OzGrav

ARC Centre of Excellence for Gravitational Wave Discovery

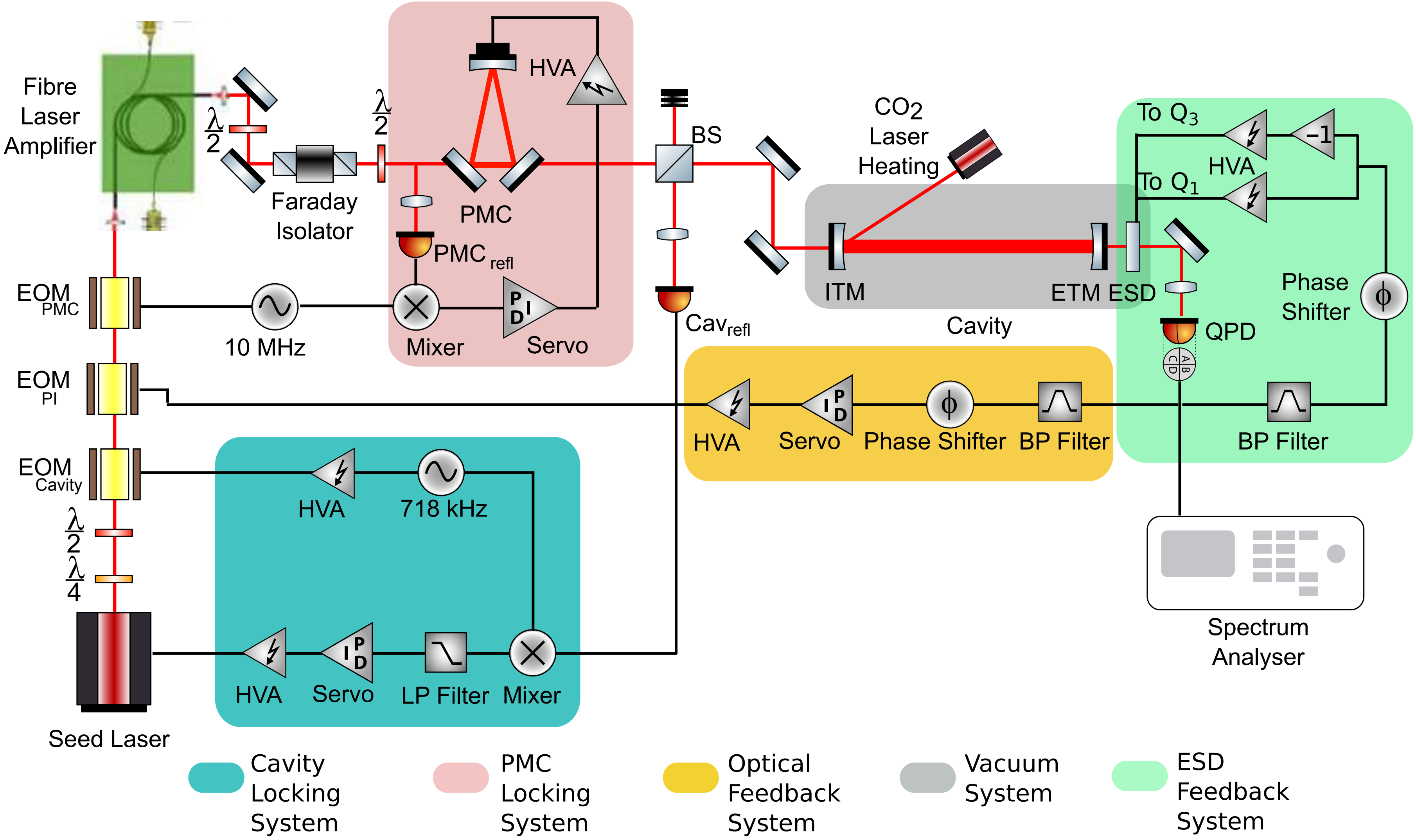
Instabilities and Distortion Program updates

Chunnong Zhao & David Ottaway

Outline

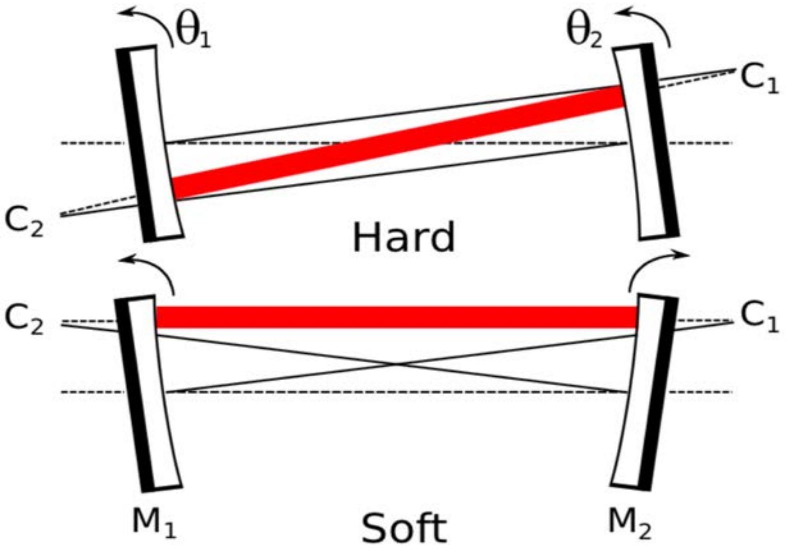
- ➢Angular instability and control *(Vladimir Bossilkov, Jian Liu)*
- ➢Parametric instability and control *(Vladimir Bossilkov, Vahid J. Hamedan, Jian Liu, Bin Wu, Jue Zhang)*
- ➢Distortion sensing and control *(Huy-Tuong Cao, Alexei Ciobanu, Deeksha Beniwa, Craig Ingram, Sebastian Ng, Dan Brown)*
- ➢Mode matching sensing and control *(Alexei Ciobanu, Vahid J. Hamedan, Joris Van Heijningen, Dan Brown)*
- ➢Thermal-optic stabilisation of an optic spring *(Layla Steed, Paul Altin)*

