Optical configurations for Advanced VIRGO
Is SR/RSE an option?

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WP3 Meeting
Pisa, June 2005

Scope

- At the Glasgow meeting we heard that the timescale for Advanced VIRGO is quite short
  - we can only consider relatively mature technology as there is not time for a long R&D phase
  - in this case should signal recycling be a part of Advanced VIRGO?
  - What are the options for how to add signal recycling?
  - What are the advantages offered by signal recycling?
  - What are the costs of adding signal recycling?

Options for SR

- The "Advanced LIGO approach"
  - high finesse arms, thermally limited (with strong thermal compensation) 1.6MW in arms 40kg mirrors
  - minimum intrinsic bandwidth (~20 Hz)
  - some RSE used to widen the bandwidth and tune to give an overall noise minimum matched to NS:NS inspirals (~200 Hz FWHM, at ~200 Hz)
  - optimisation includes optical spring effects
  - RSE does not help with contrast defect

Options for SR

- A wide-band approach
  - moderate finesse arms bandwidth close to desired observing bandwidth (~200Hz?)
  - mild SR used to balance shape of shot-noise curve against that of thermal noise (to some extent)
  - probably gives a modest (~ factor 2 in power) improvement in SNR for some signals above the cavity bandwidth
  - how important this is depends on science goals (does not help much with inspirals)

Options for SR

- Optional narrowband approach
  - the response of a broadband detector (such as in the previous slide) could, when required, be tuned to enhance the sensitivity at high frequencies (where high means up to a few times the natural arm cavity corner frequency)
  - this makes sense as part of a large array of detectors, but is otherwise unlikely to be attractive for a ”discovery” instrument

Benefits of SR

- Where the arm-cavity bandwidth is less than the signal frequency (RSE)
  - higher finesse arm cavities allow potentially higher power
  - shaping of the response at low frequency
  - the response broadening provided by RSE is limited by loss in the central interferometer - low loss is needed, and mode-healing is not very effective
  - in the extreme case the system can slightly beat the SQL due to the optical spring

