P.N. Lebedev Physical Institute
Russian Academy of Sciences

Free-Standing Cryogenic Target Facility created at the Lebedev Physical Institute

Elena Koresheva

2nd ETFW, Abingdon, October 27, 2008

Free-standing target (FST) approach to cryogenic target technology and delivery is under development in the Cryotarget Group of Lebedev Physical Institute (LPI) over the last 20 years

❑ **FST APPROACH**

Operation with free-standing targets at each production step:

fuel filling → fuel layering → target injection

❑ **MOTIVATION**

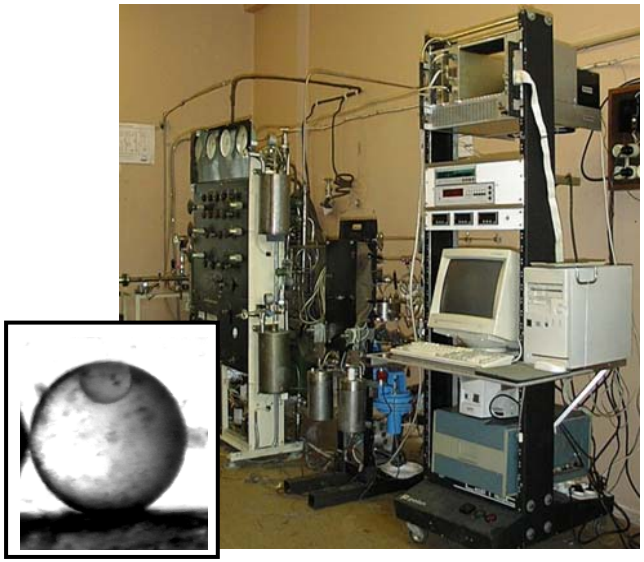
- time and space minimization at each production step ⇒

⇒ tritium inventory minimization

- possibility for high rep-rate target fabrication and injection

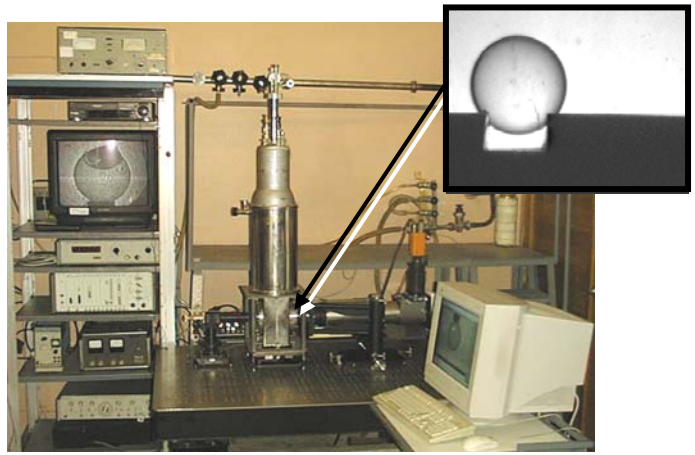
THE FST-SYSTEM CREATED AT LPI ALLOWS THE REP-RATE FABRICATION OF A FUEL LAYER INSIDE MOVING FREE-STANDING SHELLS

- shell diameter of 0.8÷1.8 mm
- layering time 4÷15 sec
- cryogenic layer thickness of 10÷100 μm
- production rate up to 0.1 Hz (currently)

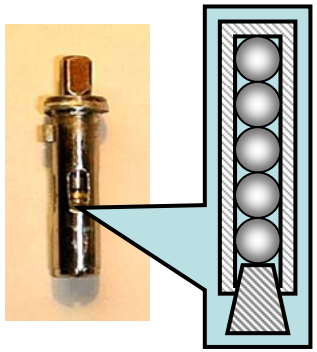


Computer-aided facility for micro shells permeation filling with gas up to 1000 atm at 300 K

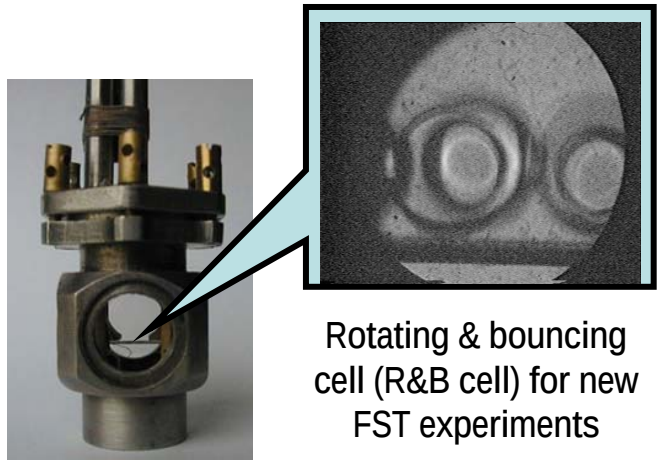
FST LAYERING MODULE



A 100-projections visual-light tomograph for precise control of the free-standing microshells and cryogenic targets



