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ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

LS-161

RESULTS OF DESIGN CALCULATIONS
Specification of a Prototype Zone Plate for Focusing Hard X-rays

by
W. B. Yun, J. Chrzas, and P. J. Viccaro
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SPECIFICATION OF A PROTOTYPE ZONE PLATE FOR FOCUSING HARD X-RAYS

W.B. Yun, J. Chrzas and P.J. Viccaro

A zone plate capable of focusing hard x-rays to less than 1 μm spot size is designed and specified. This design is based on the state-of-art fabrication technology available today.[1] This zone plate consists of Cu/Al layers sputtered alternatively on a round stainless steel core. Parameters of this zone plate (see Fig. 1) are given below:

stainless steel core diameter a	$100\mu m$
zone plate focal length f	30cm (E=8Kev)
zone plate diameter d	$160\mu m$ (i.e. total deposition is $30\mu m$)
zone plate material	Cu/Al
zone plate thickness t	$13.5\mu m$

where the focal length f is given for 8Kev x-rays and the thickness is optimized for focusing efficiency for the same x-ray energy. a and d can be translated and presented by zone index k and associated zone width δR_k using zone plate equation

$$R_k^2 \simeq fk\lambda,$$

where R_k is the radius of the kth zone.

Considerations in the specification

1. Spatial resolution: this zone plate is designed in such a way that it could be used to obtain about 0.3 micron spatial resolution with a 10 micron source pinhole located at about 10 meters away from it. This requires that the smallest zone width be less than $0.3\mu m$ and that the focal length be less than 30cm. The zone plate can be characterized by measuring intensity distribution at the primary and higher order foci. Difference in the measured intensity distribution from those calculated for a perfect zone plate yields information about the registry of all the zones fabricated. The ratio of the integrated intensities at the higher order foci to that at the primary focus gives information about the aspect ratio of Al and Cu layers.

2. Material selection: Cu/Al has been shown to be suitable sputtering materials for producing zone plate with smooth and uniform layers.[1] X-rays transmitting through the core of a zone plate are not focused and contributes to the background at the focus. It is therefore necessary to reduce this transmission. In addition the core on which the zone plate is to be fabricated has to be circular and its surface smooth. Stainless steel core appears as good choice for x-ray energies between the K-edge absorption of Fe and Cu, which are 7.1Kev and 8.9Kev, respectively. The transmission through the 13.5μm stainless core is shown in Fig.2 (solid line). For comparison, transmission through a 13.5 μm Cu film is also shown in this figure (dotted line). Note that the transmission through the stainless core is appreciably smaller than that through the Cu film for x-ray energies between 7.1Kev and 8.9Kev.

3. Focusing efficiency: The difference in the refractive indices between Al and Cu and relative low attenuation of both materials for x-ray energy greater than 7.1kev provide also a good opportunities to utilize the relative phase delay of x-rays in transmission through the two materials to increase the focusing efficiency. Effective use of the phase effect requires the zone plate to be made with proper thickness such that the relative phase shift between a Cu zone and its neighboring Al zones are $n\pi$, where n is odd integer 1,3,.... The thickness for $n\pi$ phase shift is equal to n times of that for $n = 1$. Since the absorption of x-rays in transmitting through a zone plate increases with the thickness of the zone plate, maximum focusing efficiency is obtained for the zone plate thickness such that $n = 1$. This thickness is dependent on the energy of x-rays to be focused and can be calculated exactly. For 8 Kev x-rays it is 3.85μm. It is however difficult at the present time to produce a zone plate of this thickness. We therefore choose the thickness to be 13.5 micron (corresponding to $n = 3$), which is practically feasible at the present time. The foucsing efficiency of this zone plate is calculated to be 25% for 8 Kev x-rays.

