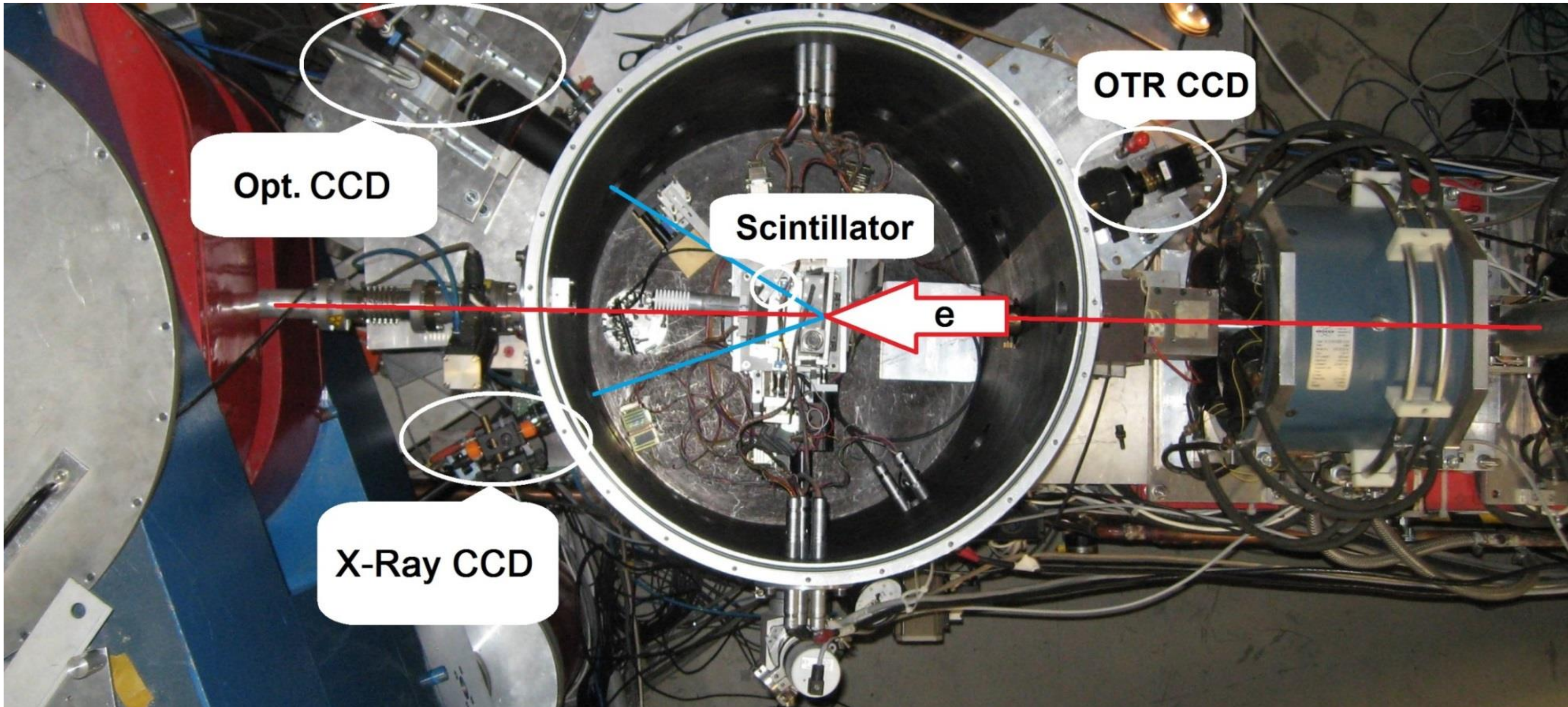
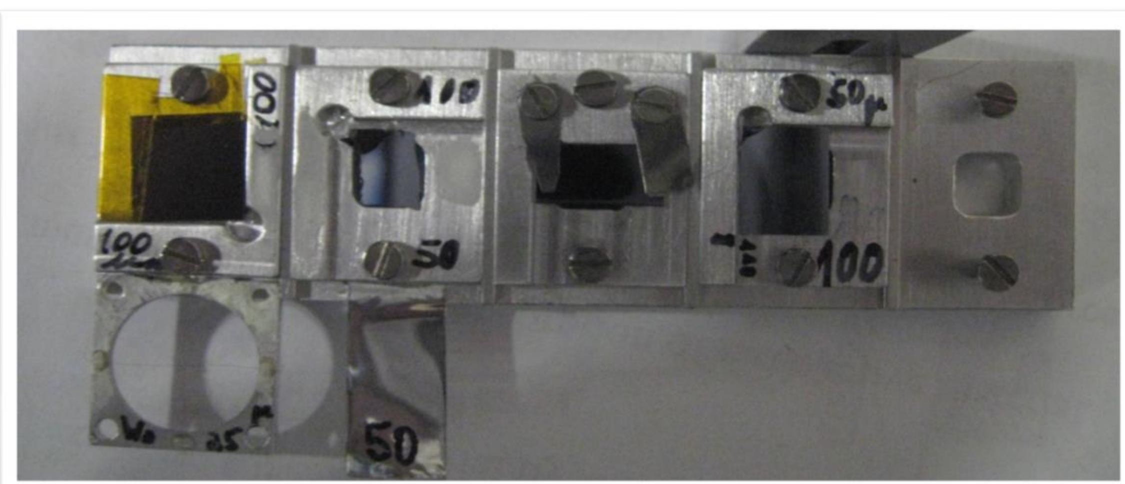
To measure the longitudinal and transverse beam size of XFEL using CPXR & PXR

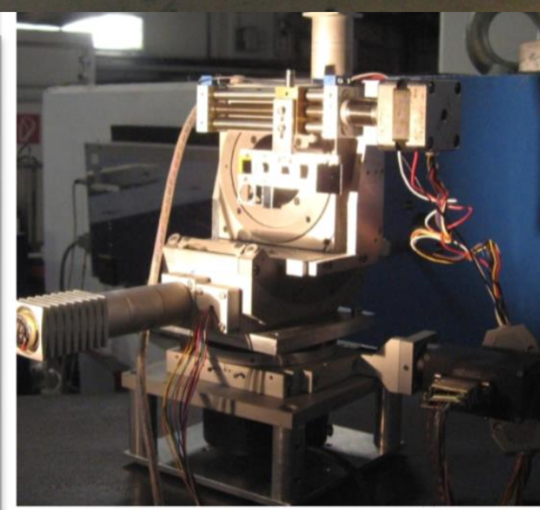
First step: *the first results of experiment on video observation of parametric X-ray radiation from electrons with energies of 855 MeV in a silicon crystal, and a comparison with the simulation results.*

[Kube G., Behrens C., Gogolev A.S., Popov Y.A., Potylitsyn A.P., Lauth W., Weisse S. **Investigation of the applicability of parametric x–ray radiation for transverse beam profile diagnostics** [Electronic resorces] // 4th IPAC: Proceedings, Shanghai, May 12-17, 2013. - Geneva: CERN, **2013** - p. 491-493.]

