

# The experimental plan of displacement- and frequency-noise free laser interferometer

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## (I) Introduction

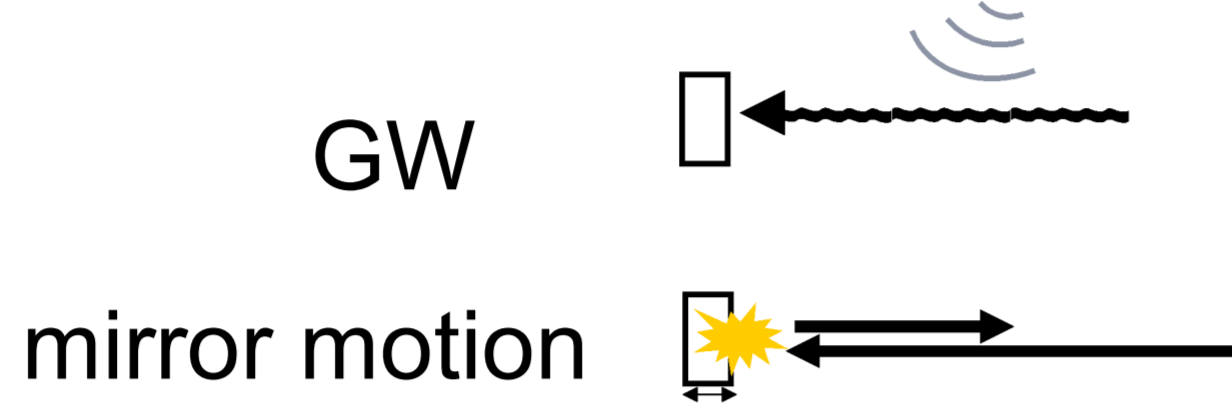
**DFI (Displacement - and frequency-noise Free Interferometer) can take away all kinds of displacement noise.**

Displacement noise : seismic, thermal and radiation pressure noise  
Therefore, in theory, DFI is limited by only shot noise.

S.Kawamura & Y.Chen, PRL 93, 211103 (2004)  
Y.Chen & S.Kawamura, PRL, 96, 231102 (2006)

## (II) Principle

(1) GWs and mirror motions affect the light differently



In the low frequency region, GW effects and mirror motions can not be distinguished, but when wavelengths of GW and light path lengths are comparable, they can be distinguished

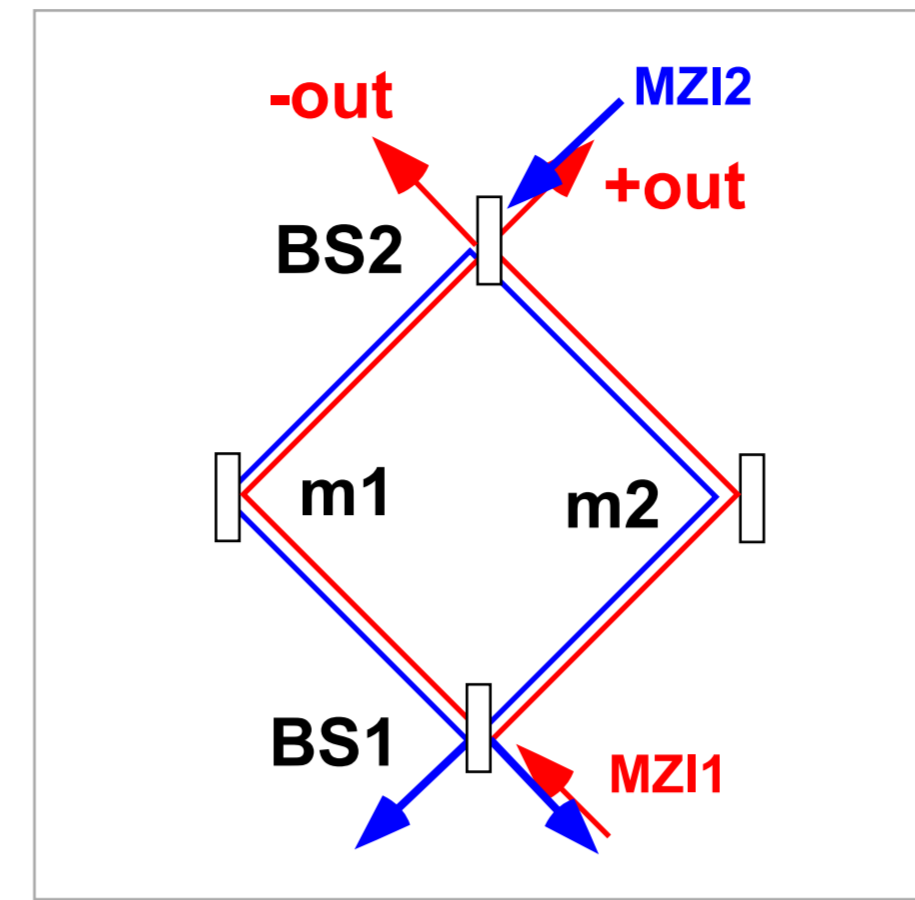
(2) Multiple interferometers

One takes their signal combination so that the displacement noises are canceled while GW signals are surviving

- DFI will be 3D configuration
- DFI will contain "bidirectional Mach Zehnder Interferometer"

