Cold aberrations and locking of Central Interferometer of Advanced Virgo+

EPS-HEP 2021 Conference

26th July, 21

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On behalf of Virgo Collaboration

Outline

- AdV+ central interferometer (CITF) configuration
- Working point
- Cold aberrations and Thermal Compensation System (TCS)
- Central Heating (CH) installation
- Pre-commissioning of CH
- CITF without TCS
- CITF locking
- Conclusions

AdV+ Configuration

Addition of Signal recycling mirror (SRM) for Advanced Virgo+ in O4. Hence, we need to control 5 longitudinal DOFs.

$$DARM = \frac{L_N - L_W}{2}$$

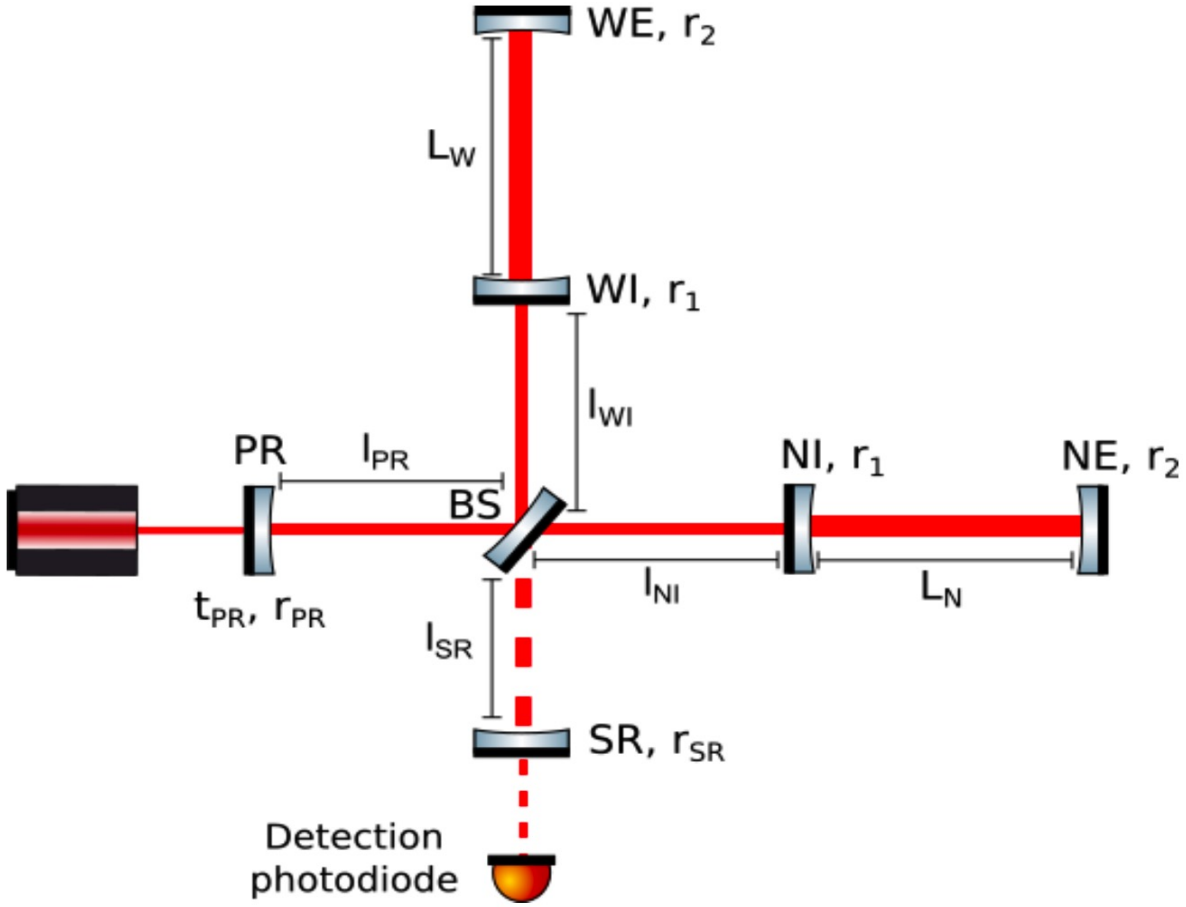
$$CARM = \frac{L_N + L_W}{2}$$

DRMI

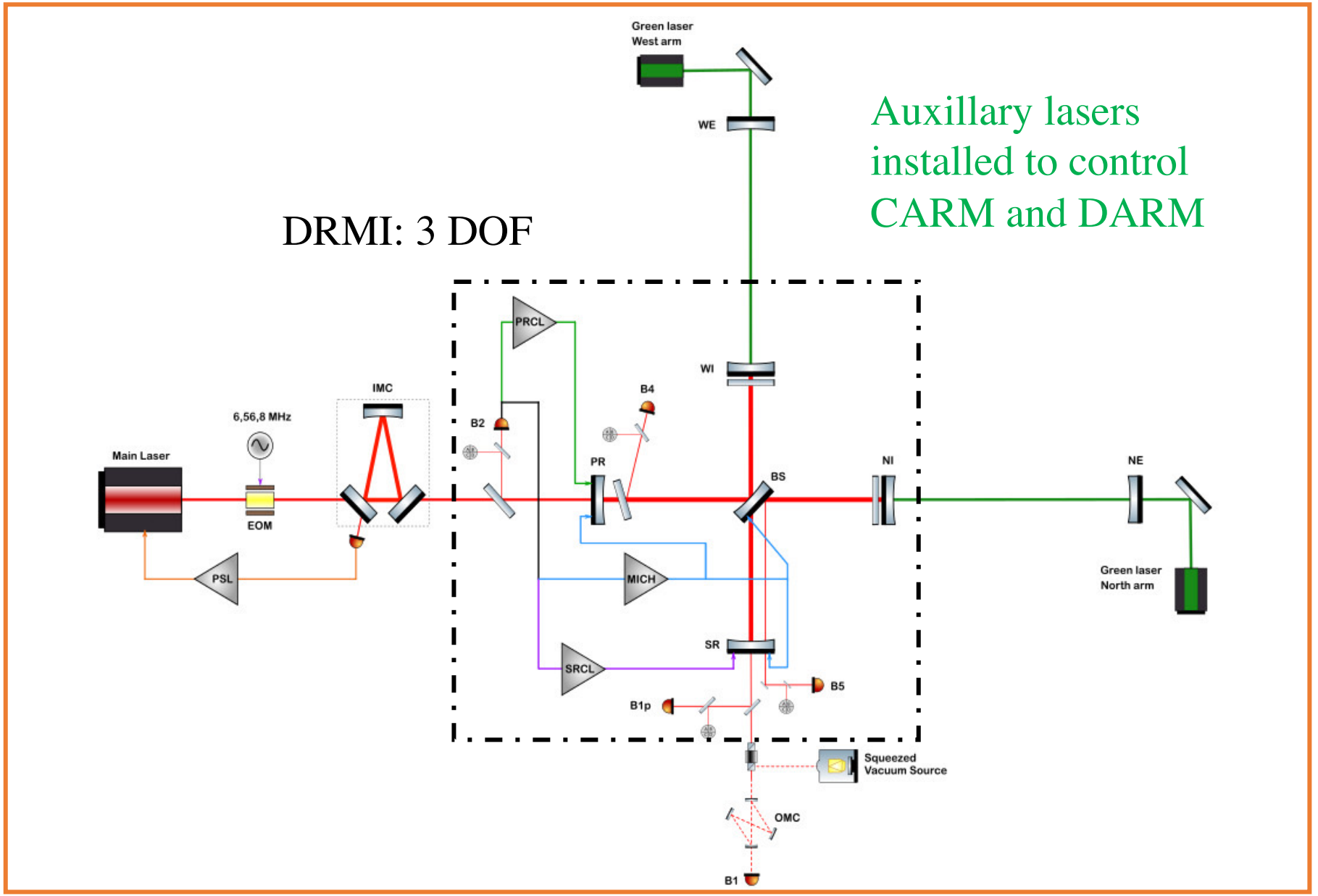
$$MICH = l_{NI} - l_{WI}$$

$$PRCL = l_{PR} + \frac{l_{NI} + l_{WI}}{2}$$

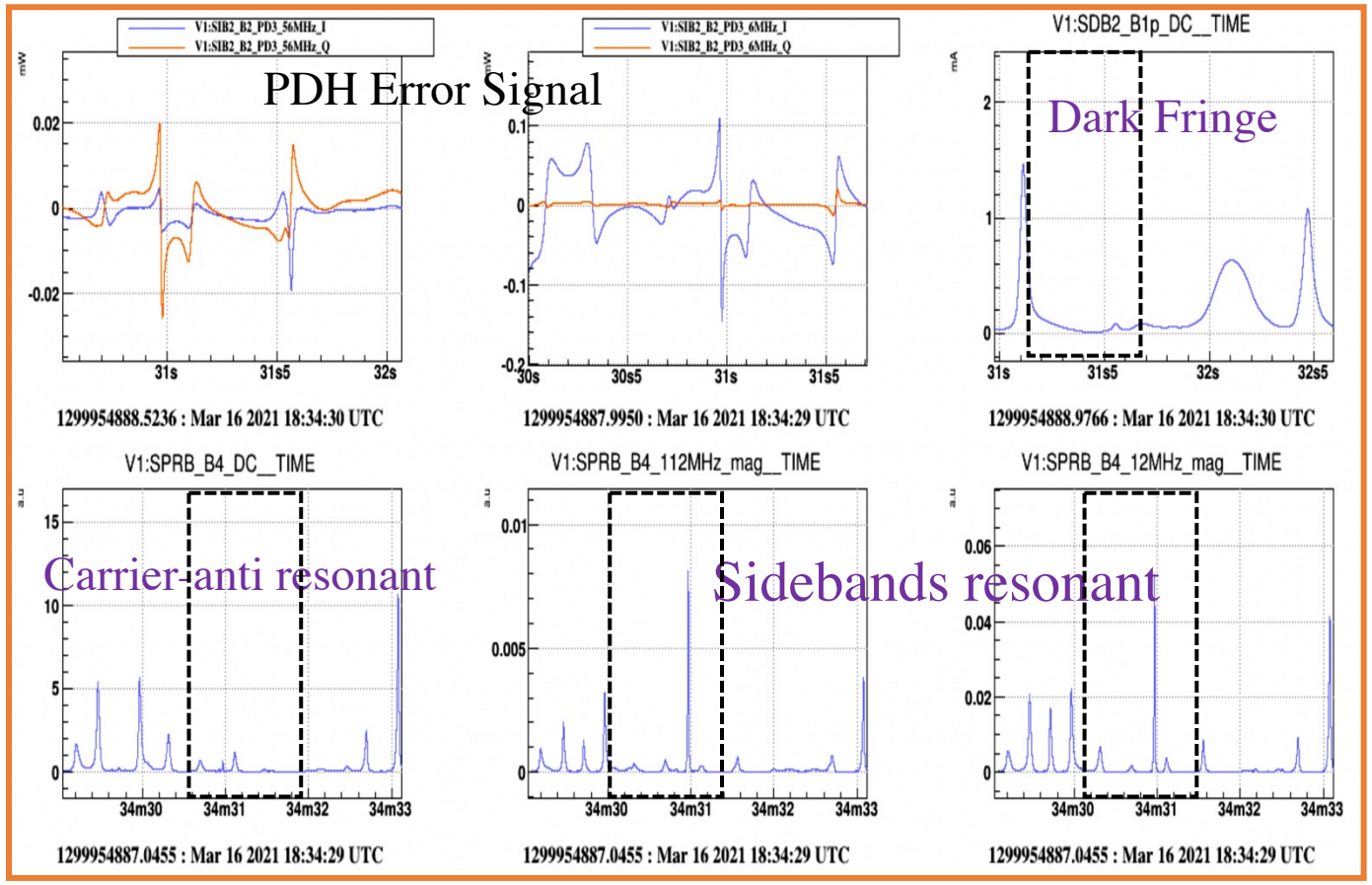
$$SRCL = l_{SR} + \frac{l_{NI} + l_{WI}}{2}$$

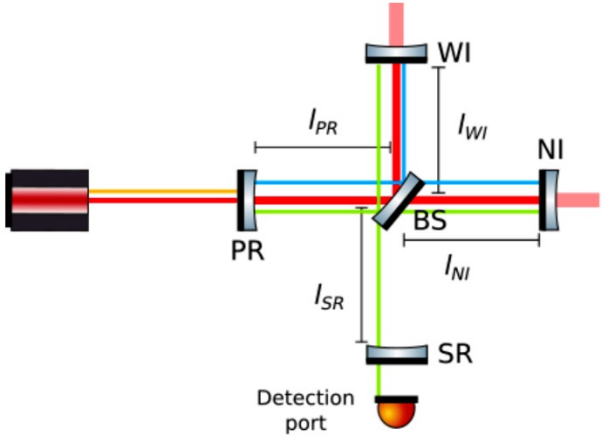


DRMI Controls' Scheme in O4



Working Point





Carrier: *resonant* on the **PRC** and the **arms** and *anti-resonant* on the **SRC**

