Current Status of the 40m Detuned RSE Prototype

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Gravitational Wave Advanced Detector Workshops

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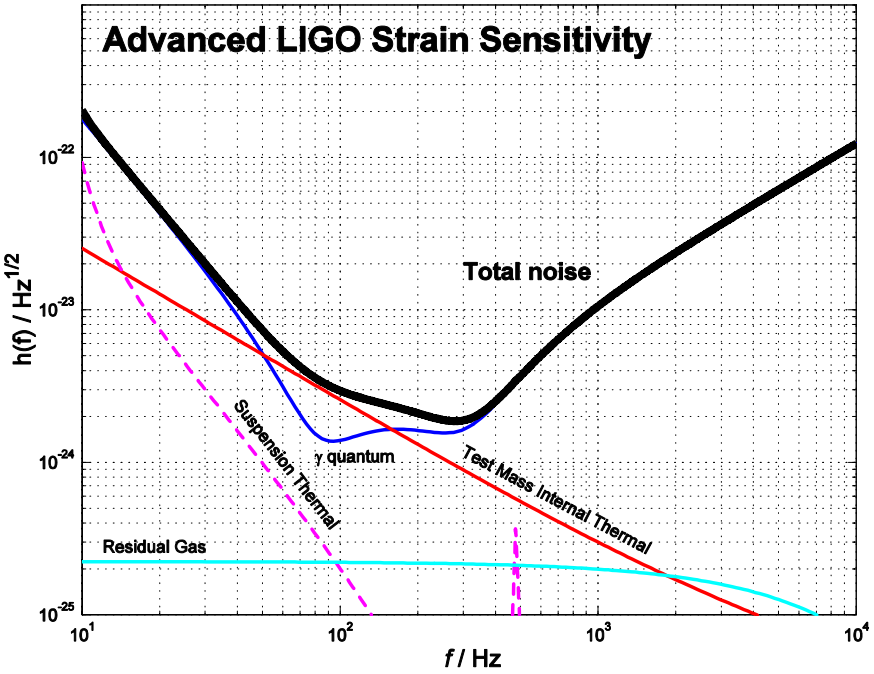
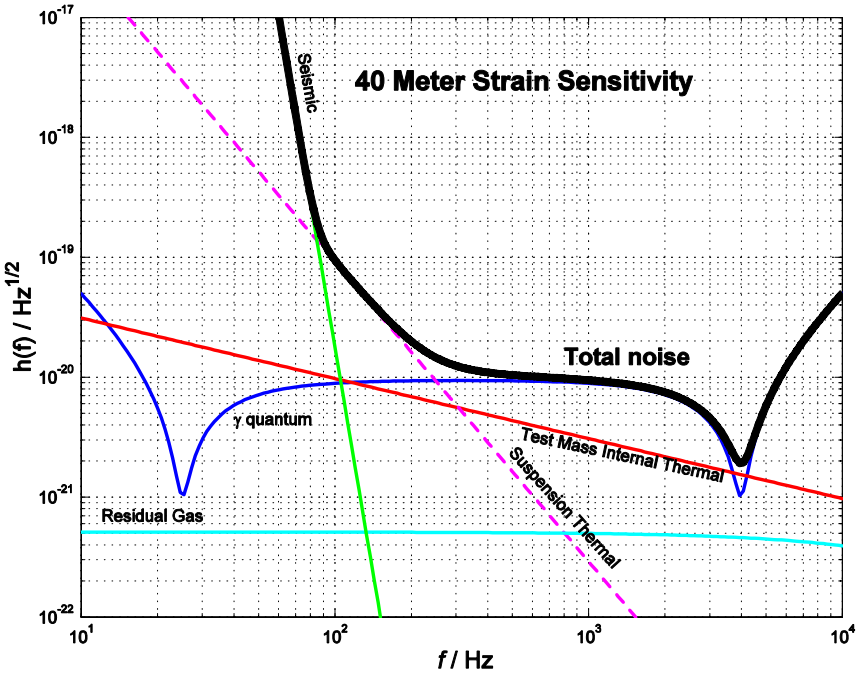
Objectives

- Develop **lock acquisition procedure** of detuned Resonant Sideband Extraction (RSE),
- Characterize noise mechanism,
- Verify optical spring effect,
- Develop DC readout scheme,
- etc.

for Advanced LIGO, LCGT,
and other future GW detectors

Target Sensitivity of Advanced LIGO and 40m

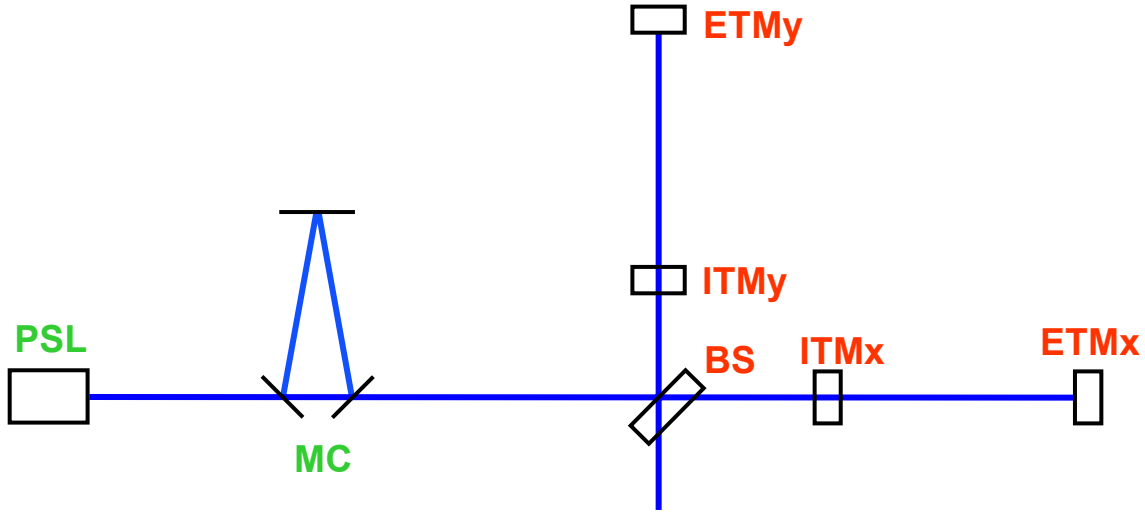




Important Achievement (1)
Installation of FP Michelson

September, 2003

- Four TMs and BS: installed



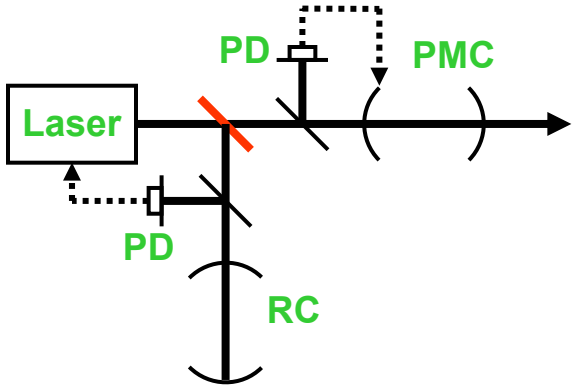
Important Achievement (2) Modification of PSL

October 2003

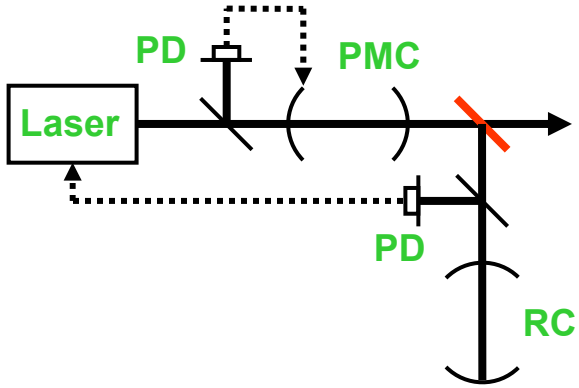
- Stabilize frequency of light with Reference Cavity (RF) after Pre-Mode Cleaner (PMC) instead of before PMC
- Noise sources associated with PMC and steering optics after PMC should be suppressed!

[S.Kawamura, "Configuration Study of Pre-Mode Cleaner and Reference Cavity in the 40m PSL System, LIGO-T030149-00-R (2003)]

[C. Mow-Lowry, R. Abbott, and B. Abbott, "Frequency Stability Servo Modifications Made at the 40 meter Laboratory", LIGO-T030205-00D (2003)]



Previous Configuration



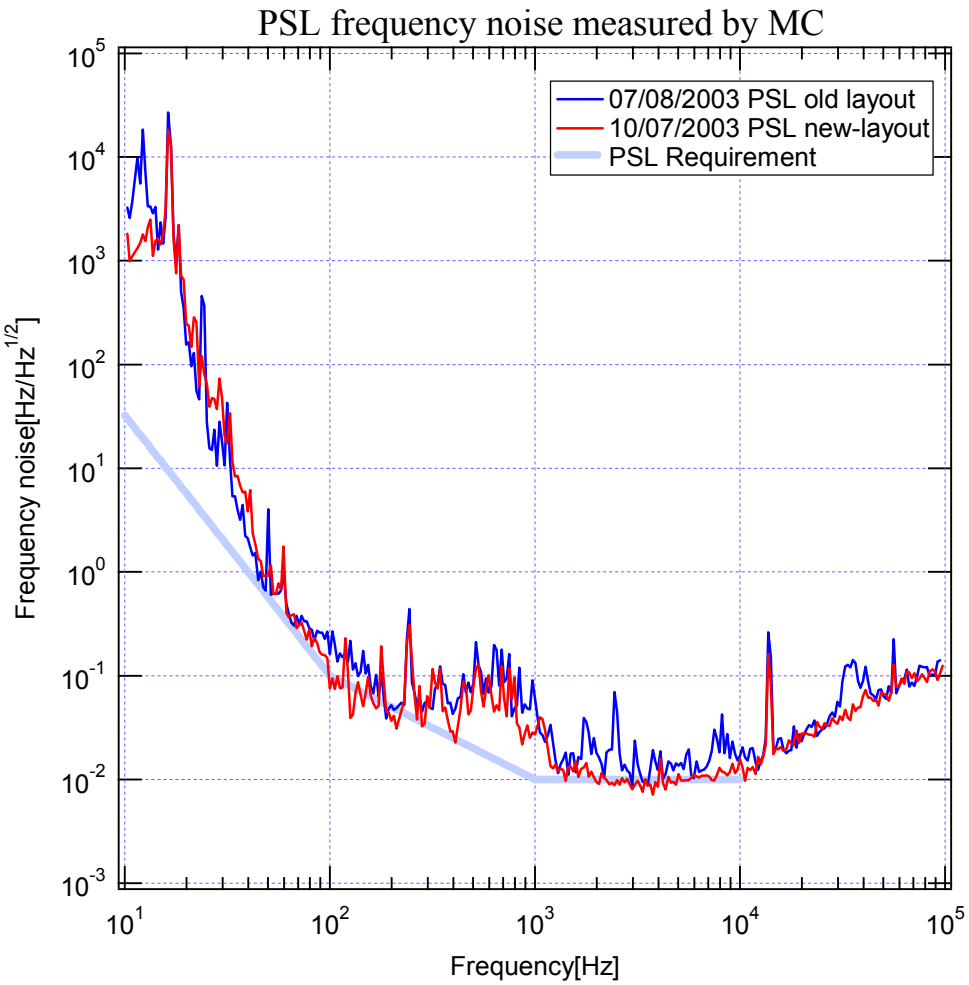
New Configuration

Important Achievement (3) Improvement of PSL Noise

October 2003

- PSL noise improved above 1 kHz
- New Calibration Method (AOM as a reference) used

