Squeezing at 1064nm

...towards a GEO-Squeezer Mk2

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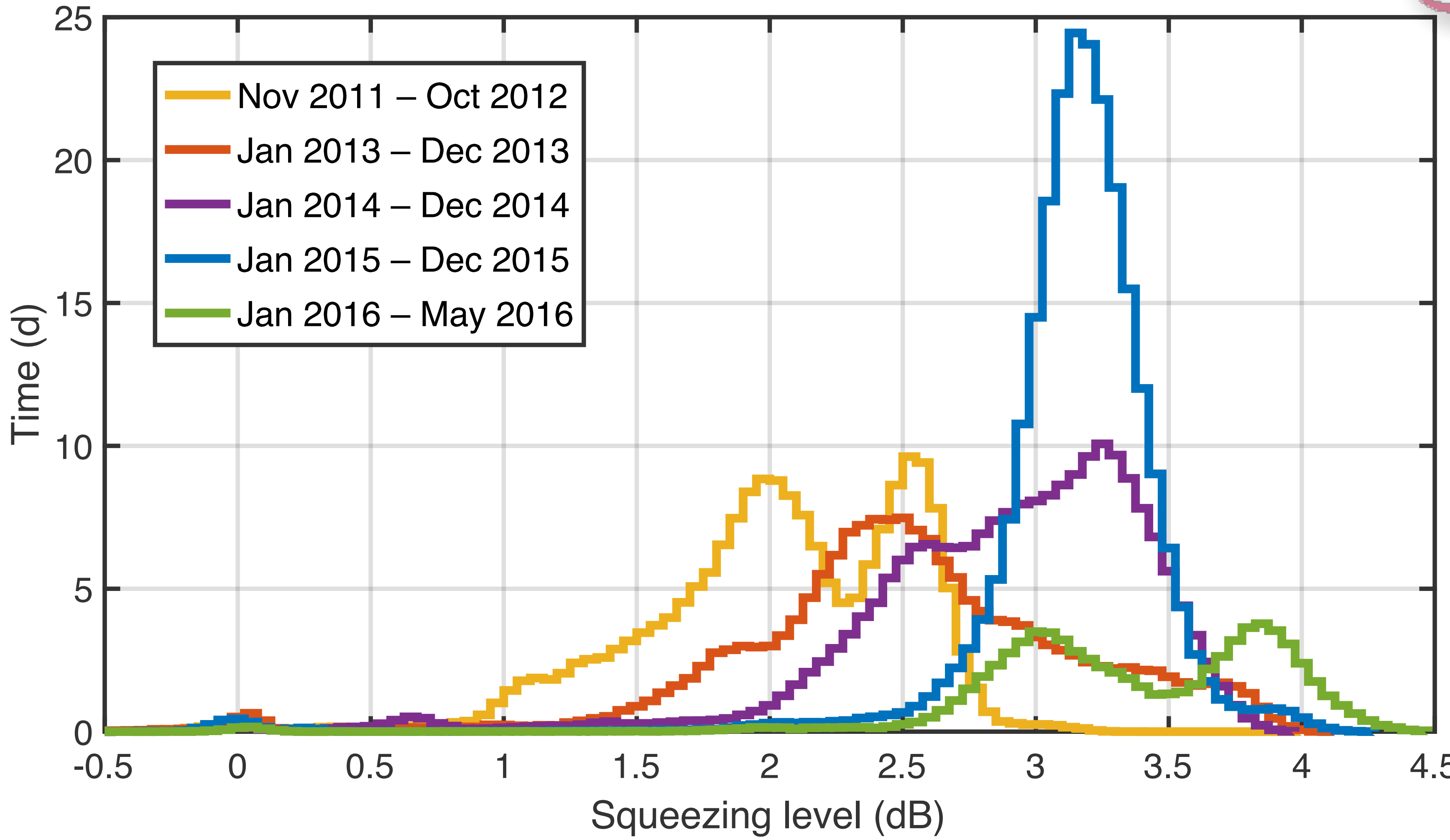
Squeezing performance

- Squeezing at GEO since 2010
- Stable operation with high duty cycle
- Slow but steady improvements

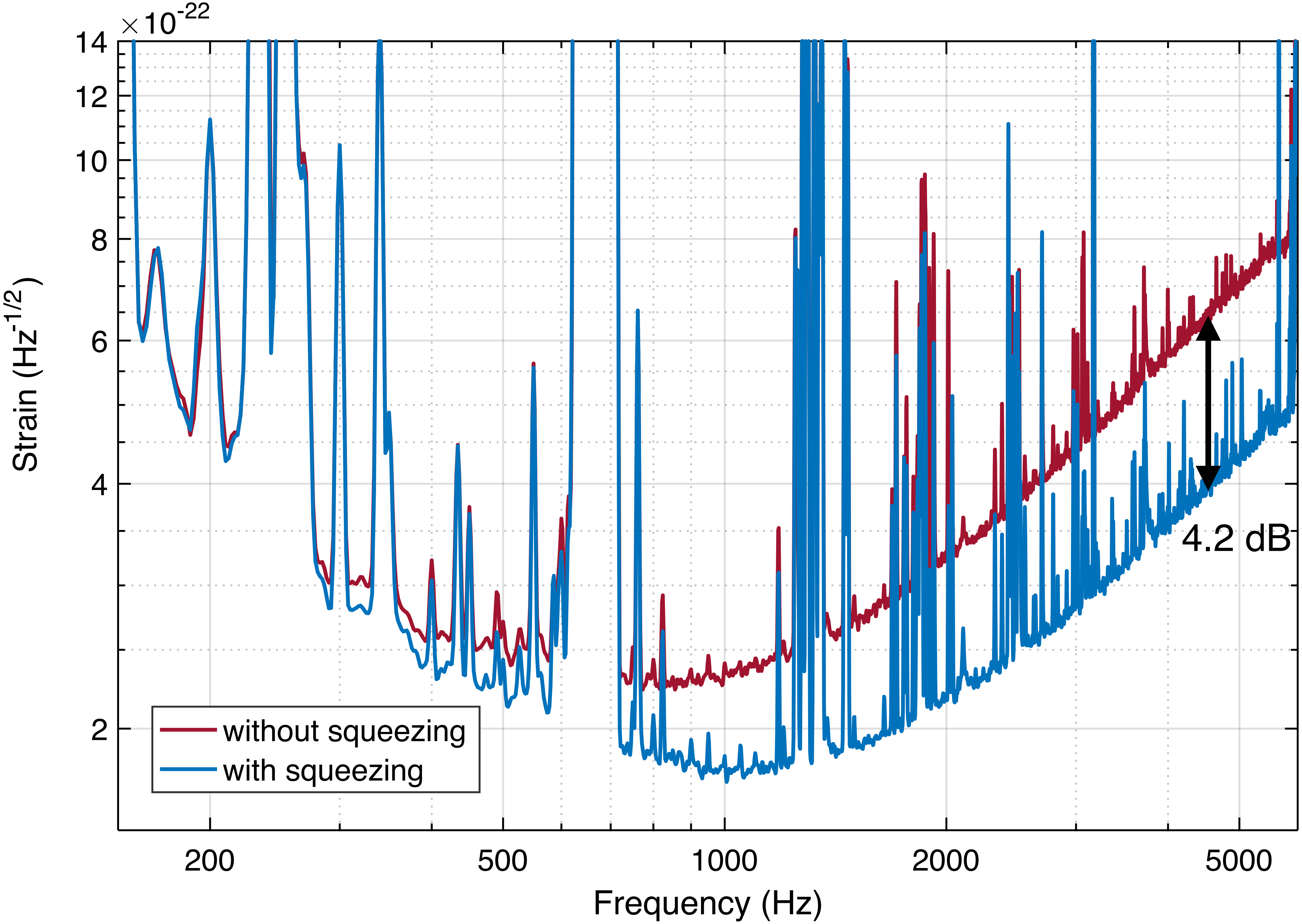


- Alignment sensing and control for squeezed vacuum states of light,
Emil Schreiber et. al, Opt. Express 24, Issue 1, pp. 146-152 (2016)