6 MHz: *resonant* on the **PRC** and *anti-resonant* on the **SRC** and the **arms**

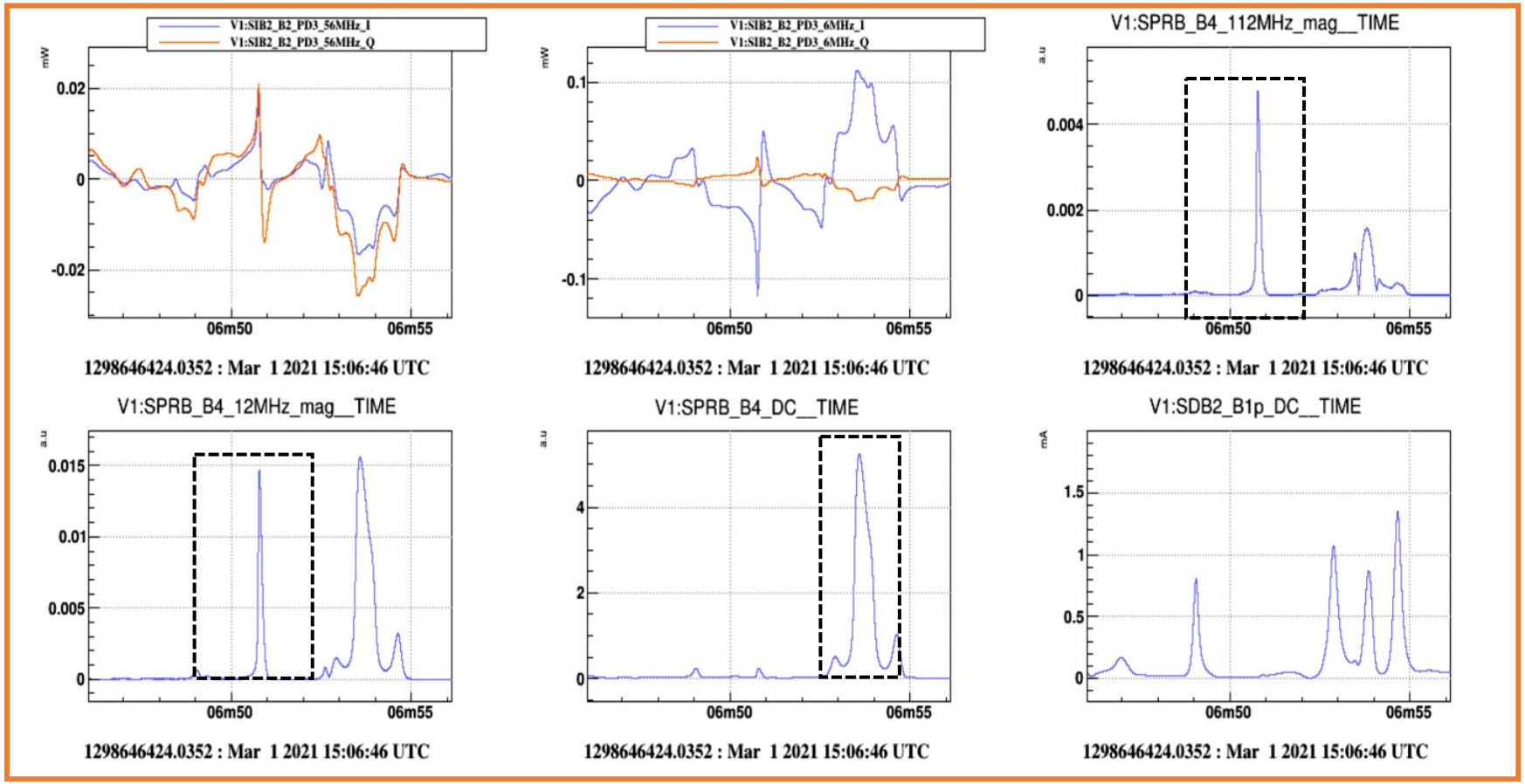
56 MHz: *resonant* on the **PRC** and the **SRC** and *anti-resonant* on the **arms**

8 MHz: *anti-resonant* on the **PRC**

- MICH in dark fringe (DF)
- PRCL in resonance for 6 and 56 MHz sidebands
- SRCL in resonance for 56MHz sideband
- Carrier anti-resonant in PRC.

CITF locking

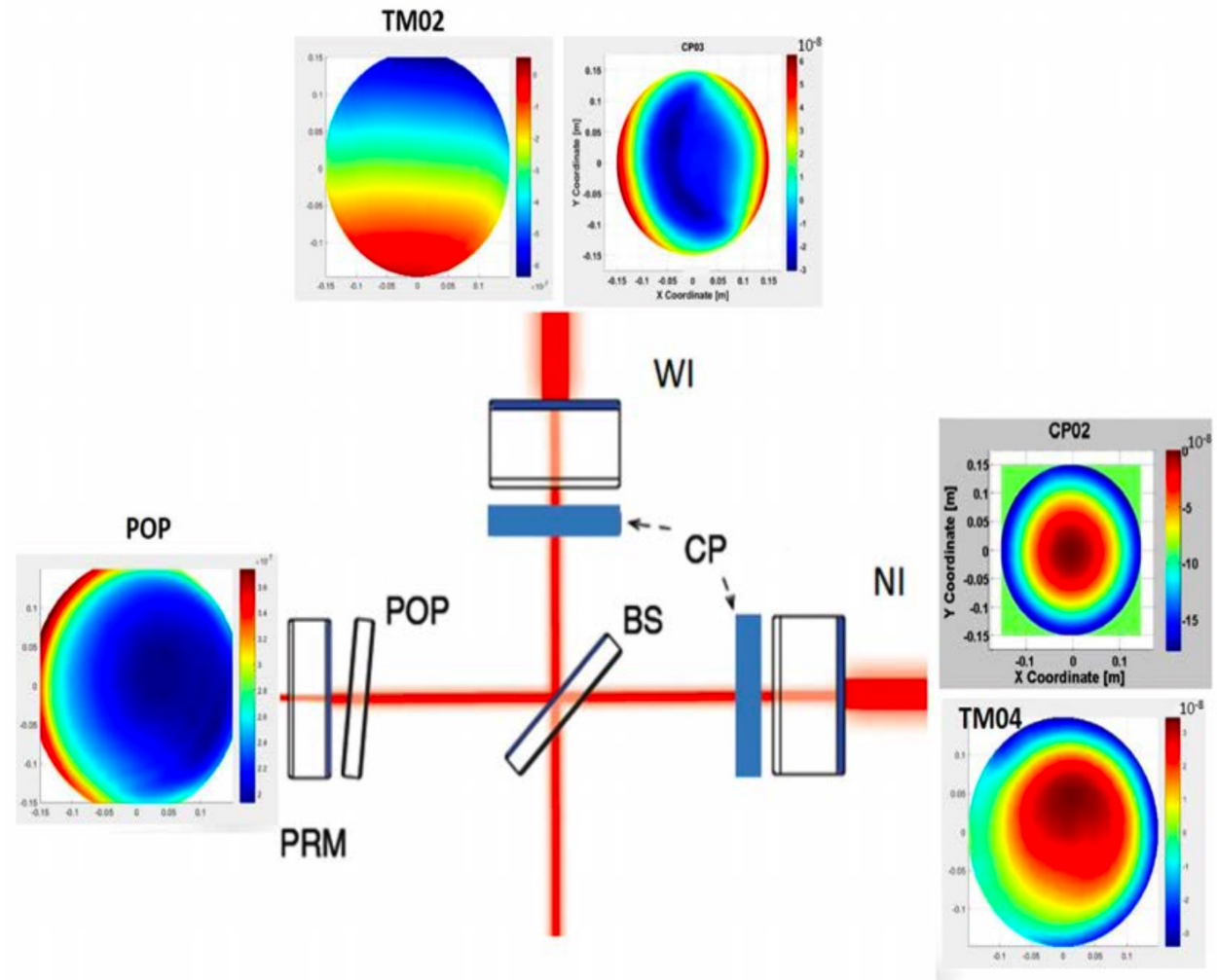
Reason?



No zero-crossing
PDH error signal

Low power on sidebands

Cold Aberrations



- Non-uniformity of the substrate transmission map
- The most offending optic is NI CP. Other optics are hundreds of km of RoC.
- NI CP is 70km of RoC and converging.
- PRC and SRC are marginally stable cavities (g~0.9999885), more sensitive to these defects.

*Aiello Ph.D. thesis, Development of new approaches for optical aberration control in gravitational wave interferometers

Thermal Compensation System

Compensates for:

- Cold defects (present in central interferometer)

- Optical aberrations due to thermal effects (present in Fabry- Pérot cavities)

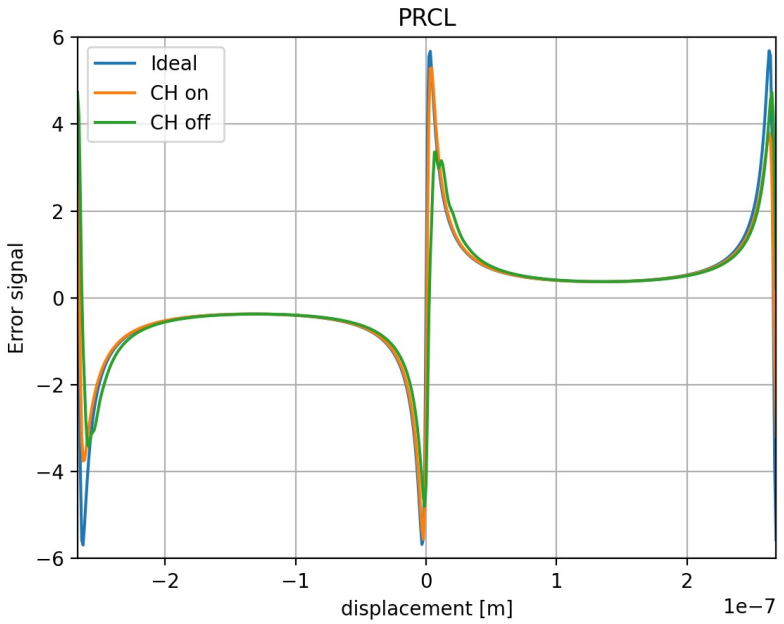
1. The plan is to project an aberration complimentary to induced by thermal effects

