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FREE ELECTRON LASERS OF EUROPE

WP8 FEL Source - Highlights

Patrick Gessler (WP8 leader deputy)

Overview

- WP8.1: Femtosecond Timing and Synchronization
- WP8.2: Longitudinal Feedback and associated Diagnostics
- WP8.3: High Harmonic Generation (HHG) Laser

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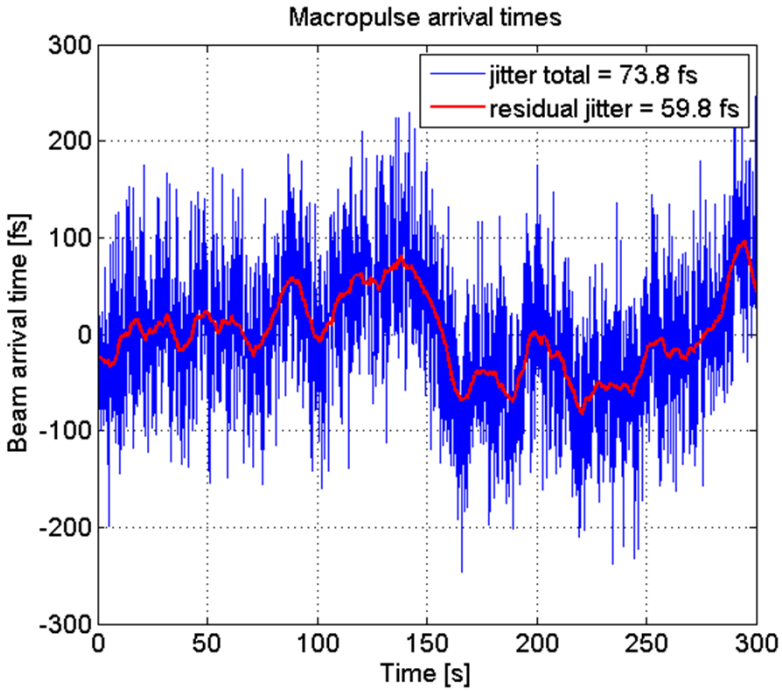
Femtosecond Timing and Synchronization

Lead by DESY

Beam based Feedback results

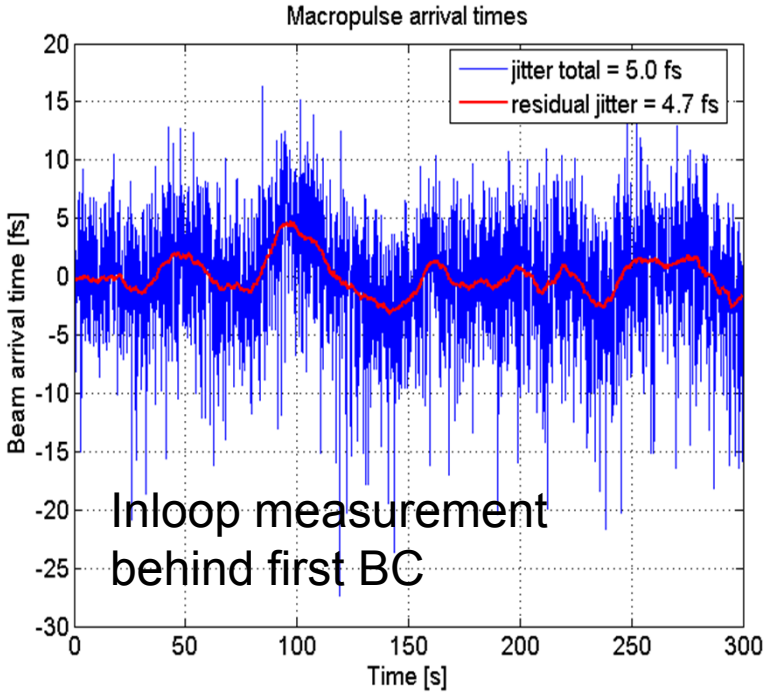
No Beam Based Feedback
Learning Feed Forward ON
rms = 74 fs



LLRF Regulation Performance → $\Delta A_1 / A_1 \sim 10e\text{-}4$

$\Delta \varphi_1 < 0.03^{O}$

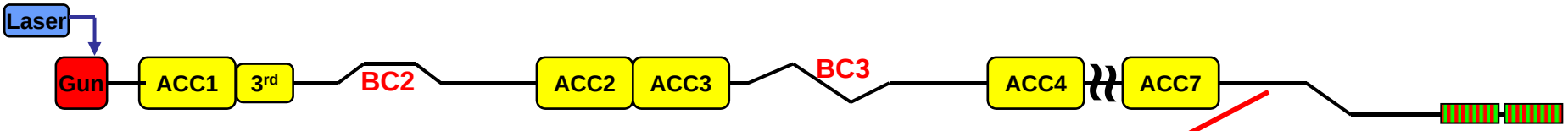
With Beam Based Feedback
running in ACC1 and ACC39
rms = 5 fs

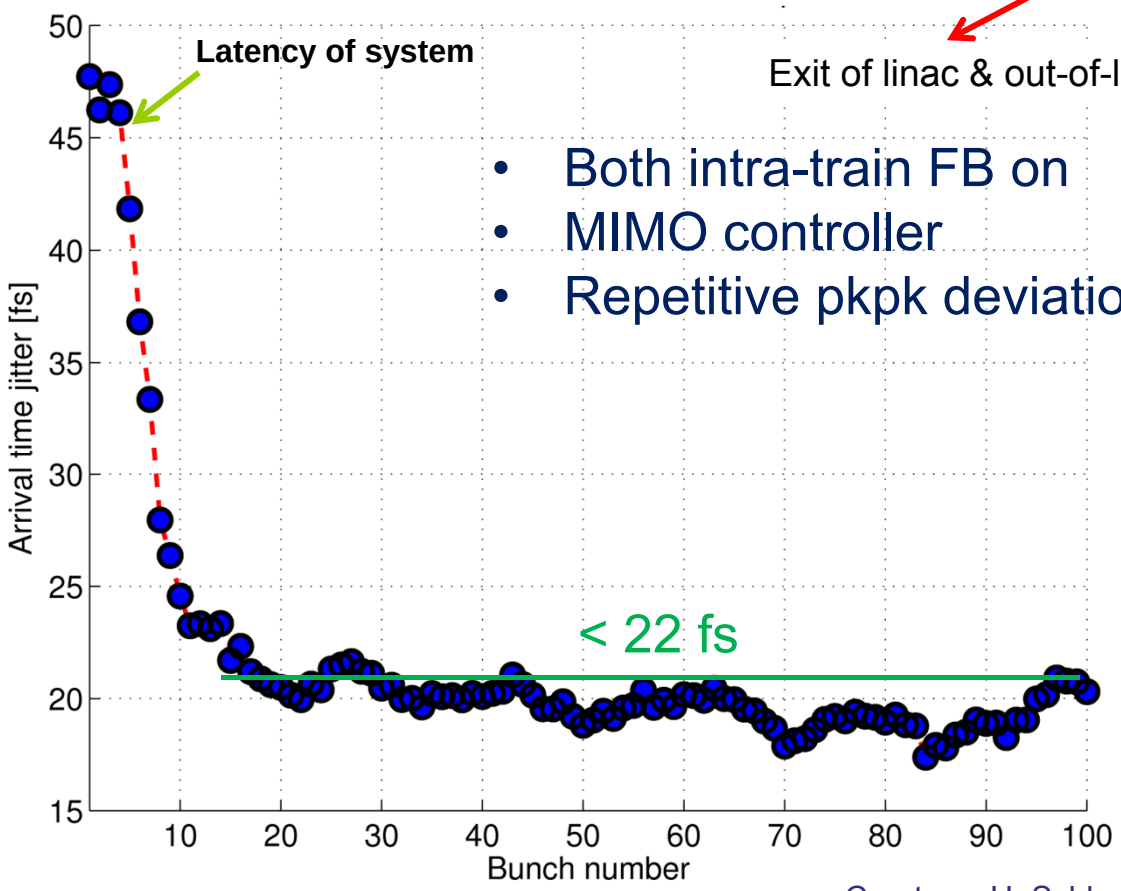


- rapid fluctuations averaged out
- resolution of BAM ~ 10 fs for single shot can be reduced to ~ fs for macro pulse