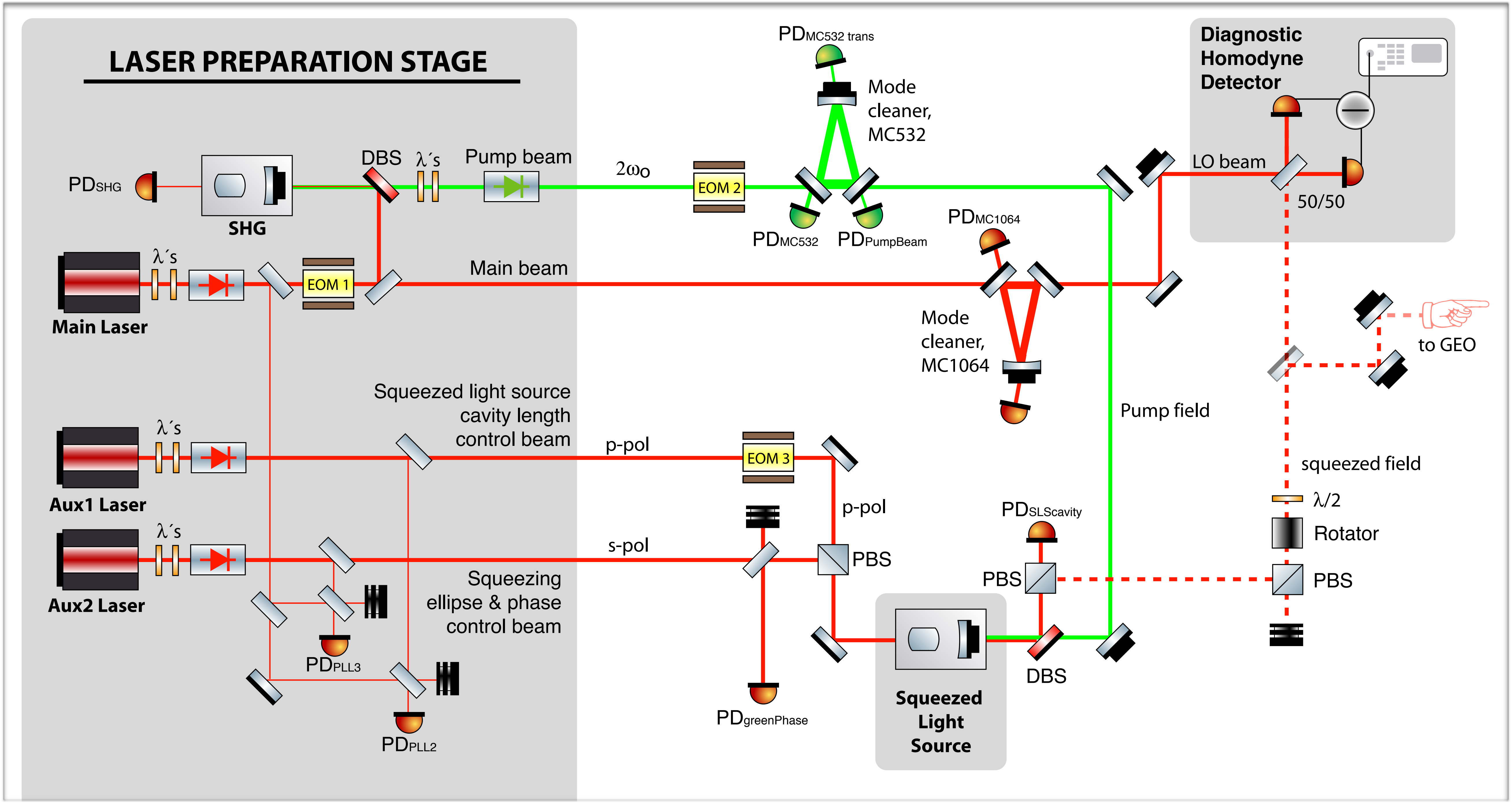
- Phase control of squeezed vacuum states of light in gravitational wave detectors
Kate Dooley et al., Opt. Express 23, 8235–8245 (2015).

- High power and ultra-low-noise photodetector for squeezed-light enhanced gravitational wave detectors,
Hartmut Grote et al. LIGO DCC: P1500203)

