



# SACMI **COMPUTER VISION**

## Università “La Sapienza” - Roma

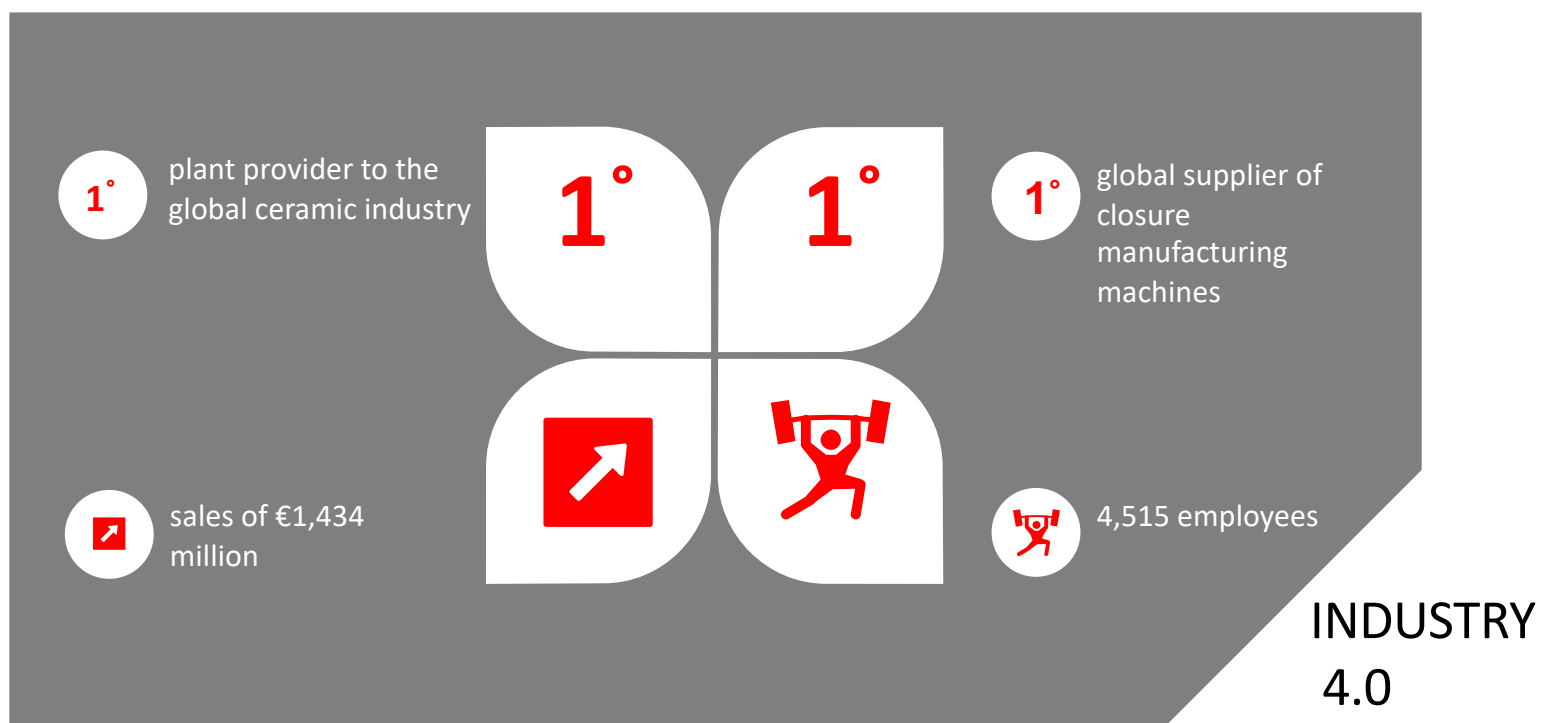
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Donato Laico  
Vision Systems Engineering Department  
SACMI IMOLA S.C.

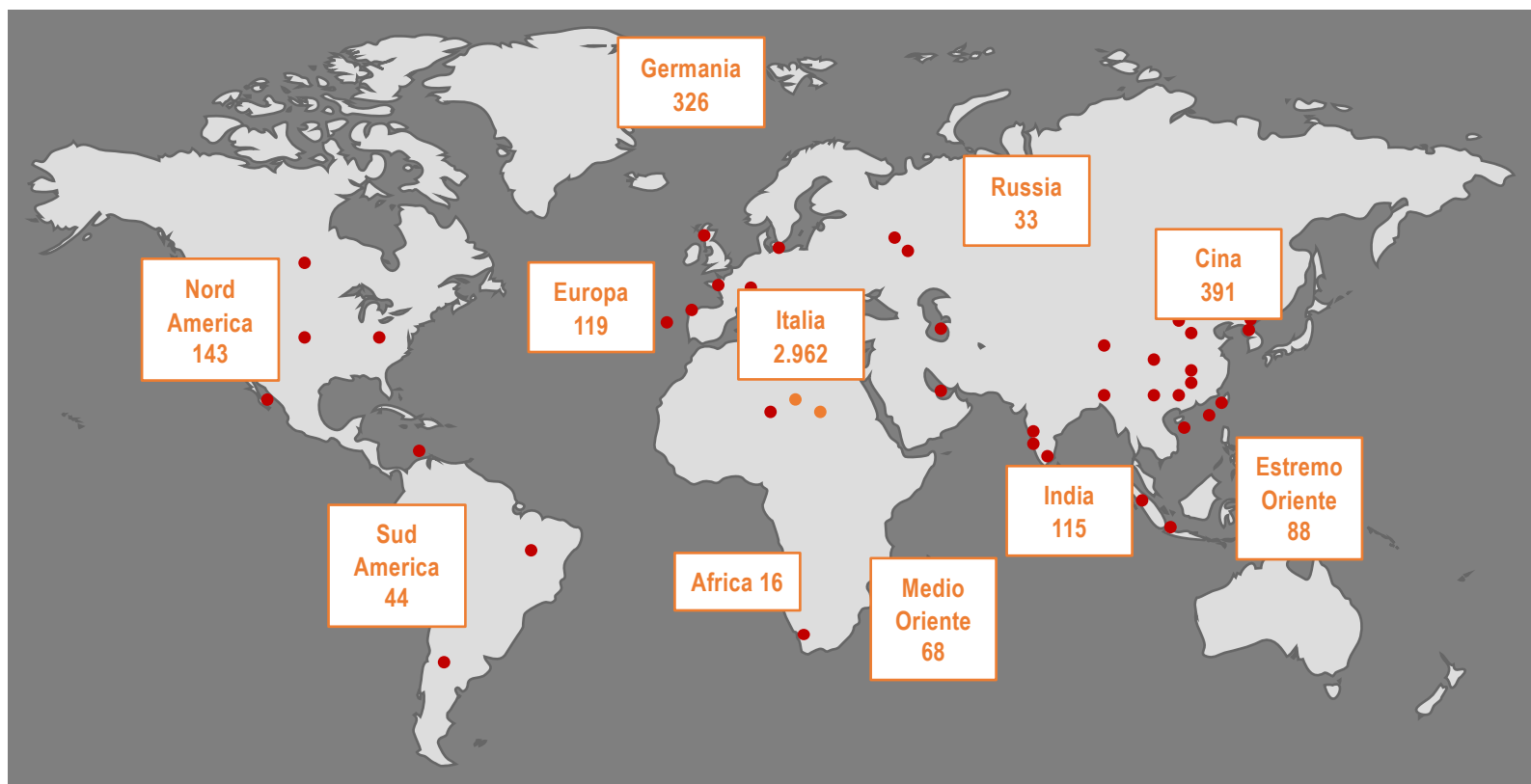
## SACMI Imola

SACMI Imola is the parent company of the SACMI Group, an Italian cooperative that is the leading international designer, producer and marketer of manufacturing plants and industrial technology for the ceramic and packaging sectors. SACMI has enjoyed market success for 100 years and is now a major Italian enterprise in terms of size, sales, areas covered and services provided.

# The SACMI Group



# SACMI employees around the world

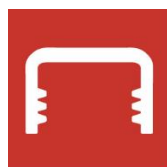


## SACMI - Business Units

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**Ceramics**



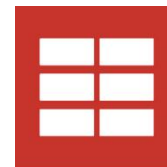
**Closures &  
Containers**



**Beverage**



**Metals**



**Packaging &  
Chocolate**



**Quality &  
Process  
Control**



**Customer  
Service**

## Sacmi Computer Vision

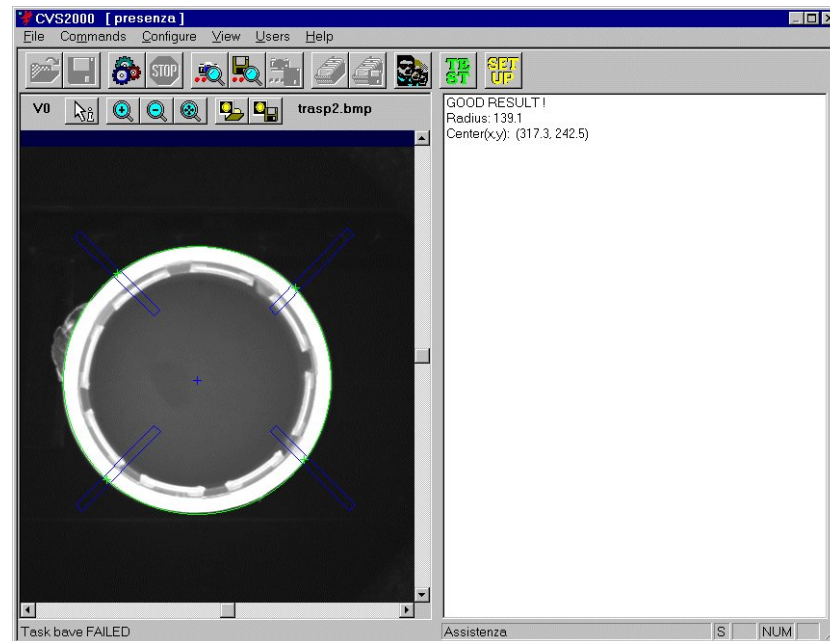
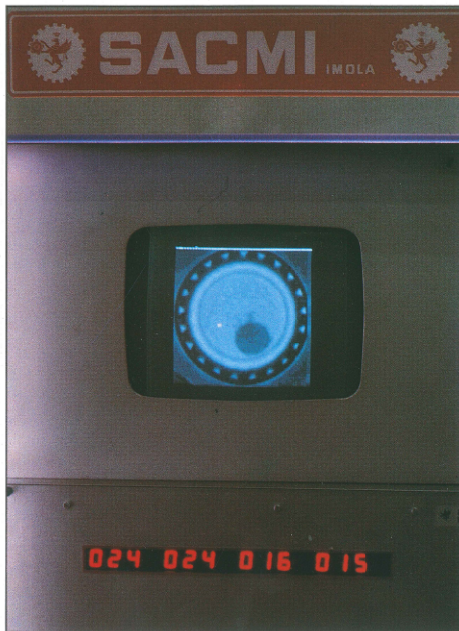
The use of a vision system comes from the need to control the quality of the products obtained from Sacmi machines.

The first System was installed in 1987 on a machine for crown caps (*l'istogrammatore hardware*)











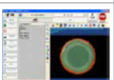
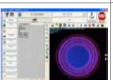
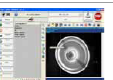



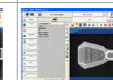

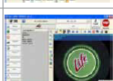

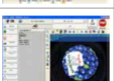
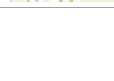
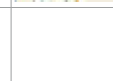
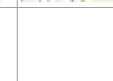
Currently they are designed (hardware and software) and made in the Quality & Process Control business unit and is controlled the quality of plastic and metal caps, bottles, labels, cans, lithographed sheets ...



# Sacmi Vision: A Continuous Evolution...



# SACMI Inspection Systems application list

	CROWN CAP	ALUMINIUM CAP	PLASTIC CAP	TWIST CLOSURE	END/EASY OPEN END/PEEL OFF/EASY PEEL	FOOD&BEVERAGE CAN	LITHOGRAPHED SHEET	PREFORM	LABEL	CONTAINER
<b>APPLICATION</b>										
										
