Doppler

IdeaSquare Cern

2023-10-15
4th EPS TIG Hands-on Event

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Theoretical Basics

Doppler frequency:

$$\nu_D = \nu_0 - 2nV_p\frac{\nu_0}{c} \tag{1}$$

where $V_p = 0.5\,\frac{\text{mm}}{\text{s}}$, $\lambda_{\text{He-Ne}} = 632\,\text{nm} \Rightarrow \nu_{\text{He-Ne}} \simeq 4.75 \cdot 10^{14}\,\text{Hz}$

$$2nV_p\frac{\nu_0}{c} \simeq 1.6 \cdot 10^3\,\text{Hz}$$

Experimental Setup

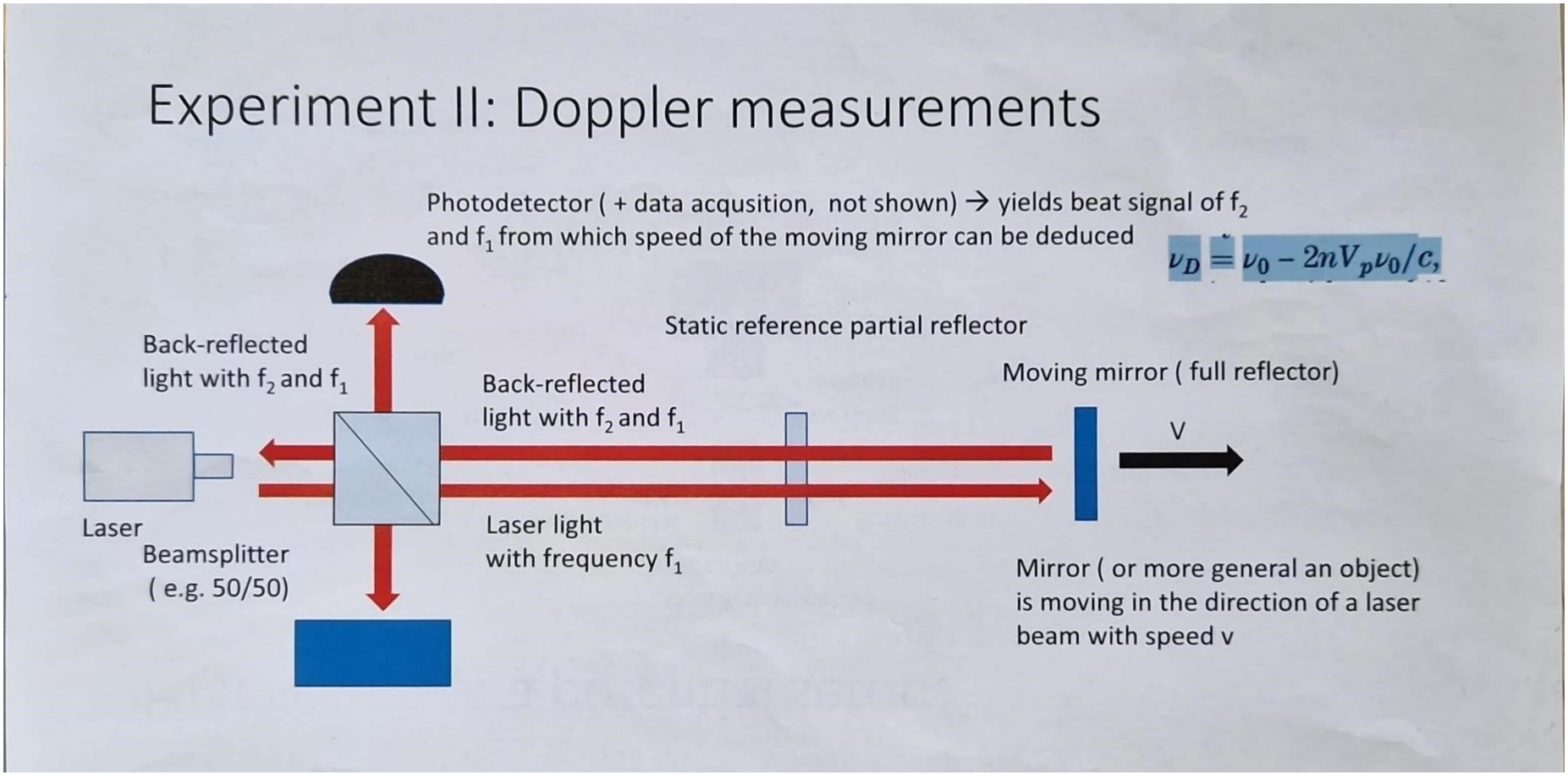
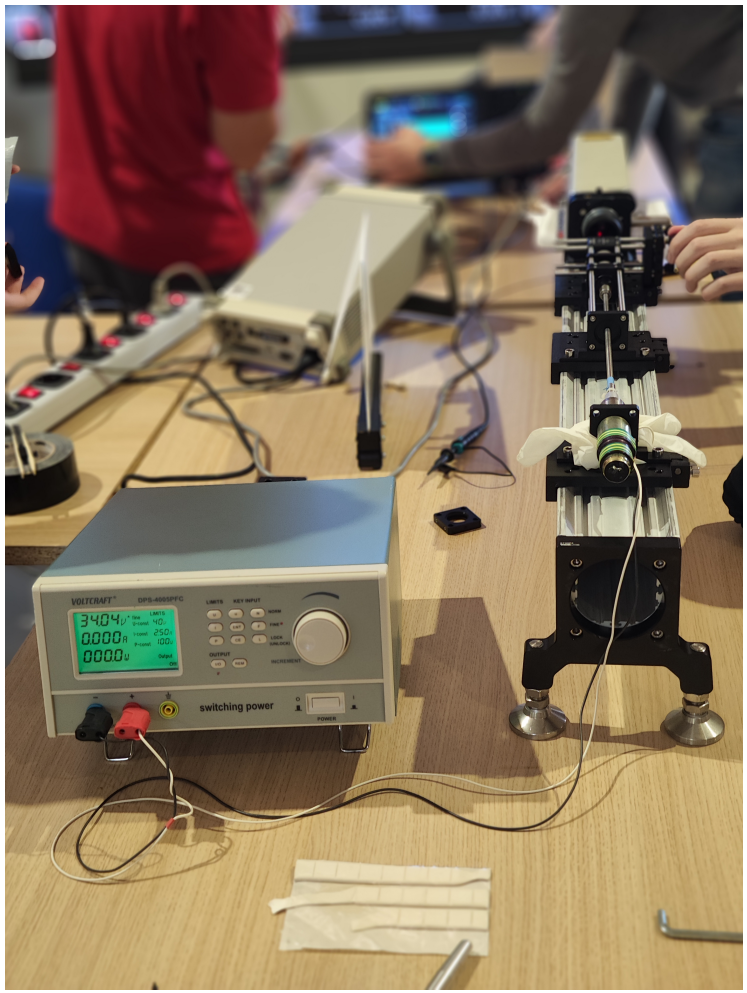
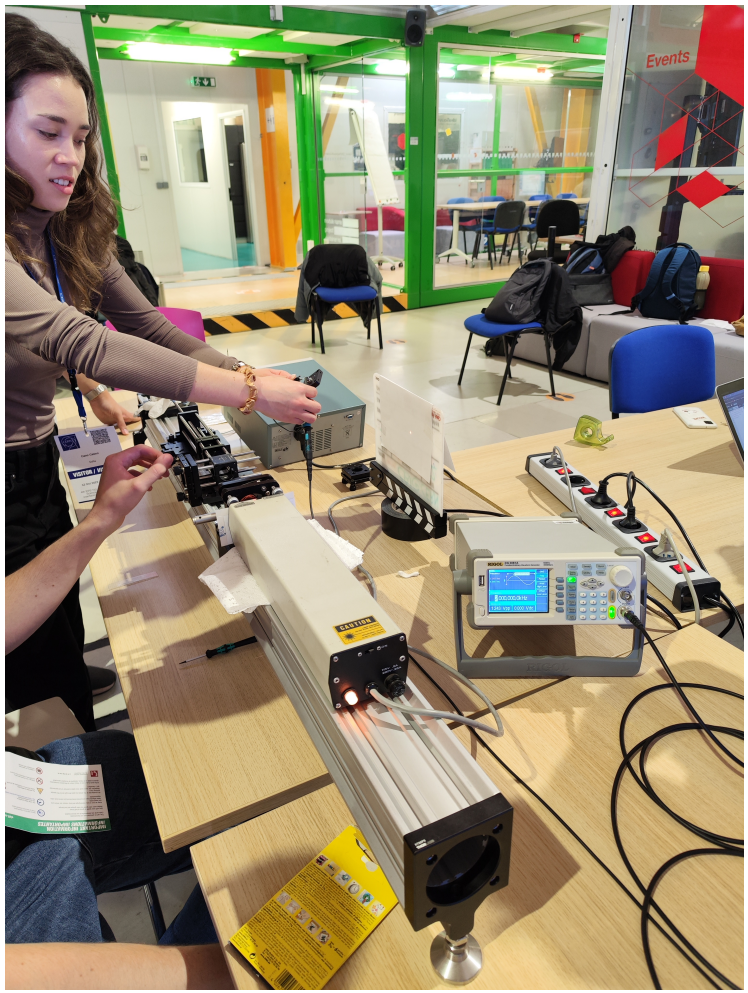


