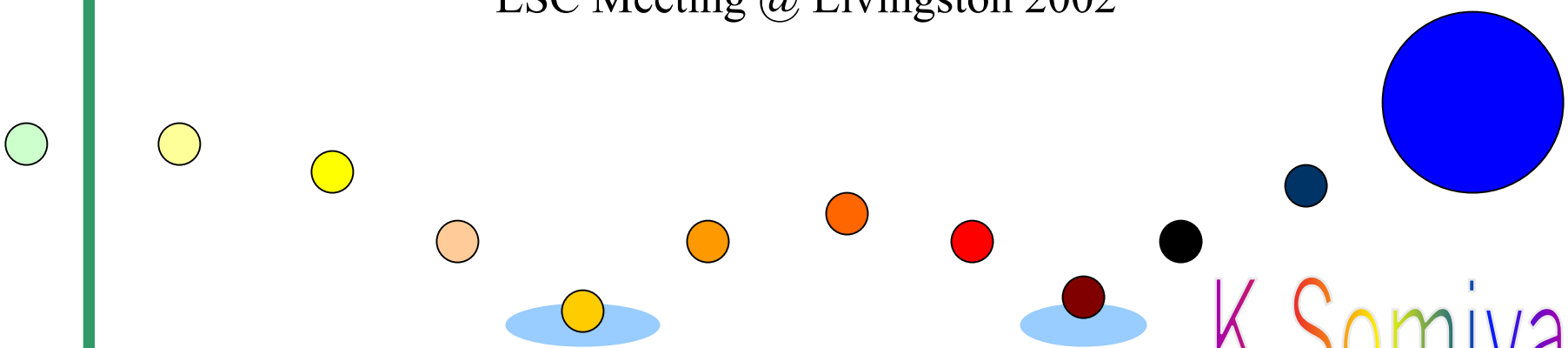
1) Unbalanced Sideband Detection

-- Complement of Last LSC meeting talk --

Kentaro Somiya
University of Tokyo

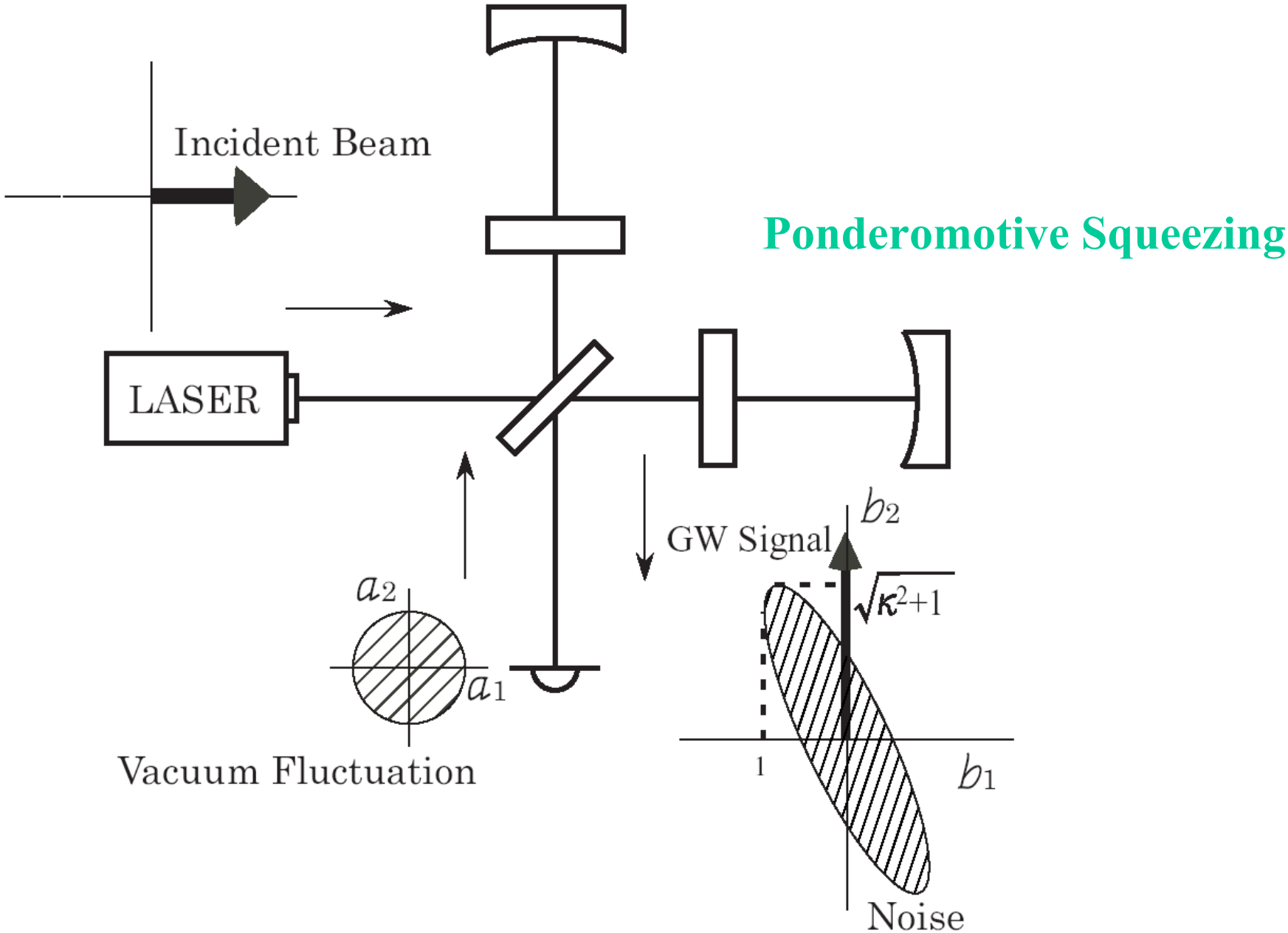
LSC Meeting @ Livingston 2002



LIGO-G020089-00-Z

At the last LSC meeting, I proposed that unbalanced sidebands might make homodyne detection possible. This is a complementary talk about the unbalanced sideband detection.