										
<b>DESCRIPTION</b>	Complete inside and outside crown cap inspection for colour and printing. Speed up to 5000 ppm. Main detectable defects: malformation, contamination, liner defects, corrugation integrity, printing defects, colour shift, missed decorations, scratches, flash and spots.	Complete inside and outside aluminium cap inspection for colour and printing. Speed up to 3600 ppm. Main detectable defects: malformation, contamination, liner defects, printing defects, colour shift, missed decorations, scratches, flash and spots. Tamper evident band defects.	Complete inside and outside plastic cap inspection for colour and printing. Speed up to 3600 ppm. Diameter inspected from 12mm to 99mm. Main detectable defects: malformation, contamination, liner defects, printing defects, colour shift, missed decorations, scratches, flash and spots. Tamper evident band defects, detection of micro-hole and micro-crack.	Complete inside and outside twist closure inspection Speed up to 3600 ppm Diameter inspected from 40mm to 110 mm. Main detectable defects: malformation, contamination, corrugation integrity, printing defects, scratches, flash and spots.	Complete inside and outside end inspection Speed up to 3600 ppm Diameter inspected from 40mm to 150 mm. Main detectable defects: malformation, contamination, corrugation integrity, printing defects, scratches, flash and spots.	Complete inside and outside can inspection Speed up to 3600 ppm Diameter inspected from 40 mm to 160 mm Height inspected from 30mm to 250 mm. Main detectable defects: malformation, contamination, compound and curl defects, corrugation integrity, printing and color defects, scratches, flash and spots.	Lithographed sheet inspection Speed up to 10.000 sheet/hour Main detectable defects: registration errors, missed colour plains, colour deviations, colour shifts, deco center to edge offset. Other visible printing defects.	Complete Preform Inspection Wide Range of Necks diameter inspection 28,38, 30,25 Height Inspected from 40 mm up to 160 mm from necking Main detectable defects: malformation, contamination, corrugated surfaces, mould defects, print defects, craters, holes in body and injection point, inclusions, bubbles, colour variation, humidity, opacity, milk stripes, crystalline formations, cavity number, relevant points ecc.	Complete Full-facet, Self-Adhesive, Hot Melt or Cold glue label inspection Speed up to 1200 ppm Diameter inspected from 160 mm Height Inspected up to 370 mm Main detectable defects: label skew, corrugated surfaces, label misplacement or unsticking, print defects, contamination and dirt, barcode readings, wrong label reference reading, label orientation, label position in relation to main relevant point in the container.	Container Inspection Speed up to 1000 ppm Diameter inspected from 40 to 160 mm Height Inspected from 150 to 370 mm Main detectable defects: contamination before filling and dirt, container integrity, wrong filling level, bottle leak or bad capping, filling level, relevant points
<b>CONFIGURATION</b>	In line: it can fully fit into the lining machine Stand alone CAT300: it can inspect crown caps as a stand alone inspection system.	In line: it can fully fit into the lining machine Stand alone CHS-AC: it can inspect aluminium caps as a stand alone inspection system.	In line CVS-PC: it can fully fit into the lining, slitting and folding machine, into compression moulding machine and into injection moulding machine Stand Alone CHS-PC it can inspect plastic caps as a stand alone inspection system. Spark Tester: Option for microholes detection on caps moulded by injection	In line CVS-TWCL: it can fully fit into customer conveyor Stand alone CVS-TWCL: it can inspect ends as a stand alone inspection system.	In line CVS-ENDS: it can fully fit into customer conveyor Stand alone CVS-ENDS: it can inspect cans as a stand alone inspection system.	In line CVS-CAN: it can fully fit into customer conveyor Stand alone CVS-CAN: it can inspect cans as a stand alone inspection system.	In line: it can be fully fit into existing decoration line	In line PVS001: it is an integrated inspection system placed before the blow moulder or after the injection machine to check preforms in line at the speed of 40000 bph with general inspection on preforms body Stand Alone PVS002: it is a modular stand alone system to check preforms outline at the speed of 1100 bph with a detailed inspection on preforms body, neck and third	In line LVS001 vision system integrated in multi brand labelling machinery to inspect the label attached to the container with high precision In line LVS002 vision system integrated in multi brand labelling machinery to orientate the container in the right position before the label attachment process Stand Alone LVS00 Vision system to inspect containers in conveyors	In line: it can be fully fit into existing bottling line Stand Alone LVS360 Vision System to inspect containers in production conveyors
<b>SPECIAL FEATURES</b>	<ul style="list-style-type: none"> <li>• Prearrangement for promotional printings inside crown caps</li> </ul>	<ul style="list-style-type: none"> <li>• External side wall inspection by 360° degrees</li> <li>• Lateral inspection</li> <li>• Advanced pericaps detection</li> <li>• Cavity recognition</li> </ul>	<ul style="list-style-type: none"> <li>• External side wall inspection by 360° degrees</li> <li>• Lateral inspection</li> <li>• Advanced pericaps detection</li> <li>• Cavity recognition</li> <li>• Microholes detection</li> </ul>	<ul style="list-style-type: none"> <li>• Printing Inspection</li> <li>• Color Inspection</li> </ul>	<ul style="list-style-type: none"> <li>• Printing Inspection</li> <li>• Color Inspection</li> </ul>	<ul style="list-style-type: none"> <li>• External side wall inspection by 360° degrees</li> <li>• OCR/OCV features</li> <li>• Barcode detection</li> </ul>	<ul style="list-style-type: none"> <li>• Colour inspection LAB or other spaces</li> </ul>	<ul style="list-style-type: none"> <li>• Cavity recognition</li> <li>• Preform weight</li> <li>• Thread inspection</li> <li>• Quick format changer</li> </ul>	<ul style="list-style-type: none"> <li>• Vertical/horizontal label position</li> <li>• Parting line alignment</li> <li>• OCR/OCV features</li> <li>• Barcode detection</li> </ul>	<ul style="list-style-type: none"> <li>• External side wall inspection by 360° degrees</li> <li>• OCR/OCV features</li> <li>• Barcode detection</li> </ul>

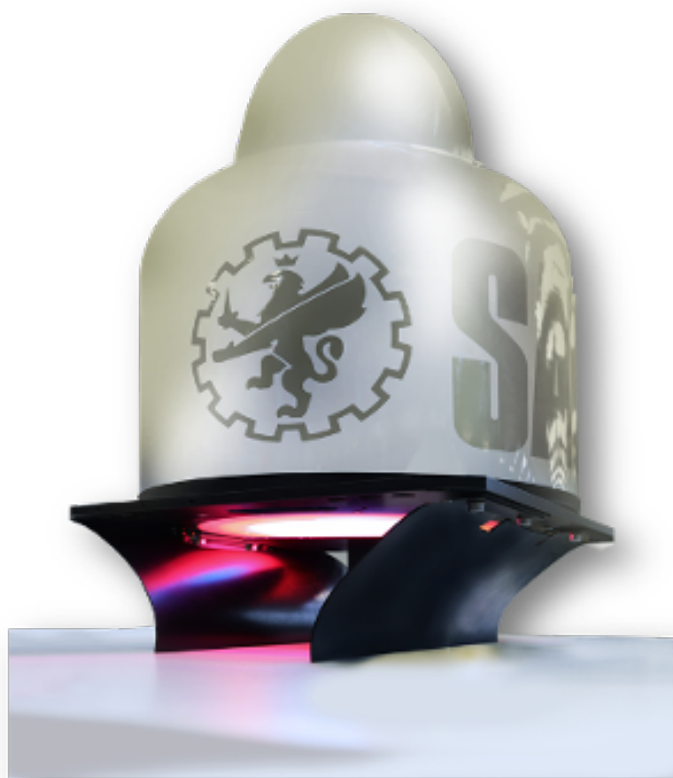


## Can ends: how to inspect them?

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# Chrometriq



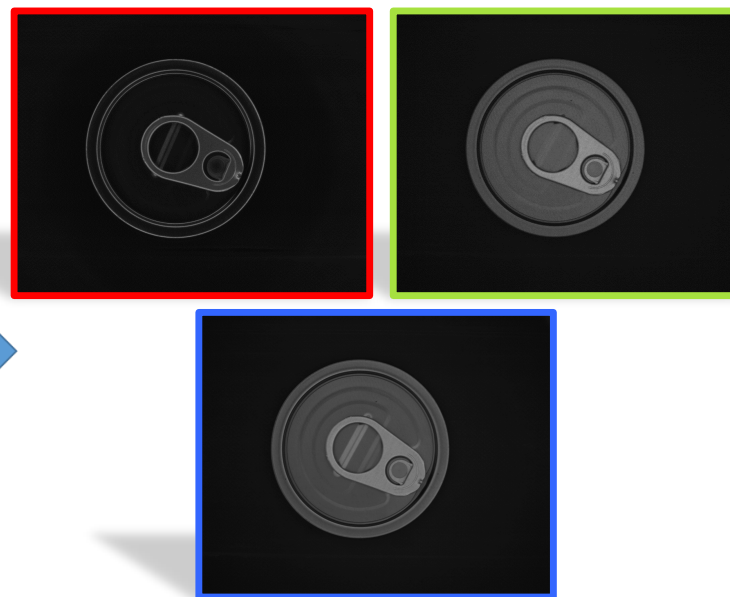
The detection of different type of defects in metal closures having different coatings (tin plate, white plated, silver plated, chrome plated...) requires different light sources with different incidence angles.

SACMI answer to this challenge is our new high performance illuminator...

# Chrometriq

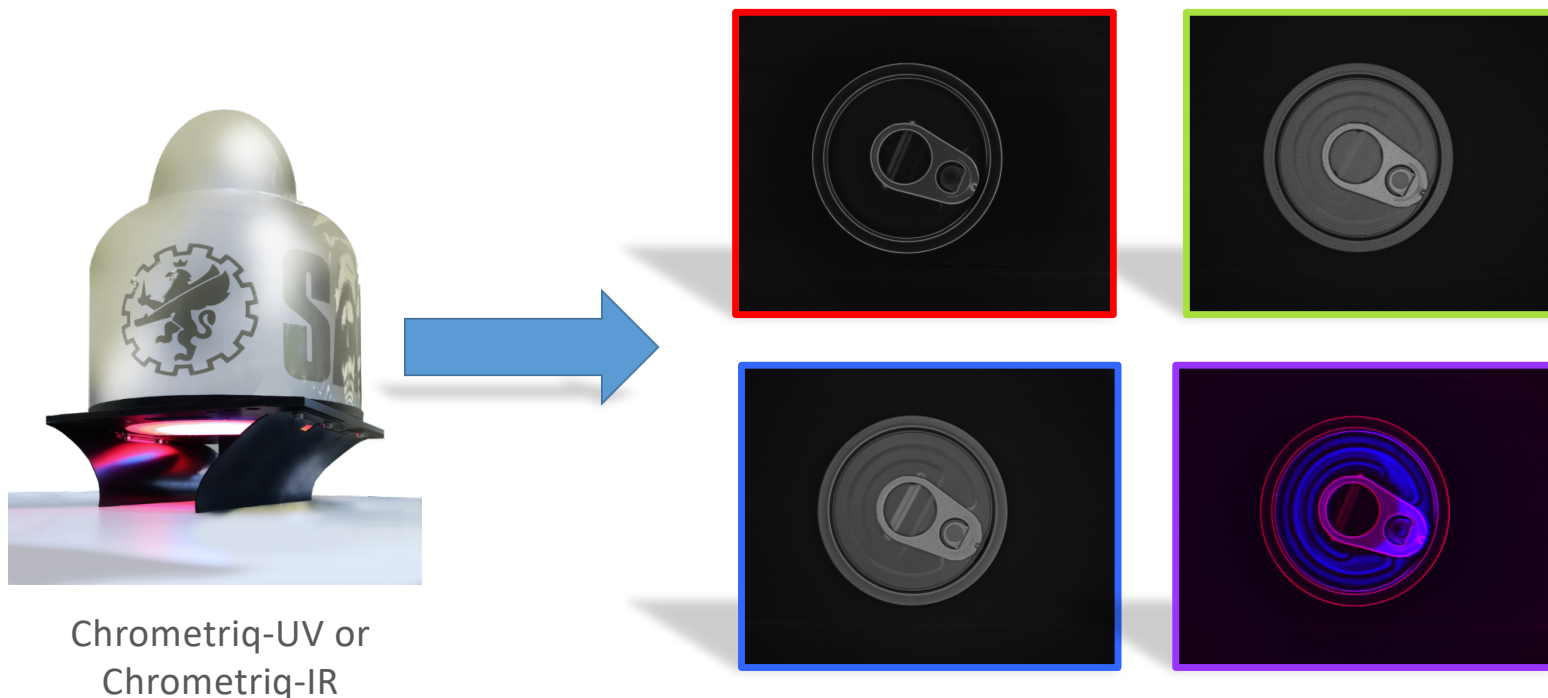


**CHROMETRIQ**  
*Illuminator*



**3 different views of the  
same closure!!!**

# Chrometriq with *Double Shot* technology IR or UV illumination



Chrometriq-UV or  
Chrometriq-IR

**4 different views of the same closure!!!**

## Cans and Tins: how to inspect them?

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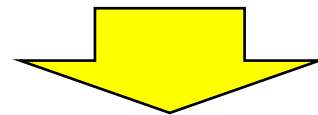
# CVS360



Is the heart of our inspection system, fully developed in our R&D labs.

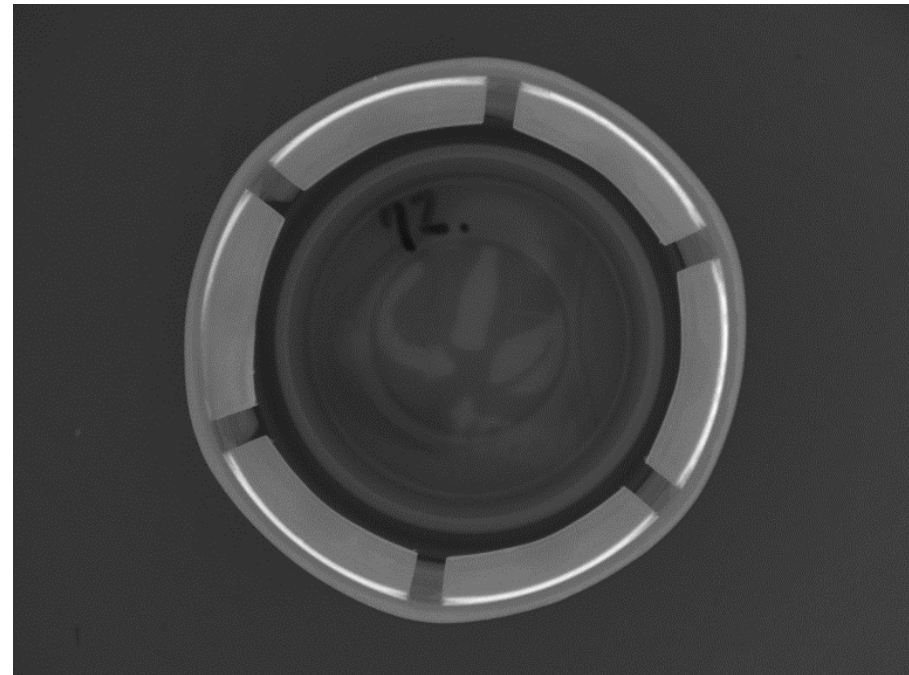
It can perfectly reconstruct a 2D image of a 3D object having any shape

