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Technical note

Characterization of a confocal three-dimensional micro X-ray fluorescence facility based on polycapillary X-ray optics and Kirkpatrick–Baez mirrors

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Abstract

A new confocal three-dimensional micro X-ray fluorescence (3D micro-XRF) facility based on polycapillary X-ray optics in the detection channel and Kirkpatrick–Baez (KB) mirrors in the excitation channel is designed. The lateral resolution (l_x, l_y) of this confocal three-dimensional micro-X-ray fluorescence facility is 76.3(l_x) and 53.4(l_y) μm respectively, and its depth resolution d_z is 77.1 μm at $\theta=90°$. A plant sample (twig of *B. microphylla*) and airborne particles are analyzed.

Keywords: Micro-XRF; Confocal-XRF; Polycapillary X-ray optics

1. Introduction

With the development of the designing techniques of the polycapillary X-ray optics [1–3], its application in X-ray analysis becomes wider [4–7]. A polycapillary parallel X-ray lens (PPXRL) can efficiently collect a relatively large solid angle of X-ray beams from an X-ray source and focus them to form a quasi-parallel beam for X-ray diffraction analysis [8,9]. Moreover, the order of magnitude of the input focal spot size of the PPXRL is 10 μm, and therefore, it is widely used in micro X-ray analysis [10–12]. The principle of the confocal technology based on polycapillary X-ray optics was first proposed in the early 1990s by Gibson and Kumakhov [13], and now, it is widely used in 3D micro-XRF analysis [14–18]. In these confocal 3D micro-XRF facilities, the focusing X-ray optics in the detection channel is a polycapillary X-ray lens, and the focusing X-ray optics in the excitation channel is a polycapillary X-ray lens [17] or compound refractive lenses [12]. In fact, because KB mirrors is often used to efficiently focus synchrotron radiation for micro X-ray analysis, a confocal 3D micro-XRF analysis may be performed based on KB mirrors in the excitation channel and a polycapillary X-ray optics in the detection channel.

In this paper, the confocal technology based on polycapillary X-ray optics and KB mirrors is proposed to perform 3D micro X-ray fluorescence experiments. The performances of the confocal 3D micro-XRF facility based on KB mirrors in the excitation channel and a PPXRL in the detection channel are

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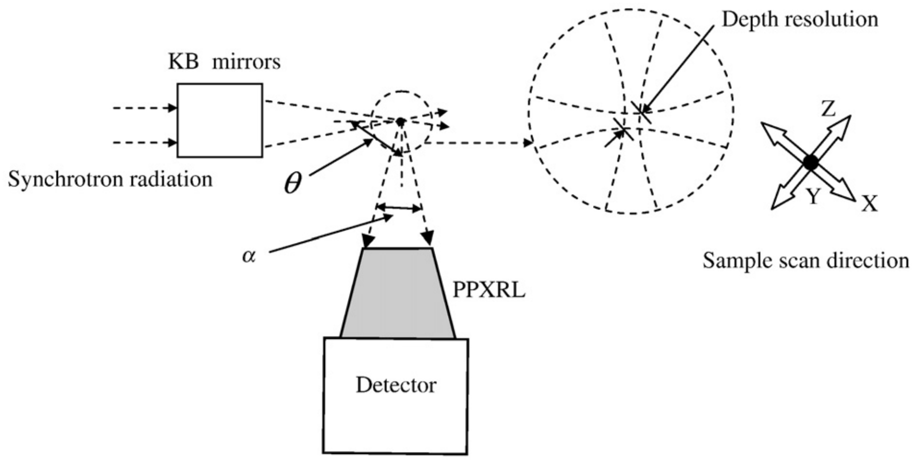

Fig. 1. Scheme of the confocal 3D micro X-ray fluorescene facility based on KB mirrors and a PPXRL.

studied. As an example of the application of this facility, a twig of *B. microphylla* and airborne particles are investigated by using this facility.

