Experimental investigation of a control scheme for a tuned resonant sideband extraction interferometer for next-generation gravitational-wave detectors

@ Moriond 2007

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Motivation

- Resonant Sideband Extraction (RSE) technique will be used in some next-generation interferometers to enhance their sensitivities

- LCGT will use tuned RSE configuration, a control scheme for a tuned RSE needs to be developed. Moreover, it could serve as a backup design for Adv.LIGO which will use tuned RSE configuration.

- Testing the control scheme with a prototype interferometer to demonstrate the control of the tuned RSE is necessary.

Contents

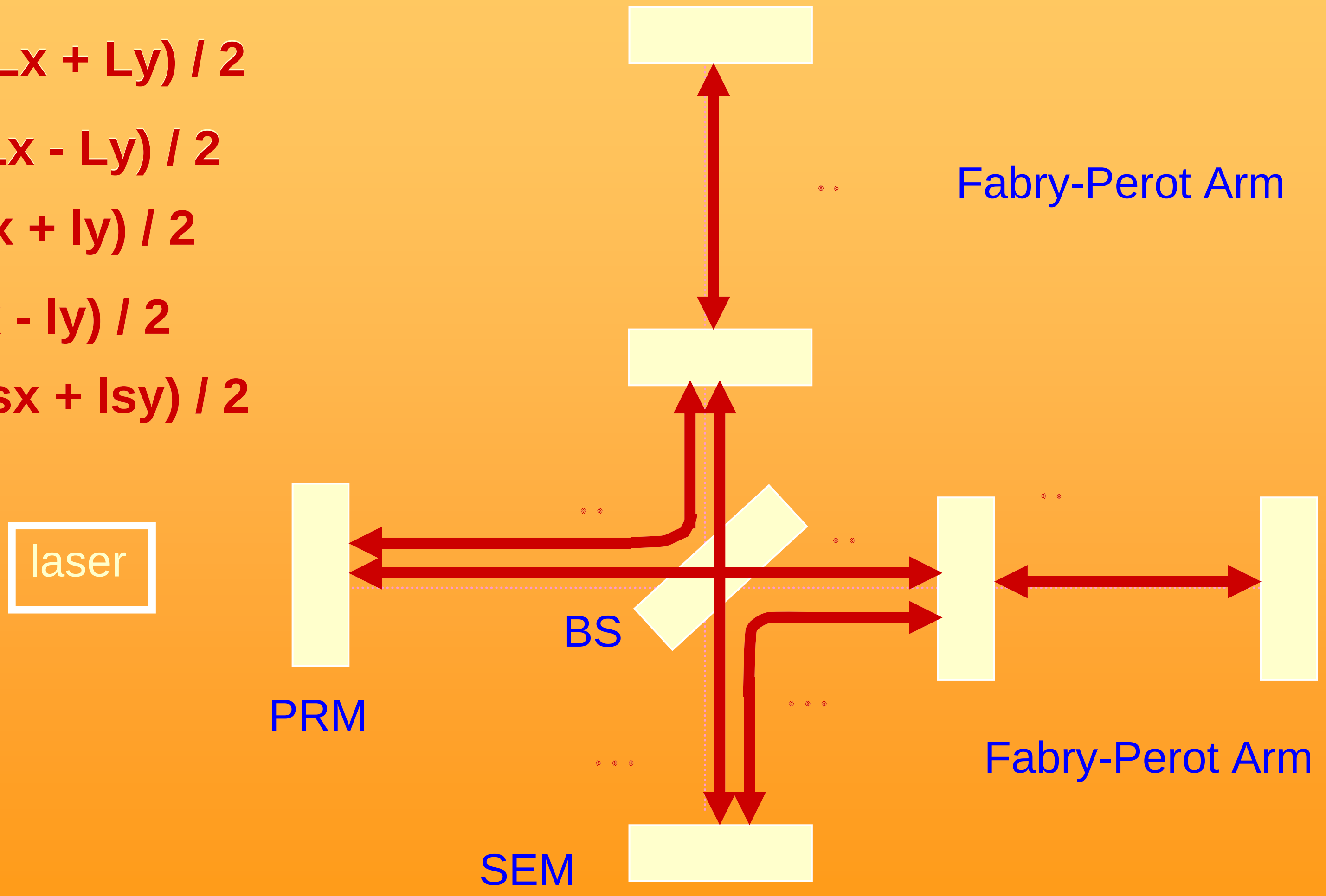
- Control scheme of the tuned RSE
- Signal Matrix
- Diagnolization of the signal matrix
- Experimental status

