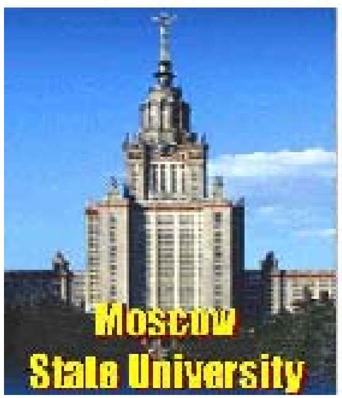
LIGO-G0900183-v2

Variant of violin mode damping system for fused silica fiber suspensions



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Introduction

- In Adv. LIGO, fused silica test mass suspension fibers will have violin modes Q-factors of about 10^8. In this case:
  - ◊ Violin modes excited accidentally will have too long ring-down time.
  - ◊ Being coupled to the test mass high-Q violin modes may cause instability of the interferometer length control servo.

  Damping of violin modes is necessary.

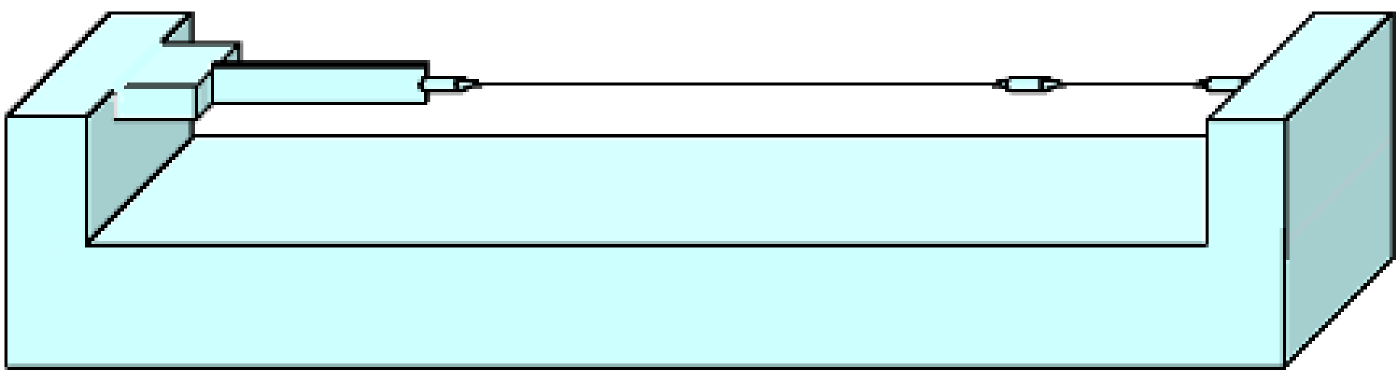
- Conventional sensors and actuators are not appropriate to control motion of thin, transparent, non-conducting fused silica fibers.

  We suggest a variant of violin modes damping system with especially developed sensors and actuators and present results of its experimental exploration using the model of suspension fiber. The damping system operates as an active feedback system.

Monolithic fused silica model of suspension fiber

Support structure – fused silica block is cut from one piece. Fiber (diameter ≈ 200 micrometers, length ≈15 cm) was welded to the block.

