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Title: Performance evaluation of DAAF as a booster materialusing the Onionskin Test.

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Los Alamos
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DAAF

PERFORMANCE EVALUATION OF ~~DIAMINOAZOXYFURAZAN~~ AS A BOOSTER MATERIAL USING THE ONIONSKIN TEST

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ABSTRACT

Initiation of insensitive high explosive (IHE) formulations requires the use of a booster explosive in the initiation train. Booster material selection is crucial, as the initiation must reliably function across some spectrum of physical parameters. The interest in Diaminoazoxyfurazan (DAAF) for this application stems from the fact that it possesses many traits of an IHE but is shock sensitive enough to serve as an explosive booster. A hemispherical wave breakout test, termed the onionskin test, is one of the methods used to evaluate the performance of a booster material. The wave breakout time-position history at the surface of a hemispherical IHE charge is recorded and the relative uniformity of the breakout can be quantitatively compared between booster materials. A series of onionskin tests were performed to investigate breakout and propagation diaminoazoxyfurazan (DAAF) at low temperatures to evaluate ignition and detonation spreading in comparison to other explosives commonly used in booster applications. Some wave perturbation was observed with the DAAF booster in the onionskin tests presented. The results of these tests will be presented and discussed.

Performance Evaluation of DAAF as a Booster Material using the Onionskin Test

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LA-UR 10-07563

Onionskin Testing

- Chamber 8 Firing Vessel and Capabilities
- Experiment Overview
- Experiment Setup
- Explosive Train
- Intermission (Disney World Photos)
- Center of Initiation
- Results
- Conclusions
- Future Work

TA-40 Chamber 8 Enclosed Firing Vessel

Summary at a Glance

- **LANL's only walk-in firing vessel**
  - Climate controlled vessel and building for sensitive shots.
  - Sealed chamber allows for product composition studies.
  - Easily darkened facility for alignment or light sensitivity issues.
  - Modern firing system and instrumentation.
  - No fire danger or environmental contamination.
  - Spotted Owl Friendly!!!
- **Limitations on vessel use**
  - 10 kg TNT equivalent HE load limit.
  - No Beryllium or Radioactive Materials.
- **Capabilities**
  - Streak Cameras, Cordin 132, and 136
  - High speed digital framing camera, 64 frames @ 800kfp
  - High speed film framing camera, 16 frames @ 2.5Mfps
  - VISAR, Streak Spectroscopy, RAMAN
  - Temperature controlled shots to simulate various environments.
  - Multiple simple shots per day to complex shots taking up to a week.
  - Firing site staff available to field experiments or assist.

Onionskin Testing

What Is The Onionskin Test

- Onionskin test is a hemispherical wave breakout test used to evaluate the corner turning performance of explosive booster materials
- Onionskin tests allow "quick" comparison of booster materials based on performance metrics such as first breakout angle, spreading efficiency, and excess transit time
  - "Quick" only applies to the comparison of data, the onionskin test fairly complex to field
- Onionskin test data allows modeling of main charge initiation without all the complexities involved with modeling the actual initiation train

Onionskin Testing

Overview and Test Materials

- A series of Onionskin Tests were conducted to evaluate the corner turning performance of several booster materials of interest.
- Selected Booster Materials:
  - LX-07 (90% HMX / 10% Viton A)
    - Considered to be the standard in this series of booster tests
  - PBX 9504 (69.8% micronized TATB / 25% PETN)
    - Originally developed as a booster for PBX 9502, difficult to maintain batch to batch uniformity
    - Worst of both worlds having the sensitivity problems PETN, and cold performance issues of PBX 9502
  - DAAF (ACN Neat Pressed, 97%DAAF / 3% Kel F)

Onionskin Testing
Explosive Train

- Booster is initiated by the aluminum flyer plate of the ER 400 detonator
- Streak image captures the breakout of the detonation wave as it exits the Onionskin surface
- Phosphorescent paint ($Al_2(SiF_6)$) is applied to the onionskin surface to provide the additional light needed to capture the event

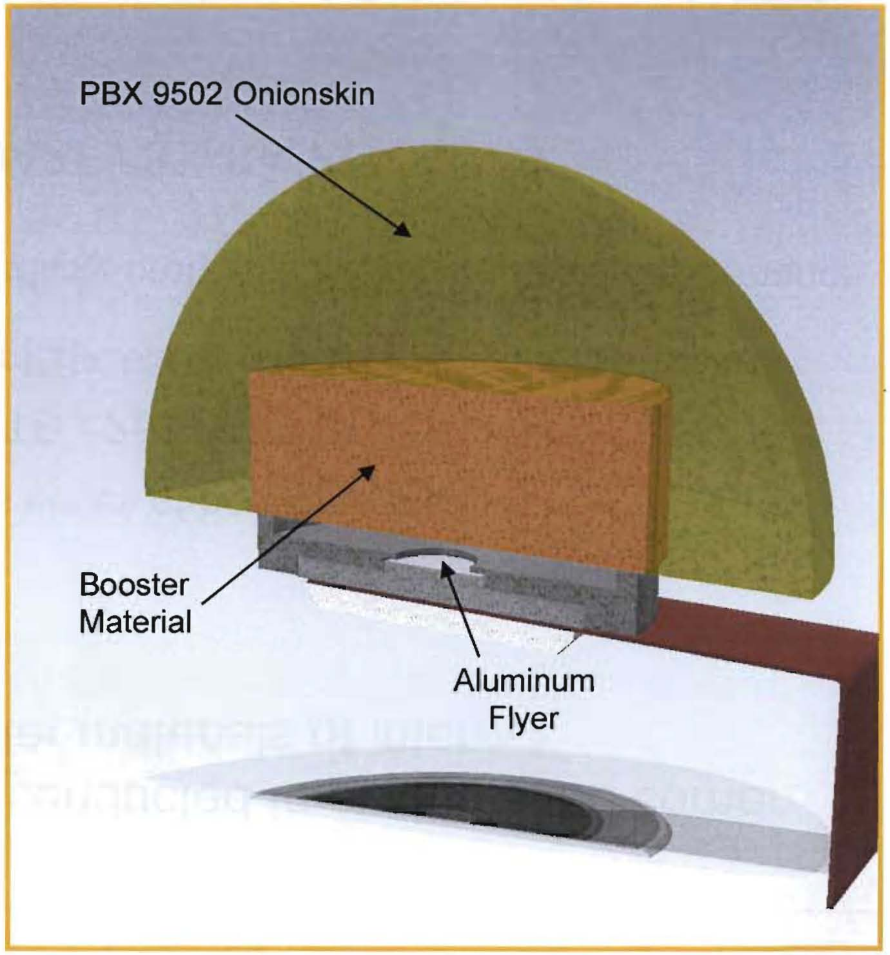
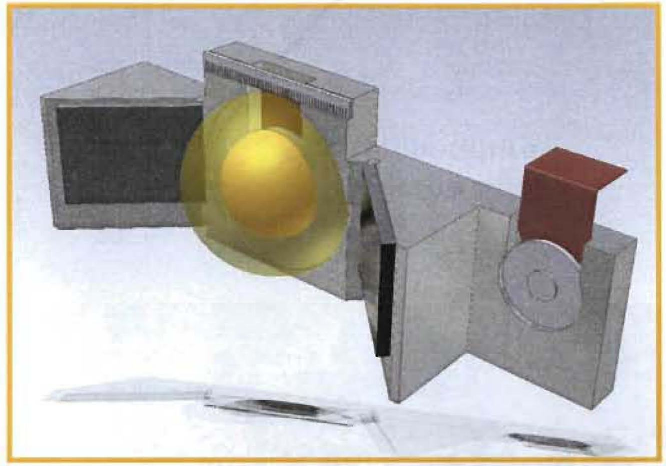
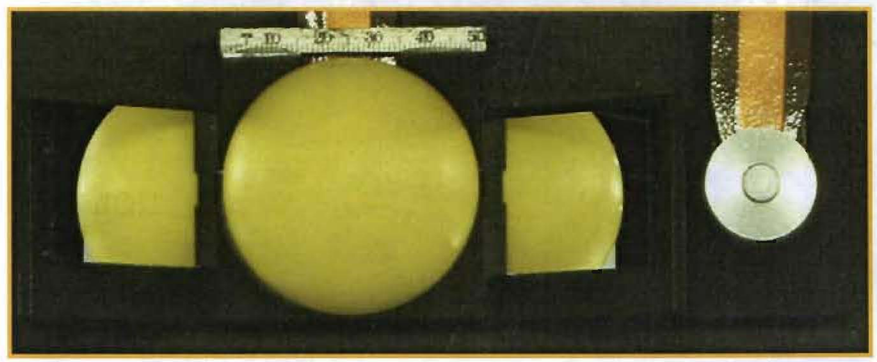


