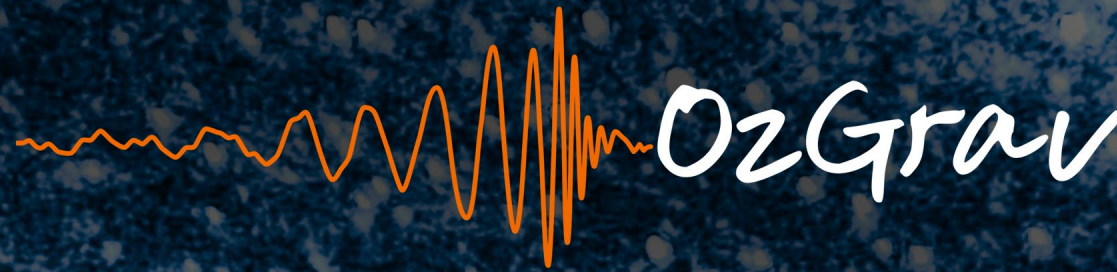




Australian Government
Australian Research Council



ARC Centre of Excellence for Gravitational Wave Discovery

High power 2 μ m cryogenic Silicon suspended coupled cavity progress and challenges

Aaron Goodwin-Jones standing in for Carl Blair

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National
University



MONASH
University



THE UNIVERSITY
of ADELAIDE



THE UNIVERSITY OF
MELBOURNE



THE UNIVERSITY OF
WESTERN
AUSTRALIA



University of Western Australia Acknowledgement of Country

The University of Western Australia acknowledges that its campus is situated on Noongar land, and that Noongar people remain the spiritual and cultural custodians of their land, and continue to practise their values, languages, beliefs and knowledge.

The Ripple Effect: Rippling Out by Wurundjeri artist Judy Nicholson



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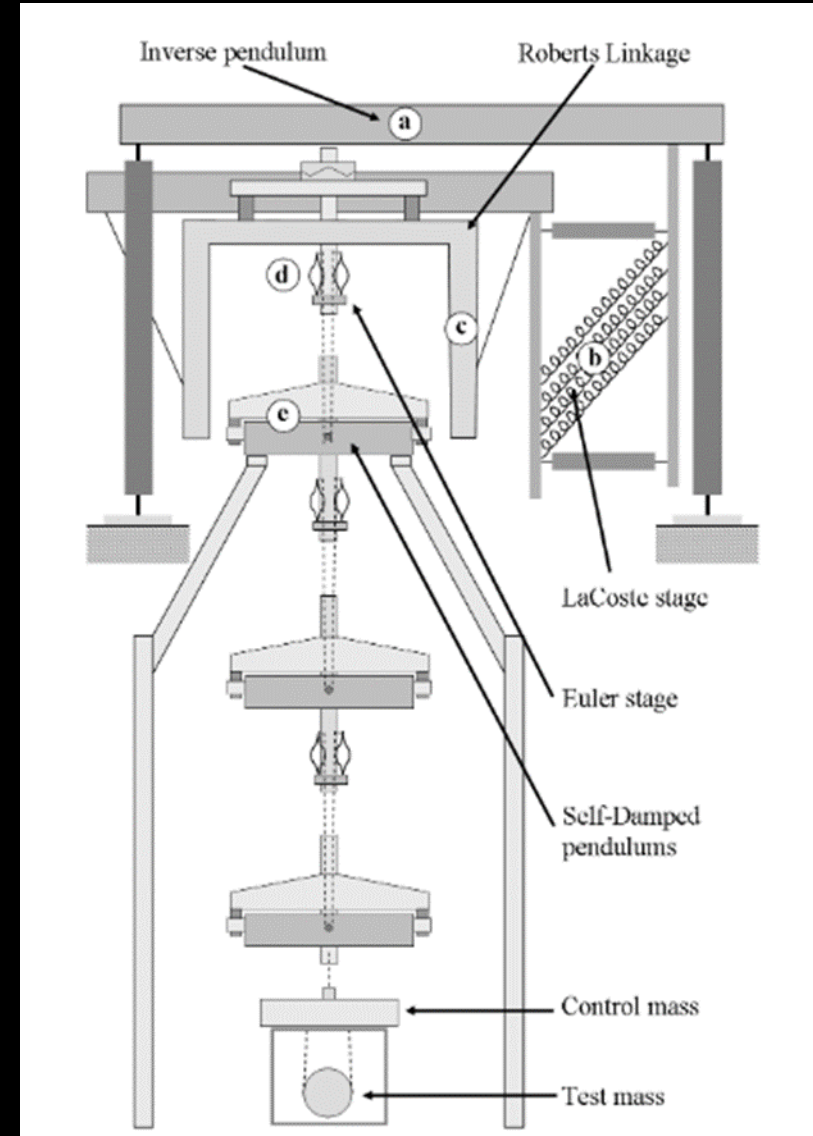
The Gingin Project