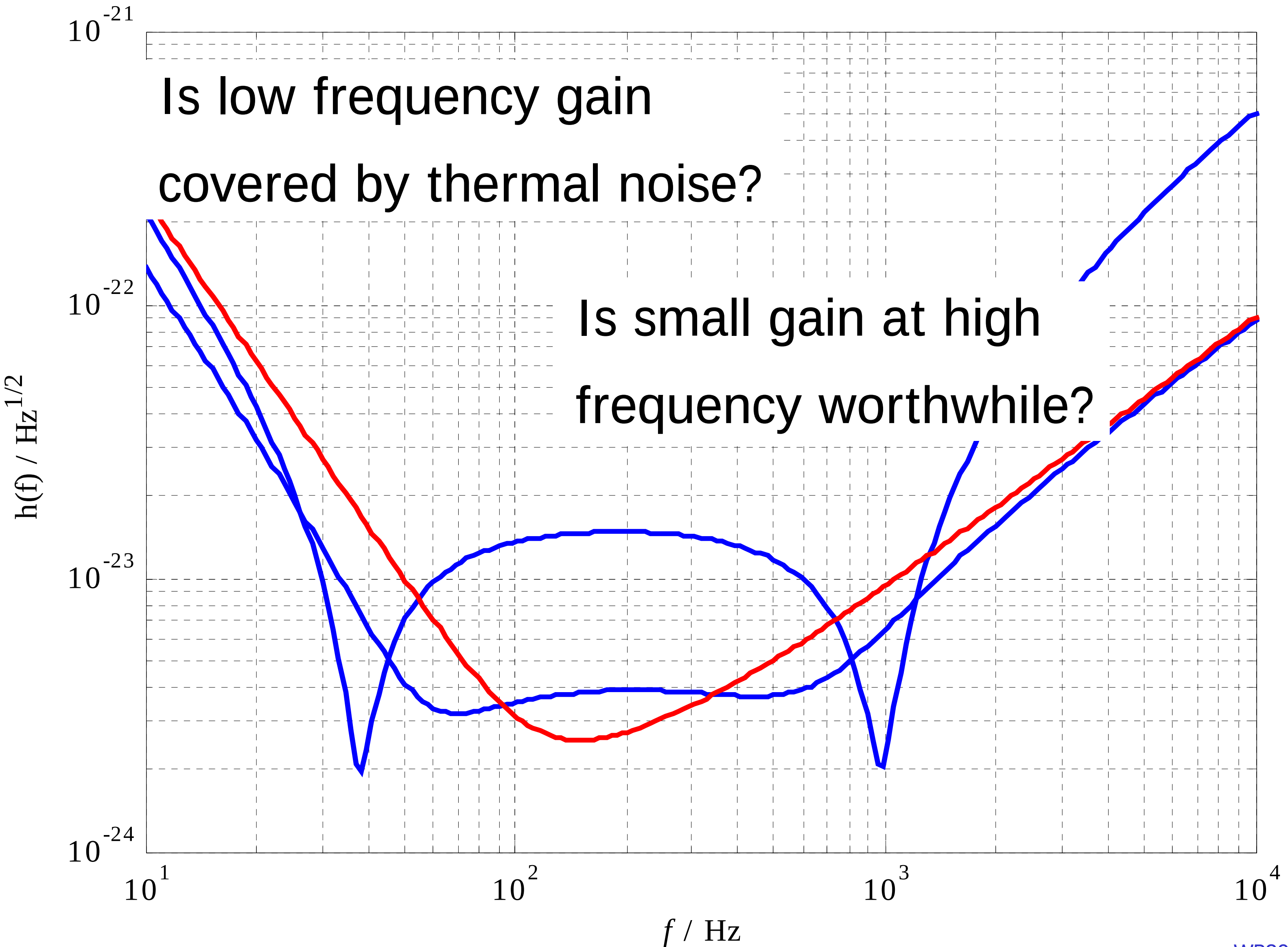
Benefits of SR

- Where the arm-cavity bandwidth is comparable to or larger than the signal frequency (signal recycling)
  - mode-healing helps against contrast defects
  - the peak response can be moved around (from about zero up to a few times the corner frequency)
  - the bandwidth is controllable if a variable SR mirror is employed (still quite new technology)

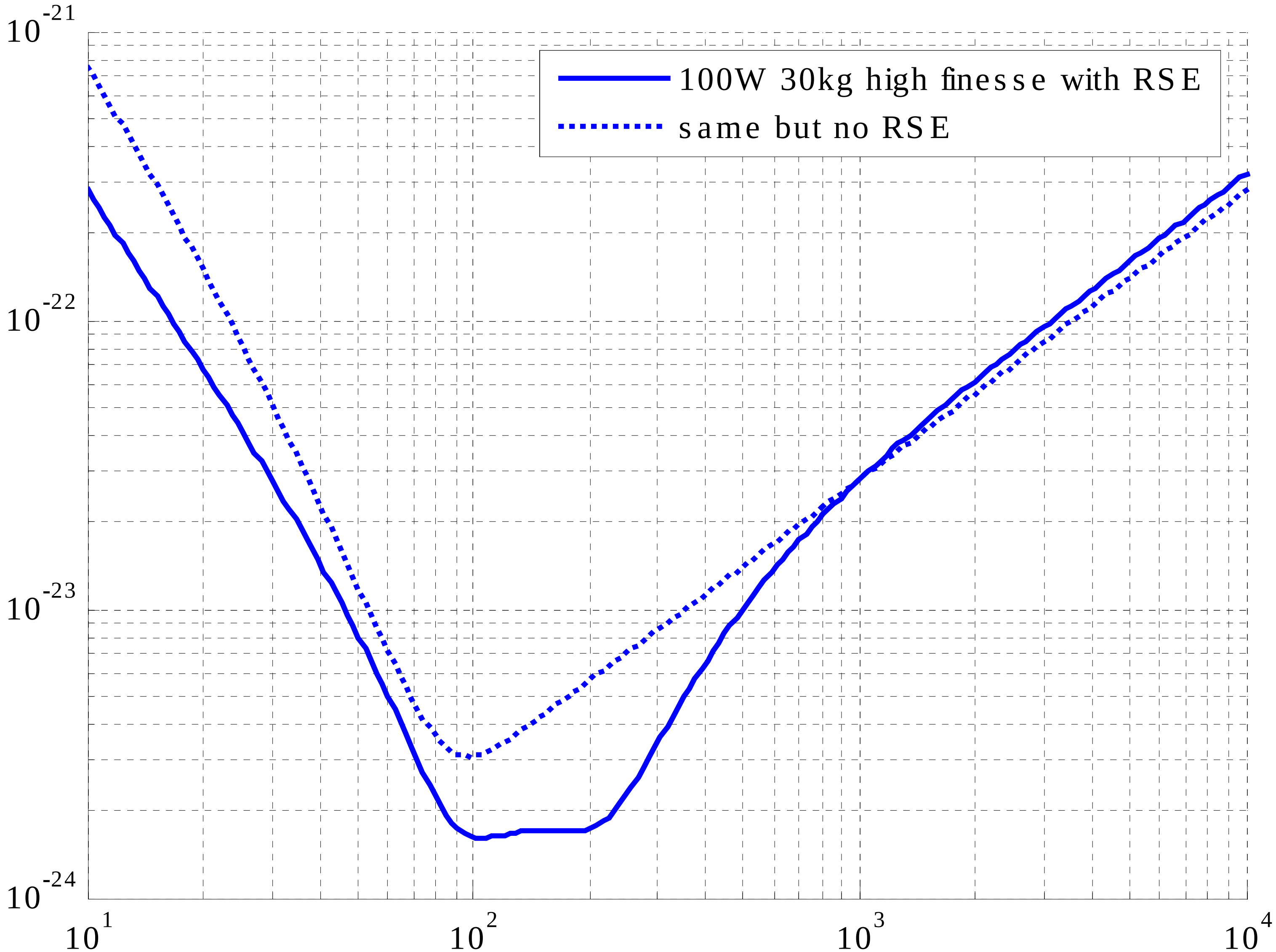
Cost of SR

- Control
  - adding 1 length and 2 angle degrees of freedom makes the system more complex
  - sideband fields all become a mixture of AM and PM (in the usual detuned case) this increases susceptibility to sideband noise (hence Advanced LIGO->DC readout)

Low finesse SR/no SR



high finesse RSE/no RSE



Notes

- figures were generated using some VIRGO-like parameters (3km etc.) and some LIGO like parameters (optic loss)
- results are examples of what may be possible

Conclusion

- The benefits of SR/RSE must be evaluated in the light of
  - other noise (particularly thermal noise)
  - constraints on arm-cavity finesse/power
  - science goals