Some Thoughts on Scattered Light in the Corner Station

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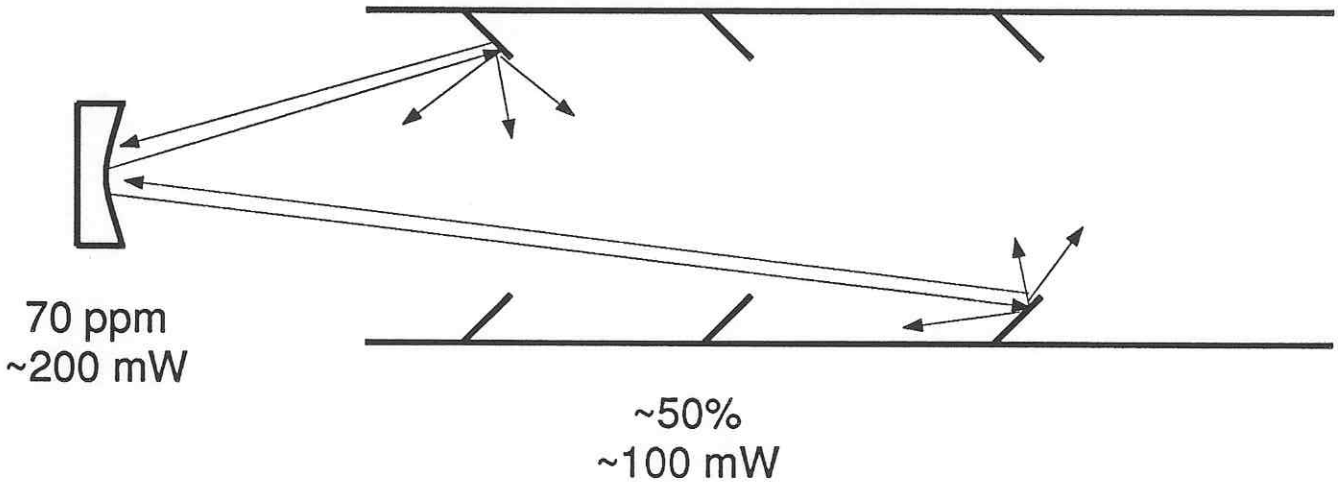
- Attempt to Raise Some Issues Related to Scattered Light in the Corner (and End) Stations
- Does NOT represent a Real Analysis
- Some Educated Guesses About Where the Problems Might Lie
- Some Suggestions About What We Can Easily Do to Reduce Potential Impact on Noise

Beam Tube Baffles: Background



- Designed with Ultimate Sensitivity in Mind
- Single Source of Scattered Light, Single Destination, Limited Number of Paths
- Back Scattered Power ~10^{-14} of Main Beam Power

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Suggested Goal

- Beam Tube Goal:

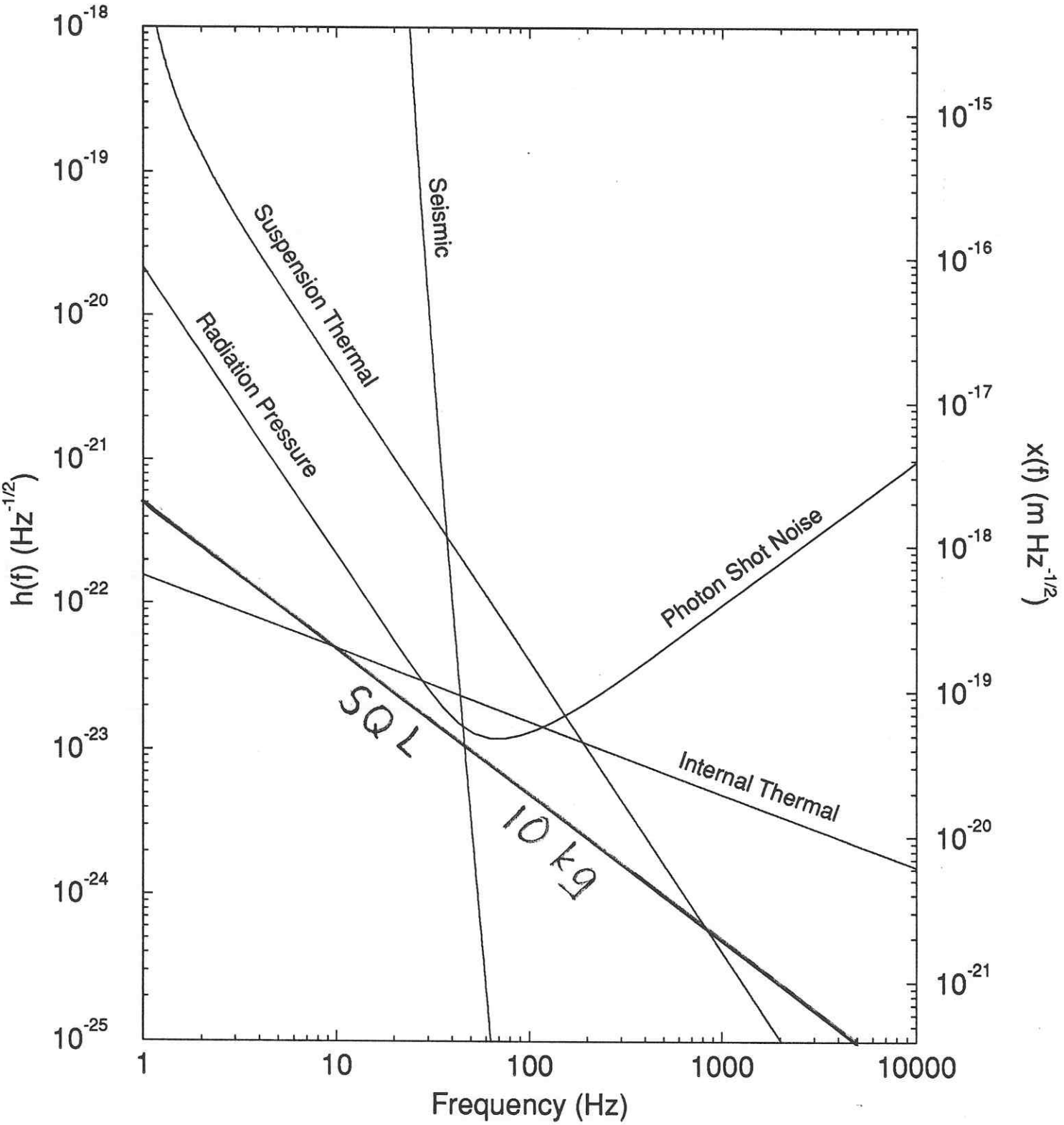
  ››Scattered Light Noise Less than 0.1xSQL for 1000 kg TM's (for Ultimate Sensitivity)

- Baffling in Chambers Can Be Modified as IFO's are Improved
- SW Suggestion:

  ››Set Goal for Initial Interferometer Scattered Light Noise at 0.1xSQL for 10 kg TM's (10 x Higher in h)

  ››Gives Generous Safety Margin (>100x in h)

  ››Scattered Light Noise Scales as E_{scat}/E_{IFO}, so Allows 100x Higher Scattered Light Levels


Seismic
Suspension Thermal
Radiation Pressure
Photon Shot Noise
Internal Thermal
SQL
10 kg
h(f) (Hz^-1/2)
x(f) (m Hz^-1/2)
Frequency (Hz)
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
10^-25
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
1
10
100
1000
10000

Determinants of Scattered Light Noise

$$\delta\varphi \sim \left(\frac{P_{scat}}{P_{main}}\right)^{1/2}\left(\frac{Ref}{R^2}\right)^{1/2}\left(\frac{\delta x}{\lambda}\right)\left(\lambda^2\frac{dP}{d\Omega}\right)^{1/2}$$