- 80 m vacuum enclosure
- Founded early 2000's
- Operated by UWA
- Accommodation on site



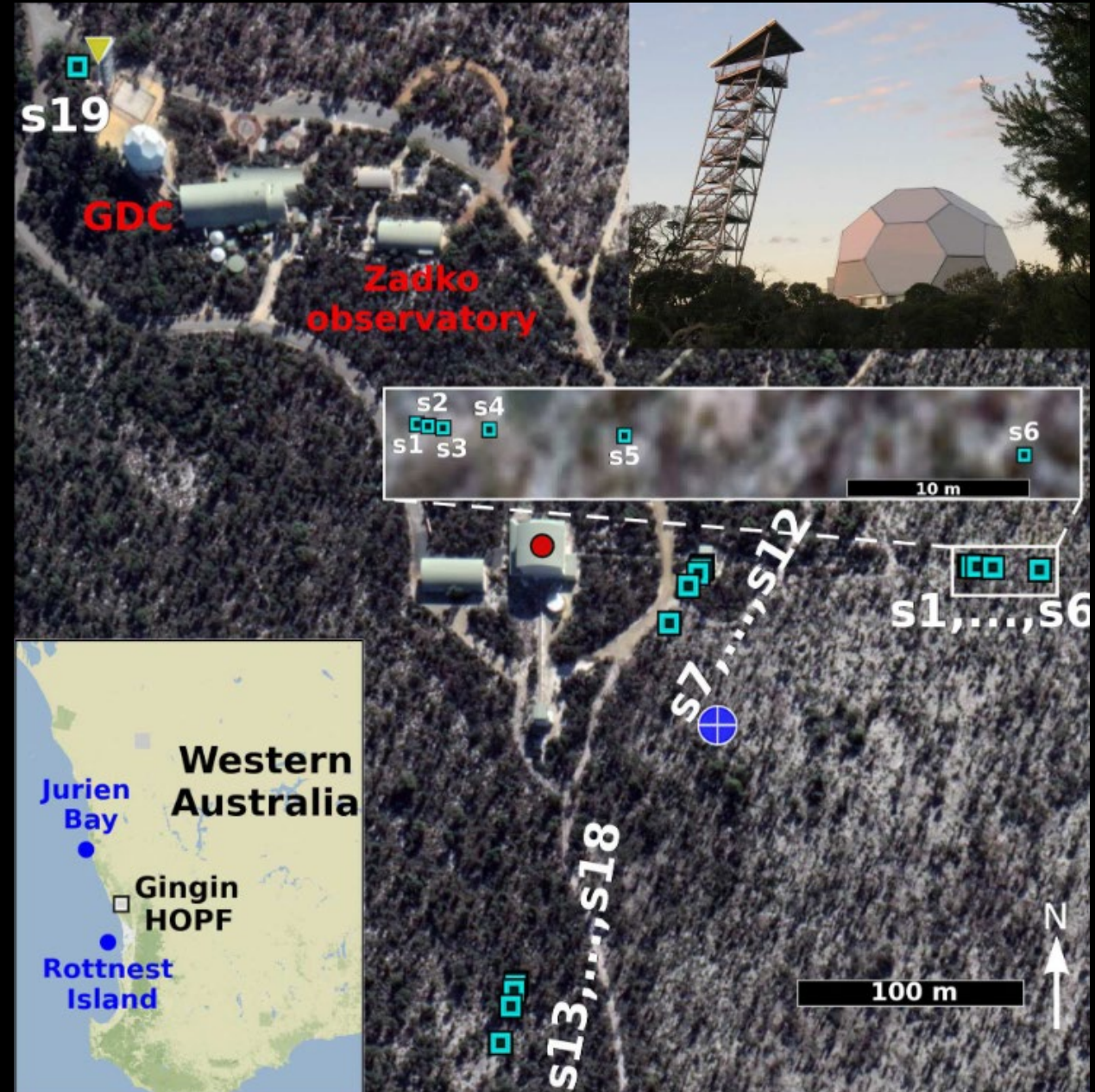
The Gingin East Arm Project

- **AIM: To test high power effects**
- Fabry Perot Cavity
- 50W 1064nm Input laser
- Can excite PI on demand
- Fully assembled
- “UWA” Compact Vibration Isolation
- Can be used for testing ET-HF and A# technology



