The new ASTRID2 Fast Orbit Feedback system

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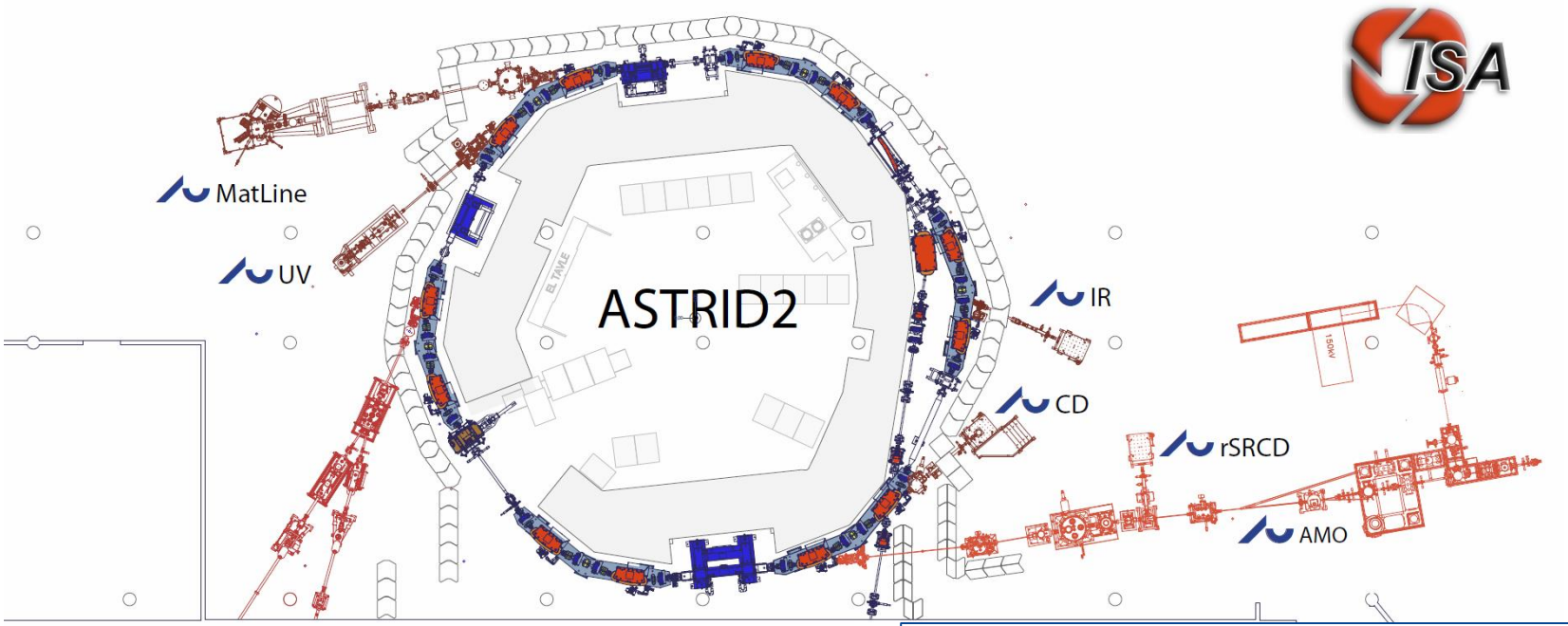
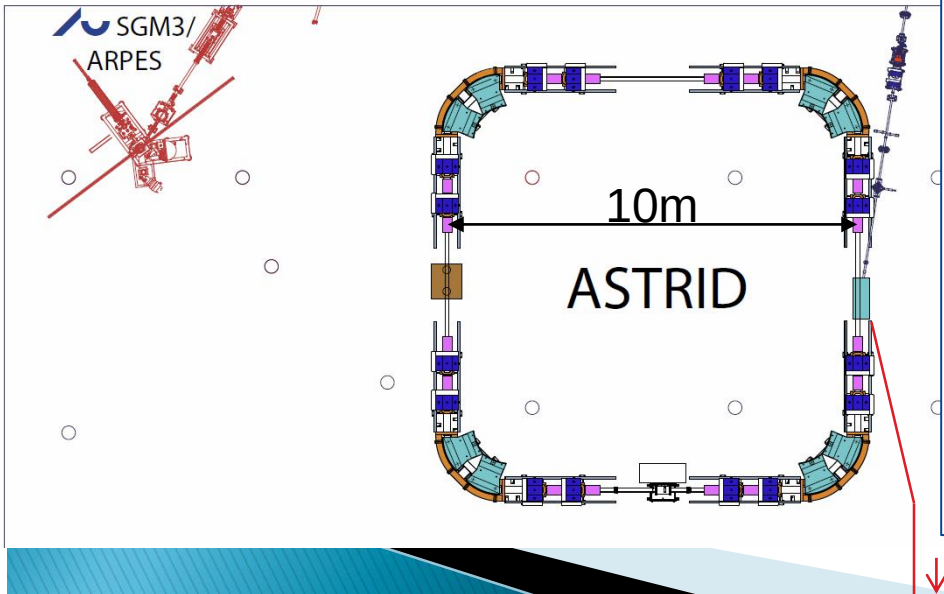
ASTRID2