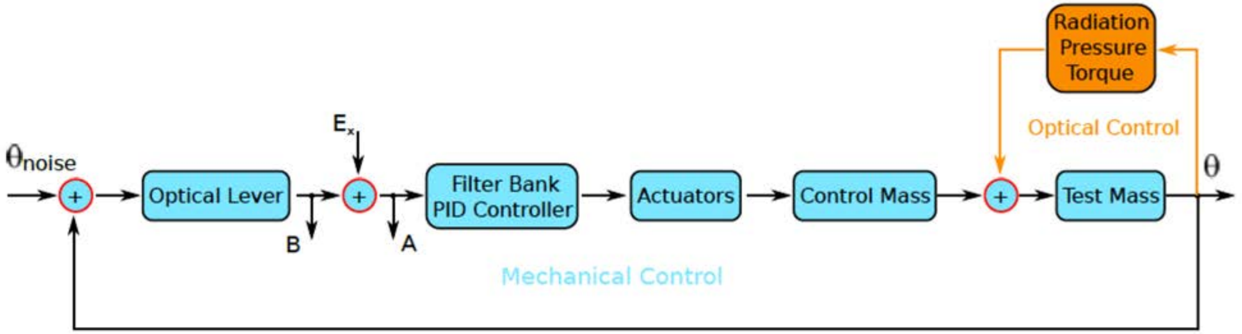
Gingin facility optical and electronics layout



Angular instability and control *(Vlad and Jian)*

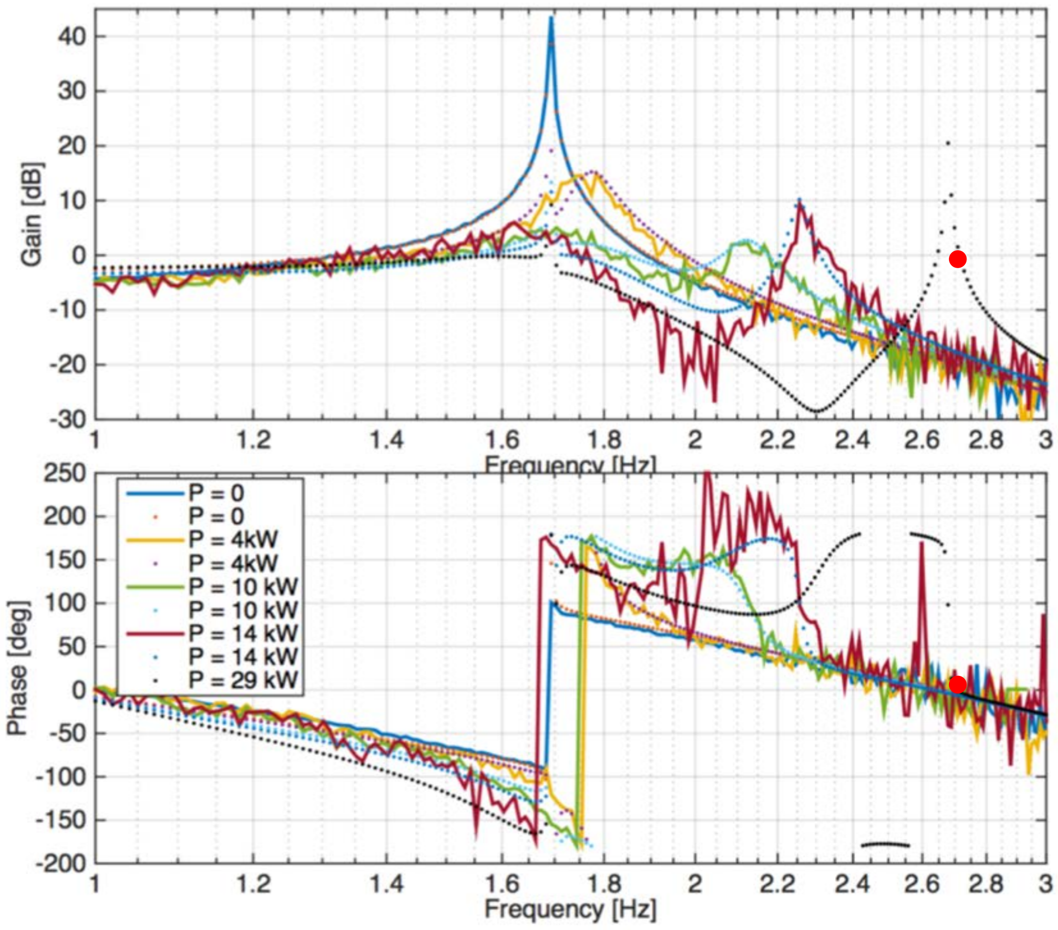
- Optical torsion spring couples two suspended test masses together





