On the possibility of X-ray microtomography for materials sciences

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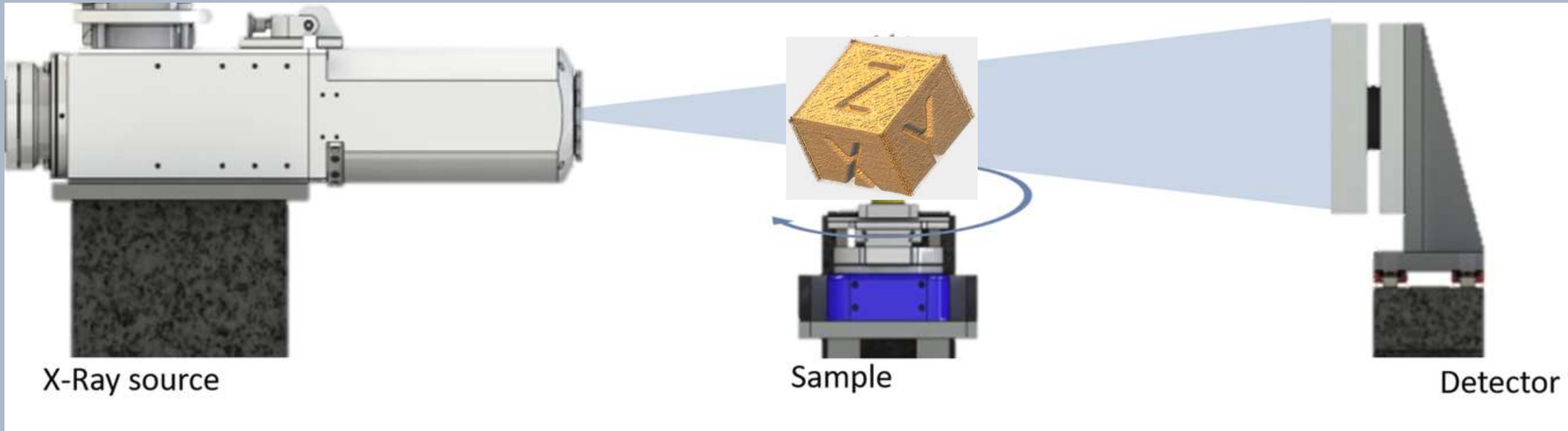
X-Ray tomography

