ESRF	**Experiment title:** Test of non-classical Fresnel transmission lenses for the focusing of x-rays	**Experiment number**: MI782
Beamline: BM05	**Date of experiment**: from: 23/11/2005 to: 25/11/2005	**Date of report**: 28/02/2007
Shifts: 6	**Local contact(s)**: Dr. Anatoly Snigirev	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

W. Jark (*), Sincrotrone Trieste

F. Perennes, Sincrotrone Trieste

M. Matteucci, Sincrotrone Trieste

Report:

The results from the proposed experiment MI-782 are reported in the following overview article, which is scheduled to be published in 2007:
"CLESSIDRA: focusing hard x-rays efficiently with small prism arrays", W. Jark, F. Pérennès, M. Matteucci, L. De Caro in "Modern Developments in X-ray and Neutron Optics", Springer Series in Optical Sciences, Springer Verlag GmbH, Berlin Heidelberg, Eds. A. Erko, M. Idir, Th. Krist, A.G. Michette
This publication has no abstract and thus the principal results will be presented here briefly.

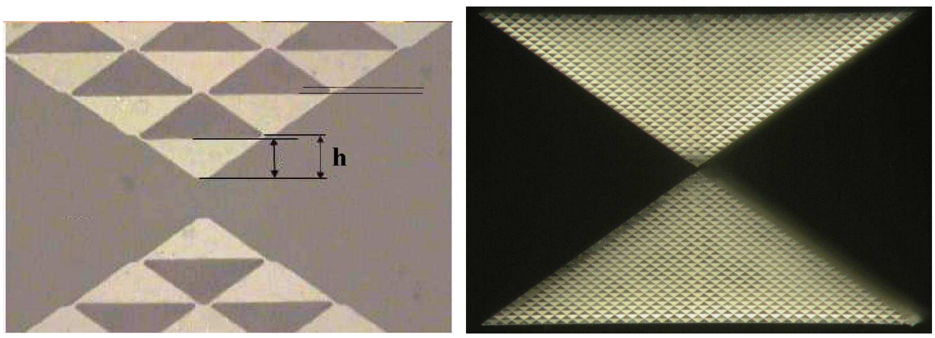

Fig. 1. Optical micrographs showing details in and an overview of the clessidra lens. H is the periodicity in the structure.

Theoretical considerations:
The properties, manufacturing and performance of the clessidra (hourglass) x-ray lenses are discussed in detail in [1-4]. Figure 1 (left) presents the details in the center in one of the prototypes, which will be discussed here, and figure 1(right) shows the whole lens structure. The principal feature is a constant height h for the single rows perpendicular to the optical axis of the lens (the coordinate system has the optical axis in direction x and the lens aperture in direction y). With the latter property the clessidra lens can be regarded as a linear transmission grating. And the special

shaping of the rows will make it a blazed grating. As far as the phase plane progression is concerned, local phase discontinuities can be avoided by adjusting the steps (i.e. the discontinuities in the material distribution) such that they correspond to multiples m of 2π (modulo 2π). This requires the prism base width in the clessidra lenses to be $m*\lambda/\delta$, where λ is the wavelength of the light and δ is the refractive index increment of the lens material δ=1-n. Away from absorption edges δ varies with the square of λ and thus for fixed prism base width the phase continuity is assured only for discrete photon energies. The particular feature of the clessidra lens is that we have m=m(y) with a linear dependence of m on y.

The data for the investigated lens are: prism height h=25.67 µm and optimum working point at 8 keV photon energy (λ=0.154 nm) with m=2. The full aperture is 1.51 mm with 29 prisms in the last row.

We will now assume the incident beam to be sufficiently spatially coherent. At the measurement position at q=53 m from the BM05 source with s=80 µm, the spatially coherently illuminated area for the working energy of 8 keV given as $A=0.44*\lambda*q/s$ [5] is A=45 µm, i.e. almost 2 prism rows. As a linear diffraction grating the lens structure will then create self images at specific positions according to the so-called Talbot effect. In the normal convention the related Talbot distance is given as $l_{Talbot}=2h^2/\lambda$. Then the periodicity of the diffraction pattern is identical to the peridicity of the diffracting structure at $l=l_{Talbot}$ and $l=0.5*l_{Talbot}$. One can easily show that in a parallel beam the regular grating structure will create a line pattern at a distance given by $h^2/(m\lambda)$, which we will call its diffractive focal distance $f_{diff}=h^2/(m\lambda)$. So we find $f_{diff}=0.25*l_{Talbot}$, i.e. a fractional Talbot effect [6], in which the periodicity in the self image is h/2. The refractive focal distance of the lens can be derived from the refraction in the single structures as $f_{refr}=h*\tan(\alpha)/(2\delta)$, with α being the angle of grazing incidence onto the prism side walls. Both focal lengths can be identical for a particular wavelength given by $\lambda=h*2\delta/(m*\tan(\alpha))$. Under this condition the blaze effect will work optimally and the intensity is refracted mostly into only one of the diffraction peaks. As we work at a finite source distance the self image distances, i.e. the position p of the diffractive and refractive images will be found by use of the lens equation $(1/f)=(1/q)+(1/p)$. If we now start to tune the wavelength the blazing effect will be reduced as discontinuities will now appear in the phase planes. And the two focal lengths will not be identical anymore. The narrowest peaks or the best resolution will continue to be observed in the diffractive focus. However, the reduced blazing will now spread the intensity over more orders and we will thus find more narrow lines in the focal plane. The position of the refractive image is not anymore at a selfimage distance. At this distance the diffraction peaks will start to widen and eventually merge, and thus the refractive image can be rather large.

Experimental verification:

The above described effects are observed in scans in which the photon energy was varied and the distance between the lens and the detector was scanned. The photon energy was varied from 8 keV to 8.5 keV. The subsequent data analysis showed that the foci coincidence would have occurred for 7.8 keV. We could verify the concentration of the intensity in fewer peaks towards lower energy, however, we cannot comment onto the concentration into a single peak in blaze maximum condition. However, in [4] it is shown that the first 10 µm of any prism tip do not refract as expected. This will distort the phase wavefronts and thus it is not expected that the intensity in this lens could be concentrated into only one peak.

The present lens was rotated around the incident beam in order to focus horizontally. As the horizontal source is larger than the vertical source the spatially coherently illuminated area at the grating was then reduced from 45 µm to 13 µm. Then only half of each prism row is illuminated spatially coherently. So one would not expect to observe a self image, or a regular diffraction pattern, anymore. This is not the case. Indeed one still can distinguish several though widened orders in the diffractive image plane, i.e. at the fractional Talbot distance.

References

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