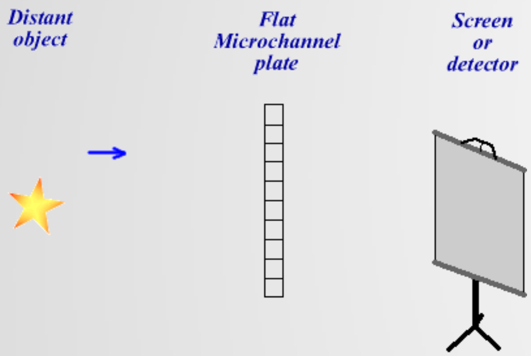
INTERACTION OF CHANNELING X RAYS, COHERENT EXCITATION OF FLUORESCENCE AND INTERFERENCE PHENOMENA OF TRANSMITTED RADIATION AT THE EXIT OF MICRO-CHANNEL PLATE:S



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CHANNELING - 2018
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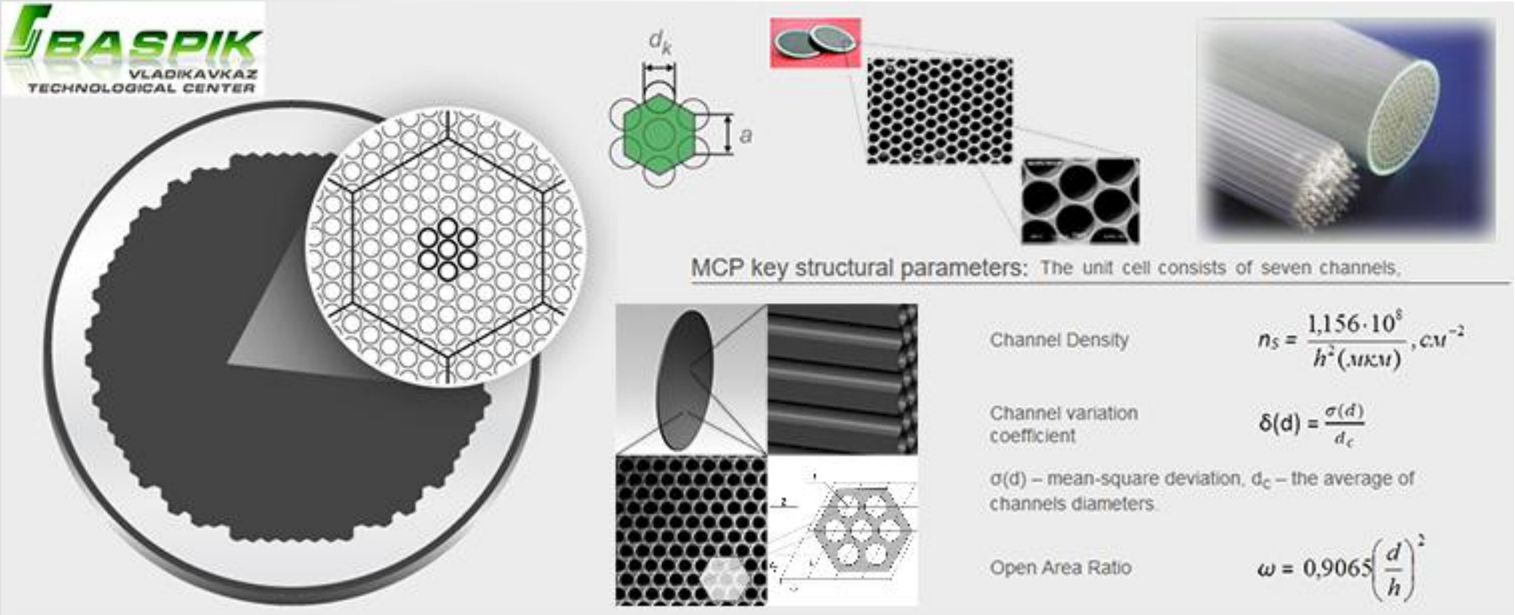
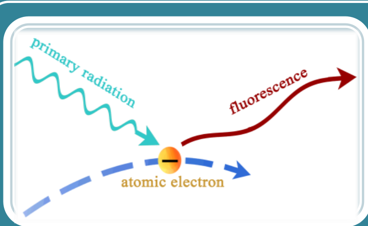
Micro-Channel Plates

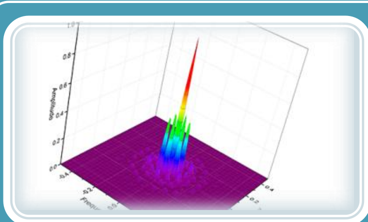


Microchannel plates (MCPs) as polycapillary X-ray optic devices consists of an array of a large number of small hollow silicon glass tubes formed with a certain shape. Hollow cylindrical micro-capillaries work as waveguides for X-ray radiation. The MCPs we used are arrays of 10^4–10^7 miniature hole microchannels oriented parallel to one another, characterized by spatial regular channels with hexagonal symmetry in the transverse cross-section. The flat plate samples investigated in the regime of X-ray transmission had channel matrix of MCPs is fabricated by silicon-lead glass. We measured both angular distributions and fluorescence of soft X-ray radiation excited inside MCPs with microchannel diameter of 3.4 μm, pitch size 4.2 μm and thickness ~0.27 mm.