- ASTRID2 is since 2013 the new synchrotron light source in Aarhus, Denmark
- ASTRID2 main parameters
  - Electron energy: 580 MeV
  - Emittance: 12 nm
  - Beam Current: 200 mA
  - Circumference: 45.7 m
  - 6-fold symmetry
    - lattice: DBA with 12 combined function dipole magnets
      - Integrated quadrupole gradient
  - 4 straight sections for insertion devices
  - Using ASTRID as booster (full energy injection)
    - Allows top-up operation

The ASTRID 2 facility





ASTRID2 main parameters

Circumference	45.71m
Energy	580MeV
Current	200mA
Characteristic energy	257eV
RF frequency	105MHz
Harmonic	16
Horiz. emittance	12nmrad
#Straight sections	6
Length of straight sections	2.82m
#ID's	3

ASTRID2 Orbit Control

- Design/Construction (2010–2012)
  - 12 HV window frame correctors + 12 H correctors
    - Home-made ±15 A power supplies
  - 24 Button BPM's (4 in each arc)
  - 24 Libera Electron BPM processors
  - Slow Orbit FeedBack
    - LabVIEW
    - Only using the 12 HV correctors
  - No Fast Orbit Feedback
    - To keep cost and complexity down

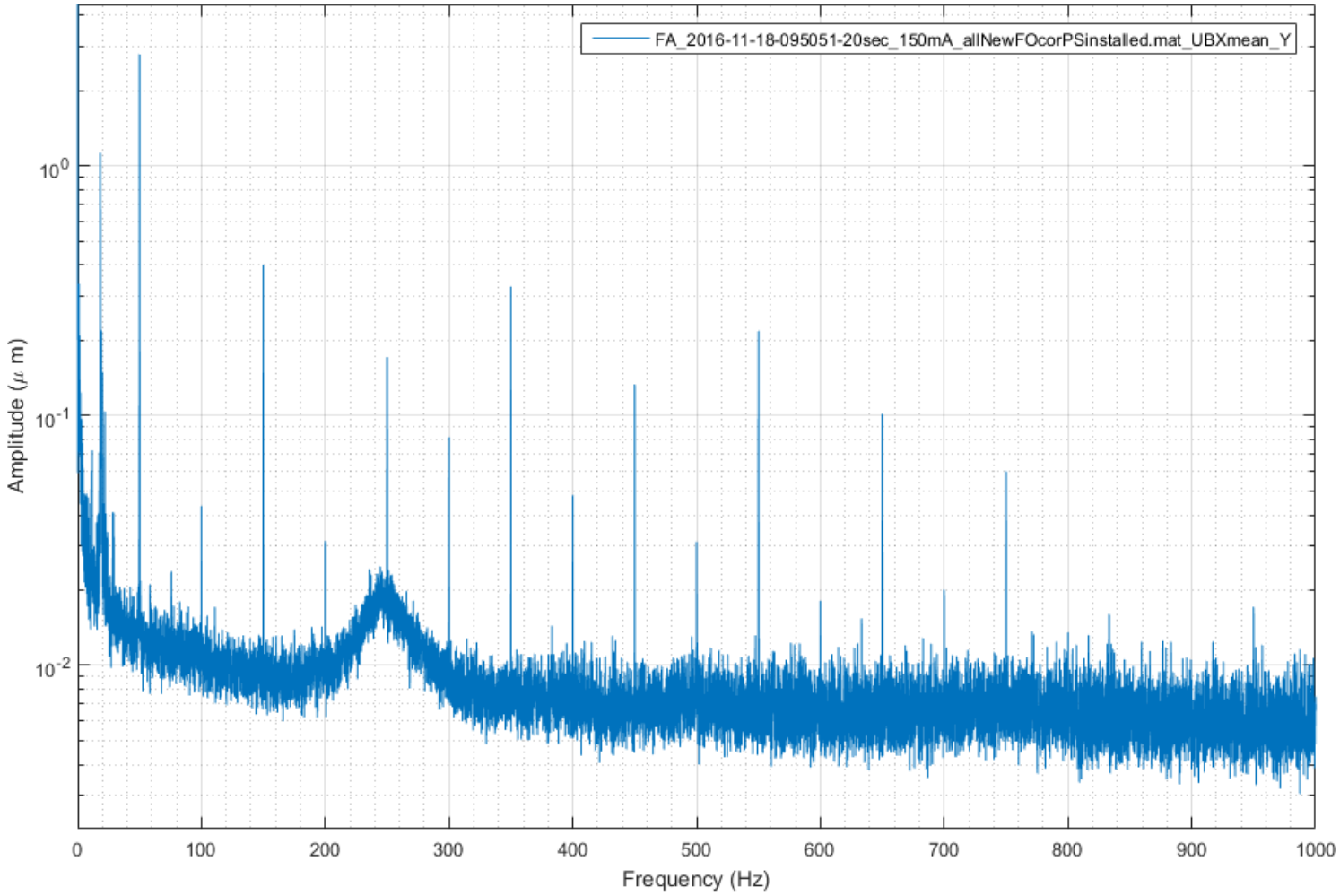
HV window frame corrector

Orbit problems (disturbances)

- Disturbance from ASTRID during injections
  - Up to ~20 μm (with feedforward)
- Cars on parking lot above ASTRID2
  - Up to ~5 μm
