Advanced LIGO Status
&
Conceptual Design

Sam Waldman

LIGO Caltech
GWADW 2008
Elba, Italy

LIGO-G080278-00-I

from Wilkinson Feb, 2008

LIGO

MREFC Funding Start

Acceptance Plan Date

FY07 | FY08 | FY09 | FY10 | FY11 | FY12 | FY13 | FY14 | FY15

Seismic Isolation

Suspensions

Suspensions (UK)

Facility Modifications & Preparation

Core Optics

Pre-Stabilized Laser

IFO Sensing & Control

Auxiliary Optic Systems

Data Acq & Controls

Input Optics

Installation & Testing Site 1

Installation & Testing Site 2

Data Computing Systems

- Development End
- IFO1 Production End
- IFO3 Production End
- Installation End

IFO1 Shutdown

IFO2/3 Shutdown

End Project Construction

from Wilkinson Feb, 2008

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LIGO

Technical Note	LIGO-T070247-01-I	2008/04/23

AdvLIGO Interferometer Sensing and Control Conceptual Design

Rich Abbott, Rana Adhikari, Stefan Ballmer, Lisa Barsotti, Matt Evans, Peter Fritschel, Valera Frolov, Guido Mueller, Bram Slagmolen, Sam Waldman

Technical Note	LIGO-T010075-01-I	2008/04/01

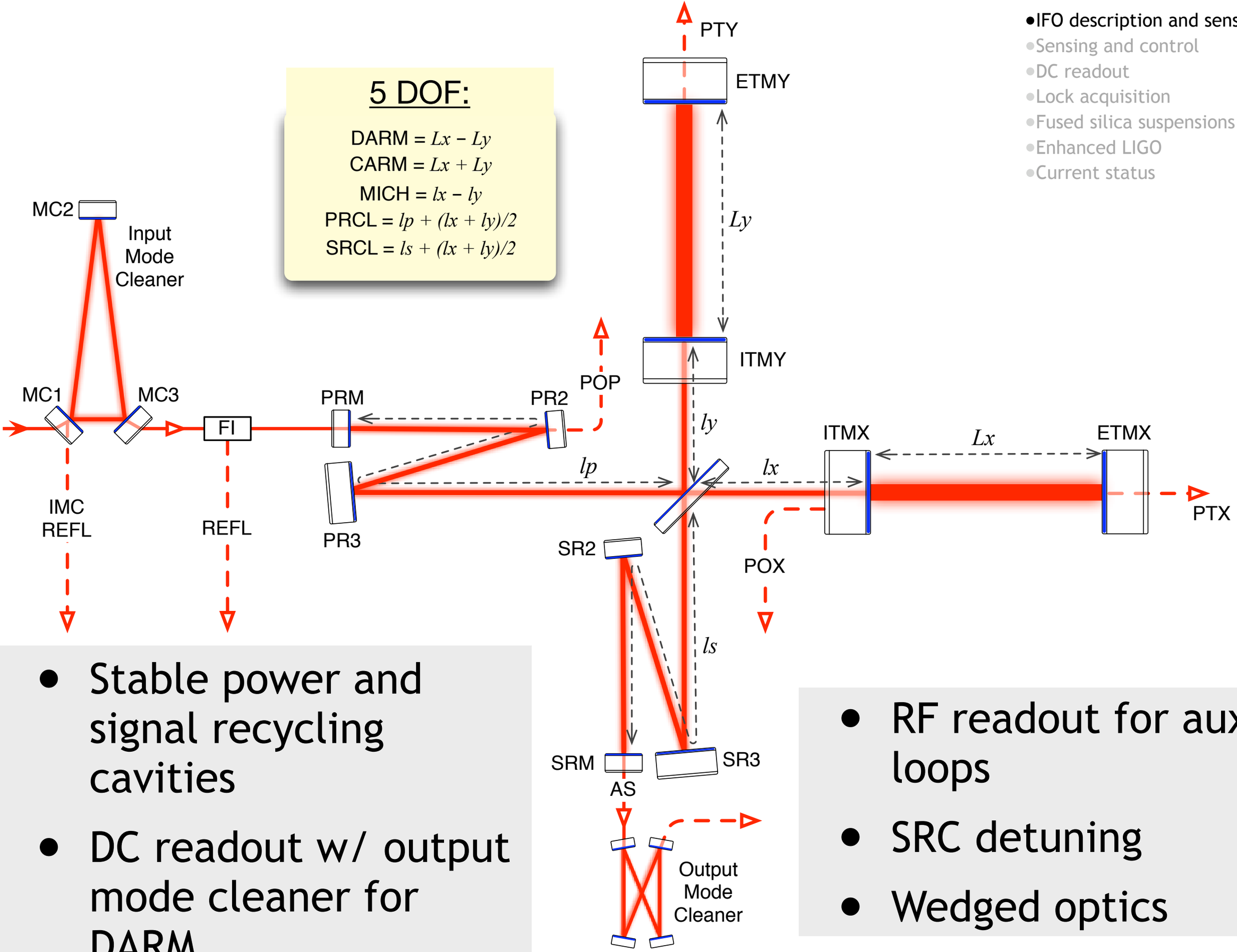
Advanced LIGO Systems Design

Avanced LIGO Systems Group, P. Fritschel, ed.

- IFO description and sensitivity goals
- Sensing and control
- DC readout
- Lock acquisition
- Fused silica suspensions
- Enhanced LIGO
- Current status

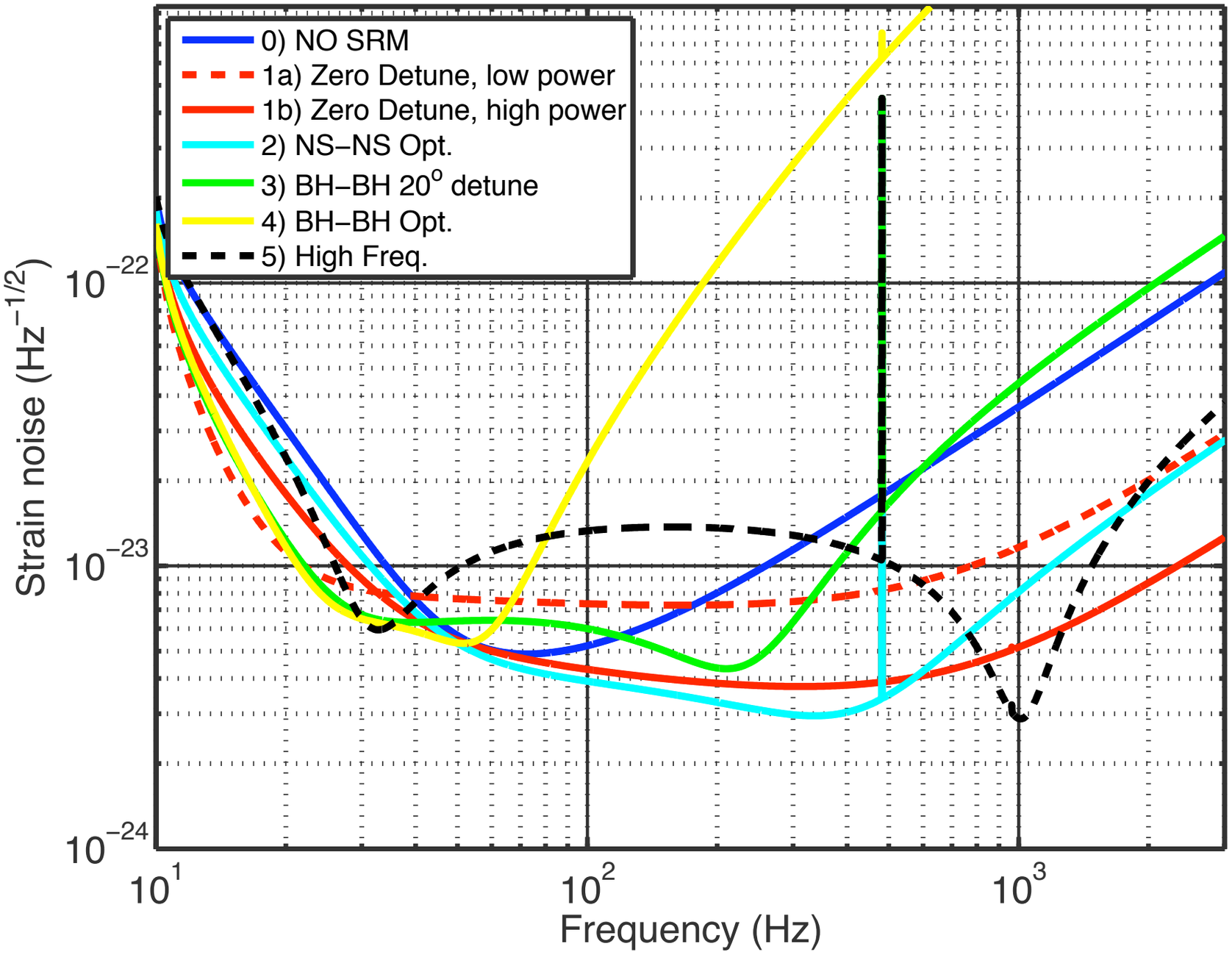
5 DOF:

DARM = $Lx - Ly$
CARM = $Lx + Ly$
MICH = $lx - ly$
PRCL = $lp + (lx + ly)/2$
SRCL = $ls + (lx + ly)/2$



- Stable power and signal recycling cavities
- DC readout w/ output mode cleaner for DARM

- RF readout for aux loops
- SRC detuning
- Wedged optics



- Tune sensitivity as a function of signal recycling phase, signal recycling reflectivity, and power
- Maximize for specific sources using *bench62* noise estimates
- Corrected thermo-optic noise contribution improves high frequency performance by 10%
- *bench70* to be released soon

