

The SUNDAE2 measurement system at European XFEL



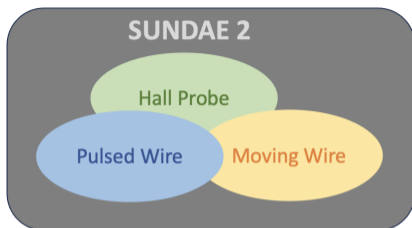
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ID26, Deauville, May 16-17



Outline



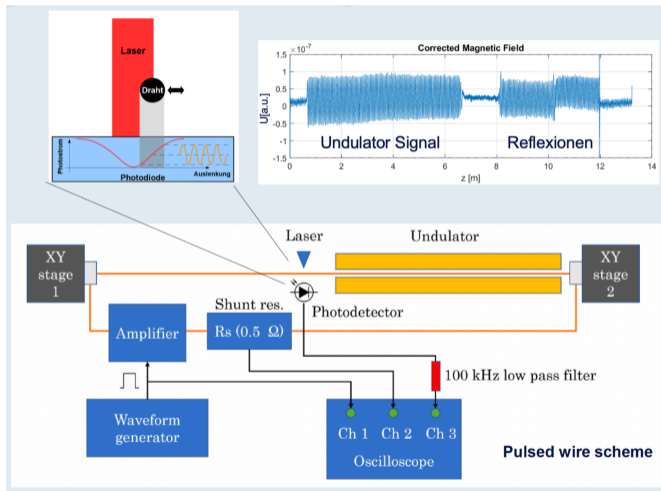
Setup:

- Pulsed Wire Method
- Experimental Setup
 - Overview
 - Vacuum Chambers
 - Stages
 - Current Pulse Sources
- Laser Cube

Measurements:

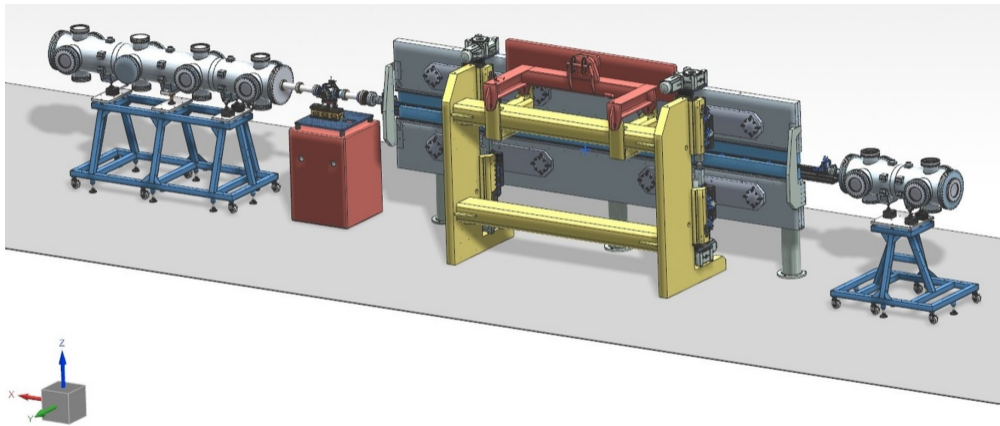
- Laser / Scope Evaluations
- Sensitivity Tests
- Arbitrary current pulses
- Signal decay
- Beat Oscillations
- Wire Calibration
- 1st Field Integral under Vacuum

Pulsed Wire Method



- electrical pulse in a thin wire
- wire stretched to yield point
- current deflects wire in magnetic field
- wave propagates in both direction
- measurement completed before reflections

