



LIGO Laboratory / LIGO Scientific Collaboration

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LIGO

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Snapshot of LIGO mechanical resonances HTML pages, circa S1-S4

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Distribution of this document:
LIGO Science Collaboration

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LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

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Below are snapshots of two HTML pages containing lists of mechanical resonances expected and/or observed in LIGO interferometers and associated PEM detectors. Section I contains resonances pertaining to the LIGO Hanford Observatory, while section II contains resonances pertaining to the LIGO Livingston Observatory. These mechanical resonances were characterized before or during the epoch of the first four science runs S1-S4. Some disturbances may have been mitigated or eliminated due to commissioning processes, while still others (e.g. pumps and fans) may have moved in central frequency due to thermal or mechanical effects.

The original (“living”) html source is available off of the CDS webages (restricted sites for the LIGO Scientific Collaboration) at LIGO Hanford and LIGO Livingston.



I. Summary of Mechanical Resonances in the Hanford LIGO Interferometers

Rachel Berkowitz, Michael Landry, David Ottaway, and Robert Schofield

Use the quick links to go directly to the desired section.

[Hanford 4k Interferometer](#), [Hanford 2k Interferometer](#), [Environmental Noise](#), [Ordered List of Resonances](#), [References](#)

Note: " f_{th} " = theoretical frequency
" f_{meas} " = measured frequency
" Q_{th} " = theoretical Q
" Q_{meas} " = measured Q

"FWHM" = Full Width at Half Maximum

Multiple references are listed in the tables to account for the multiple numbers used to describe a given resonance.
Links to elog references are accesible using the username "reader" and the password "readonly."



HANFORD 4k INTERFEROMETER

Use the quick links to go directly to the desired optic.

[Beamsplitter](#), [ITM](#), [ETM](#), [Recycling Mirror](#), [HAM](#), [BSC](#), [Small Optics Internal Modes](#), [Optical Levers](#), [Violin Modes](#), [Environmental](#), [Ordered List of Resonances](#), [References](#)

Click [here](#) for a list (viewable as pdf file) of observed peaks in a power spectrum of the undamped optics and optical levers (June 13, 2003).

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BEAMSPLITTER RESONANCES (4k)

INTERNAL RESONANCES					
Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	References
Butterfly	3785	3731.92			1/24/-/-
Butterfly	3785				1/-/-/-
drum head	5578	5478.34			1/24/-/-
3-fold-radial	7975		1.3×10^6		1/2/1/2
3-fold-radial	7975	7802.25			1/-/-/-
	11259	11133.76			1/24/-/-
	11332	11134.39			1/24/-/-
	11334				1/-/-/-



	12674				1/-/-/-
	12677				1/-/-/-
	12760				1/-/-/-
	12760				1/-/-/-
	14629				1/-/-/-
	17283				1/-/-/-
	17283				1/-/-/-
	17388				1/-/-/-
	17388				1/-/-/-
	17958				1/-/-/-
	17958				1/-/-/-
PENDULAR RESONANCES					
in-beam pendular	.744				3/6/-/-
sideways pendular					-/6/-/-
pitch	.600				3/6/-/-
yaw	.500				3/6/-/-
vertical	~12.8				-/6/-/-
roll	~18.1				10/6/-/-
violin	223				3/-/-/-

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INPUT TEST MASS RESONANCES (4k)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

PENDULAR RESONANCES					X-arm	Y-arm	
Description	f_{th} (Hz)	f_{meas} (Hz)		Q_{th}	Q_{meas}		References
pendular	.743	.761	.775				3/21/-/-
sideways pendular		.731	.732				-/21/-/-
pitch	.600	.631	.636				3/21/-/-
yaw	..499	.501	.464				3/21/-/-
vertical	12.72	11.90	11.88				3/21/-/-
violin	339						3/21/-/-
INTERNAL RESONANCES		* May be different from values measured in 2k ifo due to optics' different wedge angles (ITM 4k wedge = 1.167°)					3
(measured mode)		347.17					-/24/-/-
(measured mode)		347.27					-/24/-/-
butterfly							
drum head							
breathing							



Pathfinder Resonances (4k)

WITH DUMBBELL STANDOFFS		X-arm	Y-arm		X-arm	Y-arm	
Description	f_{th} (Hz)	f_{meas} (Hz)		Q_{th}	Q_{meas}		References
		9476.4			1.3x10 ⁶		-/5/-/5
		22421.5			4.6x10 ⁵		-/5/-/5
		25632.3			2.6x10 ⁶		-/5/-/5
		29484.2			1.1x10 ⁶		-/5/-/5
		29866.2			not measurable		-/5/-/5
		38763.2			8.8x10 ⁵		-/5/-/5
		42758.3			4.8x10 ⁶		-/5/-/5
		47332.4			5.4x10 ⁶		-/5/-/5



MAGNET/STANDOFF ASSEMBLY ATTACHED TO PATHFINDER					
		9700		130	-/5/-/5
		34600		>30	-/5/-/5

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END TEST MASS RESONANCES (4K)

PENDULAR RESONANCES	f_{th} (Hz)	X-arm Y-arm		Q_{th}	X-arm Y-arm		References
		f_{meas} (Hz)			Q_{meas}		
pendular	.744	.761	.767				3/21/-/-
pitch	.600	.621	.632				3/21/-/-
yaw	.500	.509	.498				3/21/-/-
vertical	12.85	12.02	11.99				3/21/-/-
violin	336	365.5					3/21/-/-



INTERNAL RESONANCES					
(measured mode)		343.42		1.25x10 ⁵	-/24-/24
(measured mode)		344.06		1.25x10 ⁵	-/24-/24
butterfly	6596	6615.38			4/24/-/-
butterfly	6596				4/-/-/-
drumhead	9206	9222.5			4/24/-/-
	11217	11195			4/24/-/-
	11217				4/-/-/-
	12056				4/-/-/-
	12057	12184			4/-/24/-
	12941				4/-/-/-
	12943				4/-/-/-
longitudinal	14475				4/-/-/-

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RECYCLING MIRROR RESONANCES (4k)

PENDULAR RESONANCES		X-arm	Y-arm		X-arm	Y-arm	
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Description	f_{th} (Hz)	f_{meas} (Hz)		Q_{th}	Q_{meas}		References
pendular	.741	.757					3/21/-/-
sideways pendular		.733					-/21/-/-
pitch	.600	.616					3/21/-/-
yaw	.501	.499	.452				3/21/-/-
vertical	12.86	12.392	12.368				3/21/-/-
roll							
violin	334						3/21/-/-
INTERNAL RESONANCES							

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HORIZONTAL ACCESS CHAMBER (HAM) RESONANCES (4k)

VERTICAL- VERTICAL (W-		X- arm	Y- arm		X- arm	Y- arm		VERTICAL- YAW		X- arm	Y- arm		X- arm	Y- arm	
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LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

W) TRANSFER						TRANSFER					
Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	References	Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	References
	3.3	3.2			8/8/-/-			3.1			-/8/-/-
	7.8	7.8			8/8/-/-			7.2			-/8/-/-
	12.1	12.1			8/8/-/-			8.0			-/8/-/-
								9.4			-/8/-/-
								12.1			-/8/-/-
								13.4			-/8/-/-
BEAMLINER (U-U) TRANSFER						TRANSVERSE-HORIZONTAL (V-V) TRANSFER					
	1.5	1.5			8/8/-/-		1.8	1.6			7/7/-/-



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

	2.4	2.3			8/8/-/-		3.2	2.8			7/7/-/-
	7.2	7.2			8/8/-/-		7.3	7.3			7/7/-/-
	7.7	7.7			8/8/-/-		8.0	8.0			7/7/-/-
	9.7	10.1			8/8/-/-		10.0	10.3			7/7/-/-
	13.2	13.4			8/8/-/-		13.2	13.4			

**CALCULATED RESONANT MODE FREQUENCIES FOR THE HAM OPTIC
TABLE (4k) (ALL MODES FORM [REFERENCE 11](#))**

Mode	f_{th} (Hz)	Mode	f_{th} (Hz)
1	250	10	615
2	342	11	622
3	397	12	622
4	457	13	623
5	474	14	628
6	559	15	639
7	584	16	643



8	584	17	645
9	596	18	654

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BASIC SYMMETRIC CHAMBER (BSC) RESONANCES (4k)

