UNIVERSITY OF BIRMINGHAM

Squeezed light and GEO600

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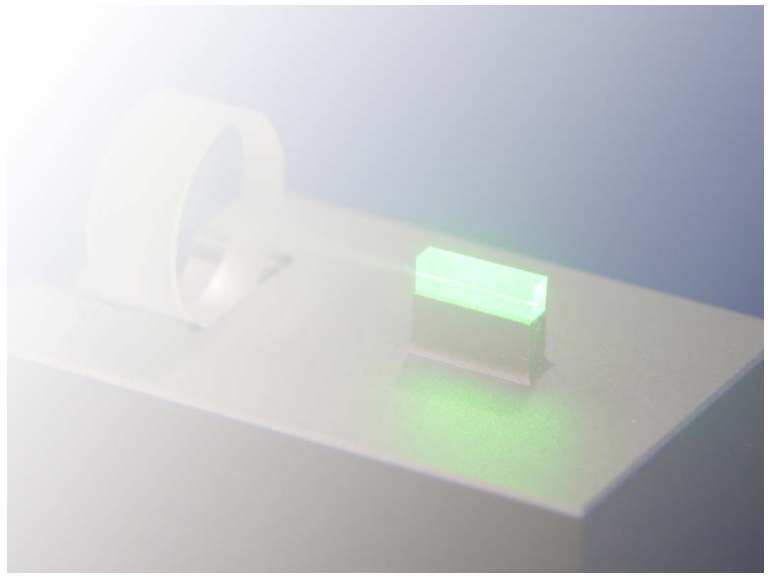
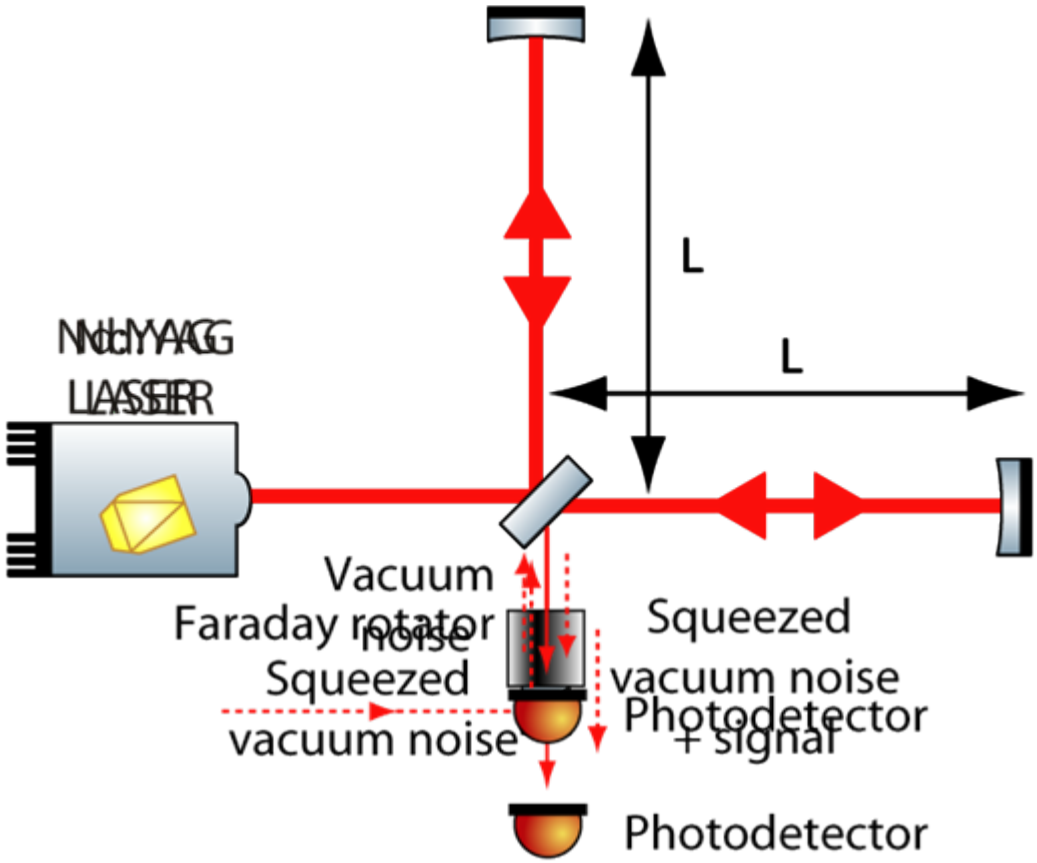
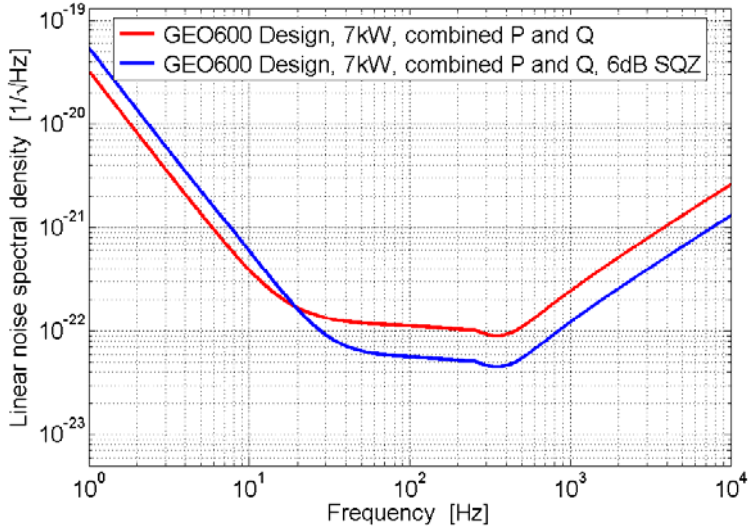


Outline

- Introduction:
  - Basic Idea of squeezed light in GW detection
  - Estimated sensitivity increase for different scenarios
- Tasks to complete:
  - Squeezing setup and integration into GEO setup
  - Sensing and control of SQZ experiment
  - Alignment of SQZ beam into GEO600
  - ...

