The Recent Results of the Measurements of the Excess Noise

V.S. Bzaginsky
Moscow State University

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The recent results of the measurements of the excess noise (MSU group)

A.Yu. Ageev, I. A. Bilenko, V.B. Braginsky

The list of goals of MSU group:

I To reduce the thermal and nonthermal noises

1) $Q_{pend} \to 10^{+9}$, fused silica fiber; $(Q_{pend})_{SQL} \simeq 10^{+8}$, (if $\tau_{MEAS} \simeq 10^{-3}$ sec)

PH.LET. A 218 (1996) 164 — $(Q_{pend})_{SQL} \simeq 10^{+10}$, (if $\tau_{MEAS} \simeq 10^{-2}$ sec)

2) $Q_{pend}(E)$, E is the electrical field from the actuator

3) The fluctuating electrical charges + + electrical field from the actuator

$$q(t) \cdot E < \frac{1}{2} h\, m\, L\, \omega_{grav}^2$$

$$2 \cdot 5 \cdot 10^{-10} \times 10^{+2} \simeq 10^{-22} \times 10^{4} \times 4 \times 10^{5} \times (10^{3})^2 \frac{1}{2} \simeq 2 \times 10^{-7} \text{ dyn}$$

4) The excess noise in the violin modes of the suspension

4a) in tungsten wires (Phys. Letts. A 227 (1997) 159).

! 4b) in steel wires

4c) is fused silica fibers

II New „topologies" in the readout (to reduce $\mathcal{E}$ and beat SQL)

Close collaboration with prof. Thorne's group.

The prelude with the bamboo crystaline: the very noisy tungten wires.

$$\bar{A} = \sqrt{\frac{2kT}{m^* \omega^2_{VIOLIN}}} \simeq 1.5 \times 10^{-3}\ \mathrm{cm} \qquad \delta A_{measur} \simeq 2 \times 10^{-10}\ \frac{\mathrm{cm}}{\sqrt{\mathrm{Hz}}}$$

The diameter of the wire	$20\,\mu m = 2 \times 10^{-3}$ cm
The lengh of the wire	15 cm
ring down time	9 – 12 sec

The main result:

many jumps of the amplitude of the violin mode oscillation which significantly exeed the „permitted" number of jumps in pure Brownian motion.

e.g. the amplitude of jumps	the observed number of jumps per 2,5 h.	the predicted number per 2.5 h
$\geq 4\bar{A}$	82	25±2
$\geq 5\bar{A}$	20	4±4
$\geq 6\bar{A}$	4	0

The stress $\simeq \frac{1}{2}$(breaking stress)

SEE DETAILS IN PHYS. LETT A 227 (1997) 159

The excess noise in the steel wires

Diameter: 80 - 90 μm (supplied by Stan and Seiji)

lengh: 15 cm

relax. time: 5 - 12 sec

$\omega_{viol} \simeq 2\pi \times 1.5$ KHZ (0.5 breaking stress)

(0.9 - 2.3 KHZ) → THE LOAD 0.5 - 0.95 OF THE BREAKING STRESS

$$\bar{A} = \sqrt{\frac{2kT}{m^* \omega_{viol}^2}} \simeq 2 \times 10^{-10} \text{ cm}$$

$$\delta A \simeq 2 \times 10^{-11} \frac{\text{cm}}{\sqrt{\text{HZ}}}$$ (one order better than in the tests of tungsten wires)

TWO WIRES WERE SIMULTANIOUSLY TESTED

(VETO PROCEDURE TO AVOID THE RESULTS OF STRONG SEISMIC KICKS).