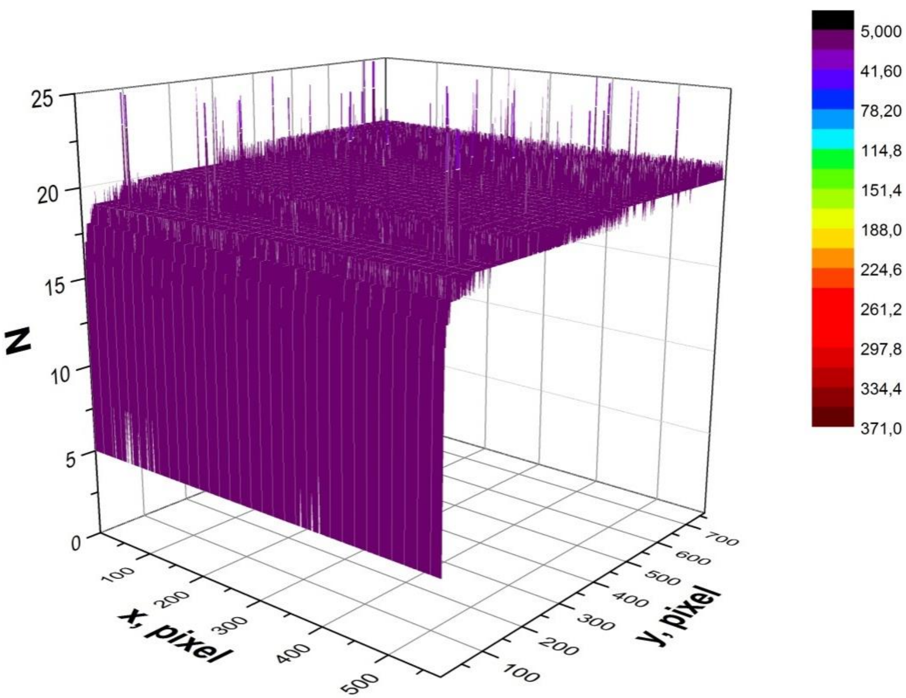
Setup

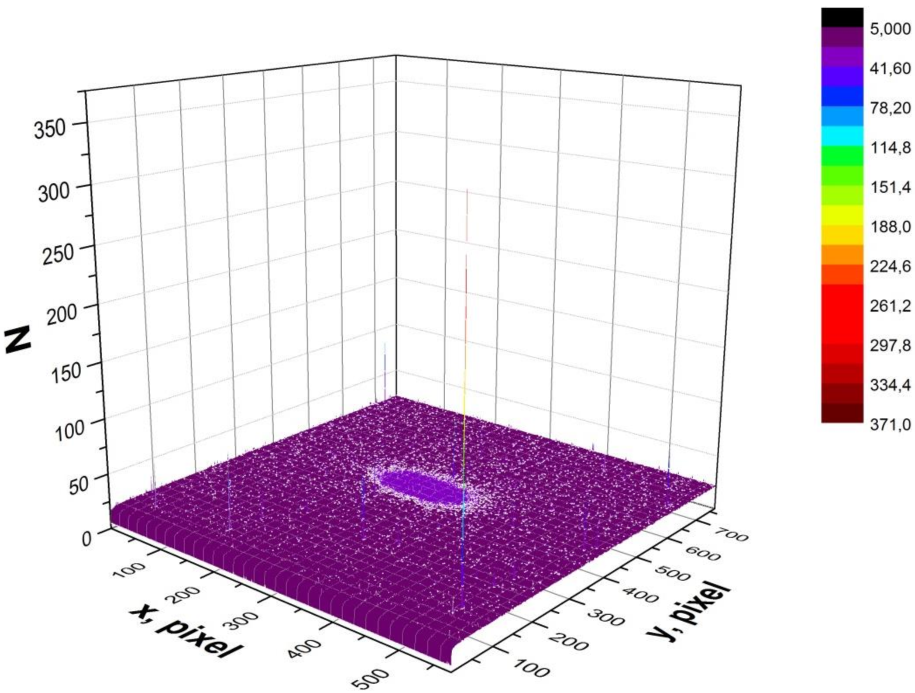






Output data from X-Ray CCD



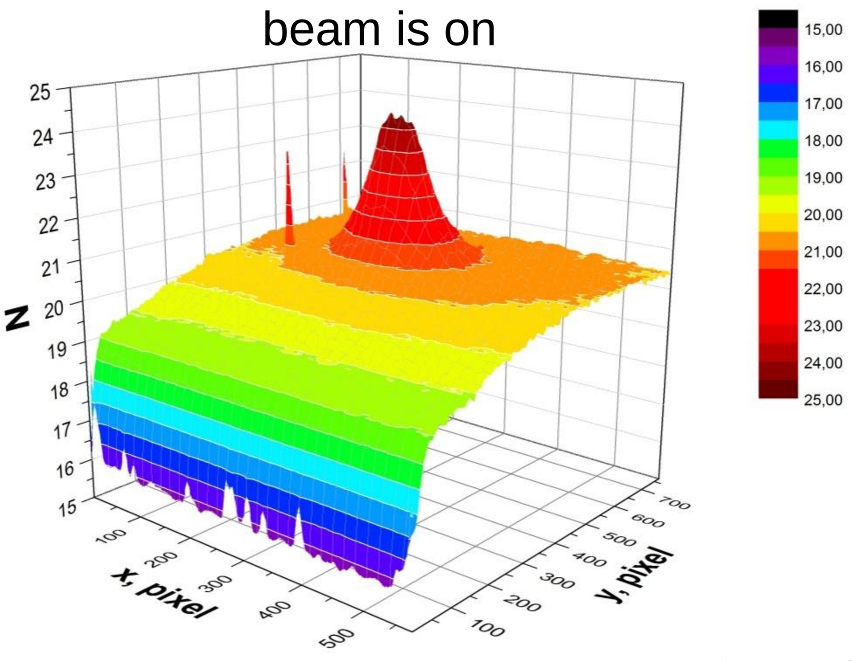


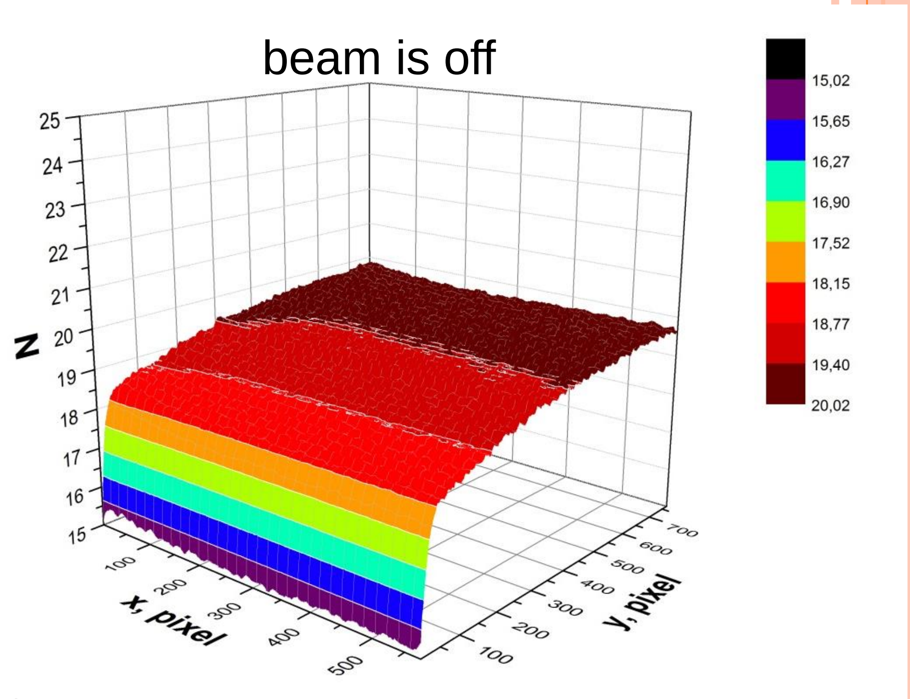
The sum of 100 frames **574x768 px**

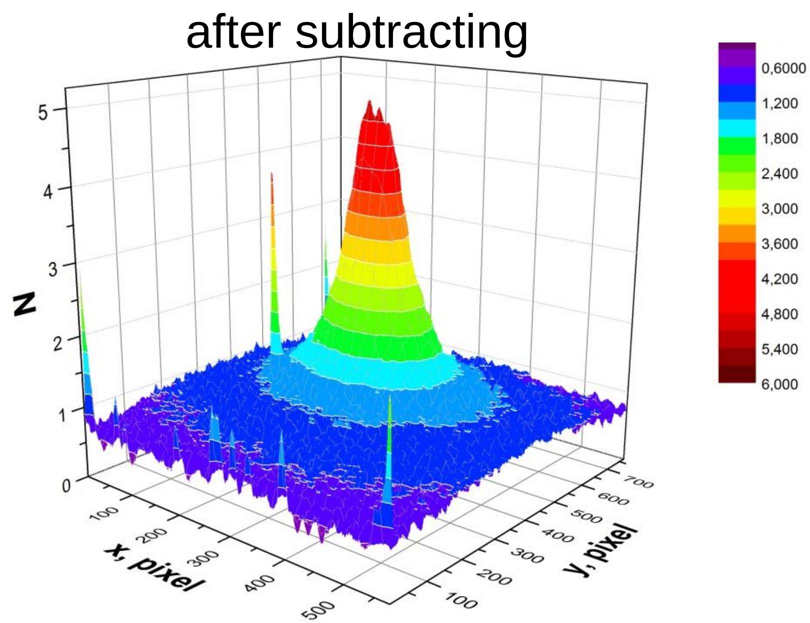
1 px = 26x26 мкм

15x20 мм

THE RESULT OF PROCESSING





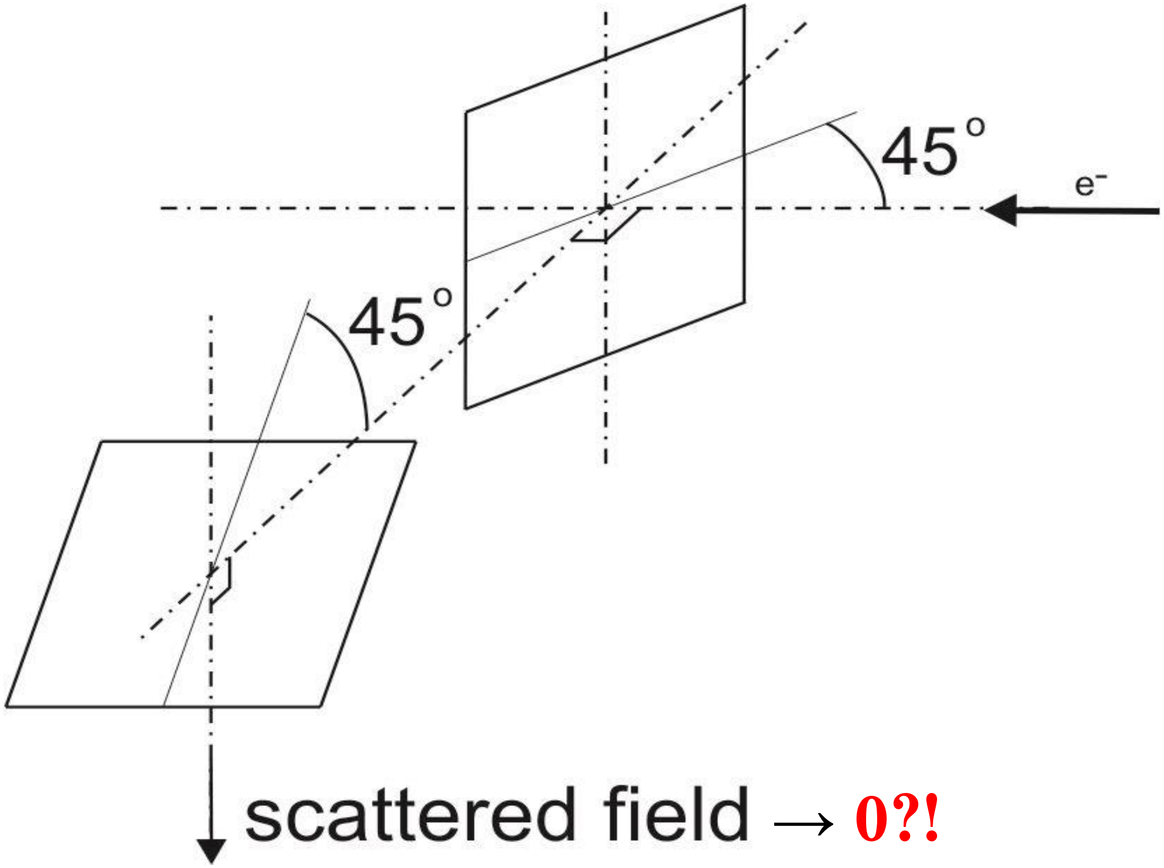


Next step: CPXR for attosecond bunch length diagnostics

- It is proposed to use coherent radiation diagnostics (CRD) based on polarization radiation in X-ray range as a tool for attosecond bunch length diagnostics.
- Compared to the intensity of incoherent emission, the coherent part is additionally amplified by the number of particles contributing to coherent emission process. For modern **FELs**, the amplification factor for a full coherent emission would amount to $\mathbf{10^{10}}$
- On a timescale of **1-2 years**, the observation of coherent polarization radiation in X-ray range can become feasible at the European **XFEL.**
- For this purpose it is proposed to design and build a test experiment behind the FEL undulator section of the E-XFEL and to study the emission process of CR.

