

# *Source of monochromatic X-radiation*

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# *Abstract*

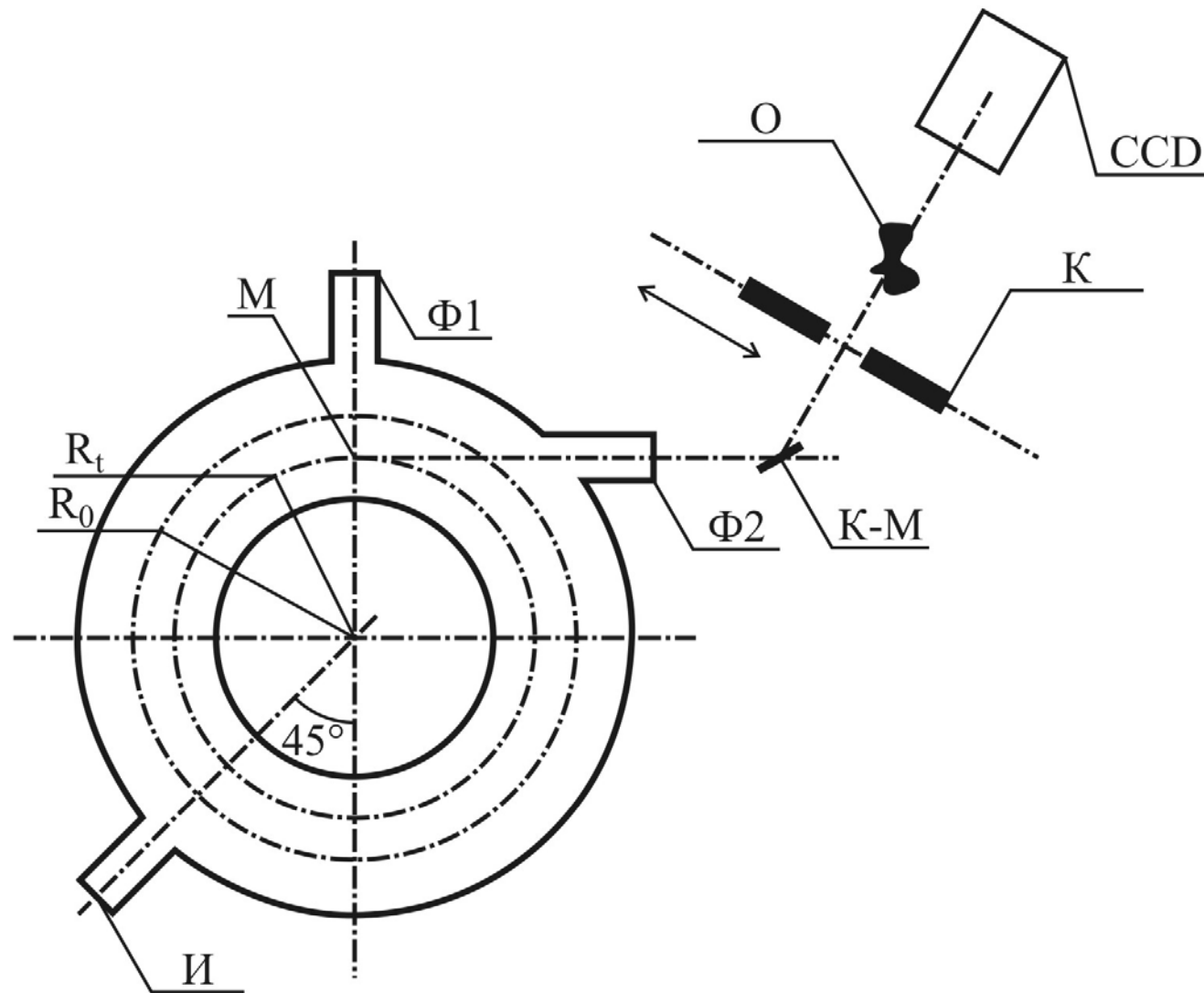
- The importance of the problem is caused by a wide use of X-ray radiation (XR) in applied sciences, e.g. analysis of the structure of matter, diagnostics in medicine, etc. The X-ray tubes are widely used to solve numerous problems, but the attempts of monochromatization of the radiation beam from X-ray tubes by means of the filters or monochromators lead to a decrease of the photon beam intensity up to the level which is not suitable for diagnostics goals.
  - In the present work, the possibility to use the bremsstrahlung beam from a betatron for generation of monochromatic X-ray radiation has been investigated, applying the effect of the Bragg diffraction of bremsstrahlung photons on the pyrolythic graphite crystal.
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# *Betatron Electron Source Layout*