HORIZONTAL-HORIZONTAL TRANSFER						HORIZONTAL-PITCH TRANSFER					
	(prototype)		(prototype)			(prototype)		(prototype)			
Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	References	Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	Reference
	1.3	1.2			1/1/-/-		1.3	1.2			1/1/-/-
	2.4	2.2			1/1/-/-		2.4	2.2			1/1/-/-
	5.5	5.5			1/1/-/-		6.9	6.5			1/1/-/-
	10.0	10.0			1/1/-/-		11.5	11.5			1/1/-/-
	13.1	13.1			1/1/-/-		14.4	14.4			1/1/-/-
VERTICAL-VERTICAL TRANSFER						VERTICAL-VERTICAL TRANSFER					
	2.9	2.7			1/1/-/-		2.9	2.7			1/1/-/-
	6.5	6.4			1/1/-/-		6.5	6.4			1/1/-/-
	10.2	10.3			1/1/-/-		10.3	10.3			1/1/-/-



	13.1	13.1			7/7/-/-			13.1	13.1			7/7/-/-

BSC DOWNTUBE RESONANCES (4k)

DESCRIPTION	f_{th} (Hz)	f_{meas} (Hz) (prototype)	Q_{th}	Q_{meas} (prototype)	References
	349	349			11/6/-/-
		350			
	355	360			11/6/-/-
	370				11/-/-/-
	371	376			11/6/-/-
	399	399			11/6/-/-
	421	420			11/6/-/-
	441				11/-/-/-
	462				11/-/-/-
	463				11/-/-/-
	478				11/-/-/-
	556				11/-/-/-
	560				11/-/-/-
	583				11/-/-/-
	611				11/-/-/-
	615				11/-/-/-



	683				11 /-/-
	690				11 /-/-
	702				11 /-/-

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IOO SYSTEM (SMALL OPTICS) RESONANCES (4k)

INTERNAL MODES		(prototype)		(prototype)	
Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th} (Hz)	Q_{meas} (Hz)	references
SUSPENSION SYSTEM RESONANCES					
pendular	1.0	1.04			15 /13/-
pitch	.75	.79			15 /13/-
yaw	.85	.85			15 /13/-
vertical	16.0	14.75			15 /13/-
violin1		708.30		2.2×10^5	-/13/-/13
violin2		1416.34		6.7×10^5	
ASSOCIATED RESONANCES					
Dumbbell Assembly		9700		130	-/ 15 /-
Suspension Support Structure		156			-/ 15 /-



CALCULATED RESONANCE FREQUENCIES OF THE PERSISCOPE BASIC STRUCTURE (4k)

Mode No.	Resonance Frequencies (Hz)	References
1	203	16
2	301	16
3	317	16
4	659	16
5	748	16
6	820	16

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OPTICAL LEVER RESONANCES (4k)

LOCATION	FREQUENCY (Hz)	FWHM	REFERENCES (DATE OF MEASUREMENT)
MMT3	12.6, 44.1, 88.5, 133, 143, 221, 233	1, <.1, <.1, <.1, 7, 1, 2	22/22 (July 24 03)
RM	9.9, 12.6, 37.4	2, 1.5	22/22 (July 23 03)
BS	18.6, 100.7, 153, 218.3, 328	___, 2, 2, 2, 1	22/22 (July 29 03)
ITMX	17.8, 25.6, 47.8, 154, 185.6	2.3, 2.7, 1.2, 5, 1.8	22/22 (July 22 03)
ITMY	27.9, 35.2, 41.9, 266.3, 269.1, 313.9	1.5, 1.6, 2.4, 1.3, 1.8, 1.6	22/22 (July 23 03)
ETMX	24.1, 29.6, 45.1, 69.5, 94.6, 139.8, 146.1, 170.5	2.5, 2, 2.2, 3, 3, 1.6, ___, 1.7	22/22 (July 23 03)



ETMY	24.8, 28, 51, 63.5, 107.5, 200.5, 477	2, 2.5, 3, 3, 2, 2, 1	22/22 (July 23 03)
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VIOLIN MODES (4k)

Frequency	Q Value	Sources	References
223		Beamsplitter Pendular Resonance (2K and 4K)	3
334		RM Pendular Resonance (4K)	3
335.82		RM?	Jan 21 02 elog
336.062		ETMX	Apr 19 02 elog
339		ITM Pendular Resonance (4K)	3
339.72		ETMY	Apr 19 02 elog
343		BS, SM, MMT1_LR, MC2_LR, ITMY ?	Aug 27 02 elog
343.413		ETMX	Dec 3 02 elog
343.4152	8.806e4	BS, MC3_LL, MMT1	23
343.4156	1.141e5		Aug 12 elog
343.42		ETMX	Dec 2 02 elog
343.93		ITMX, RM, MC2_LR ?	Feb 5 02 elog
343.94		ETMX	Dec 2 02 elog
344.06		ETMX	Dec 2 02 elog
344.0608	10.752e4	ITMY?	23
344.0609	1.022e5		Aug 12 elog



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344.7156	21.545e4		23
344.7162	1.242e5		Aug 12 elog
344.8299	9.579e4	MMT1_LL, MMT2_LR, RM?	23
344.8302	1.437e5		Aug 12 elog
347.17		ITMX	Dec 2 02 elog
347.1790	13.353e4	BS, ETMX?	23
347.1798	1.551e5		Aug 12 elog
347.27		ITMX	Dec 2 02 elog
347.2719	23.151e4	RM, MMT2_LL?	23
347.2724	1.170e5		Aug 12 elog
347.6809	1.607e4		Aug 12 elog
347.6847	1.830e4	ITMY?	23
347.7		ITMY	Apr 26 02 elog
347.7300	1.656e4	NC1_LL, MC2_LR, MMT2_LL, SM?	23
347.7334	2.037e4		Aug 12 elog
686.9169			23
686.9176	1.313e5		Aug 12 elog
688		Violin Resonance Y-arm	Dec 4 02 elog
688.2850			23
688.2860	1.689e5		Aug 12 elog
689.5115			23
689.5120	8.445e4		Aug 12 elog
689.7416			23



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

689.7431	4.728e4		Aug 12 elog
694.2828			23
694.2841	1.777e5		Aug 12 elog
694.5960			23
694.5974	1.069e5		Aug 12 elog
695.4212	1.440e5		Aug 12 elog
695.4199			23
695.4811			23
695.4828	1.503e5		Aug 12 elog
708.30		Small optics suspension system resonances	13
1030.5585			23
1030.5599	1.000e5		Aug 12 elog
1032.5874			23
1032.5884	1.000e5		Aug 12 elog
1032.5908			23
1034.4276	1.001e5		Aug 12 elog
1034.4598			23
1034.8027			23
1034.8040	1.000e5		Aug 12 elog
1041.6249			23
1041.6267	1.777e5		Aug 12 elog
1042.1226			23
1042.1253	1.348e5		Aug 12 elog



1043.3230			23
1043.3256	1.894e5		Aug 12 elog
1043.4469			23
1043.4484	2.009e5		Aug 12 elog
1416.34		Small optics suspension system resonances	13

HANFORD 2k INTERFEROMETER

Use the quick links to go directly to the desired optic.

[Beamsplitter](#), [ITM](#), [ETM](#), [Folding Mirror](#), [Recycling Mirror](#), [HAM](#), [BSC](#), [Small Optics Internal Modes](#), [Optical Levers](#), [Violin Modes](#), [Environmental](#), [Ordered List of Resonances](#), [References](#)

Click [here](#) for a list (viewable as a pdf file) of observed peaks in a power spectrum of the undamped optics and optical levers (June 13, 2003).