# CVS360



## How to inspect it?

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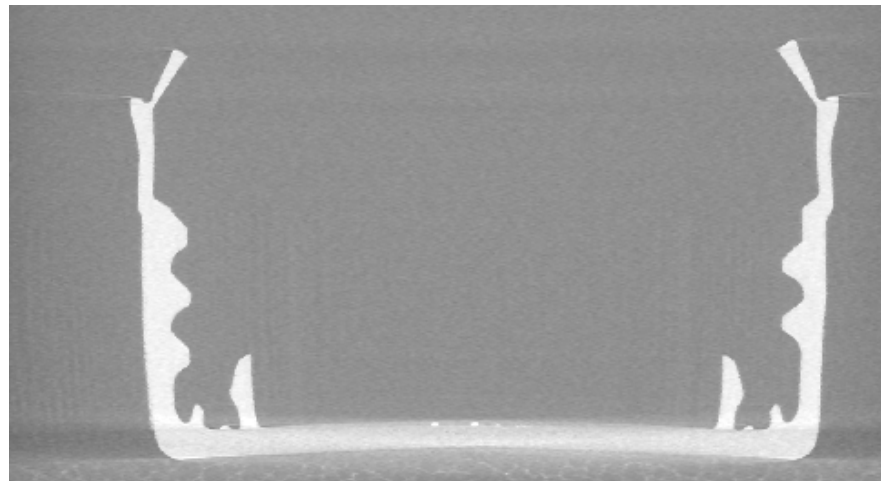
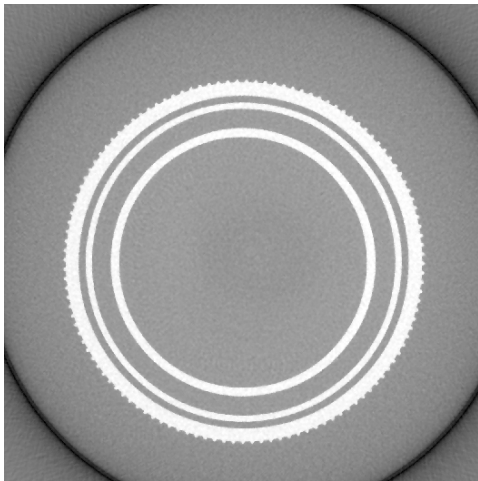


# Computerized axial tomography

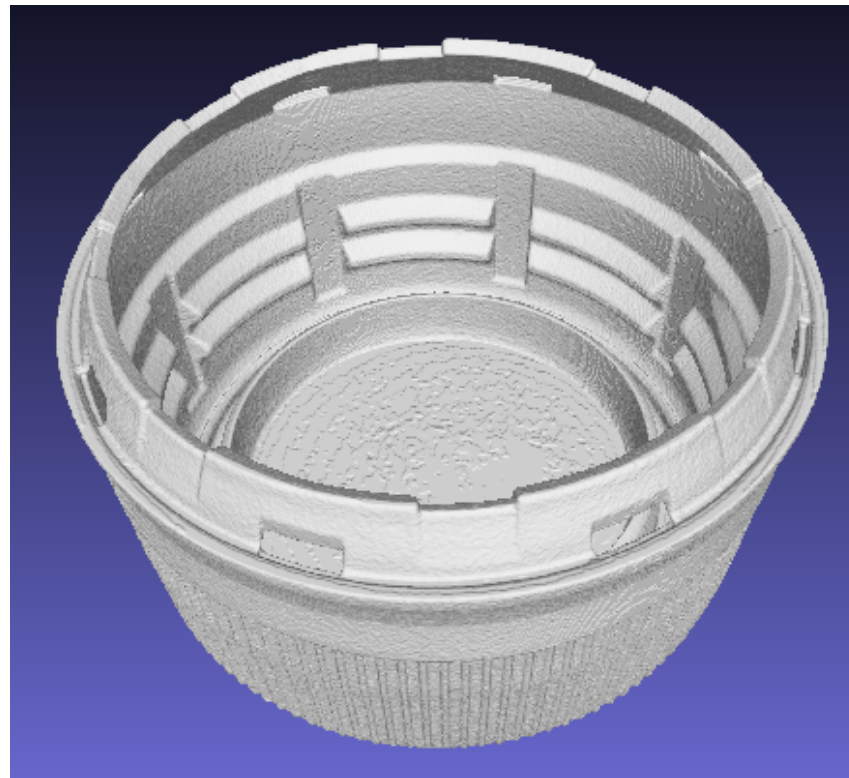
It is a technique capable of generating cross-sectional images of an object when it is irradiated by a beam of X-rays.



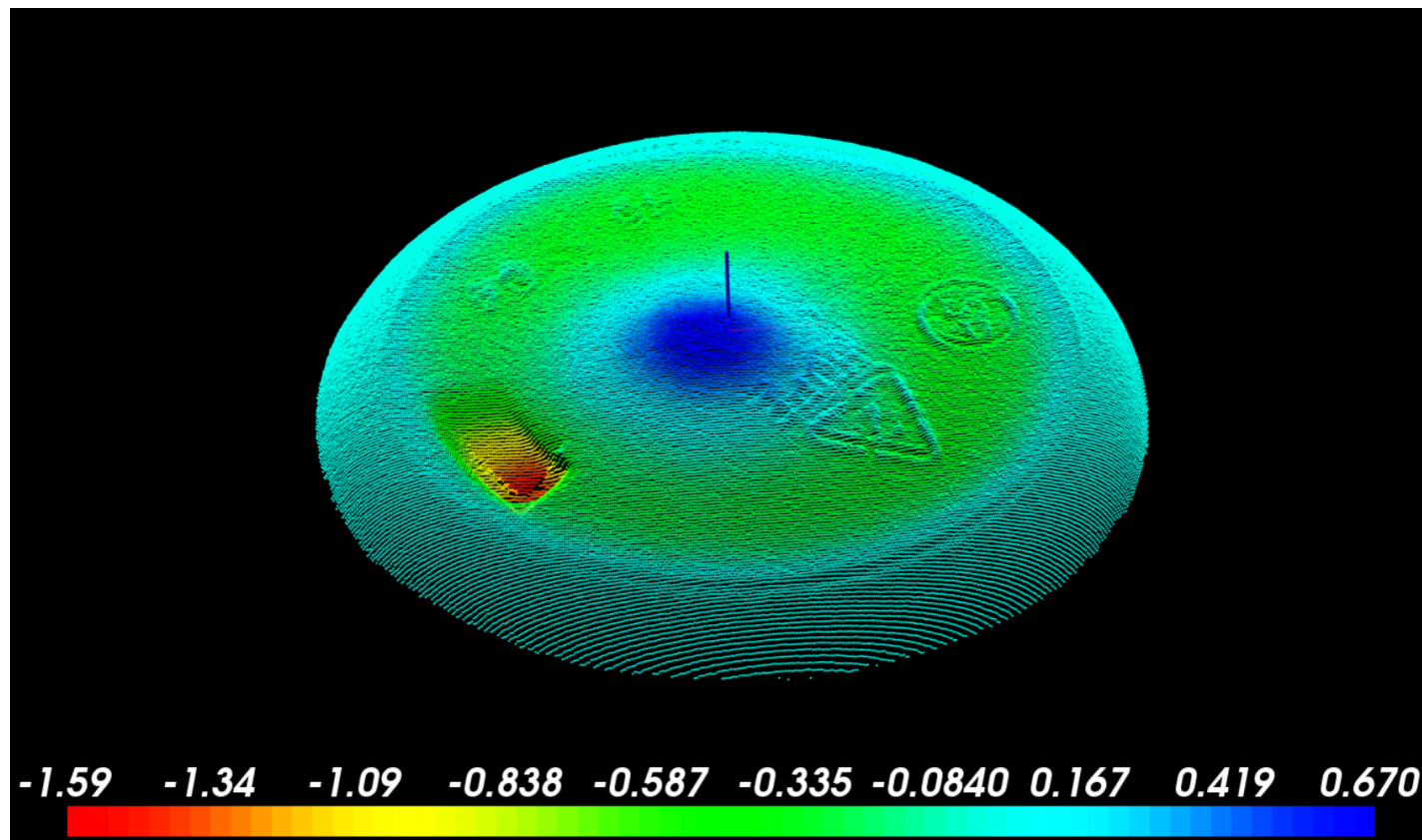
# Computerized axial tomography



# Computerized axial tomography



# Computerized axial tomography



## PET Preforms: how to inspect them?

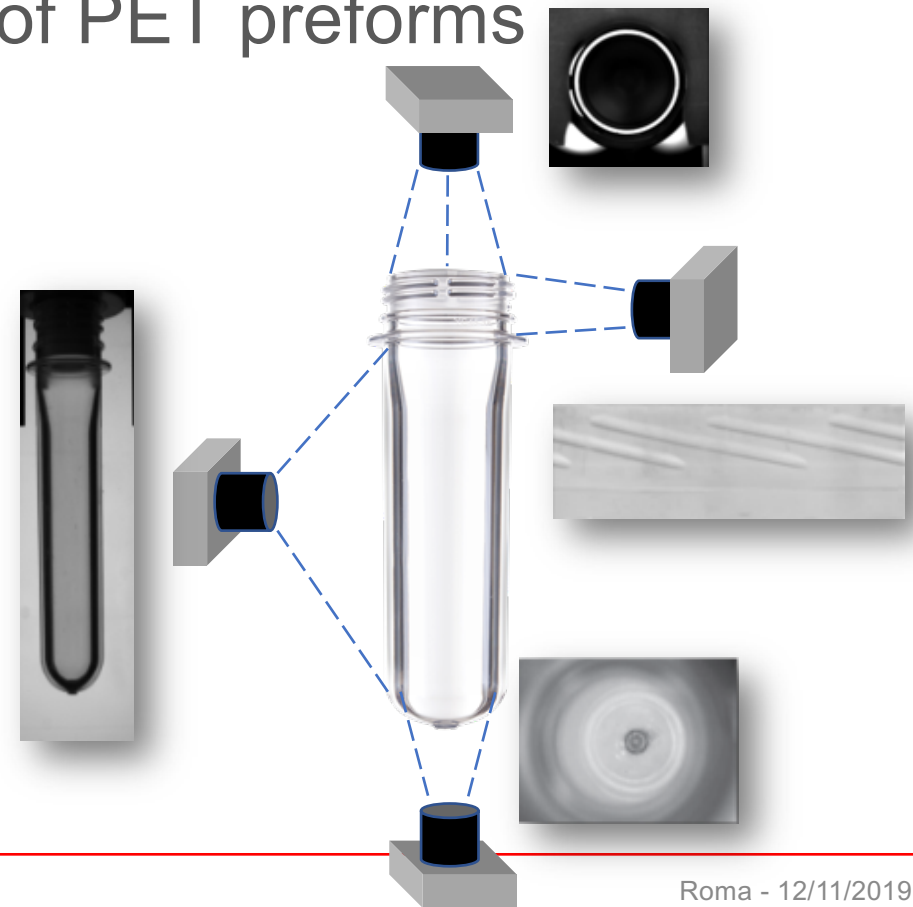
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## Automatic Quality Control of PET preforms

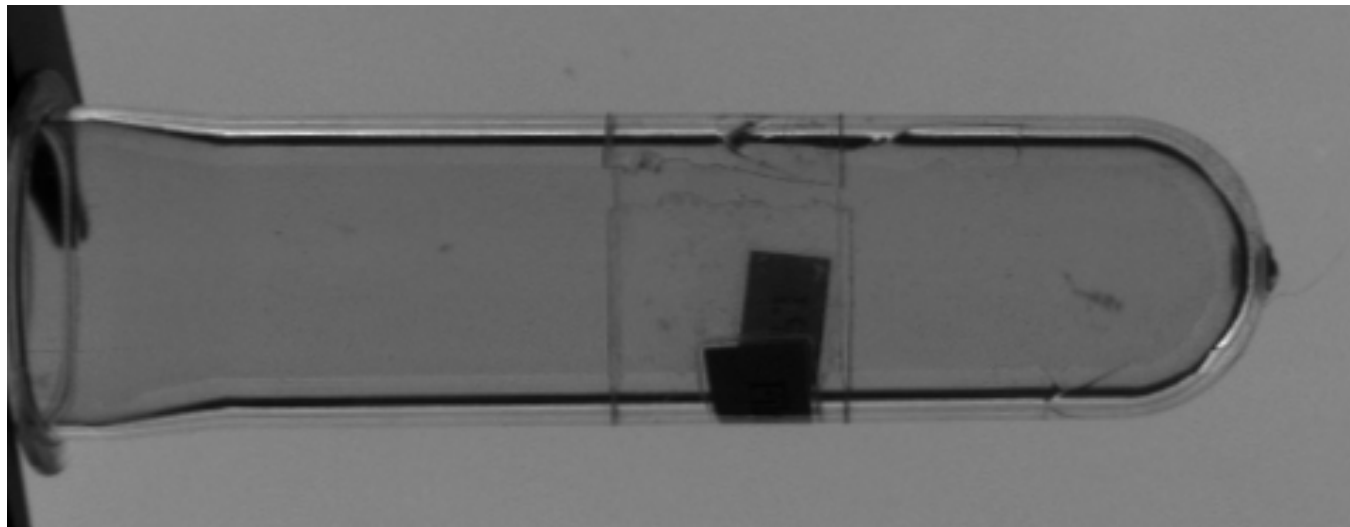
PET preforms are a rather complex object to analyse.  
Usually, the inspection is carried out by means of a set of cameras to check the top seal, the finish, the body and the bottom

All detected defects must result in changes in light absorption or, in simpler terms, must create a contrast with the background



