TEQ – electronics schedule

Date: 31/05/2019

Participants:

LNF-INFN: Catalina Curceanu, Massimiliano Bazzi, Mario Bragadireanu, Alessandro Scordo
Southampton: Hendrik Ulbricht
UCL: Antonio Pontin
Aahrus: Michael Drewsen

AGENDA

Schedule:

9:30 - 10:15 Michael: update on Aarhus electronics status

10:15 - 11:00 Peter/Antonio: update on UCL trap

11:00 - 11:30 Catalina/Max: update on electronics development at Frascati

11:30 - 12:00 Coffee Break

12:00 - 13:30 (continued) update on electronics development and start discussions

13:30 - 14:30 Lunch

14:30 - 16:00 discussion about next steps, concrete plans to realise different versions (with decreasing noise) for DC and AC electronics.

16:00 - 16:30 Coffee break

16:30 - 17:00 Conclusions

MINUTES

1) Michael update on existing electronics in Aarhus, goal to reach 25 nV/sqrt(Hz) for DC, testing noise levels of electronics (DC from DAC and mixer)
    a. New reference source gives 35 nV/sqrt(Hz)
    b. Tested with and w/o mixer: w/o below the target noise level [w/o amplifier], measured with scope.
    c. Use of battery PS reduces a bit the noise level. [see slides of Michael for details].
    d. Base noise on amplifier is 30 nV/sqrt(Hz), 10x
    e. What parameters do we need? : DC voltage amplitude: +/- 10V ??, realistic noise level: xxx nV/sqrt(Hz)
    f. DAC w/o mixer and with 10x amp: 120 nV/sqrt(Hz)
    g. That was before the skype at beginning of May 2019: list of actions (see slides of Michael)

h. Then: used DAC with 9V battery: flat noise spectrum at all frequencies, 14 nV/sqrt(Hz); but the stability of the voltage value (amplitude) is not clear.

i. Use more references in parallel, adds more noise, at low frequencies: 100 nV/sqrt{Hz}

j. Noise correlation between different outputs of DAC: measured correlation of noise of 10 nV/sqrt(Hz) for two +8V inputs, but if -8 and +8 input, then there is larger noise (uncorrelated or anti-correlated) – was done with PS, not battery.

2) Overall power supply design: for 20 electrode segments we need one PS and 20 DACs to provide the DC, then two options to add the AC: add to two electrodes which makes it completely independent, or add to DC with a mixer [gives more flexibility, but adds more noise from the mixer itself]

3) Make a general plan for electronics for TEQ experiment and define points to decide and information needed for taking the decision.

4) Antonio: update on trapping at UCL

a. Trapping in 1 cm Paul trap, loaded with electro-spray and guide (PCB mounted rods, not the blade design)
b. Imaging with a CCD, the new way, high-resolution (below the CCD pixel size of 3 um) by fitting Gaussians, calibration of detection (distance of motion), long term runs (days)
c. Charge control by using ion gauge, on the level of single elementary charges,
d. Frequency stability: effect of room temperature drifts, amplitude of AC drive (makes 30% of drift).
e. Linewidth measurement at high Q, evaluate quadratures (lock-in numerically), gamma is on order of 10 uHz.
f. Force noise extracted from data, at 10^{-7} mbar, 10^{-38} N^2/Hz
g. Do they see voltage noise at the moment?: Yes -> we need low-noise electronic to go to force noise of 10^{-44} N^2/Hz (which corresponds to 22 nV/sqrt{Hz}.

5) What trap should we build the electronics for?? The UCL trap or the blade trap??
   a. Problem with blade trap, the two sides of the blades are not connected.

6) Max: update of electronics developments at LNFrascati

a. Fresh results from last week
b. Explore analog electronics for DC supplies, instead of DAC.
c. Not just a reference voltage, then no control on switching dynamics … so we need more fancy electronics -> ramp generator.
d. This would give 2 nV/sqrt(Hz), [calculated and simulated]
e. Realized TEQ board, and did build circuit: switching as expected, 5 V signal [can be changed], noise test with special setup: achieved 3nV/sqrt(Hz) of noise floor, 2.16nV/sqrt{Hz} for the signal … in agreement with simulation.

f. The voltage cannot be changed easily with the analog version of DC, flexibility would be good to tune the trap.

7) Start with a DAC system with better reference, because of flexibility, combine the DAC with the amplifier on one board [with jumper on board to separately get voltage from reference and from amplifier], blade design as (electrode trap 2, Southampton talk by Michael) needs 12 DC supplies and AC separate (no mixing).

8) Then mixing DC with AC, AC source not tested yet for noise on the nV – level.

9) Analog option for later??, if switching can be done at right speeds (adiabatic/slow for not kicking the particle out and fast for parametric cooling)

10) Option to include raspberry pi (improved version) and microcontroller from Romania to operate the DAC.

11) AC electronics: 1kHz – 10 kHz, resonance circuits, (UCL uses a function generator and a high voltage amplifier), 50 to 100 V amplitude needed for blade trap, 300 V to 600 V for the UCL 4-rod trap. (Aarhus AC power supply design cannot be used for TEQ – frequencies are much higher in Aarhus).

    a. Very different specs (for AC) for the running UCL trap and the TEQ blade trap.
    b. AC amplifier for UCL: 500V peak to peak, needs gain 25 from 10V AC, estimated noise of 100 nV. [phase drifts are a problem of a high voltage resonance circuit, so low power + amplifier will be better].
    c. Then the mixer …
    d. AC voltage noise: 70 nV/sqrt(Hz) as defined previous @ 100V amplitude (100 Hz – 1000 Hz).
    e. Amplitude stability of AC generator: much less than 1% (which is the level of the leCroy used at UCL).

12) Actions:
    a. Testing DC references source and amplifier, come up with design of DC channel
    b. Build 12 channels (external companies at Frascati), send to Michael, then to UCL
    c. Work on AC source/amplifier/mixer at INFN, design system by Max, build with UCL electronics technician

        I. AMPLIFIER. An amplifier schematic with Gain, BW and Low Noise can easily produced in the shortest term. During the realization at UCL, an INFN's constant assistance can be provided.
        II. AC SOURCE. At the moment a design does not exist and it requires a dedicated study. In parallel, some articles can be found (like the one Hendrik sent: https://aip.scitation.org/doi/pdf/10.1063/1.1136674?class=pdf) or eventually a commercial solution can be considered.
        III. MIXER. Not enough elements on requirements at the moment, a dedicated meeting is required.

d. First complete system at UCL to be tested on the blade trap for the coming review meeting (Feb 2020).

13) Check with UK guys for electroplating blades (Matthias Keller), precursor layer of gold (some 100 nm), titanium of adhesive layer.