2. Experiments and results

2.1. Experimental setup

The experiments were carried out at beam line 4W1B-XRF of Beijing Synchrotron Radiation Facility of China. Fig. 1 schematically shows the realization of a confocal 3D micro-XRF facility based on a KB mirrors in the excitation channel and a PPXRL in the detection channel. The synchrotron radiation beam with a 250×250-μm^2 area is focused into a microfocal spot with a 20×50-μm^2 area by using KB mirrors at 15.3 keV. The energy resolution of the Si(Li) detector system is 133 eV at 5.9 keV.

A micro-volume is defined by the overlap of the output focal spot of the KB mirrors and the input focal spot of the PPXRL. By moving the sample located at the confocal position, the micro-volume to be analyzed can be displaced laterally or in a direction perpendicular to its surface. Therefore, depth information of the sample can also be obtained non-destructively. Moreover, a better peak-to-background-ratio can be reached due to the restriction of the detector field of view.

2.2. Performances of PPXRL for micro-XRF experiments

It is well known that a PPXRL accepts photons emitted within a finite region, i.e. an input focal spot, and the input focal spot size can be measured using a source scan. When the X-ray source positioning at the input focal distance of the PPXRL scans in a direction transverse to the axis direction of PPXRL, the count of detector as a function of source displacement can be obtained. If the full width at half-maximum (FWHM) of the counts curve is written as w, the input focal spot size Φ is

$$\Phi = \sqrt{w^2 - d^2} \quad (1)$$

where d is the diameter of the source spot. The X-ray source used here is an Oxford Ultra-Bright micro-focus w source, whose spot size was 15.0 μm. Fig. 2 shows the count of detector as a function of source displacement at 8.0 keV. Fig. 3 shows the energy dependence of the input focal spot size for the PPXRL. As shown in Fig. 3, the input focal spot size of the PPXRL decreases with the increasing energies. This is explained by the

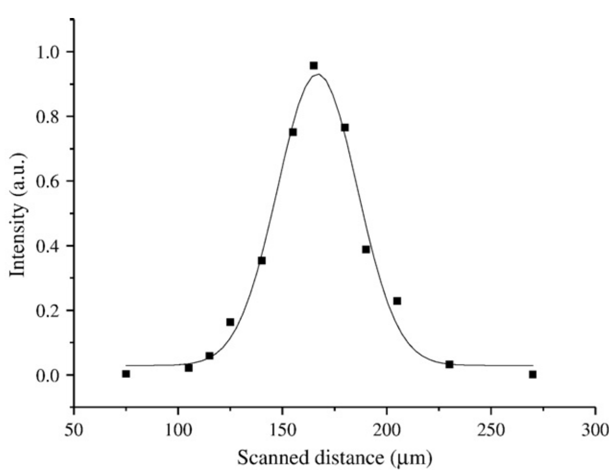

Fig. 2. Count of detector as a function of source displacement.

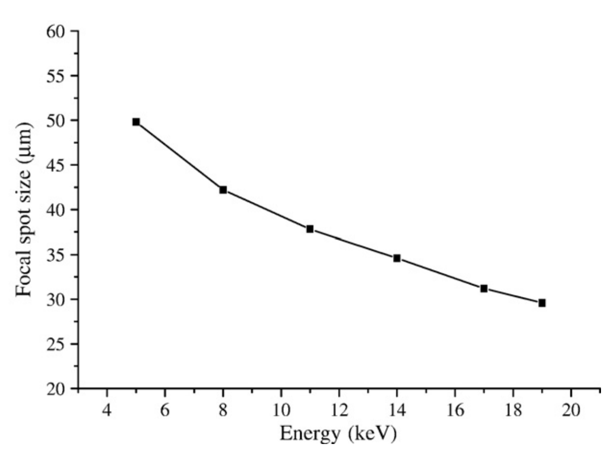

Fig. 3. Energy dependence of the input focal spot size for the PPXRL.