Fourier Transform Spectrometer Controller for Partitioned Architectures

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Instruments

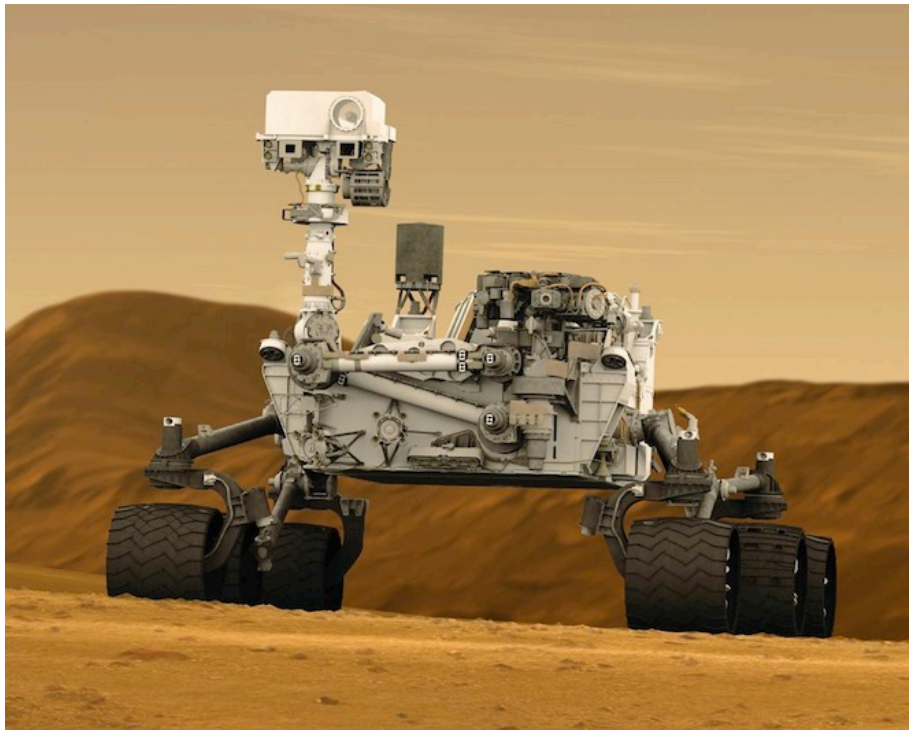
DTU Compute
Department of Applied Mathematics and Computer Science

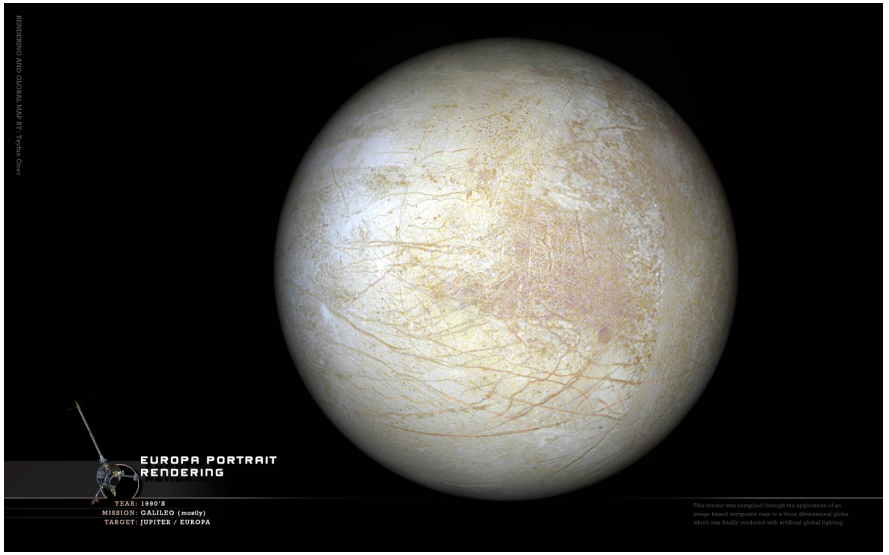
Outline

- Introduction
- Fourier Transform Spectroscopy
- CIRIS: Compositional InfraRed Imaging Spectrometer
- CIRIS Controller Implementation
- Evaluation
- Partitioned Architecture
- Conclusions

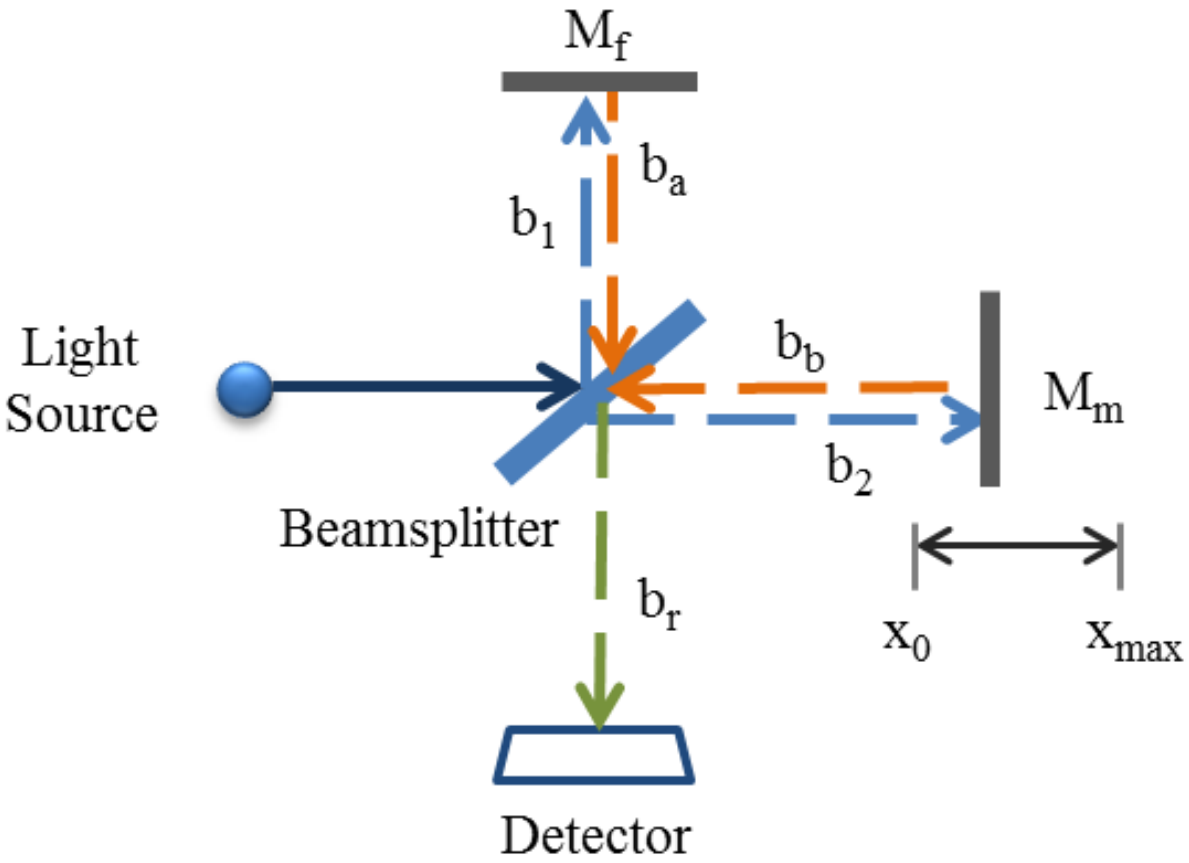
Introduction

- Spectroscopic techniques allow scientists to determine the composition of remote substances