The basic idea





- Vacuum fluctuations cause shot noise and radiation pressure noise
- squeezed vacuum can improve the sensitivity

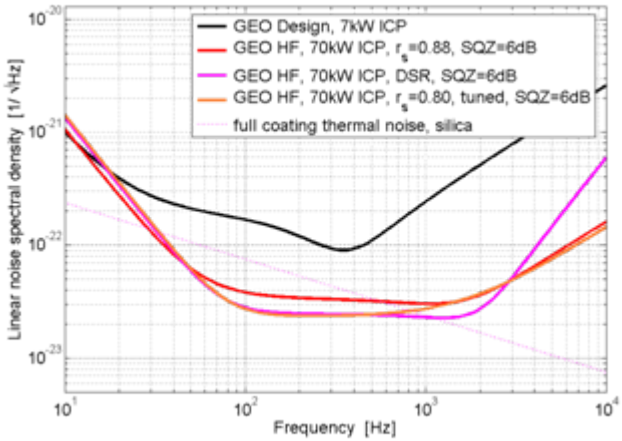
Various schemes

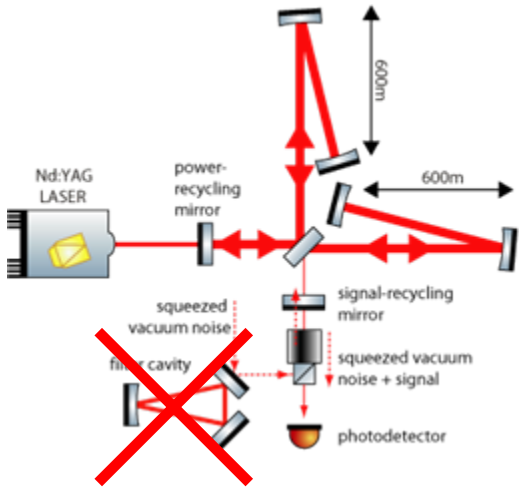
Signal recycling

- Detuned signal recyling
- Tuned signal recycling
- New techniques such as Twin-SR

Readout schemes

- Heterodyne readout
- DC readout





Whats possible?

