PROPAGATION OF ACOUSTIC WAVES THROUGH MIXING LAYER OF SUBSONIC AND SUPERSONIC FLOWS

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Motivation

To study different flows both for applied tasks and fundamental problems such as:

- boundary layers,
- shear flows,
- jets,
- mixing flow, etc.,

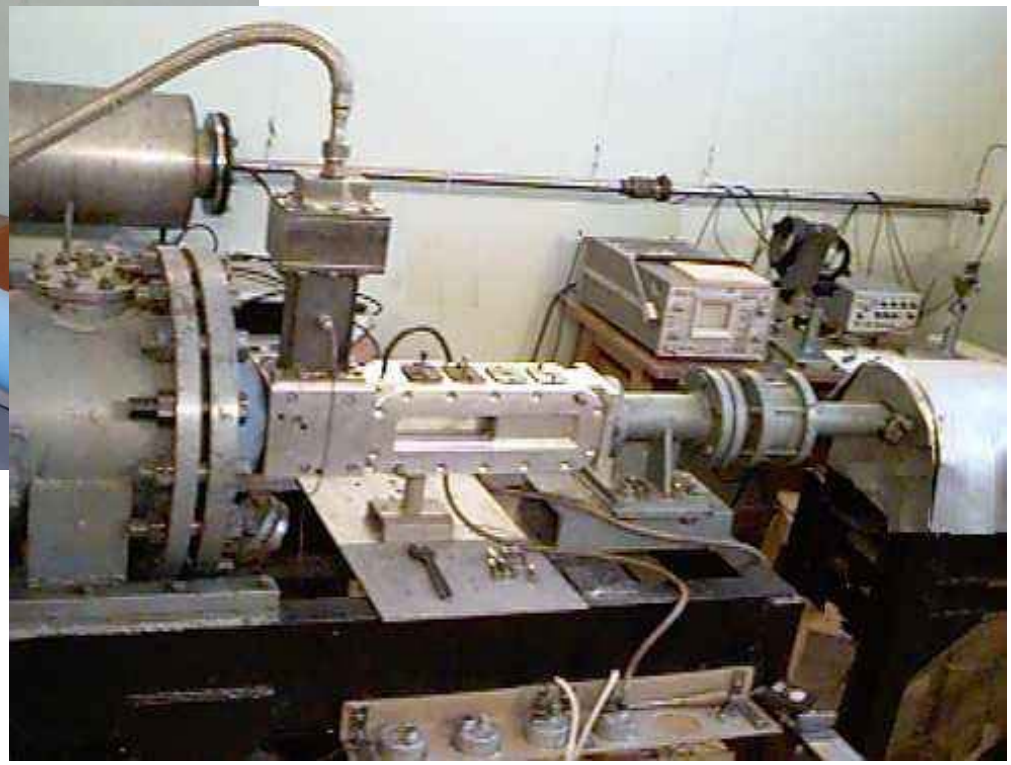
it is necessary to measure flow fluctuations.

The main goal was to develop and test approaches based on hot-wire technique

Experimental facility

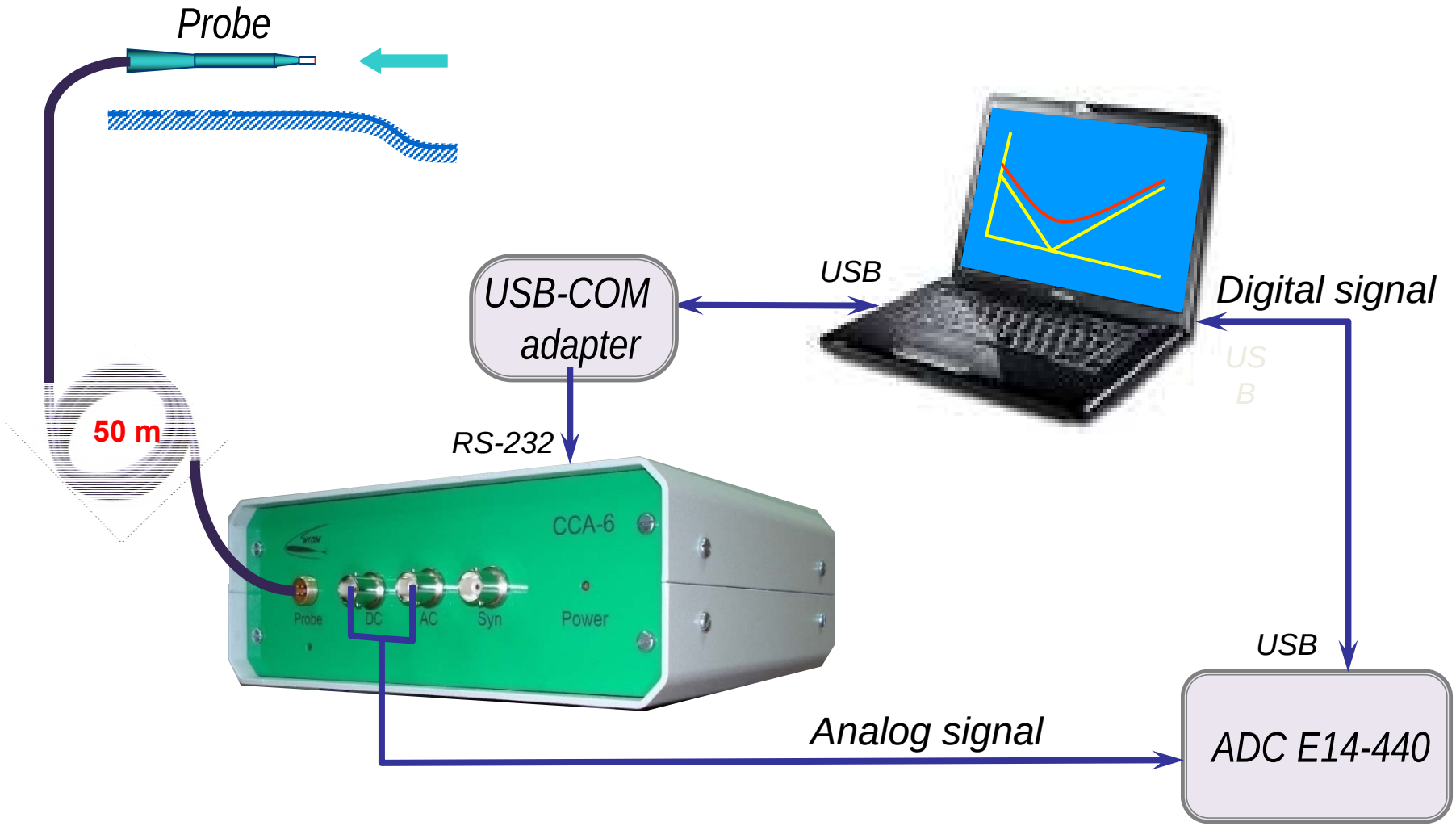
T-325M (ITAM SB RAS)

