VIPERLAB

FULLY CONNECTED **VI**RTUAL AND **P**HYSICAL
P**ER**OVSKITE PHOTOVOLTAICS **LAB**

D2.7 Final TA/VA specific user statistics and dissemination/exploitation summary

DELIVERABLE REPORT

Version: 1

Date: 30.11.2024

FULLY CONNECTED VIRTUAL AND PHYSICAL PEROVSKITE PHOTOVOLTAICS LAB VIPERLAB

DELIVERABLE

D2.7 FINAL TA / VA SPECIFIC USER STATISTICS AND DISSEMINATION/EXPLOITATION SUMMARY

Project References

Project Acronym	VIPERLAB
Project Title	Fully connected **vi**rtual and physical **per**ovskite photovoltaics **lab**
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Project Start and Duration	1st June 2021, 42 months

Deliverable References

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Version	Status	Date	Beneficiary	Author
1.0	First report	30-11-24	HZB	N. Maticiuc

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006715

DISCLAIMER

'Fully connected virtual and physical perovskite photovoltaics lab' VIPERLAB is a Collaborative Project funded by the European Commission under Horizon 2020. Contract: 101006715, Start date of Contract: 01/06/2021; Duration: 42 months.

TABLE OF CONTENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°101006715

EXECUTIVE SUMMARY

The VIPERLAB project, funded by the European Union's Horizon 2020 program, has significantly advanced perovskite photovoltaic (PV) research by offering Transnational Access (TA) and Virtual Access (VA) to state-of-the-art research infrastructures across Europe. Over its 3.5-year implementation, the project enabled access to 17 specialized facilities, supporting 108 user proposals from 31 countries. With a strong focus on collaboration, inclusivity, and innovation, VIPERLAB has facilitated groundbreaking research, fostering the rapid dissemination of knowledge and the advancement of PV technologies.

This report details VIPERLAB's TA and VA activities, including user access statistics, dissemination efforts, and the integration of experimental data into standardized databases. Key achievements include the publication of impactful research, increased gender equity among participants, and high levels of engagement from both academia and industry. Despite challenges such as administrative delays and geopolitical restrictions, the project has exceeded expectations in access days granted, contributing significantly to the global perovskite PV ecosystem.

VIPERLAB's legacy lies in its transformative impact on the research community, establishing a robust platform for continued innovation in PV technologies.

1. INTRODUCTION

VIPERLAB project is a groundbreaking initiative aimed at advancing the European perovskite photovoltaic (PV) research community by offering well-structured and financially supported Transnational Access (TA) and Virtual Access (VA) to cutting-edge research infrastructures. Over its 3.5-year duration, VIPERLAB has played a pivotal role in fostering collaboration, innovation, and scientific excellence by enabling researchers, academics, and industry users to access a wide array of state-of-the-art facilities and databases across Europe.

VIPERLAB’s infrastructure network, comprising 13 key consortium partners (Fig. 1), spans the entire value chain of perovskite PV technology, addressing critical areas such as material stability, lead-free systems, and upscaling. These facilities have been meticulously selected for their ability to attract international users and to provide unique experimental conditions and expertise. By integrating TA and VA activities, VIPERLAB not only facilitates material and device testing but also ensures seamless integration of experimental data into a standardized database, fostering interdisciplinary innovation and progress.

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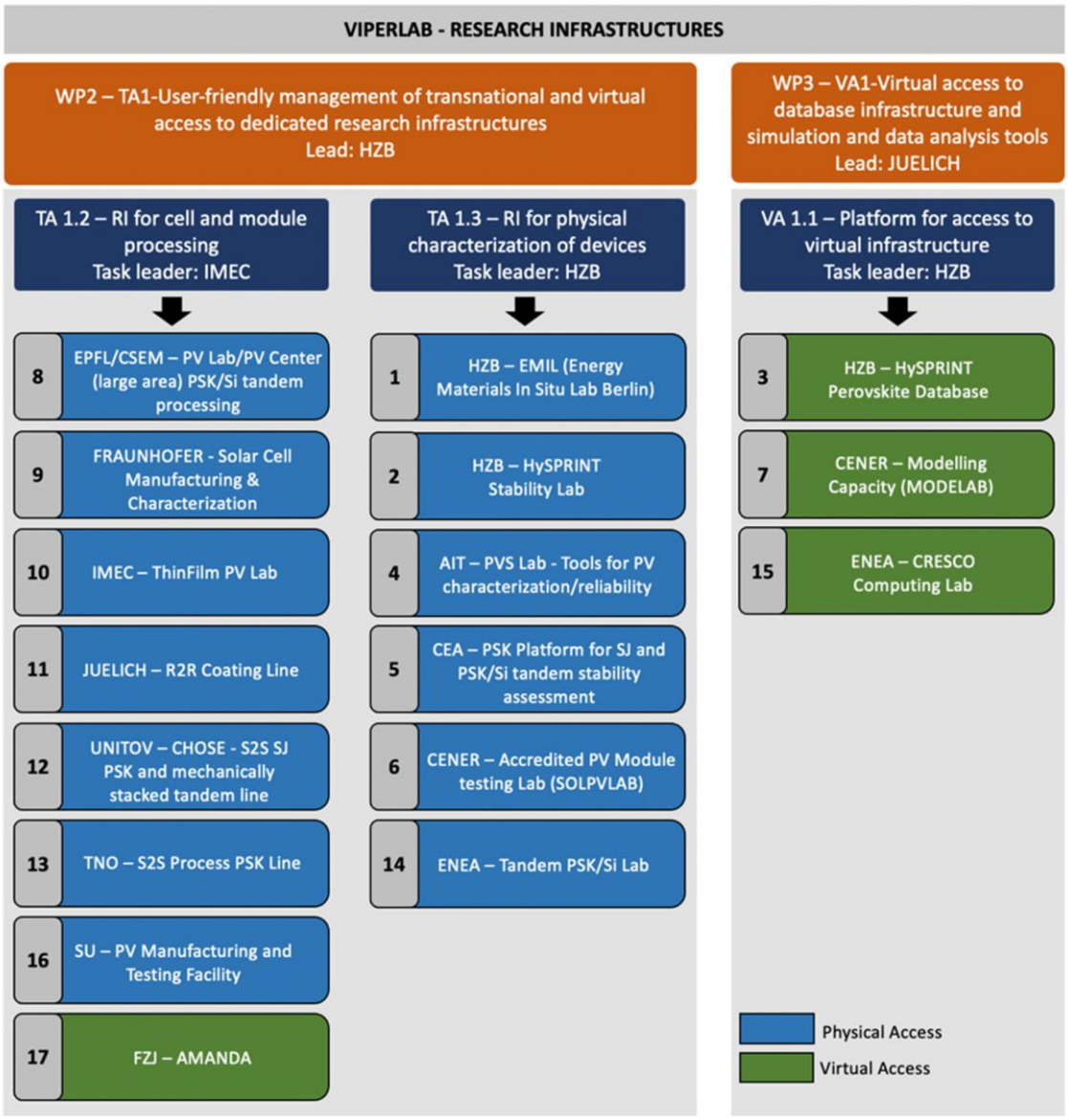

