Intensity Stabilization in Advanced LIGO

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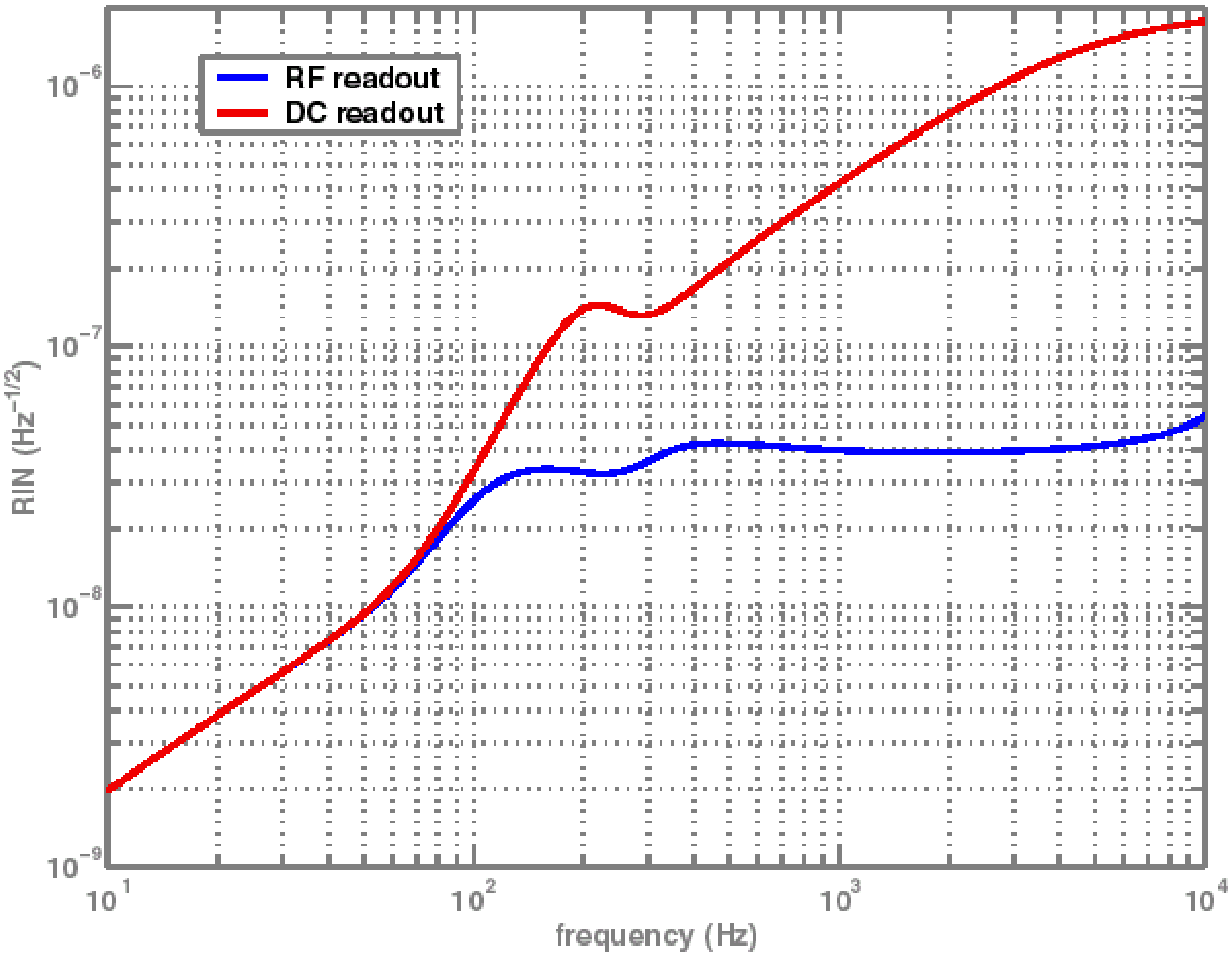
Outline

