# Analysis of corundum crystals optical and ultraviolet transmittance after electron beam exposure

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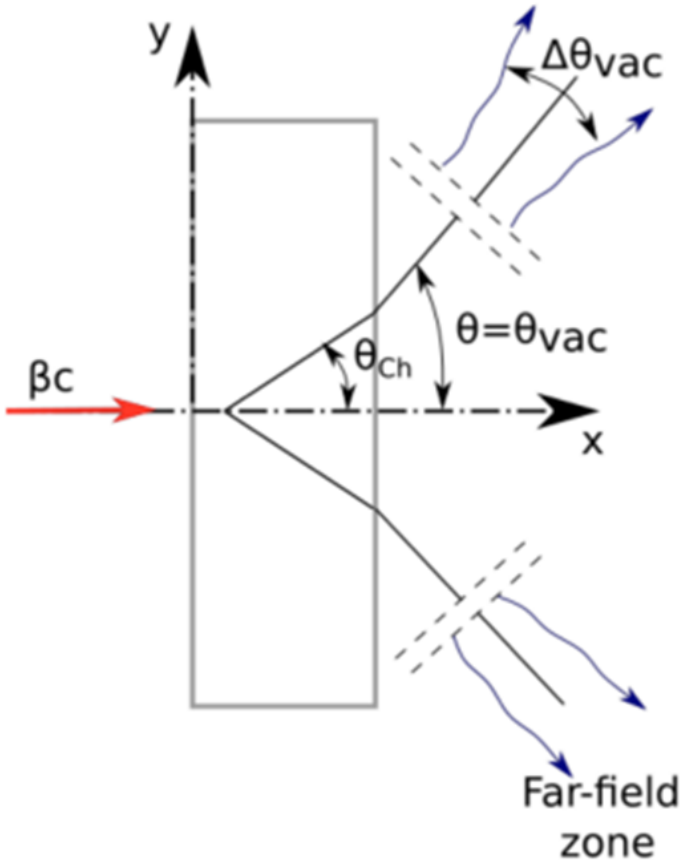
Channeling-2024

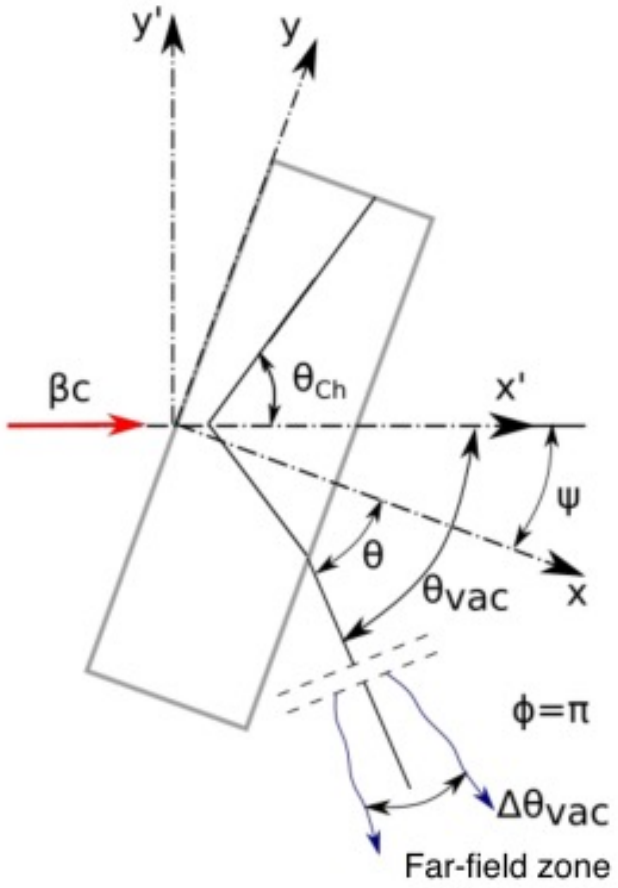



$$\cos\theta_{ChR} = \frac{1}{n\beta},$$

where $\theta_{ChR}$ is the angle of the ChR emission in the medium through which a charged particle passes with velocity $\nu = \beta c$ ($c$ is the speed of light), $n$ is the refraction index of the medium.

$$\beta_{thr} = \frac{1}{n(\lambda)} < \beta < \beta_{max} = \frac{1}{n^2(\lambda)-1}$$

For $\beta < \beta_{max}$ ChR is ejected into vacuum $\theta_{vac} = \theta$.

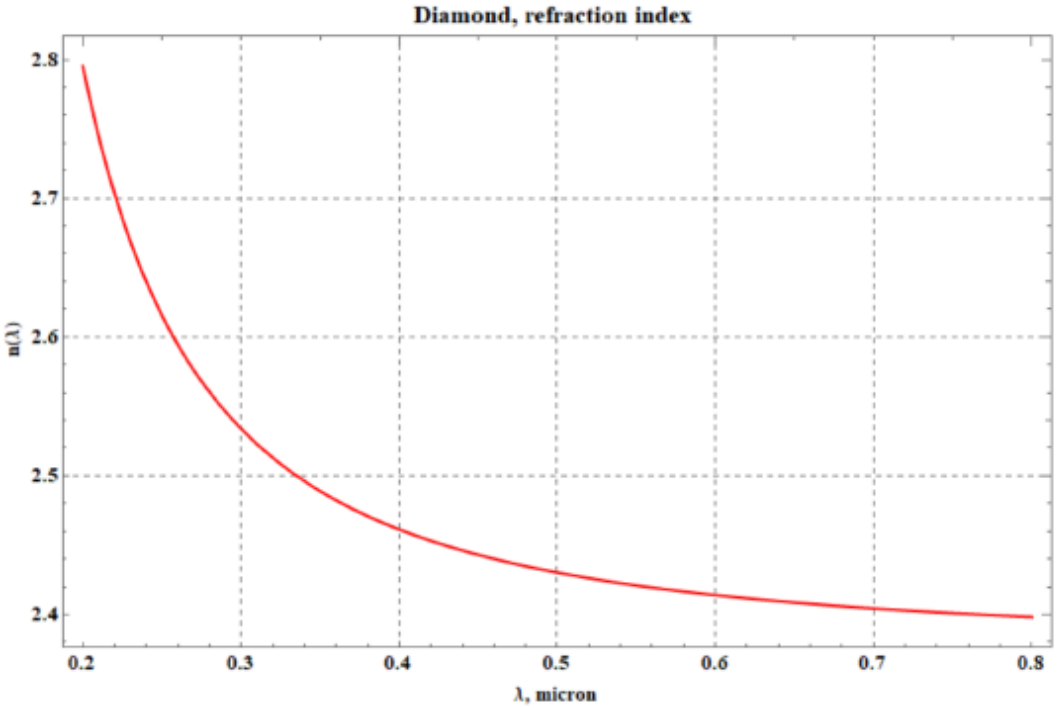


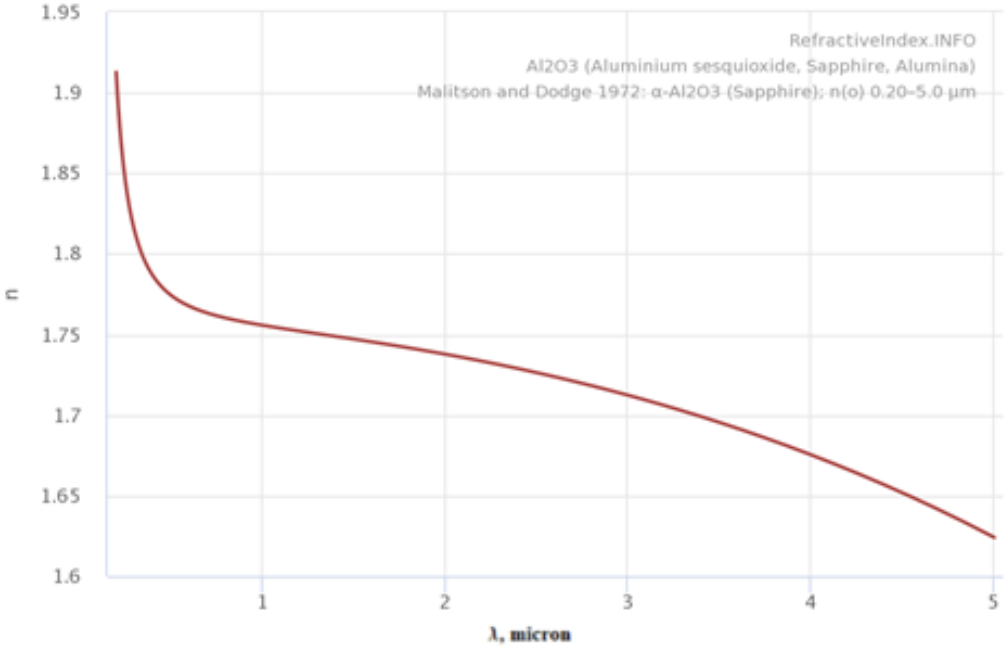

To ejected ChR of a charge into vacuum we have to tilt the plate.

