LIGO-G980113-17-M

# The Australian Consortium for Interferometric Gravitational Wave Astronomy

## Status Report for LSC 3

August 13 1998

presented by

David E. McClelland
Physics, The Faculties
The Australian National University

Australian Consortium for Interferometric Gravitational Astronomy

## Organisation

*Executive Committee*

Chair J Sandeman

D McClelland - ANU
J Munch - AU
D Blair - UWA

### ARC Funded (Primary) Institutions

**UWA-AIGRC**

David Blair
Ju Li
Mark Notcutt

Isolation and Optical materials (Nb Bar)

**AU**

Jesper Munch
PeterVeitch
Murray Hamilton

Laser and Optics Systems

**ANU**

David McClelland
Macolm Gray
Susan Scott

Topologies
Quantum Optics
General relativity

### Affiliate Institutions

**CSIRO-Optics**

Chris Walsh
Adam Leistner

High Quality optical polishing

**Monash U**

Tony Lun

General relativity

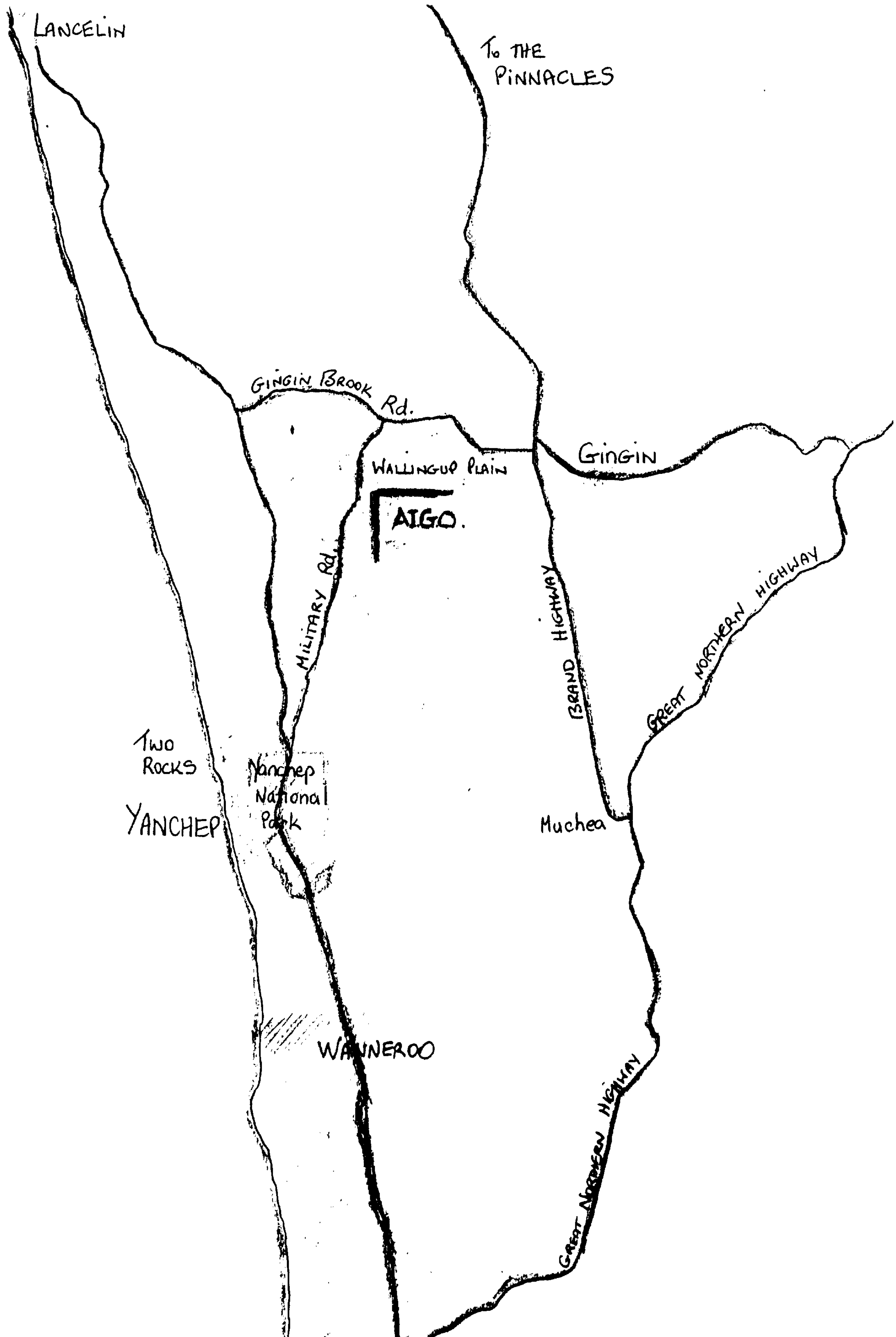
### Autonomous Society

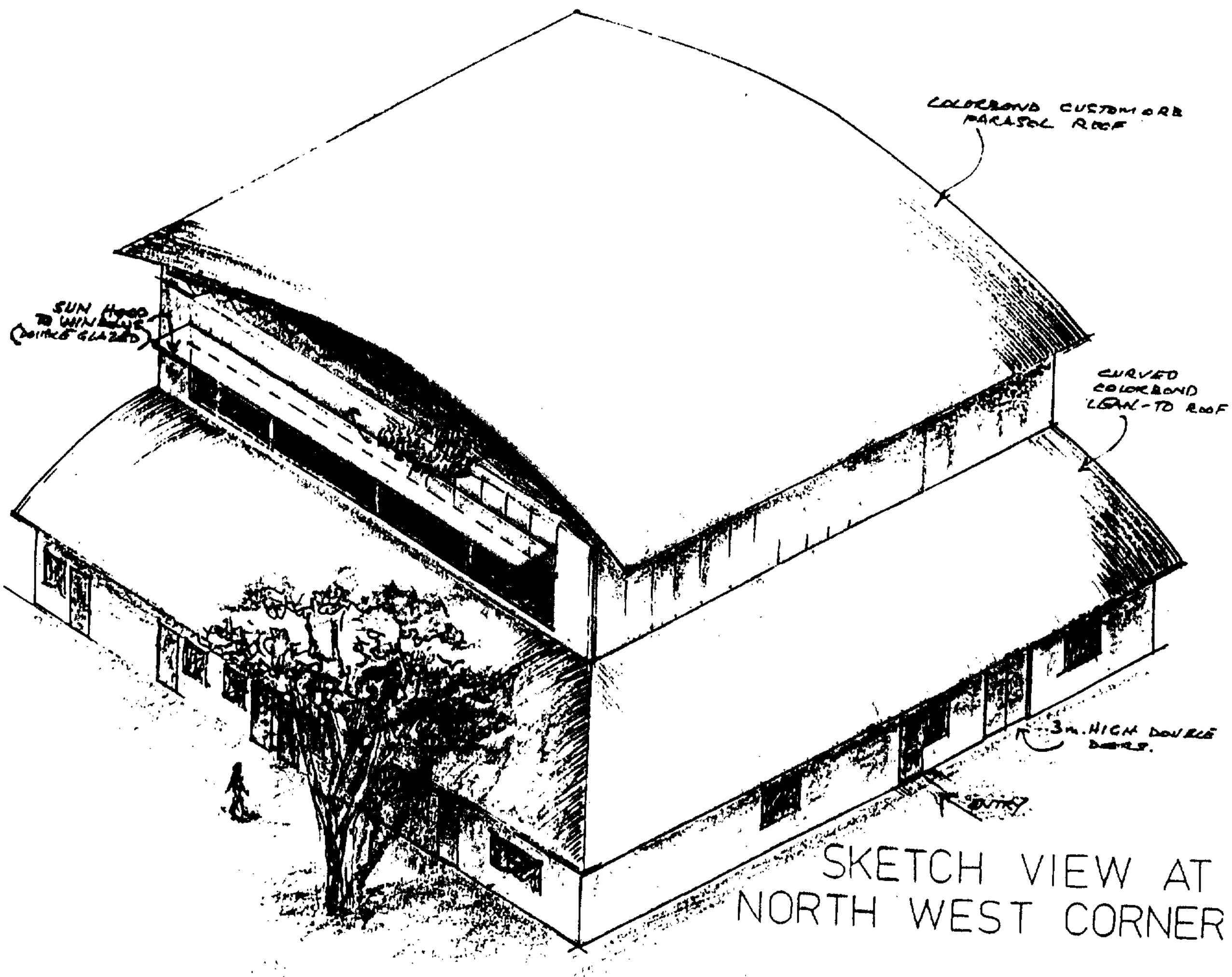
Australasian Society for General Relativity and Gravitation (ASGR&G)
Some 80 members - general relativists and gw experimentalists

# The Advanced Research Interferometers

## ARI – Gingin

- ~ 12 m baseline;
