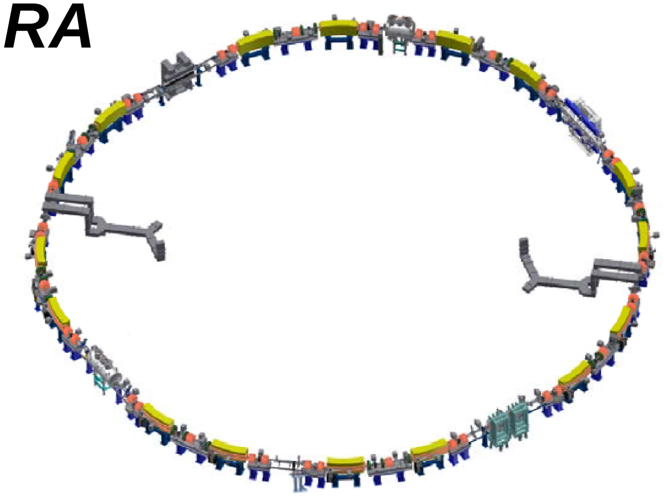
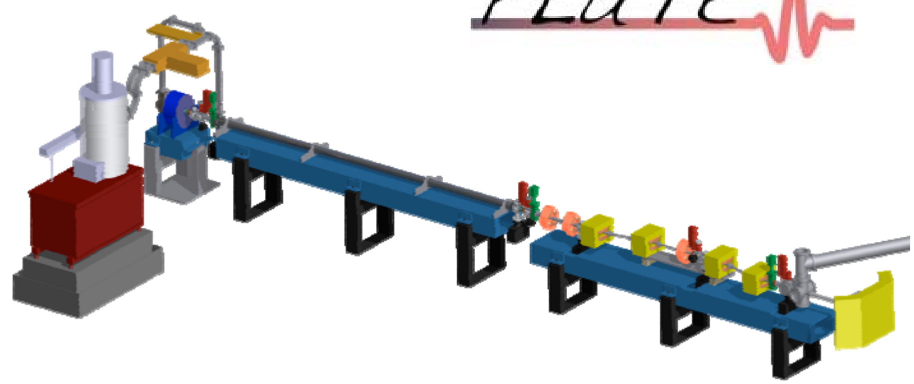
KARA and FLUTE RF Overview/status

Nigel Smale on behalf of IBPT and LAS teams

Laboratory for Applications of Synchrotron radiation (LAS)
Institute for Beam Physics and Technology (IBPT)

KARA



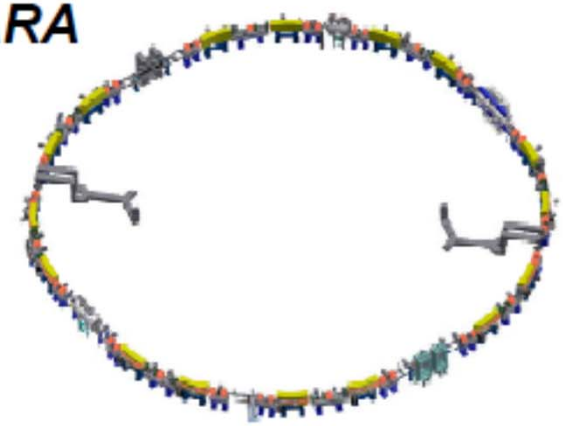


Outline

- **KIT accelerators KARA and FLUTE**
- **KArlsruhe Research Accelerator (KARA)**
  - RF system
  - LLRF
- **Far-infrared Linac and Test Experiment (FLUTE)**
  - What is FLUTE
  - FLUTE layout
  - RF
  - LLRF
- **Summary**
- **Questions to me**

Accelerators @ KIT

KARA



FLUTE

- Circumference: 110.4 m
- Energy range: 0.5 – 2.5 GeV
- RF frequency: 500 MHz
- Revolution frequency: 2.715 MHz
- Beam current: up to 200 mA
- RMS bunch length: 45 ps – few ps

