LIGO-G990079-06-M

Slide 1

LIGO II – Interferometer Configurations

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Slide 2

Contents

- Background: Options, and introduction to DR/RSE
- Top Level: configurations choice & optimization
- Next Level: read-out system design
- Status

Slide 3

Background: Available options

(1) Power Recycled Fabry-Perot Michelson

- initial LIGO configuration, evidently mature
- technical improvements and increased laser power enable a substantial sensitivity increase to be obtained

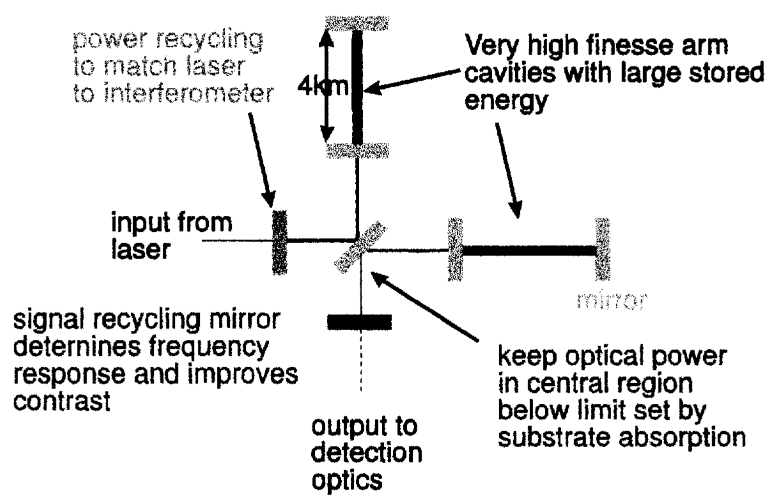
(2) Dual Recycled/Resonant Sideband Extraction Fabry-Perot Michelson

- incremental approach, one additional mirror
- allows significant further increase in science range
- requires considerable R&D to prepare for LIGO

(3) All other configurations
immature, not available on required timescale ($\sim$ 2006)

Slide 4

DR/RSE: configuration



Slide 5

DR/RSE: benefits

Frequency response

- Allows tuning of the frequency of peak response
- Allows choice of the system bandwidth

Thermal loading

- Bandwidth is no longer determined by arm-cavity finesse: the finesse can be increased to reduce the power in ITM/BS substrates

Contrast

- 'Closure' of the output port can allow better resonance conditions for both carrier and modulation sidebands. This can improve the efficiency of the read-out scheme.

Slide 6

Configuration optimisation

Options

(1) Main: Resonant Sideband Extraction Fabry-Perot Michelson

(2) Reserve: Power Recycling Fabry-Perot Michelson

- Development of option (1) is manpower limited – ready $\sim$ 2006

Optimisation

- Response shape: bandwidth and tuning frequency (1)
- Observation modes: number/range of bandwidths, tuning frequencies and powers anticipated during design phase (1)
- Loss/finesse/PR factor (1&2)

Slide 7

Read-out (length and alignment) system design

Options: no DR/RSE

- use same method as initial LIGO. Consider minor changes to improve resistance to the effects of thermal loading of the optics.

Options: with DR/RSE

- require a new read-out method
  - constraints: must fit in LIGO buildings, minimal modification of vacuum system
  - ideas: resonant sideband(s), offset locking, external modulation, output mode cleaner, etc.
  - choice: requires in-depth analysis of LSC/ASC systems

this is a major component of the planned R&D program in AIC

Slide 8

Status: 1

Configuration

- Choice: *can* be evaluated immediately SWG/L&O parameters are fixed
- Optimisation: *can* be done immediately science goals are agreed

Read-out scheme

- work needed on design and noise analysis
- work needed on lock-acquisition with revised system
- length control → SWG (signals are similar, suspensions different)

Slide 9

Status: 2

RSE research

- bench-tops, and modeling: progress review
- 10 m/40 m experimental program, becoming clear: next slide

Other configurations appropriate post 2008:

- All-reflective schemes (diffractive optics)
- Sagnacs (common path schemes)
- Squeezing (reduced shot noise)
- QND (reduced optical noise, or lighter mirrors)