- Optical torsion spring modifies suspension control and makes it unstable

Experiment results match to predictions



- Understand the mechanism of the instability
- Know how to control it

Future works: Study the control for next generation detectors

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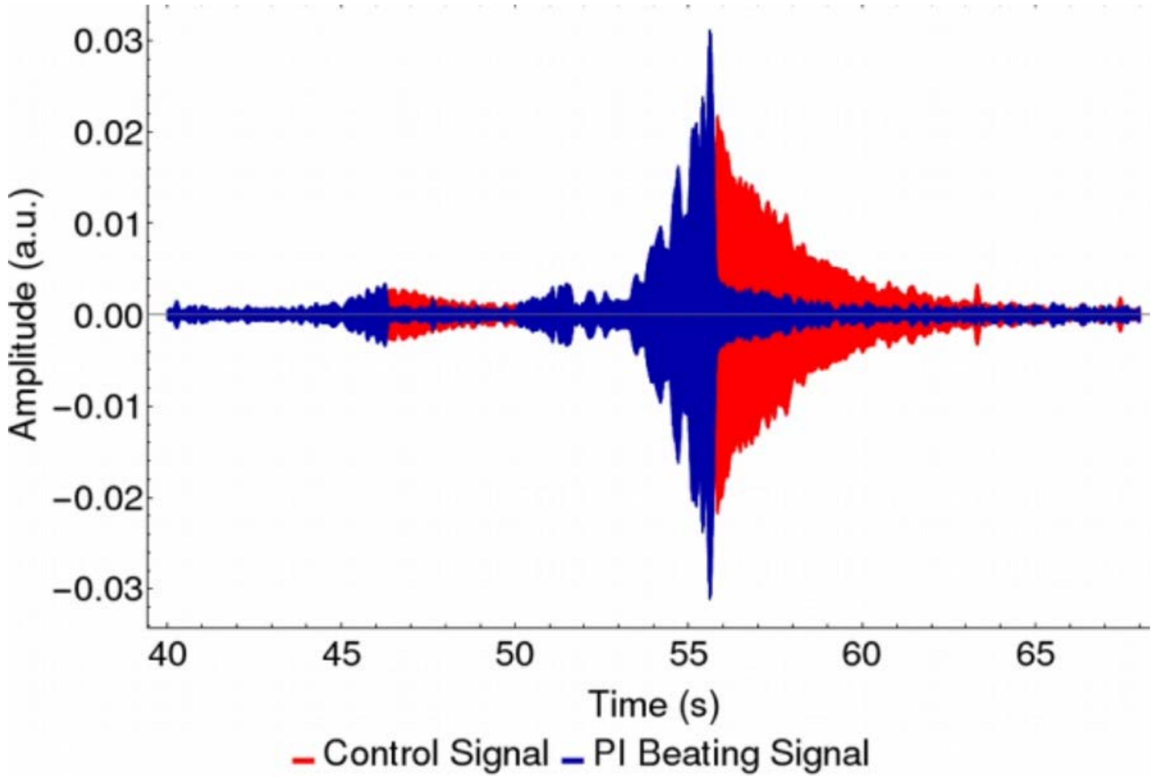
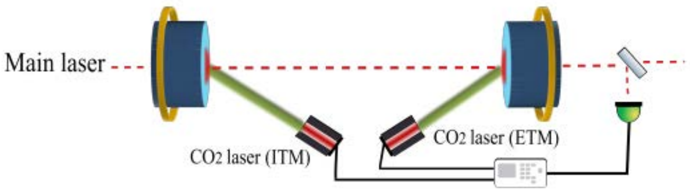
Parametric instability control using optical feedback *(Vlad and Jian)*

- The optical feedback has sufficient gain to suppress PI.
- Enabling the feedback loop, PI is suppressed; disabling the feedback loop, PI grows again.

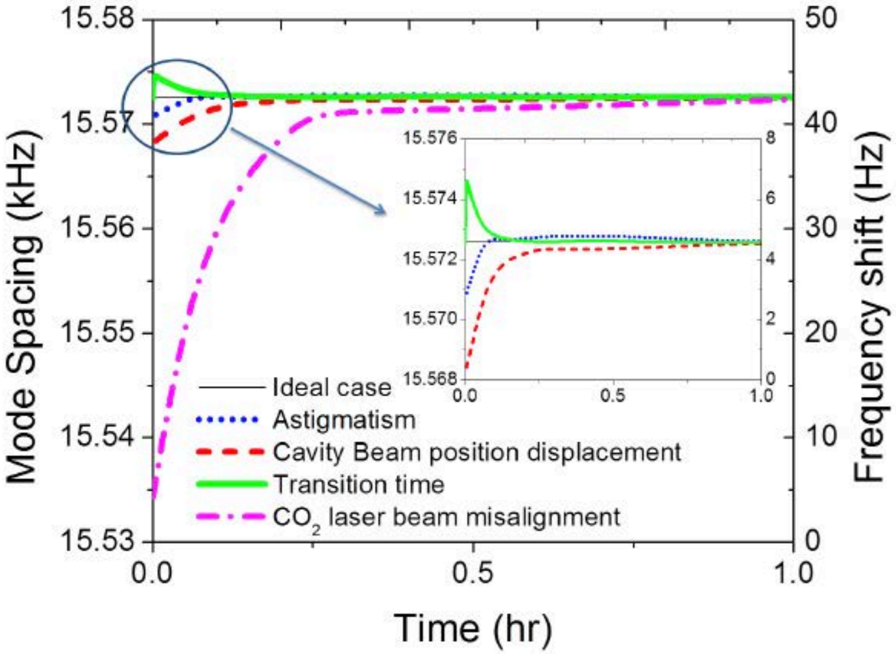
Future work: Study PI as an unstable filter for negative dispersion



