CERN-BINP workshop for young scientists
in e+e- colliders

X-ray tomography using thin scintillator films

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Plan

1. Introduction

2. Thin CsI:Tl scintillator films
- ➤ the fabrication of scintillator films
- ➤ crystalline properties
- ➤ MTF, light output
- ➤ additional treatments

3. CsI:Tl films for X-ray
- ➤ Imaging
- ➤ Tomography
- ➤ Topography and etc.

4. Conclusion

1.Introduction

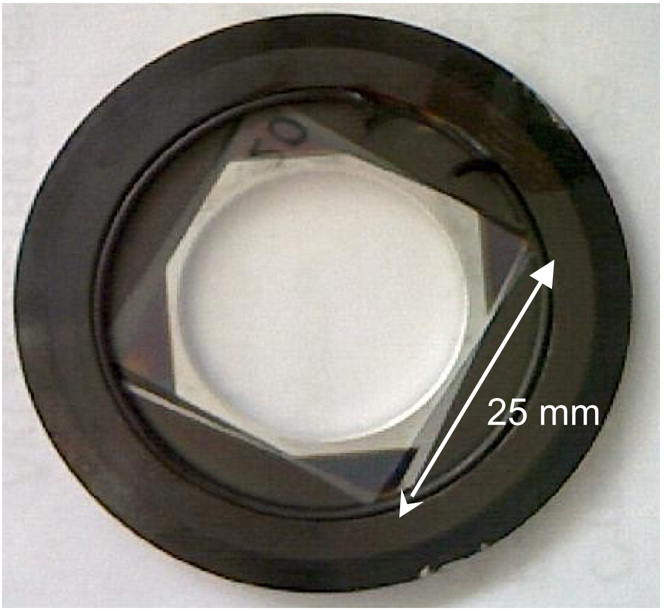
CsI(Tl) scintillator films are widely applied as the conversion screens for the indirect X-ray imaging. The CsI(Tl) is characterized by one of the highest conversion efficiencies of any known scintillator.

+ Microstructure inside volume decreases the lateral spreading of scintillating light.

Due to a wide range of applications (crystallography, microtomography, digital radiography and etc.) the development of preparation methods is relevant.

The research is aimed to develop X-ray conversion screens to visible light with minimal loss in spatial resolution

2. Thin CsI:Tl films: performance and properties



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

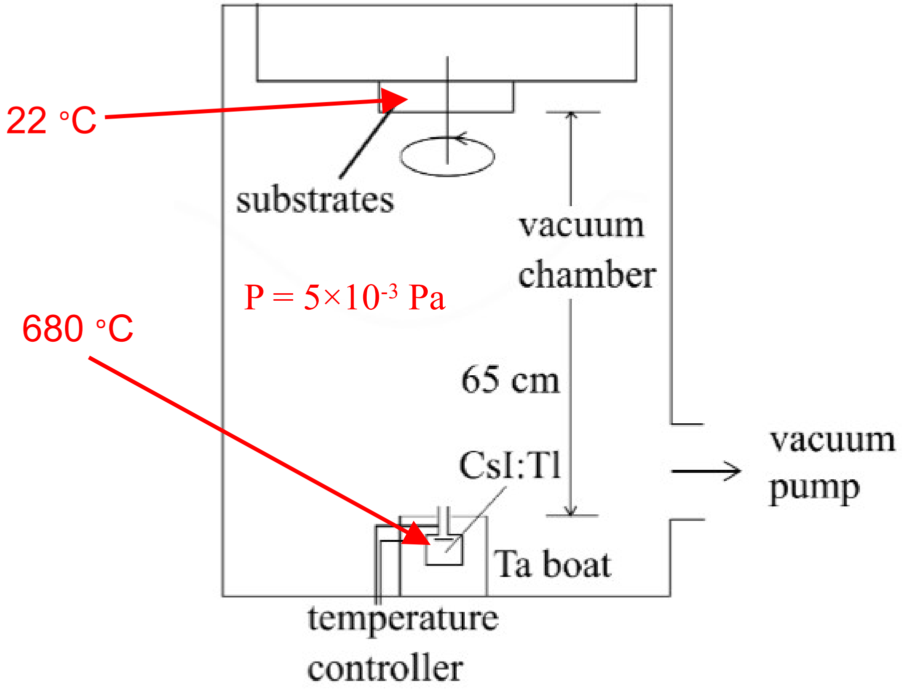
Substrates: glass (150 mkm),
Mylar (DuPont, 2.9 mkm)
saphir (800 mkm)

Thickness of CsI:Tl films: 2-10 mkm

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

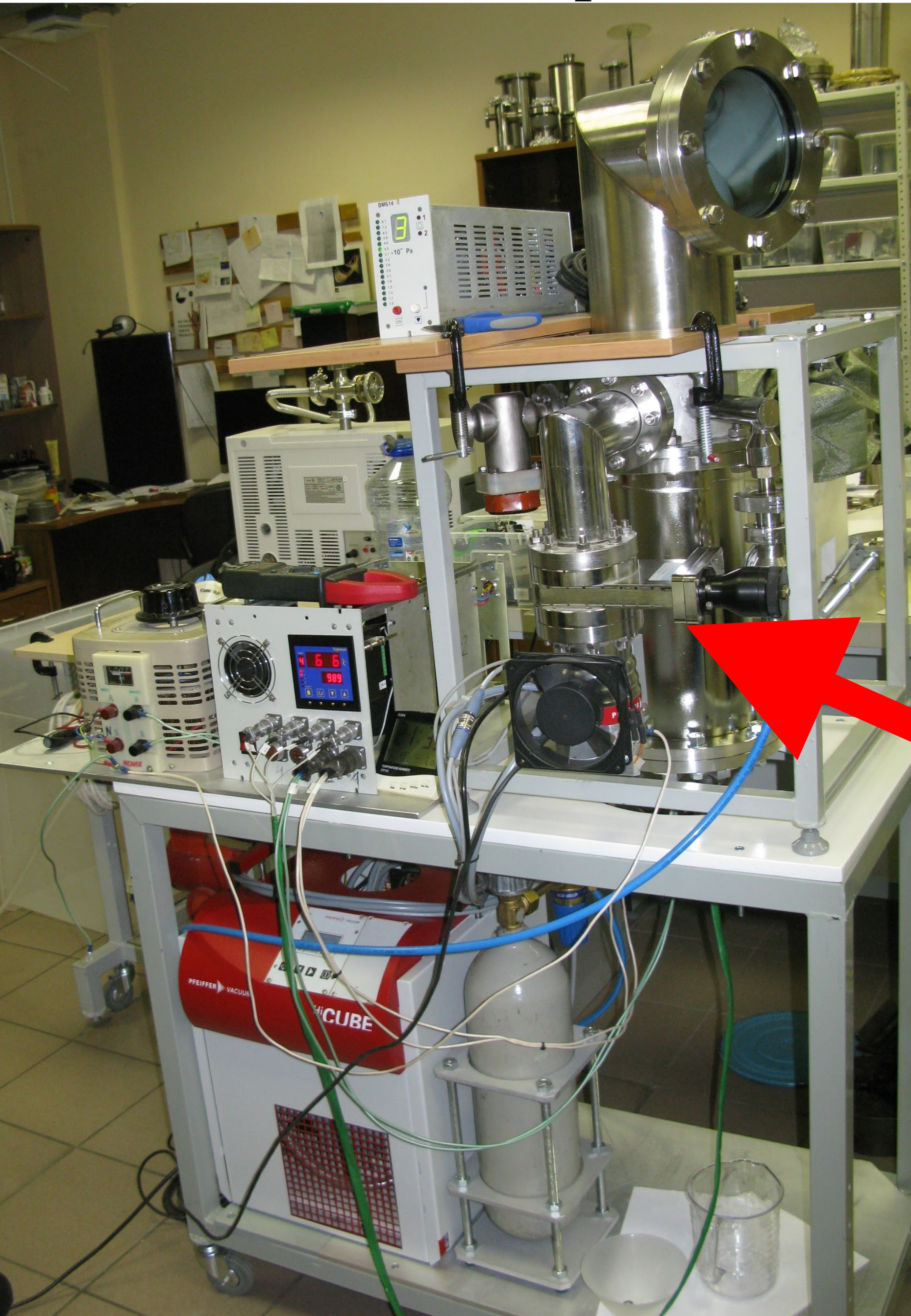
The scintillator volume is characterized by grain structure.

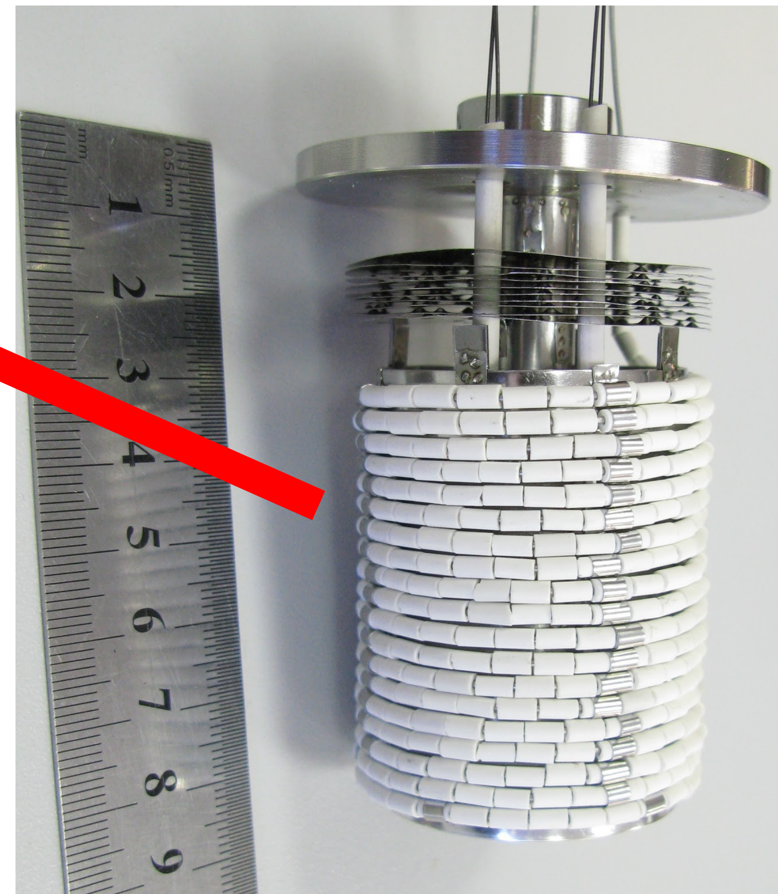
The grain structure depends on the type of used substrate and on the velocity of CsI:Tl deposition.



