High Resolution Radiography for Inertial Confinement Fusion Fuel Capsule Target Metrology from Laser-plasma Acceleration based X-ray Sources

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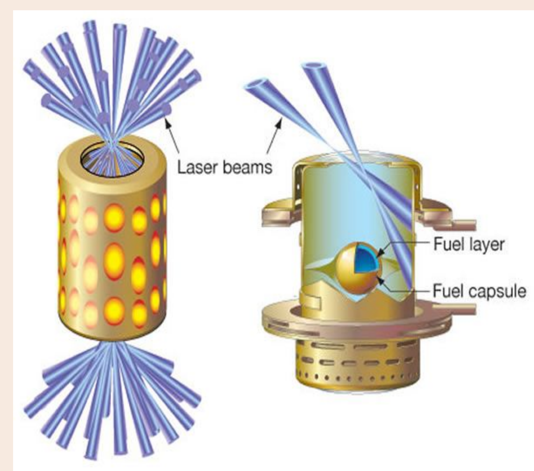
Abstract

The goal of this work is to use Laser Wakefield Acceleration (LWFA) based X-ray sources to develop a diagnostic capable of improved target metrology for Inertial Confinement Fusion (ICF) fuel capsules. We aim to develop a sub-ps, sub-10 micron X-ray source, which can image ICF fuel capsules, but also for dynamic radiography of High Energy Density Science (HEDS) phenomena. A Fresnel-diffraction based code is used for straight edge radiographs, and a modified X-ray ray tracing code for curved objects. Here, we present on the results of a Texas Petawatt experiment, where 2-3 GeV generated X-rays were used to capture radiographs of a 400 micron radius Tungsten sphere, and compare spatial data from self-injection and nanoparticle injection mechanisms. We will discuss preliminary results using X-ray Phase Contrast Imaging radiography to image ICF fuel capsules at the Advanced Laser Light Source, part of a demonstration of current LWFA application capabilities.

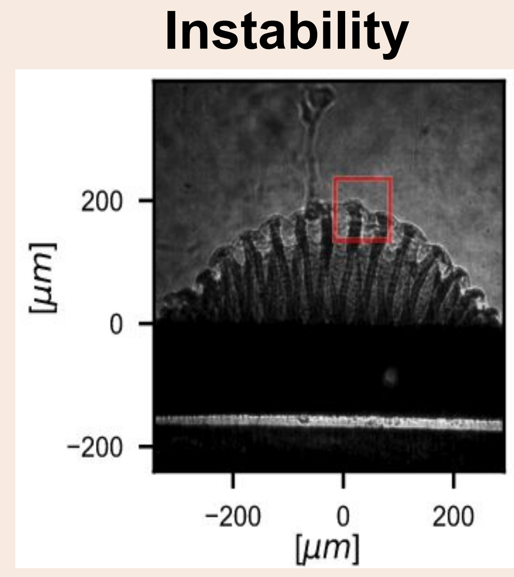
Motivation

Imaging ICF Fuel Capsules



Courtesy of LLNL

Rayleigh Taylor Instability

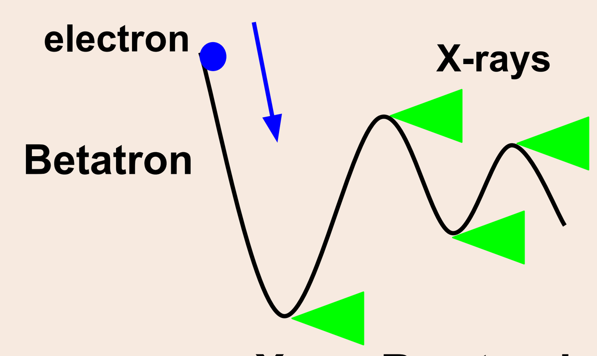


(Rigon Nat. Comm. 2021)

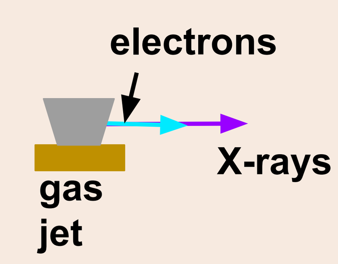
Laser Wakefield Acceleration (LWFA) generated X-rays can create a diagnostic capable of high spatio-temporal resolution.