- Fairly strong 50 Hz noise peaks
  - 50 Hz: ~3 μm
  - 150 Hz: ~0.4 μm
  - 250 Hz: ~0.2 μm
  - 350 Hz: ~0.3 μm
  - 550 Hz: ~0.2 μm
- Insufficient resolution in PS (16 bit)
  - ~1 μm

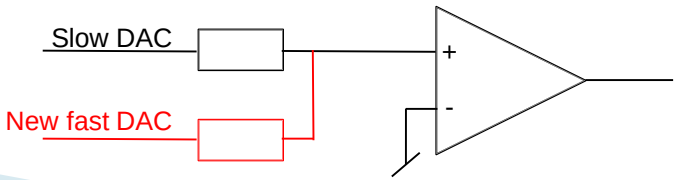
Orbit disturbances

Average of FFT of beam positions from all 24 vertical pickups



Ideas for Fast Orbit FeedBack

- Beam positions from the 10 kHz Libera Electron FA output
- Tested the original window frame correctors
  - Verified bandwidth >~1 kHz
- Possible to upgrade the existing power supplies with a fast (1 kHz) analog input
  - Summing existing 10 Hz control with fast input
  - Bandwidth of supply and magnet >~1 kHz
    - But latency (Liberas) is limiting feedback bandwidth
  - Only 1% range => (much) improved resolution



Fast Orbit FeedBack control

- Cheap and simple
  - k€ (and not 10's of k€)
- Tested various solutions
  - CompactRIO (NI-9066): too slow
  - Ethercat (from LabVIEW realtime): too slow
- Final solution
  - Standard PC running LabVIEW real-time
    - Receive Libera FA data through dedicated network card
    - Does the orbit calculations (at 10 kCalc/s)
    - Output: Using a FPGA enabled DAQ-card digital values are feed to 4 DAC chips (TI DAC8568 (8 ch, 16 bit)) via SPI-like lines at a rate of 24*10 kS/s
  - Price: ~3 k€ (plus some work)

