# The development of precise tomography technique

Evgeny Kozyrev

PHD student at Novosibirsk State University
Senior Assistant at Budker Institute of Nuclear Physics
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*about me:*

Knowledge at fundamental level of the structure of matter
Skills in the most precise experiments

• EDUCATION

Master of Science (2015 y)
Novosibirsk State University
Specialization: elementary particle physics
Thesis topic: Study of the process electron-positron annihalation into kaon-antikaon pair with the CMD-3 detector at the VEPP-2000 $e^+e^-$ collider.

• EXPERIENCE

Physicist 2011-present
Budker Institute of Nuclear Physics, Novosibirsk
a. Member of the CMD-3 collaboration for VEPP-2000 collider at the Budker Institute of Nuclear physics. Participation in extensive experimental studies on decays of light vector mesons and measurements of hadronic cross sections.
b. Participation in international projects with Stanford Linear Accelerator Center in BABAR experiment at PEP-II B-factory.
c. The development of precise tomography methodics.

Assistant 2015-present
Novosibirsk State University, the physical and mathematical
Courses in mechanics, electrodynamics, molecular physics and thermodynamics.

*about me:*

Publications Datasets External

http://inspirehep.net/author/profile/E.A.Kozyrev.1?ln=ru

1. Recent results on $e^+e^- \to hadrons$ cross sections from SND and CMD-3 detectors at VEPP-2000 collider
2. Cross section measurement of the process $e^+e^- \to K^+K^-\pi^+\pi^-$ at the VEPP 2000 collider with the CMD-3 detector
3. Recent results from CMD-3 detector at VEPP-2000 $e^+e^-$ collider
4. Preliminary results of the cross-section measurement of $e^+e^- \to \varphi(1020)\eta$ process with the CMD-3 detector at VEPP-2000 collider
5. Study of the process $e^+e^- \to K_S^0 K_L^0$ in the center-of-mass energy range 1004--1060 MeV with the CMD-3 detector at the VEPP-2000 $e^+e^-$ collider Phys.Lett. B760 (2016) 314-319
6. Study of the Process $e^+e^- \to K\bar{K}$ in the Center-of-Mass Energy Range 1004--1060 MeV with the CMD-3 Detector at $e^+e^-$ VEPP-2000 Collider
7. Measurement of the $e^+e^- \to K^+K^-\pi^+\pi^-$ cross section with the CMD-3 detector at the VEPP-2000 collider
8. Preliminary results of measurements of hadronic cross sections with the CMD-3 detector at the VEPP-2000 electron–positron collider
9. Study of the process $e^+e^- \to p\bar{p}$ in the c.m. energy range from threshold to 2 GeV with the CMD-3 detector

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Performance and characterization of CsI:Tl thin films for X-ray imaging application

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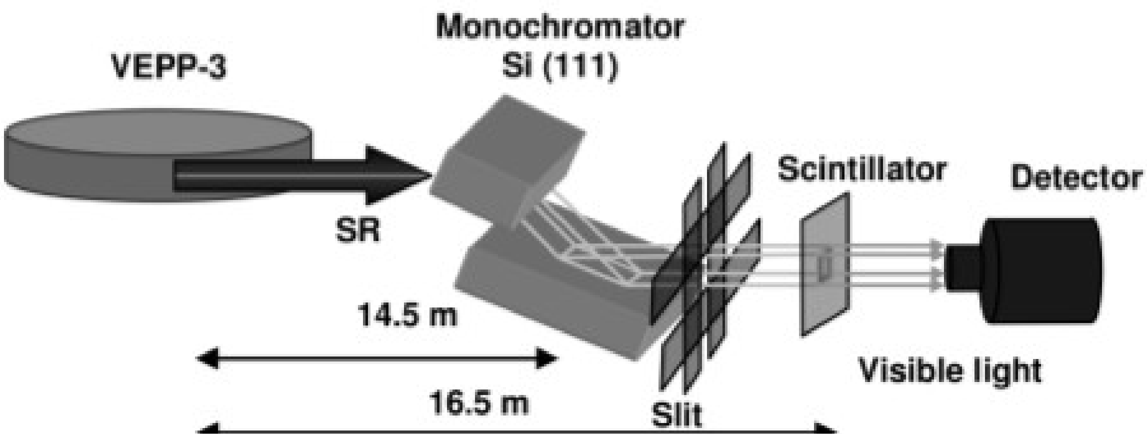
[b]*Novosibirsk State University, Novosibirsk, 630090, Russia*

Last winter we started new project «The development of precise tomography technique».

Our goal: **To develop the technique which allows to reconstruct the internal structure of wide range objects without its destruction, with high spatial resolution and with small radiation dose.**

It is important for materials science, crystallography, biology, solid state physics, chemistry, earth science, anthropology, fast processes physics.



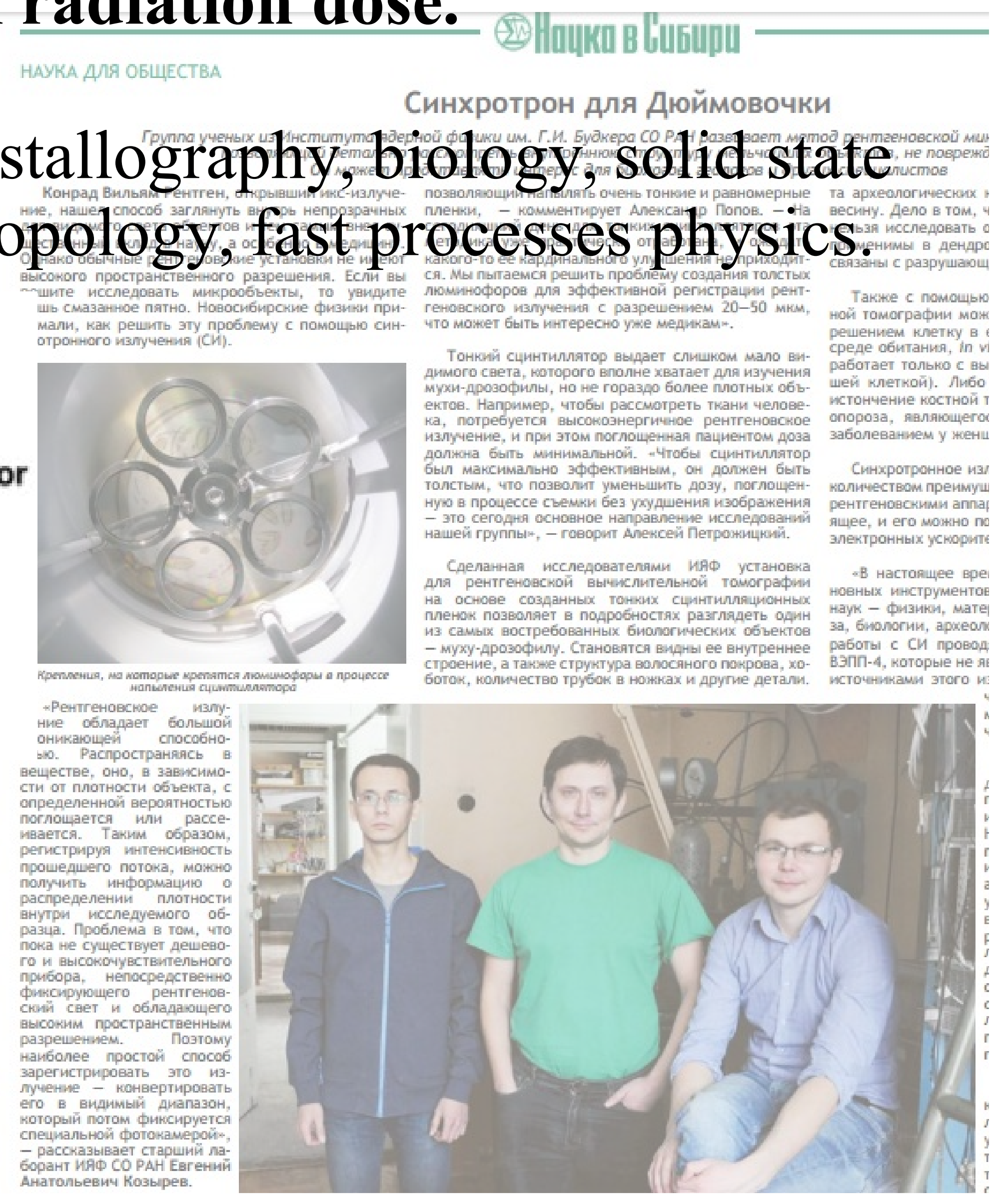

Layout of experimental setup for examination thin scintillator films.

Thin scintillation film

Thick structured scintillator

Exposure time

Spatial resolution



Наука в Сибири

НАУКА ДЛЯ ОБЩЕСТВА

Синхротрон для Дюймовочки

высокого пространственного разрешения. Если вы решите исследовать микрообъекты, то увидите лишь смазанное пятно. Новосибирские физики поняли, как решить эту проблему с помощью синхротронного излучения (СИ).

Крепления, на которые крепятся люминофоры в процессе напыления сцинтиллятора

«Рентгеновское излучение обладает большой проникающей способностью. Распространяясь в веществе, оно, в зависимости от плотности объекта, с определенной вероятностью поглощается или рассеивается. Таким образом, регистрируя интенсивность прошедшего потока, можно получить информацию о распределении плотности внутри исследуемого образца. Проблема в том, что пока не существует дешевого и высокочувствительного прибора, непосредственно фиксирующего рентгеновский свет и обладающего высоким пространственным разрешением. Поэтому наиболее простой способ зарегистрировать это излучение — конвертировать его в видимый диапазон, который потом фиксируется специальной фотокамерой», — рассказывает старший лаборант ИЯФ СО РАН Евгений Анатольевич Козырев.

