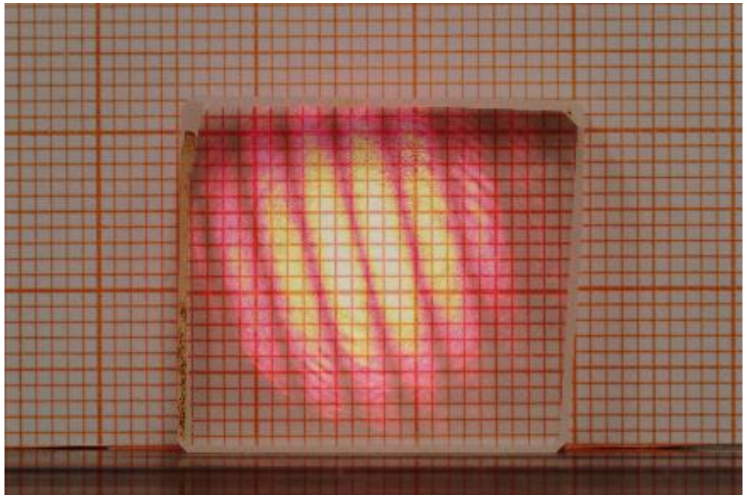
Università Politecnica delle Marche
Ancona, Italy

P.P. Natali[b], D. Rinaldi[a], F. Davì[b], N. Paone[c], P. Mengucci[a],
L. Scalise[c], L.Montalto[a,c], V.Dormenev[d]

a) SIMAU, b) DICEA, c) DIISM
d) Justus-Liebig-University Gießen, Germany

PWO preliminary analysis for Panda project



INTRODUCTION

Some preliminary tests with different techniques have been carried out on two different PWO samples: a slab (about 2,5x2,5x0,6 cm) and a large ingot (about 2x2x20 cm).

The work is aimed to:

- Quality control on PWO for PANDA
- Investigate samples with different cut and orientation
- Impurity detections

$PbWO_4$ (PWO)

- Body-centred tetragonal crystallographic structure
- lattice parameters ***a*** = 0.54619 nm and ***c*** = 1.2049 nm (ICDD card n. 19-708)
- PWO is a high-density material with $\rho = 8.26$ g/cm^3
- This crystal is uniaxial negative ($n_o > n_e$), with extraordinary and ordinary refraction indices $n_e = 2.163$ and $n_o = 2.234$, for the visible radiation with $\lambda = 632.8$ nm.

PWO SLAB QUALITY CONTROL

STRESS DETECTION

The slab is cut along its ***c*** crystallographic direction and has a distorted tetragonal shape

The interference fringe in conoscopic observation are due to

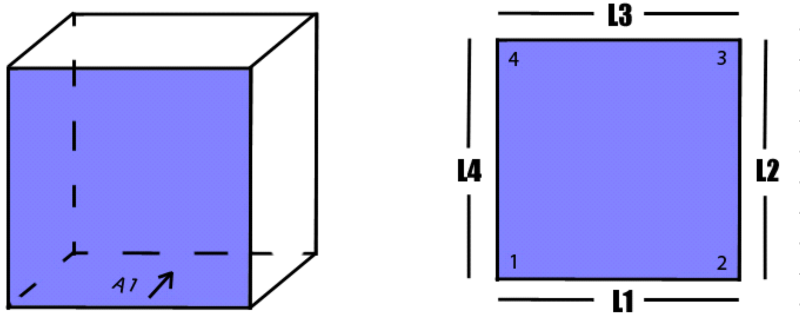
↓ Internal Stress

↓ The thickness variation

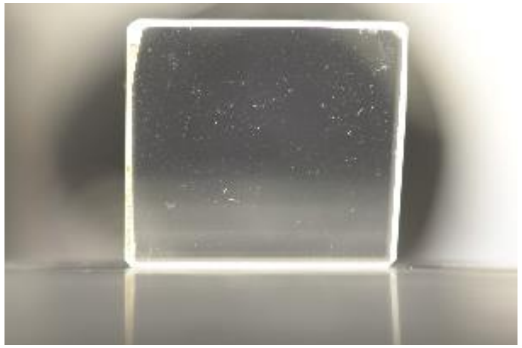
↓ The internal stress must be evaluated with care by means of Photoelasticity

Analysis of PWO slab from an ingot

Sample measurements

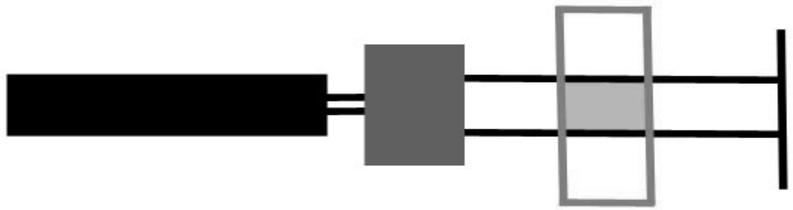


L1	19,44
L2	22,26
L3	20,11
L4	22,03



	Caliper (mm)		Thickness difference (mm)					Angles (°)			
Point			Point1-2	Point2-3	Point3-4	Point4-1		L1	L2	L3	L4
1	6,662		0,047	-0,015	-0,045	0,013		0,138524	-0,03861	-0,12821	0,03381
2	6,615										
3	6,63										
4	6,675										