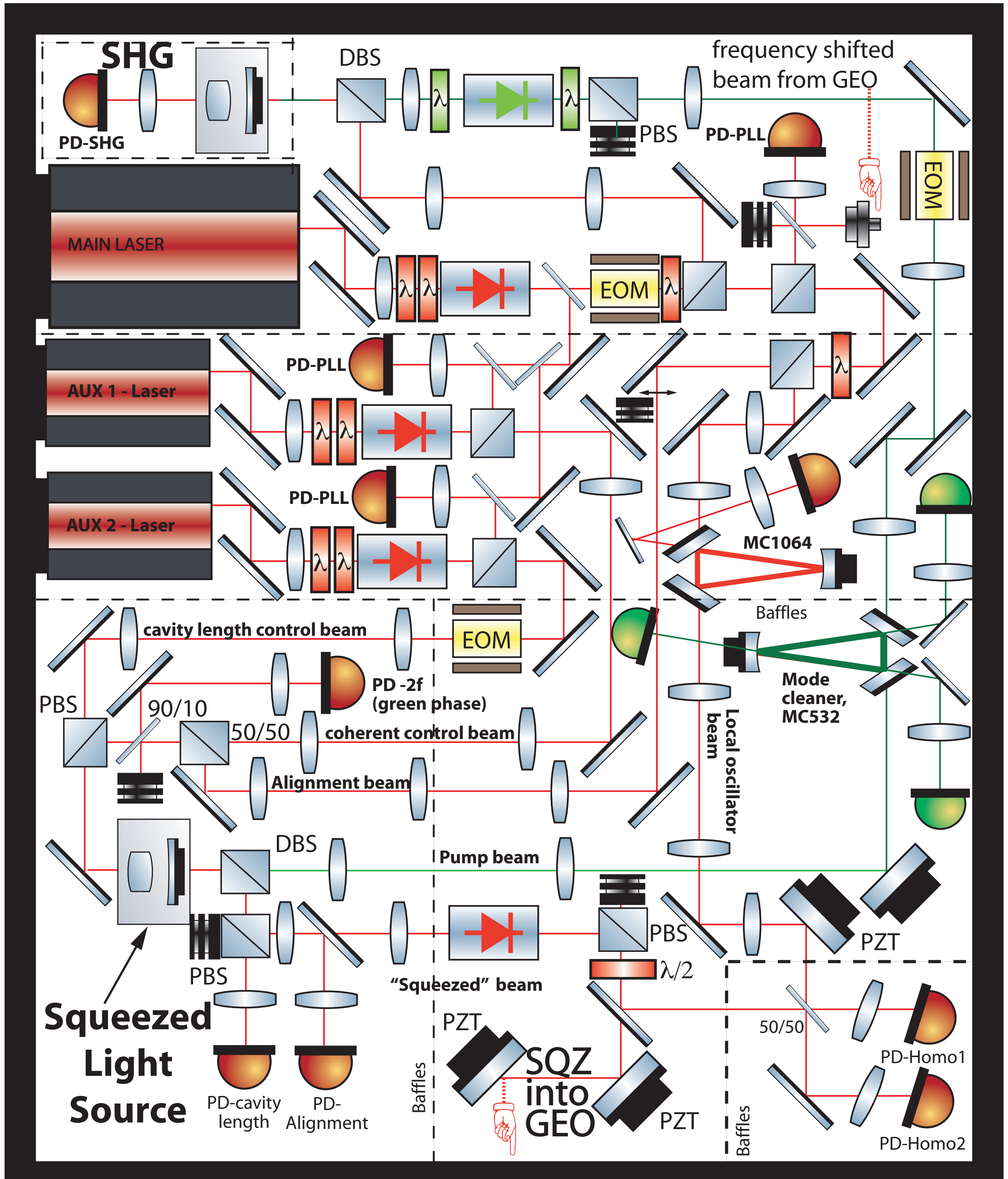
Recent squeezing

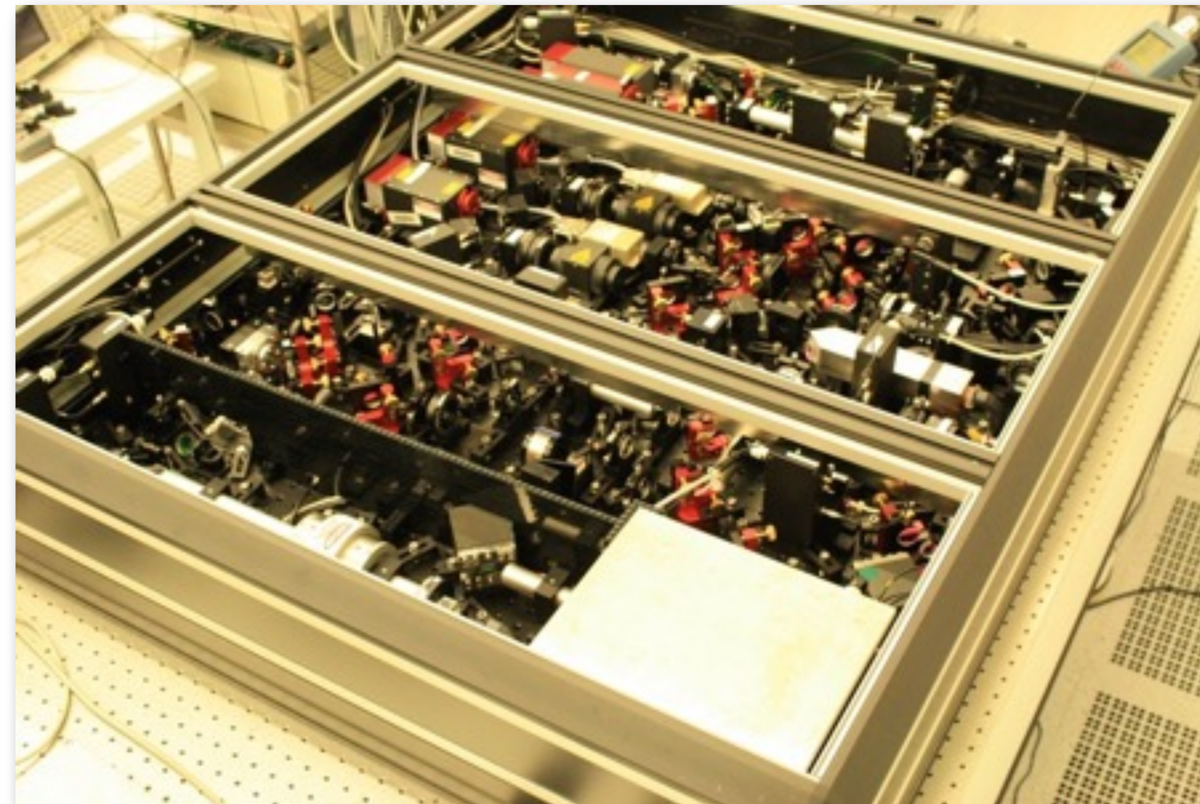


GEO-Squeezer



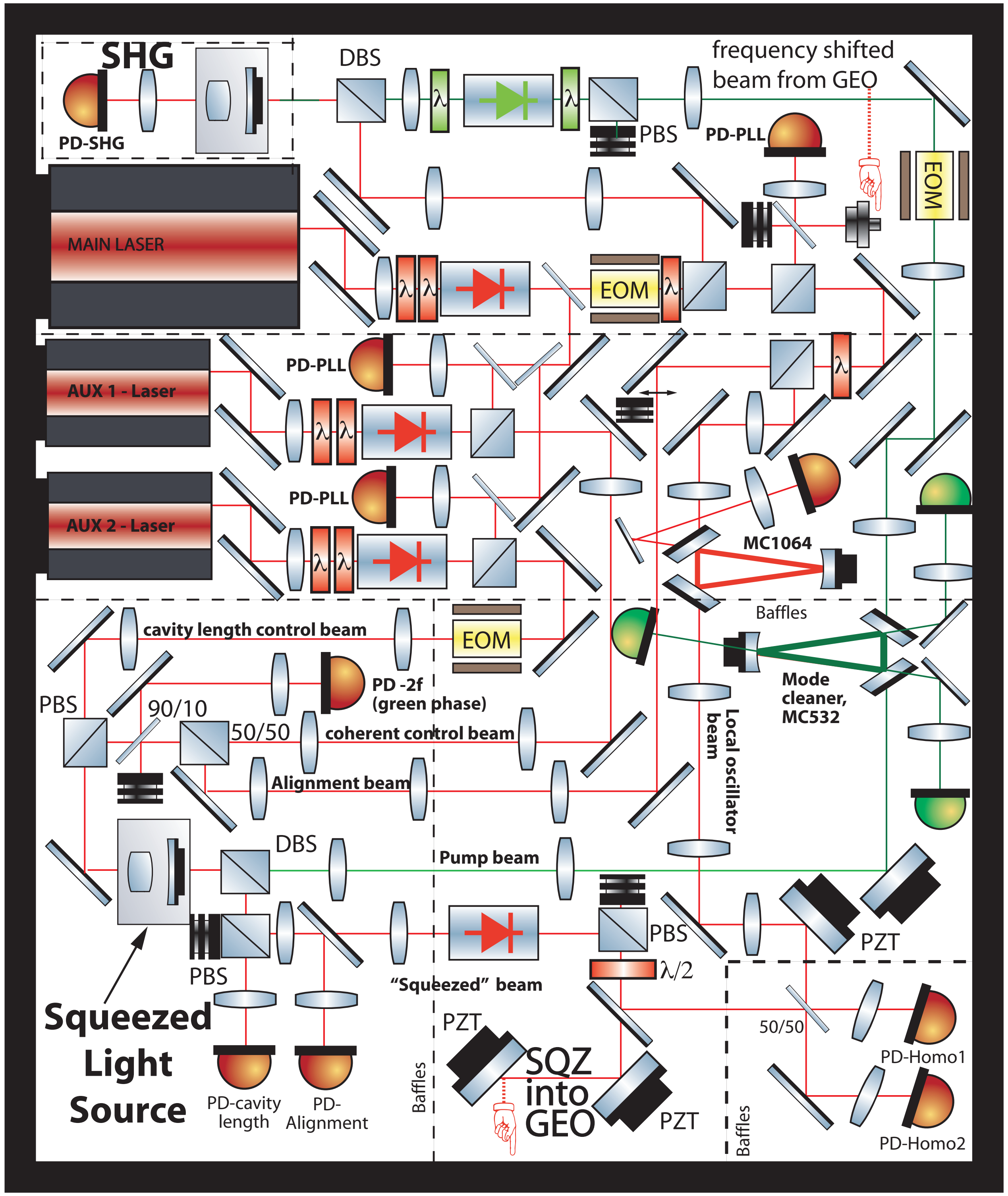
GEO-Squeezer



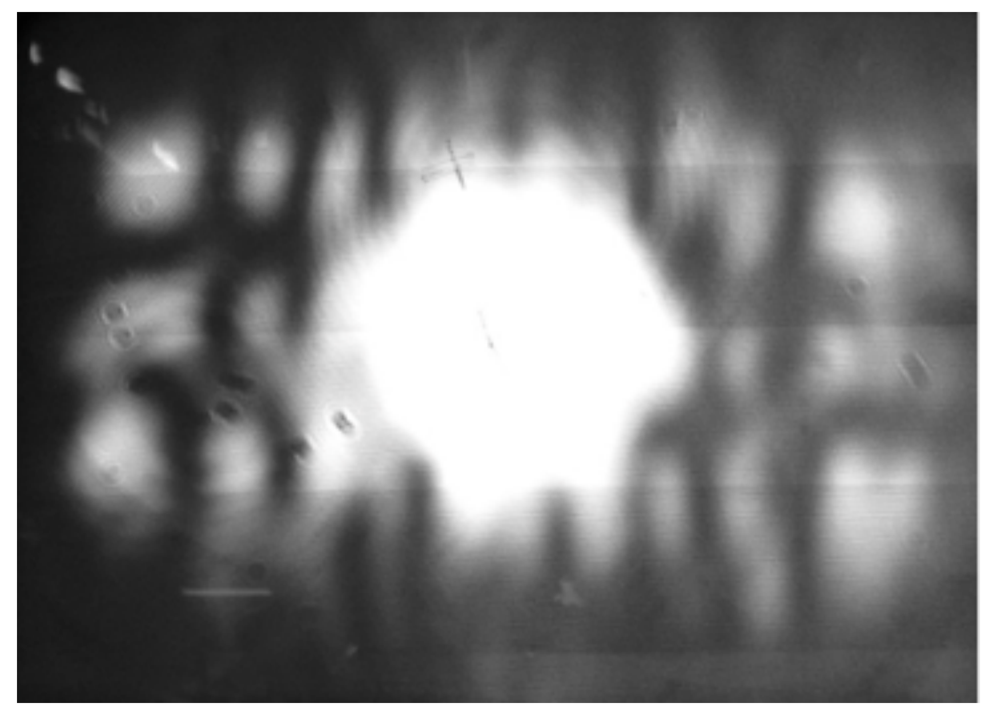


- dimensions: 1,15m x 1,35m
- weight: 120kg