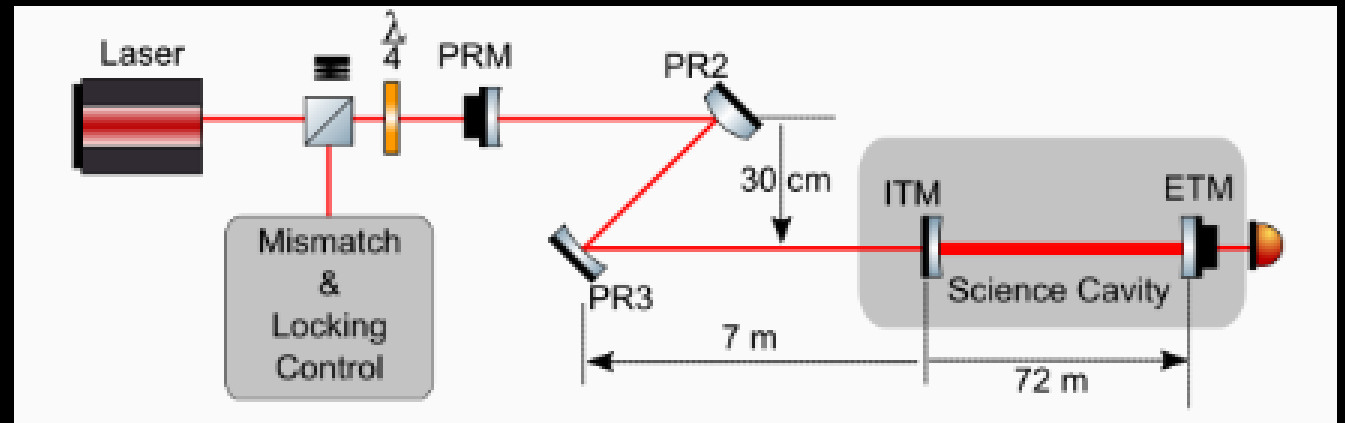
The Gingin Seismic Array

- *AIM: To test the integration of seismic array technology with a prototype facility*
- Seismic array
- Recent publications on correlation between wind speed and microseism noise
- Array partially deployed

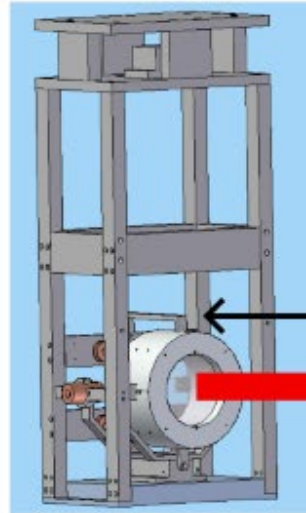


The Gingin South Arm Project

- **AIM: To test high power effects in a Silicon 3G-like facility**
- High power through a cryogenic Silicon ITM
- AlGaAs/GaAs Crystalline coatings
- 23 kW in Arm
 - 26 kW/cm² (ITM)
- 42 W in PRC
 - 190 mW/cm² (ITM), 2.6 W/cm² (PRM)
- 5 W input laser @ 1995nm
- **Target coupled cavity mode matching > 99%**



LIGO Small Optic Suspension



We are using a LIGO SOS Suspension, with a dummy mass for interchangeability between Fused Silica Substrates with Ion beam coatings & Silicon substrates with AlGaAs coatings

Contributors: AG-J, BG, CB, CZ, JL

LIGO Style Control & Data System



We are using a LIGO-Style CDS system with remote access via NoMachine.