Methods

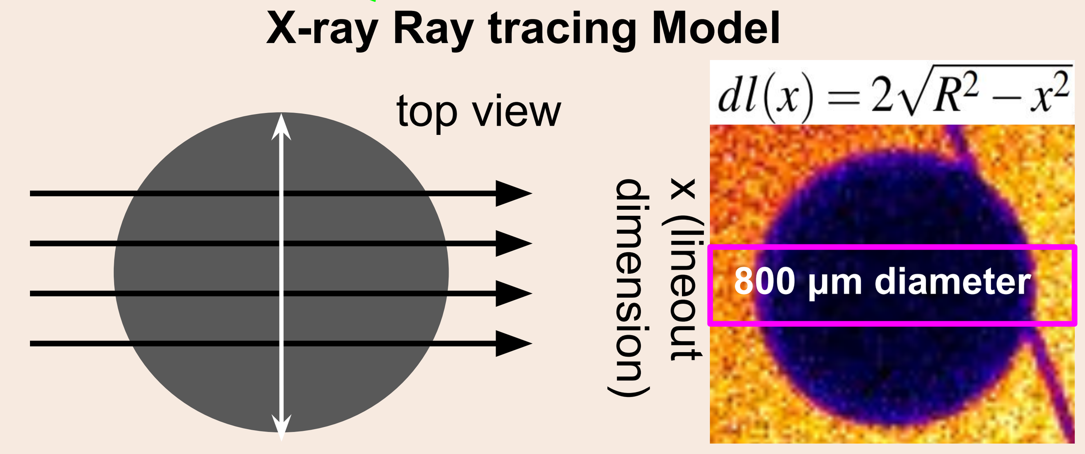
Betatron X-ray Process



Experimental Set-up



X-ray Ray tracing Model



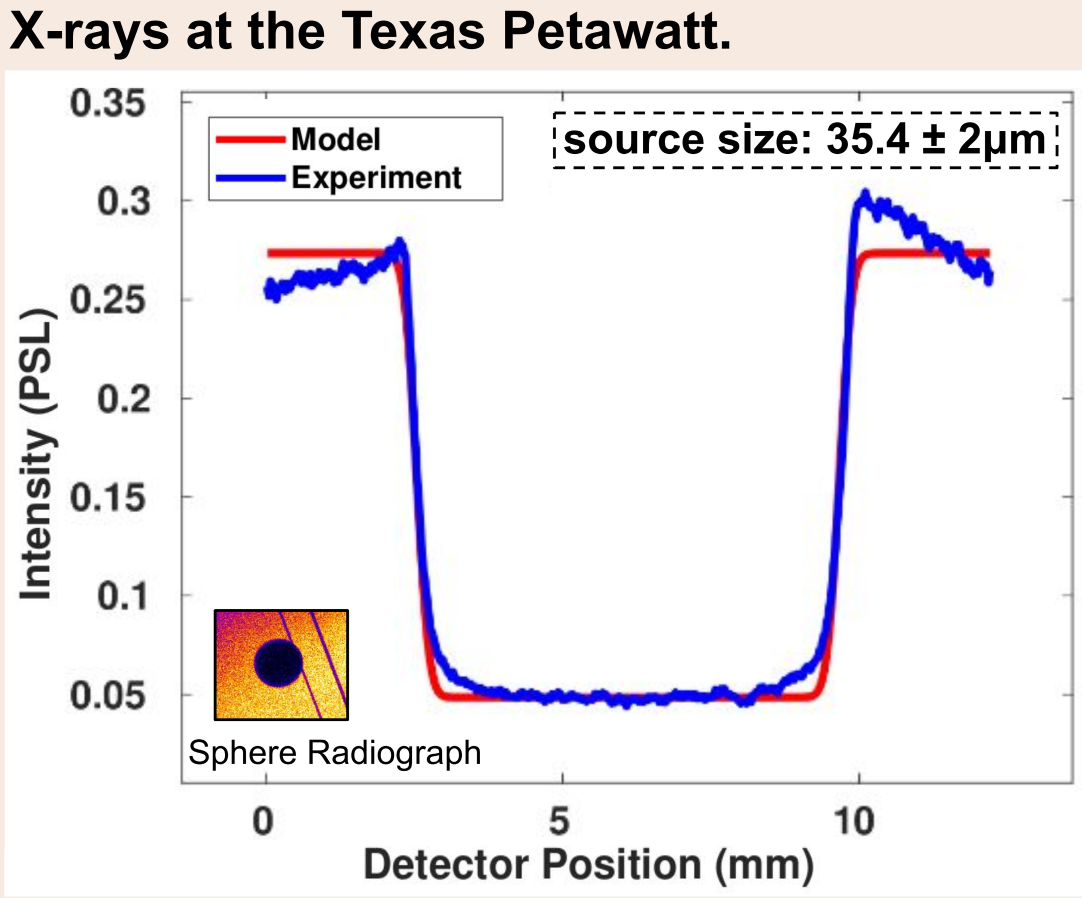
$$dl(x) = 2\sqrt{R^2 - x^2}$$

