Exploring Advanced Techniques with GEO600

H.Grote
for the GEO600 team

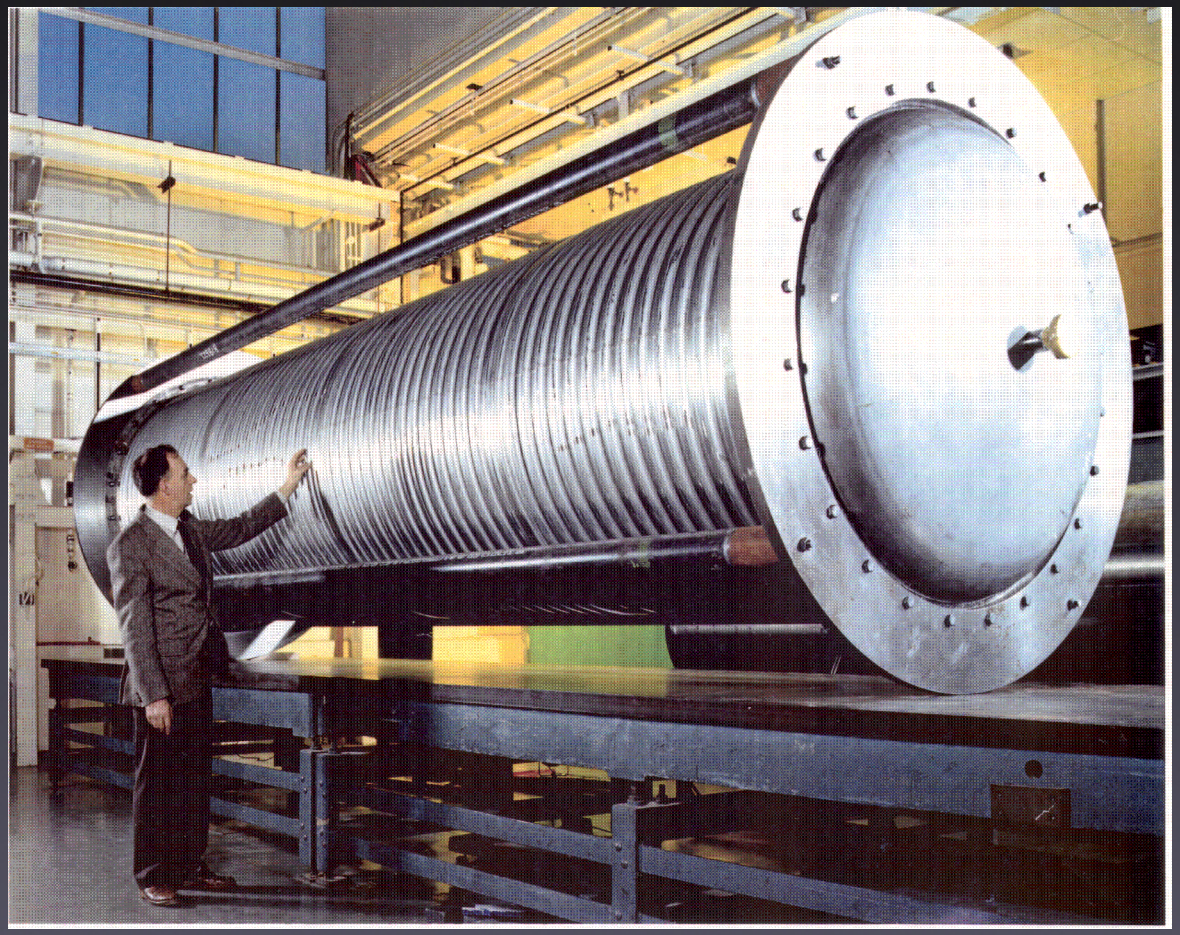
GWADW 2014

Beam Tube

AISI 316LN
Stainless Steel
0.9 mm thick

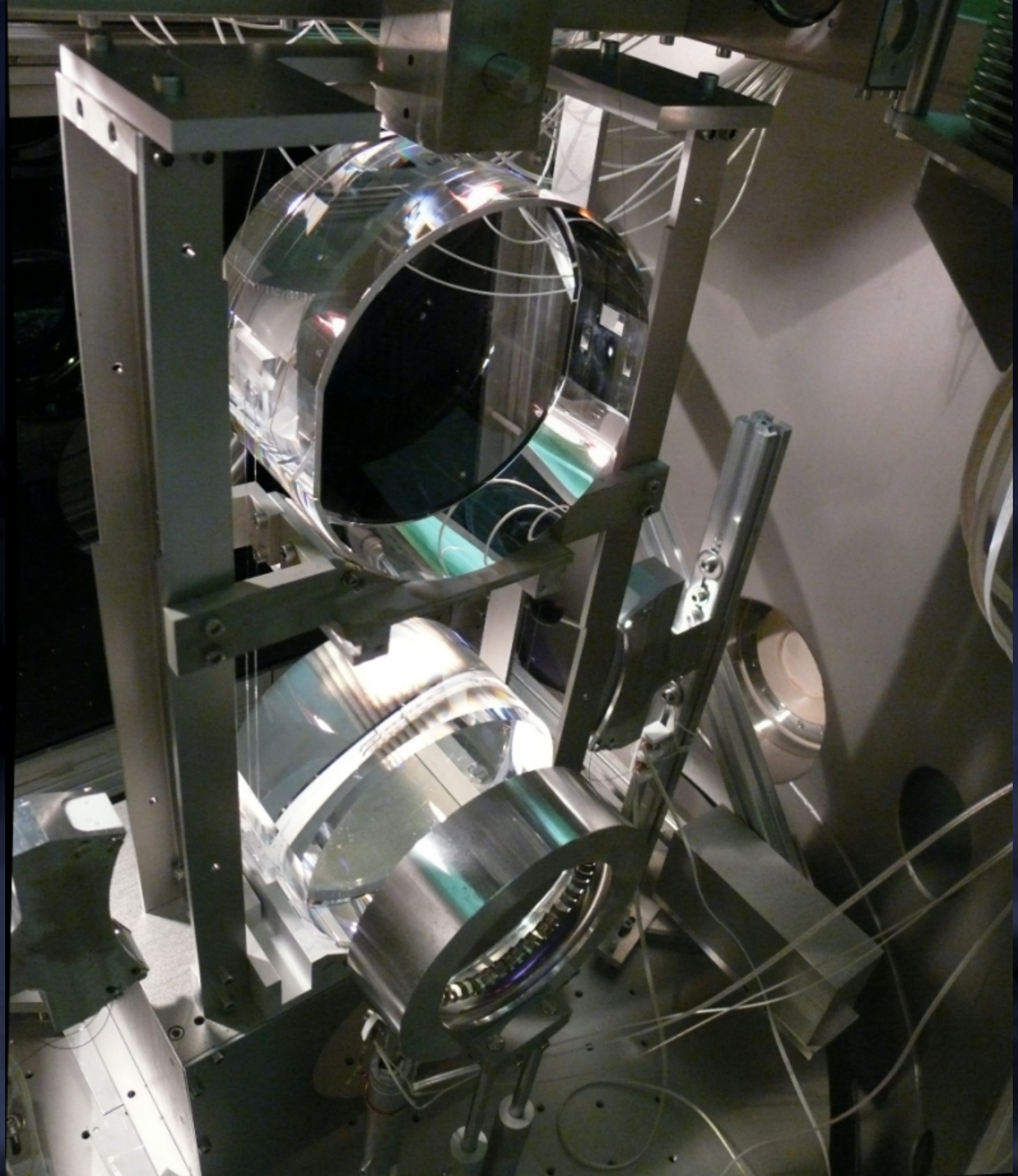
Corrugated with
Period 3 cm and
Depth 1.7 cm.

