

Advanced LIGO PSL Power Stabilisation

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Hannover LSC Meeting

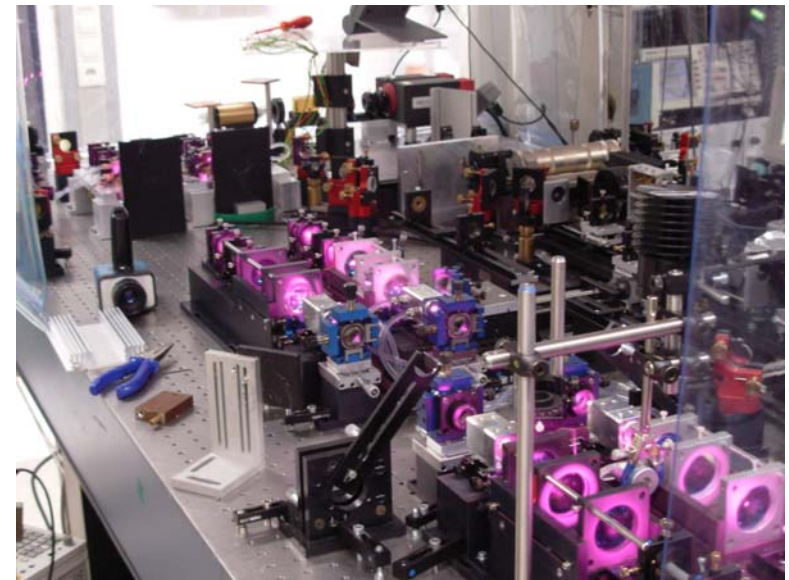
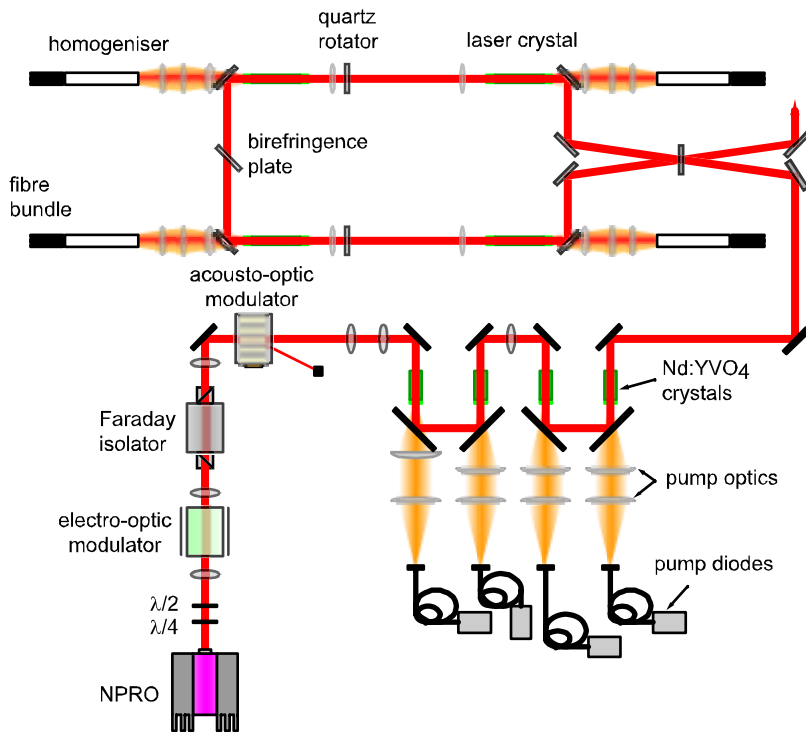
October 2007