Figure 1. Structure of VIPERLAB infrastructures from 3 different partners shared via the transnational and virtual access activities in VIPERLAB project.

The Transnational Access (TA) activities have been designed to cater to diverse users, from academic researchers to industrial innovators, offering streamlined proposal submission and evaluation processes to ensure quick and equitable access. Simultaneously, the Virtual Access (VA) activities leverage a robust perovskite database, providing a centralized platform for data sharing, performance benchmarking, and simulation tool access. Together, these efforts have established VIPERLAB as a cornerstone of the European perovskite PV ecosystem, promoting collaboration, addressing gender equity, and driving the rapid dissemination of knowledge.

This report presents the final statistics and achievements of VIPERLAB's TA and VA activities, highlighting the impact and legacy of the project in strengthening the European perovskite PV research community.

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2. USER ACCESS IN VIPERLAB

Over the 3.5 years of its implementation, the VIPERLAB project has significantly advanced the European and global perovskite photovoltaic (PV) research community. By providing streamlined Transnational Access (TA) and Virtual Access (VA) to state-of-the-art research infrastructures, VIPERLAB has supported a diverse group of researchers and institutions, fostering collaboration, inclusivity, and innovation. This report highlights the key achievements and statistical insights derived from user access activities, showcasing the impact and legacy of the project.

2.1 VIPERLAB calls

To facilitate access to its 17 research infrastructures, VIPERLAB organized three annual calls, each structured into four rounds. Figure 2 illustrates the yearly call structure, where each round consisted of a two-month submission window followed by a one-month evaluation period. This rolling access system was designed to minimize delays, allowing users to access facilities with an average waiting period of 60 days or less.

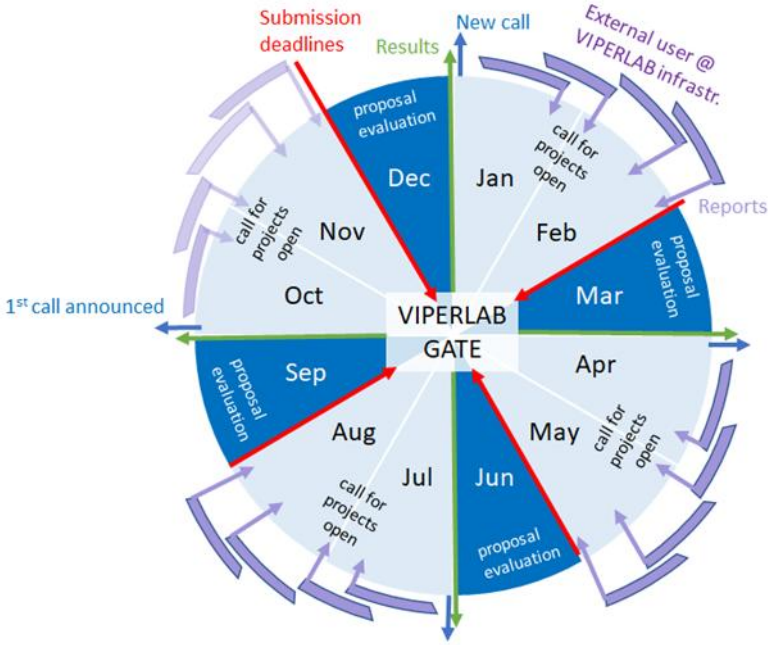

Figure 2. Schematic of one VIPERLAB yearly call with four rounds consisting of 2 months of open call and one month of evaluation.

The application process itself was designed to be user-friendly, as depicted in Figure 3, which outlines the steps from proposal drafting and submission to the final implementation and reporting phase.

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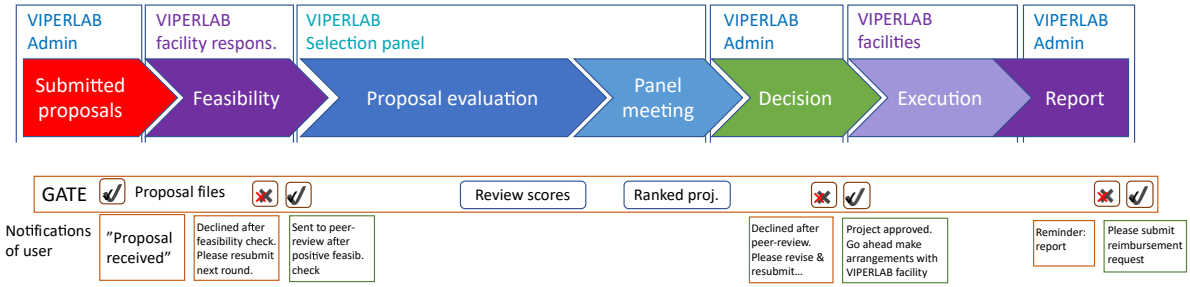

Figure 3. Step by step evolution of a proposal process.