Tube dia. 0.6 m

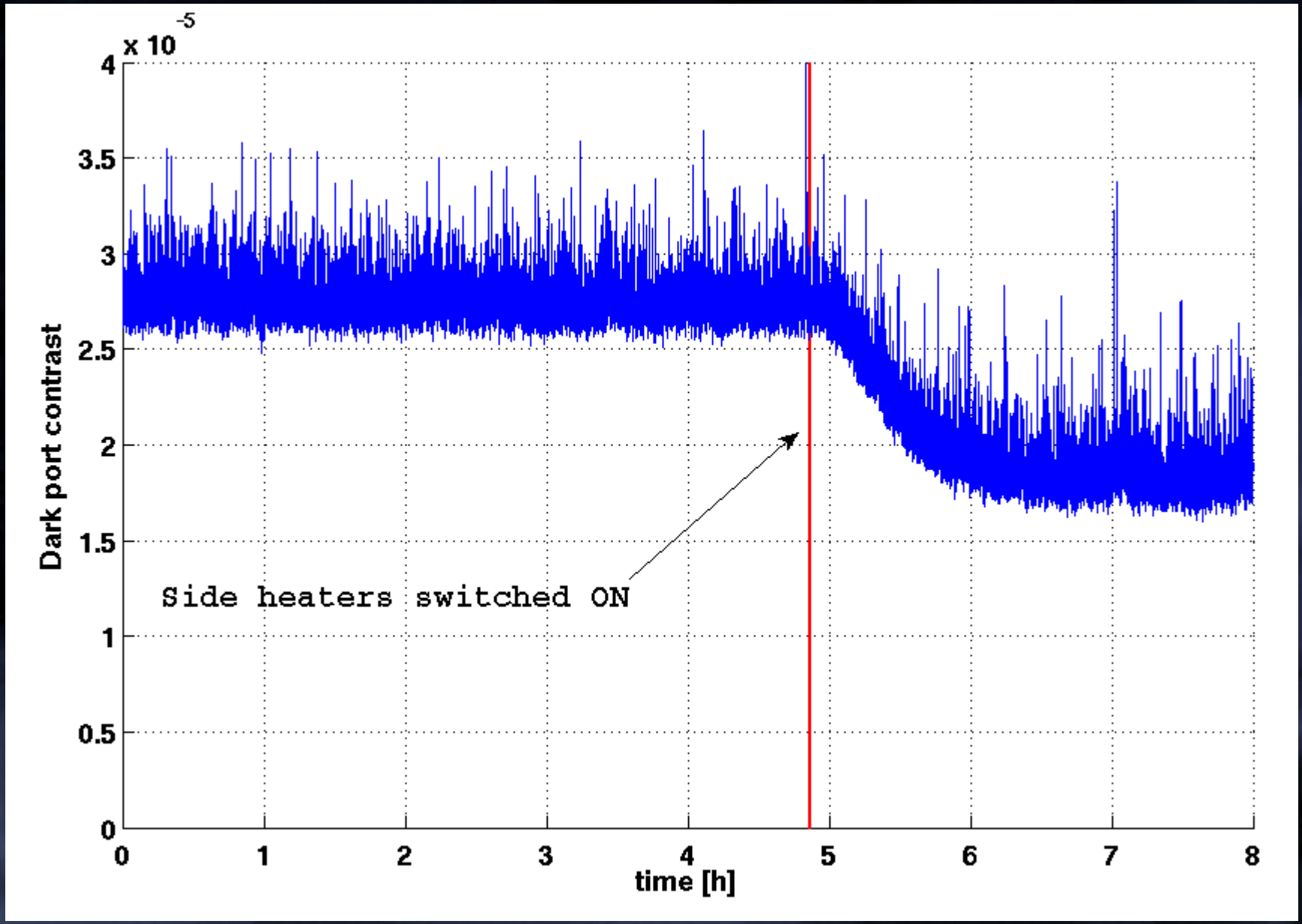


Test setup:
Tube diameter 1.5 m

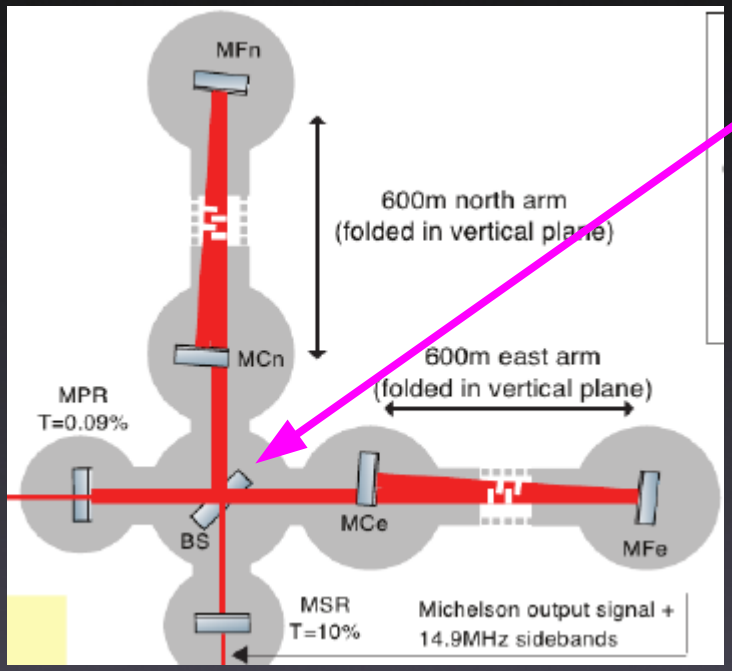
Corrugation - material saving: ~factor 2.5
Soft and leightweight tube



