

## Ultra-fast Data Acquisition System for Coherent Synchrotron Radiation with Terahertz Detectors

M. Caselle, S. Cilingaryan, M. Hofherr, V. Judin, A. Kopmann, A.-S. Müller, M. Siegel, N. J. Smale, P. Thoma, M. Weber, S. Wuensch

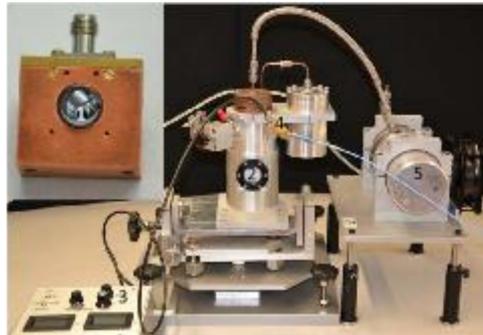
Karlsruhe Institute of Technology – author email: michele.caselle@kit.edu

### Fast detector systems with picosecond time resolution



#### The HEB detector system

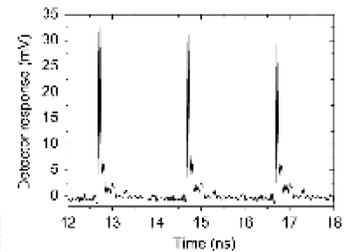
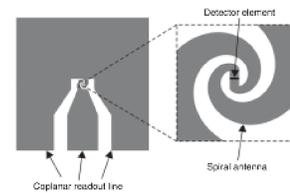
- joint development of IMS (Karlsruhe) & DLR (Berlin)
- SC niobium nitride detector
- response time < 165 ps
- spectral range 150 GHz - 1.5 THz
- study of single and multiple bunches



#### YBCO-THz Detector System

- Yttrium-Barium-Copper-Oxid detector
- based on:  $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$  high-T SC
- response time: down to 1 ps
- spectral range: depends on antenna

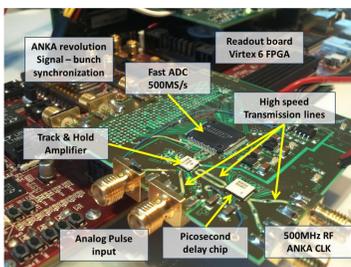
Probst et al.  
PHYSICAL REVIEW B  
85, 174511  
(2012)



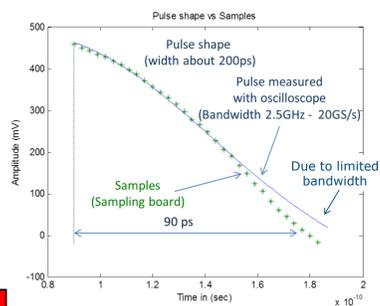
P. Thoma et al., IEEE Trans. on App. Supercond. 2012  
DOI: 10.1109/TTHZ.2012.223420

### Ultra-fast FPGA digitizer board for ANKA

#### Hardware: 1st prototype (one channel sampling board)



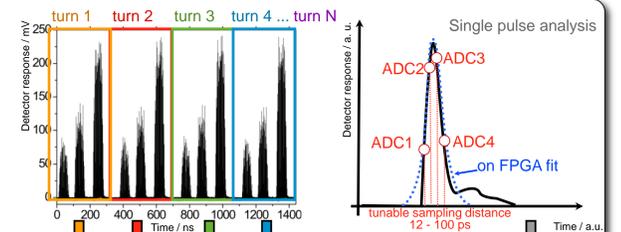
The first prototype contains a single sampling channel operating at 500 MS/s. The track-and-hold amplifier receives the analog pulse and acquires one sample in the peaking time region of each THz pulse (resp. CSR bunch emission).



The time characterization has been achieved by a sequential equivalent time sampling method where one sample per pulse is taken after a very short but well defined delay.

