

X-RAY OPTICAL PARAMETERS OF MICROFOCUS KUMAKHOV OPTICS

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There are two types of systems of Kumakhov optics (KO) [1]. The first type, transporting radiation from a point to a point, is lens; the second – transforming a divergent beam in quasi-parallel, is half-lens. The first type has application to microanalysis: fluorescent spectral analysis, microdiffractometry, including protein crystallography and high-pressure crystallography. The second type has application in diffractometry and tomographies [2-7].

Now at the Institute for Roentgen Optics (IRO), on base of KO, a new generation of devices is created: fluorescent spectrometers, reflectometers, diffractometers, and combinations of several devices in one. Such significant amount of applications speaks such distinctive features of KO as the high angular aperture ($\sim 0,1$ rad) and broad-bandness (0,1-50 keV).

Polycapillary optics has progressed significantly over the past 18 years (5 generations of X-ray and neutron lens were developed). Microfocus polycapillary Kumakhov optics represents the fifth generation of polycapillary Kumakhov optics [1-6.] The given optics has the submicronic sizes of a capillary, millimetric focal lengths, length of structures from several millimeters up to several centimeters.

Microfocus Kumakhov optics is used together with microfocus x-ray tubes on the basis of the electromagnetic focusing system, allowing to focus an electronic beam in a spot with diameter 1-10 μm , at power on a tube from several W up to several tens W [8-11]. A microfocus X-ray tube has been created in IRO. The tube is based on electromagnetic focusing of electron beam. Two types of anodes are available - reflection and transmission ones. In case of transmission anode, 10W beam is focused to a 10-micron focal spot. In this instance, for example, for CuK α , a flux of $4 \cdot 10^{12}$ monochromatic photon/sec has been obtained. This flux is unprecedented in the world for transmission anodes.

This x-ray tube has a wide range of application in science, material science, applied fields such as microelectronics, forensic sciences, jewelry industry and so on. The tube was used in phase contrast investigations of biological and other objects.

The transmission anode tube enables unique opportunities when combined with polycapillary optics because of the possibility of putting optics very close to anode. Such super compact geometry makes it possible to obtain super-bright x-ray fluxes after lens. Currently, record parameters were registered for such systems equipped with microfocus polycapillary Kumakhov optics [10, 11].

Microfocus half-lenses have length (0,7-2) mm, angle of capture (0,1-0,4) radian. Measurements were carried out under optic scheme: x-ray source – x-ray optical system - the detector [12]. Transmission of the central part (10-100 μm) is 10-35 %. Entrance diameter is 0,5-1,5 mm. Divergence for CuK α is 3-4 mrad, for MoK α - (2-3) mrad. A quasi-parallel beam in both directions with flux density of $\sim 10^{10} - 10^{11}$ photon/(sec mm^2) was obtained with X-ray tube of (3-30) W power. Microfocus full lenses allow to receive a converging beam of high intensity with the minimal diameter of section - a focal spot, about a micrometer. The flux density obtained equaled to $10^{12} - 10^{13}$ photon/(sec mm^2) for target materials Cu, Mo or Ag at 10 to 50 W tube power.

Modern microfocus polycapillary Kumakhov optics let create the density of a flux of quasi-parallel and converging beams in laboratory conditions at the level synchrotron sources with the help of x-ray tube. Such «laboratory synchrotrons» are now installed in several laboratories worldwide.

Combination of polycapillary optics and a laboratory source opens up totally new opportuni-

ties for diffractometry, in particular, in protein crystal diffractometry where parallel or convergent highly directed intensive monochromatic beams of small sizes are required. On the basis of such ultra-bright source and the bidimensional detector, a fast registration protein diffractometer has been created.

There are 3 generations of X-ray spectrometers based on Kumakhov optics has been created. 1st: the focal spot of (50-200) mkm; this system is quite popular in Russia, currently commercially available worldwide; 2nd - the focal spot varies between (10 and 50) mkm; this system has been already in operation for several years in Norilsk (Russia); commercially available; 3rd - the focal spot of 1 to 10 mkm - will be commercially available worldwide by the end of the this year. All the above instruments based on small x-ray power source with KO are designed for a wide range of applications for express in-situ analysis. They feature high precision, easy maintenance and operation, user friendliness, radiation safety, small dimensions and weight.

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1. Kumakhov M.A. *Proc. SPIE*. **4765**. (2002). 20 – 25.
2. Huang H., MacDonald C.A., Gibson W.M. *Proc. SPIE*. (2000). **4144**. 100 – 109.
3. Gubarev M., Ciszak E., Ponomarev I., Gibson W., Joy M. J. *App. Cryst.* (2000). **33**. 882 – 887.
4. Arndt U.W., Bloomer A.C. *Proc. SPIE*. (2000). **4144**. 86 – 94.
5. Kazakov S.S., Nikitina S.V., Priladyshev A.V. *Proc. SPIE*. (2000). **4155**. 21 - 24.
6. Ibraimov N.S., Nikitina S.V., Gruev D.I., Lopurko K.N. *Proc. SPIE*. (2000). **4155**. 83 - 85.
7. Kazakov S.S., Nikitina S.V., Trefilov V.I., Ibraimov N.S. *Proc. SPIE*. (2000). **4155**. 119 - 123.
8. Mikhin O.V., Ibraimov N.S., Nikitina S.V. *Proc. SPIE*. **4765**. (2002). 132 – 136.
9. Mikhin O.V., Kumakhov M.A., Ibraimov N.S. et al. *Proc. SPIE*. 4765. (2002). 194 – 197.
10. Mikhin O.V., Dabagov S.B, Gelever V.D., Priladyshev A.V. *LNF-03/16 (P)*. (2003).
11. www.iroptic.com
12. Romanov A. Yu., Dmitriev I.V., Akulov A. Yu. *Ingenernaya fizika* **1**. (2004).