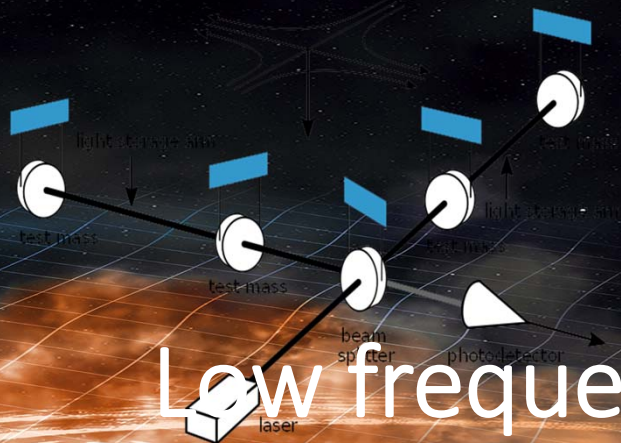




Australian Government  
Australian Research Council

OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery



# Low frequency program summary

Program Chair: Bram Slagmolen  
Li Ju



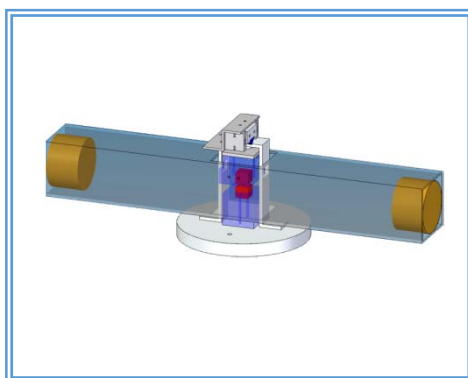
# Goals and Projects

1. Increase the sensitivity and duty cycle of GW detectors across the entire frequency band by improving the low frequency stability
2. Measure low frequency seismic noise to estimate Newtonian noise
3. To directly measure Newtonian noise

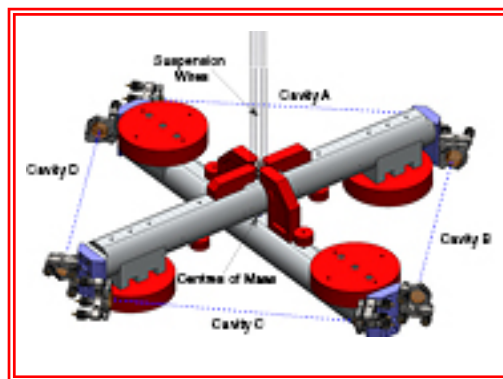


Bram Slagmolen    JU Li    Robert Ward    Joris van Heijningen    John Winterflood    Perry Forsyth    Joshua McCann    Nathan Holland    David McManus

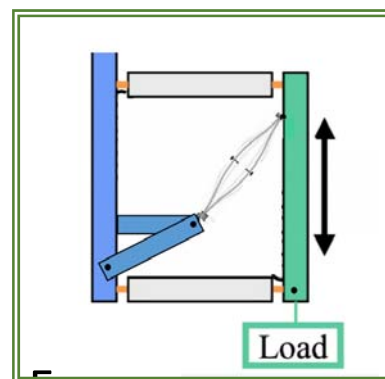
+ Master & intern students.....



