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Quantum-Dense Metrology

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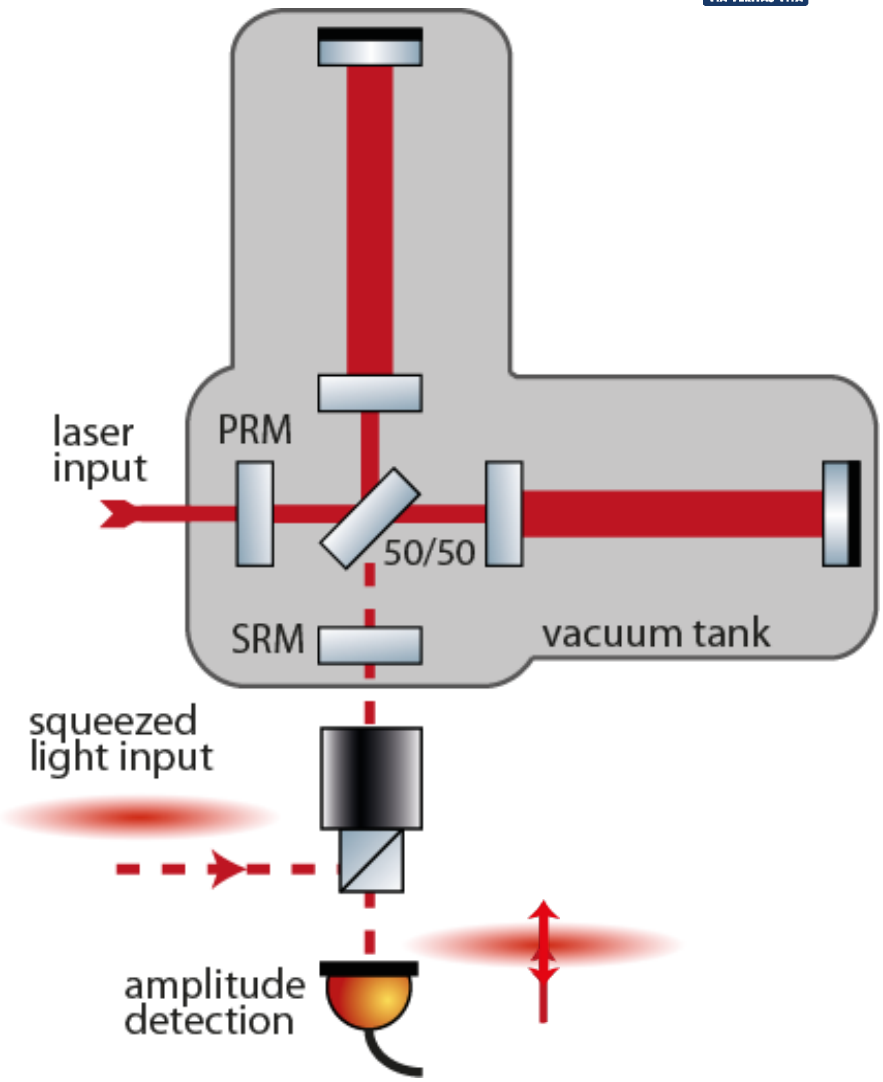
LIGO-G1601215

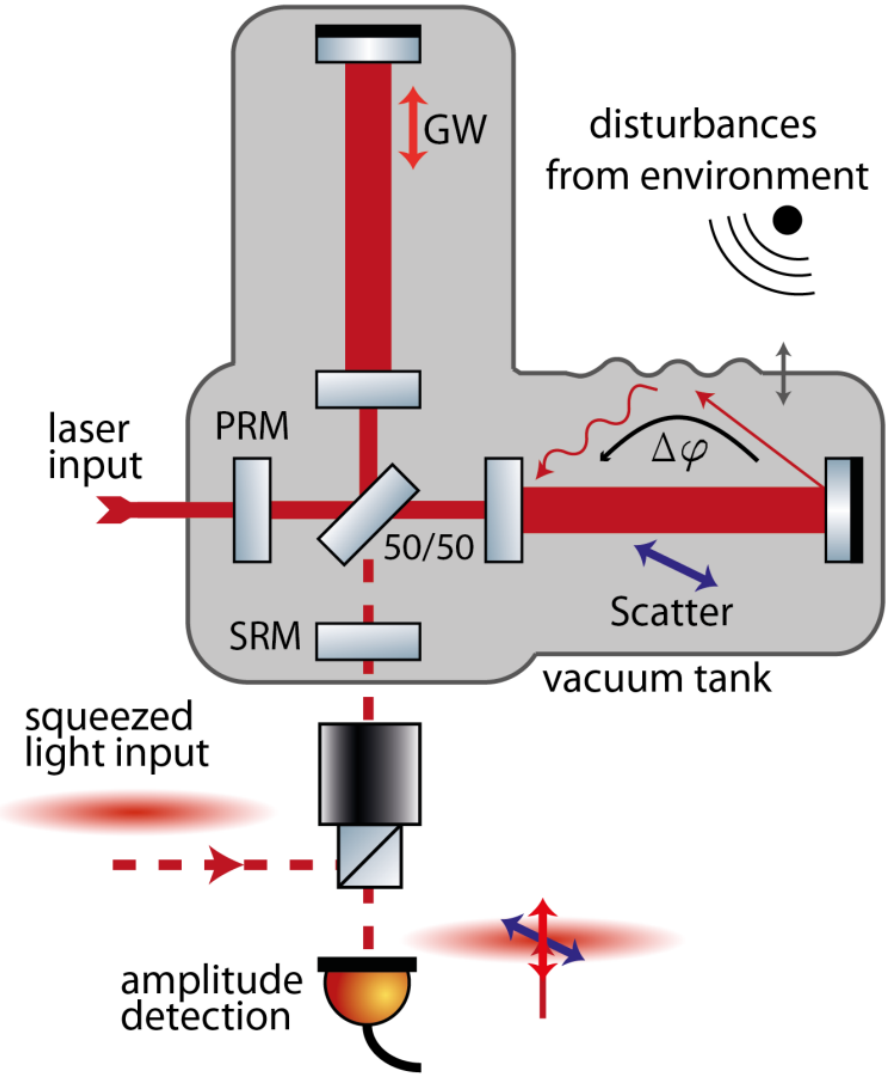
Where we are right now

- squeezed-light enhanced Michelson interferometer
- squeezing ellipse oriented (frequency dependent) such that SNR is optimised
- orthogonal quadrature is lost in anti-squeezed noise
  - no GW signal there