Test section: 40x40 mm



Special test section

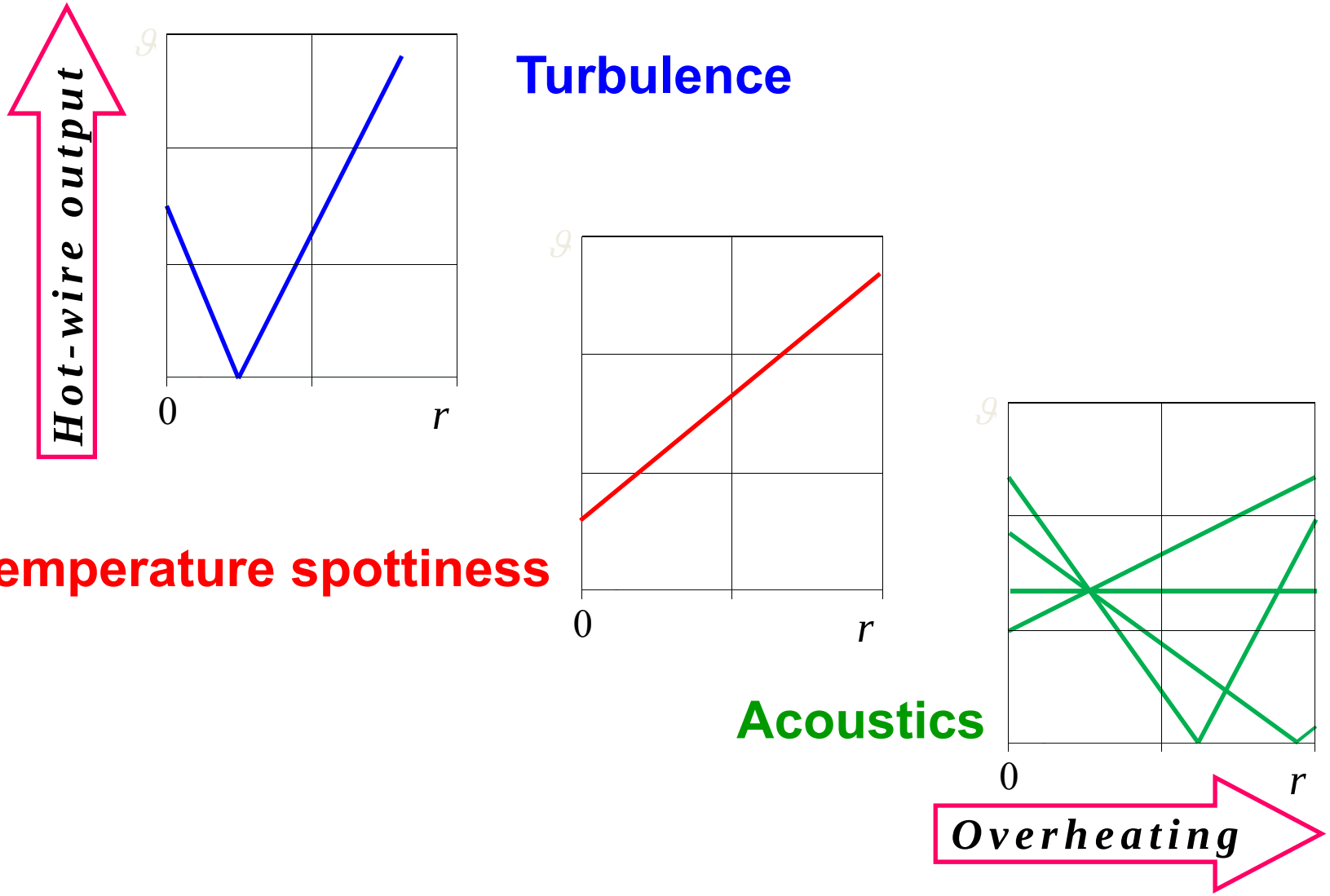
Measuring system on base of CCA-6



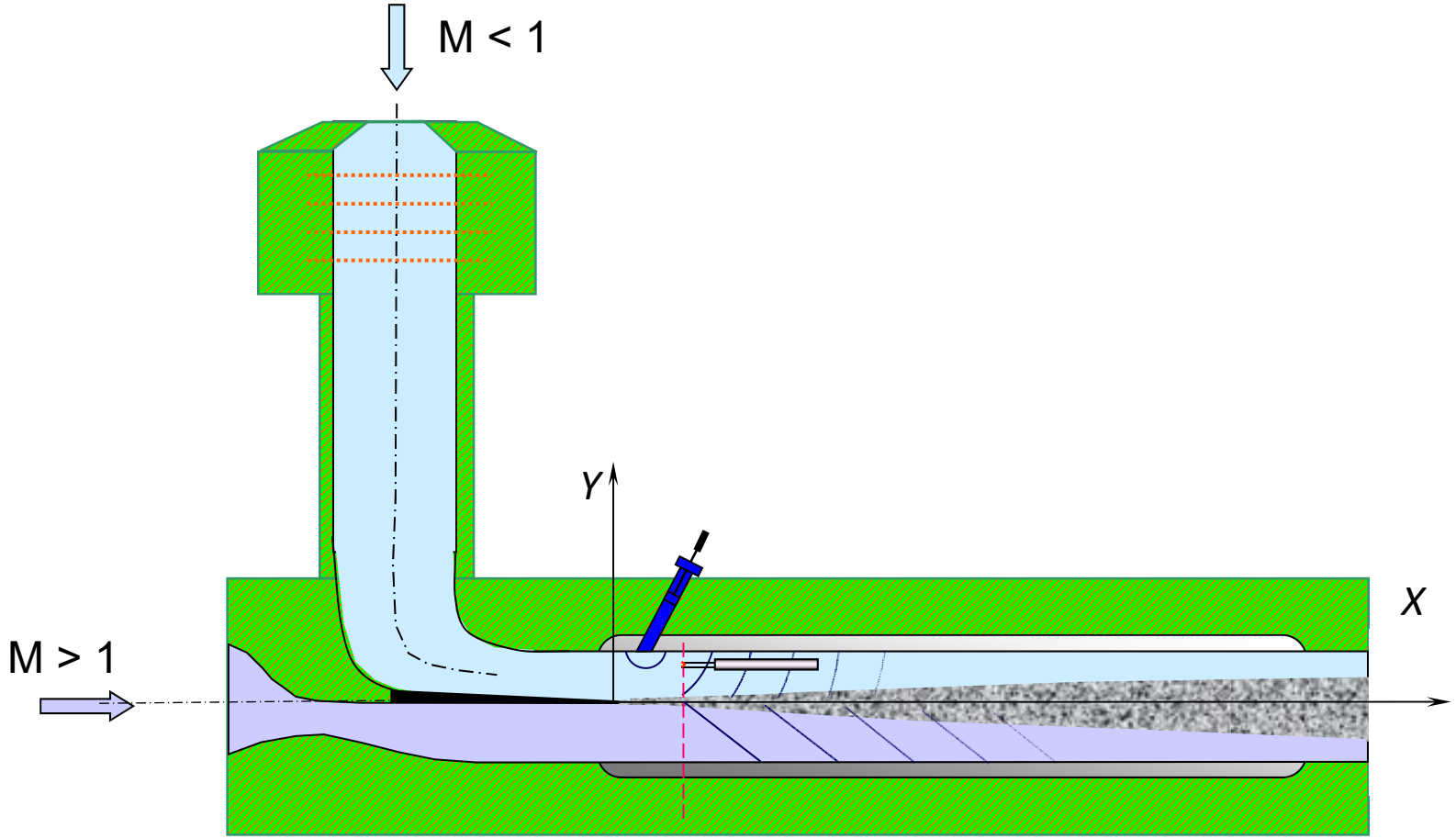
Constant current anemometer CCA-6

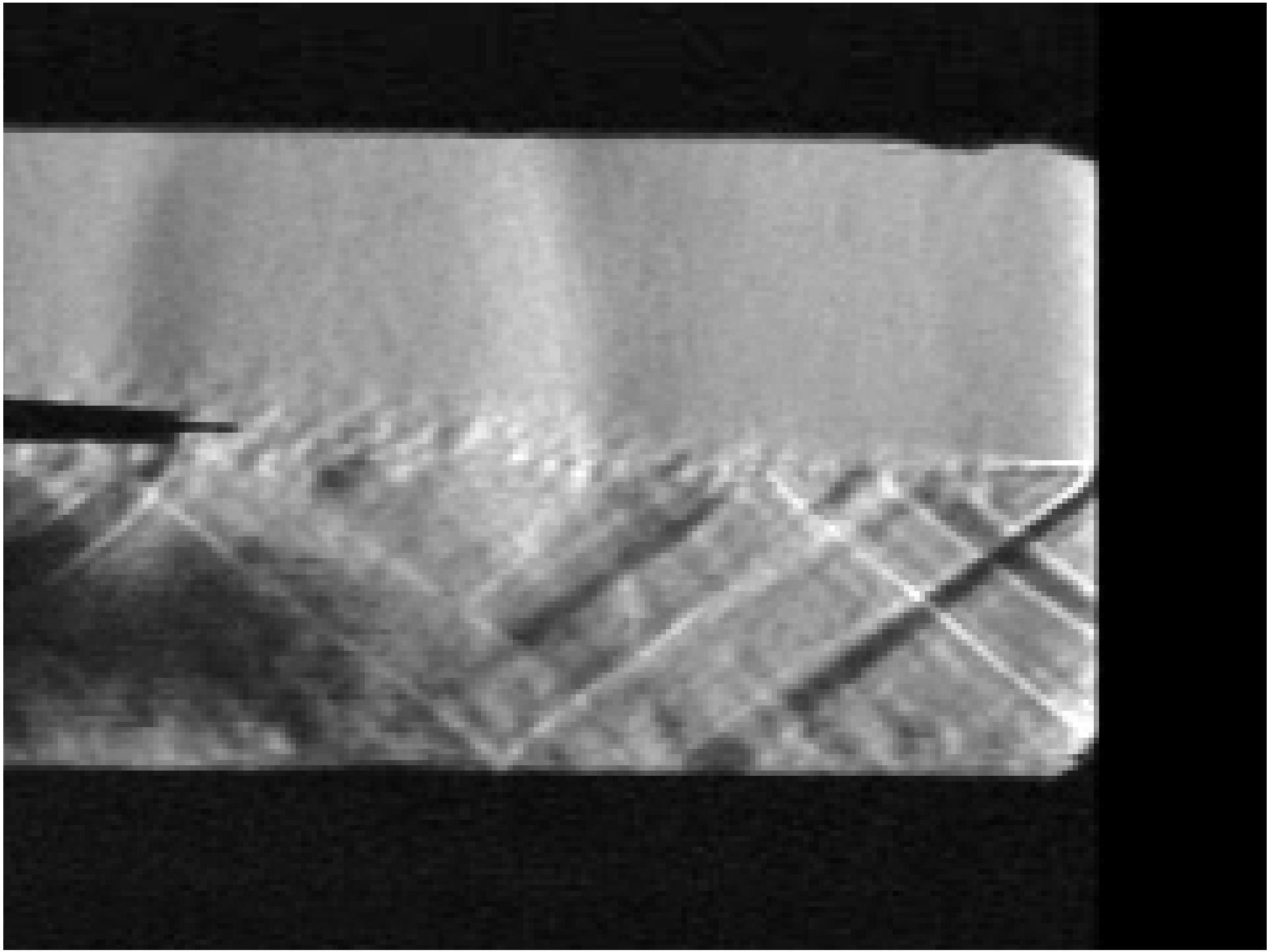
- Frequency range ---------- 200 kHz
- Probe cold resistance ---------- 0 ... 20 Ohm
- Resistance of the heated probe ---------- 0 ... 40 Ohm
- Accuracy of the probe resistance measurement ---------- < 0.01 Ohm
- Interference suppression on the mains supply is ---------- not less than - 80 dB
- Gain of instantaneous signal (AC) ---------- 1, 10, 100 and 1000
- Cut-off frequency of the filter ---------- 200, 100, 50 and 25 kHz
- Gain of the mean signal (DC) ---------- 10, 100 and 1000
- Length of the probe cable ---------- up to 50 m
- Built-in square-wave generator
- Full control of the computer's RS-232 communications