Tilt meter—ALFRA



TorPedDo Sensor



Euler-LaCoste  
ULF pre-isolator

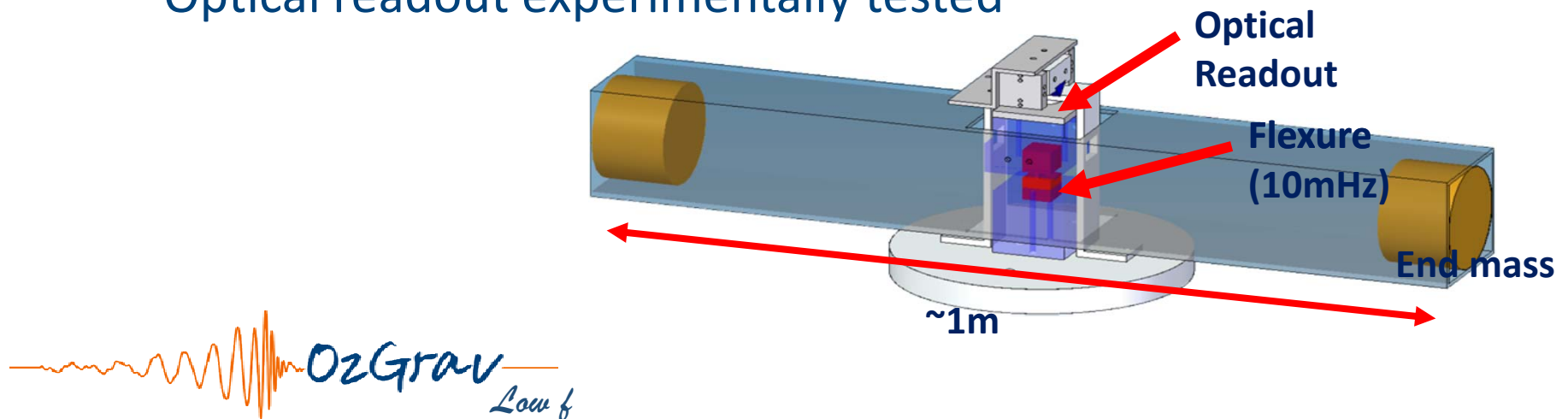


CDS: LIGO type  
digital control



## Advanced Low Frequency Rotation Accelerometer (ALFRA)

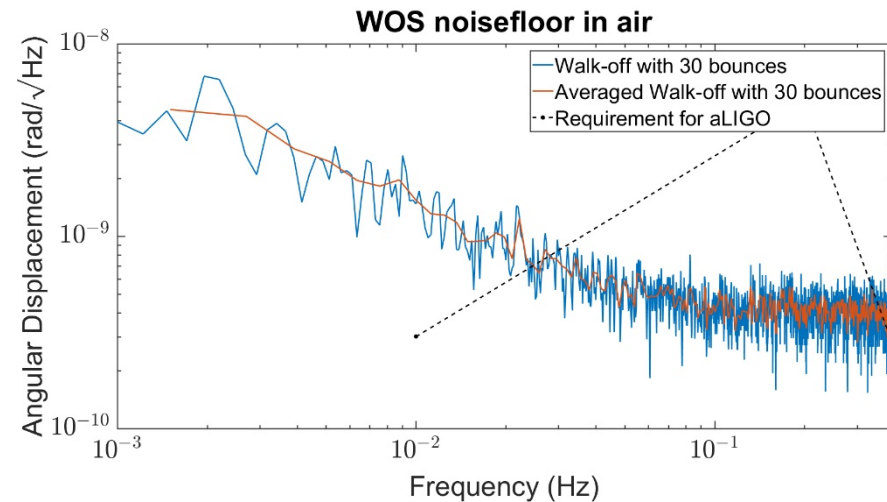
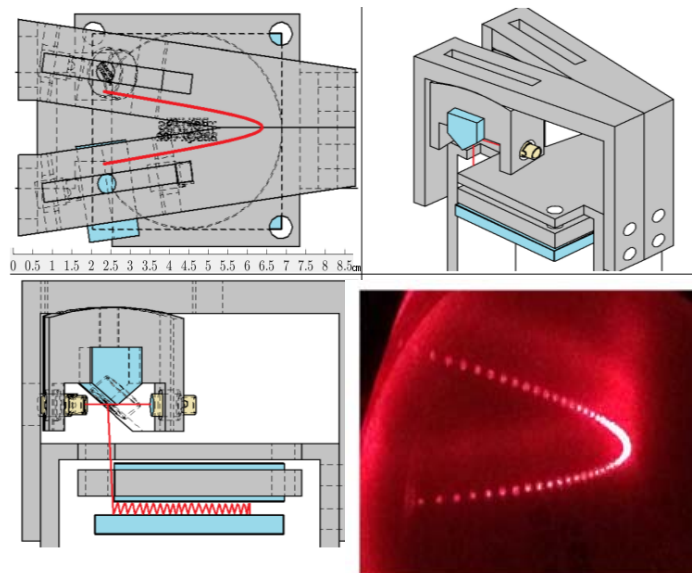
- Sensing the ground tilt and feedback to the isolation stage to reduce horizontal to tilt coupling
- Could be mounted in any orientation
  - Modelling complete
  - Bar in manufacturing stage
  - Flexure design complete
  - Vacuum chamber designed and under construction
  - Optical readout experimentally tested



