40 meter Recycling Program

- Recycling: current optical Configuration & culmination of MK II facility development

  ››Design & implementation: J. Logan (to 9/98)

  —High coupled cavity (RC and F-P arms) gain (> 20) with Schnupp asymmetry.

  —Full, LIGO like, core optics suspension: single wire loop; PM magnet actuation; 4 layer isolation stacks.

  —State of the art, low loss optics: superpolish; sputtered oxide coatings (principle difference from LIGO, 514 vs 1064 nm)

  —Single freq. frontal modulation servo scheme = LIGO (c 1996).

  ››Previous: "Recombination" (Michelson with F-P arms)

  —Demos LIGO displacement sensitivity. Finish: mid-97 with thesis

  ››Upgrade hardware for recycling ~mid 1997.

  —New ITM (F-P input "test mass"): improved optical figure & HTM rejection. Transmission increased by ~20 (to 6000 ppm). Spring '97.

  —Addition of recycling mirror (installed 9-10/98)

  —New RF side-band λ (11 meters), and re-layout in vacuum optics for λ and RC.

40 meter Recycling Program

—New PSL (still 514 nm)

—New (single wire loop) optics suspensions (RM, BS, EITM)

—WFS (Wave Front Sensing) auto-alignment (from MIT FMI 3/97)

›› Recycled operation accomplishments

—Recycling cavity (PRM) locked 11/97 (two servo loop bootstrap)

—Full recycled interferometer lock 12/97.Quantitative agreement of PRM gains & alignment sensitivity with near degenerate cavity model.

—Investigation of modal structure via RF sb resonances.

—Full control of PRM alignment via WFS

—Wide scale use of digital controls, filtering, and data acquisition.

—Determination that interferometer is under-coupled, due to anomalously high arm loss, constant with measured gain =4.4

›› Work in progress (through Winter 1999)

—elucidate instability of full lock state to optimal alignment.

—Understand servo dynamic range and gain margin limitations.

—Invoke WFS for F-P arm DOFs: confirmed to be dominant perturbation on ifo power build up.