Figure depicts "Modified" test using cylindrical booster

Onionskin Testing
Shot Design

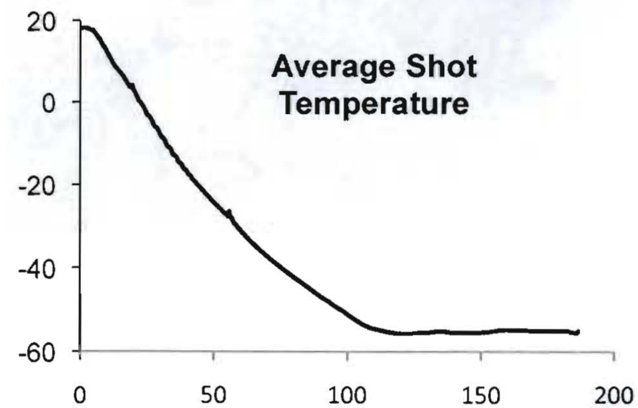
- Onionskin Fixture
  - Billet machined MIC-6 tooling plate to improve dimensional stability over test temperature range
  - Allows direct observation of detonation breakout and mirrors provide reflected views
  - Fiducial detonator located in view for breakout timing
  - Shots are fired at -55 to exaggerate booster and main charge performance issues





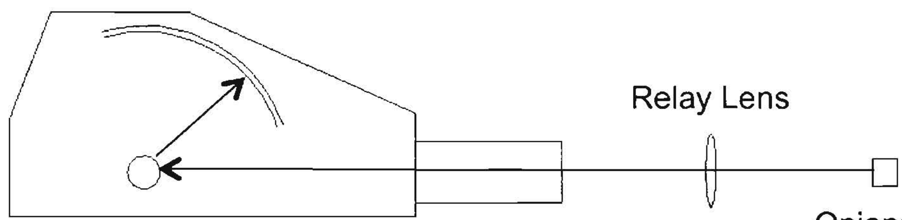
Onionskin Testing
Shot Setup

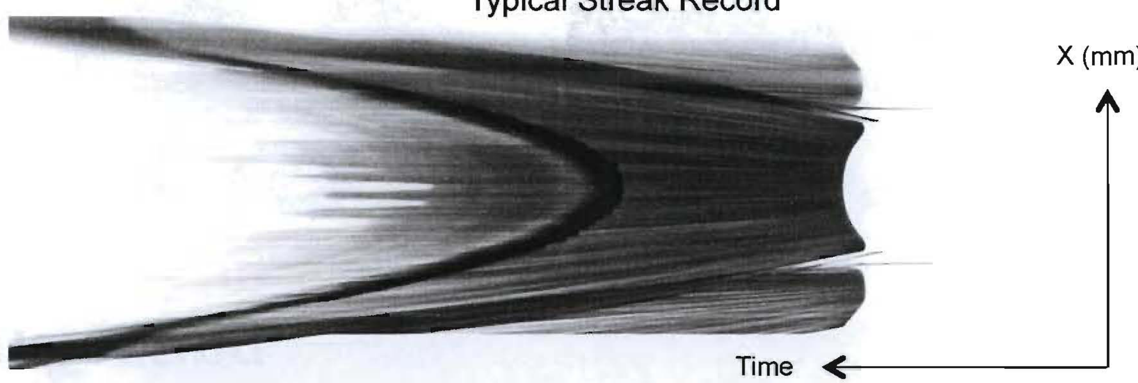
- Shot Cooling
  - Onionskin fixture inside styro-foam insulation
  - Shot cooled to -55 C using forced air, nitrogen cooled through Dewar and heated with resistive element
  - Cooling profile maintained using PID controller
  - Fixture instrumented with 5 type K thermocouples
  - Temperature data logged with LabView
  - Shot soaked at final temperature for a minimum of 30 minutes



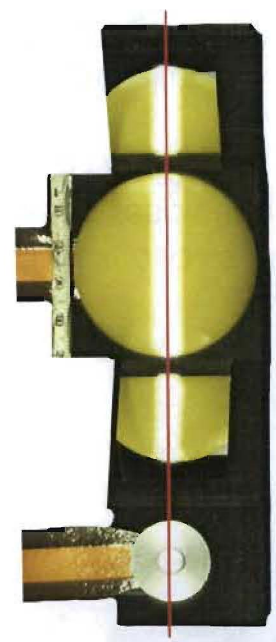
Onionskin Testing
Camera Setup

- Cordin 132 Rotating Mirror Streak Camera
  - Mirror Period set at 333.3 μs resulting in a film write speed of 12mm/μs (Mirror is rotating at approximately 3000rps, or 180,000rpm)
  - Onionskin image is magnified onto film using a relay lens, with the camera slit set to 50 μm