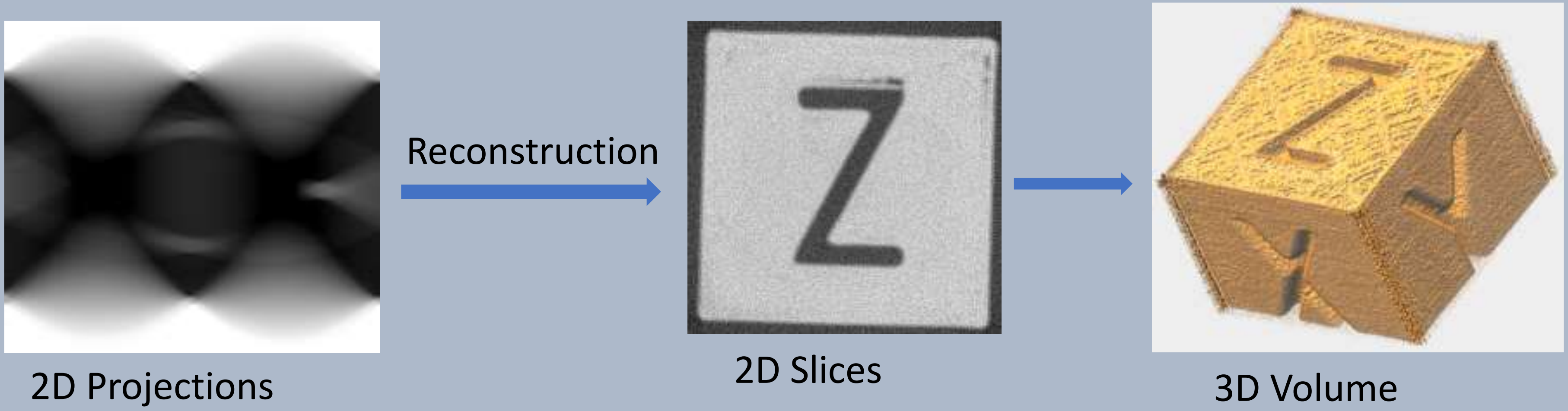
Reconstruction

Artefacts corrections

Beam hardening correction

Ring artefacts removal





X-ray computed tomography is one of the most advanced methods for the non-destructive investigation of the internal structures of various objects. An X-ray microtomograph with a corresponding software package was designed and created at our institute (IAPP NAS RA), which enables 3D scanning of a sample with a diameter up to 30 cm and a height of 22 cm with a resolution of 60 micron.
The tomograph operates on the principle of absorption contrast. The implemented software package uses standard filters and options (such as Beam hardening correction, Ring artefacts removal, etc.) and the reconstruction is carried out using Radon transformations.

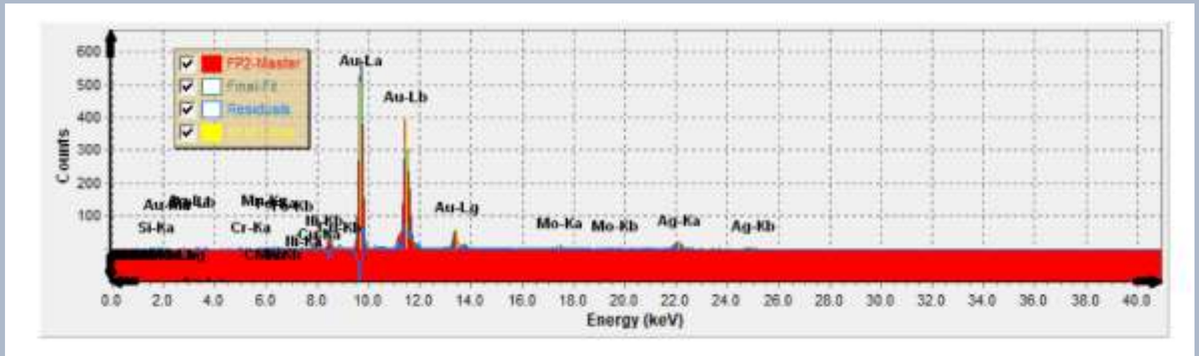
Appearance of the archaeological specimen

(burial mound of Nerqin Naver (Armenia))

MicroCT is most often used to study ancient sample, providing information about their production methods and origin.

In this regard, we recently investigated a nearly 4,000-year-old archaeological sample presented by the "Research Center for Historical and Cultural Heritage". Experimental studies were carried out to determine the composition and internal structure of the archaeological sample. The sample is close to spherical in shape, the shell is damaged in several areas, in the damaged areas the sample is filled with a gray substance with a granular structure, presumably gypsum.

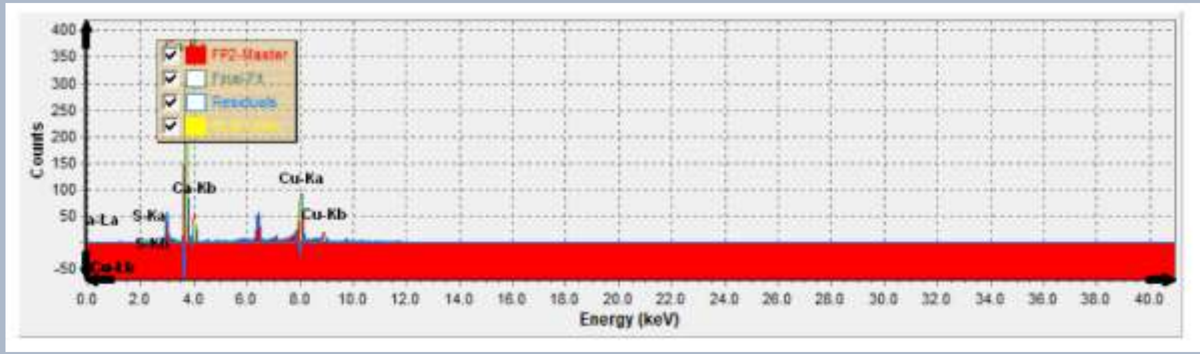
Spectrum of fluorescence excited by probe beam produced with Mo X-ray tube in metal shell area of the investigated specimen