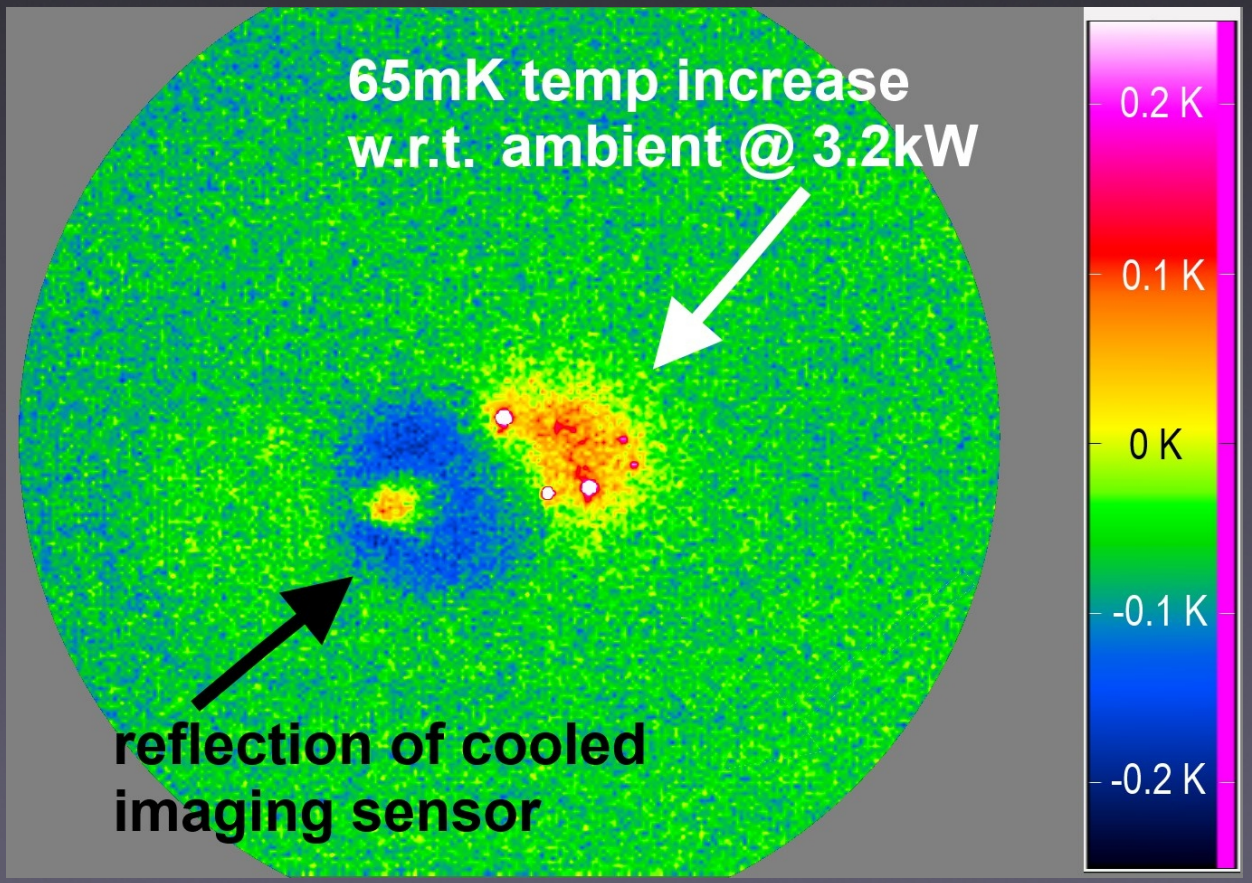
Improved IFO Contrast from side heaters



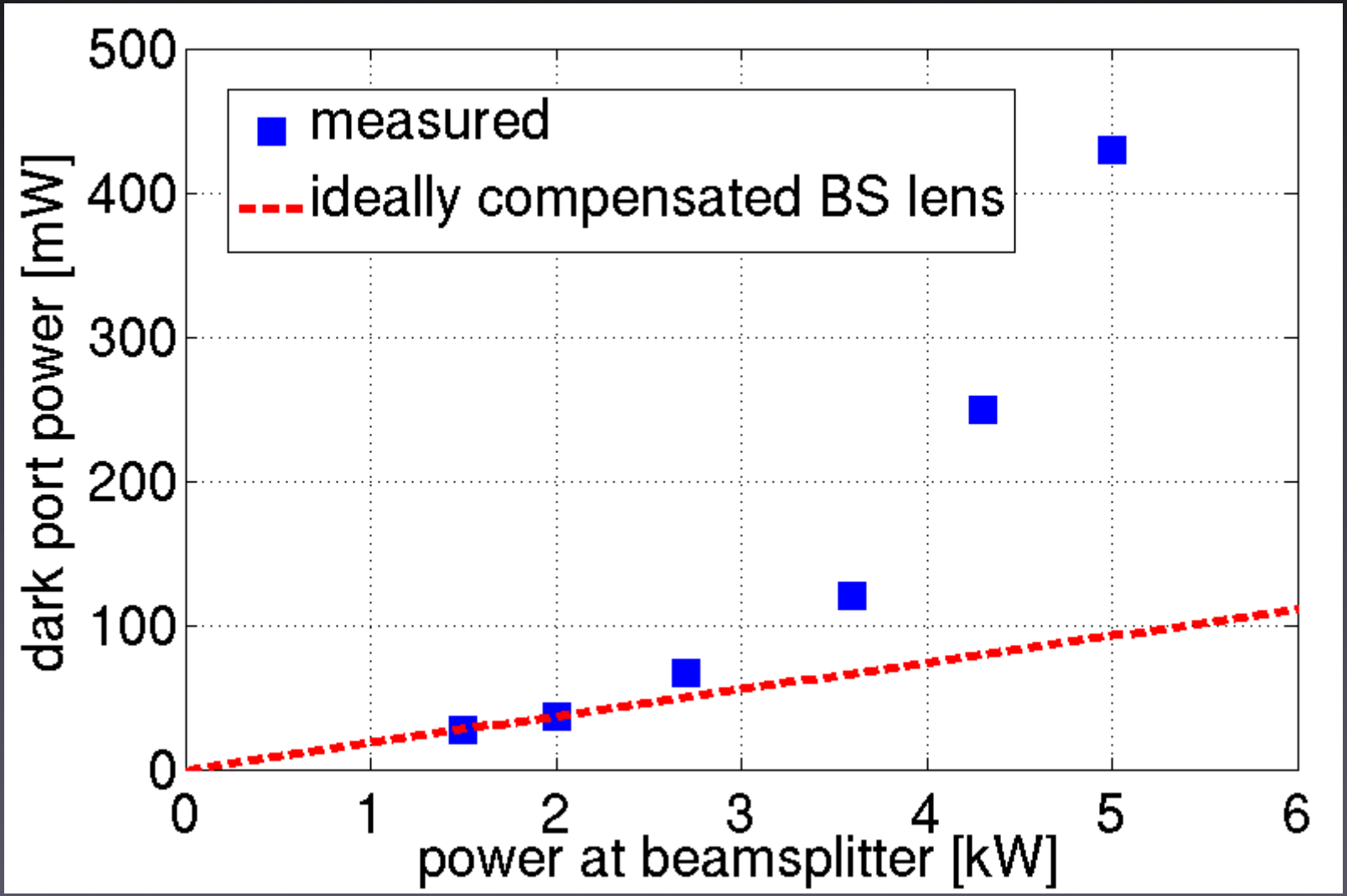
~3kW at Beamsplitter



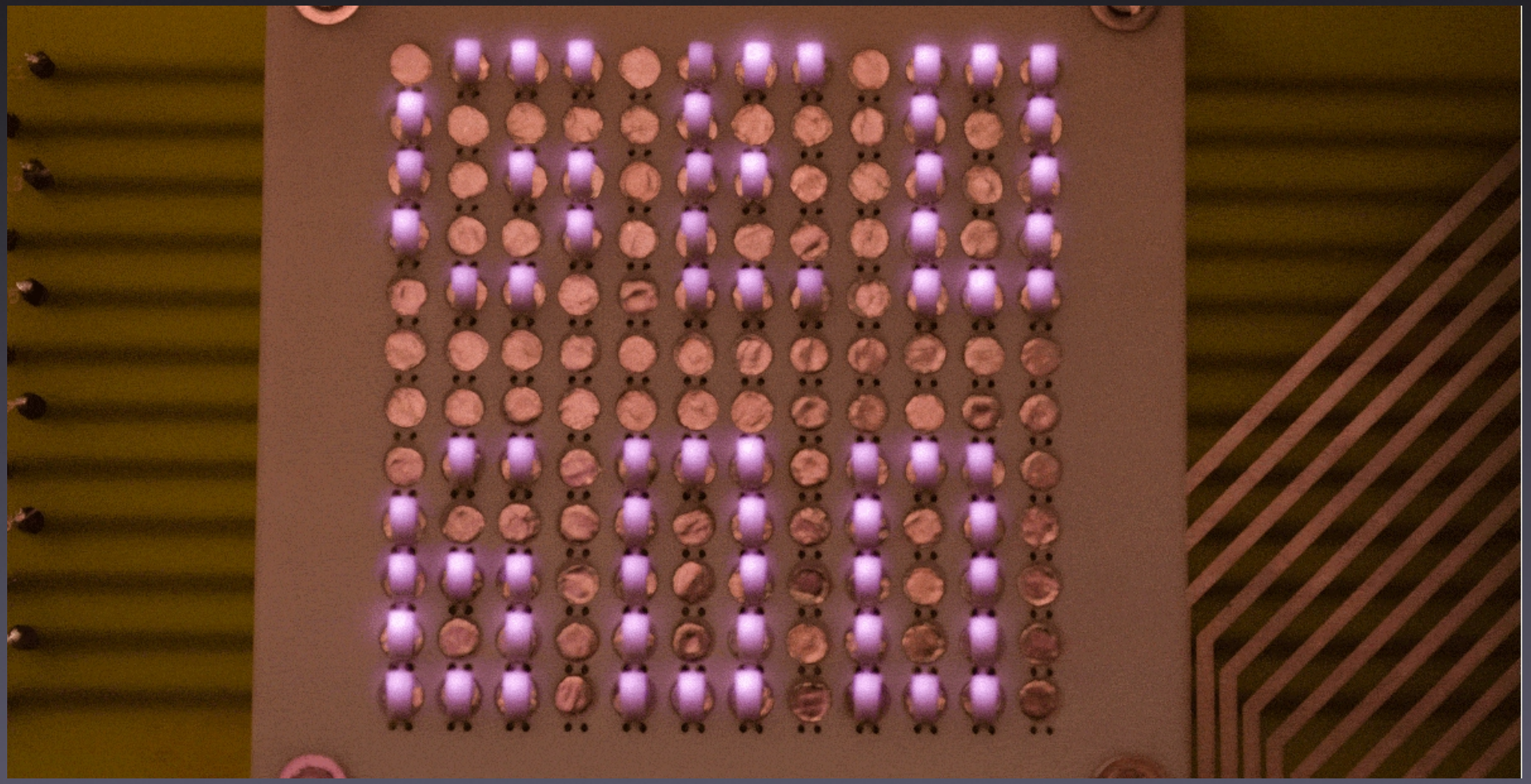
Direct measurement of thermal lens / local heating, consistent with 0.5ppm / cm absorption @ 1064 nm



