Thin YAG:Ce and LuAG:Ce single crystal imaging plates used for high spatial resolution in X-ray imaging systems

Jan Vasek, Karel Hládař, Ladislav Plha, Bruno Byško

Abstract—A high-resolution CCD X-ray camera based on YAG:Ce or LuAG:Ce thin scintillation screens is presented. The high resolution in low-energy X-ray collimation is preserved even in non-destructive beam settings. The achievable spatial resolution of the beam is better than 1 micron. The objects used for imaging are grids and small samples with parts of various materials in combination. The high-resolution imaging system can be used in different types of imaging techniques (X-ray, microwave, UV, and VIS) for non-destructive X-ray micro-imaging and transparent materials.

I. INTRODUCTION

The spatial resolution of an X-ray and imaging techniques imaging system is one of the most important parameters in X-ray non-destructive and destructive imaging techniques. The imaging technique can usually be divided into two-dimensional and two-dimensional imaging techniques (FDI). There are many different types of FDI detectors with each having its advantages and disadvantages [1]. X-ray micro-imaging in an X-ray imaging method used from a number of essential material applications related to the imaging of very small objects. The sample is irradiated with X-rays with energy sufficient for generating the X-rays and being absorbed with a thin resolution. X-ray position-sensitive detectors. Different parts of the sample are imaged by different incident angles. Various imaging techniques can be used by different inorganic and organic thin-film techniques. X-ray imaging techniques (X-ray, microwave, UV, and VIS) for non-destructive imaging systems and transparent materials. The presented X-ray micro-imaging system is a combination of a high-sensitivity digital X-ray camera and an optical system with a high-quality imaging system. The system in the described YAG:Ce (LuAG:Ce) or LuAG:Ce (LuAG:Ce) has a high spatial resolution. High-quality polycrystalline YAG:Ce or LuAG:Ce single crystals were prepared by the Czochralski method [2]. These crystals have the advantages in the optical and electrical stability and the non-hydrosolvent. The imaging scintillating screens is typically transparent. The emitted wavelength of YAG:Ce and LuAG:Ce is 510 nm and 525 nm, respectively.

Fig. 1. Experimental setup.

II. EXPERIMENT

The scheme of the experimental setup is shown in Fig. 1. The X-ray beam was placed in the focused object plane of the sample. In the experiments, the X-ray beam was the shape of a small point with thickness of several micrometers. The sample object was placed in pure water in the X-ray beam. In order to keep the focusing effect caused by the X-ray beam, the sample was placed as close as possible to the beam. In the experiments, a micro-focus X-ray tube was used. The temperature of the camera was stabilized by recirculating water cooling. The incoming images were processed via their background subtraction and the final correction.

Fig. 2. Radiography of a gold-grid taken by using LuAG:Ce thin scintillator.

III. RESULTS AND DISCUSSION

The experiments are based on a gold-grid and wire mesh objects. A plane of copper 100 objects. The images were taken by using the LuAG:Ce 30 µm screens. The effective spatial resolution of the CCD camera was 0.34 µm. The X-ray micro-imaging system was equipped at 60 kVp. The images were processed using 3 µs and the resulting high-contrast images with an anode of 25 µm.
It is shown that the resolution of the imaging system is in the order of micrometers. The line profile of one grid wire is shown in Fig. 3. The profile is compared with the geometric profile of the grid wire, which has trapezoidal shape with a base of 10.7 μm and top 6.8 μm wide (measured in an SEM image of the grid). The optical properties of YAG:Ce and LuAG:Ce materials allow to achieve the very high spatial resolution of 1 μm. The spatial resolution of the screen depends on screen thickness, photon energy and the depth of absorption of the photon. An optical system using a magnifying focus was used to transfer the scintillator screen image to the CCD image area surface.

In the next experiments the golden grid were taken by using a LuAG:Ce single crystal plate with thickness 100 μm. The CCD camera were equipped with lenses of 10 times or 20 times magnification respectively. The Fig. 6 and Fig. 7 present the results. It was shown that the high resolution was observed using optimal magnification of the image created on the single-crystal screen. In the Fig. 8 and Fig. 9 are the line profiles of both pictures of the grid.
Fig. 8. Line profile of the grid, effective pixel size is 0.65 μm.

Fig. 9. Line profile of the grid, effective pixel size is 0.3 μm.

Fig. 10. Absorption of X-ray radiation in 20 microns thick layer of YAG and LuAG [3].

The density of the light penumbra by LuAG:Ce is about 1.51 times the value of YAG:Ce. The light was detected by the CCD and measured in a square ROI of 260 x 260 pixels. The LuAG:Ce single crystal is more dense compared to YAG:Ce (density: 5.79 to 4.97 g/cm3) and the X-ray was absorbed stronger by LuAG (1.7 times more of X-ray radiation photons) in absorbed in the range between 1 and 40 keV, as can be seen in Fig. 10. Absorption coefficients are taken from [3].

IV. CONCLUSIONS

In the experimental setup presented, a high-resolution imaging system based on CCD cameras with linearly and precisely manufactured YAG:Ce and LuAG:Ce single crystal cameras was used for X-ray micro-radiography. The X-ray attenuation depth of X-ray radiation in the scintillating materials can be altered and the YAG:Ce and LuAG:Ce screens are optically component as the image of luminescence pixel in easily transfer to the CCD. However, the advantage of the materials tremendously decreases with the thickness of the imaging panel. If the scintillator is thinner, the X-ray attenuation depth is lower and the image is clearer due to less scattering of the image due to less traced spectral of the scattered photons. Hence, the thinner the imaging panel is, the clearer is the resolution added to the image. On the other hand, the absorption scintillator increases with thicker thickness.

The experiments shown that the YAG:Ce and LuAG:Ce screens are suitable for imaging with high spatial resolution. The resolution of the present imaging system is about 160 μm.

The LuAG:Ce screen has higher mean energy than the YAG:Ce screen as the signal to noise ratio of the image is better.

ACKNOWLEDGMENT

This work was supported by the grant of the Ministry of Industry and Trade of the Czech Republic no. FT-TA/102.

REFERENCES