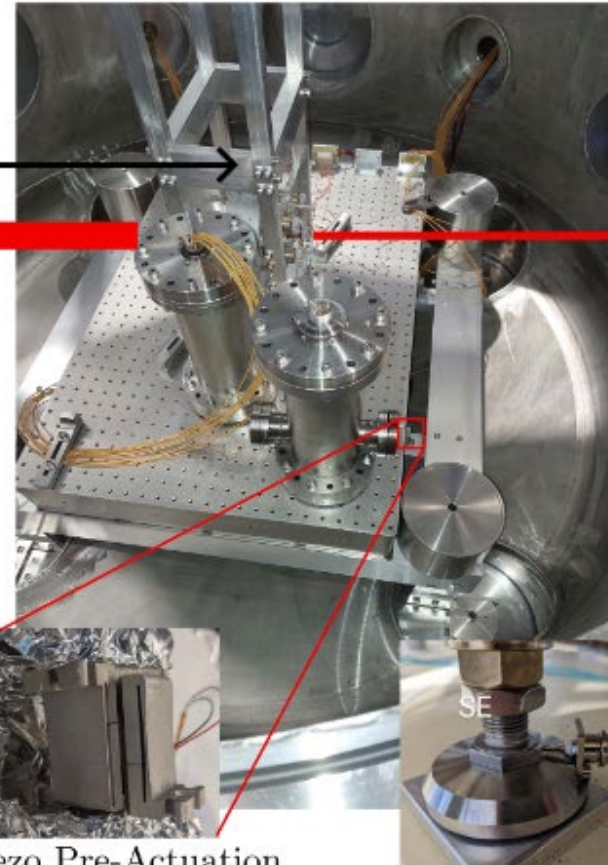
Contributors: AA-J, C.B, AG-J, BS, JL, CZ

Cryogenic ITM

Phase 1 - 7m 'Simple' Cavity

Objective: To develop an ultra-stable 1995nm laser system, locked to a suspended cavity with Silicon optics and AlGaAs + GaAs coatings.

7 meters



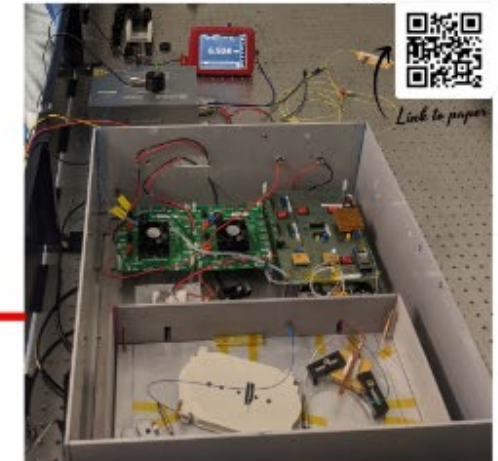
Piezo Pre-Actuation
(E/W & N/S)

Piezo Pre-Actuation
(Vertical)

We have developed a 5D piezo pre-actuation scheme to suppress suspension point motion. A Trillium Compact 120s is placed on the optical table, and table motion is suppressed using custom piezo actuation.

Contributors: JW, AA-J, AG-J, LJ, CB, BS, JL

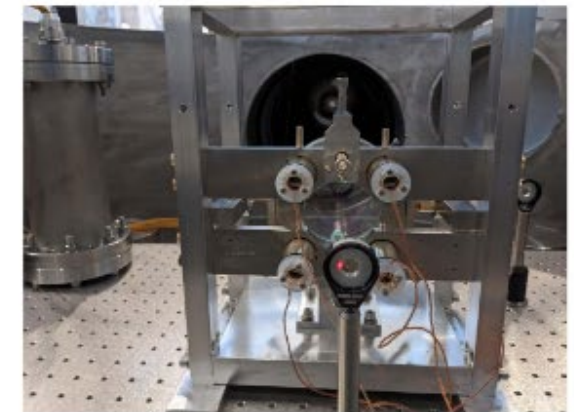
Custom 1995nm 5W Input Laser



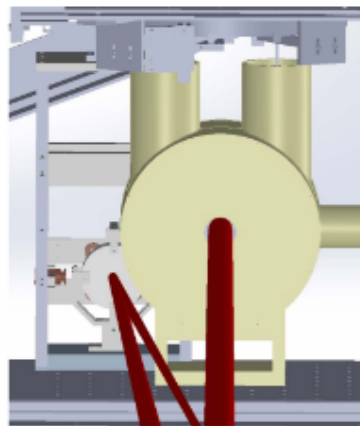
5W laser installed at Gingin.
Laser install, commissioning & mode matching: AA, AG-J & CZ

Laser: Optics Letters, Vol 45, Iss 17,
pp 4911 on

Installed ITM



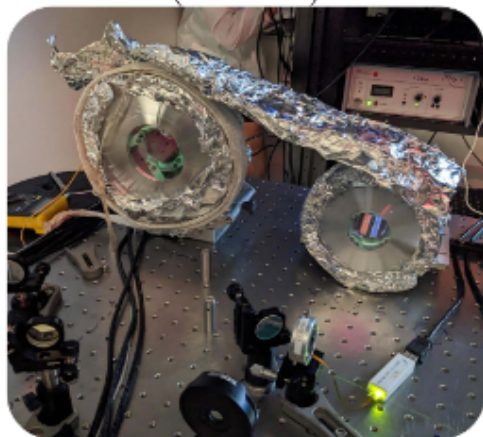
Cryogenic ITM



NEMO will operate with cryogenic test masses near 123 k. We have developed a cooling solution and are working to optimize the design.