## (III) Bidirectional Mach Zehnder Interferometer

1. Two Mach Zehnder Interferometers (MZIs) are on one square path

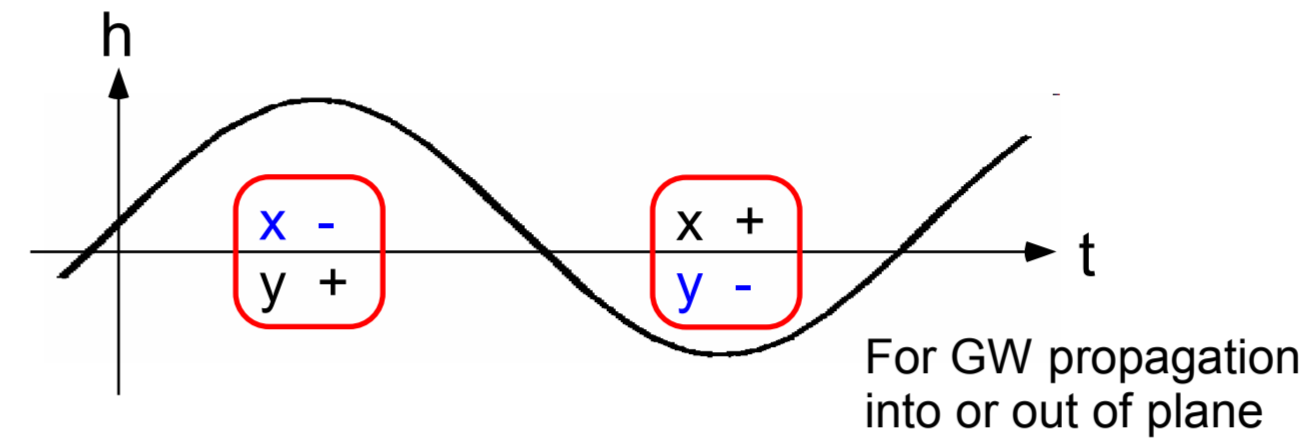


2. The BDMZI is free from mirror motions

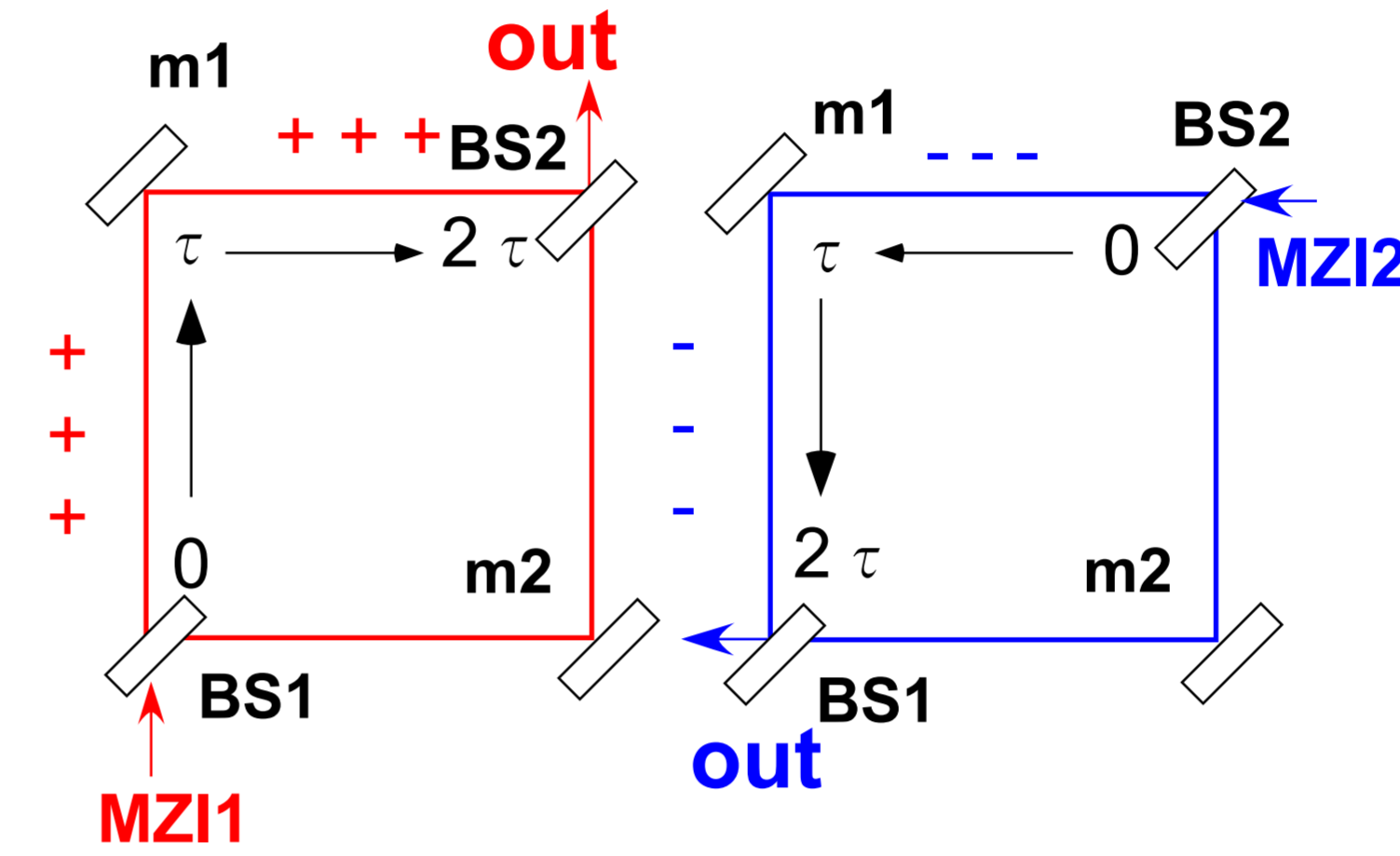
because both of the MZIs respond the same way to displacements of the mirror at the midpoint

