Peripheral Elements and Technology Associated with Pulsed Power Inertial Fusion：Part 2[1]

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[1] Supported by the Ministry of Education, Science, Culture and Sports in Japan, the Japan Society for the Promotion of Sciences, Tokyo Institute of Technology, Sandia National Laboratories, Institute of Optoelectronics, MUT, and Institute of Laser Engineering, Osaka University.

[2] Collaborations with A.Kasamatsu, Y.Kinoshita, T.Kamiya (TITech), T.Norimatsu, Y.Kozaki ,T.Yamanaka, S.Nakai (Osaka Univ.), T.Renk, C.Olson (SNL), W.Mroz, A.Prokopiuk (MUT).

Presented at the 2nd RCM of the IAEA CRP on "Elements of Power Plant Design for Inertial Fusion Energy", RC-845-F1.30.08, 21 May 2001, Vienna, Austria

Abstract

Various candidate materials were collected from many sources. They were irradiated with intense proton beams at Tokyo Institute of Technology (TITech), with intense nitrogen beams at Sandia National Laboratories (SNL), Albuquerque, and with short pulse UV laser at IOE-MUT, Warsaw. A series of preparatory numerical calculations of x-ray ablations was performed at TITech, which results were compared with the experimental ones. Our aims were to supply necessary data for the future design of inertial fusion reactor chambers. One of the key issues in this field was the ablation thickness of the various chamber wall materials with intense beams under typical inertial fusion reactions. We measured the ablation thickness of various samples, and we also observed the surface conditions of the samples before and after the irradiations with a microscope, an x-ray luminescence composition analyzer and 3D-surface profiler.

Keywords: **Inertial fusion, Reactor Chamber Database, Wall Materials, Surface Ablation with Ions, X-rays and UV Laser Light**

CONTENTS:

Sample Targets Collected for Beam Exposure:

***1-a*/LiPb/ 16x19x1/ ILE/ Manufactured in Ar environment, Melting Temperature of 233C (Peak)/**

***1-b*/SiC/ 18x23x1 etc./ ILE/**

***4-b*/Carbon G650S/ 30diax5t(1)/ TITech/ Product of Nilaco Co. Ltd./**

***6-a*/SiC/ 100diax2/ Tokaikonetsu/ Product of Tokaikonetsu, Normal Pressure Baked, Both Surface Ground/**

***6-b*/SiC-Si/ 235x235x5/ Tokaikonetsu/ Product of Tokaikonetsu, RS420/**

***6-c*/Al_2O_3/ 135x125x5/ Tokaikonetsu/ SSA-M, Product of Nihonkagakutohgyoh, Normal Pressure Baked/**

TITech, DOES, Kasuya Lab

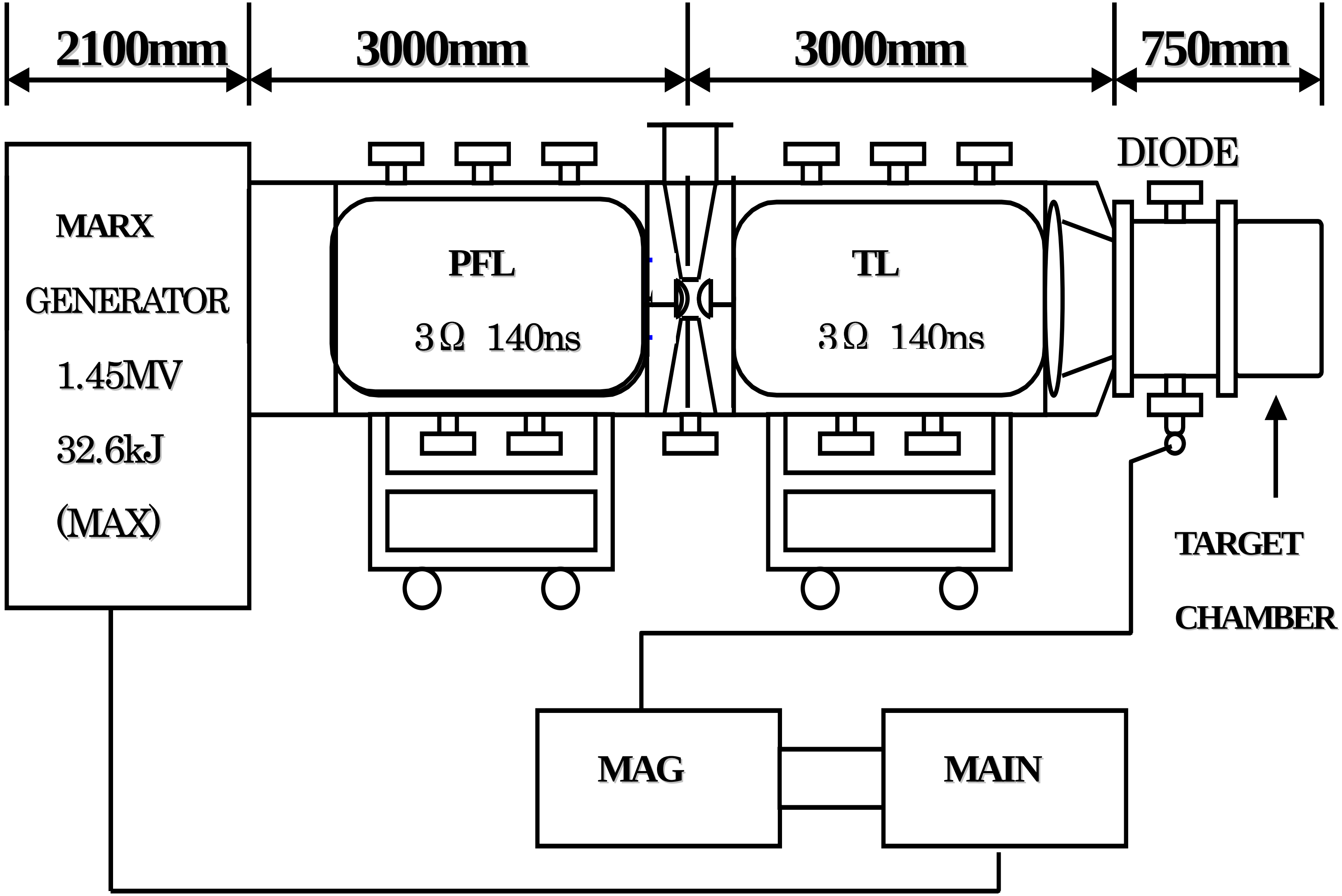

Fig. Schematic Diagram of Target Ablation with Intense Proton Beam

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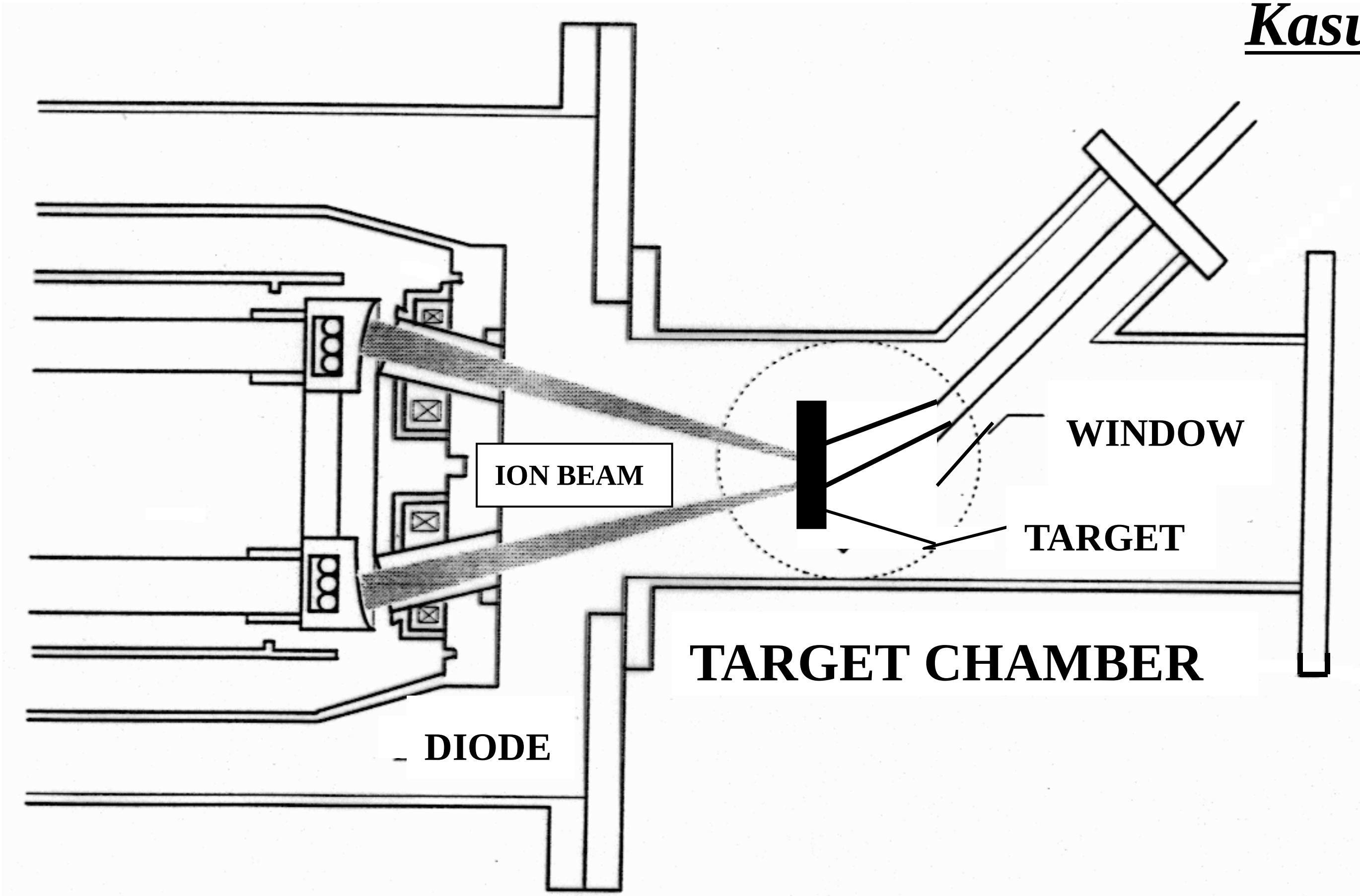