Collimated light inspection normal to the optical axis

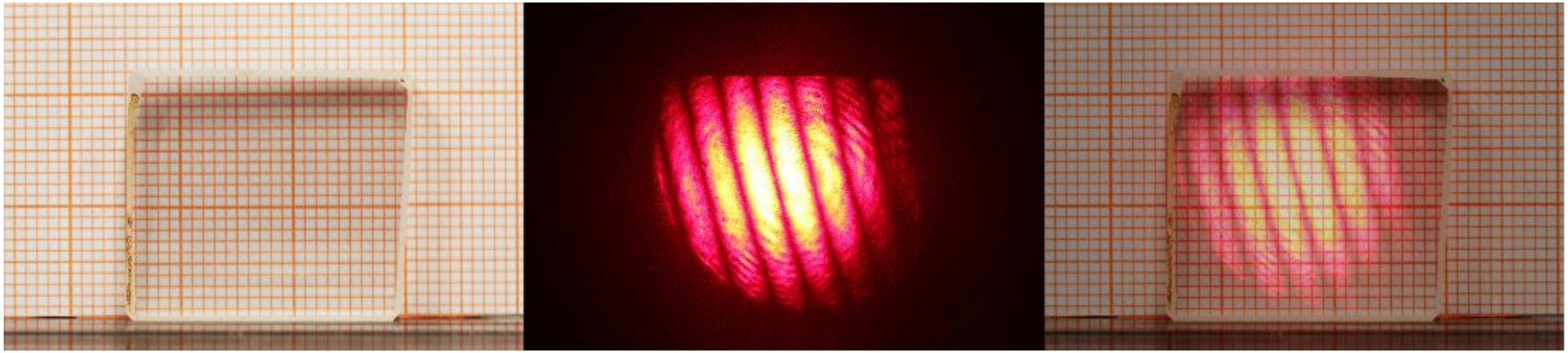


Collimated light layout

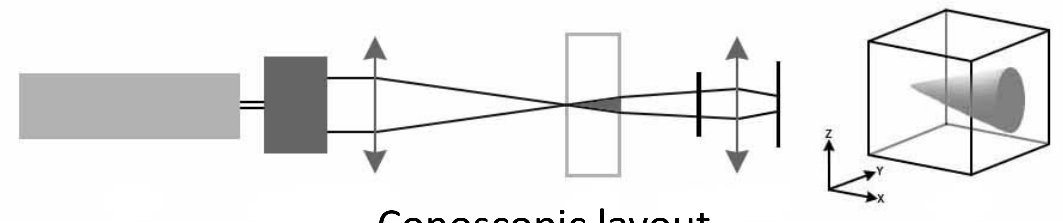
Since the sample is birefringent, the different optical path (thickness variation) generates dark or bright fringes.

Therefore, Along the fringes the sample has a constant thickness.

The sample measurement confirm the thickness variation.

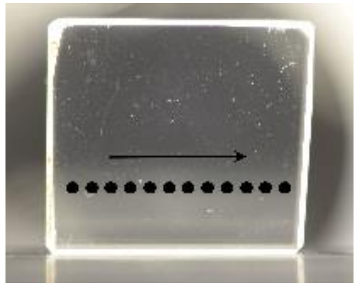


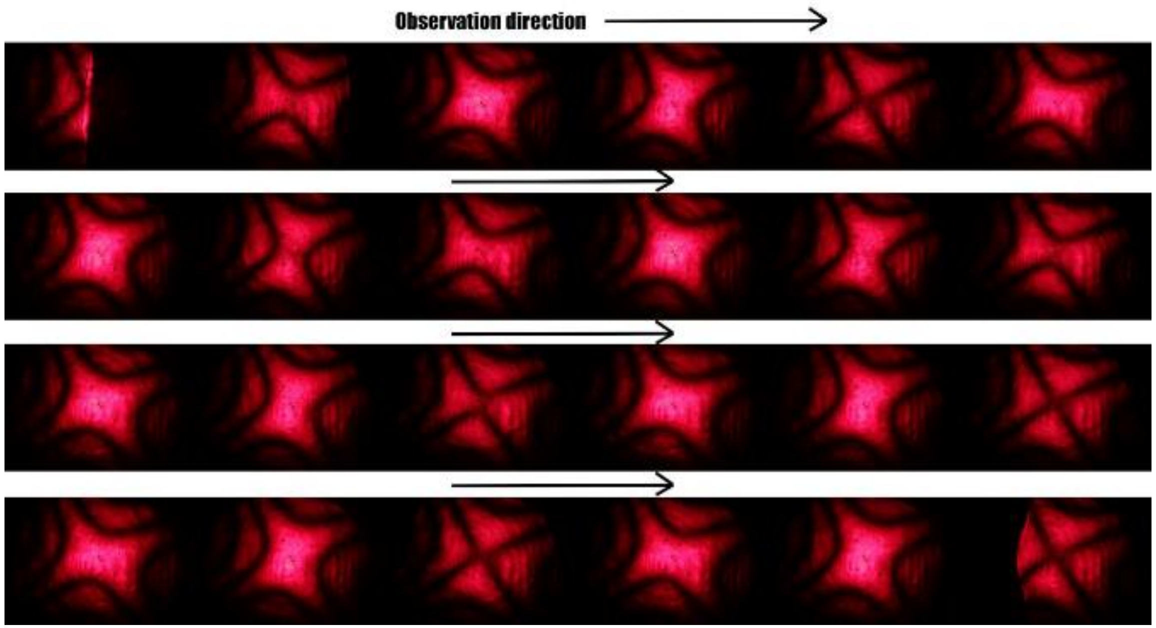
Conoscopic inspection normal to the optical axis