- built on a site which will allow extension to 500 m and eventually 4 km;
- will be be configured to serve as the central station for a future large interferometer;
- in the first instance will be used to demonstrate high performance on a reliable suspended mass instrument
- present status:
  - site being prepared
  - laboratory designed
  - isolators designed
  - topology TBD


LANCELIN
TO THE PINNACLES
GINGIN BROOK Rd.
GINGIN
WALLINGUP PLAIN
AIGO.
MILITARY Rd.
BRAND HIGHWAY
GREAT NORTHERN HIGHWAY
TWO ROCKS
YANCHEP
Yanchep National Park
Muchea
WANNEROO
GREAT NORTHERN HIGHWAY




SKETCH VIEW AT
NORTH WEST CORNER

## The ANU Facility

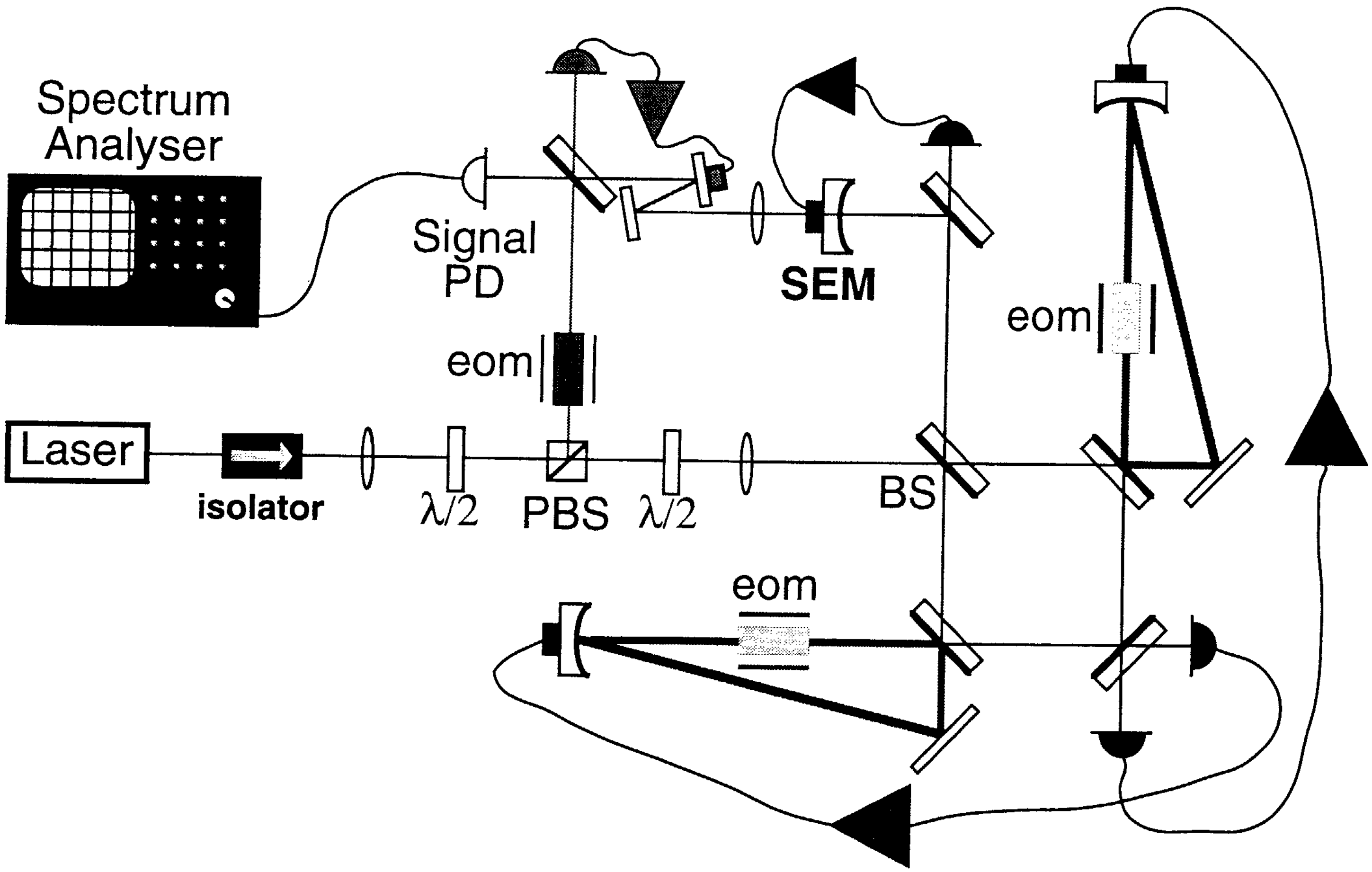
- can accept max. baseline of 10 m;
- will be built on campus;
- is designed for maximum flexibility to allow a range of R&D projects to be carried out;
- in the first instance it:
  - will house the direct measurement of thermal noise experiment;
  - prototype advanced topologies
- later it will become the R&D facility for AIGO;
- present status: building funds approved
  - design approved
  - completion date Feb. 1999.