Progress

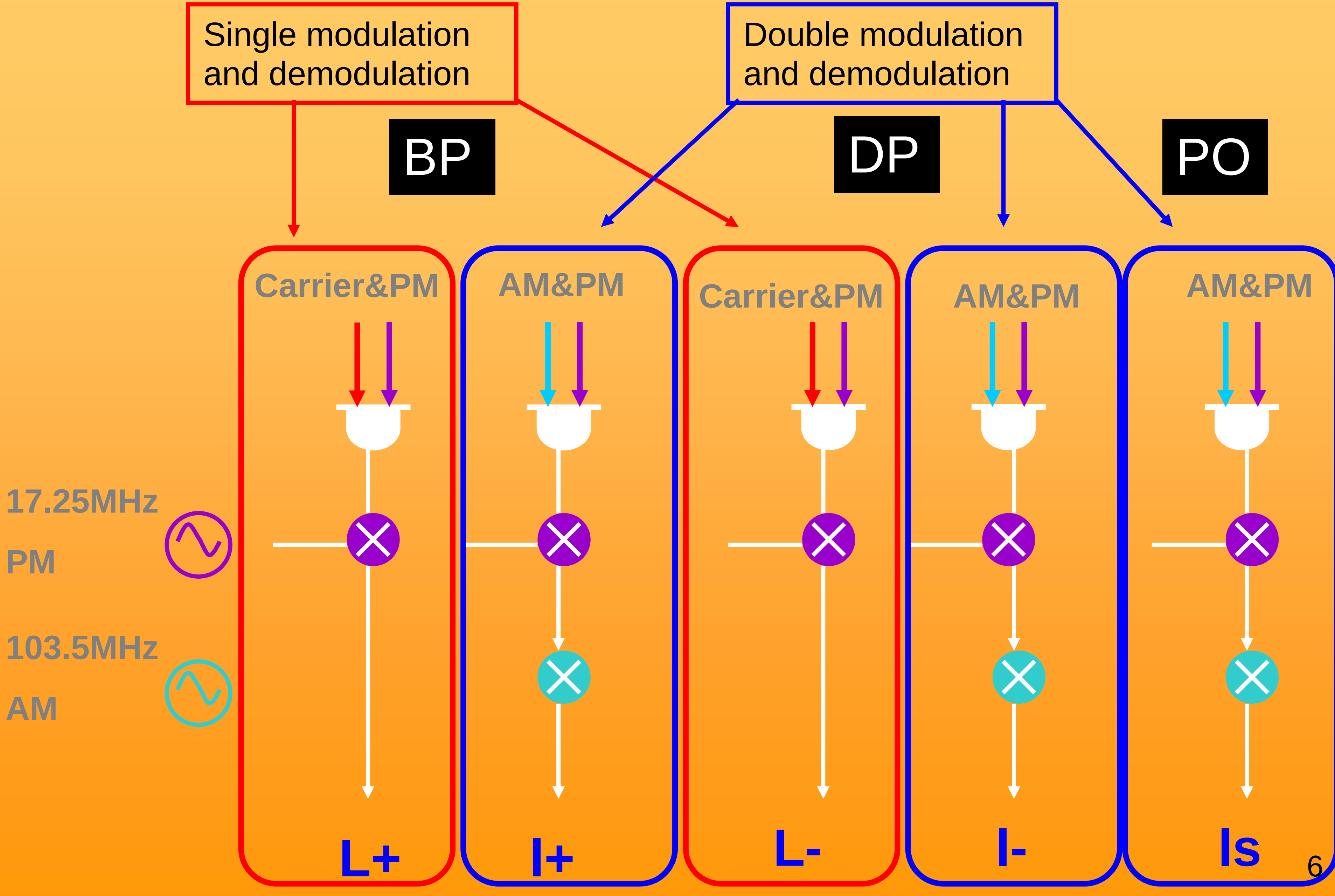
- Developed a control scheme(~2004~2005)
    - Single modulation and demodulation for Fabry-Perot arms
    - Double modulation and demodulation for the central part
- Built the RSE interferometer(~2005~2006)
    - Inside NAOJ’s campus, Tokyo.
- Have locked the central part on DD(~ March 2007)
    - Locks in the evening, for about a minute.

5 degrees of freedom

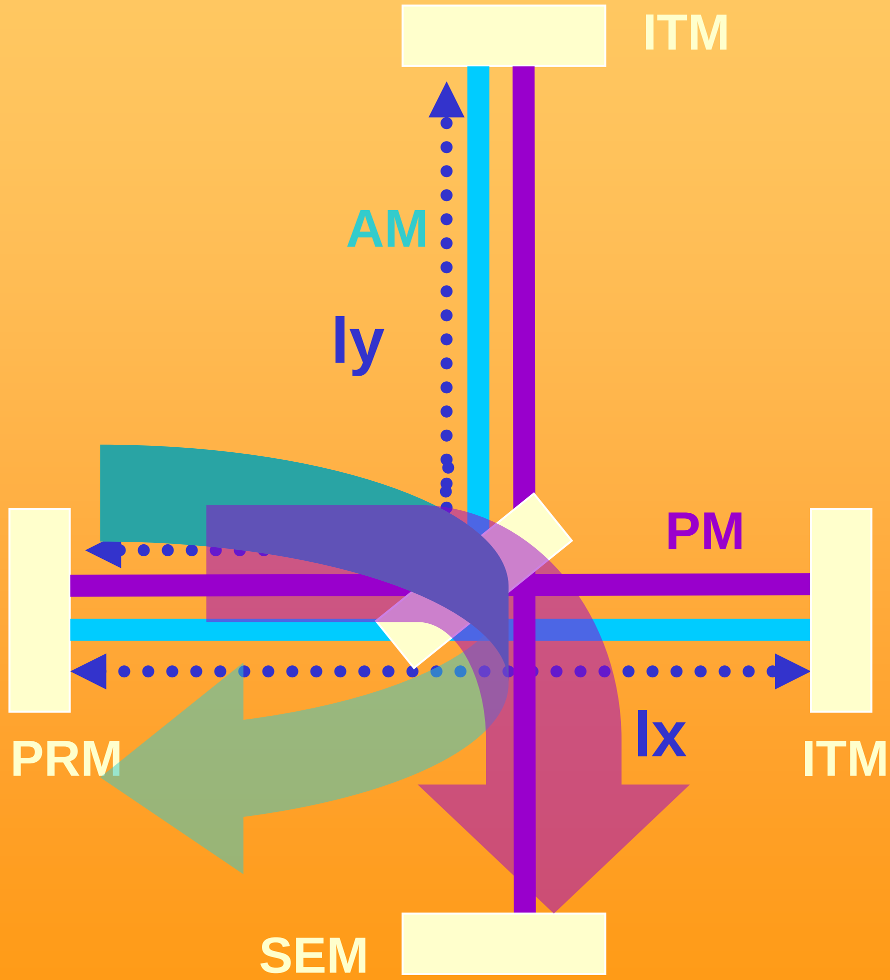
- $L_+ = (L_x + L_y) / 2$
- $L_- = (L_x - L_y) / 2$
- $l_+ = (l_x + l_y) / 2$
- $l_- = (l_x - l_y) / 2$
- $l_s = (l_{sx} + l_{sy}) / 2$



3 detection ports, 5 signals



Michelson Asymmetry and sideband resonant conditions

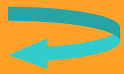


dl = ly - lx

	dl /
f_{PM} (17.25MHz)	1/2
f_{AM} (103.5MHz)	3

(f2 = 6 x f1)