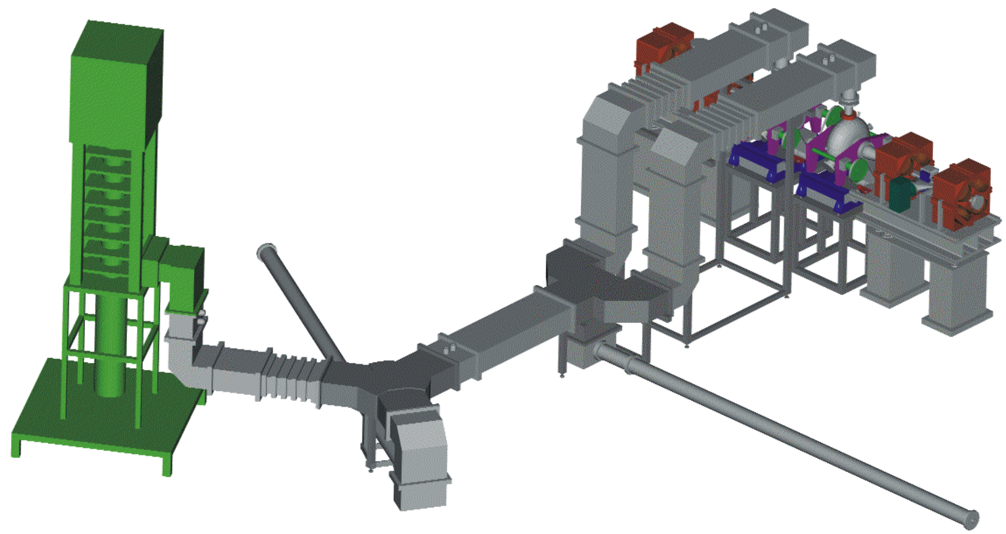
- Length: < 20 m
- Energy: ~ 41 MeV
- RF frquency: 3 GHz
- Pulse repetition rate: 10 Hz
- Electron bunch charge: 0.001 – 3 nC
- RMS bunch length: 1 – 300 fs

One of two KARA RF stations

KARA

Design Parameters	Value
Beam Energy	2.5 GeV
Energy Loss per Turn	662 keV (64 kW)
Design Beam Current	400 mA
Harmonic Number	184
RF Frequency	499.65 MHz
Momentum Compaction Factor	0.0081
Energy Spread	0.09 %
Total RF voltage	2 MV
Energy Acceptance	1.5 %
Synchrotron Frequency	36 kHz
Synchronous Phase	160.7 °
Bunch Length	9.8 mm
Number of Cavities	4

Quality factor: 40000
Shunt Impedance: 3.3 MΩ
Max volts: 650 kV



Schematic taken from 'Proceedings of the 1999 Particle Accelerator Conference, New York, 1999'

KARA Low Level RF

- The original Low Level Electronics was completely analog and was purchased from ELETTRA ~1999. Essential components are the phase, amplitude and frequency loop. Their specifications are:

	Stability	Range	Bandwidth
Phase loop	< 0.5°	20°	1.4 kHz
Amplitude	<1%	30 dB	10 – 1000 Hz
Freq Loop	< 0.5%	40 dB	30 kHz

This was replaced

- Pre-purchase tests 2014,

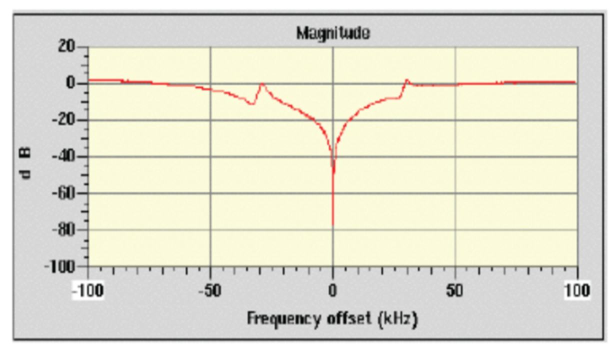
  see 'Vitali Judin, ANKA RF System-Upgrades Strategies, 18th ESLS-RF workshop 2014, DELTA, TU Dortmund, Germany'
- Dimtel LLRF for Storage ring went in 30.09.2015
- Dimtel LLRF for booster went in, 01.01.2016