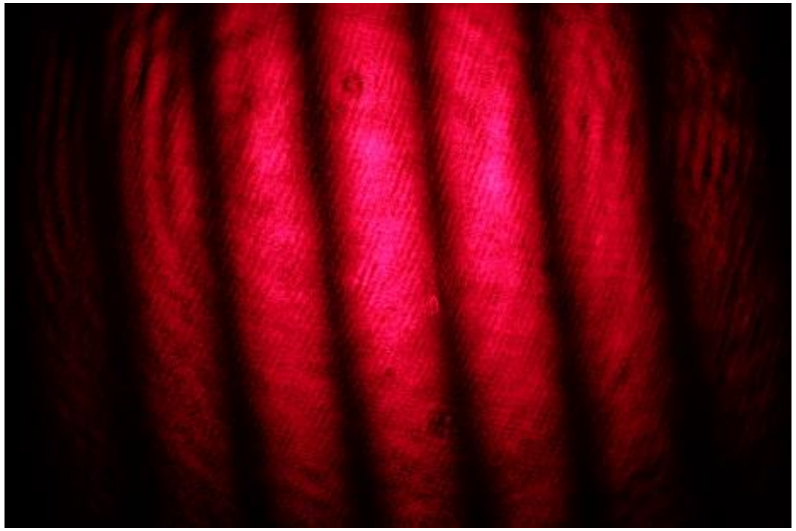
Conoscopic layout

Observation points in the Crystal



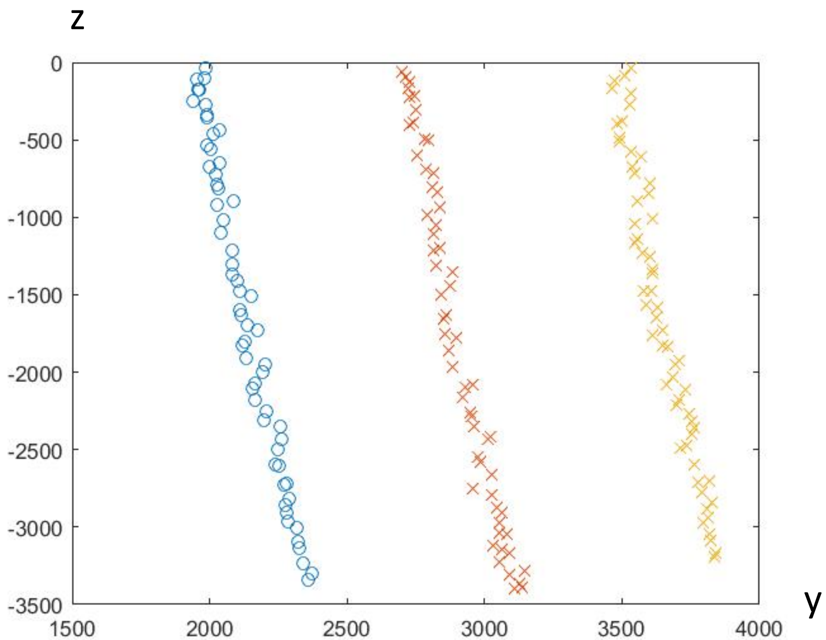


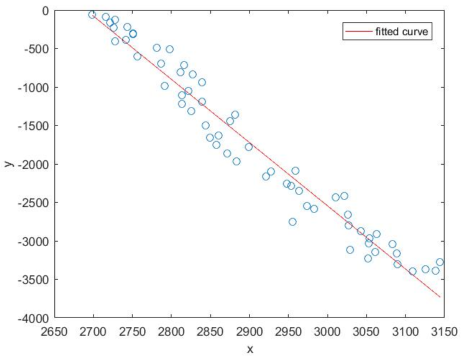
The fringe variation along a generic direction of observation (as in figure) depends not only by the stress but also by the thickness variation.

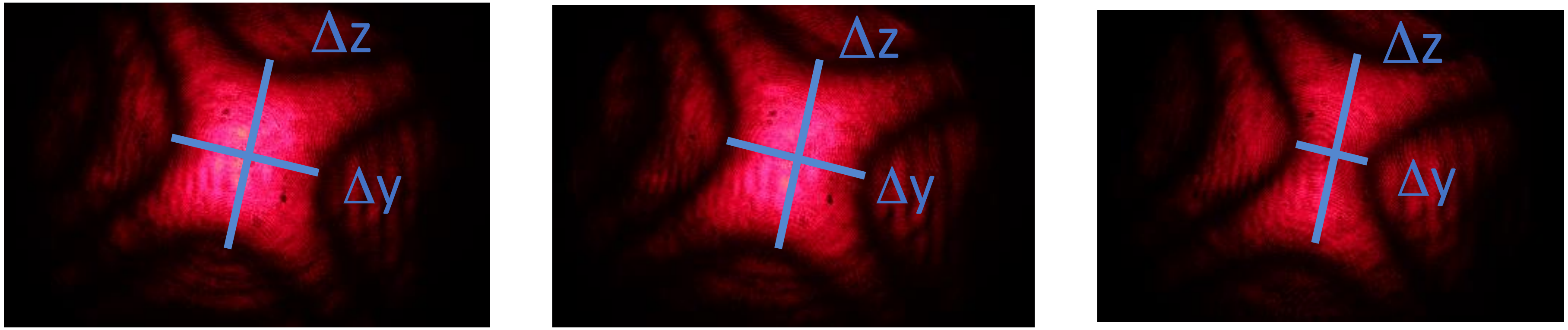


The stress analysis can be performed along the direction where the thickness is constant.

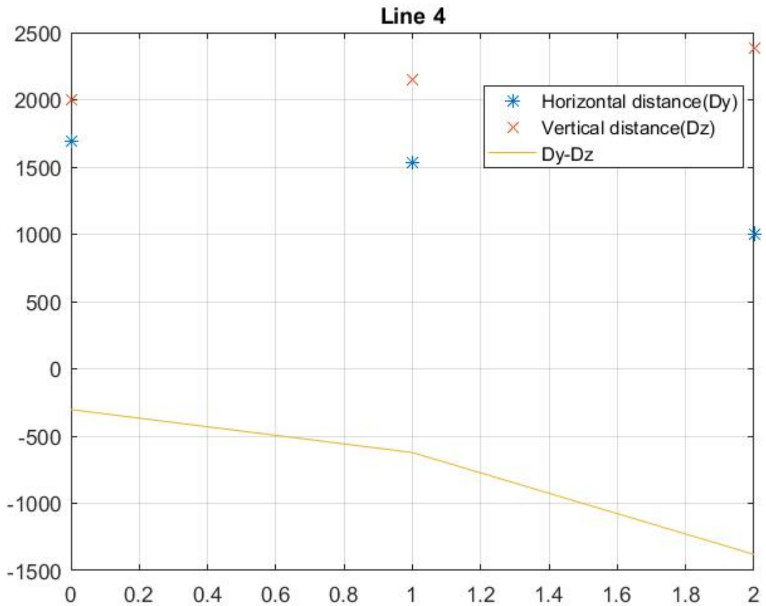
That direction coincides with the fringes direction in collimated light.