Contributors: JP, BL, CZ, CB, AG-J

Thermal Suspended Active Mode Matching Stages (TSAMS)

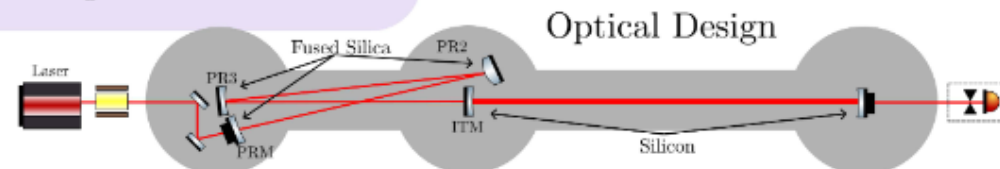


We will use a standard TSAMS and a modified large diameter TSAMS to achieve intra-cavity mode control.

Contributors: AG-J, HC, CB, MC, JL, CZ

Phase 2 - Coupled Cavity

Objective: To demonstrate a high-power coupled cavity, with cryogenic ITM, intracavity mode actuation and AlGaAs+GaAs coatings.



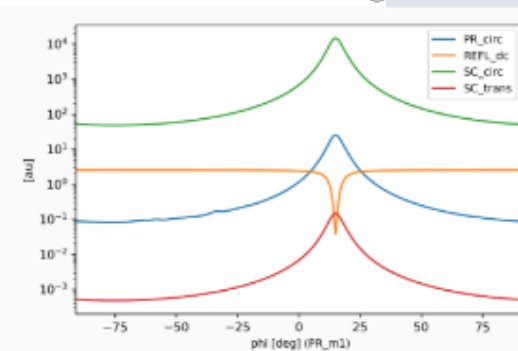
Mode mismatch losses can significantly degrade sensitivity in quantum enhanced gravitational wave detection. We propose a coupled cavity, with intra-cavity mode actuation. This cavity will allow us to demonstrate a cavity with very low mode mismatch losses. See poster #29, DCC G2301026 for details on the sensing scheme.

Contributors: AG-J, CB, BS, JL, CZ

Key Optical Parameters

Component	ETM	ITM	PR3	PR2	PRM
Type	FS TM	Si TM	SAMS	SAMS	FSM
Beam Size [mm]	7.72	7.56	11.83	2.99	2.05
Gouy Phase [deg]	-64.4	63.9	-87.6	-45.0	0.0
Acc Gouy [deg]	0	128	131	138	183
Diameter [mm]	100	100	75	50	50
Curvature [m]	44.8	44.1	∞	-4	∞
Curvature [mD]	44.6	45.4	0	-500	0
Preload [mD]	N/A	N/A	+250	+250	N/A
Actuation [mD]	N/A	N/A	-97	-91	N/A
Design [mD]	N/A	N/A	+159	-347	N/A