- Depends strongly on detector detection scheme

Heterodyne readout

DC readout

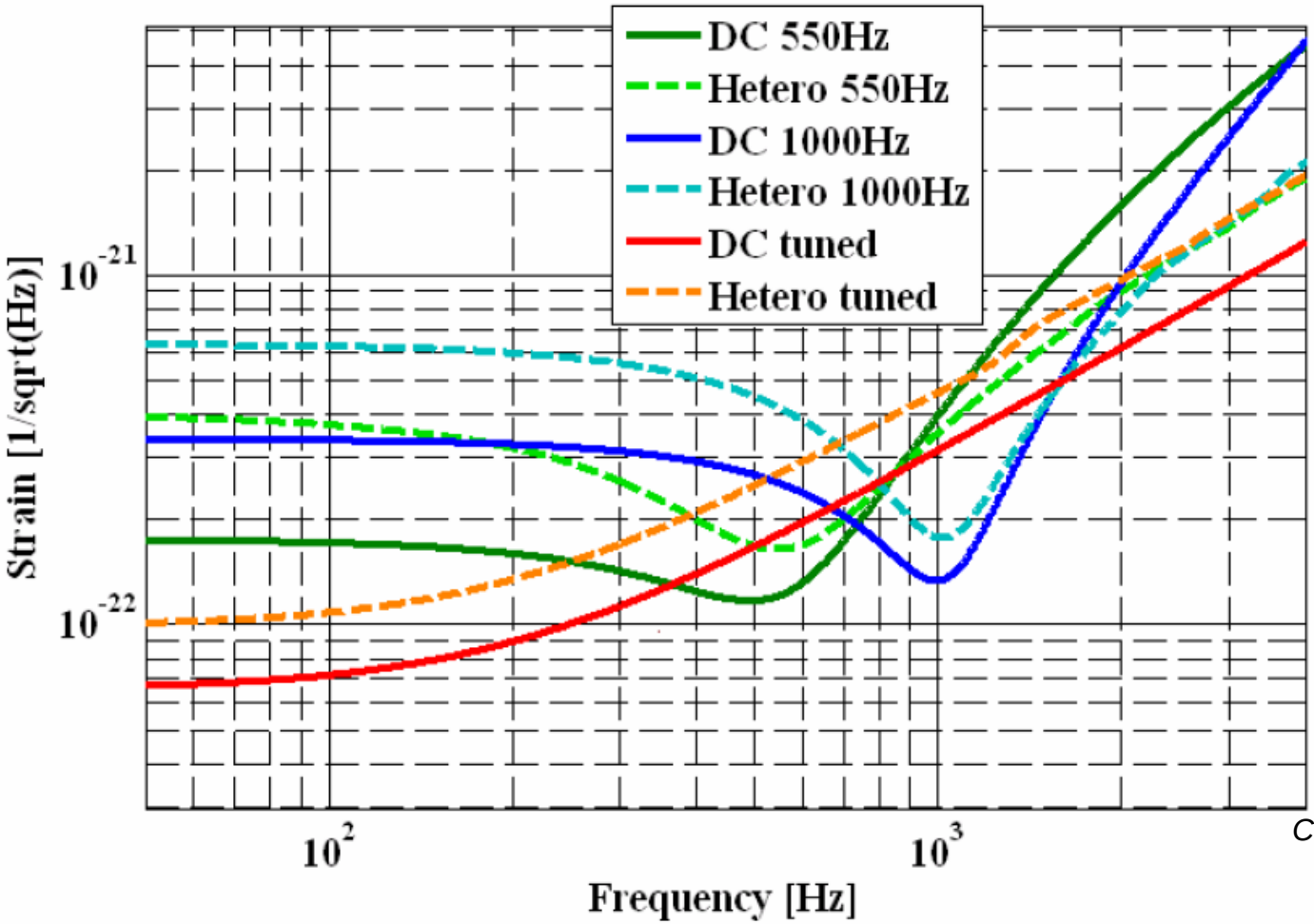
Heterodyne readout

- Amplitude and phase quad -rature simultaneously mea -sureable
  - $\Rightarrow$ combination allows higher sensitivity
- Mixing process adds more quantum noise from higher freq.
  - $\Rightarrow$ SNR decreased by at least $\sqrt{\frac{3}{2}}$

DC readout

- Reduced shot noise
  (no 2f terms)
- Reduced oscillator phase noise
- Simplify the detector
  - Easier calibration (GW signal in a single data stream)
  - Easier circuits for photodiodes and readout electronics
  - Reduced number of beating light fields
    $\Rightarrow$ simpler noise couplings
  - For more, see yesterdays talk by S. Hild

Comparison of readout schemes



Credits to S. Hild

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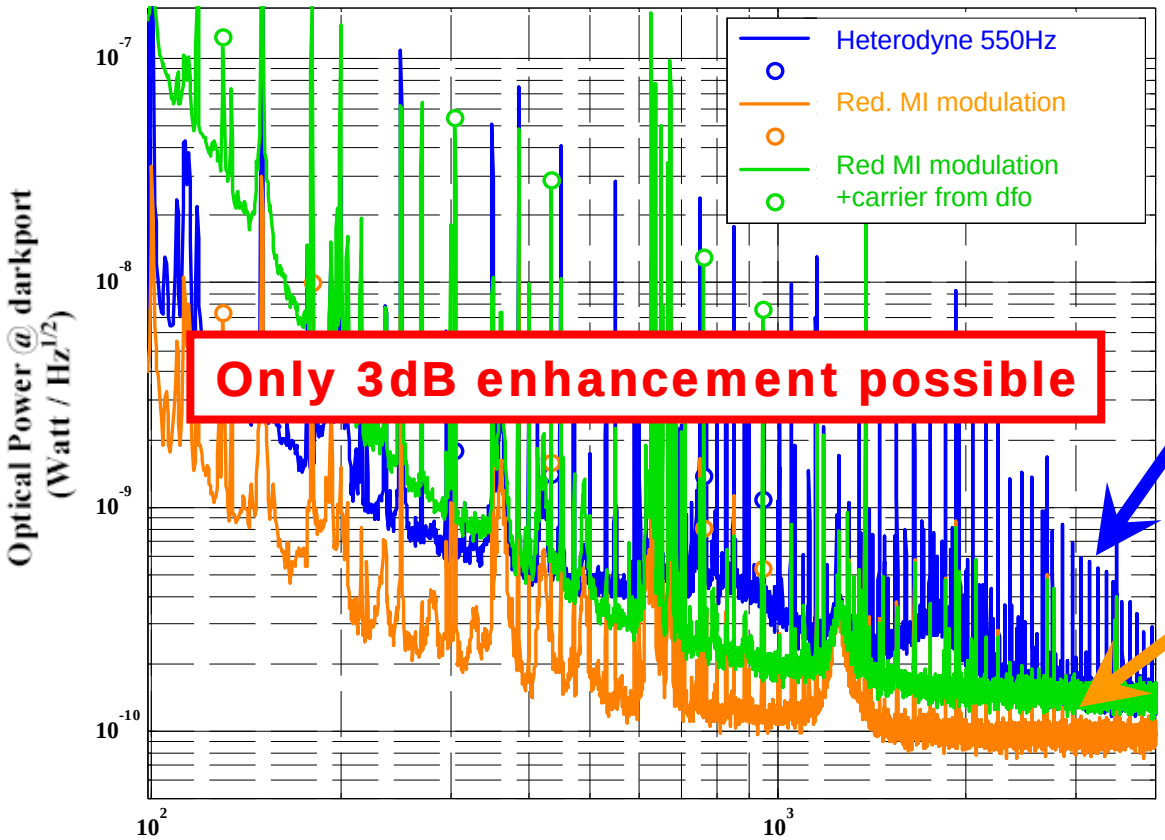
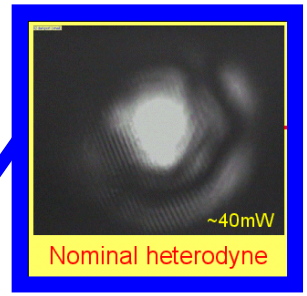
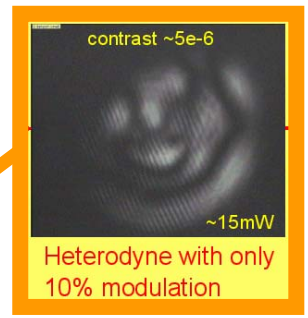
What improvement can we expect?