Hot-wire output for different modes

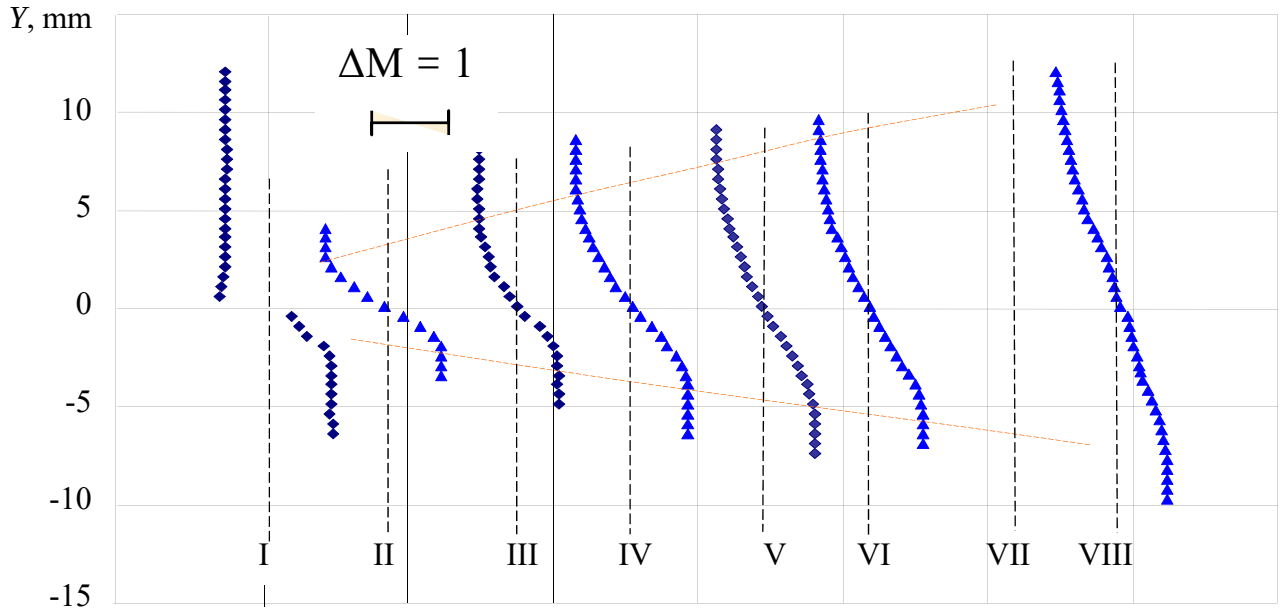


Scheme of experiments

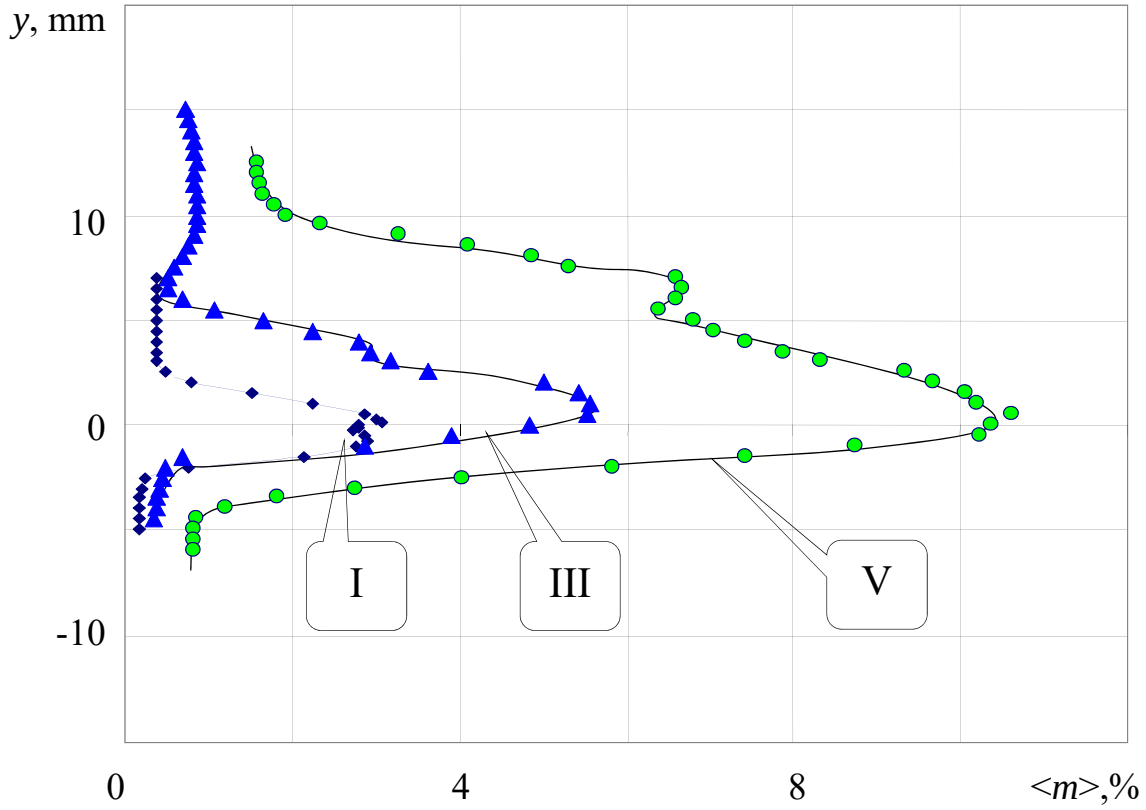


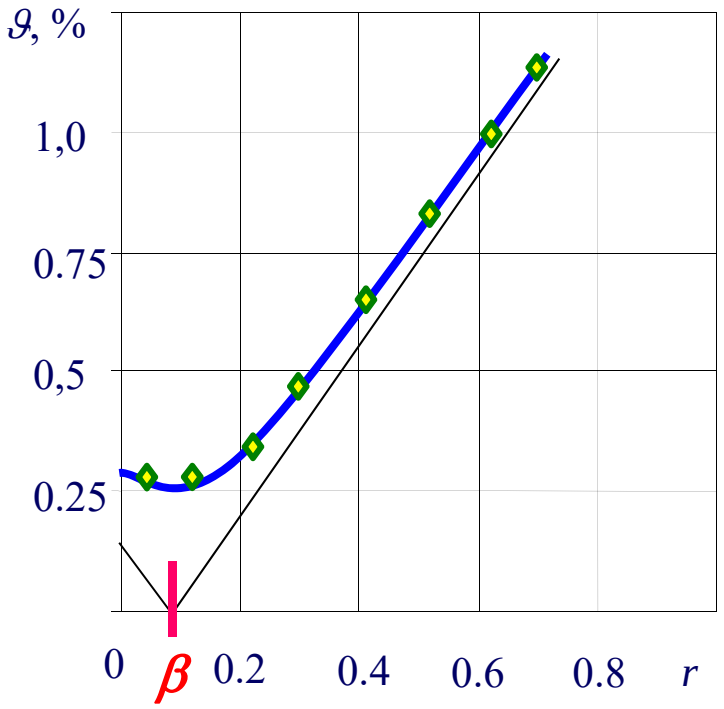


Profiles of M in different cross-sections of mixing layer

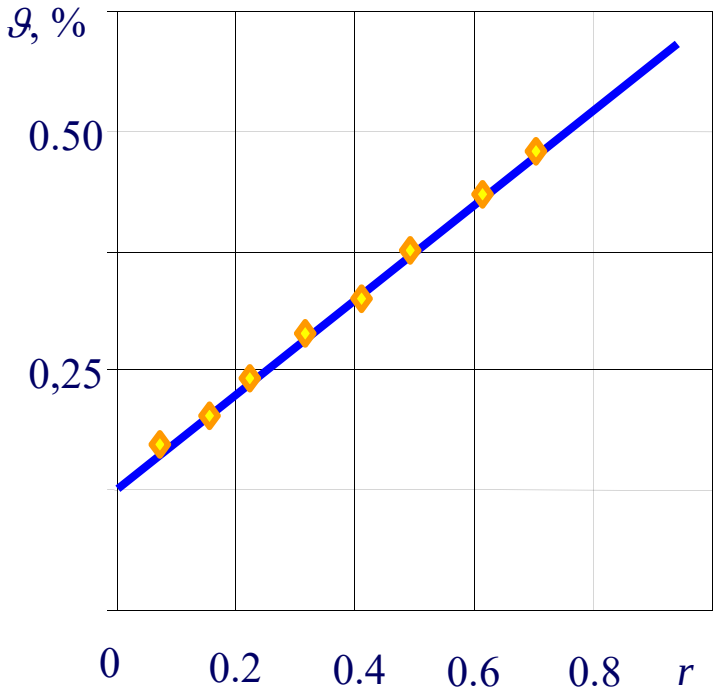