**Fig.	Configuration of Focused Proton Beams on Target**

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__Kasuya Lab.__

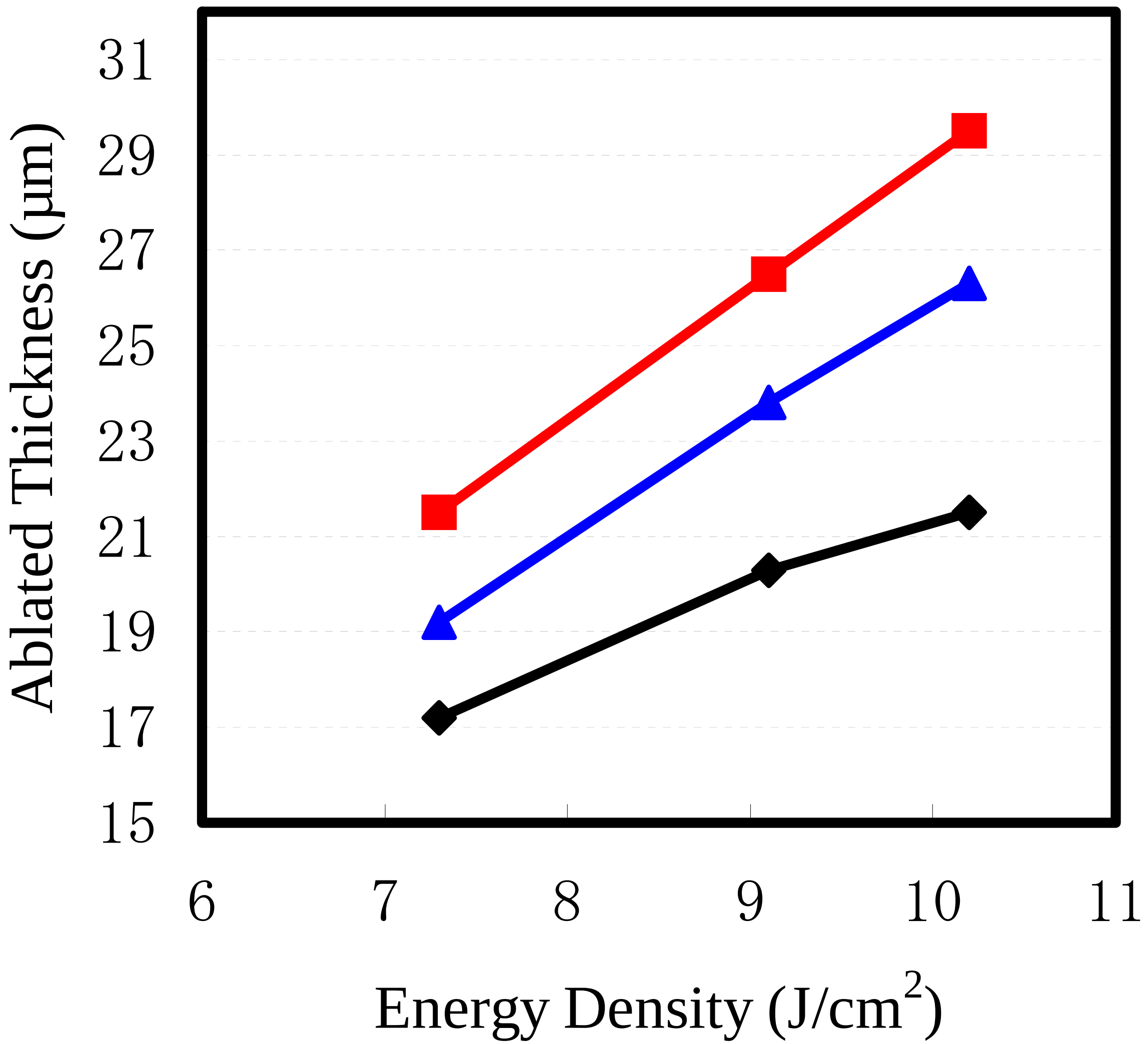
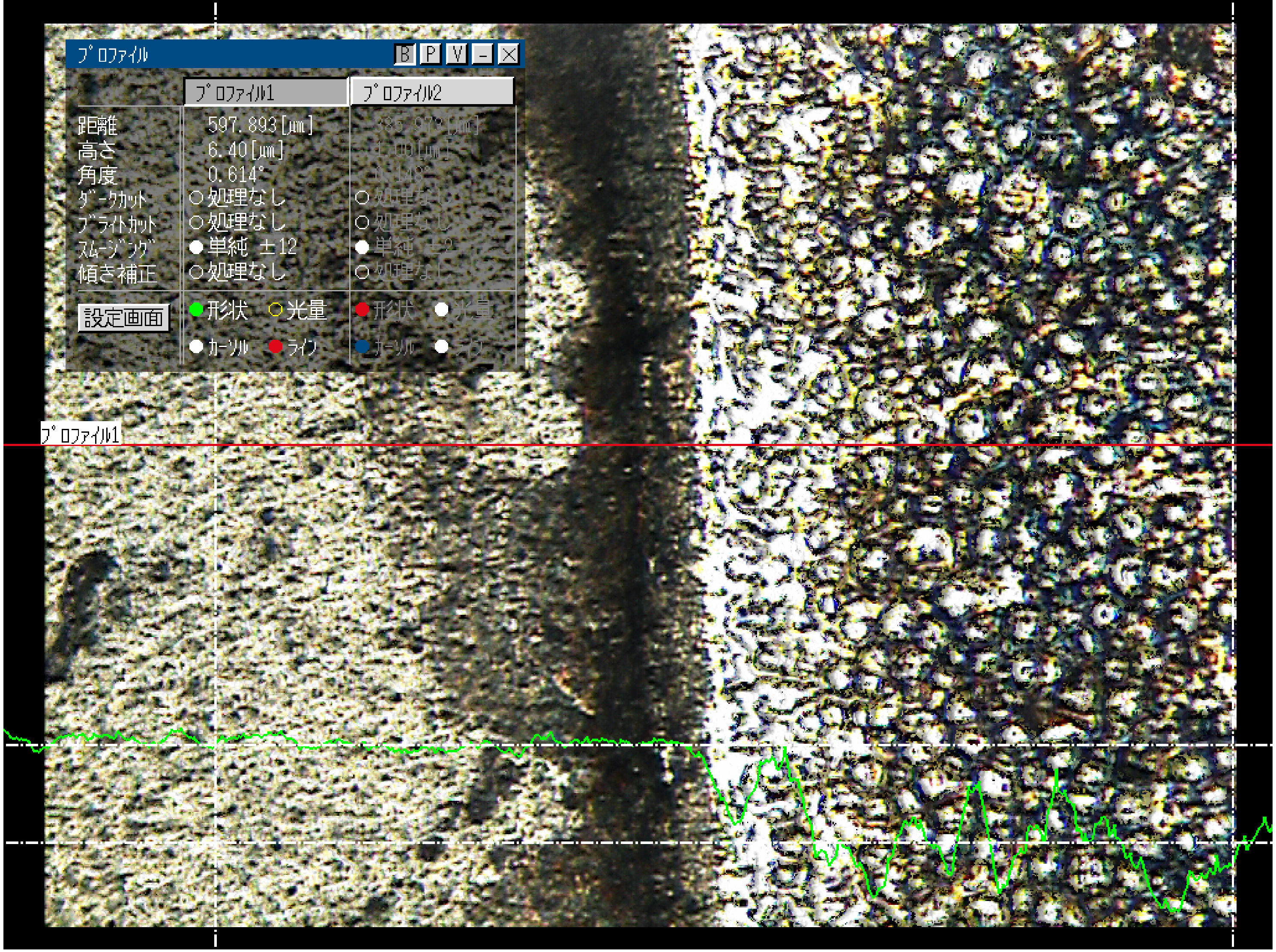


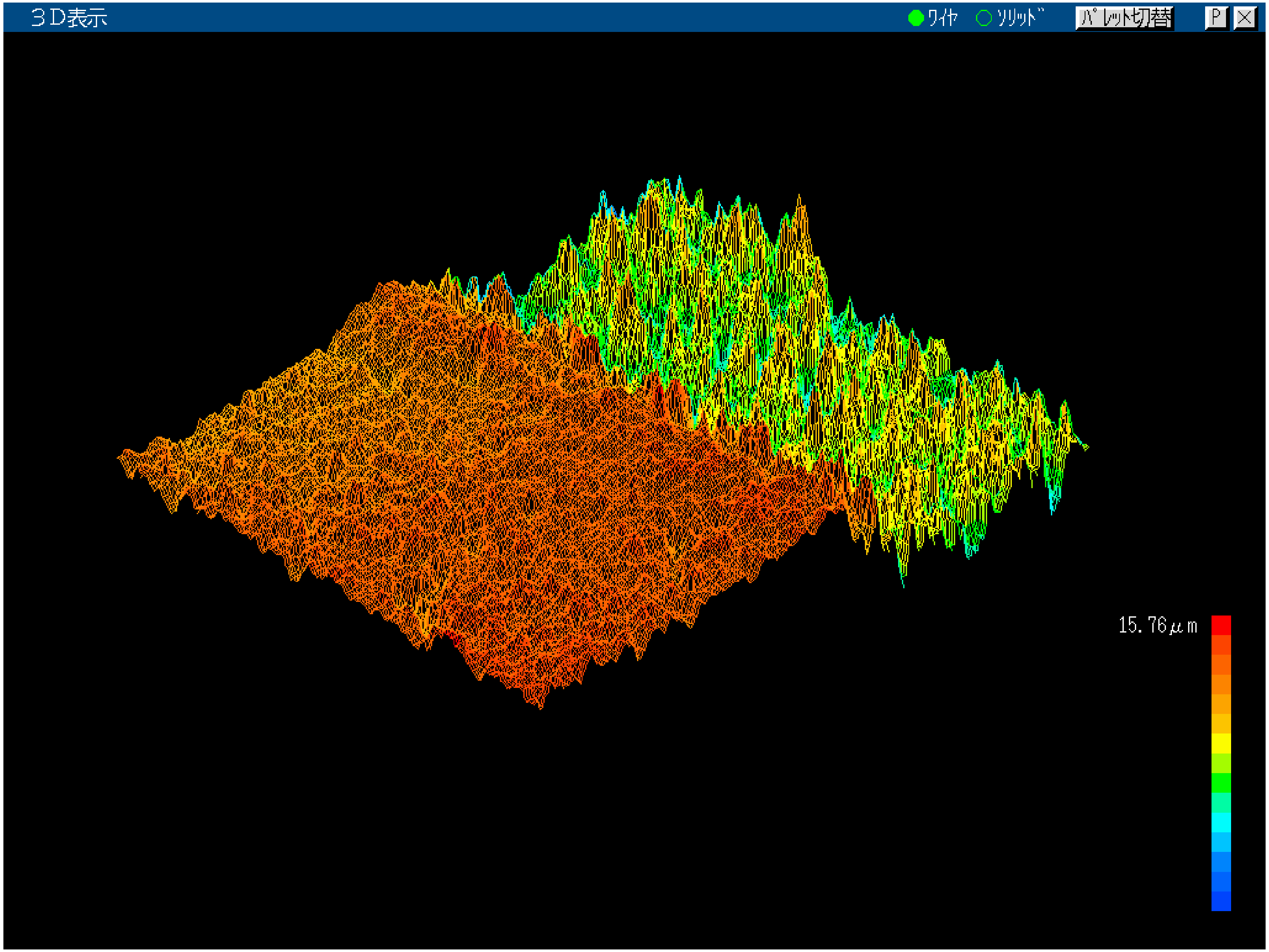
Fig. Ablation Thickness vs. Proton Dose (SiC, LiPb and C from Top to Bottom).