Schematic of the thermal evaporation setting

2. Thin CsI:Tl films: performance and properties





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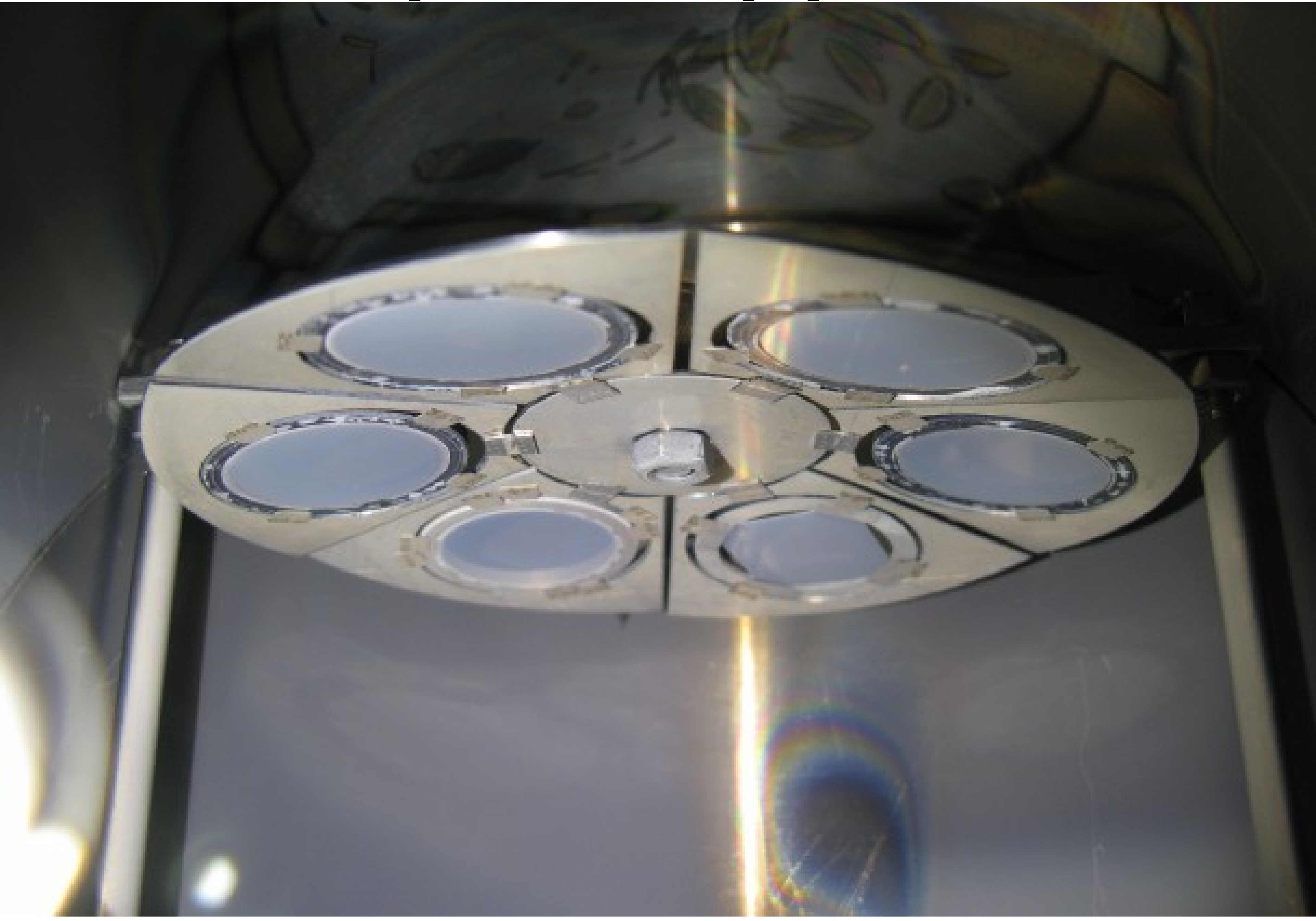
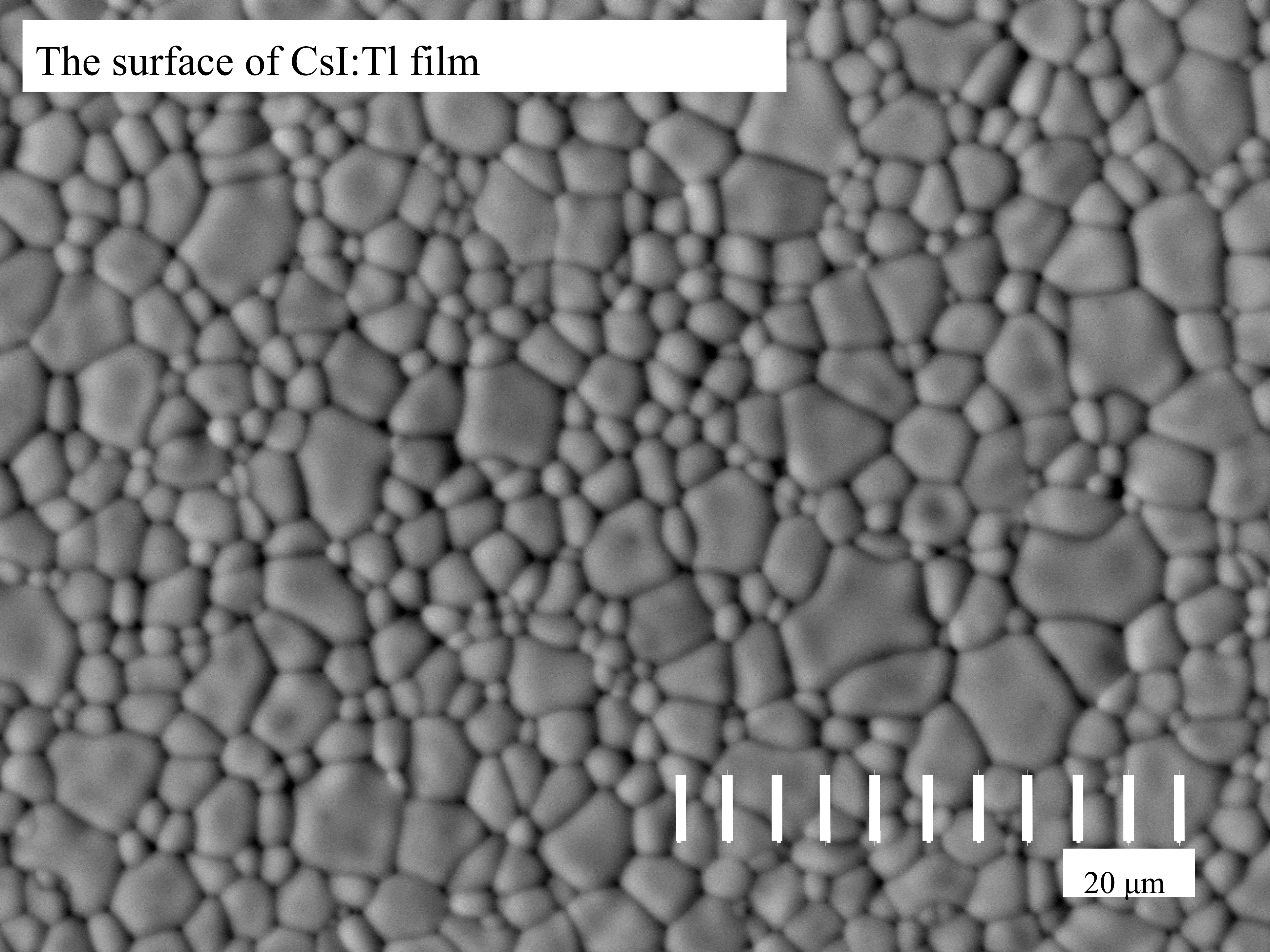
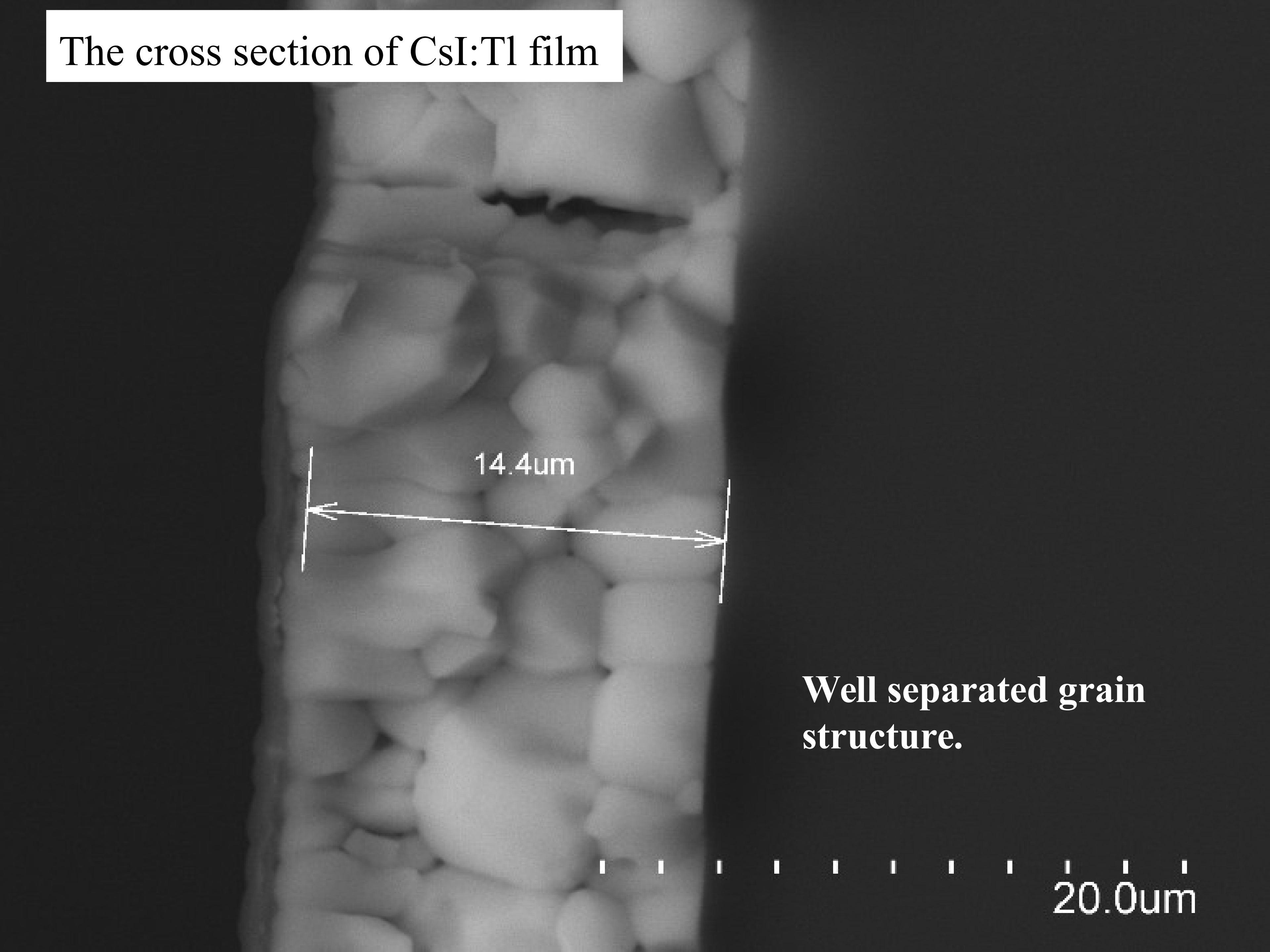
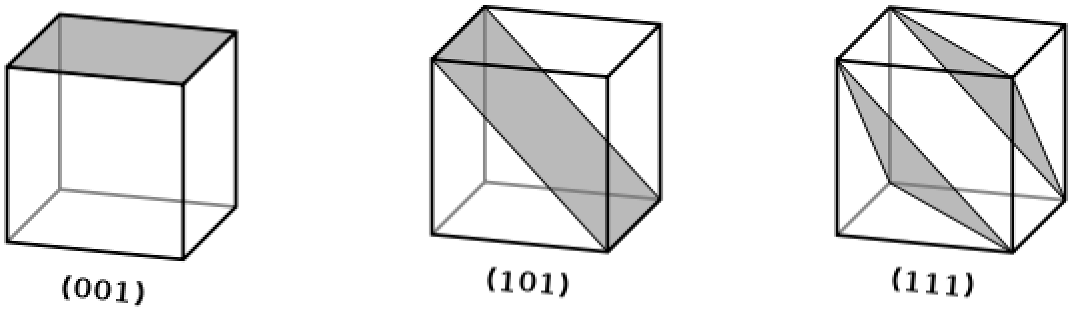