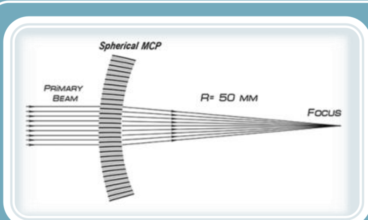
Properties and Motivation



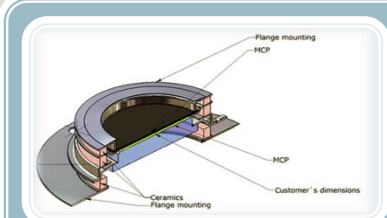
Previous studies were devoted to the characterization of the propagation of the radiation hitting the walls inside the hollow channel of a MCP and transmitting the radiation by such polycapillary structures.



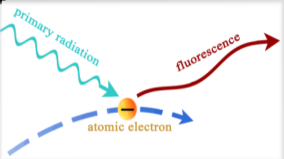
The diffraction pattern contains the central zero maximum and six first-order peaks located symmetrically with respect to the center, which corresponds to the symmetry of arrangements of the channels of the MCP.



We have studied the focusing properties of x rays by MCPs devices which are optical systems suitable to shape radiation beams at soft x-ray range.

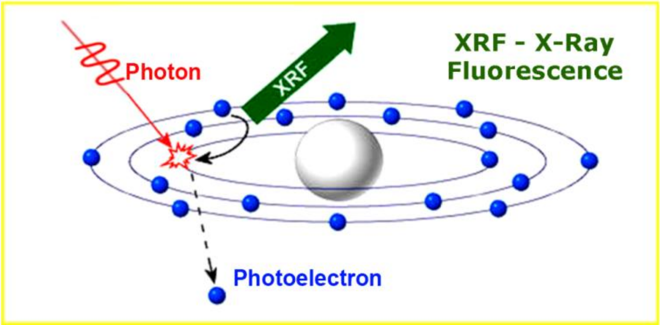


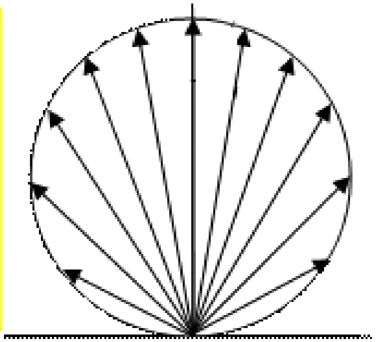
We a going to use a Solid Frame Devices with double MCPs inside (SFD-MCP) for studying of the diffraction at the exit.



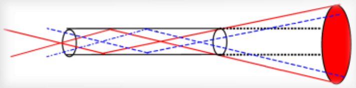
Distribution of X-ray Fluorescence

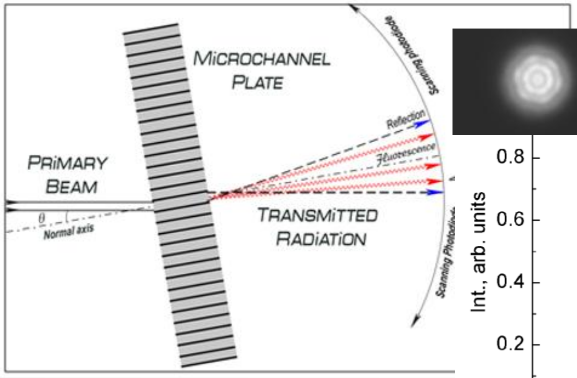
X-ray fluorescence from a flat surface has space distribution close to spherical shape

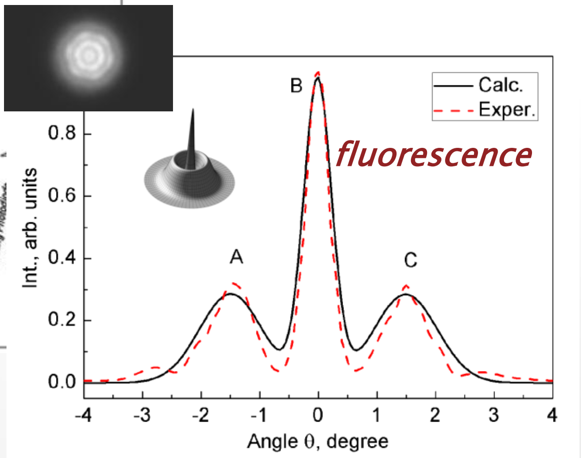




Excited X-ray fluorescence propagates along axis of microchannels and has directional distribution at the exit of MCP