Fig. Laser Microscope for Surface Ablation Analysis

(Keyence VK-8550 System)



2D Microscope Image of SiC, irradiated with N_2 Dose of 3.9J/cm^2.



3D Microscope Image of SiC, irradiated with N_2 Dose of $3.9 J/cm^2$.

X-ray Luminescence Spectrometer for Surface Composition Analysis (Philips PW2404 System)

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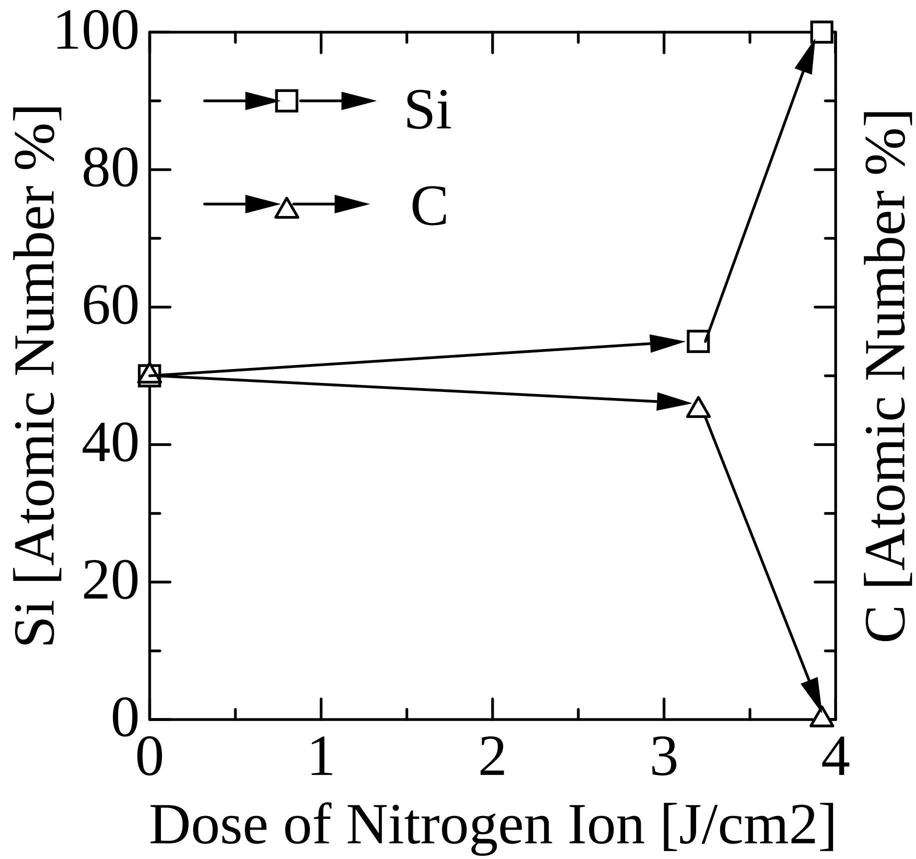

Fig. Change of SiC Surface Composition with Different Dose of Nitrogen Ion Irradiation, Measured with X-ray Luminescence Analysis.