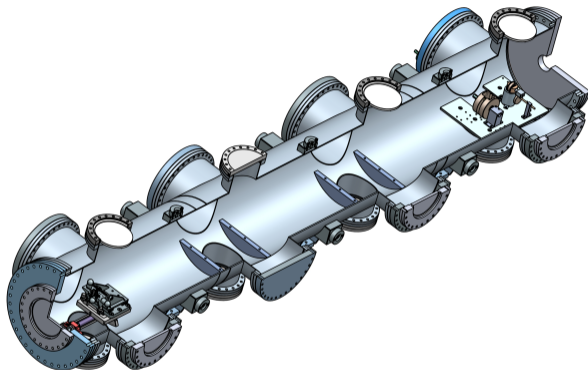
Experimental Setup - Overview



Experimental Setup: Overview

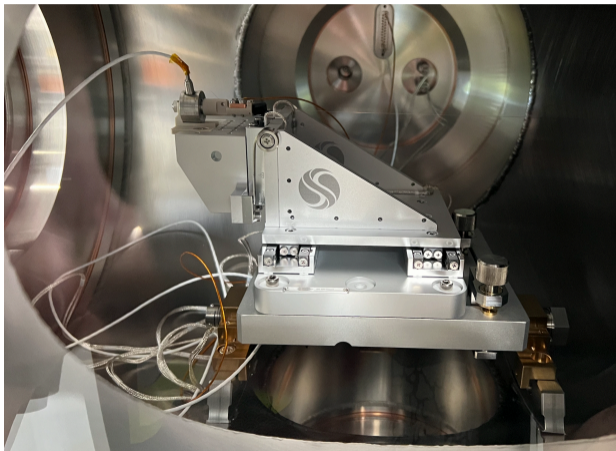


Experimental Setup: Vacuum chambers



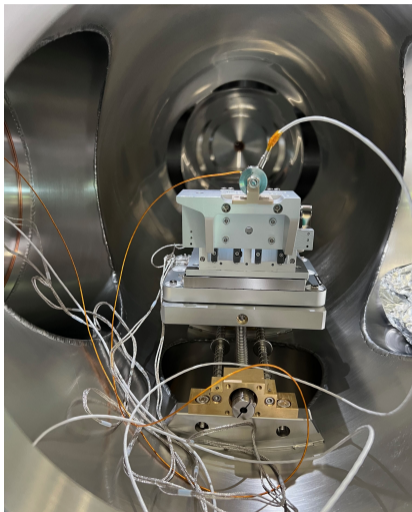
- Special Vacuum chambers produced by CECOM.
- Vacuum System following UHV rules

Experimental Setup: Stages



- xy piezo stages (SmarAct)
 - pulsed wire
 - moving wire
 - 60mm / 25mm travel
- z Phytron stepper
 - in situ tensioning
 - 150mm travel
- Tension sensor (Burster)
- Sorbothane damping

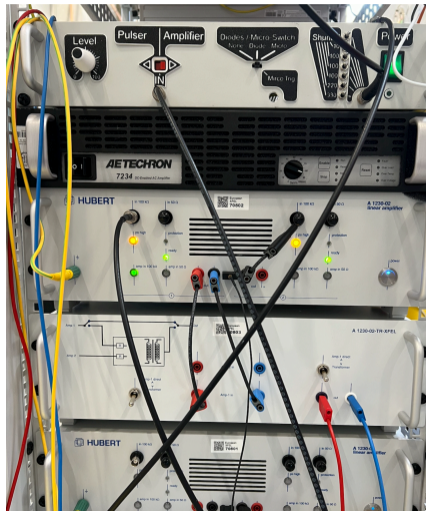
Experimental Setup: Stages



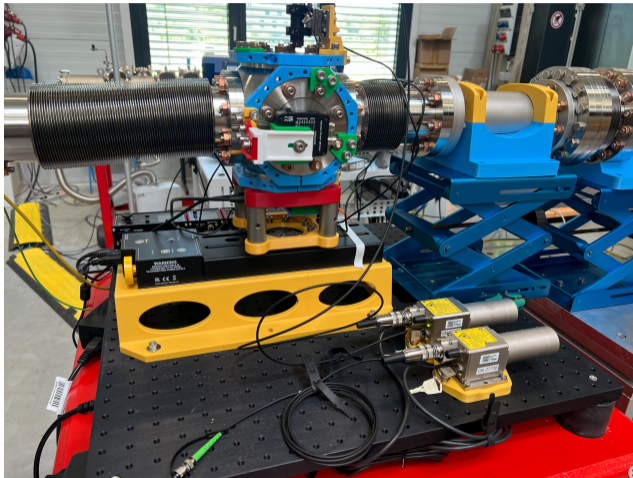
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Current Pulse Sources

