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Title: MicroPDV Positioning Project LANL Q-6 / BYU Capstone 2019/2020

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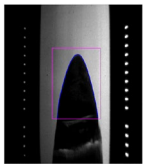
MicroPDV Positioning Project

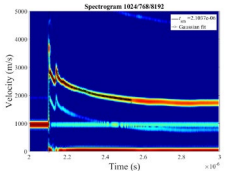
LANL Q-6 / BYU Capstone 2019/2020

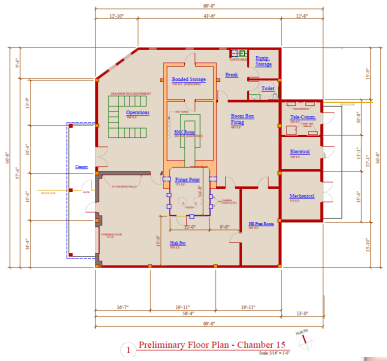
Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

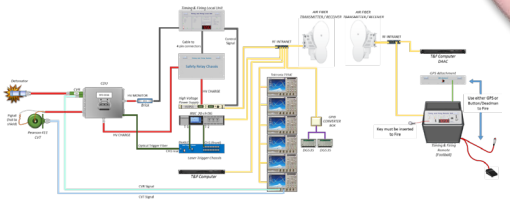
- Background
  - LANL Background
  - PDV Background
  - Current microPDV Setup
- Main Task – 5 DOF positioner
  - 5 Degrees of Freedom automated position control
  - Interface to optical camera
  - Interface to PDV signal
  - Software to control system
- Additional Tasks
  - Task 0: Laser Enclosure
  - Task 2: 2 DOF Super Positioner
  - Task 3: MicroPDV Design/Build
  - Task 4: Dynamic Testing
  - Task 5: Multipoint uPDV
  - Task 6: Motion Control Previous

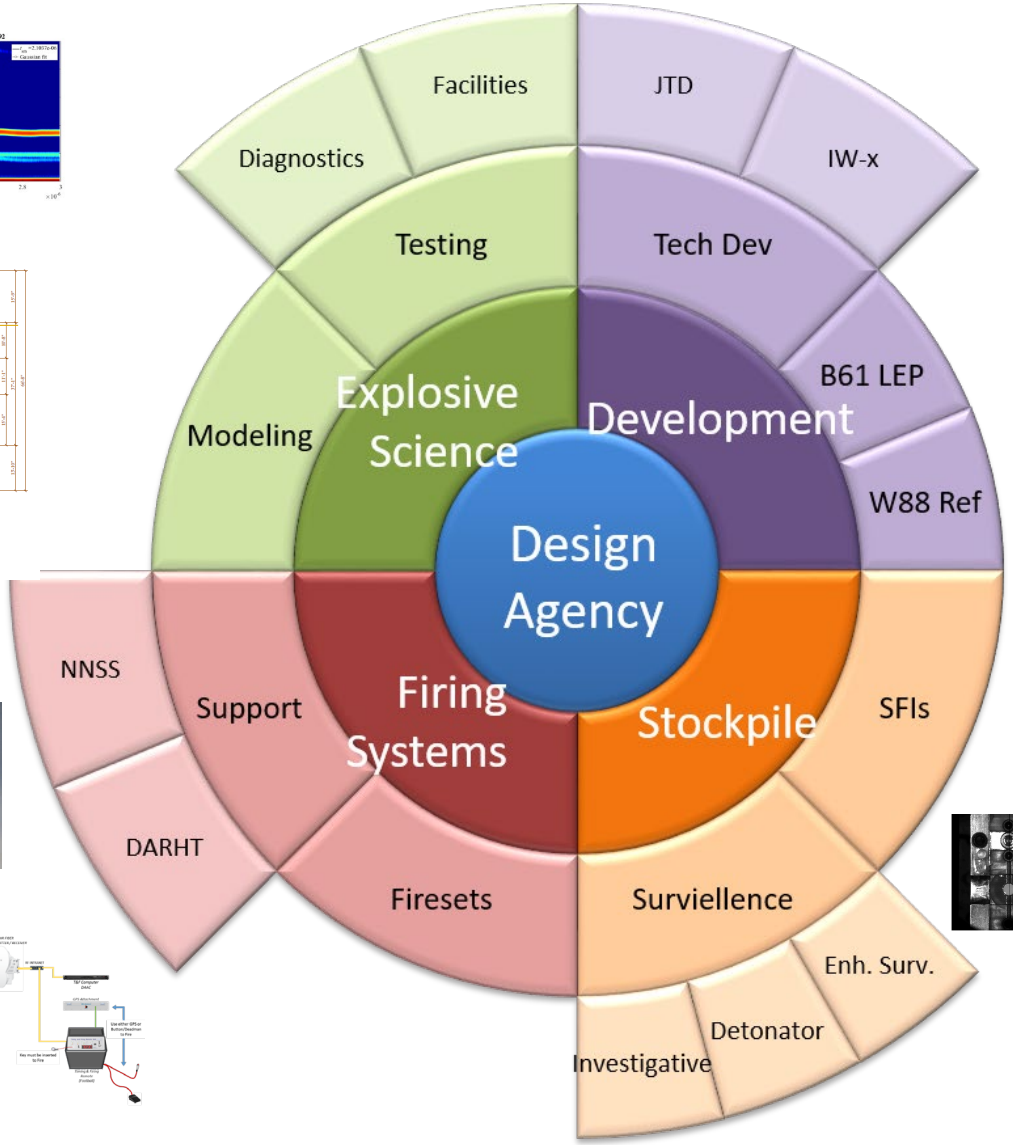
Los Alamos National Lab:
Q-6 Detonation Science and Technology:
Design Agency with Cradle-to-Grave responsibility for Detonators

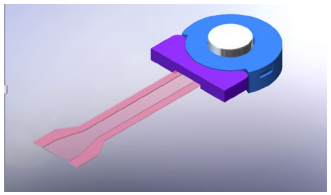


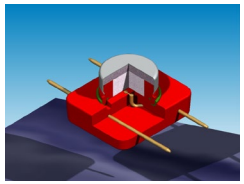




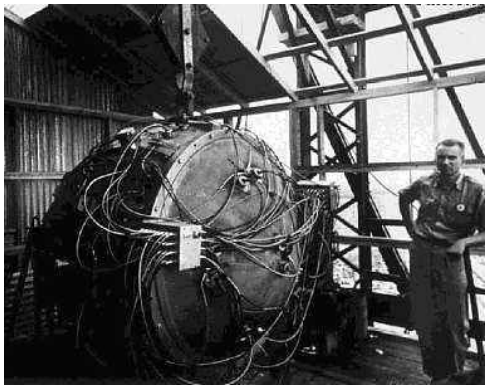


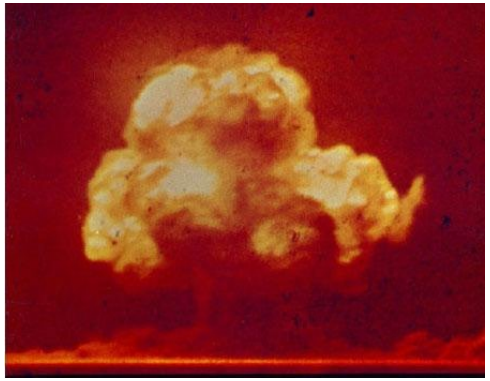






Precision Detonators were a requirement of the Manhattan Project





1943: The Manhattan Project

- **Neddermeyer proposed using HE to assemble an atomic bomb using converging detonation waves**
  - Explosives were regarded as uncontrollable destructive forces rather than precision tools
  - Blasting caps with primary explosives were unsafe and did not provide the timing necessary

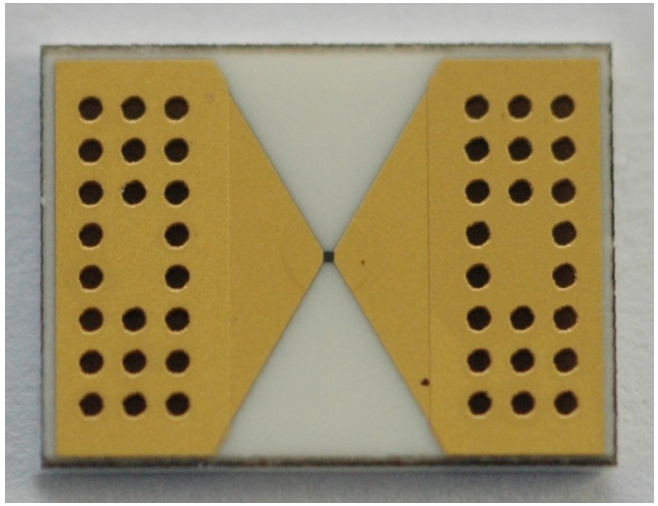
1945: Trinity Test

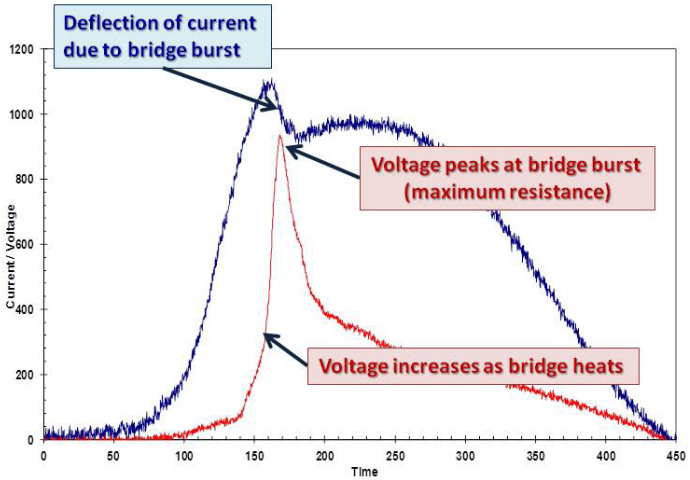
- **The 1773 EBW detonator with PETN was developed and used on the Trinity Test.**
  - PETN replaced Lead Azide, which improved safety
  - 1773 provided the precision timing required

"About one week before Trinity, the 1773 EBW detonator was declared to be the best of the competing detonator types. The 1773 EBW detonators were used on the weapon tested at Trinity and subsequently on the weapon dropped at Nagasaki."

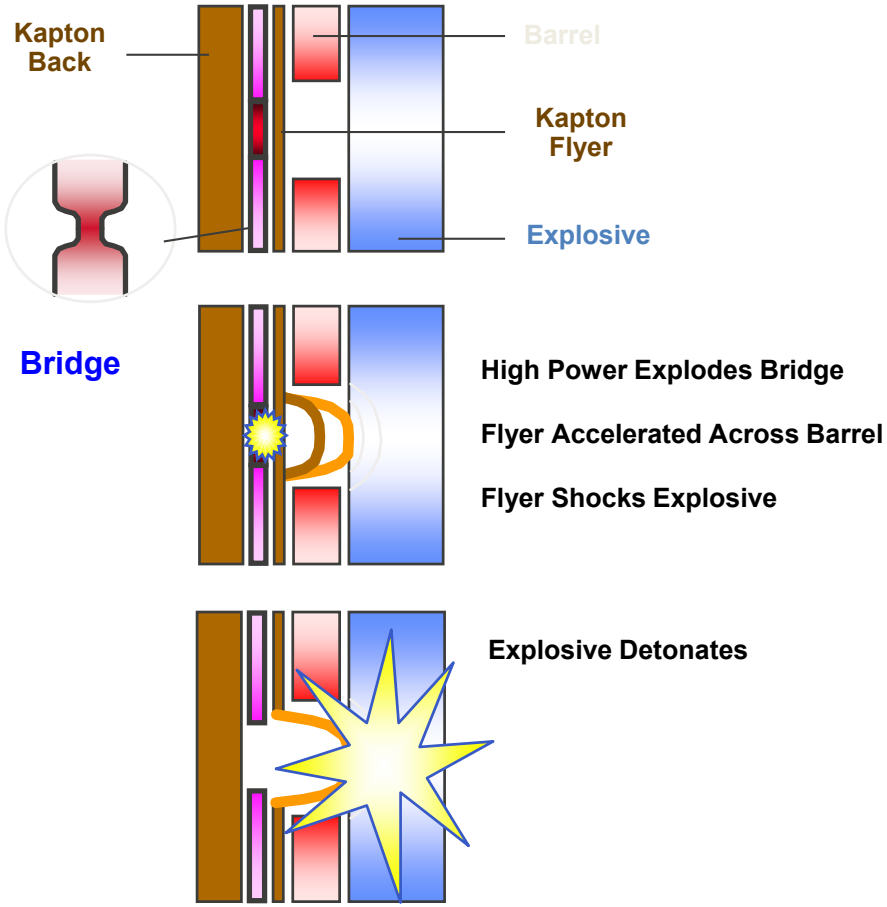
-Tucker Detonator History

Current Detonator Families: Exploding Foil Initiator (EFI) - Slapper

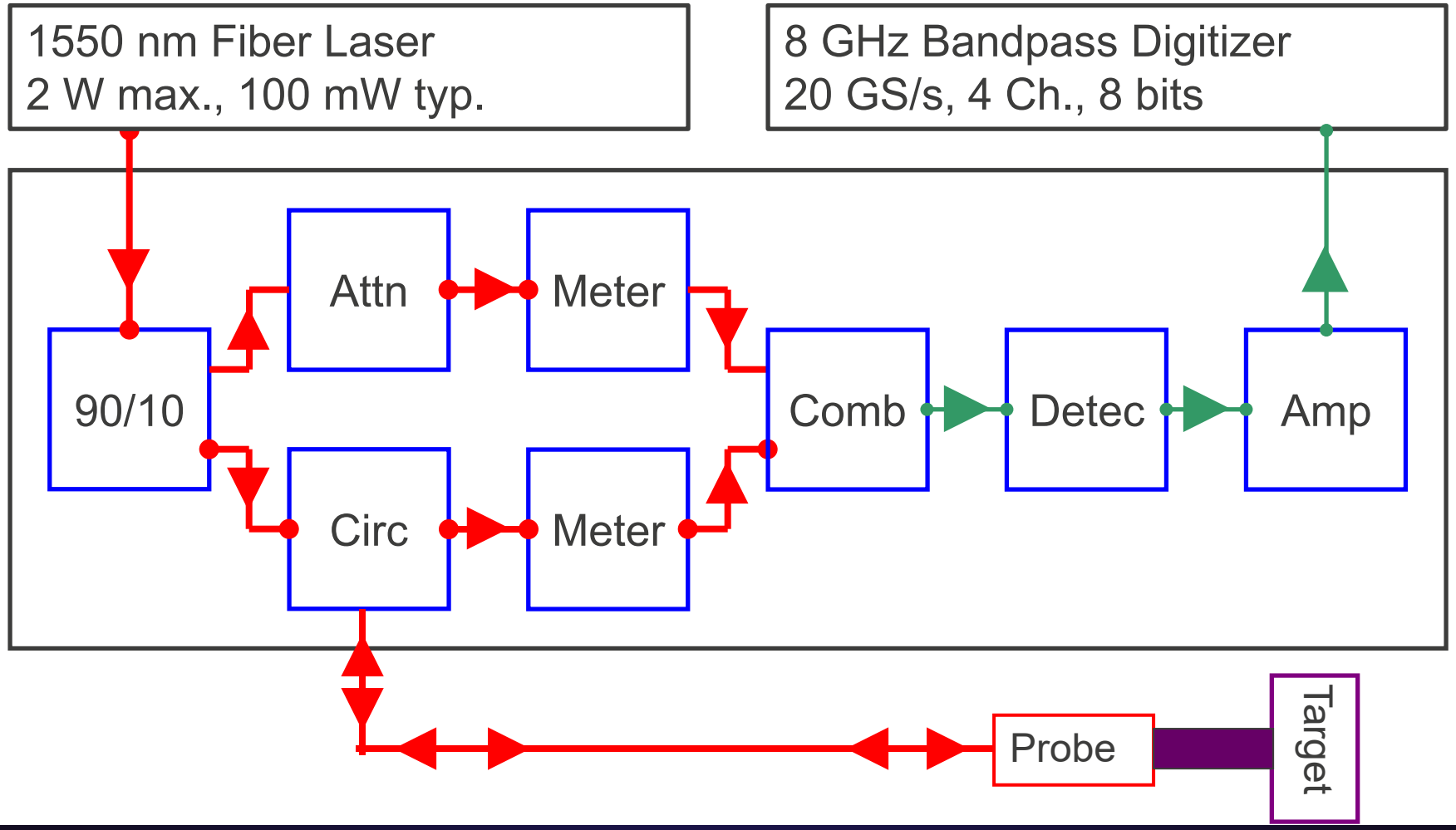




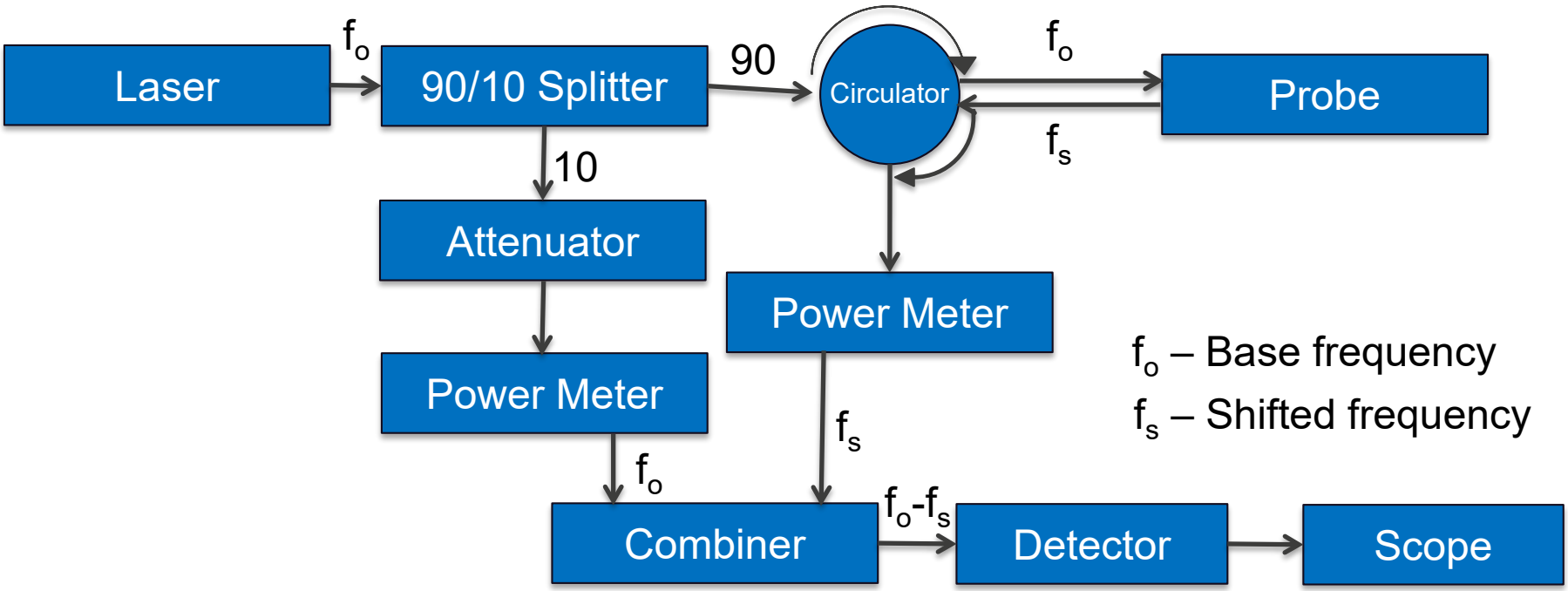
Electrical Slapper



History: 2005 LANL W-6 Adjustable Balance PDV Design



History: Current W-6 PDV internal Configuration

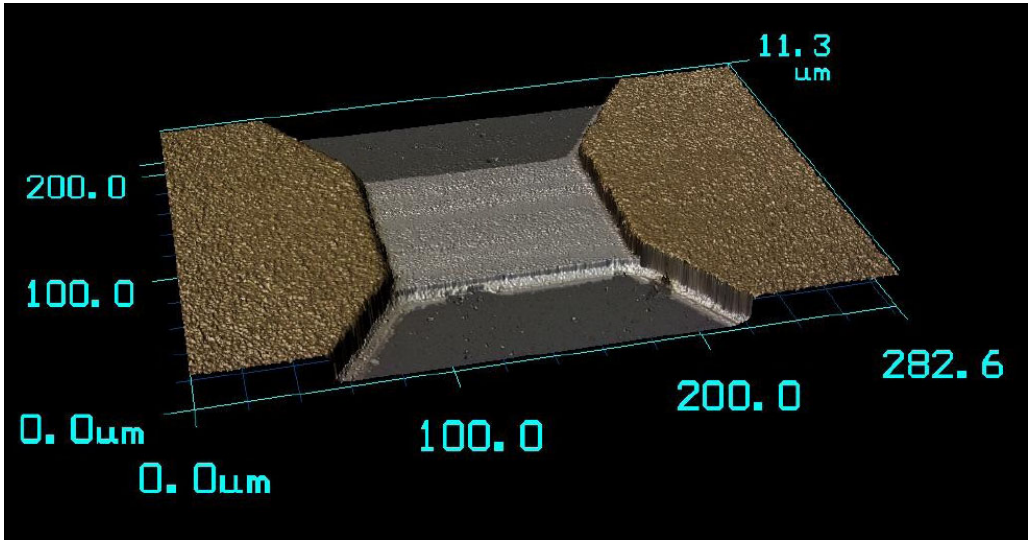


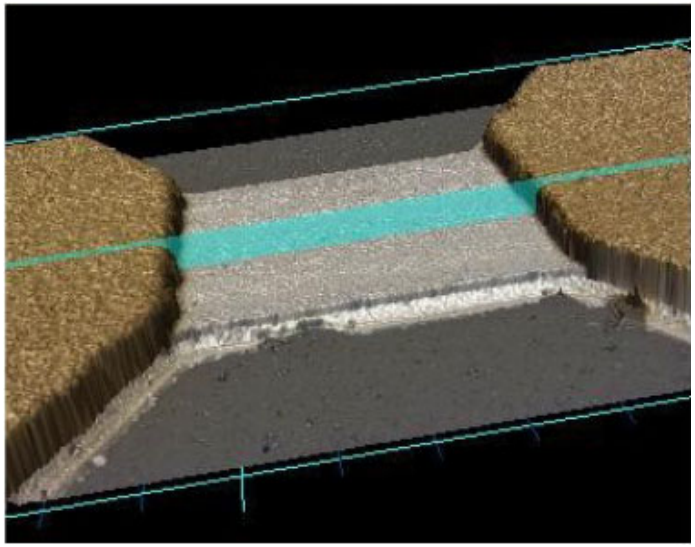
$$\cos(f_o)\cos(f_s) = \frac{1}{2}\left(\cos(f_o - f_s) + \cancel{\cos(f_o + f_s)}\right)$$

$$v = \frac{\lambda_o}{2}\Delta f$$

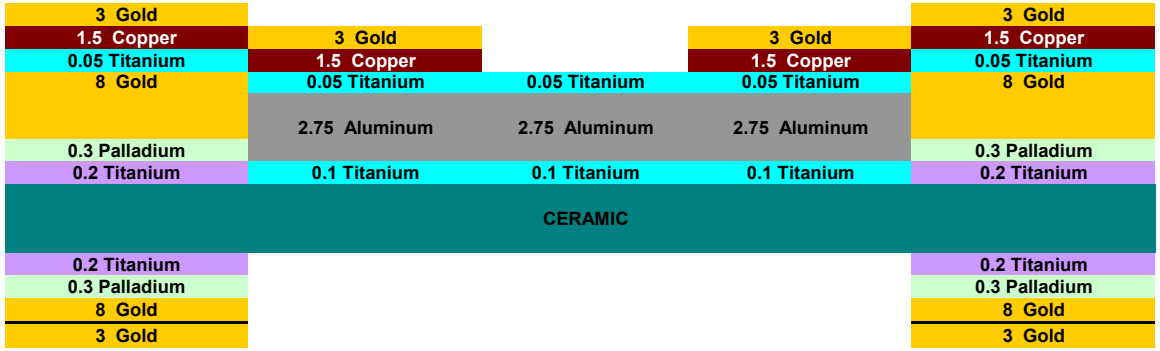
microPDV for Slapper Characterization

Chip Slapper:
Subject for the microPDV system



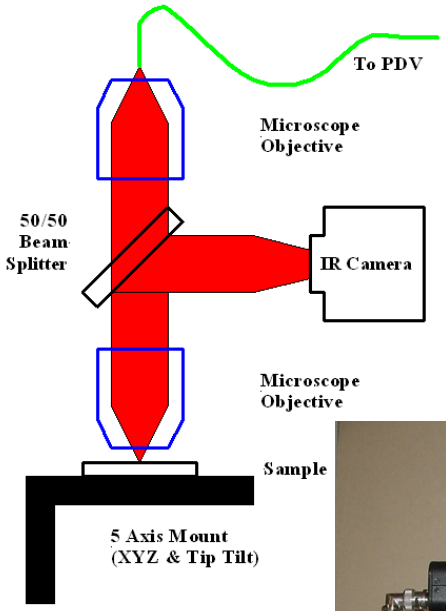


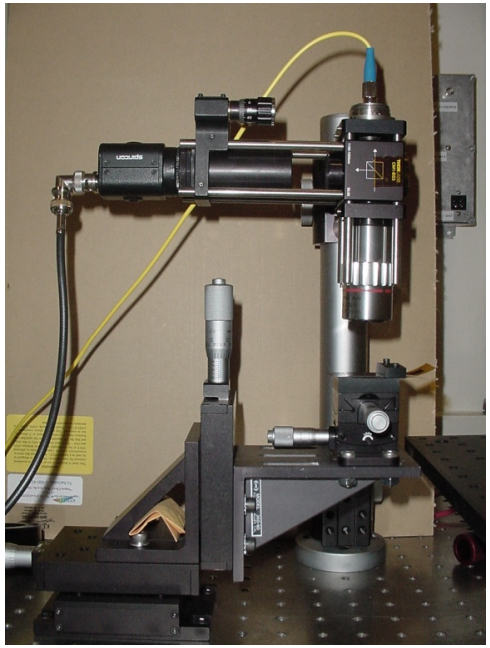
Confocal microscopy (Keyence) applied to chip slappers to characterize bridge surface and surrounding overplating



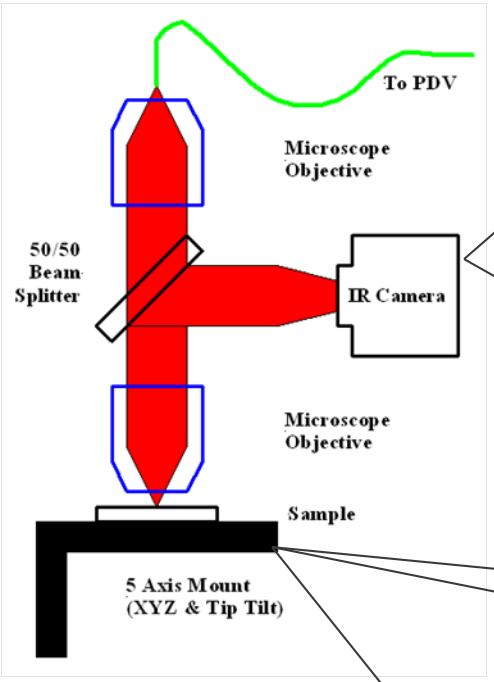
The Micro-PDV Solution: Combine IR microscope and PDV probe (Gen I μPDV)

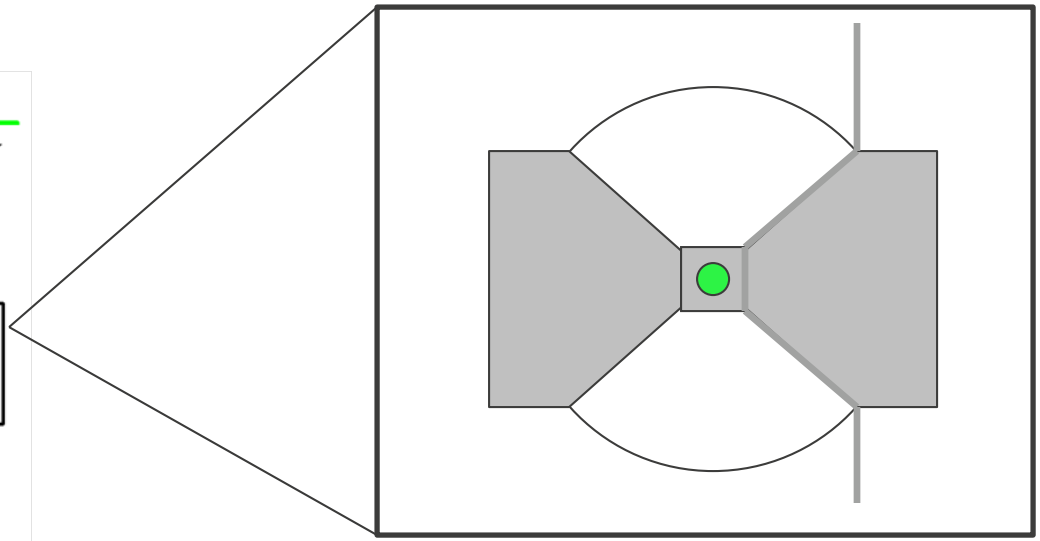
- PDV and IR Microscope System
- Allow very precise positioning of PDV probe beam on small targets (EFI Bridges, etc.)
- Very small spot size (~ 10 micron)
- 5 Axis mount allows optimal alignment of sample to PDV probe
- Using to characterize initiation events (EFI flyer, EBW bridge burst, DOI Ablation, etc.)





microPDV:
Visualize PDV spot on sample





IR camera monitor

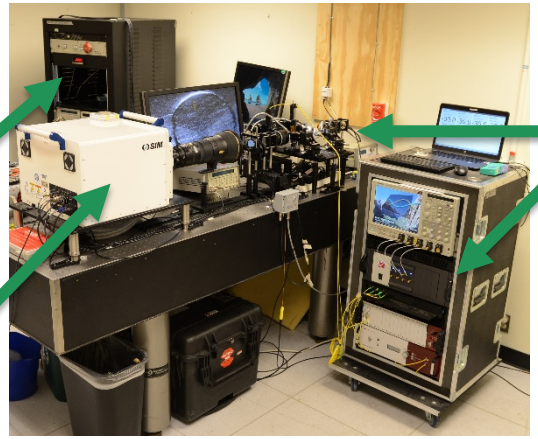
IR Camera:
Edmund Optics
PN: NT56-567

Goniometer Stage

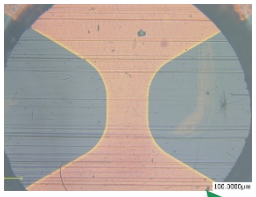
Dedicated flyer characterization lab was recently stood up by Q-6 (TA22-120-125) for the purposes of initiator-scale R&D on microclad- and chip-based flyers

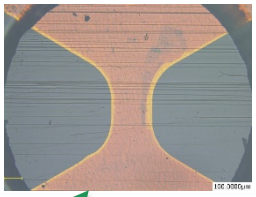
Slapper lab

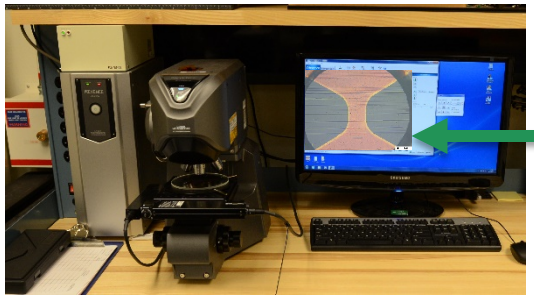
- **Highlights include:**
  - High-voltage firing rack and oscilloscope for collecting electrical diagnostics
  - Initiator-scale Shock Wave Image Framing Technique (SWIFT)



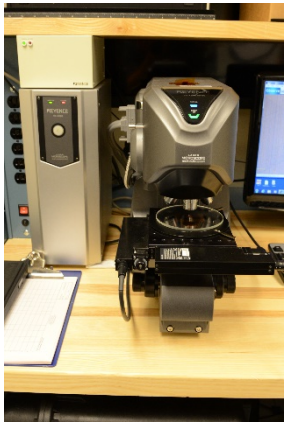
  - Micro-photonic Doppler velocimetry (μPDV)







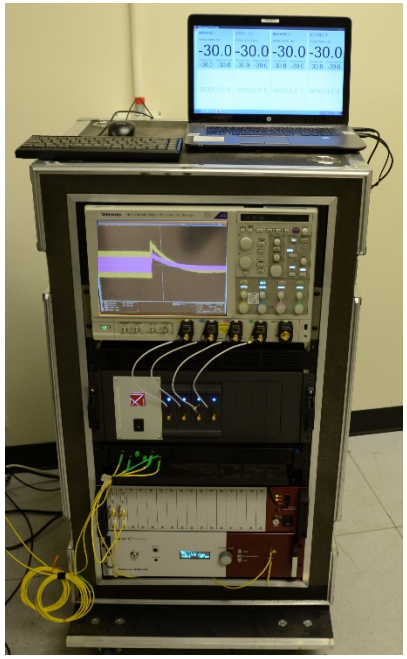
  - Keyence 3D laser-scanning confocal microscope

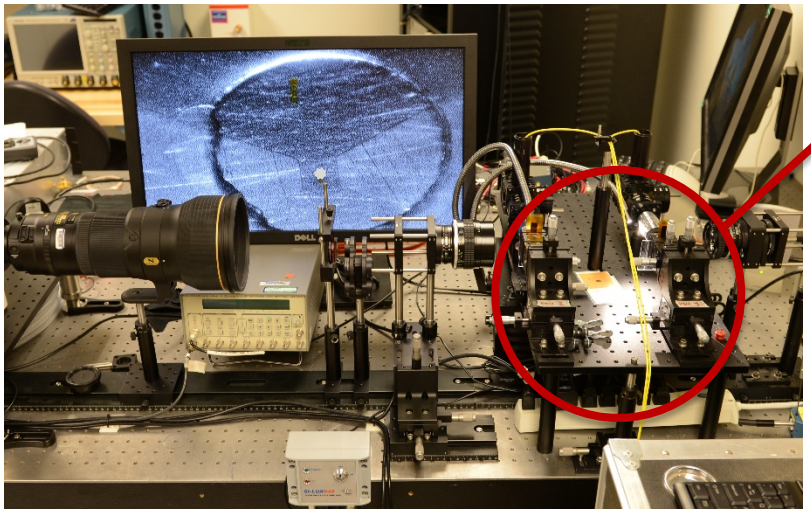


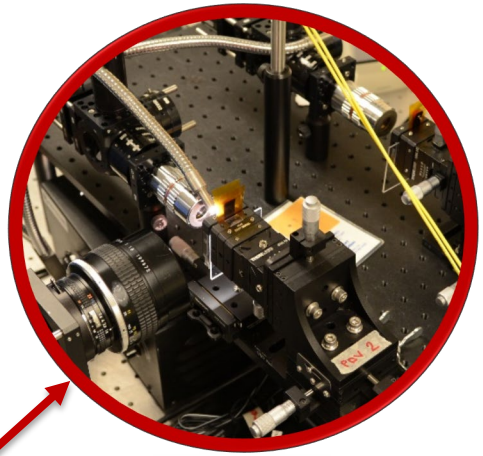
Gen IV µPDV system provided increased data return: 80/96 flyer velocities and 92/96 PMMA mass velocities measured

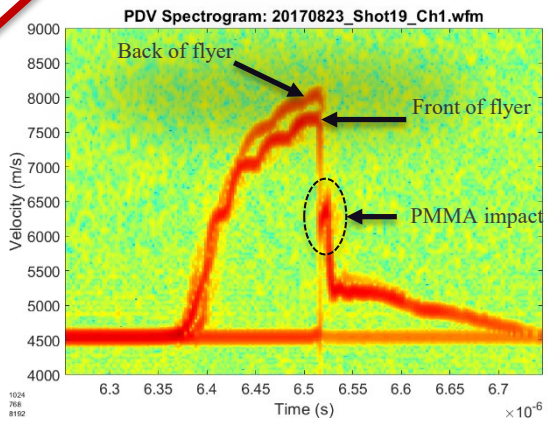
Gen IV µPDV System

- New fully computer controlled upshifted multichannel PDV system
- Floating 3-axis optical table setup with micrometer adjustments
  - Alignment decoupled from imaging diagnostics

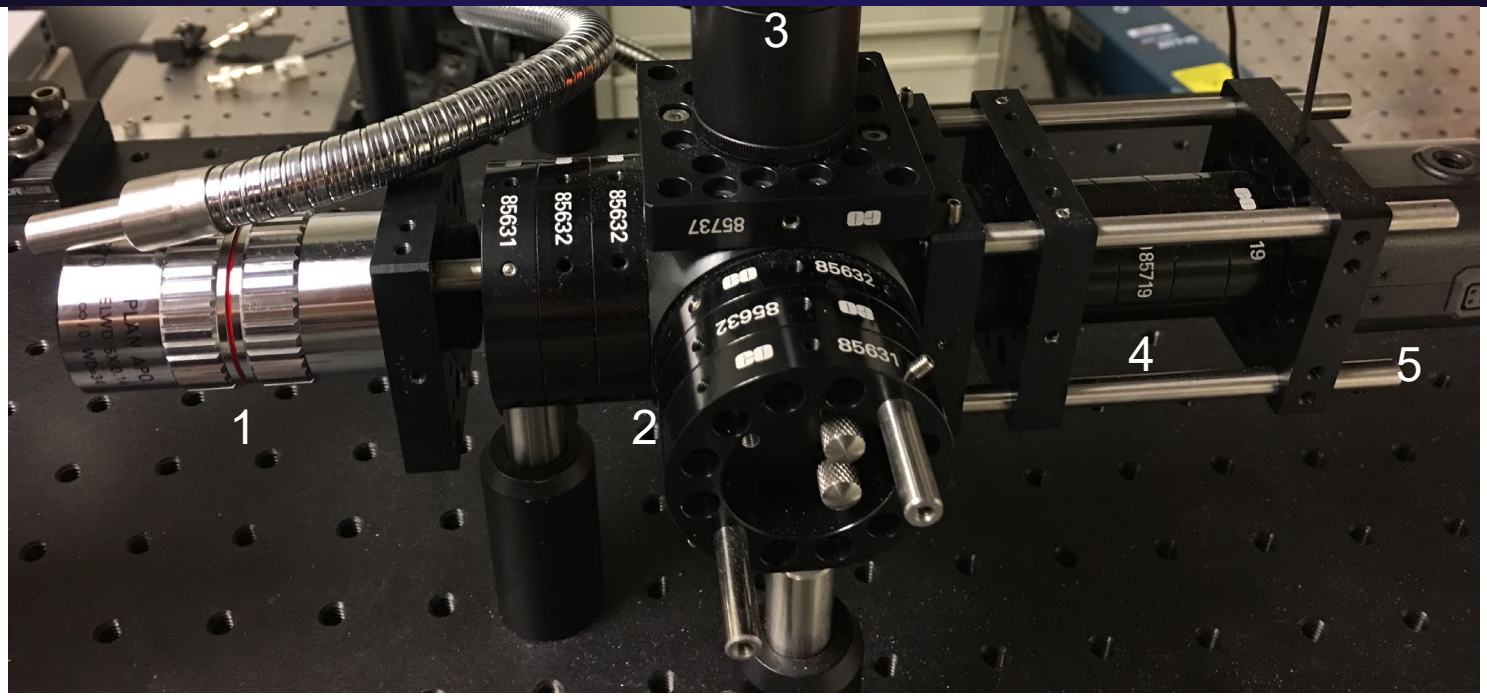








MicroPDV Probe Info



1- 10X long working distance objective
2- Dielectric Splitter with tip/tilt
3- PDV fiber Collimator injection with tip/tilt
4- Imaging lenses for camera
5- IR sensitive camera

Parts List at: https://www.edmundoptics.com/resources/application-notes/optomechanics/optical-cage-system-application-digital-video-microscope/

DICHROIC ASSEMBLY

7

Parts needed for this step:

STOCK #	Description	QUANTITY
85719	25.4mm Dia. Adapter for 85710	1
85710	Square Tip/Tile Optic Mount	1
N/A	25mm Dia. Dichroic of choice (see details under filter)	1
85624	Cage Sphere with (5) 30mm Port and (1) 43mm Port	1
85632	25mm Standard Cage Plate with M6 for Post Mounting	1
85737	30mm Square Interface Plate	1
86018	Filter Holder Plate	2

Primary Task: 5 Degree of Freedom Position Control with feedback from Imaging and PDV sources

Task 1A: Automated 5 Degree of Freedom Positioner

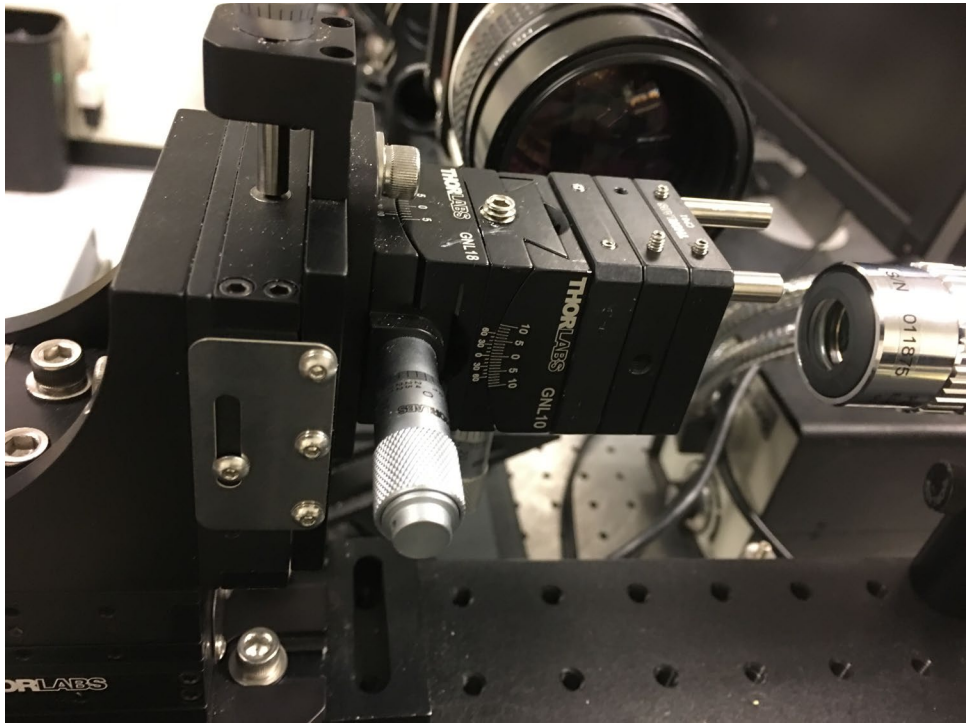
- Objective
  - Automated 5 Degrees of Freedom

- Requirements
  - X,Y position control … micron resolution (~1um) with ~1 cm range
  - Z position control … two scales Coarse on cm scale with at least 3 cm range and fine on micron scale (+/- 1um)
  - Tip / Tilt … microdegree resolution

- Capstone team to determine best solution
  - Determine best solution, and present solution to LANL (ideally before Thanksgiving)
  - Get quotes for parts for solution (ideally before Thanksgiving)
  - LANL to order parts for delivery to BYU

Current 5 DOF manual control hardware

- Tip Tilt from ThorLabs Goniometer
  - +/- 5 Degrees / +/-1 10 Degrees motion
  - .1 degree accuracy
- XYZ from Thorlabs Translation stage



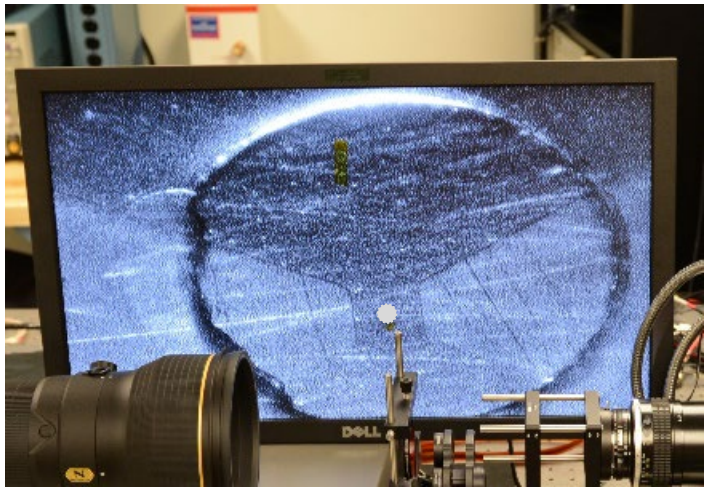
Lots of Options for 5 (or 6) Axis control

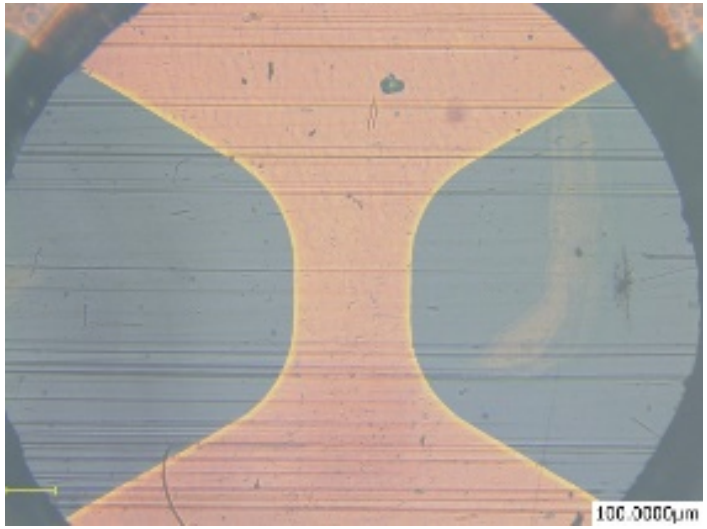
Task 1B: Computer Vision Feedback System

- Objective
  - Locate PDV spot on bridge. Move bridge in XY and Z-Coarse to position PDV spot in center of Bridge
- Requirements
  - Locate PDV Laser Spot
  - Locate Bridge
- Capstone Team to develop
  - Computer Vision software approach
  - Interface to camera (frame grabber)
  - Optional: replacement camera

Computer Vision

- Locate Bridge and PDV spot
  - Distinctive Bow-Tie shape
  - Find edges
  - Find the PDV spot
  - Position PDV in middle of bridge
  - LANL will provide a couple of different bridge pictures for preliminary work
  - LANL can provide actual parts later in project
- Interface with Camera
  - Current camera is Analog, and would require frame grabber
  - We have tried other cameras with mixed success
  - New Camera can be part of Optional Task 3

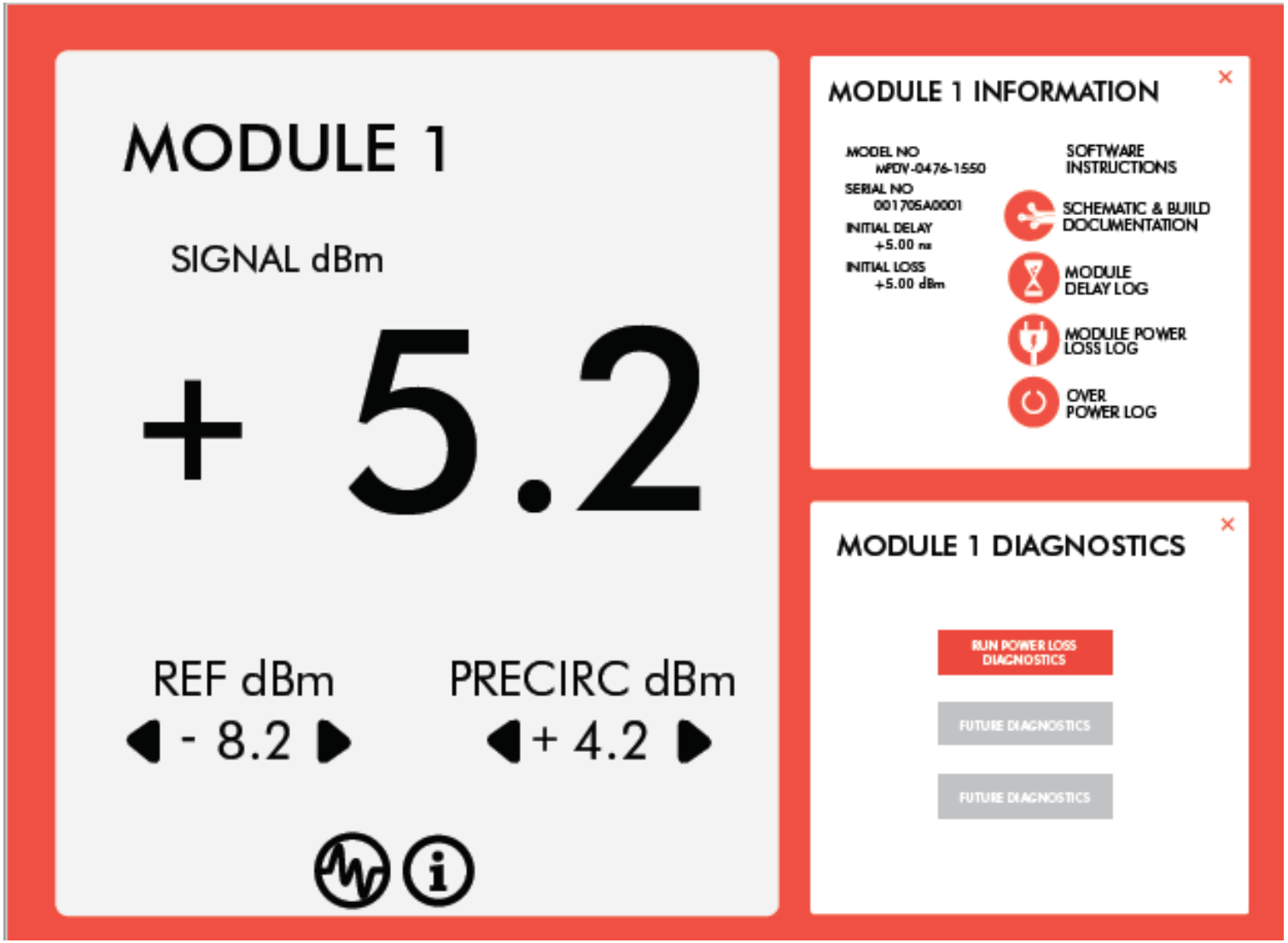




Task 1C: PDV Signal Feedback System

- Objective
  - Maximize PDV return signal by adjusting tip/tilt and Z-Fine adjust
- Requirements
  - Optimize (maximize) PDV return signal
- Capstone Team to develop
  - Interface with TS&I software
  - Tip/Tilt/Fine Z adjustment WITHOUT changing X/Y position from Task 1B
  - Optional: allow for consistent “detune” off of max signal

TS&I Software Control



Task 1D: Control Software for Full Integration

- Objective:
  - Bring together all the parts into one user friendly software package

- Requirements:
  - Control positioning equipment
  - Interface to camera and TS&I
  - Automated and manual control of adjustments
  - User Friendly

Additional Tasking: Optional Tasks for Improved System

Task 0: Laser Safety Enclosure

- Objective:
  - Develop approach for safe class 4 laser work at BYU

- Requirements:
  - Meet BYU safety requirements
  - For LANL use, we will need two Side Ports as well

Task 2: 2 Degree of Freedom SuperPositioner of MicroPDV system

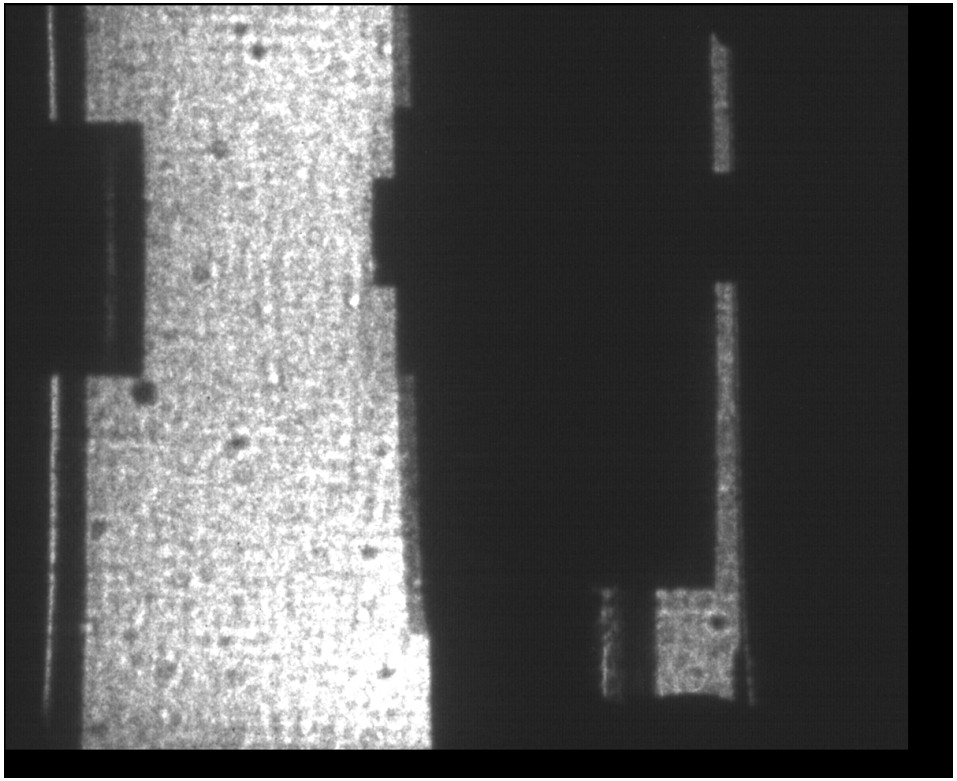
- Objective
  - Entire microPDV setup to have Rotation and Z-translation

- Requirements
  - Once completely aligned, the entire microPDV system (probe and 5-axis positioner) needs to be aligned to additional experiment, without disturbing the microPDV setup.
  - Rotation around the Y-axis (vertical), and translation along the Z-Axis
  - Could be manual control, but ideally using the same control software program and hardware interface
  - BYU Basic Design should account for this need even if Capstone team does not work on this task

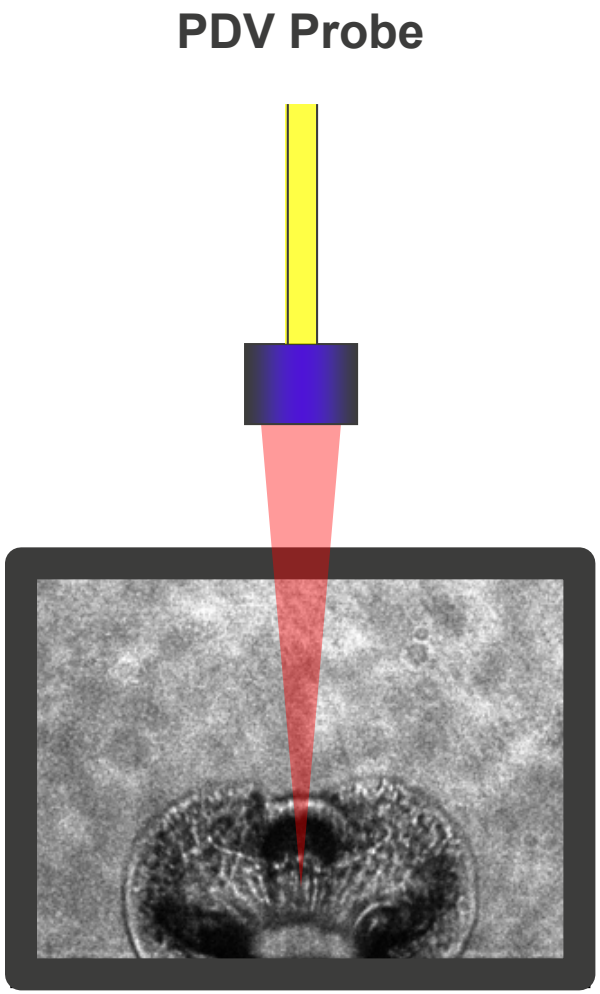
- BYU Capstone team
  - Build microPDV system in such a way as to allow for this control as well
  - Incorporate this control into the software design

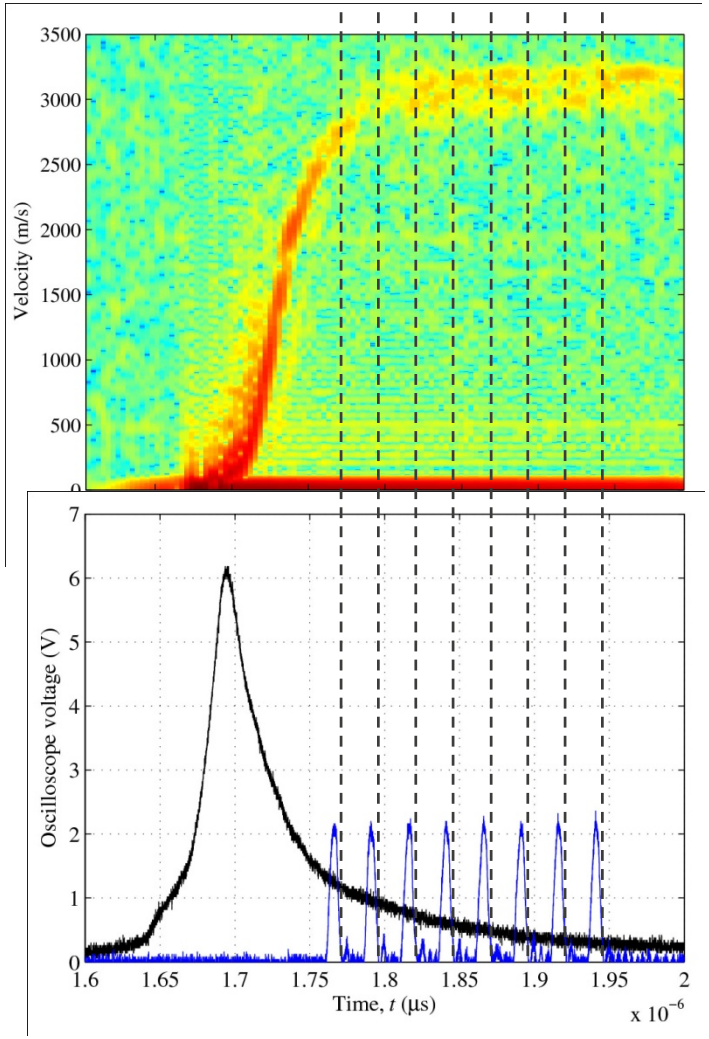
Simultaneous PDV and Laser Backlight

- Explosive drive of large flyer
- PDV of drive and flight of the flyer
- Verification of PDV and flight characteristics
- Multiple diagnostics on one shot



Simultaneous Schlieren/PDV on Chip Slapper



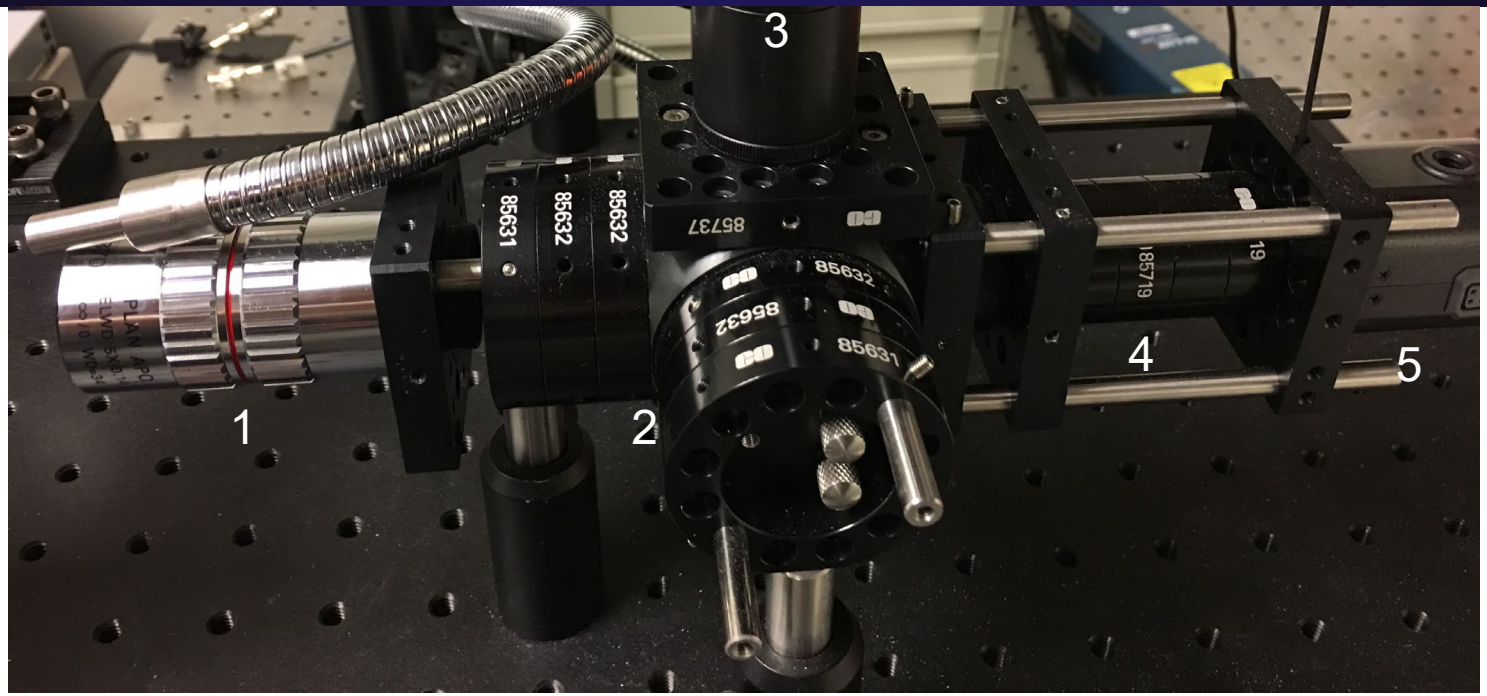


Task 3: MicroPDV Probe Build or Redesign/Build

- Objective:
  - Design/Build a GenV uPDV, with improvements over the GenIV system

- Possible areas of Improvement over Gen IV
  - Camera improvements (Analog to Digital Camera, Improved Resolution)
    - Note: Current Camera is balance between IR sensitivity for spot, and leaking visible light for location of bridge
  - IR bulk illumination of the Bridge
  - Custom parts for GenV system
  - PDV alignment tools

MicroPDV Probe Info



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Parts List at: https://www.edmundoptics.com/resources/application-notes/optomechanics/optical-cage-system-application-digital-video-microscope/

Products / Lasers / Laser Measurement and Electronics / Infrared (IR) and Ultraviolet (UV) Viewers

Family ID #2418

High Resolution 1550nm Converter for CCD Cameras

- Converter Extends Standard CCD Cameras into IR (1495 - 1595nm)
- Device for Imaging or Alignment Applications

The 1550nm Converter is a low cost alternative to expensive IR viewers. When attached to a monochrome camera with typical visible spectral response characteristics, it creates an imaging system with extended sensitivity into the NIR region. Conventional silicon based CCD cameras are predominantly sensitive around 850nm. A proprietary phosphor coating (using patented AST technology) on both the Converter's lens system and 1550nm-camera's sensor converts the 1495 - 1595nm band to Si-based CCD detectable wavelengths without fade or lag.

With an imaging lens attached to the Converter, it acts as a 1:1 relay lens for ½" sensor cameras, simultaneously relaying high resolution, low distortion, uniform NIR images while converting the images to an SI detector wavelength. A focus ring at the rear of the Converter allows adjustment for wavelength-focus variation and focus optimization onto the camera. Large Format lenses (designed for sensors >28mm) are recommended to maintain highest resolution, in order to fill the Converter's active area and maximum light throughput.

Without an imaging lens (as shown in photo), the Converter is also useful for beam alignment as the phosphor coating allows visualization of any 1550nm beam on its input window. The Converter features a large aperture window that is anti-reflection coated to ensure maximum image resolution is transferred. Increased sensitivity for beam profiling and telecommunication applications can be obtained by utilizing the IR Converter together with the 1550nm camera. Other applications include surveillance and inspection.

Note: Phosphor coating is partially transmissive outside the optimized coating band (into the visible). For viewing objects in the visible-NIR spectrum simultaneously with 1550-NIR wavelengths, an illumination source with NIR output is recommended for use with the 1550nm camera, but especially for the Converter (since the optical system significantly reduces light throughput).

Task 4: Dynamic Testing at LANL of system

- Objective:
  - Trip to LANL for installation of system and dynamic testing of real parts

- Drivers:
  - Bring system, or prototype system to LANL in early winter Semester for dynamic testing.
  - Make improvements on the system based on actual use and feedback from LANL Users

Task 5: Multipoint MicroPDV

- Objective:
  - Modify uPDV GenV system for multipoint applications

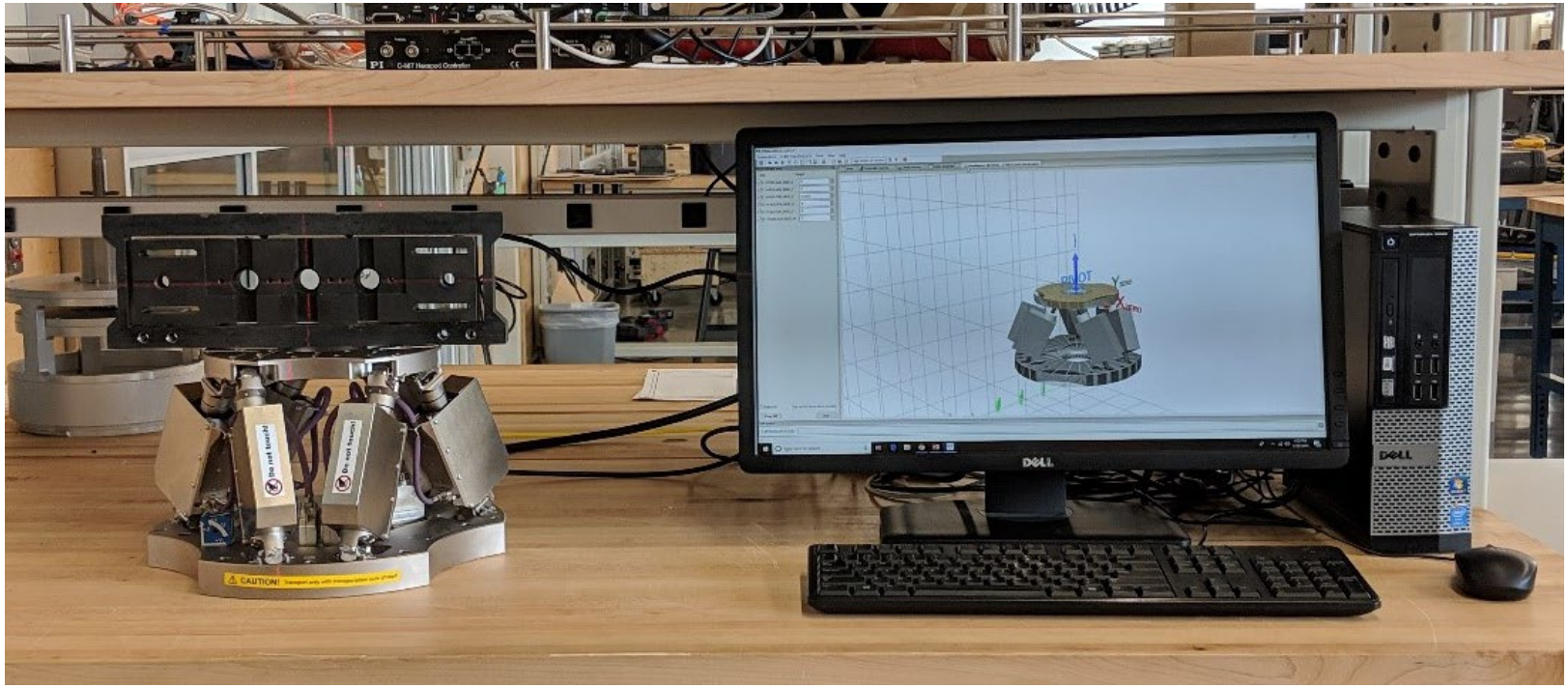
- Possible areas of improvement
  - Redesign current 3 point multipoint probe
  - Add a rotation around Z-axis degree of freedom for multipoint
  - Incorporate fiber arrays into GenV system

Task 6: AutoControl Software for LAST year's Capstone Project

- Objective
  - Image recognition application to last year's project

Areas of Improvement

- Camera interface on last year's project (Det Shot Bar Alignment)
- Auto leveling and alignment using last's year's hexapod HardWare

Image Recognition

- Control last years project using computer vision