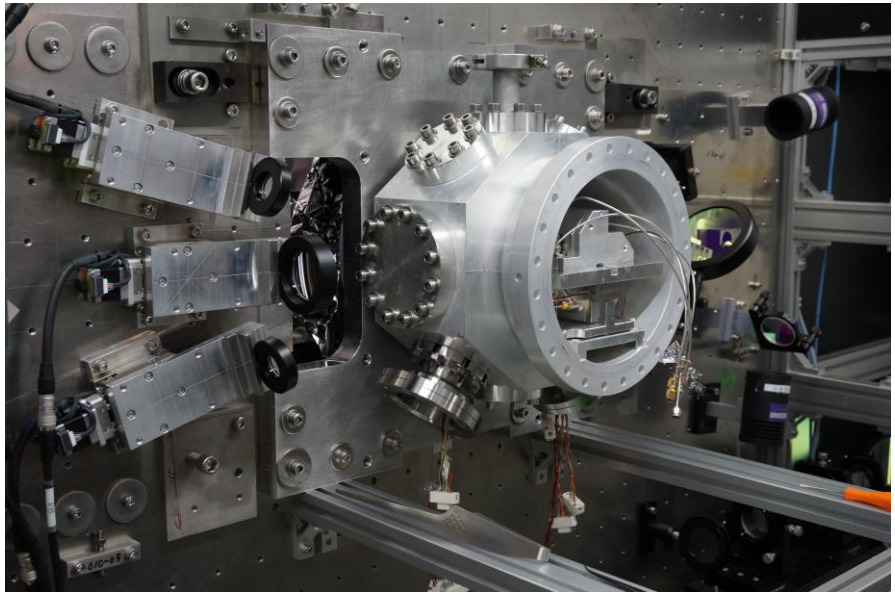
# ATF2 IP-BPMs

## displacement-scanning system

# Hardware status



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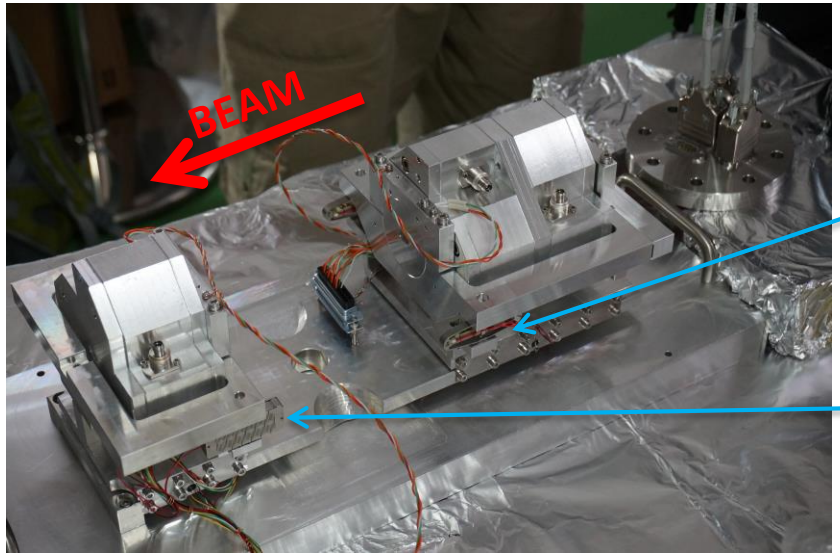
Haoua Amina BRAHAMI – Ecole Nomale Supérieure Paris-Saclay

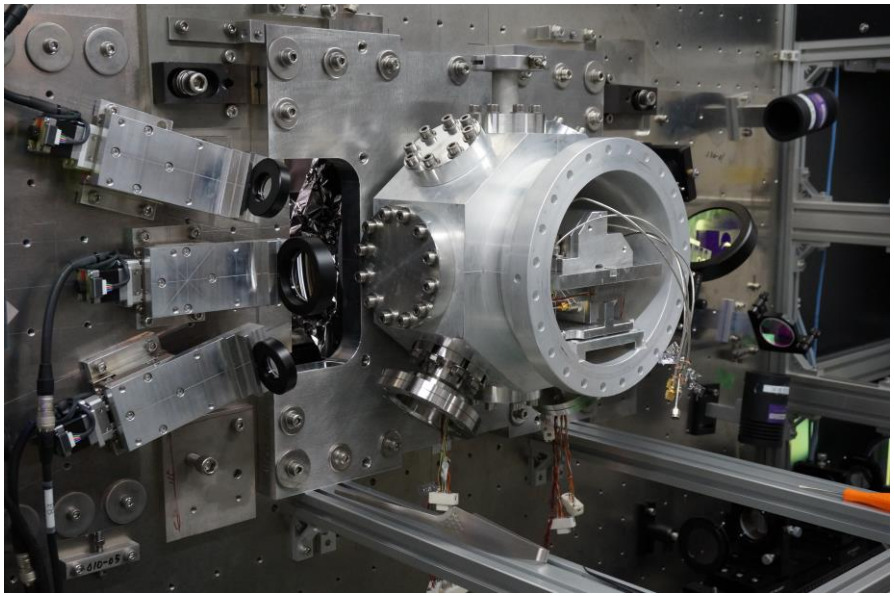
# ATF2 IP-BPMs with its displacement system

## (to bring vertical and horizontal disp + a bit of roll and pitch)

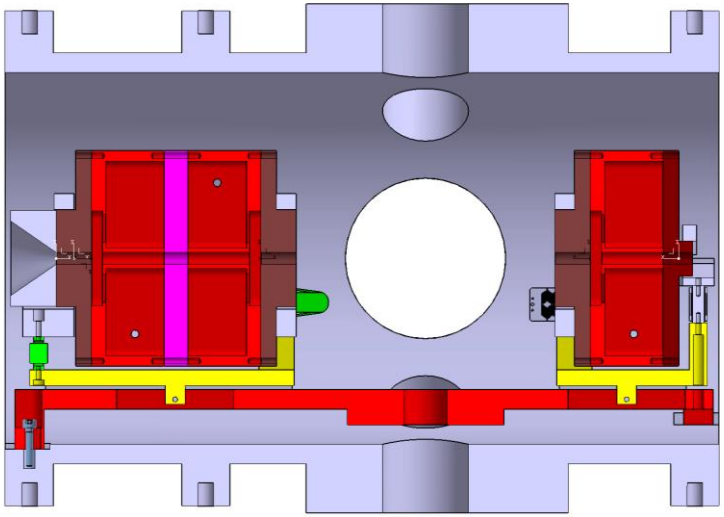



3 Cedrat APA200M piezo actuators (nom. stroke / close loop res. : 230 / 2.3 μm) acting as a tripod for BPM-AB vertical disp.
(plus 1 actuator for horizontal disp. [not shown])