FOFB overview

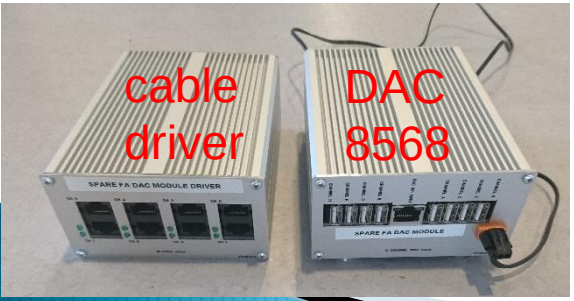
Cable driver

24 Libera Electron with Grouping
One 10 kHz FA output

Ethernet

Standard PC (i7-6700)
with NI PCI-7811R (FPGA enabled DAQ)
Running LabVIEW real-time

SPI-like connections
4 wire each



DAC 8568 | 6 Power supplies

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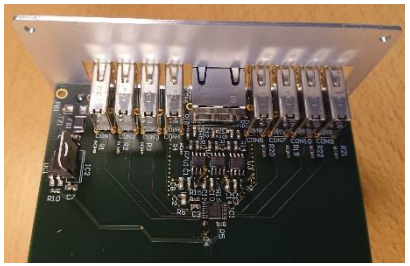
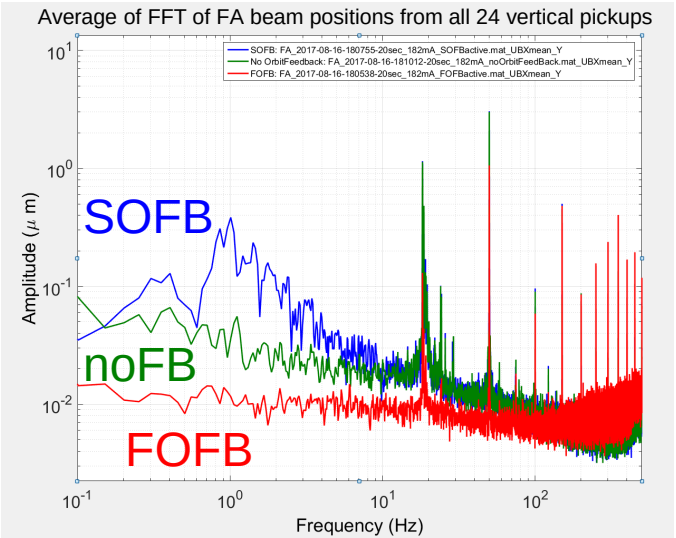


