FIBER LASER STRAIN SENSOR DEVICE

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STRAIN SENSOR part 1

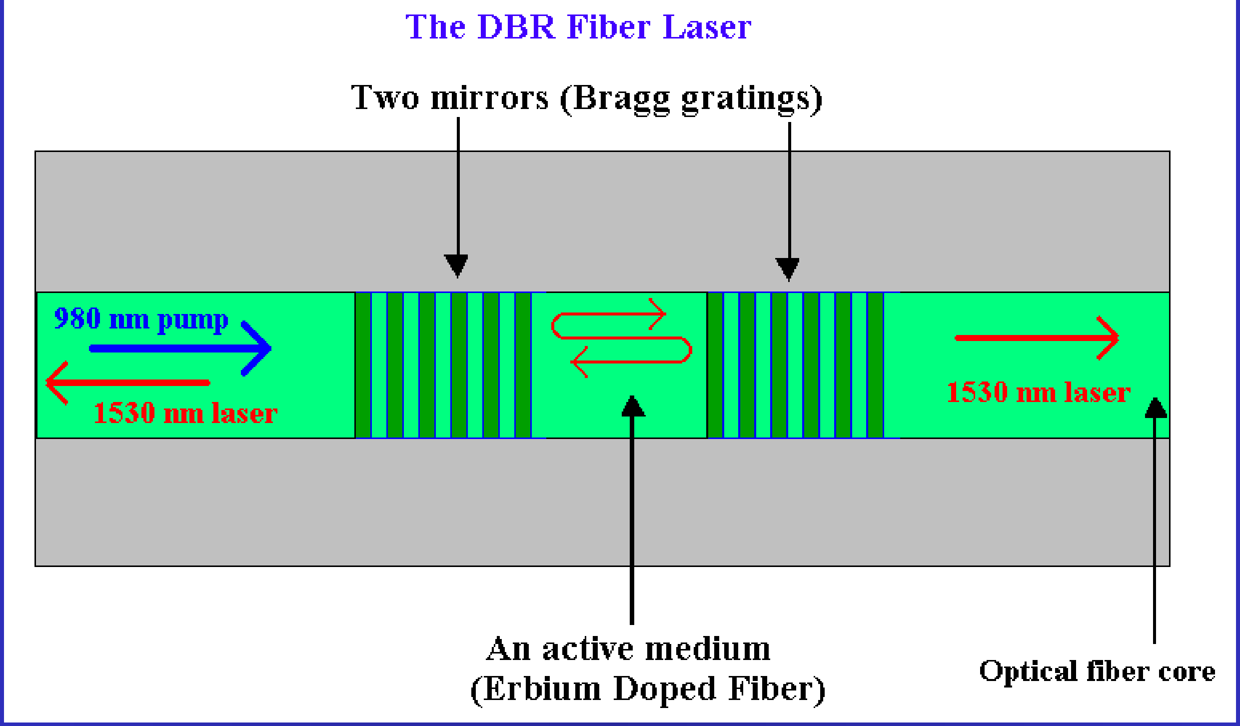
In the field of strain sensitivity, dynamic ($f > 100$ Hz) sub-nanostrain ($\text{strain } \varepsilon = \Delta l/l$) resolution was reached with interferometric detection. Fiber Bragg Lasers (FBL's), have represented the evolution in the field of fiber strain sensing. Sensitivity in the kHz regime at the level of few tens of femto-strain was demonstrated. Anyway for a lot of application (monitoring of civil structures, rock deformation probing, fiber-optic geophone, vertical seismic profiling and geodynamical monitoring) there is a

STRAIN SENSOR
part 2

In this work we present a Fiber Laser Strain Sensor (FLSS) especially devoted to very low frequency measurements. A resolution equal or better than 200 pε/(Hz)$^{1/2}$ is attained for frequencies between about 100 mHz and 3 Hz, while sensitivity at the level of few tens of picostrain is demonstrated for frequencies beyond about 3 Hz. Interferometric detection technique is used, with an imbalanced in-fiber Mach-Zender interferometer that converts wavelengths variations into intensity variations. The voltage signal recovered is analyzed both in spectrum and in time. The signal dynamic range is about four decades from 10 pε to 100 nε. The operating principle of our FLSS could be employed in realizing a device for earth monitoring as a valid alternative to volumetric strain meters that have comparable sensitivity in the frequency region of interest but are much more

THE DISTRIBUTED BRAGG REFLECTOR FIBER LASER (DBR-FL)

Two Bragg gratings with identical reflection wavelength directly inscribed on an erbium doped (active medium) optical fiber. This structure forms a Fabry-Perot laser cavity which, when pumped at 980 nm, lases with emission at ~1530 nm



DBR FIBER LASER

single stable longitudinal mode
+
very narrow linewidth

ber Laser linewidth: < **5 kHz**

$\Delta\lambda_{laser}$ < **4*10^{-8} nm**

($\Delta\lambda_{Bragg}$ = **0.2 nm**)

Coherence length > 50 km

FIBER LASER TYPICAL CHARACTERISTICS

FL characteristics

- Bragg reflectors length: 1cm
- Rear FBG reflectivity: >99%
- Output FBG reflectivity: ~ 90%
- Cavity length (distance between gratings): 1-3 cm
- Optical power emitted: 500 μW – 2 mW (pump power 300 mW)
- Stable single longitudinal mode