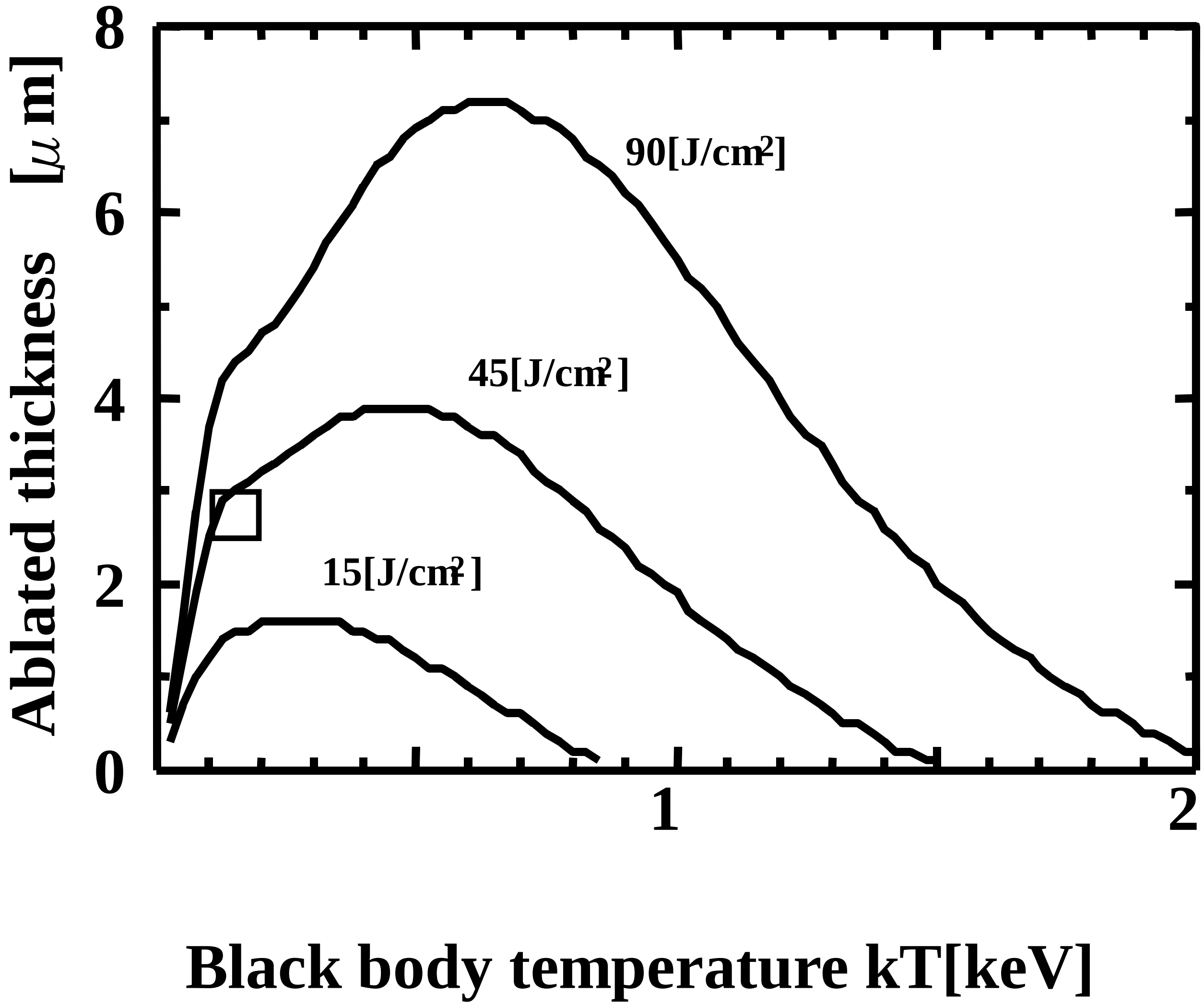

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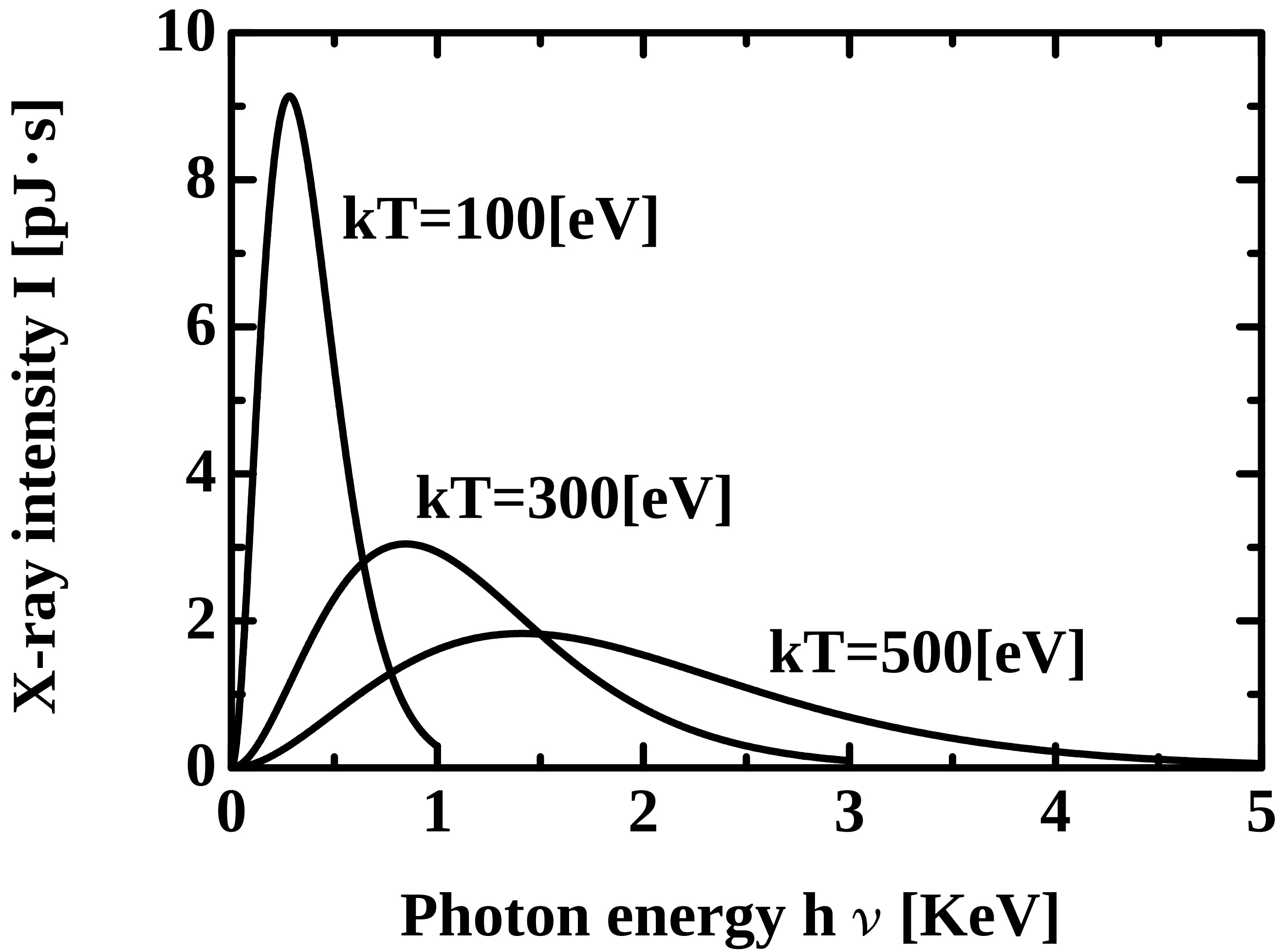
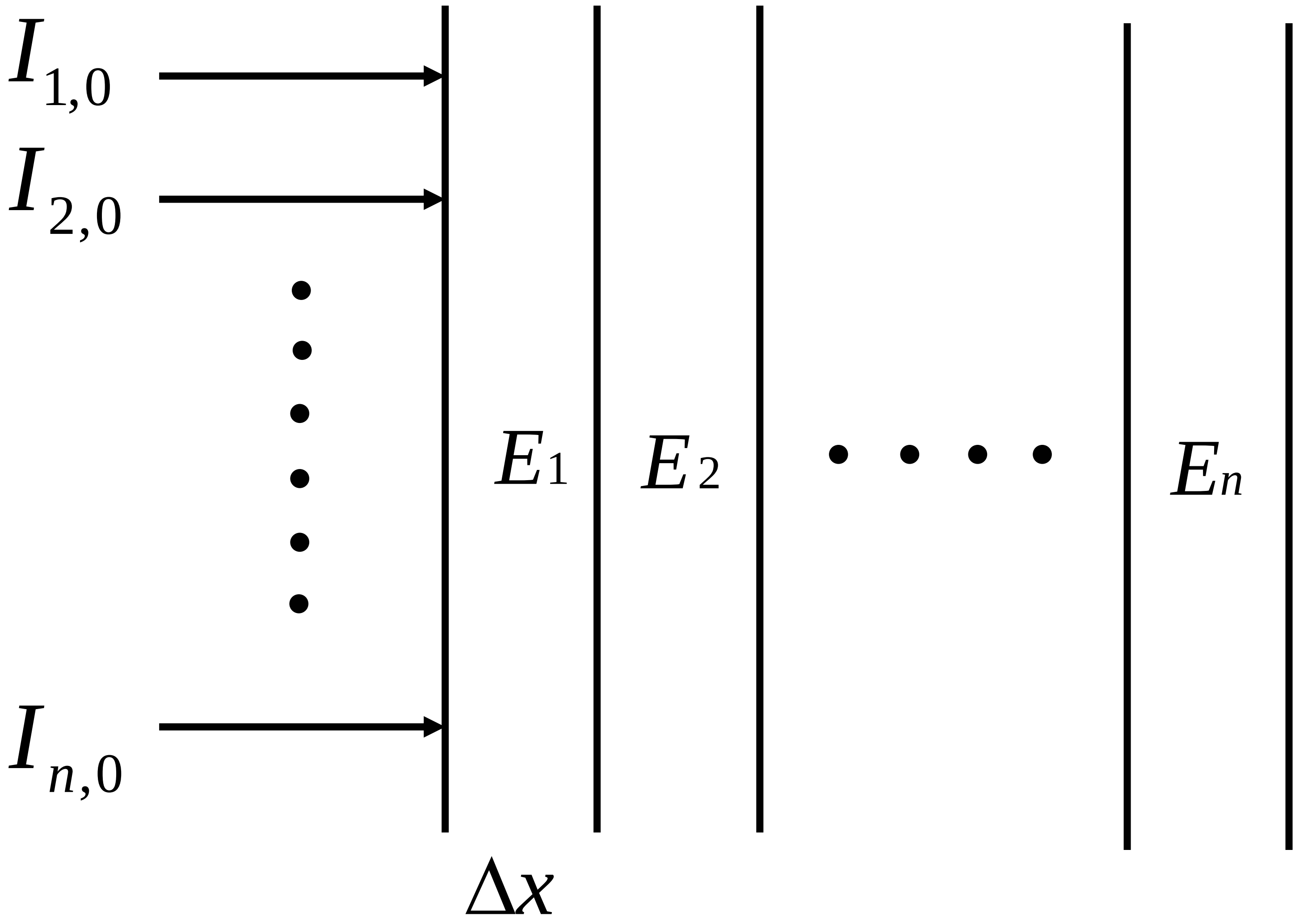
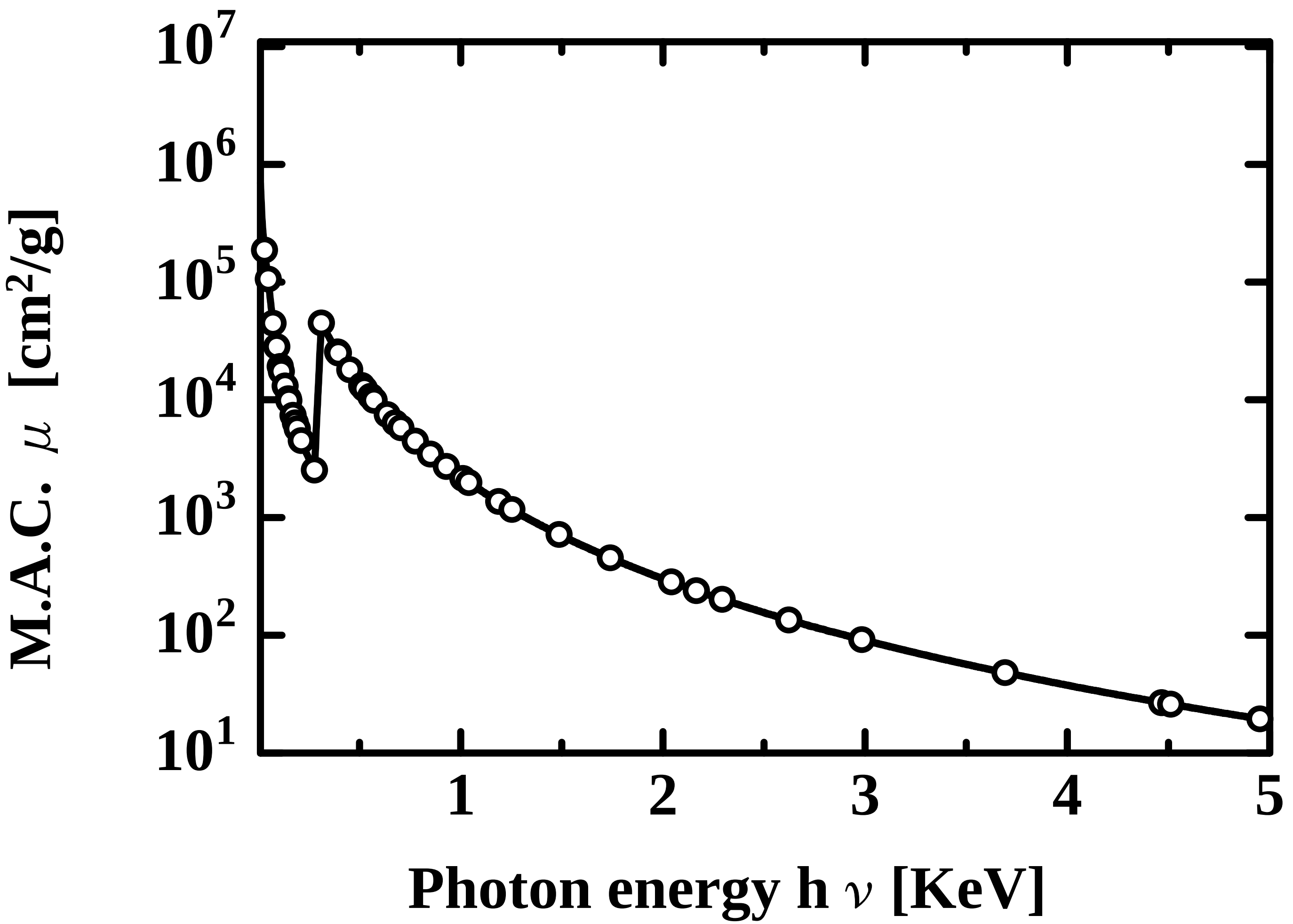