KARA

Table 1: Signal numerology and frequencies

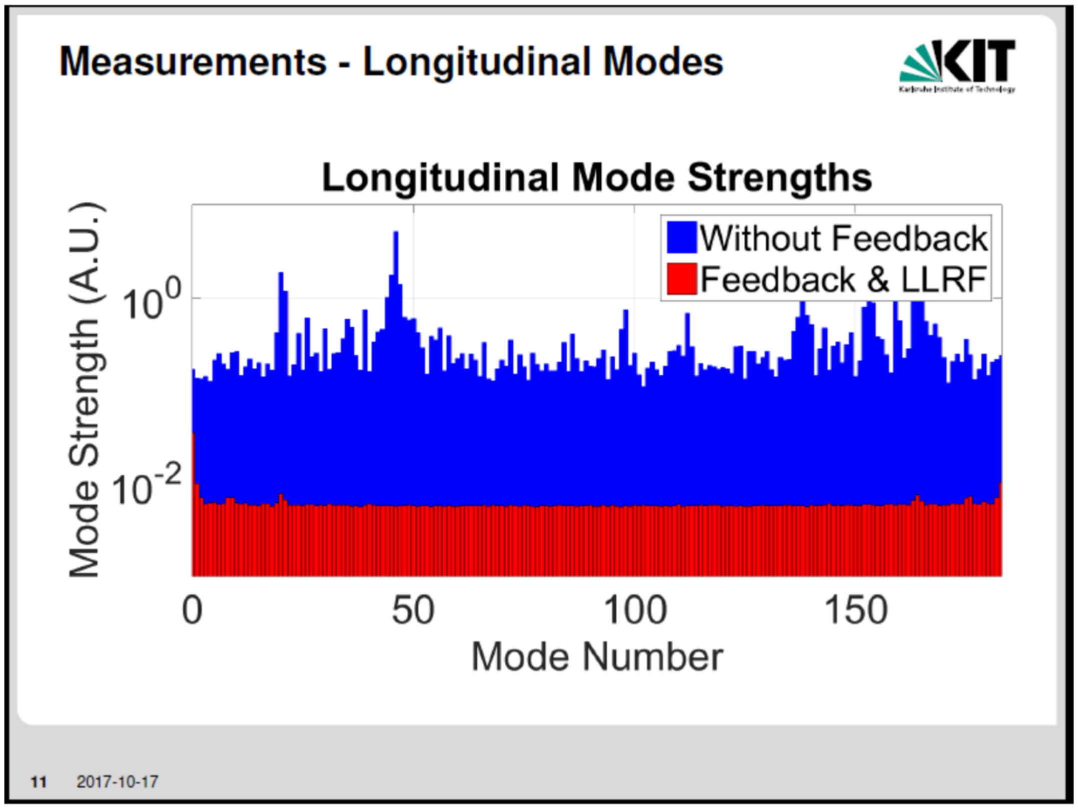
Signal	Symbol	Ratio to f_{rf}	Frequency (MHz)
Reference	f_{rf}	1	499.654
IF	f_{IF}	$\frac{1}{12}$	41.6378
Local oscillator	f_{LO}	$\frac{11}{12}$	458.0162
ADC clock	f_{ADC}	$\frac{11}{48}$	114.5040
DAC clock	f_{DAC}	$\frac{11}{24}$	229.0081

- closed-loop disturbance rejection
  - beam response at 30 kHz
  - -70 dB rejection at ~30 Hz
  - -15 dB rejection at 10 kHz



KARA

The implementation of the DIMTEL LLRF together with BBB (Bunch By Bunch) has given huge improvements in stability, diagnostics and user control for research applications, for example see "Integrated operation of LLRF and bunch-by-bunch feedback systems at KARA, software and RF Control- LLRF Workshop 2017, Barcelona, Edmund Blomley".



FLUTE

FLUTE

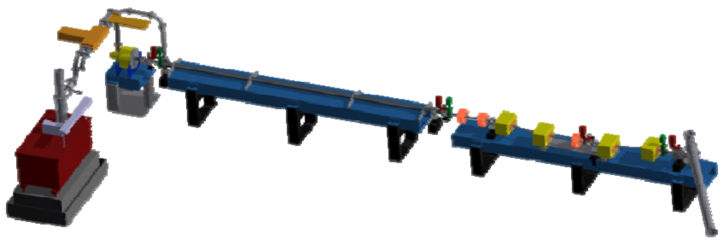
Inauguration July 2017

(l. to r.) Dr. H.-H. Braun, PSI, Prof. Dr. H. Dosch, Chairman of DESY Board of Directors, Prof. Dr. A.-S. Müller, Director IBPT, Prof. Dr.-Ing. H. Hanselka, President of KIT, and Prof. Dr. O. Kraft, Vice President Research of KIT (Photo: M. Breig, KIT)

In materials research, chemistry, biology and medicine, chemical bonds, and especially their dynamics, determine the properties of materials. The bonds can be precisely investigated with terahertz radiation and short pulses. The FLUTE accelerator at the KIT will develop novel accelerator technologies for compact and powerful terahertz sources as efficient tools for research and application. On Thursday 13th July, FLUTE was officially inaugurated during a ceremony at the Institute for Beam Physics and Technology (IBPT)