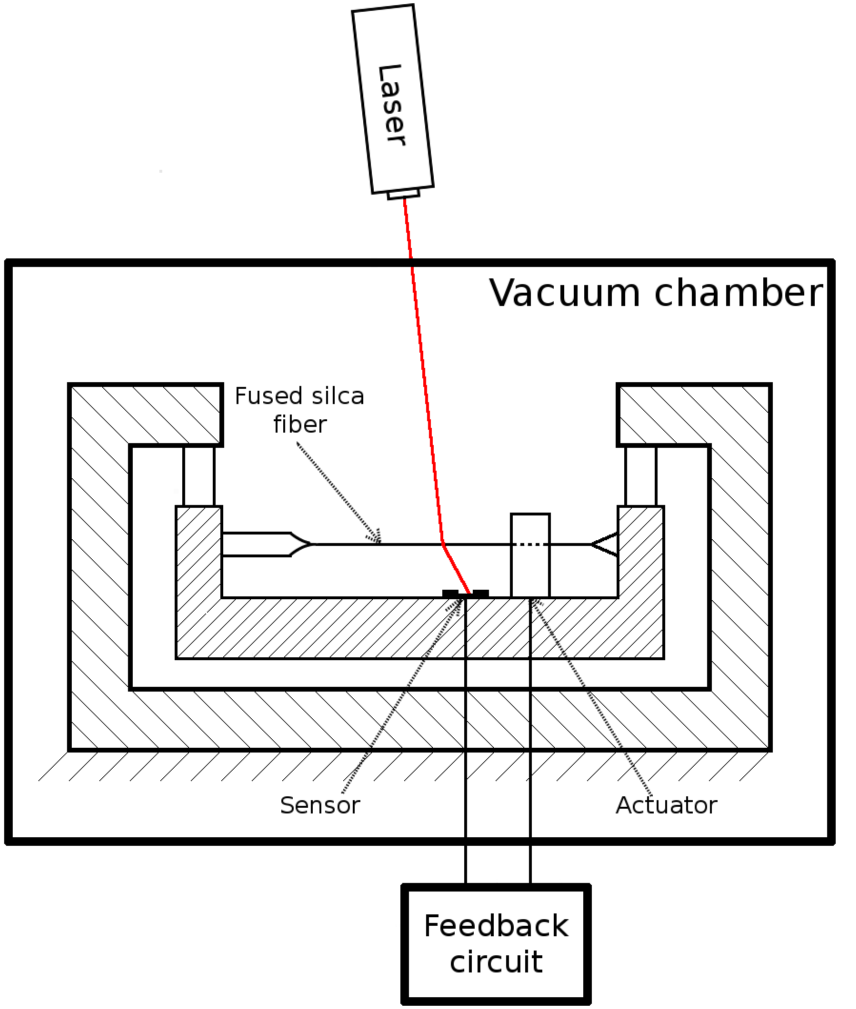
A fundamental violin mode frequency $v_1 \approx 457$ Hz.