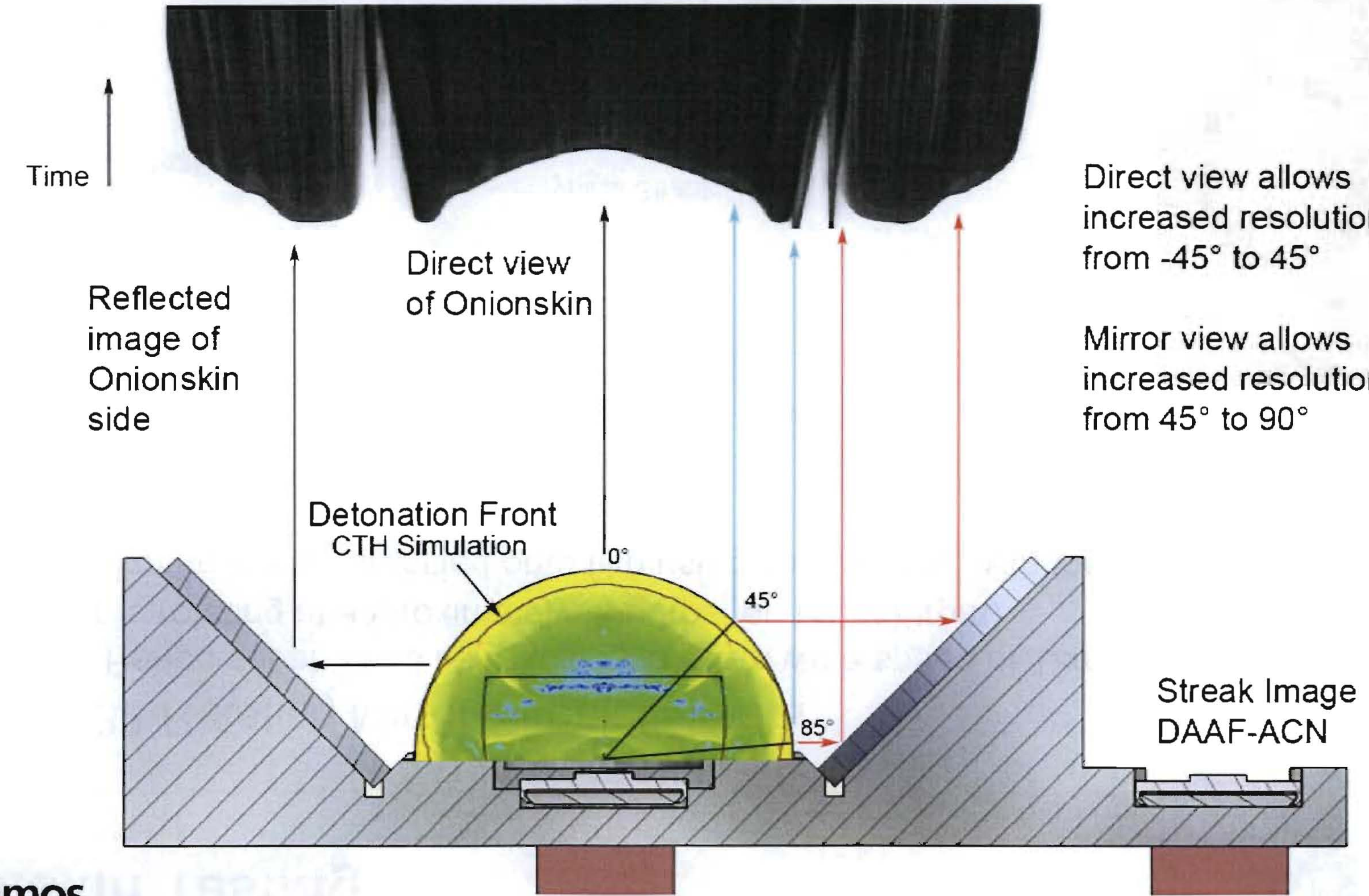




Slit Alignment On Shot



Onionskin Testing
Interpreting Streak Image



Direct view allows increased resolution from -45° to 45°

Mirror view allows increased resolution from 45° to 90°

Onionskin Testing

Center of Initiation (COI) Determination

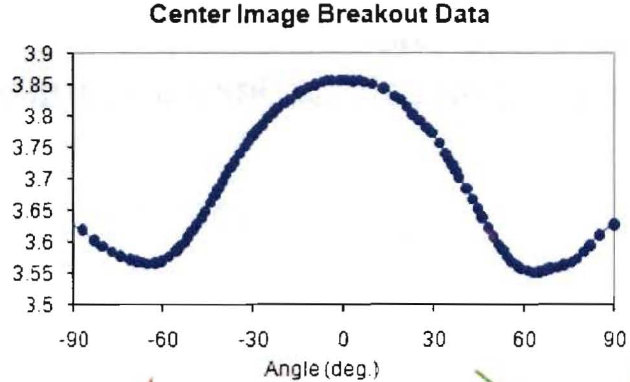
Basic Assumptions of Analysis

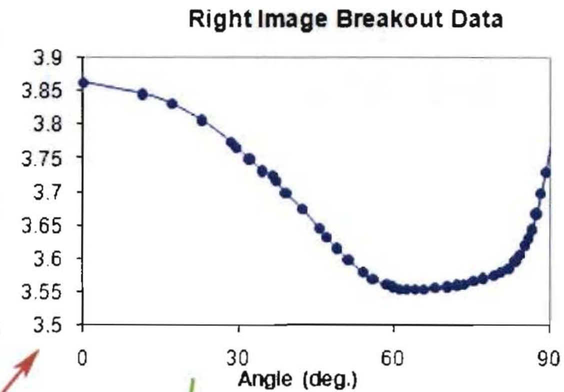
- Digitized from scanned film via AutoCAD analysis
- Primary spreading metric is First Breakout Angle (FBA)
- Efficiency is a dimensionless ranking equal to FBA/90°
- Wavefront Reconstruction is accomplished using a 2D Huygens Construction assuming a constant velocity 7.6mm/μs
- Circular curve fit to the average shock breakout taken from the average of first and last breakout times of the streak record
- COI is relative to ball center, angular window of evaluation is FBA
- Implemented in Mathematica
- Limitations:
  - Huygens reconstruction exaggerates perturbations (DSD would be better)
  - Fiducial detonator required if start time for idealized calculation desired

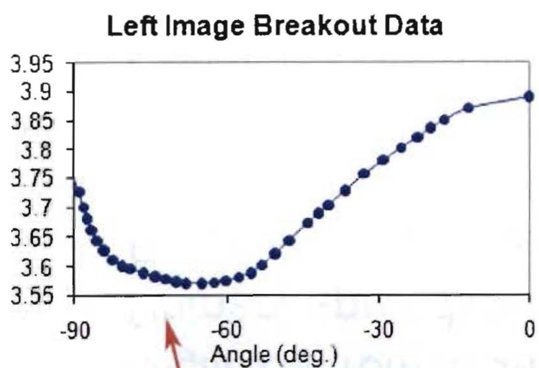
Onionskin Testing
Digitizing Streak Image

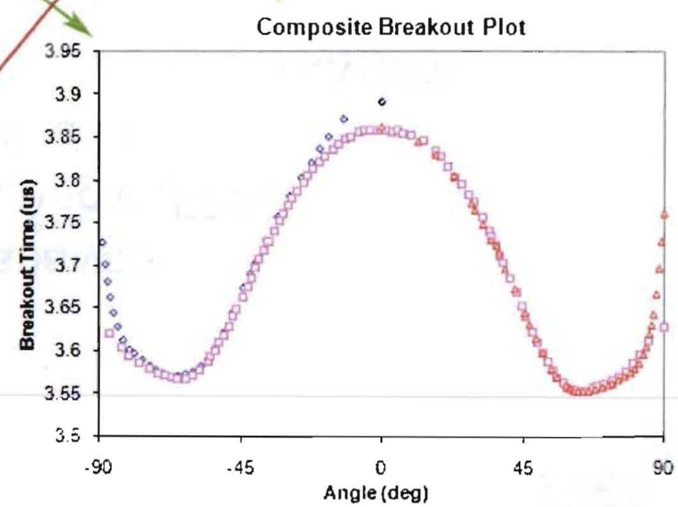
AutoCAD polyline used to digitize streak image

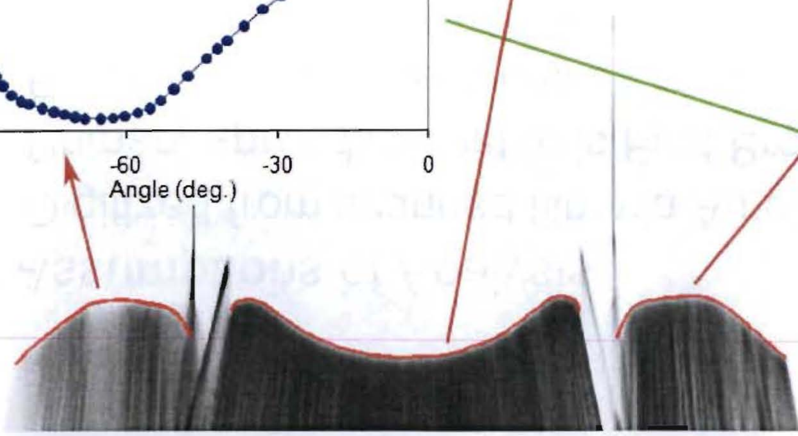
Polyline coordinates transformed in Excel and combined to create input file for COI analysis





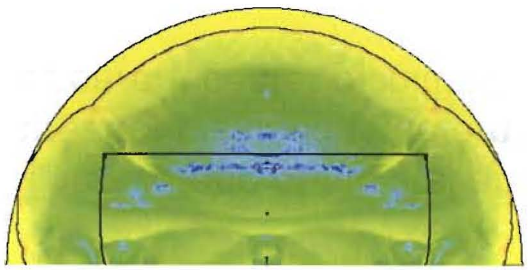






Onionskin Testing

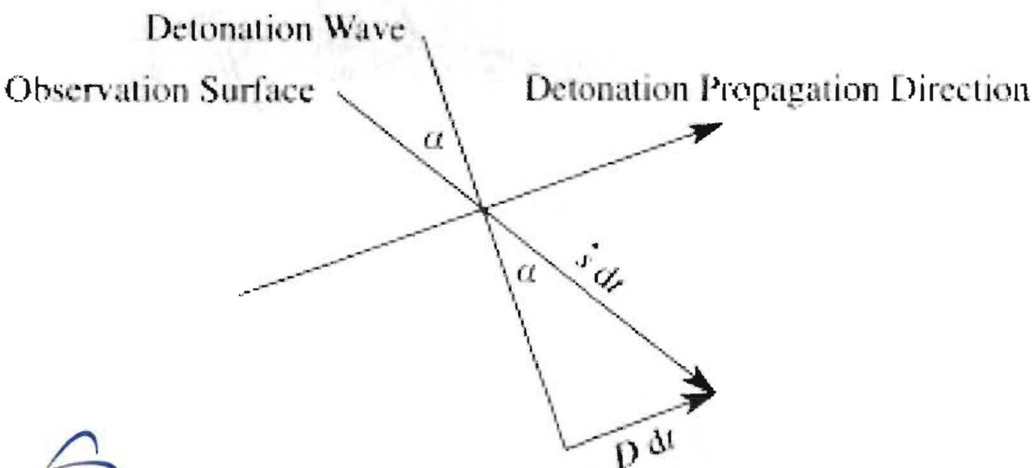
Wavefront Reconstruction

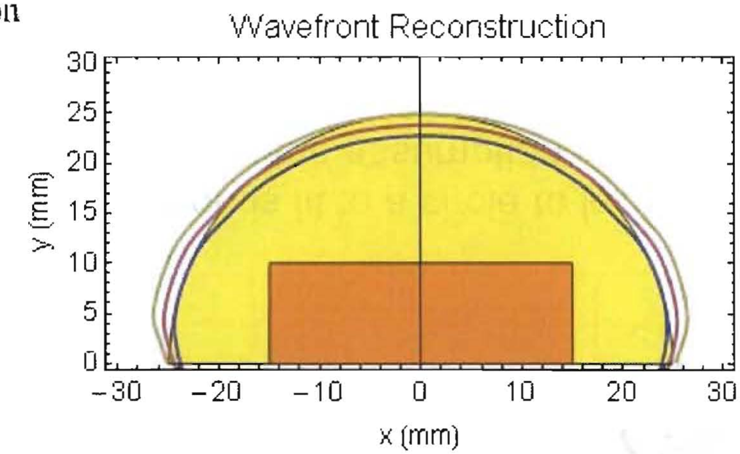


$$x = R\sin[\theta] + D(t-\tau)\sin[\theta+\alpha]$$
$$y = R\cos[\theta] + D(t-\tau)\cos[\theta+\alpha]$$
$$\tau = f[\theta]$$

$$\sin[\alpha] = \frac{D}{s'}, \qquad s' = \frac{\mathrm{d}s}{\mathrm{d}t} = R\frac{\mathrm{d}\theta}{\mathrm{d}t} = \frac{R}{\mathrm{d}t/\mathrm{d}\theta} = \frac{R}{\mathrm{f}'[\theta]}$$