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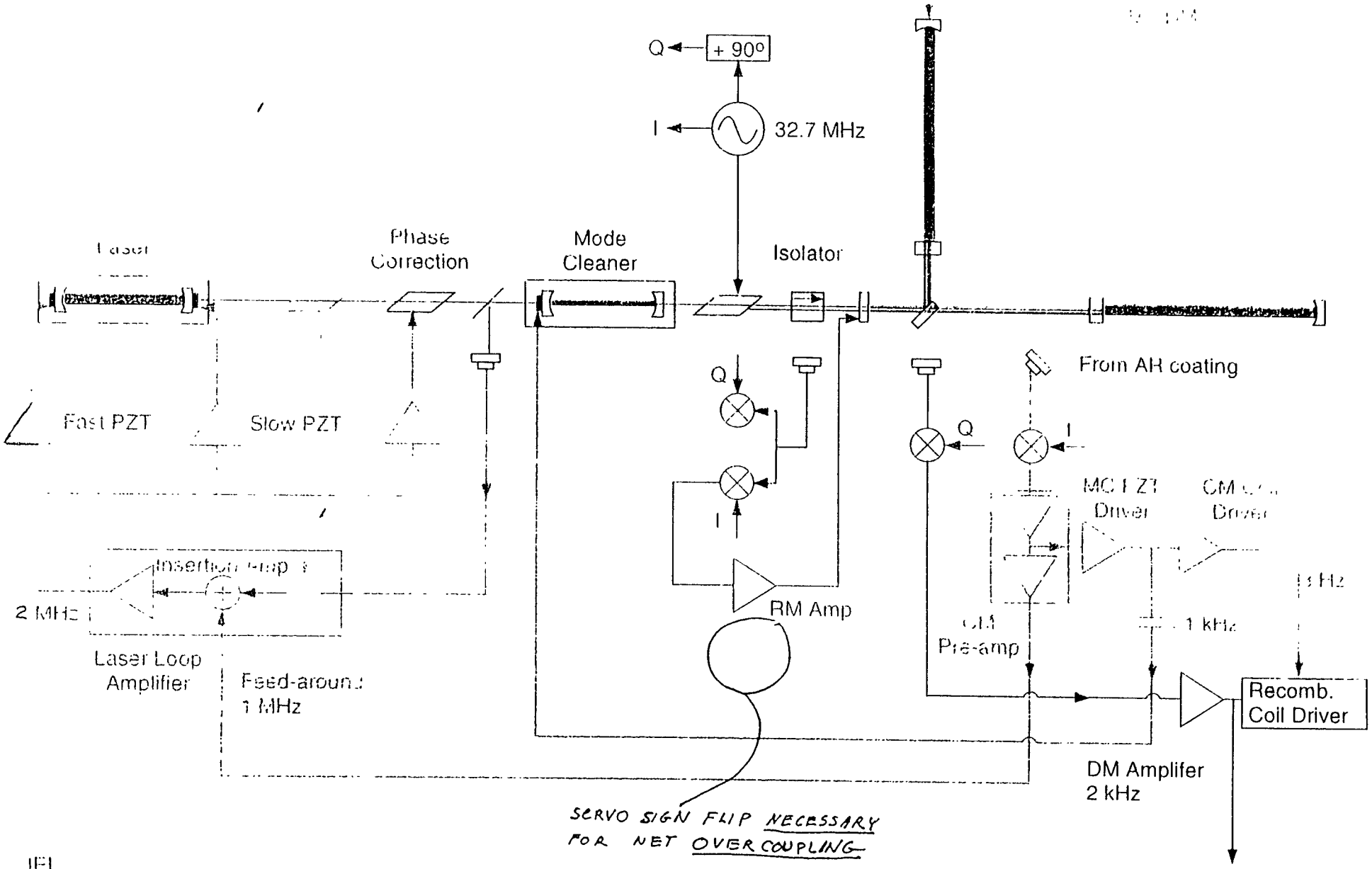
—Stage period of dedicated "data mode" full lock, writing tapes via LIGO model data acquisition system (U. Michigan team: Gustafson, Riles, Rollins)

40 meter Recycling Program

40 Meter interferometer Recycling status (11/98)

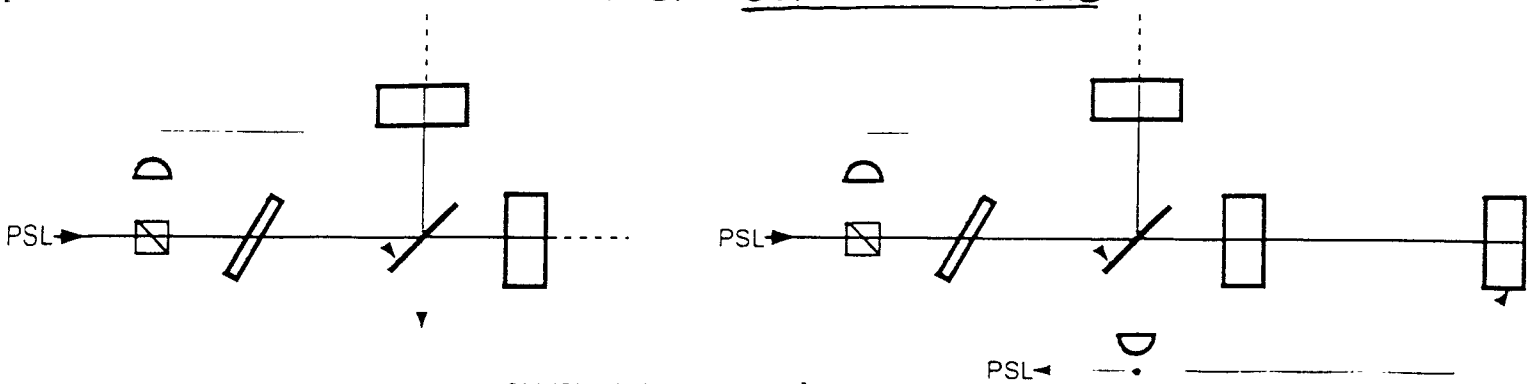
ν_{MOD}	31-34 MHz	32.700 MHz (λ=9.16m)	
L_{ARM}	38.028 / 38.550	40 m	
$\nu_{MOD,RES.}$	31.5338 / 31.0855	—	
L_{RC}	2.3m	2.29m	
T_{ARM}	5900 / 6100 ppm	5950 / 5870 ppm	
$\mathcal{L}_{oss,ARM}$	380 / 360 ppm	230 / 100 ppm	
ASYMMETRY	.540 m	.540m	
T_{RM}	.87 m	.865 m	
G^{CR}_{RC}	~20	~21.5	
G^{SB}_{RC}	5.5	6.7	
$G^{CR}_{FULL\ IFO}$	4.4	9.2	
g_{ARM}	.3766 / .3627	1/3	