Credits to S. Hild

- Turning down the radio frequency modulation (stable operation is possible with 10 times smaller sidebands)
- Dark port is dominated by carrier light (TEM00) from a 50 pm dark fringe offset

The output modecleaner

- Reduces higher order modes
  - ⇒ allows larger improvement due to squeezed light
- Simplifies mode-matching and alignment of the two beams
- Complex implementation into the current optical layout
- Proper design needed
  - ⇒ big project on ist own

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LIGO Laboratory / LIGO Scientific Collaboration

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Excess Noise Mechanism in LIGO Output Mode Cleaner		
Keita Kawabe, Luca Matone and Joseph Betzwieser		

Distribution of this document:

57 Page document

This is an internal working note of the LIGO Project.

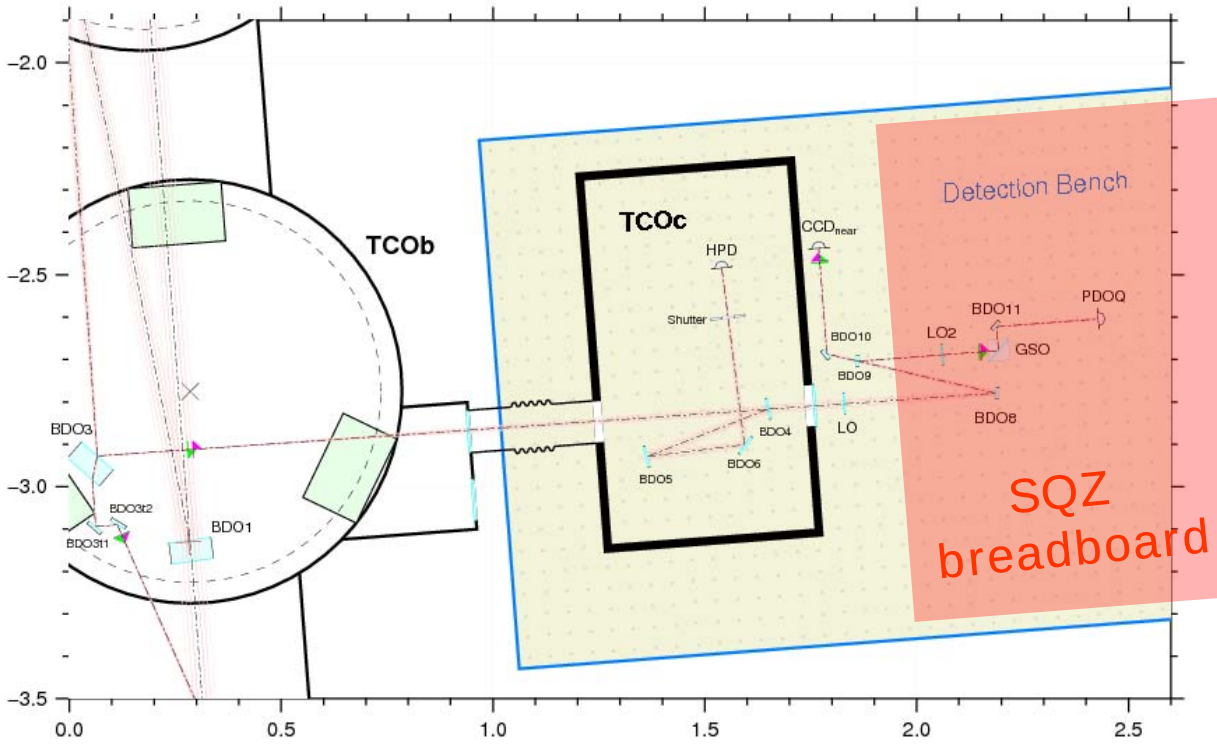
Individual tasks to do

- Integration of a Faraday Rotator
  $\Rightarrow$ redesign of the detection bench
- Setup squeezing experiment
- Online check of squeezing amount
- 24/7 sensing & control of squeezing experiment
- Autoalignment of squeezed field into the IFO
- PLL for squeezing laser

Integration of a Faraday Rotator

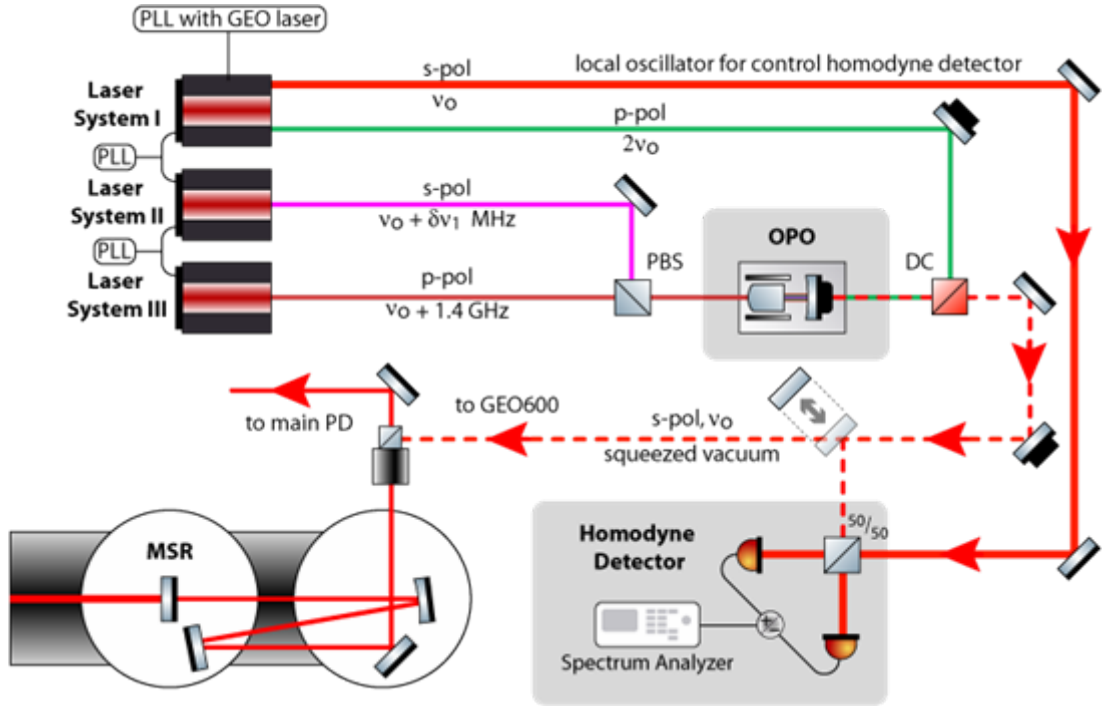
- FI with 25mm aperture will be placed on the output bench