In the directions of constant thickness, the fringe layout is only determined by the stress state.

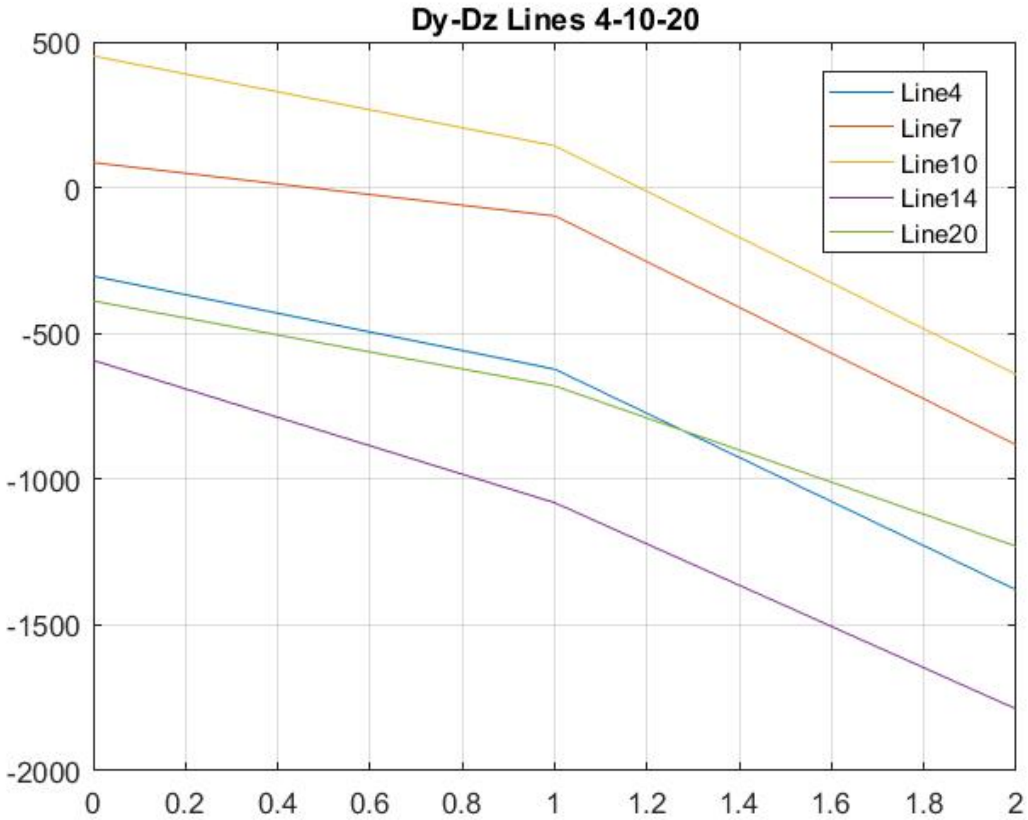


Trend of Δy-Δz measurement, function of the sample internal stress.

R = Δy-Δz

$$R(\sigma_{yy},\sigma_{zz}) = k_0 + k\sigma_{yy} + o(\sigma_{yy},\sigma_{zz})$$

"Characterization of a defective $PbWO_4$ crystal cut along the a-c crystallographic plane: structural assessment and a novel photoelastic stress analysis". JINST **12**, (12) P12035, 2017

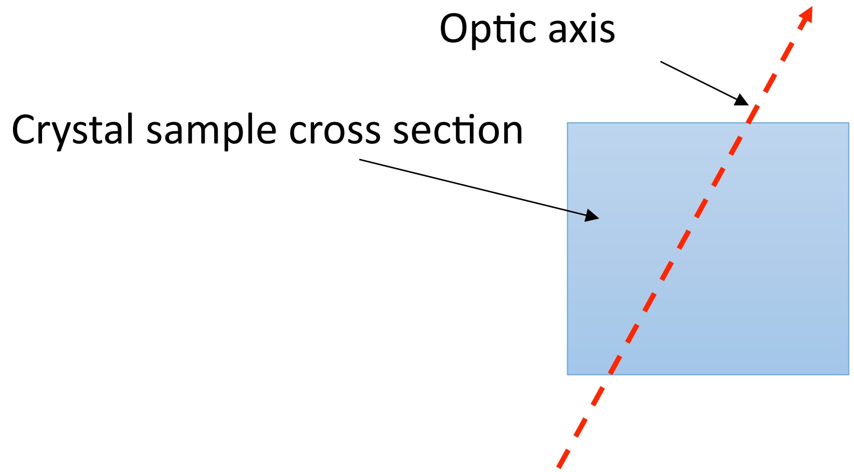


Trend of sample stress along different equal thickness lines. It is possible to note a stress gradient condition in the whole sample.

