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NETWORKING ACTIVITIES OF THE I.FAST PROJECT IN THE HIGH BRIGHTNESS ACCELERATOR FOR LIGHT SOURCES

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Abstract

The Innovation Fostering in Accelerator Science and Technology (I.FAST) project [1] aims to enhance innovation and networking in the particle accelerator community, mapping out and boosting the development of breakthrough technologies common to multiple accelerator platforms. Task 7.2 of the I.FAST project, Enabling Technologies for Ultra Low Emittance Rings, focuses on networking in the area of low emittance rings dominated by the recent X-ray storage ring upgrades and exploiting synergies with existing and future e^+/e^- colliders. The strengthening networking activities in key technologies ranging from magnet design, RF systems, vacuum, injection systems to feedback systems and beam instrumentation leads to R&D paths that are closely linked to project partners, other facilities and scientific fields. On this basis, technological challenges are tackled jointly at European level and also encourages co-operation in projects with partners worldwide. To promote networking, Task 7.2 has organized several thematic workshops to date, and is planning further workshops to expand opportunities to strengthen networking. In this contribution, we present our previous and current activities.

I.FAST TASK 7.2: THE PURPOSE AND THE SCOPE OF ACTIVITIES

In the scientific areas based on synchrotron radiation and e+/e- colliders, the demand for high-quality electron/position beams with ultra-low emittances is now becoming much higher. In ultra-low emittance rings, the transverse beam sizes typically reach the spatial diffraction limit in the keV-range of synchrotron radiation photons. Such high-quality beams enable synchrotron radiation sources with high brightness and e^+/e^- colliders with high luminosity, contributing to a wide range of scientific, engineering, and technological areas. However, the realization of such high-quality beams necessitates scientific and technological breakthroughs in several accelerator physics and technology issues. For instance, diffraction-limited synchrotron radiation light sources necessitate spatial position and angle stability of synchrotron radiation beams for the conductance of state-of-the-art experiments, which also demand beam stability on the accelerator side. In order to achieve the required beam stability, accelerators must prepare relevant hardware, such as magnets and RF accelerating systems, with high stability, and a beam diagnostic system to evaluate the beam stability must be conditioned. Moreover, a feedback system must be prepared to stabilize beams against instabilities. It is also important to note that a profound understanding and knowledge of beam dynamics, which includes magnetic lattice and RF system design considering collective instabilities, is essential to achieve the state of an ultra-low emittance beam. To realize ultra-low emittance beams and utilize them for cutting-edge experiments, extensive research and development based on profound understanding and knowledge are necessary. Given the complexity of an accelerator system, which consists of a large number of hardware devices, and networking activities that enable the exchange and sharing of information and knowledge accompanied by technology transfer, are in a high demand for projects on ultra-low emittance rings.

In response to these demands, the partners in I.FAST Task 7.2 are engaged on enabling technologies up to innovations for ultra-low emittance rings and strengthening of networking activities in these areas. This is being achieved through the organization of scientific events such as international workshops, which provide opportunities for the exchange of information and knowledge. In addition, the working group Task 7.2 organized and will organize joint experiments on accelerator physics and technology, which allow participants to work on the same experimental topics together and to discuss them with each other as well as to carry out joint hands-on experiments at a synchrotron such as a test facility like KARA. This is based on the monthly meetings where the partners of I.FAST Task 7.2 prepare the workshops, the experiments and exchange information on the latest topics, research results and innovation related to ultra-low emittance rings.

WORKSHOP ORGANIZATION

The members of Task 7.2 are engaged in organizing scientific events such as workshops and meetings in the area of ultra-low emittance rings to strengthen networking activities in essential technologies, based on monthly online task meetings. Here, we report our networking activities briefly, which have reached up to now as the framework of the I.FAST project.