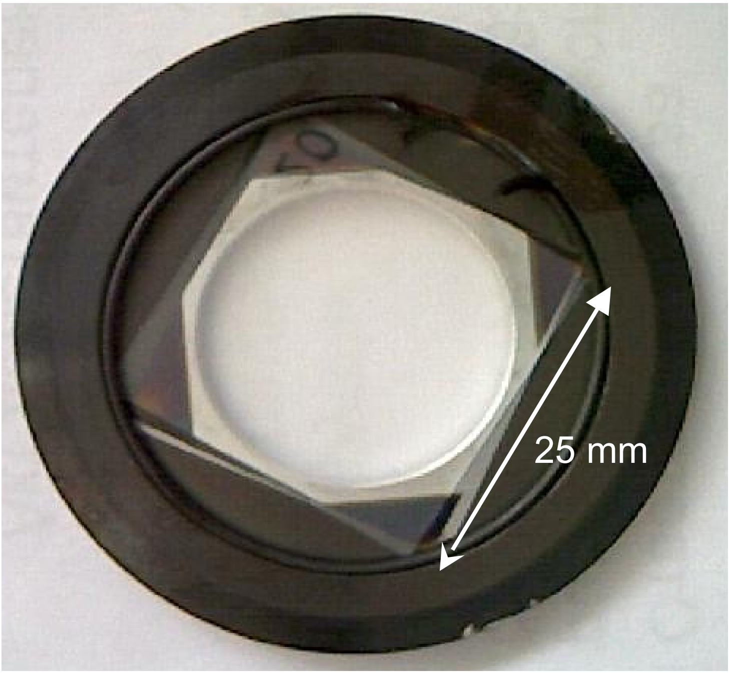
позволяющий напылять очень тонкие и равномерные пленки, — комментирует Александр Попов. —

ся. Мы пытаемся решить проблему создания толстых люминофоров для эффективной регистрации рентгеновского излучения с разрешением 20–50 мкм, что может быть интересно уже медикам».

Тонкий сцинтиллятор выдает слишком мало видимого света, которого вполне хватает для изучения мухи-дрозофилы, но не гораздо более плотных объектов. Например, чтобы рассмотреть ткани человека, потребуется высокоэнергичное рентгеновское излучение, и при этом поглощенная пациентом доза должна быть минимальной. «Чтобы сцинтиллятор был максимально эффективным, он должен быть толстым, что позволит уменьшить дозу, поглощенную в процессе съемки без ухудшения изображения — это сегодня основное направление исследований нашей группы», — говорит Алексей Петрожицкий.

Сделанная исследователями ИЯФ установка для рентгеновской вычислительной томографии на основе созданных тонких сцинтилляционных пленок позволяет в подробностях разглядеть один из самых востребованных биологических объектов — муху-дрозофилу. Становятся видны ее внутреннее строение, а также структура волосяного покрова, хоботок, количество трубок в ножках и другие детали.

# 2. Thin CsI:Tl films: performance and properties




CsI:Tl scintillation films were manufactured by the thermal deposition method.

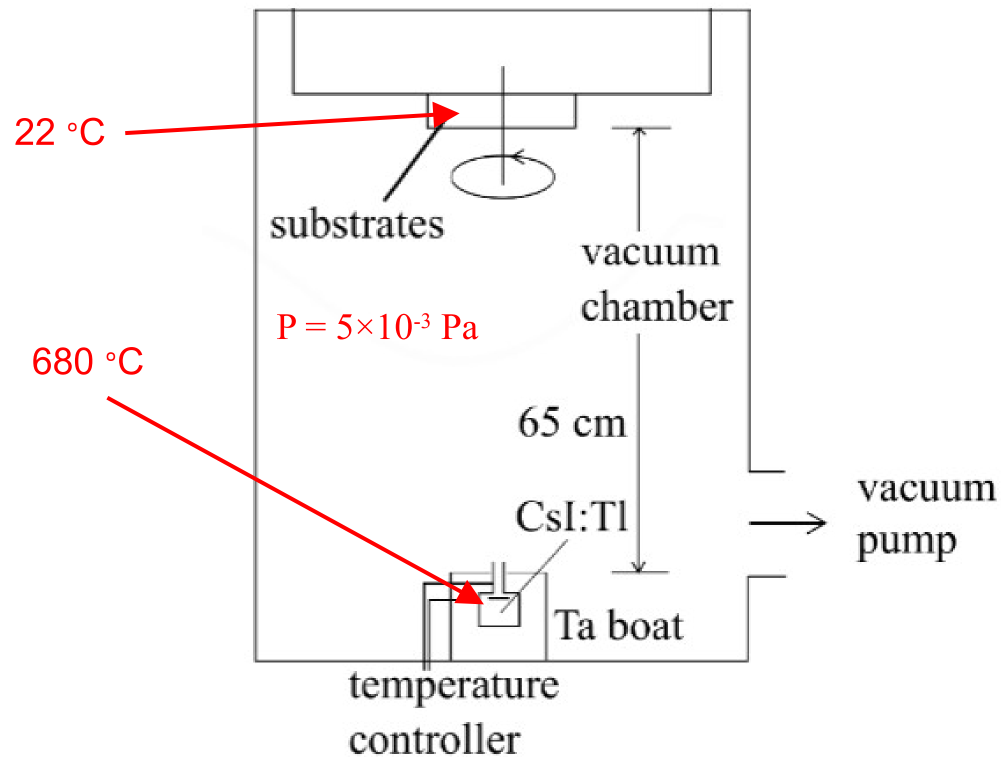
Substrates: glass (150 mkm),
Mylar (DuPont, 2.9 mkm)
saphir (800 mkm)

Thickness of CsI:Tl films: 2-10 mkm

The average velocity of deposition of CsI:Tl = 17 Å/sec.

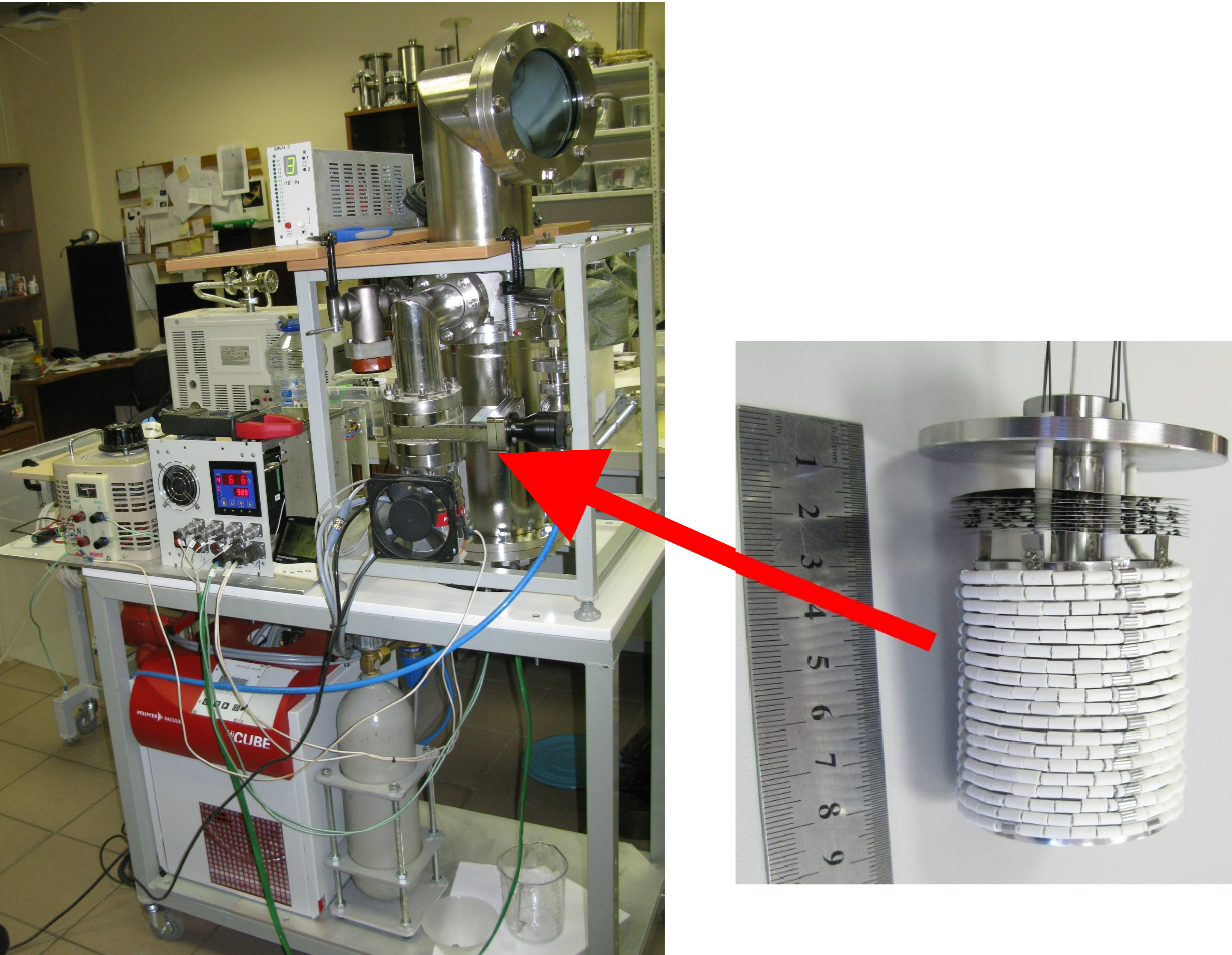
The scintillator volume is characterized by grain structure.

The grain structure depends on the type of used substrate and on the velocity of CsI:Tl deposition.