Courtesy: H. Schlarb & Team, DESY

Beam based Feedback results

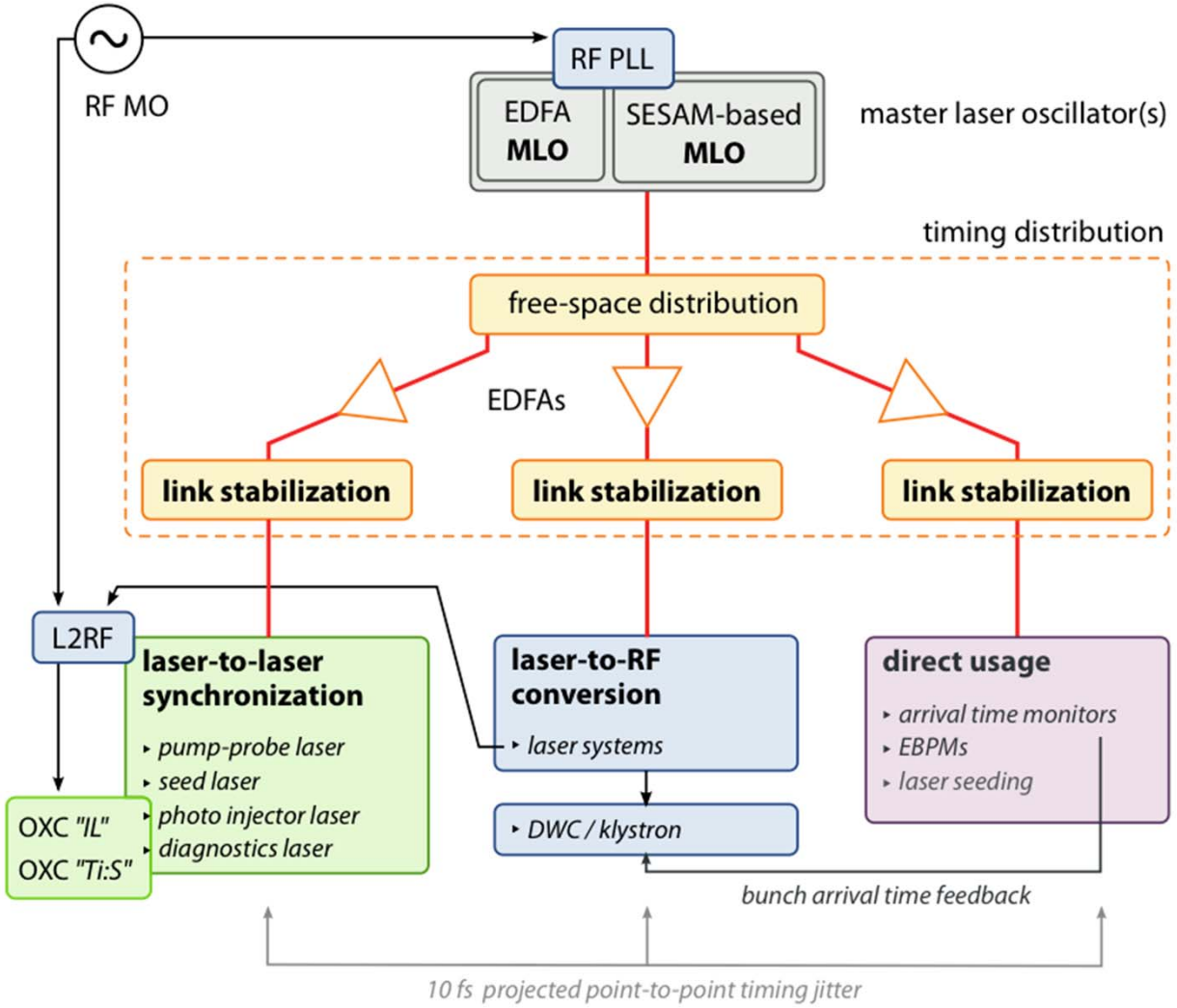




- Both intra-train FB on
- MIMO controller
- Repetitive pkpk deviation < 100fs

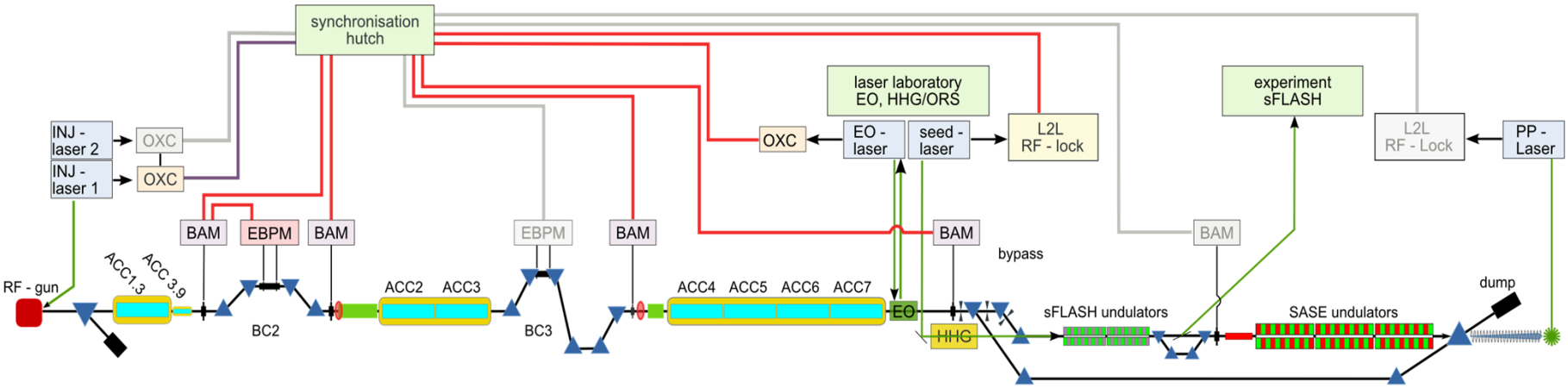
Courtesy: H. Schlarb & Team, DESY

System overview



Courtesy: S. Schulz, DESY

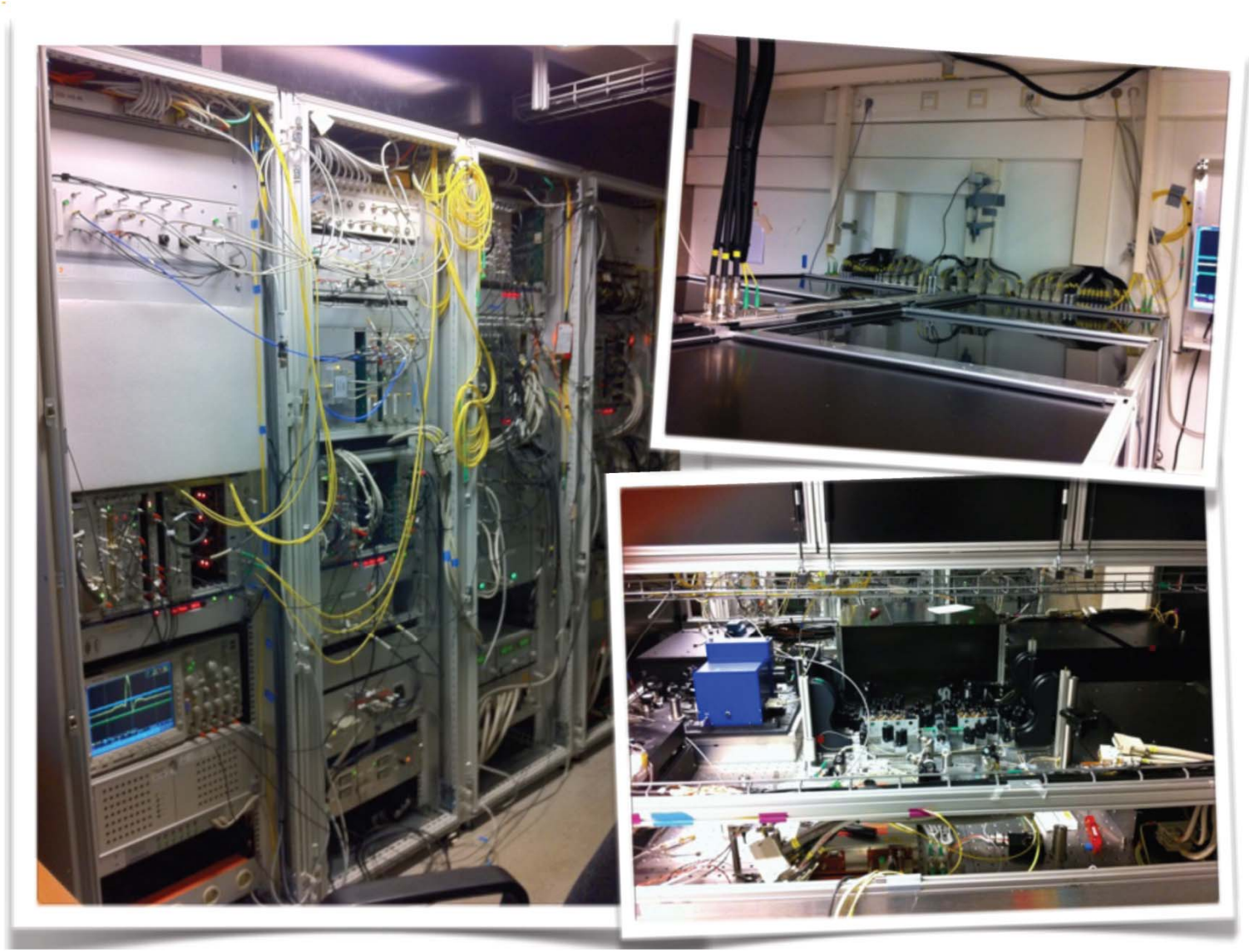
Overview at FLASH



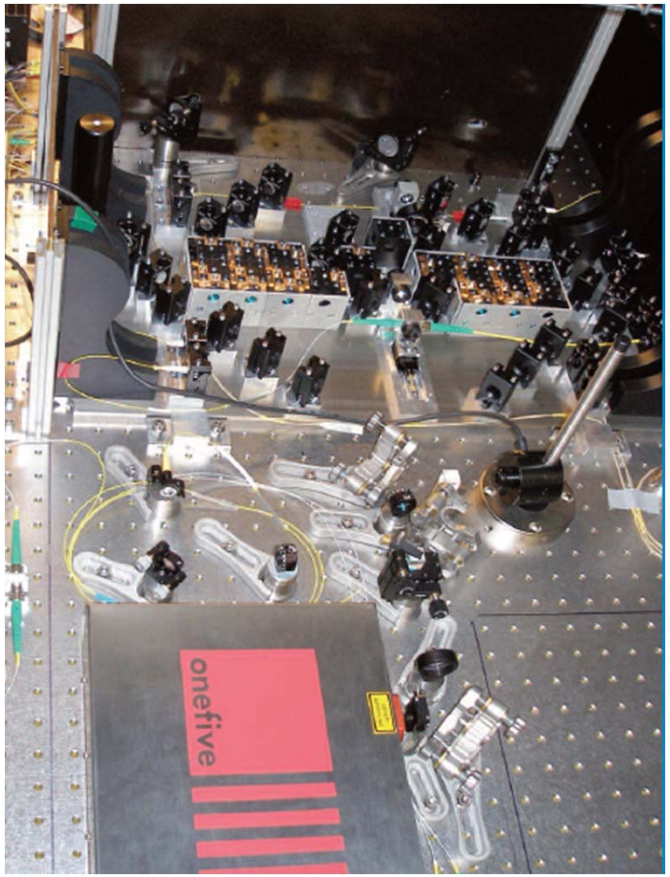
- 2 Master Laser Oscillators (RF locked to MO)
- Free-space distribution system to 16 ports
- Optical Links: 6 stabilized OXC & 1 passive
- Front-ends
  - 4 Bunch Arrival Time Monitors (BAM)
  - OXC for Injector / TiSA Lasers
  - 3 RF lock for TiSA (EO/HHG/PP)

Courtesy: M.K. Bock, DESY

Installation

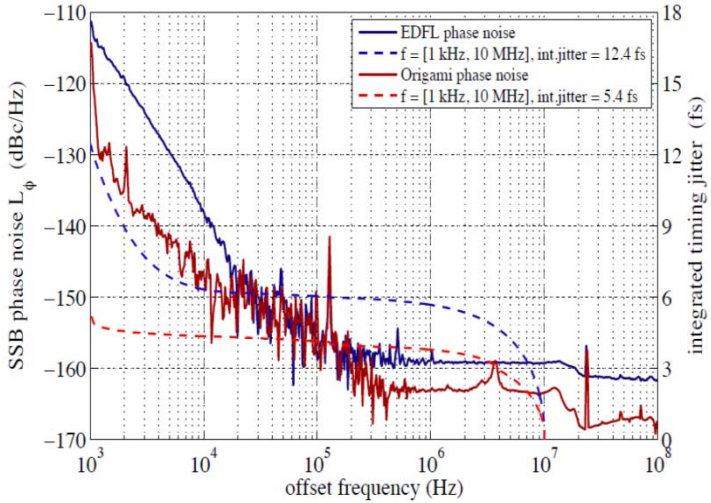


Master Laser and distribution



•Integrated timing jitter < 5 fs in the interval [1 kHz; 10MHz]

• Mechanically robust, easy to maintain



Courtesy: S. Schulz, DESY

Laser to RF conversion

Direct conversion + temp. stab.
Detectors at 1.3GHz & 216MHz
Baseband mixing scheme (no calibration)
VM for remote shift of MLO timing

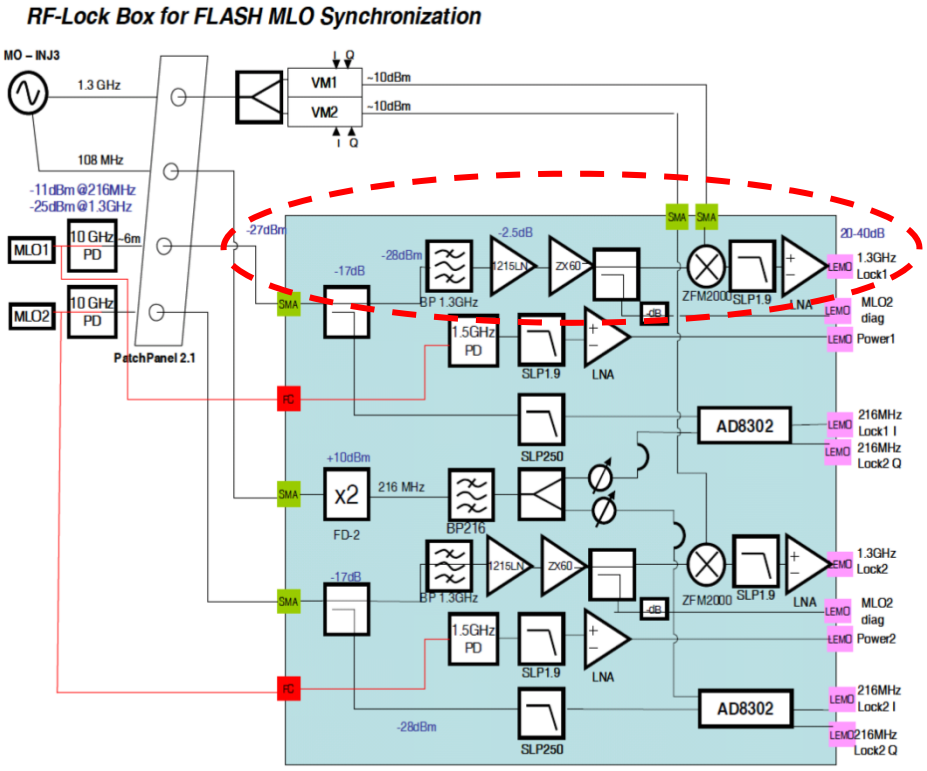
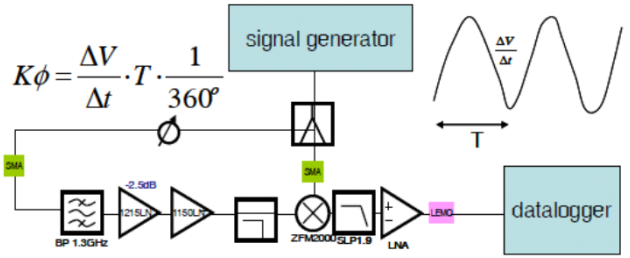


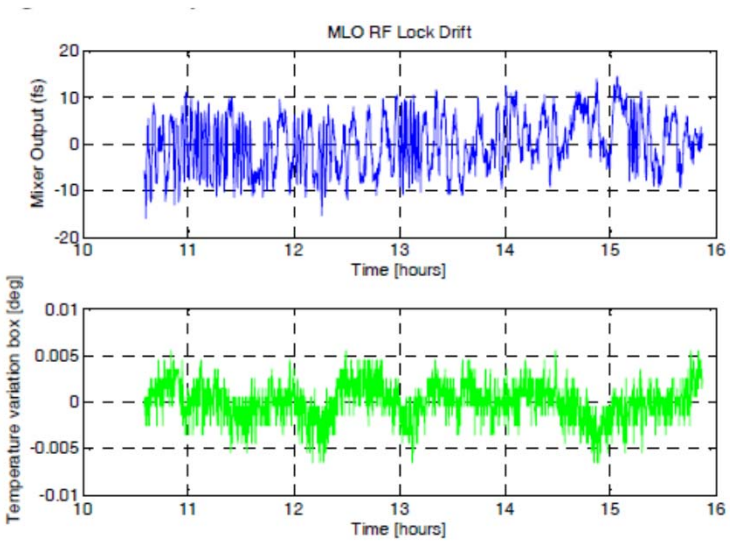
Figure1: Schematic of MLO – MO phase measurements.

