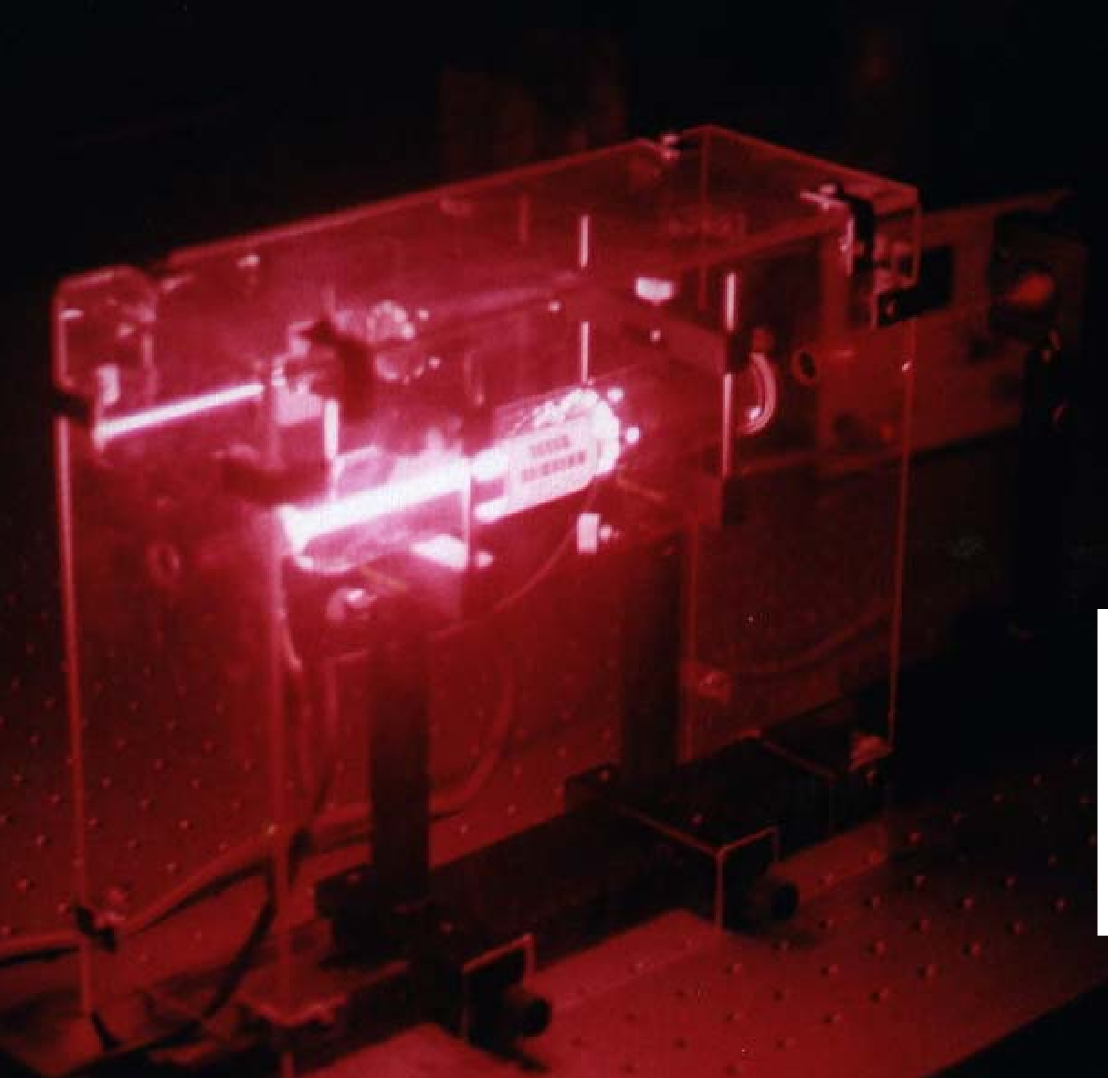
Measurements on a Variable Cavity He-Ne Laser



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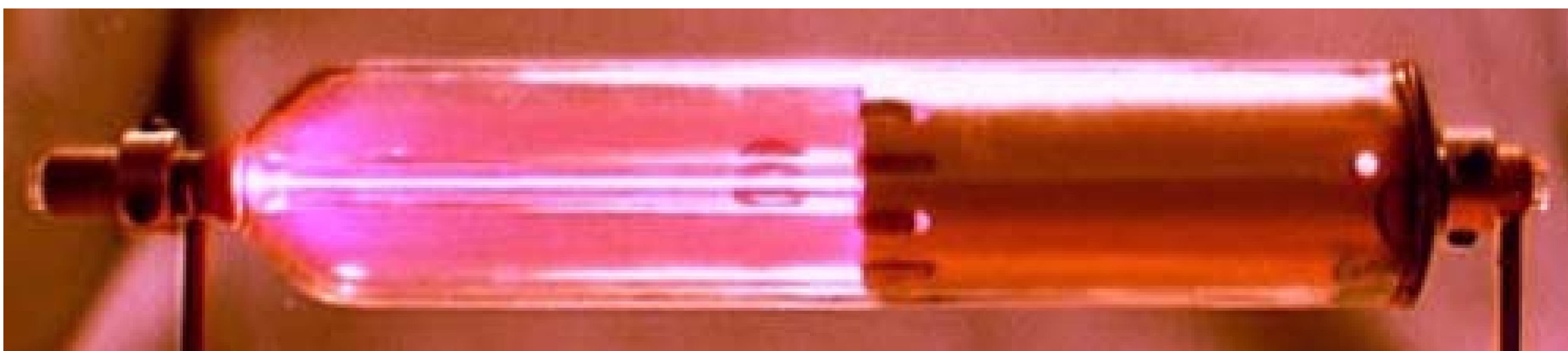
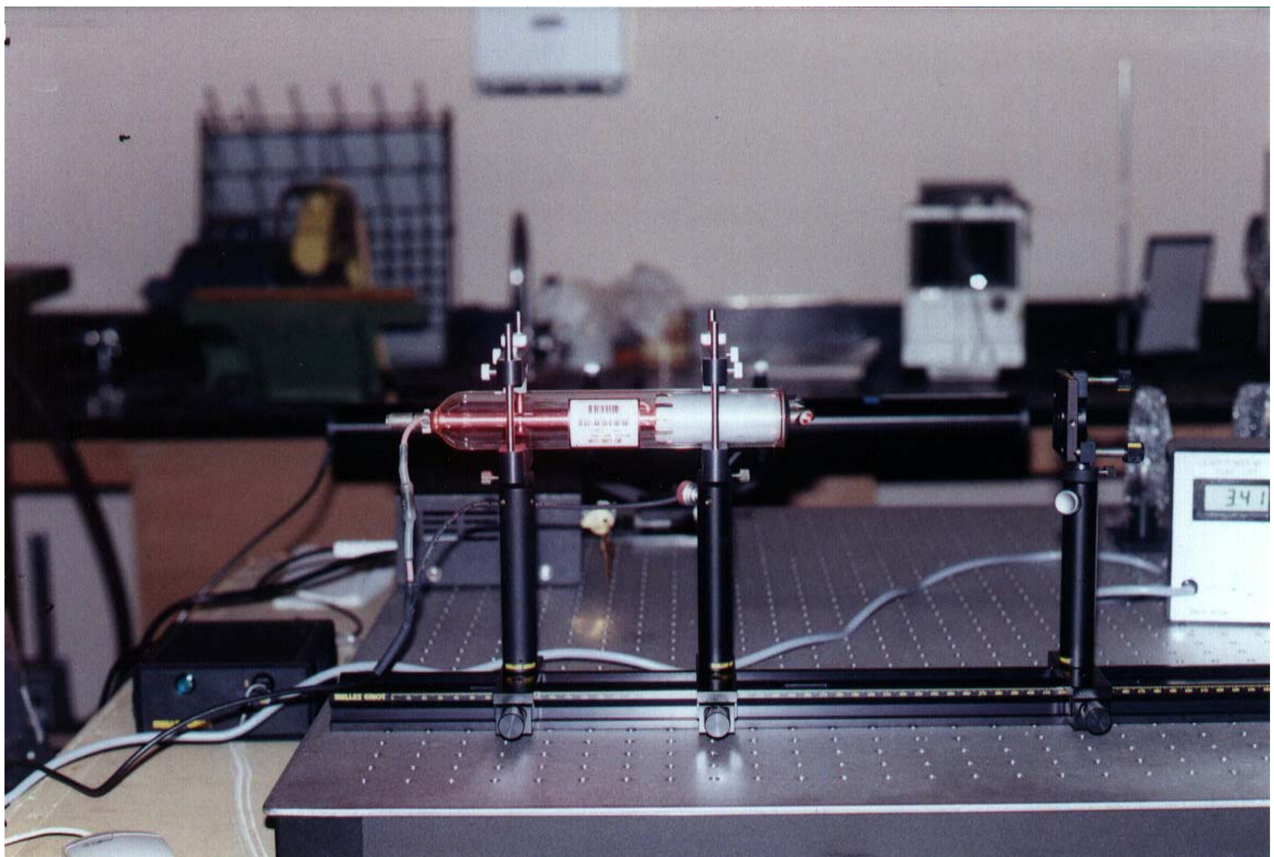
Project Purpose:

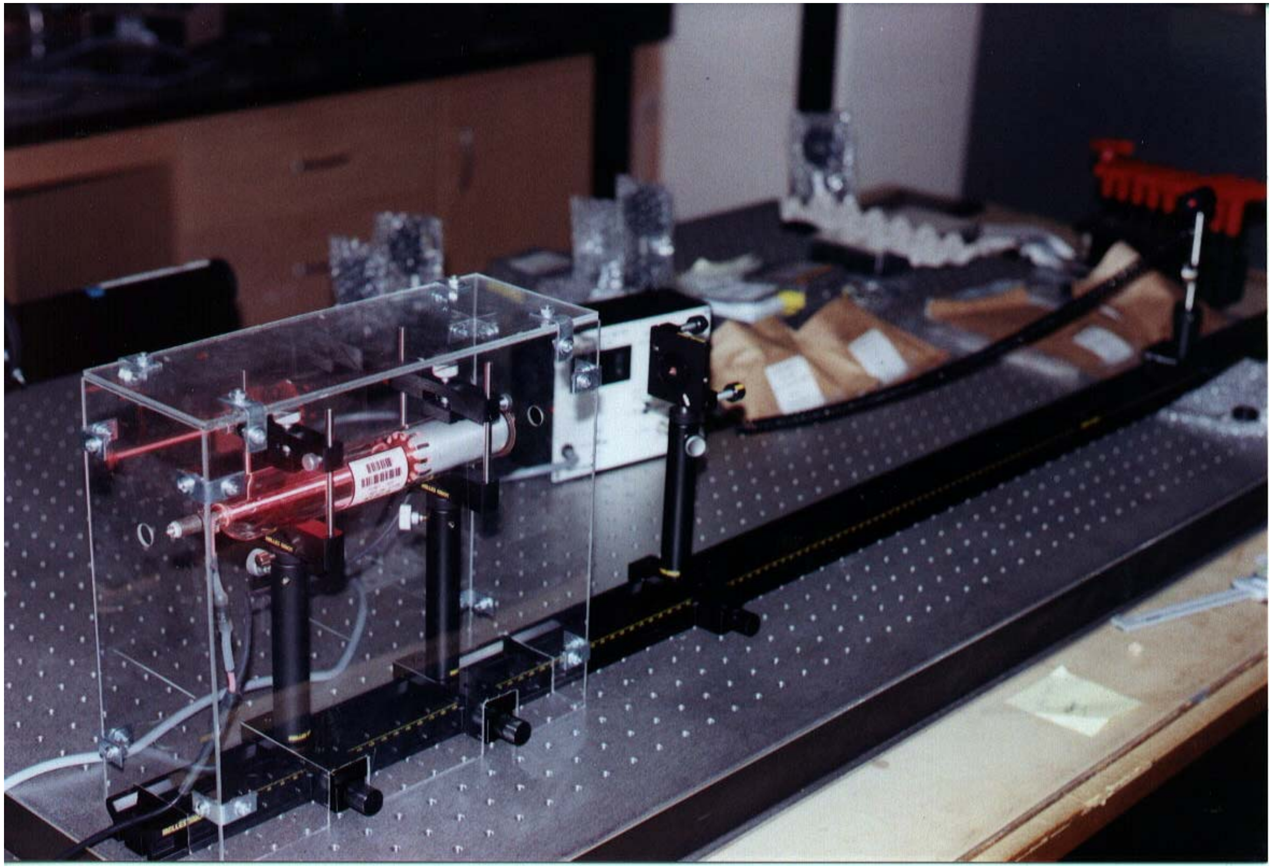
Using a variable cavity Helium-Neon laser and mirrors of various sizes, we are examining the lasing properties at different distances between the mirrors, as well as different mirror combinations. The experimental results are compared to the expected theoretical results in order to gain a better understanding of stable cavity characteristics, and any abnormalities.



Helium-Neon Laser Tube

The first step in the process involved the installation of the track, and the mounting of the laser and the mirror





Once the mirror was adjusted to produce maximum lasing, the peak output was recorded, and the mirror was moved 1 mm down the track, and readjusted. The externally mounted mirror of radius R2 was then aligned so as to induce lasing. A Plexiglas box was sub sequentially created in order to protect the fragile Helium Laser tube.

80 cm mirror	Distance from R1 (mm)	Power Output (mW)	Distance from R1 (mm)	Power Output (mW)	Distance from R1 (mm)	Power Output (mW)	Distance from R1 (mm)	Power Output (mW)
	290	2.96	561	2.76	599	1.2	679	0
R1=60cm	295	2.96	562	2.74	600	1.1	805	0
R2=80cm	310	2.97	563	2.7	601	1	806	0.02
	320	2.96	564	2.68	602	0.81	807	0.11
	330	2.97	565	2.65	603	0.65	808	0.45
	340	2.97	566	2.62	604	0.52	809	0.64
	350	2.95	567	2.6	605	0.43	810	0.73
	360	2.93	568	2.58	606	0.31	811	0.83
	370	2.91	569	2.52	607	0.26	812	0.89
	380	2.89	570	2.52	608	0.19	813	0.95
	390	2.88	571	2.51	609	0.19	814	1.03
	400	2.87	572	2.46	610	0.18	815	1.13
	420	2.89	573	2.45	611	0.19	816	1.2
	440	2.89	574	2.43	612	0.19	817	1.3
	460	2.87	575	2.41	613	0.19	818	1.38
	470	2.9	576	2.39	614	0.19	819	1.43
	475	2.91	577	2.4	615	0.19	820	1.53
	480	2.92	578	2.4	616	0.19	821	1.6
	490	2.96	579	2.4	617	0.19	822	1.67
	500	2.98	580	2.39	618	0.19	823	1.74
	505	2.99	581	2.38	619	0.19	824	1.8
	510	3.01	582	2.37	620	0.19	825	1.86
	515	3.03	583	2.34	640	0.18	826	1.9
	520	3.03	584	2.31	647	0.17	827	1.91
	525	3.01	585	2.27	650	0.17	828	1.98
	530	2.97	586	2.24	655	0.17	829	2.03
	535	2.97	587	2.21	657	0.16	830	2.05
	540	2.93	588	2.15	660	0.16	831	2.08
	545	2.92	589	2.1	665	0.14	832	2.1
	550	2.91	590	2.07	670	0.11	833	2.14
	553	2.9	591	1.97	671	0.1	834	2.21
	554	2.88	592	1.89	672	0.08	835	2.3
	555	2.87	593	1.8	673	0.07	837	2.44
	556	2.86	594	1.7	674	0.06	838	2.45
	557	2.85	595	1.64	675	0.05	839	2.34
	558	2.83	596	1.58	676	0.05	845	2.4
	559	2.81	597	1.4	677	0.03	850	2.6
	560	2.78	598	1.3	678	0.01	855	2.7
							860	2.72
							870	2.8
							880	2.76
							890	2.8
							900	2.8

Hundreds of Max power output data points were collected. Each point had to be fine tuned, therefore each mirror took many hours of adjustment to collect all the data points.

These data points are for the 80 cm radius mirror.

Stable Cavity Theory:

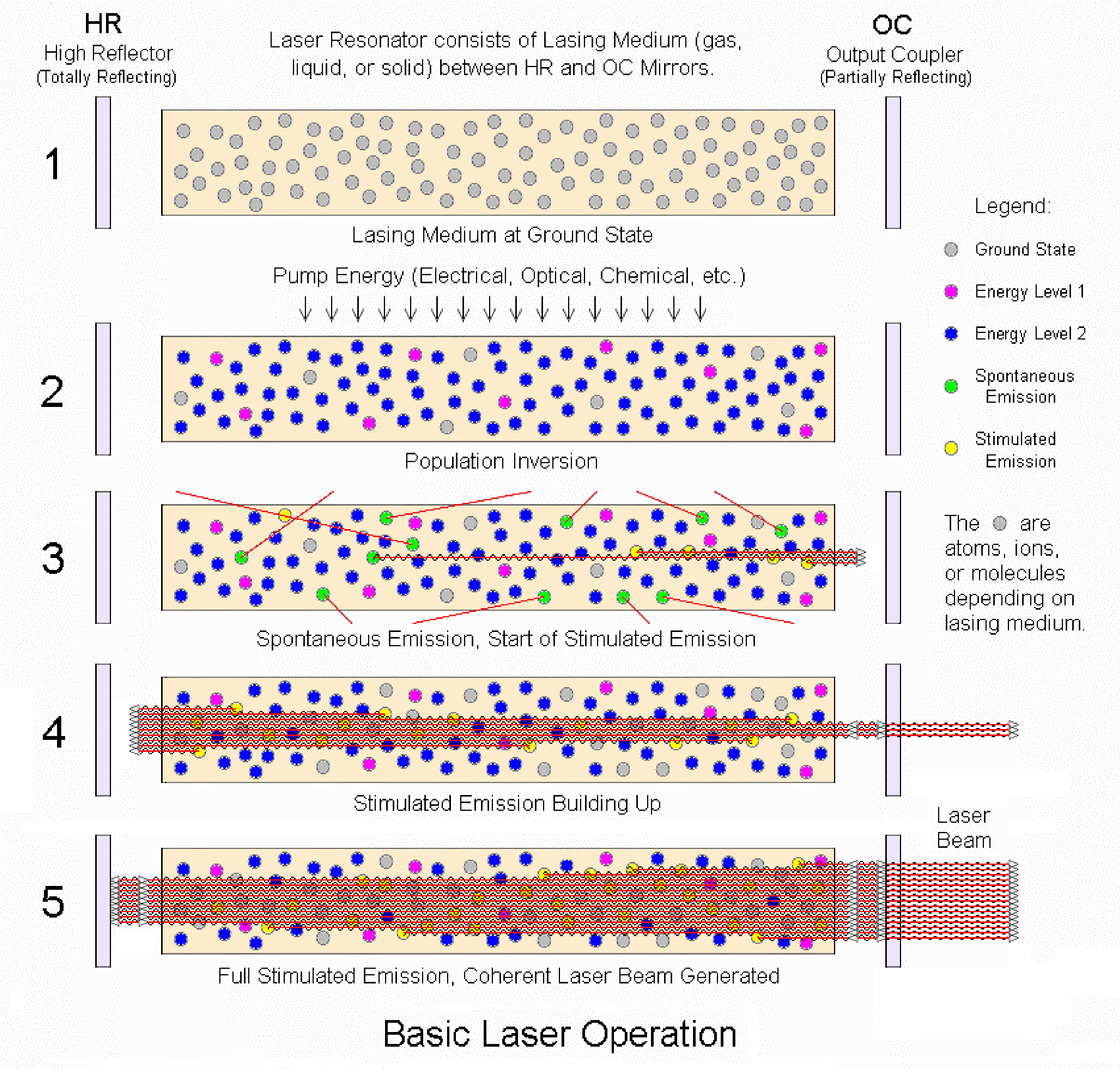
The lasing output measurements of each mirror gave an experimental value of the cavity lengths at which the cavity is stable, and the cavity is unstable.