# Walk-off sensor (WOS)

## Optical readout system for ALFRA

- Readout system tested
- Paper ready for P&P
- Integrated design complete



- Readout Sensitivity on table top (in air) :
  - Seveal nrad/rt(Hz) > 1mHz
  - 0.4nrad/rt(Hz) > 100mHz
- Needs to go into vacuum

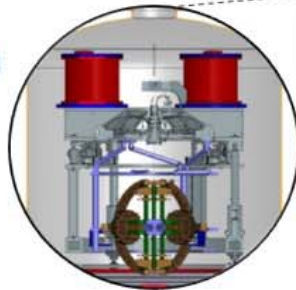
# TorPeDo Seismic Chain Design

## Torsion Pendulum Dual Oscillator (TorPeDO) --low frequency gravitational force sensor

Torpedo Sensor is operating with its initial control prototype running on a continuous basis.

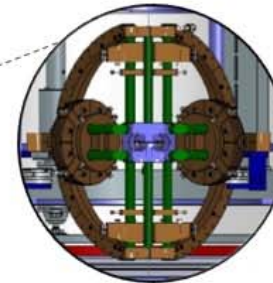
### Inverted Pendulum

- MultiSAS base
- Uses 3 Trilliums to isolate linear motion
- Soft platform for actuation
- Contains GAS filter for vertical isolation.



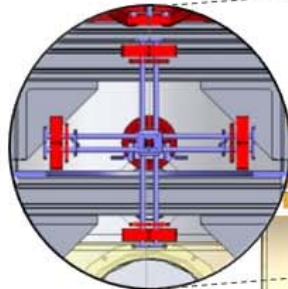
### Intermediate Mass

- 140kg 6-way cross / hollow sphere hybrid
- Large inertia combined with single wire suspension provides high passive isolation.
- Spherical structure raises the frequency of internal modes.
- 6-way cross allows for fine tuning of CoM and moment of inertia.



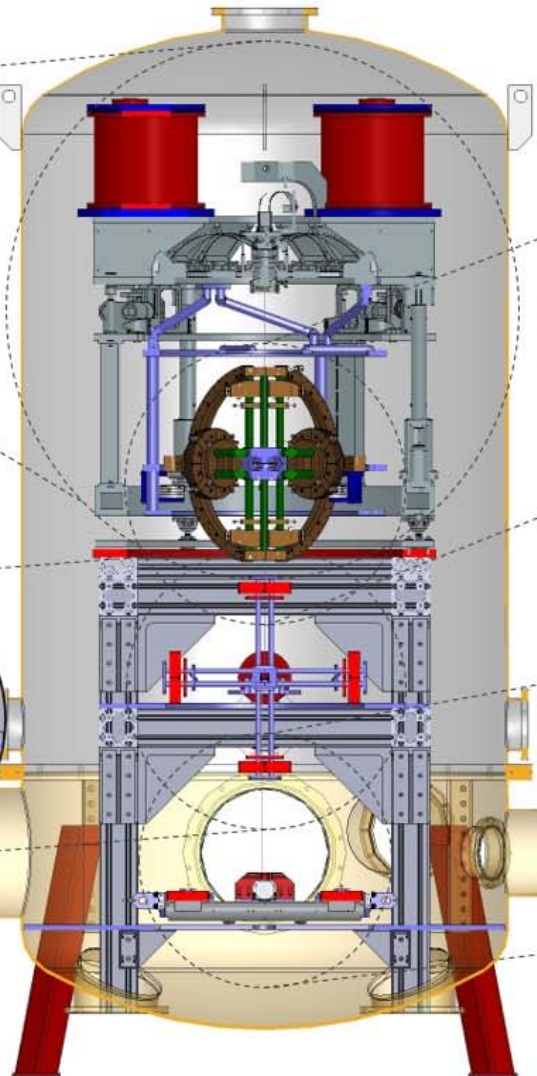
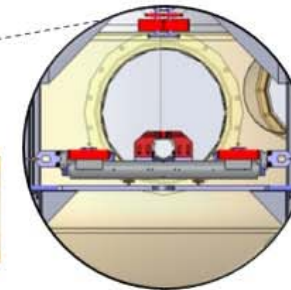
### Penultimate Mass

- 40kg 6-way cross.
- Acts as suspension point for TorPeDO system.
- High moment of inertia per mass provides additional isolation for rotation.