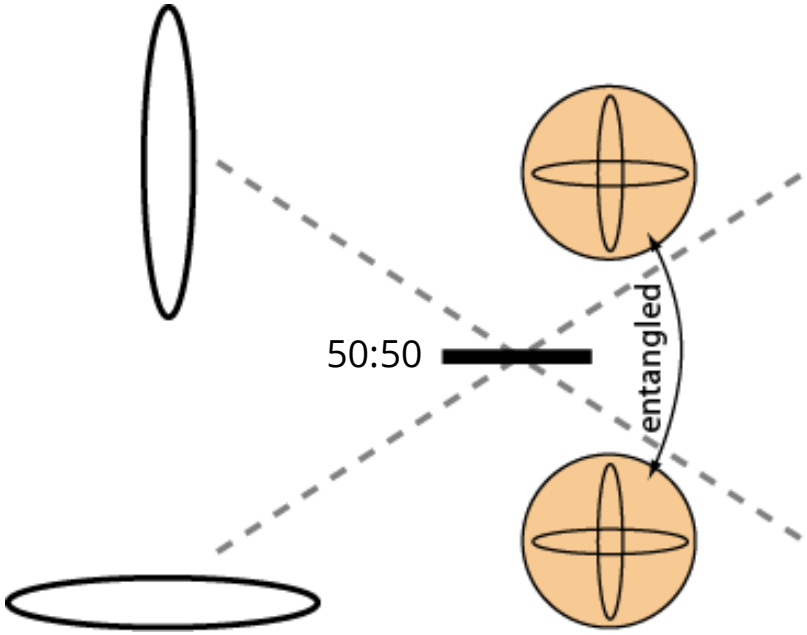


Where we are right now

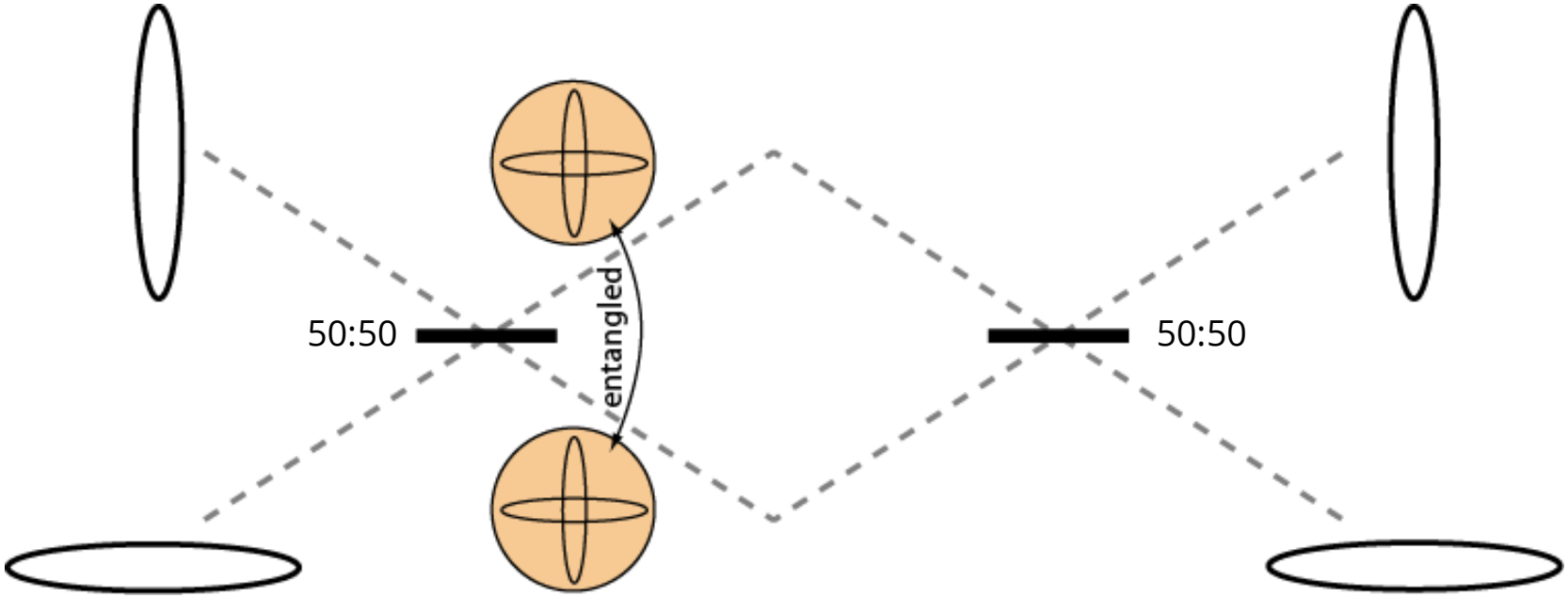
- squeezed-light enhanced Michelson interferometer
- squeezing ellipse oriented (frequency dependent) such that SNR is optimised
- orthogonal quadrature is lost in anti-squeezed noise
  - no GW signal there
  - but maybe interesting 'technical' signals
  - use as a veto/subtraction/monitor channel?
- how to recover this information?



To entanglement states...