In a *stable* cavity the ray position stays close to the optical axis, even after it has passed between the two mirrors several times. A stable-cavity environment is essential for the lasing to occur.

If the cavity is *unstable*, then the ray will naturally walk off the mirrors, and out of the cavity.

A cavity in which both mirrors must be perfectly aligned to prevent the beam from walking out is *conditionally stable*.

Basic laser operation in a stable cavity

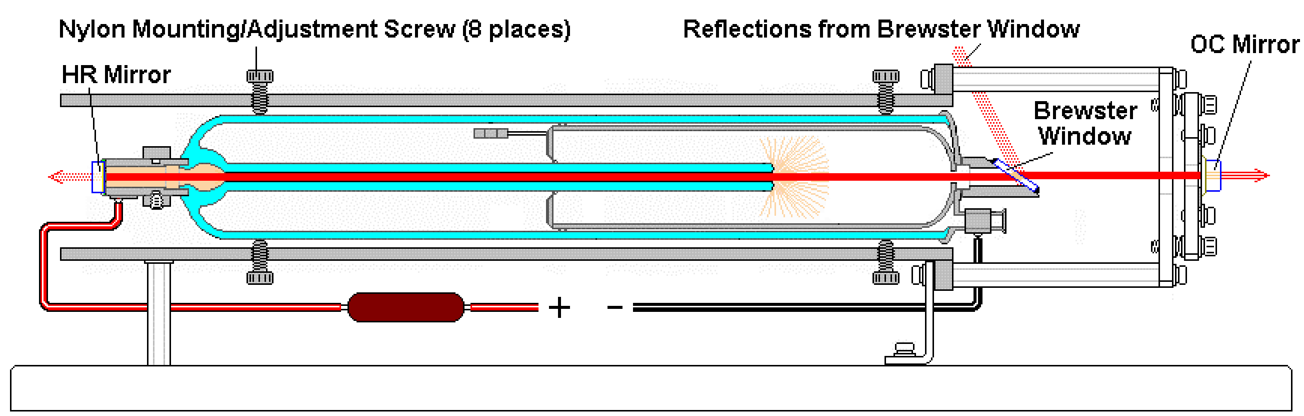


The stability of a laser cavity can be calculated mathematically by a simple set of equations:

$$0 \leq g_1 g_2 \leq 1$$

is referred to as the stability range, because this is the exact condition required for two mirrors with radius R_1 and R_2 and spacing L to form a stable cavity for emitting rays. Every two mirror optical resonator can be characterized by the parameters:

$$g1 = 1 - \frac{L}{R1} \qquad g2 = 1 - \frac{L}{R2}$$



One Brewster HeNe Laser Tube Mounted in Test Fixture

$$g1 = 1 - \frac{L}{R1} \qquad g2 = 1 - \frac{L}{R2} \qquad 0 \le g1g2 \le 1$$

$$0 \le \left[1 - \left(\frac{L}{R}\right)\right]\left[1 - \left(\frac{L}{r}\right)\right] \le 1$$

Set #1

$$0 \le \left[1 - L\left[\left(\frac{1}{R1}\right) + \left(\frac{1}{R2}\right)\right] + \frac{L^2}{R1R2}\right] \le 1$$

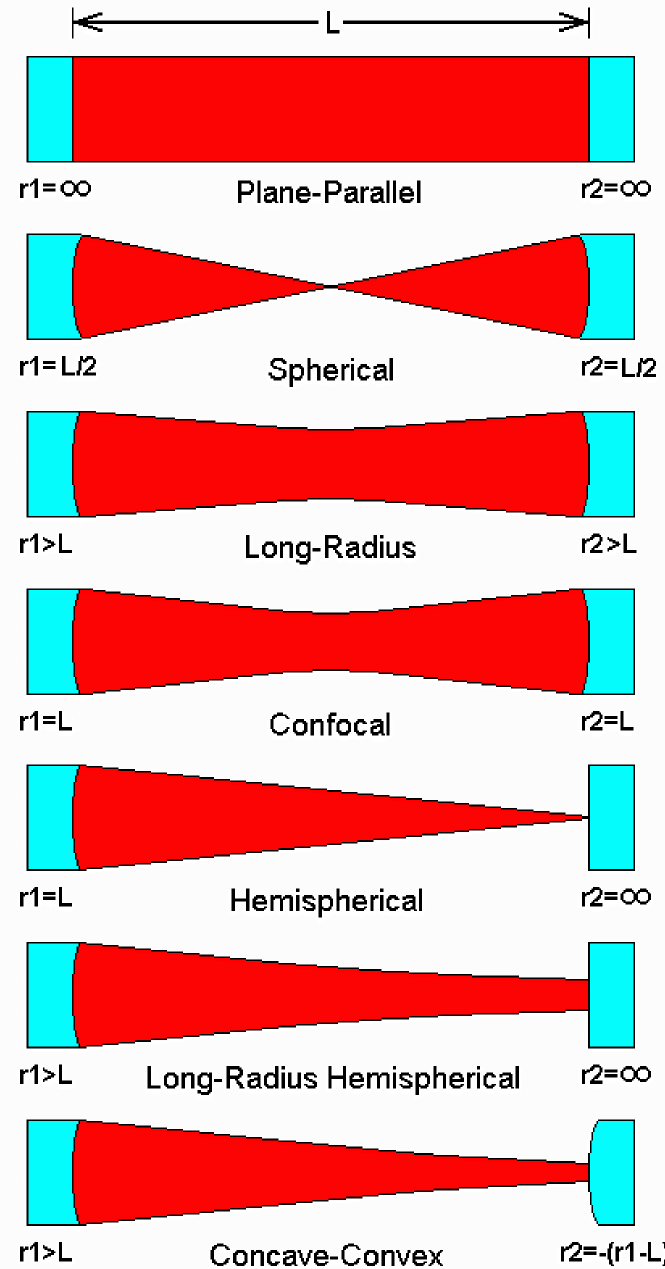
Set #2

Set #1 concludes that: $L \le (R1 + R2)$

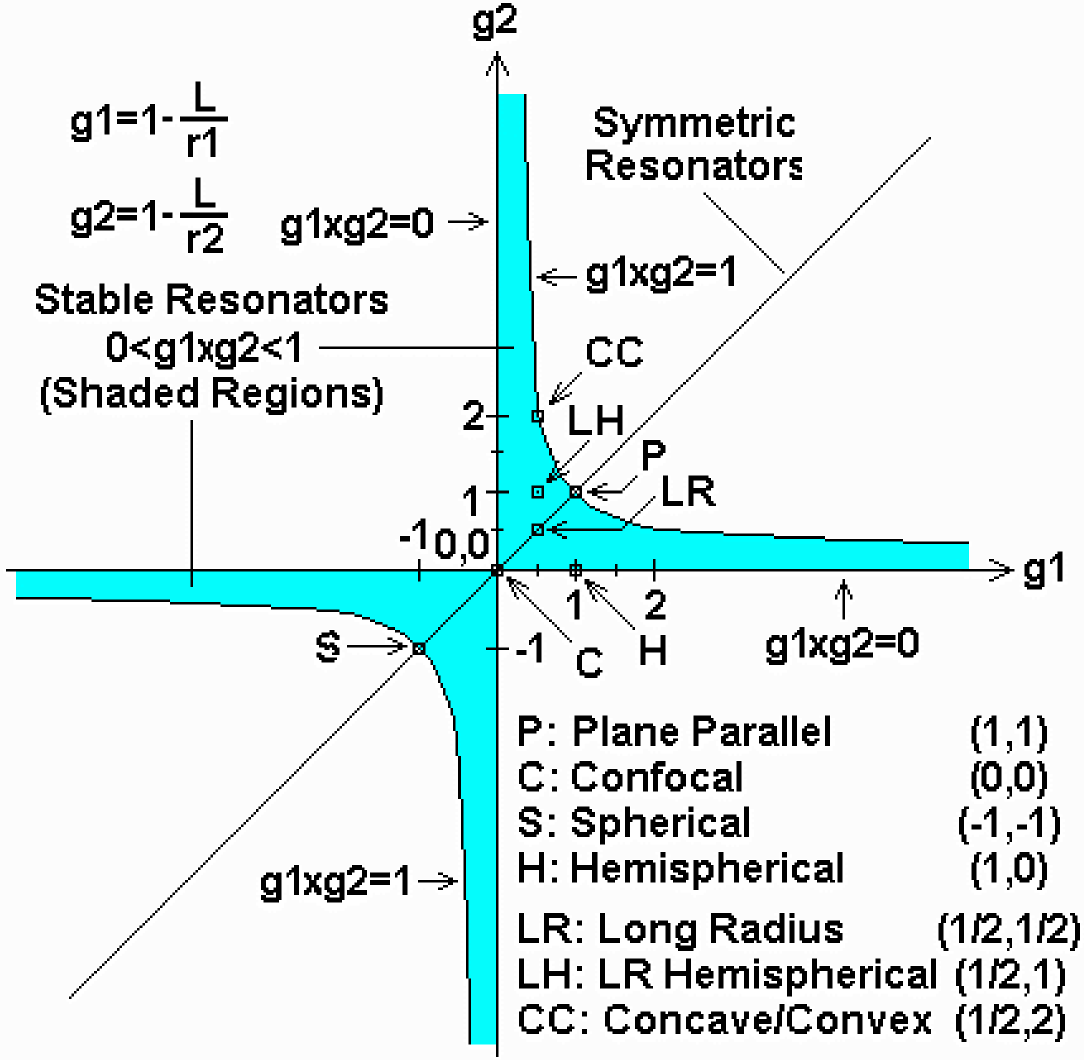
Set #2 concludes that: $(L \ge R1)$ and $(L \ge R2)$

Concluding from the first and second set:
Either:

$R1, R2 \le L \le (R1 + R2)$ or $L \le (R1 + R2)$ and $(R1 \text{ and } R2)$

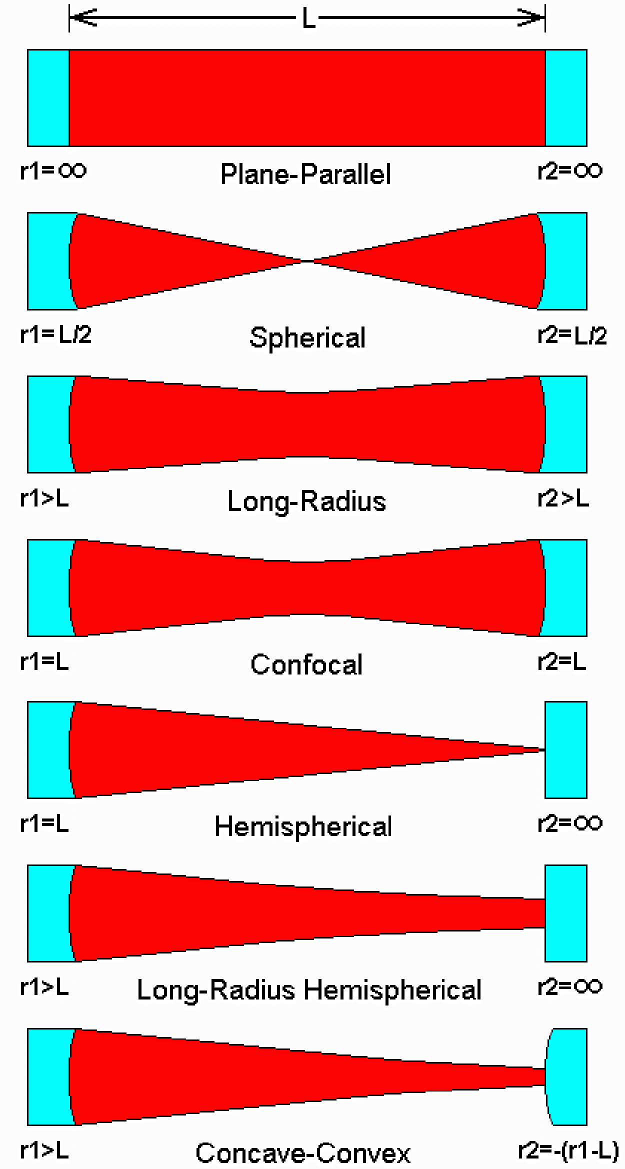


Common Laser Resonator Configurations



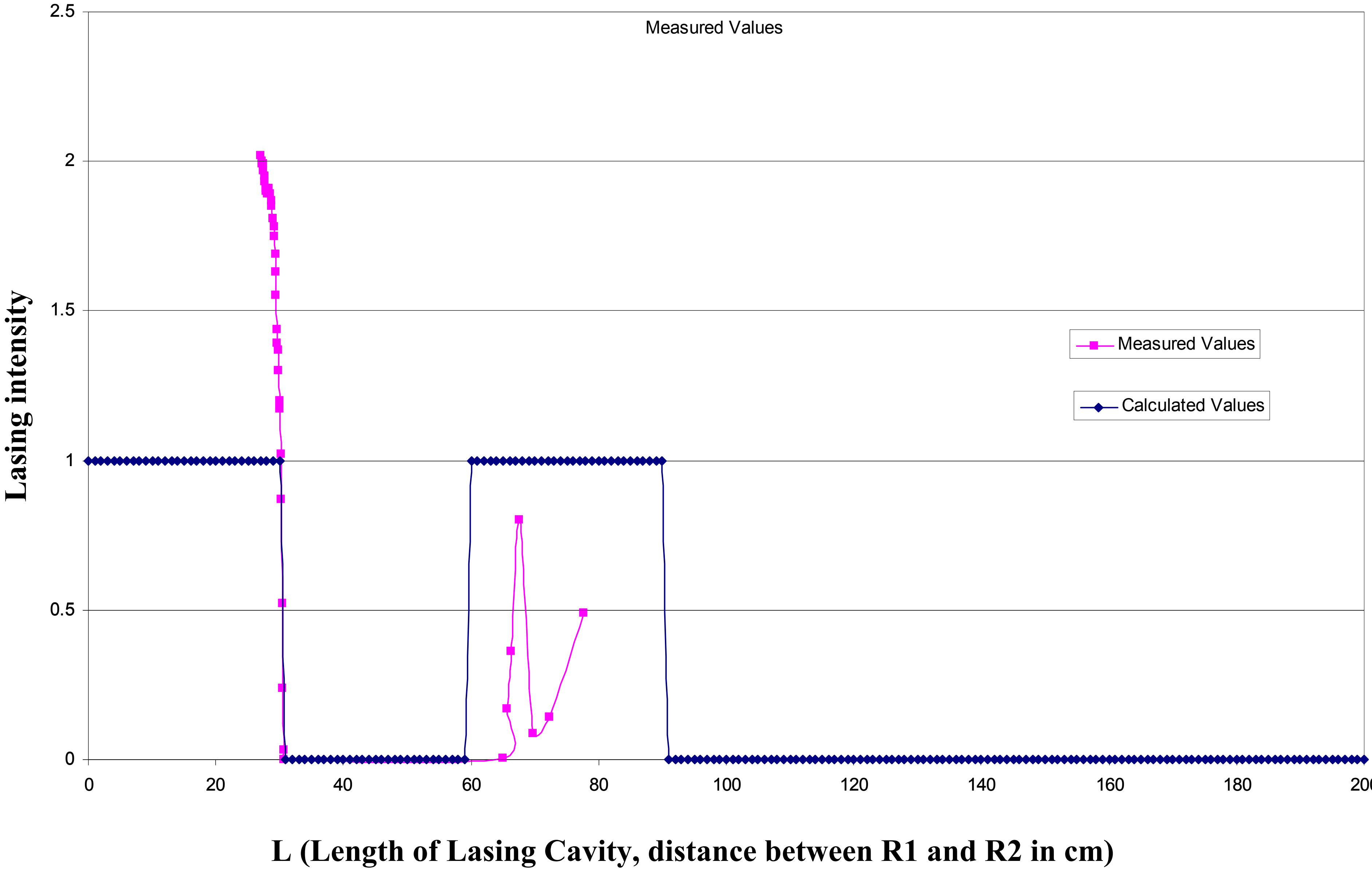
(LR,LH,CC typical; H,LH,CC with r1/r2 swapped not shown)