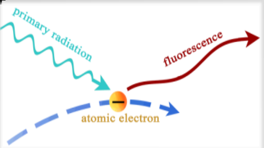




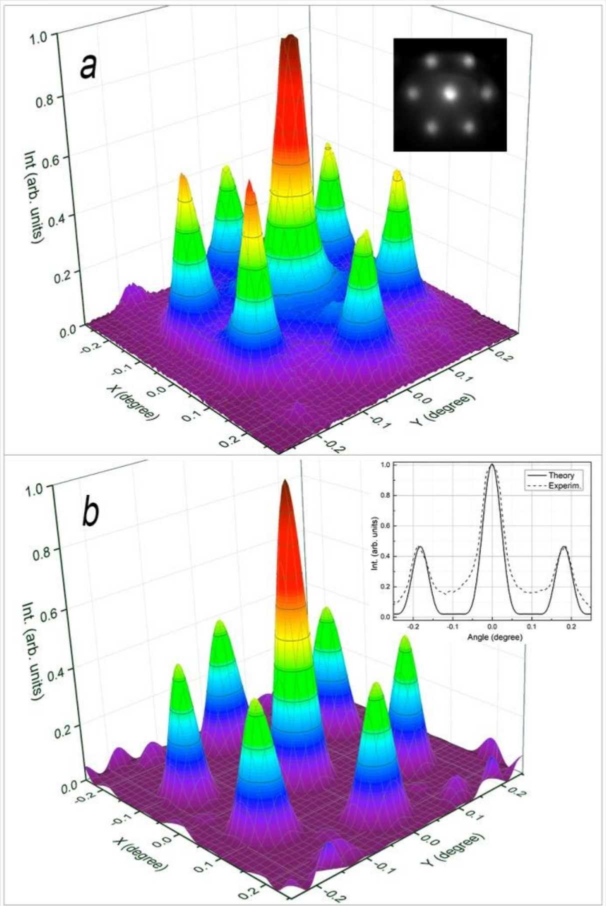
M.I. Mazuritskiy, S.B. Dabagov, A. Marcelli, A.M. Lerer and K. Dziedzic-Kocurek // J. Synchrotron Rad., **23** (2016), 274-280.

M.I. Mazuritskiy, S.B. Dabagov, A.M. Lerer K., K. Dziedzic-Kocurek, A. Sokolov, M. Coreno, S. Turcini, A. D’Elia, M. Sacchi and A. Marcelli // NIM B **402** (2017) 282-286

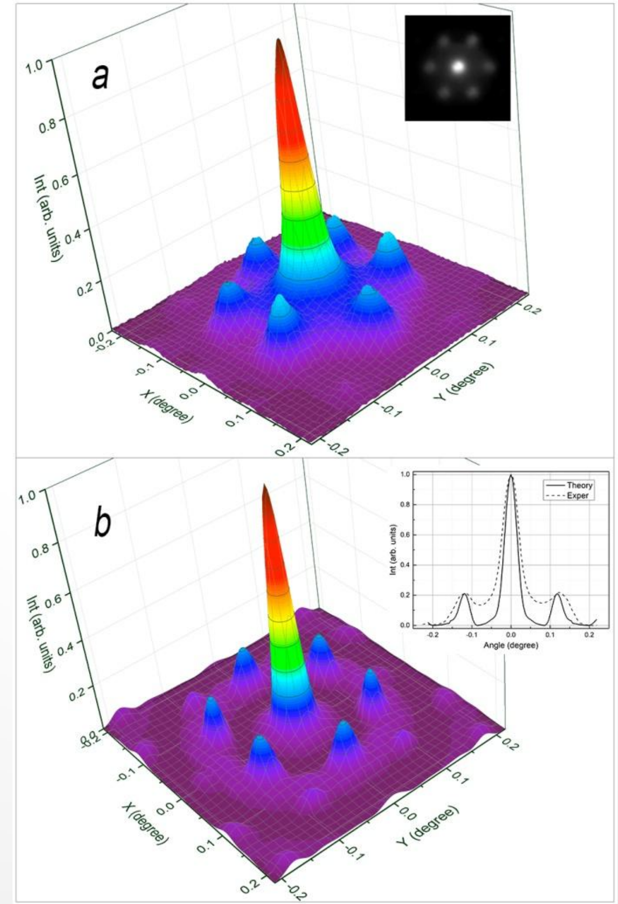
M.I. Mazuritskiy, A.M. Lerer, A. Marcelli, S. B. Dabagov, M. Coreno and A. D’Elia // JETP Letters **107** (2018) 600-605



Fluorescence at the exit of MCP



Figures show the experimental data (a) and theoretical simulation (b) of the diffraction of x rays transmitted through the MCPs. Angular distributions were obtained with use of 2D-detector for energies of primary radiation corresponding to ranges before and after SL-absorption edge (E=100 eV). These results have been published [1,2] in this year.