Courtesy: K. Hacker, DESY

Test of RF circuit performance



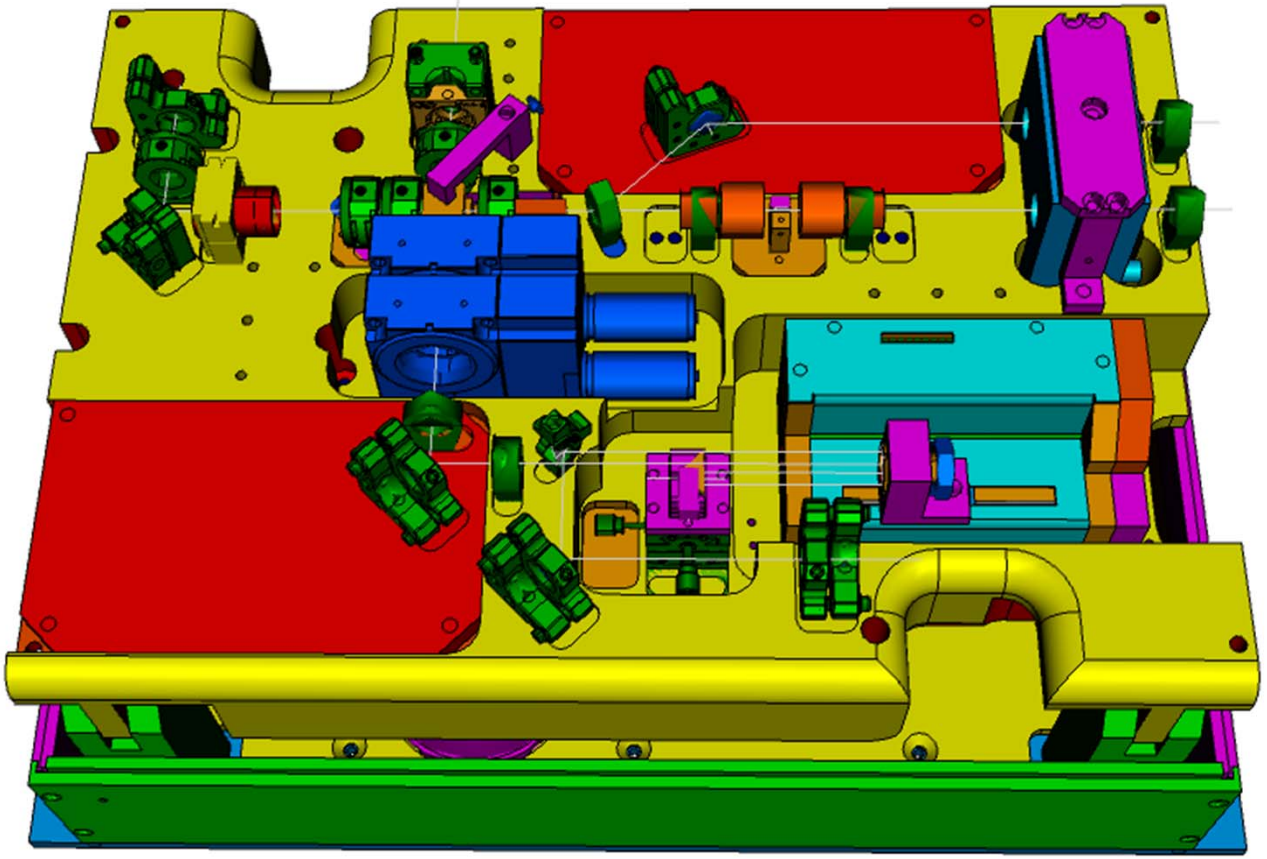
Drift performance:



Temperature stabilization 0.002deg rms
PkPK 20 fs due to vibration of 2m cable

Developments

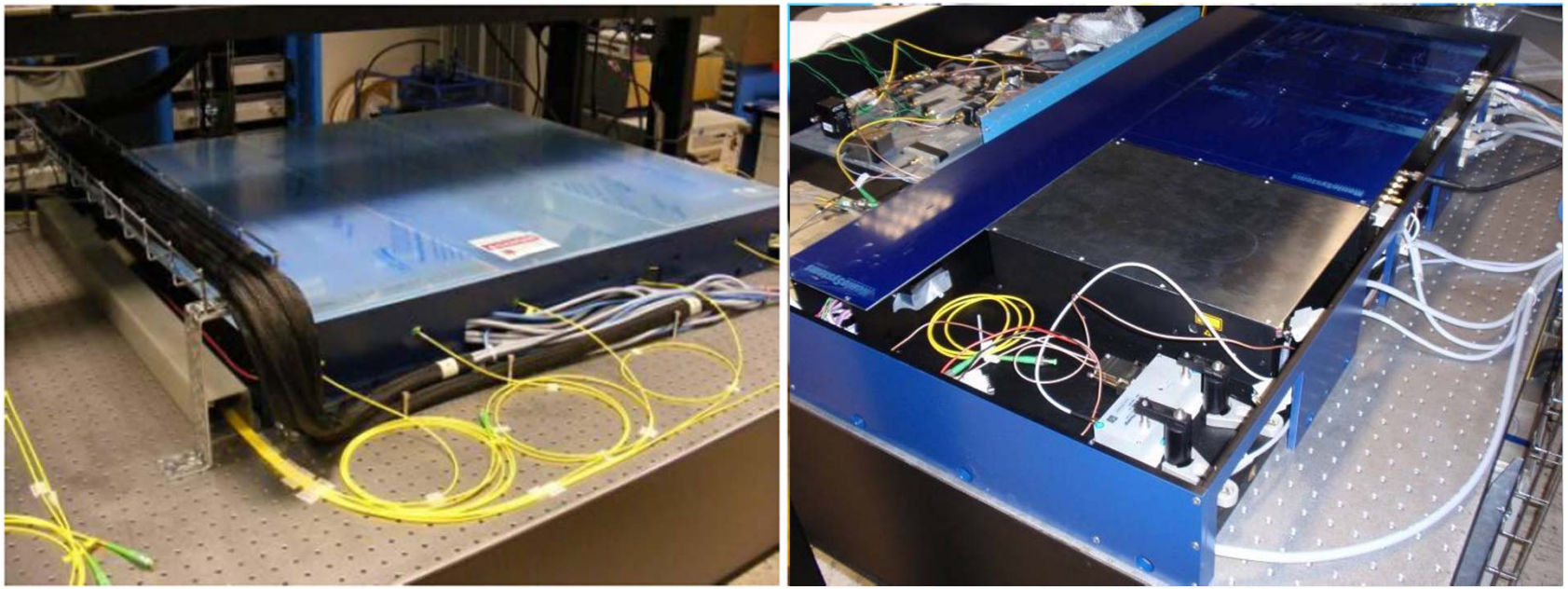
3 generation of opto-mechanics
typical in loop jitter ~ 1-2 fs rms (also smaller)



Courtesy: M.K. Bock, DESY

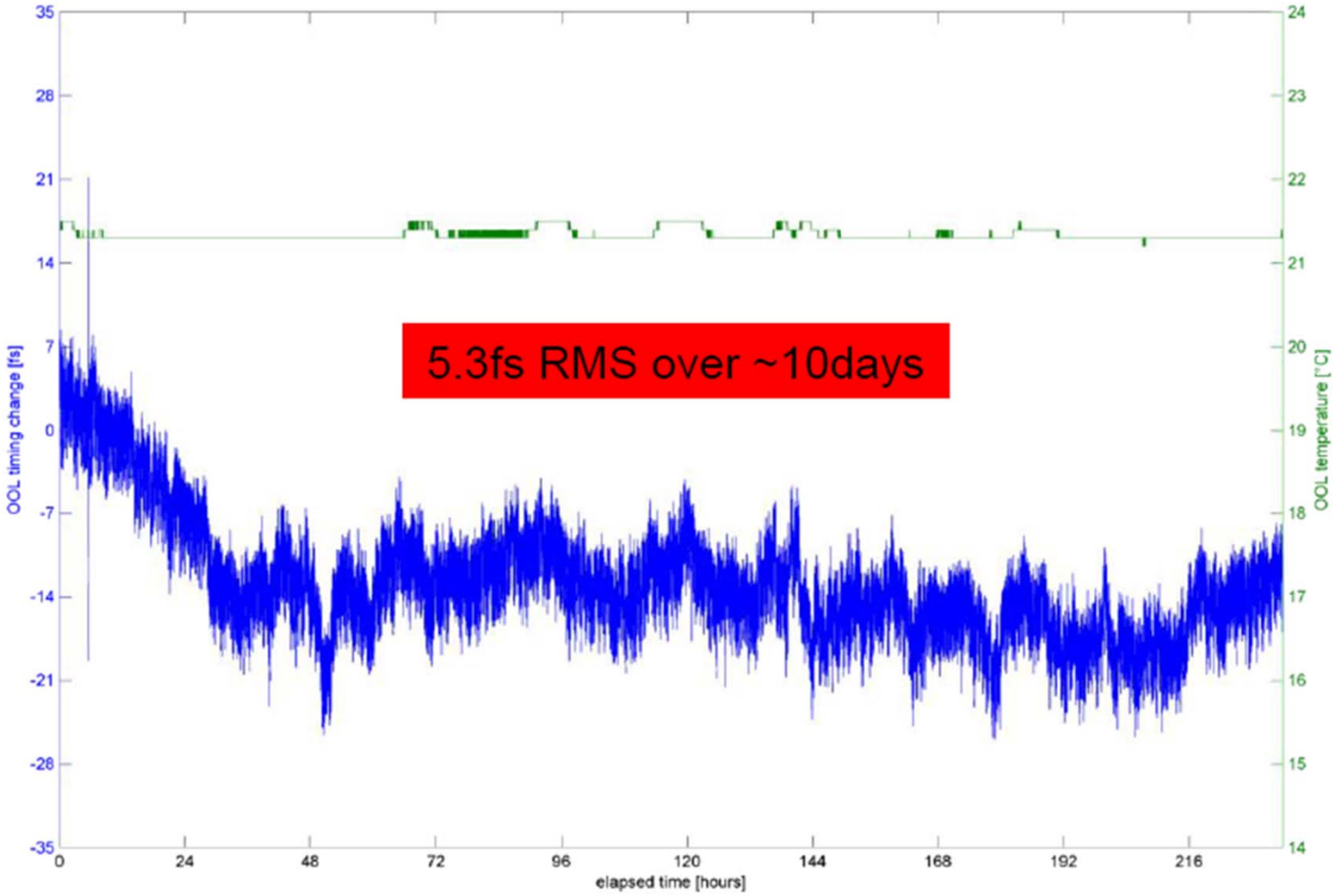
Installation at FERMI

- System integrated and running for seven months
- Master laser running 24/7 w/o big problems and minimal maintenance
- 2 Laser Links, 3 BAM Links, 1 EO Link