Profiles of mass flow fluctuations in mixing layer

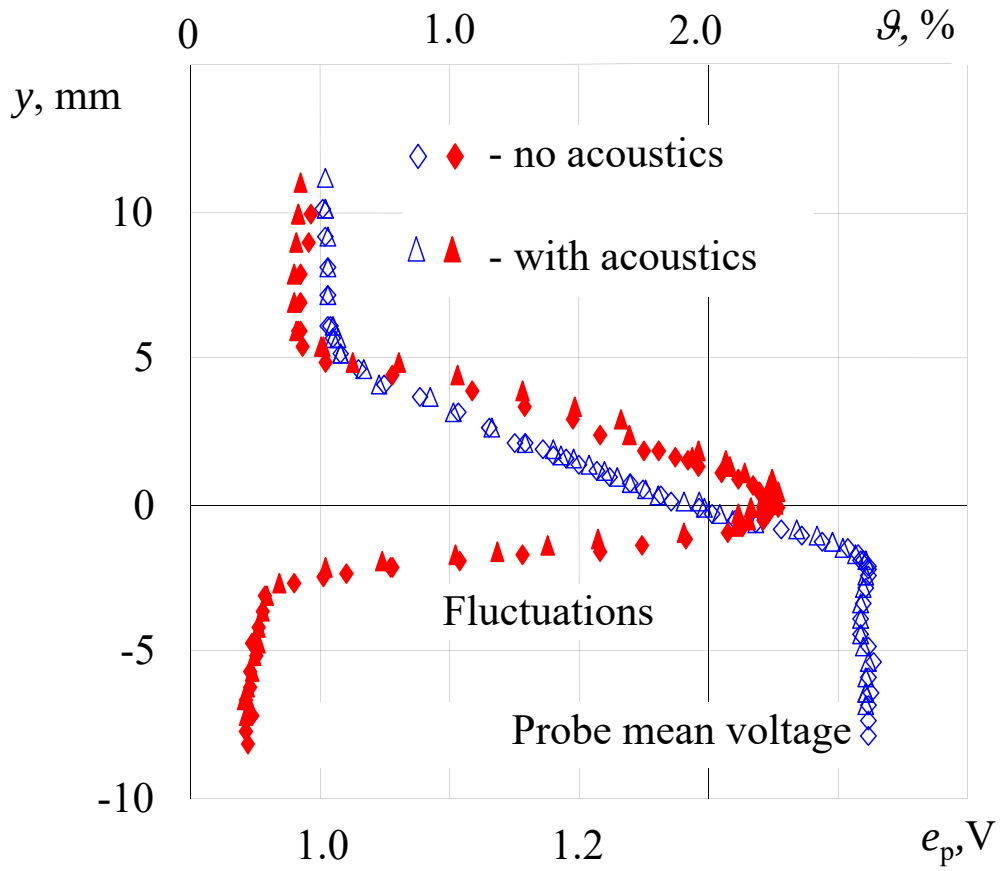




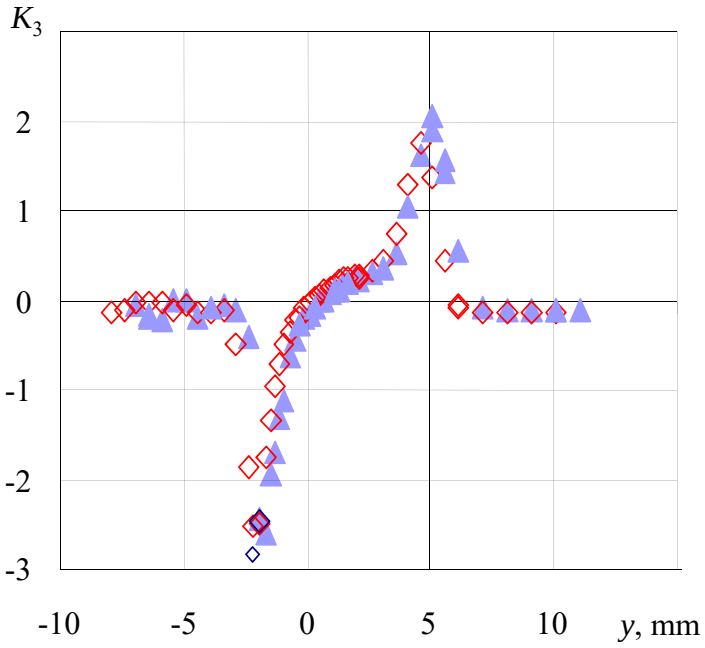
M < 1



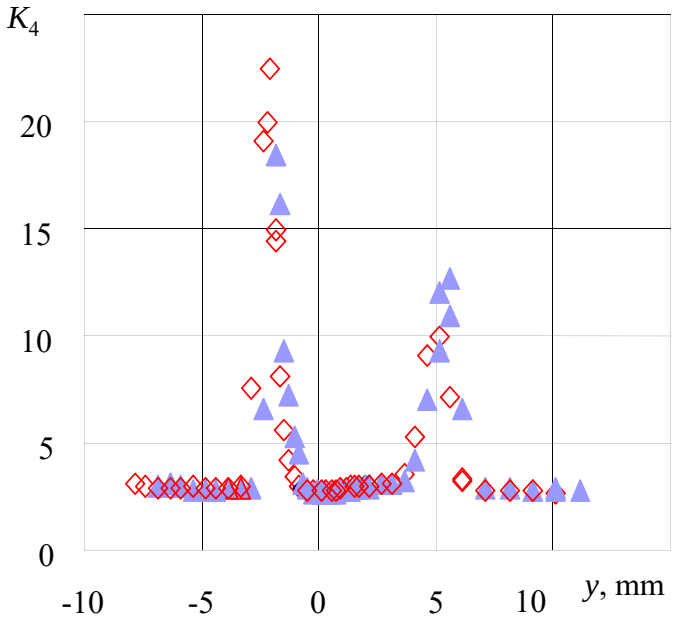
M > 1


0
1.0
2.0
ϑ, %
y, mm
10
5
0
-5
-10
- no acoustics
- with acoustics
Fluctuations
Probe mean voltage
1.0
1.2
e_p,V