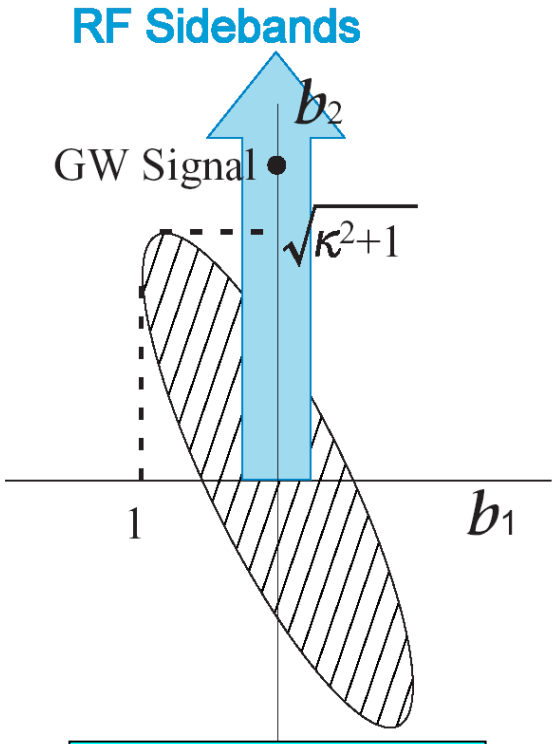
Review 1



Ponderomotive Squeezing

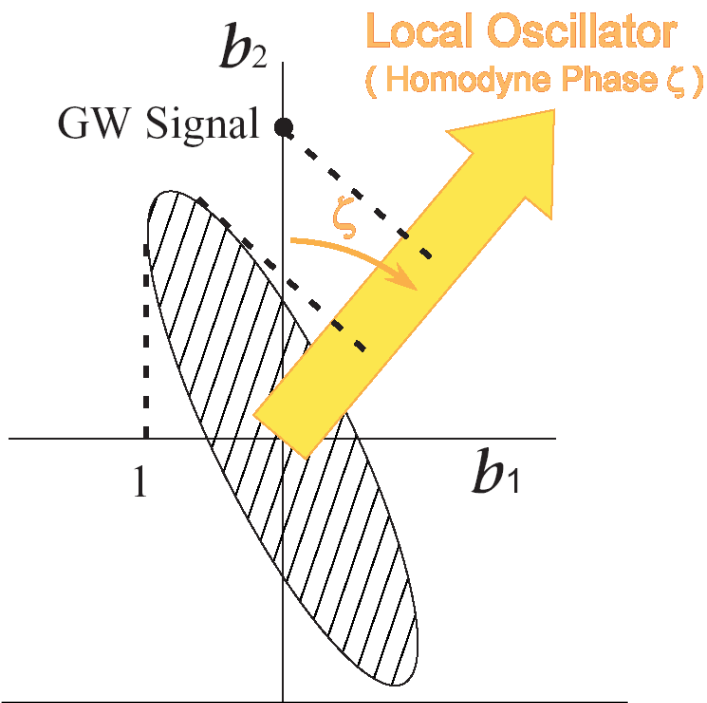
Review 2

Conventional Detection



$$h_n = h_{SQL}\sqrt{\frac{\kappa^2+1}{2\kappa}}$$