Courtesy: M. Ferianis & Team, Elettra

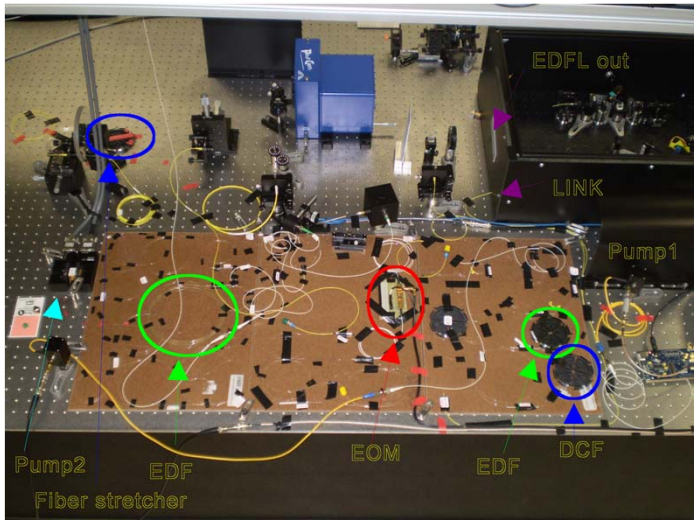
Link Stability

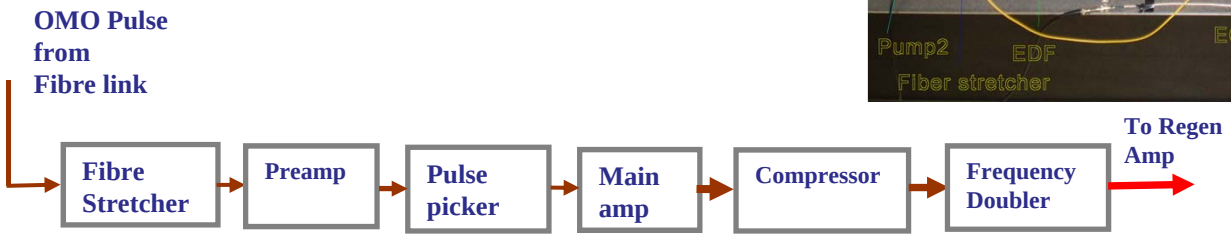


Courtesy: M. Ferianis & Team, Elettra

Direct seeding demonstration

- Developed a prototype for direct seeding of regenerative amplifiers of main laser system
- Studied applications for seeding the different ultrafast lasers at the seeded FELs



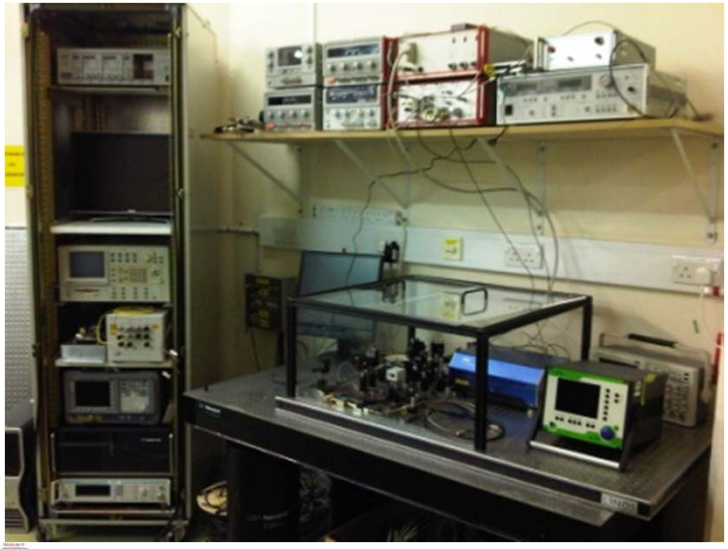


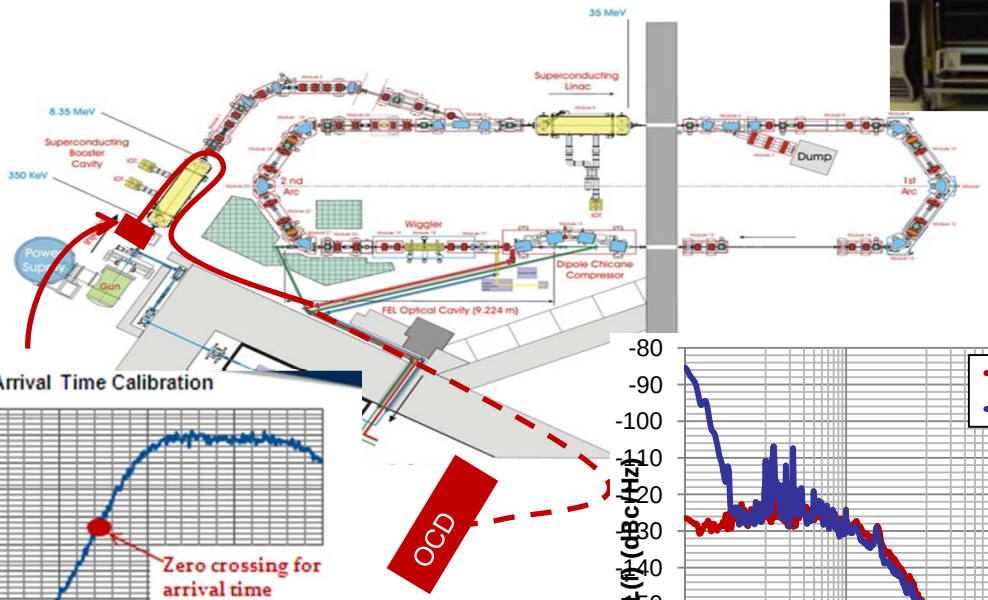
Main sub-units of the prototype

Courtesy: M. Danailov & Team, Elettra

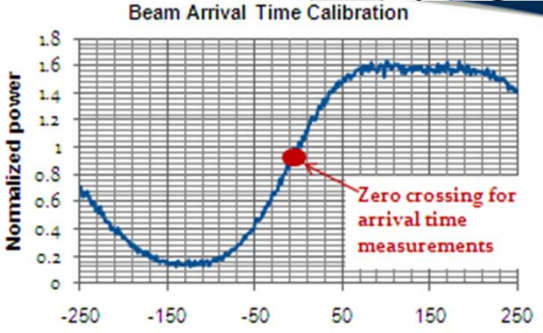
Installation at ALICE ERL

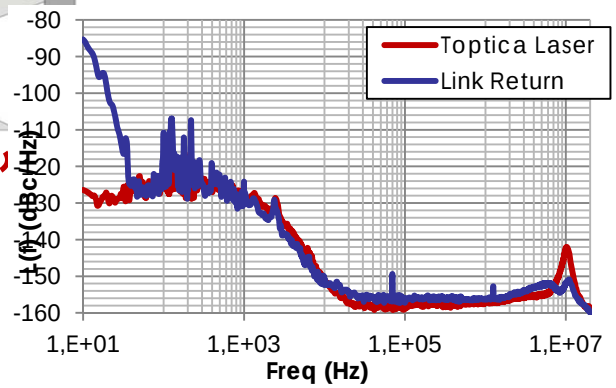
An 100m optical clock distribution system based on the propagation of ultra-short optical pulses has been installed at Daresbury Laboratory on the ALICE ERL.





Courtesy: S. Jamison & Team, STFC





Locking of the Injector Laser (PSI)

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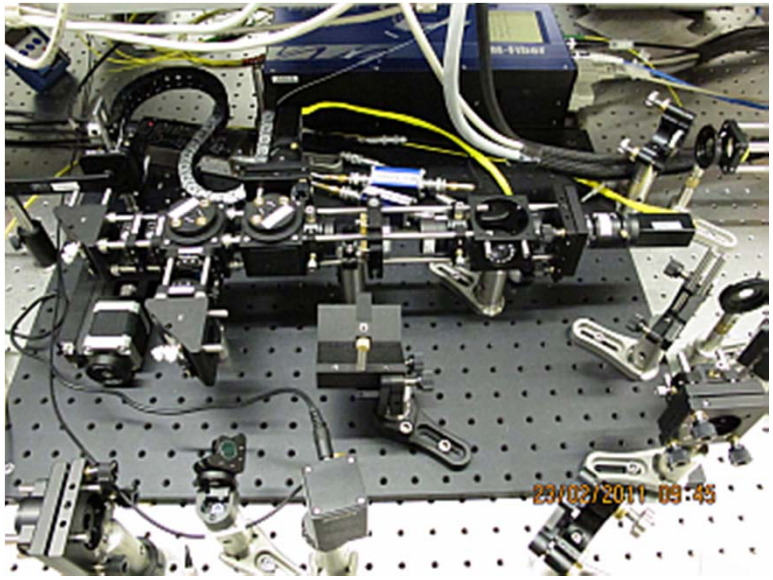
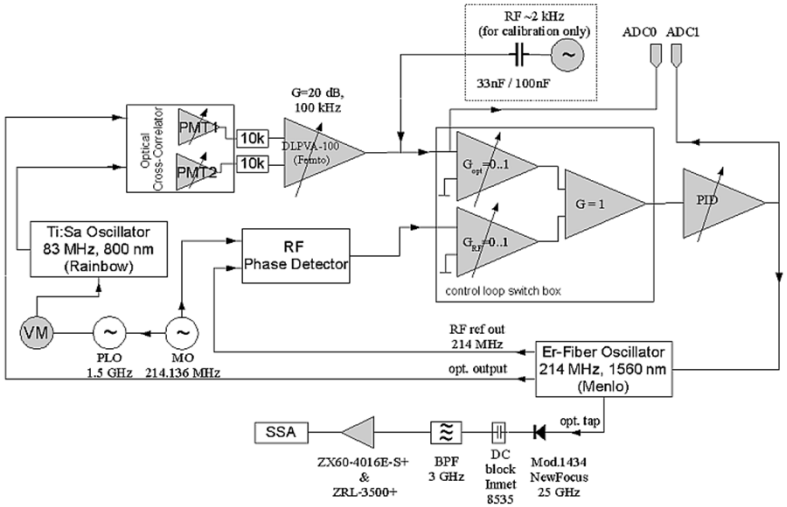
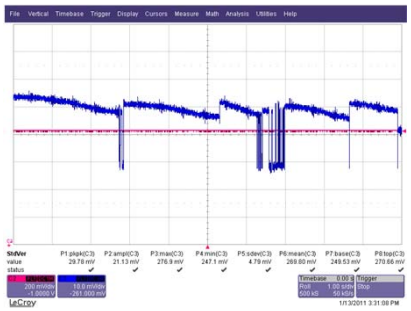
Two Color Balanced Cross-Correlation between the SwissFEL 250 MeV Test Injector Gun Laser (Ti:Sa) and the Optical Master Oscillator (ErFL)

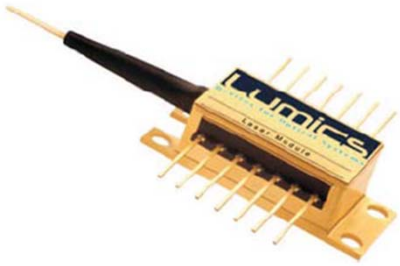




Courtesy: V. Schlott & Team, PSI

Aging and reliability studies

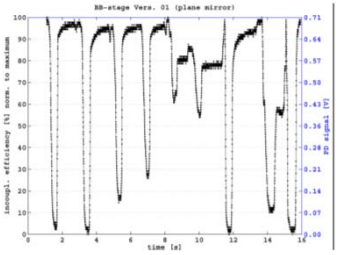


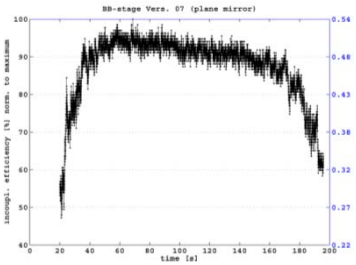


Instablities of pump laser siodes

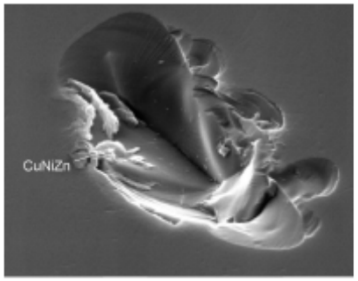
Courtesy: S. Ruzin, DESY

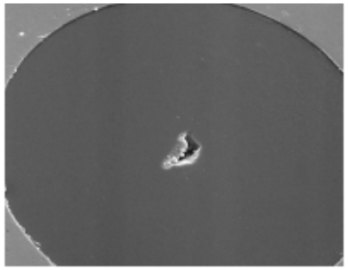
Incoupling efficiency due to motor movements of the delay stage