To assist applicants at every stage, VIPERLAB provided comprehensive guidelines on its Knowledge Exchange Platform (KEP). As shown in Figure 4, the KEP served as a central repository of resources, including step-by-step instructions, updates on infrastructure capabilities, and evaluation criteria. This ensured that applicants were well-informed and could prepare high-quality proposals.

Figure 4. Guideline for drafting, submission and evaluation: all the details available at https://www.viperlab-kep.eu/subpage.asp?i=12&p=Infrastructure&page=How__to_Apply

VIPERLAB also leveraged its LinkedIn page (Figure 5) to disseminate call announcements and updates, further broadening its outreach. This dual-channel communication strategy—utilizing both the KEP and LinkedIn—proved effective in engaging the research community and attracting high-caliber proposals.

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Figure 5. VIPERLAB LinkedIn page: https://www.linkedin.com/in/viperlab-project/

2.2 VIPERLAB infrastructures

All the details about the infrastructures and instrument scientists are available in the infrastructure catalog (Fig. 6) as well as in the collection of workshops materials and videos created and uploaded on VIPERLAB Knowledhe Exchange Platform.

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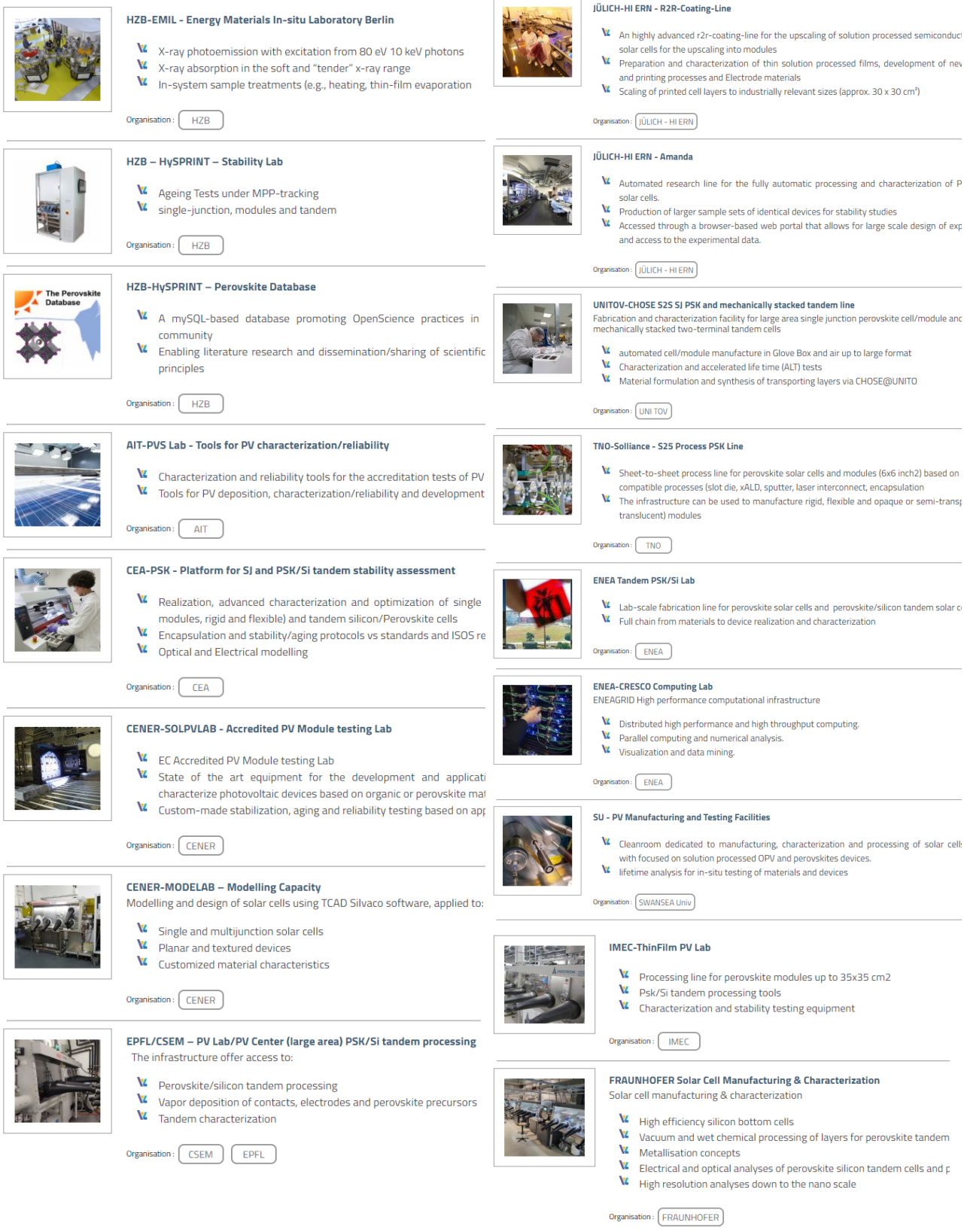

Figure 6. Infrastructure catalog with 17 VIPERLAB labs offered for transnational (TA) and virtual (VA) access (screenshot from www.viperlab-kep.eu).

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3. USER STATISTICS IN VIPERLAB

3.1 Users and their proposals in VIPERLAB

Over the course of the project, 137 user proposals were submitted across 12 access rounds, as detailed in Table 1. Of these, 108 proposals were granted access, resulting in a high implementation rate of 90%. The proposals encompassed a wide range of research activities, including material characterization, device testing, and data integration, aligning with VIPERLAB's mission to support the entire value chain of perovskite PV technology.

Table 1. VIPERLAB proposals wich were submitted, checked for feasibility, peer-reviewed, granted and implemented in the 3,5 years of VIPERLAB project.