$$\sin\theta = n\sin(\theta_{ChR} - \psi)$$

$$\theta_{vac} = \theta + \psi$$

Using radiator made of a material with a high refractive index $n(\lambda)$, for expamle diamond, the ChR will be generated by a charge at speed $\beta > \frac{1}{n(\lambda)}$ i,e. moderately relativistic.



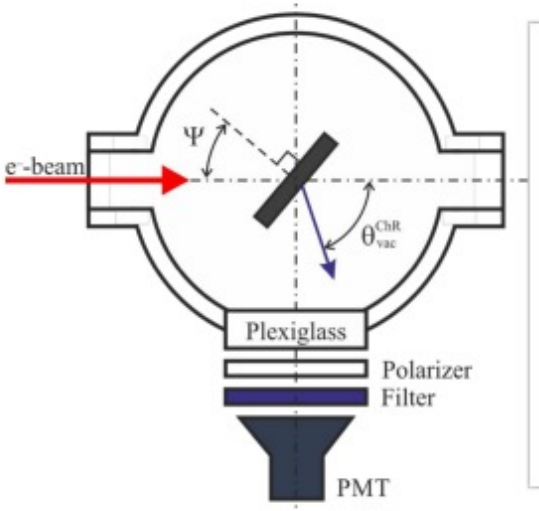



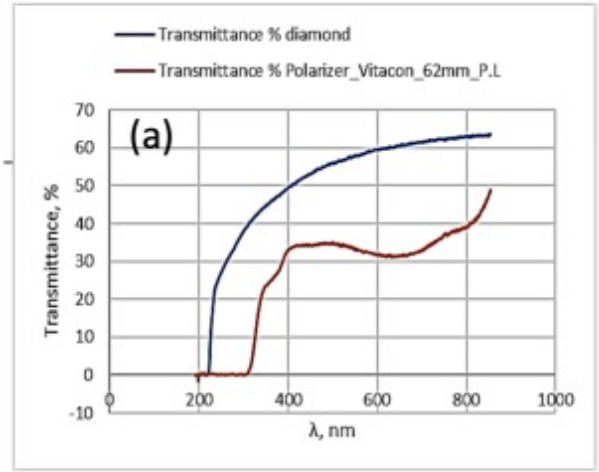
# TPU microtron

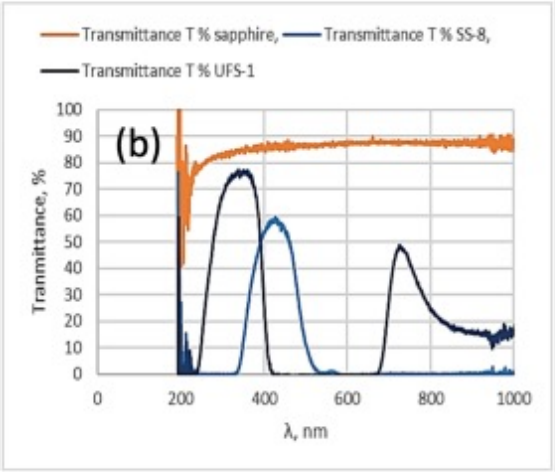
Electron beam parameters:

1. The energy of the extracted beam is from 1.5 to 5.7 MeV. With a discrete step of 0.63 MeV, 9 orbits with smooth adjustment between steps but the reconfiguration between the steps-orbits is a rather lengthy process.
2. Energy spread dE/E<0.3%.
3. Frequency 1...50 Hz.
4. The pulse duration is 0.5...4 $\mu$s.
5. The current of the extracted pulsed beam without collimation is up to 40 mA.

# Experimental scheme and information on used equipment



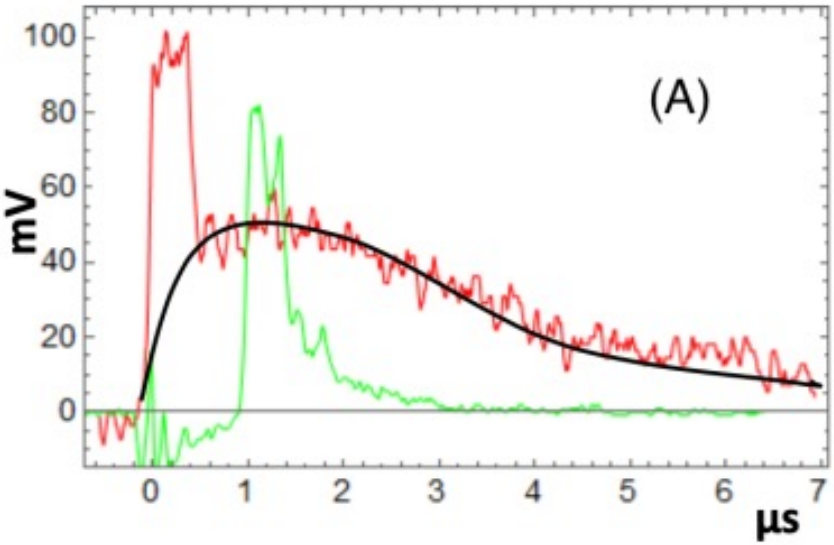



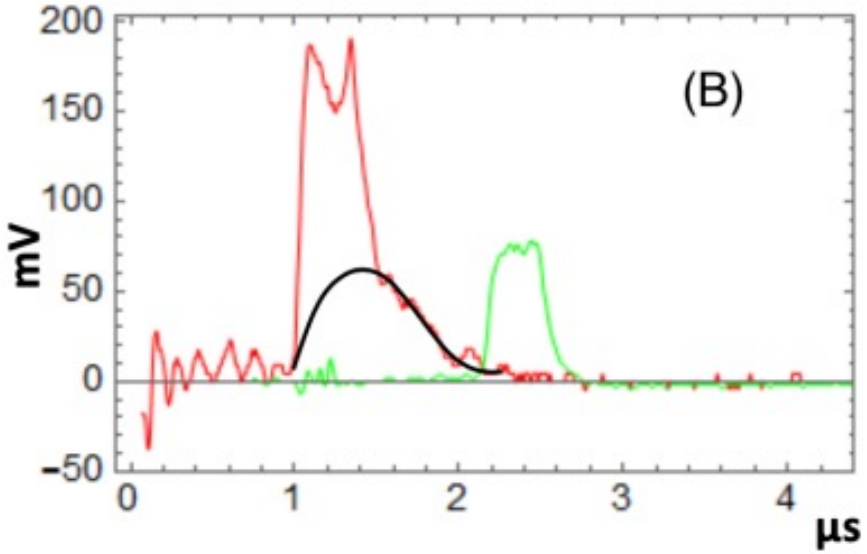




PMT parameters:

- the size of the active area is $3\times3$ mm$^2$;
- spectral range from 250 nm to 900 nm, peak wavelength 420 nm;
- photon detection efficiency $> 50\%$ at 420 nm;
- microcell recovery time from 16 ns;
- gain $(10^6)$.

