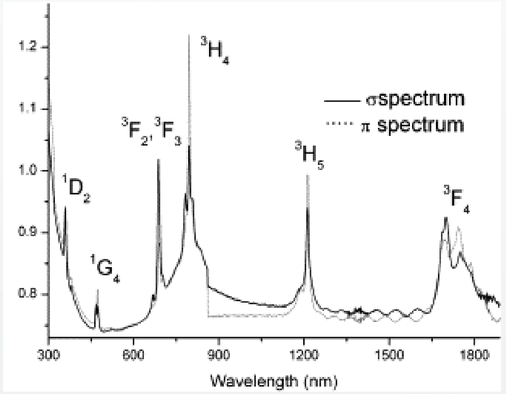
NIR has become the first choice in many areas of application

Some of the most common functional groups, e.g., C-H. O-H and N-H are measured with NIR.

Spectral imaging open new dimensions

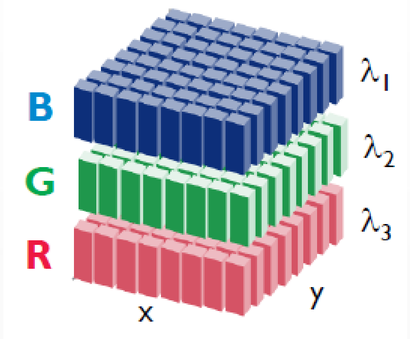
SPECTROSCOPY





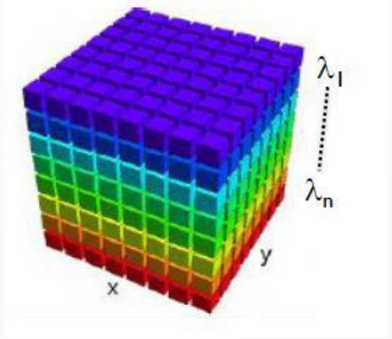
Accurate spectral analysis of one spatial pixel only

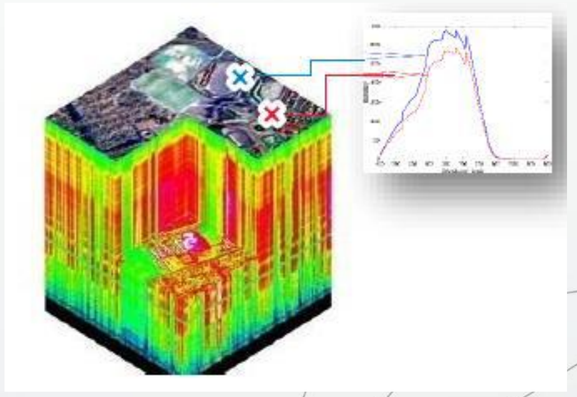
COLOR IMAGING



Seeing RGB colors of one image only

HYPERSPECTRAL IMAGING

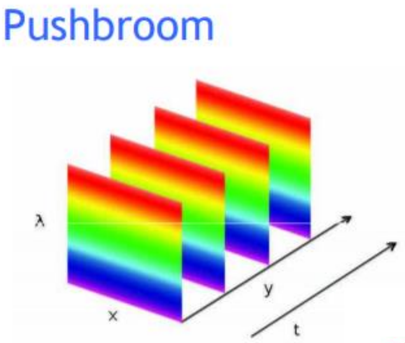


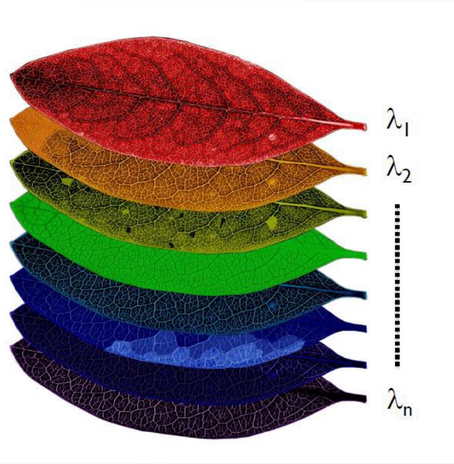


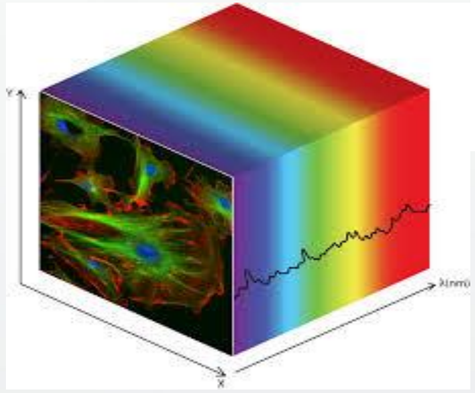
Spectral signature images revealing objects chemical composition

Hyperspectral Imaging

Hyperspectral vision system: the natural subsequent step on the evolution of the vision system starting from the black/white cameras and passing from the RGB and the multispectral cameras.



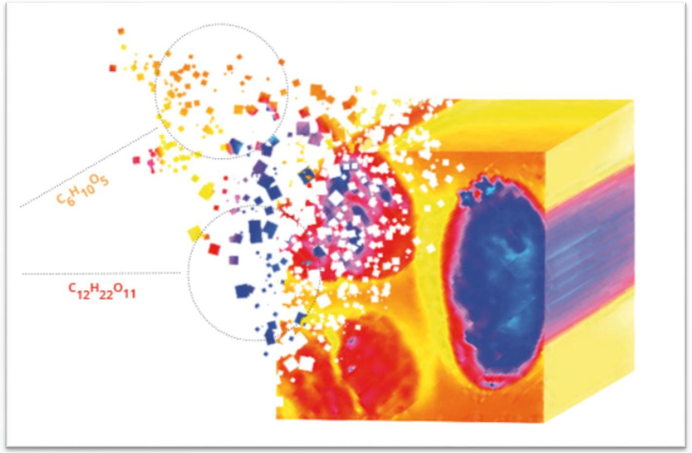




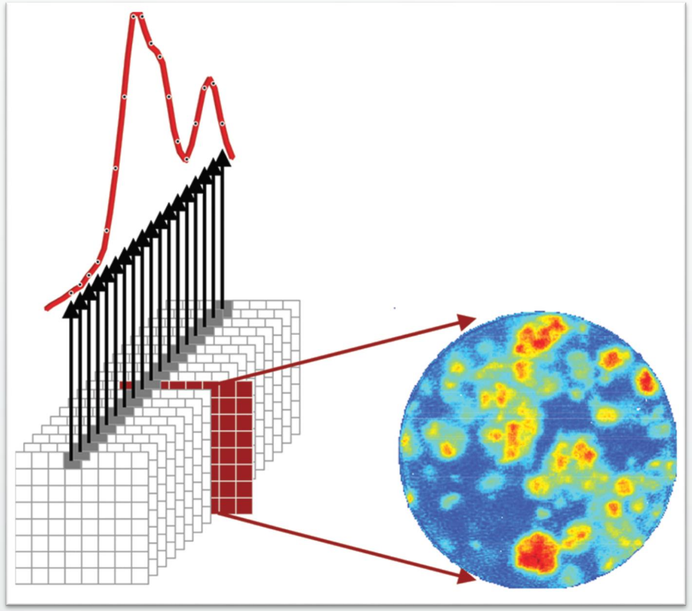
Hyperspectral System works in several spectral range:

1 – Visible Spectra range:	400 – 700nm
2 – Visible – Near InfraRed Spectral Range:	400 – 1000 nm
3 – Near InfraRed Spectral Range:	900 – 1700 nm
4 – SWIR Spectral Range:	1700 – 2500nm

Chemical imaging - General definition



Chemical imaging technique, is the combination of spectroscopy and digital imaging. A spectral image contains many spectra, one for each individual point on the sample's surface. The image contains valuable information about the spatial distribution of the materials within the sample.

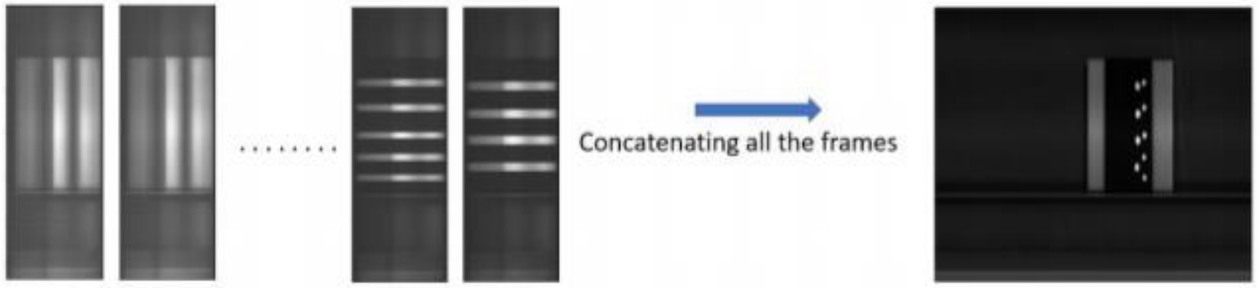


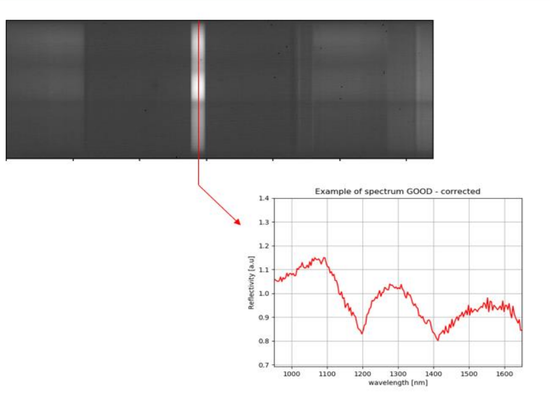
The analyst may choose to take as many data spectrum measured at a particular chemical component in spatial location at time. This is useful for chemical identification and quantification

The goal of hyperspectral imaging is to obtain the spectrum for each pixel in the image of a scene with the purpose of finding objects, identifying materials, or detecting processes.

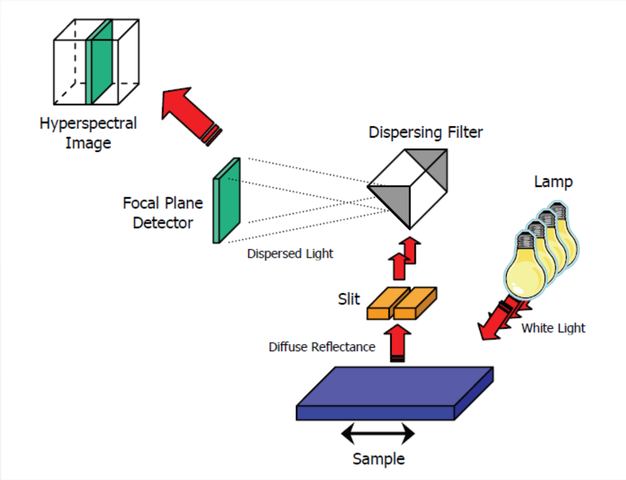
How the data are obtained? - Pushbroom imaging

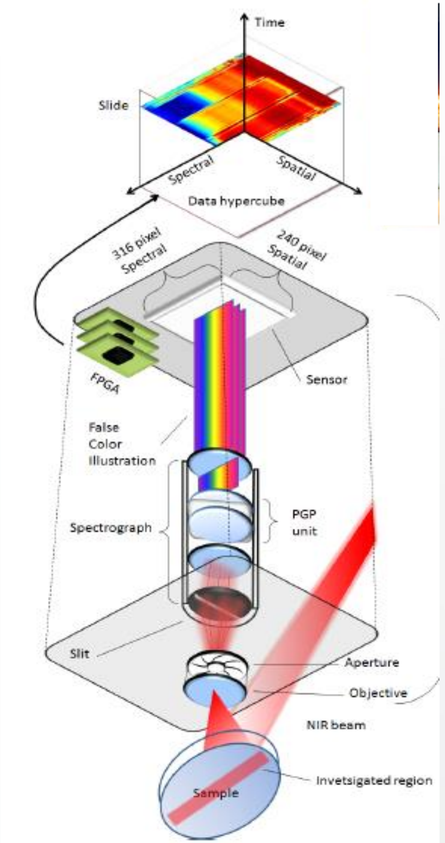
Starting from the analysis of the spectra will be possible to extract the chemical information regarding the observed objects.





Concept of frames





Analytical methods - how the data are treated?

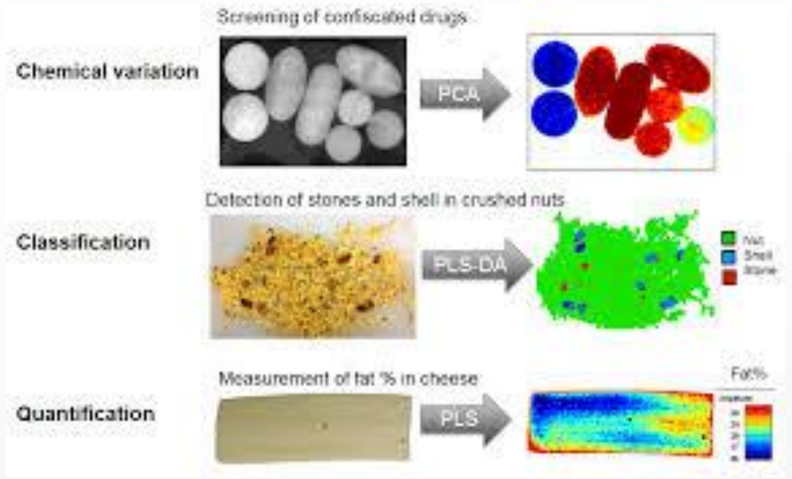
Non - Supervisioned methods → QUALITATIVE ANALYSIS

ANLYTICAL METHODS:

Pre-processing of the data: Normalisation, Derivative, Smoothing

Processing:

- Correlation function,
- Inner Product
- PCA



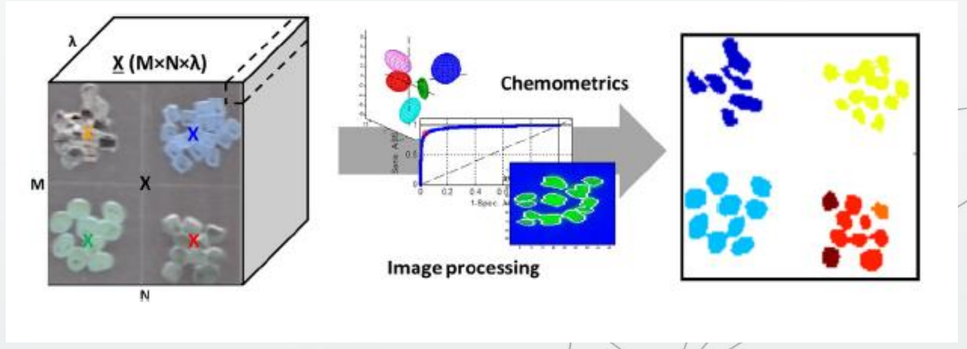
Supervisioned methods → QUANTITATIVE ANALYSIS

ANLYTICAL METHODS:

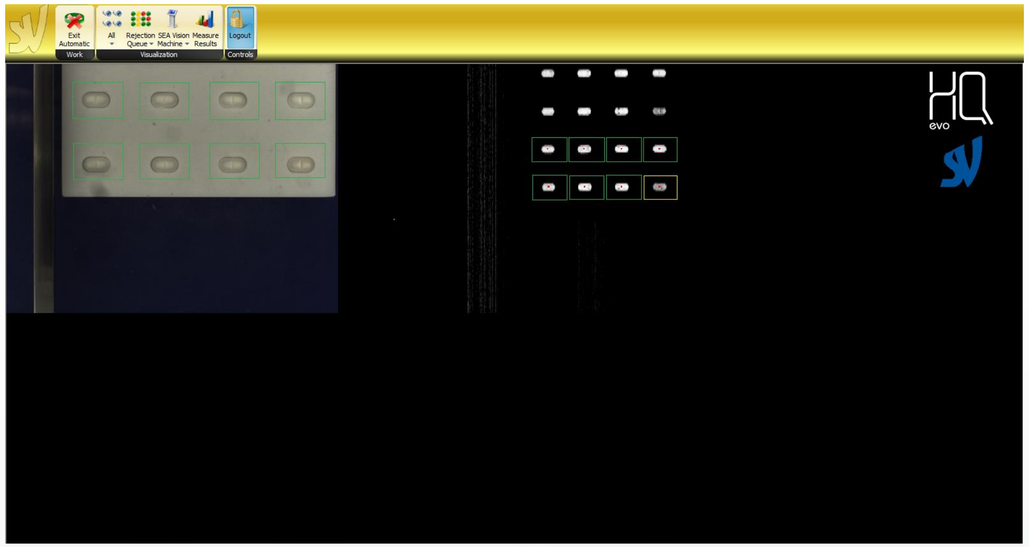
Pre-processing of the data: Normalisation, Derivative, Smoothing

Processing:

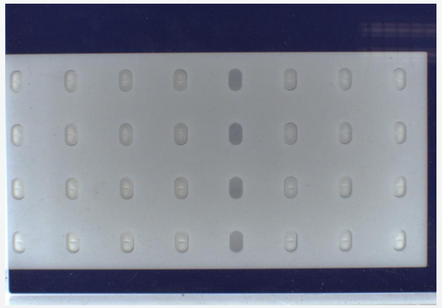
- Multivariate Analysis: PCA, PLS – DA (linear regression)
- Clusterization: K-means

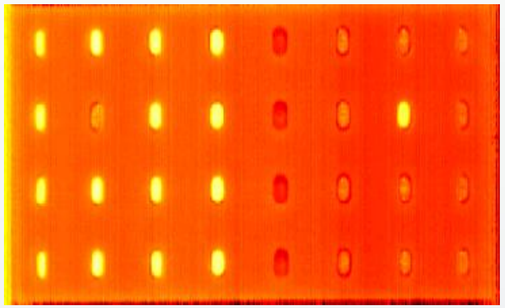


HarleNIR R&D applications - Feasibility studies



The tablets on the right column are all equal. The other tablets are different for the dosage and the distribution of principal compound. From a standard RGB camera all the tablets appears the same.