- Lots of hard work done by
 - » Frank Seifert
 - » Patrick Kwee

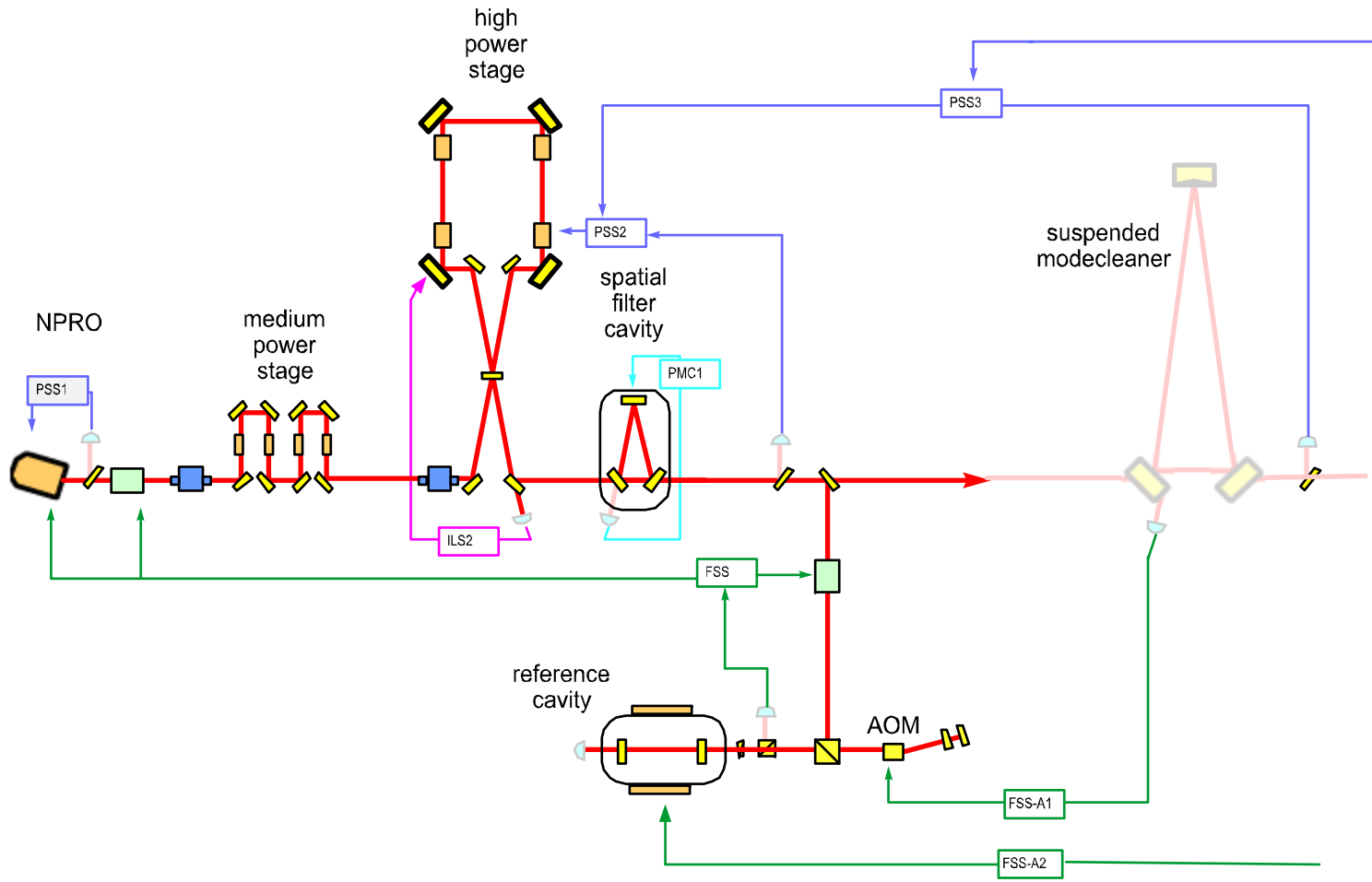


- An injection-locked high power stage seeded by a 35-W four-stage MOPA front end with a 2-W NPRO master oscillator.