- control unit
 - bipolar pulser GBS burstpuls1000
 - switch for direct / Diodes / MosFET
 - switch for Shuntss $1\Omega - 330\Omega$
- AETechron 7234
 - up to 150V
 - bandwidth 100kHz
- Hubert A1230-2
 - $2 \times 75V$
 - bandwidth 1MHz
- Hubert Transformer
 - factor 3
 - short pulses only

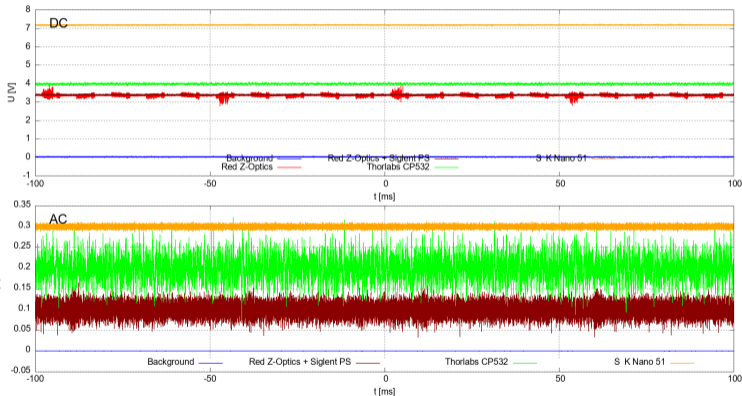


Laser Cube



- wire oscillation detection
 - in both planes xy
 - longitudinal positioning
- Laser S+K nano51-S
 - fiber coupled diode
 - low noise
 - adjustable power
 - 0.5W - class 2
- Photodiodes Thoarlabs
 - adjustable gain
 - low noise

Laser Evaluation



■ Laser / Photodiode noise

■ DC

■ AC

■ Test field

■ Thorlabs (green)

■ Z-laser (red / brown)

■ **Schäfer + Kirchhoff**
(orange)

■ Photodiode

■ **Thorlabs** (blue)

■ adjustable gain

Oscilloscope Evaluation

constant signal

signal splitted

same signal 4all

Oscilloscopes 12bit ADC

LeCroy

Pico HD "16bit"

Rhode & Schwarz HD
"18bit"

HD modes

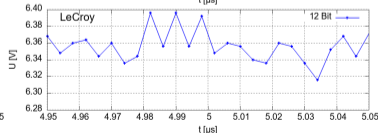
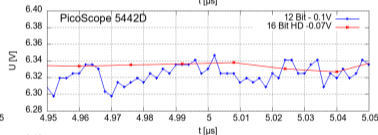
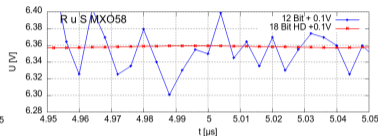
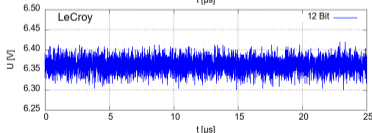
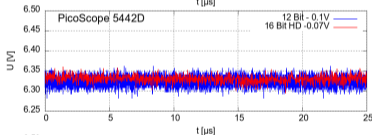
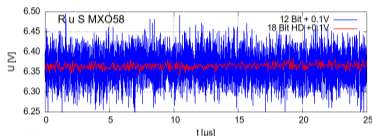
lower noise