Fig. Ablated Thickness vs. Black Body Temperature of X-ray Source. Calculation in Case of LiF. White Small Box is Experimental Result for Comparison.



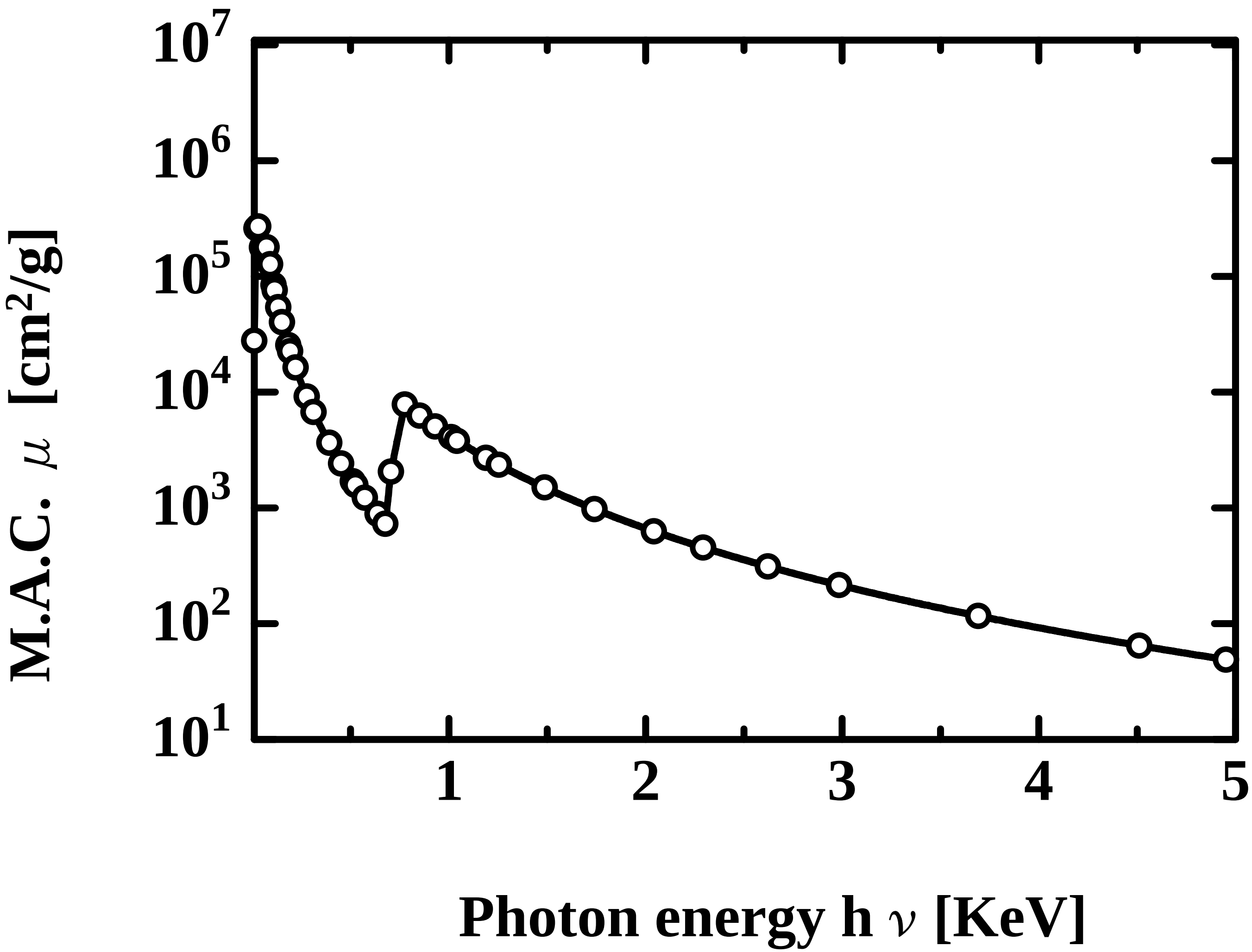
The plots of Planck's law.



