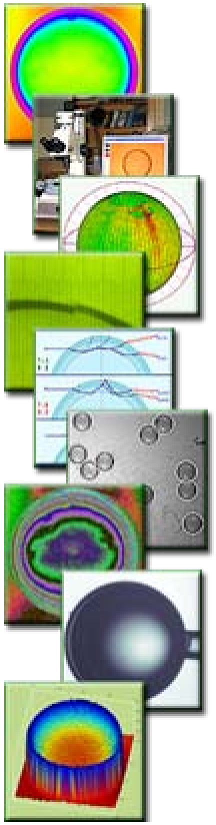
A.I. Nikitenko, S.M. Tolokonnikov.

Lebedev Physical Institute,

Moscow, Russia, 2007

Laser Target Parameters Reconstruction Using Shadow Images.



A part of this work had been carried out under the support of the ISTC (project #1557)

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ICF targets optical characterization. Problem statement.

Input data:

backlight shadowgraph images;
interference images;
X-ray images;
set of backlight shadowgraph projection.

Parameters need to be recovered:

diameter and average wall thickness;
shell nonroundness and wall nonuniformity;
spectrum of target surfaces spatial nonuniformities;
shape and relative position of target surfaces.

Result presentation:

tables (diameter, wall thickness, nonuniformity, etc.)
2D curves (intensity profiles, power spectra, etc.)
3D visualization (shape and relative position)

It is hard or impossible to solve all this problems using existing software; therefore the set of specialized software packages had been developed.

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How to obtain parameters of ICF targets from its images ?

Aims:	**Tools:**
Clear quantitative understanding of transparent multilayered shell optic.	Physical optic + mathematics model + digital modeling.
Initial data extraction from target images with maximum possible precision.	Details of images formation in real experimental systems + mathematics for correct image processing + related algorithms.
Reliable reconstruction of target parameters from initial data.	Modern mathematics methods + specialized algorithms.
Result presentation and visualization adequately to human perception.	Set of convenient interfaces + extended 2D graphics + 3D visualization of shapes and complicated functions.

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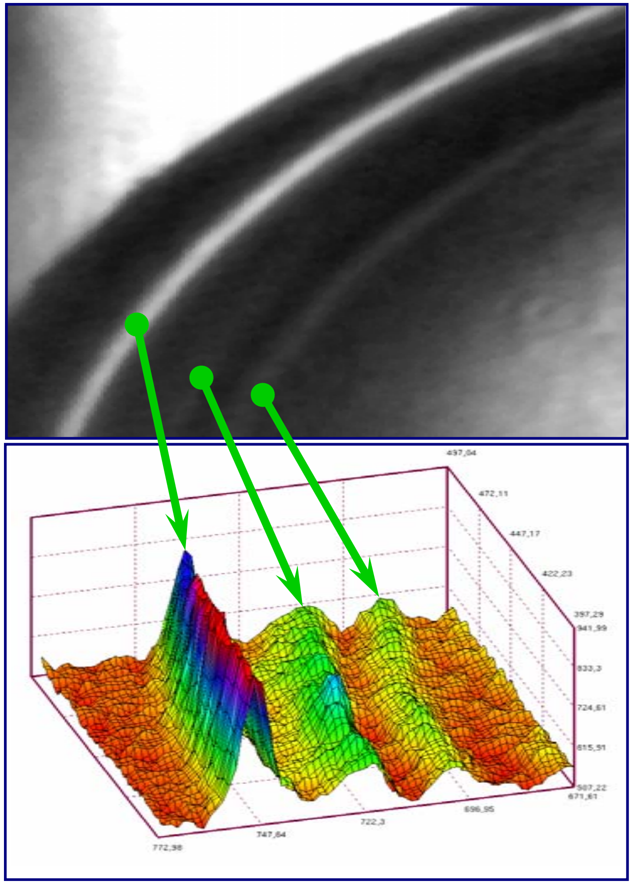
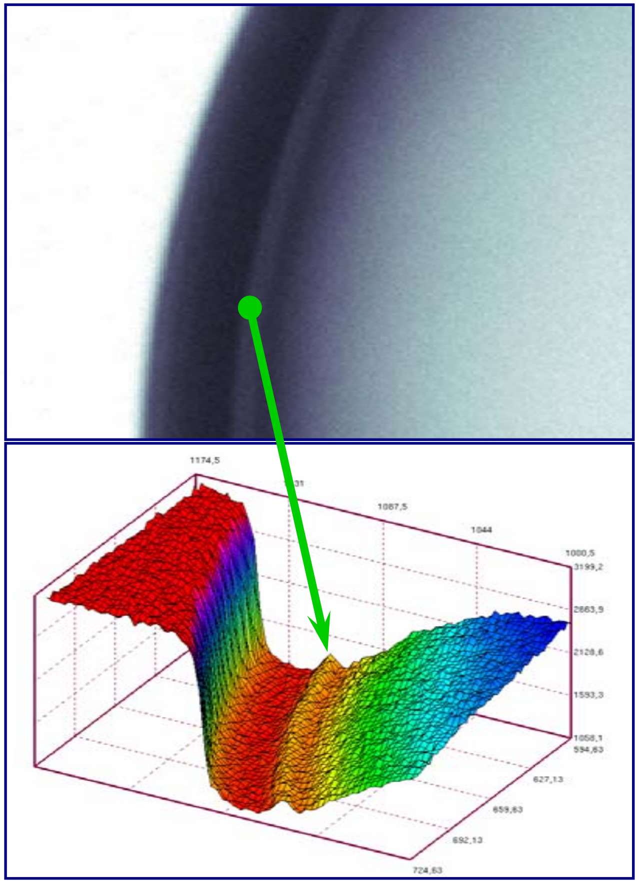
Real images bright rings.

Two layers shell



One layer shell



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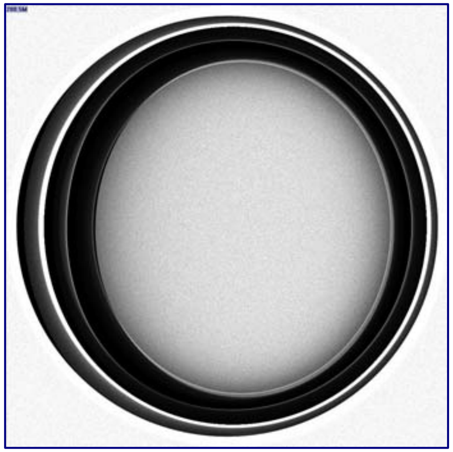
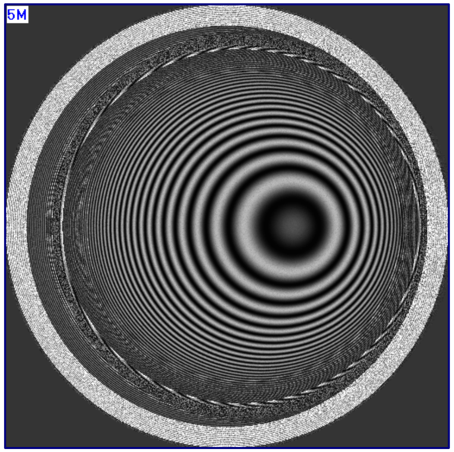
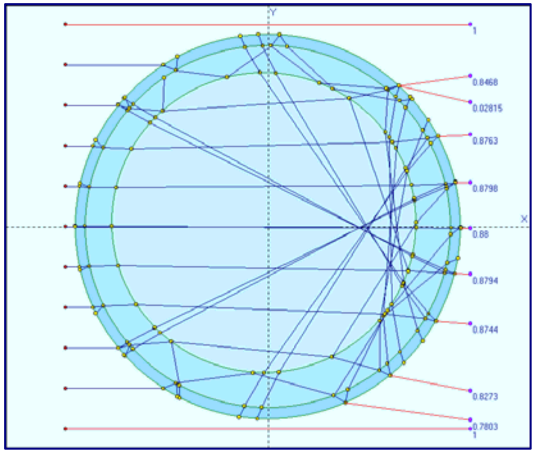
3D ray tracing model.

