

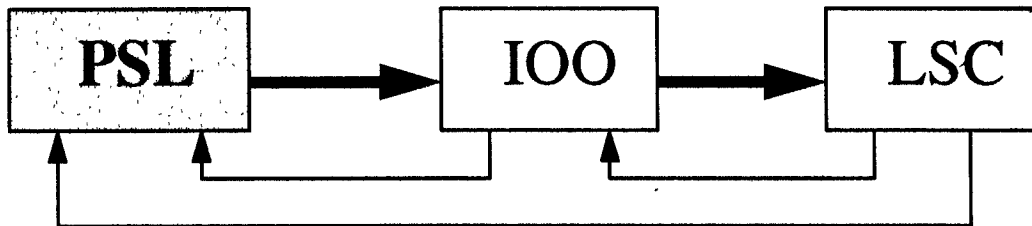
Prestabilized Laser (PSL) Subsystem

Rick Savage

Rich Abbott, Lee Cardenas, Peter King, Stefan Seel

- PSL System Overview
- Lightwave Electronics, Inc. 10-W Laser Development Contract
- Prestabilized Master Oscillator Results

PSL Performance Requirements



- Output Power

- ›› Greater than 8.5 Watts in circular TEM₀₀ mode

- Fractional Power Fluctuations

- ›› $f \geq 40\text{Hz}$: $\delta I(f)/I \leq 10^{-8} / \sqrt{\text{Hz}}$ at COC input

- ›› $f = 34.5\text{MHz}$: $\delta I(f)/I \leq 9 \times 10^{-10} / \sqrt{\text{Hz}}$ (shot noise limit for 600mW power at dark port)

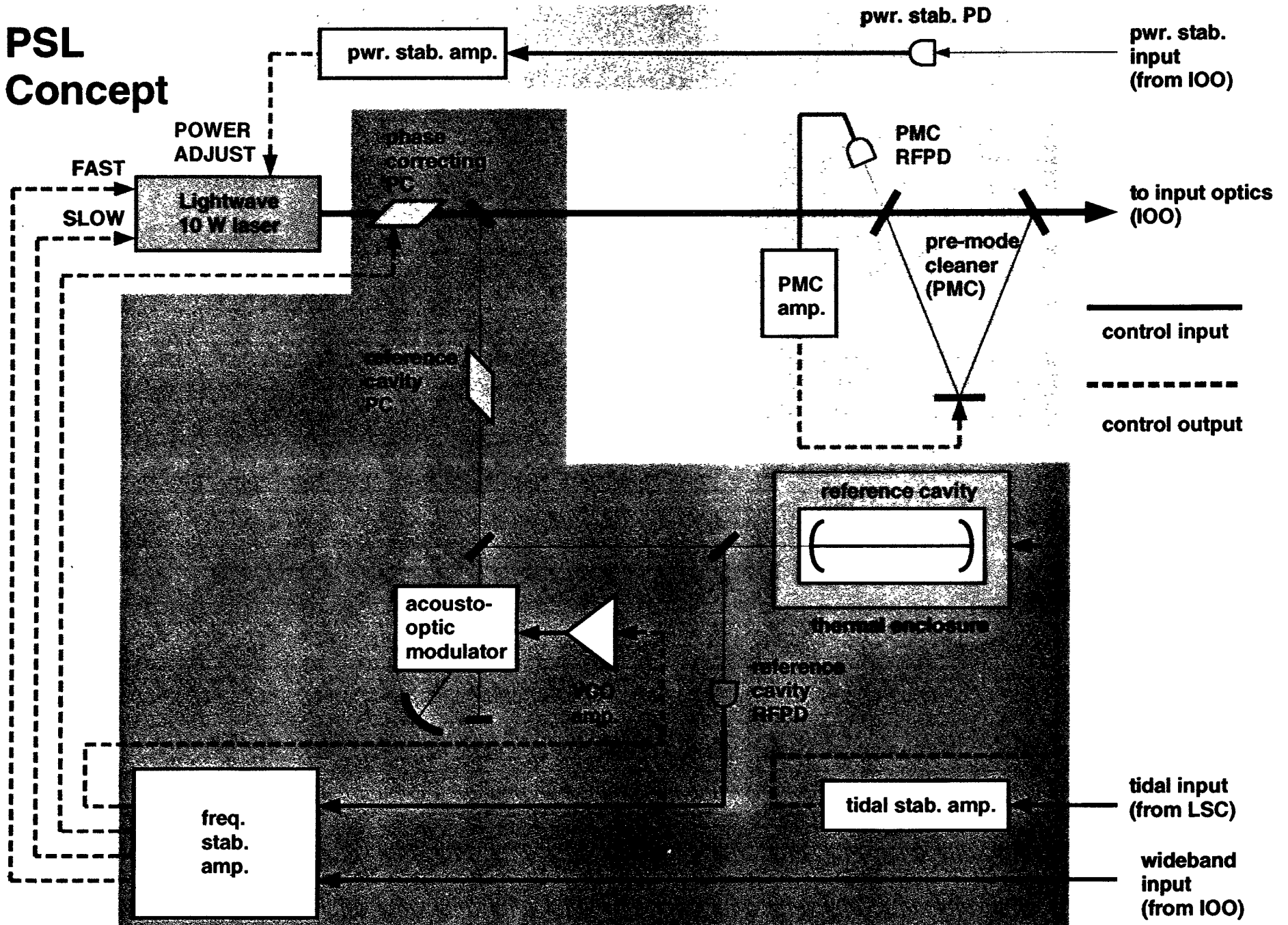
- Frequency Fluctuations

- ›› $40\text{Hz} \leq f \leq 10\text{kHz}$: $\delta f \leq 10^{-2} \text{Hz} / \sqrt{\text{Hz}}$ (further suppressed by IOO and LSC)

- Output Beam Angular Fluctuations

- ›› $f \geq 150\text{Hz}$: $\delta \theta \leq 3 \times 10^{-11} \text{radians} / \sqrt{\text{Hz}}$

