

Longitudinal Beam Diagnostics Based on Super-Radiant Coherent Cherenkov Diffraction Radiation

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Longitudinal diagnostics are essential for accelerator installations that generate short particle bunches arranged in extended pulse trains. While several methods exist for diagnosing individual short bunches - each with their own advantages and limitations - effective diagnostics for long trains of ultra-short bunches remain scarce. On the other hand, parameters such as bunch uniformity, intra-bunch spacing, and total train length are especially important to know to optimise accelerator performance.

One promising solution is based on coherent radiation emitted by short electron bunches. Since the radiation intensity scales with the square of the bunch charge, it offers a strong signal even for very low intensity bunches. Additionally, when a long train of such bunches is involved, intra-train resonances occur, producing ultra-monochromatic spectral lines. The shape of these lines encode valuable information about the number of bunches, bunch separation, and overall train length.

A particularly suitable mechanism for generating this radiation is Cherenkov Diffraction Radiation (ChDR), which is produced when a charged particle moves near and parallel to a dielectric interface. ChDR offers several benefits for diagnostics: it is a non-invasive method, as the beam does not interact directly with the material, and its intensity scales linearly with the radiator length, providing an adjustable parameter for optimization.

In this report, we present experimental measurements of ChDR in the super-radiant regime, generated by an extremely long train of electron bunches. The experiment was performed at MT-25 microtron in Dubna. We demonstrate how the average single bunch length can be extracted from the envelope of the super-radiant spectrum, and how the individual spectral lines reveal the number of bunches and the total train length. These results are then validated against reference data provided by the accelerator operators.

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