DITANET: A EUROPEAN INITIATIVE IN THE DEVELOPMENT OF BEAM INSTRUMENTATION FOR FUTURE PARTICLE ACCELERATORS

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Abstract

Without an adequate set of beam instrumentation, it would not be possible to operate any particle accelerator, let aside optimize its performance. In a joint effort between several research centres, Universities, and partners from industry, DITANET aims for the development of beyond-state-of-the-art diagnostic techniques for future accelerator facilities and for training the next-generation of young scientists in this truly multi-disciplinary field. The wide research program covers the development of beam profile, current, and position measurements, as well as of particle detection techniques and related electronics.

This contribution introduces this new Marie Curie Initial Training Network, presents the DITANET partner institutes, and gives an overview of the various research and training activities.

INTRODUCTION

Marie Curie Initial Training Networks (ITN) are aimed at improving the career perspectives of researchers who are in the first five years of their career by offering structured training in well defined scientific and/or technological areas as well as providing complementary skills and exposing the researchers to other sectors including private companies.

The European Training Network DITANET - "DIagnostic Techniques for particle Accelerators – a Marie Curie initial training NETwork" - covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ions. It is the largest-ever education action for PhD students in the field of beam diagnostic techniques for future particle accelerators and officially started on 1.6.2008 with a total budget of up to 4.2 M€.

DITANET covers the development of advanced beam diagnostic methods for a wide range of existing or future accelerators, both for electrons and ions. DITANET consists of the following <u>network participants</u>:

University of Heidelberg (coordinator, Germany), CEA (France), CERN (Switzerland), DESY (Germany), GSI (Germany), HIT GmbH (Germany), IFIN-HH (Romania), Stockholm University (Sweden), Royal Holloway University of London (UK), and the University of Seville/Centro Nacional de Aceleradores (Spain).

The network is complemented by twelve associated partners from all over the world:

ESRF (France), idQuantique (Switzerland), INFN-LNF (Italy), Instrumentation Technologies (Slovenia), MPI for Nuclear Physics (MPI-K), PSI (Switzerland), THALES (France), Thermo Fisher Scientific (USA), TMD Technologies Limited (UK), TU Prague (Czech Republic), ViALUX (Germany), and WZW Optics (Switzerland).

TRAINING

Beam diagnostics systems are essential constituents of any particle accelerator; they reveal the properties of a beam and how it behaves in a machine. Without an appropriate set of diagnostic elements, it would simply be impossible to operate any accelerator complex let alone optimize its performance. Beam diagnostics is a rich field in which a great variety of physical effects are made use of and consequently provides a wide and solid base for the training of young researchers. Moreover, the principles that are used in any beam monitor or detector enter readily into industrial applications or the medical sector, which guarantees that training of young researchers in this field is of relevance far beyond the pure field of particle accelerators.

Young researchers participating in DITANET will not only get the possibility to perform state-of-the-art research, they will also get a much wider training in the domain of beam diagnostics by interaction with other network participants and close collaboration with associated partners from the industrial sector. This includes regular exchanges of trainees between the partners that will thus get the possibility to participate in ongoing R&D work at linked institutes and universities.

This way, DITANET will provide a cohesive, flexible framework for the training and professional development of researchers in beam diagnostic techniques for particle accelerators, with a strong focus on possible applications of these principles in industry.

In addition, DITANET will organize one week courses on beam diagnostic techniques in spring 2009 at Royal Holloway University of London and in fall 2010 at Stockholm University that will be open to all network participants as well as to external participants. Details on these courses will be published on the DITANET web site [1].

RESEARCH

Future accelerator projects will require innovative approaches in particle detection and imaging techniques to provide a full set of information about the beam characteristics. DITANET covers a wide range of future accelerators, ranging from the next generation of linear colliders (ILC, CLIC) and the most advanced high energy accelerators (LHC, FAIR), to innovative light sources (X-FEL) and novel low-energy storage ring projects (DESIREE, USR). A few examples of the research projects within DITANET are outlined in the following sections.

High-Intensity Klystrons

The performance of high power electron devices is presently limited by the quality of the electron beam propagation along the interacting structures. These beams reach power densities as high as 5 MW/cm^2 and any interception of the beam with the structure risks damaging it.

Presently, simulation codes are commonly used to predict the behaviour of the electron beam, while very little has been achieved in the field of diagnostics for klystron applications. These physical measurements are necessary to validate and possibly improve the simulations codes, to rank limiting phenomena, and finally, to improve the design and performance of high power electron devices that will be used extensively in the future linear colliders like the ILC and CLIC.

In the frame of DITANET, the most pertinent instruments that can be adapted to the RF electron device problematic and geometry shall be identified. This work will be followed by the design and realisation of a set of diagnostics, including mechanics, control and signal processing.

This project will be realized in partnership with Thales Electron Devices, a world leading manufacturer of klystrons, and CEA Saclay.

Beam Diagnostics for CLIC

One of the major decisions in particle physics over the next 3 years will be to decide on the next major accelerator to access the multi-TeV energy scale. The CLIC two-beam acceleration scheme [2] is one of the candidates for the next accelerator for the high-energy frontier, and the CLIC Test Facility (CTF3) at CERN [3] is the unique facility to test the CLIC acceleration principle and to prove the feasibility of associated RF systems.