Increasing Energy

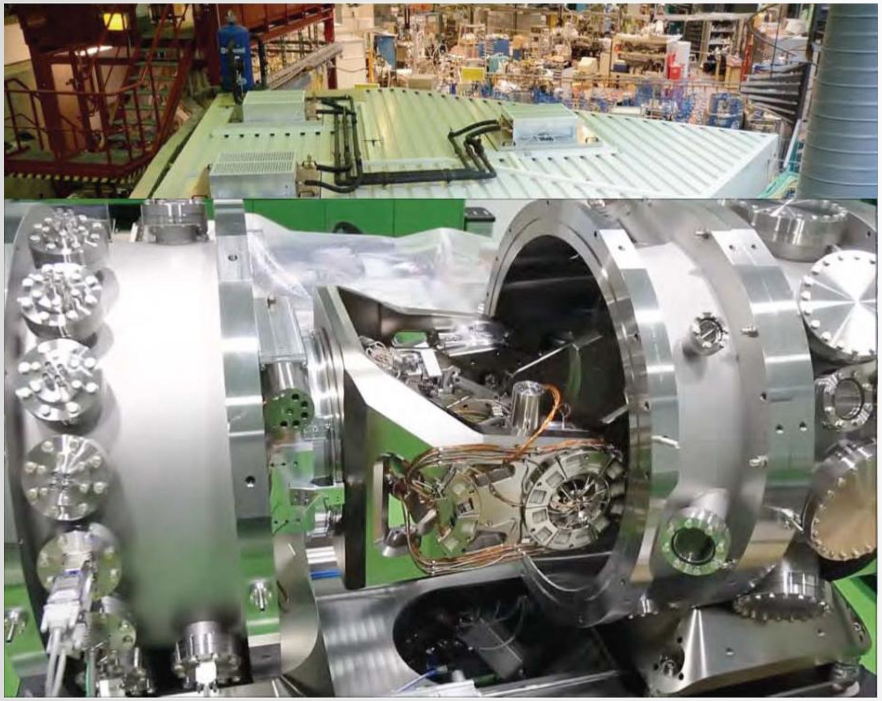
E1=93.6 eV (before)

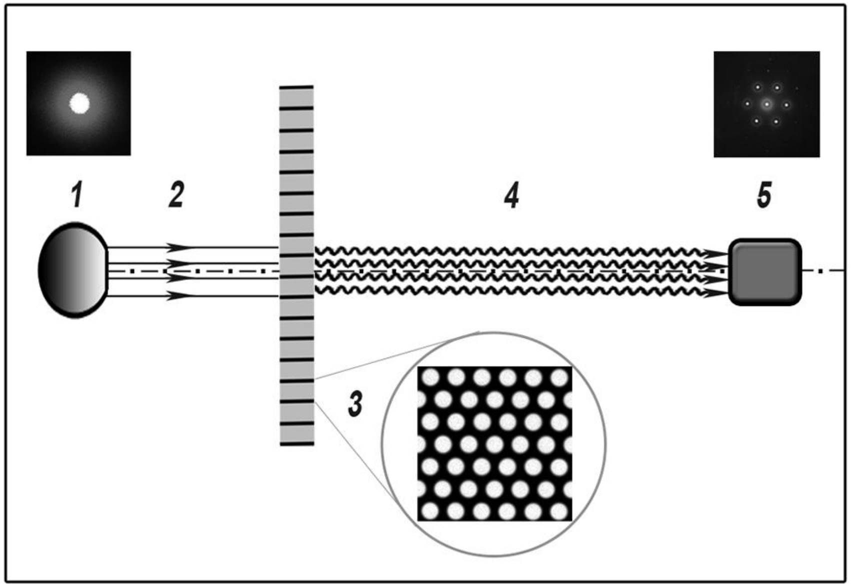
E=100 eV (SiL edge)

E2=147 eV (after)

1. A. Marcelli, M.I. Mazuritskiy, S.B. Dabagov, A.M. Lerer K., D. Hampai, A.M. Lerer, E.A. Izotova, A. D'Elia, S. Turchini, N. Zema, F. Zuccaro, M. de Simone, S.J. Rezvani, and M. Coreno // JINST, V13, March, 2018.
2. M.I. Mazuritskiy, A.M. Lerer, A. Marcelli, S. B. Dabagov, M. Coreno and A. D'Elia // JETP Letters **107** (2018) 600-605

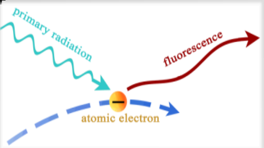
Reflectometer BESSY II. Experimental Layout.





