On-line arrival time and jitter measurements using electro-optical spectral decoding

Nino Čutić
for test-FEL group

MAX-lab

Outline

1. 3 major parts of the test-FEL

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2. Electro-optical spectral decoding (EOSD)

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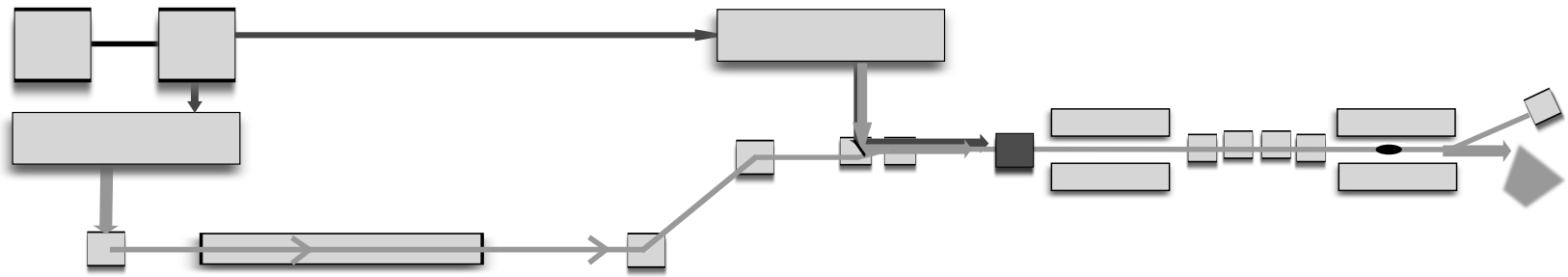
2. Electro-optical spectral decoding (EOSD)
3. Results

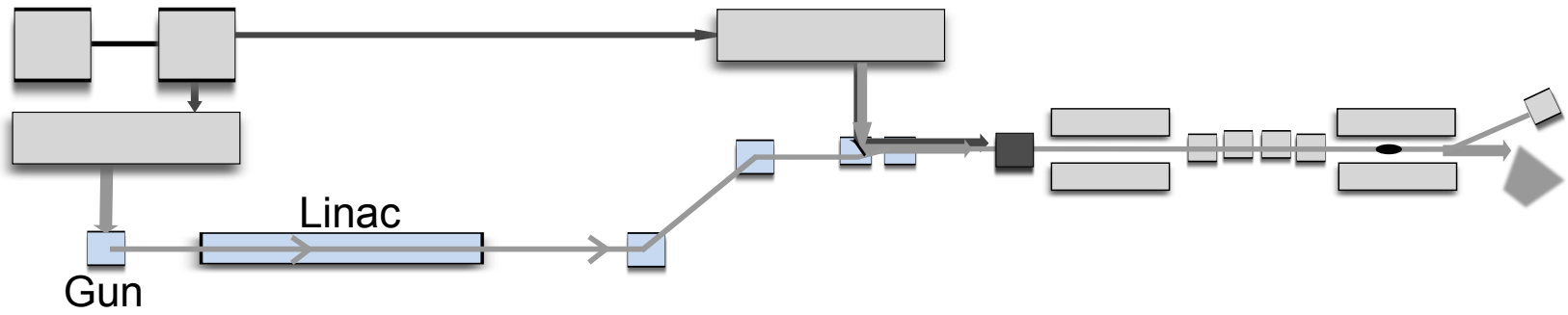
Outline

1. 3 major parts of the test-FEL
2. Electro-optical spectral decoding (EOSD)
3. Results (feedback and 50 Hz lock)

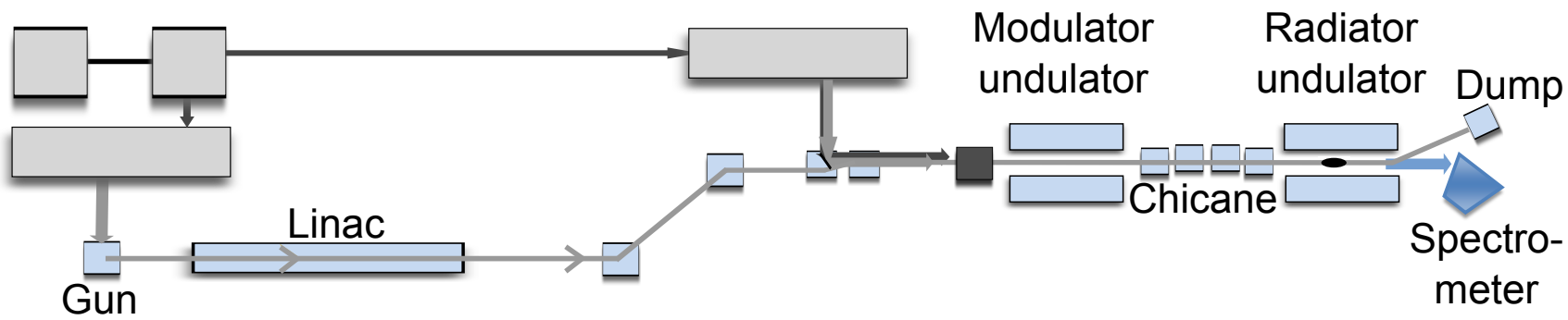
test-FEL



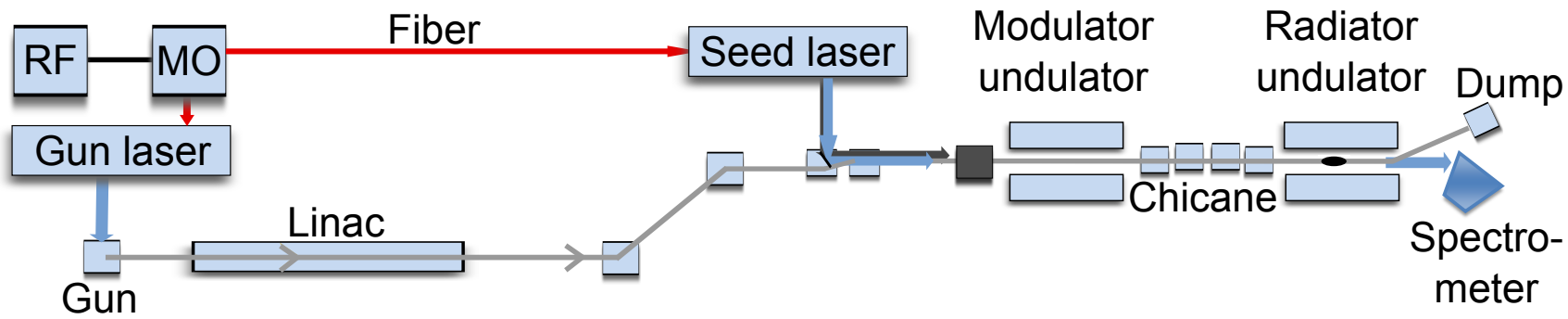
test-FEL



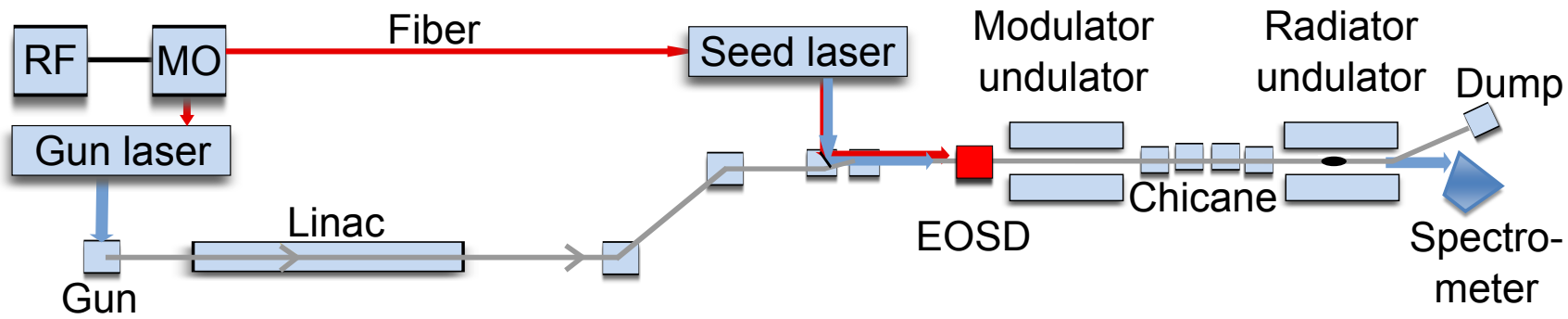
test-FEL


Modulator
undulator
Radiator
undulator
Dump
Chicane
Linac
Spectro-
meter
Gun

test-FEL


RF
MO
Fiber
Seed laser
Modulator undulator
Radiator undulator
Dump
Gun laser
Linac
Chicane
Gun
Spectro-meter

test-FEL


RF
MO
Fiber
Seed laser
Modulator undulator
Radiator undulator
Dump
Gun laser
Linac
Chicane
EOSD
Spectro-meter
Gun