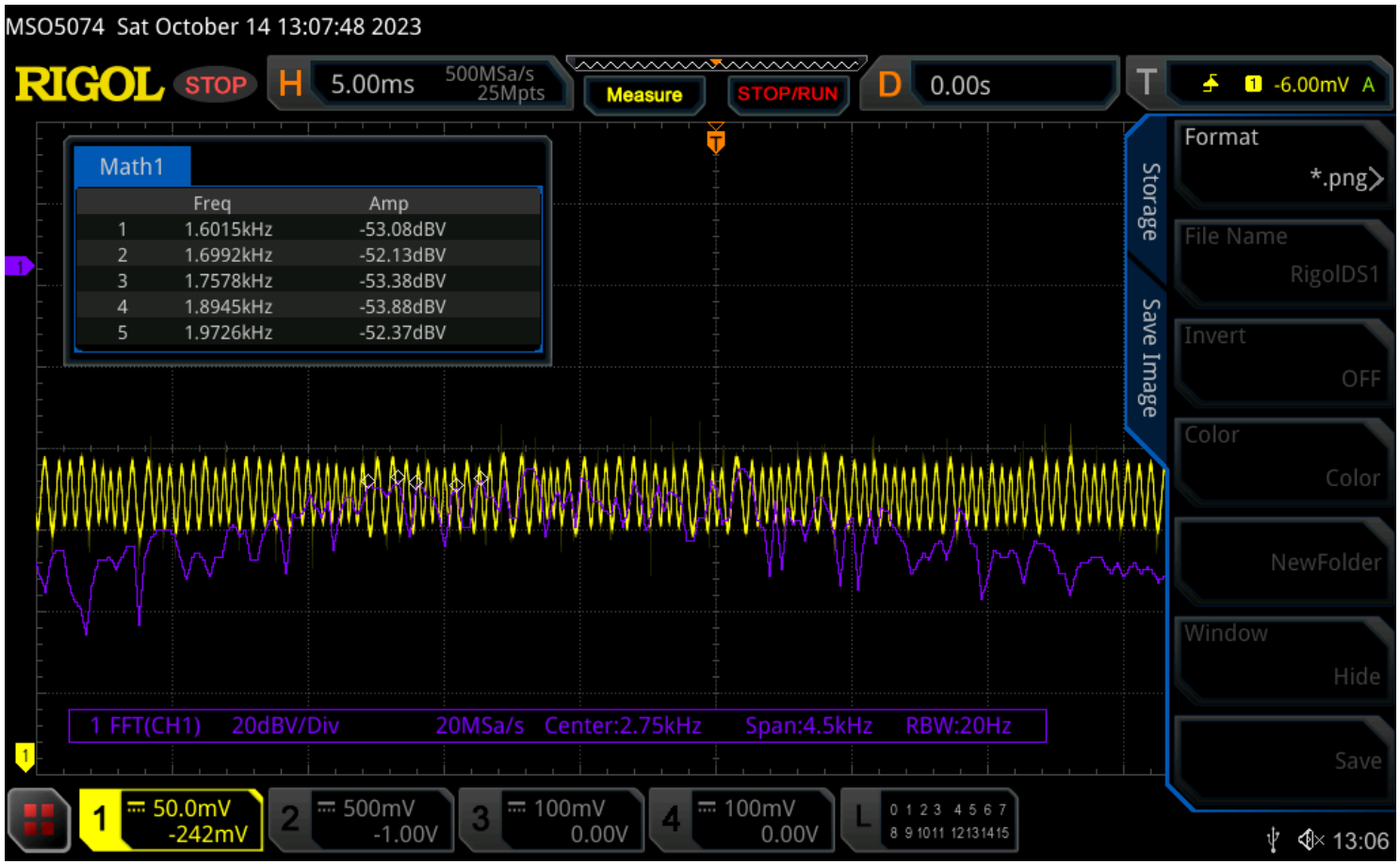
Figure: Schematic setup

Setup

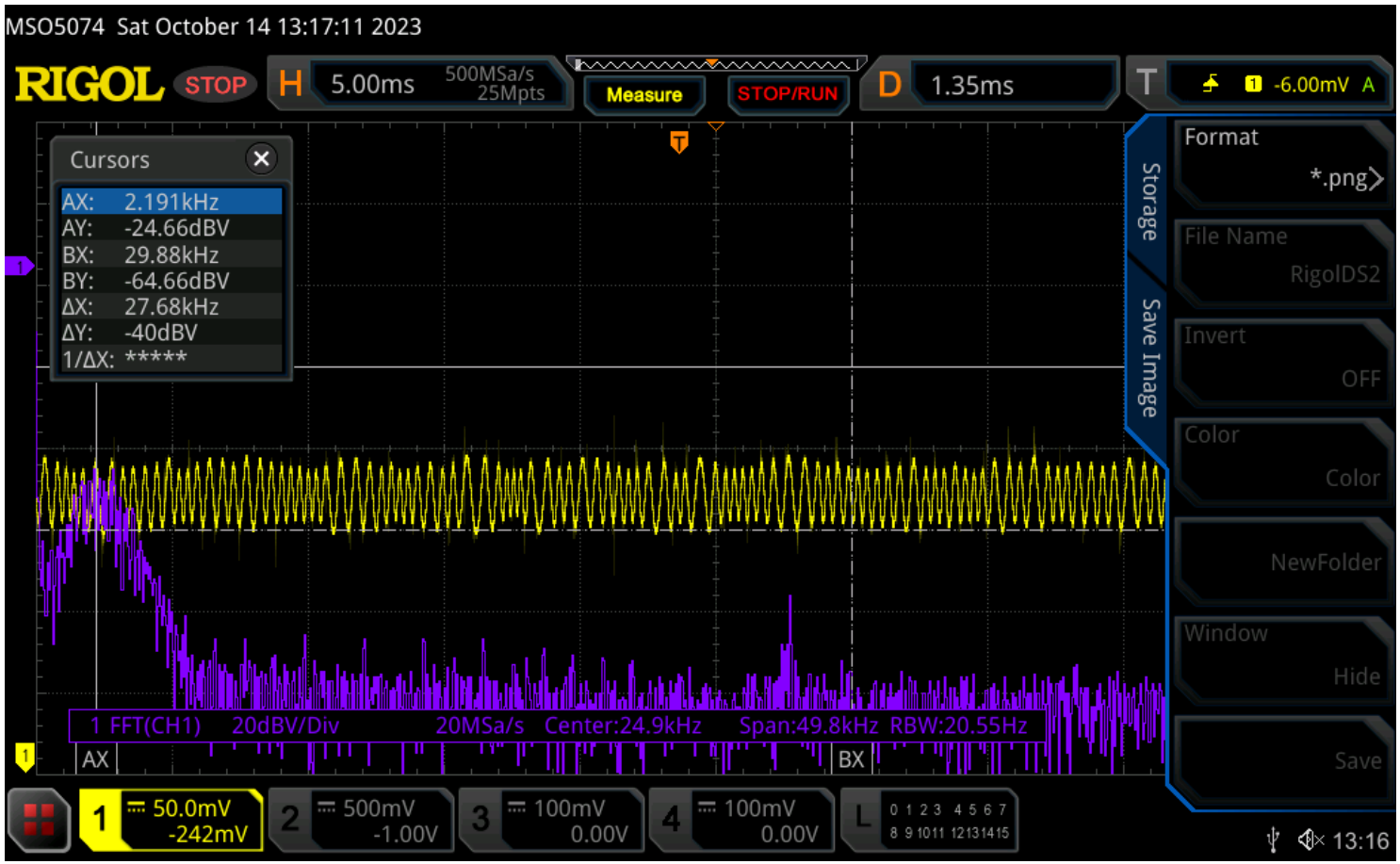




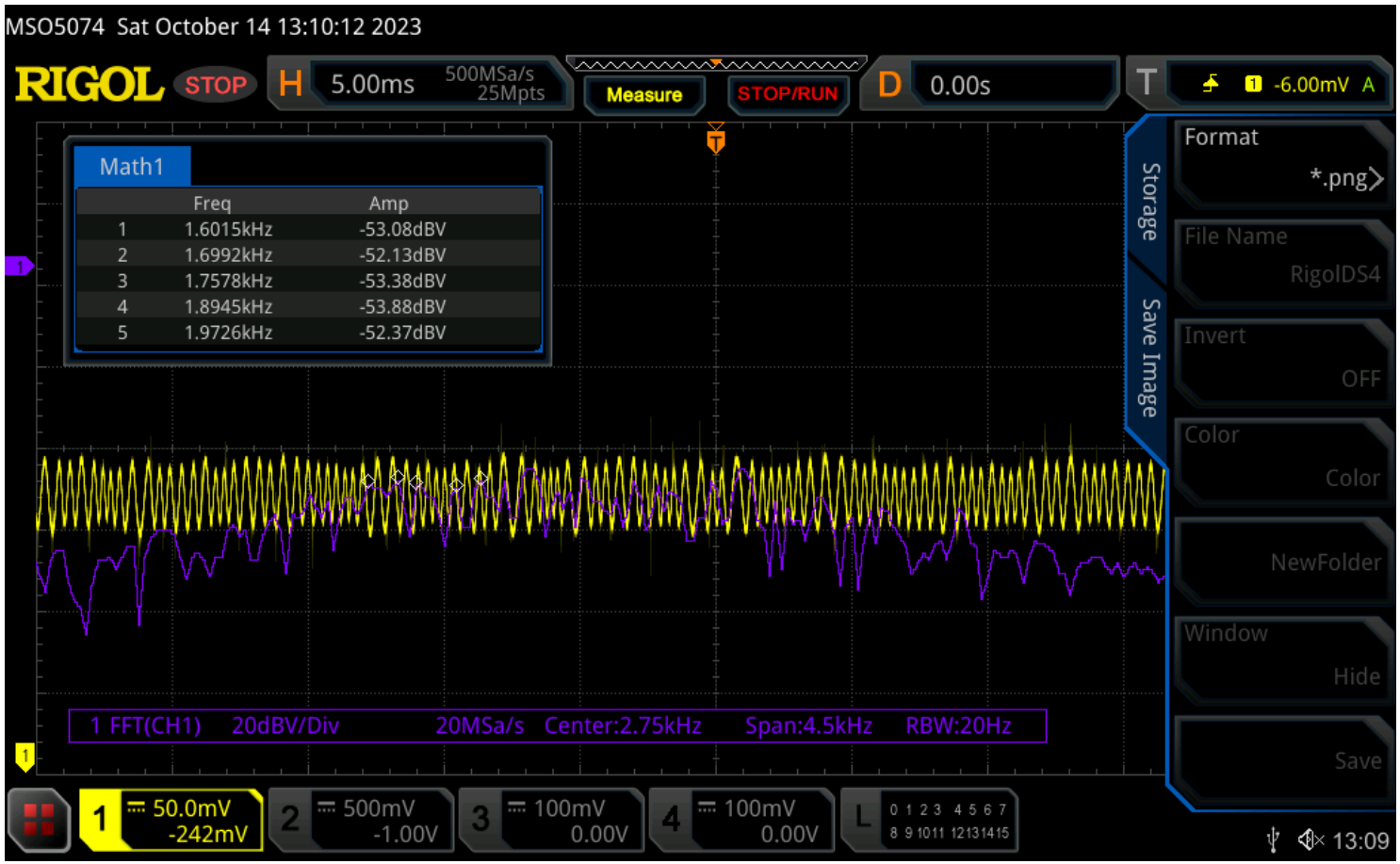
Results


MSO5074 Sat October 14 13:07:48 2023
RIGOL
STOP
H 5.00ms 500MSa/s 25Mpts
Measure
STOP/RUN
D 0.00s
T -6.00mV A
Math1
Freq Amp
1 1.6015kHz -53.08dBV
2 1.6992kHz -52.13dBV
3 1.7578kHz -53.38dBV
4 1.8945kHz -53.88dBV
5 1.9726kHz -52.37dBV
Storage
Save Image
Format *.png
File Name RigolDS1
Invert OFF
Color Color
NewFolder
Window Hide
Save
1 FFT(CH1) 20dBV/Div 20MSa/s Center:2.75kHz Span:4.5kHz RBW:20Hz
1 50.0mV -242mV
2 500mV -1.00V
3 100mV 0.00V
4 100mV 0.00V
13:06