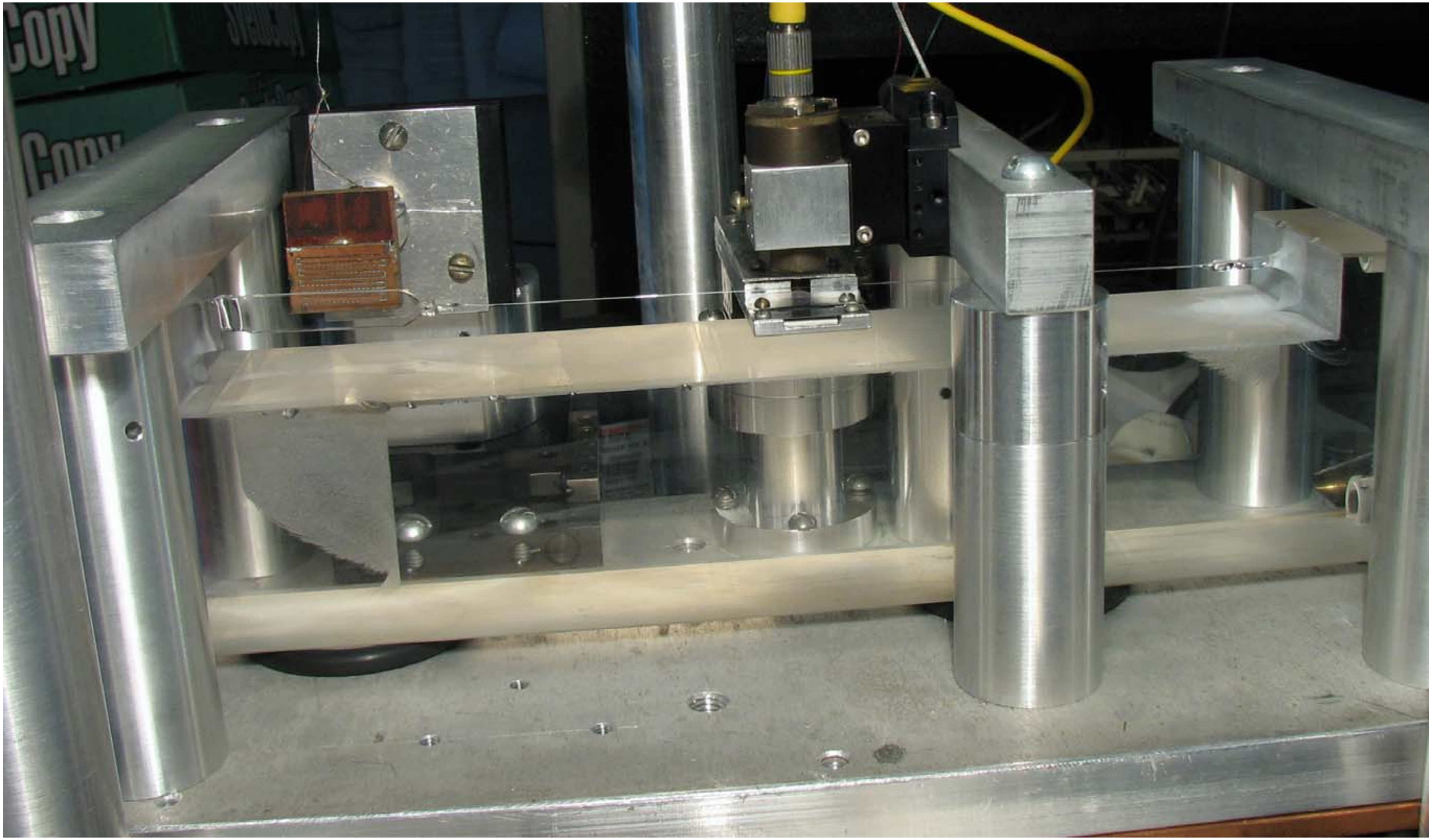
Experimental setup

Fused silica block is suspended with 4 silk threads to decrease leakage of the fiber energy to surroundings. Construction provides a fundamental violin mode Q = 1.2×10^{7}.

Original optical sensor and electrical actuator were developed.

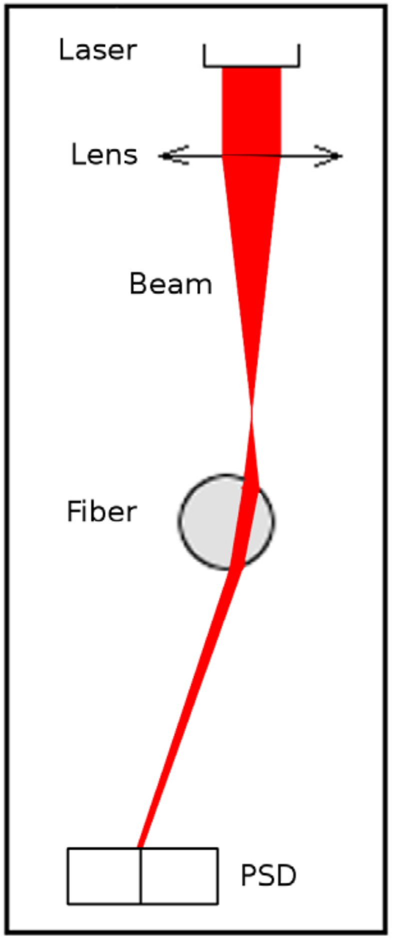


Experimental setup



Schematic of the optical sensor

The sensor bases on the optical beam deflection technique. Focused laser beam is incident onto the fiber. Off-center direction of the laser beam results in an angle deflection of the beam passing through the fiber. The fiber acts as a cylindrical lens. Beam passing through the fiber focuses on the position sensitive detector. Transversal displacement of the fiber Δx results in a displacement of the laser spot Δs on the detector. Optical aberrations limit the sensor sensitivity. Measured value of displacement responsibility was found to be in the range of 0.03 $(\mu m)^{-1}$.



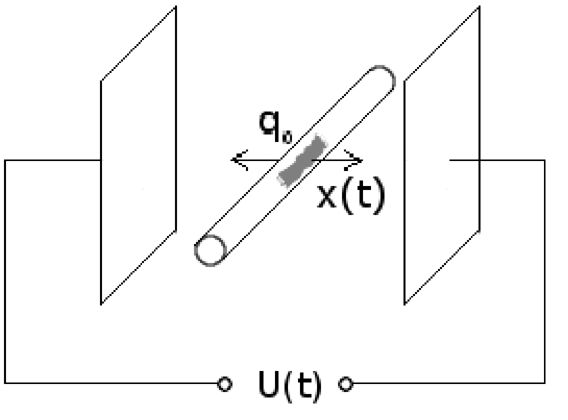
Schematic of the actuator

To realize force action on the fiber two parallel electrodes were installed near the fiber with a separation gap ***d*** of about 1 mm.