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BEAMSPLITTER RESONANCES (2k)

INTERNAL RESONANCES					
Description	f_{th} (Hz)	f_{meas} (Hz)	Q_{th}	Q_{meas}	References



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

butterfly	3785	3733.7		1.85x10 ⁶	<u>1</u> /-/-2
butterfly	3785				<u>1</u> /-/-
drum head	5578	5477.5		2.50x10 ⁴	<u>1</u> /2/-2
3-fold-radial	7975	7812	1.3x10 ⁶	2.65x10 ⁵	<u>1</u> /2/ <u>1</u> /2
3-fold-radial	7975	7812			<u>1</u> /-/-
	11259	11138.7		3.60x10 ⁵	<u>1</u> /2/-2
	11332				<u>1</u> /-/-
	11334				<u>1</u> /-/-
	12674				<u>1</u> /-/-
	12677				<u>1</u> /-/-
	12760				<u>1</u> /-/-
	12760				<u>1</u> /-/-
	14629				<u>1</u> /-/-
	17283				<u>1</u> /-/-
	17283				<u>1</u> /-/-
	17388				<u>1</u> /-/-
	17388				<u>1</u> /-/-
	17958				<u>1</u> /-/-
	17958				<u>1</u> /-/-
PENDULAR RESONANCES					
in-beam pendular	.744	.758			<u>3</u> /6/-
sideways pendular		.736			-/6/-
pitch	.600	.617			<u>3</u> /6/-



yaw	.500	.492			3/6/-/-
vertical	~12.8	12.586			-/6/-/-
roll	~18.1	18.575			10/6/-/-
violin	223				3/-/-/-

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INPUT TEST MASS RESONANCES (2k)

PENDULAR RESONANCES	f _{th} (Hz)	X-arm	Y-arm	Q _{th}	X-arm	Y-arm	References
		f _{meas} (Hz)			Q _{meas}		
pendular	.743	.764	.776				3/21/-/-
sideways pendular		.723, .732, .764, .772	.722, .735, .743				-/21/-/-
pitch	.600	.656	.660				3/21/-/-
yaw	.497	.497	.500				3/21/-/-
vertical	12.63	11.71	11.72				3/21/-/-
violin	341						3/-/-/-
INTERNAL RESONANCES		* May be different from values measured in 4k ifo due to optics' different wedge angles (ITM 2k wedge = .567°)					3



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

butterfly (mode 7)		6749.188	6746.625	1.3x10 ⁶	1.75x10 ⁶	1x10 ⁶	-/24/2/24
butterfly (mode 8)		6749.719	6746.992		7.74x10 ⁵	1.77x10 ⁶	-/24/-/24
drum head (mode 9)		9394.718	9388.932	1.3x10 ⁶	6.74x10 ⁵	2.3x10 ⁵	-/24/2/24
mode 10		11203.500	11202.516		4.66x10 ⁶	6.3x10 ⁵	-/24/-/24
mode 14		12546.788	12545.640		7.80x10 ⁴	1.5x10 ⁶	-/24/-/24
mode 15		12547.828	12546.640		2.03x10 ⁵	1.5x10 ⁶	-/24/-/24
breathing (mode 16)		14373.750	14370.159		1.34x10 ⁷	6.7x10 ⁶	-/24/-/24
2nd drum head (mode 32)		22321.359	22317.203		2.34x10 ⁶	8.6x10 ⁶	-/24/-/24

Pathfinder Resonances (2k)

WITH DUMBBELL STANDOFFS		X-arm	Y-arm		X-arm	Y-arm	
Description	fth (Hz)	fmeas (Hz)		Qth	Qmeas		References
		9476.4			1.3x10 ⁶		-/5/-/5
		22421.5			4.6x10 ⁵		-/5/-/5



		25632.3		2.6x10 ⁶	-/5/-/5
		29484.2		1.1x10 ⁶	-/5/-/5
		29866.2		not measureable	-/5/-/5
		38763.2		8.8x10 ⁵	-/5/-/5
		42758.3		4.8x10 ⁶	-/5/-/5
		47332.4		5.4x10 ⁶	-/5/-/5
MAGNET/STANDOFF ASSEMBLY ATTACHED TO PATHFINDER					
		9700		130	-/5/-/5
		34600		>30	-/5/-/5

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END TEST MASS RESONANCES (2K)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

PENDULAR RESONANCES		X-arm	Y-arm		X-arm	Y-arm	
Description	f_t (Hz)	f_{meas} (Hz)		Q_{th}	Q_{meas}		References
pendular	.744	.749	.764				3/21/-/-
sideways pendular		.736	.734				-/21/-/-
pitch	.600	.640	.629				3/21/-/-
yaw	.500	.456	.497				3/21/-/-
vertical	12.85	9.886, 12.00	10.743				3/21/-/-
violin	336	365.5					3/-/-/-
INTERNAL RESONANCES							
(measured mode)		342.82			>4x10 ⁴		-/24/-/24
(measured mode)		343.81			7.8x10 ⁴		-/24/-/24
(measured mode)		344.055	349.202		>4x10 ⁴		-/24/-/24
butterfly	6595	6639.00			3x10 ⁶		4/24/-/24
butterfly	6595	6639.0					4/-/-/-



drumhead	9206	9200.00			1x10 ⁵		4/24/-/24
	11217						4/-/-/-
	11217						4/-/-/-
	12056						4/-/-/-
	12057						4/-/-/-
	12941						4/-/-/-
	12943						4/-/-/-
longitudinal	14475	14374			7.3x10 ⁶		4/20/-/20

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FOLDING MIRROR RESONANCES (2k)

PENDULAR RESONANCES	f _{th} (Hz)	f _{meas} (Hz)		Q _{th}	Q _{meas}		References
		X-arm	Y-arm		X-arm	Y-arm	
pendular	.744	.723, .732, .764, .772	.722, .735, .743, .776				3/21/-/-
pitch	.600	.617	.656	>3x10 ⁴	1.9x10 ⁴	7.9x10 ⁴	3/21/3/17
yaw	.500	.503	.427	<3x10 ⁴	1.9x10 ⁴	3.1x10 ⁴	3/21/3/17



vertical	12.85	11.723, 12.052	11.725, 12.061			3/21/-/-
roll		17.589	17.610			-/21/-/-
sideways pendular		.723, .732, .764, .772	.722, .735, .743, .776			-/21/-/-
violin	336		335			3/9/-/-
INTERNAL RESONANCES						

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RECYCLING MIRROR RESONANCES (2k)

PENDULAR RESONANCES	ftheoretical (Hz)	fmeasured (Hz)		Qtheoretical	Qmeasured		References
		X-arm	Y-arm		X-arm	Y-arm	
pendular	.741	.815					3/21/-/-
sideways pendular		.707, .718					-/21/-/-
pitch	.600	.620					3/9/-/-



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

	3.3	3.2			8/8/-/-			3.1			-/8/-/-
	7.8	7.8			8/8/-/-			7.2			-/8/-/-
	12.1	12.1			8/8/-/-			8.0			-/8/-/-
								9.4			-/8/-/-
								12.1			-/8/-/-
								13.4			-/8/-/-
BEAMLINE (U-U) TRANSFER						TRANSVERSE- HORIZONTAL (V-V) TRANSFER					
	1.5	1.5			8/8/-/-		1.8	1.6			7/7/-/-
	2.4	2.3			8/8/-/-		3.2	2.8			7/7/-/-
	7.2	7.2			8/8/-/-		7.3	7.3			7/7/-/-



	7.7	7.7		8/8/-/-		8.0	8.0		7/7/-/-	
	9.7	10.1		8/8/-/-		10.0	10.3		7/7/-/-	
	13.2	13.4		8/8/-/-		13.2	13.4			

**CALCULATED RESONANT MODE FREQUENCIES FOR THE HAM OPTIC
TABLE (2k) (ALL MODES FORM [REFERENCE 11](#))**

Mode	f_{th} (Hz)	Mode	f_{th} (Hz)
1	250	10	615
2	342	11	622
3	397	12	622
4	457	13	623
5	474	14	628
6	559	15	639
7	584	16	643
8	584	17	645
9	596	18	654



BSC DOWNTUBE RESONANCES (2k)

DESCRIPTION	f_{th} (Hz)	f_{meas} (Hz) (prototype)	Q_{th}	Q_{meas} (prototype)	References
	349	349 350			11/6/-/-
	355	360			11/6/-/-
	370				11/-/-/-
	371	376			11/6/-/-
	399	399			11/6/-/-
	421	420			11/6/-/-
	441				11/-/-/-
	462				11/-/-/-
	463				11/-/-/-
	478				11/-/-/-
	556				11/-/-/-
	560				11/-/-/-
	583				11/-/-/-
	611				11/-/-/-
	615				11/-/-/-
	683				11/-/-/-
	690				11/-/-/-



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IOO SYSTEM (SMALL OPTICS) RESONANCES (2k)