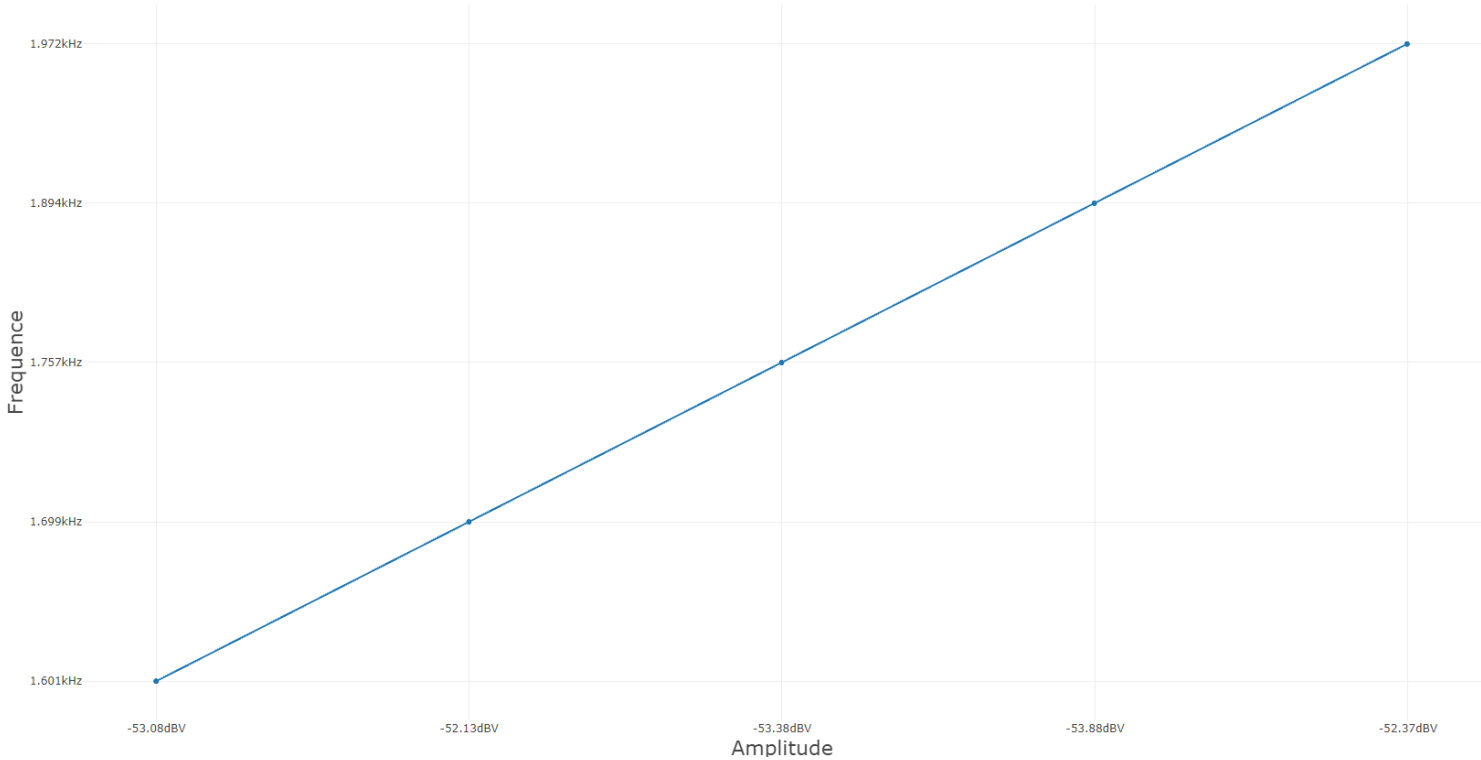
Results


MSO5074 Sat October 14 13:17:11 2023
RIGOL
STOP
H 5.00ms 500MSa/s 25Mpts
Measure
STOP/RUN
D 1.35ms
T -6.00mV A
Cursors
AX: 2.191kHz
AY: -24.66dBV
BX: 29.88kHz
BY: -64.66dBV
ΔX: 27.68kHz
ΔY: -40dBV
1/ΔX: *****
Storage
Save Image
Format *.png
File Name RigolDS2
Invert OFF
Color Color
NewFolder
Window Hide
Save
1 FFT(CH1) 20dBV/Div 20MSa/s Center:24.9kHz Span:49.8kHz RBW:20.55Hz
AX
BX
1 50.0mV -242mV
2 500mV -1.00V
3 100mV 0.00V
4 100mV 0.00V
13:16

