LIGO-T970253-00-D

The Australian Consortium for Interferometric Gravitational wave Astronomy

The Australian National University

Interferometry and Squeezing: Quantum Optics Research at the ANU.

David E. McClelland

Overview

- about ACIGA
- about the Quantum Optics Group

Quantum Noise

- Injection locking
- Squeezing in SHG
- making squeezed light robust

Advanced configurations

- Signal Recycling
- ~~Sagnac vs. Michelson~~
- ~~RSE on a Sagnac~~

Quantum noise and advanced configurations

- Squeezing and signal recycling

Welcome to the **Australian Consortium for Interferometric Gravitational Astronomy (ACIGA)** web page.

Objectives

In collaboration with the world gravitational wave community to:

- Undertake research and development aimed at improving the performance of present laser interferometer gravitational wave detectors through advanced designs to ultimate limits set by mechanics, quantum mechanics, lasers and optics;

- Transfer this R&D into practical designs for inclusion in existing and future detectors including the Australian International Gravitational Observatory as the Southern Hemisphere component of the world wide observational network;

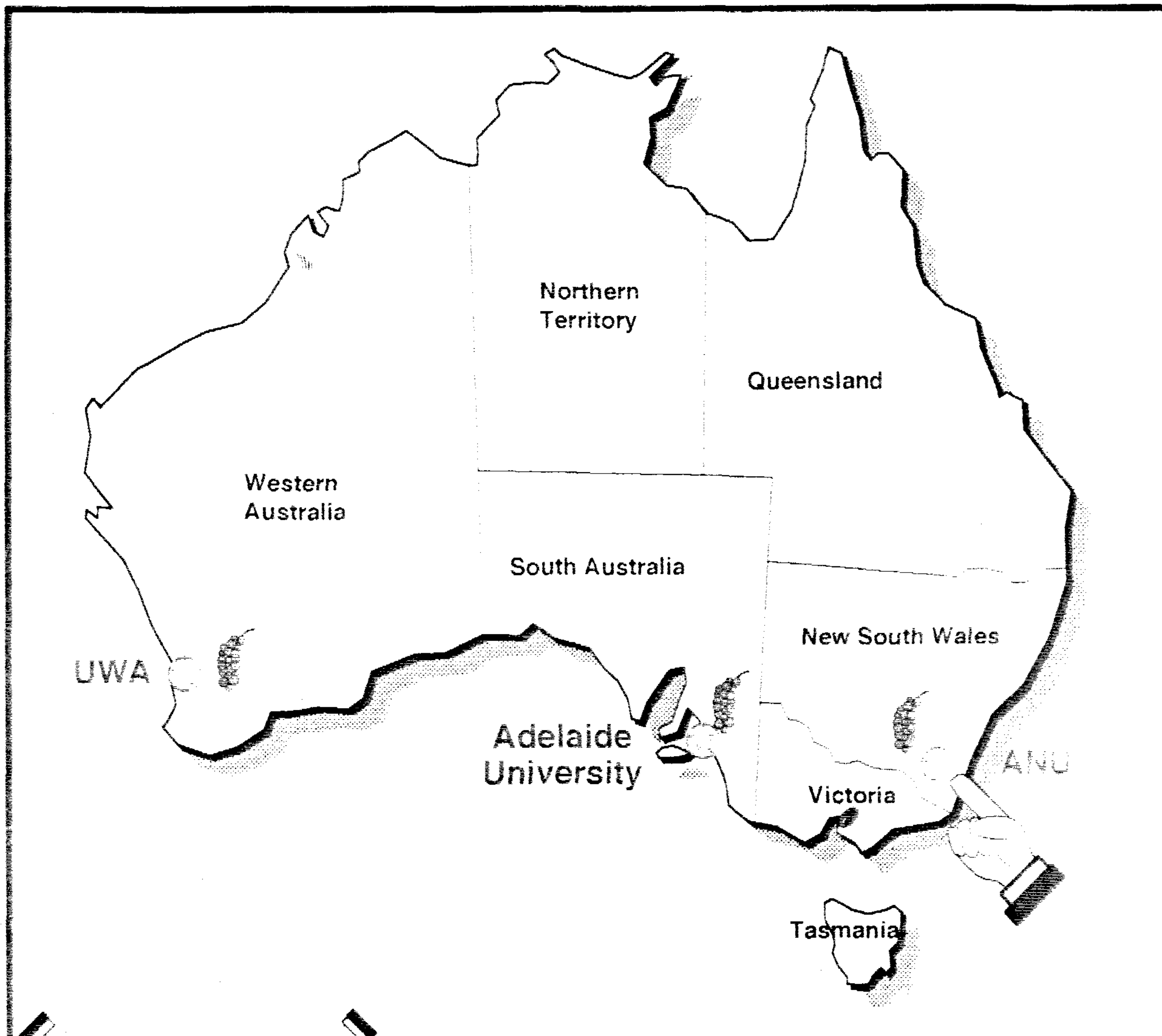
- Transfer the R&D where appropriate to the Industrial partners for the production of commercial products (see note below re intellectual property rights):

- Arrange conferences, seminars and workshops as required to compliment and enhance the research of the members of the consortium.