Software loops

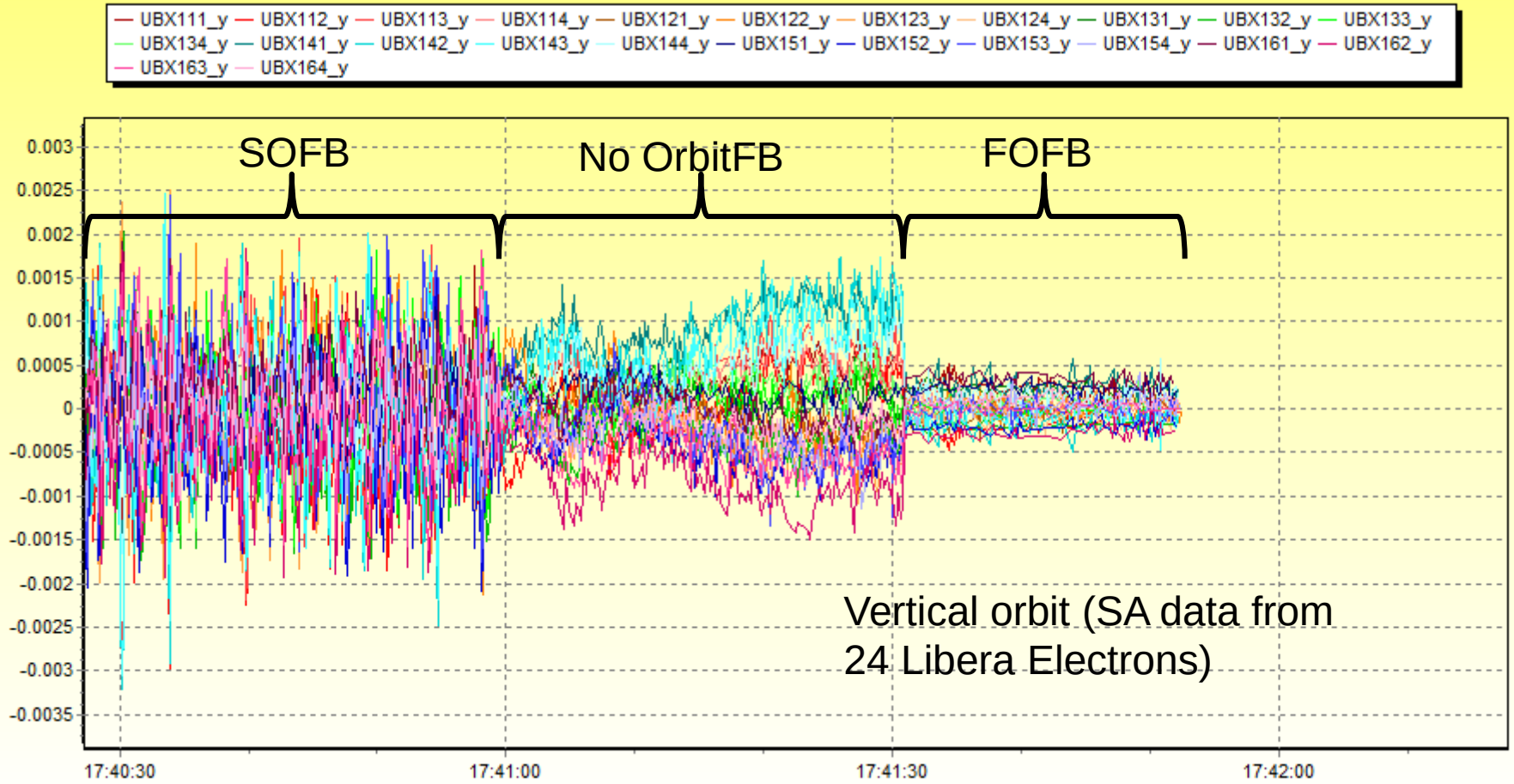
- Timed loops for
  - High priority (10 kHz):
    - Receive network data (FA data) and unpack these
      - ~45% CPU load
    - Orbit correction calculation, summing (PID), and transfer of new dac values to FPGA card (for transmission)
      - ~20% CPU load
  - Low priority (1–10 Hz)
    - Analyses
      - Averaging, rms, min/max
      - Optional FFT
  - Data are transferred between the loops via Realtime FIFO's

FOFB results

- Clear improvement below ~100 Hz
- Much improvement 0.1~10 Hz range
  - Where SOFB made noise (partly due to insufficient resolution)
- Disturbance from ASTRID during injections
  - Hor: From ~20 μm (after feedforward) to a few μm
  - Vert: From ~10 μm to not really noticeable
- Cars on parking lot above ASTRID2
  - From ~5 μm to almost not noticeable
- 50 Hz noise peaks
  - 50 Hz: ~3 μm -> ~1 μm
  - 150 Hz: ~0.5 μm -> same
- Very pleased

