Research and development beamline for the BESSY II Booster

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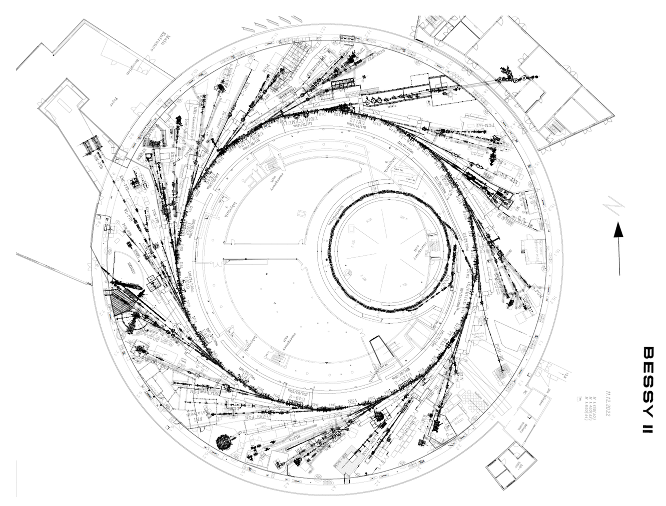
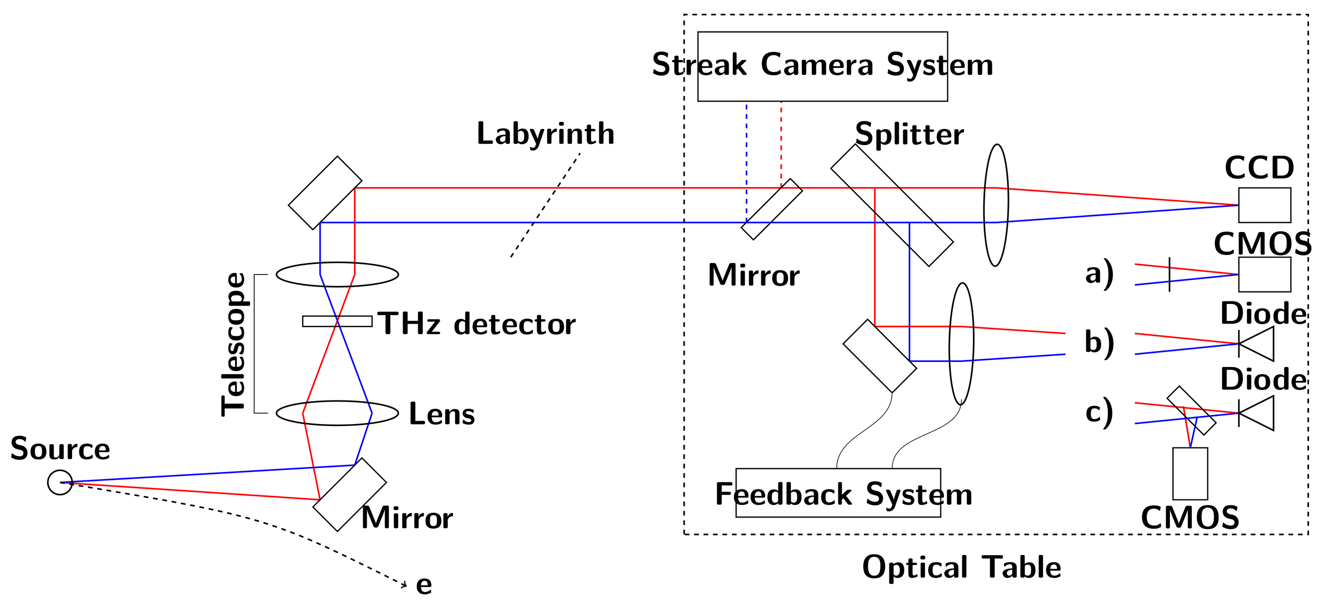
Abstract

After the optimisation process of the high-end diagnostic, the main focus was on expanding the beamline further. [1] This summary reports on their status focusing in particular on the R&D beamline branch. The additional branch is equipped with programmable mirror and lens position controllers allowing elaborate optical optimisation. This system is used for educational purposes and for improving the source point imaging system through the study of polarisation characteristics. Test systems for an ultra-fast diode and a THz detector are equipped with CMOS cameras and polarisation filters. Furthermore the R&D branch complements the existing diagnostics to measure bunch lengths and investigate non-linear beam dynamics.