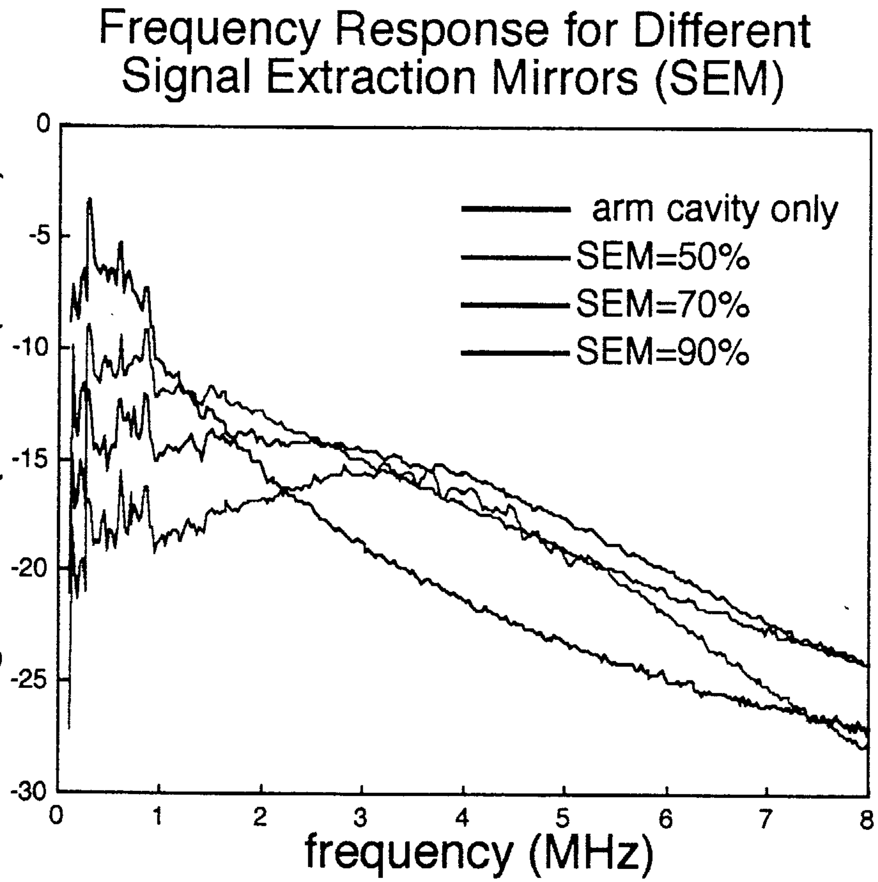
# Resonant Sideband Extraction in a Sagnac Interferometer

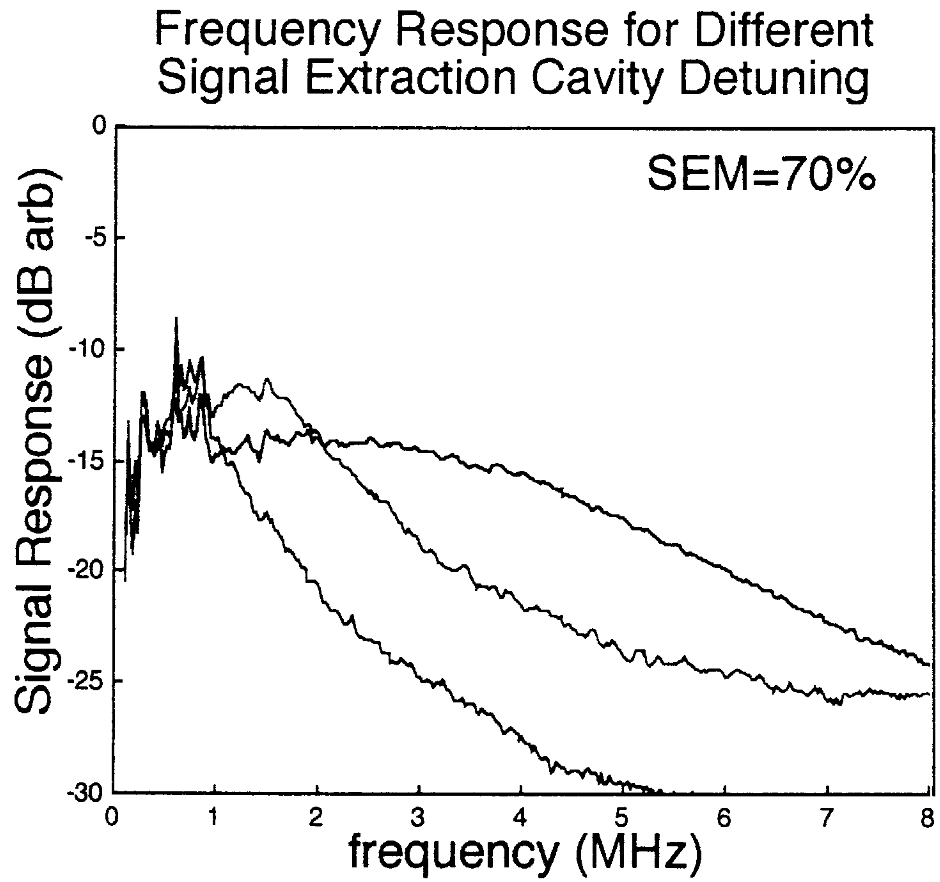
Daniel Shaddock, Malcolm Gray, Karl Baigent
and David McClelland

THE AUSTRALIAN
NATIONAL UNIVERSITY

# Detailed Experimental Setup




Frequency Response for Different
Signal Extraction Mirrors (SEM)
arm cavity only
SEM=50%
SEM=70%
SEM=90%
0
-5
-10
-15
-20
-25
-30
0 1 2 3 4 5 6 7 8
frequency (MHz)


Frequency Response for Different
Signal Extraction Cavity Detuning
SEM=70%
Signal Response (dB arb)
0
-5
-10
-15
-20
-25
-30
0 1 2 3 4 5 6 7 8
frequency (MHz)