40 m POWER RECYCLING TOPOLOGY

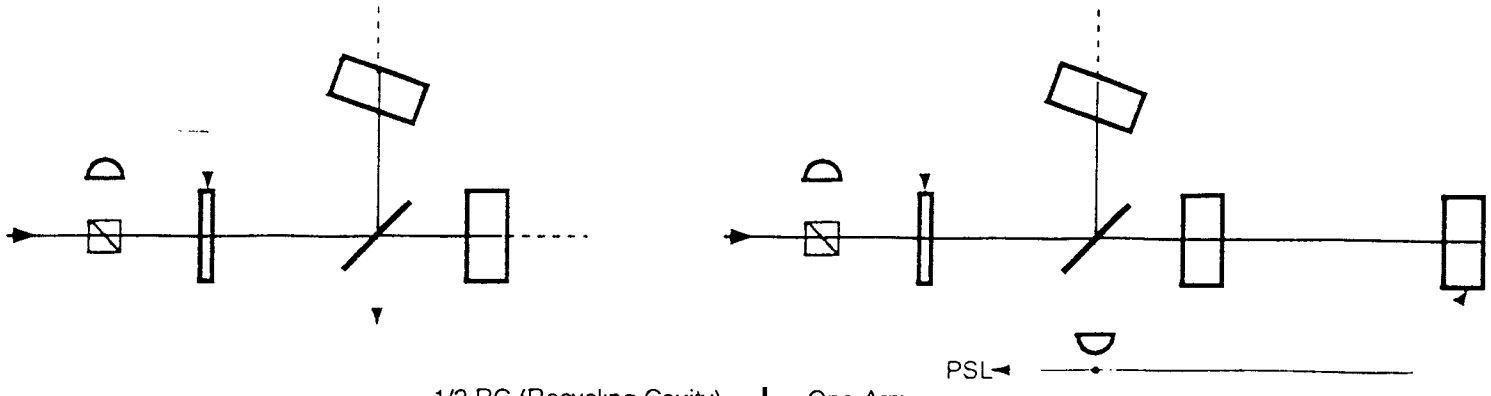


JEL
-jlogan/40m/Diagrams/rec_config.ild

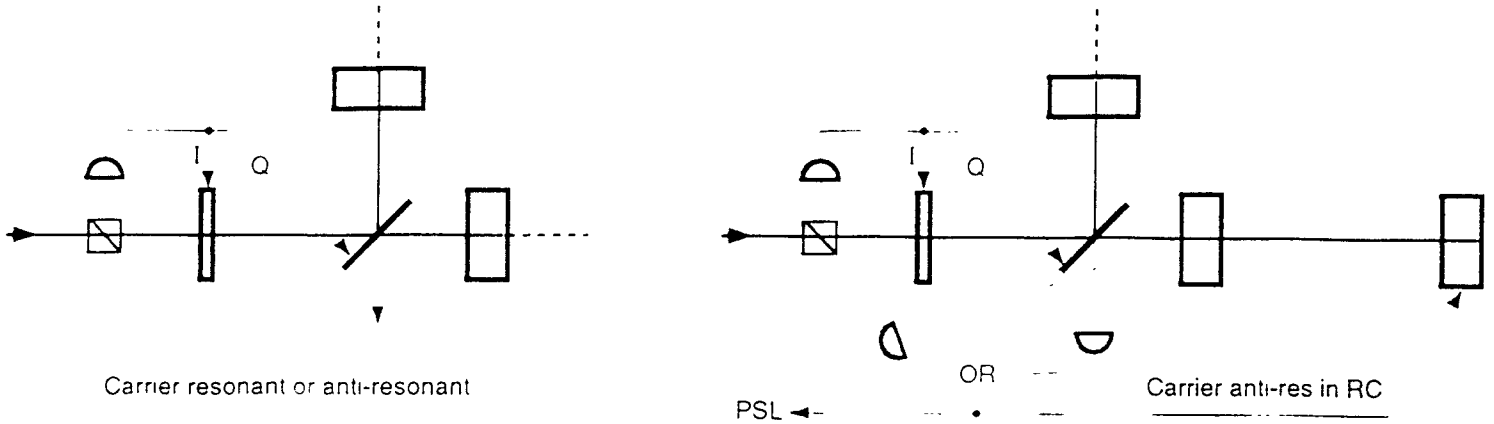
40meter CONFIGURATIONS



SM (Simple Michelson) + One Arm
bright or dark Splitter Lock

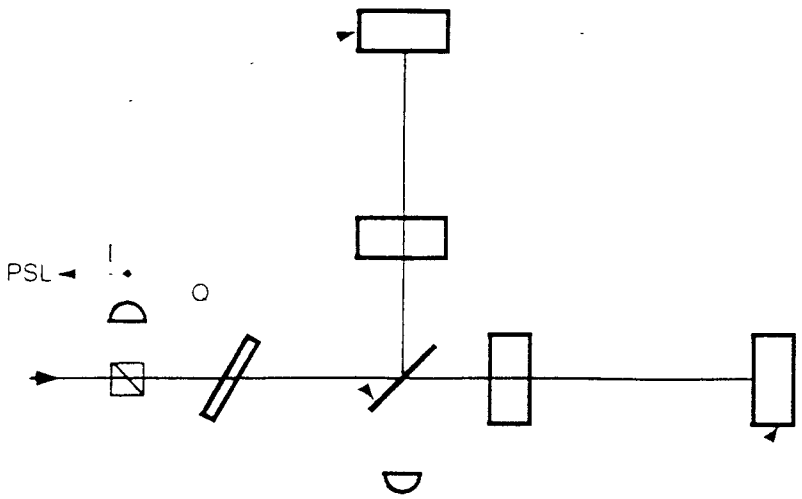