Total fluctuations



Asymmetry coefficient

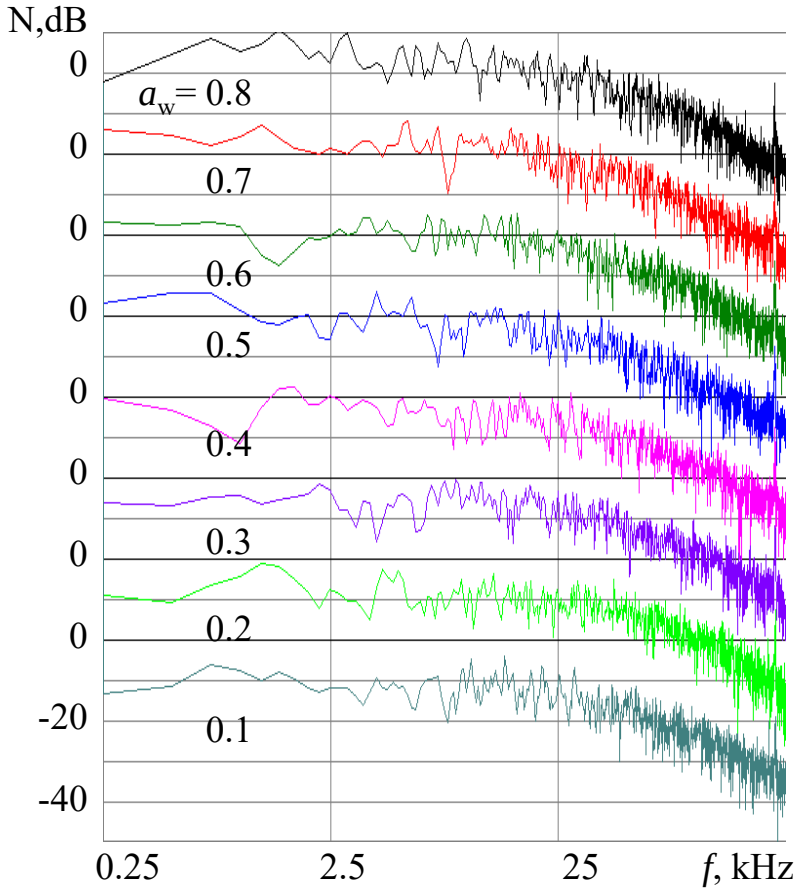


Excess coefficient

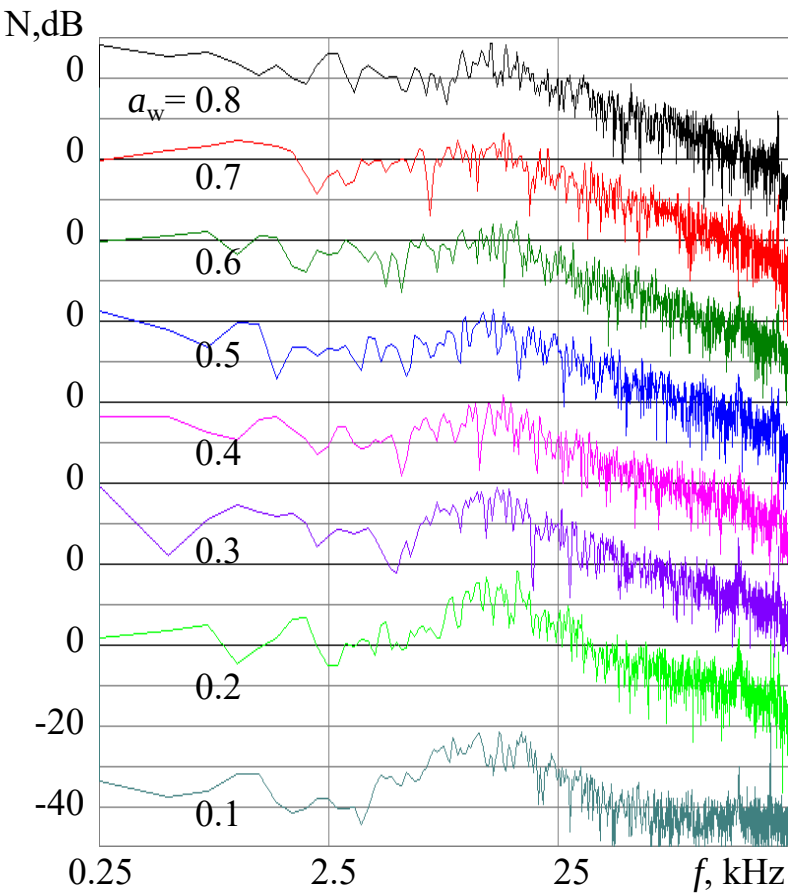
◇ no acoustics

▲ with acoustics

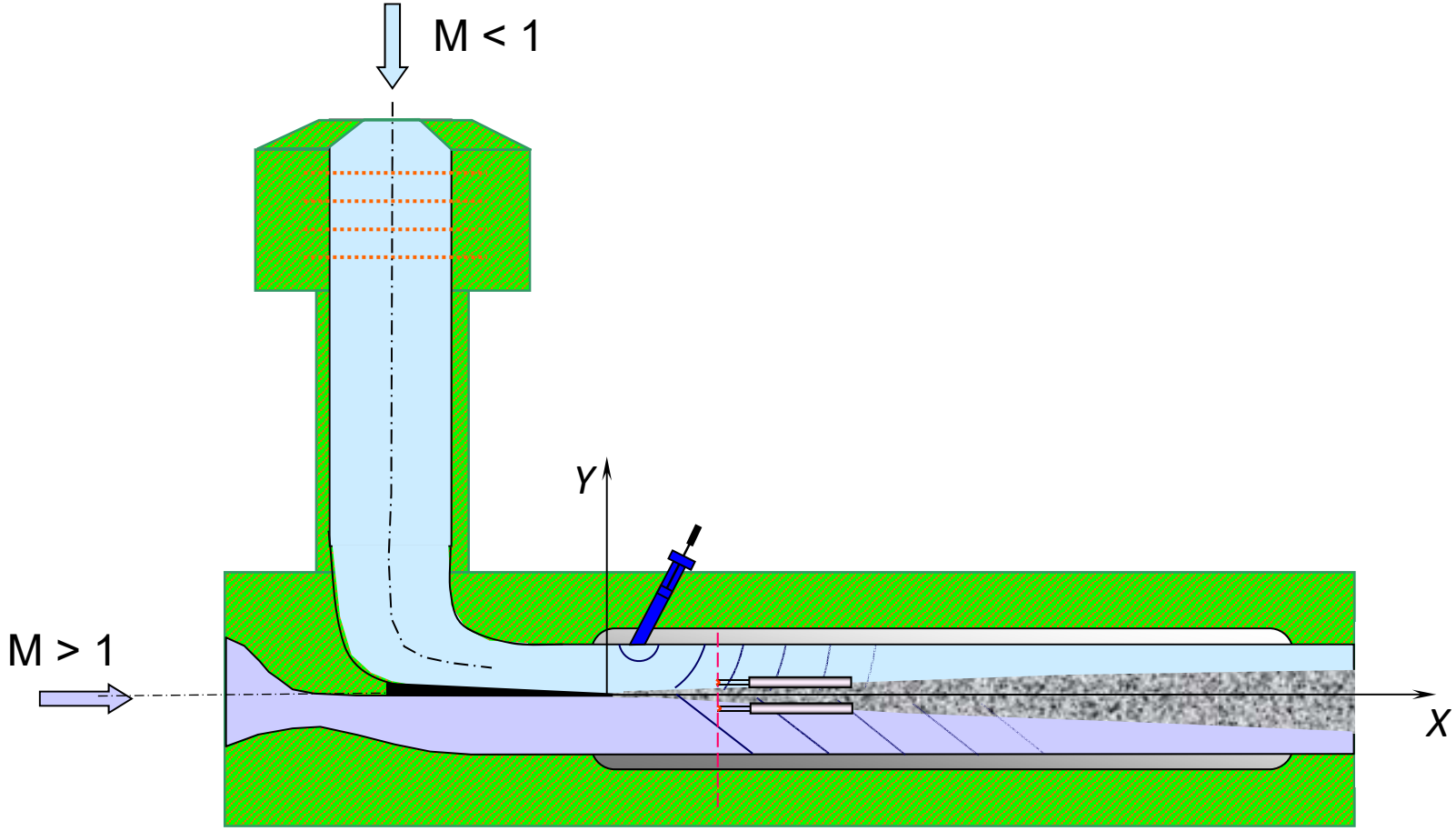
Spectra of free stream fluctuations



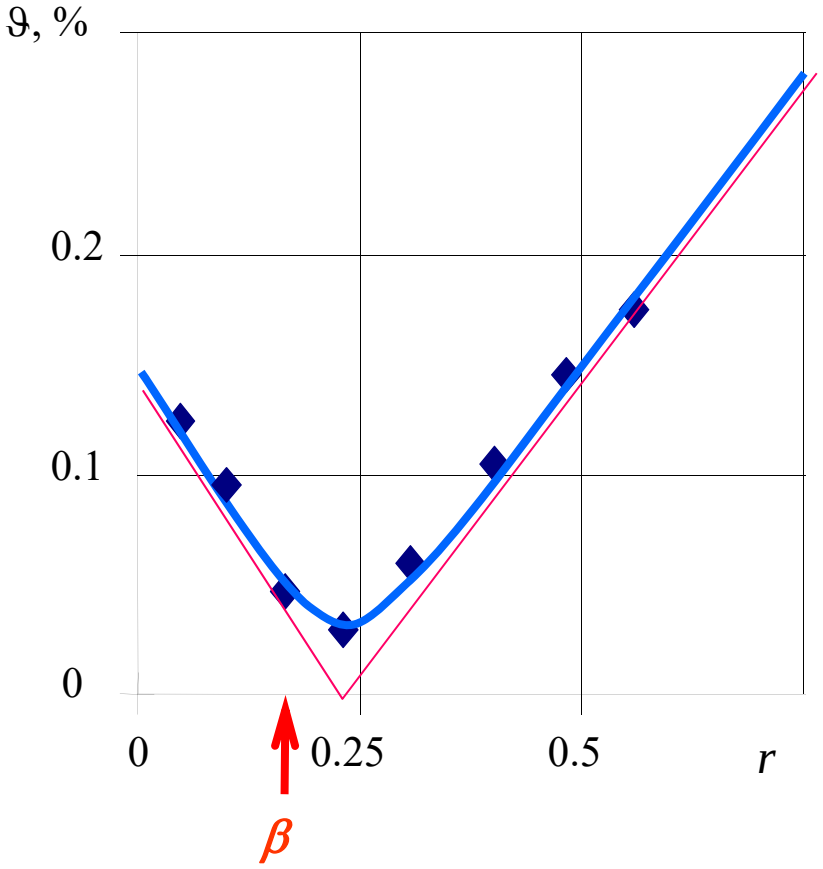