Component Table

Layer	Component	Type	Conc.	Error	Units	Mole%	Error
1	Cr	Calc	0.115	0.135	wt.%	0.336	0.396
1	Mn	Calc	0.404	0.264	wt.%	1.120	0.732
1	Fe	Calc	1.364	0.395	wt.%	3.724	1.079
1	Ni	Calc	0.779	0.246	wt.%	2.023	0.639
1	Mo	Calc	0.828	0.145	wt.%	1.315	0.231
1	Si	Fixed	1.000	0.000	wt.%	5.428	0.000
1	Cu	Calc	6.147	0.534	wt.%	14.745	1.280
1	Ag	Calc	3.362	0.390	wt.%	4.751	0.551
1	Au	Calc	86.002	2.285	wt.%	66.558	1.769

Spectrum of fluorescence excited by probe beam produced with Cu X-ray tube operated with 9 kV voltage in area of damaged specimen shell

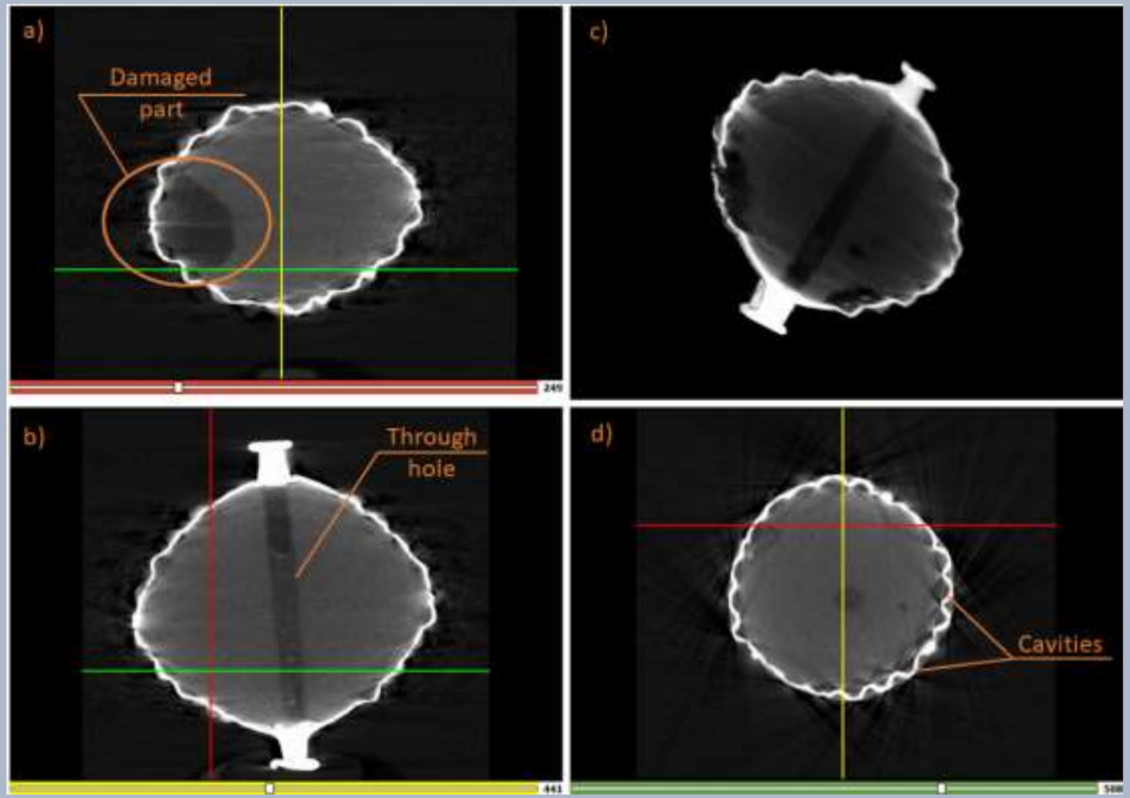


Component Table

Layer	Component	Type	Conc.	Error	Units	Mole%	Error
1	S	Calc	14.766	5.272	wt.%	17.974	6.417
1	Ca	Calc	82.496	3.587	wt.%	80.344	3.493
1	Cu	Calc	2.738	0.181	wt.%	1.682	0.111

X-ray fluorescence analysis was performed to determine the materials contained in the sample.