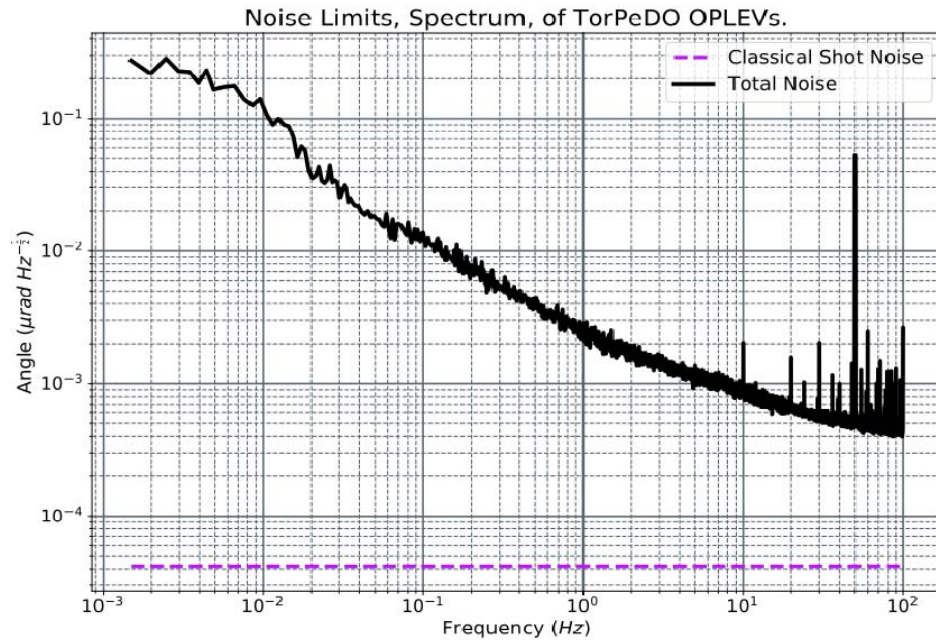


### TorPeDO System

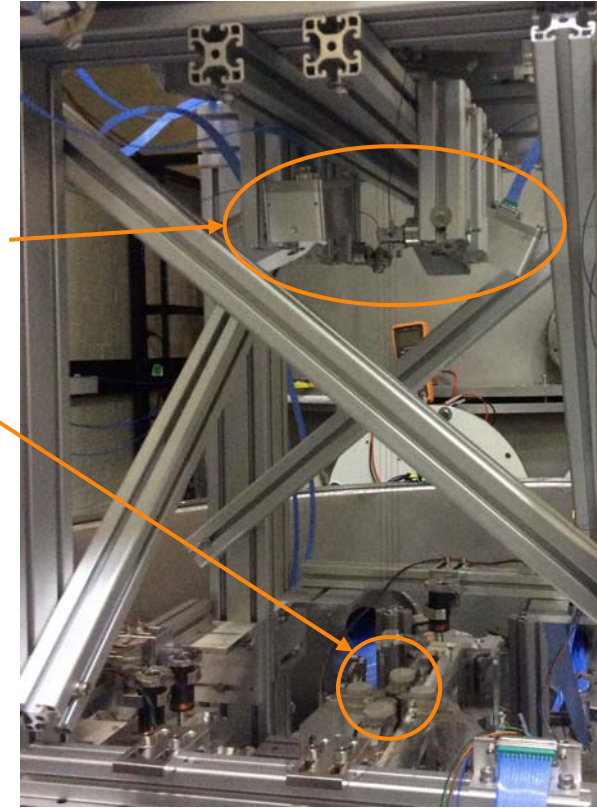
- Two dual wire torsion pendulums.
- Operation between 30mHz to 10Hz.
- Optical differential yaw readout.



# TorPeDO Local Sensing and Damping



Collimators (x4)  
and  
Quadrant  
Photodiodes  
(x4).  
  