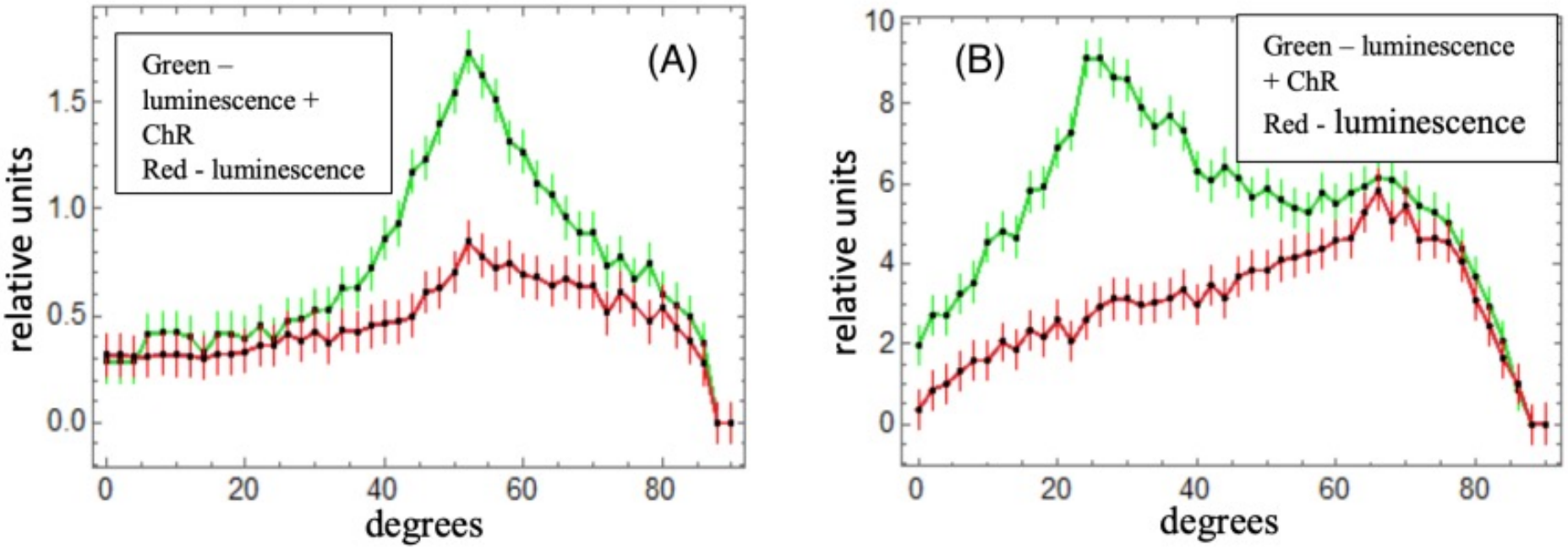
# Waveforms of radiation pulses



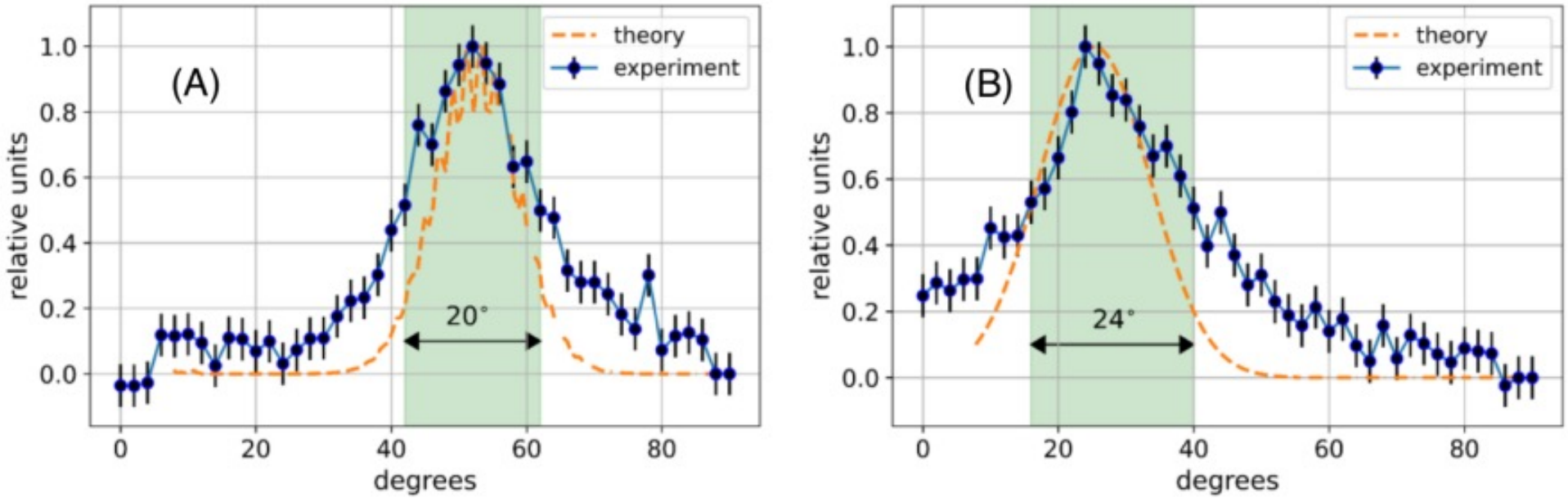

Typical waveforms of radiation pulses measured by oscilloscope for $\psi = 40°$. (A) - radiation produced in sapphire crystal, (B) - radiation produce in diamond, red curve - measurements without filters, green curve - measurements with filters shifted by 1.5 $\mu$s, black curve - luminescence contribution.

# Measurements of orientation dependence for $\theta_{vac} = 90^{\circ}$




Orientation dependence of ChR: (A) - diamond, (B) - sapphire crystal, red curve - vertical polarization, green curve - horizontal polarization.

# Experimental scheme and information on used equipment




Orientation dependence of Cherenkov light with subtraction of the luminescence contribution: (A) - diamond, (B) - sapphire crystal, dots - measurements, dashed curve - theoretical calculations.