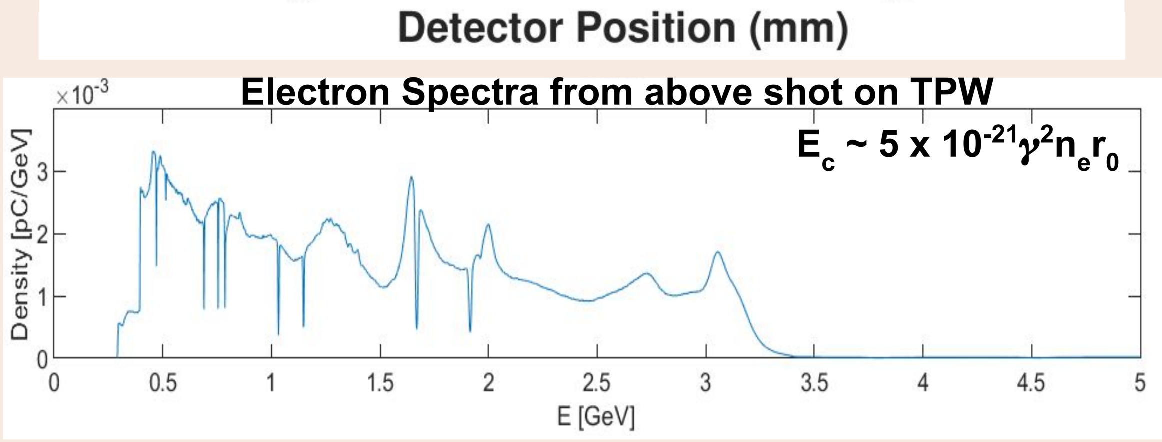
$$\Delta(x) = I(0)\int \Lambda(E)e^{-\mu(E)\rho dl(x)}p(E)F(E)dE$$

Using a modified X-ray ray tracing code we detect the source size from a curved object radiograph.