**Schematic of the thermal evaporation setting**

# 2. Thin CsI:Tl films: performance and properties



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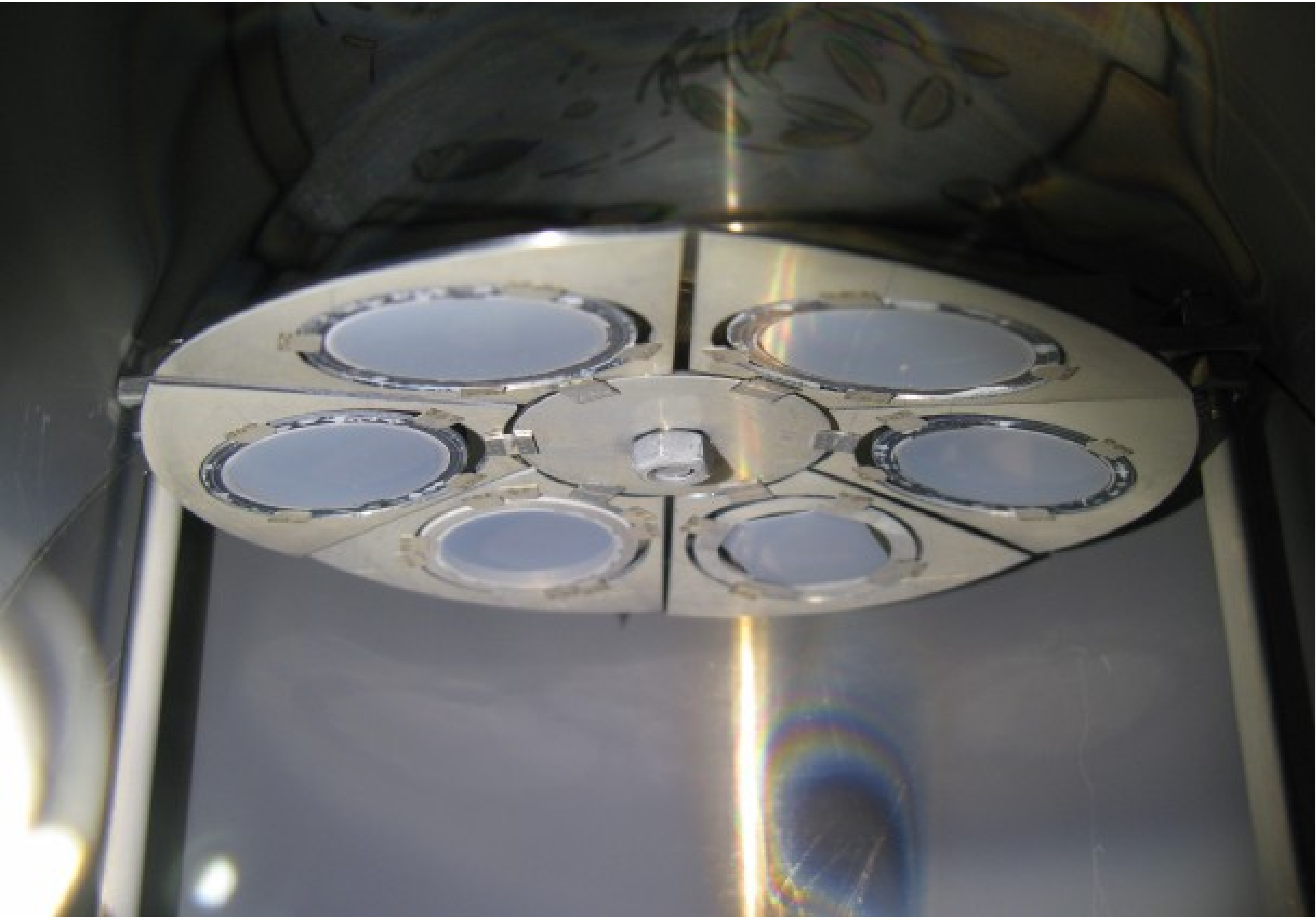

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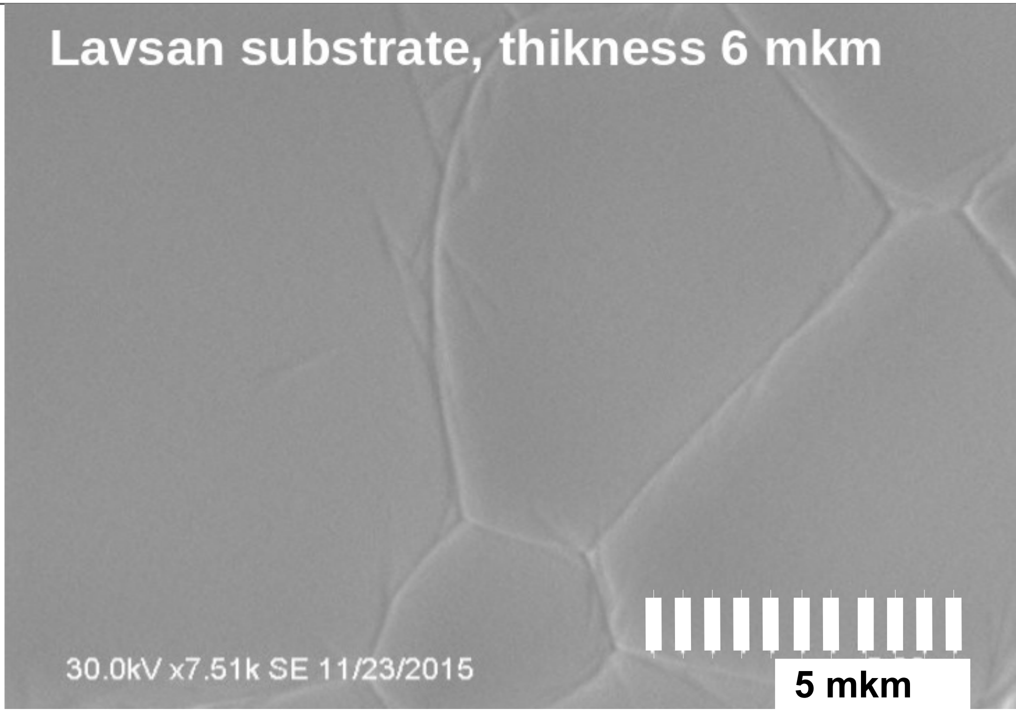
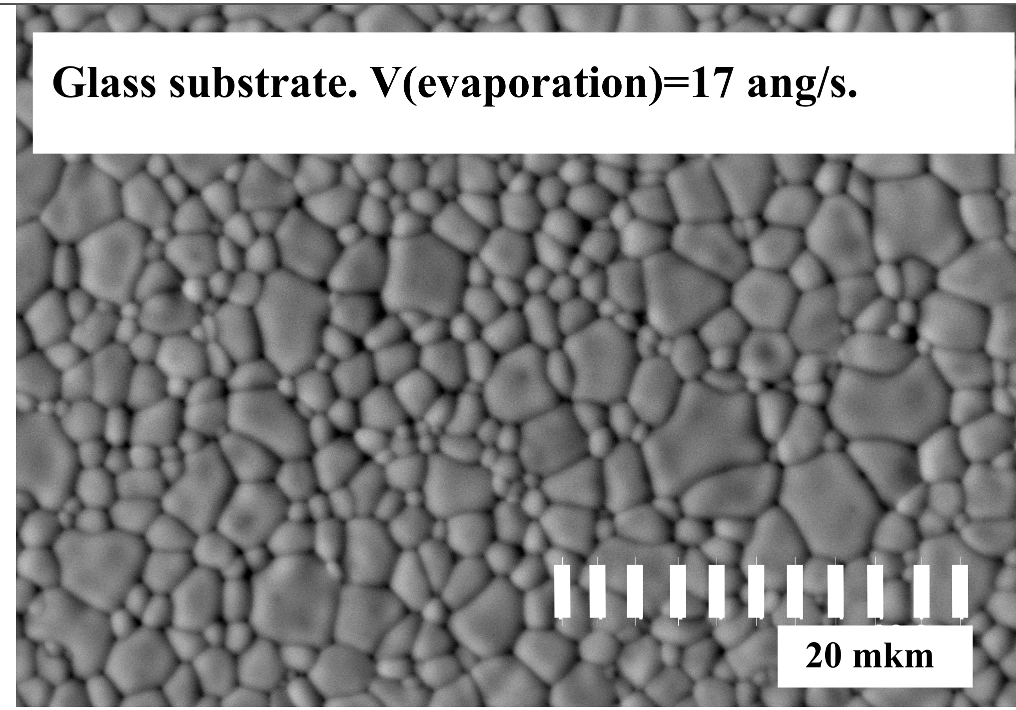
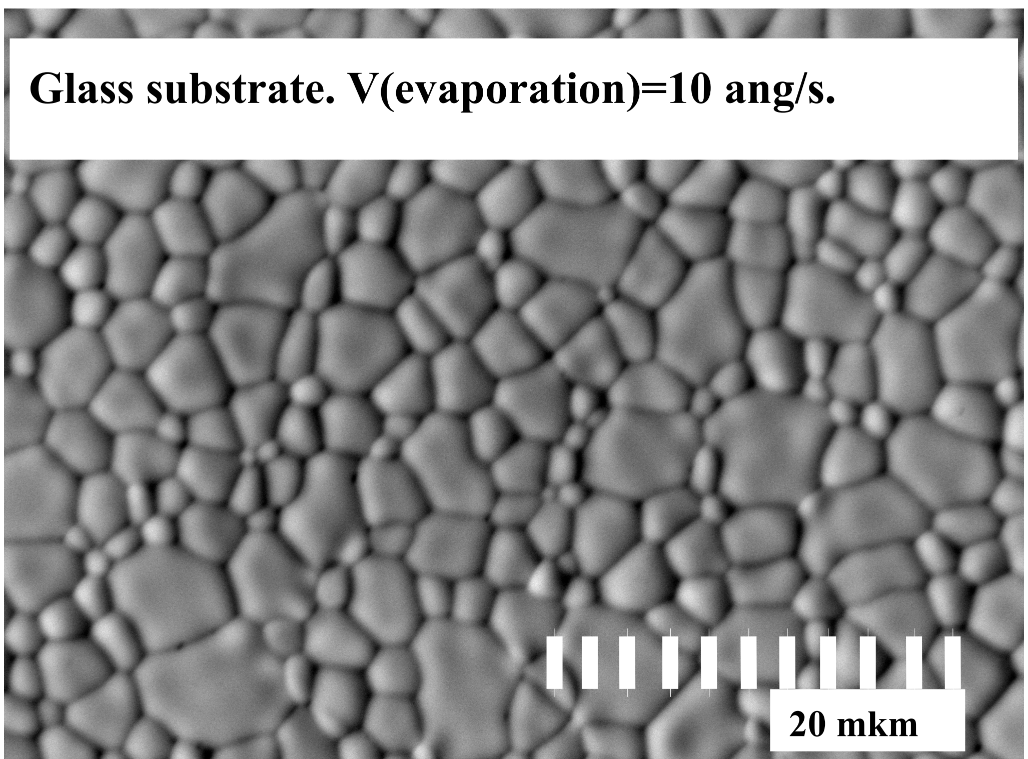
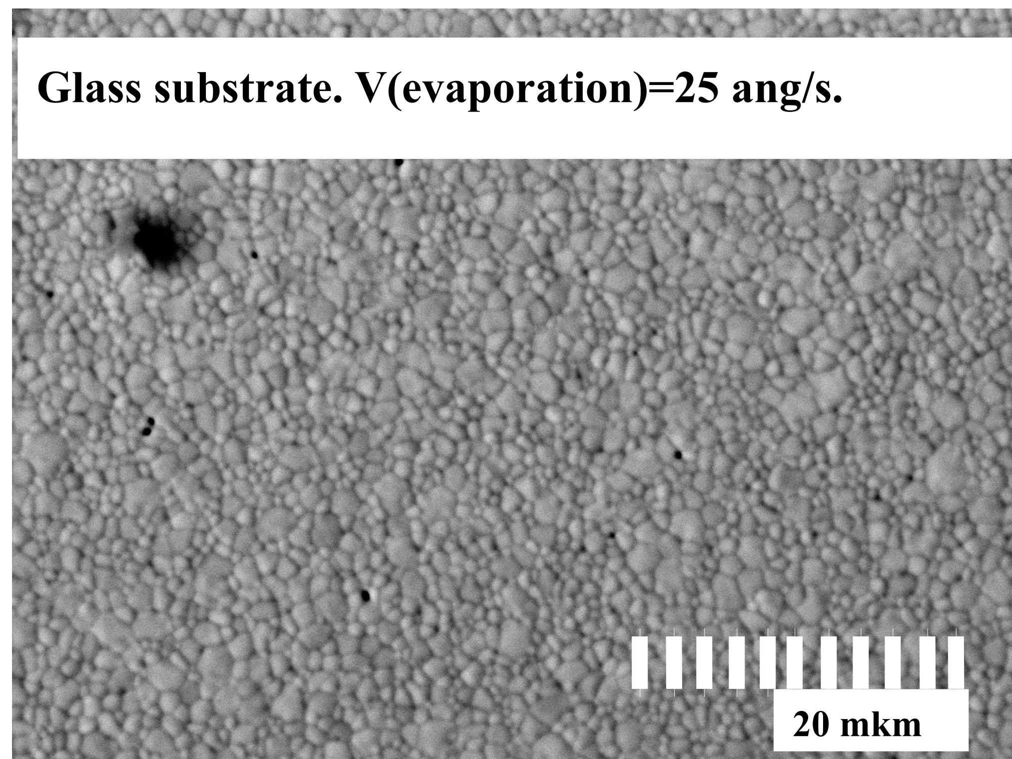