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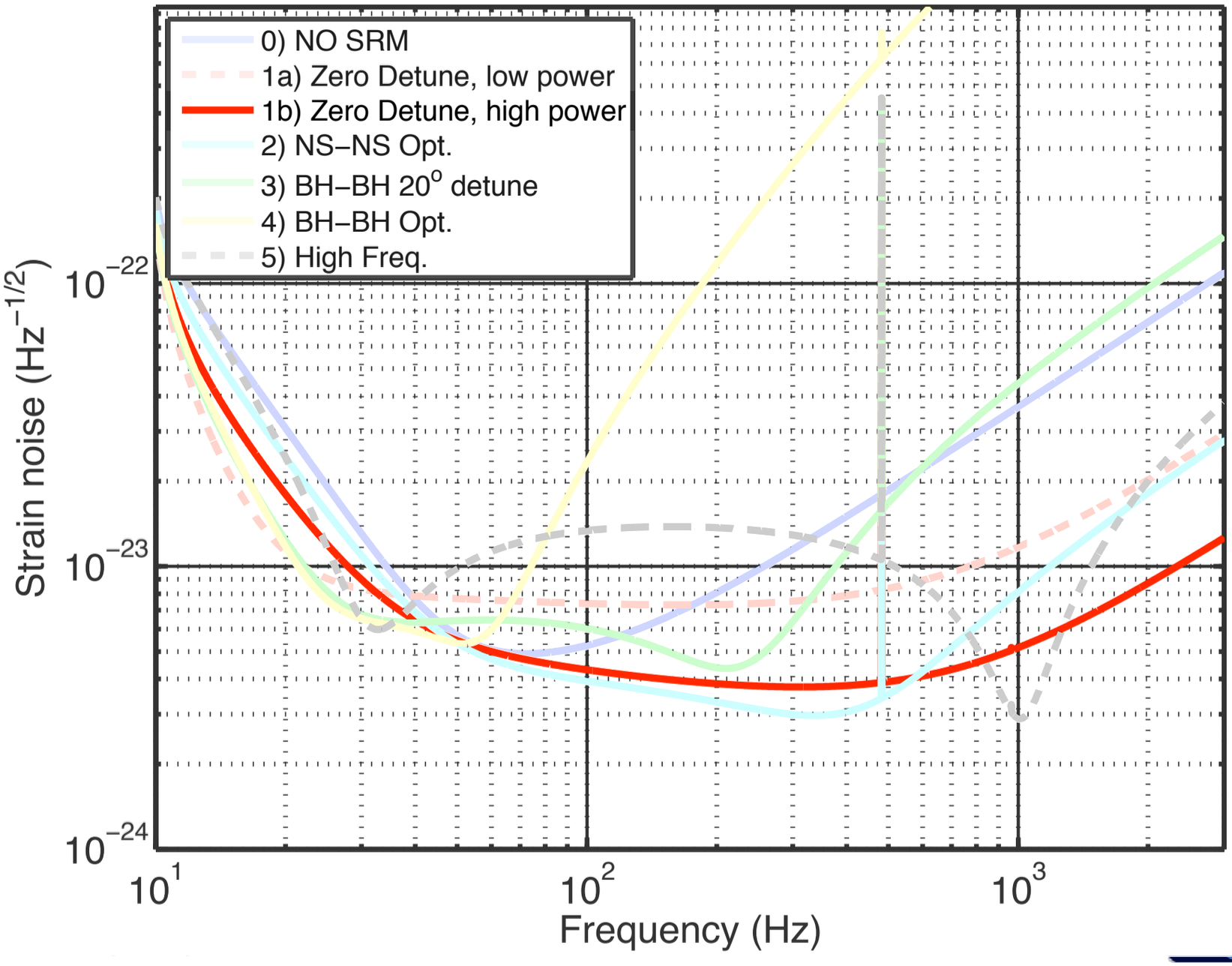
Mode	*NS-NS Range*	*BH-BH Range*	P_{in}	T_{SRM}	ϕ_{SRC}
0	137 Mpc	1.17 Gpc	25 W	100%	–
1a	148 Mpc	1.49 Gpc	25 W	20%	0 deg.
1b	**180 Mpc**	**1.23 Gpc**	**125 W**	**20%**	**0 deg.**
2	200 Mpc	1.03 Gpc	125 W	20%	11 deg.
3	168 Mpc	1.61 Gpc	20 W	20%	20 deg.
4	158 Mpc	1.96 Gpc	4.5 W	20%	72 deg.
5	122 Mpc	1.38 Gpc	125 W	1.1%	4.7 deg.



- Zero detune choice simplifies the length sensing and control,
- is within 10% of the optimum NS/NS range,
- improves BH/BH by 20%,
- and increases sensitivity above 1kHz by 2x

- IFO description and sensitivity goals
- **Sensing and control**
- DC readout
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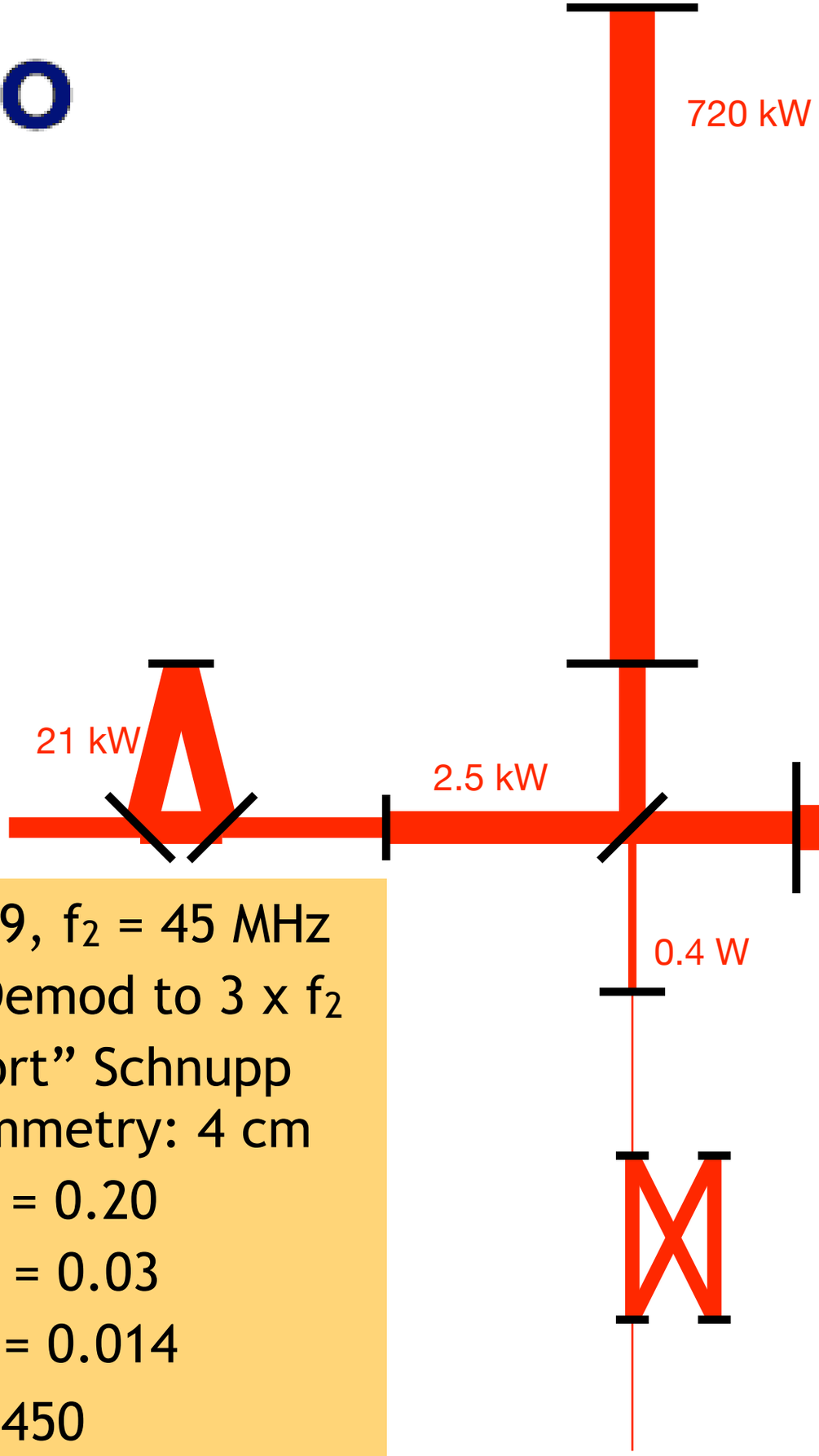
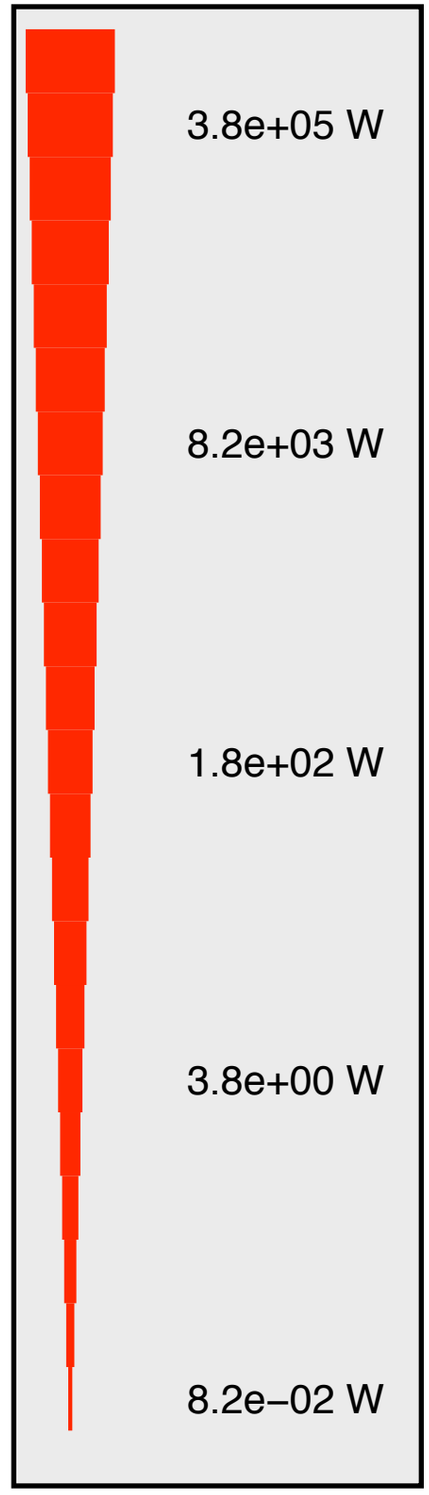
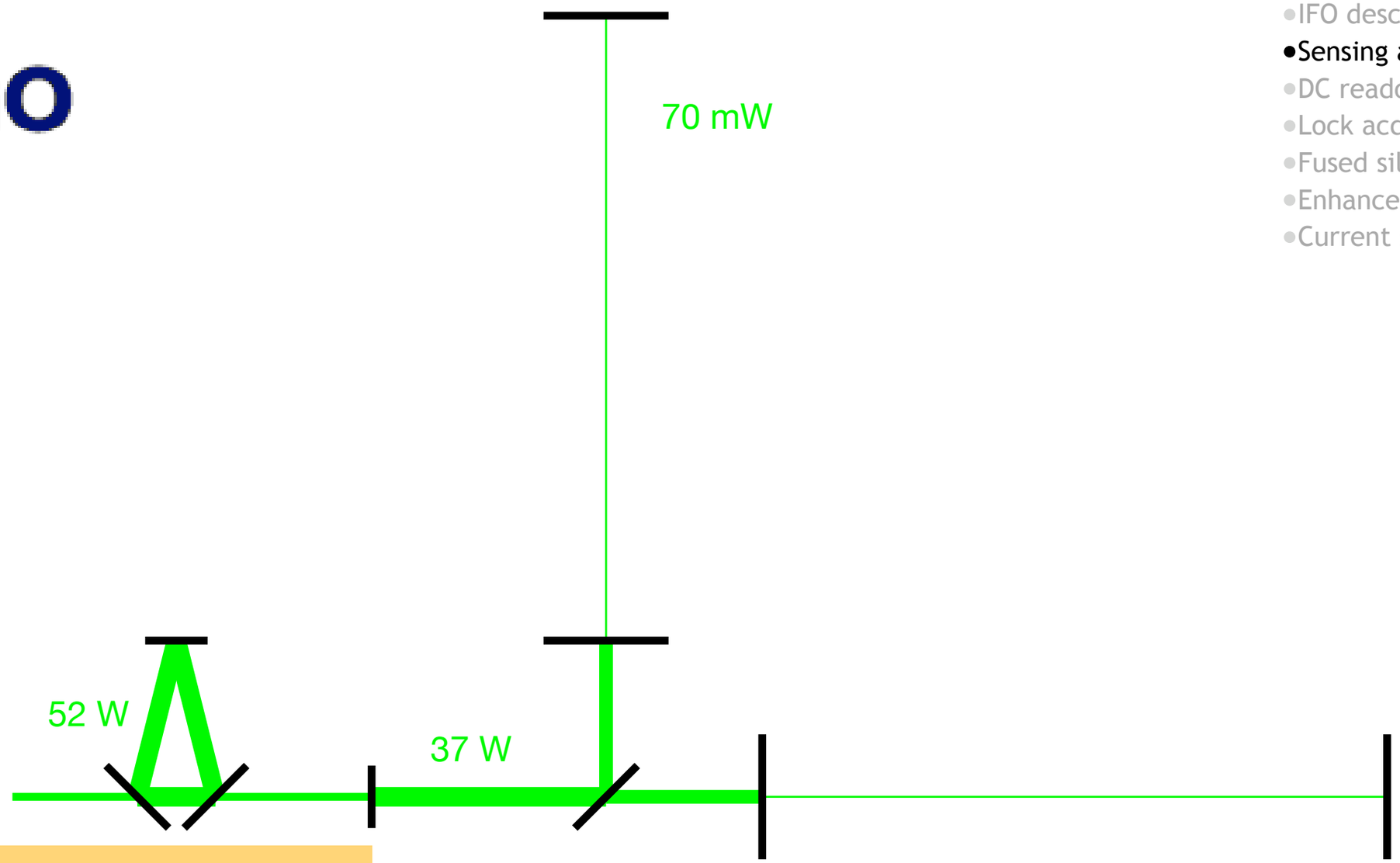
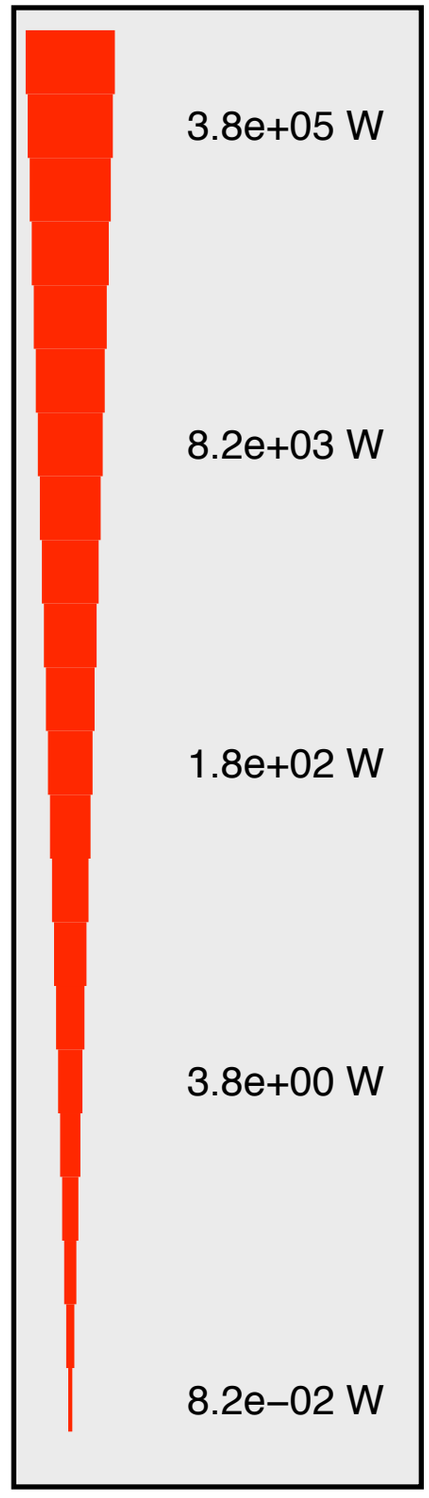