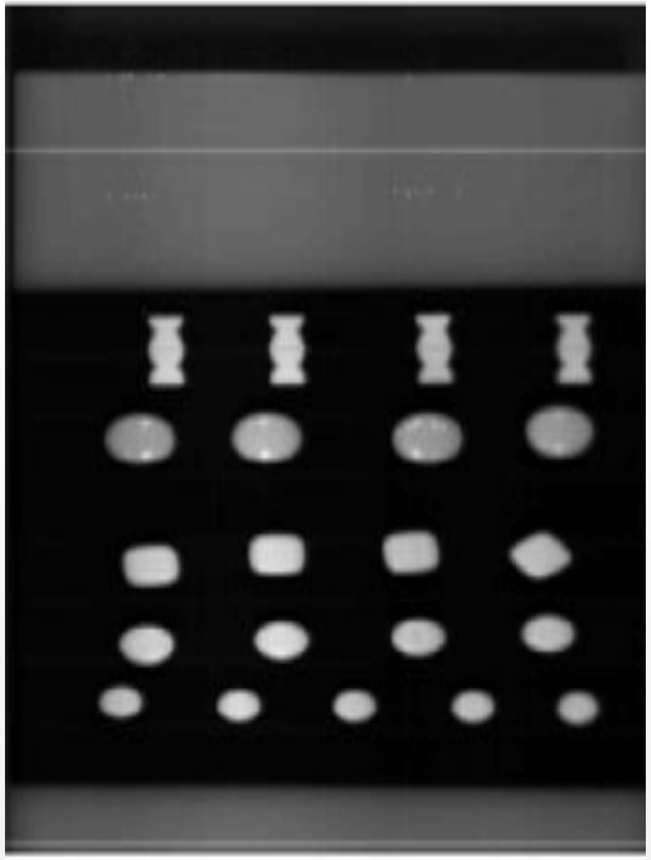




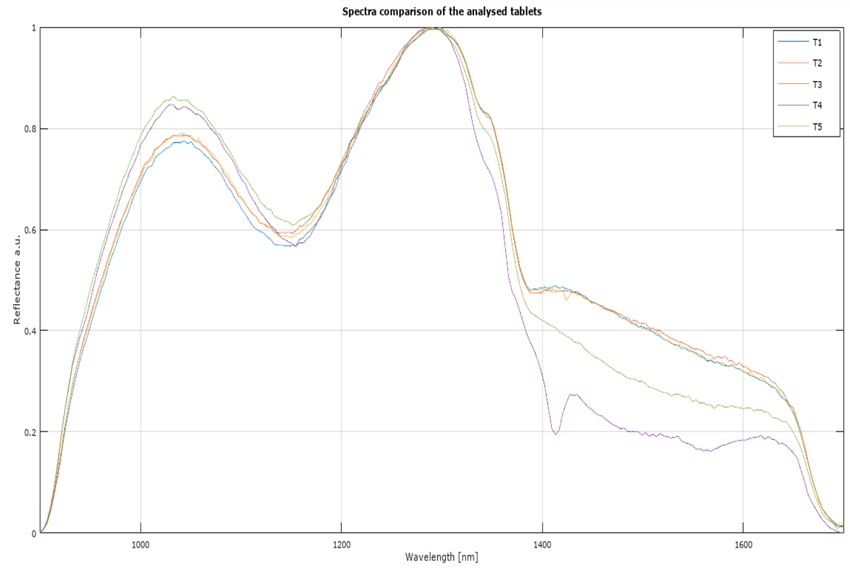
Mix-Up detection

HarleNIR - Example of identification

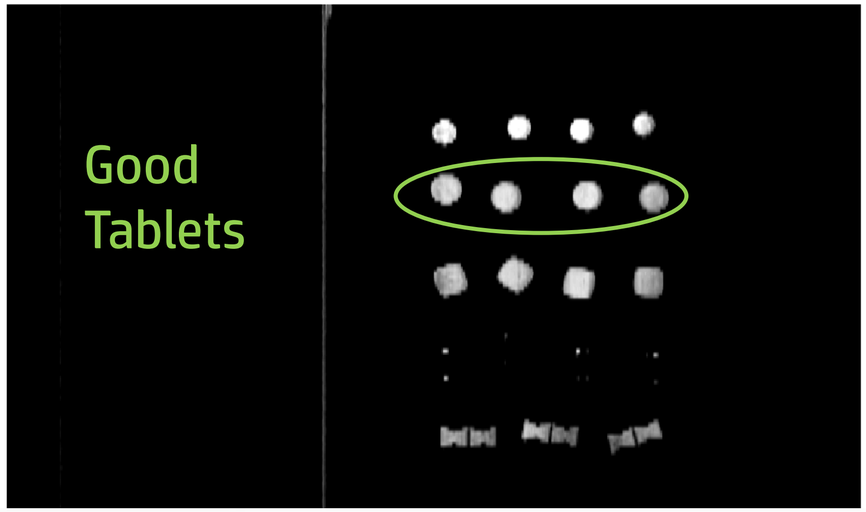
RGB image

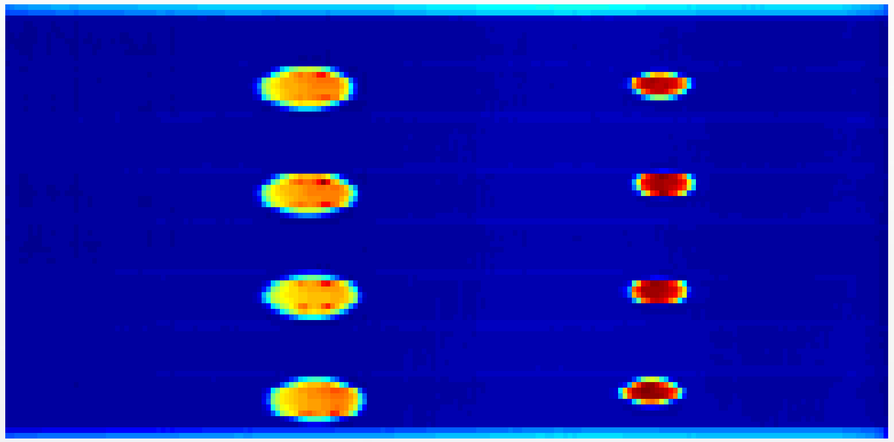


Hyperspectral image

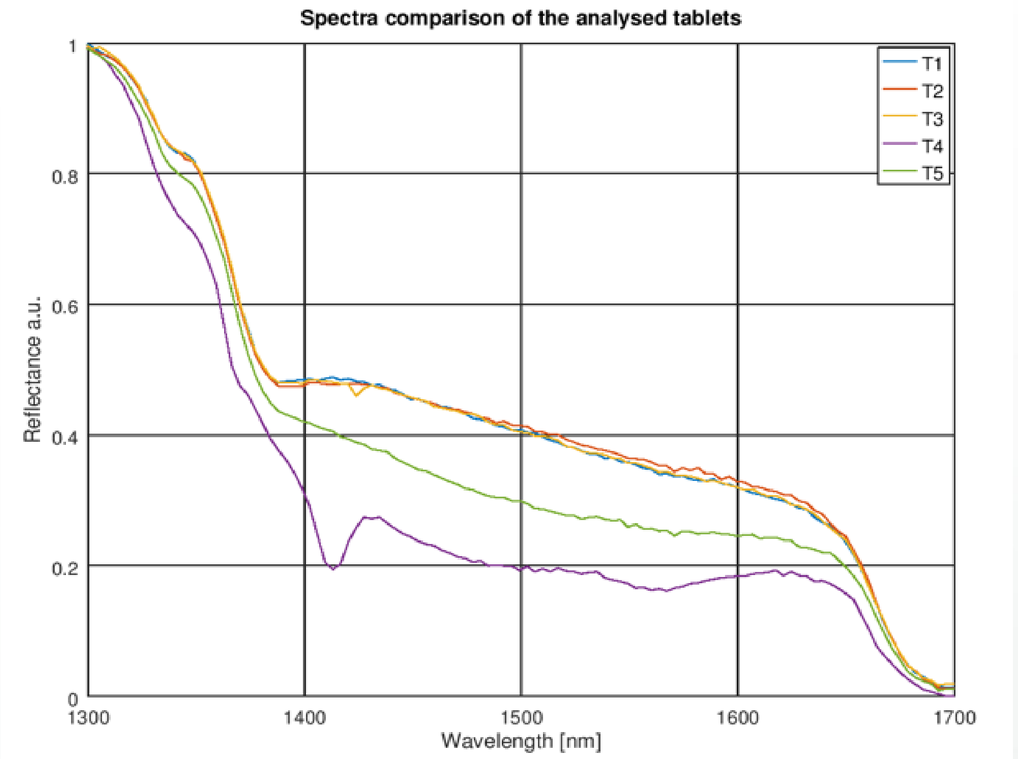


Data extraction

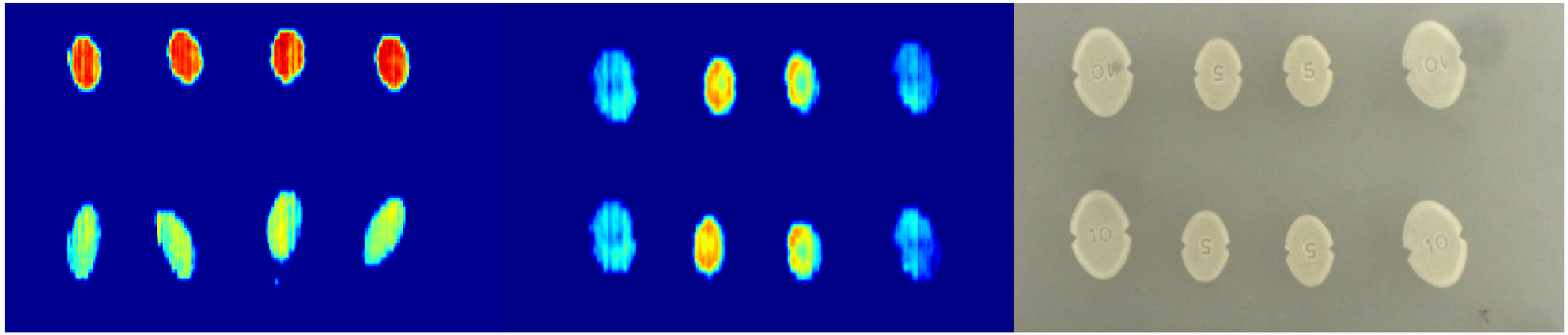




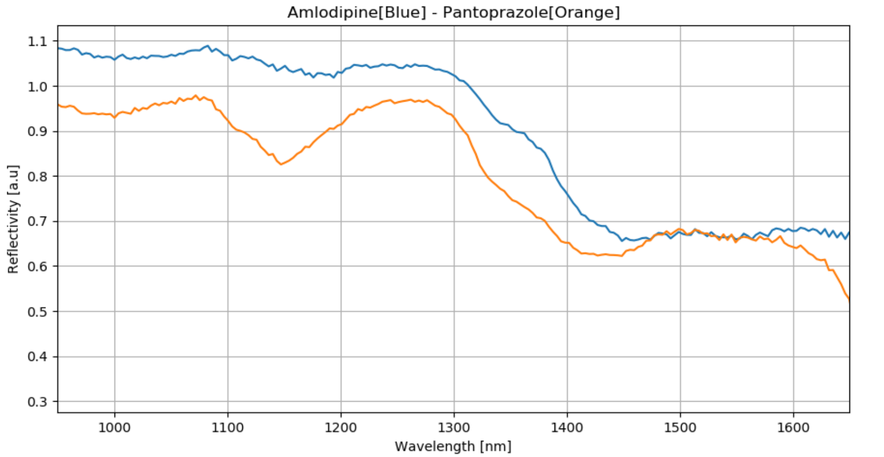
False color image of
tablets with different API

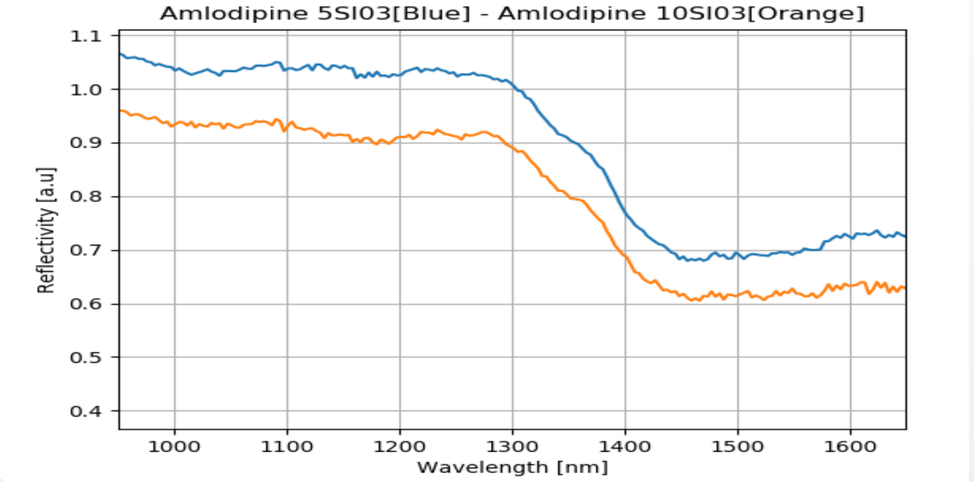


Spectral range extraction



Tablets with different dosage





Tablets with different API

HarleNIR - PAT tool for pharmaceutical product inspection

Customized light source
Linear Halogen bulb

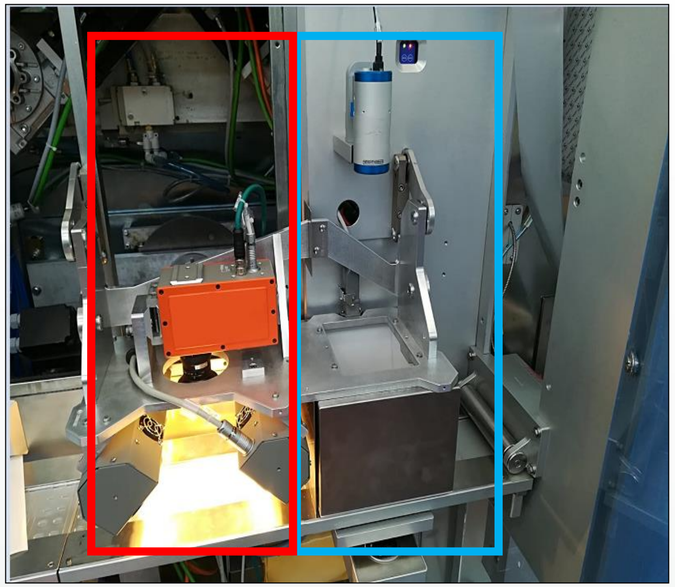
Process analytical technology (PAT) has been defined by the United States Food and Drug Administration (FDA) as a mechanism to design, analyse, and control pharmaceutical manufacturing processes through the measurement of Critical Process Parameters (CPP) which affect **Critical Quality Attributes** (CQA)

Critical Quality Attributes (CQA):

- API content uniformity
- Tablets moisture
- API mix-up avoidance
- Tablet coating uniformity

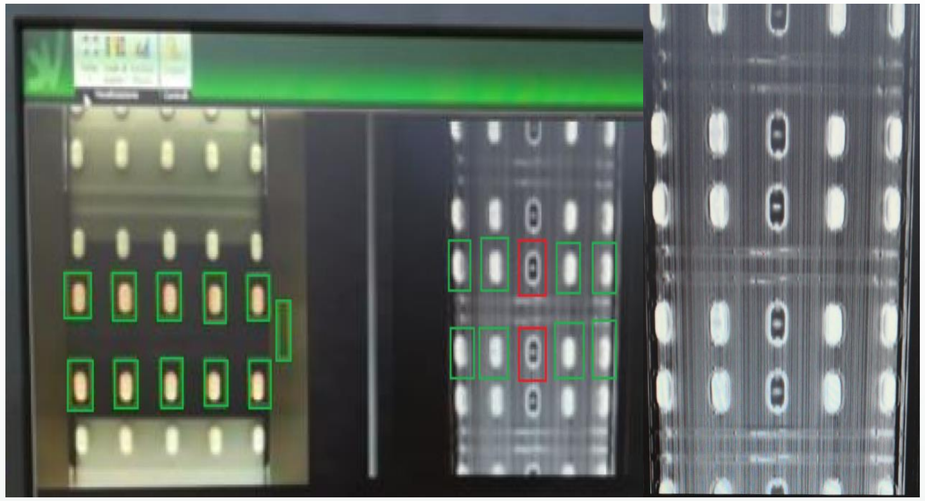
Use of the hyperspectral camera for the API content uniformity → On line products release!