PSL Concept



Lightwave 10-W Laser Requirements

- Output Power

- ›› Greater than 10 Watts in circular TEM₀₀ mode

- ›› Less than 0.5 Watts in all other modes

- Fractional Power Fluctuations

- ›› $100\text{Hz} \leq f \leq 10\text{kHz}$: $\delta I(f)/I \leq 10^{-5} / \sqrt{\text{Hz}}$

- ›› $10\text{kHz} \leq f \leq 3\text{MHz}$: $\delta I(f)/I \leq 10^{-6} / \sqrt{\text{Hz}}$

- ›› $f = 10\text{MHz}$: $\delta I(f)/I \leq 6 \times 10^{-9} / \sqrt{\text{Hz}}$ (shot noise limit for 10 mA photocurrent)

- Frequency Fluctuations

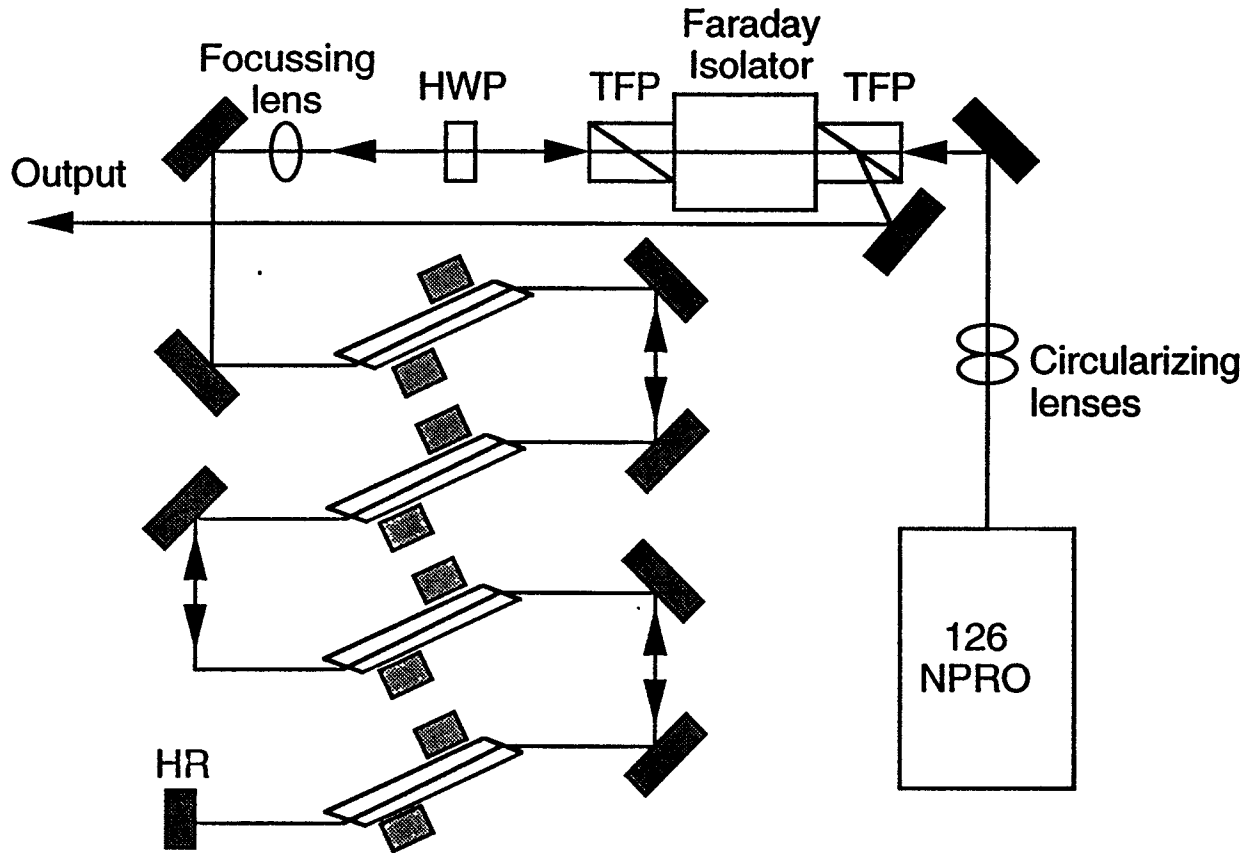
- ›› $f = 100\text{Hz}$: $\delta f \leq 3 \times 10^3 \text{Hz} / \sqrt{\text{Hz}}$

- ›› $f = 1\text{kHz}$: $\delta f \leq 3 \times 10^2 \text{Hz} / \sqrt{\text{Hz}}$

- Output Beam Angular Fluctuations

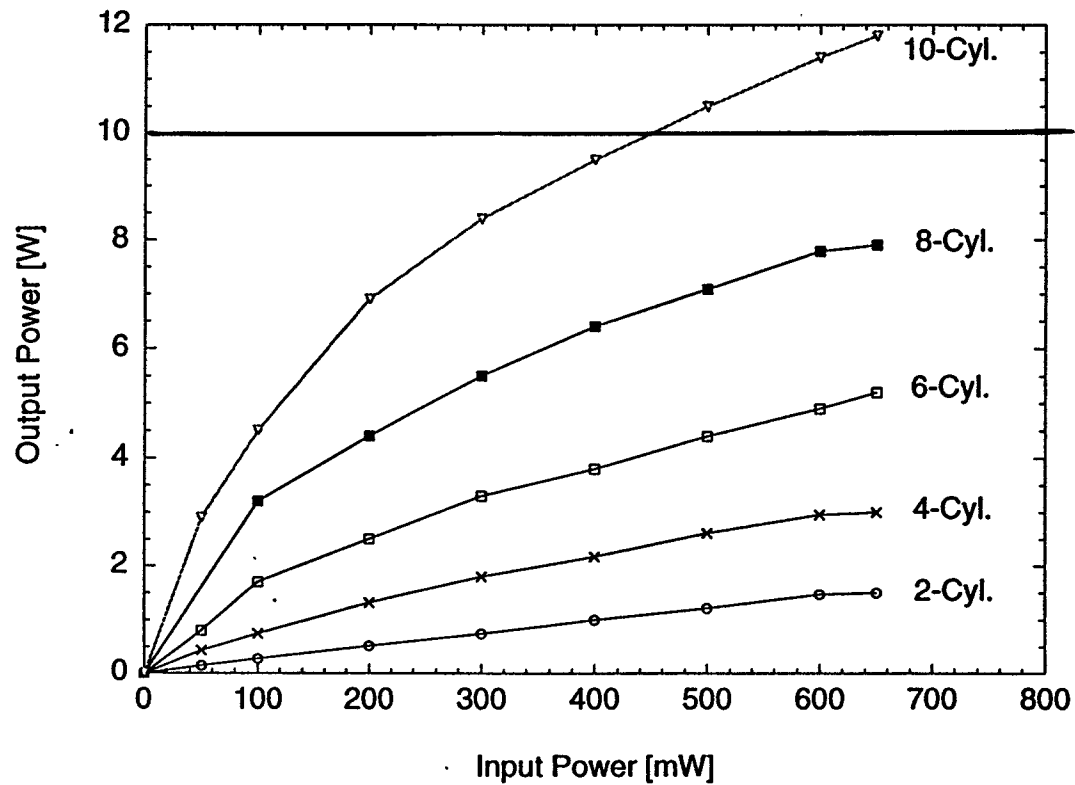
- ›› $f \geq 150\text{Hz}$: $\delta\theta \leq 3 \times 10^{-11} \text{radians} / \sqrt{\text{Hz}}$