Dark port power vs. BS power

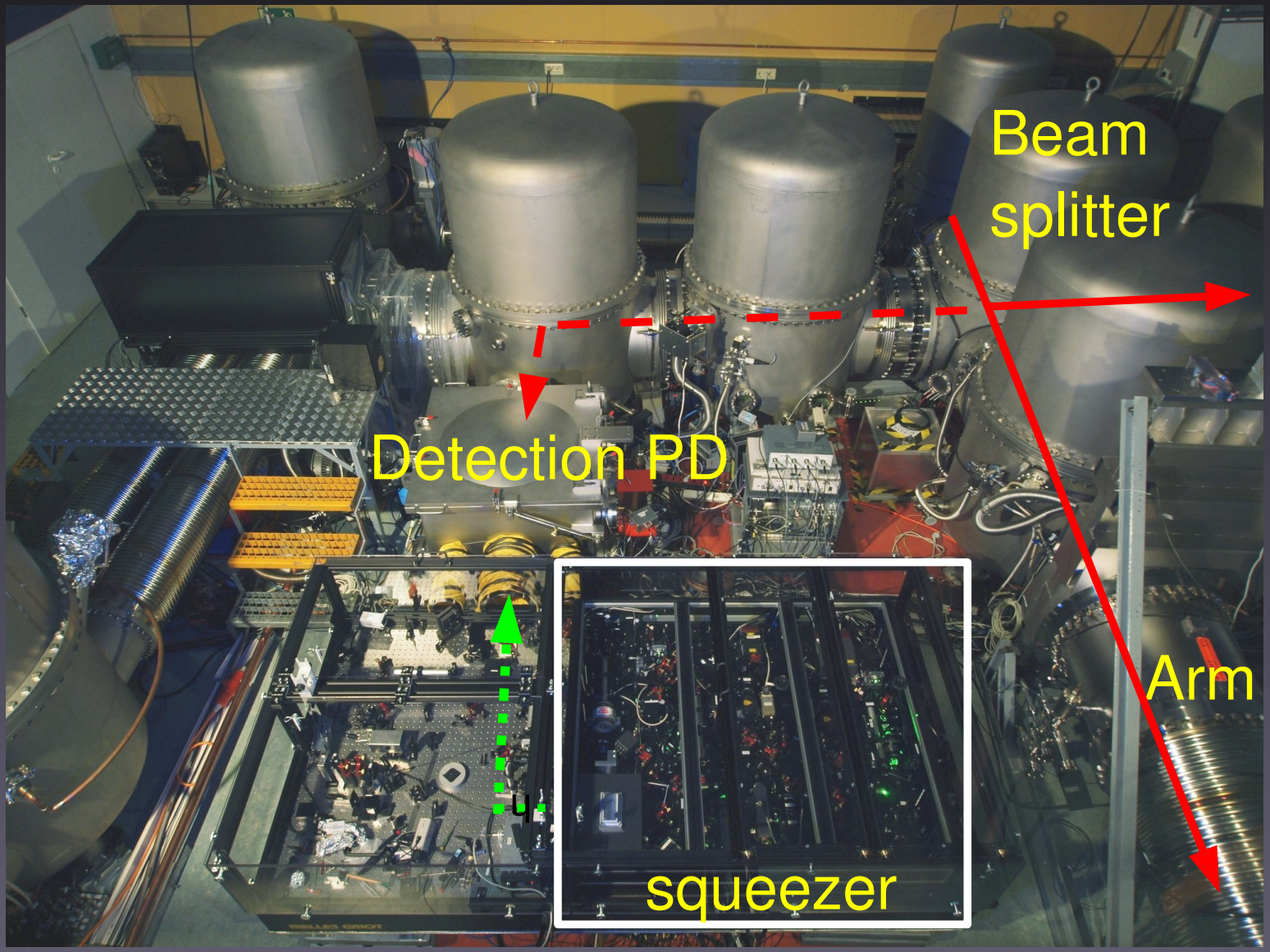


12 x 12 Matrix Heater

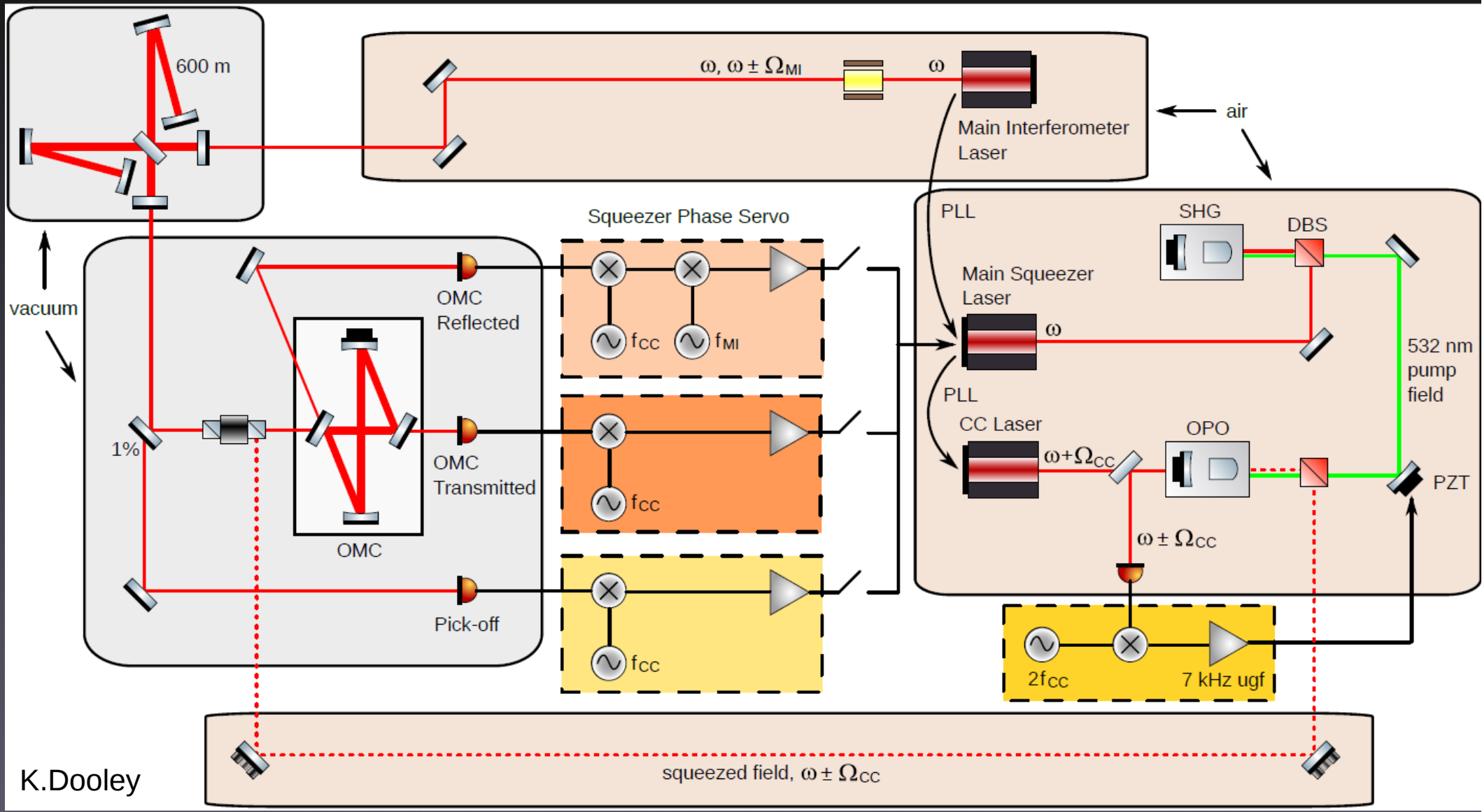


See poster by H. Wittel

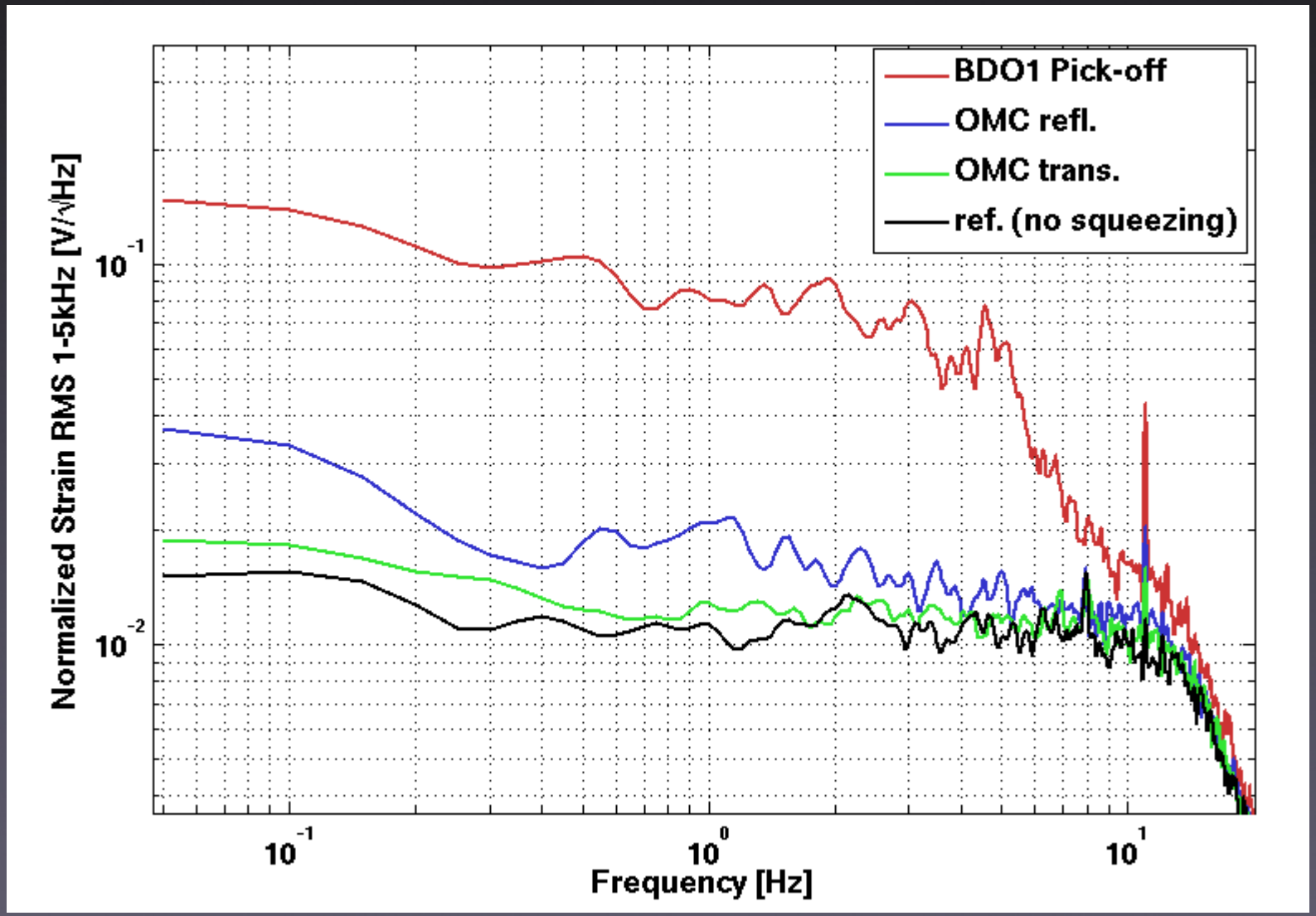
Squeezed Light at GEO600:



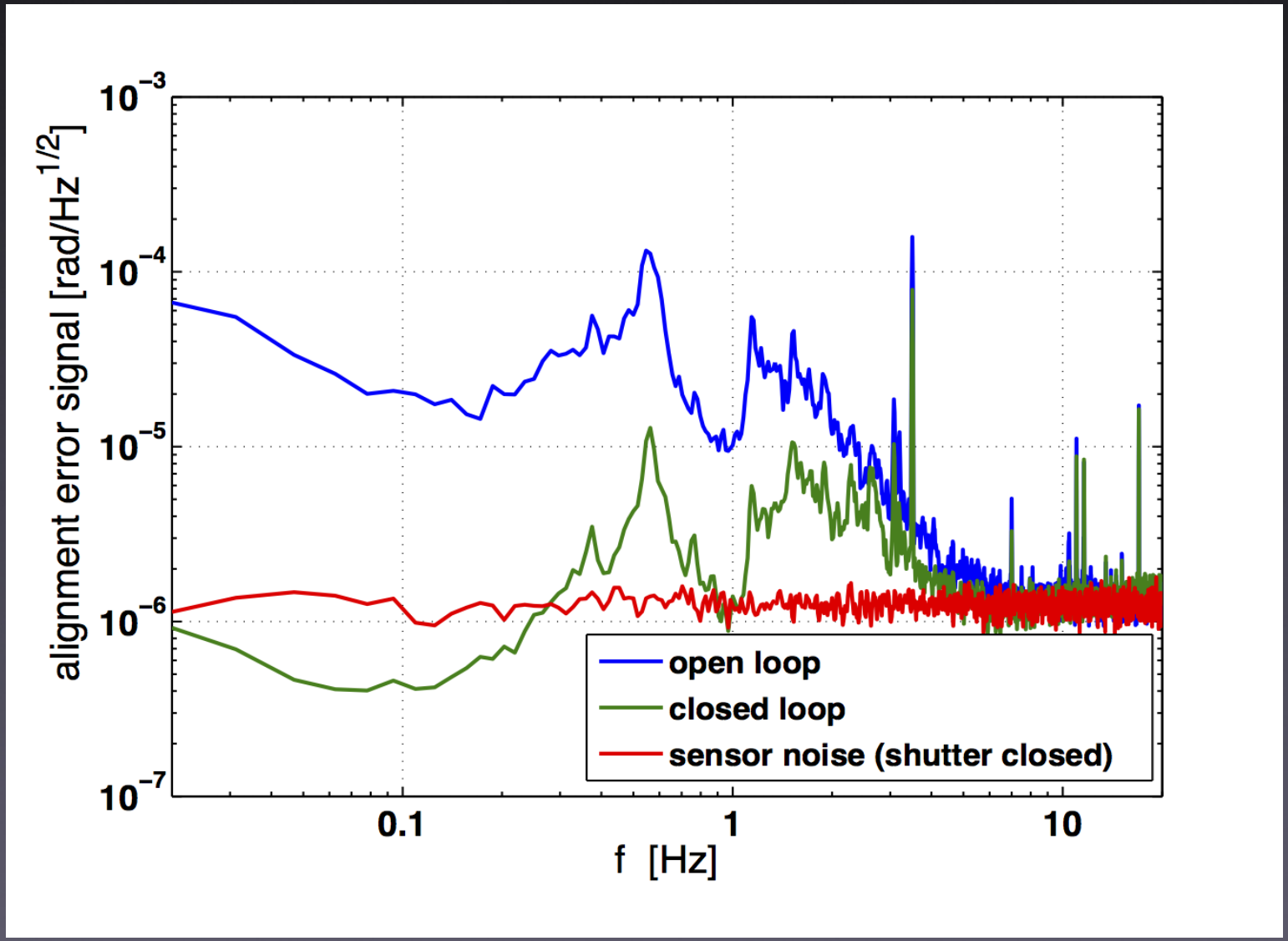
Squeezing Setup / Phase Control Signals



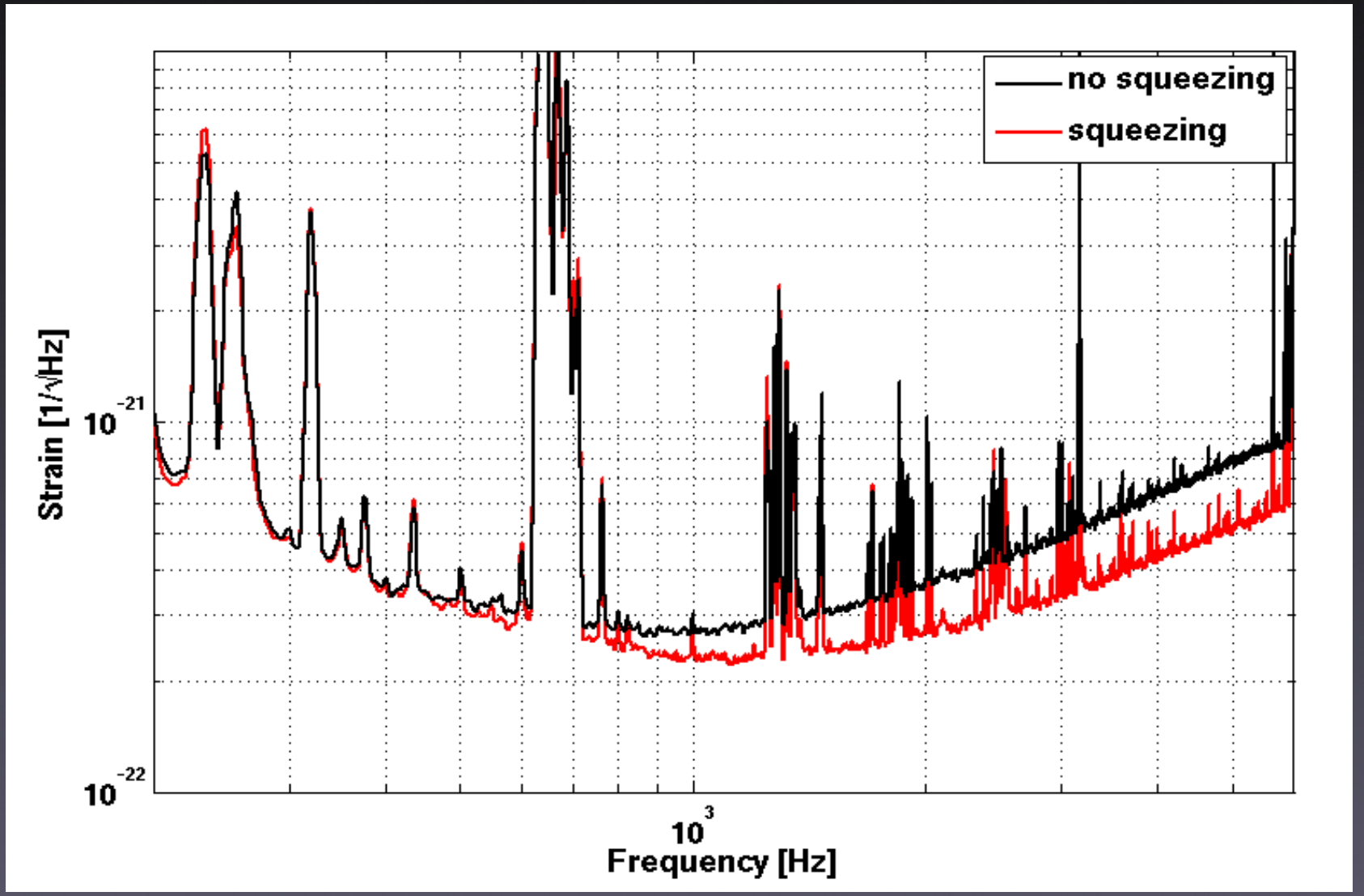
Fluctuation of Strain at 1-5kHz, for 3 squeezing phase control signals and intentional misalignment



