Scintillation Material Encapsulation Fixture

Daniel Bucknell

LCLS Intern, Oregon State University

Linac Coherent Light Source, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94025, USA.

Contact: Matt Hayes

Introduction

It's important to understand the characteristics of the **X-ray Free-electron Beam (FELs)** when setting up for an experiment. One device for this is a **YAG (Yttrium Aluminum Garnet)** crystal. The YAG is inserted into the beam, becoming fluorescent from the X-Ray beam.

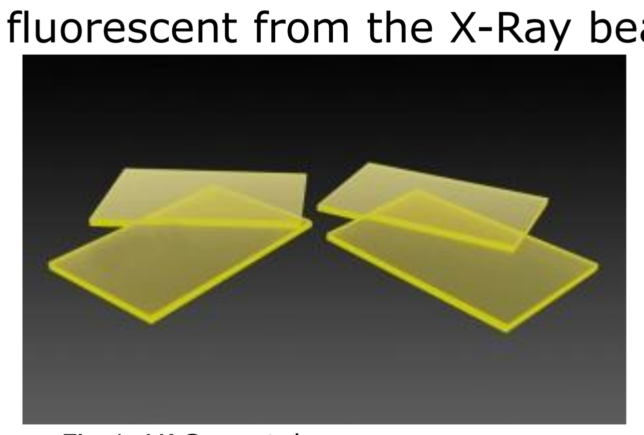


Fig 1. YAG crystals

Research

Background

The technique used to detect beam arrival time is known as **"pump-probe"**. An **optical laser** "pumps" the YAG to an excited state, then an FEL "probes" the YAG. Sample optical material then can be seen as it's luminescent intensity changes through a **Charge-Coupled Device (CCD)** camera. Comparing the two arrival times is necessary information to prevent reduced optical laser transmission through the YAG.

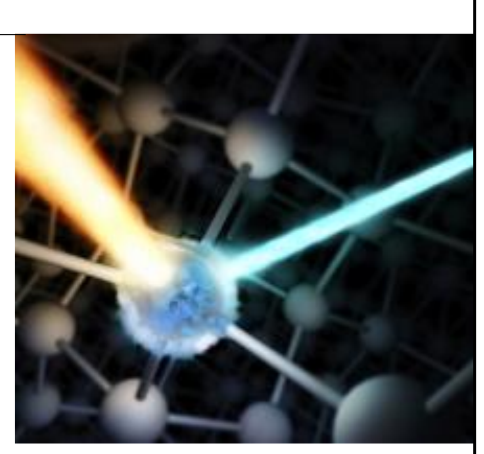


Fig 2. shows a sample being hit by both an optical laser (red) and x-ray pulse (blue).

The YAG crystal is very fragile. A common use is to attach it to an injector rod and insert it into the sample chamber. Many YAG crystals have been broken during this process.

Requirements for Encapsulation Fixture

The encapsulation device have to fit and protect, but any portion exposed to X-Ray must not interact with the X-Ray beam itself. The fixture must also allow for ease of installation for a YAG crystal all the while maintaining the YAG at the focus point of the beam.