Traditional Michelson Spectrometer



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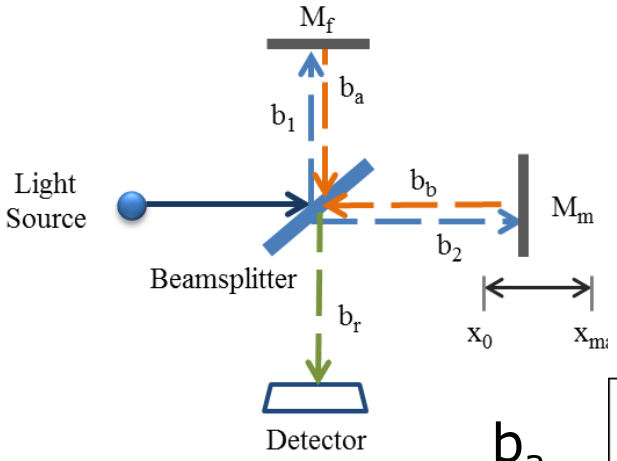
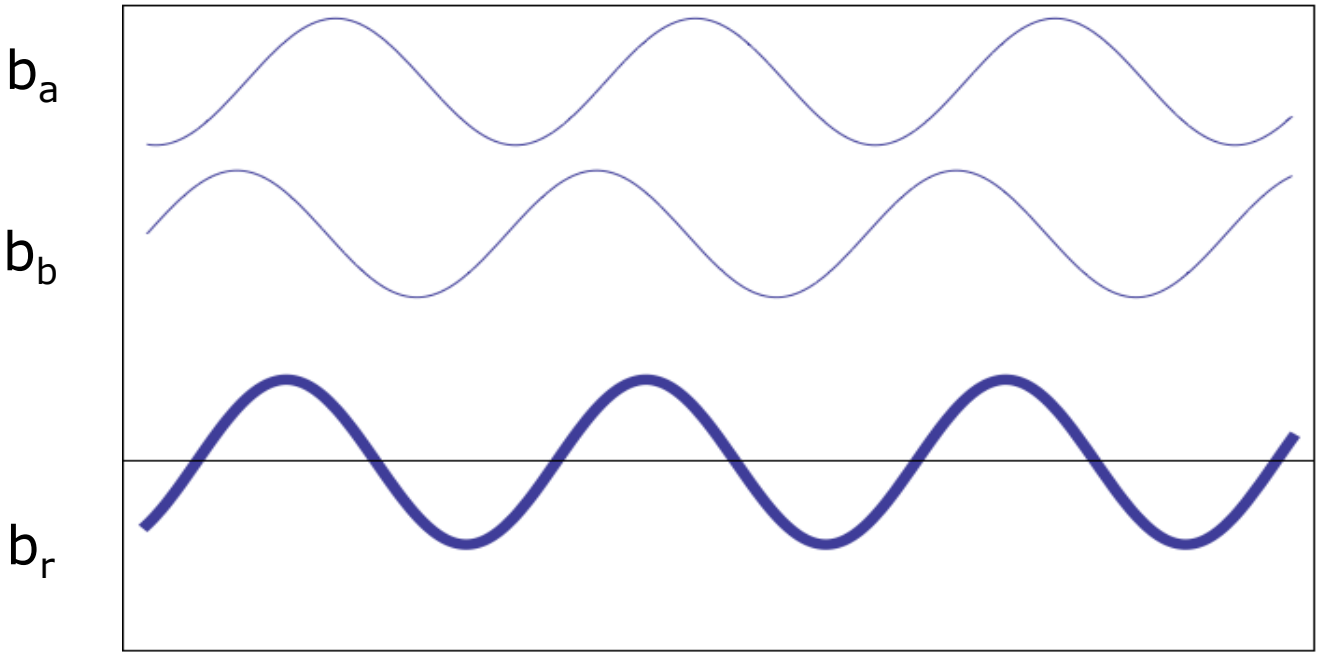
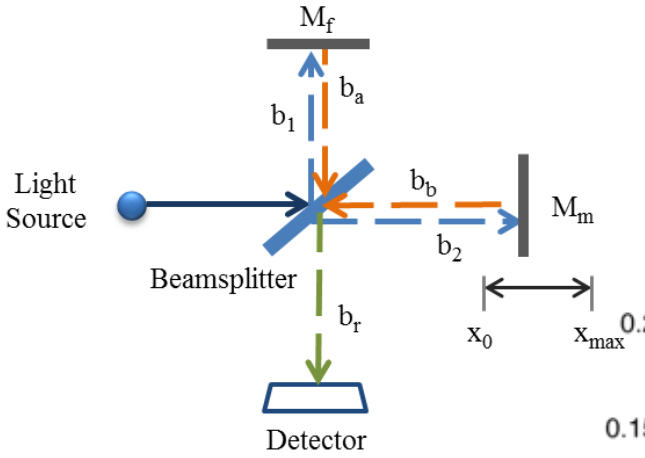
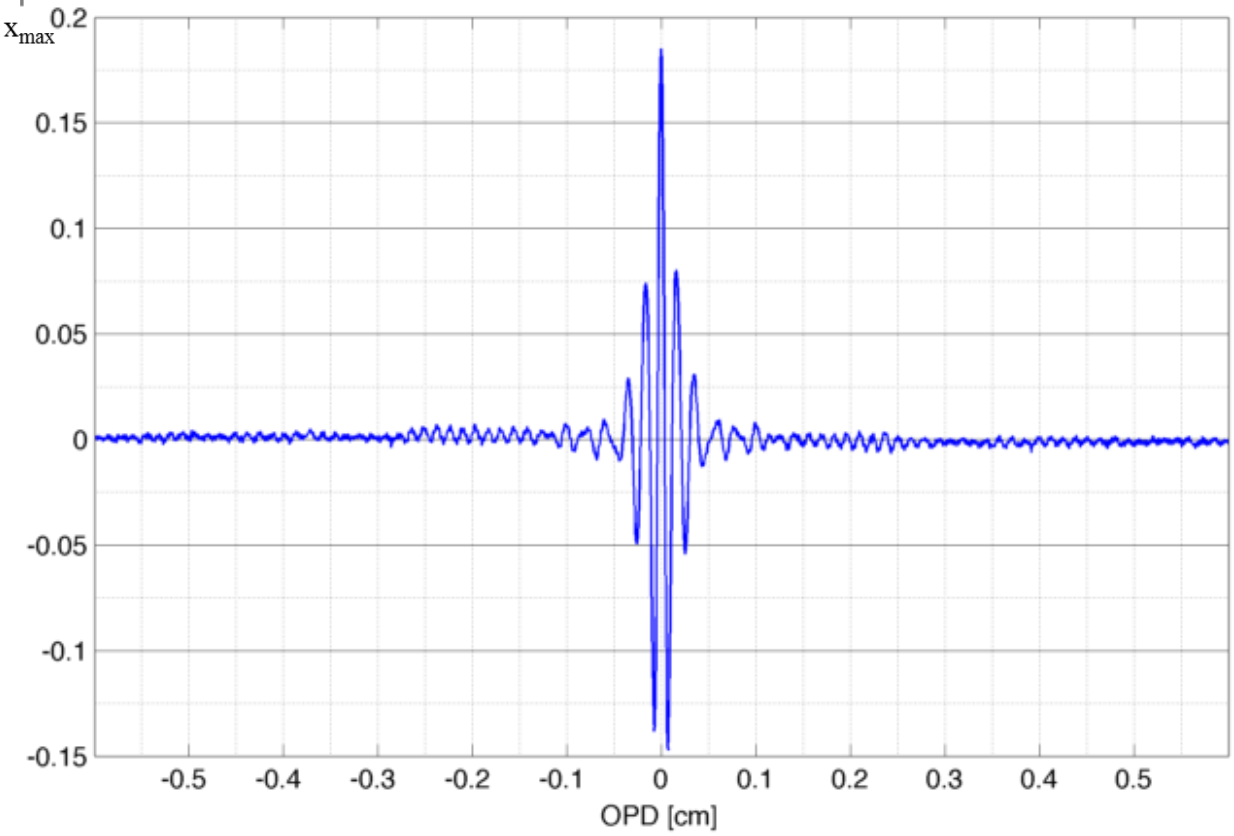




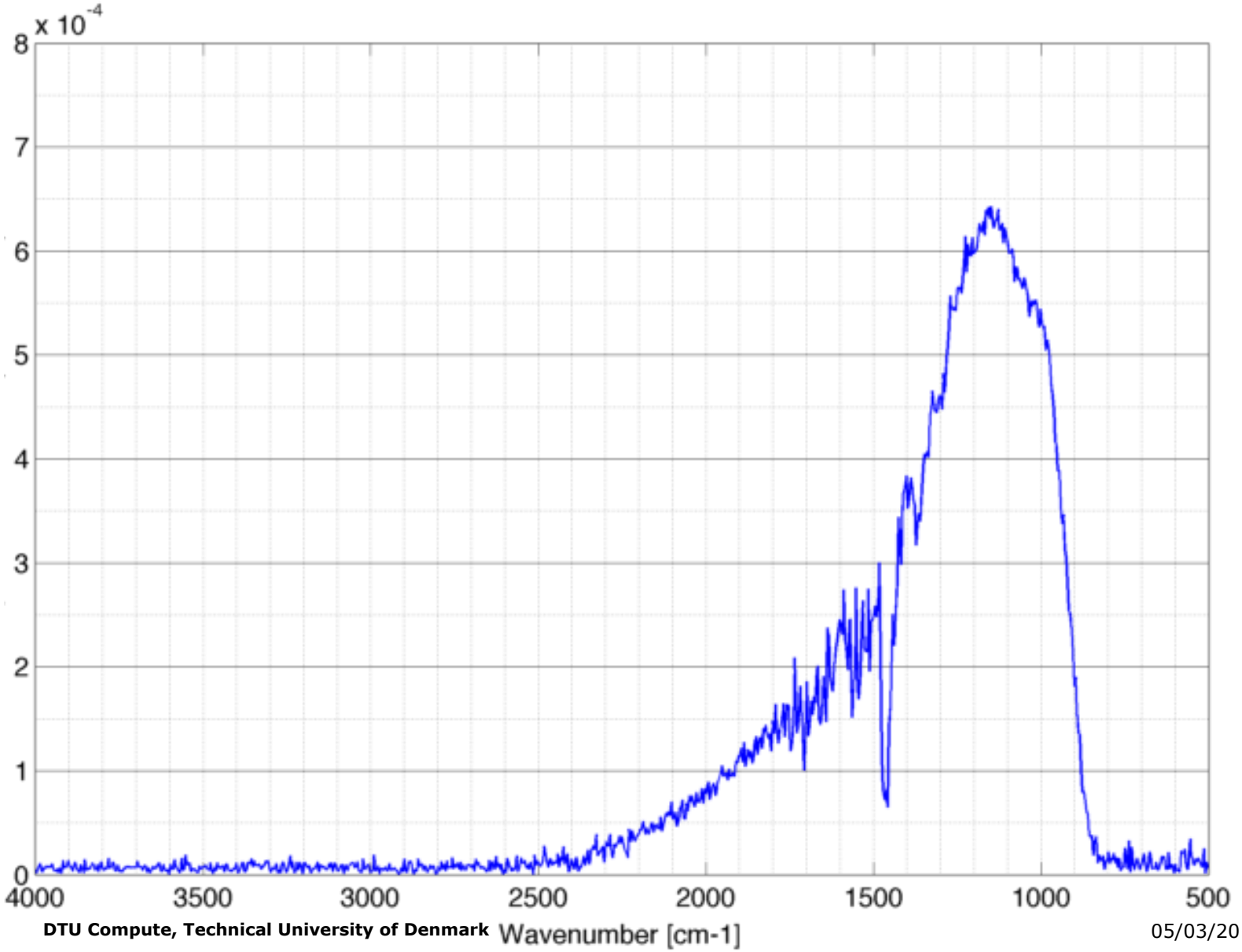
Source: www.acs.psu.edu/drussel/Demos/superposition/interference.gif