sacrificing bandwidth

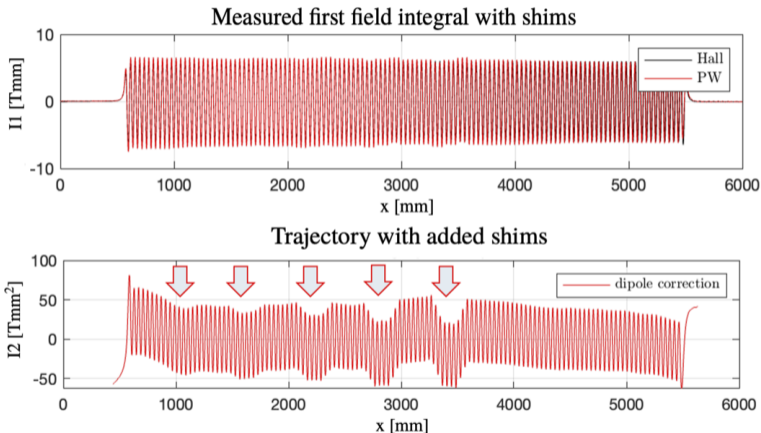
Pulsed Wire

pulse 1 - $25\mu\text{s}$

signal 5 - 50 kHz

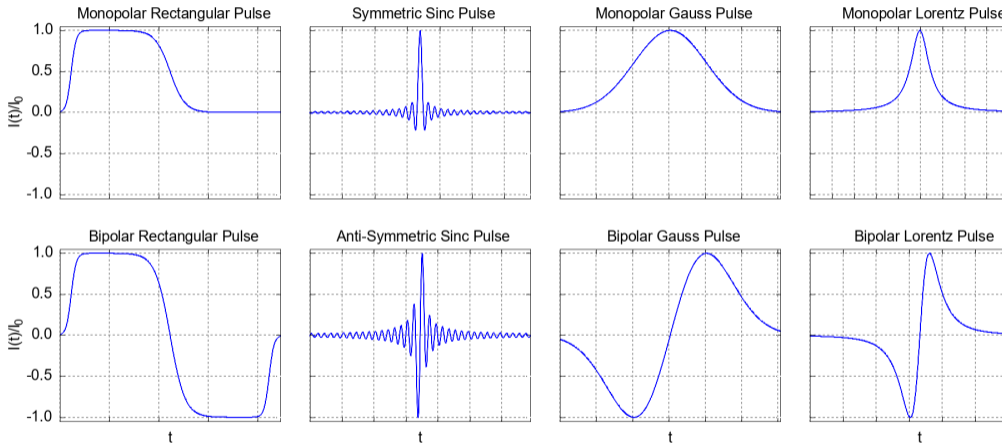


Sensitivity Tests in first and second field integrals



shim thickness $50\mu m$, $100\mu m$, $200\mu m$, $300\mu m$, $400\mu m$

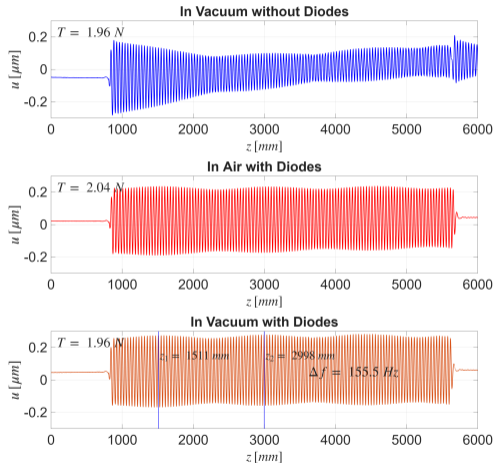
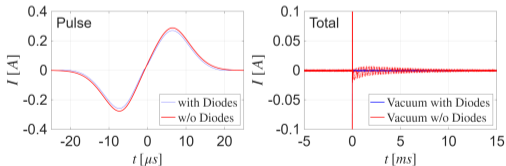
Pulse Forms: new approach



Decay

Observation:

- strong decay
- Diodes reduce decay strongly
- decay not visible anymore in vacuum



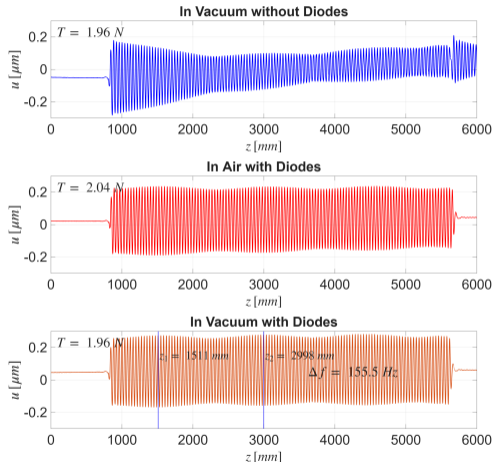
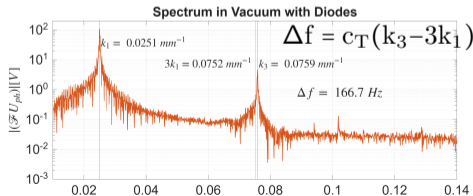
Beat Oscillations

