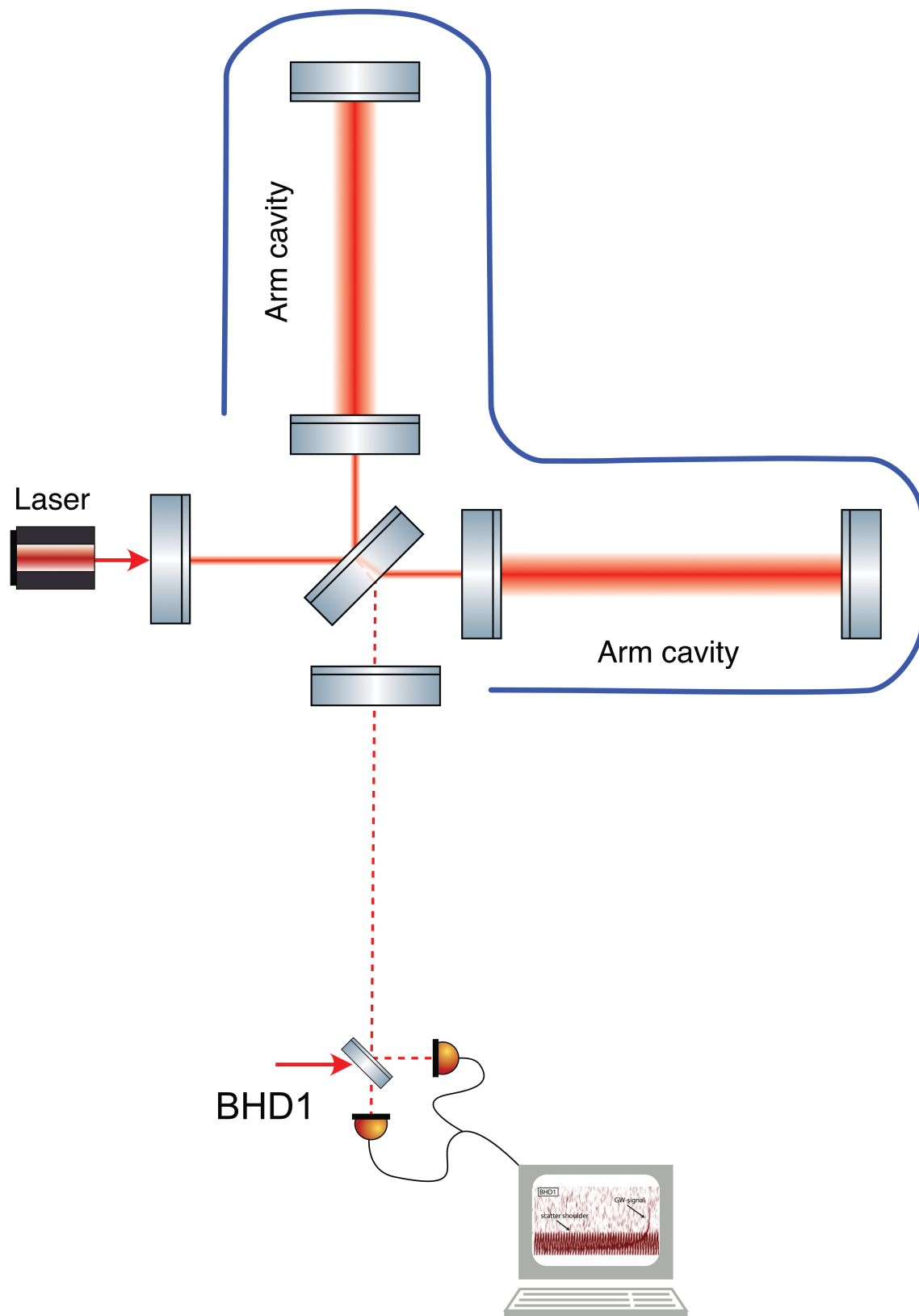


# Mitigating back-scatter light with dual homodyne readout

Mikhail Korobko, Roman Schnabel — University of Hamburg  
Sebastian Steinlechner — Maastricht University  
Melanie Ast — University of Hannover

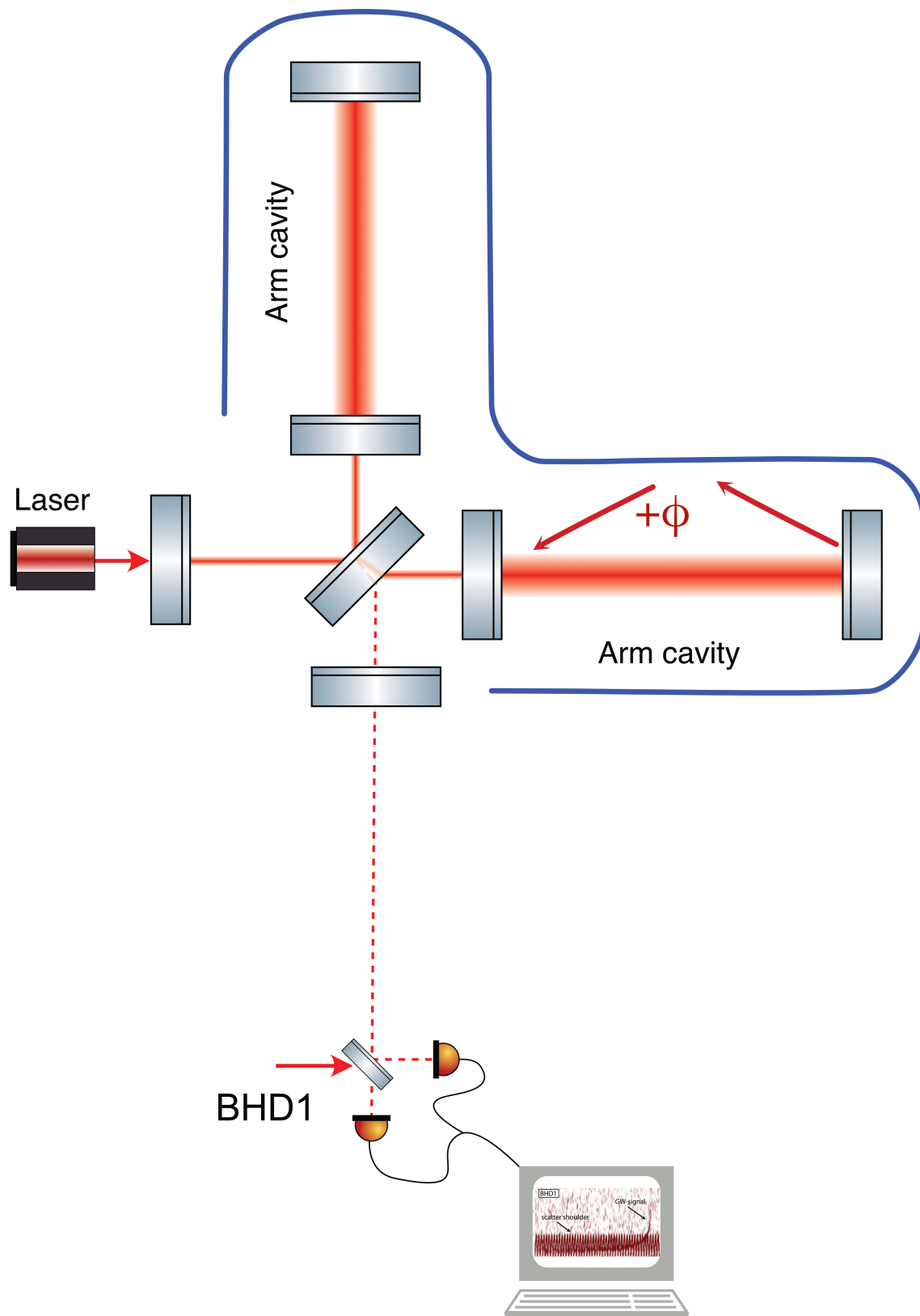
# The back-scatter problem

2



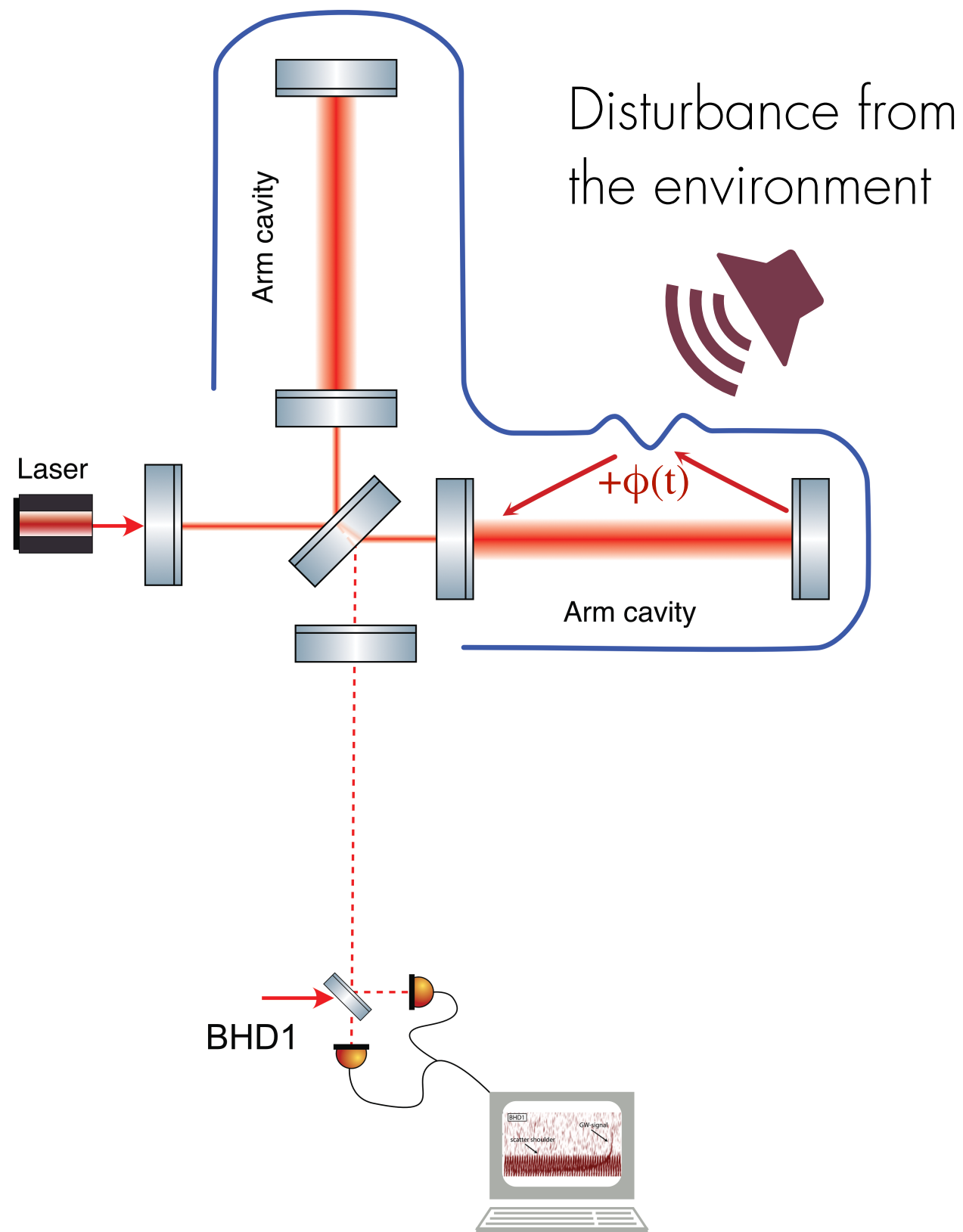
# The back-scatter problem

3

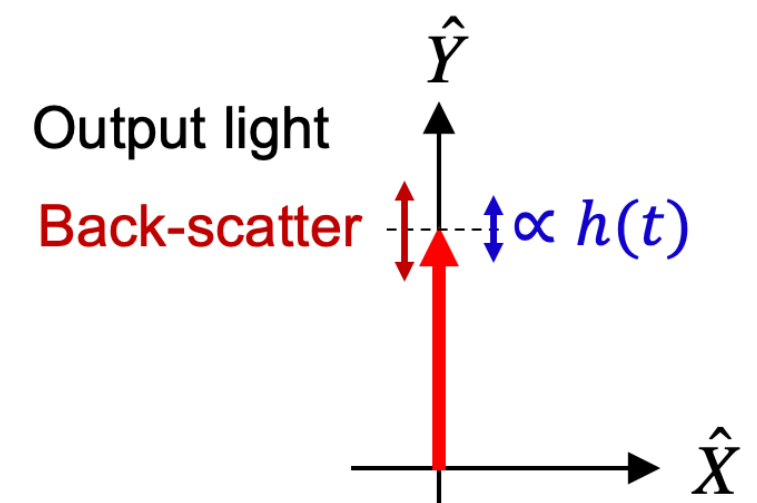


# The back-scatter problem

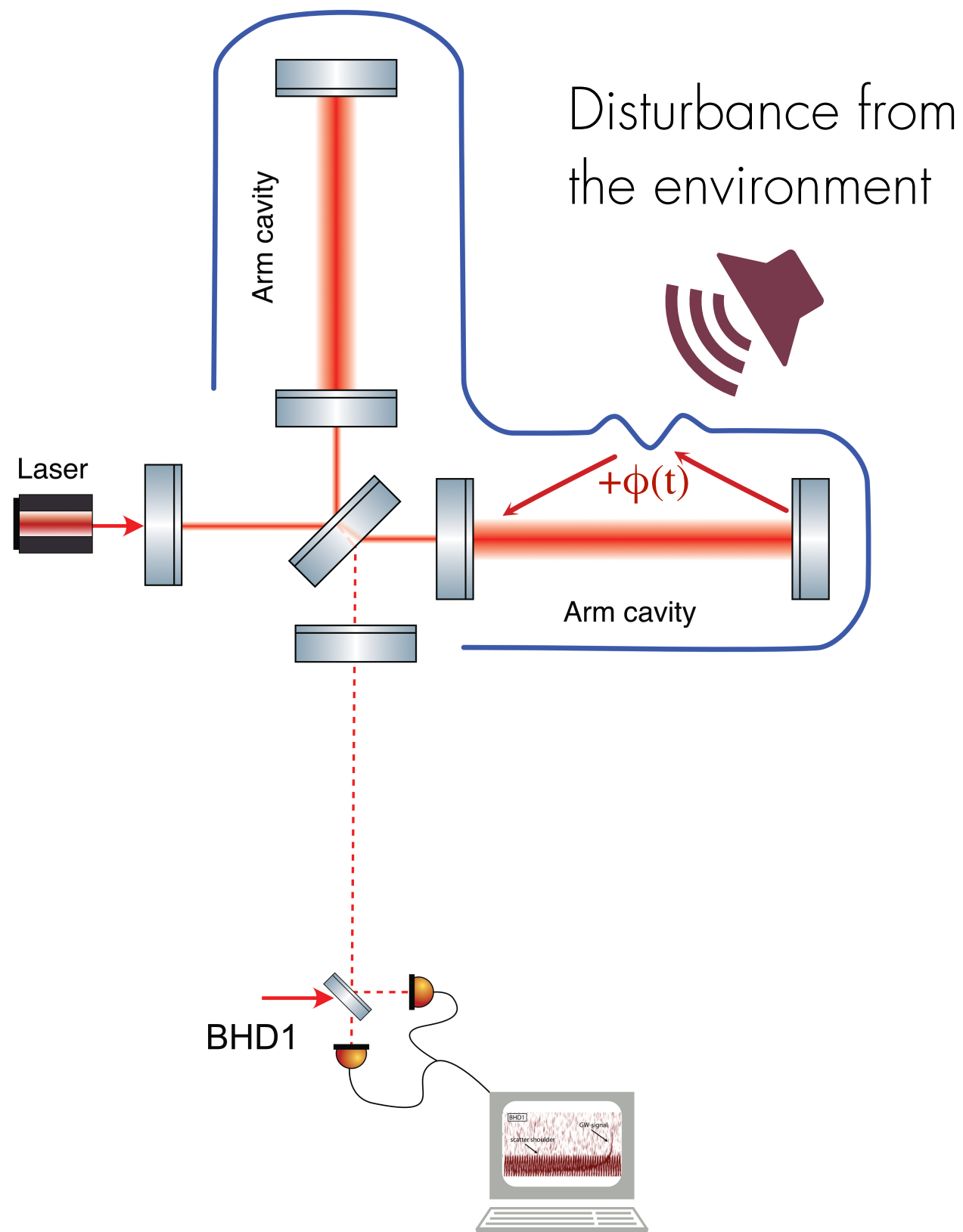
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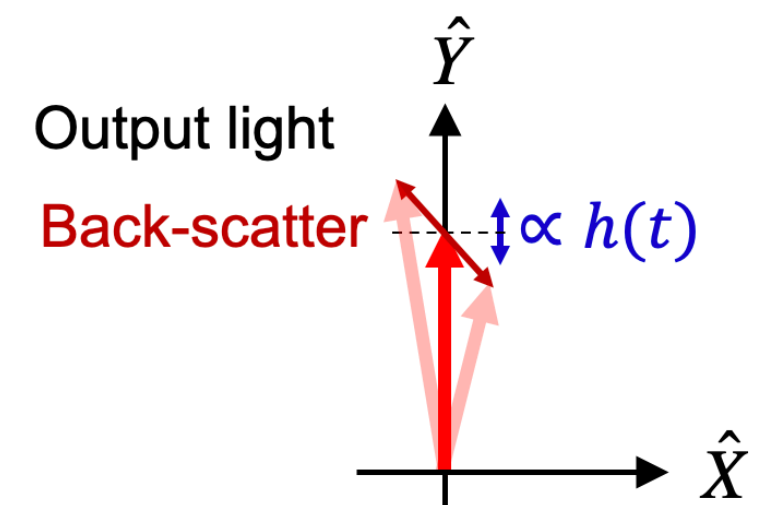
- Scattering is indistinguishable from GW signal