# Sagnac or Michelson?

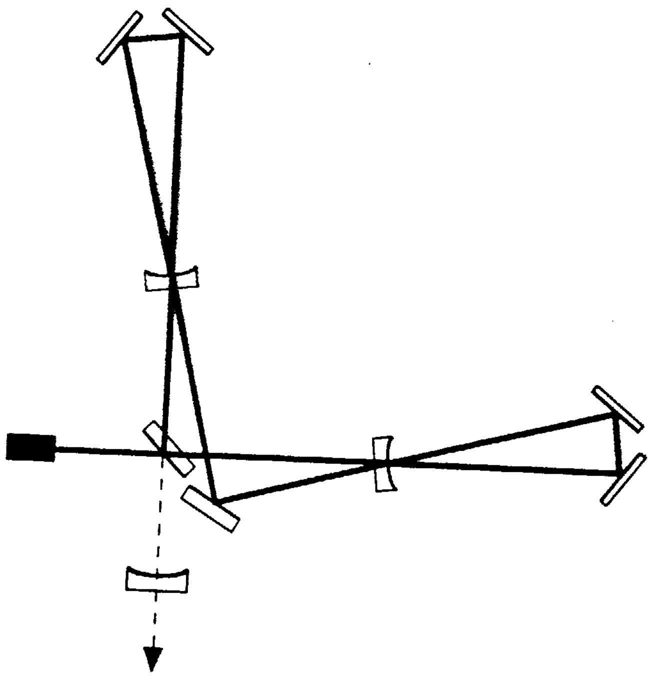
Control systems similiar in complexity.

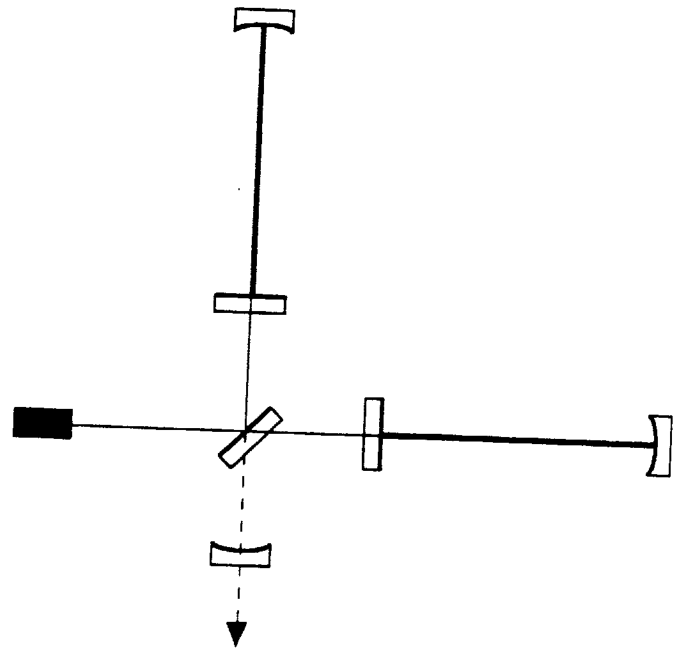
Insensitivity to arm length losses in a Sagnac balanced by insensitivity to beamsplitter ratio for a Michelson.

Sagnac unable to store as much energy as a Michelson due to increased losses.

Power Loss: Sagnac arm cavity 3 mirrors
Michelson arm cavity 2 mirrors

Signal Loss: Sagnac signal cavity 4 mirrors
Michelson signal cavity 2 mirrors





# Intensity Stabilisation

Inside a feedback loop the free field uncertainty relation for amplitude and phase is no longer valid.

$$\Delta X_1 \Delta X_2 \not\geq 1$$

**Cavity** field is "in-loop" and so intensity noise can be suppressed below the standard quantum limit **without a phase noise penalty.**

For an impedence matched cavity the circulating field inside the cavity can be supressed by (up to) 3dB below shot noise.

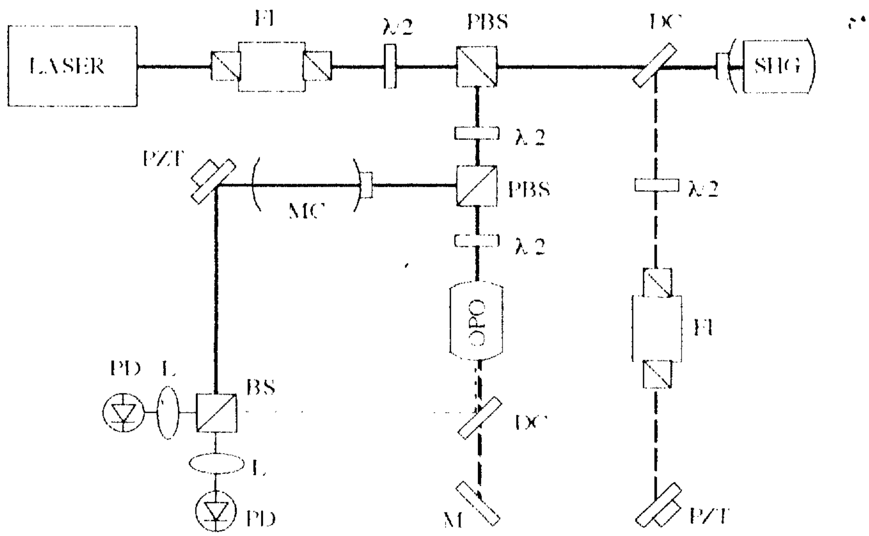
*Ping Koy Lam, Jiangrui Gao*, D. E. McClelland and H. -A. Bachor.*

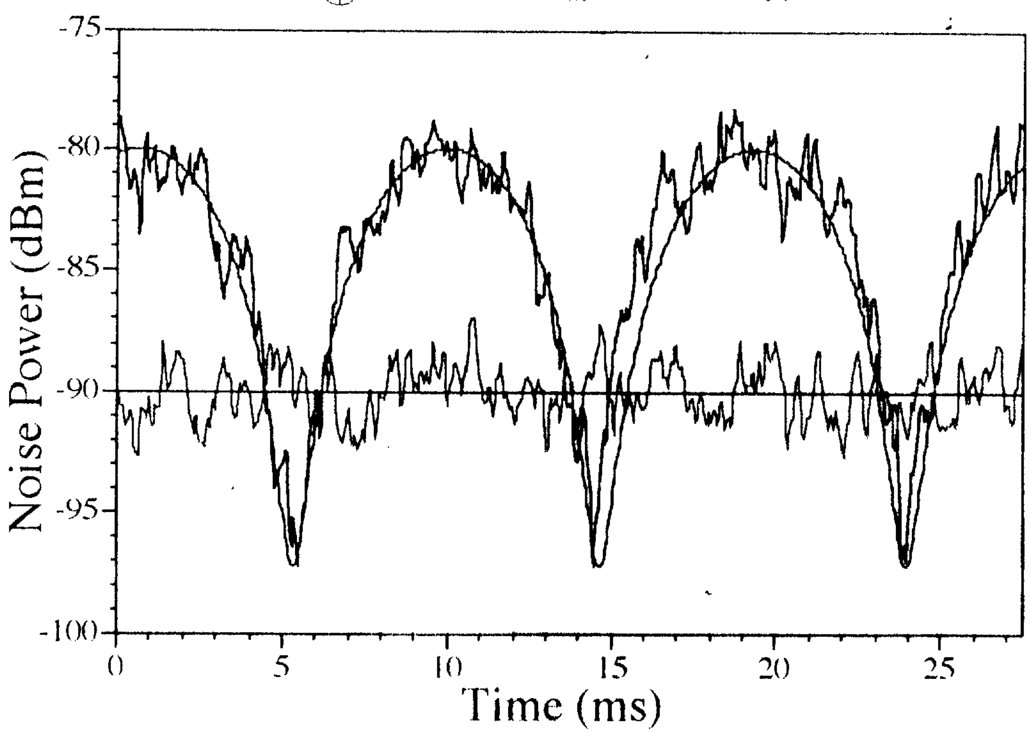
*Quantum Optics Group, Department of Physics, The Australian National University.*

