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Short communication

LIGA METHOD OF FORMING HIGH-CONTRAST COLLIMATORS AND ANTI-SCATTER GRIDS WITH HIGH ASPECT RATIO

B.G. Goldenberg[1 *], A.G. Lemzyakov[1], V.P. Nazmov[1], E.I. Palchikov[2]

[1] Budker Institute of Nuclear Physics, Siberian Branch of the Russian Academy of Sciences, 11 Lavrentyeva av., Novosibirsk, Russian Federation, 630090

[2] Lavrentyev Institute of Hydrodynamics, Siberian Branch of the Russian Academy of Sciences, 15 Lavrentyeva av., Novosibirsk, Russian Federation, 630090

Abstract

The article deals with creation and application of high-contrast anti-scatter X-ray grids for X-ray imaging in the range of 20–200 keV from microfocus X-ray tubes. A prototype high-aspect-ratio nickel grid structure is used to consider the impact of anti-scatter grid on the directional patterns of the IMA-2-150D X-ray tube. The suppression of scattered radiation and narrowing of the directional radiation pattern are demonstrated. The contrast of the nickel prototype is apparently insufficient. The article presents LIGA methods for manufacturing anti-scatter X-ray grids made of gold in Siberian Synchrotron and Terahertz Radiation Centre. A method for forming resistive grid structures using deep X-ray lithography is described and test structures are shown. The development of manufacturing technology for anti-scatter X-ray grids is in progress.

Key words: LIGA, deep X-ray lithography, anti-scatter X-ray grids, X-ray imaging, microfocus tube.

1. Introduction

Radiographic methods are widely used in advanced fundamental research in the field of materials science, geology, extreme state of matter, and medical studies of the internal organs of patients. In radiography, the quality of radiation sources and detectors is of great importance. The use of microfocus X-ray tubes with a focal spot size of up to several micrometers makes it possible to achieve high spatial resolution. However, this limits the power and increases the exposure time. In addition, microfocus tubes tend to rapidly degrade. It is believed that the spatial resolution of images can be improved through the use of pulsed X-ray machines with a focus size of 2 to 5 mm and correction of the wavefront propagation patterns. An image recorded on an X-ray film, a memory screen, or a CCD matrix is generally blurred due to divergence of the original radiation flux and scattering in the sample material and in the X-ray sensitive material of the detector. Using anti-scatter X-ray grids in experiments will improve the signal-to-noise ratio, increase the spatial resolution, and reduce the undesired scattered radiation.

[*] Corresponding author. E-mail: goldenberg@inp.nsk.su (B.G. Goldenberg)

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2. Production of high-contrast collimators and anti-scatter grids

LIGA technology, which combines deep X-ray lithography and electroforming, seems to be the most promising for manufacturing X-ray anti-scatter grids. A straight intense SR beam ensures the formation of deep microstructures in a polymer resist with smooth vertical walls, which then can be used for electrochemical formation of a metal grid structure.

The grid structure of nickel with hexagonal packing of cells was used as a prototype for pretesting. The structure was produced in advance by the LIGA method. During the production, nickel was electroplated around the PMMA bumps. The thickness of the deposited Ni layer was up to 1200 µm. Then, the PMMA bumps were removed using flood exposure to X-rays with subsequent dissolution in GG developer. The roughness of the sidewalls of nickel structures made 30 nm at most. The grids consisted of hexagonal cells with an inscribed circle diameter of 80 µm and a wall thickness of 10 µm.

The nickel grid described, IMA2-150D type X-ray tube with explosive electron emission and a grounded rhenium anode operated in the pass-through mode, and an ImagePlate detector were used in test experiments [1]. The arrangement of the components of the X-ray tube and anti-scatter LIGA raster is schematically shown in Fig. 1.

