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Z-Machine Laser Triggering System Design and Safety Features

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Sandia National Laboratories

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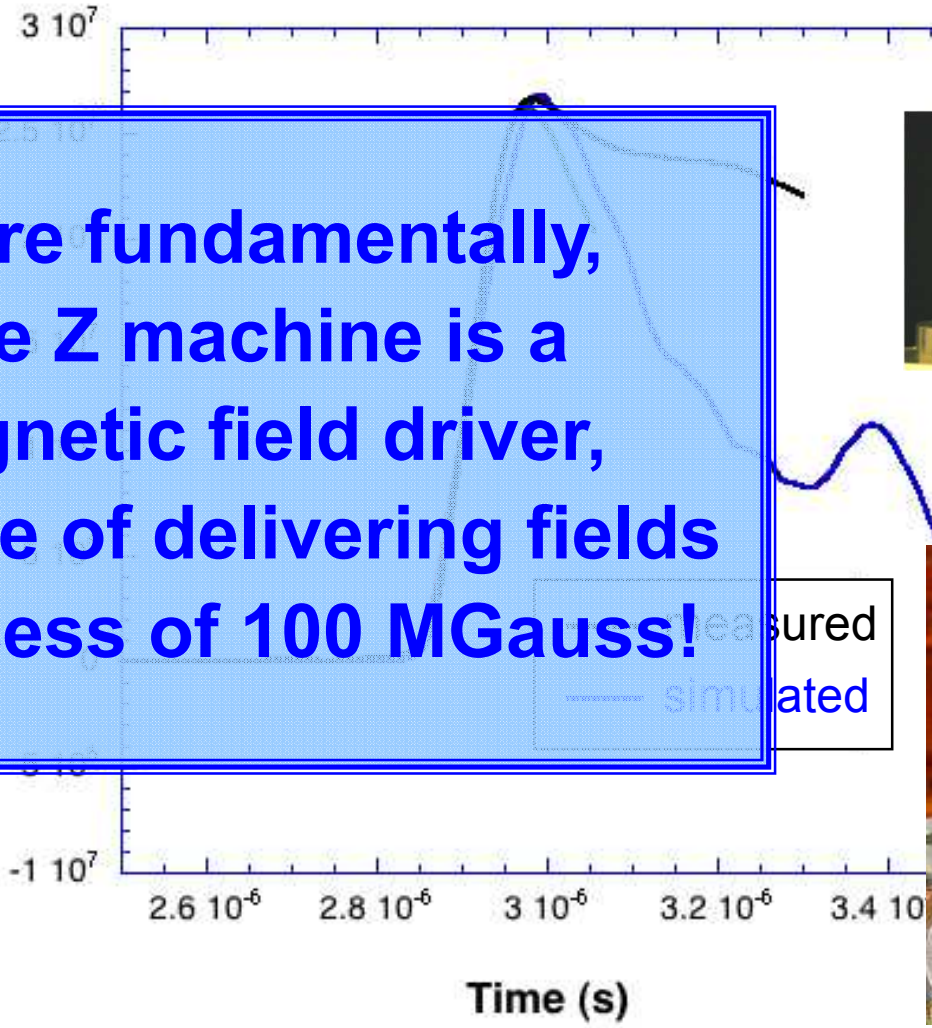
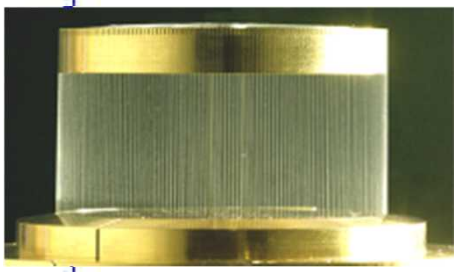
The Z-machine is a pulsed power driver that delivers a peak load current of ~26 MA with an adjustable rise time from 100 to 400 ns.

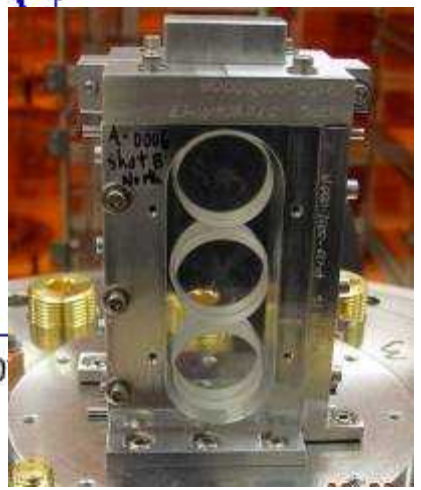
More fundamentally, The Z machine is a Magnetic field driver, Capable of delivering fields in excess of 100 MGauss!



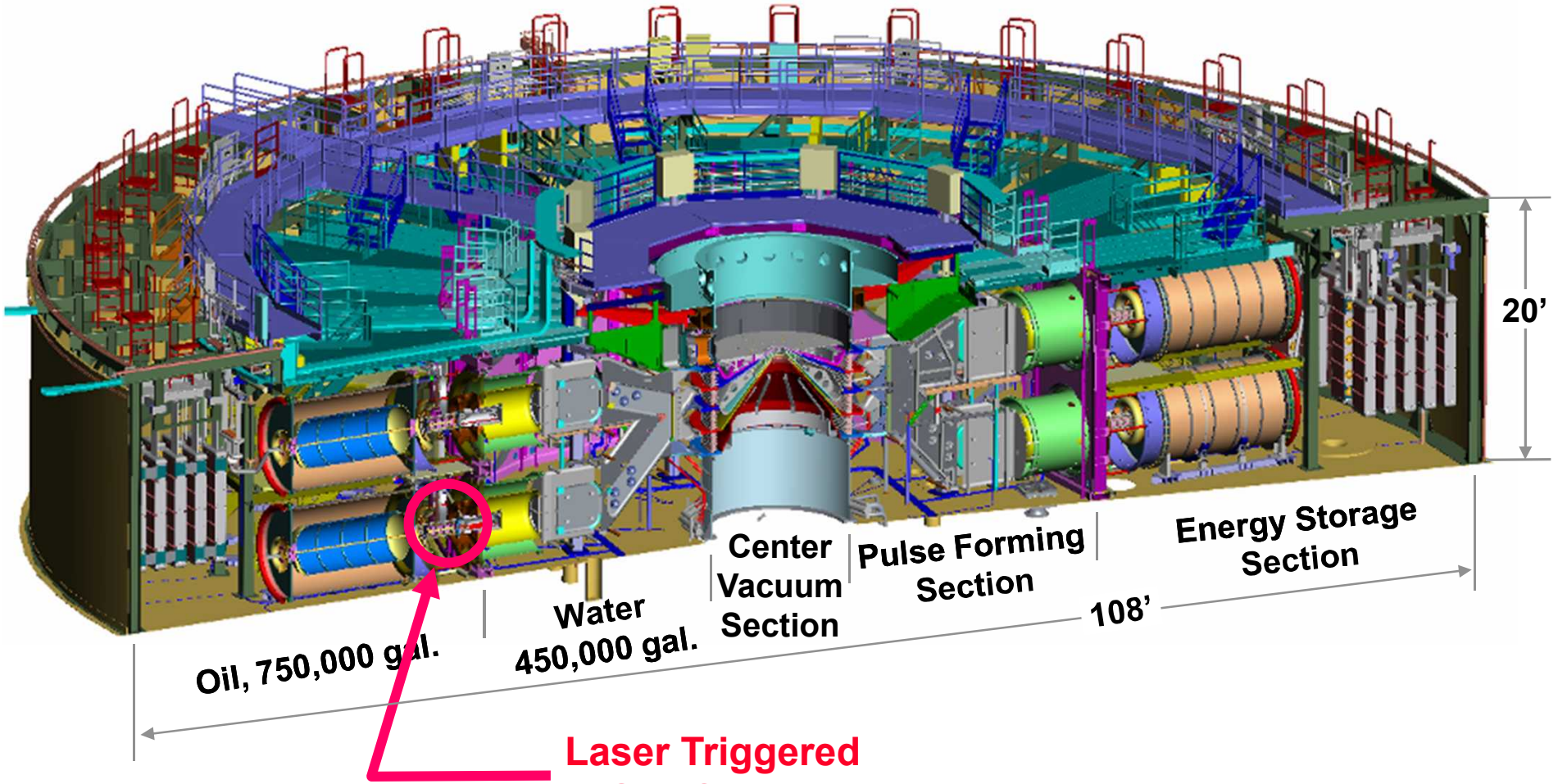
Wire Array Radiation Load



Material Dynamics Load



Cross sectional view of the Z-machine highlights the 36 individual modules and respective oil, water and vacuum sections.



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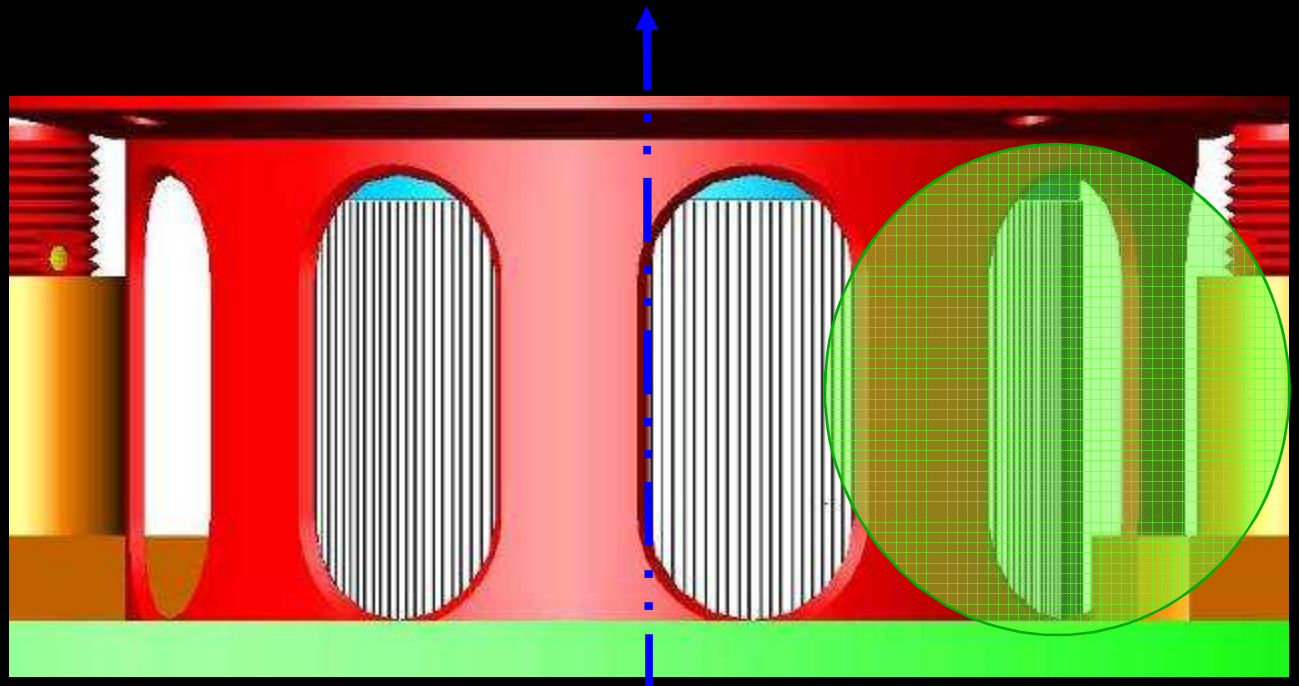
Z1311 Coverdale: Self Emission of a Large Diameter Copper Single Array

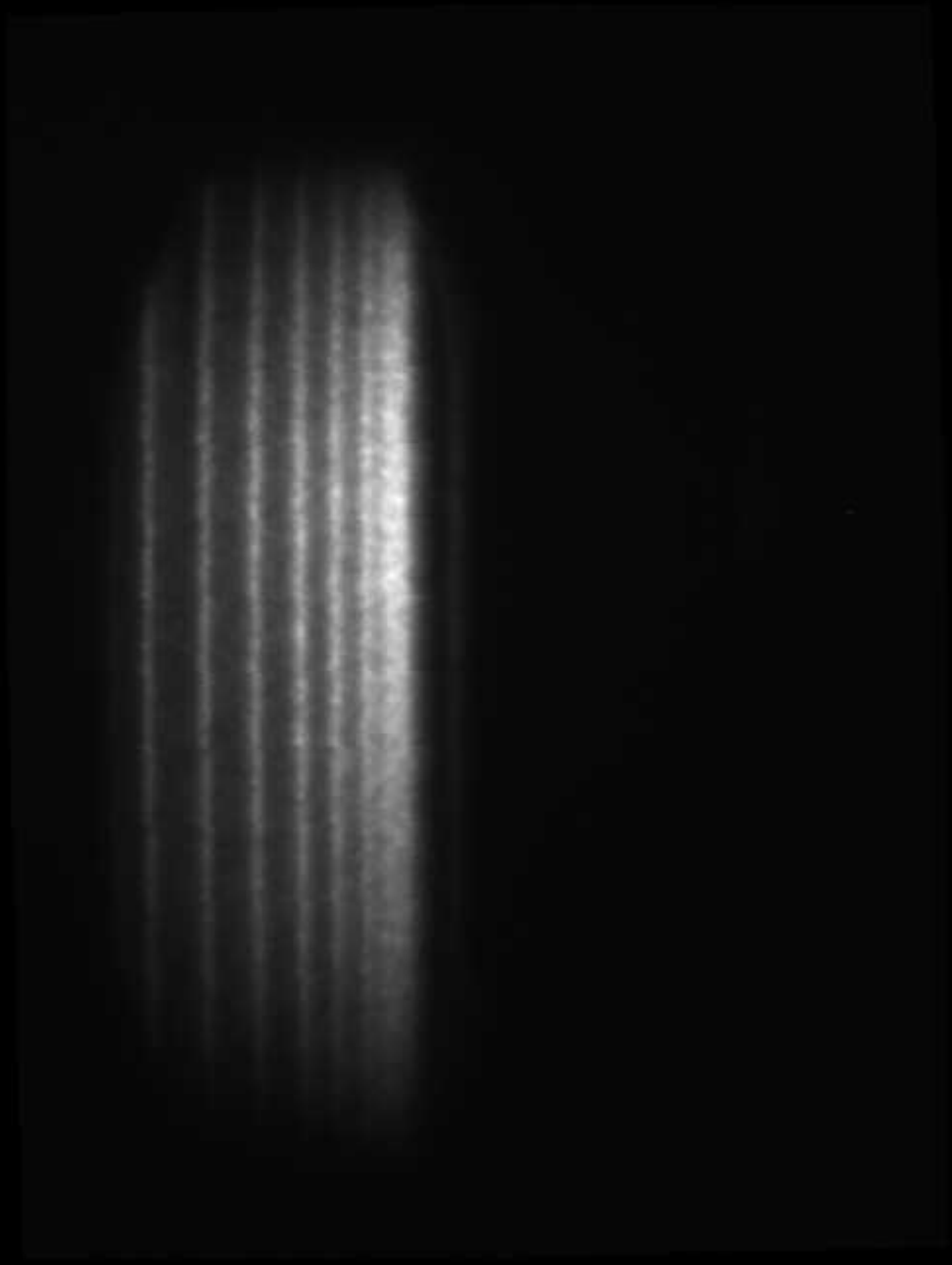
Material: Copper

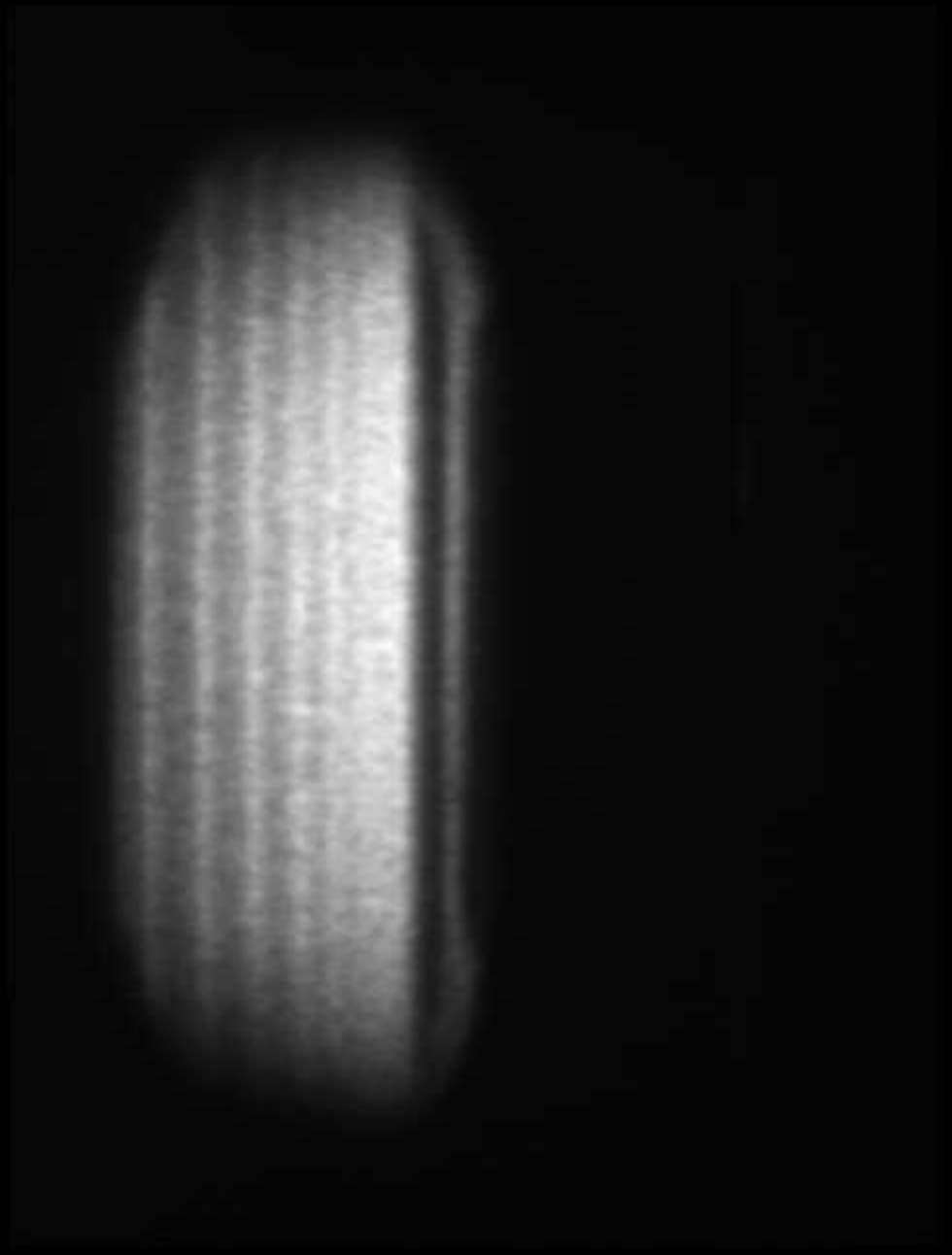
Array Diameter

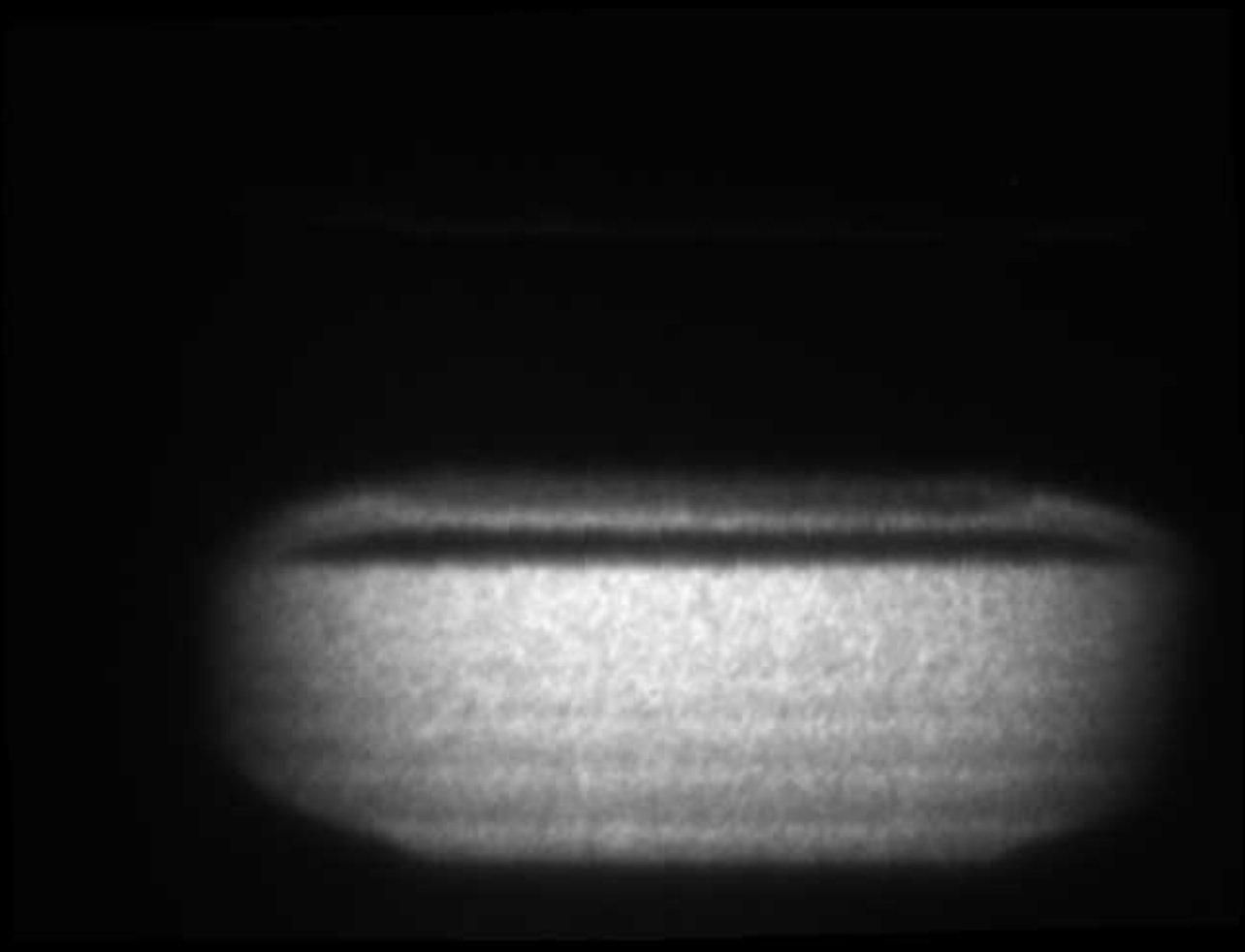
60 mm, 88 wires

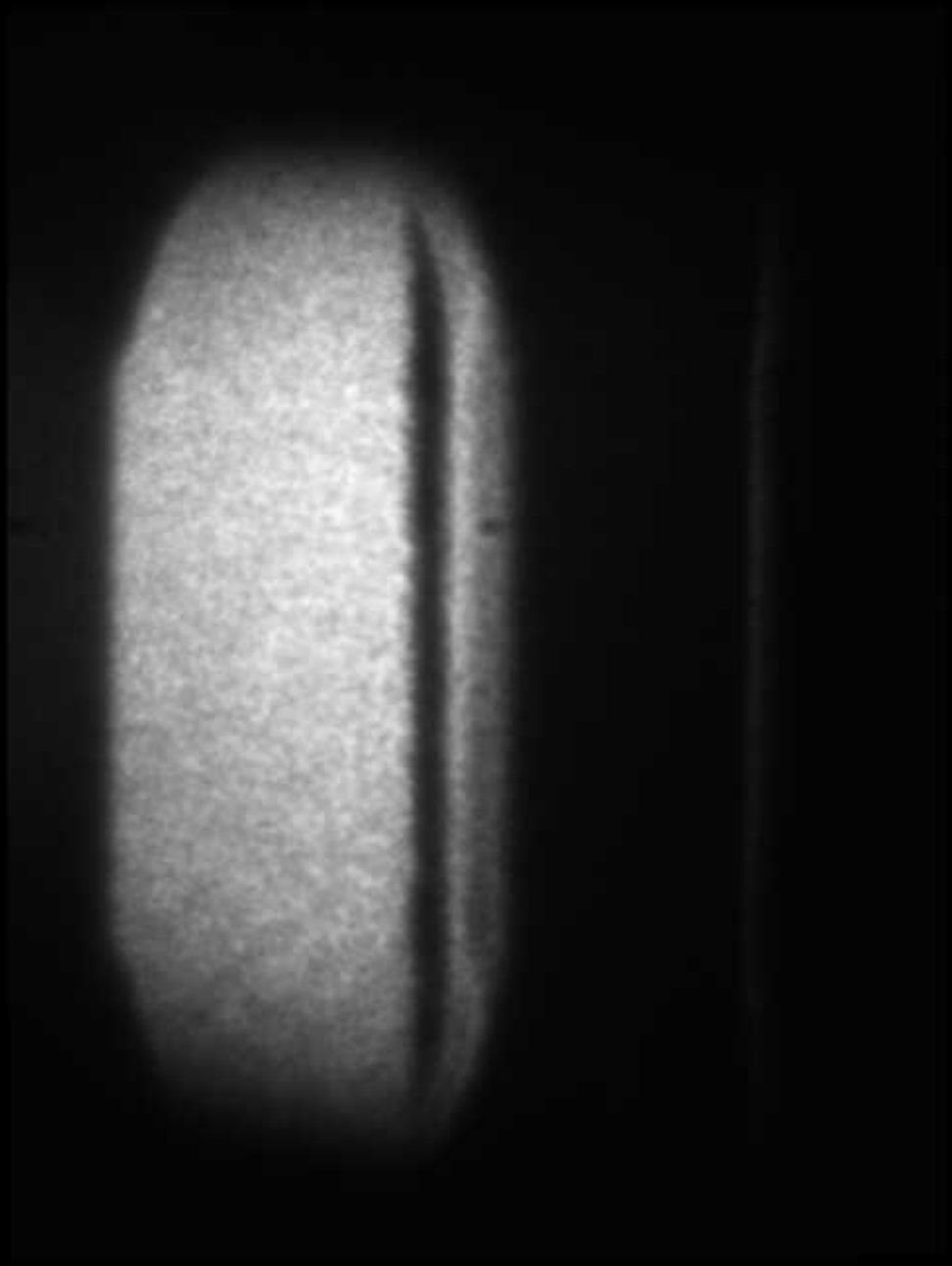
Wire Φ: 11.09 um

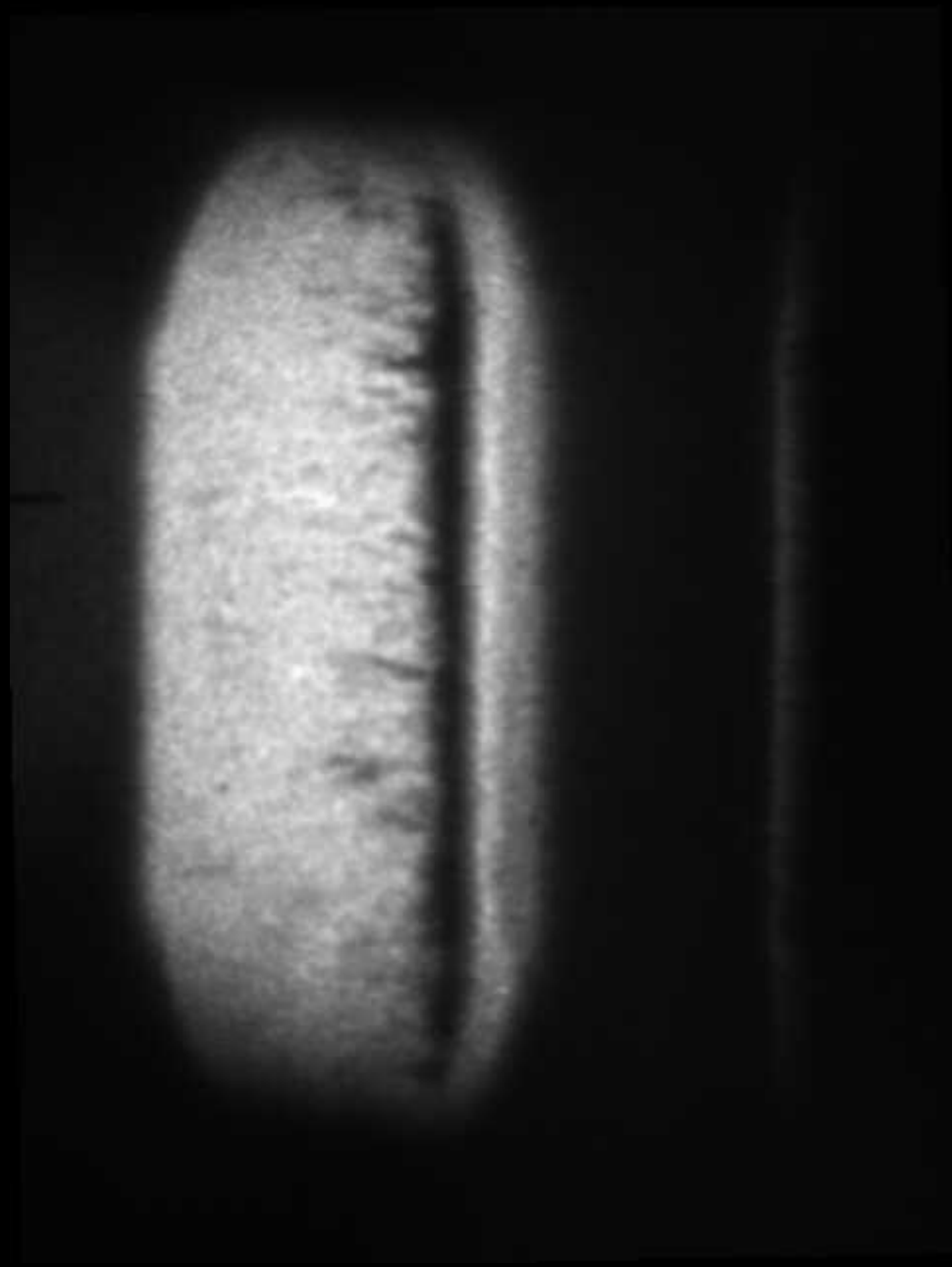






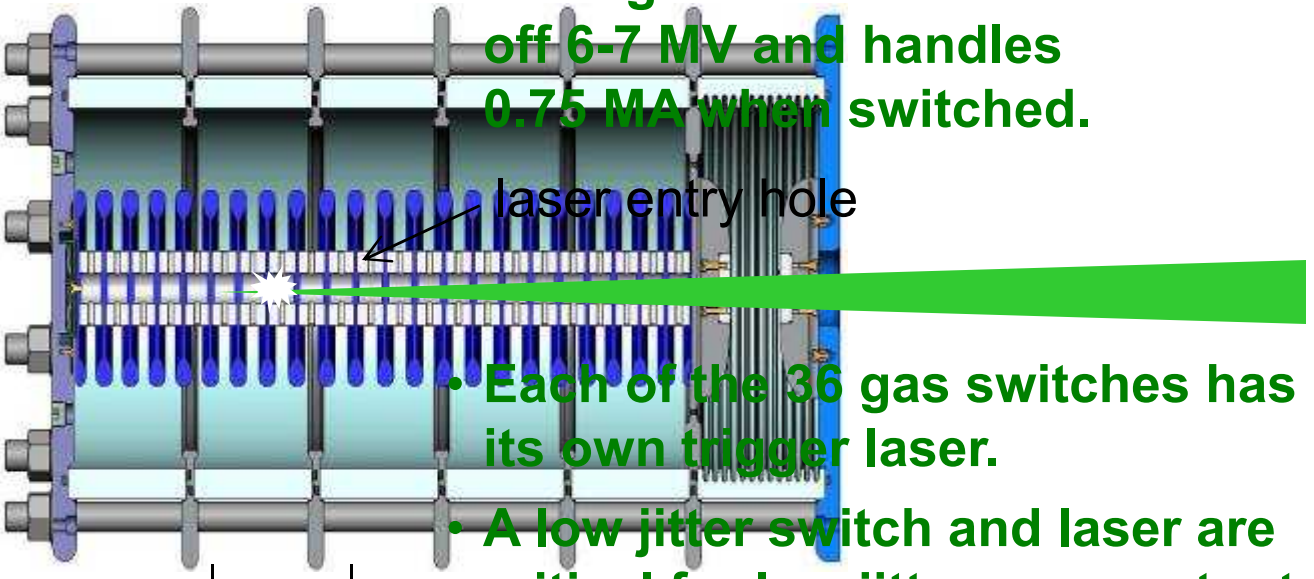






The Laser Triggered Gas Switch is the last actively controlled pulsed power component on the machine.

Switch filled with ~45 psia SF_6 gas.



- Each gas switch holds off 6-7 MV and handles 0.75 MA when switched.
- Each of the 36 gas switches has its own trigger laser.
- A low jitter switch and laser are critical for low jitter x-ray output.
- Independent laser timing enables electrical pulse shaping.

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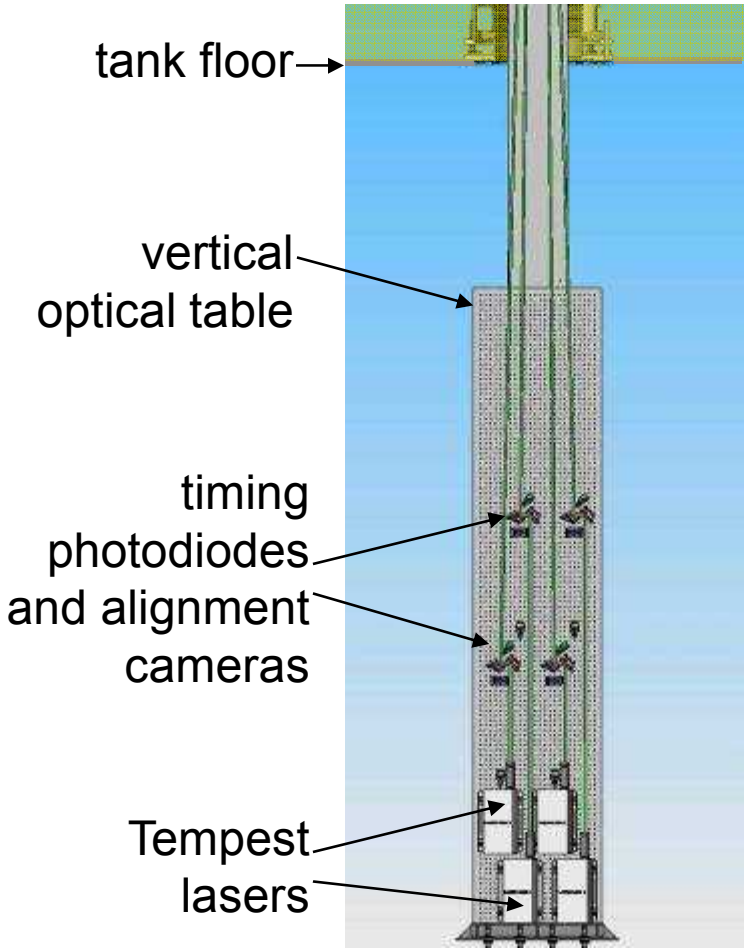
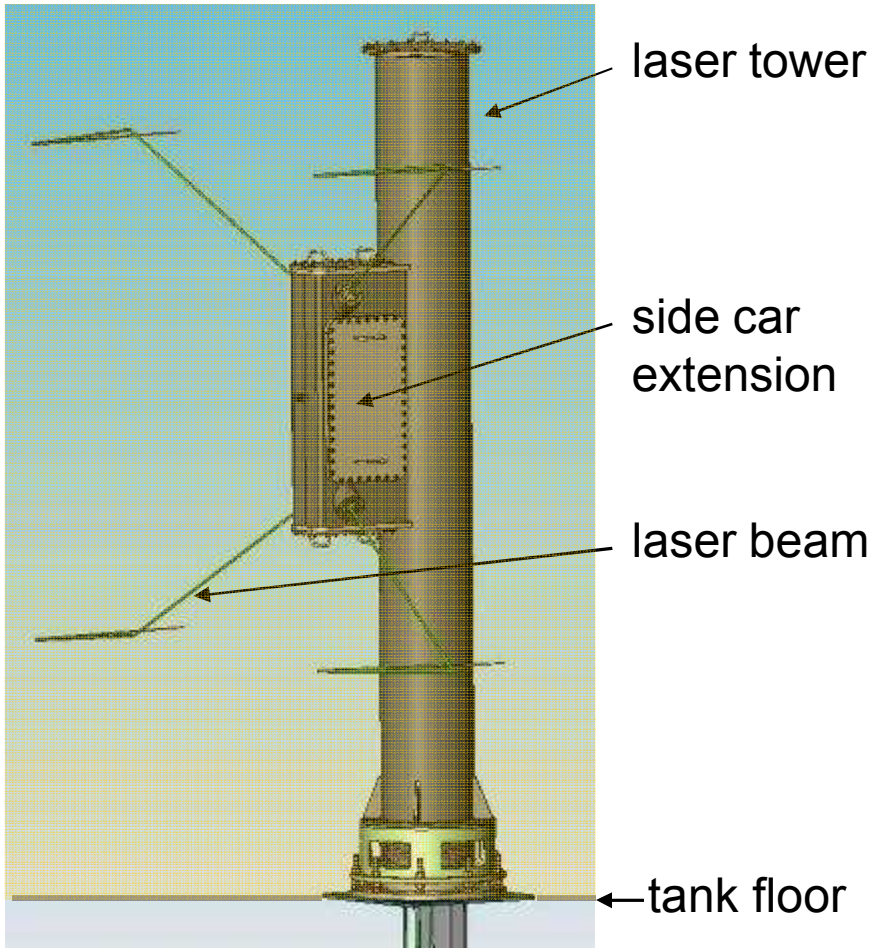
Mike Baremore

The LTS lasers are in the basement of Z and access the machine through the bottom of the tank into the sealed laser tower.



Below the tank floor in the basement



Above the tank floor in the oil section

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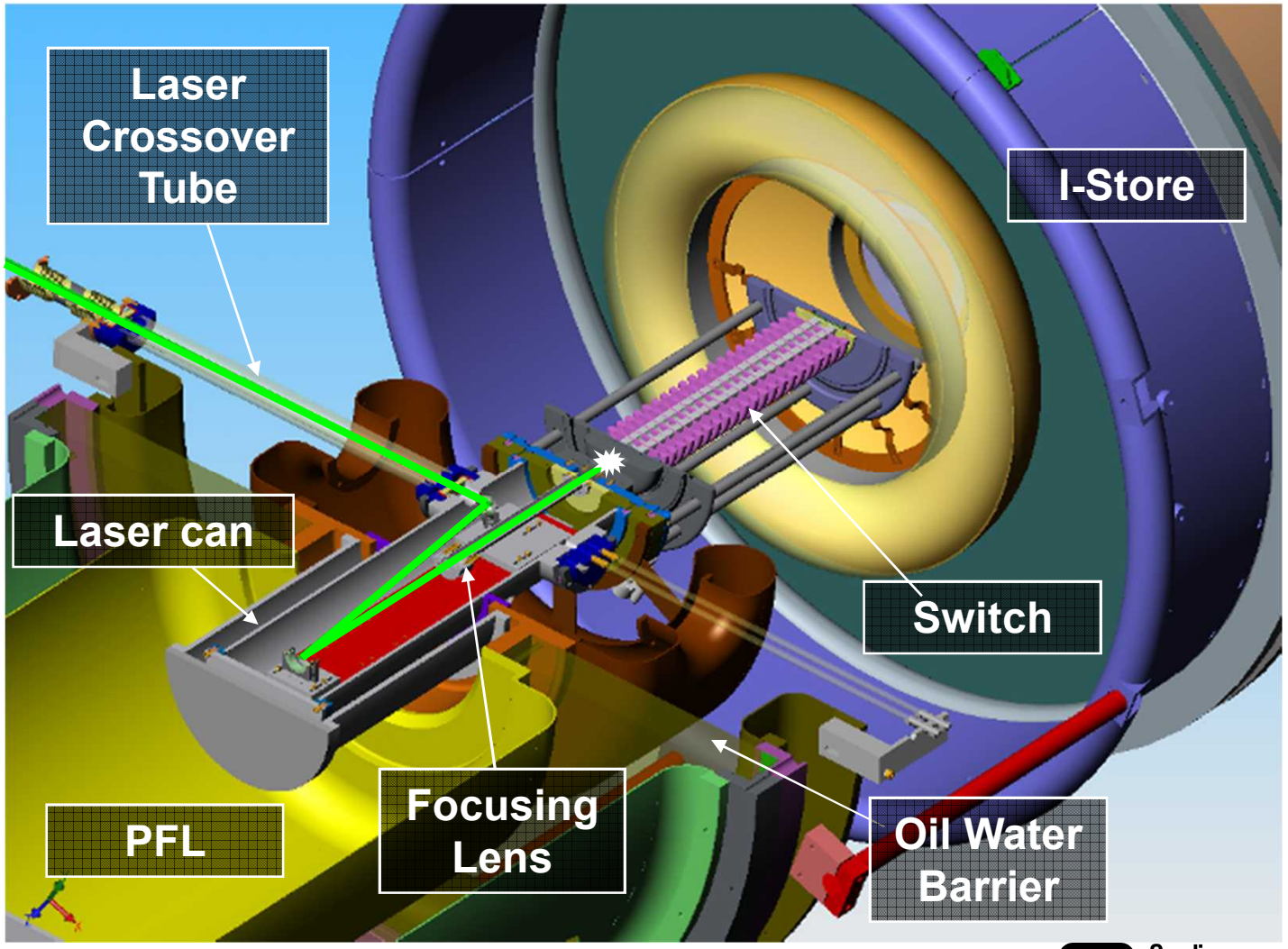
Cutaway view shows laser beam path from the tower, through the crossover tube into the laser can and focusing into the switch.

LTS Parameters

- **Nd:YAG Laser:**
  E = 35 mJ,
  λ = 266 nm,
  t = 4 ns FWHM.
- **Focusing lens:**
  f = 50 cm singlet.
- **Optical train:**
  6 mirrors,
  3 windows,
  1 lens,
  10 m total optical path length



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Switch
Installation

LTS is aligned with the green second harmonic light illuminating reflective targets.

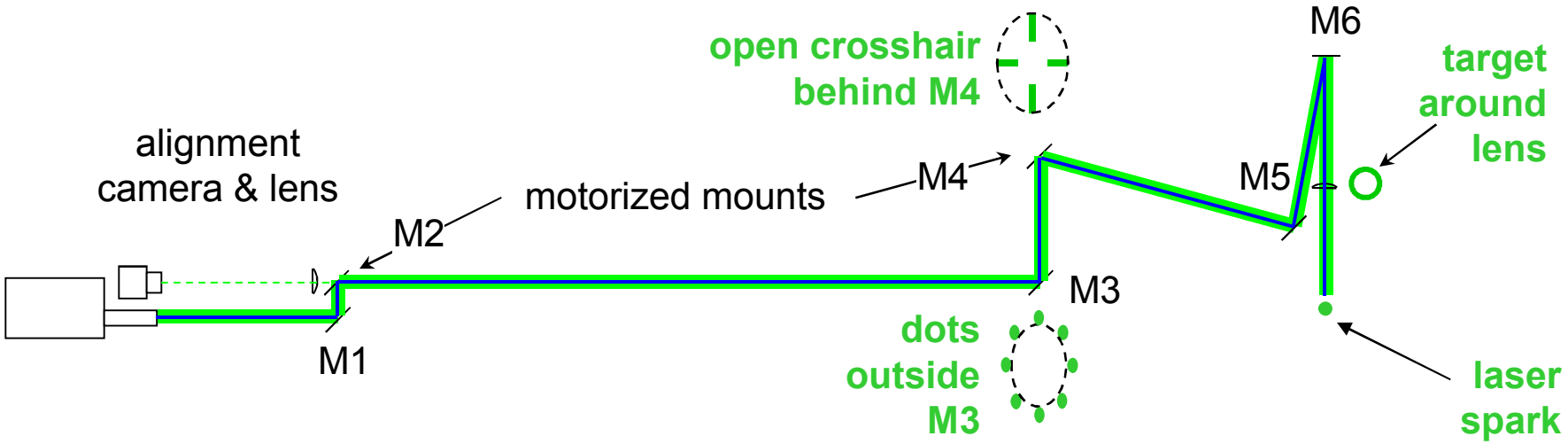
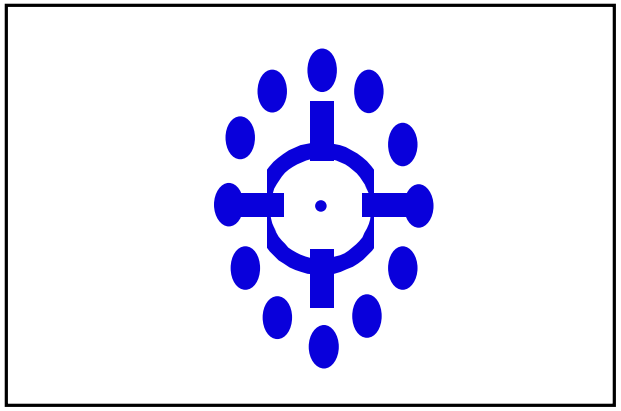


Image of targets on CCD alignment camera



Chromatic aberration in the beam expander causes the green beam to diverge slightly compared to the 12mm UV beam. The larger green beam is used to flood illuminate targets.

A GOOD OPTICAL DESIGN USES ABERRATIONS TO AN ADVANTAGE

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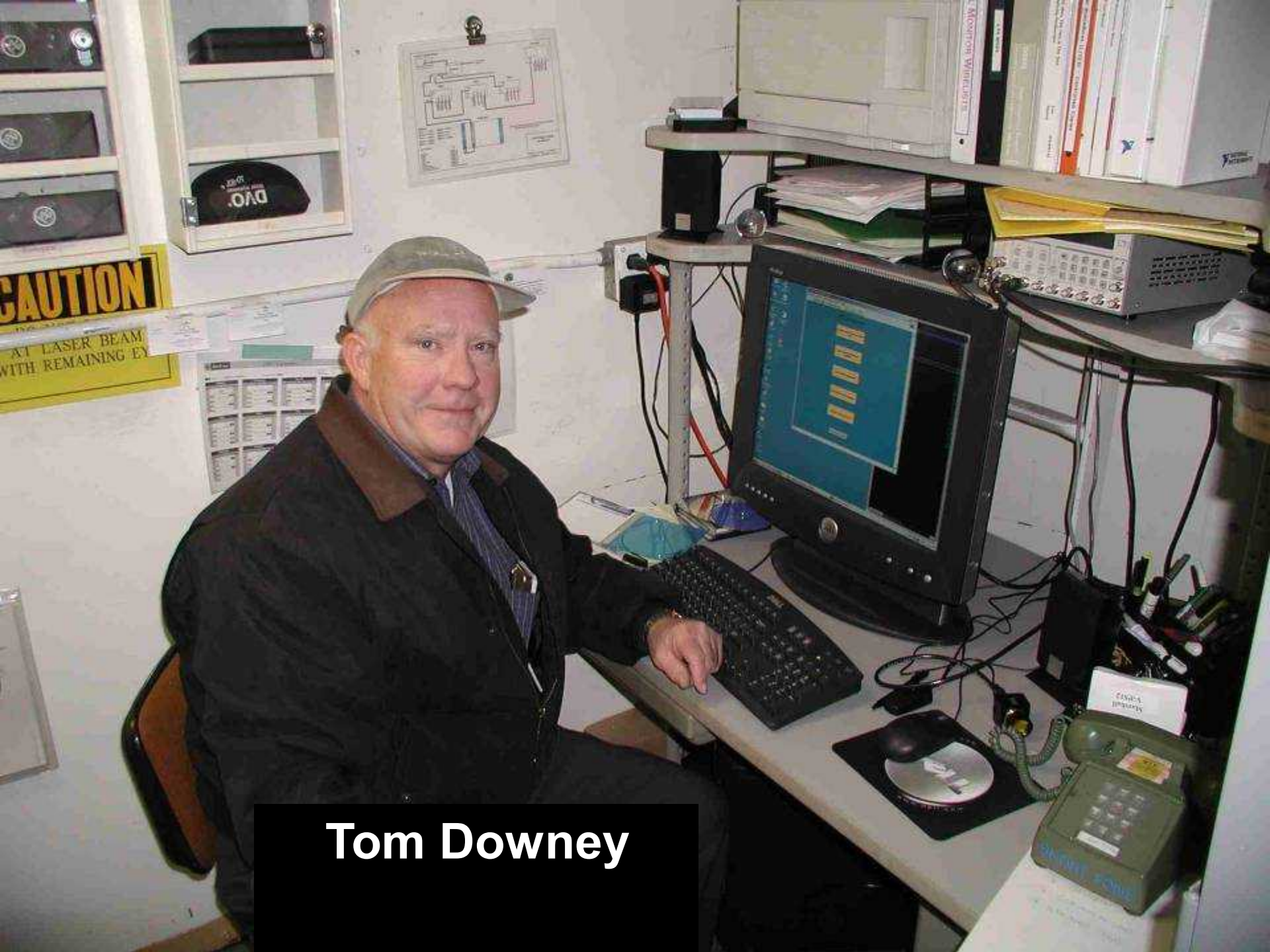
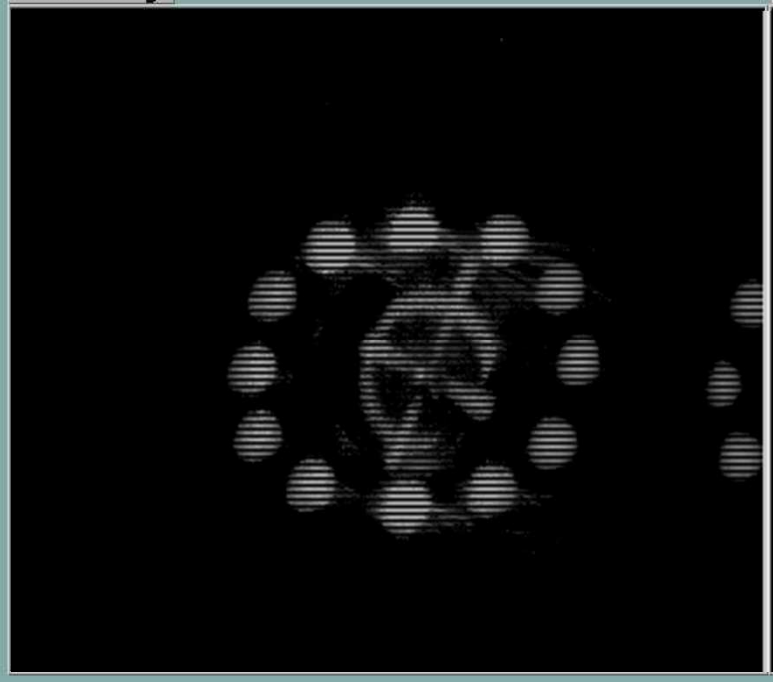

CAUTION
Tom Downey

LTS System Alignment

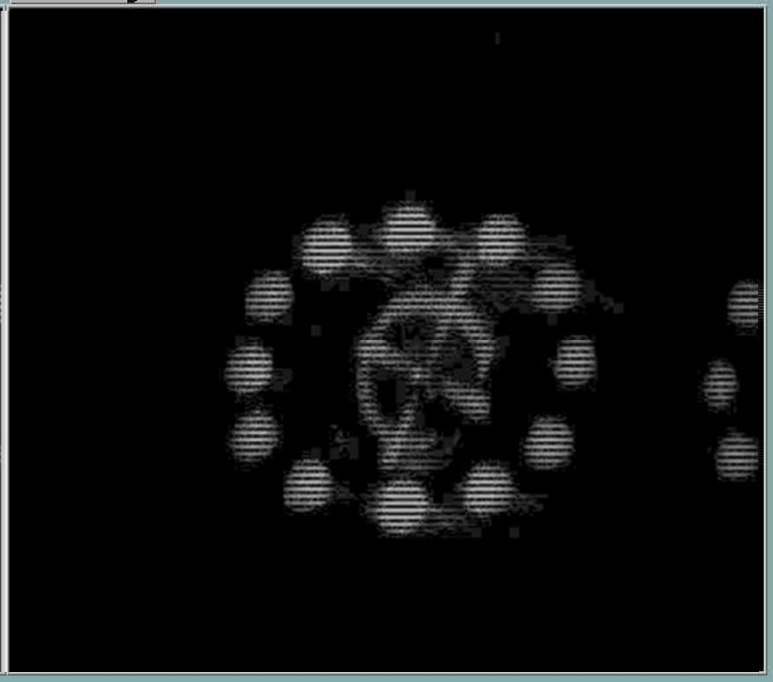
File Edit Operate Tools Browse Window Help

LTS SYSTEM ALIGNMENT

Current Image



Initial Image



Redo All Alignments

Redo Laser No.

Laser No. 1

PLC loop counter 64

Motion loop counter 1

new directory C:\Alignment\2007_06_15_1314

Video ON

Trigger Rate (Hz) 5.0

Drive 5 Motor B

Motor Started

TOWER

Motor Control Status

	1	2	3	4	5	6	7	8	9
LASER/ MODULE NUMBER	35	3	7	11	15	19	23	27	31
	36	4	8	12	16	20	24	28	32
	1	5	9	13	17	21	25	29	33
	2	6	10	14	18	22	26	30	34

Confirm Alignment

Mirror Controls

Active Mount Select

Module # 3

M4/ UPPER

Laser Ready

Laser PFN (%)

100 75 50 25 0

73

Vset - PLC readback 73

Motor Velocity Select

500 1000 1500

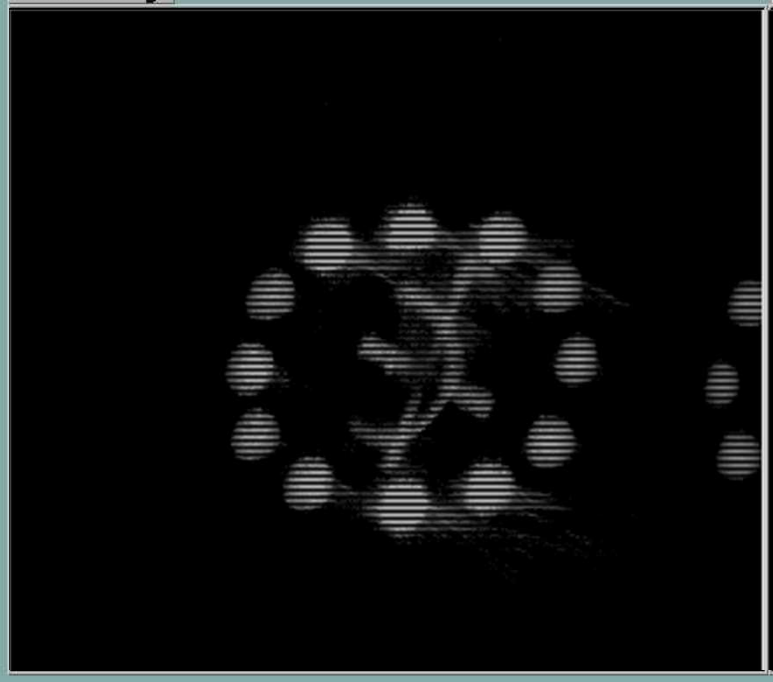
STOP PROGRAM

LTS System Alignment

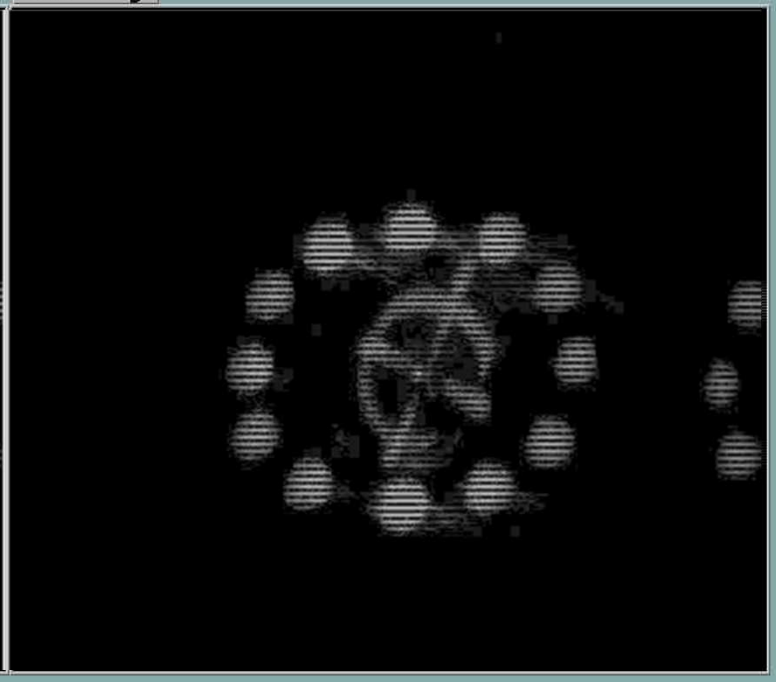
File Edit Operate Tools Browse Window Help

LTS SYSTEM ALIGNMENT

Current Image



Initial Image



Redo All Alignments

Redo Laser No.

Laser No. 1

PLC loop counter 1529

Motion loop counter 15

new directory C:\Alignment\2007_06_15_1314

Video ON

Trigger Rate (Hz) 5.0

Drive 4 Motor C

Motor Started

TOWER

Motor Control Status

	1	2	3	4	5	6	7	8	9
LASER/ MODULE NUMBER	35	3	7	11	15	19	23	27	31
	36	4	8	12	16	20	24	28	32
	1	5	9	13	17	21	25	29	33
	2	6	10	14	18	22	26	30	34

Confirm Alignment

Mirror Controls

Active Mount Select

Module # 3

M4/ UPPER

Laser Ready

Laser PFN (%)

100 75 50 25 0

73

Vset - PLC readback 73

Motor Velocity Select

500 1000 1500

STOP PROGRAM

Many hazards exist at the Z facility!!

PPE or procedures for one hazard can enhance the danger for another hazard!

Several means of controlling hazards are combined to ensure safety at Z.

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A range of controls are used to make laser operations safe.

- Laser alcove interlocked.
- Tower doors interlocked.
- Modular Hardware.
  - Replace malfunctioning units and service offline.
- Curtain placed in front of tower when servicing lasers in place.
- Curtain used as an extra layer of protection within the alcove.
- LTS operations passes control to CM when ready. CM can only operate lasers when allowed to.
- Lucite LOTO plates

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Lucite LOTO plate allows alignment of lasers, while reducing UV intensity below eye-safe levels without entirely blocking laser.

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Conclusions

- ✓ The Laser Trigger System is a versatile subsystem for low jitter triggering and pulse-shaping at Z.
- ✓ When implementing safety controls on a large machine, the designer must consider the interaction of all subsystems.
- ✓ A combination of controls and good communication habits creates the safest work environment.

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Extra Slides

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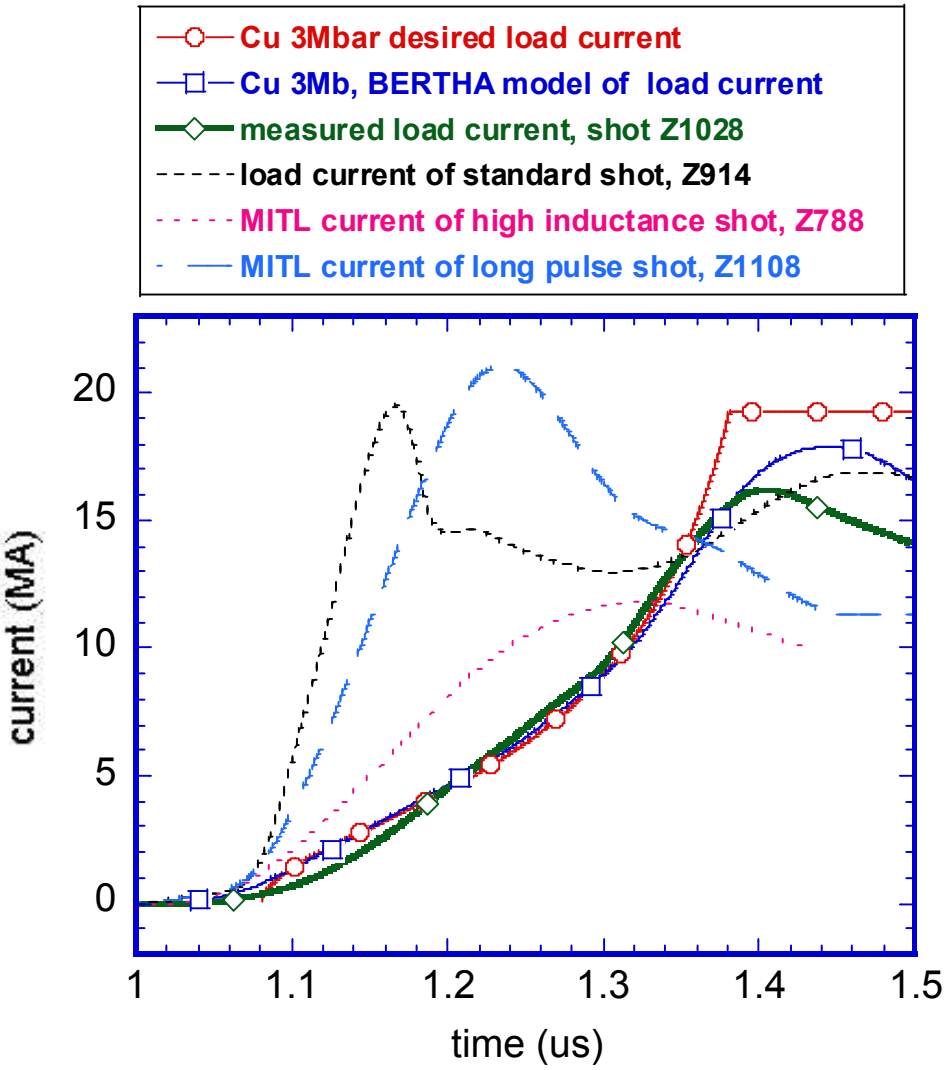
The new Tempest Laser Trigger System (LTS) brings extreme flexibility and precision to shaping the load current on Z



Advantages of the new Tempest LTS over previous methods for creating long pulse shapes on Z:

1. More Flexibility: The desired current waveform can be more closely matched. The experimenter can tailor the pulse shape to his experiment.
2. The pulse can be stretched to longer time scales, ~400 ns from foot to peak.
3. Higher maximum currents for pulse-widths >200 ns.

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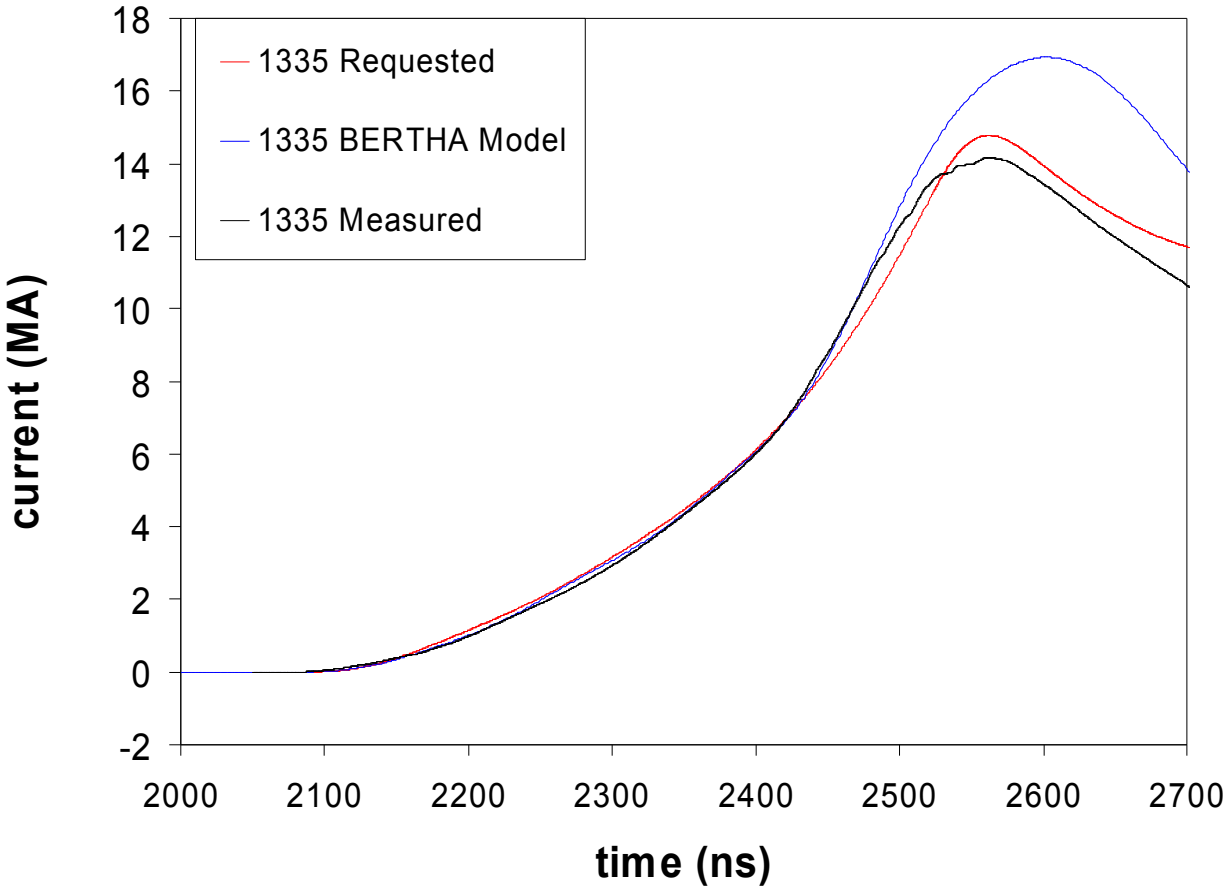
Comparison of Requested, Modeled and Measured Load Currents, Z1335



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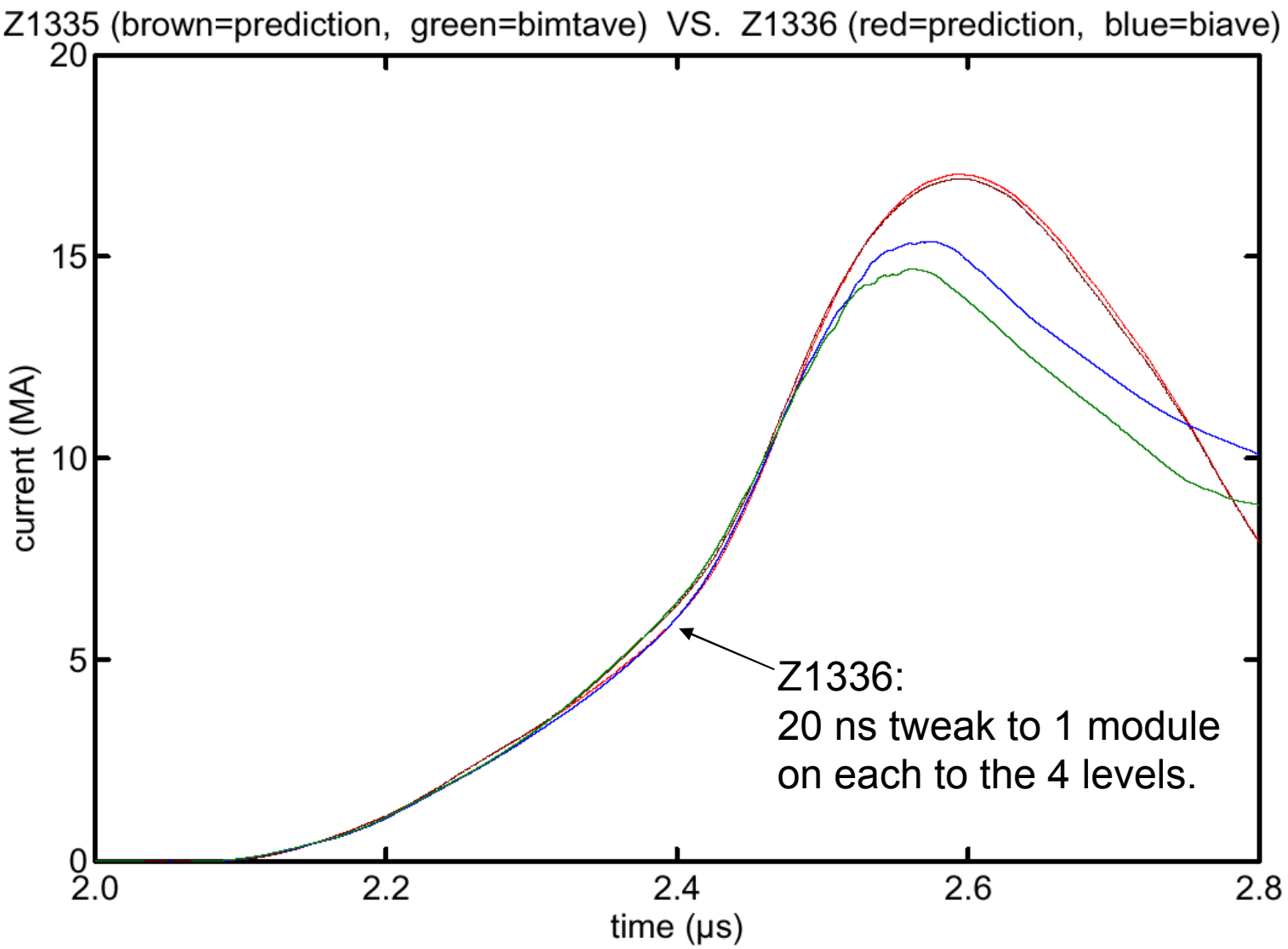
Modeling and experiment verify that subtle changes to the waveform can be made by adjusting the laser timing!!



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The Z-machine is a pulsed power driver that delivers a peak current of ~26 MA in a ~100 ns pulse!

Cut away view of a pair of ZR modules.