1 Amount of Scattered Light Generated

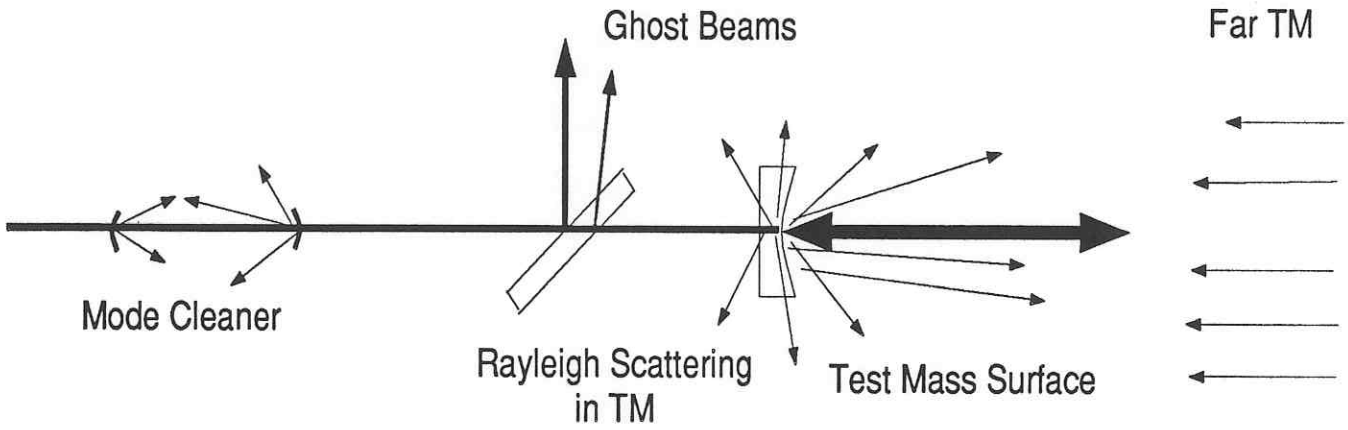
2 Fraction of Scattered Light Returned to Optics

3 Motion of Reflecting/Scattering Surface

4 Recombination Probability (shown for recombination by scattering)

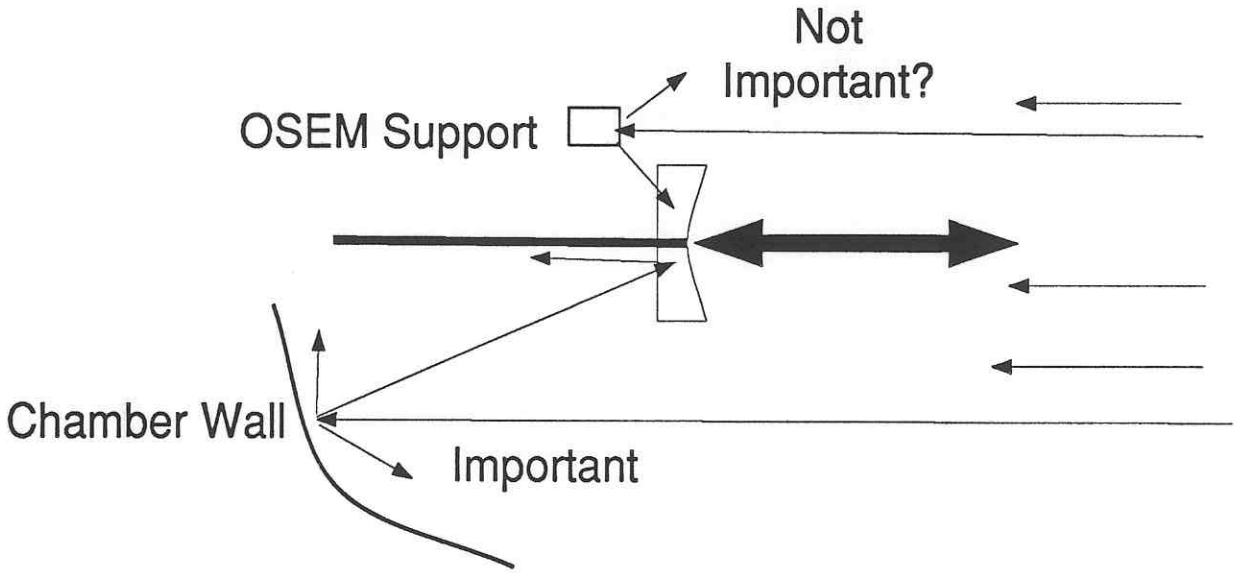
- Scattered Light Noise h(f) is Proportional to Square Root of Items 1,2,4
- Scattered Light Noise h(f) is Directly Proportional to Item 3
- Recombination on Photodiode was not Important for Beam Tube Scattering, But is Likely to be Important for Chambers