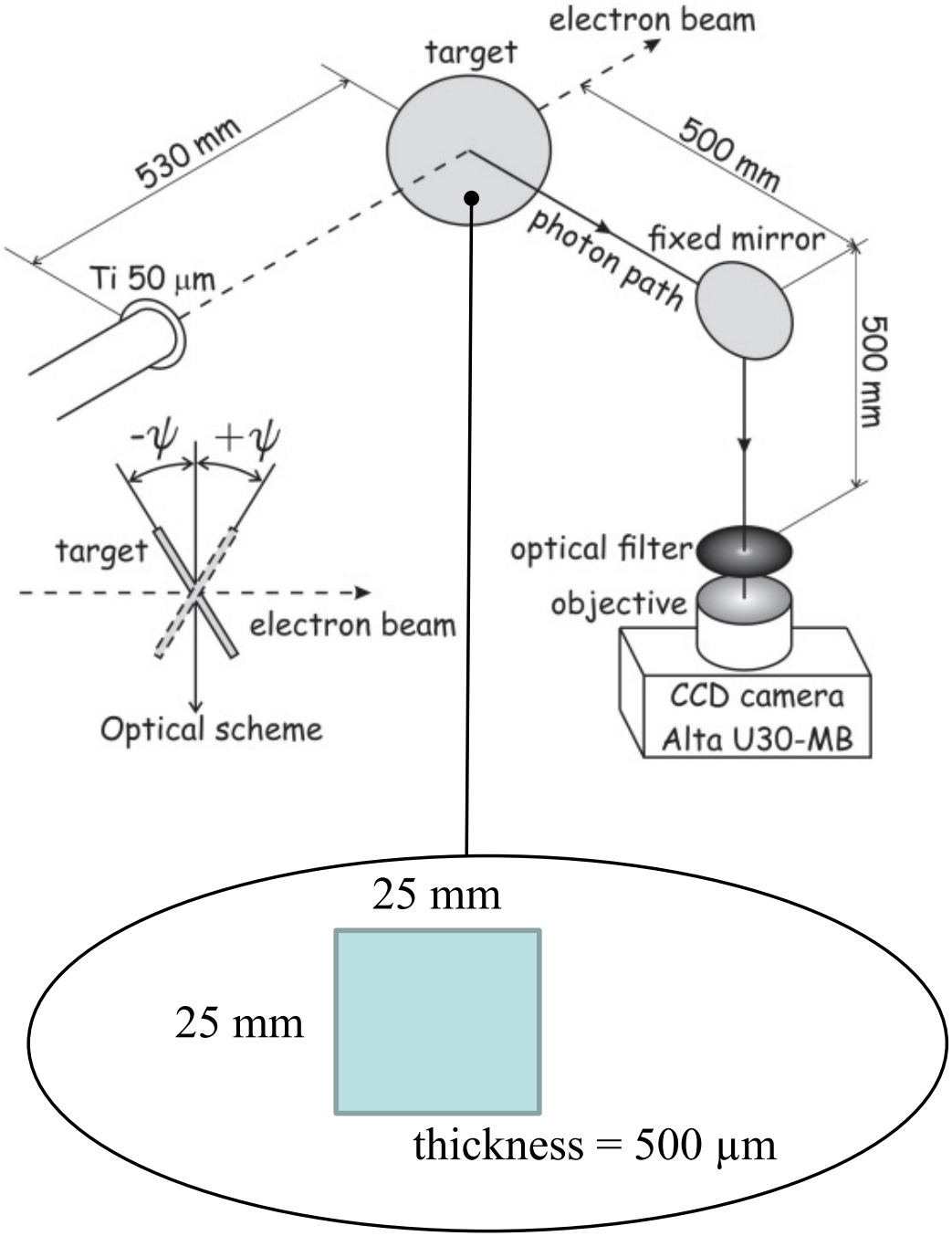
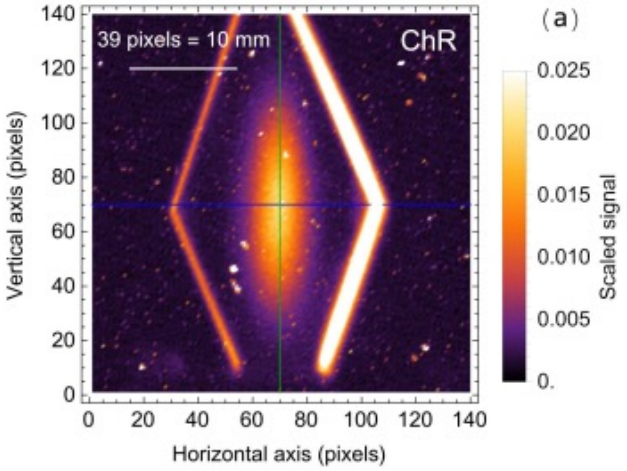
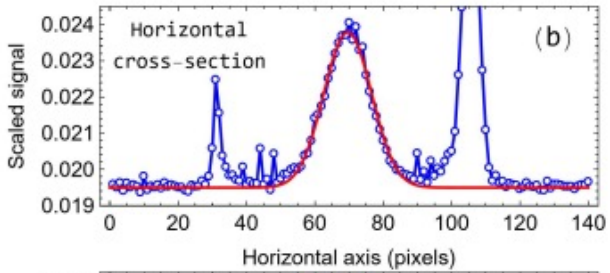
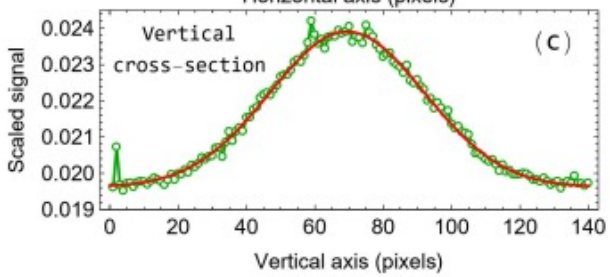



TABLE I. LINAC 200 parameters.

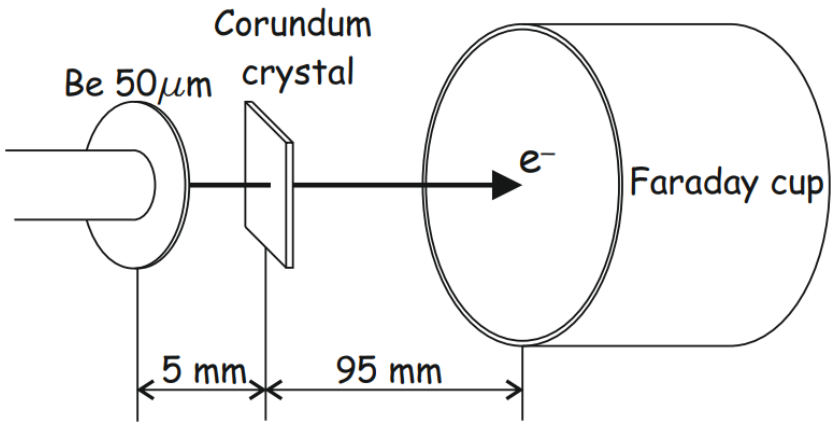
| | |
|---|---|
| Electron energy | 26 ÷ 200 MeV |
| Macro-pulse duration | 30 ÷ 300 ns |
| Bunch duration | $\sigma_z = 0.3$ mm |
| Beam current | 0 ÷ 60 mA |
| RF frequency | 2865 MHz |