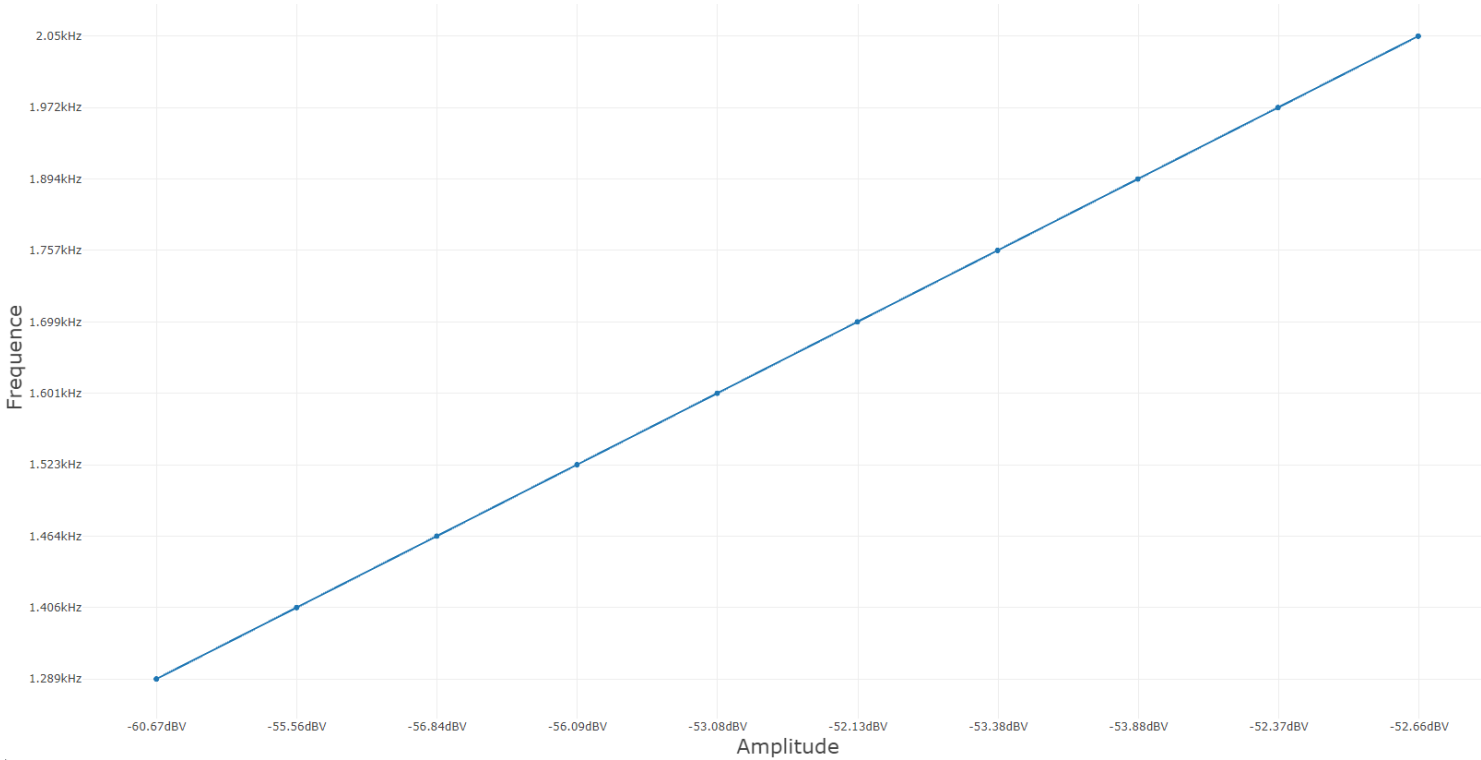
Results


MSO5074 Sat October 14 13:10:12 2023
RIGOL
STOP
H 5.00ms 500MSa/s 25Mpts
Measure
STOP/RUN
D 0.00s
T -6.00mV A
Math1
Freq Amp
1 1.6015kHz -53.08dBV
2 1.6992kHz -52.13dBV
3 1.7578kHz -53.38dBV
4 1.8945kHz -53.88dBV
5 1.9726kHz -52.37dBV
Storage
Save Image
Format *.png
File Name RigolDS4
Invert OFF
Color Color
NewFolder
Window Hide
Save
1 FFT(CH1) 20dBV/Div 20MSa/s Center:2.75kHz Span:4.5kHz RBW:20Hz
1 50.0mV -242mV
2 500mV -1.00V
3 100mV 0.00V
4 100mV 0.00V
L
13:09

Results


1.972kHz
1.894kHz
1.757kHz
1.699kHz
1.601kHz
Frequence
-53.08dBV
-52.13dBV
-53.38dBV
-53.88dBV
-52.37dBV
Amplitude

Results


2.05kHz
1.972kHz
1.894kHz
1.757kHz
1.699kHz
1.601kHz
1.523kHz
1.464kHz
1.406kHz
1.289kHz
Frequence
-60.67dBV
-55.56dBV
-56.84dBV
-56.09dBV
-53.08dBV
-52.13dBV
-53.38dBV
-53.88dBV
-52.37dBV
-52.66dBV
Amplitude

Discussion

- no measurement background/ noise only
- mechanical motion and misalignment
- blurred maxima