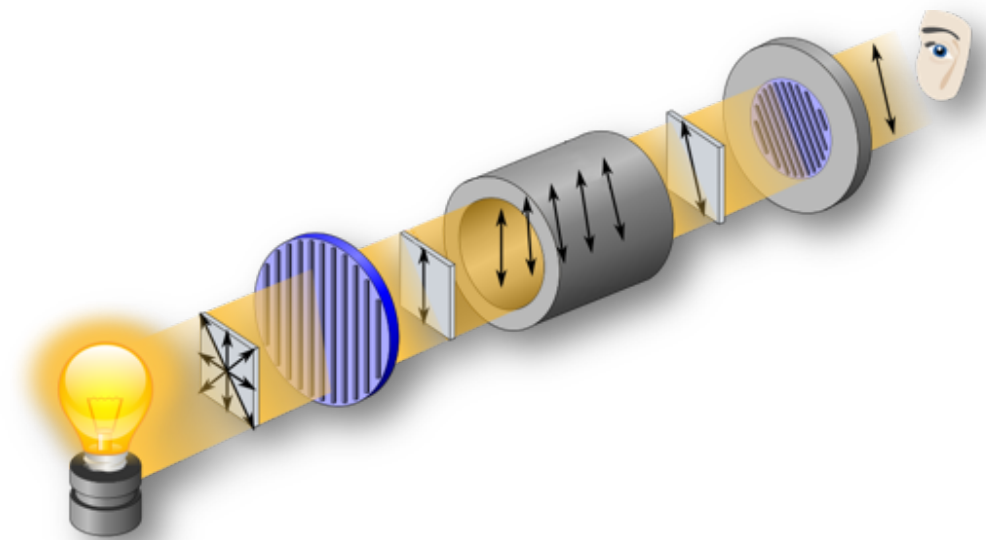
## 'Invisible' defects

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## Detection of 'invisible' defects

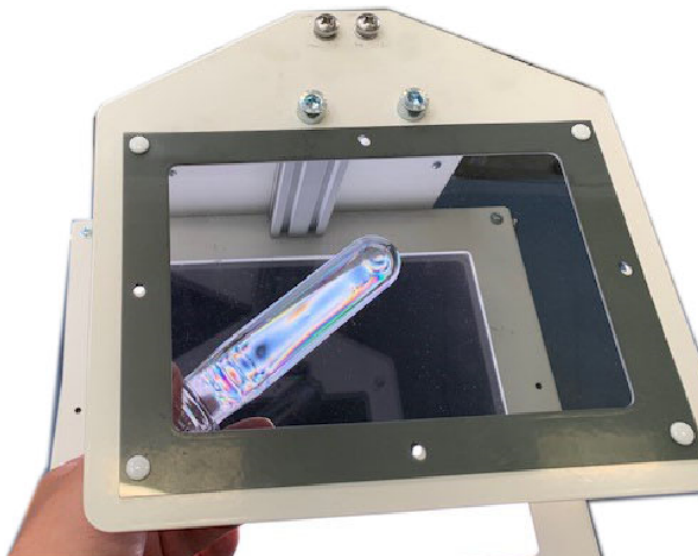
PET preforms can have defects that don't create any contrast with the background: *shrinkage*, *watermarks*, *orange-peel*, *material stress* and many other do not absorb light and they are practically invisible to the naked eyes. Operators usually detect these defects using a *polarized light*.





## Daily operation in a Quality Control lab

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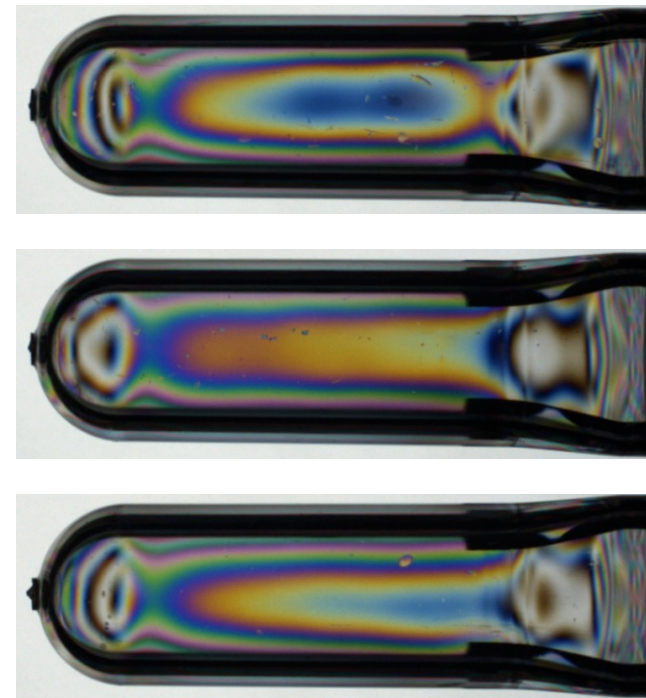


## Application of the polarized light

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The polarized light produces different colours depending on the tensions that the resin assumes in different points of the object.

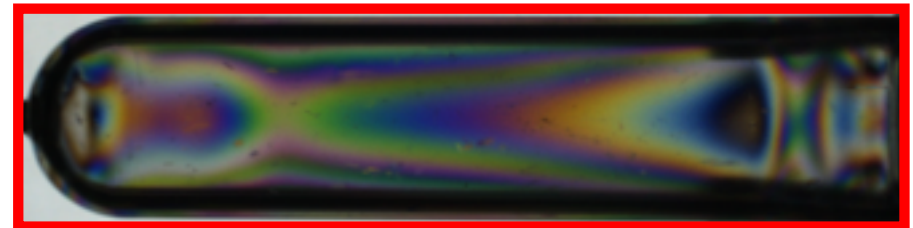
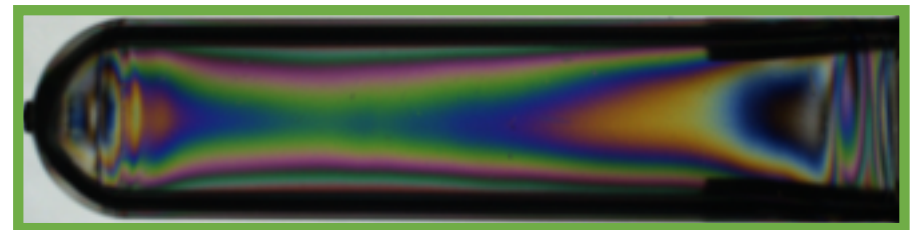
The images on the right are referred to good preforms and it is clearly perceptible that the distribution of the tensions alongside the whole body is very changeable



# Polarized light and Computer Vision

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Traditional *Computer Vision* techniques cannot be successfully applied because it is difficult to clearly define the rules that make the difference between good and bad preforms

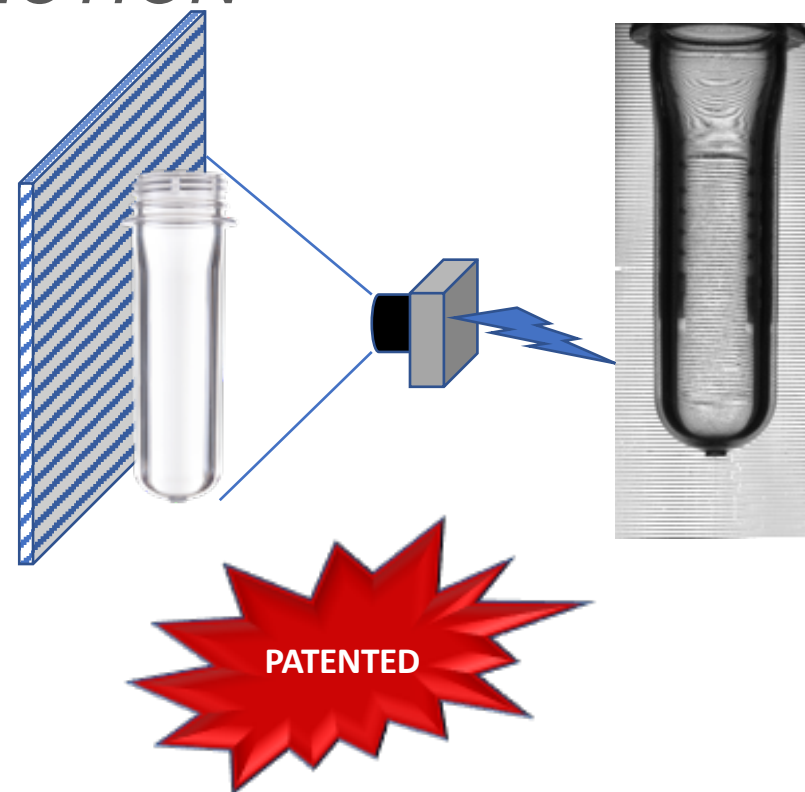




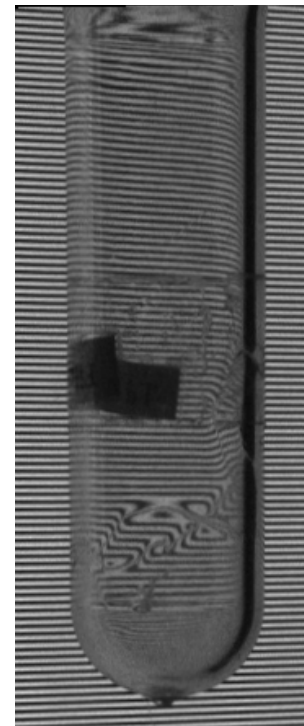
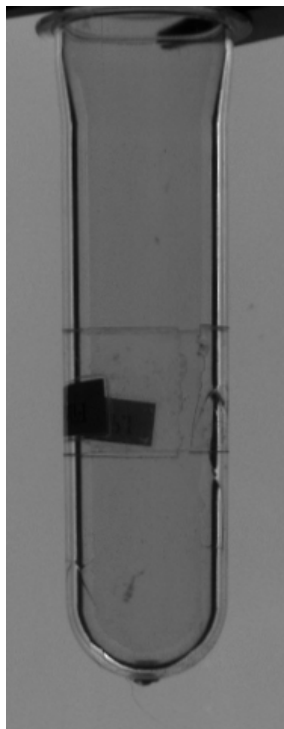
## Year 2005: the *GRID INSPECTION*

In **2005** SACMI launched **PVS-1**, a PET preform inspection machine that included a patented system for inspecting defects that are only visible with polarised light.

The idea was to project a set of parallel lines (a **grid**) behind the preforms and then inspect the deformation that the defects cause to the straight lines