[S.Kawamura and O. Miyakawa, "Convenient and Reliable Method for Measuring Frequency Noise of the Pre-Stabilized Laser", LIGO-T030239-00-R (2003)]

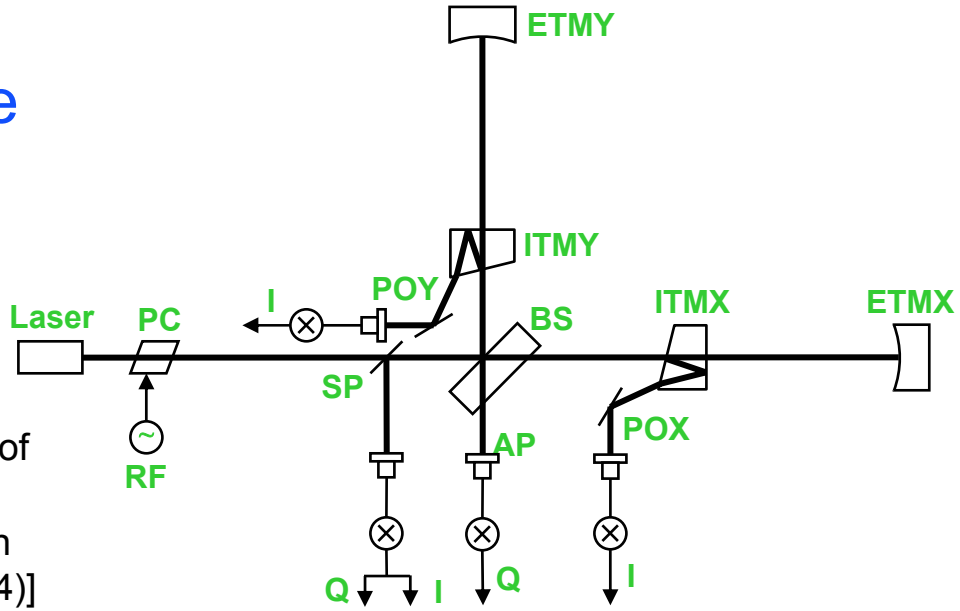


Important Achievement (4)
Lock Acquisition of FP Michelson

November 2003

- FP Michelson locked
- Method similar to the one used for TAMA
- Interesting phenomena observed

[S. Kawamura and O. Miyakawa, "Polarity of Michelson Length Signal Obtained at the Symmetric Port In a Fabry-Perot Michelson Interferometer", LIGO-T030295-00-R (2004)]

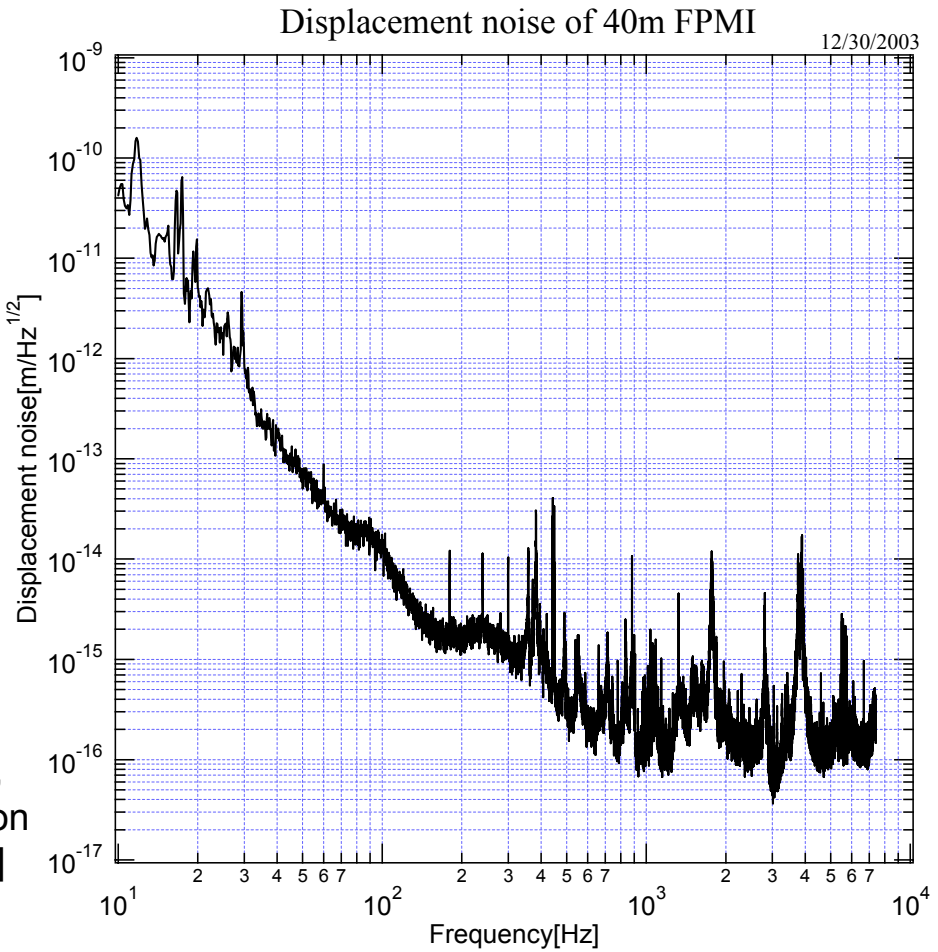


Important Achievement (5) Spectrum of FP Michelson

December 2003

- Displacement spectrum obtained
- With all the whitening/de-whitening filters ON
- Convenient calibration method (Michelson mid-fringe locking) used

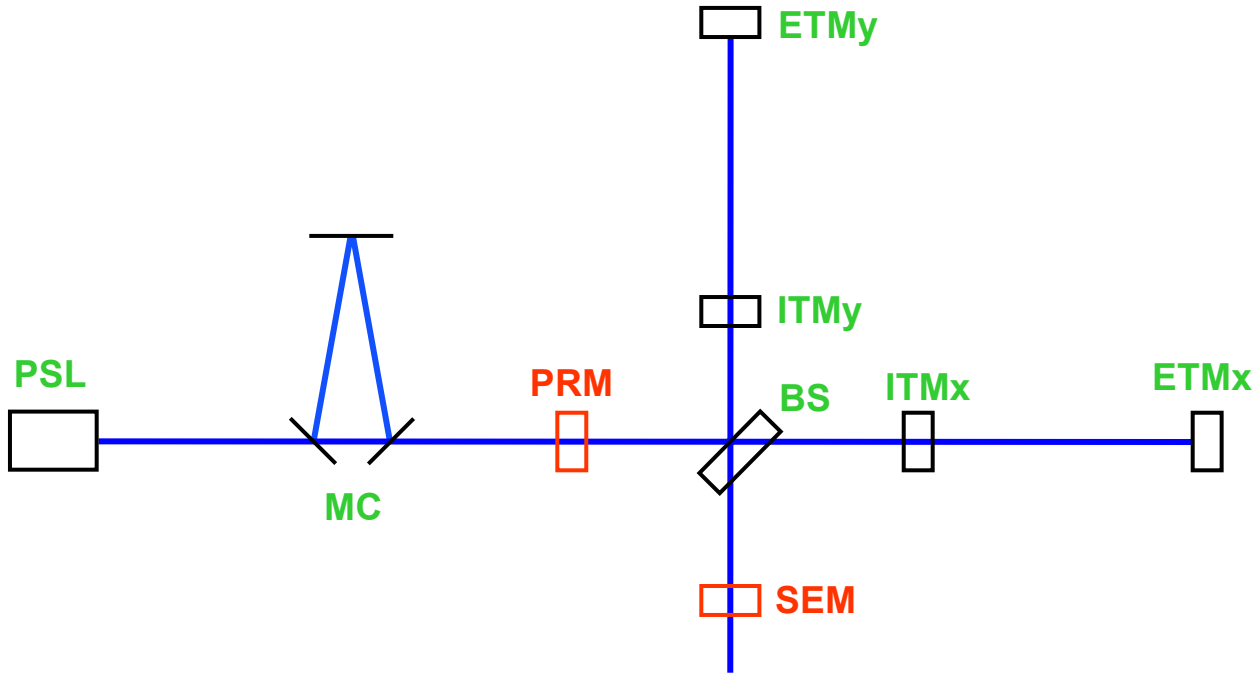
[S. Kawamura, O. Miyakawa, and S. Sakata, "Calibration of the 40m Fabry-Perot Michelson Interferometer", LIGO-T030287-00-R (2003)]



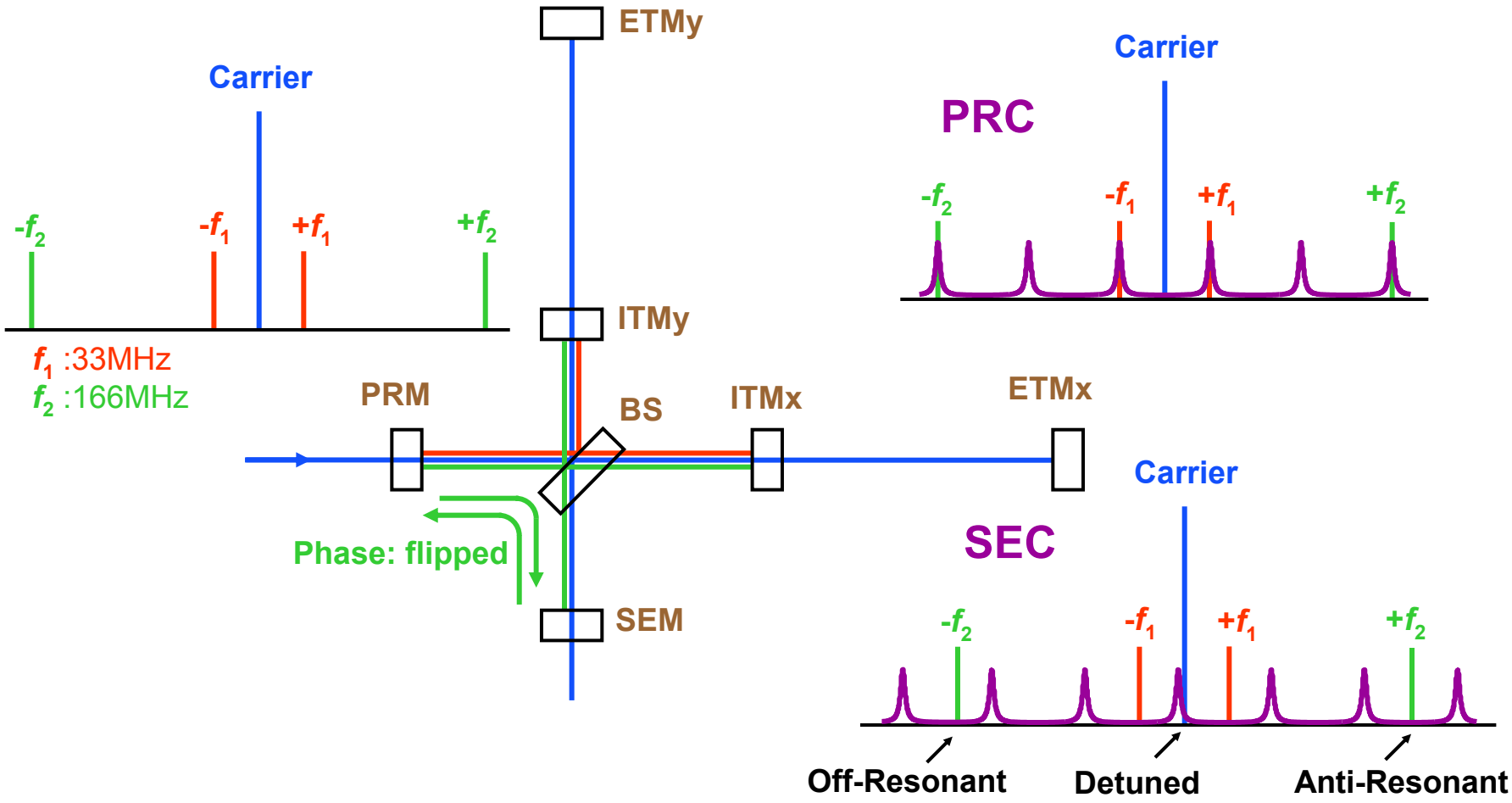
Important Achievement (6)
Installation of PRM and SEM