→ The mirror motions can be canceled by subtracting the two outputs

3. BS motions can NOT be canceled because they are not at the midpoint of the paths



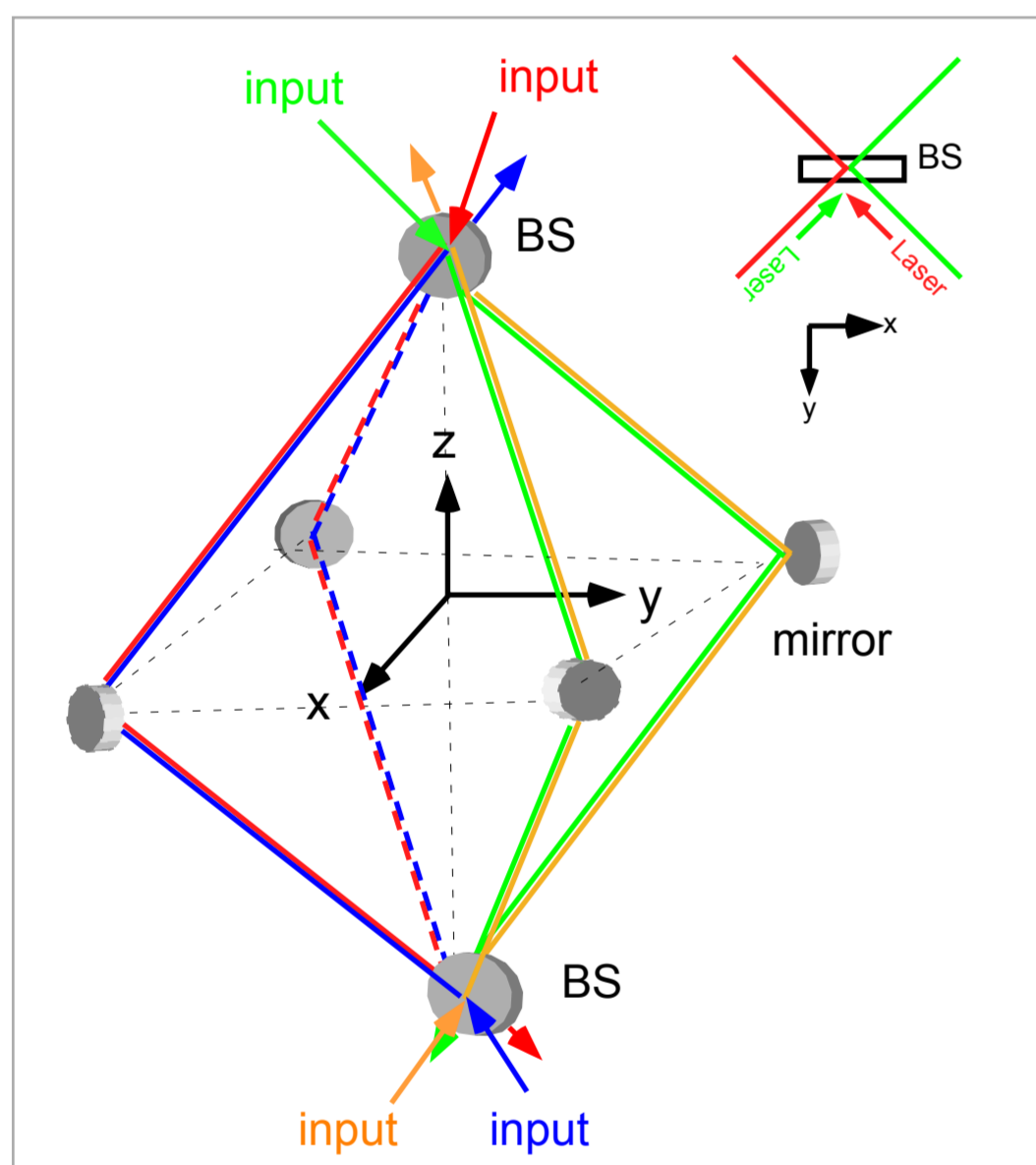
4. GW signals survive after the subtraction



out = + delta L  
out = - delta L  
out = out - out = 2 delta L

## (IV) 3D Configuration

Two sets of bidirectional MZI on octahedron light path  
They share two BSs



Y. Chen et al., Phys. Rev. Lett. 97, 151103

out<sub>BDMZI1</sub> = GW signals + BS motion  
- ) out<sub>BDMZI2</sub> = - GW signals + BS motion  
final output = only GW signals!