Workshop on Beam Diagnostics and Dynamics in Ultra-Low Emittance Rings

In the future, synchrotron radiation sources and e+/e- colliders will require high-quality beams with ultra-low emittance. To assess the beam quality and stability, technological breakthroughs in beam diagnostics are necessary to evaluate the beam quality achieved at a level that previous accelerators have never reached. In order to direct the development of the beam diagnostic system in the optimal direction for

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ultra-low emittance beams, it is essential to enhance the understanding of beam dynamics and to facilitate the exchange of information and knowledge between the beam diagnostics side and the beam dynamic side. Based on these ideas, the workshop on beam diagnostics and dynamics in ultra-low emittance rings was organized [2]. The workshop period was from April 25 to 29, 2022, during the international pandemic. During this period, it was challenging to proceed with workshop activities. However, the workshop was conducted online by the Karlsruhe Institute of Technology (KIT) with participants from around the globe. Due to differing time zones, the scientific sessions were held only in the afternoon Central European Time. The workshop included sessions on beam diagnostics and beam dynamics, with the objective of exchanging information and knowledge between the two sides of beam diagnostics and beam dynamics. Topical sessions included discussions of beam injection and collective beam instabilities from both the beam dynamics and diagnostics perspectives. Other topics included long-term beam stability, such as mechanical vibrations occurring in experimental halls and slow drift motions due to ambient temperature, as well as the application of machine learning to beam diagnostic systems. The workshop's contents have also been summarized briefly and published as the I.FAST project report [3].

Low Emittance Ring - Permanent Magnet Workshop

Nowadays, permanent magnet technology has been strongly focused on, accompanied by technological progress and the demand to reduce energy consumption for accelerator operation. Motivated by these backgrounds, the workshop on permanent magnet was organized jointly by LEAPS-PerMaLIC [4] and I.FAST from November 14 to 15, 2023 at Trieste with the local support of Elettra Sincrotrone Trieste. In the workshop, the state-of-the-art topics regarding the permanent magnet systems were discussed widely with the participants worldwide, not only from accelerator institutes but also from industrial areas. This showed the success of the workshop from the point of view of innovating new technologies, which is one of the purposes of the I.FAST project. The workshop was organized with the following five key topics, each of which is relevant for proceeding with applications of permanent magnets to ultra-low emittance rings.

- Magnet design,
- Permanent magnets technological challenges,
- Permanent magnet material,
- Production & industrialization,
- Magnetic measurements challenges.

This shows that the workshop comprehensively covered scientific and technological topics related to permanent magnets and also focused on innovations with a wide range of discussions, including the production and industrialization of permanent magnets. The workshop was a great success and the contents of the workshop, including the presentation slides, have been published on the Indico workshop website [5].

Low Emittance Rings Workshop

The concept of ultra-low emittance rings is based on a variety of key technologies and beam dynamics knowledge relevant for achieving high quality beams. In order to share the latest information and knowledge covering a wide range of accelerator physics and technology, the partners of Task 7.2 organized an international workshop, the "Low Emittance Rings Workshop 2024", at CERN from February 13 to 16, 2024. The aim of the workshop was to share knowledge and information on ultra-low emittance rings across a wide range of design approaches and performance goals that drive key technologies, including lattice design, optics measurement and correction, nonlinear dynamics, magnet design, beam stability, feedback and diagnostics, ring design challenges, collective effects, harmonic cavity design and experiments, energy calibration, machine learning and artificial intelligence. In particular, a full session organized in collaboration with I.FAST WP 11 (Sustainable Concepts and Technologies) [6] was dedicated to power consumption, energy efficiency and sustainability. All the presentations discussed were state-of-the-art topics worldwide, and the participants were able to strengthen the network in the field of ultra-low emittance rings, including light source storage rings, damping rings, and e^+/e^- circular colliders, by sharing knowledge and the latest advances in the field. The total number of registered participants reached almost one hundred, and the participants came from various fields of accelerator physics and technology, including institutes and industrial areas worldwide, with diversity. It should be emphasized that such diversity, with a wide range of scientific and technological fields and cultures, greatly strengthens the activities related to the research and development of ultra-low emittance rings. Therefore, it can be said that the networking activities in which I.FAST Task 7.2 is now engaged should be continuously enhanced.

The workshop reached many relevant conclusions and the contents of the workshop have been summarized and published on the Indico workshop website [7].