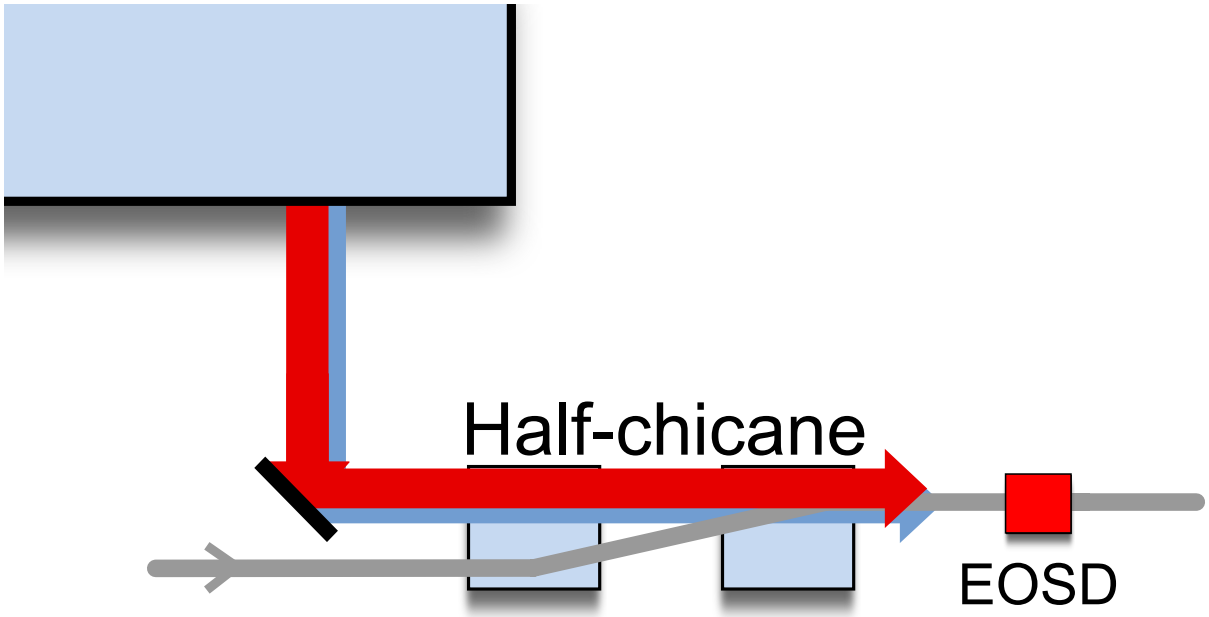
Characteristics

Electron bunch

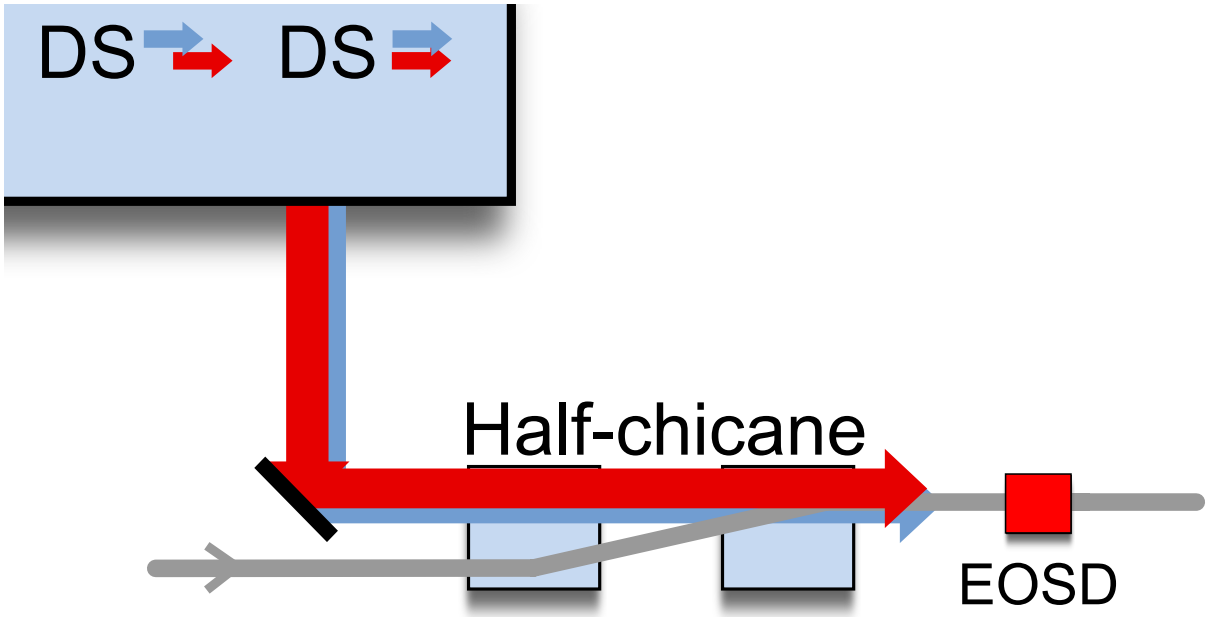
- Charge: 30 pC
- Energy: 380 MeV
- Bunch length: 0.95 - 1.25 ps
- Repetition rate: 2 Hz (safety limit)

