LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

RECORD OF DECISION/AGREEMENT (RODA)

Document	LIGO-M080371-00-Y
Date:	24 October 2008
Title:	RODA: Arm Length Stabilization system to use end-station injection of a 532 nm beam, and PDH cavity sensing.
To the Attention of:	Aligo_sys, aligo_coc, aligo_aos, aligo_cds, aligo_isc
cc:	
From/ signatories:	Name/Title: Peter Fritschel/Systems Scientist & ISC leader Signature: Peter Fritschel Digitally signed by Peter Fritschel DN: cn=Peter Fritschel, c=US, o=M.I.T., email=pf@ligo.mit.edu Reason: I am approving this document Date: 2008.10.24 17:40:12 -04'00' Name/Title: Garilynn Billingsley, COC leader Signature: GariLynn Billingsley 2008.10.29 19:06:18 -07'00' Name/Title: Mike Smith, AOS leader Signature: Michael Smith Digitally signed by Michael Smith DN: cn=Michael Smith, c=US, ou=LIGO, email=smith@ligo.caltech.edu Date: 2009.02.25 06:01:19 -08'00' Name/Title: Rolf Bork, CDS leader Signature: Rolf G. Bork Digitally signed by Rolf G. Bork DN: cn=Rolf G. Bork, c=US, o=LIGO, ou=Caltech, email=rolf@ligo.caltech.edu Date: 2009.02.25 06:09:58 -08'00'
System(s) affected:	Advanced LIGO
Nature/ Scope:	Design decision (ISC). Requirements impact (COC, AOS, potentially CDS).
Subsystem(s) affected	ISC, COC, AOS, (potentially) CDS
Primary Contacts	Peter Fritschel, Bram Slagmolen
Reference Documents:	LIGO-T080139-00

DECISION/AGREEMENT STATEMENT:

The Advanced LIGO interferometers will include Arm Length Stabilization systems for aid in lock acquisition (see the Advanced LIGO Systems Preliminary Design, T010075-01, sec. 3.15). These systems must be able to control the length of each arm cavity to a determined length (relative to a resonance for the main beam, and typically a few linewidths away from a main beam resonance), with residual fluctuations of order 1 nanometer. Three schemes for achieving this have been studied, and are described in T080139-00, "Adv. LIGO Arm Cavity Pre-Lock Acquisition System" (the schemes are named: Suspension Platform Interferometer (SPI); Digital Inteferometry (DI); Frequency-shifted Pound-Drever-Hall (PDH)).

A Technical Review Board was assembled in June 2008 to evaluate the three schemes and choose which one to adopt. The members of this TRB were: Peter Fritschel (chair), Rana Adhikari, Dennis

Coyne, Matt Evans, David McClelland, Daniel Shaddock, Daniel Sigg, Bram Slagmolen, Sam Waldman. In July 2008 the TRB adopted the scheme of PDH sensing of the arms cavities using a different wavelength probe beam (other than 1064 nm). A probe beam wavelength of 532 nm is the favored choice, as it can be tied to the main beam wavelength using frequency doubling techniques, and the test mass coating design to accommodate this wavelength appears straightforward. In July the issue of where the probe beams would be injected (vertex versus end-stations) was left open. Since then Bram Slagmolen has looked more closely at both options; a technical note on end-station injection and a set of viewgraphs on vertex injection can both be found on the SPI wiki page.[1] The conclusion is that there is no real advantage to vertex injection, and there are more interfaces and constraints to deal with vertex injection than with end station injection. Therefore, end-station injection is adopted.

To sum up, the ALS adopts the following scheme: PDH sensing of each arm cavity, using 532 nm wavelength probe beams injected from each end-station; samples of the 1064 nm wavelength main beam will be sent down the arms on single-mode fibers to allow locking of the 532 nm source to the main beam frequency.

For the record, the main reasons for choosing the frequency-shifted PDH scheme over the other two schemes were:

- The suspension platform interferometer (SPI) scheme does not sense directly the test mass separation, so there is a risk it would not adequately stabilize the real arm cavity (even though modeling suggested it could).
- The sensitivity of the digital interferometry (DI) scheme has little or no margin for actuator range.
- The DI scheme appeared to be too vulnerable to probe beam pointing fluctuations; these would produce false length signals that could limit the length stabilization performance.
- In comparison the PDH scheme is a simple, familiar sensing method; it has plenty of margin in signal-to-noise, and its resonant mode nature gives it some immunity to input beam pointing. Altering the test mass coating design to give a suitable cavity for the probe beam appears straightforward. The single-mode fiber that carries the 1064 nm reference to the ends may need to be actively stabilized, but techniques for doing this are now well-established in the literature.

Subsystem Impact:

ISC. The ALS system is a component of the ISC subsystem, and ISC will provide the design and components required to implement the chosen scheme. The Australian National University is interested in being responsible for delivering the ALS (under the umbrella of ISC).

COC. The test mass coating specifications will need to include R/T specifications at 532 nm. The specific values are TBD, but the nominal values/ranges are: ITM, high-reflector at 532 nm (T less than 1%, or as small as possible without degrading 1064 nm performance); ETM, partial

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[1] http://ilog.ligo-wa.caltech.edu:7285/advligo/Seismic_Platform_Interferometer

transmitter, with T in the range of 2-15%. The anti-reflection surfaces of the ETM and the ETM reaction mass will also need to include a specification at 532 nm (nominally AR less than 4%).

AOS. The 532 nm probe beam will be transmitted and expanded by the ETM transmission beam reduction telescope (part of AOS). This telescope will thus need to include a specification for minimum transmission at 532 nm (suggest T > 90%).

CDS. The nominal plan is to use the existing single-mode fiber runs down the arms to transport samples of the 1064 nm main beam to the end stations (one fiber down each arm, at each site, is required). However, these are single-mode fibers at the communications wavelength of 1310 nm, and will not be strictly single-mode for 1064 nm. Nonetheless, Ye et al.[2] report using a similar communications fiber to successfully transport 1064 nm over several kilometers with more than enough stability for our purposes, so we expect we can make it work. In case this does *not* work as expected, though, we may conclude we need to lay new fiber for the 1064 nm reference. This added scope would fall under CDS.

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[2] J. Opt. Soc. Am. B, Vol. 20, No. 7 / July 2003 / 1459