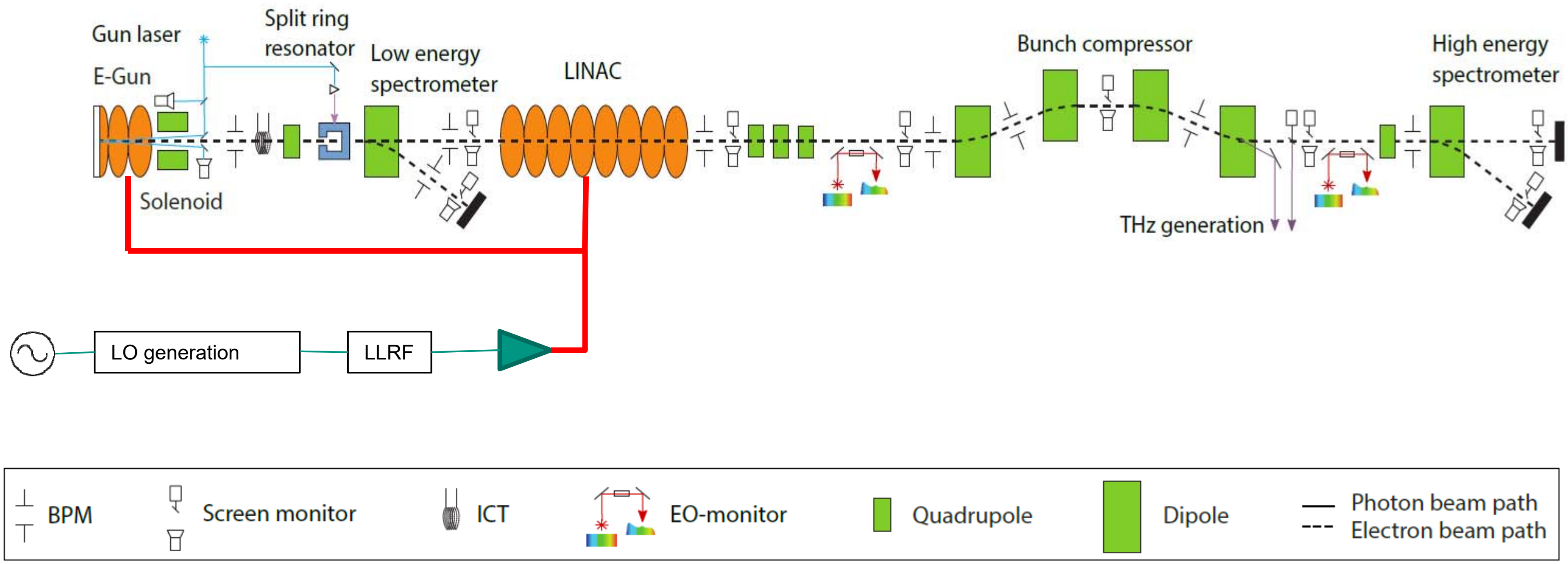
Goals for FLUTE

- Study for a **future** compact, broadband accelerator based **THz source**
- Test bench for new beam **diagnostics & instrumentation**
- Compare in simulation and experiment:
  - Coherent *Synchrotron* Radiation (CSR)
  - Coherent *Transition* Radiation (CTR)
  - Coherent *Edge* Radiation (CER)



- Systematic **bunch compression** studies:
  - Different compression schemes
  - 0.1–3 nC → Study **space charge** and **CSR induced effects** and instabilities
- **Experiments** with THz & X-rays, e.g.: Pump-probe, 2D spectroscopy, new materials,...
- Test facility for accelerator studies within the **Helmholtz “ARD“ initiative**