Automatic Alignment of Squeezed Vacuum: works in 4 DOF

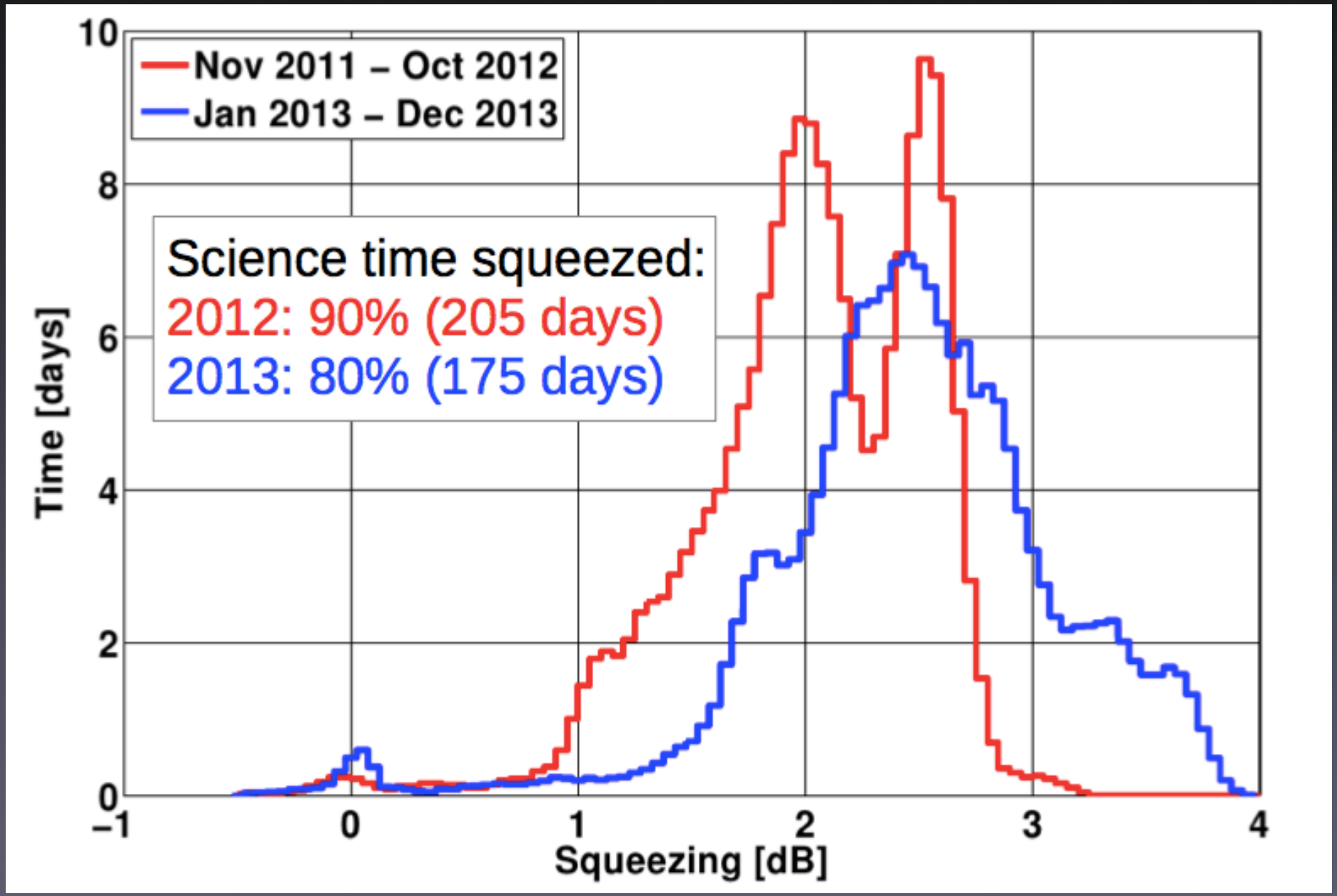


Up to 3.7 dB Squeezing Observed



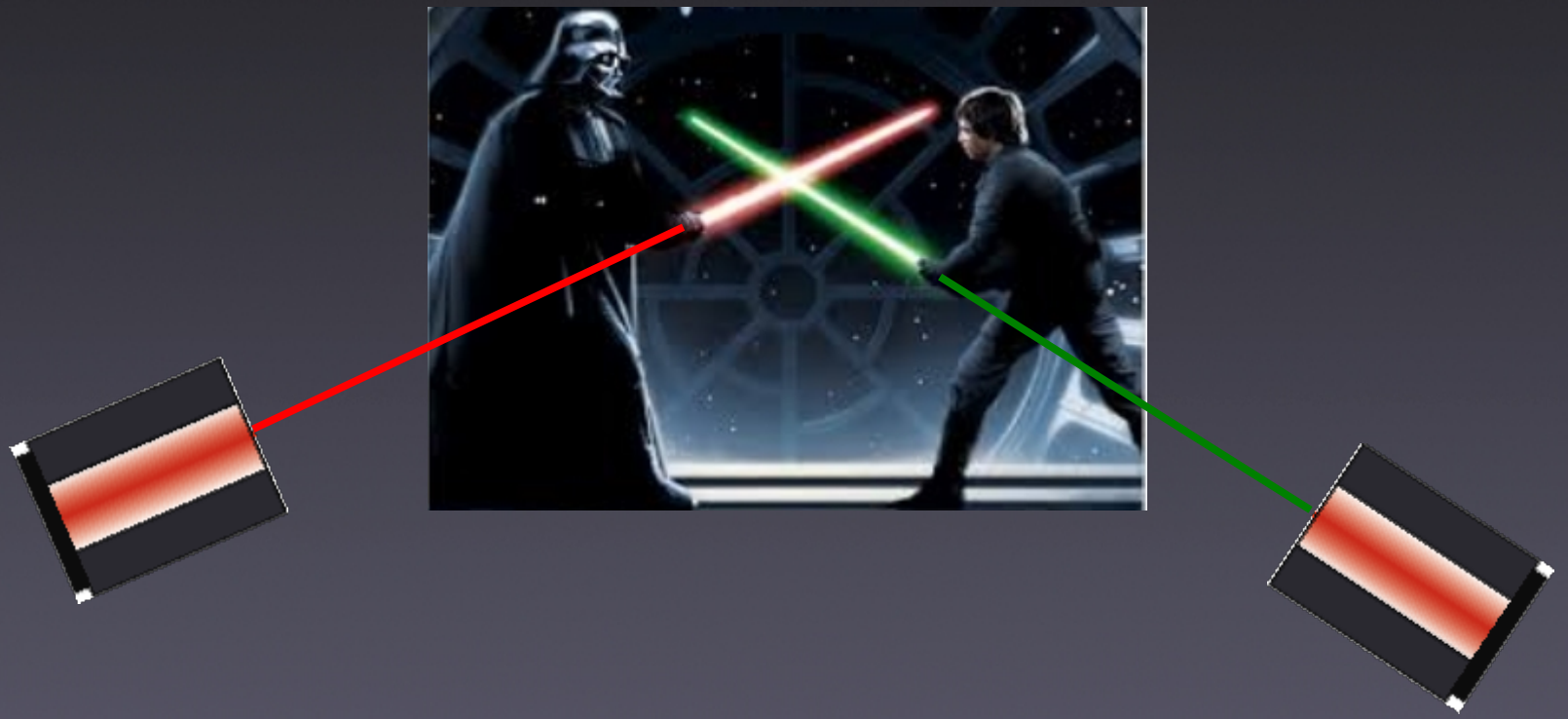
Consistent with ~37% losses and ~20mrad phase noise