At the first glance the sample appears <u>inhomogeneous</u>

Analysis of PWO ingot

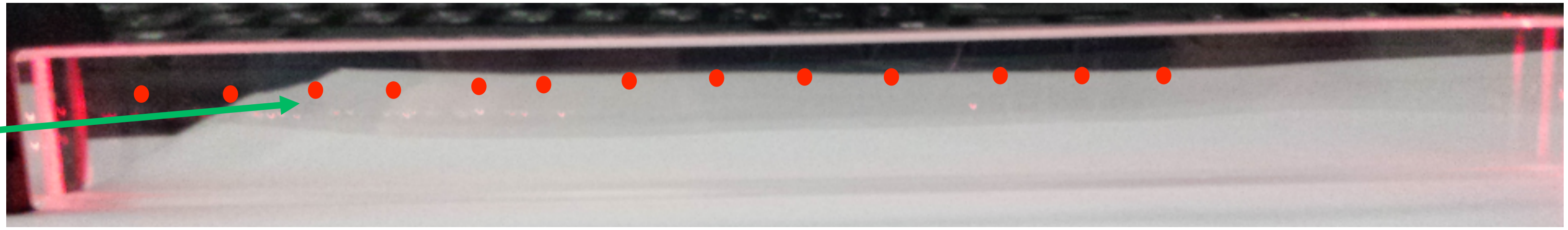
A photoelastic analysis as well as a test for the detection of the impurities have been carried out on the large PWO sample.

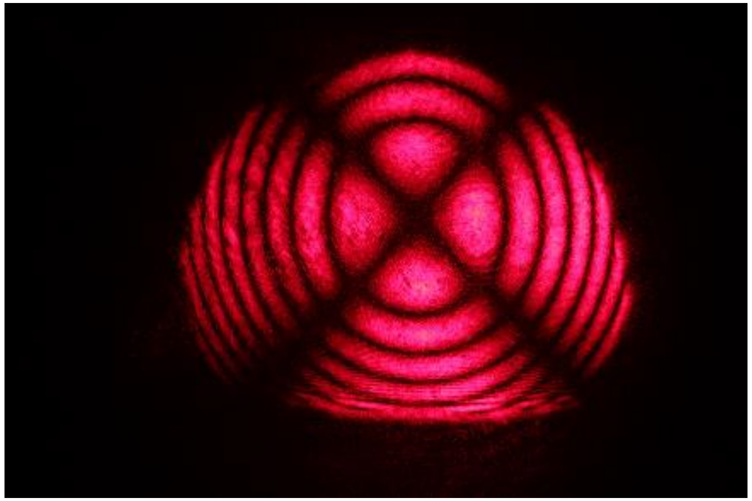


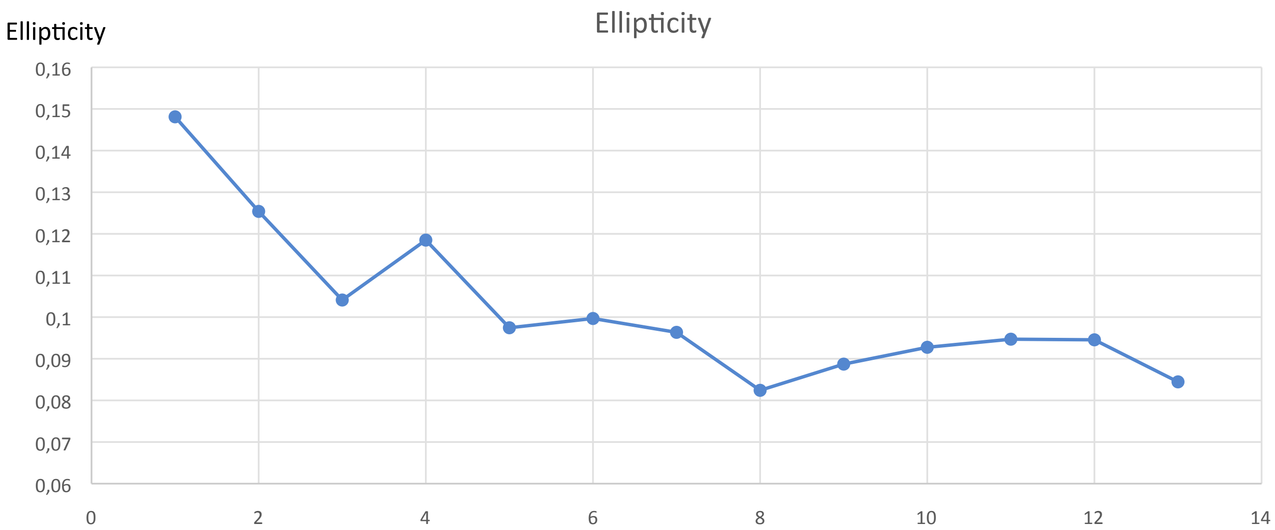
The sample has been cut with the large surfaces in random position with respect to the optic ***c*** axis.

Conoscopic inspection along the ingot axis

Inspection points over the sample



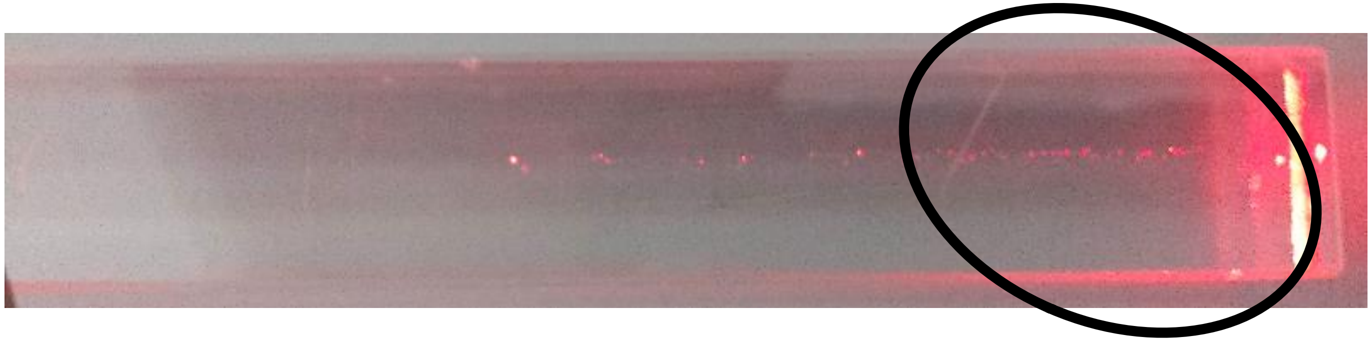




The trend of the ellipticity correspond to a stress variation along the inspection line.