- Three-dimensional ray tracing model for multi layer capsules was designed and C^{++} codes were written.
- The model based on principles of geometrical optic, every ray forms image is traced from light source to detector. Capsules are considered as a set of arbitrary 3D ellipsoids.
- Windows XP software package with friendly interface allows getting shadowgraphs, interferograms, intensity profiles and pictures of rays passing through the shell.
- Parameters of the capsule – refraction indexes, absorption coefficients of layers, geometrical parameters as aperture, position of light source and observation plane can be easy varied. Possibility of capsule scanning (rotation of light source and detector around the shell) is provided.







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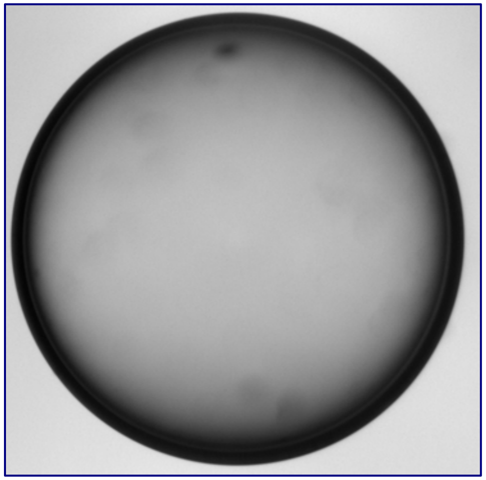
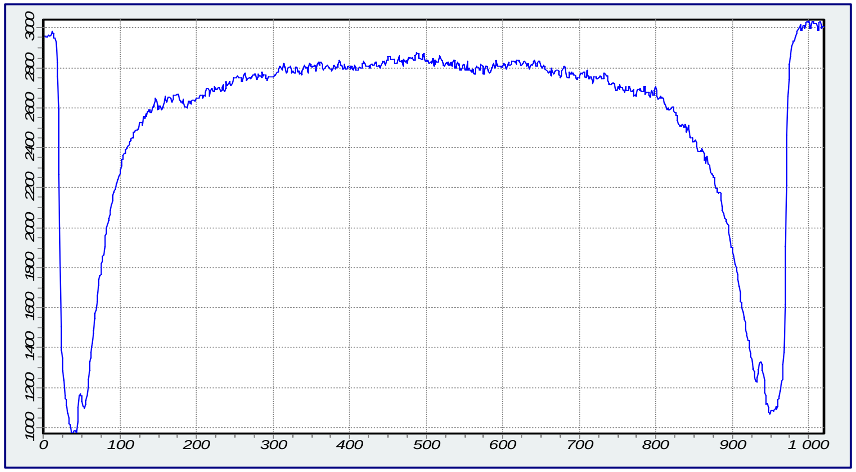
Model validation test. Polystyrene shell.