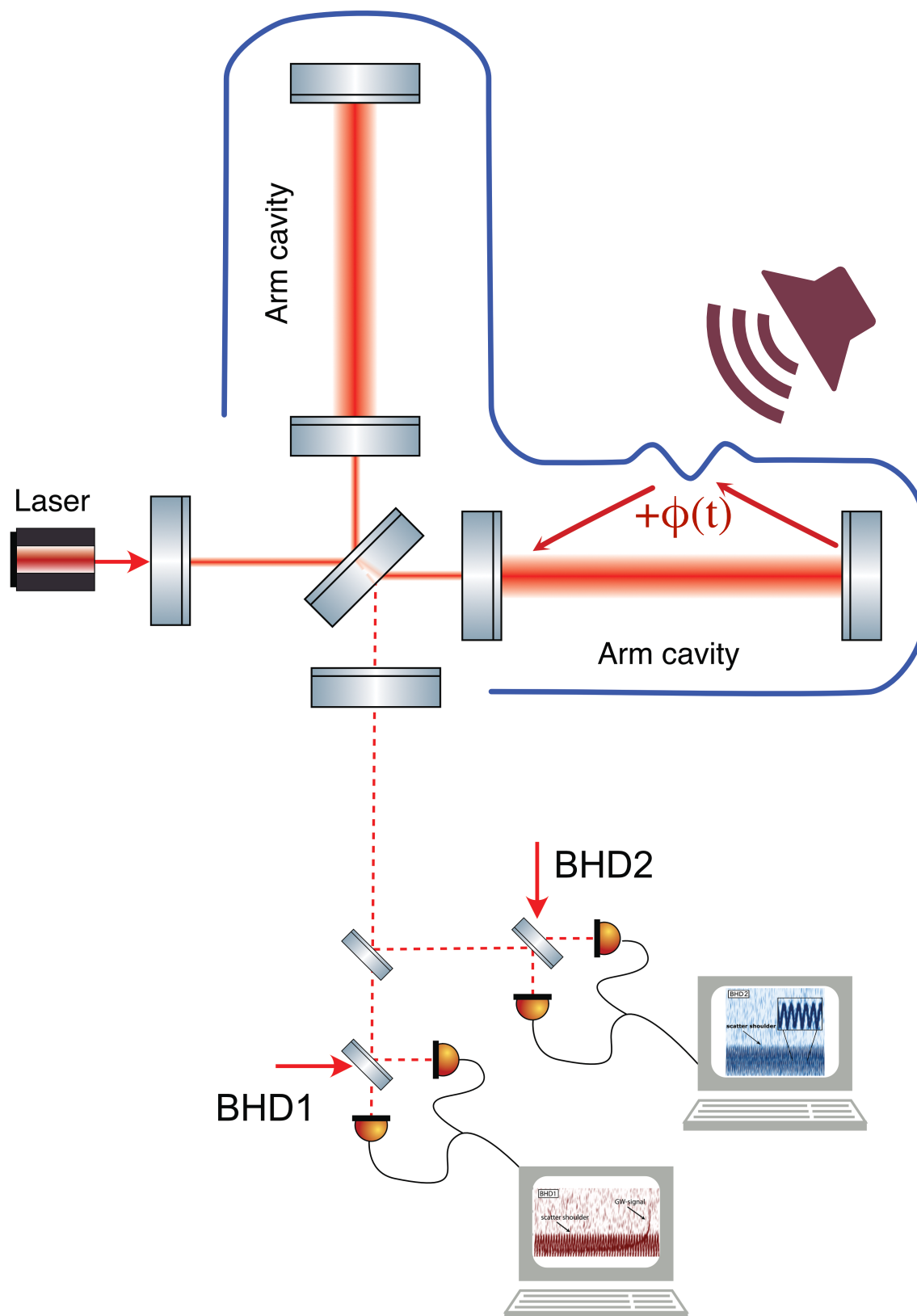




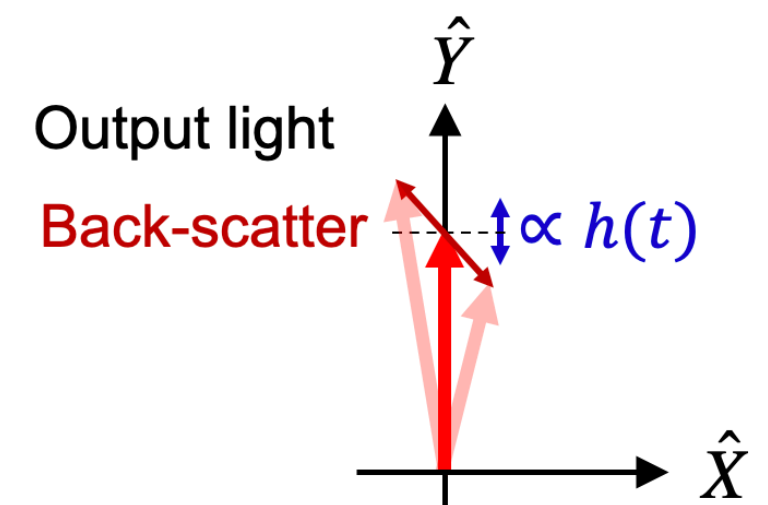


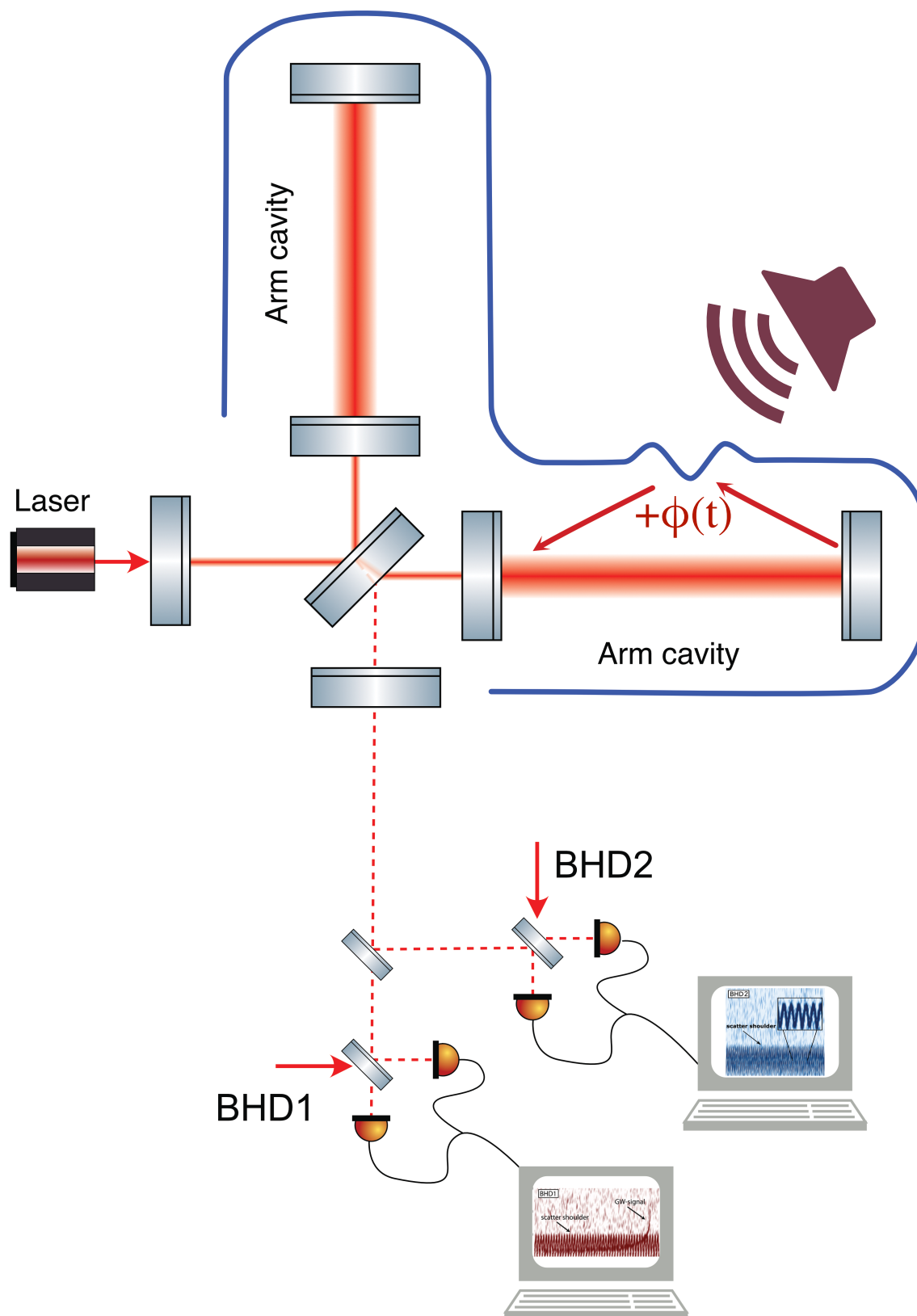
- ▶ Scattering is indistinguishable from GW signal
- ▶ Scattering is never in exactly the same quadrature as GW signal



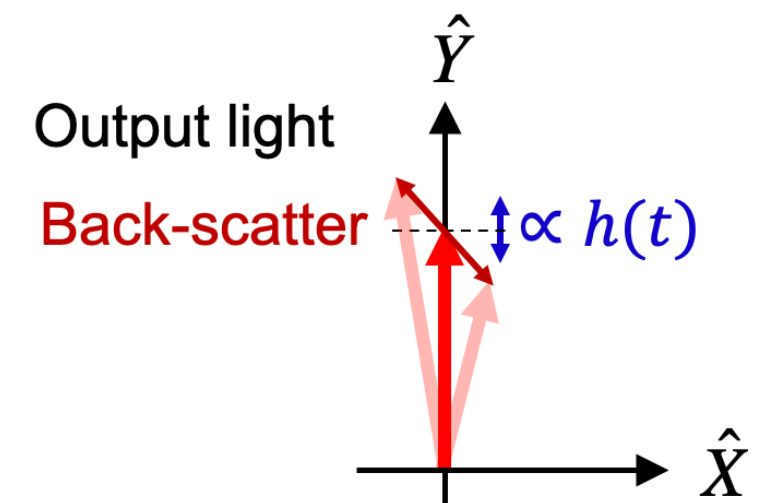


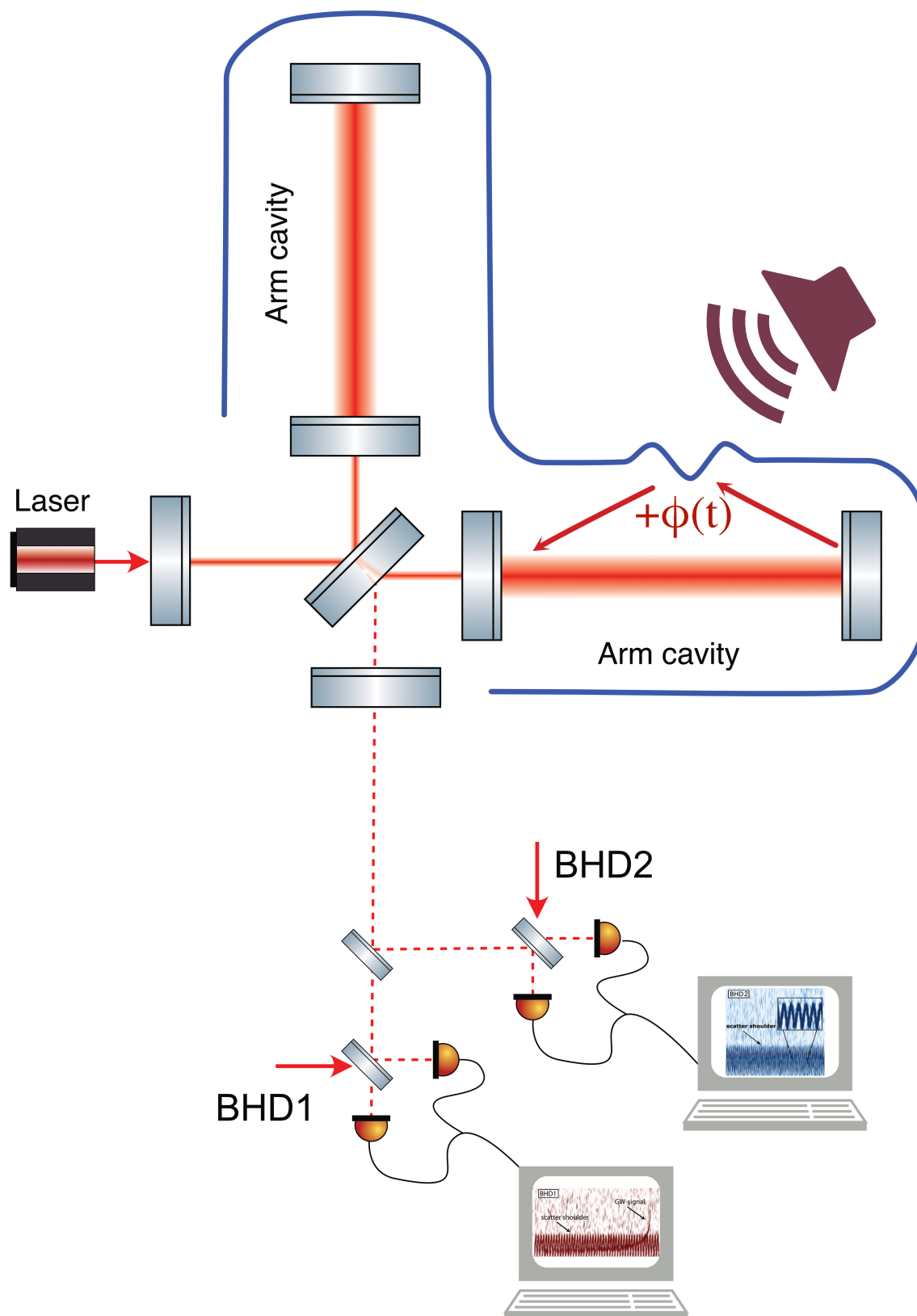
- Adding the second homodyne to read out X quadrature



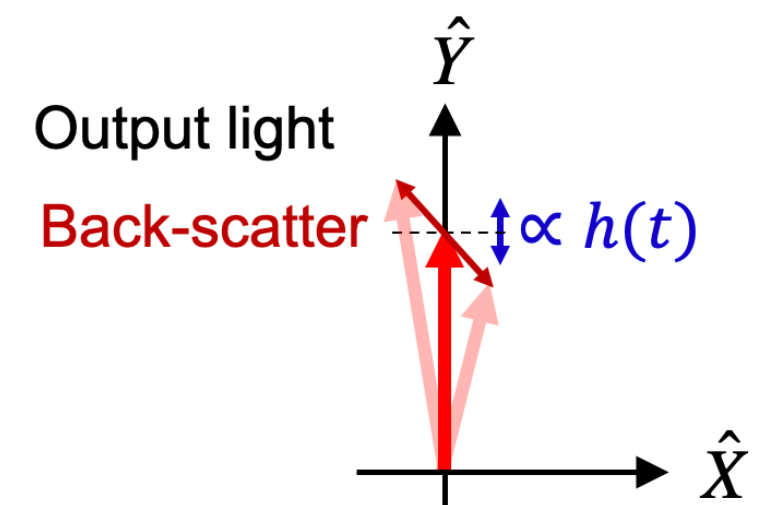


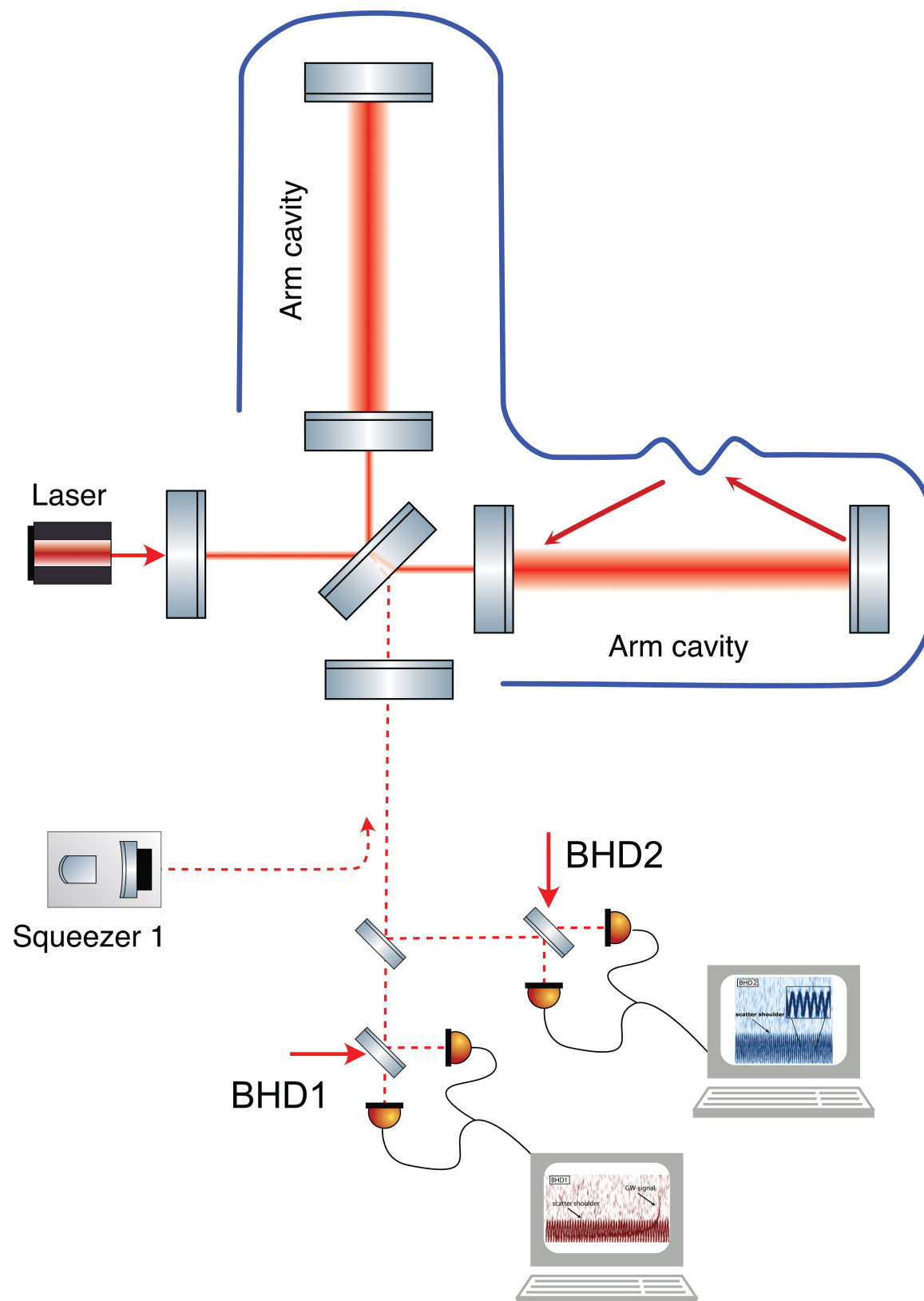
- ▶ Adding the second homodyne to read out X quadrature
- ▶ Post-processing to extract data from combined X & Y



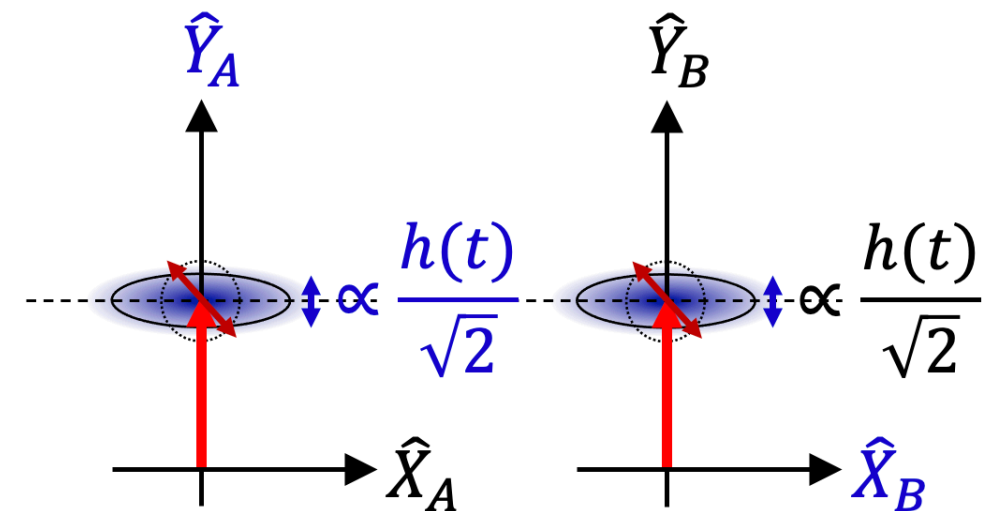


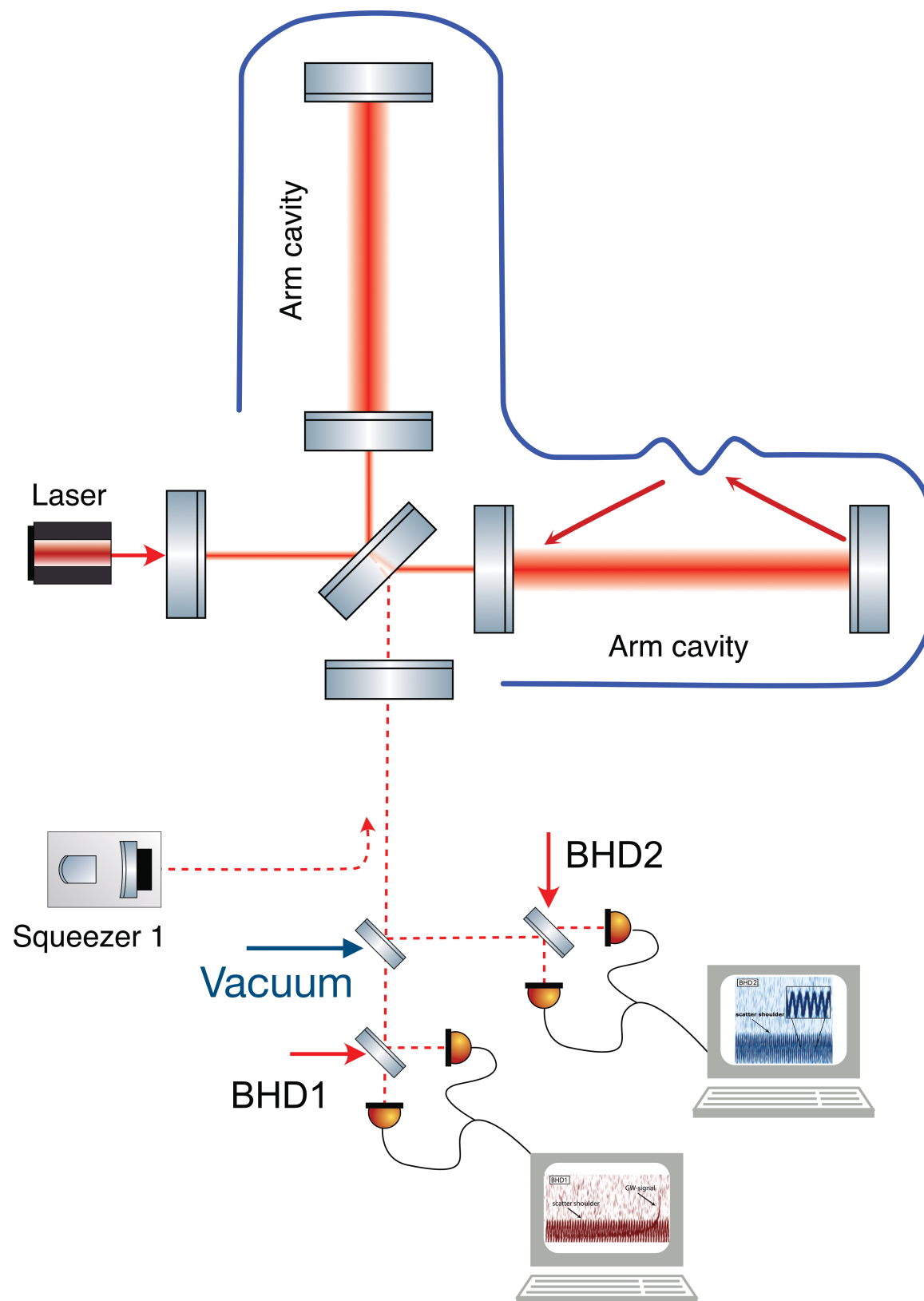
- ▶ Adding the second homodyne to read out X quadrature
- ▶ Post-processing to extract data from combined X & Y
- ▶ 3dB loss in GW signal