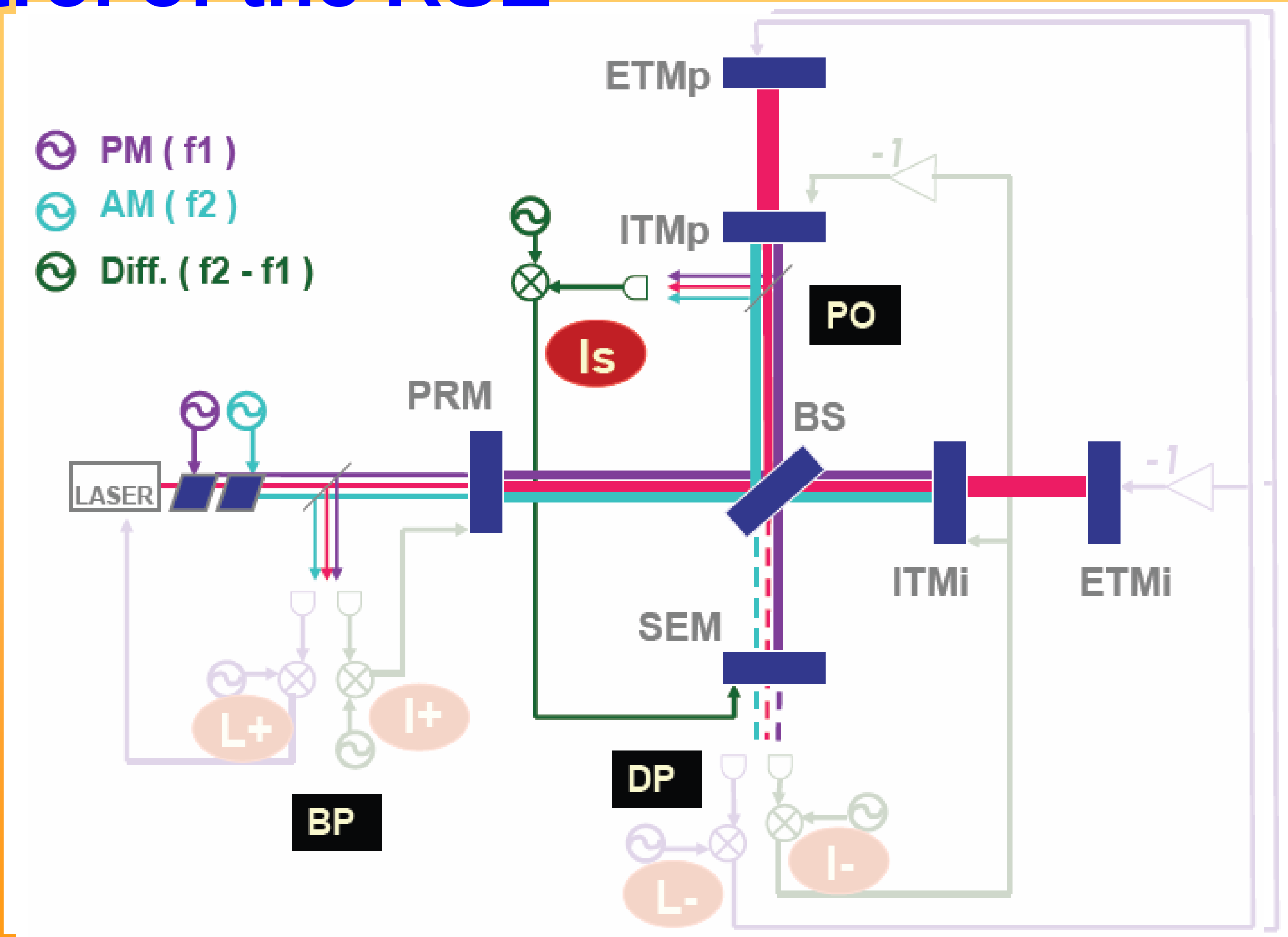
PM transmit through Michelson 

AM reflect from Michelson 

PM resonant inside PRC + SEC

AM resonant inside PRC

Control of the RSE



L+, L- by single modulation & demodulation (arms)
Ip,Is,I- by double modulation & demodulation (central part)

Signal Matrix

	L+	L-	l+	l-	ls
BP	1	7.6e-6	-2.6e-2	5.9e-4	1.3e-2
DP	-4.9e-8	1	3.2e-8	1.3e-2	4.6e-8
BP	-4.9e-2	-1.1e-4	1	-8.8e-3	-5.3e-1
DP	-1.0e-4	7.6e-2	1.4e-3	1	1.2e-5
PO	-1.5e-1	-1.2e-2	1.1	-2.2e-2	1