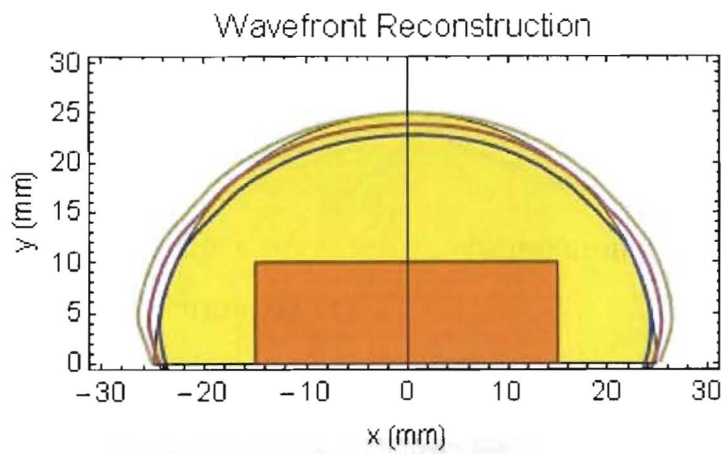
$$\alpha = \arcsin\left[\frac{D\,\mathrm{f}'[\theta]}{R}\right]$$





Onionskin Testing

Center of Initiation Determination



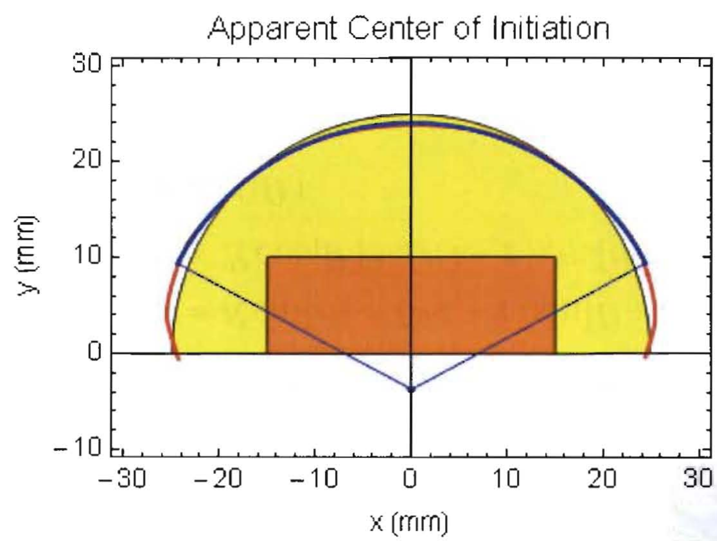
FBA region is fit to a circle to locate the COI with the assumption is made that the COI will be centered on the hemisphere such that a = 0.

$$(x-h)^2+(y-k)^2=r^2$$

$$y=k+\sqrt{r^2+(x-h)^2}$$

The average of the first and last breakout is used to determine the apparent center of initiation.

The region of the average wavefront used to determine the COI is bounded by the first breakout angle for each side of the onionskin.



Onionskin Testing

LX-07 Hemispherical Booster @ -56°C ρ= 1.842 g/cc

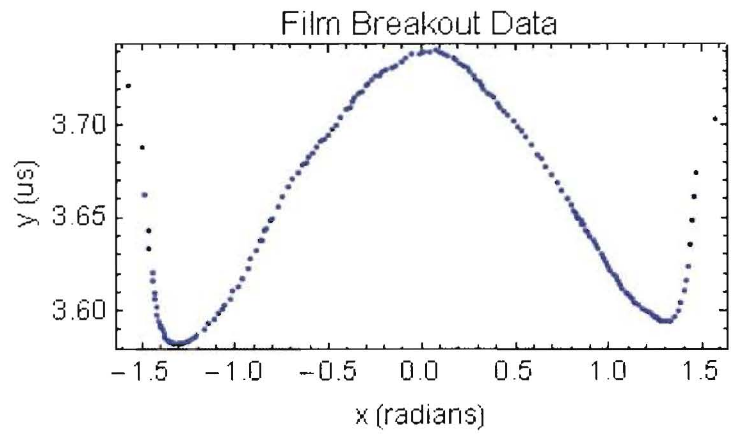
Considered to be the "Standard" for comparison

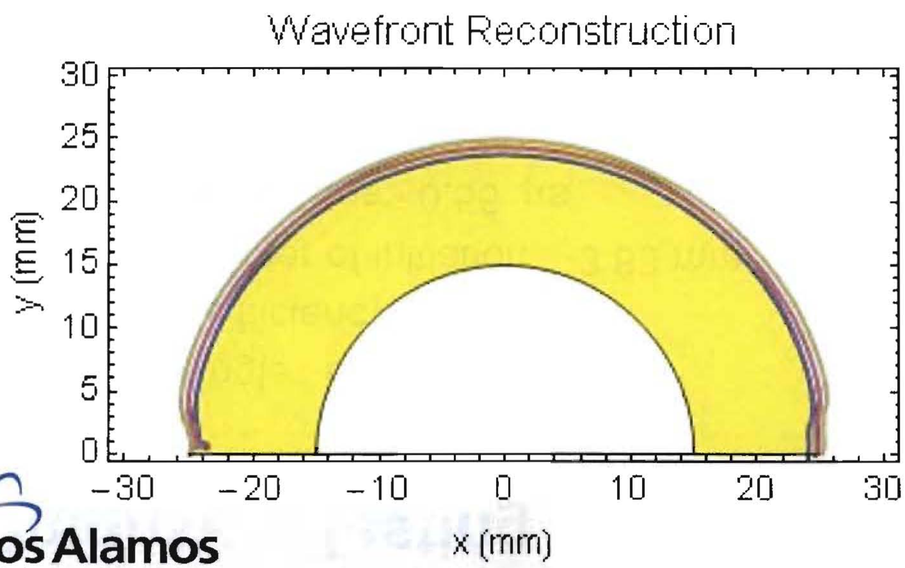
Breakout Angle: 74.62 °

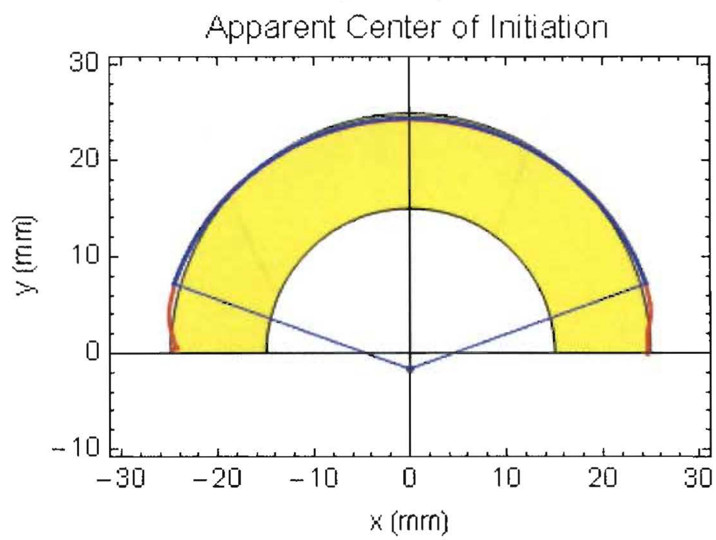
Spreading Efficiency: 82.92 %

Apparent Center of initiation: -1.63 mm

Excess Transit Time: 0.46 μs







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Onionskin Testing

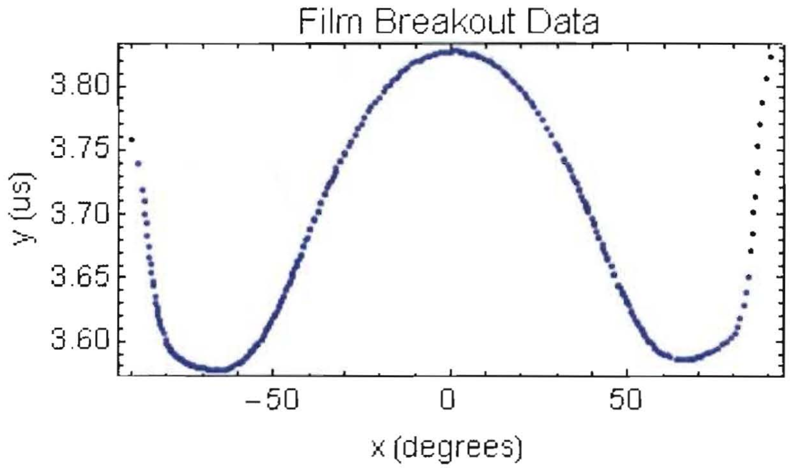
LX-07 Cylindrical Booster @ -53°C ρ= 1.845 g/cc