Flute layout

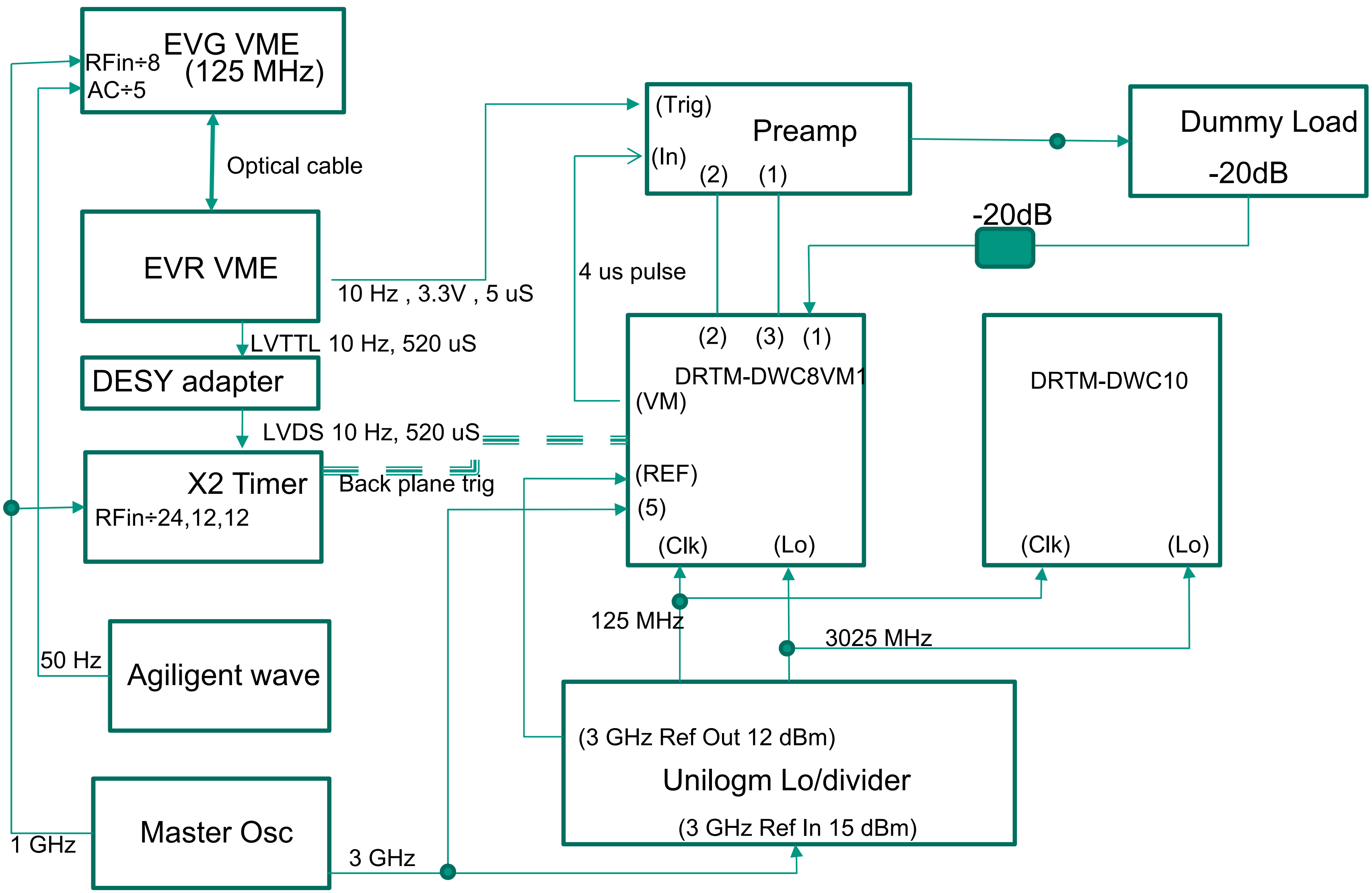


What needs to be synchronized, coincident, phase stable; relative to each other:

Master oscillator e.g 3 GHz
LLRF for power to the cavities
Gun laser for firing E-Gun cathode and split ring resonator THz generatio
ADC triggers
EO-monitor (Electrical optical sampling) for diagnostics
50Hz mains to reduce noise
10 Hz trigger

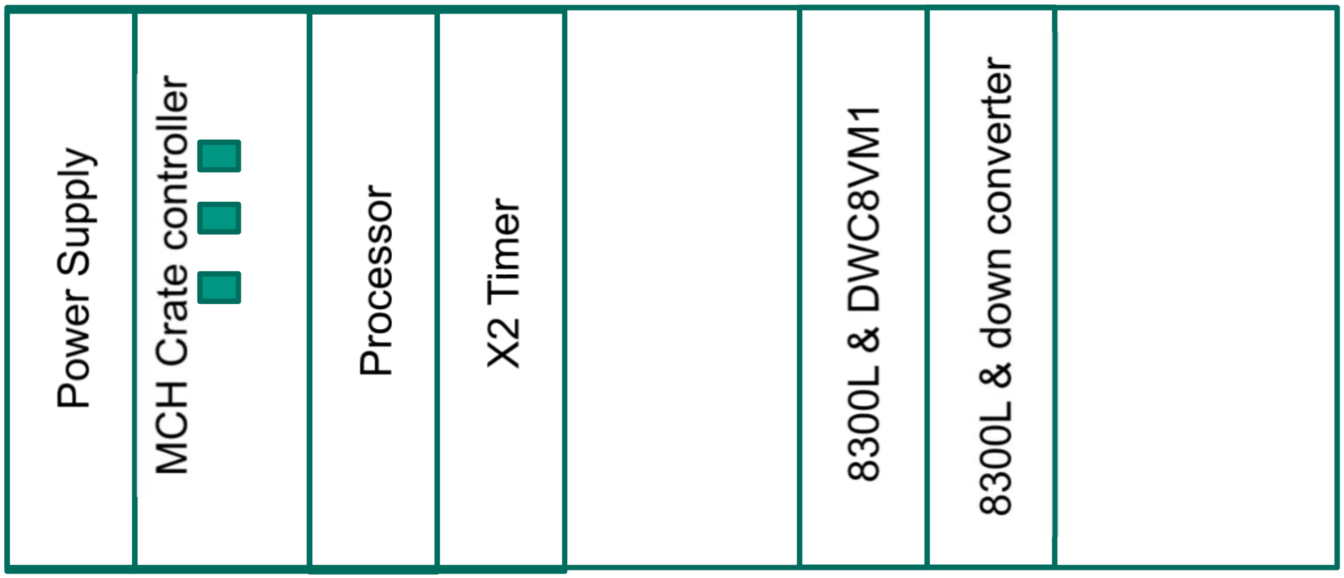
Parameter	Value	Unit
Final electron energy	~ 41	MeV
Electron bunch charge	1 – 3000	pC
Electron bunch length	1 – 300	fs
Spectral bandwidth	~0.1 – 100	THz
THz pulse power	up to ~ 5	GW
THz pulse energy	up to ~ 3	mJ
THz E-field strength	up to ~ 12	MV/cm
Pulse repetition rate	10	Hz