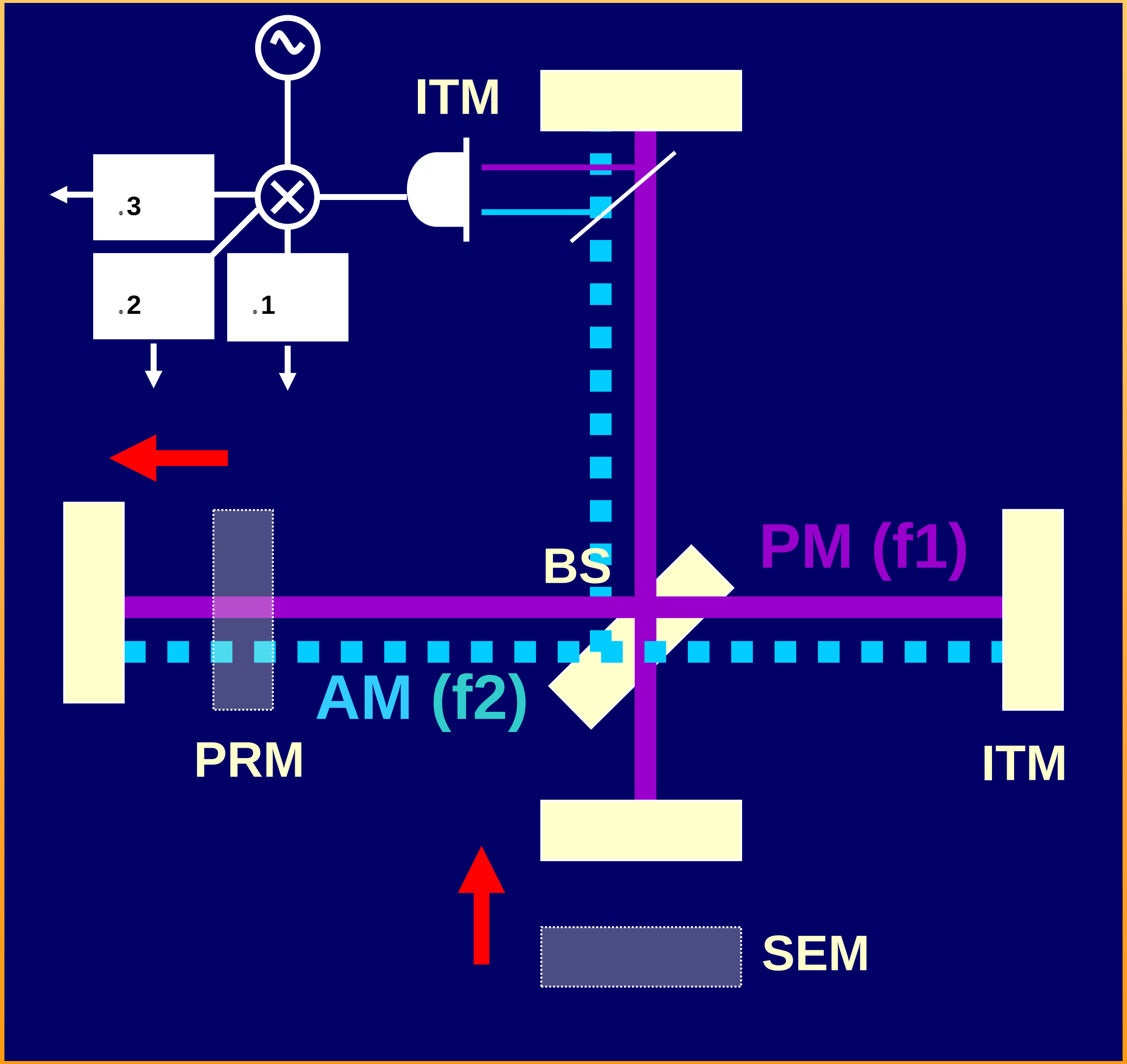
A linearly independent signals can be obtained

By FINESSE

In addition, we have developed a technique to diagonalize the signal matrix.

Obtaining an inherent diagonal signal matrix with no electronic operation might be advantageous (signal to noise ratio, dynamical nature of lock acquisition, robust control)

Diagonalizing the signal matrix @ PO (Delocation technique)



Move SEM and PRM the same distance in the same direction

⬇

f1 stays resonant due to Michelson asymmetry while f2 becomes off-resonant

⬇

Will introduce a phase shift in the f 2 demodulation phase making the optimum demodulation phase for the tree DOFs 45° apart from each other