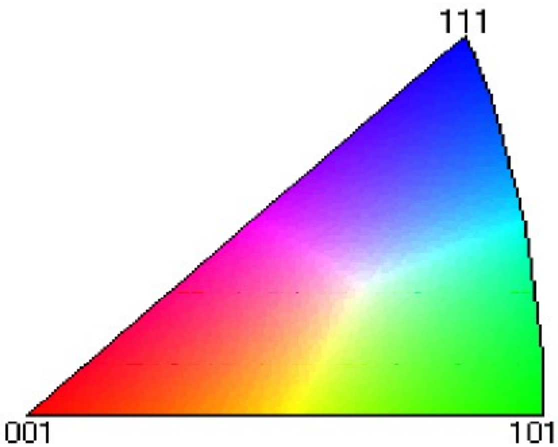

The surface of CsI:Tl film
20 μm

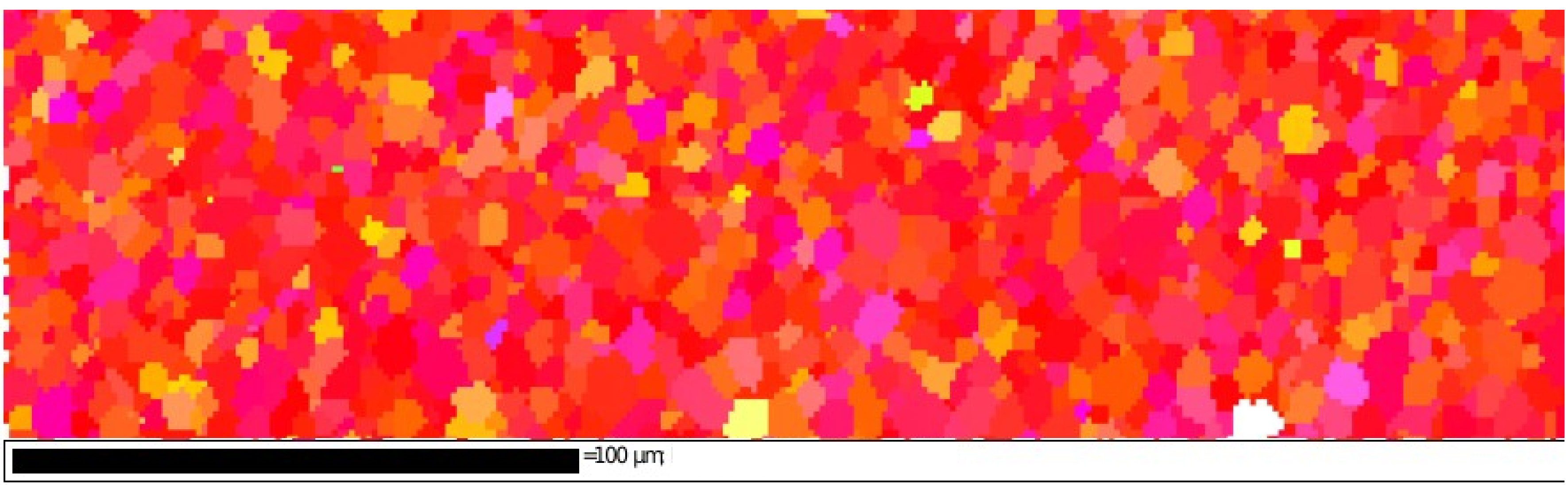

The cross section of CsI:Tl film
14.4um
Well separated grain structure.
20.0um

2. Thin CsI:Tl films: performance and properties

The CsI:Tl orientation was measured using electron backscattering diffraction



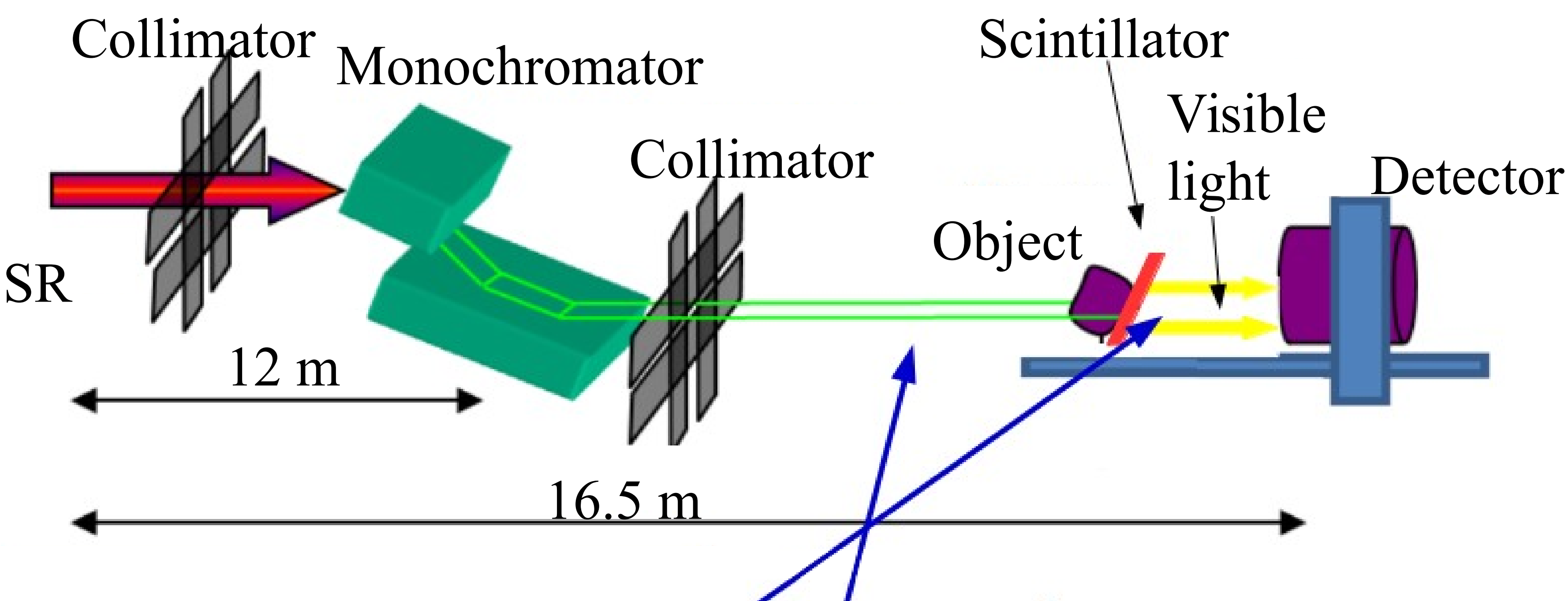




2. Thin CsI:Tl films: performance and properties

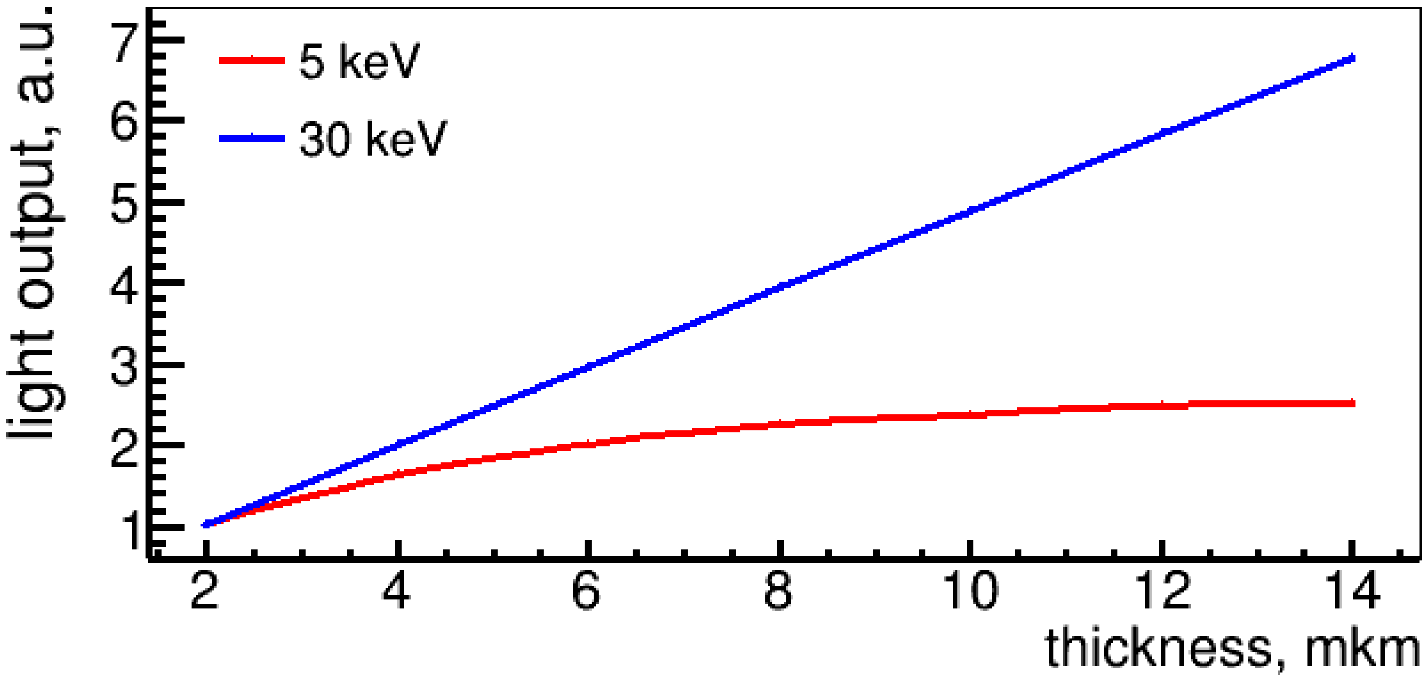
The CsI:Tl films was performed with different

- thicknesses
- substrates
- evaporation velocities
- post evaporation treatments



$$I = I_0 \exp(-\int_L \mu(\lambda, s)\rho(s)ds)$$

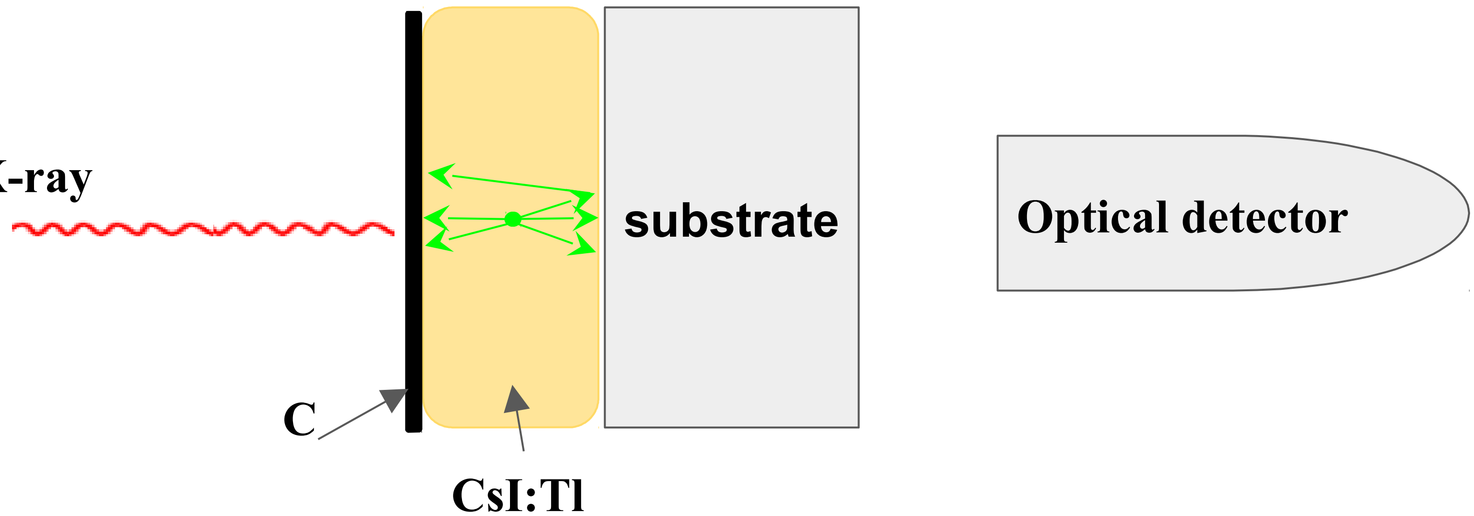
2. Thin CsI:Tl films: performance and properties



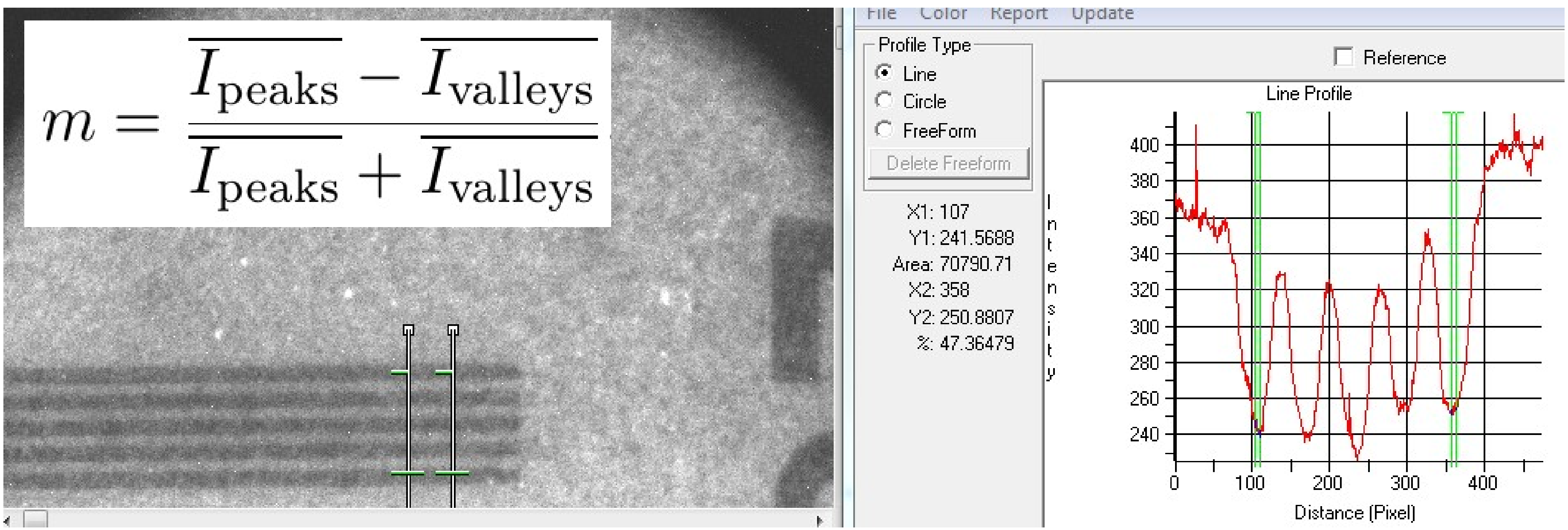
The light output in dependence on CsI:Tl thickness

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.



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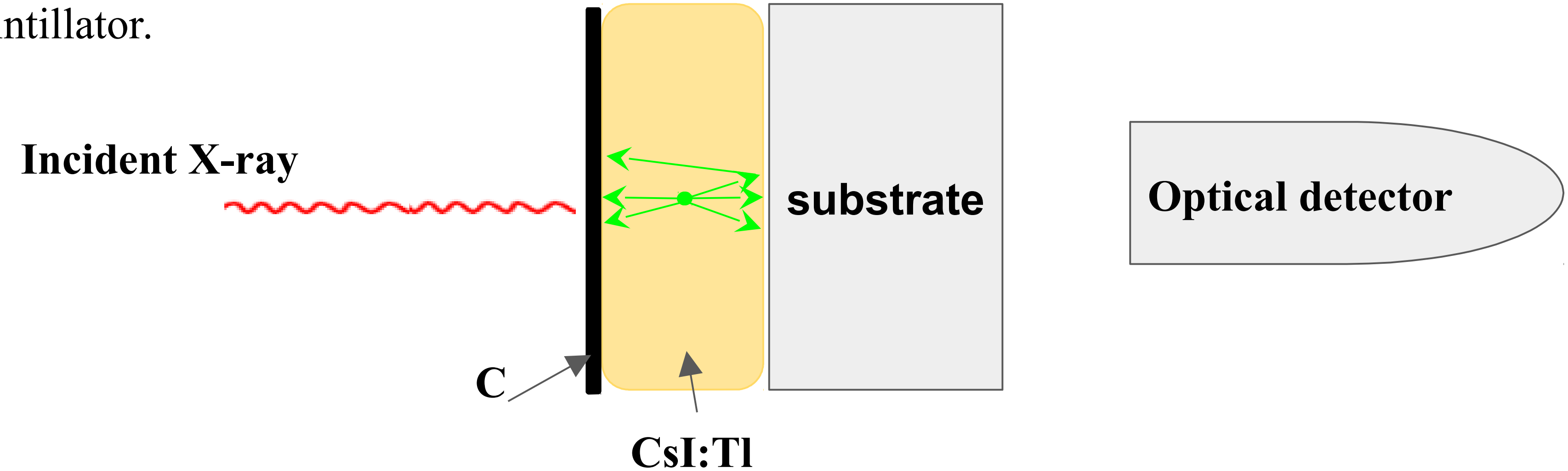

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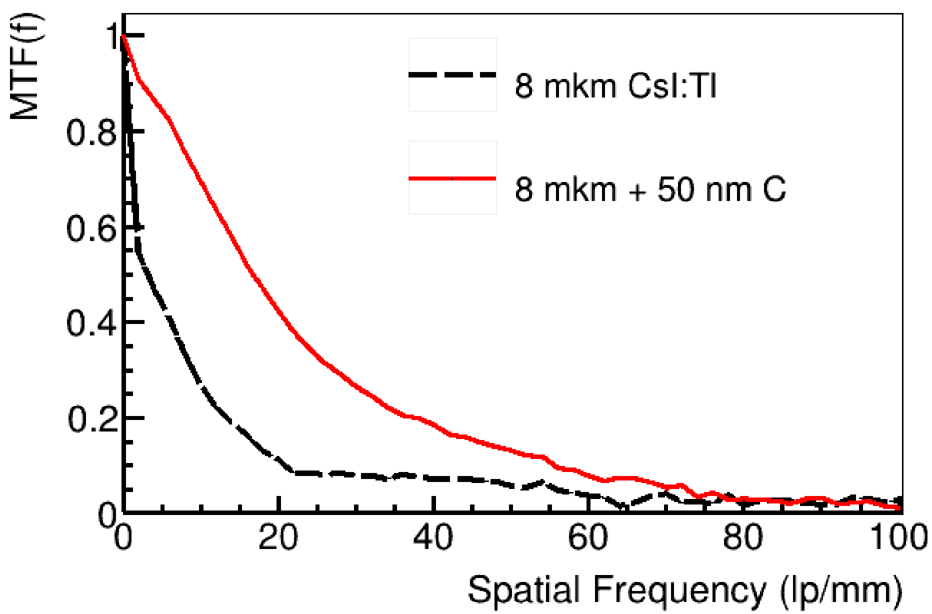