- f_1 = 9, f_2 = 45 MHz
  - Demod to 3 x f_2
- "short" Schnupp asymmetry: 4 cm
- T_{SRM} = 0.20
- T_{PRM} = 0.03
- T_{ITM} = 0.014
- $\mathcal{F}$ ~ 450



M. Evans, S. Ballmer





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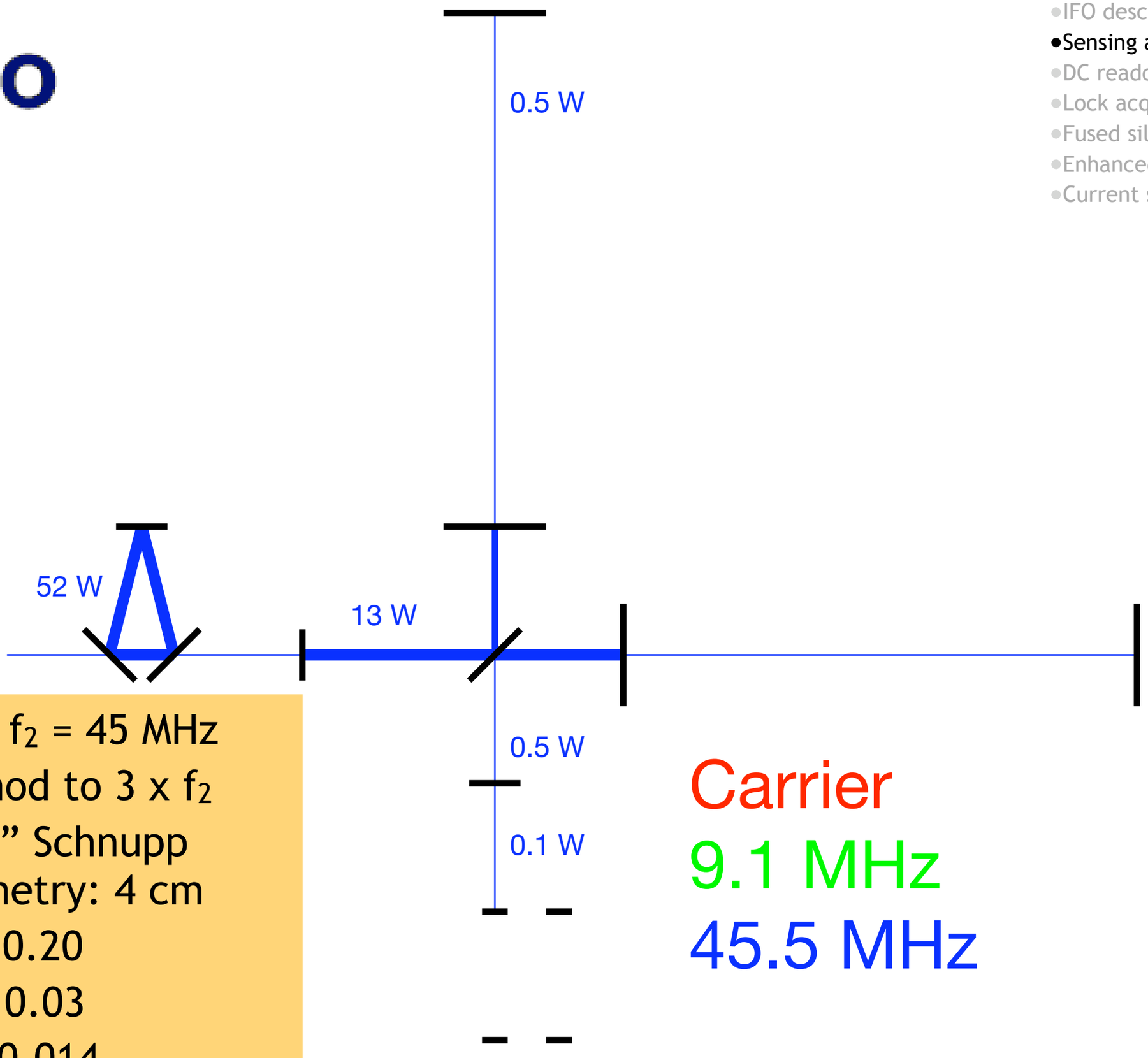
— Carrier
9.1 MHz
– – 45.5 MHz
– –



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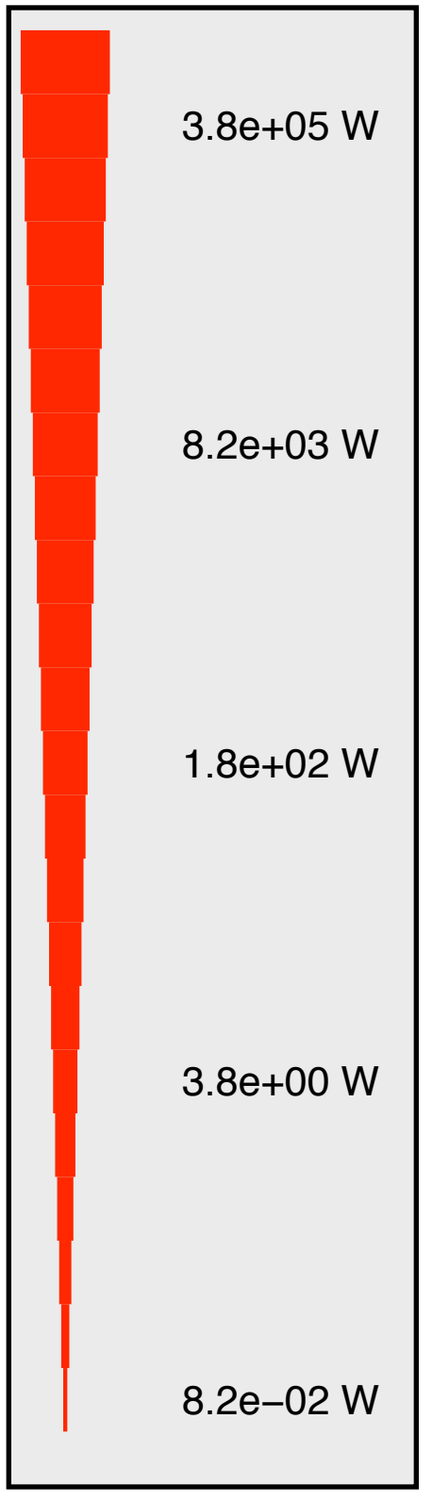

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- **Sensing and control**
- DC readout
- Lock acquisition
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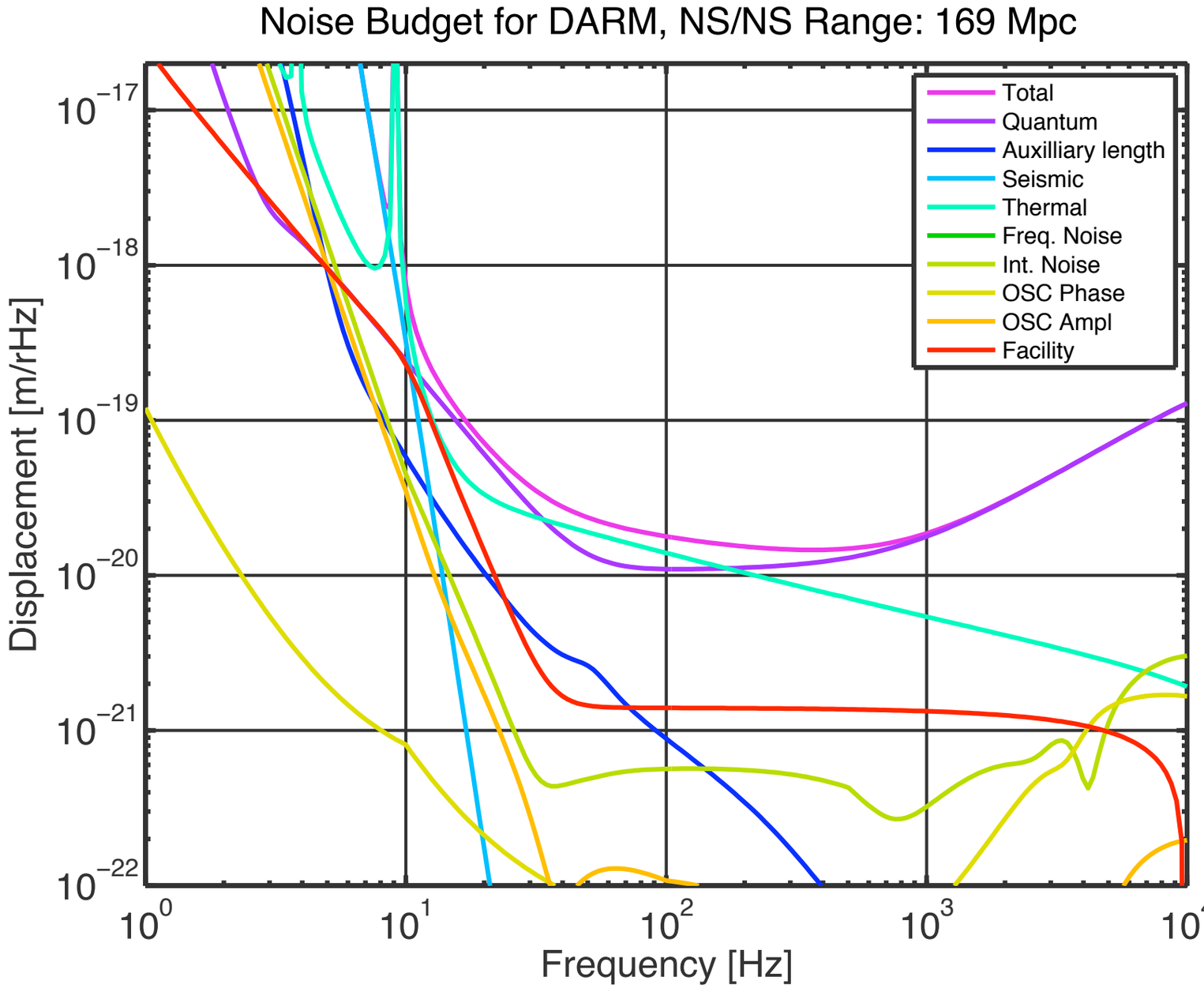


