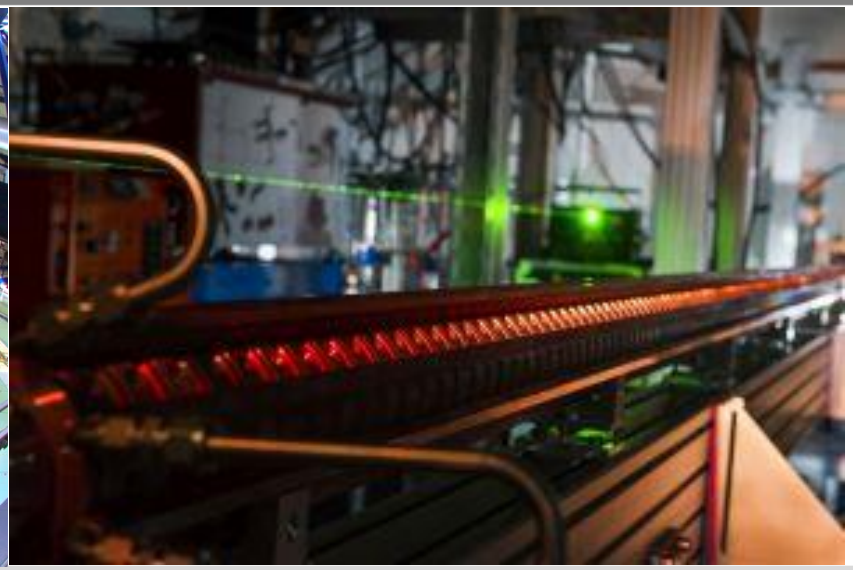
The KIT accelerator test facilities: Karlsrhe Research Accelerator KARA, short-pulse linac FLUTE and magnet characterizaton facilities

Akira Mochihashi, On behalf of IBPT test facilities
Karlsruhe Institute of Technology (KIT)



IBPT - KIT

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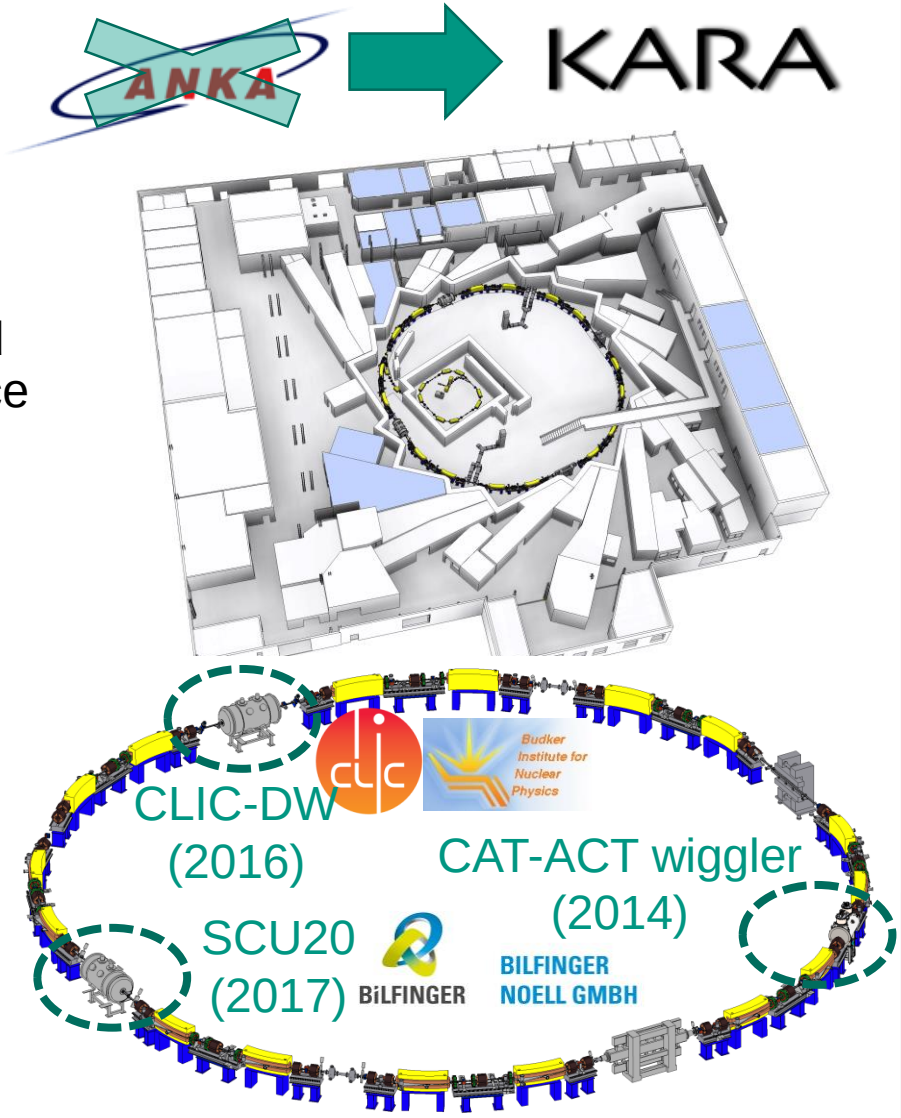
Karlsruhe Research Accelerator KARA

- From ANKA „users facility“ to **KARA „accelerator test facility“**
  - **Misson:** research & development of beam physics and technology
  - **Additionally,** KARA can be operated as a synchrotron radiation light source

