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ARIES
Promoting Innovation
Progress Report from WP14

ARIES Annual Meeting -
Geneva - April 22nd , 2020

Marcello Losasso, CERN

On behalf of WP14 team in: BrevettiBizz, Brucker, CERN, CNI, COSYLAB, Wigner, RHP,STFC,UNIGE

Few highlights and Status of WP14 at April 2020

- Participation to Annual Meeting – Budapest April 2019
- Progress activities on PoC projects and industrial tasks
- Deliverables & Milestones are all on time
- Workshop on AM in Budapest
- Preparation (*and cancellation*) of workshop on RAMI
- Preparation for the next step…*I.FAST*

CERN – Wigner – CNI – RHP - BrevettiBizz
CosyLab – Brucker – STFC - UNI Ge

WP14 – contractual obligations (D, MS)

Y1	D14.1	Set-up of the Proof-of-Concept innovation-funding scheme	14.2	M12	23.04.18	Report
Y2	D14.2	Academia meets industry event 1	14.3	M24	09.05.19	Report
	D14.3	Production of material samples of carbon-based composites and metal-diamond composites	14.4	M24	30.10.18	Report
Y3	D14.4	First long length industrial High Temperature Superconductor	14.5	M30	31.10.19	Report
Y4	D14.5	Real-time Event Distribution Network brought to openly accessible "product grade level"	14.6	M46		
Y1	MS42	Appointing of an Industrial Advisory Board, (IAB)	14.3	M12	09.04.18	Report
	MS47	Reviewed requirements document	14.6	M12	18.04.18	Report
Y2	MS45	First HTS Short Length produce via new process	14.5	M14	13.06.18	Report
	MS48	Reviewed design and system configuration document, updated software	14.6	M21	11.03.19	Report
	MS43	1st academia-meets-industry event	14.3	M24	30.04.19	Report
Y3	*MS44*	*2nd academy-meets-industry event*	*14.3*	*M36*		
	MS46	Characterization of first long length conductor	14.5	M36	03.04.20	Report

Milestones / Deliverables/ MS44

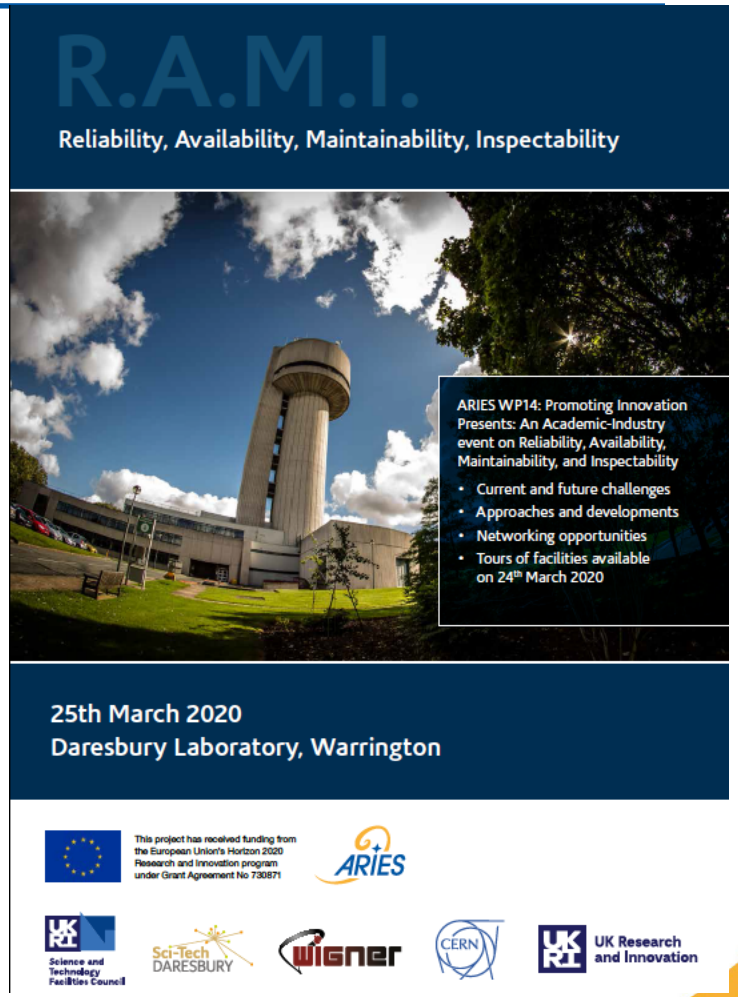
After organizing, https://indico.cern.ch/event/850946/

we had to put off the 2nd industrial event:
RAMI workshop, co-organized by STFC, Wigner and CERN

Accelerator technologies need to embrace high industry standards, impacting the overall cost and usefulness of systems and increasing opportunities for new uses and applications.