Round	Submission Period	Proposals for TA and VA access			Implementation status	
		Total	Rejected	Granted	Completed	Cancelled
1	14.10.21 - 05.12.21	15	3	12[2]	12	0
2	03.01.22 - 28.02.22	14	5	9[2]	7	2
3	01.04.22 - 31.05.22	7	0	7[1]	7	0
4	01.07.22 - 31.08.22	15	1	14[2]	13	1
1st VIPERLAB yearly call		**51**	**9**	**42[7]**	**39**	**3**
5	01.10.22-30.11.22	10	3	7[2]	5	2
6	01.01.23-28.02.23	11	3	8	7	1
7	01.04.23-31.05.23	7	3	4	3	1
8	01.07.23-31.08.23	17	7	10[3]	9	1
2nd VIPERLAB yarly call		**45**	**16**	**29[5]**	**24**	**5**
9	01.10.23-30.11.23	14	0	14[4]	14	0
10	01.01.24-29.02.24	10	1	9[1]	8	1
11	01.04.24-31.05.24	14	2	12[4]	10	2
12	01.07.24-31.08.24	3	1	2[1]	2	0
3rd VIPERLAB yearly call		**41**	**4**	**37[10]**	**34**	**3**
Total		**137**	**29**	**108[22]**	**97**	**11**
				% from total granted	**90%**	**10%**

[nr]Number of Virtual Access proposals

The geographic diversity of participants was another key success factor. Proposals came from researchers affiliated with institutions in 31 countries, spanning Europe, Asia, the Americas, and beyond (Figures 7 and 8). This broad international participation underscores the global relevance of VIPERLAB's research infrastructure and its ability to attract users from both European and non-European countries.

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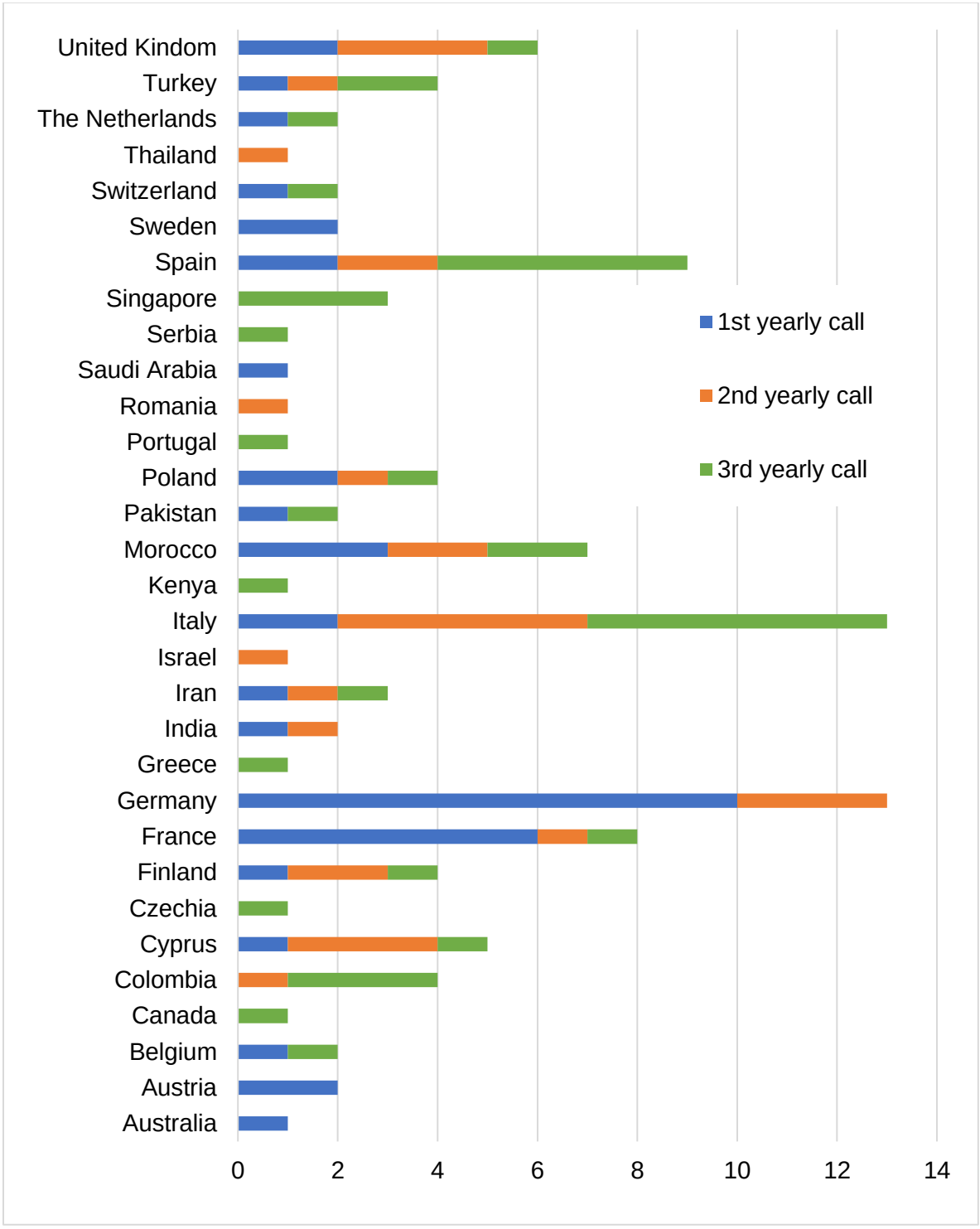

Figure 7. Country affiliation of VIPERLAB users with granted proposals over the three yearly calls.