1 – magnet counters, 2 – magnet pole, 3 – magnet bobbin, 4 – direction counters, 5 – accelerating chamber, 6 – injection transformer, 7 – injection module, 8 – module of electron throw on target, 9 – beam pipe, 10 – vacuum pump

# *Experimental setup*

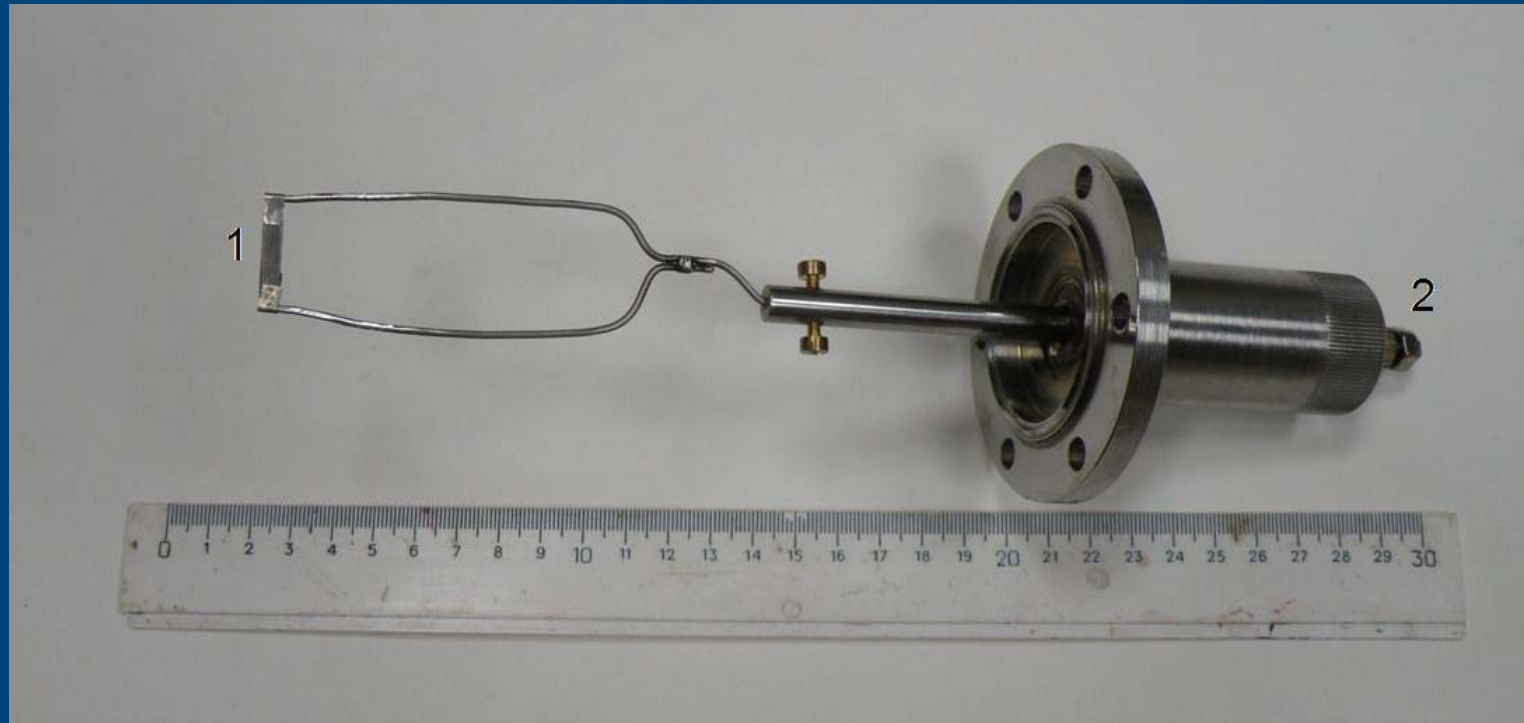


# *Primary Electron Beam and target Parameters*

- Energy of electrons – 17 MeV
- Average electron current – 0.4 microamper
- Maximal beam rate – 180 Hz
- Accelerating time - 2 millisec
- Pulse of radiation - 2 microsec
- Integral dose 1meter from target – 157,2 mGy/min