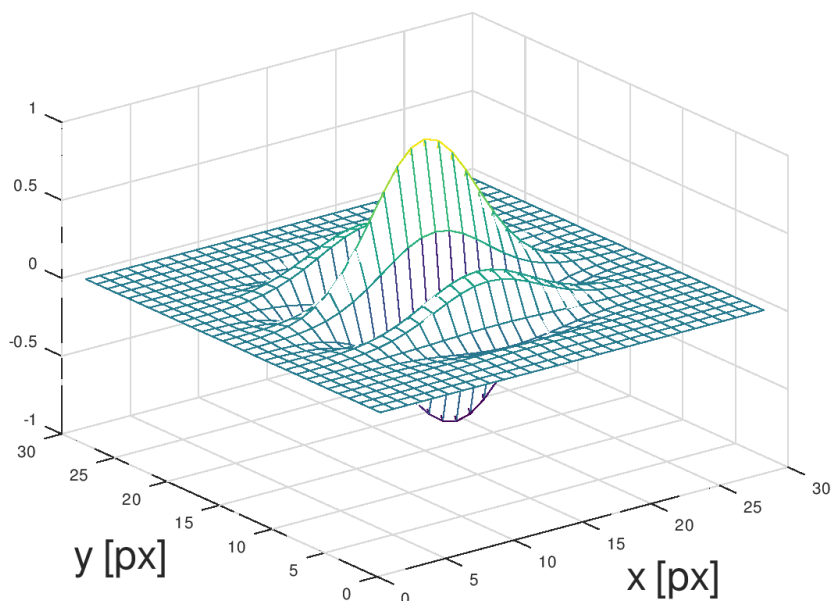


## Year 2005: the *GRID INSPECTION*

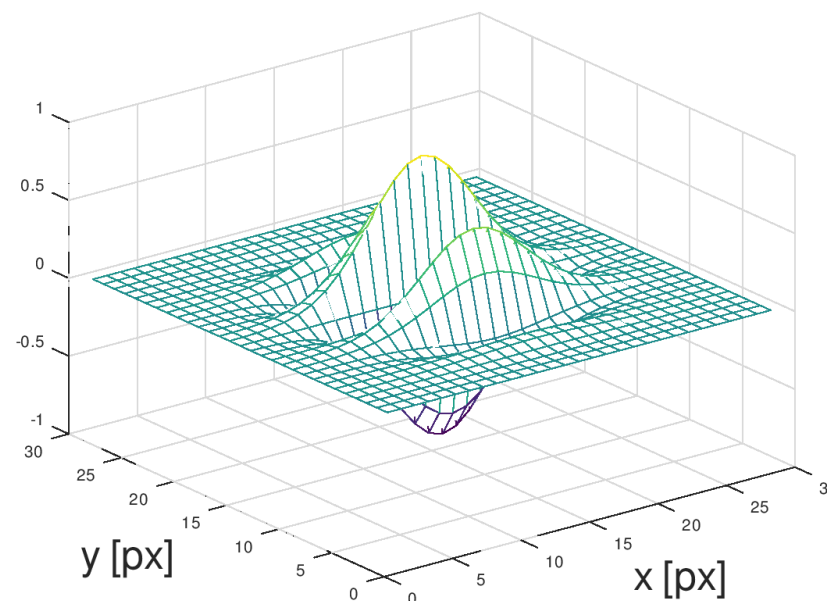


## Year 2005: the *GRID INSPECTION* - Gabor filter

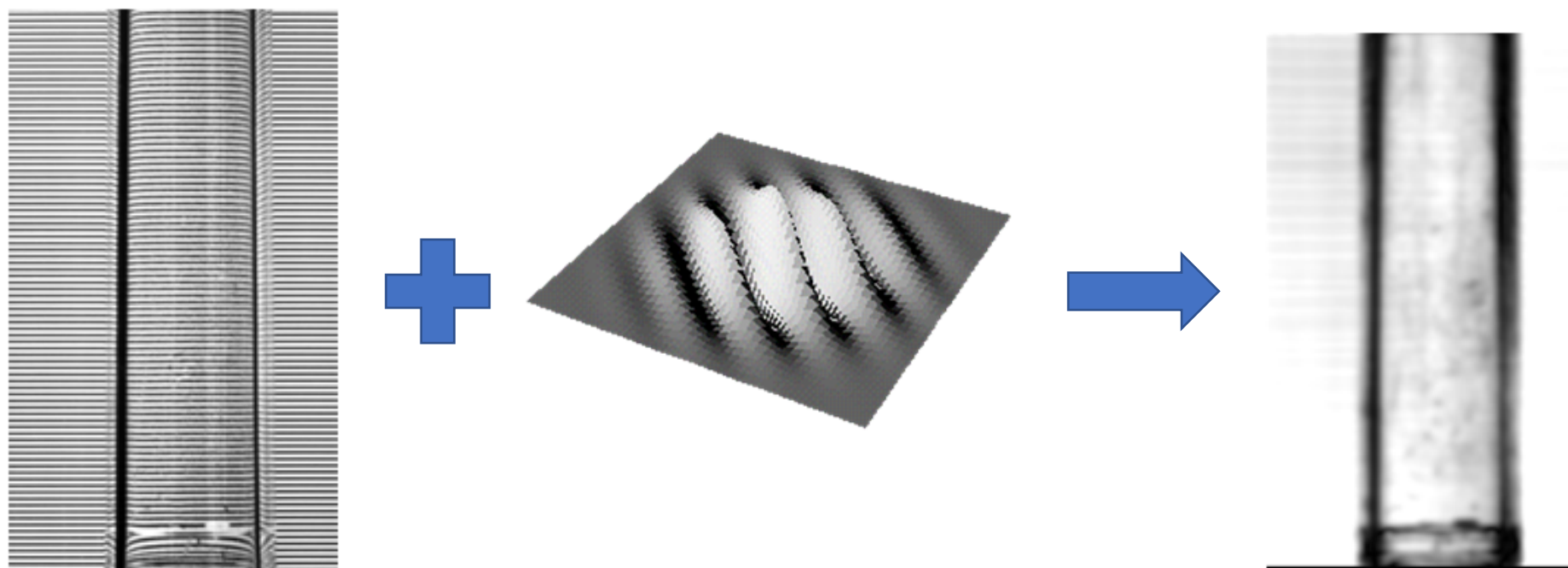
**RE del filtro, dominio spaziale**



**IM del filtro, dominio spaziale**

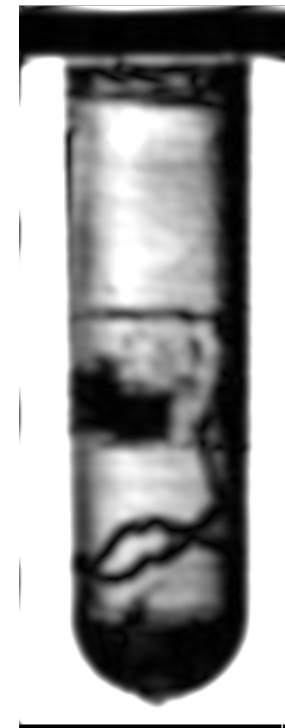
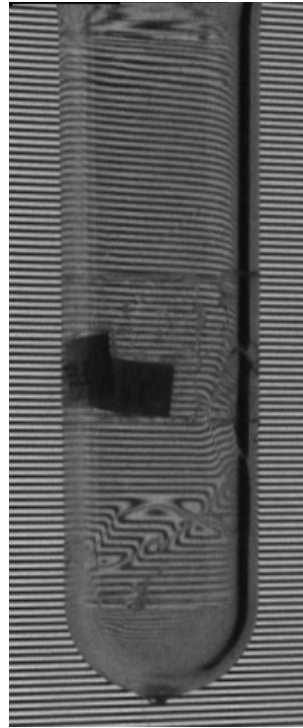
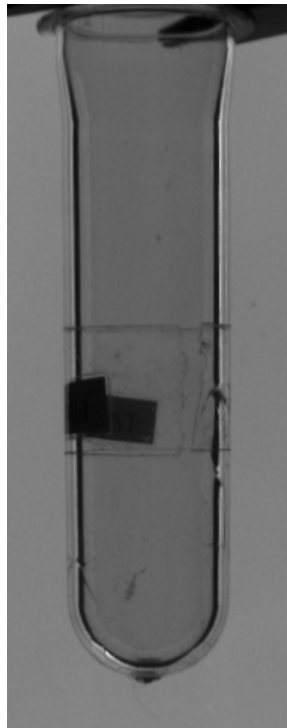


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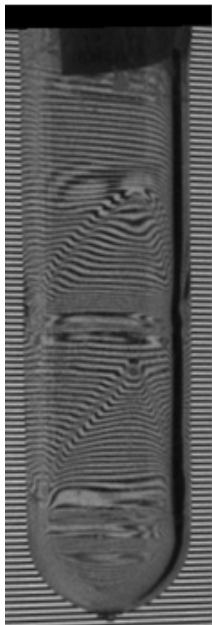




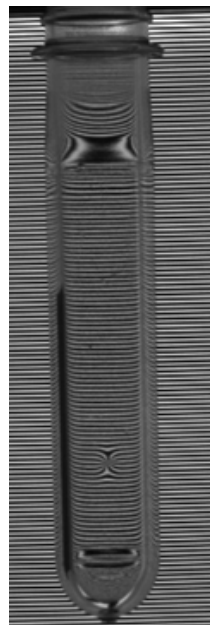
## Grid inspection: results



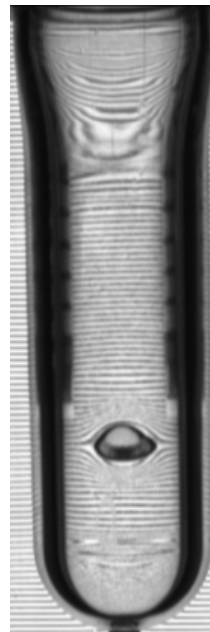
## Grid inspection: results



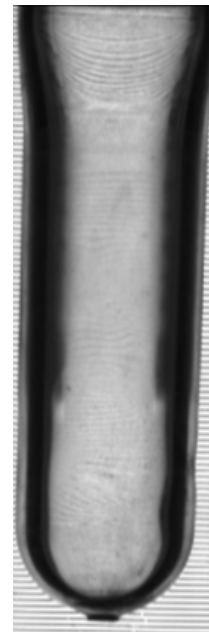
Condensation



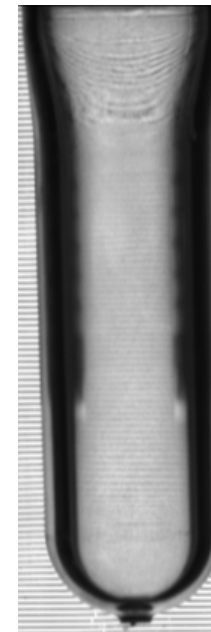
Pinch



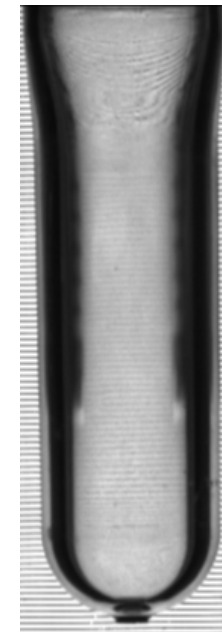
Bubble



Haze



Stress



Abnormal  
tension

## Lacks of the *Grid Inspection*

The *Grid Inspection* works pretty well for many defects, but it can be successfully applied only in the straight part of the body, leaving the bottom and the area under the support ring uncovered

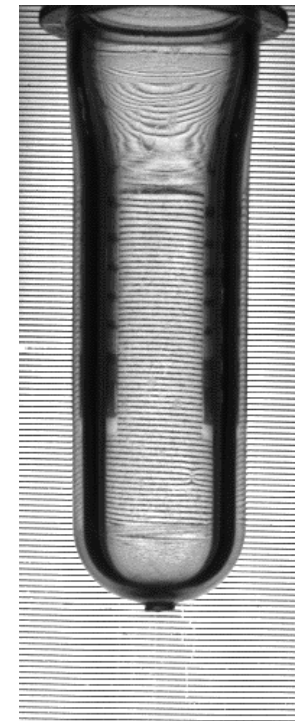


## Lacks of the *Grid Inspection*

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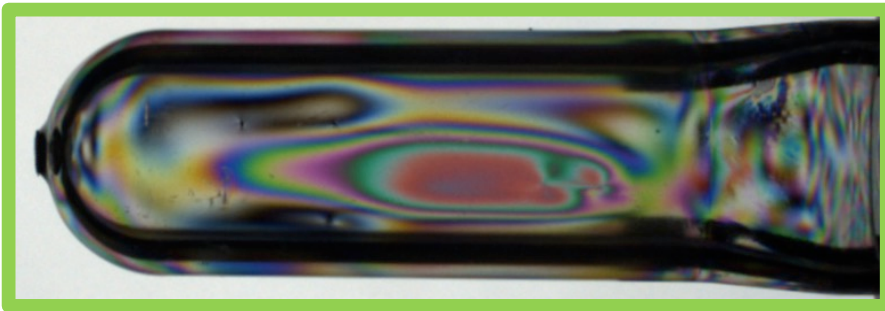
The *Grid Inspection* has other limits: it cannot identify those defects that don't wave the lines, such as the *abnormal stress*.

There are also some limitations in the defect size, since it must cover at least two lines.

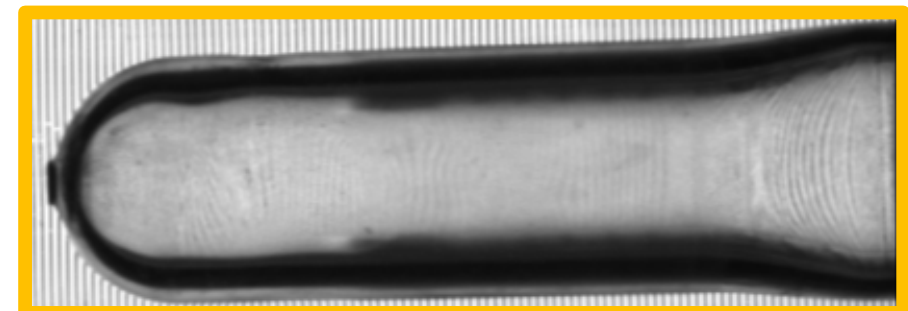
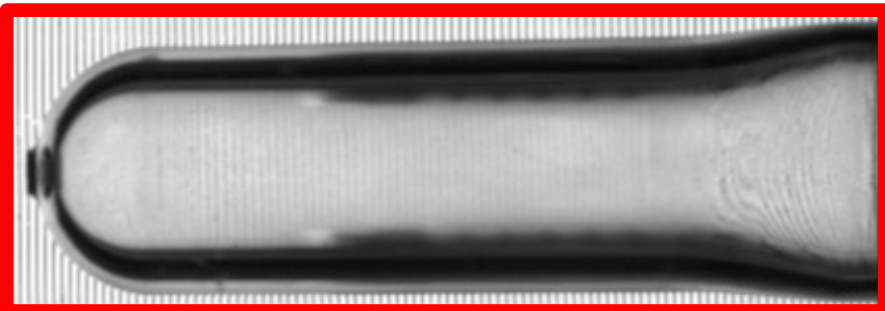
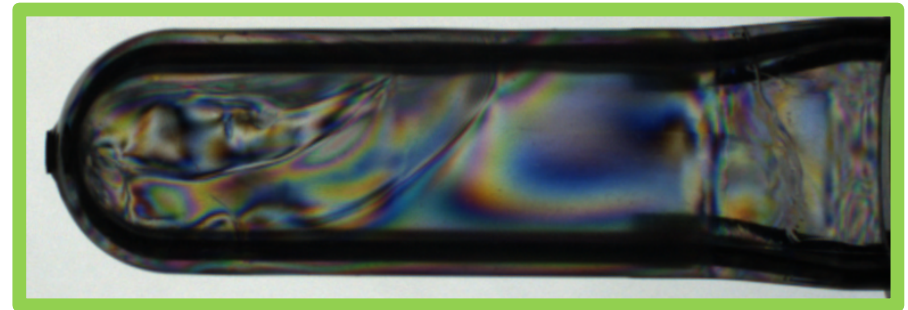