Two BS motion are canceled by subtracting two bidirectional MZIs

The motion of the four mirrors are canceled by each bidirectional MZI itself

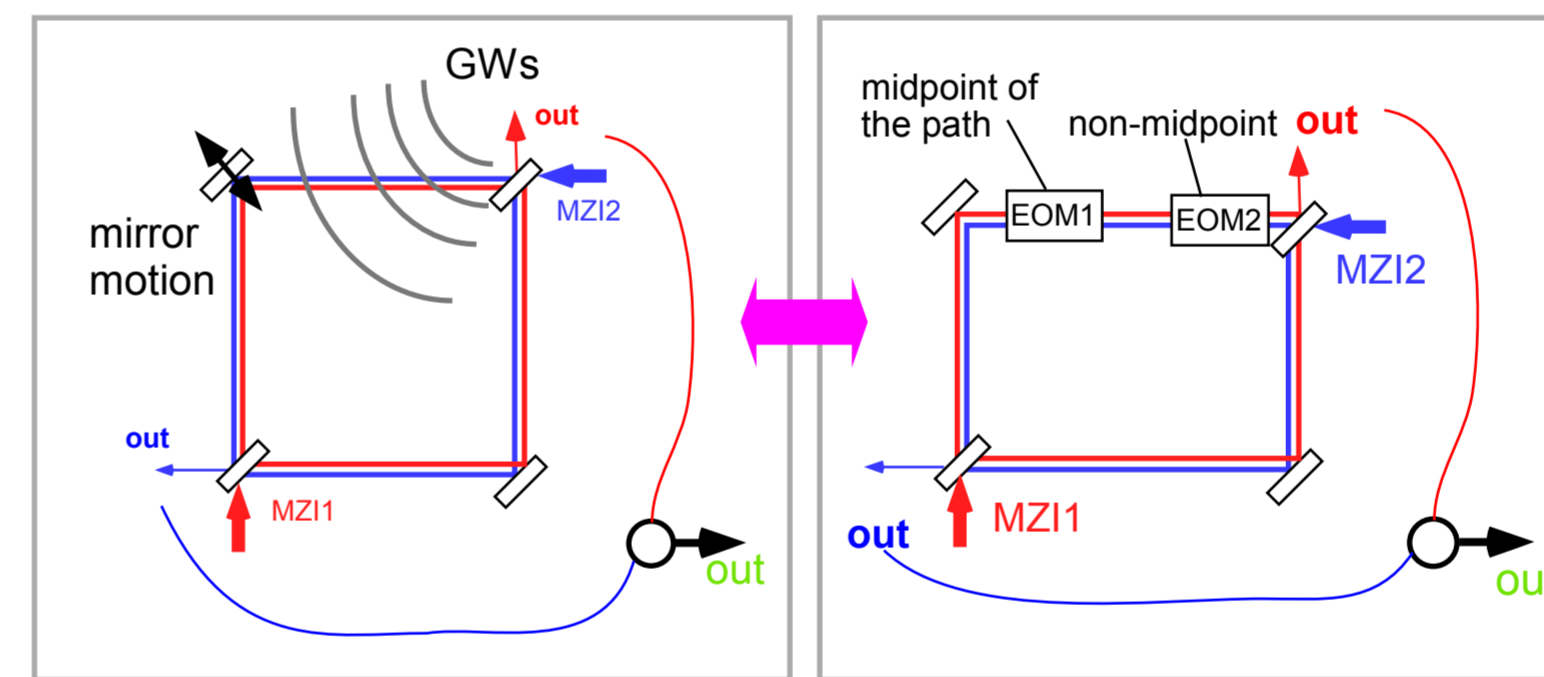
## (V) Proof-of-principle Experiment 1

### Experiment 1

A bidirectional MZI was demonstrated

