NRL LASER FUSION PROGRAM

March- April 2002 Bimonthly Highlights

Bent Bragg-Fresnel Lenses for X-ray Imaging Diagnostics

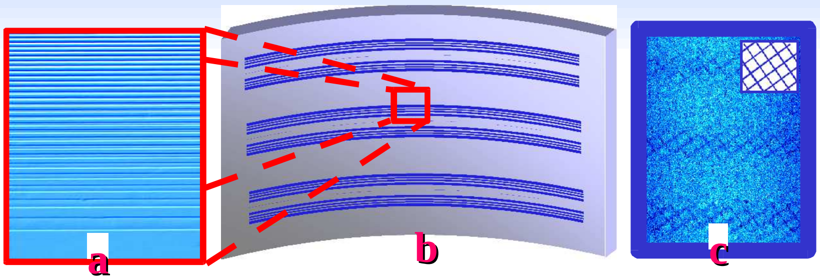

Fig. 1. a) Microphotograph of the linear Bragg-Fresnel structure; b) Cylindrically bent crystal with 3 BF parallel structures makes 3 Bent Bragg-Fresnel Lenses; c) Three 2D images created by three BBFLs. Insert shows the test target imaged.

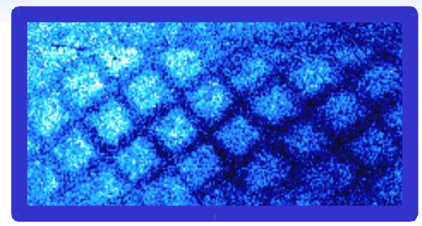

Fig. 2. Image of 500 lpi mesh taken with suppression of background radiation.

An X-ray imaging system based on Bragg reflection from the spherically bent crystals has been routinely used in Nike planar Inertial Confinement Fusion (ICF) experiments. The monochromatic nature of this diagnostic, high resolution and large field of view are very attractive features, particularly for x-ray backlighting applications. We report on our continued efforts to provide current and future experiments with new tools for x-ray imaging in the 1-10 keV range.

Bent Bragg-Fresnel lenses (BBFL) incorporate high resolution and 1D focusing of the linear Fresnel structure, as well as monochromatic and 1D focusing nature of cylindrically bent Bragg crystals. This hybrid 2D x-ray imaging diagnostic was tested under conditions relevant to the monochromatic backlighting experiments ongoing at the NRL Nike Laser facility.

Bragg-Fresnel lenses made of Silicon (111) and Quartz (10$\underline{1}$1 and 10$\underline{1}$0) with a focal length of 125 mm were manufactured using microelectronics technology. The process consisted of two main stages: electron beam lithography generates a pattern in a resist layer on a crystal surface; and then reactive ion etching transfers the pattern into the crystal (Fig.1a). Due to a specially chosen groove profile that adds a phase of π between adjacent zones, contemporary Bragg-Fresnel lenses perform with diffraction efficiency of 26% which is close to the theoretical limit of about 40 %.

The spatial resolution of a Bragg-Fresnel lens structure is determined by the width of its outermost zone. An increase of the BFL aperture requires a larger number of zones and, the outermost zone must be as thin as possible (it can be as narrow as 100 nm).

Additional bending of the linear BFL adds one more dimension to the focusing and makes it similar to a torroidally bent crystal that allows compensating for astigmatism inevitable in non-normal Bragg reflection. Also, when the Bragg reflection angle does not have to be close to normal, one can use a wider range of crystals and matching intense spectral lines.

In a backlighting geometry BBFLs combined with a small symmetric backlighter create a field of view that is extended in one direction but is quite short in the perpendicular one. A longitudinal field-of-view is an obvious good match for applications involving streak cameras. Otherwise, several Bragg-Fresnel structures positioned parallel to each other on the same crystal (Fig.1b) and using one backlighter, can generate a corresponding number of images (Fig.1c) necessary for framing camera operation. The images presented here are blackened partially due to the penumbra of the light reflected undiffracted from the cylindrical, untreated parts of the crystal. It is possible to clean an image from unwanted x-rays just by cutting the incoming x-rays from any part of the crystal but the BBFLs. Fig. 2 represents an improvement of observed contrast by stopping the unwanted radiation from contaminating the 2D focused image of the target. Finally, if a wide, the nearly-symmetric field-of-view is a necessity, one can use a backlighter extended perpendicularly to the short side of BBFL.

It should be mentioned, that BBFLs built on crystals used in transmission mode represent a straightforward way to achieve hard x-ray focusing that can be used either for self-imaging or backlighting.

Future development of the imaging technique presented here will include a comprehensive test of spatial resolution with new-generation, high-contrast BBFLs, including the ones operating in a transmission mode.

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