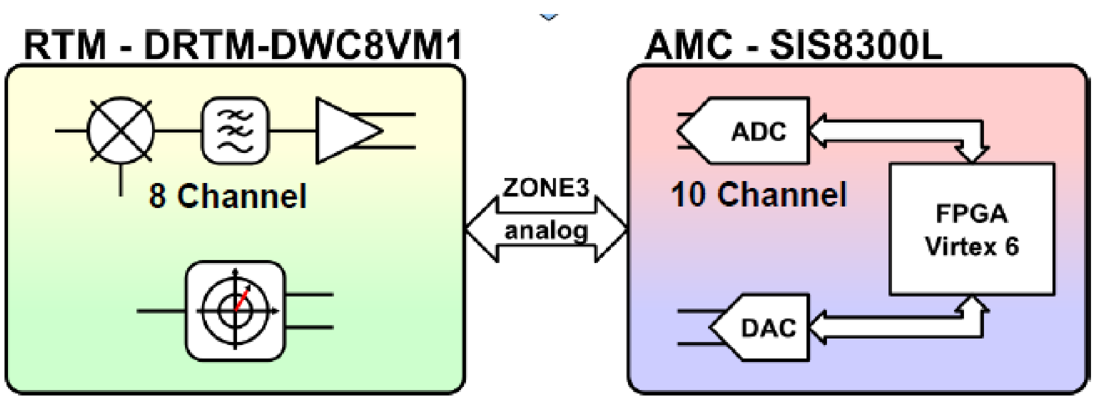
Schematics of FLUTE LLRF



FLUTE

mTCA crate Front View



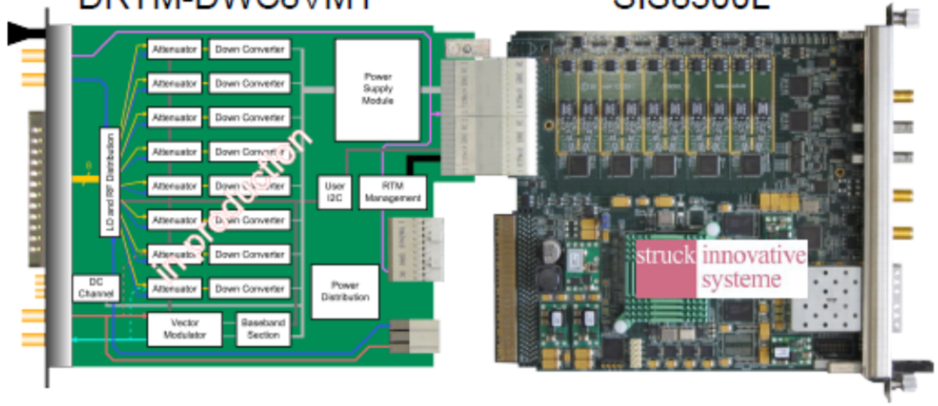


FLUTE MTCA Down converter and digitizer

Single Cavity LLRF Hardware.

- DRTM-DWC8VM1 – 8 channel down- / 1 channel upconverter
  - 700MHz to 4GHz (upgrade: 500MHz to 6GHz)
  - Excelent amplitude (<0.005%) and phase resolution (<10fs)
- SIS8300L – 10 channel 125MHz/16Bit digitizer
  - Xilinx Virtex 6
  - Low jitter clock distribution

DRTM-DWC8VM1 SIS8300L

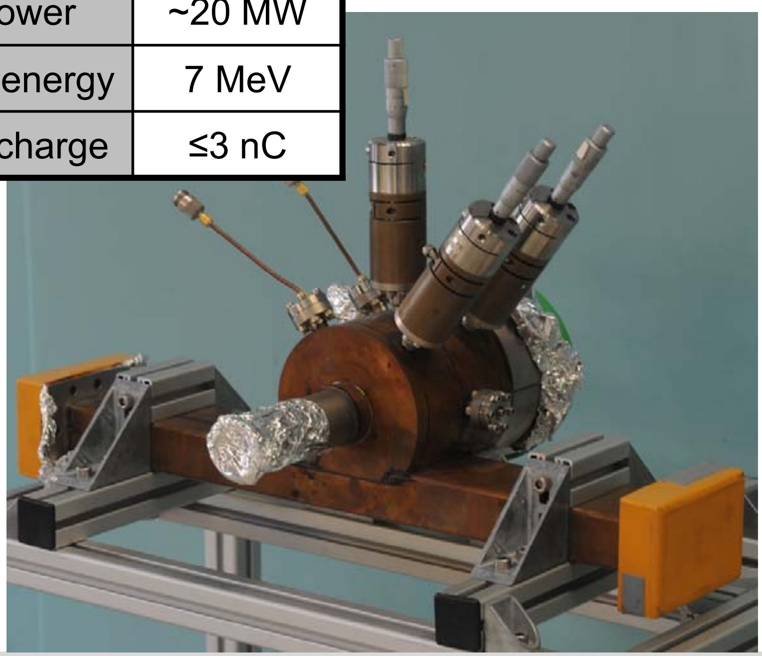


Matthias Hoffmann | Single Cavity RF controls based on MTCA4_HZDR | 12. December 2012 | Seite 11/26