February 2004

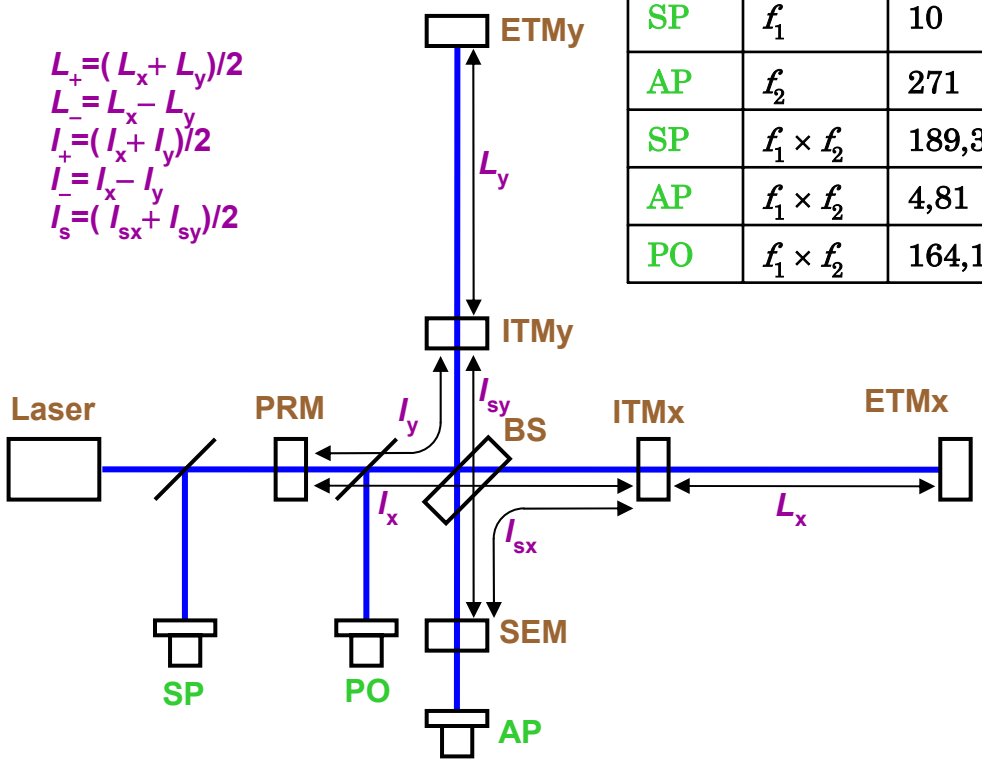
- Power Recycling Mirror (PRM) and Signal Extraction Mirror (SEM) installed



Signal Extraction Method



Signal Extraction Matrix



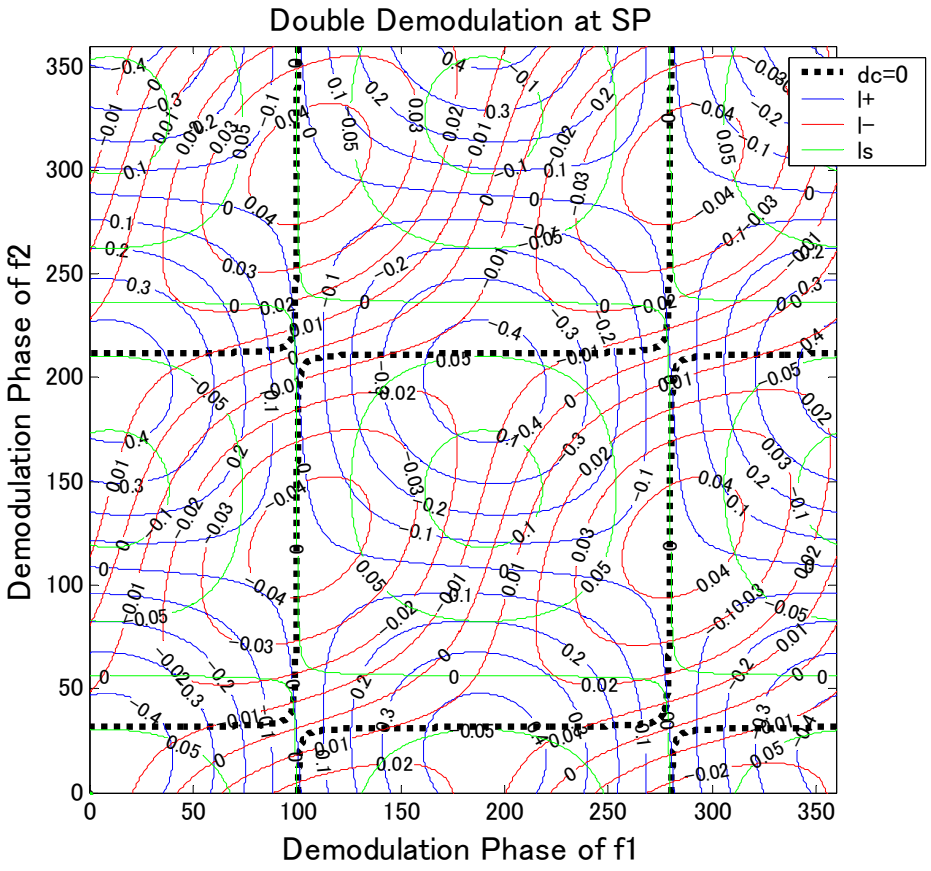
Port	Dem. Freq.	Dem. Phase	L_+	L_-	l_+	l_-	l_s
SP	f_1	10	1	-3.8E-9	-1.2E-3	-1.3E-6	-2.3E-6
AP	f_2	271	-4.8E-9	1	1.2E-8	1.3E-3	-1.7E-8
SP	$f_1 \times f_2$	189,32	-1.7E-3	-3.0E-4	1	-3.2E-2	-1.0E-1
AP	$f_1 \times f_2$	4,81	-6.2E-4	1.5E-3	7.5E-1	1	7.1E-2
PO	$f_1 \times f_2$	164,12	3.6E-3	2.7E-3	4.6E-1	-2.3E-2	1

- Calculated by FINESSE
  (A. Freise: http://www.rzg.mpg.de/~adf/)
- PO: light from BS to ITMy

Double Demodulation

- Double Demodulation used for I_+, I_-, and I_s
- Demodulation phases optimized to suppress DC and to maximize desired signal

[S.Kawamura, “Signal Extraction Matrix of the 40m Detuned RSE Prototype”, LIGO-T040010-00-R (2004)]



Length Tolerances

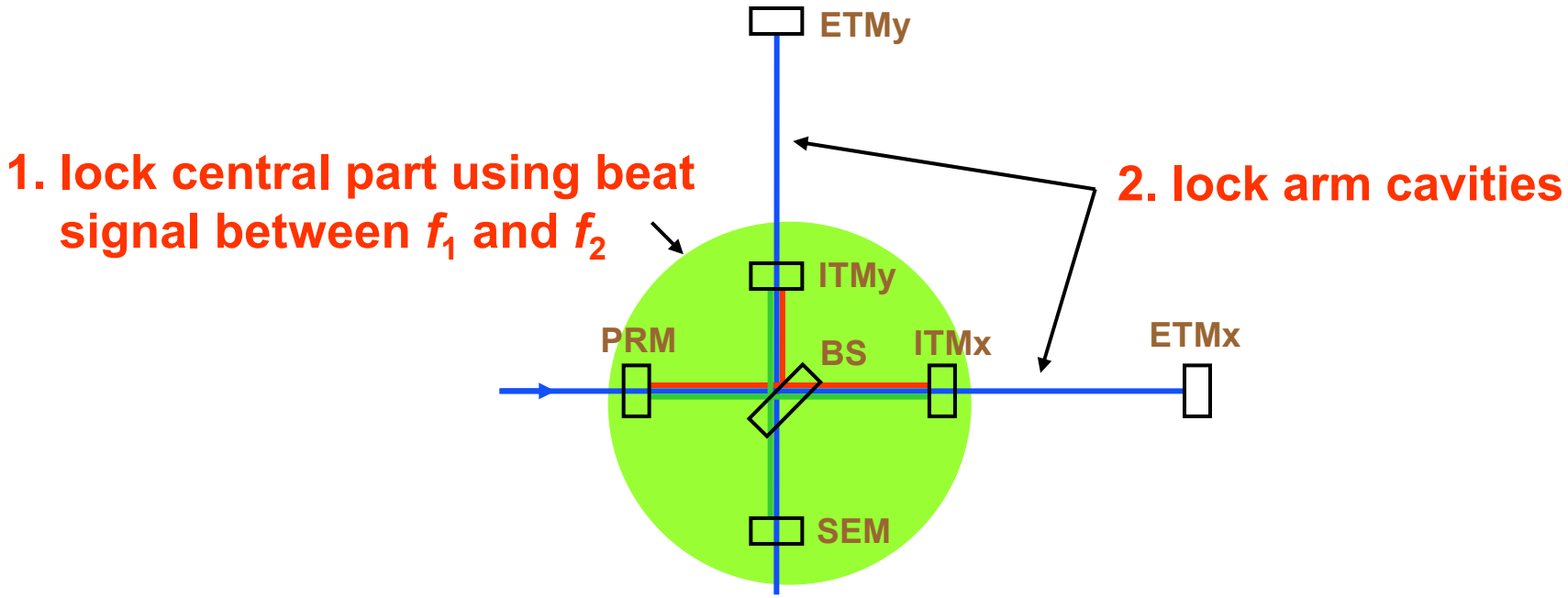
- Acceptable cavity length deviations from the ideal points:
  - 6 cm for l_-
  - 3 mm for l_+
  - 3 mm for l_s

