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Observation of Coherent Transition Radiation in Super-radiant Regime and its Application for Longitudinal Diagnostics

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Electromagnetic radiation in millimetre and sub-millimetre wavelength range is a area of intense studies due to its application for longitudinal beam diagnostics and for generation of intense radiation beams. Transition radiation (TR) appearing when a fast charge particle crosses an vacuum-matter interface is one of the mechanism broadly used for this purpose, because its spectral angular distribution has been invested in details during the past few decades. Deep understanding of TR properties enables us to predict its behaviour in a broad range of electron beam parameters including energy from non-relativistic to ultra-relativistic region, beam sizes form sub-micron to hundreds of microns, angular divergence form micro- to miliradians, etc.
Coherent TR (CTR) is generated when the radiation wavelength is comparable to or larger than the bunch length. In that case all particles emit radiation more or less in phase, and the radiation intensity is proportional to a square of the number of particles in a bunch. However, if we have a sequence of bunches (a train) separated by a fixed distance form one another, the radiation is generated in a so called super-radiant regime [1]. In that case the coherent radiation generated by individual bunches interfere. The radiation spectrum, in this case, is no longer continuous, but represents a set of very narrow lines separated by the bunch sequence frequency, which is proportional (if not equal to) the RF frequency of the accelerating structure. The width of those lines depends on the number of bunches in the train. For example, for 7000 bunches the relative monochromaticity can reach 10^-4 - 10^-7 depending of which radiation harmonic is observed. With modern interferometer based Fourier Transform spectrometers or gratings it is not possible to achieve sufficient resolution.
In this report we will present CTR measurements in super-radiant regime using a horn antenna and a spectrum analyser at MT-25 microtron in Dubna. The measurement system enabled us to precisely resolve several radiation harmonics. We will demonstrate how RF frequency shifts during the acceleration and evaluate the single electron bunch length from the extracted spectrum.
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References:
[1] A. Gover, R. Ianconescu, A. Friedman, C. Emma, N. Sudar, P. Musumeci, C. Pellegrini, Rev. Mod. Phys. 90, 035002 (2018).

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