Two Workshops: Bunch-by-Bunch Feedback Systems and Injectors for Storage Ring Based Light Sources

Two other topical workshops on "Bunch-by-Bunch Feedback Systems and Related Beam Dynamics" and "Injectors for Storage Ring Based Light Sources" were organized in the same week (March 4 to 8, 2024) at KIT, aiming at synergies between two different scientific fields. In ultra-low emittance rings, due to the high quality of the beams, collective beam instabilities can be stimulated by interactions between the beams and the environment, such as RF cavities and vacuum

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chamber walls, leading to a degradation of the beam quality. Bunch-by-bunch feedback systems are becoming one of the indispensable devices to ensure beam quality in ultra-low emittance rings. The bunch-by-bunch feedback systems have been installed in several ring-based synchrotron light sources, damping rings and e^+/e^- circular colliders. The aim of the bunch-by-bunch feedback systems workshop was to strengthen the networking in the field of feedback systems in order to exchange the latest information and experiences that feedback system specialists have established so far. The workshop had four session categories, namely beam instrumentation and high power systems, hardware for fast signal processing, related beam dynamics, and applications and new ideas. It should be emphasized that people involved in the development of bunch-by-bunch feedback systems worldwide attended the workshop together and shared their knowledge and experience, which was one of the results of the networking activities.

The workshop on injectors for storage ring based light sources was held directly after the bunch-by-bunch feedback workshop. In ultra-low emittance rings, injectors such as booster synchrotrons supply beams to main storage rings that function as light sources. To ensure stable beam operation of the main storage rings, the injectors must be operated to deliver high quality beams to the main rings while maintaining high stability. The injector workshop also aimed to share the latest information and experience on the operation and upgrading of injectors in operation and under consideration, accompanied by new projects for the main storage ring light sources. The injector workshop had three session categories to discuss injectors comprehensively, namely new injectors and modifications to old machines, proposed and future injectors, injection technologies and development, and related beam dynamics. Since the injector workshop was held immediately after the bunch-by-bunch feedback workshop, several participants from the feedback workshop also attended the injector workshop, and several discussions were held using technical terms from the bunch-by-bunch feedback systems. This showed that the two workshops achieved synergies and could contribute to networking between two different scientific fields.

Two workshops were organized jointly with the I.FAST Task 7.2 partners. The bunch-by-bunch feedback workshop was jointly organized by SOLEIL and KIT, and the injector workshop was organized by PSI, SOLEIL and KIT. Both workshops resulted in relevant and sufficient scientific and technological conclusions with strengthened networking activities. The contents of the workshops have been published on the Indico workshop websites [8, 9] and will be summarized as I.FAST project reports soon.

Joint Experimental Campaign on Bunch-by-Bunch Feedback Systems

Between the workshop on bunch-by-bunch feedback systems and the workshop on injectors, a joint experimental campaign [10] took place at the Karlsruhe Institute of technology (KIT) in collaboration with partners of I.FAST 7.2 and the EU project EURO-LABS [11], where the workshop participants conducted experiments with the Karlsruhe Research Accelerator (KARA), a 2.5 GeV electron storage ring, and its bunch-by-bunch feedback system as well as in the 500 MeV Booster. Beyond the preparation of the experimental campaign, the team Task 7.2 has organized online meetings called "Feedback Meeting" to exchange information and knowledge about bunch-by-bunch feedback systems as a networking activity with specialists of feedback systems. Experimental topics and contents for the joint experimental campaign were discussed there and during the feedback system workshop to ensure the networking activity and search for relevant topics concerning the feedback system with the workshop participants. Three experimental topics were selected and conducted in a 1.5-day experimental period, namely vertical emittance/beam size control with feedback system, search for a common way to commission feedback systems, and test for modulating the longitudinal motion of the KARA booster synchrotron beam with stripline kicker. The data and results have been shared with all interested participants, and the data analysis and subsequent discussions are ongoing.

CONCLUSION

The purpose of I.FAST Task 7.2 is to strengthen the networking in the field of ultra-low emittance rings. The partners of Task 7.2 has actively organized workshops and joint experimental campaigns focused on key technologies like magnet design, vacuum, beam instrumentation, RF-, injection-, and feedback-systems. The networking activities will be further intensified in the I.FAST project, to establish technologies in the field of high brightness synchrotron light sources.

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