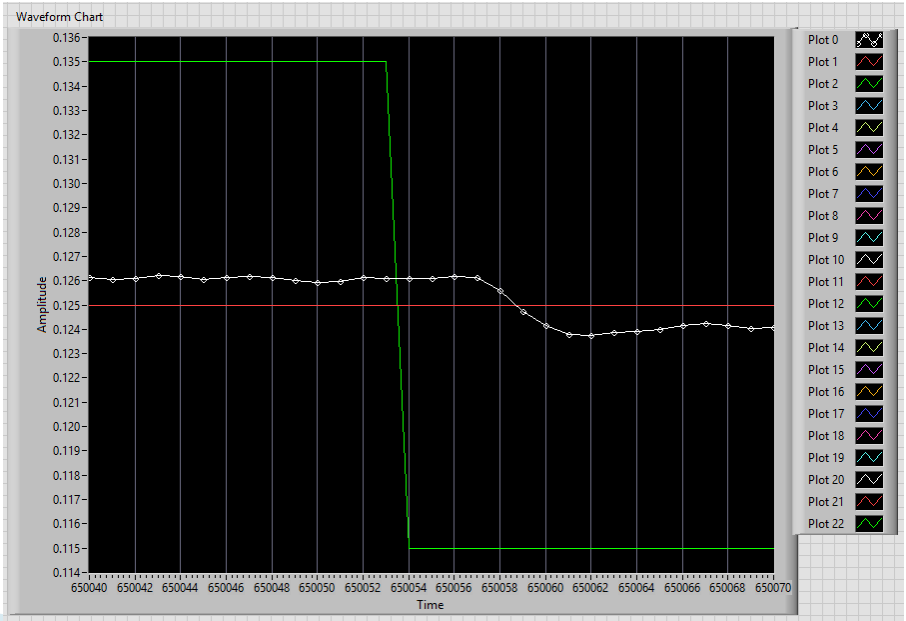


FOFB results



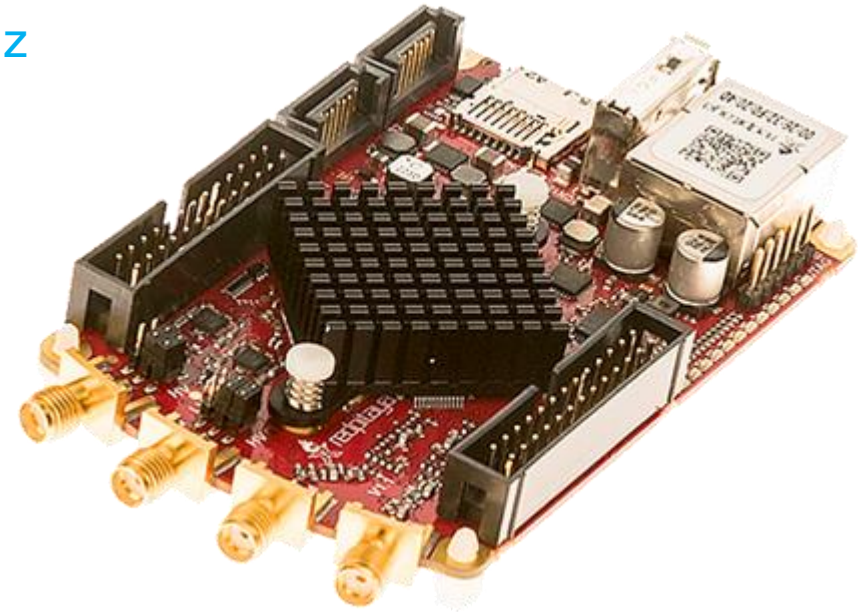
FOFB improvements

- Still much 50 Hz and harmonics
- Bandwidth is limited (only up to ~150 Hz)
  - Latency is 600–800 µs (delay of 400 µs + change takes 400 µs)
    - Libera: ~250 µs, RT program: 100–200 µs
- Ideas:
  - Improve feedback algorithm
    - Tried with proper PID, but no improvement
    - Tried with in-loop filter but no success
    - 50 Hz is predictable (on short term)
      - Should allow some feed-forward
  - Inputs from you



Ideas for LBbB feedback system

- Following a suggestion from Gunther Rehm we are contemplating using a Red Pitaya for a LBbB feedback processor
- Red Pitaya:
  - Xilinx ZYNQ XC7Z010 SoC
  - 125 MS/s ADC and DAC (x2)
    - ASTRID2 RF frequency is 105 MHz
  - Price: ~300 €
- Status:
  - We have made our first FPGA code modifications for the Red Pitaya