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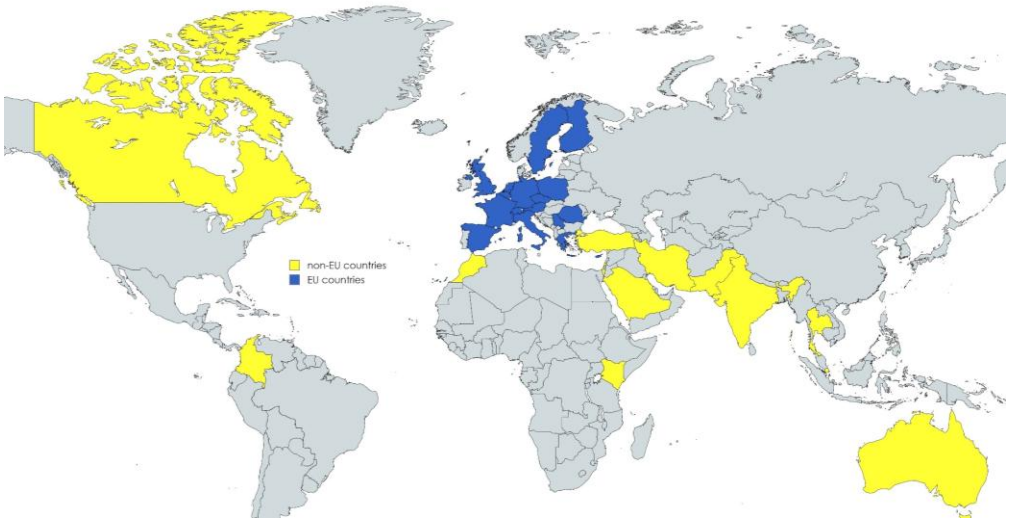

Figure 8. Geographical distribution of affiliation countries from granted VIPERLAB proposals.

A notable feature of VIPERLAB's access activities was the balance between EU and non-EU participants. As shown in Figure 9, the ratio of non-EU proposals occasionally exceeded the 20% threshold stipulated in the grant agreement, particularly in specific rounds such as 2023-III and 2024-I. However, the overall trend remained consistent with the project's goals, ensuring that European users maintained priority access while still accommodating global collaboration.

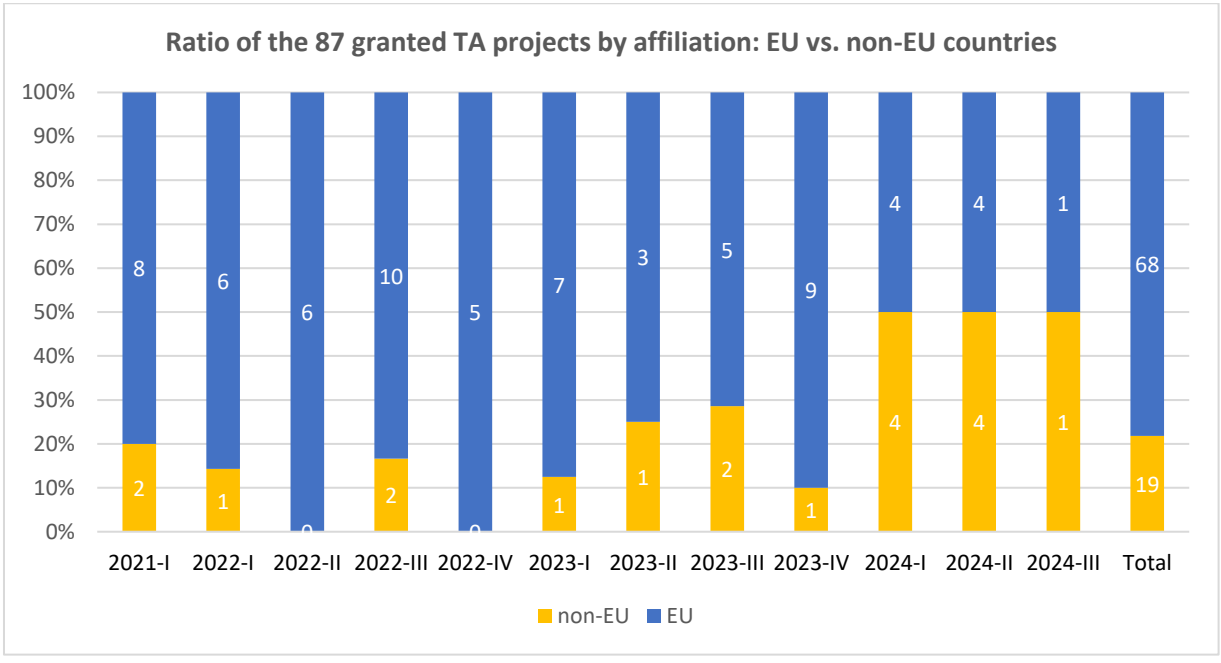

Figure 9. Ratio between number of **TA proposals** with affiliation from EU and non-EU countries in the 12 rounds of VIPERLAB.

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VIPERLAB placed a strong emphasis on inclusivity, particularly in terms of gender representation. Figure 10 highlights the improvement in gender balance among applicants for both TA and VA proposals over the course of the project. This achievement reflects VIPERLAB's commitment to fostering an equitable research environment and promoting diversity within the perovskite PV community.