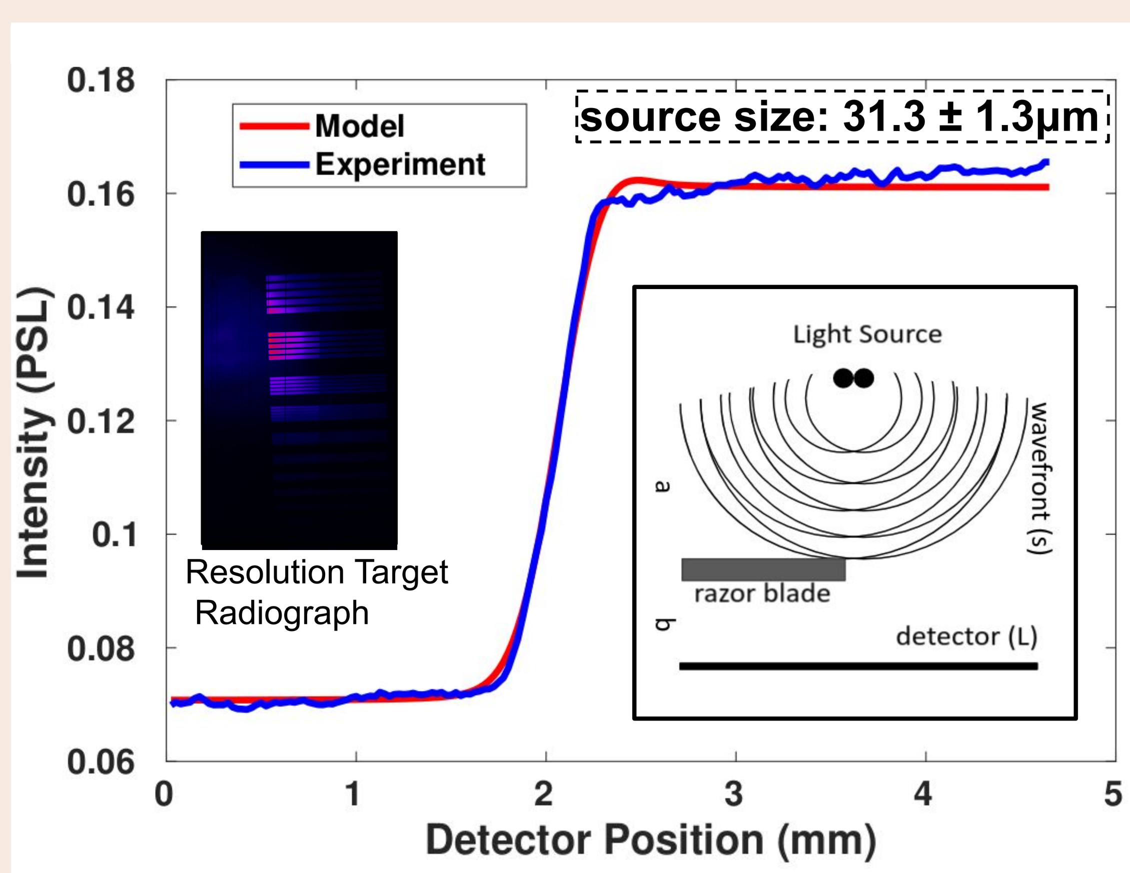
Results

We used our modified X-ray ray tracing code to determine the source size of Betatron X-rays at the Texas Petawatt.