The aim of the workshop was to bring together experts from industry, academics and accelerators, fusion and nuclear facilities, to discuss the methodologies of RAMI management.

NEW DATE TBD, but probably in October



PoC - Status of the play

The 4 projects approved for funding under the PoC are progressing towards the end of their activities. D14.1 reports details of the process implementation.

Final reports originally due at this AM with in-person presentations by project leaders. Postponed to November STC cause of COVID-19. I will provide here only summary info.

- **Riga Technical University** "Development of an hybrid electron accelerator system for the treatment of marine diesel exhaust gas."
- **RHP**, "Investigation of new methods for the manufacturing of copper diamond composites with tailored thermo-physical properties".
- **CEA**, "Atomic layer deposition: an innovative approach for next generation particle accelerators"
- **University of Liverpool**, "Accelerator Diagnostic using innovative Adaptive Optics".

PoC

Development of an hybrid electron accelerator system for the treatment of marine diesel exhaust gas

Main objective: to demonstrate in field condition the integration of a diesel engine with a PAC and a scrubber. A dedicate experiment has been set-up in Riga shipyards.

Main caveat: **confirmation (measured) that with low-energy and non-homogeneous electron irradiation dose (penetration level) and standard wet-scrubber hybrid system, NOx reduction at full engine load reached 45% of removal efficiency**

The consortium is confident that using a higher, homogenous irradiation dose, the NOx removal efficiency can be much higher.

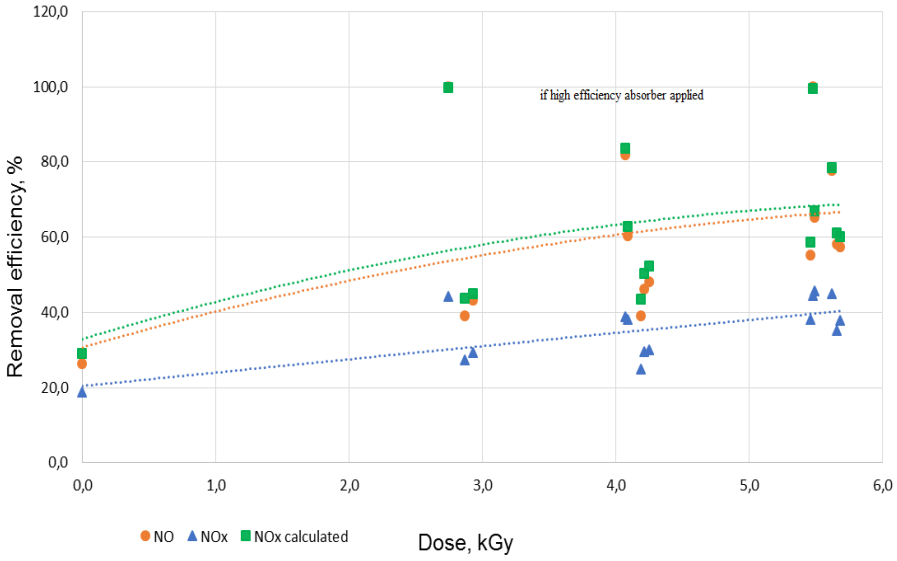
A patent is in preparation for submission (not much tech details can be disclosed now)

The final closing meeting of the project will be held online on April 23rd.
https://indico.cern.ch/event/906791/

PoC

Development of an hybrid electron accelerator system for the treatment of marine diesel exhaust gas

Improvements are possible due to the gathered field experience gained in PoC experiment



The PoC has been instrumental into mobilizing resources and interests from different actors, that have materialized into the submission of a H2020 proposal that even if not funded it is on a reserve list.