Real Image

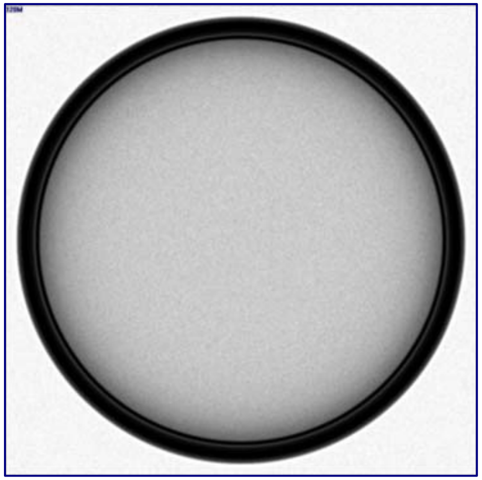


Polystyrene shell R = 490μm; ΔR = 14μm

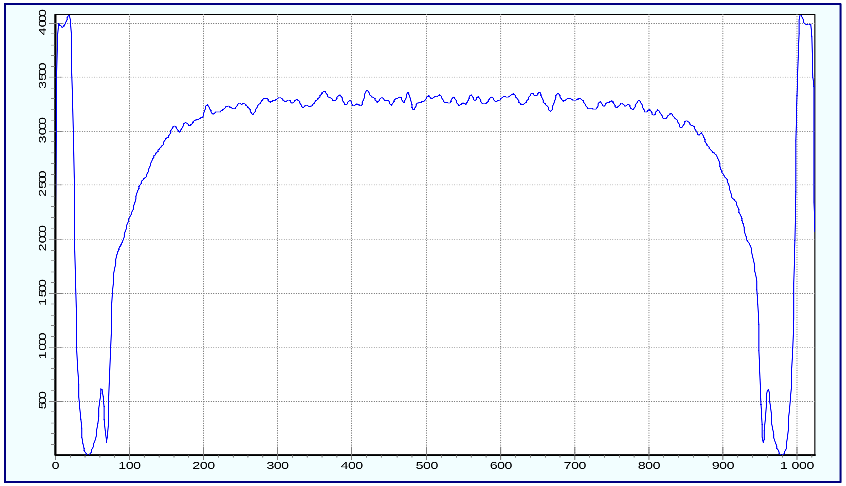


Intensity along diameter. Polystyrene shell R = 490μm; ΔR = 14μm

Simulated Image



1 Surface :: a = 1.00, b = 1.00, c = 1.00
2 Surface :: a = 0.93, b = 0.93, c = 0.93



Intensity along diameter. Simulated image $120 \cdot 10^6$ rays

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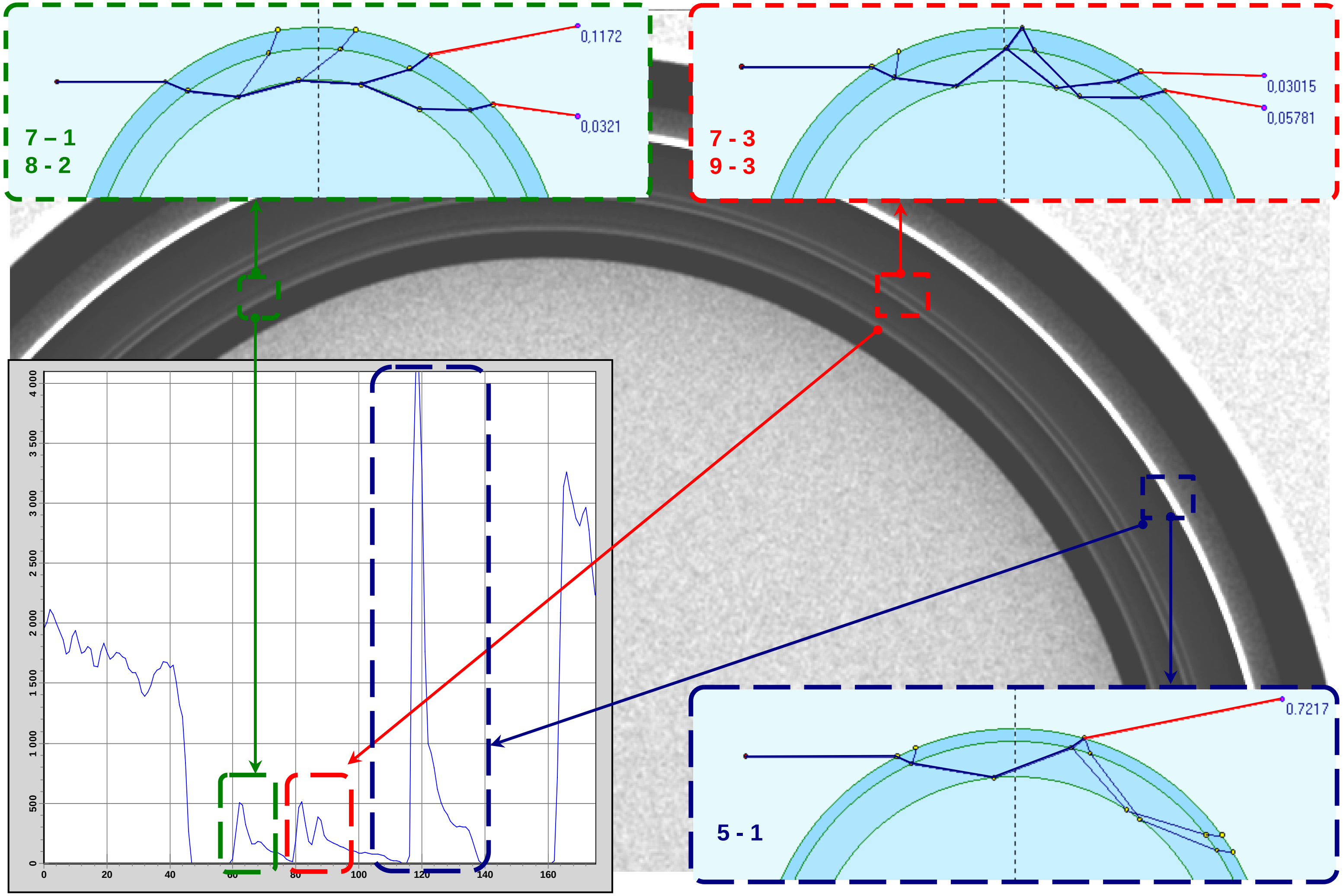
Bright rings formation scheme.



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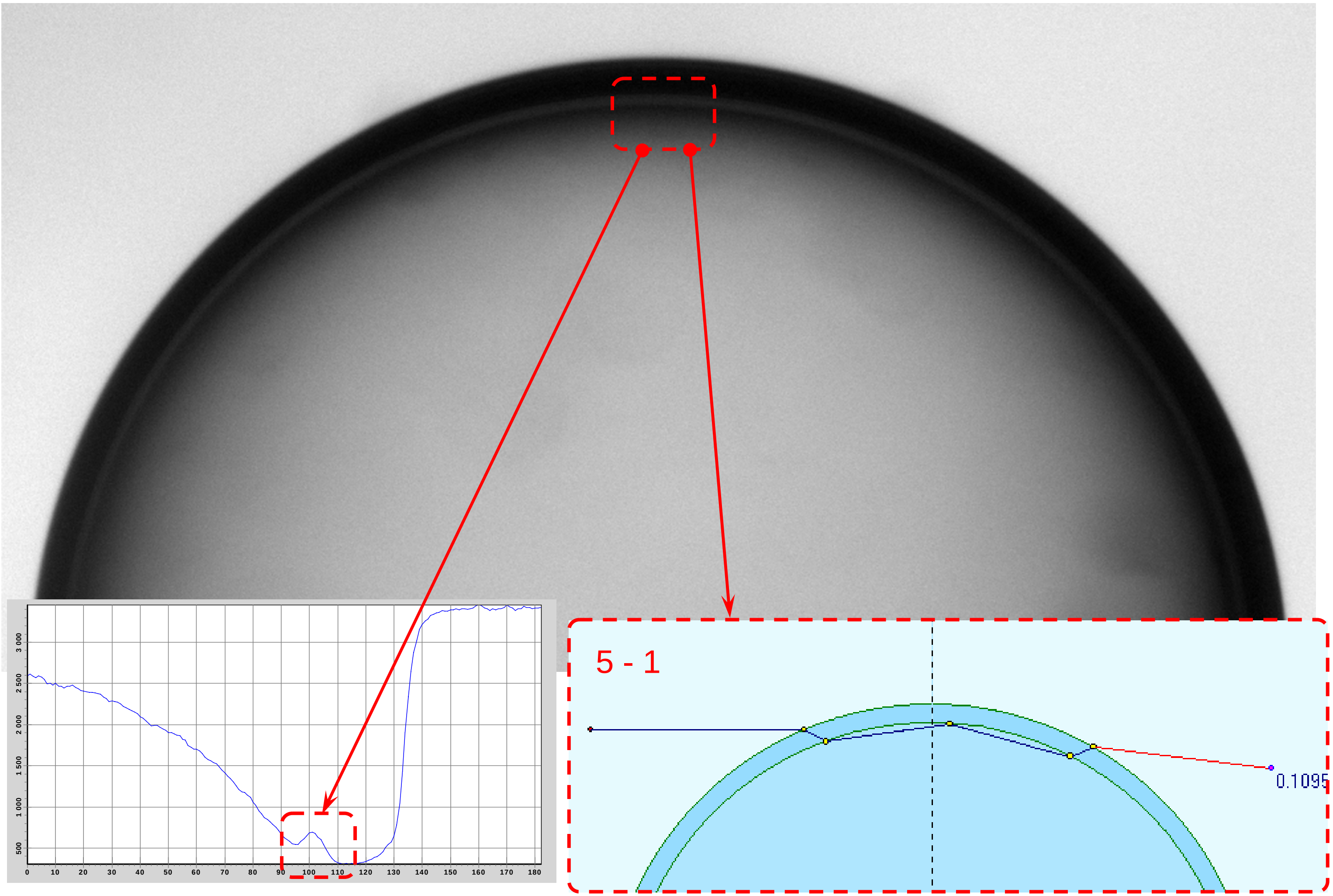
Light ray passing through 1-layer shell.



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Ray passing through 2-layers shell.

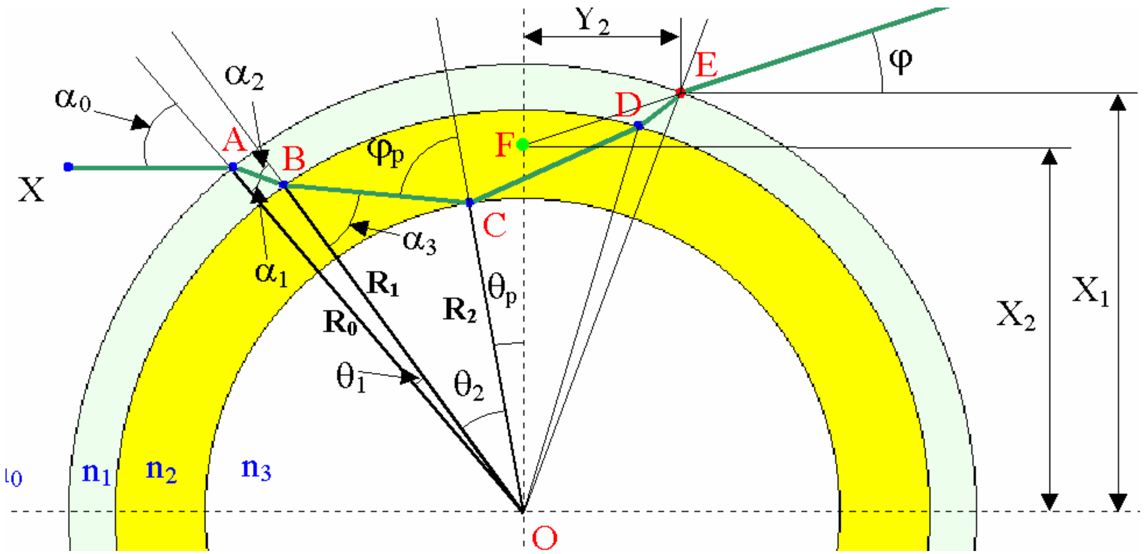
$$\alpha_0 = \arcsin X$$

$$\alpha_1 = \arcsin\left(\frac{n_0}{n_1} X\right)$$

$$\alpha_2 = \arcsin\left(\frac{n_0}{n_1}\frac{X}{R_1}\right)$$

$$\alpha_3 = \arcsin\left(\frac{n_0}{n_2}\frac{X}{R_1}\right)$$

$$\varphi_p = \arcsin\left(\frac{n_0}{n_2}\frac{X}{R_2}\right)$$



$$\theta_p = \frac{\pi}{2} - \alpha_0 + \alpha_1 - \alpha_2 + \alpha_3 - \varphi_p \qquad \varphi = 2\theta_p$$