INTERNAL MODES		(prototype)		(prototype)	
Description	f_{th} (Hz)	f_{meas} (kHz)	Q_{th} (Hz)	Q_{meas} (Hz)	References
		20.15194		4.9×10^5	-/14/-/14
		20.18583		2.7×10^5	-/14/-/14
Drumhead		28.40520		3.1×10^5	-/14/-/14
		37.97721		2.4×10^5	-/14/-/14
		37.99493		2.4×10^5	-/14/-/14
					-/14/-/14
Drumhead MC1		28.22700		9.4×10^4	-/24/-/24
Drumhead MC2		28.19720		6.7×10^4	-/24/-/24
Drumhead MC3		28.17490		9.3×10^5	-/24/-/24
SUSPENSION SYSTEM RESONANCES		f_{meas} (Hz)			
pendular	1.0	1.04			15/13/-/-
pitch	.75	.79			15/13/-/-
yaw	.85	.85			15/13/-/-
vertical	16.0	14.75			15/13/-/-
violin1		708.30		2.2×10^5	-/13/-/13



violin2		1416.34		6.7x10 ⁵	
ASSOCIATED RESONANCES					
Dumbbell Assembly		9700		130	-/15/-/-
Suspension Support Structure		156			-/15/-/-

CALCULATED RESONANCE FREQUENCIES OF THE PERSISCOPE BASIC STRUCTURE (2k)

Mode No.	Resonance Frequencies (Hz)	References
1	203	16
2	301	16
3	317	16
4	659	16
5	748	16
6	820	16

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OPTICAL LEVER RESONCANCES (2k)

LOCATION	FREQUENCY (Hz)	Q VALUE	REFERENCE (DATE OF MEASUREMENT)
MMT3	9.9, 11.1, 144.4, 218, 233, 295, 351.7,		22 (July 25 03)



	383.4, 424.7, 490		
RM	136.6, 147.9, 152.6, 160.4, 219.5	2.3, 4, 2.5, 2.1, 1.4	22/22 (July 28 03)
BS	36, 39.9, 151.5, 152.6	1.4, 1.6, 2.1, 2.5	22/22 (July 24 03)
ITMX	17.9, 25.4, 26.9, 35.6, 211.8, 345.6	1.8, .9, 1.6, 1.6, 1.1, 2.7	22/22 (July 28 03)
ITMY	15.9, 25.5, 28, 34.9, 48.4, 52.6, 266.4, 269.1, 405.1	2.3, 2.1, 2.4, 1.4, 1.6, 2.5, __, 1.4, __	22/22 (July 25 03)
ETMX	25.1, 27.5, 66.5, 105.1, 169.2	3.4, 2.9, 2.4, 2.6, 1.9	22/22 (July 24 03)
ETMY	21.9, 27.2, 47.7, 54.1, 92.6, 196.6	2.5, 1.8, 2.4, __, 2.4, __	22/22 (July 24 03)
FMX	34.5, 81	1.8, 2.3	22/22 (July 25 03)
FMY	11.4, 32.4, 138.7, 159.3, 424.2, 679.3	1.3, __, 12.1, 6.1, 6.9, 7	22/22 (July 28 03)

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VIOLIN MODES (2k)



Frequency	Q Value	Sources	References
223		Beamsplitter Pendular Resonance (2K and 4K)	3
334		RM Pendular Resonance (2K)	3
336		FM(y) Pendular Resonance	3
341		ITM Pendular Resonance (2K)	3
343.59		Violin Mode?	Feb 23 03 elog
343.68		Violin Mode?	Feb 23 03 elog
343.7501	13.750e4	MMT1_LR?	23



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

343.754		ETMY	Oct 16 01 elog
343.814	8x10^4	ETMX	Aug 27 02 elog
343.8149	12.734e4	ETMY?	23
344.0508	9.054e4	MMT1?	23
344.051	7x10^4	ETMX	Aug 27 02 elog
344.1018	13.764e4	MMT1?	23
344.102		Violin Mode?	Feb 23 03 elog
344.110		ETMY	Oct 16 01 elog
349.1996	13.431e4	ITMX?	23
349.201		ITMX ??	Oct 16 01 elog
349.2428	15.184e4	MMT1_LL?	23
349.245		BS?	Oct 16 01 elog
349.2817	15.186e4	BS?	23
349.282		BS?	Oct 16 01 elog
349.6566	17.483e4	ITMY?	23
349.659		ITMY?	Oct 16 01 elog
687.4467			23
687.45		Violin Mode?	Feb 23 03 elog
687.67		Violin Mode?	Feb 23 03 elog
687.6720			23
688		Violin Resonance Y-arm	Dec 4 02 elog
688.18		Violin Mode?	Feb 23 03 elog
688.1839			23



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

688.2552			23
688.26		Violin Mode?	Feb 23 03 elog
698.45			Feb 23 03 elog
698.4543			23
698.5652			23
698.57		Violin Mode?	Feb 23 03 elog
698.64		Violin Mode?	Feb 23 03 elog
698.6434			23
699.3785			23
699.58		Violin Mode?	Feb 23 03 elog
708.30		Small optics suspension system resonances	13
1031.3595			23
1031.6298			23
1032.4419			23
1047.8365			23
1048.0275			23
1048.1847			23
1049.2395			23
1375.5286			23
1375.8970			23
1376.8970			23
1377.1250			23
1397.1262			23



1397.4747			23
1397.6244			23
1397.8887			23
1416.34		Small optics suspension system resonances	13
1719.9970			23
1720.3925			23
1720.3945			23
1721.726			23
1721.9262			23
1747.3425			23
1747.878			23

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Summary of Environmental Noise at Hanford (All frequencies from [Reference 18](#))

Frequency (Hz)	Source or Comments	Date
.03 - .09	distant earthquake	1/00



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

1.2	seismic and magnetic peak excited by moving Y-end crane	11/01
2.5	seismic and magnetic peak excited by moving Y-end crane	11/01
3 - 12	truck traffic on Hwy 240 and other roads (about 60 mph; given by velocity and axel spacing)	5/00
3.2	seismic and magnetic peak excited by moving Y-end crane	11/01
5 - 15	stomp	11/00
6.5	seismic and magnetic peak excited by moving Y-end crane	11/01
7 - 15	truck traffic on Hwy 240 and other roads (about 60 mph; given by velocity and axel spacing)	5/00
9 - 11	seismic and magnetic peak excited by moving Y-end crane	11/01
10 - 15	Yakima Firing Center tank shot signal	11/00
19	seismic and magnetic peak excited by moving Y-end crane	11/01
19.3	optic lab ventilator?	11/00
21	office area air handler fan belt harmonic	9/99
22 - 27	clean room fans	9/99
24	unknown source - on magnetic and control signals	
30	office area air handler fan motor	9/99
30	LVEA air handler	9/99
30	Kobelco purge aircompressor pump	9/99
30	Culligan water conditioner pump	9/99
32	office area air handler belt harmonic	9/99
35	office area air handler fan	9/99
40 - 47	power supply for optical levers	elog: 11/13/01



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

40	4k PSL table leg	6/01; elog: 6/09/01
42	office area handler fan belt harmonic	9/99
54	4k PSL table leg	6/01; elog: 6/09/01
55	LVEA chiller pad air compressor	1/01
55 - 65	4k PSL periscope	6/01; elog: 6/09/01
57 - 60	LVEA pad water-chiller compressors (12 compressors)	9/99
57.5	LVEA pad main pumps	9/99
58.5	mechanical room chilled water supply pump	9/99
59	Culligan water conditioner pump (LVEA access bay)	9/99
59	Kobelco purge air compressor compressor	9/99
59	Edwards turbo packing pump	9/99
64	office area air handler belt harmonic	9/99
69.9	Gateway monitor	4/01
72	chiller pad air compressor	1/01
76	Sun monitor	4/01
98.7	possibly power supply for optical lever lasers	elog: 12/07/01
100	magnetic field at vault	5/01
133	dust monitors	3/00
255	reference cavity periscope	6/00
255	turbo pump power supply	6/00
256	PSL periscope at laser (main beam)	6/00
256	E. O. power supply fan	11/00; elog: 10/11/00



266	dust monitor	3/00
320	4k PSL periscope mirror support	6/01; elog: 6/9/01
388	Electronics Solutions crate power supplies	2/01; elog: 2/17/01
390	4k PSL periscope mirror support	6/01; elog: 6/9/01
394	Electronics Solutions crate power supplies	2/01; elog: 2/17/01
510 - 550	dust monitors	3/01
6 - 8k	pre-mode cleaner body modes	6/00

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ORDERED LIST OF MECHANICAL RESONANCES

Method in which Frequency Value for Particular Resonance was Obtained

<i>Code</i>	<i>Description</i>
OL	Measured on a component installed at LIGO Hanford
LHL	Measured at LIGO Hanford on a component prior to installation
P	Measured on a prototype structure
C	Calculated using a model