The bremsstrahlung beam of the betatron falled down onto pyrolythic graphite crystal (HOPG) of the thickness 100 micrometers (which served as a monochromator) , at the angle  $16,64^{\circ}$  and 28 with respect to the reflecting (002) planes.

# Copper - target



- 1 - The internal target of the betatron was the copper plate of the thickness about 7 micrometers.

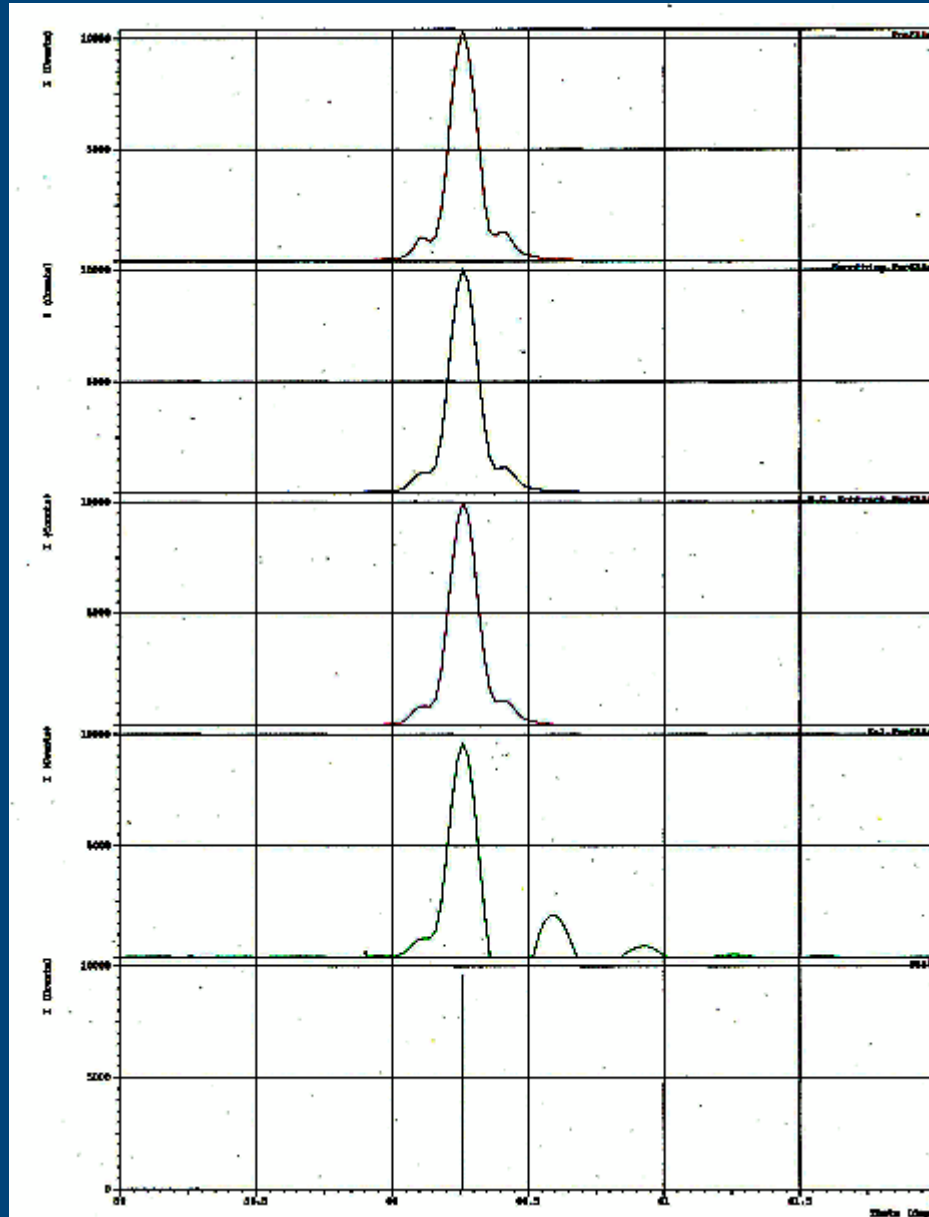
# *Monochromator targets*



1 – HOPG; 2 – Germanium (111); 3 –, 4 –, 5 – Quartz (thicknesses 1.5, 0.75, 0.5 mm)