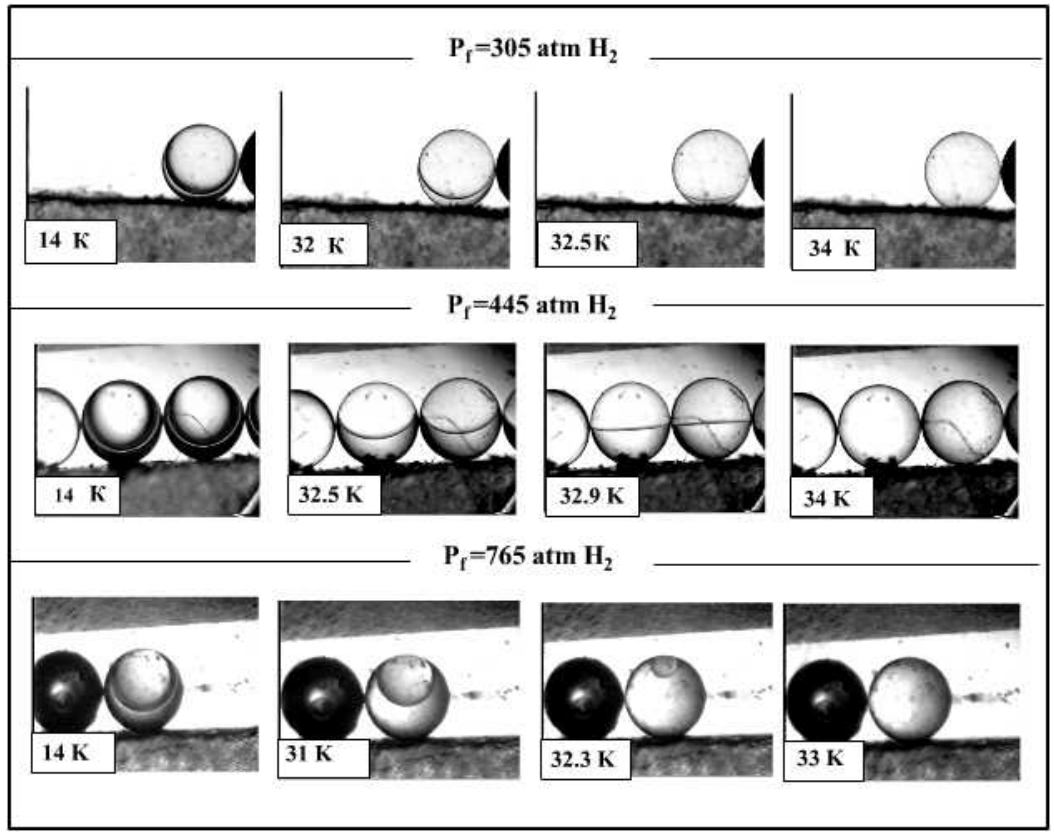
Shell container for transporting a batch of fuel filled shells at 300 K



Rotating & bouncing cell (R&B cell) for new FST experiments

Permeation fuel filling of a batch of free-standing shells

COMPUTER AIDED FILL FACILITY



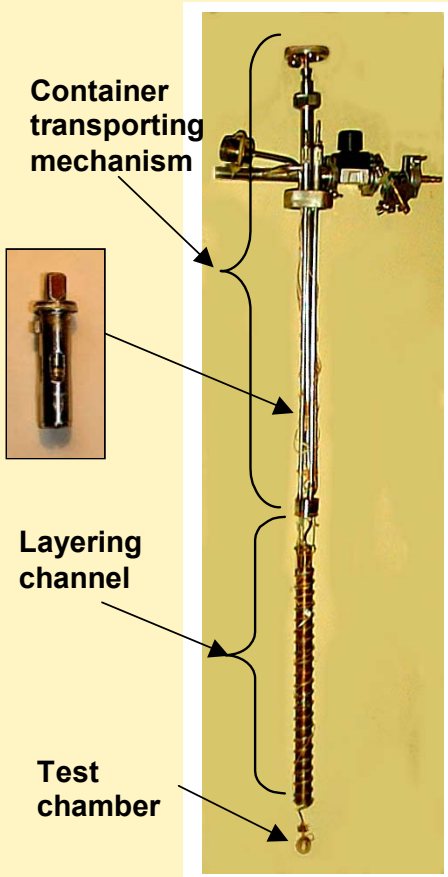
FILLING CAPABILITY OF THE FACILITY

Fill pressure: 10-to-1000 atm
Fill procedure:
- ramp filling (ΔP=const)
- step filling (P =const)

Work temperature:
- 300 K (CH shells) & 650 K (glass shells)

Work gases:
- D2, H2, H2+D2 (different mixtures) & Ar, Ne, Xe, He (as additives)

Experimental facility for research in the area of cryogenic layering inside free-standing targets

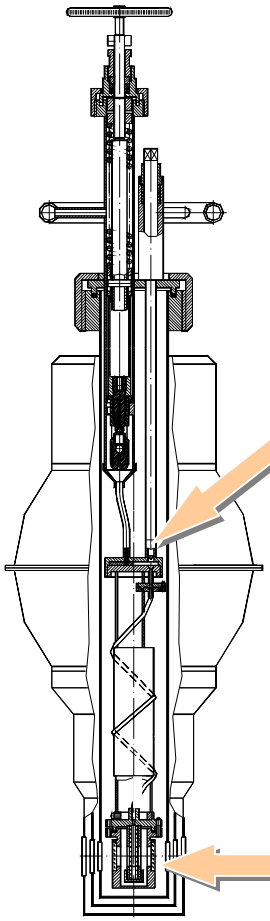


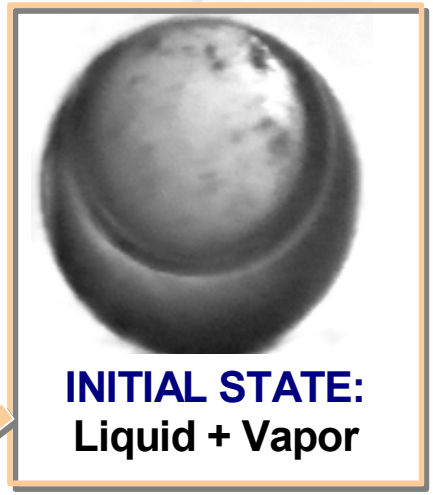
Shell Container positioning in LM

Layering module in assembly with commercial cryostat UTREX-1-RTA

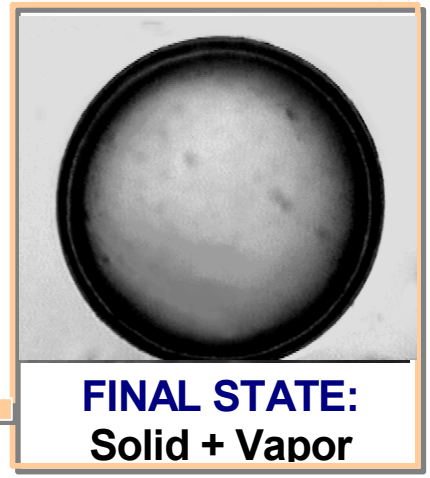
Experimental Facility

The layering module operates according the FST method: rapid fabrication of a fuel layer inside moving free-standing target