- build in 2009 / sign of wear

GEO-Squeezer upkeep

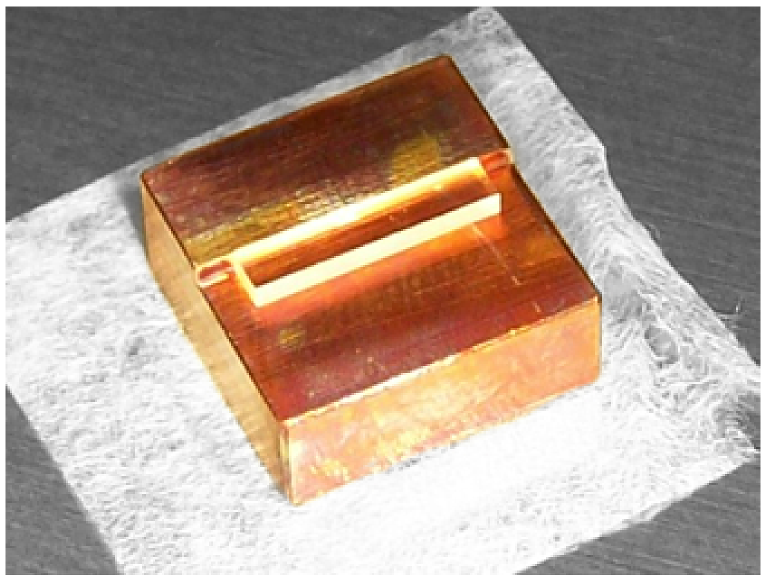


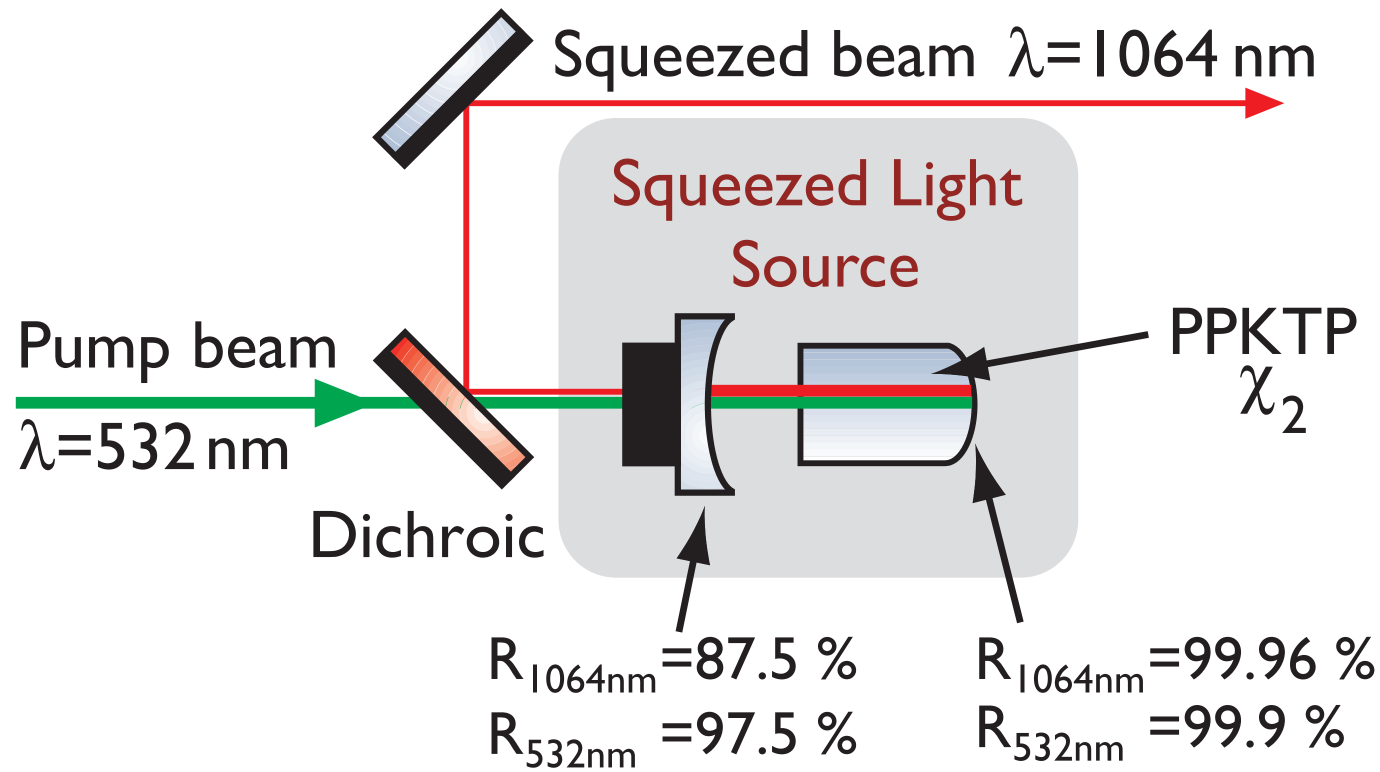
- SHG was replaced
- MC532 was replaced
- Broken OPA crystal
- Auxiliary lasers show occasional excess noise