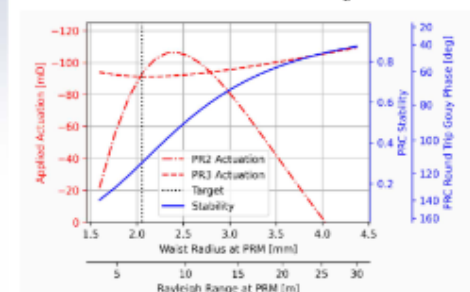
>10 kW Circulating Power



50k Cold Head

7 meters

Tune-able PRC Gouy Phase



Power Recycling Mirror Tank

ITM Tank

Injection Room

72 m

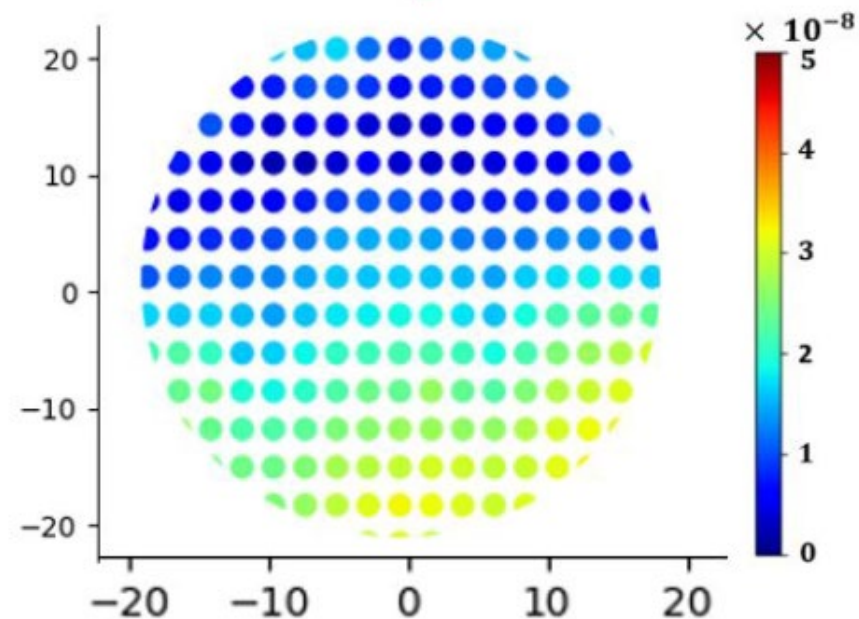
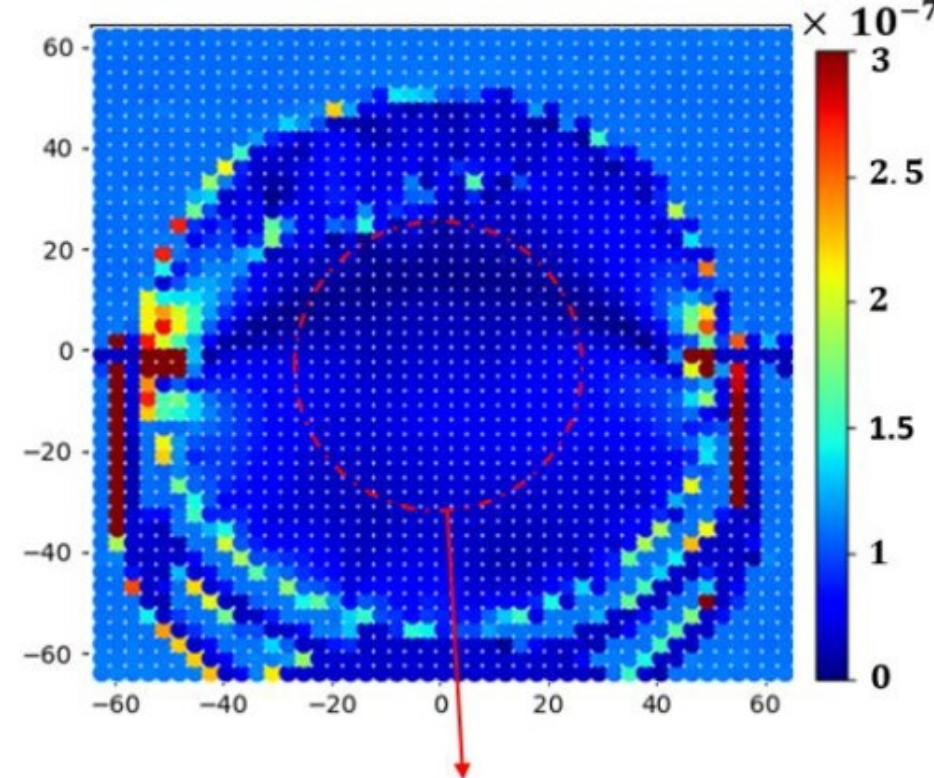
ETM Tank

ITM Seismic Isolator



Test Mass Characterisation

- Extensive programme of test mass characterisation
 - Birefringence Mapping <https://dcc.ligo.org/LIGO-P2200357>
 - Q Factor measurements <https://dcc.ligo.org/LIGO-P2200168>



Conclusion

Prototype facility at Gingin able to test multiple subsystems

East Arm

- High Power Effects

- South Arm
- High Power
- AlGaAs + Silicon
- Full Suspension
- Cryogenic
- Active Mode Control
- Seismic Array / Rotation Sensor / Newtonian Noise