3 PI P-602.3S0 piezo actuators (nom. stroke / resolution : 300 / 3 μm) acting as a tripod for BPM-C vertical disp.
(plus 1 actuator for horizontal disp. [not shown])



BEAM



ATF2 IP-BPMs with its disp. system installed in a chamber at IP (cross section)

CEDRAT TECHNOLOGIES
Innovation in Mechatronics

**Piezoelectric Actuators**

**Factory Verification: Cypher_v7.8**

| Date of test (DD/MM/YY) | Model | Options | Serial Number | Test performed by | Signature | Quality Assurance |
|---|---|---|---|---|---|---|
| 22/09/2017 | APA200M | SG VAC | 17-029 | CS | | Date: 29 SEP. 2017 Signature: Name: Stamp: |

CEDRAT TECHNOLOGIES CONFORME CONTROLE QUALITE

**Electrical Admittance vs. Frequency**

**Mechanical conditions:**
Free-Free

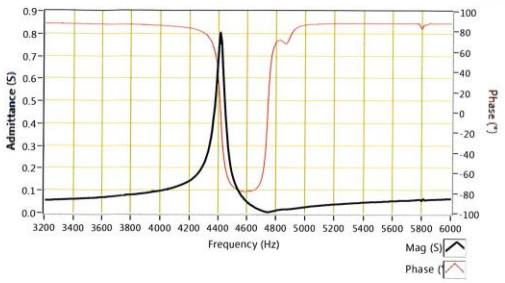
**Measurement Apparatus:**
Cypher Instruments C60

**Resonance Frequency:**
4414 Hz

**Effective Coupling Coefficient**
36 %

Acceptance limits :3910 Hz < Fr < 5060 Hz.

Notes:




**Displacement vs. Input voltage**

**Mechanical conditions:**
Blocked-Free

**Measurement apparatus:**
Capacitive sensor MC2930

**Sensor gain:**
50 µm/V

**Tension gain probe:**
x20.00

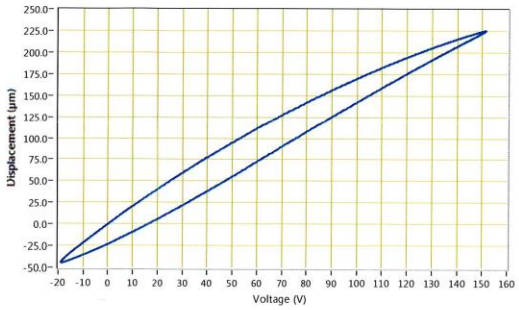
**Driving frequency**
10.00 Hz

**Measured displacement :**
270.56µm pk-pk for 170.28V pk-pk

**Maximum displacement:**
270.12µm pk-pk for 170V pk-pk

Acceptance limits : Vmax=150V ; Vmin= -20V; 207 µm < U < 299 µm.

Notes:




**SG vs. Displacement**

**Mechanical conditions:**
Blocked-Free

**Displacement measurement apparatus:**
Capacitive sensor MC2930 - 50 µm/V

**SG measurement apparatus:**
SG75-3 SG22-06012

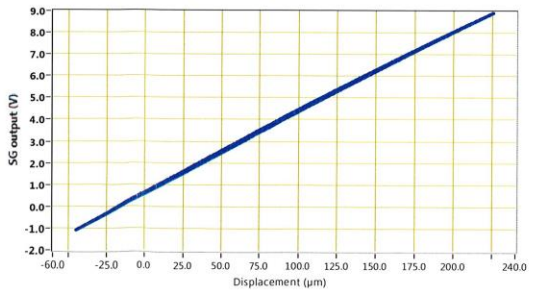
**SG controller gain:**
948.6400

**Driving frequency (Hz):**
10.00 Hz

**Max measured displacement:**
270.12µm pk-pk for 170V pk-pk

**Strain Gauge Gain (mV/µm/V):**
7.808E-3

**Vcc:**
5.0000




# Movers factory's calibration

(Data used in EPICS, currently through a gain in µm/V)

Example of factory calibration of a spare cedrat mover to be used.
NB. During factory calibration :
- main mover's parameters are established;
- the mover is matched to "its" electronics control board.

# Setup for piezo movers calibration during 2016.10 (1) and 2017.05 (2) short campaigns

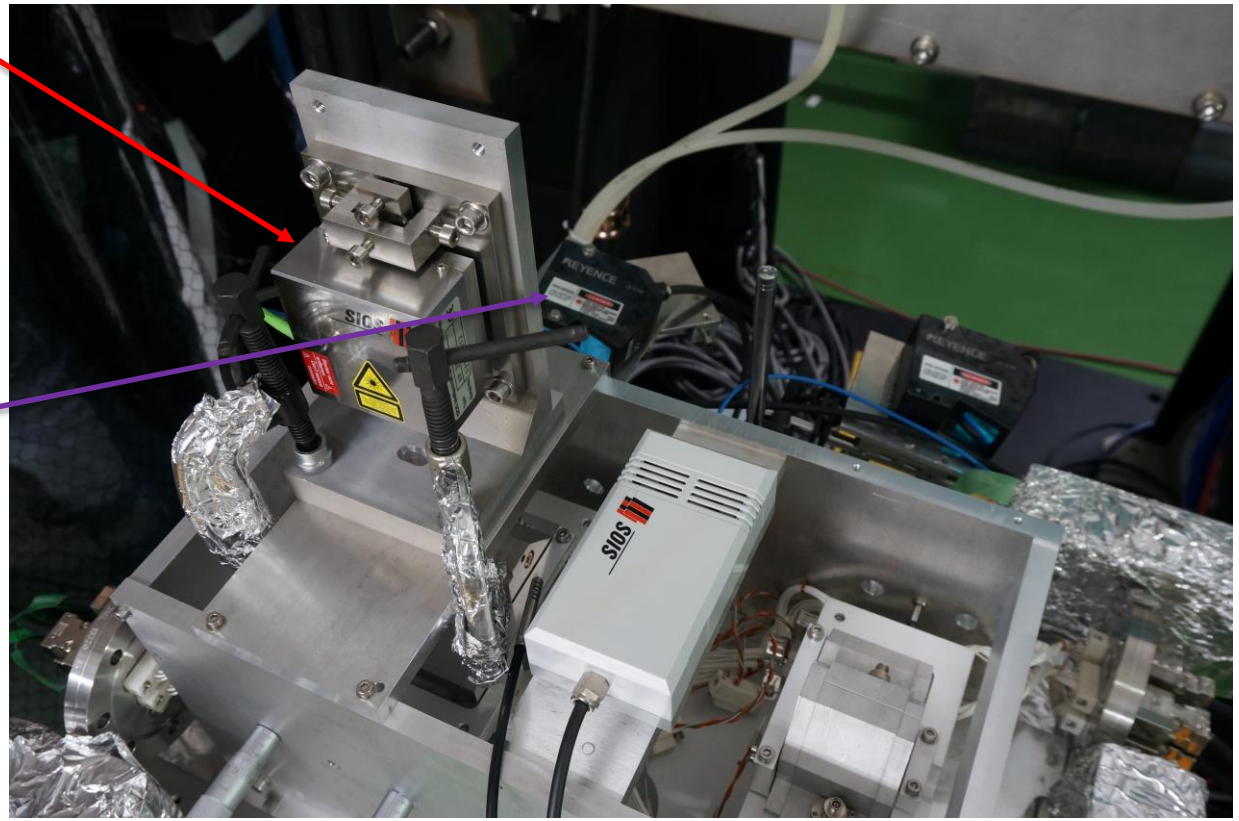
Below : IP-BPMs with its disp. system installed in a frame to measure displacements