- Key parameters of **KARA**
  - Beam energy: 0.5 – 2.5 GeV
  - Beam current: up to 200 mA
  - Circumference: 110 m
  - 500 MHz RF system
  - RMS bunch length: 50 to few ps

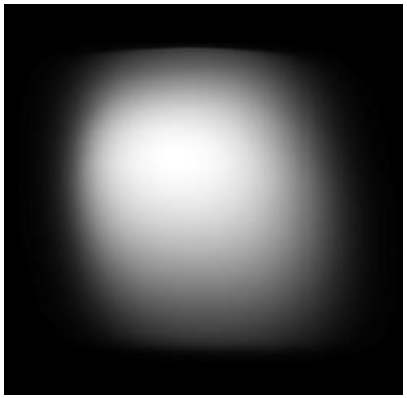
- Outstanding features
  - **Superconducting undulators**



MCF: Magnet Characterization Facilities

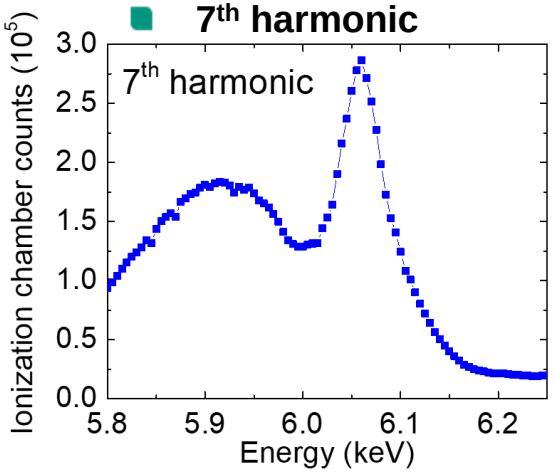
SCU20: First commercial product worldwide

- **Installation in December 2017**
- **Successfully operating in the KIT synchrotron since January 2018 without quenches**
- **First X-rays 10.1.2018**



S. Casalbuoni et al., SRI2018

- **7th harmonic**



Courtesy of Dr. S.Casalbuoni

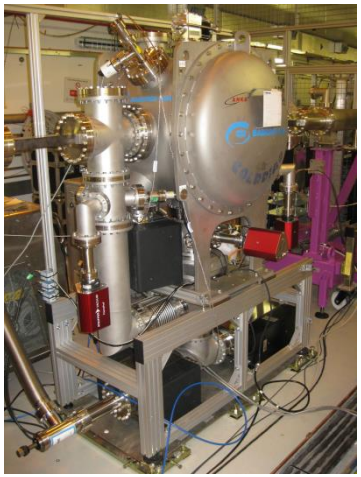
Infrastructure at KIT for SCU technology

- To advance SCU technology unique infrastructure to characterize the magnetic field (MCF) of the superconducting coils (quality assurance) and to measure input parameters necessary for the design have been developed.

CASPER I

CASPER II

COLDDIAG

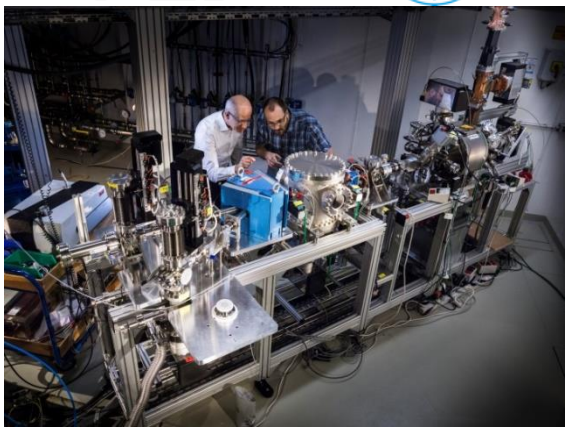


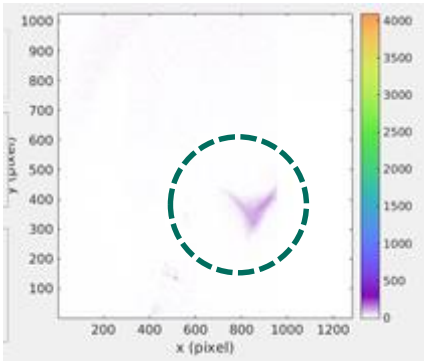
A. Grau et al., IEEE Trans. Appl. Supercon. 26-4 410804 (2016)
R. Voutta et al., PRSTAB, 19, 053201 (2016)

Courtesy of Dr. S.Casalbuoni

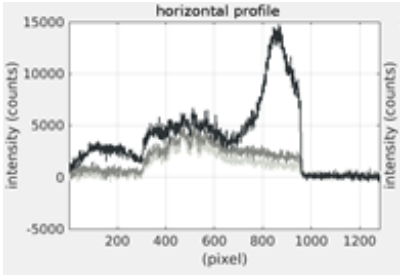
FLUTE: short-pulse linac test facility

- FLUTE (**F**erninfrarot **L**inac- **U**nd **T**est-**E**xperiment)
  - Linac test facility for **femtosecond electron beam**
  - Generaton of **THz coherent synchrotron radiation**
- R&D topics
  - Test bench for new diagnostic methods in fs-range
  - Synchronization on a femtosecond level
  - Bunch compresson, beam physics