Half-chicane
EOSD

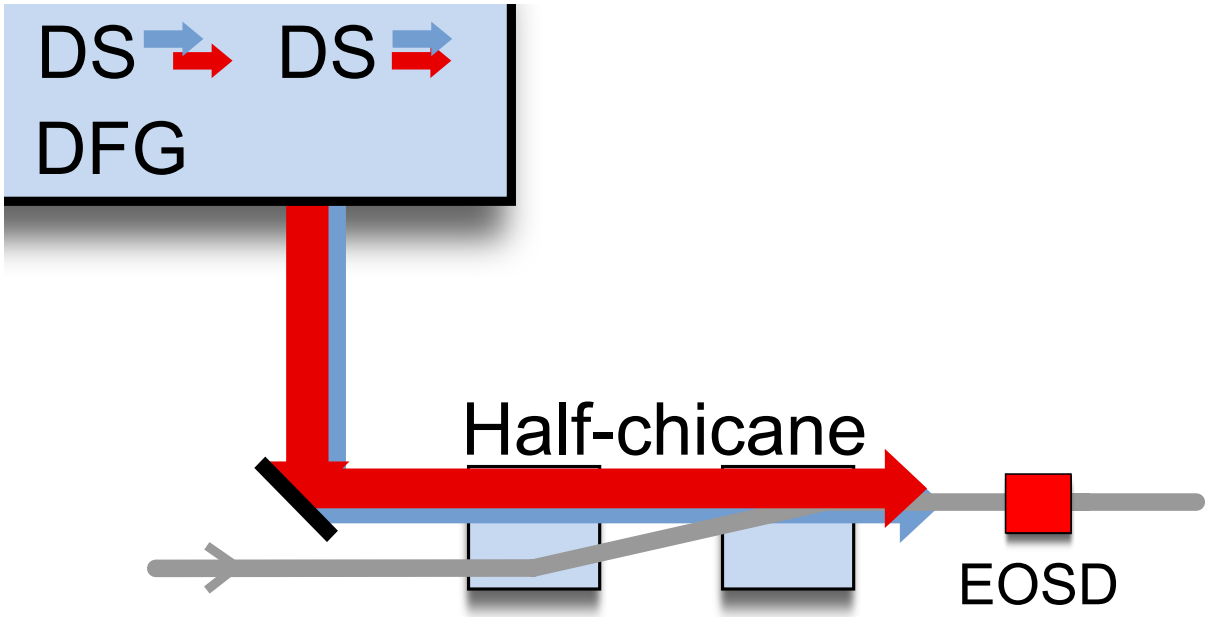
test-FEL /EOSD IR pulse



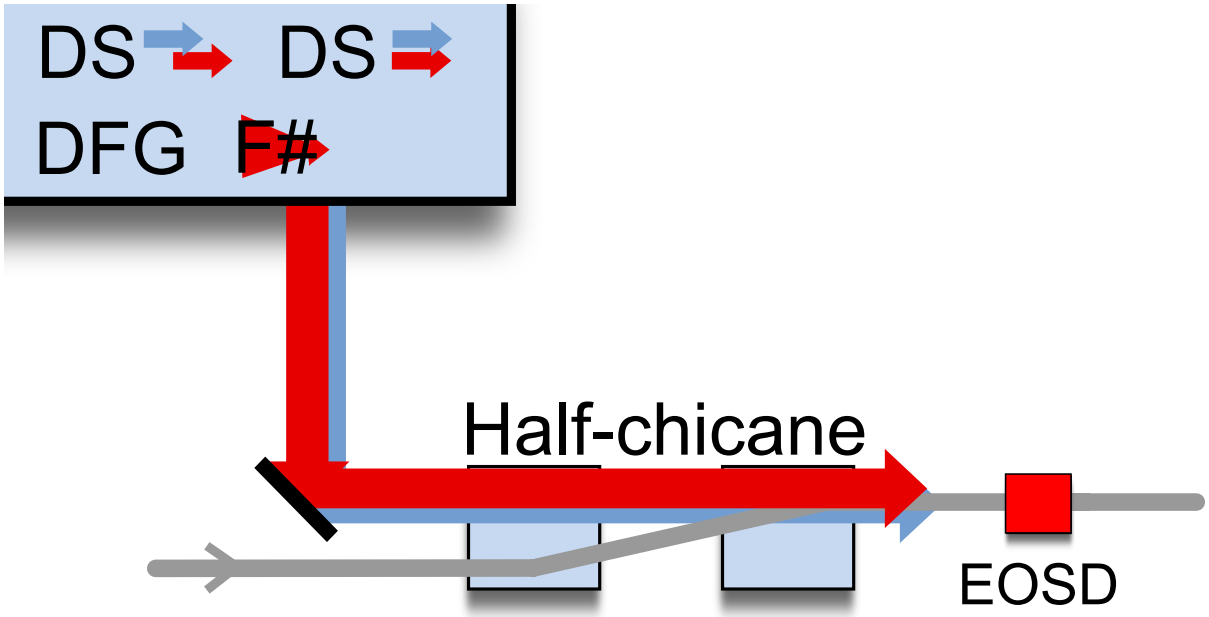
test-FEL /EOSD IR pulse



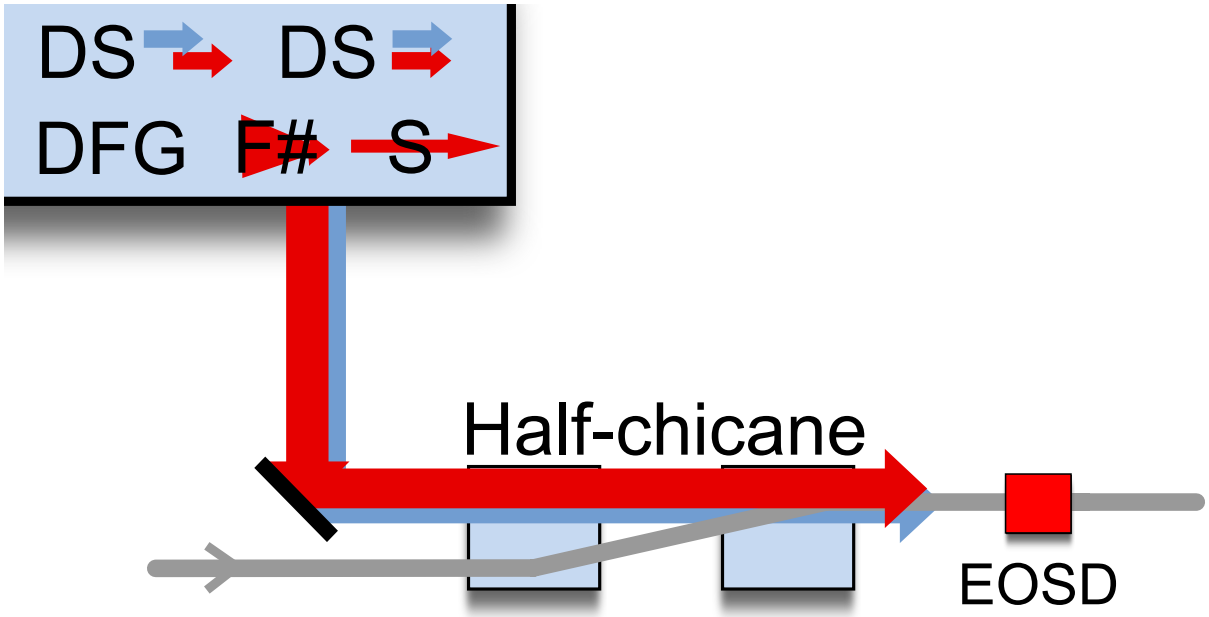
test-FEL /EOSD IR pulse



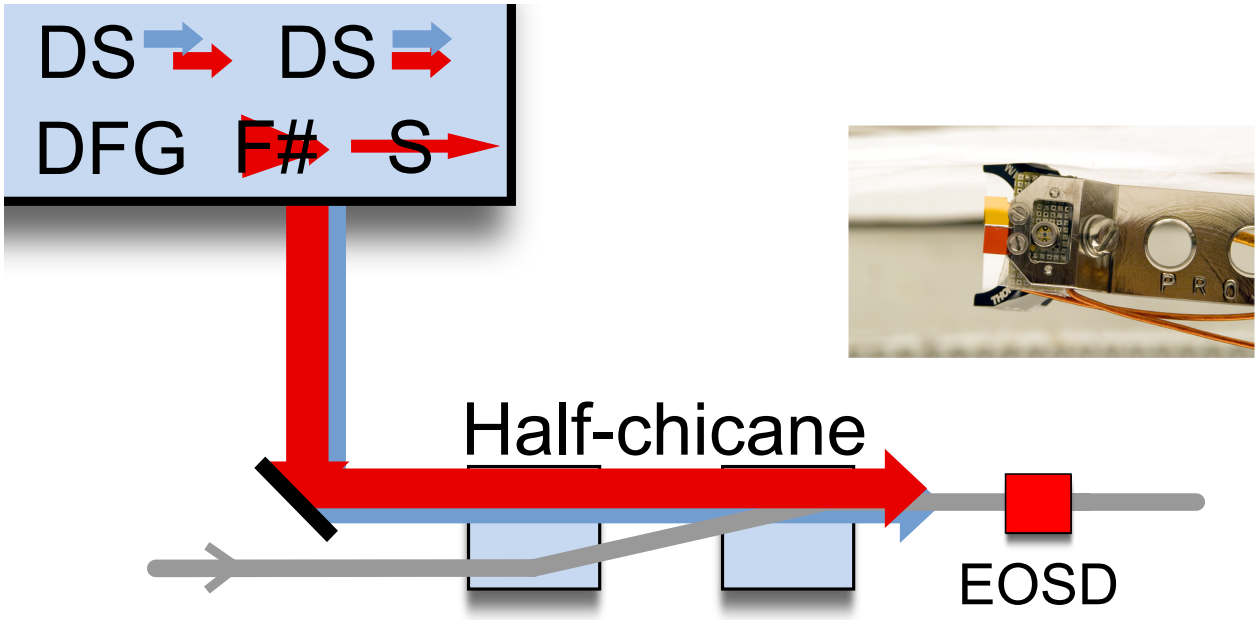
test-FEL /EOSD IR pulse



test-FEL /EOSD IR pulse



test-FEL /EOSD IR pulse



Characteristics

IR pulse

- Central wavelength: 790 nm
- Bandwidth: 5 nm FWHM
- Energy: < 1 μJ
- Chirped length: 3.3 ps FWHM
- Repetition rate: 10 Hz

Characteristics

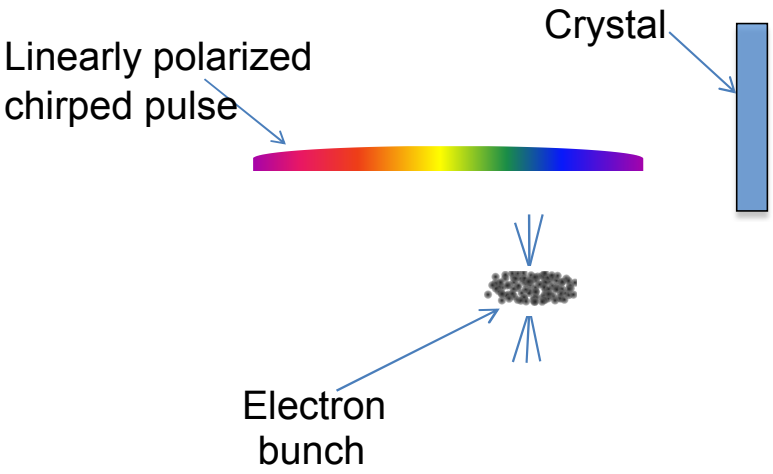
IR pulse

- Central wavelength: 790 nm
- Bandwidth: 5 nm FWHM
- Energy: $< 1\ \mu$J
- Chirped length: 3.3 ps FWHM
- Repetition rate: 10 Hz