## Rocking curve HOPG-crystal



The pyrolythic graphite crystal surface disorientation with the plane (002) has been 22 angular minutes. The investigation of the quality and mosaicity of the target C(002) on the crystal-diffractometer has shown that the “rocking curve” full width at the half-height maximum  $\text{FWHM} = 0.14380$  degrees, and the dislocation density has been  $\approx 10^{-4}/\text{cm}^2$ .



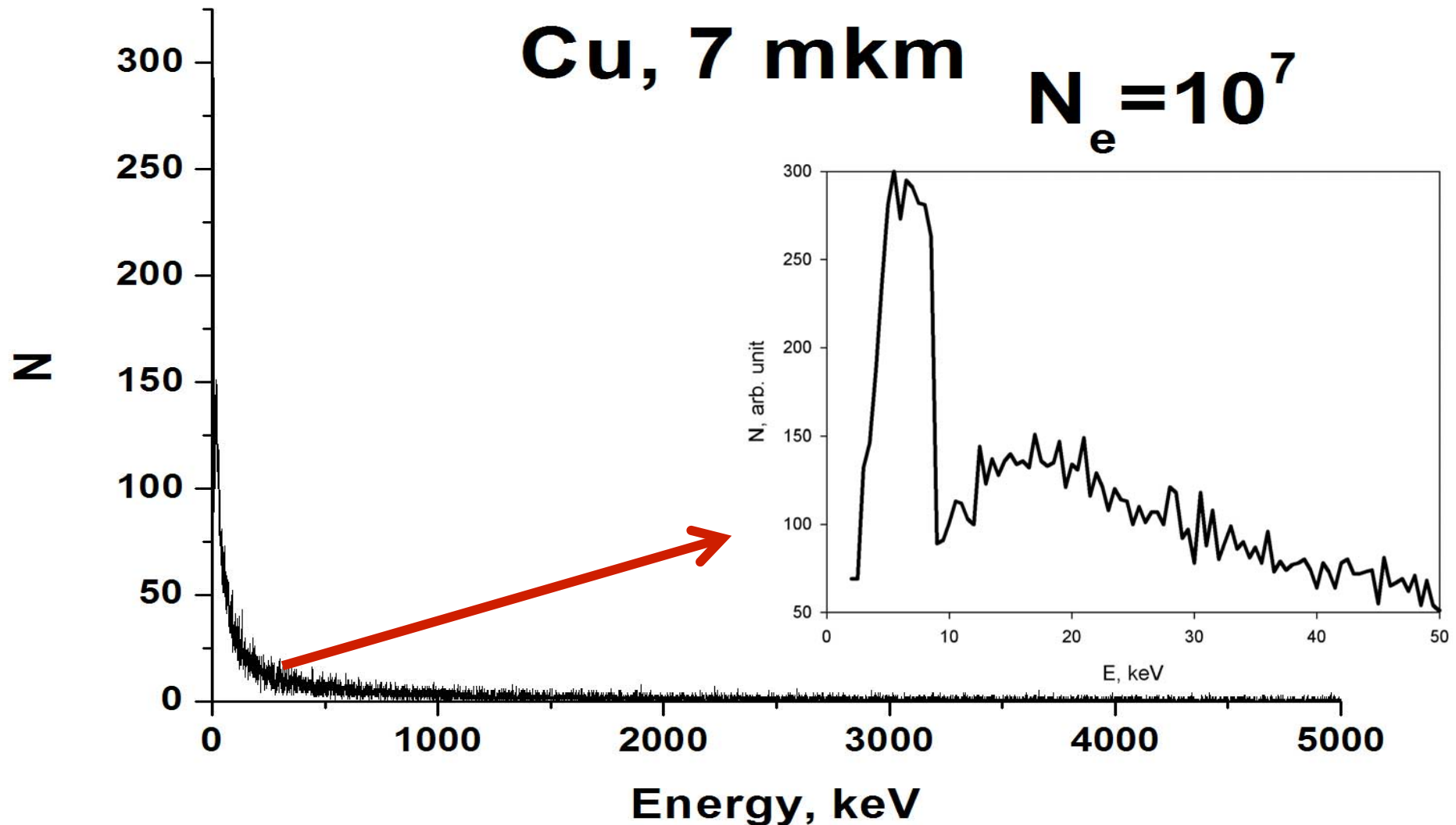