1/2 RC (Recycling Cavity) + One Arm
Carrier resonant or anti-resonant



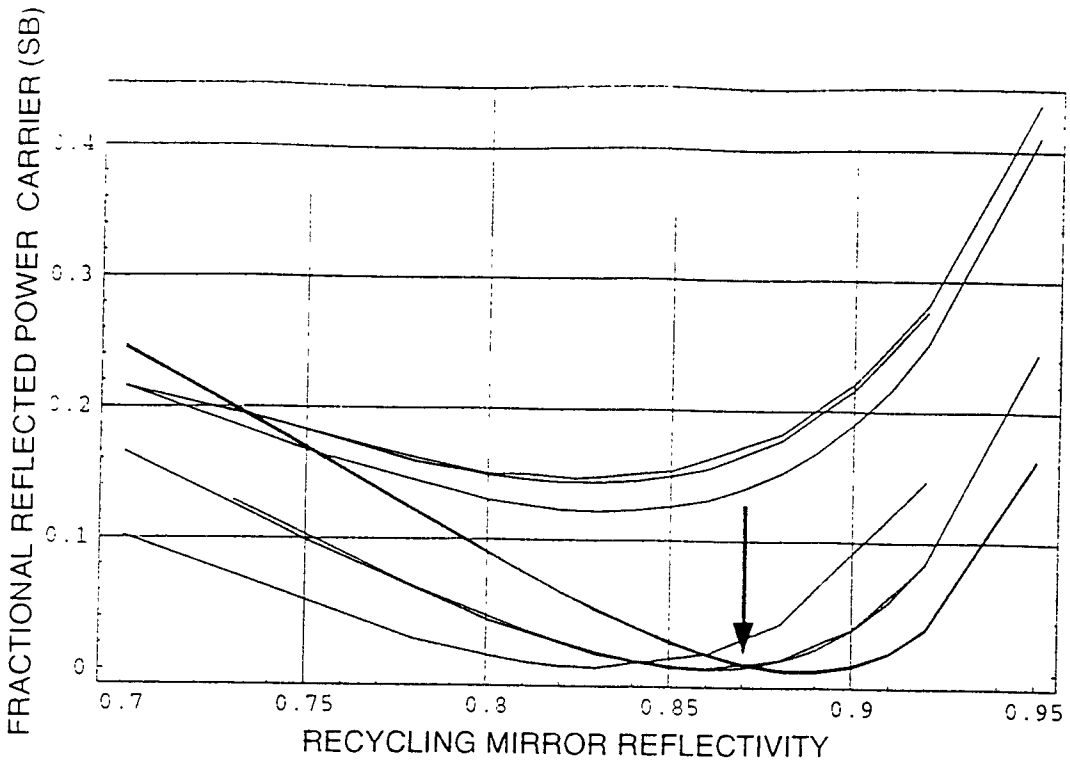
Carrier resonant or anti-resonant

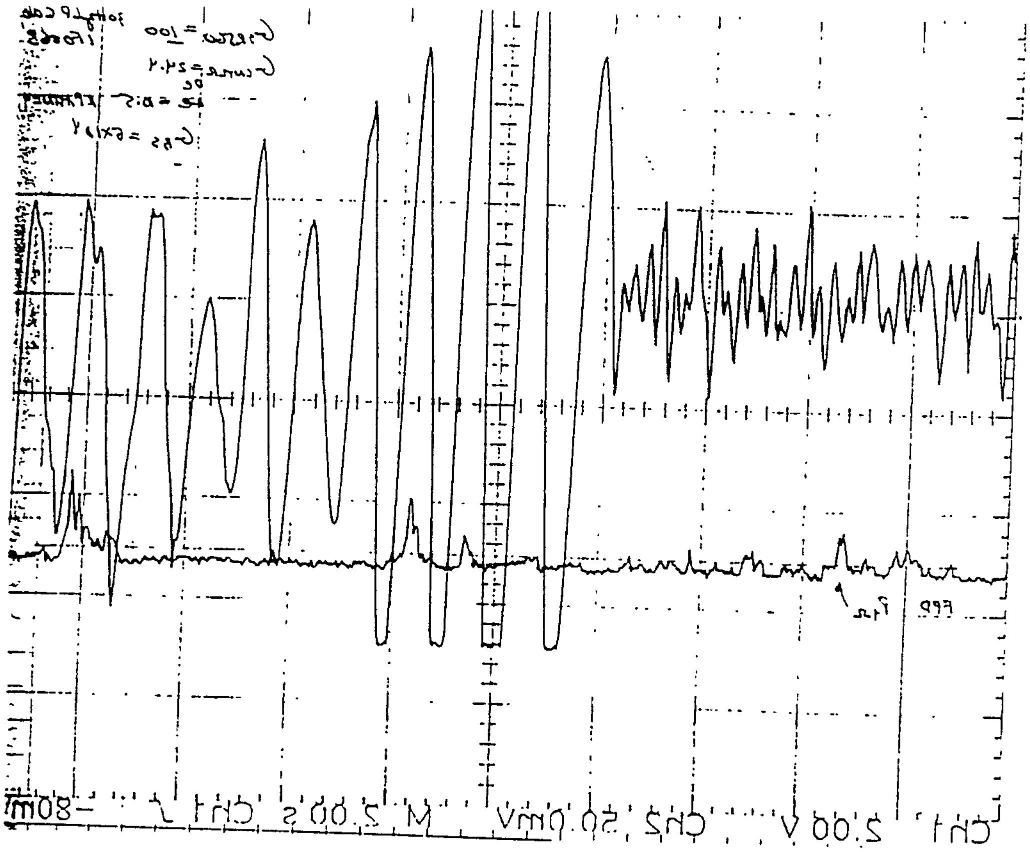
RCM (Recycled Michelson) + One Arm



RECOMBINATION (attenuated)
bright or dark Splitter Lock