Mirrors  
(x4)

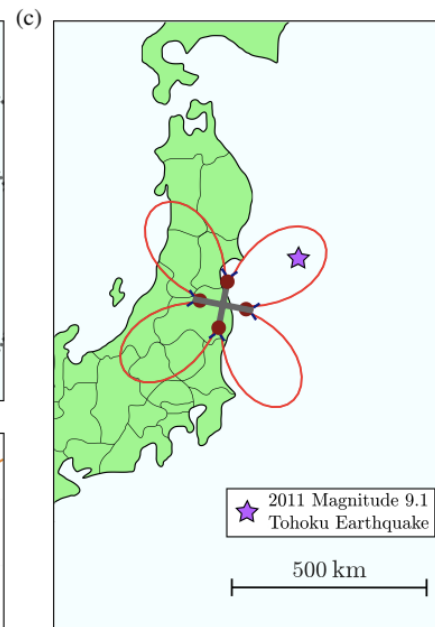
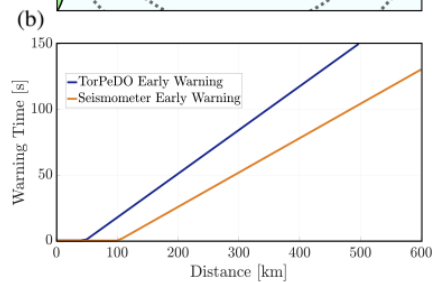
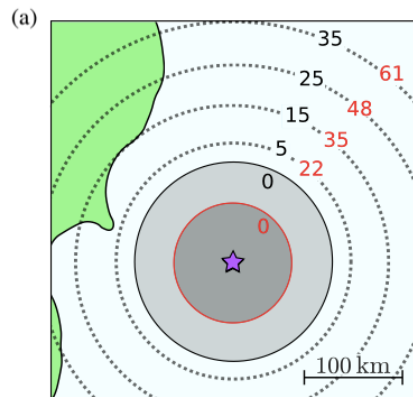
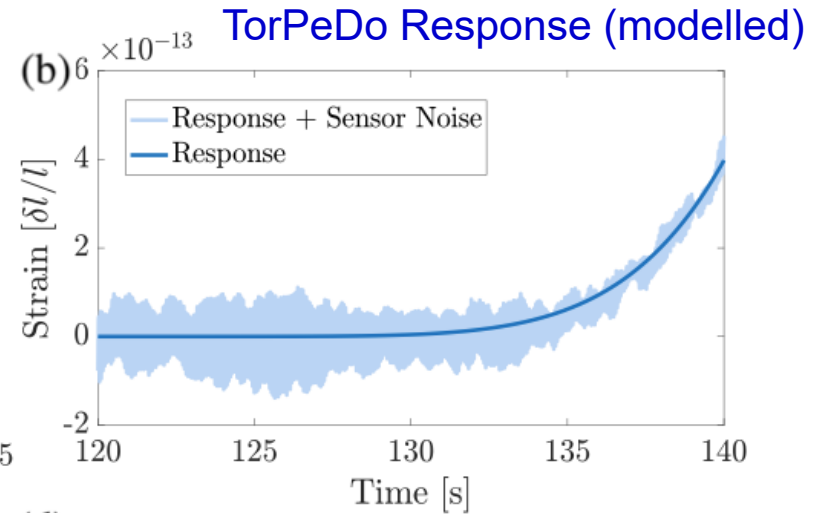
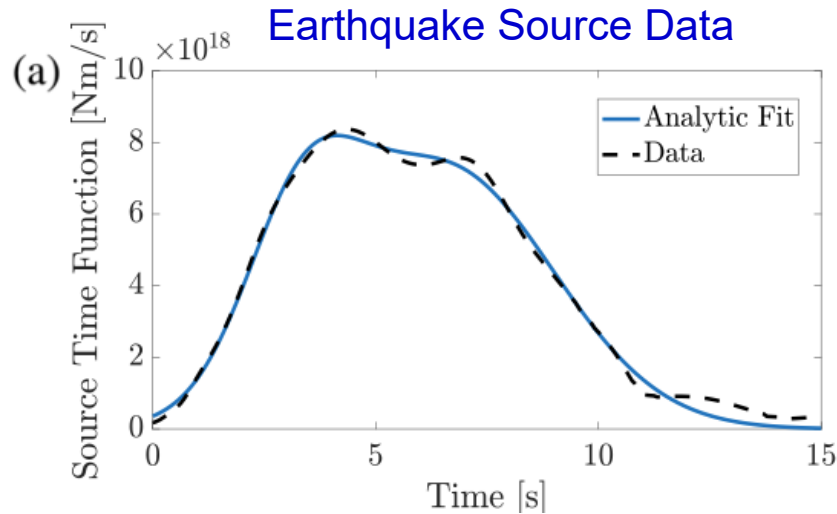


Optical levers have been implemented on the TorPeDO for sensing:

- Pitch, Roll and Vertical modes.
- We now have control of all six degrees of freedom of each bar.