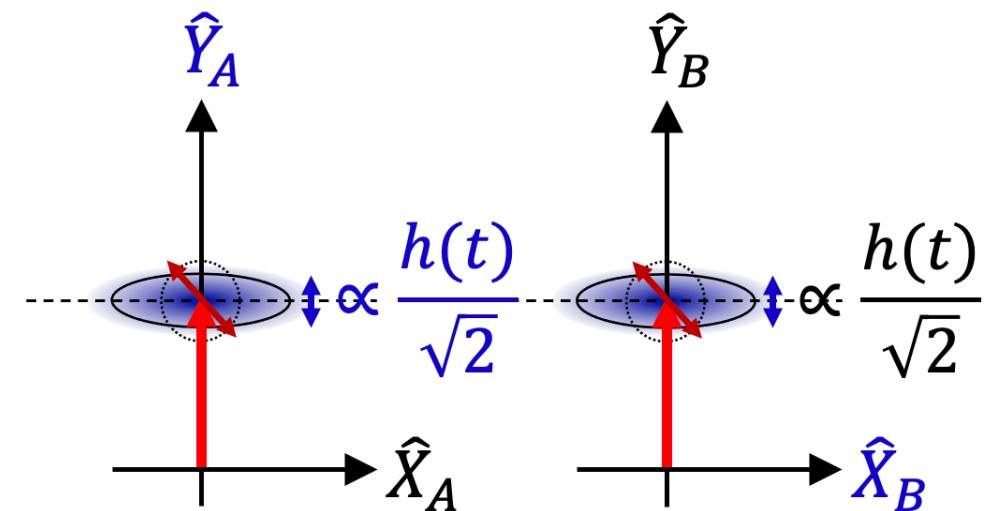


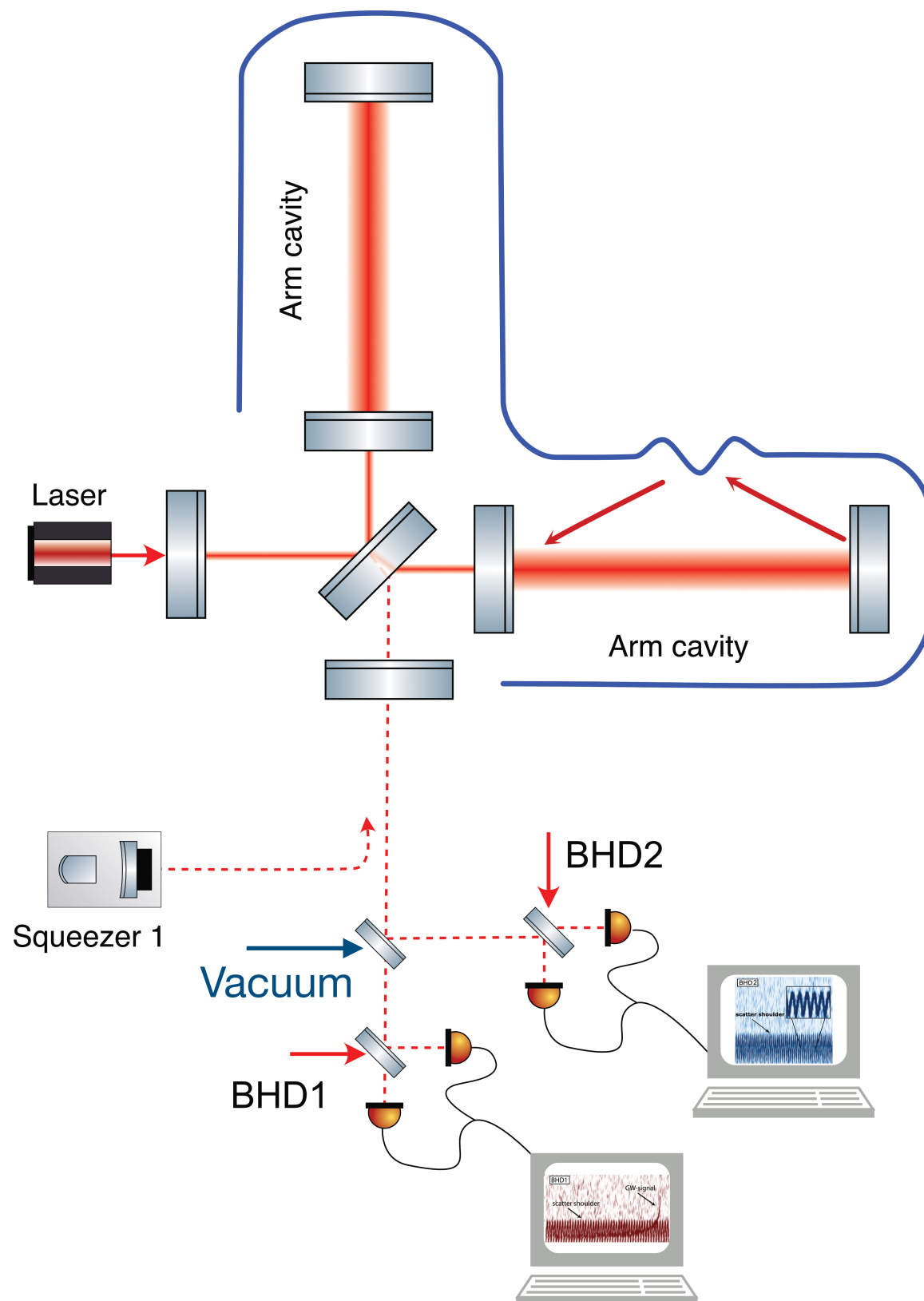
- Squeezed light allows to reduce the shot noise in Y quadrature



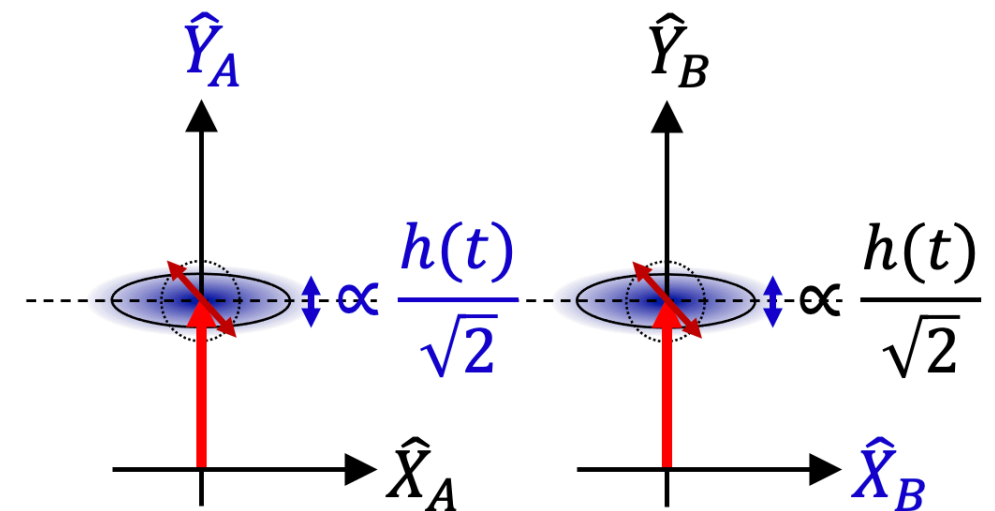


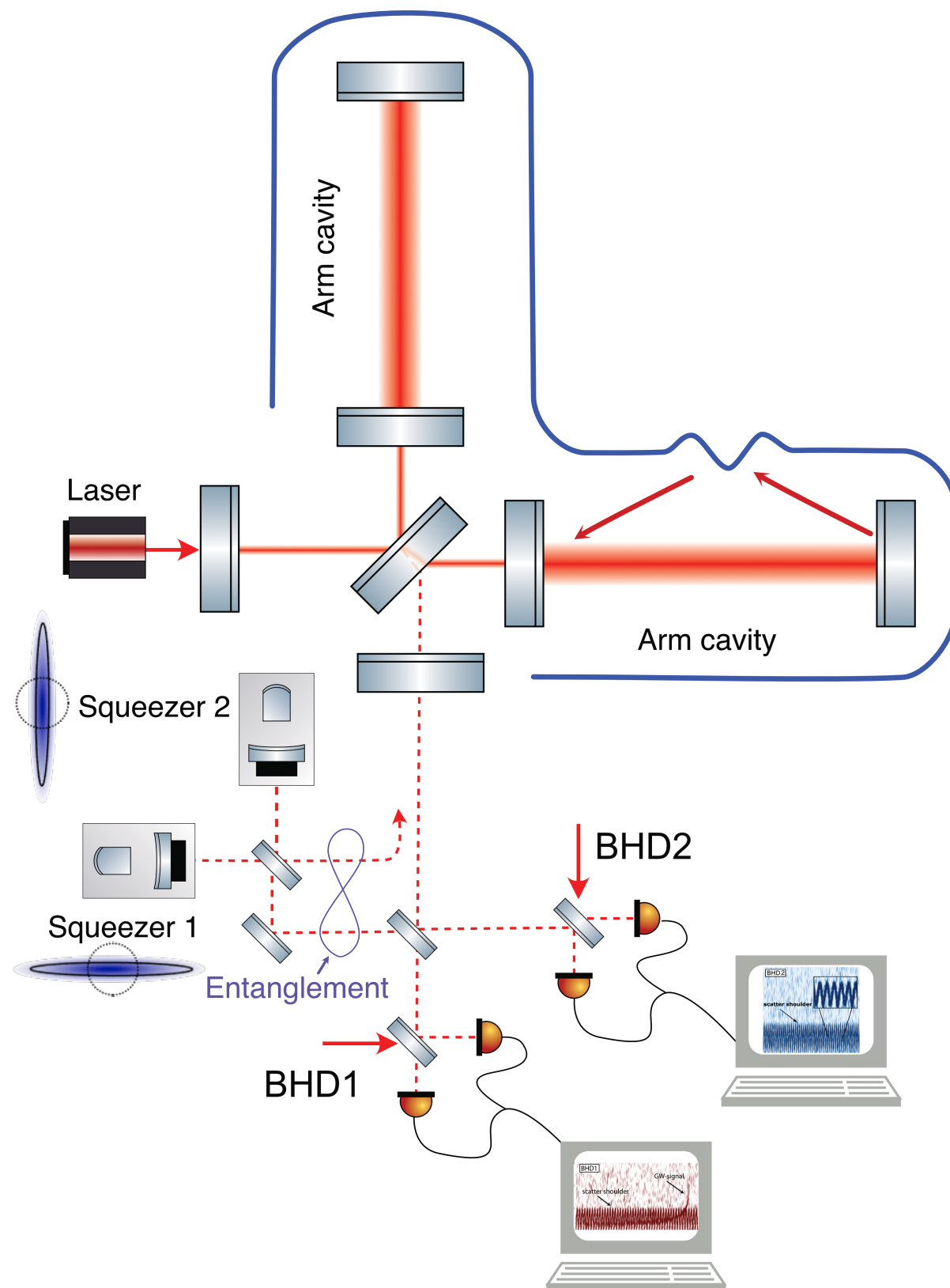
- Squeezed light allows to reduce the shot noise in Y quadrature
- Squeezing is lost due to vacuum mixed in at the BS



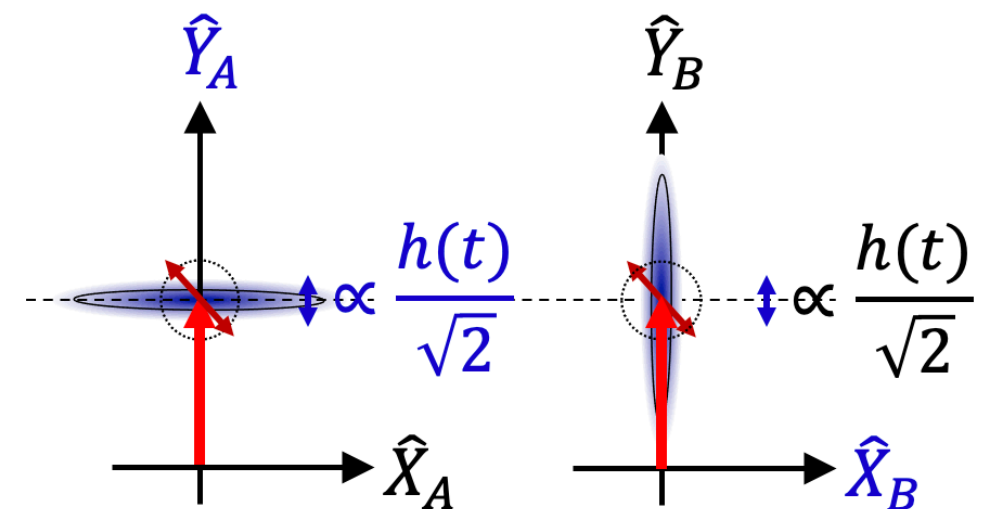


- ▶ Squeezed light allows to reduce the shot noise in Y quadrature
- ▶ Squeezing is lost due to vacuum mixed in at the BS
- ▶ X & Y don't commute
- ▶ X quadrature is anti-squeezed





- $X(t)$  and  $Y(t)$  can be measured simultaneously using entanglement



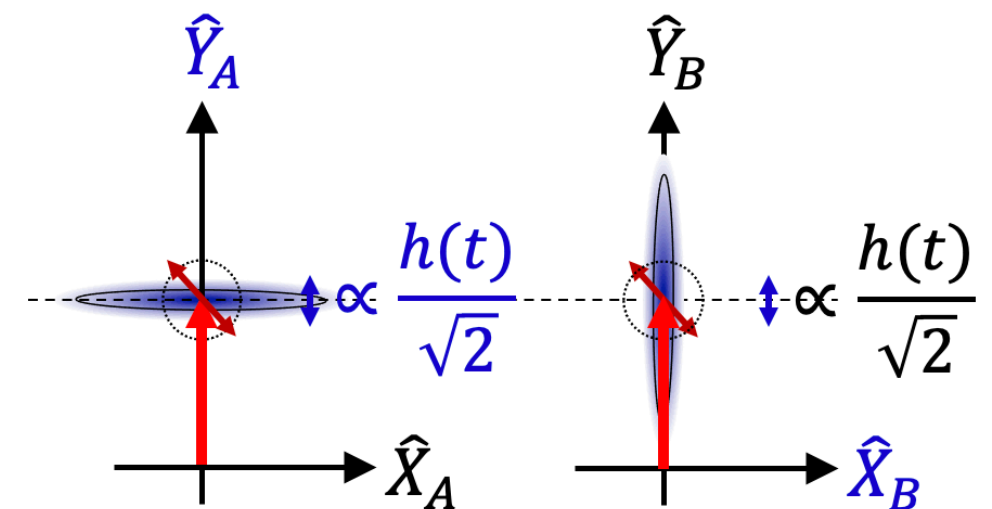
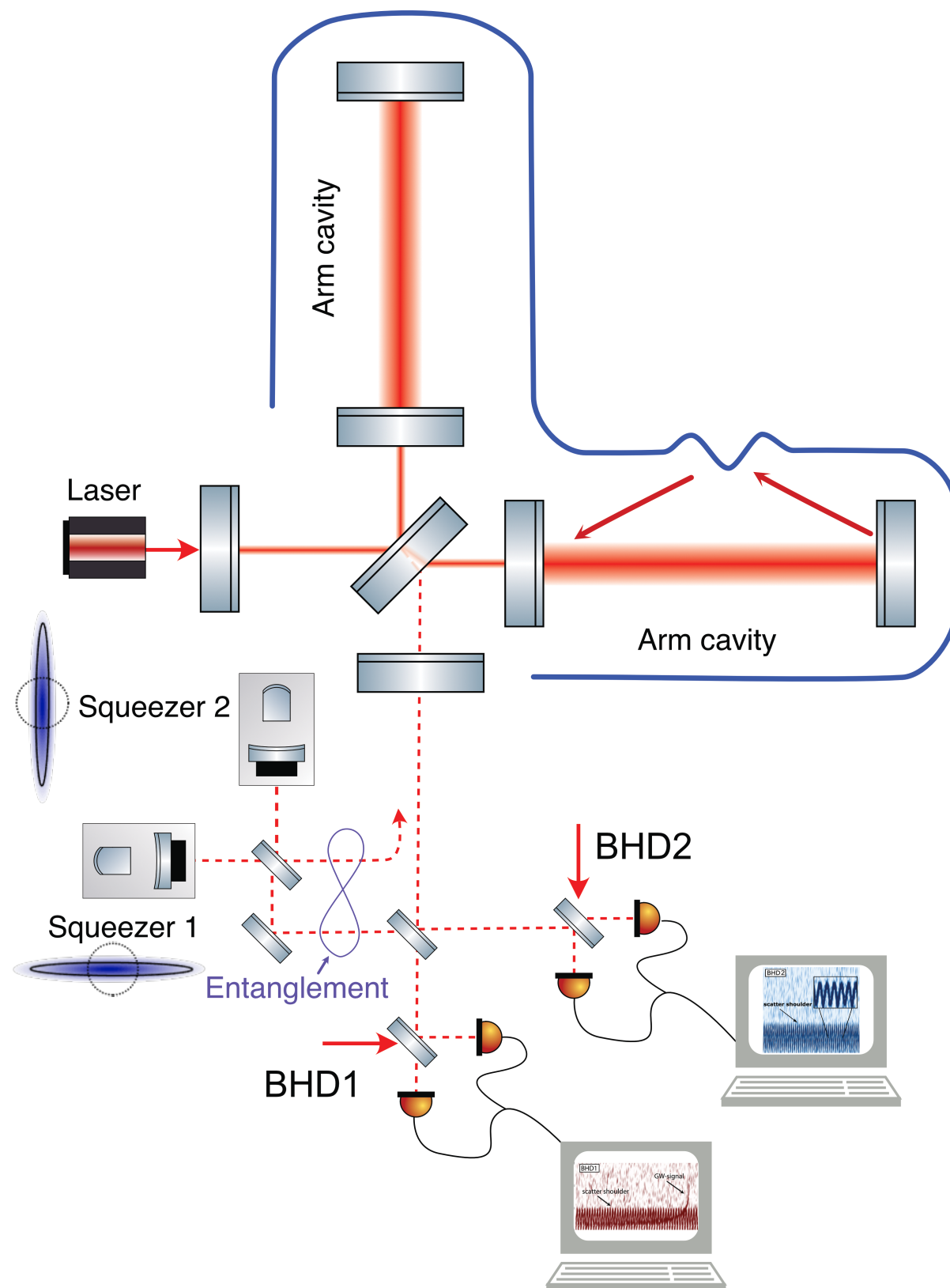