Brassboard Layout



8-cylinders, double pass

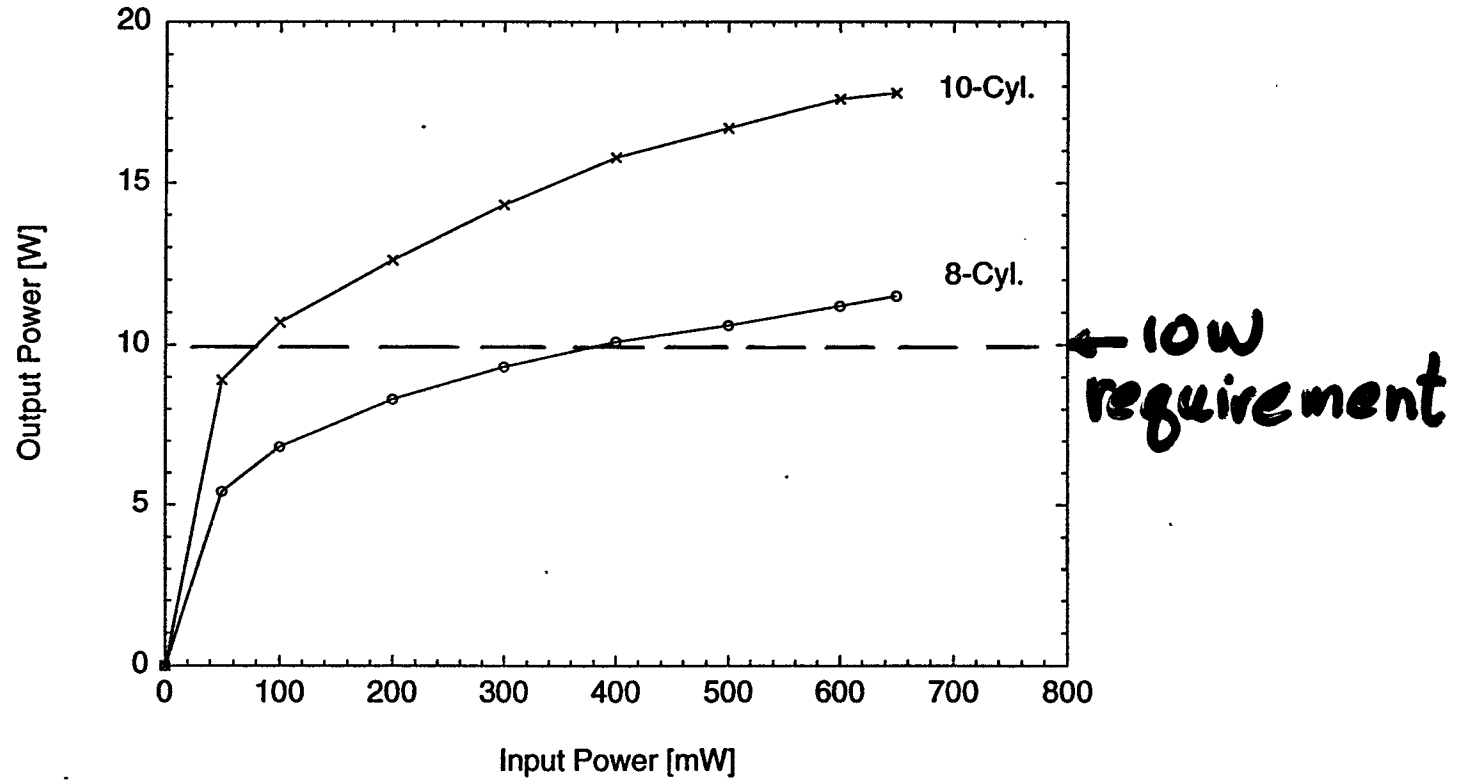
Brassboard Data



10-W
requirement

Single pass

Brassboard Data

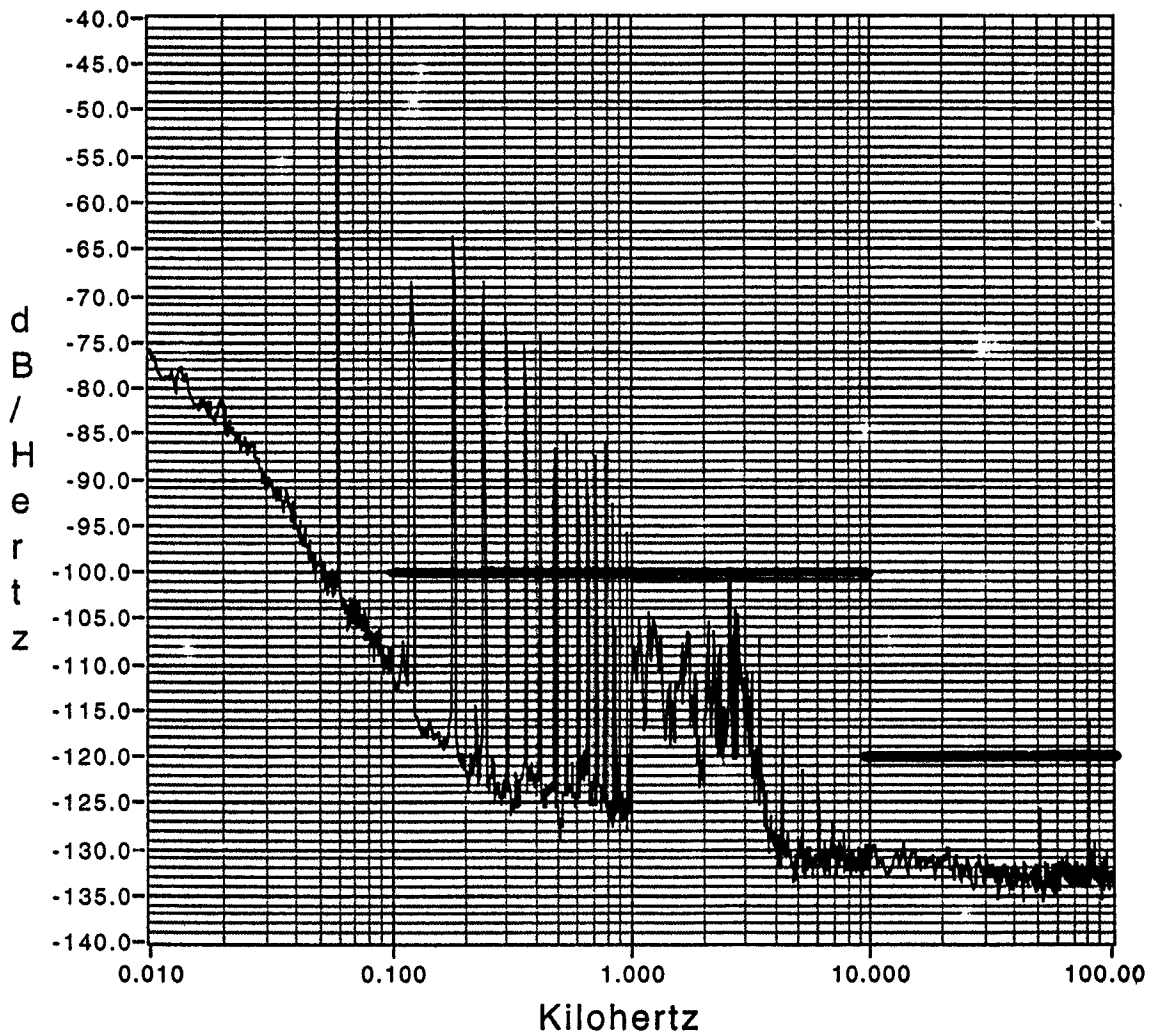


Double pass

Lightwave Brassboard Data.

