LIGO Laboratory

California Institute of Technology
MC 18-34, 1200 E. California Blvd.
Pasadena CA 91125 USA
TEL: 617.395.2129
FAX: 617.304.9834
www.ligo.caltech.edu

LIGO Livingston Observatory
P.O. Box 940
Livingston LA 70754 USA
TEL: 225.686.3100
FAX: 225.686.7189
www.ligo-la.caltech.edu

LIGO Hanford Observatory
P.O. Box 159
Richland WA 99352 USA
TEL: 509.372.8106
FAX: 509.372.8137
www.ligo-wa.caltech.edu

Massachusetts Institute of Technology
MIT NW22 – 295, 185 Albany St.
Cambridge MA 02139 USA
TEL: 617.235.4824
FAX: 617.253.7014
www.ligo.mit.edu

Date:	27 October 2008
DCC:	L080130-00
Refer to:	L080140-00 (review report) and T070265-D (updated proposal)
Subject:	Response to Action Items of the Interim Review Committee Report on the “First Stage Evaluation of the H1 Squeezing Test Proposal”
To:	Review committee (Fred Raab, chair)
From:	Squeezer team
cc:	LIGO management

Action Item 1:

1) Develop and present a **brief** strawman scenario for the design and implementation of vacuum squeezing in the baseline AdLIGO interferometer. The scenario should identify **at top level** the steps to enable initiation of an engineering design. This should address:
    a. What are the major questions that need R&D or technical demonstration?
    b. Where does the proposed experiment fit into this scenario?
    c. What are the likely impacts of this scenario on AdLIGO operations? For example, would a success in the proposed squeezing experiment be sufficient to allow a turn-key implementation of squeezing with minimal commissioning time? Or is it likely that further protracted R&D on AdLIGO interferometers would be needed.

Response:

In order to implement vacuum squeezing in the advanced LIGO baseline three major development steps are needed:

1. The demonstration of low noise performance on an instrument with high sensitivity.
2. The demonstration of long term continuous operation of a squeezer breadboard. This includes:
    - The characterization of the degradation of squeezing performance over time,
    - The monitoring of contamination over time,
    - The characterization of the performance of the non-linear material over time, and
    - The monitoring of the alignment drifts over time.
3. The demonstration of the long term continuous operation of a squeezer on a suspended interferometer.

A successful squeezing experiment on H1 (item 1 in above list) will provide all the information to judge, if a turn-key squeezing implementation on advanced LIGO can be realized. Additional testing on a large interferometer is unlikely to be necessary. Of course, the H1 sensitivity is not as good as the advanced LIGO one, and therefore additional commissioning time may be required once the system is deployed.
The GEO600 experiment (item 3 in the above list) will demonstrate long term operations of a squeezer. Additional laboratory tests (item 2) may be required to fully characterize the aging of a squeezer. These tests will be carried out off-line. There will be no demonstration of an auto-alignment system on a high sensitive instrument, but we consider the technical risk small. Advanced LIGO can help the squeezer effort by implementing the Faraday design developed for the squeezer experiment on the AS ports of all three interferometers and by paying careful attention to losses in the AS port detection path.
If these experiments are successful, we do not foresee any need for further protracted R&D on an Advanced LIGO interferometer before a full-scale implementation.

Action Item 2:

2) Present a plan for establishing a detailed noise budget. The plan should identify the major anticipated noise sources, the modeling effort necessary to evaluate them and the schedule and required manpower for completion of the modeling.

Response:

Sheila D. (MIT grad) will work on the noise budget. We hope to finish this by the second half of 2009.

Action Item 3:

3) Estimate the contributions to the losses during injection into H1, with expected central values, ranges, and consequences for the achievable level of squeezing.

Response:

Nic Smith (MIT grad) has estimated the current losses in the H1 asymmetric port chain. The losses in the beam path from squeezer to AS port DC detector are as follows:

Component	Transmission	Uncertainty	Reference
Vacuum window	0.998	0.002	
1st Faraday isolator	0.95	0.02	
2nd Faraday isolator (side injection)	0.95	0.02	
Reflection Michelson/arm cavities	0.98	0.01	
2nd Faraday isolator (through)	0.94	0.02	[1]
Septum window	0.998	0.002	

OMC mode matching	0.95	0.02	[2]
OMC cavity losses	0.967	0.005	[3]
DC photodetector QE	0.98	0.01	[4]
Total	**0.745**	**0.043**	

Action Item 4:

4) Revise the proposal to give more detail on plans for initial alignment and alignment monitoring.