Fluctuation spectra in subsonic flow



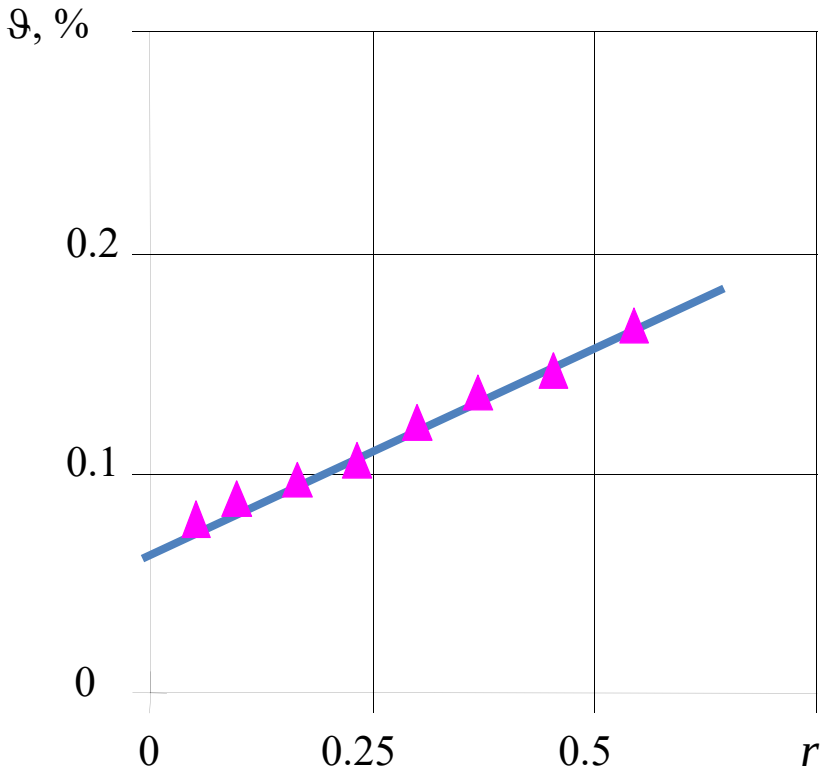
Fluctuation spectra in supersonic flow


M < 1
M > 1
Y
X

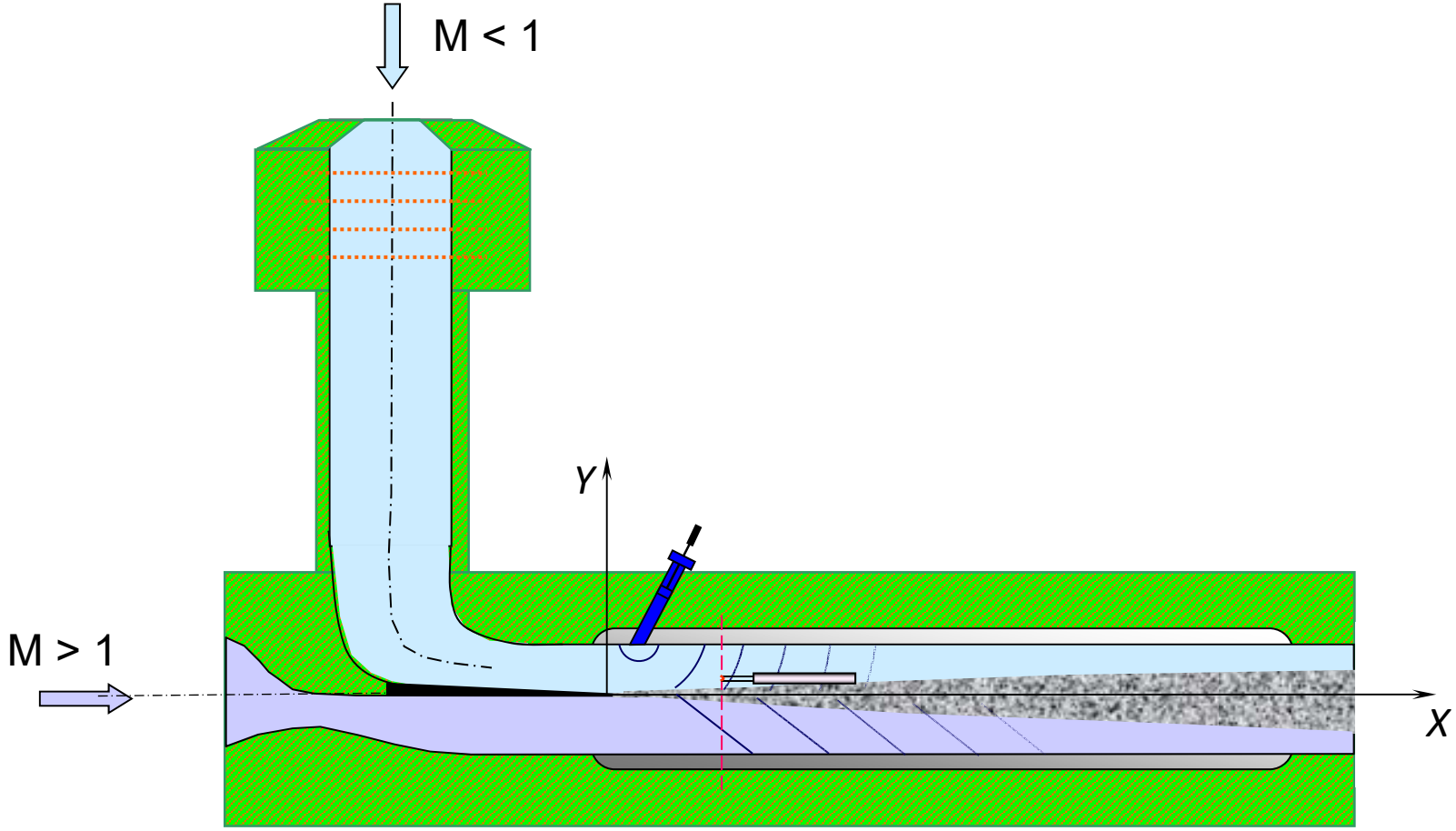
f=6.8 kHz



M < 1



M > 1

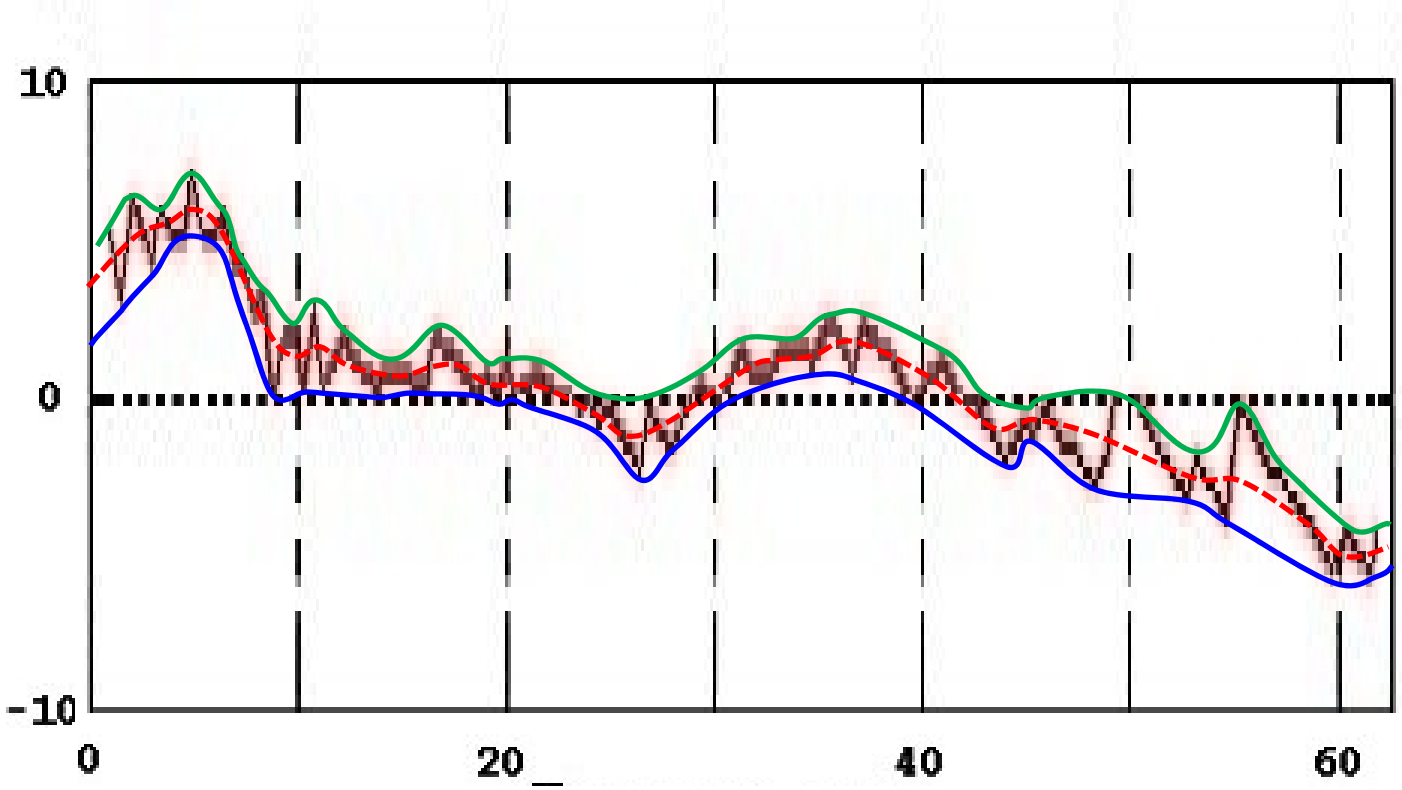


M	<*p*>	cos hi	hi grad	hi (M)	*c/u*
0,5	0,39	0,4868	61	-	-
2,5	0,38	- 0,8465	148	114	0,53