Parametric instability control by pre-heating
(Vahid)

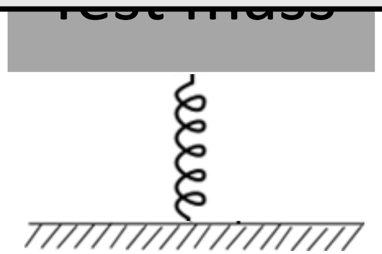


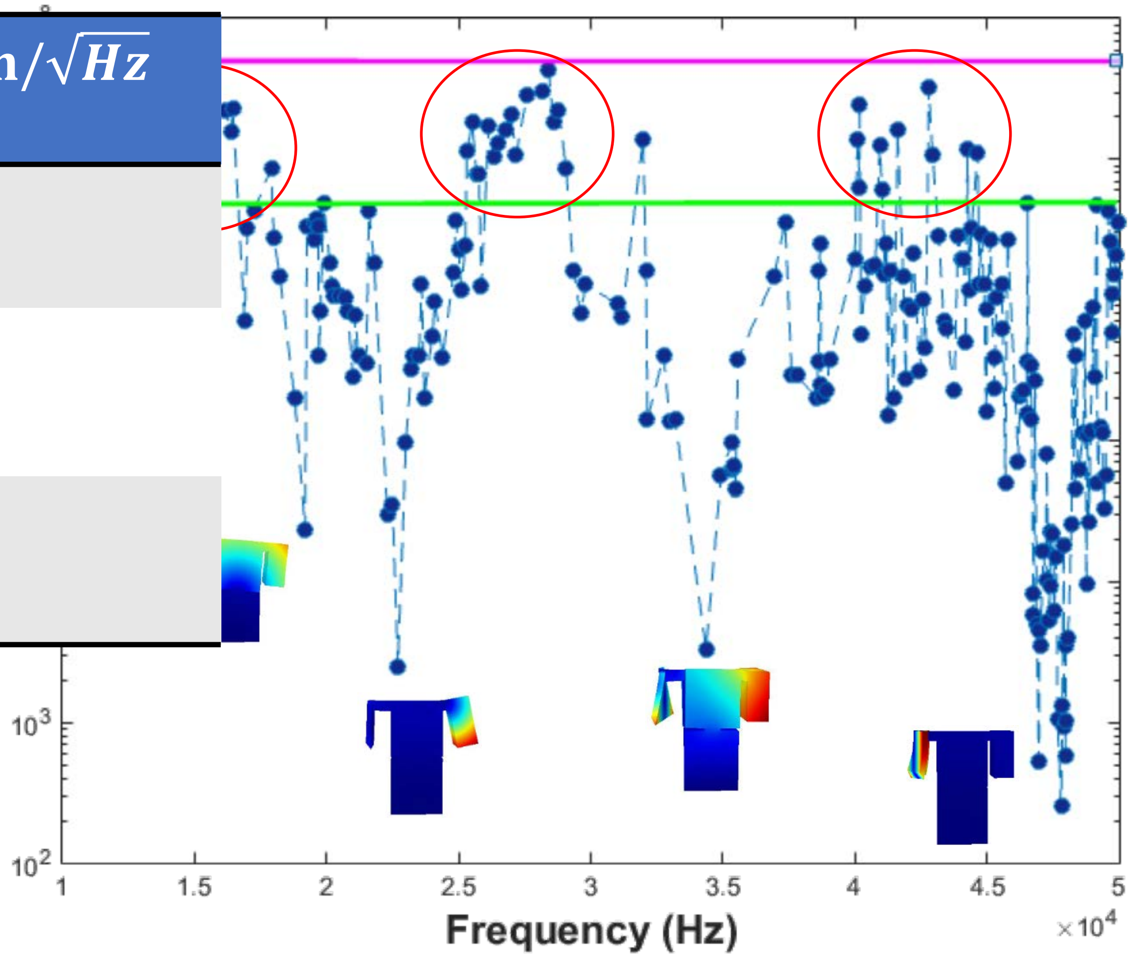
- Thermal transient compensation by pre-heating test masses to maintain constant thermal state.
- Avoid the thermal transient induced PI



Acoustic mode damper (Vahid)

Thermal noise at 100Hz , units 10^{-22} m/$\sqrt{Hz}$	
Total TM (ETM)	**77.64**
LIGO-AMDs	**5.5**
M-AMD	**2.8**





Acoustic mode damper

Future works:

- *Optimisation of multi-stage AMDs structures and parameters*

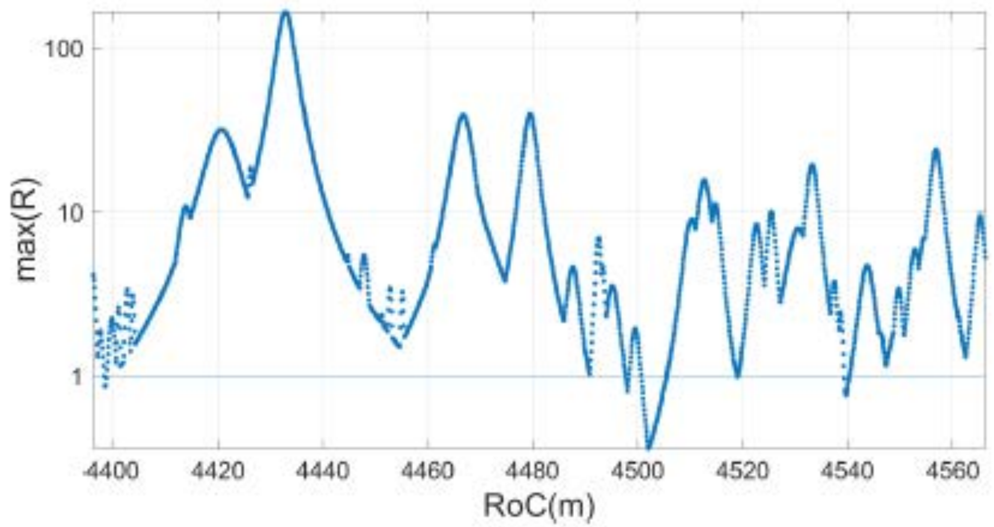
- *Design AMDs for HF detectors*

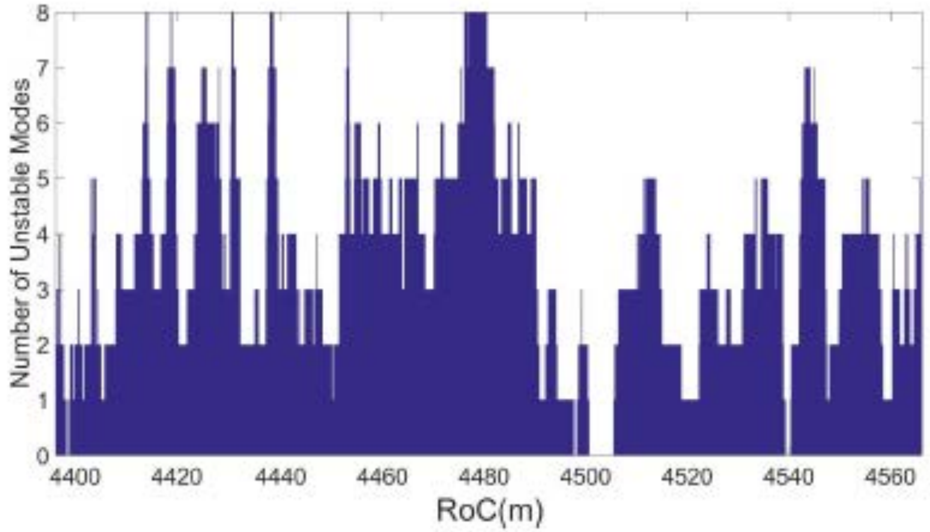
PI simulation for future detectors *(Jue Zhang)*

Simulation shows that optimization can reach PI-free design for long-baseline detectors

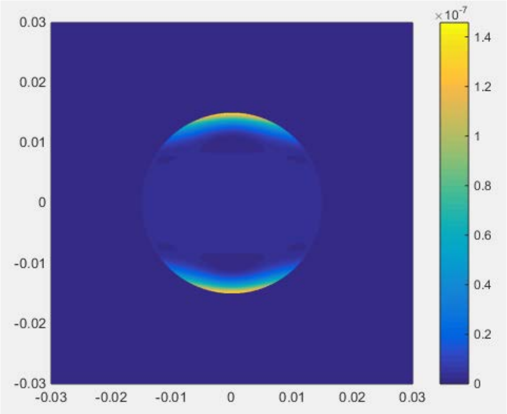
Future works:

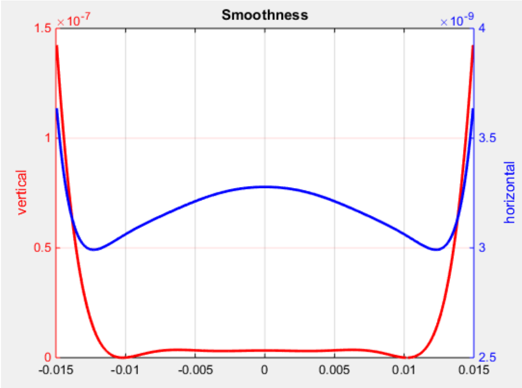
Analysis PI in HF detectors





Selectively tune optical mode frequencies *(Bin Wu)*



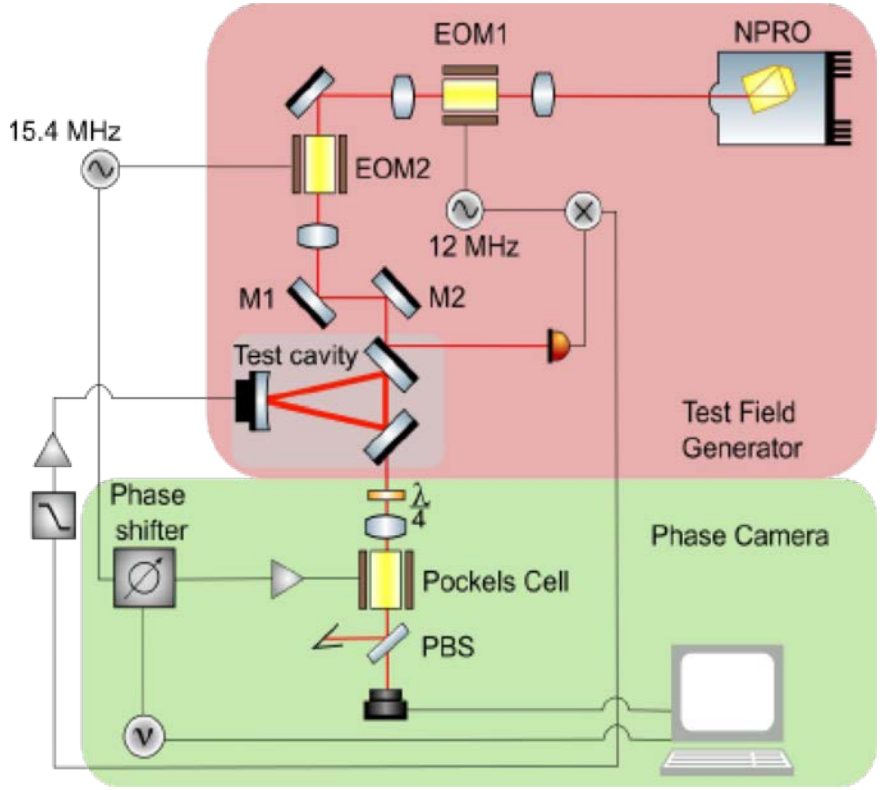


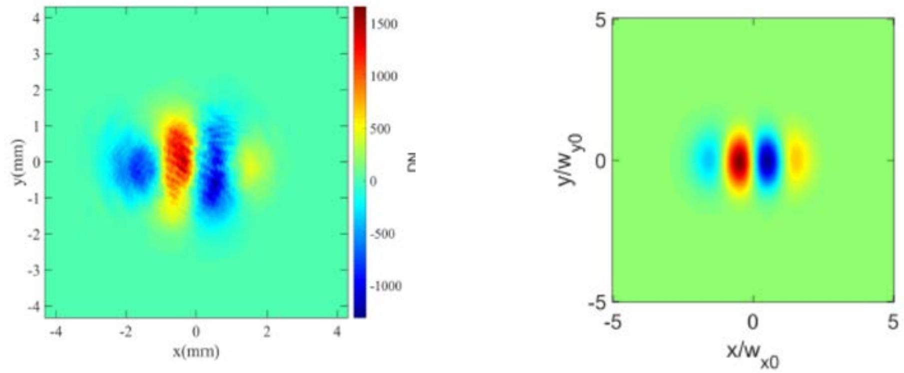
HG_mode	dw_give	dw_found
01'	0	0.237092
02'	0	3.886547
03'	1000	1039.844
04'	0	292.3736
10'	0	0.033486
11'	0	0.967668
12'	0	12.82501
13'	0	111.3626
20'	0	0.241584
21'	0	3.881156
22'	0	41.6803
30'	0	1.51827
31'	0	14.27104
40'	0	8.628339

- Simulation shows that we can selectively tune an unstable mode frequency with small frequency changes in other modes, by specific mirror surface profile

Future works: Simulation to find thermal heating pattern to achieve required surface profile

The second generation phase camera *(Huy-Tuong Cao)*

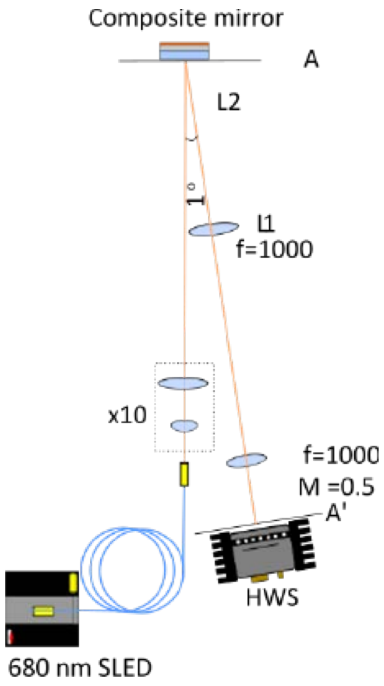


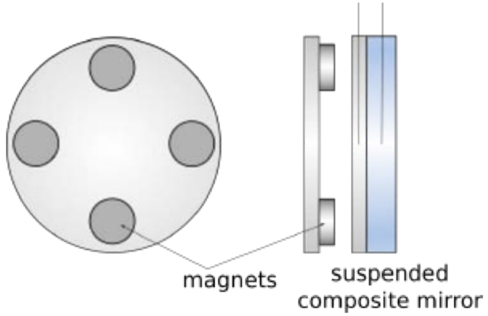


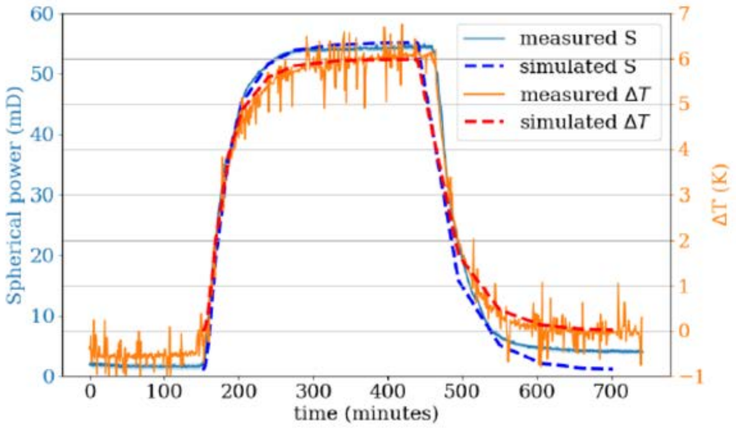
Phase camera result shows strong TEM30 mode as predicted by simulation