1. Booster Beamline & Feedback System



In the tunnel system the beamline consists of

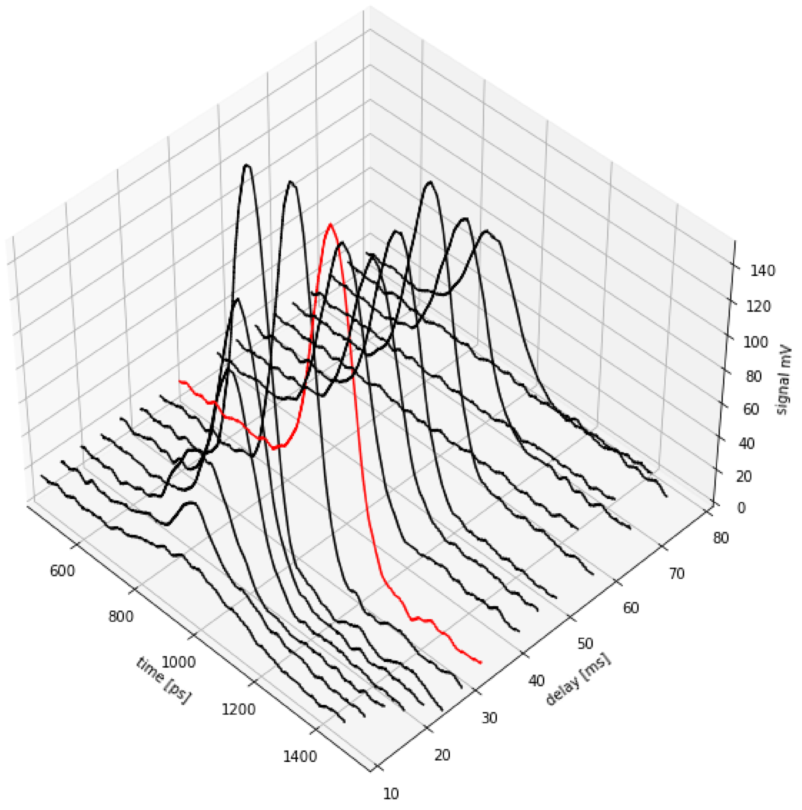
- photon source (predetermined bending magnet of the booster)
- wedged vacuum windows for compensating angular dispersion
- motorized achromatic telescope, of 400 mm and 80 mm focal length lenses
- THz detector [2]
- seven planar mirrors (three motorized for fine tilt)

On the optical table the beamline is divided in three branches: the two main diagnostic tools on the optical table are a CCD camera with a 500 mm focusing lens for source point analysis a streak camera with a 300 mm focusing lens for bunch length studies [3] and the R&D beamline uses a programmable motorized mirror and 500 mm lens to focus on one of the three different main set-ups:

a) a CMOS camera from Basler [4] with a rotatable polarizer
b) an ultra-fast diode from Hamamatsu [5] connected to a 12 GHz oscilloscope and digital multimeter
c) an ultra-fast diode connected to a multimeter combined through a 30/70 splitter with a CMOS camera

All lenses in the beamline system are achromatic doublets.

