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APPLICATION OF SIMPLE COMMERCIAL CCD CAMERAS FOR IMAGING PULSED PLASMA X-RAY SOURCES

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Abstract. A pinhole X-ray imaging camera with the use of a simple 8-bit commercial CCD module has been fabricated. The camera was used for testing the operation of a CCD in direct-detection mode (i. e., without a phosphor) and for checking the methods of processing data from a CCD. The primary reason for developing this camera was to gain experience with this type of detector. The camera is provided for direct imaging X-ray emission from different plasma sources, which could differ greatly in pulse duration, such as laser plasma and tokamak

1. Introduction

A CCD camera has an application as a direct detector for imaging X-ray emission from hot plasmas [1,2,3] or as a recording device for other X-ray diagnostics used for temporal analysis and for spectroscopy [4,5]. A direct-write X-ray camera provides a suitable replacement of film with a linear response, dynamic range and intrinsic signal-to-noise response sometimes superior than current X-ray film, and provides real-time access to the data. An attractive possibility is the adaptation of a simple, commonly used optical CCD camera for the measurement of continuous or pulsed radiation from plasmas [6,7]. The primary advantage of such an application is its low cost in comparison to (equivalent) commercially available imaging packages and the possibility of realising even risky experiments without bothering about damaging the applied equipment. In this paper we describe the results of our experiments with a fabricated by us, simple X-ray CCD camera (based on a simple optical module), mostly used in a pinhole configuration. One of the primary reasons for developing this camera was to gain experience in the range of imaging techniques applied to laser and tokamak plasmas. Our aims was to test the camera for the measurement of X-rays in the vacuum environment, improvement of the method of image processing and development of the relevant synchronisation systems which were applied for different modes of the camera operation.

2. Description of X-ray pinhole camera

The X-ray pinhole camera (Fig. 1) was fabricated with the use of an electronic module taken from a low-cost commercial black-and-white optical CCD camera of the LR38269, Sharp, chipset. The module is equipped with a CCD sensor of 3.2×2.4 mm^2 dimension (1/4"). The sensor, normally used in the optical range, was made sensitive to X-rays by

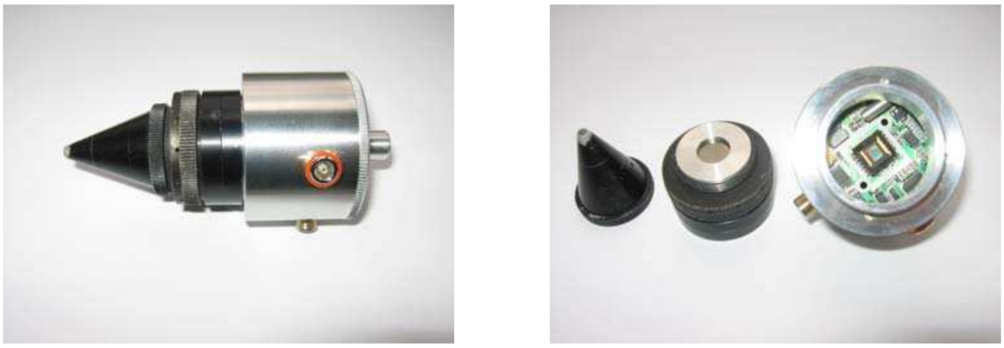


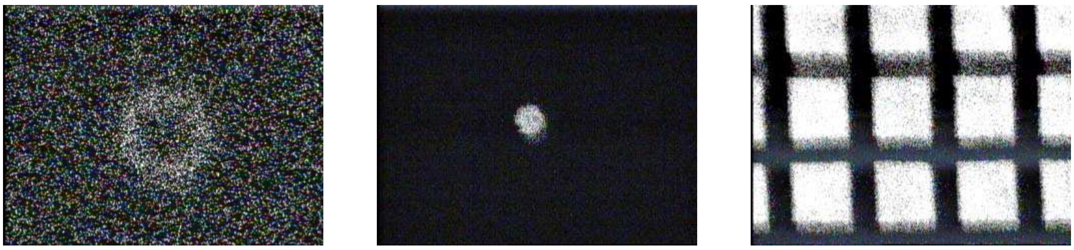
Fig. 1. Overall view and internal structure of the CCD pinhole camera.

removing the entrance glass window. The process of removing was carried out at a high temperature kept for a pre-set period at a constant level. The module was then mounted in a light-tight enclosure designed for placing in vacuum, equipped with a pinhole, a beryllium filter and a light-tight labyrinth for pumping air out. The approximate range of sensitivity of the pinhole camera is 2-5 keV that is determined by the thickness of the filter used (10 μm Be) and the surface dead layer of the CCD chip, as well as the thickness of the active layer in the CCD sensor, which is about 15 μm.