Example: Signal matrix with l_+ deviation of 1 cm

Port	Dem. Freq.	Dem. Phase	L_+	L_-	l_+	l_-	l_s
SP	f_1	334	1	-7.6E-9	-1.2E-3	-4.1E-6	-2.3E-6
AP	f_2	230	-1.3E-9	1	3.0E-8	1.3E-3	-1.7E-8
SP	$f_1 \times f_2$	162,73	-6.5E-4	3.5E-4	1	-5.6E-2	1.3E-1
AP	$f_1 \times f_2$	173,218	1.5E-3	4.2E-4	-2.1	1	-2.4E-1
PO	$f_1 \times f_2$	329,153	1.1E-3	2.7E-3	2.6	-1.6E-1	1

S. Kawamura, “Signal Extraction Matrix of the 40m Detuned RSE Prototype”, LIGO-T040010-00-R (2004)

Lock Acquisition of Detuned RSE



- Central part: not disturbed by lock status change of arm cavity
- Question: Not disturbed by flash of SBs or SBs of SBs in arms?
- Promising: TAMA using 3rd harmonic demodulation in PRFPMI

Lock Acquisition of Central Part

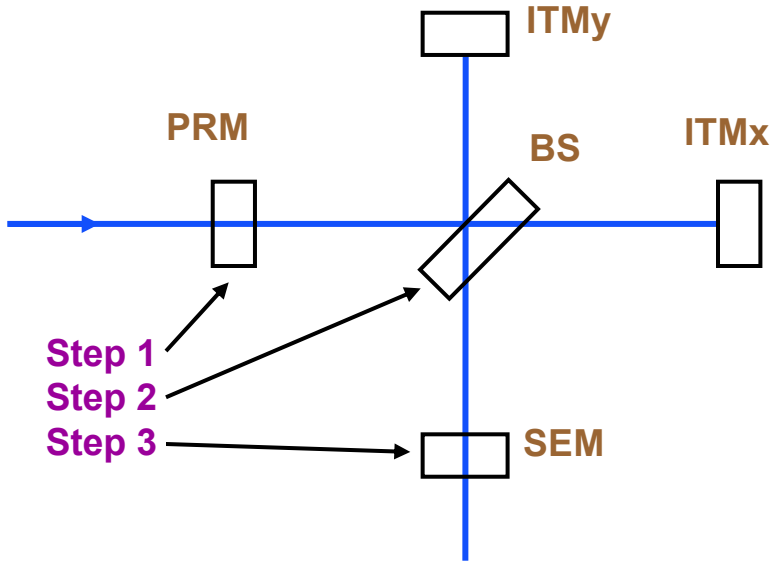
Ideal Procedure: Lock one by one

[for example]

Step 1: Lock l_+ robustly

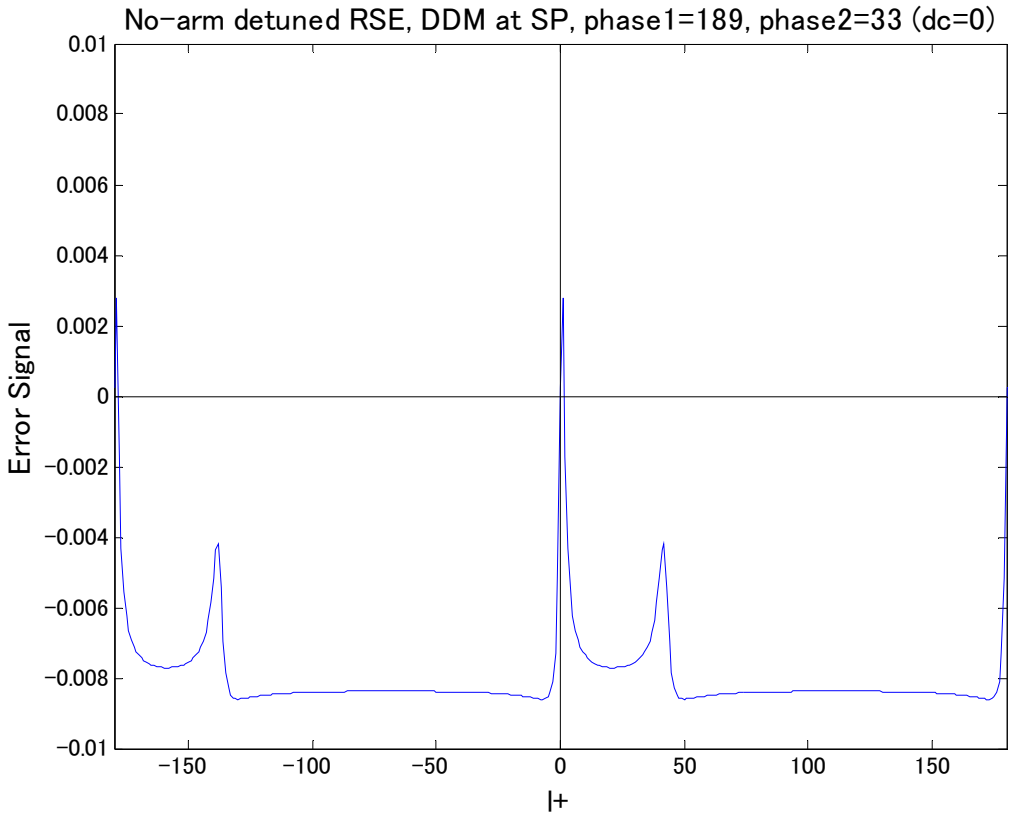
Step 2: Lock l_- robustly

Step 3: Lock l_s

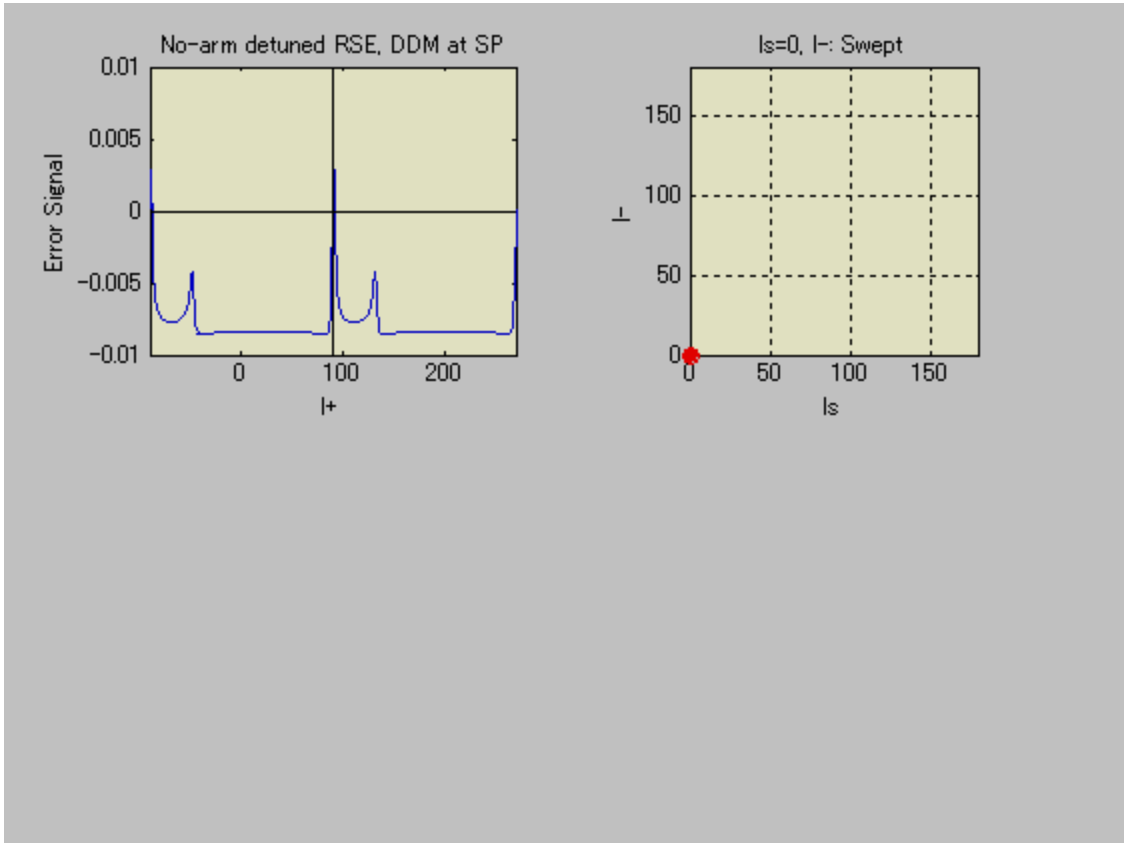


- Find primary signal not disturbed by the other two DOFs
- Find secondary signal not disturbed by the residual DOF

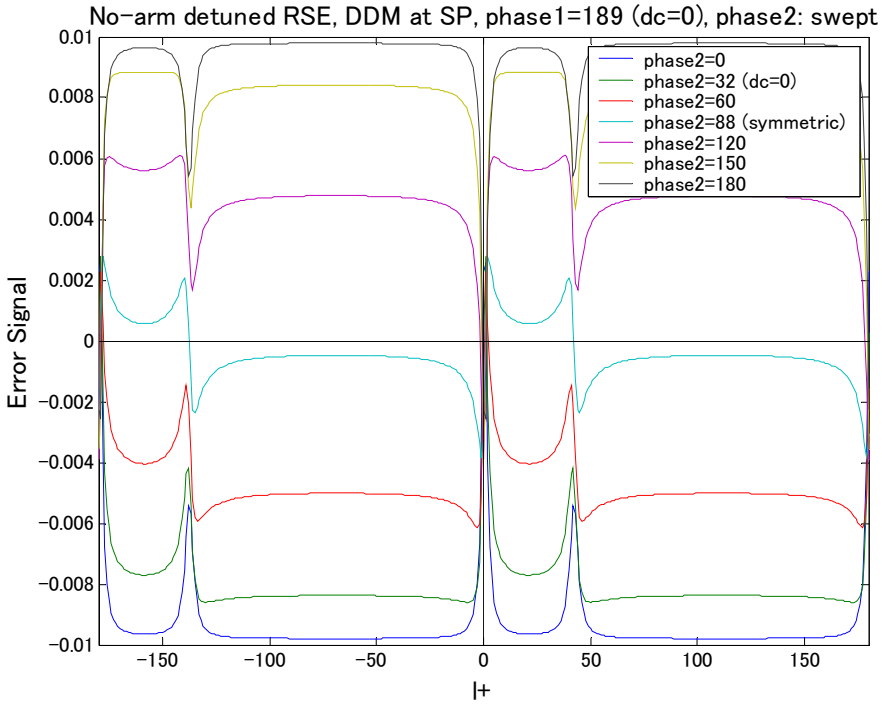
Quality of I+ Signal (dc=0, I+:Max)