11.5 Watts out

Relative Intensity Noise

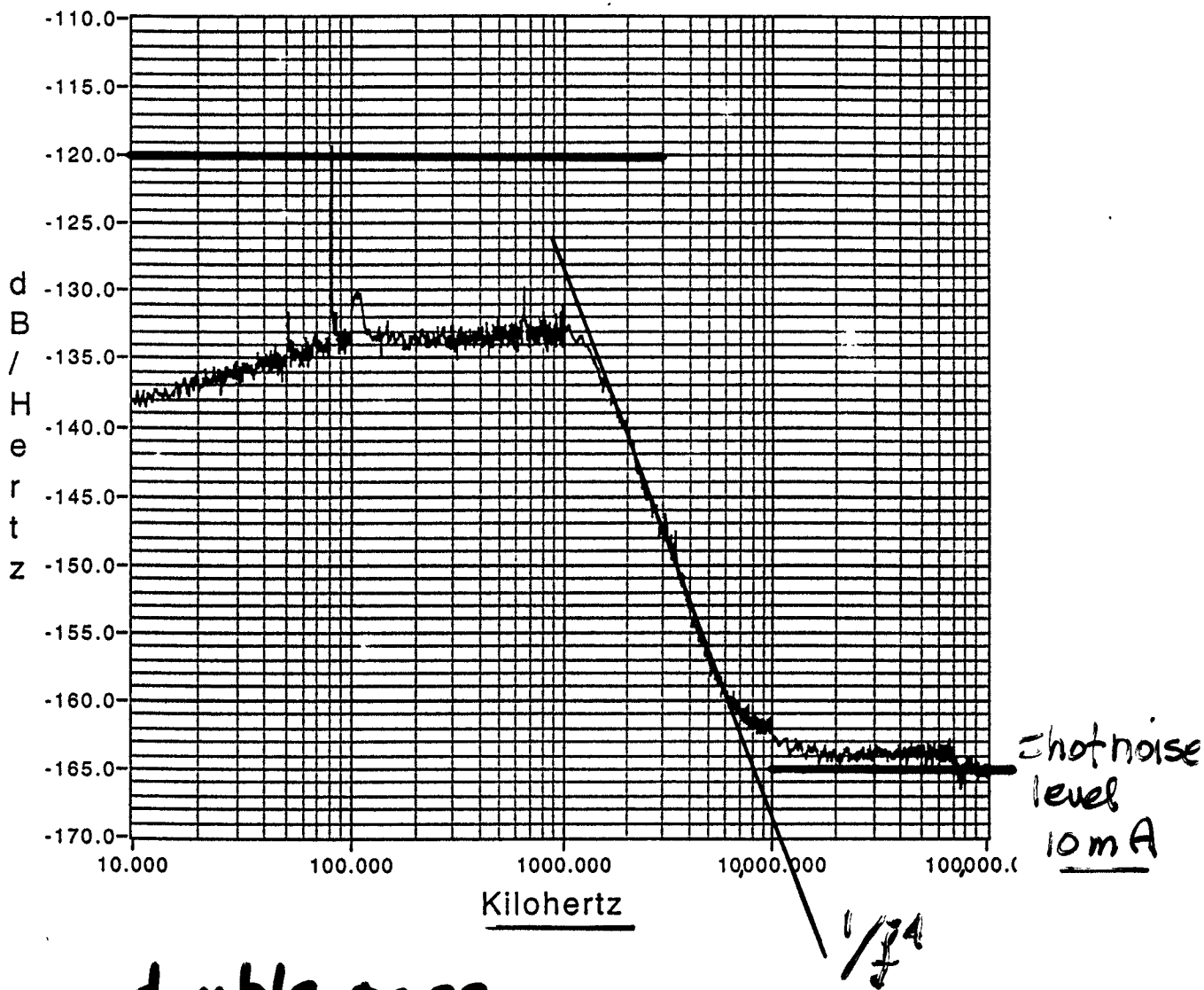


— requirement level

Brassboard Data

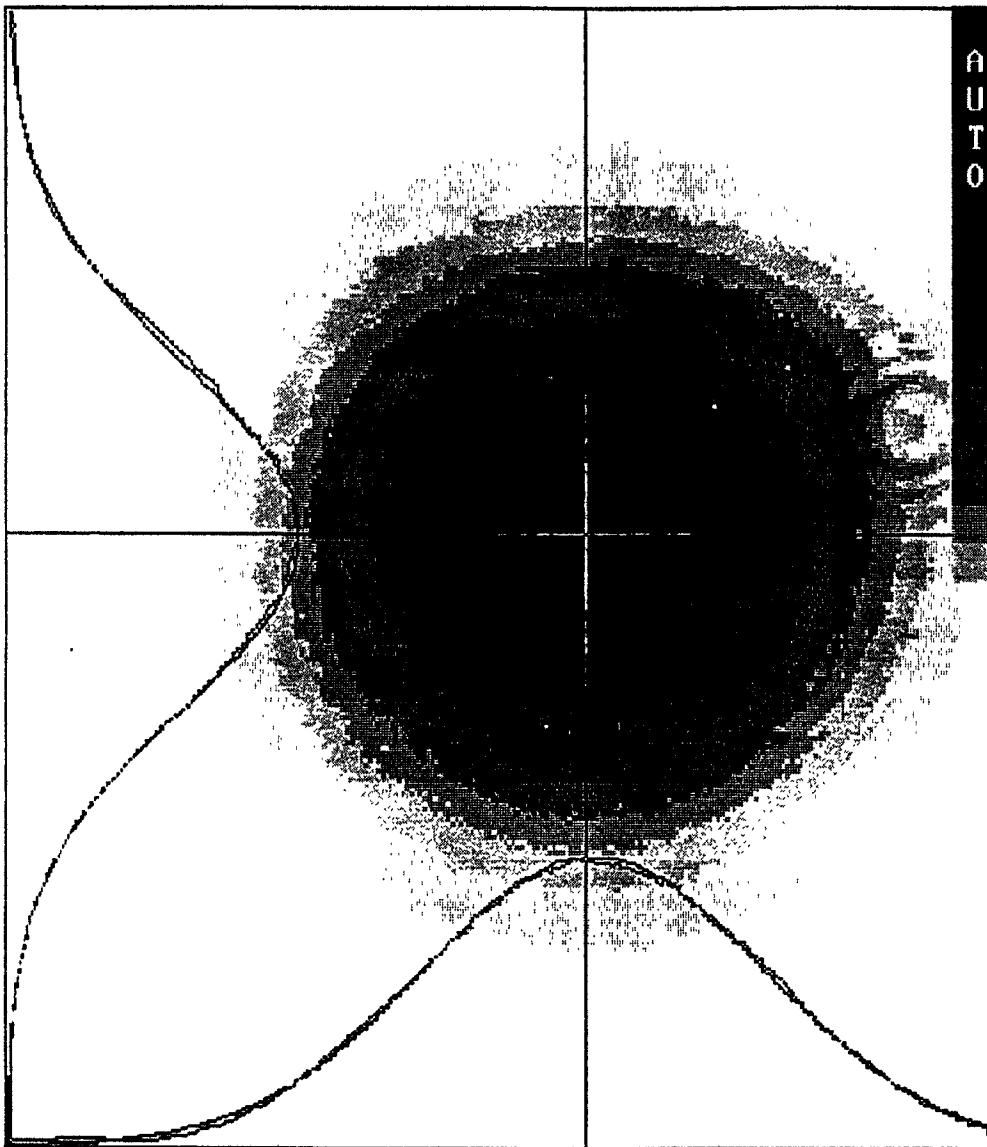
11.5 Watts out.

Relative Intensity Noise



double pass

Brassboard Output at 11.5 W



BeamView - View Screen		
28 Mar 1997 B115W205.ADP		
Location (x,y)[mm] radial		
Peak(2.312, 2.178)	3.176	
Cent(2.397, 2.178)	3.239	
Peak % Response:	92.9	
Power [mW]	10.000	
Diam @86.5%[mm]	2.758	
Eff Area [mm ²]	2.774	
Pk Dnsty [W/cm ²]	0.360	
Peak to Average	2.484	
Diverg@86.5%[mr]	2.713	
% Power In Aper	63.7	
—Ellipticity @ 86.5%—		
Majr,Minr[mm]	2.83, 2.68	
θ°,Circularity	57.4,0.948	
—Gauss Fits: Horz,Vert—		
Coefficient	0.97, 0.97	
Centroid	142, 110	
Peak Intensity	257, 257	
Diameter [mm]	2.83, 2.84	
—Aperture Uniformity—		
Min,Mean,Max	29,133,237	
RMS,Sigma	138.1, 36.4	
Cursor (x,y)[mm] radial	(2.397, 2.178) 3.239	
Pixel [% Peak]	80.8	
SRC: CW	CAP: Cont	BG: On
ZOOM: 1	MODE: Stop	SH: 22
RMT:		WARN

Coherent Mode Master measurements:

$$M_{hor}^2 = 1.01 \quad M_{vert}^2 = 1.04$$

variation ± 0.02

$$P(\text{non-TEM}_{00}) = P_{out} \left(1 - \frac{1}{M_{hor} M_{vert}} \right)$$

$$= \boxed{100 - 400 \text{ mW}} \text{ non-TEM}_{00} \text{ with } P_{out} = 10 \text{ W}$$