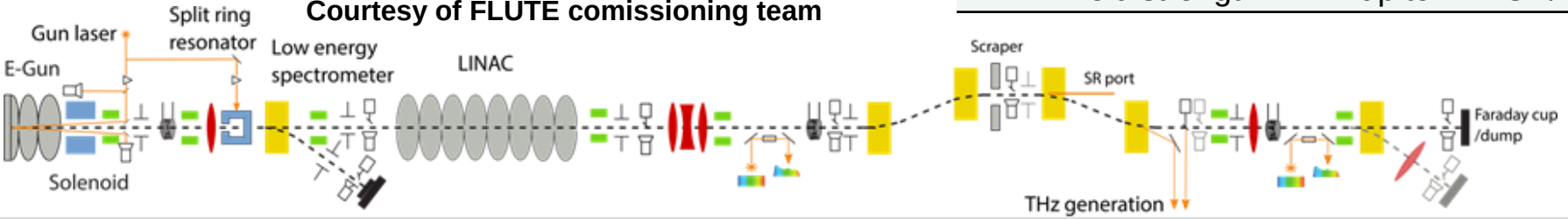


First beam from FLUTE



Courtesy of FLUTE comissioning team

Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 3	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m



KARA storage ring: accelerator operation Today

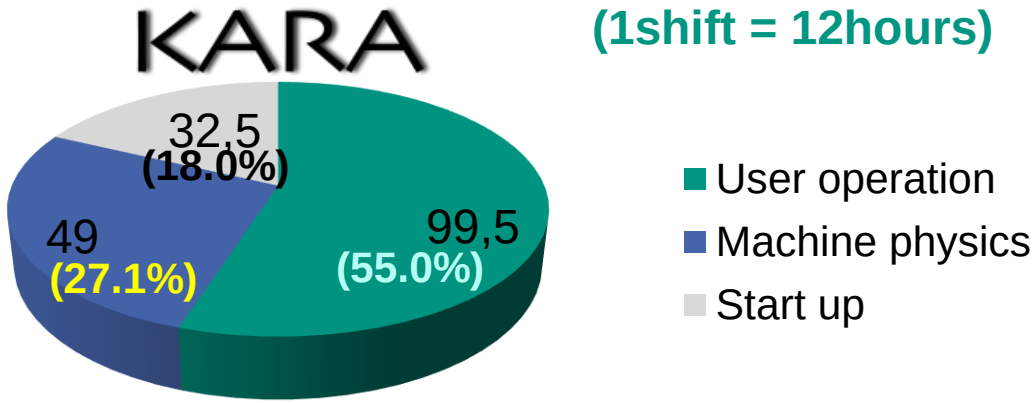
- **Machine physics (588 hrs.)**
  - 1week per month (in average)
  - Test for new diagnostic device
  - Beam physics & development
  - Low alpha operation etc.

- User-operation (1194 hrs.)
  - From Tuesday to Friday
  - Injection: once per a day (150 mA)
  - Energy ramping: 0.5 to 2.5 GeV
  - 70 mA at next injection
  - Beam injection by 1-2 operators
  - Stable beam delivery

- Start-up
  - Monday afternoon
  - Accelerator tuning

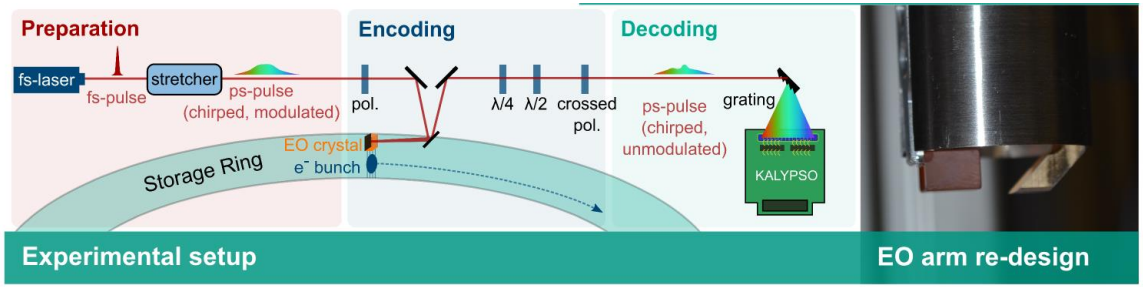
We have good activities for machine physics experiment.

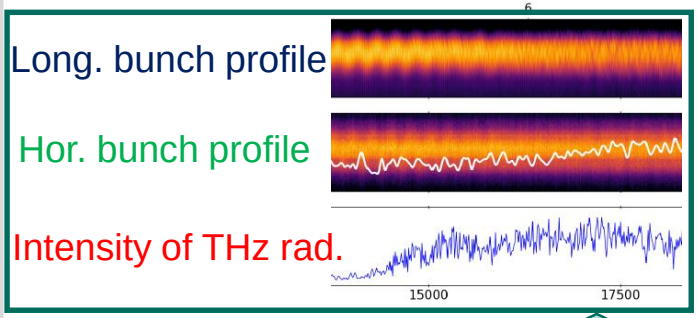
2018 Operation calendar: Total 181 shift (1shift = 12hours)