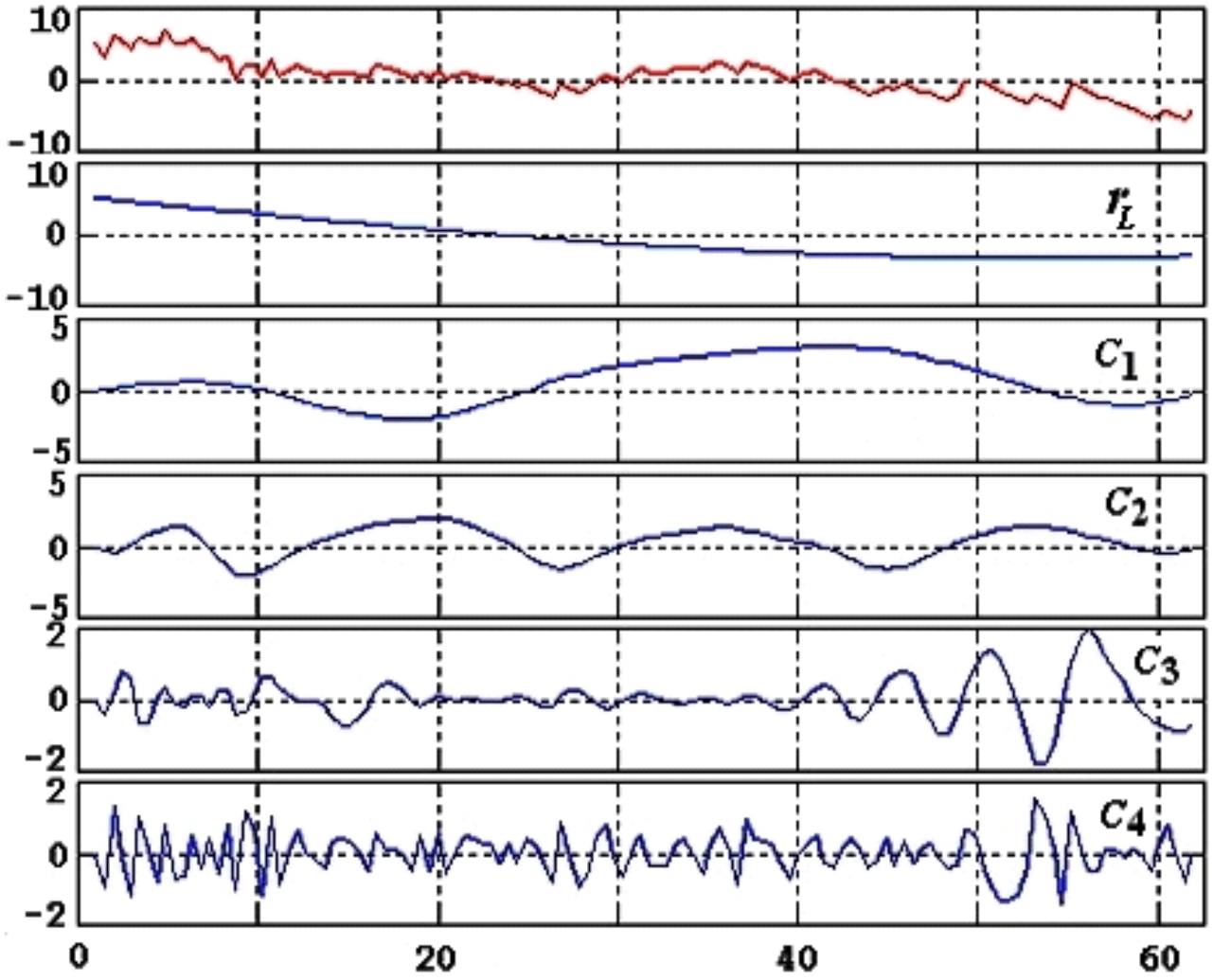
Methods of fluctuation analysis:

- Fourier transform
- Wavelet
- Hilbert-Huang transform (EMD)

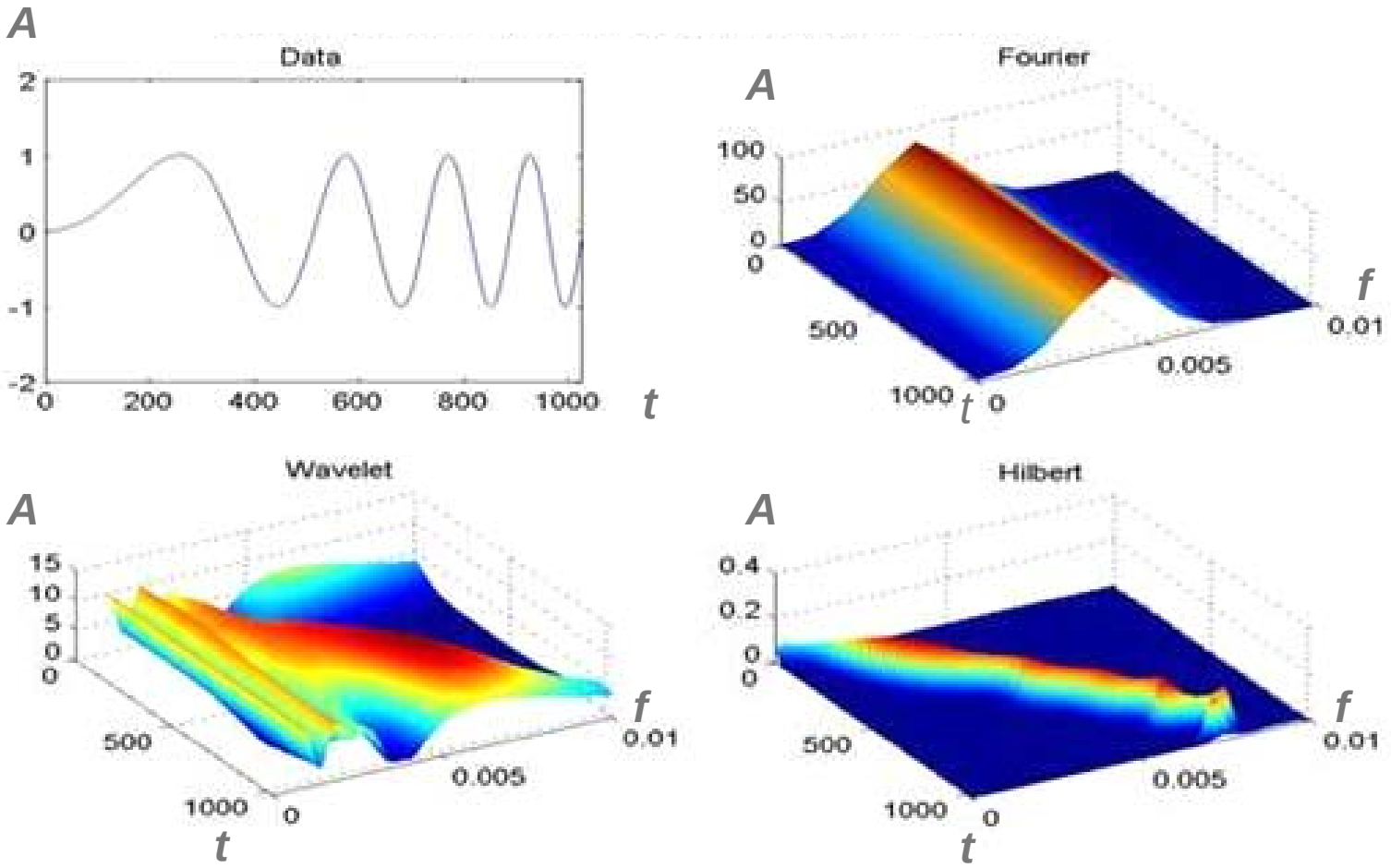
Hilbert-Huang transform (EMD)



Hilbert-Huang transform (EMD)