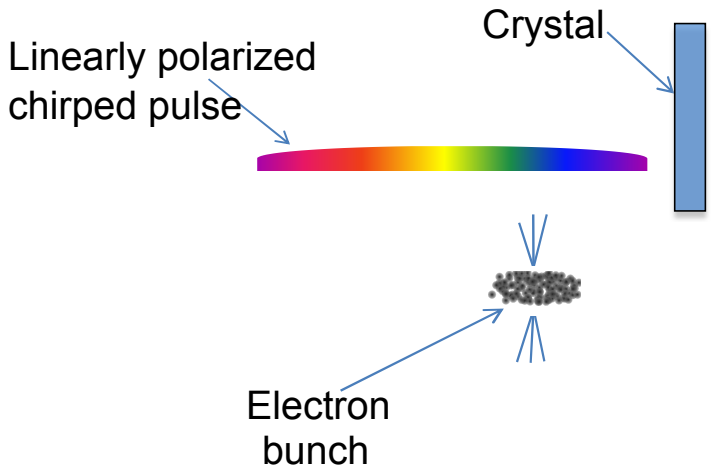
Crystal

- Type: ZnTe
- Cut in: $< 110 >$
- Thickness: 1 mm
- Size: $5 \cdot 5$ mm^2

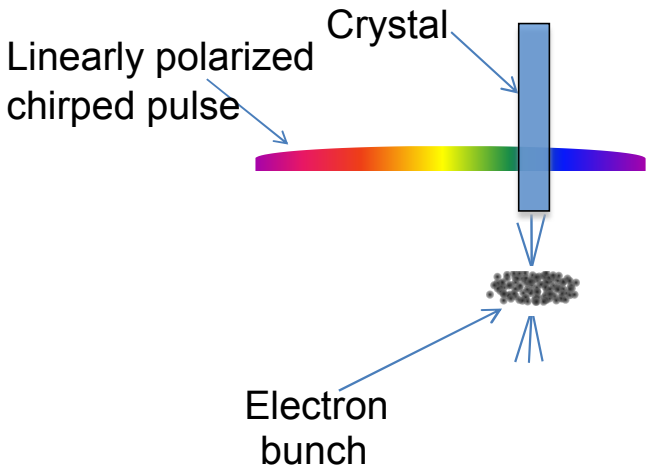
EOSD



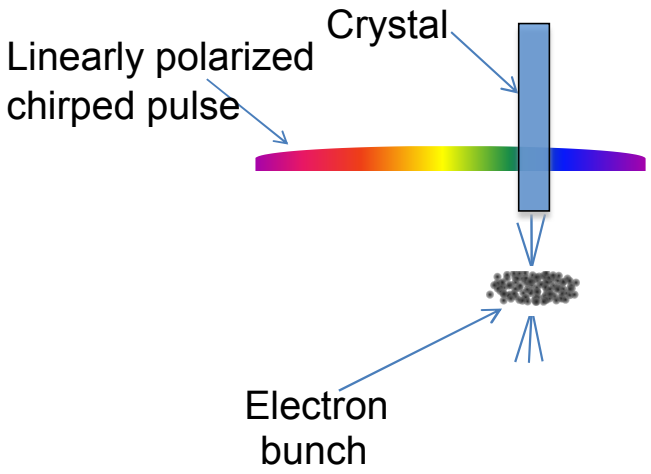
EOSD



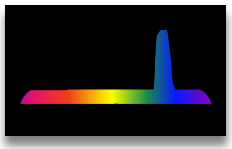
EOSD



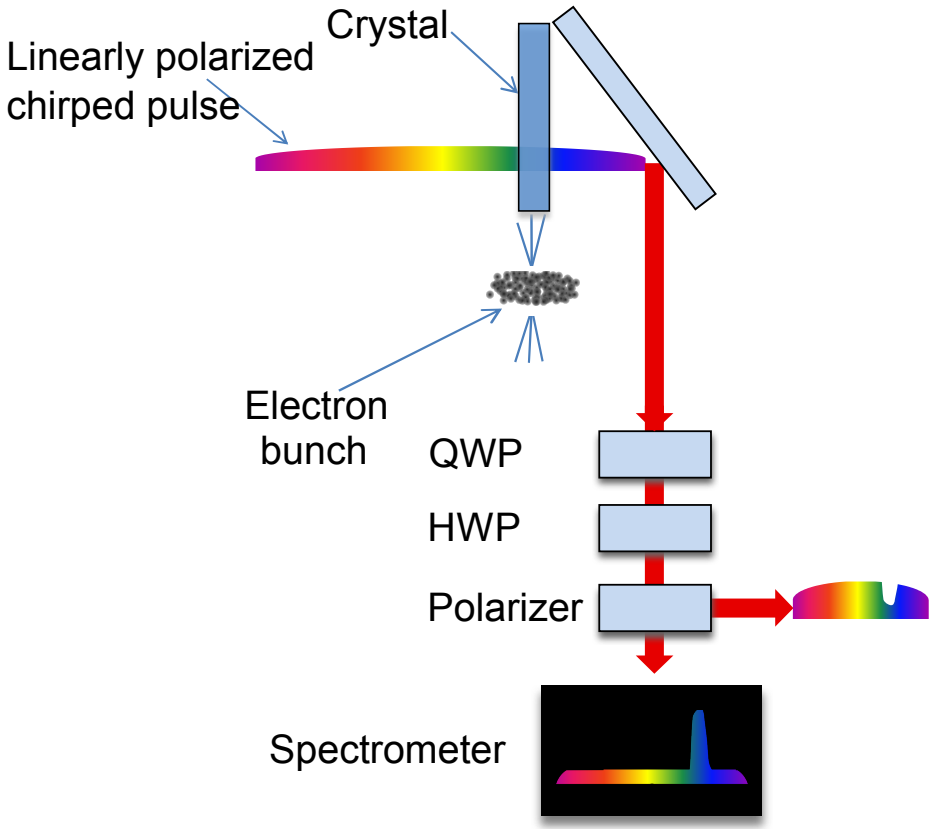
EOSD

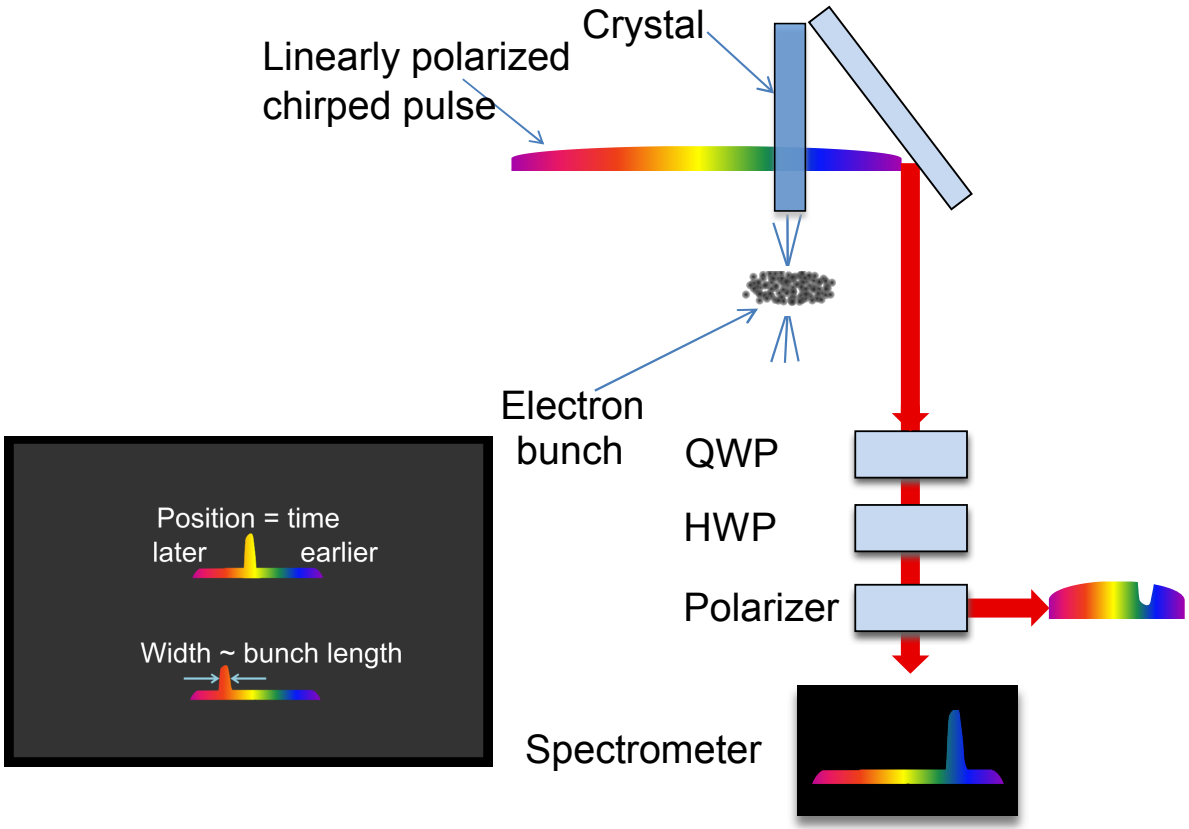


Spectrometer

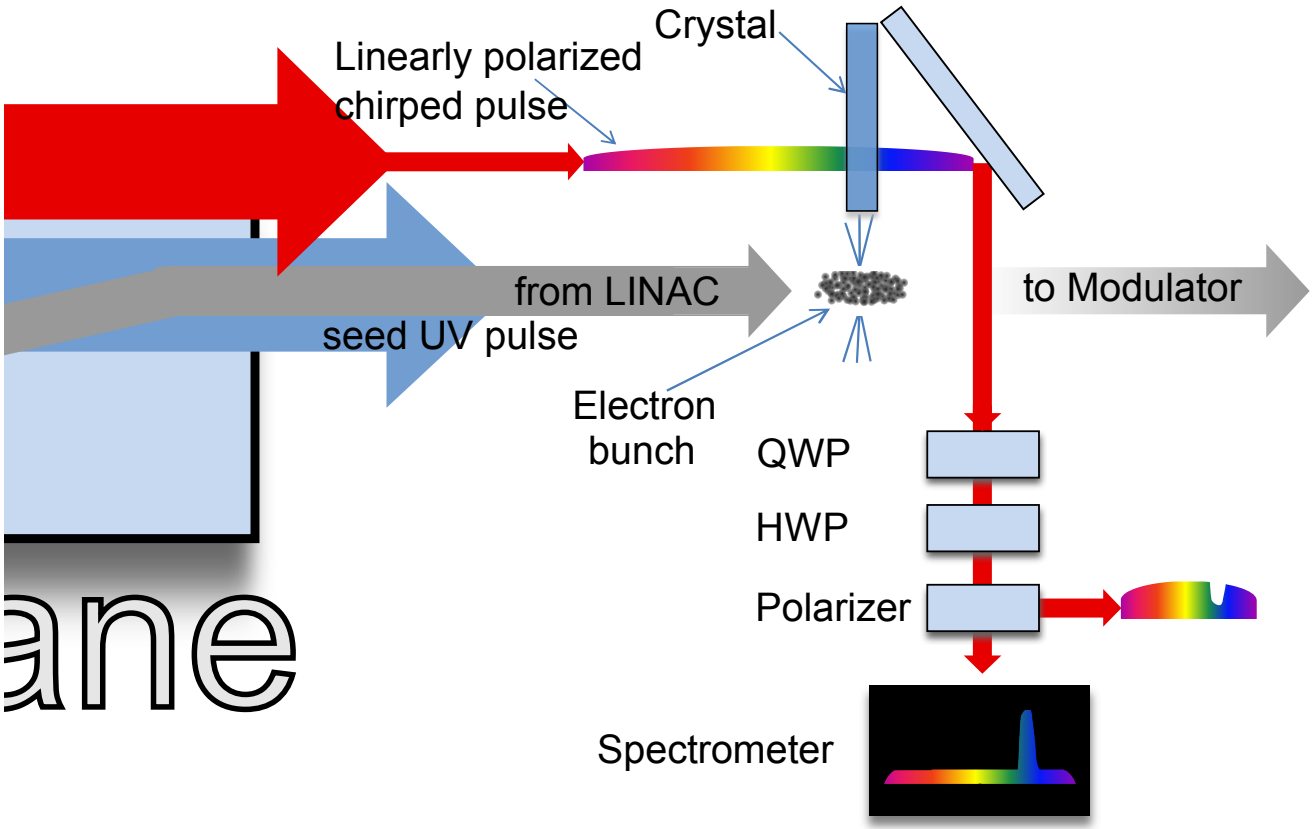


EOSD

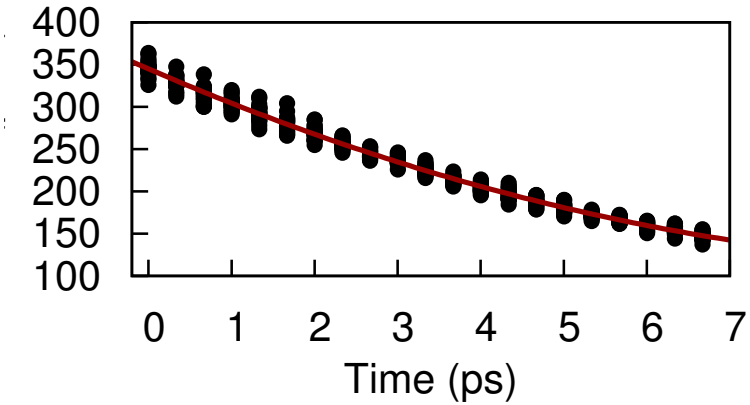

Crystal
Linearly polarized
chirped pulse
Electron
bunch
QWP
HWP
Polarizer
Spectrometer