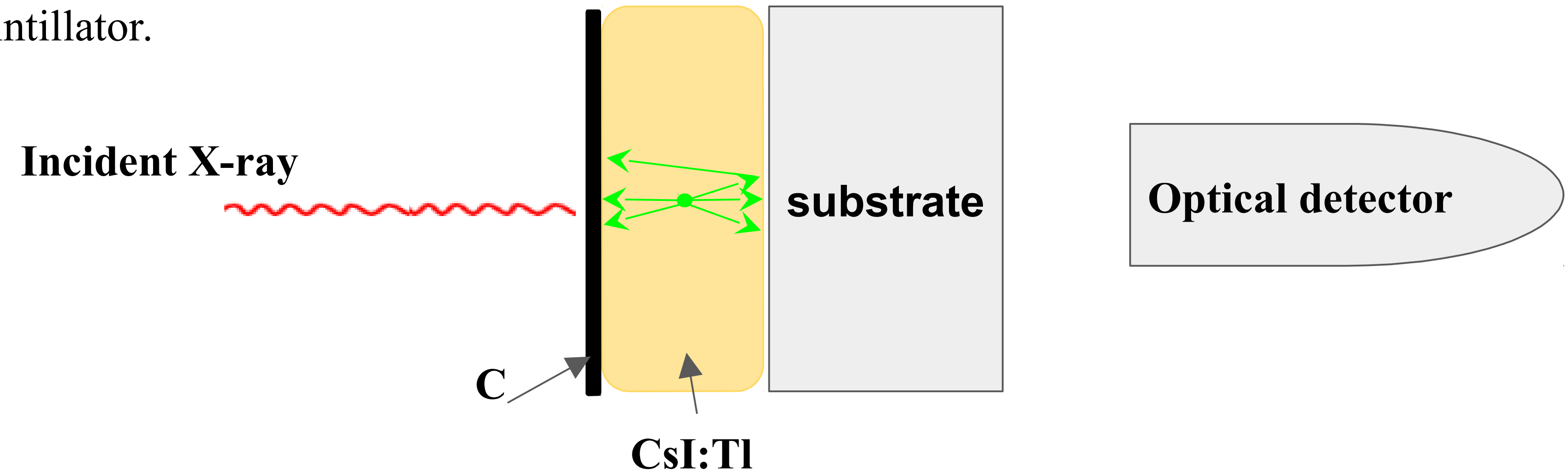



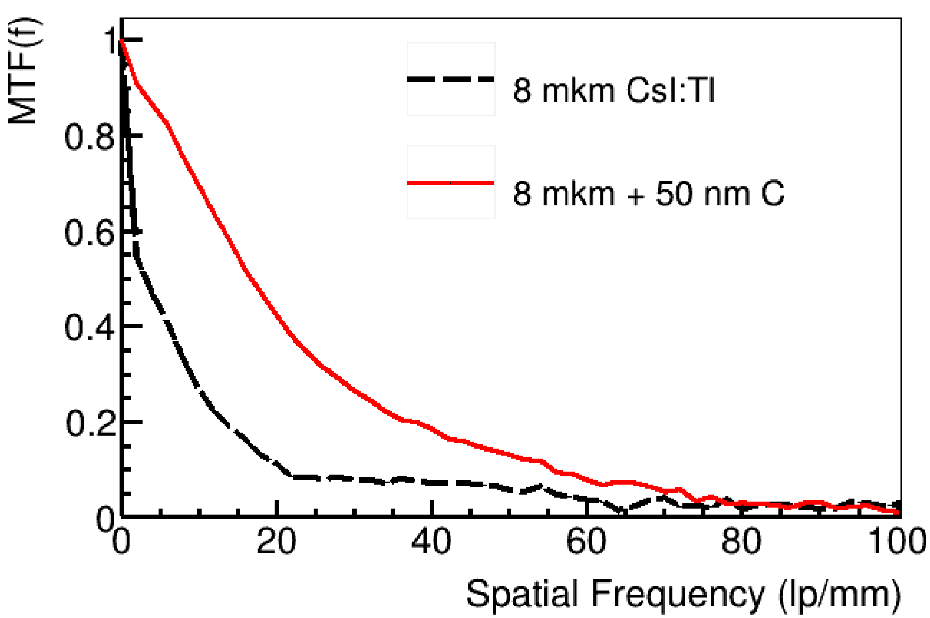



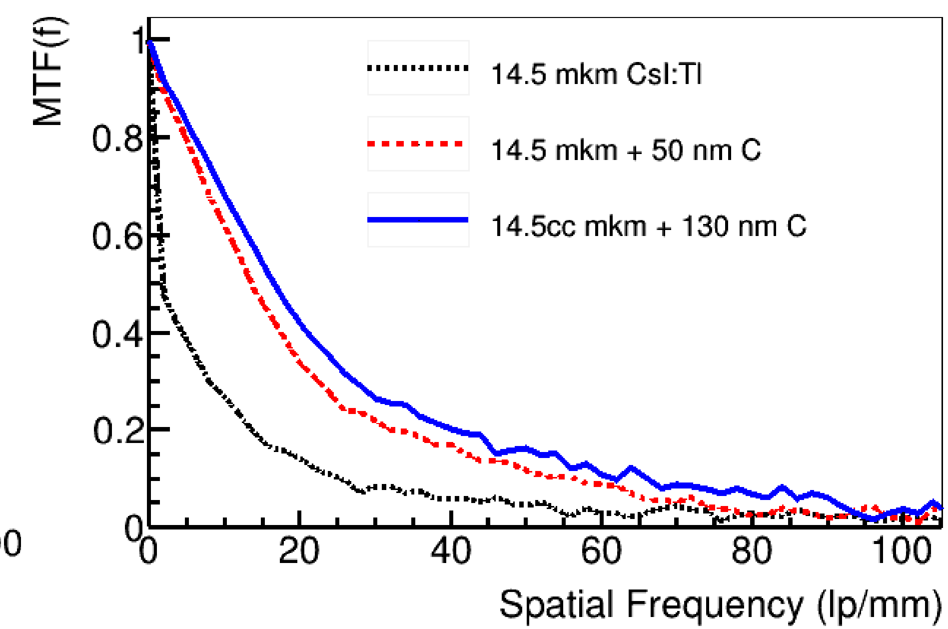
# 2. Thin CsI:Tl films: performance and properties (MTF)

The additional carbon layer removes the multiple scattering of visible photons inside scintillator.