Nanopositioning

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Experimental Setup

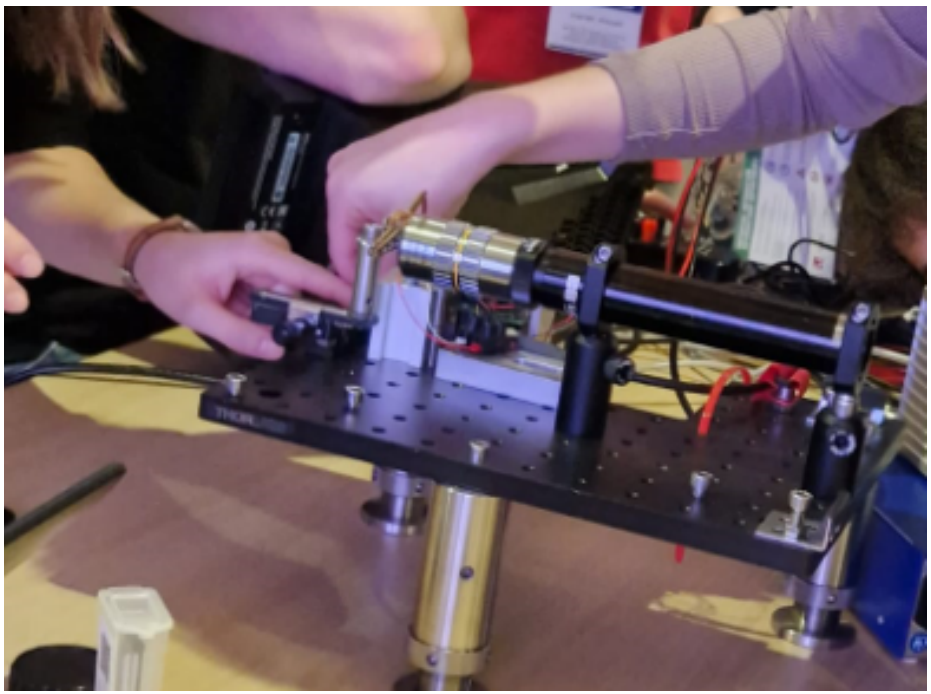


Figure: Piezo+wheatstone setup

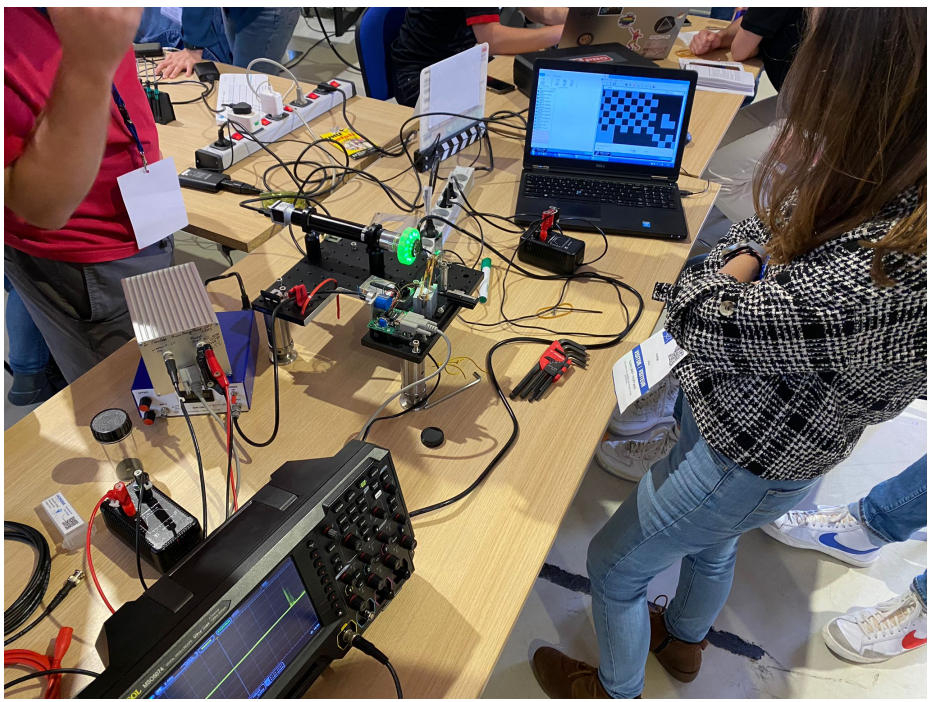
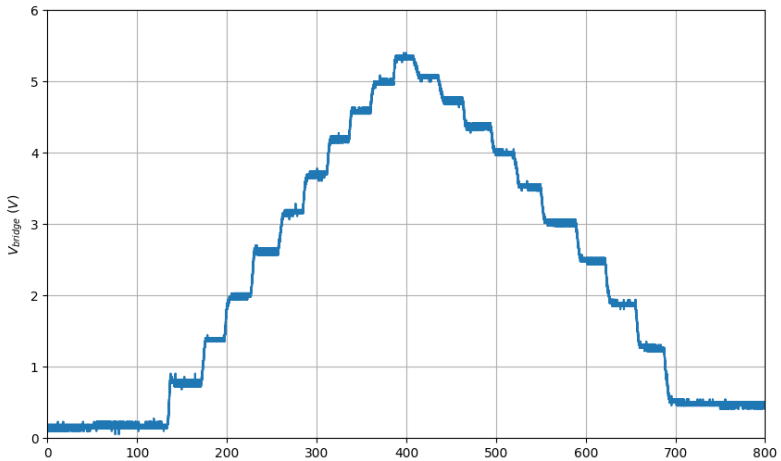
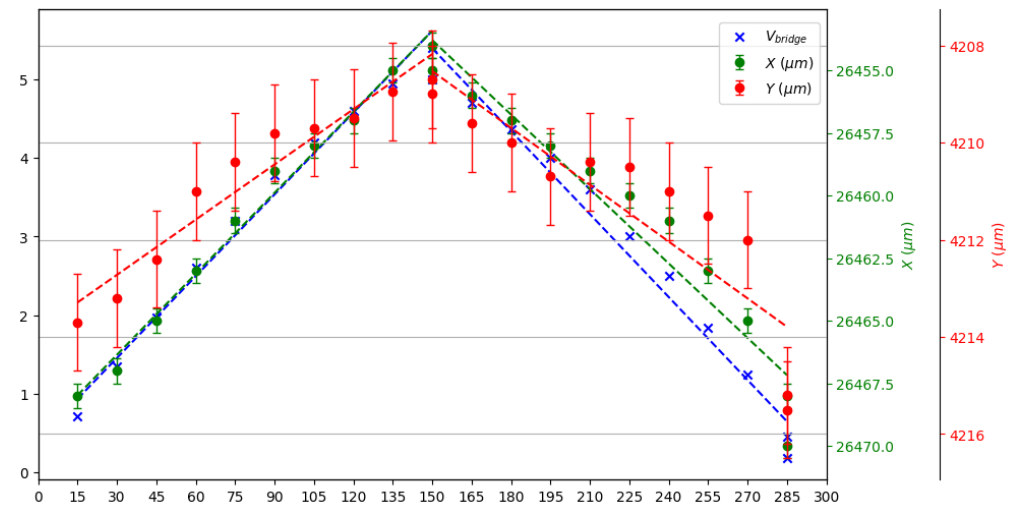