- Intensity Noise in Advanced LIGO
- The Pre−stabilized laser
- Intensity Stabilization Servo
- PSL Current Actuators
- Low−noise, High−power Photodiode
- Results

Advanced LIGO
Intensity Noise Requirement

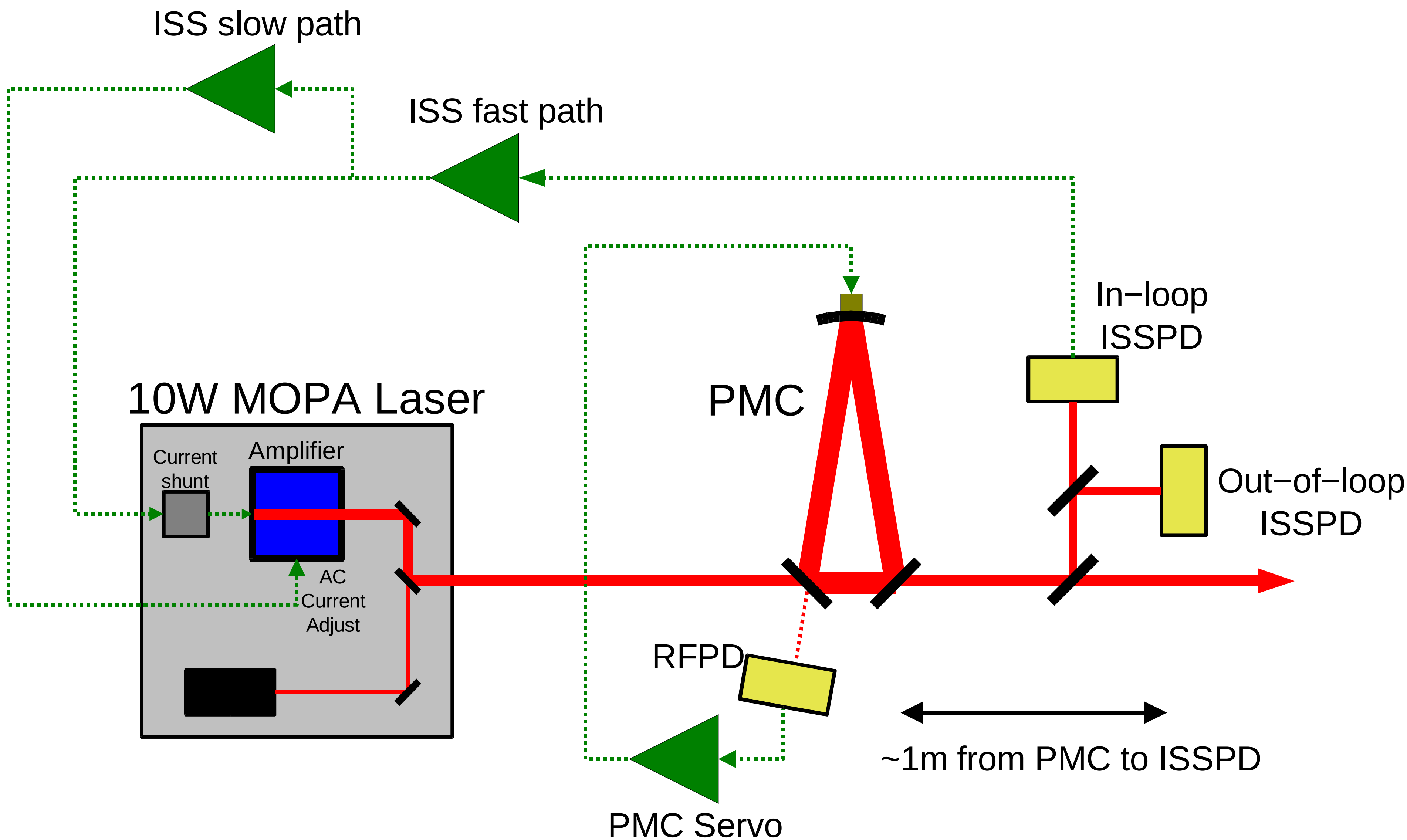


- Radiation pressure on test masses with 1% arm power mismatch
- RIN: $2x10^{-9}$/rtHz @ 10Hz
- Requirement based in part on readout scheme at high frequency