# Goniometer



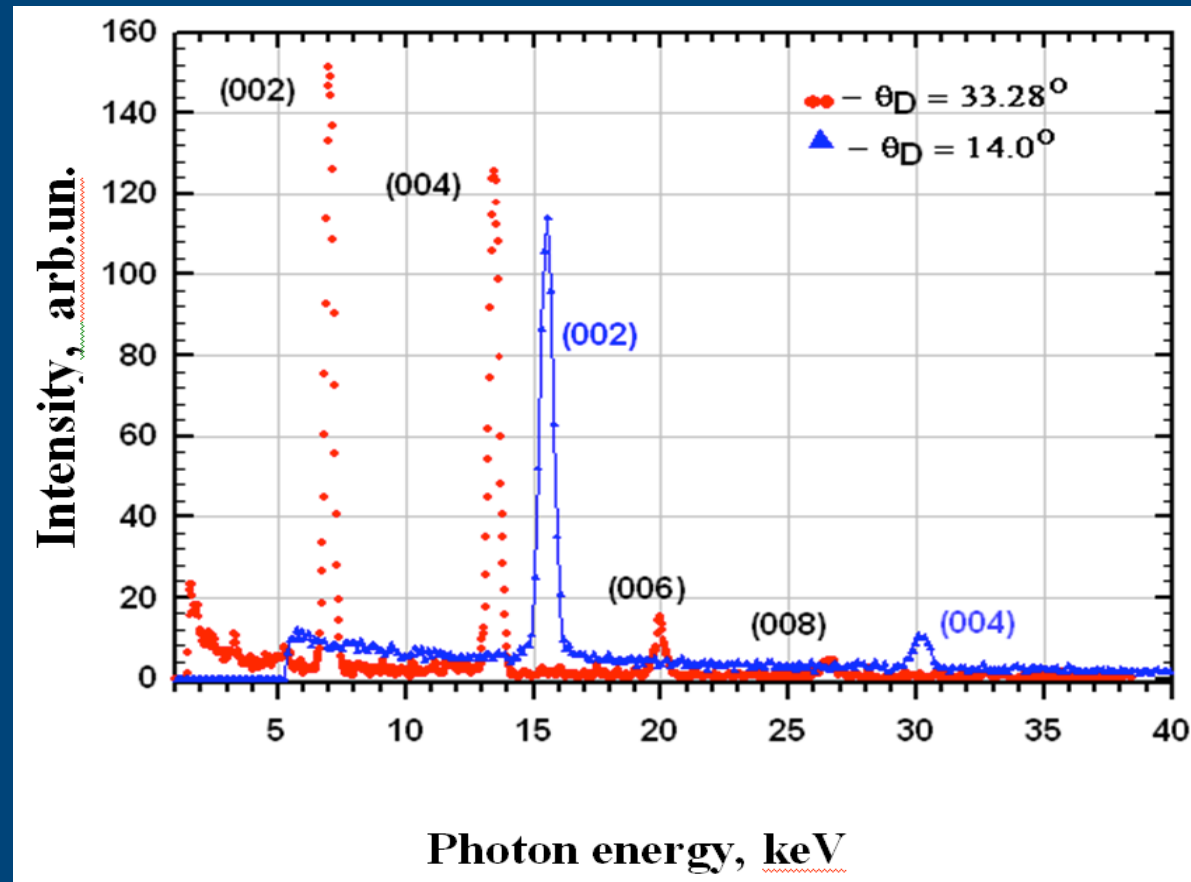
- Precision of axial orientation target – 10 microrad

# *Bremsstrahlung spectrum of betatron ( $E = 17 \text{ MeV}$ )*

GEANT4



# *Spectrum of photons outgoing of HOPG-target*



$$2d\sin\Theta = nhc/E,$$

d- plane distance,  $\Theta$  – Bragg angle, n – diffraction order

# *Digital X-Ray imaging system*



## Characteristics:

Ionization chamber МИК 1536 (Kr). Gas Pressure = 2 MPa at 22 grad C.