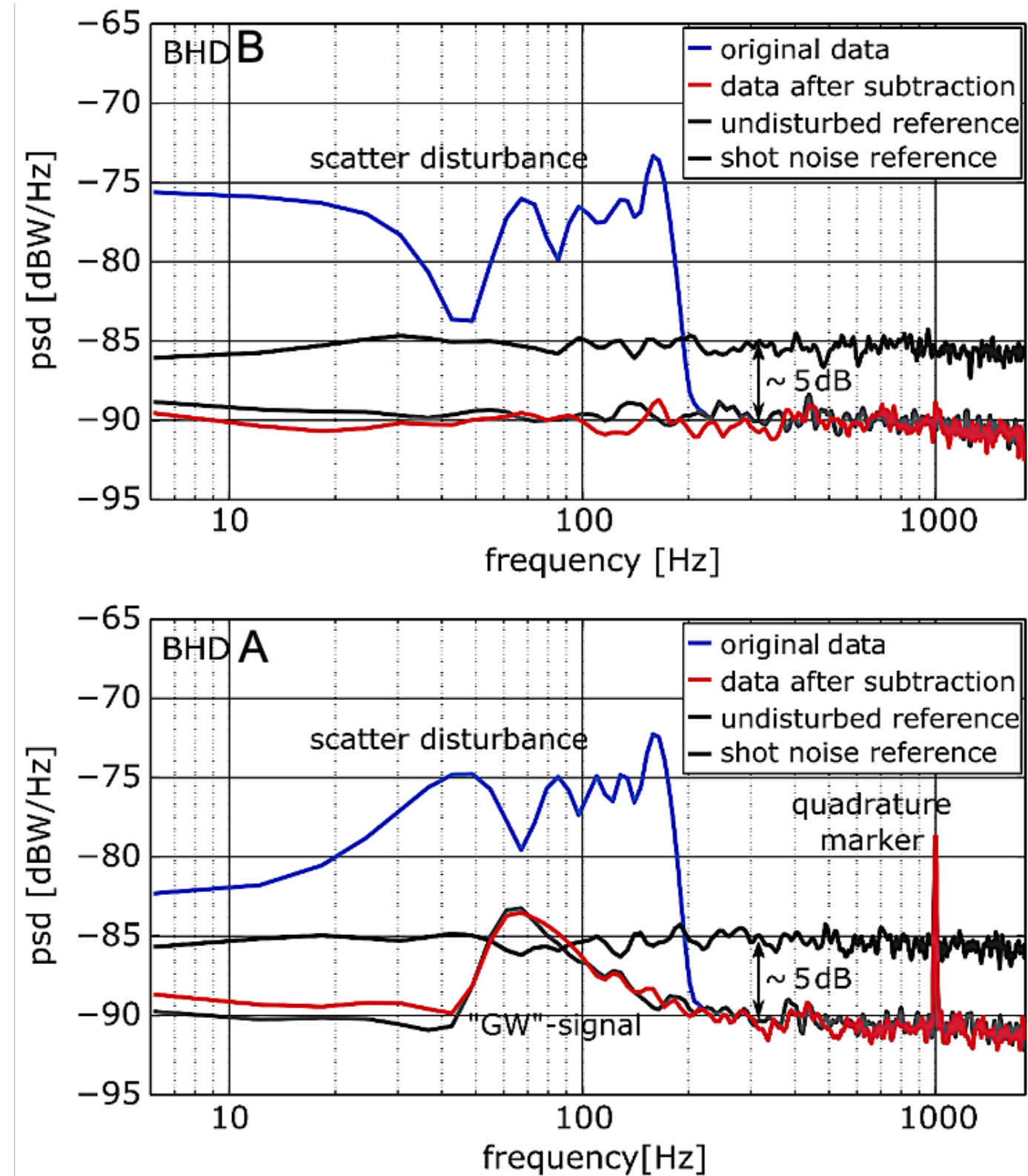
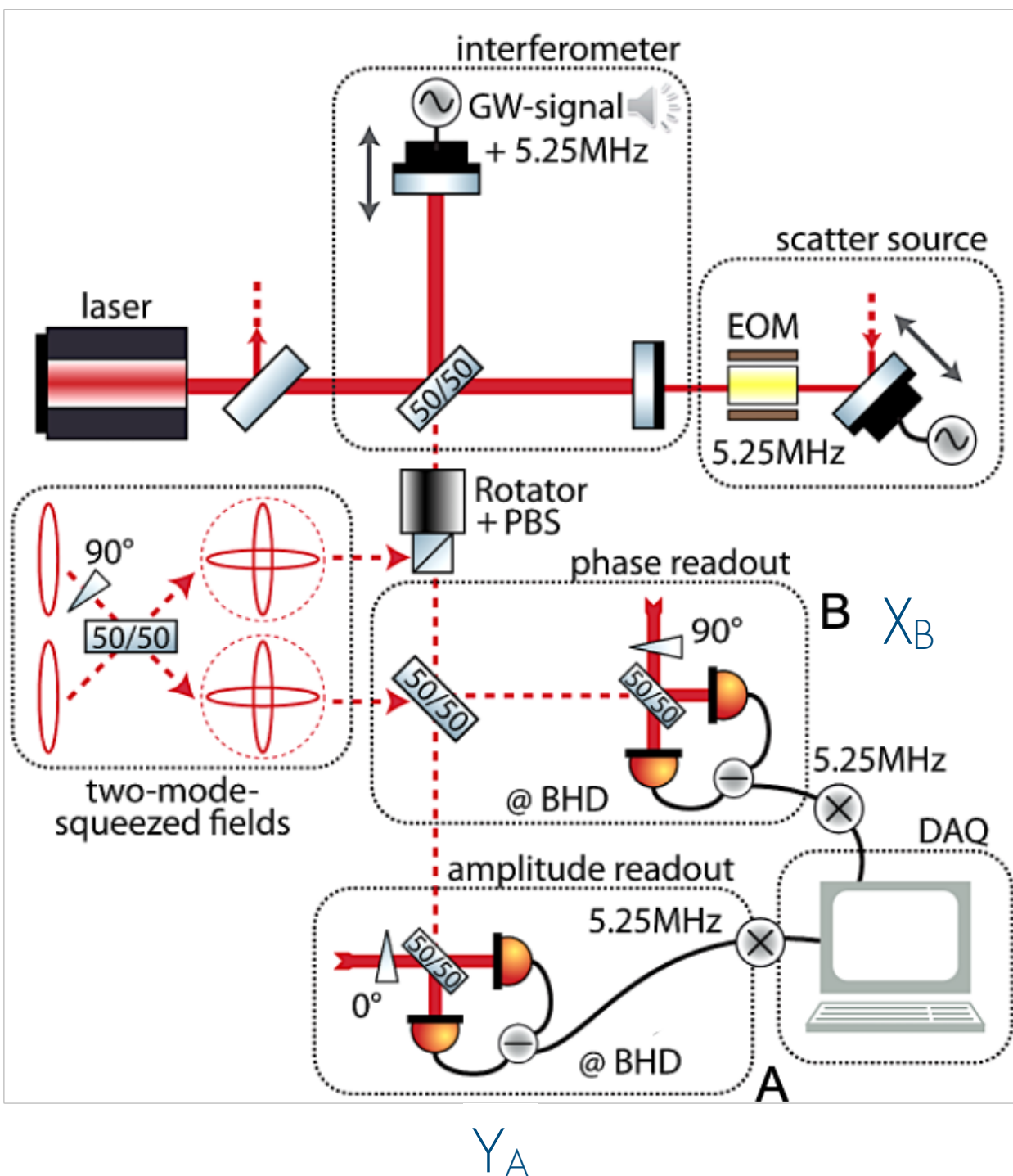
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G.M. D'Ariano, P. Lo Presti, M.G.A. Paris, Using Entanglement Improves the Precision of Quantum Measurements, Phys. Rev. Lett. **87**, 270404 (2001)

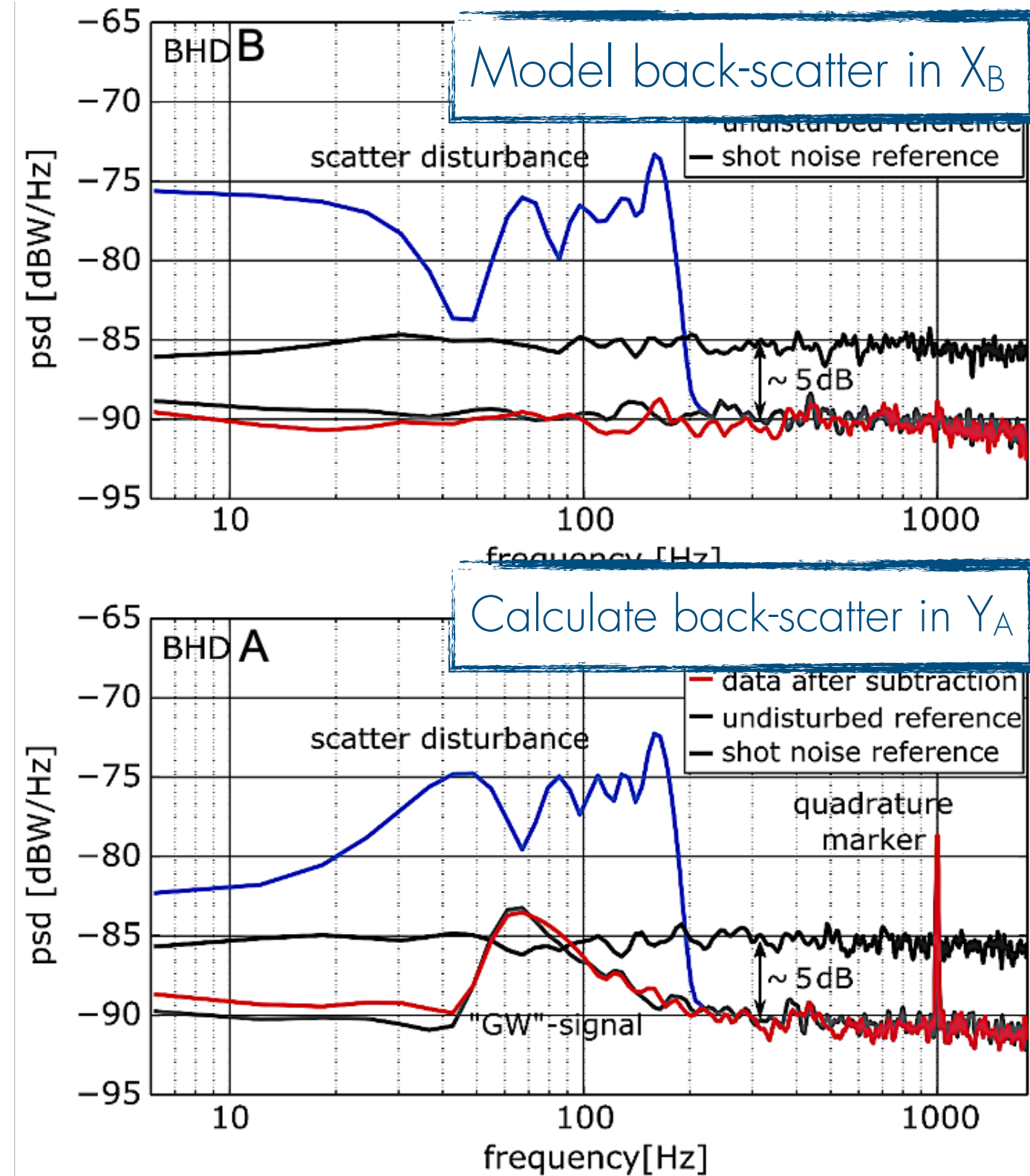
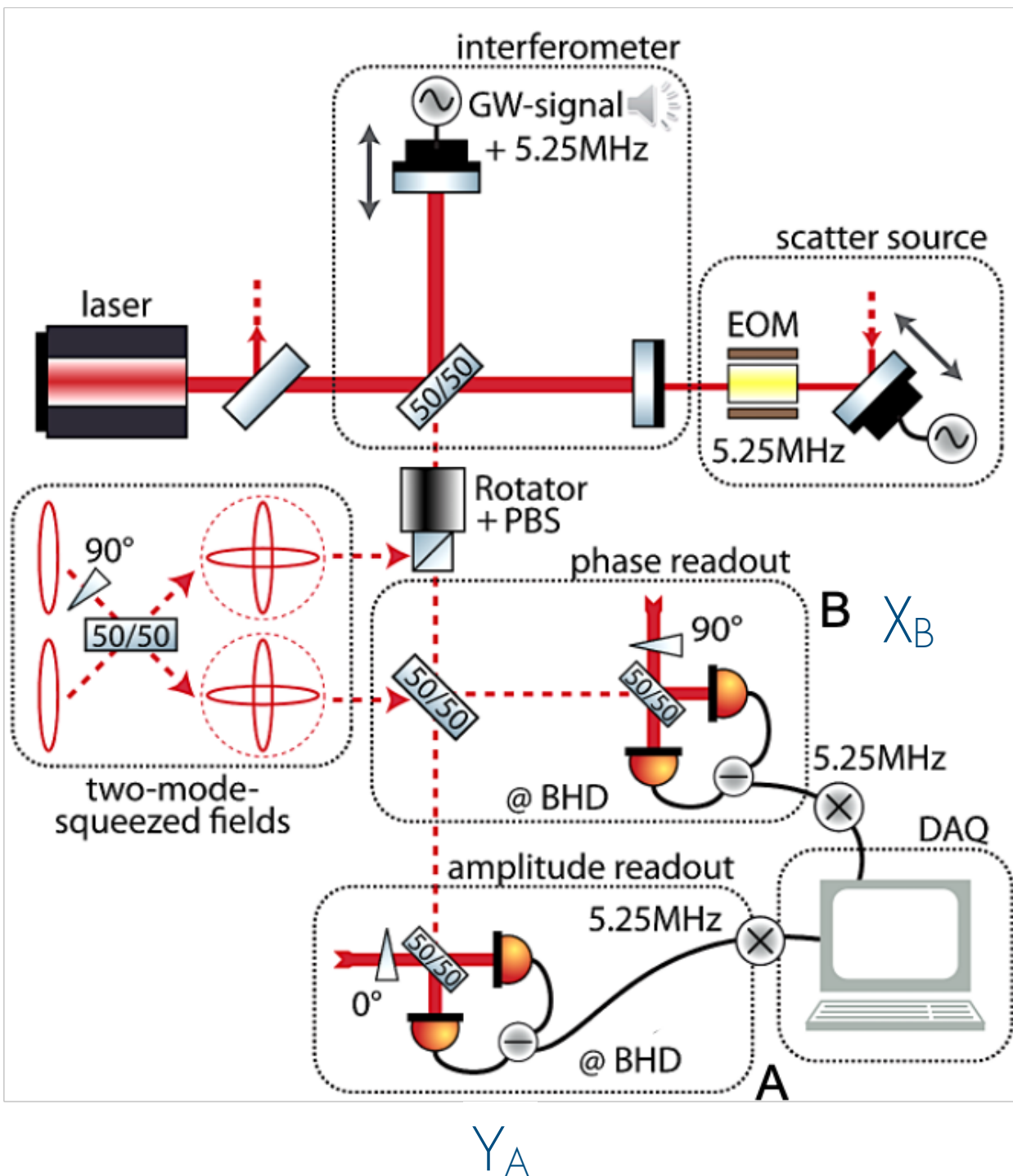
W. Wasilewski et al., Quantum noise limited and entanglement-assisted magnetometry, Phys. Rev. Lett. **104**, 133601 (2010).

S. Steinlechner et al., Quantum-dense metrology, Nature Photonics **7**, 626 (2013).

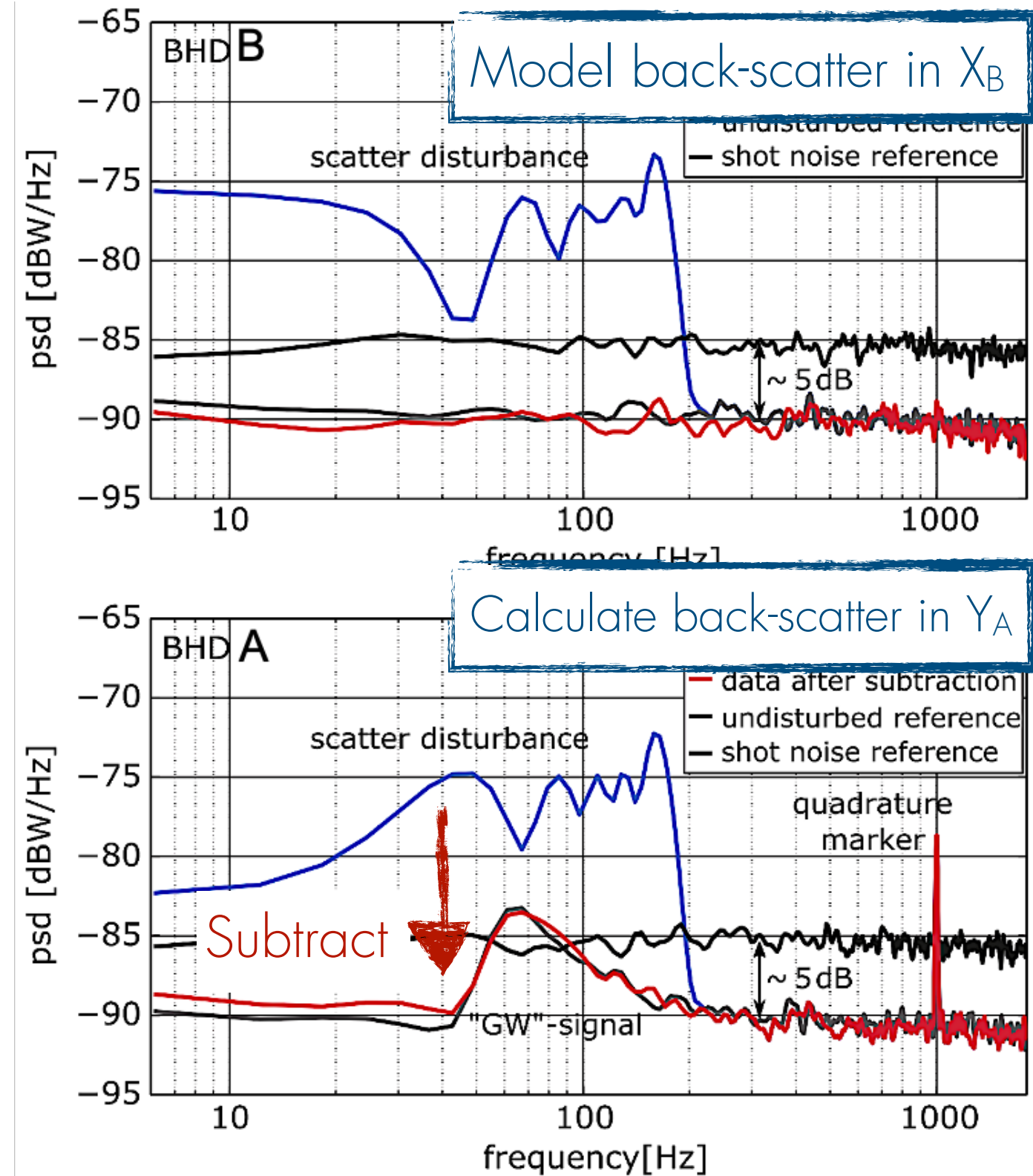
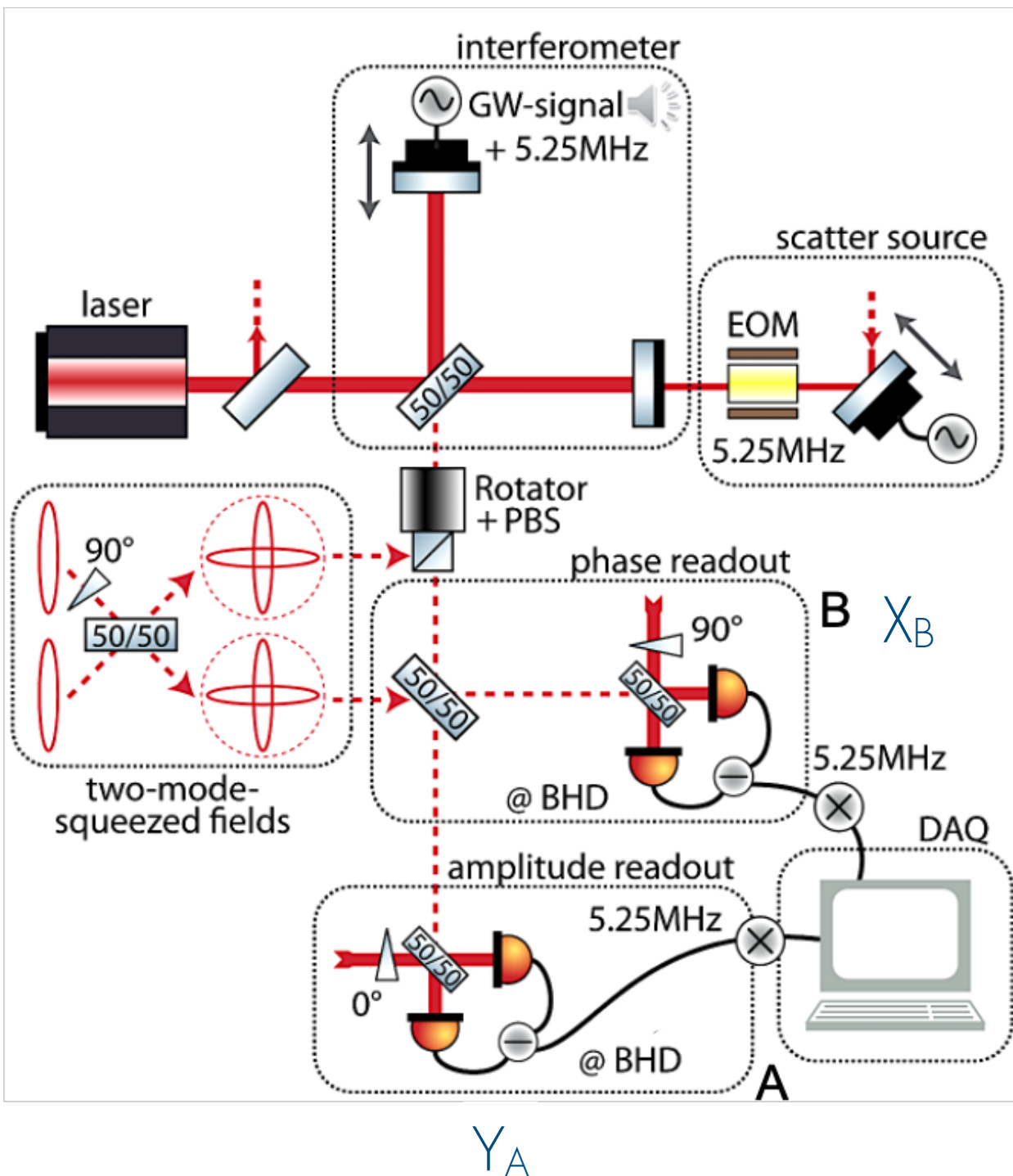