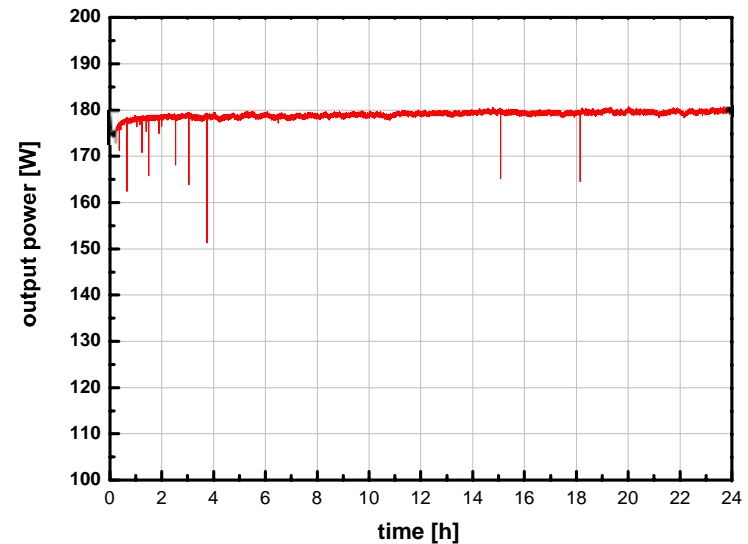
- Power actuators available:
 - » NPRO pump diode current
 - » AOM located between master oscillator and power amplifier
 - » Power amplifier pump diode current
 - Possibly via a current shunt
 - » High power stage pump diode current
 - Possibly via a current shunt

The Advanced LIGO PSL





- Low frequency variations over 24 hours, less than 1% peak to peak
- Control band
 - » 0.1 to 0.4 Hz $< 10^{-3}$
 - » 0.4 to 10 Hz $< 10^{-4}$
- software routine to vary pump diode current



free running



| Frequency [Hz] | Relative Intensity Noise [1/Sqrt[Hz]] |
|----------------|--|
| 10 | 2×10^{-9} |
| $10 < f < 500$ | $2 \times 10^{-10} f$ |
| $f \geq 500$ | 1×10^{-7} |

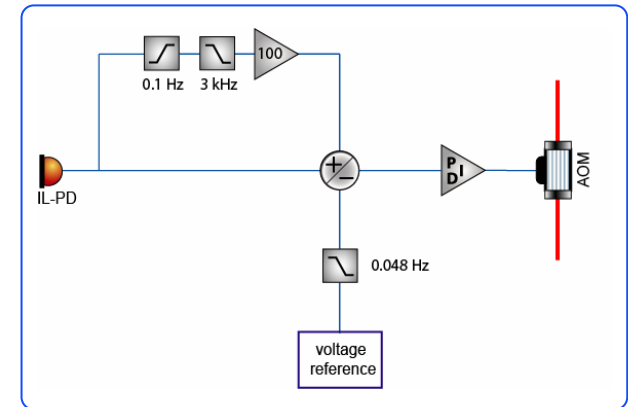
- The requirement at 10 Hz is very tough due to the combination of:
 - low noise level
 - low frequency specified



