Master 2 “Photonics, Complex and Quantum Systems (PhoCQS)”: Research Training 2023-2024

Supervisor: Evain Clément

Topic: Dynamics of complex systems (in accelerator based light sources)

Dynamical manipulation of relativistic electron-bunches circulating in storage rings during a spatio-temporal instability

Relativistic electron-bunches (i.e. bunch composed of electrons with velocities near the light velocity) are used worldwide as light sources, to produce intense and broadband synchrotron radiation (from THz frequencies to hard X-rays). In these systems, complex phenomena as instabilities appear commonly, in particular due to the interaction of the electrons with their own radiation. Usually this phenomena impose limitations on this type of sources, but sometimes they can also be used as advantages.

In our group, a part of our activities concern the investigation of such complex phenomena in so- called *storage rings*, which are one of most used facilities to produce synchrotron radiation. In these storage rings, when a high number of electrons are used, *micro-structures* appears spontaneously inside an electron-bunch, and permits the emission of a very strong THz radiation, but often with very high fluctuations (and thus not directly usuable as a THz source for synchrotron radiation users).

The subject of this research training concerns the manipulation of the electron-bunch dynamics during this instability, to produce intense or/and regular THz emission. On this subject, important first results were recently obtained, in the frame of a collaboration between the PhLAM laboratory and the Synchrotron SOLEIL (the national synchrotron radiation source) [1-2]. Thanks to numerical simulations and experimental studies, we have show that it is possible to stabilize some electron- bunch state, using a feedback loop, and thus produce intense and stable THz radiation.

Theses exploratory studies have opened new strategies to manipulate the dynamics of electron bunch circulating in storage rings. The objective of *this training* is to investigate – in a first time with numerical simulations – the potential of these type of methods (in particular, a promising subject consist to trig and enhance the apparition of the micro-structures). Depending on the obtained numerical results, it will be also possible to prepare the experimental studies at the Synchrotron SOLEIL (in France) or at KARA facility (in Germany).

This training will include a part of bibliography on accelerator physics and on synchrotron radiation, numerical studies (using and developping a C++ homemade code working on a local cluster), and possibly the preparation of an experiment (discussion with collaborators, programmation of a FPGA card to generate control signal, etc.).

[1] *Stable coherent terahertz synchrotron radiation from controlled relativistic electron bunches*, C. Evain, C.Szwaj, E. Roussel, J. Rodriguez, M. Le Parquier, M.-A. Tordeux, F. Ribeiro, M. Labat, N. Hubert, J.- B.Brubach, P. Roy & S. Bielawski, Nature Physics 15, 635 (2019).

[2] *Stabilization of the bunch position during the control of the microbunching instability in storage rings,* C. Evain , F. Kaoudoune, E. Roussel , C. Szwaj , M.-A. Tordeux, F. Ribeiro, M. Labat, N. Hubert, J.- B. Brubach, P. Roy and S. Bielawski, Physical Review Accelerators and Beams, 2023 (accepted)

Key words: Dynamics of complex systems, accelerators physics, control of dynamical system, numerical and experimental studies