DBR FIBER LASER

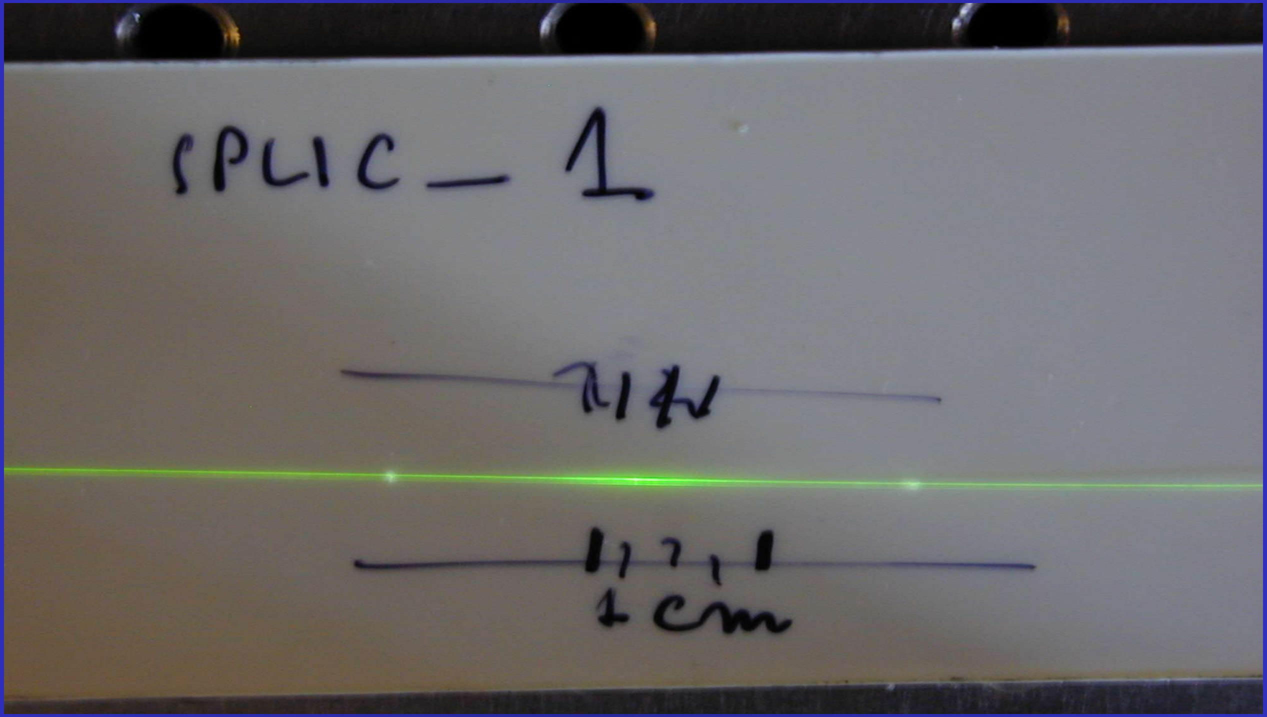
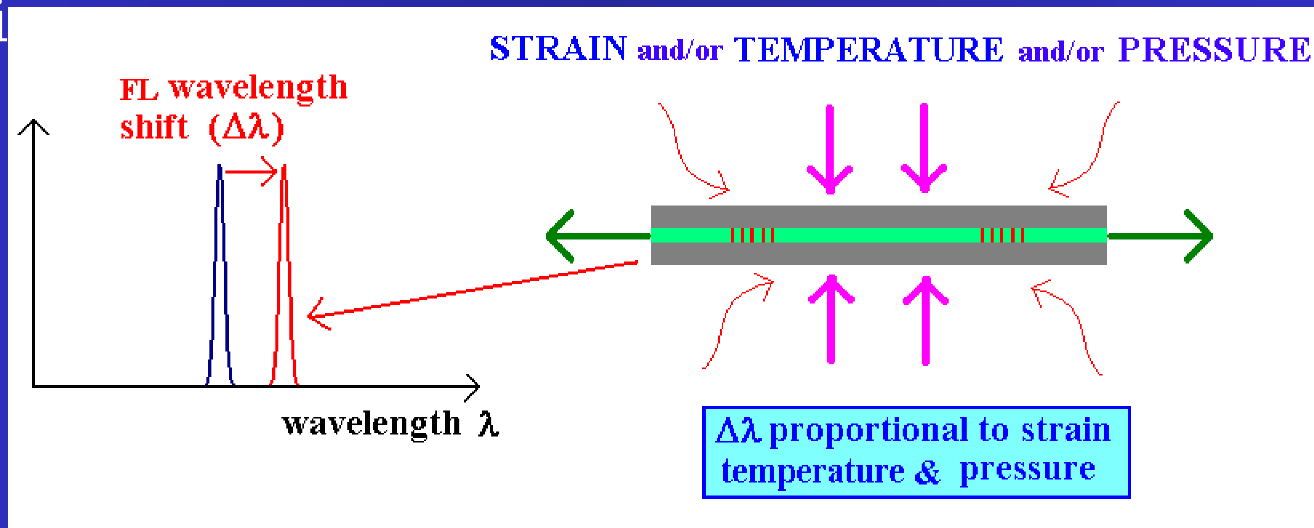


Photo of one of the realized DBR lasers. The green light is due to “up conversion” (collision of two erbium ions with energy jump at higher levels).

The Erbium Doped fiber is cut and spliced to a standard fiber (low loss <0.3 dB/Km) very close to the cavity.