X-ray absorption with sliced thin layers.



Mass absorption coefficient of C



Mass absorption coefficient of LiF [1]

Calculation for heat capacity of Carbon's thin layer

$$R = 1.000[m]$$

$$\rho = 2.253\times10^{6}[g/m^{3}]$$

$$\Delta x = 1.000\times10^{-8}[m]$$

$$Q_{sub} = 5.975\times10^{4}[J/g]$$

$$C_p(T) = 17.17 + 4.27\times10^{-3}T - 8.79\times10^{5}\times T^{-3}$$

$$T_1 = 298.15[K]$$

$$T_2 = T_{sub} = 4200[K]$$

$$\therefore 4\pi R^2\Delta x\rho\left(Q + \int_{T_1}^{T_2} C_P(T)\,dT\right) = 19.2[KJ]$$

Calculation for heat capacity of LiF's thin layer

$$R = 1.000[m]$$

$$\rho = 2.653 \times 10^{6}[g/m^{3}]$$

$$\Delta x = 1.000 \times 10^{-8}[m]$$

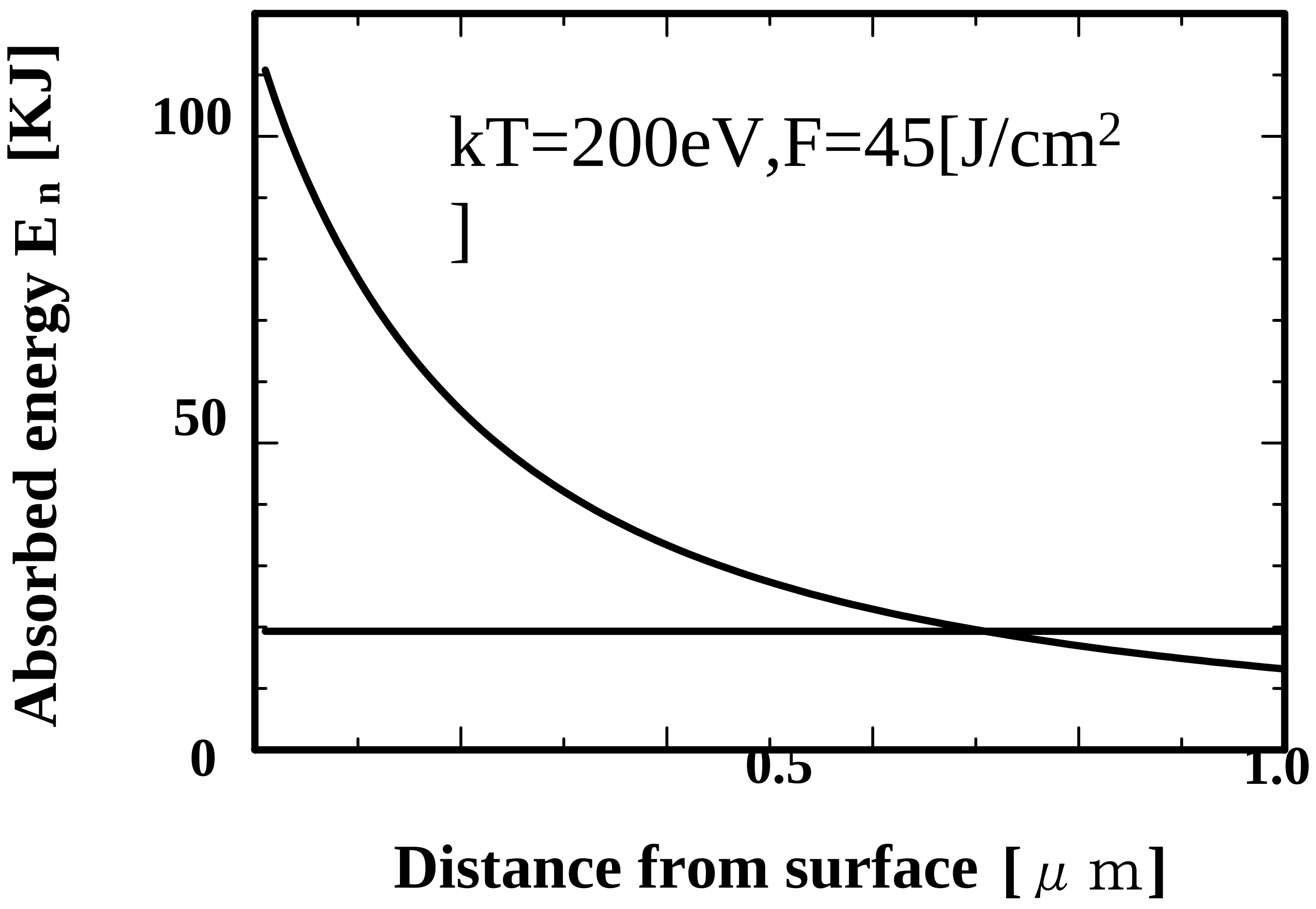
$$Q_{eva} = 8.211 \times 10^{3}[J/g]$$

$$C_p = 2.474[J/K \cdot g]$$

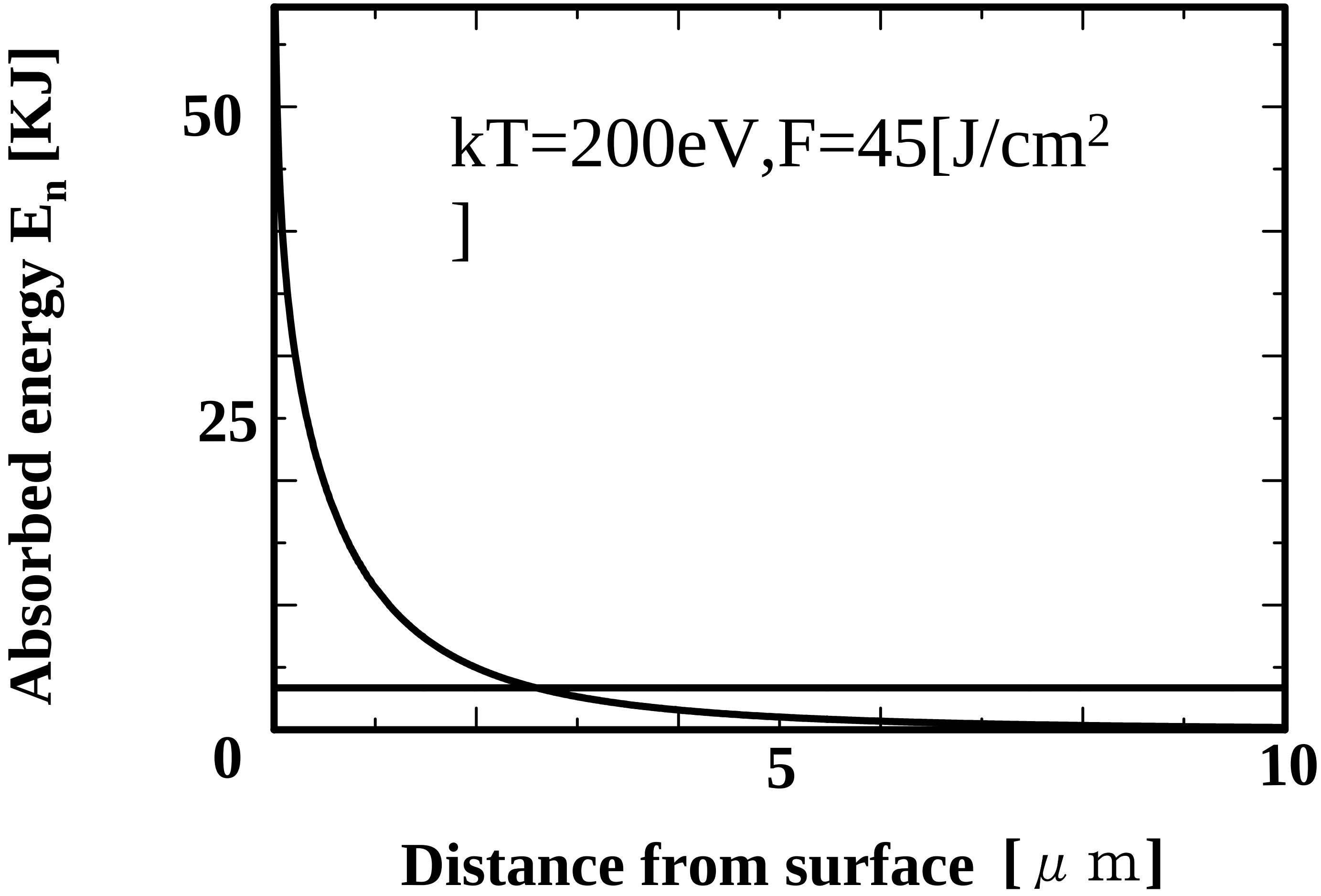
$$T_1 = 1200[K]$$

$$T_2 = T_{eva} = 1954[K]$$

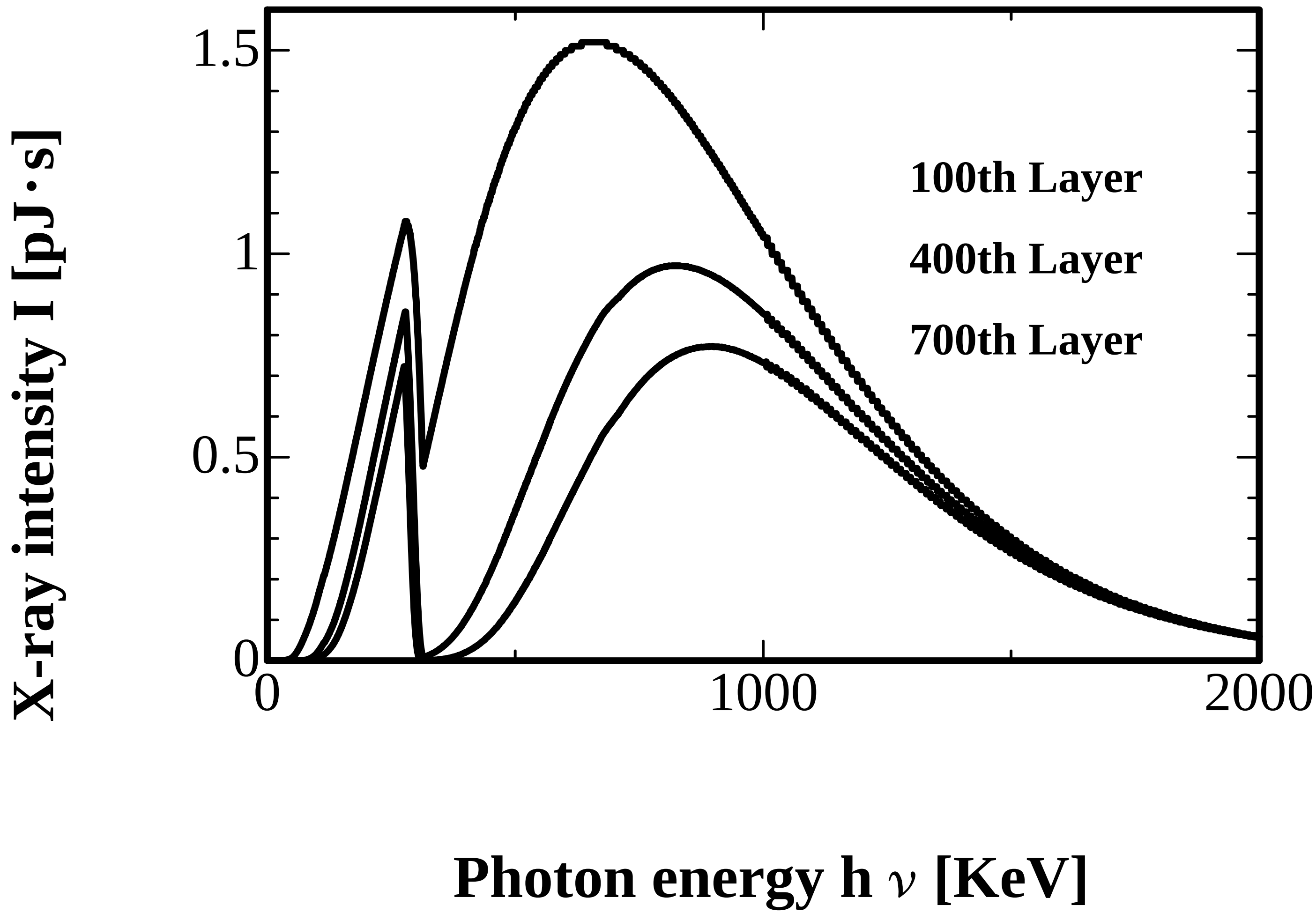
$$\therefore 4\pi R^2 \Delta x \rho (Q + \int_{T_1}^{T_2} C_P(T)dT) = 3.4[KJ]$$