Long-term Squeezing Performance



Laser vs. Squeezer

2010-2014 @ GEO:
~250 entries vs. ~900 entries



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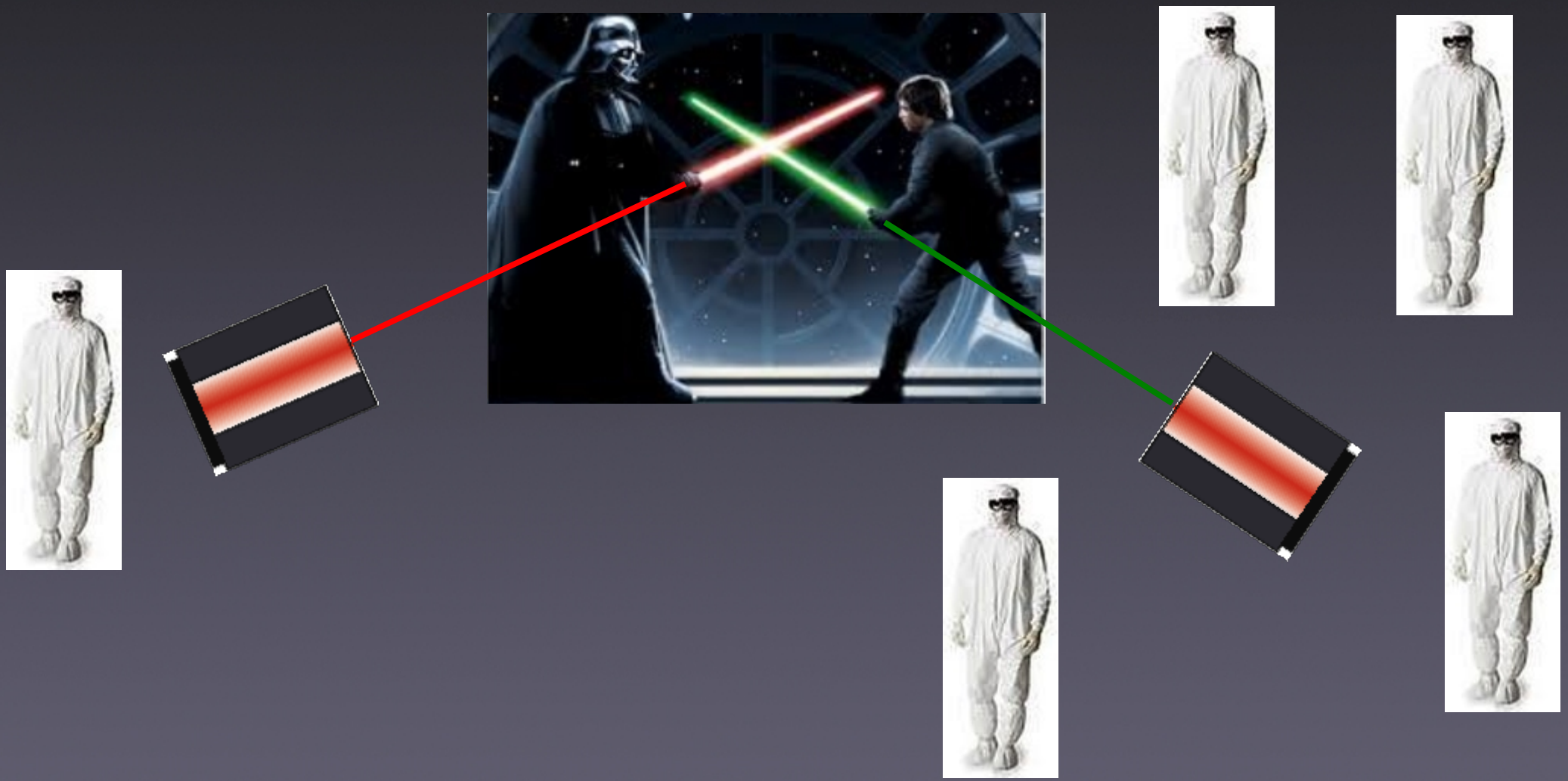


'broken & cable': 2010

- GEO: 19
- LHO: 41
- LLO: 55
- Virgo: 26

→ need better/more engineering
For complexer detectors

'broken & cable': 2010 / 2014

- GEO: 19 / 24
- LHO: 41 / 48
- LLO: 55 / 24
- Virgo: 26 / 8

→ need better/more engineering
For complexer detectors

'broken & cable': 2010 / 2014

- GEO: 19 / 24
- LHO: 41 / 48
- LLO: 55 / 24
- Virgo: 26 / 8

→ need better/more engineering
For complexer detectors

→ has improved,
But still need better/more engineering
For ever complexer detectors...

'broken'

GEO: 146 / 5400 : 2.7%
LHO:
LLO: 125 / 12400 : 1 %
Virgo: 219 / 29200 : 0.75 %

Sensor, coil, main gate, QPD B, DAC, Pico Motor, microphone, MEDM link, Kantech, PZT, IRLED filter, AA board, WFS A, GEO, ...

→ good enough for third generation ?