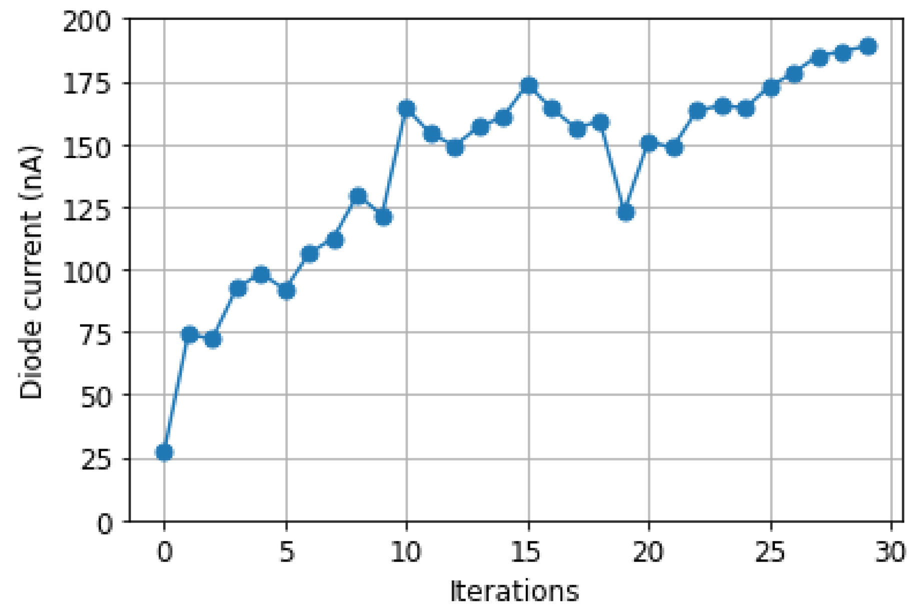
2. Bunch Length Studies



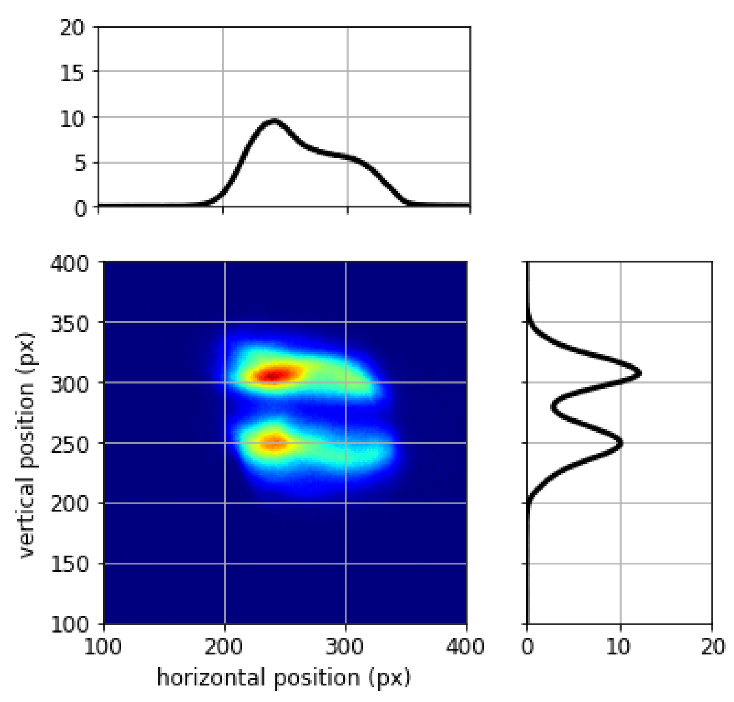
Optimizing the R&D System through two different approaches

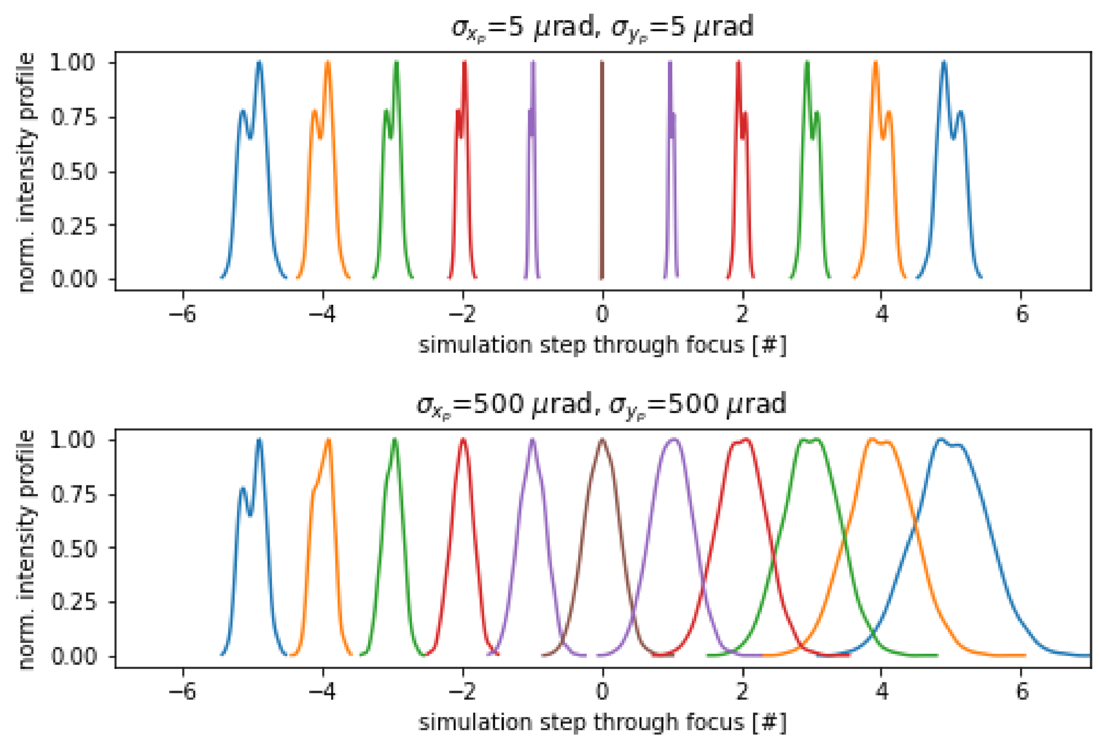
1. Combination of the diode linked with a CMOS camera through a feedback code. Feedback code moves the motors of the mirror, changing the angle, and analyzes the following movement on the camera. Using a grid, the highest intensity on the diode can be determined in relation to a pixel position on the CMOS camera.
2. Without using a CMOS camera for orientation and is less target-oriented. Beam lands directly on the diode and, using a biased random walk optimizer coded in python, highest signal can be found and measured on a multimeter.