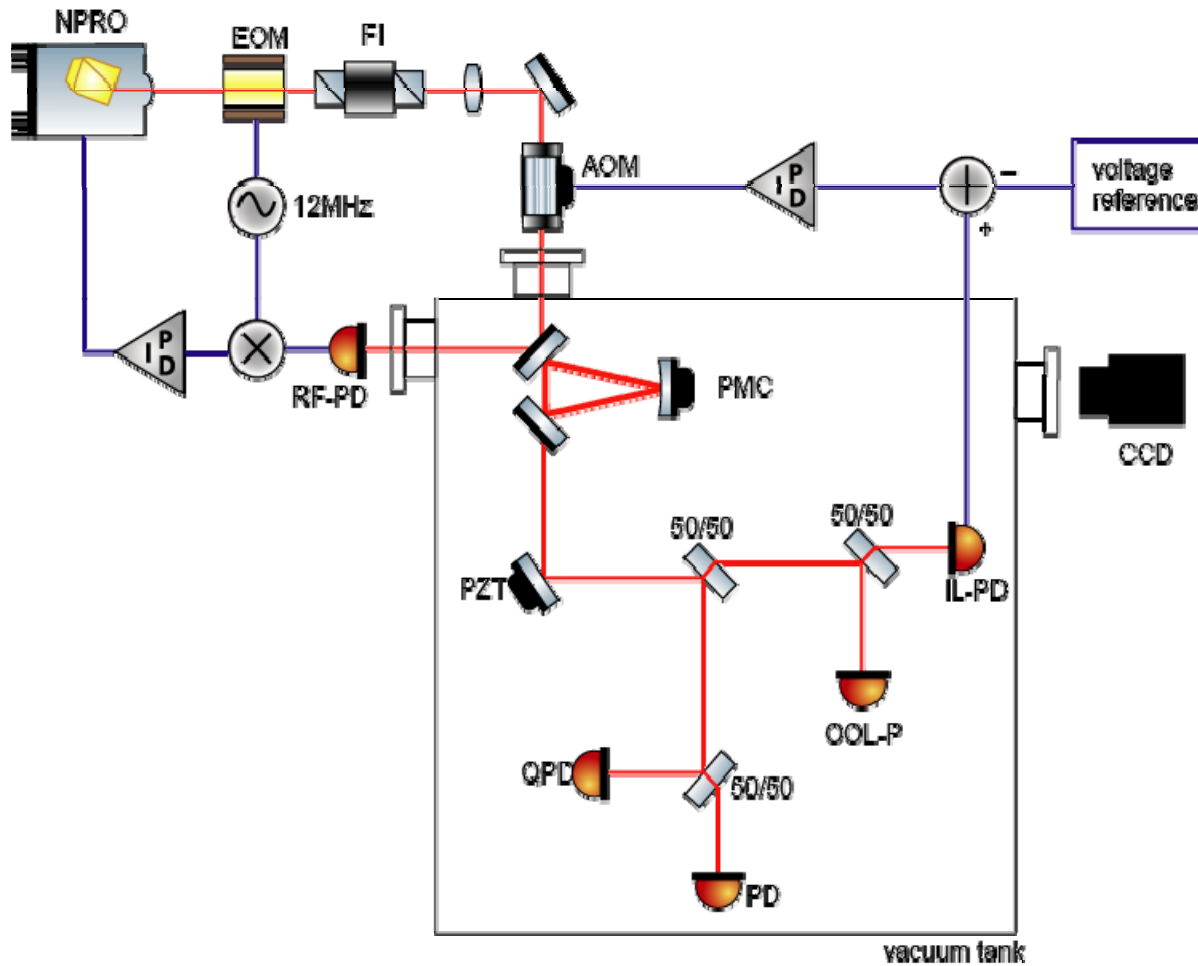
- What limits the power stabilisation performance?
 - » Typically more than enough servo gain to suppress the relative intensity noise to the required level.
 - Observe a difference between an in-the-loop photodetector and an out-of-the-loop photodetector.
- Is there a fundamental limit? Or are there noise mechanisms not found yet?
 - » Photodiode performance?
 - Uniformity of the diode response
 - Temperature effects
 - » Beam pointing?
 - » Acoustics



- Uses an AOM
 - » Power actuator independent of laser
- Beam pointing filtered by a pre-modecleaner ($F \sim 4100$)
- Active temperature stabilisation of the photodetector
 - » With 130 mW on photodetector, temperature rises ~ 10 K
- Optimisation of stabilisation loop shape
 - » AC-coupled loop for lowest noise
 - » DC-coupled loop for a stable operating point