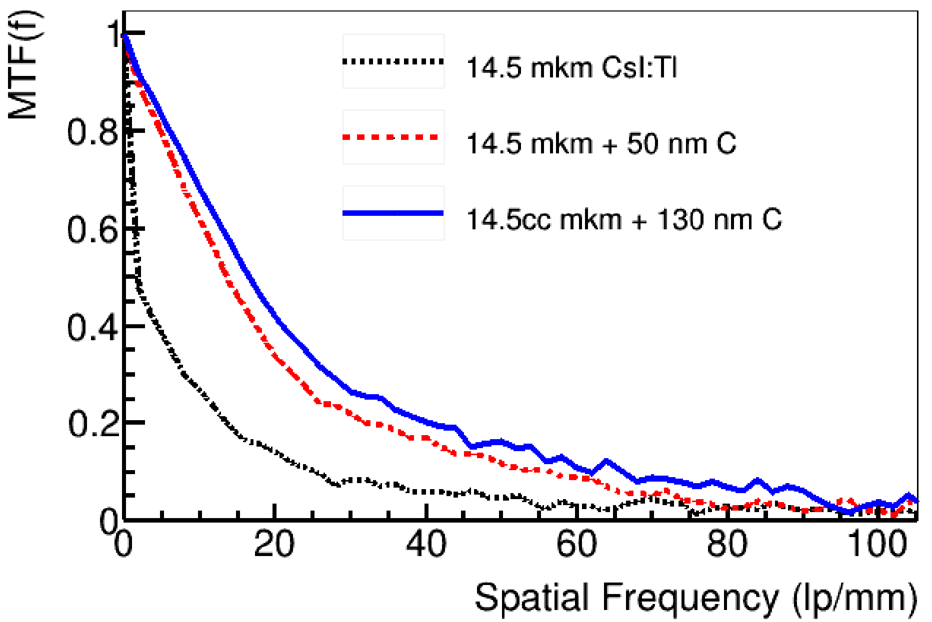

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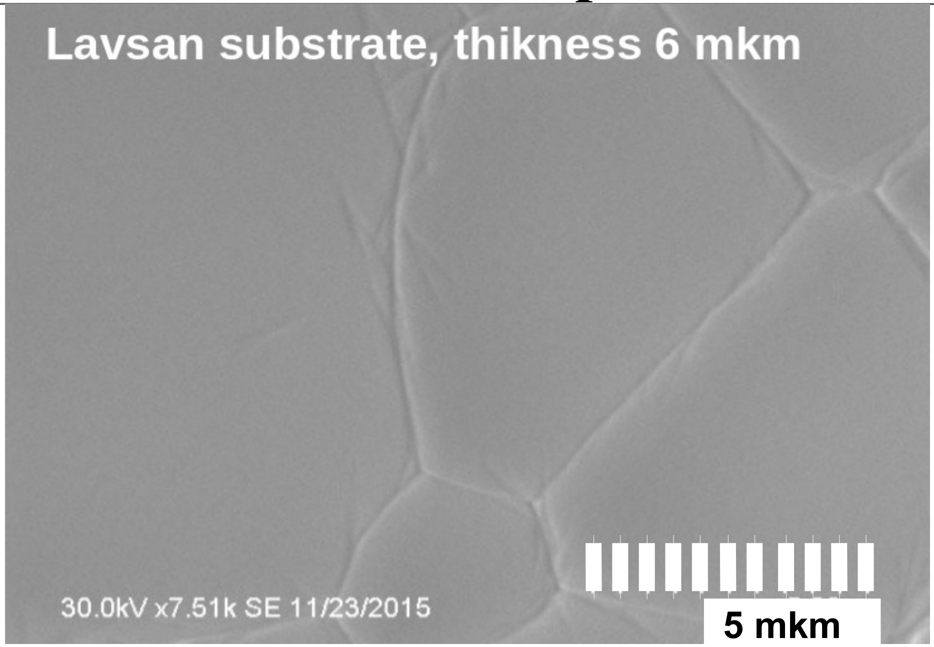
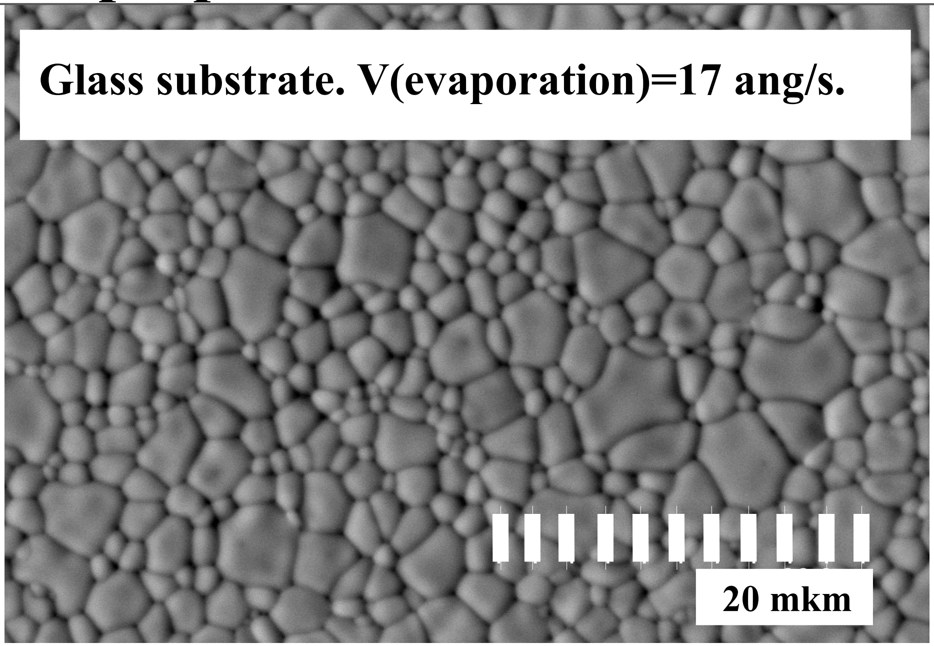
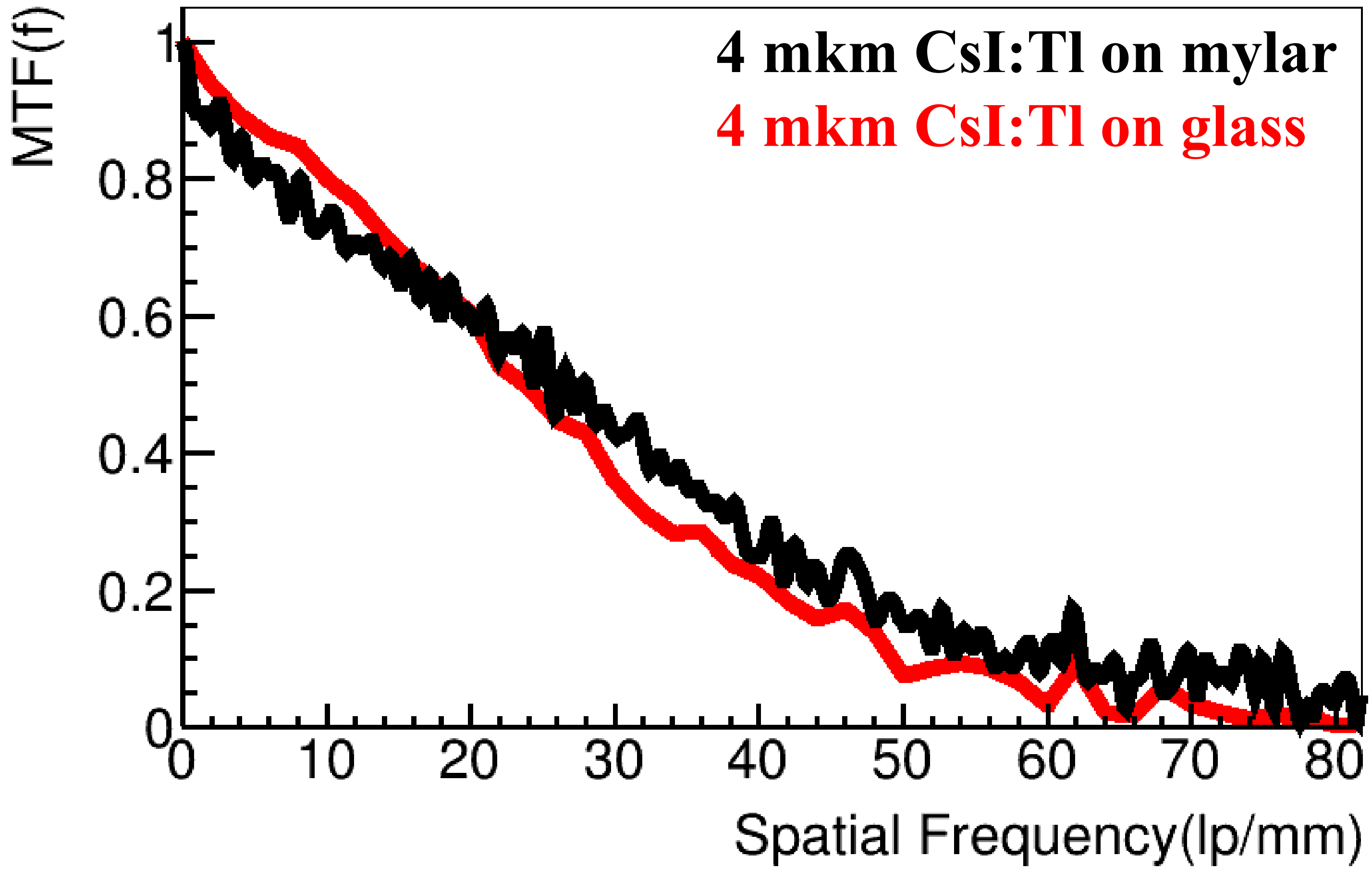




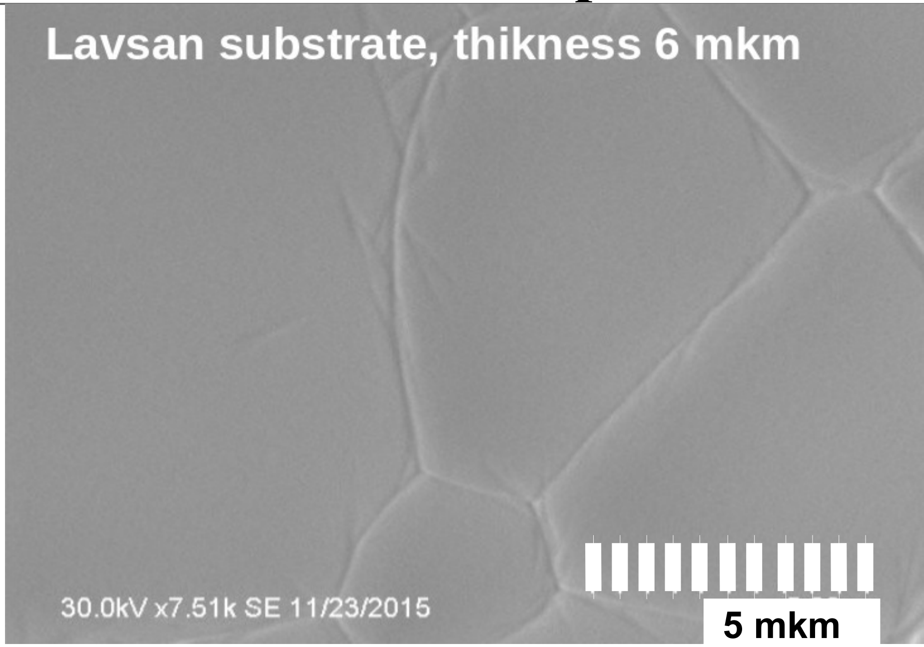
2. Thin CsI:Tl films: performance and properties (MTF)

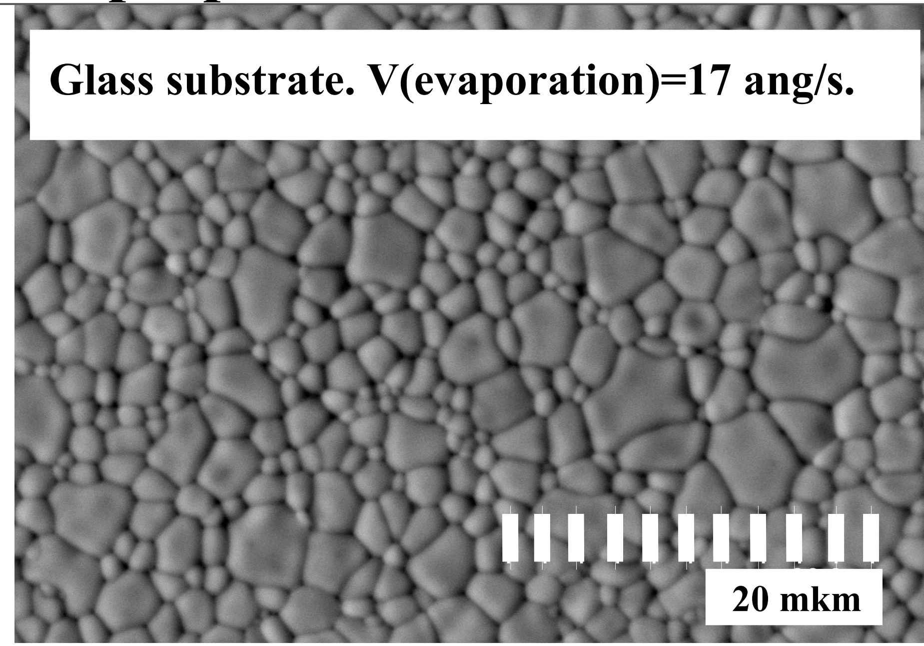
The size of grains in thin scintillator is not strongly correlated with spatial resolution.

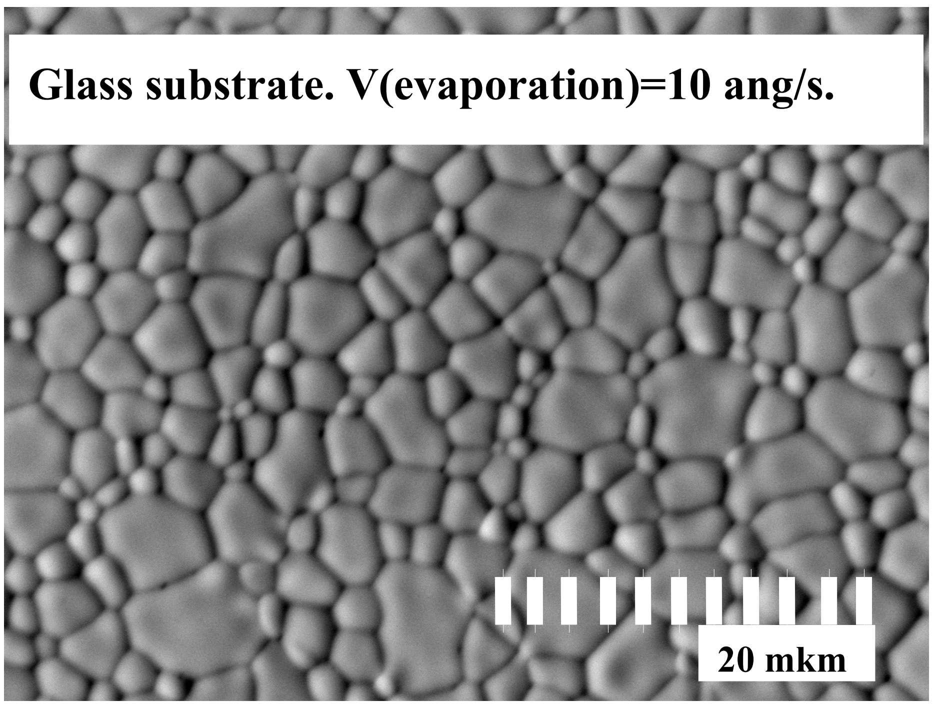


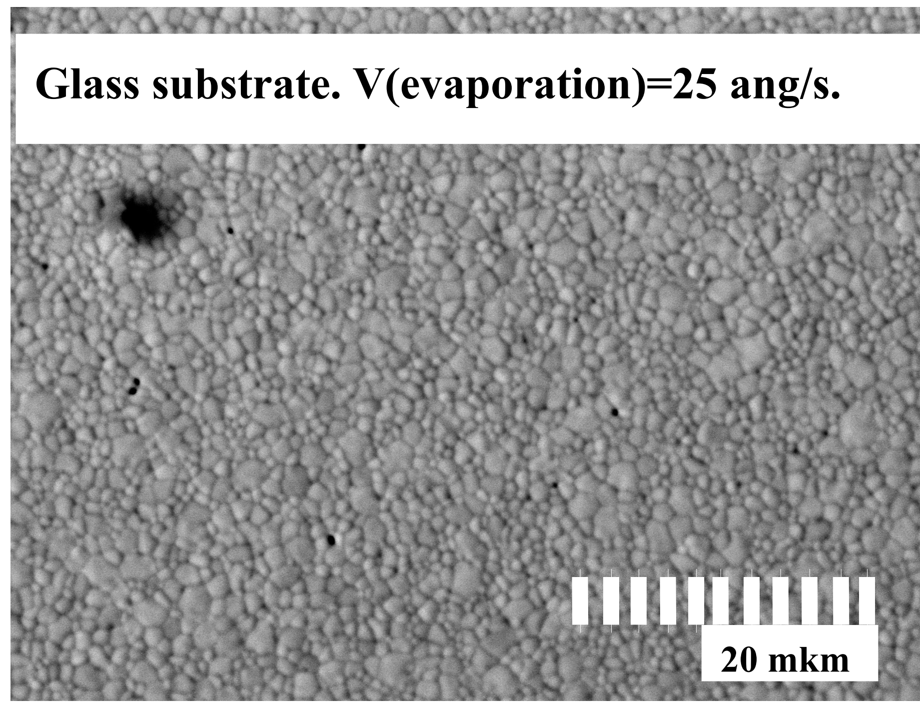
Problem!!! During carbon deposition on scintillator with mylar substrate, the heating of mylar leads to the evaporation of 90% thallium.