Traditional Michelson Spectrometer

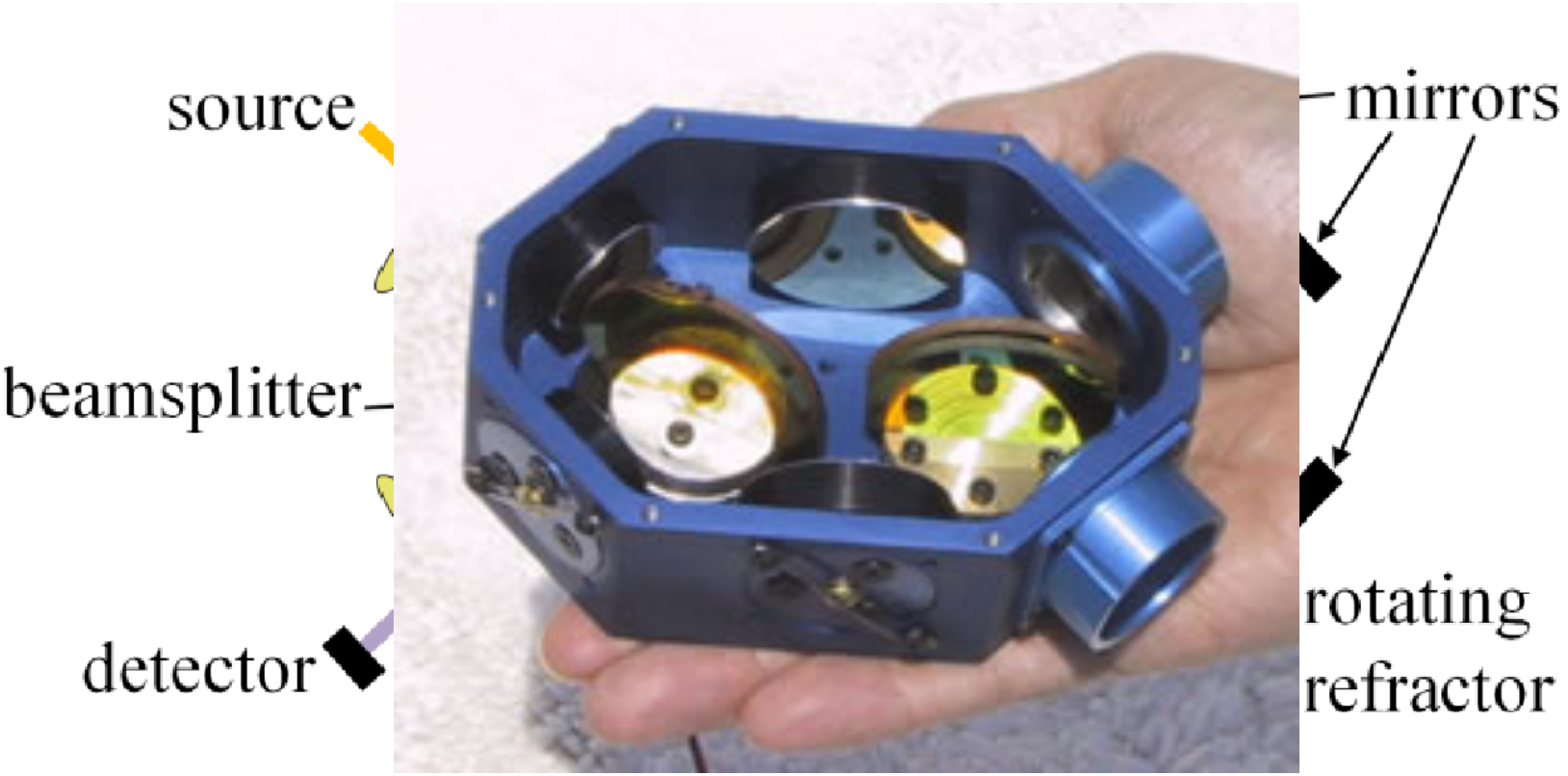




FFT'd Interferogram Resulting Spectrum



CIRIS: Compositional InfraRed Imaging Spectrometer

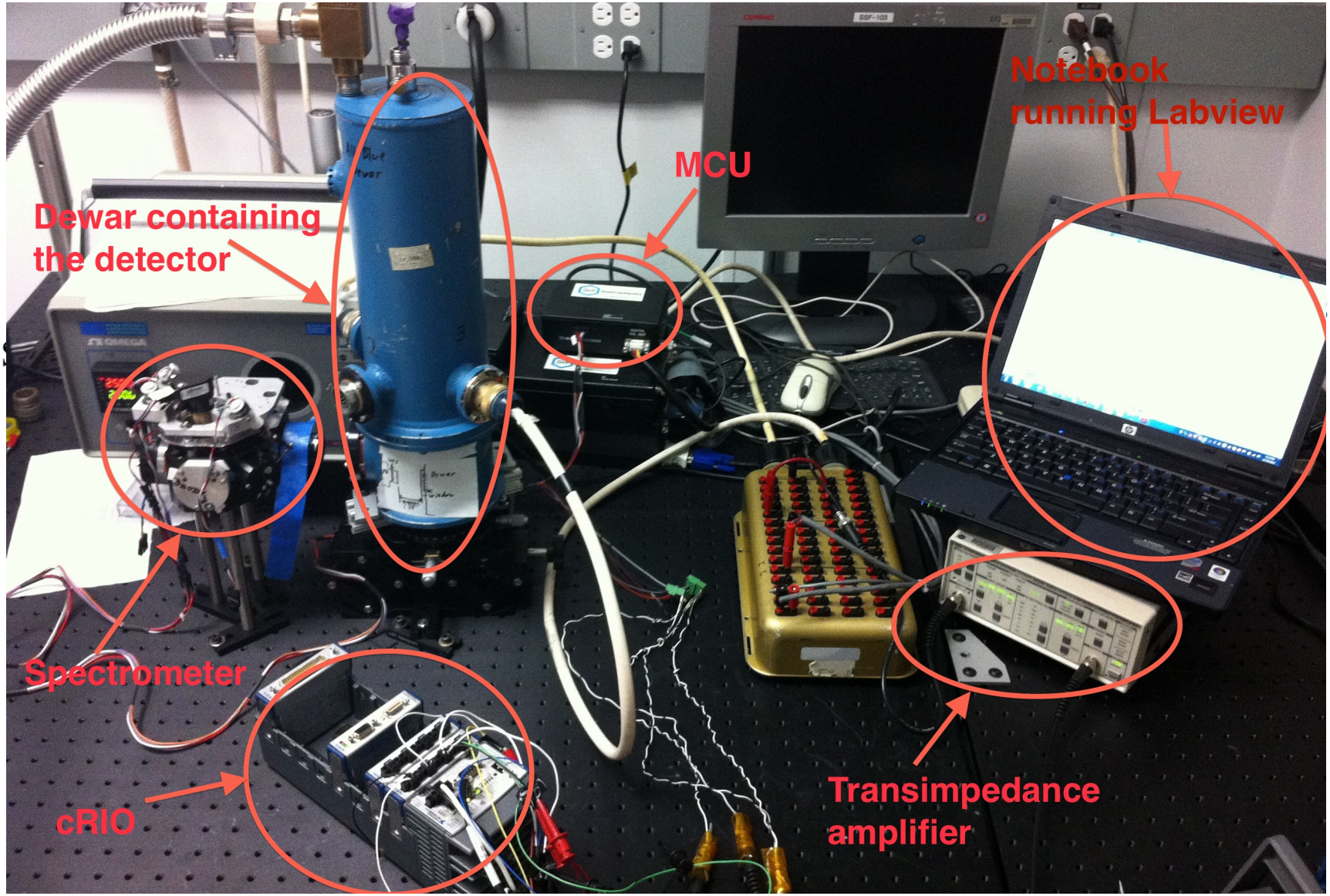


- Spectral range of 2.8 to 18 μm, or 3571 to 555 cm^{-1}
- 4 cm^{-1} resolution, or 754 points between 3571 and 555 cm^{-1}

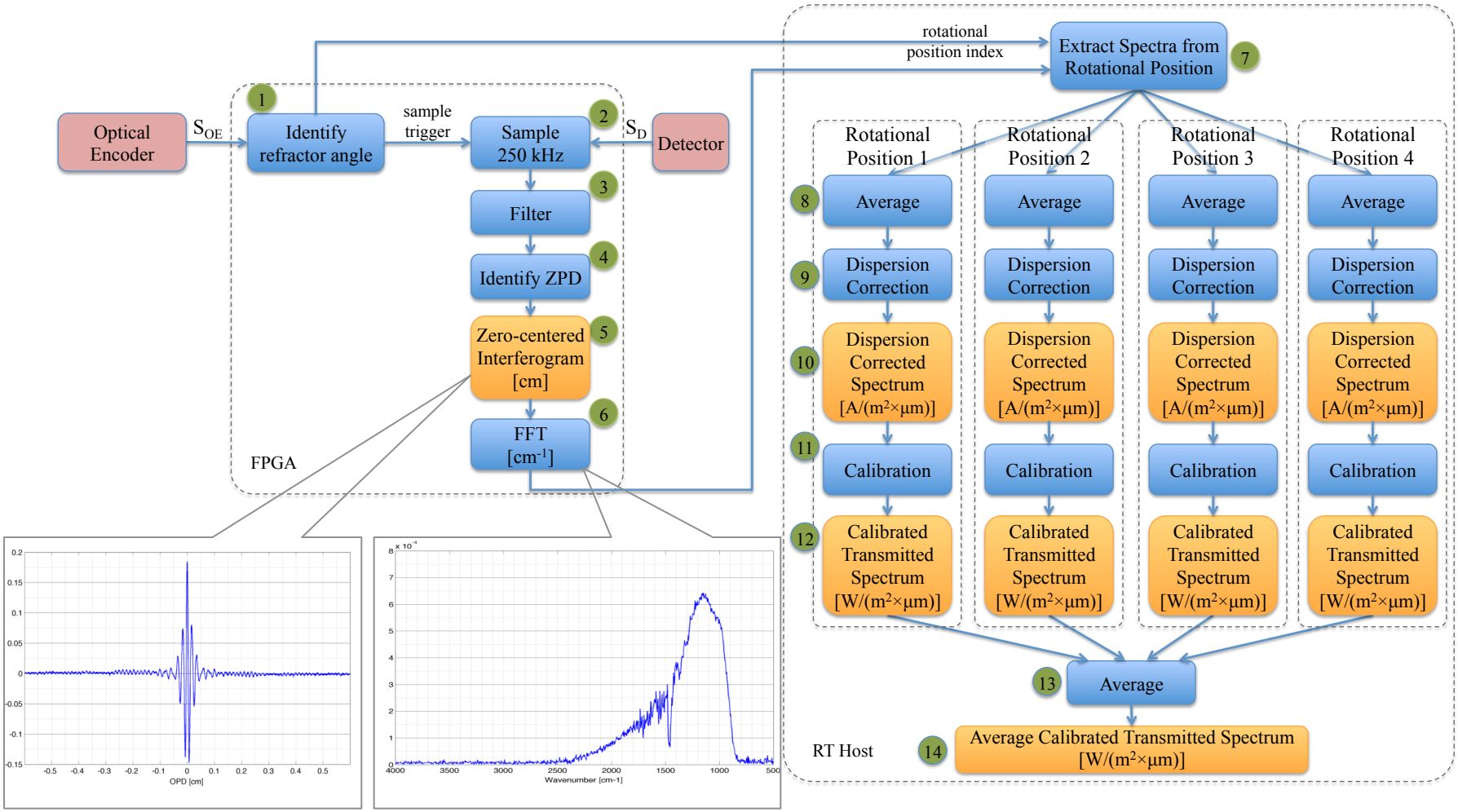
CIRIS Facts

- 4 interferograms per revolution
- 2.5 revolutions per second
- An interferogram is captured for 33 ms every 100 ms
- Operational in the spectral range of 2.8 to 18 μm, or 3571 to 555 cm^{-1}
- 4 cm^{-1} resolution, or 754 points between 3571 and 555 cm^{-1}
- Spectra computable from a double sided interferogram insensitive to phase change of 3016 points
- CIRIS records 8192 points for each interferogram