  ⇒ easily accessible for the sqz. field
- Straylight maybe a problem



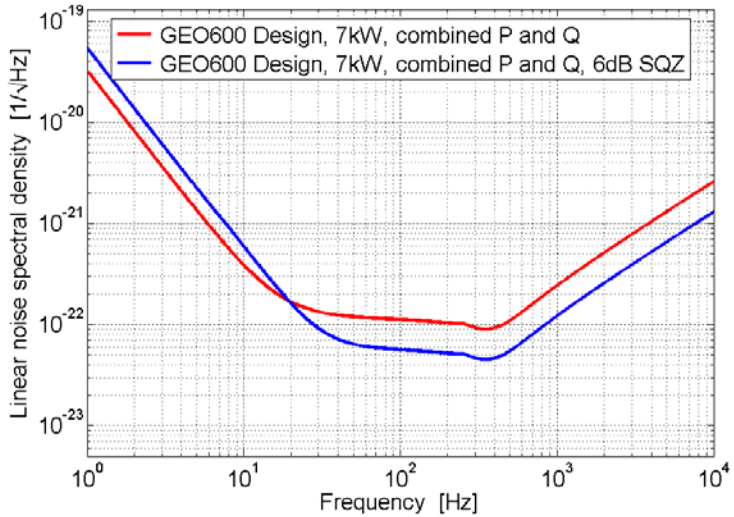
Setup of the squeezing experiment

- Setup will be placed on a 1.1m*1.1m breadboard
- Uses three individual lasers and one OPO to produce SQZ
- Separate homodyne detector for online measurement of squeezing amount

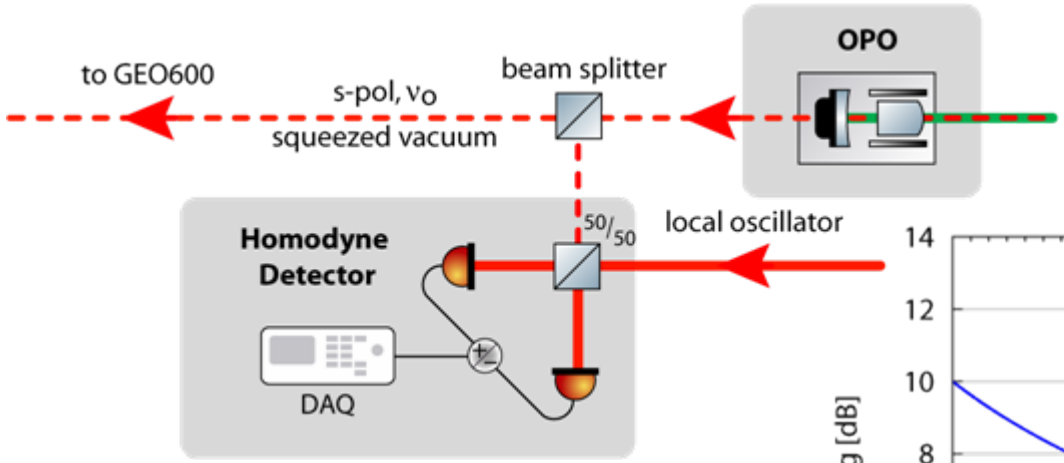


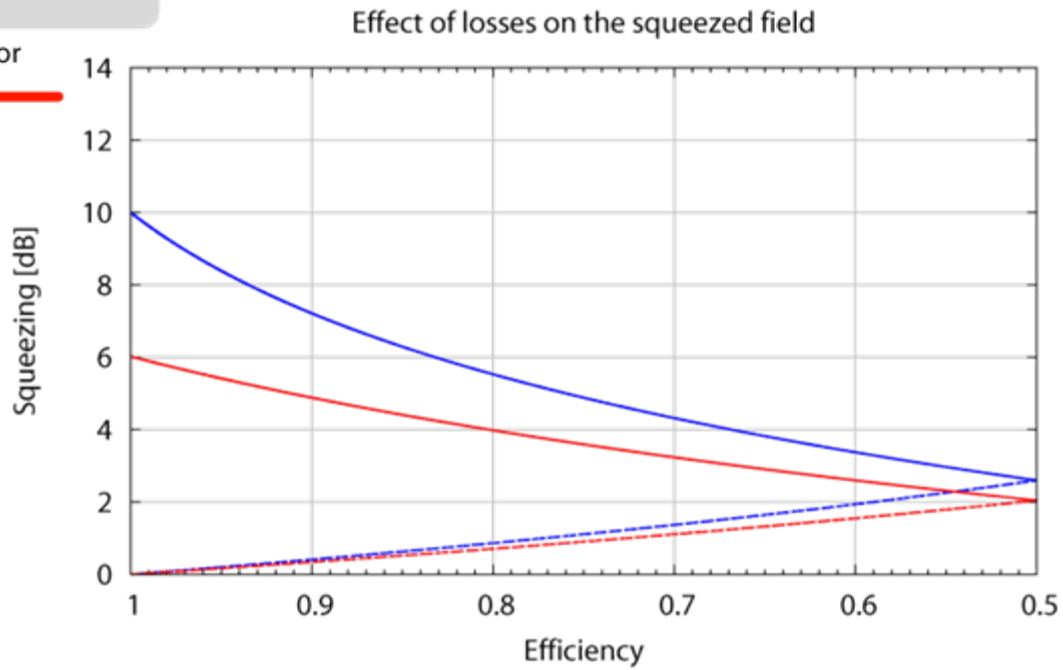
Online check of squeezing amount

- Motivation:
  - Need steady squeezing amount
  - Changes from nominal value will be interpreted as signals
  - Need separate control channel as veto channel