in reality

experiment

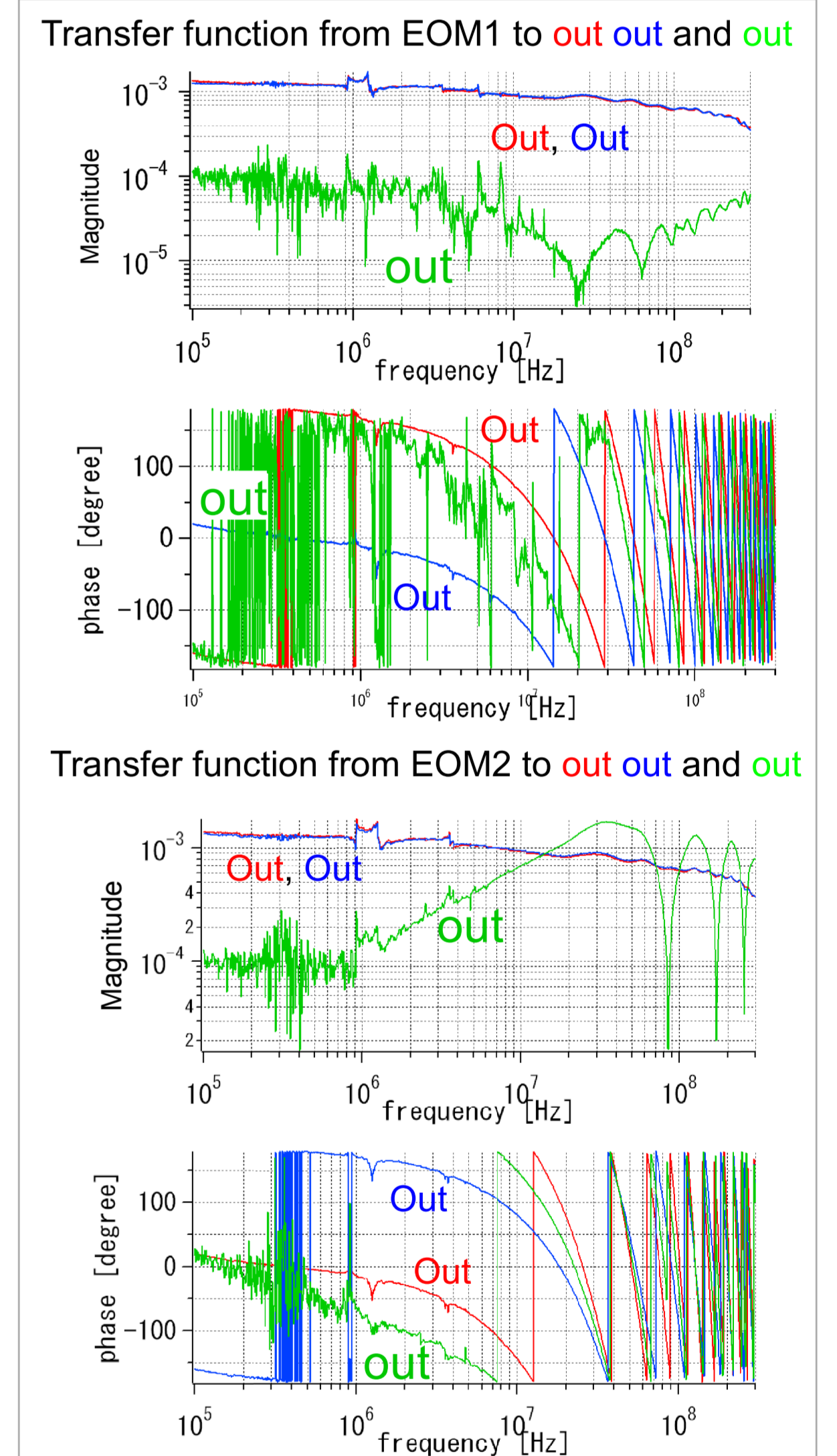


out = out - out

In the out signal, we looked for ;

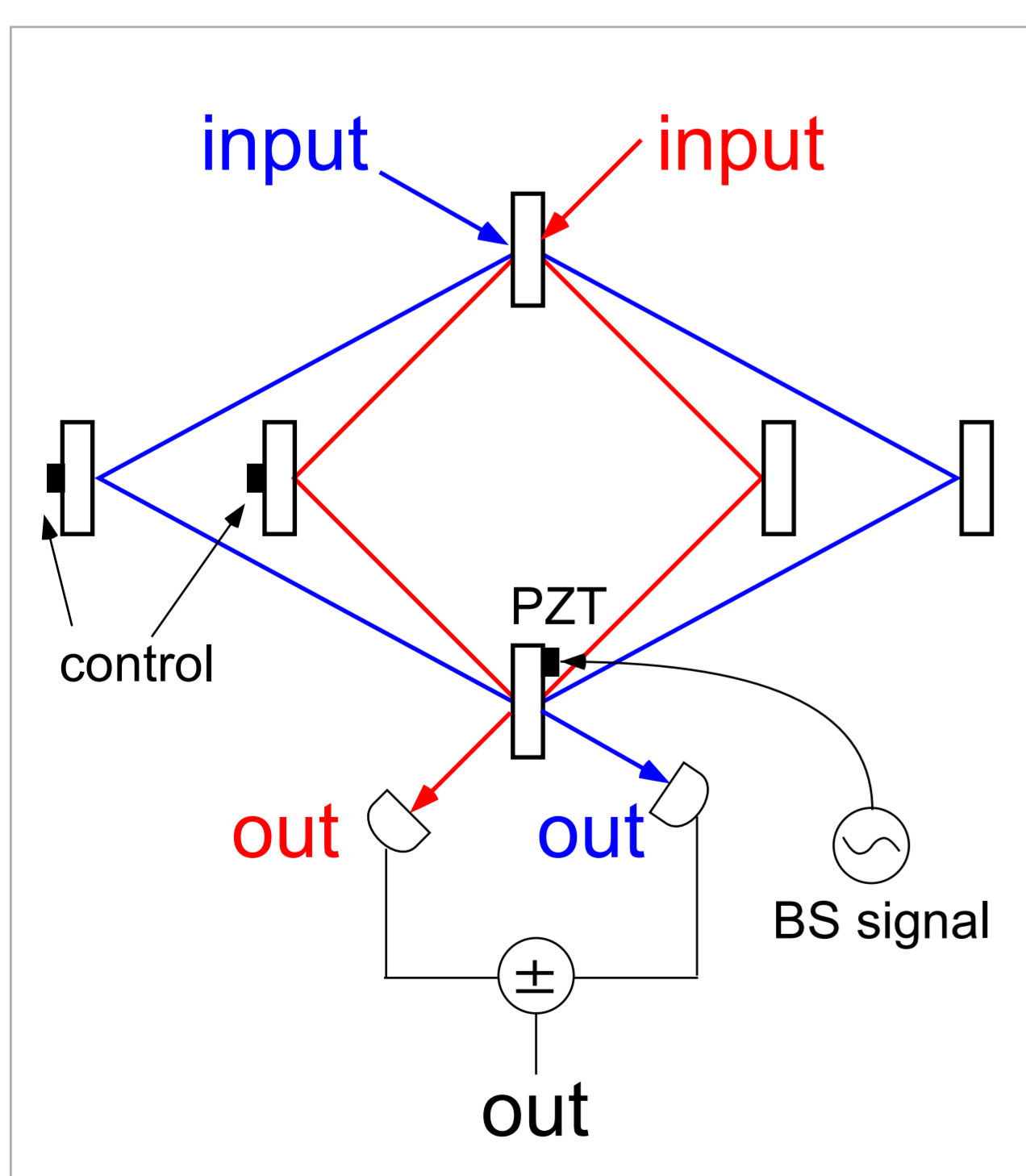
1. Cancellation of the mirror motion
2. Non-vanishing GW-like signals

