Measurement and Correction of Beam Properties at the MAX IV Laboratory

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June 2017

The particle accelerators which appear in popular media are often of the high energy physics kind, such as the LHC at CERN, Geneve. These machines investigate the fundamental laws of physics through the use of particle collisions at very high energy. A more common type of particle accelerators are the synchrotron light sources. They use a beam of accelerated electrons to generate high intensity light. To ensure that the generated light has the desired properties it is important to be able to properly measure and control the electron beam.

MAX IV is a state-of-the-art laboratory in Lund, Sweden, which was inaugurated in June, 2016. It is a storage ring based synchrotron light source. The facility has two storage rings which use magnets to contain beams of elections travelling in a closed loop at almost the speed of light. These electrons are used to generate soft and hard X-rays at several systematically positioned sections throughout the rings. The X-rays are used as probes for experiments in fields ranging from life sciences to material science and archaeology. As the generated radiation depends highly on the parameters of the electron beam, it is important that these can be accurately measured and controlled.

The transverse position of the electron beam is monitored by *Beam Position Monitors*, or BPMs. They consist of four pin shaped electrodes capable of detecting the position of the electron beam through electromagnetic induction. The BPMs need to be calibrated in order to report the correct values. The calibration makes use of the electron beam itself, and the fact that the magnetic field in the transverse centre of many types of magnets is zero. Changing the strength of such a magnet has no effect on the electron beam that is centred in the magnet. By placing the beam at a few positions in this magnet and modulating its strength, the centre of the magnet relative to the BPM can be calculated.

Two other important electron beam parameters are the horizontal and vertical beta functions. These can essentially be interpreted as a combination of the transverse size and divergence of the beam throughout the circumference of the storage ring. At all the sections in the ring where the desired X-rays are generated, the beta functions should preferably have the same constant value.

The beta functions can be determined by modulating the focusing of the beam and measureing the resulting oscillations of the beam. They can also be found by comparing how the beam in the machine is affected by changes in magnet strength compared to a simulation of the machine. From this simulation the magnet strengths needed to attain the correct beta function values can be calculated.

The calculated values can be used when adjusting magnet strengths in the machine. This yields a machine with a performance closer to the nominal model.