Conclusions

- Have shown you a FOFB system, which is simple and cheap, but still does a quite good job
- Good value for money

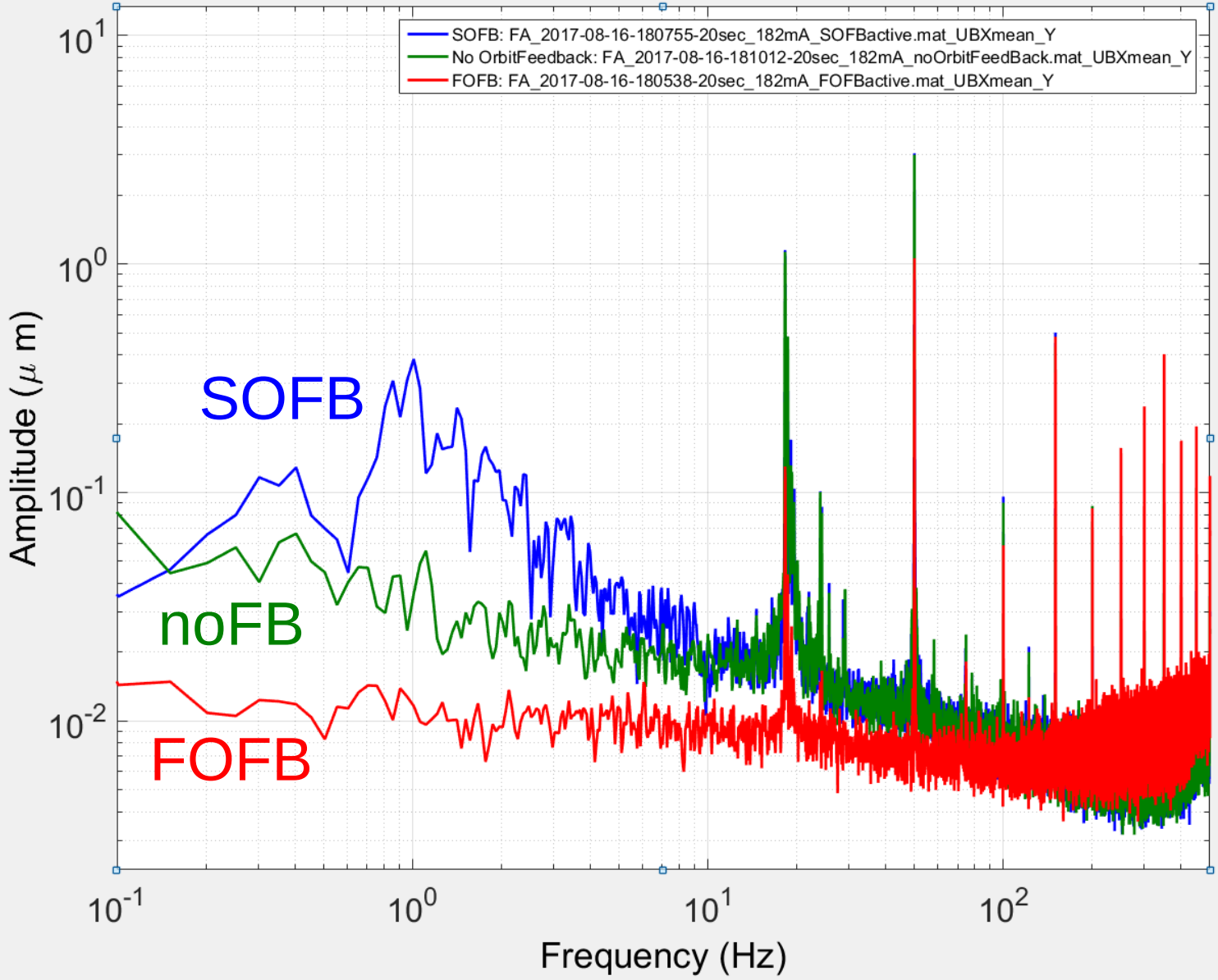
Thanks to
Martin Stougaard and Per Christensen from Department of Physics and Astronomy for power supply modifications, DAC modules and DAC data transmit system (incl. LabVIEW FPGA code)