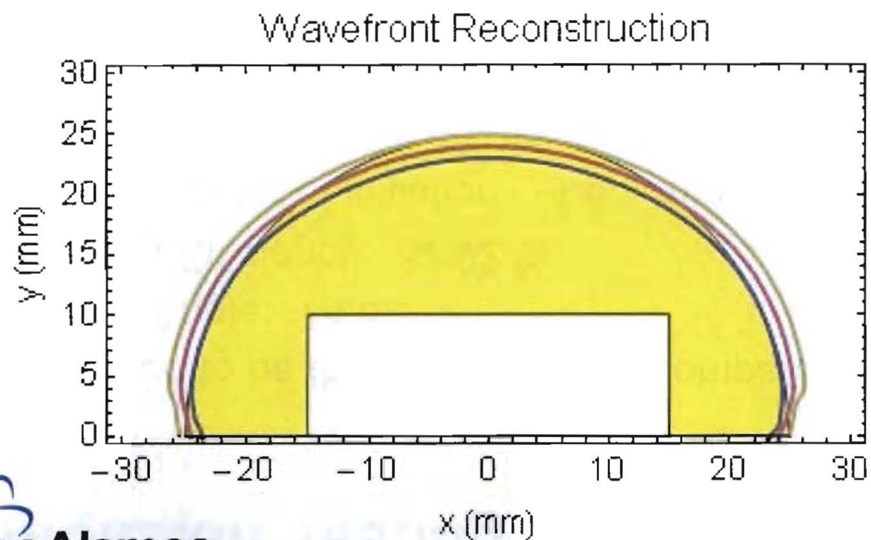
Breakout Angle: 66.21 °

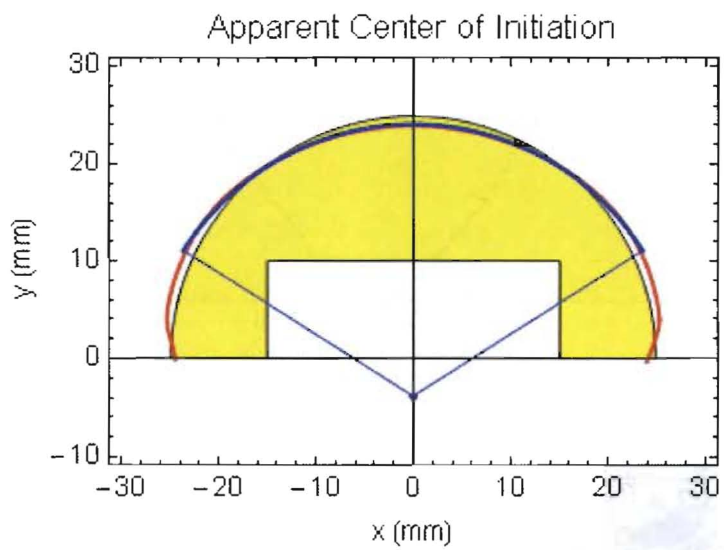
Spreading Efficiency: 73.57 %

Apparent Center of initiation: -3.83 mm

Excess Transit Time: 0.55 μs







Onionskin Testing

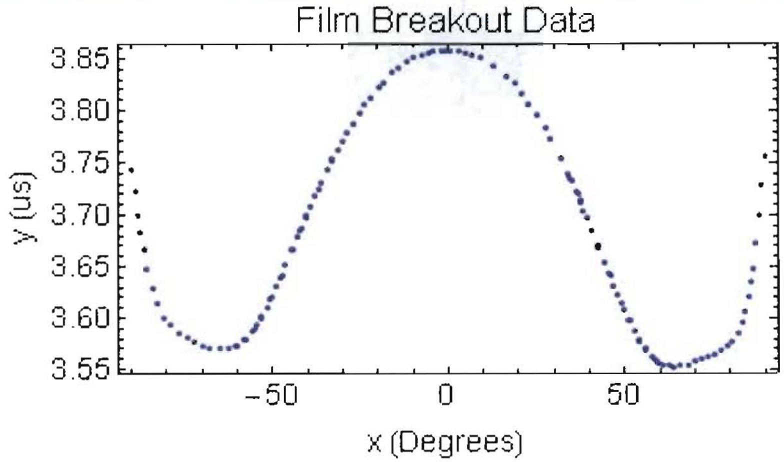
LX-07 Cylindrical Booster @ -55°C ρ= 1.842 g/cc