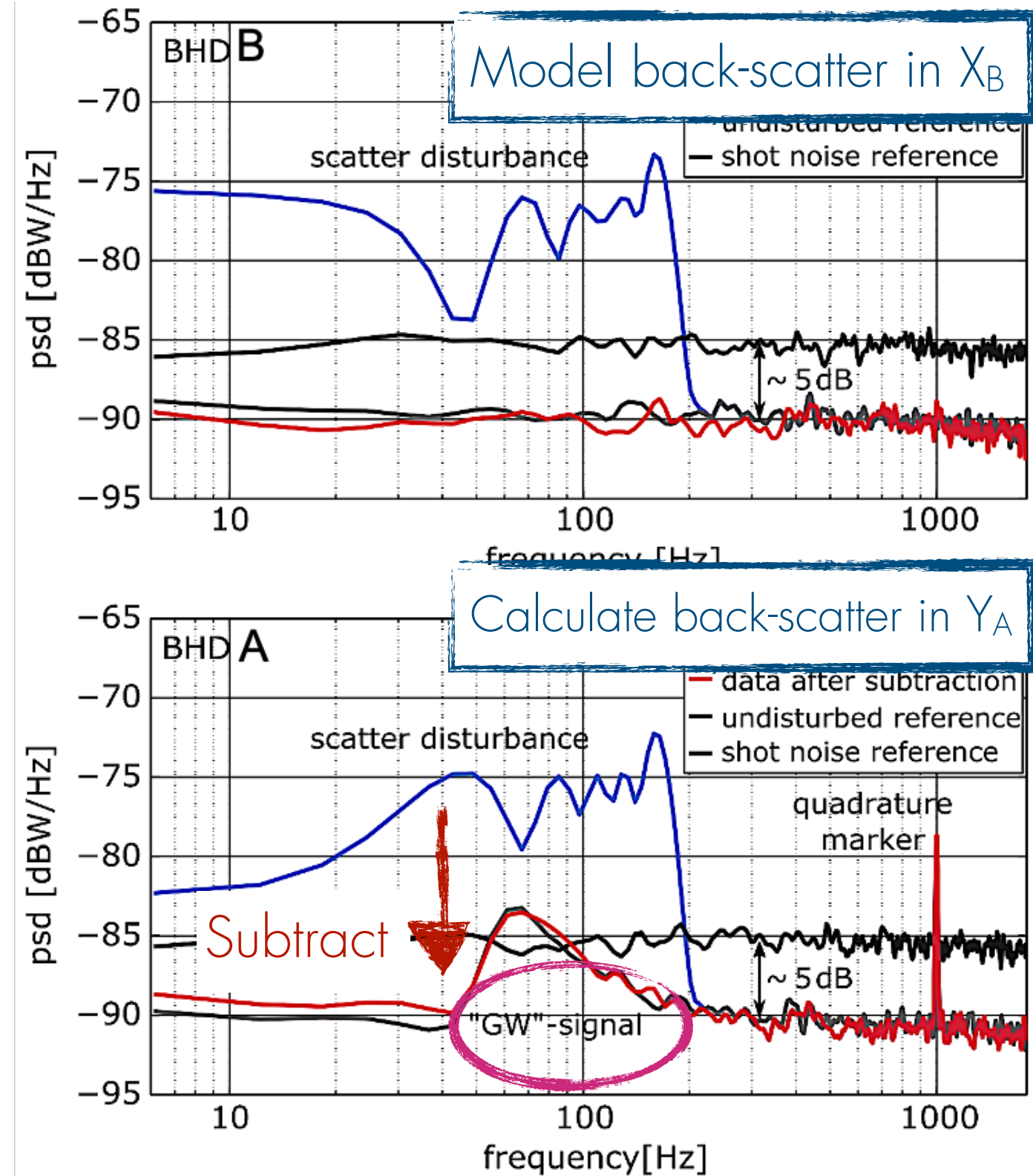
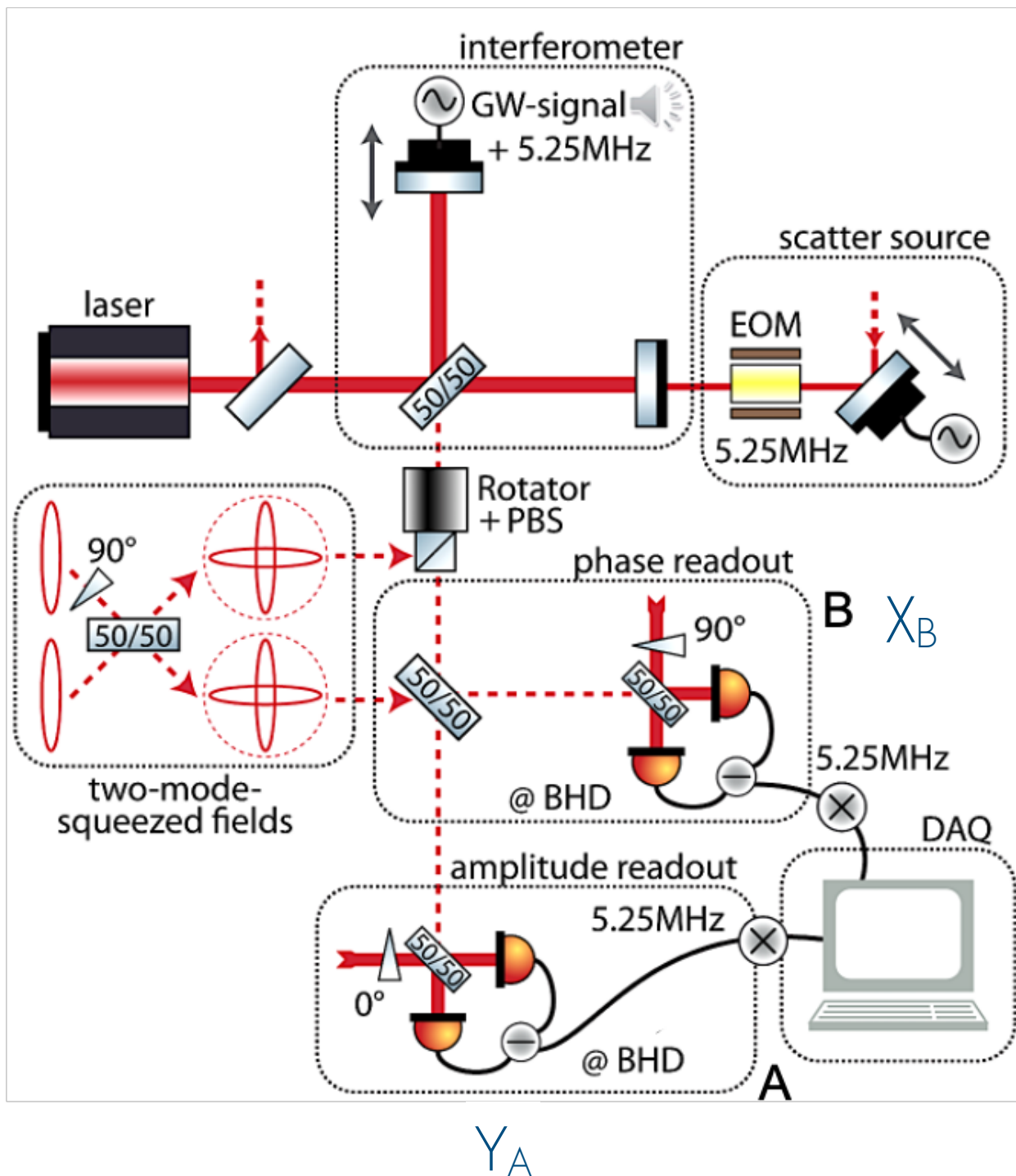


[M. Ast, S. Steinlechner, R. Schnabel, Phys. Rev. Lett. **117**, 180801 (2016)]

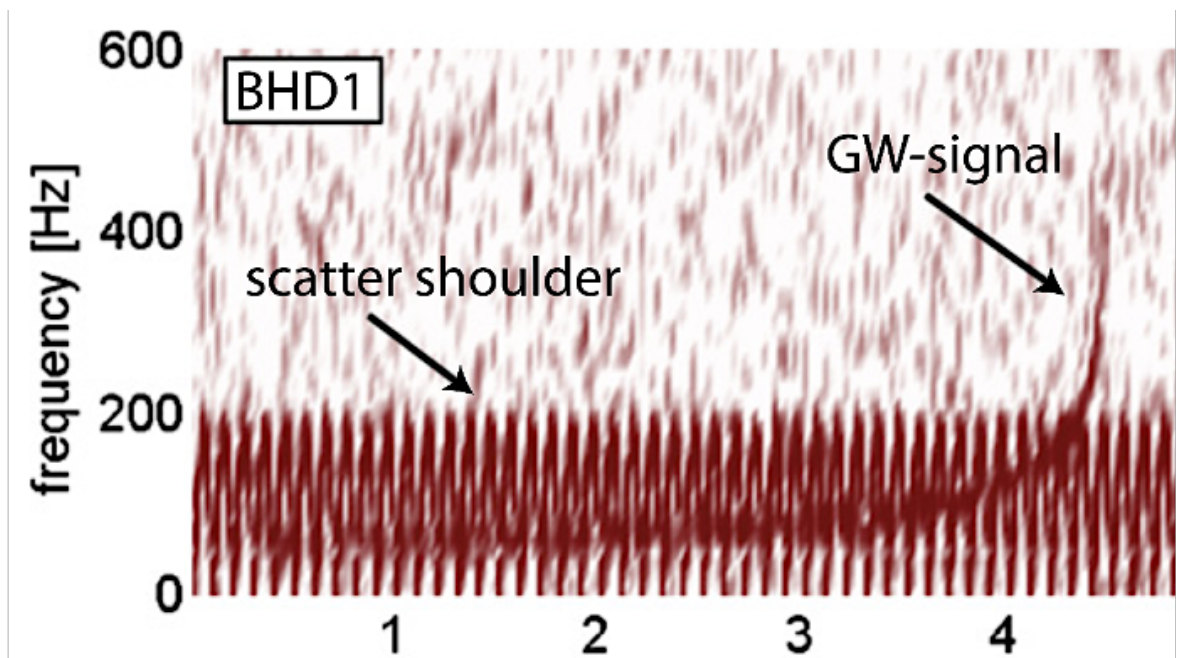
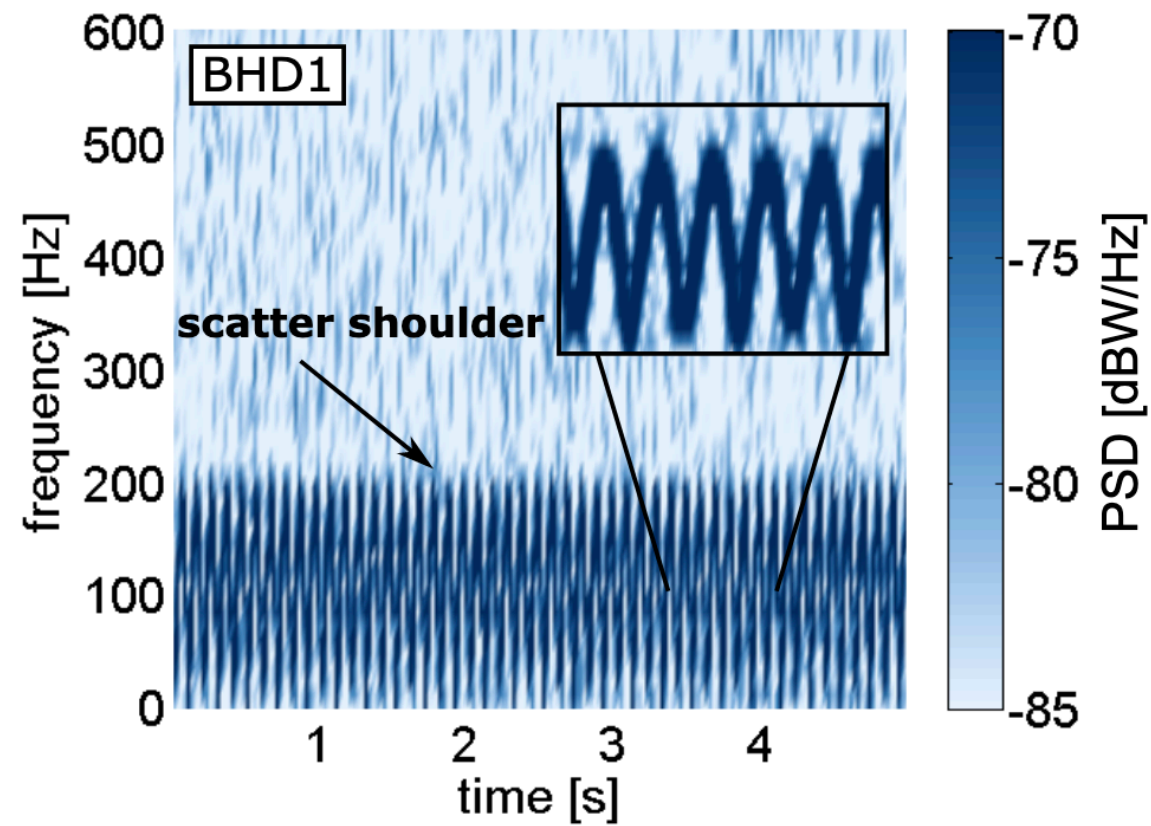


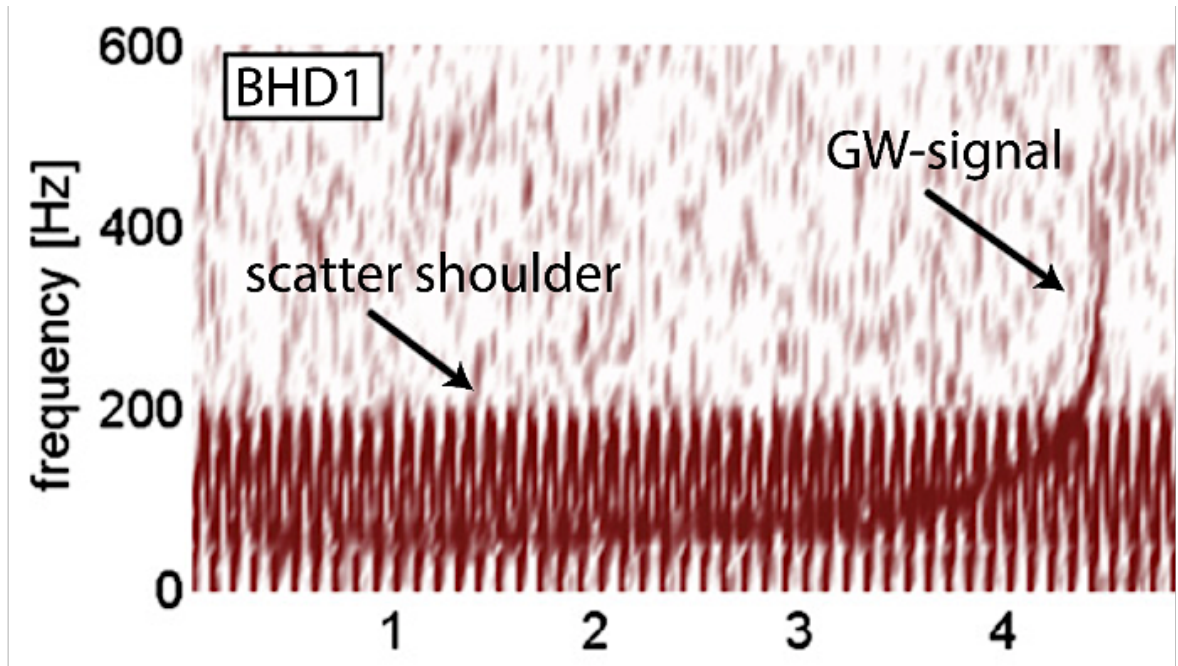
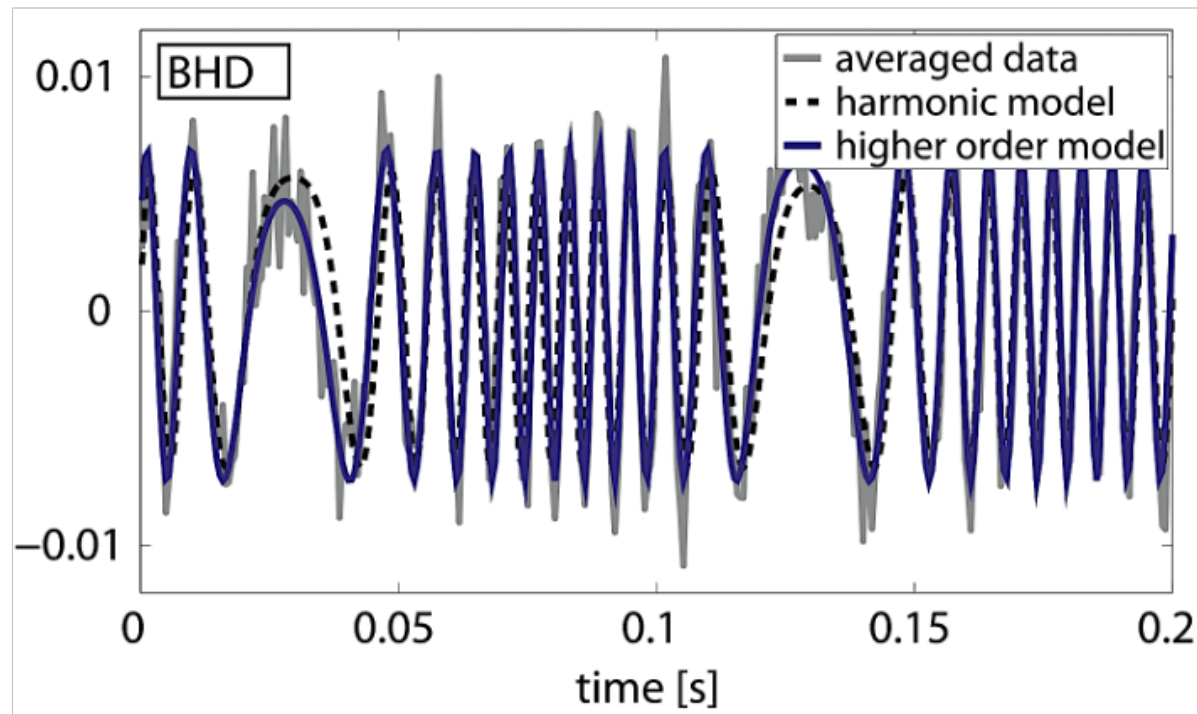




