RIGA TECHNICAL UNIVERSITY

WP10 on project preparation Advanced accelerator technologies

IFAST - Open Steering Committee

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RTU / CERN

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WP10

Task 10.1: Coordination and communication

M1 – M48 by **RTU – Prof. Toms TORIMS + Dr. Andris RATKUS**

- ✓ Coordination of the WP, monitoring of progress and technical actions
- ✓ Promote communication strategies on **opportunities offered by new technologies for accelerators**

Task 10.2: Additive Manufacturing – Survey of applications and potential developments

M1 – M36 by **PoliMi – Prof. Maurizio VEDANI**, RTU, CERN, CNRS, CEA, INFN, TalTec + Fraunhofer IWS

- ✓ **Survey** of current Additive Manufacturing (AM) applications in accelerators and identification of needs for future development and research actions
- ✓ Promote initiatives to identify how **AM can address the needs** of the accelerator community
- ✓ Define strategic directions for **future AM technologies** and foster their impact on accelerator applications identifying technology barriers and challenges

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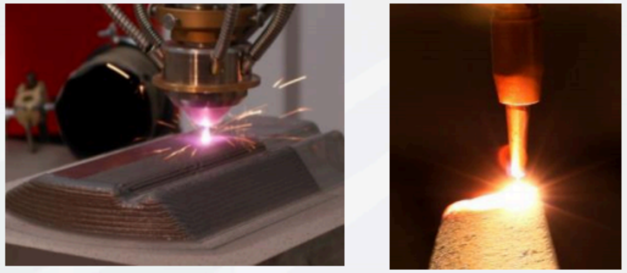
Task 10.3: Refurbishment of accelerator components by AM technologies

M1 – M24 by **RTU – Dr. Andris RATKUS**, PoliMi, CERN, CEA, INFN, CNRS, TalTec + Fraunhofer IWS

- ✓ Definition of applications and components for the **repairing activities in the accelerator(s)**
- ✓ Identification of **AM strategies** that can be adopted to repair parts
- ✓ Study **post-processing methods** to control surface roughness and surface cleanliness of AM parts
- ✓ Identification of a **sample demonstration prototype** of AM repaired unit for an accelerator component(s)

Strong link to Task 10.2 and related to Task 10.4



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Task 10.4: Development of AM-manufactured superconductive RF cavities

M1 – M24 by **INFN – Dr. Adriano PEPATO** and CNRS

- ✓ Develop the design approach and test relevant properties of **AM-manufactured Niobium RF cavities**, to be tested at room and at cryogenic temperature
- ✓ Develop the design approach and test relevant properties of AM-manufactured **Ultra-Pure Cu-made RF body cavities, coated by a Niobium** thin layer at the inner surface, to be tested at room and at cryogenic temperature

Task 10.5: Photon Stimulated Desorption (PSD) from NEG coatings for accelerator vacuum chambers

M1 – M48 by **UKRI – Dr. Oleg MALYSHEV**, DLS, SOLEIL

- ✓ Build facilities for photon stimulated desorption - **PSD yield measurement on beamlines**
- ✓ Obtain and **analyse the PSD experimental data** from NEG coated prototypes under conditions similar to future light sources

Strong link to WP9

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Task 10.6: Machine learning techniques for accelerator and target instrumentation

M1 – M36 by **ESS – Dr. Thomas SHEA** and RTU

- ✓ Develop Machine Learning (ML) **predictive algorithms with the capability to diagnose and protect high power accelerators**
- ✓ **Implement a selected algorithm** on a low-latency network of diverse instrumentation and verify performance in the realistic conditions of the ESS facility

Task 10.7: Development of electro-optical waveguide sensors as beam electric field sensors M1 - M24 by **RHUL – Prof. Stephen GIBSON** and CERN

- ✓ Develop **novel electric-field sensors**, based on electro-optic waveguides to address new challenges in fast time response (<50 ps) beam instrumentation
- ✓ **Demonstrate the capability** to optically measure the intra-bunch transverse displacement of a passing relativistic bunch, with a bandwidth that is beyond state-of-the-art

Work package number	10	Lead beneficiary	RTU		
Work package title	*Advanced accelerator technologies*				
Participant	**Person months per participant**	**Participant**	**Person months per participant**	**Participant**	**Person months per participant**
1. CERN	1.4 + 1.8	9. SOLEIL	3.3 + 8.7	43. DLS	5.3 + 6.7
2. ESS	3 + 7.5	25. INFN	5 + 1.5	45. RHUL	0.9 + 5.8
4. TalTech	3.8 + 4.7	28. PoliMi	10.8 + 11.2	47. UKRI	5 + 7
7.CNRS	8 + 0	29. RTU	17.4 + 13.1		
Start month	1	**End month**	48		

Deliverables related to WP10	
D10.1: Potential AM applications in accelerators. *Report on output of the survey on AM applications, further needs for the accelerator community, and perspective developments.*	30
D10.2: Survey of AM applications and strategies for repairing accelerator components by AM. *Report listing possible strategies and technologies for repairing of parts.*	24
D10.3: Additive-manufactured Superconductive RF cavities. *Production and tests of superconductive RF cavities, made by Nb and/or Cu coated by an Nb thin film.*	12
D10.4: First PSD data from NEG coating. *First PSD data from NEG coating reported.*	36
D10.5: Technical Report on machine learning at ESS. *Evaluation and verification results, architecture of the final implementation, and achieved performance at the ESS facility.*	34
D10.6: Electro-optic performance report. *Final report on the performance of the electro-optic pick-up prototype with beam.*	24