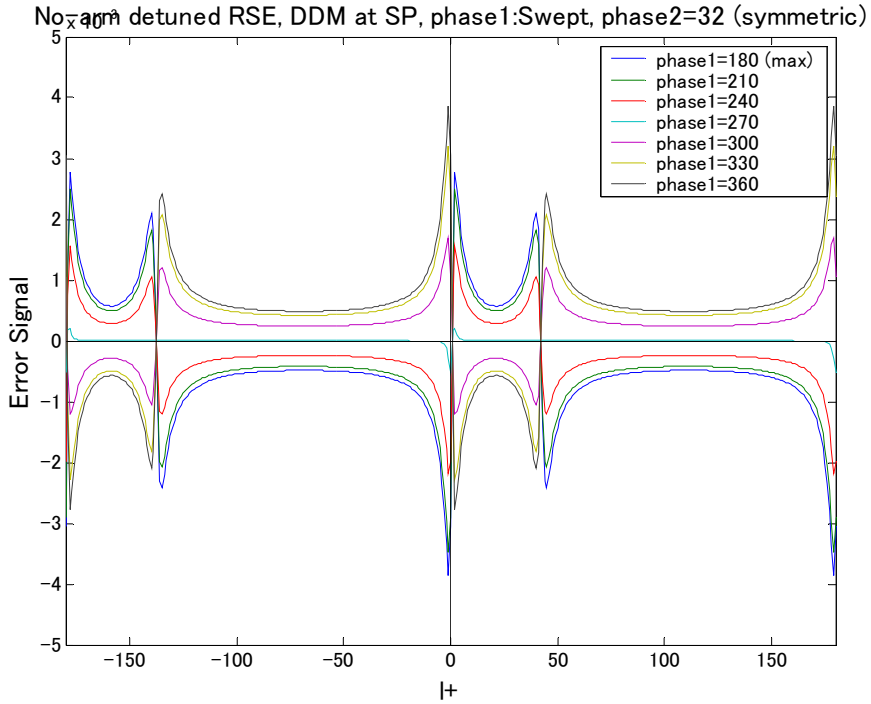


Dependence of I+ Signal (dc=0, I+:Max) on I-

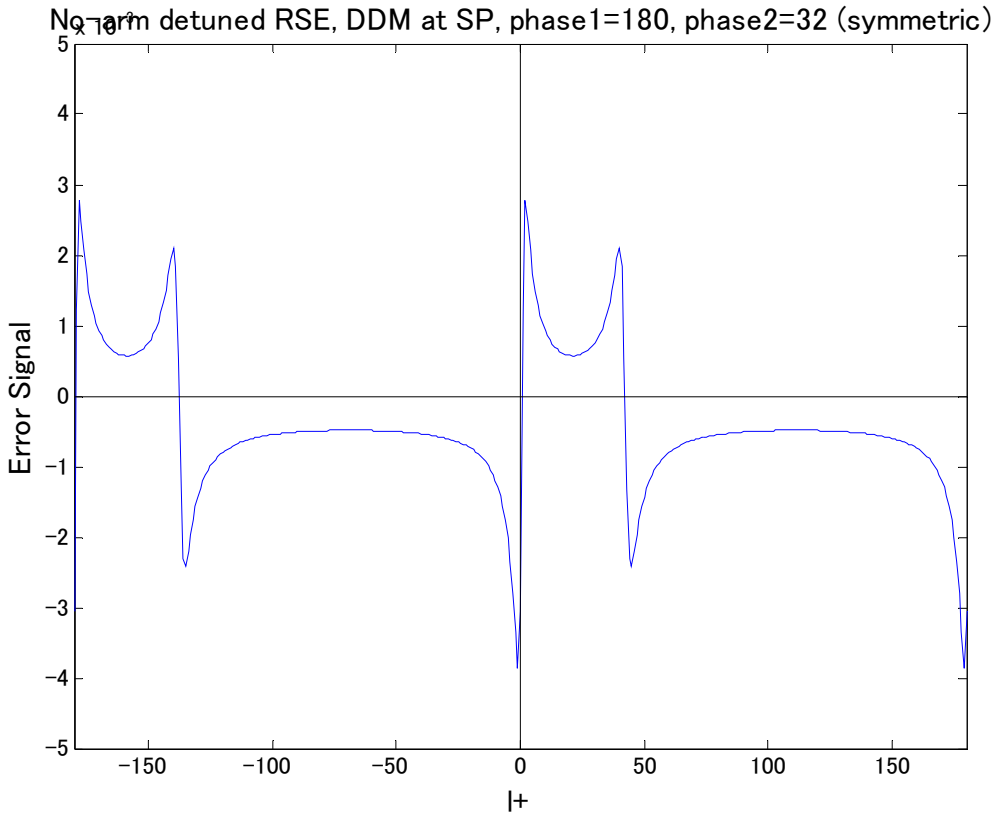


Dependence of I+ Signal on Demodulation Phases



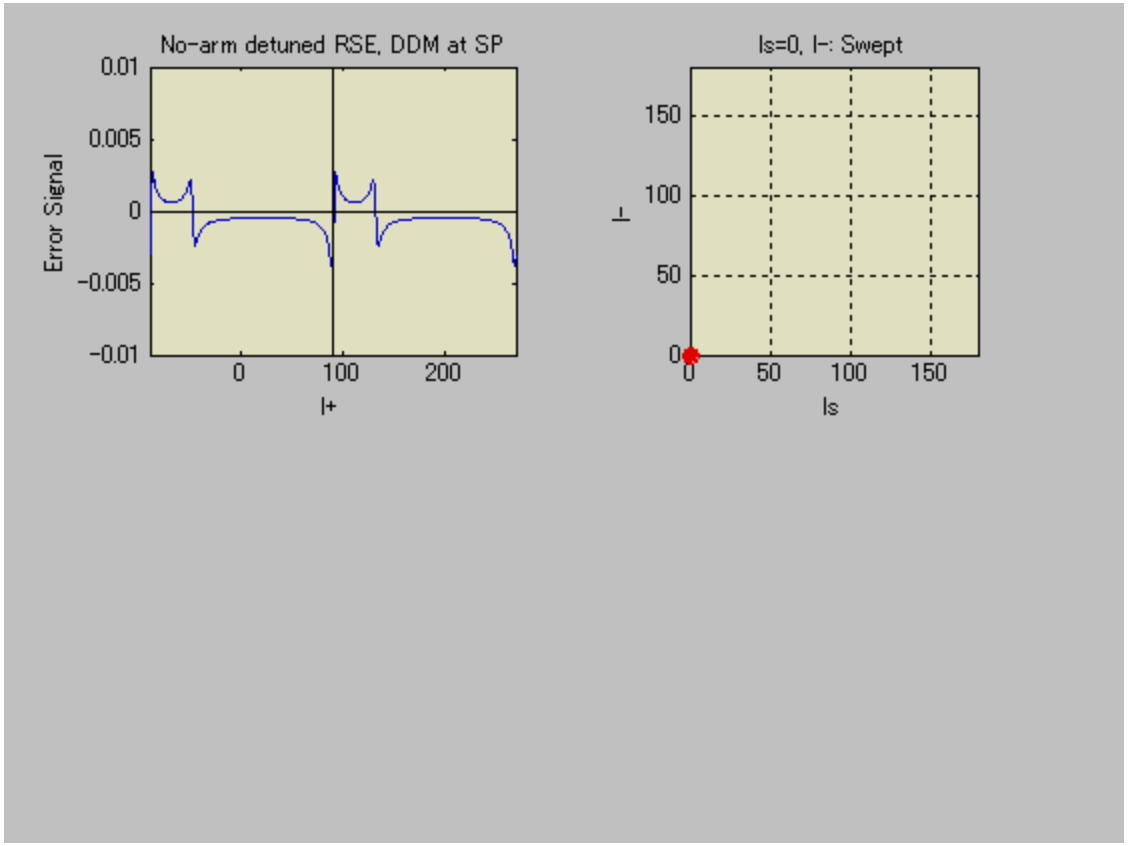


Quality of I+ Signal (Symmetric, dc≠0)