Sato, Kawamura, Kokeyama, Ward, Chen, Pai and Somiya  
PRL 98, 141101 (2007)

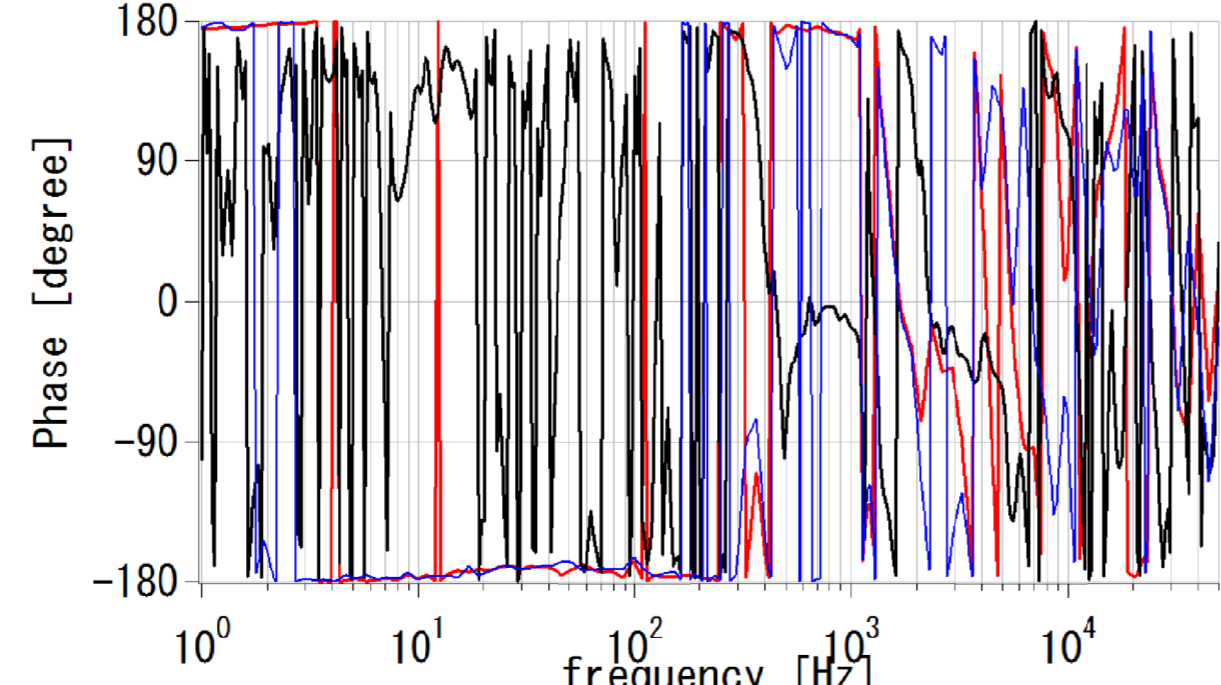
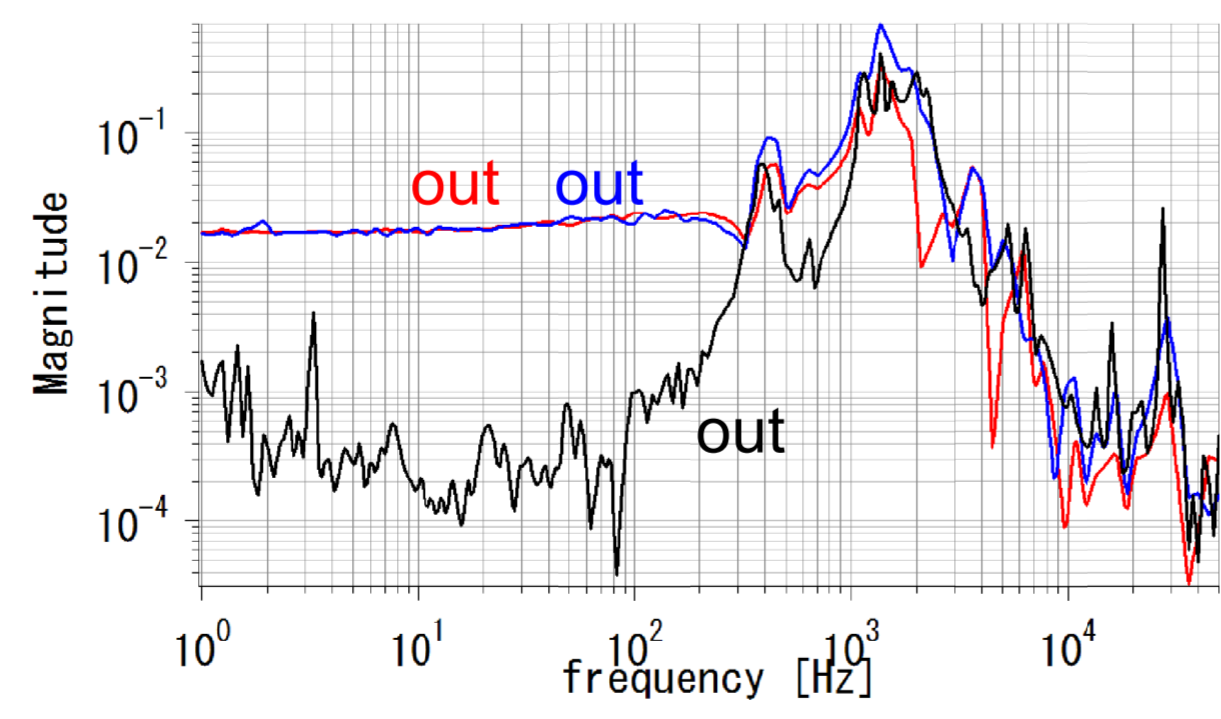