The measurements were carried out using Mo and Cu X-ray tubes with different operating parameters.
The study concluded that the metal shell was made mainly of gold with small amounts of copper and silver, and filling material is a gypsum.

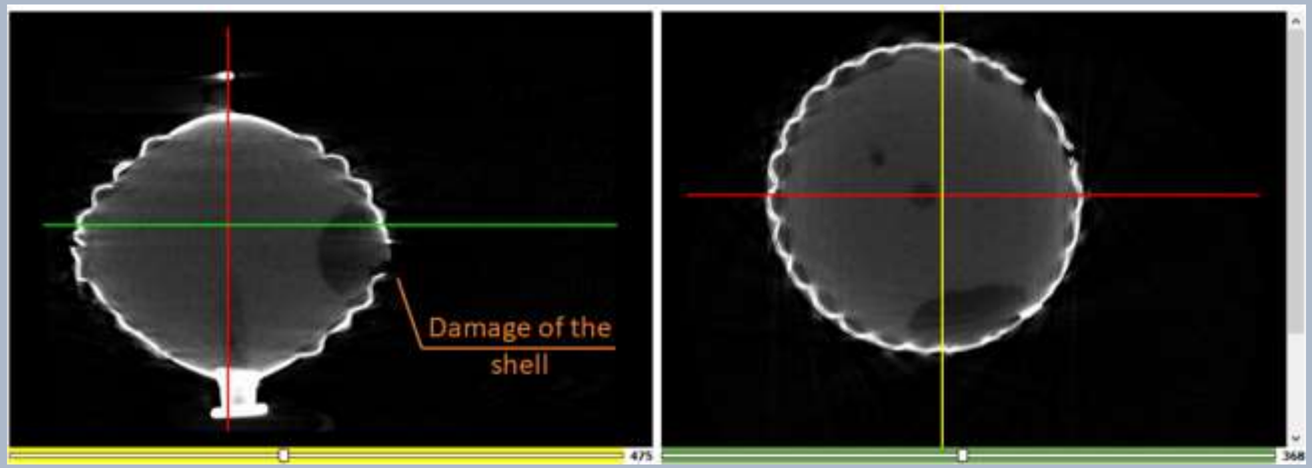
μCT images obtained with 150 kV X-ray beam



To determine peculiarities and defects of sample internal structure we conducted microtomographic studies. As a source we used tungsten X-ray tube operated at 130 or 150 kV. In the first case the X-ray beam was “more soft” which provides better contrast between shell and filling material and more sensitive analysis of internal structure. In the second case, we suppressed “beam hardening” artefacts which allows better visualization of the metal shell structure.
Here is shown an example of slices obtained in the frontal (a), sagittal (b) and horizontal planes (d). Also shown the 3D model (c) obtained from reconstructed tomographic slices.

