X-ray High Resolution Imaging CCD Camera Based On a Thin Scintillator Screen

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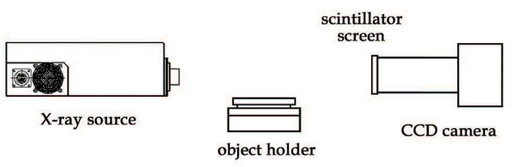
Abstract

A high-resolution imaging X-ray CCD camera based on YAG:Ce or LuAG:Ce scintillating screens is presented. The obtained spatial resolution of X-ray images is in order of micrometers. The high resolution is proved on several objects and compared to the resolution of a standard P43 (Gd_2O_2S:Tb) powder scintillator screen.

The high resolution imaging system is a combination of a high sensitive digital CCD camera and an optical system with a thin scintillator screen. The screen is the YAG:Ce ($Y_3Al_5O_{12}$) or the LuAG:Ce ($Lu_3Al_5O_{12}$) inorganic scintillator. These materials have the advantages in the mechanical and chemical stability, non-hygroscopicity, and a high radiation hardness.

Experiment

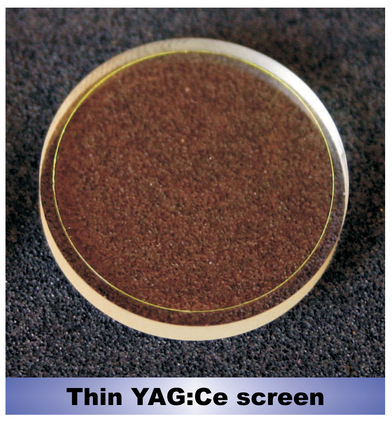


Experimental setup

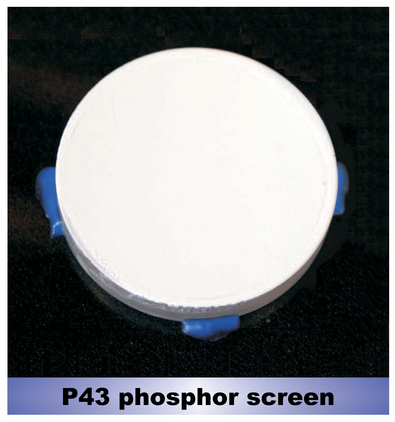
The experimental setup consists of a 40kV X-ray microfocus source and a high resolution CCD camera with an optical system. Objects are in a very close position to the scintillation screen. It is then possible to take X-ray images with the resolution better than 10 micrometers by combination of the thin screen and the high resolution CCD detector.

High-resolution X-ray digital camera

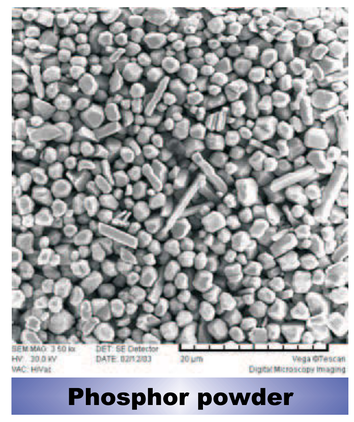
The high resolution imaging screen is the basic part of the high-resolution imaging system. The very thin imaging screens are based on the YAG:Ce or the LuAG:Ce single crystal scintillation material.



Thin YAG:Ce screen



P43 phosphor screen

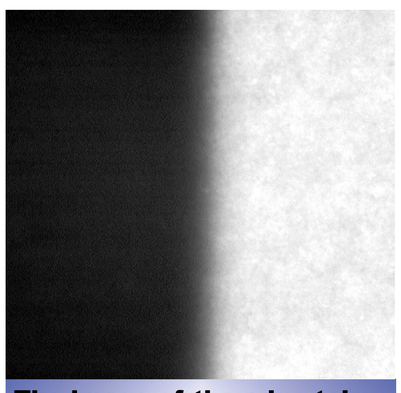


Phosphor powder

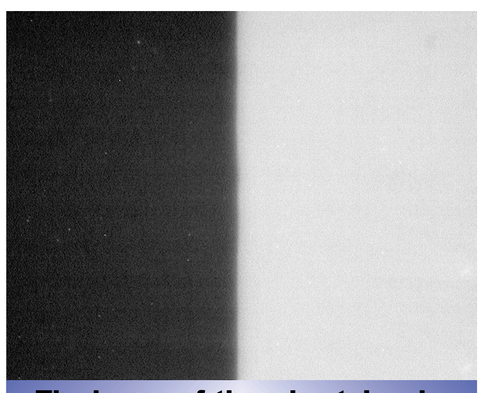
An optimal thickness of the screen is a compromise between the detection efficiency and the high resolution. The very thin screen on a precise optical substrate is imaged by an optical system with the Peltier cooled CCD detector. The P43 screen is made from powder of 2-4 micrometers particle size.The thickness of the layer is about 20 micrometers.

Experiment results

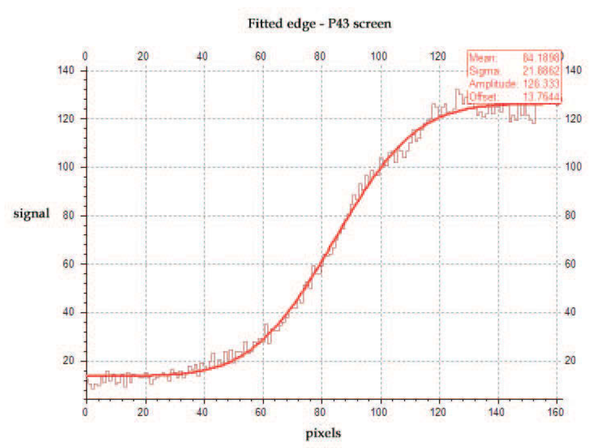
The imaging system was tested on several objects. The high resolution of the system with YAG:Ce thin screen is compared to a standard P43 phosphor screen using the same conditions. The objects are an edge of 100 micrometers thick iron plate and a gold grid with the wires 8 microns wide. The images were taken by using the 20 micrometers thick YAG:Ce imaging screen or 20 microns thick phosphor P43 (GADOX), both on quartz glass. An acquisition time for both screens is different due to different detection efficiency of the materials.