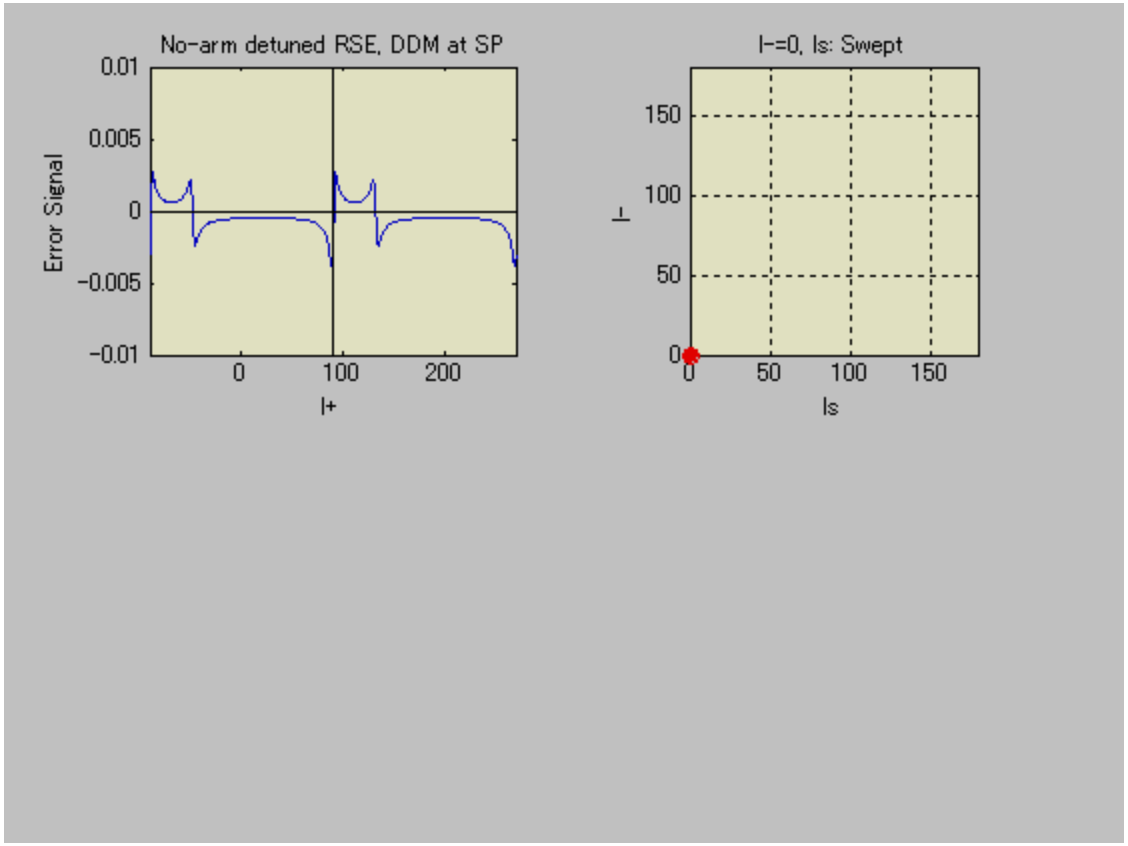


See Movie

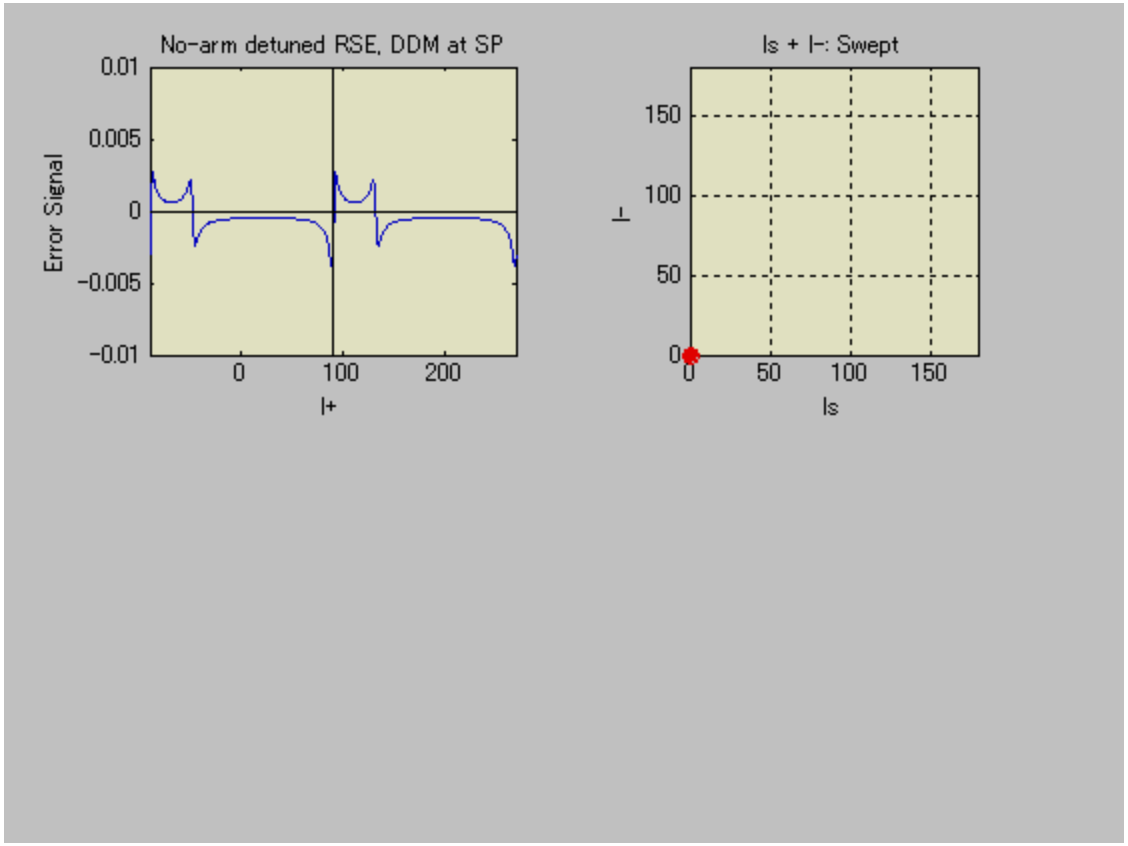
Dependence of I+ Signal (Symmetric, dc≠0) on I-



Dependence of I+ Signal (Symmetric, dc≠0) on Is

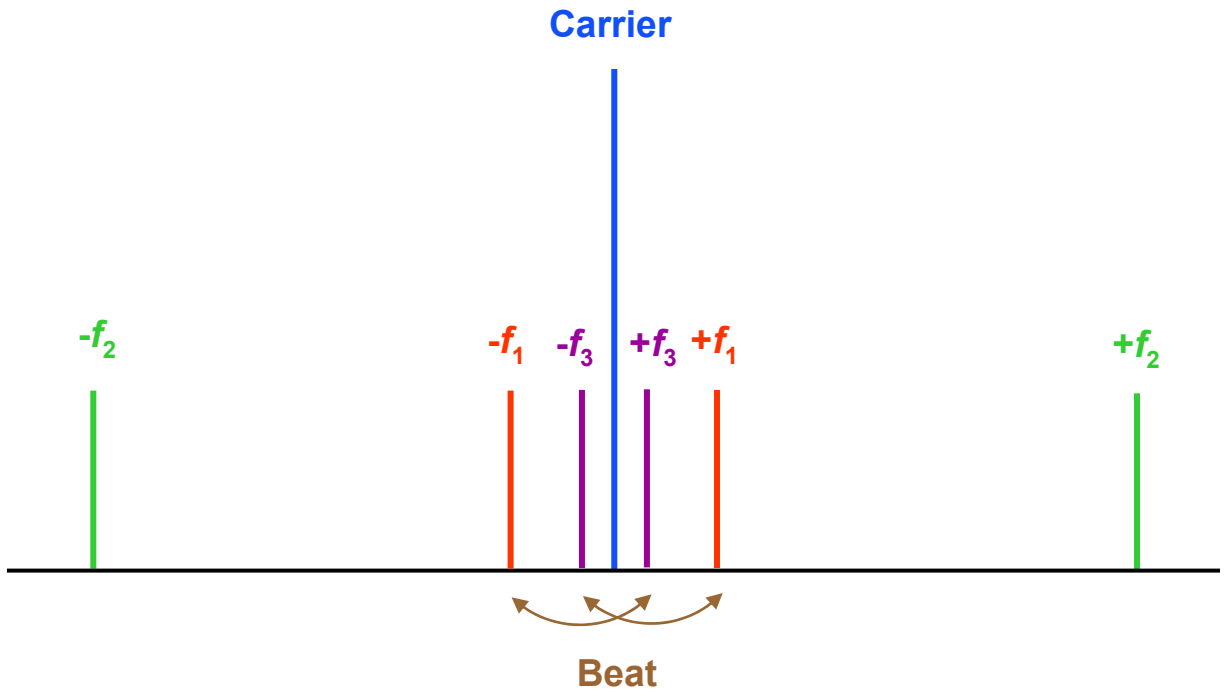


Dependence of I+ Signal (Symmetric, dc≠0) on I- and Is

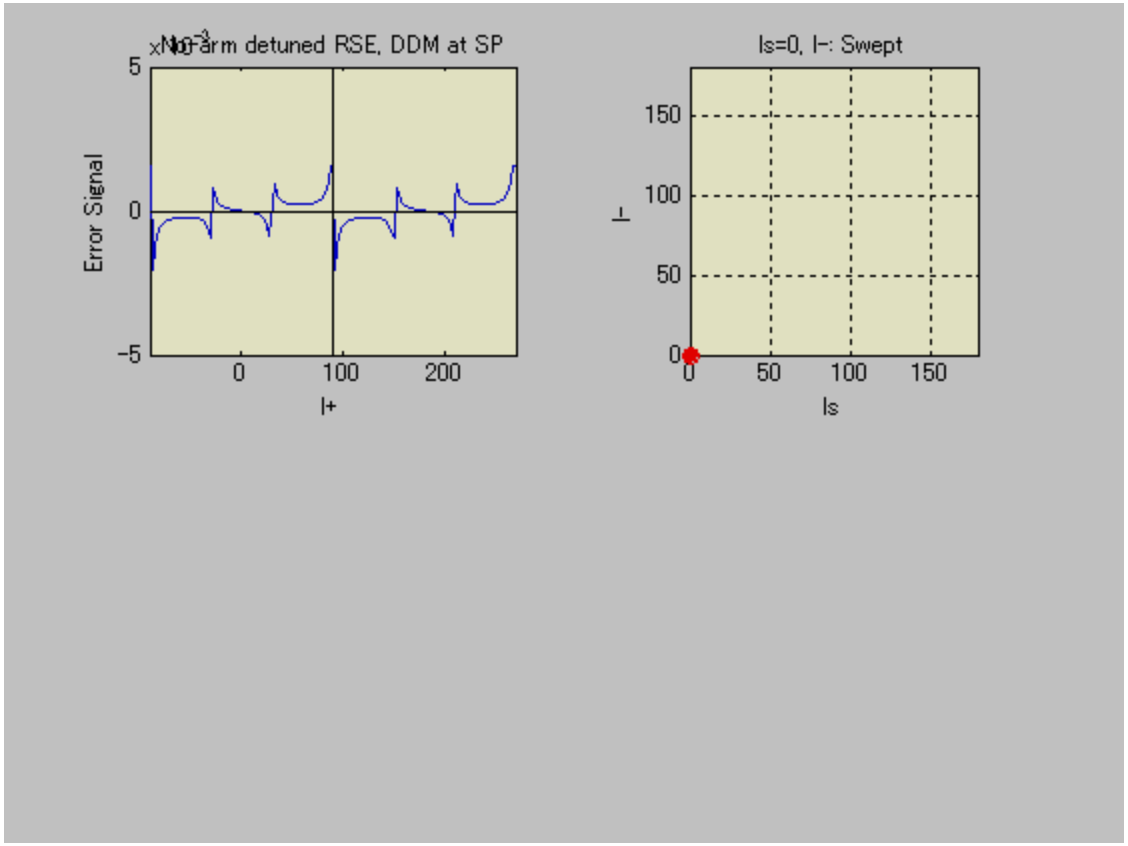


Beat between f1 and Non-Resonant SB f3 (AM)