INITIAL STATE:
Liquid + Vapor



FINAL STATE:
Solid + Vapor

CH SHELL ∅ 1.0-1.8 mm

P_f = 10÷1000 atm
at 300 K

LAYERING TIME
$t \leq 15$ sec

W = 10-to-100 μm

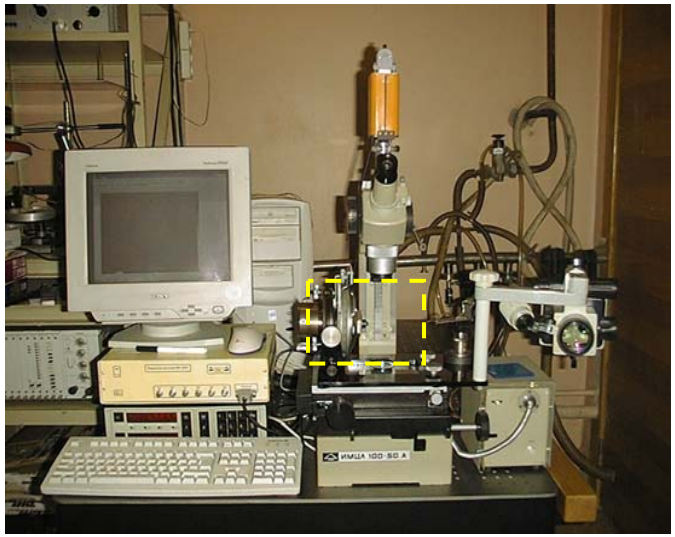
The layering channels of different shape for the FST technology optimization

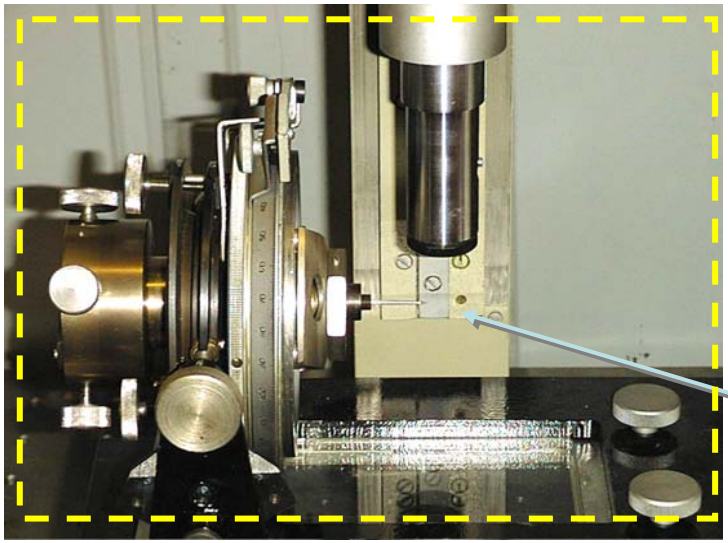
Tomograph “Shell Tester” to control CH and glass shells parameters

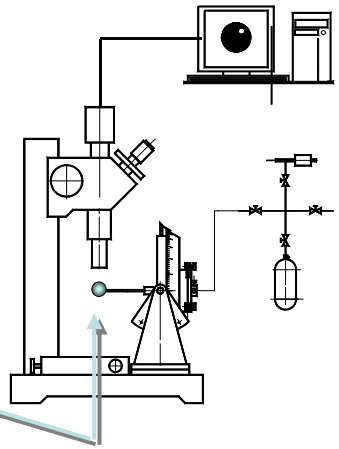
- Scanning Parameters

- Full scanning angle: 360 deg.
- Number of projections (max) – 1000
- Positioning accuracy: ± 1.5 min