Further actions and follow-up of project are being discussed by the consortium

PoC: Atomic Layer Deposition : innovative approach for next generation PAC

Project objective: to develop new materials and structures able to improve performances of PAC components and of SRF cavities by using Atomic Layer deposition (ALD) technique

Strategy is developing a methodology for improving SRF cavity performance on coupon scale and apply it to a cavity

ALD can develop thin films hetero-structures that can be synthesized in a conformal and controlled manner on almost any substrates materials and geometry.

ALD compared to usual deposition techniques, can be easily scalable to large objects and industrial production once the “recipe” have been optimized on coupons and bench scale.

PoC has allowed the preparation of ALD set-up and to produce promising results.

other possibilities are open (Q bit, sc photocathodes, electron sources…)

Poc

Atomic Layer Deposition : innovative approach for next generation PAC

Work Package 1: ALD apparatus Set up

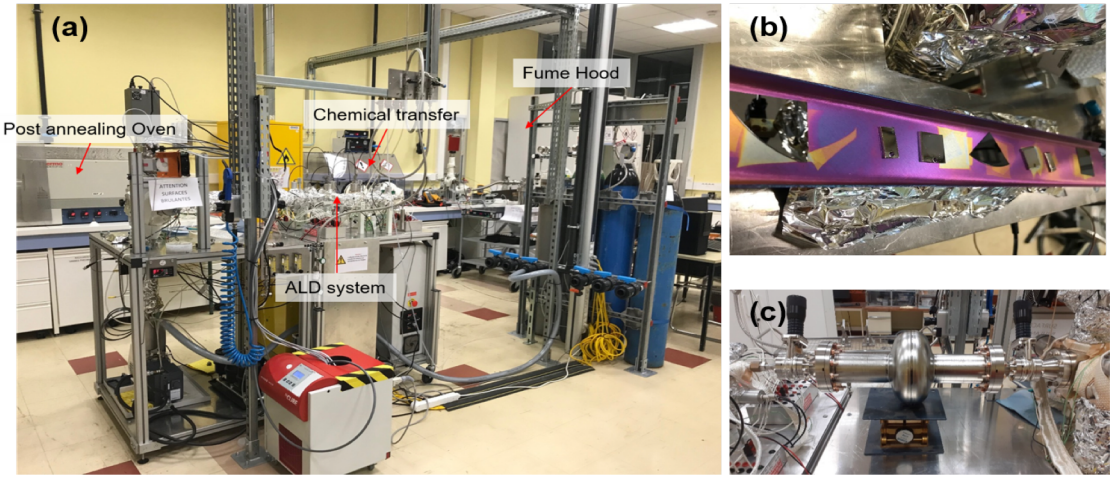


Figure 1 : (a) ALD apparatus at CEA-Saclay. (b) test deposition on Si and Nb coupons. (c) a 1.3 GHz Nb cavity hook up to the ALD system prior to deposition.

Work Package 2: ALD engineering of Nb surface with Oxide thin films.

ALD deposition of a ~ 5-10 nm oxide or N film on cavity grade Nb coupons, + T treatment in HV to replace it with a more efficient diffusion ALD barrier. alloys tested: Al_2O_3, Y_2O_3, MgO, TiN.

Optimization of parameters shows absence NbO and integrity and stability in air of the ALD layer. Process applied to 1.3 GHz monocell Nb cavity. Q factor measured up to 19 MV/m. The RF results from a second run of test will condition patent application.

Work Package 3: Superconducting Multilayer structure.

Titanium Nitride TiN is the most used ceramic coating on machine tools. Molybdenum Nitride MoN is a potential candidate for ultra-incompressible and hard material. The predicted superconducting temperature of MoN is the highest of all refractory carbides and nitrides

Investigation of new methods for the manufacturing of CuD composites with tailored thermo-physical properties

Project objective: by using plasma metal deposition processes (PMD) manufacture a high thermal conductive metal diamond composites with a low coefficient of thermal expansion to be applied, e.g. in Collimators.

PMD processes could allow building large components or more complex geometries using a layer by layer approach.

one approach identified to manufacture small scale samples where pre-compacted feedstocks combined with a fast thermal process are combined. Sample K_t of around 350 -400 W/mK could be realised.