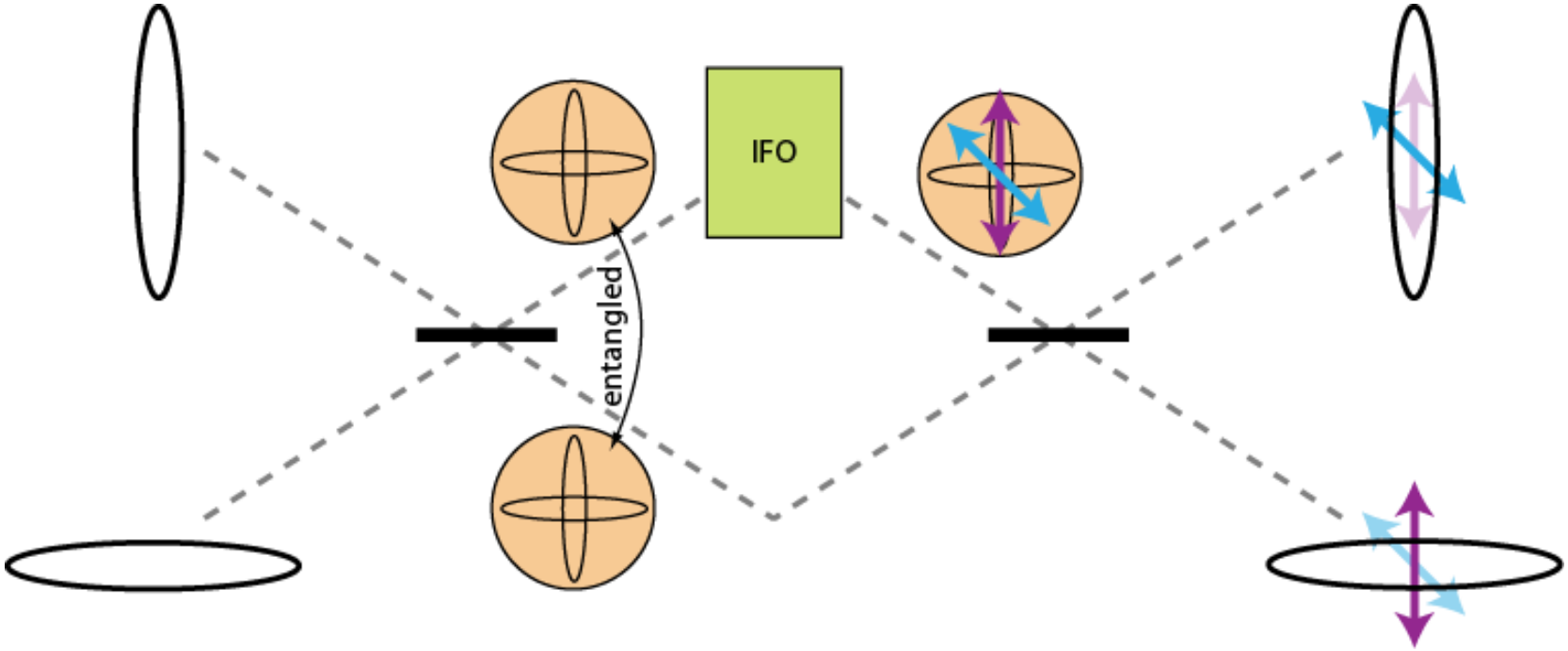


… and back



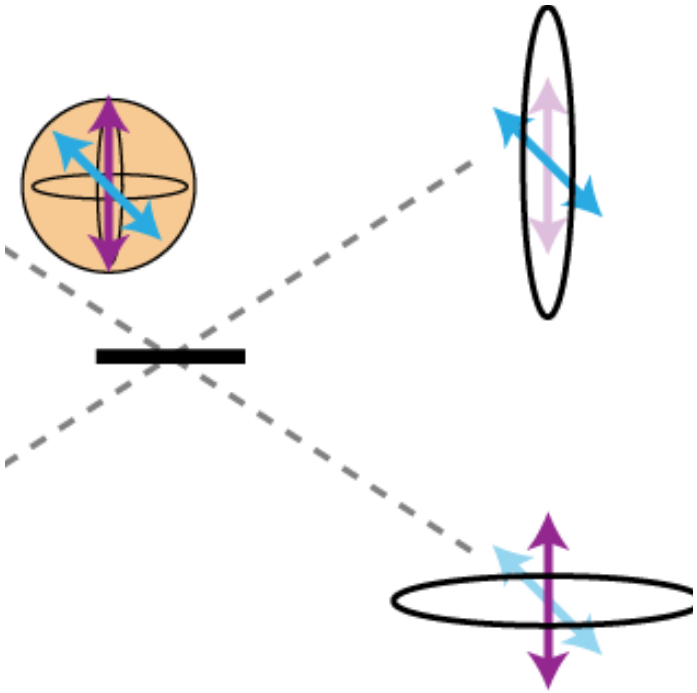
Two-mode squeezed readout

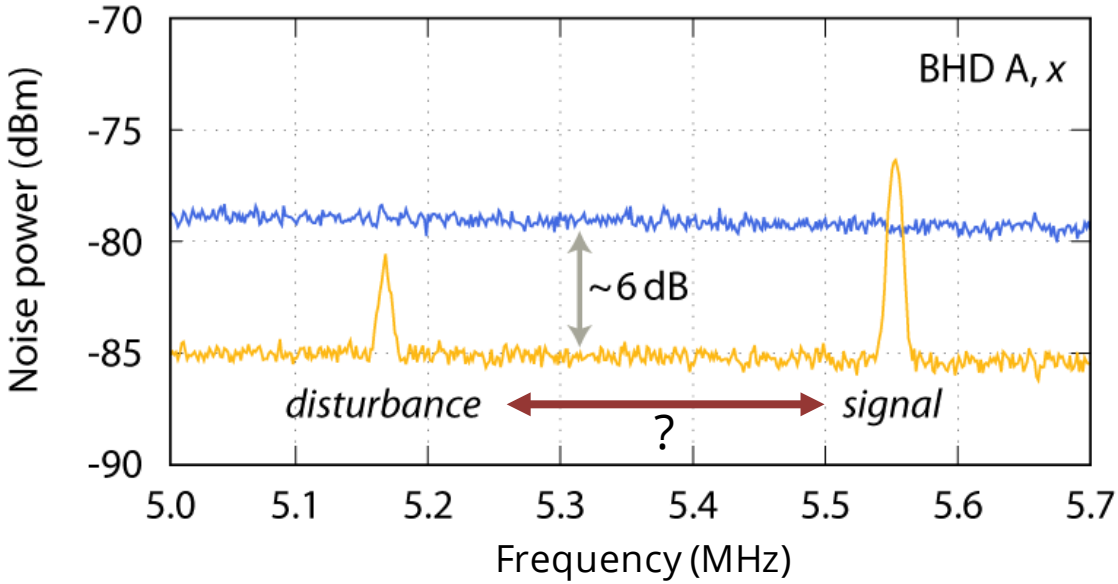
"Quantum-Dense Metrology (QDM)":
Sub-shot noise signal readout of two orthogonal quadratures of a single signal field



Steinlechner et al, 10.1038/nphoton.2013.150

Conceptual demonstration: veto channel





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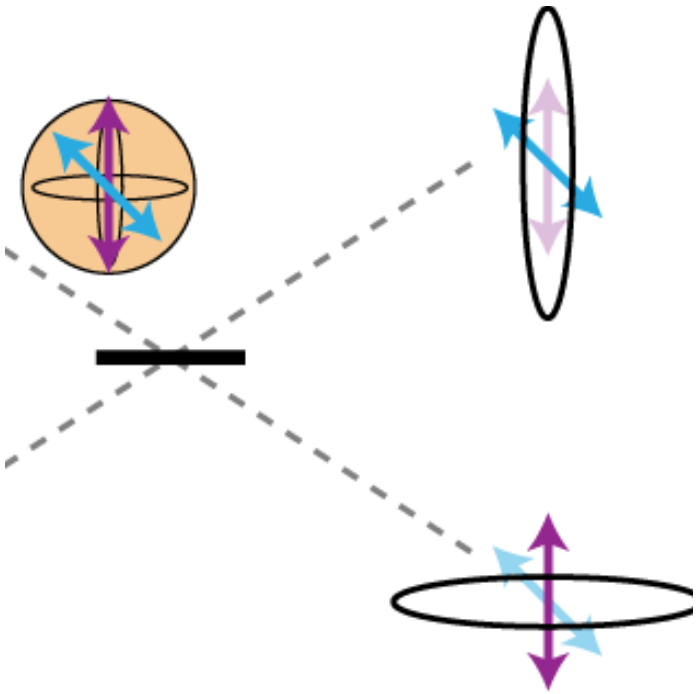