Online check of squeezing amount





- Losses lower the SQZ amount
- BS with R=0.1

  ⇒ initial 6dB decrease to 4.9dB

  ⇒ 0.3dB as monitor

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24/7 sensing and control

- Until now, no SQZ experiment was done on a 24/7 basis

- Digital control needed

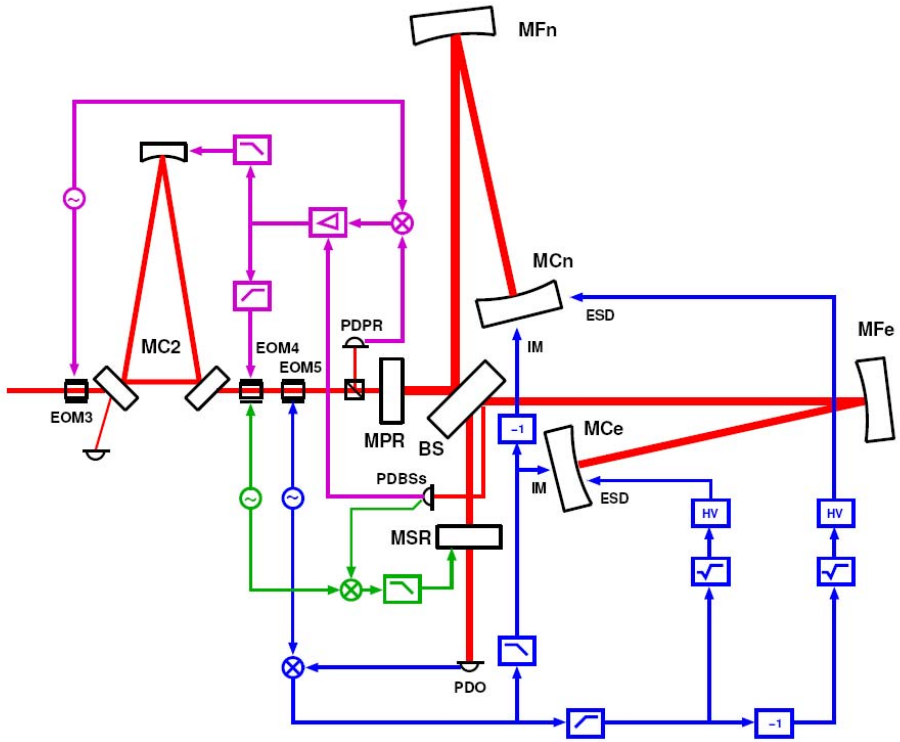
  $\Rightarrow$ simplifies sensing, control, data storage, etc...

  - Can we use the current DAQ and control system or do we need something new?

Comparison of complexity

GEO600

- One laser
- Control via Labview
- Uses digital and analog controls
- ~250 servo loops
- DAQs utilises 359 monitor channels:
  - 30/32 channels 16kHz
  - 53/64 channel with 512Hz
- DAQ and control systems are at there limit

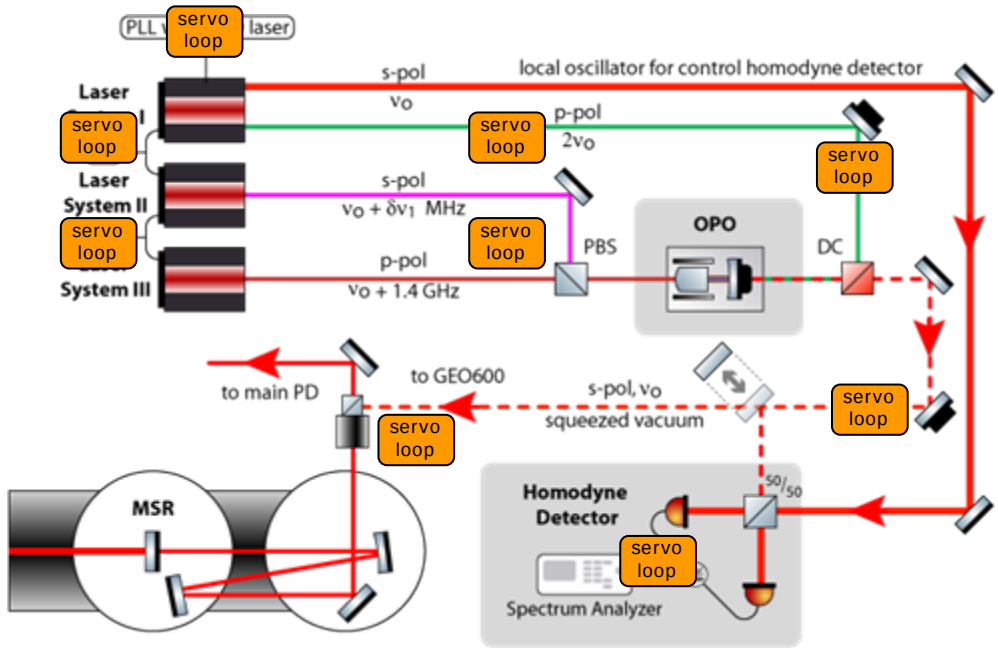


Comparison of complexity

SQZ setup

- Three lasers
- At least 11 servo loops needed witout auto-alignment
- ~ 80 Labview & DAQs channels
  - 11 channels with 16kHz
  - 33 channels with 512Hz