The Pre−stabilised Laser

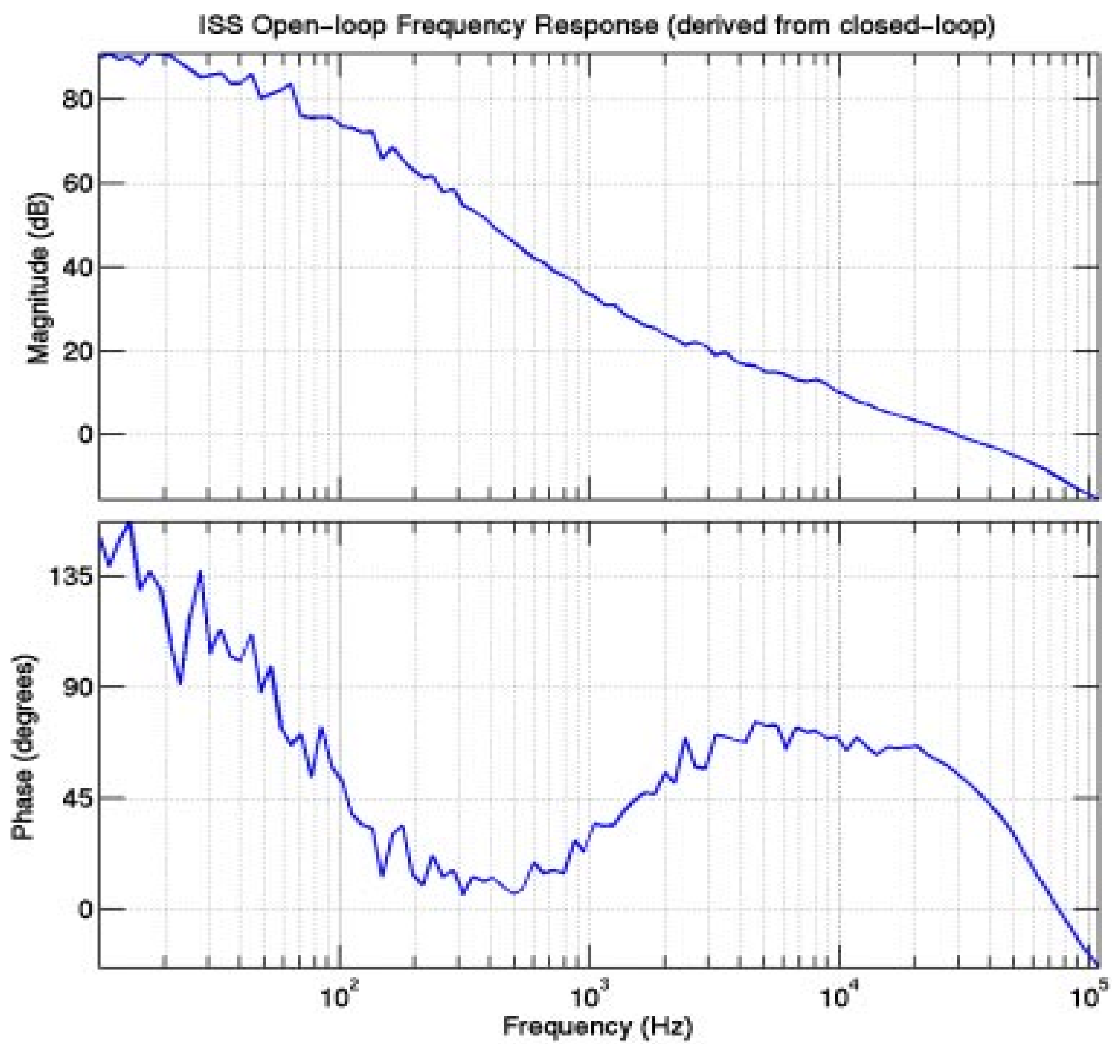
- LASTI LIGO−I 10 Watt MOPA
  - » Operates at about 9 Watts output, 6 Watts through PMC
- Pre−modecleaner
  - » Spatial filter for modes higher than TEM:00
  - » Filter for very high−frequency intensity noise
    - – Pole at cavity half−width/half−max (~2 MHz)
  - » Reduces beam jitter
- Frequency stabilized
  - » LIGO−I frequency stabilization servo with reference cavity