Electrical charge $\boldsymbol{q_0}$ was deposited on the fiber between the electrodes by contact charging with bunch of 5 human hairs by means of special manipulator.

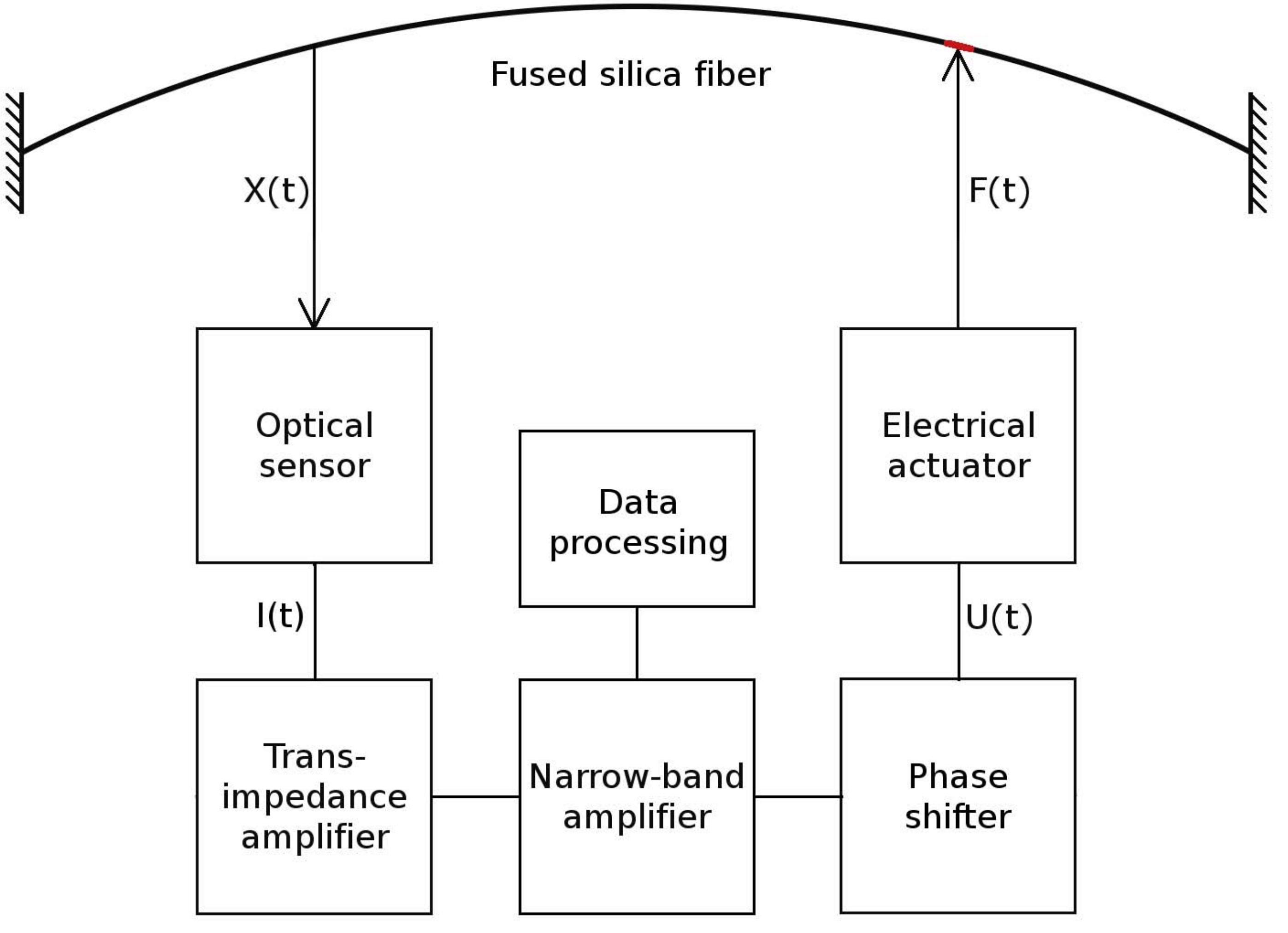
(Decay time of charge sitting on fused silica exceeds 3 year).

