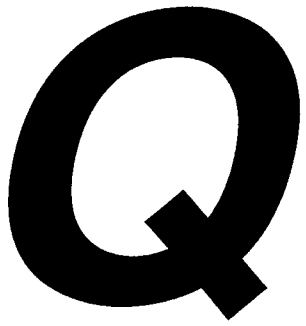
Investigation of Violin Mode *Q* for Wires of Various Materials

Science Meeting

Dec. 3, 96



Jonathan Dawid (SURF Student)

Seiji Kawamura (Research Supervisor)

Robbie Vogt (Sponsor)

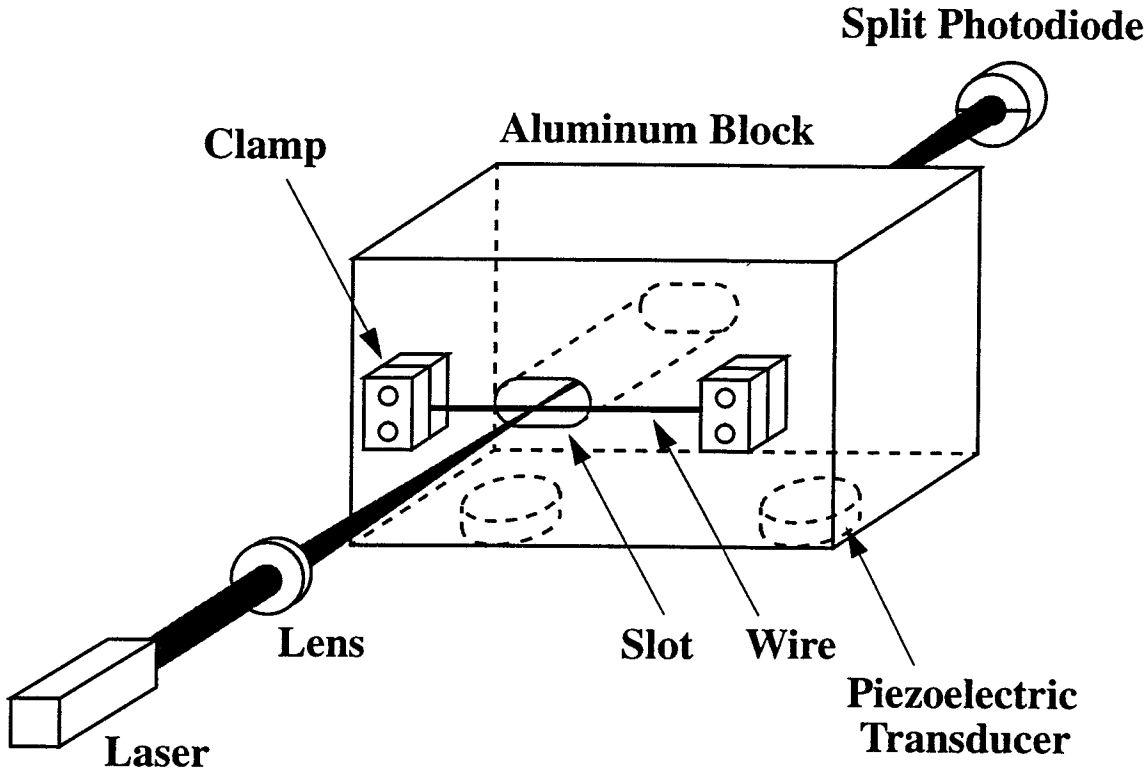
Objectives

- Determine which wire would be most suitable for the initial LIGO suspension.
- Establish the dependence of Q on tension

  ›› $\varphi_v(\omega) = \frac{\sqrt{\pi}}{4} \cdot \sqrt{E} \cdot \frac{d^2}{L\sqrt{T}} \cdot \varphi_w(\omega)$

- Suppress all the practical loss from the measurement
  - ››Losses due to clamps