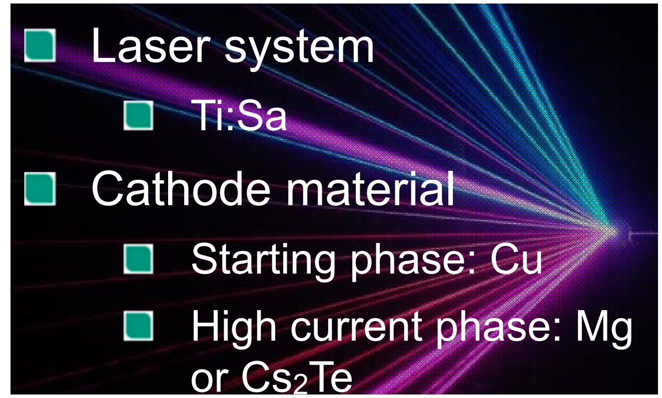
FLUTE Laser photo-injector gun

- CERN CTF (CLIC Test Facility) gun
- Designed for high current

Property	Value
Frequency	2.998 GHz
Cells	2.5
Acc. gradient	~100 MV/m
Peak power	~20 MW
Output energy	7 MeV
Bunch charge	≤3 nC



thenewnewinternet.com

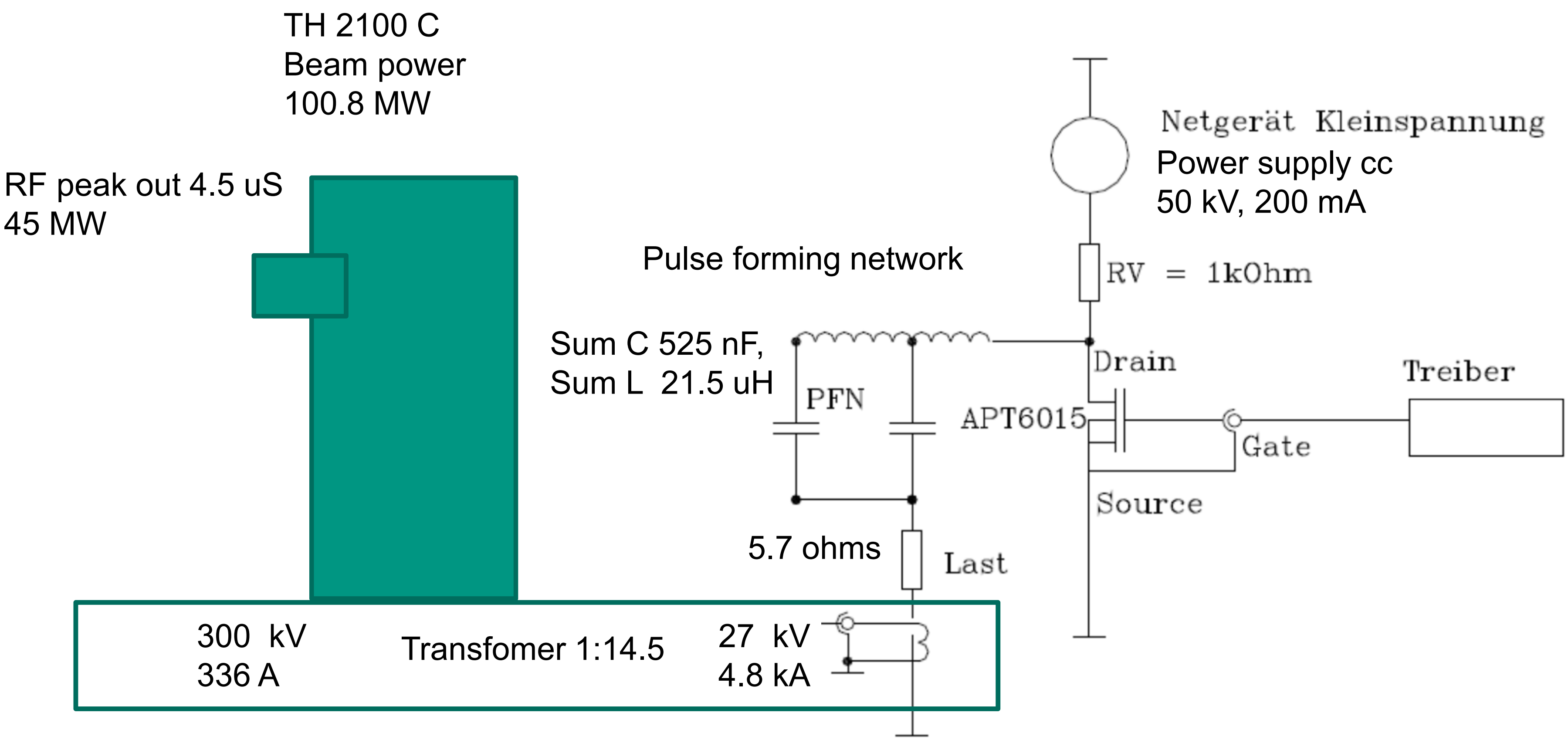


- Laser system
  - Ti:Sa
- Cathode material
  - Starting phase: Cu
  - High current phase: Mg or Cs_2Te