In addition to the RF accelerating systems themselves, a host of beam diagnostics will need to be developed to cope with the challenging environment of CLIC. There exists space at the CLEX area of the CTF3 facility to build a new Instrumentation Test Beam (ITB). One of the first tasks of the trainee will be to design the machine optics for the ITB in collaboration with the CERN experts and to work with the CLIC diagnostics team to optimize the layout and functionality for future key diagnostics projects.

In addition to the ITB design, the Early Stage Researcher (ESR) with work with TMD technologies to assess the opportunities for RF system development and to identify a fruitful new line of R&D where the expertise of TMD can be combined with the expertise at RHUL and CERN to develop a new product of use to the CTF3/CLIC project.

The system design work will be complemented by frequent data taking and machine operation at CTF3. This combination of practical experience, beam-line design, and industrial collaboration, will provide a unique training opportunity.

A Beam Profile Monitor based on Light Emission from Rest Gas Atoms

Many accelerator projects make use of high intensity ion beams, e.g. for the production of neutrons (ADS, IFMIF), at neutrinos factories, or in nuclear physics research (FAIR, SPIRAL 2). The transverse distribution of these beams needs to be accurately known to avoid any unwanted interaction with the vacuum chamber walls and to properly impact the target.

The power of these beams prevents using intrusive methods since any kind of screen would be rapidly destroyed by the temperature increase. One solution can be to use the neutral gas in the vacuum chamber which is excited by the beam. The light emitted by this gas may then be used to obtain a good representation of the beam itself.

Within DITANET the first focus will be the adaptation of this scheme to a particular accelerator project, including a theoretical description of the light emission, characterisation of the beam and an estimation of the required space in the vacuum chamber. Tomography algorithms will then be investigated to reconstruct the 2D transverse beam profile observed along various directions.

This work will then be followed by the design and realisation of the detector, followed by measurements on a specific ion beam and application of these measurements to fine-tune the accelerator.

Development of a CCC-based Current Monitor

The FAIR storage rings have to be capable of the operation with very low ion currents, i.e. much below 1 μA. In particular, in the case of radioactive ion beams and antiprotons the amount of stored particles in the FAIR storage rings is too low for standard beam diagnostic devices. For the slow extraction from the SIS100 synchrotron the high-energy beam transfer-lines require diagnostic devices for the non-destructive measurement of ion currents down to the nA region. For this purpose, the installation of Cryogenic Current Comparators (CCC) is foreseen, offering a non-intercepting and absolute current measurement. The basic principle is the determination of the beam's magnetic field using a sensitive SQUID-based magnetic flux detector. A CCC prototype was realized at GSI already in 1996 [6] and an improved design is now planned to be used at DITANET participant DESY [7] for dark-current detection at the X-FEL acceleration cavities. The optimization, standardization and commissioning of a new CCC is the goal of the DITANET PhD work with the time frame of DITANET.

INVOLVEMENT OF INDUSTRY

The participation of industry is an integral part of DITANET. As shown in the beginning of this article, a number of private companies are included as associated partners to the network. They are members of the supervisory board to ensure that industry-relevant aspects are covered in the different projects carried out within the network and to enhance knowledge transfer. In addition, one third of the DITANET Steering Committee members come from industry.

From the beginning, the DITANET management encouraged the involvement of these partners in the training program at the highest possible level. This led to the participation of HIT GmbH as a full network member with a PhD project that will be hosted by this company. In addition, the associated partner THALES, who is considered as a world-wide leader in the development of klystron technology, will host the trainee from CEA during up to 25% of the PhD project, thus taking over a considerable part of the training.

WZW Optics , Vialux, Thermo Fisher and idQuantique are among the leading companies in the field of optics, scientific cameras and detector systems. Instrumentation Technologies from Slovenia and TMD technologies from the UK have long-standing links to accelerator laboratories and have pushed the development of beam diagnostic techniques on various occasions in the past.

All companies as well as the other associated partners from academia (TU Prague, MPI for Nuclear Physics) and research (PSI, INFN, ESRF) have agreed to host the DITANET trainees during some weeks up to several months. This ensures that every trainee will get the possibility to realize an extended research stay at a leading partner institute from industry and to take part in its R&D efforts.

Thereby it is guaranteed that all trainees will be provided with a true multi-disciplinary and inter-sectorial training, where they will not only work on their main project, but learn about neighboring fields and get a view of possible applications and of the impact of their work in the industrial sector.

These measures will complement the scientific training and actively bridge between the academic and the industrial sectors within DITANET.

IMPLEMENTATION

The DITANET Marie Curie Initial Training Network will form a consortium which comprises 10 network participants and a roughly equal number of associated partners. It is the goal of the management structure to profit from the individual expertise of the participating institutions while maintaining an effective decision making and controlling process.

The key bodies of the DITANET managerial structure are the Supervisory Board, the Network Coordinator assisted by the Management Office in scientific, management and financial matters, and the DITANET Steering Committee. Whenever required, a spin-off board will complement this structure.

CONCLUSION

The largest ever coordinated EU education action for young researchers in the field of beam diagnostic techniques for particle accelerators has been awarded to a consortium of ten partners from all over Europe within the EU-Marie Curie program for initial training networks. The joint effort in setting up DITANET and the corresponding administrative and training-related boundary conditions will guarantee a continuous training of young researchers in this field. Close collaboration between the network participants and the associated partners with a very prominent role of industry, ensures that the basis for DITANET is laid in a true international approach with a clear long term perspective.

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