From: **Billingsley, GariLynn** gbtuned@caltech.edu
Subject: Re: BS figure - breadcrumbs-1
Date: March 12, 2020 at 10:13 PM
To: Fritschel Peter pf@ligo.mit.edu

Current Requirements:
mirror diameter of 225 mm mirror radius of 112.5 mm
R>300Km cc = sag of 21 nm or less
R>1000Km cx = sag of 6 nm or less

if you look at section 2.3.2.1 of
https://dcc.ligo.org/DocDB/0003/E080494/003/COC_Final_Design_E080494-v3.pdf
You see a discussion of change in ROC upon coating for iLIGO in the 20-25 nm range. Along with a lot of discussion of stress balance. There are also questions in the FDR sessions about this.

The above seem to indicate that we expected 20-25 nm of sag change (toward the cx), so allowed a generous cc spec and a very tight cx spec. So, probably looking for less than 20 nm from flat (225 mm dia)

So, what did we get:
BS02-LLO a change of ~3nm, consistent with a compressive coating stress.
Polished 1332.0 km cc, or 5nm sag on 225 mm diameter
Coated 2nm cc sag on 225 mm diameter

BS06-LHO a change of ~11 nm, also in the expected direction, toward convex.
Polished 328350 km cx or 0.02nm sag on 225 mm diameter - don't know how anyone can claim that with a straight face….
Coated 11 nm cx on 225 mm diameter

I've filed some .pdfs at the BS filecards in the DCC. Still not pretty, but at least present.

I know that some of the BS were annealed for quite a long time in an attempt to get the absorption to come down, I wonder if this might be the reason for the variable change after coating.

- Gari

> On Mar 12, 2020, at 2:31 PM, Peter Fritschel <pf@ligo.mit.edu> wrote:
>
> Just noting that for R = 300 km, and mirror radius of 22 cm, the sag is 80 nm.
>
> > On Mar 12, 2020, at 5:21 PM, Billingsley, GariLynn <gbtuned@caltech.edu> wrote:
> >
> > - Gari
> >
> > > Begin forwarded message:
> > >
> > > From: GariLynn Billingsley <billingsley_g@ligo.caltech.edu>
> > > Subject: Re: TRB Recycling cavity mirror figure
> > > Date: September 21, 2011 at 12:39:14 PM PDT
> > > To: Aidan Brooks <brooks_a@ligo.caltech.edu>
> > > Cc: Peter Fritschel <pf@ligo.mit.edu>, Hiroaki Yamamoto <hiro@ligo.caltech.edu>,
> > > Wilkinson Carol <wilkinson@ligo.wa.caltech.edu>, Dennis Coyne

Wilkinson Carol <wilkinson@ligo-wa.caltech.edu>, Dennis Coyne <coyne@ligo.caltech.edu>, Bill Kells <kells@ligo.caltech.edu>

Hi Aidan,
I understand that you are the new Phil, and so want to invite you to join a discussion about TCS command authority. Our current specification for maintaining optic figure of a BS or FM through coating:

Over a 225 mm diameter aperture, coating uniformity
& stress from the coating process shall not change the
Sagitta more than 8 nanometers, and shall not add
surface figure Zernike terms higher than second order
with amplitude > 0.5 nanometers.

The intention was to keep the figure of recycling cavity optics controlled at a similar level at the ITM HR surface. It looks like this may cost us a chunk of money, and so... we are looking back at that spec to see what is truly required of the optics given the current maturity of the TCS system.