⇒ Upgrade of DAQ system needed! ⇒ new problem



Infrastructure sensing and control

- Current system:
  - DAQs:
    - Based on ICS-110B (not available any more) successor maybe not be compatible
    - Timing cards custom made, software to program altera chips is missing
  - Control:
    - Labview, system maybe at its limit
- Solution:
  - New AdvLIGO CDS Prototype

New AdvLIGO CDS Prototype

- Hardware:
  - Multi CPU PC, 19“
  - ADCs/DACs now PCI based, Linux
  - GPS timing included
  - Extensions in separate chassis
- Software:
  - EPICS based
  - Open source
  - Partly realtime operated
- Challenge to combine with existing DAQs

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	DRAFT	
AdvLigo CDS Prototype Users Guide		
R. Bork		

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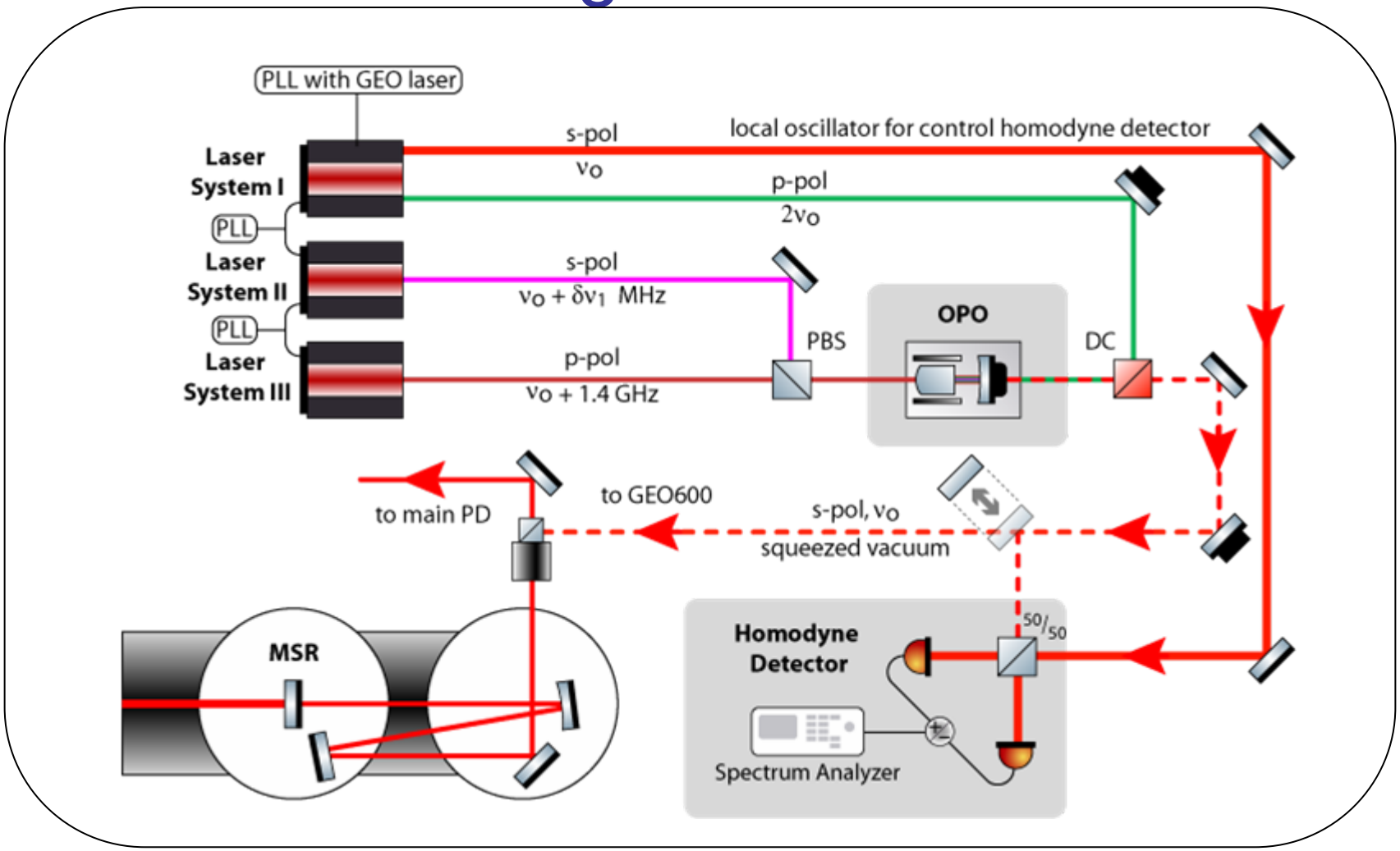
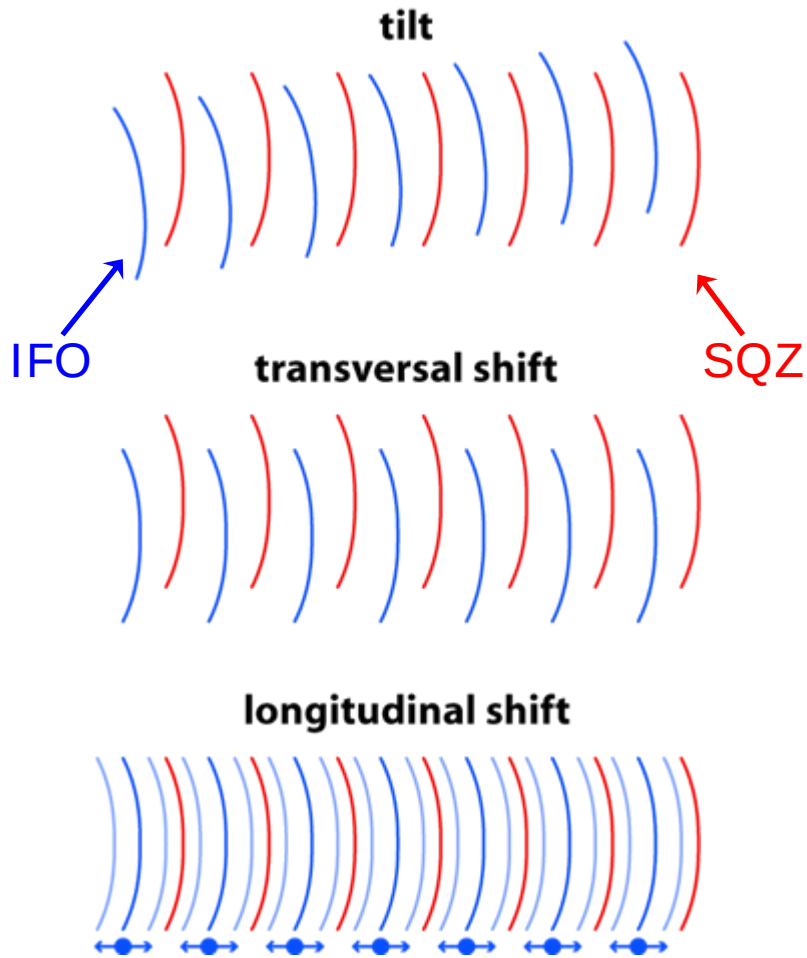
Autoalignment into IFO