Problem is registration CR

It is proposed to measure a scattered field



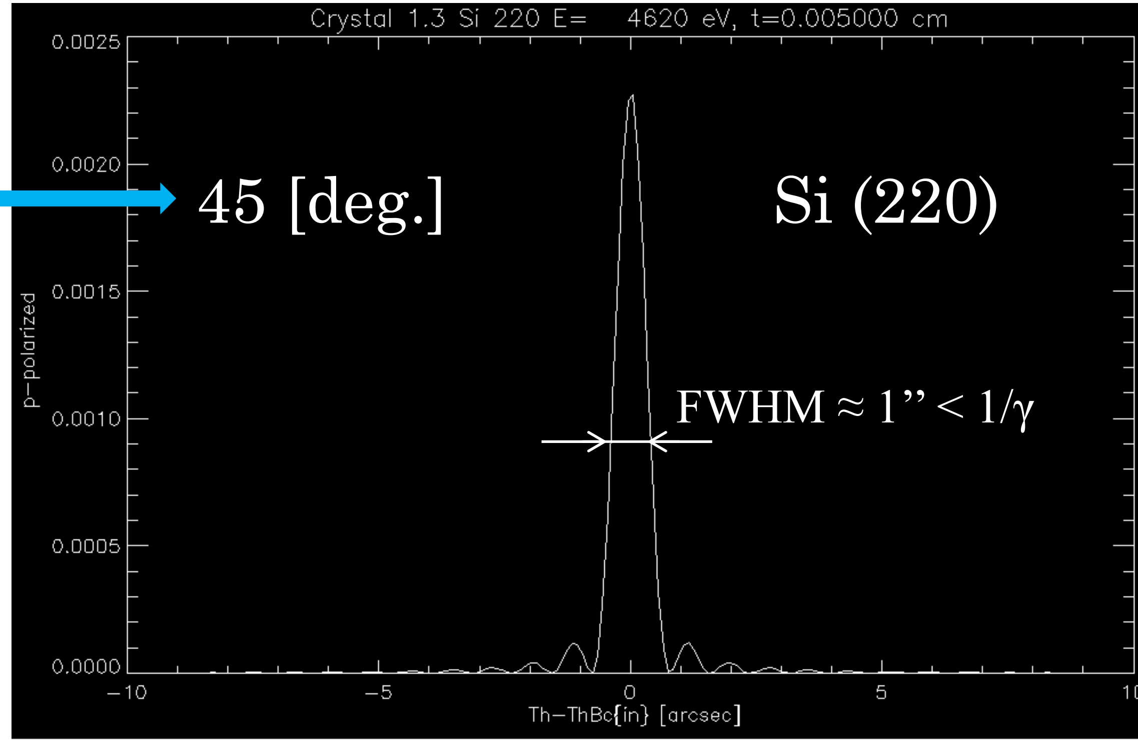
Intensity may be about 10^4 photon/sec

Scattered field intensity estimation

p-polarized radiation of real diffracted photon on single crystal

Decreased intensity is about into 10^3 times

After a second crystal is not expected to decrease of this polarization



But kill s-polarization

And after of tow crystals we will expect <u>coherent factor</u> of $10^{10}10^{-5\div-3}=10^{5\div7}$

Upper level of CPXR intensity may be $10^{-5\div-3}$ ph/bunch; $10^{1\div3}$ ph/train; $10^{2\div4}$ ph/sec. (PXR $10^{-7\div-5}$ ph/sec)

Tomsk Polytechnic University

DETECTOR MODU*PIX*

High speed spectral camera

Sensor Material:	Si
Sensor Thickness:	675 µm
Sensitive Area:	14x14 mm
Readout Speed:	**850 frames/s**
Vacuum compatible:	Yes
Number of Pixels:	256 X 256
Pixel Pitch:	**55 µm**
Pixel Mode of Operation:	Counting, Time-over-Threshold, Time-of -Arrival
Threshoid Step Resolution:	0.1 keV
Energy Resolution:	0.8 keV (THL) and 2 keV (ToT)
Pixel Photon Counting Speed:	**1e5 photons/s/pixel**
Readout Chip:	Timepix
Resolution:	9 lp/mm

Hard X–ray Laue monochromator

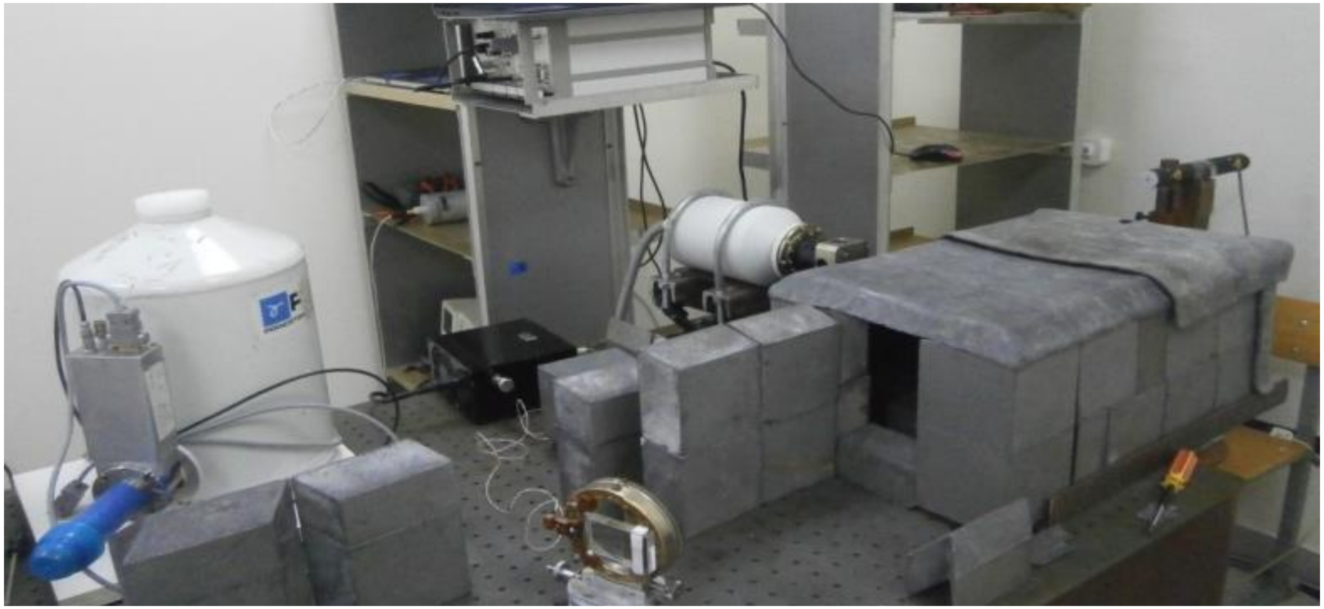
PROPOSAL

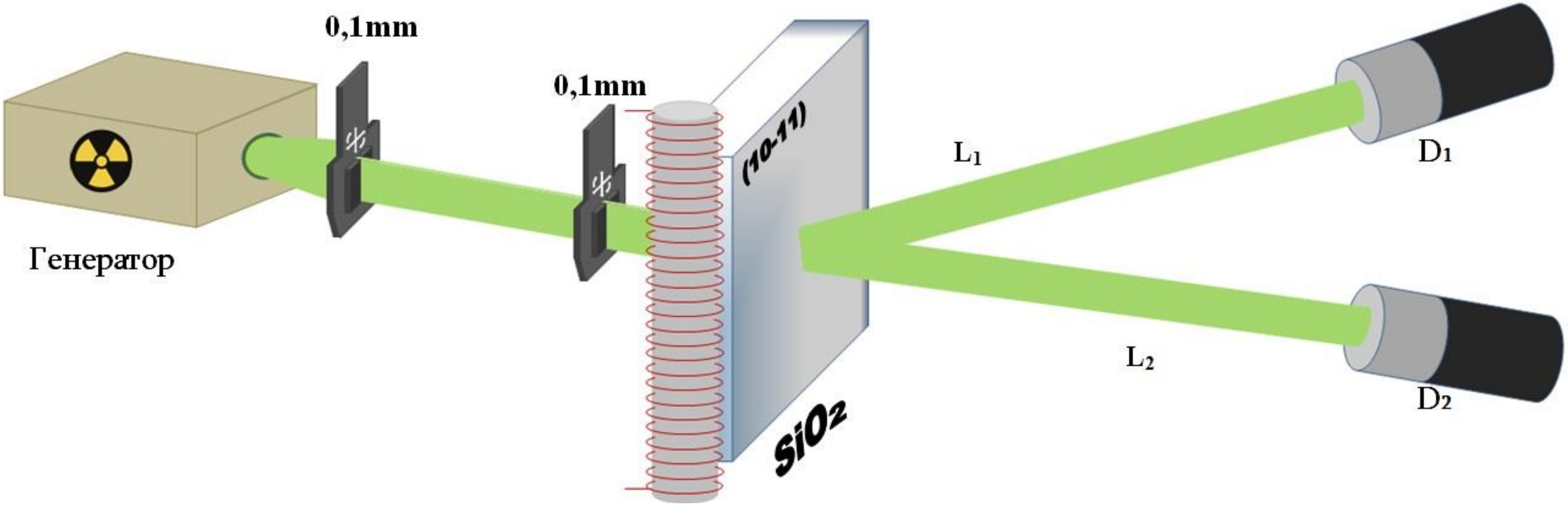
To experimental studies of X-ray diffraction from reflecting atomic planes (10-1 1) of X-cut quartz single crystal in Laue geometry influenced by the temperature gradient.

For this at the X-ray optics lab. has been constructed setup based on:

- **RAP-150MN,** U=120 kV and I=95 μA
- **crystal quartz** (30x30 mm^2) with t=9 mm
- **energy dispersive silicon spectrometer**

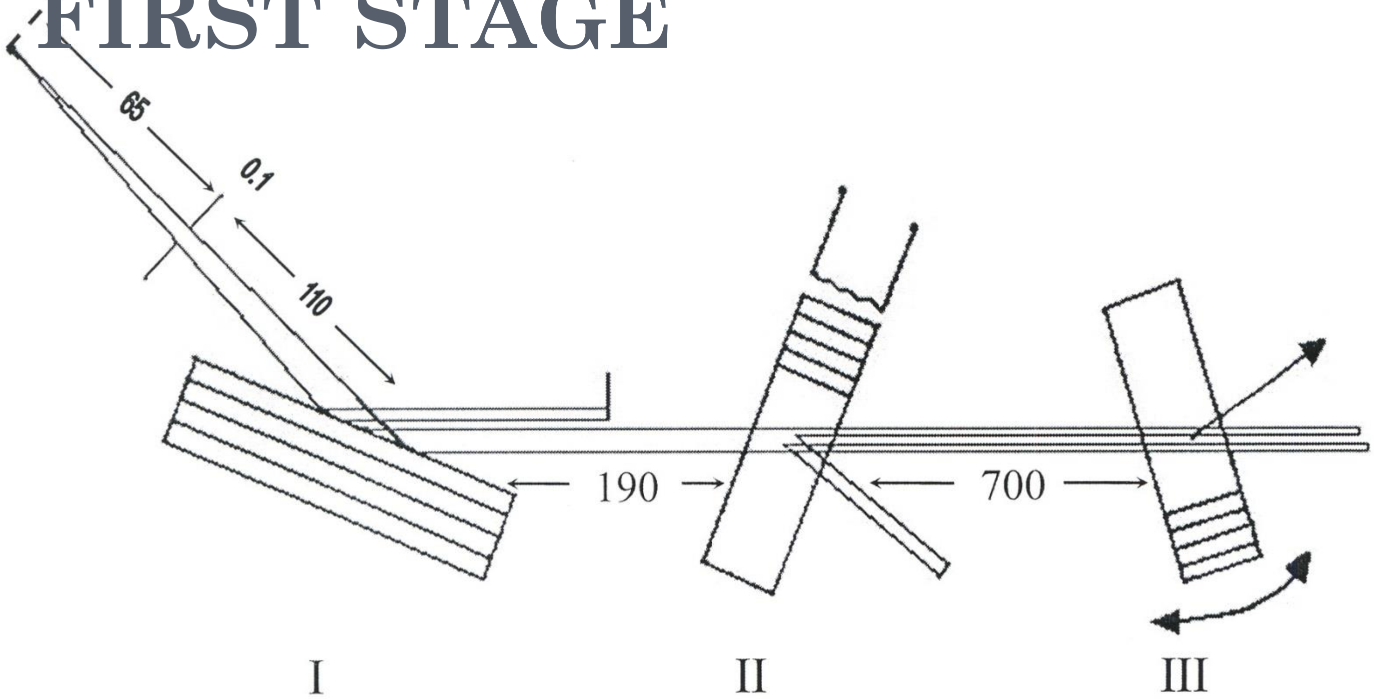
Experimental setup





Experimental scheme

The first stage



A typical experimental scheme from a number works on investigation of the external influences impact on the X-ray diffraction, for example:

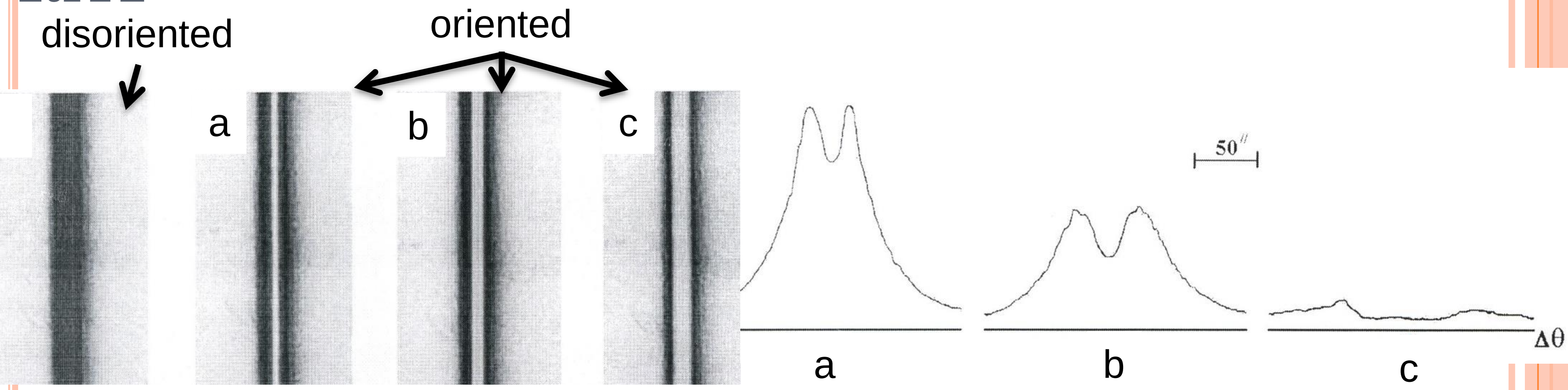
[1] A.R. Mkrtchyan, M.A. Navasardian and V.K. Mirzoyan//Technical Physics Letters 8, 11 (**1982**) 677 (in Russian)

[2] A.R. Mkrtchyan, M.A. Navasardian, R.G. Gabrielyan, L.A. Kocharian and R.N. Kuzmin, Solid State Commun., 59 (**1986**) 147

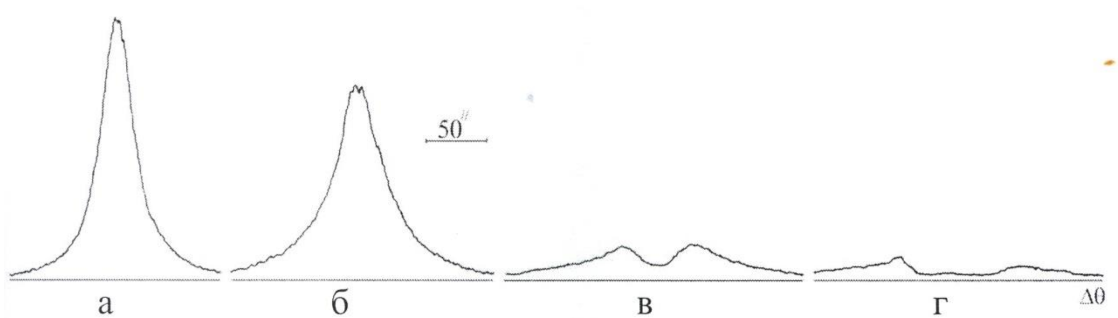
[3] V.R. Kocharyan, R.Sh. Aleksanyan, K.G. Truni//Journal of Contemporary Physics, **2010**, V. 45, No.4, pp. 190–194

………..

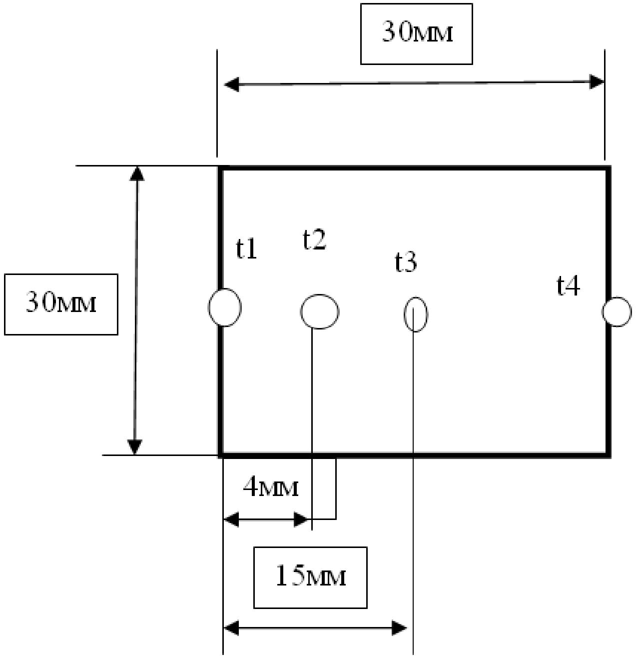
Effect of temperature gradient on X-ray

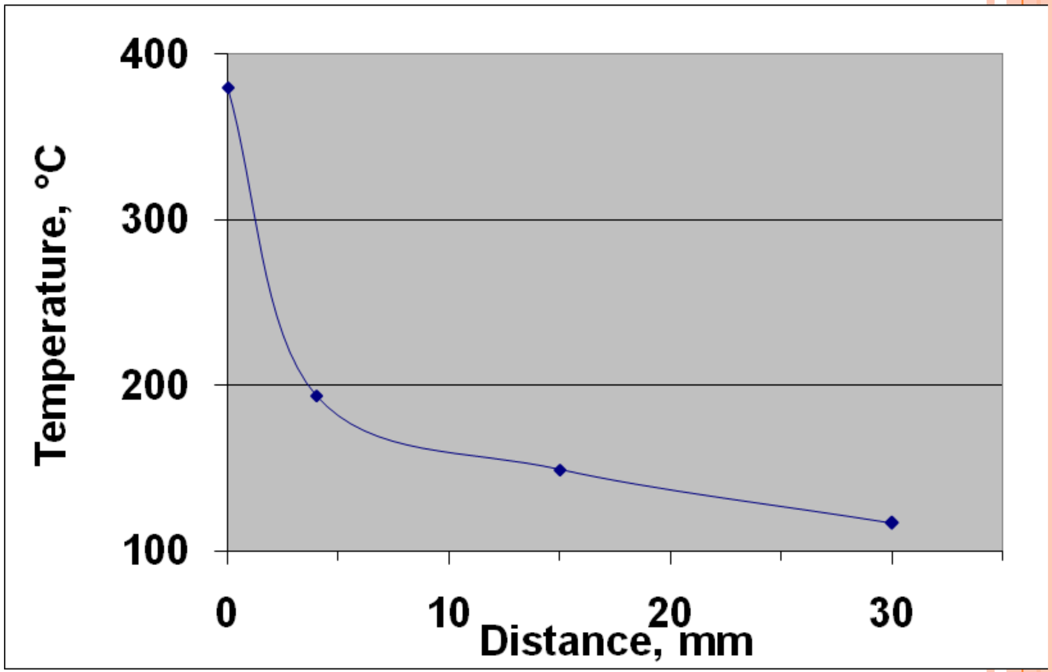


Cross sections and rocking curves of passing monochromatic X-ray beam in complete transfer mode under the influence of the temperature gradient for different crystal thickness: a) t=1.4 mm; b) t=2.8 mm; c) t=3.5 mm

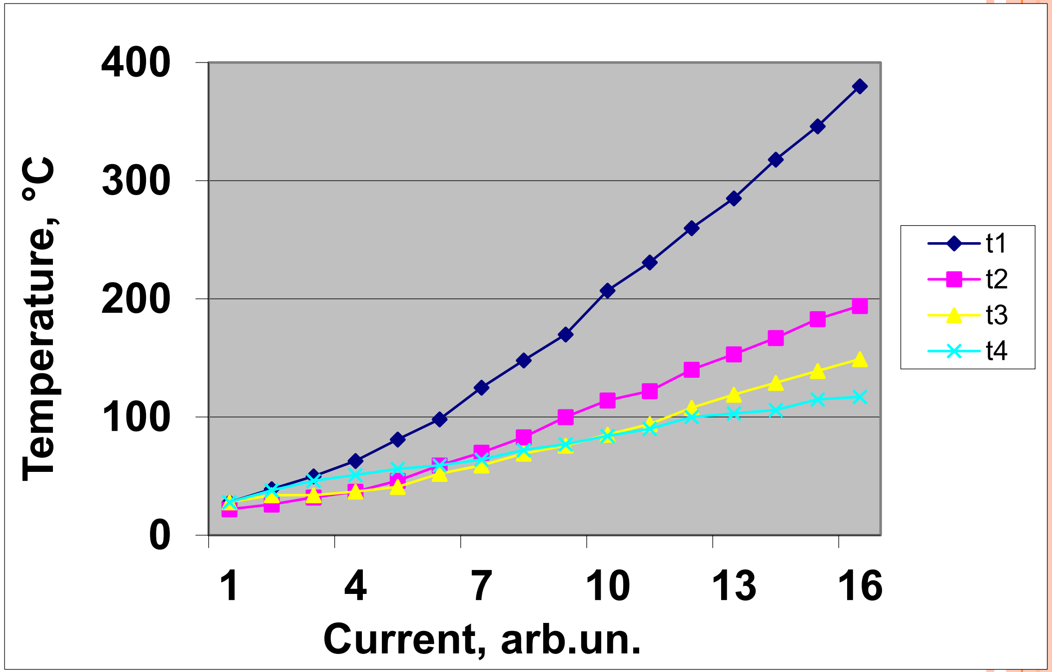


Rocking curves depending on the temperature for the thickness t=3.5 mm:
a) $\Delta T/\Delta X=0$ deg/cm; b) $\Delta T/\Delta X=15$ deg/cm; c) $\Delta T/\Delta X=35$ deg/cm; d) $\Delta T/\Delta X=70$ deg/cm.