Management Structure

www.anu.edu.au /Physics/ACIGA/

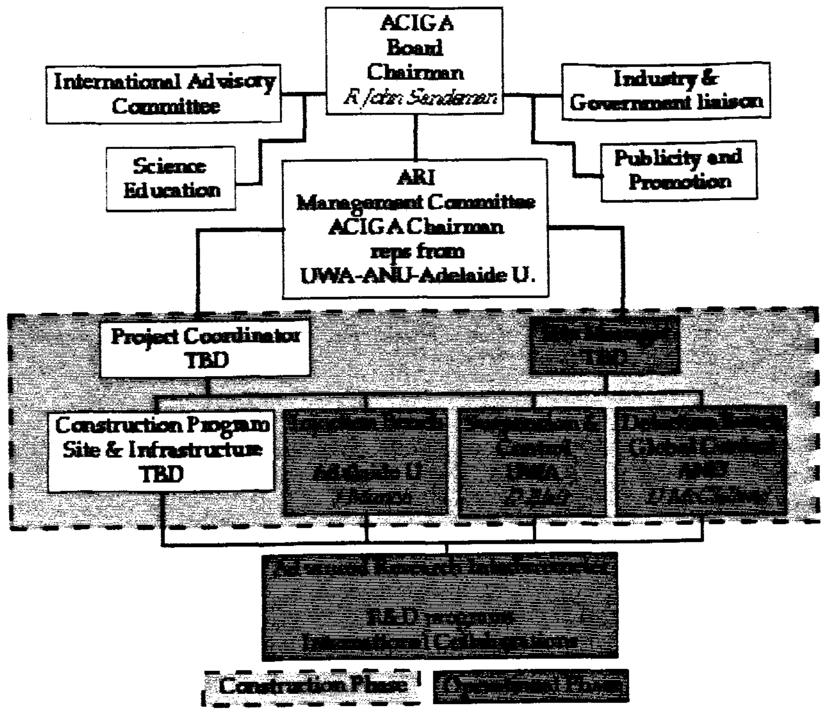
ACIGA



ANU :*Optics* — Interferometric configurations, control, signal extraction, quantum optics (squeezed states), laser injection locking

UWA : *Mechanics* — Mirror suspensions, seismic/mechanical isolation, High-Q resonators, Sapphire transducers

Adelaide : *Lasers* — Diode-pumped solid state lasers, Holographic beamsplitters and beam correcting elements



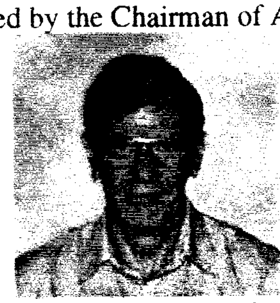
ACIGA Board

Consists of the representatives of the ACIGA membership including all partners. Acts as an advisory board for all ACIGA operations including input from the International groups and Australian government and industry bodies.

ARI Management Committee

The committee which oversees the construction and operation of the ARI including its planning for as a corner station for an operational gw detector. It implements policy decisions of the ACIGA board. Oversees the coordination of the construction and operation of the ARI.