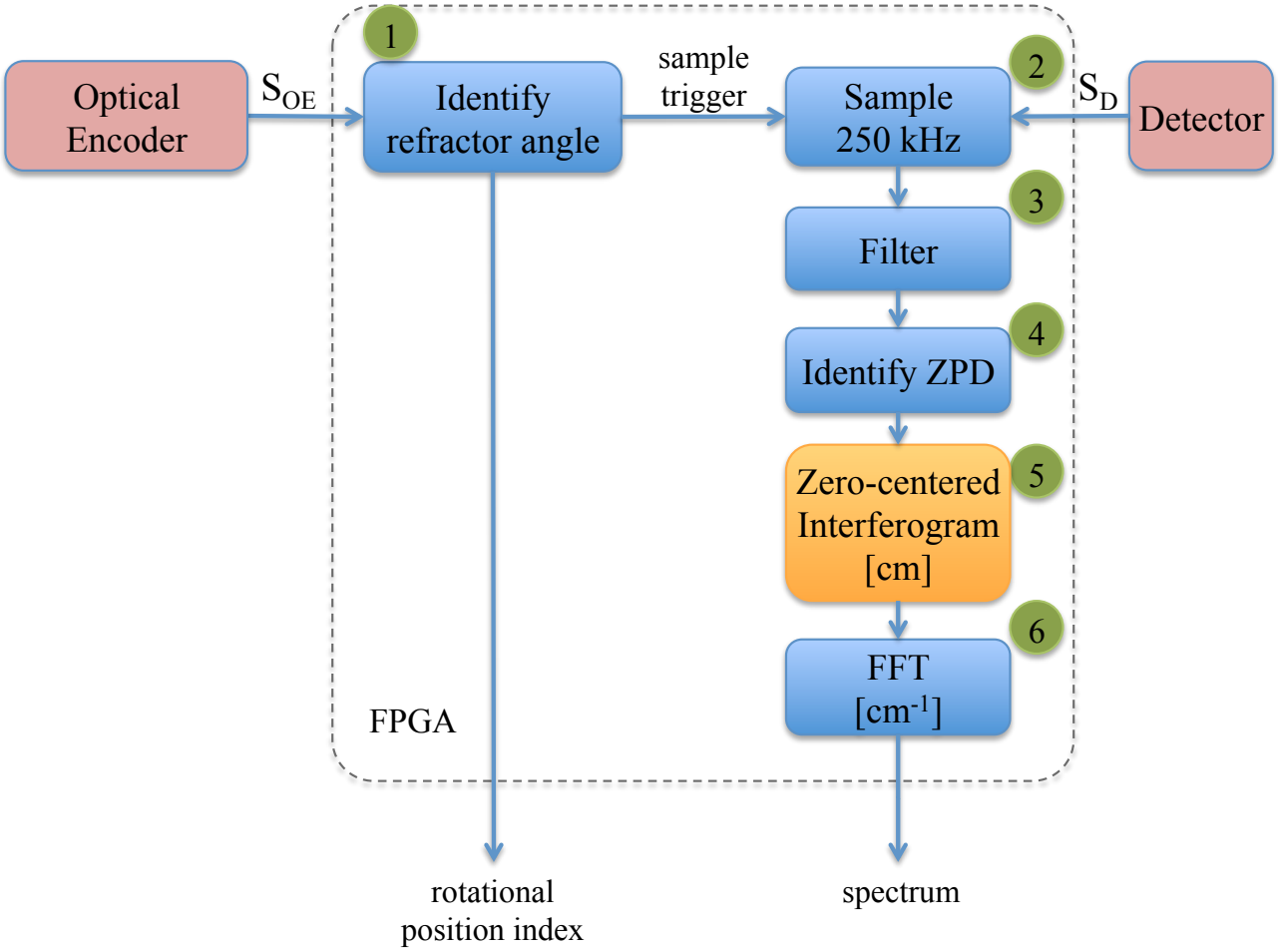
CIRIS Setup Schematic



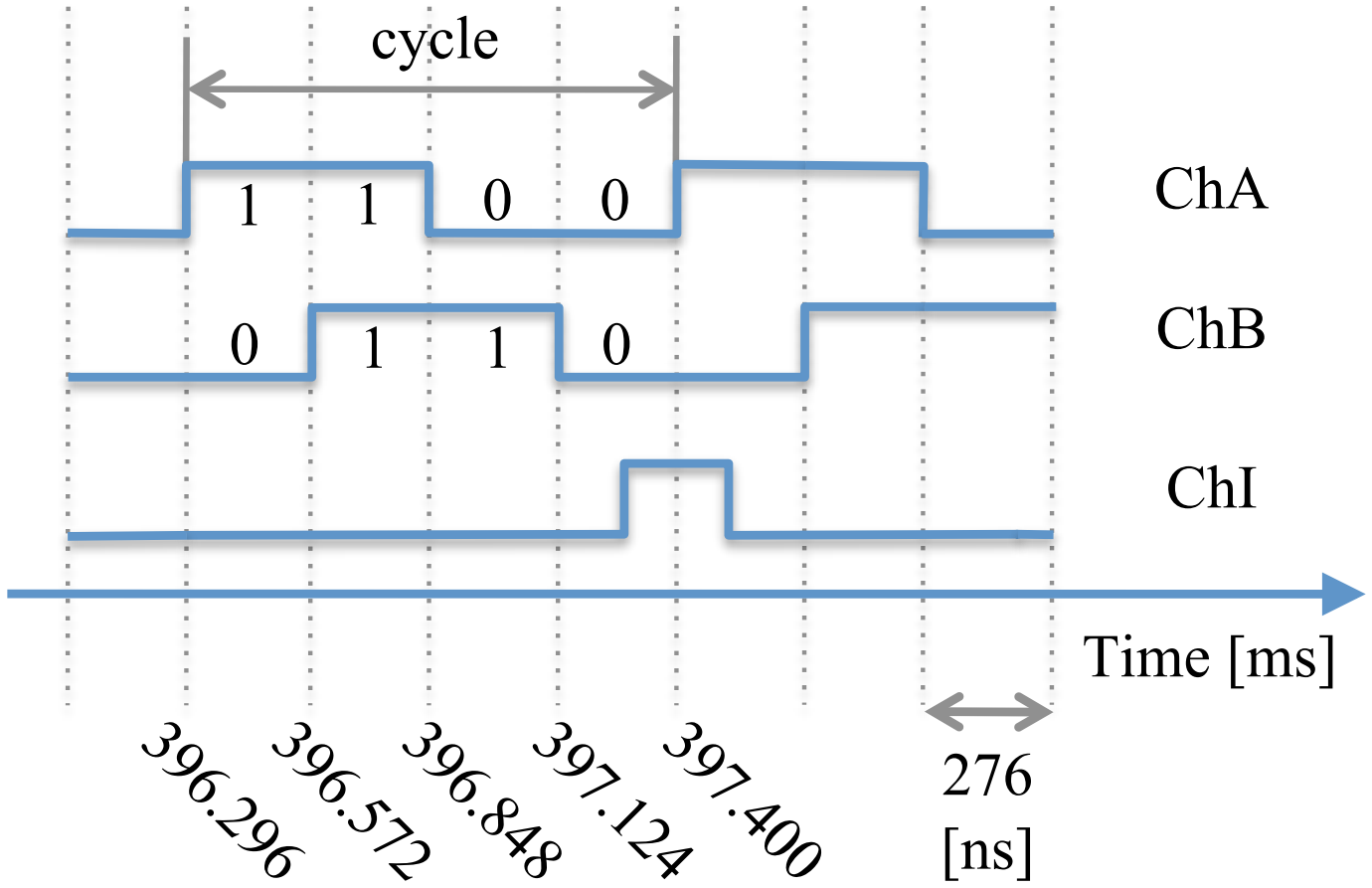
Acquisition and Processing Controller Algorithm