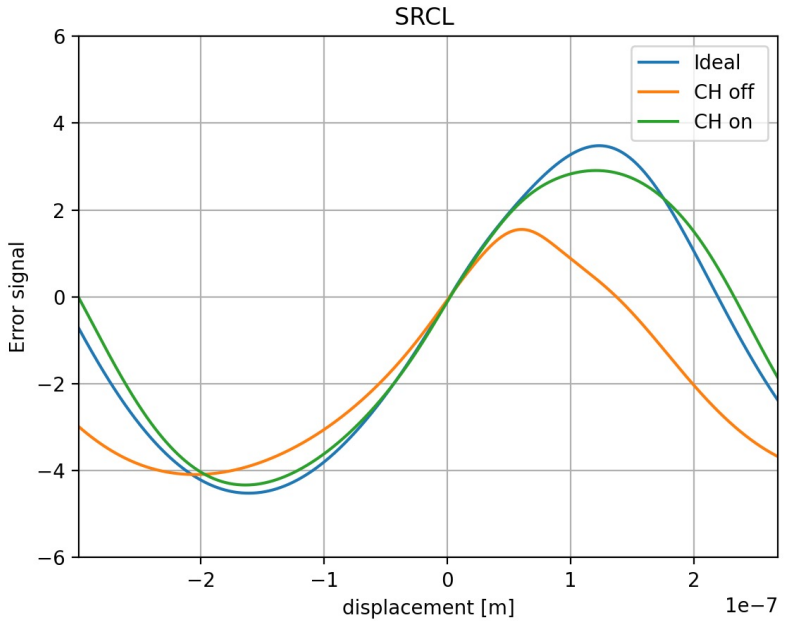
2. A CO2 laser, as its wavelength is completely absorbed by the fused silica optics (ITMs, ETMs etc)

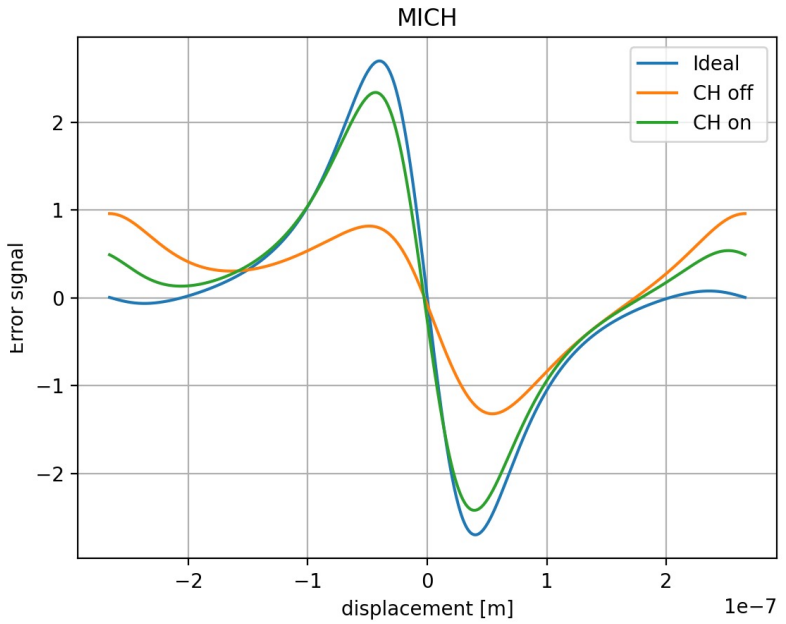
3. Central Heating (CH) is a gaussian beam which mimics the main laser beam, for cold defects compensation.

Central Heating Effect

Improvement in the Optical gains can be observed in PRCL and MICH when Central Heating is turned on while demodulation phases were unchanged.

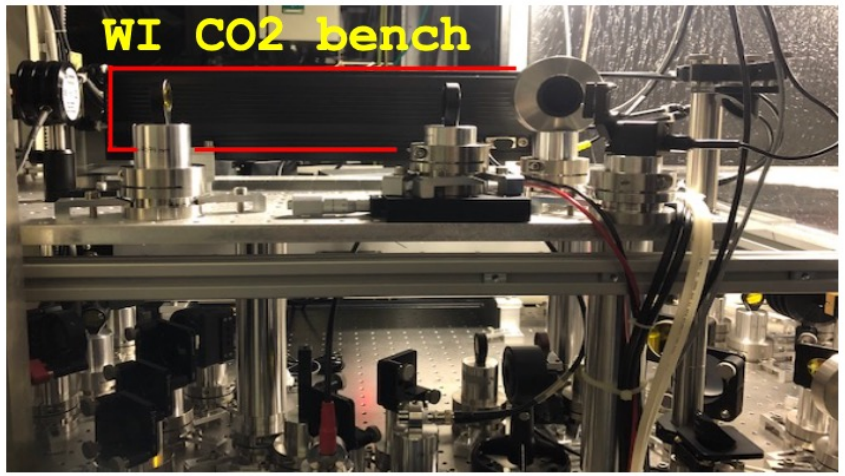


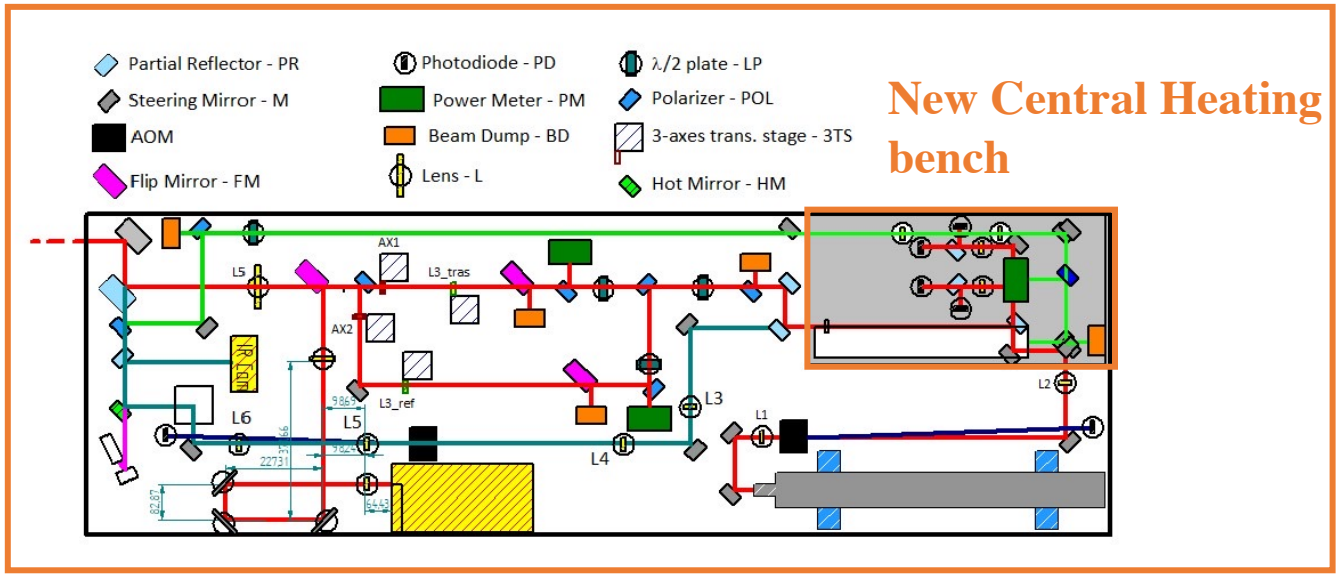




TCS New Benches

New central heating (CH) benches were installed to compensate the (cold) optical aberrations for both input mirrors to achieve the beam size 50mm (same as IR).