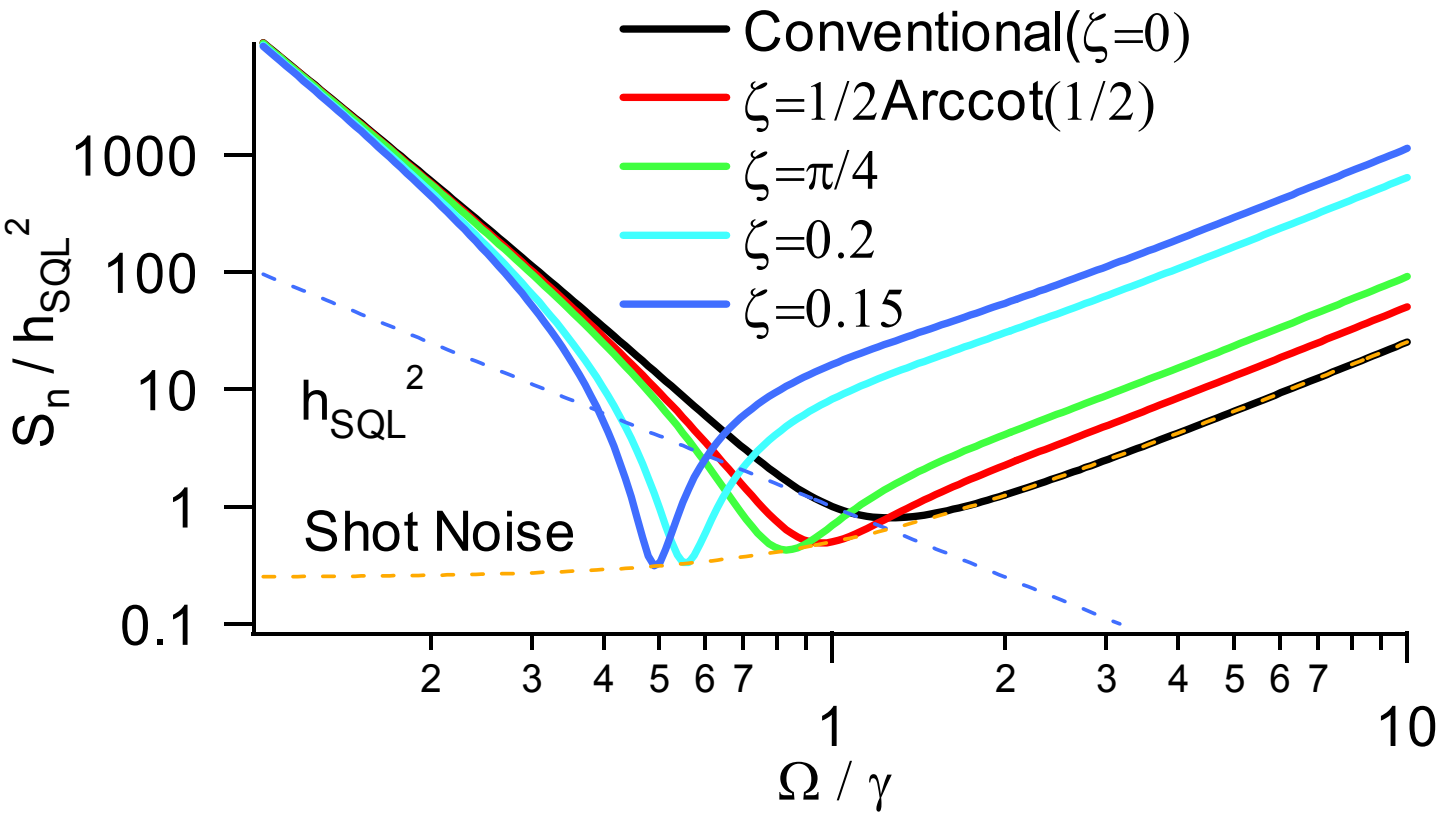
Homodyne Detection



$$h_n = h_{SQL}\sqrt{\frac{(\kappa-\tan\zeta)^2+1}{2\kappa}}$$

(NOTES: GW Signal $\propto \sqrt{\kappa}$, $\kappa = \dfrac{(I_0/I_{SQL})2\gamma^4}{\omega^2(\omega^2+\gamma^2)}$)