2. Thin CsI:Tl films: performance and properties

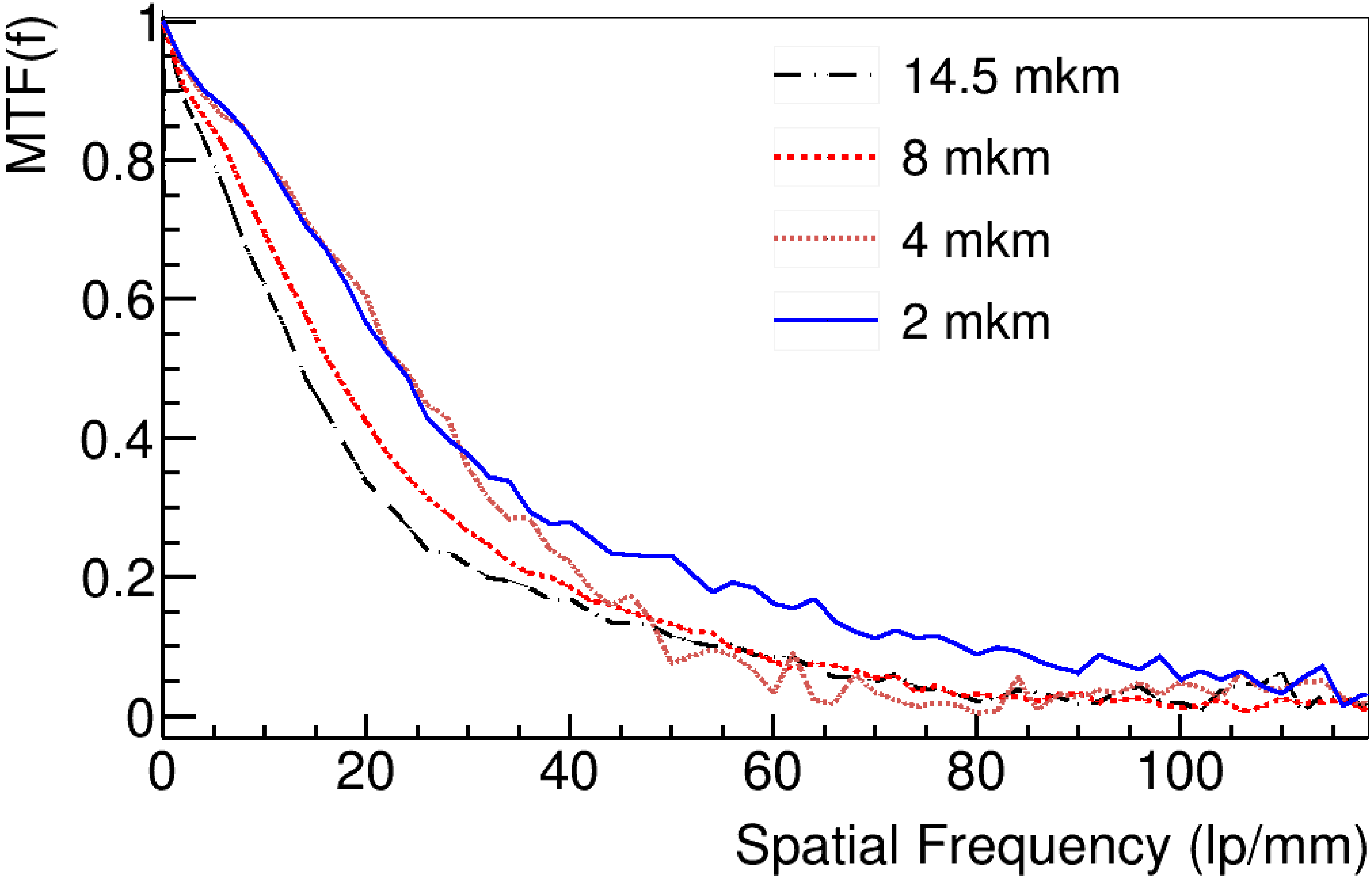








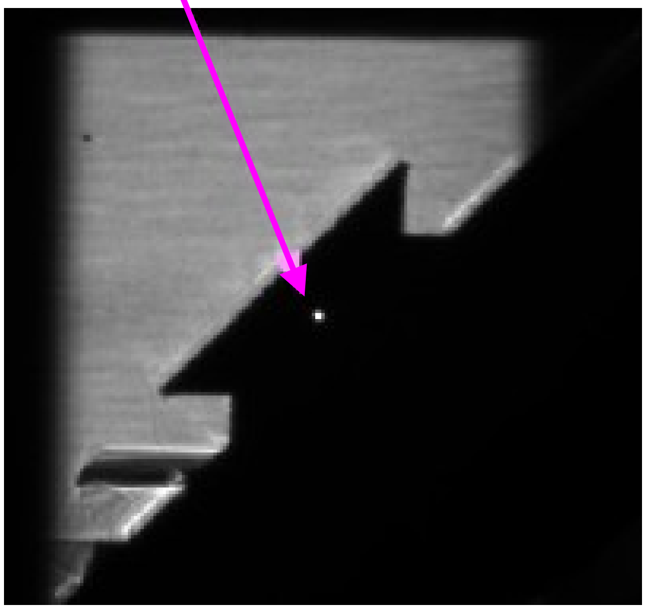
2. Thin CsI:Tl films: performance and properties (MTF)

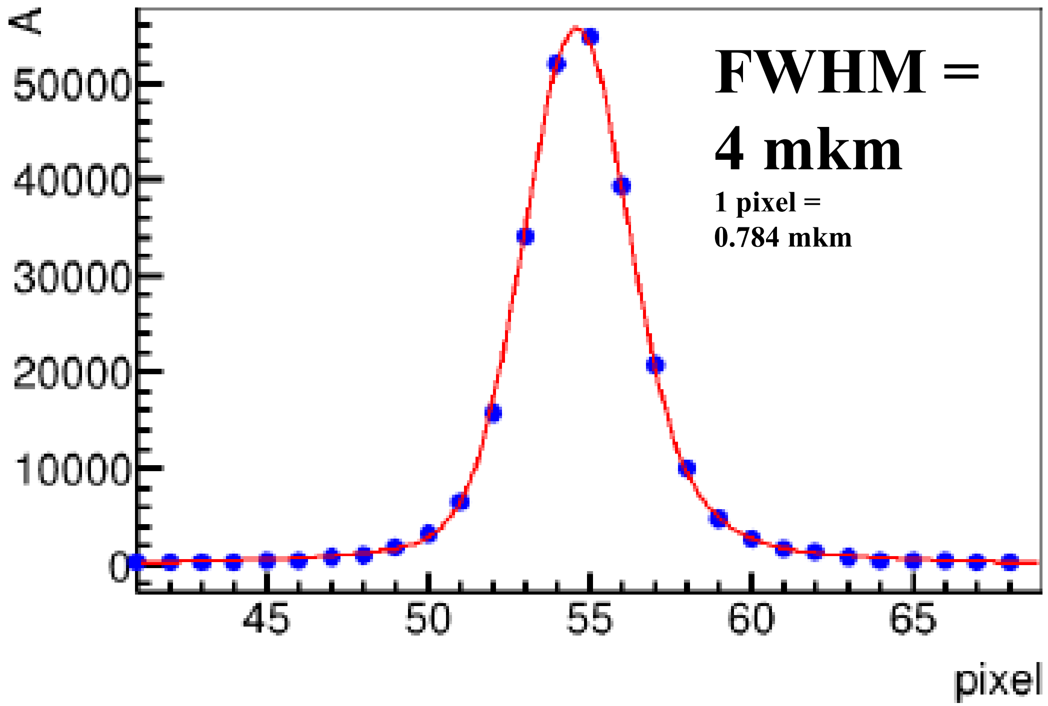


2. Thin CsI:Tl films: performance and properties (MTF)

The using of SU-8 refractive compound lens allows to obtain the approach to point spread function.

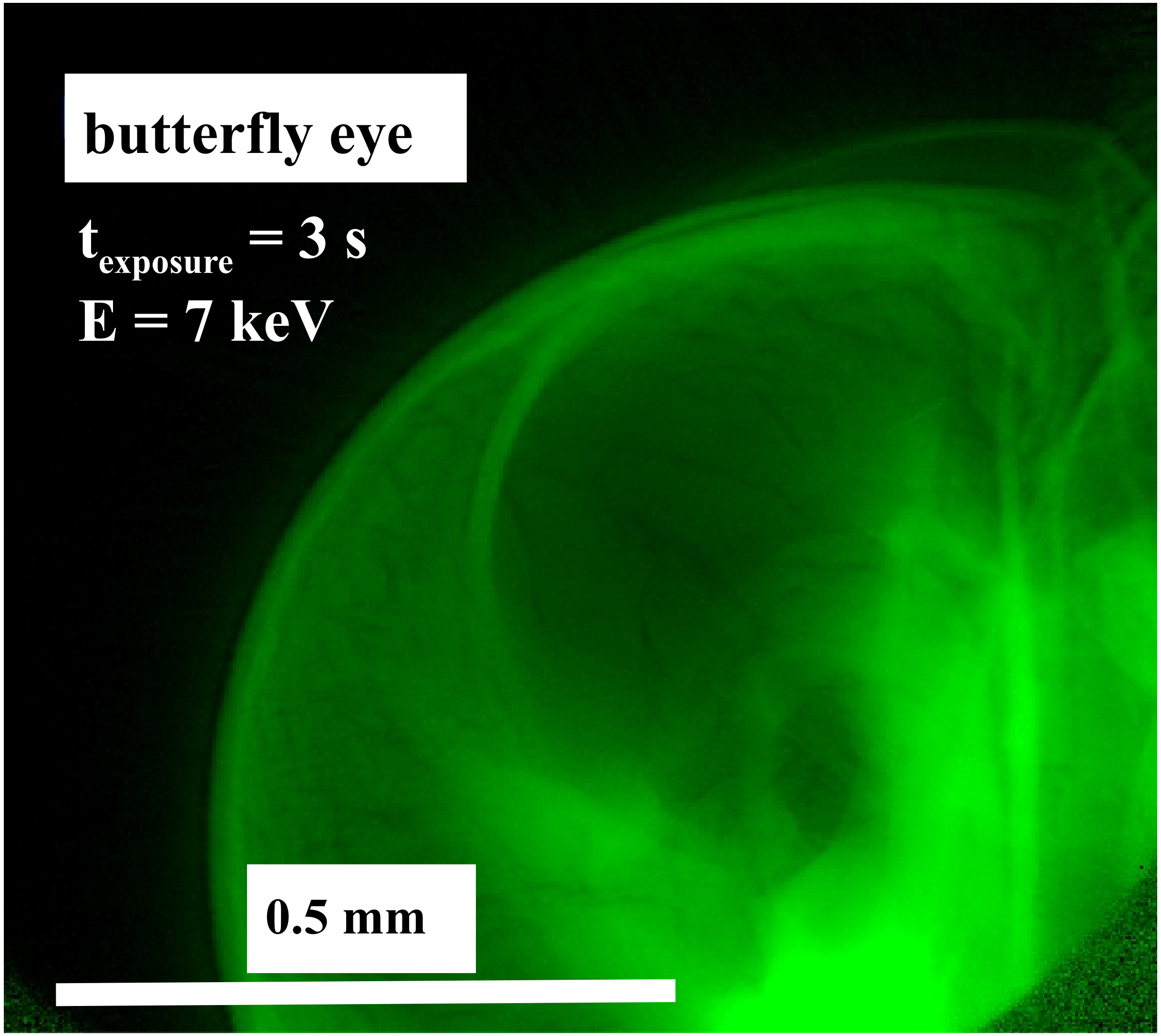
The focus on scintillator film





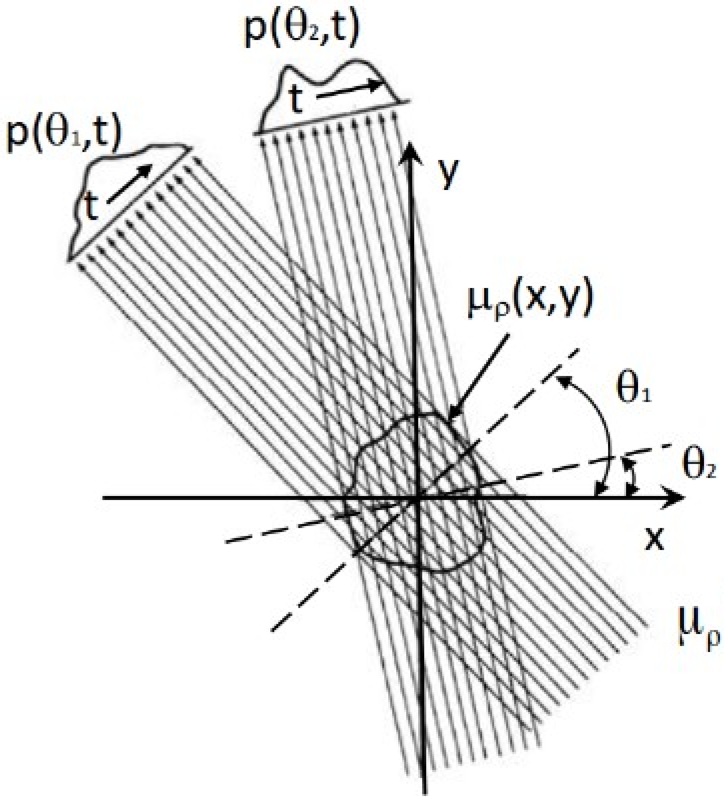
3. CsI:Tl films for X-ray Imaging

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



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.