Ordered List

Resonance Description	Specific Mode	f_{meas} (Hz)	Q_{meas}	Description Code	Reference/Measurement Date
Distant earthquake		.03 - .09		OL	18
RM Pendulum (2K)	yaw	.452		OL	21
ITMy Pendulum (4K)	yaw	.464		OL	21
ETMx Pendulum (2k)	yaw	.456		OL	21
FMy Pendulum	yaw	.427	3.1×10^4	LHL	21/3
BS Pendulum	yaw	.492		OL	6
ITMx Pendulum (2k)	yaw	.497		OL	21
ETMy Pendulum (2k)	yaw	.497		OL	21
ETMy Pendulum (4k)	yaw	.498		OL	21
RM Pendulum (4k)	yaw	.499		OL	21
ITMy Pendulum (2k)	yaw	.500		OL	21
ITMx Pendulum (4k)	yaw	.501		OL	21
FMx Pendulum	yaw	.503		OL	21
ETMx Pendulum (4k)	yaw	.509		OL	21
RM Pendulum (2k)	pitch	.6		C	3
RM Pendulum (4k)	pitch	.616		OL	21
BS Pendulum	pitch	.617		OL	6
FMx Pendulum	pitch	.617		OL	21



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

RM Pendulum (2k)	pitch	.62		LHL	3
ETMx Pendulum (4k)	pitch	.621		OL	21
ETMy Pendulum (2k)	pitch	.629		OL	21
ITMx Pendulum (4k)	pitch	.631		OL	21
ETMy Pendulum (4k)	pitch	.632		OL	21
FMy Pendulum	pitch	.656	7.9×10^4	LHL	21/17
ITMy (4k)	pitch	.636		OL	21
ETMx Pendulum (2k)	pitch	.640		OL	21
ITMx Pendulum (2k)	pitch	.656		OL	21
ITMy Pendulum (2k)	pitch	.660		OL	21
RM Pendulum (2k)	sideways pendular	.707		OL	21
RM Pendulum (2k)	sideways pendular	.718		OL	21
FMy Pendulum	(sideways?) pendular	.722		OL	21
ITMy Pendulum (2k)	sideways pendular	.722		OL	21
ITMx Pendulum (2k)	sideways pendular	.723		OL	21
FMx Pendulum	(sideways?) pendular	.723		LHL	21
ITMx Pendulum (4k)	sideways pendular	.731		OL	21
FMx Pendulum	(sideways?)	.732		OL	21



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

	pendular				
ITMy Pendulum (4k)	sideways pendular	.732		OL	21
ITMx Pendulum (2k)	sideways pendular	.732		OL	21
RM Pendulum (4k)	sideways pendular	.733		OL	21
ETMy Pendulum (2k)	sideways pendular	.734		OL	21
FMy Pendulum	(sideways?) pendular	.735		OL	21
ITMy Pendulum (2k)	sideways pendular	.735		OL	21
BS Pendulum	sideways pendular	.736		OL	6
ETMx Pendulum (2k)	sideways pendular	.736		OL	21
FMy Pendulum	(sideways?) pendular	.743		OL	21
ITMy Pendulum (2k)	sideways pendular	.743		OL	21
ETMx Pendulum (2k)	pendular	.749		OL	21
RM Pendulum (4k)	pendular	.757		OL	21
BS Pendulum	pendular	.758		OL	6
ETMx Pendulum (4k)	pendular	.761		OL	21



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

ITMx Pendulum (4k)	pendular	.761		OL	21
ETMy Pendulum (2k)	pendular	.764		OL	21
ITMx Pendulum (2k)	(sideways?) pendular	.764		OL	21
FMx Pendulum	(sideways?) pendular	.764		LHL	21
ETMy Pendulum (4k)	pendular	.767		OL	21
FMx Pendulum	(sideways?) pendular	.772		OL	21
ITMx Pendulum (2k)	sideways pendular	.772		OL	21
ITMy Pendulum (4k)	pendular	.775		OL	21
FMy Pendulum	(sideways?) pendular	.776		OL	21
ITMy Pendulum (2k)	pendular	.776		OL	21
SO Pendulum (2k)	pitch	.79		LHL	13
RM Pendulum (2k)	pendular	.815		OL	21
SO Pendulum (2k)	yaw	.85		LHL	13
SO Pendulum (2k)	pendular	1.04		LHL	13
BSC Horizontal-Horizontal	f1	1.2		P	7
BSC Stack Horizontal-Pitch	f1	1.2		P	7
Seismic & magnetic peak excited by moving Y-end crane		1.2		OL	18
Ham Stack beamline (U-U)	f1	1.5		LHL	8



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

HAM Stack, transverse-horizontal (V-V)		1.6		LHL	<u>7</u>
BSC Horizontal-Horizontal	f2	2.2		P	<u>7</u>
BSC Stack Horizontal-Pitch	f2	2.2		P	<u>7</u>
Ham Stack beamline (U-U)	f2	2.3		LHL	<u>8</u>
Seismic and magnetic peak excited by moving Y-end crane		2.5		OL	<u>18</u>
BSC Stack, Vertical-Vertical		2.7		P	<u>7</u>
HAM Stack, transverse-horizontal (V-V)		2.8		LHL	<u>7</u>
BSC Stack Vertical-Vertical	f1	2.9		P	<u>7</u>
Truck traffic on 240 and other roads		3 - 12		OL	<u>18</u>
HAM Stack vertical-yaw	f1	3.1		LHL	<u>8</u>
HAM Stack vertical-vertical (W-W)	f1	3.2		LHL	<u>8</u>
Seismic and magnetic peak excited by moving Y-end crane		3.2		OL	<u>18</u>
Stomp		5 - 15		OL	<u>18</u>
BSC Horizontal-Horizontal	f3	5.5		P	<u>7</u>
BSC Stack Horizontal-Pitch	f3	6.5		P	<u>7</u>
BSC Stack Vertical-Vertical	f2	6.5		P	<u>7</u>
Seismic and magnetic peak excited by moving Y-end crane		6.5		OL	<u>18</u>
Car traffic on 240 and other roads		7 - 15		OL	<u>18</u>
HAM Stack vertical-yaw	f2	7.2		LHL	<u>8</u>



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

HAM Stack beamline (U-U)	f3	7.2		LHL	8
HAM Stack, transverse-horizontal (V-V)		7.3		LHL	7
HAM Stack beamline (U-U)	f4	7.7		LHL	8
HAM Stack vertical-vertical (W-W)	f2	7.8		LHL	8
HAM Stack vertical-yaw	f3	8		LHL	8
HAM Stack transverse-horizontal (V-V)		8		LHL	7
Seismic and magnetic peaks excited by moving Y-end crane		9 - 11		OL	18
HAM Stack vertical-yaw	f4	9.4		LHL	8
ETMx Pendulum (2k)	vertical	9.886		OL	21
Optical Lever RM (4k)		9.9	1.5 (FWHM)	OL	22 /22 (July 23 03)
Optical Lever MMT3 (2k)		9.9		OL	22 (July 23 03)
BSC Horizontal-Horizontal	f4	10		P	7
Ham Stack beamline (U-U)	f5	10		LHL	8
Yakima Firing Center tank shot signal		10 -1 15		OL	18
BSC Stack Vertical-Vertical	f3	10.3		P	7
ETMy Pendulum (2k)	vertical	10.743		OL	21
BS Pendulum	vertical	10.852		OL	6
Optical Lever MMT3 (2k)		11.1		OL	22 (July 25 03)
Optical Lever FMY (2k)		11.4	1.3 (FWHM)	OL	22/22 (July 28 03)
BSC Stack Horizontal-Pitch	f4	11.5		P	7
ITMx Pendulum (2k)	vertical	11.71		OL	21



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

ITMy Pendulum (2k)	vertical	11.72		OL	21
FMx Pendulum	vertical	11.723		OL	21
FMy Pendulum	vertical	11.725		OL	21
ITMy Pendulum (4k)	vertical	11.88		OL	
ITMx Pendulum (4k)	vertical	11.90		OL	21
ETMy Pendulum (4k)	vertical	11.99		OL	21
ETMx Pendulum (2k)	vertical	12.00		OL	21
ETMx Pendulum (4k)	vertical	12.02		OL	21
FMx Pendulum	vertical	12.052		OL	21
FMy Pendulum	vertical	12.061		OL	21
HAM Stack vertical-vertical (W-W)	f3	12.1		LHL	8
HAM Stack vertical-yaw	f5	12.1		LHL	8
RM Pendulum (2k)	vertical	12.638		OL	21
RM Pendulum (4k)	vertical	12.392		OL	21
BS Pendulum	vertical	12.586		OL	6
Optical Lever MMT3, RM (4k)		12.6	2 (FWHM)	OL	22/22 (July 24 03)
BSC Horizontal-Horizontal	f5	13.1		P	7
BSC Stack Vertical-Vertical	f4	13.1		P	7
HAM Stack vertical-yaw	f6	13.4		LHL	8
HAM Stack beamline (U-U)	f6	13.4		LHL	8
BSC Stack Horizontal-Pitch	f5	14.4		P	7
SO Pendulum (2k)	vertical	14.75		LHL	13
Optical Lever ITMY (2k)		15.9	2.3 (FWHM)	OL	22/22 (July 25 03)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