broken OPA crystal

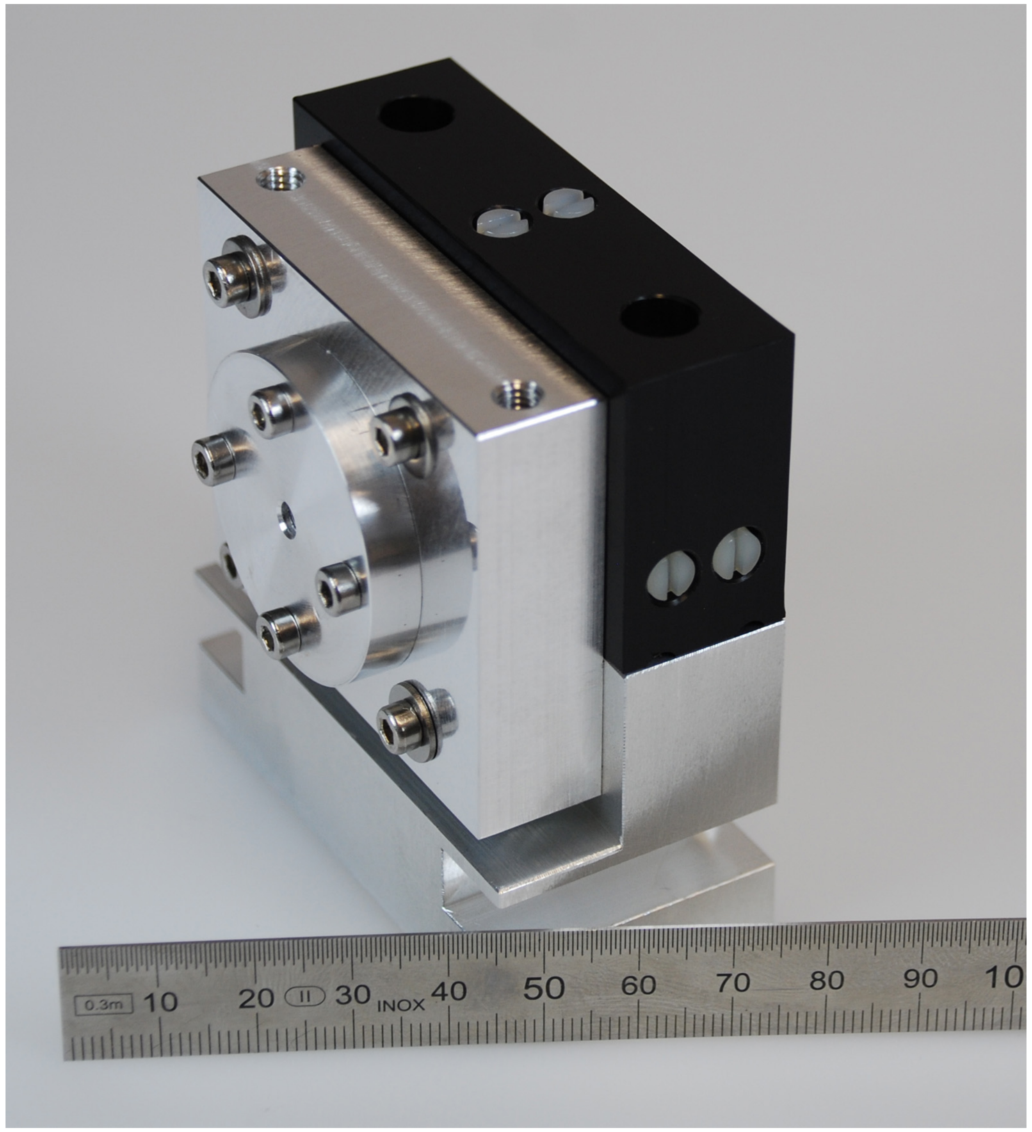
Doubly resonant OPA



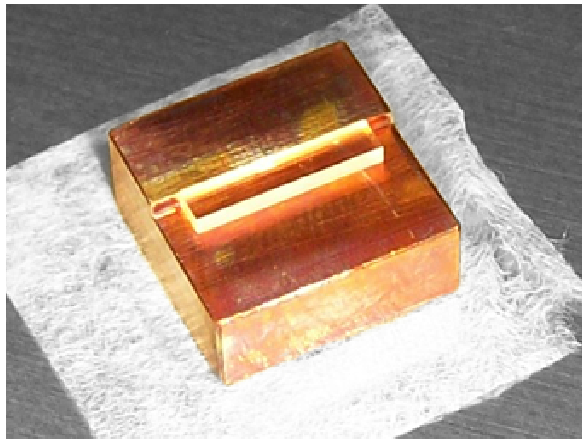


- Linear cavity design
- Finesse of 240 at 532nm
- Low loss OPA (Finesse of 47 at 1064nm)
- Simultaneous resonance tuned via crystal temperature

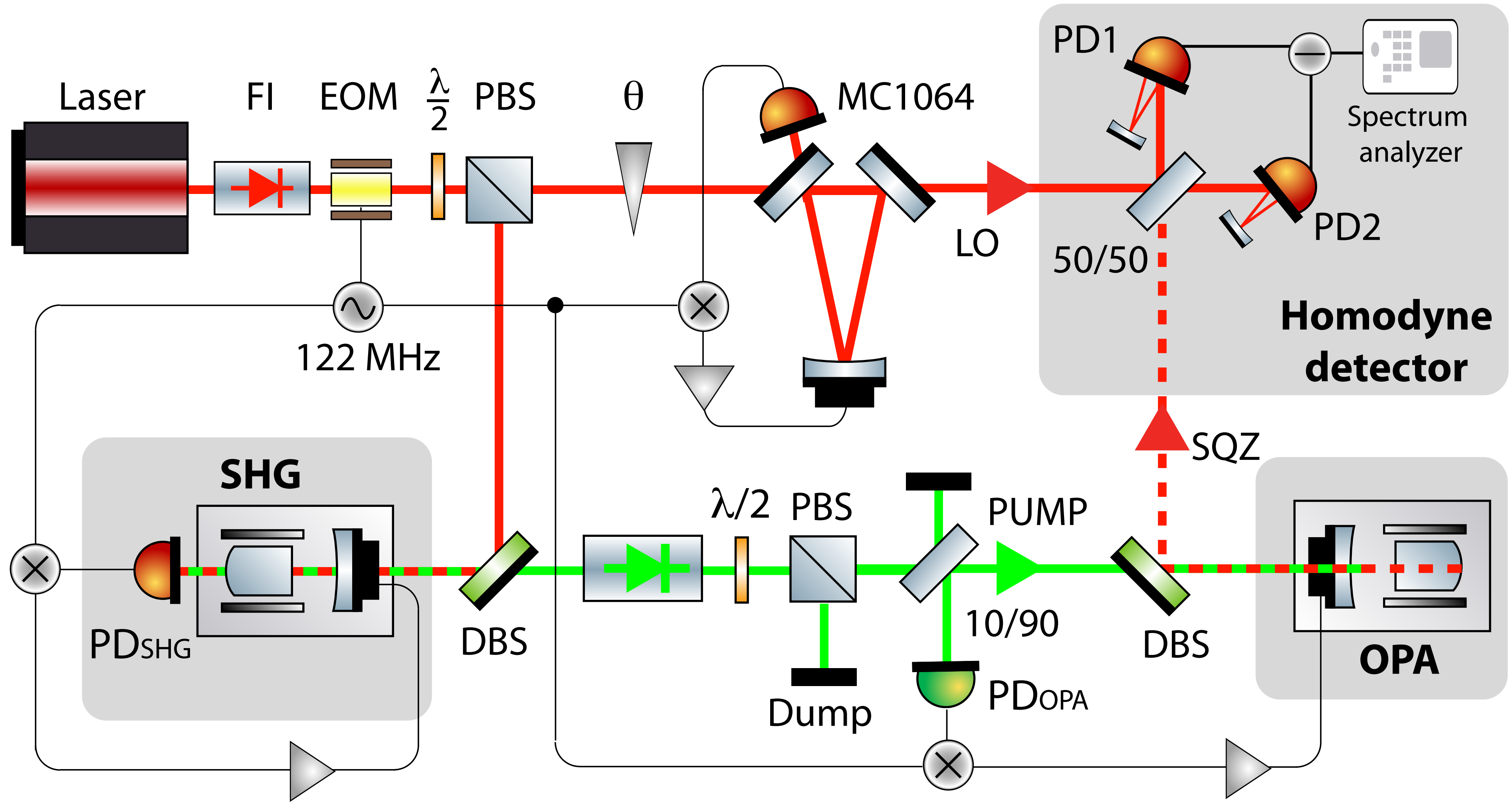
Mechanical OPA design



- Compact design
- High mechanical stability
- Sealed air gap
- Easy to assemble
- In air design
- Can be made vacuum compatible