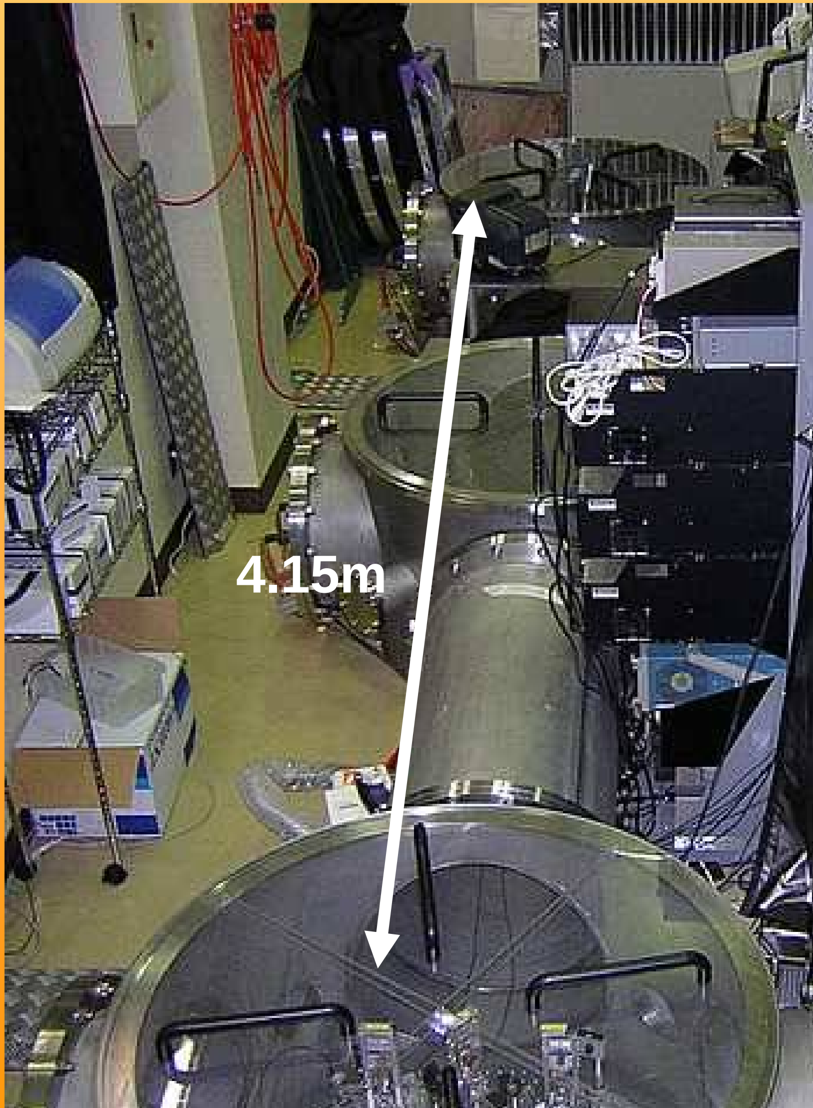
⬇

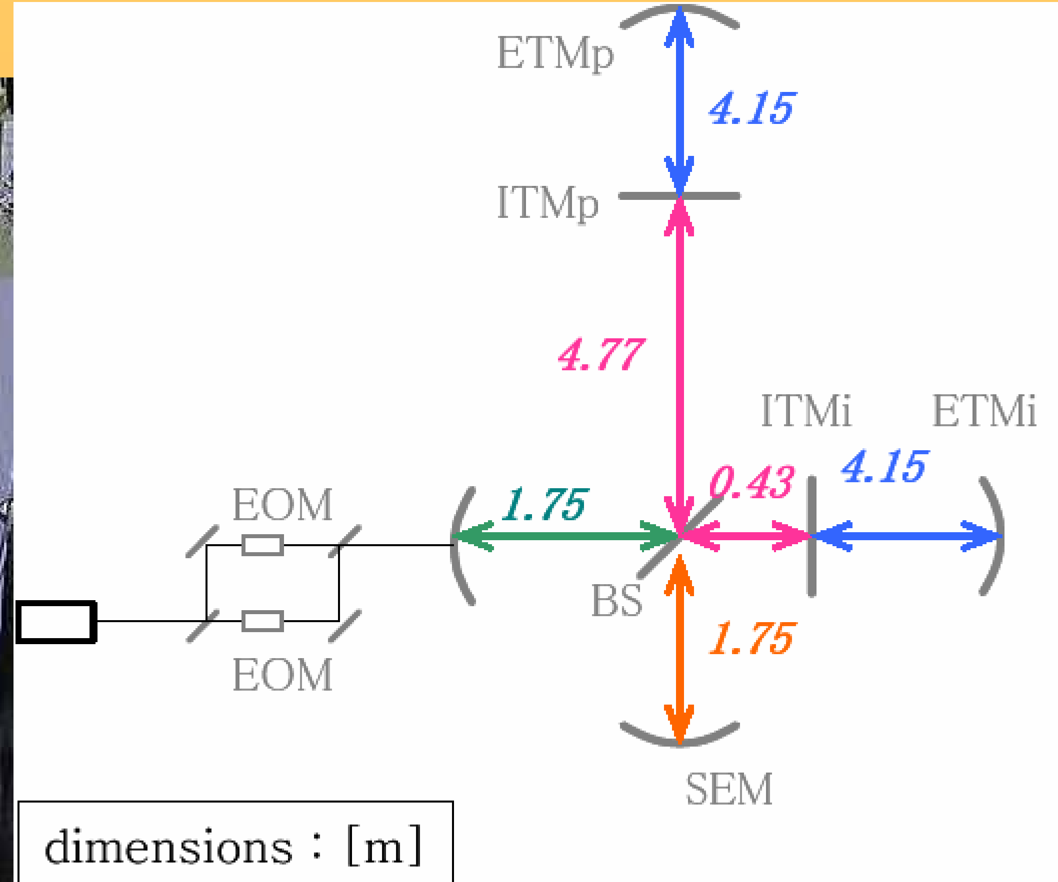
Diagonalizing the matrix at PO is possible

Diagonalized signal matrix

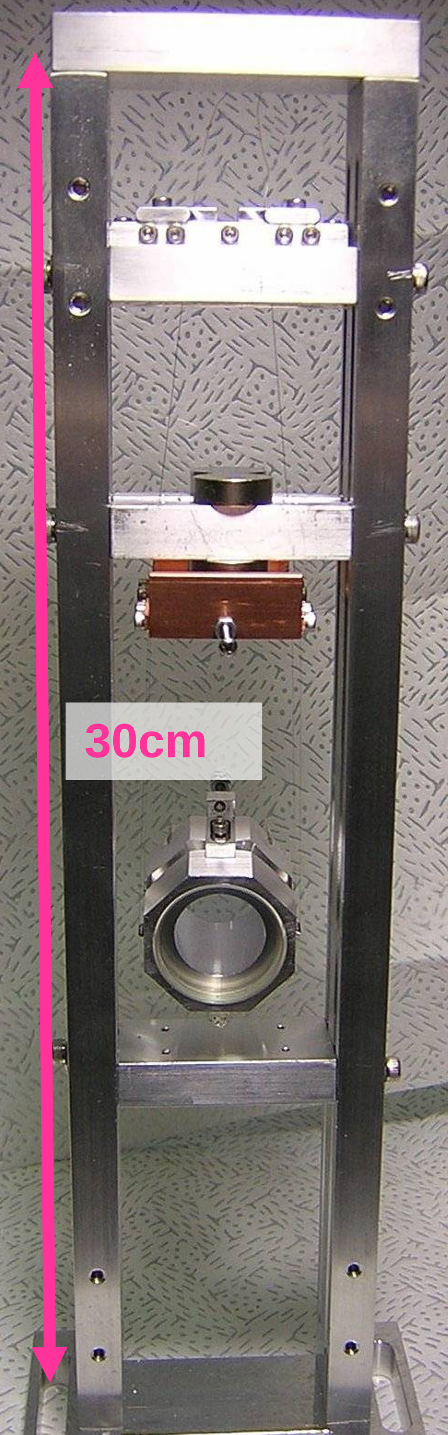
	I+	I-	Is
PO	1	-4.3 e-3	-7.7 e-8
DP	2.2 e-3	1	-1.9 e-6
PO	-5.7 e-6	4.9 e-7	1