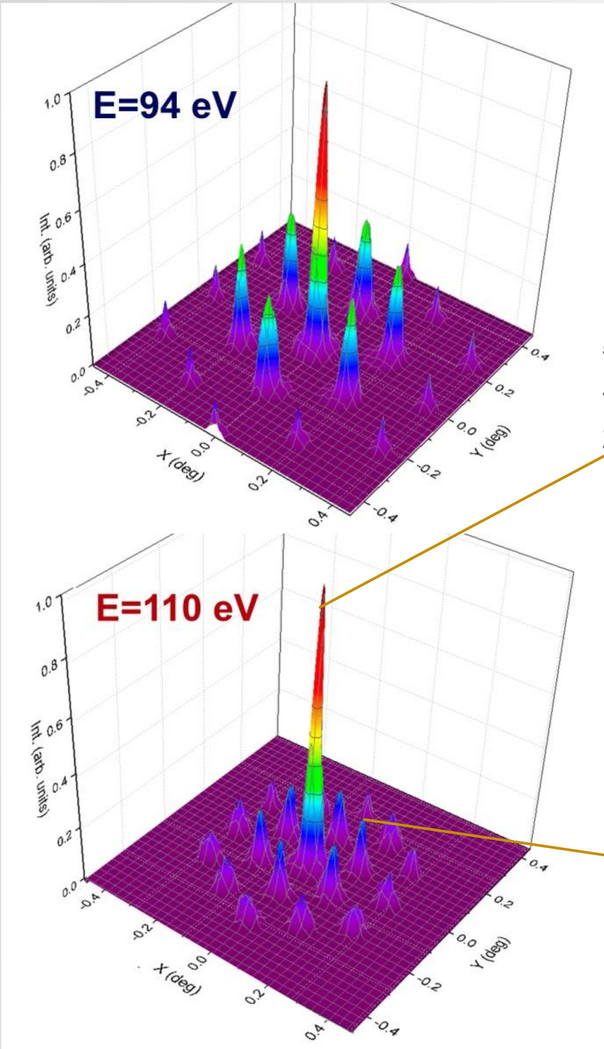
- In Figure showed the layout of the rotational geometry of the photodiode (5) at the exit of the MCP (3). The detector can rotate in the perpendicular plate to the direction of primary radiation. In the transmission geometry the primary beam (2) has size of 100x100 μm^2. Data have been collected by a photodiode with a window of 100 μm and the distance between the sample and the photodiode was 310 mm.

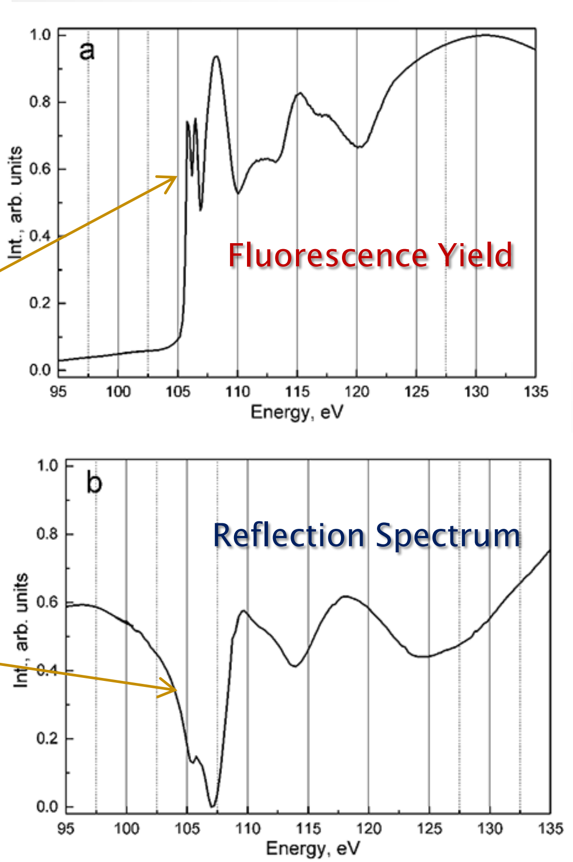
A.A. Sokolov, F. Eggenstein, A. Erko, et. al., An XUV Optics Beamline at BESSY II, *Proceed. SPIE* 9206, 92060J-1 (2014) doi: 10.1117/12.2061778
F. Schäfers, P. Bischoff, F. Eggenstein, A. Erko, A. Gaupp, S. Künstner, M. Mast, J.-S. Schmidt, F. Senf, F. Siewert, A. Sokolov and Th. Zeschke, J. Synchrotron Rad. (2016). 23, 67-77



X-Ray diffraction and Fine Structure

E=100 eV
Si L-absorpt. edge





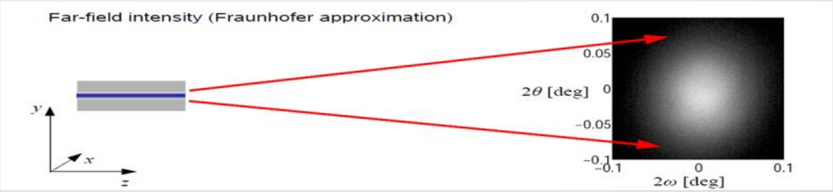
X-Ray diffraction experimental data have been collected with high angular resolution at the BESSY II Reflectometer recently. On the angular distributions the ratio of intensities of the central maximum to the maximum of the first order for radiation energies above the Si L-edge (110 eV) is ~1.5 higher than that this value measured below the absorption edge (94 eV).

The fine structure of the energy spectra were measured for in the mode of fixed angular positions of the photodiode: central peak or the first order peak. The result is clearly associated to an enhanced propagation of the fluorescence radiation along the axis of the micro-channels for an excitation energy above the Si L-edge.