Courtesy: M.K. Bock, DESY



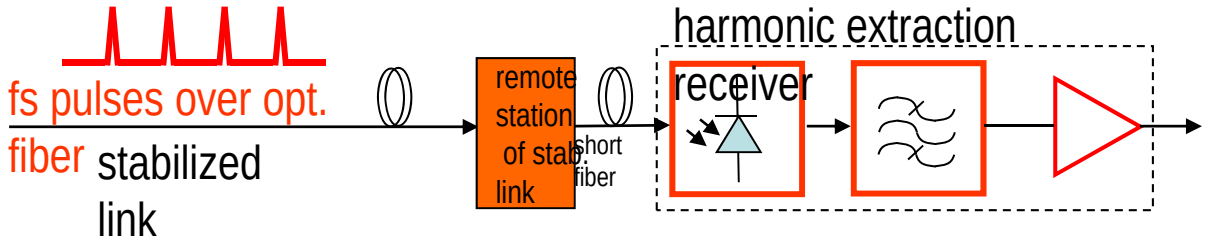


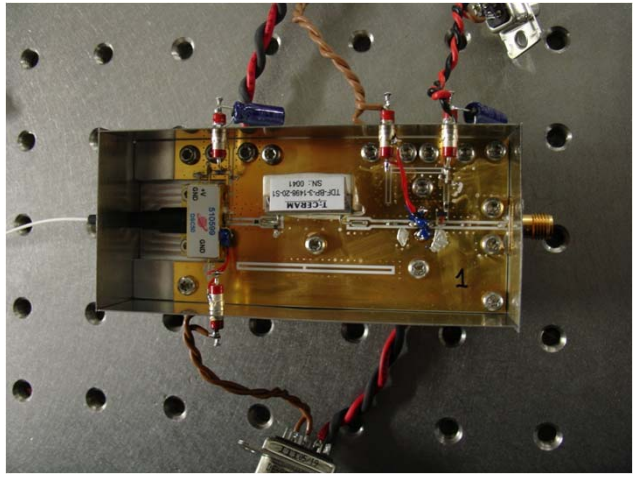
Damage due to metallic contamination

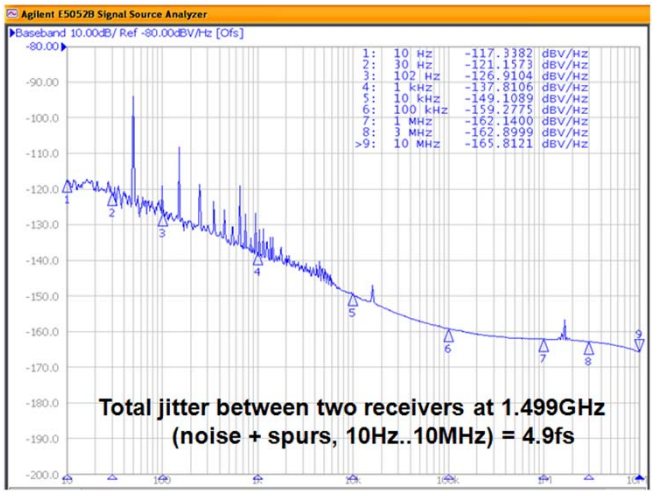
Courtesy: R. Kraehenbuehl (Huber+Suhner)

Industrialization: RF Extraction

Feasibility study including literature survey and optimized prototype design has been done with IRUVX support, Goal: “<10fs drift/jitter”

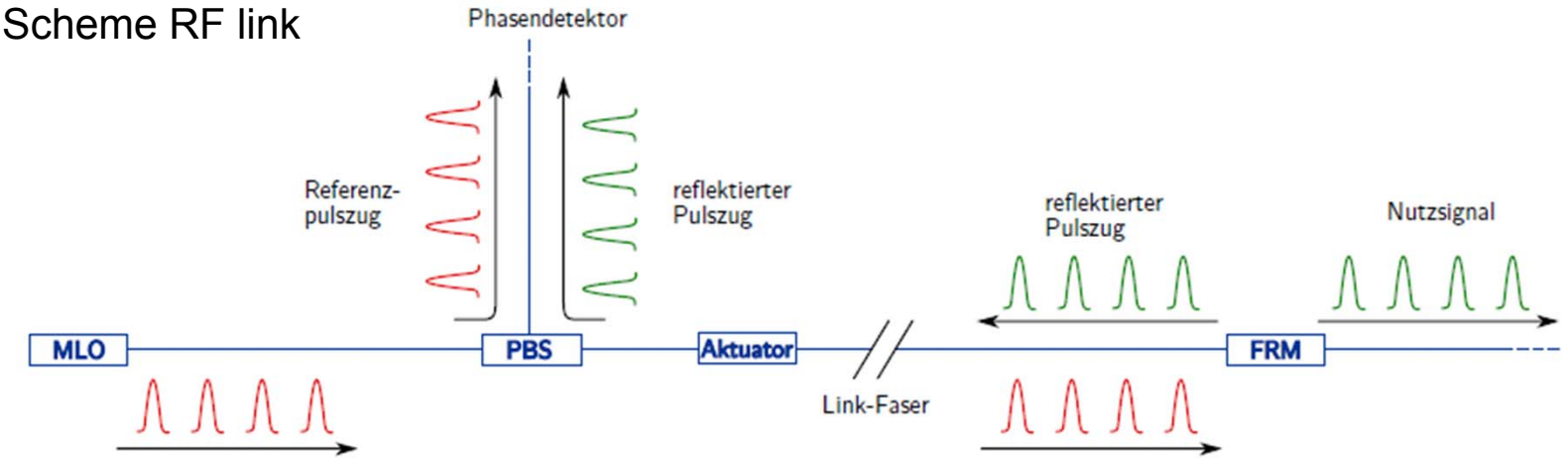






Industrialization: RF Link

Scheme RF link



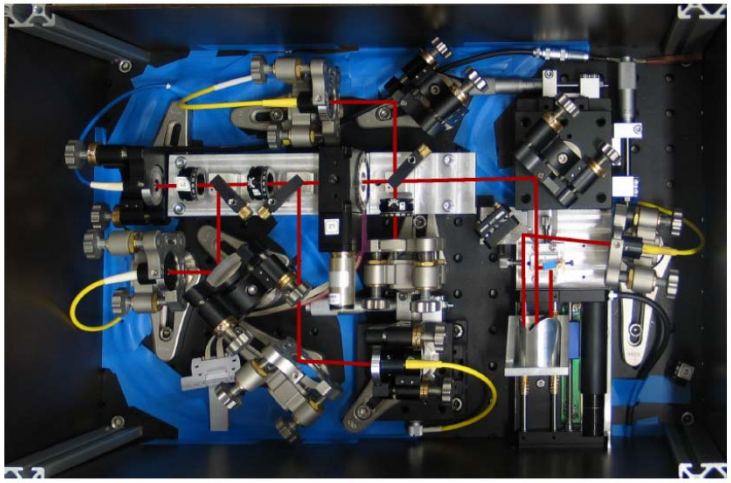


Abbildung 4.10.: Testaufbau der Optik mit eingezeichnetem Strahlverlauf

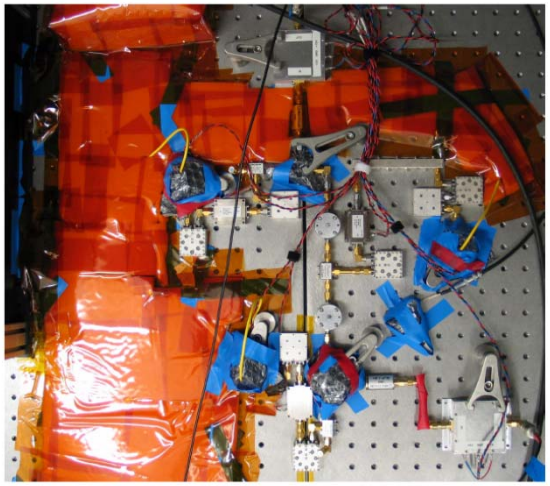
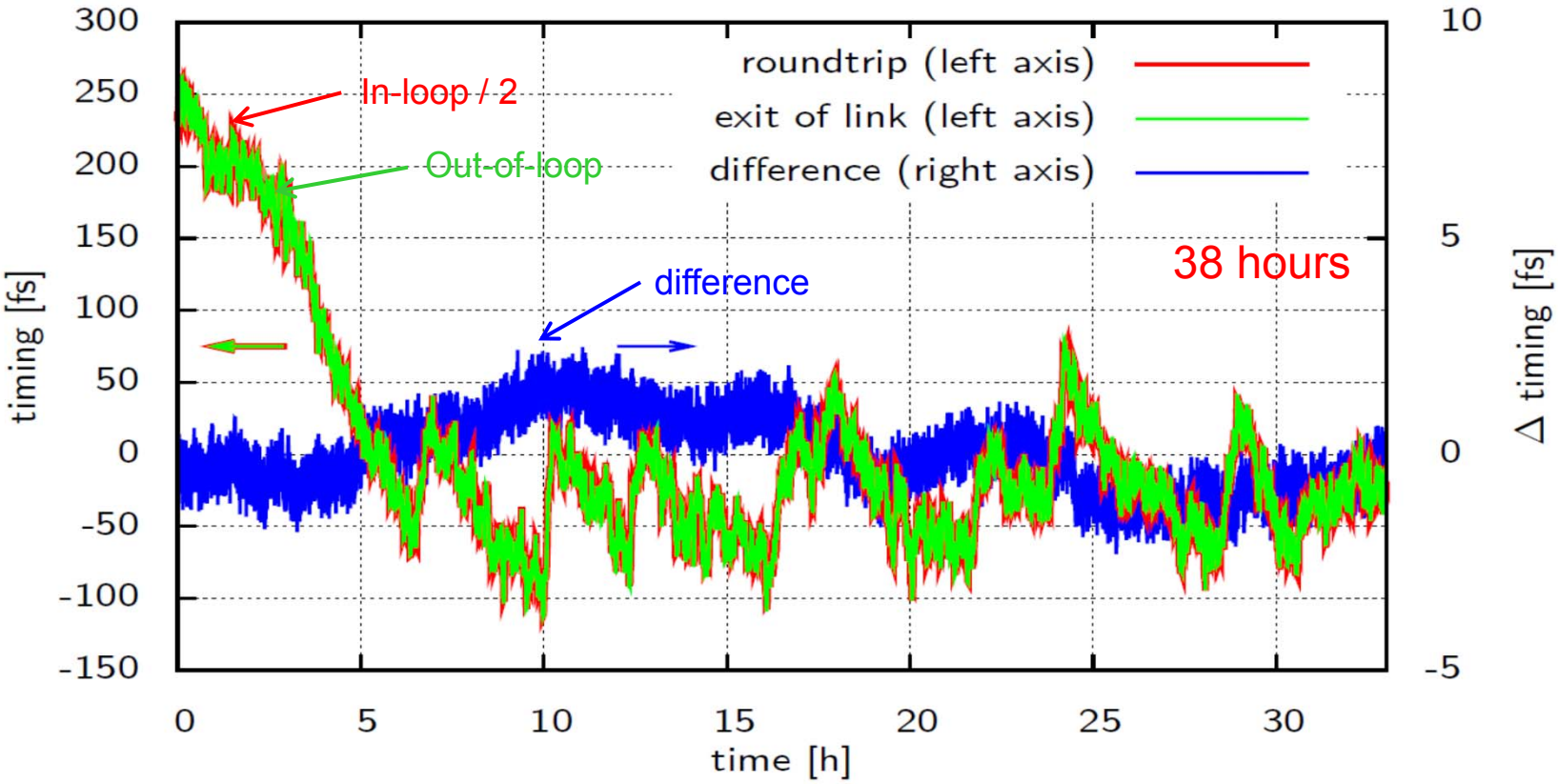


Abbildung 5.7.: Foto des aufgebauten Detektors

Industrialization: RF Link

Error between in-loop and out of loop ~ 0.8fs rms, 4.8 fs pkpk,
(30 m long fiber in laboratory, not stabilized, only monitored)



- **Overcomes AM-PM conversion in photo-detectors**
- **Several advantages compared to OXC link (low opt. power, monitoring possible, simple disp. comp.)**
- **Low cost version link with still high performance**

Tutorial given by leading Experts

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Preliminary Agenda for the Tutorial on Optical Synchronization
This tutorial is held in course of the IRUVX-PP project