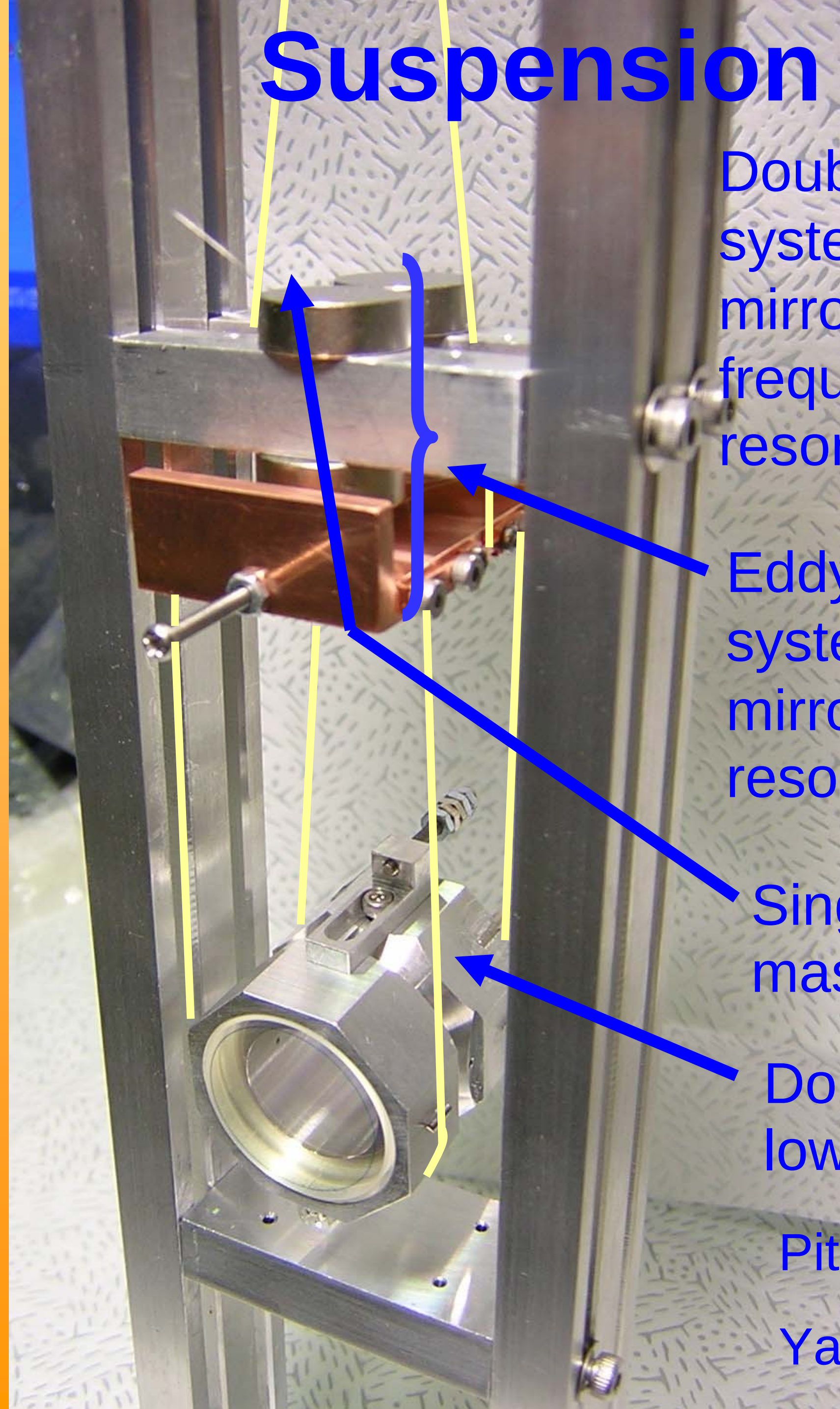
Optical Layout





Suspension System





Double suspension system to suppress the mirror motion at frequencies above the resonant frequency.

Eddy current damping system to damp the mirror motion around its resonant frequency.

Single loop for the upper mass.

Double loop for the lower mass.