Spatial resolution - 2 lp/mm

Number of sensitive elements in row – 1536

Signal Integration time – 2.5 ms

ADC capacity – 14 bit

Contrast sensitivity – 1.5 %

Scanner velocity = 46 mm/sec

Step = 0.2 mm

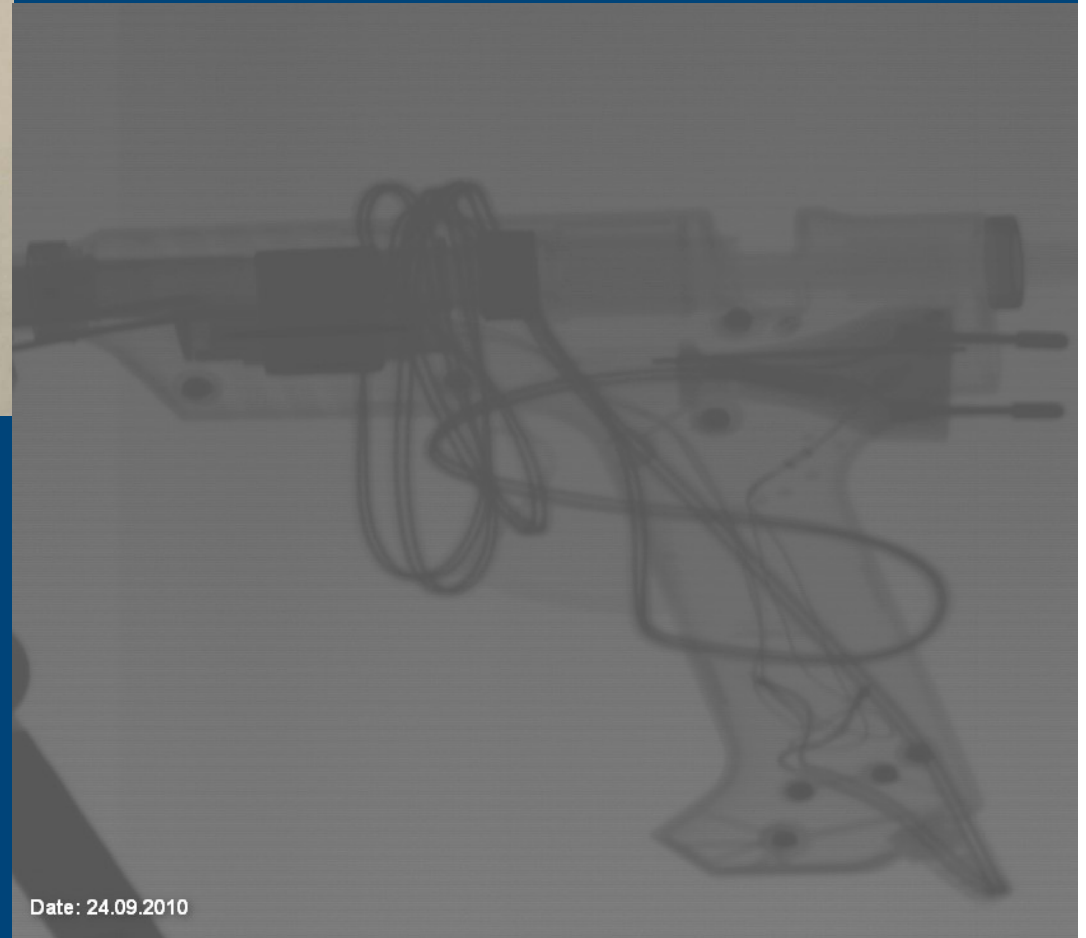
Focus = 1350mm



# *Term gun*

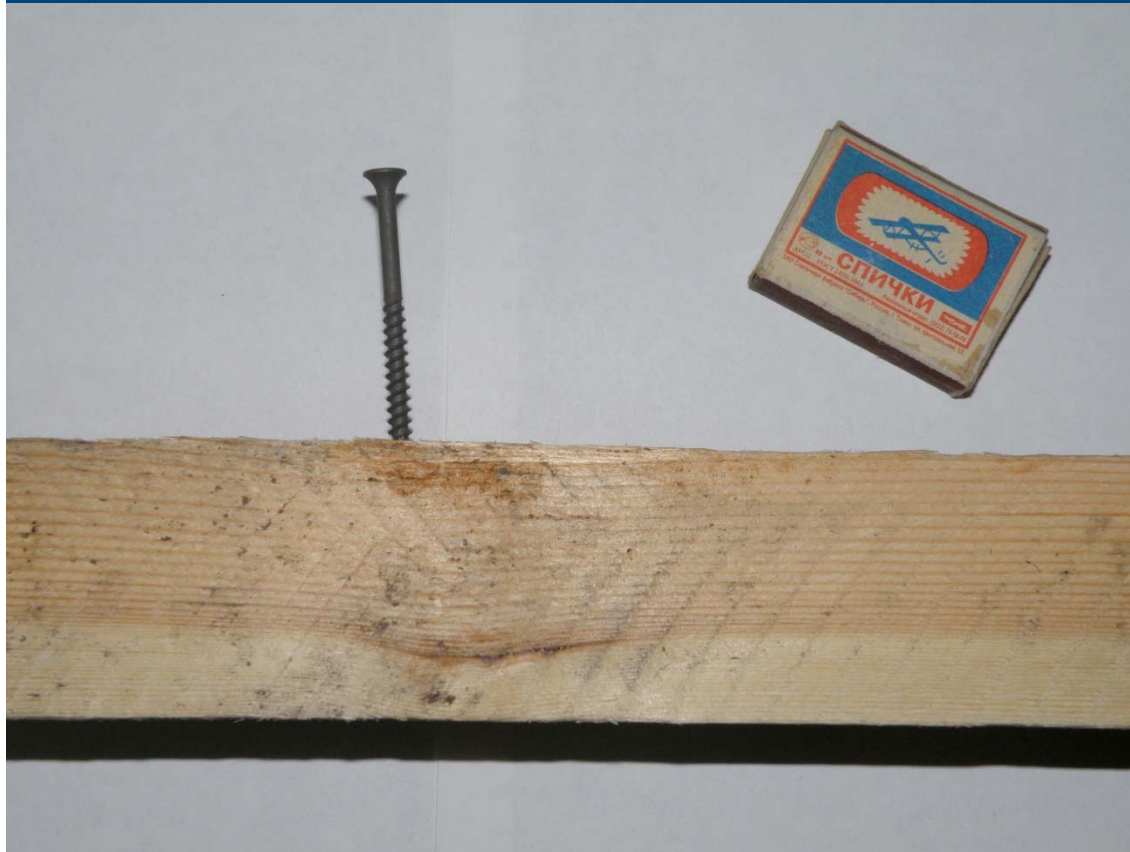


$D = 4,52 \text{ mGy/min}$   
 $D_{\text{max}} = 157,2 \text{ mGy/min}$



Date: 24.09.2010

# *Screw into the board*



$D = 4,52 \text{ mGy/min}$

$D_{\text{max}} = 157,2 \text{ mGy/min}$

Date: 27.09.2010

# Summary

- Using thin internal target (7 mcm Cu) we have achieved multiple passing of electrons through the target (at least 86 times).
- We have obtained monochromatic tunable X-ray beams using pyrolytic graphite as monochromator at the 17 MeV betatron bremsstrahlung beam.
- We observed 4 diffraction orders in spectrum ( $\hbar\omega = n \times 6.4 \text{ keV}$ ,  $n = 1,2,3,4$ ) with line monochromaticity less than 0.5 keV.
- The imaging system based on gas detectors provides space resolution 0.2 mm or 2 pl/mm possibility to use one for a pulse source.
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