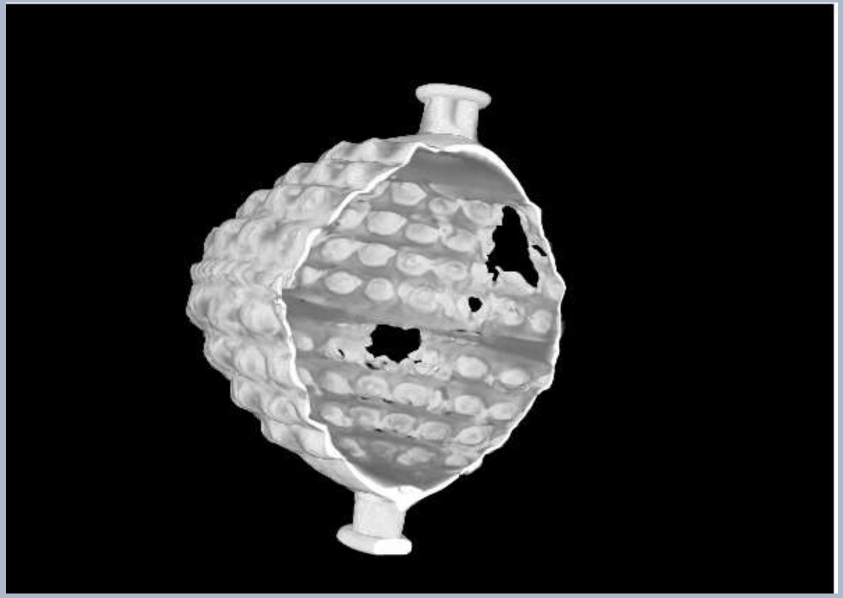
As a final step, the volume then mass of the sample were calculated based on the obtained reconstructed slices.
Estimated mass of the sample is quite close to the real mass value, that indicates the correctness of the assumptions about the sample composition.

Slices obtained from μCT study with 130 kV aluminum filtered X-ray beam



The figure demonstrates two slices obtained with “soft” X-ray beam.
These images allow to better distinguish the filling material.