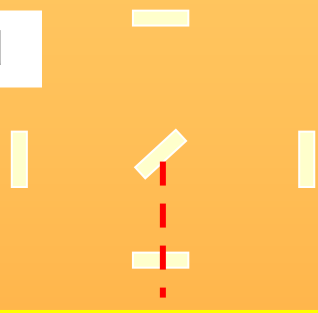
Pitch Q: 8

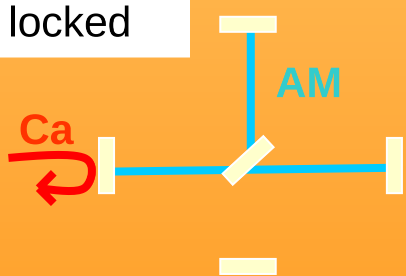
Yaw Q: 4

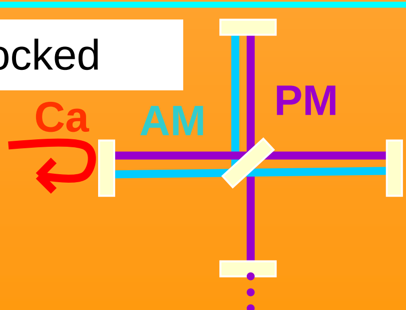
Central Part Lock

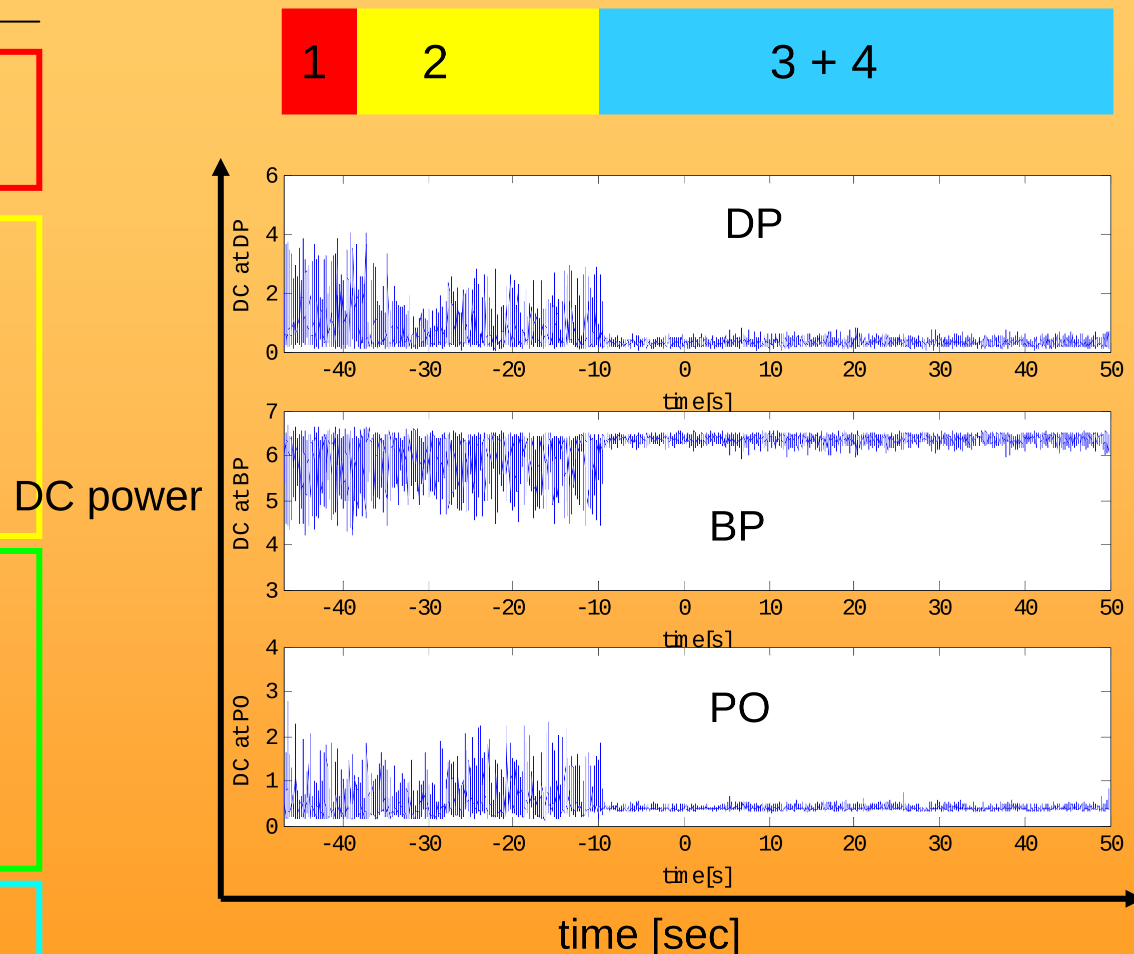
(Delocation technique not being used at present)

State	Light inside
1	Nothing is resonant
2	MICH locked
3	PR MICH locked
4	All three locked









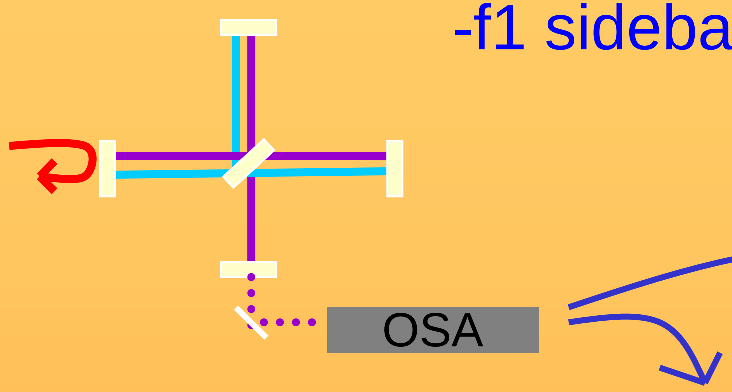
Simulation results say it works but

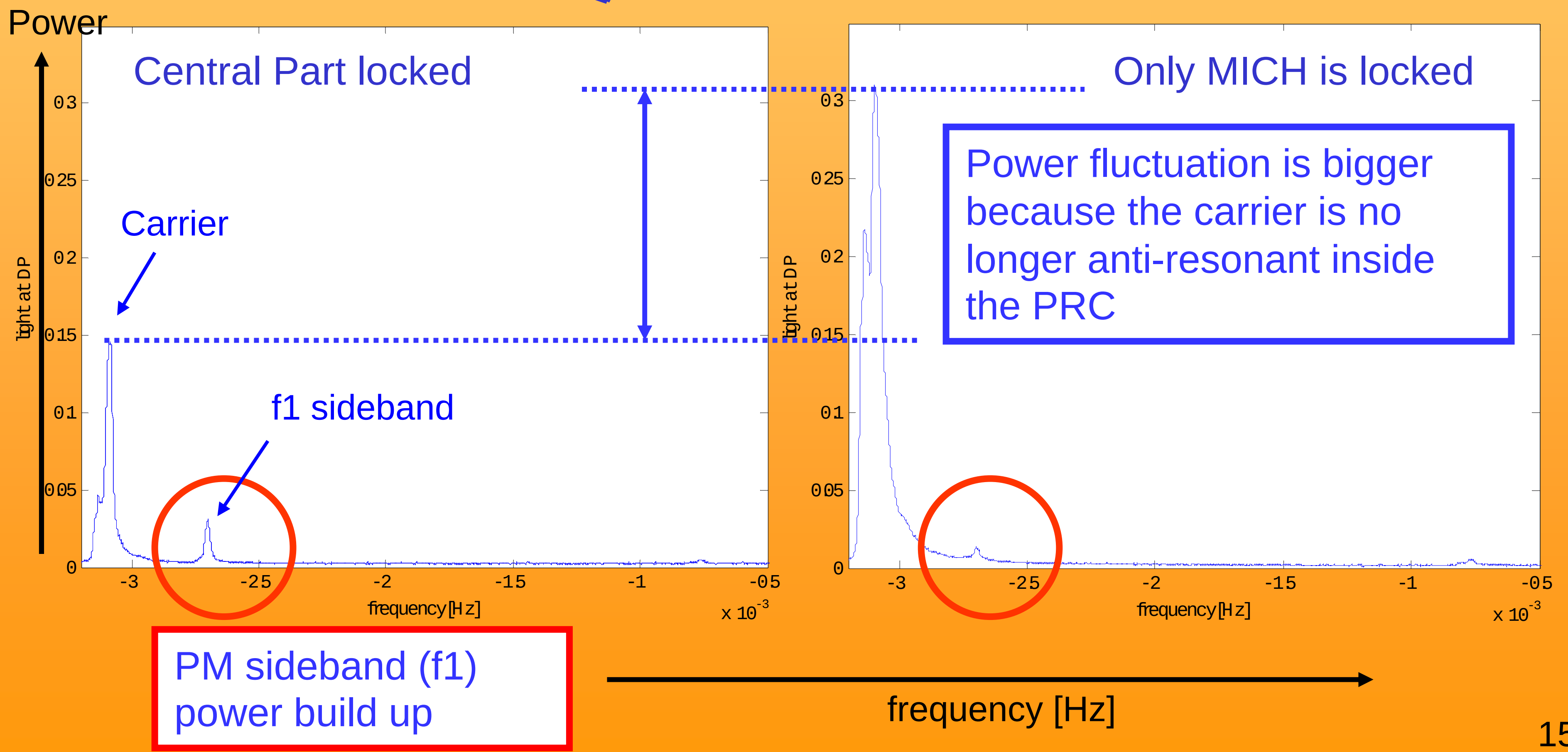
At present, state 3 is realized only when state 4 is realized