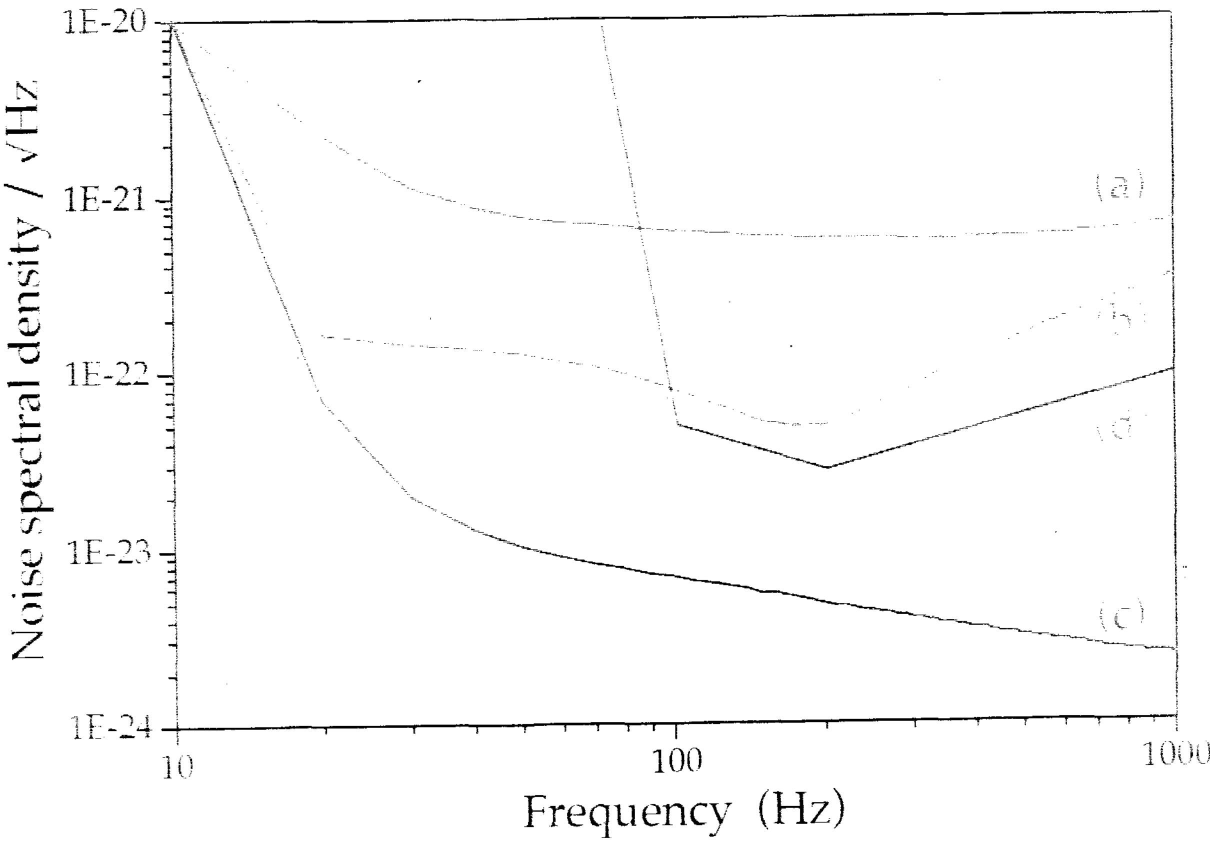
Chaired by the Chairman of ACIGA



Emeritus Professor R John Sandeman

Representatives of

AIGO 400
TOTAL NOISE BUDGET



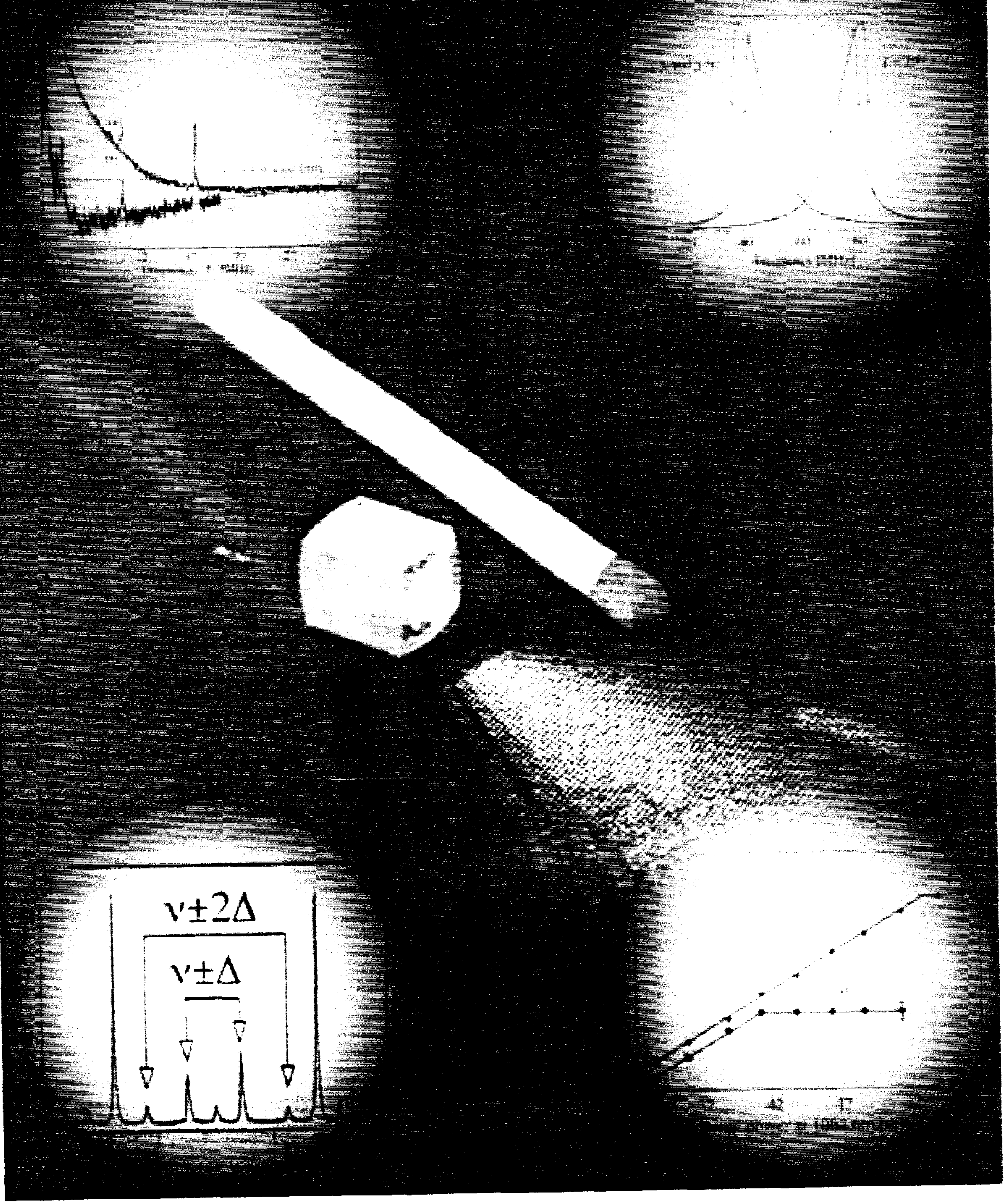
[illegible] stage: laser power 5 W and assuming PR and SR [illegible] 30 kg test masses, and Qs ~ 1e05 to [illegible]

[illegible] PR ~ 1700, SR ~ 800; 100 kg masses: Qs ~ [illegible]

[illegible] thermal noise floor;

[illegible] stage 1 noise budget.

Quantum Optics
1996 Annual Report
ANU



People

ACIGA:

Malcolm Gray
Boris Petrovichev
Dan Shaddock
Karl Baigent

Charles Harb

Elanor Huntington

Quantum Optics

Hans Bachor
Tim Ralph
Ping Koy Lam
Jinwei Wu

Matthew Taubman
Andrew White

Linearised model:

$$\hat{a} = \alpha + \delta\hat{a}$$

operator — classical value — operator

Scaled intensity noise
= amplitude quadrature noise

$$\mathrm{Var}(n) = n \; \mathrm{Var}(X1)$$

All Q-functions are 2 dim Gaussian.