HarleNIR - In line application & Machine integration



Machine speed → 300 blisters/min

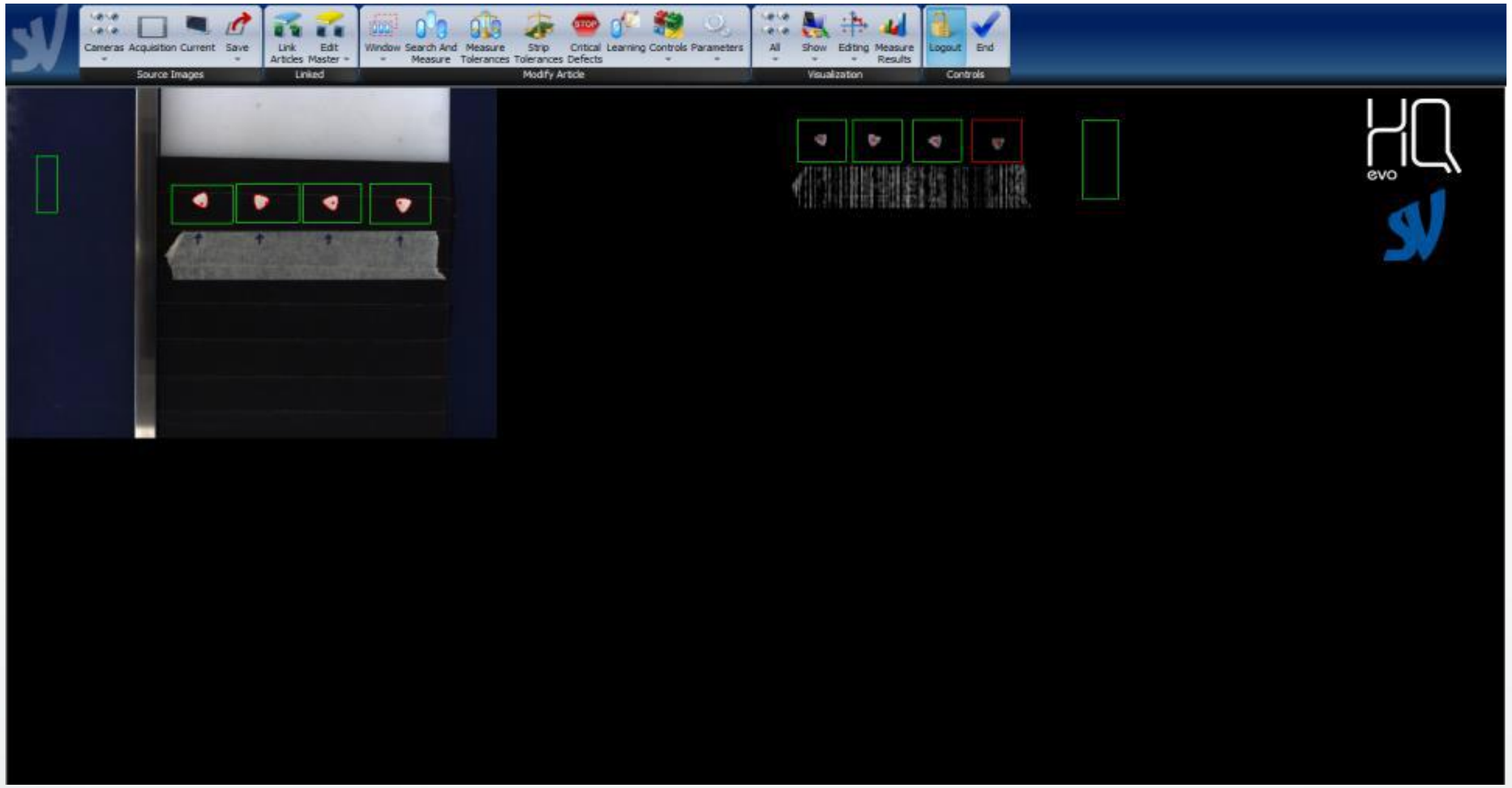
Acquisition rate → From 520 (full band) to 15000 frame/s



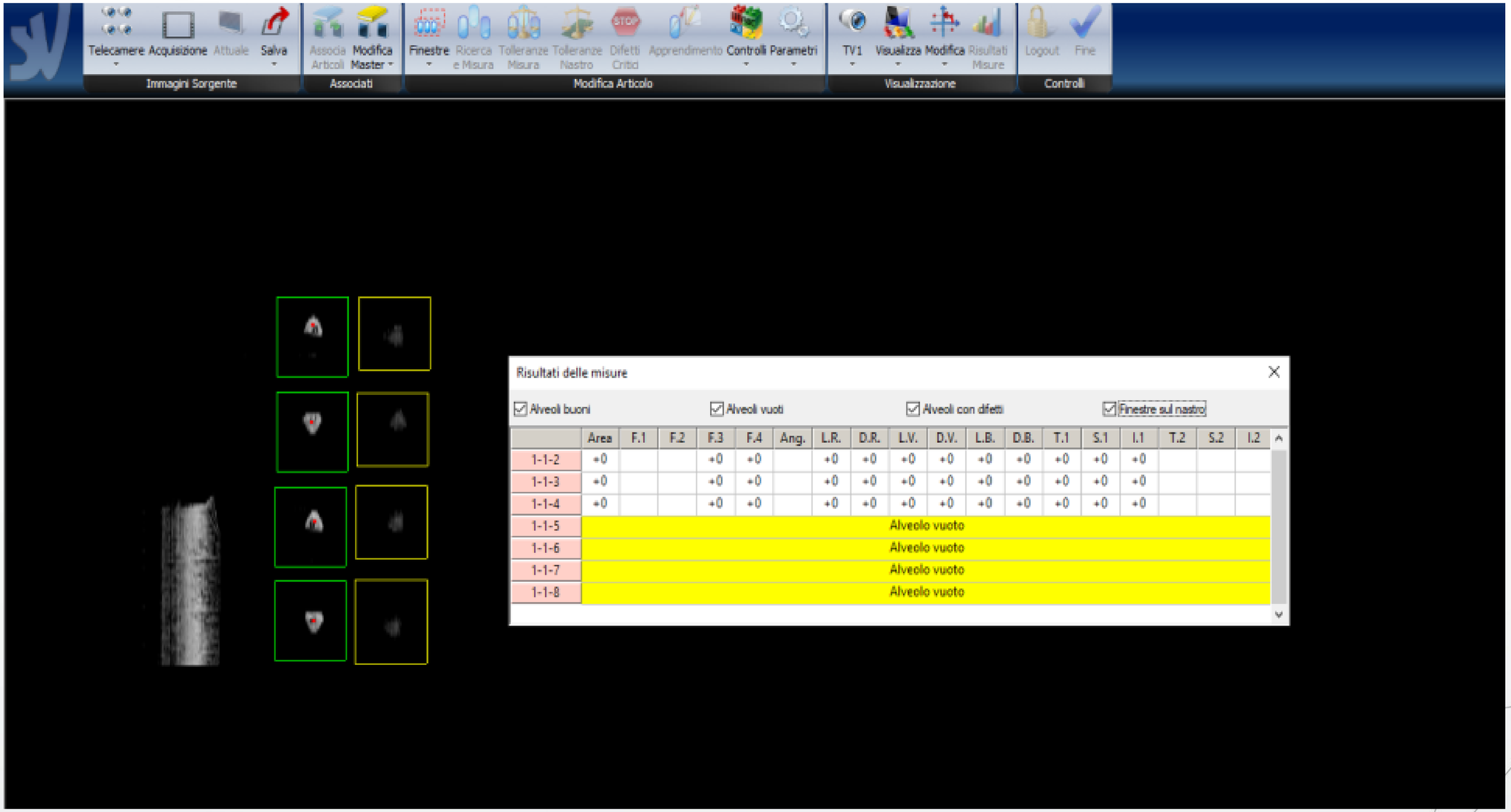
The tablets with different chemical composition are well visible

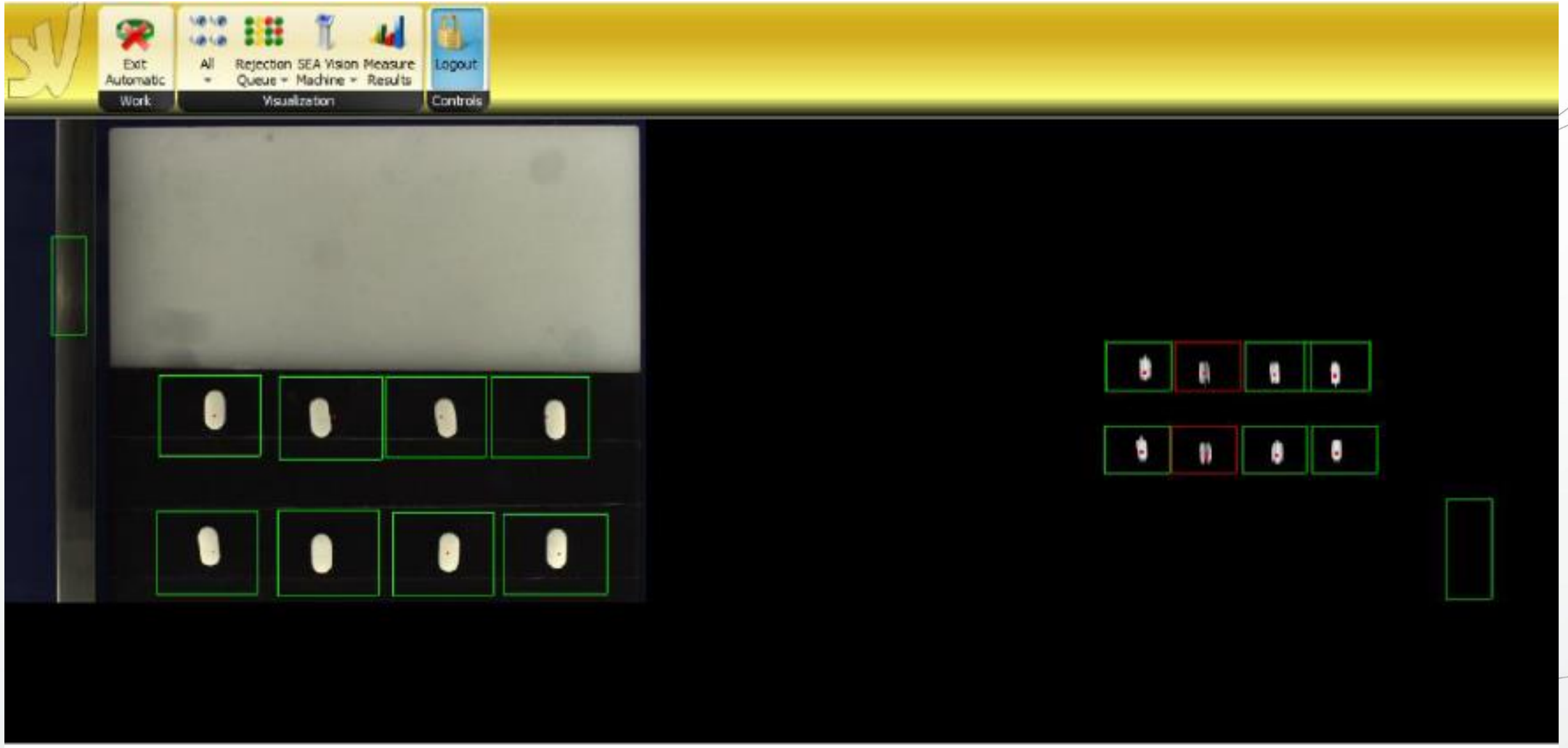
Produced tablets on the blister machine

HarleNIR - Example of identification

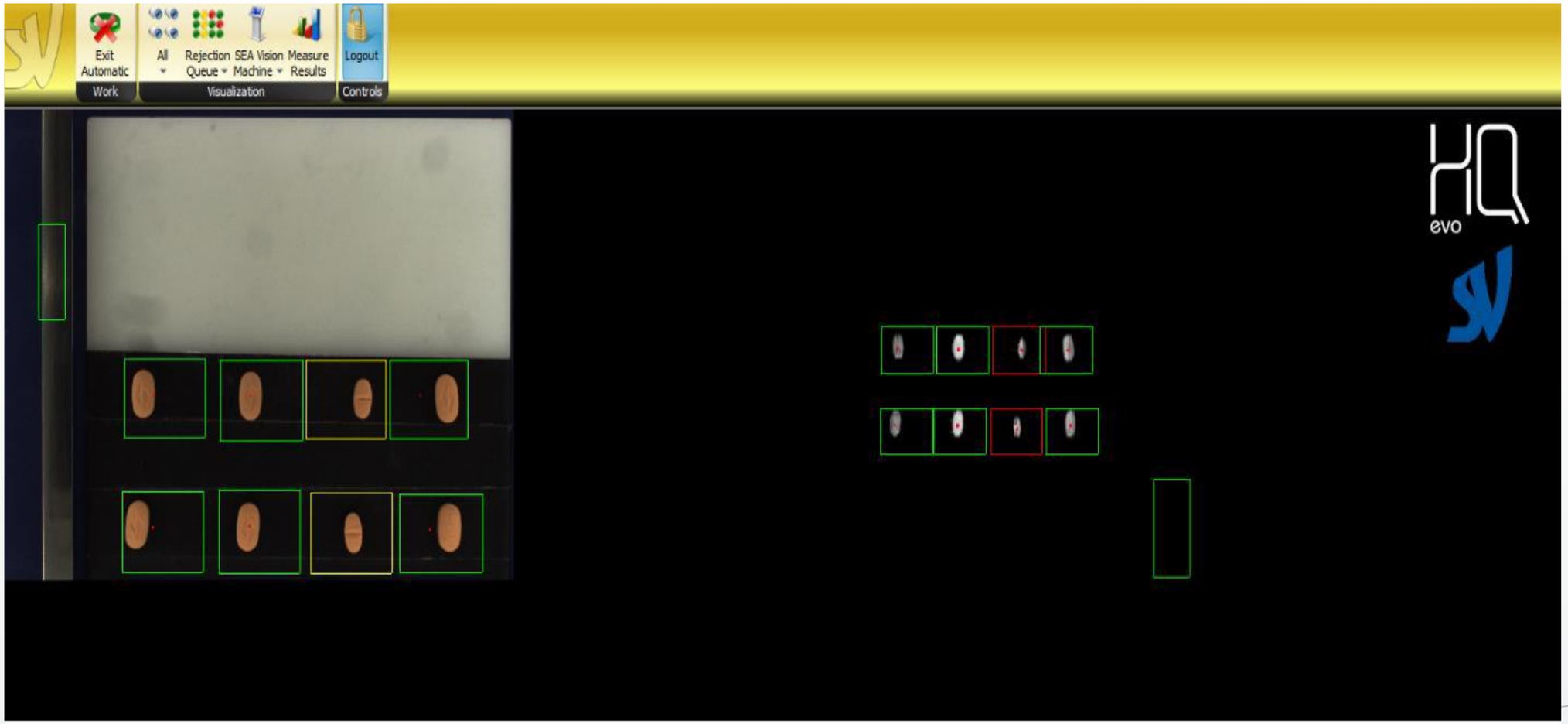


Distinction of product with different dosages


Telecamere
Acquisizione
Attuale
Salva
Immagini Sorgente
Associa Articoli
Modifica Master
Associati
Finestre
Ricerca e Misura
Tolleranze Misura
Tolleranze Nastro
Difetti Critici
Apprendimento
Controlli
Parametri
Modifica Articolo
TV1
Visualizza
Modifica
Risultati Misure
Visualizzazione
Logout
Fine
Controlli
Risultati delle misure
Alveoli buoni
Alveoli vuoti
Alveoli con difetti
Finestre sul nastro
Area F.1 F.2 F.3 F.4 Ang. L.R. D.R. L.V. D.V. L.B. D.B. T.1 S.1 I.1 T.2 S.2 I.2
1-1-2 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0
1-1-3 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0
1-1-4 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0 +0
1-1-5 Alveolo vuoto
1-1-6 Alveolo vuoto
1-1-7 Alveolo vuoto
1-1-8 Alveolo vuoto

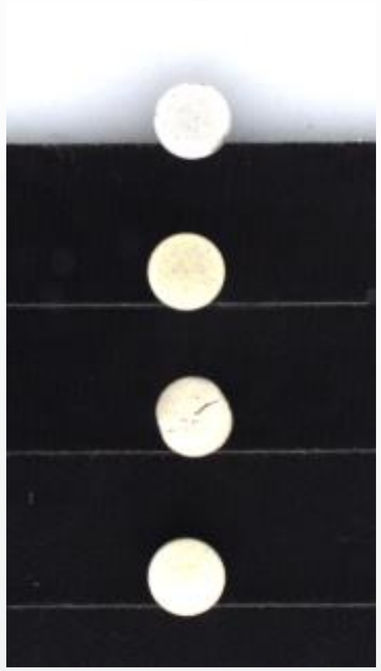


Distinction of product with different dosages

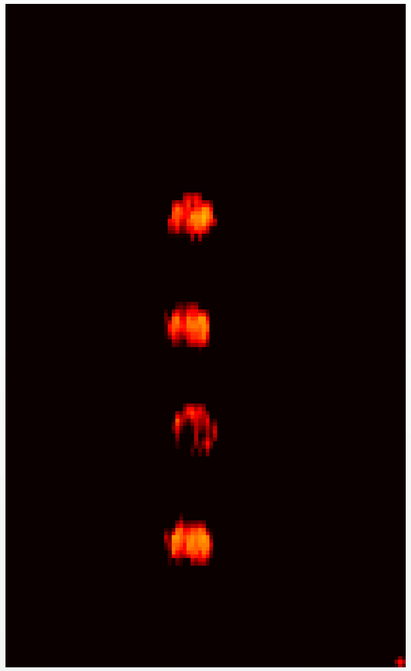


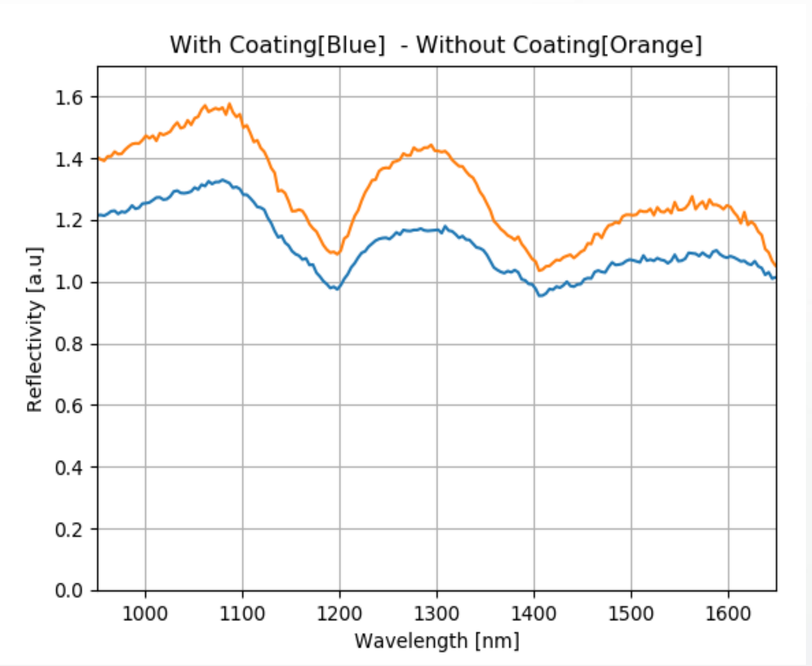
Double check – Visual inspection and dosage content control

