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Subject: Re: Homogeneity measurements of Sapphire

Hi sapphire gazers,

I have been re-evaluating the consequences of ITM inhomogeneity for LIGO-II.
This is the first of a series of comments on that.

First as a concrete example I have examined the specific OPD measurement "saphbh0a" in GariLynn's link below. This is the wost case of those given, however it is better than the apparent distortion in the more recently descibed 25 cm dia test blank (which power term can be compensated in the polish/coating. Of course the ideal would be to strive to have polishing compensate all of the inhomogeneity, but these pieces seem to indicate that a substantial portion is in very high [spatial] frequency terms which could not practically be comp'd.On the other hand a substantial portion of the inhomogeneity is also contained in the lowest order terms beyond power: astigmatism and spherical. My conclusions suggest that serious effort be made to have the polishers compensate those terms as well (or perhaps include them in the thermal distortion compensation).

So I imagine a benchmark ideal interferometer where the two arms cavities are perfectly matched to the input beam, and the RC is nominally degenerate. That is, the HR polishing and coating is to design, any thermal effects have been compensated, and the cold ITM OPD is zero. Then introduce the perturbation of a 48 nm rms phase plate distortion just before the ITMs (randomly different, arm to arm). How does this affect the ifo performance? In this mail I limit comment to the affect on the Carrier light. Previously (eg in the thermal lensing discussions) focus had been on the nominally larger effect of such perturbation on the SB light. This still holds, but the effect is large enough that I probably cant reasonably evaluate it without further FFT studies using specific OPD phase maps.So for now, when I evaluate the affect of the perturbation on the CR, I assume some fixed 00 mode SB tramsmission to the GW port. So the conclusion will be a lower limit.

The reason that attention (wrt ITM "phase plate" distortions) had been focused on the SB was that a general cancellation effect held, whereby the reflected field from the arm as a whole bore no component of the phase plate perturbation. For example the RC 00 mode gain is unaffected by such a perturbation. Similarlly, there is essentially no contribution to the contrast defect (and even in the case of the SB, any change from the design, Schnupp, contrast would be small) for arbitrarily different ITM OPDs.

However it is not true that there is no degredation of the GW strain sensitivity. The resonant arm power level is reduced (since the 00 wave passing through the phase plate distorts and cant all match into the arm cavity), which directly lowers the amplitude of the GW modulation. The GW strain sensitivity is reduced exactly by the amount the arm power is reduced via this mechanism. The amount by which the arm power is reduced by the phase distortion mismatch is:

$$dP/P = 2\,Pi\,(OPD\ rms/lambda)^2 = 8.3\%$$

Note that The thermal lensing distortions will have a similar CR degradation effect, in addition to the SB recycling gain degradation.

Bill K.

Dennis Coyne wrote:

> Peter & Bill,
> The inhomogeneity of the sapphire samples, with compensation for power polished into the optic, is estimated to be 20 - 50 nm rms (based on the CSIRO measurements cited below). The transmission OPD requirement for LIGO-1 ITMs is < 21 nm rms (COC DRD, T950099-03, Table4). Is this acceptable for LIGO-2? I imagine that LIGO-2 may require a lower contrast defect than LIGO-1, and therefore a smaller ITM transmitted wavefront distortion. Have either of you made a calculation/estimate for an appropriate specification on the inhomogeneity? Jordan has indicated that Crystal Systems does not think they can significantly improve the inhomogeneity with further material development. If the level of performance estimated from a power correction isn't sufficient, then we may have to look into 'spot' polishing, with a likely considerable increase in risk & cost.
> Dennis
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> GariLynn Billingsley wrote:
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> > CSIRO has completed the measurement of our first two 15 cm m-axis sapphire pieces. On the referenced web page you will find their report for these measurements along with pictures of the maps, similar to those shown at the LSC meeting. These pictures are screen shots from "Vision" software, the analysis software which is run in the metrology lab at Caltech and at CSIRO. The software is fairly powerful, if you would like more information than is shown, please contact me.
> >
> > http://ligo.caltech.edu/~gari/LIGOII/homogeneity.htm