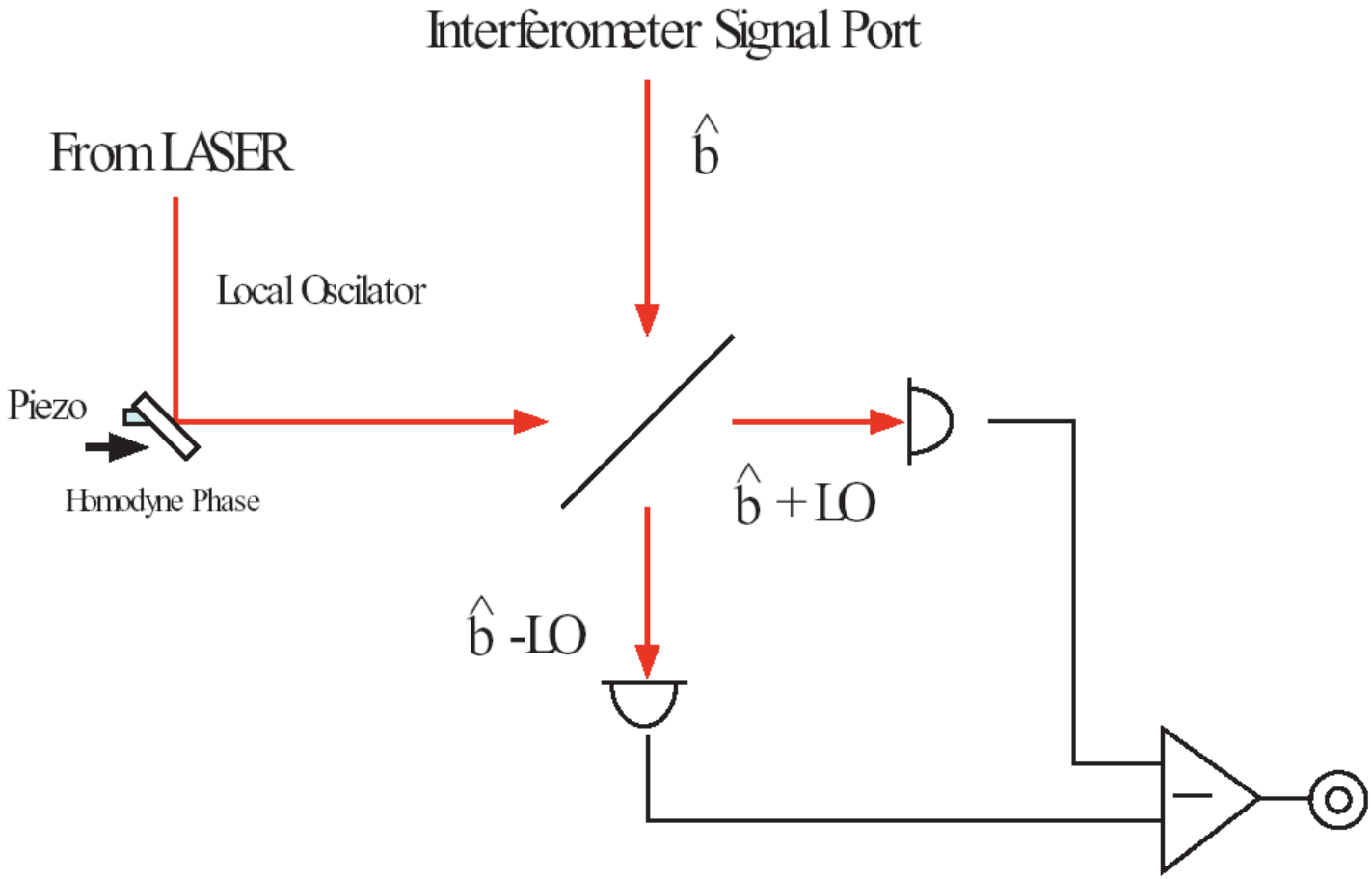
Review 3



- Radiation pressure noise disappears at particular frequency.
- We can beat the standard quantum limit.
- We can also change the shape of optical spring.