Lightwave 10-W Laser Schedule

- Phase I: Preliminary Laser Design
 - ›› Initiate contract: 6/1/96
 - ›› Interim Design Review: 12/18/96
 - ›› Preliminary Design Review: 4/25/97
- Phase II - Fabrication of Three Lasers
 - ›› Initiate product development team: 4/1/97
 - ›› Deliver first Alpha laser: 7/6/97
 - ›› Deliver three Beta lasers: 10/15/97
- Phase III- Option: Fabrication of Additional Lasers
 - ›› Deliver up to five additional lasers: 4 mos. ARO

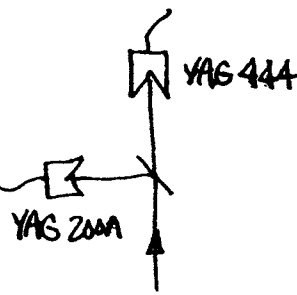
Master Oscillator Stabilization (NPRO-PSL)

(with R. Abbott and J. Mason)

- Goal: Frequency and power stabilization of Lightwave model 126 laser
 - ›› Head start on IR-PSL
 - Same oscillator used for Lightwave 10-W laser
 - ›› Provide stabilized IR source for PNI IR conversion
 - System delivered to MIT in January 1997
- Strategy and techniques similar to strawman conceptual design for PSL
 - ›› Fixed-spacer reference cavity and frequency shifter (VCO)
 - ›› Frequency stabilization via SLOW, FAST, and PC actuators
 - ›› Power stabilization via POWER ADJUST actuator
 - ›› Feedback control loop electronics designed and fabricated by LIGO CDS group
 - Implemented in NIM - no computer interface

1/14/97 ELS

NPRO-PSL RIN DATA



Upper traces - free running
 Lower traces - stabilized

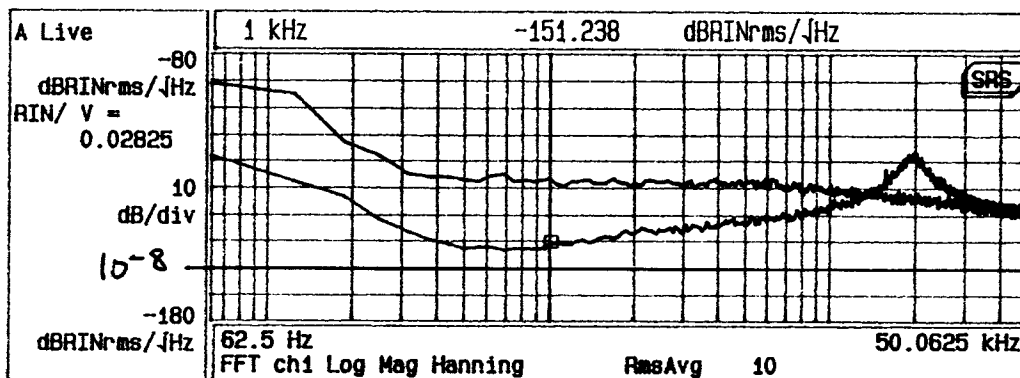
Stabilized RIN NPRO S/N 170

PSA Gain knob: 3.4

Switch ~~set~~: 10

PSA input YAG 444 (in-line)

"inside the loop"

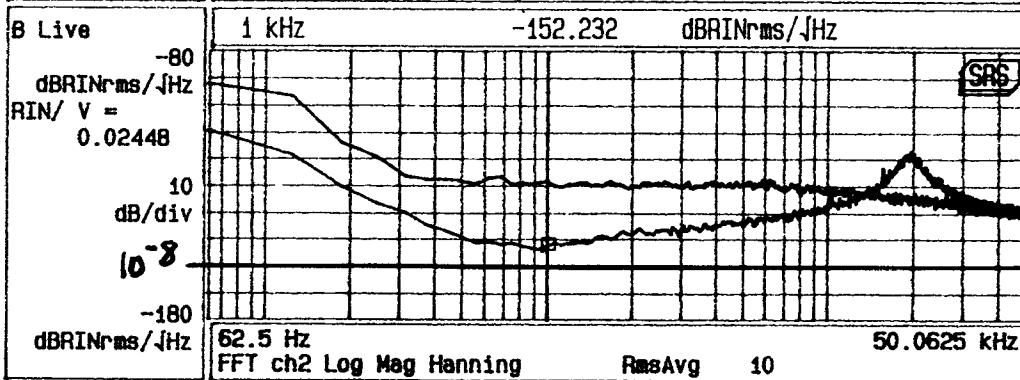


PSPD w/ YAG 444

Upper trace - file RIN44FRA

Lower trace - file RIN44C

"outside the loop"