$X_2 = X_1 - (Y_1 - a)\,tg\,\varphi$, *where* $X_1 = \sin(\alpha_0 + \varphi)$ $\quad Y_1 = \cos(\alpha_0 + \varphi)$

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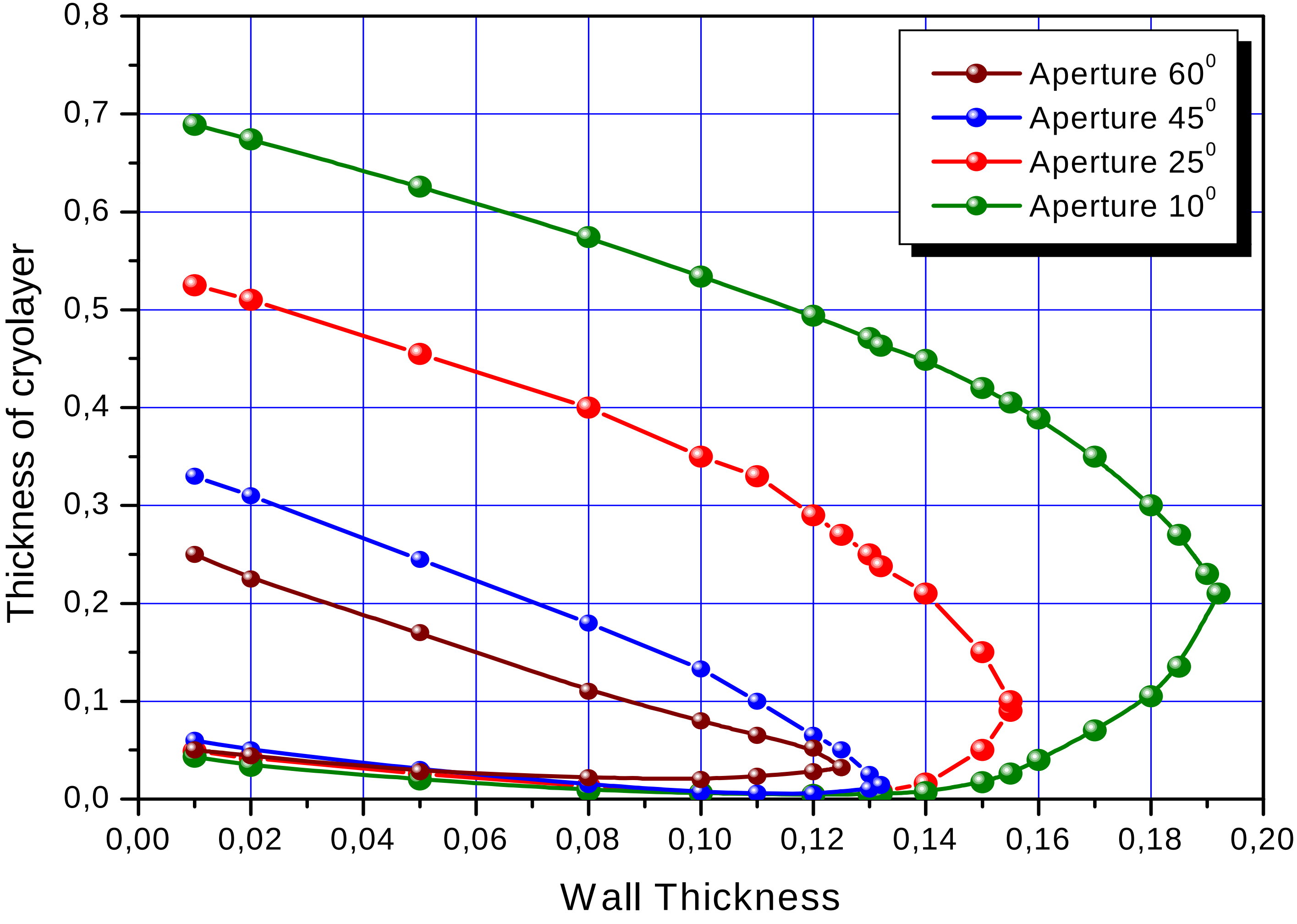
Zone of bright ring discernibility.



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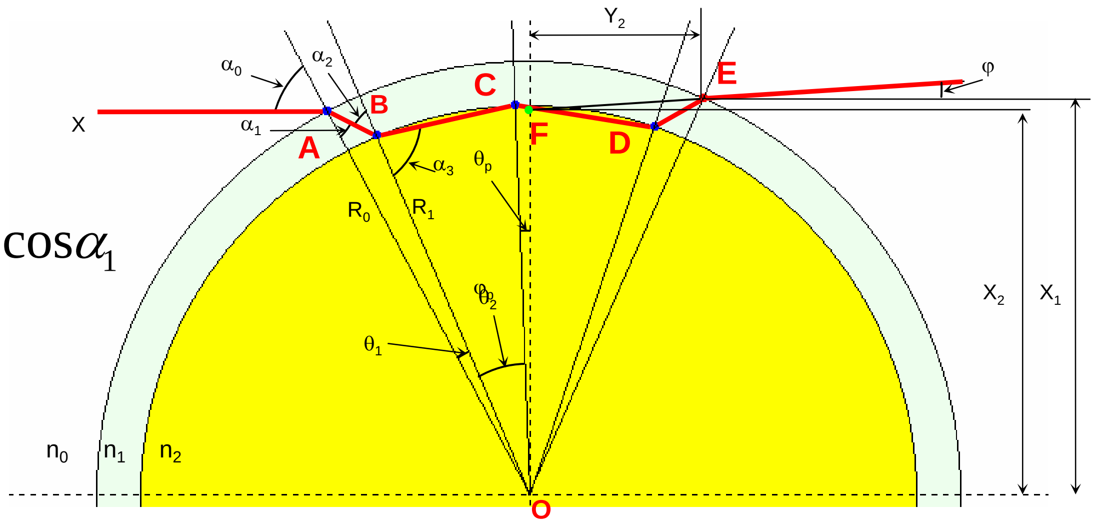
Ray passing through a shell.