FIBER LASER SENSORS

Physical elongation (strain), temperature and pressure variations, which changes the FBG pitch **Λ,** the cavity length, and fiber refractive index **n_{eff}**, produce a shift in the fiber laser emission li



TYPICAL SENSITIVITIES FOR A BARE FIBER LASER

STRAIN [ε]	**TEMPERATURE**	**PRESSURE**
~1.2 pm/με @ 1550 nm	~ 10 pm/°C @ 1550 nm	~ -4.6 pm/**MPa** @ 1550 nm

FIBER LASER SENSORS CHARACTERISTICS

- Intrinsic safety and immunity from electromagnetic fields

  the fiber is realized entirely with dielectric materials (glass and plastic)

- Very small dimensions of the optical fiber (~ 125 μm)

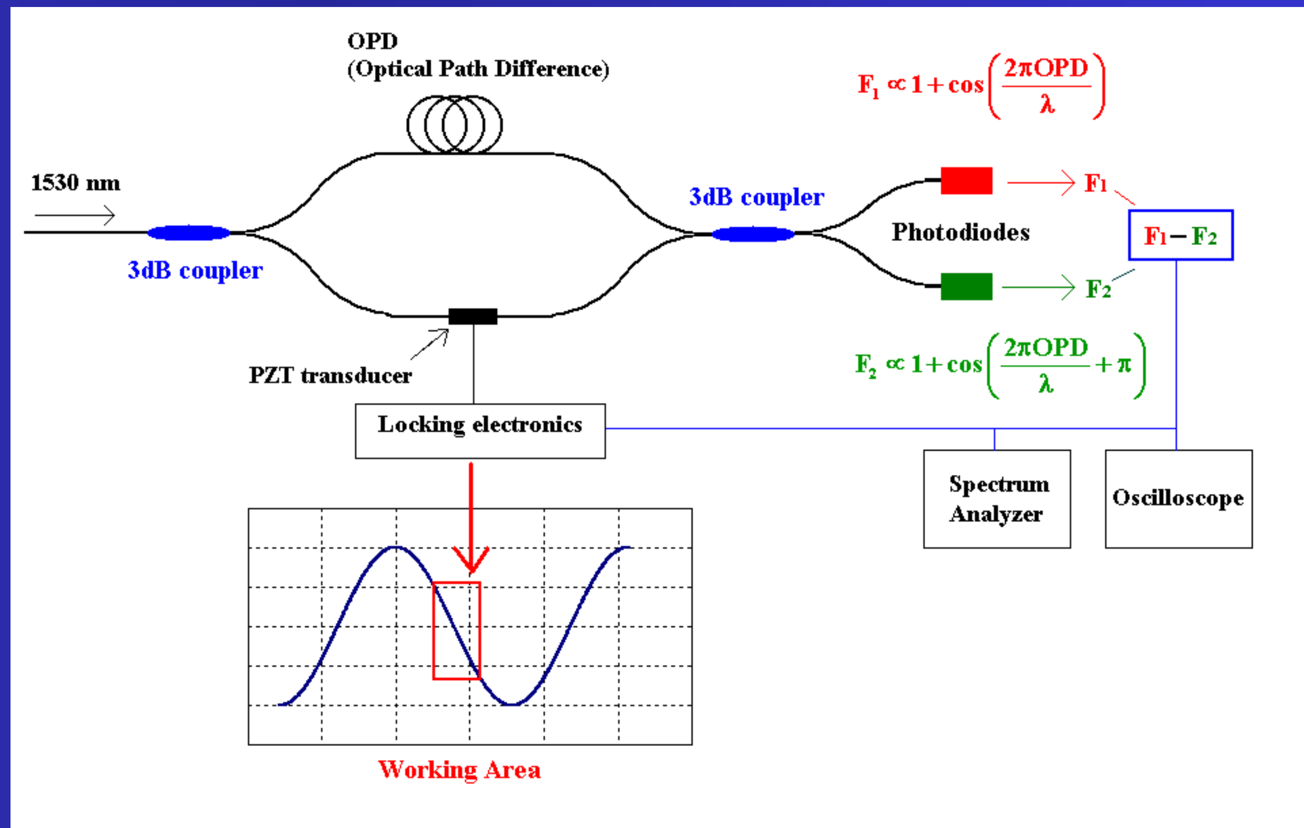
- ED fiber is compatible with standard telecom fibers (very low signal attenuation ~ 0.3 dB/km)

- The optoelectronics control unit can be placed several km far from the measurement point