Review 4

How to realize the homodyne detection?



We need an additional interferometer at signal port.

Unbalanced Sideband Detection

What if there is only a single sideband?

$$h_n = h_{SQL}\sqrt{\frac{(\kappa - \cot\zeta')^2 + 1}{2\kappa}}$$

(ζ'=demodulation phase)

You must notice ζ' is not a homodyne phase but a demodulation phase!

This fact shows we can realize the homodyne detection only with a single sideband.

There are three questions.

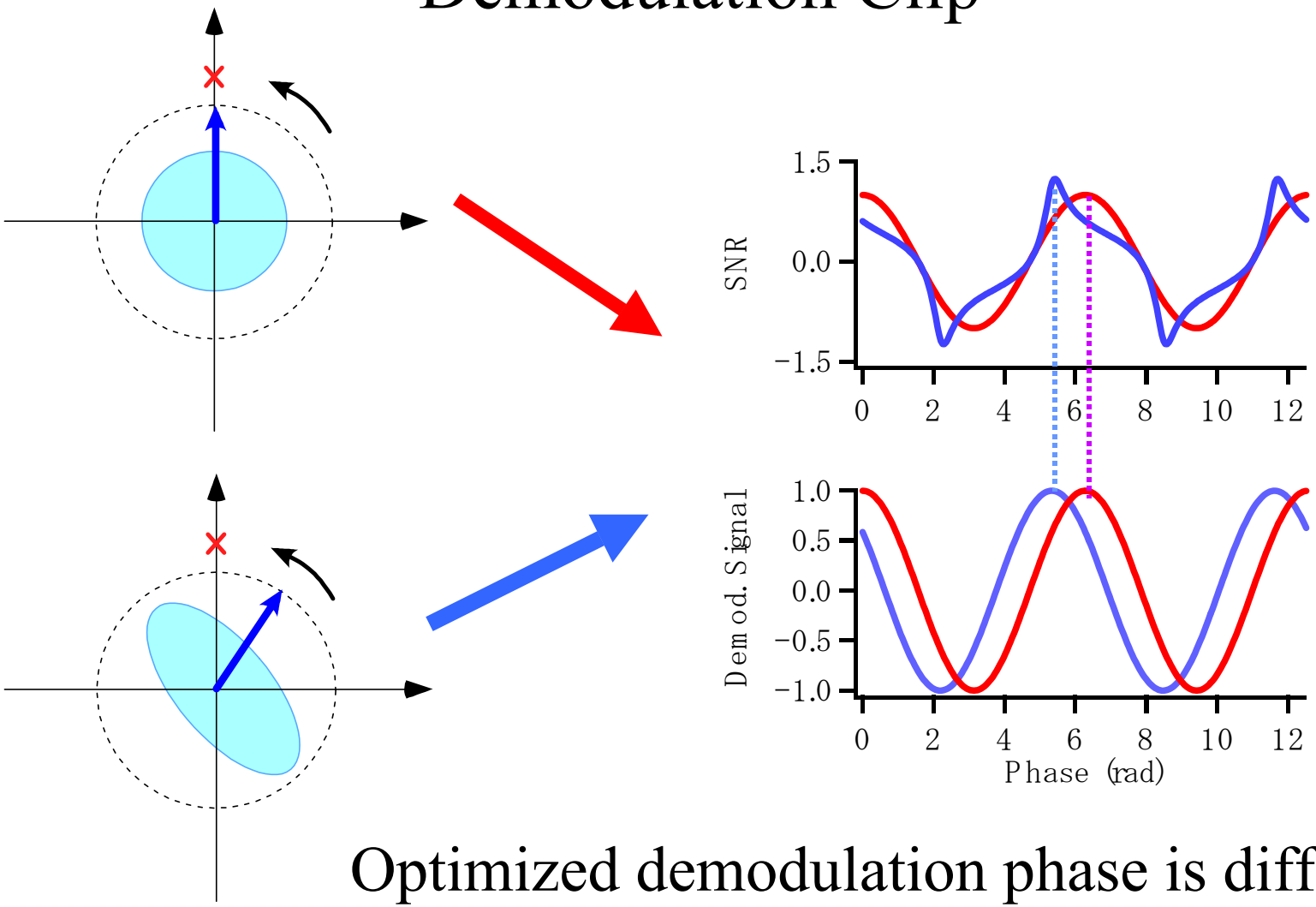
1)Why the demodulation phase is important?