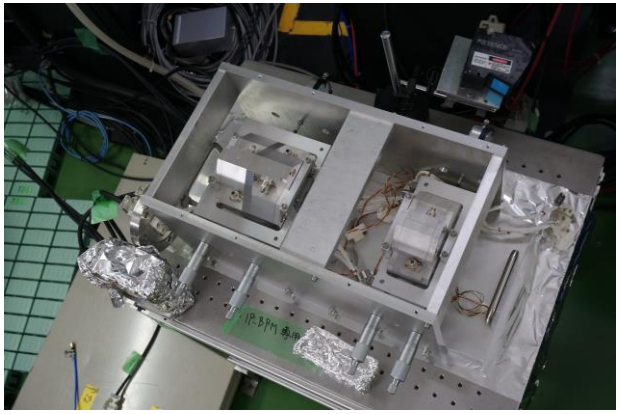
**MAIN MEASUREMENT : Vertical calibration** done at IP with SIOS interferometer (same sub nanometric resolution device used by Cedrat Cie) for :

- BPM-AB Cedrat vertical movers system
- BPM-C PI vertical movers system

(Mirror for interferometry measurement set on BPM's top, therefore calibration is done for the tripod system, not for each movers)

**OTHER MEASUREMENT : Horizontal calibration** done at IP with Keyence lasermeter (sub micrometric resolution).



Specs for measurements :
- 0.1 V step then 0.5 V for 2017.05 campaign
- 3 sec holding time (same for PI factory calibration)
- 5 Hz acquisition
- 10 to 13 measurements kept at every steps (measurements when moving from step to another are rejected)

For each setting voltage, 10 to 13 measurements are displayed on the following plots (i.e. not error bar).

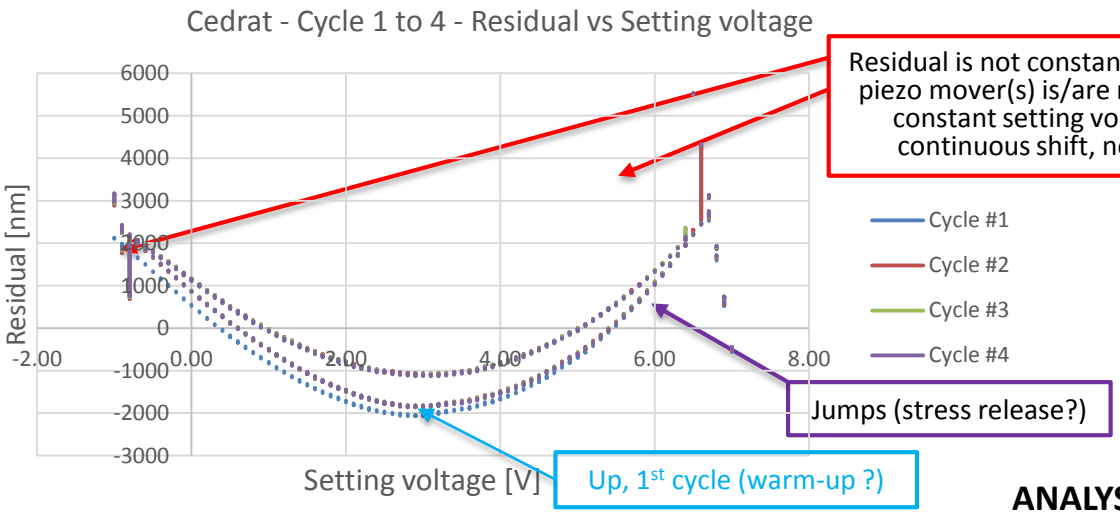
(1) purpose : new calibration needed due to movers aging?

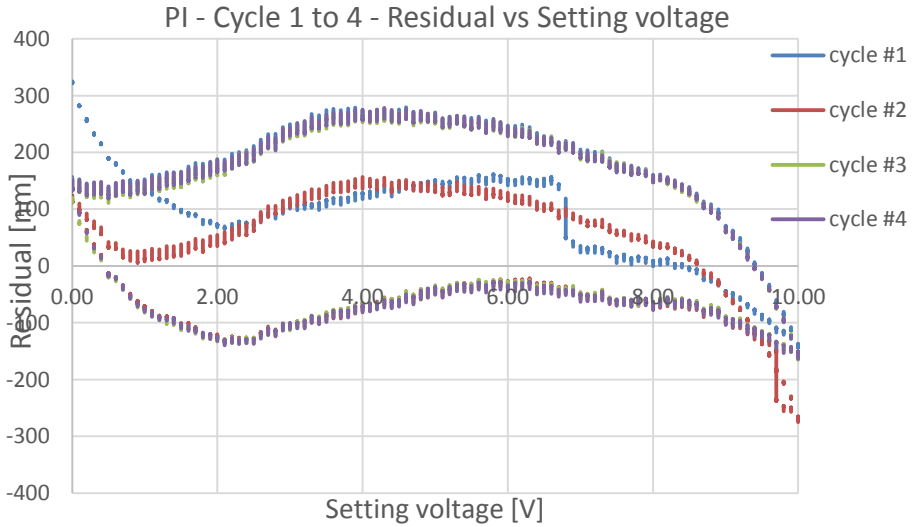
(2) purpose : lack of data for a suitable statistical analysis (4 cycles → more than 150)

# Vertical mover tripod system - residual (4 cycles)

(Residual = measured displacement minus calculated disp. from linear fit)

2016.10's plots




**ANALYSIS**

a) At full range, smaller gain standard deviation for PI than Cedrat (0.0063 vs 0.0203 µm/V), but lack of data to be relevant (only 4 cycles).

b) Cedrat : Accident in the ranges -1 to -0.8V and 6.4 to 7V. With reduced range (i.e. previous ranges excluded), tripod system raw accuracy is -2.1/+1.9 µm (max deviation from linear fit) → accuracy ~ 1/120 of stroke (reduced stroke) when ~ 1/700 is expected (for a single actuator) !

c) PI : Good accuracy for the tripod system : -0.28/+0.32 µm for full range operation, reduced to -0.14/+0.27 µm when rejecting 0 to 0.5V (warm up?) and 9.5 to 10V (shift) → accuracy ~ 1/1000 of stroke as expected.