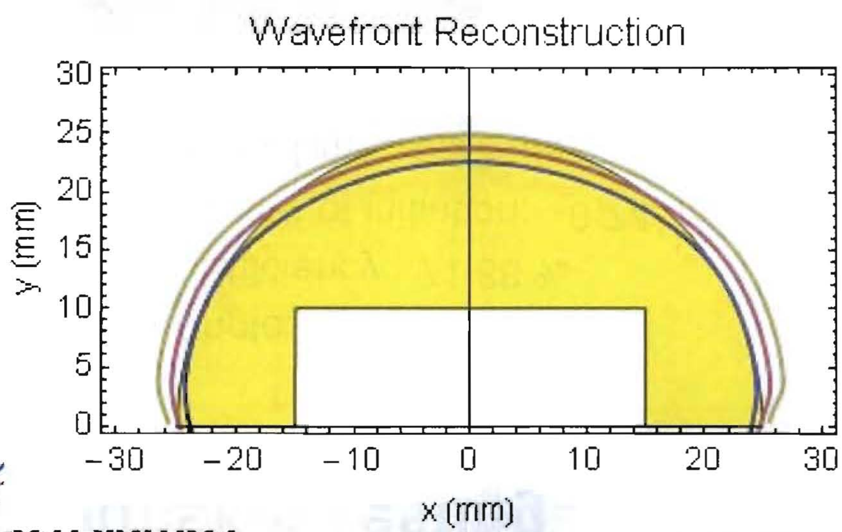
Breakout Angle: 64.49 °

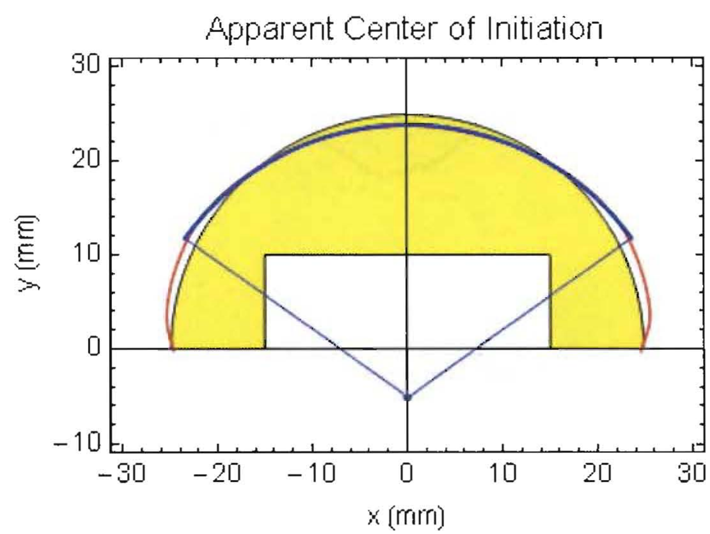
Spreading Efficiency: 71.65 %

Apparent Center of initiation: -5.11 mm

Excess Transit Time: 0.58 μs







Onionskin Testing

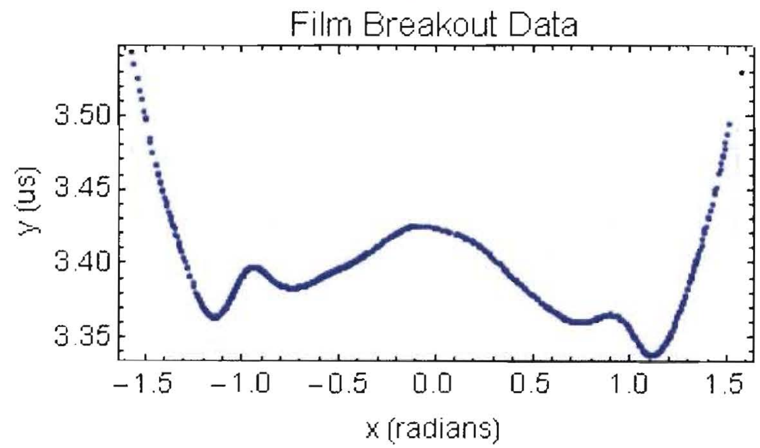
PBX 9504 @ -55°C ρ = 1.855 g/cc

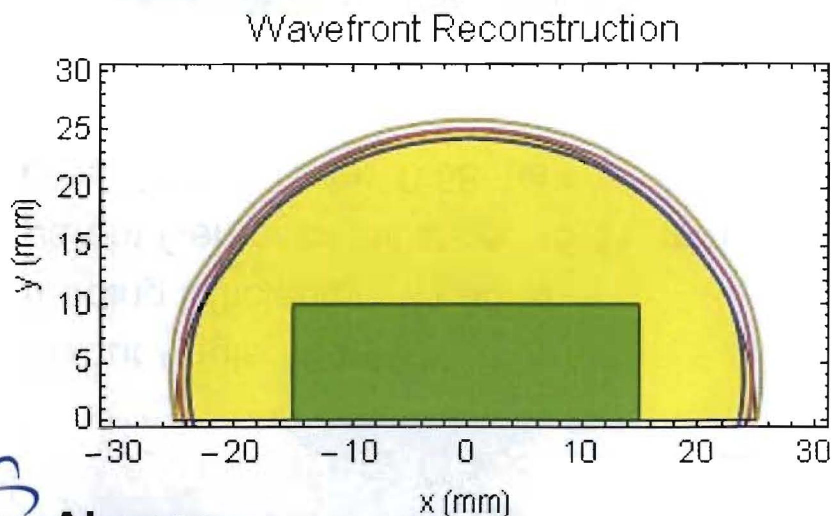
Breakout Angle: 64.69 °

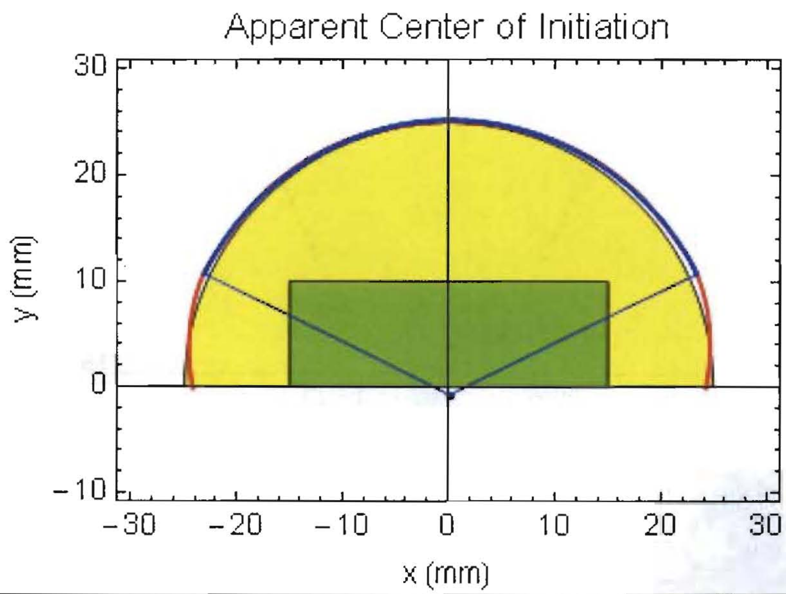
Spreading Efficiency: 71.88 %

Apparent Center of initiation: -0.74 mm

Excess Transit Time: 0.27 μs







Onionskin Testing

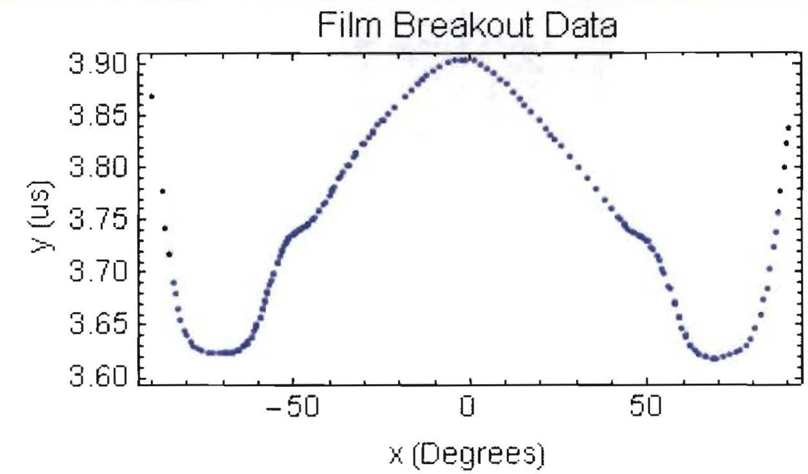
DAAF-2.43-ACN @ -55°C

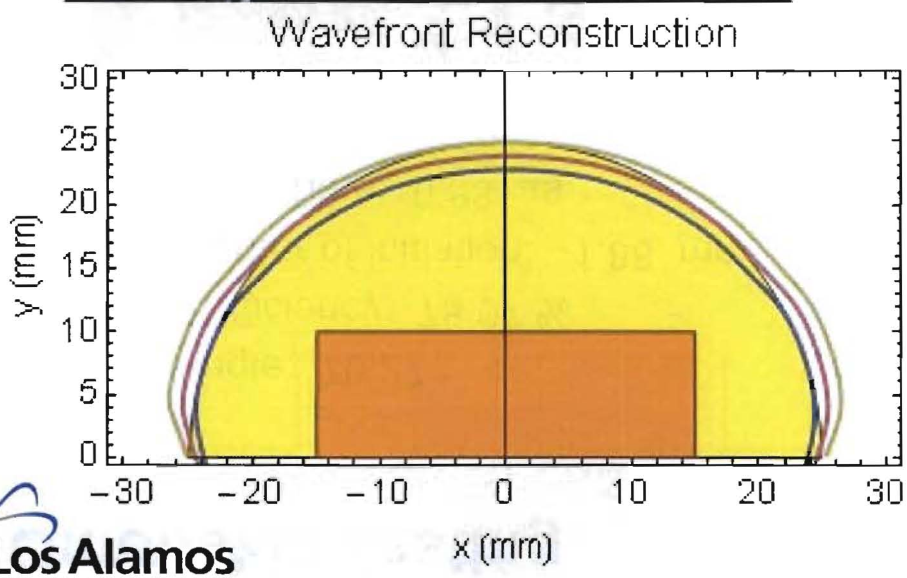
Breakout Angle: 69.85 °

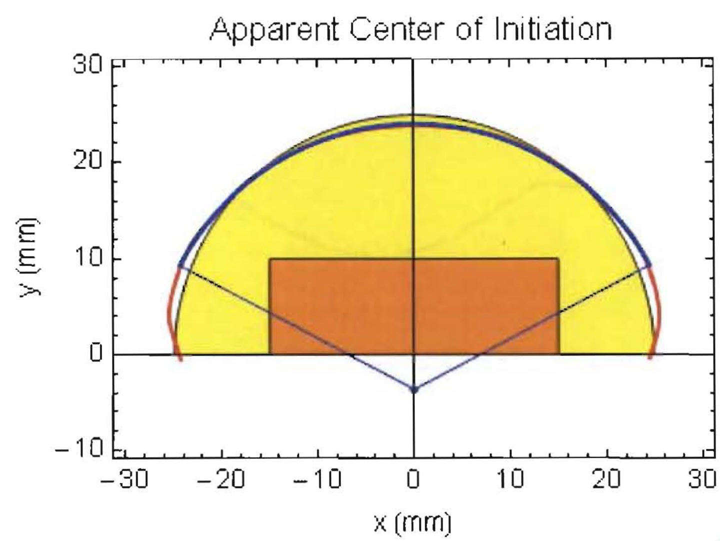
Spreading Efficiency: 77.61 %

Apparent Center of initiation: -3.64 mm

Excess Transit Time: 0.63 μs







Onionskin Testing

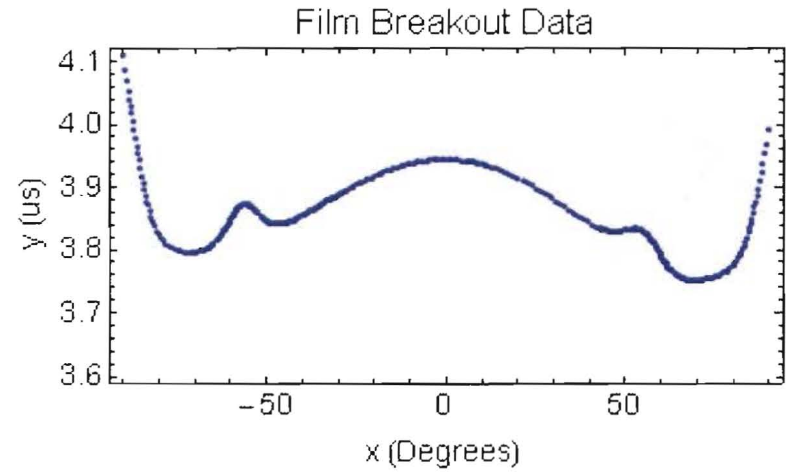
DAAF Cylindrical Booster @ -55°C   ρ= 1.662 g/cc