*See poster by Nathan A. Holland, et al.*

# Sensor response and Detection



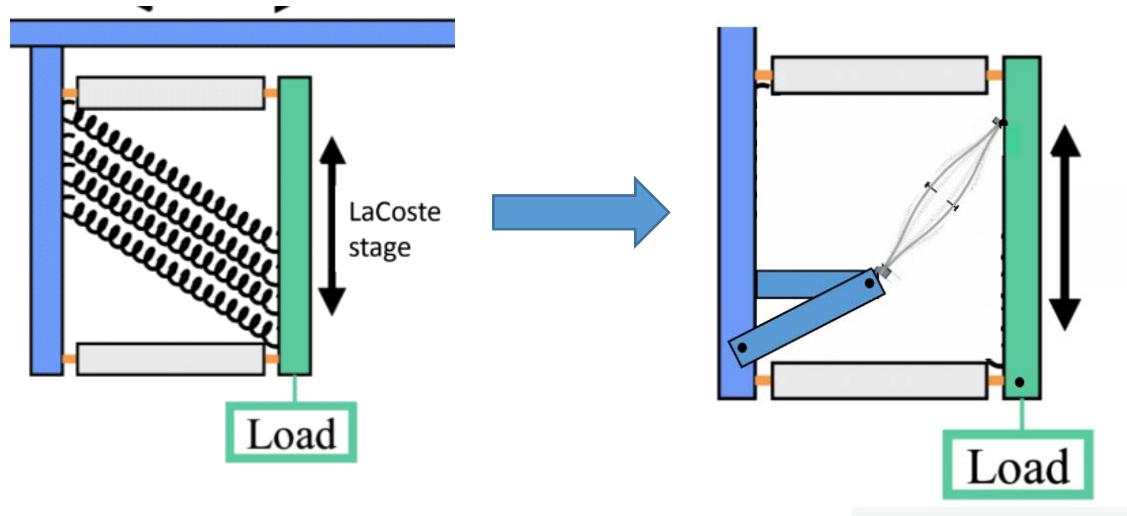
Range / Warning Time

**See David McManus' poster**



# Euler-LaCoste ULF pre-isolation stage

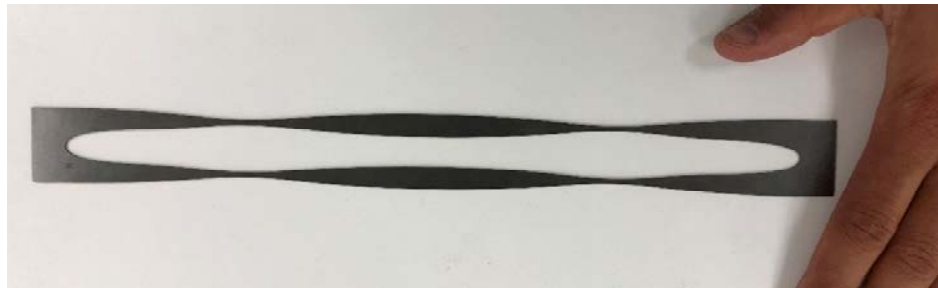
- Replacing the coil spring in LaCoste stage with maraging steel Euler springs
  - Reducing the creep of the coil spring
  - Higher internal frequency of the spring elements





# Improved Euler Spring design

- New Euler blade shape designed and tested
- Euler-LaCost designed
- Frame under construction



- Special shape with uniform stress and minimum blade mass
- Monolithic double blade for symmetry and minimum clamping loss.

*See Joris van Heijningen's poster*



Contoured Euler springs in compression tester



# Control and Data acquisition System (CDS) @ ANU and UWA

- LIGO type digital control system CDS are operational in both groups
  - Extensive discussions between the groups
  - With the help from Keith Thorne (LLO), problems are being discussed and solved



# Exchange and Collaboration

- Weekly **low frequency** program zoom meeting
- Sharing ideas, experiences, tips and tricks
- UWA PhD Joshua McCann visited ANU for 2 weeks in June

Next....

- Instruments running
- More mutual visits