- Spatial resolution: 1 μm

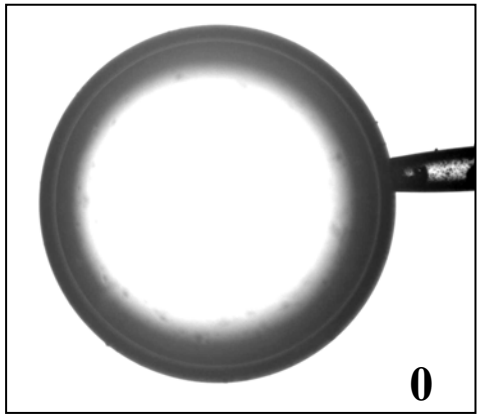


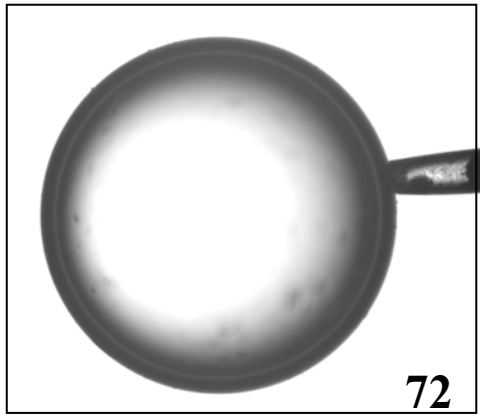


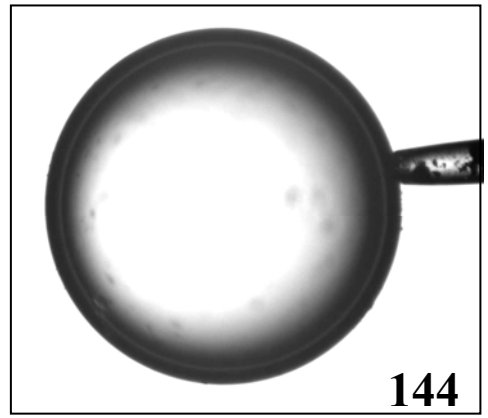


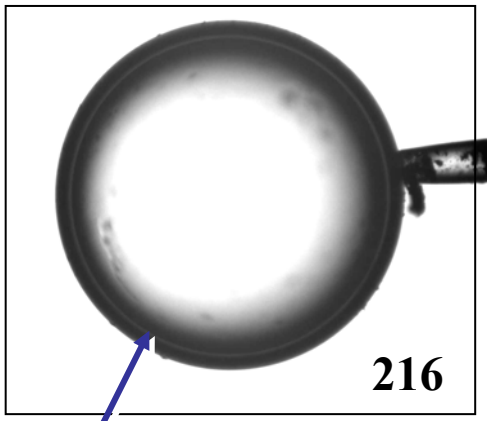
Shell vacuum mount

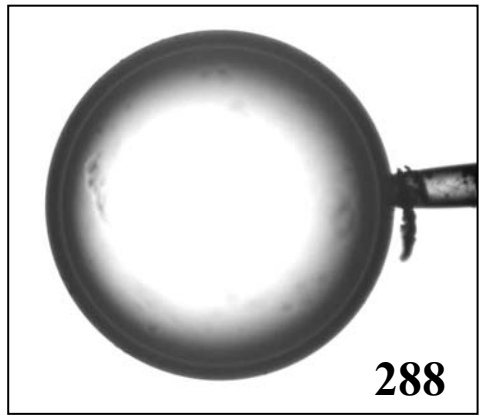
Tomograph Shell Tester: image projections data

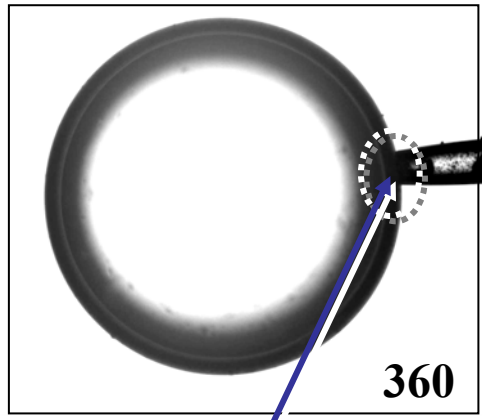








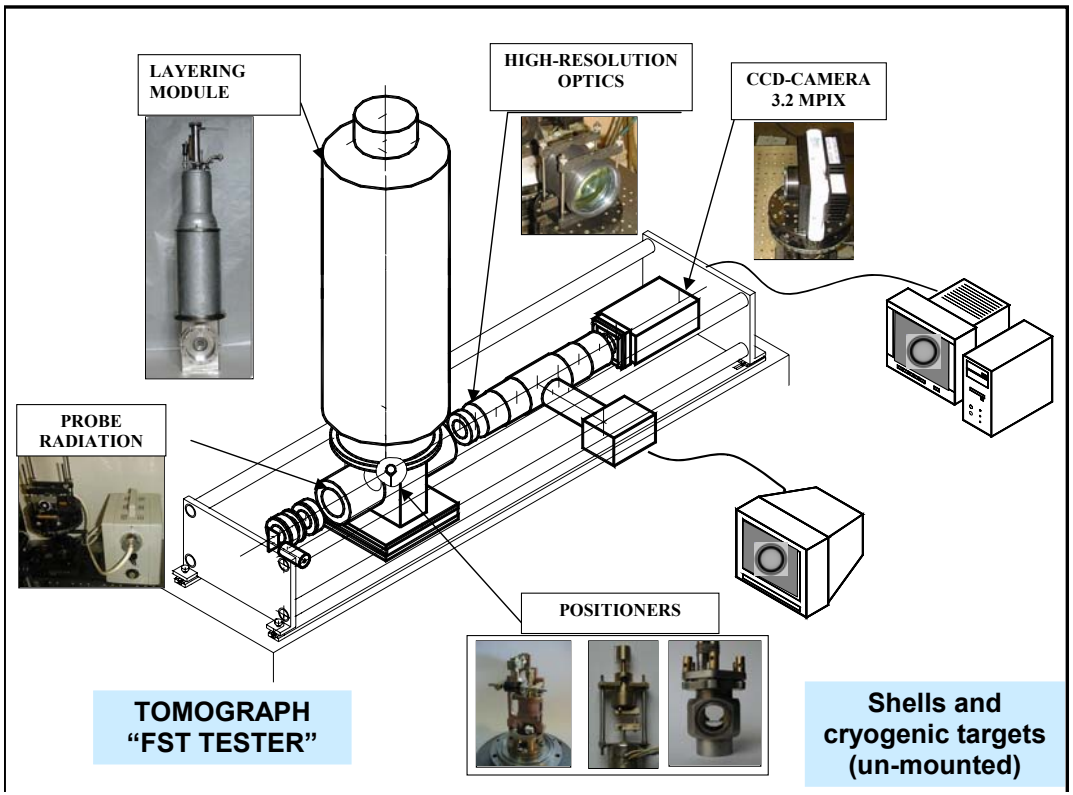


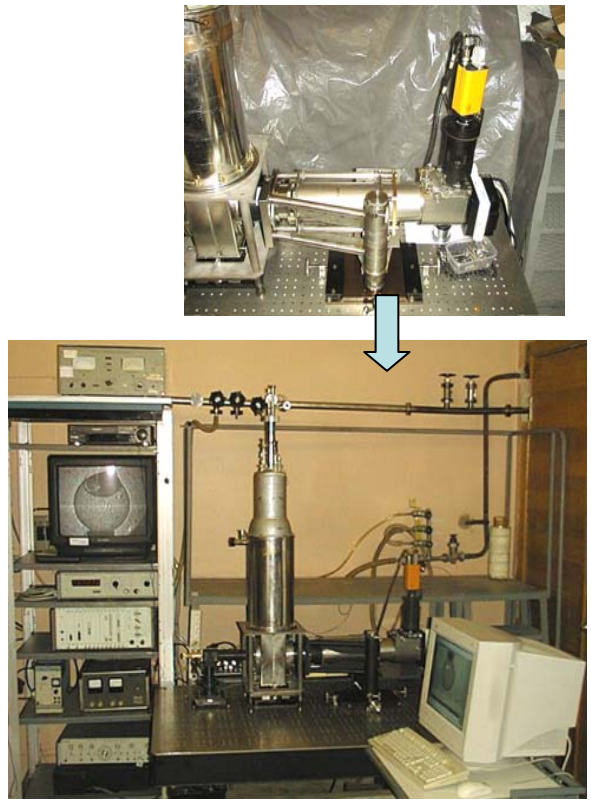


Bright band

"vacuum" mount

A 100-projections visual-light micro-tomograph for free-standing microshells and cryogenic targets precise characterization

