Coating Thermal Noise: Research Directions

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March 15, 2010

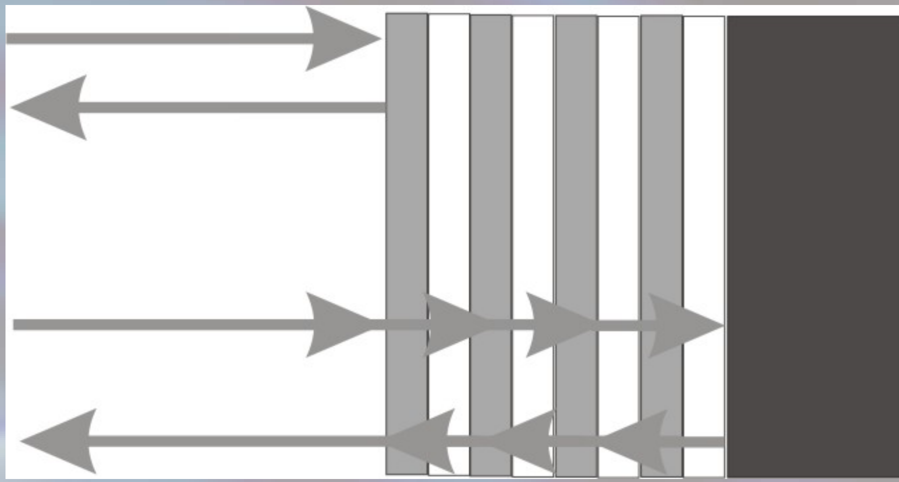
Optics Parallel Session

LIGO-Virgo Collaboration Meeting

G1000209-v1

Coating Thermal Noise Theory

- Effect of coating penetration solved by Yanbei et al.
  - Roughly a 5% effect, no major concerns



- Needs:
  - Paper/tech note
  - Deviation from standard theory for aLIGO coatings
  - Included in GWINC model

$$S_x(f) = k_B\, T\, d\, Y_{coat}\, \phi / (\pi^2 f\, \omega^2\, Y_{sub}^2)$$

Torsional ϕ_{coat} Measurement

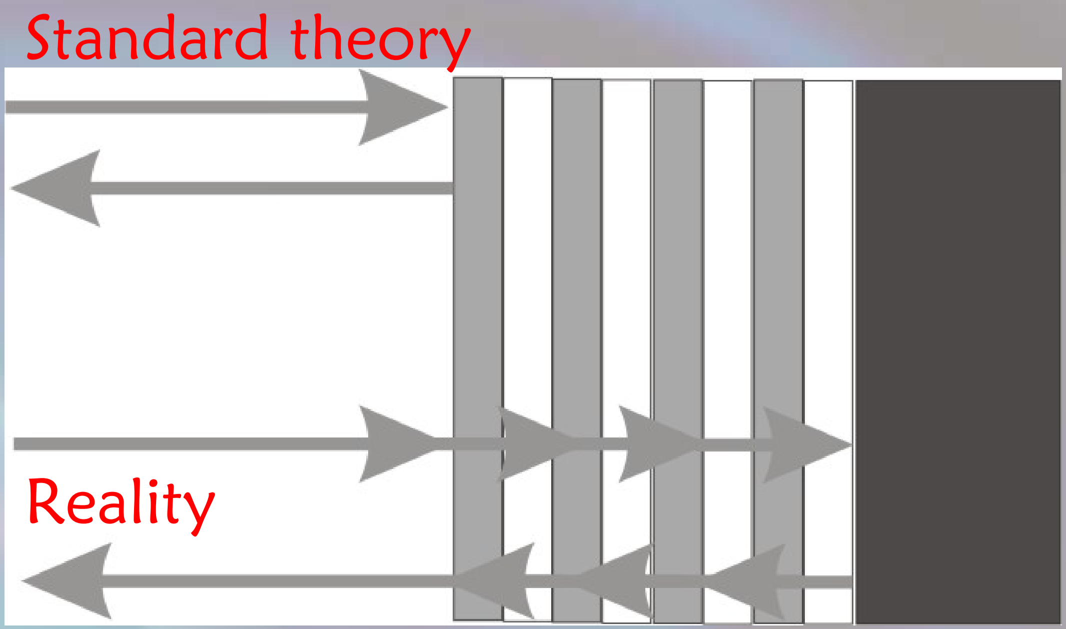
- Standard theory ignores second loss angle in amorphous materials
- Coating design from Chen et al includes possible thermal noise reduction from including torsional loss
- Need experimental values: Si, Ta, Ti-Ta, etc
- Capital "I" like design
  - ATF approached about coating
- Need FEA models of normal modes

Change in Wavelength

- Shorter wavelength
  - Smaller coating, direct thermal noise reduction
  - More problems with color centers; greater absorption, scatter? Needs study
- Longer wavelength
  - Wavelengths up to ~3 μm seem realistic
  - New possibilities for materials; silicon
  - Need a study of realistic wavelengths and materials with indices, scatter, absorption
    - Measure loss angles