Thank you for your attention

Extra slides

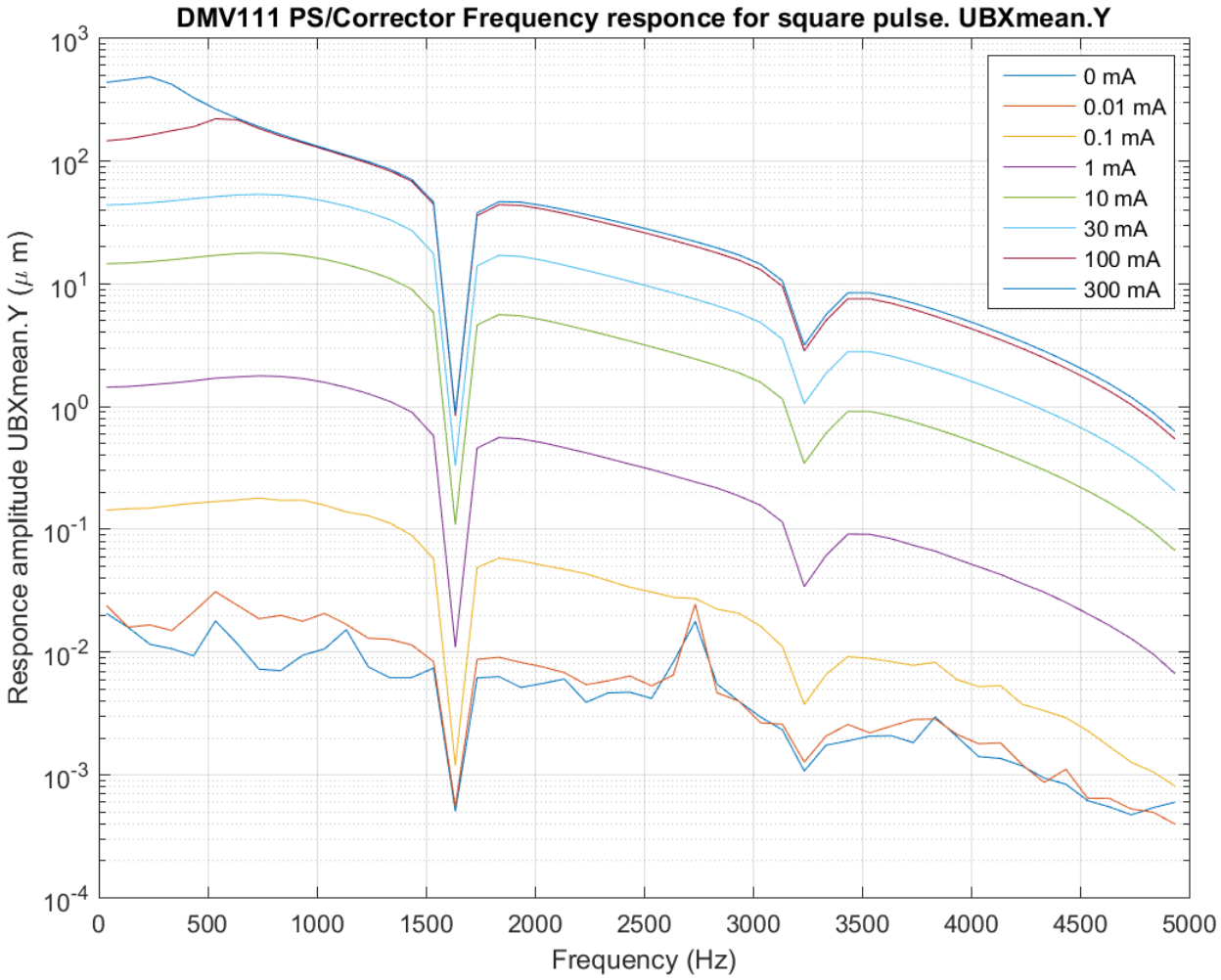
FOFB results

Average of FFT of FA beam positions from all 24 vertical pickups



Corrector Responce

- Measured frequency response



FOFB Open Loop Responce