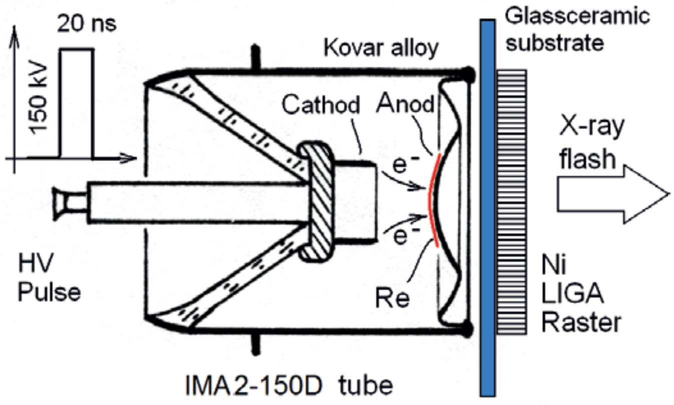

Fig. 1. Schematic arrangement of X-ray tube (with detailing) and LIGA raster

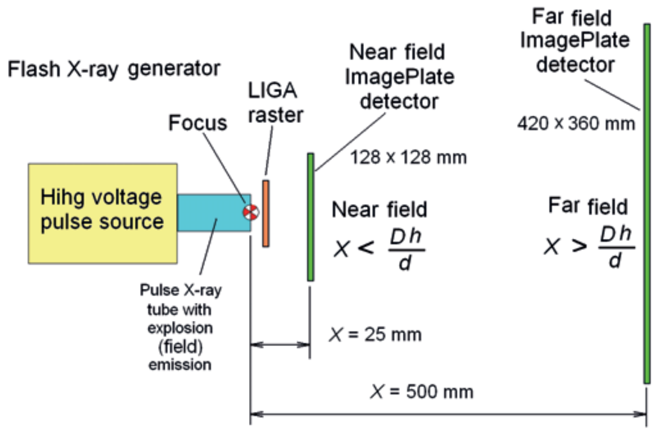

Fig. 2. Scheme of experiment. Arrangement of X-ray source, raster, and detector

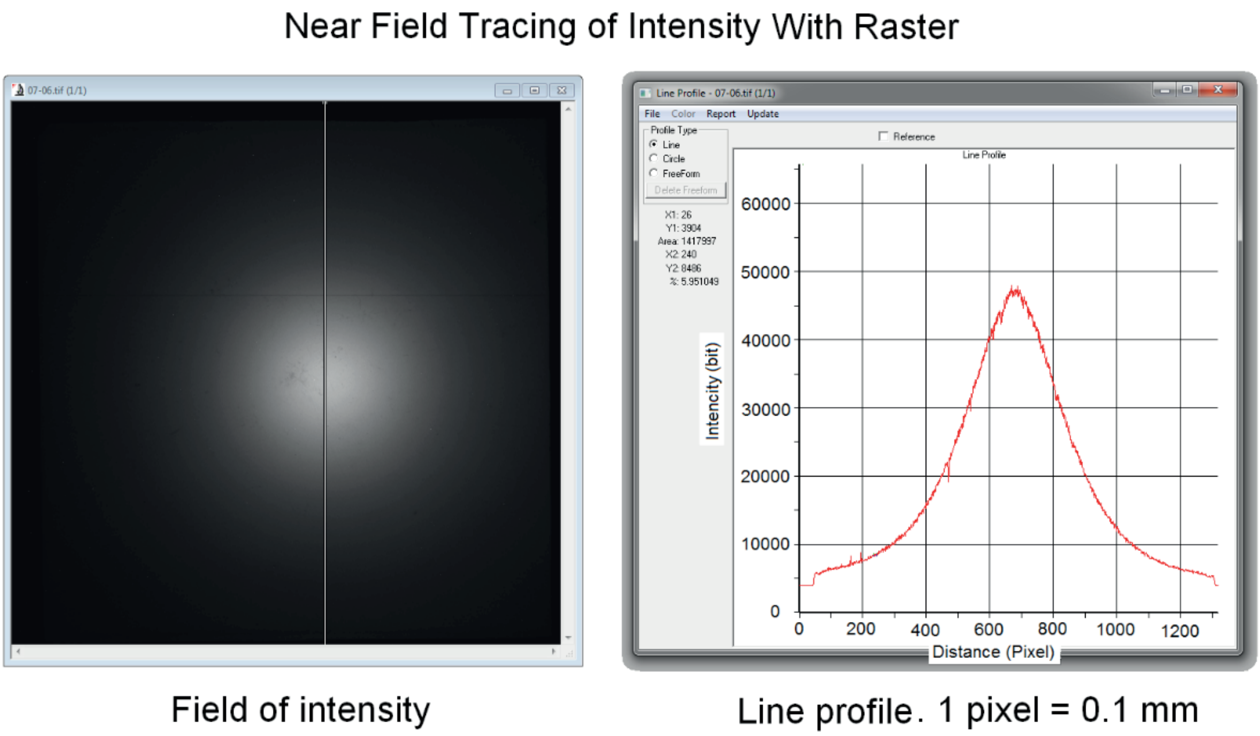

Fig. 3. Intensity distribution in detector plane for near-field conditions. Left: two-dimensional distribution; right: one-dimensional distribution in vertical cross-section (along the continuous line in the left image)