(100 mW ~ 2x10^{-10} W/Hz$^{1/2}$)

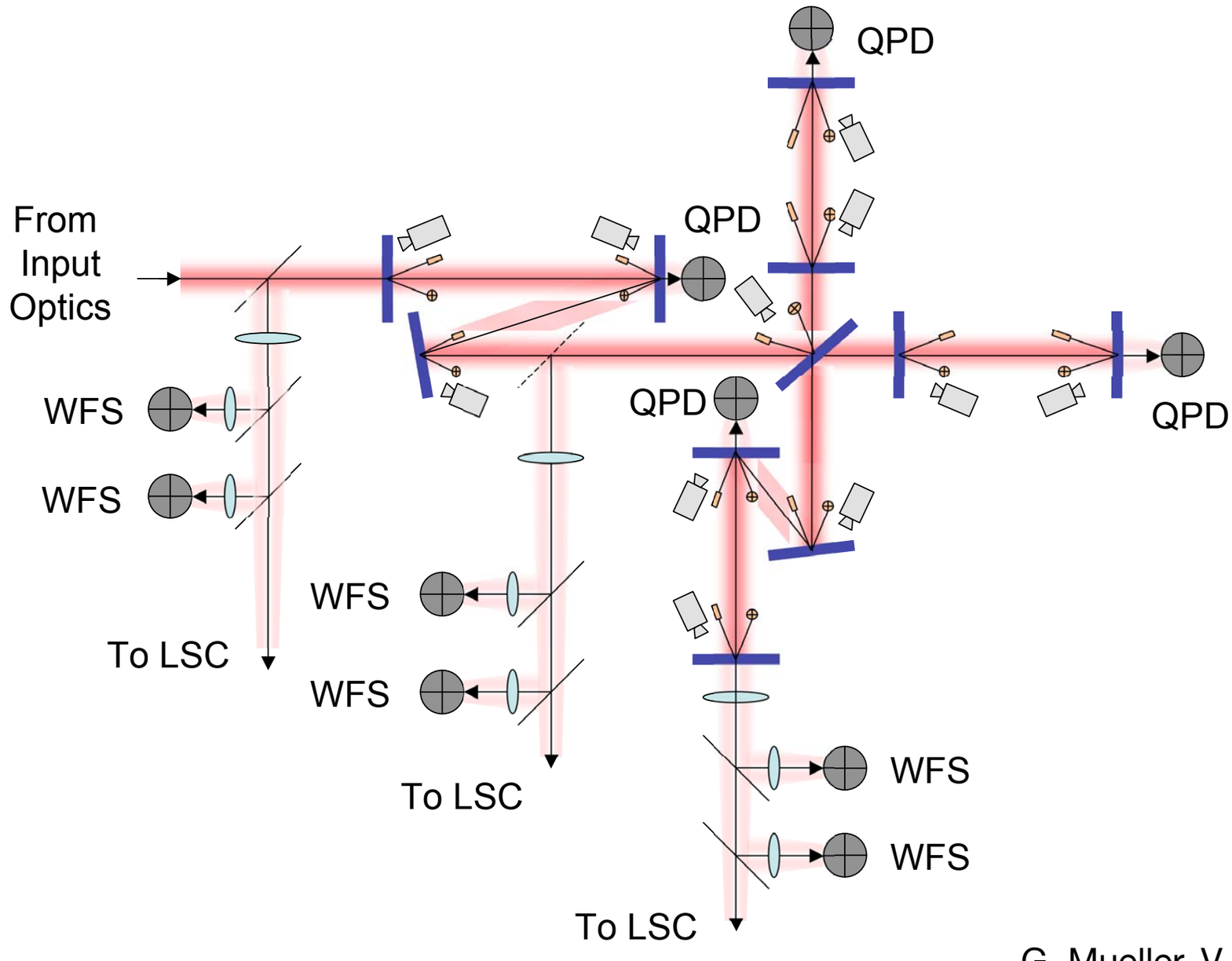
use *Looptickle* model to simulate AdvLIGO plant

Sensing Matrix in Watts per meter at 1 kHz, for Science Mode 1 (zero detuning)

Port	CARM	DARM	PRCL	MICH	SRCL
REFL I1	**9.4e+08**	1.3e+05	7.3e+07	1e+06	**1.4e+04**
AS DC	3e+06	**9.7e+09**	6.7e+05	3.4e+07	7e+03
POP I1	3.2e+07	4.4e+03	**1.2e+07**	**6.6e+03**	**3e+02**
POP Q2	8.7e+06	4.2e+04	**4.6e+05**	**7.4e+05**	**8.8e+04**
POP I2	8.7e+06	9e+03	**1.8e+06**	**9.9e+04**	**3e+05**

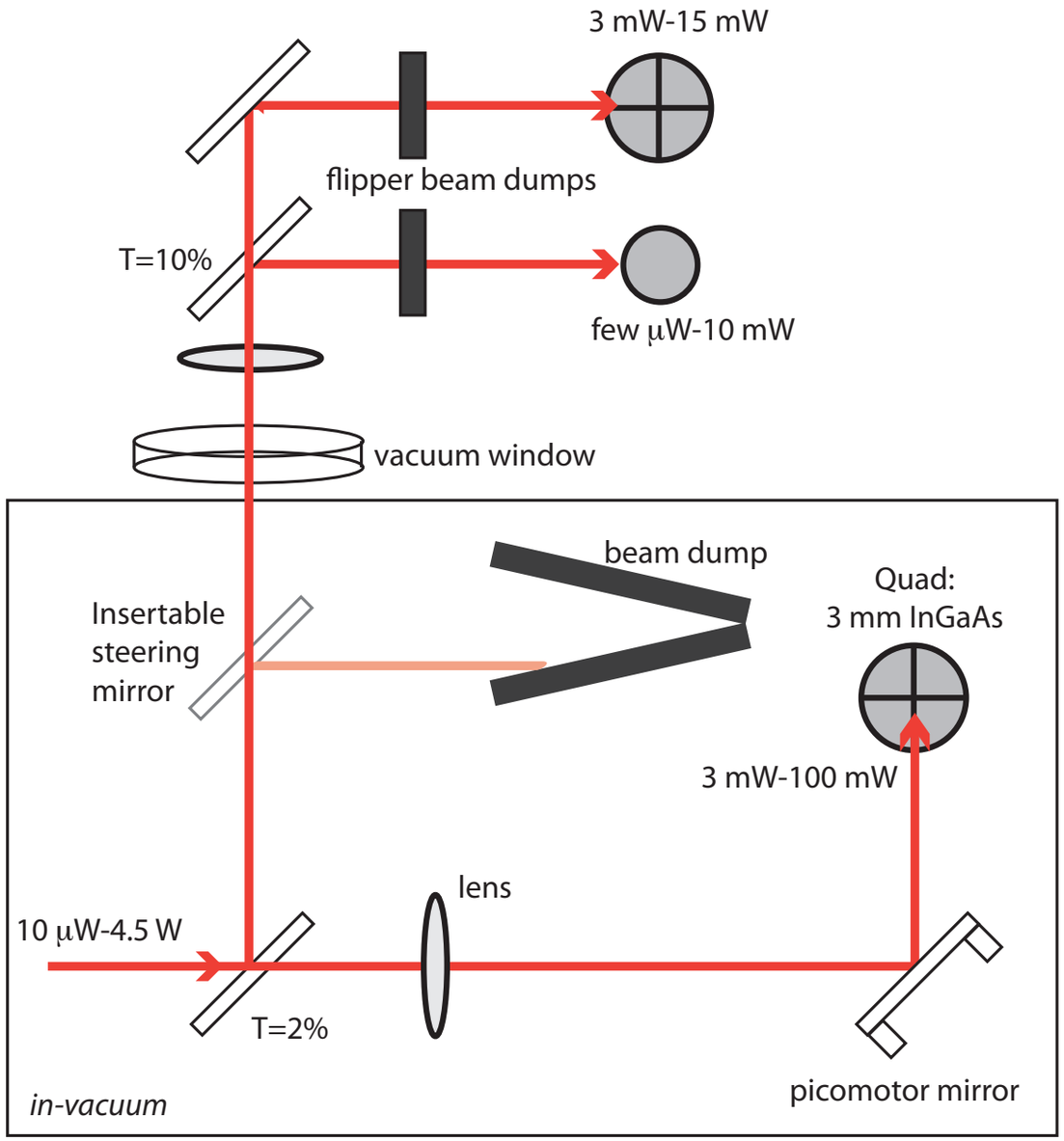
S. Ballmer

- Initial unlocked alignment, in-lock cavity optimization, angular spring damping
- Optical levers
- Wavefront sensors
- QPDs
- Non-diagonal sensing matrices
- 5 to 125 W operation