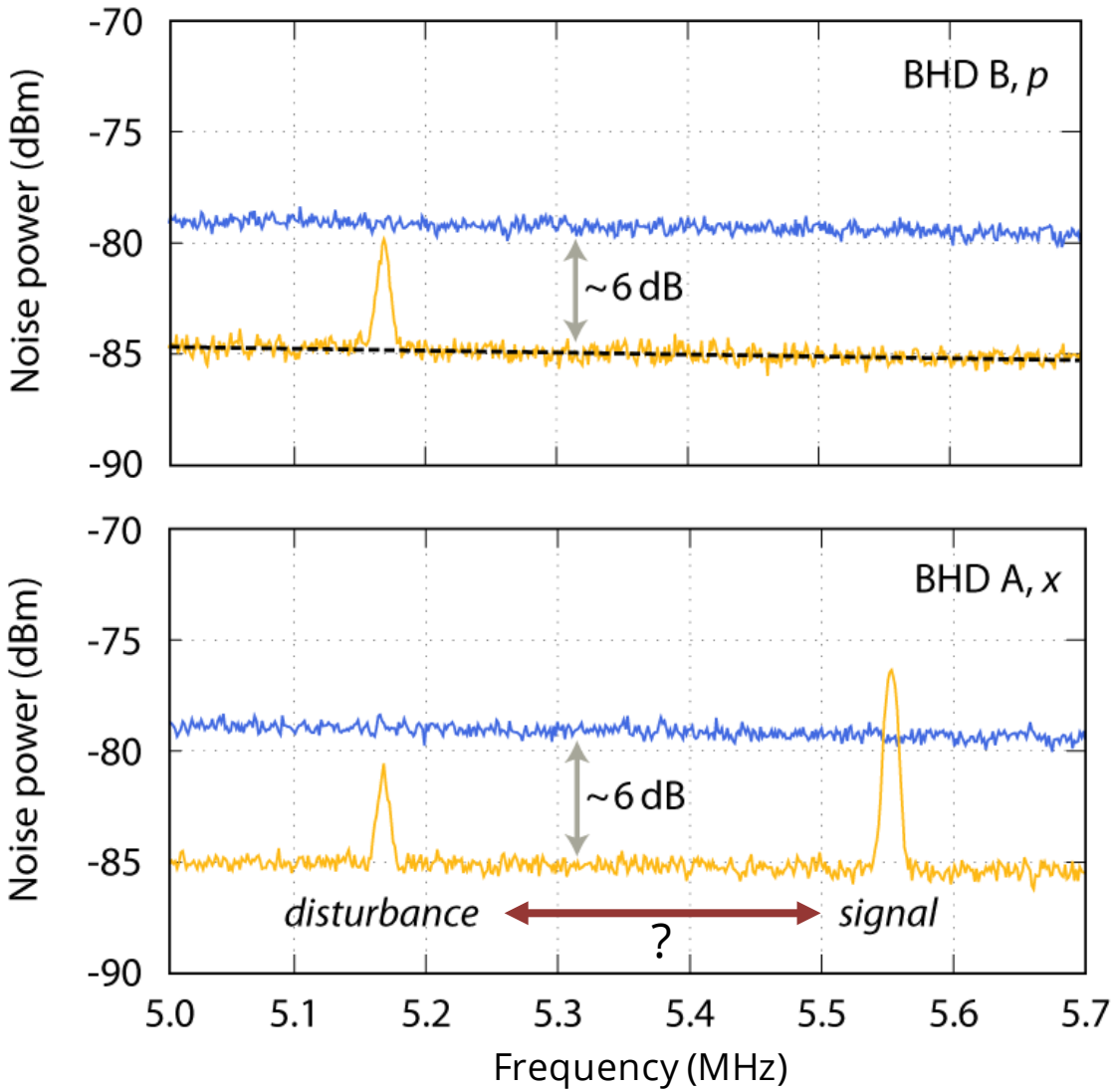

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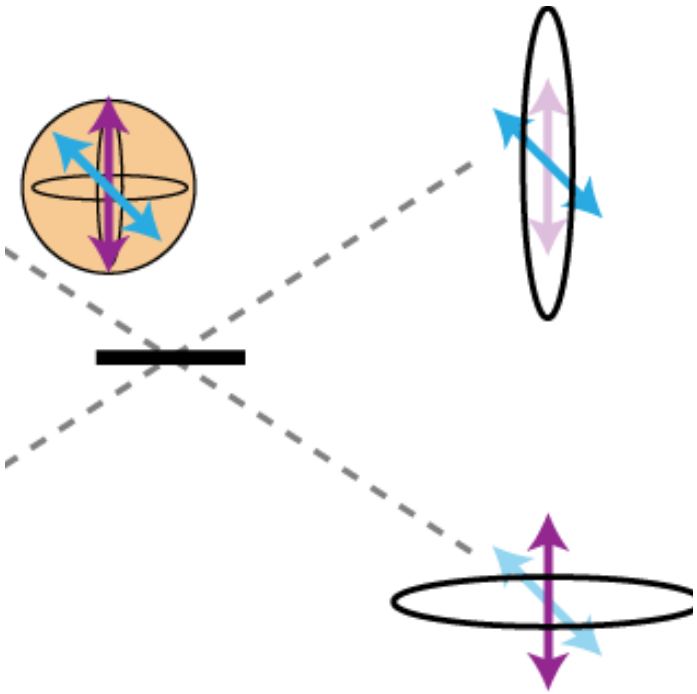
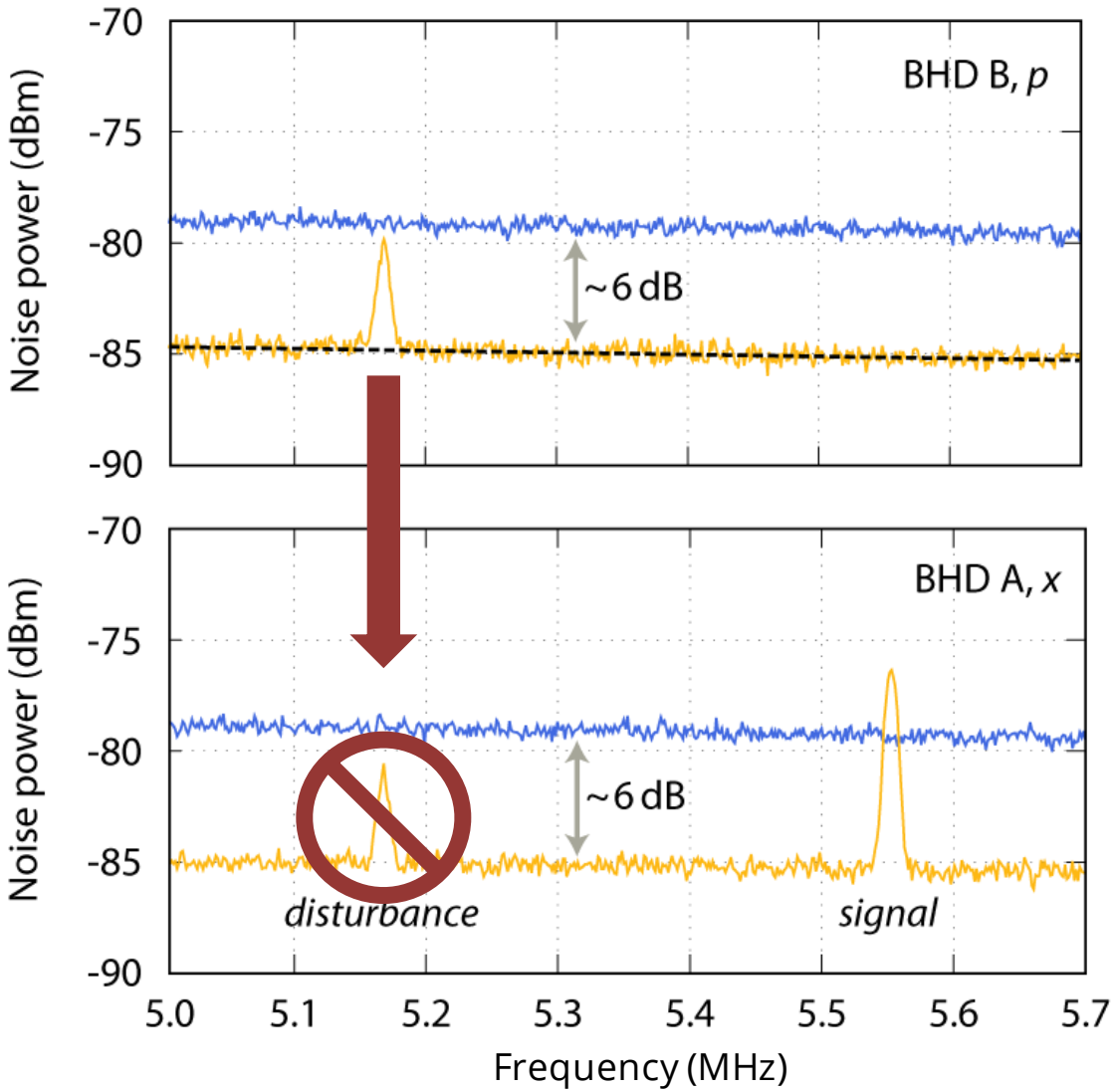
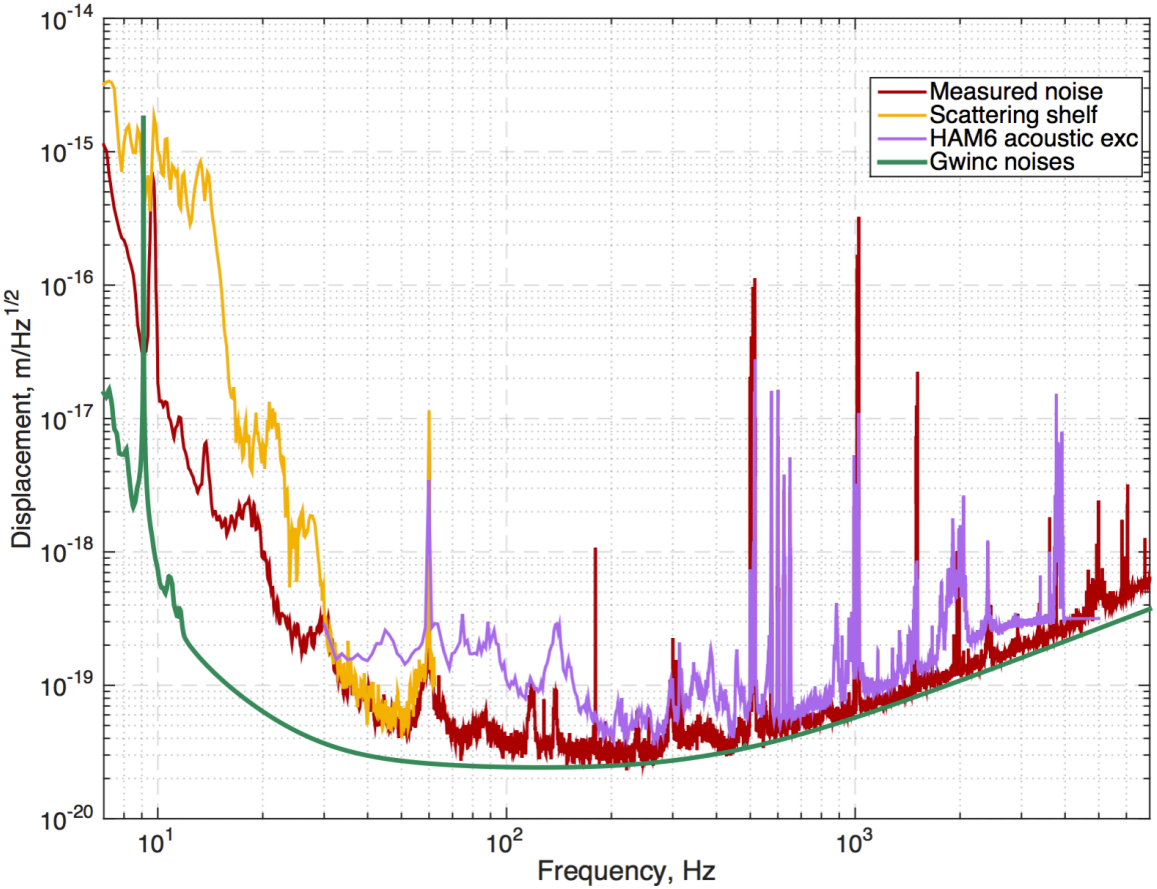