*Institute of Opto-electronics, Shanxi University, Taiyuan, Shanxi, P. R. China.*

山西大學

# Squeezed Vacuum from an OPO




Res BW 30 kHz,VBW 500Hz.

Fitted curve is based on 7.1dB squeezing.

# Progress towards a system for the measurement of thermal noise

Karl Baigent, Mal Gray, Daniel Shaddock,
David McClelland

Department of Physics and Theoretical Physics
Faculty of Science
Australian National University

# Thermal Noise Measurement System

Aim: Develop a benchtop prototype of a system capable of measuring the thermal noise of test masses.

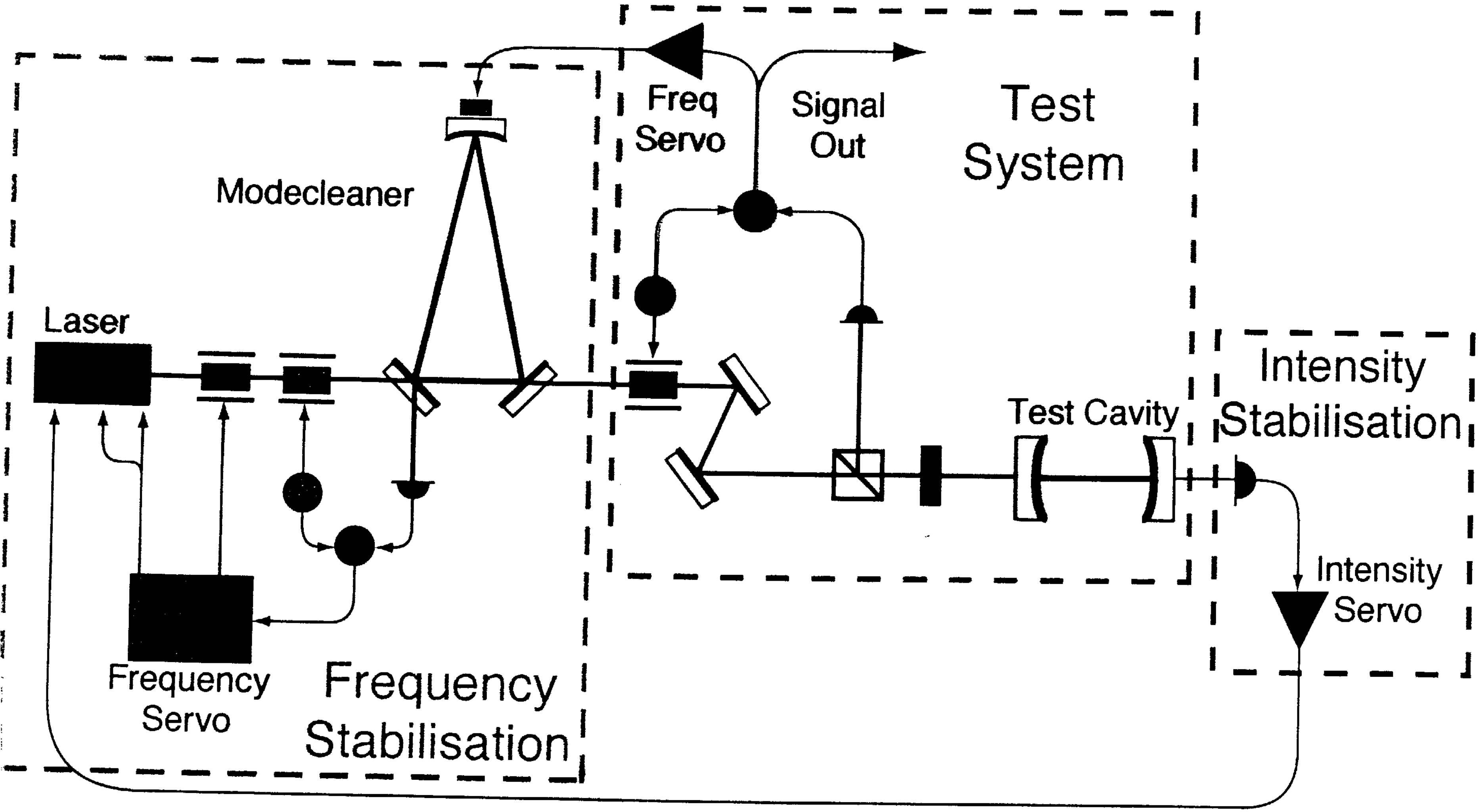
Measure mirror motion due to thermal noise using a Fabry-Perot cavity and a Pound-Drever signal readout.

To successfully measure thermal noise there are a number of other noise sources which must be minimised.

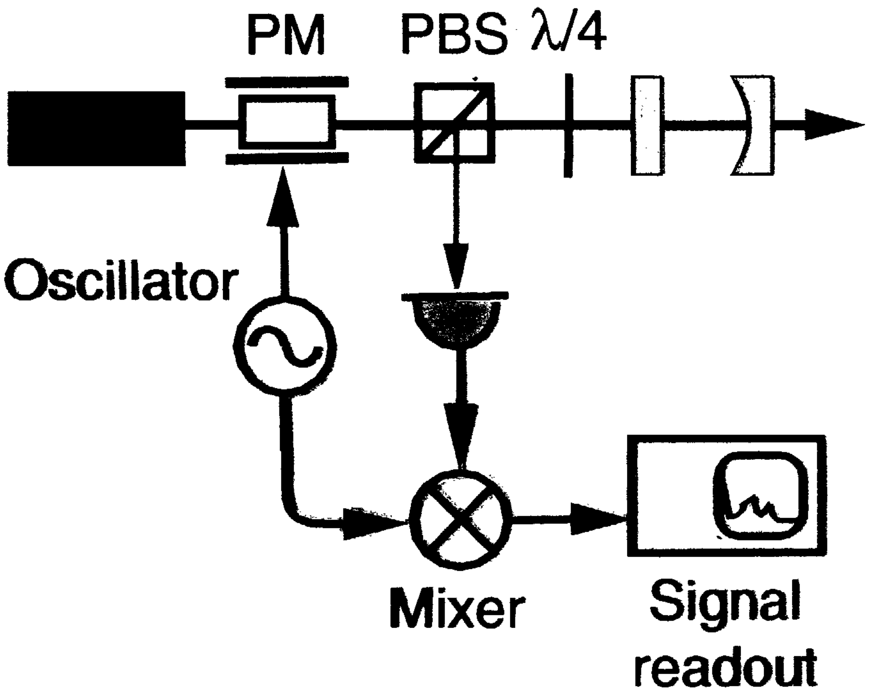
Laser frequency noise

Classical radiation pressure noise (due to excess laser intensity noise)