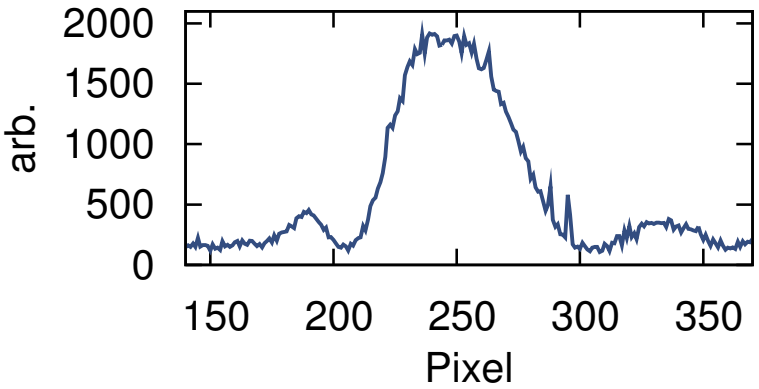

Crystal
Linearly polarized
chirped pulse
Electron
bunch
QWP
HWP
Polarizer
Spectrometer
Position = time
later
earlier
Width ~ bunch length

EOSD

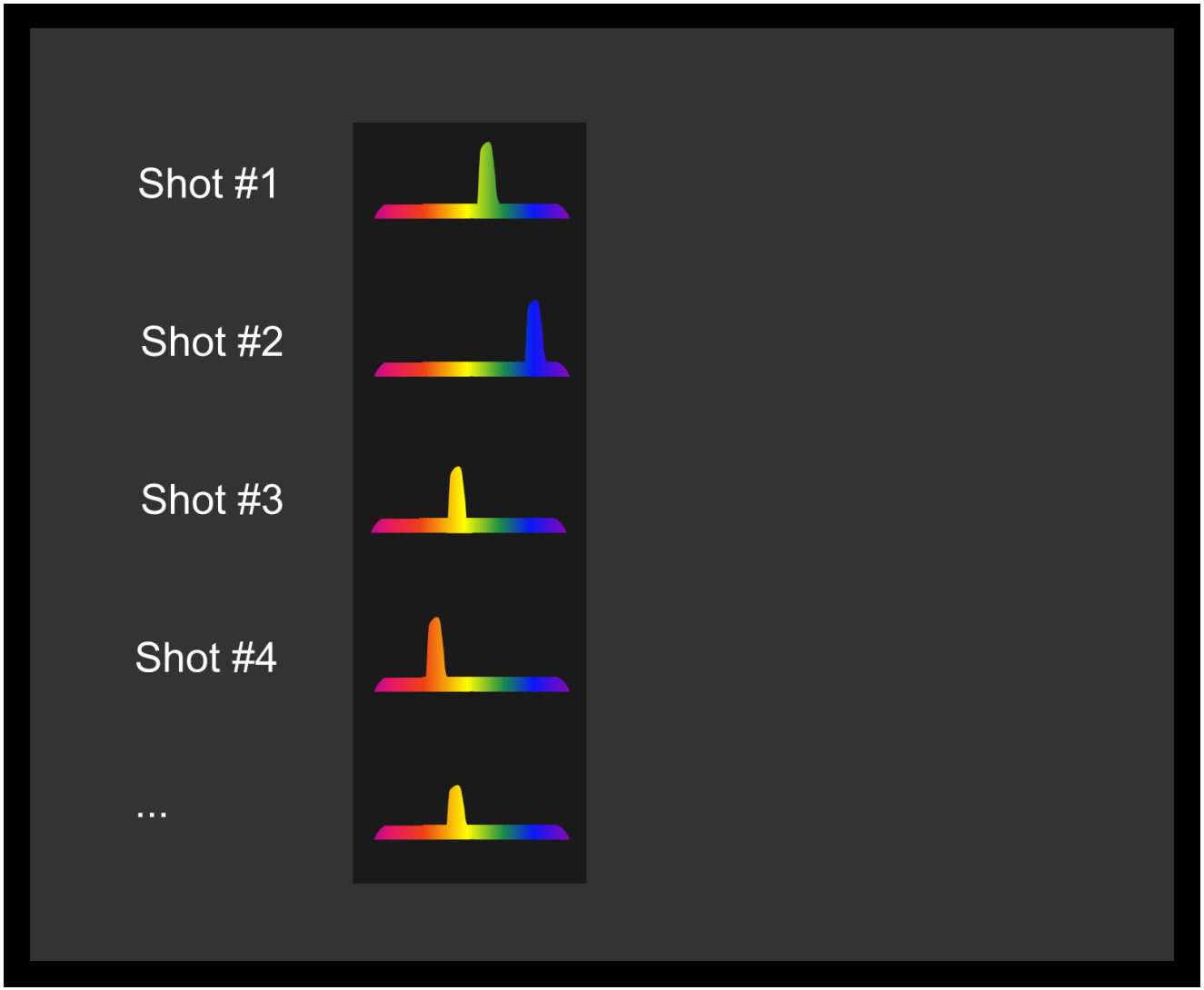

Crystal
Linearly polarized
chirped pulse
from LINAC
seed UV pulse
to Modulator
Electron
bunch
QWP
HWP
Polarizer
Spectrometer