# Vertical movers calibration

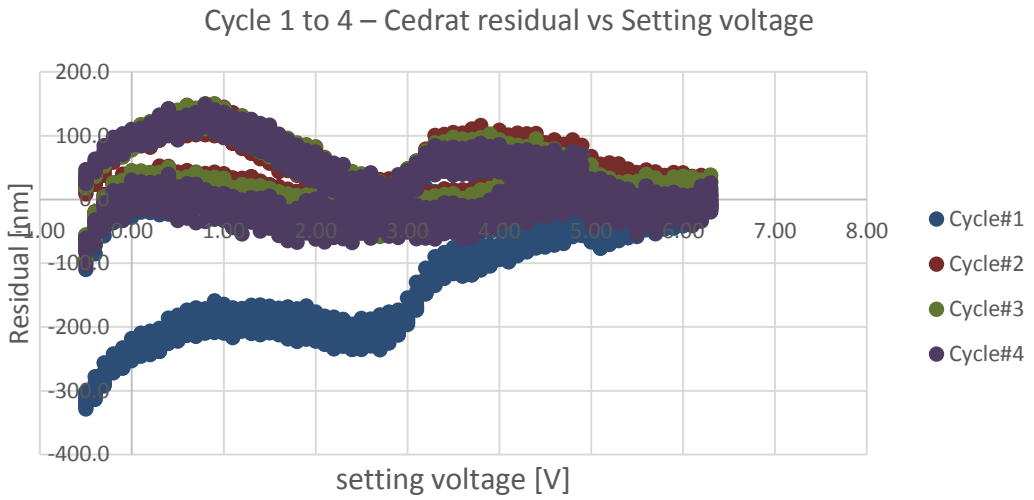
(non-linear fit + slightly reduced stroke)
Residual from cubic polynomial fit

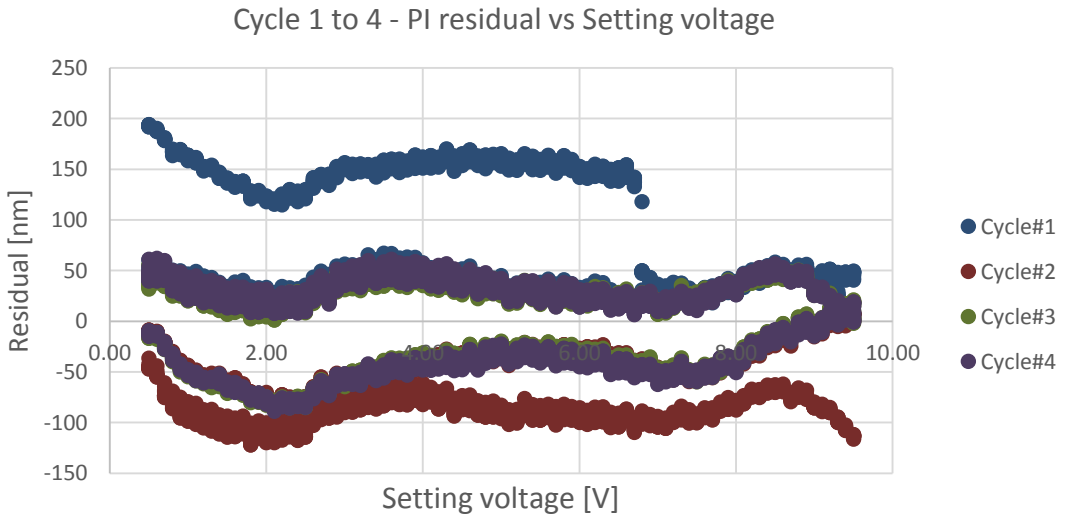
2016.10's plots

| | Cedrat polynomial fit coeffs (-1 to 7 to -1V travel ; calculated without -1 to 0.4V and 6.4 to 7V data) | | | |
|---|---|---|---|---|
| | a [nm/V^3] | b [nm/V^2] | c [nm/V] | d [nm] |
| 4 ups | 9.63397 | 222.106 | 29013.5 | 29234.1 |
| 4 downs | 6.52030 | 198.9 | 29255.2 | 29594.1 |

With cubic polynomial fit and reduced stroke (see in red), Cedrat and PI movers are almost in the same range of accuracy (roughly +100/-200 nm or +200/-100 nm)

| | PI polynomial fit coeffs (0 to 10 to 0V travel ; calculated without 0 to 0.4V and 9.6 to 10V data) | | | |
|---|---|---|---|---|
| | a [nm/V^3] | b [nm/V^2] | c [nm/V] | d [nm] |
| 4 ups | -1.63945 | 21.8446 | -30055.1 | -293.296 |
| 4 downs | -0.49394 | -2.33170 | -29919.0 | -272.911 |



# Vertical calibrations (cubic polynomial fit) – analysis

2016.10's campaign

Cedrat's systematic error can be dramatically reduced with cubic polynomial fit. In this case, Cedrat is close to the PI's accuracy level, especially with short range around mid-stroke.

**Full range with rejected data :**

PI → raw rel. accuracy ~$8 \times 10^{-4}$ (200 nm / 270µm)

Cedrat → raw rel. accuracy ~1.1 to $1.7 \times 10^{-3}$ (200 or 300 nm / 174µm)

Raw accuracy = no statistical analysis (only 4 cycles taken)

**Around mid-stroke, 2V range :**

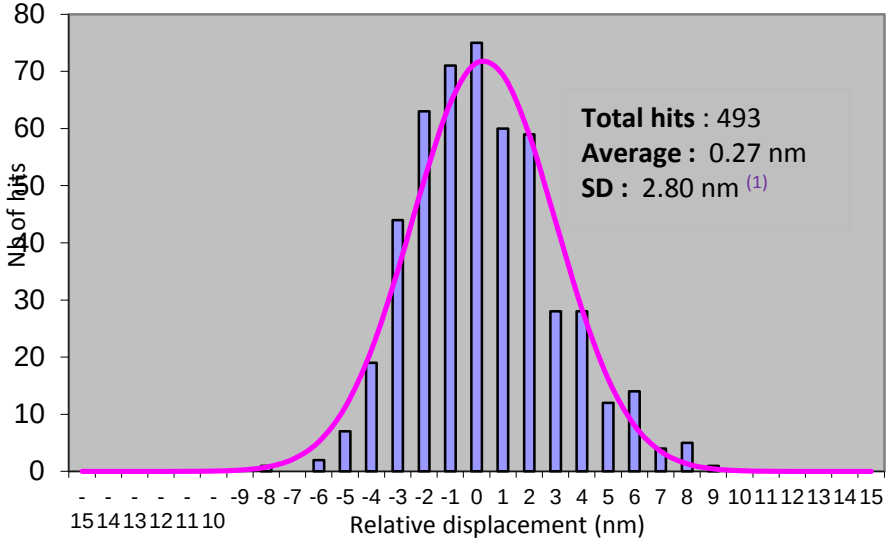
Lack of data for PI (only 2 cycles), but both Cedrat and PI tend to be within a band of +/- 60 nm for the same reduced stroke (60 µm).