Theoretical model and approximations

(i) The amplitudes of the modes at the input of microchannels were calculated by the Kirchhoff-Huygens method.
(ii) The propagation and amplification (attenuation) constants of waveguide modes in a single capillary were calculated using the Helmholtz equation. In addition, we took into account a small polarization of X-ray waves in the waveguide and the field is described with a scalar potential.
(iii) The model of a multilayer cylindrical optical waveguide was used to theoretically simulate and analyze the properties of modes of hollow capillary systems.
(iv) The amplitudes of the modes at the output of capillaries were calculated using the found amplification (attenuation).
(v) The radiation pattern for radiation emitted from the channels of the polycapillary system at a large distance was calculated by the Kirchhoff-Huygens method.

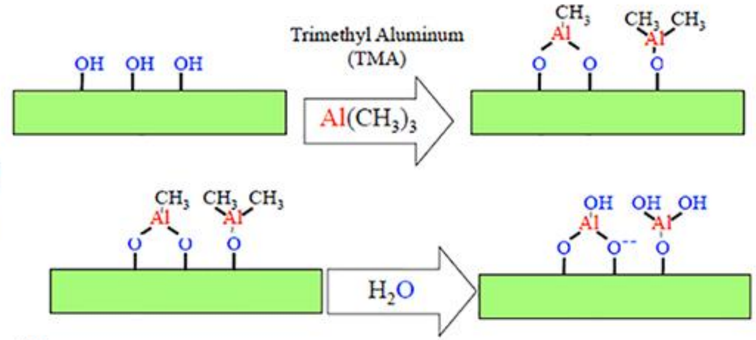
In the used theoretical model, the process of attenuation or excitation of radiation propagating inside the waveguides is determined by the sign of the imaginary part of the permittivity.

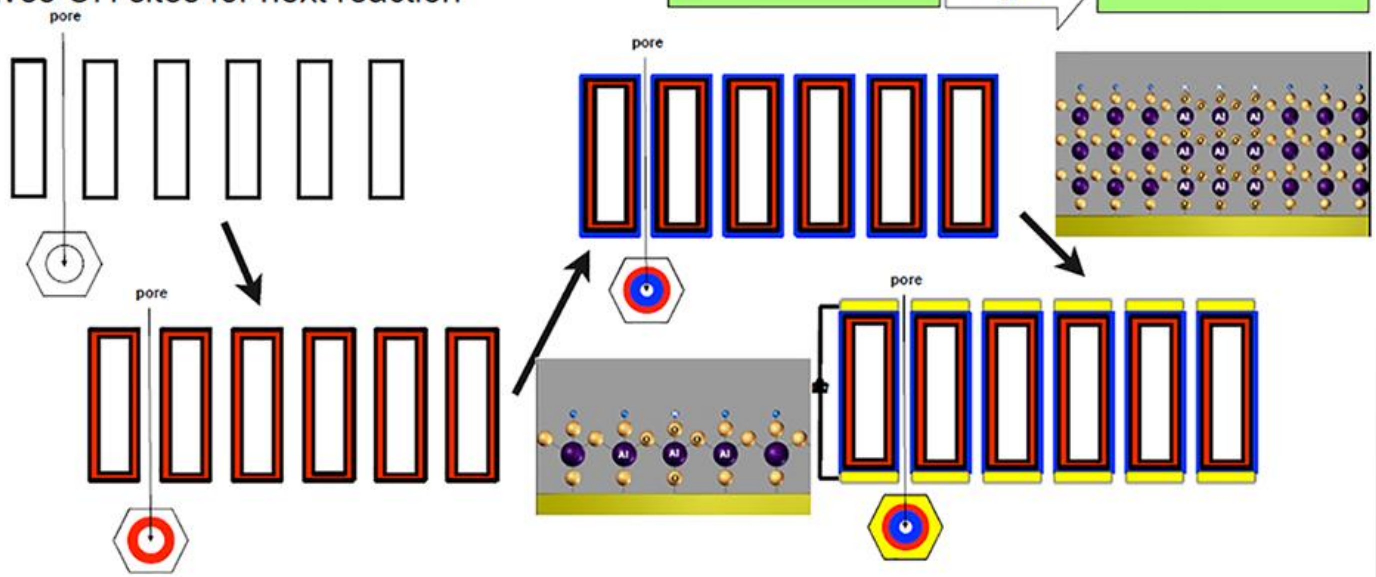


Pore Activation via Atomic Layer Deposition (ALD)

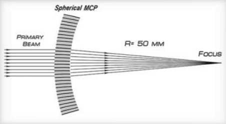
Example:

- OH on surface provide reaction sites
- Trimethyl aluminum reacts liberating methane, forms Al_2O_3 layer. Leaves methyl group inhibiting further reaction on surface
- Exposure to H_2O removes methyl group. Leaves OH sites for next reaction