Laser Resonator Stability Diagram

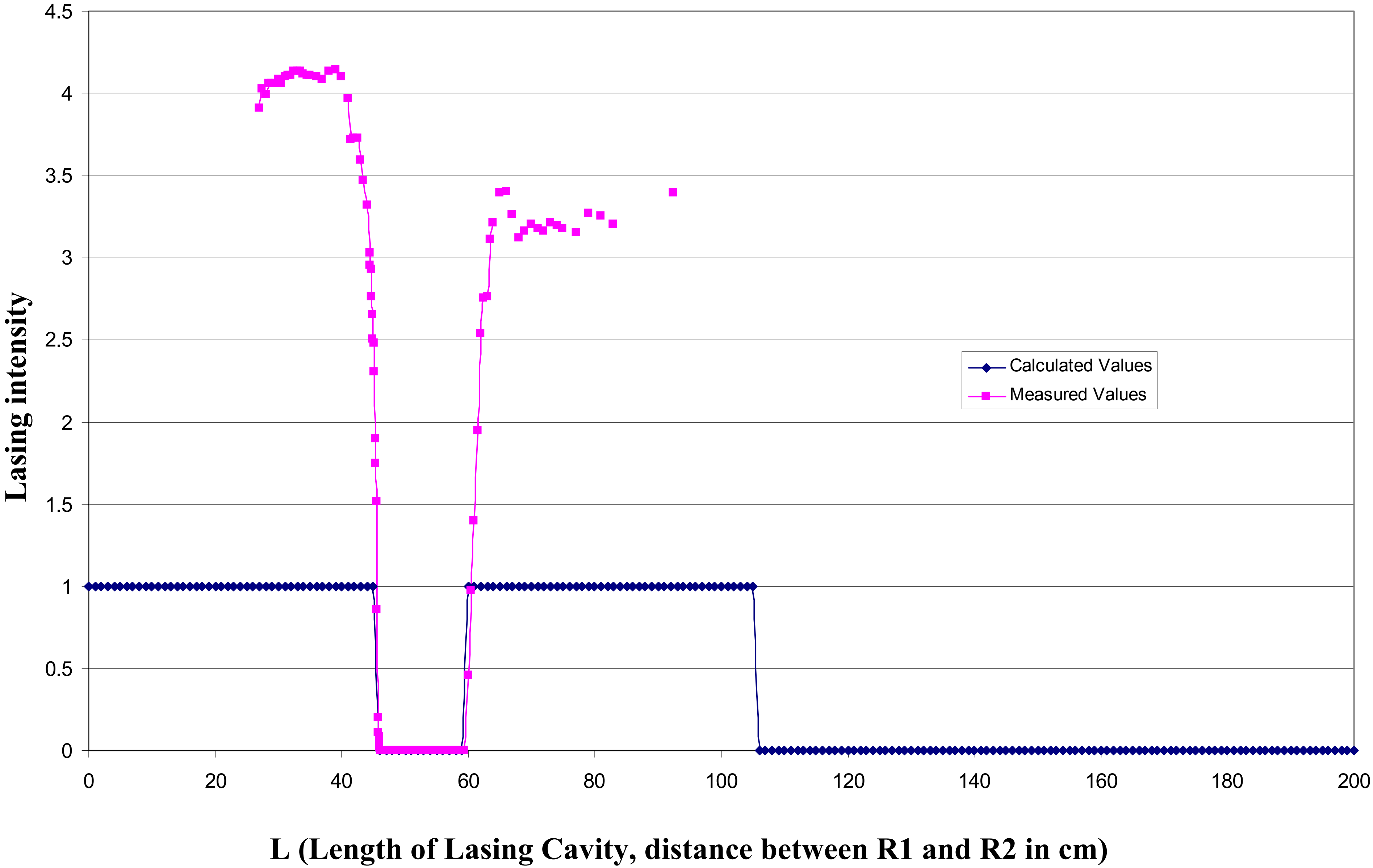


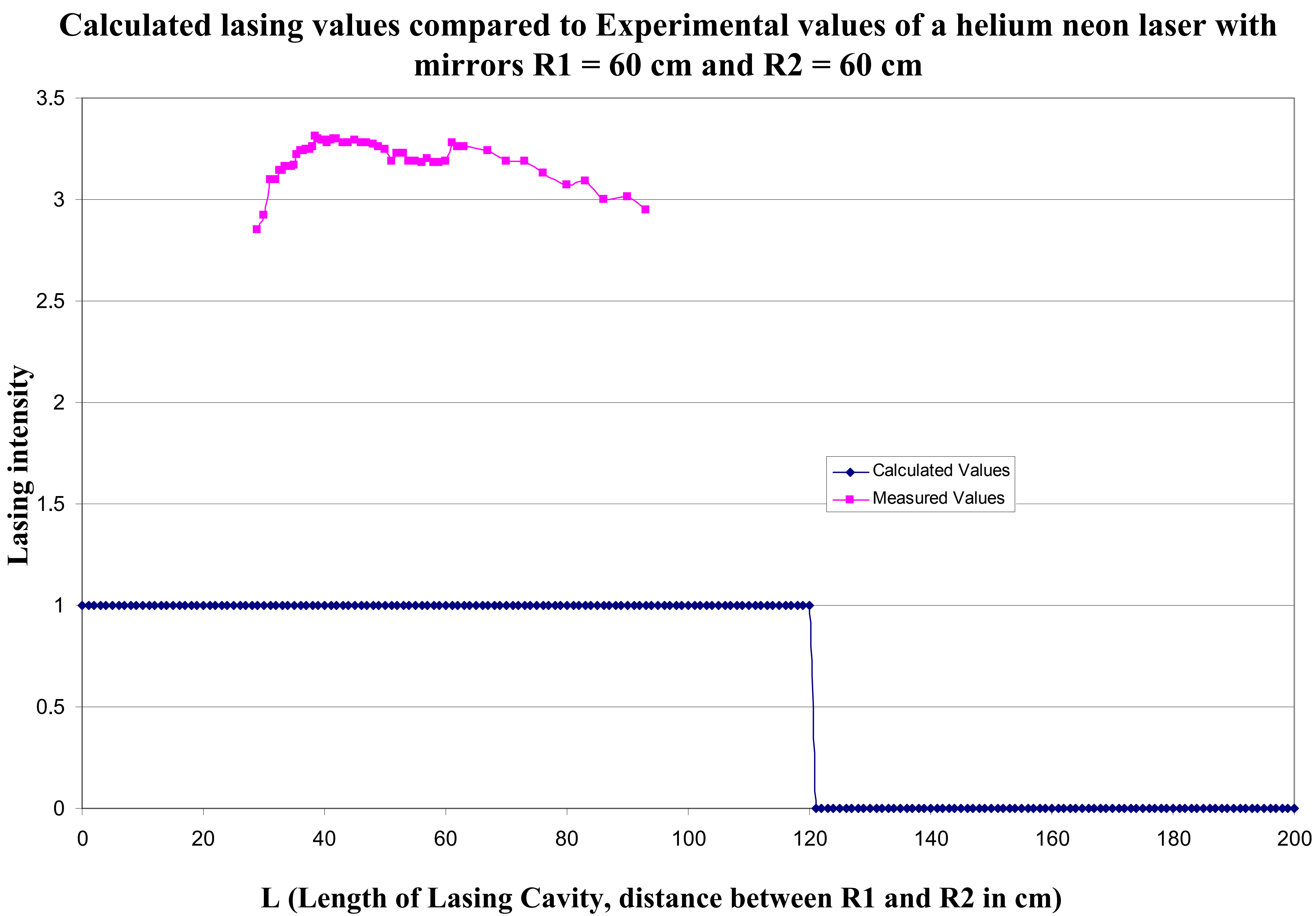
Common Laser Resonator Configurations

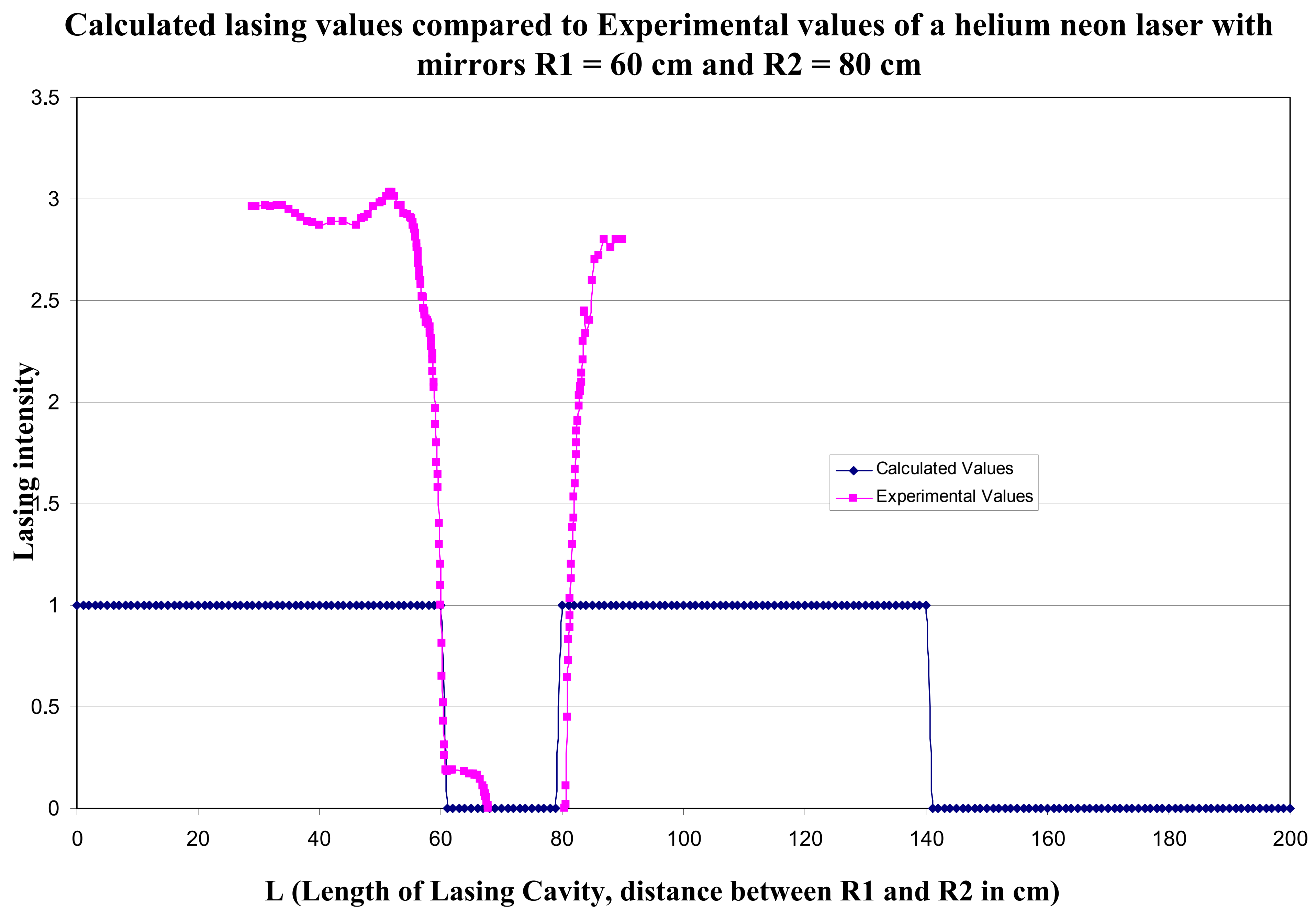
Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = 30 cm



Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = 45 cm

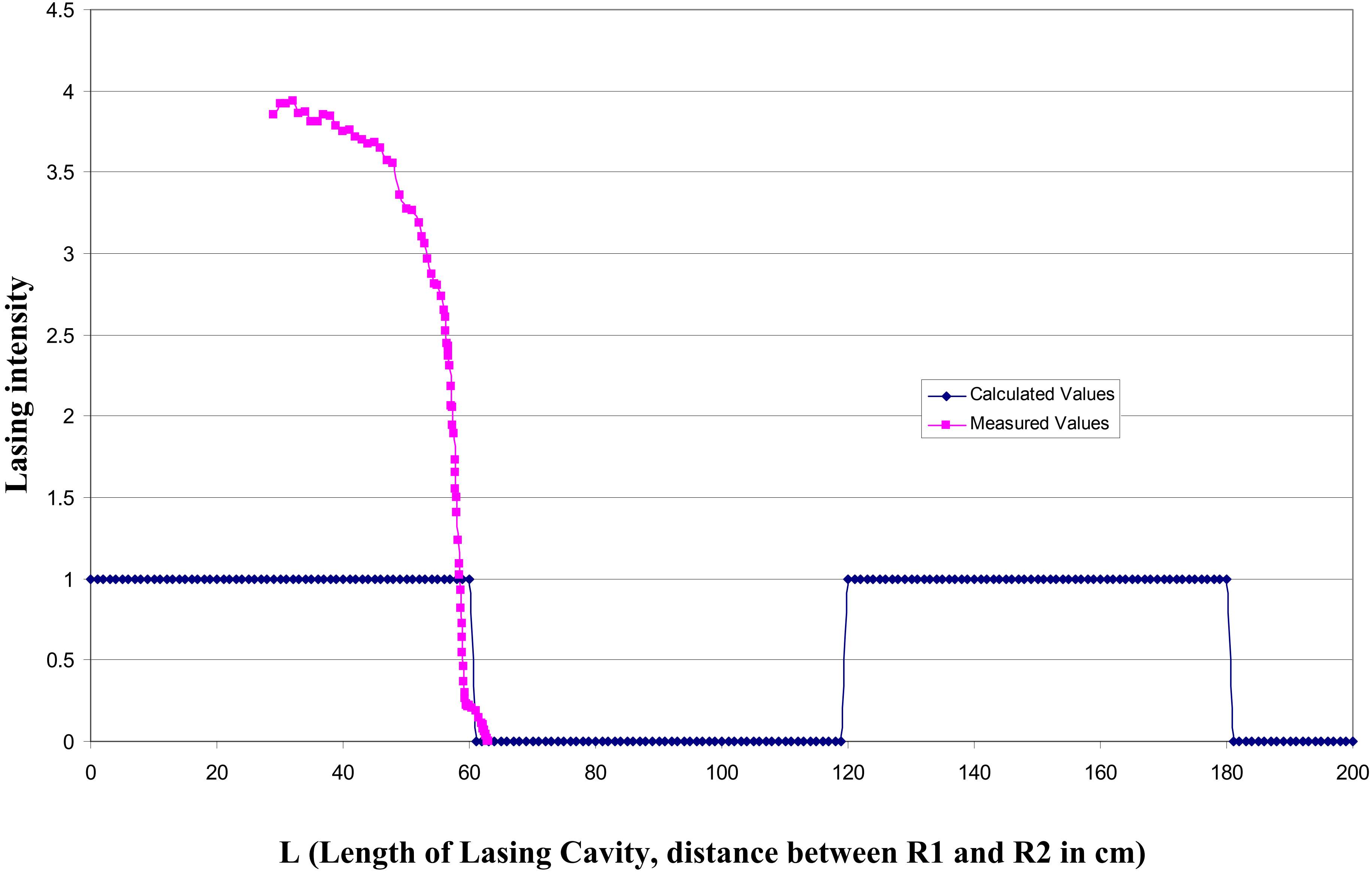


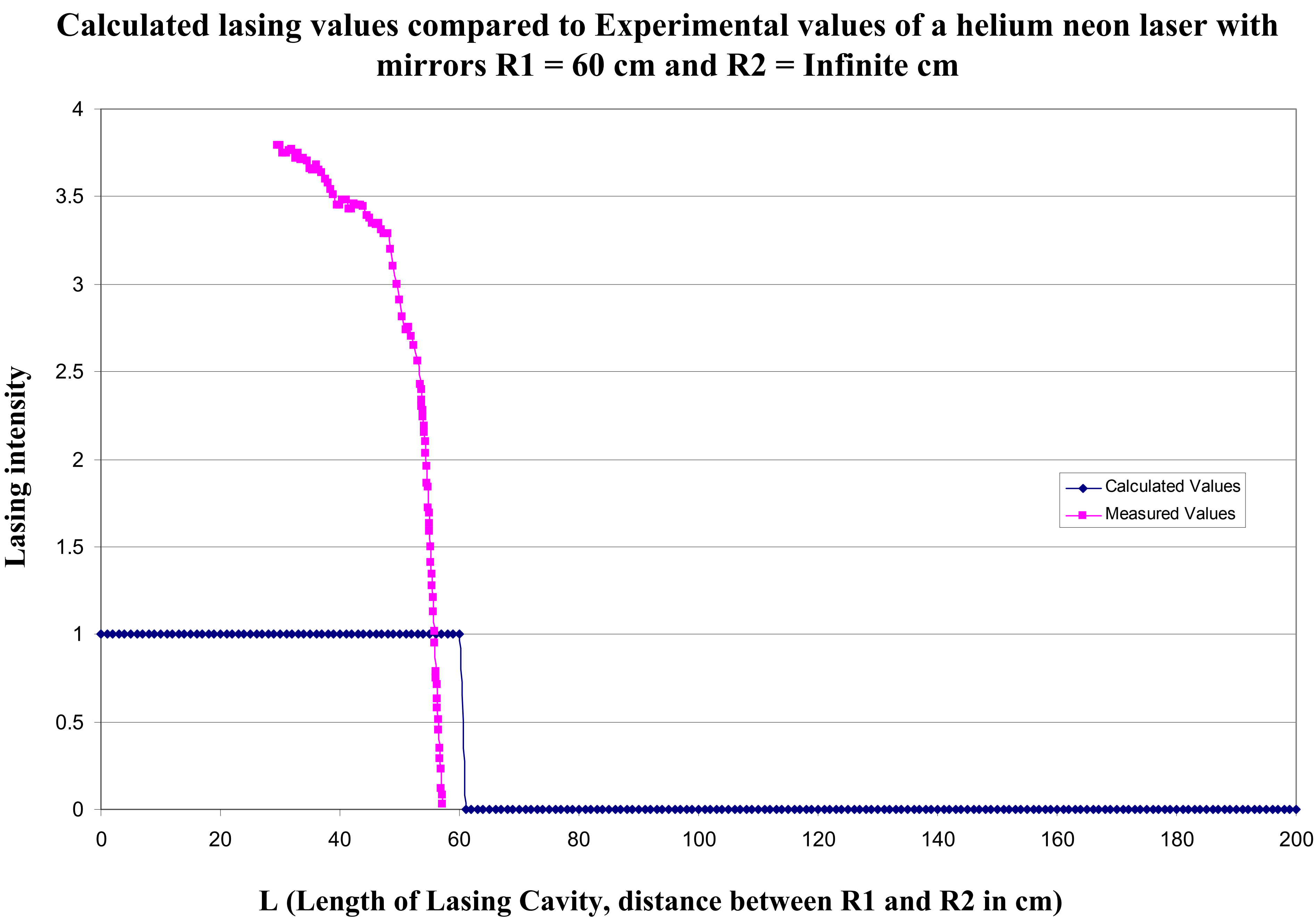

Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = 60 cm
Lasing intensity
L (Length of Lasing Cavity, distance between R1 and R2 in cm)
Calculated Values
Measured Values
0
0.5
1
1.5
2
2.5
3
3.5
0
20
40
60
80
100
120
140
160
180
200



Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = 80 cm
Lasing intensity
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
160
180
200
Calculated Values
Experimental Values
L (Length of Lasing Cavity, distance between R1 and R2 in cm)

Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = 120 cm



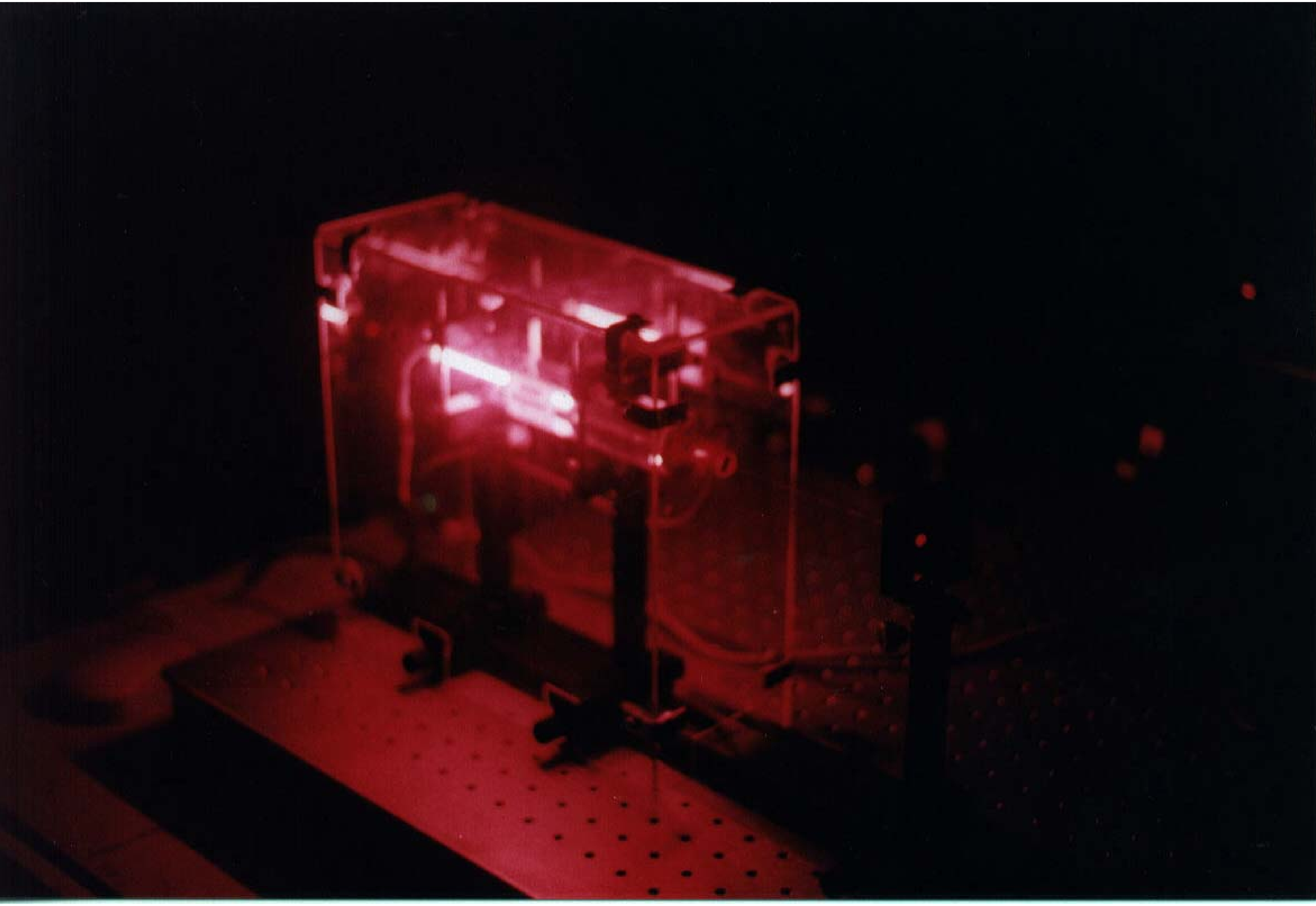

Calculated lasing values compared to Experimental values of a helium neon laser with mirrors R1 = 60 cm and R2 = Infinite cm
Lasing intensity
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
160
180
200
Calculated Values
Measured Values
L (Length of Lasing Cavity, distance between R1 and R2 in cm)