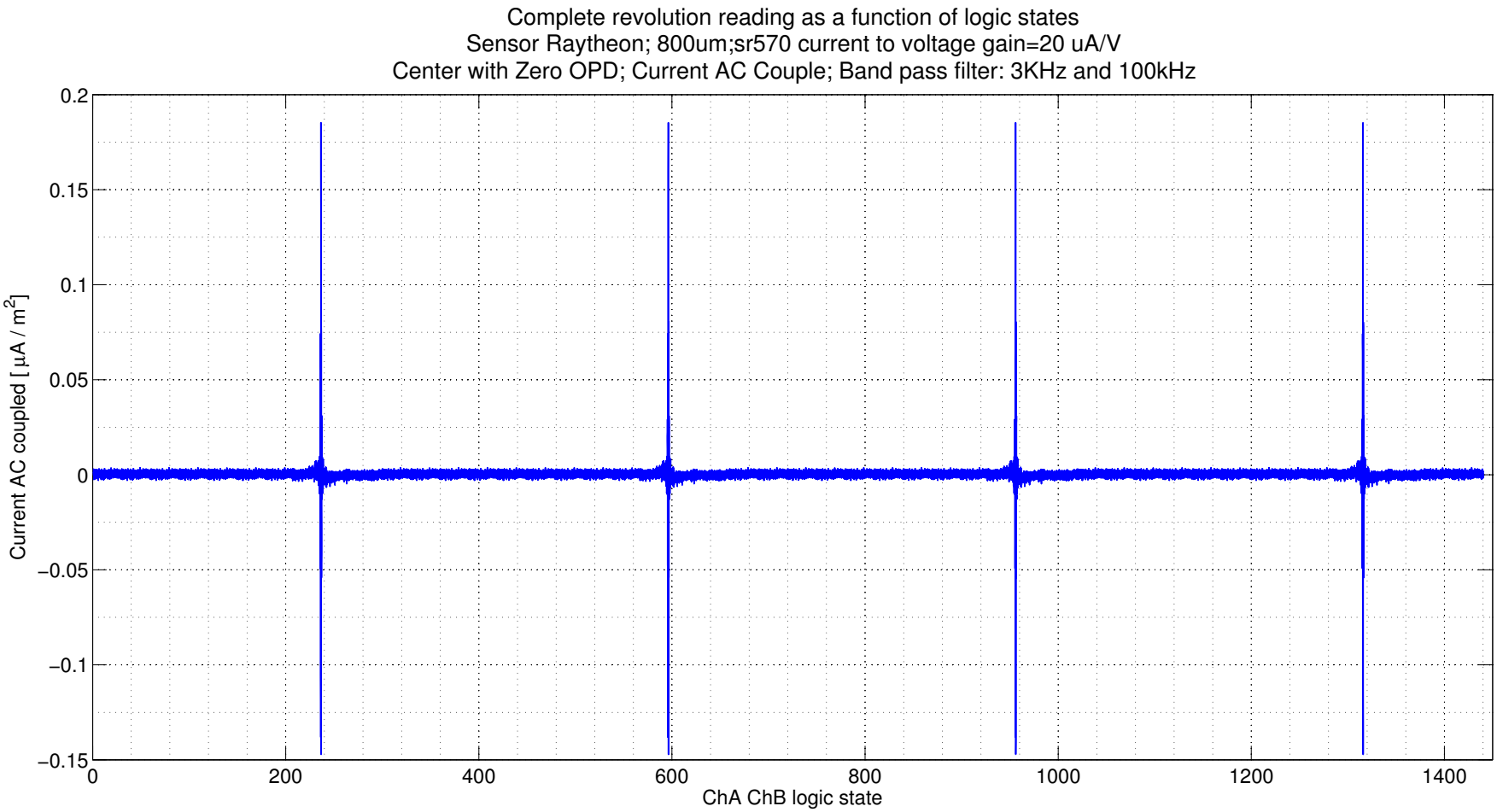


FPGA Implemented Algorithm

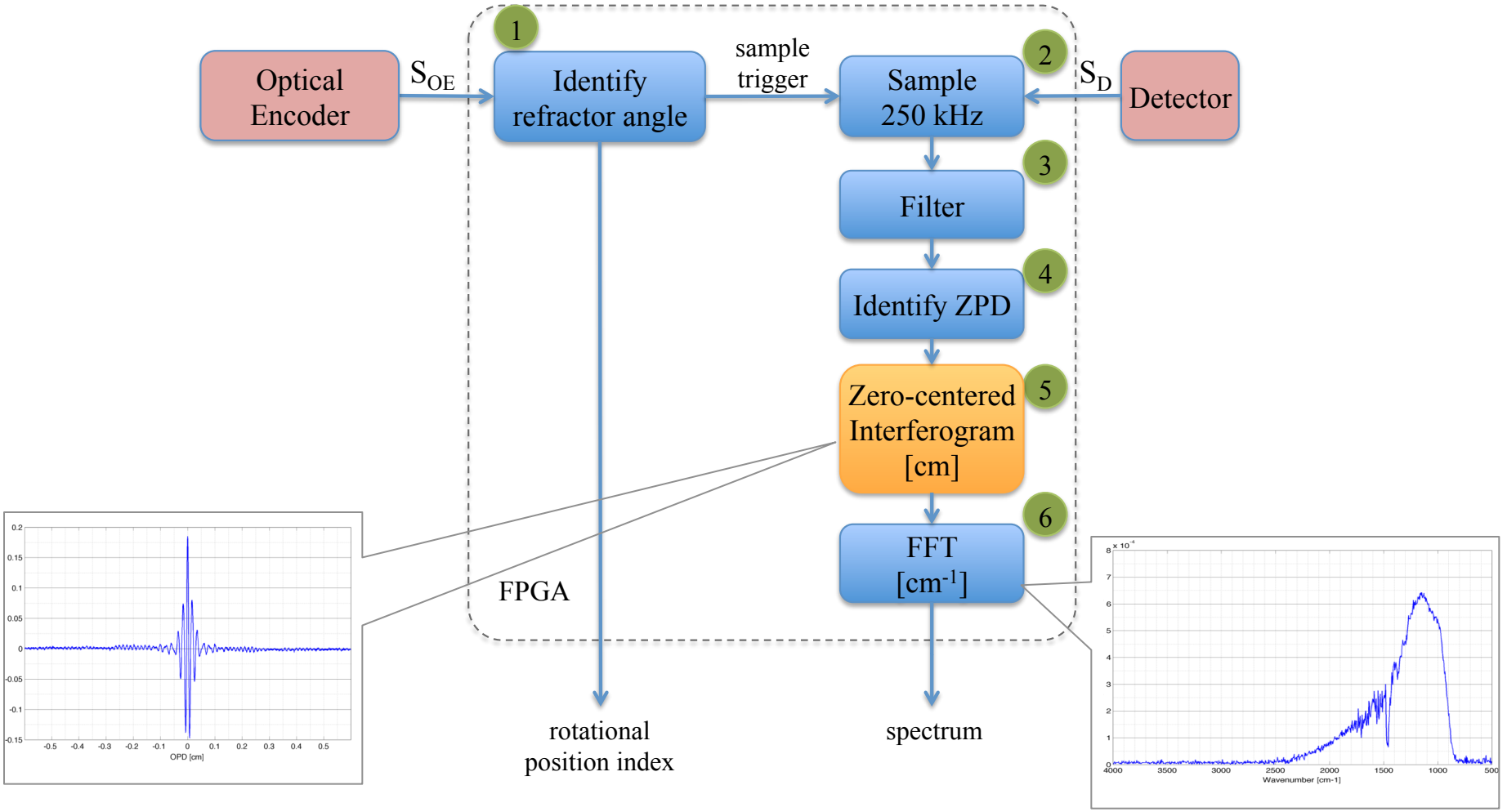


E2-360I Optical Encoder Signals

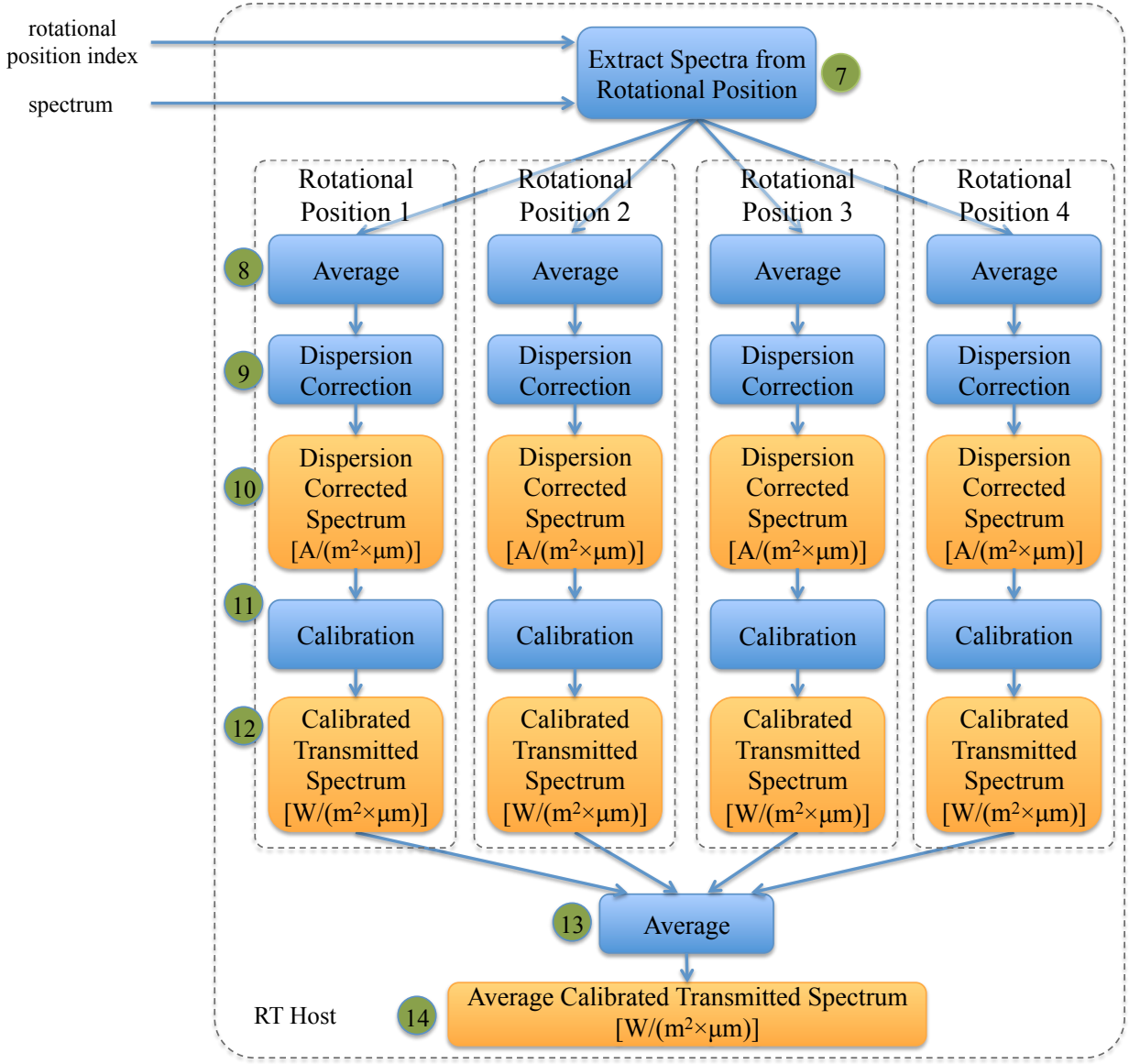



Complete revolution reading as a function of logic states
Sensor Raytheon; 800um;sr570 current to voltage gain=20 uA/V
Center with Zero OPD; Current AC Couple; Band pass filter: 3KHz and 100kHz
Current AC coupled [µA / m2]
ChA ChB logic state
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
0
200
400
600
800
1000
1200
1400

