Assignments

(all the extra reading materials for the assignments are enclosed with the lecture notes)

Lectures 1-5

1. Gravitational lensing: briefly review strong lensing, weak lensing and microlensing. (indicate URLs or papers you consulted)
Consider the gravitational lensing time delays expected for gamma ray bursts (GRBs). These bursts have duration ~ a few seconds, and occur at redshifts from 0.1 to ~8. The path of the burst signal may pass near a typical galaxy or a galaxy cluster, or close enough to a star to create a gravitational lensing time delay. Calculate the time delay you might expect for typical scenarios. What should astronomers look out for?

2. Summarise the science of Gravity Probe B. Explain the two precession signals expected. Explain in simple nonmathematical terms the meaning of gravitomagnetism

3. Summarise the classical theorems, conjectures and predictions about black holes that should be verifiable through the observation of gravitational waves

4. Demonstrate the tiny gravitational wave output from any imaginable terrestrial source (be imaginative but realistic). Work through and present (by hand, not using computer algebra) the derivation which converts from terrestrial quantities to black hole quantities and which predicts the enormous gravitational wave luminosity for binary black hole coalescence.

5. A) Explain why gravitational waves carrying enormous amounts of energy still have tiny strain amplitude. B) Present a rough estimate of the amplitude of gravitational waves from a black hole coalescence at 200Mpc distance. C) Make a rough conversion of this amplitude into watts per square meter at the earth.

Lecture 6

6. Assuming the laser interferometer arm length is 5km limited by various reasons, Please optimize the number of round trips for a delay line configuration and the cavity finesse for a F-P configuration to have maximum sensitivity at 200 Hz.
Draw a graph to show the frequency response of the delay line and F-P configurations between 10 Hz to 1 kHz using above parameters, compare them, and explain the difference between them, i.e. qualitatively explain why there are zero sensitivity at some frequencies in the delay line configuration but not in the F-P configuration.

Lecture 7

7. Read papers about the power recycling, signal recycling and resonant sideband extraction schemes enclosed,

   1.Describe the principle of each scheme in your own words
   2.Compare signal recycling and resonant sideband extraction schemes

Lecture 8

8.1. Work out the analytical formula of the PDH error signal and draw a graph of the error signal as a function of the frequency offset similar to the one in the lecture notes, assuming r1=r2=0.9, L=1 m, E0 =1, δ=0.1.

8.2. Read the references about GW readout and compare the advantages and disadvantages of DC-readout and heterodyne readout.

Lecture 9

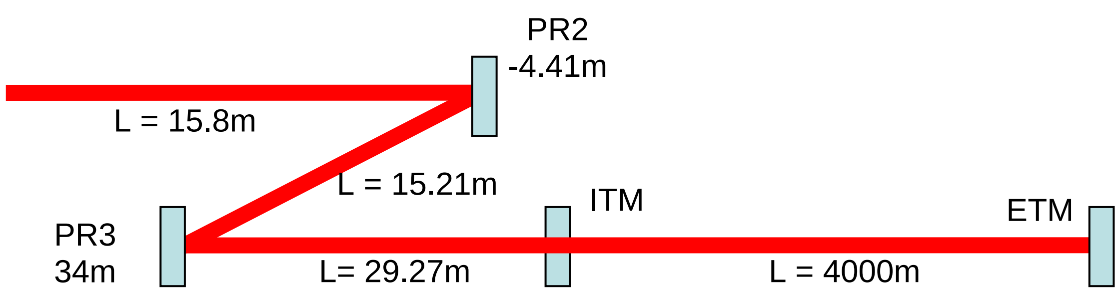
9. After reading the papers given, write a summary of possible control strategies for parametric instabilities. (You can get all references online except CQG , which you can get from link given with the lecture note)

References:
[1] Braginsky V B, Strigin S E and Vyatchanin S P 2001 Phys. Lett. A 287 331–8
[2] Braginsky V B, Strigin S E and Vyatchanin S P 2002 Phys. Lett. A 305 111–24
[3] Zhao C, Ju L, Degallaix J, Gras S and Blair D G 2005 Phys. Rev. Lett. 94 121102
[4] Ju L, Gras S, Zhao C, Degallaix J and Blair D G 2006 Phys. Lett. A 354 360–5
[5] Gurkovsky A G, Strigin S E and Vyatchanin S P 2007 Phys Lett. A 362 91–9
[6] Gras S, Blair D G and Ju L 2008 Phys. Lett. A 372 1348–56
[7] L. Ju, et al, Class. Quantum Grav. 26, 015002

Lecture 10

10.1.- Assuming a cavity of 4km with an ITM of 1934m radius of curvature and an ETM of 2245m radius of curvature. Calculate the following parameters:
- Waist size and position
- Spot size on both ETM and ITM
- Stability g factor for both mirrors and the whole cavity
- Free spectral range
- High order mode spacing

10.2.- To the previous cavity we add two mirrors with the following radius of curvature: 34m and -4.41m. Distance between ITM and the first mirror is 29.27m, from this mirror to the second mirror is 15.21m.
Assuming a vacuum environment and fused silica substrate determine the radius of curvature of the wavefront at a distance of 15.8m from the second mirror.



Lecture 11-13

11.1 Derive radiation pressure noise

11.2 Read the paper “Quantum Noise in Gravitational-wave Interferometers” by Thomas Corbitt and Nergis Mavalvala and write a short Summary about the methods of beating the quantum limit

12 Assuming a seismic noise with α=10-9 m/√Hz, for advanced LIGO detector, theoretically how many stages of 1 Hz pendulum is sufficient to meet the requirement before thermal noise dominate (Use the noise curve for the 4km interferometer in lecture 11, slide 8 for thermal noise estimation)? What would be the corner frequency of such a system?

13.1 Read the attached article “loss angle” and write a paragraph of your understanding of the loss angle

13.2 Derive the expression of pendulum and test mass thermal noise in terms of Q (use mode expansion approximation for test mass thermal noise). Give an expression for $f \gg f_p$ for pendulum, and $f \ll f_i$ (use the lowest mode) for test mass. (hint: assuming very high Q factor and using f_0=sqrt(k/m)). What will be the requirement of the pendulum Q and test mass Q for advanced GW detector? (use the advanced detector noise budget for refernce).

Lecture 14-15

1. Read the Nature paper on stochastic background and give a presentation

Lecture 16-18

See Yanbei's lectures online.