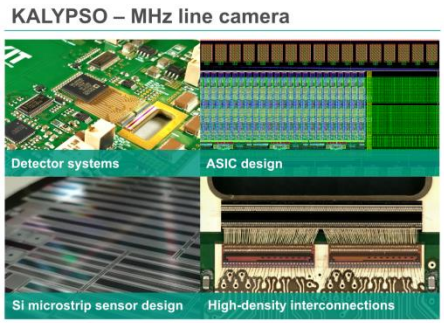


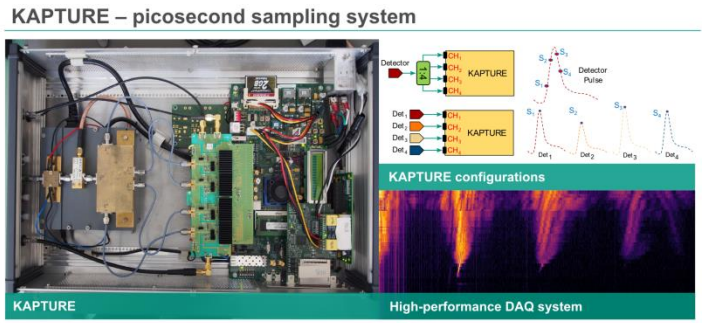
An example of activities: THz CSR&beam physics

- Bursting THz CSR observation: **time-resolved phase space tomography**
  - Low alpha 1.3 GeV
  - MHz line camera **KALYPSO**
  - Picosecond sampling system **KAPTURE**
  - **EO sampling** in KARA



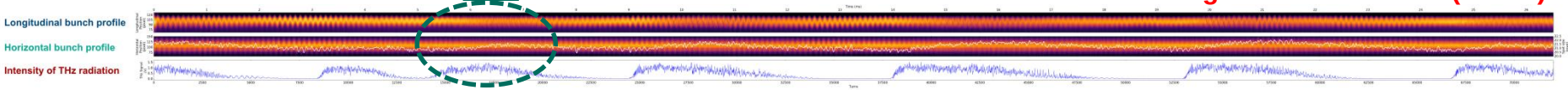




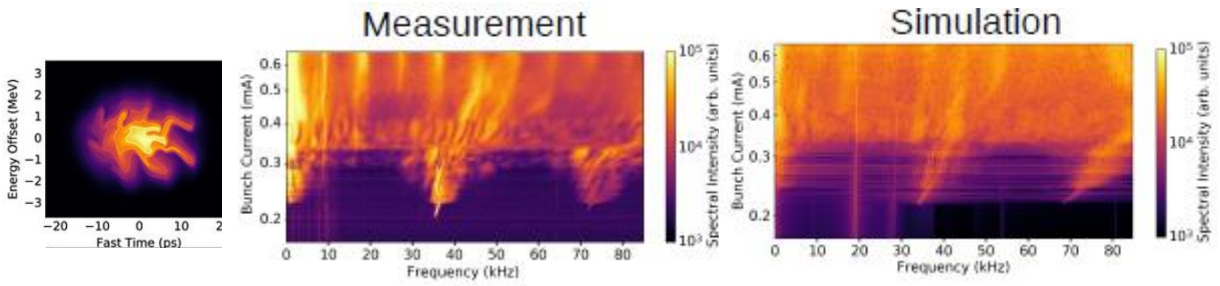


Turn-by-turn resolution

Longer than 70000 turn(26 ms)

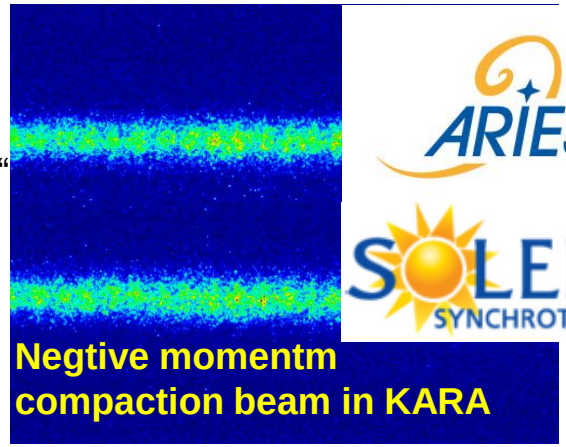


- Microbunching instability
  - Vlasov-Focker-Planck Solver **„Inovesa“**
  - Physics of microbunching instability

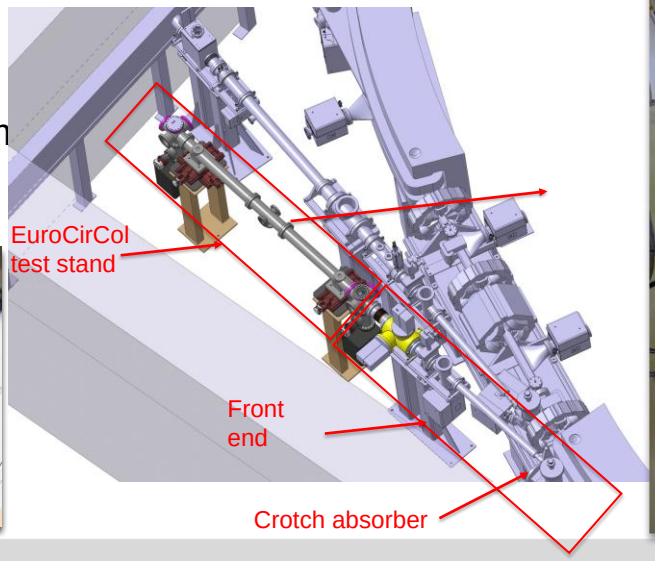


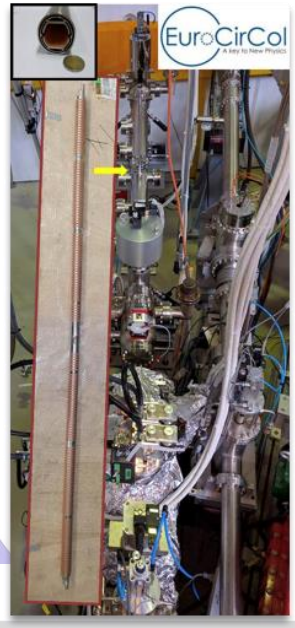
An example of activities: ARIES and EuroCirCol