## (VI) Proof-of-principle Experiment 2

The BS-motion cancellation was demonstrated



Transfer function from BS signal to out, out and out



In the out signal, we looked for ;

Cancellation of the BS motion

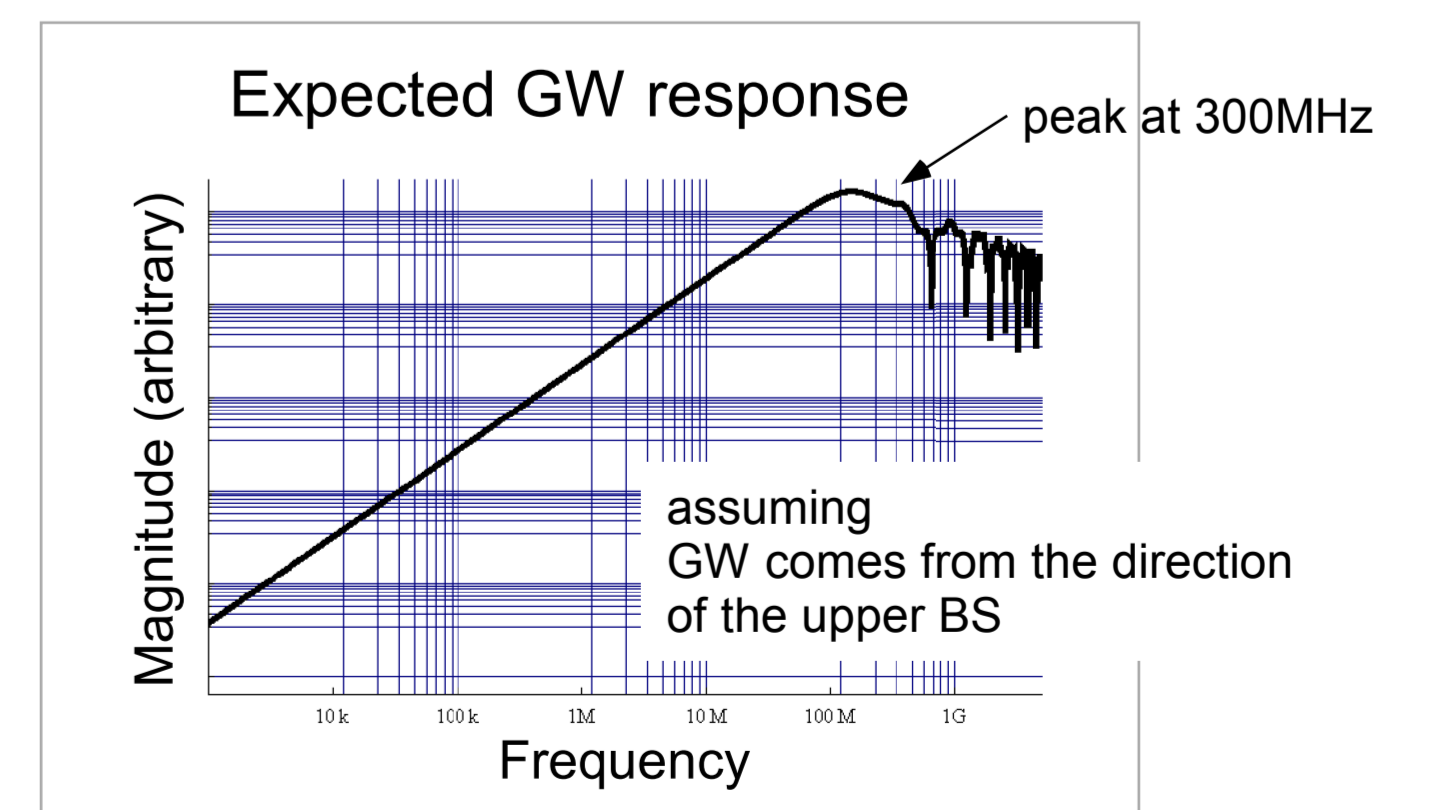
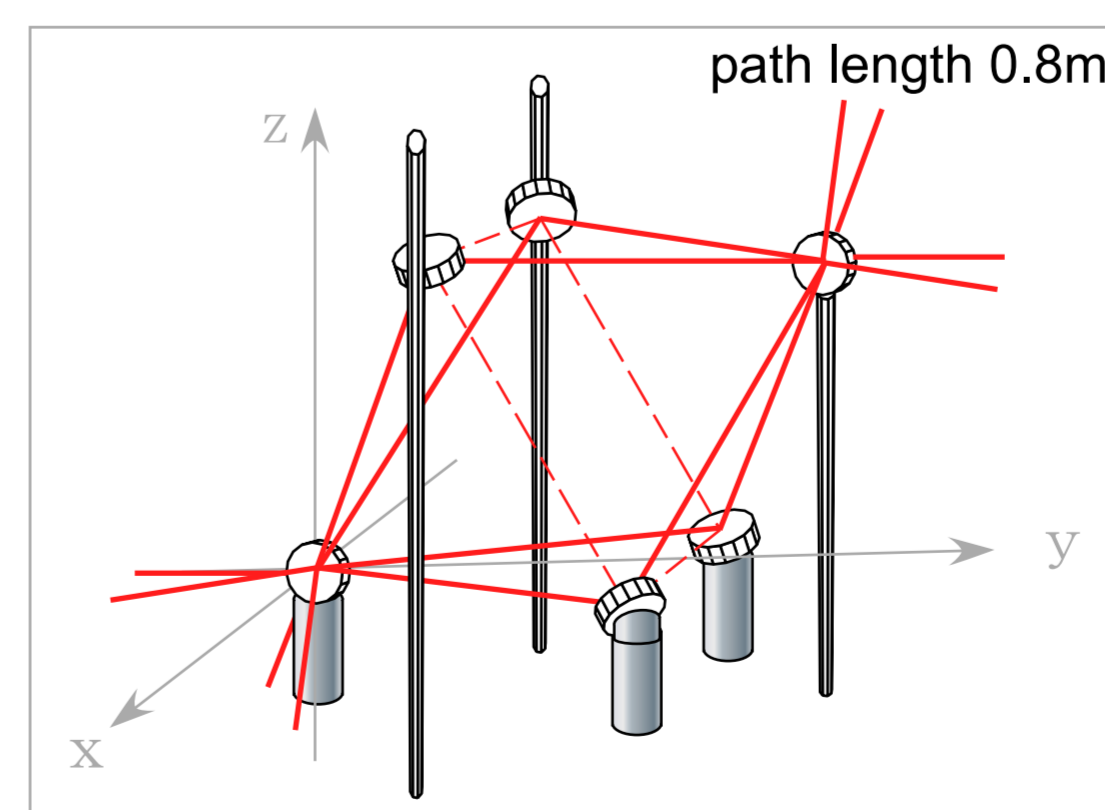
- GW-like signals were not injected
- The BS was actually shaken