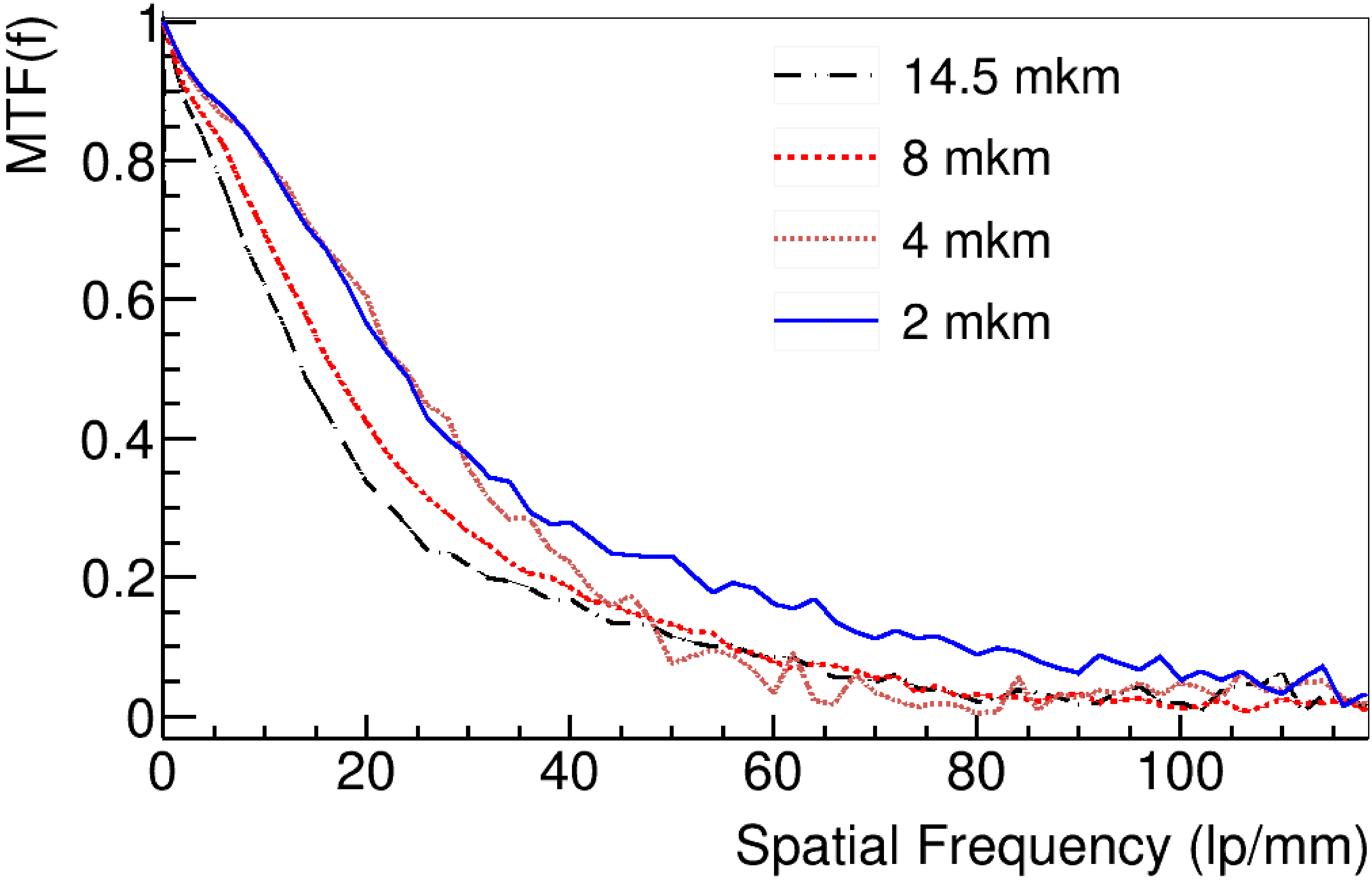



Additional carbon layer was performed by magnetron deposition method. Required carbon thickness is about 150 nm. Light output decreases by 2-3 times.



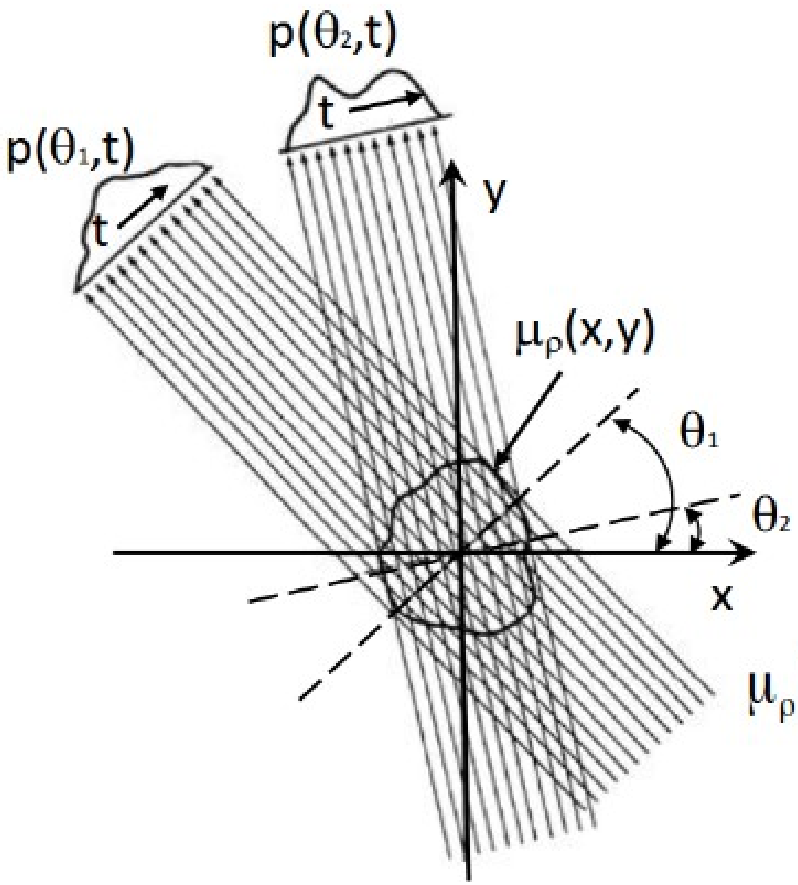



# 2. Thin CsI:Tl films: performance and properties (MTF)



# Computer tomography

The array of proections, obtained by the rotating of sample




$$p(t,\theta_1) = \int_L \mu_\rho(t,s)ds$$

$$p(t,\theta_2) = \int_L \mu_\rho(t,s)ds$$

..................................

$$p(t,\theta_n) = \int_L \mu_\rho(t,s)ds$$

**Набор проекционных данных, где $\mu_\rho = \mu \cdot \rho$ - удельный коэффициент поглощения рентгеновского излучения.**

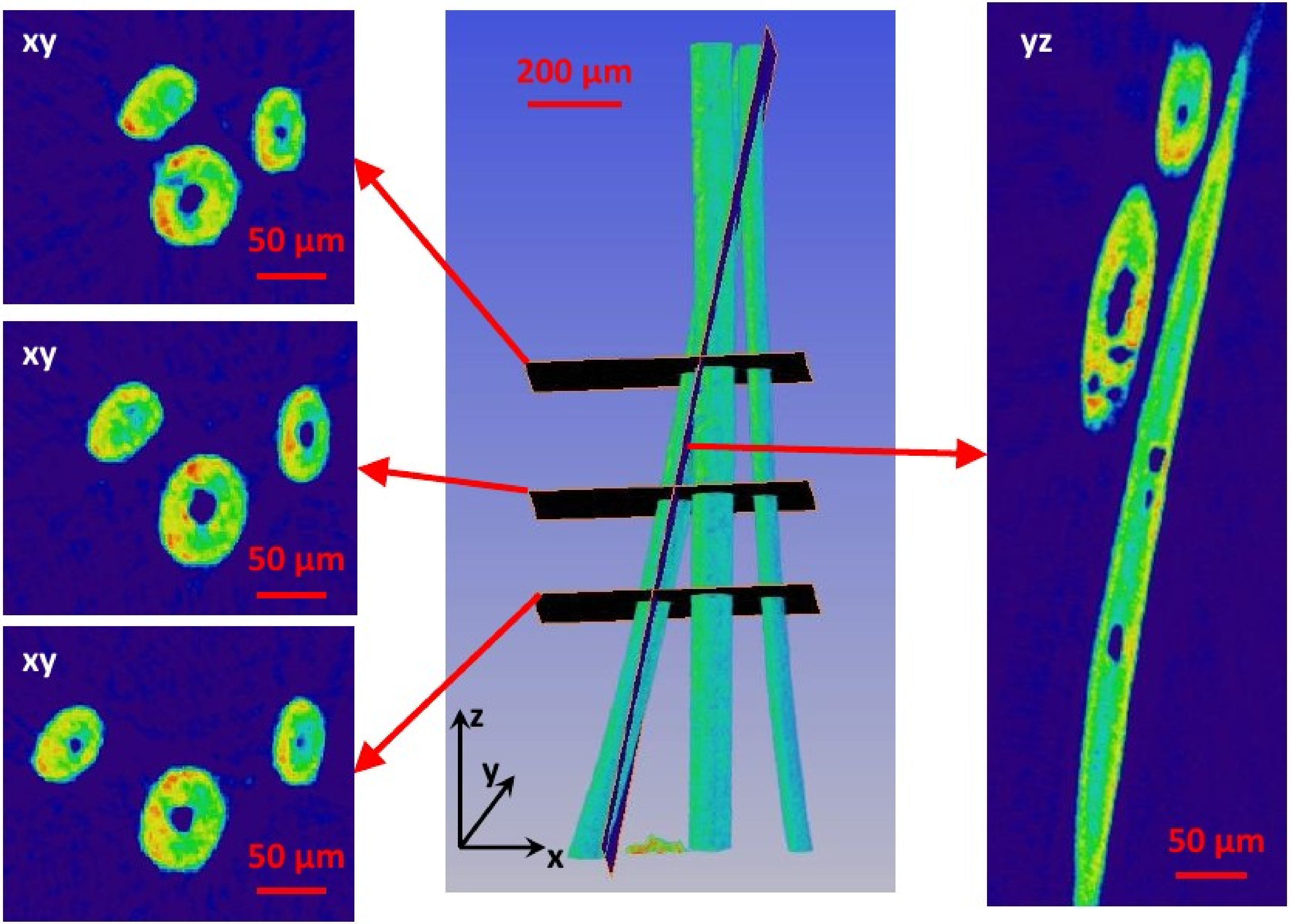
**Теорема о центральном сечении**

Фурье-образ $P(\omega, \theta) = F(\omega \cdot \cos\theta, \omega \cdot \sin\theta)$, где F — Фурье-образ μ