FMx Pendulum	roll	17.589		OL	21
FMy Pendulum	roll	17.610		OL	21
Optical Lever ITMX (4k)		17.75	2.3 (FWHM)	OL	22/22 (July 25 03)
FMx Pendulum	roll	17.891		LHL	9
RM Pendulum (2k)	roll	17.891		LHL	9
Optical Lever ITMX (2k)		17.9	1.8 (FWHM)	OL	22/22 (July 28 03)
BS Pendulum	roll	18.575		OL	6
Optical Lever BS (4k)		18.6		OL	22 (July 29 03)
Seismic and magnetic peaks excited by moving Y-end crane		19		OL	18
Optic lab ventilator (?)		19.3		OL	18
Office area air handler		21.2		OL	18
Optical Lever ETMY (2k)		21.9	2.5 (FWHM)	OL	22/22 (July 24 03)
Clean room fans		22 - 27		OL	18
Unknown source--on magnetic and control signals		24			18
Optical Lever ETMX (4k)		24.1	2.5 (FWHM)	OL	22/22 (July 23 03)
Optical Lever ETMY (4k)		24.5	2 (FWHM)	OL	22/22 (July 23 03)
Optical Lever ETMX (2k)		25.1	3.4 (FWHM)	OL	22/22 (July 24 03)
Optical Lever ITMY (2k)		25.5	2.1 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ITMX (4k)		25.6	2.7 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ITMX (2k)		25.4	9(FWHM)	OL	22/22 (July 28 03)
Optical Lever ITMX (2k)		26.9	1.6(FWHM)	OL	22/22 (July 28 03)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Optical Lever ETMY (2k)		27.2	1.8(FWHM)	OL	22/22 (July 24 03)
Optical Lever ETMX (2k)		27.5	2.9(FWHM)	OL	22/22 (July 24 03)
Optical Lever ITMY (4k)		27.9	1.5 (FWHM)	OL	22/22 (July 23 03)
Optical Lever ITMY (2k)		28	2.4(FWHM)	OL	22/22 (July 25 03)
Optical Lever ETMY (4k)		28	2.5 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ETMX (4k)		29.6	2 (FWHM)	OL	22/22 (July 23 03)
LVEA Air Handling System		30		OL	18
Kobelco purge air compressor (pump)		30		OL	18
Culligan water conditioner		30		OL	18
Office area air handler (fan motor)		30		OL	18
Office area air handler		31.8		OL	18
Office area air handler belt harmonic		32		OL	18
Optical Lever FMY (2k)		32.4		OL	22 July 28 03
Optical Lever FMX (2k)		34.5	1.8 (FWHM)	OL	22/22 July 25 03)
Optical Lever ITMY (2k)		34.9	1.4 (FWHM)	OL	22/22 (July 25 03)
Office area air handler (fan)		35		OL	18
Optical Lever ITMY (4k)		35.2	1.6 (FWHM)	OL	22 /22 July 23 03
Optical Lever ITMX (2k)		35.6	1.6 (FWHM)	OL	22/22 (July 28 03)
Optical Lever BS (2k)		36	1.4 (FWHM)	OL	22/22 (July 24 03)
Optical Lever RM (4k)		37.4		OL	22 (July 23 03)
Optical Lever BS (2k)		39.9	1.6 (FWHM)	OL	22/22 (July 24 03)
Power supply for optical levers		40 - 47		OL	18
4k PSL table leg		40		OL	18



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Optical Lever ITMY (4k)		41.9		OL	22 (July 23 03)
Office area air handler		42.4		OL	18
Optical Lever ETMX (4k)		45.1		OL	22 (July 23 03)
Optical Lever ETMY (2k)		47.7	2.4 (FWHM)	OL	22/22 (July 24 03)
Optical Lever ITMX (4k)		47.5		OL	22 (July 25 03)
Optical Lever ITMY (2k)		48.4	1.6 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ETMY (4k)		51	3 (FWHM)	OL	22 /22 (July 23 03)
Optical Lever ITMY (2k)		52.6	2.5 (FWHM)	OL	22/22 (July 25 03)
4k PSL table leg		54		OL	18
Optical Lever ETMY (2k)		54.1		OL	22 (July 24 03)
LVEA chiller pad air compressor		55		OL	18
4k PSL periscope		55 - 65		OL	18
LVEA pad water chiller compressors (12 compressors)		57 - 60		OL	18
Main water chiller (main pumps)		57.5		OL	18
Culligan water conditioner		58.5		OL	18
Main water chiller (fan motors & compressors)		59		OL	18
Kobelco purge air compressor (mech. room)		59		OL	18
Edwards turbo backing pump		59		OL	18
Optical Lever ETMY (4k)		63.5	3 (FWHM)	OL	22/22 (July 23 03)
Office area air handler		63.6		OL	18
Optical Lever ETMX (2k)		66.5	2.4 (FWHM)	OL	22/22 (July 24 03)



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Optical Lever ETMX (4k)		69.5	3 (FWHM)	OL	22/22 (July 23 03)
Gateway monitor		69.9		OL	18
Chiller pad air compressor		72		OL	18
Optical Lever FMX (2k)		81	2.3 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ETMY (2k)		92.6	2.4 (FWHM)	OL	22/22 (July 24 03)
Optical Lever ETMX (4k)		94.6	3 (FWHM)	OL	22/22 (July 23 03)
Possibly power supply for optical lever lasers		98.7		OL	18
Optical Lever MMT3(4k)		88.5	<.1 (FWHM)	OL	22/22 (July 24 03)
Magnetic field at vault		100		OL	18
Optical Lever ETMX (2k)		105.1	2.6 (FWHM)	OL	22/22 (July 24 03)
Optical Lever BS (4k)		100.7	2 (FWHM)	OL	22/22 (July 29 03)
Optical Lever ETMY (4k)		107.5	2 (FWHM)	OL	22/22 (July 23 03)
Dust monitors		133		OL	18
Optical Lever RM (4k)		133		OL	22 (July 24 03)
Optical Lever MMT3 (2k)		136.6	2.3 (FWHM)	OL	22/22 (July 28 03)
Optical Lever FMY (2k)		138.7	12.1 (FWHM)	OL	22/22 (July 28 03)
Optical Lever ETMX (4k)		139.8	1.6 (FWHM)	OL	22/22 (July 23 03)
Optical Lever MMT3 (4k)		143	7 (FWHM)	OL	22/22 (July 24 03)
Optical Lever MMT3 (2k)		144.4		OL	22 (July 25 03)
Optical Lever ETMX (4k)		146.1		OL	22 (July 23 03)
Optical Lever RM (2k)		147.9	4 (FWHM)	OL	22/22 (July 28 03)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Optical Lever BS (2k)		151.5	2.1 (FWHM)	OL	22/22 (July 24 03)
Optical Lever RM (2k)		152.6	2.5 (FWHM)	OL	22/22 (July 25 03)
Optical Lever BS (2k)		152.6	2.5 (FWHM)	OL	22/22 (July 24 03)
Optical Lever BS (4k)		153	2 (FWHM)	OL	22/22 (July 29 03)
Optical Lever ITMX (4k)		154	5 (FWHM)	OL	22/22 (July 25 03)
SO Suspension Support Structure		156		P	15
Optical Lever FMY (2k)		159.3	6.1 (FWHM)	OL	22/22 (July 28 03)
Optical Lever RM (2k)		160.4	2.1 (FWHM)	OL	22/22 (July 25 03)
Optical Lever ETMX (2k)		169.2	1.9 (FWHM)	OL	22/22 (July 24 03)
Optical Lever ETMX (4k)		170.5	1.7 (FWHM)	OL	22/22 (July 23 03)
Optical Lever ITMX (4k)		185.6		OL	22 (Aug 4 03)
Optical Lever ETMY (2k)		196.6		OL	22 (July 24 03)
Optical Lever ETMY (4k)		200.5	2 (FWHM)	OL	22/22 (July 23 03)
Periscope Structure IOO	f1	203		C	16
Optical Lever ITMX (2k)		211.8	1.1 (FWHM)	OL	22/22 (July 28 03)
Optical Lever MMT3 (2k)		218		OL	22 (July 25 03)
Optical Lever BS (4k)		218.3	2 (FWHM)	OL	22/22 (July 29 03)
Optical Lever RM (2k)		219.5	1.4 (FWHM)	OL	22/22 (July 28 03)
Optical Lever MMT3 (4k)		221	1 (FWHM)	OL	22/22 (July 24 03)
BS Pendulum	violin	223		C	3
Optical Lever MMT3 (2k)		233		OL	22 (July 25 03)
HAM Table	f1	250		C	11
Reference cavity periscope		255		OL	18