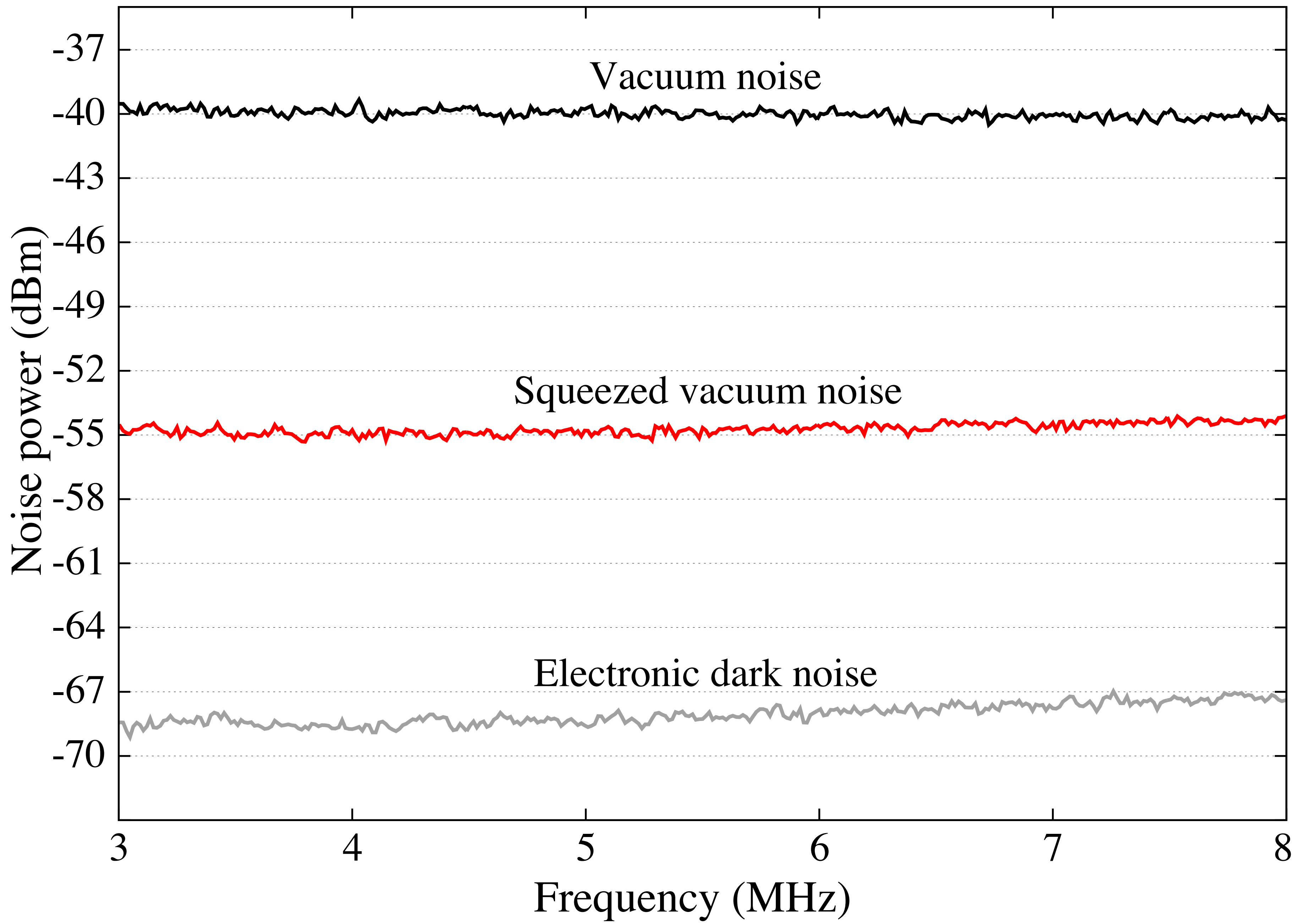


Experimental setup



- 500um custom made photo diodes (made in 2009 by Laser components) installed for homodyne detection
- measured 0.3% PD-AR reflection
- Homodyne quantum yield enhanced using retro reflectors

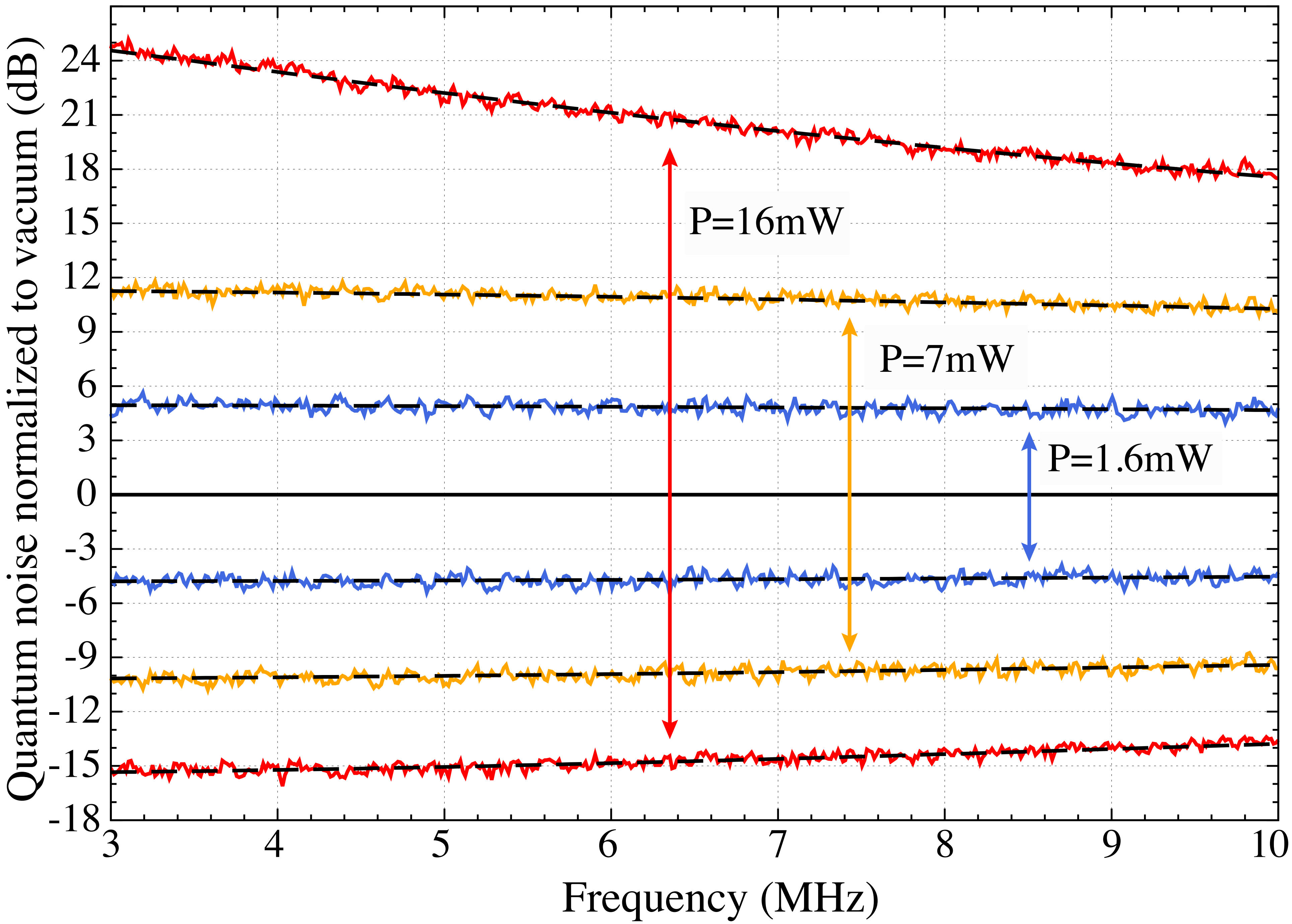
15dB squeezing



- 15dB squeezing directly measured w/o dark noise correction
- only 16mW OPA pump power required