FFT Simulations of 40m Recycling




CH1 2.00 V CH2 50.0mV M 2.00s CH1 ƒ -80mV

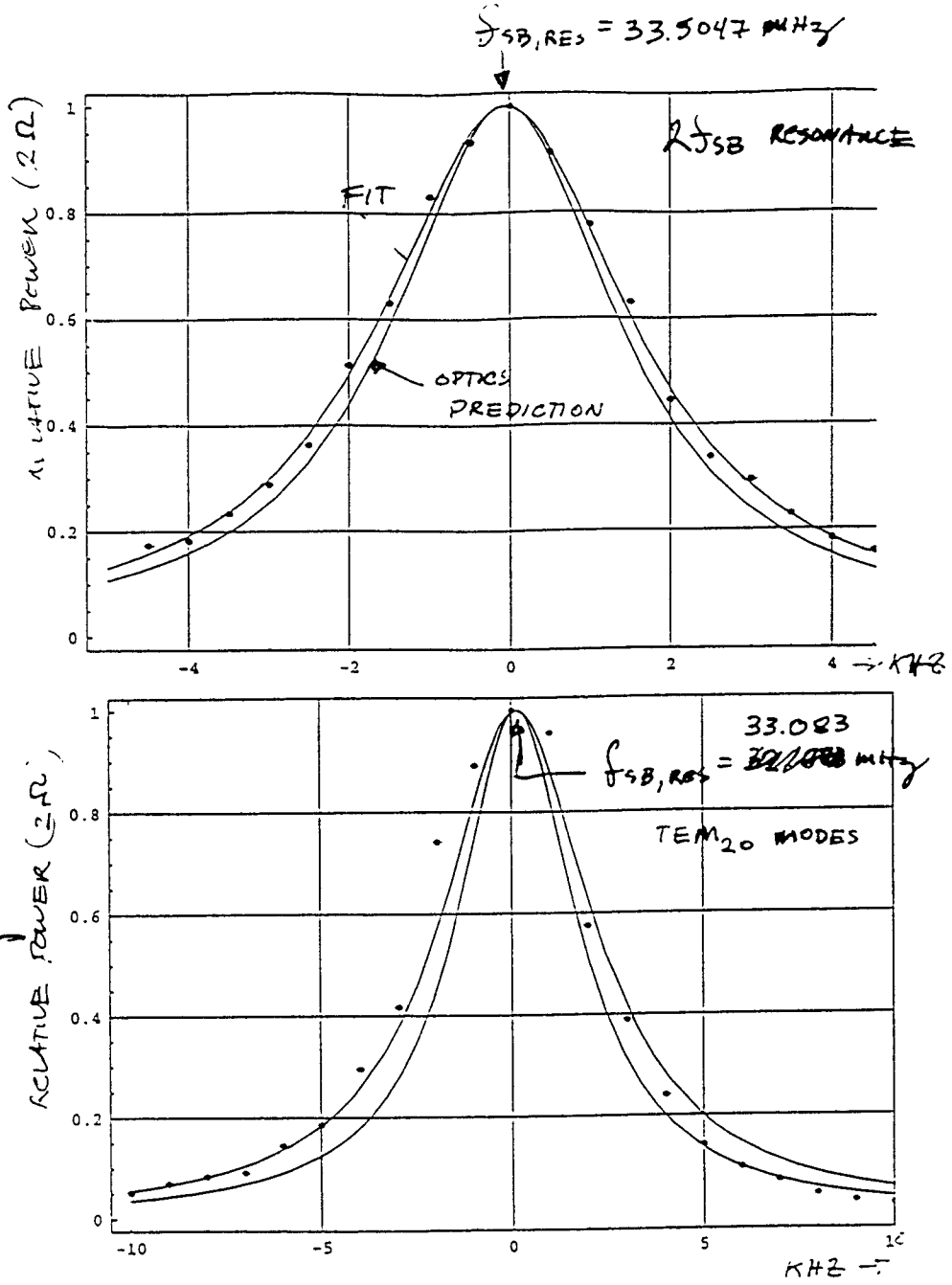
SIDE BAND TRANSMISSION THROUGH 40m ARMS

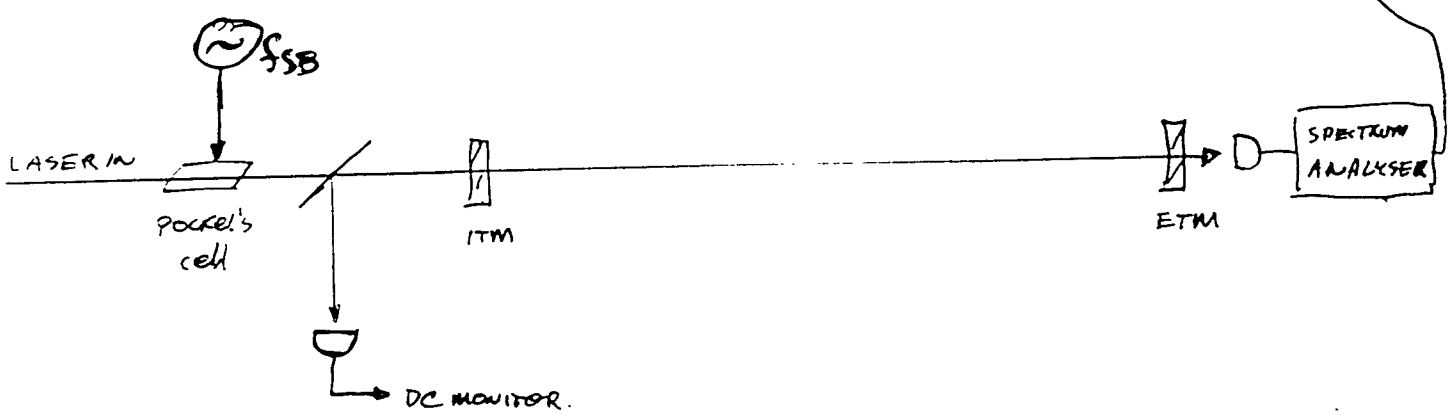
WIDTH GIVES CAVITY LOSS

f_{RES} GIVES HIGH PRECISION CAVITY LENGTH