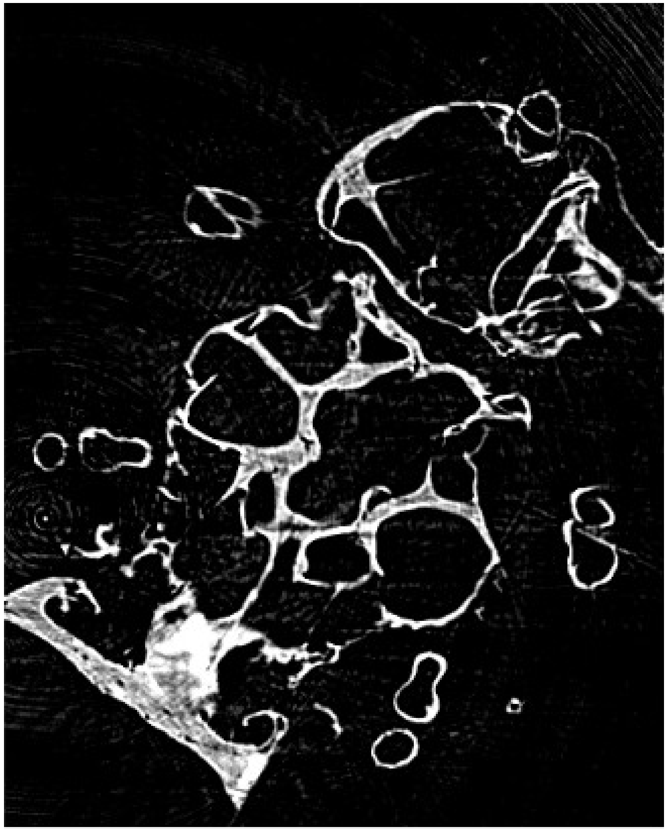
$$\mu_\rho(x, y) = \frac{1}{4\pi^2} \iint \omega P(\omega, \theta) e^{i\omega(x\cos\theta + y\sin\theta)} d\omega d\theta$$

# 3. CsI:Tl films for X-ray Imaging

3D image of ancient hair from Ak-Alaha tomb (Altai, plateau Ukok). E = 9 keV.
A hollow hair is unsuitable for genetic analysis. The goal of the investigation is to find not damaged regions.

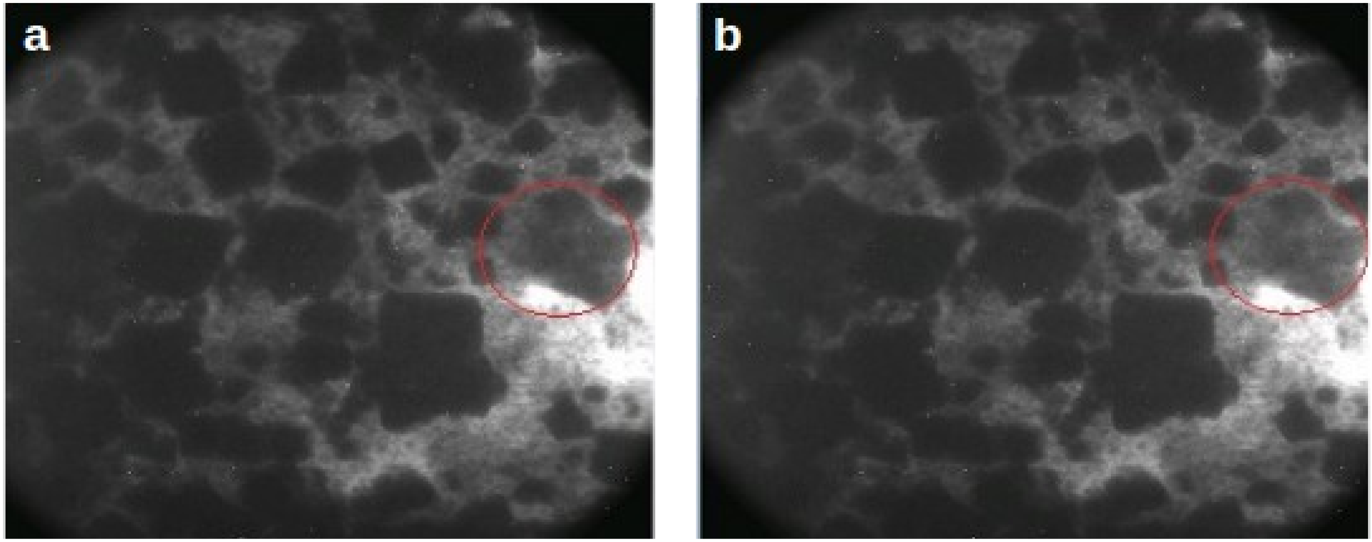


# 3. CsI:Tl films for X-ray Imaging

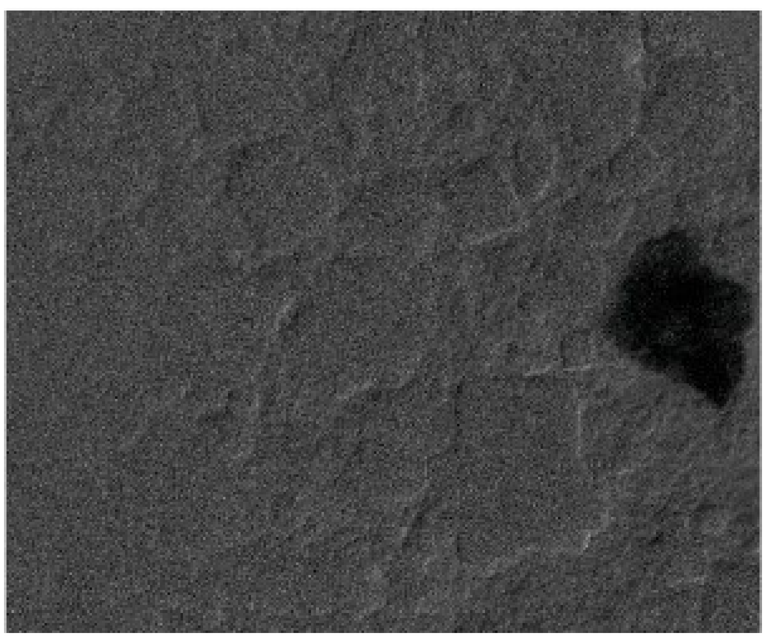


3D tomography of drosophila. E = 9 keV.
$N_{rotation}$ = 180. $T_{exposure}$ = 3 s.

# 3. CsI:Tl films for X-ray Imaging




The imaging of multicomponent high-energy fuel with X-ray energies
E = 6.537 keV (a) and E = 6 keV (b)



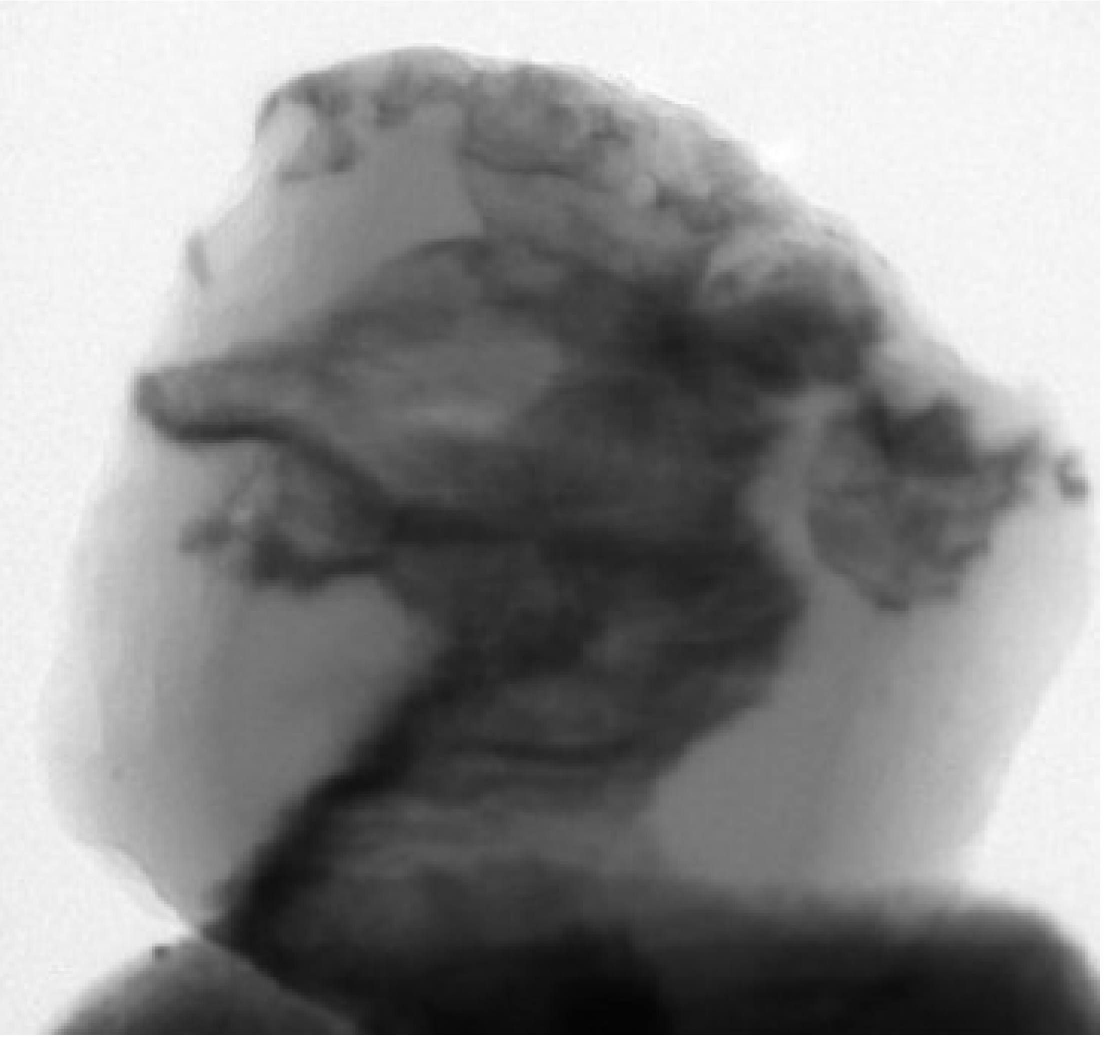
**The difference Fig.a - Fig.b.**

The energy of Mn K-edge $E^{Mn}_{K} = 6.29$ keV

The contrast area corresponds to Mn element.

