



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
RECORD OF DECISION/AGREEMENT (RODA)

Document	LIGO-M 040006-00 -Y	
Title:	RODA: Same size FM and BS optics	
To/ Distribution:	COC: Bill Kells, GariLynn Billingsley, Helena Armandula, Gregg Harry SUS: Norna Robertson, Janeen Romie, Mark Barton, Calum Torrie, Ken Strain, Caroline Cantley, Jim Hough Systems: Shoemaker, Carol Wilkinson, Peter Fritschel cc: aligo_systems, aligo_sus	
From/ signatories:	Name/Title: Dennis Coyne (System Engineer)	Signature: _____
	Name/Title: GariLynn Billingsley (COC Leader)	Signature: _____ <small>for G.B.</small>
	Name/Title: Norna Robertson (SUS Cog Sci)	Signature: _____
System(s) affected:	<input type="checkbox"/> Initial LIGO <input checked="" type="checkbox"/> Advanced LIGO <input type="checkbox"/> Other: _____	
Nature/ Scope:	<input checked="" type="checkbox"/> Design Decision <input type="checkbox"/> Requirements Decision <input type="checkbox"/> Work Scope Decision <input type="checkbox"/> Working Agreement between Groups <input type="checkbox"/> Other _____	
Subsystem(s) affected	<input checked="" type="checkbox"/> Relevant Subsystem(s)/Component(s): Core Optics Components (COC) subsystem: Beamsplitter (BS) and Folding Mirror (FM) optics Suspension (SUS) subsystem: BS and FM suspensions	
Primary Contacts	Group or Affiliation and Contact: GariLynn Billingsley and Norna Robertson	
Reference Documents:	<u>Relevant SUS references:</u> 1) GEO Suspension Team, Advanced LIGO Suspension Reference Designs, T000012-00 2) N. Robertson, Advanced LIGO Suspension System Conceptual Design, T010103-03 3) P. Willems et. al., Cavity Optics Suspension Subsystem Design Requirements Document, T010007-01 <u>Relevant COC references:</u> 1) G. Billingsley, et. al., COC Design Requirements Document, T00127-00 2) H. Armandula, et. al., COC Conceptual Design, T000098-00	

DECISION/AGREEMENT STATEMENT:

We agree to adopt into the baseline design, a folding mirror (FM) optic with identical dimensions as the beamsplitter (BS) optic.

Discussion (not binding in the agreement):

For commonality of design and parts, the SUS group would like to make the FM suspension chain identical to the BS. Since the BS optic is used in transmission and should remain fairly thin to prevent significant heating effects, this implies making the FM as thin as the BS. However coating

strain, in the much thicker high reflectance (HR) coatings required for the FM, might warp a thin (BS-like) optic. If we coat both faces of the FM with the same multi-layer HR coating so that the residuals strains cancel (to first order) then the radius of curvature (ROC) change is approximately zero. The added cost of approximately \$20K x (2 + 1 spare) FM optics = ~\$60K is less than a development effort to accurately and repeatedly determine how to polish in a compensating ROC.

One might argue that we would need to implement a compensating ROC polish for the BS coatings anyway. In initial LIGO, the 50/50 coating was ~7 layers. I calculate that a 7 layer 50/50 coating and a 2 layer AR coating would induce ~170 nm sagitta. Since we need to implement an AR coating which is not first order sensitive to the outer layer thickness (and so not first order sensitive to etching effects from cleaning), the AR coating will get thicker. It should be possible to design a 50/50 coating and an AR coating such that they have roughly compensating effect on the ROC (e.g. multiple SiO₂ layers on the AR side under the AR coating to just add stress and have little optical effect).

Even if we coat both FM surfaces with nominally the same coating, we are not assured of success; We are essentially asking that the difference of two large effects to be zero. I estimate that a 40 layer HR coating (SiO₂/Ta₂O₅) on a thin FM (35 cm dia x 6 cm thick) would cause a 1280 nm sagitta (with high uncertainty). If we need (as was the case for initial LIGO) about ~10 nm maximum sagitta, then we need the coatings to be identical (in strain effects) to ~ 1%. Not impossible, but not easy either since the two sides are coated in separate runs. According to Stan Whitcomb, initial LIGO experience was *not* close to 1%, but considerably higher (i.e. controlling coating thickness is not an assurance of controlling residual coating strain.) Nonetheless, the balance in differential ROC (between the X and Y FMs, which I'd guess is < 100 nm) should be within the capability of the active thermal compensation (ATC) system to handle. Furthermore, we know how to readily etch the coatings (using a hot DI and liquinox solution); We could adjust the back side coating thickness, guided by ROC measurements, and iterate to a ROC within tolerance.

In summary we agree to a FM optic of the same dimensions as the BS with the assumption that we will apply nominally identical coatings on both sides (the back side de-tuned from 1064 nm slightly) and compensate any residual ROC imbalance by iteratively etching the back-side FM coating and ultimately compensating any residual ROC using the ATC system.