Drift feedback with femtosecond arrival time stability for the pump probe laser system at the FLASH free electron laser.

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Introduction

At FLASH2 ultrafast processes (< 100 fs) are investigated in pump-probe experiments using FEL XUV pulses together with optical laser pulses. Both light sources need to be extremely well synchronized and long-term stable. To achieve this requirements two main concepts are applied:

- State-of-the-art optical synchronization of FEL and laser oscillator to the same timing source.[1]
- Drift compensation for the laser amplifiers [2], transport and compression.

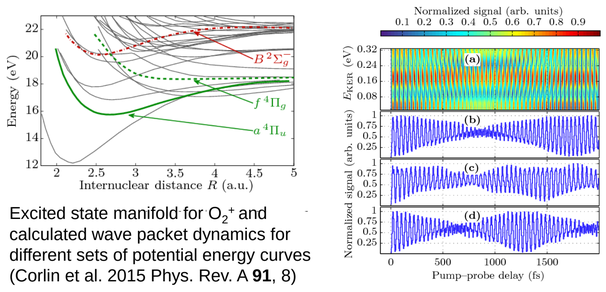
Goal within the FLASH 2020+ upgrade project:

Time resolution 20 fs FWHM in XUV FEL – laser experiment

- Short pulses (few fs)
- High relative arrival time stability for the duration of one measurement (0.5 to 8 h)

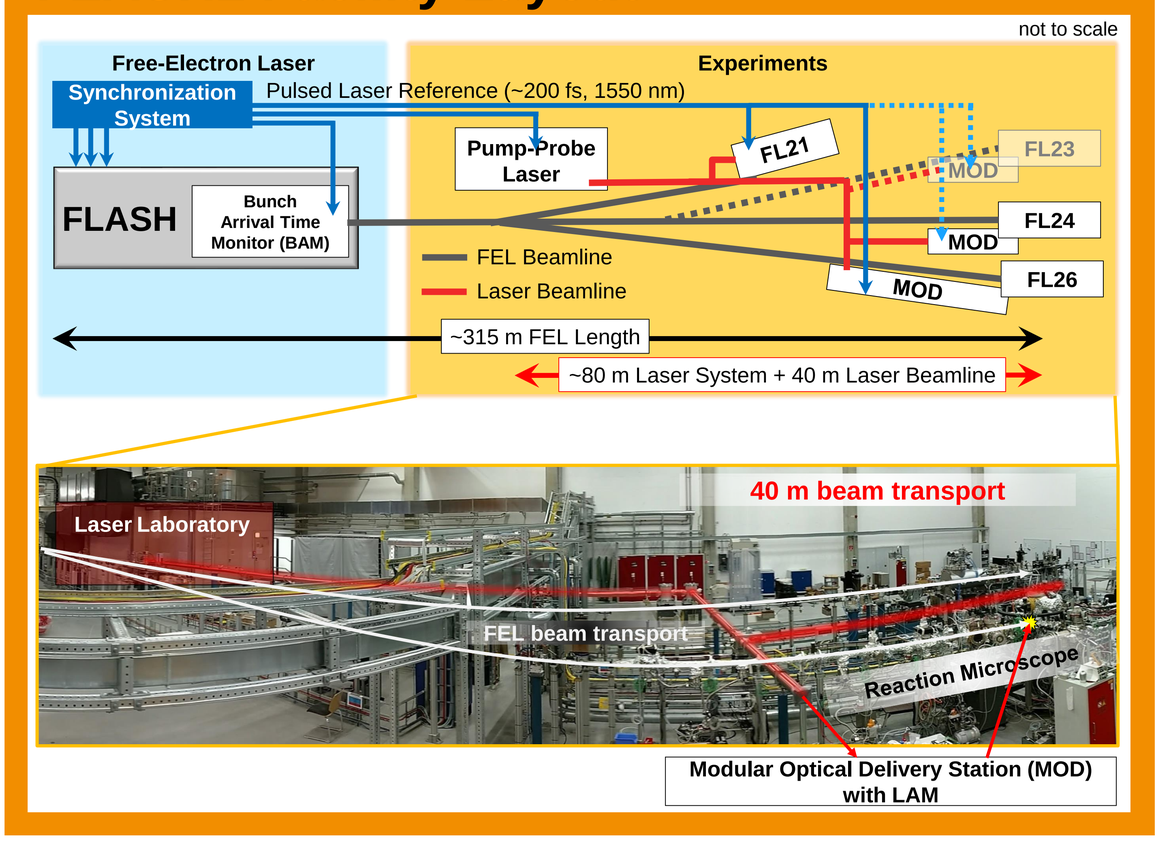
Laser arrival time monitor (LAM) at experimental end-stations with feedback

to enable experiments like:

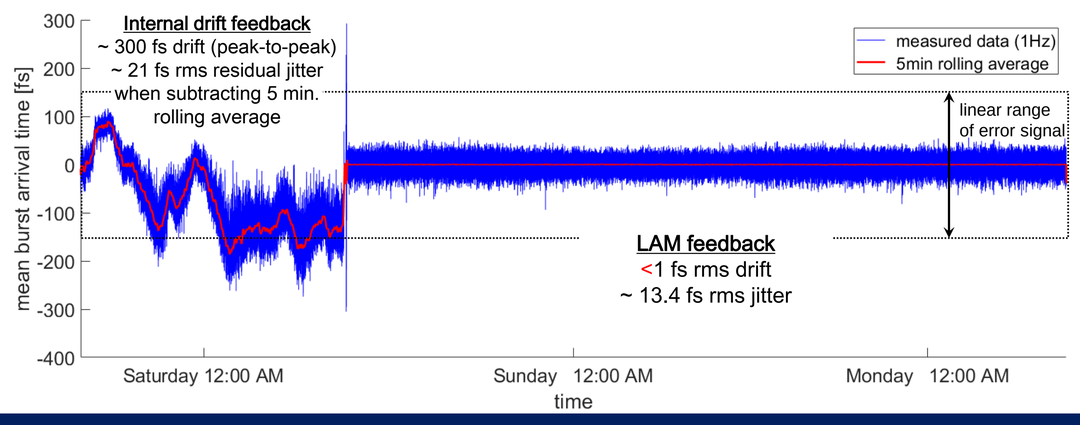


Excited state manifold for O_2^+ and calculated wave packet dynamics for different sets of potential energy curves (Corlin et al. 2015 Phys. Rev. A **91**, 8)

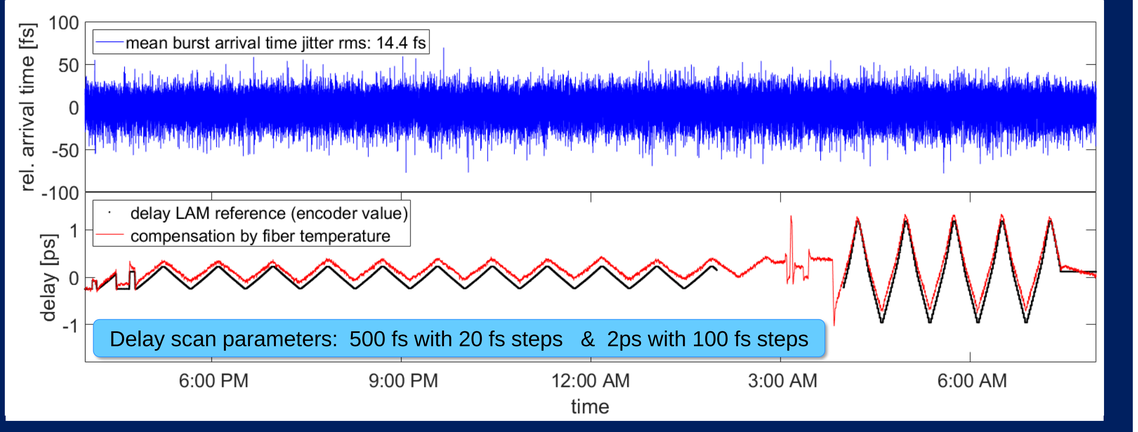
FLASH2 Facility Layout



Laser Arrival Time Stabilization at MOD2.6

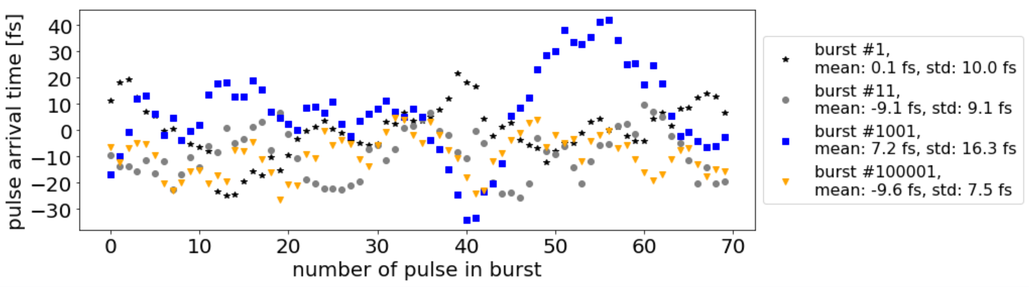


Internal vs. LAM feedback at MOD2.6



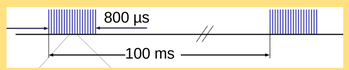
Stabilization during delay scans

Pulse resolved arrival times



Laser Pulse Parameters

Burst mode:



100 kHz – 80 pulses intra-burst

< 15 fs pulse duration
Center Wavelength: 800 nm
Wavelength fluctuation: < 10 nm rms
~ 20 fs rms oscillator jitter

Pulsed Optical Reference

~200 fs pulse duration
Center Wavelength: 1550 nm

Distributed facility-wide by length stabilized fiber links

Results

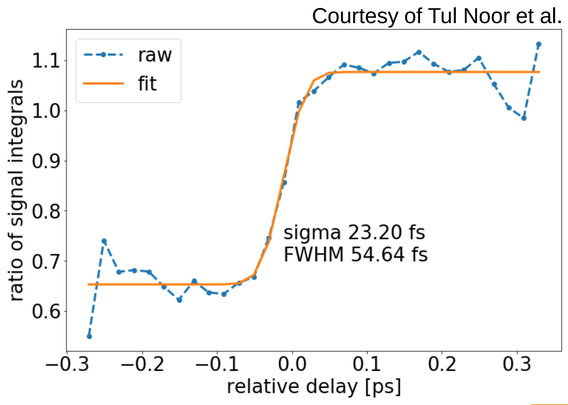
Time resolution of FEL - laser experiments at FLASH2 before: ~ 180 fs FWHM

Time resolution improved to ~ 55 fs FWHM !

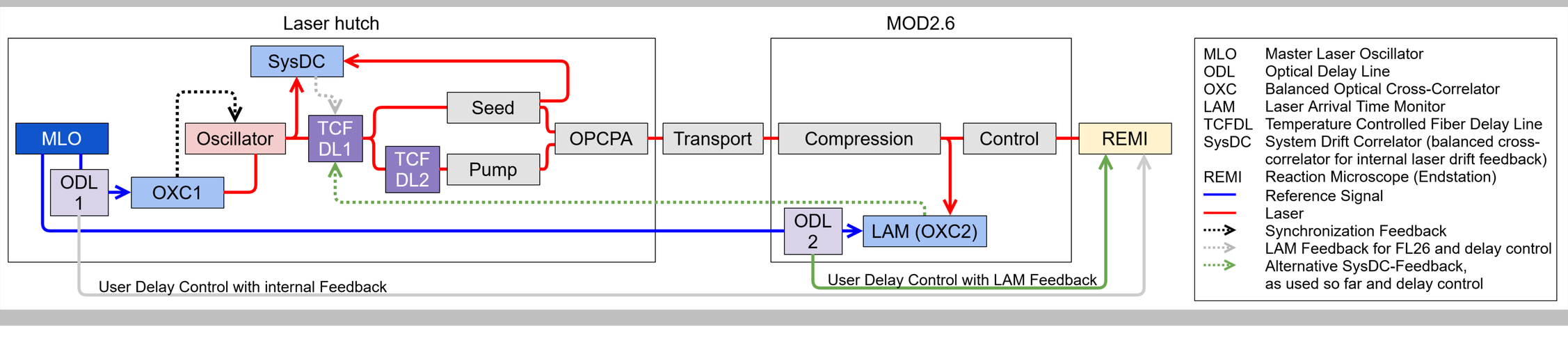
Courtesy of Tul Noor et al.

Measures taken:

- **Slow LAM feedback close to interaction region**
- Short FEL pulses < 15 fs FWHM
- Short laser pulses < 15 fs FWHM
- Implementation of delay stage encoders
- Correction for FEL arrival time measured with BAM



Drift Compensation Feedback



[1] S. Schulz, et al. “Femtosecond all-optical synchronization of an X-ray free-electron laser,” Nat. Commun. 6, 5938 (2015).

[2] N. Schirmel et al. “Sub 10-fs drift stability feedback for broadband burst-mode OPCPA System at FLASH,” 8th EPS-QEOD Europhoton Conference 2018, Barcelona, Spain (2018).

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