Intensity Stabilization Servo

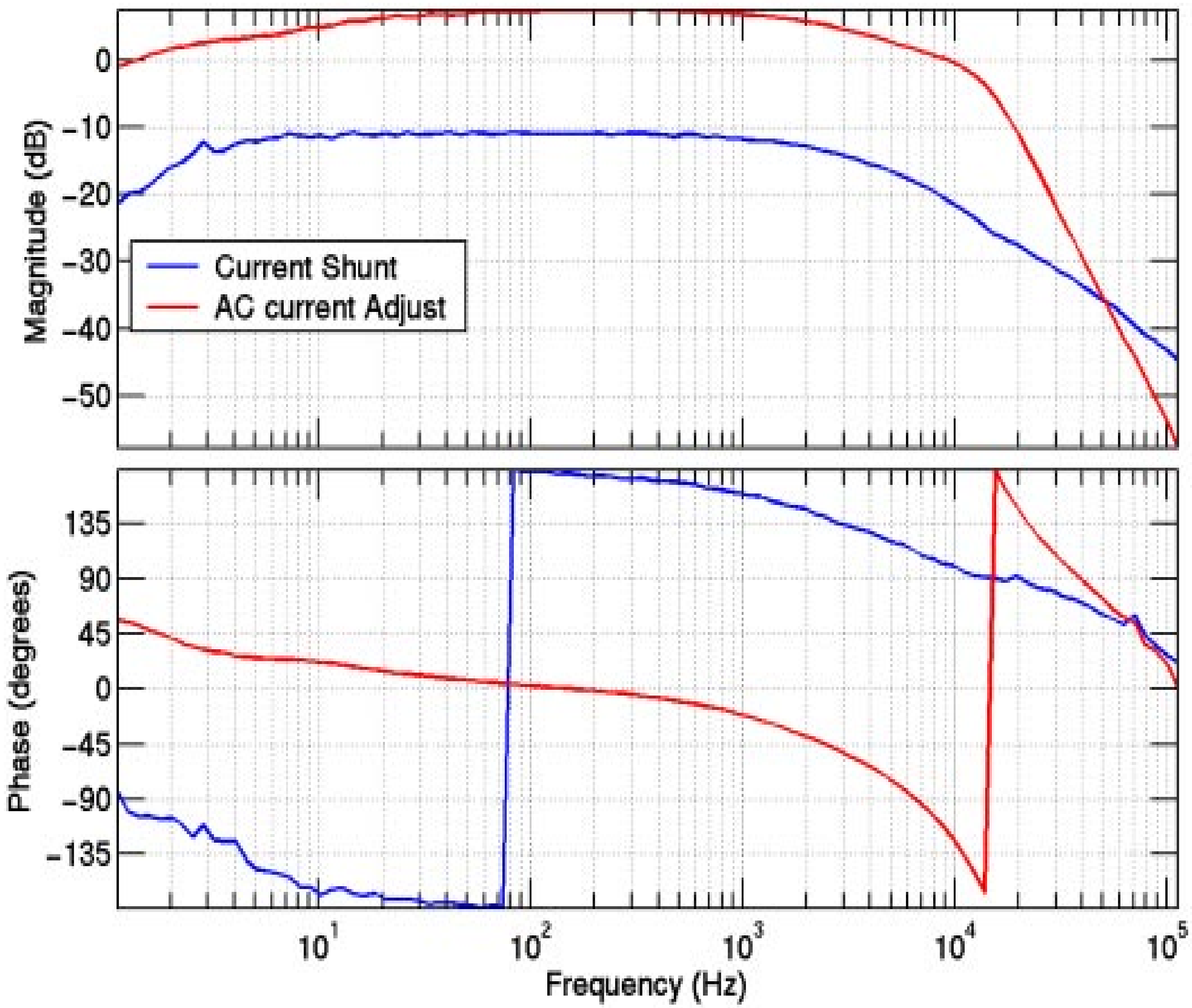


Intensity Stabilization Servo

- Requirements:
  - 80dB of gain @ 10Hz
  - 10kHz unity gain
- 2−loop topology
  - Current shunt alone did not have enough dynamic range.
  - Used high−dynamic range AC current adjust at low frequency.
- AC coupled
  - Had problems with drift −−> found ground loop DC path