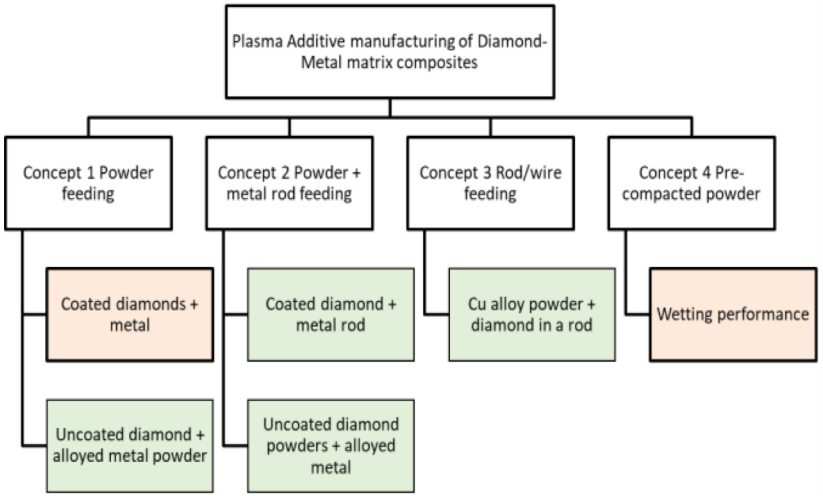
Open issues: remaining porosities linked to process optimisation

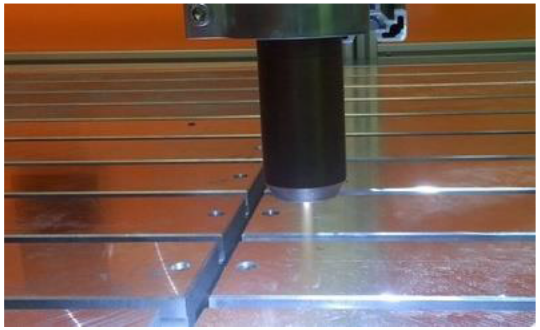
and

upscaling of the process (it would require a very high degree of process control and therefore the setup of a dedicated manufacturing system)

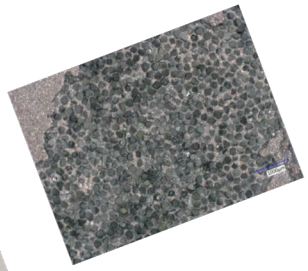
PoC

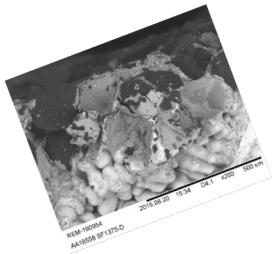
Investigation of new methods for the manufacturing of CuD composites with tailored thermo-physical properties





Concepts designed for the AM of diamond metal matrix composites and plasma metal deposition process





Final report available.
Where to upload?

- Pre-cursor materials
- Coating of the diamonds to enable wetting in the matrix
- suitable “feedstocks” (wires) availability
- Avoid graphitization of diamond
- Homogeneous distribution of diamond particles
- High diamond loading (>30 vol%)
- Manage homogeneity in multilayers
- Achieve required thermal properties
- Oxygen sensitivity of the matrix

The InnoAdO project in on track to produce planned deliverables by Dec 2020.

It has suffered setbacks in the form of personnel change in the business partner D-Beam, and a lack of facility access due to the Covid-19 pandemic.

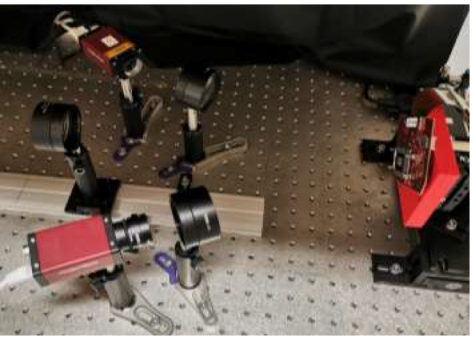
Project objective: to design, build and test a Prototype optical DMD (digital micromirror device) interferometry (ODI) and optical phase space mapping (OPSM) systems
These systems shall produce the PoC measurements required by Q4 2020.

Simulation studies are going on with the added benefit of the DMD benchmark measurements and the ODI/OPSM system designs to aid with progress.