Monday, October 13th

14:00 – 14:10	Welcome & Tutorial Organization	Dr. Axel Winter (DESY)
14:10 – 16:10	Sources of Timing jitter for SASE FEL's	Dr. Josef Frisch (SLAC)
16:10 – 16:30	Coffee Break	
16:30 – 17:30	Balanced optical and optical-microwave phase detectors Part 1	Prof. Franz X. Kärtner (MIT)
17:30 – 18:30	Discussion	

Tuesday, October 14th

08:30 – 10:00	Balanced optical and optical-microwave phase detectors Part 2	Prof. Franz X. Kärtner (MIT)
10:00 – 10:50	Coffee Break	
10:50 – 12:50	Dynamics of fiber lasers	Prof. Omer Ilday (Bilkent University)
12:50 – 13:30	Lunch Break	
13:30 – 15:30	Introduction into phase noise and timing jitter	Mr. Jesse Searls (Poseidon Scientific Instruments)
15:30 – 16:00	Coffee Break	
16:00 – 18:00	Cutting edge technology for phase and amplitude noise measurements	Mr. Jesse Searls (Poseidon Scientific Instruments)
18:00 – 18:30	Discussion	
19:00	Workshop Dinner	

Wednesday, October 15th

08:30 – 10:30	Feedback Control & Theory	Dr. Gerwald Lichtenberg (TU Harburg)
10:30 – 10:50	Coffee break	
10:50 – 11:50	Optical clocks	Prof. Franz X. Kärtner (MIT)
11:50 – 12:50	RF Frequency standards and oscillators Part 1	Mr. Jesse Searls (Poseidon Scientific Instruments)
12:50 – 13:30	Lunch break	
13:30 – 14:30	RF Frequency standards and oscillators Part 2	Mr. Jesse Searls (Poseidon Scientific Instruments)
14:30 – 15:00	Discussion with all Experts	Searls, Kärtner, Ilday, Frisch, Lichtenberg
15:00 – 15:15	Closing remarks	Dr. A. Winter

DESY

Workshops

3 Workshops on Timing and Synchronization

Timing and Synchronization Workshop
Trieste, 26 – 28 March, 2008

Wednesday, 26th March

08:30	*Departure time of the bus from Hotels to Sincrotrone*
09:00	*Welcoming Words and Charge to the Participants – What do we want to accomplish, S. Milton (ST), L. Palumbo (INFN), G. Dattoli (ENEA)*
09:20	*Machine Requirements, P. Craievich (ST)*
09:50	*Beamline synchronization issues and solutions, S. Duesterer (DESY)*
10:20	*Timing and Synchronization – State of the Art 10:20 – 10:50 MIT, F. Kaertner (MIT)*
10:50-11:00	*Coffee Break 11:00 – 11:30 LBL, R. Wilcox (LBL) 11:30 – 12:00 DESY, H. Schlarb (DESY)*
12:00	*FERMI timing system requirements, status and schedule, M*
12:15	*SPARX timing system requirements, A. Gallo (INFN)*
12:30	*Visit to the FERMI Optical timing laboratory*
13:20	*Lunch*
14:30	*Sync requirements for PLASMON-X experiments: laser drive and Thomson scattering, L. Gizzi (CNR - INFN)*
15:00	*Sub-Nanosecond Machine Timing for the FERMI LLRF Syste T. Rohlev (ST))*
15:30	*Discussion / working session A - Reference Generation and*

Tuesday, 22 March 2011
3rd IRUVX-PP Annual Meeting

3rd IRUVX-PP Annual Meeting, 21-23 March 2011, Helmholtz-Zentrum Berlin

Satellite meeting
Timing and synchronization mini workshop (room 3303) *Chair: P. Gessler (DESY)*

08:30	**Welcome** P. Gessler (WP8 leader deputy, DESY)
08:40	**Experiences with different optical synchronization systems at Elettra** M. Ferianis (Elettra)
08:55	**The optical synchronization system at Daresbury** S. Jamison (STFC)
09:10	**Optical synchronization developments and experiences at DESY** S. Schulz (DESY)
09:30	**Ultra-stable direct detection harmonic extraction** S. Hunziker (PSI)
09:45	*Coffee break*
10:05	**RF link** H. Schlarb (DESY)
10:20	**Laser to laser synchronization of photo injector laser** V. Arsov (PSI)
10:35	**Laser to laser synchronization at Elettra** M. Danailov (Elettra), Paolo Sigalotti (Elettra)
10:50	**Reliability and stability of laser diodes** S. Ruzin (DESY)
11:00	*End of meeting*

II Timing & Synchronization Workshop
ICTP, Trieste - 9 March 2009

PROGRAMME
Giambiagi Lecture Hall, Adriatico Guesthouse

09:00	Welcome	A. Gallo - INFN-LNF
:10	Installation, commissioning and operation of the master laser oscillator at FLASH	P. Gessler - DESY
:30	Specifications of the FERMI@Elettra optical hybrid timing system	M. Ferianis - Sincrotrone Trieste
:50	Layout and specification of the synchronization system for SPARC-X	M. Bellaveglia - INFN-LNF
:10	Layout of the PSI-XFEL synchronization system and latest results	S. Hunziker - PSI
:30	Layout of the synchronization system for the NLS (incl. experience with fiber laser system at the ERL)	S. Jamison / G. Hirst - STFC
:50	*Coffee Break*	
:20	Synchronization of Ti:Sapphire lasers to the optical reference system	V. Arsov - DESY
:40	Latest results on laser synchronization at Elettra	M. Danailov / P. Sigalotti - Sincrotrone Trieste
:00	Options and performance of laser to RF conversion schemes	F. Ludwig / P. Gessler - DESY
:20	Precision timing distribution for LCLS laser synchronization	R. Wilcox - LBL
:40	*Lunch*	
:15	Challenges on a BAM implementation in an accelerator	F. Loehl - DESY
:35	Required infrastructure for the implementation of an optical synchronization system	A. Winter - ITER
:55	New developments and missing components of an optical synchronization system	H. Schlarb - DESY
:15	*Coffee Break*	
:45	Discussion: Engineering of main components and global T&S system implementation over large scales issues	
:45	Conclusions	

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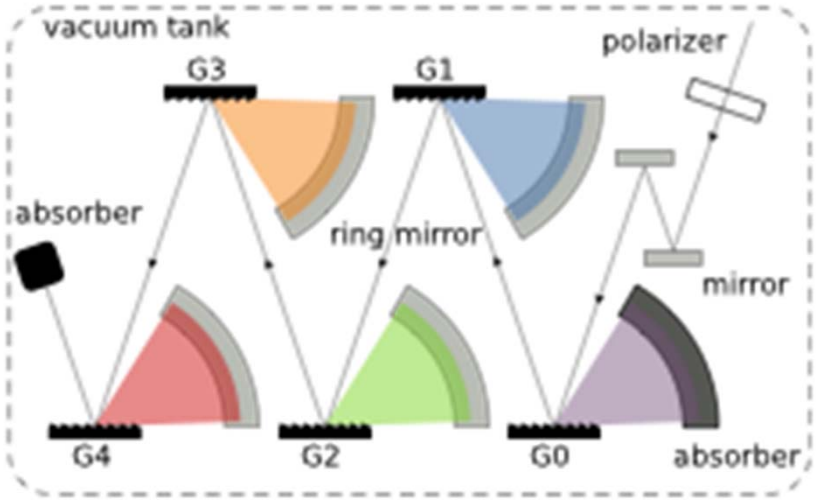
Longitudinal feedback and associated diagnostics

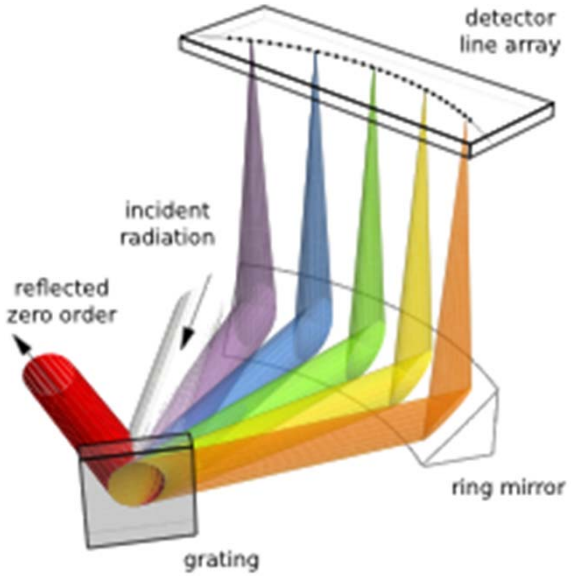
Lead by STFC

Compression Control in Frequency Domain

The four-stage single shot grating spectrometer for the wavelength range 4 µm to 400 µm has been developed, commissioned and installed at FLASH



layout of the device



one stage with grating, ring mirror and line detector

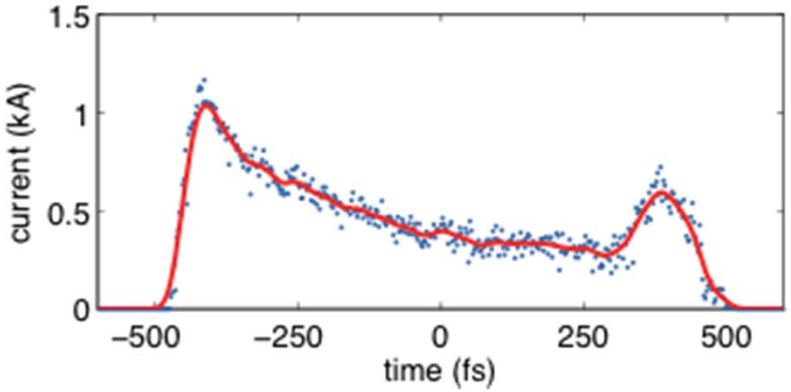
Courtesy: S. Wesch, B. Schmidt, DESY

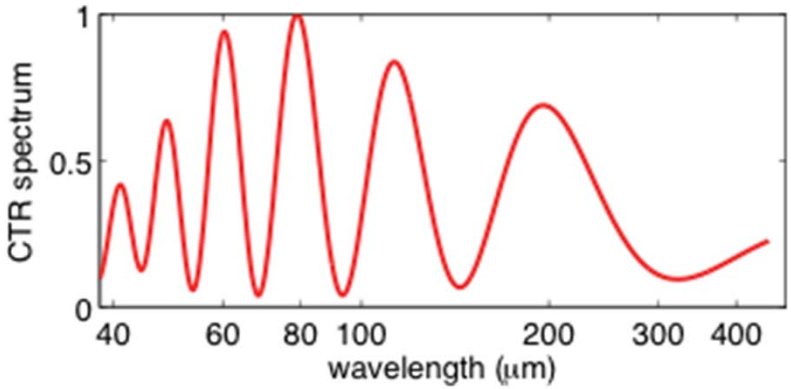
Compression Control in Frequency Domain

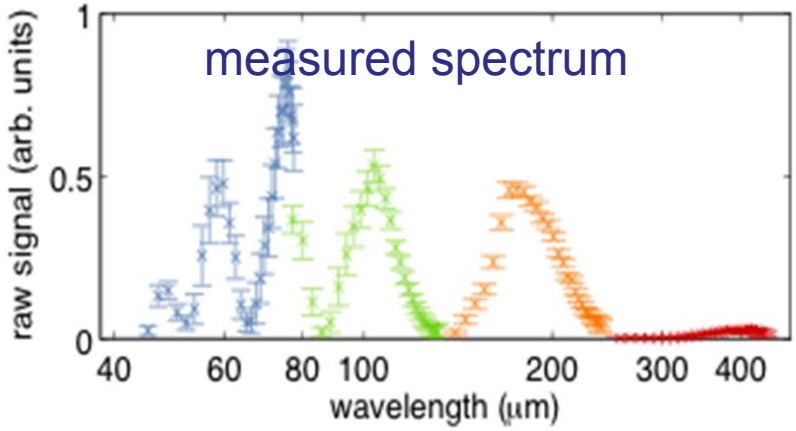
test measurements comparing with bunch shapes from TDS