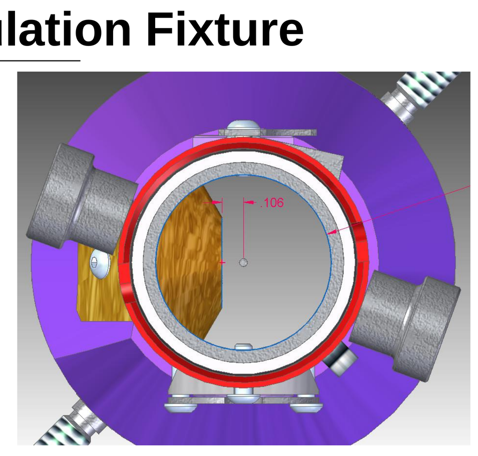
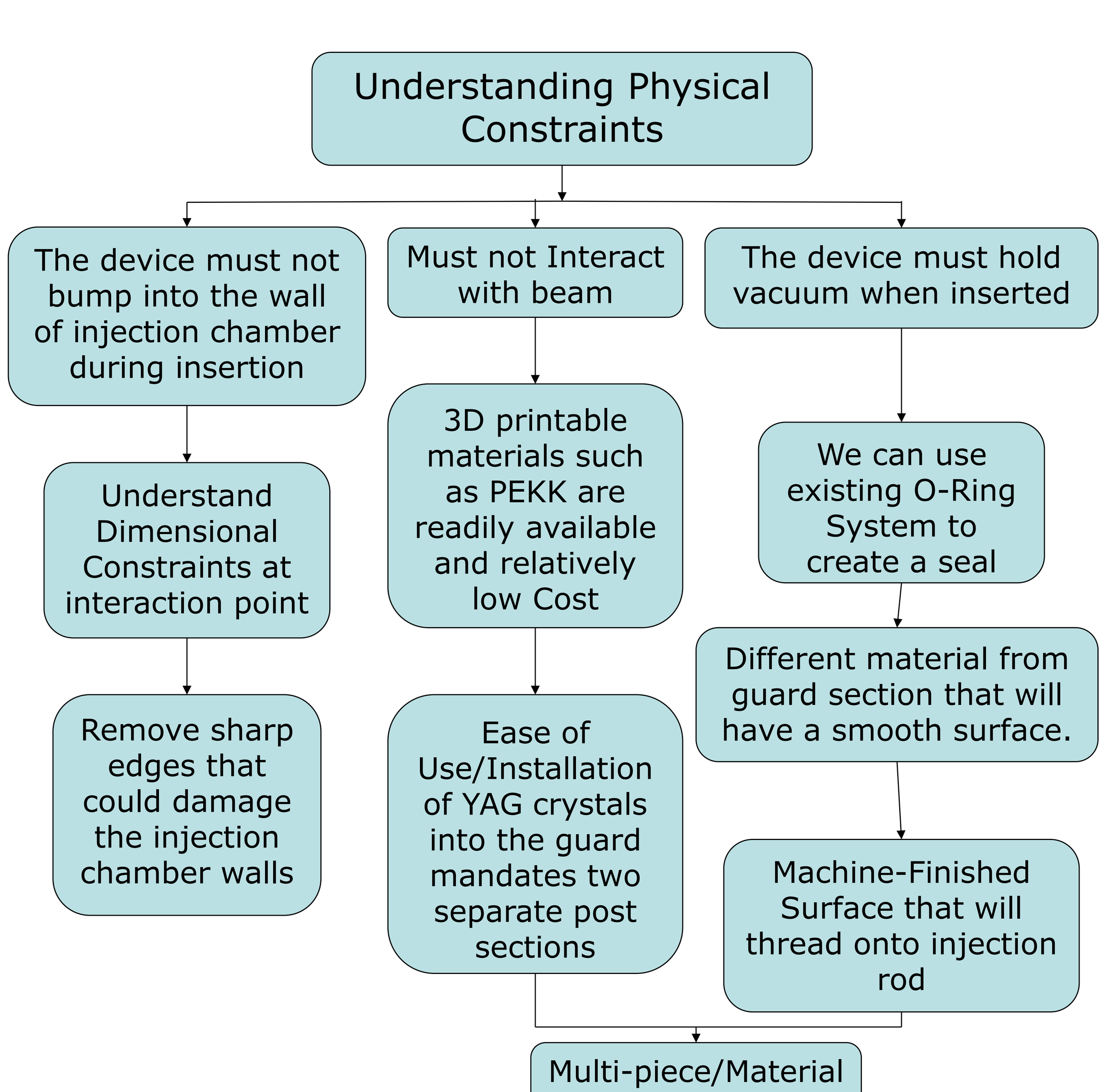


Fig 3. shows a CAD model of a vertical view of the chamber.

