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Sensors and Readout Electronics for High Brilliance Terahertz Radiation

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The ANKA storage ring can generate brilliant coherent synchrotron radiation (CSR) in the THz range due to a dedicated low-αc -optics with reduced bunch lengths. At higher electron currents the emission of CSR is not stable, but occurs in powerful bursts caused by micro-bunching instabilities. This intense THz radiation is very attractive for users. However, the reproducibility of the experimental conditions is very low due to those power fluctuations. For the investigation of multi-bunch dynamics of the electrons in the storage ring, novel THz detectors and ultra-fast readout electronics have been developed and commissioned at different accelerators machines: ANKA [1], Eu-XFEL [2], ELBE [3] and DELTA [4]. An overview of the status of high intensity THz sources and activities within the machine physics German community will be presented. Pico- and femto-second beam diagnostic systems including THz sensor and electronics technologies will be deeply discussed.

Summary

The synchrotron radiation source ANKA is located in Karlsruhe, Germany. The user facility is based on an electron storage ring with a circumference of 110.4 meters and is being operated by the Karlsruhe Institute of Technology. For a few years special user operation with reduced bunch length in the order of few picoseconds is available and offered to the research community. In this mode, high brilliant coherent synchrotron radiation (CSR) is generated in the THz band. Moreover, above a certain current threshold, a coherent modulation of the longitudinal particle distribution (micro-bunching) occurs due to CSR impedance. This particle dynamics effect changes the characteristics of the CSR tremendously.
Due to progress in the multi-bunch readout electronics development at KIT, a completely new type of measurement was realized at ANKA. New superconductor film detectors and new readout electronics have been developed at KIT and then installed in other accelerator facilities in Germany.
To detect and study the emission characteristics of CSR in the THz range over multiple revolutions several detector systems based on superconductor film layers have been developed. The first generation of THz detector was based on Niobium nitride (NbN) detectors with a response time of less than 165 ps. The new generation of detector is based on thin Yttrium barium copper oxide (YBCO) superconductor film with an intrinsic response time down to 1 ps.
The KAPTURE readout system opens up a new possibility to monitor all bunches in a synchrotron storage ring over an unlimited number of turns. The system was successfully commissioned and tested in a real measurements environment in 2013. KAPTURE is used as ANKA and DELTA to follow turn-by-turn bursting behavior of the generated THz radiation. This novel diagnostic tool is used to explore the fundamental physical mechanism of their generation and thus on the long term to improve the stability of the emitted CSR.
The KALYPSO system has been developed to measure the longitudinal bunch profile and its instabilities during the emission of CSR. Thanks to its high frame-rate (2.7 MHz) it allows continuous monitoring of the beam dynamics with femtosecond resolution (down to 300 fs). The system was successfully tested in real measurements in 2014/2015 and is permanently installed at ANKA, XFEL, DELTA and ELBE.

[1] http://www.anka.kit.edu/
[2] http://www.xfel.eu/
[3] https://www.hzdr.de/db/Cms?pNid=145
[4] http://www.delta.tu-dortmund.de/cms/de/DELTA/

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