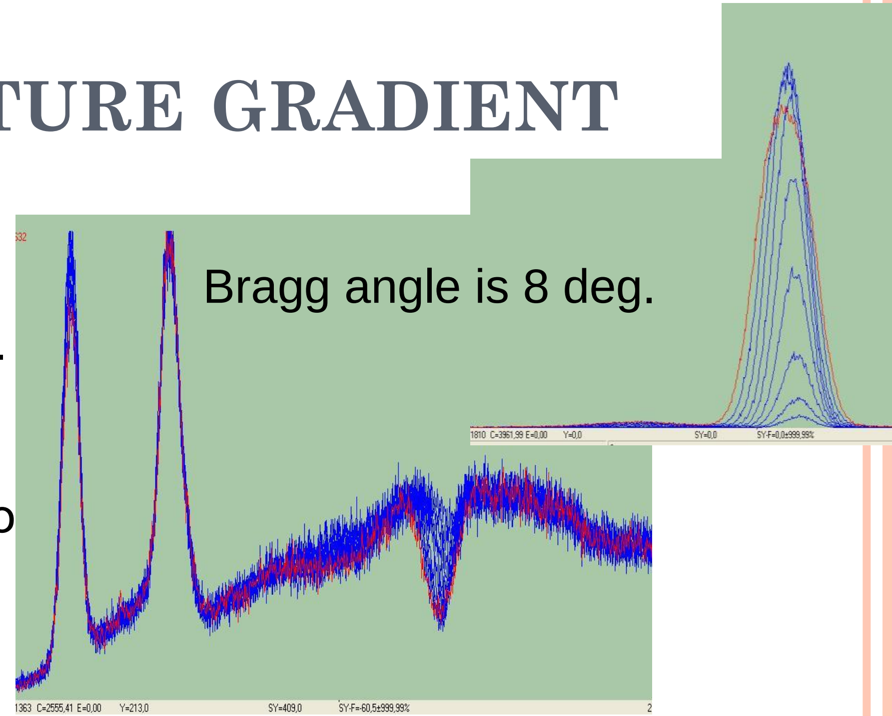


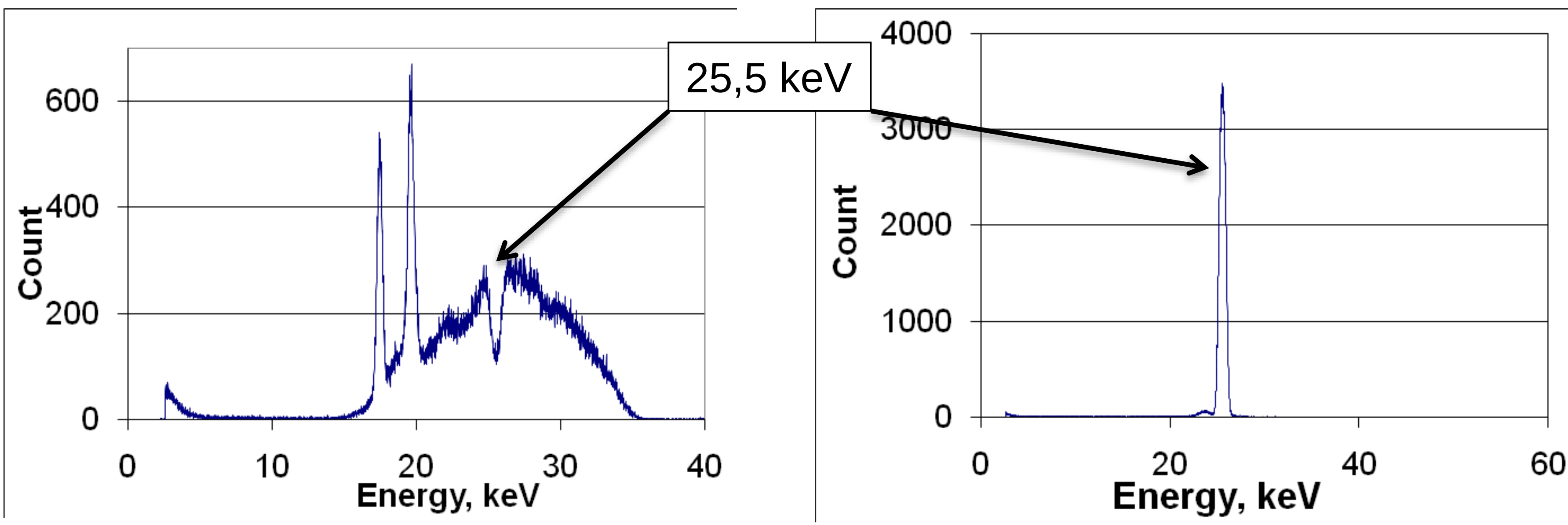
Temperature distribution on the crystal surface



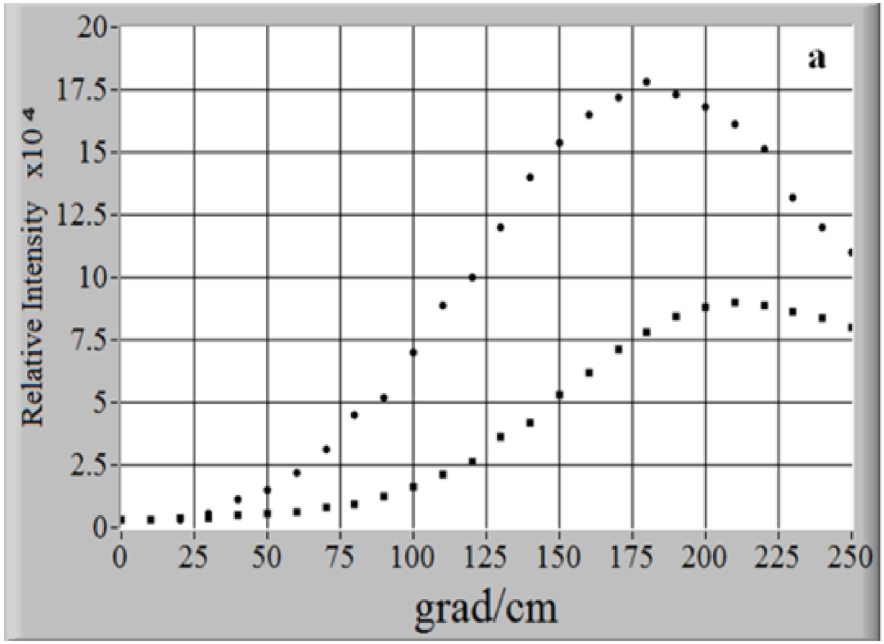
Effect of temperature gradient

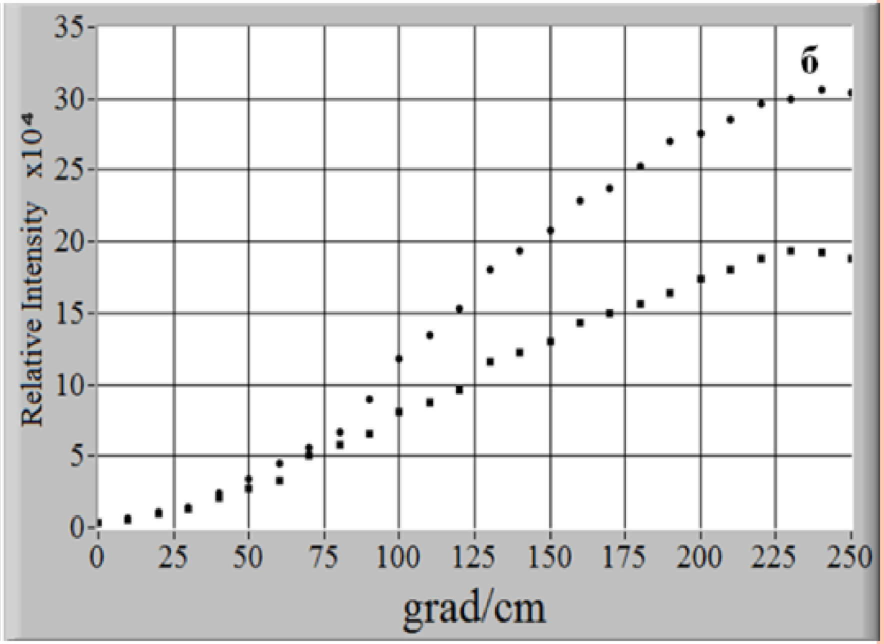
Наблюдение эффекта «переброски» в зависимости от температурного градиента. Разогрев от 23 град до 400 град. Интенсивность отраженного излучения в Лауэ геометрии возрастает на 2 порядка по сравнению с однородным температурным режимом кристалла.





The intensity of the reflected X-rays on the magnitude of the temperature gradient