Reflection by Doublet

- Standard theory: All light reflected at coating face
- Reality: Some light penetrates into coating to various depths



$$S_x(f) = k_B\, T\, d\, Y_{coat}\, \phi / (\pi^2 f\, \omega^2\, Y_{sub}^2)$$

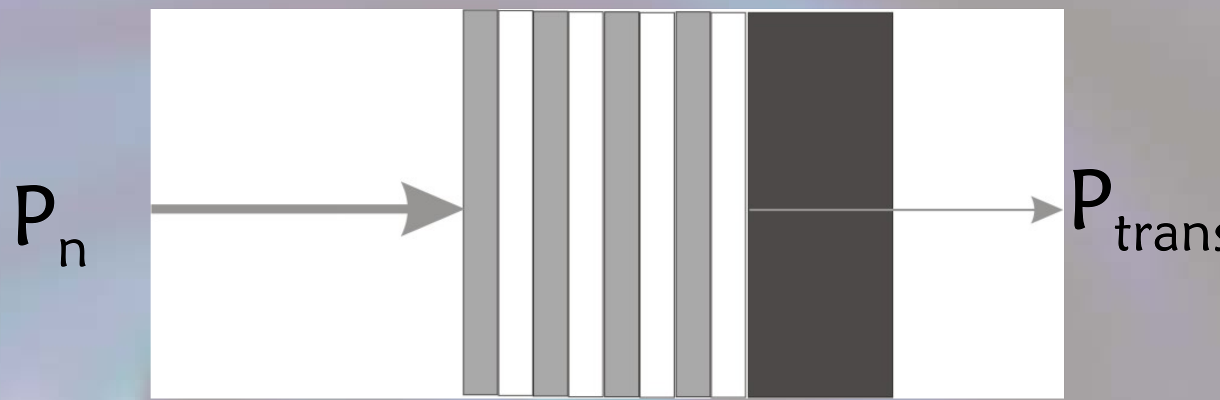
Calculation of Light Penetration

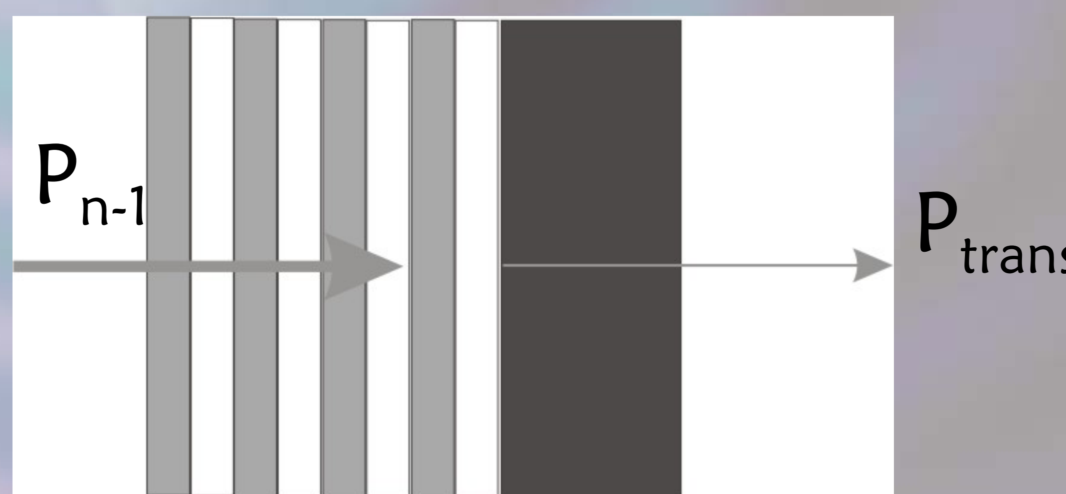
$P_{trans} = \alpha_n P_n$

$P_{trans} = \alpha_{n-1} P_{n-1}$

$P_{n-1} / P_n = \alpha_n / \alpha_{n-1}$

- P_{n-1} / P_n is what we want
- Can calculate α's





Reflected Light by Doublet

- α's from coating modeling code
  - From Andri
- Calculate relative amount of optical power in each doublet
  - Used 20 doublet, ¼ wave stack

Doublet Number	Amount of Reflected Light
20	51%
19	25%
18	12%
17	6%
16	3.1%
15	1.5%
14	0.7%

Effective Doublet Number

- Assume thermal noise seen by each beam depends on the amount of coating between beam and substrate

$$0.51 \times 20 + 0.25 \times 19 + 0.12 \times 18 + 0.06 \times 17 + 0.031 \times 16 + 0.015 \times 15 + 0.007 \times 14$$

$$= 19 \text{ effective doublets}$$

- Traditional theory uses 20 doublets
- Effective number is 19 doublets
- Traditional theory overstates coating Brownian thermal noise by 1:20, 5%

Issues and Questions

- Is this a (somewhat?) accurate optical model?
  - Difficult to localize optical power in coating?
- Is optical power the correct weighting?
- Redo with actual aLIGO coating
  - Optimized layers
  - Actual coating models for ITM and ETM
- How does this effect thermo-optic noise?