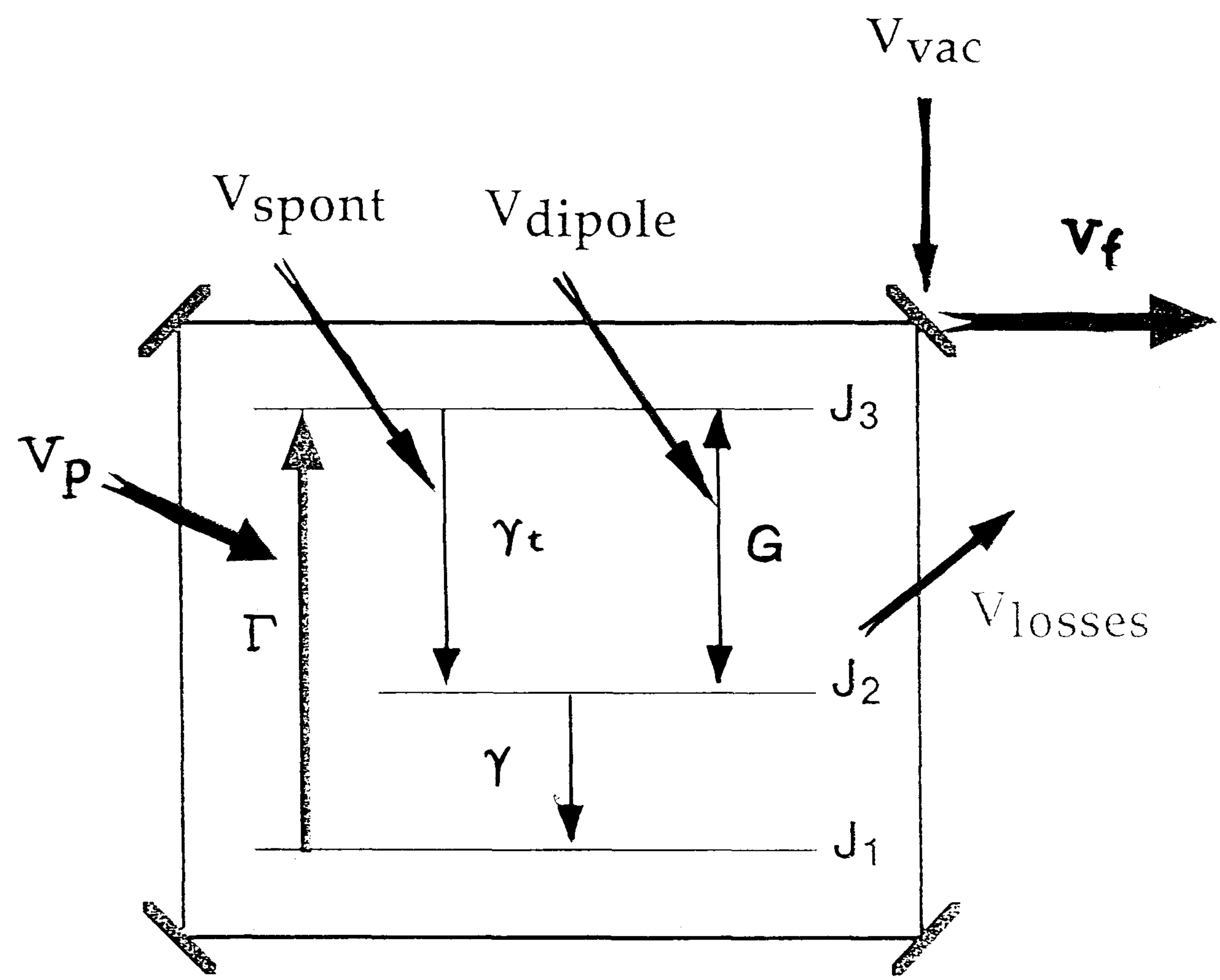
$V1(\Omega)$ contains all necessary information

Optical systems can be described by noise transfer functions

Theory + Exp. Tests: Tim Ralph, et al.

See also : Squeezed state of light
C.Fabre Physics Report 219 (1992)

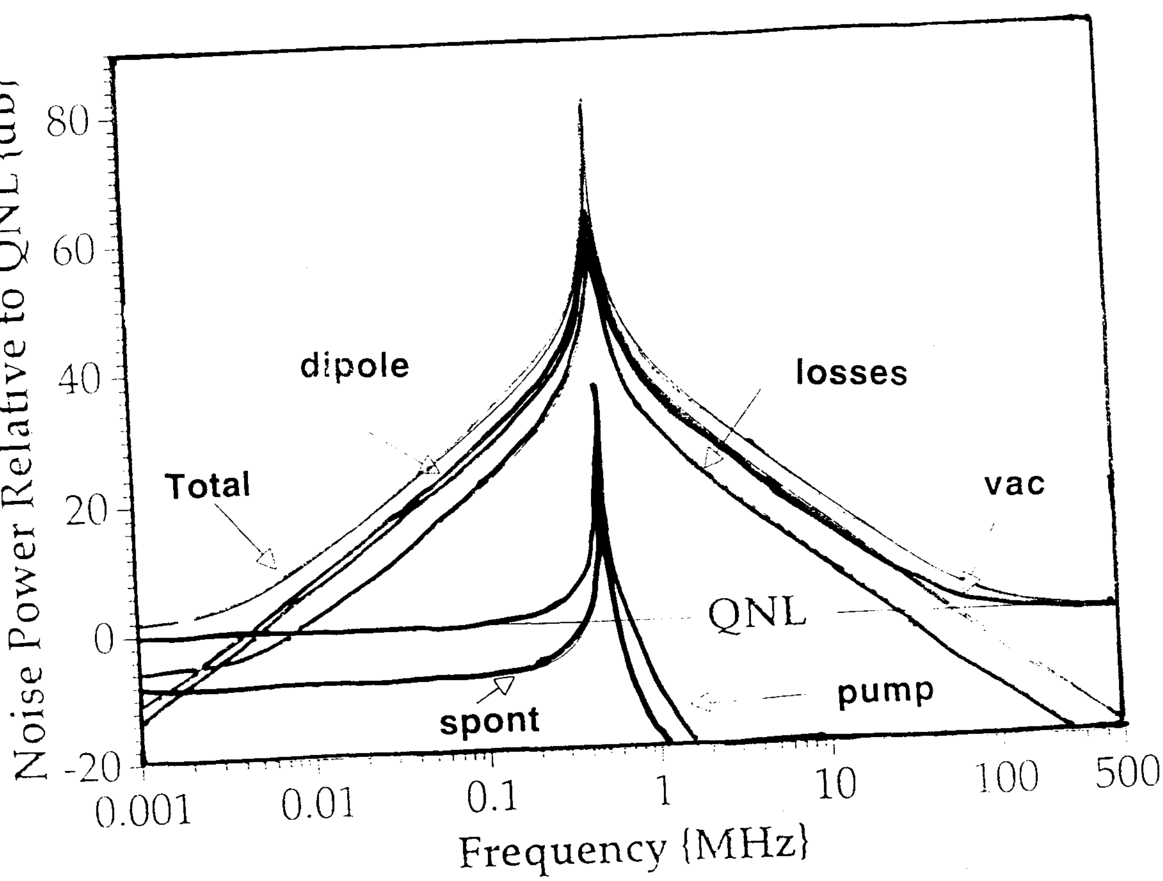
Nd:YAG laser model:



...