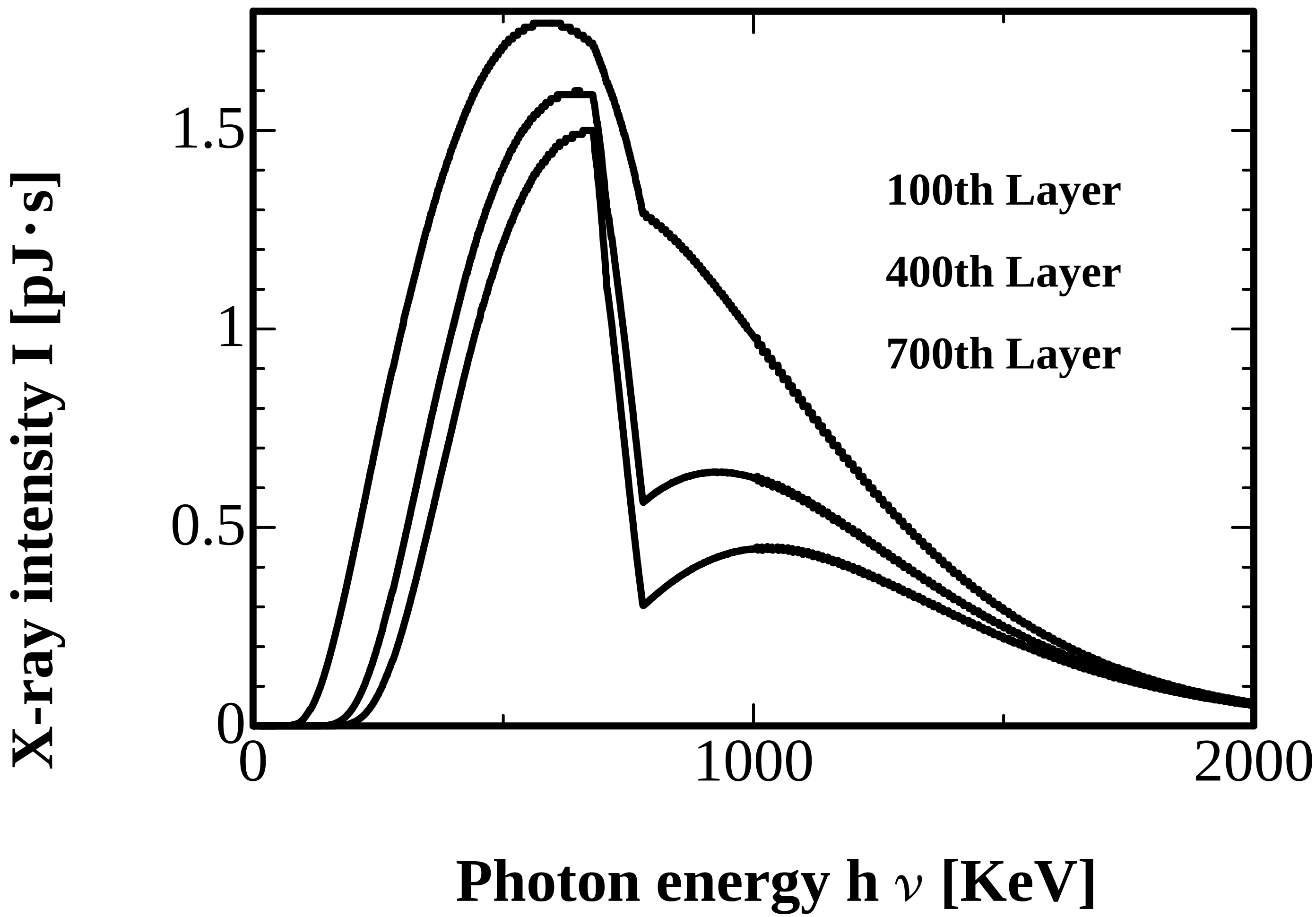
Ablation Estimation for C



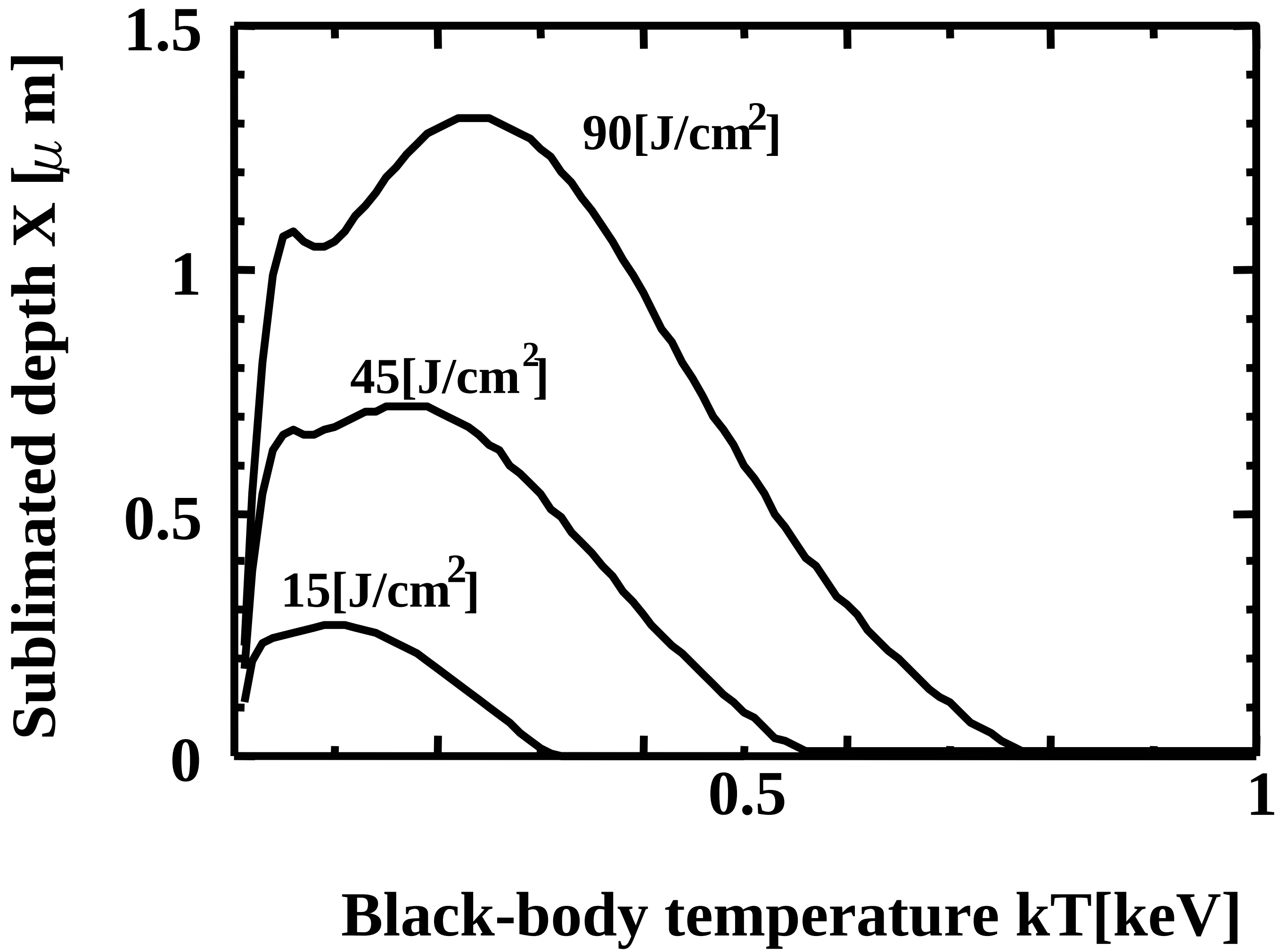
Ablation Estimation for LiF



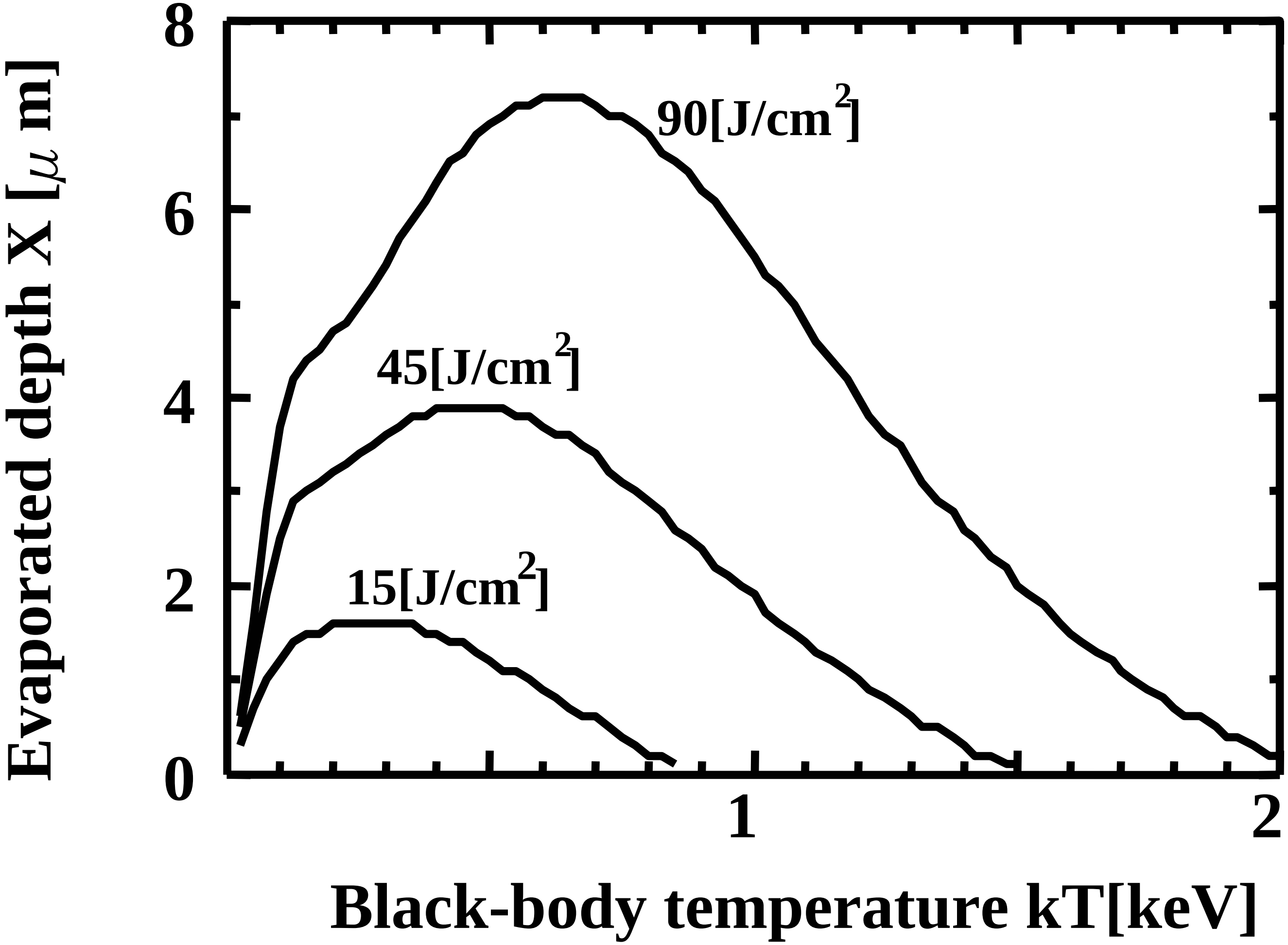
Absorbed energy in one C layer with kT=200[eV],F=45[J/cm^2]



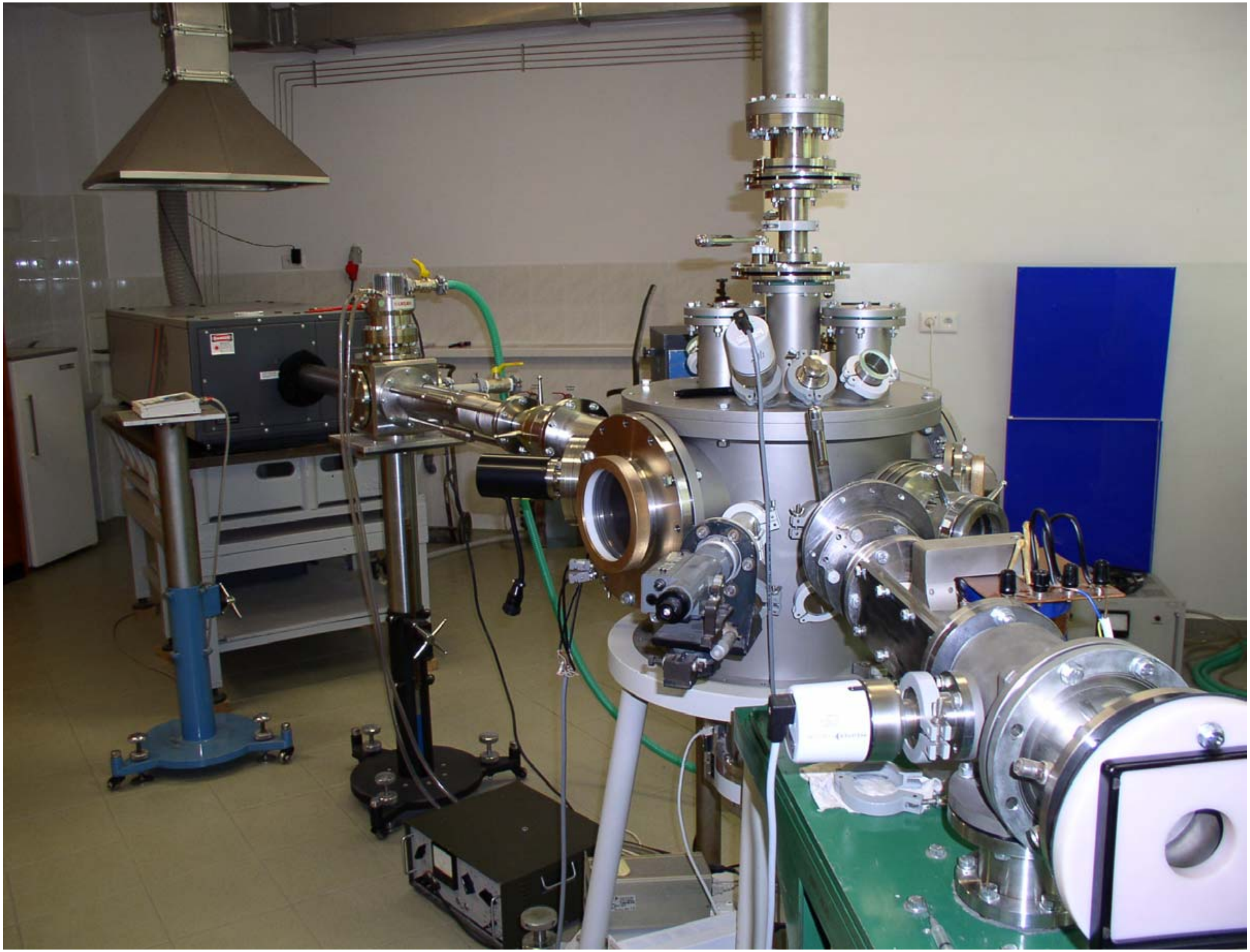
Absorbed energy in one LiF layer with kT=200[eV],F=45[J/cm^2]