As Fig. 2 shows, the distance between the X-ray tube and the ImagePlate detector varied in the experiment. The minimum distance X relates to the near-field condition, when the angular dimension of the X-ray source D/X observed from a point in the detector plane exceeds the angular acceptance of a single tube d/h (Fig. 3). The maximum distance X corresponds to the far-field condition, when, on the contrary, the angular dimension of the radiation source D/X is less than the single-tube angular acceptance d/h. D is the focal spot with a diameter D=2.4 mm (FWHM); d is the cell size, h is the thickness of the nickel.

Fig. 3 shows the recorded intensity distribution in the near field. The intensity extends with cylindrical symmetry around the optical axis, which is orthogonal to the detector plane.

Fig. 4 shows the recorded intensity distribution in the far field. The distribution has a sharp central peak, corresponding to the collimated beam, as well as X-rays extending with hexagonal symmetry around the center.

Thus, the trial experiments demonstrated the feasibility of improving the directional pattern radiation from X-ray tube using a metal raster. Obviously, to suppress the scattered radiation and increase the contrast it is necessary to use metal with high absorption in the X-ray range of 20–200 keV. Gold is the best choice. To suppress 99 % of the X-ray flux in the 100 keV region, a gold layer 480 μm in thickness is required, 250 μm being enough to suppress 90 % of the flux. This material has excellent properties. However, due to its high cost, a cheaper material was chosen for the earliest stage. At the next stage, the authors are piloting the production of X-ray rasters from gold.

The creation of a polymer matrix for subsequent galvanic deposition of gold is an important technological stage. The authors believe that this may be achieved by a modified method of deep X-ray lithography, namely direct multi-beam drawing in a thick SU-8 resist layer [2].

The facility includes a beamline, an experimental station for deep X-ray lithography on the VEPP-3 storage ring, and equipment for processing resistive layers [3].

Using the multibeam system (Fig. 5) it is possible to form an array of regularly located elements of a given size quickly without creating and using a full-size

