THE INPUT OPTICS OF ENHANCED AND ADVANCED LIGO

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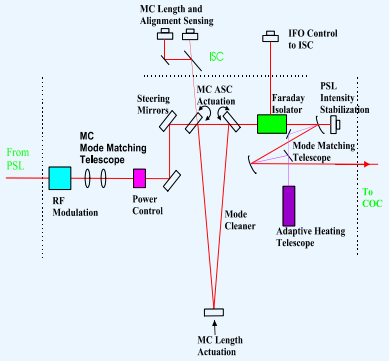
ABSTRACT

The Input Optics (IO) of LIGO is responsible for RF modulation of the light, the input mode cleaner, optical isolation, mode matching of the light to the interferometer, and beam steering into the interferometer. For Advanced LIGO, the scope of the IO includes the following hardware: phase modulation Pockels cells, laser beam power adjustment, input mode cleaner, an in-vacuum Faraday isolator, mode matching telescopes, and thermal adaptive compensation of the mode matching. The IO group has developed and characterized new RTP-based phase modulators capable of operation at 180 W cw input power. In addition, the Faraday isolator is compensated for depolarization and thermal lensing effects, and can achieve greater than 48 dB isolation. Enhanced LIGO will use a three-electrode RTP modulator and Advanced-LIGO style Faraday isolators.



	Laser Power (W)	EOM type	Freqs (MHz) H1/L1	Mod index (nom)	Configs	MC Suspensions	PRC	Faraday type
LIGO	8	vFocus $LiNbO_3$	24.5 61.2 33.3 (mc)	0.5 0.05 0.05	3x	SOS single	Marginal	EOT TGG
eLIGO	30	UF RTP	24.5 61.2 33.3 (mc)	0.5 0.05 0.05	1x, 3 electrodes	SOS single	Marginal	IAP TGG Qtz TGG
Adv LIGO	180	UF RTP	9 45/63/180 TBD	0.8! 0.8! TBD	Baseline: Mach Zehnder	MC Triple	TBD: Stable or marginal	IAP TGG Qtz TGG

Introduction

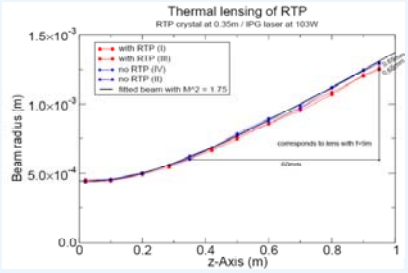
The Input Optics conditions the light from the pre-stabilized laser, sending it to the main interferometer.

The IO includes:
- –Phase modulation
  - • Electro-optic modulators
- –Interferometer power control
  - • Continuous variable attenuation
- –Spatially and temporally filter the light
  - • Mode cleaner
- –Optical isolation + diagnostic signals
  - • Faraday isolator
- –Mode match into the interferometer
  - • Adaptive beam-expanding telescope

RF Modulation

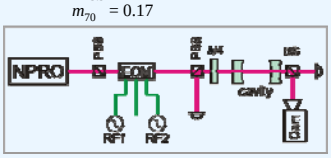
Requirements:
- Amplitude and phase stability:
  - Amplitude: differential radiation pressure
    - noise due to arm cavity carrier imbalance
    - $\Delta m < (10^{-9}/m)(f/10\ \mathrm{Hz})/\mathrm{rtHz}$
  - Phase: no direct coupling for DC readout, but
    - possible couplings through auxiliary loops

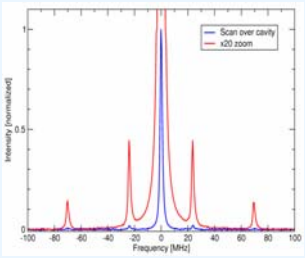
•Rubidium titanyl phosphate (RTP)
- •Electro-optic response similar to $LiNbO_3$



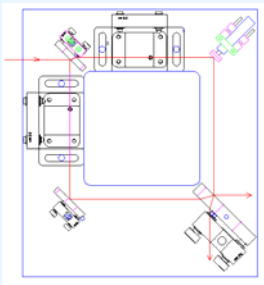
eLIGO: 3 frequencies / 1 crystal / 3 separate electrodes

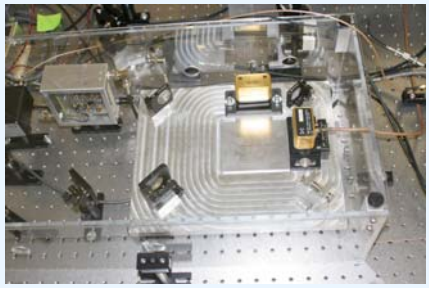
Modulation index measurement. 10 V pk-pk RF signal gave:
$m_{23.5} = 0.29$
$m_{70} = 0.17$





Advanced LIGO: Mach Zhender

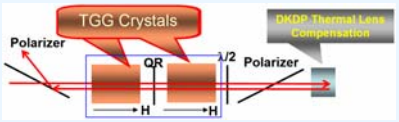


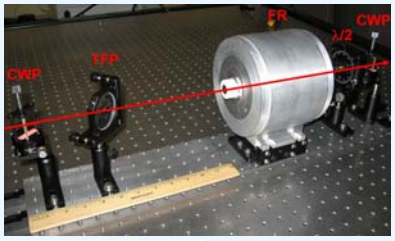


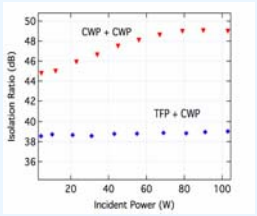
$\Delta L \sim 7 \times 10^{-14}$ m/rHz in 20 – 80 Hz band

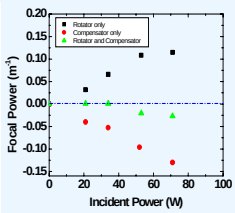
Faraday isolator

Faraday rotator uses two 22.5° TGG-based rotators with a reciprocal 67.5° quartz rotator between
- Polarization distortions from the first rotator compensated in the second.
- ½ waveplate to set output polarization.
- Thermal lens compensation: negative *dn/dT* material: KD_2PO_4, or 'DKDP'). Adaptive MMT uses DKDP also





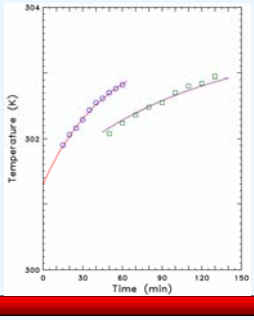




- • Suppression is set by the polarizers.
- • Calcite wedge superior to thin film Brewster's polarizers

Thermal effects: 3° C change in *T*
-> 1° change in rotation angle
-> 5 dB change in isolation ratio
(at 30 W, 3x worse at 100 W)

=> Add motorized adjustment to HWP.



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