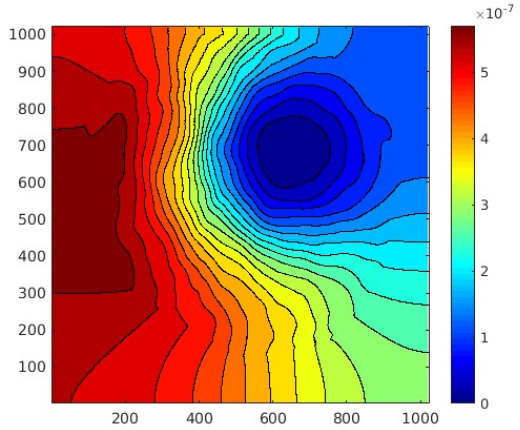


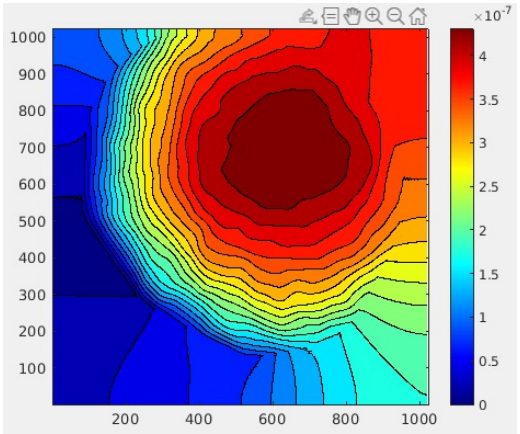
Centering of TCS CH

Central Heating Centre

Mechanical Centre

NI





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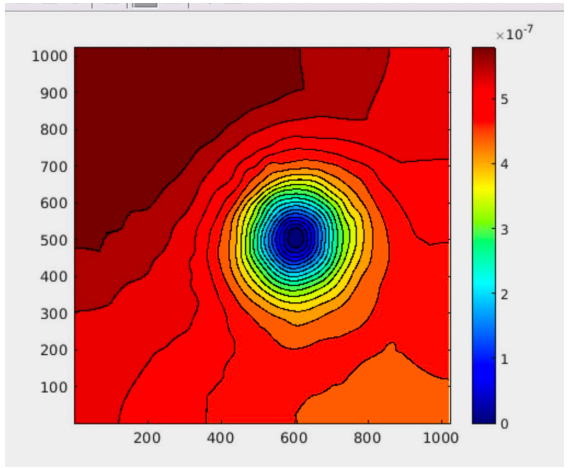
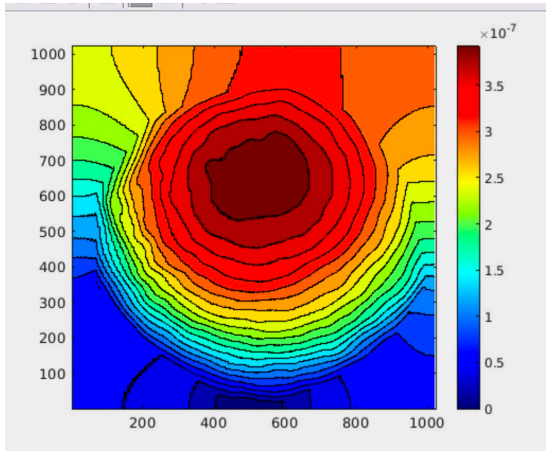
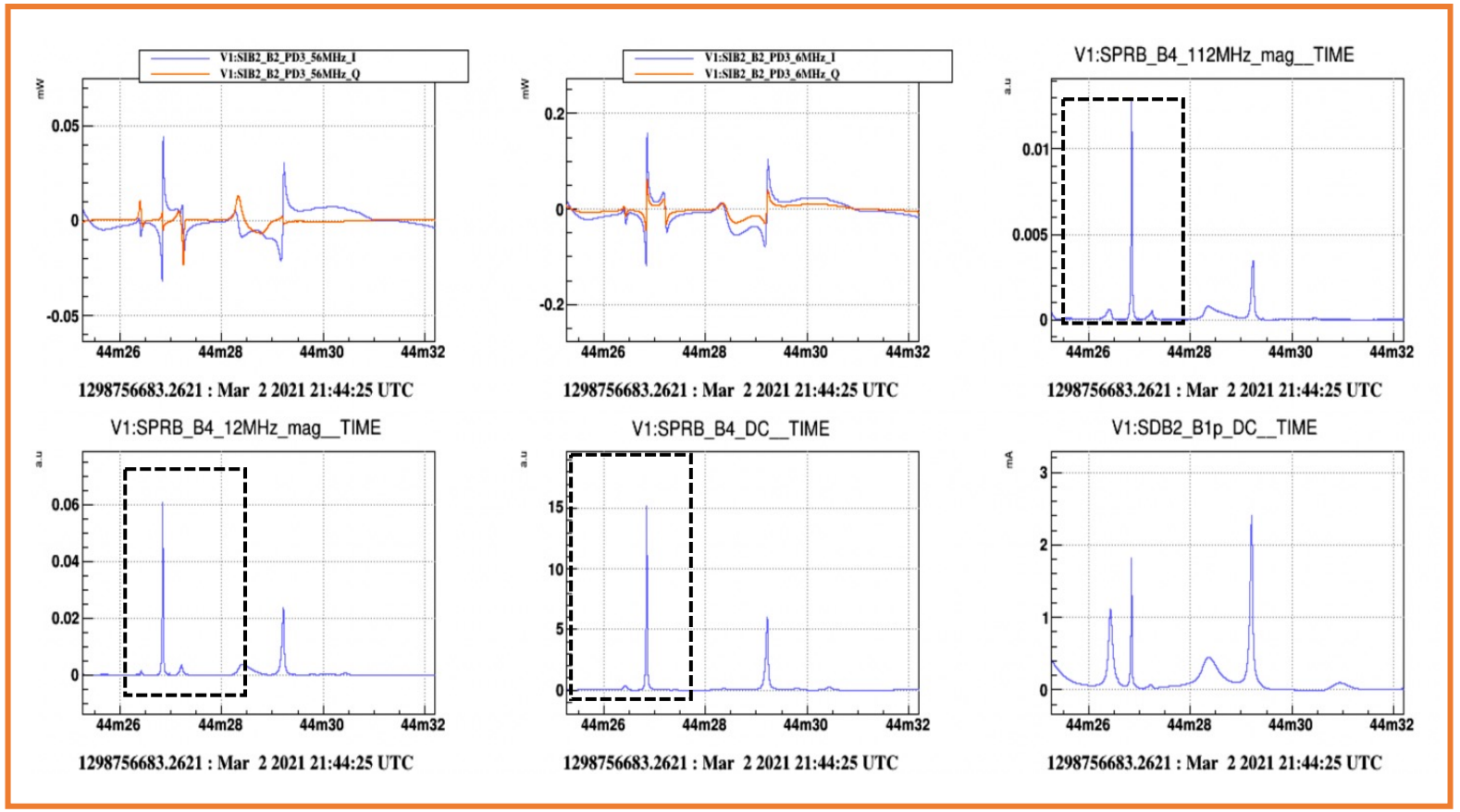




- By moving HM on the bench, we can centre the CH beam on the CP.
- CH was brought to the centre of the CPs within 0.5cm precision(#50832 #50827)

TCS Tuning

Central Heating was switched on 2nd March, 21 to improve quality and optical gain of the error signals for PRC and SRC for the CITF/DRMI lock (Logbook entry no.- 50951).