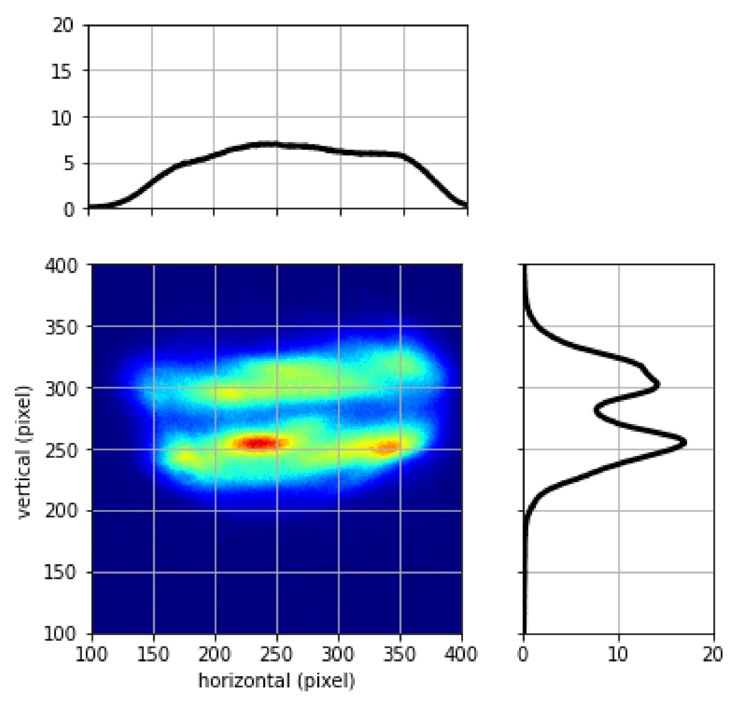
Second approach is less stable over long periods but is quick to set up and delivers a high photon intensity used for a bunch length measurement. Main goal confirming the streak camera measurements and observing the elusive first turn in the booster at 50 MeV. The longitudinal profiles at the different energies are determined with an oscilloscope. Due to the limited rise time of the diode only rms bunch lengths over 1 GeV (approx. 50 ps) can be reliably measured.