STRENGTH GIVES BEAM FOCUS MISMATCH INTO CAVITY

f_{RES} GIVES CAVITY FINESSE





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[37]:= Plot[.25 Abs[1 + Erfl[0.9114, -.9114 + .00081 x, .0][[1]] ]^2 /. r -> .997 /. f -> .999965,
    {x, -4, 4}, GridLines -> Automatic, Frame -> True]
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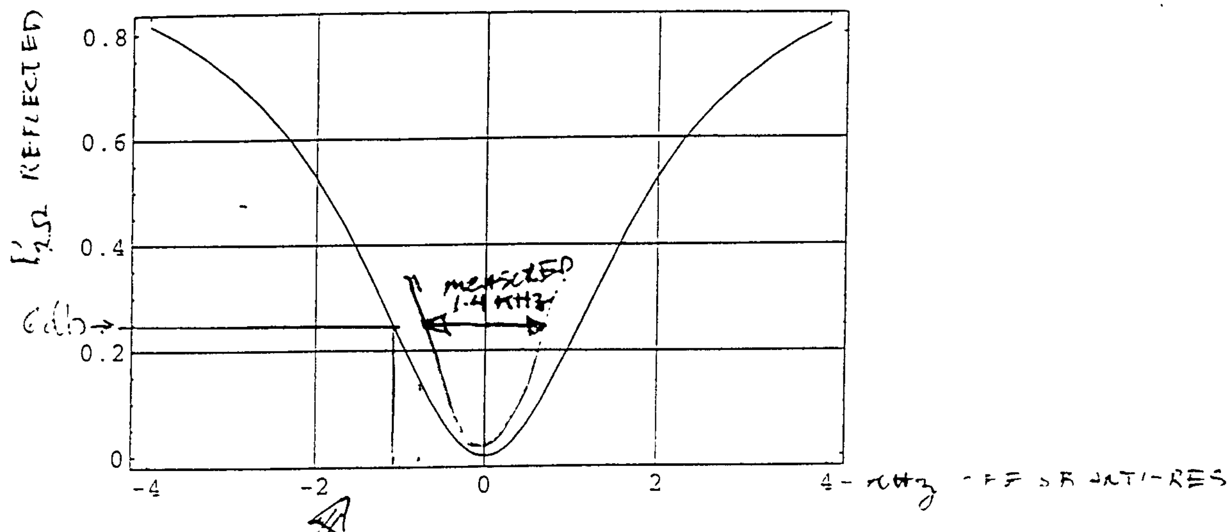

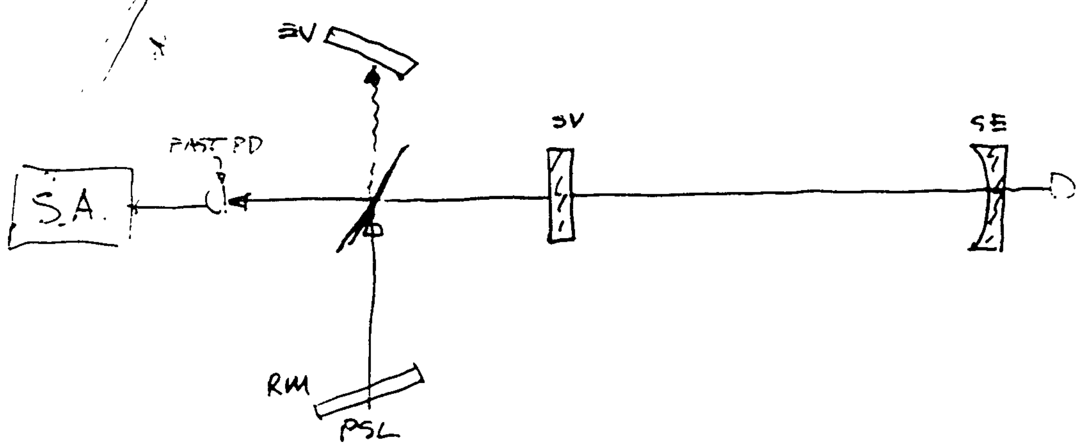

THEORY: – PHASE MOD LIGHT: $E_0 e^{i(\nu_{LASER} + \Gamma \cos \Omega t)} \sim E_0 (J_0 + 2J_1 i \cos \Omega t - 2J_2 \cos 2\Omega t)$

$$- V_{FPD} \sim |E|^2 \sim J_1^2 - J_0 J_2 \approx 0$$

CARRIER (only) RESONANT: $J_0 \to -J_0$

$$- V_{FPD} \sim |E|^2 \sim J_1^2 - (-J_0) J_2 = 2J_1^2 \propto P_{2\Omega}$$

CARRIER & SB ANTI-RES: $J_0 \to -J_0$ $J_2 \to -J_2$

$$- V_{FPD} \sim J_1^2 - (-J_0)(-J_2) \approx 0$$

TYPICAL FULL LOCKED INTERFEROMETER PERFORMANCE