# 3. CsI:Tl films for X-ray Imaging

The imaging of dense objects using monochromatic X-ray beams

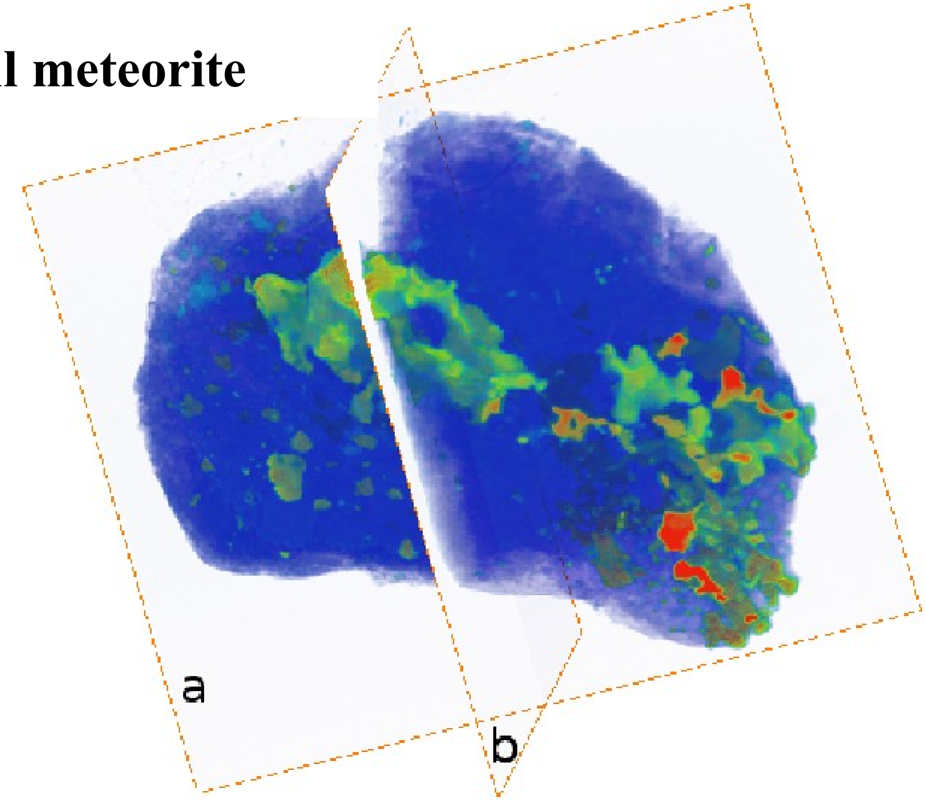


**Diamond crystal topography**

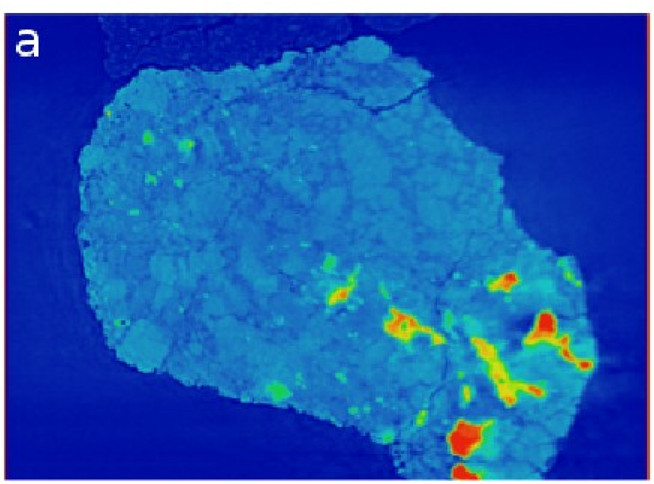
# 3. CsI:Tl films for X-ray Imaging

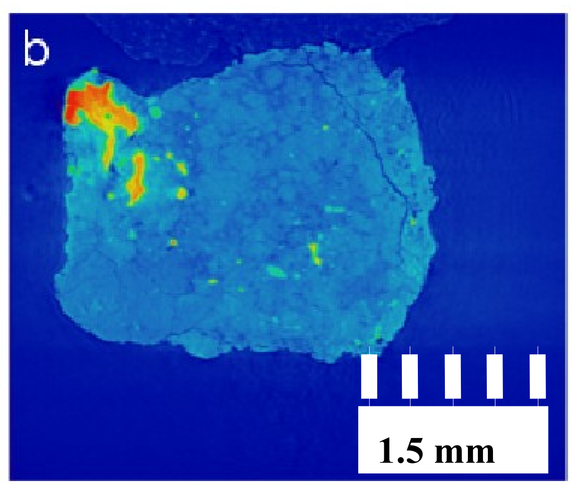
The tomography of dense objects using monochromatic X-ray beams

**Chebarkul meteorite**



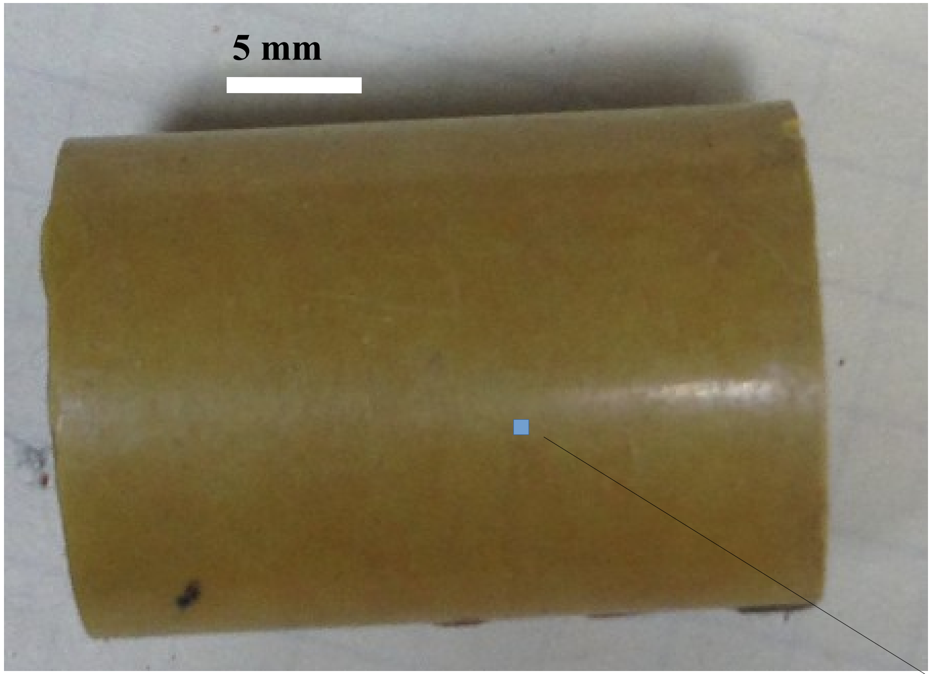

3D image of meteorite essentially represents a density map of the sample, from which one can extract the sizes, shapes, textures, and locations of individual inclusions. 3D models of the samples reveal clearly the spatial relationships between metal incisions (red color) and their surroundings. This may be to give the key to understanding the thermal processes occurring in the meteorites during to propagation in Earth atmosphere.