Read on to see Bill's and Hiro's responses as well.
Gari

> On 9/20/2011 9:07 PM, GariLynn Billingsley wrote:
>
> We will be going to CSIRO to negotiate future costs to coat our optics. As we look at future cost risks, one that sticks out is the job of maintaining the figure of the BS and FM to a sag change of <8nm over the clear aperture. From their breakdown in costs it appears that they have allocated about 600K for this task. (they are asking for 1.4M going forward, so this is a significant fraction)
>
> The question; do we need the 8nm control on sag (beam splitters and Fold mirrors)? How much can TCS handle?
>
> What we know: iLIGO BS were measured before/after coating, the combination of coating non uniformity and coating stress changed the sag in the center 150 by ~20-25 nm. These are a similar form factor to the aLIGO BS, however in the iLIGO case the concave uniformity balanced the convex coating stress.
>
> For aLIGO there is no guarantee that coating uniformity will work in our favor. AR reflectivity scans done on CPs do show nicely uniform distribution, which hints that we will get no opposing sag from the non-uniformity. LIGO-E1100754-v1
>
> We know that for the BS CSIRO is planning on HR and AR coatings of roughly the same thickness, so stresses should balance somewhat.
>
> Fold mirror; iLIGO coatings were dominated by coating non-uniformity (so concave), and the FMs were 100mm thick (so very different form factor). CSIRO plans a balancing coating on the back, laid down before the AR coating as follows:
>
> HR coating then anneal, then put a shape correcting layer (may need more than 1 iteration to straighten,) then apply AR coating - not annealing the AR (no absorption requirement)
>
> I propose: they do their BS deposition and we buy off on whatever it is. If we want it further refined, we send it back to CSIRO and pay for further development. Fold mirrors; we monitor it by iteration and decide to pay per iteration. They should lay out a per-cycle cost.

> That's all I can manage to put out tonight, let me know your thoughts.
> Gari

Begin forwarded message:

> From: Hiroaki Yamamoto <hiro@ligo.caltech.edu>
> Date: September 21, 2011 9:23:28 AM PDT
> To: GariLynn Billingsley <Billingsley_G@ligo.caltech.edu>
> Cc: Peter Fritschel <pf@ligo.mit.edu>, Bill Kells <kells@ligo.caltech.edu>, Wilkinson Carol <wilkinson@ligo-wa.caltech.edu>, Dennis Coyne <coyne@ligo.caltech.edu>
> Subject: Re: TRB Recycling cavity mirror figure
>
> Gari,
>
> I support your proposal. That sounds practical, if the schedule allows when taking the time into account to ship back and forth between CSIRO and us. In the past, some signature we worried turned out to be not the major factor but others turned out to be more problematic, like the astigmatism of RM3.
>
> There is no TCS for BS, I think. Do you mean to use two CPs in front of ITMs to cancel the lens in BS?
>
> Regarding 8nm sag, where does it come from? This sag corresponds to 2000km ROC change (assuming the clear aperture means 37cm, it will be 800km if the clear aperture means 22.5cm), while the HR side ROC requirement is 300km.
> Most polished surfaces are > 1000km, but some are 400km.
> One case bothered me, the one I mentioned sometime ago about the single pass TWE of BS03.
>
> Compared to this BS03 lens, and 300km ROC requirement, 8nm sag seems to be a too stringent requirement. In other words, I don't think this stringent requirement is not necessary, can be possible factor 2 looser to induce effective ROC of 500km. If the clear aperture is 22.5cm, 10cm sag will induce effective ROC of 500km.
>
> The net effect will be the combination of this sag by the coating together with the polished surface profile and single pass TWE.
> So, back again, it will be practice to go for the proposal by Gari.

On Sep 21, 2011, at 10:00 AM, Bill Kells wrote:

> Gari,
>
> Your [proposed] strategy sounds sufficiently flexible to cover any necessary tweeks,
> so it should be adequate.
>
> I think we should bring 'on board' someone involved in the final TCS design to understand and comment on this. We shouldnt just extrapolate and conclude ourselves. In principle TCS is
> scoped for other tasks, so some heads need to be put together to conclude reasonable margins
> for other tasks.
>
> Do I recall correctly that the "8nm" figure was actually an assumption as to what polishers could
> reasonable achieve on flats? Maybe it was not reasonably extrapolated for the

reasonable achieve on flats? Maybe it was not reasonably extrapolated for the coating/annealing operations.
On the other hand, without any TCS correction, a limit can be set by asking what contrast defect a curved FM
would give in an otherwise perfect [S]RC. I'll try to work this value.

bill