PWO Ingot:
detection and qualification of particles inside the volume

Sample dimension: 2x2x20cm

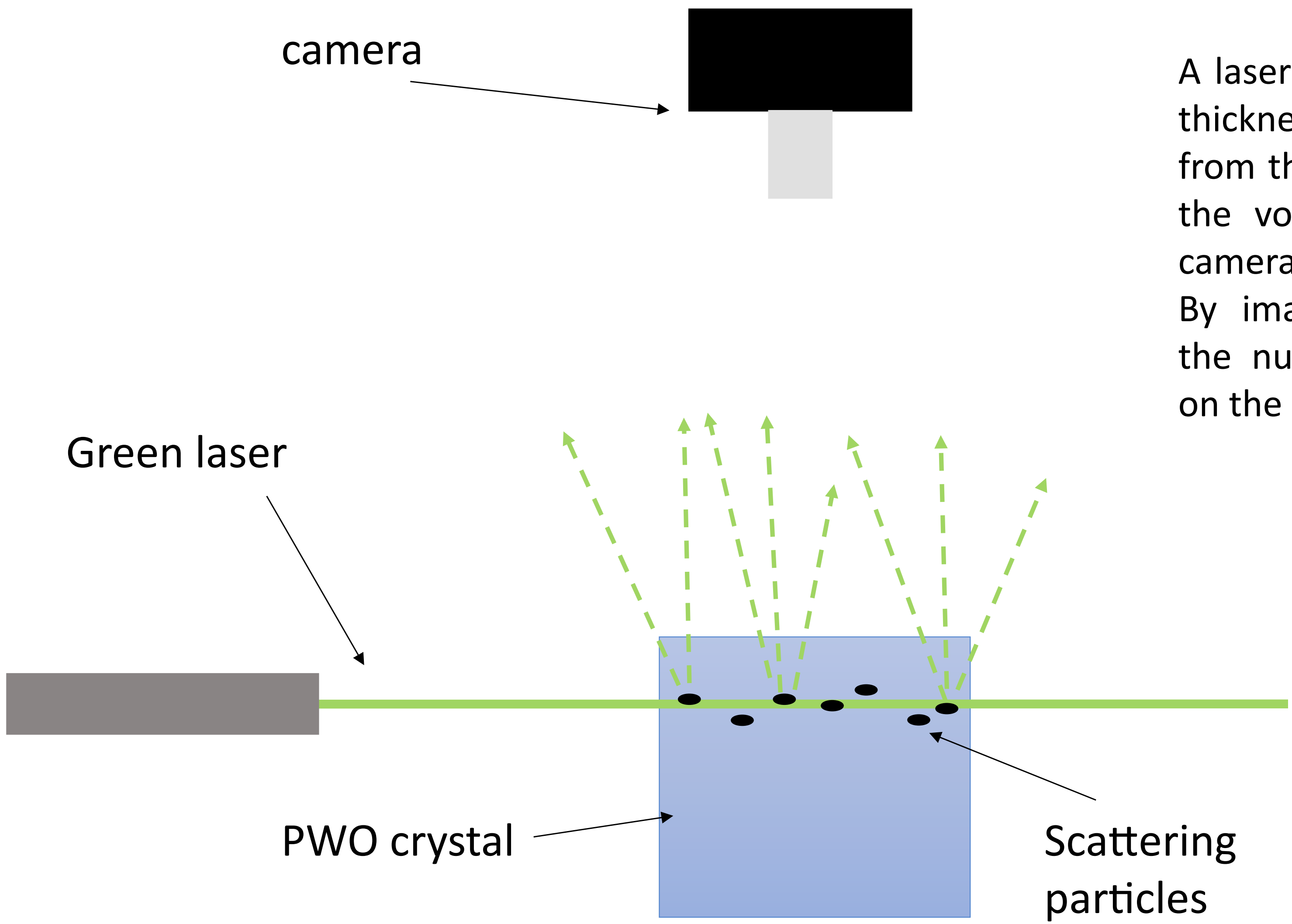


By the scattered light, some particles inside the volume are clearly visible

This causes a degradation of the crystal performances and quality

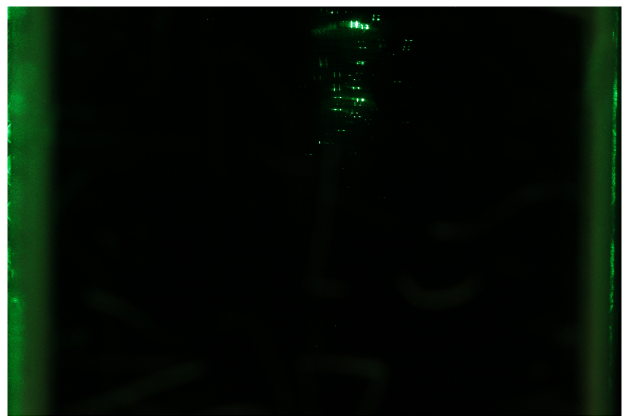
System to detect and quantify number and dimension of the particles