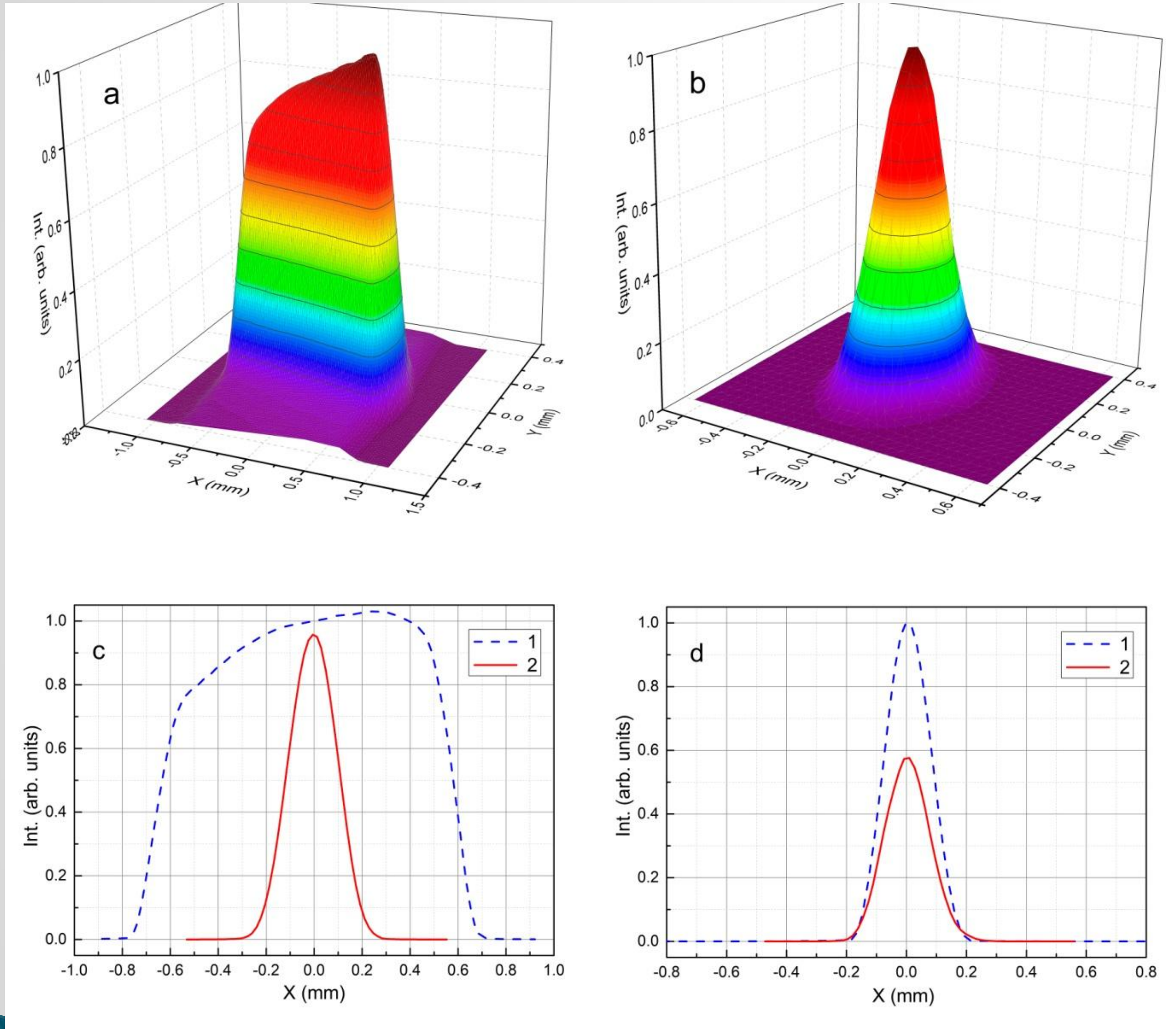




Atomic layer deposition (ALD) is a vapor phase technique capable of producing thin films of a variety of materials. ALD can be used to deposit conformal thin films of metal or oxides of Al, Ti, Fe, Zn … as buffer layers on the surface of the microchannels. Using this technique it is possible to model of fluorescence energy of spectrum at the exit of MCPs.



Focusing properties of bent MCPs

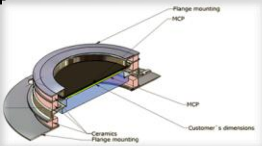


BESSY experimental data for a primary beam at the energy of 1800 eV (dash line - profiles) and spherically-bent MCP (solid line) with the radius of 50 mm: a), c) slit of 1000 μm; b) and d) slit of 100 μm.