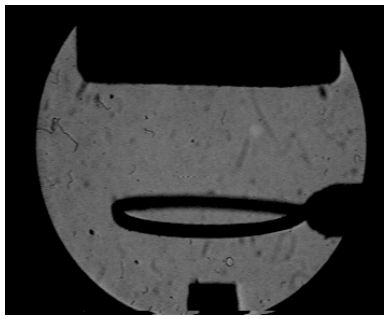


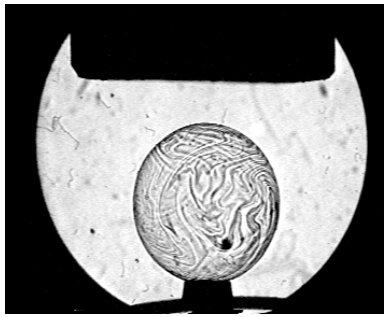


- Target temperature: room & cryo (77–4.2 K)
- Probing radiation wavelength: 490±7 nm
- Total scanning angle: 360 degree
- Accuracy of positioning: ± (1.5–2.5) min

- Current number of projections: 100
- Spatial resolution in one projection: ~1 μm
- Studied target diameter: ≤ 1.5 mm
- Accuracy of reconstruction: ~ 1 μm

DEVICES FOR FREE-STANDING TARGET POSITIONING: TARGET ROTATING AROUND THE FIXED AXIS





UP-1: Rotating around vertical axis

PERFORMANCE DATA

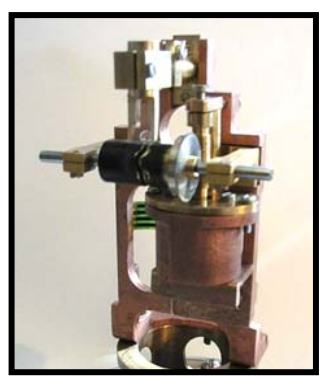
Scanning angle 2.5 deg., full angle 360 deg.

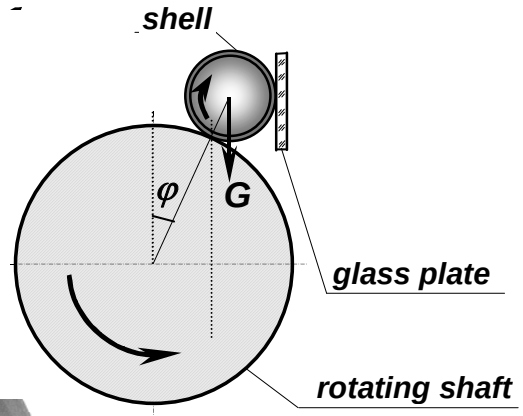
Target ∅ – unlimited

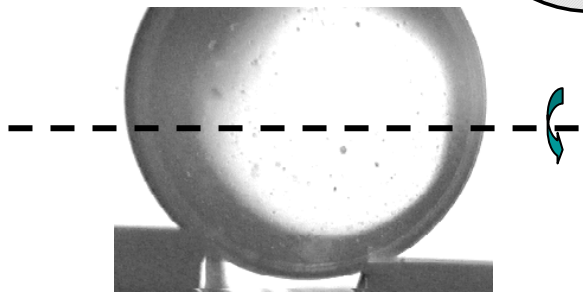
Control of projection angle: stepper motor

Number of rotation axes – 1

Number of projections – 144 (max)







UP-2: Rotating around horizontal axis

PERFORMANCE DATA

Scanning angle 2.9 deg., full angle 360 deg.

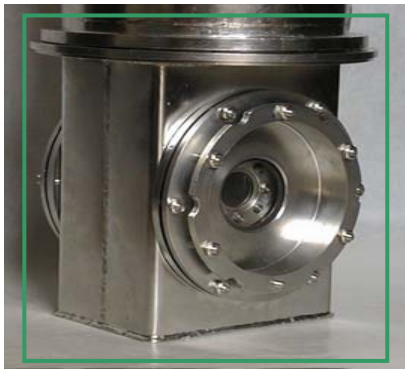
Target ∅ – ≥ 1.2 mm

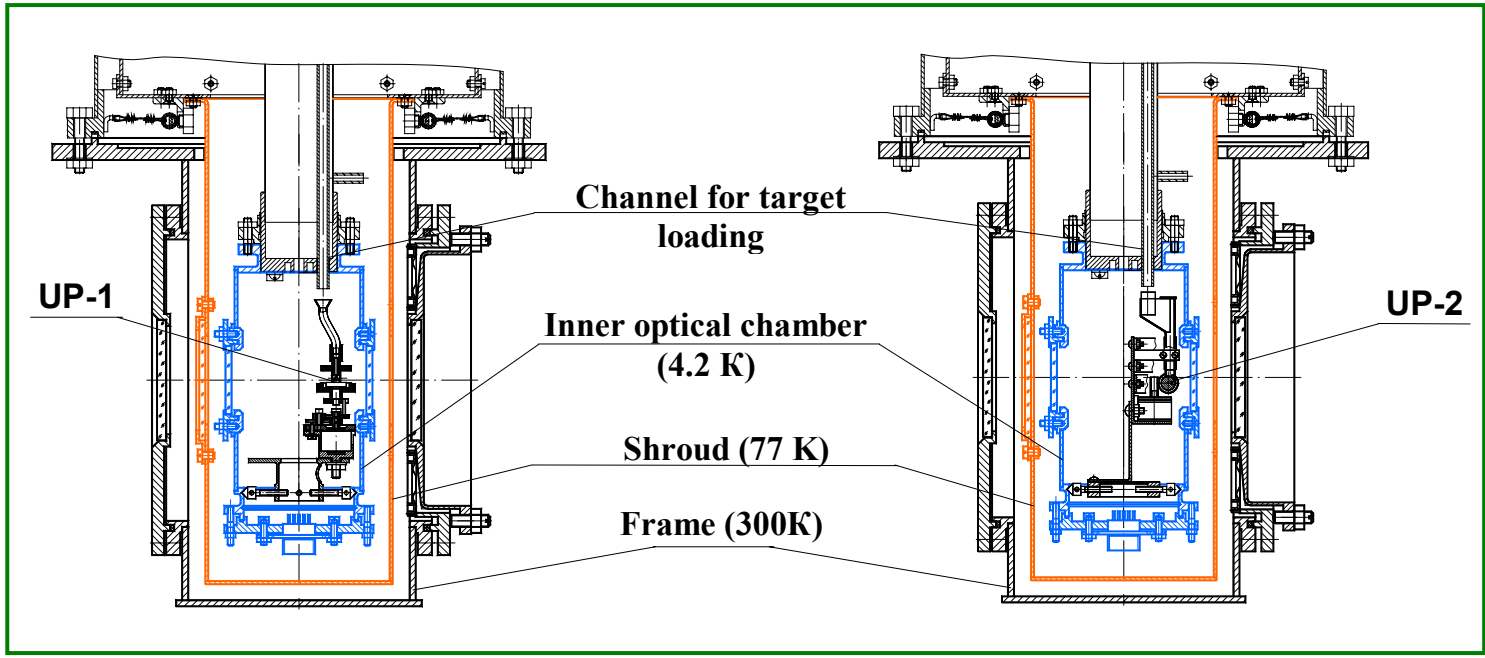
Control of projection angle: stepper motor