*Carrier should become resonant inside the PRC when arms are present

Confirmation of Central Part Lock

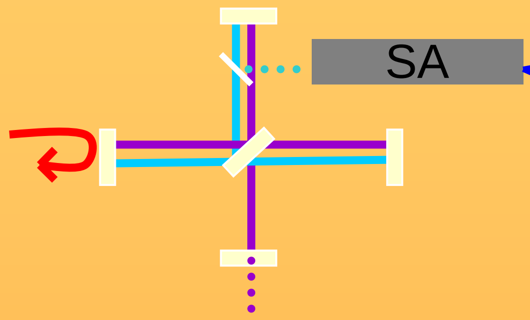
-f1 sidebands power build up

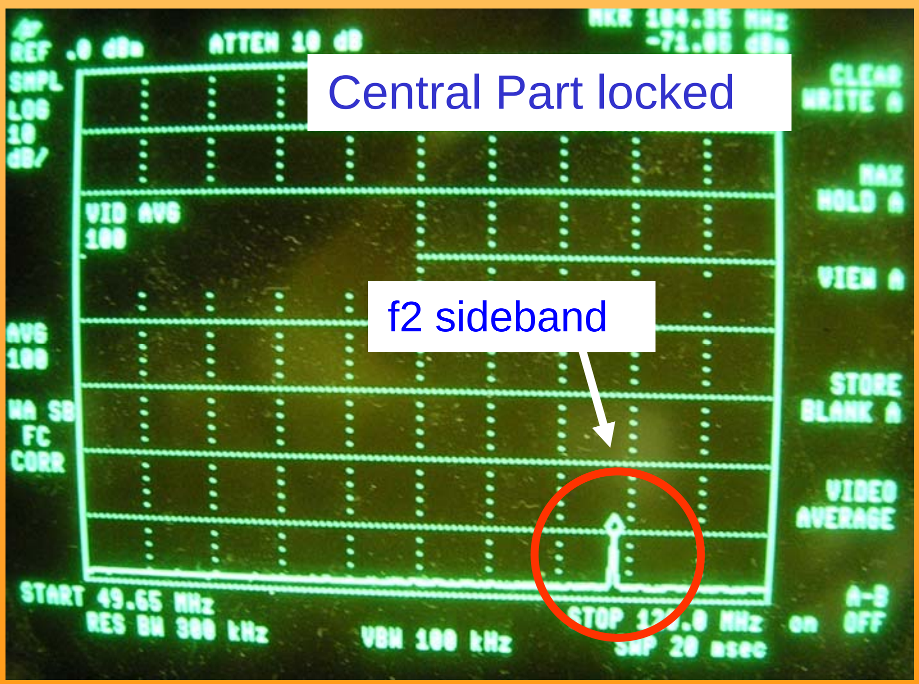


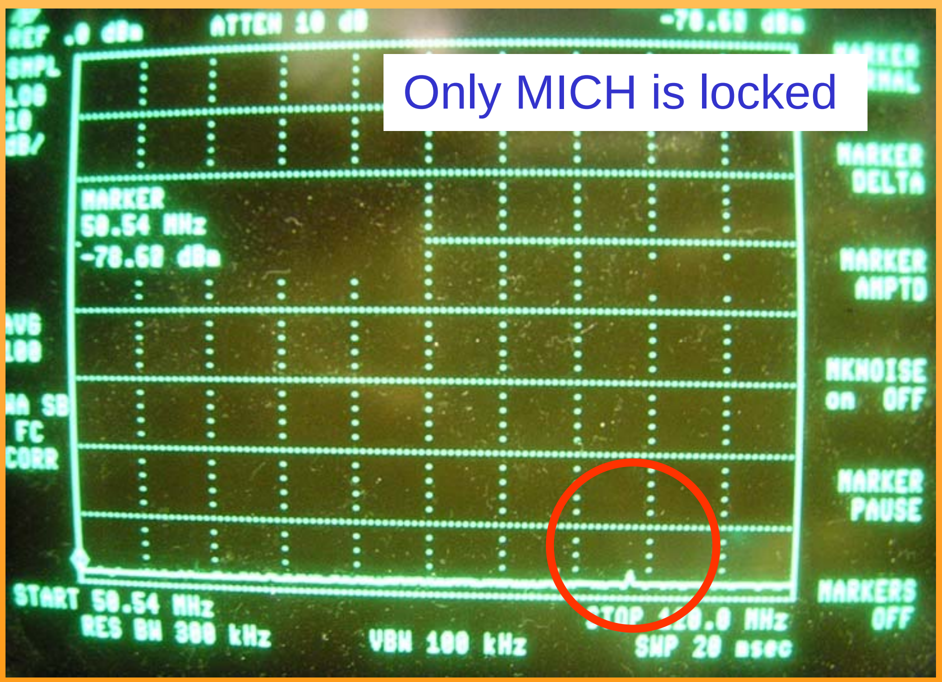


Confirmation of Central Part Lock

-f2 sidebands power build up







AM sideband (f2)
power build up

Summary

- A control scheme for a tuned RSE interferometer was developed and has been tested with a prototype interferometer.
- The control of the central part of the RSE interferometer has been demonstrated with the control scheme.

Future work

- Improve the lock of the central part.
    - Better alignment
    - More sideband power?
- Add Fabry-Perot arms.
- Lock the full RSE interferometer.
- Diagonalise the signal matrix for the central part.

The end