- **ARIES** (**A**ccelerator **R**esearch and **I**nnovation for **E**uropean **S**cience and Society)
  - KIT as a member of „Rings with Ultra-Low Emittance (RULE)“ in **ARIES-WP7**
  - Beam dynamics in low and **negative momentum compaction factor**
  - Transnational Access Scheme (**TNA**) in ARIES
  - KARA & FLUTE: as facilities offering TNA for „Electron and proton beam testing“ in **ARIES-TNA-WP11**



- **EuroCirCol** (The **Euro**pean **Cir**cular Energy-Frontier **Col**lider Study)
  - „Measurements of cryogenic beam vacuum system prototype (**KIT**, INFN, CERN)“ in **WP4 Task4.6**



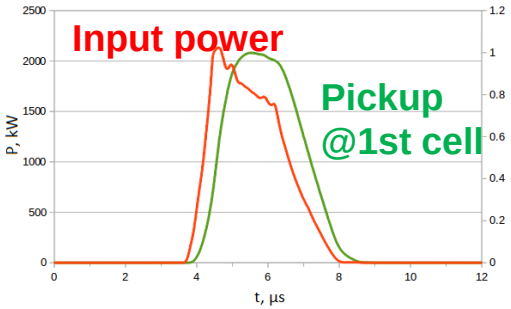


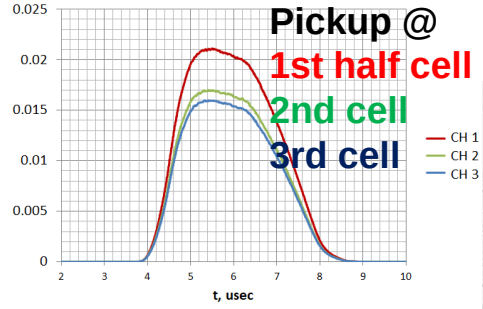
FLUTE short-pulse linac facility: present status

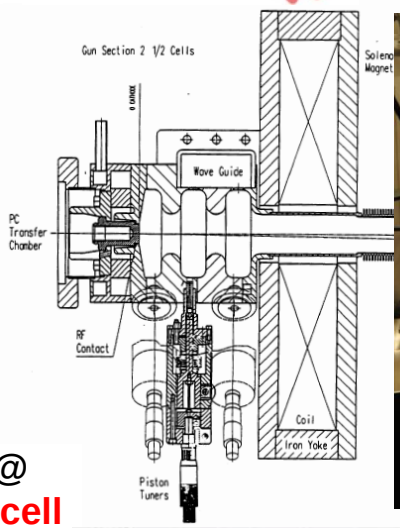
- Commissioning of RF photo injector

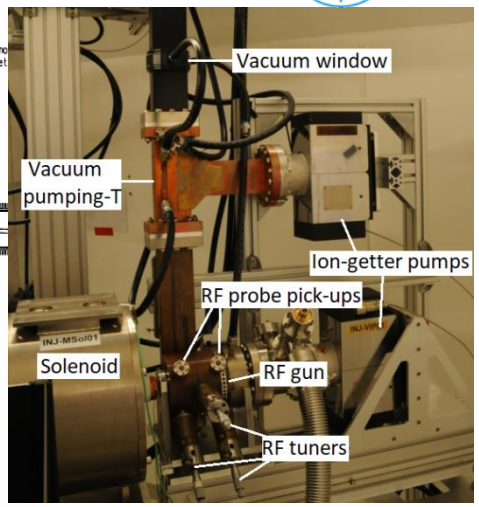
RF photo-injector parameters		
Frequency	2.998	GHz
Cells	2.5	
Peak E-field	100	MV/m
Peak power	20	MW
Output energy	7	MeV

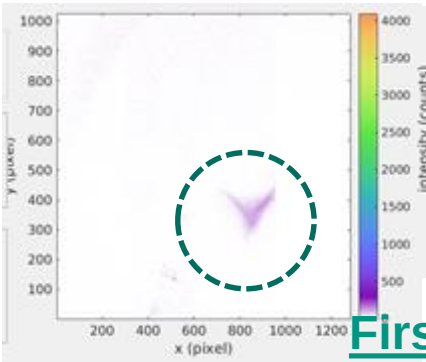
Input power to RF gun: 4 MW

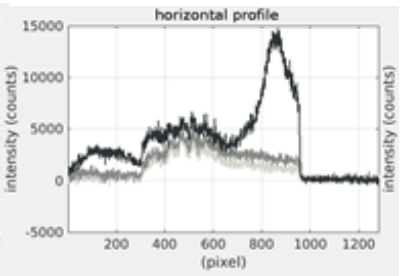












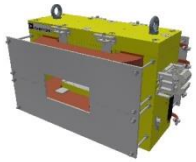
First beam on YAG screen

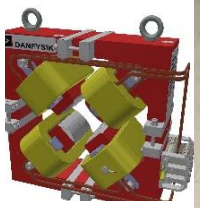
Courtesy of FLUTE comissioning team

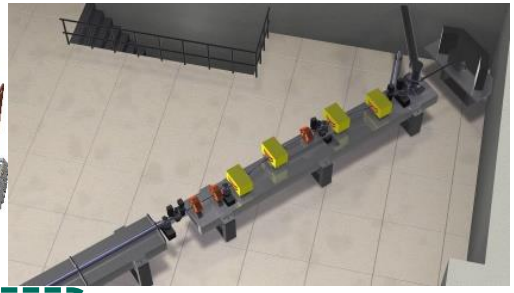
- To go proceed RF commissioning:
  - Replacement of Circulator on April 2019
  - Commissioning of different RF components can be possible after the replacement