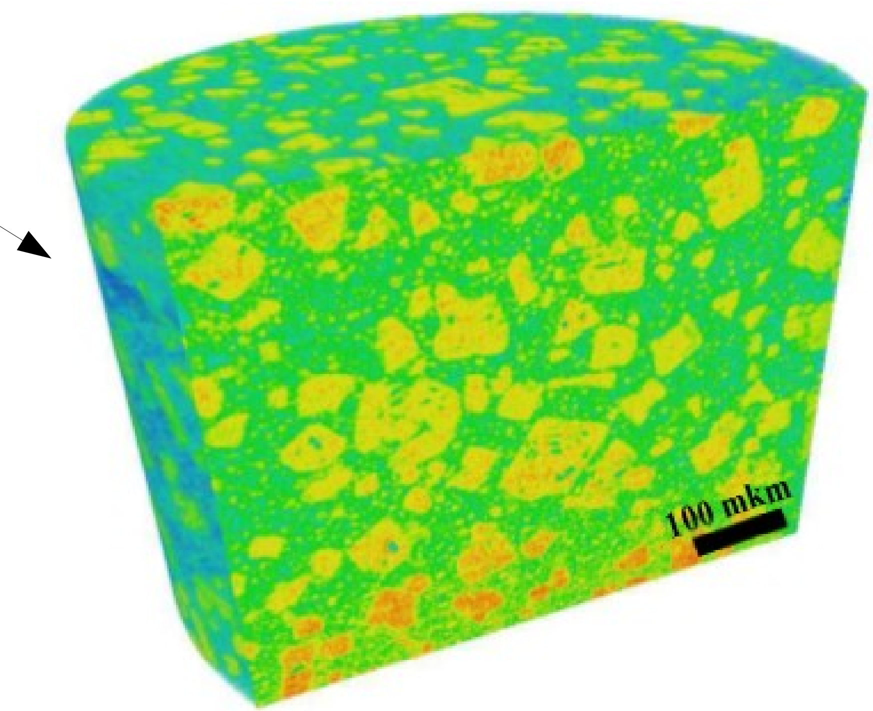



# 3. CsI:Tl films for X-ray Imaging

## The local tomography of dense objects using monochromatic X-ray beams



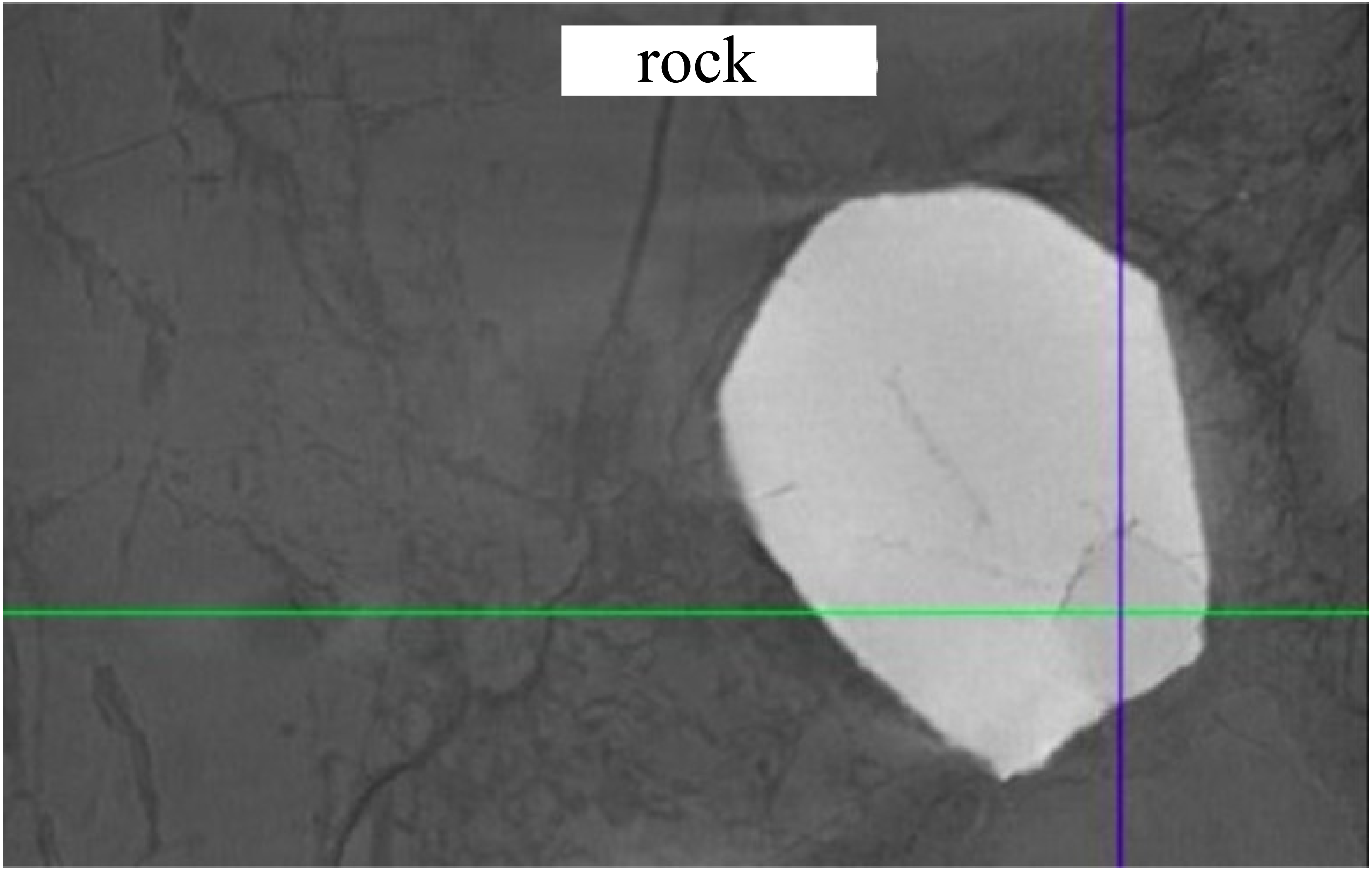

The shown structure demonstrates high quality of its performance due to homogeneous distribution of different components without cracks and pores.




3D image of selected area inside compound detail which is applied in aerospace technology.

# 3. CsI:Tl films for X-ray Imaging

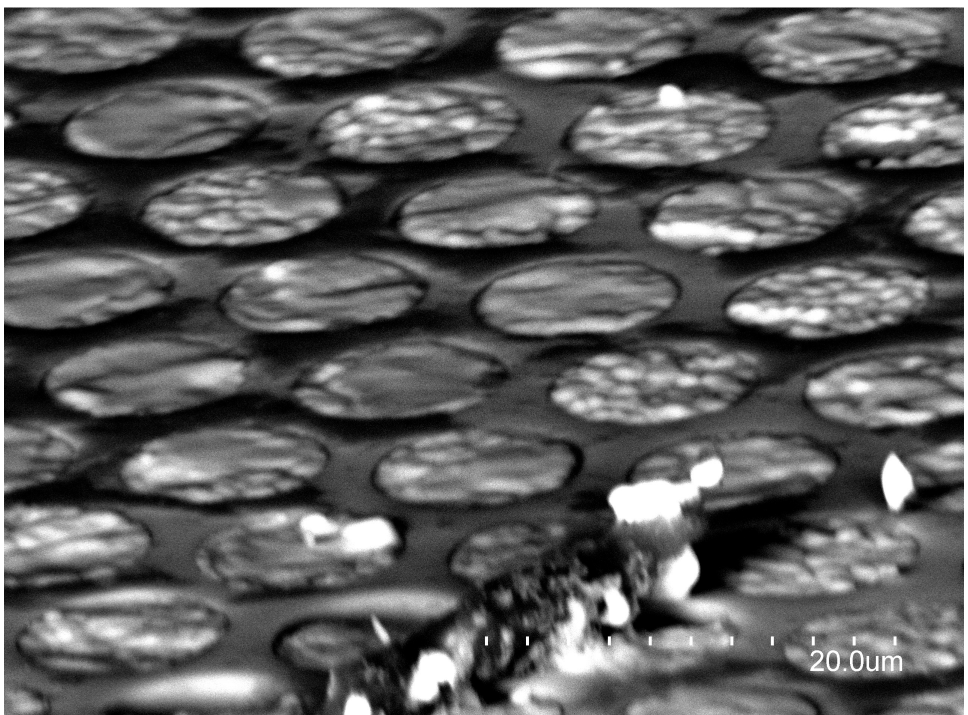
The local tomography of dense objects using polychromatic X-ray beams

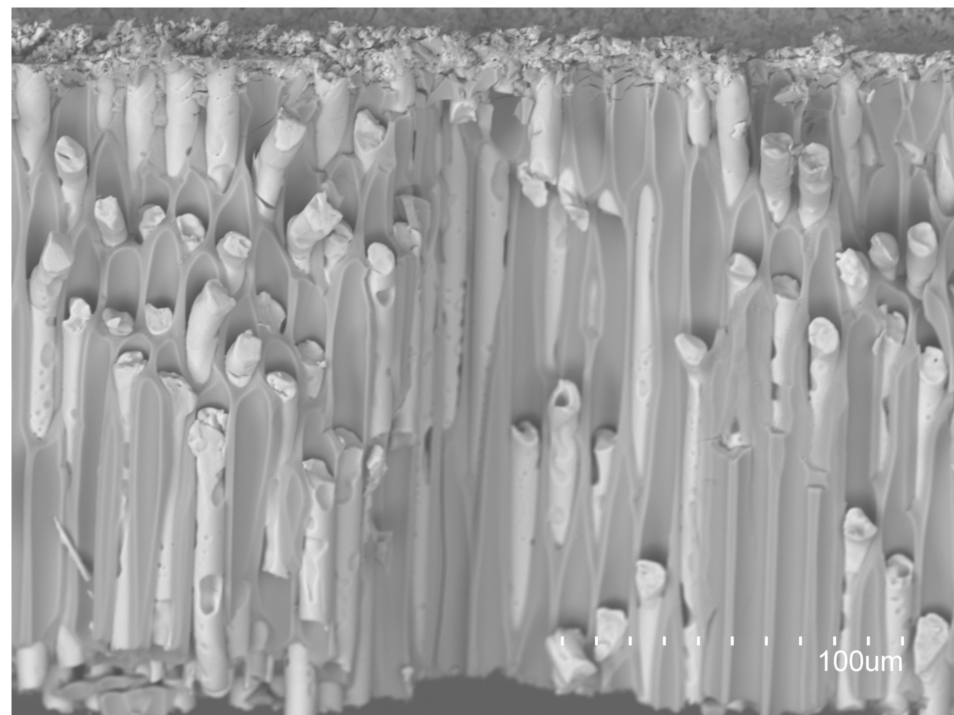


# Thick structured CsI:Tl screens

It was demonstrated that CsI:Tl provides, in principle, better detective quantum efficiency and spatial resolution than powder phosphors and gas detectors. (Med. Phys. 31, 9 (2004), Med. Phys. 35, 968 (2008))

«The xray sensitivity is found to be only 2.5%–4.5% of a commercial CsI layer of similar thickness, thus very low. This work shows that scintillator filled pore arrays can provide xray imaging with high spatial resolution, but are not suitable in their current state for most of the applications in medical imaging, where increasing the xray doses cannot be tolerated.»



# Conclusion

- ➤ **The methodics of performance of thin CsI:Tl films was developed.**

- ➤ **The performance of thick CsI:Tl structured screens was initiated.**

- ➤ **We plan to develop portable X-ray tomograph for fast and precise imaging of wide range objects from 10 mkm of biological tissue up to 10 cm of dense rock.**

# 3. CsI:Tl films for X-ray Imaging

Performed CsI:Tl films allow to make radiography in wide X-ray energy region [5-100] keV.