AVERAGING TIME $\tau_{AVER} \simeq 0.2$ sec

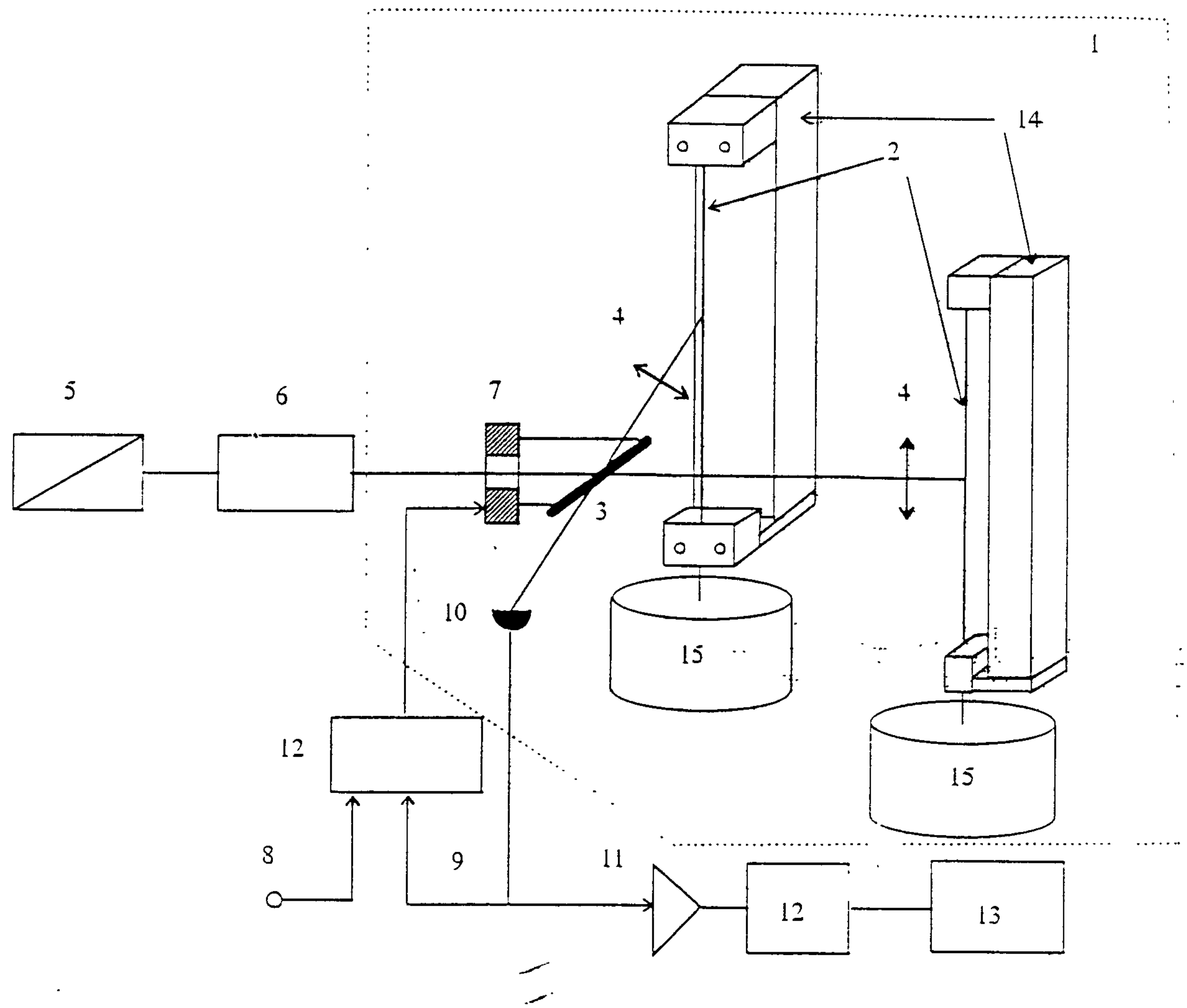
(1024 POINTS FFT → BANWIDTH ≃ 0.5 HZ ; $\frac{S}{N} \approx 10-5$)

THE MAIN RESULTS:

1) Brownian motion was recorded with ≲15% error (metrological accuracy)

2) The excess noise is easy to register,

3) it is 5-8 times smaller than in tungsten



1. Vacuum chamber containing fiber samples and readout interferometer.
2. Fiber sample.
3. PZT driven beam splitter.
4. Aspherical lens with a focal spot of 5 μm in diameter at the fiber surface.
5. Helium-neon frequency-stabilised laser.
6. Optical insulator.
7. PZT drive.
8. Calibrating signal input.
9. Slow drift compensation loop.
10. Detector.
11. Low noise amplifier.
12. Band pass filter.
13. ADC.
14. Rigid frame for fiber fixation.
15. Lead load.