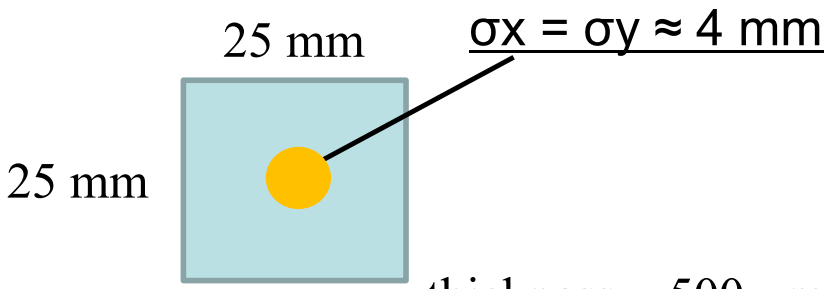


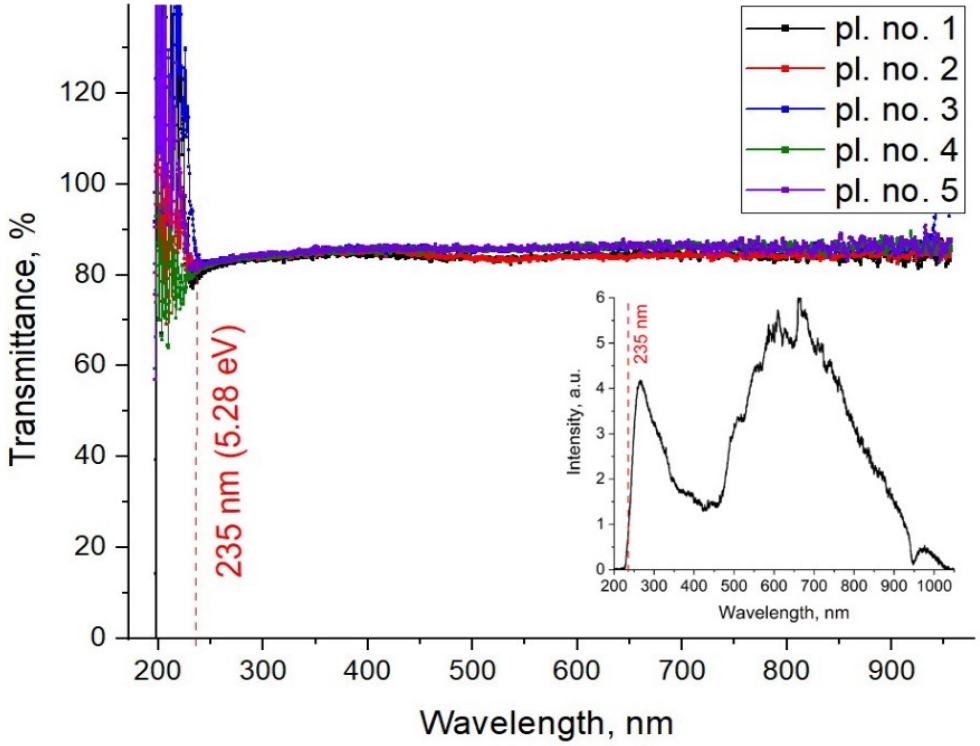
Electron beam 5.7 MeV, 230 nA




16 hours = 960 minute;
$3.12 \cdot 10^{15}$ e registered by the cup

Avantes AvaLight-DHc



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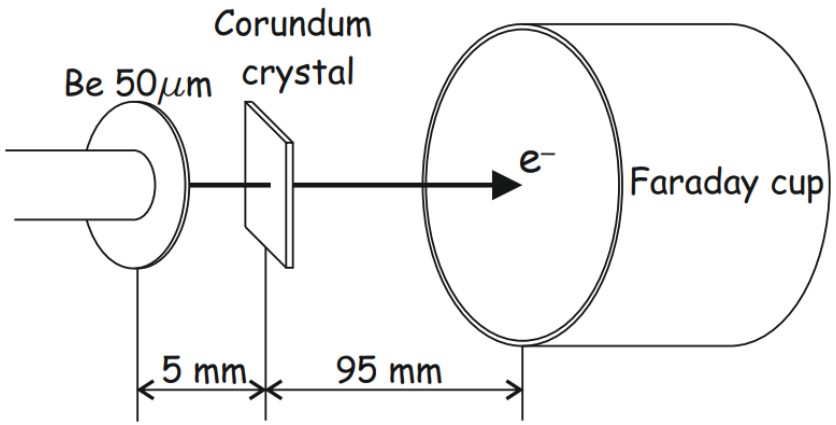


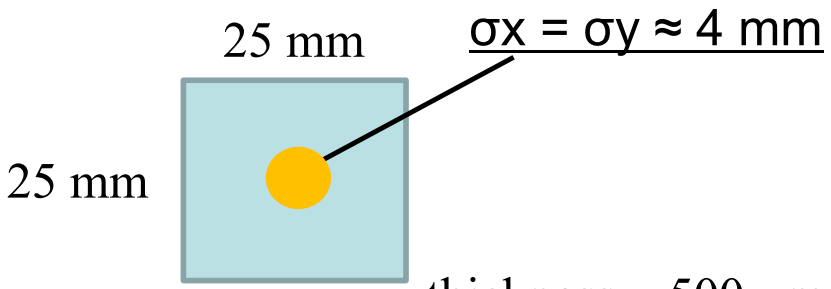


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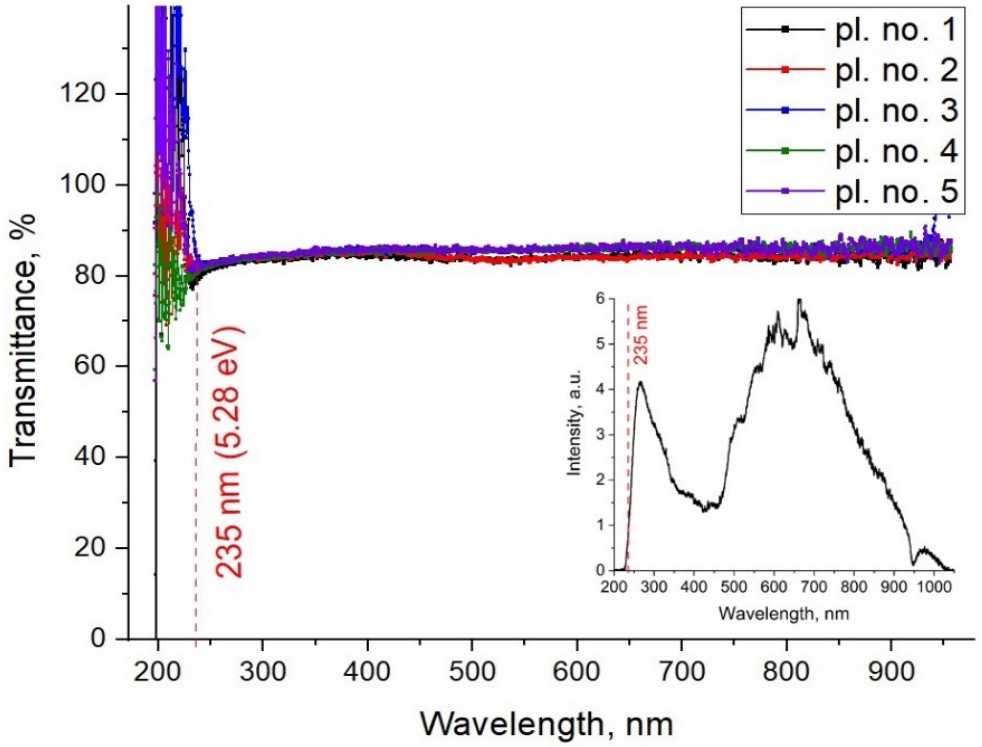
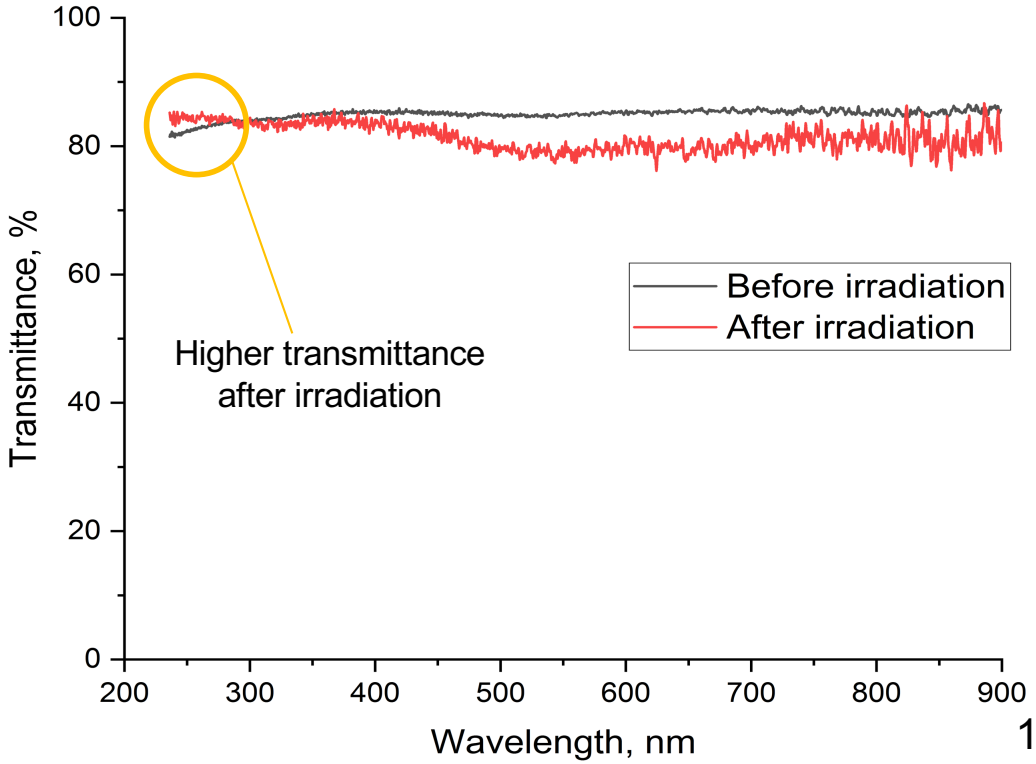
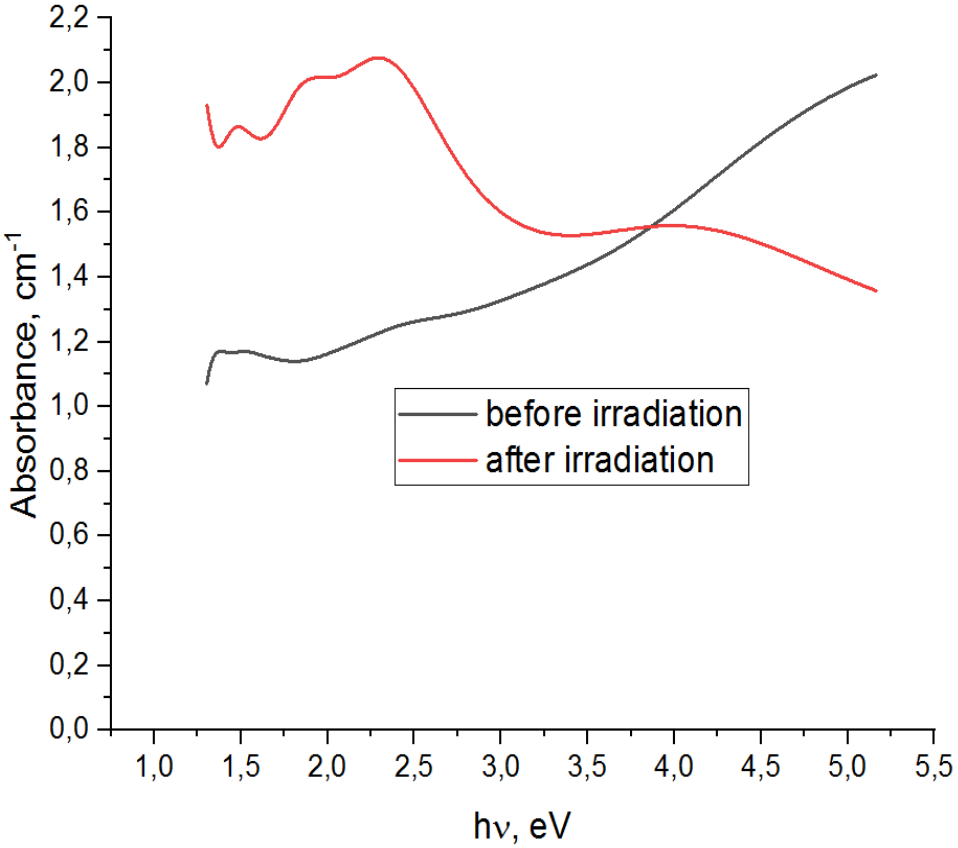
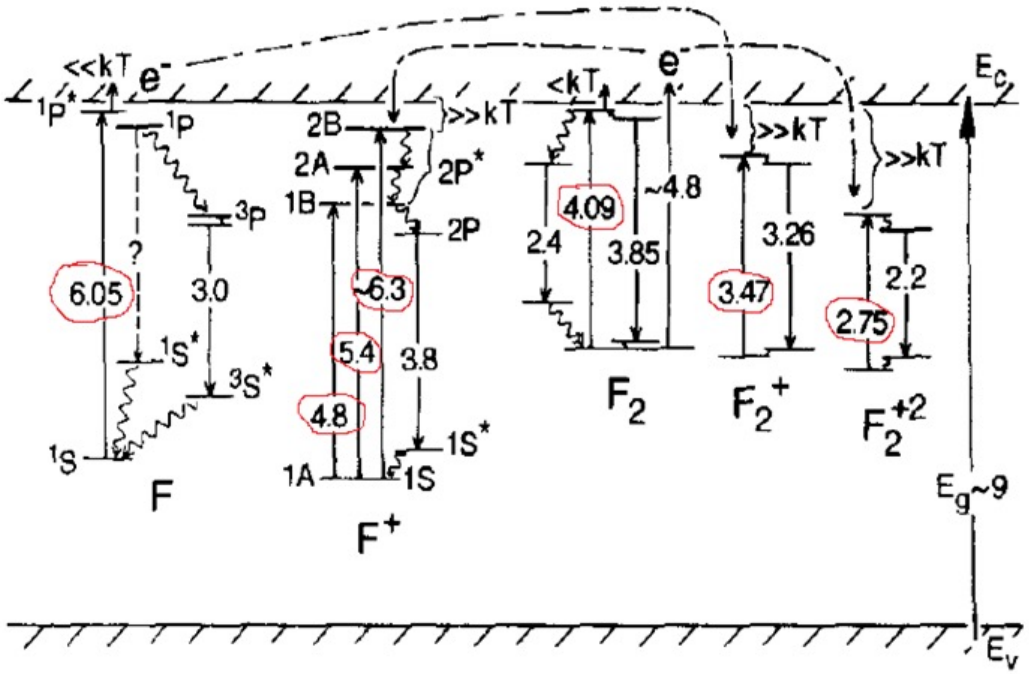