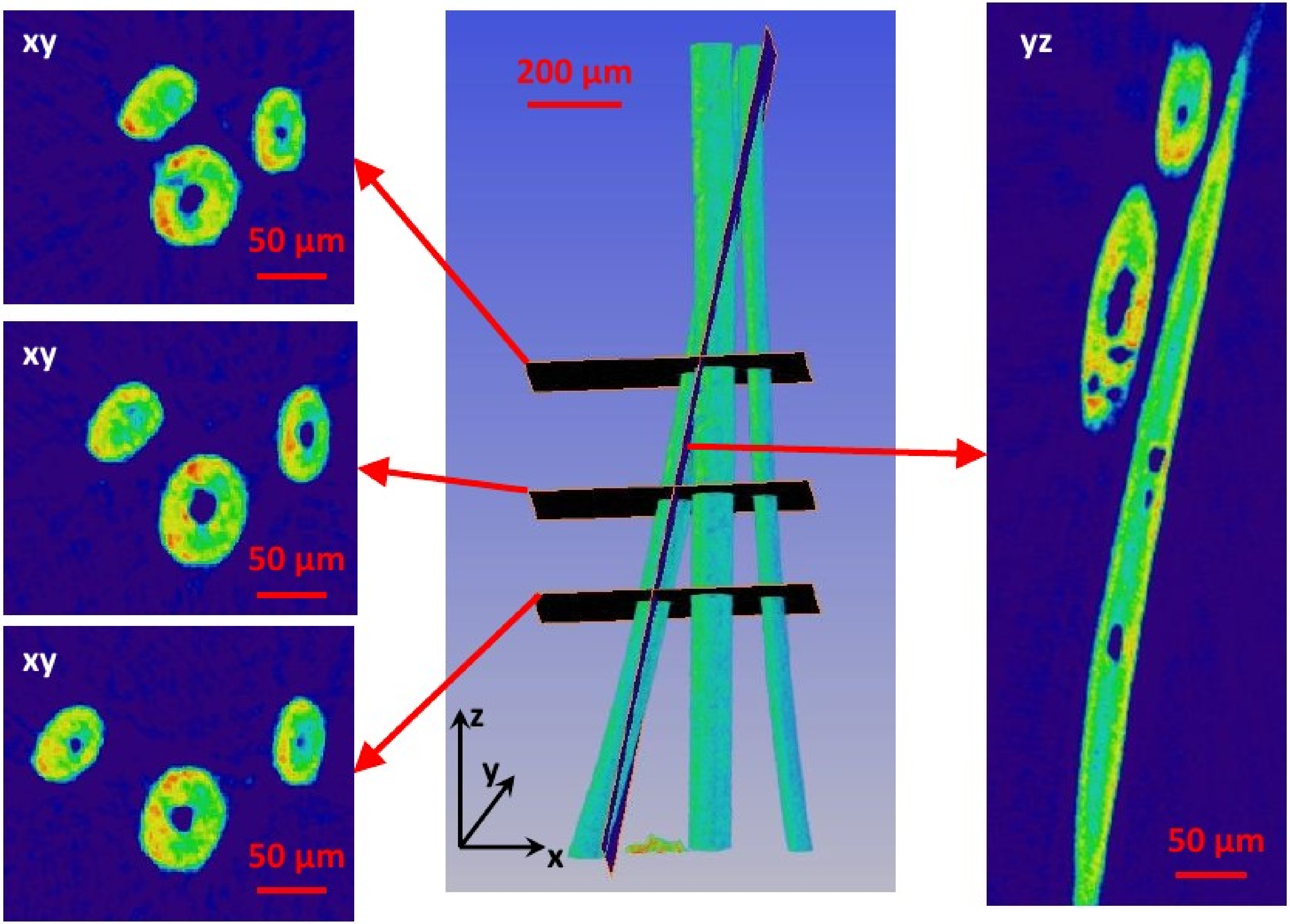
Теорема о центральном сечении

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

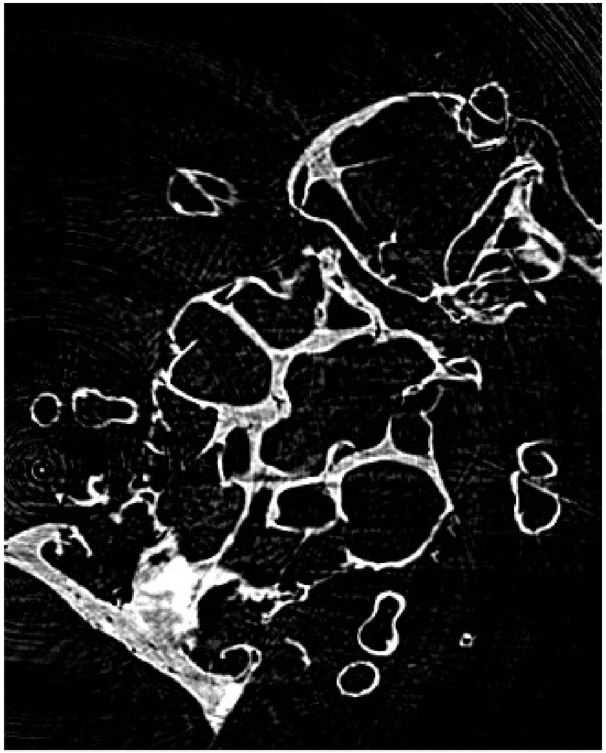
$$\mu_\rho(x,y) = \frac{1}{4\pi^2}\iint \omega P(\omega,\theta) e^{i\omega(x\cos\theta + y\sin\theta)} d\omega d\theta$$

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.

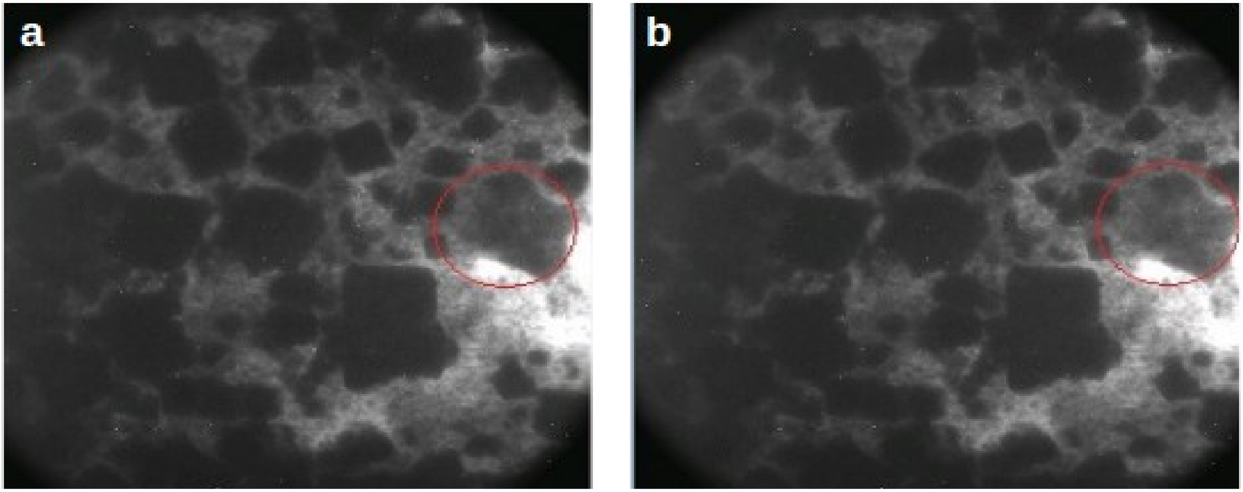


3. CsI:Tl films for X-ray Imaging

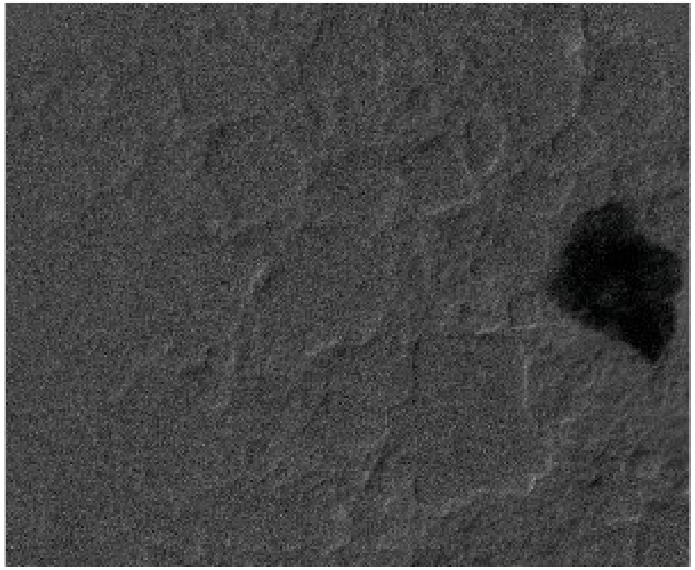


3D tomography of drosophila. E = 9 keV.
$N_{rotation}$ = 180. $T_{exposure}$ = 3 s.

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)



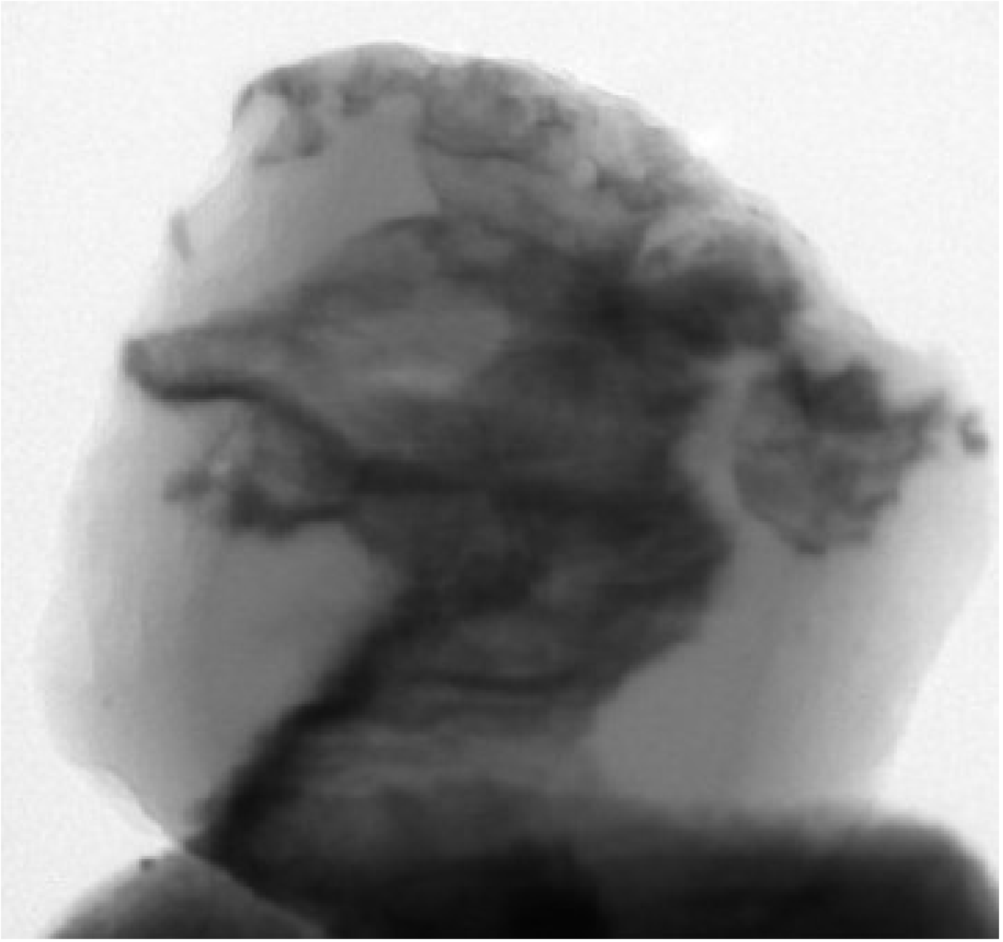
The difference Fig.a - Fig.b.