Corner Station Sources of Scattered Light



Source	Scattered Power	Comment
Test Mass Surface	200 mW	Directed along axis of Arm, but ~30% Remains in Corner Station
Far Test Mass	30 mW	Very Well Collimated
Rayleigh Scattering in TM Substrate	10-20 mW	Extremely Broad Distribution; May be Important as Recombination mechanism
Ghost Beams	3-30 mW each	Well Defined Spots, Easy to Trap
Mode Cleaner	150 mW	Assume 5% of input power

Scattered Light From Far Test Mass: Estimated Noise



$$\left(\frac{P_{scat}}{P_{rec}}\right)^{1/2}\left(\frac{1}{R^2}\right)^{1/2}\left(\frac{\delta x}{\lambda}\right)\left(\lambda^2\frac{dP}{d\Omega}\right)^{1/2}$$

$$\delta\varphi \sim \left(\frac{30mW}{30W}\right)^{1/2}\left(\frac{1}{3m}\right)\left(\frac{10^{-11}}{10^{-7}}\right)\left(10^{-12}\ \frac{10^{-6}}{10^{-2}}\right)^{1/2}$$

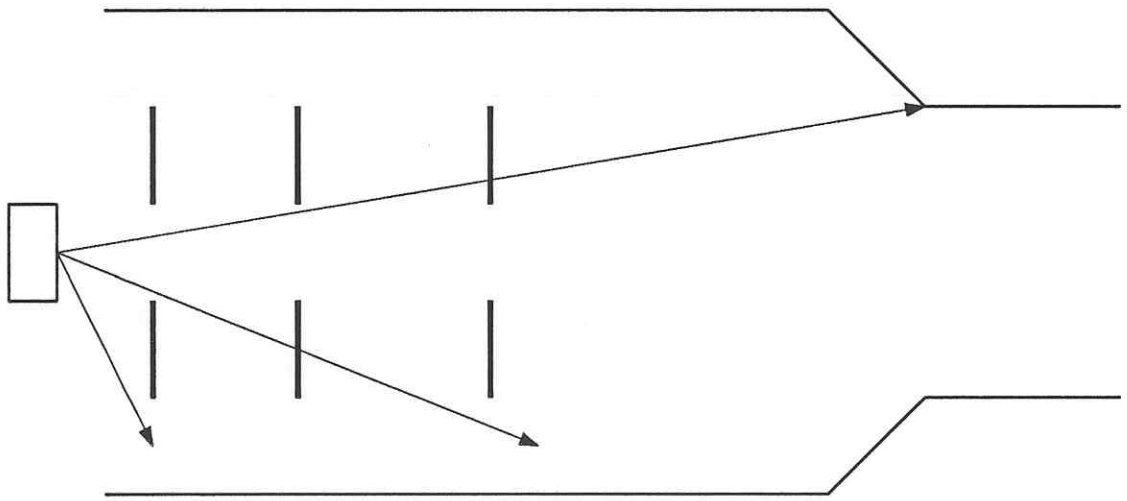
10^{-13} rad/ $\mathrm{Hz}^{1/2}$ at 100 Hz

Light From Far Test Mass (continued)