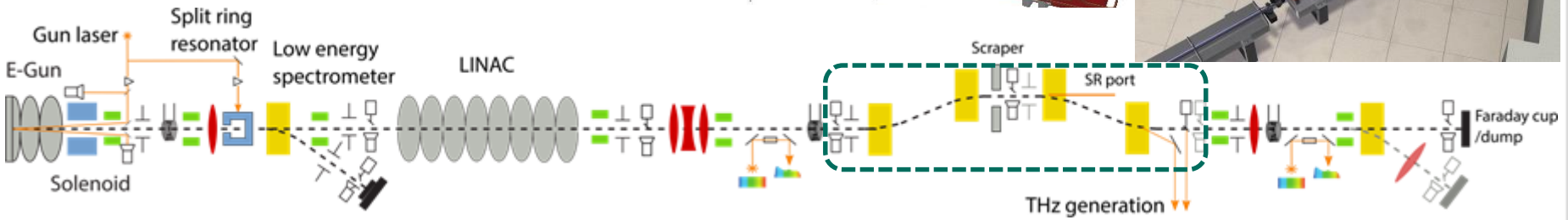
FLUTE short-pulse linac facility: ongoing plan

- Construction of **bunch compressor**
  - Dipoles have been delivered
  - Quads are in production





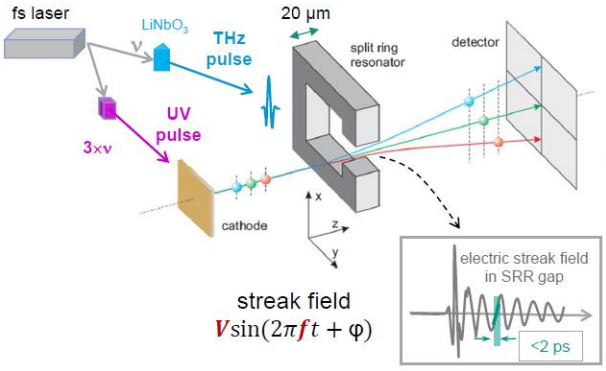


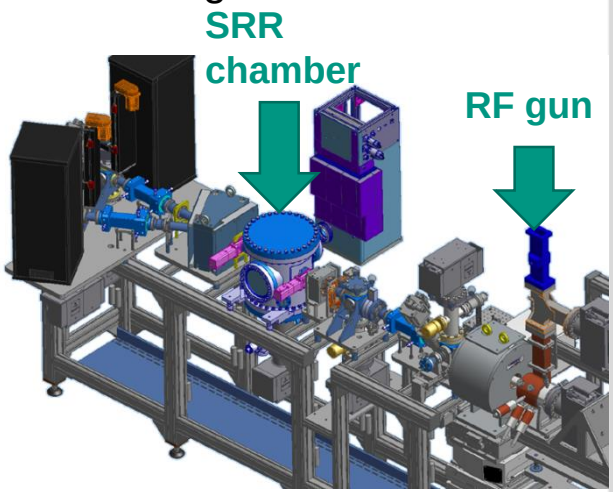


- **Ultra-short bunch diagnostics**
  - Split ring resonator **SRR:** femtoseconds beam streaking with THz high intense EM field
  - Driven by fs laser for the RF photocathode

Table: SRR parameters

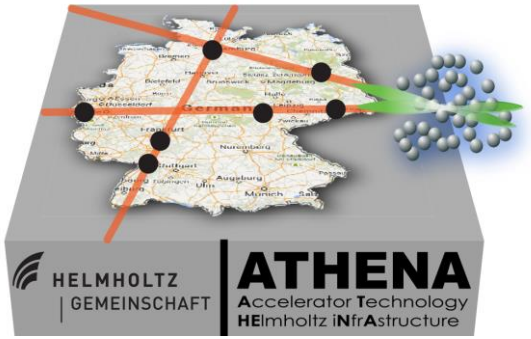
Gap size in x	20 μm
Gap size in y	20 μm
Gap width in z	10 μm
Resonant frequency	300 GHz
Peak electric field	500 MV/m
Integrated field	10kV





Distributed accelerator test facility: ATHENA

- **ATHENA**: **A**ccelerator **T**echnology **He**lmholz I**nfra**structure
  - **Distributed accelerator test facility in Germany**
  - **Collaboration and Synergy** of 6 Helmholz centers
  - DESY, GSI with HI Jena, HZB, HZDR, FZJ, and **KIT**
  - **Funded on 2018 with 30 million Euro**