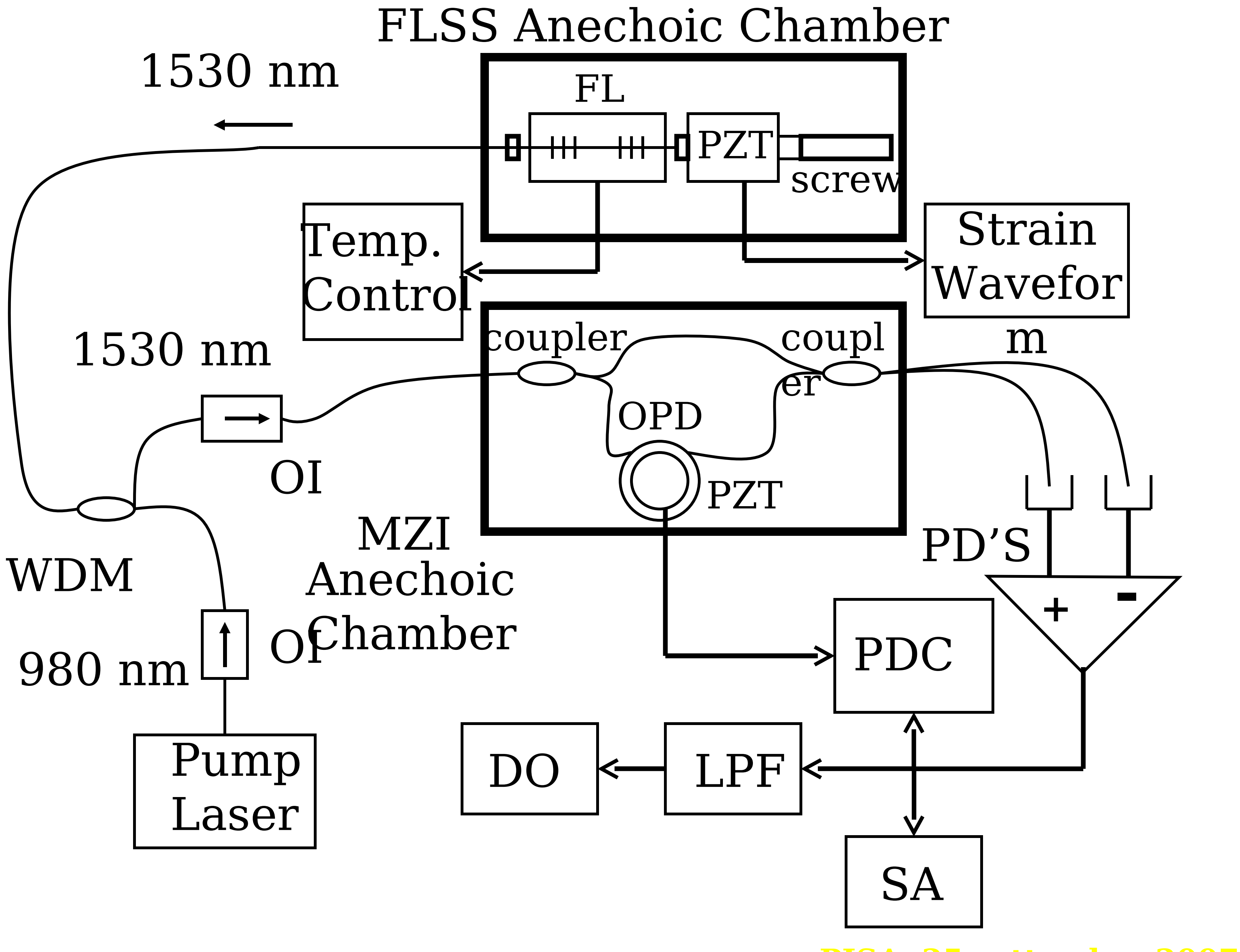
MACH-ZENDER INTERFEROMETER (MZI)

Balanced Quadrature Detection

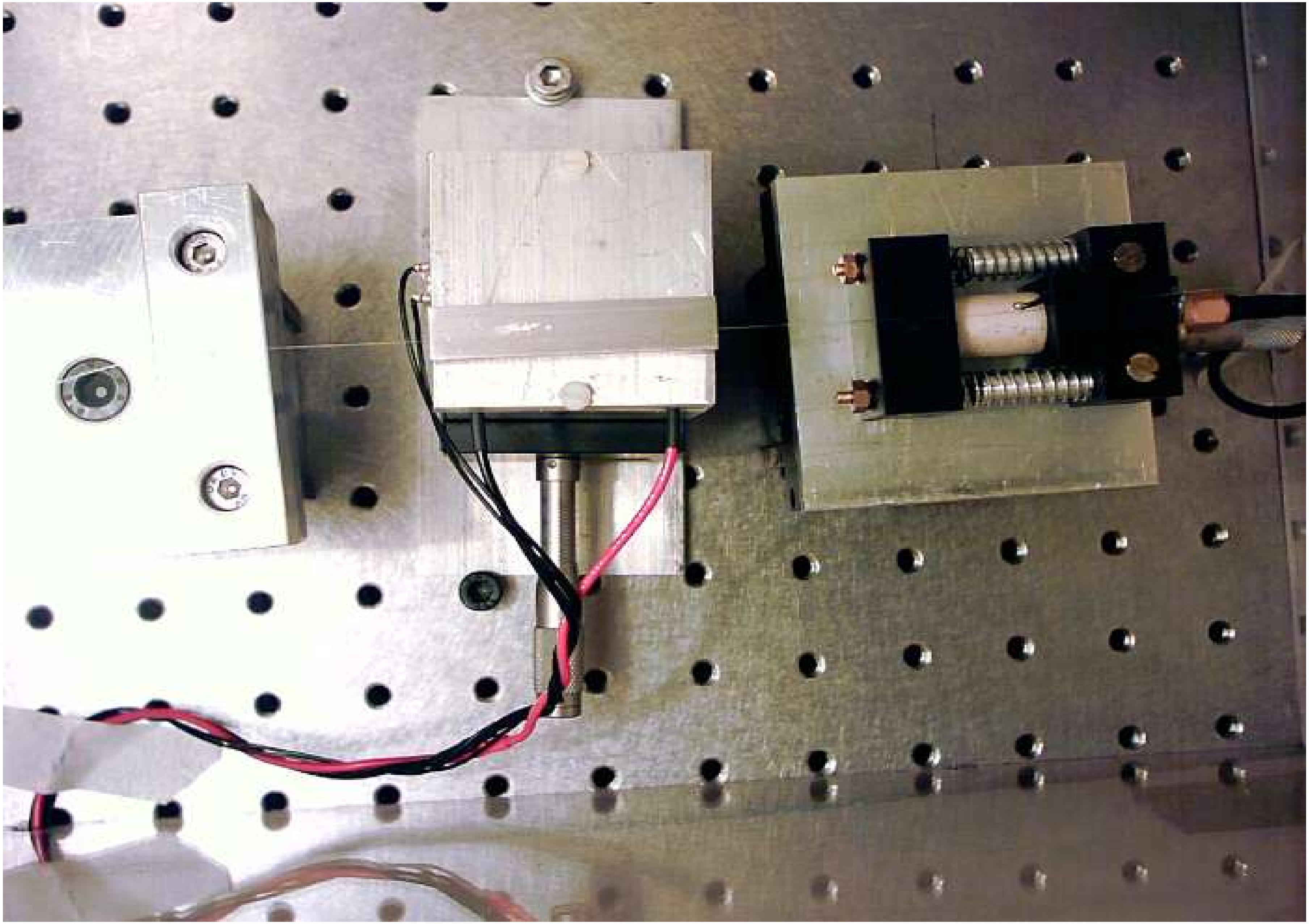
The laser signal is splitted and then recombined thus obtaining a signal proportional to a raised cosine function at the MZI output. The phase depends on the laser frequency c/λ (which depends on the strain signal) and on the Optical Path Difference (OPD).

