High-speed measurements of the electron beam size at KARA

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Application Note

KARA is a 2.5 GeV storage ring and synchrotron light source located at the Karlsruhe Institute of Technology (KIT). In the 110 m long ring, highly relativistic electron packages called bunches with a charge of up to around 1 nC can be stored for several hours in order to emit brilliant synchrotron radiation pulses on every round trip. The spectrum of the emitted synchrotron radiation ranges from microwaves up to hard x-rays and can be used for various user experiments such as tomography, spectroscopy, diffractometry, lithography and many other techniques in various spectral ranges.

The storage ring is typically operated in a so-called multi-bunch mode where around 100 electron bunches are stored with a bunch spacing of 2 ns. When driving the accelerator at its limits (either with very short or small electron bunches, or with a very high charge), strong instabilities can occur that cause the bunches to dynamically deform in all three dimensions. Ultra-high speed, single-shot measurement techniques are required to monitor the beam size / position, and to investigate these instabilities.

The fast-gated ICCD camera (Andor iStar DH340T-18U-03) offers the possibility to open the intensifier gate for the duration of less than 2 ns. This allows imaging the horizontal beam profile of a single pass of a particular synchrotron radiation pulse rather than averaging images from several passes or several subsequent bunches with a conventional CCD camera.

The operation with a trigger opening the gate at a maximum rate of 500 kHz allows recording the same electron bunch several times (for example on every n-th turn within the acquisition of one image, with n being an integer of 6 or larger). The setup has also been extended by a programmable, rotating, galvanic mirror that made it possible to displace the beam profiles for different turns on the sensor in order to detect dynamic changes of the horizontal beam size and position [1,2]. Figure 1 shows a schematic drawing of the measurement setup, as well as an example camera image.

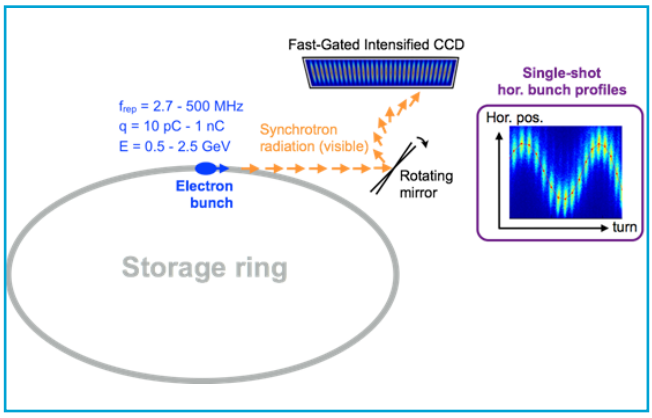

Figure 1: Schematic drawing of the fast-gated camera setup in combination with a rotating mirror at KARA. To the right, an example image showing the horizontal bunch profile of a single bunch for several bunch round trips is shown.

By adjusting the rotation velocity and the gate repetition rate, the setup gives full flexibility to monitor one bunch for several round trips on different time scales ranging from several microseconds to seconds. An example of such a measurement can be seen in Figure 2 for which we recorded the bunch movement over 14 ms while applying a periodic excitation (every 10 ms) that kicks the beam transversely and also leads to a blow up of the horizontal beam size [3].

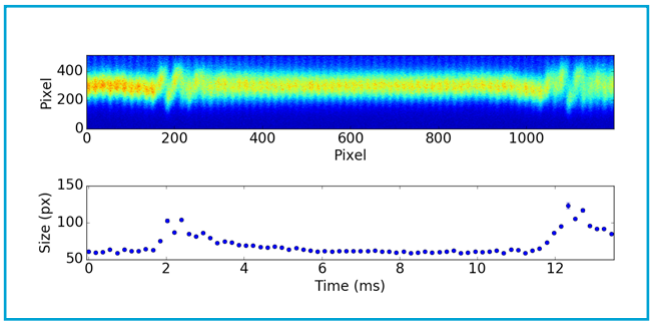

Figure 2: Measurement of the horizontal beam profile over 14 ms while applying a periodic beam excitation

The camera is also integrated into our synchronization scheme [4] that allows the synchronous investigation of the horizontal bunch profile (and thus the energy spread) and the longitudinal bunch profile as well as the emission of coherent synchrotron radiation (CSR) [5].

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