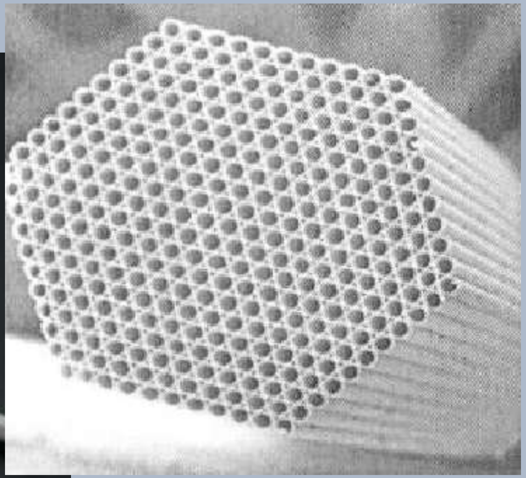
3D model of specimen shell

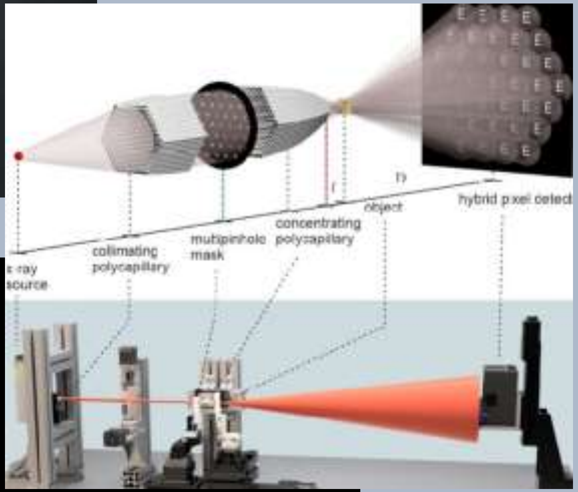


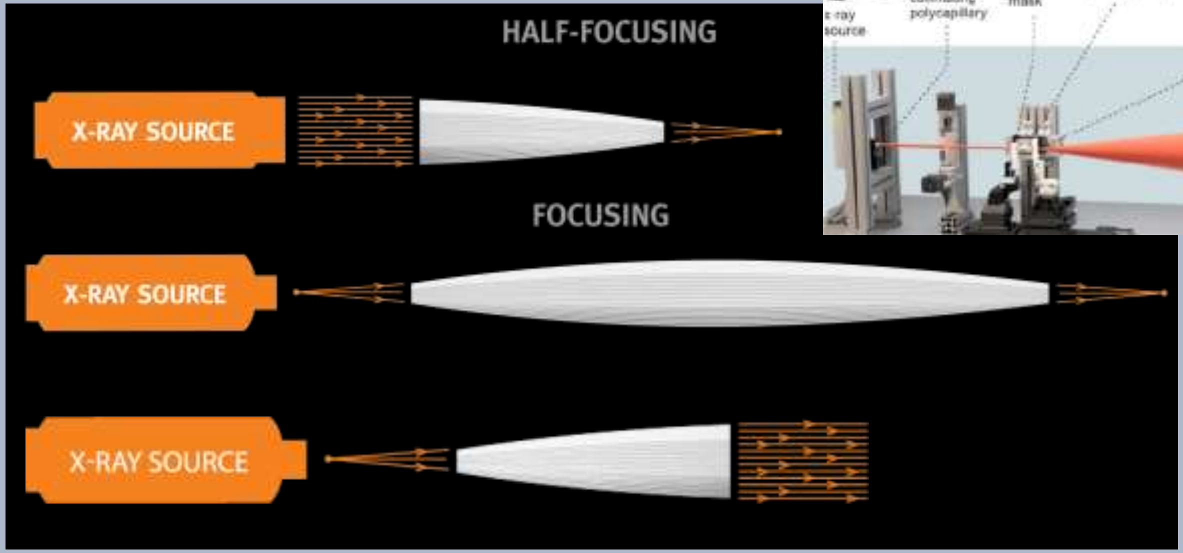
3D model of metal shell was separately obtained with “harder” X-ray beam.
This model allows detailed visualization of structure and damages of the shell

