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Modeling of X-ray transport through polycapillary optics

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Abstract

Polycapillary optics is highly efficient for focusing X-rays and thermal neutrons. Here we present our studies by modeling and simulating X-ray transport through cylindrical polycapillary optical system using PolyCAD, a ray-tracing original package developed by our group namely, experimental data obtained in various conditions are compared with theoretical predictions; focusing properties of a cylindrical lens have been visualized by collecting 3D images and reconstructed using PolyCAD simulations. The acquired images demonstrated how the focal spot profiles by the intensity and width at different projection distances agree with calculations.

We present some characterization methodologies by means of the angular measurements to study several kind of polycapillary optics in order to learn the transmission coefficient and focusing properties, and the CCD images, of the focal spots.

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1. Introduction

Our interest in the development and the application of a new X-ray systems based on polycapillary optics creates a flexible and complete ray-tracing program, named PolyCAD [1], to simulate and visualize the processes of radiation propagation through any kind of polycapillary optical systems and the radiation distributions at the optics output. In the last 20 years, many software packages based on various approximations—simplifications have been developed [1] taking into consideration only specific aspects of X-ray propagation.

In the first part of the present paper, we show possible application of PolyCAD, i.e. even if sources are more than one and have three dimensionals (3D) structures the software is able to distinguish and discriminate them, as for tomography images.

In the second part, we compare our software with a real cylindrical polycapillary optics. First, we will describe the transmission coefficient as a function of angular measurements, and then compare images obtained by a CCD detector and by simulations.

2. 3D source

In order to show how PolyCAD can simulate different optical configurations, the behavior of a polycapillary lens in the case of a source having a 3D structure was estimated. It was simulated for a source formed by two spheres, in particular, when a little spherical source is "hidden" by a second bigger source located on the optical axis (Fig. 1).

For simulations, we have used the following parameters: two X-ray spherical sources with radii of $S_1 = 0.3$ cm and $S_2 = 0.1$ cm, respectively, emitting isotropically 1 keV photons.

The distance of the bigger sphere from the polycapillary inlet plane is 30 cm, while the distance for the smaller one

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equals to 40 cm. The cylindrical polycapillary has the length of 10 cm, cross-section radius of 1 cm, single-channel radius of 0.9 μm.

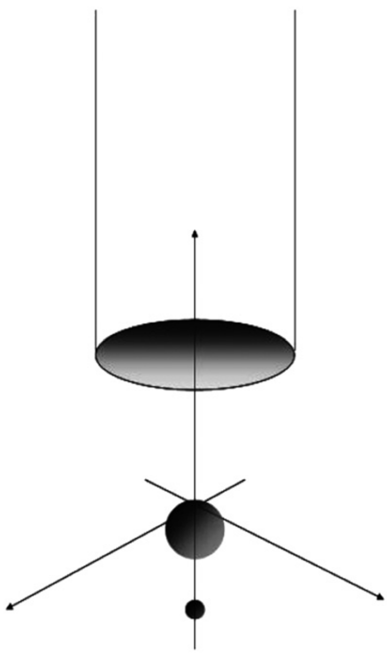

Fig. 1. Geometrical description of the simulation used, when both the sources are aligned along the optical axis and the first sphere obscures the second one.

In Fig. 2a the radiation intensity distribution extracted from the contour map along the axis $x = 0$ is given. The source S_2 is completely hidden by S_1: in this case only a little bump due to S_2 is present in the upper right side of a contour map (Fig. 2a), but a priori it is not possible to evaluate the S_2 conjugate position.

Now, in order to operate a deconvolution procedure by means of the PolyCAD simulations, for the same optical configuration, we evaluated the situation with the source S_1 alone (Fig. 2b). By subtracting the intensity distribution 2b from the distribution 2a in the resulting profile (Fig. 2c), the presence of the little source S_2 becomes evident and its position could be evaluated at about 40 cm from the lens. In order to confirm this result we have reconstructed the intensity distribution only due to the radiation coming from the source S_2 and passing through the lens (Fig. 2d). Comparing the two last images proves that the second source is located exactly at the 40 cm distance from the lens entrance.

3. Characterization methodologies

We proceed showing some procedures to make a systematic characterization of cylindrical polycapillary optics properties. In our case we used a conventional X-ray source (K_αCu), two detectors (NaI(Ti) scintillator

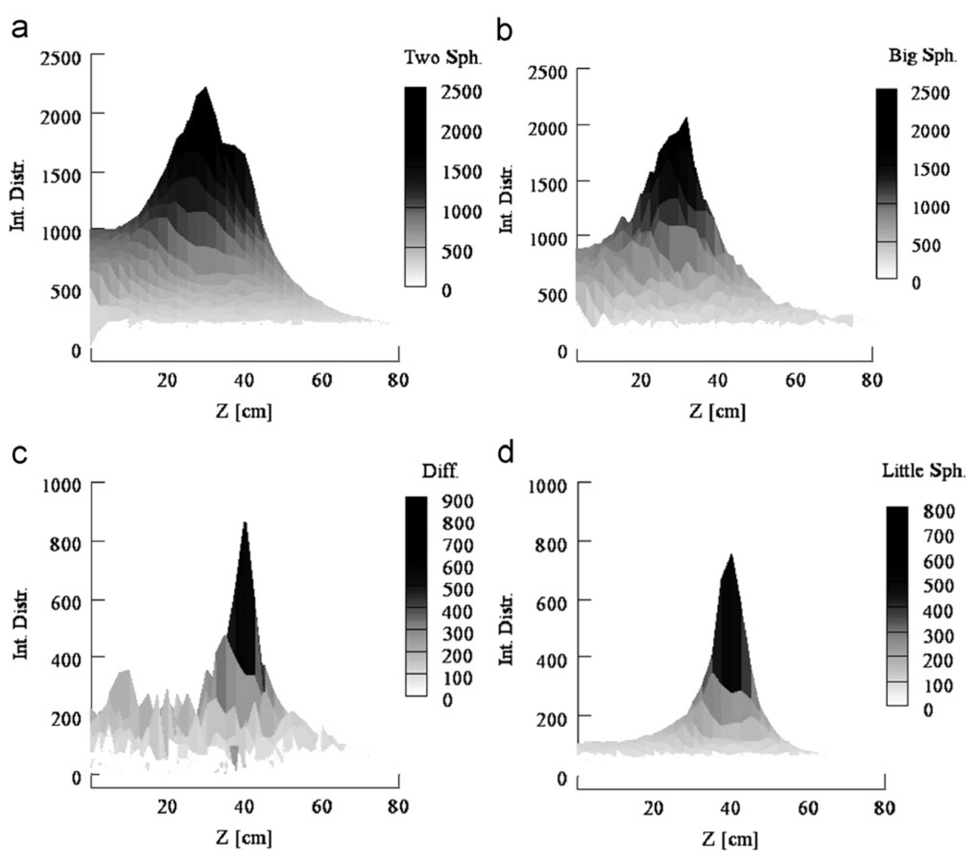

Fig. 2. (c) and (d). Intensity distributions for: (a) two sources (S_1 and S_2), (b) only the source S_1; (c) the distribution (b) subtracted by (a); (d) evaluation of the intensity distribution S_2. From comparison of the two last images, it becomes evident that both the calculated and evaluated focal positions are equal, with the same intensity distributions.