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ScienceDirect

Physics Procedia 84 (2016) 238 – 244

Physics Procedia

International Conference "Synchrotron and Free electron laser Radiation: generation and application", SFR-2016, 4-8 July 2016, Novosibirsk, Russia

Influence of LIGA raster on spatial distribution of radiation from flash X-ray generator

V.P. Nazmov[a]*, E.I. Palchikov[b,c], T.S. Krivtsov[c]

[a]*Budker Institute of Nuclear Physics SB RAS, Novosibirsk, 630090, Russia*
[b]*Lavrentyev Institute of Hydrodynamics SB RAS, Novosibirsk, 630090, Russia*
[c]*Novosibirsk State University, Novosibirsk, 630090, Russia*

Abstract

The development of microcollimators for photon energy in the range of 30-200 keV was carried out. A quasi-spherical or quasi-plane X-ray wave can be formed when the propagation vector of the collimator is locally parallel to the wave front, either near the X-ray focus or away from it. The method was tested to collimate the widespread beam from an X-ray generator. In the experiment, a flat nickel raster 1200 μm thick with tubes of 80 μm in diameter manufactured using LIGA technique, was used. For a flash X-ray device with an explosive electron emission and an anode voltage of 150 kV, a quasi-collimated X-ray beam with an angular divergence of up to 2.8 degrees (FWHM) was formed.

Keywords: LIGA technique, raster, X-ray optics, explosive electron emission, flash X-ray

1. Objective

The development of essentially new methods of manufacturing of X-ray optics in the energy range of 30-200 keV is a challenge. Since the refractive index of X-rays in the above spectral range is close to the unity and the wavelength is extremely short, such devices require both higher manufacturing accuracy and increased roughness of sidewalls as compared with instruments being developed for low-energy photons. The method that can meet the

* Corresponding author. Tel.: +7-383-329-4298; fax: +7-383-330-71-63.
E-mail address: V.P.Nazmov@inp.nsk.su

doi:10.1016/j.phpro.2016.11.041

given requirements is the LIGA technique employed at the Budker Institute of Nuclear Physics by Goldenberg et al. (2016), which was applied to the development of X-ray microrasters consisting of microstructures with high aspect ratio.

Nomenclature

D	diameter of X-ray tube focus
L	distance from focus to nearest part of LIGA raster
d	diameter of tubes in LIGA raster
h	thickness of LIGA raster
X	distance from focus to plane of recording
δ	refractive index decrement
β_a	absorption coefficient
n	refractive index, $n = 1 - \delta + i\beta_a$

Explosive and fast processes are usually recorded using a pulsed X-ray source with a pulse duration of 1 ns to 100 ns, photon energy of 50 keV to 2000 keV, and electric power of 10^8 W to 10^{11} W. The X-ray flash technique is suitable for investigations of fast processes which are coupled with light production and therefore cannot be examined by light or which happen in a light-absorbing or reflecting area. A direct measurement of densities is possible by means of X-rays. These qualities give the X-ray flashes an important and unique role as a means for specific investigations, as summarized by Germer (1979). Because of the X-ray beam has to be collimated very well to yield a sharp diffraction pattern, it is difficult to provide a long service life of X-ray tubes with a small focus and aforementioned parameters. Therefore, the enhancement of quality and intensity of collimated beams is a challenging for Debye-patterning and Laue-patterning of fast- and explosive processes presented by Jamet and G. Thomer (1976).

So, for stationary X-ray recording, the focus can be made smaller than one micron due to a long exposure time and a low power of the device, as shown by Nachtrab et al. (2011). However, Palchikov (2012) reasons that in the case of pulsed single-exposure X-ray machines (one flash yields one shot), a tube with a focus size of less than 1 mm is actually a single-use one. And, Bichenkov and Palchikov (1997) found that improvement of the spatial resolution of images suggests application of earlier developed techniques for correction of both the directional pattern and the radiation propagation front of pulsed X-ray devices with a focus of 2 mm to 5 mm.

In the case of X-ray tube of any type, including flash generators applied at the Institute of Hydrodynamics SB RAS for diagnostics of high-speed and explosive processes, a three-dimensional microraster can be used as a collimator. This can enable collimation of widespread X-ray beam from an X-ray tube. One can form a spherical X-ray wave via placing a network with microtubes on a spherical surface, either near the X-ray focus or far away from it. In the case of a plane raster, a quasi-plane wave with divergence determined by the ratio of the tube diameter to the length will form.

2. Experimental arrangement

The study of the X-ray optical properties of the fabricated raster was performed with the application of a pulsed X-ray source with a cathode voltage of 150 kV, installed at the Institute of Hydrodynamics of SB RAS. An IMA2-150D type tube with explosive electron emission and a grounded rhenium anode operated in the pass-through mode. Electrons that were emitted by a plasma cloud that emerged at the edge of the cathode of 10 mm in diameter and was expanding towards the anode with a speed of ~ 100 km/s are under the pinch effect and thus are collected on the anode in a focal spot with a diameter D=2.4 mm (FWHM). The pulsating current in the tube as high as 500 A. The flash duration is less than 20 ns. The arrangement of the elements of the X-ray tube, and the LIGA raster in the experiment are shown in Fig. 1.