Alignment noise causes phase jitter

- Phase between IFO and SQZ beam changes
- Any noise in shift and tilt results in phase variation



Phase jitter decreases SQZ

- Phase jitter ⇒ decreased SQZ

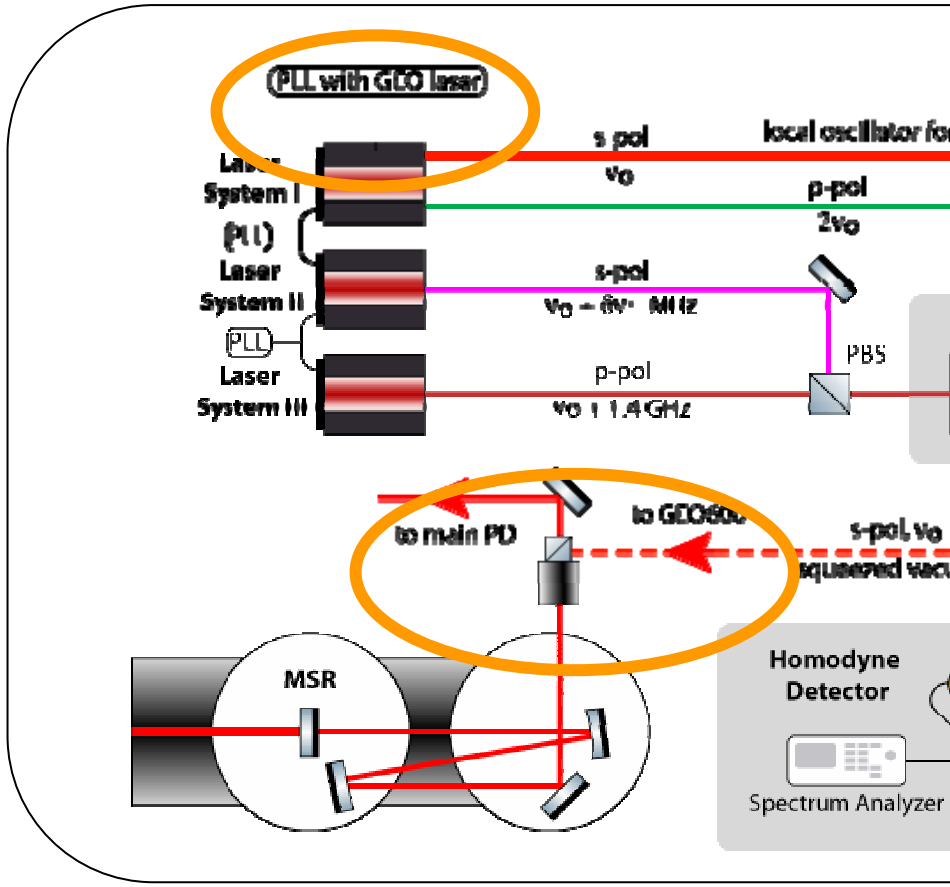
⇒ Autoalignment needed

- What accuracy is needed?

⇒ Longitudinal phase needs to be controled as well

⇒

- PLL needed to lock GEO laser to SQZ laser
- Phase stabilization needed between the IFO and the SQZ beam



Phase noise issue

- How much phase noise can we afford?
  - Applies to:
    - mode matching
    - direct longitudinal phase jitter
- What accuracy is needed?
  - PLL
  - AA
    - DWS
    - Spot position control
    - Mixture of both
- Currently under investigations

Summary

- The injection of queezed light into GEO600 is currently worked on
- SQZ setup is currently in preparation
- Many tasks have to be performed simultaneously
- Some tasks still need help (DAQ and Control, Phase noise analysis, etc...)

http://www.sr.bham.ac.uk/dokuwiki/doku.php?id=geosim:squeezing_geo_home