$$\sin\alpha_0 = X$$
$$n_0 \sin\alpha_0 = n_1 \sin\alpha_1$$
$$n_1 \sin\alpha_2 = n_2 \sin\alpha_3$$
$$AB \sin\alpha_1 = R_1 \sin\theta_1$$
$$AB = R_1 \cos(\pi - \alpha_2) + R_0 \cos\alpha_1$$
$$\theta_1 = \alpha_2 - \alpha_1$$
$$R_0 \sin\alpha_1 = R_1 \sin\alpha_2$$
$$\alpha_0 = \arcsin X$$
$$\alpha_1 = \arcsin\left(n_0 X / n_1\right)$$
$$\alpha_2 = \arcsin\left(n_0 X / n_1 R_1\right)$$
$$\alpha_3 = \arcsin\left(n_0 X / n_2 R_1\right) \qquad \theta_2 = \pi - 2\alpha_3 \qquad \theta_p = \frac{\pi}{2} - \alpha_0 - (\theta_1 + \theta_2)$$



$$\theta_p = \frac{\pi}{2} - (\alpha_0 + \alpha_2 - \alpha_1 + \pi - 2\alpha_3) = (\alpha_1 - \alpha_0) + (\alpha_3 - \alpha_2) + \alpha_3 - \pi/2$$
$$\varphi = 2\theta_p$$

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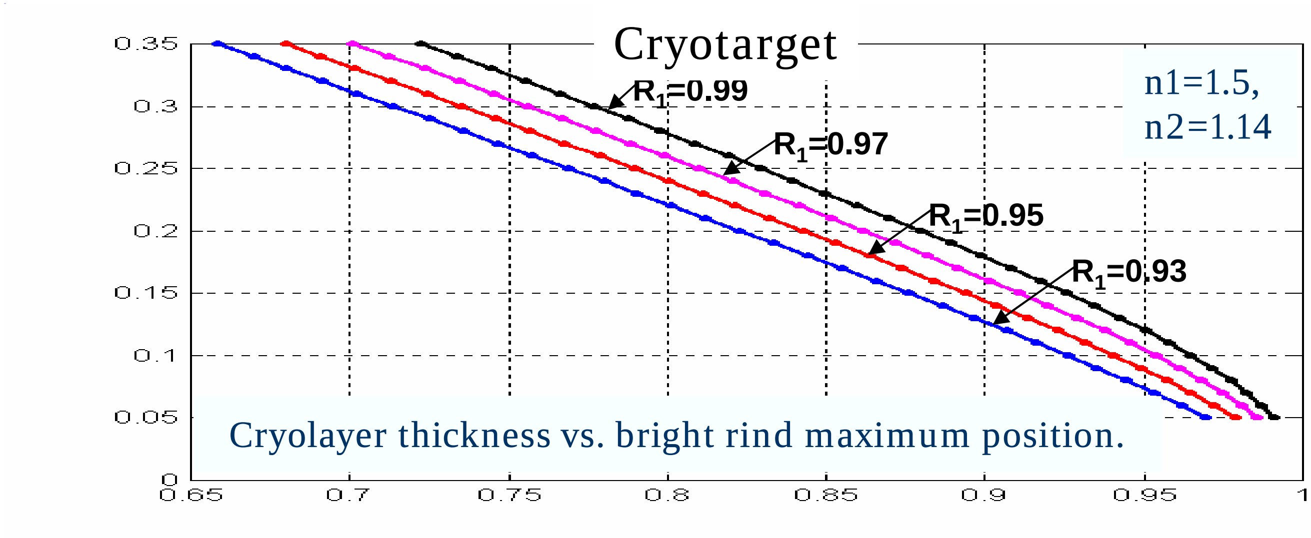
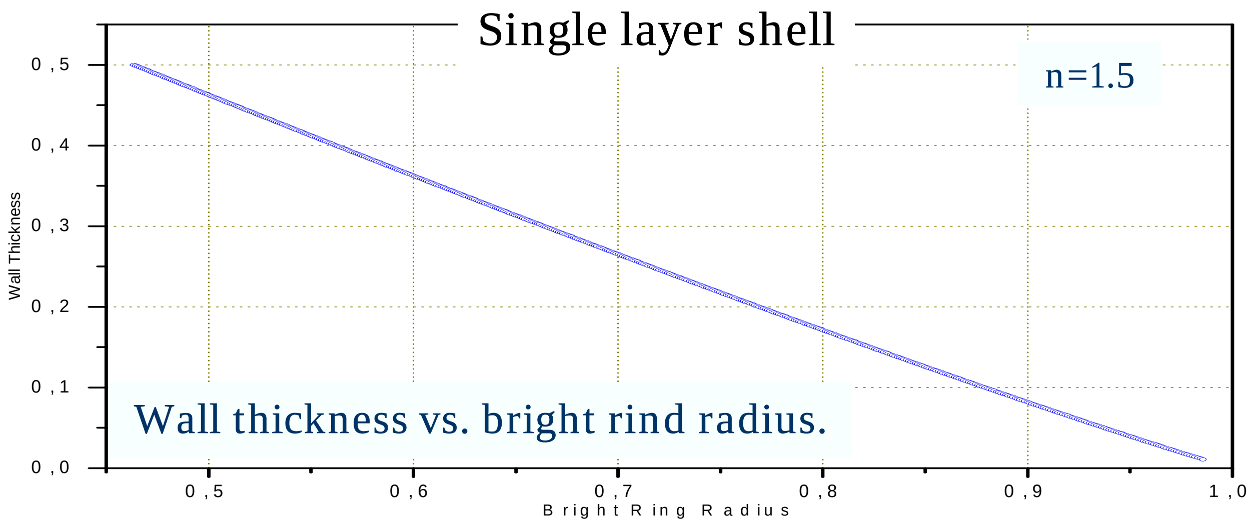
Parameters defined by bright rings position.



Cryolayer thickness vs. bright rind maximum position.



Wall thickness vs. bright rind radius.