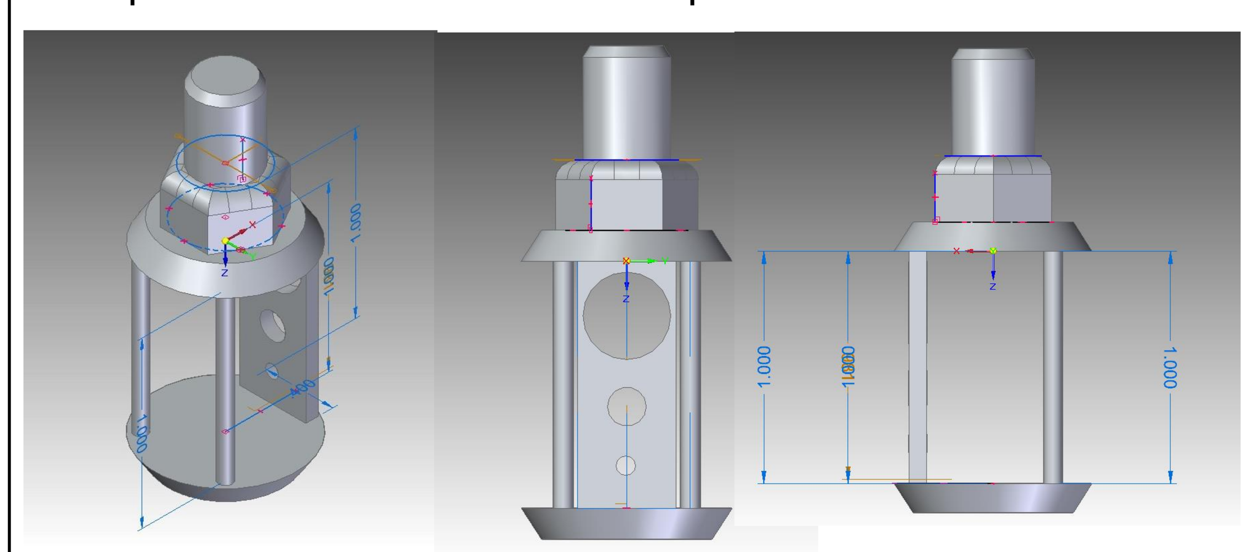
Design Procedure



Production

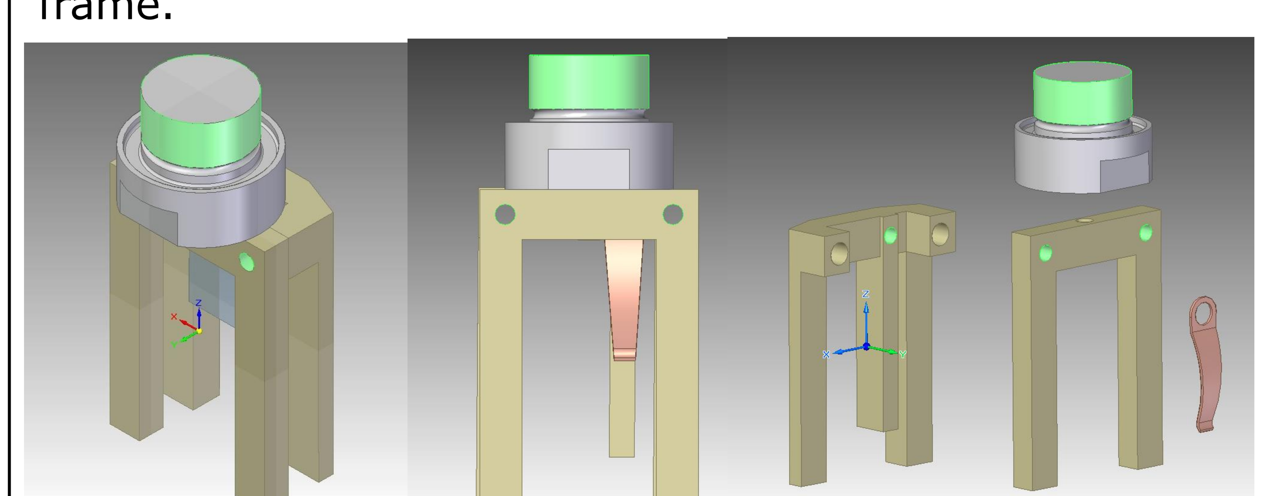
Designing

The first iteration focused on making the fixture fit within the diameter of the chamber without causing risk of scarring/damaging the walls. It was to feature chamfered edges. Issues existed with this design including vacuum sealing, visibility of the YAG, fragility of the guard posts, lacked features to hold other materials, high risk of colliding with other components at the interaction point.