1. R. M. Bionta et al. "8 Kev x-ray zone plates", SPIE Proc. Vol. 1160, ed. R. B. Hoover, 12(1989)..

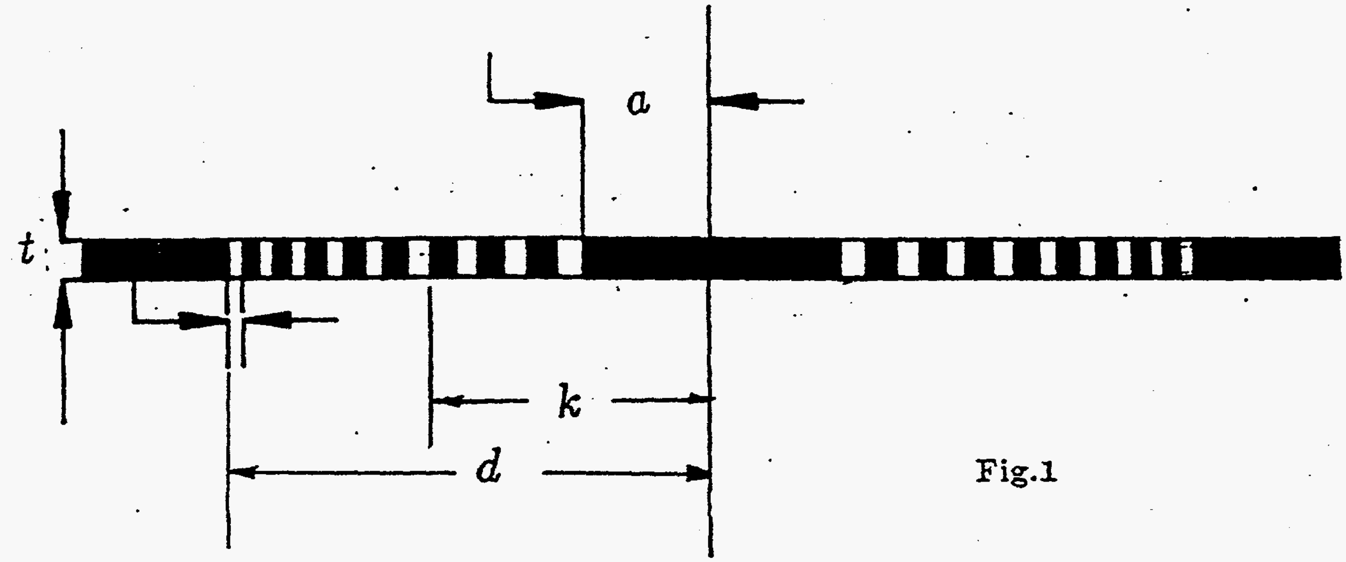
a
t
k
d

Fig.1

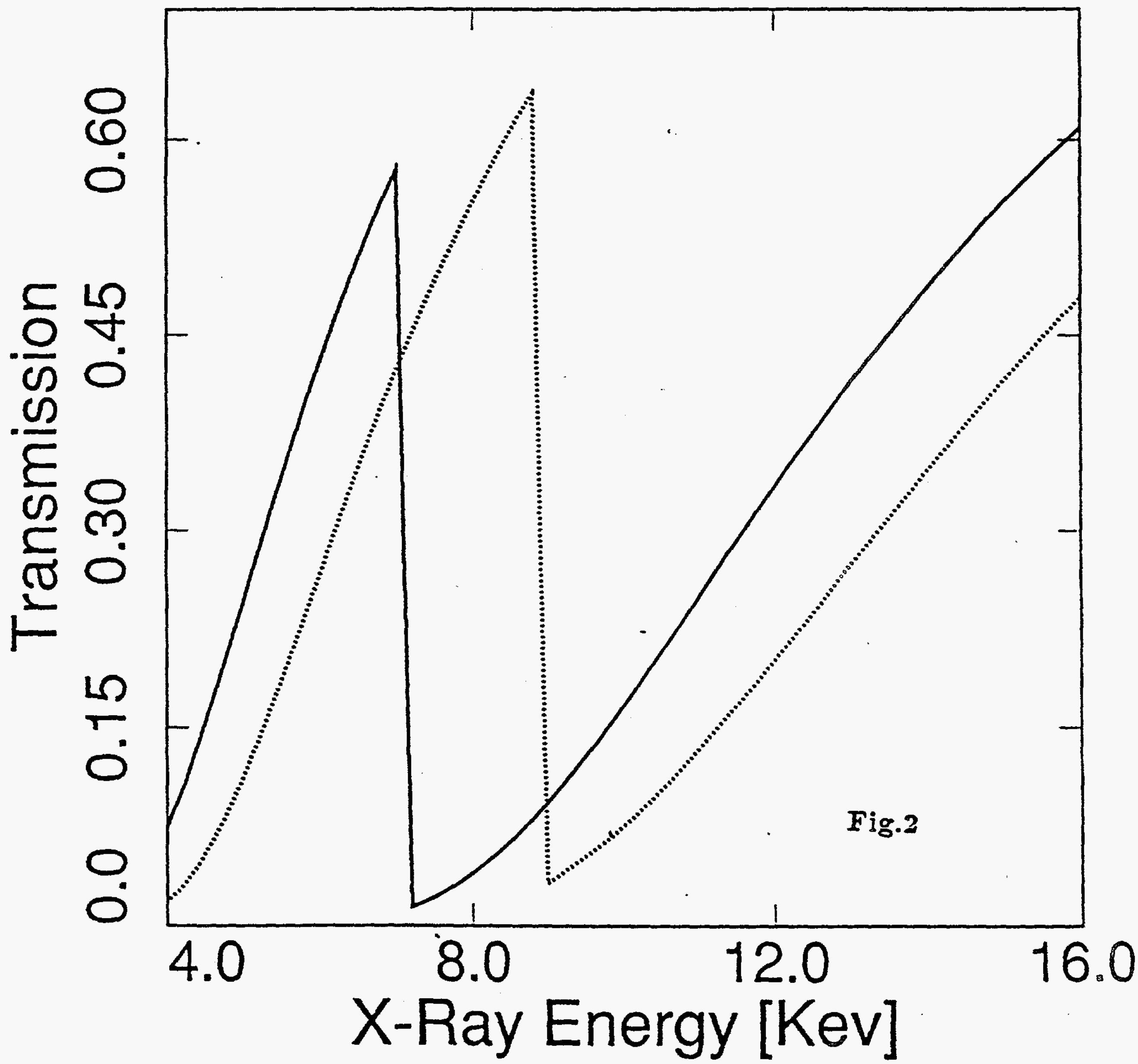
Transmission
0.0
0.15
0.30
0.45
0.60
4.0
8.0
12.0
16.0
X-Ray Energy [Kev]

Fig.2