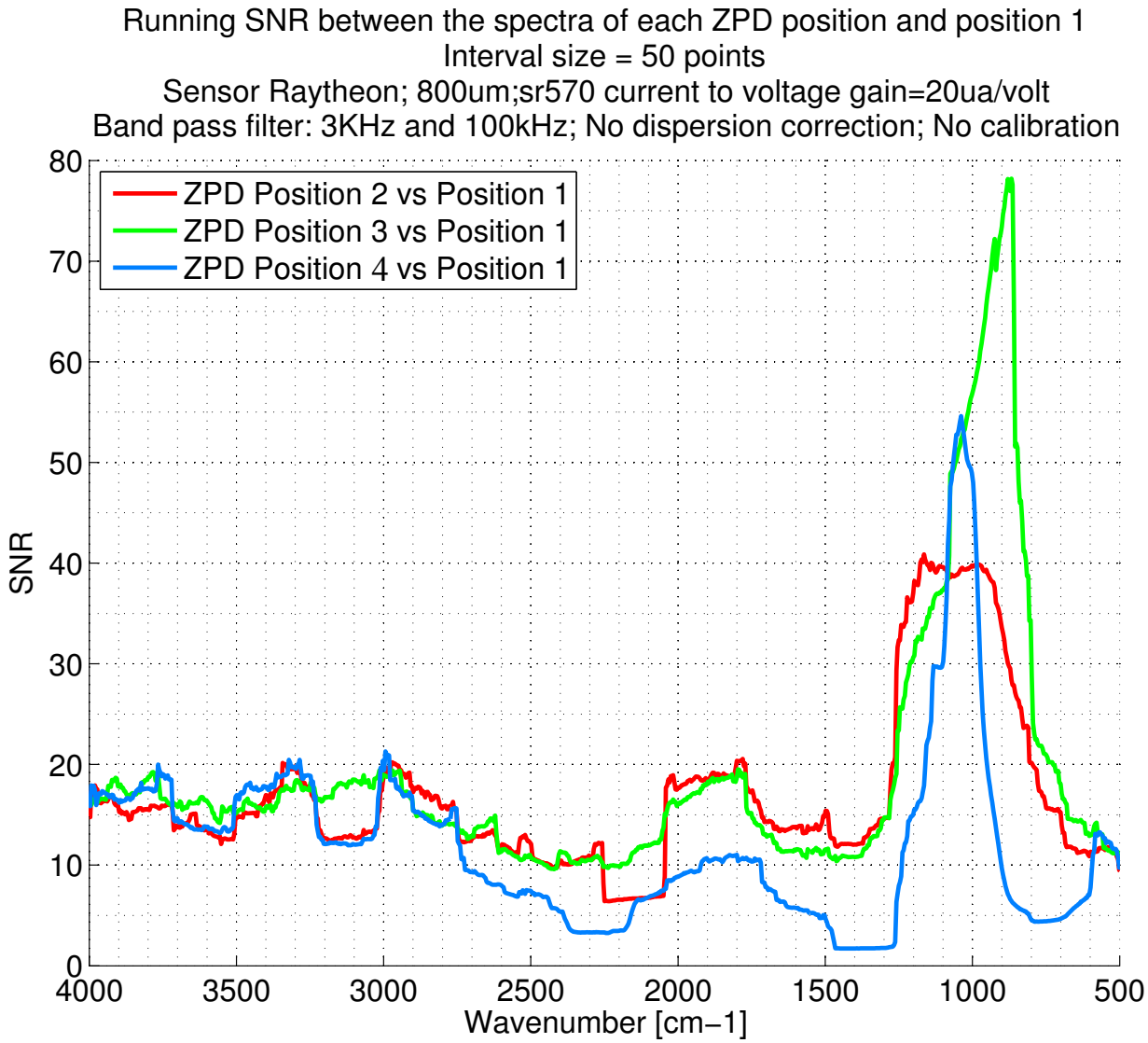
FPGA Implemented Algorithm



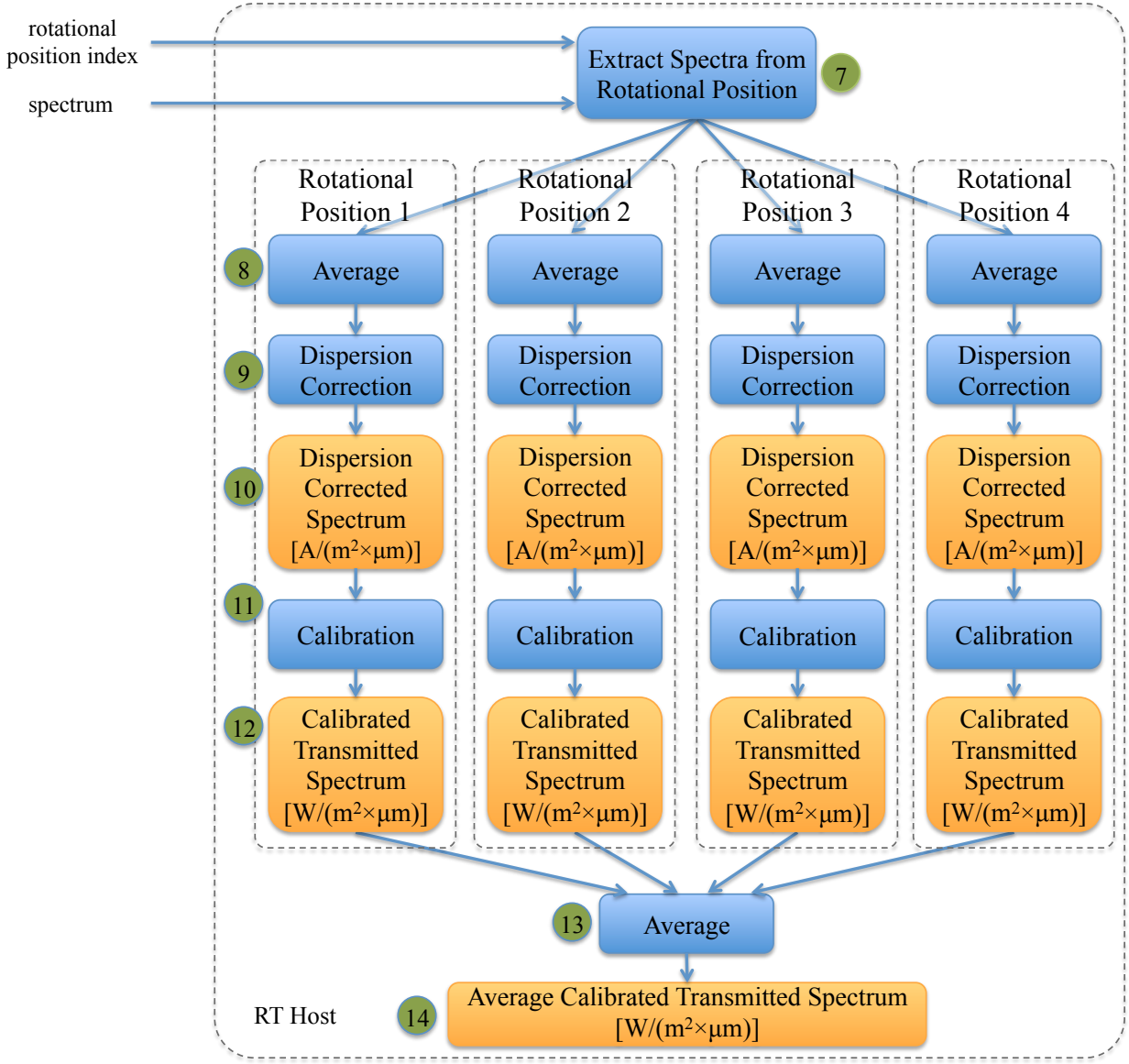
RT Host Implemented Algorithm



Differences Between the Spectra Obtained at Different Rotational Positions



RT Host Implemented Algorithm

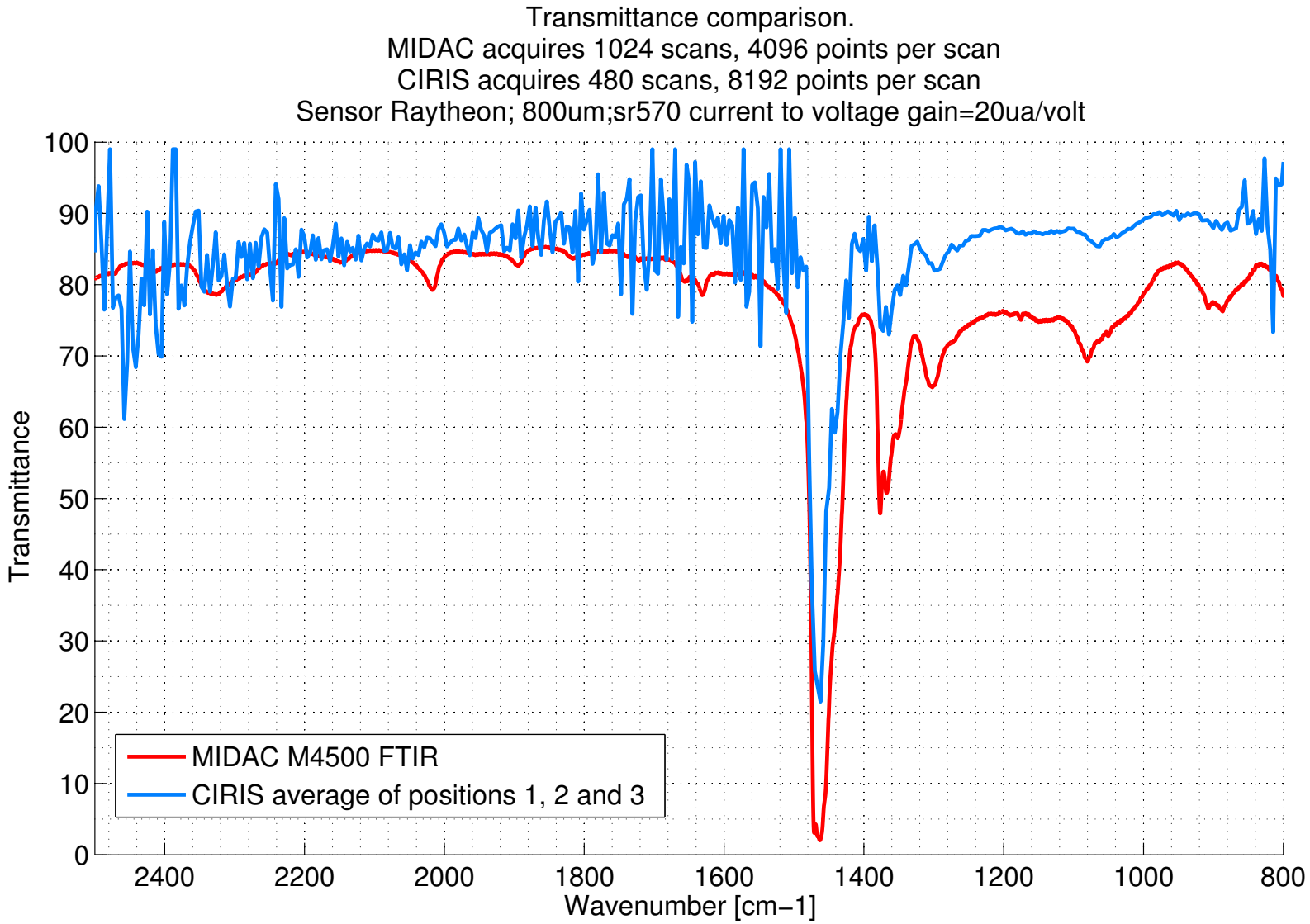


Evaluation

- Compare CIRIS results with a MIDAC M4500 FTIR spectrometer.
- MIDAC
  - Resolution of 4 cm^{-1}
  - Wavenumbers 6000 to 600 cm^{-1}
- Transmittance comparison

$$T(\upsilon) = \frac{T_{sample}(\upsilon)}{T_{background}(\upsilon)}$$

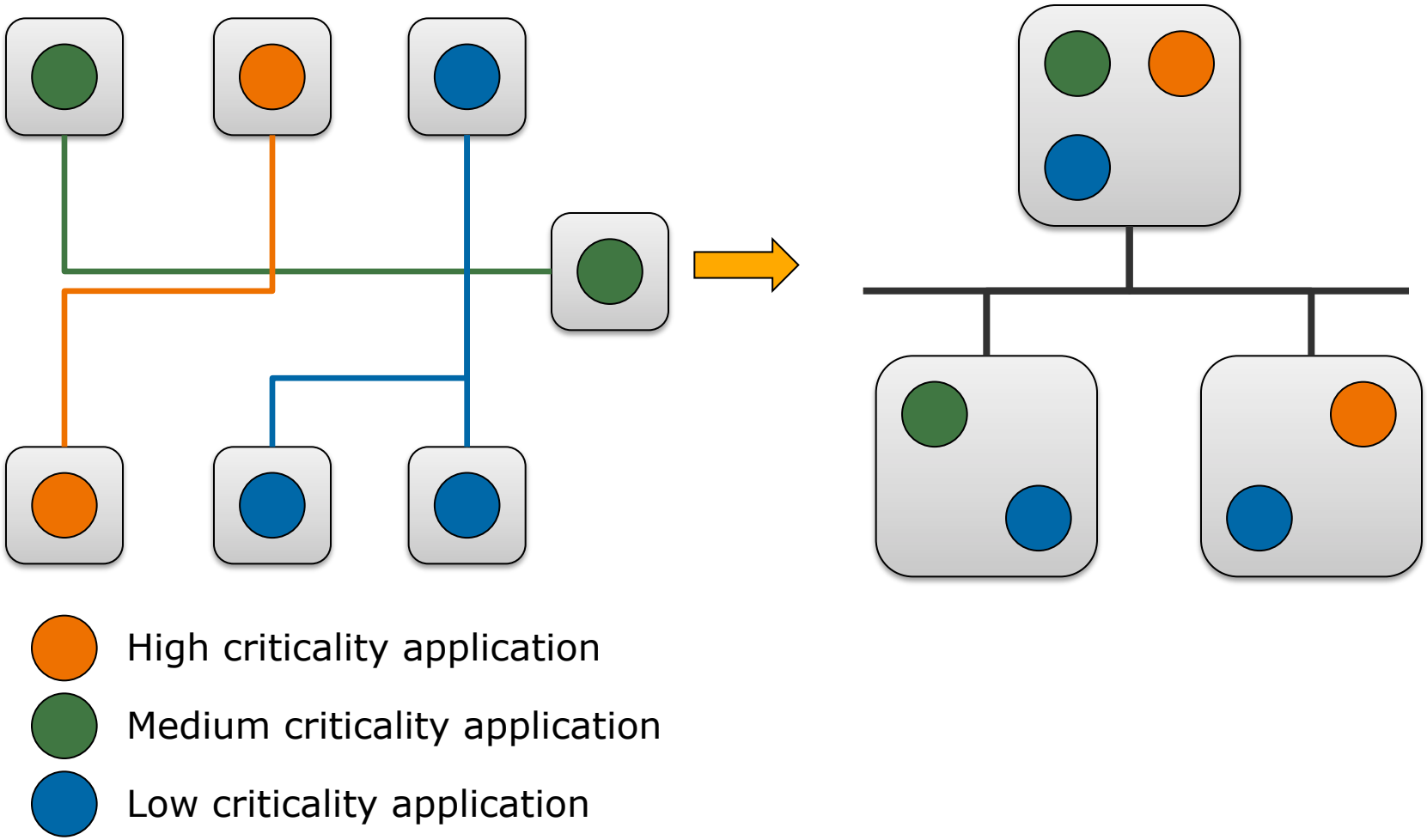
Evaluation


Transmittance comparison.
MIDAC acquires 1024 scans, 4096 points per scan
CIRIS acquires 480 scans, 8192 points per scan
Sensor Raytheon; 800um;sr570 current to voltage gain=20ua/volt
Transmittance
Wavenumber [cm−1]
MIDAC M4500 FTIR
CIRIS average of positions 1, 2 and 3
100
90
80
70
60
50
40
30
20
10
0
2400
2200
2000
1800
1600
1400
1200
1000
800