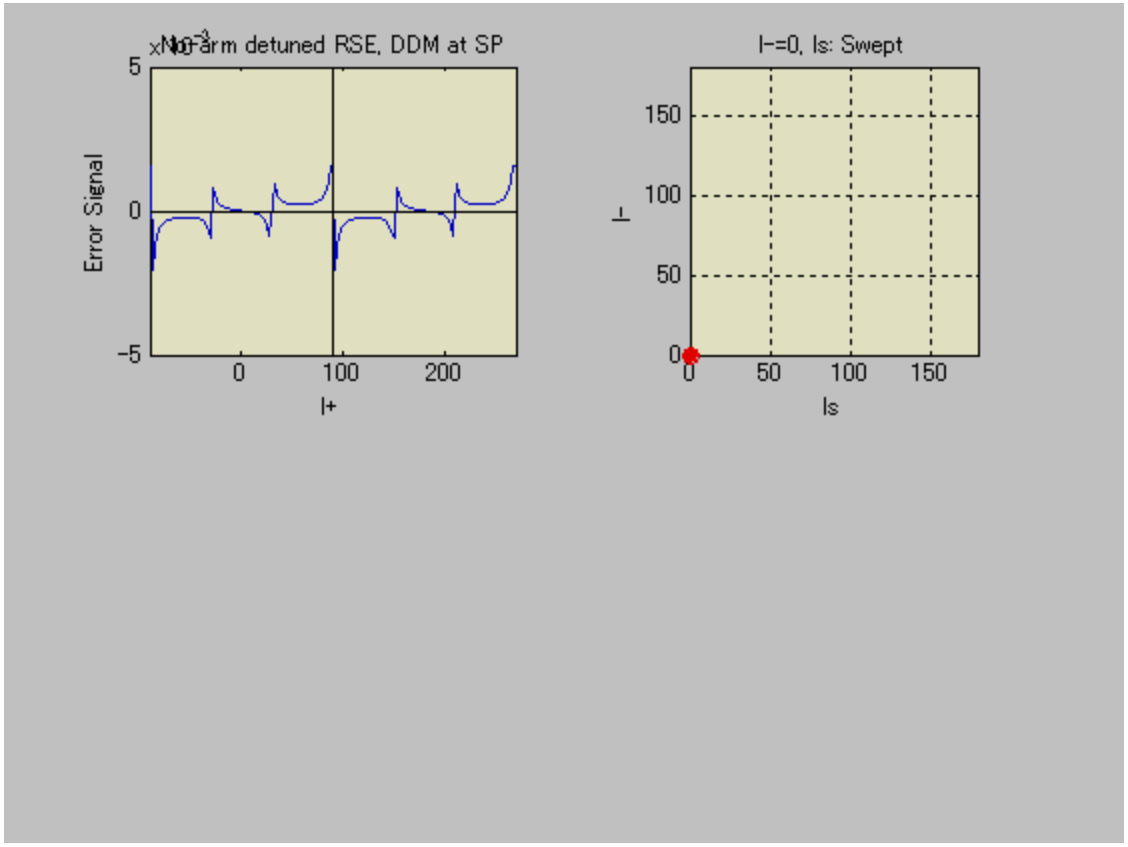
Hint: G. Heinzel at Garching 30m



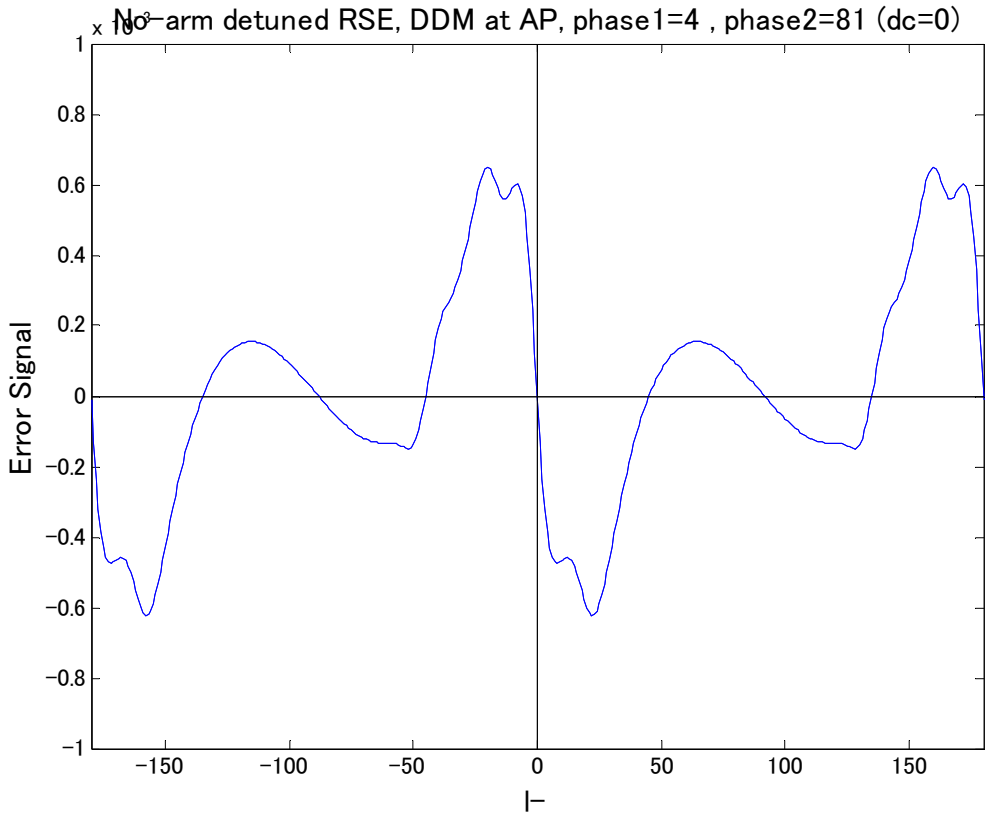
Dependence of Beat Signal between f1 and f3 on I-



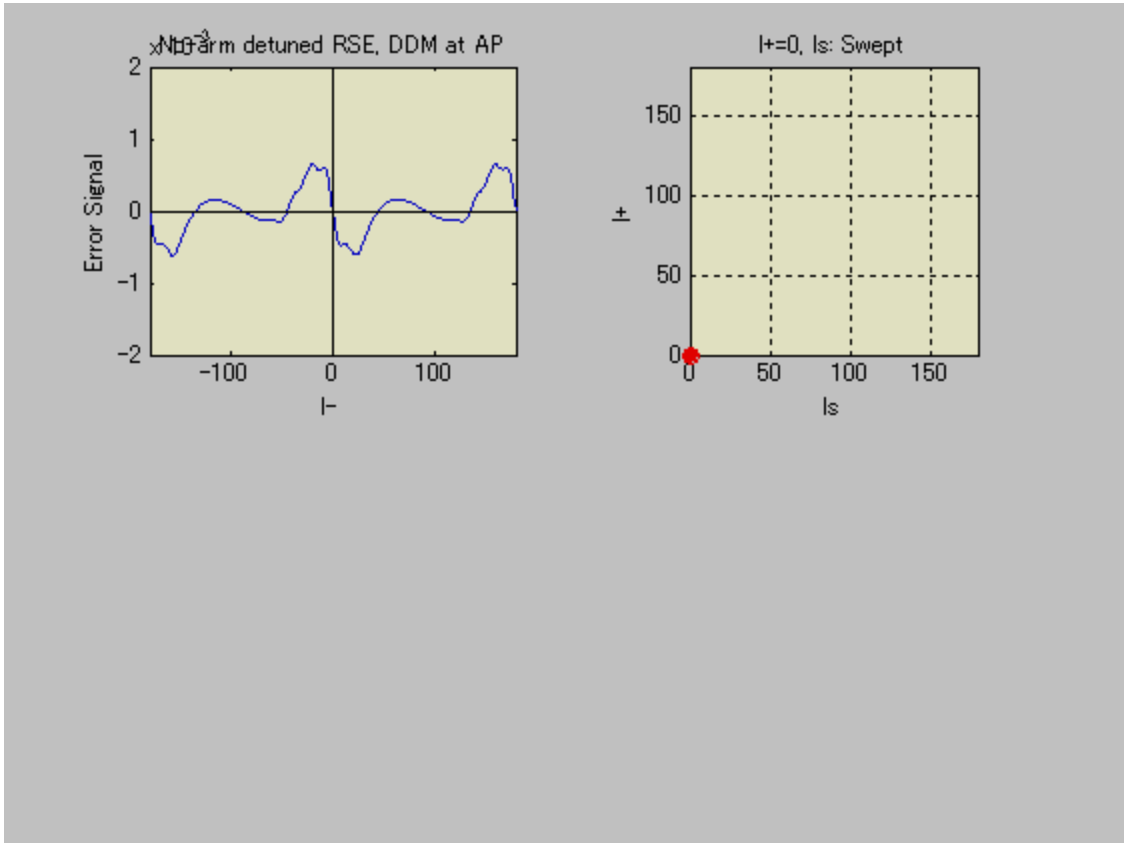
Dependence of Beat Signal between f1 and f3 on ls