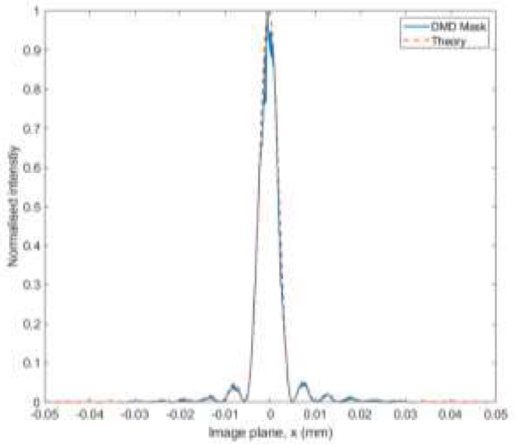
Interim report available.

WP1 - Results for both ODI and OPSM / WP3 – DMD simulation package

benchmarking measurements to compare the theoretical diffractive properties of DMD masks.



Technical setups for the Optical DMD interferometry and OPSM (optical phase space mapping) systems have been designed and implemented in Cockcroft optics laboratory



Comparison of the diffraction intensity distribution for a theoretical slit and a DMD mask with a width of 0.1mm.

WP2 – Applications of existing DMD techniques

- improved High Dynamic Range imaging technique at DLS (and by other light sources)
- Lyot stop imaging at DLS
- Fourier plane filtering for AWAKE project at CERN,
- photocathode laser transverse profile modulation.

Each of these techniques to be demonstrated by Dec 2020, pending the availability of facilities and the ability to travel in the coming month

WP14 Industrial R&D task 14.4 – Materials for HT management

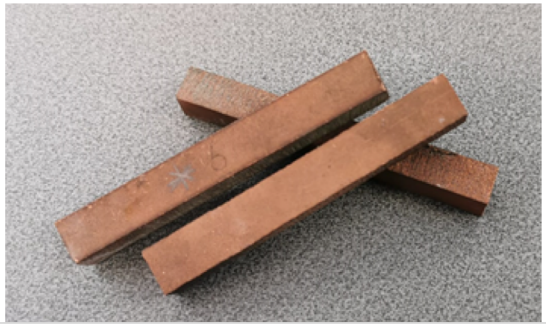
F.Carra

Industrial partner is RHP -- D14.3 submitted in M14, to cope with the material requirements of WP17.

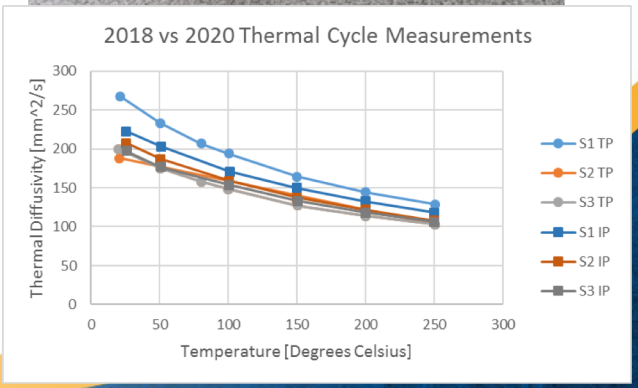
Since then WP14.4 has focused on two main R&D and production lines.

- additional production of luminescence and collimator-related samples required to complete the production targets.
- development of MgB2-coated samples. This second line became priority for RHP after the completion of D14.3.

several samples sent for luminescence tests at GSI and at CERN. 21 additional samples were produced, investigating combinations of substrates



Production target (n. of samples)	Description	Producer	Production November 2018 / April 2020	Total production
30	MgB_2 on metal substrate samples	RHP	28	28
50	Copper-diamond samples for collimators		31	59
40	Metal-diamond samples for luminescence screens		21	31
50	Carbide-graphite or metal-graphite samples for collimators	Brevetti Bizz	0	61
1	Large size block of carbide graphite or metal-graphite with tight mechanical tolerances to proof industrialization		0	0



WP14 Industrial R&D task 14.4 – Materials for HT management

F.Carra

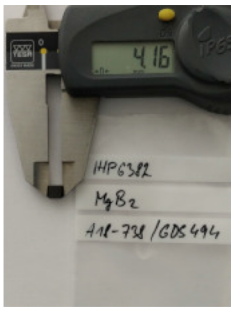
RHP performed tests of direct synthesis of the MgB_2 powders to be used for the deposition of a sc MgB_2 layer by AM coating.