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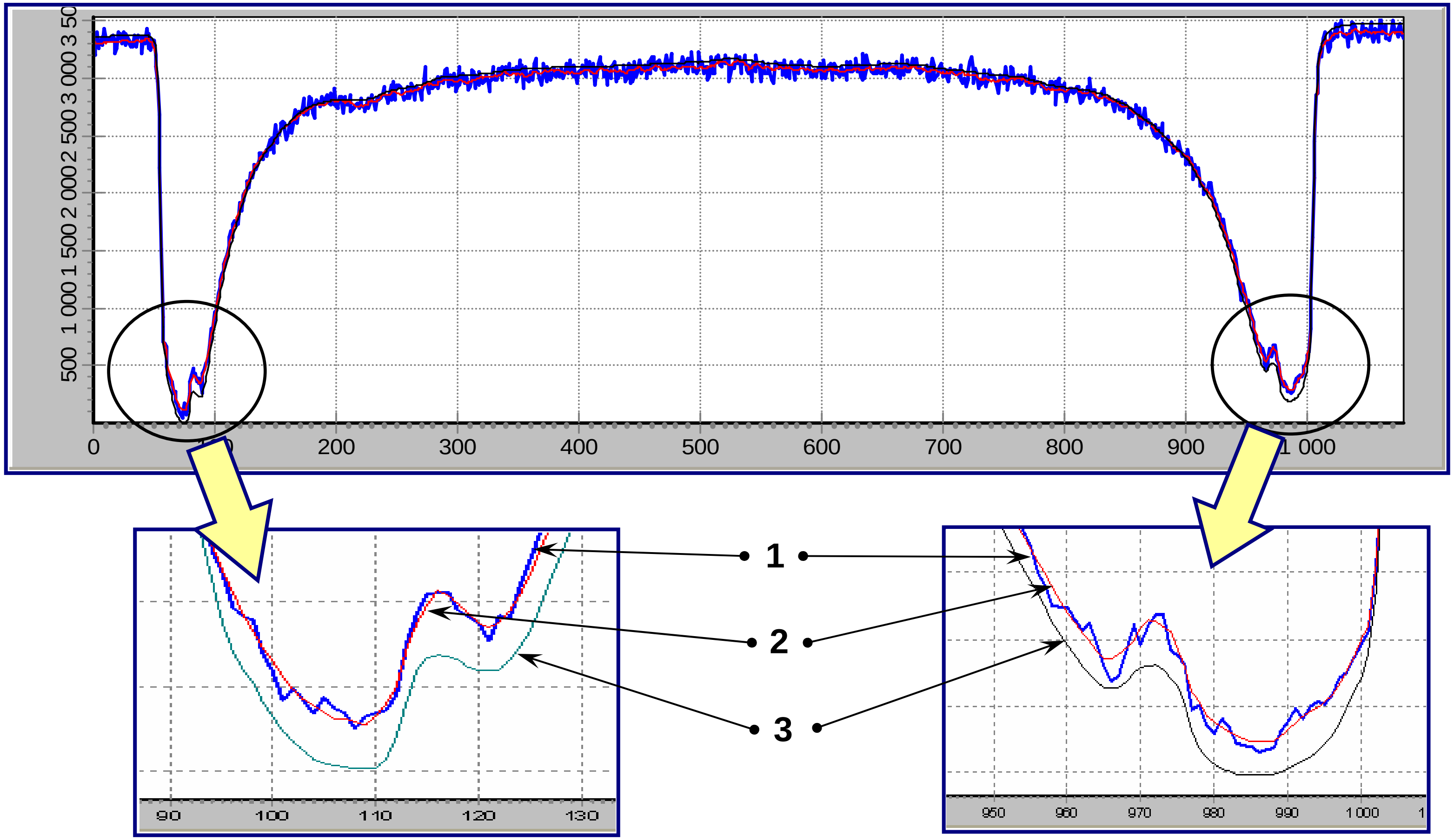
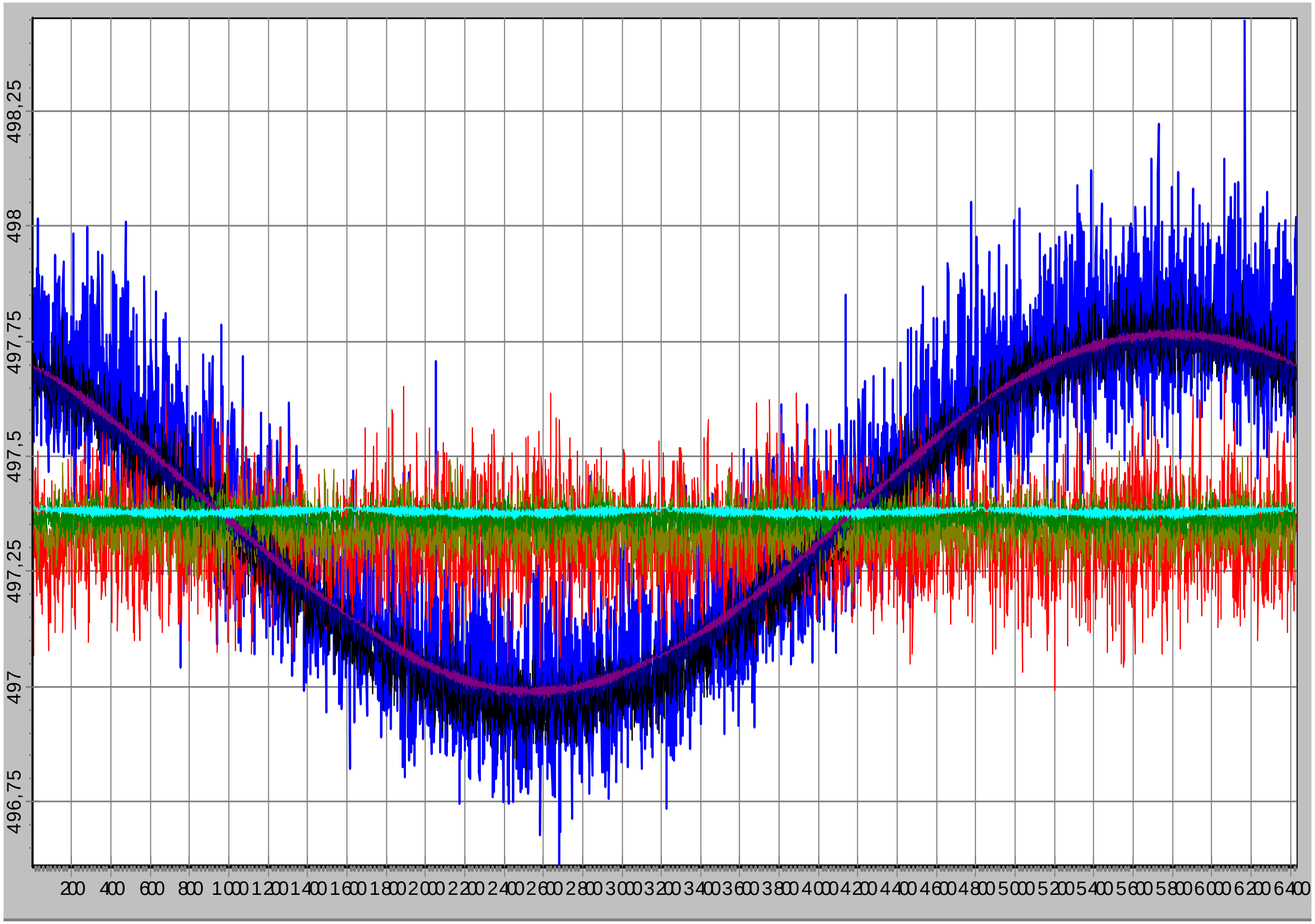
Image filtration.



1 - unprocessed image: 2 - Wiener filter application (filter kernel size 5); 3 – wavelet filter application (wavelet – db2, decomposition level – 5, threshold selection - by entropy criteria).

Center determination (test image).



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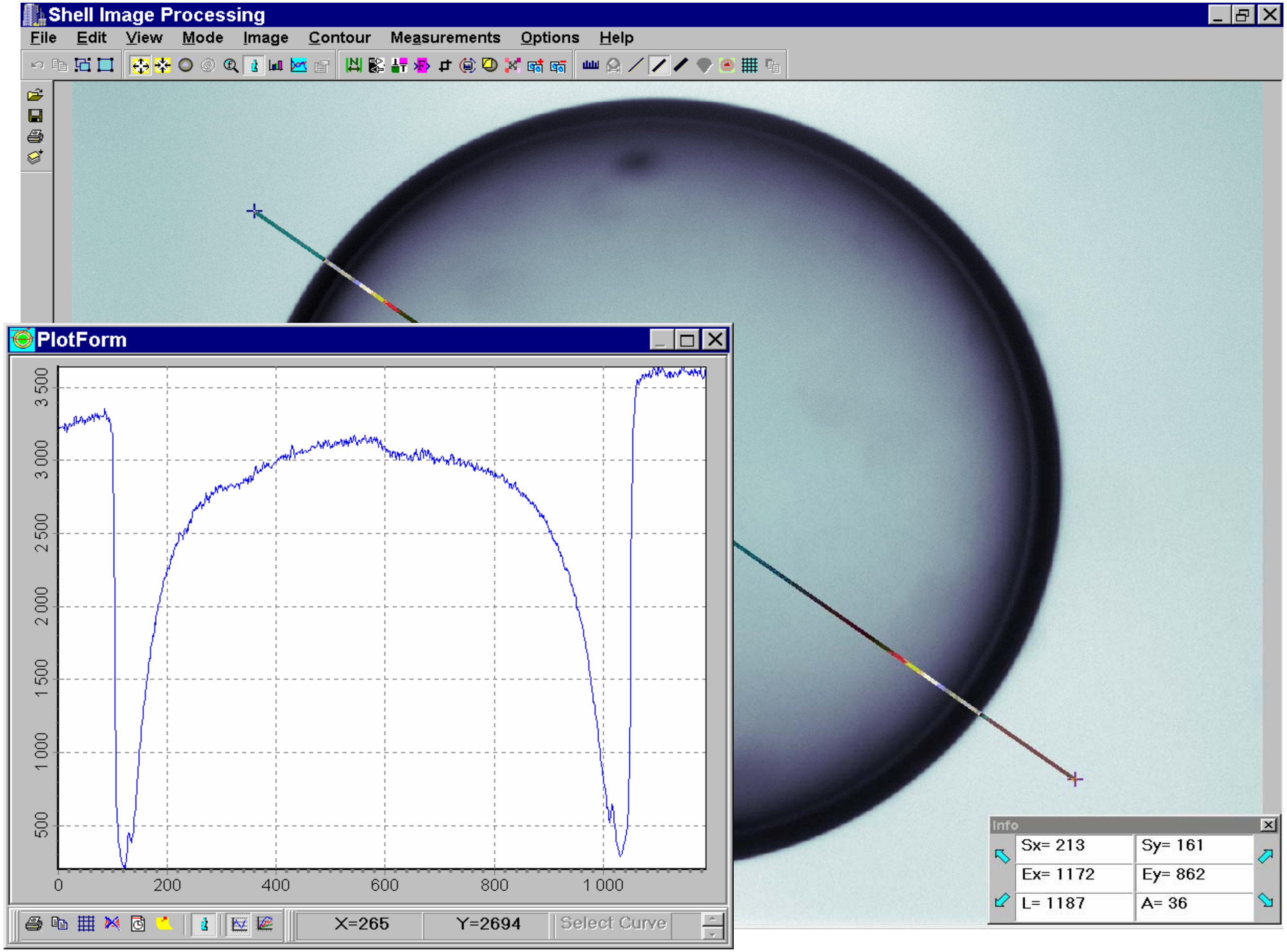
“Shell Image Processing” program interface.