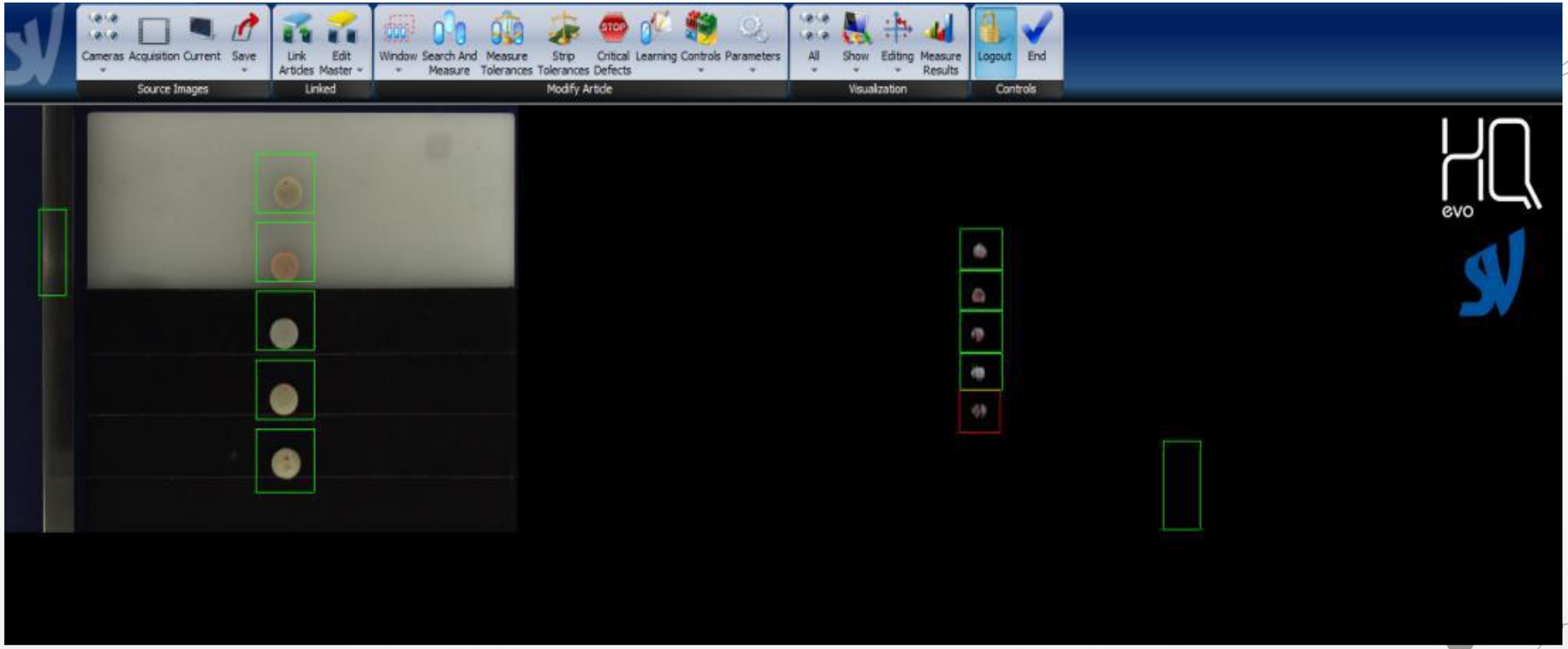
HarleNIR - Tablet coating inspection



Without Coating



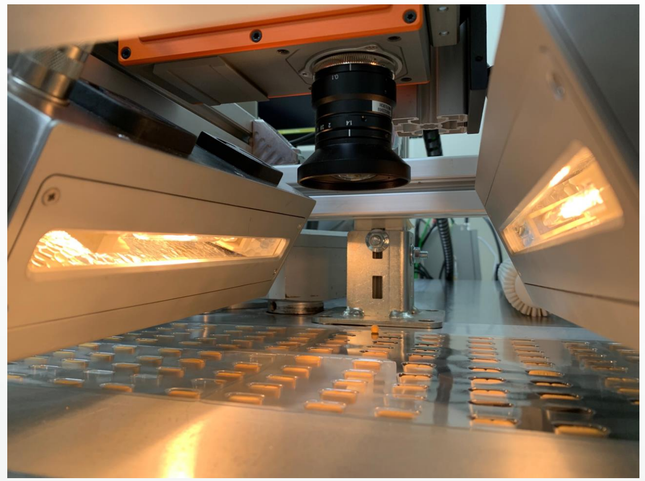




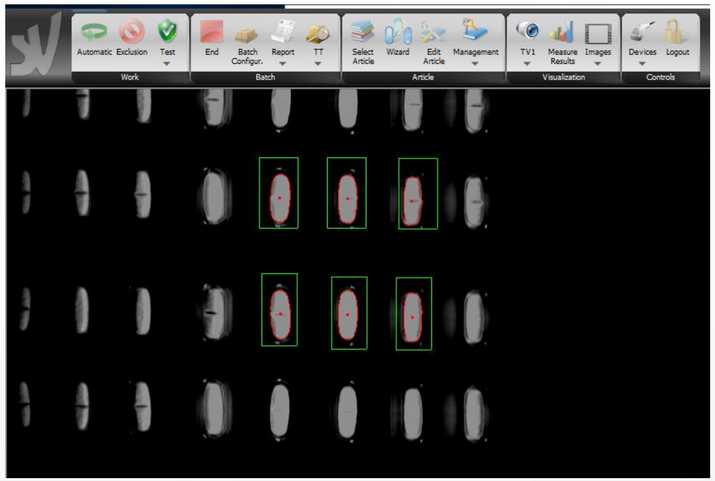
Distinction of product with missing coating

HarleNIR - API Content uniformity

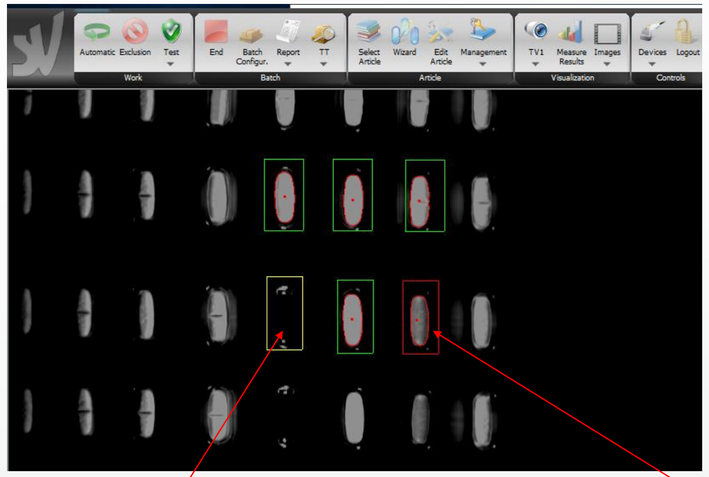
A different gray intensity level reveals foreign tablets