LIGO Document P1600153-v2

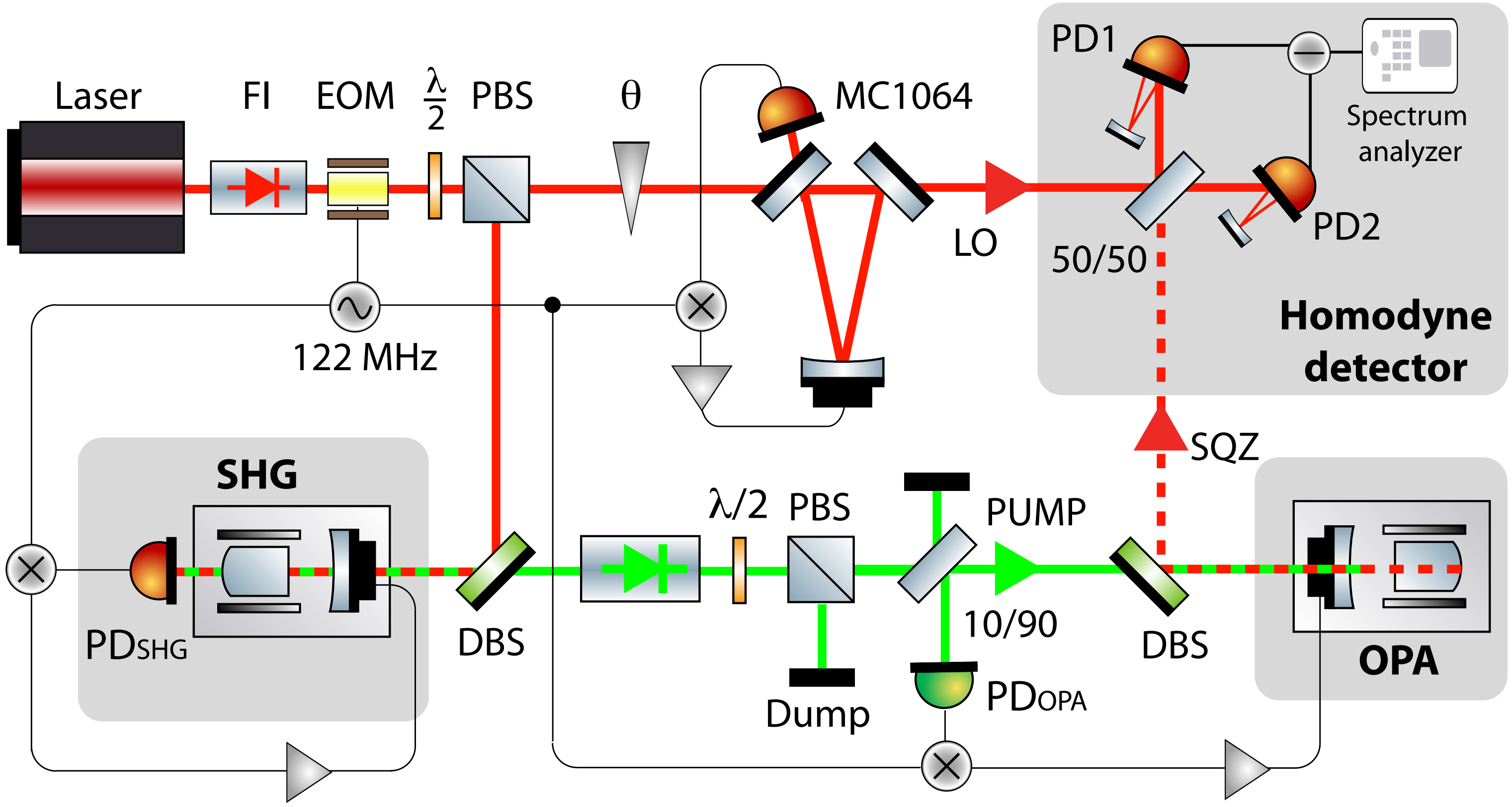
Squeezing vs pump power



- 15.3dB squeezing if dark noise corrected
- only 7mW pump required for 10dB squeezing with only 11.5dB anti-squeezing
- High purity!
- only 2.5% total optical loss
- ultra low 1.7mrad phase noise

DCC: P1600153-v2

Loss budget



2.5% total optical loss

$$\eta_{\text{homodyne}} = 99.2^{+0.1}_{-0.1}\,\%$$

$$\eta_{\text{propagation}} = 99.8^{+0.01}_{-0.01}\,\%$$

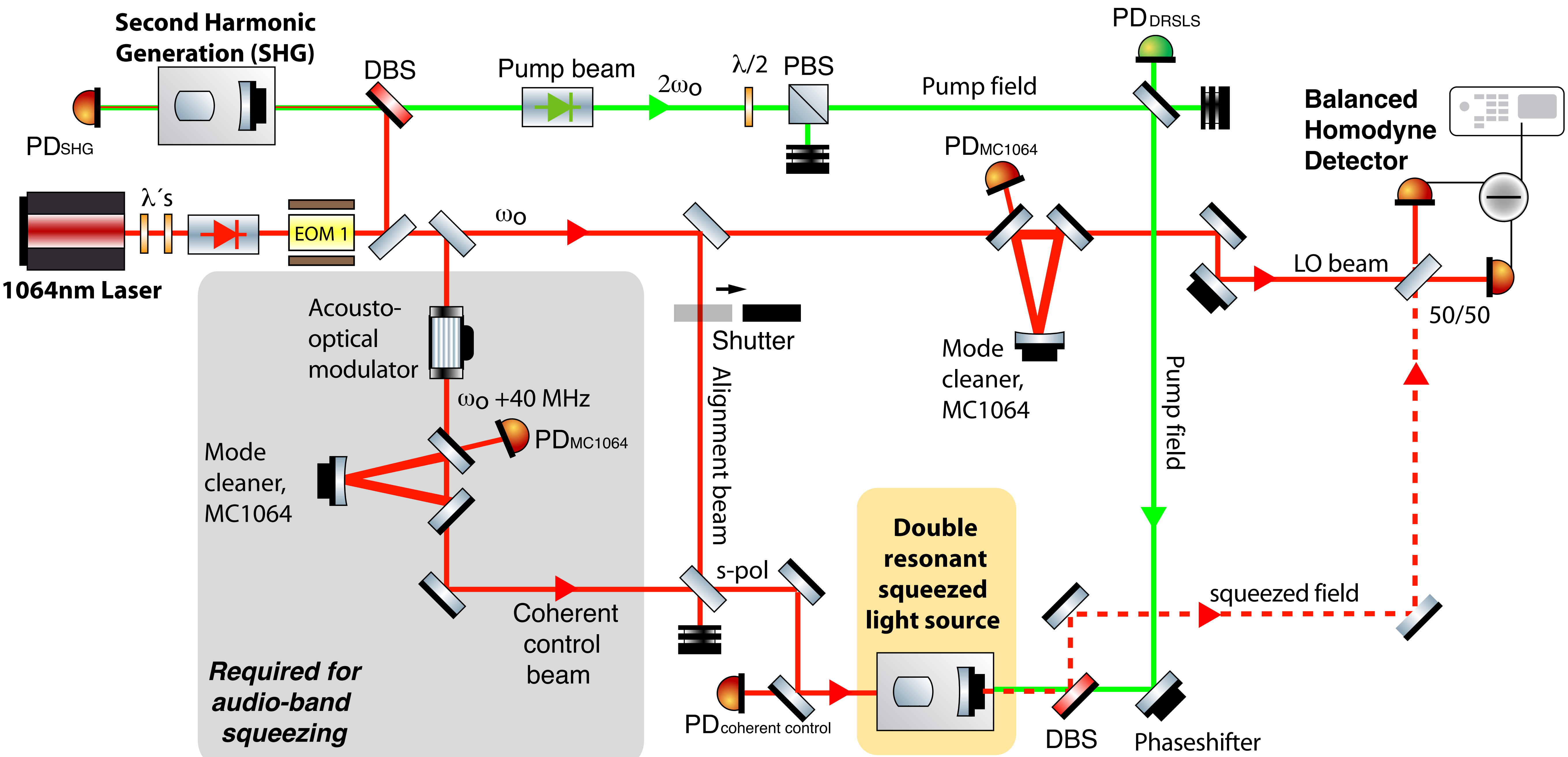
$$\eta_{\text{escape}} = 99.05^{+0.4}_{-0.45}\,\%$$