Calibration

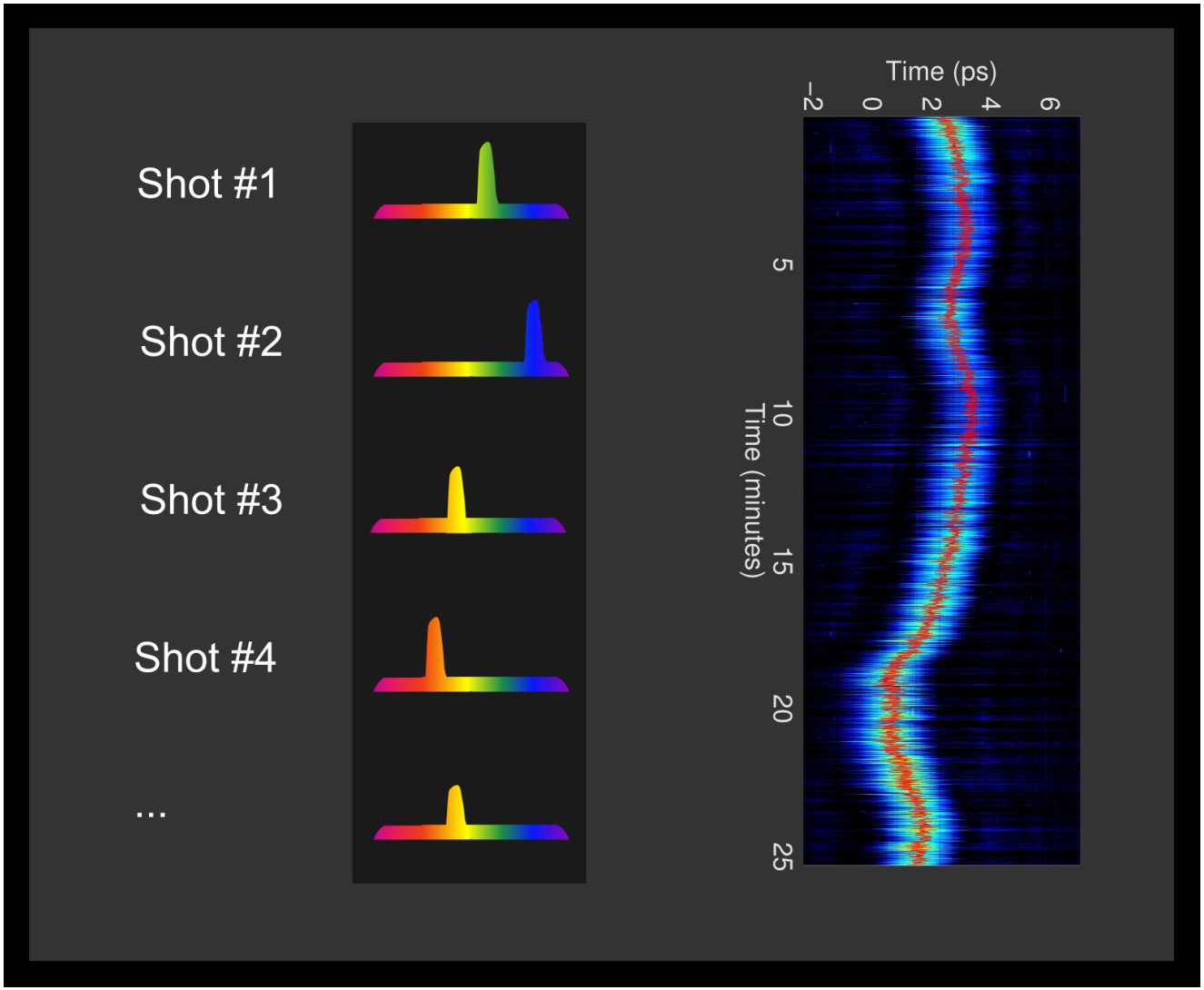




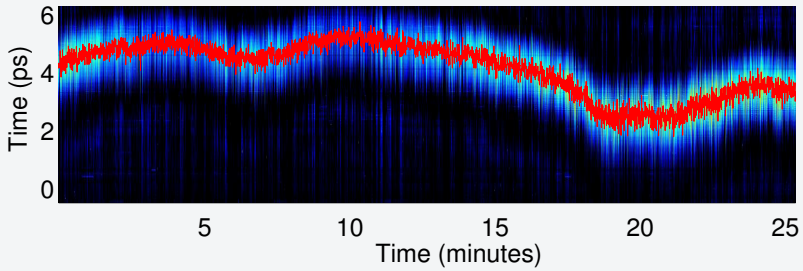
Results



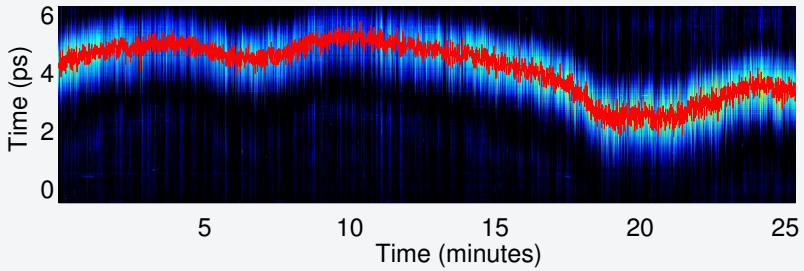
Results

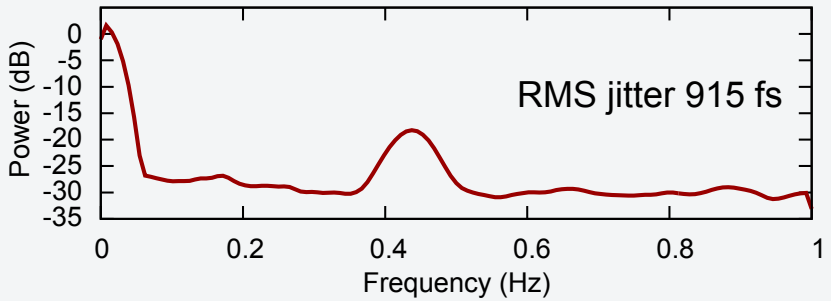

Shot #1
Shot #2
Shot #3
Shot #4
...
Time (ps)
−2
0
2
4
6
Time (minutes)
5
10
15
20
25

Results

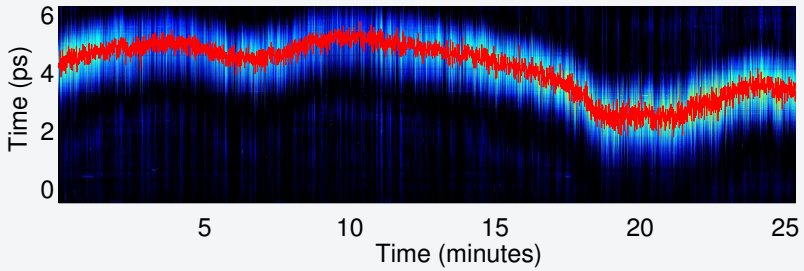


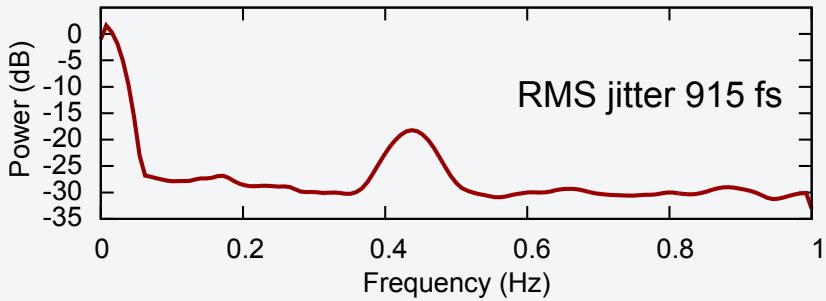
Results

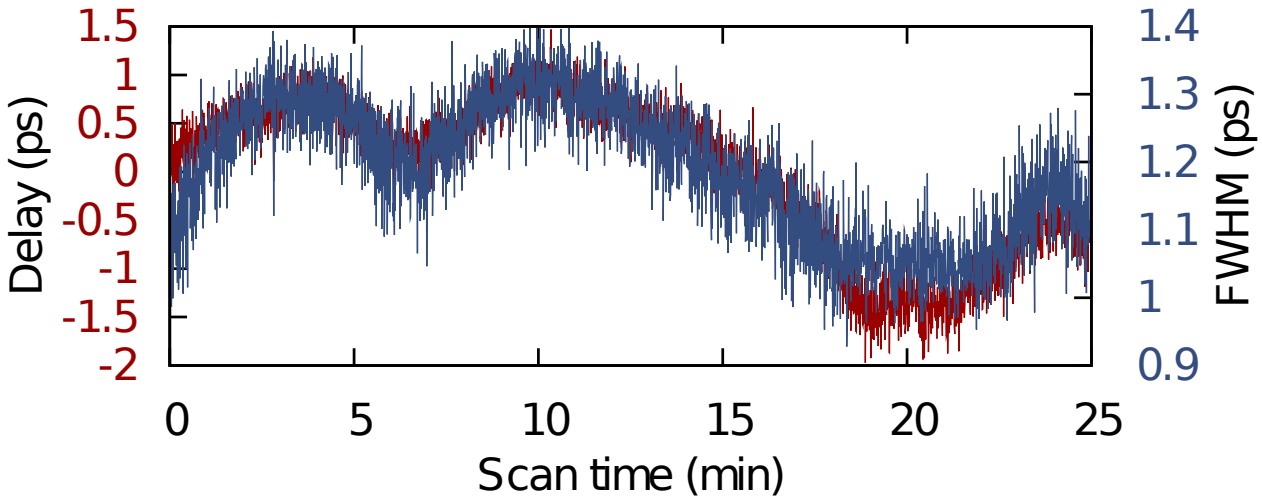

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)


Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

Results


Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)


Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

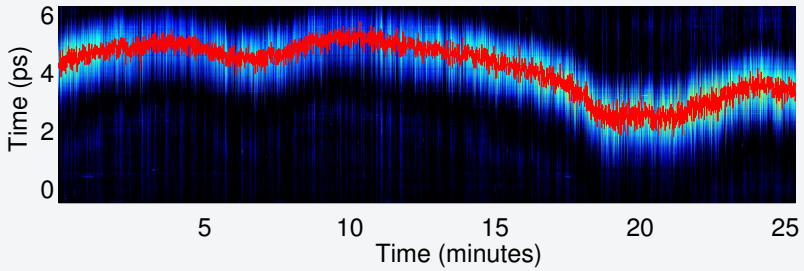

Delay (ps)
1.5
1
0.5
0
-0.5
-1
-1.5
-2
1.4
1.3
1.2
1.1
1
0.9
FWHM (ps)
0
5
10
15
20
25
Scan time (min)

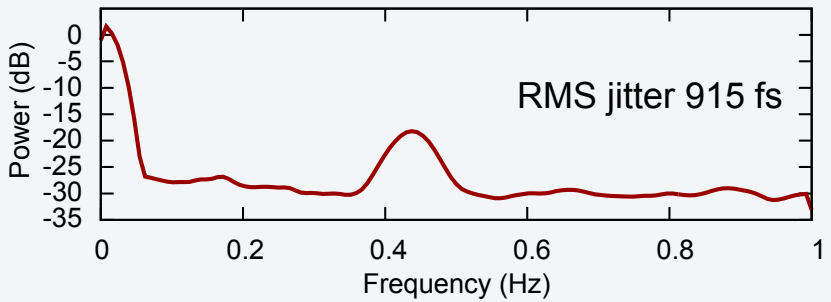
Characteristics

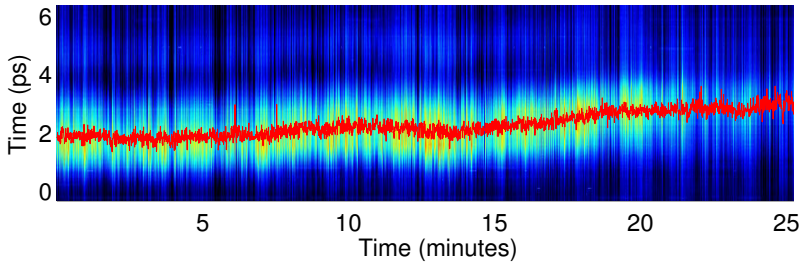
50 Hz lock

- Microcontroller
- 50 Hz $\rightarrow$ 10 Hz
- Triggers masterclock (which triggers lasers and klystrons)