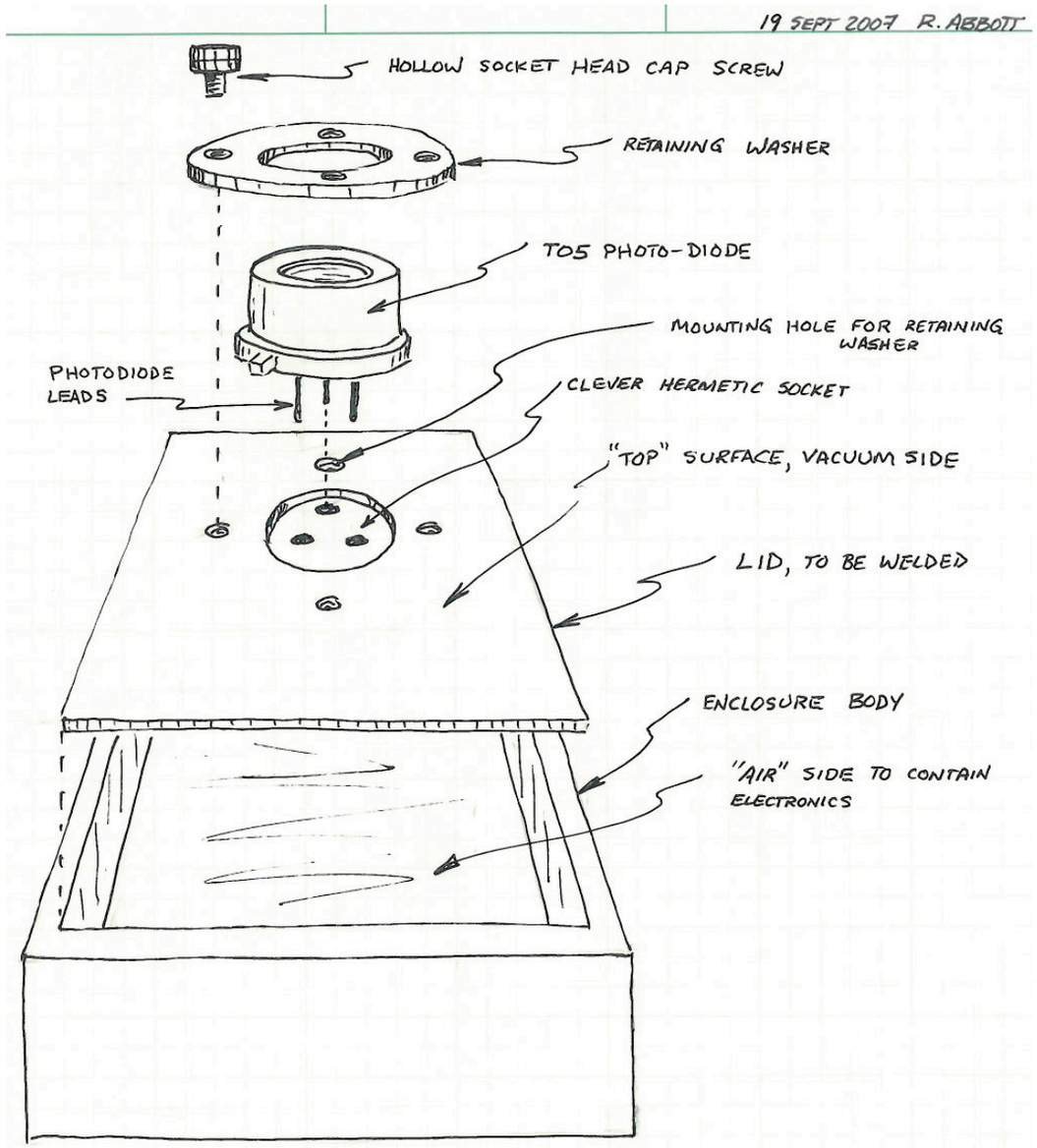


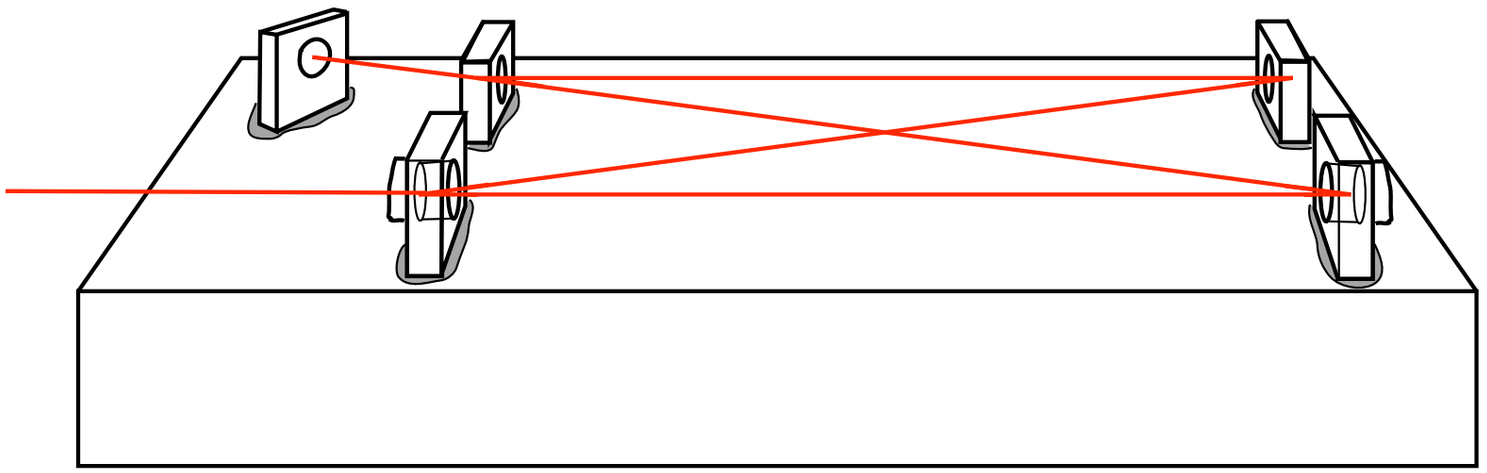
G. Mueller, V. Frolov, *et al.*

• In-vacuum sensing for all DOF

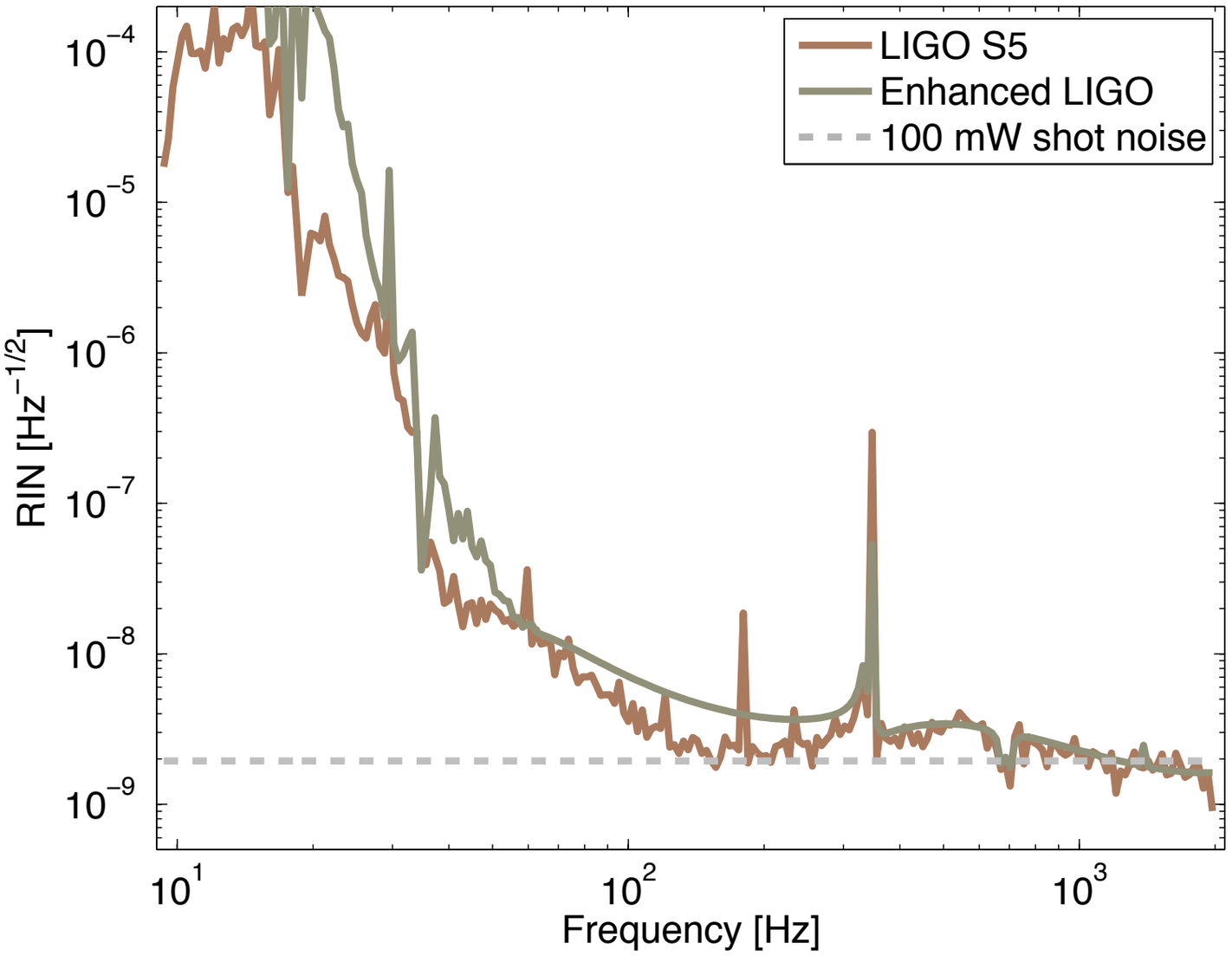


ETM transmission

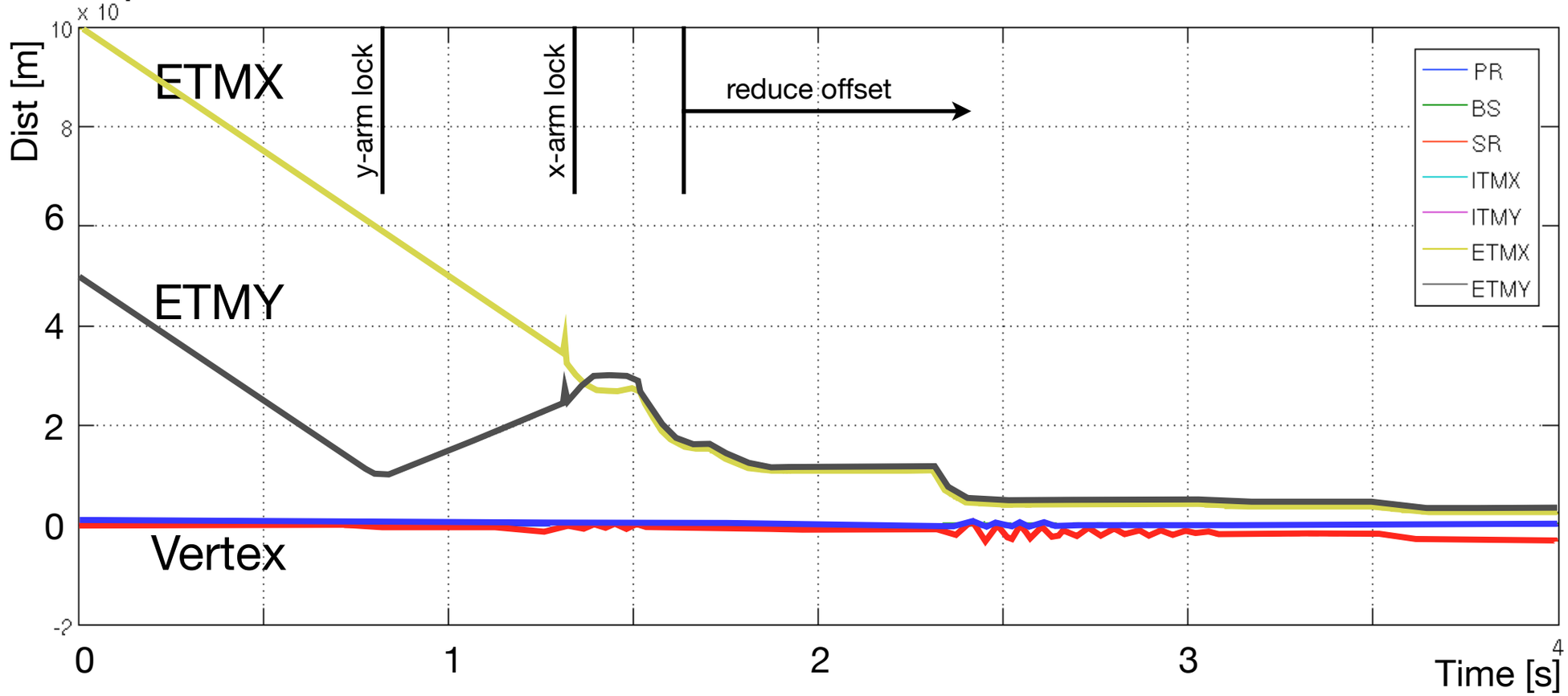




- Homodyne detection of DARM: use the carrier as the reference oscillator
- ~10 pm DARM offset
- Requires RIN ≈ 10^{-9} $Hz^{-1/2}$ at 10 Hz
- Output Mode Cleaner



- Rapid, deterministic lock acquisition
- Use LAI for initial de-tuned arms
- Compensate for CARM optical spring
- 3f vertex signals
- Early common mode locking?