The analogue signals from the X-ray camera were directed to a simple plug-in video card, type DVR2K v 2.30 (processor CONEXANT FUSION 878A) and then processed in a PC. A computer code for operating the camera and data processing after capturing a picture was developed. The code is written in the *Delphi* language. When using the code, it is possible to acquire and display data both in continuous and triggered mode, memorise them, and to read out a saved image when needed. In the continuous mode the camera reads and displays pictures at a constant rate of 25 Hz. In the triggering mode, the camera reads (captures) one picture, when triggered. The process of capturing is initiated by auto triggering from the first occurrence of a video signal (monitored in some pre-set numbers of pixels - 4, 8 and 16) of a level above a certain pre-set value, or by an external pulse. It is also possible to acquire (and then summarise if needed) a sequence of some pictures, up to 125 (when the source operates in a repetitive mode). The pictures are delivered by this code in 2D or 3D configuration. The CCD camera delivers three-colour signals (R,G,B) in TV standard. Each colour can be processed independently.

1. Application of the pinhole CCD camera for imaging X-ray and light sources.

Preliminary tests of the camera and the code, which was used for its operation, were done with the use of a pulsed light source (LED). The first tests with X-ray imaging were carried out with the use of X-ray lamp of a cold cathode, Dina 1 which sends hard X-ray radiation over 5 keV. The X-ray emission area of the source in Dina 1, measured for the first time, occurred to be shaped as a ring of 2.5-mm external diameter (Fig. 2A). Finally, the camera



(A) (B) (C)

Fig. 2. Exemplary images obtained with different X-ray sources: (A) - with the lamp of a cold cathode Dina 1, (B) and (C) - with laser-plasma source.

was demonstrated to be operational on a pulsed laser-plasma source. The camera was utilised in the measurement of the X-ray emission from laser plasma obtained with the use of a small, repetitive Nd:YAG laser, type NL303HT, EKSPLA,Vilnius. The parameters of the laser are: wavelength - 1064 nm, pulse duration - 4 ns, pulse energy - 800 mJ, and repetition rate - 10-Hz. The CCD camera (CCD chip) was placed at a distance of 52 mm from a Cu target. To obtain a measurable X-ray emission, the laser beam was collimated to the spot of less than 0.2 mm in diameter. Figures 2B and 2C show the X-ray pictures measured from one shot. Fig.2b was obtained using a pinhole of 170 μm in dimension. Because of low space resolution this picture does not represent the real shape of the source. Picture 2C presents the measurement of plasma emission through a metal grid (thickness of a wire 0.16 mm, period 0.43 mm, placed close to the CCD chip, made without using a pinhole).

When applying the camera in vacuum, we encountered some problems with its stability because of the rise of its temperature and noise. To solve this problem, the camera was switched on just before a shot. Other solutions would be improving the thermal contact of the camera with the experimental chamber or active cooling.

We also found that the camera cannot be always triggered or synchronised to the sequence of shots of the laser. It can be explained by the specific operation of the computer, which is not always able to accept data from the video card fast enough (it does not operate in the real time).

4. Conclusions

An X-ray camera based on elements obtained from a simple optical camera has been fabricated. The CCD chip was adapted for a measurement of X-rays by removing a glass window. The camera can be used for measurement of X-ray radiation in the medium spectral range of 2-5 keV. The tests proved that the camera could be applied for imaging continuous and pulsed X-ray sources. Its use in vacuum needs applying special means, such as special construction to improve heat flow or application of active cooling which should also lower noise.

References

[1] J. Dunn, B.K.F. Young and S.J. Shiromizu, Rev. Sci. Instrum. 66 (1) 706-708 (1995)

[2] D.S. Marzi, A. Giulietti, D. Giulietti, L.A. Gizzi and A. Salvetti, Laser and Particle Beams, 18, 109-118 (2000)

[3] L.D. Conder, J. Dunn and B.K.F. Young, Rev. Sci. Instrum. 66 (10 709-711 (1995)

[4] M. Koenig, J.M. Boudenne, P. Legrier, A. Benuzzi, T. Grandpierre, D. Batani, S. Bossi, S. Nicolella and R. Benattar, Rev. Sci. Instrum, 68, 2387 (1997)

[5] E. Pace and L. Tommasi, Rev. Sci. Instrum., 69 (4), 1622-1628 (1998)

[6] G.X. Zhang, P. Lee, X. Feng, L.H. Liu and S. Lee, ICCPP&25th EPS Conf. on Contr. Fusion and Plasma Physics, Prague, Vol. 22C, 1598-1601 (1998)

[7] W. Wang, S. Kumar, B. Zheng, P. Lee and S. Lee, Journal of Accelerator and Plasma Research, 5, (2), 278-290 (2000)