Partitioned Architectures

Federated architecture

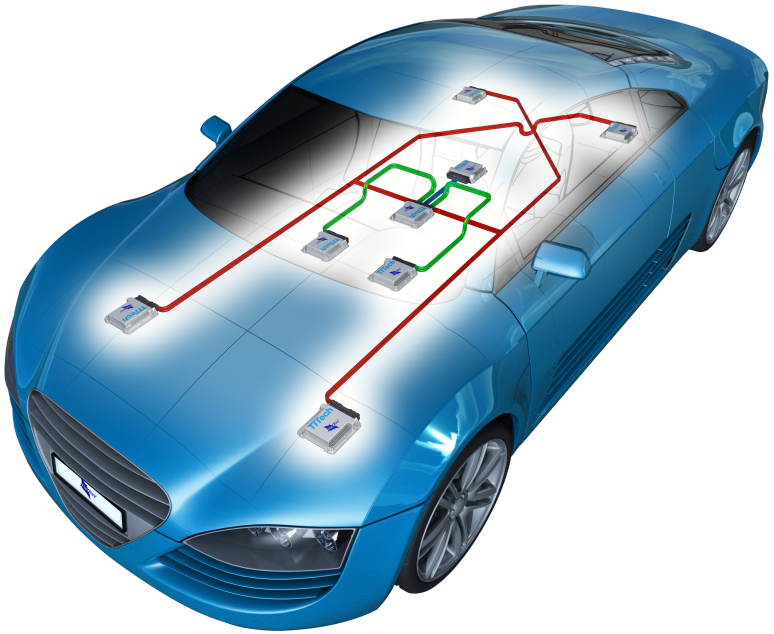
Integrated architecture



Partitioned Architectures

Federated architecture

Integrated architecture



High criticality application

Medium criticality application

Low criticality application

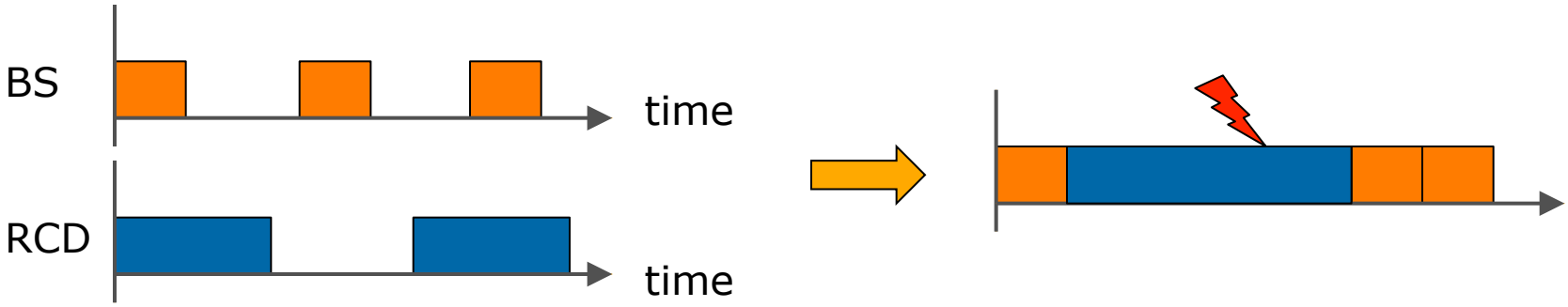
Breaking System

Radio CD

Partitioned Architectures

Federated architecture

Integrated architecture



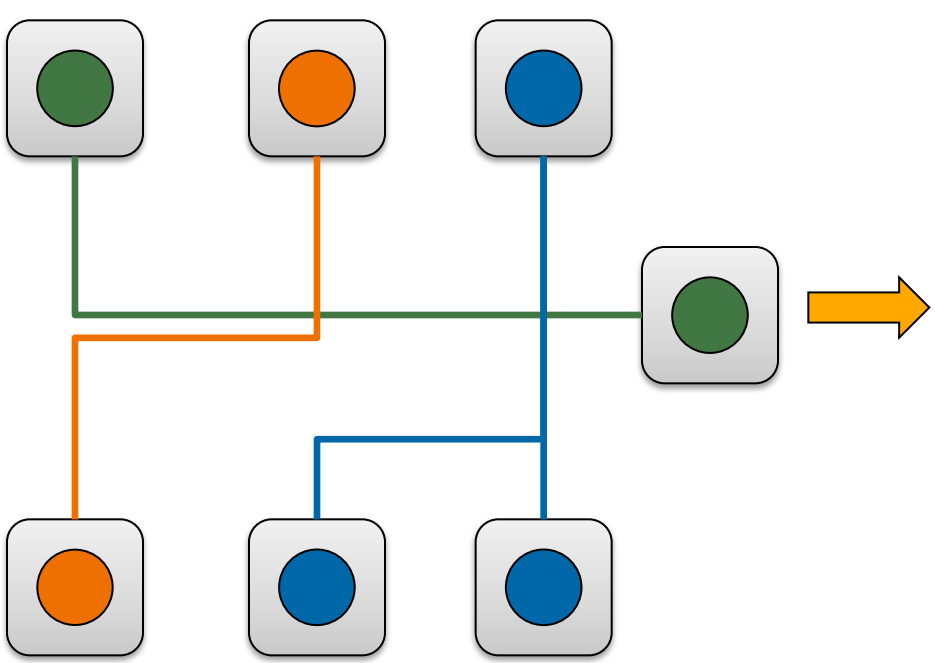
High criticality application — Breaking System

Medium criticality application

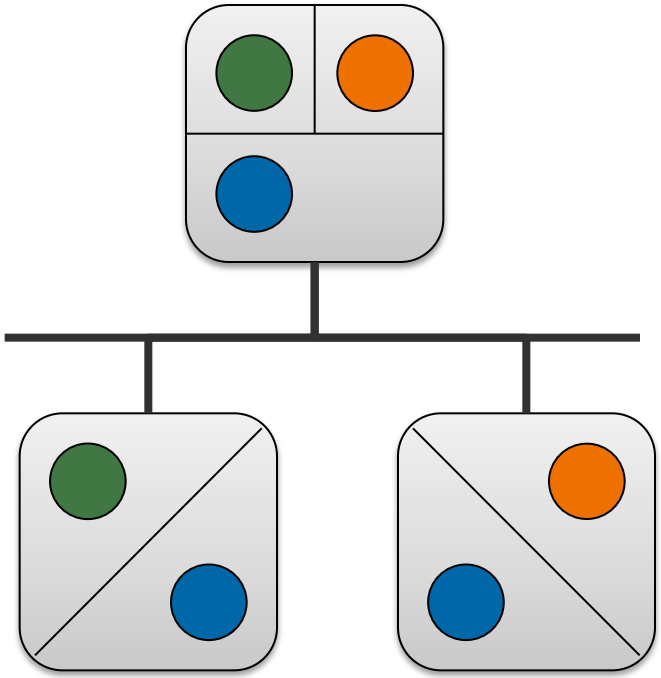
Low criticality application — Radio CD

Partitioned Architectures

Federated architecture



Integrated architecture



High criticality application

Medium criticality application

Low criticality application

Partitioned architecture

Partitioned Architectures

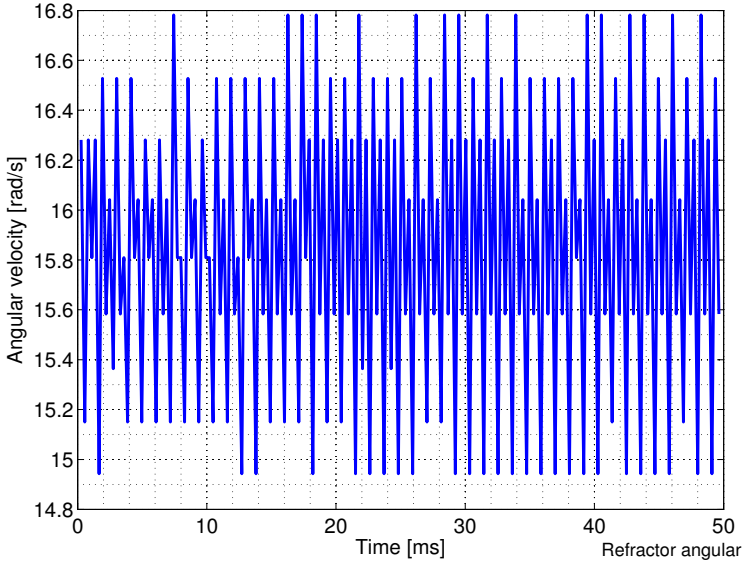
- Each application is running in its own partition
- Partitioning mechanism
  - Temporal partitioning
    - Partitions the CPU time among applications
  - Spatial partitioning
    - Protects one application's memory and access to resources from another application
  - OS enforced, with hardware support

Partitioned Architectures

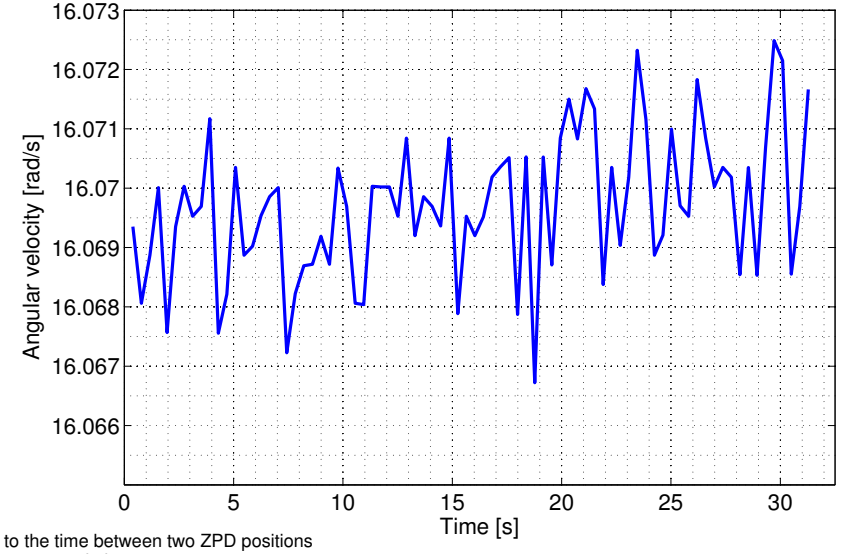
- Benefits:
  - Allows the safe and secure integration of applications of different criticality levels and from different stakeholders
  - Provides a robust fault containment
  - Reduces the development, verification and integration efforts and associated costs
  - Proven in use in the avionics and automotive industries
- ESA views PAs as an intermediate step to introducing multi-core processors in spacecraft computers (Windsor et al., 2011)

Need for Partitioned Architecture: MCU

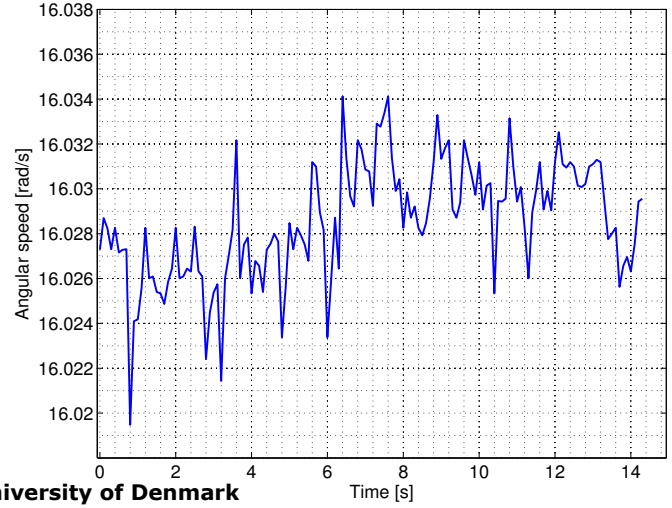
Refractor angular velocity, relative to the duration of a logic state
Measured over 45 ChA ChB cycles
FAULHABER E2–360I optical incremental encoder; 360 cycles per revolution



Refractor angular velocity, relative to the duration of a revolution
Measured over 80 revolutions
FAULHABER E2–360I optical incremental encoder; 360 cycles per revolution



Refractor angular velocity, relative to the time between two ZPD positions
Measured over 36 revolutions
FAULHABER E2–360I optical incremental encoder; 360 cycles per revolution