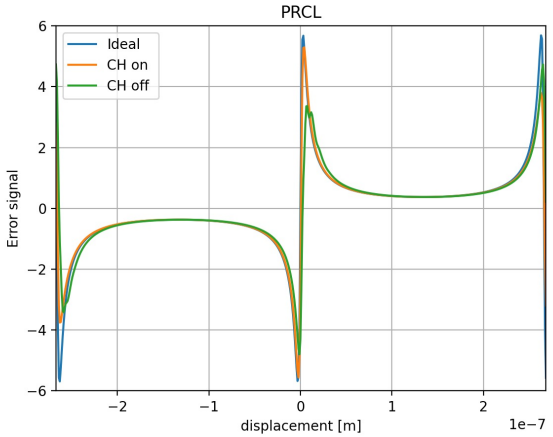
Zero-crossing PDH error signal

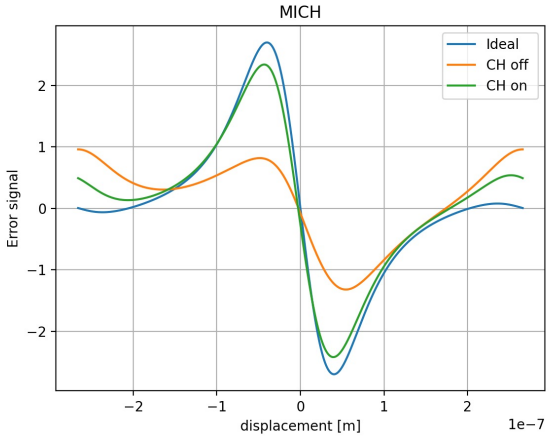
Siginificant power on sidebands

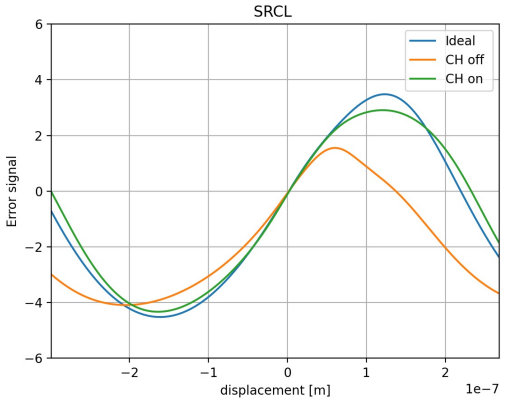
Central Heating Effect

Improvement in the Optical gains were observed in PRCL and MICH when Central Heating was turned on while demodulation phases were unchanged.

