# LuAG:Ce Single Crystal Films For High 2D-resolution Scintillation Detectors


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## Abstract

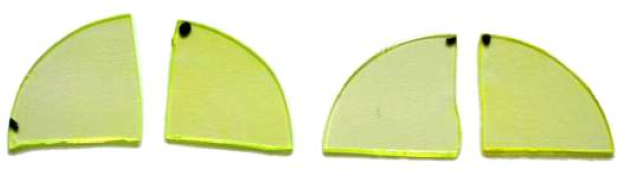

**Apart from the bulk scintillator segments used in different geometries in applications in high energy physics, medical or other applications, there is also a need for thin (several or tens of micrometers) and large area (up to 50 mm) single crystal plates or films to be used with position sensitive photodetectors (CCD), which can enable imaging of tiny objects in the X-ray (electron) beam down to micrometer scale.**

**Lu-based compounds are under intense research as they often reach high density together with an excellent scintillation figure-of-merit. LuAG:Ce ($Lu_3Al_5O_{12}$:Ce) has recently been reported to be a highly efficient scintillator material, the scintillation efficiency of which can reach up to 700% of BGO under X-ray excitation, while its light yield is lowered down to less then 200% of BGO due to delayed recombination phenomena.**

**In this contribution, the imaging ability of LuAG:Ce ($Lu_3Al_5O_{12}$:Ce) films grown by Liquid Phase Epitaxy (LPE) is demonstrated and compared with a thin plate of the same thickness made from bulk LuAG:Ce crystal. The integral scintillation efficiency, quality of image and 2D-resolution achievable in such scintillation detectors will be discussed .**

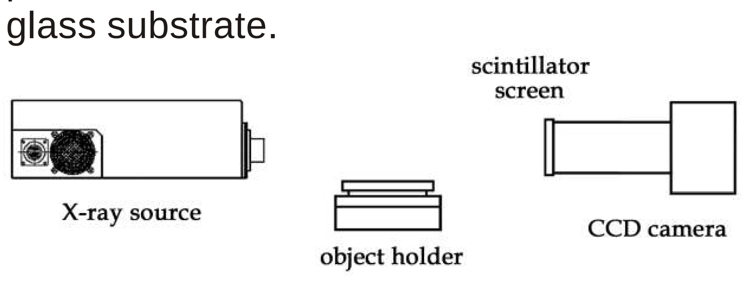

## Experiment

LPE-grown LuAG:Ce films grown from a PbO-$B_2O_3$ melt-solution are compared to a thin plate made from bulk LuAG:Ce crystal grown by the Czochralski method using a molybdenum crucible under a reductive atmosphere. The LPE samples were lightly polished down to 20 micrometers thickness. The bulk crystal thin plate was about the same thickness and was glued onto a glass substrate.



LPE grown film samples

Thin LuAG:Ce plate



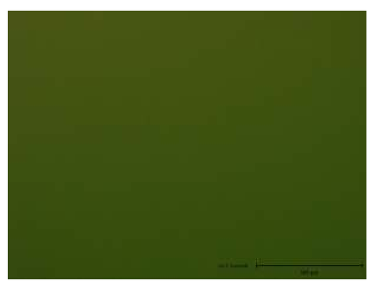

Experimental setup

- The optical quality was inspected by an optical microscope.
- The integral scintillation efficiency was measured by a high-sensitive digital CCD camera using an X-ray beam (Cu-anticathode, 40kV/2mA).
- The 2D resolution was inspected using the same X-ray beam and an imaging technique. A very small object with defined dimensions was placed between the X-ray source and imaging screen (LPE film or bulk plate) and the absorption image was taken by the CCD camera. The X-ray source had an anode spot of several micrometers to avoid the smear effect.