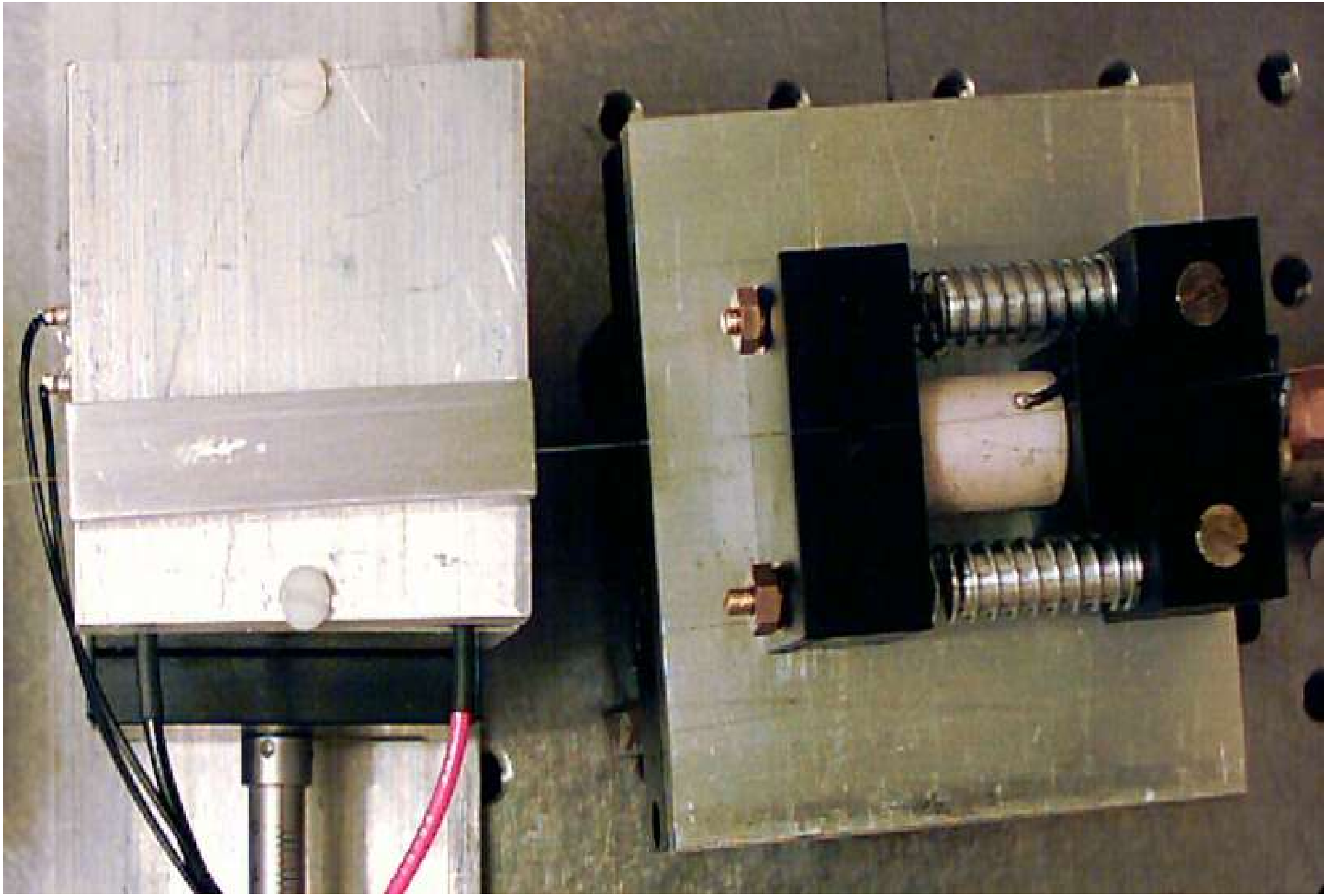


The MZI is locked, at low Fourier frequencies (≤ 50 mHz), at one side of a fringe in the middle point, where the sensivity has its maximum value, by using a servo loop that acts on the length of one arm of the interferometer by stretching the fiber through a