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Turbo pump power supply		255		OL	18
PSL periscope at laser (main beam)		256		OL	18
E. O. power supply fan		256		OL	18
Dust monitors		266		OL	18
Optical Lever ITMY (4k)		266.3	1.3 (FWHM)	OL	22/22 (July 23 03)
IOptical Lever ITMY (2k)		266.4		OL	22 (July 25 03)
Optical Lever ITMY (4k)		269.1	1.8 (FWHM)	OL	22/22 (July 23 03)
Optical Lever ITMY (2k)		269.1	1.4 (FWHM)	OL	22/22 (July 25 03)
Optical Lever MMT3 (2k)		295		OL	22/22 (July 25 03)
Periscope Structure IOO	f2	301		C	16
Optical Lever ITMY (4k)		313.9	1.6 (FWHM)	OL	22/22 (July 23 03)
Periscope Structure IOO	f3	317		C	16
4k PSL periscope mirror support		320		OL	18
Optical Lever BS (4k)		328	1 (FWHM)	OL	22/22 (July 29 03)
RM Pendulum (2k)	violin	334		C	3
RM Pendulum (2k)	violin	335		LHL	3
ETM Pendulum	violin	336		C	3
FM Pendulum	violin	336		LHL	3
ITM Pendulum (4k)	violin	339		C	3
ITM Pendulum (2k)	violin	341		C	3
HAM Table	f2	342		C	11
ETMX Internal (2k)		342.82	$>4 \times 10^4$	OL	24/24
ETMX Internal (4k)		343.42	1.25×10^5	OL	24/24



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

ETMX Internal (2k)		343.81	7.8×10^4	OL	24/24
ETMX Internal (2k)		344.055	$>4 \times 10^4$	OL	24/24
ETMX Internal (4k)		344.06	1.25×10^5	OL	24/24
Optical Lever ITMX (2k)		345.6	2.7 (FWHM)	OL	22/22 (July 28 03)
ITMX Internal (4k)		347.17		OL	24
ITMX Internal (4k)		347.27		OL	24
BSC Down Tube	f1	349		OL	6
ETMY Internal (2k)		349.202		OL	24/24
Optical Lever MMT3 (2k)		351.7		OL	22 (July 25 03)
BSC DownTube	f2	360		OL	6
ETM Pendulum	violin	365.5		OL	6
BSC Down Tube	f3	370		C	11
BSC Down Tube	f4	376		OL	6
Optical Lever MMT3 (2k)		383.4		OL	22 (July 25 03)
4k PSL periscope mirror support		390		OL	18
Electronics Solutions crate power supplies		394		OL	18
HAM Table	f3	397		C	11
BSC Down Tube	f5	399		OL	6
Optical Lever ITMY (2k)		405.1		OL	22 (July 25 03)
BSC Down Tube	f6	420		OL	6
Optical Lever FMY (2k)		424.4	6.9 (FWHM)	OL	22/22 (July 28 03)
Optical Lever MMT3 (2k)		424.7		OL	22 (July 25 03)



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

BSC Down Tube	f7	441		C	11
HAM Table	f4	457		C	11
Optical Lever ETMY (4k)		477	1 (FWHM)	OL	22/22 (July 23 03)
BSC Down Tube	f10	478		C	11
Optical Lever MMT3 (2k)		490		OL	22 (July 25 03)
Dust monitors		510 - 550		OL	18
BSC Down Tube	f11	556		C	11
HAM Table	f6	559		C	11
BSC Down Tube	f12	560		C	11
BSC Down Tube	f13	583		C	11
HAM Table	f7	584		C	11
HAM Table	f8	584		C	11
HAM Table	f9	596		C	11
BSC Down Tube	f14	611		C	11
BSC Down Tube	f15	615		C	11
HAM Table	f10		615	C	11
HAM Table	f11		622	C	11
HAM Table	f12		622	C	11
HAM Table	f13		623	C	11
HAM Table	f14		628	C	11
HAM Table	f15		639	C	11
HAM Table	f16		643	C	11
HAM Table	f17		645	C	11



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

HAM Table	f18	654		C	11
Periscope Structure IOO	f4	659		C	16
Optical Lever FMY (2k)		679.3	7 (FWHM)	OL	22/22 (July 28 03)
BSC Down Tube	f16	683		C	11
BSC Down Tube	f17	690		C	11
BSC Down Tube	f18	702		C	11
SO Pendulum (2k)	violin1	708.3	2.2×10^5	P	13/13
Periscope Structure IOO	f5	748		C	16
Periscope Structure IOO	f6	820		C	16
SO Pendulum (2k)	violin2	1416.34	6.7×10^5	P	13/13
BS Internal (4k)	butterfly	3731.92		OL	24
BS Internal (2k)	Butterfly	3733.7	1.85×10^6	OL	2/2
BS Internal (2k)	Drumhead	5477.5	2.50×10^4	OL	2/2
BS Internal (4k)	drumhead	5478.34		OL	24
Pre-mode cleaner body modes		6000 - 8000		OL	18
ETMX Internal (4k)	butterfly	6615.38		OL	24
ETMx Internal (2k)	butterfly	6639.00	3×10^6	OL	24/24
ITMy Internal (2k)	butterfly (mode 7)	6746.625	1×10^6	OL	24/24
ITMy Internal (2k)	butterfly (mode 8)	6746.992	1.77×10^6	OL	24/24
ITMx Internal (2k)	butterfly (mode 7)	6749.188	1.75×10^6	OL	24/24
ITMx Internal (2k)	butterfly (mode 8)	6749.719	7.74×10^5	OL	24/24
BS Internal (4k)	3 fold radial	7802.25		OL	24
BS Internal (2k)	3 fold radial	7812	2.65×10^5	OL	2/2



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

ETMx Internal (2k)	drum head	9200.00	1×10^5	OL	24/24
ETMX Internal (4k)	drumhead	9222.5		OL	24
ITMy Internal (2k)	drum head (mode 9)	9388.932	2.3×10^5	OL	24/24
ITMx Internal (2k)	drum head (mode 9)	9394.718	6.74×10^5	OL	24/24
SO Dumbbell Assembly		9700	130	C	15/15
BS Internal (4k)		11133.76		OL	24
BS Internal (4k)		11134.39		OL	24
BS Internal (2k)		11138.7	3.60×10^5		2/2
ETMX Internal (4k)		11195		OL	24
ITMy Internal (2k)	mode 10	11202.516	6.3×10^5	OL	24/24
ITMx Internal (2k)	mode 10	11203.500	4.66×10^6	OL	24/24
ETM Internal	f4	11217		C	4
ETM Internal	f5	11217		C	4
BS Internal	f4	11259		C	1
BS Internal	f5	11332		C	1
BS Internal	f6	11334		C	1
ETM Internal	f6	12056		C	4
ETM Internal	f7	12057		C	4
ETMX Internal (4k)		12184		OL	24
ITMy Internal (2k)	mode 14	12545.640	1.5×10^6	OL	24/24
ITMy Internal (2k)	mode 15	12546.391	1.4×10^6	OL	24/24
ITMx Internal (2k)	mode 14	12546.788	7.80×10^4	OL	24/24
ITMx Internal (2k)	mode 15	12547.828	2.03×10^5	OL	24/24