Number of rotation axes – 1

Number of projections – 124 (max)

Positioning devices disposal inside the tomographic test chamber of cryostat



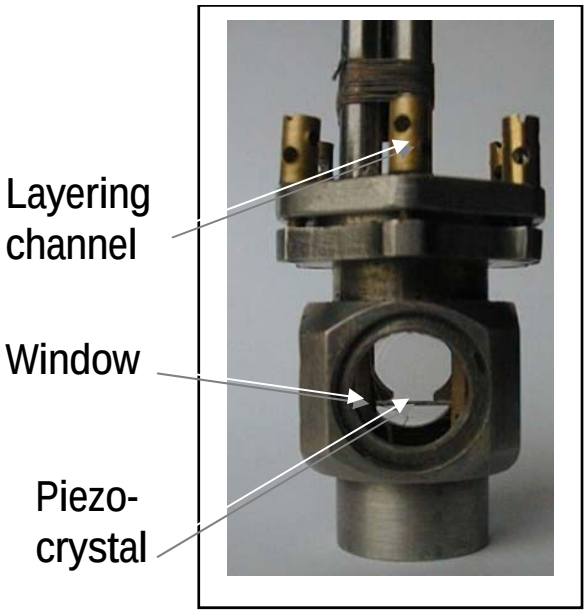


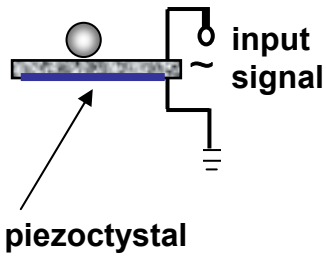
PERFORMANCE DATA

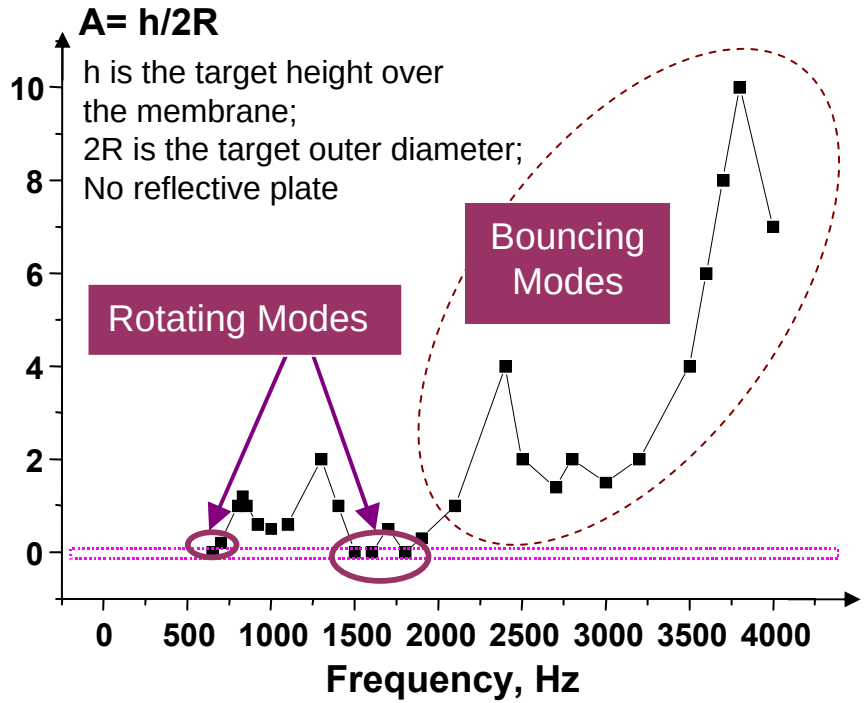
- Observation aperture (max): 63^0
- Outer window diameter: 54 mm
- Target/objective stand-off distance (min): 54 mm
- Work temperatures range: 4.2-20 K, 300 K

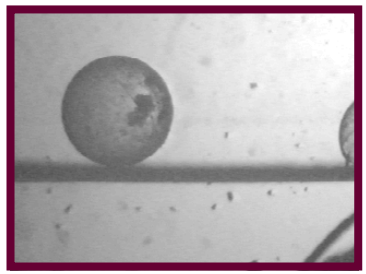
ANOTHER APPROACH TO STUDY THE TARGET ALL OVER AROUND:
target positioning with random angle of displacement using the R&B cell

- Control of the target movement is based on the reverse piezo-electrical effect.
- The couple "membrane & target" is driven by an input signal of 0.3 Hz -to- 4.0 MHz
- Device has been tested at the temperature of 4.2 -to-77 K and 300 K