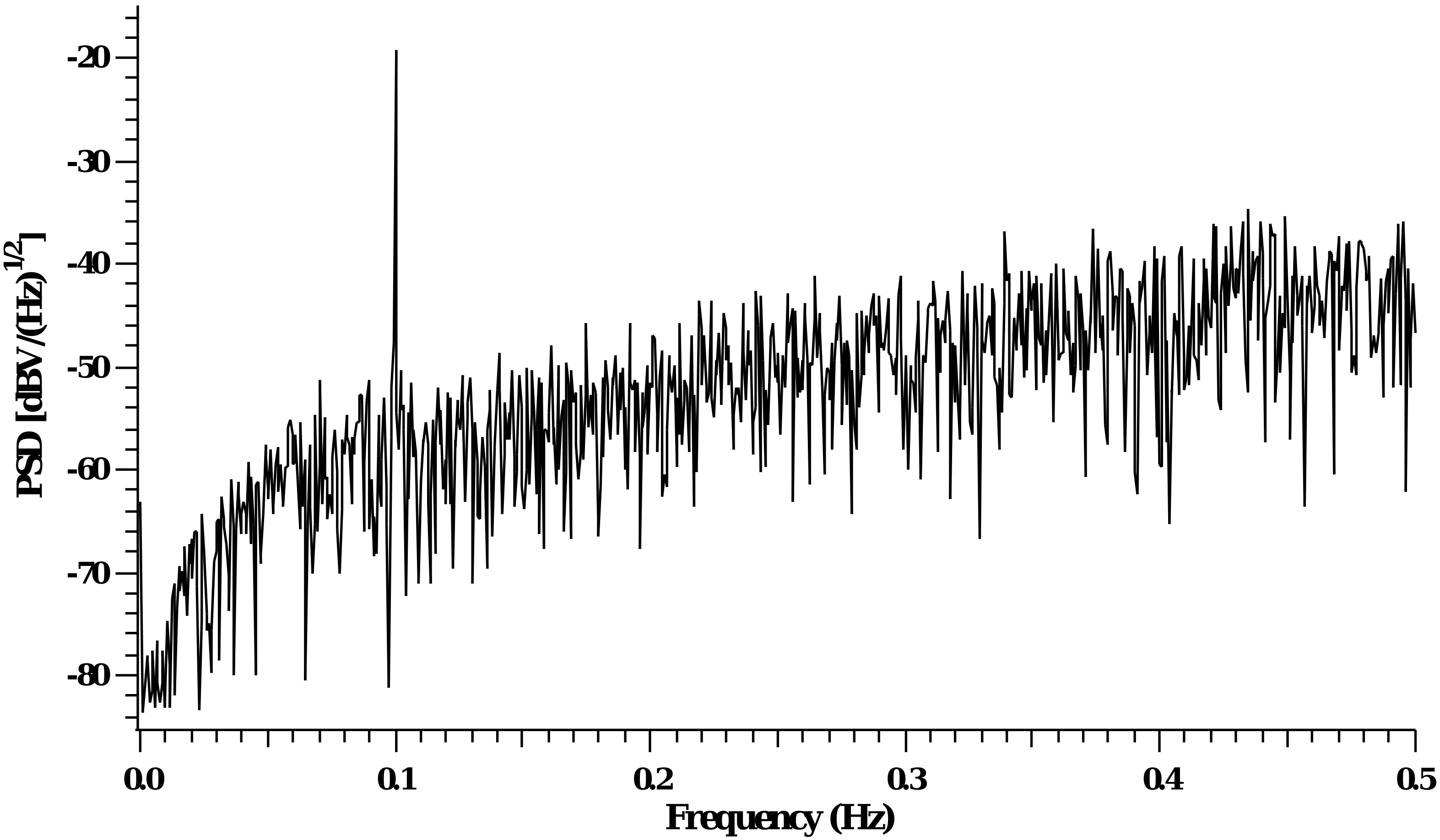


FLSS Anechoic Chamber
1530 nm
FL
PZT
screw
Temp.
Control
Strain
Wavefor
m
1530 nm
coupler
coupl
er
OPD
OI
PZT
MZI
Anechoic
Chamber
PD'S
WDM
+
-
OI
980 nm
PDC
Pump
Laser
DO
LPF
SA