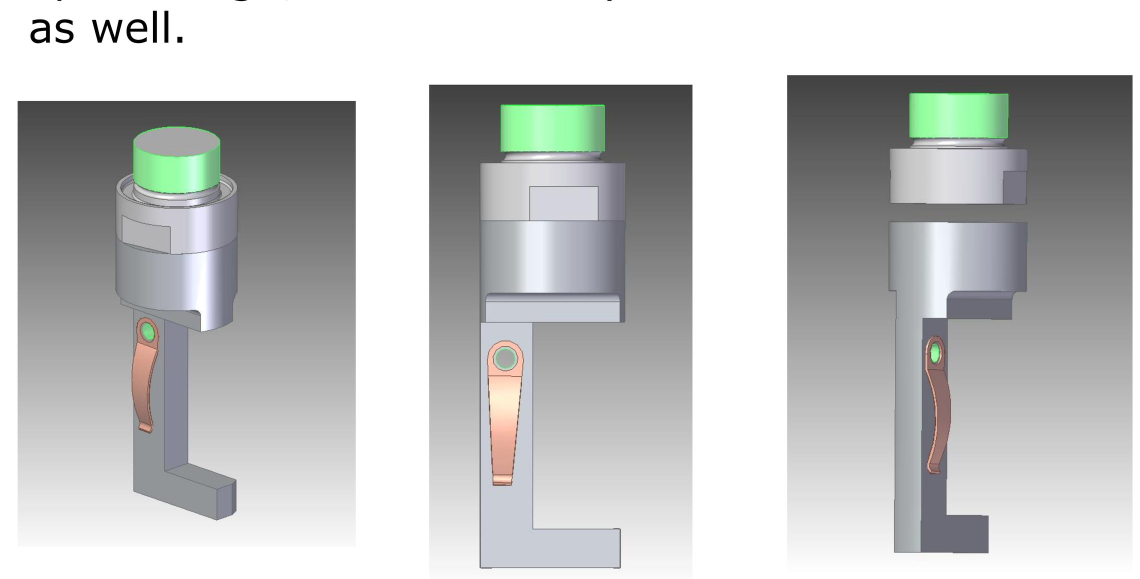
Figs 4 through 6. Shows an early design

The second iteration was intended to maximize ease of use, protection, and visibility at the interaction point. This called for a 3-part design where the user would have to remove the unit from the sealing mechanism to install the YAG. The part features cropped corners and a post with a copper clip that centers the YAG at the interaction point. This design would have reduced maneuverability due to its wide frame.



Figs 7 through 9. show the second alternative

The third and final iteration maximized maneuverability and visibility at the cost of frontal protection. With an L-shaped bracket to protect the YAG, and a threaded head to seal against vacuum, this would be the most affordable and easiest to manufacture alternative. The simple design would be easy to manipulate and the lower guard would not only protect the YAG during insertion into the chamber but house other sample materials. With an open design, a wider variety of YAGs could be used as well.



Figs 10 through 12. show the third alternative

Decision and Prototyping

The third iteration was used to 3D print a prototype. The fixture was first produced in PLA using a Makerbot 2+. Design corrections were implemented to make it easier for the final component to be produced.

Fig 13. Shows the prototype in PLA.