Comparison of FFT, Wavelet, HHT

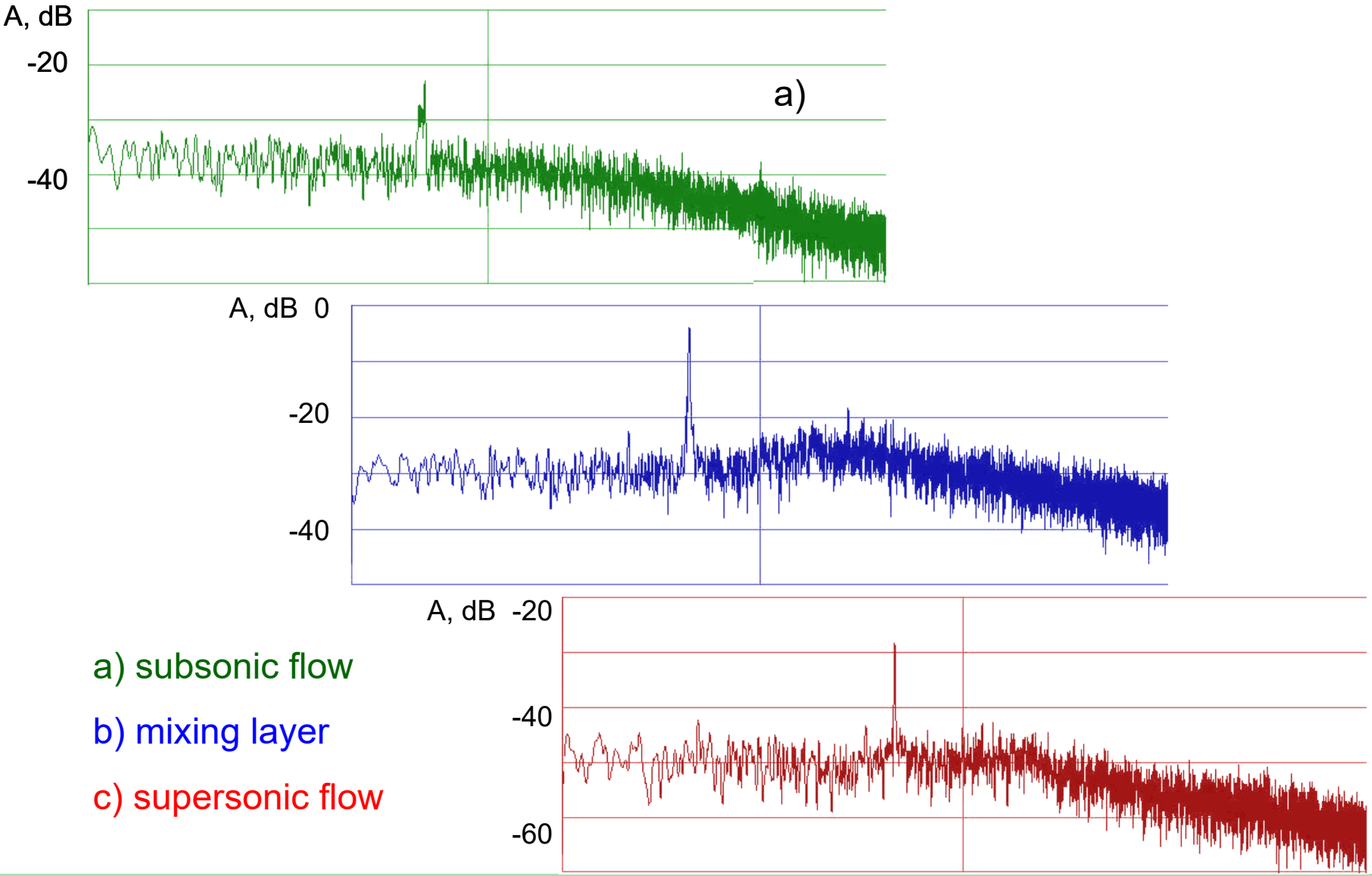


Application of fluctuation analysis

- **Fourier transform**
- **Wavelet**
- **Hilbert-Huang transform (EMD)**

to results of measurements in the mixing flow

Fourier spectra of fluctuations with whistle

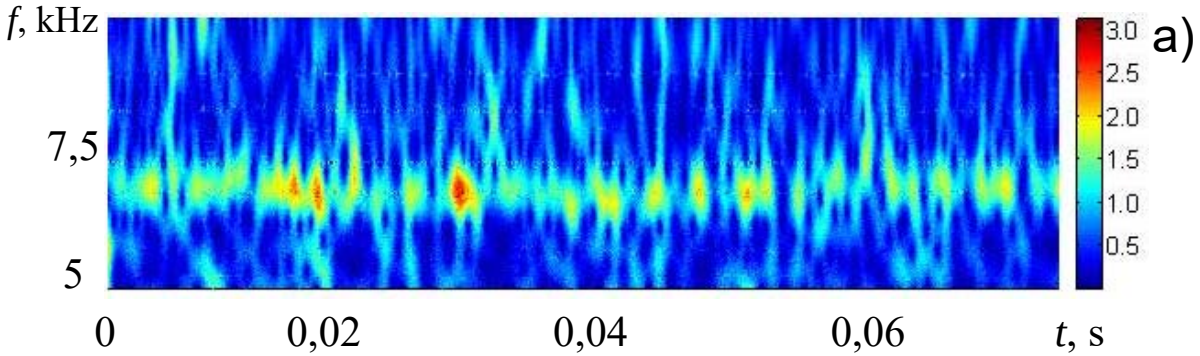


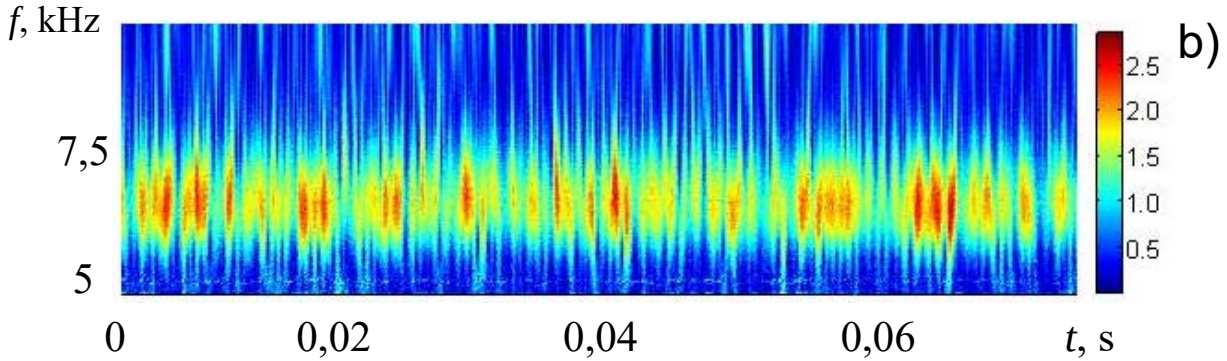
a) subsonic flow

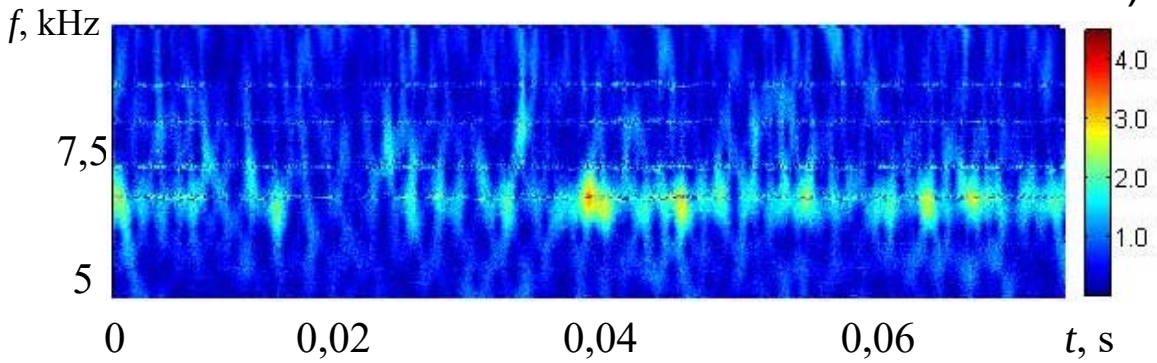
b) mixing layer

c) supersonic flow

Wavelet spectra of fluctuations with whistle





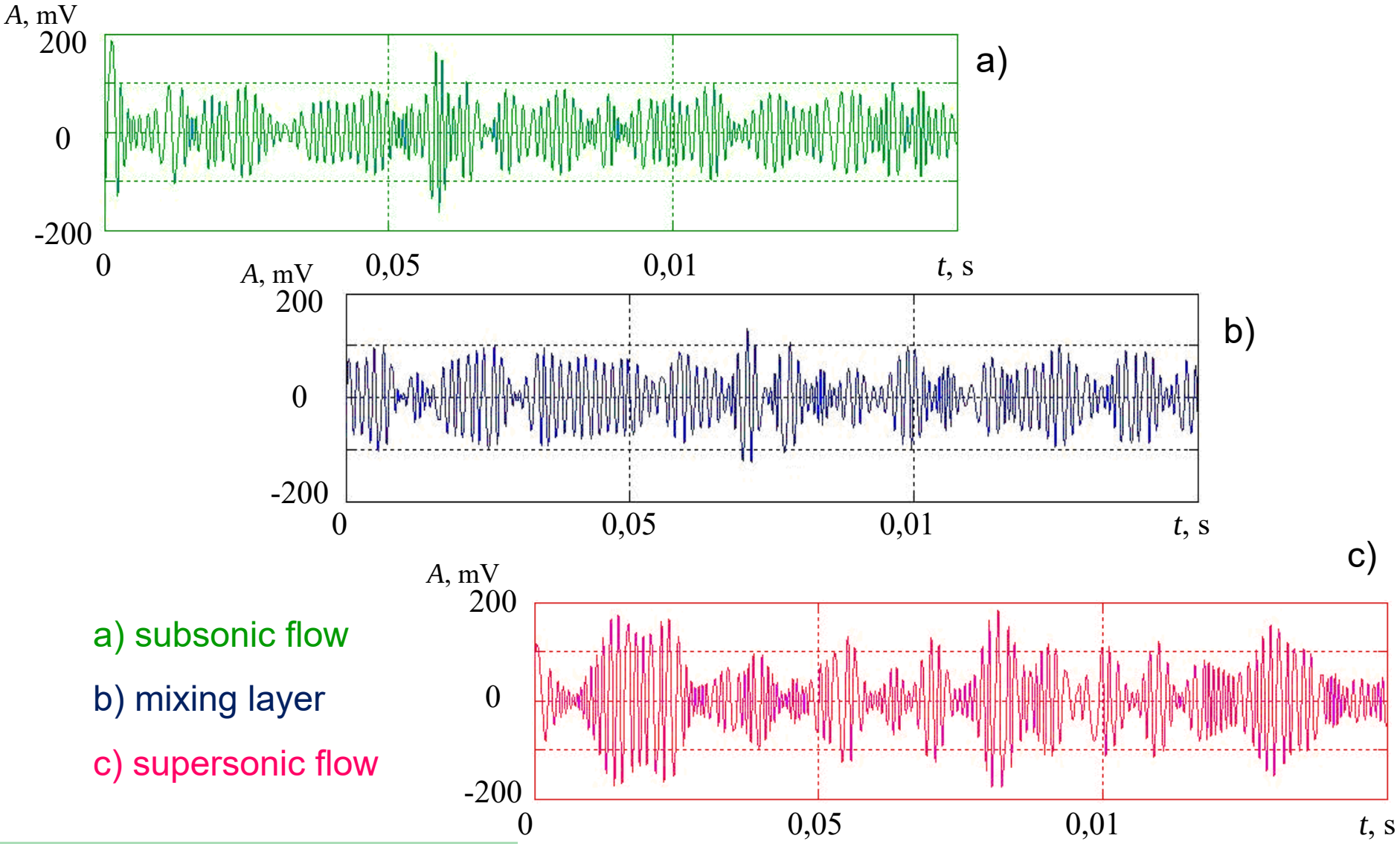


a) subsonic flow

b) mixing layer

c) supersonic flow

Empirical mode of artificial acoustic fluctuations



a) subsonic flow

b) mixing layer

c) supersonic flow

Concluding remarks:

Various experimental methods of measurement and data analysis have been tested for a model problem of passing acoustic waves through the mixing layer of subsonic and supersonic flow.

It was shown that the hot wire technique, supplemented by an appropriate analysis, allows investigate in detail shear flows, including at the presence of acoustic waves.

Thank you for your attention!