Slide 10

Status: 3

RSE research: 10 m prototype program aims

- to investigate optical properties of the RSE interferometer
- to select and test suitable read-out methods, considering noise performance etc.
- initial studies of lock-acquisition

RSE research: 40 m prototype program aims

- with the final read-out method
  - detail lock-acquisition studies
  - integration of sensing with LIGO length control systems
  - integration of alignment sensing and control

Status: 4

RSE research: Length and Aligment Sensing and Control

1 selection of a control solution (by end 2000)

2 analysis of noise performance (by end 2000)

3 analysis of lock acquisition (by late 2002)

4 experimental demonstration of technology (by late 2002)

5 final selection of sensing scheme (by late 2004)

6 engineering prototype demonstration (by late 2004)

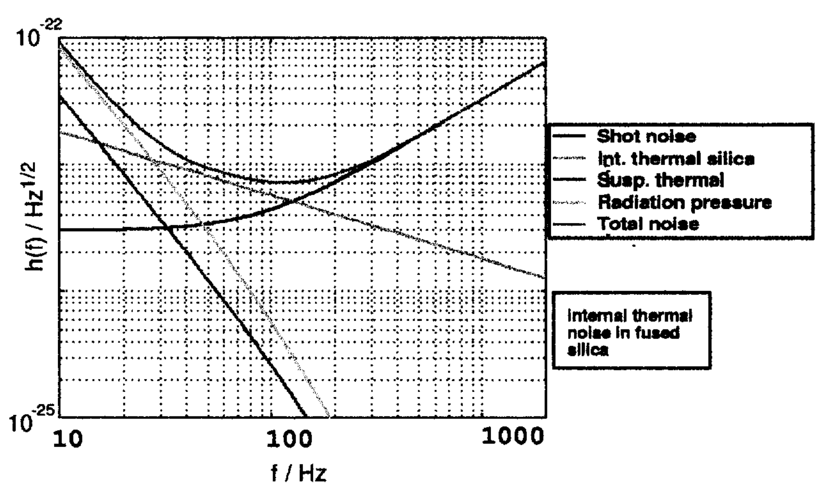
Slide 11

Comparisons of detector sensitivity

- we choose a particular *neutron-star: neutron-star binary inspiral* model as the benchmark for detector sensitivity comparisons (cbi.m, Finn)
- initial LIGO scores $\sim 15\,\text{Mpc}$

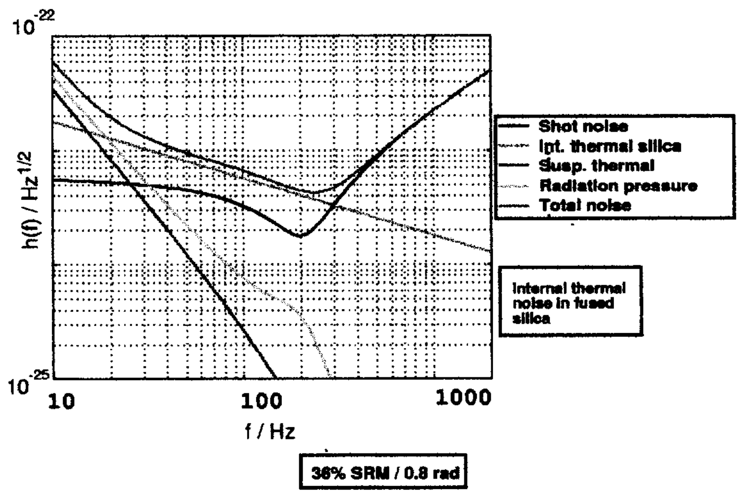
Slide 12

Inspiral response (PRFPMI): silica (95 Mpc)



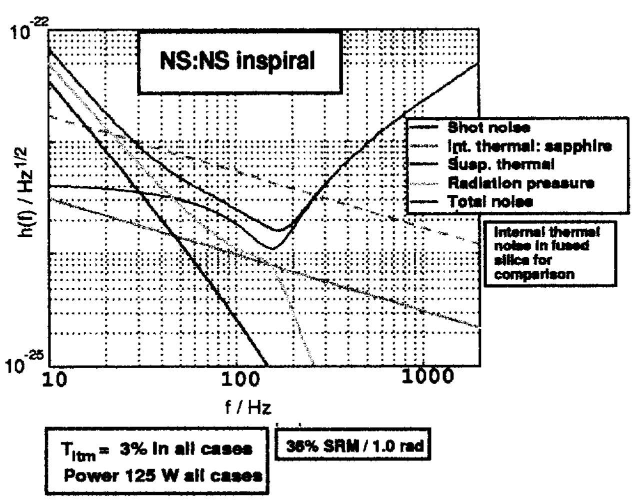
Slide 13

Inspiral optimised (RSE) response: silica (120 Mpc)