Figure 1. Schematic diagram of the interferometric readout for an excess noise measurement.

The methods of the detection of the excess noise in the recorded signal:

1) χ^2 criterion

2) the analysis of the variations of the amplitudes

$$\Delta A_{rms} \simeq \sqrt{\frac{2kT}{m^* \omega^2_{VIOL}}} \times \sqrt{\frac{2\tau_{aver}}{3\tau^*}} \simeq 0.12\bar{A} .$$

($\tau_{aver} \to 0.2$ sec, $\tau^* \to 10$ sec)

THE RESULTS:

1) $\tau_{aver} = (1-3)\tau^*$ + χ^2 = recorded slow rises and falls several times per hour which are significantly larger than expected (no correlation in two wires)

2) 6 samples, $t_{TOTAL} > 100$ hours

$\Delta A_{\tau_{AVER} = 0.2\,sec \ll \tau^*}$ were STATISTICALY ESTIMATED

	RECORDED	PREDICTED
e.g. $\Delta A > 3\Delta A_{rms}$	1208	760
$\Delta A > 5\Delta A_{rms}$	4	0

16 hours of observation, 0.5 of breaking stress
No correlation in two wires

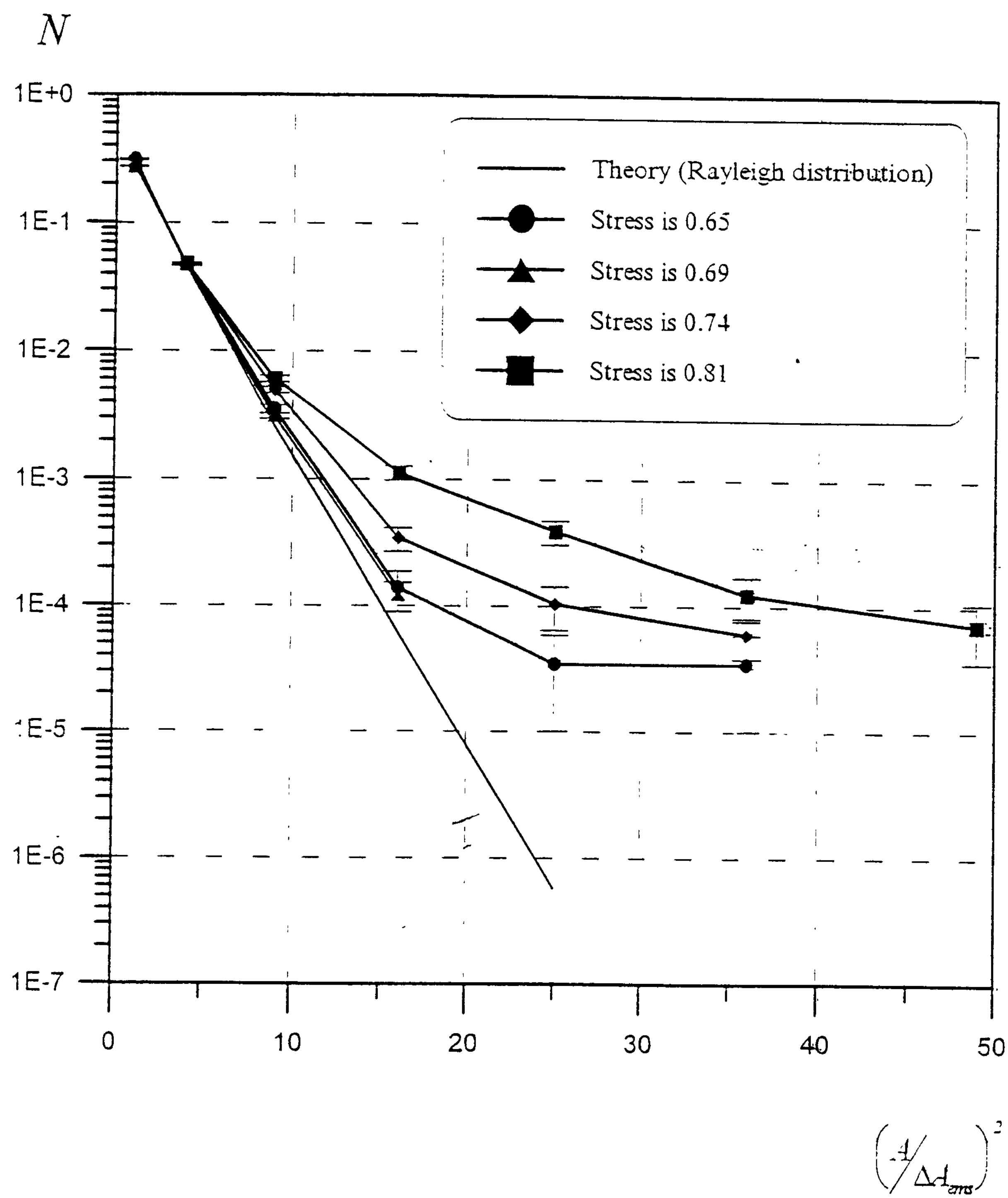


Figure 3.
Amplitude variation intensity cumulative histogram. N is the relative number of variation per hour with amplitude exceeding the threshold A.