Response:

Section 3.6 in the proposal has been extended. A detailed initial alignment procedure as well as a description how to monitor the alignment drifts has been included.

Action Item 5:

5) Revise the proposal to identify a prioritized list of tests to be done in the experimental time window with estimates of time required for the tests and brief explanation of how the test and modeling efforts connect.

Response:

A prioritized list of tests has been identified:

1. Characterize the injected squeezed light path (losses, mode matching, etc.). We estimate this to take 6 weeks.
2. Take the transfer function from the new squeezer injection port to the AS port by injecting classical AM and FM light. We estimate this to take 3 weeks.
3. Measure the shot noise sensitivity as function of the LO angle. We estimate this to take 2 weeks.
4. Change the H1 differential arm cavity dark port offset in order to change the DC LO power and characterize the effect on the sensitivity. We estimate this to take 2 weeks.
5. Take the highest performance squeezed spectrum and compare it with the loss model. We estimate this to take 4 weeks.
6. Characterize the risk of back scattering by shaking SQT4. We estimate this to take 1 week.
7. Characterize the angular effects by dithering the angle of the injected light or the orientation of the interferometer. We estimate this to take 1 week.

Optional:

8. Characterize the effect of the fiber stabilization servo. We estimate this to take 1 week.
9. Try locking the squeezer laser to the AS port light. We estimate this to take 4 weeks.

Measurements (1) through (4) will provide input data for checking the model in step (5). Both measurements in step (6) and (7) are important to estimate the squeezing potential in Advanced LIGO and inform the final design. The measurements in step (8) and (9) are

considered optional and will give insights in the possibility to eliminate the fiber stabilization scheme.
Assuming we have to wait 4 weeks after the vent to pump out the water out of the vertex we estimate to finish measurement step (7) after approximately 23 weeks (out of an available 33 weeks). This leaves 10 weeks to anticipate the unexpected, or to work on the optional measurements.

Action Item 6:

6) Revise the proposal to explain why a different squeezer implementation would be used in the GEO600 and H1. (The information provided to the committee in e-mails by McClelland, Schnabel and Sigg were helpful, but the proposal itself should contain the relevant information for the record.)

Response:

Appendix E in the proposal now incorporates the rational behind the differences between the H1 and the GEO squeezers.

Action Item 7:

7) Identify staff support (e.g., operators, vacuum and facilities labor) and space needs for staging and implementation work conducted at LHO. Work with John Worden (AdLIGO FMP lead) to identify potential availability or conflicts.

Response:

Staff support and space needs have been discussed with John Worden. The plan is as follows:

Space needs:

- During S6 an optics table in a LHO optics lab is required to test the squeezer breadboard. There has to be enough room for 2 electronics racks as well. This space will be available in the optics lab of the OSB or the LSB. Obviously, laser safety protocols will need to be upgraded.
- During the H1 experiment space is required for the new squeezer table. This is no problem.

Staffs support:

- The first task after S6 will be a vacuum vent of HAM6 and the rework of the AS port Faraday. This will be a 1-2 day vent and will require staff support. This will be ok.
- During the 6 months of the experiment we request support to run the interferometer and keep it up. This will require 1 trained operator. This will be ok (especially if the alternative is full science mode operations).
- During 2009 the electronics for the squeezer has to be built and assembled. The current re-planning has identified H2 as the primary source of reusing electronics. But, additional help of the order of half an operator is required for assembling, rework and ordering. This will be provided by the off-shift hours of 2 operators during S6.
- We need support to design the new AS port Faraday. This will be provided by Mike Smith et al. as part of the advanced LIGO design.

Action Item 8:

8) Revisit the question of locking to the AS port light rather than the PSL light, and potentially eliminating the need for a stabilized fiber.

Response:

The general consensus is that changing the baseline at this time would be too risky. Photons from the PSL are “cheap”, whereas photons from the AS port are not. Furthermore, it was felt that basing the squeezer on the AS port light—which comes and goes every time the interferometer is locked—will introduce more of a headache than can be justified by the simplification from the elimination of the fiber stabilization. However, we plan to investigate this issue again at the end of the H1 experiment, if there is sufficient time.