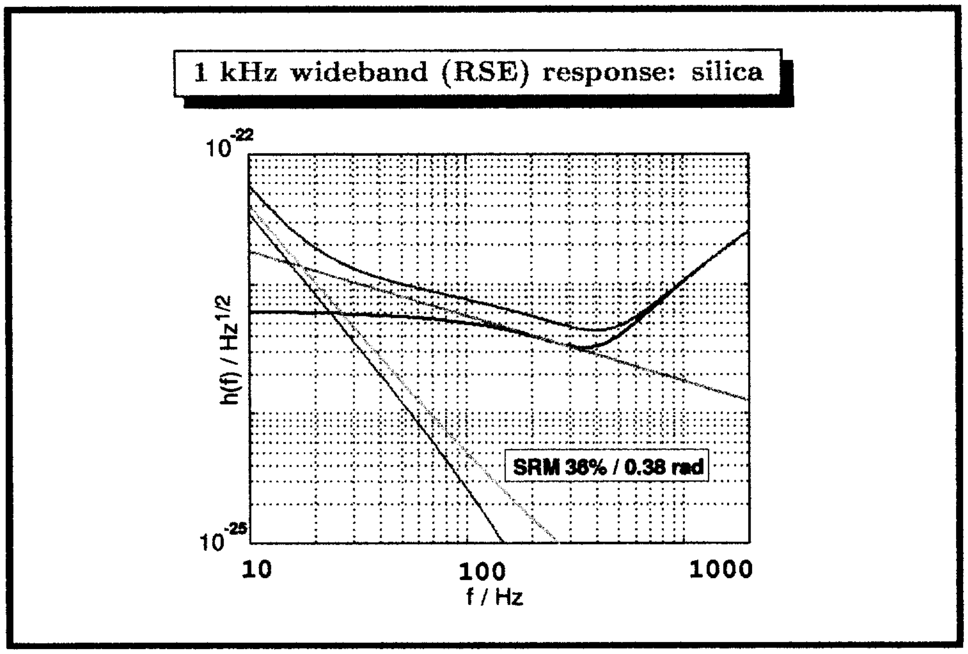


Slide 14

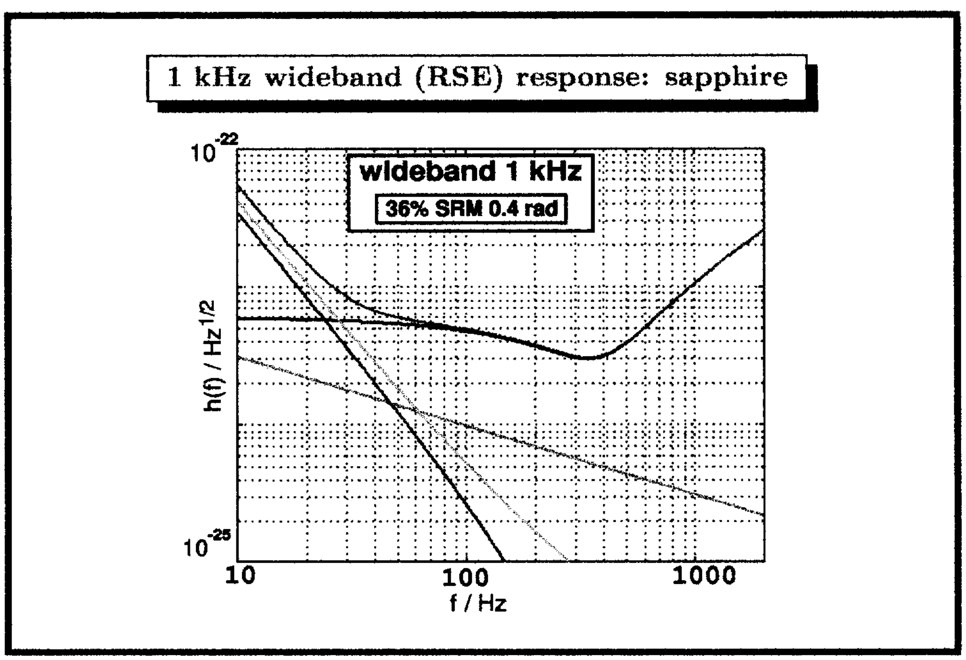
Inspiral optimised (RSE) response: sapphire (270 Mpc)