Future works: testing at Gingin and aLIGO detectors

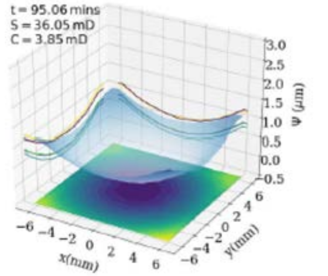
Optical Surface Control via deformable mirrors (*Huy-Tuong Cao, Deeksha Beniwa)*



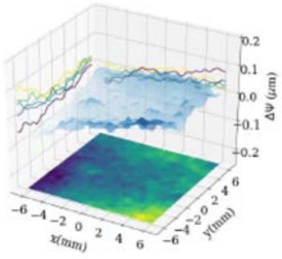




Total wavefront distortion



Higher order aberration



- >50 mD change at ΔT = 6K
- ΔWFrms ~ 6 nm, mainly quadratic term
- Actuation range, time constant agree well with FEM model

Future works:

Study and design optimization on mass, stress and adhesive

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Mid-infrared fibre lasers for wavefront correction
(Deeksha Beniwal, Huy Tuong Cao, and Sebastian Ng)

- Highly spheric wavefront change measured with an Er:ZBLAN fibre laser heating beam
- Non-quadratic wavefront distortion meets aLIGO requirements

Future works:

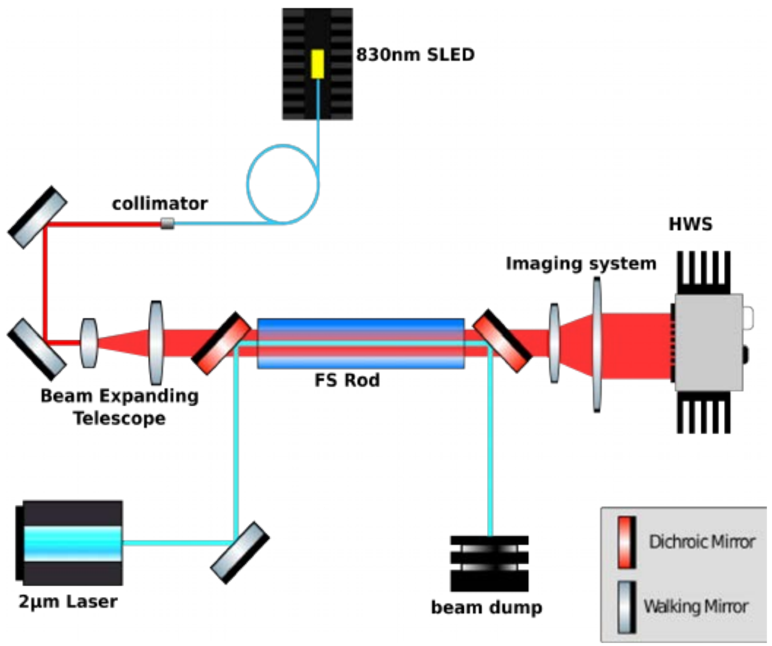
- *Laser intensity stabilization*
- *Fibre Bragg grating required for wavelength stabilization*
- *Exploring monolithic design for better long tern durability and power scaling capability*
- *Further testing at different beam diameter and power levels*

Characterization of optical absorption of fused silica at 2 μm (*Craig Ingram, Huy Tuong Cao*)

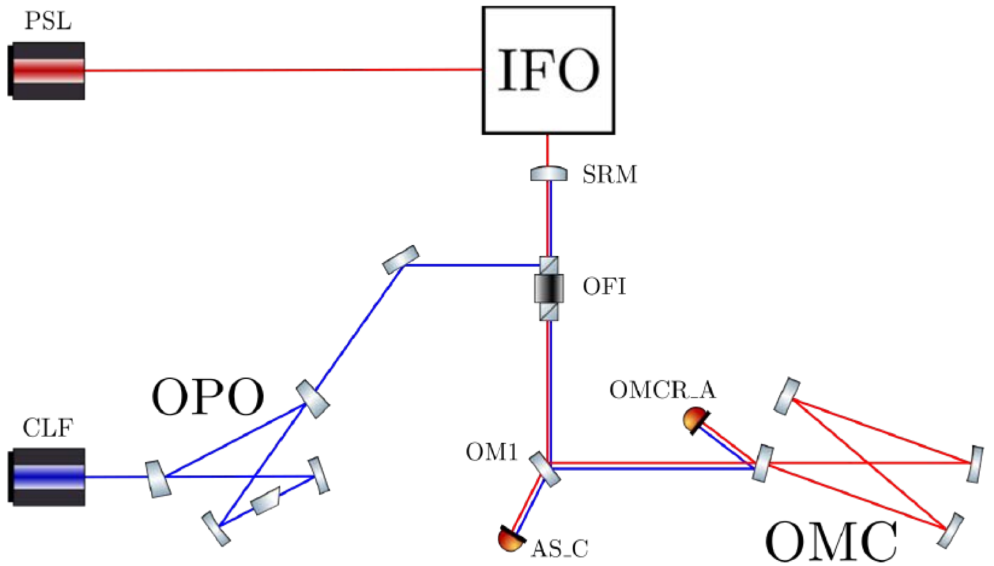
- Preliminarily measured 2 μm laser light absorption induced wavefront distortion in fused silica

Future works:

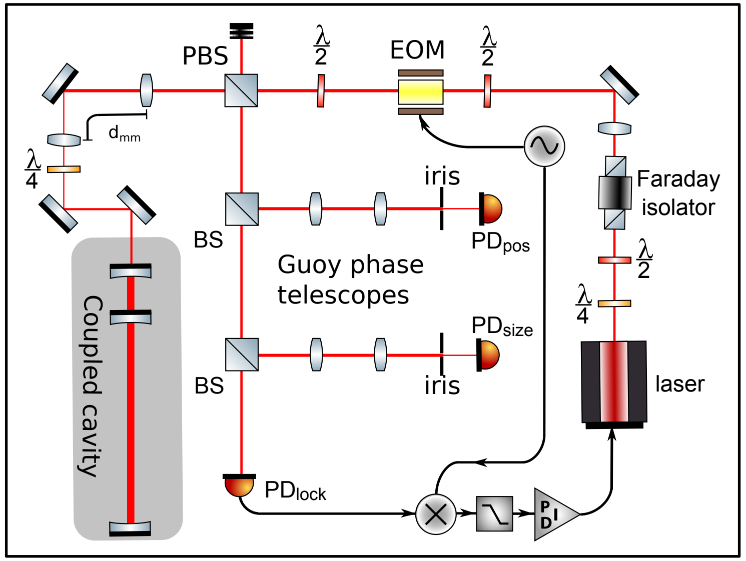
- *Obtain absorption spectrum using tunable source to scan across 1920-2020nm to determine optimum wavelength*
- *Investigate possible alternative materials such as CaF_2*



Mode matching sensing and control (*Alexei Ciobanu, Vahid J. Hamedan, Dan Brown, Joris Van Heijningen*)

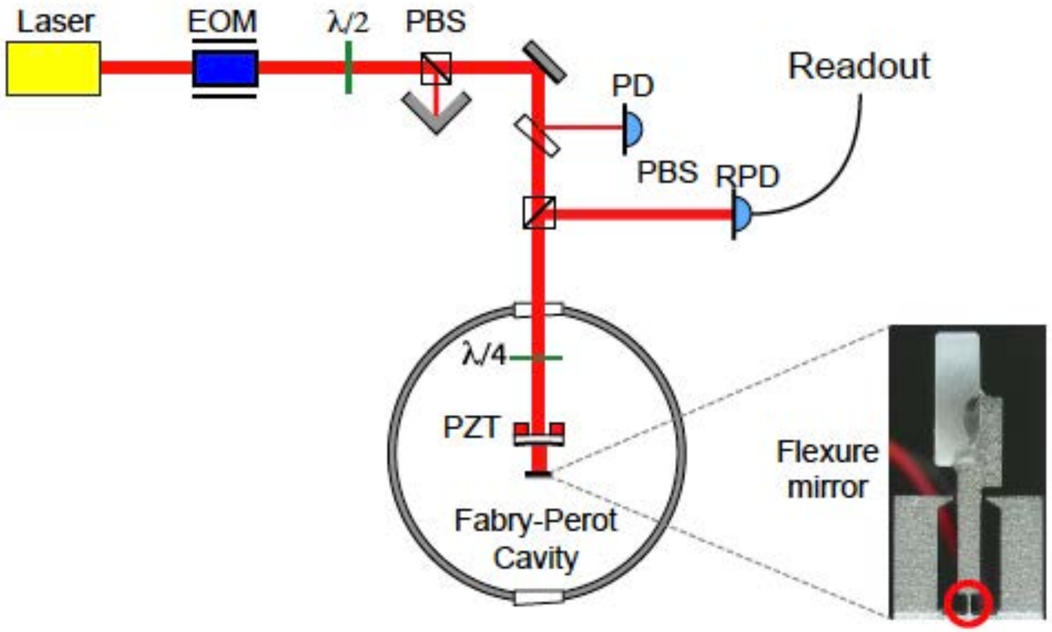


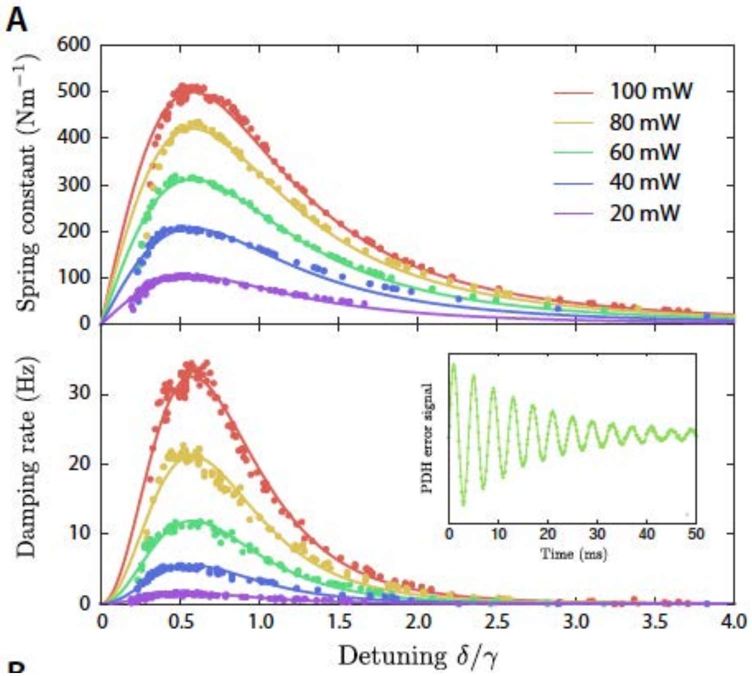
The second order mode modulation for mode-mismatch sensing



The fundamental mode modulation and Gouy phase telescope for mode-mismatch sensing

Thermal-optic stabilization of an optical spring *(Layla Steed and Paul Altin)*





Future work: Engineering a custom mirror coating to exploit thermal-optic feedback to stabilize the optical spring