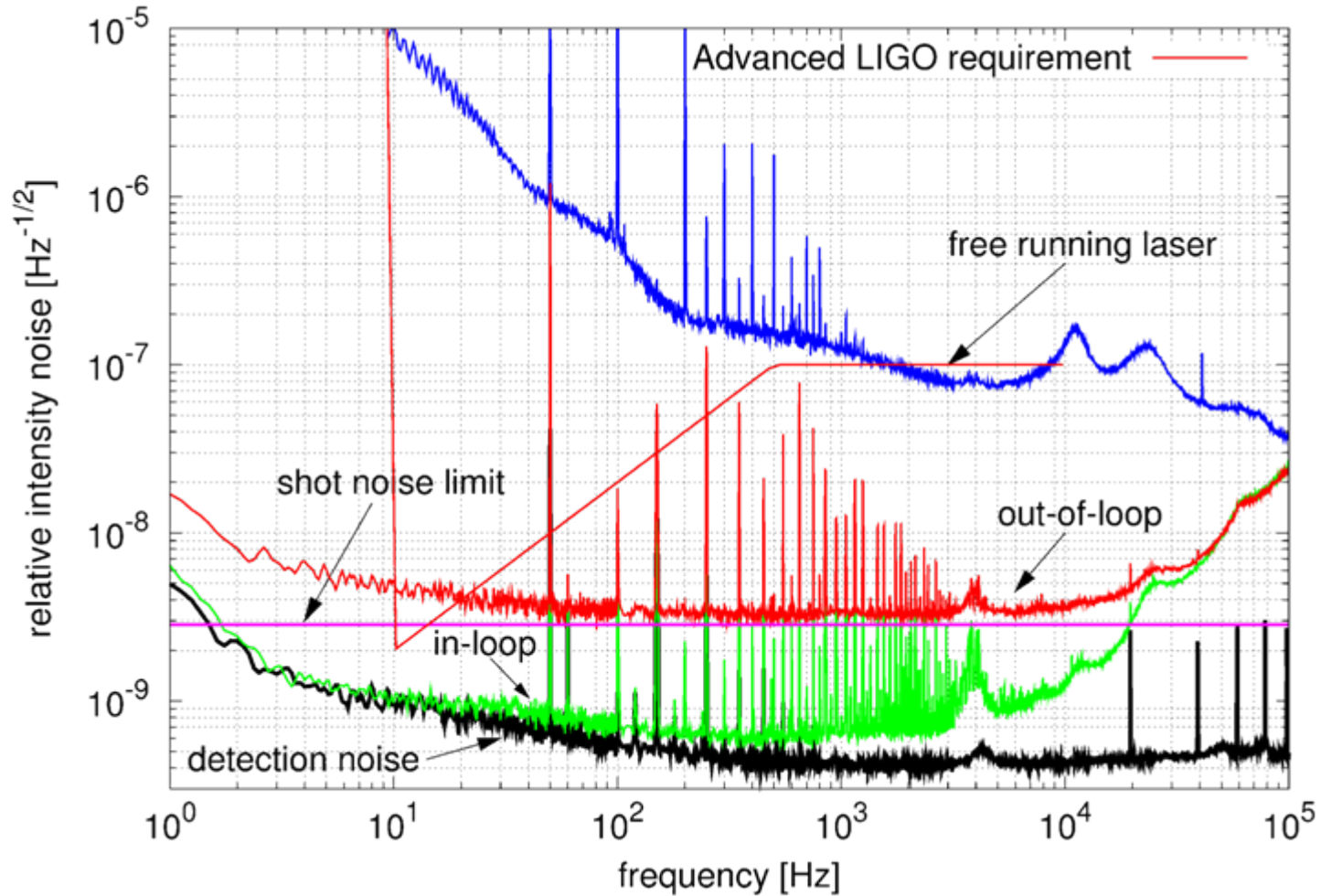


Power Stabilisation Setup (cont.)