# Thermal Noise Measurement System



# 4.4 Readout sensitivity




## Readout shot noise

F = 10 000, L = 0.01 m
$P_i$ = 30 mW, $\eta$ = 0.85

$\Delta L = 7.2 \times 10^{-20}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$

## Radiation pressure noise

Coherent input
M = 10 kg

$\Delta L = 8.1 \times 10^{-20}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$
@ 10 Hz

## Frequency noise

FWHM = 174 kHz
$P_i$ = 35 mW, $\eta$ = 0.85

$\Delta L = 1.4 \times 10^{-21}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$

# 5. Conclusions

Characterized the laser

Displacement sensitivity

Constructed and tested reference cavity

→ should detect thermal noise

Frequency stabilization operating

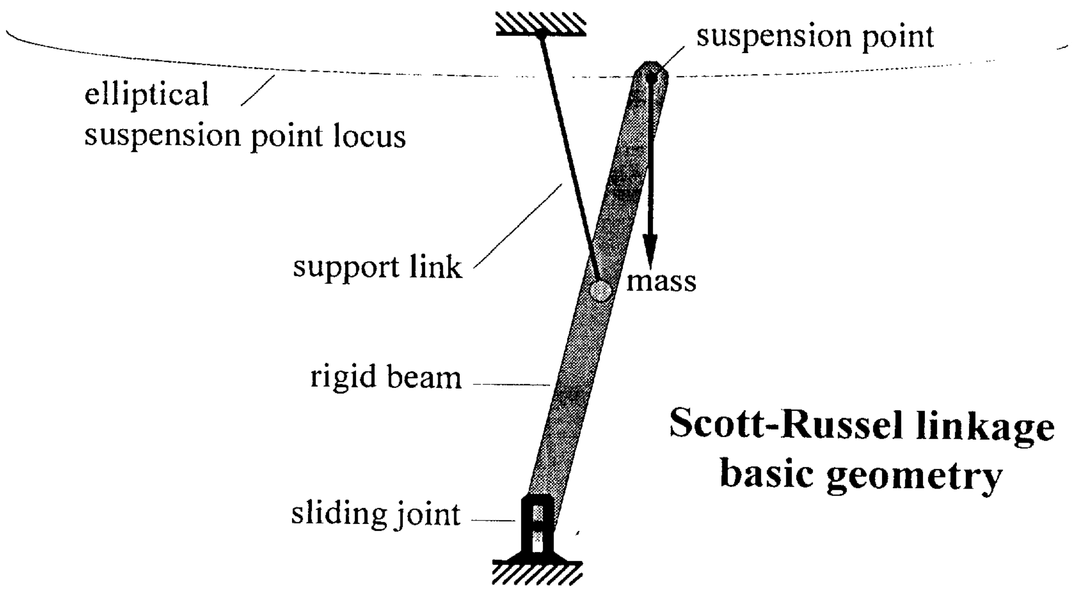
Designed new intensity stabilization system

Sensitivity of $\Delta L < 10^{-19}\ \mathrm{m}/\sqrt{\mathrm{Hz}}$

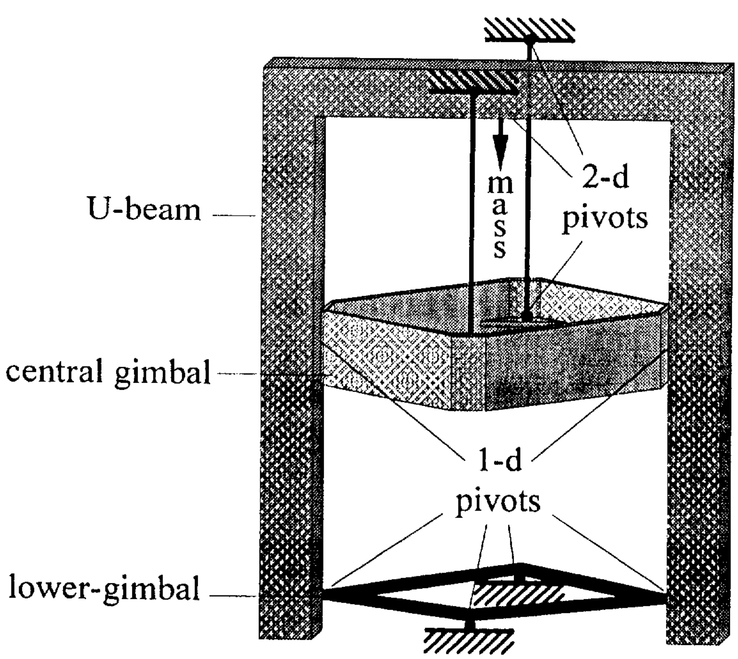
# AIGIC Vibration Isolation Configuration