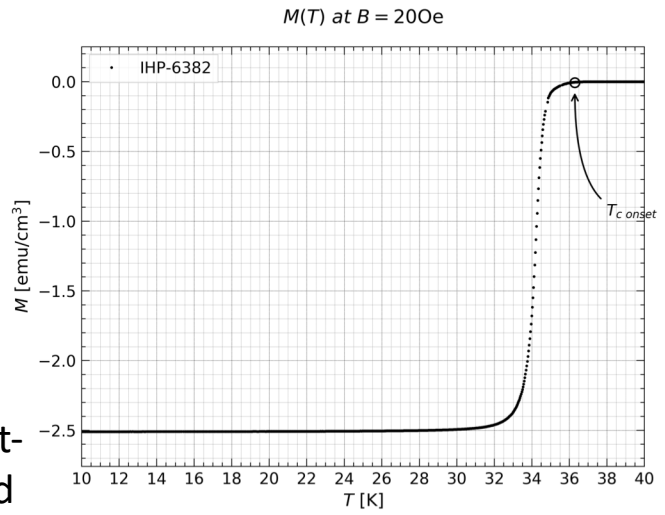
3 runs of samples production in 2019, in January, March and December

Sc properties of the samples were measured at UNIGE and a significant improvement was seen in the results of the second campaign, in line with best results found in literature

Batch	Sample	Material	IHP Temperature [°C]	Densification [%]	T_c [K]	B * T=4.2 K [T]	B * T=10 K [T]	B * T=20 K [T]
1st	IHP5660-1	MgB_2 C	1300	92,15	26,8	1,45	1,1	0,35
	IHP5660-2	MgB_2 C	1300	92,15	27,6	1,1	0,85	0,25
	IHP5660-3	MgB_2 C	1300	92,15	27,6	0,7	0,5	0
	IHP5660-4	MgB_2 C	1300	92,15	27	0,2	0,1	0
2nd	IHP6007	MgB_2 C ball milled 12h/HM + 50 vol% Mg (45 µm)	900	80,57	34,6	3,65	3,1	1,75
	IHP6030	MgB_2 A :	1100	96,84	38,3	5,85	5,05	3,25
	IHP6040	Mg (300 µm) + B (2 µm); 10wt% excess of Mg	640->1000	83,64	34,3	4,2	3,5	1,75
	IHP6042	MgB_2 C ball milled 12h/HM + 50 vol% Mg (45 µm)	1000	95,20	34,6	4,5	3,85	2,2
	IHP6046	MgB_2 A	1000	88,61	38,1	5,75	5,05	3,3
ref 1	reference	BYNARY IMD 2h	850	-	38,8	3,85	3,43	2,27
ref 2	reference	one of the best binary samples	-	-	38,3	6,1	5,2	4,3

* B at $J_c=10^4$ A/cm^4





3rd run of samples: MgB_2 specimen made by RHP prepared by hot-pressing synthesized powders. Up to 10 layers of MgB_2 deposited by plasma spray on Cu and Al_2O_3 substrates. The latter have not shown good results due to background noise.

WP14 Industrial R&D tasks 14.5 – HTS conductor

L.Rossi

Bruker HTS GmbH (BHTS) is the industrial partner. It has adapted equipment and process to manufacture HTS (High Temperature Superconductor) coated conductor by depositing REBCO (Rare-Earth Barium Copper Oxyde) on a 50 μm thick SS substrate.

Tapes obtained with record current density, above the ARIES goals.

MS45 reports about a unexpected issue (bi-directional bending) affecting the process.

Lately the process has been adjusted to mitigate this effect.
The consequence is Jc reduced of 30%, BUT still fulfilling the goal of > 100 m with > 600A/mm2 at 4.2K, 20 T.

D14.4 reports the manufacturing of total 413 m of HTS tape 12 mm width and 50 μm substrate thick - delivered in Feb 2020 to CERN. Many units above 25 m target length.
The yield of tape is not high enough: about 40%.

possible measures to overcome the low yield: back to 100 μm thick SS tape and improving the PLD process, or use Hastelloy as substrate. But this is out of ARIES scope.