Relative Intensity Noise NPRO - vacuum - 2006/02/19

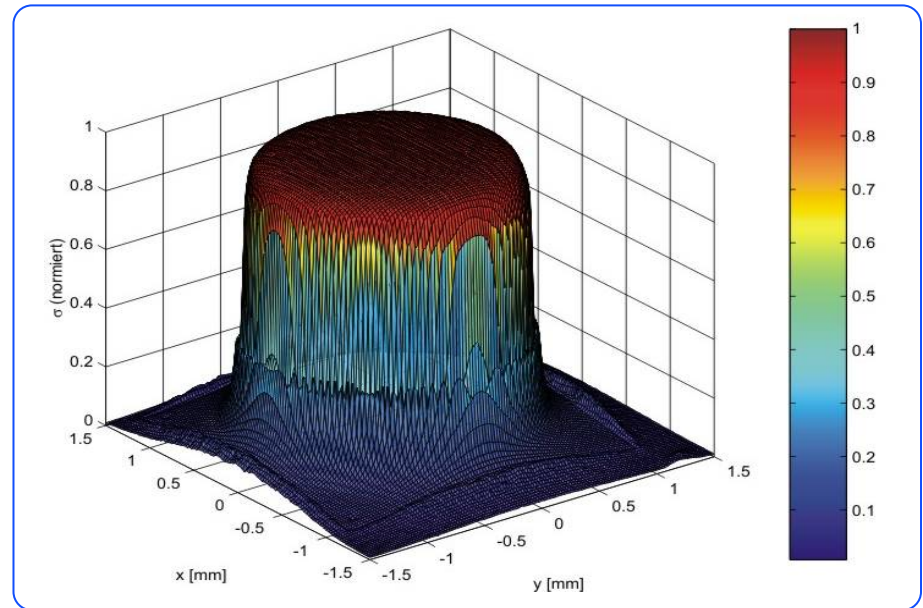




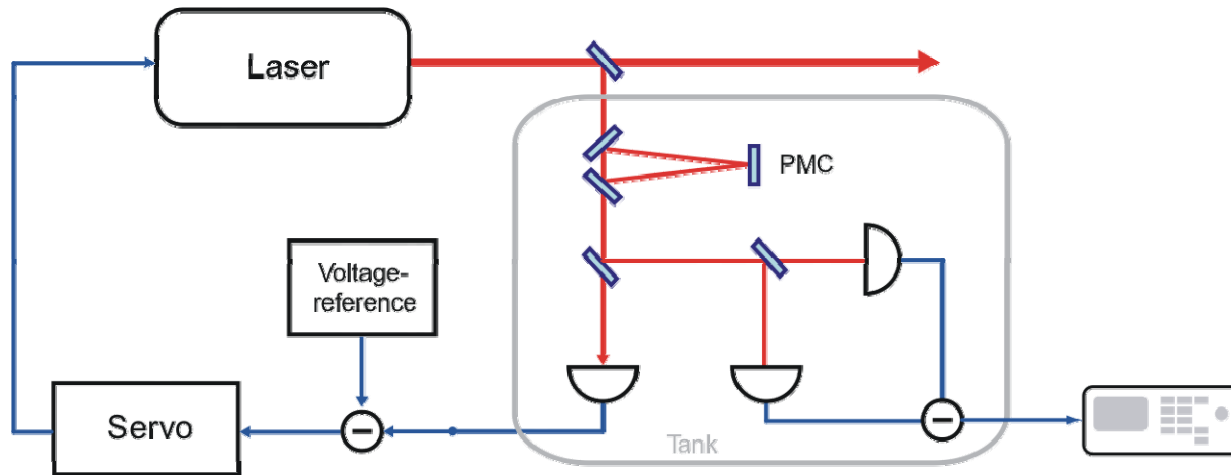
- Avoid ground loops, even at RF frequencies
 - » Use battery powered devices
 - » Separate power supplies for components
- Beam pointing
 - » Use pre-modecleaner
 - » Adjustment of photodetectors
- Acoustics
 - » Quiet environment
 - » Proper mechanical design
- Convection currents
 - » Place components in vacuum