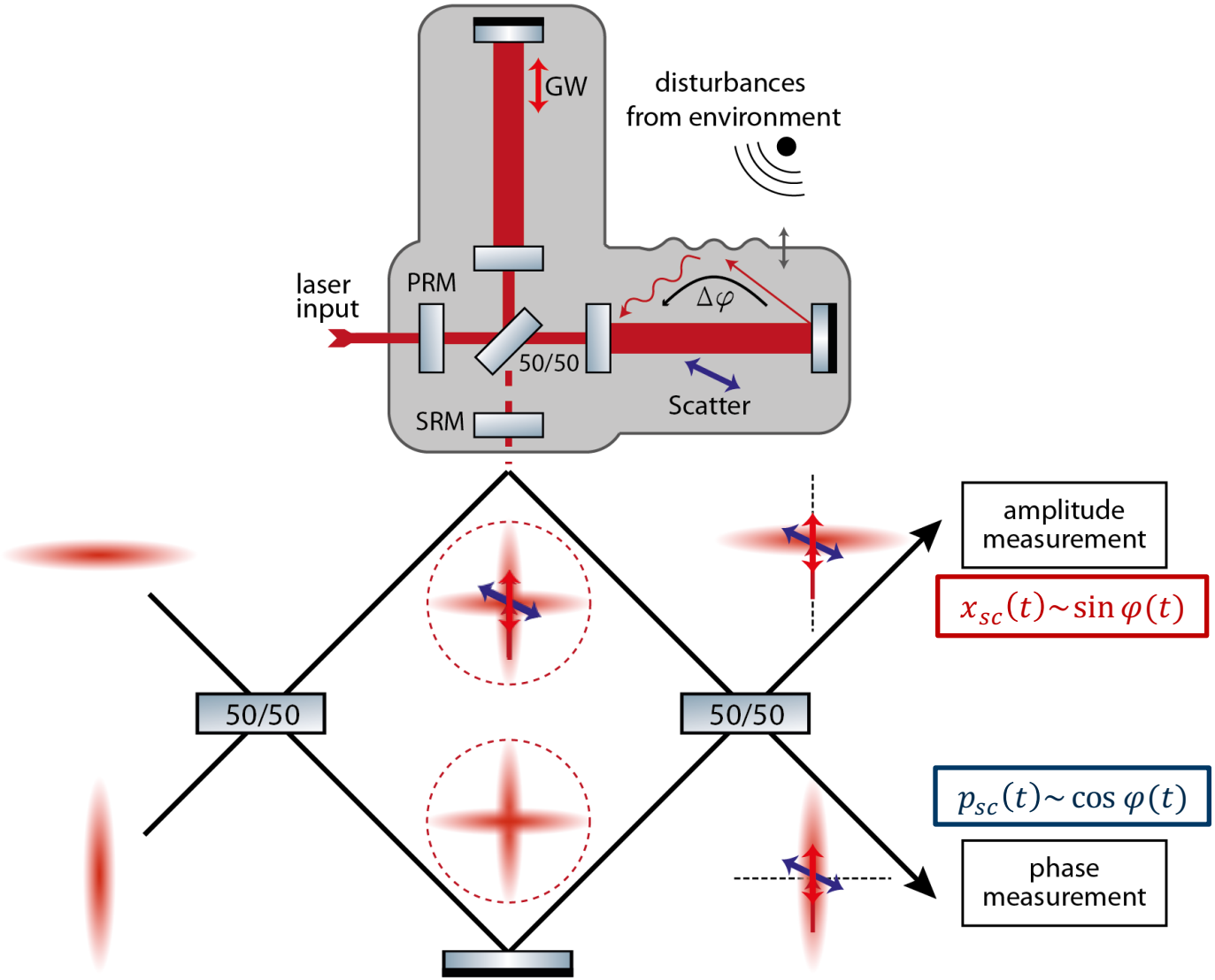


Possible application: Scattered light

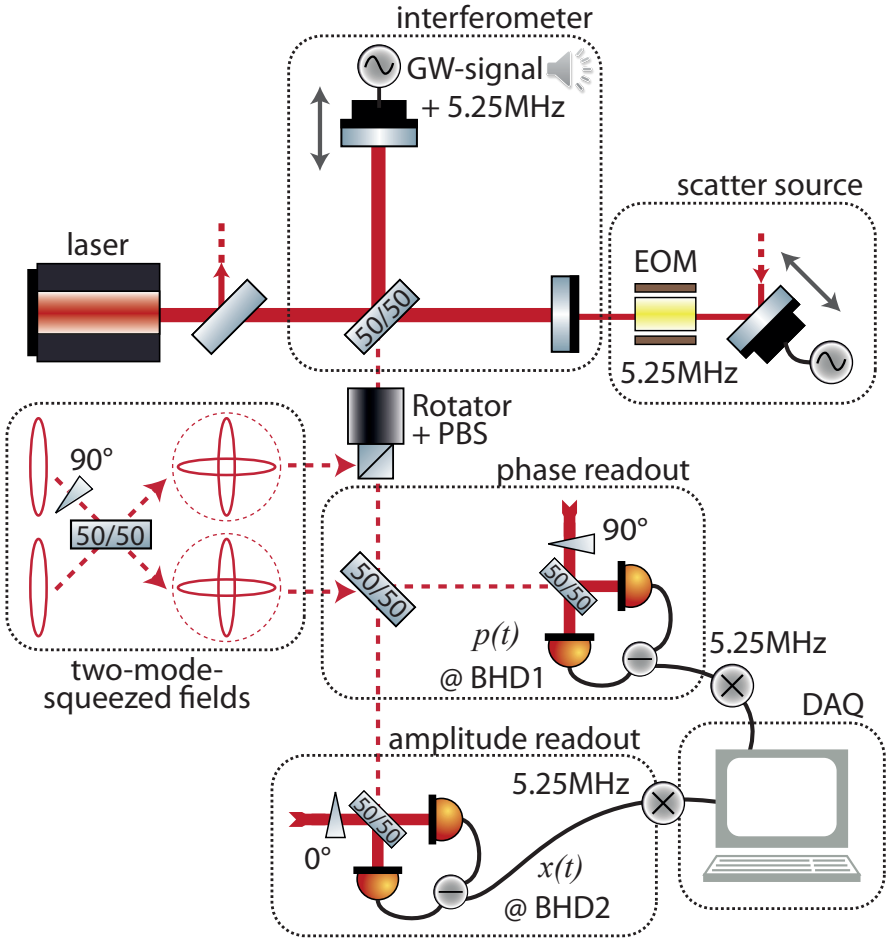


D. Martynov, PhD thesis

Scattered light in IFOs



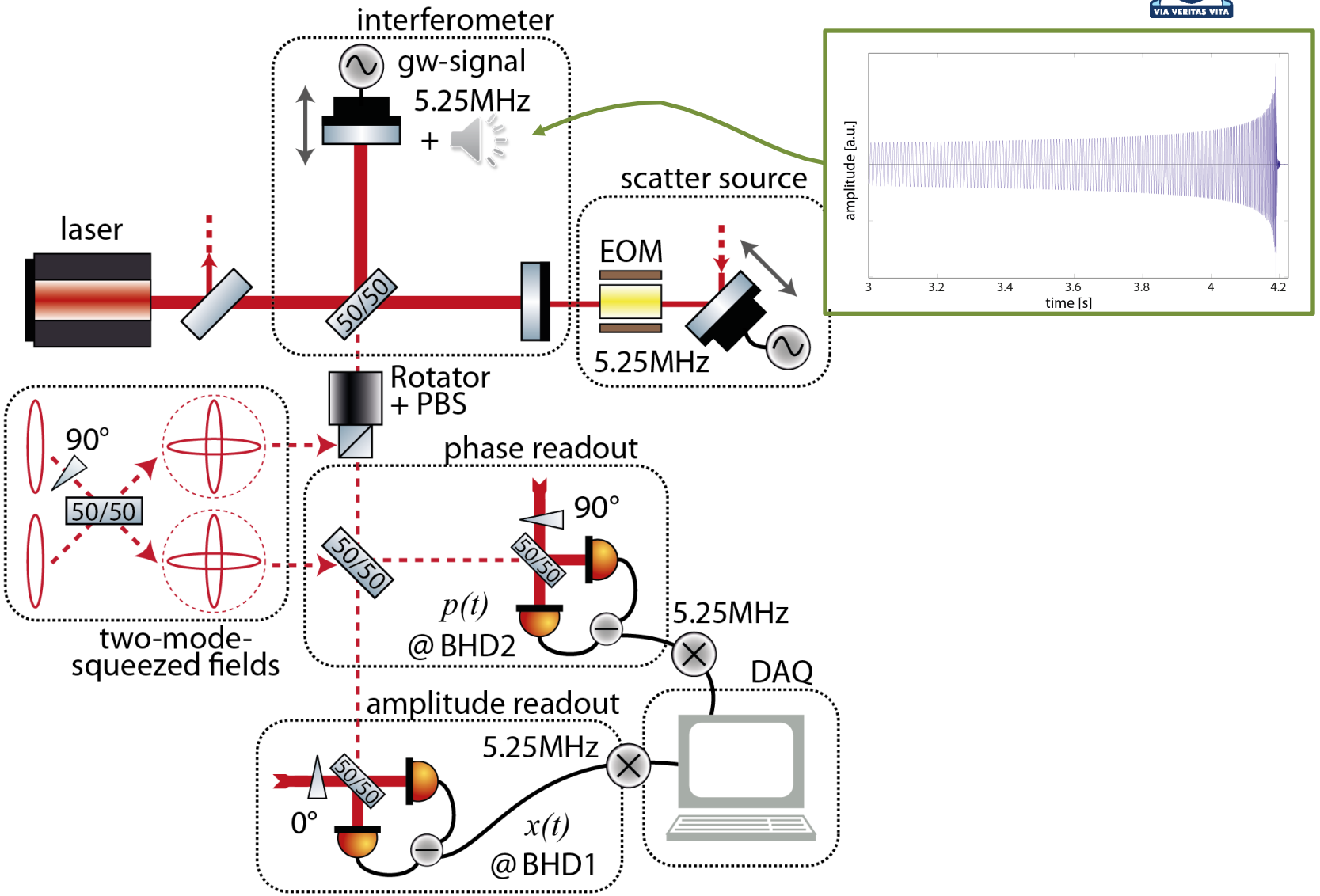
Experimental demonstration



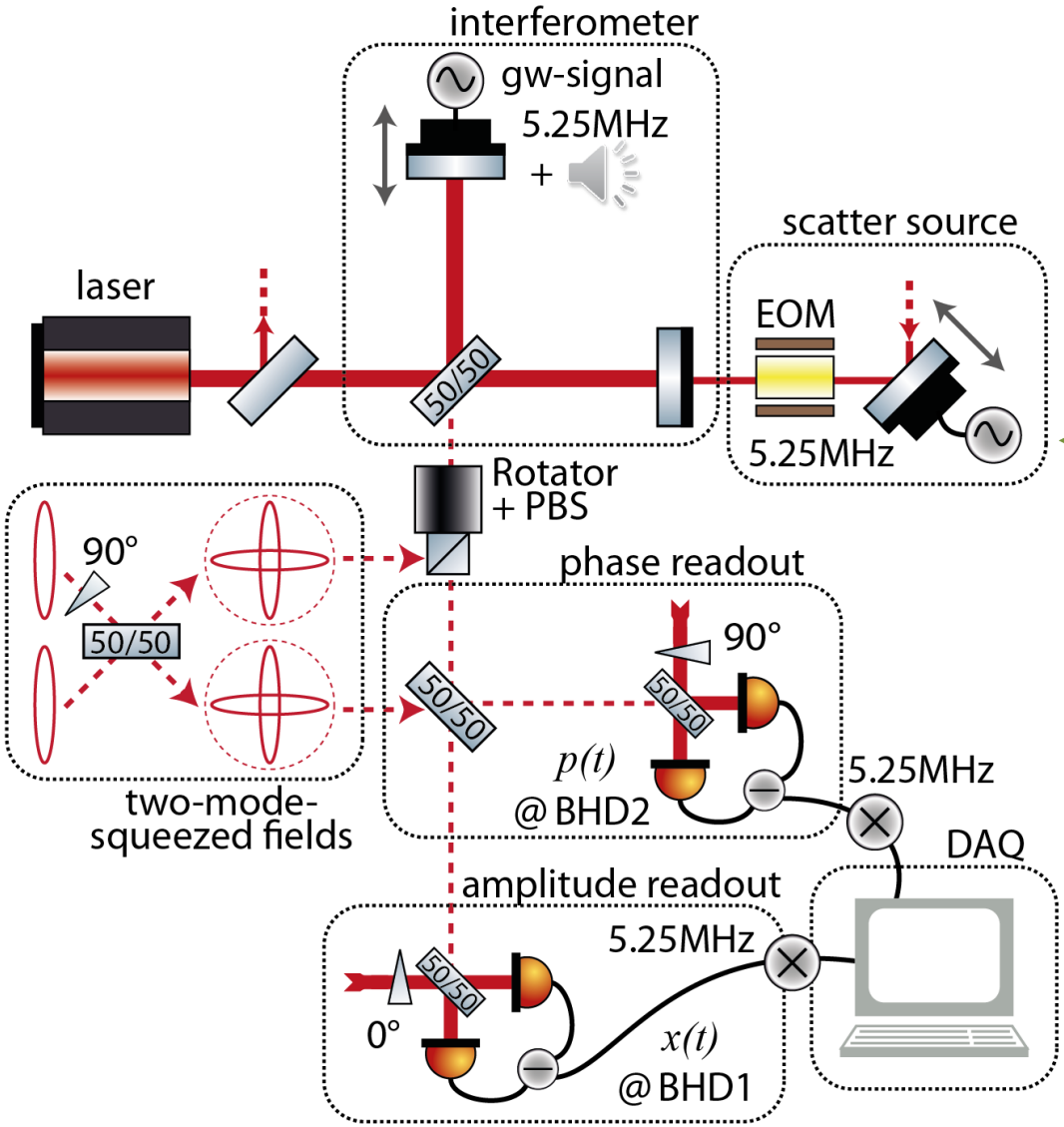
- Laser source: Nd:YAG, 2W @ 1064nm
- Signals at audioband frequencies, shifted to MHz and demodulated
- Two-mode-squeezed light source: one monolithic squeezer, one hemilithic squeezer, PPKTP, squeezing >10dB
- Detection with two balanced homodyne detectors (BHD1&2)

M. Meinders, R. Schnabel, CQG (2015), 10.1088/0264-9381/32/19/195004
M. Ast, S. Steinlechner, R. Schnabel, in preparation (LIGO-P1600163)