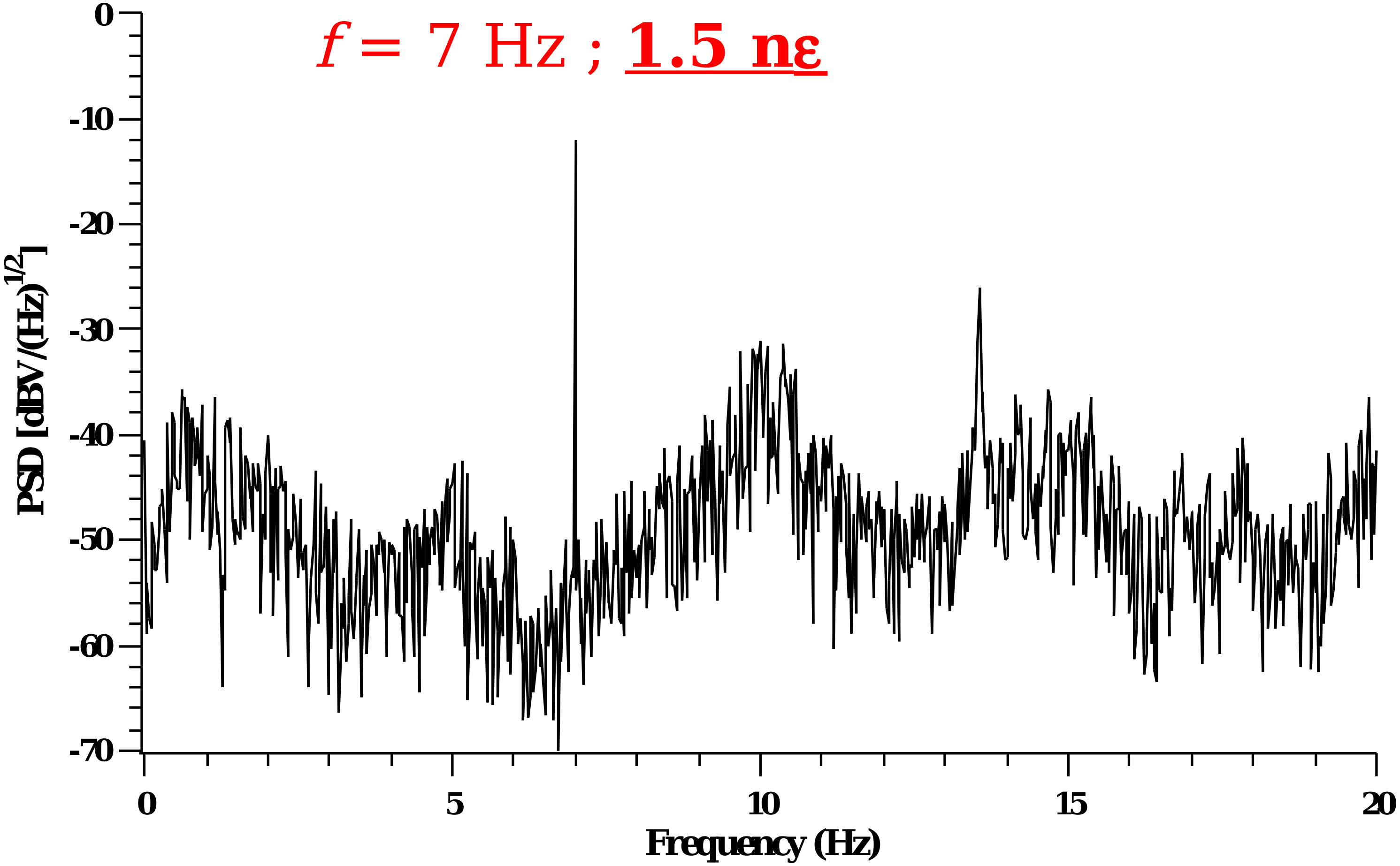




f = 100 mHz ; 15 nε

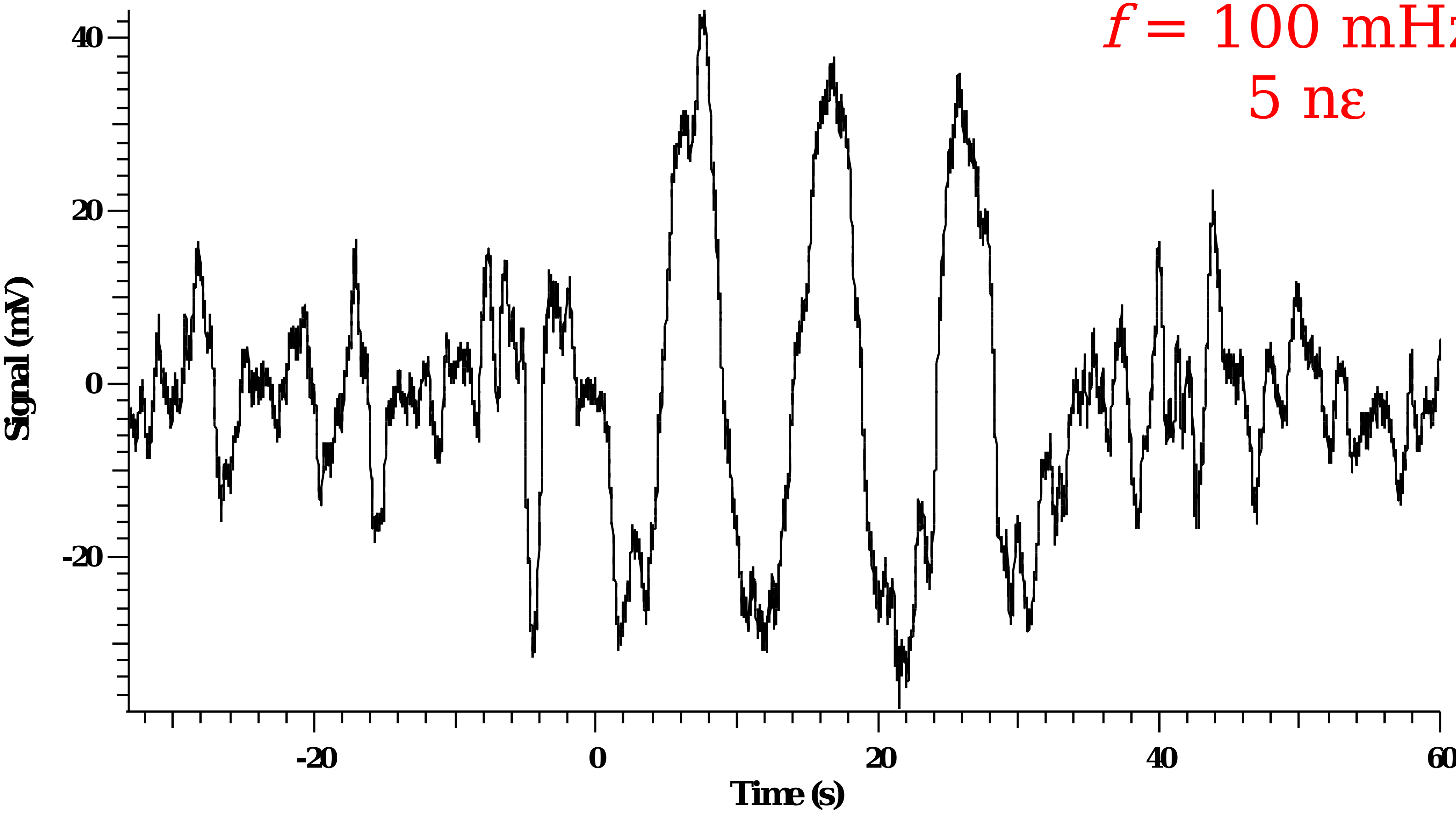


Resolution 250 pε/(Hz)$^{1/2}$



Resolution 15 pε/(Hz)1/2