accounts for $2.0^{+0.5}_{-0.6}\,\%$ loss

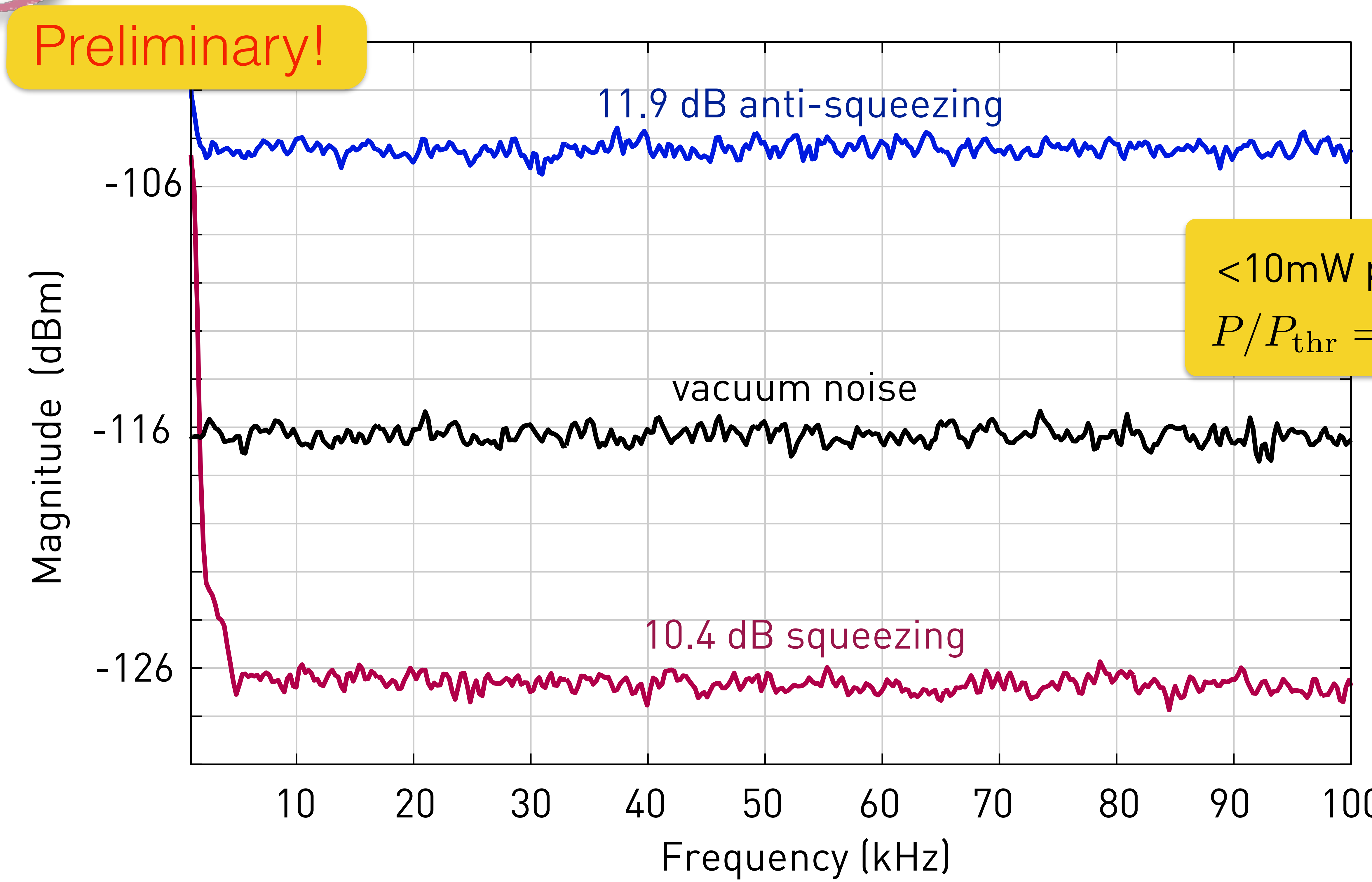
Photo diode quantum efficiency of $\eta_{\text{PD}} = 99.5^{+0.5}_{-0.5}\,\%$

DCC: P1600153-v2

Added coherent control scheme



High purity squeezing at kHz

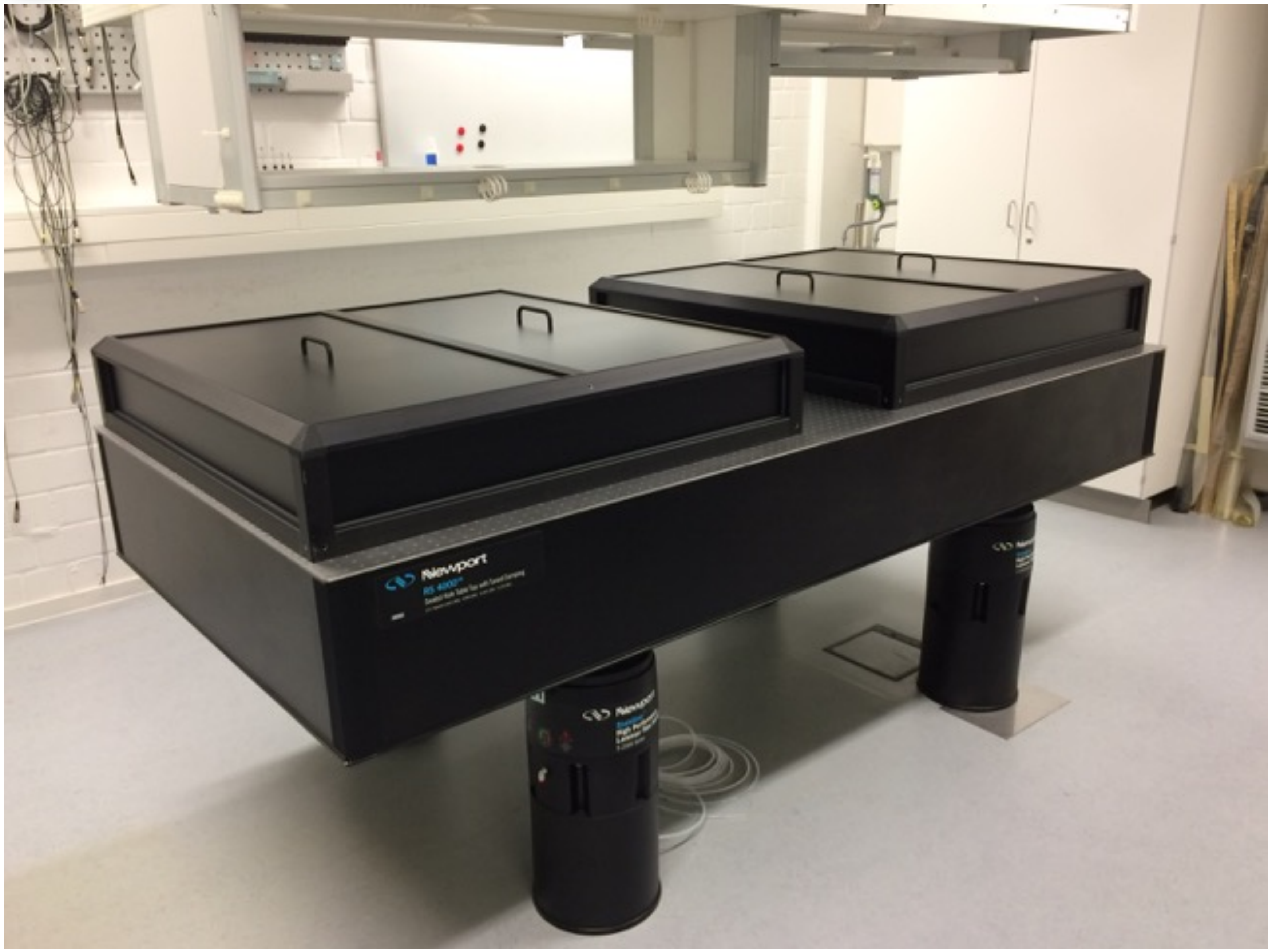


<10mW pump

$P/P_{\text{thr}} = 34\%$

GEO-Squeezer Mk2

Leibniz Universität Hannover



- Based on doubly resonant linear OPA cavity design
- Stand-alone squeezer
- Only 1m^2 size
- 2 units in preparation
- Fully automated as the current GEO Squeezer
- Free choice of coherent control frequency

Summary / Outlook

- 15dB vacuum squeezing demonstrated in a doubly resonant linear OPA cavity design
- Operated in air with only 1.7mrad phase noise
- 10dB squeezing with only 11dB anti-squeezing with low pump power
- Calibration of PD quantum efficiency to 99.5 +/-0.5%
- Doubly resonant linear OPA design transferable to the GEO-Squeezer layout