Abnormal stress

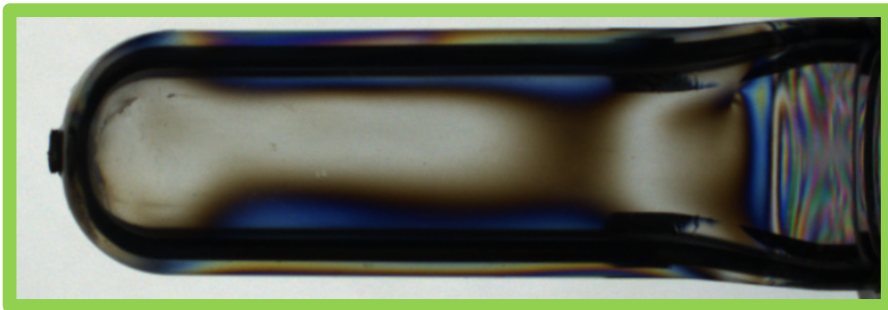
### Abnormal stress



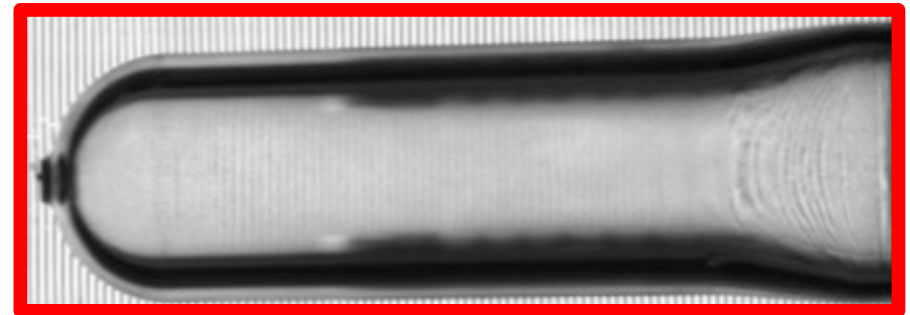
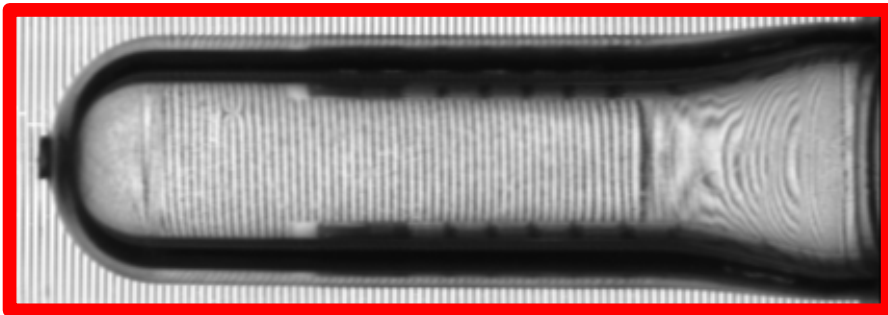
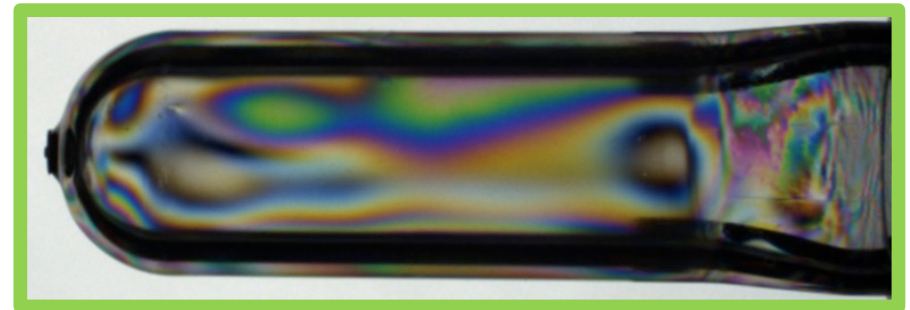
### Haze



Absence of tensions



Irregular tension

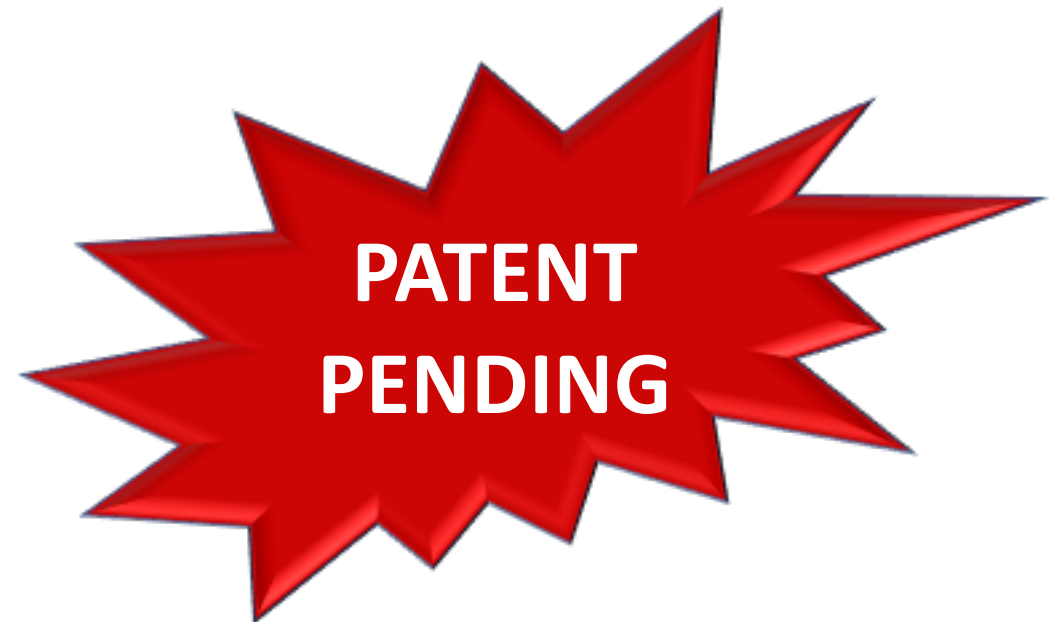




## Artificial Intelligence applied to the polarized light

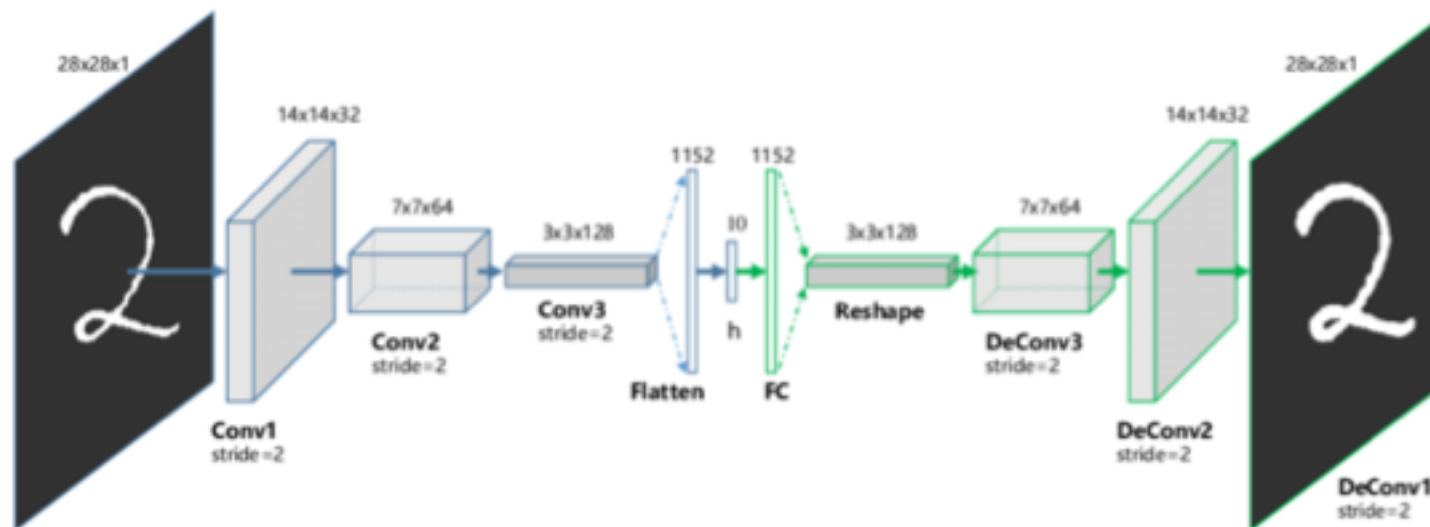
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Artificial Vision and Deep Learning algorithms overcome the problem to mathematically describe the difference between good and bad preforms when submitted to polarised light. Images are acquired through an *unmanned process* and then analysed by **CVS3000-AI** algorithms.





# Autoencoder

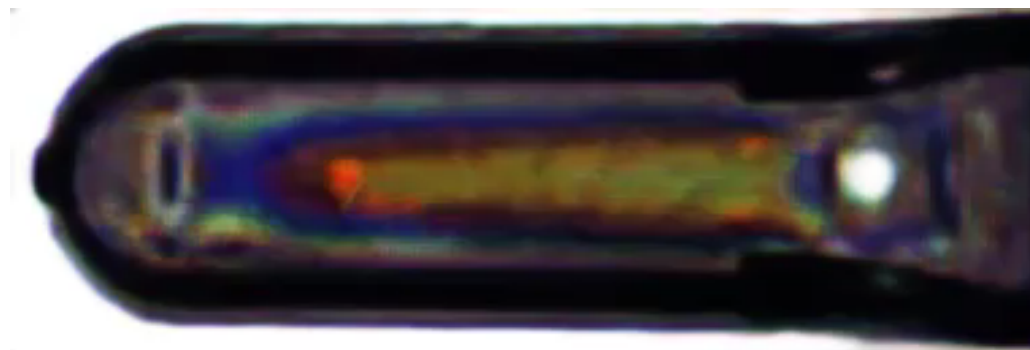
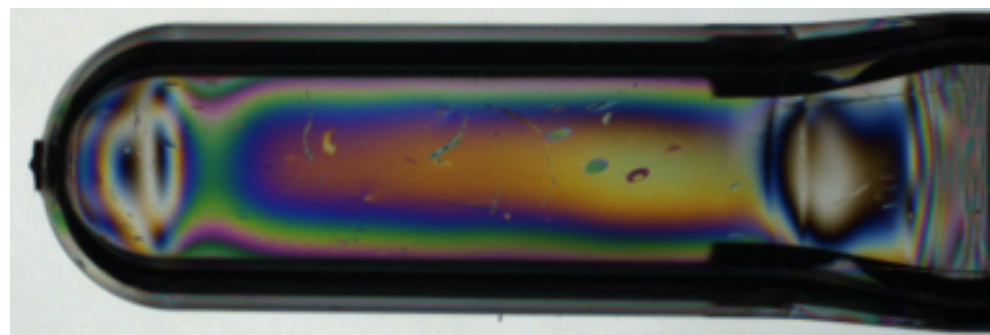


# Autoencoder

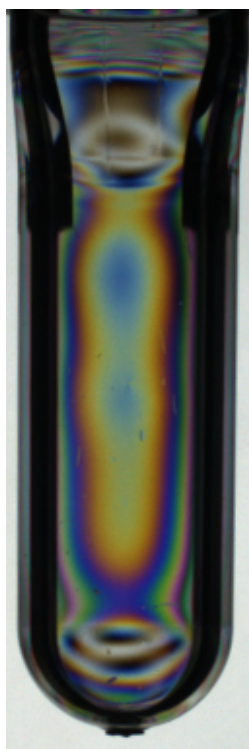
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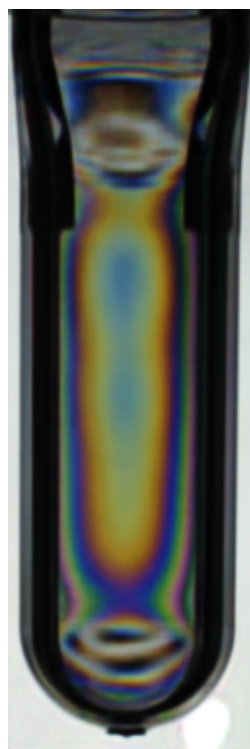
# Autoencoder: training