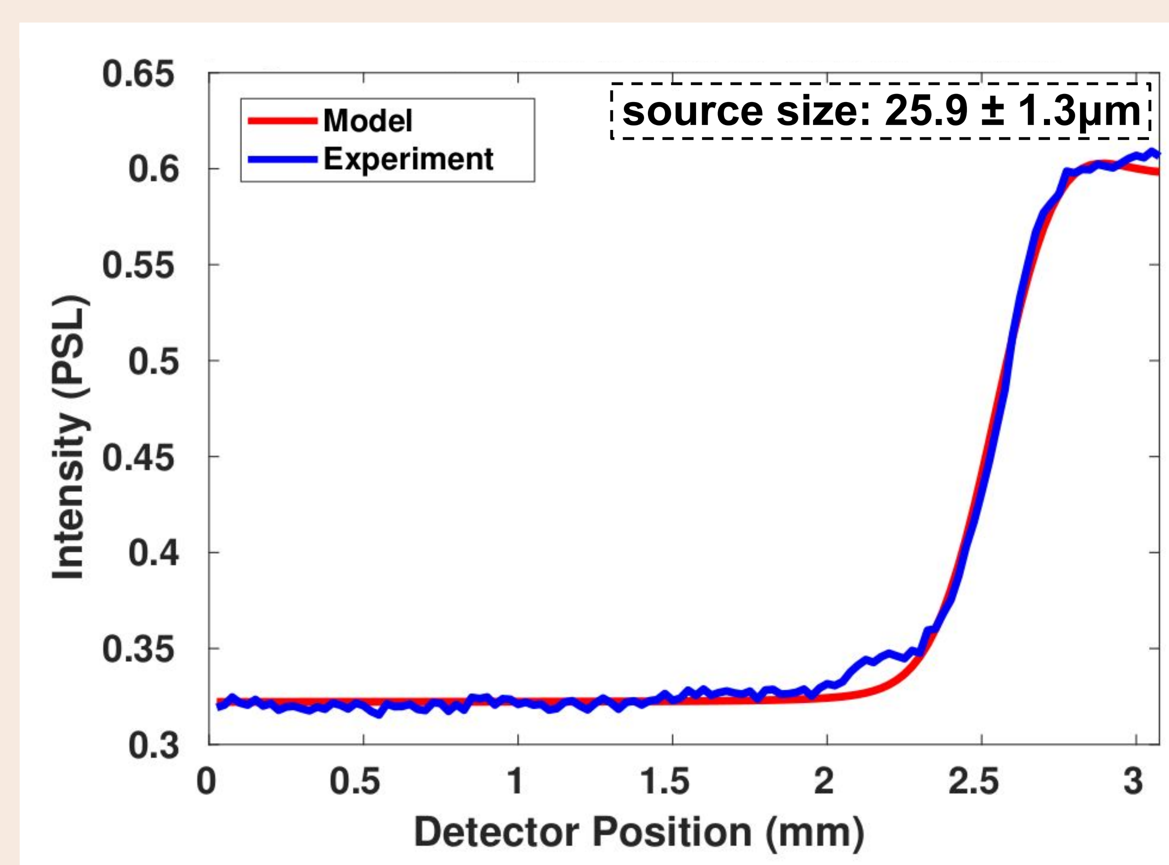


Fresnel diffraction pattern of Betatron X-rays from Blowout regime LWFA with Self Injection



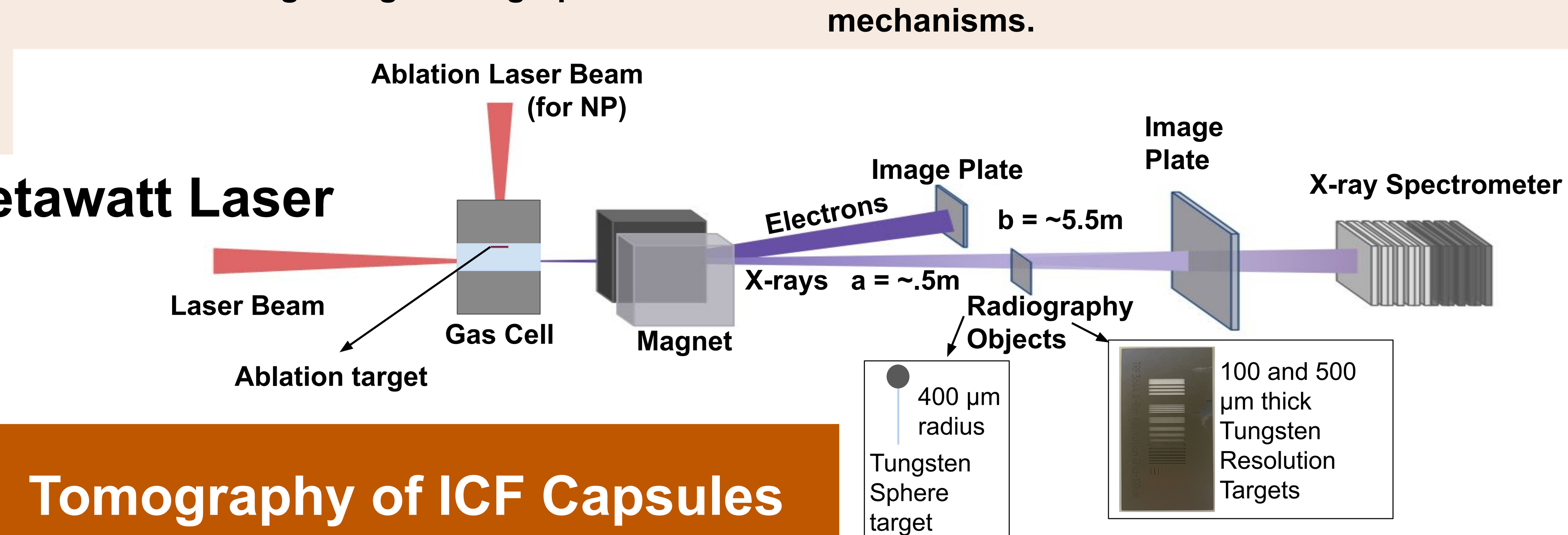
Fresnel Diffraction based source size analysis is performed on straight edge radiographs.