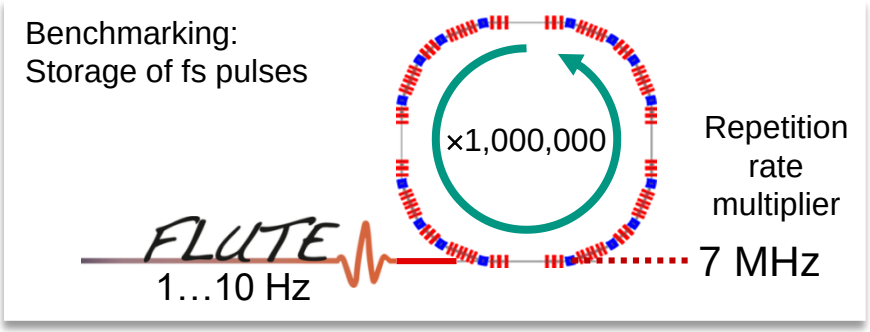
- **ATHENA at KIT**
  - Real-world applications of **LWFA** electron beams
  - Enable multi-user access for materials and life sciences applications
  - *Example*: MHz-repetition rate terahertz medical imaging facility (TMED)
  - Benefits from **cSTART** and sensor technologies

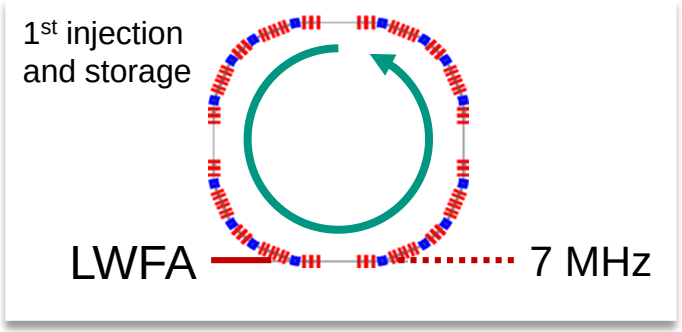
- **From acceleration towards accelerators and user-readiness**

Compact storage ring test facility: cSTART

- **cSTART: c**ompact **St**orage Ring for **A**ccelerator **R**esearch and **T**echnology

  - **Storage of ultra-short (fs) electron bunches**
  - 1st study[1)]: laser wakefield accelerator(LWFA) injection in ring-based light sources
  - Unique design[2)]: non-equilibrium ring with **very large momentum acceptance**
  - Goal: world-wide 1st **injection & storage of a LWFA beam** in a storage ring





[1)]S. Hillenbrand (RU5) *et al.*, NIM A 740, 153 (2014); S. Hillenbrand, Ph.D. thesis (2013).
[2)]A. Papash, E. Bründermann, A.-S. Müller (all RU5), Proc. IPAC2017, TUPAB037 (2017).

As facilities of ARIES Transnational Access

- **KARA & FLUTE**
  - Transnational Access Scheme (**TNA**) in **ARIES**
  - As facilities offering TNA for **„Electron and proton beam testing“ in ARIES-TNA-WP11**
  - New experiments and projects in the framework ARIES-TNA has been planned **JUST NOW.**

Please contact to ARIES-TNA if you have some new ideas of interesting experiments in KARA and FLUTE.

We are looking forward to seeing you at KIT with good collaboration!

https://aries.web.cern.ch/ta

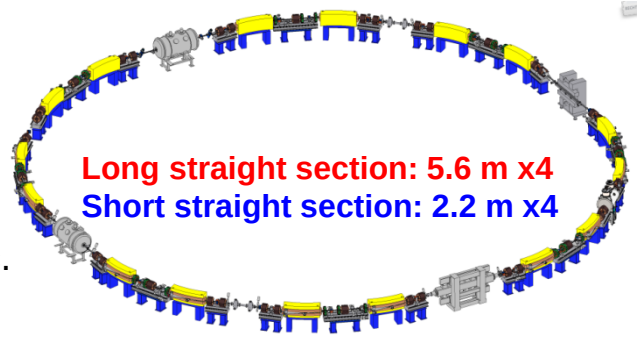
Future KARA: Beam Physics Test Facility

- **As a platform of beam physics experiment**
  - Installation of **„universal device section“** into KARA storage ring
  - Users perform **„Plug & Play“ experiment** with 0.5 – 2.5 GeV beam

- **Examples of the Plug & Play experiment**
  - Vacuum chamber with variable aperture & coating: ***impedance***
  - Beam test for insertion devices & magnets: ***light source development***
  - Beam instrumentation devices: ***beam dynamics & diagnostics***
  - RF devices : ***RF acceleration & beam manipulation*** and more..

So many world-wide contributions to the accelerator physics and technology can be expected

- **Advangates of experiment at KARA**
  - Systematic beam diagnostic measurement is possible **now**
  - Flexibility of beam condition: bunch length, beam energy
- **R&D topics for Plug&Play experiments**
  - Science: improvement of beam tuning knobs, diagnostics etc.
  - Technology: vacuum system design, alignment method etc.

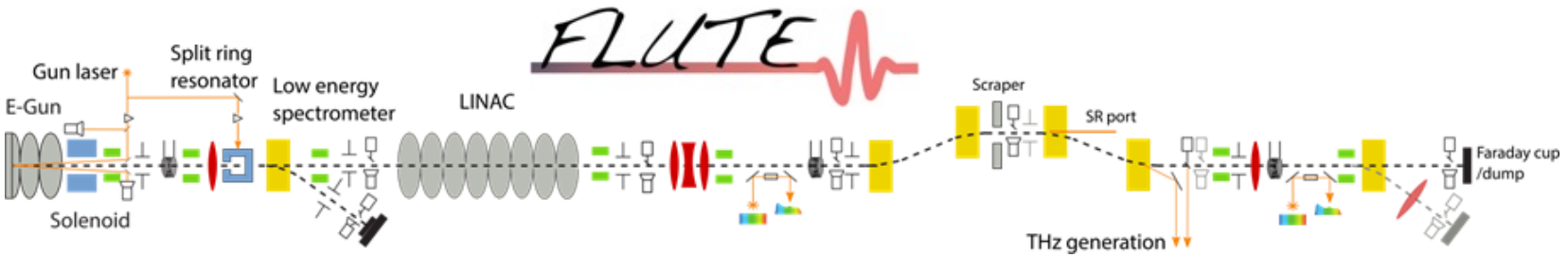


Future FLUTE: Short-pulse Beam Facility

- **Beam physics experiment with real short-pulse electron beam**
  - Preparation for **experimental station beamline**
  - Users perform experiments with their own instrumentation