→ raw rel. accuracy ~$10^{-3}$ (60 nm / 60µm)

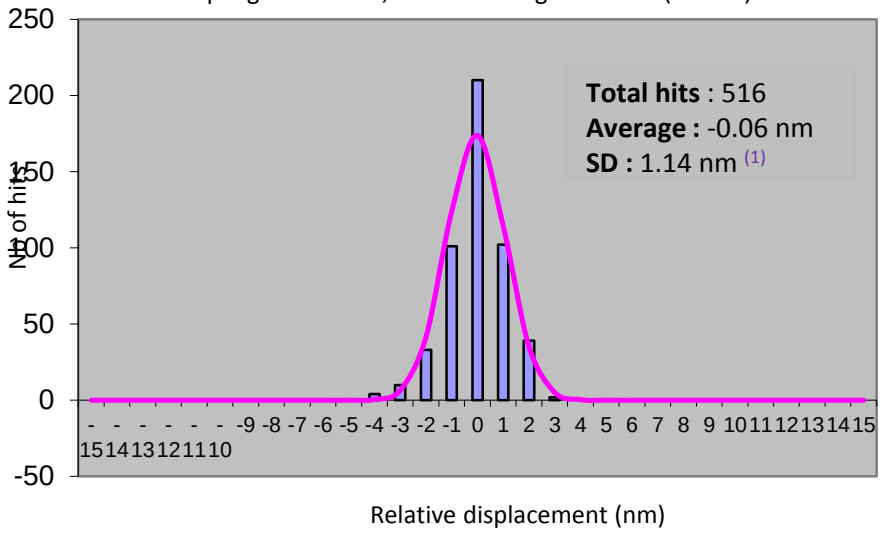
# Vertical movers stability at mid stroke (see “living movers”)

## (at LAL in June 2013 [100 sec] vs at KEK in Oct. 2016 [200 sec])

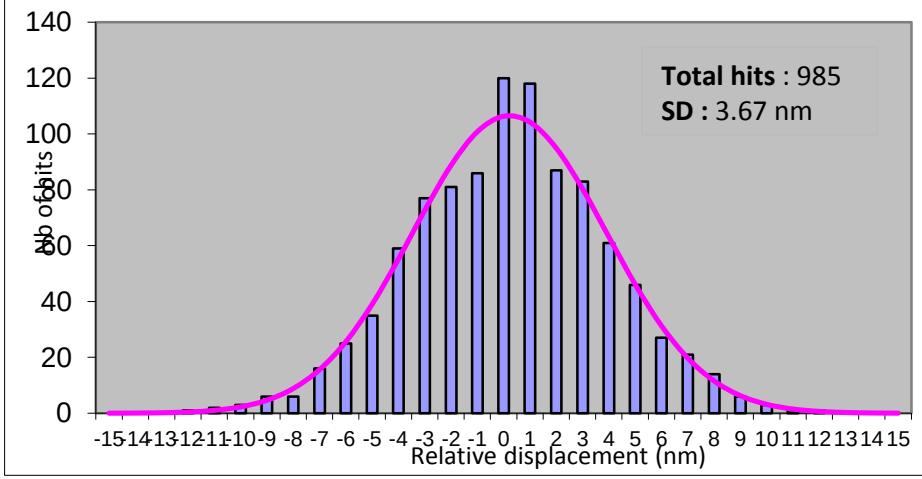
**2013** - Mirror on BPM-AB, all **Cedrats** at 3V (with feedback)
Sampling rate : 5 Hz ; Linear shift extracted (16 hits window)