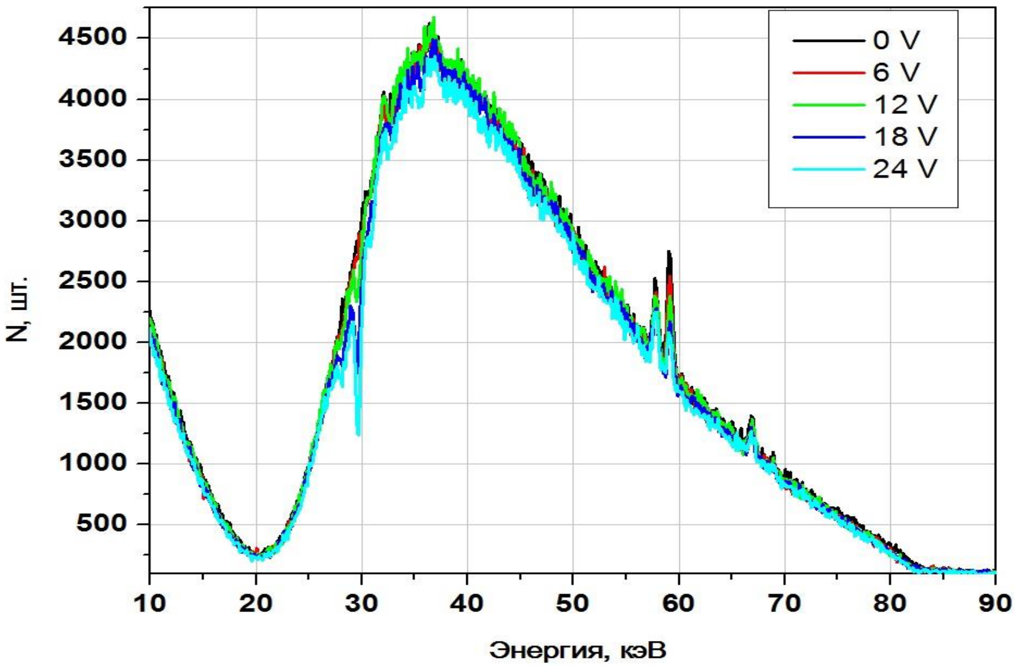


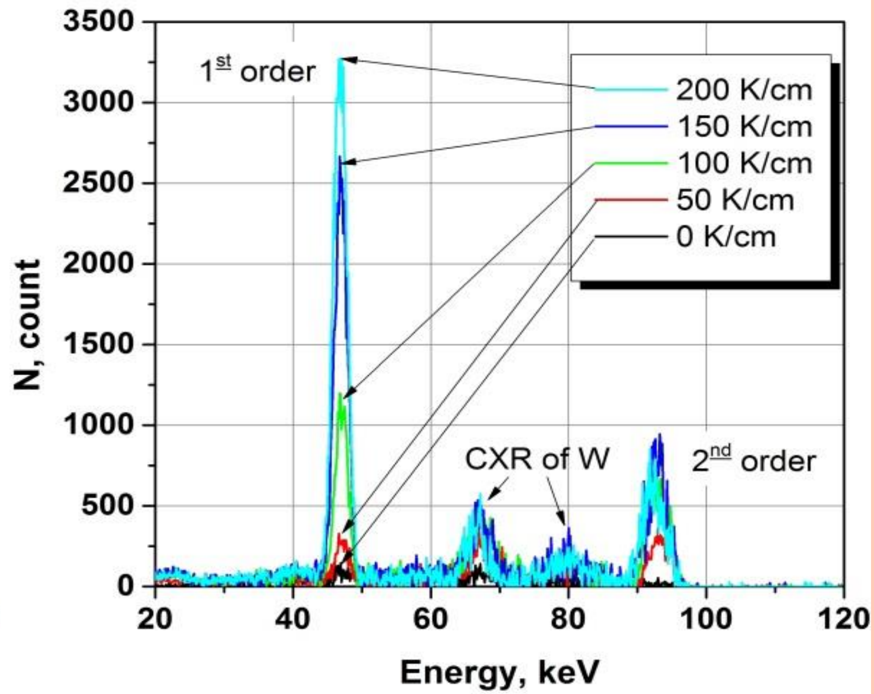


На рисунке круглыми точками приведена зависимость для энергии 30кэВ, а квадратными – для энергии 40кэВ. а) толщина монокристалла 6мм, б) толщина монокристалла 9мм.

Увеличение интенсивностей отраженных пучков более 60 раз при энергии 30кэВ и более 45 раз при энергии 40кэВ, когда толщина монокристалла составляет 6мм. Для толщины монокристалла с 9мм увеличение интенсивностей отраженных пучков достигает уровня в 90-110 раз для энергий фотонов 30 кэВ (рис. б), а для энергий фотонов 40 кэВ увеличение получается больше 80 раза (рис. б).

Studies of a hard X-ray diffraction





Shown the filtered with 1.6 mm Cu radiation spectrum of "transfer effect" depending on the temperature gradient for the crystal quartz of 9 mm thickness.

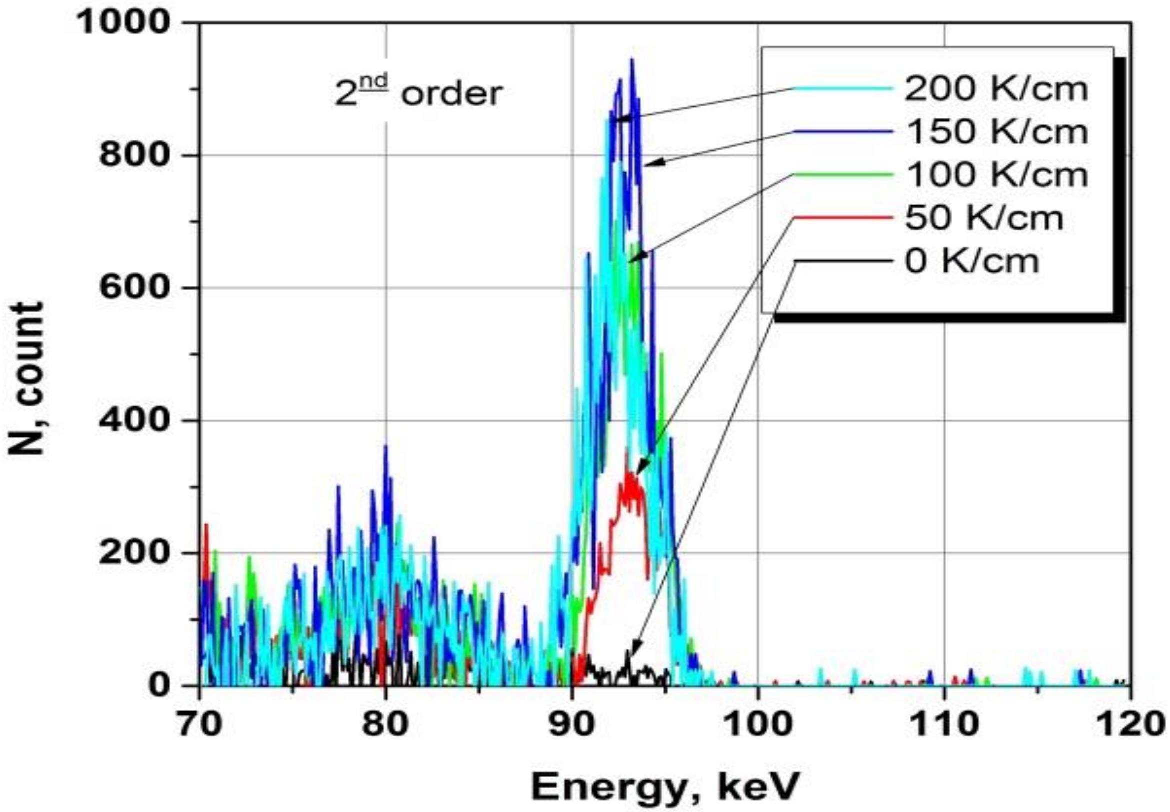
Energy of the first and the second order were determined from the spectrum and it values are equal to

46.86±0.05 and 93,33±0.05 keV,

FWHM is

2.2±0.1 and 3.4±0.3 keV.

STUDIES OF A HARD X-RAY DIFFRACTION

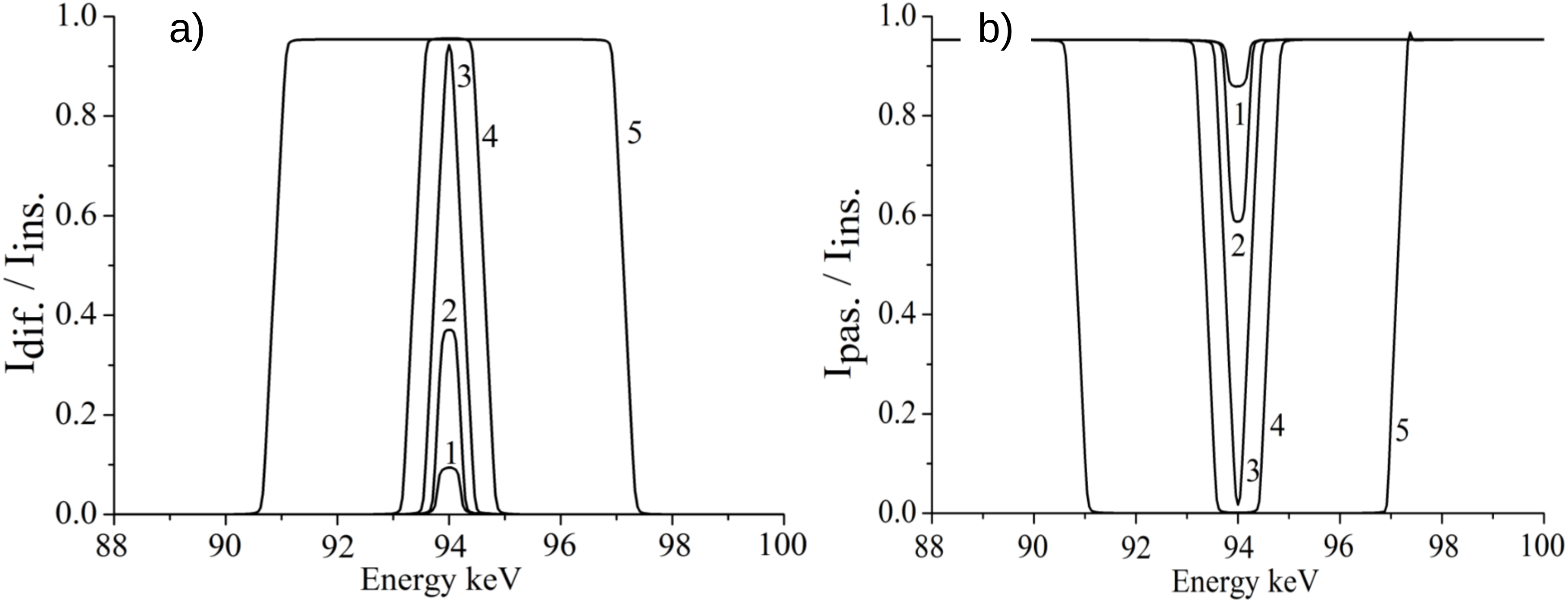


Shown the second order depending on the temperature gradient for the crystal quartz

Peak energy is **93,33±0.05** keV,

FWHM is **3.4±0.3** keV

Theoretical prediction



The spectrums of the reflected (a) and passed (b) beams for the different values of the parameter deformation of the reflecting atomic planes of the quartz single crystall with the thickness of 9 mm:

1) A = 0; 2) A = 250; 3) A = 800; 4) A = 2000; 5) A=10000.