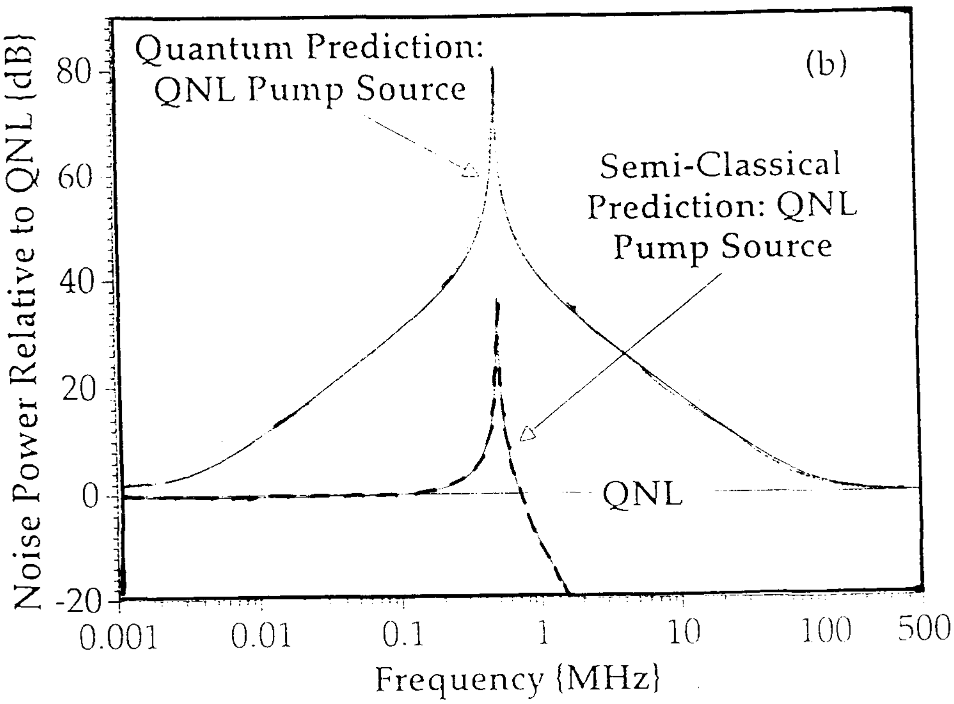
Noise contributions:

$$V_f = \left\{ 1 + \frac{4\kappa_m^2(\omega^2 + \gamma_l^2) - 8\kappa_m \kappa G \alpha_f^2 \gamma_l}{(\omega_r^2 - \omega^2)^2 + \omega^2\gamma_l^2} \right\} V_{vac}$$
$$+ \left\{ \frac{2\kappa_m G^2 \alpha_f^2 \Gamma}{(\omega_r^2 - \omega^2)^2 + \omega^2\gamma_l^2} \right\} V_p$$
$$+ \left\{ \frac{2\kappa_m G^2 \alpha_f^2 \gamma_l J_3}{(\omega_r^2 - \omega^2)^2 + \omega^2\gamma_l^2} \right\} V_{spont}$$
$$+ \left\{ \frac{2\kappa_m G J_3((\gamma_l + \Gamma)^2 + \omega^2)}{(\omega_r^2 - \omega^2)^2 + \omega^2\gamma_l^2} \right\} V_{dipole}$$
$$+ \left\{ \frac{4\kappa_m \kappa_l(\gamma_l^2 + \omega^2)}{(\omega_r^2 - \omega^2)^2 + \omega^2\gamma_l^2} \right\} V_{losses}$$

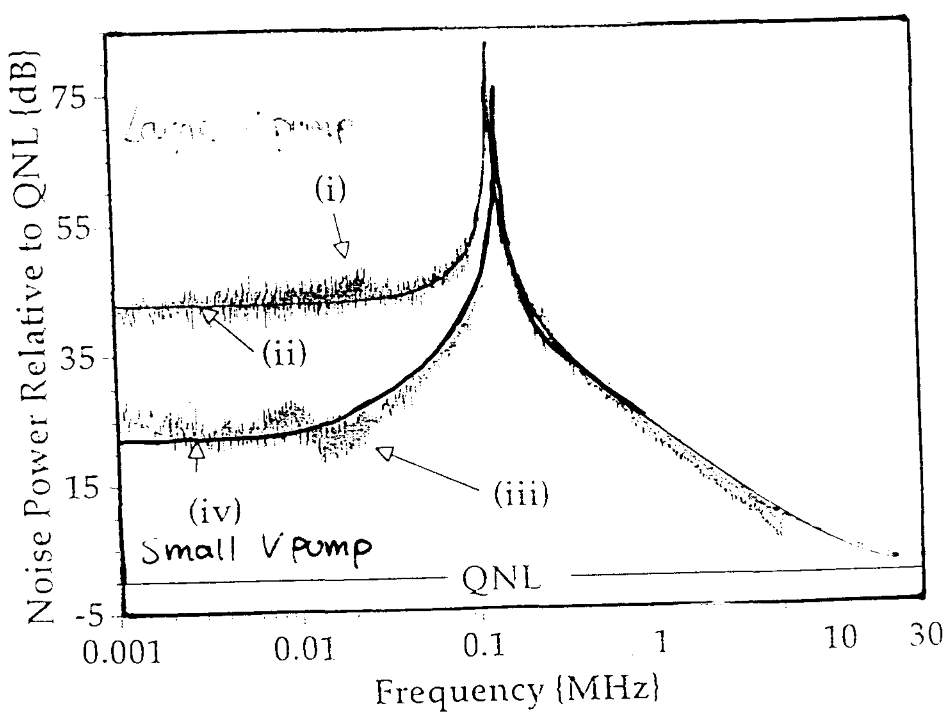


Intensity noise dependence of Nd:YAG lasers on their diode laser pump source C.C.Harb, T.T.Ralph, E.Huntington, D.E.McClelland, H-A.Bachor, I.Freitag submitted to J.Opt.Soc.Am. B (1997)