# Analysis of the brightening of a corundum target in the UV range




Evans, B. D. J. Nucl. Mater., 219, 202-223 (1995)

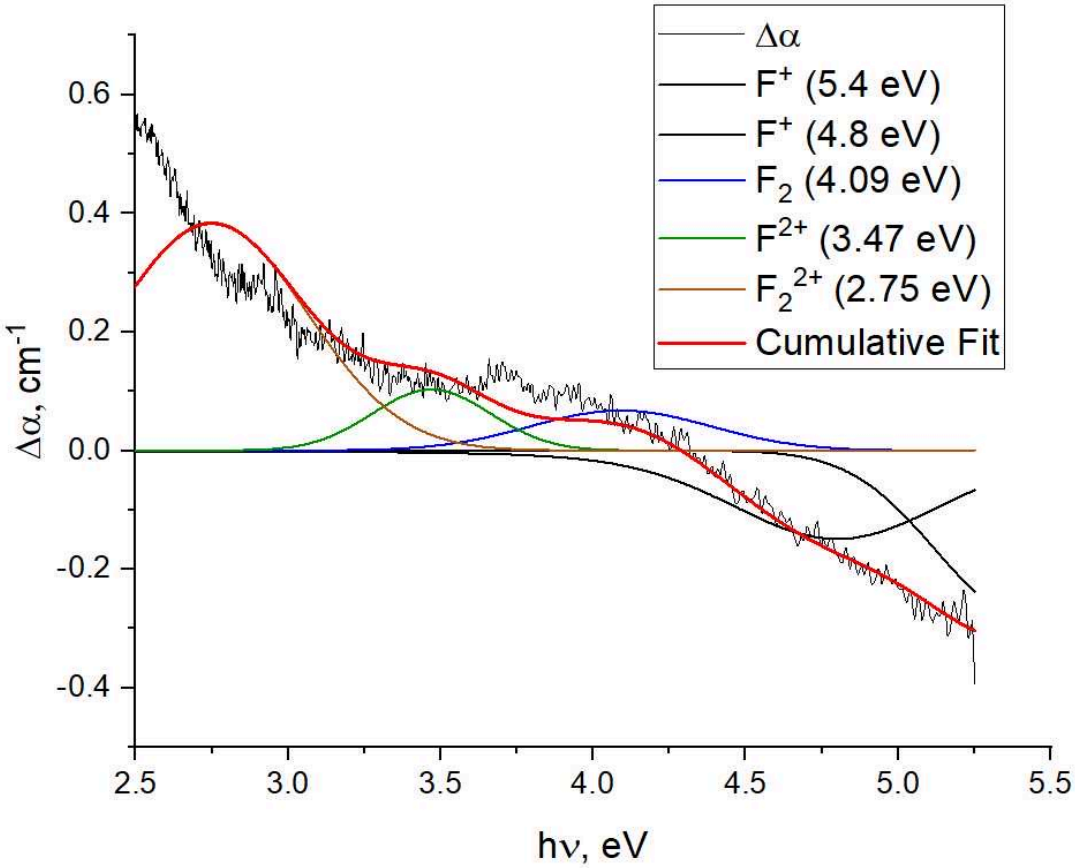
$$\alpha = \frac{1}{d}\log_{10}\left(\frac{\Phi_0}{\Phi_d}\right)$$

# Analysis of the brightening of a corundum target in the UV range

Smakula's equation

$$N = 0.87\times10^{17}\times n/((n+2)^2)\times\frac{\gamma}{f}\times\alpha_0$$

$n$ – refractive index,
$f$ – transition oscillator strength,
$a_0$ – absorption coefficients at the maximum of the band with the center $h\nu$ and half width at half maximum (HWHM) $\gamma$.

