Laser driven electrons and X-ray Betatron radiation generation at VEGA

C. Salgado 1*, A. Longman 2, S. Malko 1, G. Zeraouli 1, M. Huault 1, X. Vaisseau 1, J. A. Pérez-Hernández 1, J. I. Apíñanz 1, E. García 1, O. Varela 1, C. Méndez 1, J. Hernández-Toro 1, G. Gatti 1, L. Volpe 1, L. Roso 1 and R. Fedosejevs 2

1 Centro de Láseres Pulsados (CLPU), Parque Científico, E-37185 Villamayor, Salamanca, Spain
2 Department of Electrical and Computer Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2V4
3 Universidad de Salamanca (USAL), Salamanca, Spain

* csalgado@clpu.es

Abstract

Laser wakefield acceleration (LWFA) can produce beams of energetic electrons in the range of a hundred of MeVs reaching, in some cases, the GeV regime [1,2]. In addition the Betatron radiation generated by the transverse motion of the electrons in the LWFA represents nowadays a promising source of spatially coherent X-ray for a multiple direct applications in atomic spectroscopy and in the phase contrast images [3-5]. We present the first electron acceleration spectra driven by the Laser system VEGA, as well as the first Betatron spectrum recorded. Also we report the first phase contrast images by VEGA when the Betatron beam is sent through different biological samples. These results perform the first stage of the experiment that is being carried out at the CLPU in close collaboration with the Alberta University. The main goal of this experiment consists in measuring the ionization states of warm dense aluminum using Betatron X-ray radiation generated by the LWFA regime [5].

Acknowledgements

Authors acknowledge to FURIAM project FIS2013-4774-R, PALMA project FIS2016-81056-R, Junta de Castilla y León project CLP087U16 and LaserLab Europe (EU-H2020 654148).

References


Institution: Centro de Láseres Pulsados (CLPU), Parque Científico, E-37185 Villamayor, Salamanca, Spain

Department: Department of Electrical and Computer Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2V4

University: Universidad de Salamanca (USAL), Salamanca, Spain

Email: csalgado@clpu.es

Abstract

Laser wakefield acceleration (LWFA) can produce beams of energetic electrons in the range of a hundred of MeVs reaching, in some cases, the GeV regime [1,2]. In addition the Betatron radiation generated by the transverse motion of the electrons in the LWFA represents nowadays a promising source of spatially coherent X-ray for a multiple direct applications in atomic spectroscopy and in the phase contrast images [3-5]. We present the first electron acceleration spectra driven by the Laser system VEGA, as well as the first Betatron spectrum recorded. Also we report the first phase contrast images by VEGA when the Betatron beam is sent through different biological samples. These results perform the first stage of the experiment that is being carried out at the CLPU in close collaboration with the Alberta University. The main goal of this experiment consists in measuring the ionization states of warm dense aluminum using Betatron X-ray radiation generated by the LWFA regime [5].

Experimental setup

An ultraintense ultrashort laser pulse of VEGA II is focused into a millimeter-scale He gas target, consisting in a supersonic gas jet expanding to vacuum. The laser travels through the plasma, activating the LWFA mechanism. The ponderomotive force of the pulse induce huge charge separations in the plasma (electrostatic waves), which co-propagate with the pulse, sustaining GeV/cm electric fields. If some electrons are injected properly they can be accelerated and detected by a magnetic spectrometer. Furthermore, these relativistic electrons can oscillate radially due to the restoring radial field of the wake, emitting ultrashort synchrotron-like X-rays pulses, which can be detected by a X-ray CCD.

Summary

Betatron (E_{crit} ~ 12 keV)

- X-ray free-space propagation phase contrast imaging (PCI) of biological samples implemented with Betatron as source.
- PCI relies in phase changes due to variations in the real part of the refraction index (n) of the sample, rather than in high absorption gradients (i.e. Im(n)).
- Perfect for low-density samples, where contrast is impossible in absorption (interest in medicine, possibility of tomographic reconstruction).
- Enhanced edge contrast.

BETATRON SOURCE

- Spatial coherence (main requirement, small source size).
- Cheaper than synchrotrons.
- Better flux than microfocus X-ray tubes (less exposition time).

Phase Contrast

- Upto GeV energies
- Ultrashort bunches (few fs)
- Broadband spectrum, up to hard X-ray range (~ 10 keV) > HHG
- Ultrashort pulses (few fs) < Synchrotron
- Directional (~20 mrad) < Laser-driven K_{c}
- Spatially coherent (better resolution and PCI)
- Perfect source for X-ray PCI, atomic spectroscopy and laser pump/X-ray probe experiments.

References


ELECTRONS

- Acceleration in centimeter-scale length with table-top laser
- Up to GeV energies
- Ultrashort bunches (few fs)

Next step: time resolved (fs-level) atomic absorption spectroscopy of laser-generated Warm Dense Matter [5].