Experimental Results

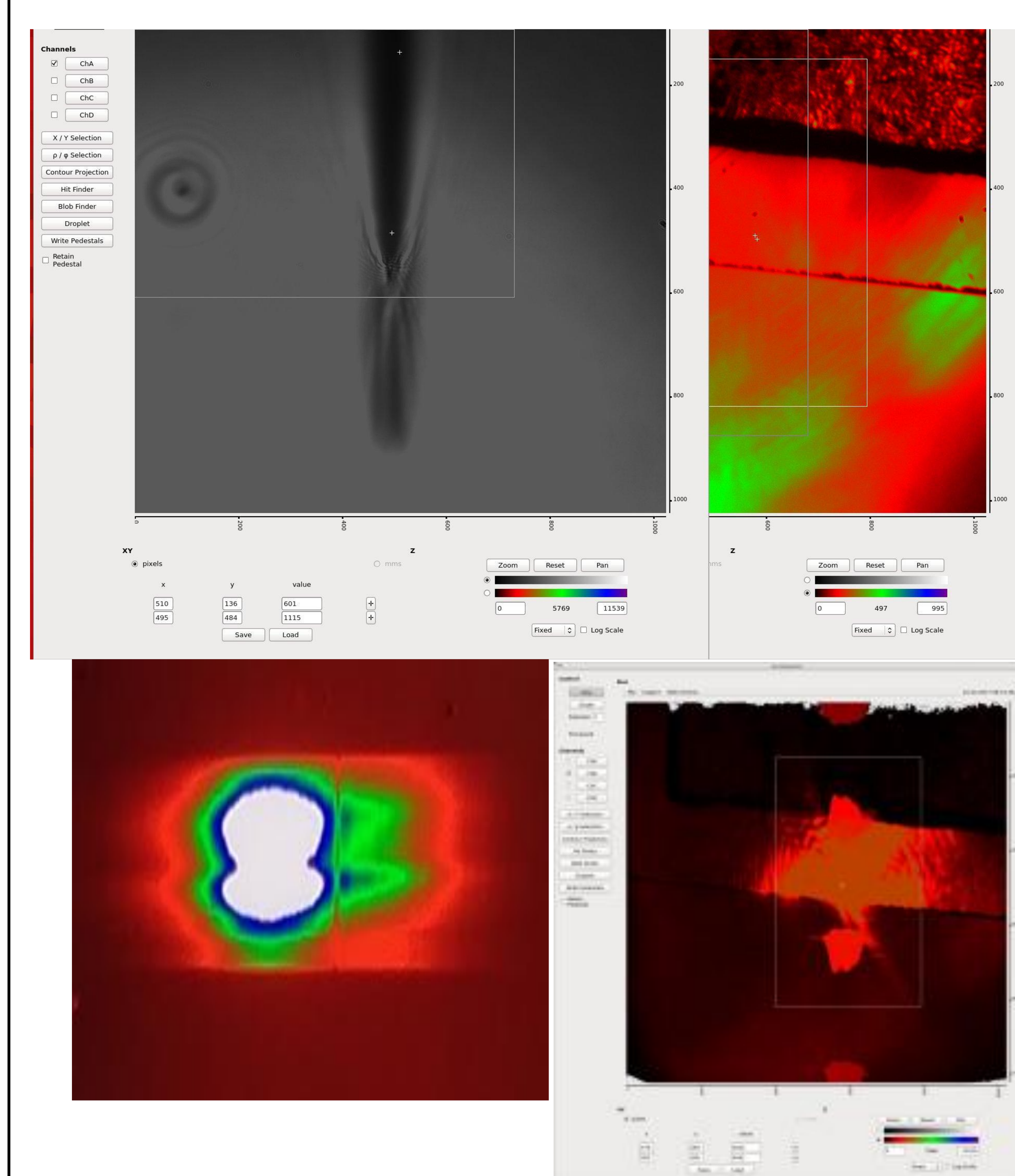


Fig 14. The top image shows a side view of a YAG being struck by X-Ray and Laser. The Bottom Left image shows a direct view of YAG being struck by just X-Ray, and the Bottom Right image shows a direct view of a YAG being struck by Laser. The color scale indicates Luminescent change.

The final selected design was 3D printed in PEKK and 316L Stainless. It's an all-in-one device that can house materials during an experiment. The device is simple, easy, and affordable to fabricate, modify and remanufacture for other select tasks.

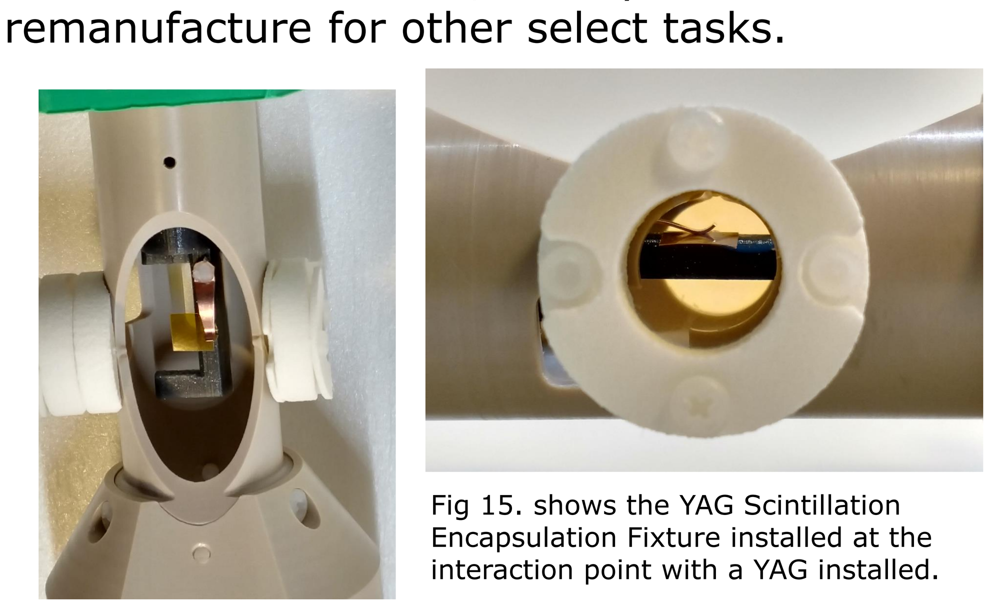


Fig 15. shows the YAG Scintillation Encapsulation Fixture installed at the interaction point with a YAG installed.

Conclusions

YAG crystals are a key component in locating optical laser vs X-Ray beam arrival time. Having the ability to manipulate them but to protect them is a valuable resource. This design will need further experimental testing to reach a definite conclusion. But it is a dramatic improvement to the current apparatus.

Acknowledgments

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