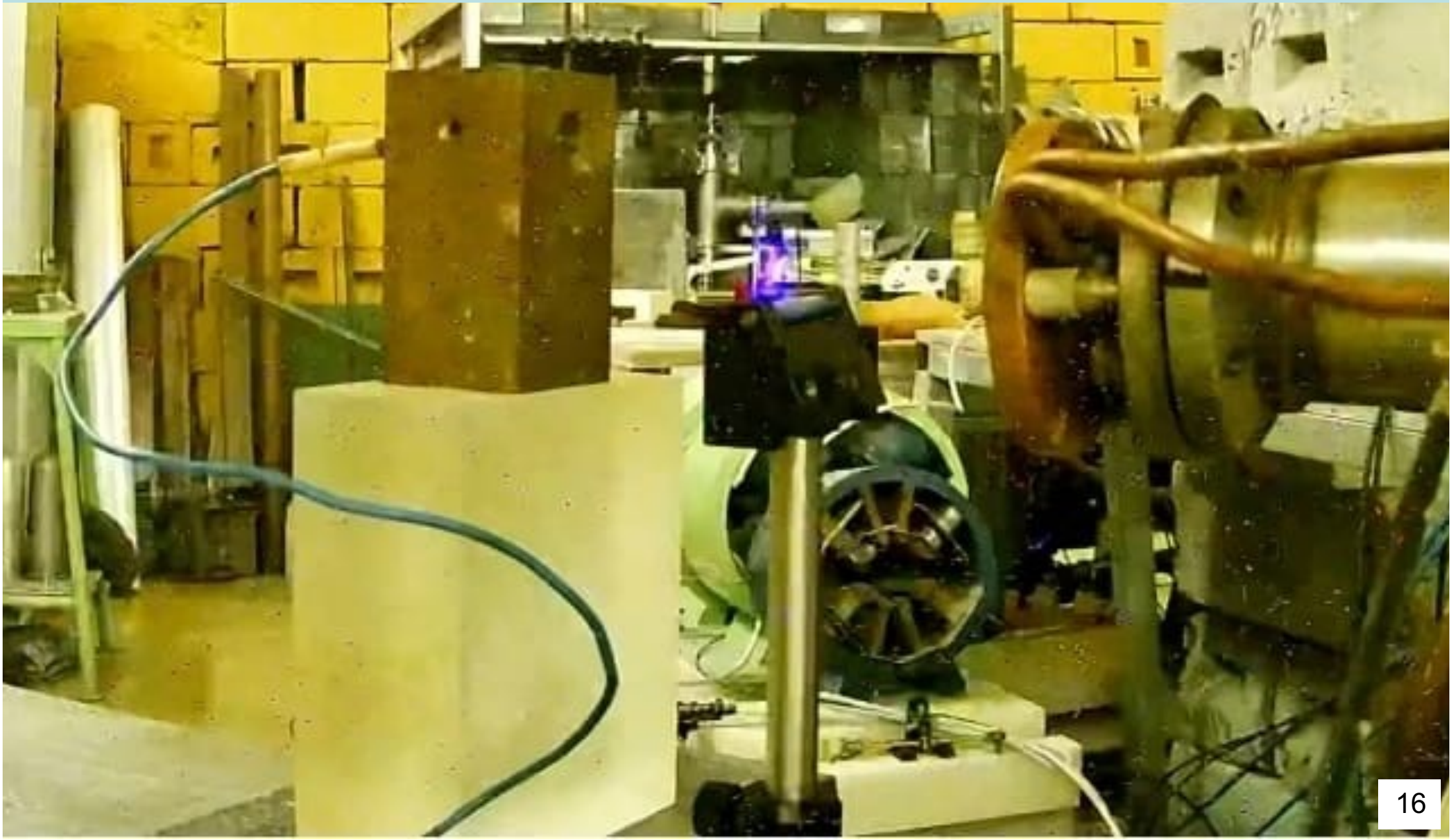


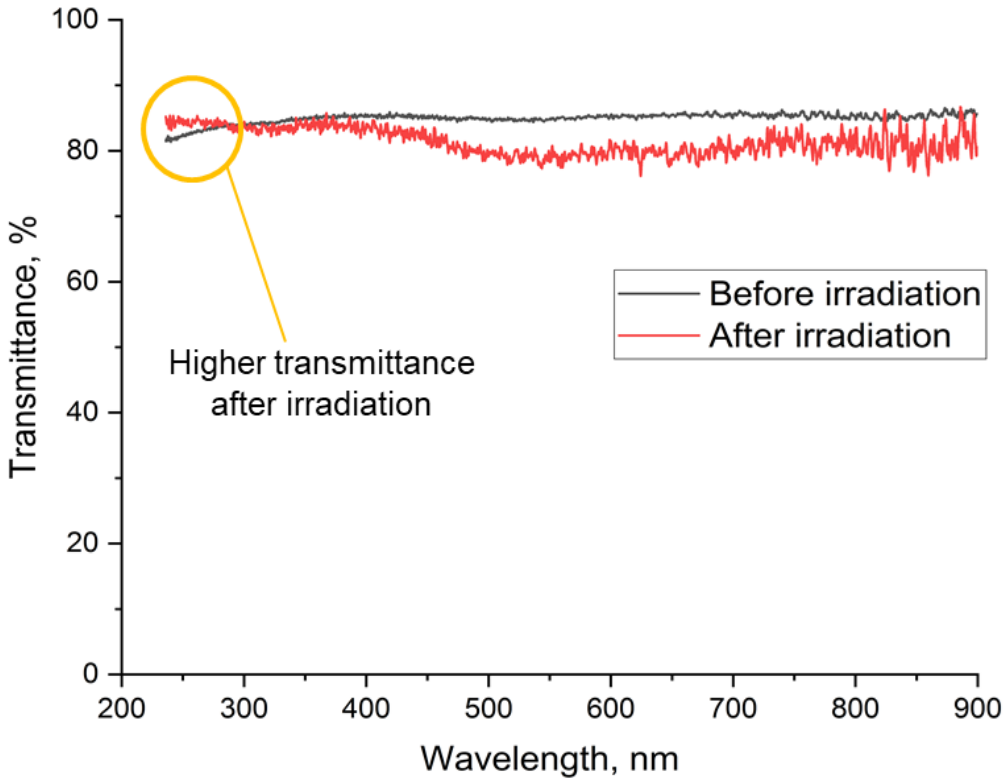

Decomposition of the induced spectral absorption coefficient

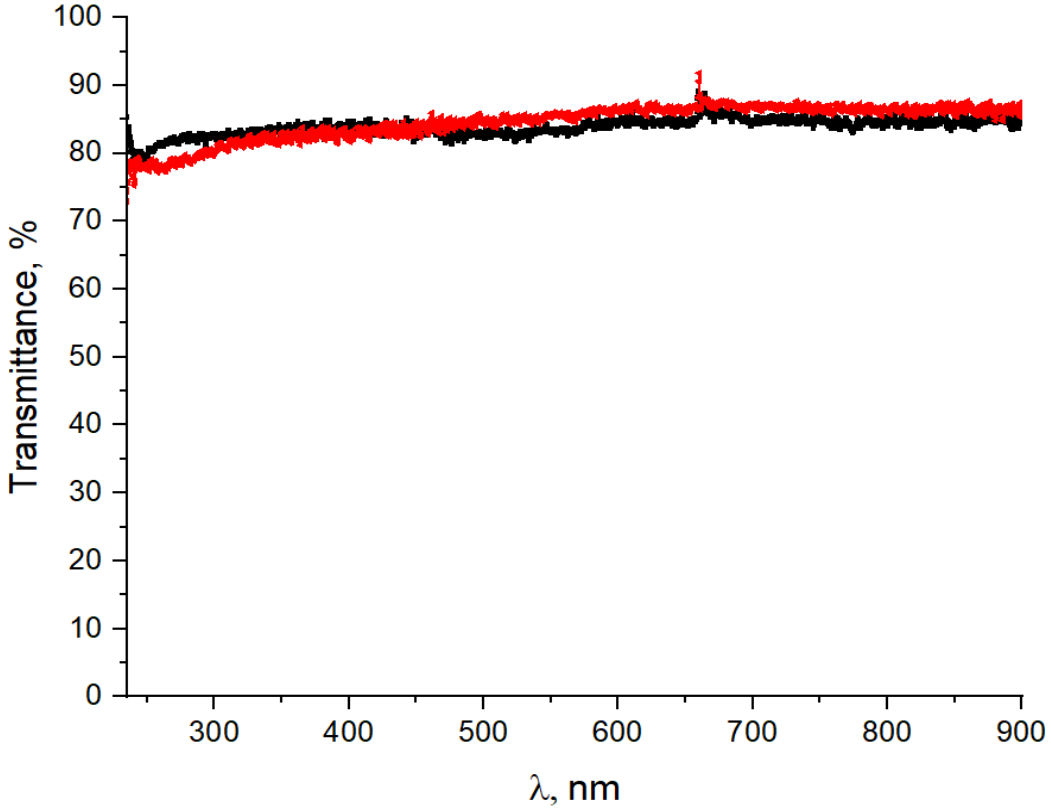
# Analysis of the brightening of a corundum target in the UV range