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

BS Internal	f7	12674		C	1
BS Internal	f8	12677		C	1
BS Internal	f9	12760		C	1
ETM Internal	f8	12941		C	4
ETM Internal	f9	12943		C	1
ITMy Internal (2k)	breathing (mode 16)	14370.159	6.7×10^6	OL	24/24
ITMx Internal (2k)	breathing	14373.750	1.34×10^7	OL	24/24
ETMx Internal (2k)	longitudinal	14374.00	8×10^6	OL	24/24
BS Internal	f10	14629		C	1
BS Internal	f11	17283		C	1
BS Internal	f12	17388		C	1
BS Internal	f13	17958		C	1
ITMy Internal (2k)	2nd drumhead (mode 32)	22317.203	8.6×10^6	OL	24/24
ITMx Internal (2k)	2nd drumhead (mode 32)	22321.359	2.34×10^6	OL	24/24
SO Internal (2k)	f1	201519.4	4.9×10^5	P	14/14
SO Internal (2k)	f2	20185.83	2.7×10^5	P	14/14
SO Internal (2k)	MC1 Drumhead	28227.00	9.4×10^4	OL	24/24
SO Internal (2k)	MC2 Drumhead	28197.20	6.7×10^4	OL	24/24
SO Internal (2k)	MC3 Drumhead	28233	1.3×10^6	OL	24/24
SO Internal (2k)	3 Drumhead	28405.2	3.1×10^5	P	14/14
SO Internal (2k)	f4	37977.2	2.4×10^5	P	14/14
SO Internal (2k)	f5	37994.9	2.4×10^5	P	14/14



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II. Summary of Mechanical Resonances in the LIGO Livingston Interferometer

Use the quick links to go directly to the desired mirror.

[Beamsplitter](#), [Recycling Mirror](#), [ITMX](#), [ITMY](#), [ETMX](#), [ETMY](#), [MMT3](#), [LOS Violin Modes](#), [MC1](#), [MC2](#), [MC3](#), [MMT1](#), [MMT2](#), [Steering Mirror](#), [Small Optics Internal Modes](#)

Large Optics Resonances

Beamsplitter Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
in-beam pendular	0.744	0.764	-	-
sideways pendular	-	0.732	-	-
pitch	0.600	0.625	-	-
yaw	0.500	0.502	-	-
vertical(bounce)	~12.8	12.58	-	-
roll	~18.1	18.59	-	-
violin	223	-	-	-
butterfly	-	3726.382	-	>10 ⁶



Recycling Mirror Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	0.741	0.760	-	-
pitch	0.600	0.627	-	-
yaw	0.501	0.508	-	-
side	-	0.728	-	-
vertical(bounce)	12.86	12.38	-	-
roll	18.18	16.00	-	-
violin	334	335.4	-	-

Intermediate Test Mass X Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	0.743	0.760	-	-
pitch	0.600	0.625	-	-
yaw	0.499	0.502	-	-
side	-	0.730	-	-
vertical(bounce)	12.72	11.87	-	-



violin	339	346.656	-	7771
roll	18.18	-	-	-

ITMX Internal Modes

Mode Number	Frequency (Hz)	Q
7	6695.878	4.15*10 ⁵
8	6696.281	4.57*10 ⁵
9	9327.594	9.13*10 ⁵
10	11200.656	6.41*10 ⁶
14	12545.938	6.07*10 ⁶
16	14372.938	1.24*10 ⁷
17	15055.513	6.85*10 ⁶
18	15055.969	6.34*10 ⁶
19	17118.406	1.09*10 ⁷
20	17119.344	1.82*10 ⁶
32	22343.031	1.762*10 ⁶

Intermediate Test Mass Y Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
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pendular	0.743	0.760	-	-
pitch	0.600	0.615	-	-
yaw	0.499	0.504	-	-
side	-	0.732	-	-
vertical(bounce)	12.72	11.89	-	-
violin	339	-	-	-
butterfly(I)	-	6640.275	-	$3.1 \cdot 10^6$
butterfly(II)	-	6640.726	-	$1.10 \cdot 10^6$
roll	18.18	-	-	-

ITMY Internal Modes

Mode Number	Frequency (Hz)	Q
9	9326.67	$9.86 \cdot 10^5$
16	14368.666	$5.78 \cdot 10^6$

End Test Mass X Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	0.744	0.766	-	-
pitch	0.600	0.625	-	-
yaw	0.500	0.498	-	-



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side	-	0.732	-	-
vertical(bounce)	12.85	12.01	-	-
violin	336	343.656	-	3593
butterfly(I)	-	6648.05	-	-
butterfly(II)	-	6648.62	-	-
roll	18.18	-	-	-

ETMX Internal Modes

Mode Number	Frequency (Hz)	Q
-	9264.75	3*10 ⁵

End Test Mass Y Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	0.744	0.756	-	-
pitch	0.600	0.678	-	-
yaw	0.500	0.490	-	-
side	-	0.730	-	-
vertical(bounce)	12.85	12.03	-	-
violin	336	-	-	-
butterfly(I)	-	6640.13	-	2.34*10 ⁶



butterfly(II)	-	6640.58	-	8.79*10 ⁵
roll	18.18	-	-	-

ETMY Internal Modes

Mode Number	Frequency (Hz)	Q
-	6640.8125	8*10 ⁵
-	6640.375	3*10 ⁶
-	9356.5	7*10 ⁵
-	14376.5625	6*10 ⁶

MMT3 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	-	0.762	-	-
pitch	-	0.627	-	-
yaw	-	0.506	-	-
side	-	0.732	-	-
vertical(bounce)	-	12.32	-	-
violin	-	-	-	-
roll	18.18	-	-	-



Large Optics Violin Mode Frequencies

Optic	measured frequency (Hz)
-	343.065
-	343.481
-	343.653
-	344.421
-	346.650
-	346.926
-	346.974
-	347.041

Small Optics Resonances

MC1 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.981	-	4000
pitch	0.75	0.802	-	2400
yaw	0.85	0.837	-	2000



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side	1.00	0.996	-	8700
vertical(bounce)	16.0	16.296	-	-
violin(I)	-	708.30	-	2.2×10^5
violin(II)	-	1416.34	-	1.3×10^6
drumhead	-	28166	-	1.82×10^5
roll	$2^{(1/2)} \times \text{bounce} \sim 22.6$	23.046	-	-

MC2 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.976	-	4000
pitch	0.75	0.735	-	1800
yaw	0.85	0.823	-	2200
side	1.00	0.994	-	5800
vertical(bounce)	16.0	16.255	-	-
violin(I)	-	708.30	-	2.2×10^5
violin(II)	-	1416.34	-	1.3×10^6
drumhead	-	28208	-	3.3×10^5
roll	$2^{(1/2)} \times \text{bounce} \sim 22.6$	22.988	-	-

MC3 Resonances



<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.992	-	4500
pitch	0.75	0.799	-	1300
yaw	0.85	0.858	-	1400
side	1.00	0.997	-	6800
vertical(bounce)	16.0	16.247	-	-
violin(I)	-	708.30	-	$2.2 \cdot 10^5$
violin(II)	-	1416.34	-	$1.3 \cdot 10^6$
drumhead	-	28238	-	$8.4 \cdot 10^4$
roll	$2^{1/2} \times \text{bounce} \sim 22.6$	22.977	-	-

MMT1 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.980	-	4300
pitch	0.75	0.791	-	-
yaw	0.85	0.825	-	1600
side	1.00	0.992	-	6100
vertical(bounce)	16.0	16.315	-	-



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violin(I)	-	708.30	-	2.2×10^5
violin(II)	-	1416.34	-	1.3×10^6
roll	$2^{(1/2)} \times \text{bounce} \sim 22.6$	23.073	-	-

MMT2 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.978	-	2600
pitch	0.75	0.750	-	1500
yaw	0.85	0.820	-	1000
side	1.00	0.992	-	6100
vertical(bounce)	16.0	16.00	-	-
violin(I)	-	708.30	-	2.2×10^5
violin(II)	-	1416.34	-	1.3×10^6
roll	$2^{(1/2)} \times \text{bounce} \sim 22.6$	22.6	-	-

SM1 Resonances

<i>description</i>	theoretical frequency (Hz)	measured frequency (Hz)	theoretical Q	measured Q
pendular	1.0	0.997	-	-



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Theoretical Reference: LIGO document [T000020-00-W](#) Summary of Mechanical Resonances in the LIGO Hanford Interferometers.

DTT xml of the BS, RM, ETMX, and ETMY: [SUS Resonances](#)

DTT xml of the MMT3: [MMT3 Resonance](#)

DTT xml of the small optics: [SOS Resonances](#)

DTT xml of the small optics side: [SOS Side Resonances](#)

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