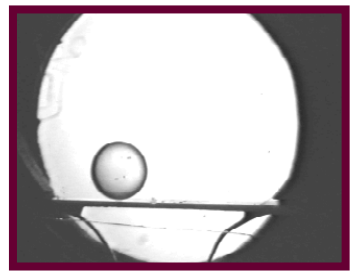






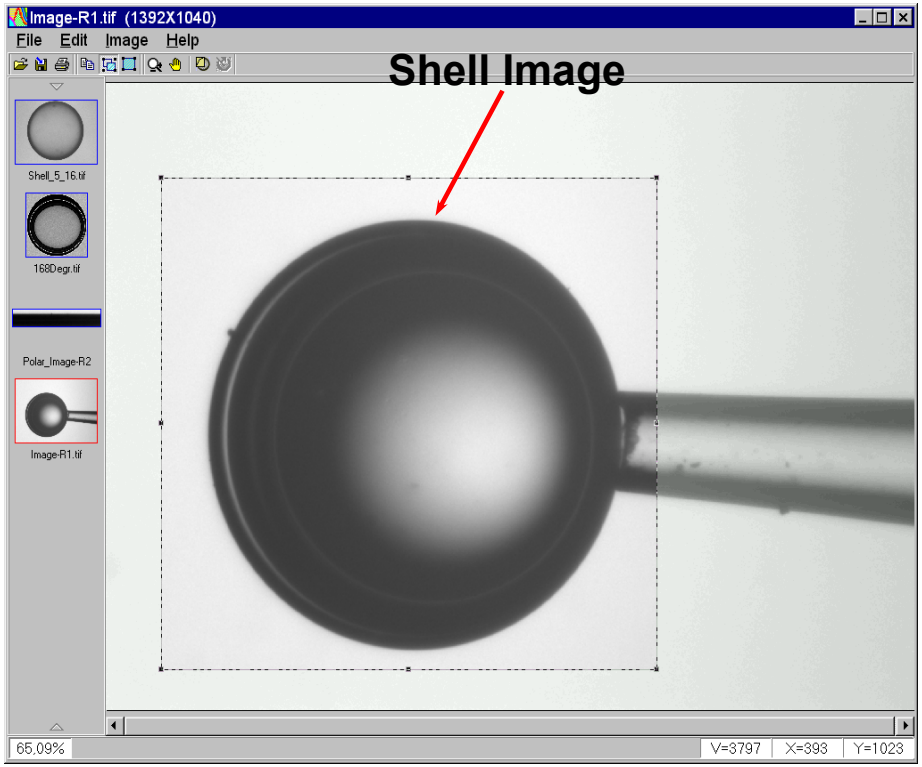


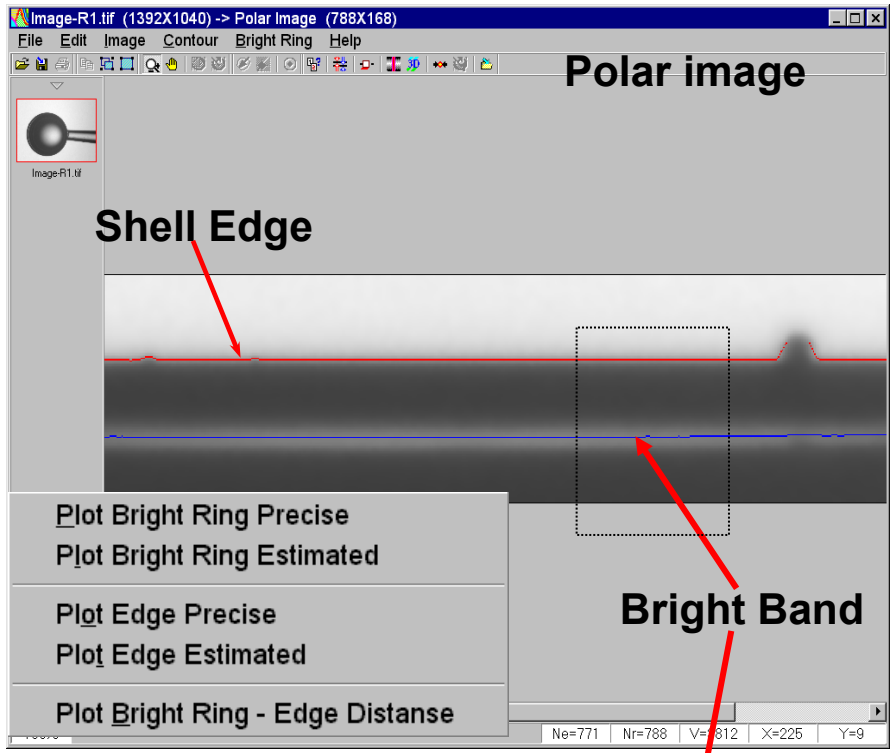
Target rotation all over around at 6 K, 1.7 MHz

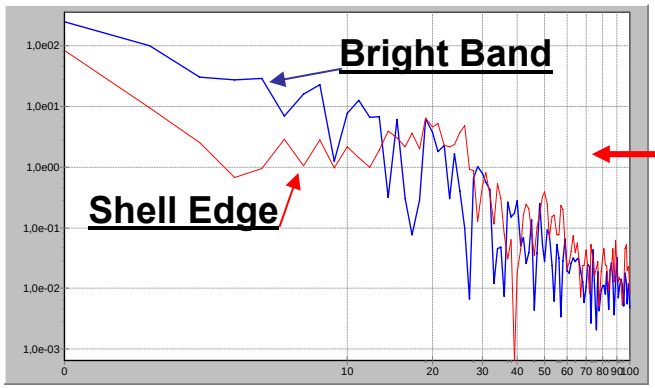


Target bouncing, T=77 K, 3.7 MHz

Target Studio software for 3D reconstruction of target parameters using a set of its backlit images. Reconstruction algorithm is based on the analysis of bright band position on target backlit images.