Testing the technique

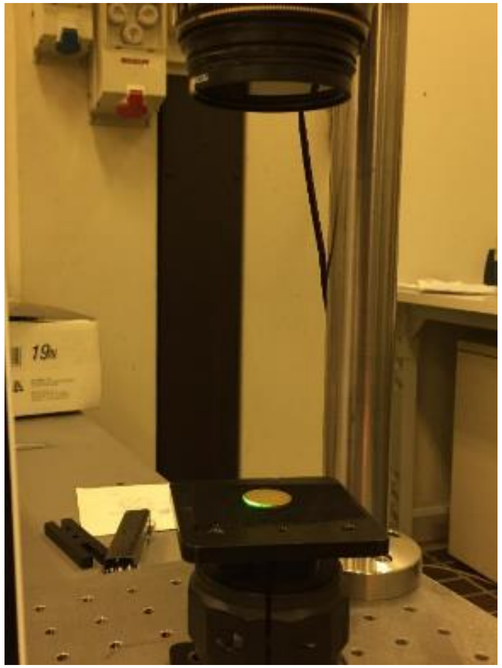


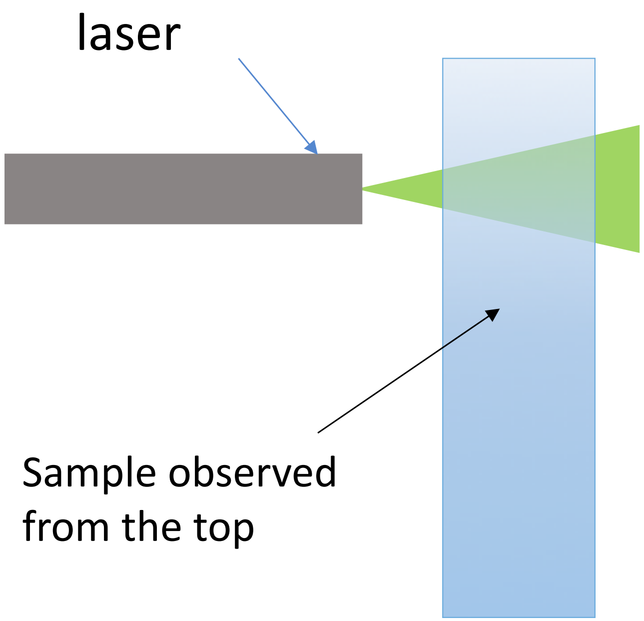
A laser blade crosses the sample thickness, the scattering light from the possible particles inside the volume is acquired by the camera.

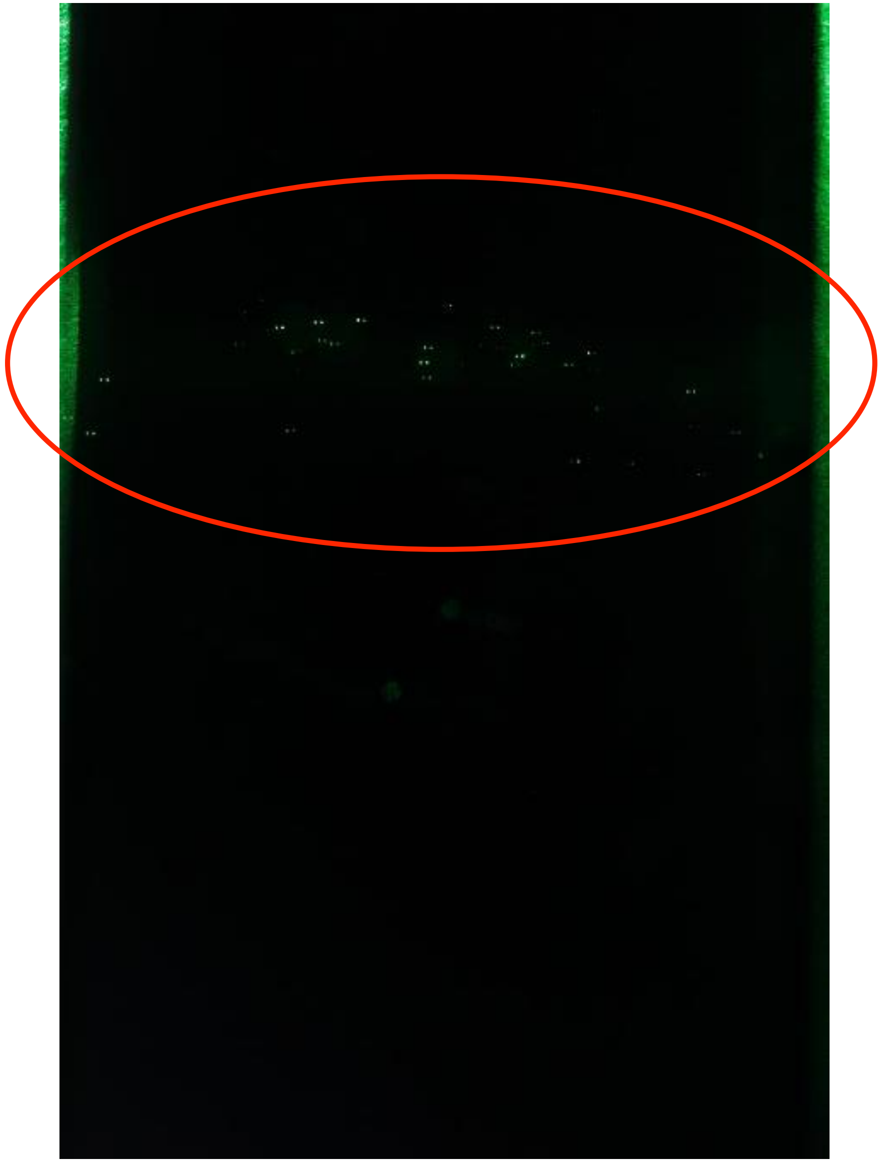
By image processing technique the number and the dimension on the particles can be evaluated



