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Deliverable 32.9
Report on the characterisation and optimisation of X-ray FEL and synchrotron for different laser and plasma parameters

Lead Beneficiary: 20 STRATH

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Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

A. Abstract / Executive Summary

Potential instabilities occurring during the acceleration leading to those secondary sources have been explored numerically. New polarization geometries have been explored theoretically and experimentally for producing elliptically polarized high harmonics as free-electron laser seeds. Relativistic corrections to numerical models have been included to take into account the effect of electron recoil. Synchrotron radiation from a permanent magnet undulator has been investigated in the 30-200 nm spectral range. XUV radiation has been measured simultaneously with the electron energy spread and the correspondence between the two spectra has been established. Excellent beam transport has been established. Coherent transition measurement indicate that the bunch is around 2 fs in duration at the undulator entrance. The photon number scaling with charge has been measured establishing that it is linear. A study of emittance development through the transport system has been undertaken, which shows that the emittance is not spoiled and remains close to 1 π mm mrad. Work has continued on the ion channel laser, betatron emission and the role of radiation reaction in highly radiating systems.

B. Deliverable Report

1 Introduction

Synchrotron and free-electron laser (FEL) developments depend on an understanding and matching of the accelerator and beam transport system. A programme to optimise the laser-plasma wakefield accelerator and beam transport has been undertaken to make it suitable for driving a free-electron laser or compact x-ray synchrotron source. This has involved both experimental and theoretical studies of the FEL driven by ultra-short electron bunches and the build-up of coherence. The injection of HHG source to control the FEL properties has also been investigated theoretically.

2 Objectives

Characterisation and optimisation of X-ray FEL and synchrotron radiation

Characterisation and optimisation of X-ray FEL and synchrotron for different laser and plasma parameters

3 Work performed / results / description

IST have continued the development of OSIRIS in order to model and optimize plasma-based secondary sources, including synchrotrons and FELs. Potential instabilities occurring during the acceleration leading to those secondary sources have been explored numerically, such as the self-modulation instability of ultra-relativistic particle bunches with finite rise times, or the effect of ion motion in the wake driven by long particle bunches.

New polarization geometries have been explored both theoretically (by studying the interaction mechanism with laser pulses with orbital angular momentum) and experimentally, by producing elliptically polarized high harmonics for use as FEL seeds. Finally, relativistic corrections taking into account the effect of electron recoil have been implemented in the X-ray radiation post-processing.

STRATH has undertaken a comprehensive study of synchrotron radiation from a permanent magnet undulator. The electron beam from a LWFA has been conditioned using two triplet quadrupole sets of magnets. The XUV radiation has been measured from 30 nm to 200 nm simultaneously with the electron energy spread and the correspondence between the two spectra has been established. 90% of the charge of the beam has been transported through the 4 m long, 6 mm diameter tube through the undulator, indicating excellent transport parameters. Furthermore, a comprehensive study of bunch lengthening as the electrons pass through the undulator has been carried out. Coherent transition measurement indicate that the bunch is around 2 fs in duration at the undulator entrance and 1 fs at the LWFA. The photon number scaling with charge has been measured establishing that it is linear, which indicates that FEL bunching is not occurring. This has instigated another round of beam transport design to ensure that the bunch properties, such as emittance, duration and energy spread, are preserved. These studies have been published. A study of emittance development through the transport system has been undertaken, which shows that the emittance is not spoiled and remains close to 1 π mm mrad. This work has been published. Work has continued on the ion channel laser as an alternative to the FEL, betatron emission and the role of radiation reaction in highly radiating systems. The ion channel laser and radiation reaction work has been published.

4 Conclusions

These studies should improve access opportunities because they contribute to better characterised radiation from an undulator, as a pre-requisite for a future free-electron laser. Furthermore, new numerical studies of secondary sources will contribute to the development of new types of sources with unique characteristics.

5 Publications

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