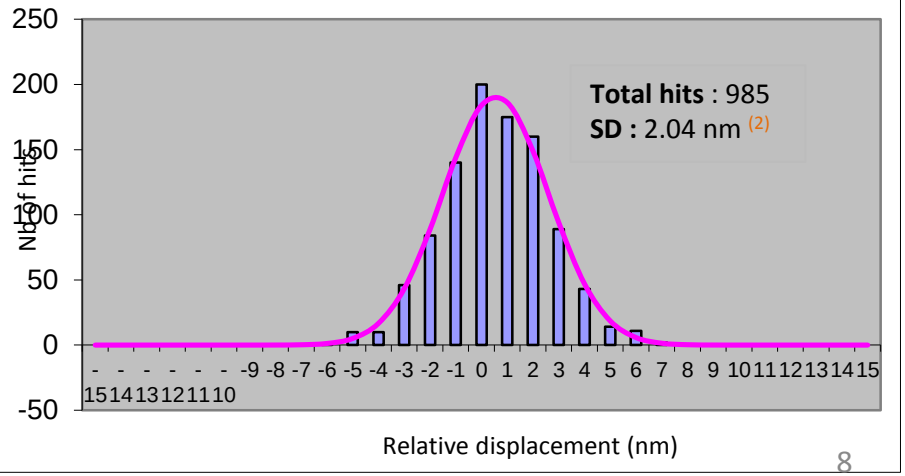

**2013**- Mirror on BPM-C, all PIs at 5V (with feedback)
Sampling rate : 5 Hz ; Linear shifting extracted (16 hits)



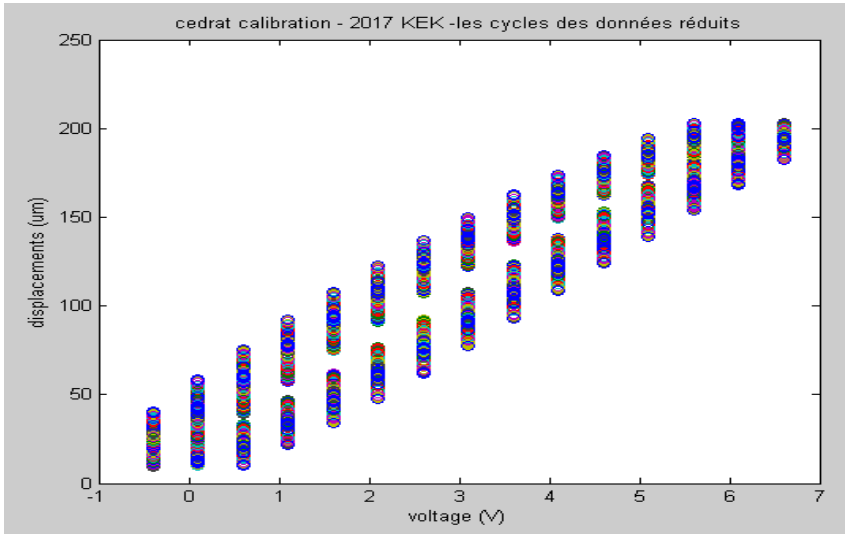

**2016** - Mirror on BPM-AB, all **Cedrats** at 3V (with feedback)



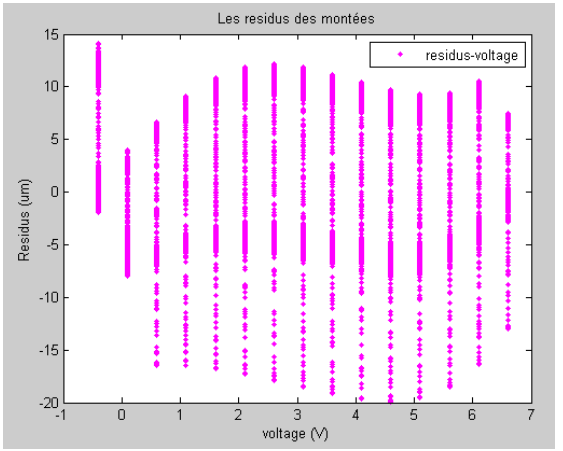

**2016** -Mirror on BPM-C, all PIs at 5V (with feedback)

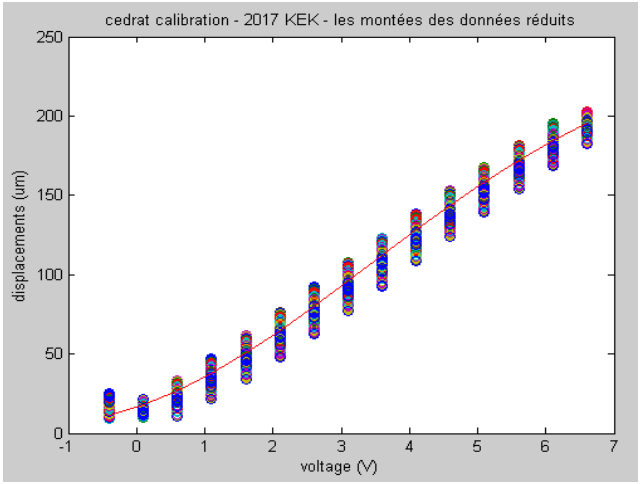


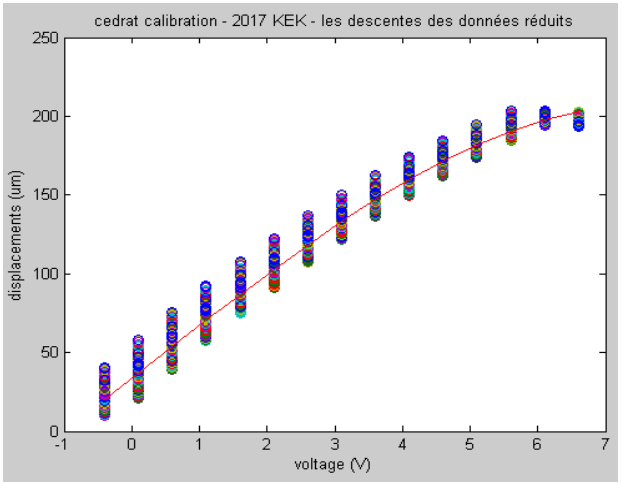
# Cedrat vertical mover tripod system - residual (150 cycles)

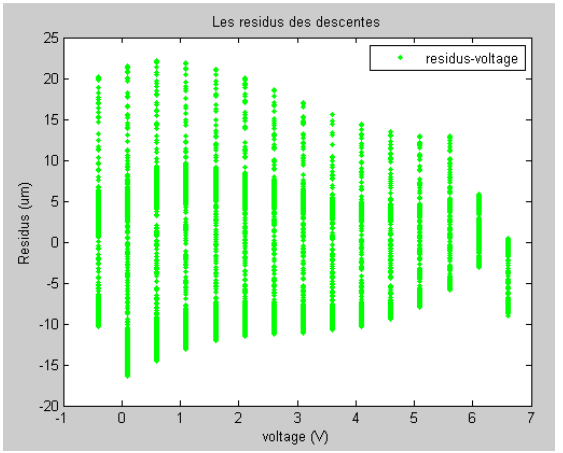



2017.05's plots
Courtesy of Haoua Amina BRAHAMI,
M1 student at Ecole Normale Supérieure Paris Saclay