Customized light source
Linear Halogen bulb



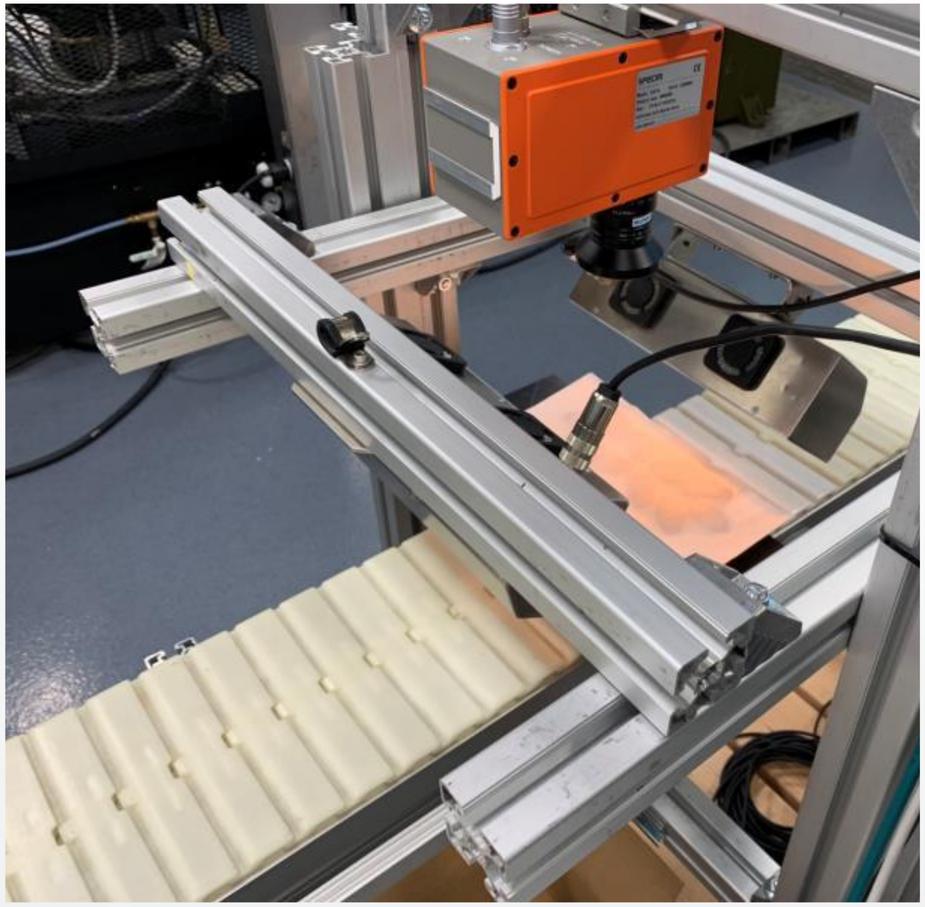
Good blister



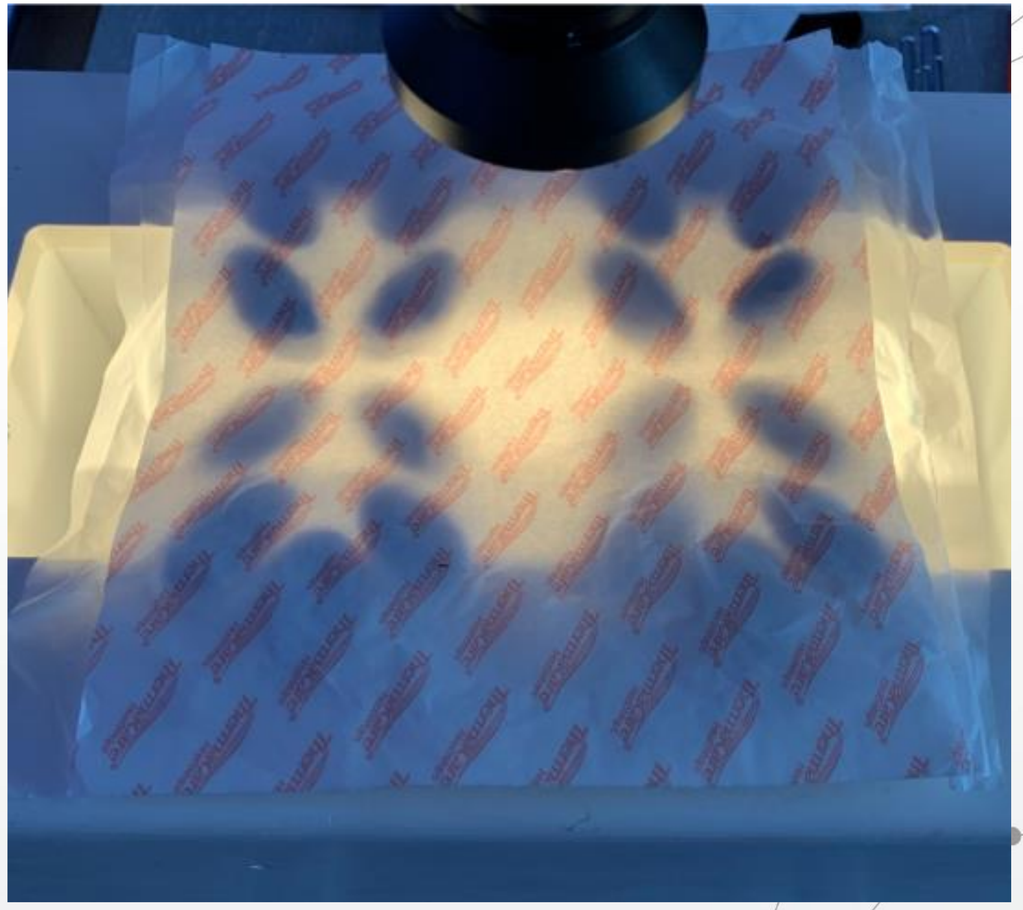
Missing tablet

Blister with Mix-up

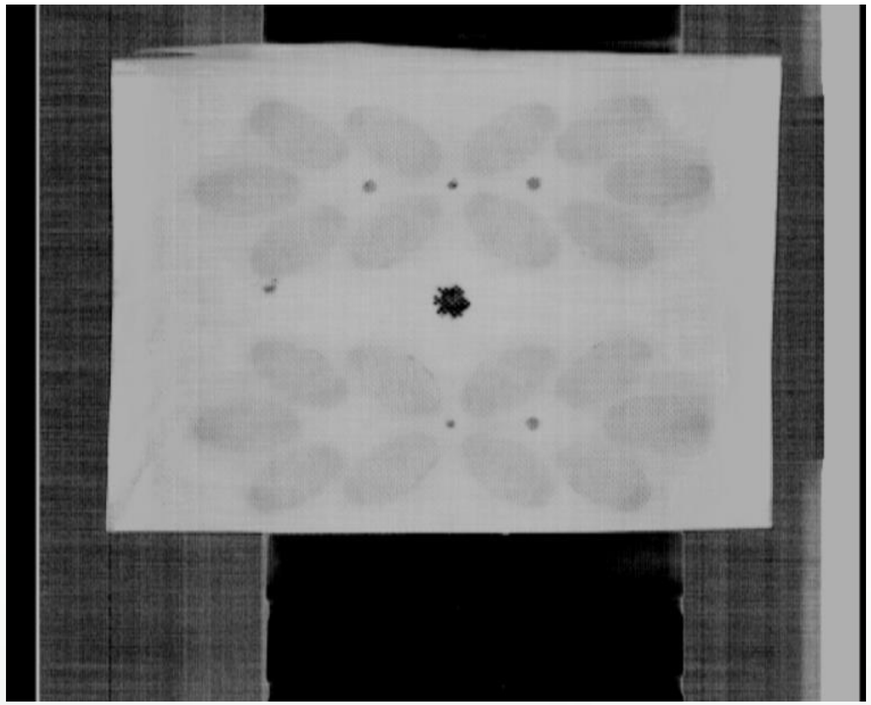
HarleNIR - Moisture measurements

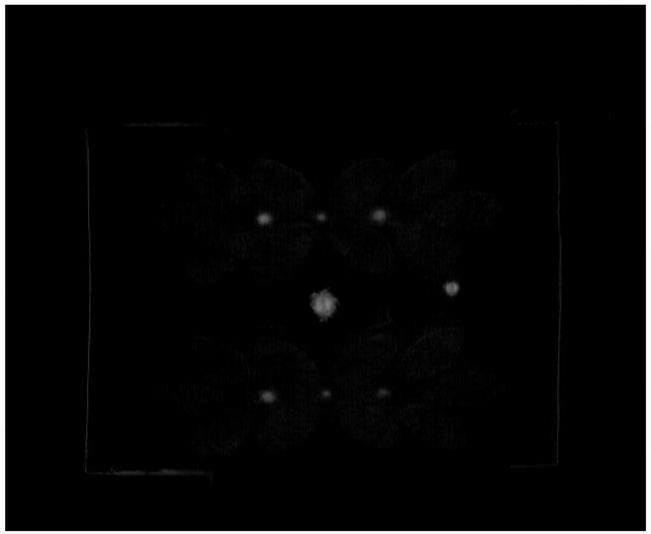


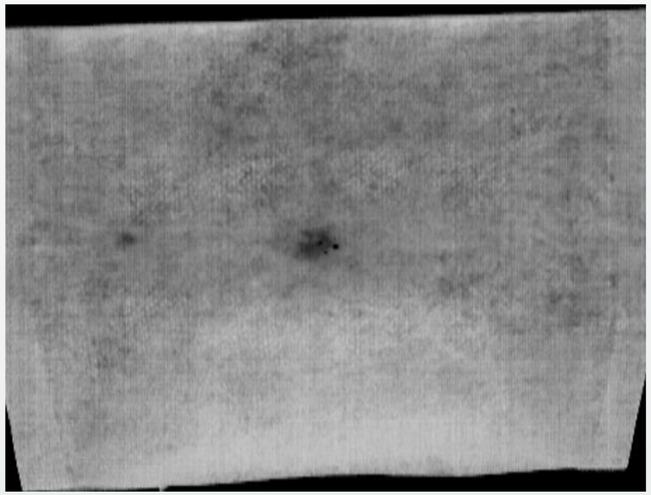
Measurements in reflection



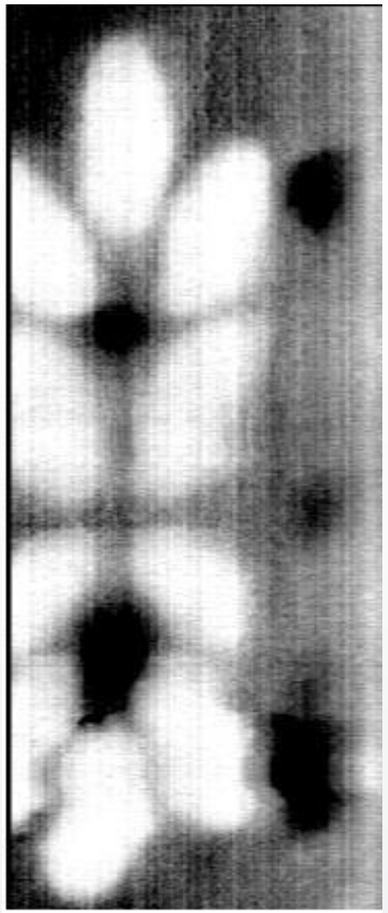
Measurements in transmission

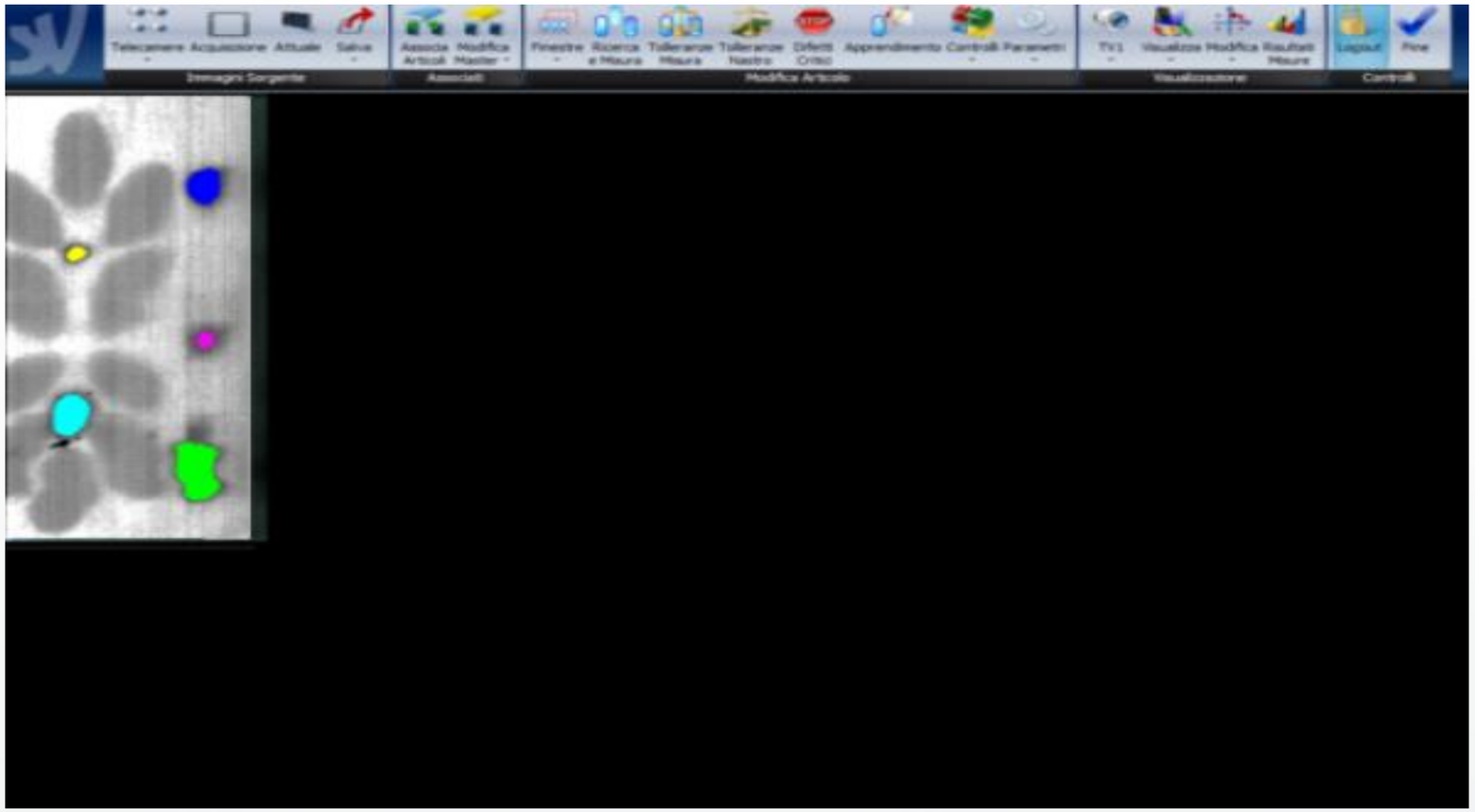




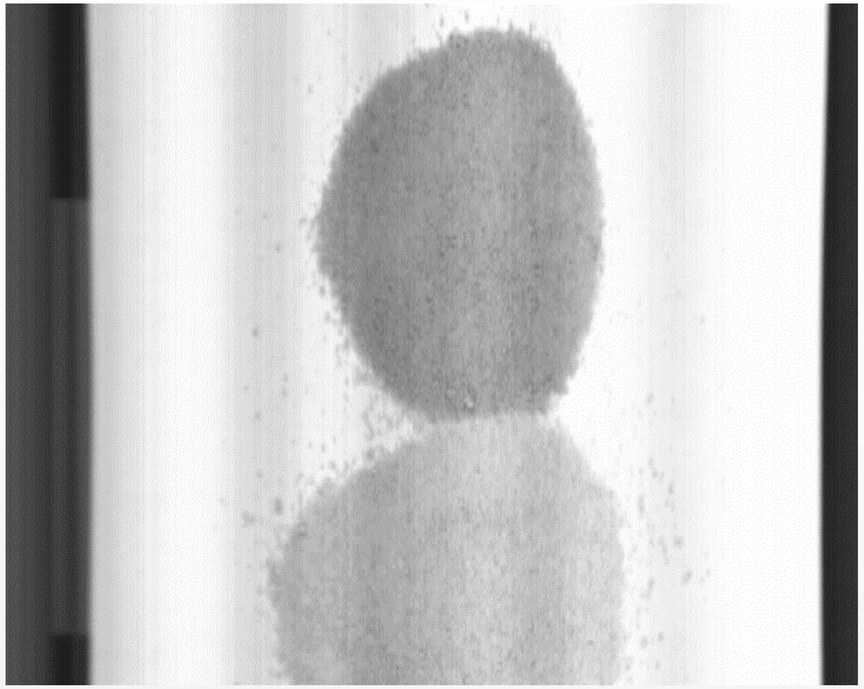


Transformation from
reflection to absorption

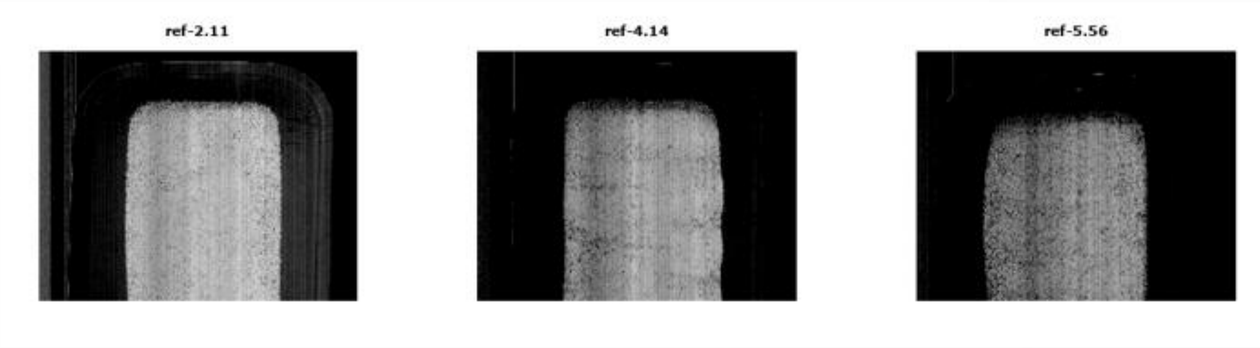


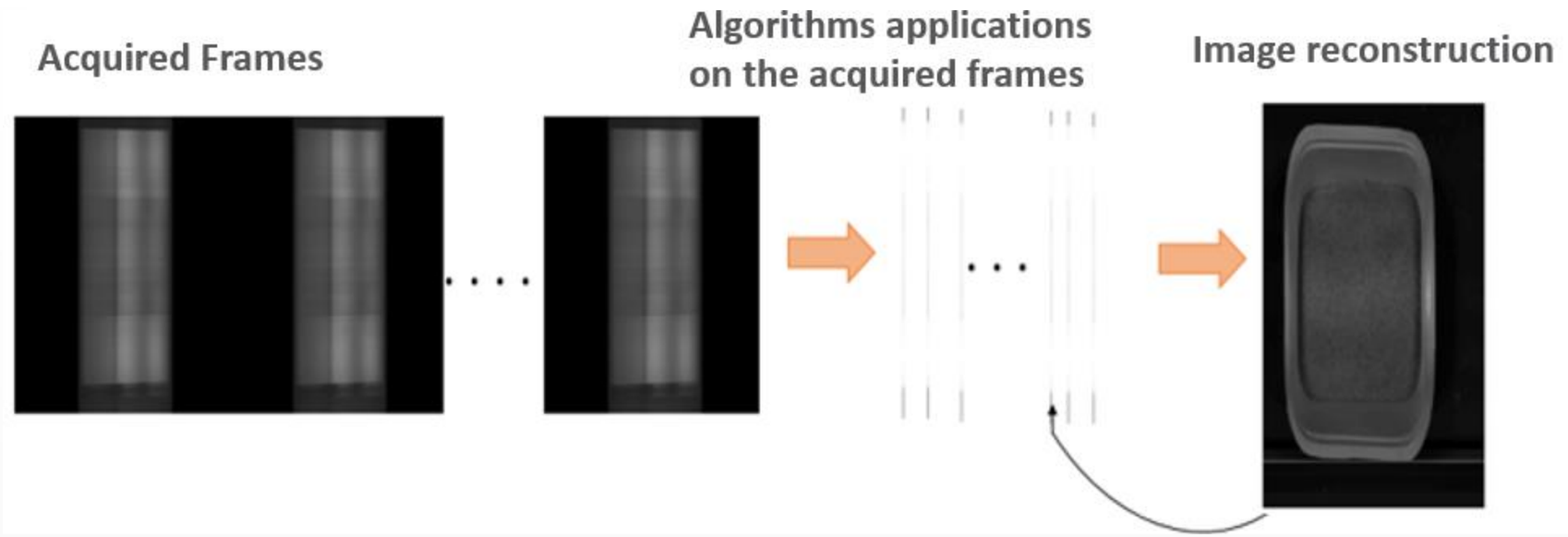

Telecamere
Acquisizione
Attuale
Salva
Immagini Sorgente
Associa Articoli
Modifica Master
Associati
Finestre
Ricerca e Misura
Tolleranze Misura
Tolleranze Nastro
Difetti Critici
Apprendimento
Controlli
Parametri
Modifica Articolo
TV1
Visualizza
Modifica
Risultati Misure
Visualizzatore
Logout
Fine
Controlli

HarleNIR - Other applications & Inspection of ceramic material

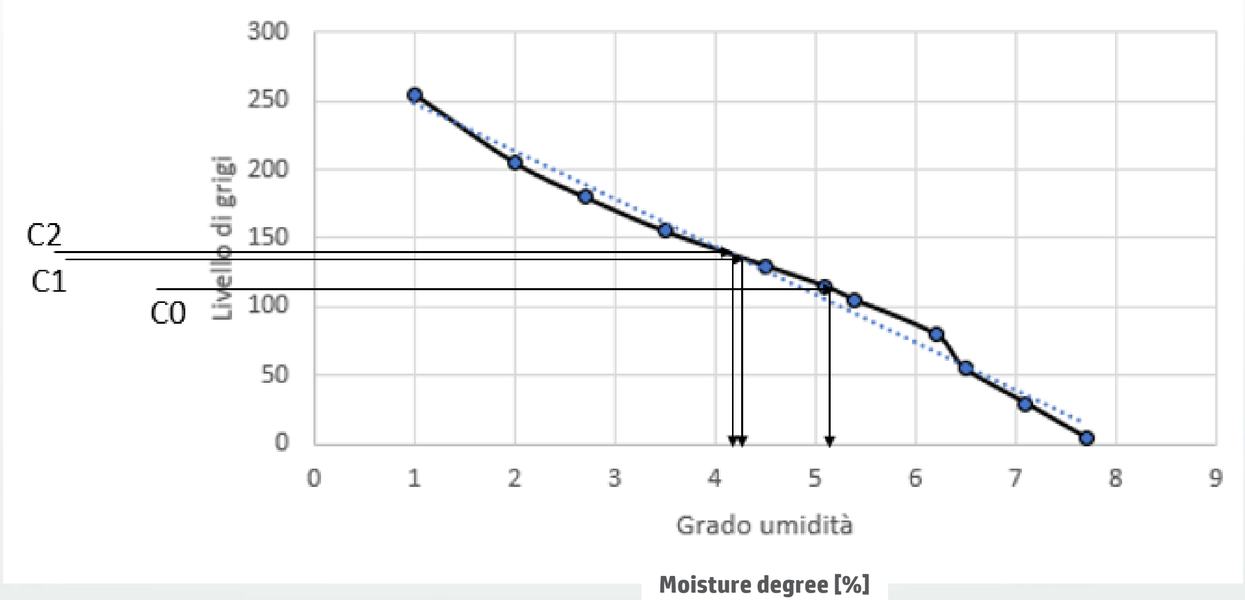


Moisture content of ceramic powder





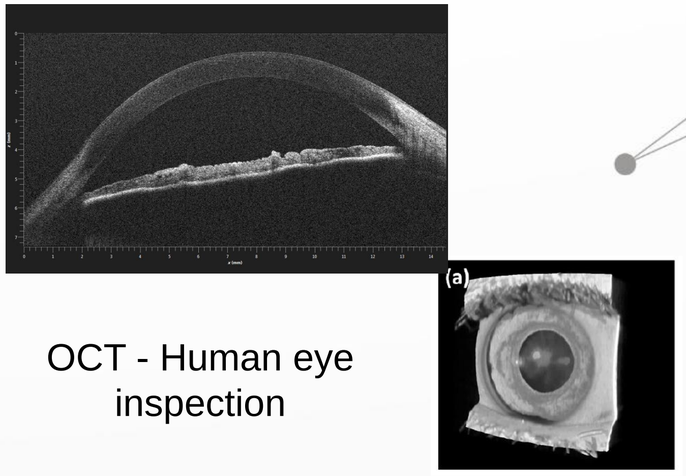
Calibration curve obtained by a thermobalance



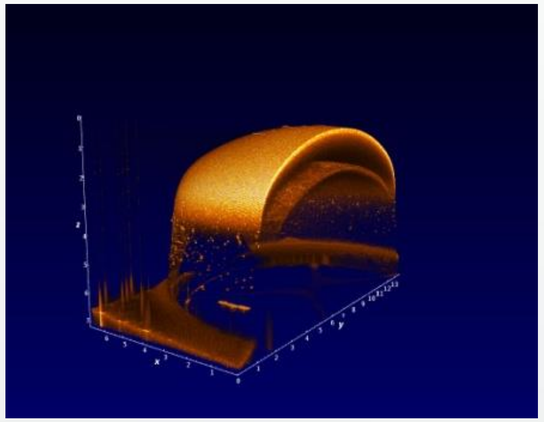
Optical Coherence tomography

OCT is an optical imaging technique that is:

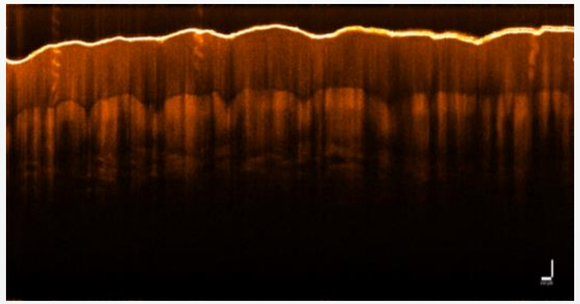
- Fast
- Very sensitive
- Non-contact
- Non-destructive
- Provides a resolution on the micron scale
- Provide a cross-sectional images with an high penetration depth (Not for all materials)



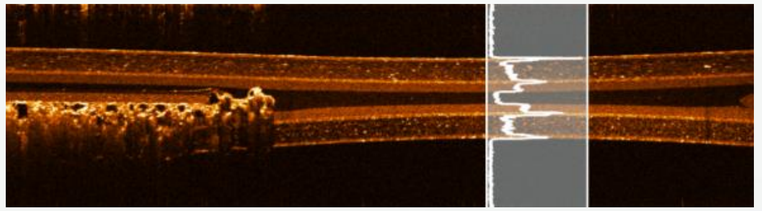
OCT - Human eye inspection



OCT 3D image of a tablet inside the blister



OCT image of fingerprint



OCT image of thin plastic film

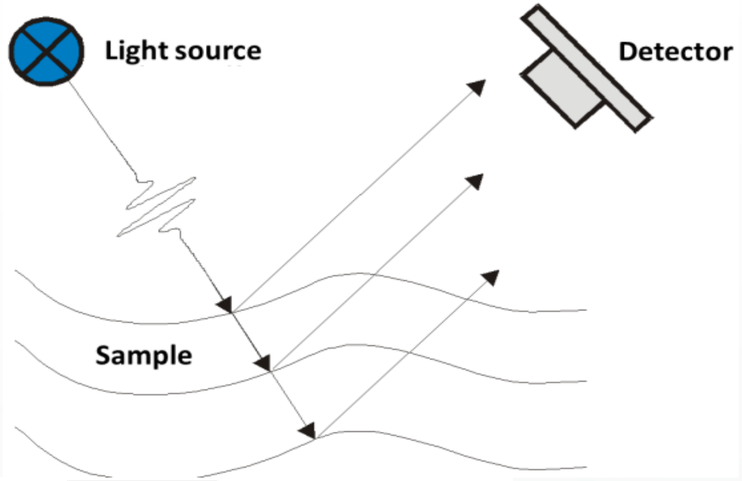
How does OCT work?

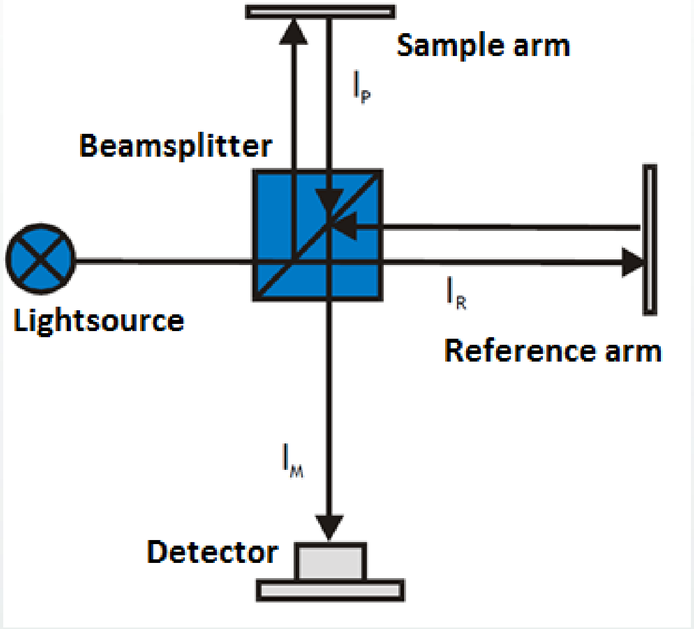
OCT is based on white light interferometry

Probe beam is focussed into sample

Light is back-scattered from different structures

A Michelson interferometer is used to measure the travelling time of photons



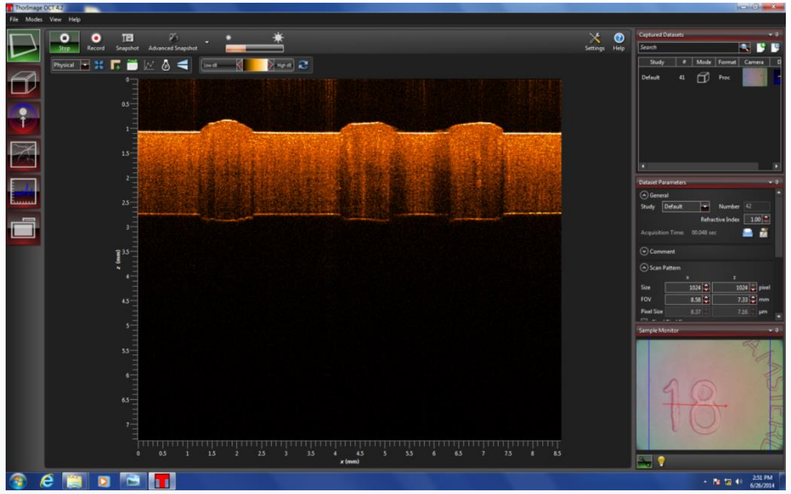


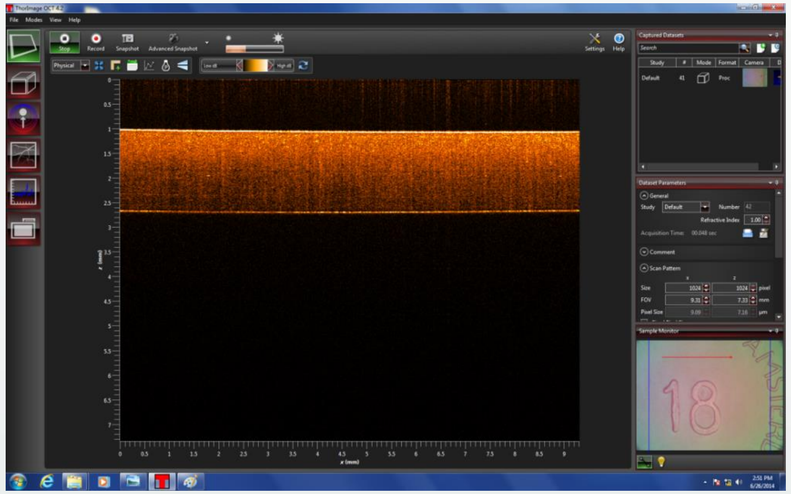
Signal on the detector

$$I = I_P + I_R - 2\sqrt{I_P I_R}\cos\left(\frac{2\pi}{\lambda}\Delta l_{opt}\right)$$