Two signals from the MZIs are subtracted to cancel the BS signal  
They are mid-fringe controlled by PZTs respectively

## (VII) Experimental Plan for 3D Full Configuration

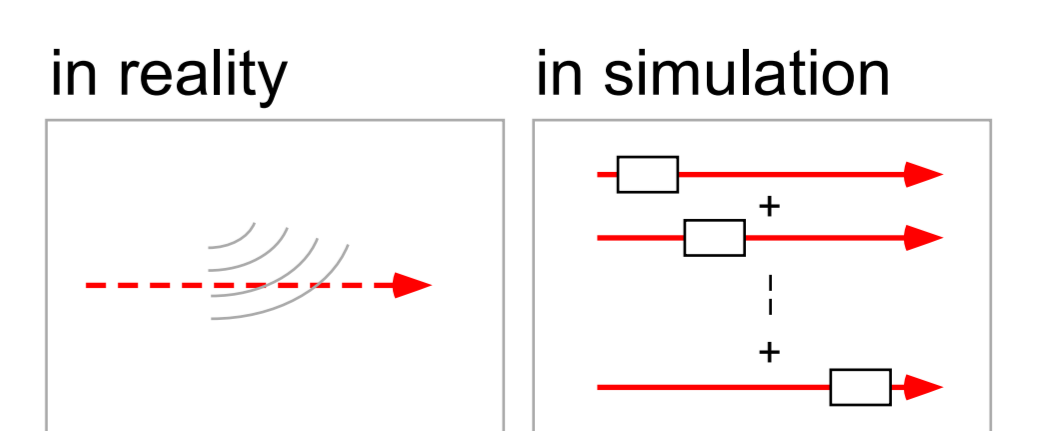
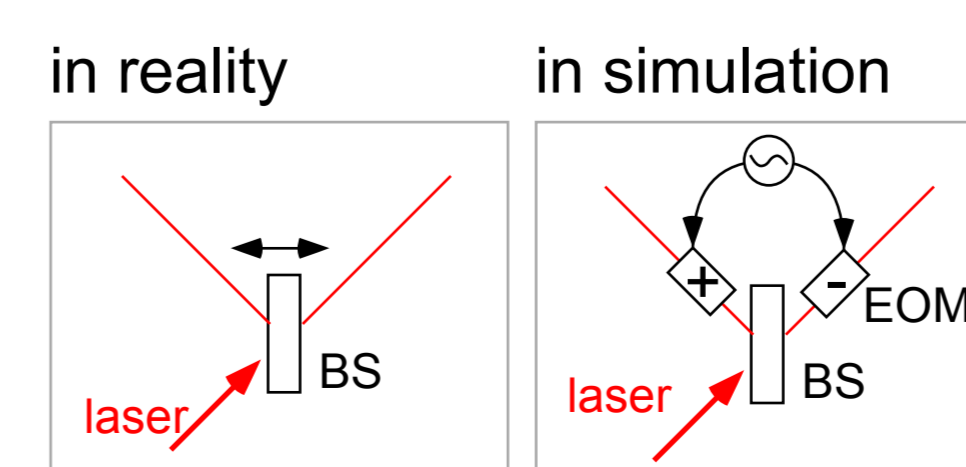
We look for ;

1. Cancellation of ALL optics motion
2. Non-vanishing GW wave signals



**Mirror :**  
put EOMs at the mid points of the path  
**BS :**  
put two EOMs after the BS and send opposite sign signals

**GW :**  
use several EOMs  
and take data independently, then add them



The laser light acquires phase shifts along its entire path (simulating GW)