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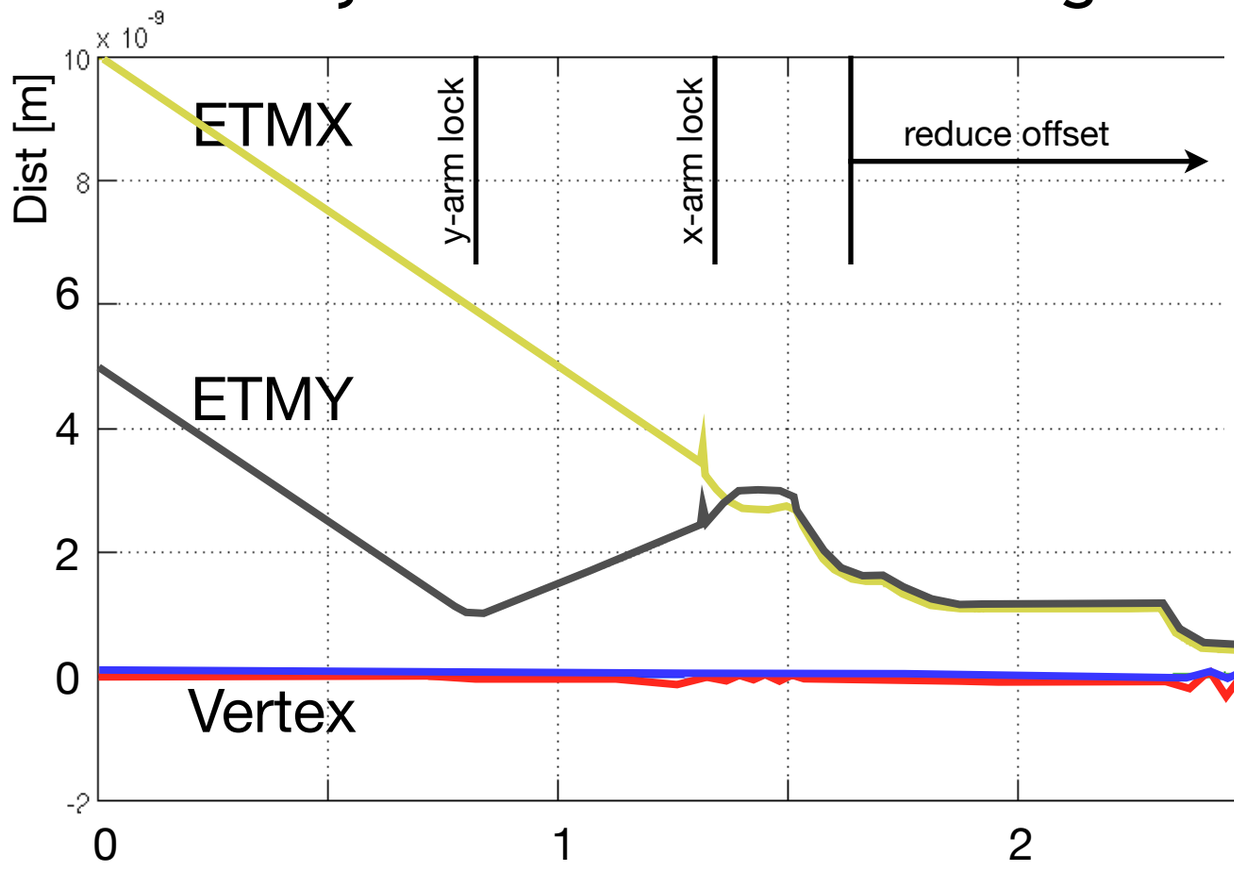
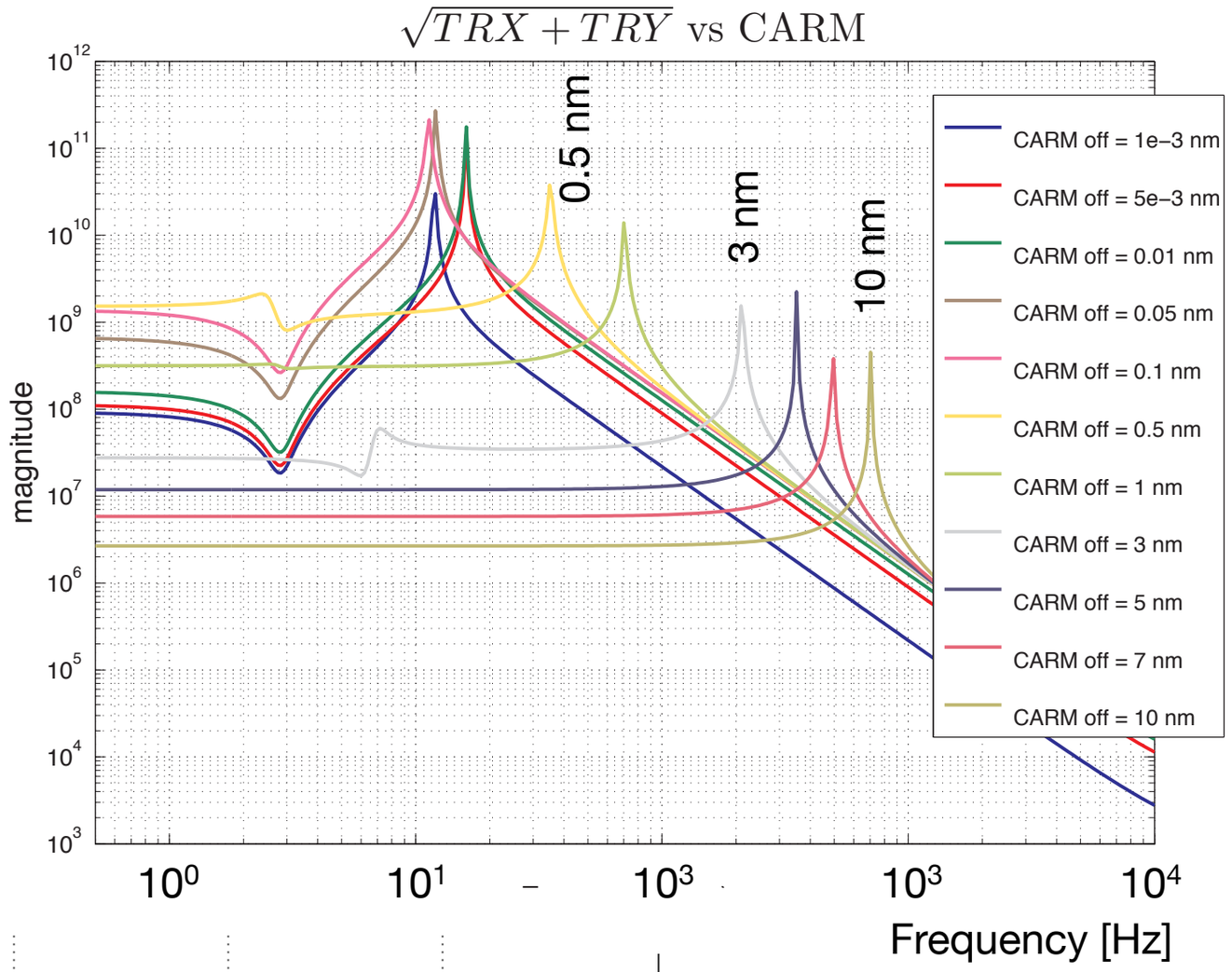
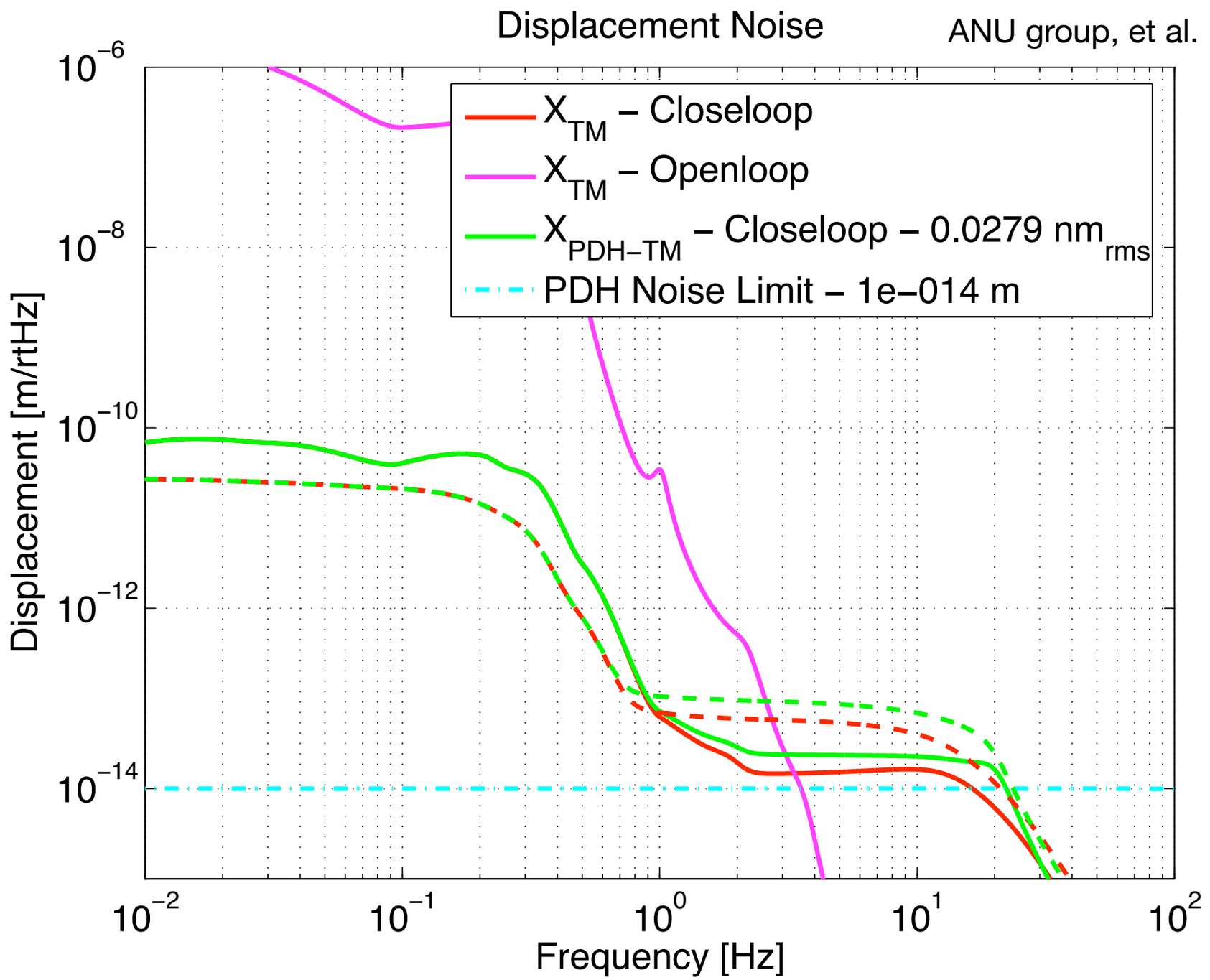
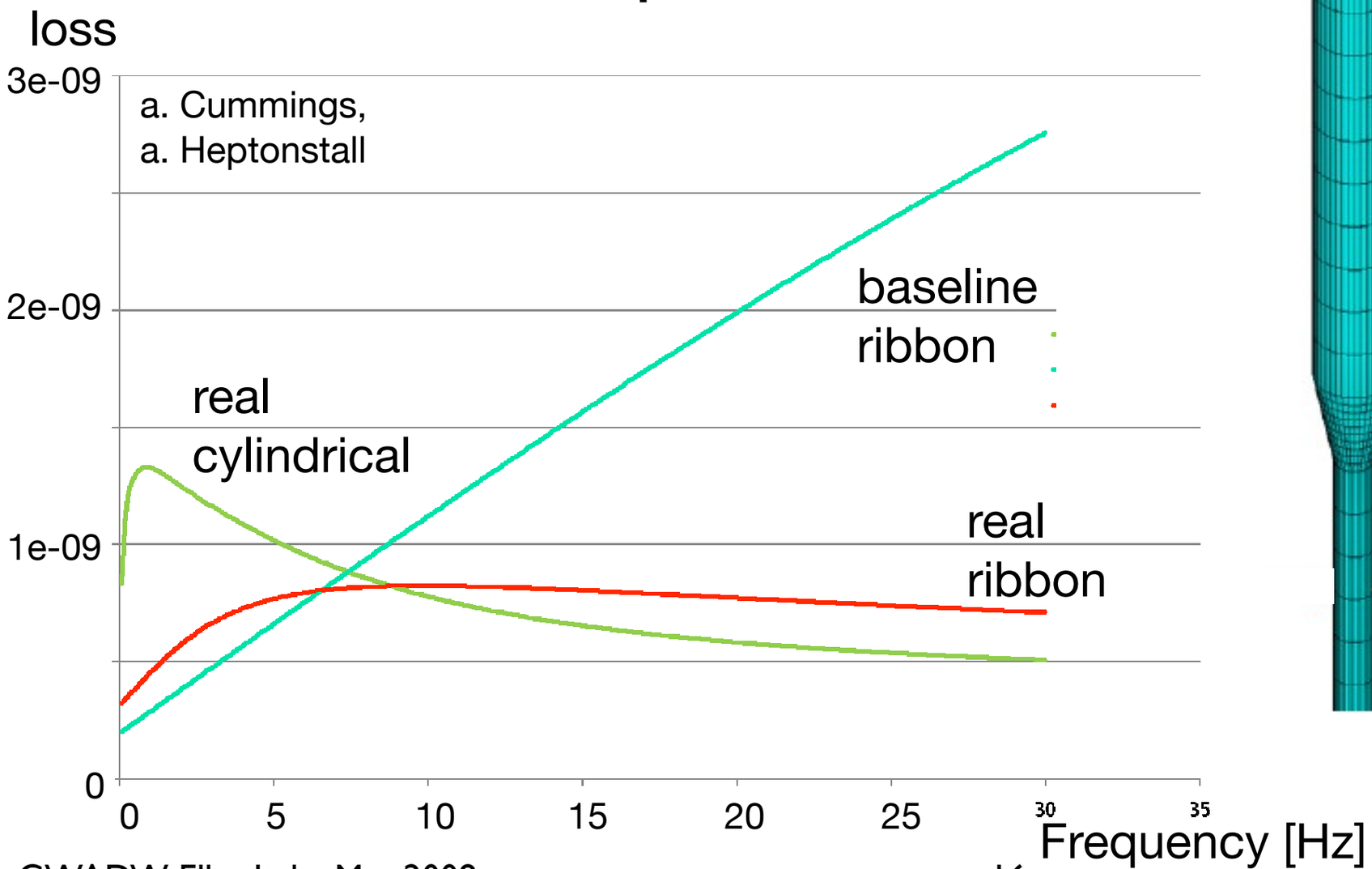