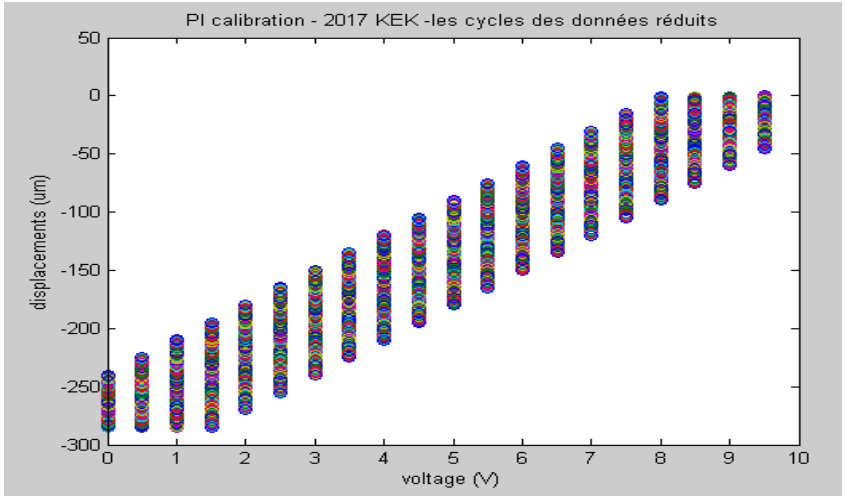



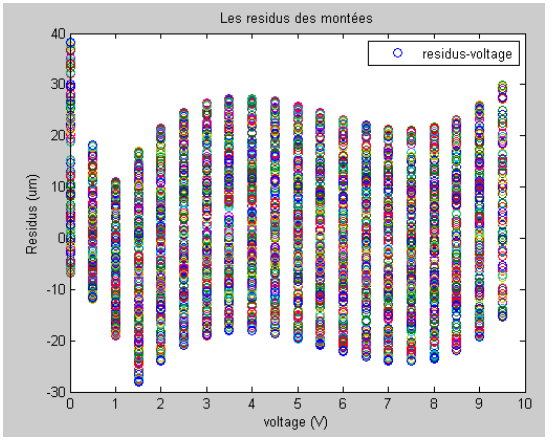



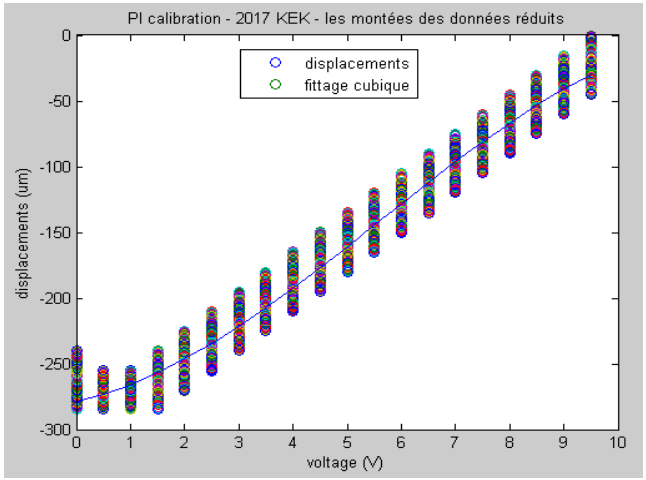

In 2016.10 (~30 min data acq.), with cubic polynomial fit and reduced stroke, Cedrat accuracy is roughly +100/-200 nm. In 2017.05 (~210 min data acq.), drifts along 150 lead to a 100 times lower accuracy (max residual) [statistical error plot missing showing residual drift, i.e. not a gaussian]

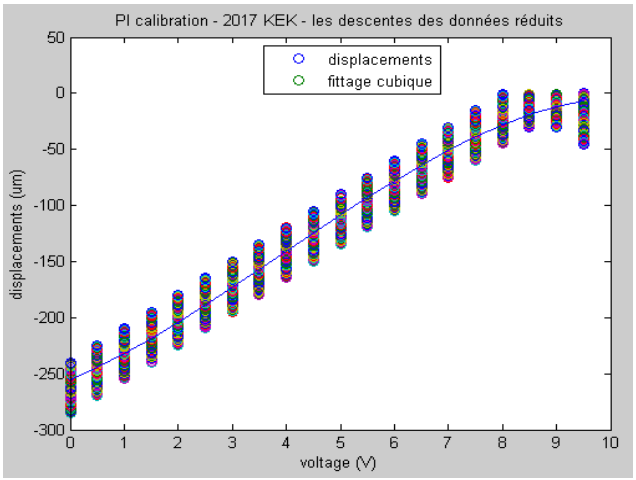
# PI vertical mover tripod system - residual (211 cycles)

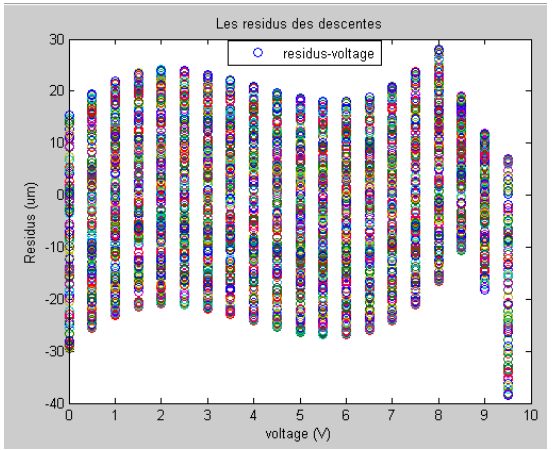



2017.05's plots
Courtesy of Haoua Amina BRAHAMI,
M1 student at Ecole Normale Supérieure Paris Saclay




In 2016.10 (~40 min data acq.), with cubic polynomial fit and reduced stroke, PI accuracy is roughly +200/-100 nm. In 2017.05 (~420 min data acq.), drifts along 150 lead to a 100 times lower accuracy (max residual) [statistical error plot missing showing residual drift]

# And then, the upstream Cedrat mover showed malfunction during 2017.05 campaign

- → Unappropriated feedback regarding setting value meaning strain gauges (mounted on piezo elts stacks) failure (unglued for instance), or SG electronics failure, or piezo mover broken (piezo elts stacks or more probably the “amplification” frame according manufacturer).
- → Cross checks showed the upstream mover’s SG electronics works fine (with other movers) and later on piezo mover SG resistance was found at expected value by Tauchi-san.

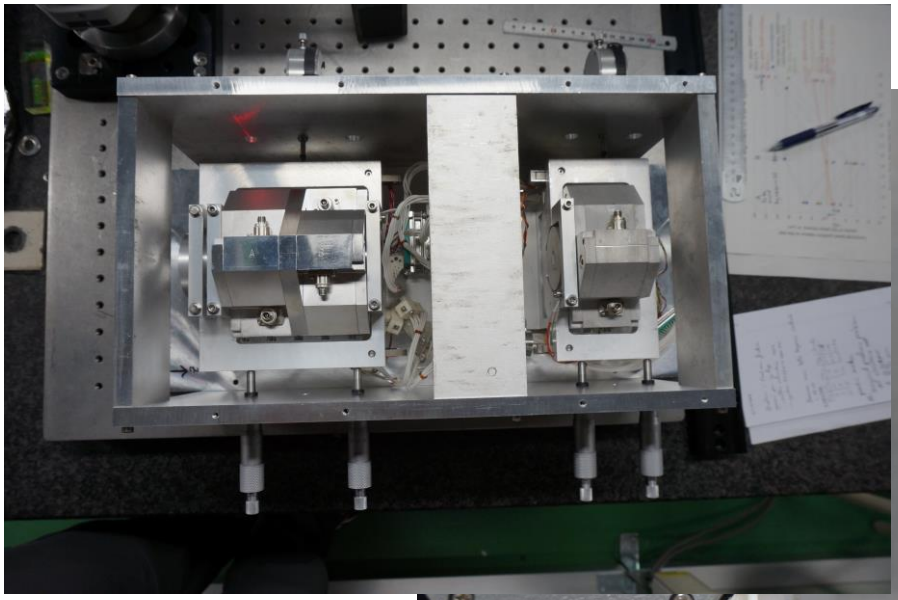
Therefore a piezo mover failure is the most likely situation, to make the ATF2 IP-BPMs displacement-scanning system functional again, we plan to change the upstream Cedrat mover by a new one, and recalibrate the whole system (i.e. the 2 tripod systems) during the 2018.03.26 to 2018.04.06 period