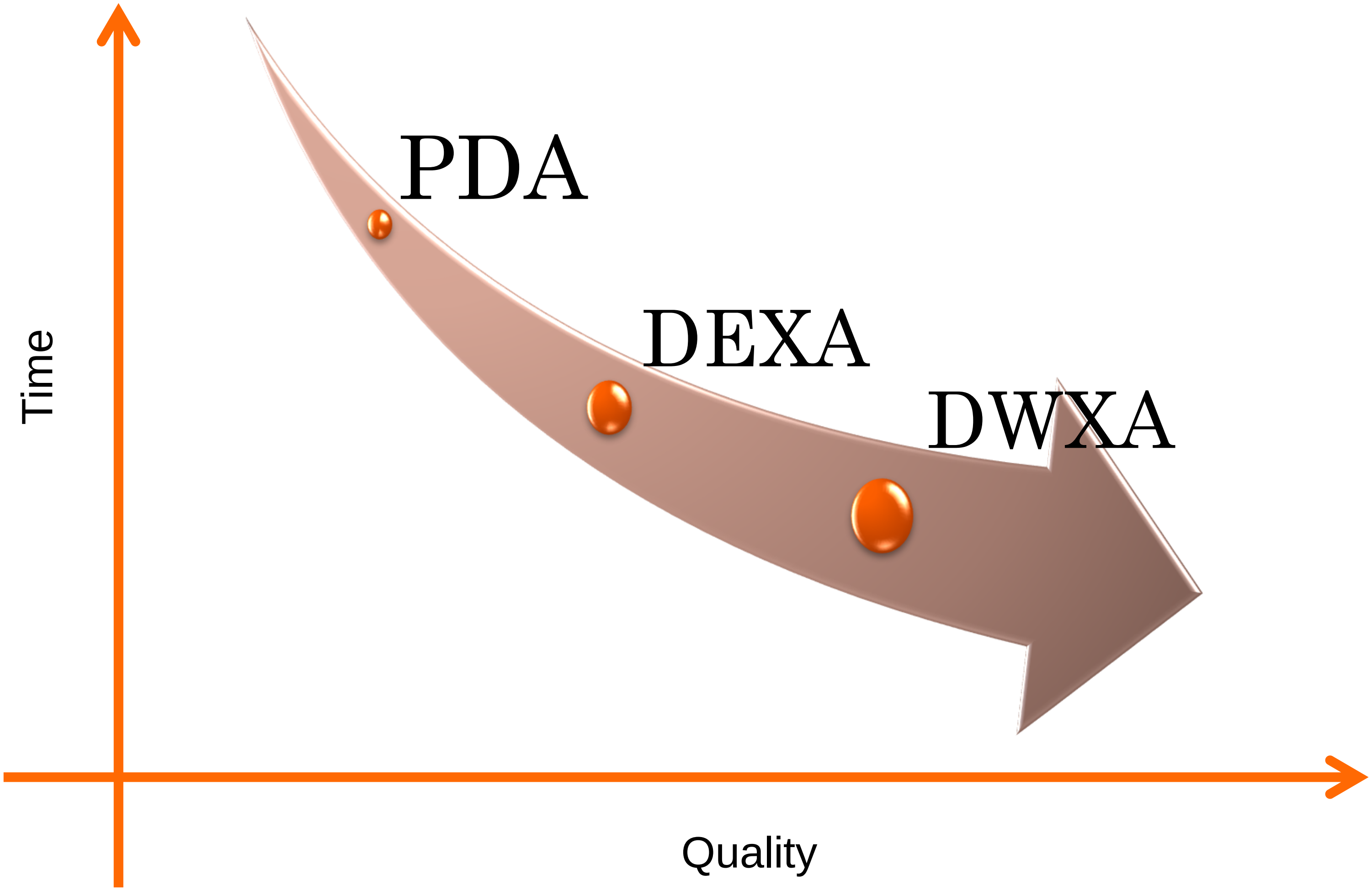
Background X-ray scattering in wavelength dispersive absorptiometry

DPA, DEXA, DWXA?

- Dual energy X ray absorptiometry (DEXA) is an extension of an earlier imaging technique called dual energy photon absorptiometry (DPA). The DEXA technique differs from DPA only in that DPA uses the attenuation of monochromatic emissions from a ***radioisotope*** (i.e. ^{153}Gd), while DEXA uses ***polychromatic X ray spectra*** for each image, centred at different energies.
- Dual wavelength X ray absorptiometry when uses the attenuation of ***two waves of a polychromatic X ray spectrum***.

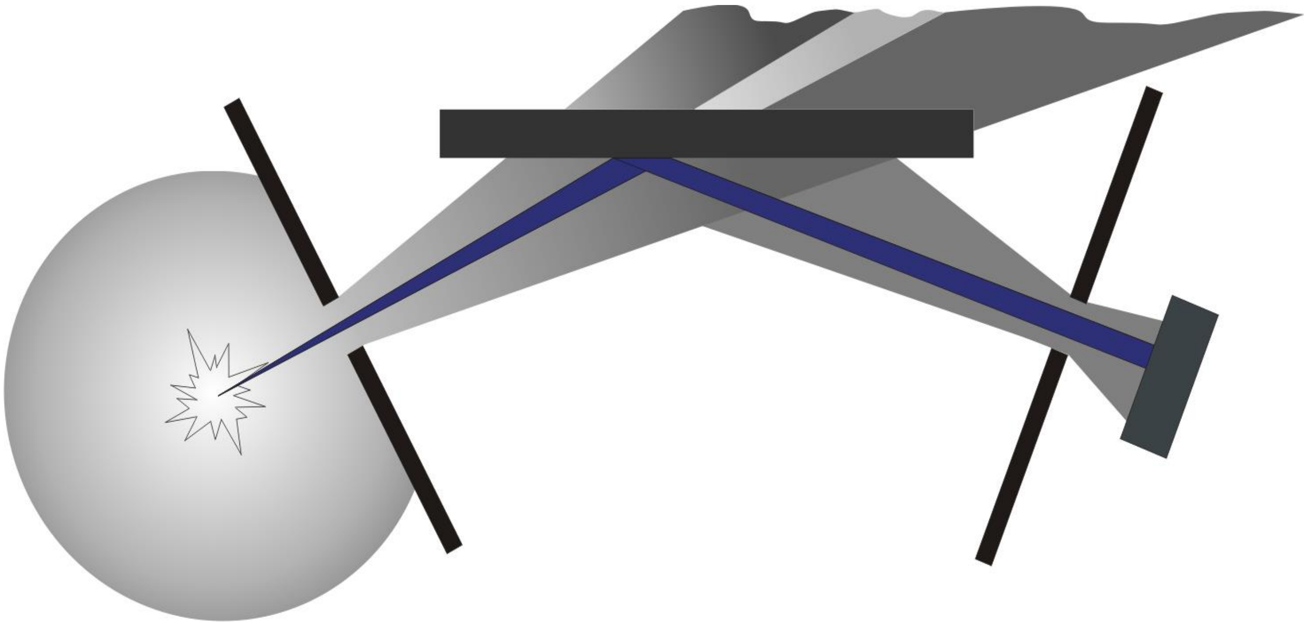
DPA, DEXA, DWXA FOR INDUSTRY

- The main objective is to reduce the analysis time

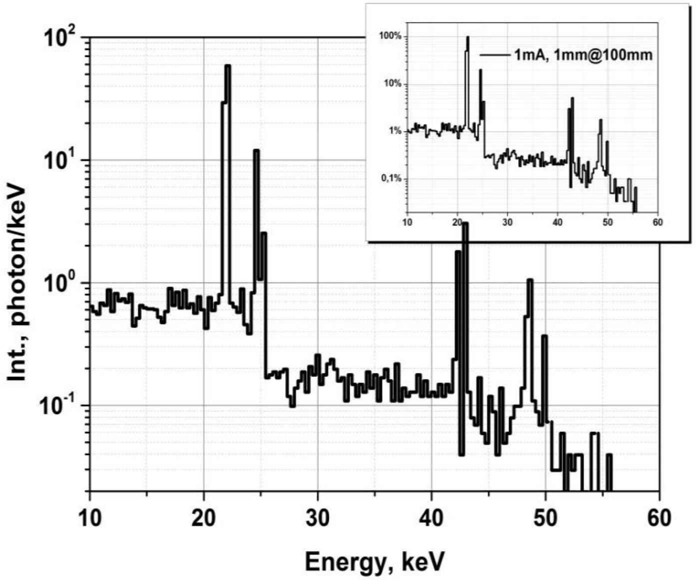


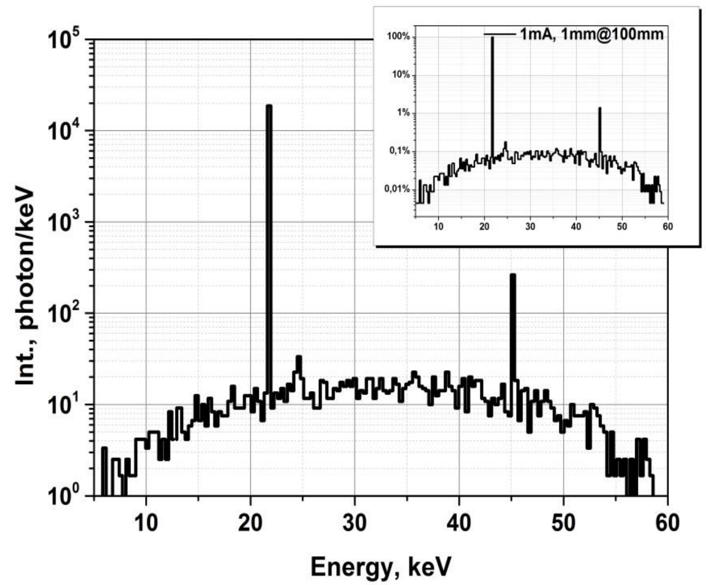
THE MAIN PROBLEMS

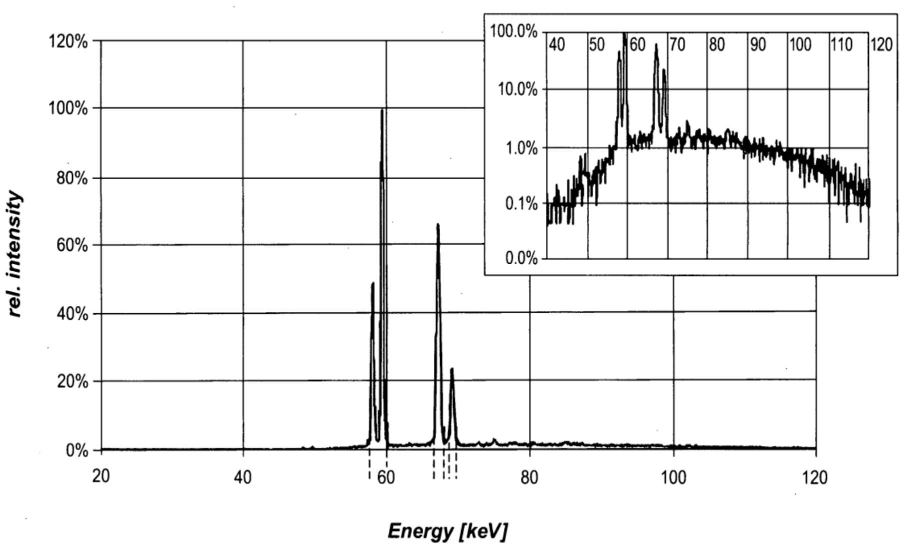
- **PDA:** low flux & high risk
- **DEXA:** complex spectral composition of radiation
- **DWXA:** background scattered X-rays