1. Experimental test : LASER

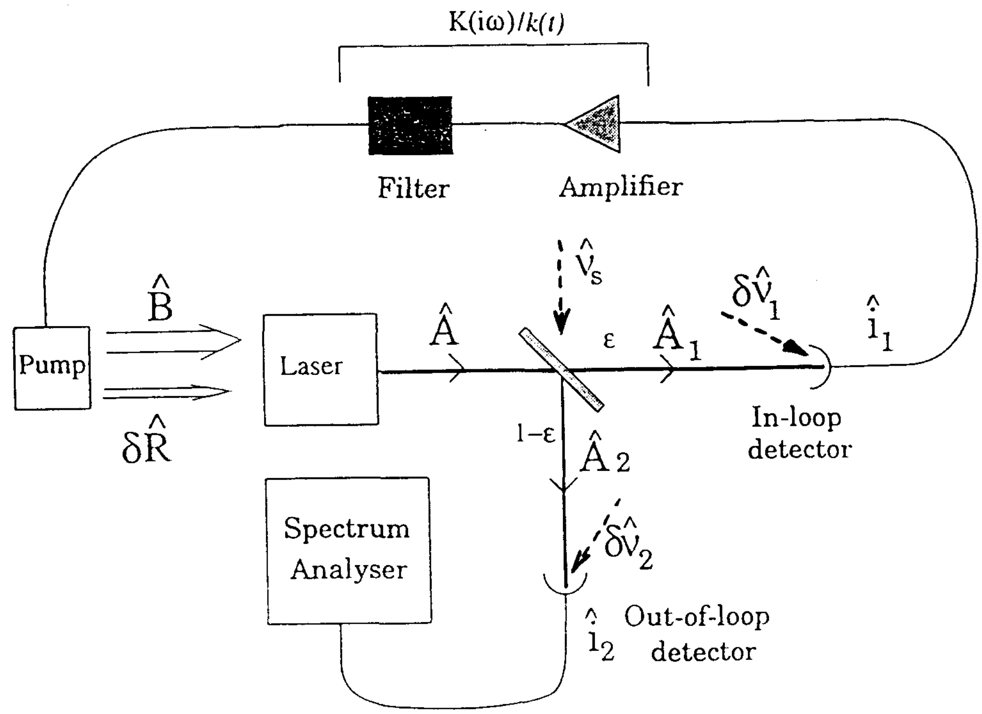


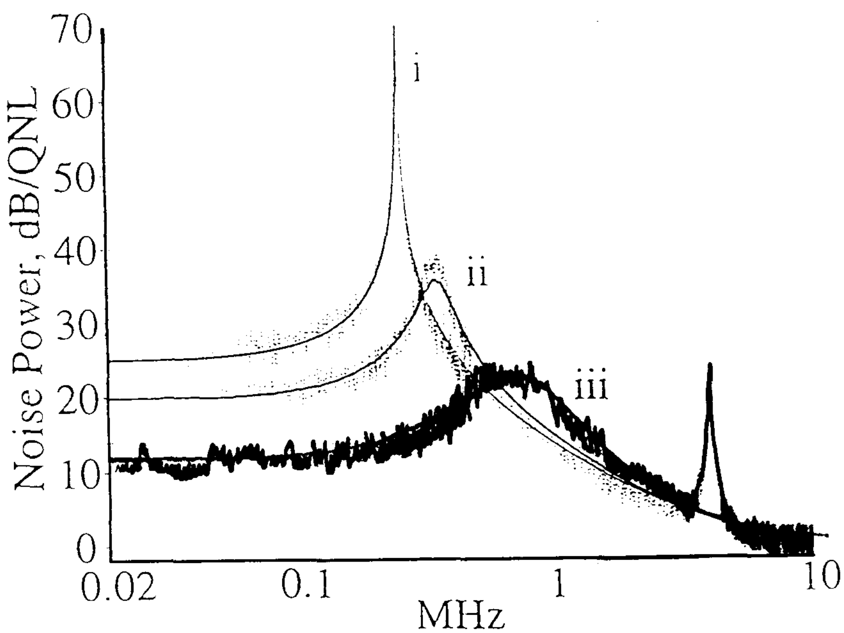
The quantum model is vastly different to semiclassical model



The experiments agree, once the noise of the pump is taken into account

Experimental Test: Laser with Feedback

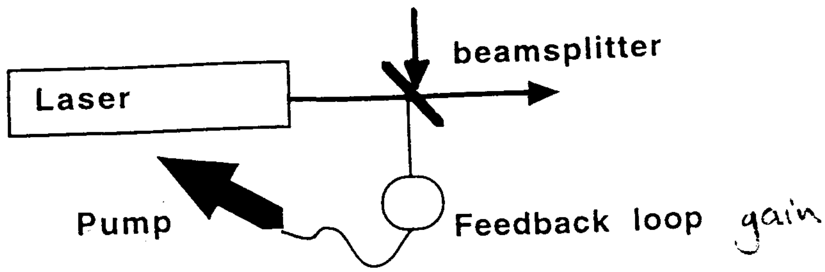




Modelling a Laser Noise Eater

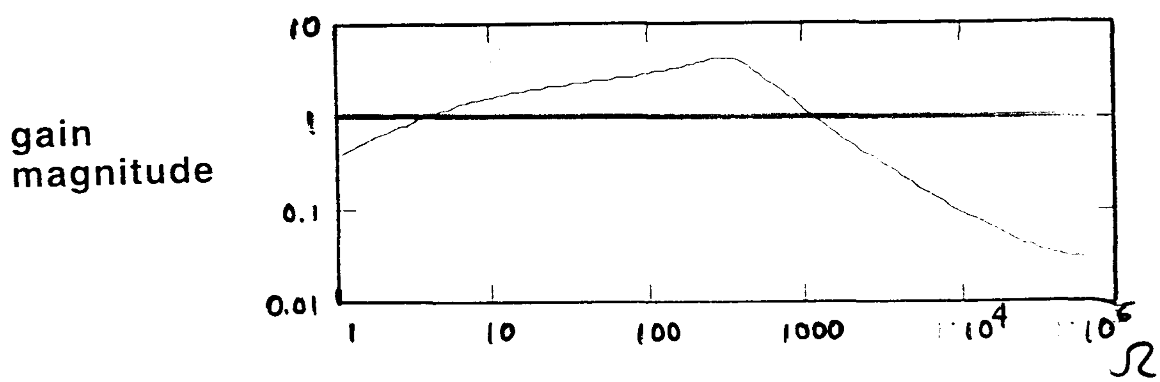
i No Gain in Feedback Loop
ii 0.01 X Maximum Gain in Feedback Loop
iii Maximum gain in Feedback Loop