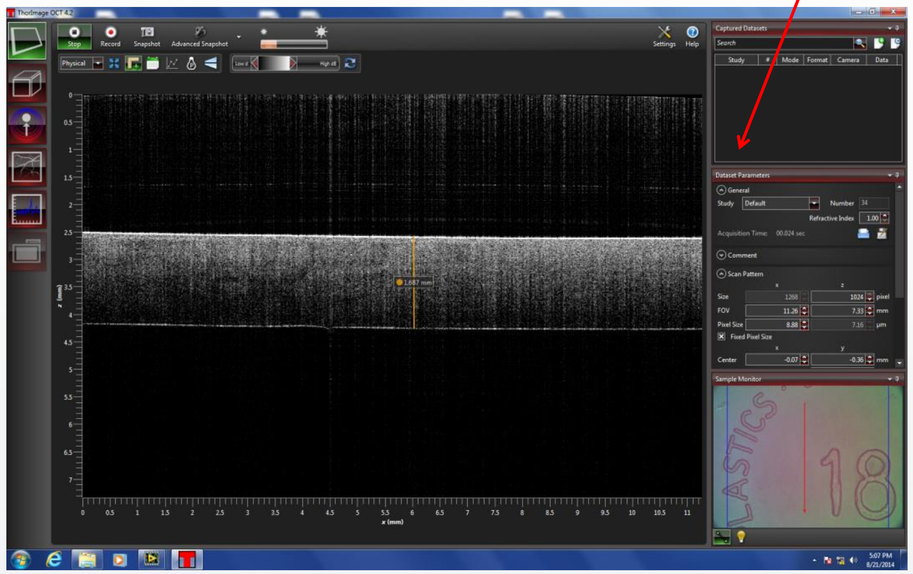
I_P: Intensity sample light
I_R: Intensity reference light
Dl_{opt}: Optical path difference
l: Wavelength

OCT feature: Penetration on materials

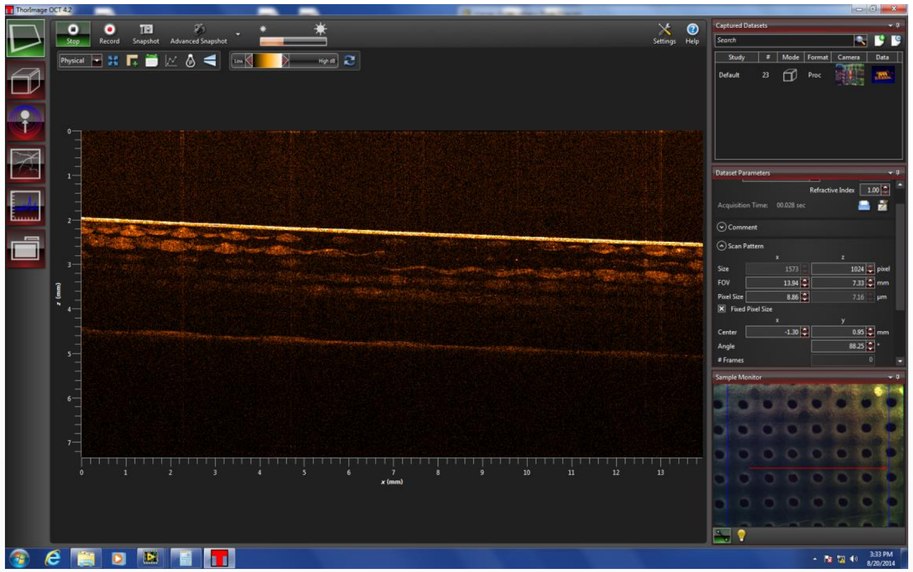


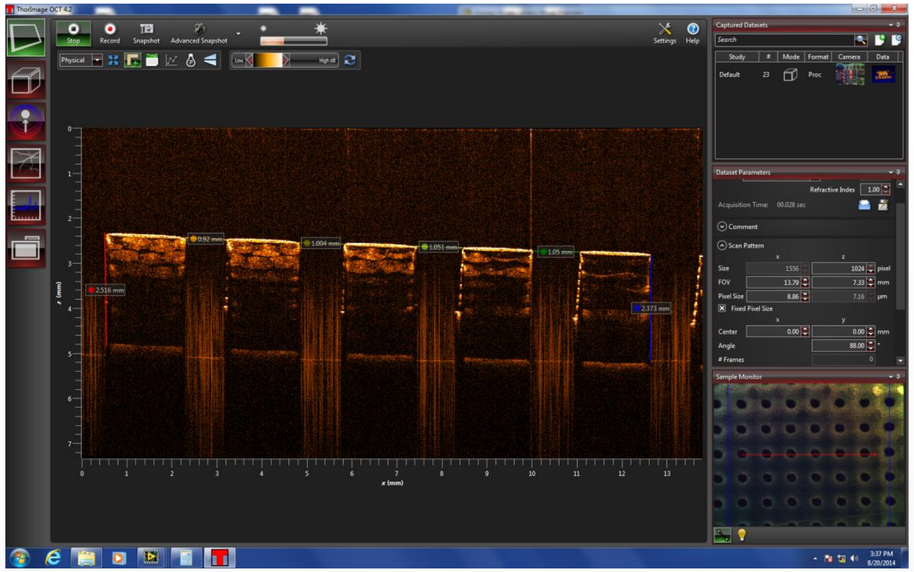


Plastic material - **Thickness of 1.6mm**



The images represents the section of the sample along the red line





The images represents the section of the sample along the red line.

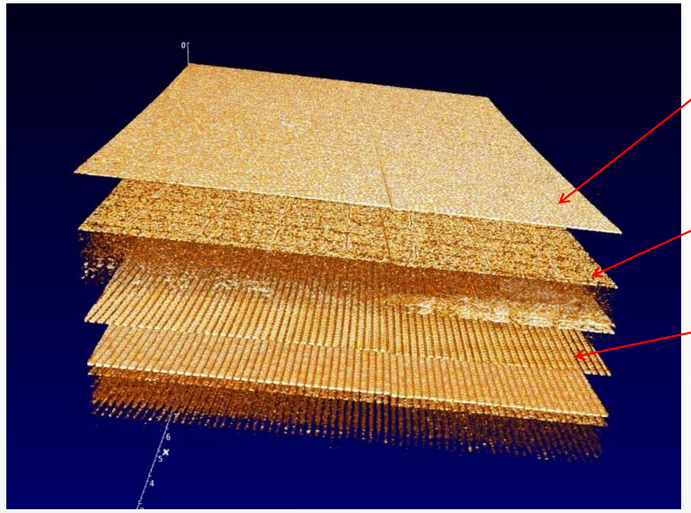
Thickness and distances measurements can be performed.

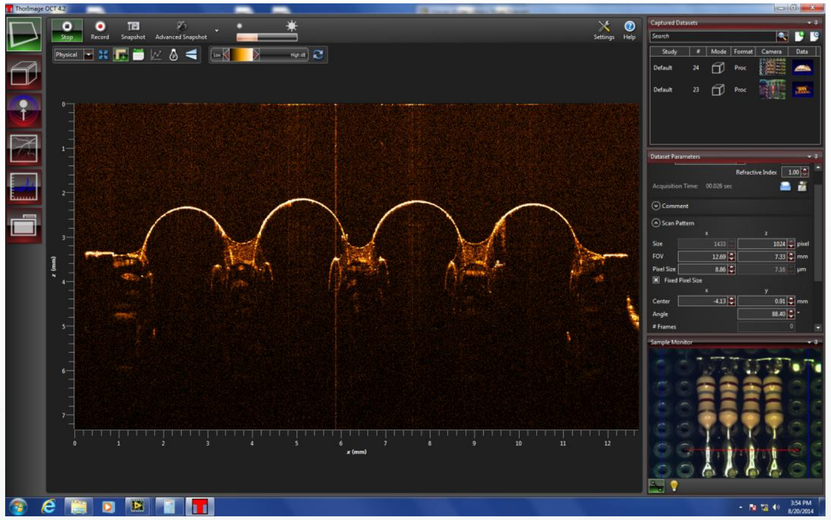
Printed circuit board – the inner structure is well visible. Structural analsys can be performed.

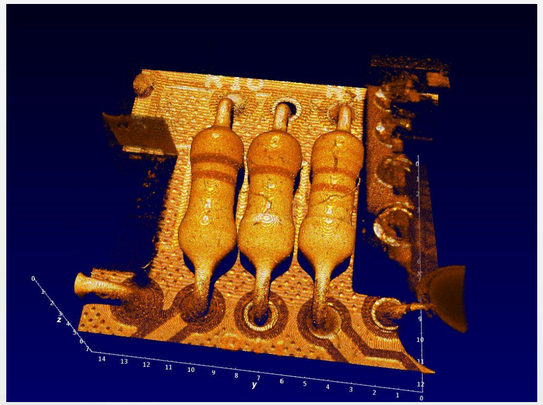
Possibility to verify the presence of unbonded and unwelded layers.

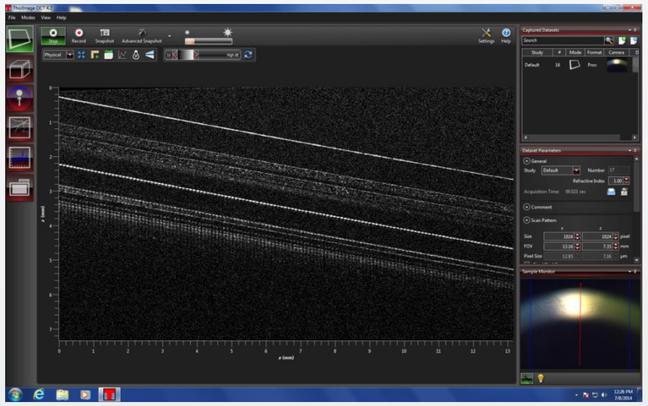
OCT applications: electronics

Mobile phone inspection



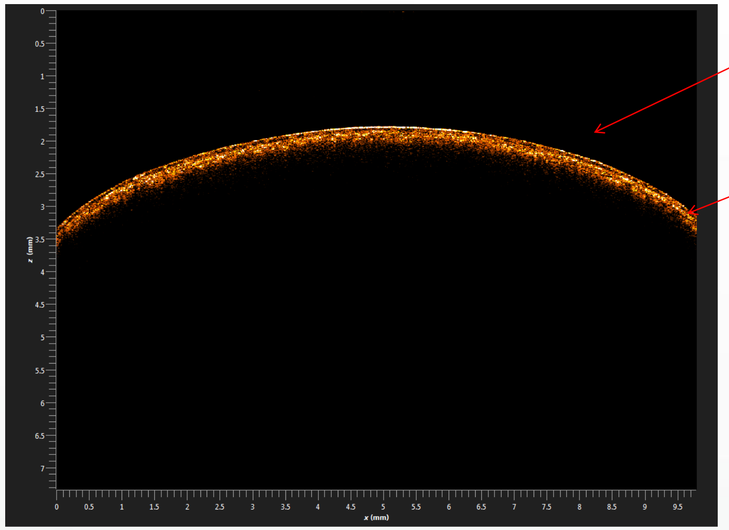






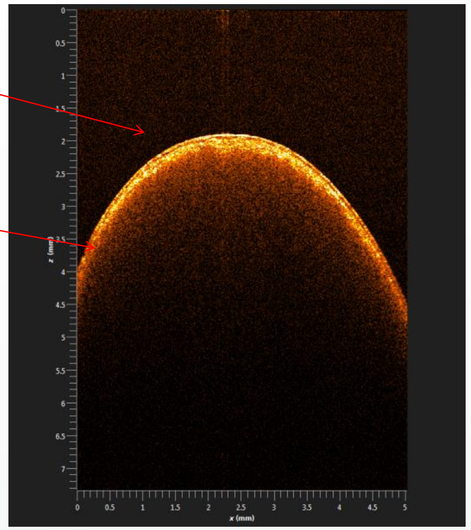
OCT applications: pharmaceutical/medical

Iboprufen tablet

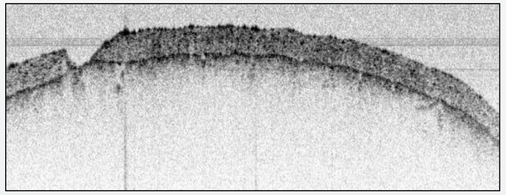


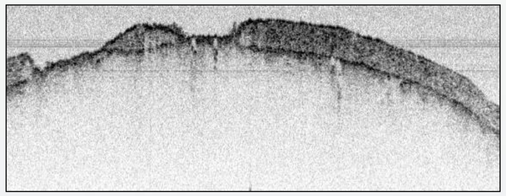
Coating

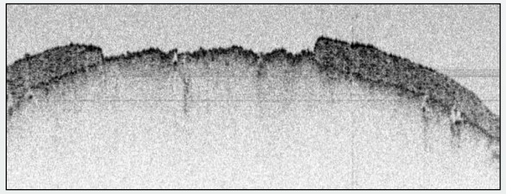
Inner structure

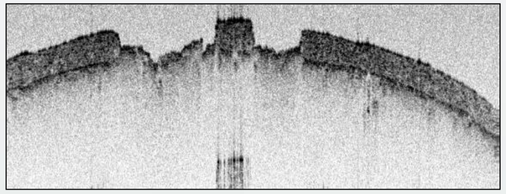


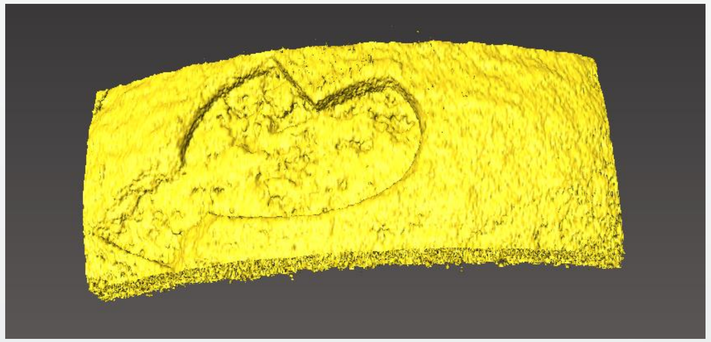
Defects on the coating



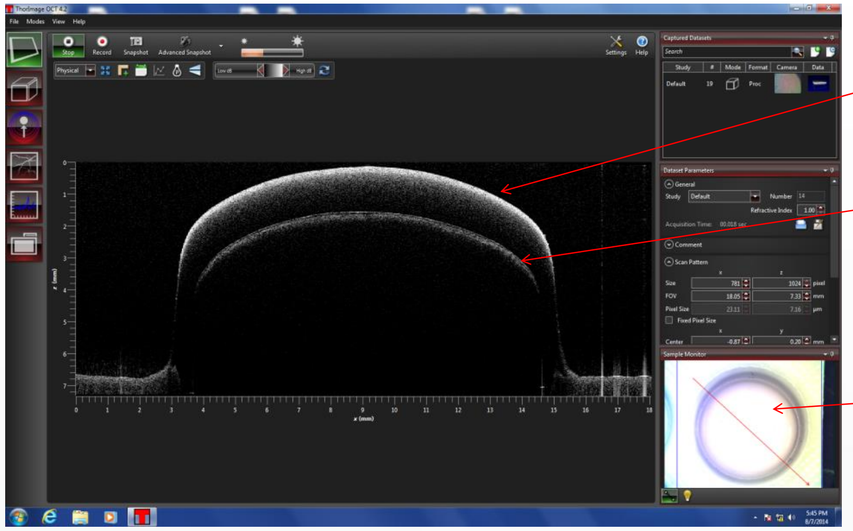








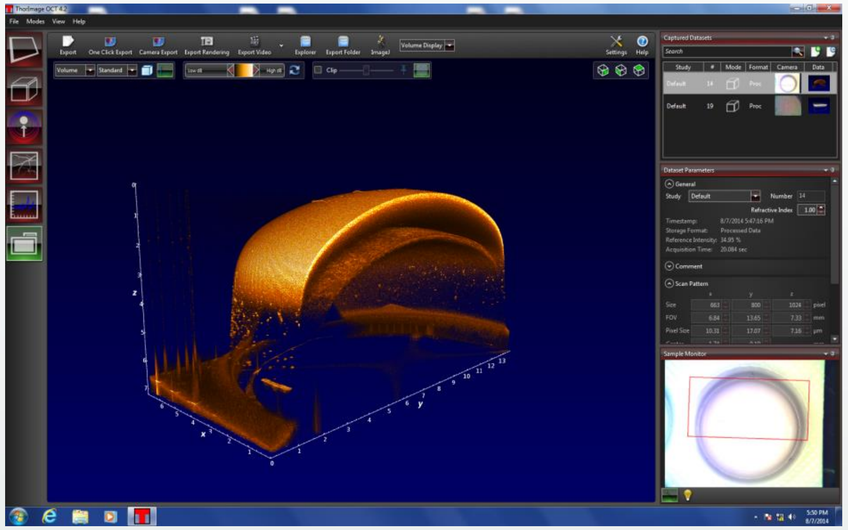
Iboprufen pill inside the blister



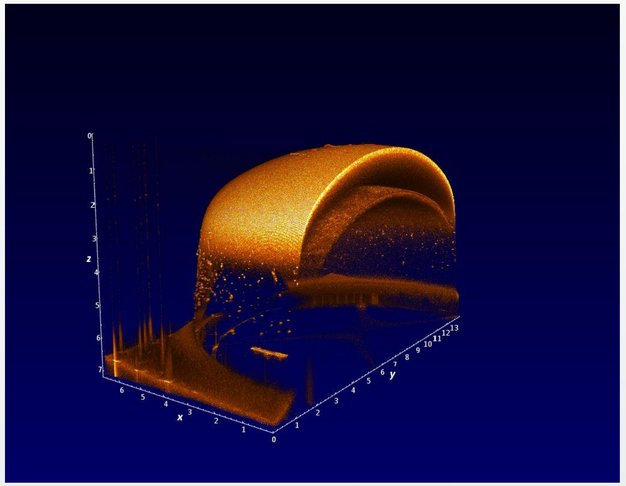
Blister surface

Scan line

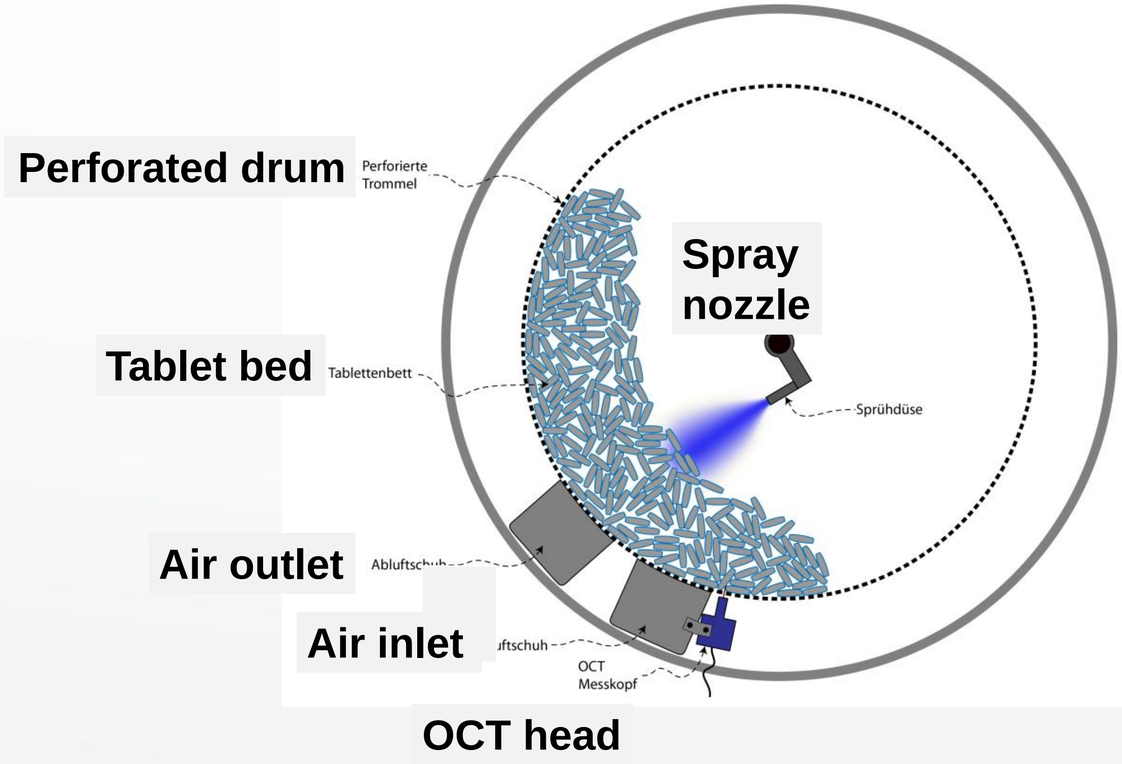
Possibility to control the presence of the pill inside the blister