Signal injection



Scattered light generation

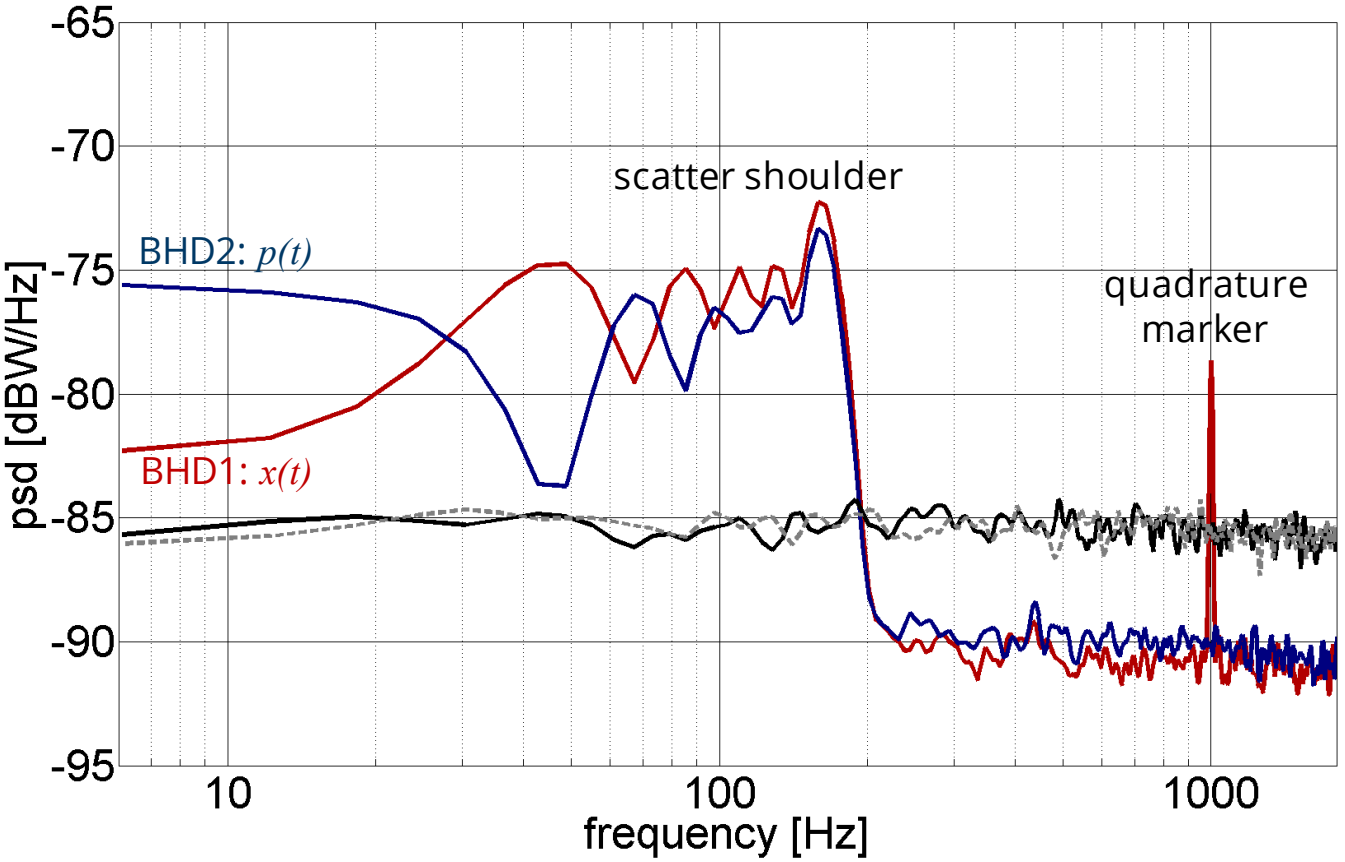


A_m: several λ

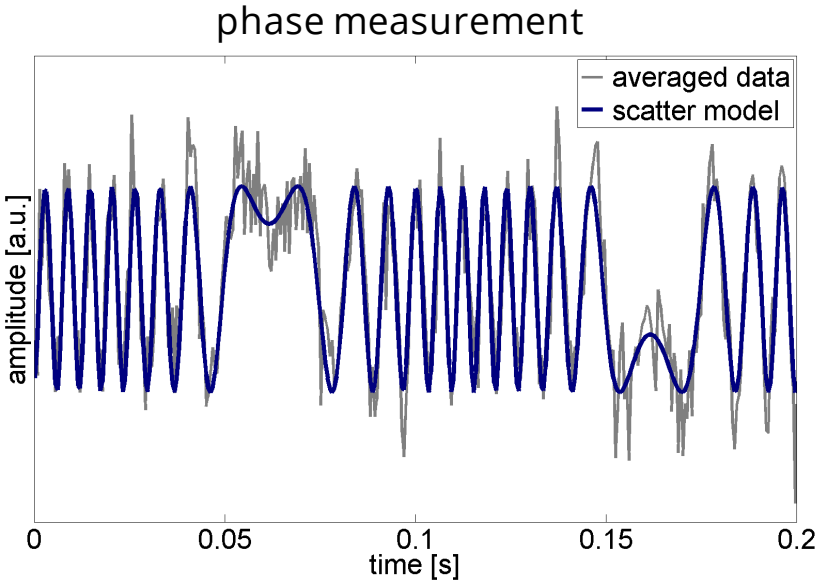
f_m: few Hz

$f_{\max} = 2\pi A_m f_m / \lambda$

Output spectra without subtraction



Subtraction of the scatter signal



$$p_{\mathrm{sc}}(t) \propto \cos(\varphi_0 + \tfrac{2\pi}{\lambda} A_{\mathrm{m}} \sin(2\pi f_{\mathrm{m}} t + \varphi_{\mathrm{m}}))$$

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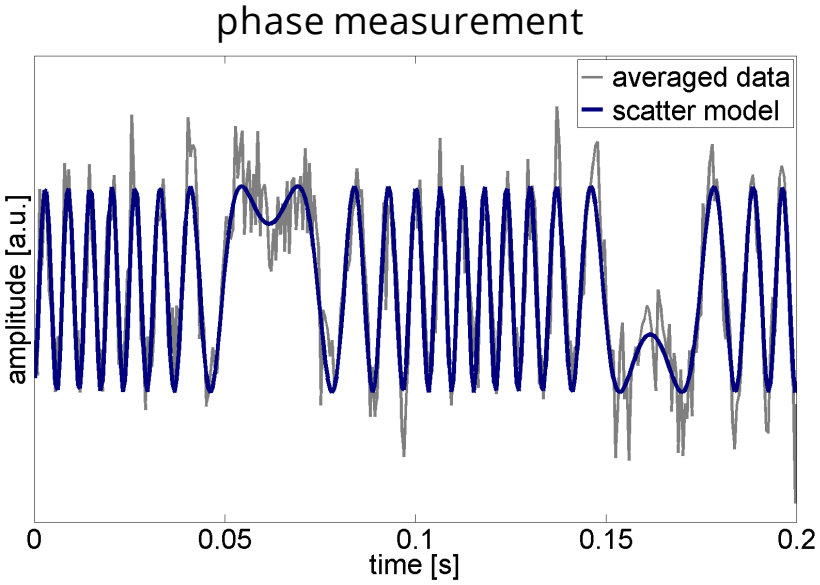