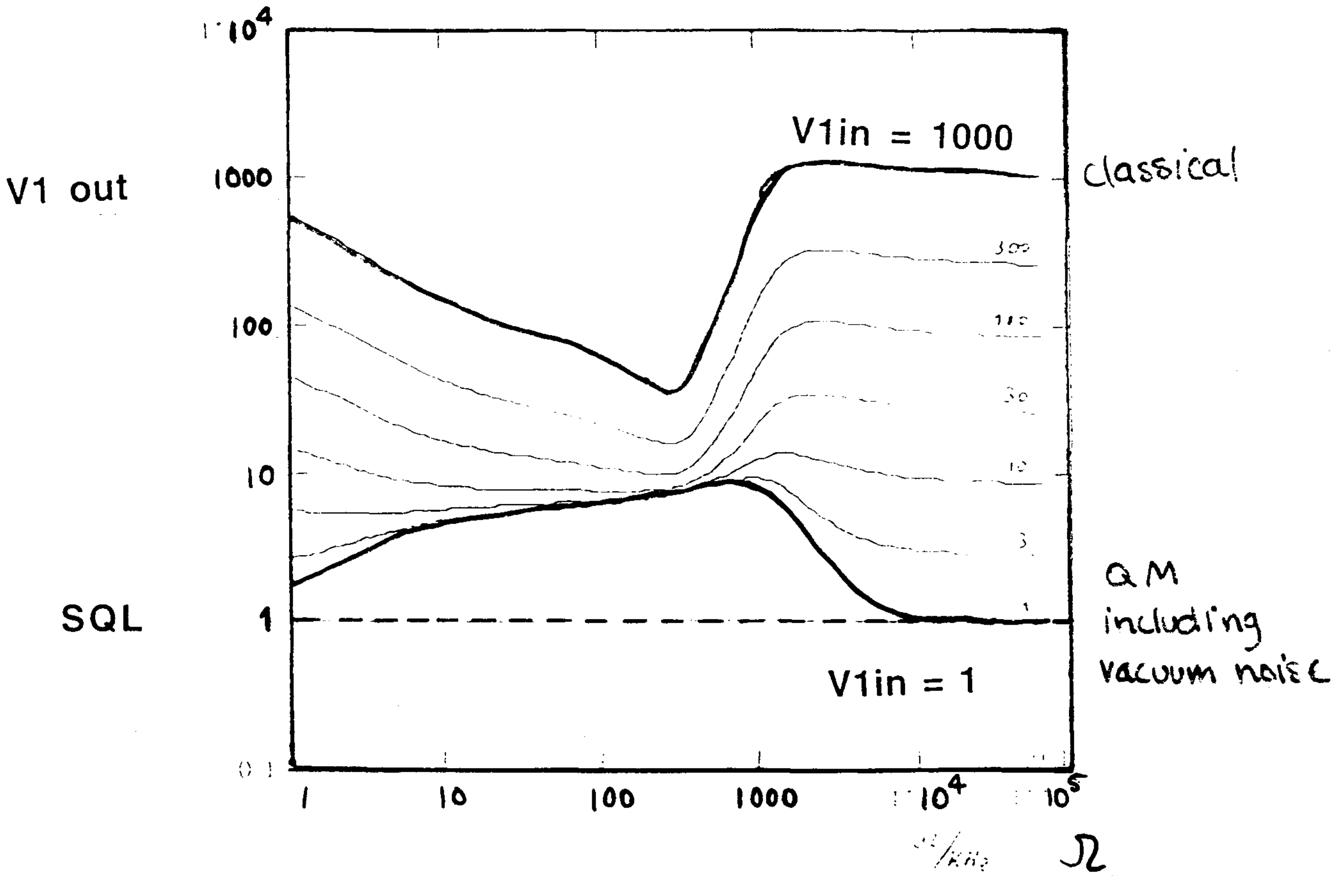
Electro Optic feedback



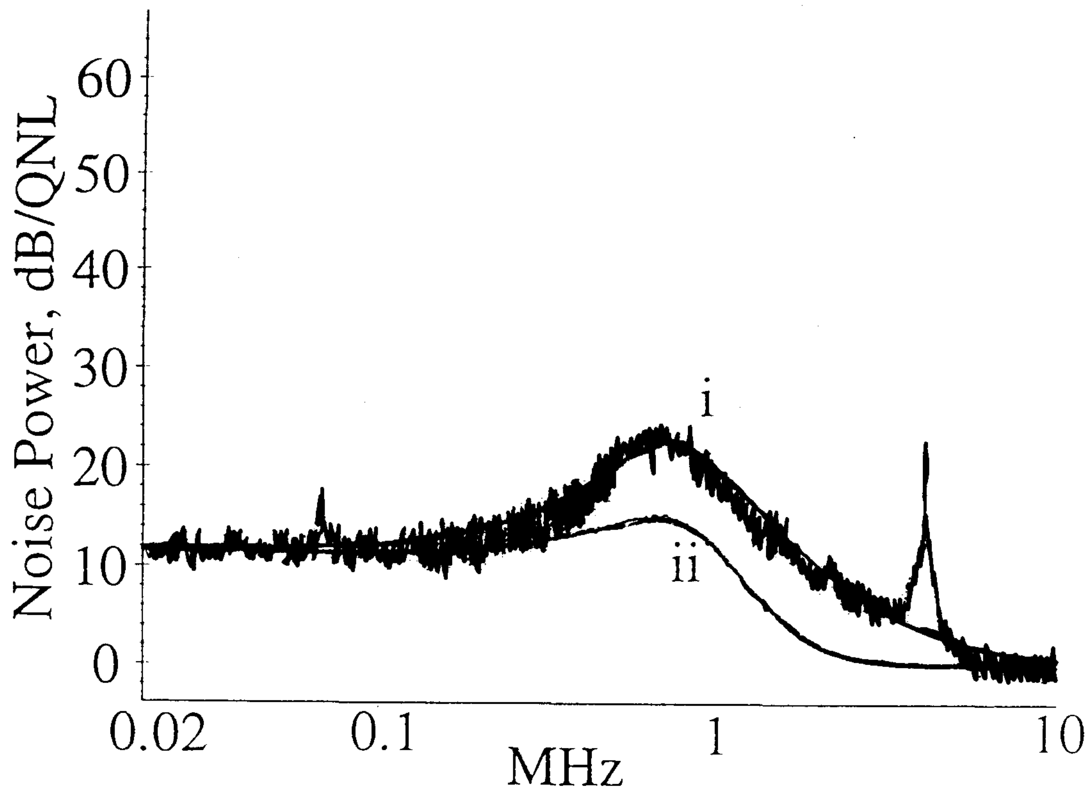
Feedback loop introduces extra noise.