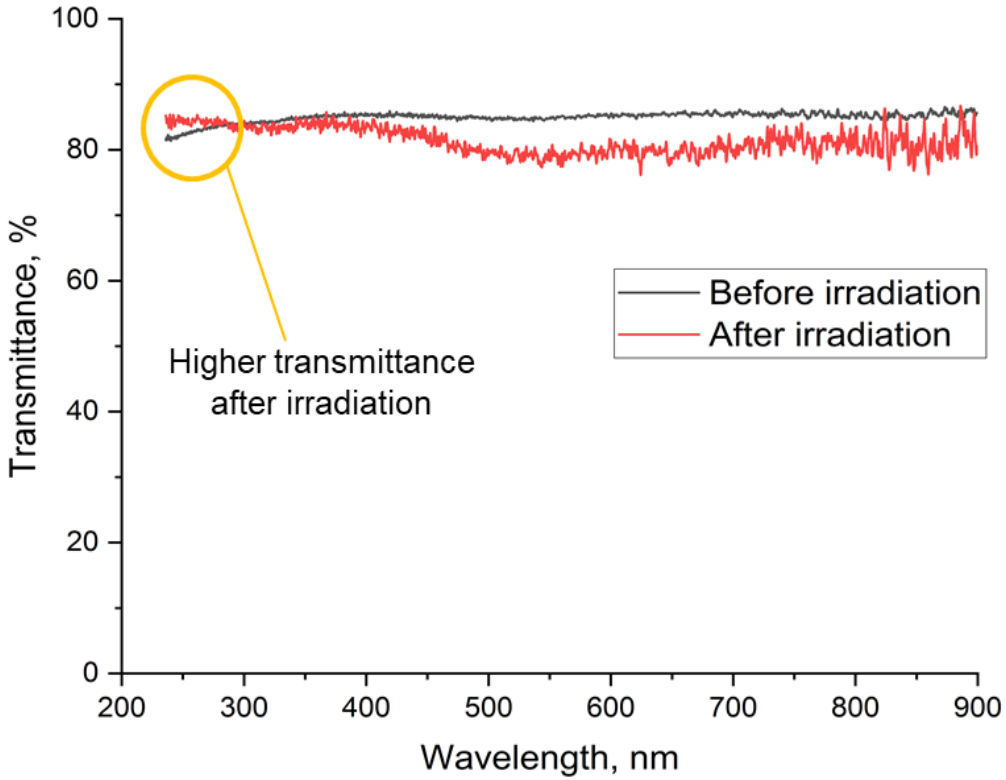
| **Absorption band center, eV** | **Refractive index *n*** | **Type of defect (F center)** | **ΔN, $cm^{-3}$** |
|---|---|---|---|
| **5,4** | 1,87 | $F^+$ | < 0 |
| **4,8** | 1,84 | $F^+$ | $-1.13 \cdot 10^{15}$ |
| **4,09** | 1,81 | $F_2$ | $0.51 \cdot 10^{15}$ |
| **3,47** | 1,80 | $F_2^+$ | $0,52 \cdot 10^{15}$ |
| **2,75** | 1,78 | $F_2^{2+}$ | $3,04 \cdot 10^{15}$ |

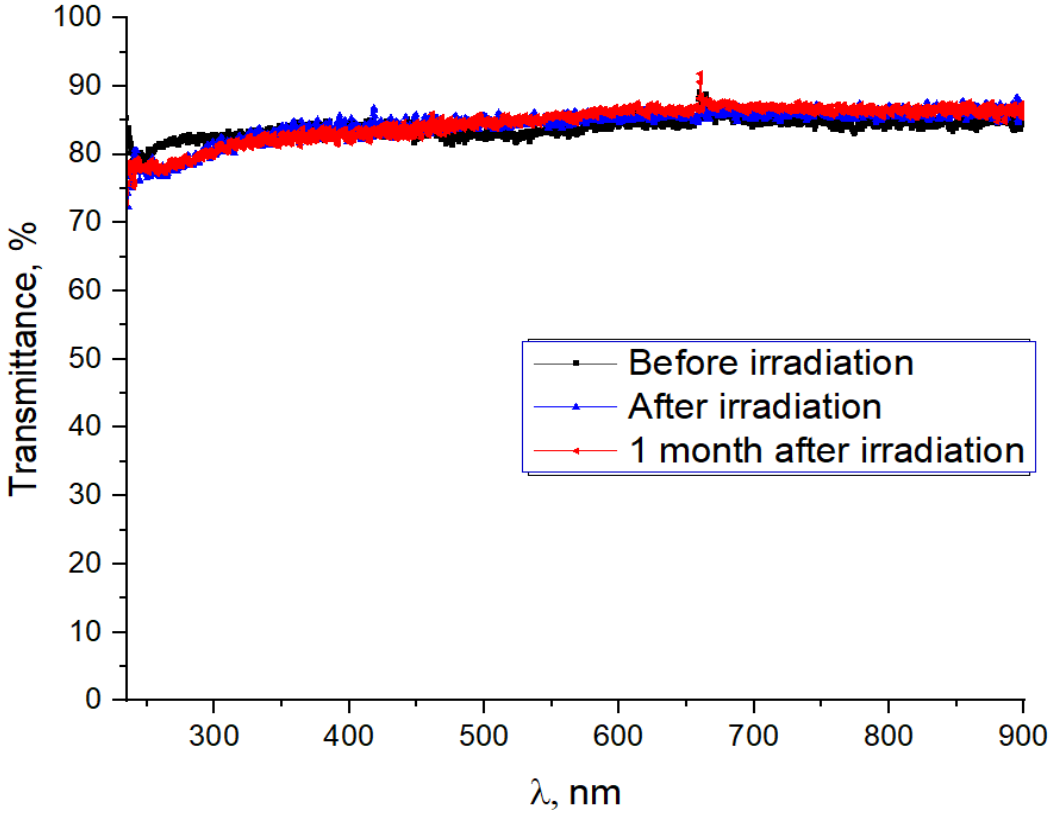
# Experiment at JINR (Dubna) microtron. 7 MeV, 6 μA




Transmittance, %
Wavelength, nm
Higher transmittance
after irradiation
Before irradiation
After irradiation


Transmittance, %
λ, nm


Transmittance, %
Wavelength, nm
Higher transmittance
after irradiation
Before irradiation
After irradiation


Transmittance, %
λ, nm
Before irradiation
After irradiation
1 month after irradiation

# Future plans


| **Parameters of ASTRA-M accelerator** | |
|---|---|
| Electron beam energy, keV | 250 |
| Pulse duration, ns | 100 |
| Pulse frequency, Hz | 40 |
| Pulse current density, A/cm$^2$ | 9 |

Average current ~ 6 μA (3×3 mm spot)

# Analysis of corundum crystals optical and ultraviolet transmittance after electron beam exposure

# Thank you for attention!

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