Figure: Oxyo setup

Results





Total Displacement, $D = \sqrt{X^2 + Y^2} = 17.38 \pm 0.60\ \mu m$

PZS001
Co-Fired Piezo Actuato, 17.4 µm Stroke
6.0 mm x 7.0 mm x 20.0 mm

Heat, Noise, Cooling

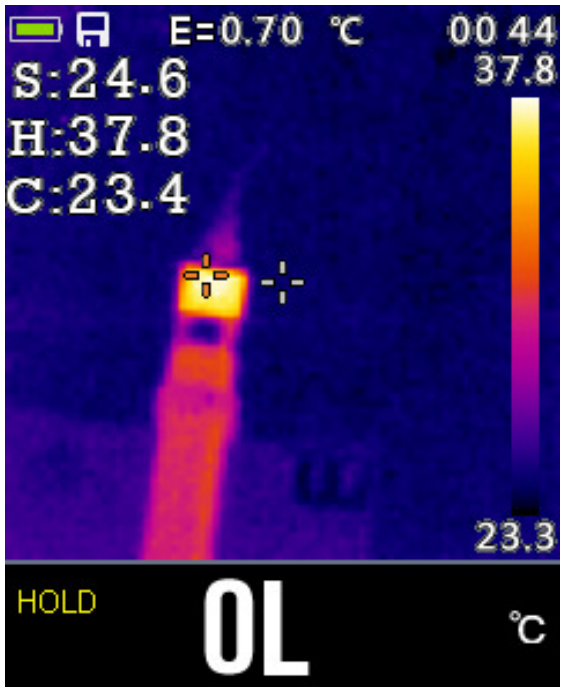


Figure: Heat seen on camera through an infrared camera

Heat, Noise, Cooling

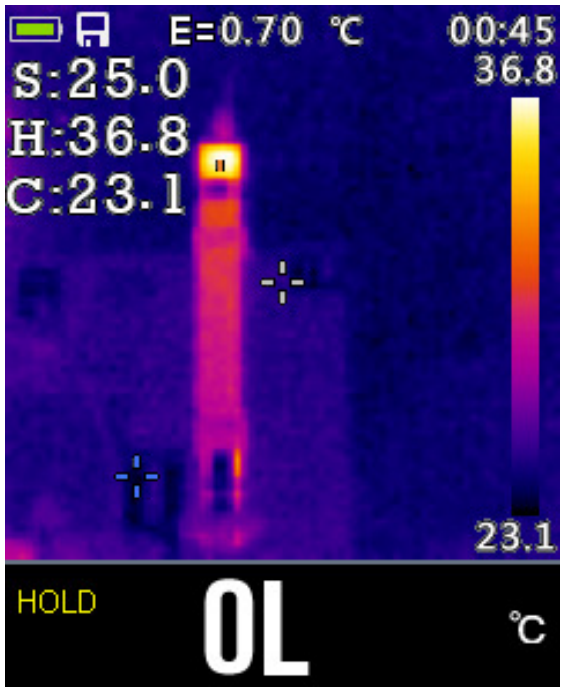


Figure: Heat seen on camera through an infrared camera

Backup

Results and discussion

The theoretical prediction/guess of the wanted frequency that was made in the beginning isn't actually that far from the experimentally observed results.

Abstract

Michelson Interferometers have been used since the beginning of the 20th century initially to measure the diameters of stars. In september 2015, the LIGO-VIRGO project allowed the first measurement of gravitational waves to be taken at an intervall of 10 ms across the USA. This revolutionised modern astrophysics. At a smaller scale, we too can measure a shift in frequency for example by observing the doppler effect as shown in this experiment.

Uncertainties

No Gauß error propagation was conducted and taken into account, however one can assume that type A errors must theoretically be taken into account since more than one series of measurement was conducted. Type B errors could be exactly determined but haven't been for this experiment. How would they change the results of this experiment? This isn't really relevant in this situation because the precision of the measurement wasn't the main goal. One can add that the measurements were made with background agitation and no test measurement was conducted only with background noise.