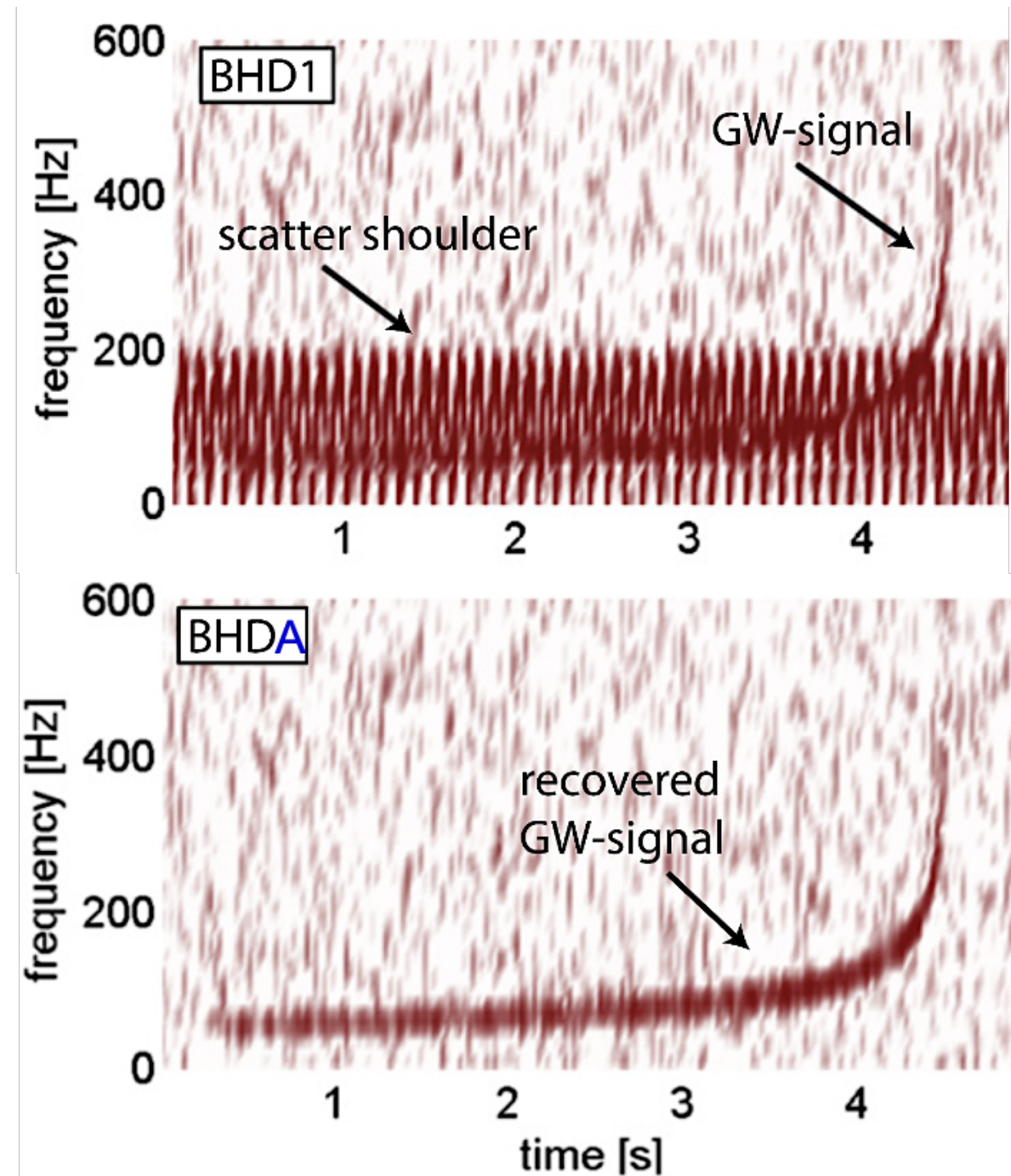
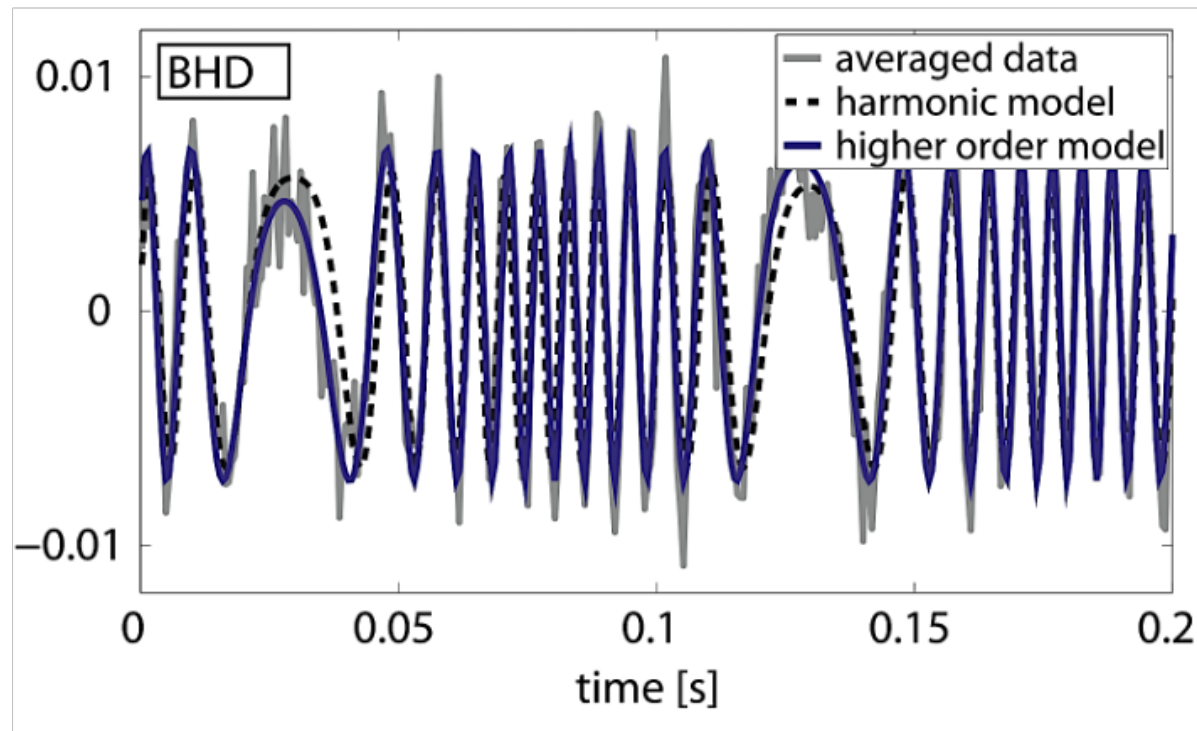






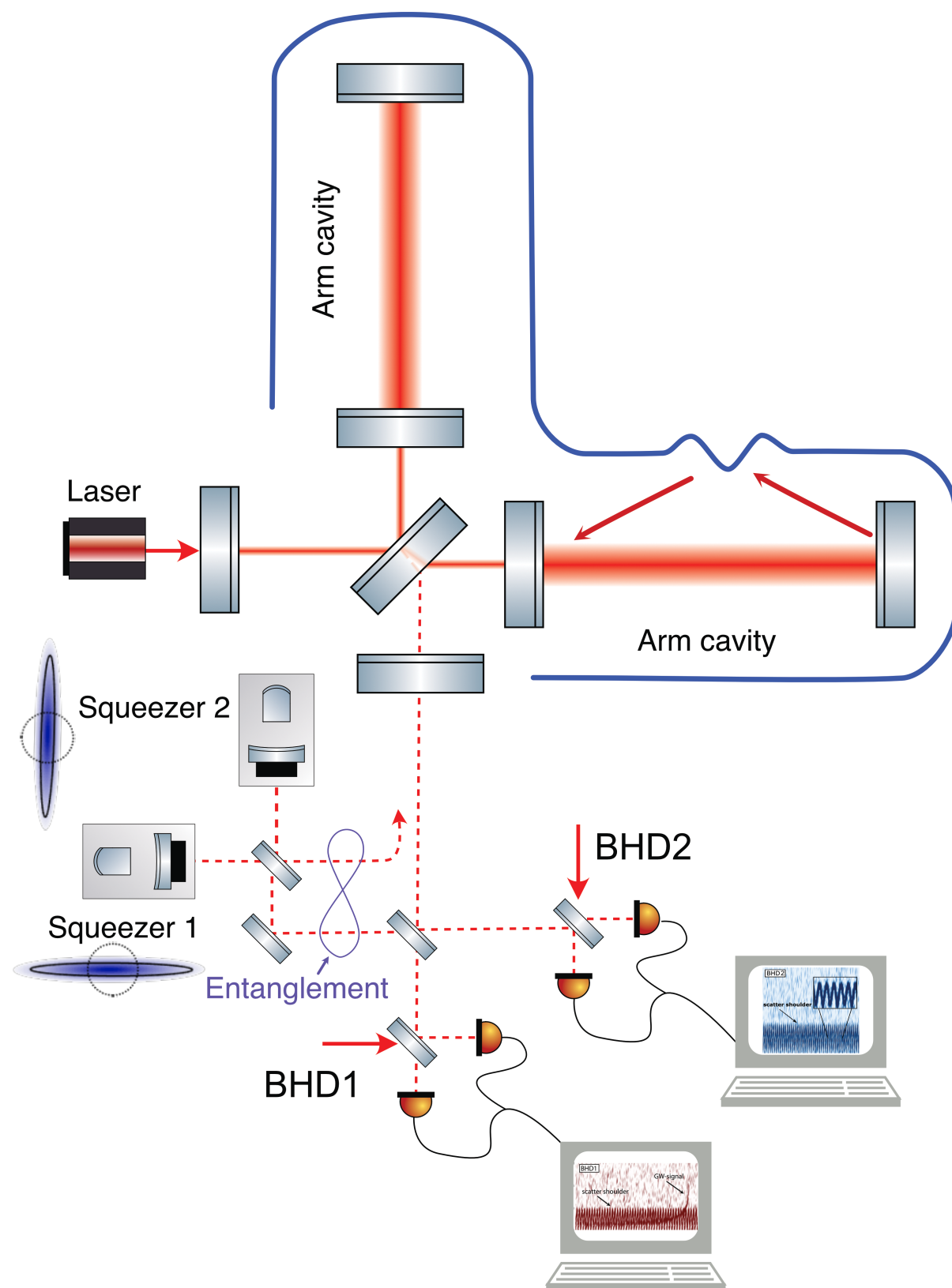




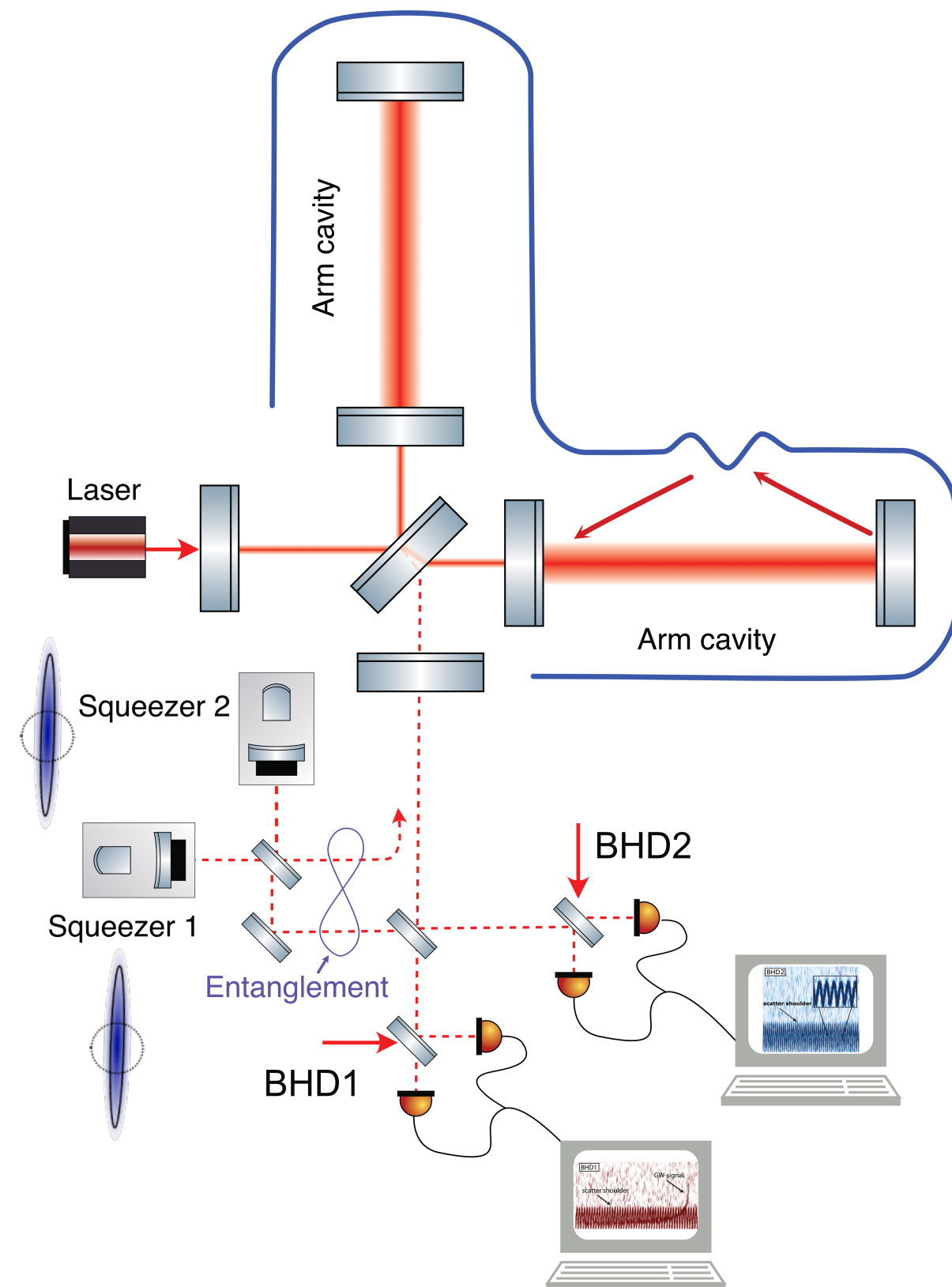




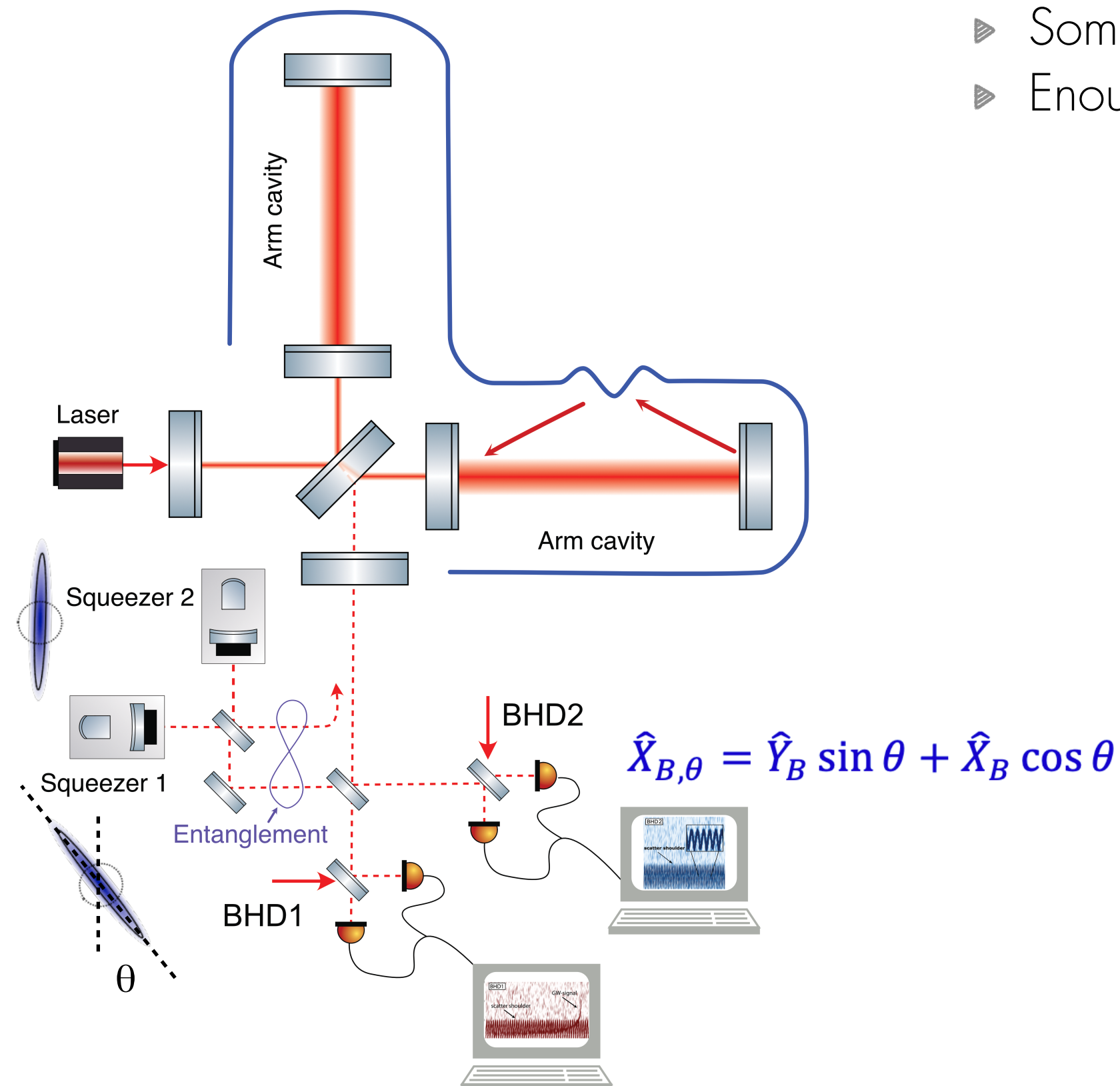
- ▶ 1/2 signal is lost



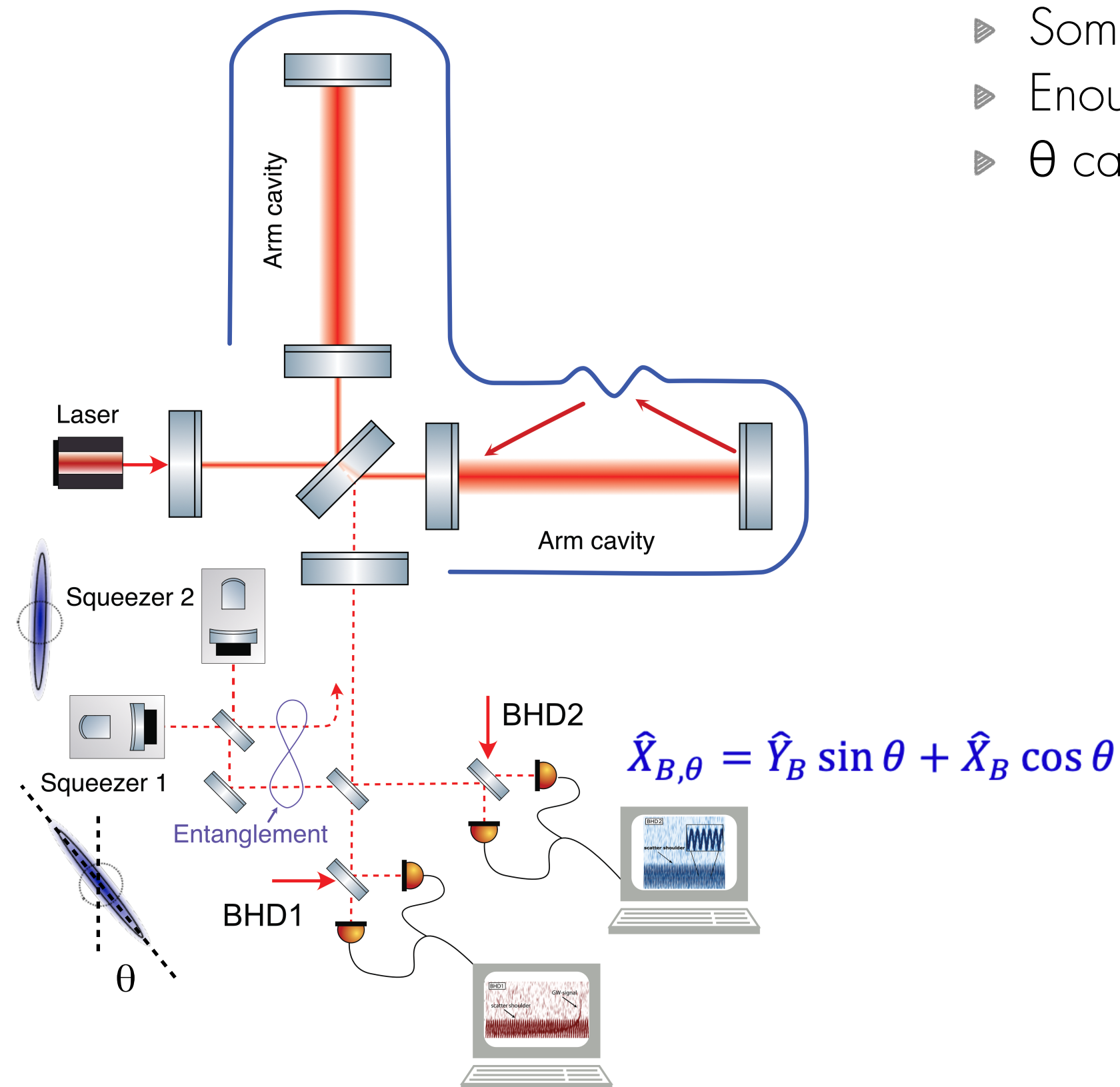
- ▶ No signal is lost
- ▶ No scattering is measured