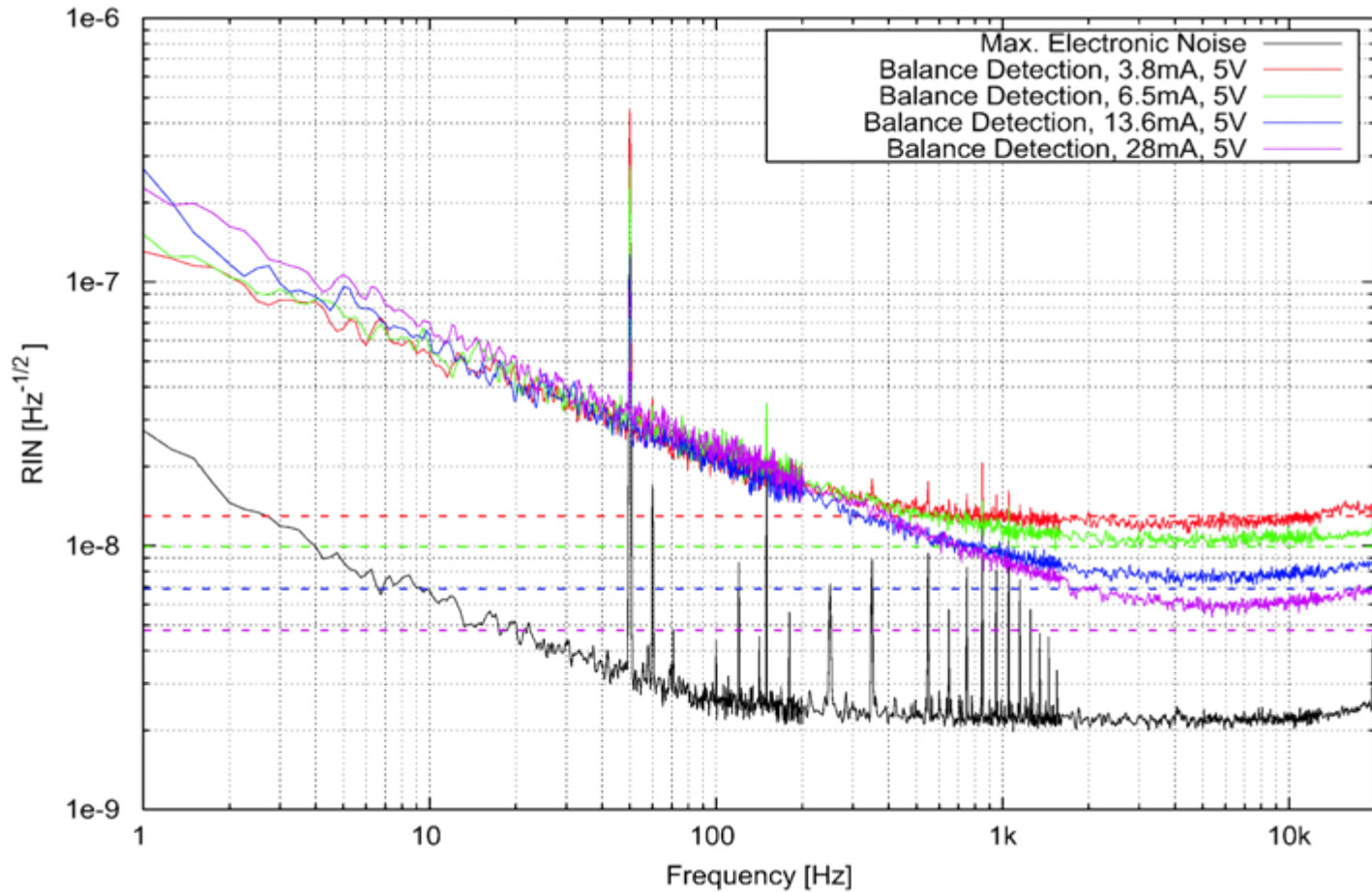
- There is a “sweet spot” on a photodiode.
 - » Not necessarily at the centre!
 - » Minimises the coupling between pointing and intensity noise.