More detailed information

Task 10.2: Additive Manufacturing – Survey of applications and potential developments (PoliMi, RTU, CERN, CNRS, CEA, INFN, TalTec)

- The task aims at improving knowledge about the potential of AM applied to particle accelerators by introducing aspects related to innovative materials, new design approaches for complex parts and assemblies. The objective is to raise awareness about advantages of AM in the accelerator community, covering both research infrastructures and societal applications.
- The Task **will develop a roadmap** for a wider uptake of advanced technologies and particularly of AM into the community. The partners will jointly produce an **inventory** of current AM applications in accelerators, identify specific needs for accelerators, and define further applications of AM, in particular, for industrial and medical accelerators. The Task will also analyse opportunities offered by digitalization in accelerators, evaluating market and economical aspects concerned with AM in the accelerator sector. The activity will also include organization of **workshops and meetings**, one per country or region during the first year, in at least 5 different regions, open to partners, accelerator experts and other industrial stake-holders to identify how AM can address the needs of the accelerator community.

Task 10.3: Refurbishment of accelerator components by AM technologies (RTU, PoliMi, CERN, CEA, INFN, CNRS, TalTec)

- Many accelerator parts that require repairing can benefit from the advantages of using AM. This Task will analyse the potential impact from exploiting AM technologies for repairing strategies of damaged accelerator components. The extreme operating conditions of modern particle accelerators have a strong impact on many complex components that are worn or damaged by thermal fatigue cracks or any other reasons. They can be refurbished by removing the damaged volume and depositing the missing volume of material according to an AM approach.
- The technical feasibility of using AM technologies will be studied by RTU in collaboration with PoliMi. CERN, CEA, CNRS, INFN and TalTec will provide actual data and experience. The Task will result in a **final report**.

Task 10.4: Development of AM-manufactured superconductive RF cavities (INFN, CNRS)

- The Task aims at the development of AM-manufactured superconductive RF cavities, made by Nb or Cu coated by an Nb thin film, to be tested at room and at cryogenic temperature. The goal is to simplify the process and reduce cost for the production of RF cavities of complex shape. This challenging approach would significantly decrease the size and the cost of new accelerating facilities.
- The Task will select suitable materials or material alloys that can be printed by AM (e.g. pure Cu or Cu alloys), identify the most convenient AM technology (e.g. laser-powder bed fusion, direct energy deposition, binder jetting …), and study the post-processing methods.
- INFN will produce the test 6.0 Ghz Nb and Cu cavities and CNRS will perform the functionality test.

Task 10.5: Photon Stimulated Desorption (PSD) from NEG coatings for accelerator vacuum chambers (UKRI, DLS, SOLEIL)

- Two dedicated synchrotron radiation (SR) beamlines are currently under design and construction at DLS and SOLEIL synchrotrons. Facilities for photon stimulated desorption (PSD) yield measurement will be built on these beamlines employing the UKRI experience in experimental studies of PSD/ESD from desorbing surfaces. DLS and SOLEIL will provide the vacuum chamber porotypes, which will be coated with NEG film at UKRI. Various types of NEG coating will be explored, with varying parameters such as composition, morphology and thickness. The prototypes will be installed on dedicated beamlines and irradiated following a specific procedure.

Task 10.6: Machine learning techniques for accelerator and target instrumentation (ESS, RTU)

- This Task will develop low-latency Machine Learning (ML) techniques to improve performance and availability of high-power facilities at the intensity frontier. Operating near their engineering limits, these facilities will benefit from ML-based systems that can predict and mitigate beam-induced damage to accelerator and target components.
- The Task will assess the predictive capabilities of several ML models trained and evaluated with operation data from SNS (USA, 13 years of operations data), with commissioning data from the ESS, and with simulation results. The most promising model will be then implemented on a Field Programmable Gate Array (FPGA)-based system at the edge of the ESS controls network. Lastly, by processing measurements from a diverse suite of accelerator instrumentation, the system will identify signatures of potential errant beam conditions and then request operator intervention, initiate automated corrections, or, in the most severe cases, suppress beam production on interpulse (<70 ms) or even intrapulse (<2.86 ms) timescales.
- The ESS team will provide the accelerator and instrumentation systems, and FPGA-based expertise. Programming and implementation of the system will be supported by RTU.

Task 10.7: Development of electro-optical waveguide sensors as beam electric field sensors (RHUL, CERN)

- This task will develop novel, high bandwidth (>10 GHz) electric-field detectors, based on exquisitely sensitive electro-optic waveguides made from birefringent lithium niobate. The waveguides will be integrated into an Electro-Optic Beam Position Monitor (EOBPM) based on electromagnetic and mechanical designs developed and optimised by RHUL and CERN. The goal is to reduce the size and complexity of the existing EO-BPM designs by using lithium niobate waveguides in place of crystals. The waveguides are readily fibre-coupled to form a Mach-Zehnder interferometer embedded in the pick-up(s), which enhances the sensitivity and eliminates the necessity for complex free space optics.
- RHUL and CERN will perform electromagnetic simulations to optimize the mechanical design of the pick-up in terms of simplicity, robustness and cost, while achieving the best sensitivity and time resolution. A photonics specialist company will develop and manufacture a prototype batch of thin-film lithium niobate Mach-Zehnder interferometric waveguides that RHUL will equip with miniature electrodes and incorporate into an EO beam pick-up. RHUL will bench test the expected signals of the prototypes and then the team will validate the response of the electro-optic pick-ups at a CERN beam facility.