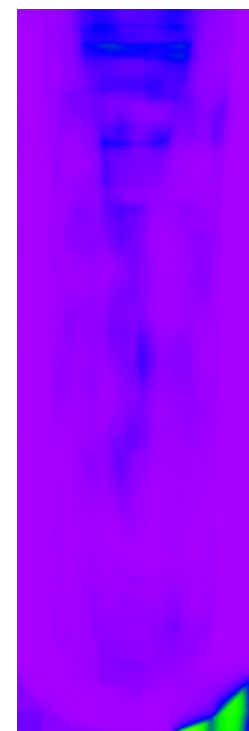
# Autoencoder: good preform



Real

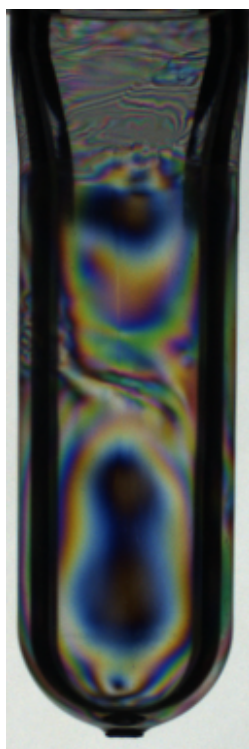


Reconstructed



Error Map

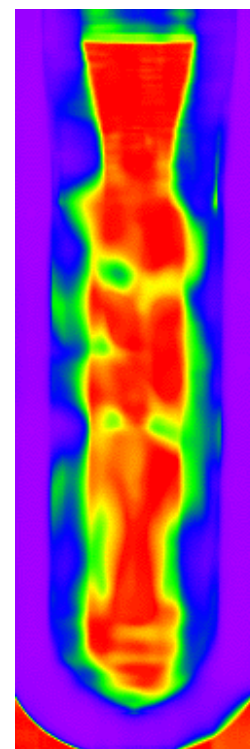
# Autoencoder: bad preform



Reale



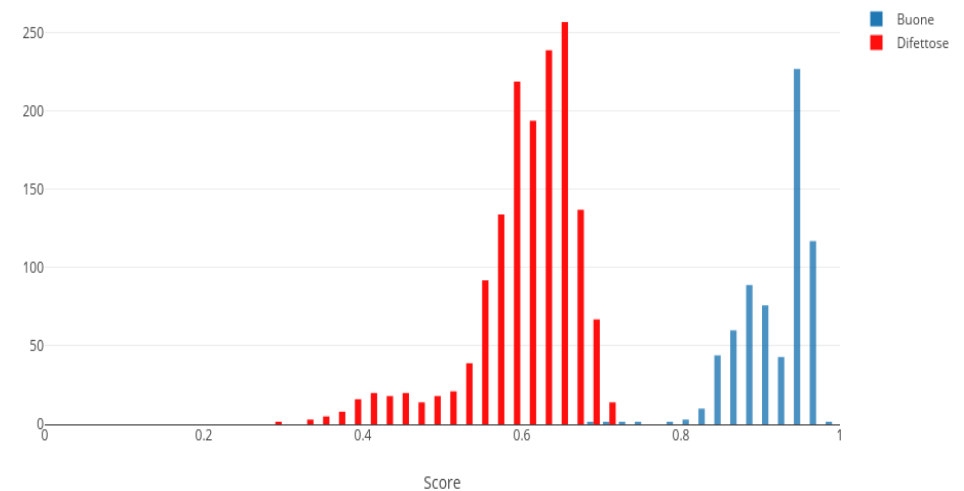
Ricostruita



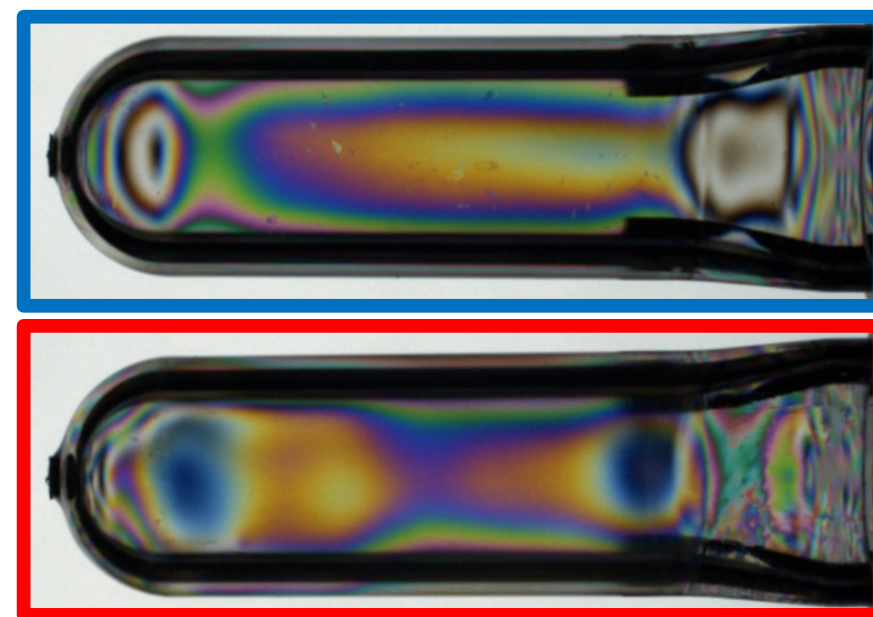
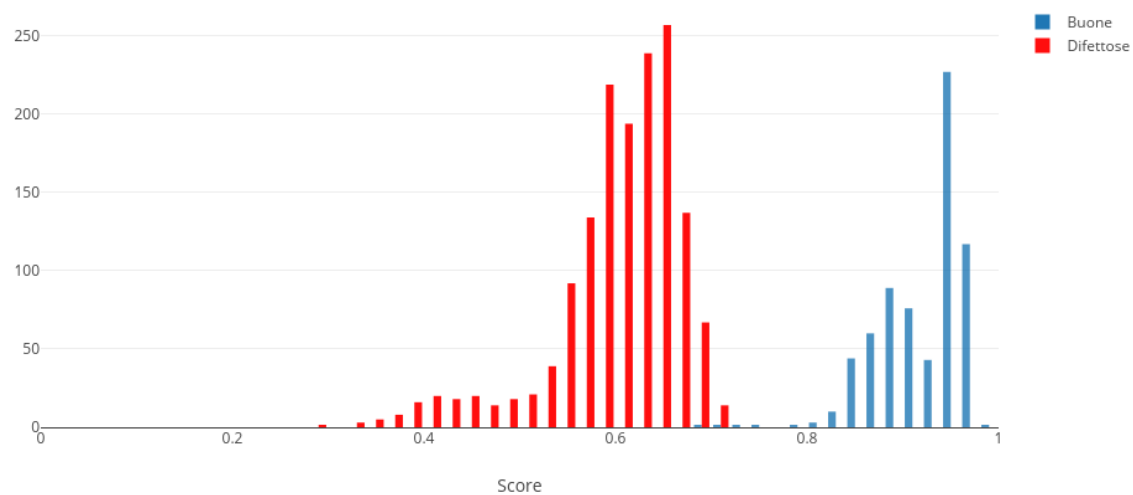
Error Map

# Classifier

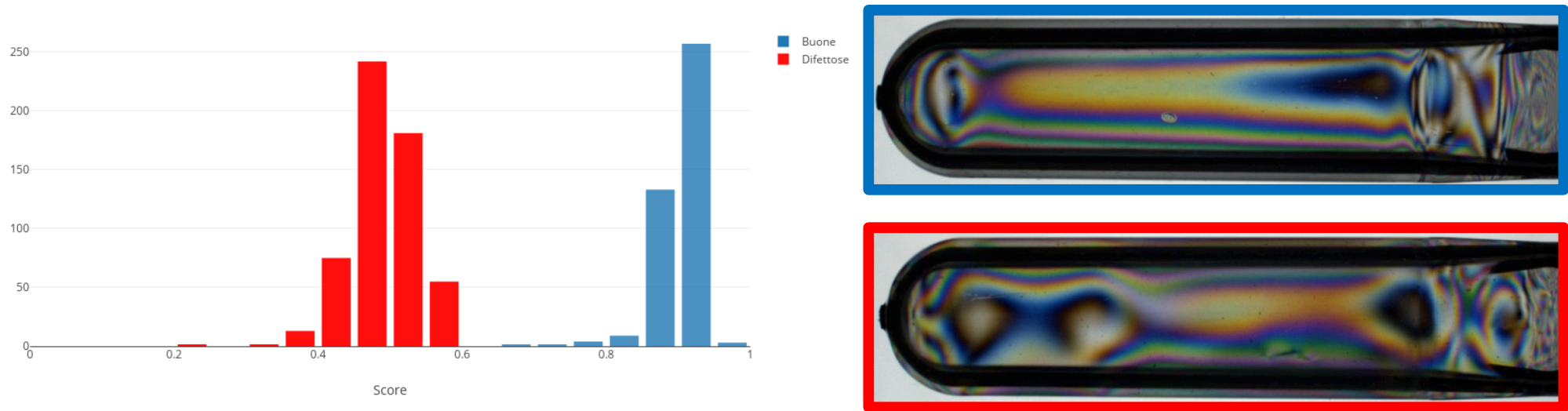
The results of the AI algorithms applied to the acquired images, are then submitted to a *classifier* that returns a score in the range 0-1, where **0** is assigned to a preform classified as **BAD** and **1** is assigned to a preform classified as **GOOD**.



## Results: PCO1810 finish, 21 grams

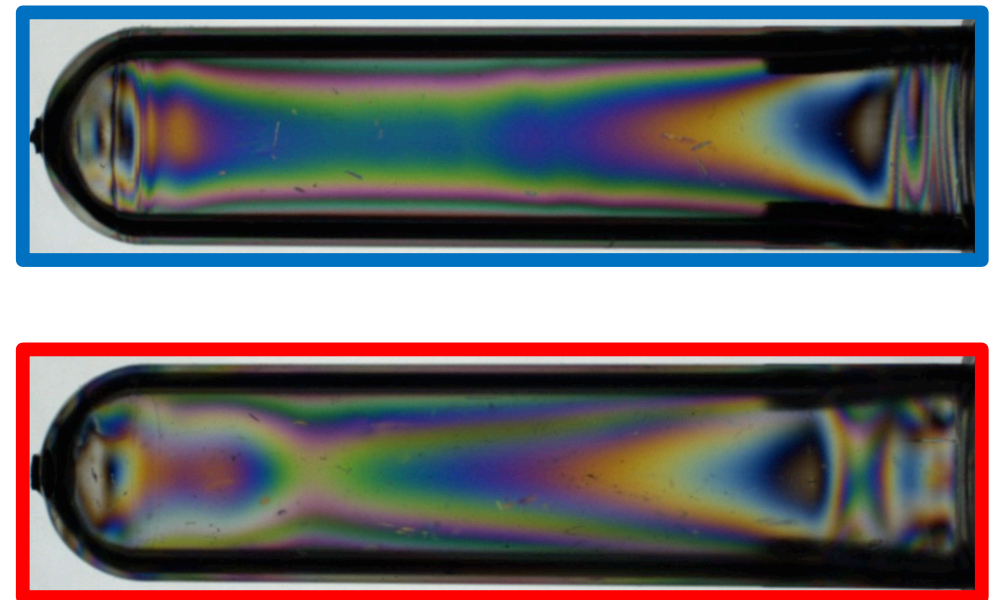
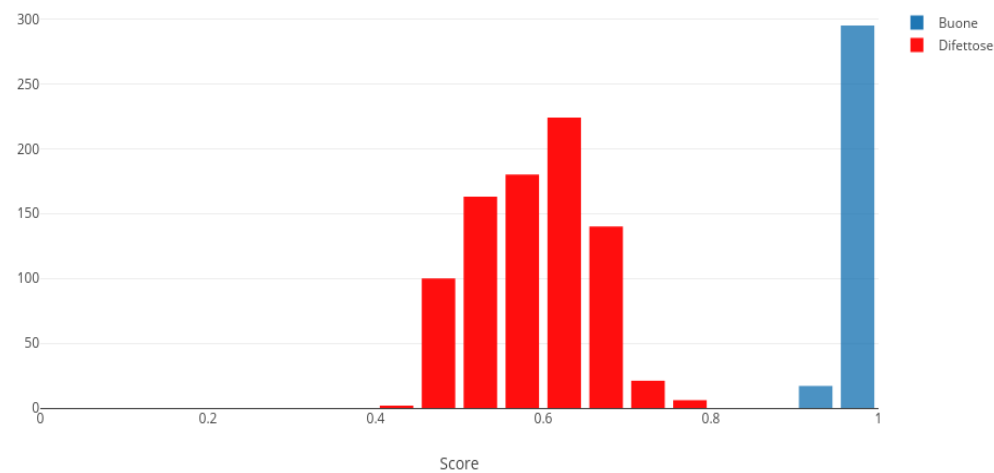


# Results: PCO1810 finish, 43 grams

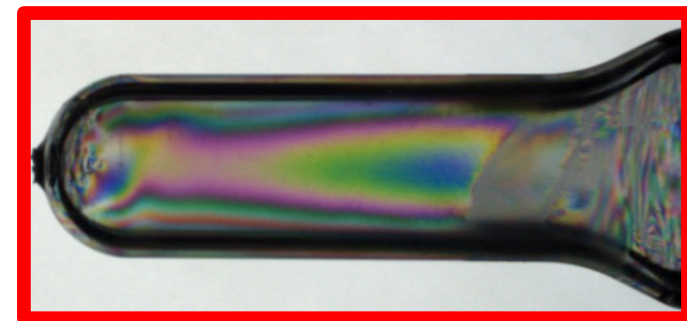
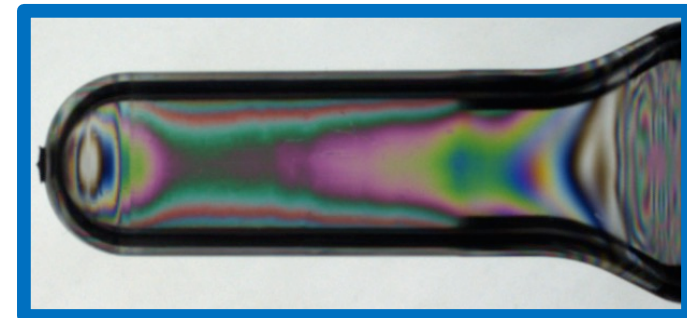
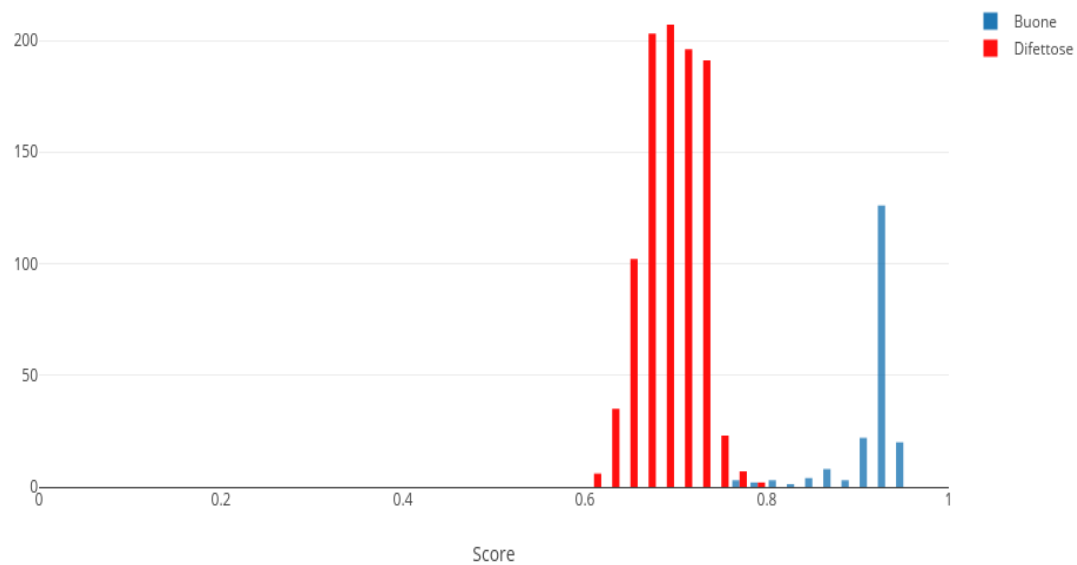




# Results: Corvaglia finish, 13 grams

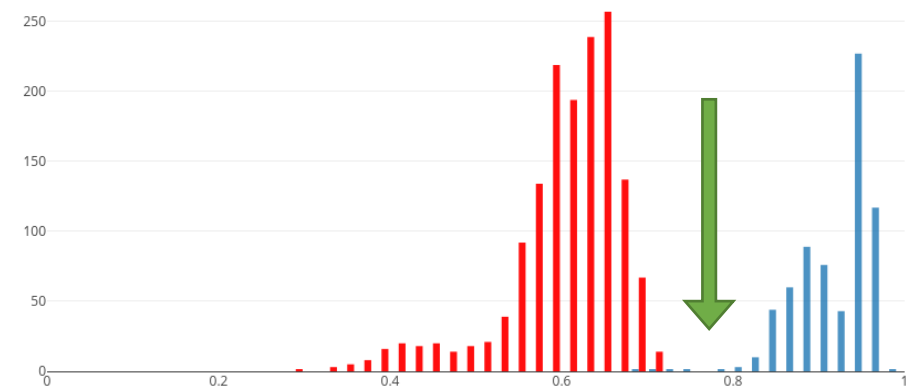


## Results: PCO1881 finish, 9 grams



## Outstanding advantages

- **Robust identification** and ejection of all those defects visible only with a polarized light
- **Easy and intuitive** adjustment of the inspection threshold
- Inspection area applied to the **whole body**
- **Small defects** are detectable
- **Quick** to train
- **Fast** to run during production



## Another application of the Artificial intelligence: **CAVITY RECOGNITION**

**Cavity recognition** is a function that allows to read the cavity number engraved in the finish. With this number, **CVS3000-AI** produces statistics of defects by cavity or it can sort the preforms, ejecting all those whose number is in a black list.