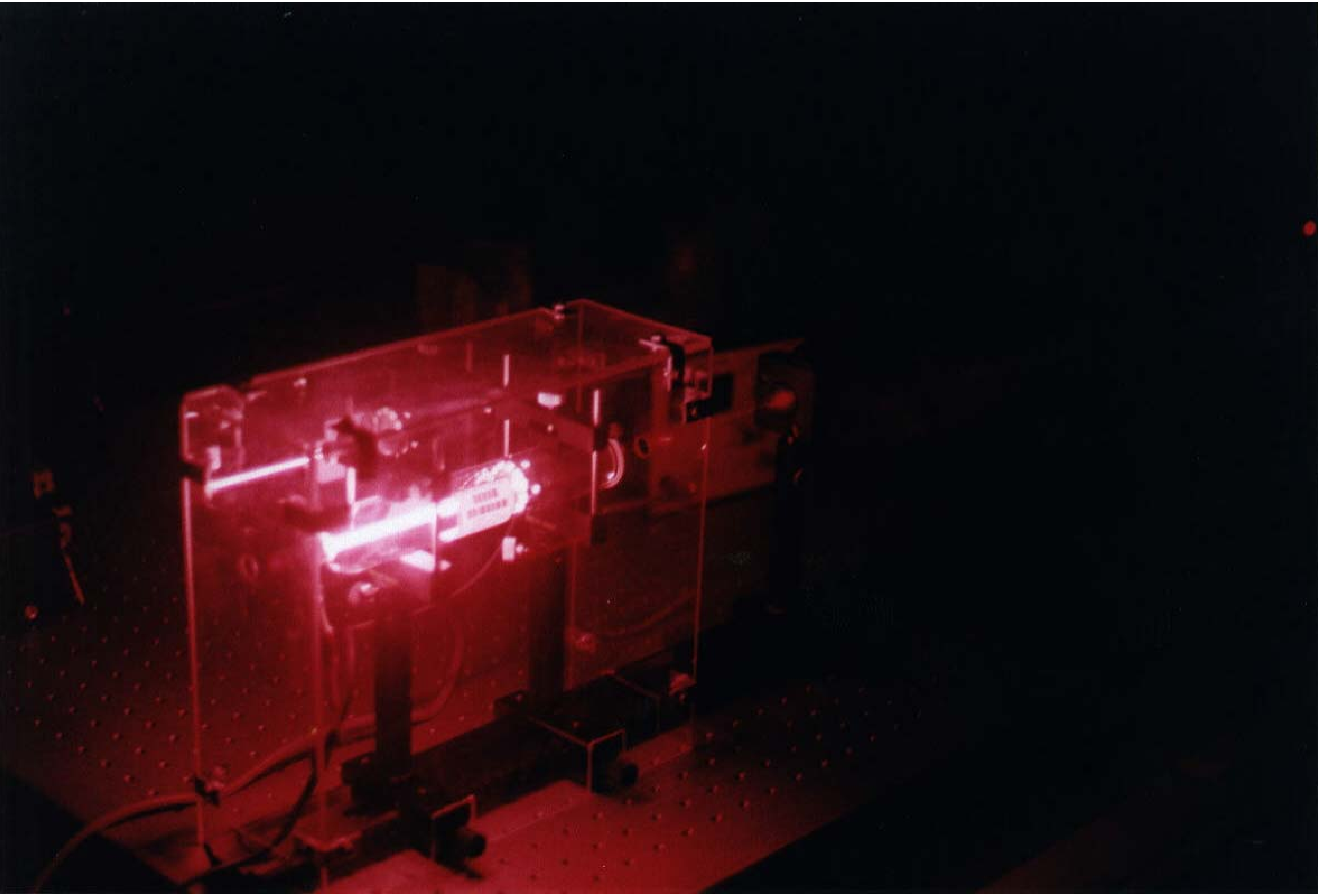
Results:

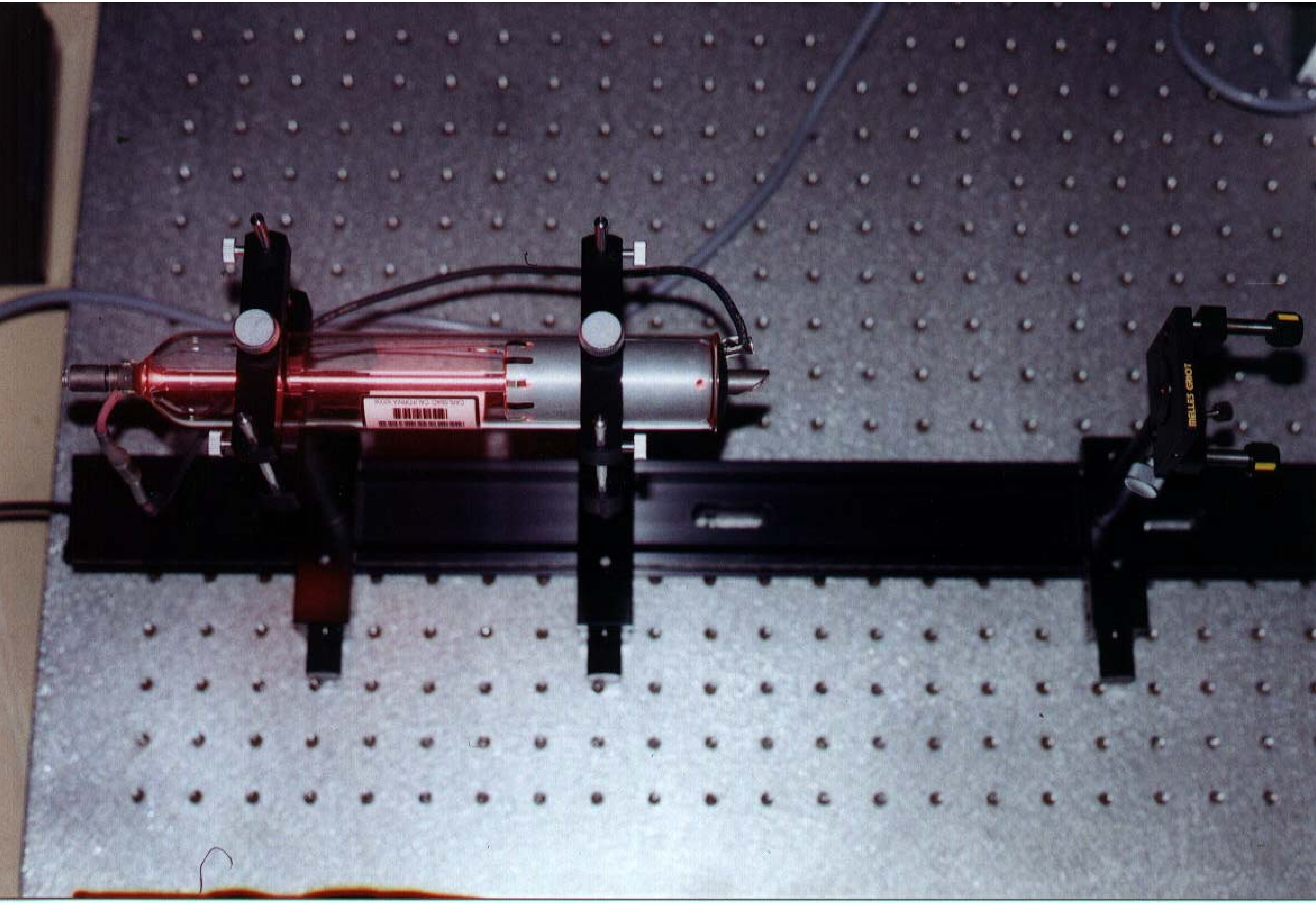
We constructed a variable cavity laser to study the stable cavity characteristics. By performing this experiment, we tested the validity of the stability equations, and proved that they are correct. The results collected from the experiment closely matched the results predicted by the calculations derived from the stability equations.

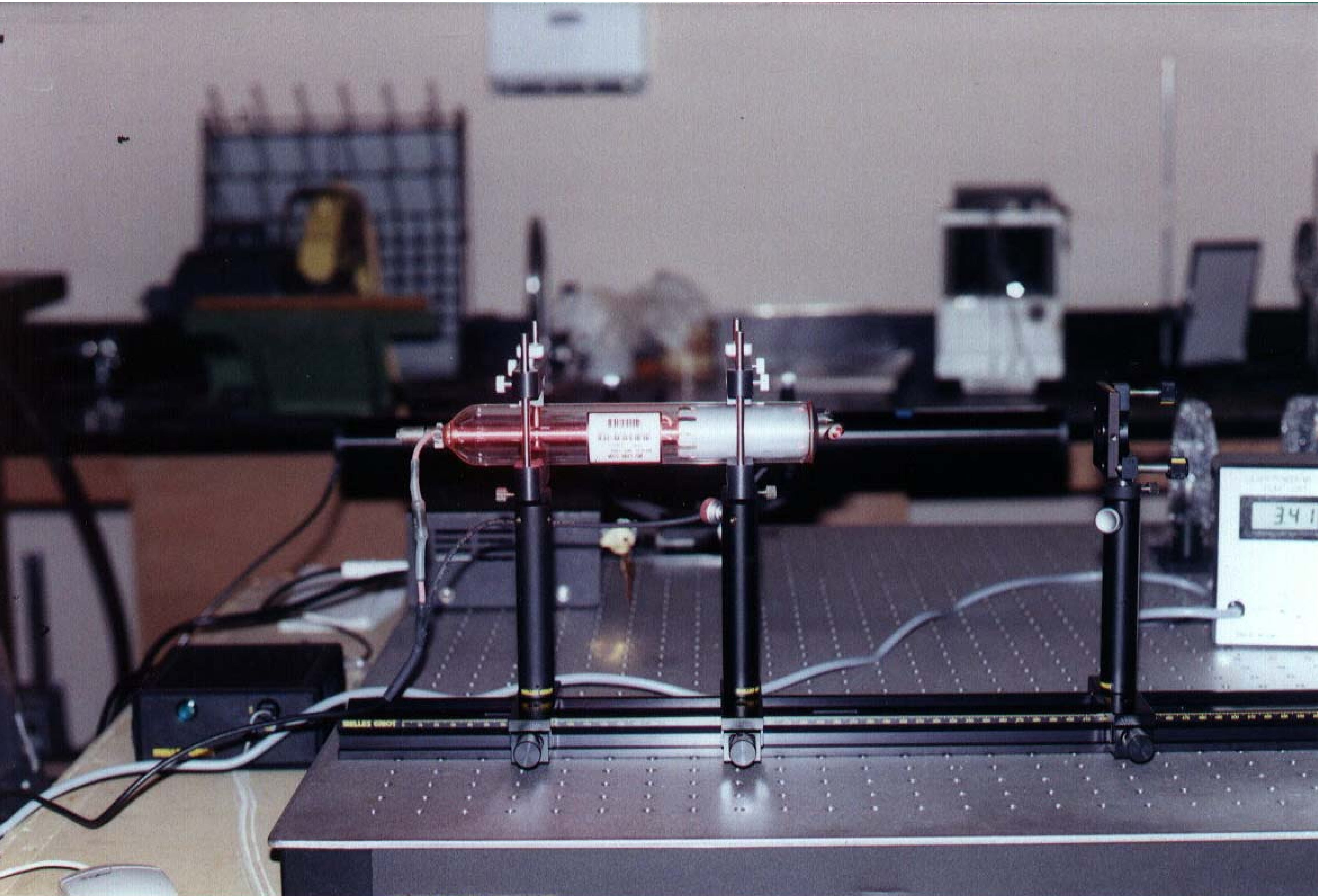
Future Implications:

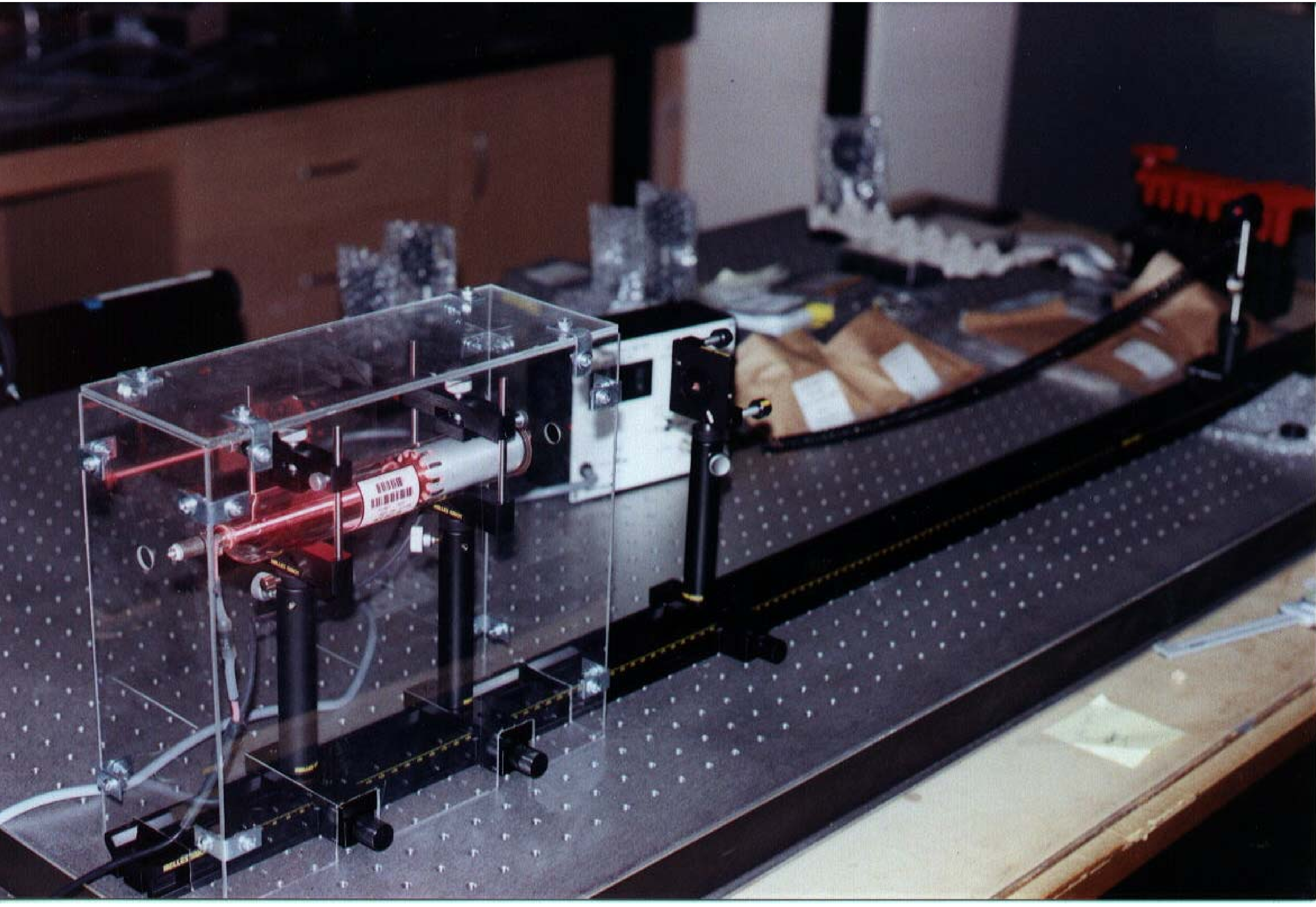
This project expands my knowledge on the characteristics of lasers, which could be shared with optical engineering companies like Lucent-Fitel.

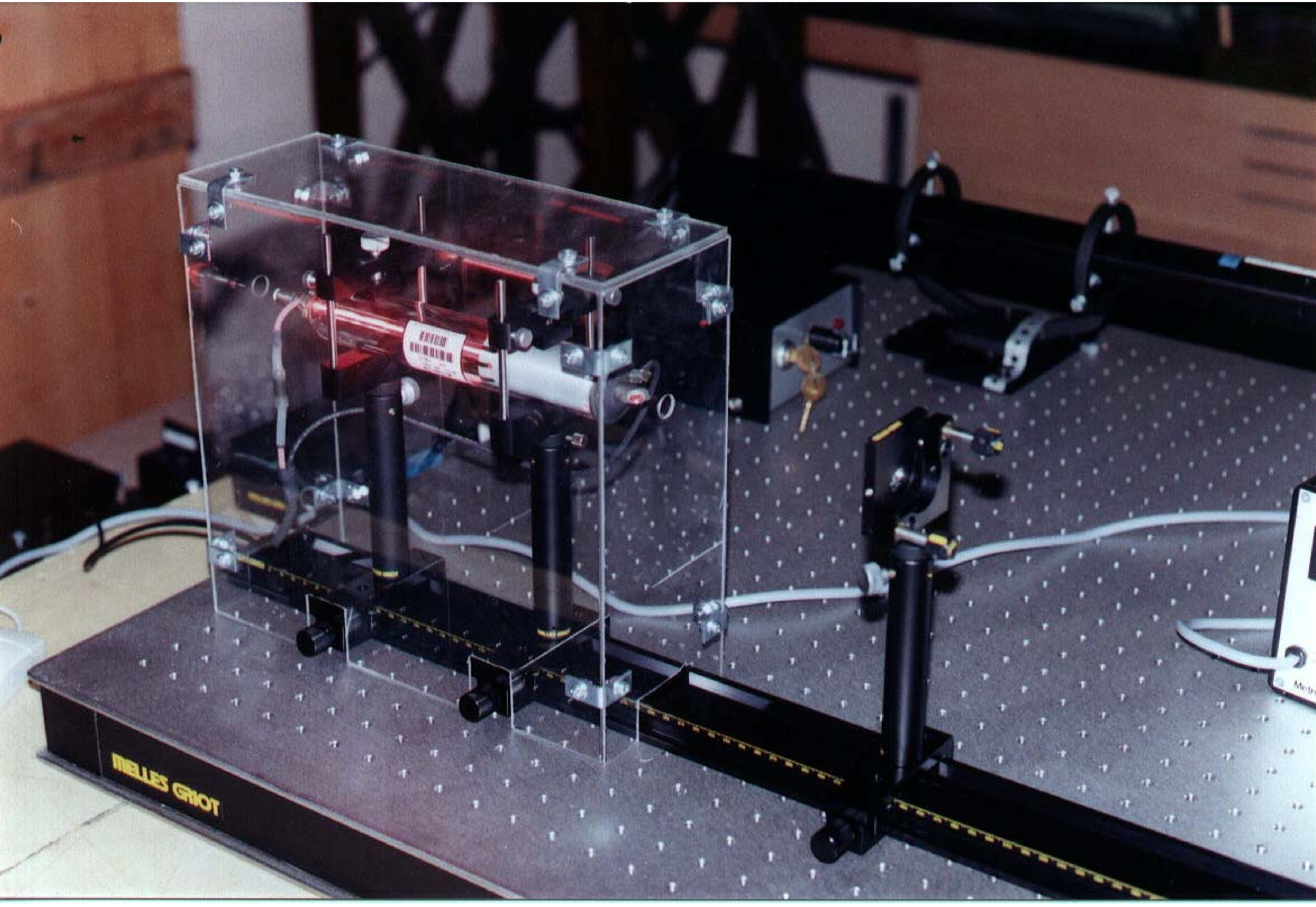





MELLES GRIOT






MELLES GRIOT


LASER POWER METER
PEAK\CONT.
3.40
200μW
2mW
20μW
20mW
CAL
ZERO
CONT.
RESET
100%
ON
POWER
OFF
OUTPUT
Metrologic
MELLES GRIOT

DANGER

LASER RADIATION

AVOID DIRECT EYE EXPOSURE

HELIUM-NEON LASER

5 mW MAX OUTPUT at 632.8 nm

CLASS IIIa LASER PRODUCT