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

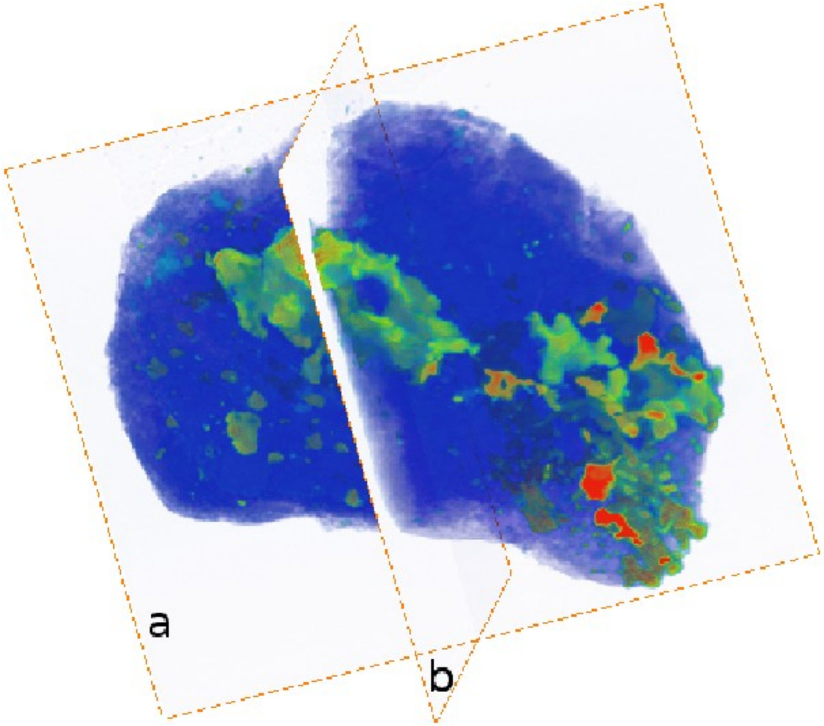
The imaging of dense objects using monochromatic X-ray beams



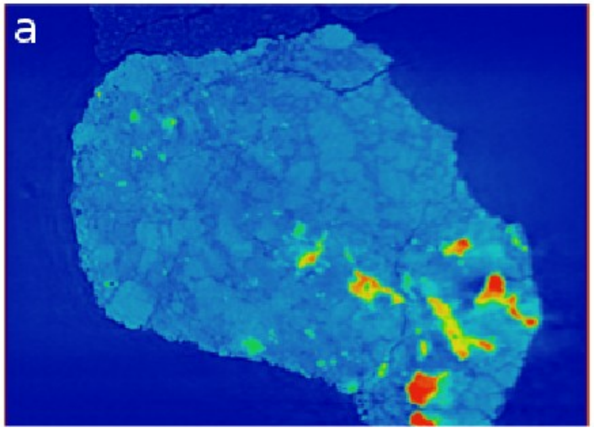
Diamond crystal topography

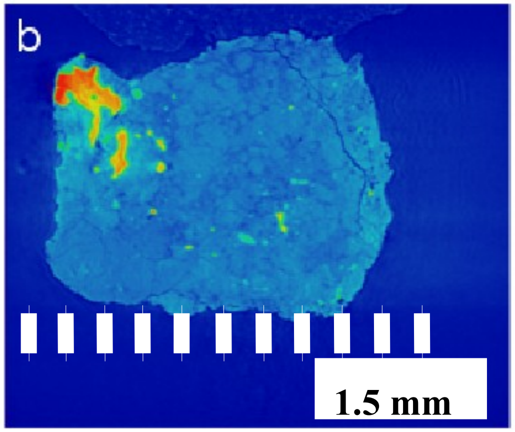
3. CsI:Tl films for X-ray Imaging

The tomography of dense objects using monochromatic X-ray beams



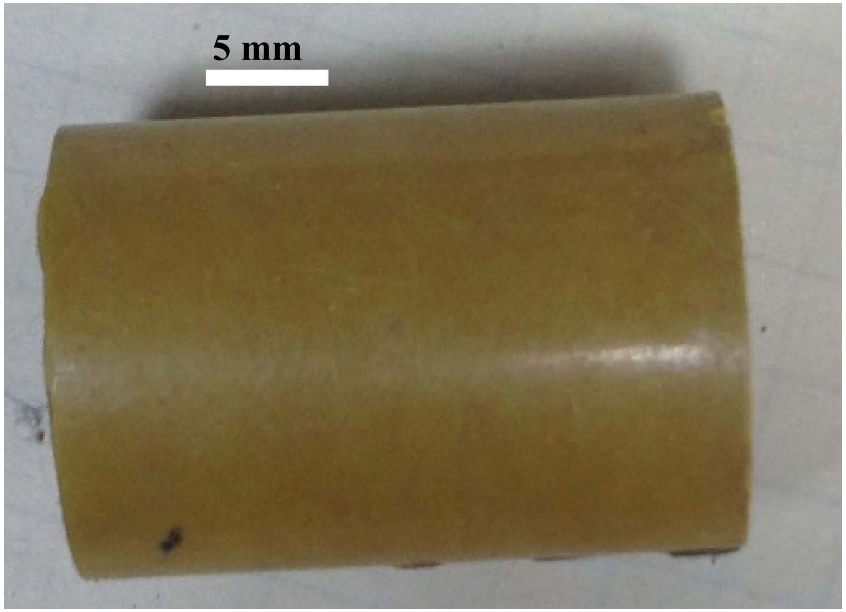
Chebarkul meteorite

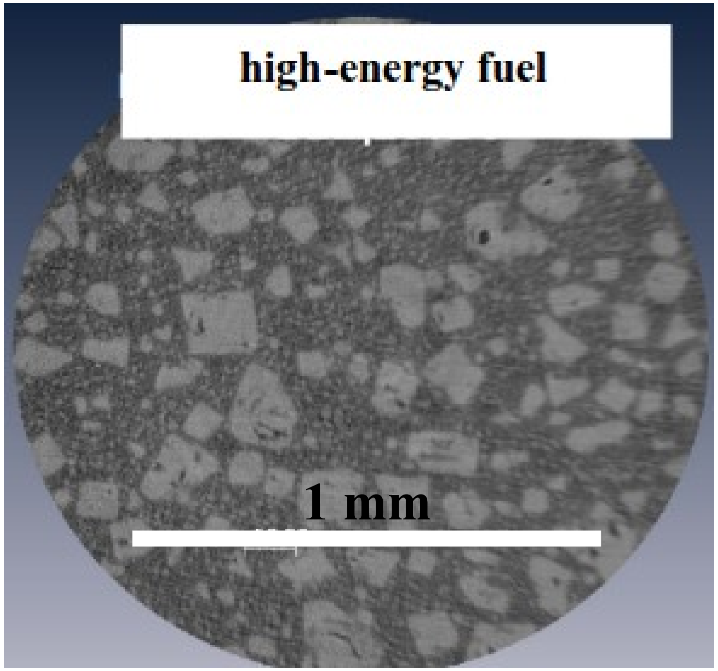




3. CsI:Tl films for X-ray Imaging

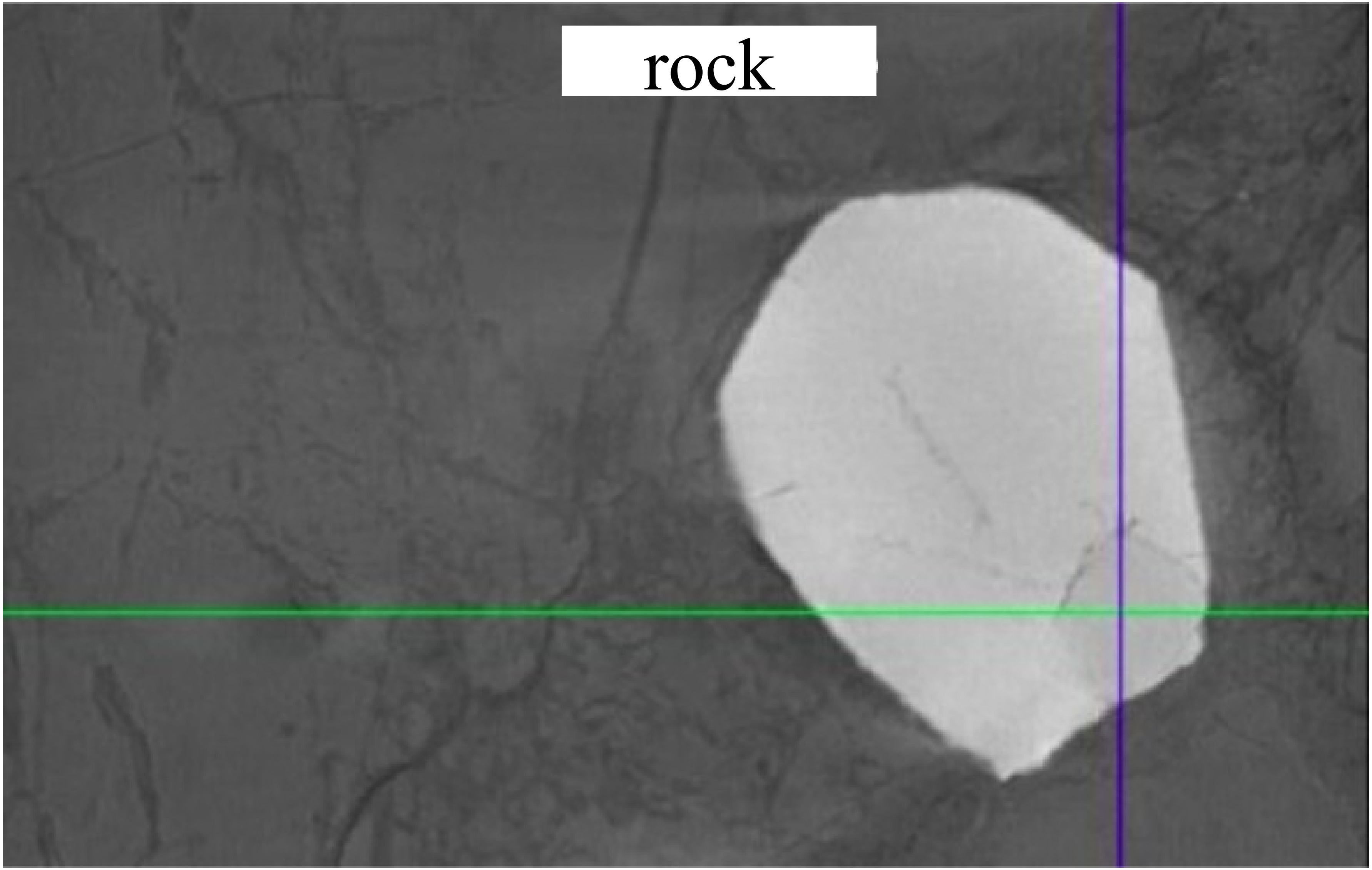
The local tomography of dense objects using monochromatic X-ray beams





3. CsI:Tl films for X-ray Imaging

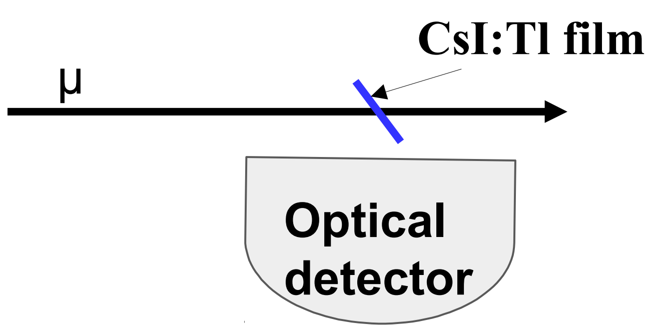
The local tomography of dense objects using polychromatic X-ray beams

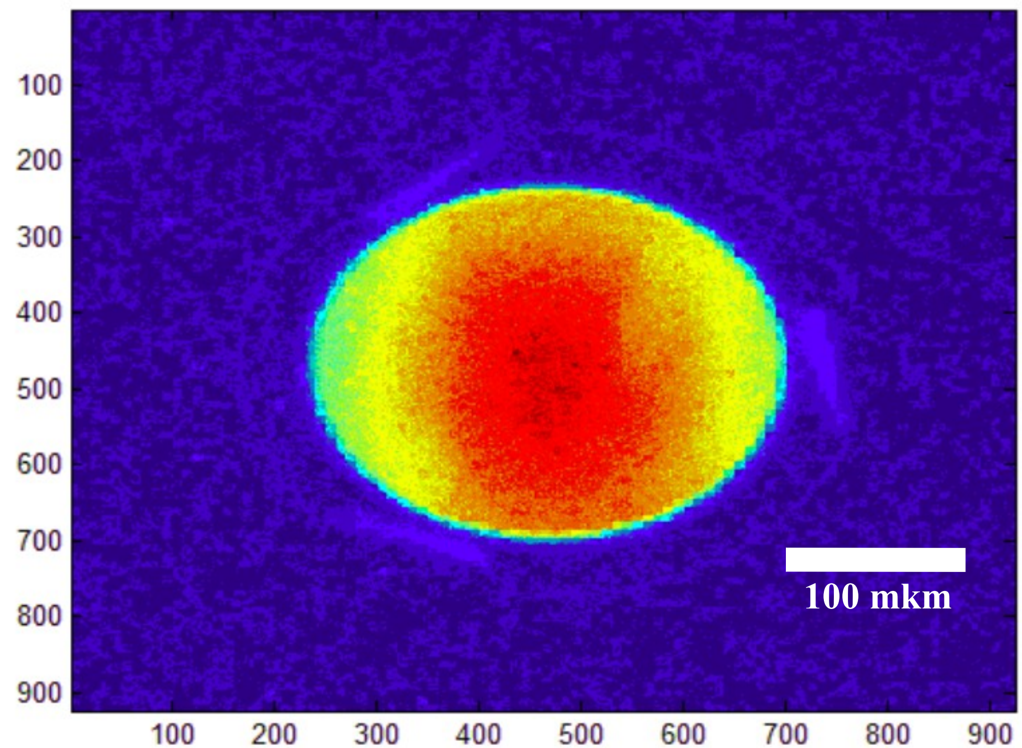


Other prospects

1. The registration of SR with high prcesion can be used for the monitoring of beam orbit (also Super c-τ, FCC and etc.). The time resolution is restricted by CsI:Tl decay time ~ 1 μs.

2. Thin CsI:Tl films deposited on Mylar substrates can be used for **non-destructive diagnostics of the spatial profiles of low energy beams of charged particles**





The profile of muon (28 MeV/c) beam of MEG experiment (may 2016 y.)

The method allows to perform the beam monitoring simultaneously with experimental data acquisition.