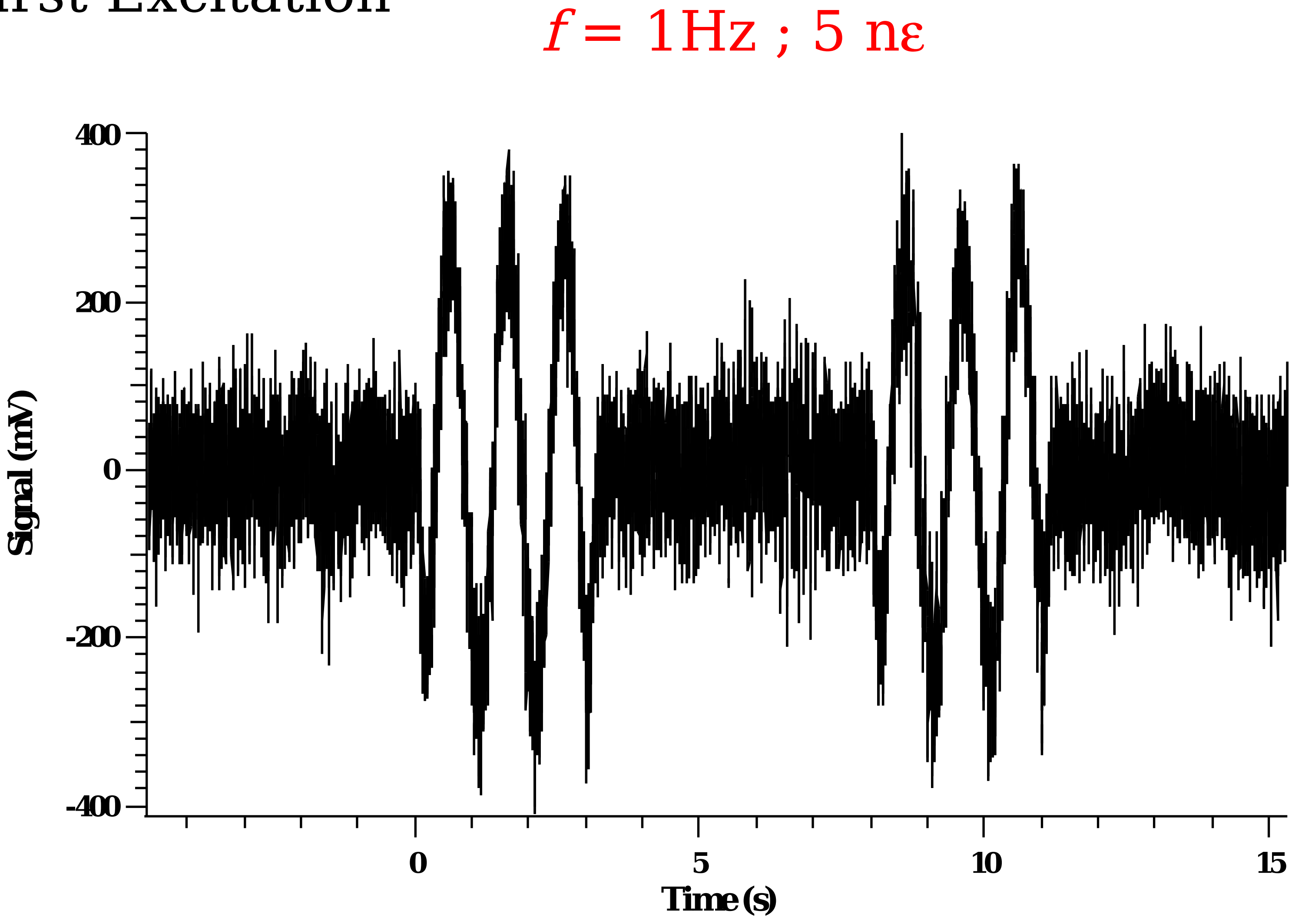
Burst Excitation – Time Domain Acquisition



f = 100 mHz ;
5 nε

0.3 Hz Low-Pass Filter

Burst Excitation



Burst Excitation

f = 7Hz ; 5 nε