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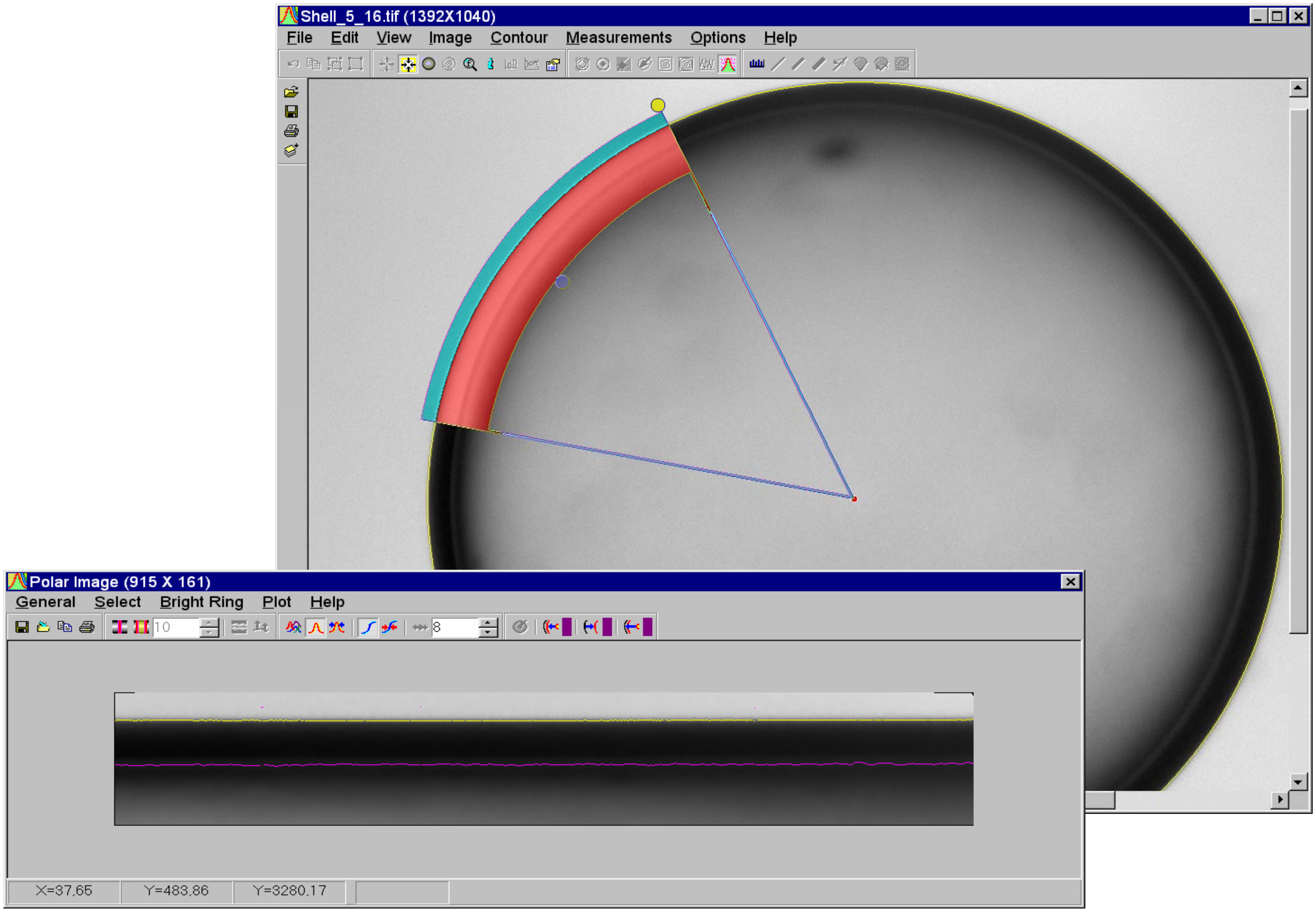
“Bright Ring” program interface.



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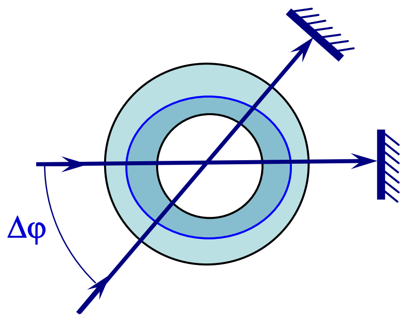
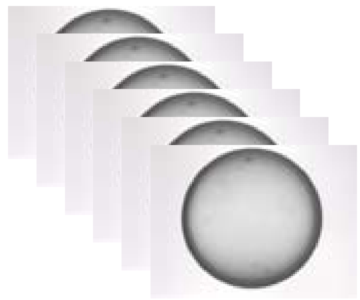
Cryolayer "tomography". Method definition.