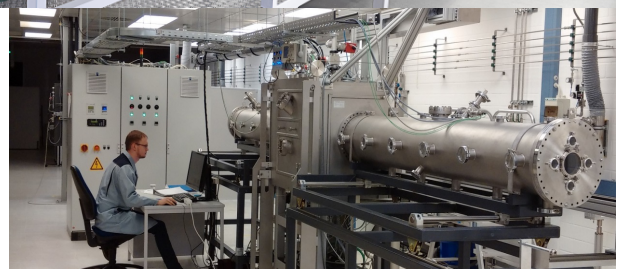
WP14 Industrial R&D tasks 14.5 – HTS conductor

L.Rossi

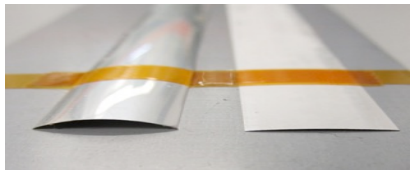
PLD300 system used for ARIES co-owned by BHTS and CERN

PROCESSING CHAIN OF HTS PILOT-LINE PRODUCTION

- SUBSTRATE PREPARATION (SUB)
- BUFFER LAYER COATING (ABAD)
- HTS LAYER COATING (PLD)
- METAL COATING (MET)
- COPPER PLATING (PLA)
- FINAL TAPE INSPECTION (INS)



			Ic(B=5T)	Ic(B=18T)	Ic(B=20T)	Je (B=18T)	Je (B=20T)
Tape ID	Length(m)	Cu layer (µm)	measured	scaled	scaled	calculated	calculated
15088-1-1-1	27	2x20	1,564	598	553	499	461
15088-1-2-1	30	2x20	1,888	722	668	602	556
15088-1-2-2	27	2x20	1,888	722	668	602	556
17702-1-1-0	79	2x20	1,621	620	573	517	478
17703-1-1-1	1	2x20	3,386	1,296	1,197	1,080	998
17703-1-1-2	1	2x20	2,707	1,036	957	863	798
17703-1-2-0	8	2x7	2,063	789	729	889	821
17703-1-3-0	15	2x20	2,105	805	744	671	620
17705-1-1-0	75	2x5	1,866	714	660	850	785
17706-1-1-0	75	2x5	2,330	892	824	1,061	980
17707-1-1-1	24	2x5	1,025	392	362	467	432
17707-1-1-2	26	2x5	1,090	417	385	497	459
17707-2-1-0	25	2x5	902	345	319	411	380



The best tapes are under investigation by UNIGE and Univ. of Twente is carrying out measurements of other HTS Rutherford cables, to compare with the results.

WP14 Industrial R&D task14.6 - REDNet Timing System

J.Gutleber

Industrial partner is Cosylab

Scope of the project is to industrialize a PAC main timing system originally conceptualized in the frame of the MedAustron project, by CERN and Cosylab - for academic, industrial and healthcare applications.

PoC ARIES funding has been used by Cosylab as seed capital to develop a commercial product for a PAC main timing system

The system has been demonstrated to the first customer, who has adopted it for its cancer treatment proton PAC product line.

The D14.5 deliverable planned in M46 could be submitted ahead of time in this year.

IP management is in progress.

Press release foreseen to announce the result and to market the product

WP14 Industrial R&D task14.6 - REDNet Timing System

J.Gutleber

MS47 → requirements spec

MS48 → architecture & design

Adaptation of the timing system to a commercial proton PAC for cancer treatment (AVO ADAM)
more healthcare application-specific features implemented by Cosylab.

A document describing the openly accessible IP available under "Creative Commons Attribution 4.0 International" license will be entered with the delivery of D14.5.

The investment made by EC throughout ARIES PoC has produced contracts for Cosylab with private clients (at March 2020) till 9 times the original value.
This for the benefit of an emerging high-tech company in Slowenia

Conclusions

- ✓ WP14 has achieved all the deliverables and milestones on the plan, but MS44 due to COVID-19
- ✓ PoC projects are concluded or well progressing to conclusion. The R&D in cooperation with industry has so far produced valuable impacts
- ✓ We will prepare the 2nd industrial event (RAMI for PAC) probably in October