2)Why we can't with dual sidebands?

3)What if there are unbalanced dual sidebands?

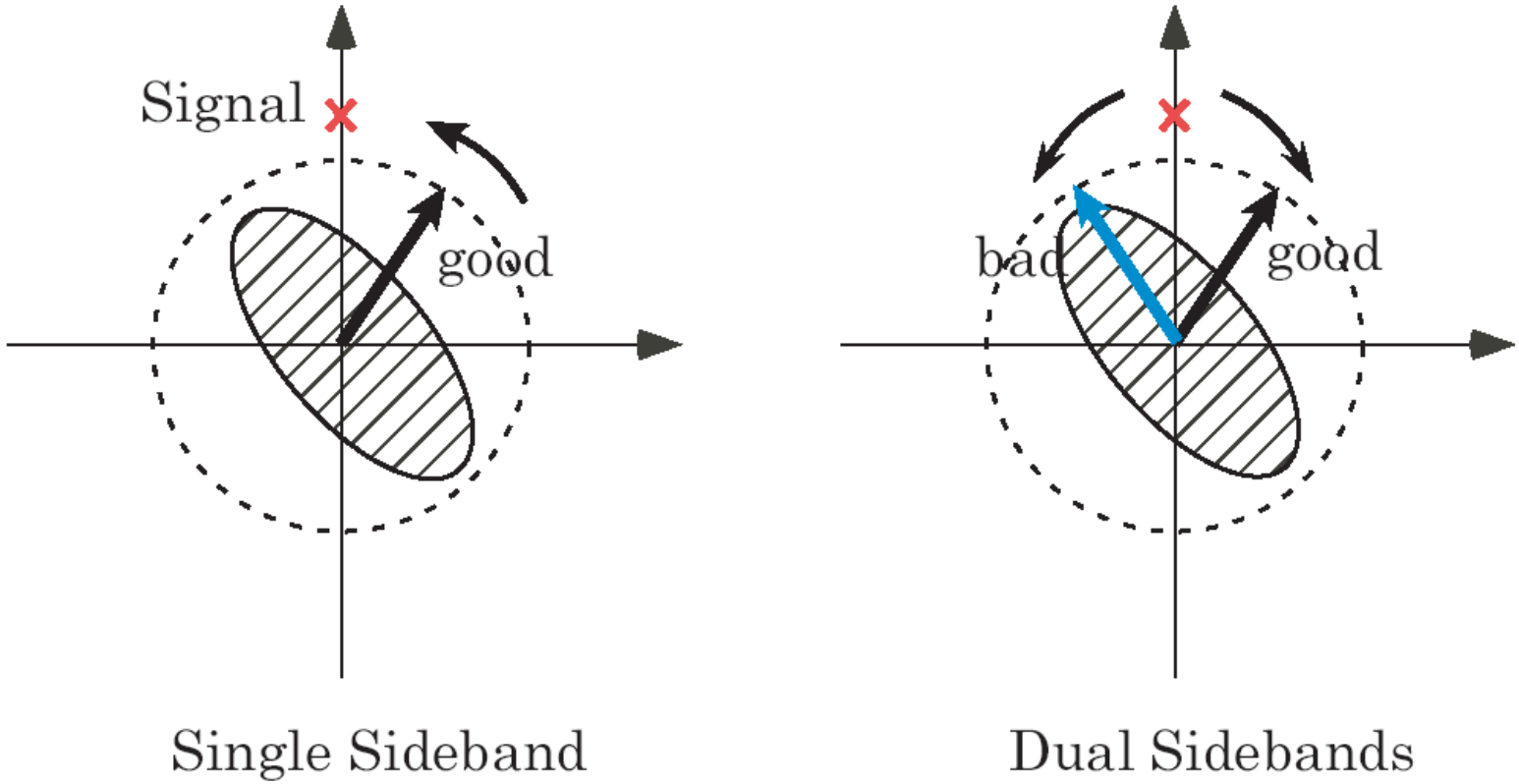
Answer (1)

Demodulation Clip



Optimized demodulation phase is different between ordinary case and squeezed case.

Answer (2)



With dual sidebands, even if demodulation phase is set to be optimized for one of the sidebands, the other make SNR so worse as to be equivalent to the case $\zeta'=\pi/2$.