PSPD w/ YAG 200A

Upper trace - file RIN20FRA

Lower trace - file RIN200C

1/14/97 20: 41: 23

Lights off, AC off, NE ON

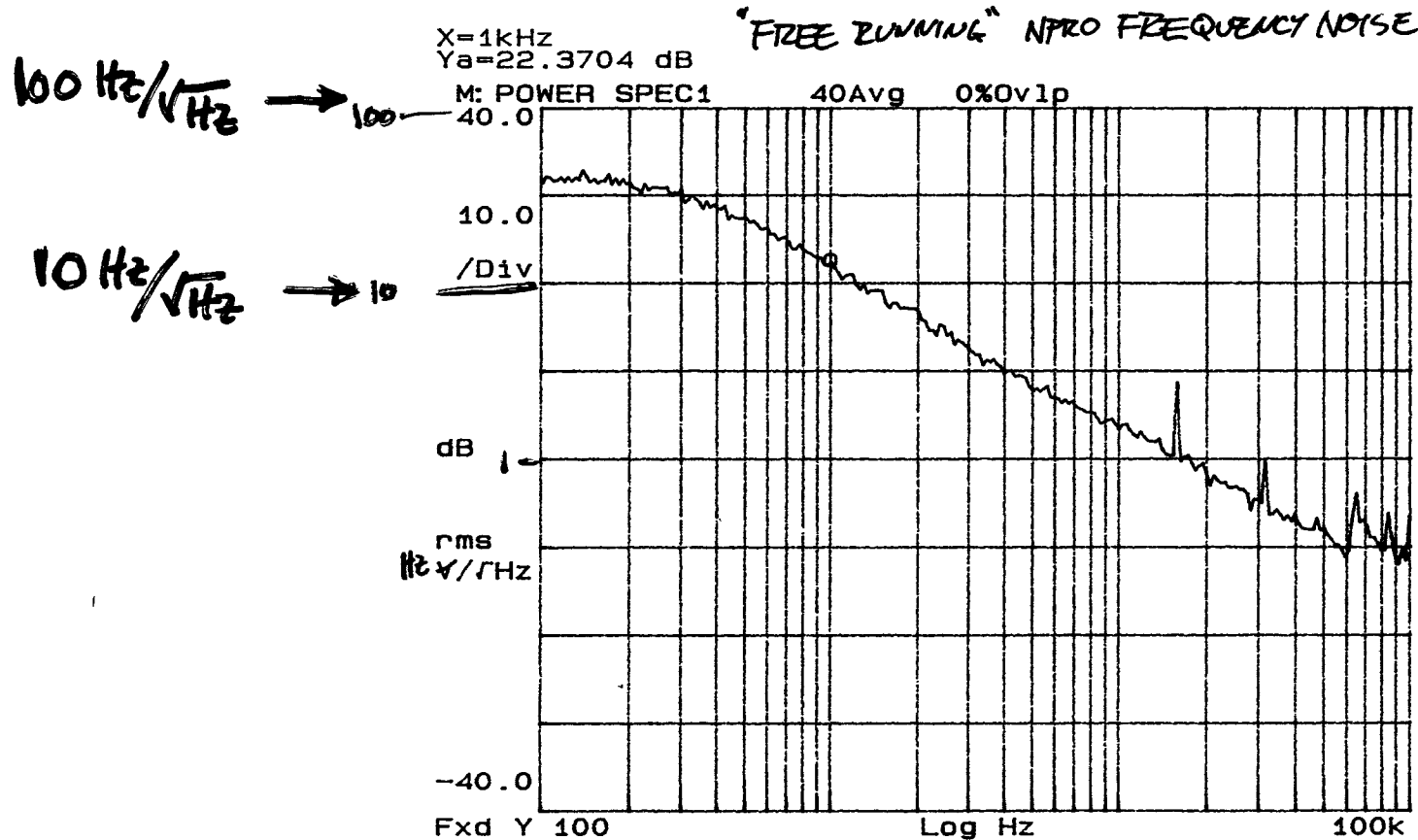
NPRO Data

free-running frequency noise

10/16/96 23:30

JEM
[CORRECTED 10/18/96]

UN-CONVERTED DATA SAVED AS
"1016PS2"



- LASER LOCKED WITH 200 Hz UNITY GAIN
- \therefore FREQUENCY NOISE $\geq 500\text{Hz}$ AND $\leq 20\text{kHz}$ (DUE TO CAVITY RING) IS ~ FREE RUNNING NOISE
- MEASUREMENT MADE OF DEMOD OUT VOLTAGE USING 310000 Hz/V
- LOOP GAIN WHERE THIS MEASUREMENT IS SHOWN BELOW.

Lightwave 10-W laser requirements:

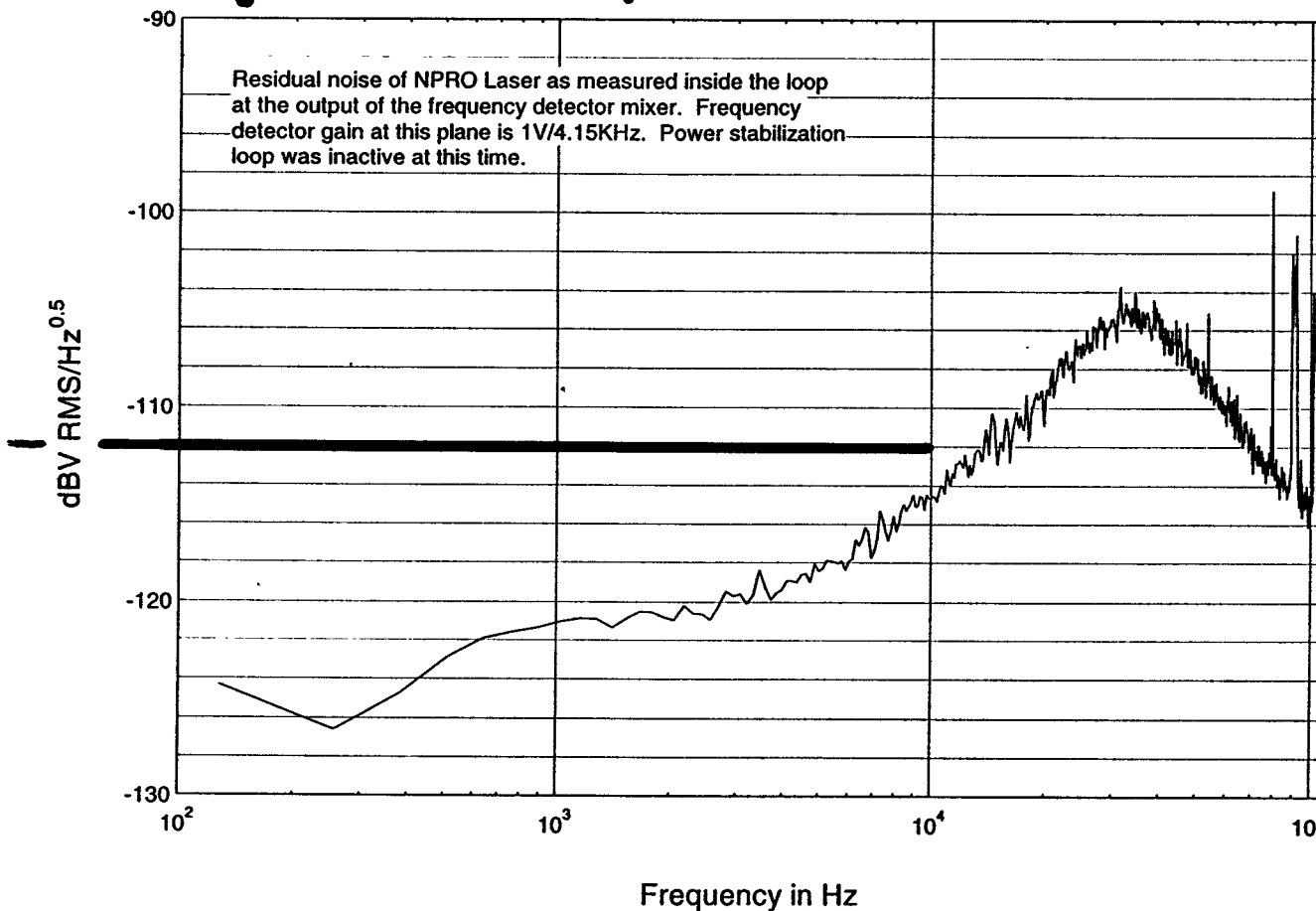
$3 \cdot 10^3 \text{ Hz}/\sqrt{\text{Hz}}$ at 100 Hz