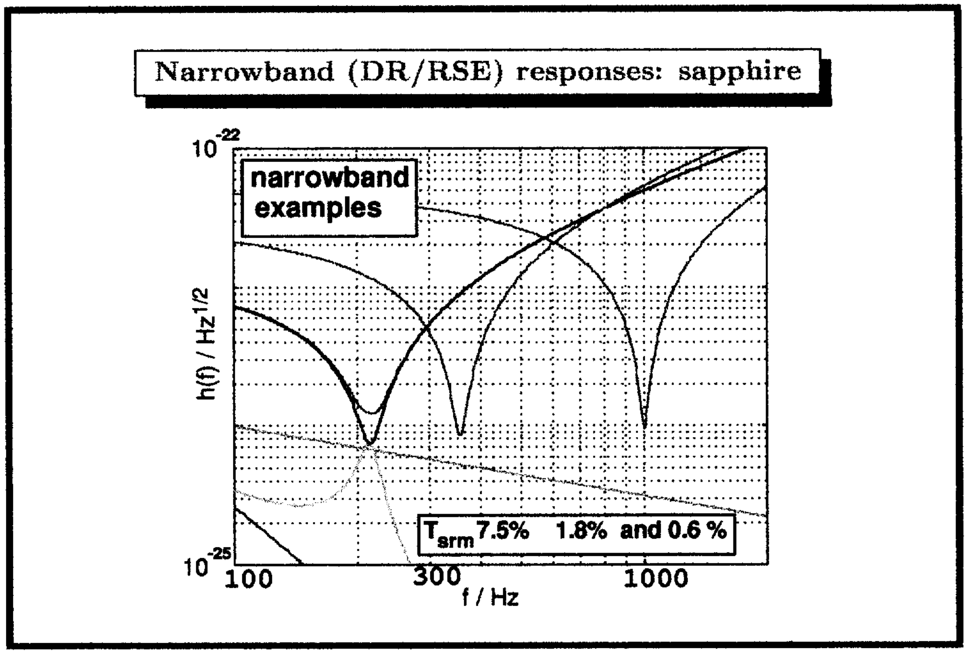
Slide 15



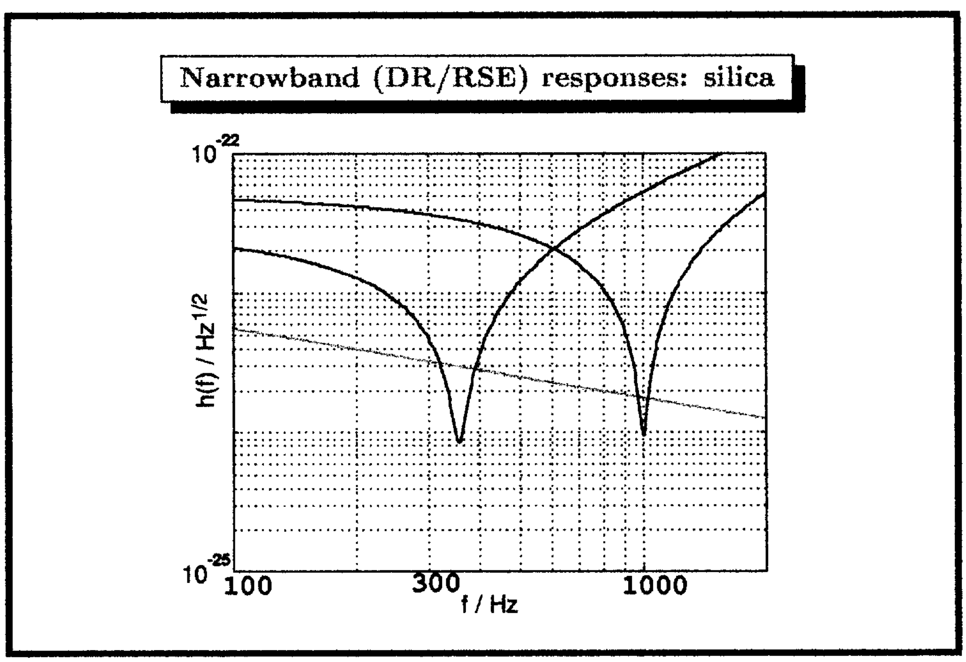
Slide 16



Slide 17



Slide 18



Slide 19

Inspiral range results

fused-silica mirrors

- with RSE and 11 kg mirrors inspiral range is 110 Mpc
- with RSE and 30 kg mirrors inspiral range is 120 Mpc
- no RSE: 30 kg → 95 Mpc
- no RSE: 11 kg → 85 Mpc

sapphire mirrors (denser, 11 kg too small for beam)

- RSE: 30 kg → 270 Mpc,
- no RSE: 30 kg → 200 Mpc,

remember: initial LIGO range for this source is $\sim$ 15 Mpc

Slide 20

Laser power and thermal loading

uncertainty principle (UP)

- SWG, L&O set available mass broadband observation sets maximum useful power (may want to allow operation at reduced power for < 40 Hz signal searches)

thermal loading

- the effect of thicker (30 kg) mirrors is not very important (if the absorption coefficient is no larger due to the increased size)
- factor of up to 10 adaptive thermal correction with:-
  - fused-silica: Suprasil SV ($\sim$ 0.5 ppm/cm absorption)
  - sapphire: $\sim$ 20 ppm/cm absorption
- allows power up to roughly the optimum set by the UP with 30 kg mirrors

Slide 21

Conclusions

Configuration

- Choice: can be evaluated immediately SWG/L&O parameters fixed
- Optimisation: can be done immediately science goals agreed

Read-out scheme

- work needed on design and noise analysis
- work needed on lock-acquisition with revised system

LSC Advanced Configurations Working Group: Progress and Targets 7/99

Proximate events:

Top level requirements: this meeting

Conceptual Design Summit: spring 2000.

Objectives for this meeting:

Ensure we are prepared for the first NSF submission which needs to be written in August 1999

Identify the main sub-tasks for the group

Appoint sub-task co-ordinators

Review progress on the RSE experiments

Look at a discussion document prepared for this meeting

Presented by:

K.A. Strain
University of Glasgow
and
GEO 600

LSC Advanced Configurations Working Group: Top Level Requirements

Performance should not be significantly limited by sensing noise (shot noise and radiation pressure).

- very hard given thermal noise in sapphire mirrors

This requirement is evaluated in the context of a number of target signals

- compact object binary inspirals
- pulsar signals (known or unknown) and other narrowband signals such as LMXBs
- unknown wideband signals

Requires flexibility of response to meet all goals (-> signal recycling)

Signal recycling applied to the initial LIGO configuration forms the basis for the proposal (with options for an interim stage)

Other configurations are candidates for up-grades after 2008
Sagnacs   Squeezing   QND   All-reflective systems