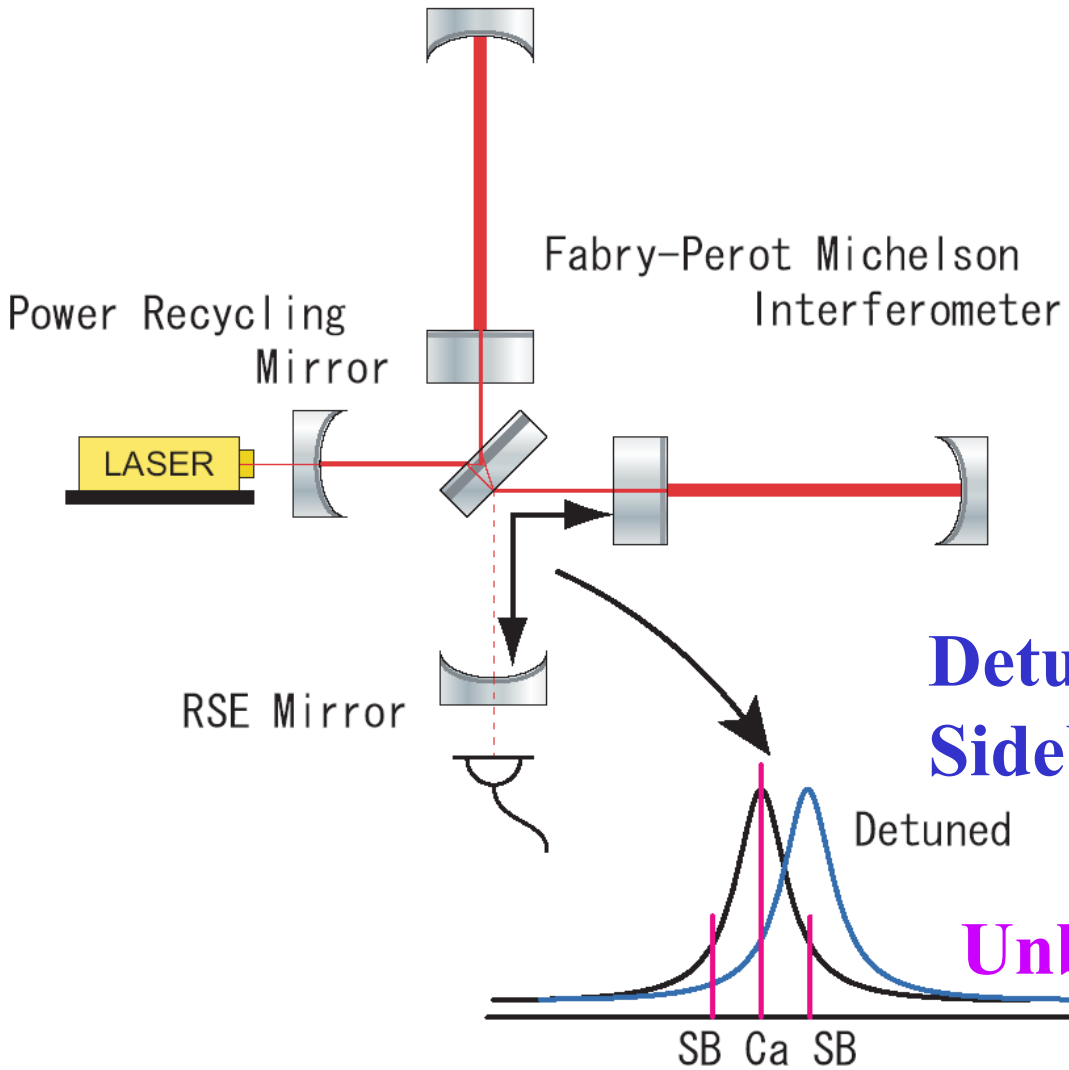
Answer (3)

If there are not a single but unbalanced dual sidebands, SNR can be also improved with defining the phase to be optimized for the bigger sideband.

Result: $$h_n = h_{SQL}\sqrt{\frac{\left(\kappa - \Delta\alpha \cot\zeta'\right)^2 + 1}{2\kappa}}$$

Here, $\Delta\alpha = \left|(\text{UpperSB} - \text{LowerSB})/(\text{UpperSB} + \text{LowerSB})\right|$

How to realize this detection?