show very good agreement with measured spectra

TDS bunch profile → expected spectrum



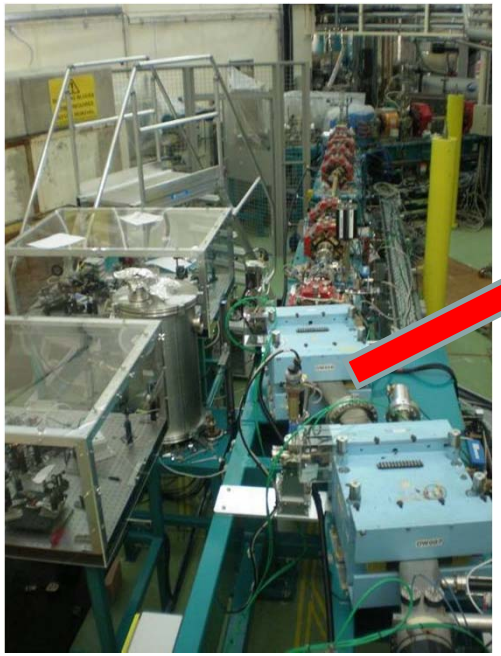


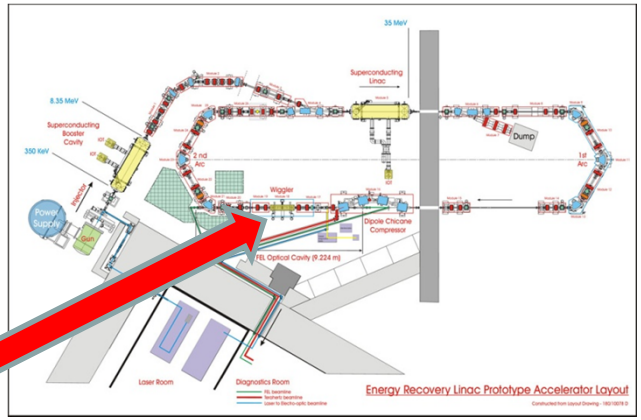


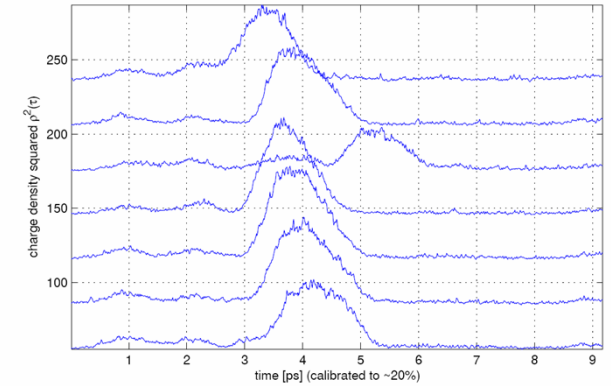
Courtesy: S. Wesch, B. Schmidt, DESY

On-line Bunch Profiling in Time Domain

- Electro-optic prototype on ALICE ERL in use with control room operation







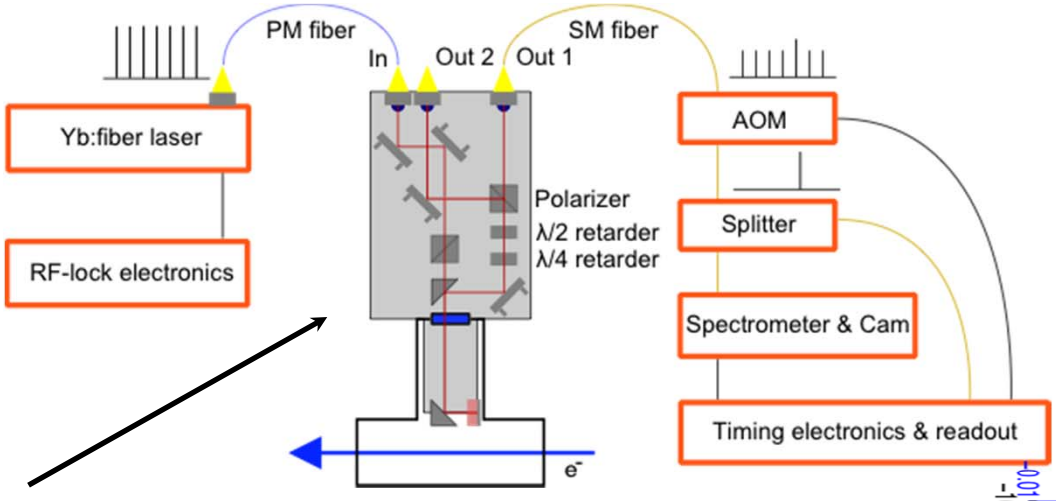
Courtesy: S. Jamison, STFC

Spectral decoding results for 40pC bunch

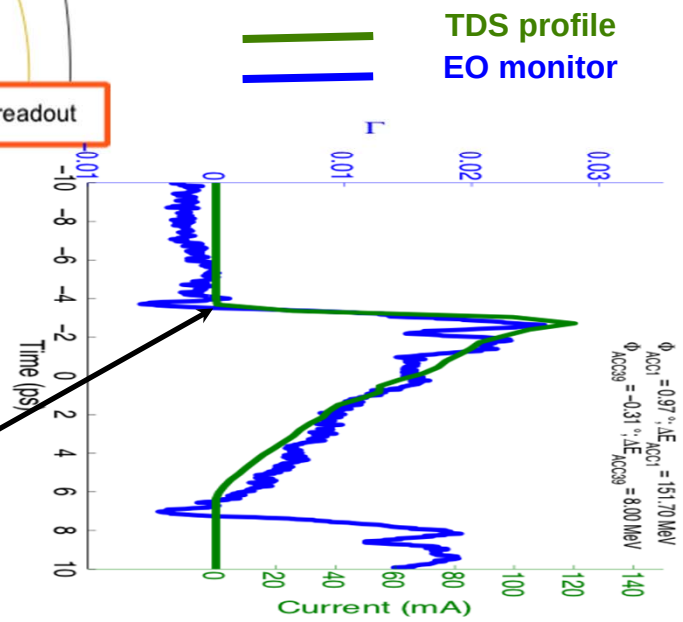
On-line Bunch Profiling in Time Domain

New compact electro-optic monitor installed at FLASH

location : after first bunch compressor



EO front-end designed at PSI



commissioned
with well defined bunch shapes

Courtesy: J. Breunlin, B. Steffen, L. Wissmann, DESY

Development of an 11GHz X-Band Linearizer

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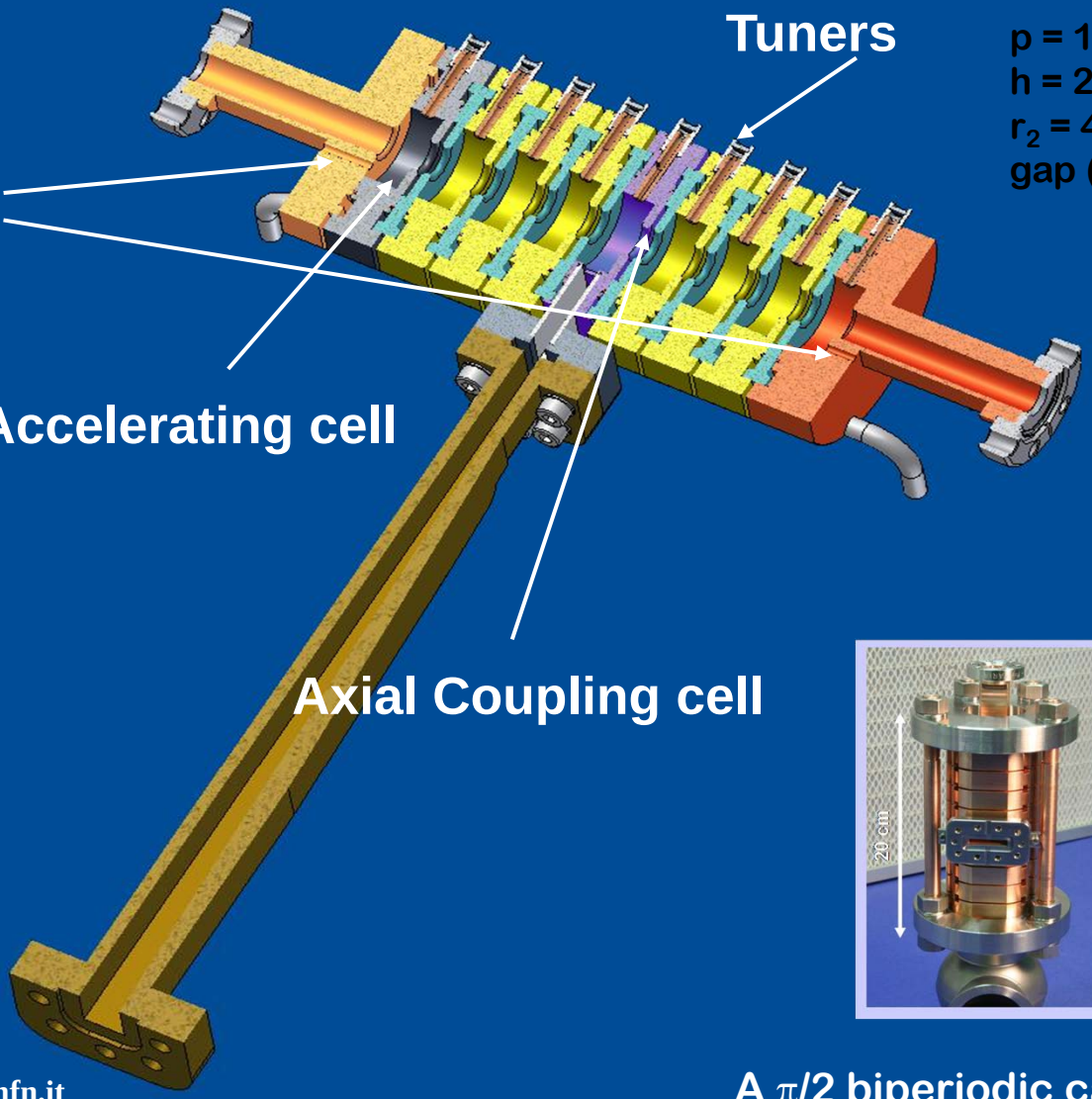


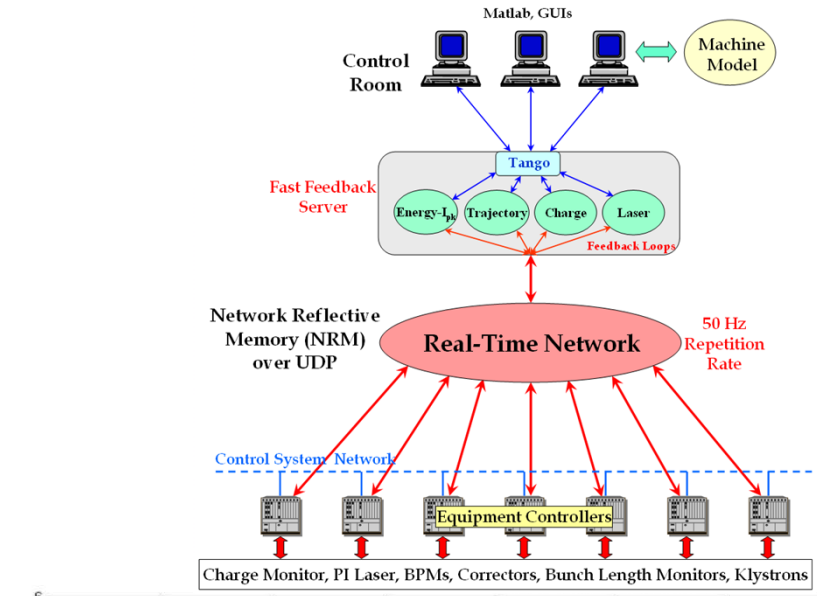
p = 13.121 mm
h = 2 mm
r_2 = 4 mm
gap (coupling cell) = 1 mm