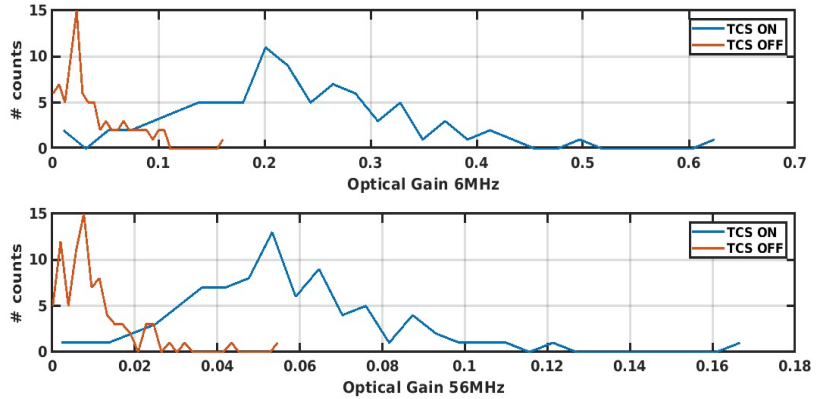
Simulations

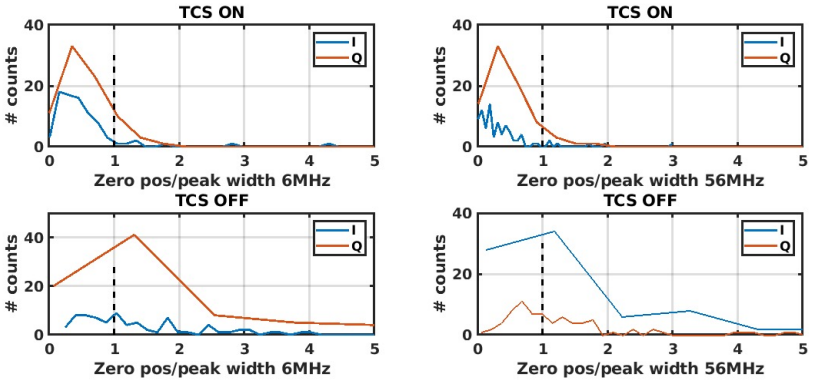






Analysis

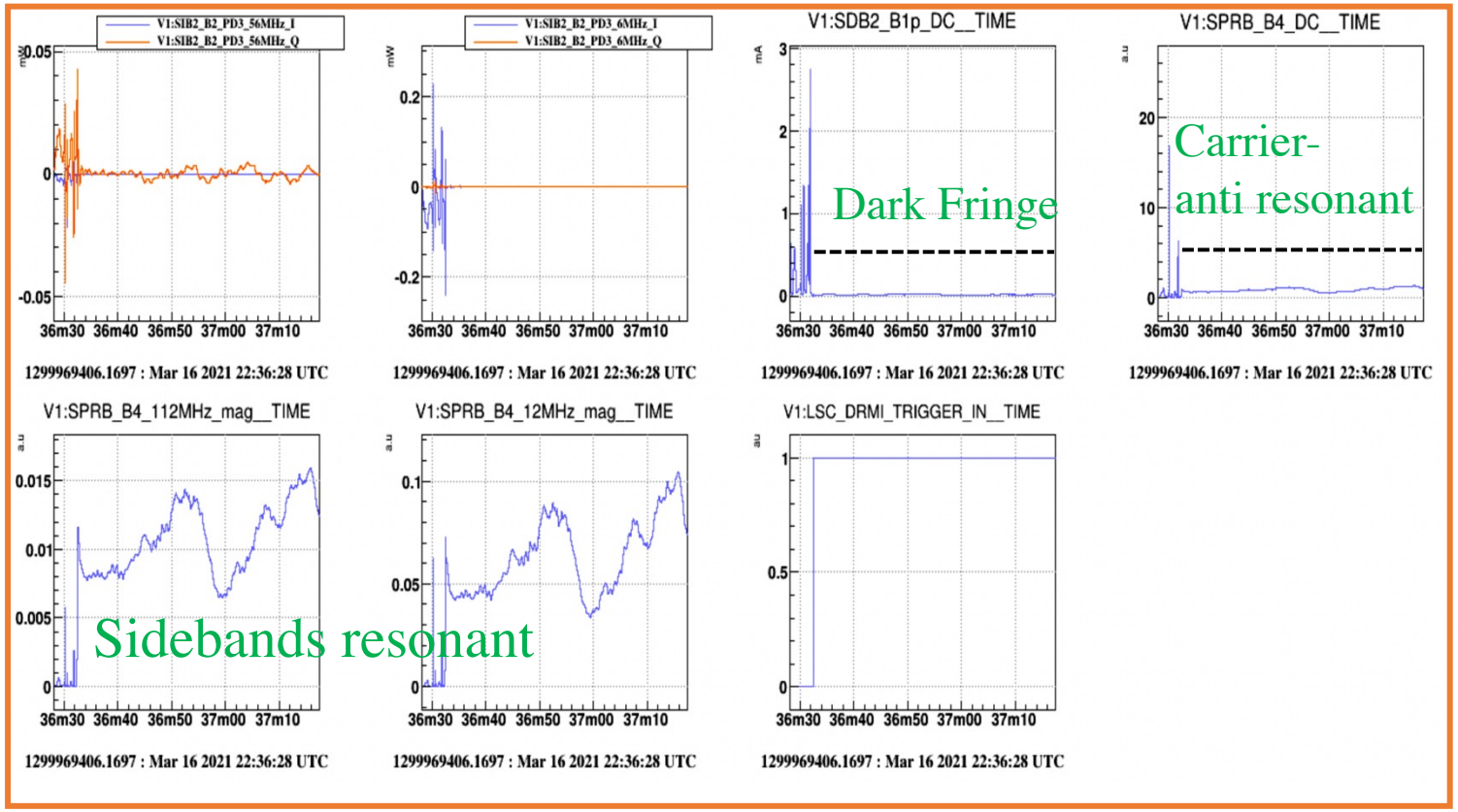


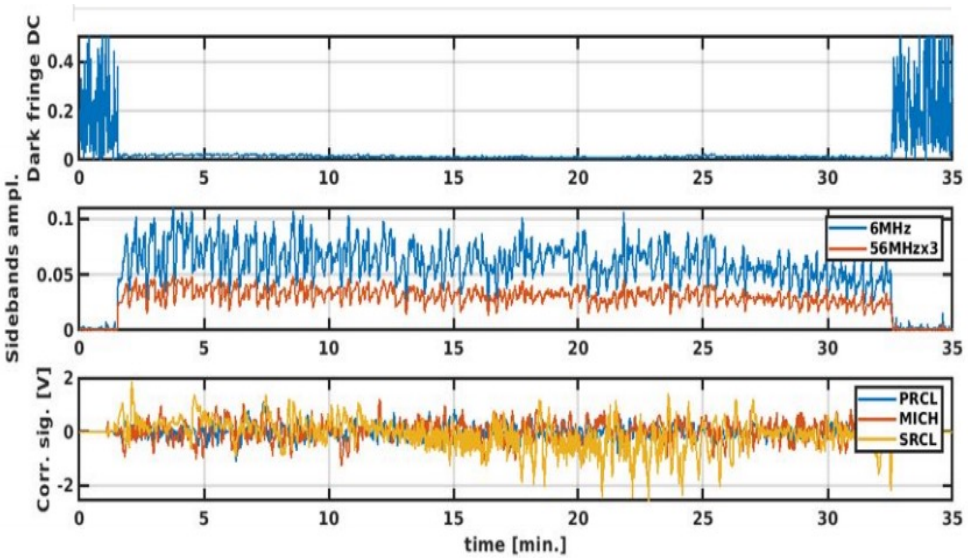


M.Mantovani

CITF Lock

First robust DRMI lock was achived on 16th March, 21 (Logbook entry no.-51118) with marginally stable cavities and was stable for ~ 30 mins.