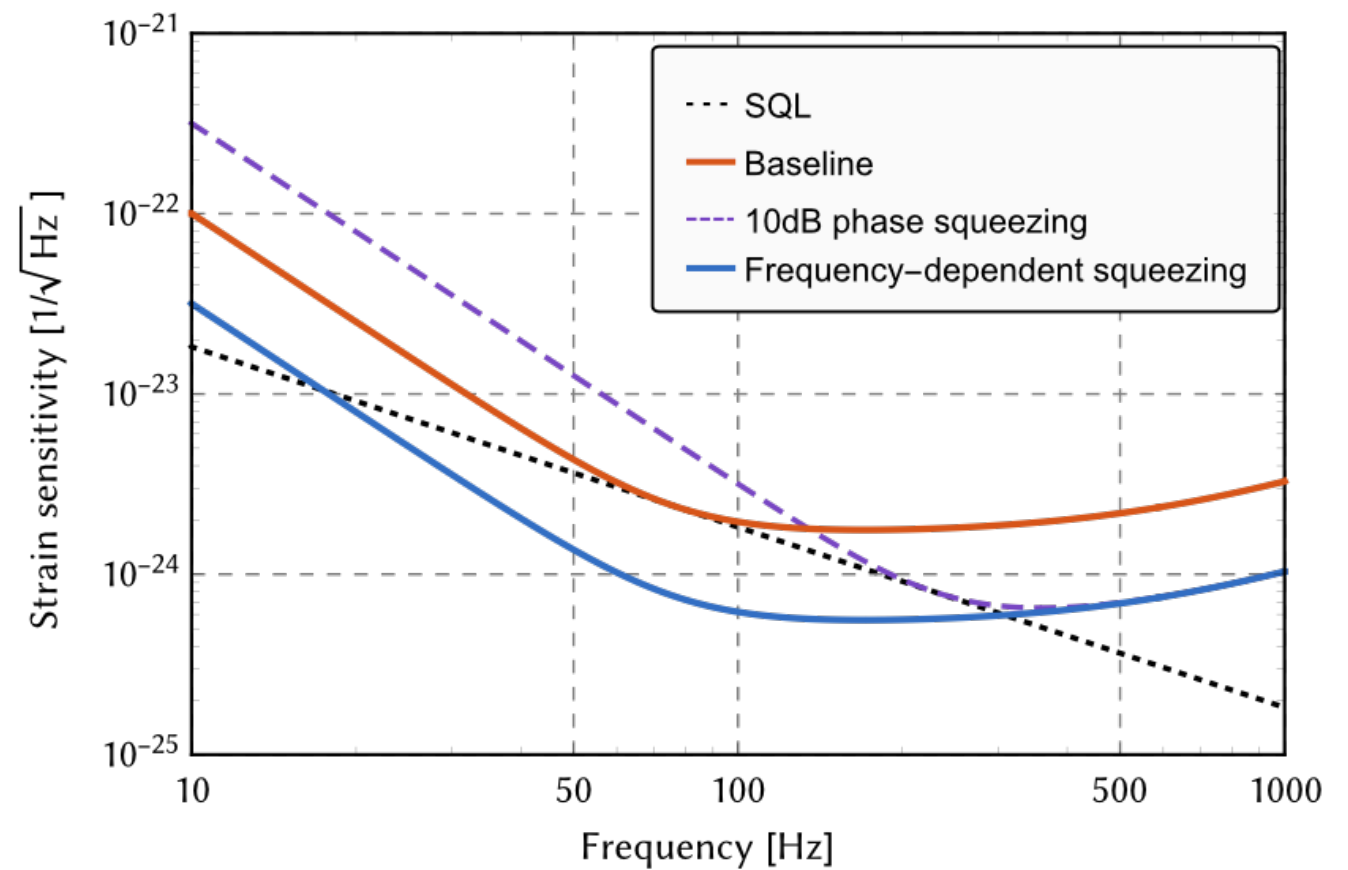
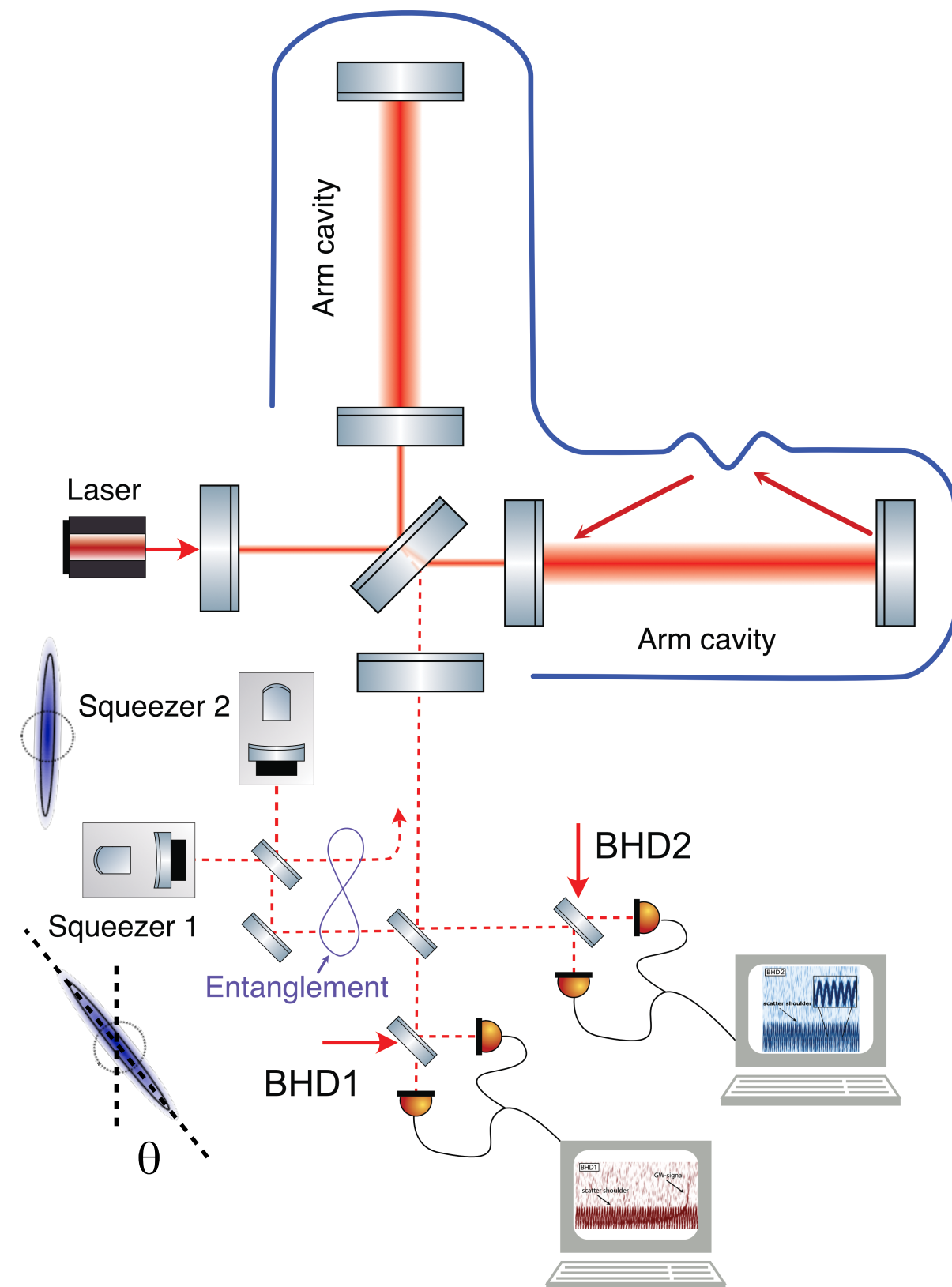
- Some signal is lost
- Enough data for back-scatter model



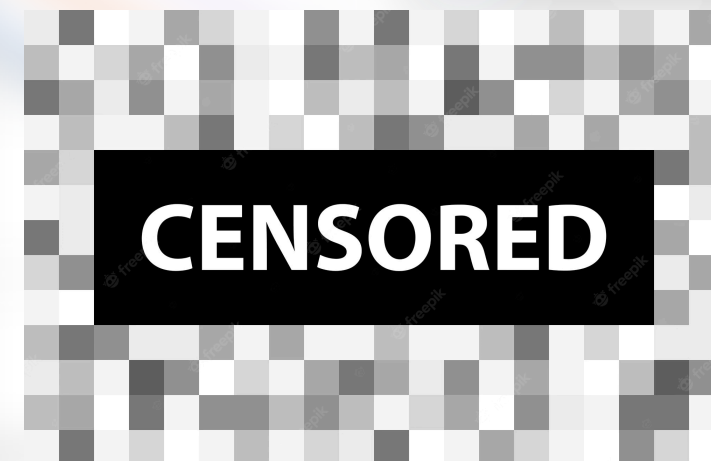
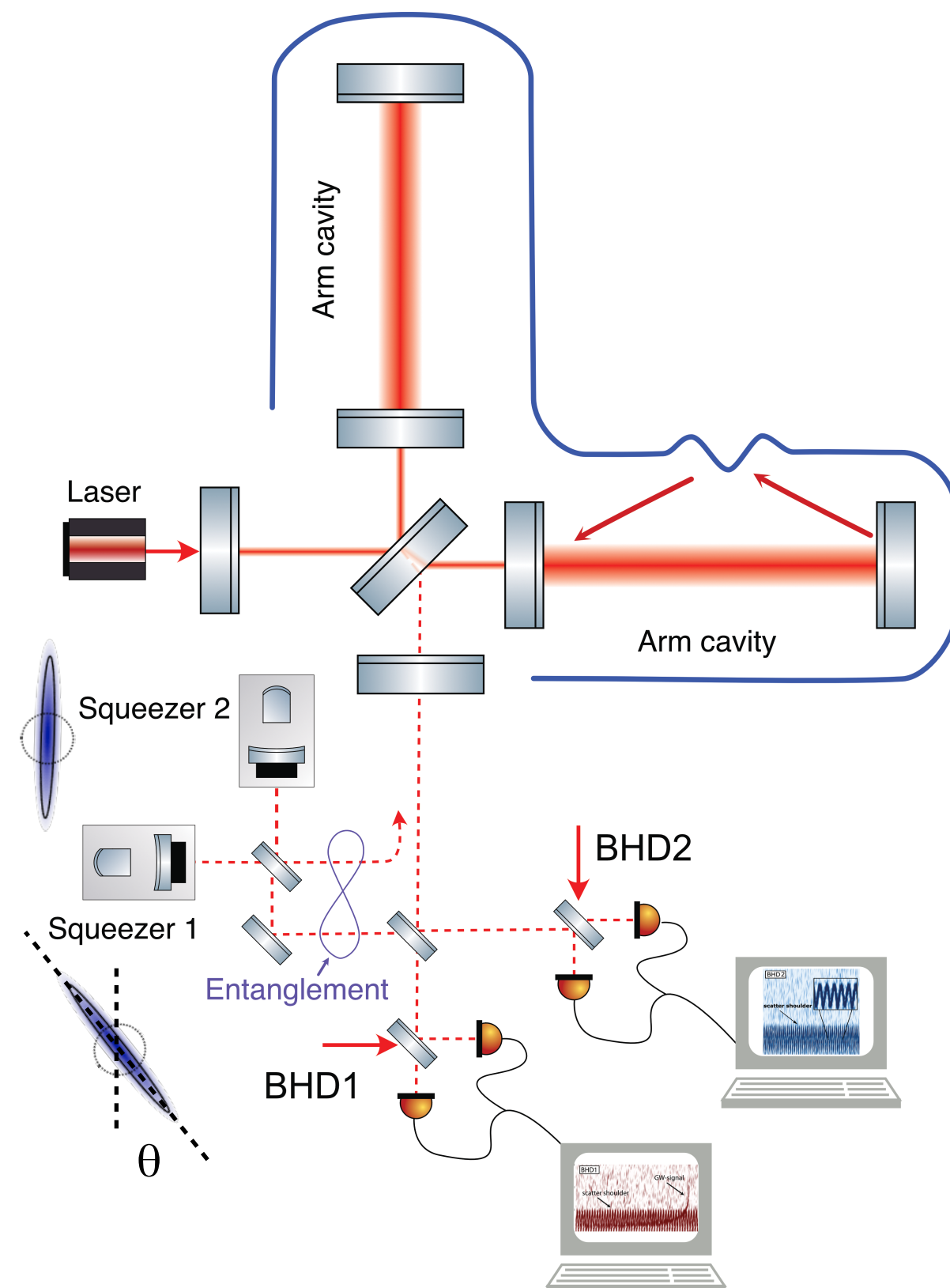
- Some signal is lost
- Enough data for back-scatter model
- $\theta$  can be frequency-dependent



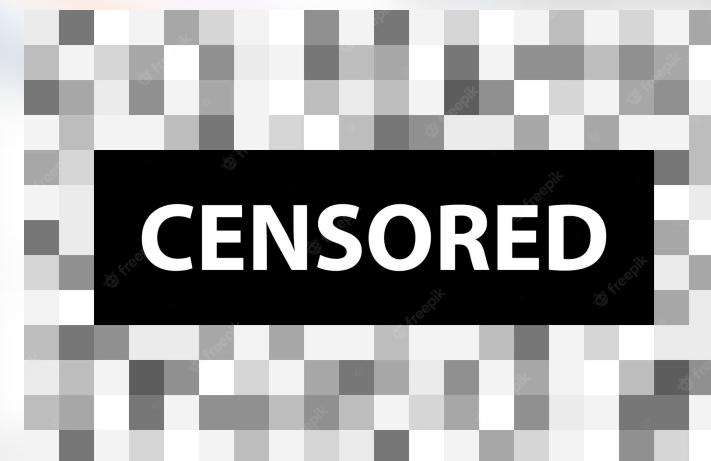
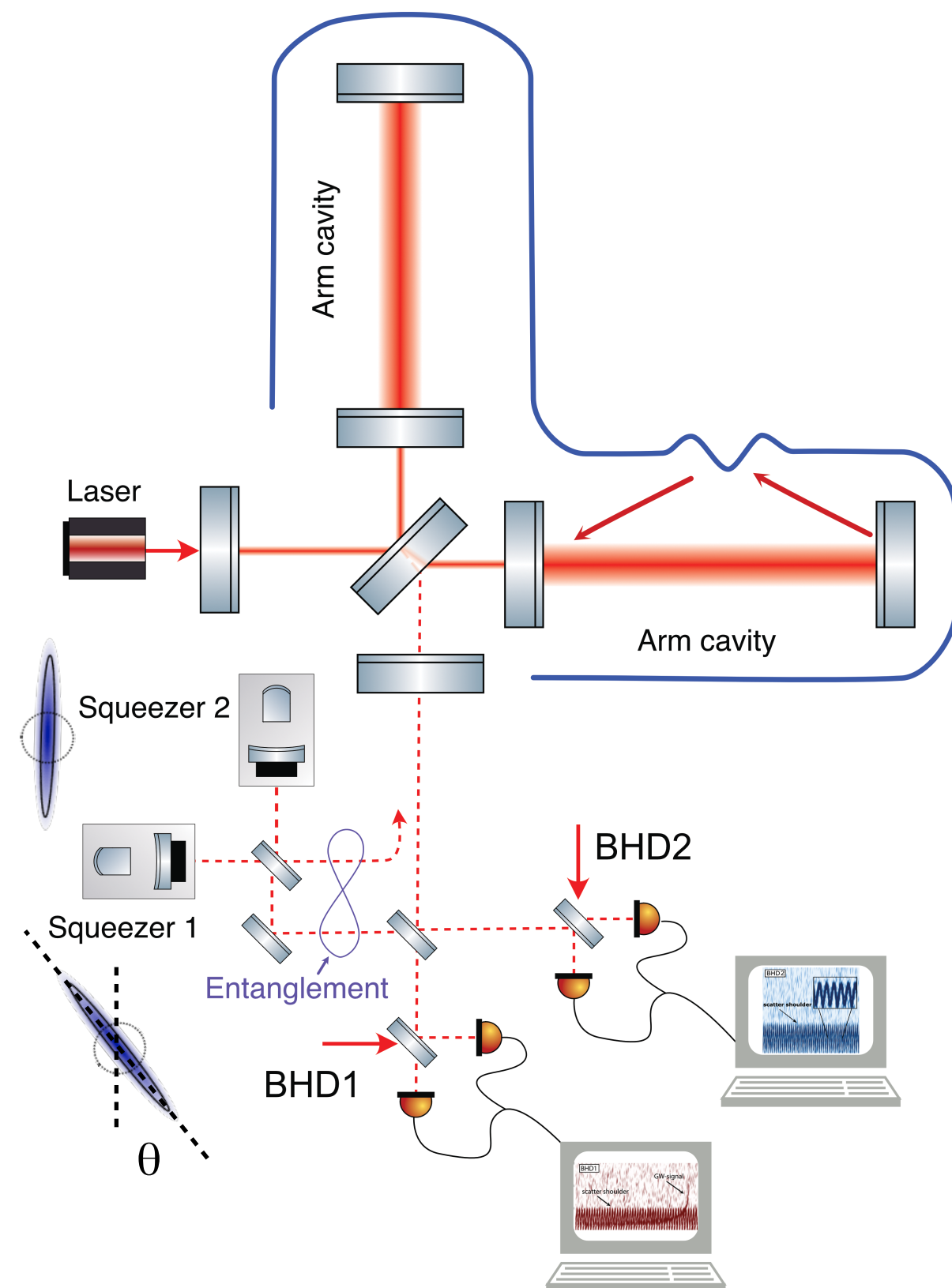
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- ▶ Some signal is lost
- ▶ Enough data for back-scatter model
- ▶  $\theta$  can be frequency-dependent
- ▶ Fully compatible with frequency-dependent squeezing

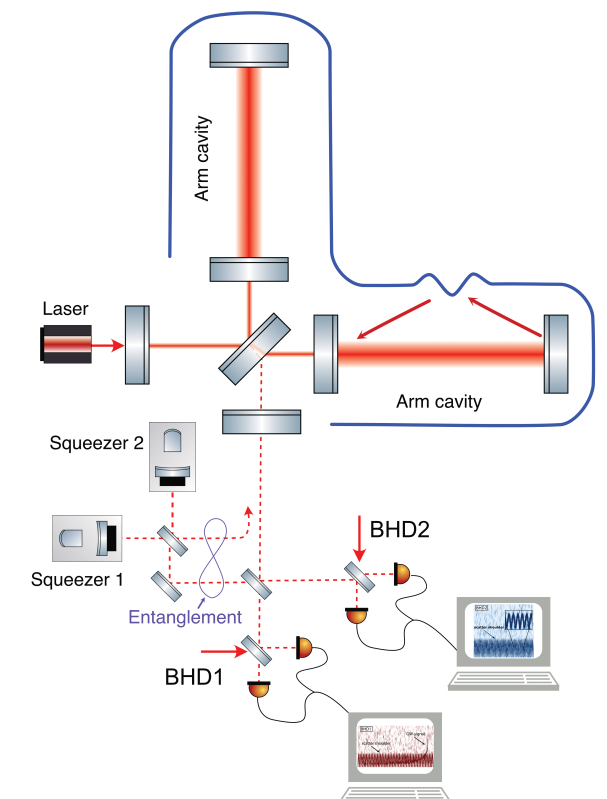
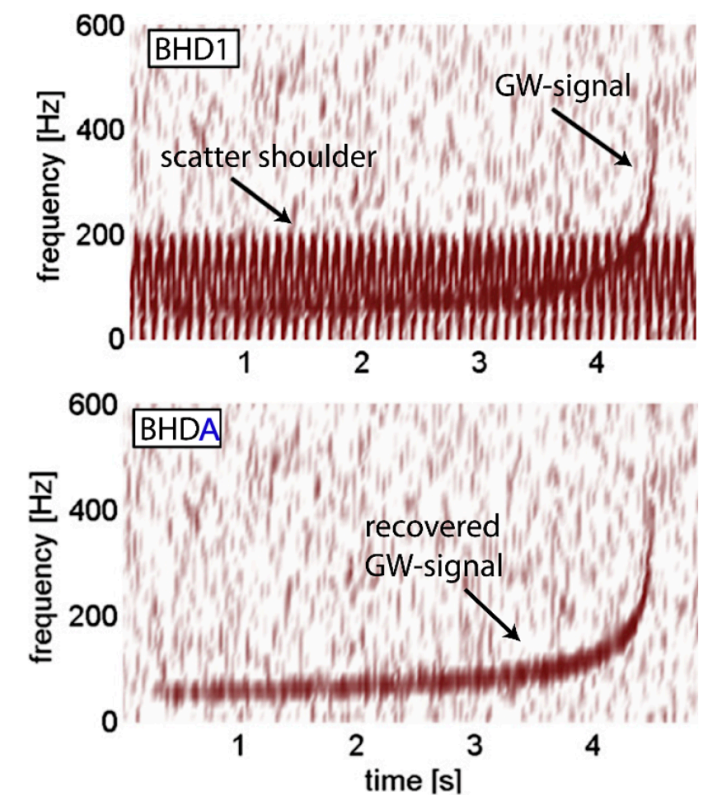