The structure is designed for brazing

bruno.spataro@lnf.infn.it

A π/2 biperiodic cavity: 17 cells copper prototype NIM: A 586 (2008

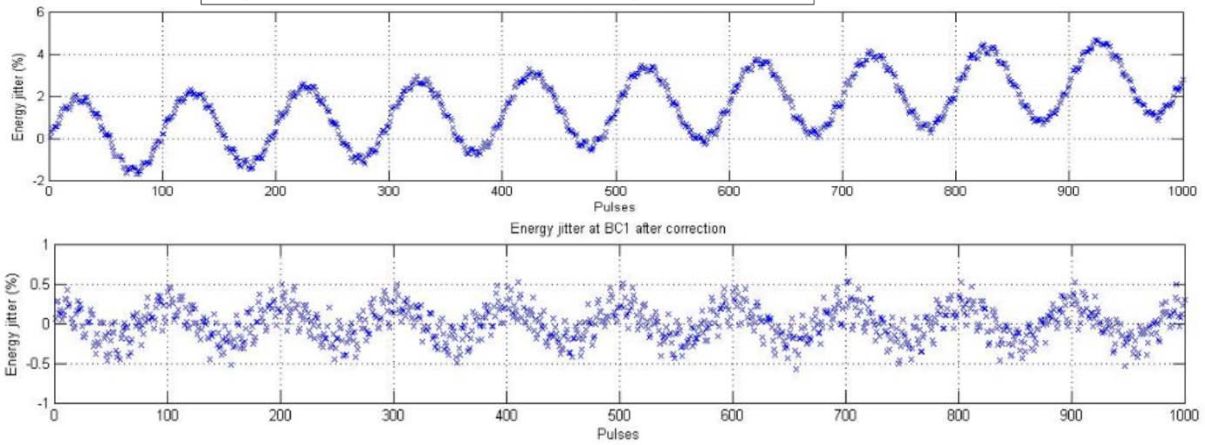
Feedback Software Developments



(Open Loop)

Energy Jitter Simulated

(Closed Loop)



Courtesy: M. Lonza & Team, Elettra

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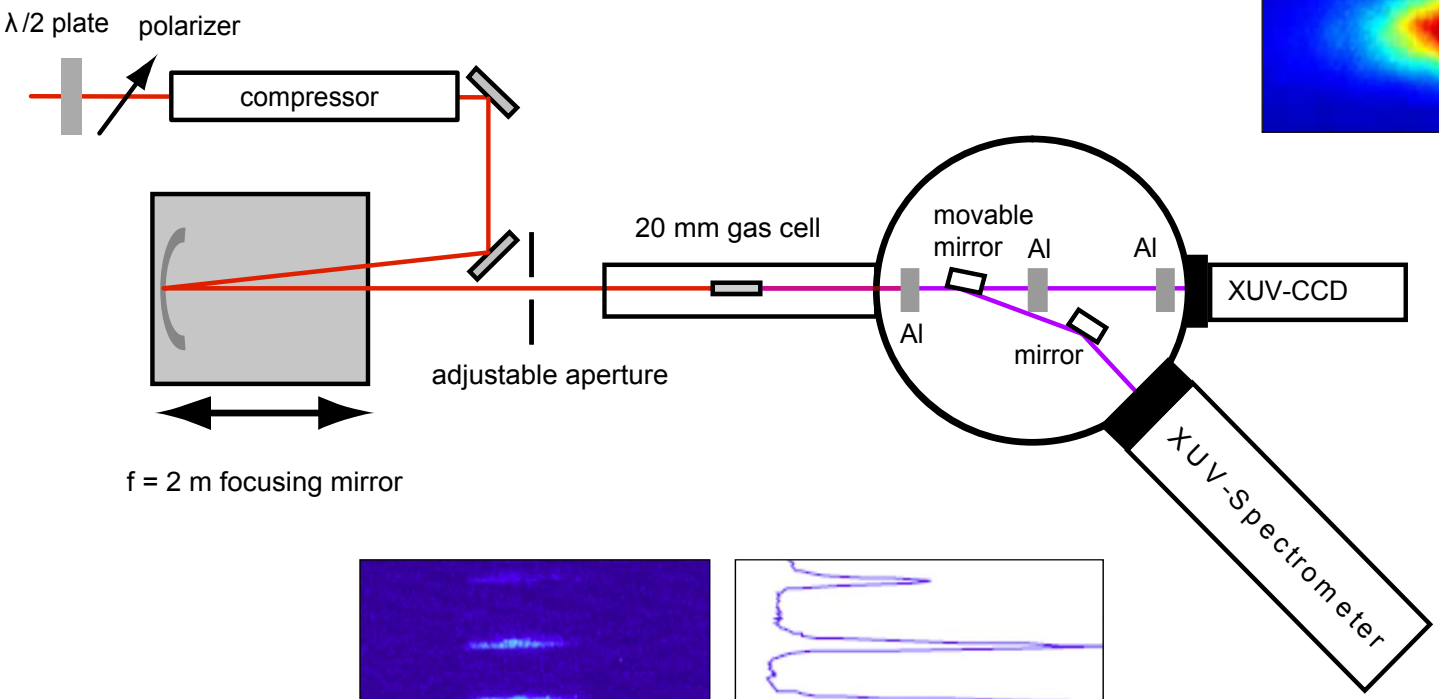
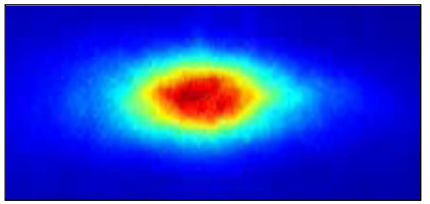
High Harmonic Generation (HHG) Laser

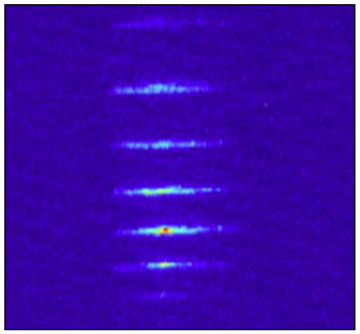
Lead by MAX Lab

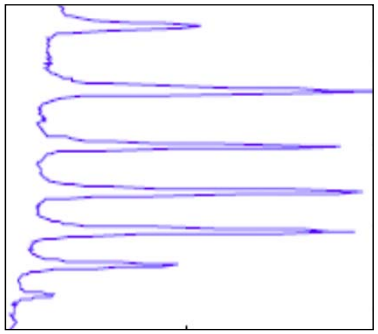
Verification of HHG source performance for FEL seeding radiation

Experimental setup





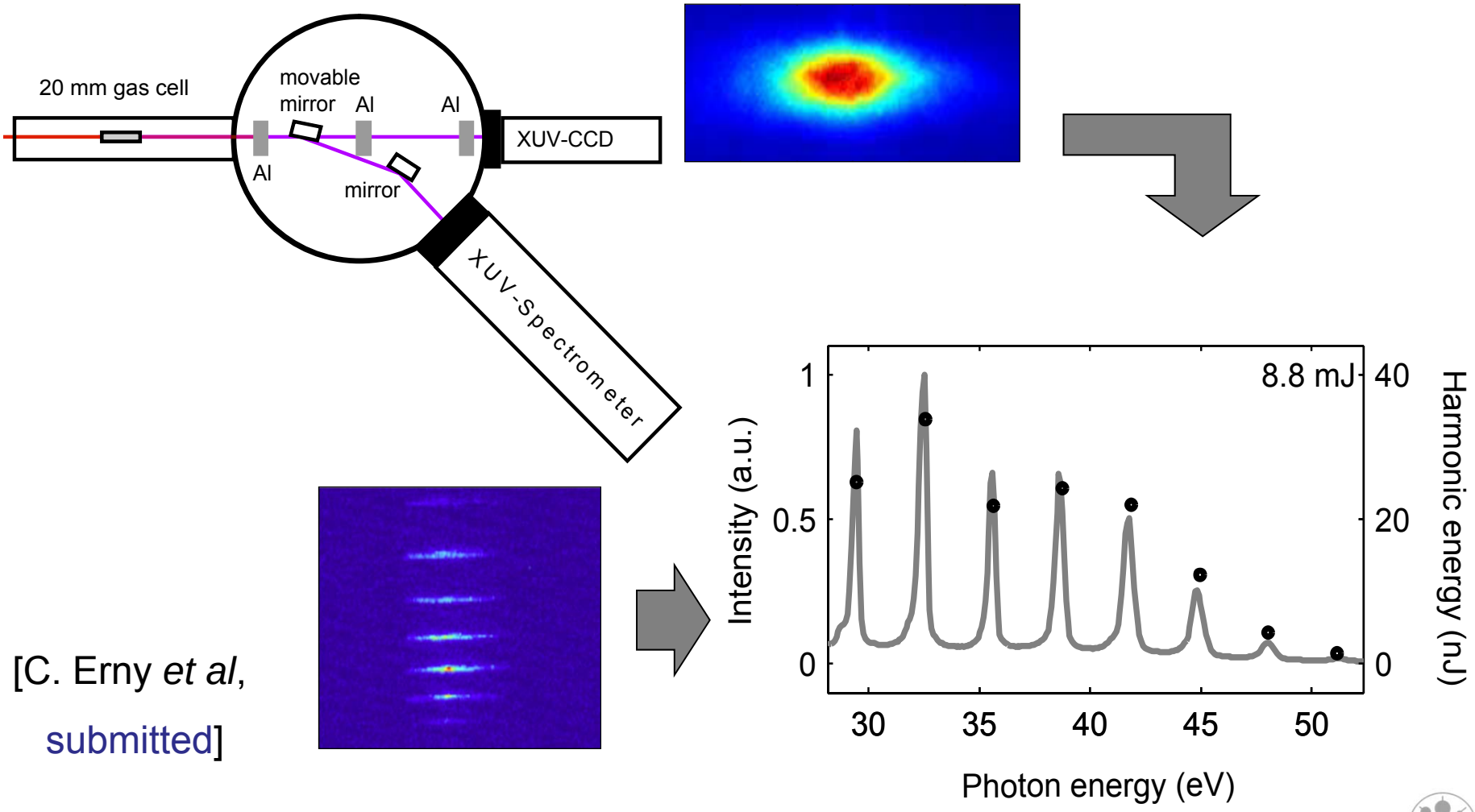




Courtesy: E. Mansten, S. Werin, MAX-Lab

Verification of HHG source performance for FEL seeding radiation

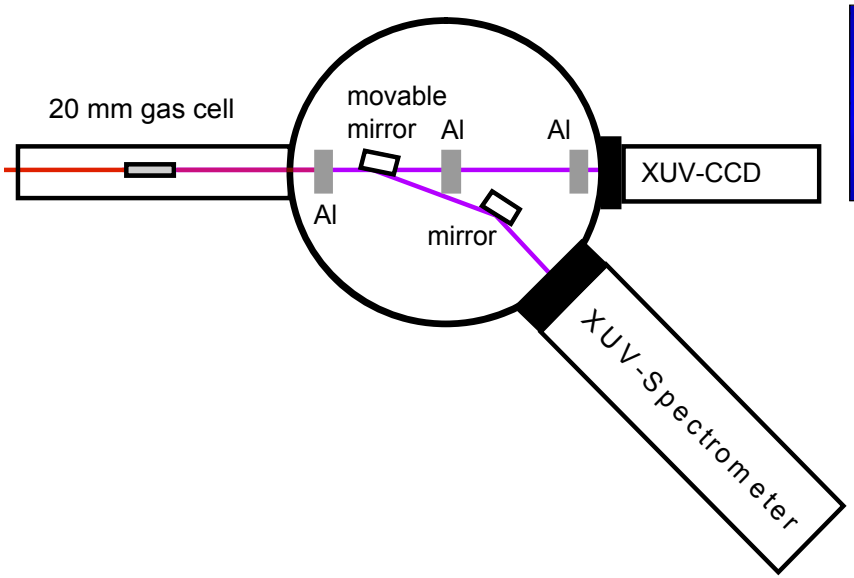
Number of HHG photons

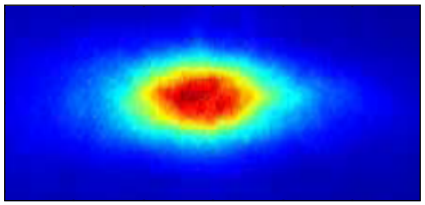


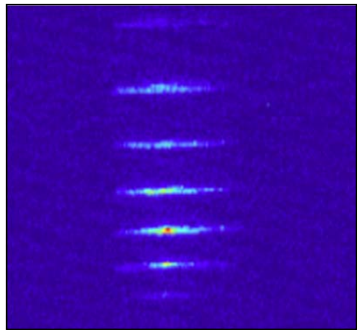
[C. Erny *et al*, submitted]

Verification of HHG source performance for FEL seeding radiation

Number of HHG photons







[C. Erny *et al*, submitted]

Take home message:

The energy and pointing stability of an HHG source is good enough for FEL seeding!

[C. Erny *et al*, submitted]

[A. Azima et al, Proc. of FEL 08, page 235, 2008.]

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Thank You!

I’m looking forward to continue the collaborations in the future!