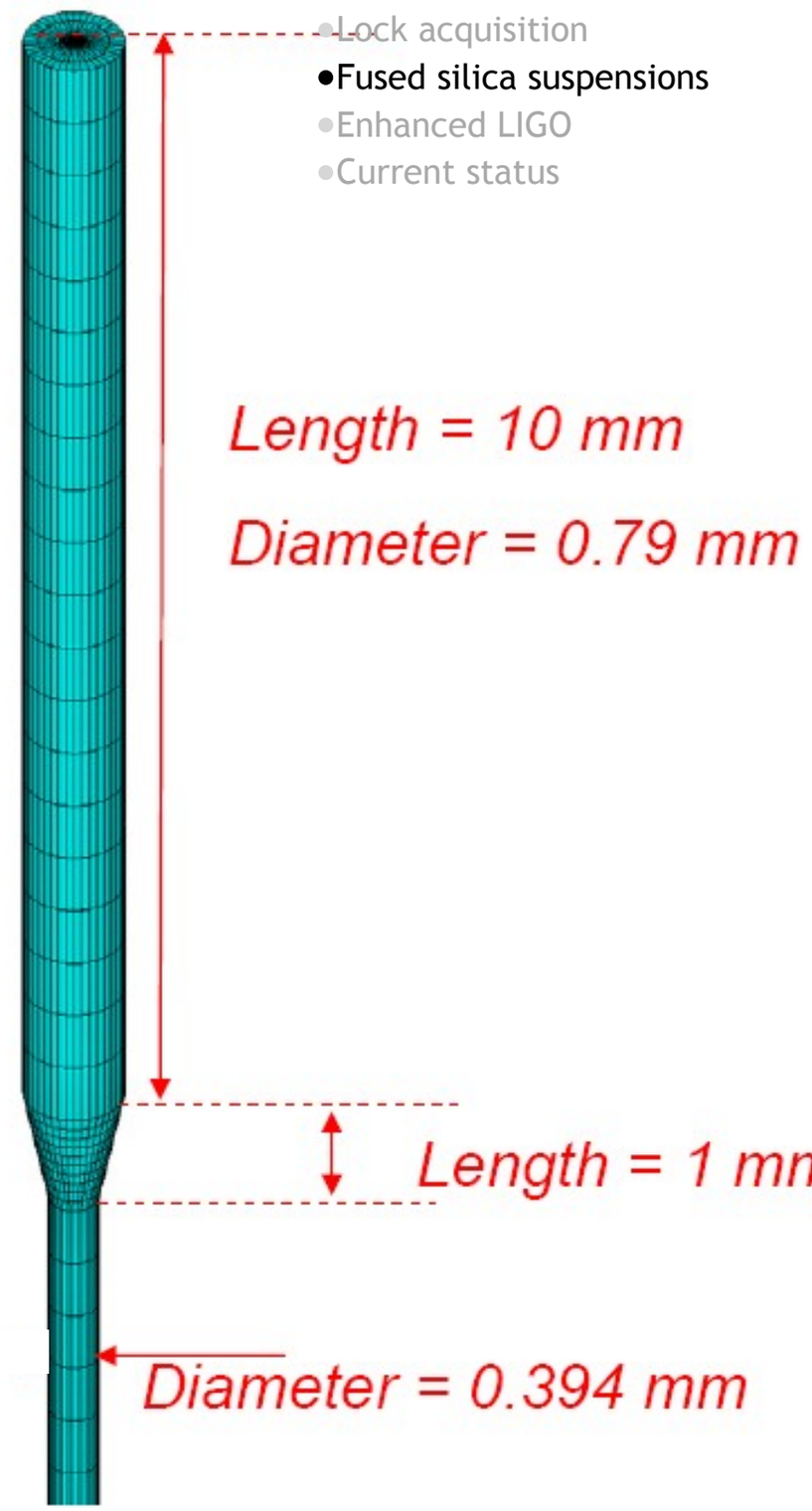


- Lock Acquisition Interferometer to control arm cavities independent of vertex
- Digital Interferometery, Seismic Platform Interferometer, frequency shifted PDH
- Reduce RMS arm motion to $\lesssim$ 1 nm
- Reduce force required from quad actuators

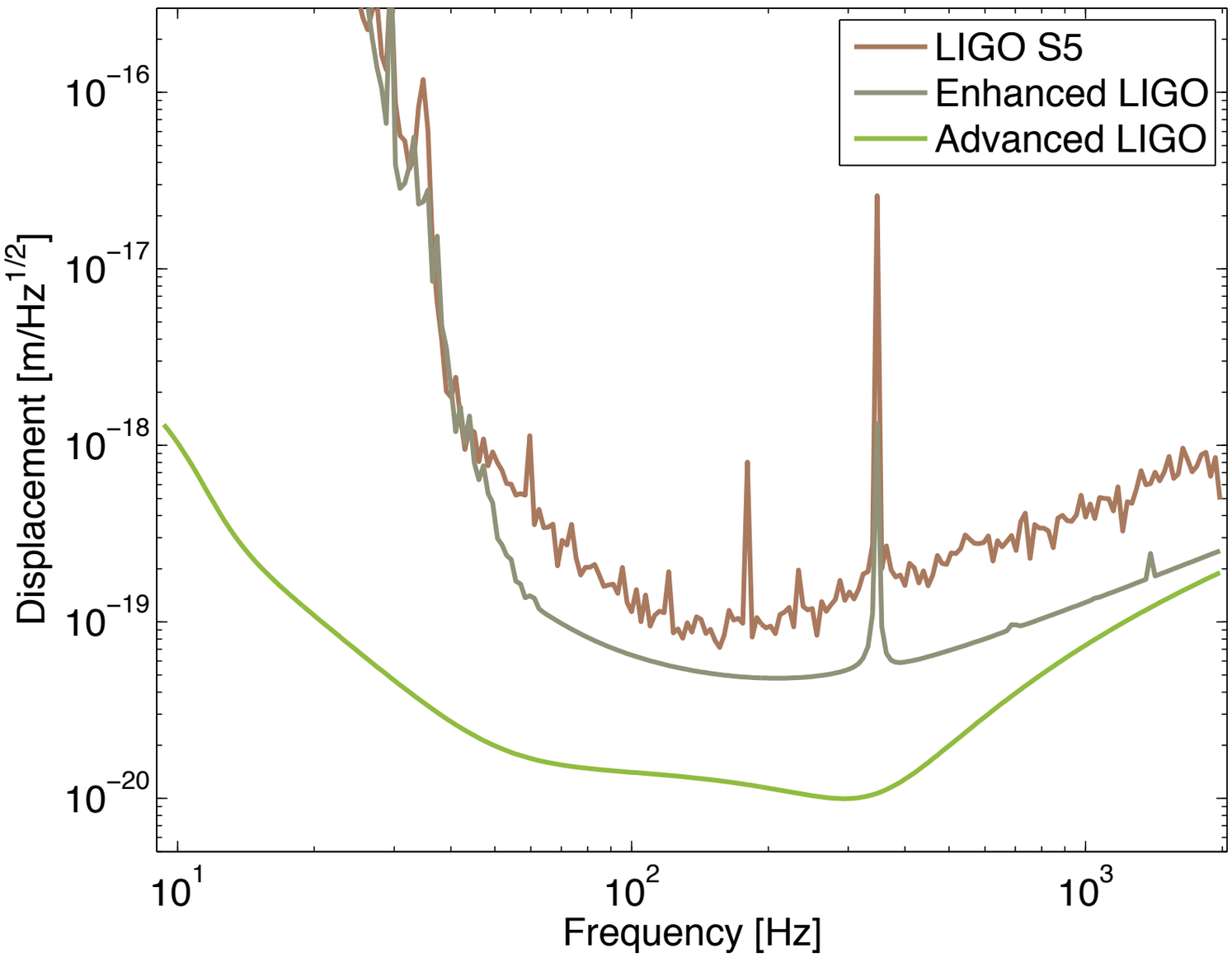


- Stepped circular fiber new advLIGO baseline
- Already produced at LASTI
- Cylindrical fibers proven in GEO600 suspensions