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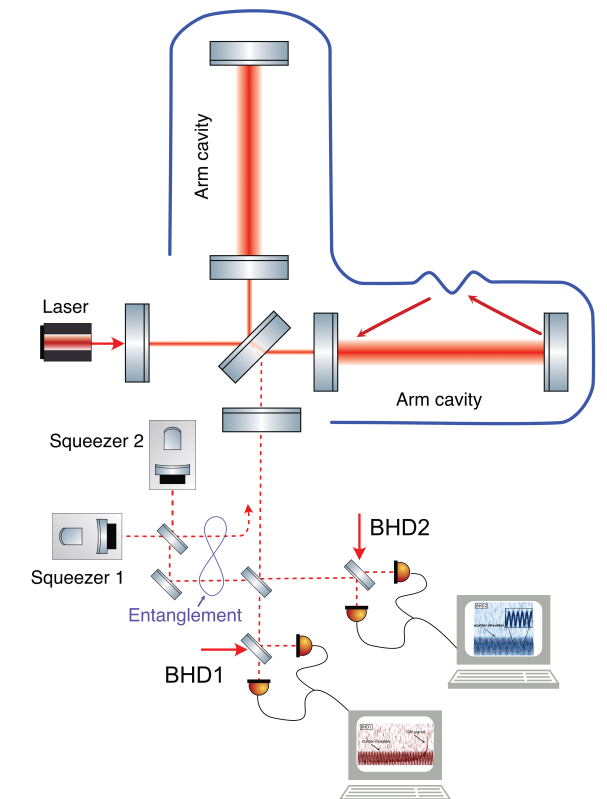
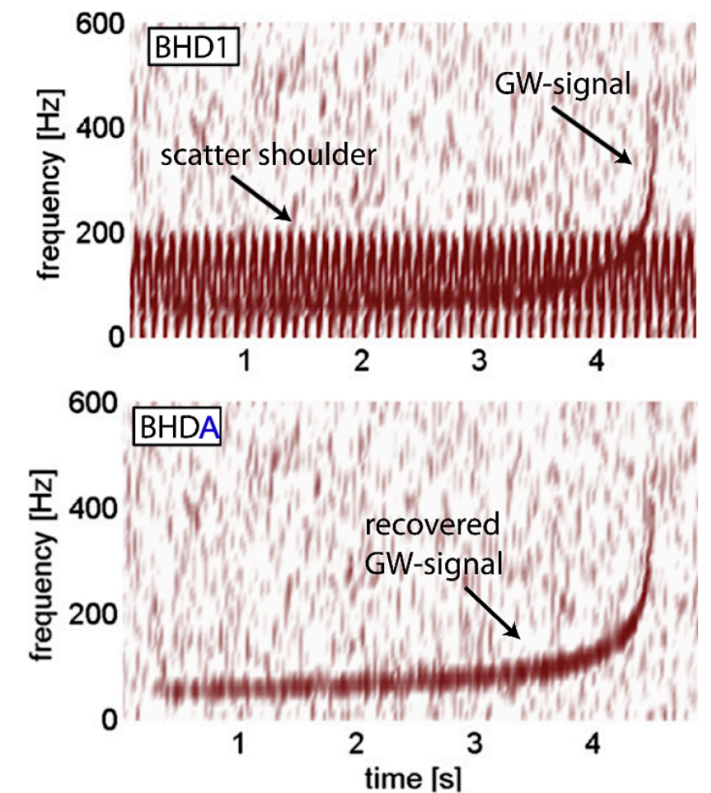


- Dual homodynes allow to subtract scattered light

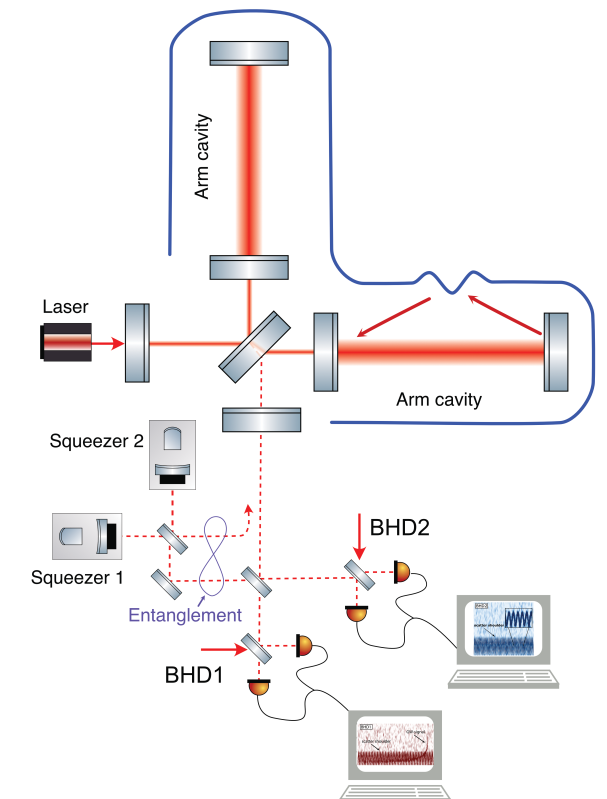
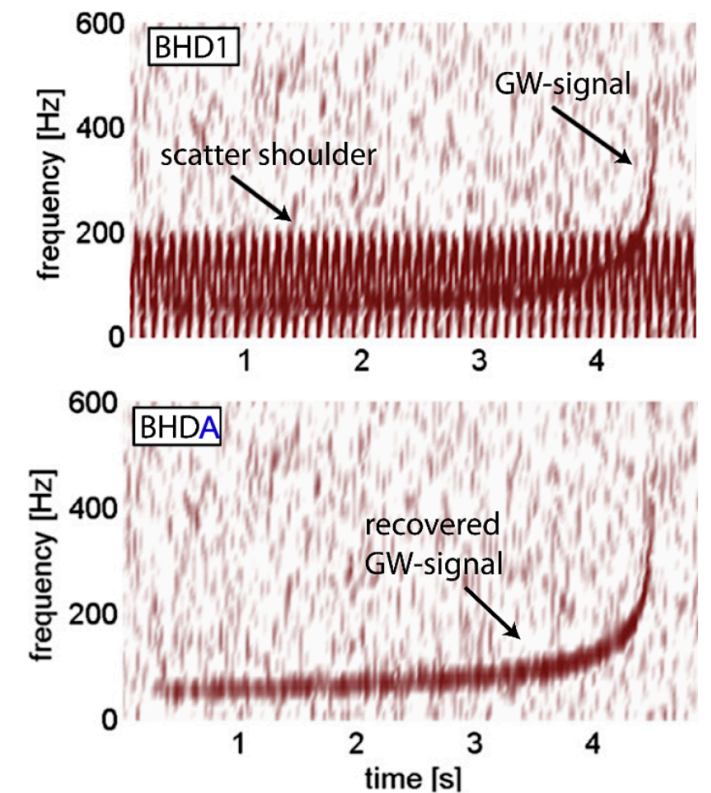




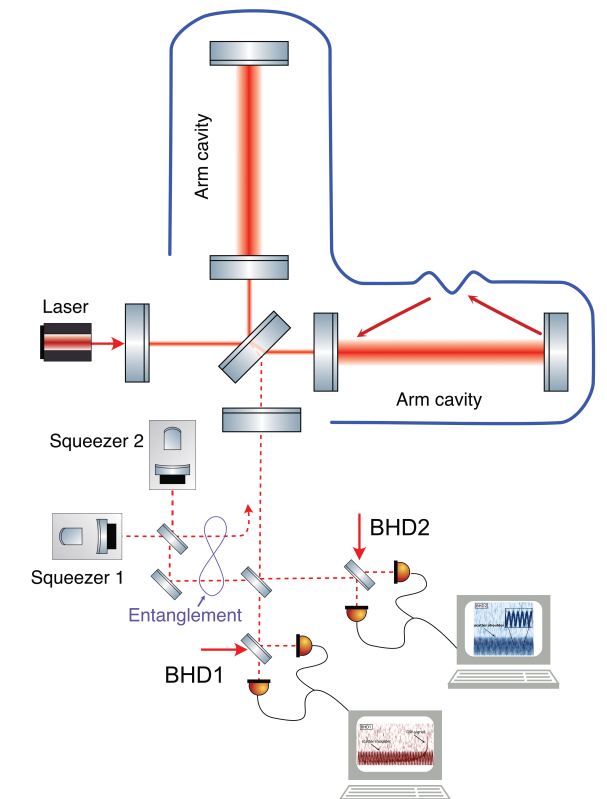
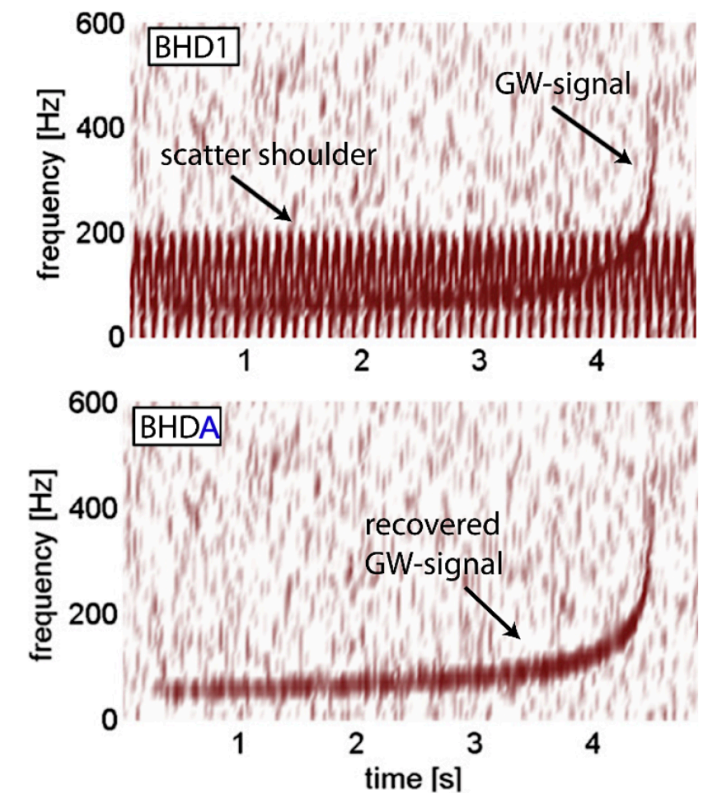
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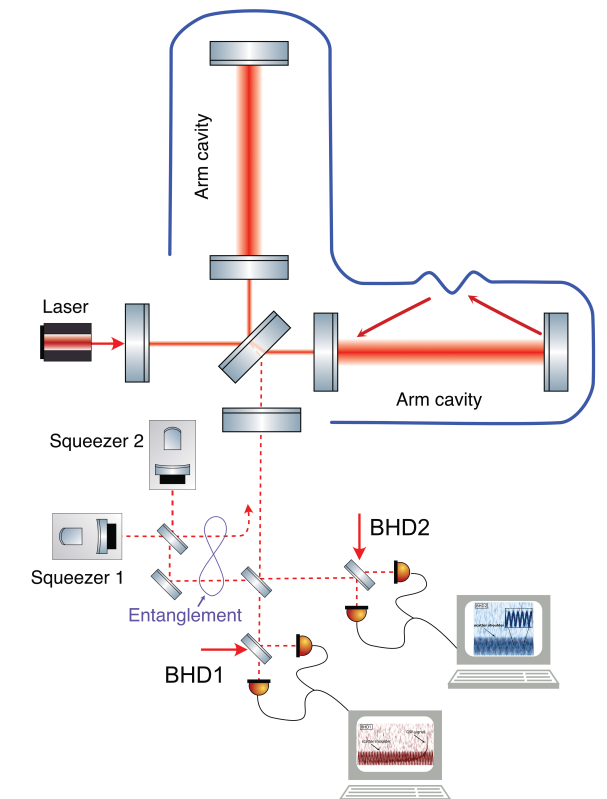
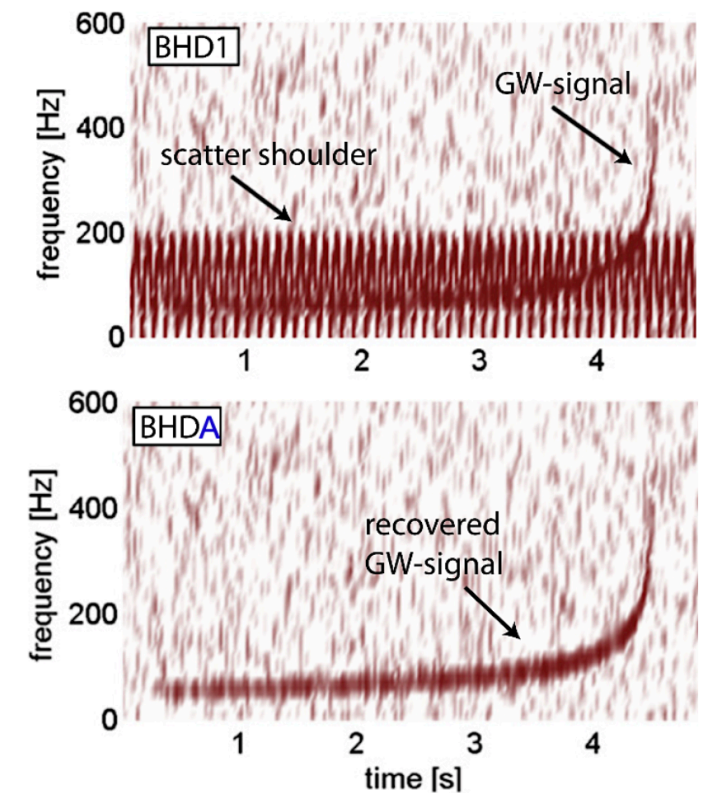
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- ▶ Optimal choice of angle allows to reduce it

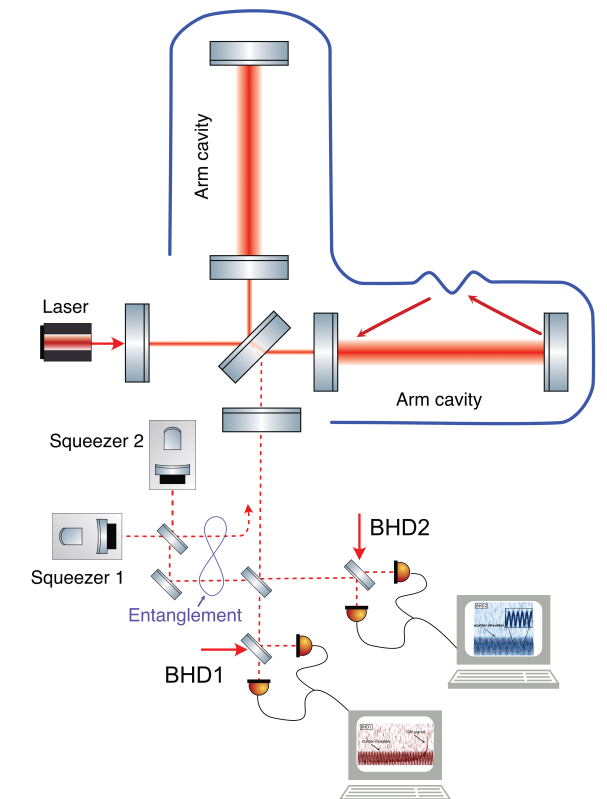
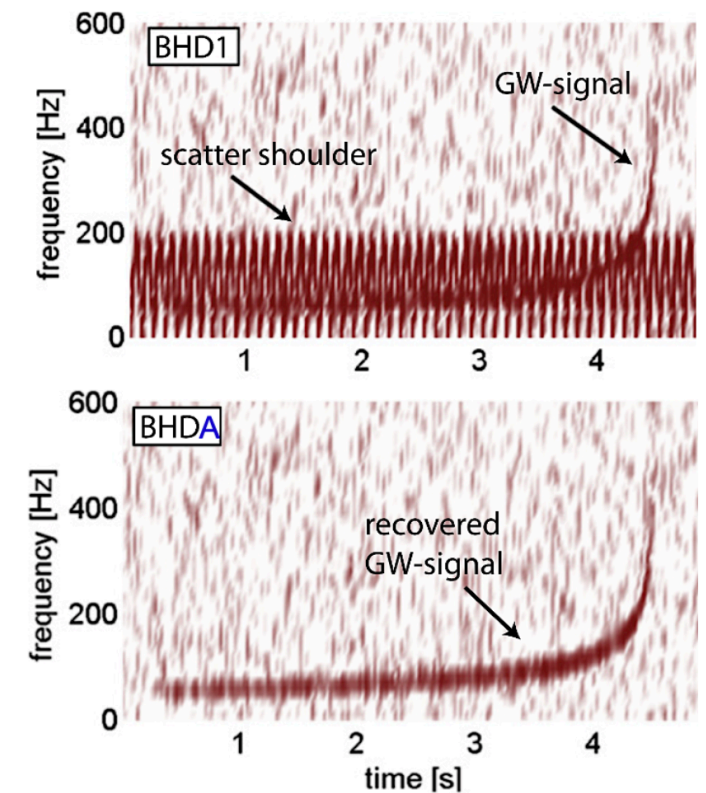


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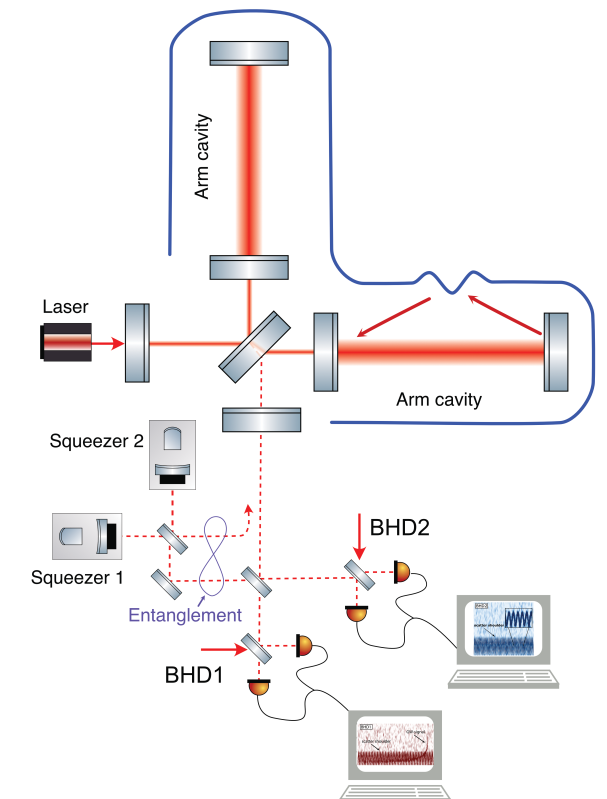
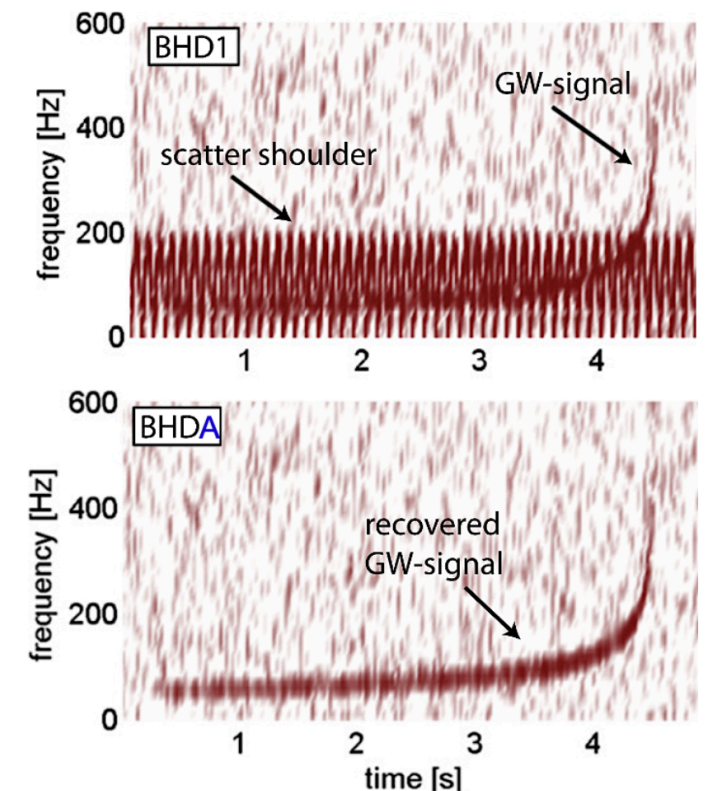




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Thank you!



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