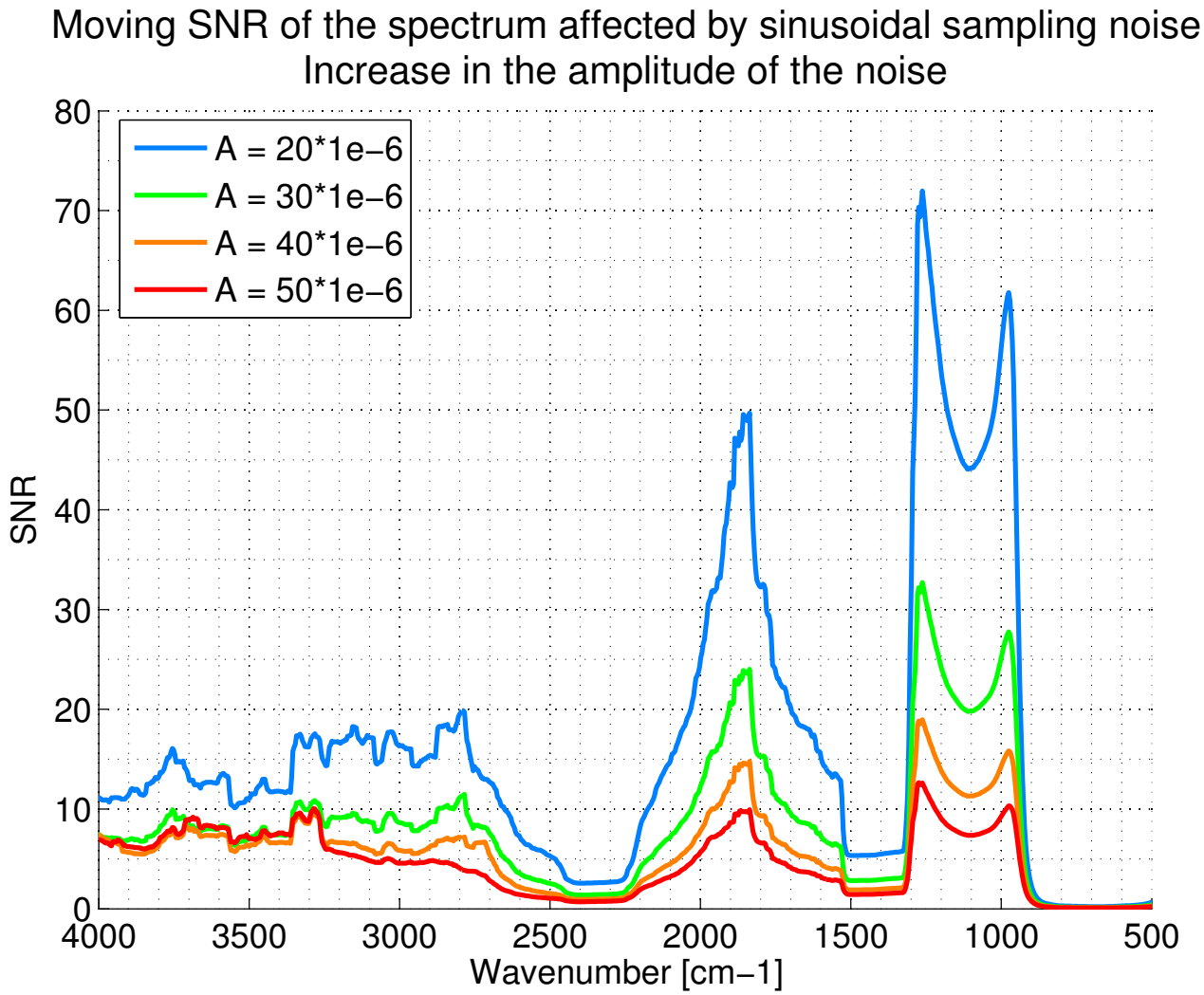
Rotating refractor velocity mean and standard deviation

Frequency [Hz]	Mean velocity [rad/s]	Standard deviation [rad/s]
3600	15.834	0.606000
10	16.028	0.003611
2.5	16.069	0.001211

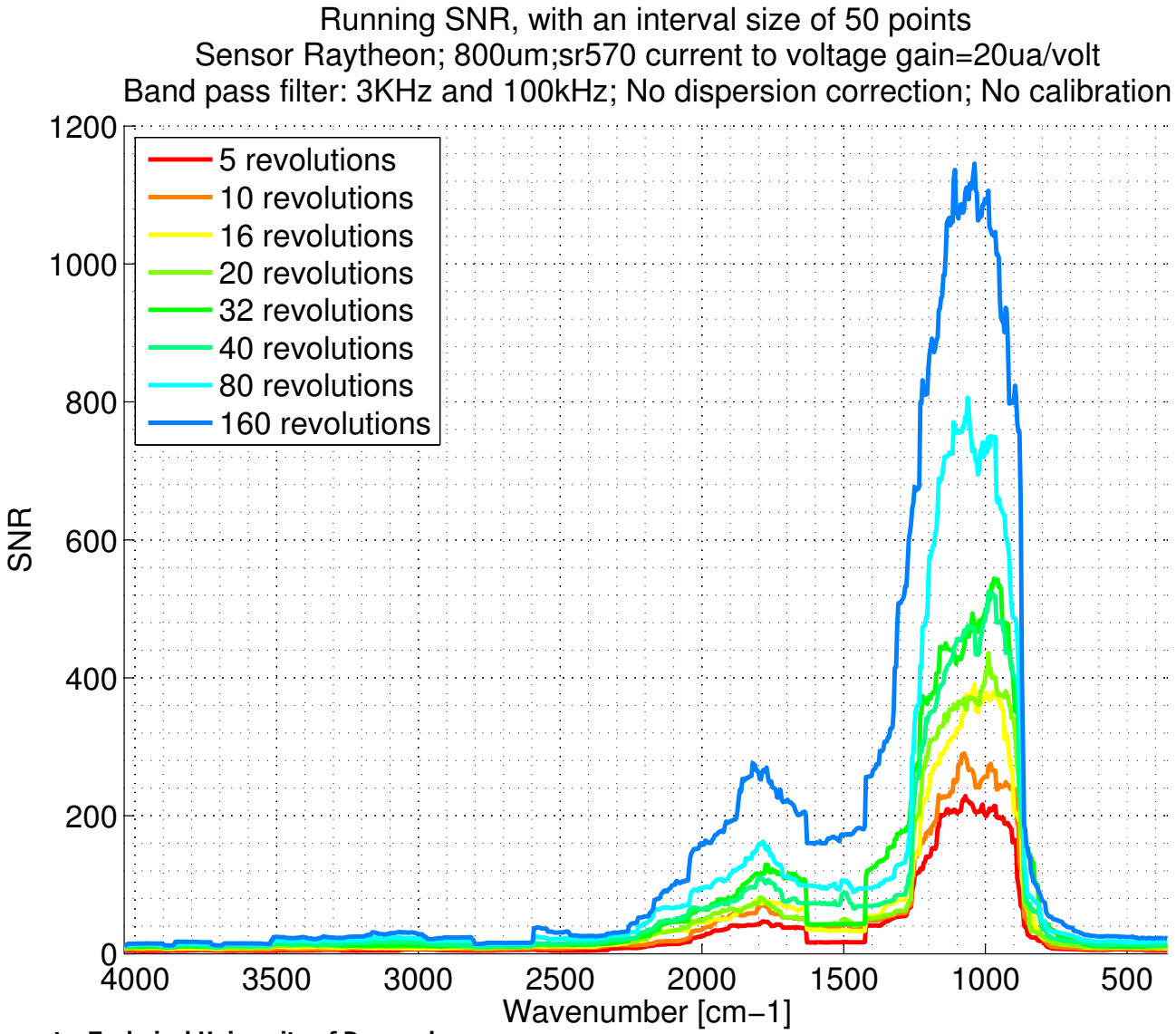
Logic state numbers of the ZPD positions

ZPD position	Mean value of ChA ChB logic state number	Standard deviation
1	233	0
2	595	0
3	956	0
4	1315	0

Velocity Control Affected by Sinusoidal Noise



Impact of the Number of Spectral Scans

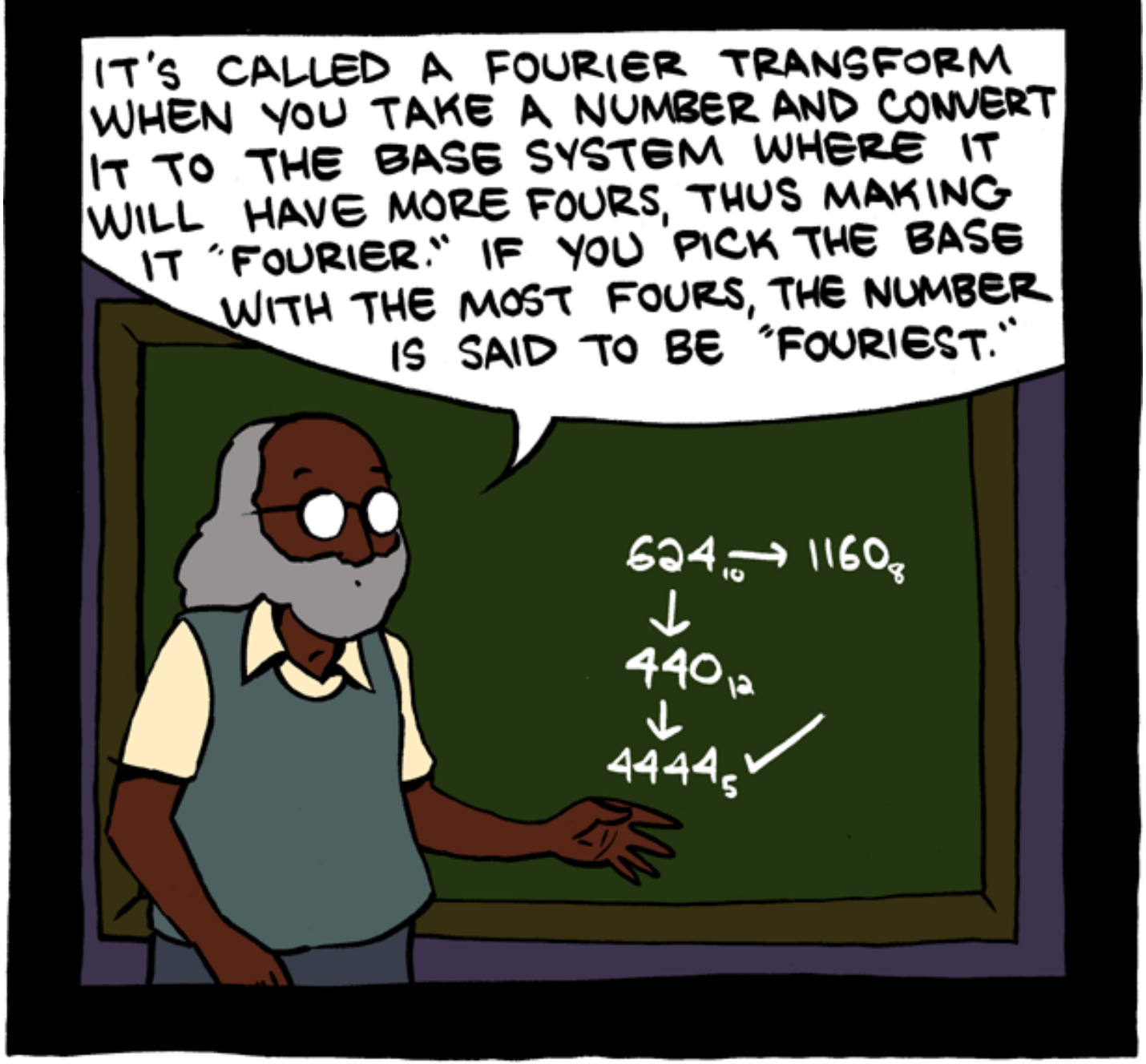


Conclusions

- Partitioned architectures allow the safe integration of applications of different criticality levels and from different stakeholders on the same platform

- We developed a controller for a rugged rotary FTIR spectrometer on a FPGA and real-time processor

- We evaluated the SNR performance impact of implementing the controller on a partitioned architecture.



Teaching math was way more fun after tenure.