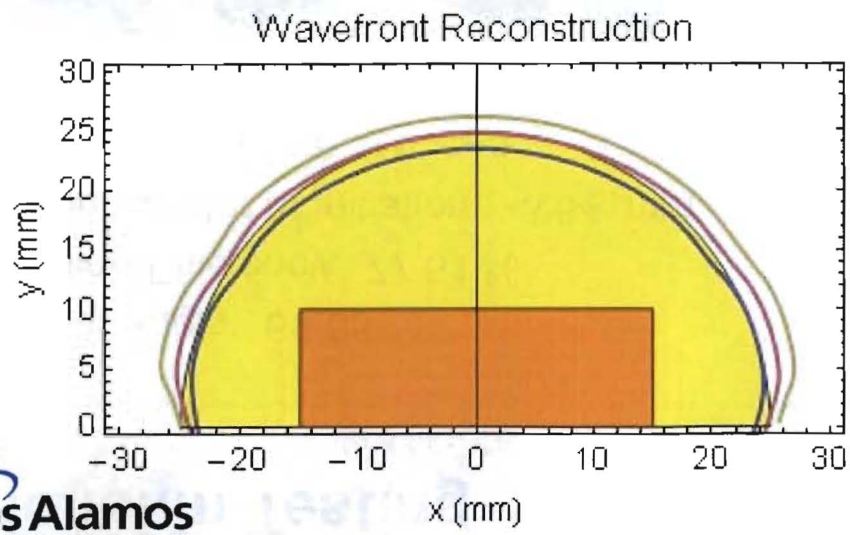
Breakout Angle: 70.27 °

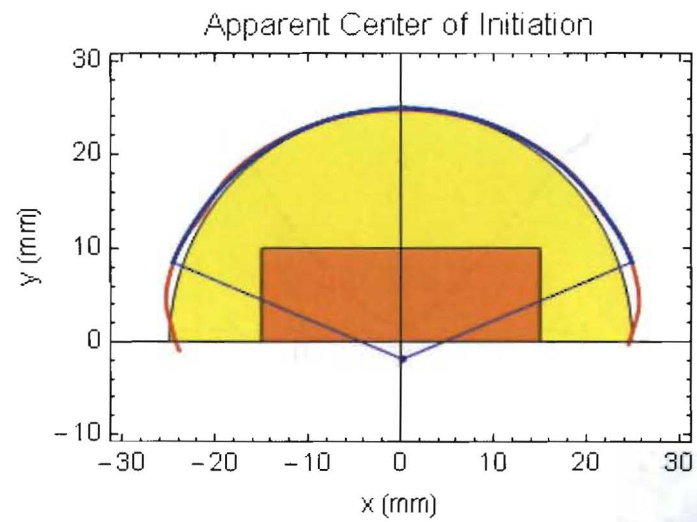
Spreading Efficiency: 78.07 %

Apparent Center of initiation: -1.88 mm

Excess Transit Time: 0.83 μs







Onionskin Testing

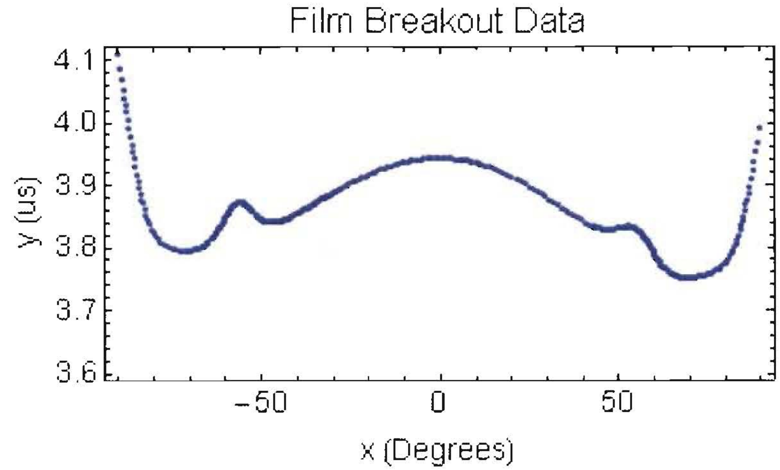
DAAF Machined Cylindrical Booster @ -55°C ρ= 1.684 g/cc

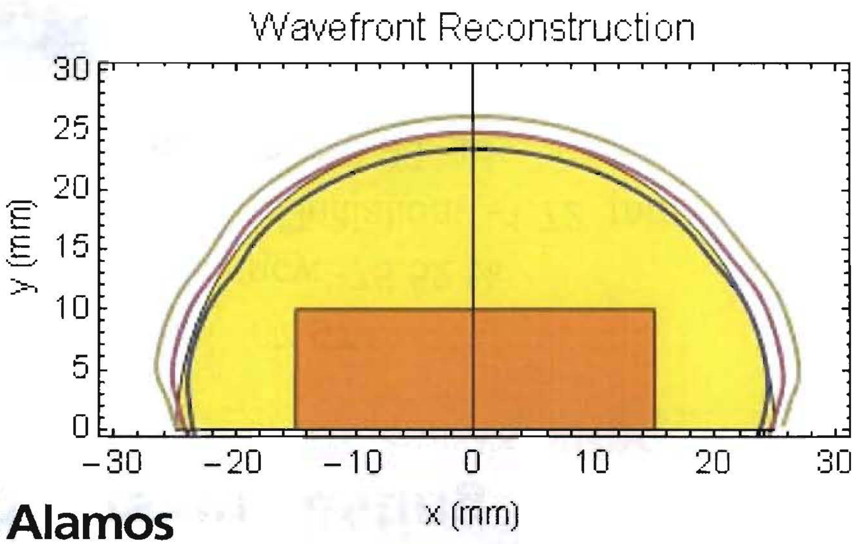
Breakout Angle: 78.37 °

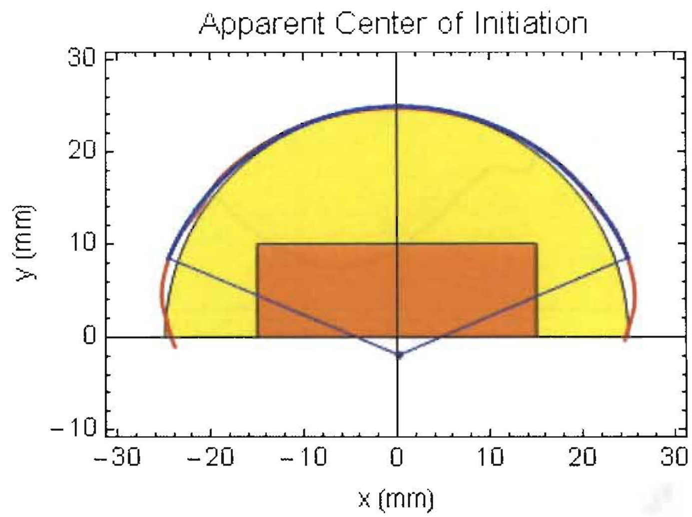
Spreading Efficiency: 75.97 %

Apparent Center of initiation: -2.16 mm

Excess Transit Time: 0.69 μs







Onionskin Testing

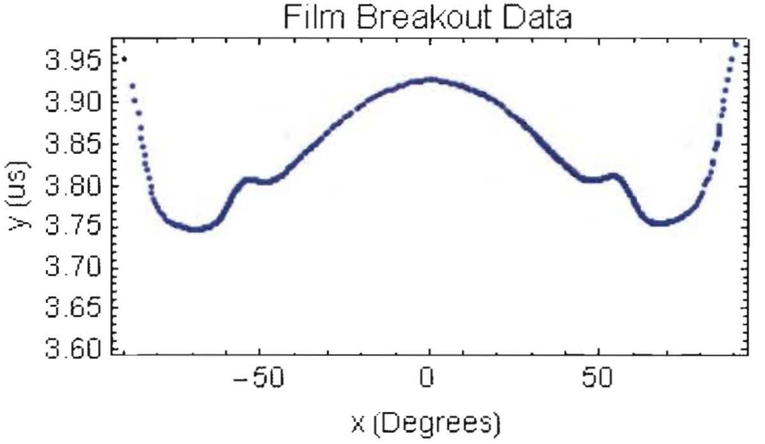
DAAF Pressed/Faced Cylinder @ -55°C ρ= 1.676 g/cc