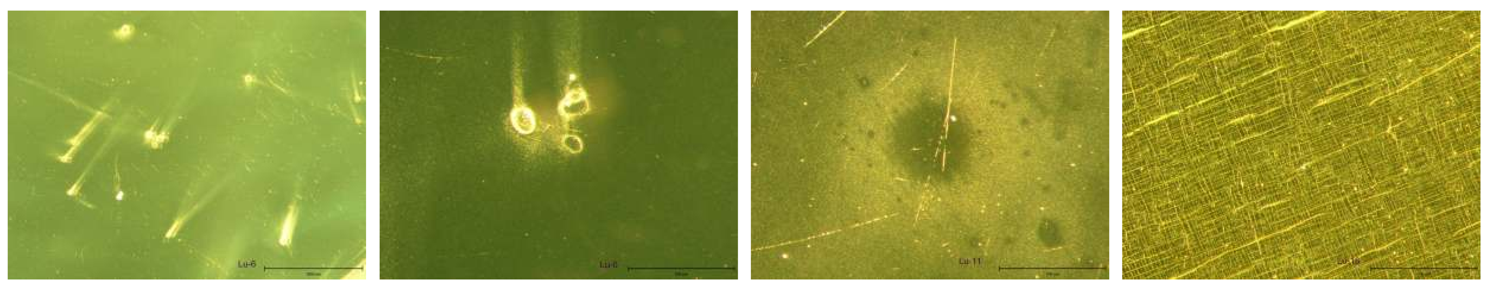
## Results and Discussion

### Optical Quality Inspection

Bulk plate



LPE films

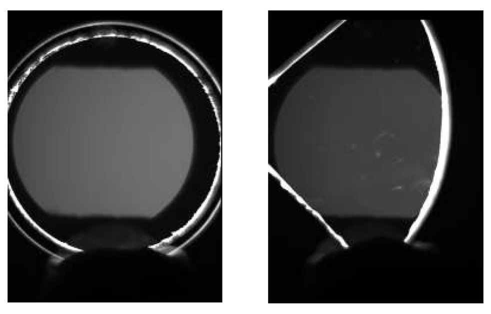


The imaging plate made from bulk single crystal was optically clean.
The LPE film samples had optical defects. The shining spots in some parts of the film are structural irregularities (incrustations, bubbles of melt/solution, etc.), which cause light scattering.

### 2D Resolution Capability

A golden grid with wires eight micrometers thick (see the SEM image below) was imaged using an X-ray source with a Cu anticathode. The grid was place close to the imaging screen. The absorption image was detected by a Crytur X-ray Hi-res CCD camera. The exposure time was five seconds.

### Integral Scintillation Efficiency



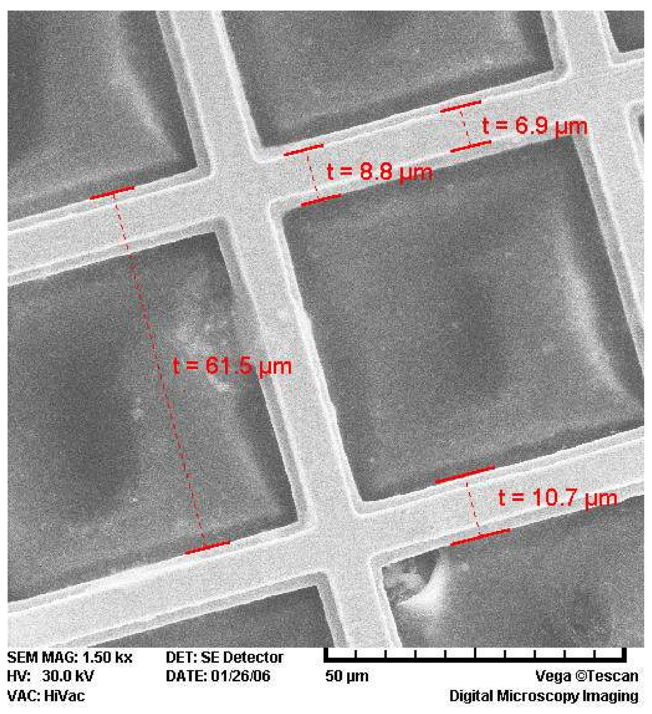
Images of samples exposed to X-ray bulk plate (left), LPE sample (right)

Experimental setup

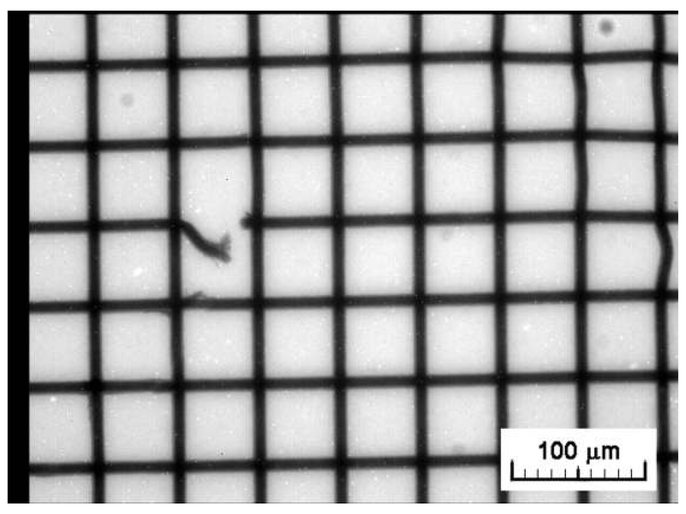
The samples were exposed to X-rays from a Bede micro-source (40kV/2mA). The images were taken by the Crytur High-res X-ray CCD camera. The exposure time was 500 ms and the image was averaged 25 times.