LSC Advanced Configurations Working Group: need for science goals

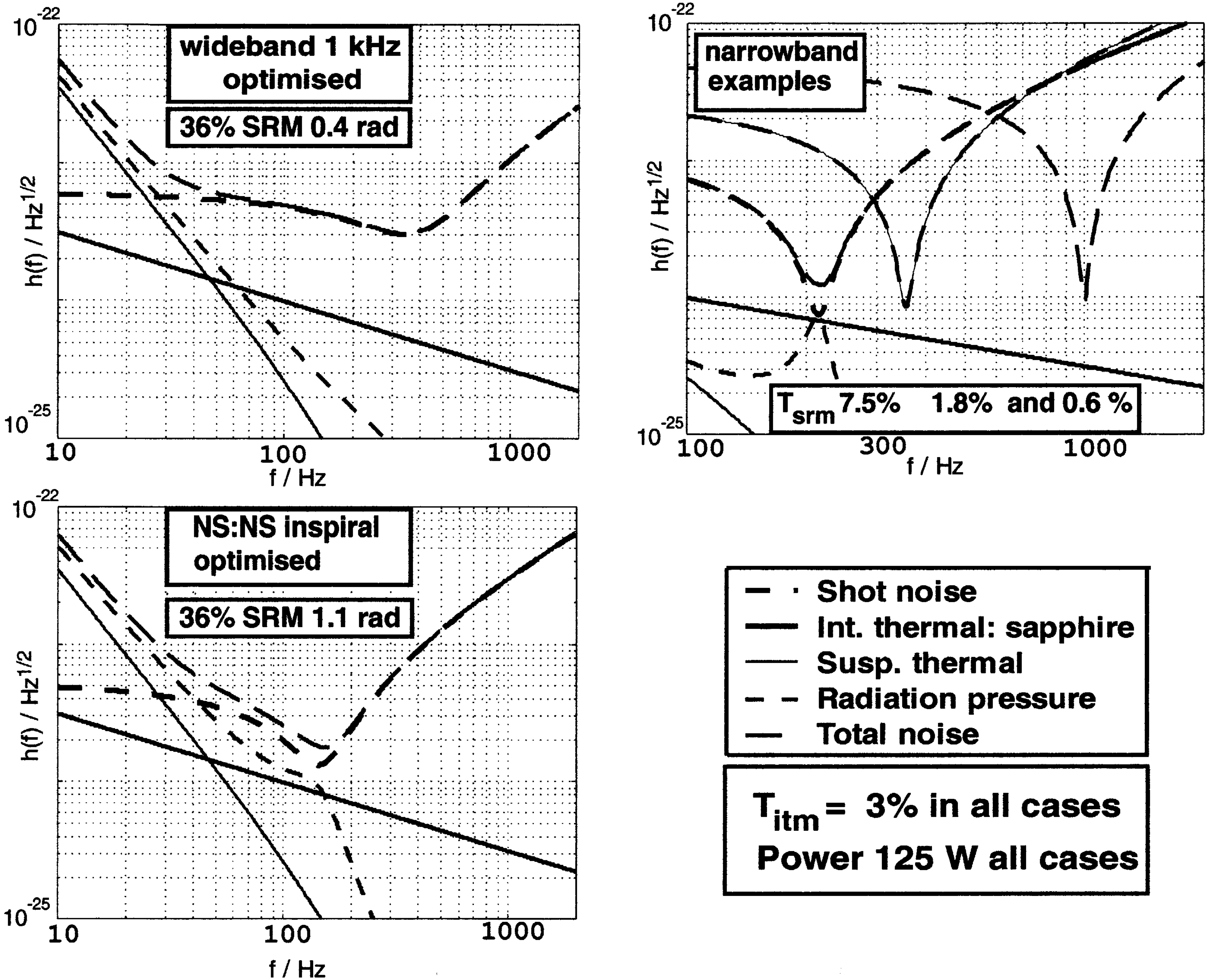
Signal recycling provides a variety of adjustable responses:-

- variable tuning frequency (electronic, fast)
- options for variable bandwidth
  - multiple signal recycling mirrors
  - variable signal recycling mirrors
    - temperature tuned etalon (slow, simple)
    - compound SRM (fast, complicated)
- variable light power to alter the shot noise / quantum radiation pressure noise trade-off (timescale of days, perhaps complicated)

These options require a prioritisation of observational science goals, before data are collected.

Examples
- inspiral search
- pulsar searches
- LMXB search

Questions
- how long to spend on each?
- **which options to include in the design?**



wideband 1 kHz optimised
36% SRM 0.4 rad
narrowband examples
T_{srm} 7.5% 1.8% and 0.6 %
NS:NS inspiral optimised
36% SRM 1.1 rad
h(f) / Hz^1/2
f / Hz
10^-22
10^-25
10
100
300
1000
Shot noise
Int. thermal: sapphire
Susp. thermal
Radiation pressure
Total noise
T_{itm} = 3% in all cases
Power 125 W all cases

Note 1, Linda Turner, 08/17/99 07:34:51 PM
LIGO-G990079-06-M