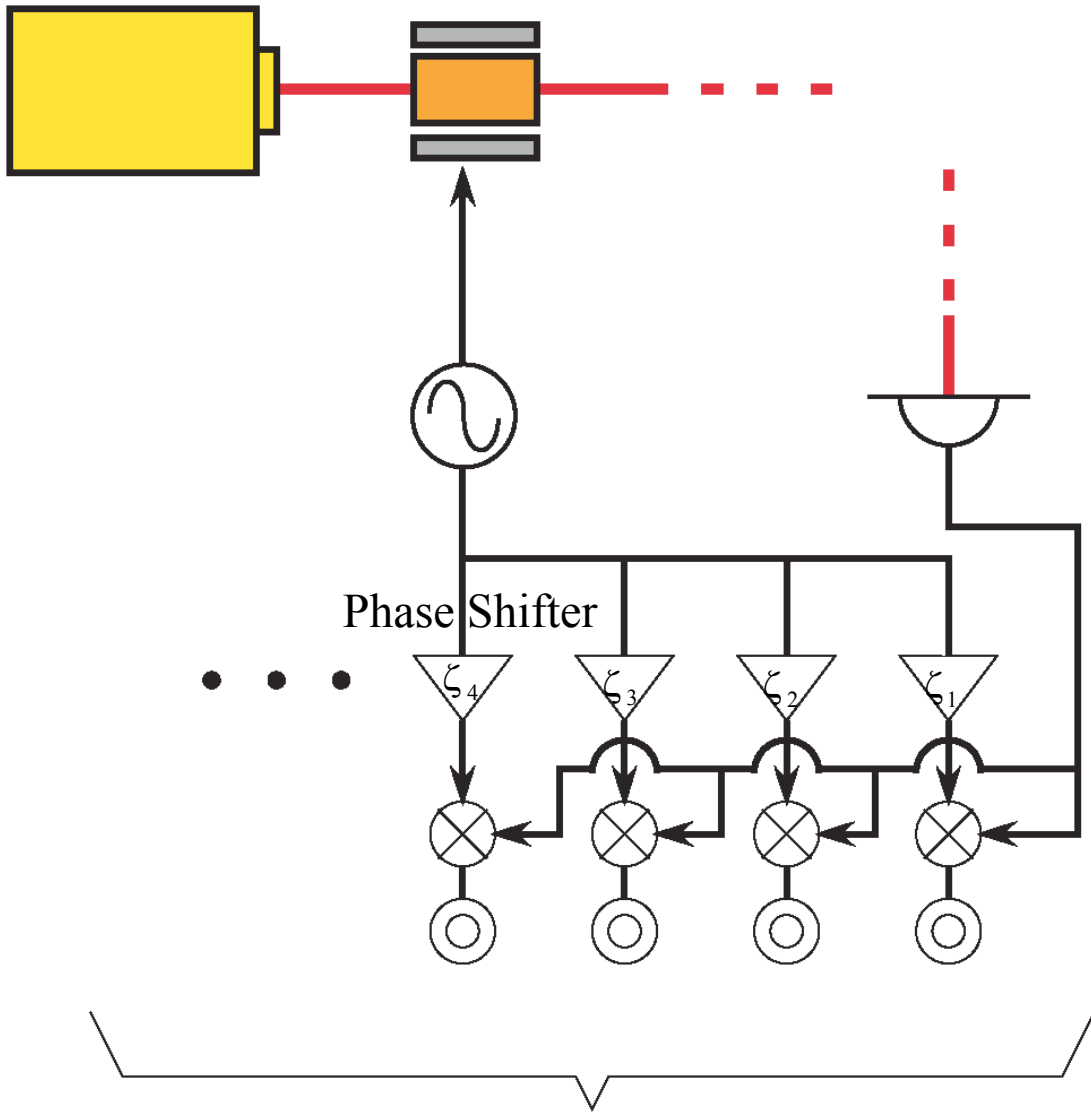
Detuned RSE with Sideband locking

Unbalance!

LIGO-G020089-00-Z

There is no other equipment than planned configuration.

Wonderful option!!



It requires no optical process!

LIGO-G020089-00-Z

Integrate → Broadband QND IFO

Conclusion and Discussion

We can realize QND (Quantum Non-Demolition) detection easily with this **Unbalanced Sideband Detection** which requires no additional optics other than planned configuration for detuned RSE.
And also we can realize **broadband QND detection** only with electrical process.

We need to remove common mode noise such as L+ or l_{RSE} at the same port for L-. It would be a problem for any QND detection.