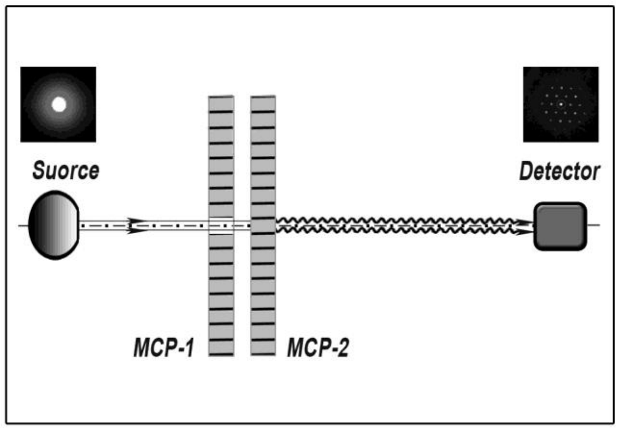
The results point out that a bent MCP in the soft x-ray range can collimate and focus the radiation. We found that parallel monochromatic beam can be focused by a thin spherically bent MCP with micro-channels of ~10 μm diameter and a curvature radius of few cm.

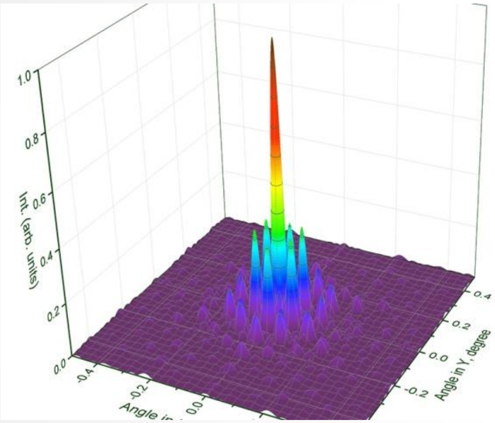
The efficiency of these micro-holed devices can reach a transmission value near 60%, which corresponds to the open area fraction of these devices.

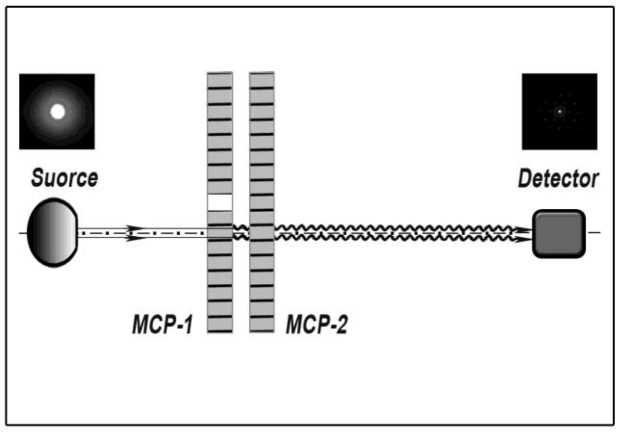
M.I. Mazuritskiy, S.B. Dabagov, A. Marcelli, K. Dziedzic-Kocurek, D. Hampai and A.M. Lerer // J. Synchrotron Rad., (submitted)

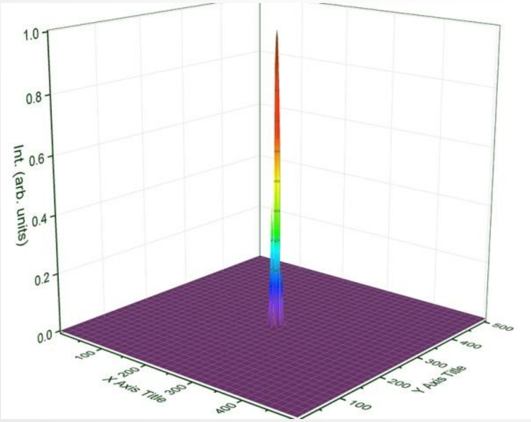


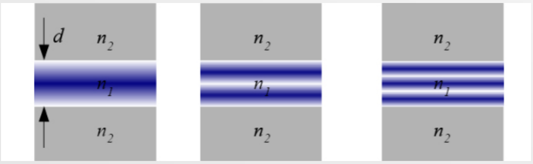
Solid Frame Device on the base of Double MCPs











We are going to study the Solid Frame Device with double MCPs inside (SFD-MCP), which sketch presented on the Figure.

In this device the first MCP plays role an object for primary coherent and monochromatic radiation. The diffracted radiation at the exit of the first MCP can be considered as primary electromagnetic field for the second MCP. In this consideration the second MCP is a "coding" matrix of the diffraction image obtained from the first plate. We suggest to develop the method for x-ray imaging of object placed inside the SFD-MCP. We will take in account for theoretical model a full field transmission mode of the soft x-ray radiation.

Conclusion and Outlook

- We have presented here recent experimental and theoretical results on the transmission of soft X-ray synchrotron radiation: fluorescence, diffraction and focusing radiation collected at the exit of MCPs.
- The results are a clear evidence of the channelling phenomenon of the excited fluorescent radiation inside the MCPs.
- In the next step we are going to employ a coded aperture pattern in front of a CCD detector to image diffracted x-rays at the exit of double MCPs irradiated with synchrotron radiation. Coded aperture imaging is a two-step process. The first step is the generation of an overlapping image or a coded image when photons pass through the two MCPs and projected onto the detector. The second step is the decoding or the reconstruction of the image with the help of special created math reconstruction method.

COLLABORATION