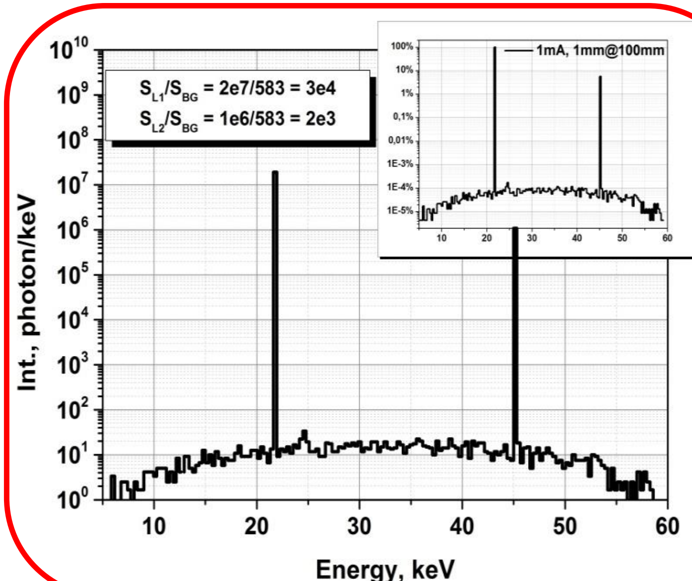
SECONDARY FLUORESCENCE VS DIFFRACTION







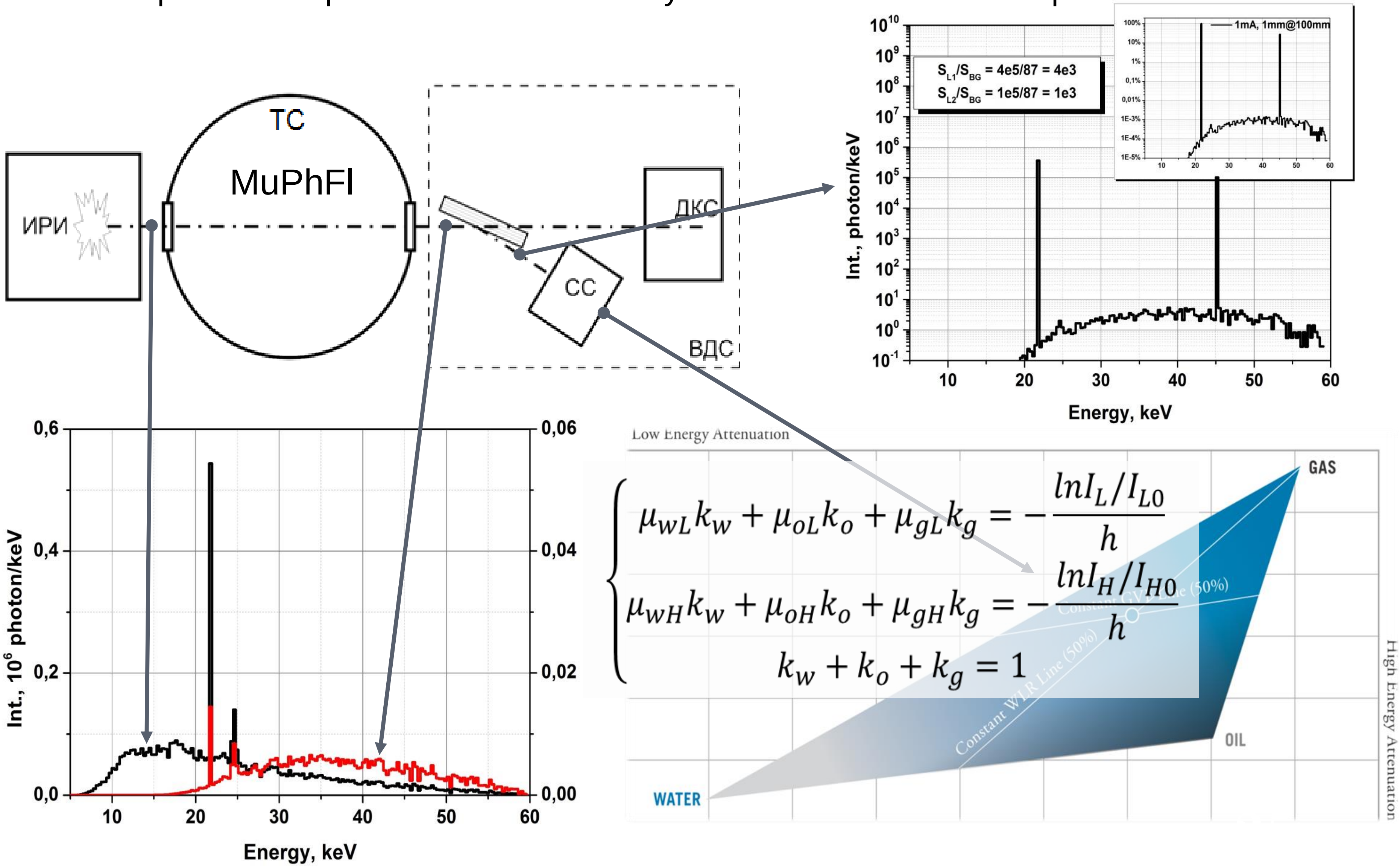
Fluor’X [US 20120087467]



How to use

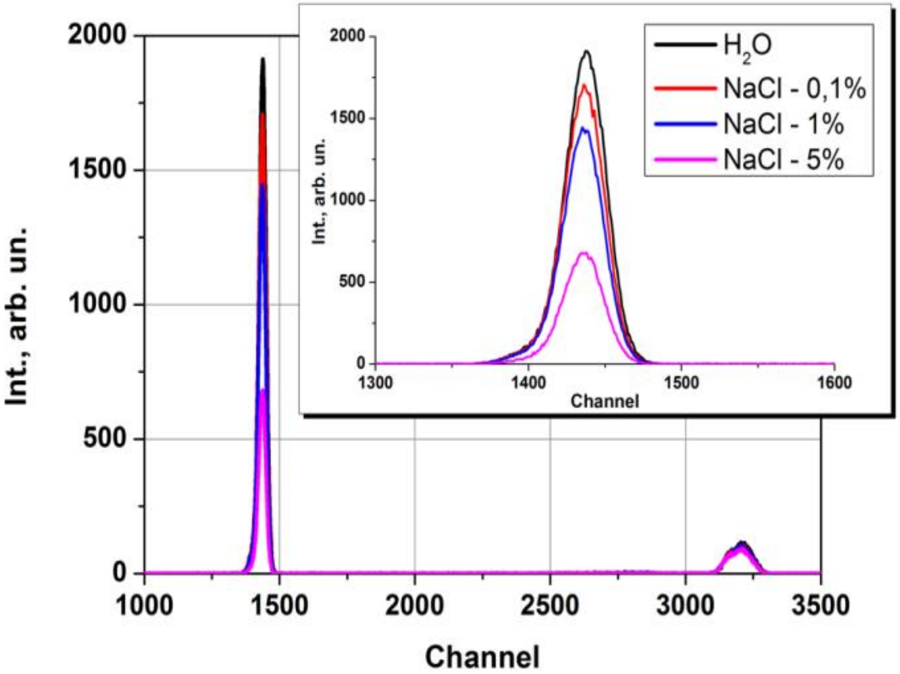
For example:

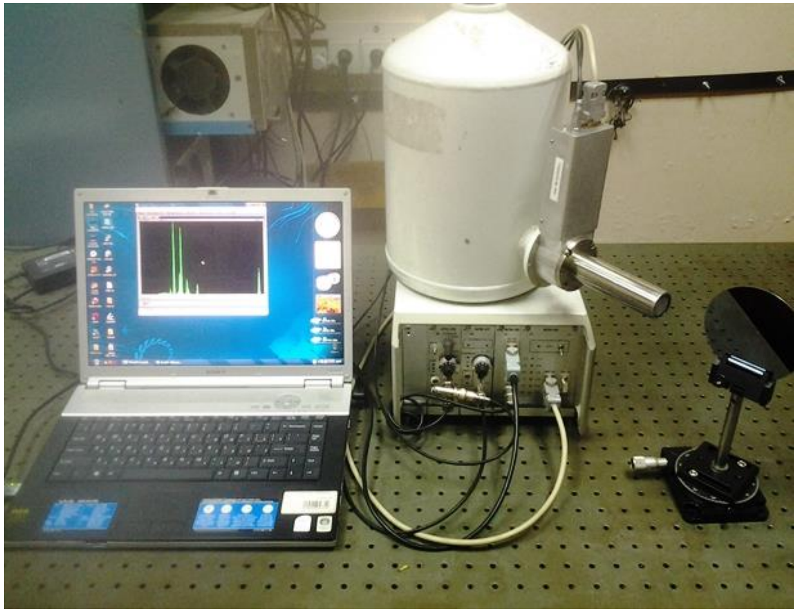
- analysis of the radiation from the x-ray tube passing through the flow
- component composition is determined by the ratio of the diffraction peaks

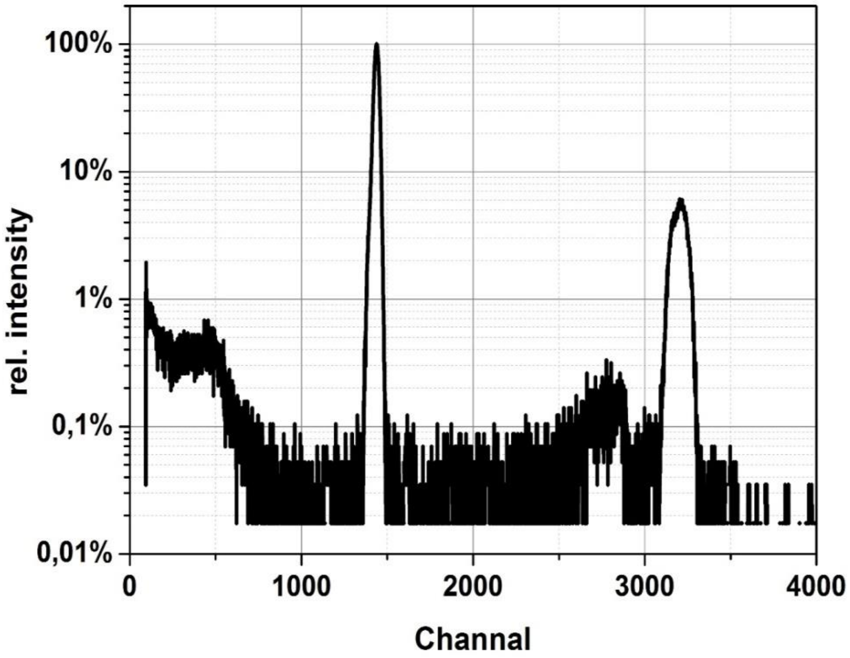


$$
\begin{cases}
\mu_{wL}k_w + \mu_{oL}k_o + \mu_{gL}k_g = -\dfrac{lnI_L/I_{L0}}{h} \\
\mu_{wH}k_w + \mu_{oH}k_o + \mu_{gH}k_g = -\dfrac{lnI_H/I_{H0}}{h} \\
k_w + k_o + k_g = 1
\end{cases}
$$

Testing results







NOW accuracy ±2,5%

In conclusion,

- Continuous source operation with the lens is not less than 3 years
- Additional channel information
- high speed
- safe use