- **X-ray LWFA-Based FEL by: Ameneh Kargarian.**

Objective: The objective of this project is research and development of compact FELs based on the LWFA beams (Fig. 1). The main motivation behind this is the investigation of production of short, intense, and coherence pulses in X-ray region. To this end, different solutions in order to further improve the quality of LWFA beams are proposed. In spite of their interesting specificities, LWFA beams are also characterized by an energy spread, a large divergence and a certain lack of stability. Although much work has already been done in order to enhance the quality of LWFA beams [1-3], it is currently still necessary to improve the energy spread, divergence and stability of the beams. Another issue of this scheme lies in the transport of the bunch from the accelerator to the undulator. The transport and collimation are indeed made difficult by the high divergence of the bunch, at the exit of the accelerator. Therefore, we aim to provide solutions for these critical issues.

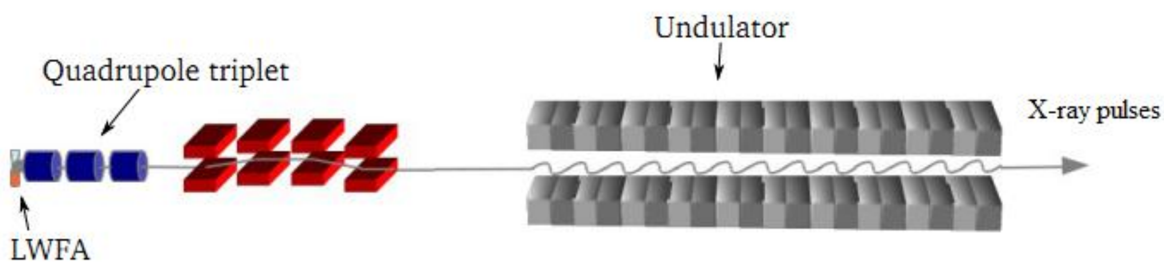

Fig.1. Schematic representation of the setup considered for an FEL based on an LWFA beam.

Relying on recent developments, the X-ray LWFA-based FEL now seems achievable within the next few years. If successful, these efforts would pave the way for cheaper and more wide-spread FEL facilities, which would then pen many new opportunities in atomic physics, biochemistry, and material science.

Importance of project implementation: FELs are by far the brightest existing X-rays sources, and they are instrumental in many areas of research, including atomic physics, solid-state physics, fundamental chemistry and biochemistry. However, the existing X-ray FELs are very large and costly facilities, and there are only a few of them world-wide. Furthermore, these facilities require a long accelerator to provide the necessary GeV-level electrons. For instance, the accelerator of SACLA, the most compact existing XFEL, is 750m long [4], and the accelerator of the European XFEL, currently under construction in Germany, will even reach 2.1 km [5]. In view of these numbers, the possibility to accelerate electrons to the same energies in a meter-scale distance and using a ten-meter scale laser system is indeed attractive. This has spurred a global effort in the LWFA community towards the development of more compact LWFA-based FELs [6-7]. Laser-Wakefield acceleration (LWFA), is a developing acceleration technique, which is considerably different from conventional radiofrequency acceleration. In a laser-wakefield accelerator, a high-power femtosecond laser pulse is focused into a gas jet, where it generates a powerful accelerating structure. Inside this structure, the accelerating field can exceed 100 GV/m which is three orders of magnitude higher than the maximum field of conventional radiofrequency accelerators. As a result, laser-wakefield acceleration is characterized by shorter acceleration distances, and opens up interesting prospects towards more compact accelerators. Over the past ten years, the development of LWFA has reached several major landmarks. These landmarks include for example the observation of the first quasi-monoenergetic beam [8], production of more tunable and more stable beams, and the production of the first beam beyond 1 GeV [9]. Today LWFA is still undergoing a rapid evolution, as recently-available Petawatt laser systems provide ever increasing laser power and allow to reach unprecedented electron energies [10]. In addition to their compactness, laser-wakefield accelerators produce interesting beams with a short duration, a small transverse size, and a high peak intensity. Moreover, laser-wakefield accelerators are also considered for the design of more compact linear colliders and x-ray sources (especially synchrotrons and Free-Electron Lasers). While these technologies currently require expensive large-scale facilities, their compact LWFA-based counterparts could be more affordable, and would thus open new opportunities in many fields of research.

Project implementation phases: The following are the four general phases of project.

1- Feasibility study
2- Simulation and analytical modeling
3- Conceptual design
4- Construction

Collaborators:

References:

1. Faure, J., et al., (2006). Nature (London), 444:737–739.
2. Gonsalves, A. J., et al., (2011) Nat. Phys., 7:862–866.
3. Rechatin, C., et al., (2009). Phys. Rev. Lett., 102:164801.
4. Tanaka, T. and Shintake, T. (2005). SCSS X-FEL conceptual design report. RIKEN Harima Institute, Hyogo, Japan.
5. Altarelli, M. (2006). XFEL: The European X-ray Free Electron Laser: Technical Design Report DESY (Series).
6. Couprie, M. E., et al., (2013) LUNEX5EDP Sciences.
7. I. A. Andriyash, et al., (2014). Nat. Comm. 5: 4736.
8. Mangles, S. P, et al., (2004). Nature, 431:535–538.
9. Leemans, W. P., (2006) Nat. Phys., 2:696.
10. Wang, X.,et al., (2013) Nat Commun, 4. 1988.