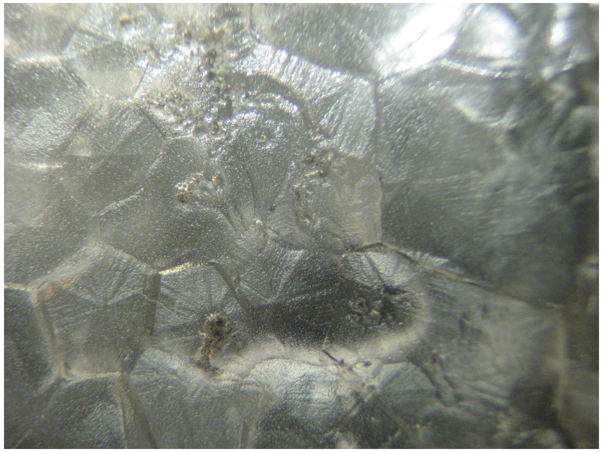
4. Conclusion

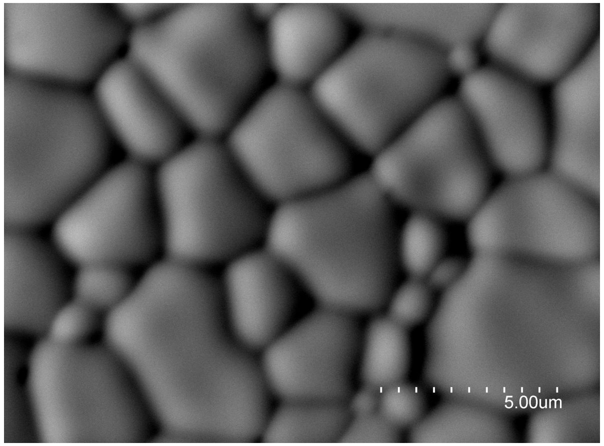
➤ **The methodics of performance of thin CsI:Tl films was developed.**

➤ **The relationship between the morphology of deposited layers and the characterization of the film was presented.**

➤ **The post-deposition treatment by carbon leads to significant improvement of spatial resolution.**

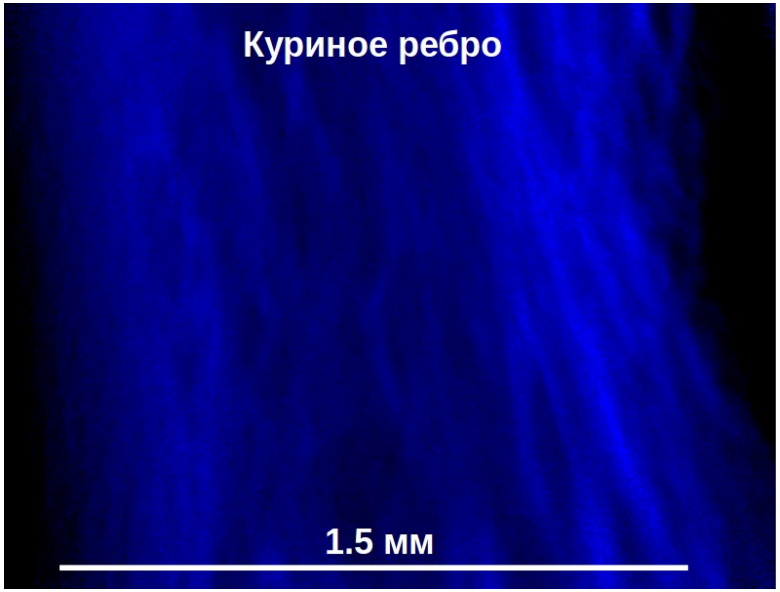
➤ **All X-ray radiographic methods can be employed with the films in polychromatic and monochromatic modes from 10 mkm of biological tissue up to 5 cm of dense rock.**

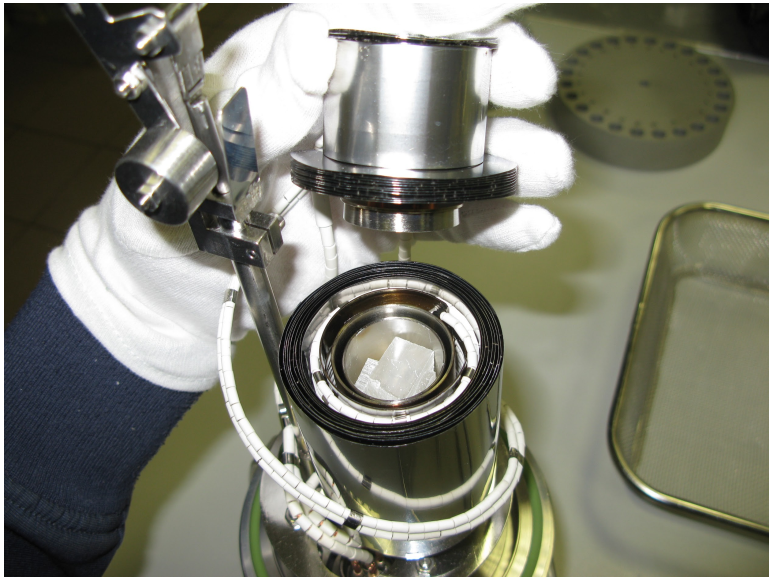




Thank you for your attention!

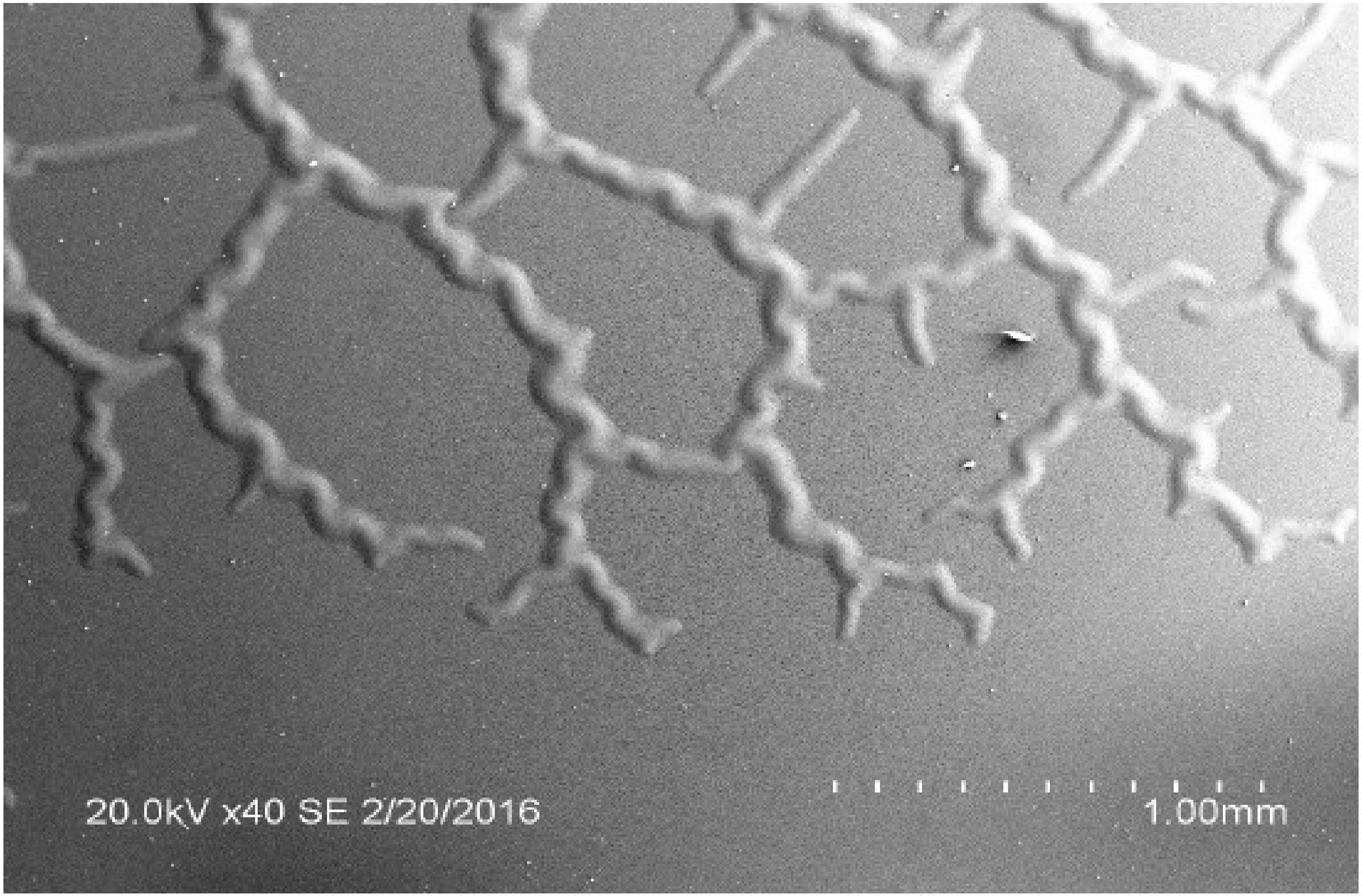
If you are interesting in precise imaging we are open for interaction.



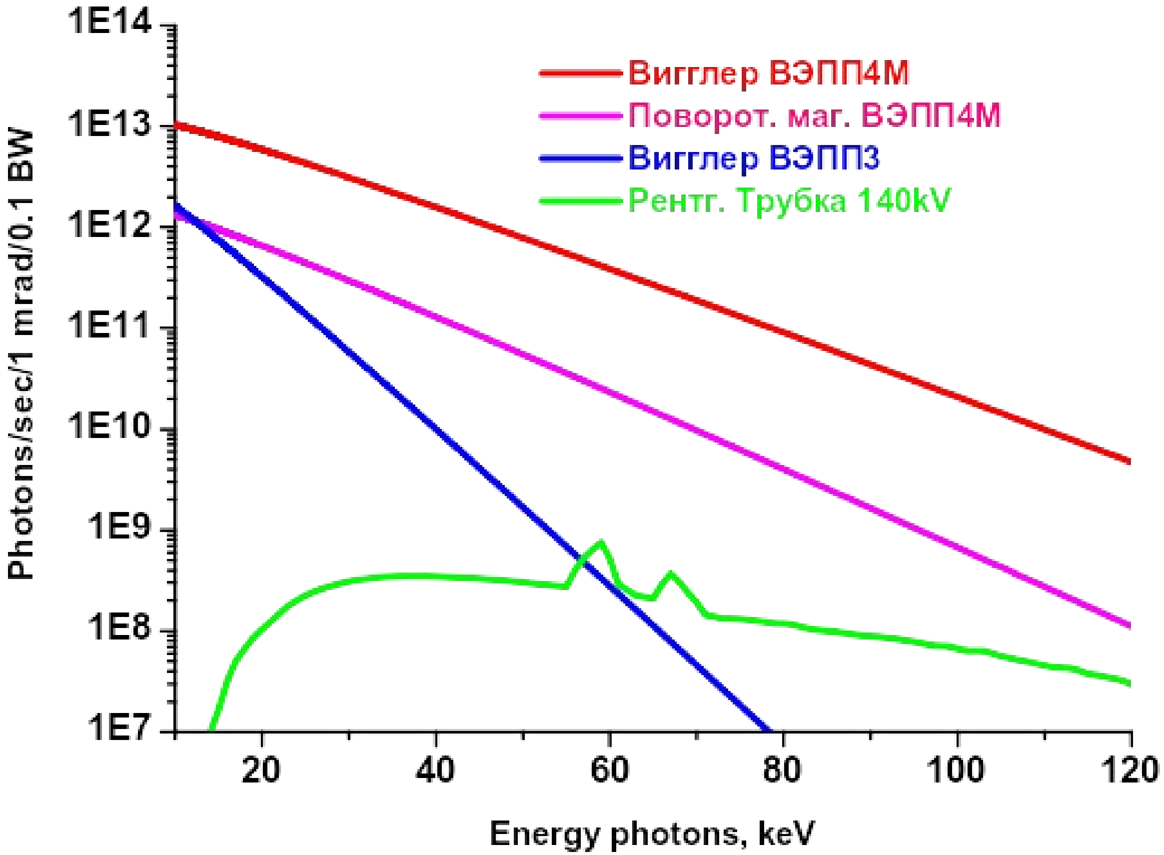


3. CsI:Tl films for X-ray Imaging

Destruction scintillator surface caused by ozone produced by interaction polychromatic SR with air.



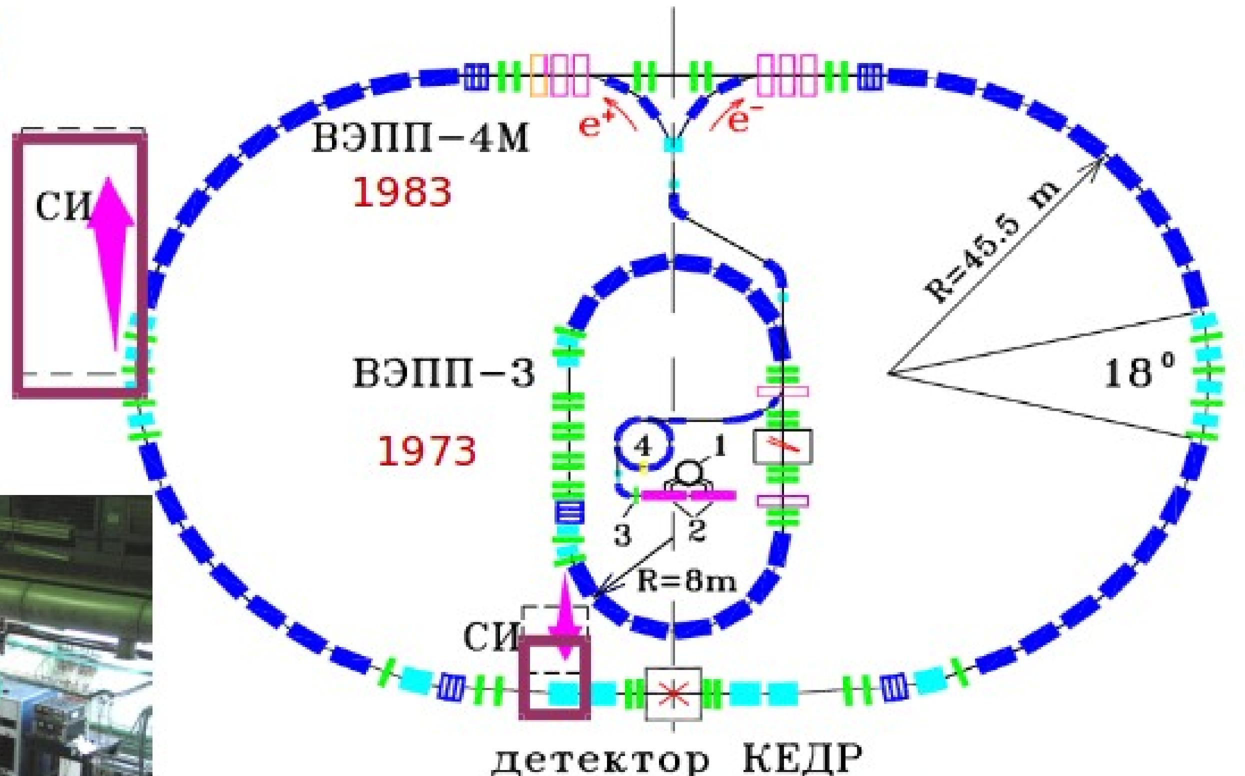
Источники СИ в ИЯФ СО РАН



Широкий энергетический спектр **[5-100] кэВ** позволяет диагностировать объекты разной толщины, начиная от ~ **10 мкм биологической ткани** и заканчивая ~ **5 см горной породы**.

Источники СИ в ИЯФ СО РАН

Инжектор:
1 — Гиротрон (430 МГц)
2 — Линейный ускоритель (50 МэВ)
3 — Электрон-позитронный конвертор
4 — Синхротрон Б-4 (350 МэВ)



2. Thin CsI:Tl films: performance and properties

An X-ray fluorescence analysis allow to measure the concentration of Tl relatively to Cs: