Imperial College London

CDS and Laser Diffuser Ball

WCTE Collaboration Meeting 22/07/22

Lauren Anthony

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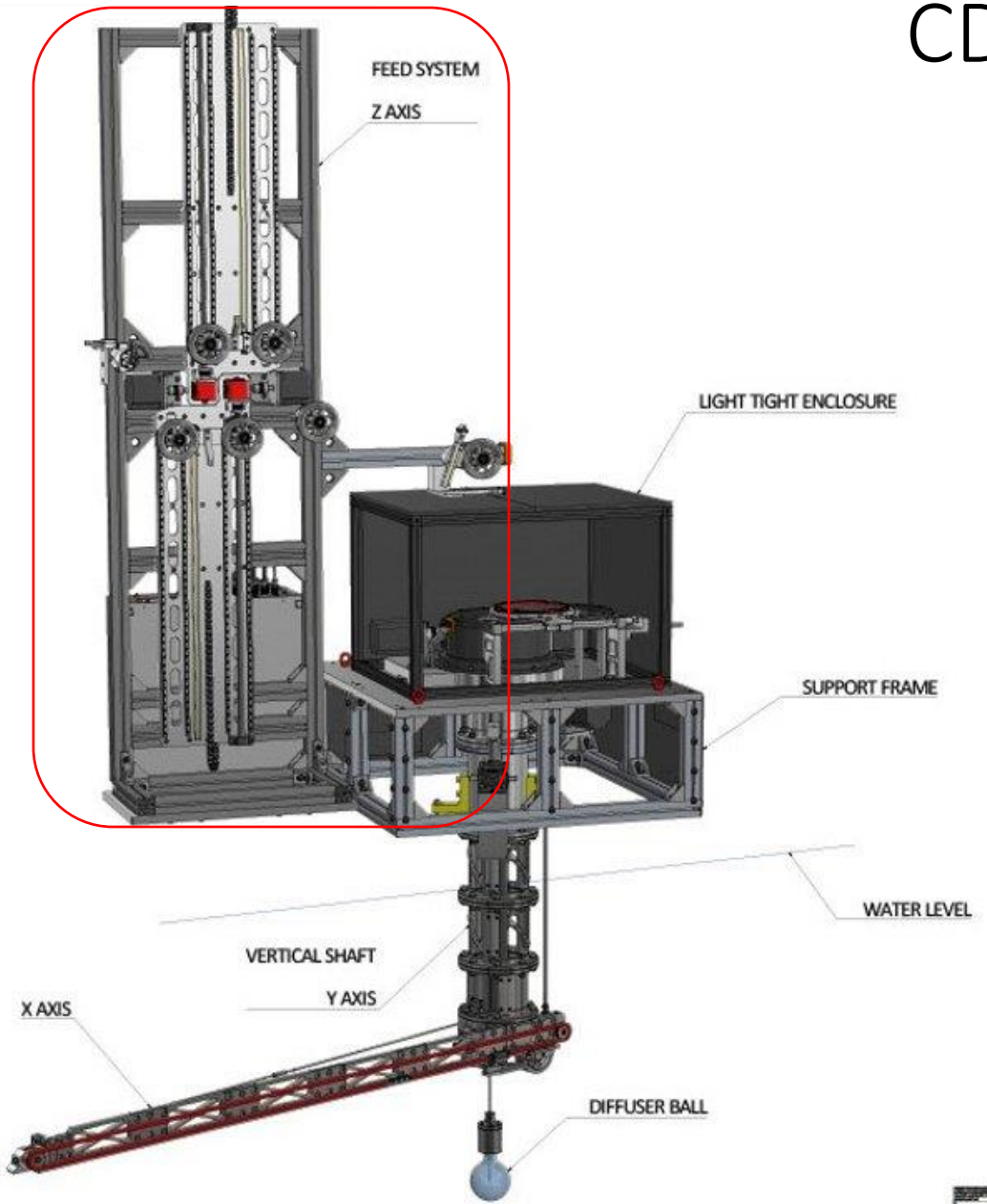
CDS WCTE collab
22/07/22

CDS Overview



Designed for calibration sources to be interchangeable

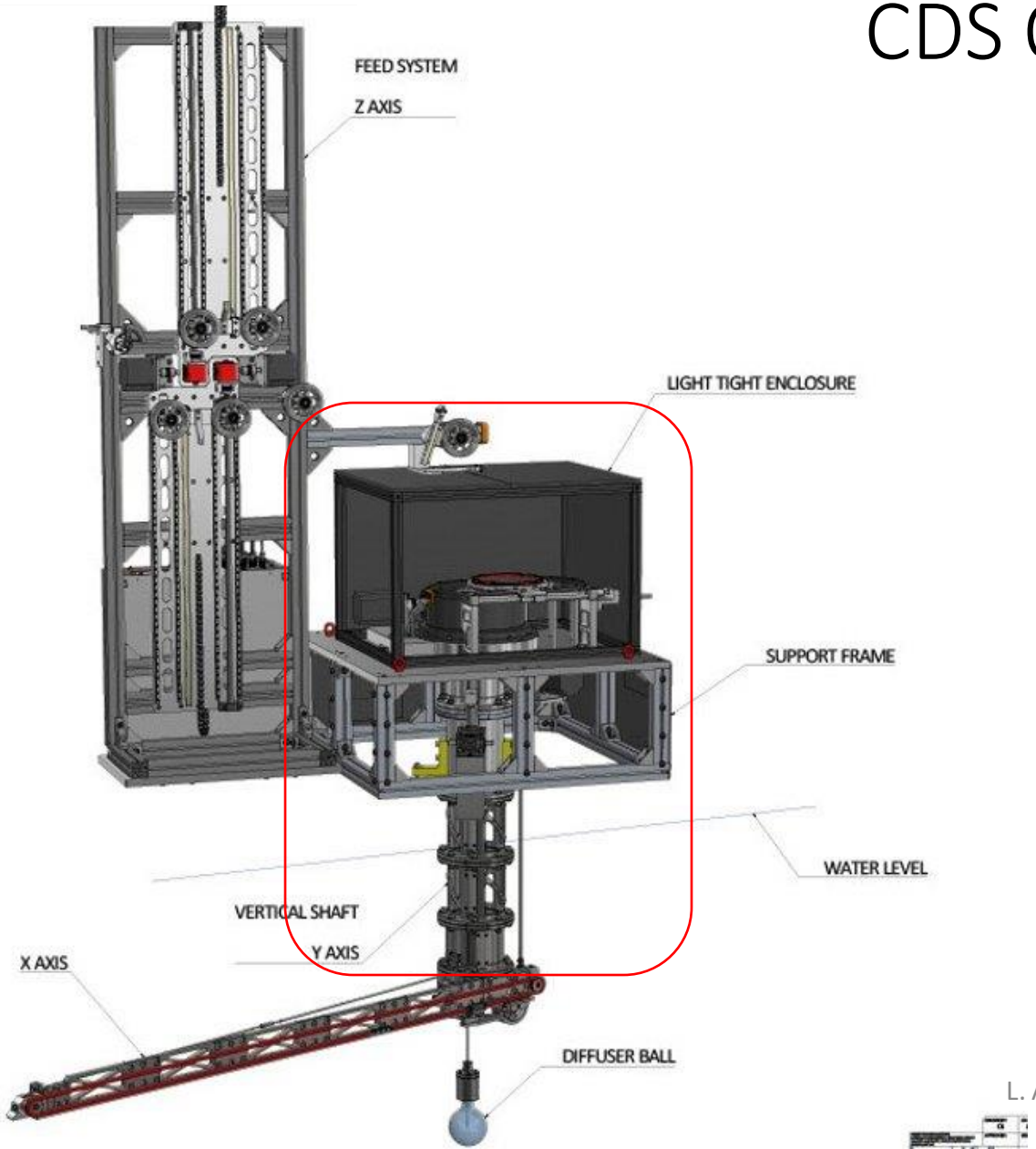
Z Axis – 92% complete
- Encoders to be added
- Electronics cabinet to be added

Y Axis – 70% complete
- Vertical shaft to be manuf.
- Dark box to be built / small frame to raise up
- Encoder to be fitted

X Axis - 60% complete
- Modification to arm stiffness
- To be remade in SS316 (prototype is Al)

Software and GUI to be developed by LA / OJ & Alie, Yassine

CDS Overview



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General
- Encoders still to be integrated with electronics

Software and GUI to be developed by LA / OJ & Alie, Yassine

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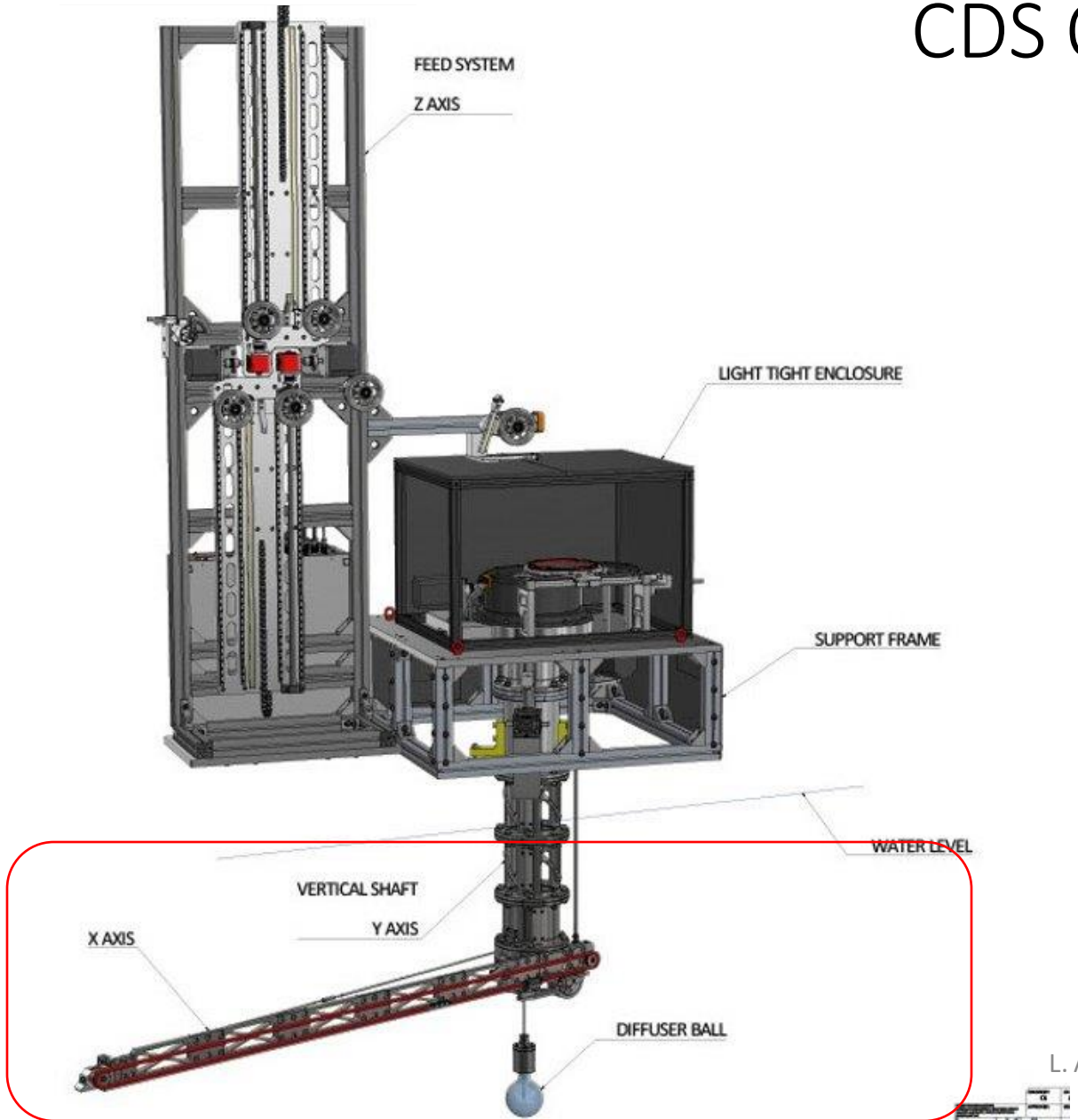

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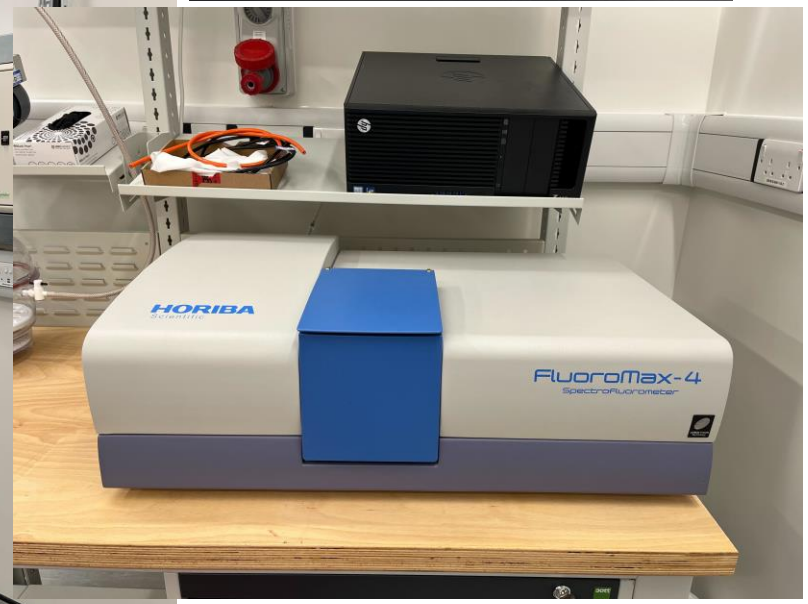
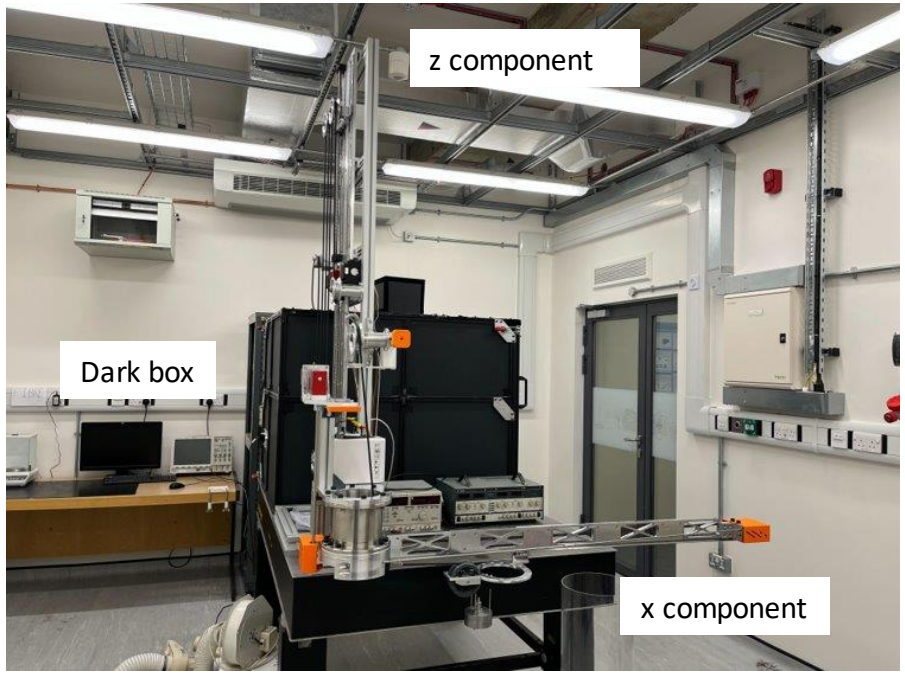
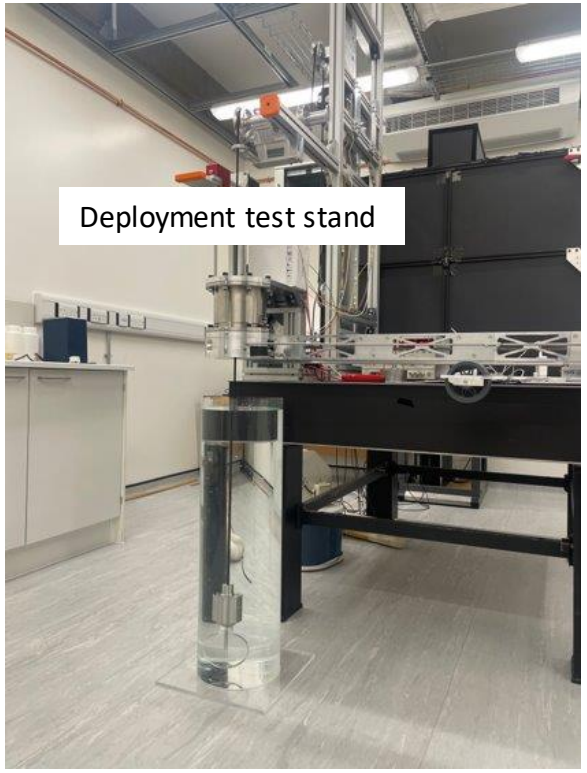
Current Status in Lab

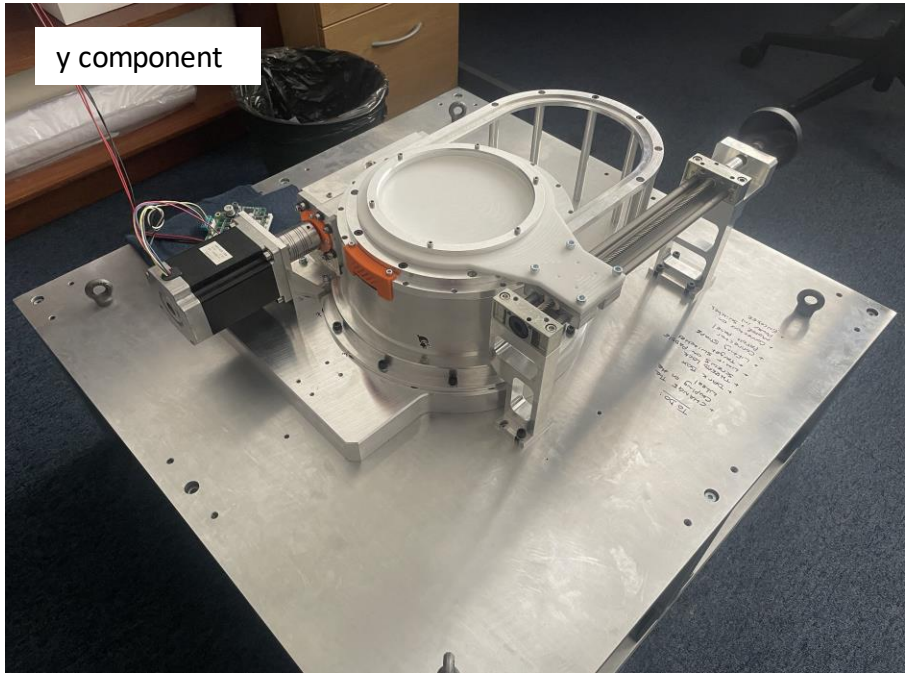


CDS prototype

- X and Z components built in lab and motors wired in
- Y component built separately
- Laser ball deployment test stand also in place







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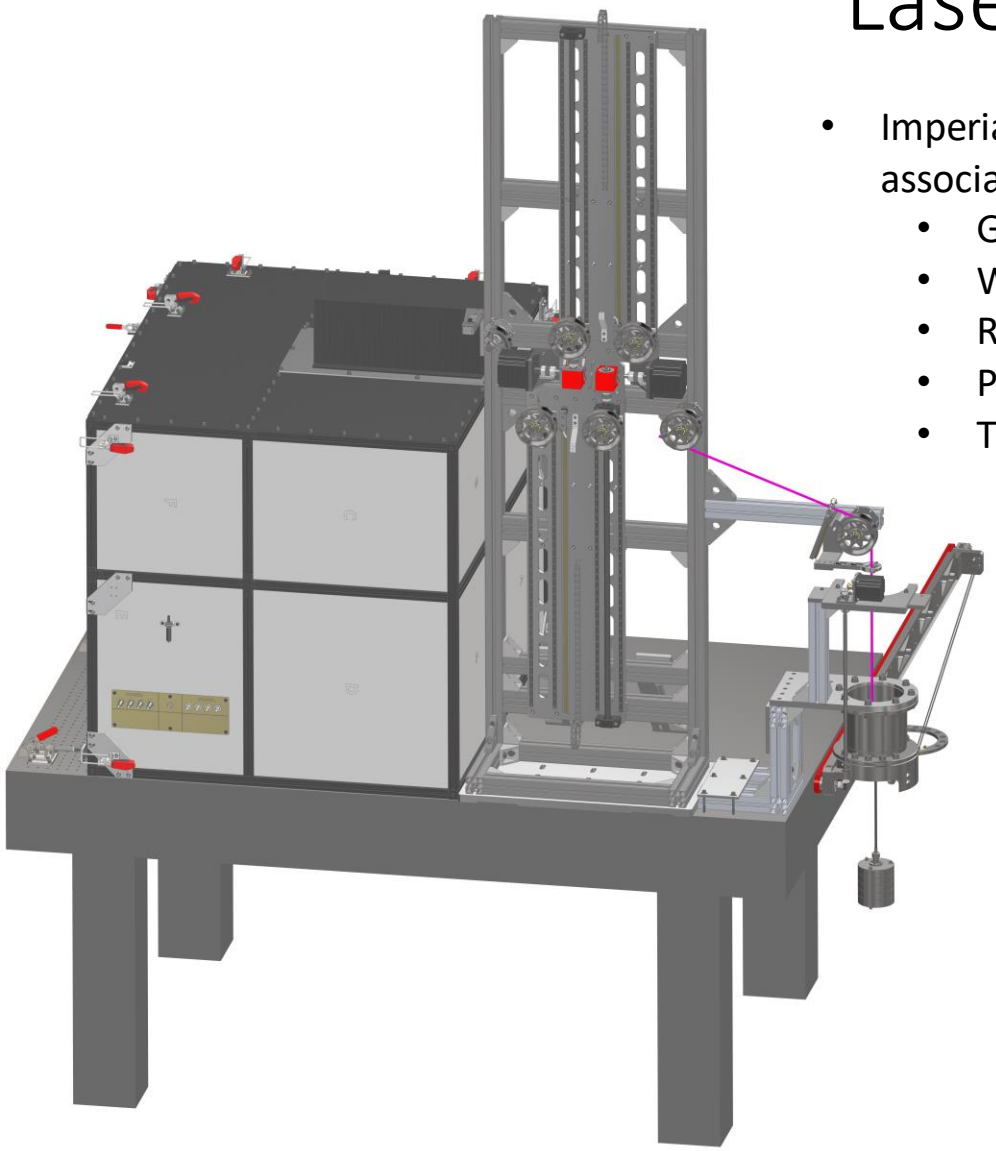
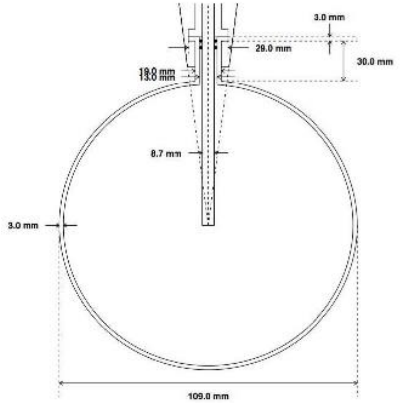
Laser Ball Development



- Imperial group is designing/fabricating a laser diffuser ball and associated deployment system for HK/IWCD/WCTE to measure:
  - Geometry
  - Water See Alie's talk in the analysis session
  - Reflections
  - PMT response
  - Timing



- Build on SNO/SNO+/DEAP3600 design
  - Quartz flask
  - Suspended glass spheres
  - Optical gel
- Using WACKER silgel
  - 612 (softer setting)
  - 604 (harder setting)
  - 3M glass microspheres @ 0.4% by mass

Diffuser Ball - Design

Split clamp

O rings (All seal – FKM)

Inner Seal

V Seal

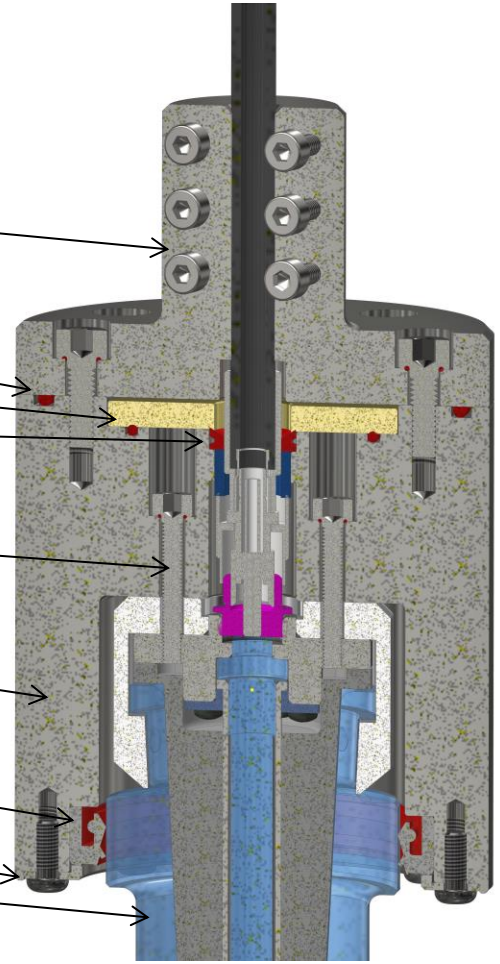
Sealed Screws

316 Preload mass – 1.5Kg

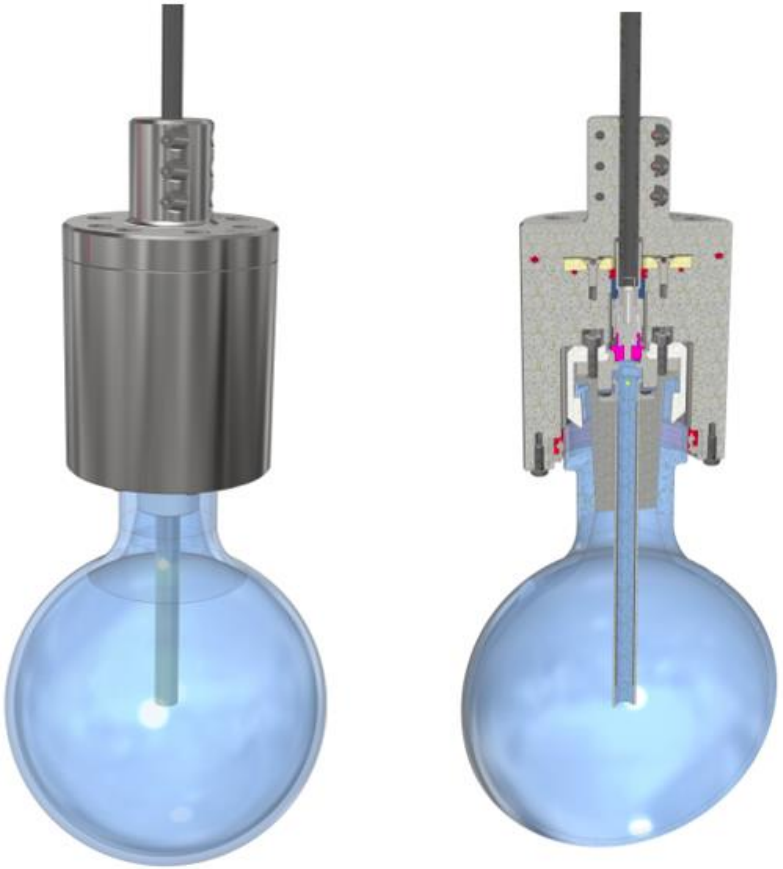
Fluid Seal

Fluid seal retaining ring

Flask with sealing feature



1.5Kg Stainless Steel Mass



Diffuser Ball - Internals

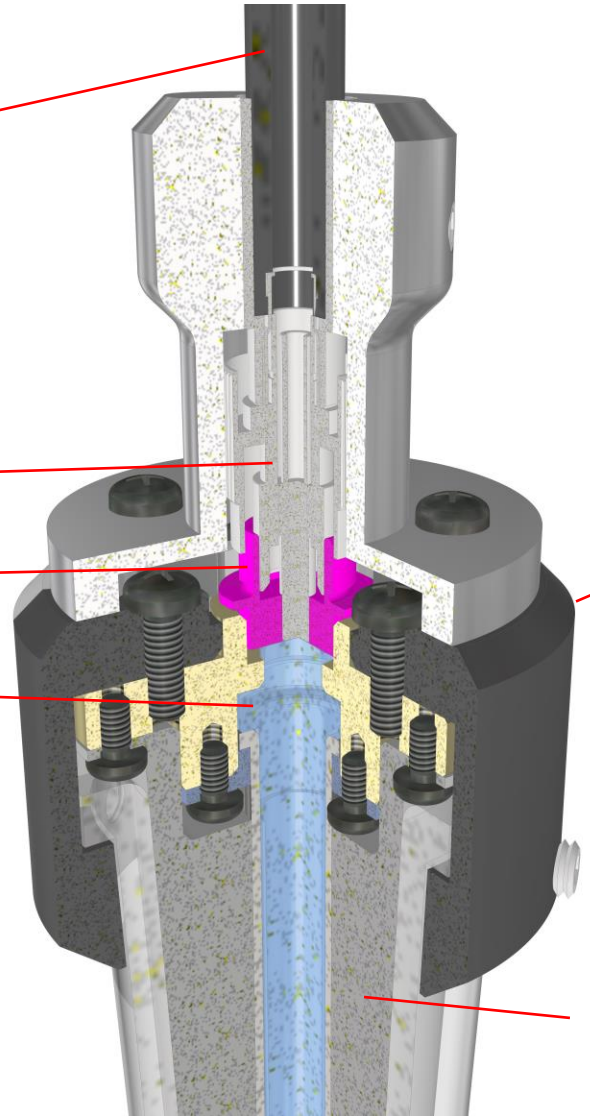
Stainless Steel Mass
(not shown)

Thor Labs Umbilical Tube

Fibre Connector

Thor HAFC Bulkhead Connector

Quarts / Acrylic Light Guide (with SS sleeve)



Retaining split clamp

Taper Neck Bung

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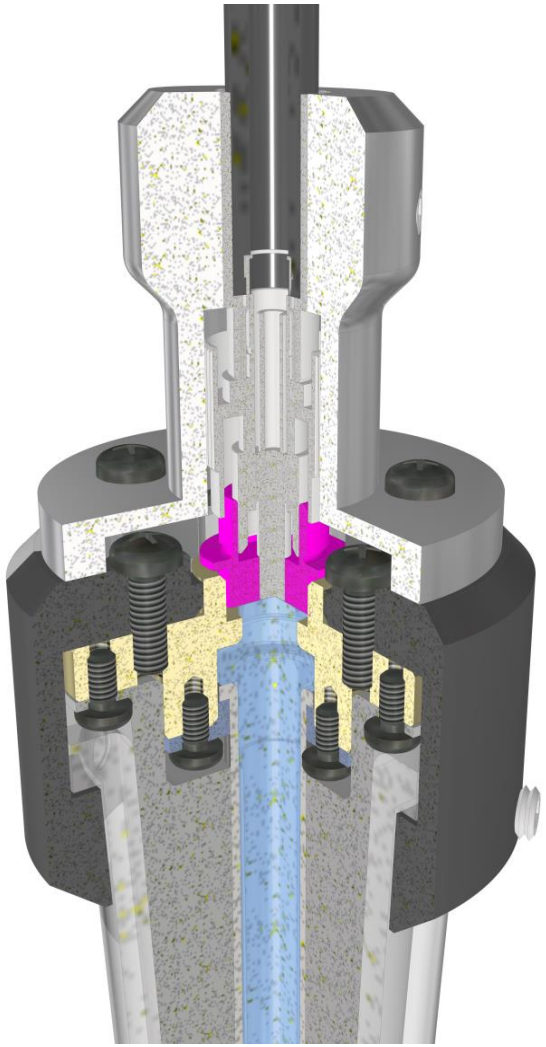
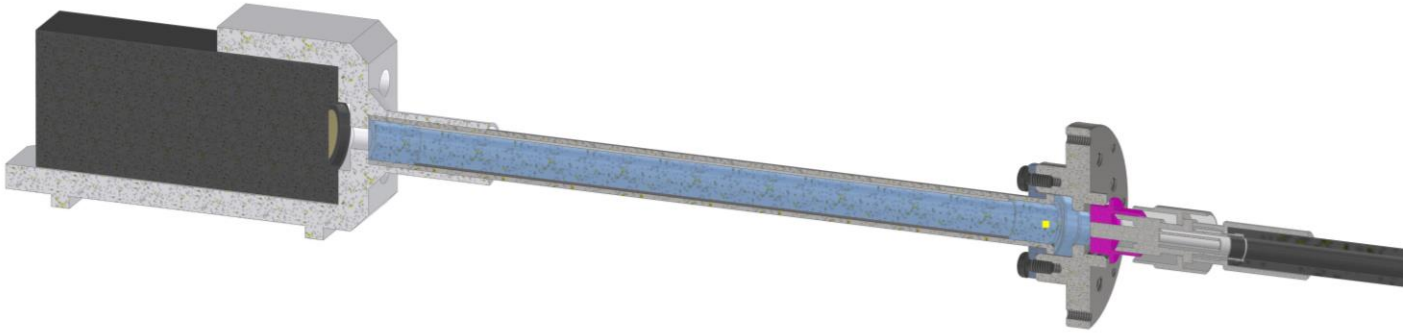
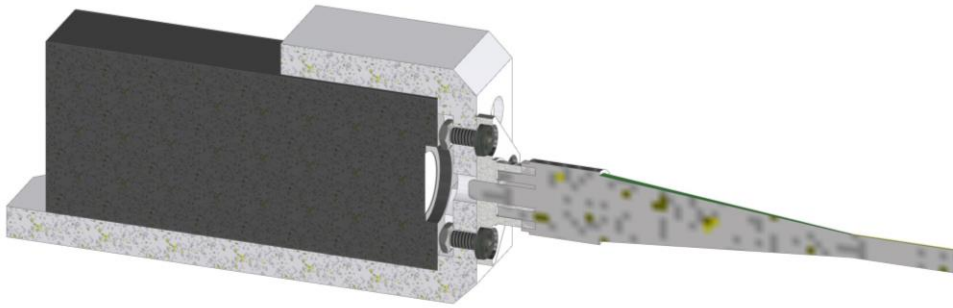
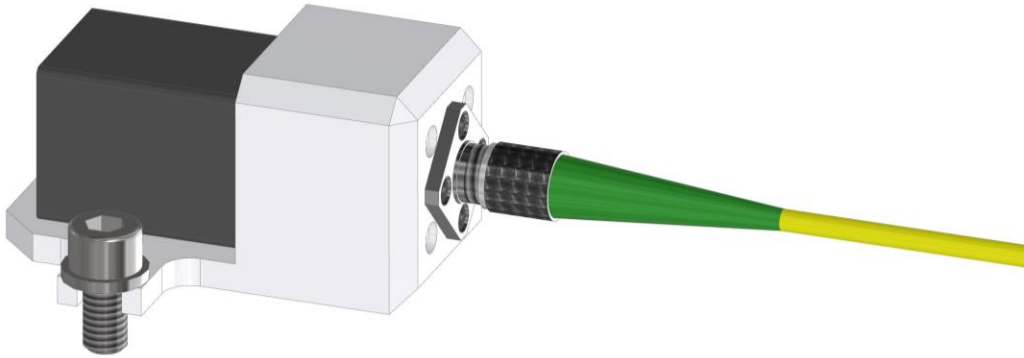
Diffuser Ball Development



Light Loss Test







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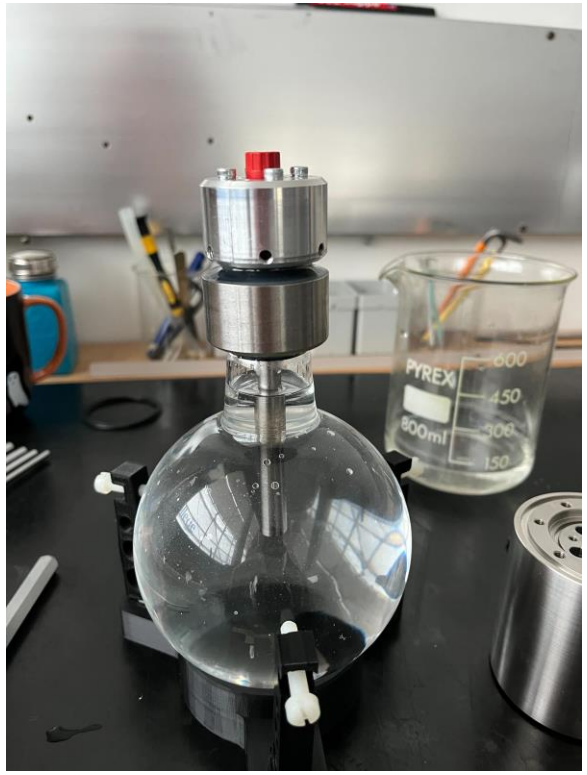
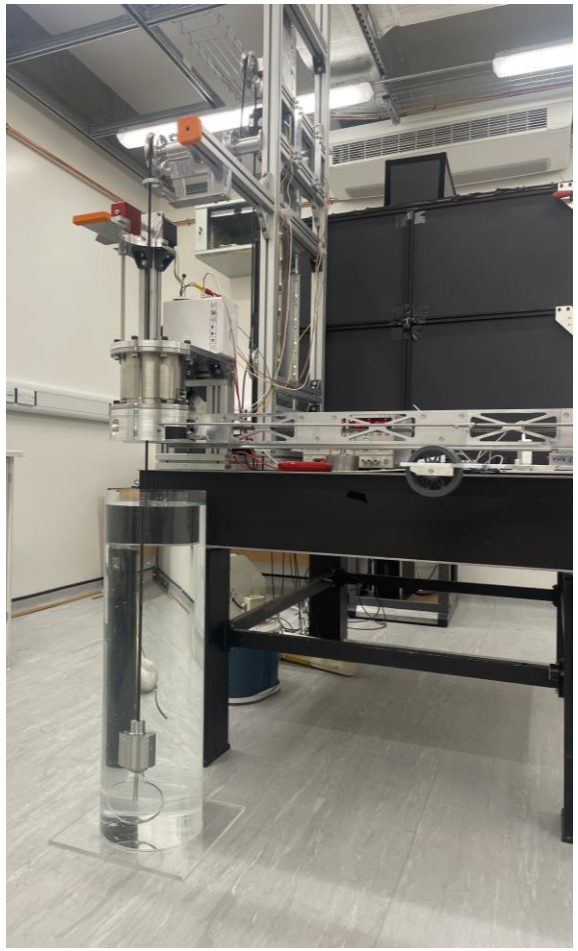
Laser Ball Prototype

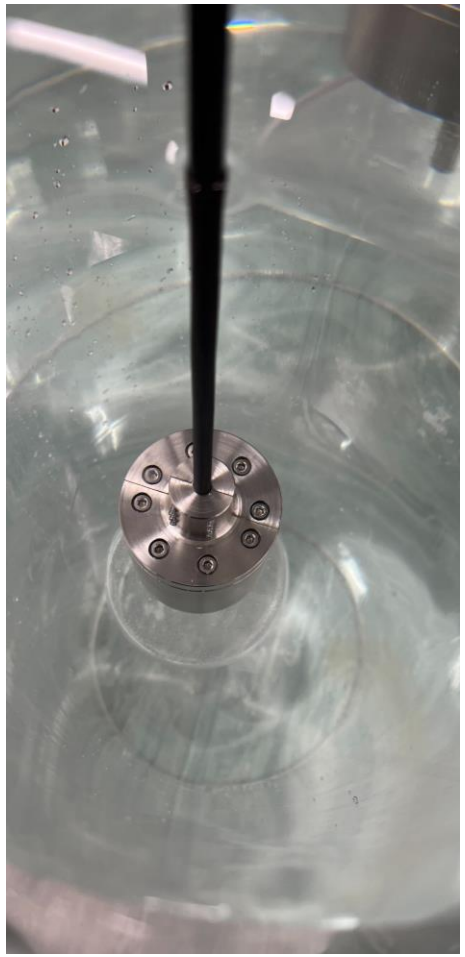
Araldite uniform stainless 40mm collar to seal around



Ball filled with water in images for buoyancy and immersion test

Laser Ball Buoyancy Testing

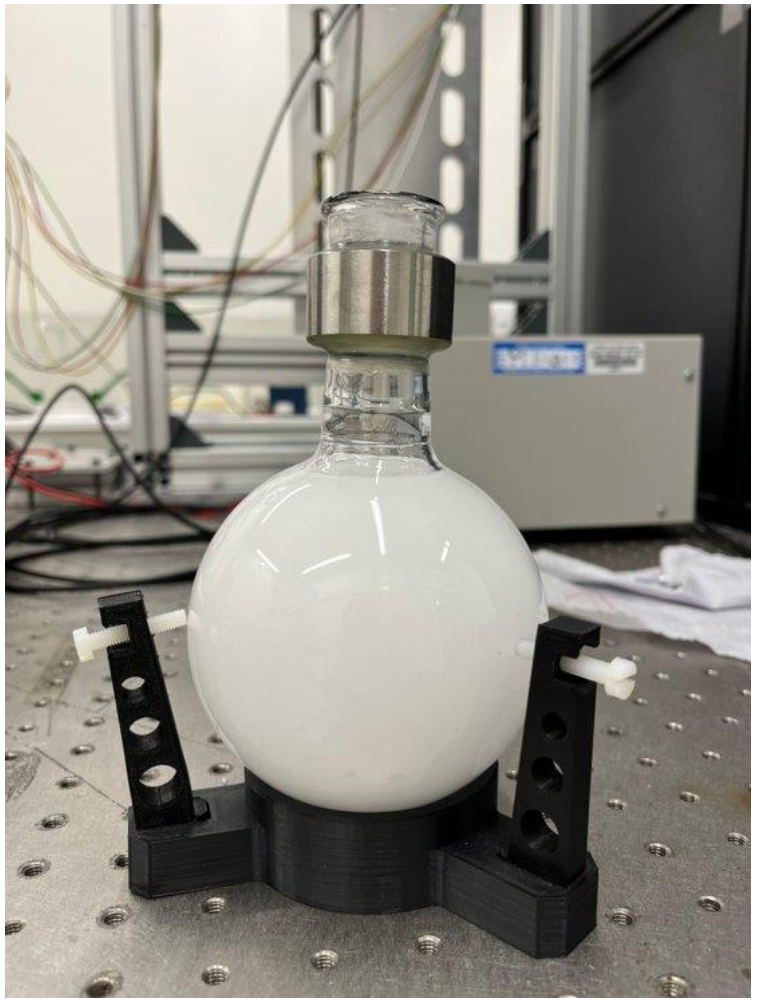




- Drop of laser ball is smooth, no sway
  - Controlled drop using motor
- Umbilical doesn't slip when wet and retains grip on Al rollers
- Submerged laser ball overnight
  - Used standard screws rather than screws with incorporated seal
  - Some water ingress however was expected
  - Next step is to do more comprehensive submersion test and add tamper stickers within pre-load

Status of laser ball prototype

- First prototype of laser ball started – used WACKER optical gel 612 soft setting
- Will insert light guide later
- 109 mm Quartz flask
- Will make prototypes with different flask diam. and variations in light guide exposure within gel
- Remainder of gel ~ 3 kg of each gel, one laser ball ~ 0.5 kg
  - Enough to make 6 units
    - Gel difficult to get hold of
    - Other companies stopped producing/too expensive



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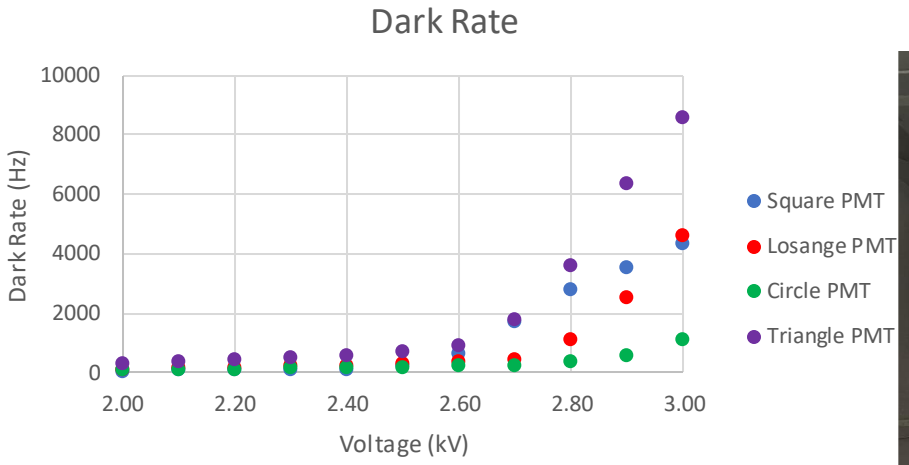
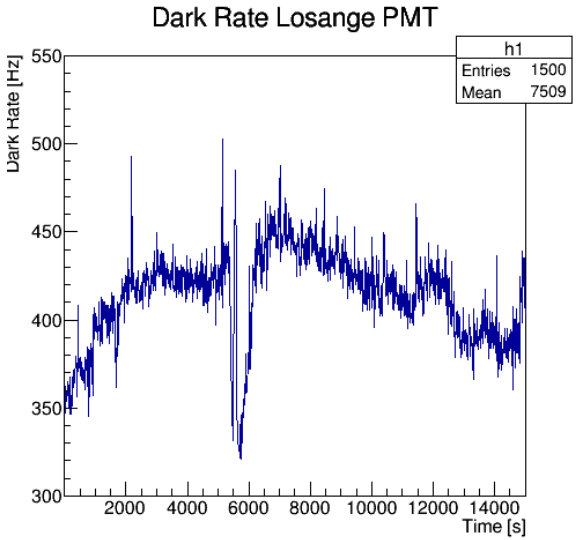
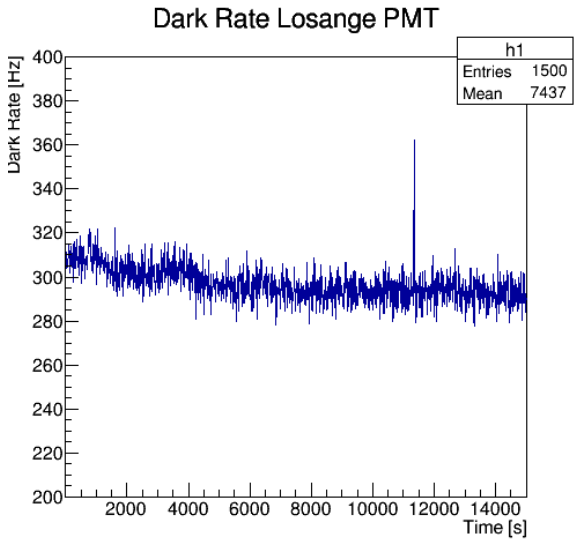
Characterization of Prototype

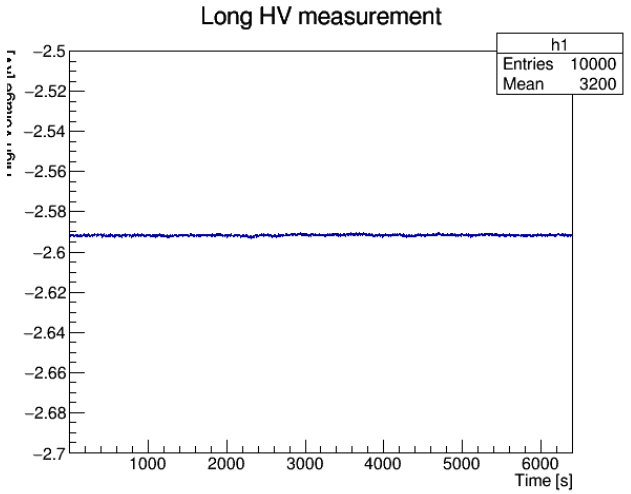
Y. Alj Hakim

- Using dark box that was built last year
- Characterizing the 4 PMTs which will be used to characterize the laser ball
  - Find beast operating voltage based on dark rate and gain
  - Confirm dark box is light tight









Calibration Sequence

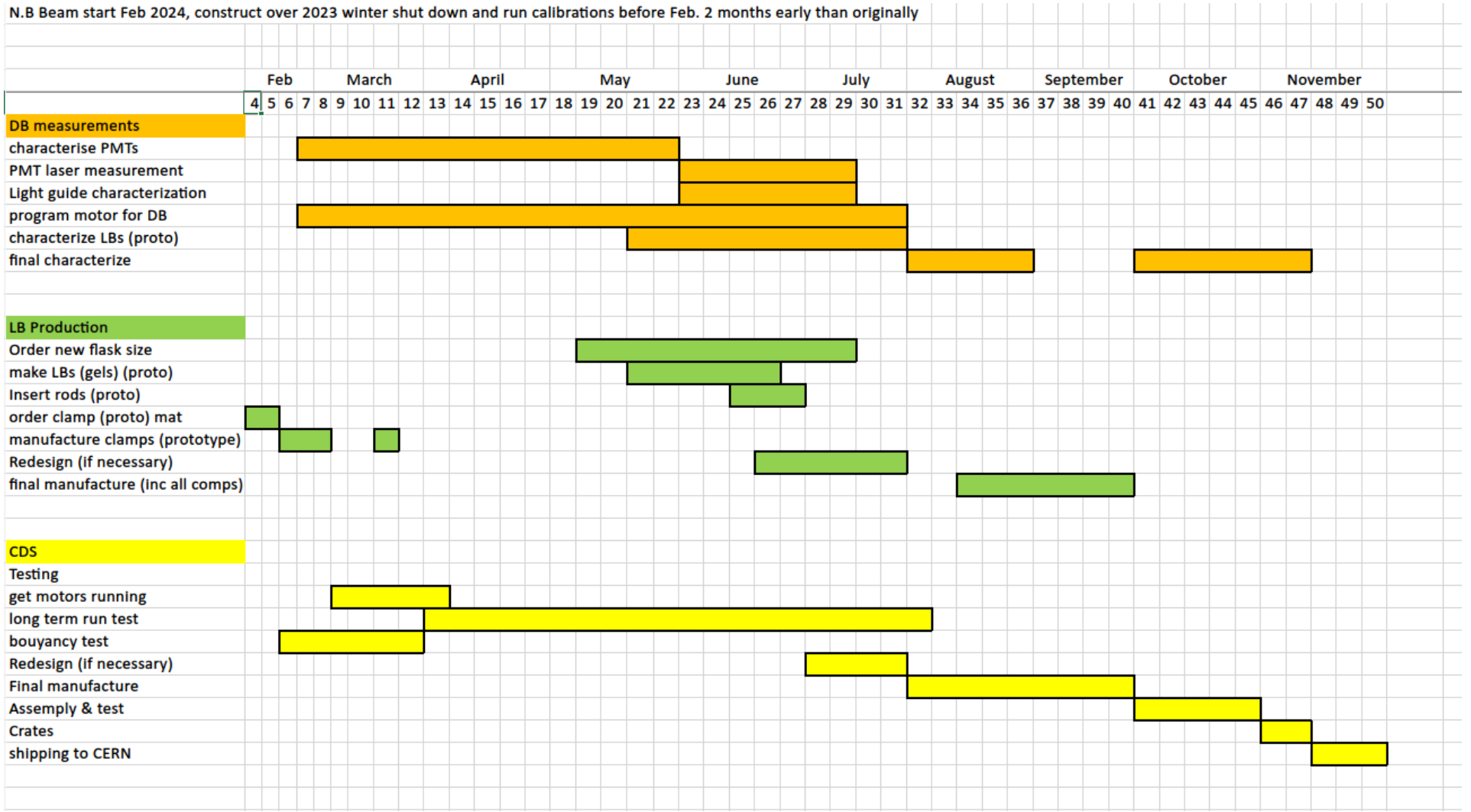
- Initially estimated 27 positions for full calibration
- Approximately 5h to run
- Can likely be optimised with further analysis
  - Work by Alie can show how we can get uniform coverage of mPMTs
- Likely different requirements for timing and attenuation length analysis.

X Axis - Along Arm

Z Axis - LB in Depth of Detector

Axis	Position	Pos. Note	Opp No.	Axis Position Y	X	Z	In Seconds Move Duration	In Seconds Laser Pulse Duration	Notes
Y1	0°	Park Position	0	Y1	X1	Z1	0	x	Home position, arm, Car and LB at park position
Y2	90°		1	Y1	X3	Z3	120	600	
Y3	180°		2	Y1	X3	Z2	20	600	
Y4	270°		3	Y1	X3	Z1	20	600	
			4	Y1	X2	Z3	80	600	car moves to half way pos, Z axis deploys to bottom
X1	0 mm	On Detector Centre Line	5	Y1	X2	Z2	20	600	LB moves from bottom to half way up tank
X2	660 mm	Halfway along Arm	6	Y1	X2	Z1	20	600	LB moves to top of tank
X3	1320 mm	At End of Arm	7	Y2	X3	Z3	60	600	Y axis moves through 90°
			8	Y2	X3	Z2	20	600	
Z1	0 mm	At Park Position	9	Y2	X3	Z1	20	600	
Z2	~1350 mm	Half Way down Detector	10	Y2	X2	Z3	80	600	
Z3	~2700 mm	Bottom of the Detector	11	Y2	X2	Z2	20	600	
			12	Y2	X2	Z1	20	600	
			13	Y3	X3	Z3	60	600	
			14	Y3	X3	Z2	20	600	
			15	Y3	X3	Z1	20	600	
			16	Y3	X2	Z3	80	600	
			17	Y3	X2	Z2	20	600	
			18	Y3	X2	Z1	20	600	
			19	Y4	X3	Z3	60	600	
			20	Y4	X3	Z2	20	600	
			21	Y4	X3	Z1	20	600	
			22	Y4	X2	Z3	80	600	
			23	Y4	X2	Z2	20	600	
			24	Y4	X2	Z1	20	600	
			25	Y1	X1	Z3	80	600	
			26	Y1	X1	Z2	20	600	
			27	Y1	X1	Z1	20	600	
									17260 Sec
							1060	16200	
									287.67 Min
							17.67		
									4.79 Hours

System Timeline



Summary and Next Steps

- Dark Box
  - PMTs almost fully characterized
  - Motor control work for laser ball rotation is started
- Diffuser ball
  - Buoyancy tests successful
  - Need further submersion tests
  - Make prototype laser ball in multiple sizes after potential redesign of preload
    - Designing and testing variations of the acrylic light guide
      - Rounded/flat finish, clear/frosted acrylic, flush or protruding acrylic
- Soak Tests
  - Soak testing all equipment to be used inside WCTE
    - Ready to analyze some samples (running late due to issues with spectrofluorometer)

Back Up

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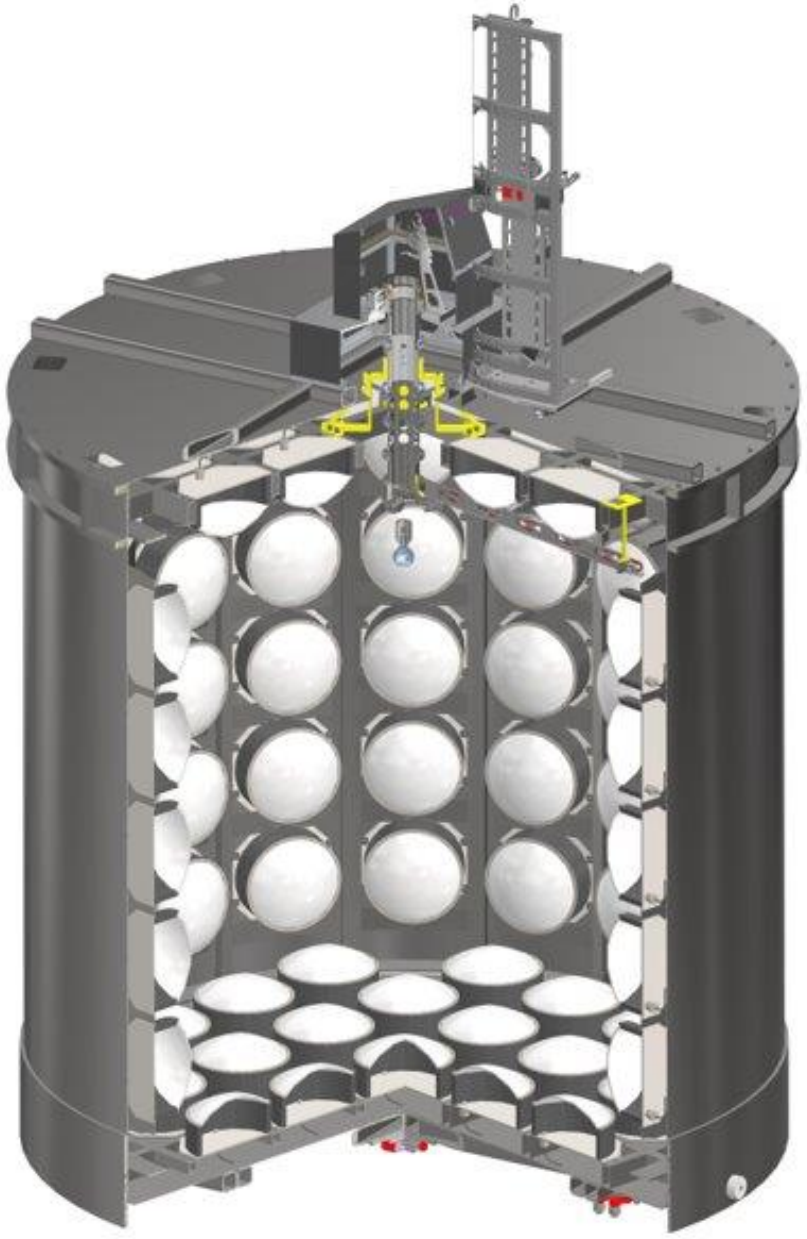
Reminder: WCTE

- Small scale **W**ater **C**herenkov (**T**est **E**xperiment) detector to be commissioned at CERN in 2022/23
  - **Potential to become platform for neutrino measurements at CERN**
- Study detector systematics and response 200 MeV/c - 1000 MeV/c
- ~4m * 4m cylindrical detector
  - Proposal document can be found here: http://cds.cern.ch/record/2712416/files/?ln=en
- Gadolinium sulphate doped



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Reminder: CDS

CDS – Central Deployment System
Designed for the ***Water Cherenkov Test Experiment***

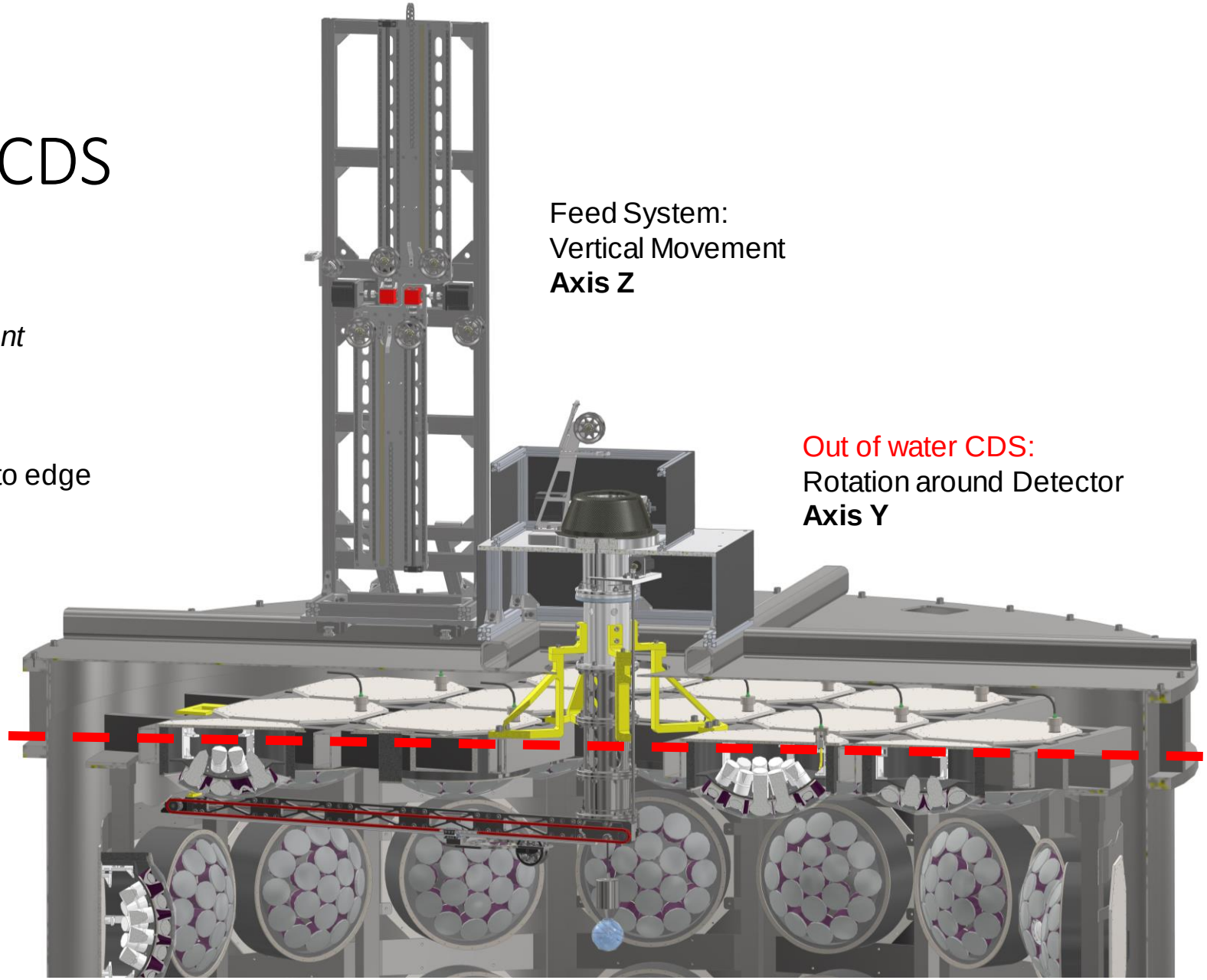
3 Axis System

- X – Laser ball from vertical center line, radially to edge
- Y – Rotation around tank +/- 180 degree
- Z – Laser Ball vertical +/- in tank

In Water part of CDS:
From CL radially out
Axis X

Feed System:
Vertical Movement
Axis Z

Out of water CDS:
Rotation around Detector
Axis Y



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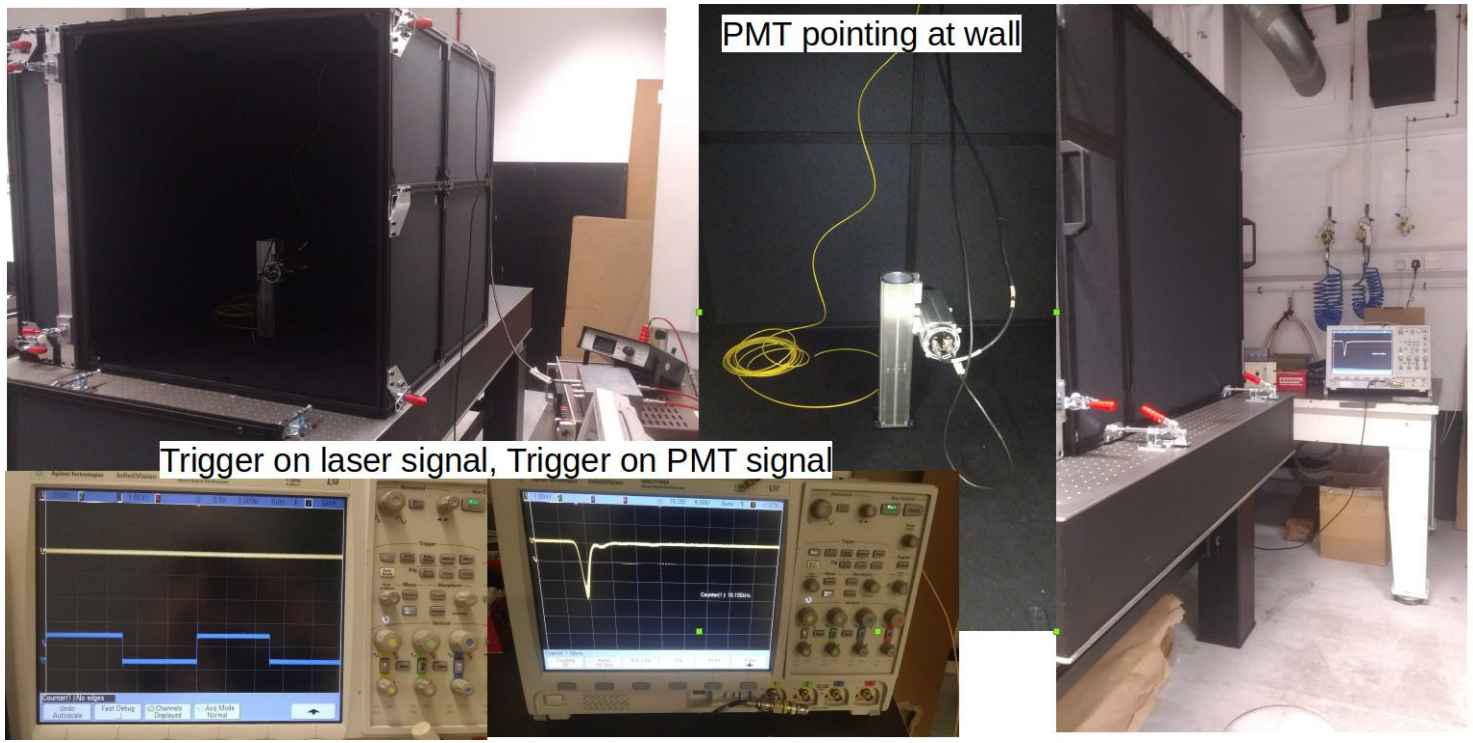
Lab Measurements

- Laser : Tamadenshi LBD 405-200
  - Coupled to 405nm ±5nm, 1→2 50/50 pure silica fibre splitter (Gooch & Housego/GouldFO)
- PMTs : 4 x Hamamatsu H2431-50
  - 0.36ns TTS
  - 0.8ns rise time
- Monitor PMT : 1 x Hamamatsu H10721-110
  - Same as monitor PMT used in UKLI system at SK

- Began characterization of PMTs back in December (Y. Al Hakim), however had to relocate experiment to a new lab which had some delays



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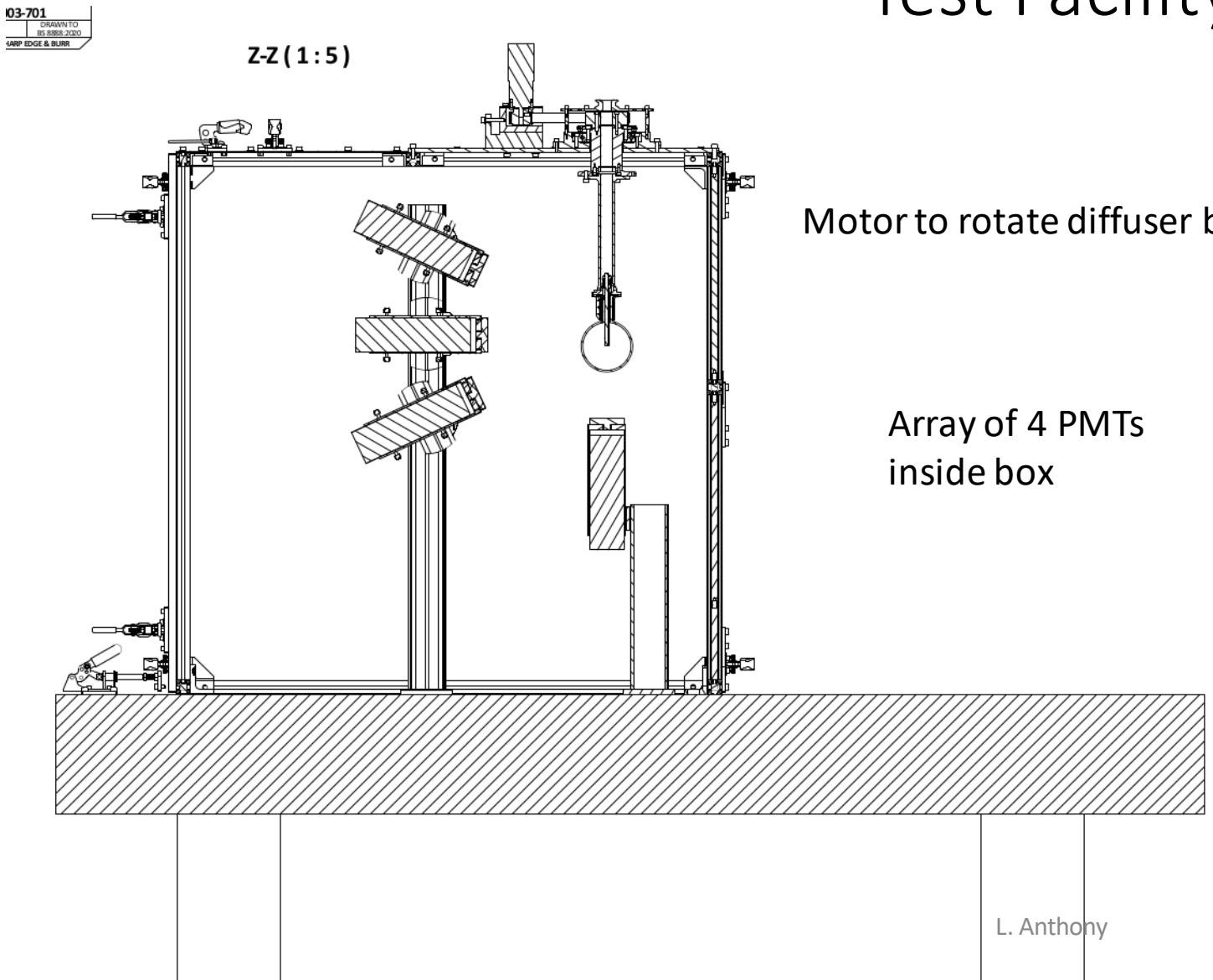
Test Facility



Motor to rotate diffuser ball

Array of 4 PMTs inside box

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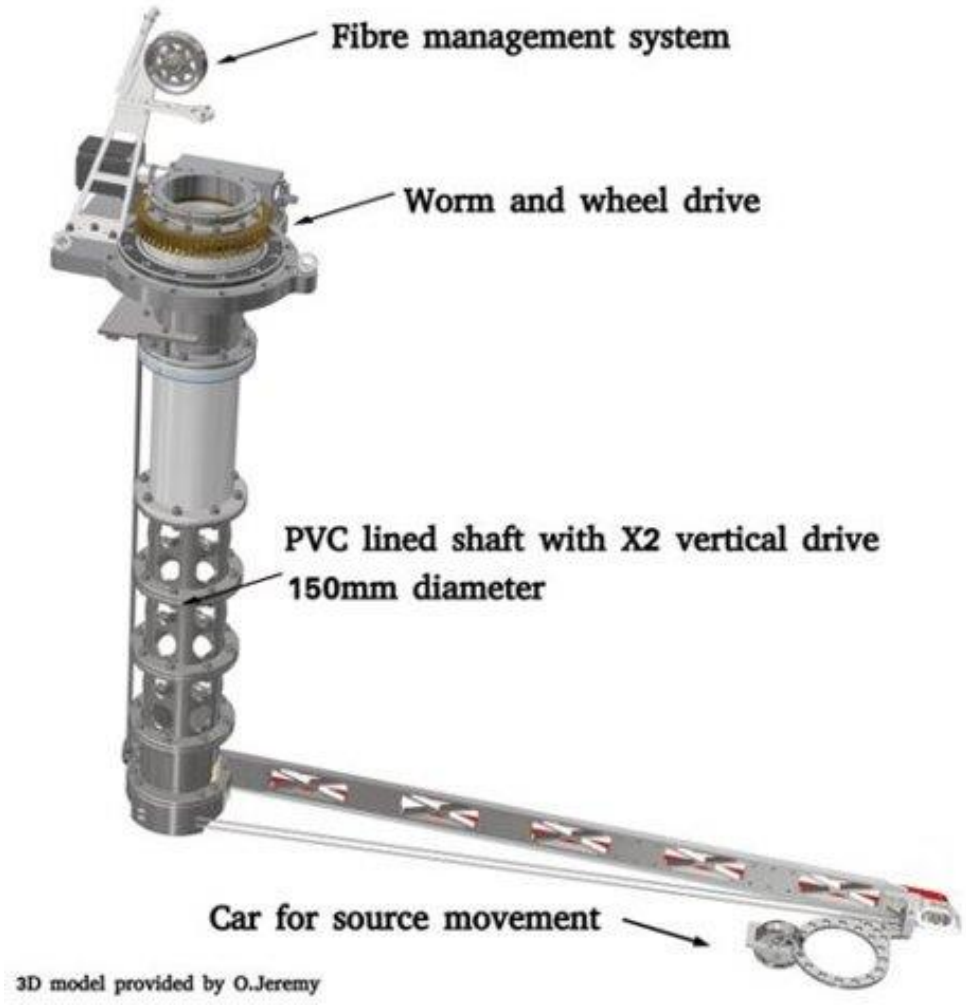
Detailed View of CDS



- Developing multi-axis system to deploy various calibration sources into the detector
- Movement in 3 axes
- Deploy sources at user defined calibration points
- Sources
  - Isotropic light source
  - Camera for photogrammetry
  - Radioactive source
- Other fixed source include mounted cameras and LED system (see slide 11)

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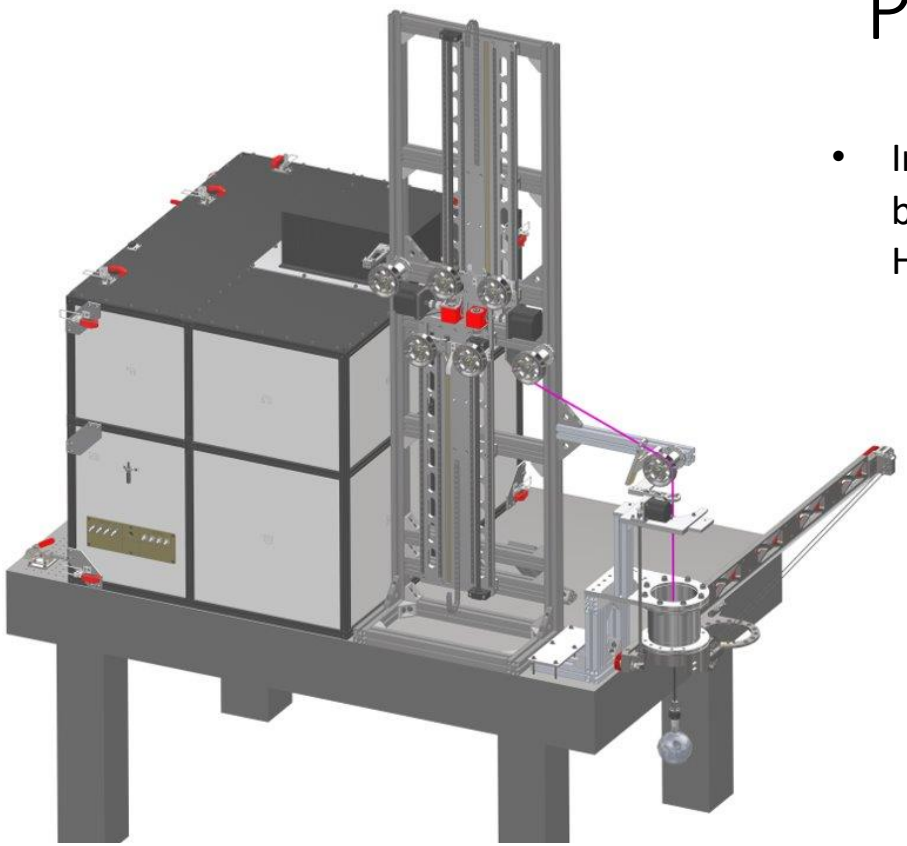
Laser Diffuser
HK calib 17/02/22

Prototype Development



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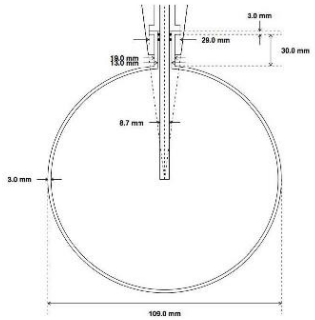

- Build on SNO/SNO+/DEAP3600 design
  - Quartz flask
  - Suspended glass spheres
  - Optical gel

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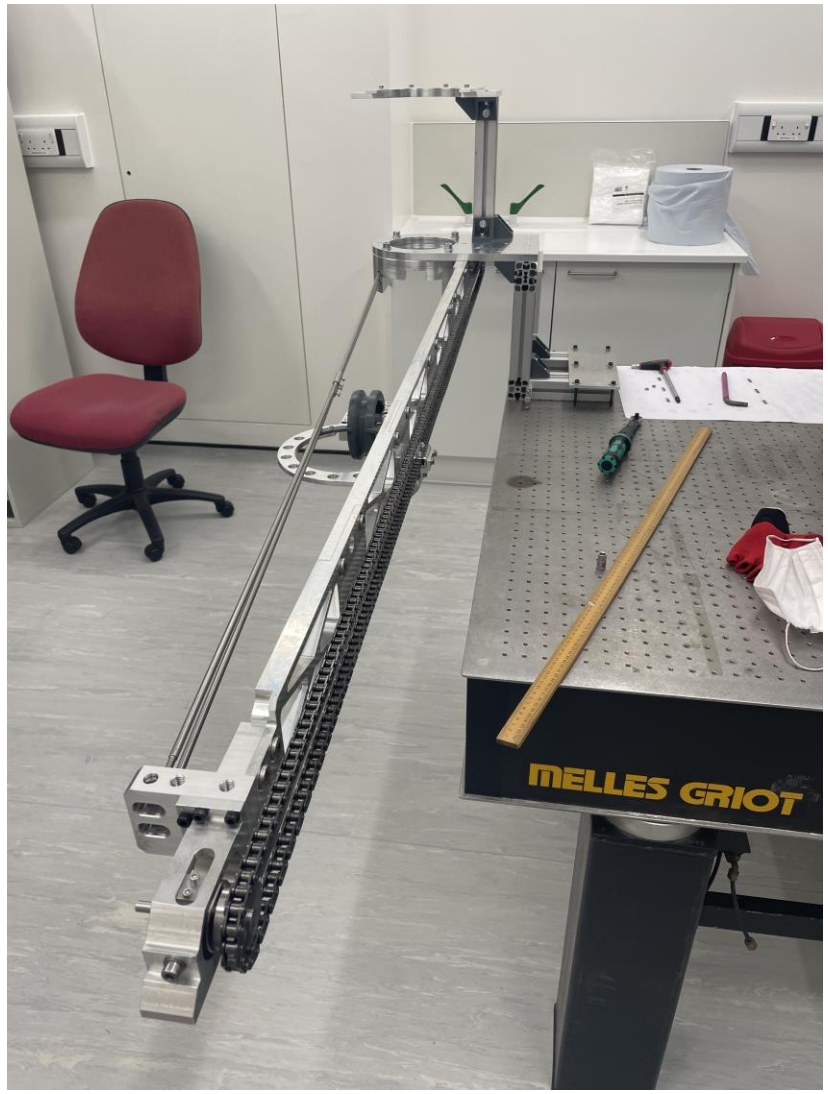
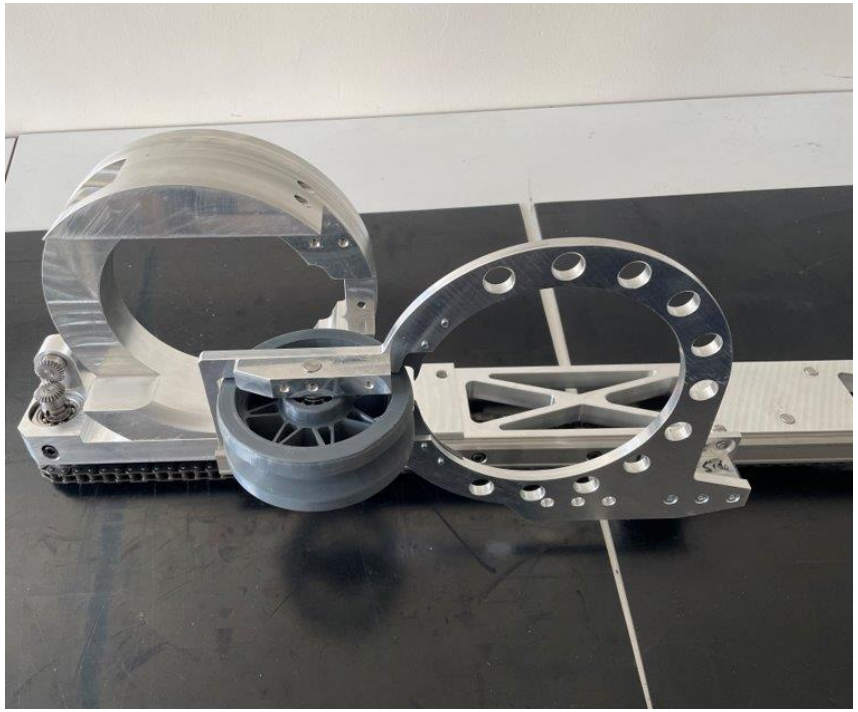
Prototype Development



- Bearing Material: SS Deep groove Ball BRG or Polymer Plain Bearing
- Gears SS

Currently we have a regular steel chain, for WCTE we could:

- A custom made 316 chain
- Polymer / SS Chain



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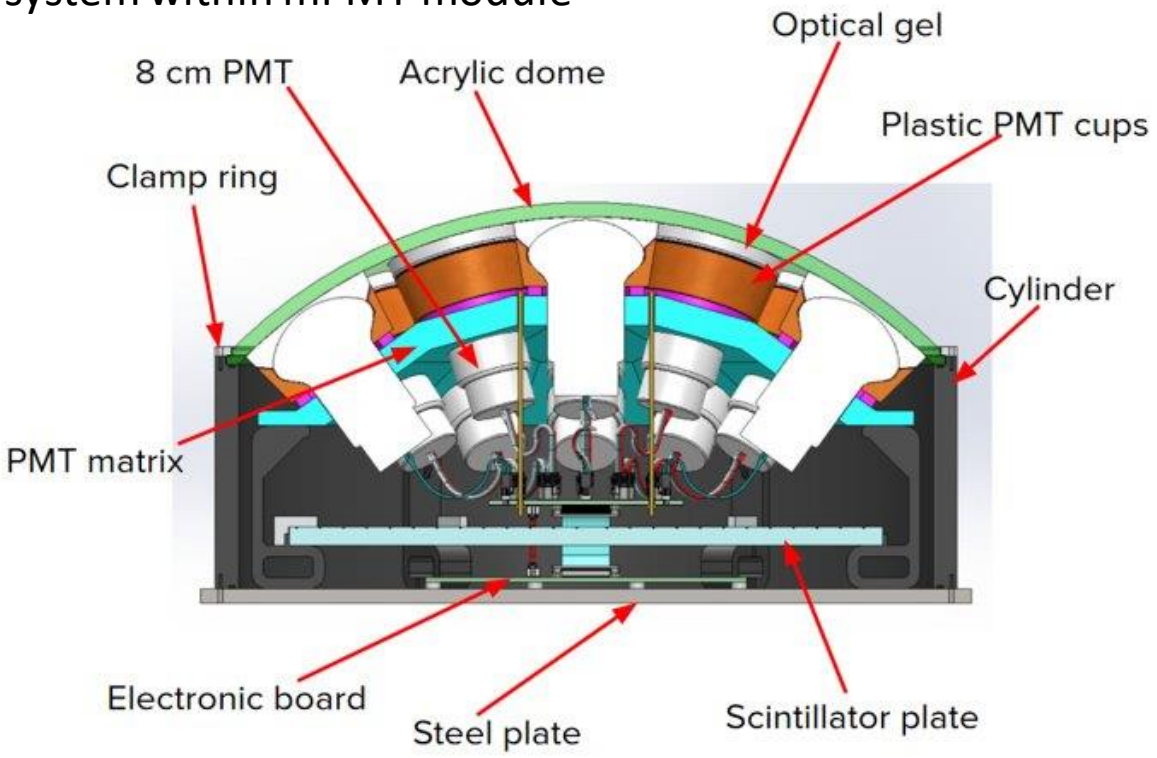
mPMTs

- Nineteen 8cm diameter PMTs (Hamamatsu R14374) - multi-PMT modules (mPMT)
- Improved granularity and timing compared to larger PMTs
- Integrated LED calibration system within mPMT module



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Umbilical R&D

- Trialing Thor Labs FT061PS Furcation tubing for umbilical
    - **Coating still needs to be verified by soak test**
    - Ø6.1 mm Stainless Steel Tubing inside
    - Dynamic bend R19 mm (empty tube)
    - Dynamic bend of fibre ~R40 mm

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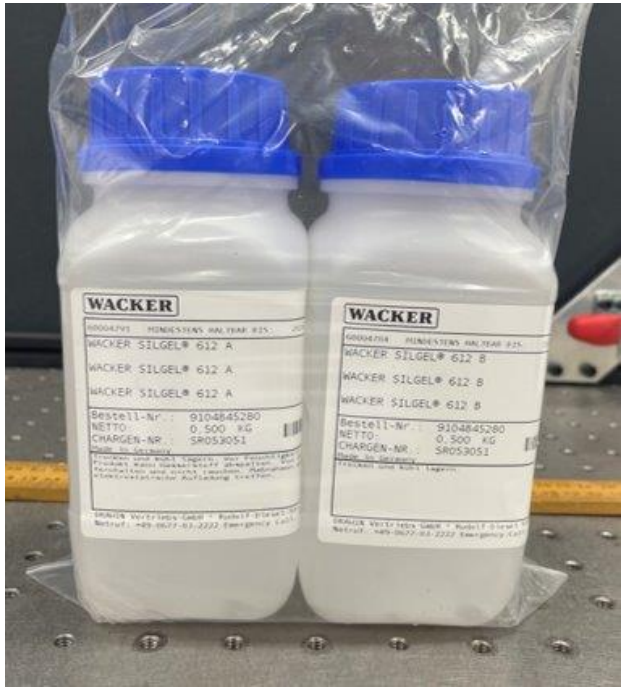
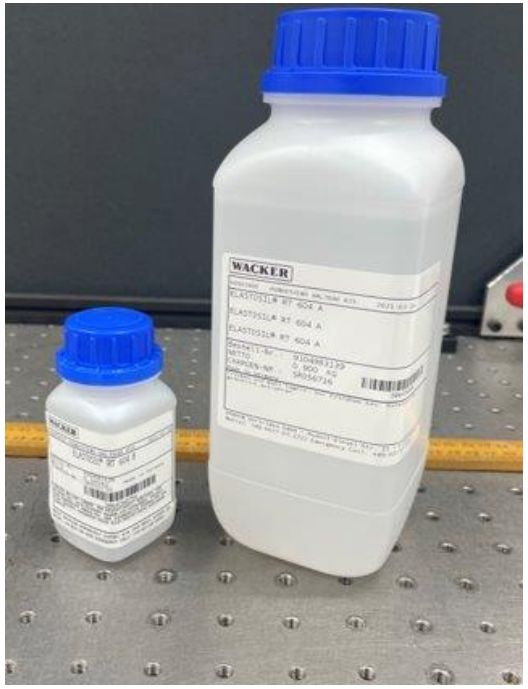
Optical Gel Testing

- **Testing 2 types of WACKER gel**
  - 612, mix 50:50, softer setting (8h cure @ room temp)
  - 604, mix 90:10, harder setting (24h cure @ room temp)
  - Degas in vacuum chamber
  - Gels are out of date by ~1year but seem ok to use
    - Good transparency and viscosity

Work by Y. Alj Hakim & L. Anthony





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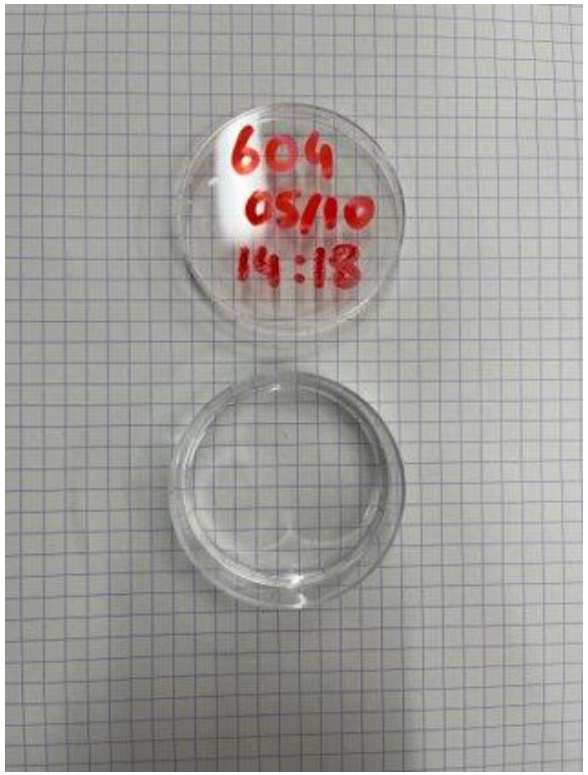
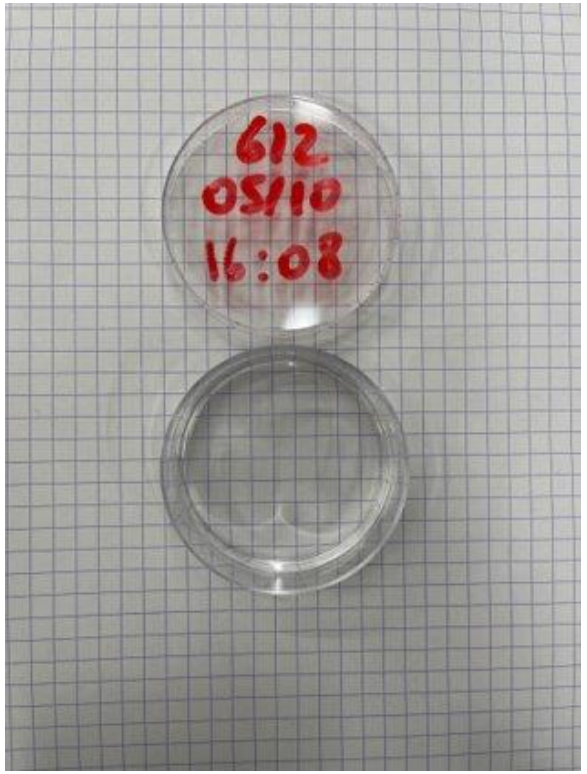
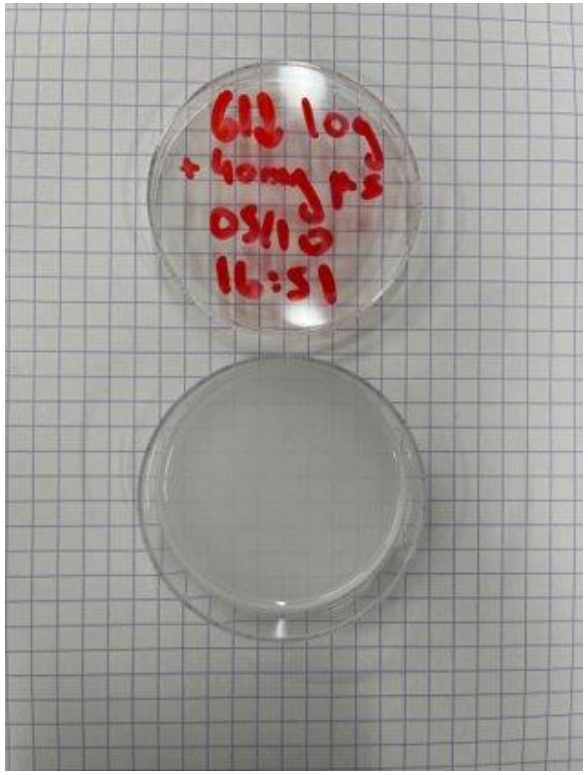
Optical Gel Testing

- **All small samples degassed in vacuum chamber to remove air bubbles**
  - Left to cure in air at room temp
  - 3M 40micron glass spheres (hollow) rise during degassing







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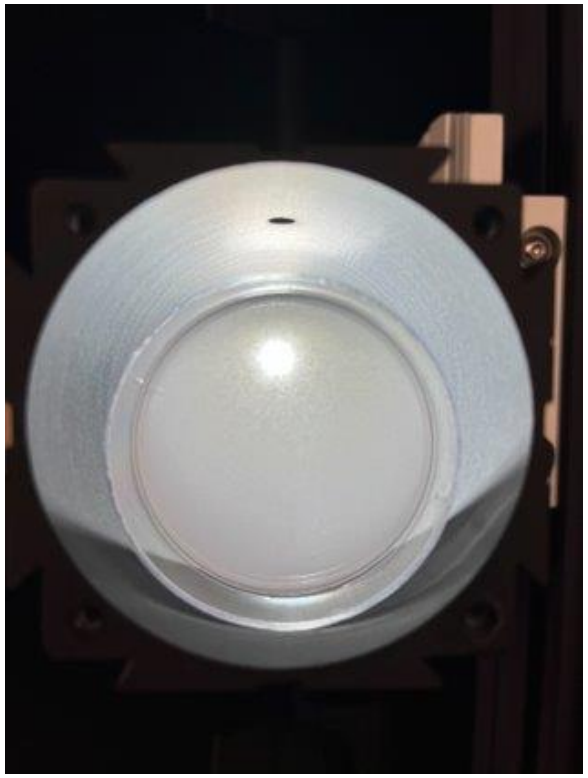
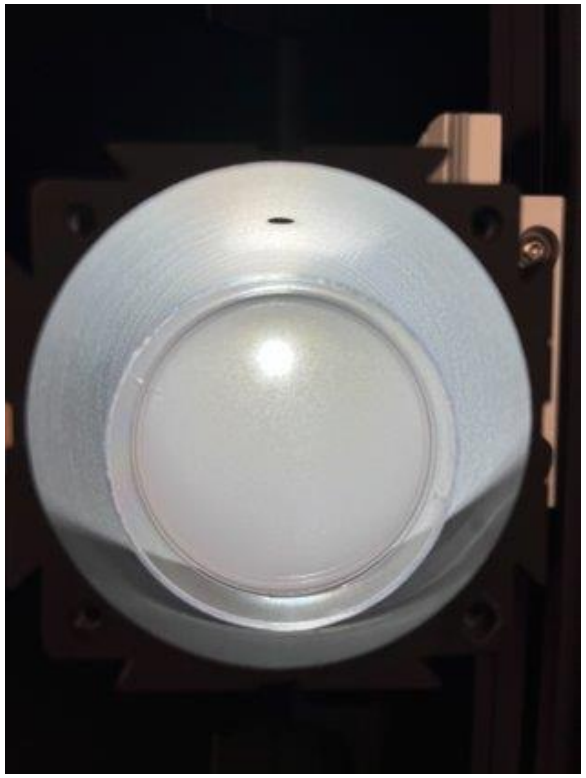
Optical Gel Testing

- **Testing mixing gels using various methods**
  - **Mixing glass beads in 1 part of gel and degassing parts 1 and 2 separately**
  - **Finally degas mixture again**





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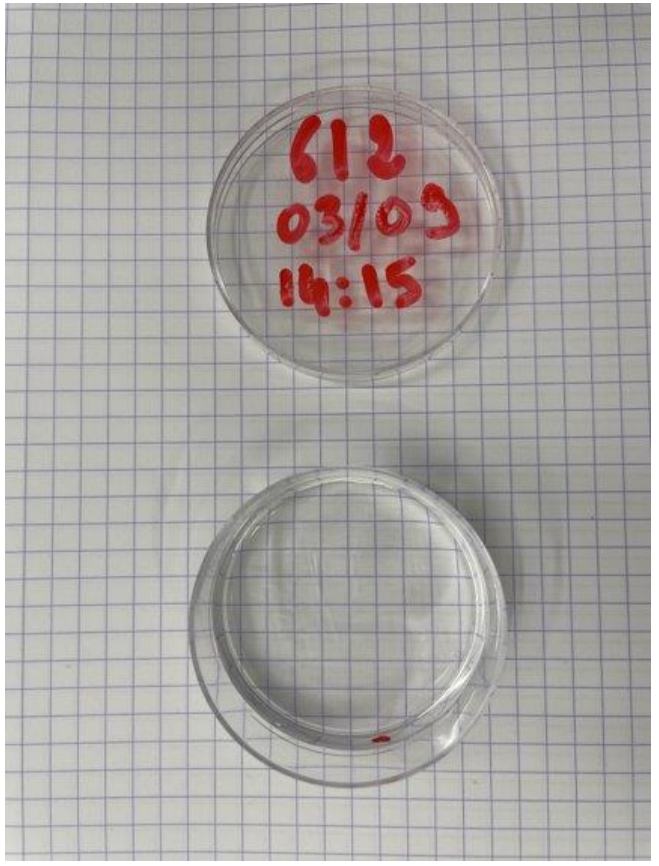
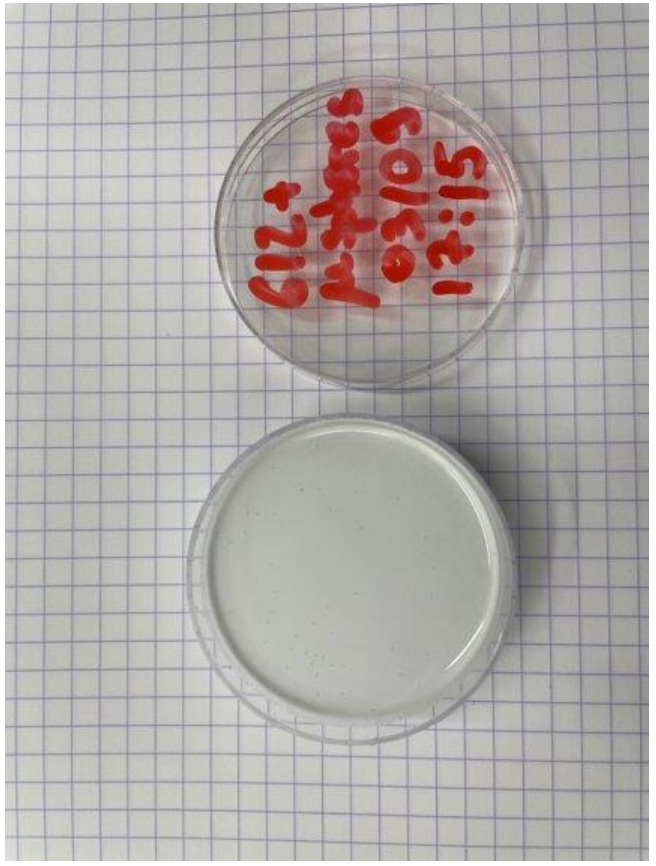
Initial Optical Gel Testing

- **All small samples degassed in vacuum chamber to remove air bubbles**
  - Left to cure in air at room temp
  - 3M 40micron glass spheres (hollow) rise during degassing





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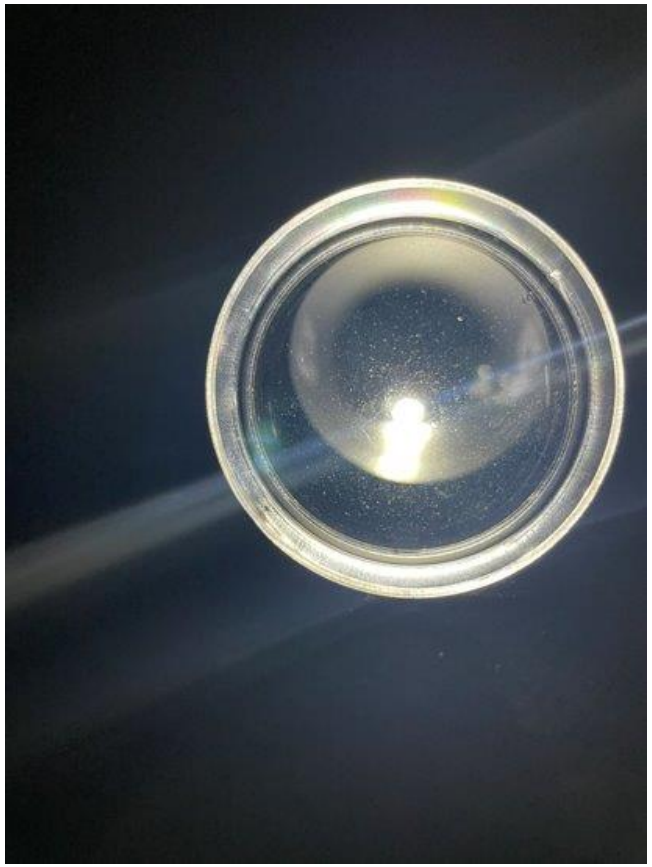
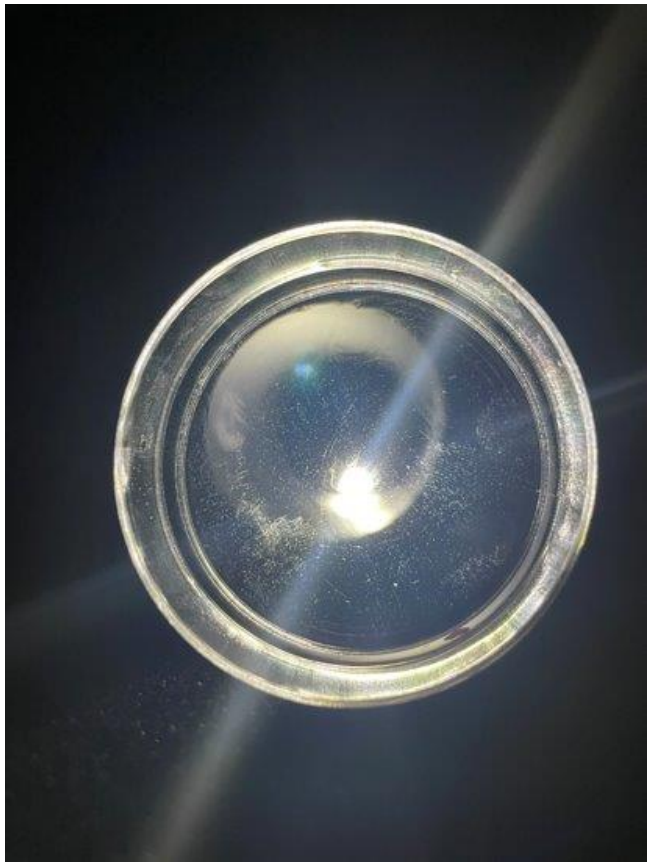
Initial Optical Gel Testing

- **604** no pattern and fully translucent
- **612** gel has some pattern – maybe not mixed for long enough?
- **612** with glass spheres (~0.5 tsp) uniformly distributes light and shows no pattern in gel