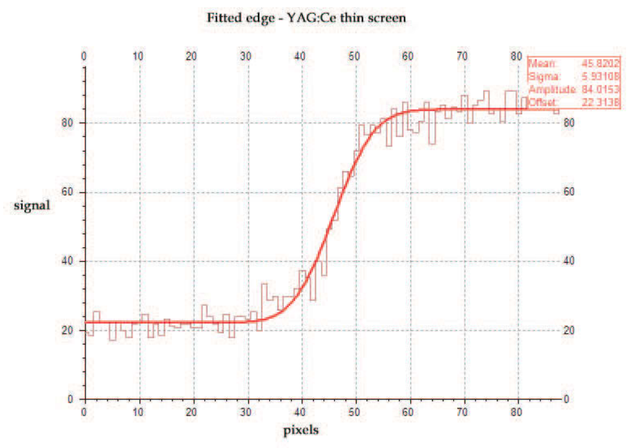
The image of the edge taken by using the P43 screen



The image of the edge taken by using the thin YAG:Ce Screen

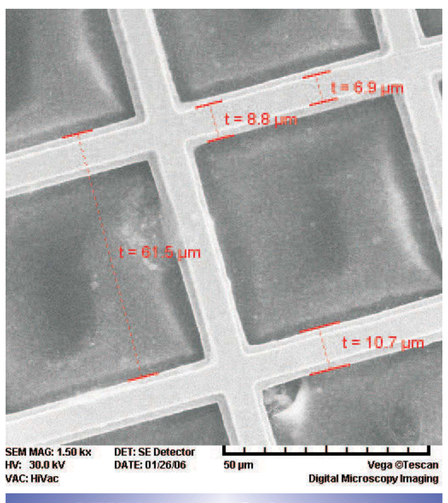


The edge fitted by a distribution function, image taken using P43 screen

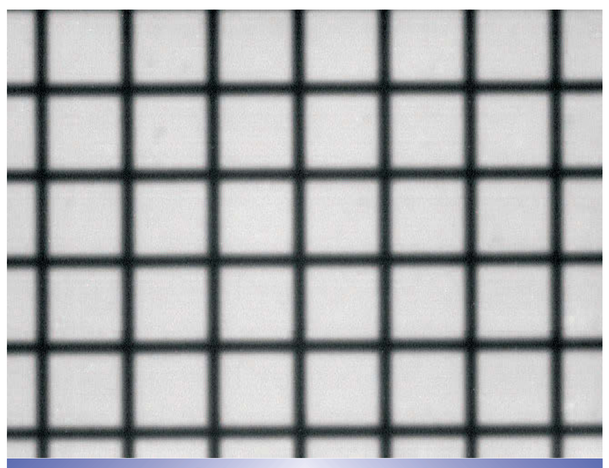


The edge fitted by a distribution function, image taken using YAG:Ce screen

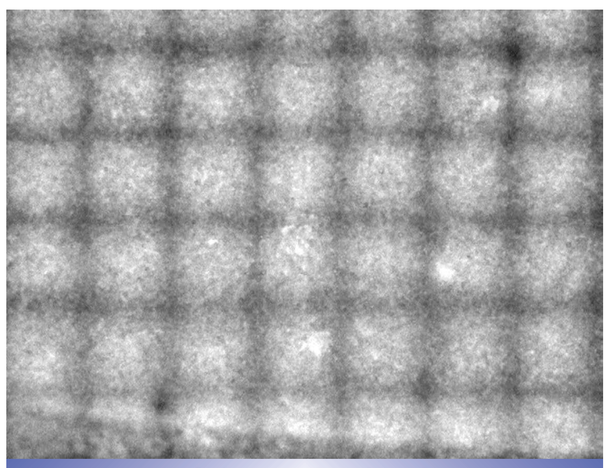
The images of the edge were inspected by a line profile. The transverse cut of the image of the edge is fitted by an error distribution function (erf). The sigma means the edge width. The resolution of the YAG:Ce screen is then about 4.4 micrometers and the resolution of P43 screen is about 16.2 micrometers in the low energy X-ray radiation.
The image of the testing golden grid taken by using the P43 screen shows that the wires cannot be resolved. The width of the wires on the image taken by using the YAG:Ce screen is about 14 pixels. The effective pixel size is 0.74 micrometers.
The high resolution images of biological objects show a termite and a tick imaged by using the high resolution system.



SEM image of the mesh



The image of the mesh taken by using the thin YAG:Ce Screen



The image of the mesh taken by using the P43 phosphor screen

A termite

The tick - a detail

A tick

Conclusions

The results

- **the resolution obtained by means of the thin single crystal imaging screen is higher than the resolution of the standard P43 screen**

High resolution depends on

- **minimal thickness of the plate**
- **excellent parallelism of faces**
- **high optical quality**
- **space homogeneity of luminescence**
- **optical coating**

Advantages

- **long life operation**
- **high resolution better than 10 microns (up to 1 micron)**
- **X-ray, electron and UV detection**

Application

- **industry and science**
- **defects inspection**
- **biological imaging**
- **technical imaging**
- **X-rays, electrons and UV**

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