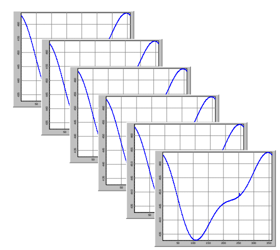


Make projection images



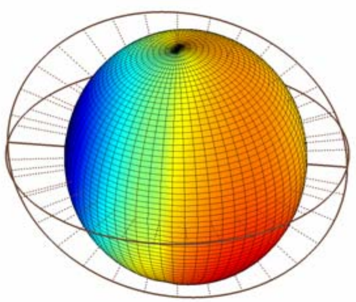
Set of projection images

Projection images processing



Bright ring data for each projection

Reconstruction of inner cryolayer surface shape



View and analyze result

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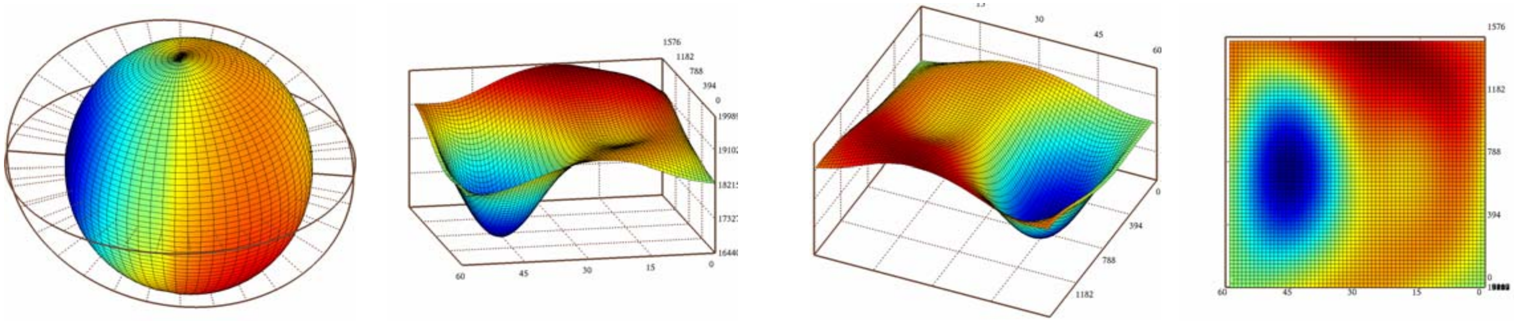
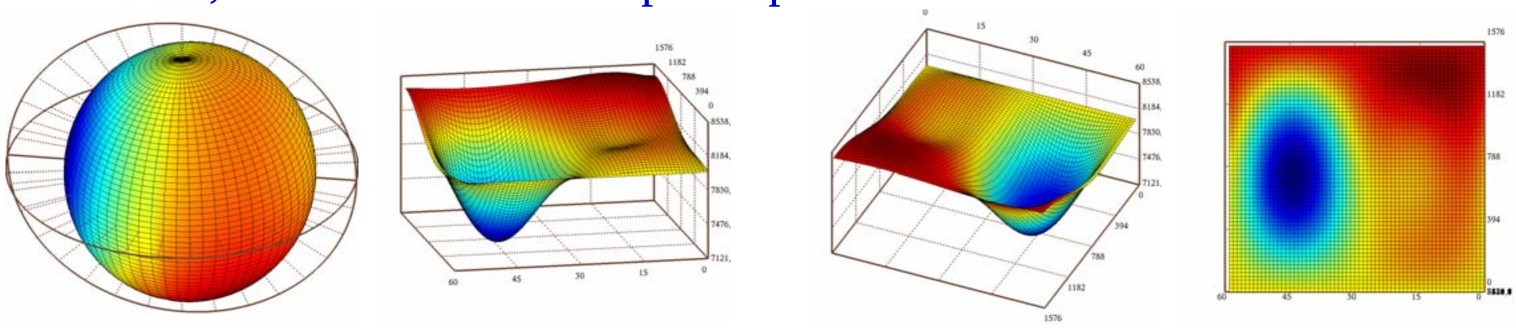
Cryolayer “tomography”. Validation test.

Reconstructed surface



Surface, calculated from ellipsoid parameters



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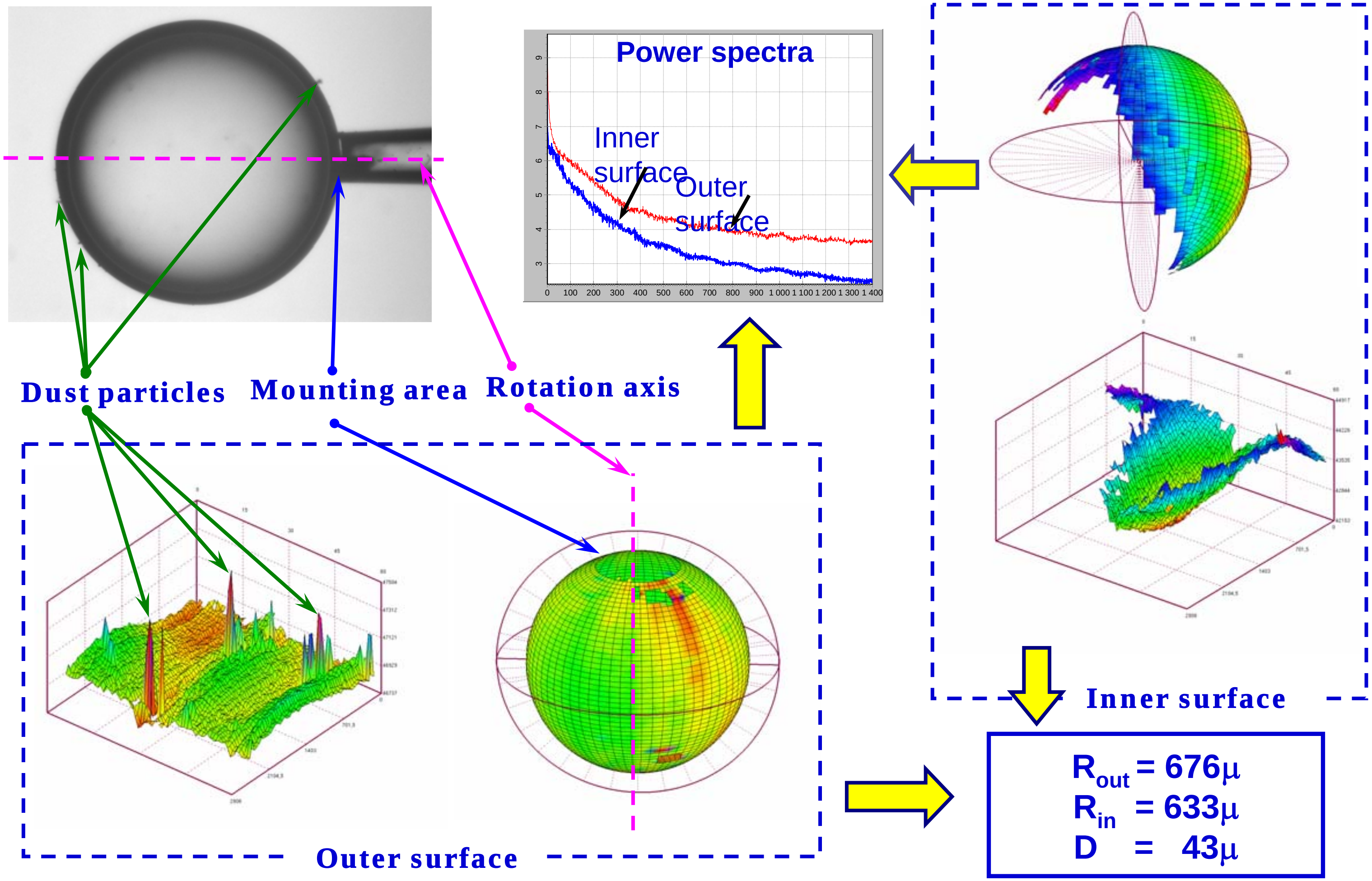
Real single layer shell mapping.



Results.

Details of light passing through transparent multilayered shell where carefully investigated.

Digital methods and algorithms had been developed, based on obtained knowledge.

Bright rings, observed on real transparent shell images, had been used successfully for ICF targets characterization.

Cryolayer “tomography” method, using many projection bright ring parameters as an input data, had been proposed and developed.

Its validity and precision were tested and good agreement between reconstructed and test objects had been found.

7 software packages and a lot of different utilities had been written to implement developed methods and to give convenient tools for ICF targets characterization.

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S.M. Tolokonnikov

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