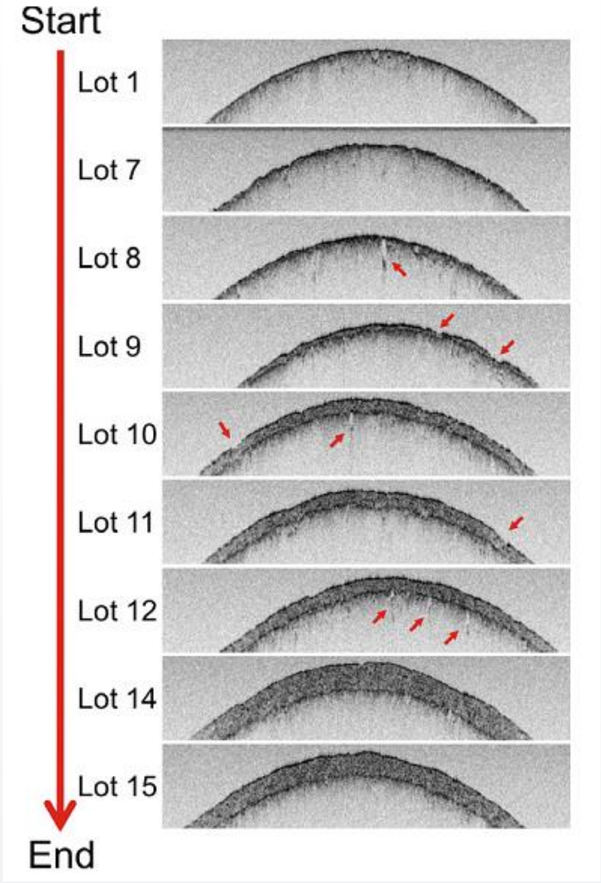


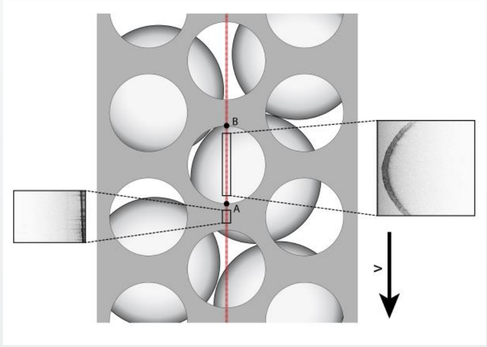
Iboprufen tablets surface



Inline monitoring of the coating growth

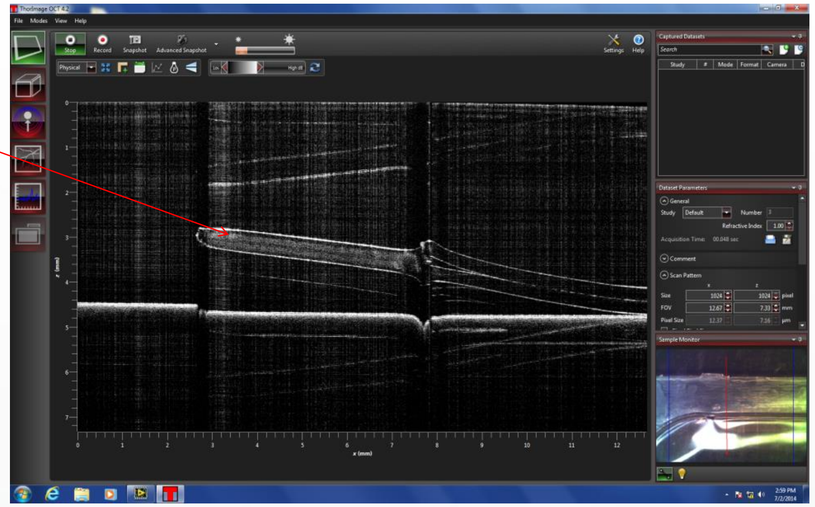


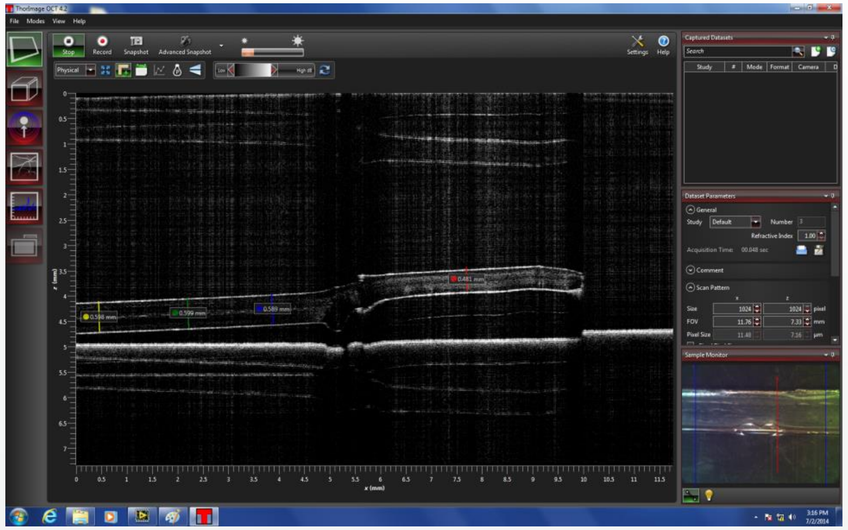




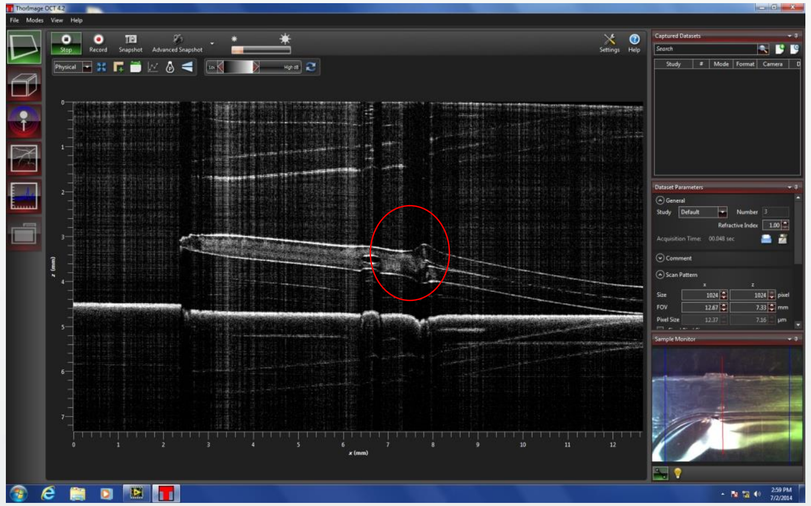
Inspection of welded plastic bags for medical applications

The changes on the “white color”
Is an indication of the quality of the welding





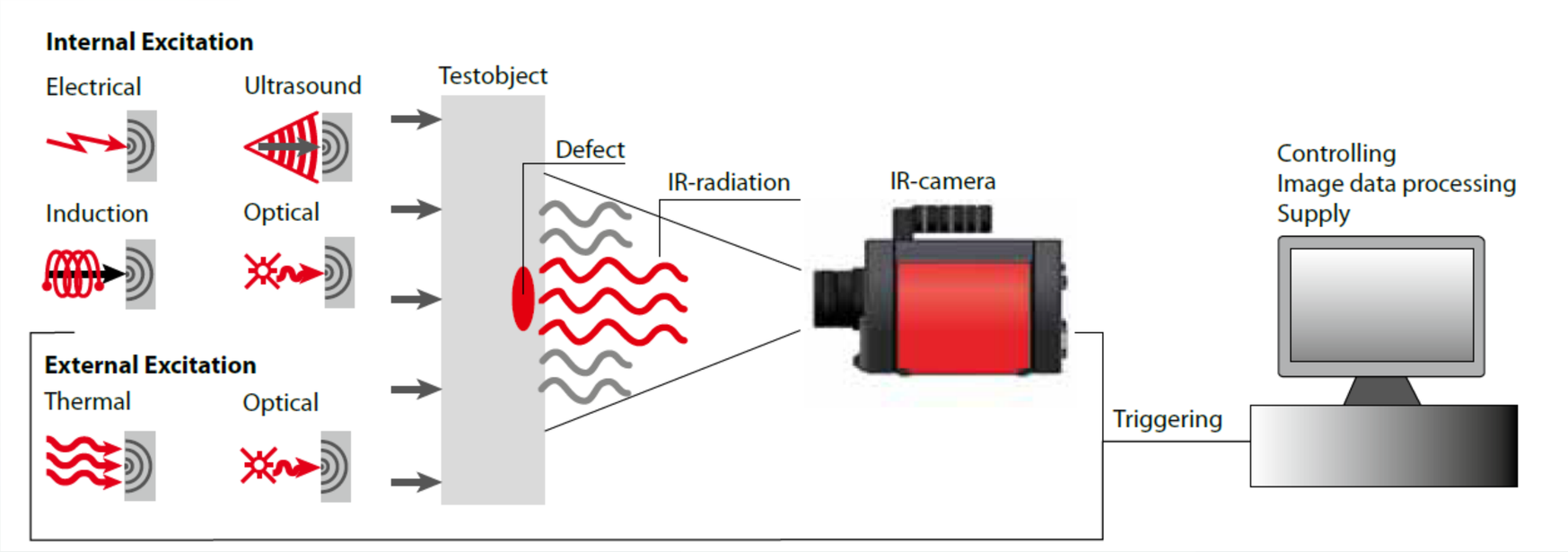
An Automatic inspection system for the presence of bubbles was developed



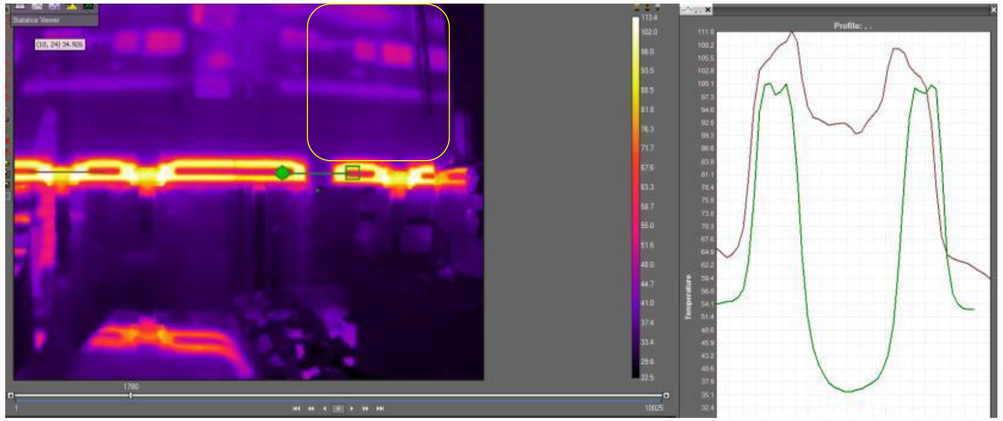
Active thermography

Active thermography is an imaging procedure for non-destructive material testing.

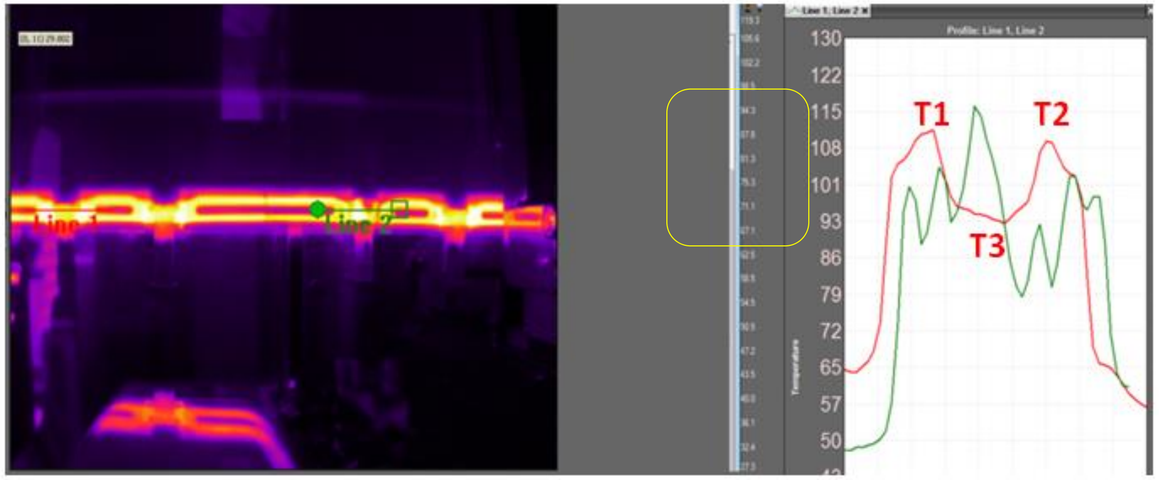
A heat flow is induced by an energetic excitation of the test object, which can be done in a transmissive or a reflective setup. The resulting heat flow is influenced by interior material layers and defects. These inhomogeneities can be captured on the object surface by high-precision thermal cameras.



Monitoring of the single bag - example of data extraction



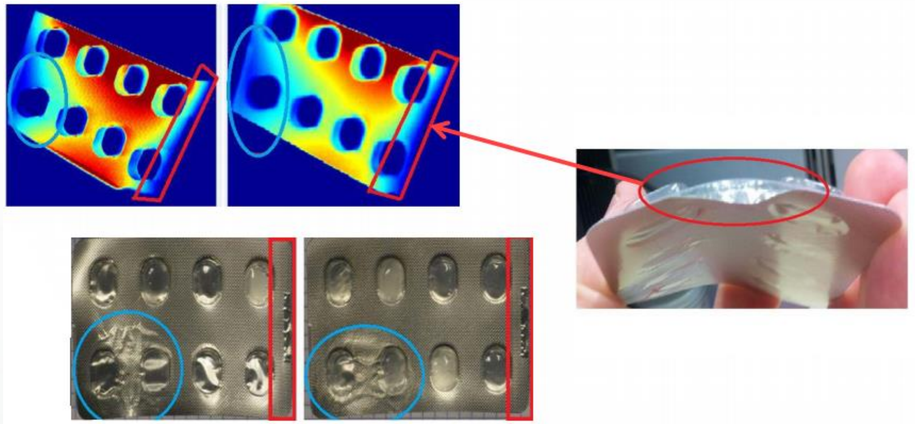
Example of temperature profile for
a bag with and without port.

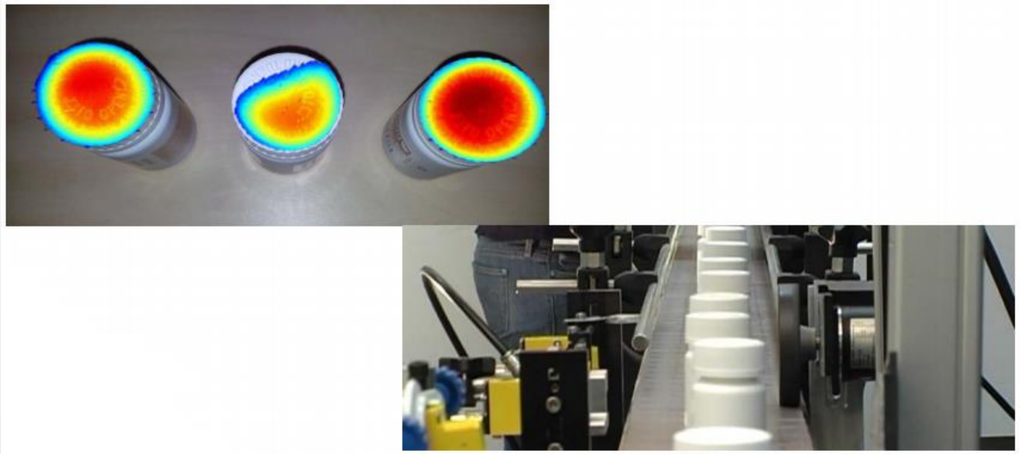


Example of temperature profile
For a bag with rotated port.

