

# Concepts and technologies for ultra-short beams

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version 23.2.2014 (H. Schlarb, M. Gensch, ASM)



## Sub-topic 3 in short...



### ... the hunt for a photon scientist's dream beam ...





ultra-short pulse lengths



## **Sub-topic 3 within ARD**





Cooperation with German universities, international cooperation partners and industry



## **Sub-topic 3 within ARD**









## **Science with short pulses**

- Short pulses of electrons and photons (X-ray to THz)
- Applications include
  - ultra-short pulse spectroscopy to study
    - catalytic reactions
    - phase transitions in solids
  - coherent imaging to:
    - make the molecular movie
    - extend protein crystallography to small crystals and individual molecules
    - follow nonlinear dynamics on the nanoscale







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## **Challenges & concepts**

- Short-pulse accelerators
  - tailored THz mid-IR pulses with high peak and average power
  - fully coherent XUV and X-ray light with (sub-) fs pulse duration
  - injectors to plasma wakefield accelerators (
     -> ST4)
- Short-pulse beams require
  - precise and fast controls with high demands on diagnostics and instrumentation (

     DTS)
  - a deep understanding of the complex beam dynamics
  - careful numerical simulations benchmarked by experimental results
- Activities structured into three major research areas
  - beam dynamics & photon sources
  - ps-fs beam diagnostics
  - stability, controls & synchronization





## Our sub-topic at work...





#### strong emphasis on

- education and exchange of technology & people
- sharing of test facilities (free access for students/young researchers)
- Information exchange / decision taking in topical workshops



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## Beam dynamics & photon sources - achievements



Beam dynamics & Photon Sources

Short bunches in linear accelerators

Coh. radiation & high fields in storage rings

Custom beams: bunch shape manipulation

Advanced photon sources development

Iong. phase space manipulation in storage rings

Rev. Accl. Sci. Tech., (03)165 (2010)

world-wide first fully synch.
 THz pump X-ray probe facility

Nature Photon. 3(2009), 523 Nature Photon. 5(2011), 162

 tape stacked undulator development (HTS)

T. Holubek et al., IEEE Trans. on Appl. Supercond. 4602204 Vol. 23-3 (2013)









## Beam dynamics & photon sources - goals





por de la comparación de la co





- Precise modeling of collective instabilities
  - understand and control underlying physics processes

- Femtosecond control of longitudinal bunch form
  - emittance improvement by factor > 2
  - femtosecond pulse compression

High charge short bunches for multi-user operation in circular accelerators

→ stable user operation with ultra-short bunches

## ps-fs beam diagnosticsachievements

ps-fs beam

diagnostics

Time domain

Frequency domain

Electron beams

Photon beams



N. Hiller, PhD Thesis (2013)

Iow charge electron bunch arrival time measurements at quasi-cw accelerators

C. Kaya et al., Appl. Phys. Lett. (2012)

ultra-fast detectors & high data throughput DAQ systems

- opens new window to beam dynamics
   DTS
- P. Thoma et al., Appl. Phys. Lett. 101, 142601 (2012)



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#### PAGE 11

## ps-fs beam diagnostics - goals

#### Online femtosecond arrival time diagnostics

electron and photon arrival monitors suitable for low charge and high repetition rate

#### Online femtosecond bunch profile diagnostics

- frequency domain approaches
- laser based monitor systems

#### ► High data rate detector systems for high repetition rate accelerators

high speed 1D and 2D beam monitoring systems for fast transient phenomena

strong connection to sub-topic 4 and DTS









## Stability, controls & synchronization





#### RF stabilization to femtosecond optical reference



T. Lamb, IBIC 2013



## Stability, controls & synchronization



- Optical synchronization with femtosecond accuracy
  - → two approaches: accuracy vs cost efficiency
- Modern crate system MicroTCA.4 for precision controls in accelerators
  - $\rightarrow$  establish technology, make us of high speed detectors  $\rightarrow$  DTS
  - → adapted software & firmware to specific facility control architecture



- Establish femtosecond RF controls for normal and sc accelerators
  - → precision phase and amplitude stability for ps-fs beam controls
  - typical goals 1..10fs (depending on facility layout)
- Seeding at XUV wavelength at FLASH and DELTA established



## **Available test facilities**



development and testing of ultra-

- complementary infrastructures
- preparing the technology for next generation accelerators



## **Test facilities & outlook**





## **Summary**



- Short electron & photon pulses
  - enable the world-leading research in the MML program (e.g. FLASH, X-FEL)
- Short-pulse research in ARD aims at:

  - understanding of the beam dynamics
  - complimentary test facilities
- Sub-topic 3 developments have strong impact on:
  - plasma acceleration research -> ST4
  - SRF developments → ST1
  - future user facilities → MML & MU

Paving the way for the future ....





### **Backup slides**





## **Core test facilities**

**TELBE (THz Electron Linac for** beams with high **B**rilliance and low **E**mittance):

- test facility for quasi-cw electron beams
- pC to 1nC bunch charge
- Europe's only quasi-cw electron beams with repetition rate of up to 13 MHz

**PITZ (Photo Injector Test Facility at the DESY location in Zeuthen):** 

- test facility for electron beams in the burst mode
- exact same burst mode pattern as FLASH and European XFEL
- unique photo-injector laser which for longitudinal bunch shaping
- transverse deflecting cavity

FLUTE (Ferninfrarot Linac- Und TestExperiment):

- test facility for single-shot diagnostics
- few pC to 3 nC bunch charge
- repetition rate of 10 Hz

nELBE

on bunches electron-laser

interaction

- achieve bunch lengths down to 1 fs
- diagnostics & dynamics for future plasma wakefield injectors

TELBE

plasma cell



photo gun

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## **Funding and research areas**



#### **Research areas**





beam dynamics & photon sourcesps-fs beam diagnostics

stability, controls & synchronization



## **Funding and work packages**



#### Work packages



#### ST3: ps-fs electron and photon beams



- Precise modelling of collective instabilities
- Femtosecond control of longitudinal bunch form
   Beam studies with high charge (circular acc.)
- Online fs arrival diagnostics
- Online fs bunch profile diagnostics
- High data rate fast beam monitoring detectors
- uTCA high speed precision control systems
  - Fs RF control systems
- Optical synchronisation with fs accuracy
- Seeding at short wavelength at FLASH and DELTA

![](_page_21_Picture_15.jpeg)