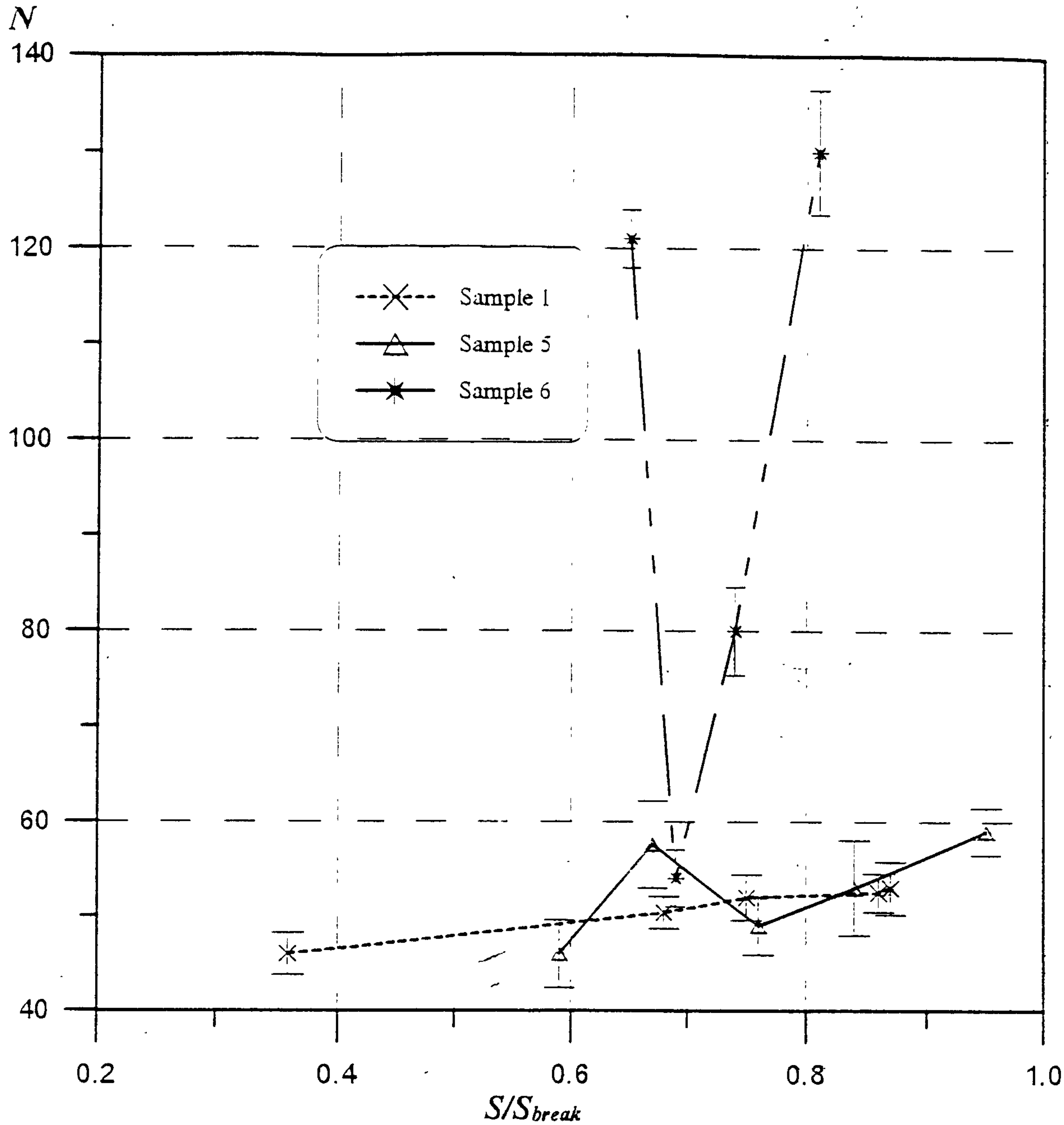


Figure 2.
The dependencies of the amplitude variation intensity on the stress value.
N is the number of variation $\Delta A > 3\ \Delta A_{rms}$ per hour.

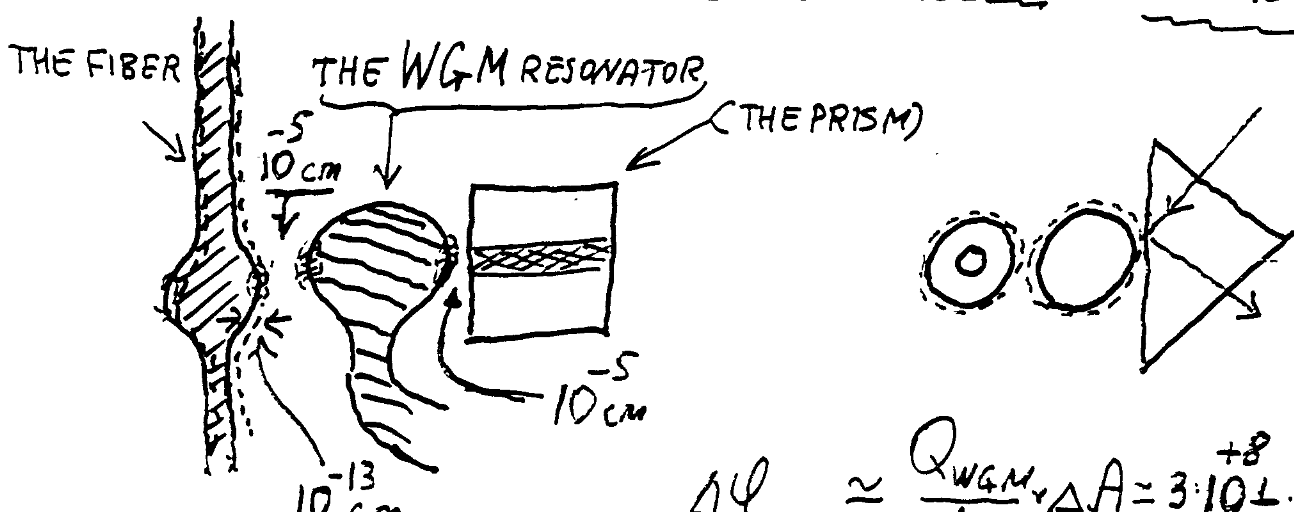
No monotonic correlation between the number of the excess noise events (ΔA) and the stress was observed
(several samples were very noisy).

The extrapolation for LIGO-I.:
The mimic of $h \simeq 5\times10^{-21}$ once per hour?

The MSU group plans for the future:

~~steel wires~~ $\rightarrow$ SiO_2 fibers

$$Q_{viol} \simeq 10^{+8} \rightarrow \Delta A_{SiO_2} \simeq 10^{-2} \Delta A_{steel} \rightarrow \delta A_{meas} \lessapprox 10^{-13} \frac{cm}{\sqrt{Hz}}$$



$$\Delta\varphi_{optics} \simeq \frac{Q_{WGM}}{d_{eff}} \times \Delta A \simeq 3\cdot10^{+8}\frac{1}{cm}\cdot10^{-13}\,cm \simeq 3\times10^{-5}\,rad$$

V. ILCHENKO, M. GORODETSKY

Please see MSU semi-annual report L980424-00-M for further information.