Fresnel diffraction pattern of Betatron X-rays from LWFA with Nanoparticle (NP) enhanced injection



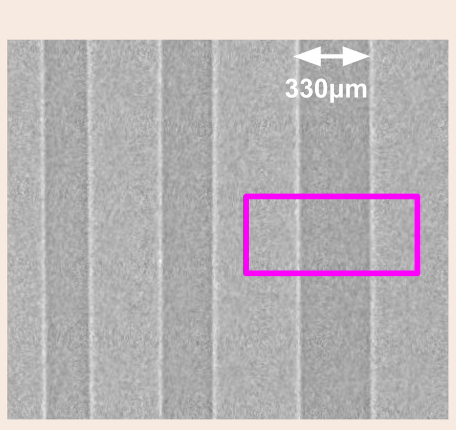
A comparison between X-ray characteristics of self-injection and Nanoparticle injection mechanisms.

Experimental Setup at the Texas Petawatt Laser



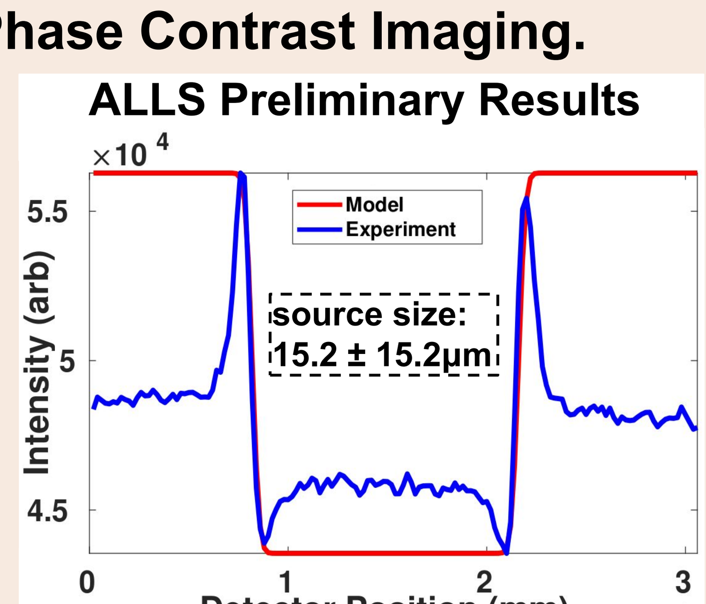
Future Work

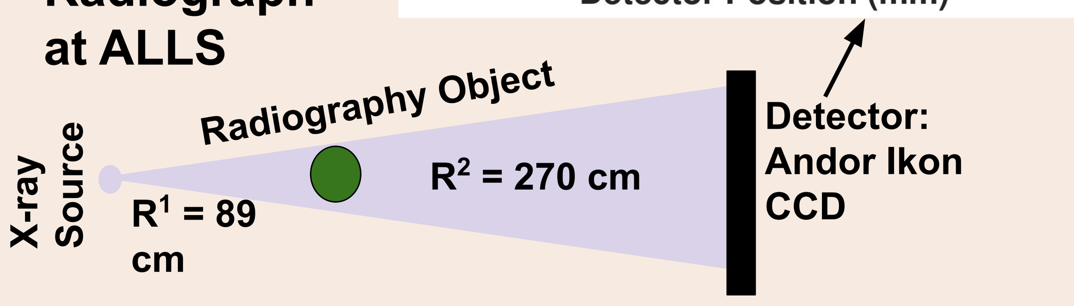
We will adapt analytical methods to include X-ray Phase Contrast Imaging.



Fiber XPCI Radiograph at ALLS