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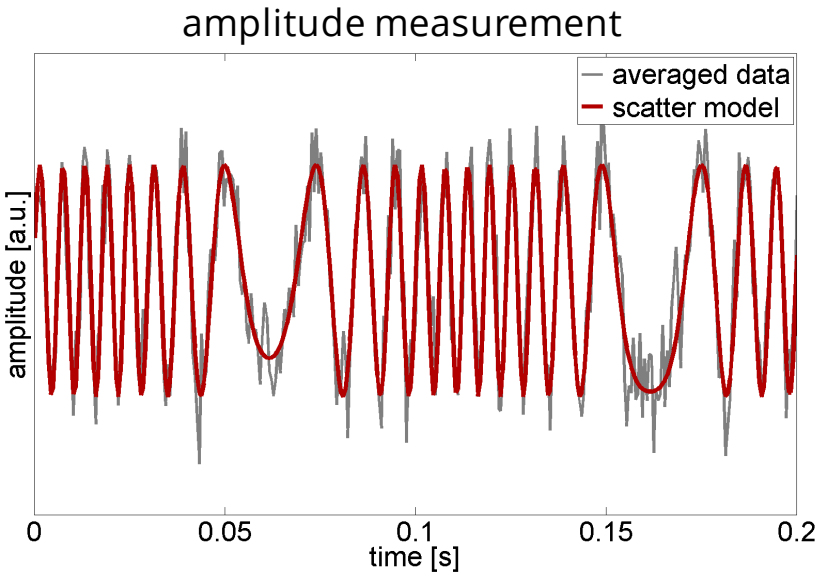
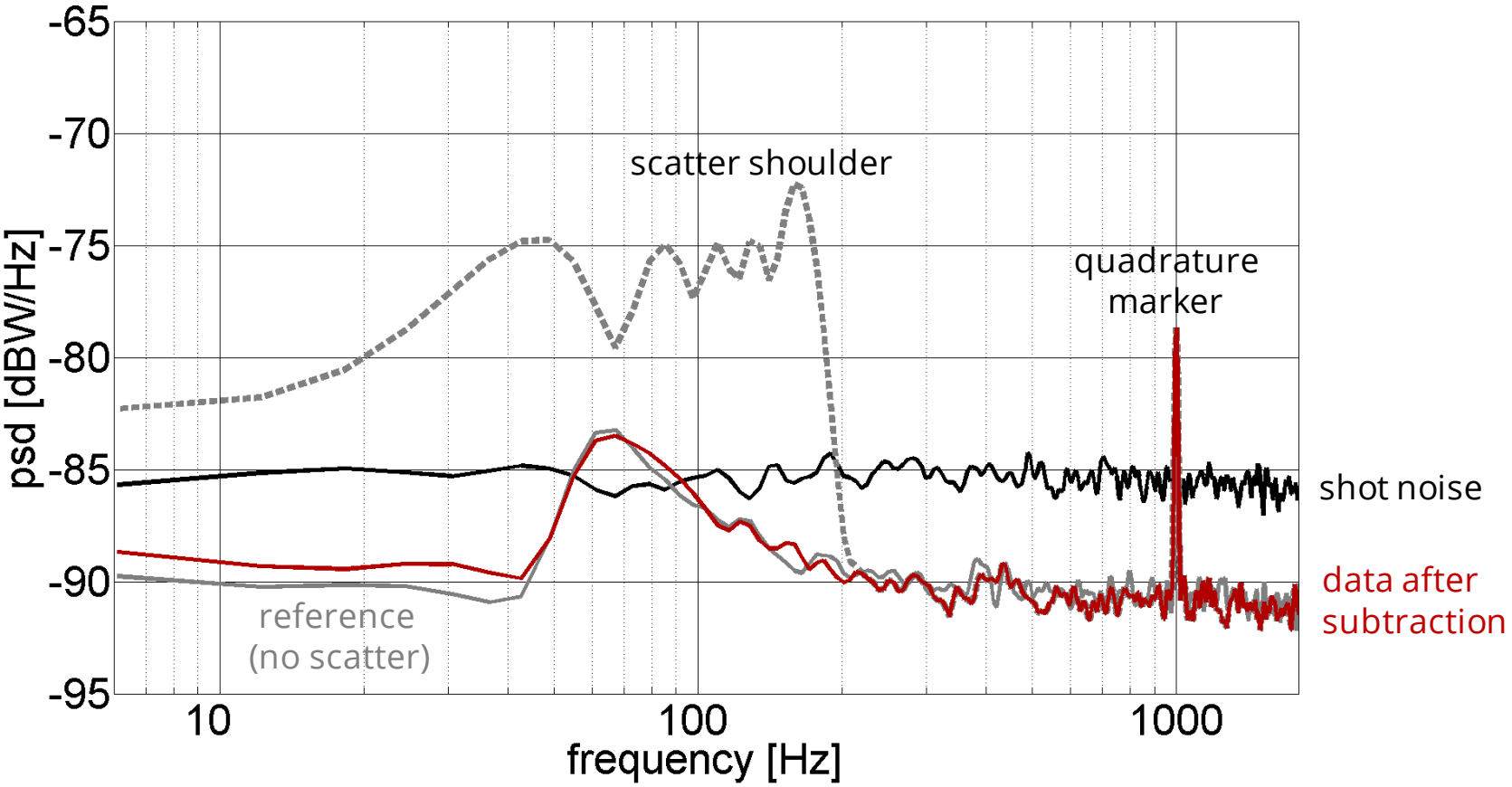


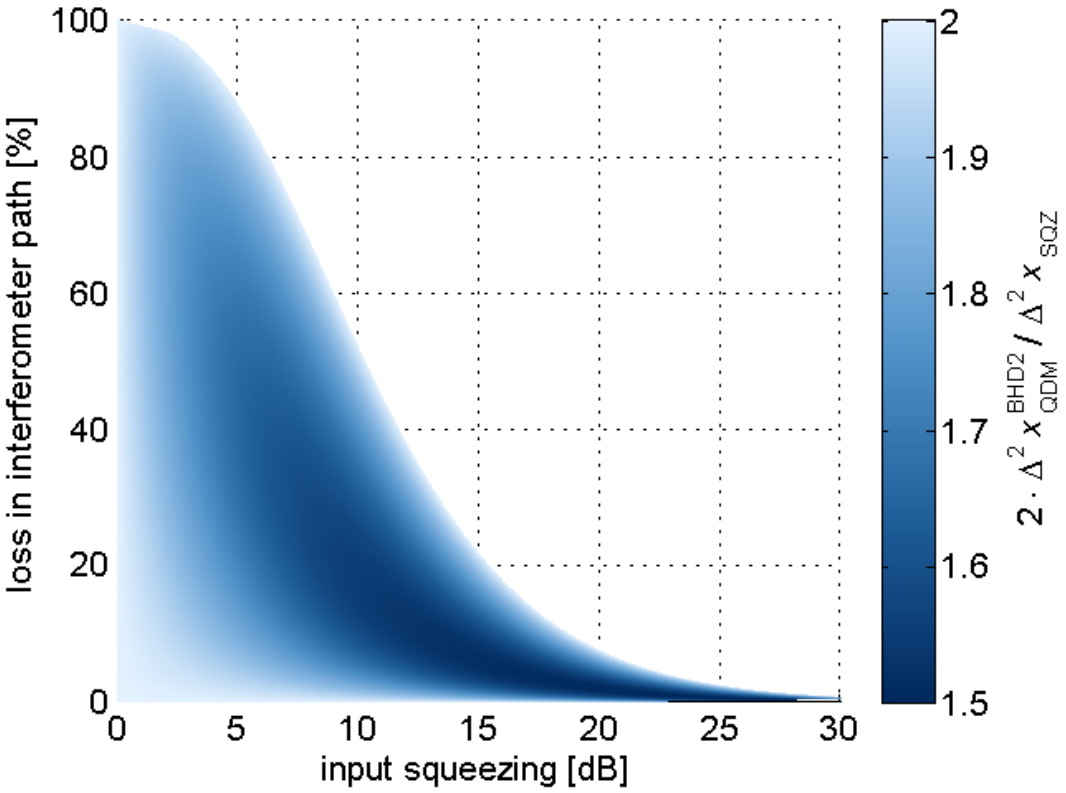
$$\Rightarrow \quad \varphi(t) \quad \Rightarrow \quad x_{\mathrm{sc}}(t) \propto \sin \varphi(t)$$

Result of the subtraction

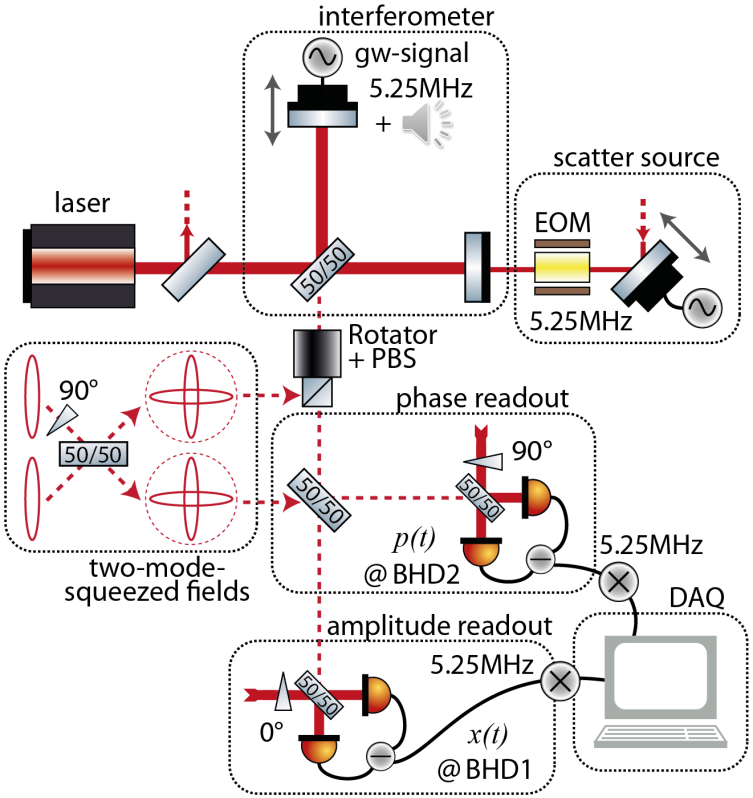


Effective attenuation of signal

- In worst case, SNR reduction of 2 compared to squeezed-light injection
  - ONLY if readout is not limited by noise that limit squeezed-light readout, but can be removed with QDM
  - signal is split at output beam splitter
  - only one half is detected
- More favourable with realistic injection loss



Conclusion



- QDM allows simultaneous sub-shot noise readout of two orthogonal quadratures
- application in subtraction of excess noise with quadrature signature that is different from GW signal
- demonstrated subtraction of (single) scattering source, recovering the previously hidden signal