The intensity in a particular part of the scintillation light-emitting area of every sample was averaged. Relative values of the intensity are in the table. The LPE films reach up to 76% of the best bulk sample.

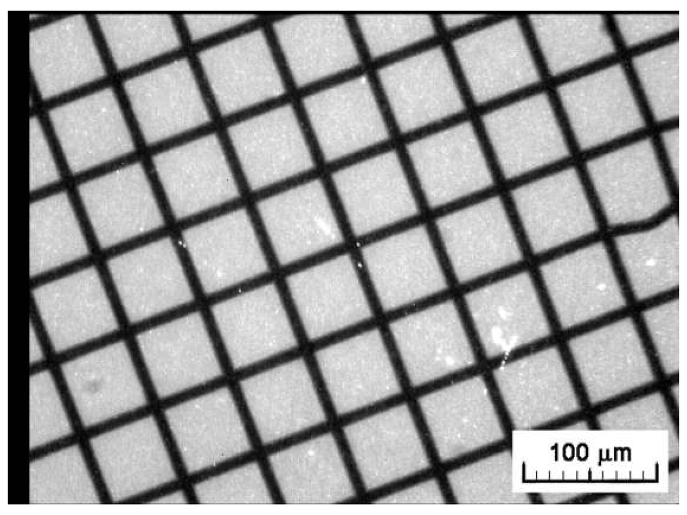
| Sample type | Relative Intensity |
|---|---|
| Bulk 1 | 100% |
| Bulk 2 | 93% |
| Bulk 3 | 90% |
| LPE 1 | 76% |
| LPE 2 | 62% |
| LPE 3 | 70% |
| LPE 4 | 52% |
| LPE 5 | 50% |
| LPE 6 | 42% |
| LPE 7 | 42% |



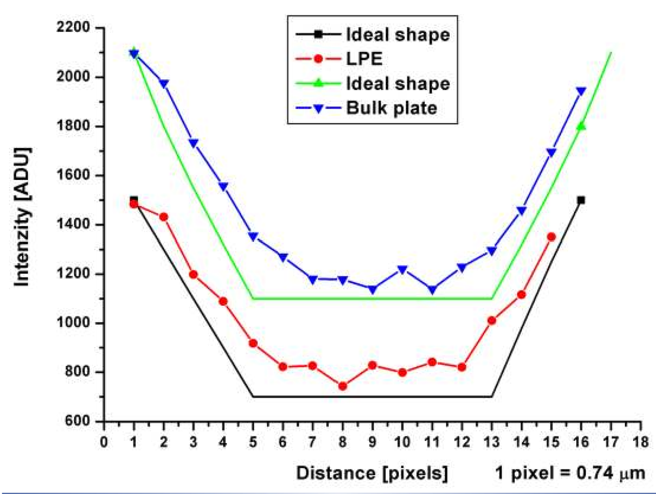

SEM image of the grid



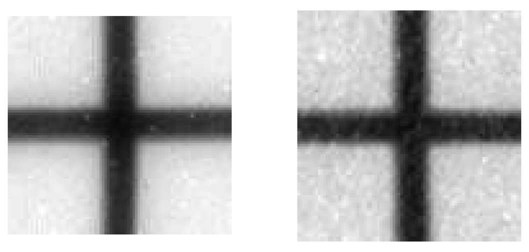

The image of the grid taken by using the bulk LuAG screen




The image of the grid taken by using the LPE screen




The line profiles of a grid wire (LPE and bulk screens)



Details of the grids (left-bulk, right LPE)

Both types of screens provide similar resolution. The image taken by the bulk screen has better contrast due to the higher intensity of the light emitted (better s/n ratio). The line profile of a grid wire shows the resolution of the imaging system used.

## Conclusions

**Optical Quality**
The LuAG:Ce LPE films were compared to LuAG:Ce bulk plates. The optical quality of LPE films needs improvement for applications in high resolution imaging.

**Integral Scintillation Efficiency**
The intensity of the LPE films (detected by the CCD camera) is up to 76% of the intensity of the bulk plate.

**High Resolution in Imaging**
The resolution of the LPE films is comparable to the resolution achieved by bulk plates. The resolution achieved by the 20 micrometers thick LuAG:Ce imaging plate is about 1 micrometer.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