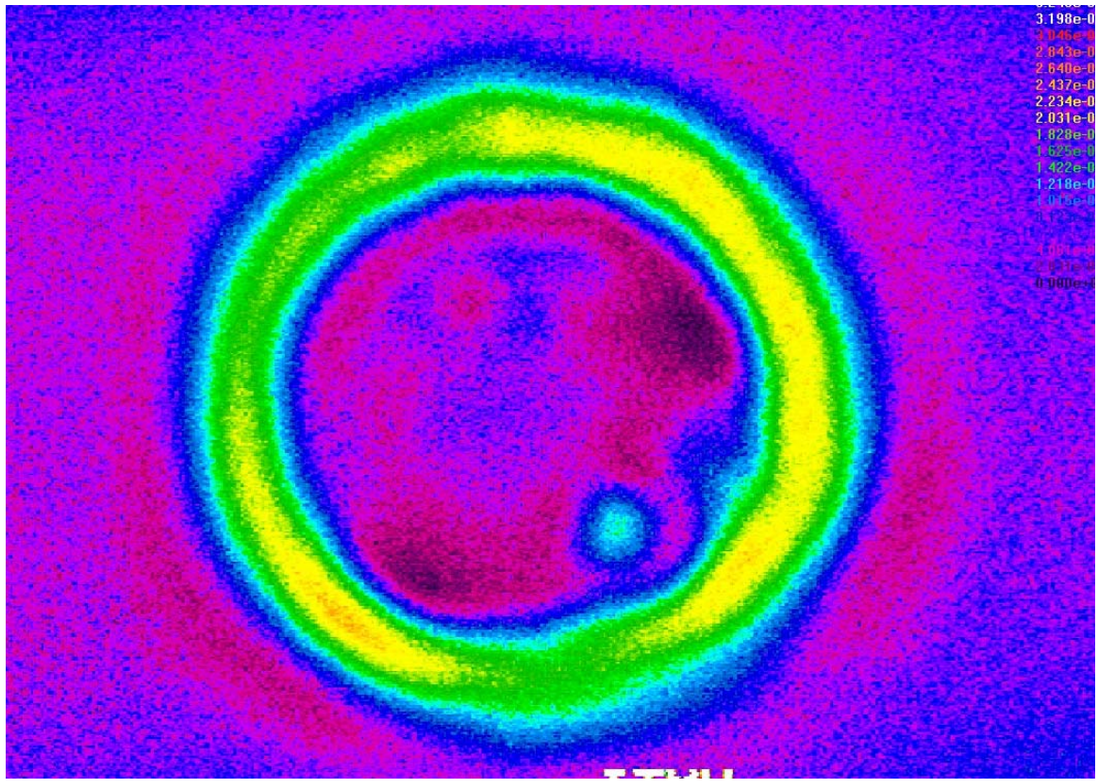


- Advanced LIGO approved by NSF
- Stable power- and signal- recycling
- Zero detune, 125 W, 180 Mpc **baseline**
- 9, 45 MHz RF sidebands with short Schnupp asymmetry
- DC readout with output mode cleaner
- Lock acquisition interferometer
- Tapered, cylindrical suspension

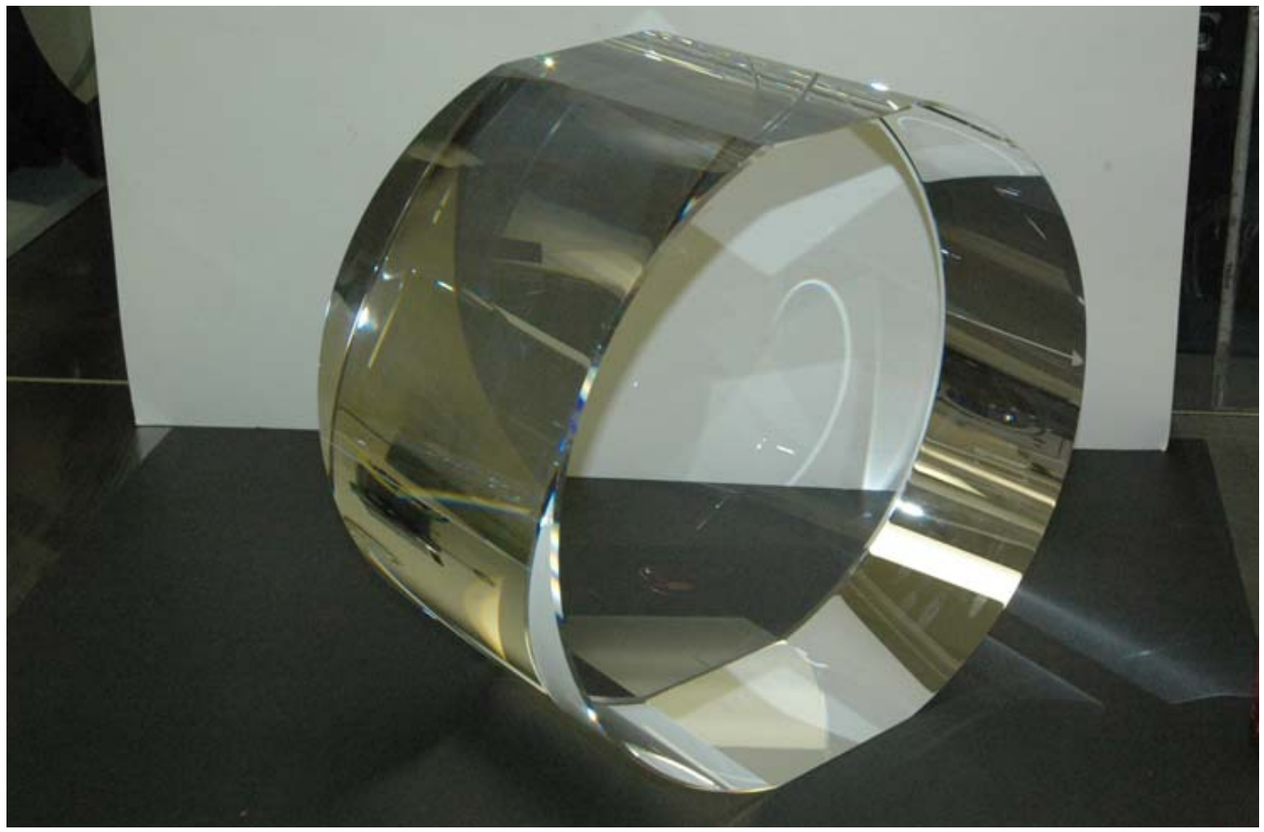


- Enhanced LIGO commissioning underway, S6 in January 2009
  - DC readout with OMC
  - HAM Internal Seismic Isolation (ISI)
  - 35 W LZH laser
- Advanced LIGO at LASTI
  - BSC ISI
  - Quadruple suspension prototype

TCS upgrades



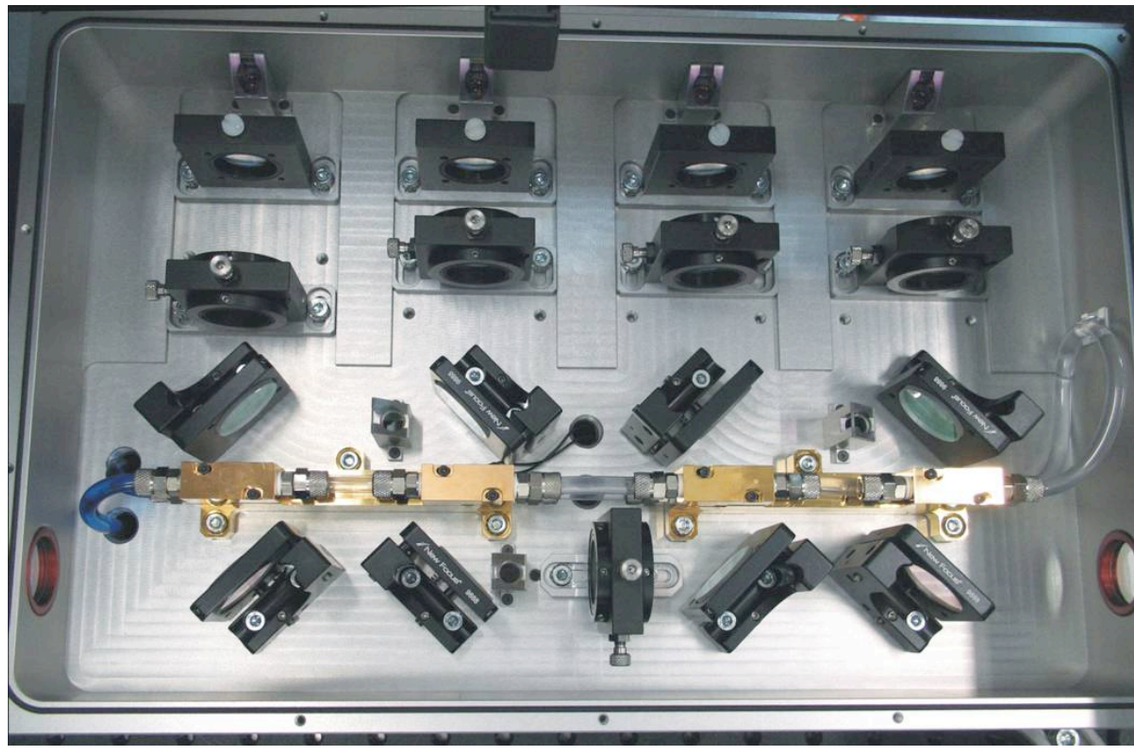
Quad at LASTI

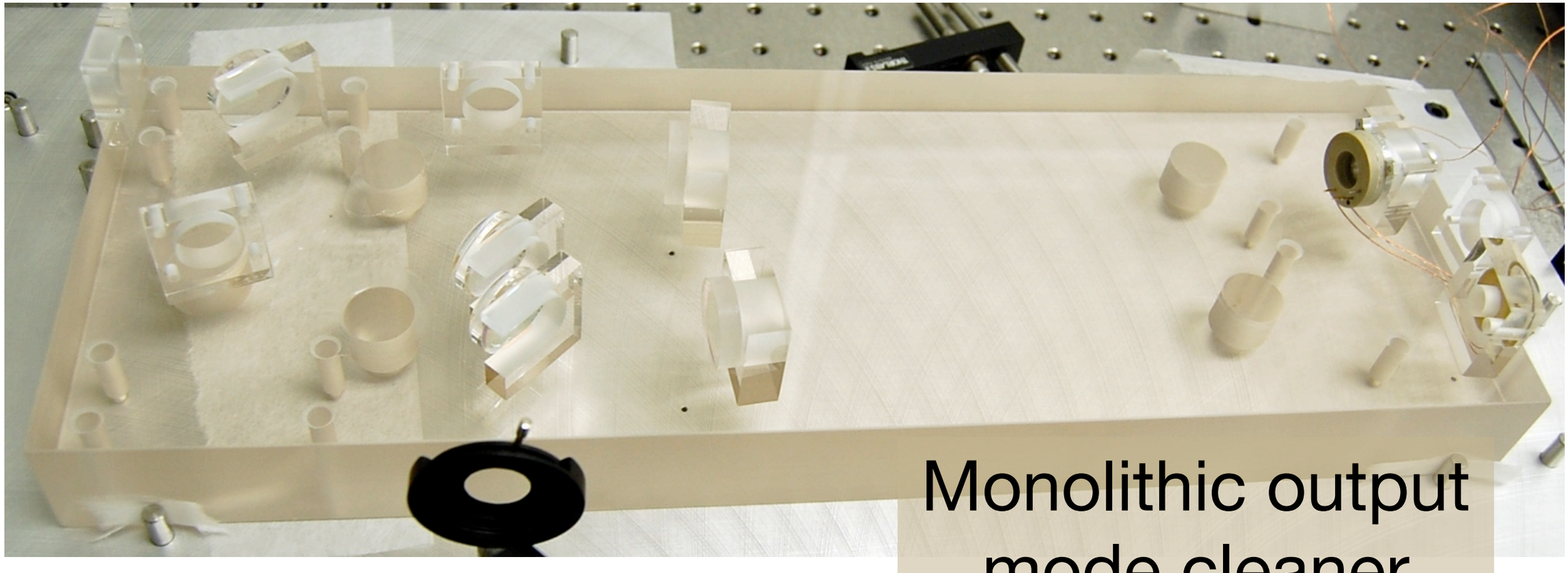


RFQ's for blanks "out on the street"

LIGO

3x 35 W LZH PSL delivered





Monolithic output mode cleaner

LIGO

HAM ISI at LLO with OMC and suspension