

# POLYCAPILLARY OPTICS AND X-RAY ANALYTICAL TECHNIQUES

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Research on capillary x-ray optics was started in 1931 by F. Jentzch and E. Nähring. A. Rindby and others published the first article in 1986 on the application of tapered monocapillaries for increasing the power density of X-rays in X-ray fluorescence (XRF) experiments. Since that time, monocapillary optics have been widely applied.

The important invention of M. Kumakhov - the polycapillary X-ray focusing system - appeared in 1986. Later, the rapid progress of capillary optics included design and manufacture of monolithic polycapillary optics. A monolithic X-ray collimating or focusing lens is made up of tens, or even hundreds of thousands of capillary channels fused into a single bundle. It is made by drawing a bundle of glass capillaries to the desired shape with a drawing tower. The monolithic lens is compact, solid, with high efficiency and is very convenient for most applications.

At present, mainly three kinds of monolithic X-ray optics are available: focusing lens (for XRF analysis); slightly focusing quasi-parallel beam optics (for single crystal X-ray diffraction (XRD) analysis); and parallel beam collimating optics (for wavelength dispersive XRD analysis). In addition, the remarkable scatter-rejection properties of polycapillary optics can be utilized for monolithic angular filters for mammography and other applications.

For XRF analysis, the main advantage of an X-ray focusing lens is that it can greatly increase the power density of the X-ray beam up to 1000 times and reduce the beam size down to 10-15  $\mu\text{m}$ . Further reduction of the beam spot size is difficult technologically, the more so as, small spot size requires very short focal distance, inconvenient for X-ray detection.

The monolithic X-ray lens provides in essence, many parallel, small area, incoherent, slightly divergent X-ray sources. Even though largely independent of each other, these beams can form uniform X-ray illumination in the beam spot area. The local divergence of X-ray beams, limits the angular resolution in diffraction experiments. Currently, the angular resolution is about 0.15 degree for diffraction applications of the Cu  $K\alpha$  characteristic line, which is worse than the best resolution for crystal diffractometers. But the quasi-parallel beam from a monolithic polycapillary collimating optic can increase a crystal diffracted beam by orders of magnitude and thereby greatly increase the efficiency of crystal diffractometers.

Slightly focused quasi-parallel beams are widely used in single crystal diffraction applications. Therefore, a slightly focusing monolithic optic can give a greatly increased power density and a small beam spot with sufficient parallelism for many diffraction experiments. It has also been recently shown that more strongly focused beam diffraction can also be used with even higher intensity and smaller beam spot size. Such optics could be very important for simultaneous  $\mu\text{XRF}$  and  $\mu\text{XRD}$  analyses.

In the present paper, we give a short review of applications of polycapillary monolithic optics for X-ray analysis, and discuss the advantages, limits, and the expected further development.