Blister and Bottles sealing monitoring - Inline monitoring

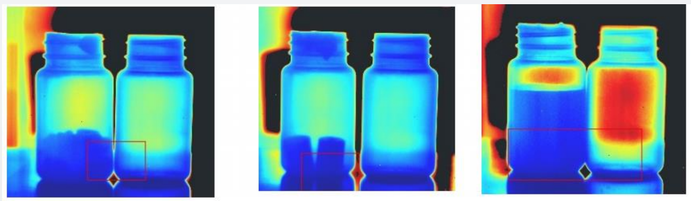
Dynamic Infrared Vision





Advantages of DIR Technology:

- Real-time testing of 100% of the products
- Real-Time process monitoring
- Full records for every products
- Very high throughput→ no product slowdown
- Non-destructive, non-interfering

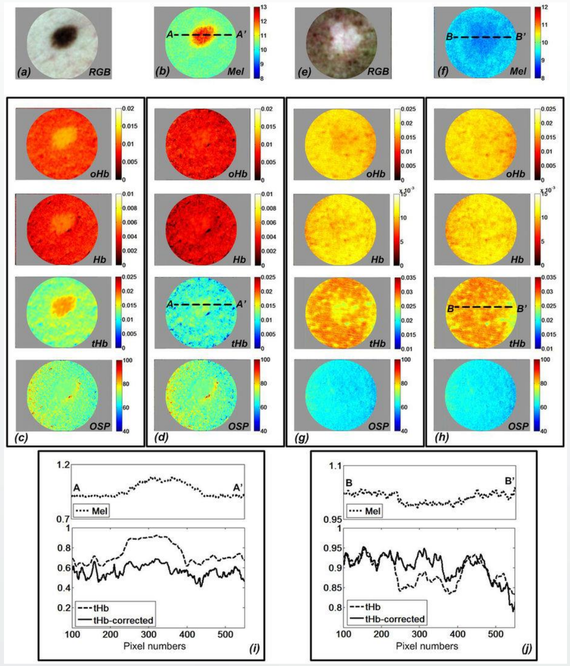


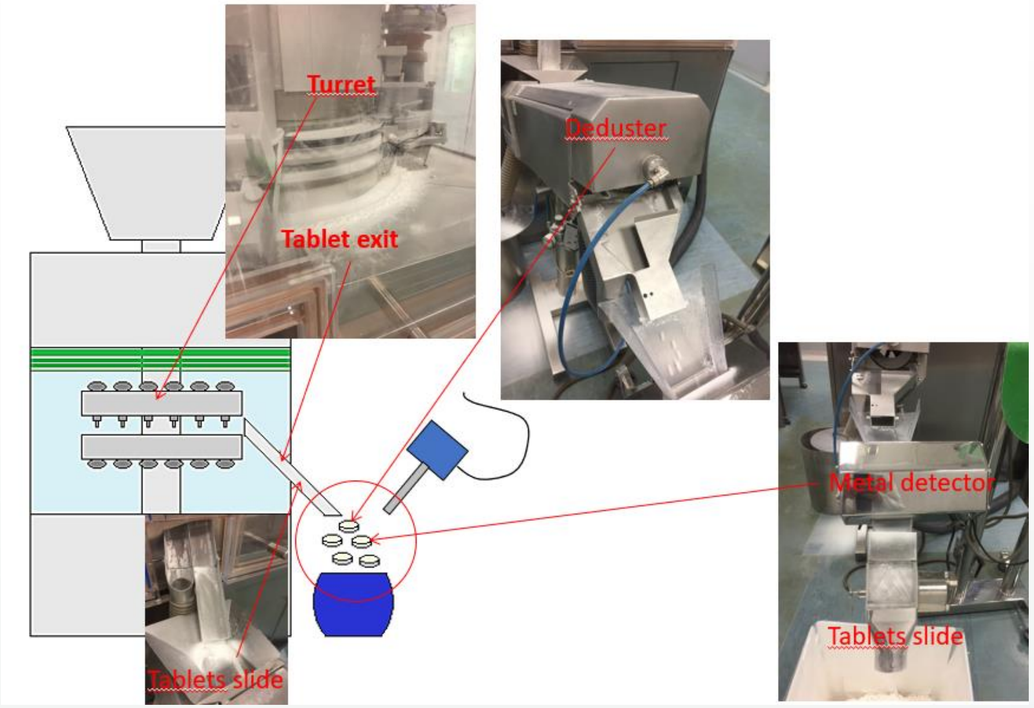
Optical spectroscopy

Suitable for point-by-point inline inspection

What we can measure?

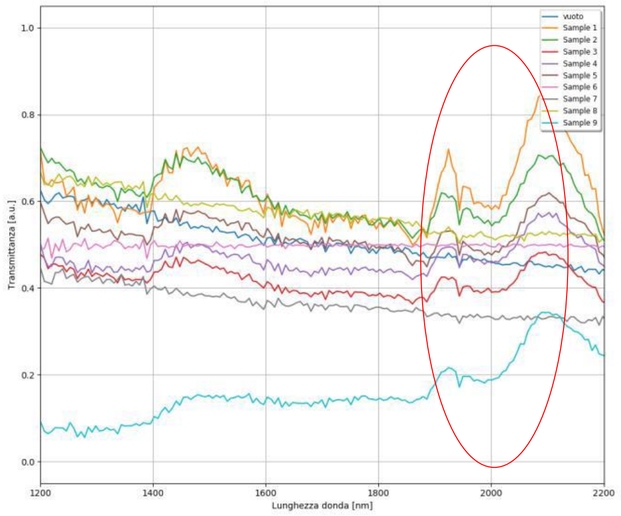
- API Content
- Moisture
- Crystalline Structure
- POINT BY POINT Measure!



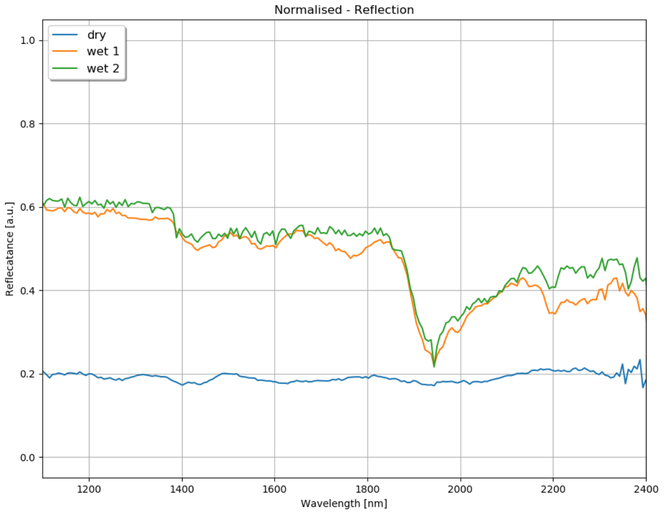


Miniaturisation and high speed acquisition

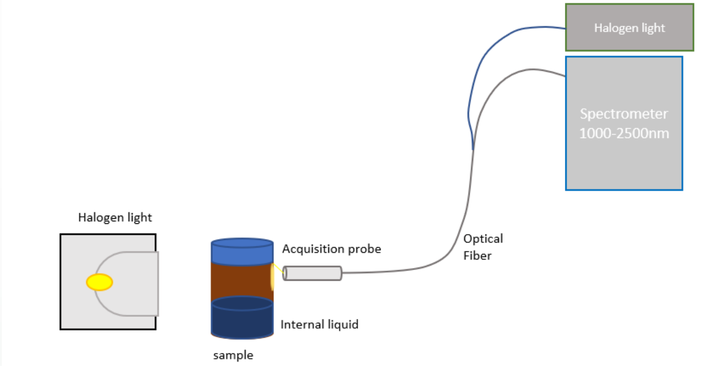
Optical spectroscopy



CO2 determination on vials.
The absorption peak of the CO2 at 1920nm is well visible



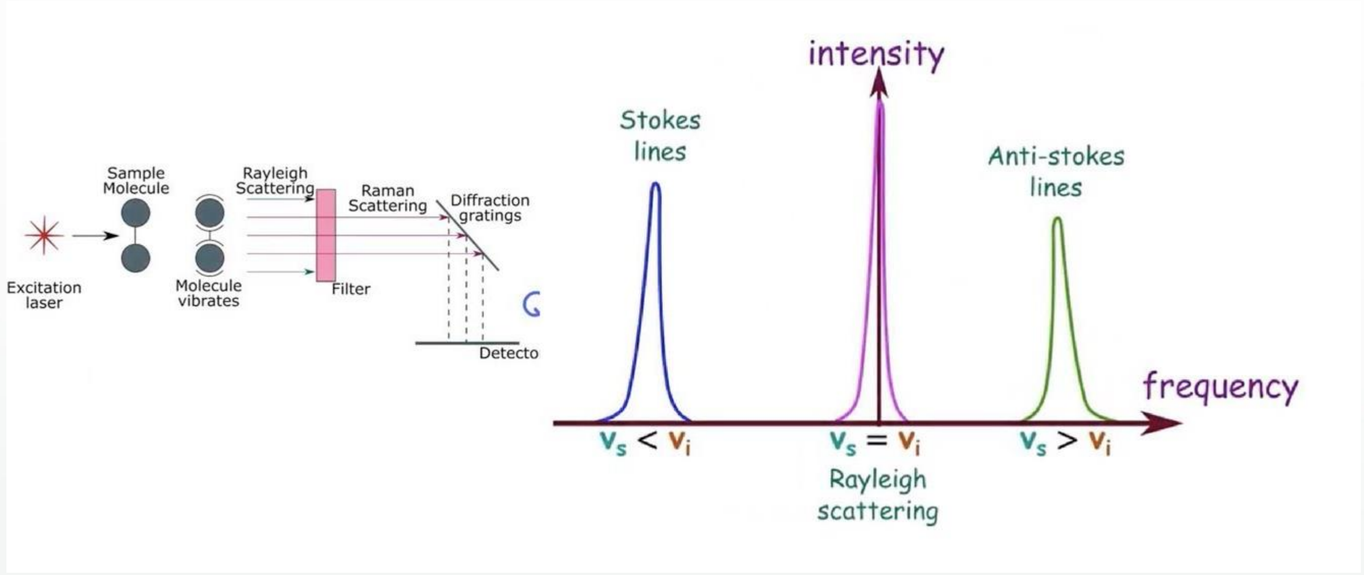
Moisture measurements
on Lyo cake
The absorption peak of the water at is well visible

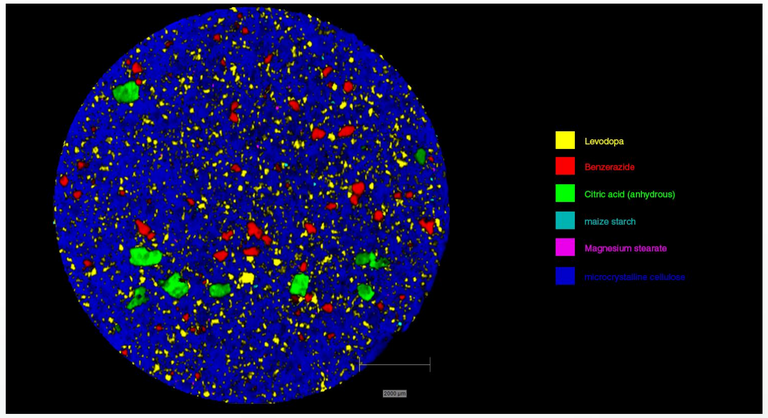


Measurements performed
in transmission mode

Raman spectroscopy imaging

Suitable for point-by-point inline inspection



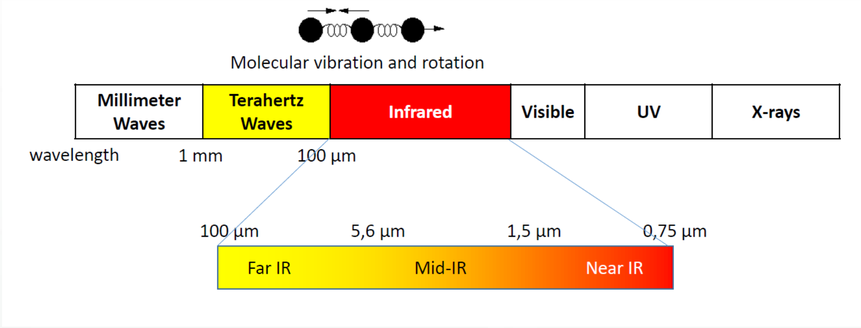


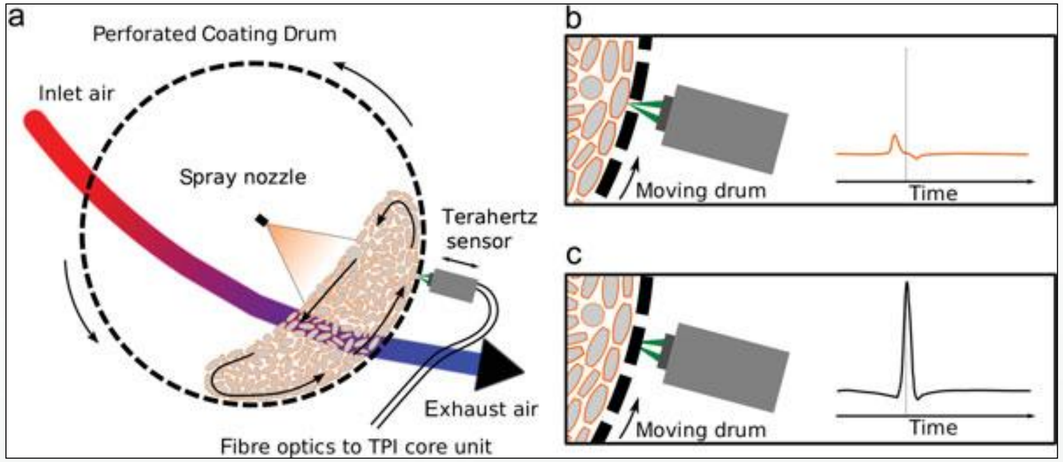
Laser wavelength used for Raman spectroscopy:
532 nm → Green
785 nm → Red
1064 nm → Infrared

Long time acquisition

Terahertz imaging

On the THz range (300 GHz to 3 THz) and on the Infrared range (3 THz to 190 THz), the which molecules exhibit molecular vibrational and rotational modes, which enable to identify and quantify products compounds.





Terahertz radiation corresponds to frequencies between the microwave and infrared regions of the electromagnetic spectrum: 300 GHz to 10 THz, or wavelengths of 1mm to 1µm.

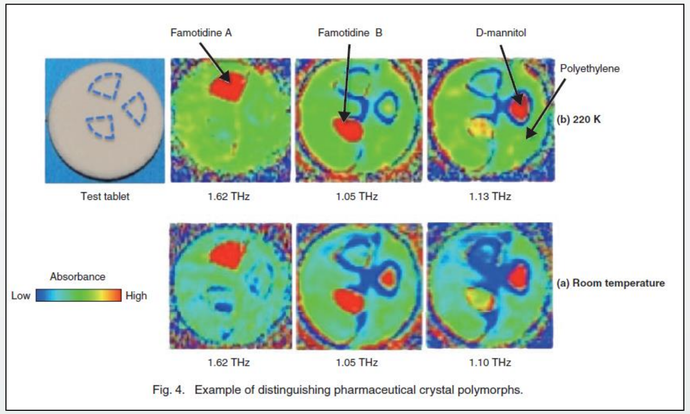
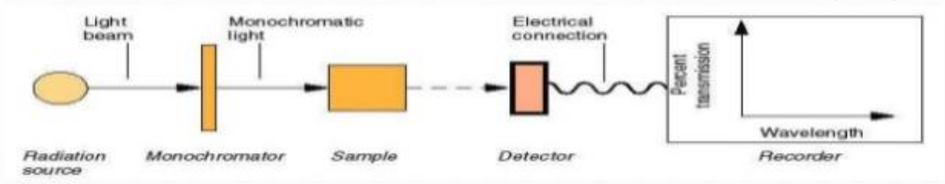
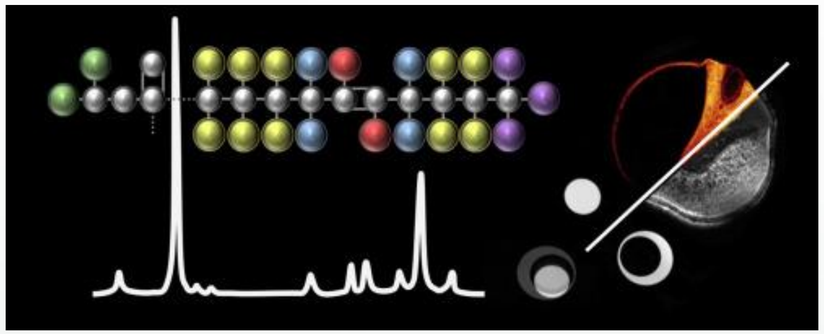


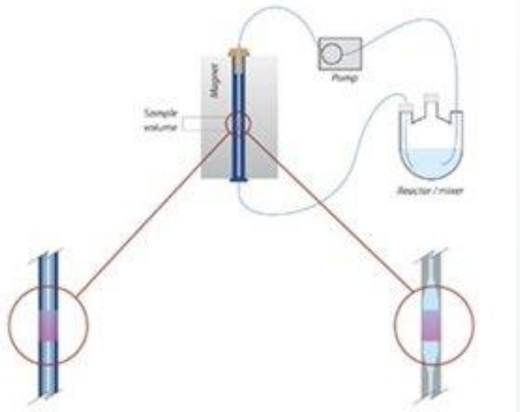
Fig. 4. Example of distinguishing pharmaceutical crystal polymorphs.

Nuclear Magnetic Resonance

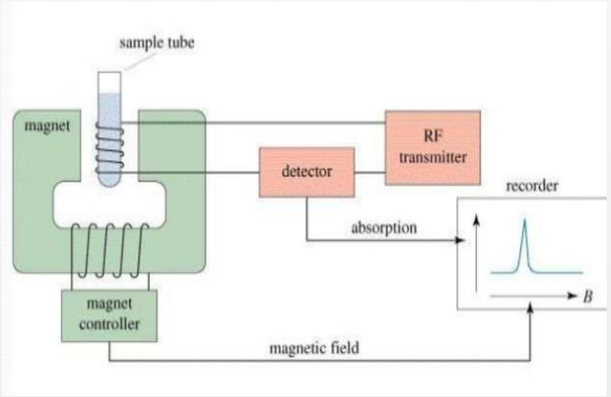
NON-DESTRUCTIVE spectroscopic analysis method based on the magnetic properties of the nuclei of some atoms and isotopes. Possibility to extract information on the structure of the molecules and monitor the synthesis reactions and drug formation.







- **Linear response**
- **Orthogonality**
- **Signal Variance**
- **Structural info**



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