Ju Li, J. Winterflood, D.G. Blair et al
ACIGA / UWA

# Horizontal pre-isolator

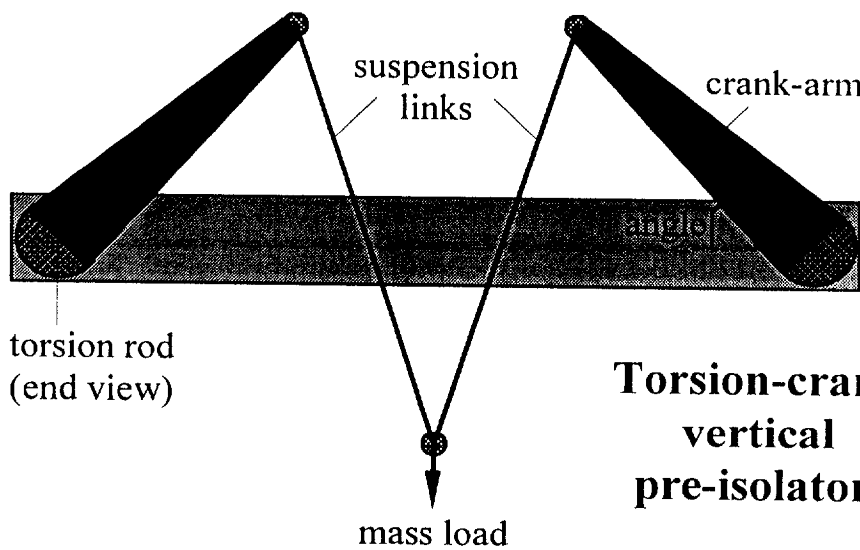



**Scott-Russel linkage basic geometry**

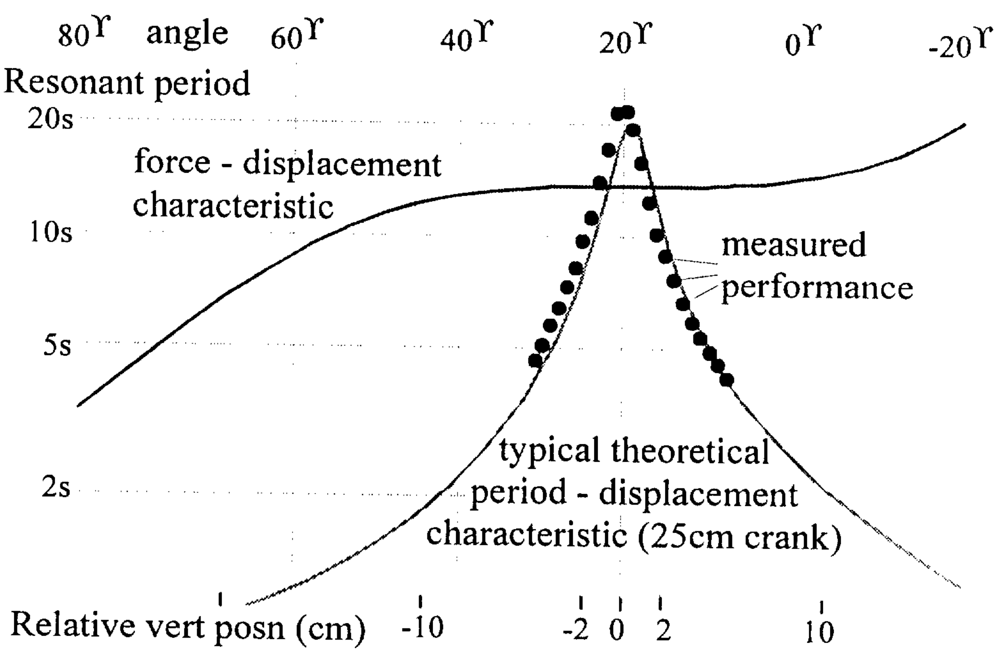



**One possible Pre-isolator Realisation**

# Vertical pre-isolator

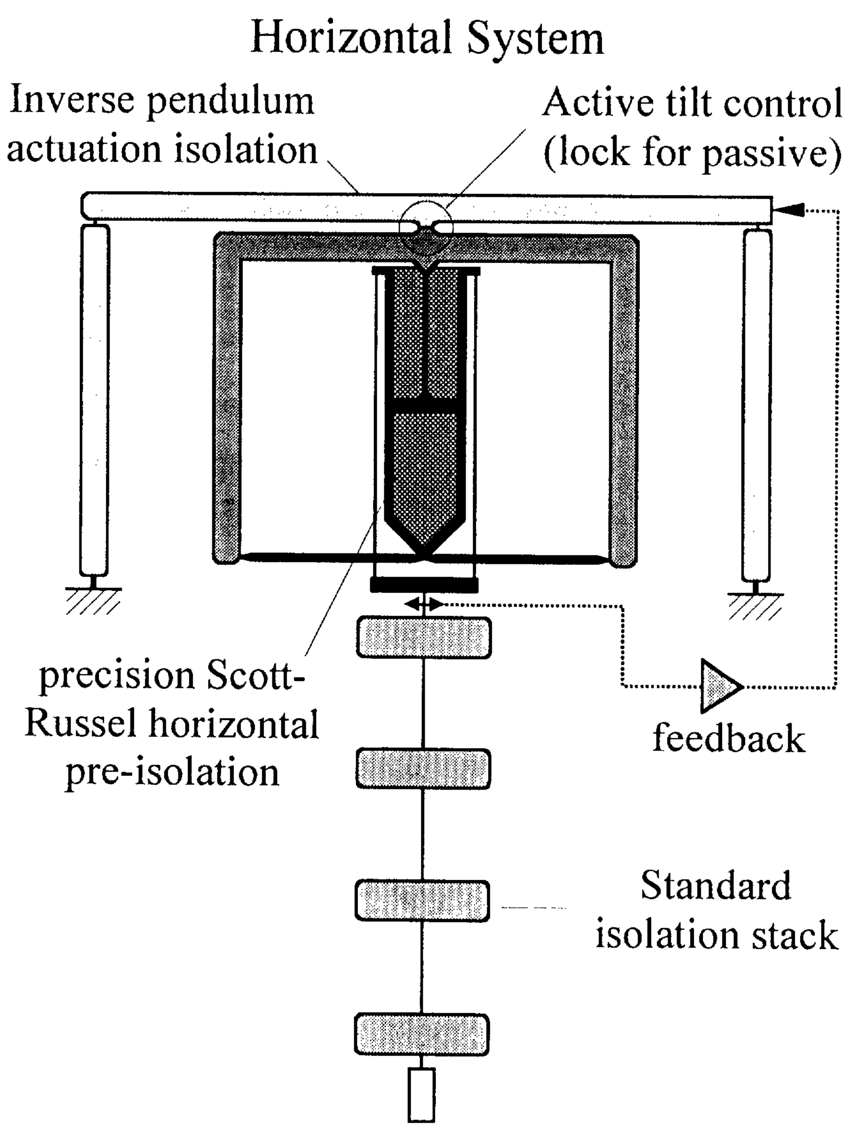