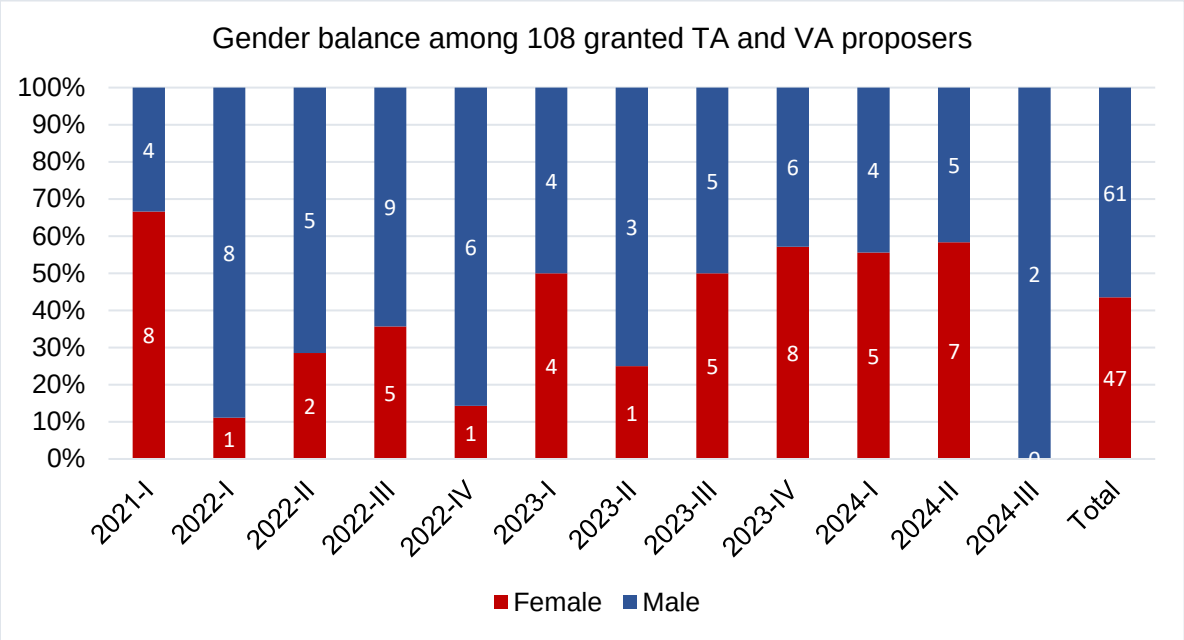

Figure 10. Gender distribution of users with granted **TA and VA proposals** over the 12 rounds.

In addition to supporting academic researchers, VIPERLAB actively engaged with industry partners, bridging the gap between fundamental research and practical applications. As illustrated in Figure 11, a significant proportion of proposals came from industry, with numerous industry partners benefiting from access to VIPERLAB's facilities.

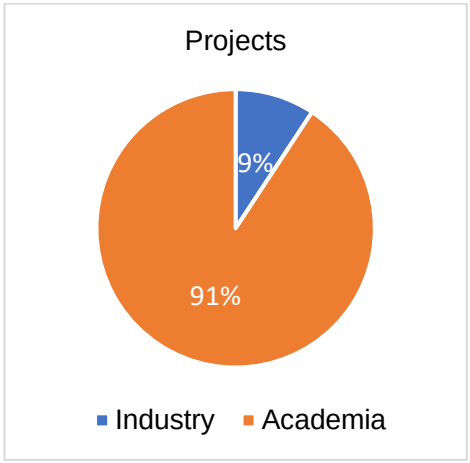

Figure 11. Left: Ratio between proposals from academia and industry. Right: Industry partners who befeited from user access in VIPERLAB.

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3.2 Implementation of user proposals in VIPERLAB

In line with the procedures described above 137 submitted proposals underwent rigorous evaluation. This evaluation included assessments for transnationality criteria, feasibility, and scientific merit. Each proposal was subjected to review by two experts from the Selection Panel, comprising one internal and one external reviewer. Following the review process, the authors of successful proposals were promptly notified of the referees' decisions. Subsequently, they were connected with infrastructure scientists to plan and schedule their experiments or visits.

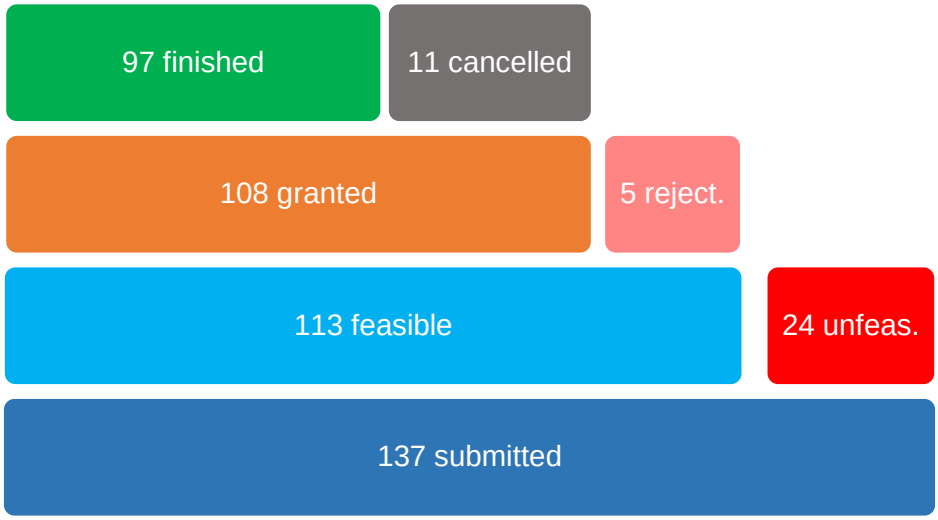

Figure 12. Snapshot of the 137 proposals received in VIPERLAB calls, highlighting their journey through feasibility check, peer-review, and implementation.

The reasons for **rejection of 29 proposals**:

- Lack of alignment with the facility's capabilities or specific experimental requirements – Proposals that were found to be unfeasible after a thorough feasibility check.
- Low quality, lack of novelty, or misalignment with VIPERLAB objectives – Five proposals were rejected due to these issues.
- Unfeasible experimental requirements – Twenty-four proposals were rejected because their experimental demands could not be met by the requested facility.
- Resubmission to different facilities or adaptation to facility capabilities – A large portion of the rejected proposals were resubmitted to other facilities or revised to fit the capabilities of the requested facility.
- Repeated submissions without significant revisions – Many of the rejected proposals had previously applied multiple times without significant improvements or changes in alignment with the program.

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The **delays in project implementation** were caused by several factors, outlined below:

- Complex administrative procedures that significantly hindered the timely implementation of proposals.
- Challenges with travel expense coverage, as users often had to cover their travel costs upfront and wait for reimbursement from VIPERLAB.
- Diplomatic hurdles for non-EU and non-Schengen participants, particularly for users and institutions in the UK and Switzerland, which added complexity to the process.
- Geopolitical factors, including the cancellation of one proposal from Iran by HZB due to the outbreak of war in Israel, which was subject to Germany's embargo restrictions.
- A cyber attack at HZB in June 2023, which caused a complete disruption of planned activities, halting operations for several months before a gradual recovery.