#### Design goals

- simultaneous monitoring of all 184 buckets
- turn-by-turn acquisition
- continuous acquisition up to  $\sim 3 \cdot 10^5$  turns
- fixed reference bucket for all measurements
- online analysis on FPGA/GPU
- control system Graphic User Interface
- Real-time data analysis



184 peak values per turn will be recorded

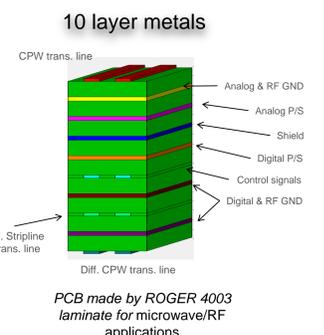
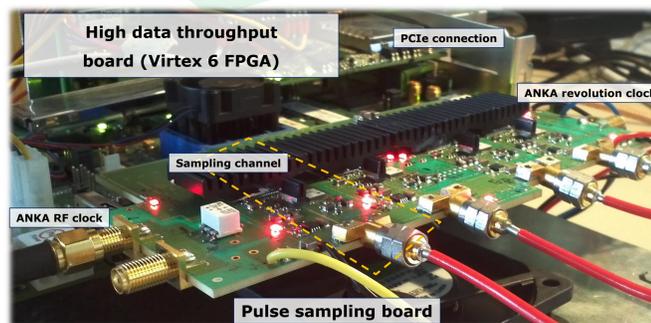
on FPGA analysis:  
• peak value, jitter  
• pulse width

#### Four sampling channels board

M. Caselle et al., proceeding of 4<sup>th</sup> International Particle Accelerator Conference, 12-17 May. WEOBB202

1. A clean jitter phase locked loop (PLL) used to generate a clock signal with high temporal accuracy.
2. Clock is distributed to the picoseconds delay chips by a low skew and jitter clock fanout.
3. The track-and-holds receive a time controlled sampling signals synchronized with the ANKA RF-clock (resp. bunches time distribution).
4. Each delay chip is individually programmable from 3 to 100 ps.
5. 12 bits ADC resolution

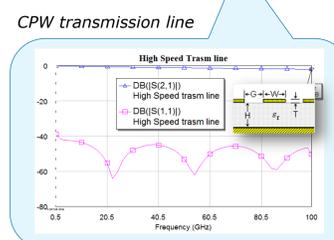
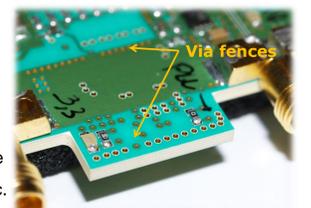
A high data throughput readout based on a bus master DMA architecture connected to PCI Express. Data throughput of up 4 GByte/s.



#### Layout techniques ..

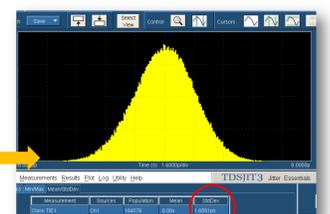


- Separation of analog and digital grounds
- Ad-hoc RF filters located closer to critical components
- Via fences and guard ring techniques have been employed in the PCB layout in order to reduce the cross-talk, electromagnetic interference (EMI), etc.

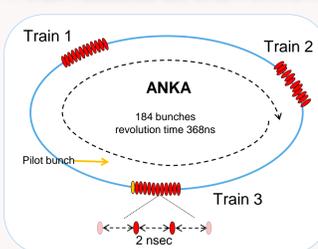


#### Board performances ..

Dynamic range	$\pm 800\text{mV}$
Incoming pulse frequency	500 MHz
Minimum sampling time	3 ps
Number of samples (per pulse)	4
Total RMS period jitter	< 1.7 ps
Noise RMS	2 mV



#### First results at the ANKA

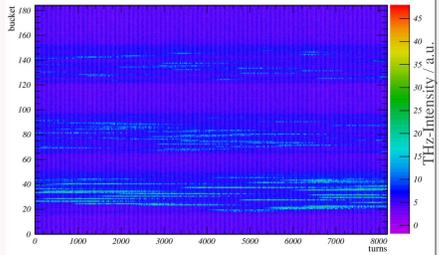


A.S: Müller, M. Caselle et al., proceeding of 4<sup>th</sup> International Particle Accelerator Conference, 12-17 May. MOPEA019

At the synchrotron light source, ANKA, up to 184 RF buckets can be filled with electrons with the distance between two adjacent buckets of 2 ns corresponding to the 500 MHz frequency of the RF system.

#### ANKA CSR measured with one channel sampling board & YBCO detector

This shows the typical filling pattern of the ANKA storage ring, consisting of three trains separated by a several ns gap. The prototype system is able to resolve single bunch fluctuation in a multi-bunch filling pattern.



### Summary and Outlook:

- Measurements using 1st prototype of FPGA board successful
- Open up new possibilities in the CSR diagnostics
- Test beam with the 4-channel board scheduled for October 2013
- **Final aim:** studies of correlations on the bursting pattern and interactions of very short pulses in the synchrotron storage rings