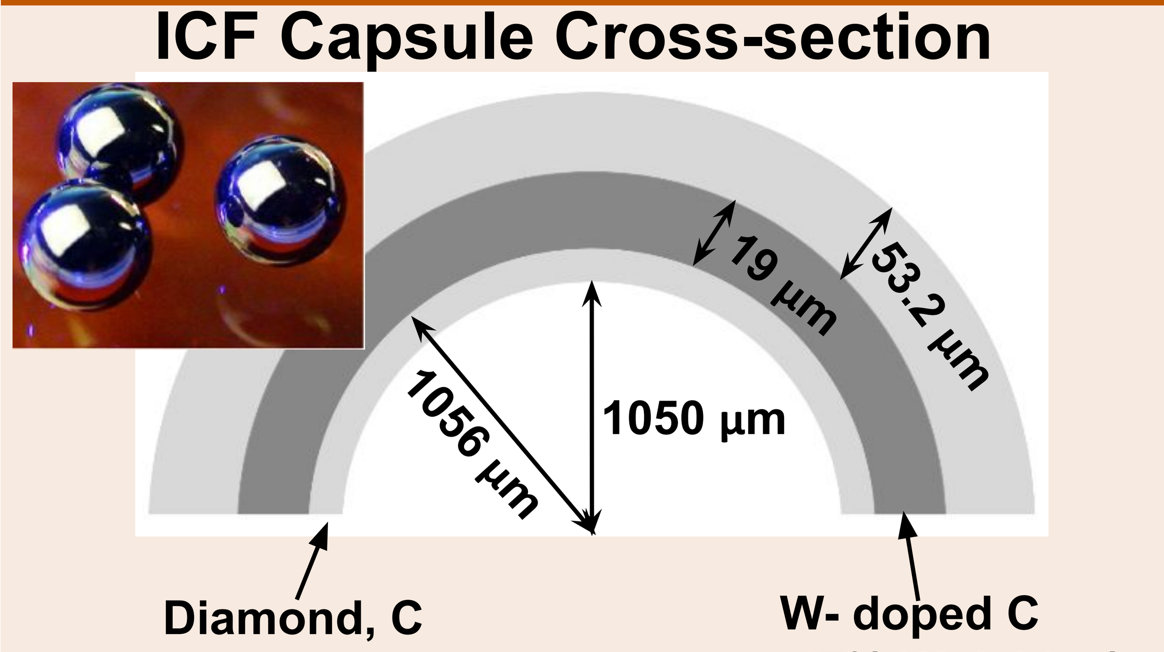
ALLS Preliminary Results





Tomography of ICF Capsules

ICF Capsule Cross-section



We will use XPCI for tomography of ICF capsules, and compare with conventional techniques.

Acknowledgements

IM #: **LLNL-POST-854127**

References: [1] M Vargas et al, PPCF 61 (2019) 054009. [2] Biener, Nuclear Fusion, 49 (2009).

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I.Pagano, Source Size Analysis of Self Modulated Laser Wakefield Acceleration generated X-rays, POP, *In Preparation.*