- **Examples of the experiment with short-pulse beam in FLUTE**
  - R&D of beam diagnostics and instrumentation: ***beam dynamics & diagnostics***
  - Generation of THz radiation: ***light source***
  - Short-pulse electron beam application: ***material science & chemistry***

So many contributions to both the accelerator physics and matter science can be expected



Summary: Present status

- **Karlsruhe Research Accelerator KARA**
  - **Accelerator test facility** with 0.5-2.5 GeV electron storage ring
  - Activities for machine physics
    - THz CSR generation, microbunching instability etc.
    - ARIES, EuroCirCol project

- **FLUTE short-pulse linac test facility**
  - **First beam confirmed** and further commissioning now
  - Ultra-short pulse generation
    - Bunch compression
    - Femtosecond beam diagnostics: splitting ring resonator

- **Distrubuted accelerator test facility: ATHETA**
  - Funded and ongoing now
- **Compact storage ring test facility: cSTART**
  - Funded and ongoing now

Summary: Future plan

- **Future KARA**
  - **Platform of beam physics experiment**
  - **„Plug & Play“ experiment in „universal device section“** at KARA storage ring
  - To keep flexibility of experimental condition and beam operation

- **Future FLUTE**
  - **Beam physics experiment station** with short-pulse electron beam
  - Users can bring their own instrumentation and perform their experiment
  - Accelerator physics, material science, chemistry etc.

So many contributions to the accelerator physics and related sciences can be expected

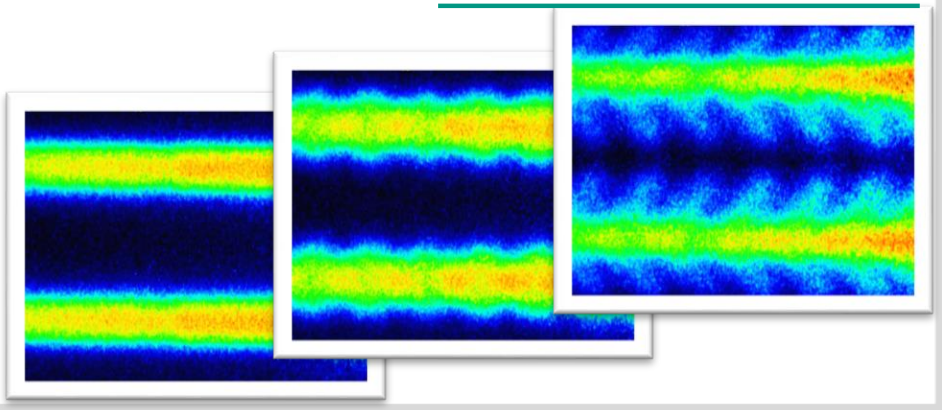
Thank you very much for your attention!

Backups

Future plan: KARA storage ring

- **Control & manipulation of accelerators and beams**
  - **Control:** optimization of operating parameters by **machine learning**
    - Optimization of injectors (booster, microtron, beam transport line)
    - Optimization of storage ring for various kind of operating modes
  - **Control:** accelerator operation with **saving energy consumption**
    - Optimization of booster operation: pattern control
    - Optimization of warm-up process in storage ring: start-up/shut-off sequence control
    - Cooling water, air conditioning control
  - **Manipulation:** 3-dimensional **beam manipulation**
    - RF gymnastics and modulation
    - Alpha (and lattice) manipulation
    - Expansion of dynamic aperture
    - Improvement of tuning knobs
    - **Control of THz CSR generation**

RF modulation in KARA



Future plan: FLUTE short-pulse linac facility

- **Control & application of ultra-short pulse beam**
  - **Control: bunch compression** to ultra-short pulse
    - Beam diagnostics of THz-CSR from bunch compressor section
    - **Feedback** to linac/laser parameters with **machine learning** by THz-CSR diagnostics
  - **Application: ultra-short pulse beam source**
    - R&D for new detectors and beam diagnostcs devices
    - Electron beam & THz-CSR beam
  - **Application:** an injector for cSTART ultra-short pulse storage ring
    - Optimization of injection condition for ultra-short pulse beam

... And more!

IBPT: Institute for Beam Physics and Technology

- Director: Prof. Dr. Anke-Sussane Müller
  - Coodination & project team
  - Safety & radiation protection team
  - Administration team
- Operation-1 & Accelerator R&D Gr.
  - Device team
  - Theory & beam dynamics team
  - Control & instrumentation team
  - THz/IR application team
- Operation-2 & Accelerator R&D Gr.
  - Diagnostics R&D team
  - New accelerator concept team
  - IT team
  - Insertion device team
- Technical Gr.
  - Workshop team
  - Construction team
  - Vacuum, water & cooling team
  - Electricity & electronics team

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