The control is different at the quantum noise limit





Experimental Test

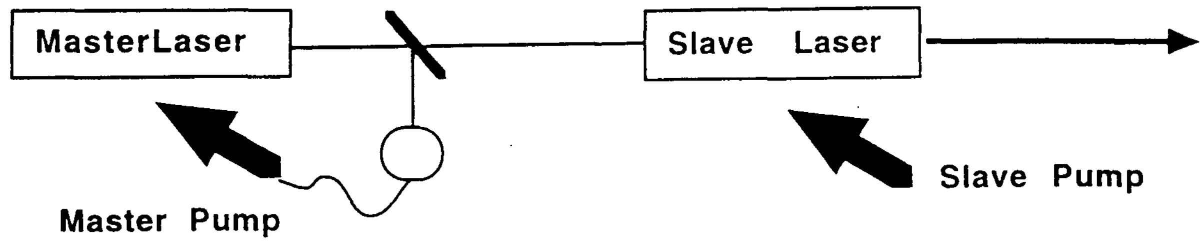


Modelling a Laser Noise Eater with;

i Quantum Model.

ii Classical Model.

Experimental test: Injection Locking

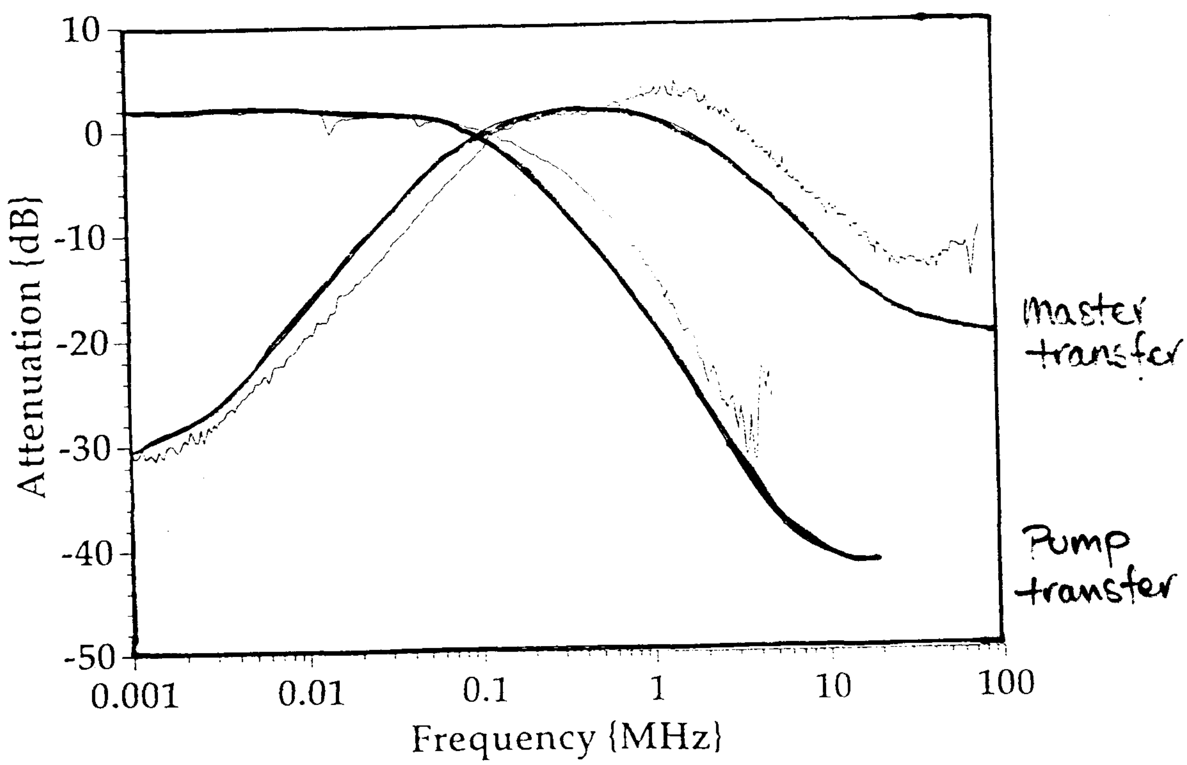


Slave laser (large power) is locked to Master laser (low noise)

I.Freitag, H. Welling   App.Phys.B.58,537 (1994)

A.D.Farinas, E.K.Gustafson, R.L.Byer   Opt.Lett. 19, 114 (1994)

R.Barillet, A.Brillet, R.Chiche, F.Cleva, L.Latrach, C.N.Man
Meas.Sci and Tech. (1995)



Low frequency: pump noise,
medium: amplified master,
high frequency :   QNL master noise

C.C.Harb, T.C.Ralph,E.Huntington, I.Freitag, D.E.McClelland, H-A.Bachor
Phys.Rev.A, 54,4370 (1996)