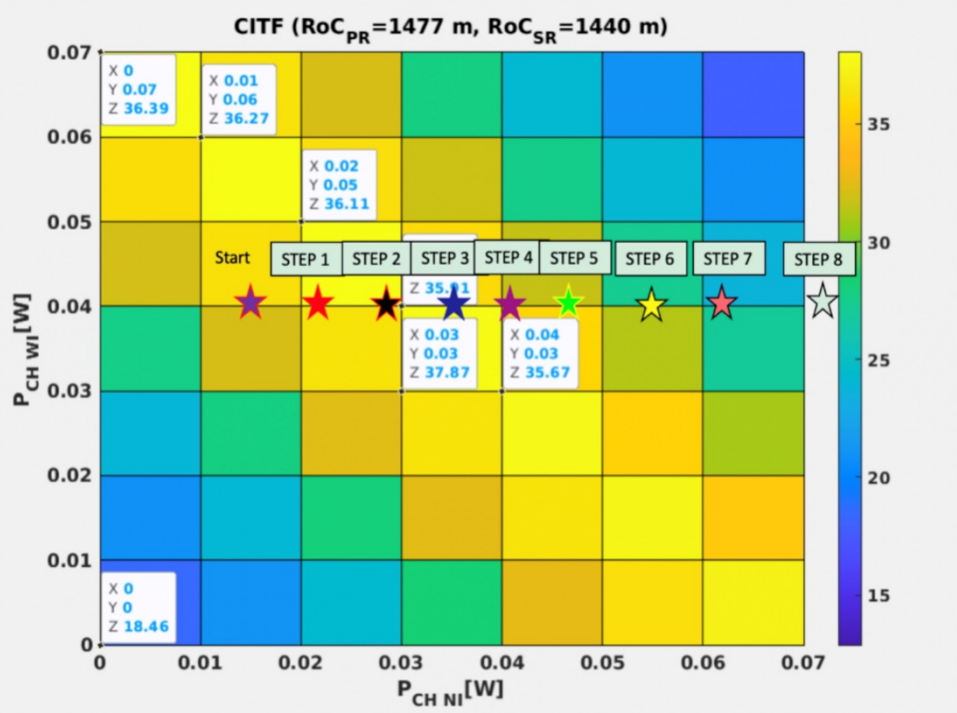




Optimize Power in Sidebands

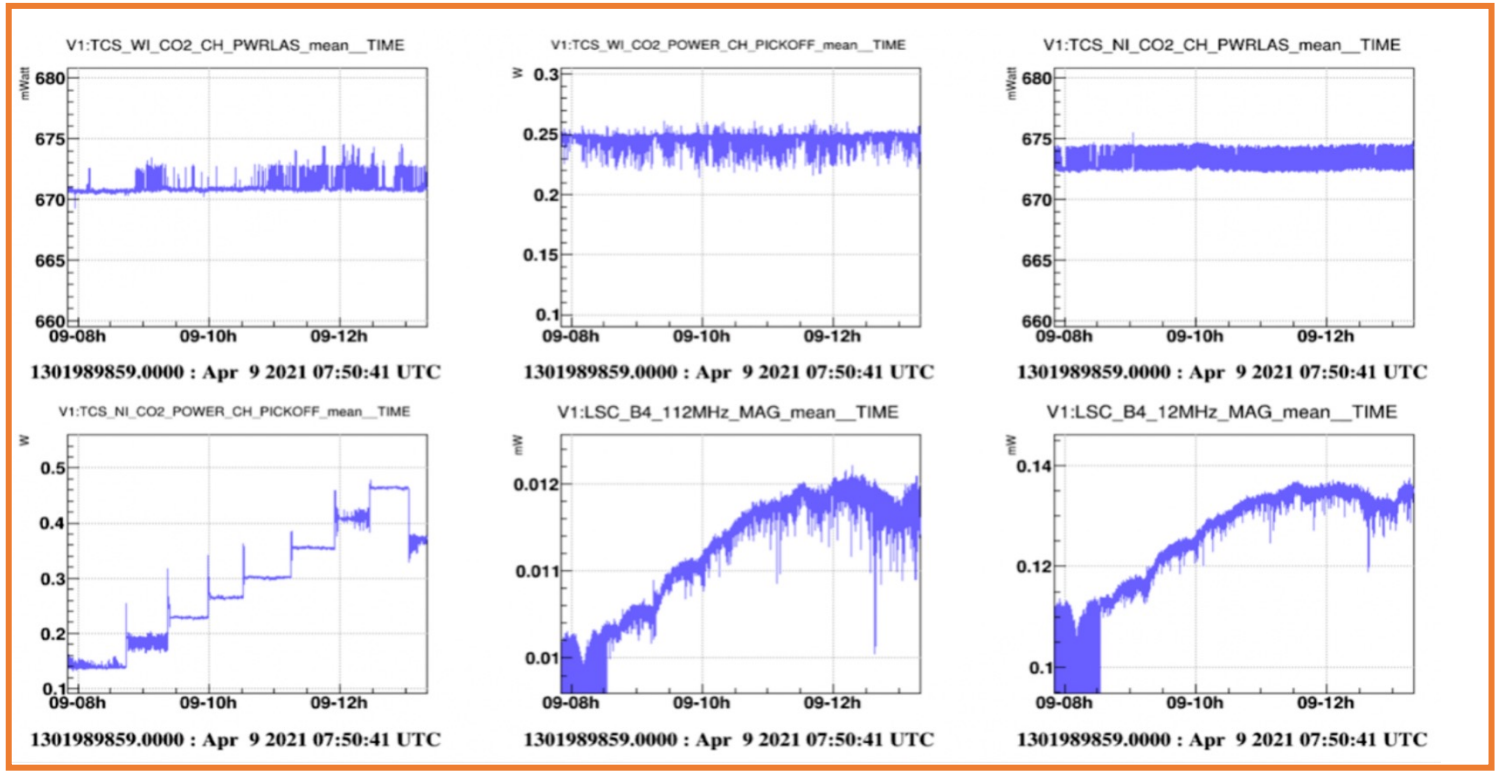
To further improve the power in sidebands to robust the lock of DRMI, NI CH was tuned and gains were adjusted to have almost constant UGF. (Logbook Entry no-51373).

Simulations



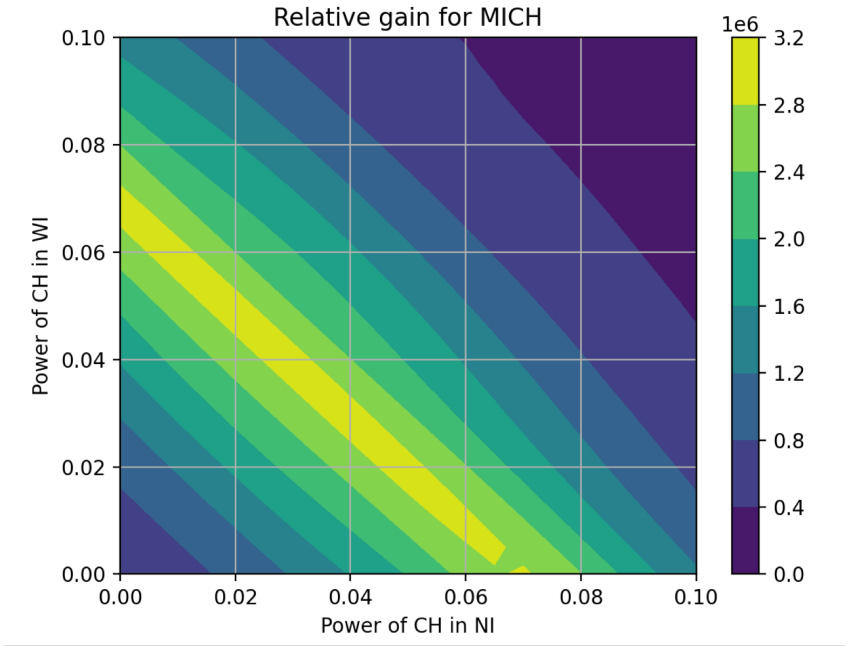
I. Nardecchia

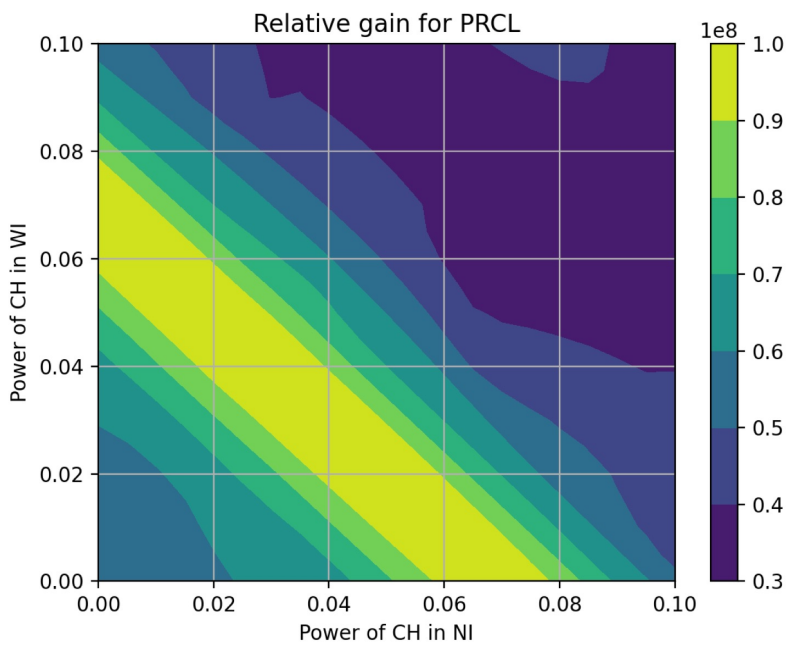
Data

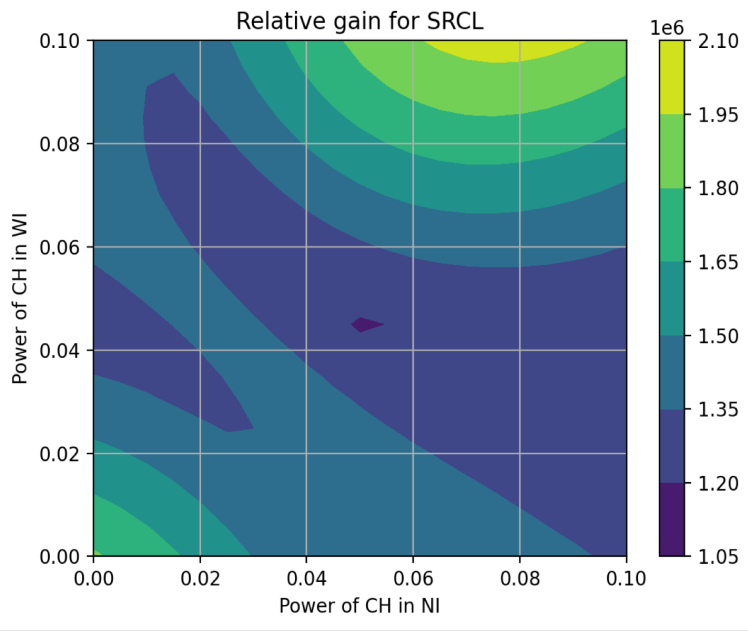


Maximize Optical Gains

Preliminary results while maximizing optical gain for MICH, PRCL, and SRCL with Central Heating power.







Conclusions

- Stable lock of the two marginally stable cavities have been accomplished.
- Central Heating was important for locking the CITF of AdV+
- Commissioning activities have validated the simulations outcomes for the ITF behaviour.

THANK YOU!