Sublimated depth of C

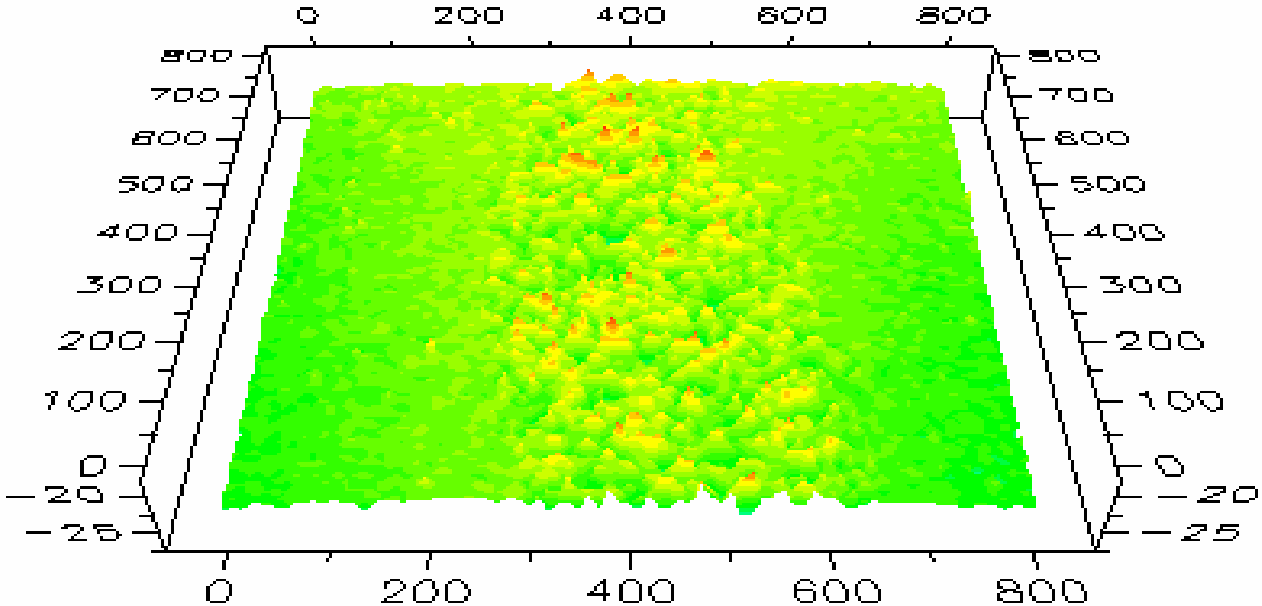


Evaporated depth of LiF

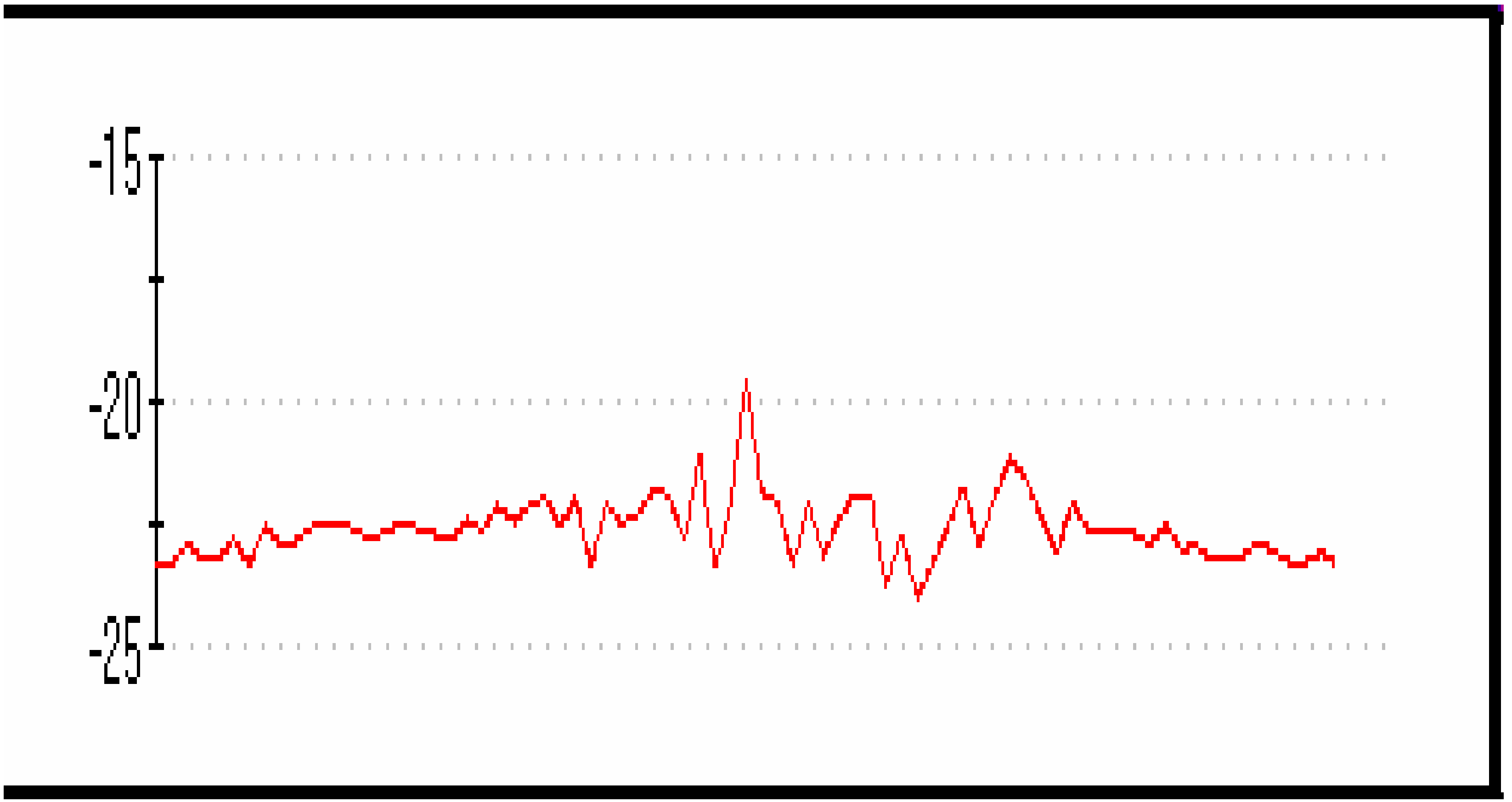


Apparatus for UV Laser-Target Interaction

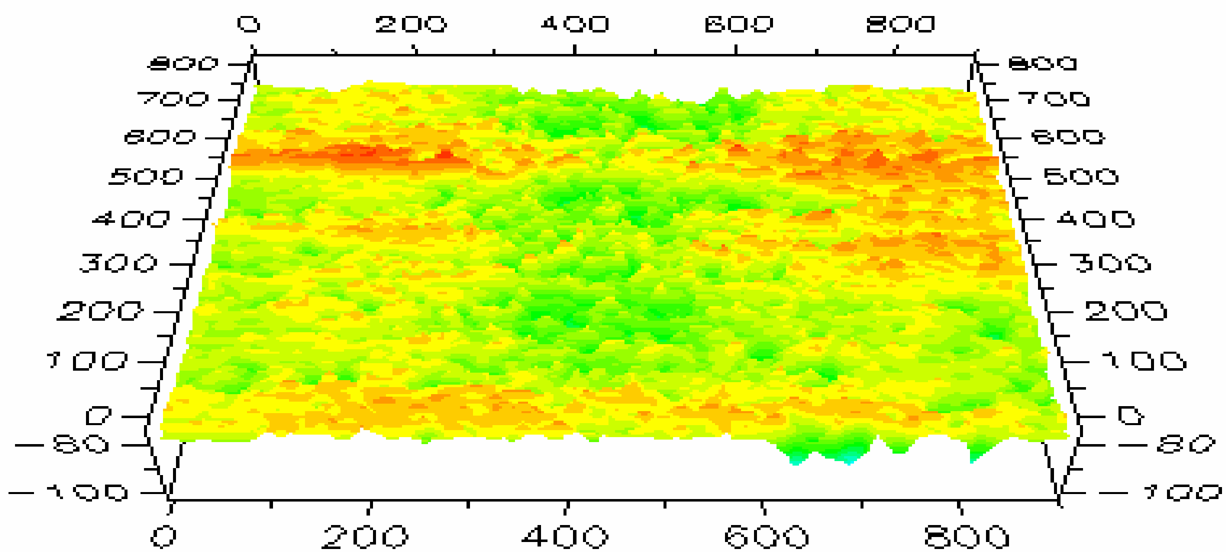
Excimer laser LPX 305i (LPX 300 series) for laser target interaction ($E_L \le 1{,}2$ J, wavelength 157 nm, 193 nm, 248 nm, f = 50 Hz, $\tau \cong 20$ ns)



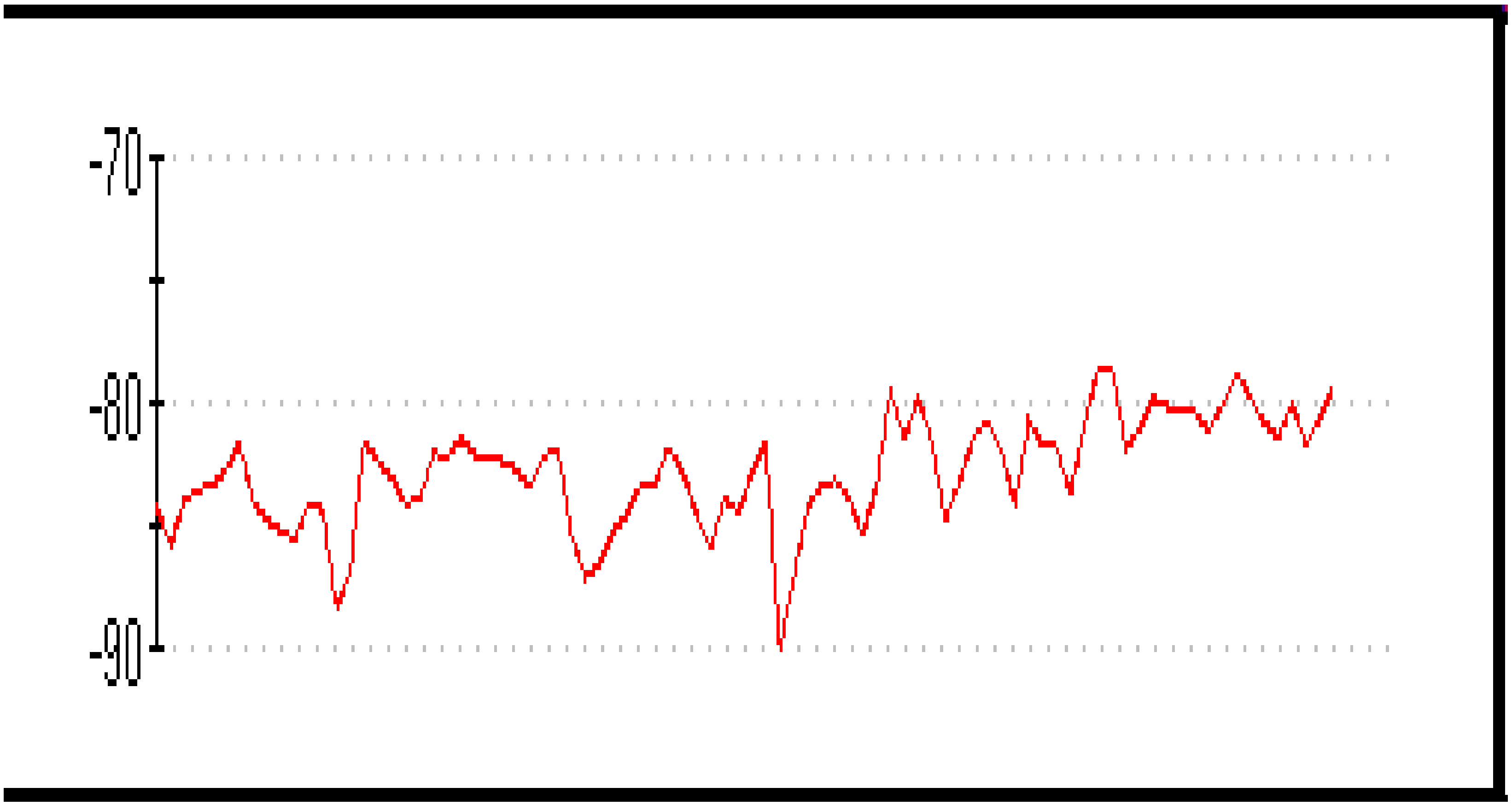
3D Analysis of Tungsten Surface with Profiler



2D Analysis of Tungsten Surface with Profiler



3D Analysis of Graphite Surface with Profiler



2D Analysis of Graphite Surface with Profiler

Summary

Under the proton beam irradiation with the dose of about $10J/cm^2$ per shot, the ablated rates were up to 20 micron for carbon, and 26 micron for LiPb and SiC. The change of the rate was investigated with the change of the dose. Under the nitrogen beam irradiation with the dose of $4J/cm^2$, the ablated thickness of up to 6 micron was observed for SiC, while no remarkable ablation was observed for Al_2O_3. Surface conditions before and after the nitrogen beam irradiation was investigated with a microscope and x-ray fluorescence analysis. SiC surface turned into Si surface, while no discernible change was seen for Al_2O_3. Under the x-ray irradiation of LiF, SiC/Si and SiC, the ablation thickness of 3 , 0.5 and 0 micron was observed under the dose of 40, 7 and $7J/cm^2$. Under the UV laser irradiation of W and C, the surface change could be observed with a 3D surface profiler. More experiments and calculations with more advanced methods are scheduled in the near future.