**Torsion-crank vertical pre-isolator.**

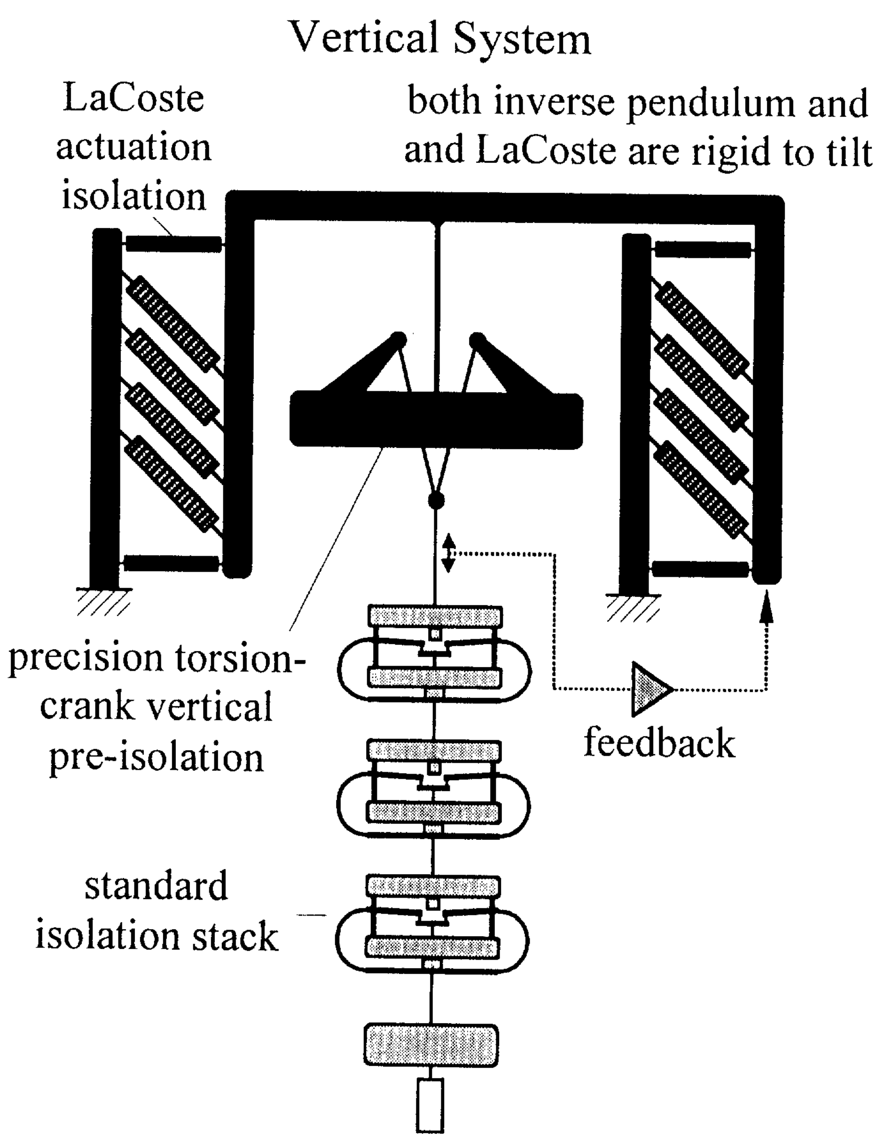



**Theoretical curves and measured performance**

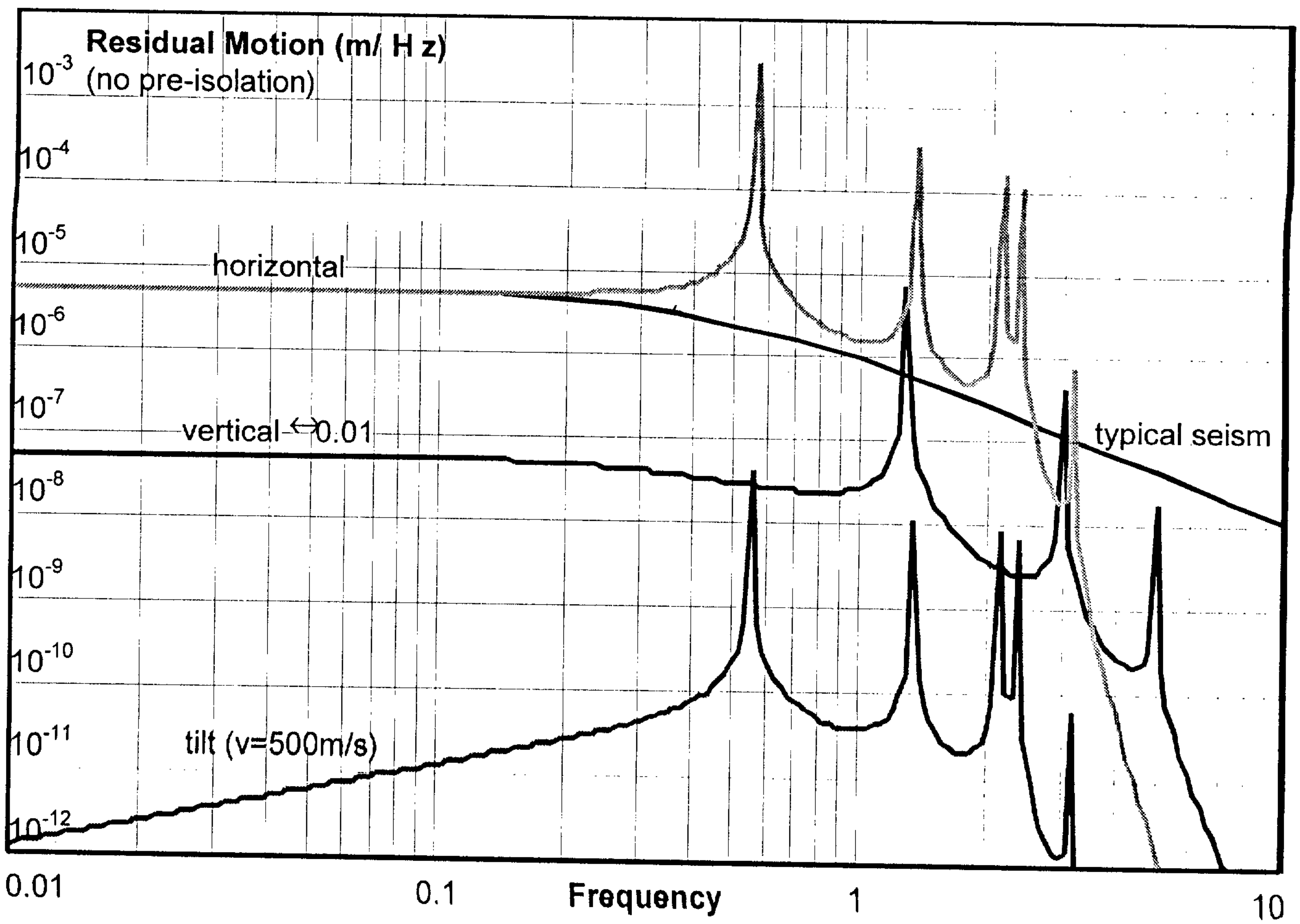
# Second stage horizontal pre-isolator



# Second stage vertical pre-isolator



# Transfer function of a low frequency isolator without pre-isolation



*Note 1, Linda Turner, 08/20/98 01:11:29 PM*
LIGO-G980113-17-M