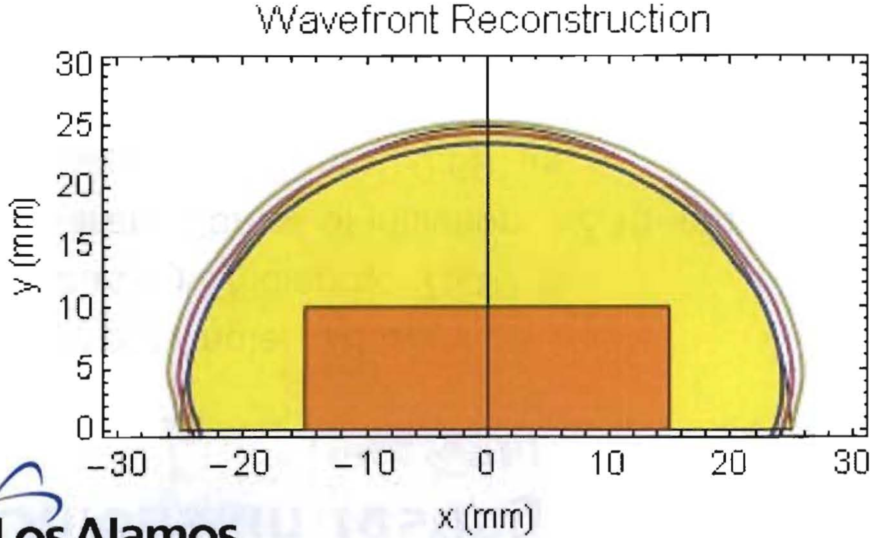
Breakout Angle: 67.97 °

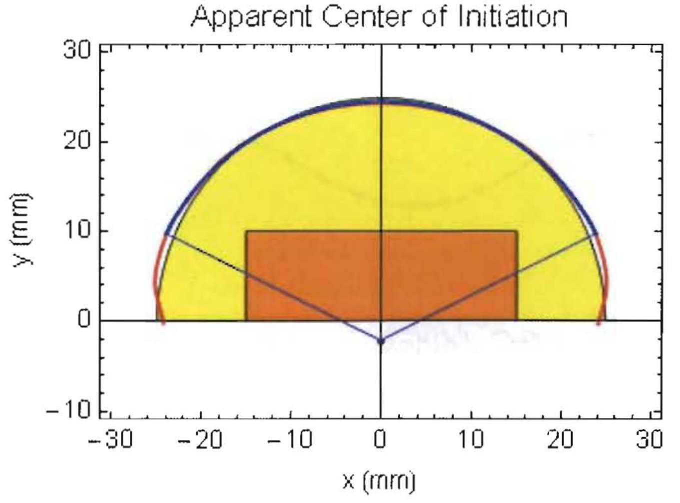
Spreading Efficiency: 75.52 %

Apparent Center of initiation: -1.72 mm

Excess Transit Time: 0.96 μs







Onionskin Testing

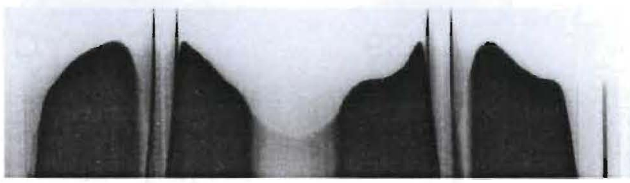
DAAF Machined Hemispherical Booster@ -54°C

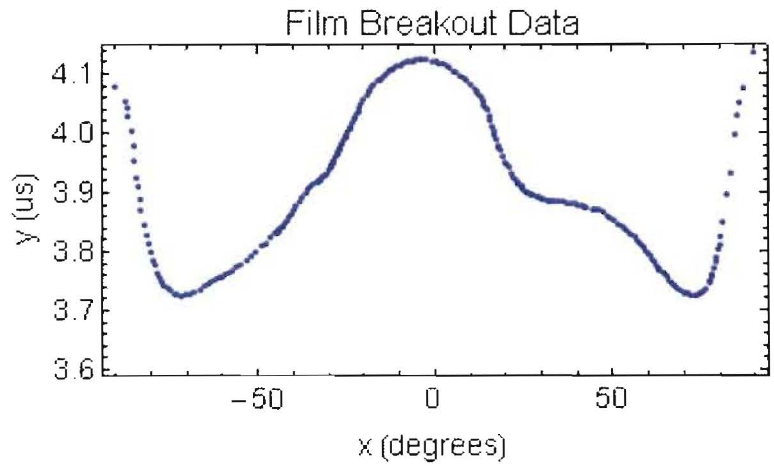
Breakout Angle: 72.397 °

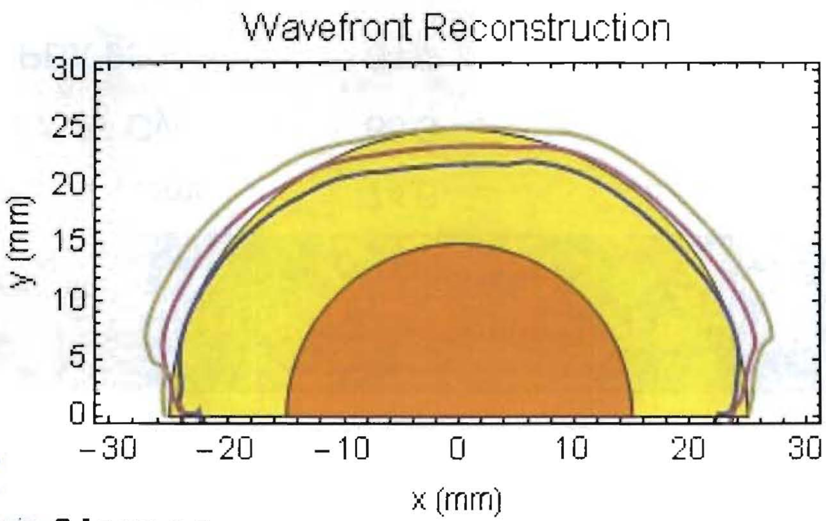
Spreading Efficiency: 80.44 %

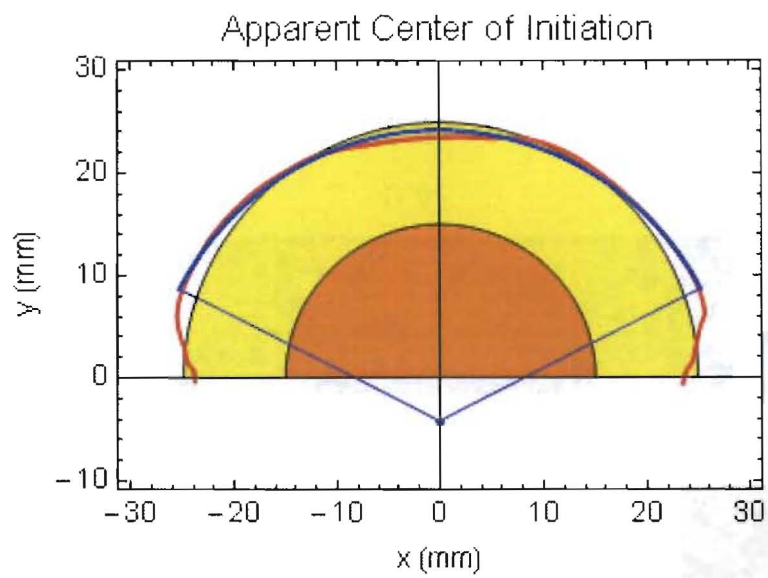
Apparent Center of initiation: -4.20 mm

Excess Transit Time: 0.86 μs









Onionskin Testing
Tabulated Results

Material	FBA (degrees)	Spreading Efficiency	Apparent COI (mm)	Excess Transit Time (μs)	Comments
LX-07 Hemi	74.6	82.9%	-1.63	0.46	Standard
LX-07 Cyl.	65.3	72.6%	-4.47	0.56	Average of 2
PBX 9504	64.7	71.9%	-0.74	0.27	Weak in center
DAAF-ACN Cyl.	69.9	77.6%	-3.64	0.63	Comparable to LX-07
DAAF Cyl.	68.9	76.5%	-1.92	0.83	Average of 3
DAAF Hemi	72.4	80.4%	-4.20	0.86	Weak in center

Onionskin Testing

Conclusions

- DAAF showed best FBA and spreading in the modified tests, but shape was perturbed
  - particle size issues in formulation?
  - Input shock duration vs. run distance in PBX 9502
- LX-07 showed best shape and tied with PBX 9504 for spreading
- PBX 9504 showed best Apparent COI, but shape was perturbed

Onionskin Testing
Future Work

- Cold DAAF Rate Sticks
- Wedge Testing of PBX 9502 using DAAF donor charge
- Determining the reacted E.O.S of DAAF