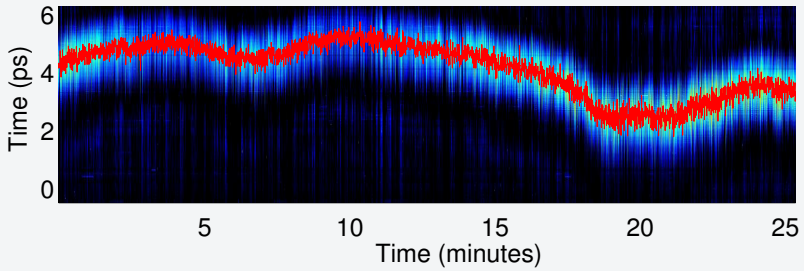
Results

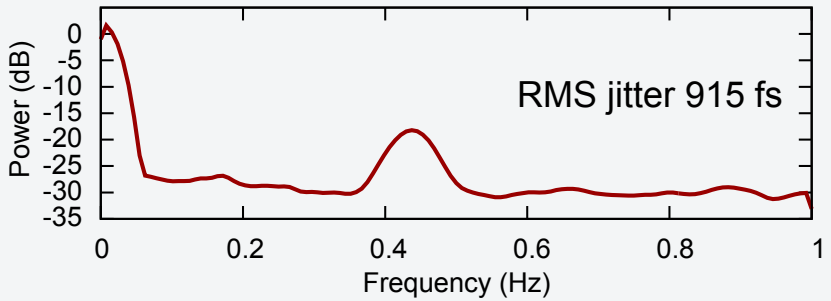

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

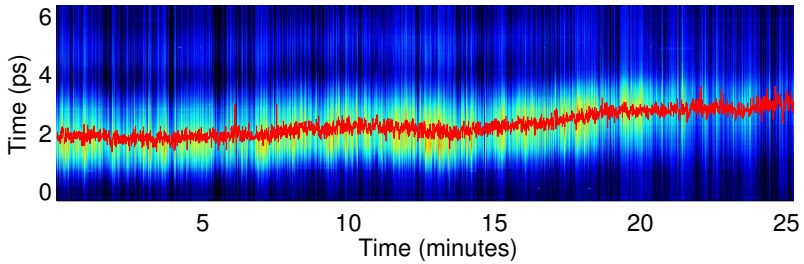

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

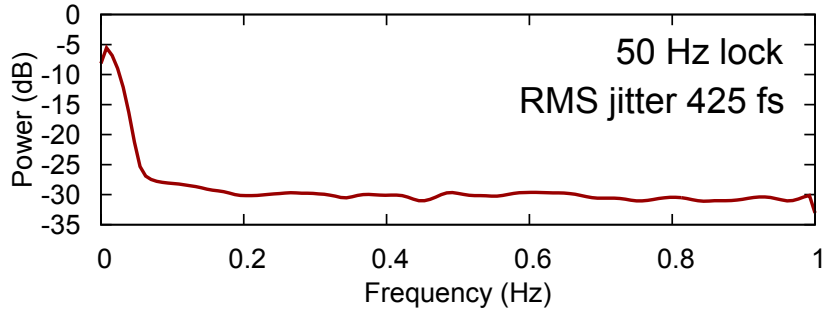

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

Results


Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)


Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)


Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

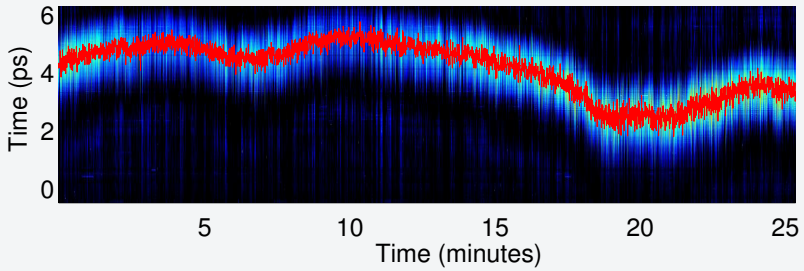

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
50 Hz lock
RMS jitter 425 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

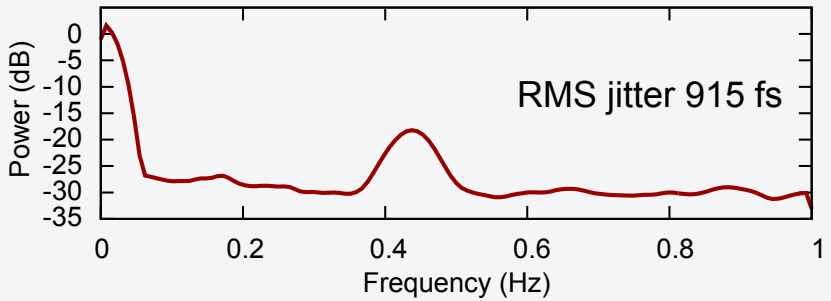
Characteristics

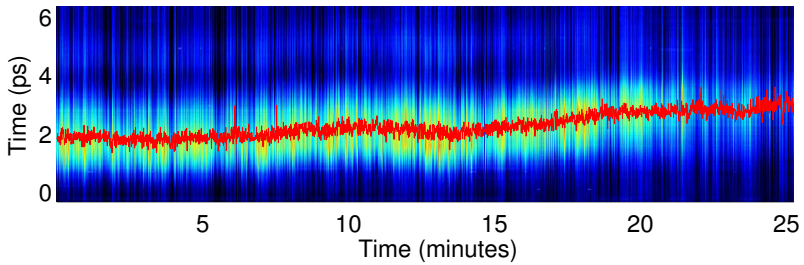
Feedback

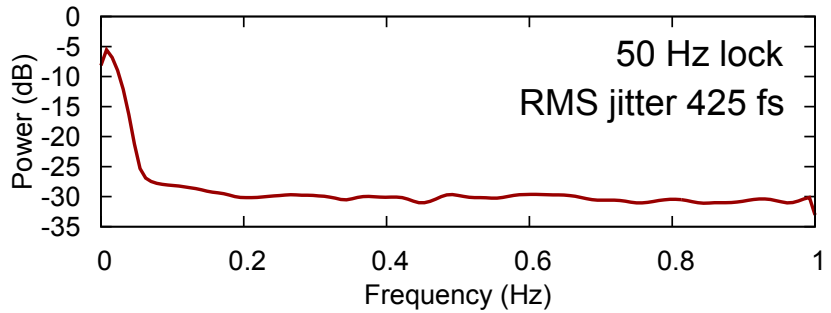
- Image processing, Median-averaging
- PI controller (Ziegler-Nichols method)
- Delay stage: mechanical Thorlabs 150 mm

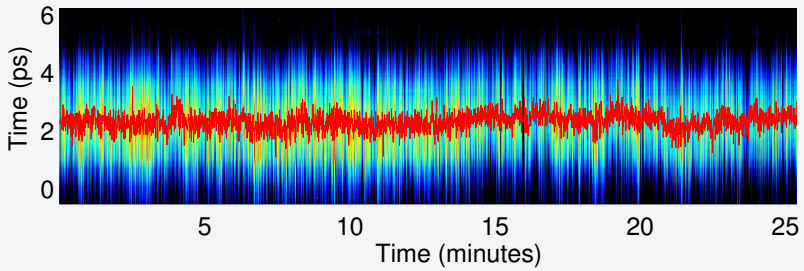
Results


Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

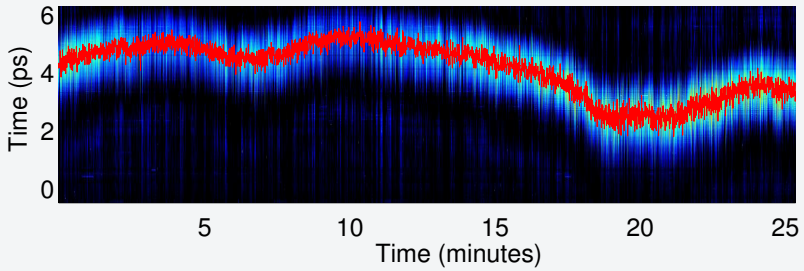

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

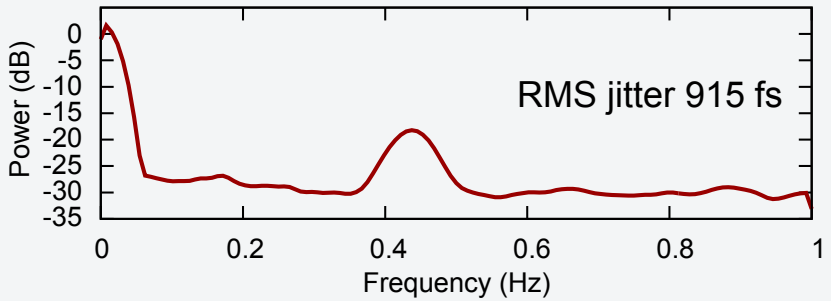

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

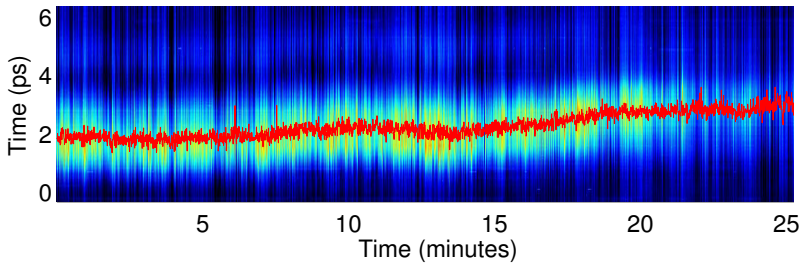

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
50 Hz lock
RMS jitter 425 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

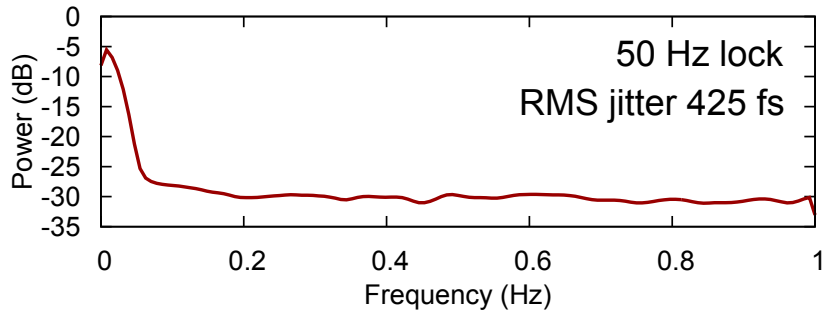

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

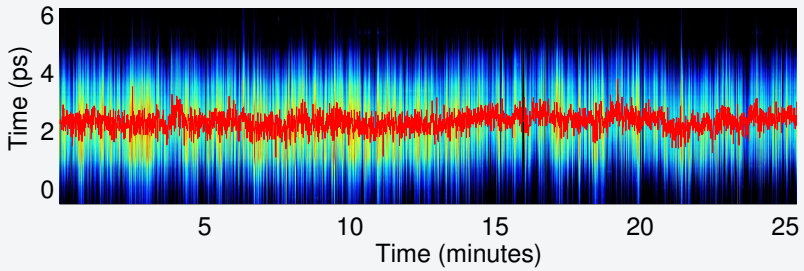
Results

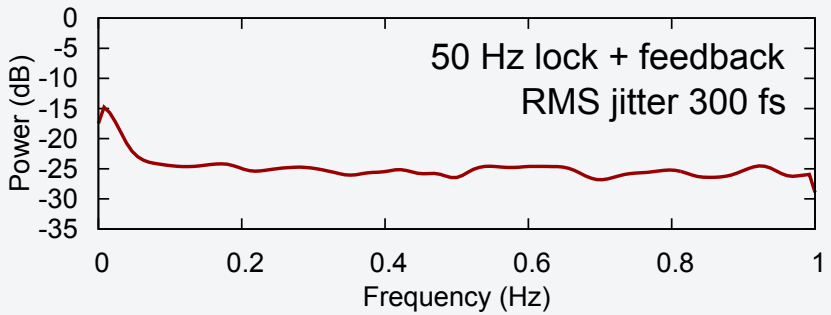

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)


Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
RMS jitter 915 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

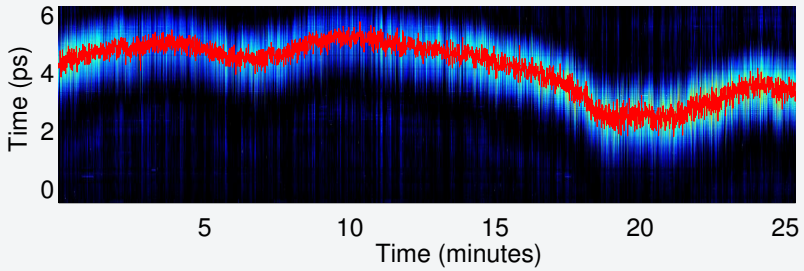

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

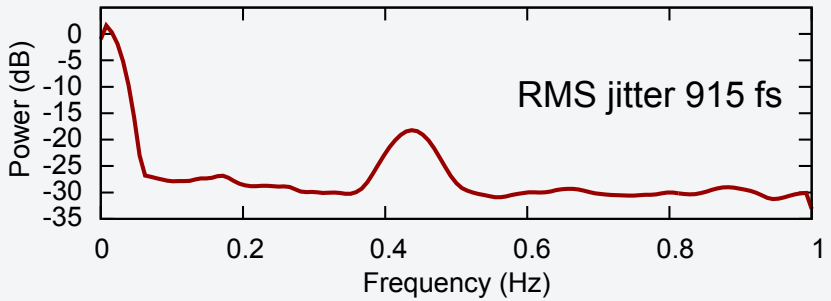

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
50 Hz lock
RMS jitter 425 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

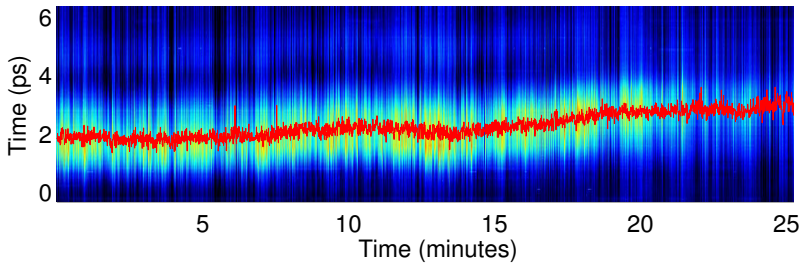

Time (ps)
6
4
2
0
5
10
15
20
25
Time (minutes)

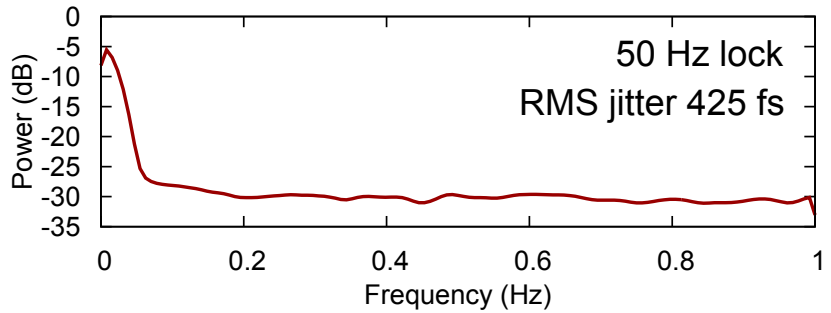

Power (dB)
0
-5
-10
-15
-20
-25
-30
-35
50 Hz lock + feedback
RMS jitter 300 fs
0
0.2
0.4
0.6
0.8
1
Frequency (Hz)

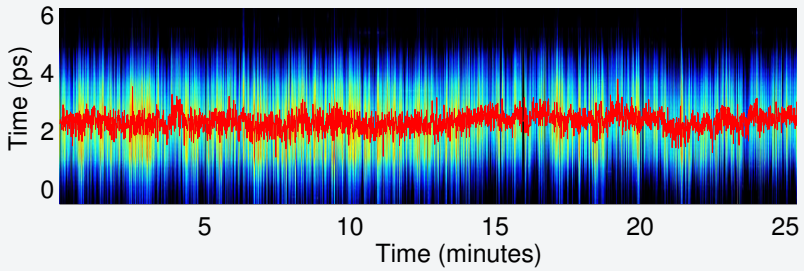
Conclusion

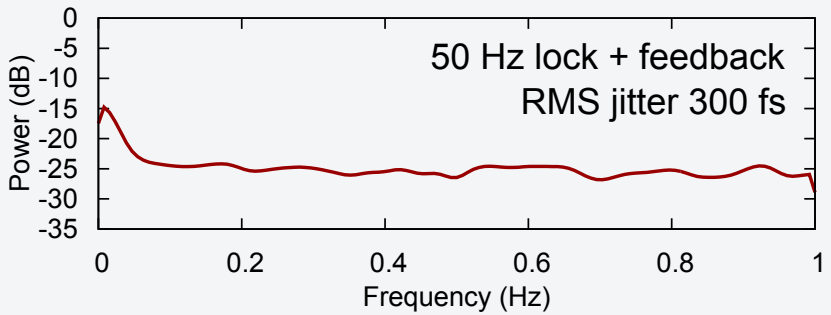

Time (ps)
Time (minutes)


RMS jitter 915 fs
Power (dB)
Frequency (Hz)


Time (ps)
Time (minutes)


50 Hz lock
RMS jitter 425 fs
Power (dB)
Frequency (Hz)


Time (ps)
Time (minutes)


50 Hz lock + feedback
RMS jitter 300 fs
Power (dB)
Frequency (Hz)

Thanks to /References

People that contributed to this work

- Filip Lindau and Sverker Werin
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- Johannes Bahrdt, Karsten Holldack
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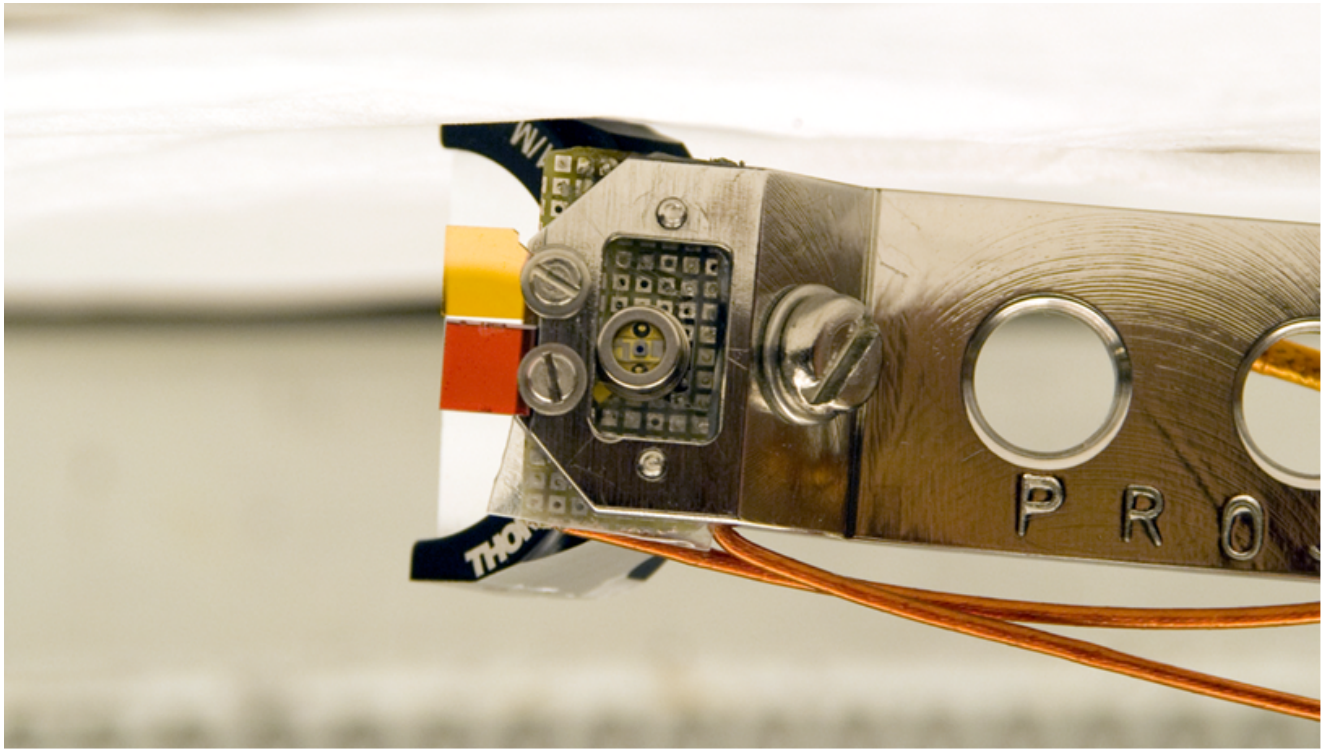
People at the conference with lots of experience in the area

- B. Steffen
- A. Gillespie
- ...

Extra