High contrast resolution imaging

(Poly/Mono)capillary optics

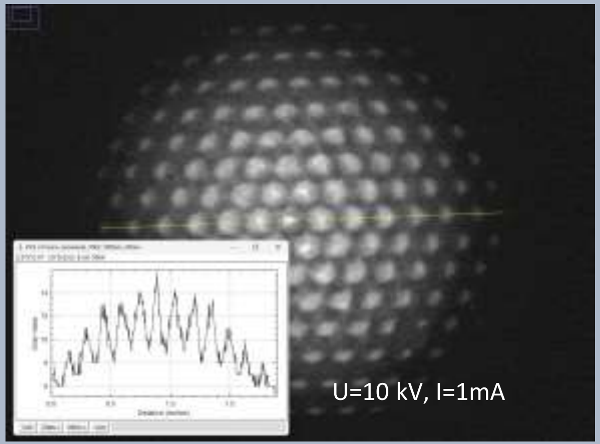


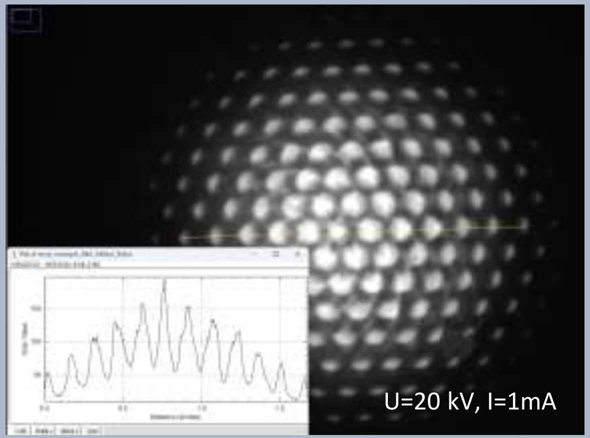


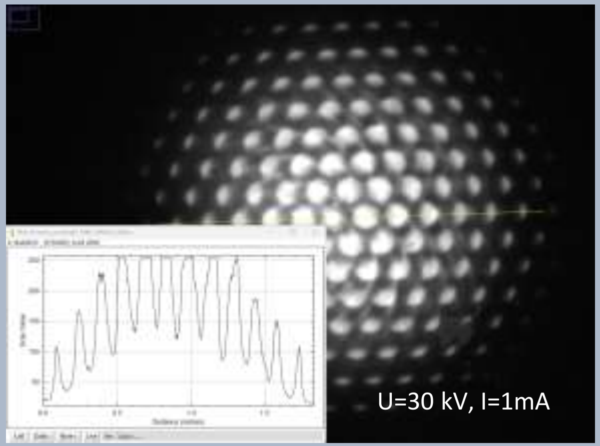


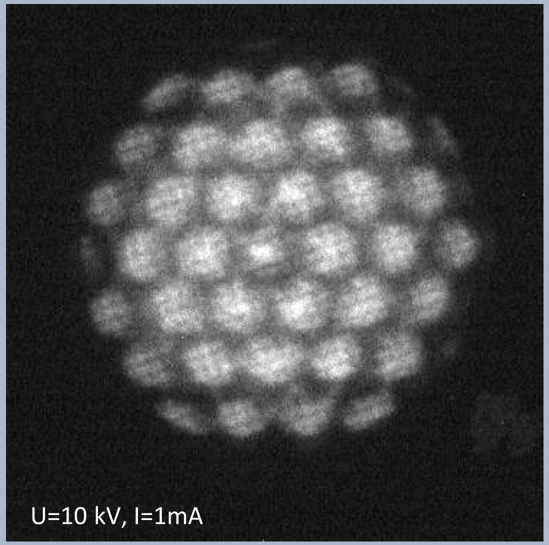
The problem of obtaining high-resolution images is of increasing interest in the field of tomography and we are currently working on increasing the spatial and contrast resolution of our microtomographic device.
From this point of view, the polycapillary optical elements play an interesting role.
These optical elements are usually used to enrich photon flux, suppress scattered rays, and sometimes to modify spectral distribution of probe X-ray beam.
As the channel size of these lenses are significantly lower than the sizes of pixels of available matrix X-ray detectors, imaging studies with them allows obtaining of averaged brightness of several capillaries in each particular pixel.
In contrast, monocapillary X-ray optics with much higher capillaries size allows registration of X-ray signal from different part of capillary and potentially to obtain difference in X-ray response from parts of investigated samples corresponding to different part of capillaries.

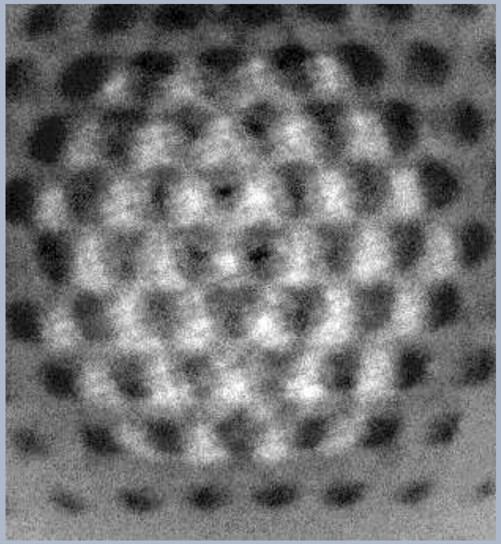
The preliminary experimental results











In this regard, most recently, under the leadership of Professor Dabagov, we have conducted research with monocapillary semilens in LNF INFN Italy and the first preliminary experimental results are presented here.

Obtained direct images from monocapillary semilens in 3 different operating mods of X-ray source: 10, 20 and 30 kV respectively. The monocapillary semilens was then used as an imaging mask for a gold mesh sample with a wire width of 20 microns. And when we subtract the background from the image obtained using the gold grid, we obtain a periodic distribution on the edge zone of the capillaries. The periodic distribution is an image of a metal mesh and is absent in the central part of the capillaries.

Thus, we observe contrast resolution in the edge zone of capillaries, which can be further used in microtomography.

Thank You