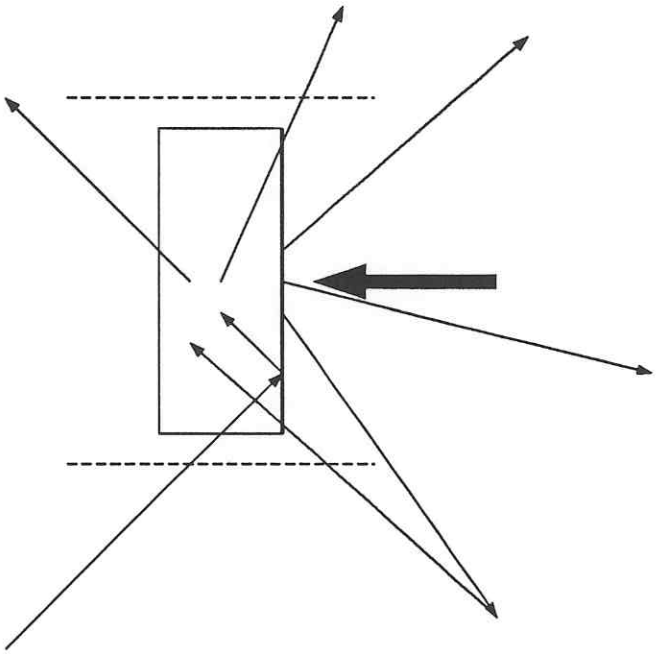
- Scattered Light From TM Paraphernalia Mounted on Seismic Stack Probably not Important because of Small Motion
- Light Scattered Back Toward Far Mirror Unimportant for Initial Interferometers
- Scattering From Walls to IFO Optics Worrying
  - ››Estimate Shows Substantial Margin, BUT
  - ››Lots of Paths, Difficult to Anticipate Possible Glints
  - ››Increased Wall Motion Would Reduce Margin
- Simple Solution: Flat Plate to Block Chamber from Viewing Beam Tube
  - ››Black Glass with Aperture for Main Beam
  - ››Cost ~ $few k x 10 locations
  - ››May Help with Scattered Light Control inside Chamber
  - ››Need to Consider Effect of Aperture (~25 diameter)

Beam Tube Manifold

- Back of Envelop Guess: Worse than Beam Tube By Factor of 30 Because of Higher Reflectivity, But Probably OK For Initial IFO
- Series of 3-5 Baffle Plates (Black Glass?) Could Eliminate Most Lines-of-Sight from Mirror to Vacuum Wall
- This is an Area Which Needs More Analysis



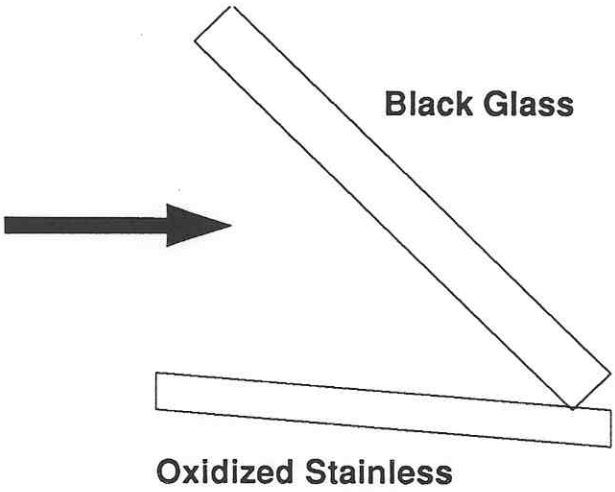
Test Mass Shielding



- Need to Leave Aperture for Beam Limits Coverage to 50 - 75%, But Win Both for Generation and Recombination
- For Angles >15° From Cavity Axis, Rayleigh Scattering Recombination Dominates Over Surface Scattering

Ghost Beams

- 3-30 mW per Beam, 2-5 Beams per Optic
  - ››Many May Be Used for LSC, ASC
- Earlier Layouts included Beam Dumps for All Beams $>10^{-7}$ W
  - ››Level Based on Requiring $<3\times10^{-14}$ Return From Uniform Scattering Surface at 2 m distance
  - ››Possibly Too Restrictive
  - ››Concern for Stray Reflections That May Re-enter IFO
- Recommend Simple Beam Dump Design to be Used for Most Intense Beams.



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Shielding from Input Optics (Mode Cleaner)

- Problem Relatively Simple:
  - ››No Need to Shield Mode Cleaner From Scattered Light
    - — Scattered Light Reintroduced to Mode Cleaner Equivalent to Frequency Noise
  - ››Desirable to Intercept Light From Mode Cleaner Before It Gets to Core Optics
  - ››Probably Essential to Intercept Before It Gets to Photodetectors
- Suggest Adopting Philosophy that Each Chamber Should Have a Stray Light Shield for Scattered Light Generated in that Chamber
  - ››Cut-outs for Desired Beams
  - ››Will Minimize Chance of Unlucky Stray Reflection