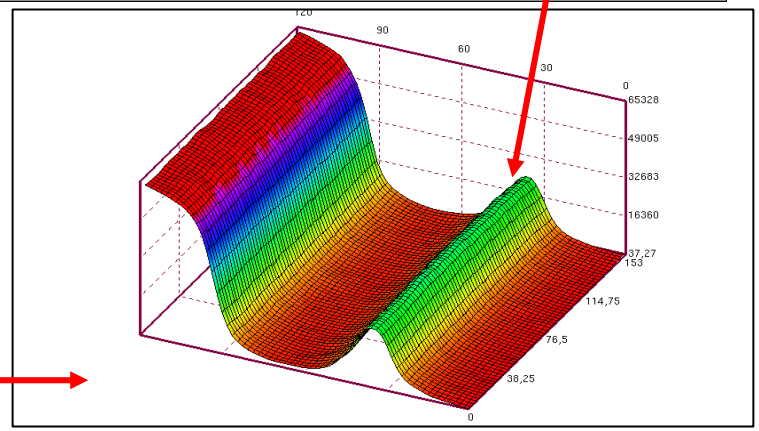






Power spectrum

3-D visualization



3D reconstruction of the parameters of the free-standing CH shell using its 90 backlit projections.

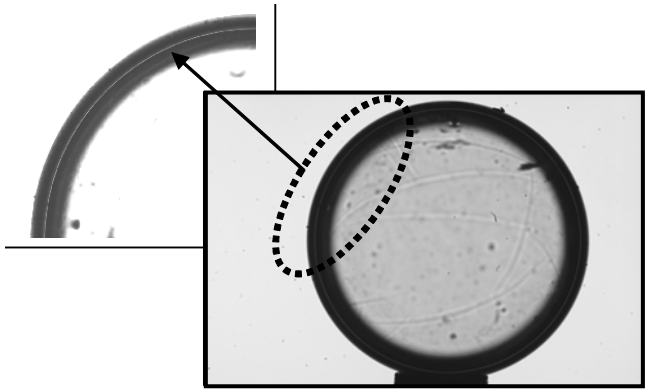
Reconstruction is performed by means of specially developed software *Target Studio*.

Reconstructed Parameters

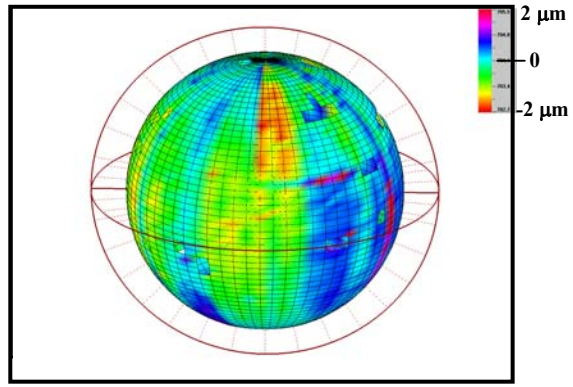
Shell's outer surface
Mean radius :: 712.4
Min radius :: 710.3
Max radius :: 716.7
Out of Round :: 0.4 %

Shell's inner surface
Mean radius :: 690.9
Min radius :: 687.3
Max radius :: 694.1
Out of Round :: 0.5 %

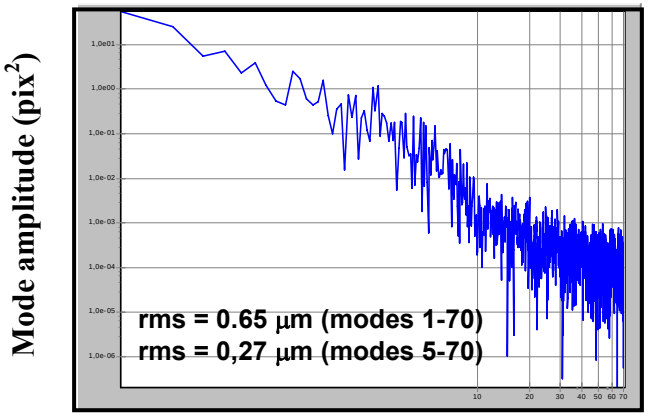
Wall parameters
Mean wall :: 21.5
Min wall :: 17.7
Max wall :: 25.6
Non-uniformity :: 19.0 %



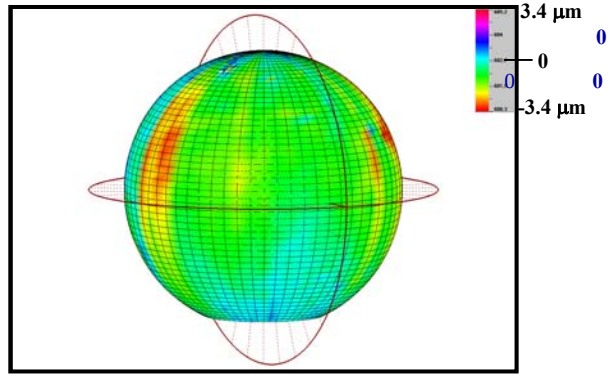
Shadow projection of polystyrene microshell (UP-1 positioner)



Outer surface of microshell (reconstruction)



Fourier spectrum of bright band



Inner surface of microshell (reconstruction)

MICROSHELLS THAT WE USED IN THE CRYOGENIC EXPERIMENTS over the period of 1987-2007

- **Products of LPI, Russia (1987-2007)**

Method: drop tower

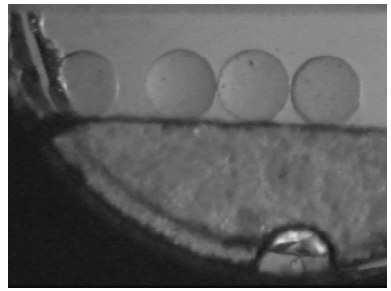
- **Glass shells ∅ 0.3 ÷ 0.6 mm, ΔR = 3-15 μm, σ ≤ 350 kg/mm² (at 300 K)**

Methods: drop tower and ballistic furnace

- **CH shells ∅ 0.7 ÷1.5 mm, ΔR = 8-20 μm**

Exp.

T, K	300	200	100
σ, kg/cm²	200	440	680
	330	720	1100



Target heating from 40 K to the moment of CH shell blowing up under the inner pressure action

- **Products of ILE, Japan (2002-2004)**

Method: microencapsulating

- **CH shells ∅ 1.4 ÷ 1.8 mm, ΔR = 18-72 μm, σ < 100 kg/cm² (at 300 K)**