$3 \cdot 10^2 \text{ Hz}/\sqrt{\text{Hz}}$ at 1 kHz

NPRO-PSL DATA

Freq. Stab. Loop Error Point Fluct.

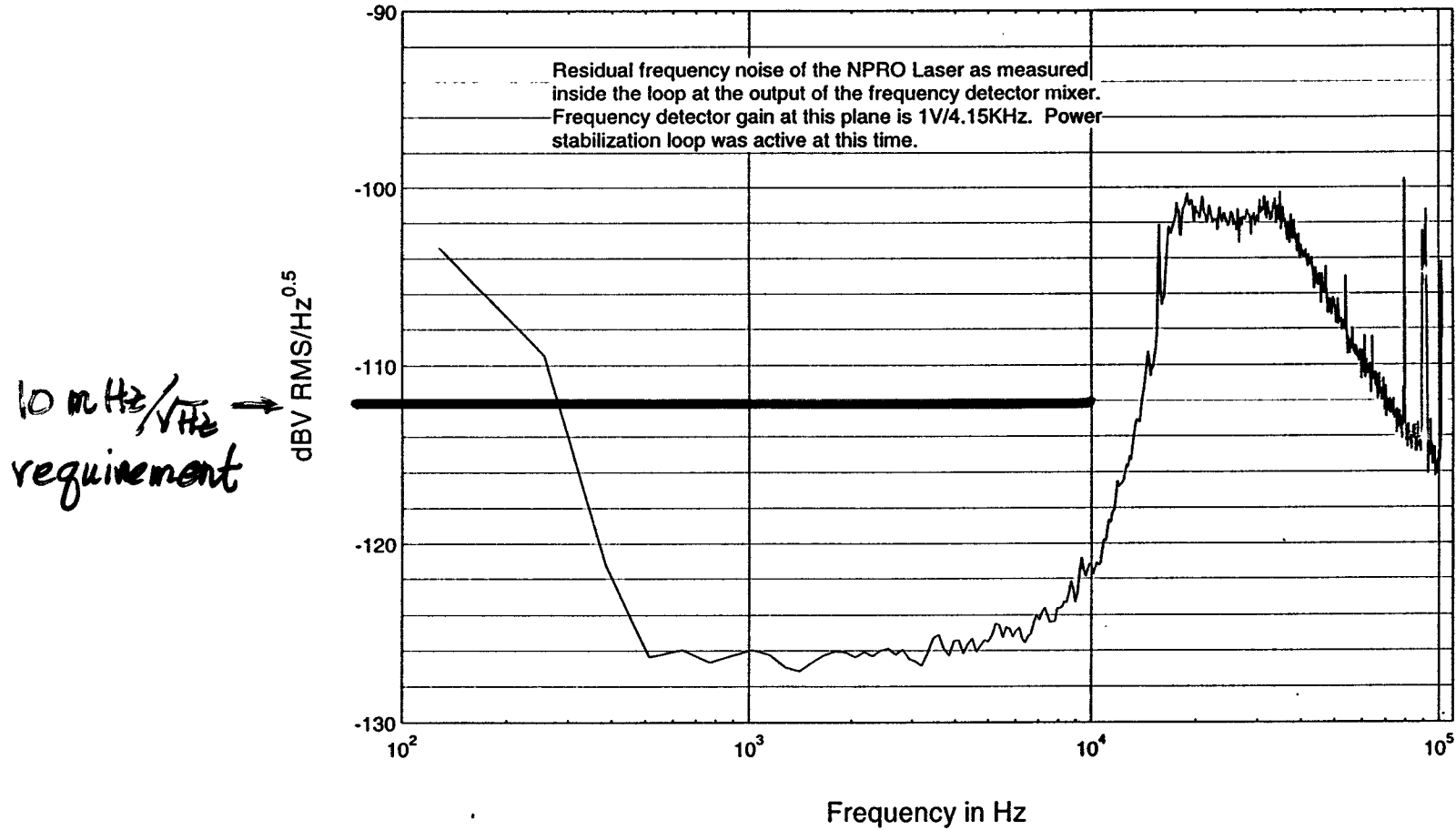
10 mHz/√Hz
requirement



Frequency Noise Measurements - in progress at MIT.

NPRO-PSL DATA

Freq. Stab. Loop Error Point Fluct.



Power Stab. Loop Active

Conclusions

- **10-W laser procurement proceeding well**
 - ›› Lightwave preliminary design review - 4/25/97
 - required output power demonstrated
 - ↳ power fluctuations - meet requirements (maybe better?)
 - frequency fluctuations - not measured (expect to follow NPRO)
 - beam quality - meets requirement (maybe better?)
 - pointing fluctuations - measurements underway
- **Master oscillator stabilization**
 - ›› Frequency stabilization results promising
 - frequency noise measurements underway at MIT
 - ›› Power stabilization close to requirement
 - experience applicable to 10-W laser
- **Prestabilized laser subsystem design**
 - ›› Conceptual design well underway
 - PSL hiring completed
 - Design requirements review (DRR) - May 1997