The reasons for the **cancellation of 11 granted proposals:**

- Prolonged administrative procedures, resulting in loss of user interest: 2 proposals
- Loss of VIPERLAB expertise shortly after granting: 2 proposals
- Projects withdrawn by users due to lack of funding: 1 proposal
- Change in users' employment: 3 proposals
- Geopolitical/embargo restrictions for Iran: 2 proposals
- Technical limitation form user’s side for virtual access of the computing facility: 1 proposal

The **successful implementation of the 97 granted user proposals** during the three VIPERLAB calls can be attributed to a combination of high approval rates and strategic allocation of access days across various research infrastructures. Table 2 summarizes the distribution of the granted 97 proposals among the 17 VIPERLAB infrastructures.

In terms of physical access days – almost all facilities exceeded their estimated allocation of access days. In terms of granted projects, facilities like EPFL/CSEM – PV Lab/PV Center and IMEC – Thin Film PV Lab were particularly efficient, granting 113% and 115% of the expected access days, respectively.

Additionally, the virtual facilities were very successful by granting hogher than estimated access days and being used by over 15.000 users.

This broad and impressive implementation is the result of the high demand for specialized facilities in the field of perovskite research.

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Table 2. Summary of user projects and access days granted during the three VIPERLAB calls.

VIPERLAB TA infrastructure	Estimated		Granted		Granted rate	
	projects	days	projects	days	projects, %	days, %
EPFL/CSEM – PV Lab/PV Center (large area) PSK/Si tandem processing	15	45	8	51	**53%**	**113%**
FRAUNHOFER - Solar Cell Manufacturing &Characterization	16	80	6	140	**37%**	**175%**
IMEC – Thin Film PV Lab	15	150	7	172	**47%**	**115%**
Juelich – R2R Coating Line	10	20	1	90	**10%**	**450%**
UNITOV – CHOSE - S2S SJ PSK and mechanically stacked tandem line	21	126	10	162	**48%**	**126%**
TNO/Solliance – S2S process PSK line	5	10	6	28	**120%**	**280%**
SU – PV Manufacturing and Testing Facility	5	15	5	109	**100%**	**660%**
HZB – EMIL (Energy Materials In Situ Lab Berlin)	8	25	7	58	**88%**	**232%**
HZB - Stability Lab	30	450	10	527	**33%**	**117%**
AIT – PVS Lab	6	18	3	19	**50%**	**106%**
CEA – PSK Platform for SJ and PSK/Si tandem stability assessment	6	60	6	57	**100%**	**95%**
CENER – SOLPVLAB	9	27	1	14	**11%**	**52%**
ENEA – PSK/Si	8	39	7	49	**86%**	**126%**
FZJ – AMANDA	10	15	3	18	**30%**	**120%**
Total TA	**164**	**1080**	**80**	**1494**	**49%**	**138%**
VIPERLAB VA infrastructure	**Estimated**		**Granted**		**Granted rate**	
	projects	**access**	**projects**	**access**	**projects**	**access**
CENER – MODELAB	9	45 days	7	118 days	**78%**	**262%**
ENEA Cresco	5	60.000 node hours	11	22.926 node hours	**220%**	**38%**
HySprint Database	50	50 users	**>1800** users			

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3.3 Public TA and VA statistics and collection of user feedback

A database of implemented proposals, as well as proposers' feedbacks is continuing to be public on the VAPO platform [at https://www.viperlab-vapo.eu/experiments/](https://www.viperlab-vapo.eu/experiments/).

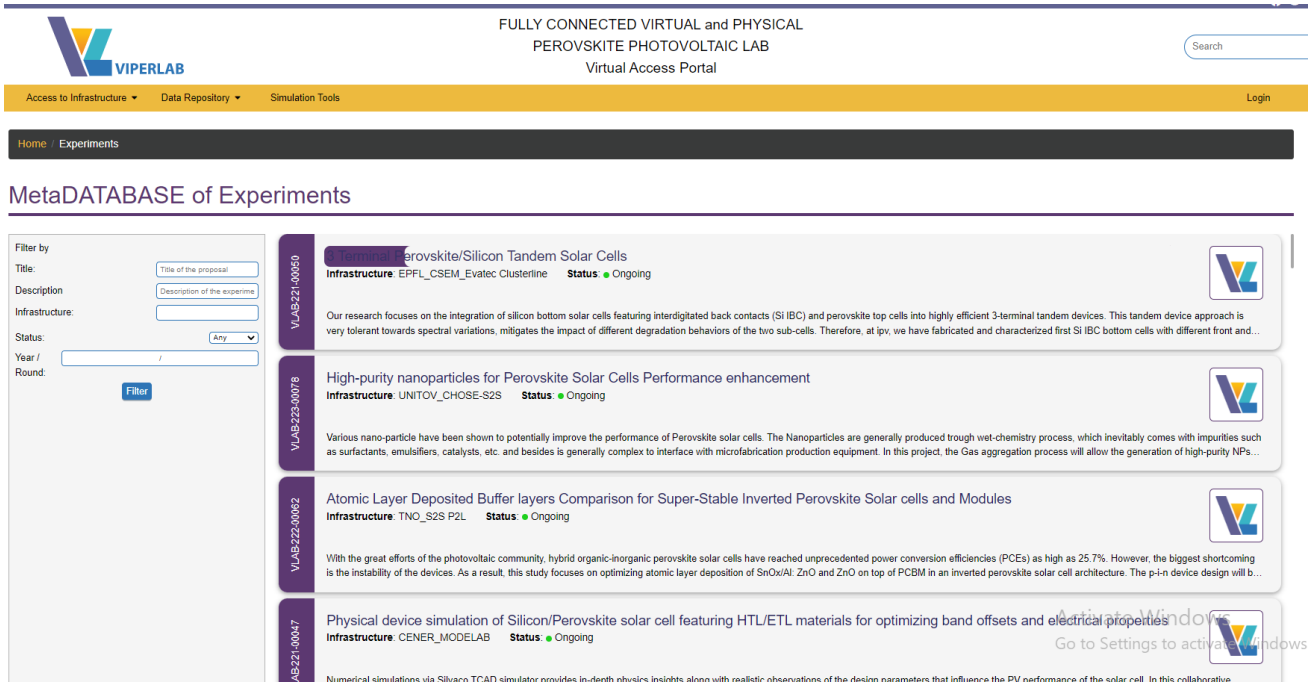

Figure 13. Screenshot from the VAPo database of the anonymously presented proposals in VIPERLAB.