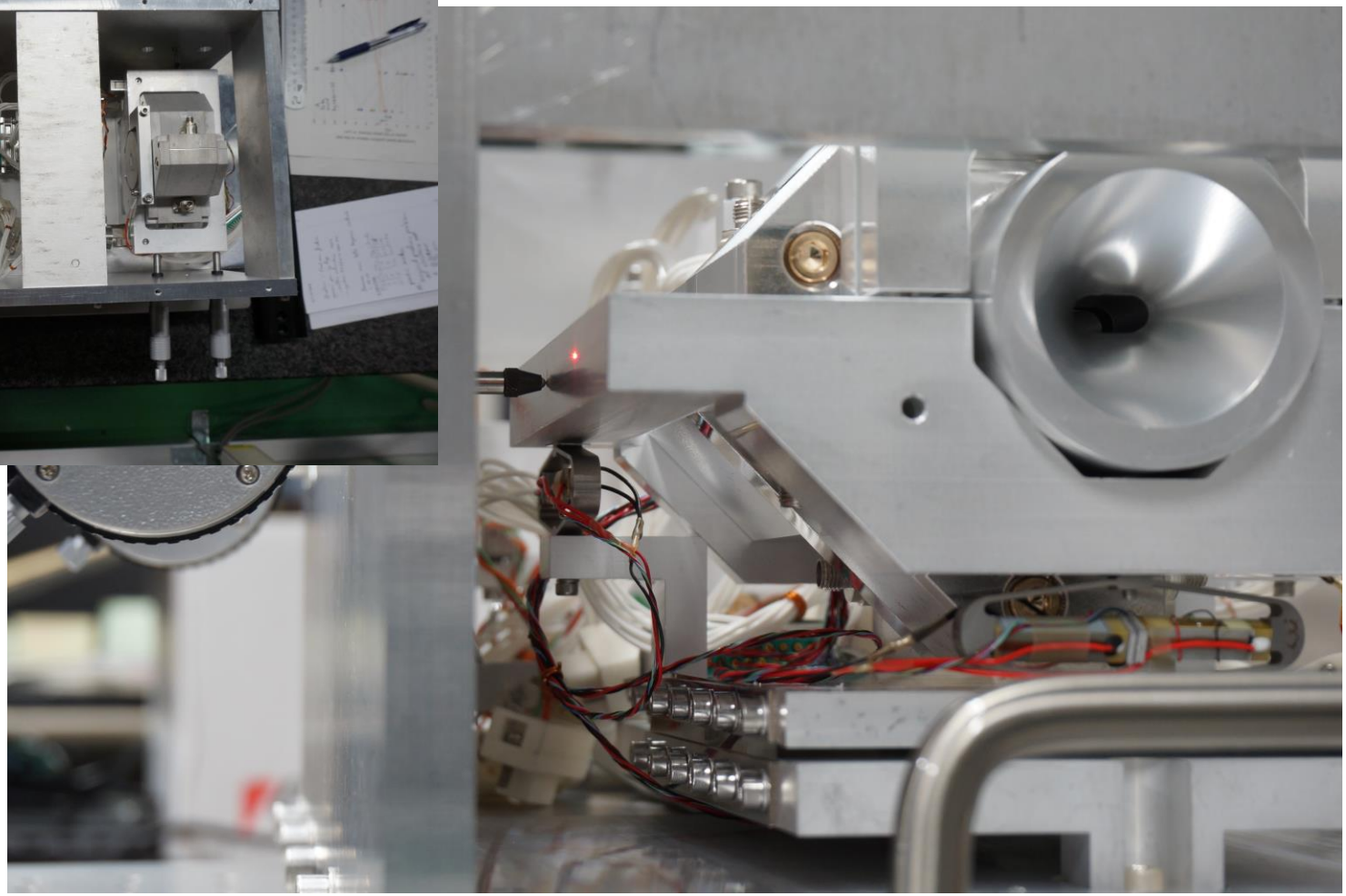
# Planning and tasks process

## for the 2018.03.26 to 2018.04.06 period

| DAY | | AM/PM | Work | Requirement |
|---|---|---|---|---|
| D1 | Mon. | AM | Drill a hole on transporting plate to enable access to the upstream cedrat mover's lower screw ; check ; install BPMs system on the transporting plate, then on bench | KEK : Drill ; Metallic marble/bench ; LAL's transporting plate ; technician with cabling skills (w/ pins ans crimping pliers) ; short cables (D-Sub) ; keyence lasermeter ; "laser room" Labview PC installed at IP and connected to the network (to reach NI DAQ) and sometimes installed in laser room with USB cable to electronics |
| | | PM | Disconnect (electrically) broken cedrat mover ; connect the new cedrat mover's wires to D-Sub connector ; check new mover correct functioning (stroke w/ keyence lasermeter) ; adjust electronics board's parameters ; check | **LAL : Long 2 mm allen key ; new cedrat mover ; mover holder (goods to be picked up at LAL)** |
| D2 | Tue. | | Install alignment frame (w/ dial gauges and micrometric stops) on transporting plate ; adjust MS to fit BPM-AB lateral position ; take off up-stream cedrat mover and add a dummy mover (post) - keep the shims ; measure/calculate (old mover height - new mover height) and adjust shims assy thickness ; place new mover (w/ shims) ; tighten screws ; check lateral and vertical position (should be unchanged) | KEK : LAL's alignment frame ; keyence lasermeter ; dummy movers (LAL's toolbox) |
| D3 | Wed. | | | |
| D4 | Thu. | | Cedrat movers (tripod) and then PI movers (tripod) vertical calibration (w/ LAL's interferometer) and stability at mid stroke | |
| D5 | Fri. | | | |
| | Sat. | | Run vertical scanning during the weekend (cedrat) and monitor vertical disp. w/ interferometer | |
| | Sun. | | | |
| D6 | Mon. | AM | Radiation training | |
| | | PM | Check measurements done during weekend | |
| D7 | Tue. | | If D4 and D5 successful, study of cedrat movers tilt (i.e. measure BPM vert. disp. at upstrem and downstream points) ; study of cedrat and PI vertical-horizontal coupling (w/ LAL's interferometer plus KEK's keyence lasermeter) | |
| D8 | Wed. | | | |
| D9 | Thu. | | | |
| D10 | Fri. | | Installation in vacuum chamber ; check movers response at several steps (after connection to feedthrought flanges ; after closing the chamber) | |

# Reaching and changing the upstream Cedrat mover





# Conclusion

1. Campaign of measurements done too quickly in Oct. 2016.
   More data should have been gathered (→ statistical study, warm up effect analysis).
   New campaign of measurements in May 2017 but a lot hardware issues
2. Upstream Cedrat mover to be change and its electronics to be tuned
3. Complete vertical calibrations plus stability at mid strike to be done ; need to understand origin of drift seen with interferometer
4. Current lateral and vertical alignment should be unchanged