spatial uniformity measurement



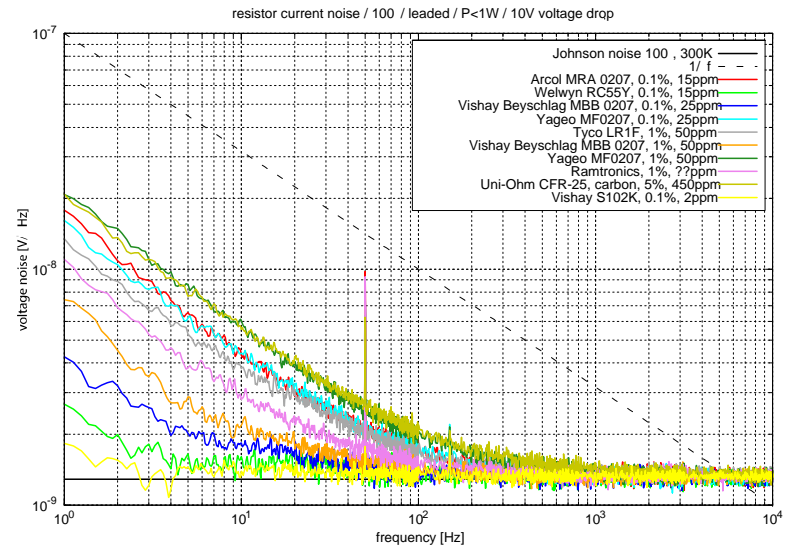
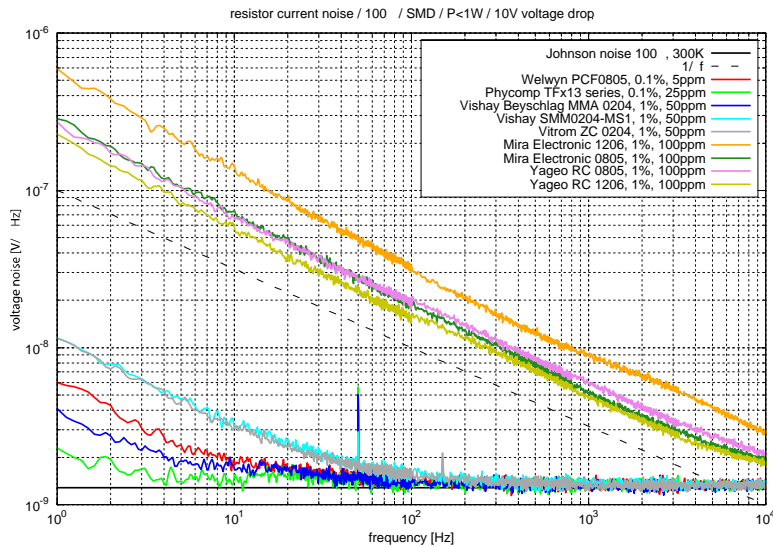
- Is excess noise at low frequencies due to the photodetectors?
- laser stabilised below 10^{-8}
- amplification *after* subtraction of photocurrents





- What is the source of the $\sim 1/\text{Sqrt}[f]$ noise at low frequencies?
 - » Beam pointing introduced by the beamsplitter after the pre-modecleaner cavity.
 - » Photodiode material
 - Noise when holes and electrons re-combine
 - » Resistor current noise

Resistor Current Noise





- Further reduction of beam pointing
 - » Elimination of the beamsplitter
 - » Use of modecleaner cavity as the beamsplitter
- Influence of photodetector temperature fluctuations



- Minimise beam pointing
- Careful selection of photodiodes
- Use metal foil resistors for best performance at low frequencies