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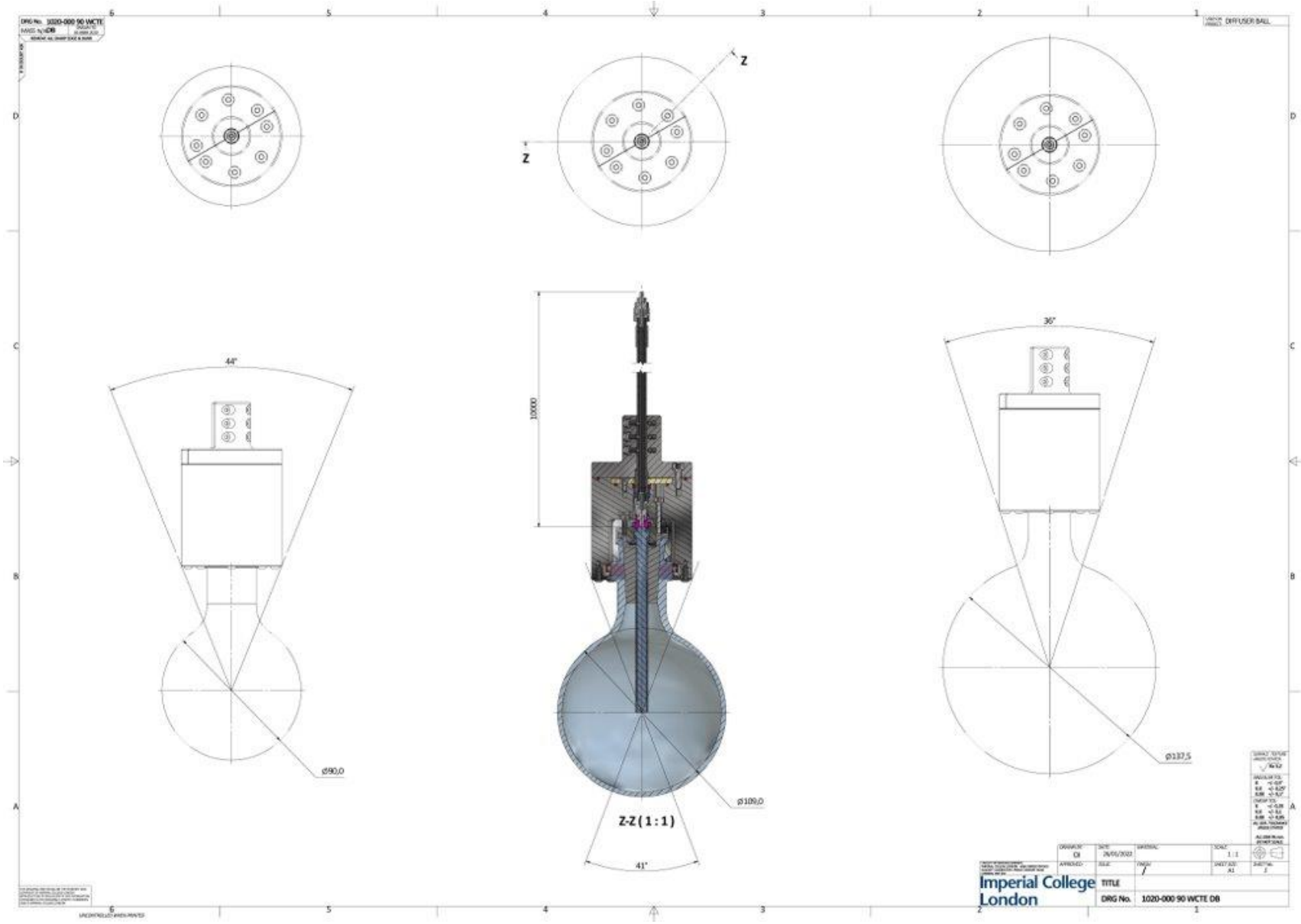
Diffuser Ball – Diameter Study

- LB diameter and shadow angle
- 90mm / 44°
- 109mm / 41°
- 137.5mm / 36°

(Note. is the max dia.)



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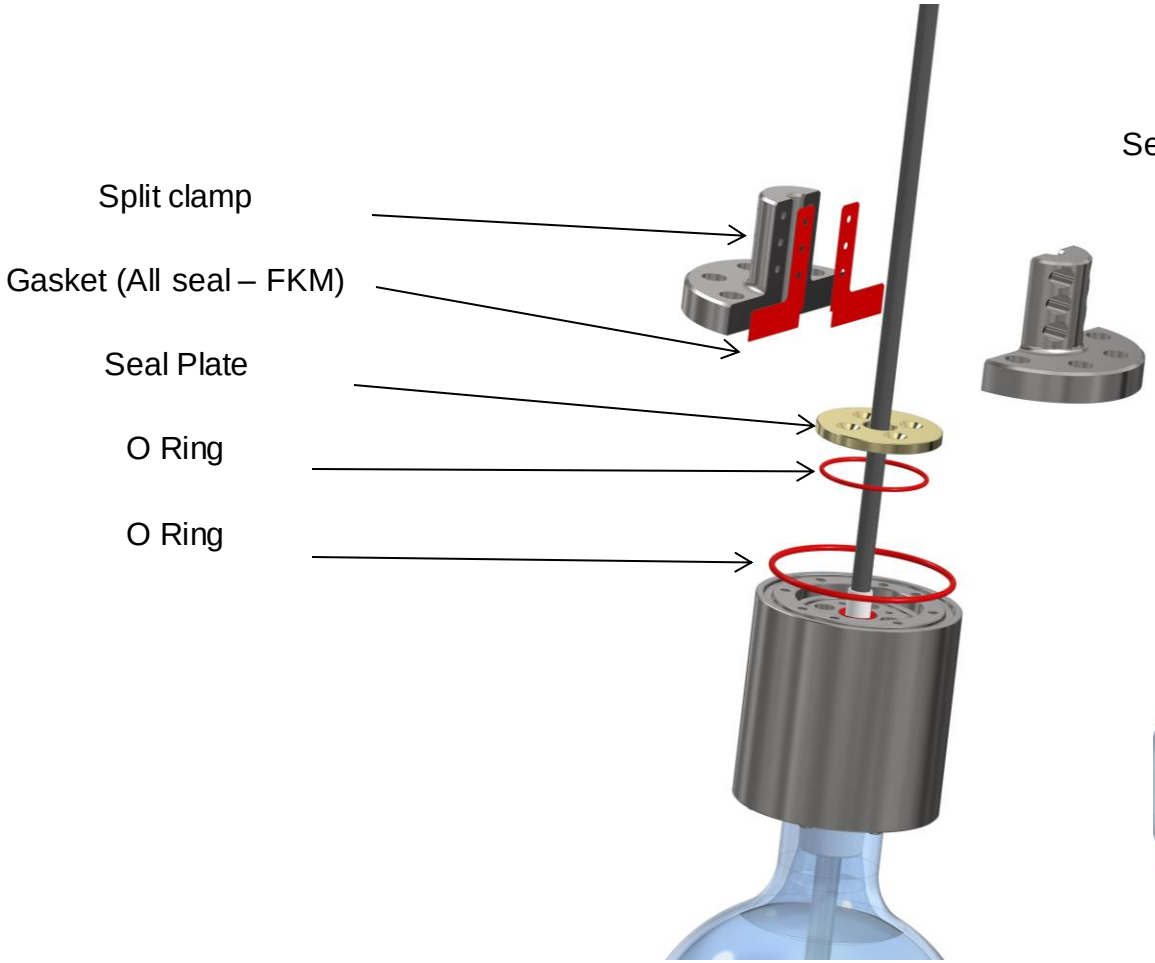
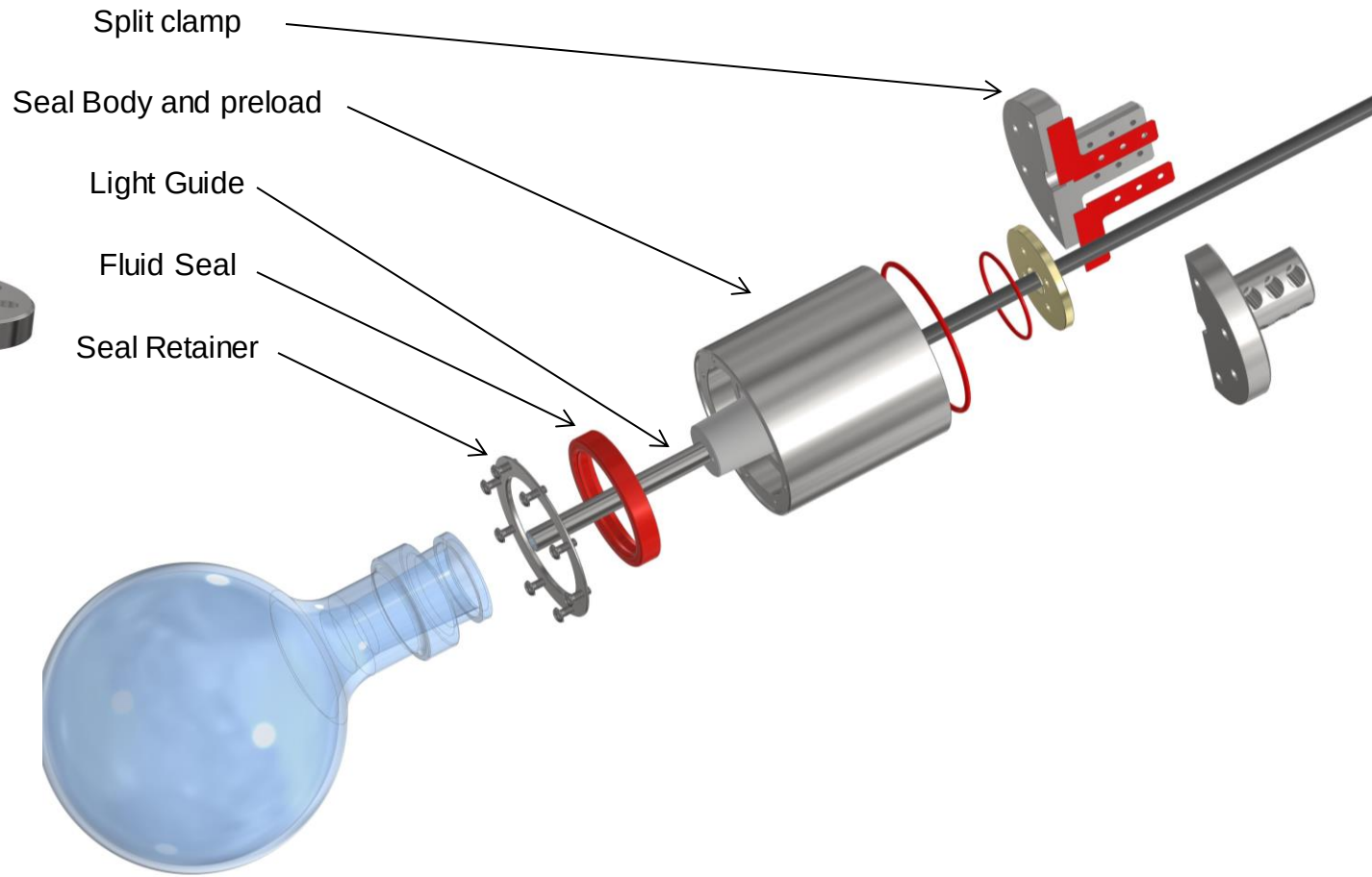
Diffuser Ball – Preload & Seal





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Diffuser Ball Development

Two clamp designs for test facility (left) and WCTE (right)

Re-designed to be modular, no clamp obstructing light close to neck

Sept 21

N.B. 109mm diam flask

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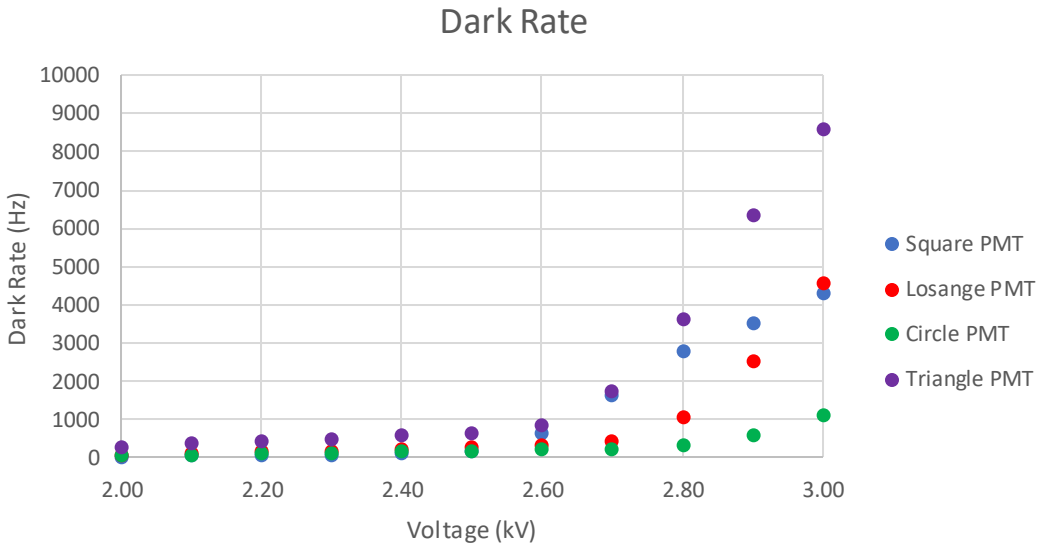
PMT characterization – Y.Alj Hakim

- Characterizing the 4 PMTs which will be used to characterize the laser ball
  - Find beast operating voltage based on dark rate and gain
  - Confirm dark box is light tight

- Laser ball prototype will be completed in coming weeks after further submersion tests and motor control work by Alie



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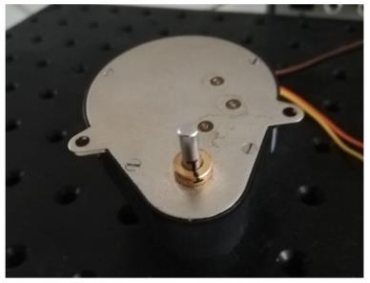
Motor Control – A. Craplet

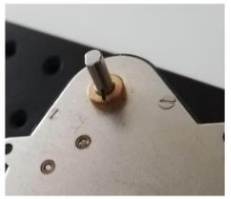
- Aim is to write code to control all 4 motors in CDS system along with program to control rotation of laser ball in lab

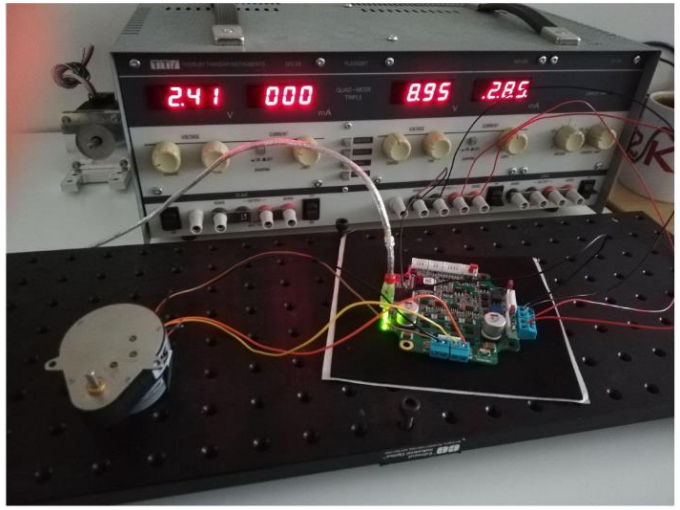
- Current status
  - Using TRINAMIC software and 5 axis control boards
  - Performing tests of position/rotation reproducibility
  - Designing some tests to calculate precision and cross-checking with data sheets

Set-up



Mark used to indicate full rotation





2

- Also working on incorporating timing calibration code into Ka Ming's water analysis code