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Report on the experimental characterisation of betatron source in the 100 keV range

Lead Beneficiary:

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

Plasma (betatron) and electromagnetic (Thomson scattering) wigglers based on laser-plasma interactions have been investigated. The spectral range has been extended to 100's of keV, and the transverse and longitudinal coherent properties has been investigated. A theoretical study of betatron emission in an ion channel including the role of emittance, energy spread and charge in determining the X-ray pulse duration and brightness at the 100 keV level has been undertaken. A new theory of the ion channel free-electron laser has been developed.

B. Deliverable Report

1 Introduction

Plasma wigglers are a new generation of ultra-compact insertion devices that can be closely coupled to laser-plasma wakefield accelerators (LWFAs). To extend their spectral range to 100's of keV and evaluate the brilliance of these sources it is necessary to investigate the transverse and longitudinal properties of the radiation emitted and establish details of the betatron motion. An experimental and theoretical study of betatron emission in an ion channel including the role of emittance, energy spread and charge in determining the X-ray pulse duration and brightness at the 100 keV level has been undertaken.

2 Objectives

Investigate the characteristics of betatron sources in the 100 keV range

3 Work performed / results / description

The IOQ/Jean team have simultaneously measured all the relevant betatron beam-parameters on each single laser shot. Broadband polarized x-ray radiation is emitted in a laser like beam with a source size of only 1.5 µm. The electron oscillation amplitude is observed to decrease with increasing electron energy. Electrons oscillate in a single plane and emit linearly polarized x-rays.

The team found that the divergence is 25 mrad and the source size is 1.5 µm for a critical photon energy of 8 keV. They measured the polarisation of the radiation using LiF crystals as analysers.

The STRATH team has been investigating betatron emission in the resonant regime where the electrons undergoing betatron motion simultaneously interact with the laser beam, which is Doppler downshifted. This enables the electron transverse momenta to increase substantially, leading to a “wiggler” parameter that can be as large as 100. This gives rise to many harmonics, which merge into a continuum but extend to 100’s of keV. The team has measured the source size, established from the phase-contrast image of thin wires, and found it to be around 7 mm, which is consistent with the large amplitude oscillation and also the high photon energies observed. A novel Compton side-scattered single-shot energy resolving detector was used to measure spectra to photon energies a large as 7 MeV and critical energies in the range of 50 keV to 500 keV. They have also characterised the electron beams from the LWFA to measure the energy and pointing stability and the charge, energy spread and emittance of the beams. They have measured narrow energy spread beams of a few percent at energies of the order of 1 GeV.

They have also investigated the ion channel laser (ICL), which is an analogue of the free-electron laser (FEL). This theoretical work, in the steady-state regime, shows the feasibility of an ultra-compact coherent source based on the ICL. The theory has now been extended to include time dependence. In addition, the STRATH group are developing a FEL code that does not use the slowly varying phase and amplitude approximation and is therefore suitable for investigating the highly nonlinear superradiant regime.

They have investigated a plasma undulator based on a corrugated channel (which STRATH have already patented), which guides the laser along a sinusoidal path and thus acts as a variable periodicity undulator for use as a compact synchrotron source or FEL.

4 Conclusions

The teams have investigated betatron sources in the resonant and non-resonant regimes and measured the polarisation, source size, critical frequency, divergence of the emitted X-ray radiation. Critical frequencies as high as 500 keV have been measured and a peak brilliance equivalent to a third generation synchrotron source ash been measured, though the average brilliance is low because of the low repetition rate of the lasers driving the LFWA. The teams have also undertaken studies of phase contrast imaging. They have also developed a new theory of the ion channel free-electron laser.

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