Cost Optimization

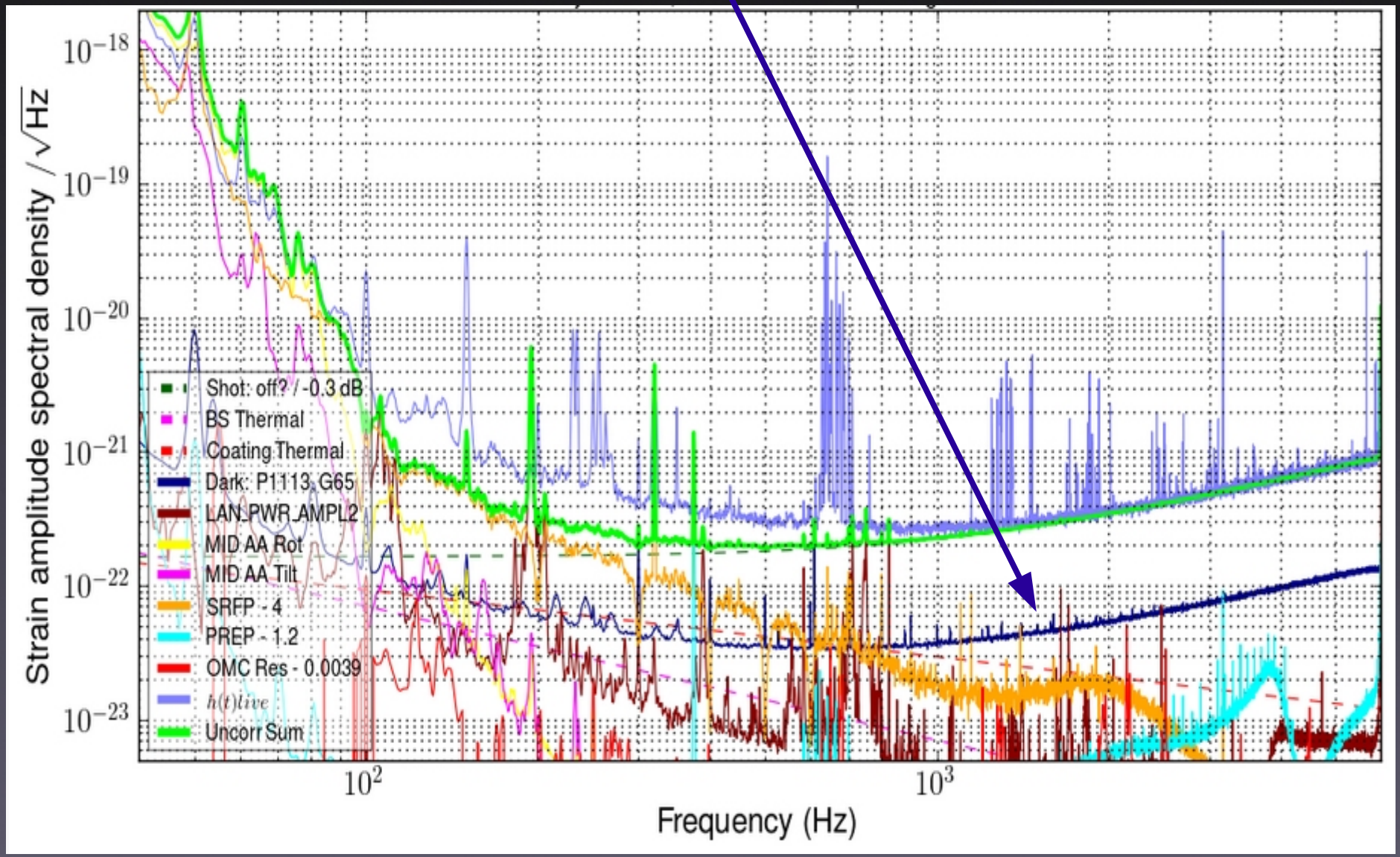
LIGO operations: 30 k$ / day

1 % in range increase
Is 3% Volume increase.

→ Science run can be
Shorter by 3%.

→ on 6-month run saves
5 x 30k$ = 150k$

Electronic noise



Readout noise/efficiency

	Strain contribution In shot-noise limited domain	Potential saving On 6-month run
• Detection electronics →	~3%	450k$
• PD QE →	0.5-4%	75k-600k$
• Faraday / PBS loss	3-5%	450k-750k$
• Mode matching	1-3%	150k-450k$
• OMC loss	1-2%	150k-300k$

Readout noise/efficiency

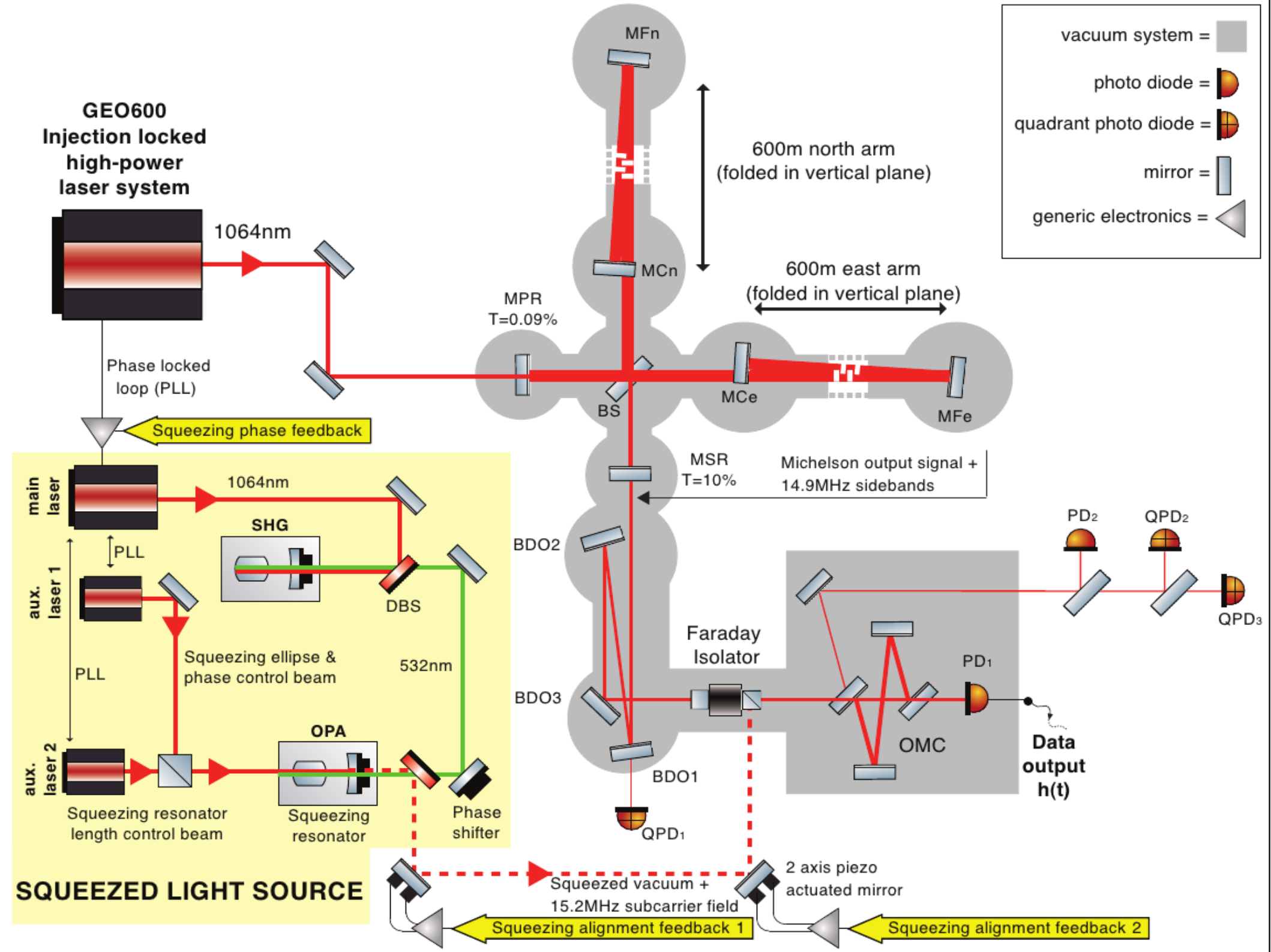
	Strain contribution In shot-noise limited domain	Potential saving On 6-month run **WITH 6dB SQUEEZING (x 6 for losses)**
• Detection electronics →	~3%	750k$
• PD QE →	0.5-4%	450k-3.6M$
• Faraday / PBS loss	3-5%	2.7M-4.5M$
• Mode matching	1-3%	900k-2.7M$
• OMC loss	1-2%	900k-1.8M$





Morals

- Pro sustainable use of Steel ressources !
- Thermal compensation: different options
- Squeezed light: works long-term,
  but needs continuos effort and research
- Lets not waste tax-payer money and
  professionally cross-optimise subsystems


vacuum system =
photo diode =
quadrant photo diode =
mirror =
generic electronics =
GEO600
Injection locked
high-power
laser system
1064nm
Phase locked
loop (PLL)
Squeezing phase feedback
MFn
600m north arm
(folded in vertical plane)
MCn
600m east arm
(folded in vertical plane)
MPR
T=0.09%
BS
MCe
MFe
MSR
T=10%
Michelson output signal +
14.9MHz sidebands
BDO2
BDO3
BDO1
QPD1
PD2
QPD2
QPD3
Faraday
Isolator
PD1
OMC
Data
output
h(t)
main
laser
1064nm
SHG
DBS
PLL
aux.
laser 1
PLL
Squeezing ellipse &
phase control beam
532nm
OPA
aux.
laser 2
Squeezing resonator
length control beam
Squeezing
resonator
Phase
shifter
SQUEEZED LIGHT SOURCE
Squeezed vacuum +
15.2MHz subcarrier field
2 axis piezo
actuated mirror
Squeezing alignment feedback 1
Squeezing alignment feedback 2