Preliminary Test



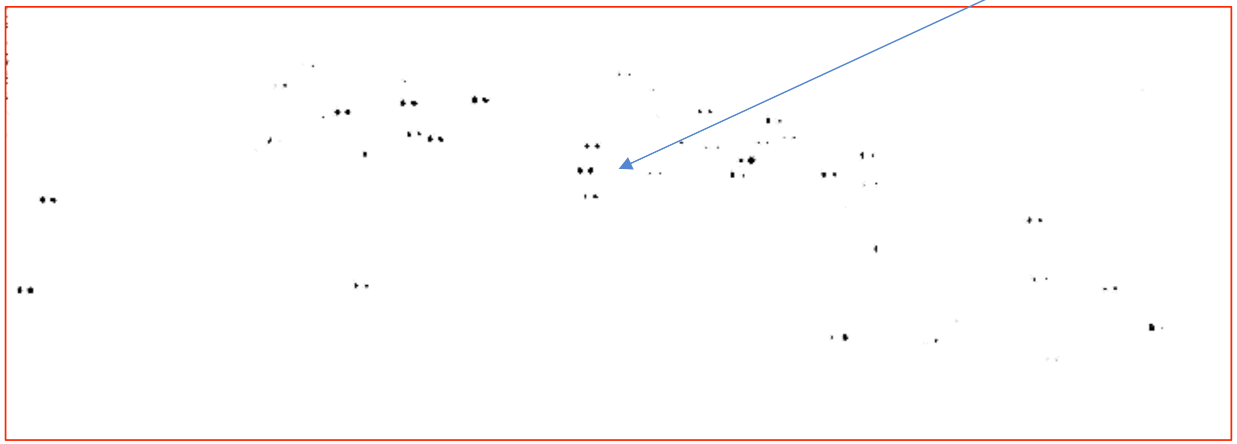




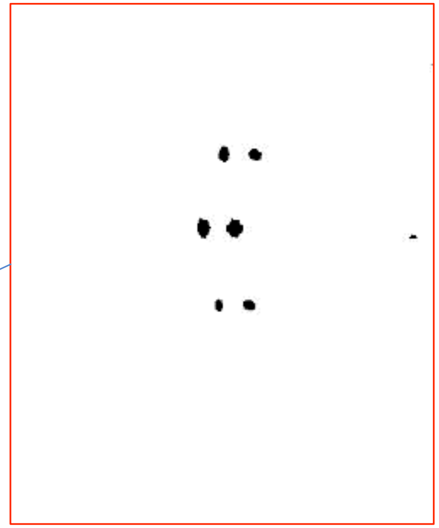
By the scattered green light the particle are clearly evident.
Their distribution is not homogeneous over the sample

Preliminary Test

Original image



Processed image



The analyzed area in the test is 7,70 X 21,80mm at the middle height of the sample.

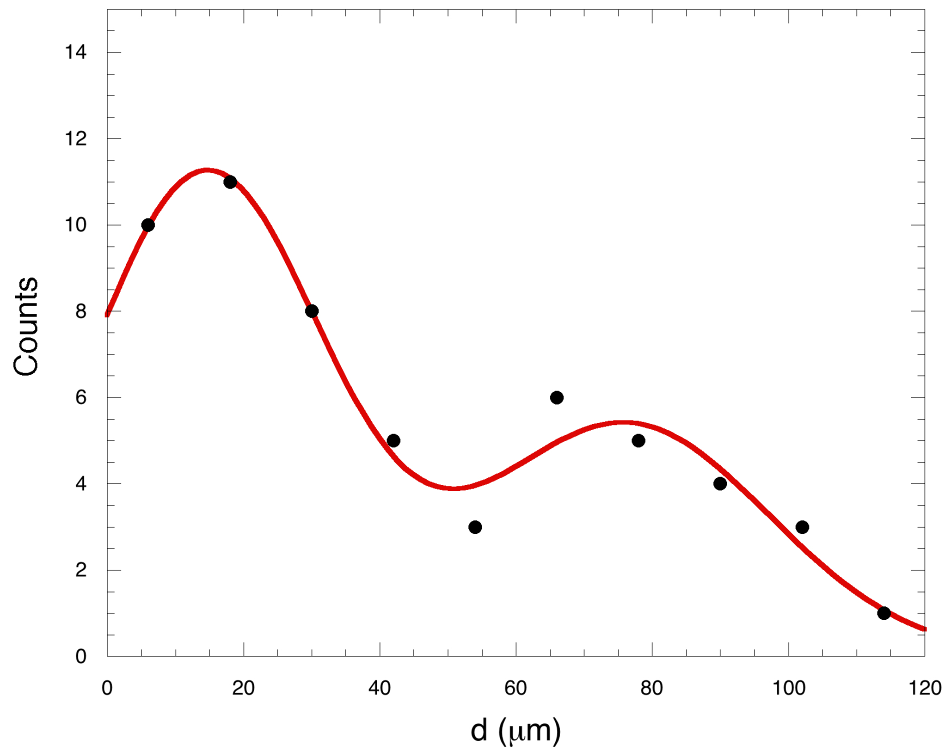
The image of the particles seems to be doubled by the birefringent effect or by a reflection.

Preliminary Test

The algorithm detects about 120 (about 60 real particles considering the birefringence) particles in the area.

The particles diameter ranges from 7 to 120 µm.

The dimension distribution seems to have a double gaussian behavior.



Test are ongoing to improve the accuracy and the reliability of the procedure.

CONCLUSIONS

- Stress distribution have been detected in both samples and indicates inhomogeneity.
- Slab sample

the complexity of the measurement is due to the distorted geometry with respect to a parallelepiped and the ***c*** axis in the slab plane. The method is capable to detect stress or homogeneity variation.

- Ingot sample

by conoscopy in "traditional" configuration, the ellipticity variation along the ingot axis has been measured. This indicates the presence of a stress gradient in that area.

A technique to evaluate the impurity distribution and size has been tested on the large sample: the technique shows reliability and sensitivity to the presence of micro inclusions.

Each method has shown suitability for quality control and detection of defects, tests are ongoing in both the direction: the analysis of the samples and the improvement of the techniques.