Q value ~ 16150 ohms
Shunt R 14.13 MΩ/m (50 mm)
Phase Stability requirement > 0.1°
Amplitude stability requirement > 0.1%

Property	Value
Repetition rate	10 Hz
Pulse length	1–4 ps
Wavelength	266 nm
Pulse energy on cathode	0.3 mJ

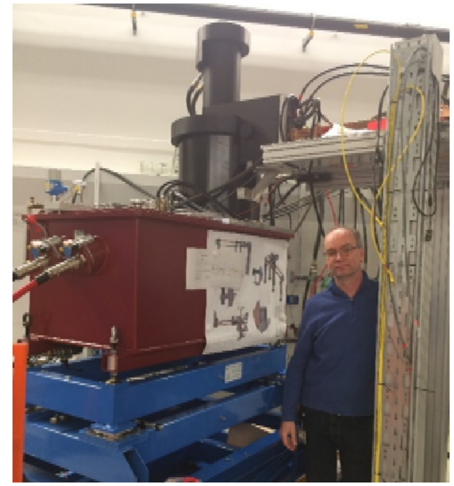
Flute Pulse forming network, transformer and Klystron



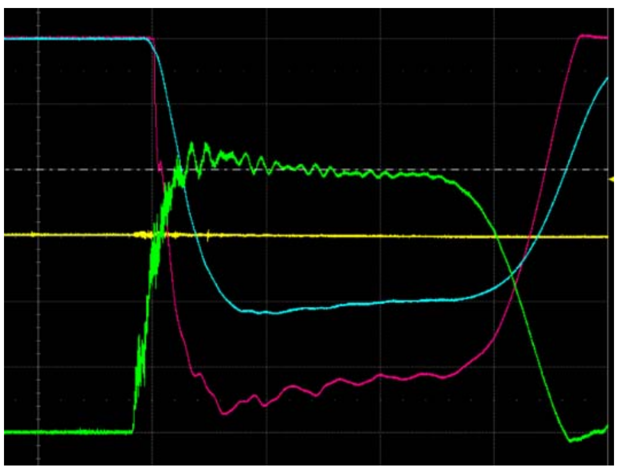
FLUTE RF

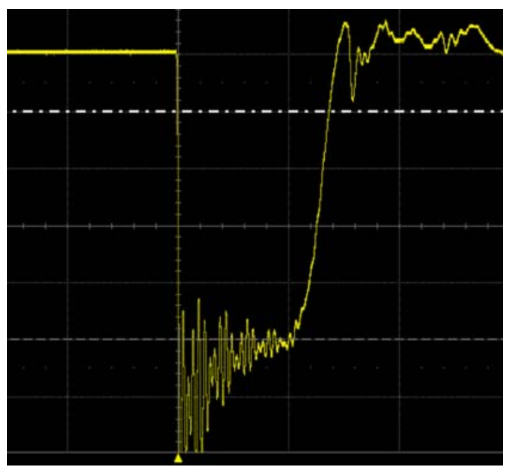
Power supply
50 kV, 200 mA

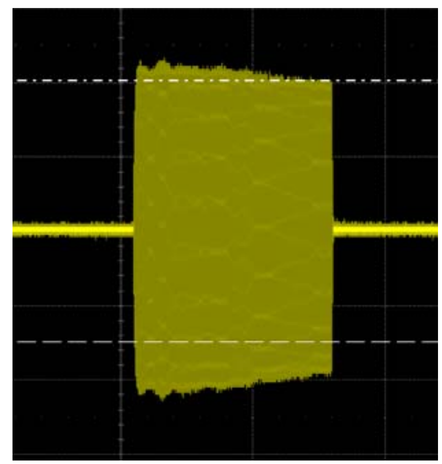
Pulse forming network 525 nF,
21.5 mH



Transformer tank 1:14.5
and 45 MW klystron







Pulse envelope is 4.5 us (NO LLRF feedback loop)

Summary

- Digitizing the LLRF for KARA was very successful in terms of both commissioning and improved performance. The LLRF combined with the new BBB brought further stability and many interesting applications. Thanks to DIMTEL for the great support.
- FLUTE is approaching the stage of first beam. Laser is operational, RF power to the gun available, and diagnostics are installed for first beam observations. Many thanks go to MAX lab for lending us some S-band waveguides to make the gun commisioning far less complicated.

For both KARA and FLUTE we have some very interesting work to do , and are looking for interesting people to do it. Scientists, Engineers and Technicians are all welcome to contact us.

Thank you all very much for your attention,

Any questions ?