Report on the ANAD WP activity related to the preparation of European projects

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Abstract

In 2005, the activity of the work-package on Advanced and Novel Accelerator Development (ANAD) has been dedicated to the prospects for the coordination of efforts in the field for the next few years, and resulted in the submission of two European proposals for research and development activities (NEST-Adventure instrument) and training activities (RTN instrument). This report presents briefly theses two proposals.

Introduction

Two proposals have been prepared and submitted in 2005: **EuroLEAP** as a NEST ADVENTURE STREP project, and **EAGLE**, as a RTN project.

The key requirement of NEST (New and Emerging Science and Technology) - ADVENTURE projects is that they must be very challenging and ambitious. They aim to develop new scientific knowledge and technological capabilities with very high potential impact, using unconventional and innovative approaches. ADVENTURE projects are implemented as STREPs (Specific Targeted Research Projects) or coordinated actions.

Research Training Networks (RTN) provide the means for research teams to link up, in the context of a well-defined collaborative research project, in order to formulate and implement a structured training programme for young researchers in a particular field of research.

We have prepared and submitted two complementary proposals: the EuroLEAP NEST proposal is focused on the control of the process of electron acceleration in plasmas; the EAGLE RTN proposal has a broader scope, including linear and non linear regimes as well as application, and has a larger number of participants in order to implement a wide training programme.

EuroLEAP NEST Proposal

The core of the **EuroLEAP (European Laser Electron controlled Acceleration in Plasmas to GeV energy range)** project is the achievement of a laser-plasma accelerator to test the issues related to the control of the properties of an electron beam accelerated to the GeV energy range in a plasma wave, combining cutting edge scientific and technological developments in ultra fast science. This prototype is a crucial step to determine the feasibility of staging in plasma based accelerators, and thus to dramatically increase the final energy. Short pulse (10 to 500 femtoseconds) electron beams, produced by laser injectors in a plasma or RF photo-injectors, will be accelerated by a linear plasma wave created over a few centimetres. The goal is to produce electron beams in the GeV energy range, with an energy spread less than 1%, in a reproducible way over a distance less than 10 cm.

In the frame of this project we plan to develop injectors and the plasma medium, and combine these to perform staged and controlled acceleration studies, through the development of advanced femtosecond electron bunches, plasma and laser diagnostics, and considerations of issues related to staging and extension to multi-GeV energy ranges.

In the first phase, two main tasks will be undertaken in parallel: the experimental development of injectors and creation of a plasma wave over a long distance. Extensive, analytical and numerical theoretical studies will be carried out to improve our understanding of the beam-physics key aspects of wakefield acceleration over a long distance: e.g. longitudinal and transverse phase-space evolution, sensitivity to misalignment of bunch and plasma wave, non-linear effects, instabilities, sensitivity to fluctuations and space-charge effects etc.

In the second phase, the laser plasma accelerator will be assembled for injection of electron bunches into the plasma wave and the properties of the accelerated bunches will be measured and optimised to obtain the smallest energy spread and emittance.

This project is proposed by 8 partners (11 labs), internationally recognised for their expertise, thus ensuring the project to be very dynamic and fostering strong, new synergies between very different laboratories with unique capabilities. Each partner plays a crucial role in the project. The Technical University of Eindhoven (TUE) and the University of Twente are pioneers in the development of ultra-short pulse RF injectors, Imperial College London (IC) and CNRS-Laboratoire d'Optique Appliquée (LOA) are world leaders in electron acceleration to high energies, CNRS-Laboratoire de Physique des Gaz et des Plasma (LPGP) and University of Oxford (UOXF) are leaders for laser guiding techniques, and the Instituto Superior Technico (IST) have state-of-the-art infrastructure for 3D full scale one-to-one numerical modelling of laser plasma interactions. The University of Strathclyde (USTRAT) has built a unique facility in Europe, where the RF injection will be combined with ultra-short, multi-terawatt laser technology. The Rutherford Appleton Laboratory (RAL) has undertaken to build the GEMINI laser facility at which two half Peta-Watt laser beams and a shielded target area will be available for acceleration experiments in the 2^{nd} half of the project. This proposal is coordinated by CNRS-LPGP (B. Cros).

A budget of 2 millions Euros has been requested for a 3 years project. EuroLEAP has successfully passed the first stage of selection and has been invited to submit a full proposal for the second stage. The full proposal has been submitted on September 15, 2005, and the outcome is expected in December 2005. This project is supported by ESGARD.

EAGLE RTN Proposal

The motivation for the **EAGLE (Electron Acceleration to Gev energies by LasErs in plasmas)** project is to foster European efforts in order to demonstrate the ability of laser plasma acceleration techniques to produce good quality electron bunches in the GeV energy range. Several national projects have recently been funded in Europe to develop ultra-short pulse, PW-class lasers, or dedicated facilities coupled to radio-frequency (RF) accelerator technology to study laser plasma wakefield acceleration techniques and their application to the generation of ultra-short pulse radiation. We thus find it timely to take advantage of the emergence of these new projects, complementing existing ones, to give a stronger impulse to the development of laser wakefield acceleration by overcoming the fragmentation of the European research in this field through a collaborative research and training project. While exchanges between high intensity laser physics and plasma physics communities have been growing over the last years, the overlap with the accelerator physics community has to be enhanced in order to achieve significant progress. The proposed Network will increase exchanges between these communities, through a concerted, coordinated training effort, on a subject that is highly interesting from a fundamental point of view as well as technologically very innovative.

The main scientific goal of this project is to achieve electron beam acceleration to the GeV energy range in a plasma wave, to characterise the beam properties, and use it to generate short-pulse, short wavelength radiation. Linear and nonlinear regimes of wakefield acceleration will be studied to produce low energy spread, high brightness, femtosecond duration electron bunches in the GeV energy range.

Non linear regimes involve the trapping of background plasma electrons into the large amplitude plasma wave generated by an intense laser pulse. As this mechanism has proved difficult to control, several issues related to its stability and reproducibility will be studied, as well as the possibility to inject the produced bunch in a subsequent plasma wave.

In the linear regime, the background plasma electrons cannot be trapped in the linear plasma wave, and it is necessary to inject them from an external source. These sources, will be developed and optimised, and acceleration of the injected bunches in a linear plasma wave will be characterised. This regime makes possible the control of the source of electrons and the accelerating structure.

The electron beams produced will then be used for two applications related to the production of short wavelength radiation: the injection of the electron bunch in an undulator and the collision of electron and laser beams to produce ultra-short duration X-rays pulses through Thomson scattering.

This project is proposed by 13 partners (18 labs) : CNRS-CPT (Centre de Physique Théorique), CNRS-LPGP, CNRS- LULI (Laboratoire pour l'Utilisation des Lasers Intenses), CNRS-LOA, IST, CNR-ILIL (Intense Laser Irradiation Laboratory), INFN (Istituto Nazionale di Fisica Nucleare)- LNF, IC, USTRAT, UOXF, TUE, HHUD (Heinrich-Heine-Universitaet Duesseldorf) ILP (Institut für Laser und Plasmaphysik) and ITP(Institut für Theoretische Physik), LLC (Lund Laser Center), LMU (Ludwig Maximilians Universität München), and MPQ (Max Planck Institut fuer Quantenoptik Garching).

Funding for 360 person-months equivalent of PhDs and 252 person-months equivalent of Post-Docs has been requested for a 4 years project. This proposal has been submitted for the first stage in September 28, 2005 and is coordinated by P. Mora (CNRS-CPT). The outcome will be known in December 05.

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