Observation:

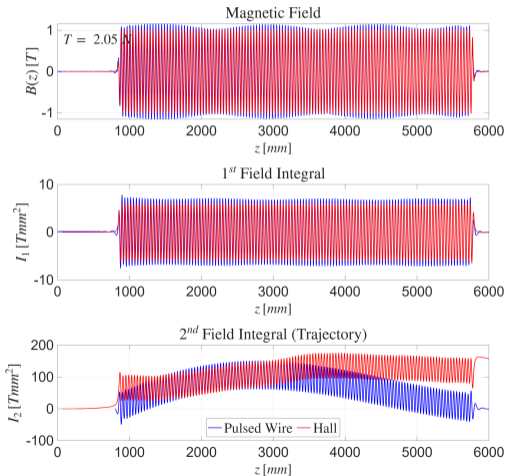
- low frequency oscillation
- matches longitudinal waves

$$c_T = \sqrt{\frac{T}{A\rho}} \approx 231 \frac{\text{m}}{\text{s}}, \quad c_L = \sqrt{\frac{E}{\rho}} \approx 3881 \frac{\text{m}}{\text{s}}$$

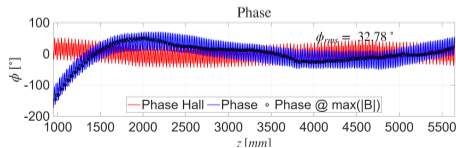
$$f_T^{(n)} = \frac{nc_T}{2L} \approx n \times 10 \text{ Hz}, \quad f_L^{(n)} = \frac{nc_L}{2L} \approx n \times 173 \text{ Hz}$$



1st Field Integral under Vacuum

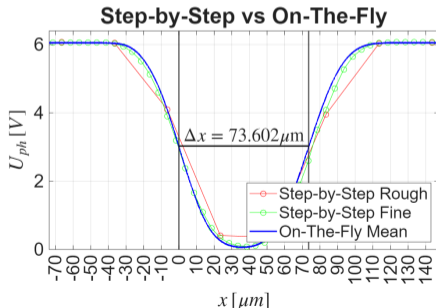


- Pulsed Wire (blue)
 - rectangular pulse
 - 10 μ s pulse width
 - 75 μ m CuBe wire, 200cN
 - 32 averages with individual calib
 - no earth field compensation
- Hall probe data (red)
- no decay, only beating
- no corrections applied
- pretty good agreement

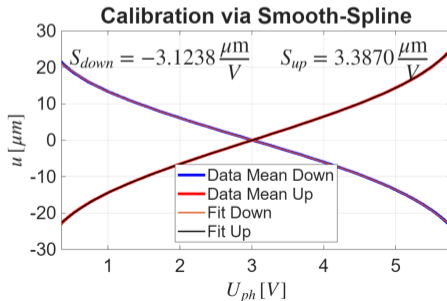


Wire Calibration

- Position data can be obtained from:
 - an internal or external position sensor
 - the stage movement speed
- Smooth spline: photo voltage vs deflection



- Continuous calibration monitoring (long pulsed-wire measurements)
- On-The-Fly measurements \Rightarrow short measurement times
- On-The-Fly: position voltage encoding



Summary

- SUNDAE2 setup optimized and tested for 5 m SCUs
- Vacuum operation successfully started
- Pulsed-wire data quality significantly improved
- Feedback current eliminated
- Remaining signal loss attributed to air resistance
- Beat oscillations still present, likely caused by longitudinal oscillations
- Beat oscillations affect:
 - field integral measurements
 - phase error analysis
- Undulator trajectory successfully reconstructed under vacuum
- System ready for trajectory measurements on SCU modules

Outlook

- include 2nd laser line
- include Hall Probe and Moving Wire
- suppress or correct beat oscillations
- extend software for arbitrary pulse shapes
- Correction algorithms and systematic effect compensation under development
- Hall probe system: currently being assembled and prepared for combined testing
- Full operational readiness planned by end of 2026



MAGNETIC DISCUSSION

Bruno Rommel

Thank you for your attention!

and all Undulator System Group members, especially

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Uwe Englisch

Sara Casalbuoni

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