PSL Current Actuators

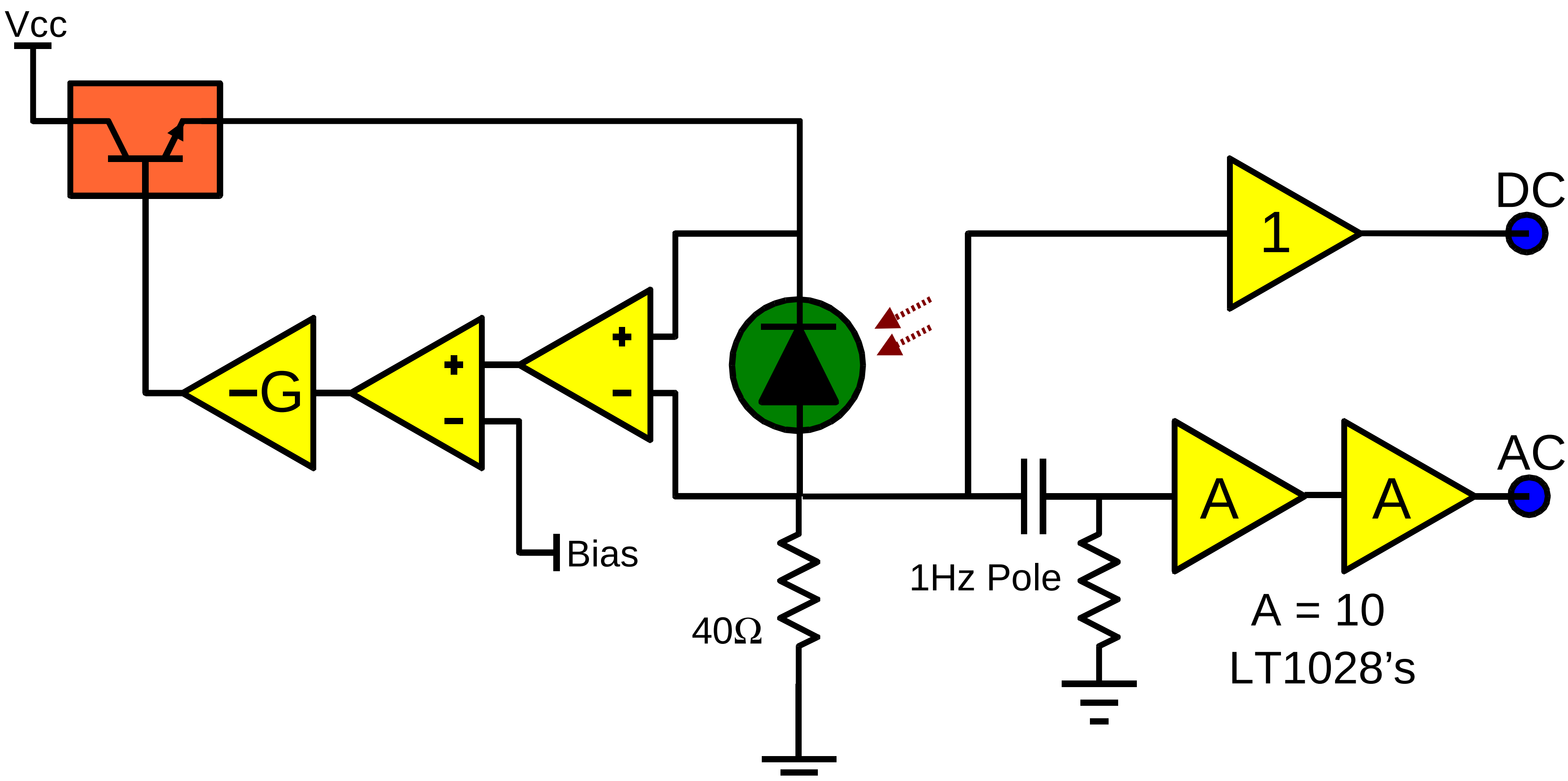


- AC current adjust
  - » ± 2.5 Amps/Volt
  - » poles:
    - – 4 @ 10kHz
- Current shunt
  - » ± 250 mAmps/Volt
  - » Poles:
    - – 1 @ 3kHz
    - – more > 200kHz