Quality of I- Signal

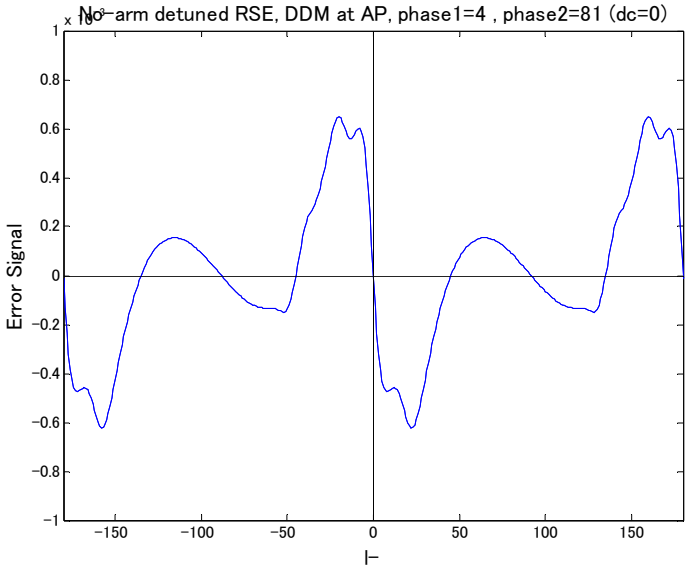


Dependence of I- Signal on Is

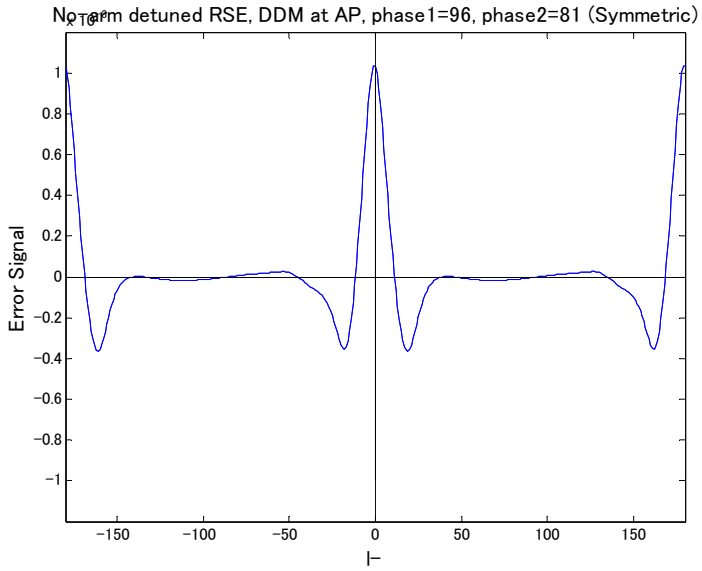


I- Signal Divided by AP signal with different Dem. Phase

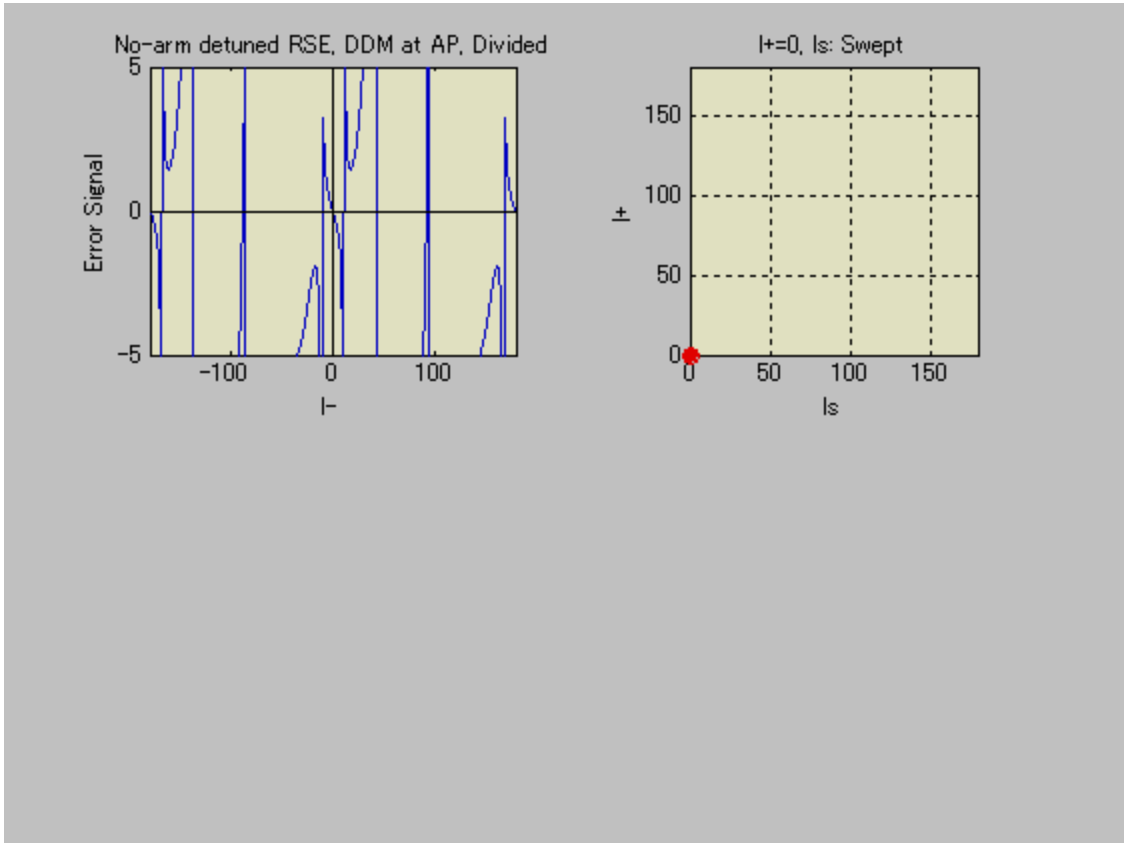
Hint: H. Grote at GEO



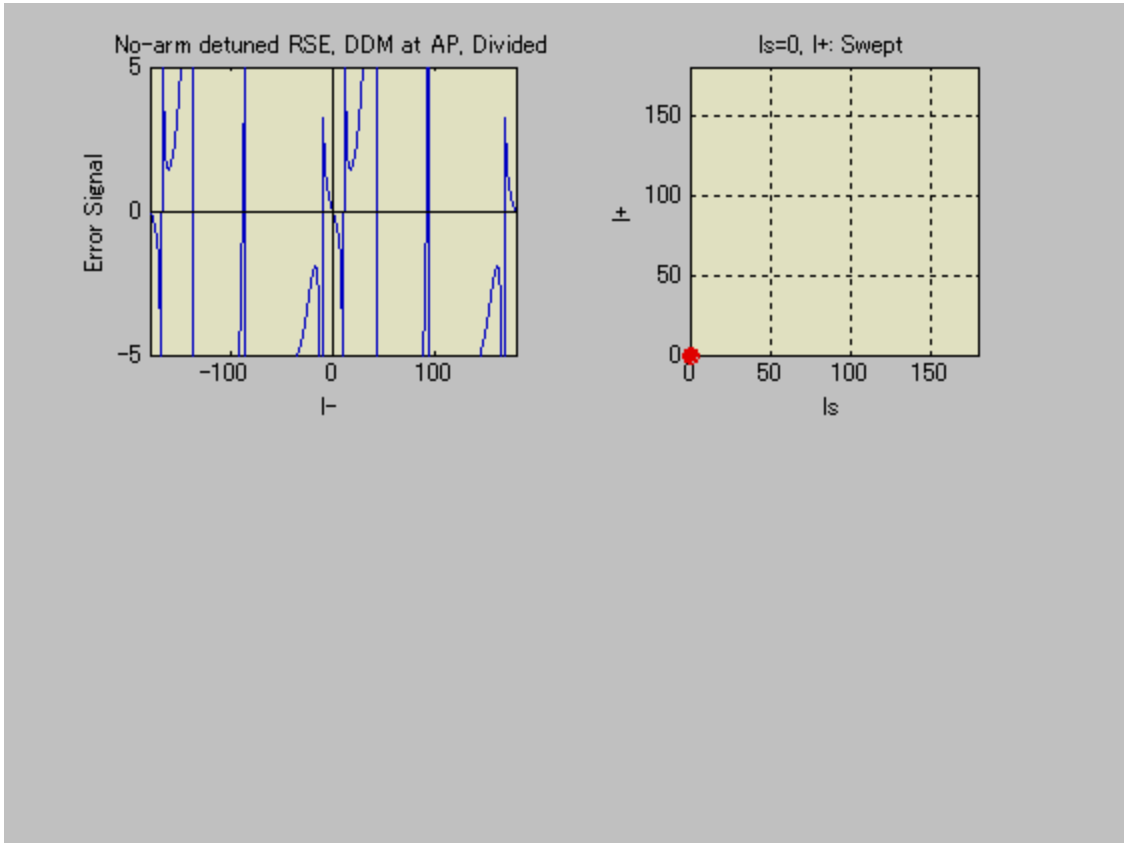
Divided by



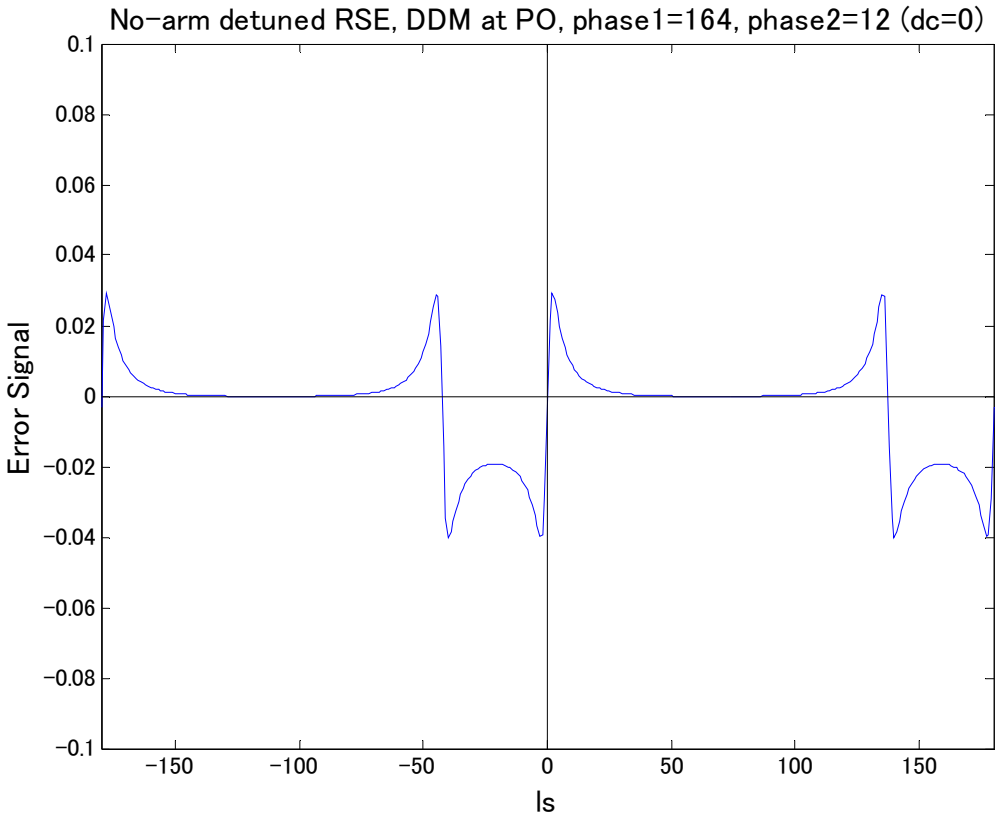
Dependence of Divided I- Signal on Is



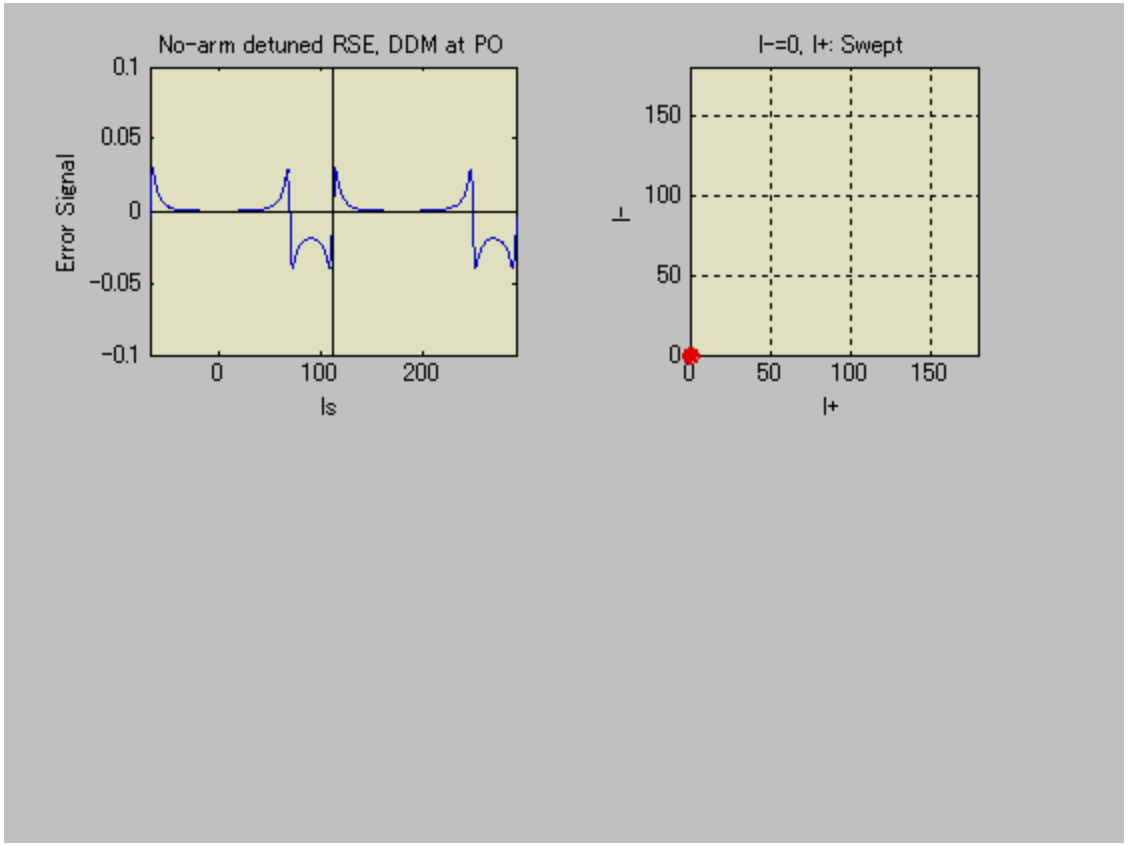
Dependence of Divided I- Signal on I+



Quality of ls Signal



Dependence of Is Signal on I+



Looking for Good Signal …

Have tried the following, but not significant improvement…

- f1-dem, f2-dem
- For I+:

  Single sideband f2, AM f2

  NR pm, am, single sideband f3:

  (f2-f3)-dem, (f1+f3)-dem
- For I-, Is:

  Signal divided by the following:

  2×f1-dem, 2×f2-dem, DDM with different dem phases, (f2-2×f1)-dem

We Should Try More …

- Analyze error signal with one DOF locked
- Try more various signals including mechanical dither signal
- Develop quick acquisition method
- Tighten suspended optics rigidly with respect to local frame, then manually bring three DOFs near lock point to acquire lock?

Summary

- Lots of achievements; experiment on 40m going very fast and smoothly
- Almost ready to try lock acquisition
- Lock acquisition: not so easy
- Need more investigation for lock acquisition

Hope we succeed in locking detuned RSE very soon!