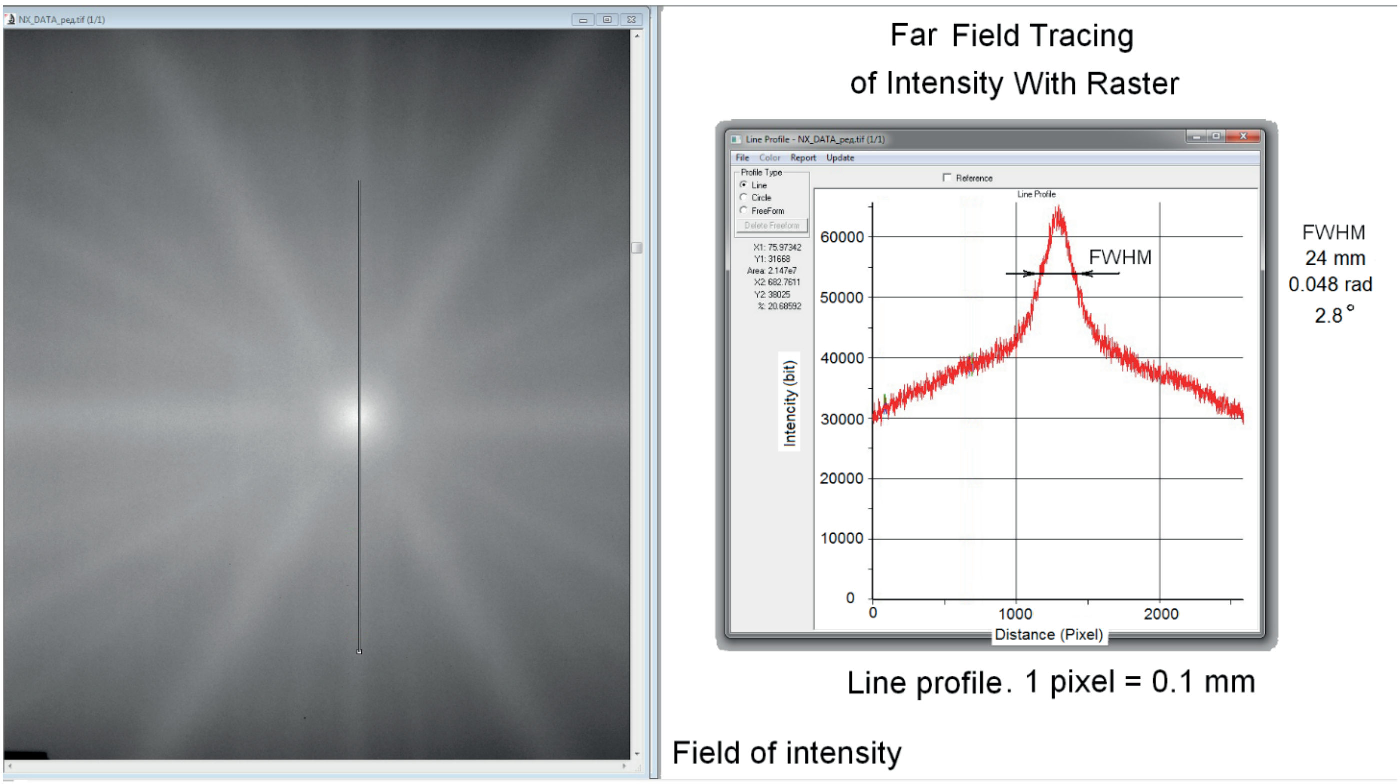

__Fig. 4.__ Intensity distribution in detector plane for far-field conditions. Left: two-dimensional distribution; right: one-dimensional distribution in vertical cross-section (along the continuous line in left image). After subtraction of the background, interpolated by a smooth function, the measured spread angle of the collimated beam makes 2.7° (FWHM)

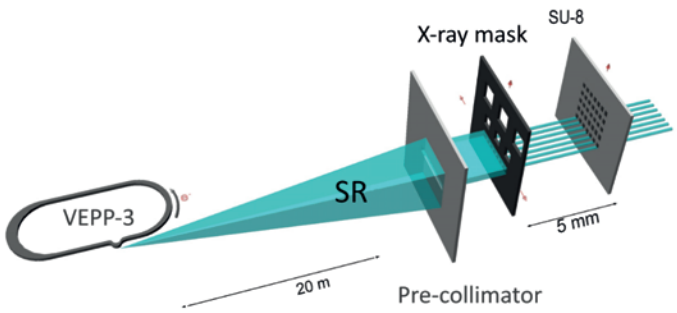

Fig. 5. Multibeam X-ray lithography installation

X-ray mask, which greatly simplifies and cheapens the process of X-ray lithography. An array of polymer bumps will be used as a matrix for electrochemical deposition of gold.

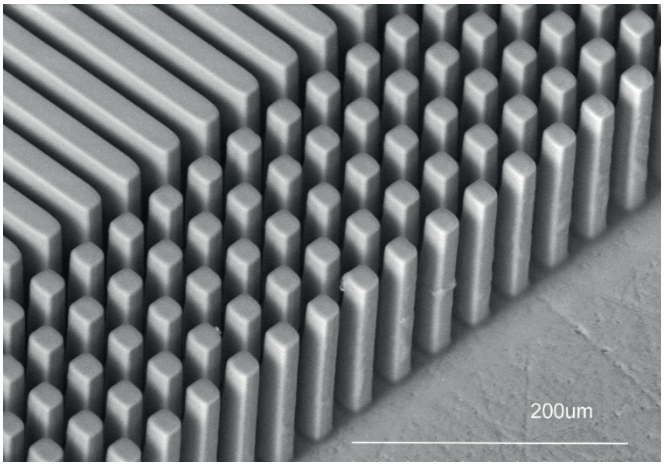

Fig. 6. *Fragment of regular microstructure of SU-8 resist; bump cross section dimensions: 20×20 μm; bump height: 120 μm*

Conclusion

The concept of using absorbing anti-scatter rasters to improve the quality of X-ray diffraction installations has been considered. The experiments demonstrated the possibility of improving the radiation of directional X-ray tube pattern using a prototype raster made of nickel. Rasters formed of high-contrast material like gold should be used for further improvement. The possibilities and a Multibeam X-ray lithographic method for forming polymer SU-8 resist rasters are shown. A practical procedure for creating gold anti-scatter X-ray grids is being currently developed.

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