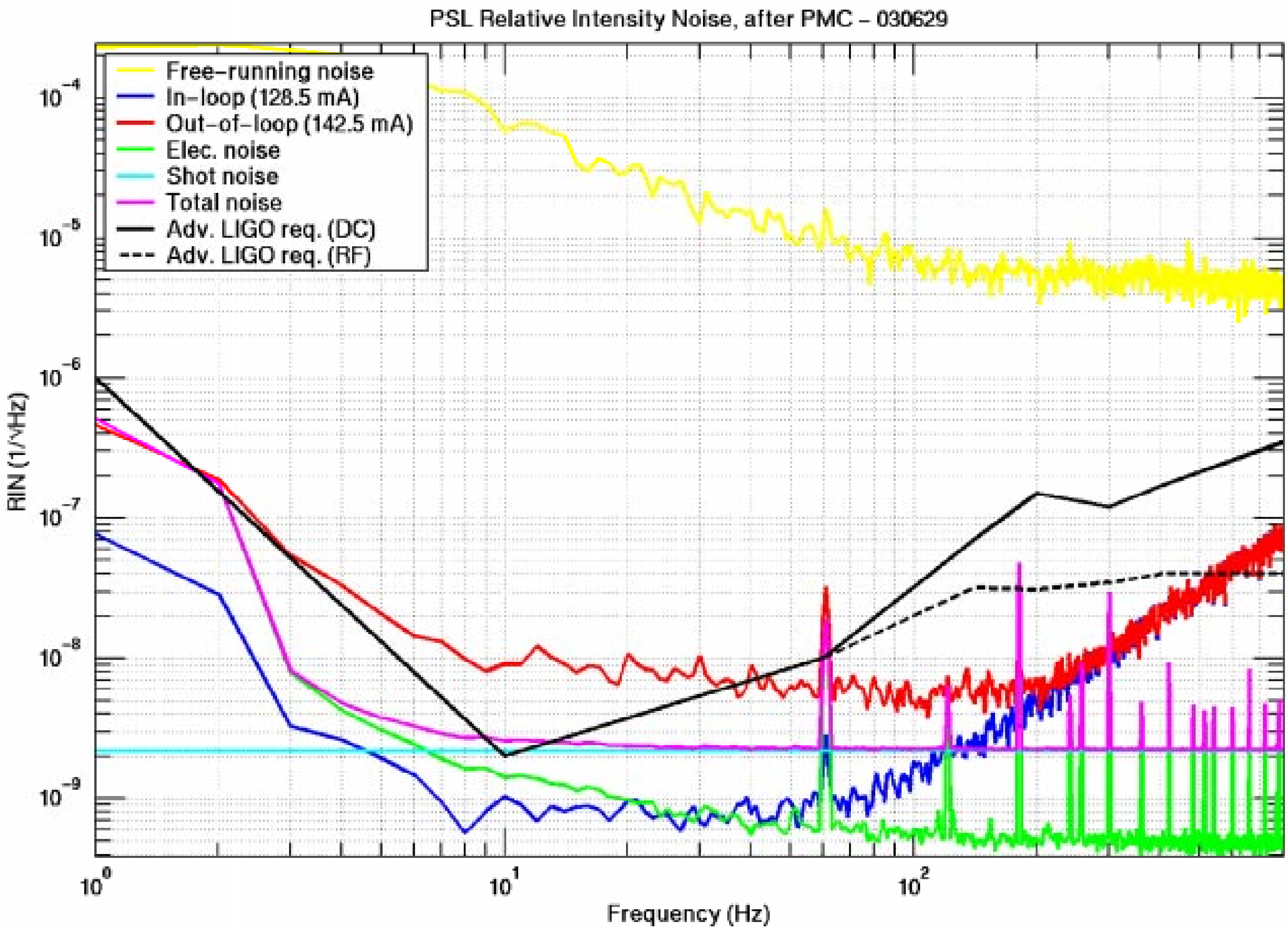
Low−noise, High−power Photodiode

- Design considerations:
  - » Required being limited by shotnoise at 10^{-9} level:
    - – I = 300mA, ΔI = 300pA
  - » Very Low noise:
    - – Need to detect ΔI across 40Ω −−> ΔV = 12nV
    - – First stage input voltage noise < 7 nVrms/√Hz @ 10Hz, < 3 nVrms/√Hz @ 100Hz
  - » High−power:
    - – 300 mA is a lot of photocurrent
    - – Heat dissipation a problem −−> lots of heat sinking
    - – Use low bias voltages (< 5V) −−> Bias feedback control circuit
  - » AC coupled:
    - – Elliminates need for high−current, low−noise trans−impedence stage
    - – Elliminates need for stable DC reference
    - – Requires high capacitance, big capacitors
- Hamamatsu G5832−02 2mm photodiodes (~.93 QE)

Low–Noise, High–Power Photodiode



Results



PSL Relative Intensity Noise, after PMC – 030629
Free-running noise
In-loop (128.5 mA)
Out-of-loop (142.5 mA)
Elec. noise
Shot noise
Total noise
Adv. LIGO req. (DC)
Adv. LIGO req. (RF)
RIN (1/√Hz)
Frequency (Hz)

Results

- What have we learned:
  - » Not limited by:
    - – Scatter (ND filters in front of pd's)
    - – Electronics noise (at photodiode or in servo/actuators)
    - – Photodiode bias noise from bias feedback (tried fixed bias as well)
    - – PMC (frequency −> intensity conversion)
    - – Lack of gain
  - » Electronic grounding noise was a problem
    - – Now receive photodiode signals differentially
  - » Low frequency intensity noiseout of MOPA (<10Hz) *increases* when loop closed

Conclusions

- Needs further investigation:
  - » Diode uniformity could be a serious issue −−> Beam jitter
    - – Have quad diode for characterization of beam motion
    - – Look at acoustic/vibrational noise on table
  - » Daily variations of closed−loop noise level −−> undiscovered environmental coupling
  - » High−frequency noise hitting slew−rate limits in early amp stages
  - » Coherence between 2 out−of−loop PD’s, at different power levels
    - – Can tell us if noise is on light or not
  - » Higher resolution measurements to reveal structure
  - » Noise vs. power measurements
- Future directions:
  - » Inner ISS loop before PMC, maybe just using ACA
  - » In−vacuum photodiodes, placed after main mode clearer
    - – Elliminate beam jitter from air currents
    - – Sit on seismic isolation stack
    - – Currently in development, prototype being tested

Low−noise, High−power Photodiode