Q Measurement Apparatus

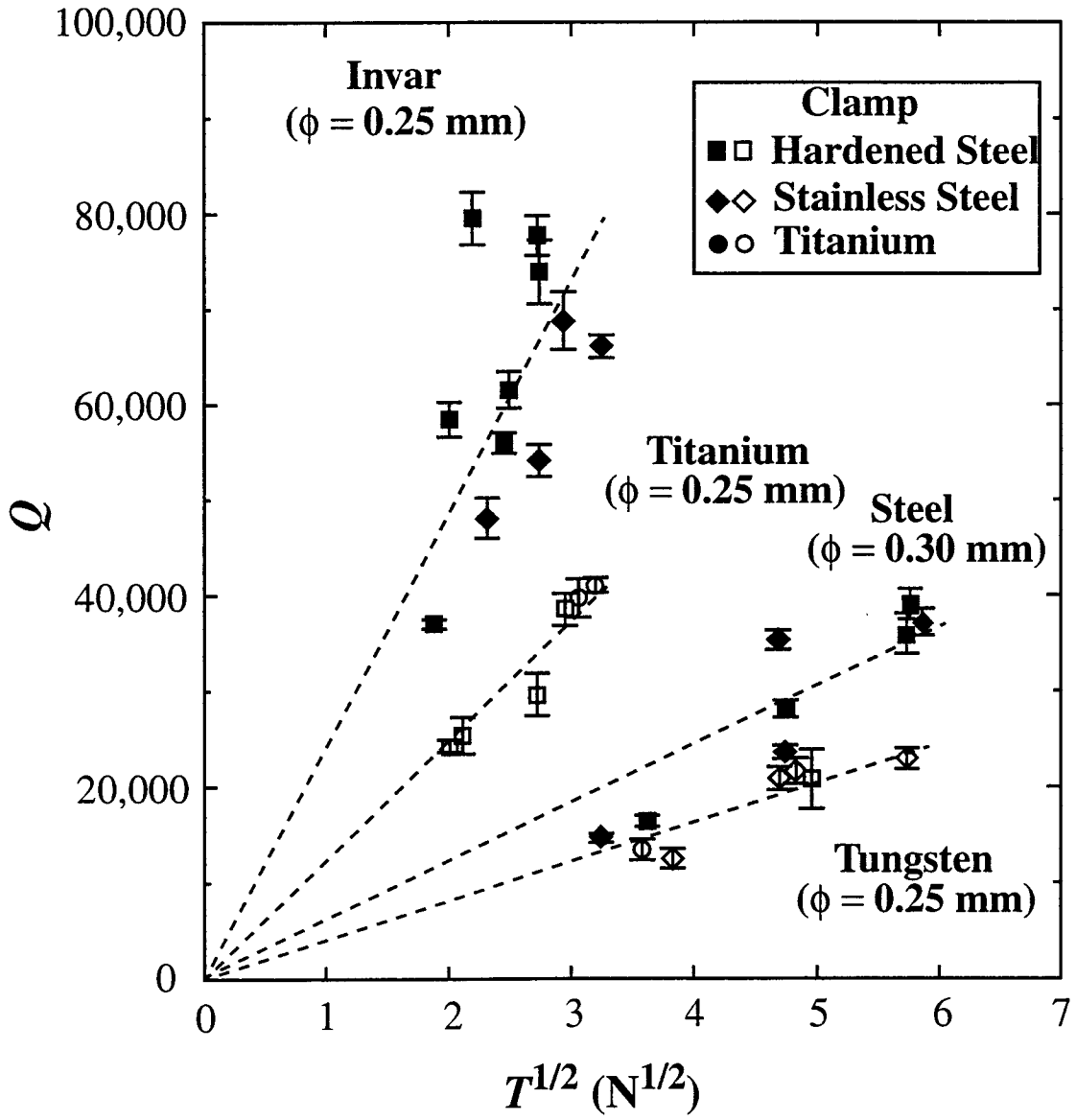


Measured *Q* and extrapolation to the LIGO Suspension

Wire[a]	*Clamp*[b]	*Tension (N)*	*Measured Q*	*Yield Tension (N)*	*Extrapolated Q for LIGO Suspension*[c]
Steel Music Wire	H, S	10 - 34	17,000 - 40,000	90	200,000
Invar	H, S	3.5 - 11	28,000 - 91,000	21	140,000
Tungsten	H, S, T	13 - 32	10,000 - 40,000	100	130,000
Niobium	S	3.6	25,000 - 31,000	10	65,000
Molybdenum	S	6 - 14	14,000 - 14,500	30	59,000
	A	1	900 - 1,600	N/A	N/A
Tantalum	S	1.3	15,000	8	46,000
Titanium	H, T	4 - 10	20,000 - 43,000	8	22,000
Beryllium Copper	S	4 - 5	1,000 - 11,000	12	20,000
Aluminum	Too weak to test			3	N/A

a. l = 10 cm, ϕ = 0.25 mm except steel music wire (ϕ = 0.30 mm)
b. H: Hardened steel, S: Stainless steel, T: Titanium, A: Aluminum
c. Diameter of wire is chosen to give half yield tension for the LIGO test mass (10.7 kg).

Measured Violin Mode Q



Comparison of Measurement with Others'

Wire		*Reference*	*Clamp Type*[a]	*Diameter (mm)*	*Length (cm)*	*Tension (N)*	*Q*	*Extrapolated Q for LIGO Suspension*[b]
Steel	Music Wire	Dawid and Kawamura	P-P	0.30	10.0	21.6	29,000	200,000
	Stainless Steel	Huang	P-P	0.125	30.3	7.4	250,000	170,000
	Music Wire	Gillespie and Raab	P-S	0.075	35.0	3.9	430,000	130,000
	Music Wire	Killbourn and Robertson	P-S	0.178	25.0	6.93	42,000	74,000
	C85 Harmonic Steel	Kovalik	P-P	0.20	71.6	50.2	240,000	69,000
Tungsten		Dawid and Kawamura	P-P	0.25	10.0	23	20,000	130,000
		Huang	P-S	0.175	37.0	36	180,000	90,000

a. P: plate-sandwich-type clamp, S: spacer-type clamp

b. Diameter: 0.30 mm (steel) and 0.25 mm (tungsten), Length: 455 mm, Tension: 52.4 N

Conclusion

- Steel wire would give the best Q for the LIGO suspension.
- Aluminum clamps are not acceptable.
- Qs are roughly frequency independent for the first two to three modes.
- Qs are roughly linear to the square root of tension.
- Practical losses including clamp losses were successfully suppressed below the level of the measured Qs.
- The potential Q of steel wire achievable for the LIGO suspension was given.