Usually $\boldsymbol{q} \approx 10^{-12}$ C.



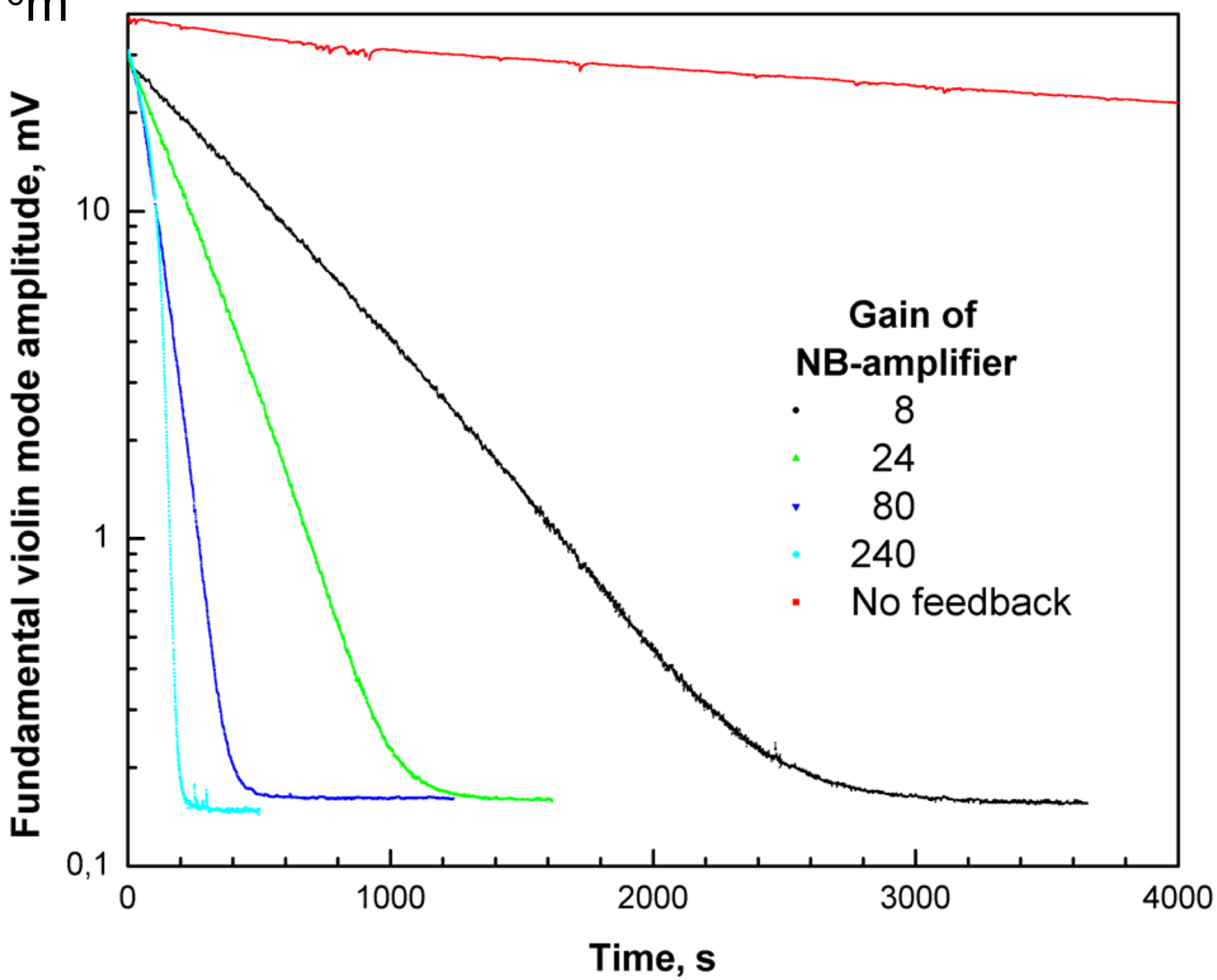
$$F(t) = q\, U(t) / d$$

Schematic of active feedback system

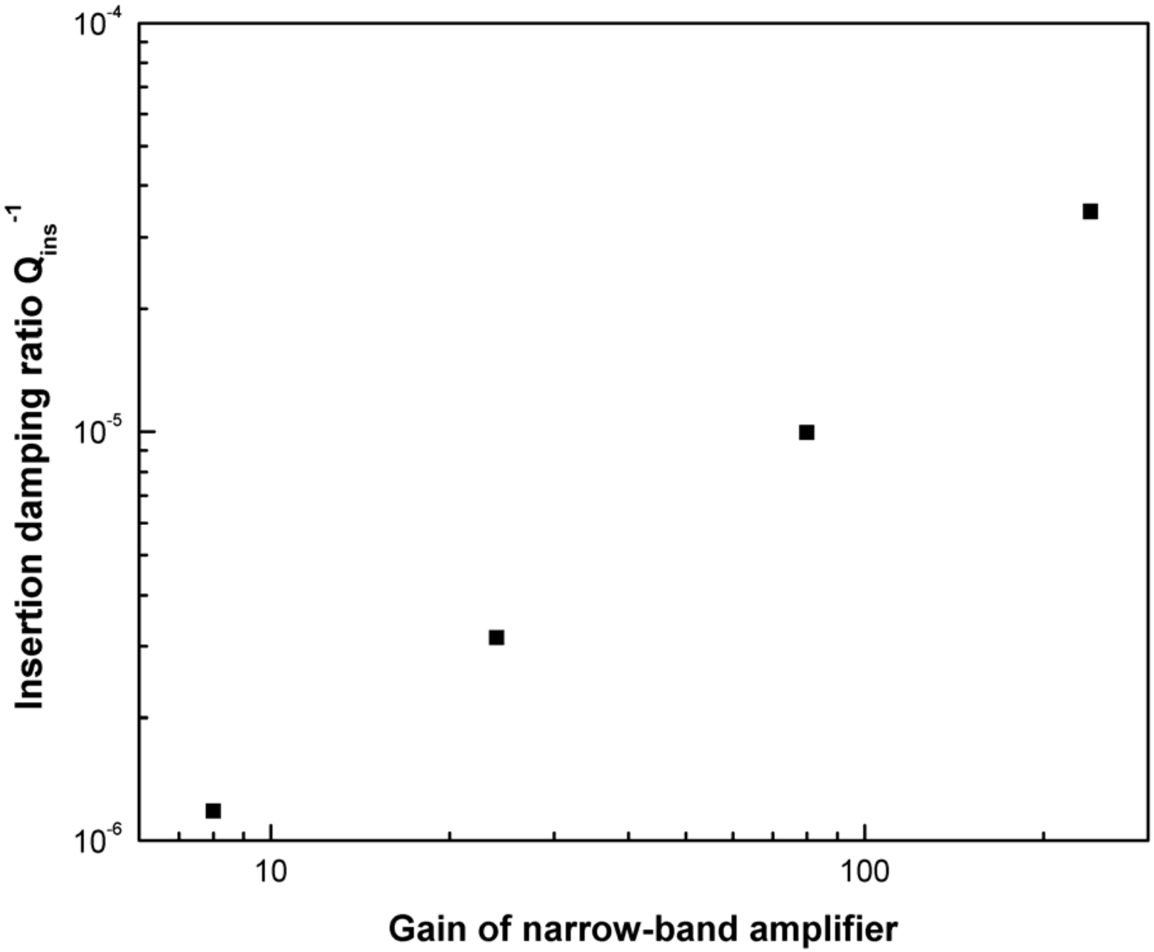


Measured decay of the mode amplitude

1mV ≈ 3 x10^{-6}m



Additional damping rate of violin mode vs amplifier gain (result of measurement)



Conclusion

- We have demonstrated dynamical properties of the developed system for damping of violin modes of fused silica fiber. Although the application of the damping system to the real test mass suspension may require more elegant construction of some elements (for example, system for deposition of charge on the fiber).

- Next step is measurement of noise properties of the damping system. Calculations show that additional noise in the fiber produced by the damping system may be made small – cold damping.