**A.I.** considerably **improves the readability** of the number, especially in those conditions where the digits are poorly marked or have a lack of contrast.



# PVS10L

## Offline inspection and sorting machine for PET preforms

## PVS10L

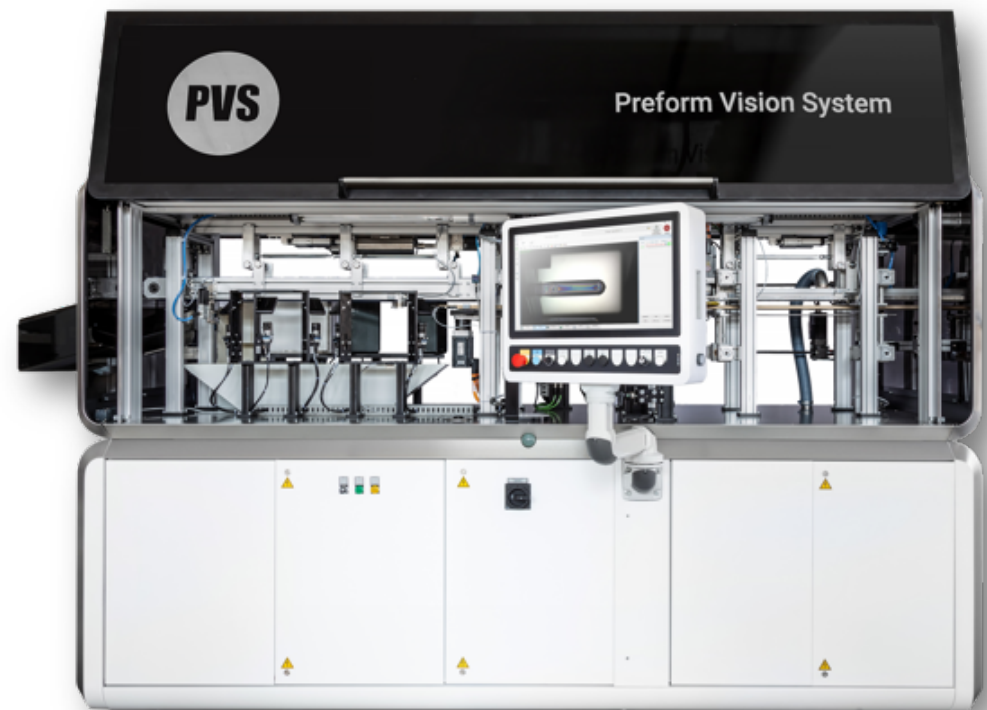
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New **PVS10L** has been conceived and designed to control off-line batches of PET preforms.



## PVS10L: Key Features

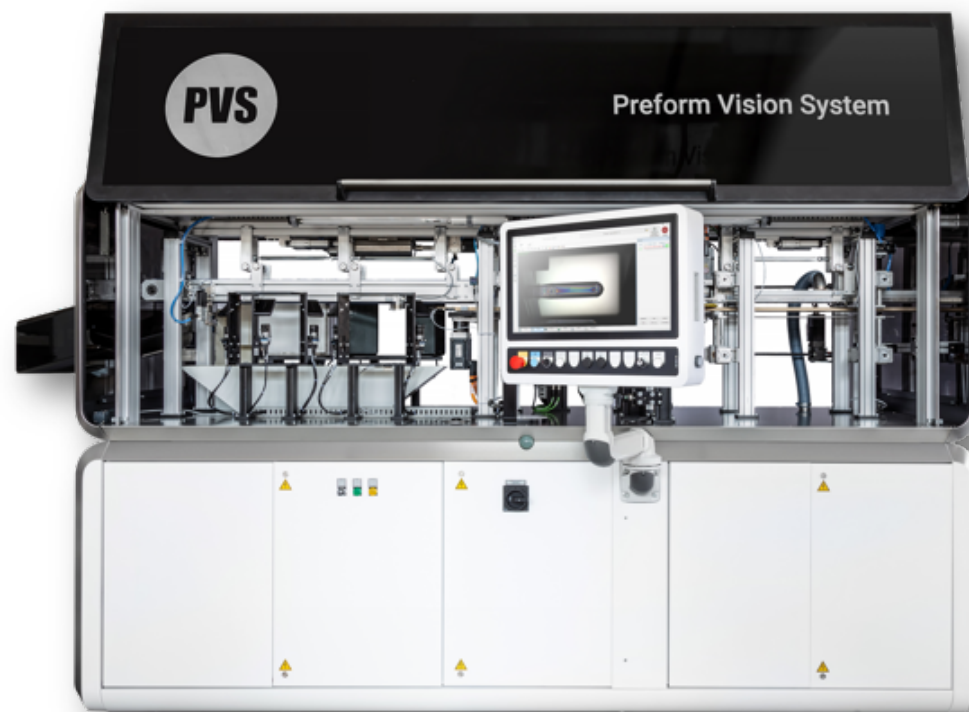
- New **CVS3000-AI** software
- 12 cameras to control the whole preform
- Linear machine: transfer of the preforms is made through conveyor belts and vacuum
- Patent pending **fully automatic format changeover**



## Fully Automatic Changeover

### Patent Pending Fully Automatic format changeover

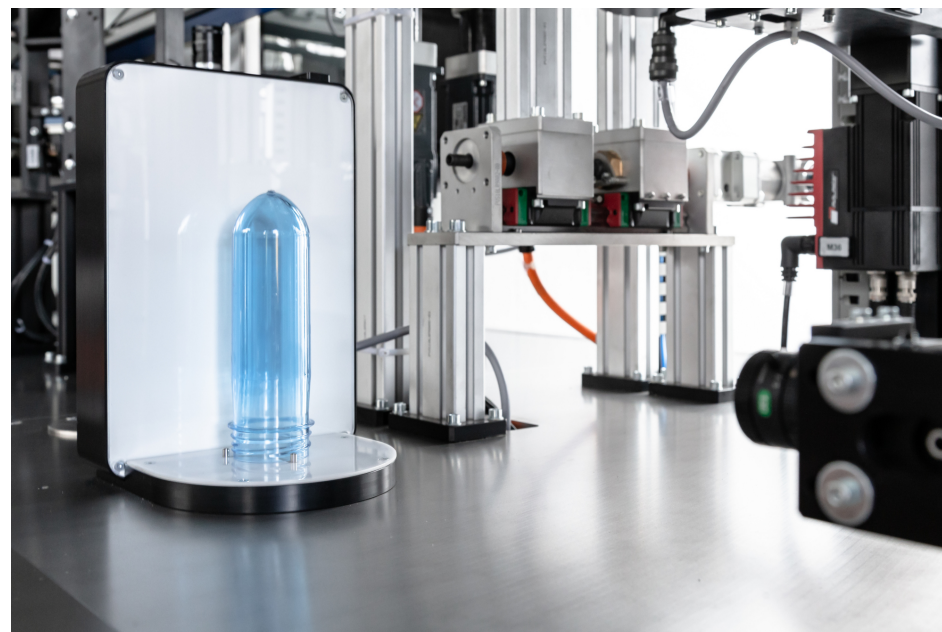
Less than **50 seconds** to set the PVS and its sorter/feeder to inspect a new preform having different diameter and length.

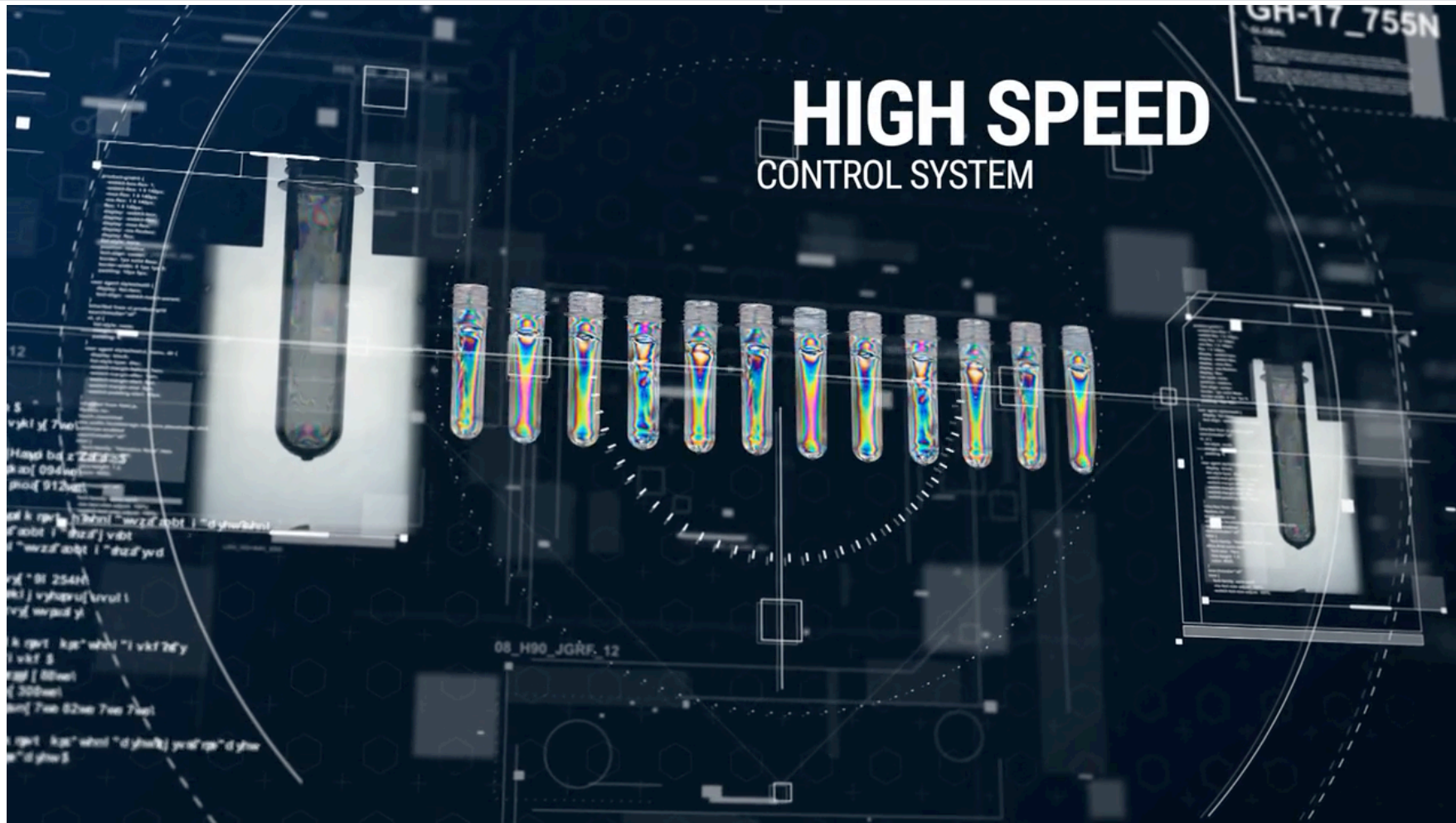




## Fully automatic changeover

- By means of an **additional camera**, **CVS3000-AI** software recognises and measures the preform to automatically adjust the positions of both **sorter/feeder** and **PVS10L** machines.
- Adjustment of the conveyor regulated by brushless motors for higher speed and precision





## Skills to work in the machine vision

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- Programming languages (C++, Javascript, Python)
- Software engineering
- Computer Vision
- Computer Graphics
- Mathematics (Geometry, Algebra, Numerical Analysis)
- Statistics (Machine Learning)
- Optics

## Universities

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- Alma Mater Studiorum Università di Bologna
- Università di Verona
- Università degli Studi di Udine
- Università degli Studi di Firenze
- Università degli Studi di Modena e Reggio Emilia

## Highly specialised competence centres

SACMI is part of the BI-REX competence centre.

BI-REX brings together 12 university and research institutions and 45 companies.

The pilot line for the production of metal products, hosted at the Opificio Golinelli in Bologna, will show the application of all Industry 4.0 technologies, in particular additive manufacturing and big data.

<https://www.mise.gov.it/index.php/it/incentivi/impresa/c-entri-di-competenza>

## Informazioni

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<https://www.sacmi.com/>

<https://careers.sacmi.com/>

<http://www.sacmi-packaging-beverage.com/>

<http://www.sacmimetalcaps.com>



**Grazie per  
l'attenzione**



**SACMI**

**[Donato.Laico@sacmi.it](mailto:Donato.Laico@sacmi.it)**