3. Characterising Polarisation

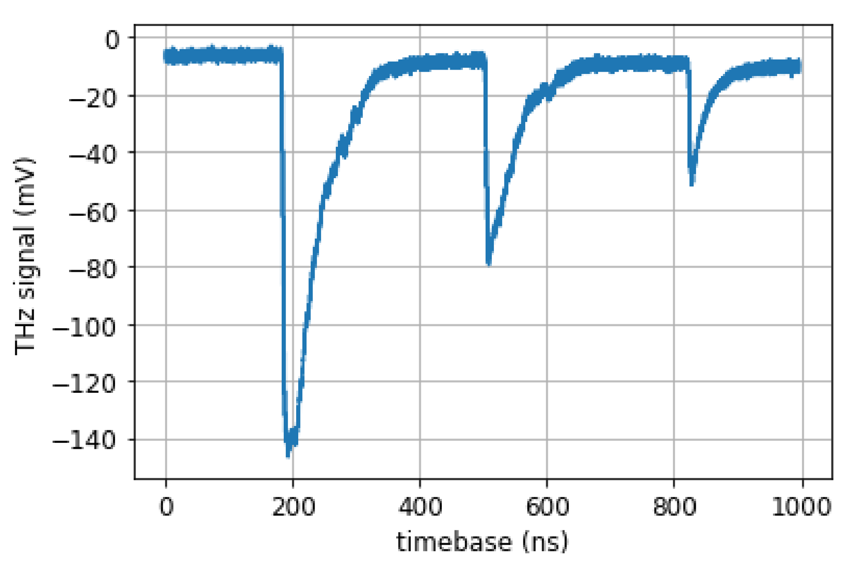




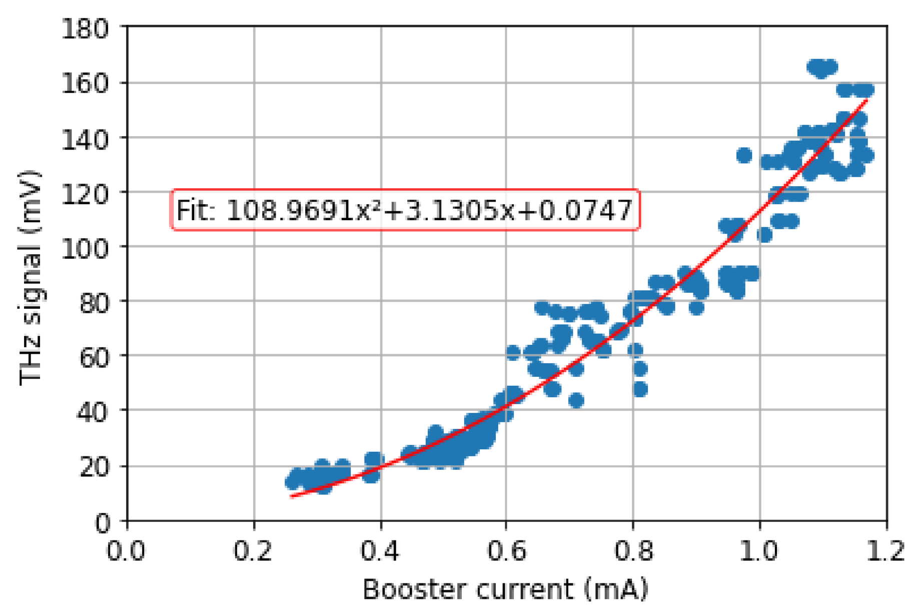


For this measurement setup a) (CMOS camera with a freely rotatable polarization filter) is used. Goal is to characterize both polarisation modes during the Booster cycle to determine working point of the source point imaging system independent of the polarisation. Circular polarisation, visible as two distinct beam lobs, dominates the vertical beam profile outside of the focal point at high Booster energies. Assuming perfect linear optic, beam lobs should show symmetrical behaviour either side of the focal plane. However results show a smearing effect, where the vertical profile does not show two clear maxima on one side of the focus. The smearing could only be slightly reduced through programmable optic alignment optimisation. Simulation study to track particle distributions through drift-lens-drift optic using a particle distribution created by the pixel intensity profiles from camera image coupled with a Gaussian spread in divergence shows the smearing effect at Gaussian divergence greater 5 μrad. Mechanical precision of the lens position limits the resolution.

4. THZ Studies



To complement the streak camera longitudinal dynamic studies, a high-sensitivity wide band THz detector was installed in the tunnel section of the beamline. Covering the low THz regime, this Schottky-barrier diode detector was used to measure coherent radiation produced in the first turn in the Booster. Amplitude of the signal detected from the first turn is of course strongly dependent on the longitudinal profile of the bunch leaving the linac. The phase of the 500 MHz pre-buncher [6] was used to optimise signal intensity. Fast signal rise time due to the diode and the slow decay due to the internal amplifier is repeated for each turn. With 1.2 mA Booster current (circa 0.4 nC single bunch charge) the detector is already saturated. The coherent quadratic nature N^2 of the radiation was measured. Future studies will be orientated towards predicting the longitudinal beam profile from the linac that could produce such a THz signal and assessing the possibility of tailoring the injection to produce multi-turn coherent synchrotron radiation CSR.



5. Conclusion

Because of its flexibility, the R&D beamline is a great tool for educating students and continually improve the high level diagnostic at BESSY II.
Within the first year of research, it has been possible to study the bunch length, polarisation and THz footprints over the energy ramp of the Booster. These online diagnostics coupled with electron beam orbit improvements help to continually optimise the booster operation. High-current stable injection in BESSY II is now possible. Further studies are envisaged as part of a future MSc. project.

Reference

[1] T. Atkinson *et al.*, "An optical diagnostic beamline for the BESSY II Booster," presented at IBIC 2022, Krakow, Poland MOP02. [Online]. Available: https://accelconf.web.cern.ch/ibic2022/papers/mop02.pdf

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