In addition to that, several user testimonials have been published in the form of_

- LinkedIn posts: https://www.linkedin.com/in/viperlab-project/recent-activity/all/
- Youtube video: https://www.youtube.com/watch?v=V736uWr5cB4

4. DISSEMINATION/EXPLOITATION OF TRANSNATIONAL ACCESS ACTIVITIES IN VIPERLAB

The dissemination and exploitation of activities carried out through VIPERLAB's transnational and virtual access are crucial for sharing the results of research and fostering scientific collaboration. The outcomes of many user projects conducted at VIPERLAB facilities are being shared with the wider scientific community through a variety of channels, including journal publications, conference talks, poster presentations, and PhD theses. These efforts help spread the knowledge gained from VIPERLAB's cutting-edge research in the field of perovskite and tandem solar cells.

The publications listed in this section highlight some of the results so far, but it's important to note that more publications are expected in the future. As is common in scientific research, it

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takes time to process experimental data and turn it into peer-reviewed articles. Therefore, **additional findings will continue to be shared in the coming months and years**, further contributing to the growth and development of solar cell technologies.

4.1 Posters

- Tandem PV 2024: "Enhancing efficiency and stability of perovskite/silicon tandem solar cells: A focus on polymer encapsulants" – Quiterie Emery. Link to Program
- ISOS 2024: "Mastering encapsulation: Key considerations for durable perovskite solar cells" – Quiterie Emery. Link to Book of Abstracts
- Tandem PV 2024: "Open-Circuit Voltage Losses in Perovskite/Cu(In,Ga)Se2 Tandem Partners" – Ana Kanevce
- Poster at HOPV 2024: "Cellulose in Perovskite Solar Cells: from Substrates to Additives" – Joaquín Valdez García et al. Link to Proceedings
- Seyma Topcu: TandemPV poster

4.2 Oral Presentations

- MRS 2024 Fall Meeting & Exhibit: "Toward a full slot-die-coated green solvent ink perovskite solar cell" – A. Flórez, F. Ünlü, N. Maticiuc, R. Betancur, D. Ramirez, F. Jaramillo, E. Unger. Link to Program
- TandemPV 2024 Workshop in Amsterdam – Urs Aeberhard
- SimOEP Conference in Winterthur/Switzerland (September 2024) – Urs Aeberhard
- EU PVSEC Conference (September 2024) – Urs Aeberhard
- Asia-Pacific PVSEC Conference in Numazu/Japan (November 2024) – Urs Aeberhard
- UK Semiconductors Conference (Sheffield, UK, July 2024) – Shaoni Kar
- Perovskite Solar Cells and Optoelectronics (PSCO) Conference (Perugia, Italy, September 2024) – Shaoni Kar

4.3 Submitted Journal Articles

- "Tips and tricks for a good encapsulation for perovskite-based solar cells" – Q. Emery et al. In review.
- "Towards Green Processing of Perovskite Solar Cells: Protic Ionic Liquids Enable Water- and Alcohol-Based MAPbI3 Precursor Inks for Slot-die Coating" – F. Ünlü, A. Flórez, K. Dodd-Clements, L. K. Reb, M. Götte, M. Grosch, F. Yang, S. Öz, F. Mathies, S. Mathur, D. Ramírez, F. Jaramillo, E. Unger. Advanced Energy Materials (In review)

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- "Optimizing the process for scaling up perovskite solar cells under ambient conditions" – A. Flórez, J. Ruiz, J. F. Montoya, R. Betancur, E. Unger, D. Ramírez, F. Jaramillo. Advanced Energy & Sustainability Research (In review)
- "Roll-to-Roll Deposition of Wide-Bandgap CsFAPbBr3 Perovskite Solar Cells in Ambient Air with Optimized Ink Formulation" – Jafarzadeh et al. Solar RRL 2400530 DOI
- "In-situ and ex-situ Spectral Response characterization of the Radiation Damage and subsequent Recovery during Proton Irradiation of Silicon and Perovskite based Solar Cells" – H.C. Neitzert, F. Lang, Felix, A. Denker, J. Bundesmann, L. Gialanella, P. Delli Veneri, L. Mercaldo, M. Heydarian, A. J. Bett and M. Schubert. Abstract Book: 50th Materials Research Society (MRS) Spring Meeting 2023, Symposium: EL15 Radiation—Hard and Lightweight Next-Generation Semiconductor Electronics Materials Research Society

4.4 PhD Theses

- "Processing of hybrid perovskite films using scalable solution methods for application as active layers in flexible solar cells" – Alejandra Yaneth Florez Velasquez, Universidad de Antioquia, Colombia. DOI pending.
- "Interfaces and Connections in Vacuum Based Perovskite Solar Cells" – Arghanoon Moeini. Expected submission in 1 month and defense on 31st January.
- "Investigation of lead-free perovskites for photovoltaic applications" – El Arfaoui, Y. Ibn Zohr University, number 632/2024
- Publications
- Nature Energy 2021: Jacobsson et al., "An open-access database and analysis tool for perovskite solar cells based on the FAIR data principles."
- ACS Energy Letters 2022: Unger and Jacobsson, "The Perovskite Database Project: A Perspective on Collective Data Sharing."
- Matter 2022: Hansen and Whittaker-Brooks, "Finding the FAIRness in perovskite photovoltaics research."
- Energy Advances 2022: Maqsood et al., "Perovskite device efficiency is a poor predictor for the number of citations a paper will get."
- Nature Communication 2022: Zhang et al., "Big data driven perovskite solar cell stability analysis."
- Solar RRL 2022: Grischek et al., "Efficiency Potential and Voltage Loss of Inorganic CsPbI2Br Perovskite Solar Cells."
- Front. En. Res. 2023: Graniero et al., "The challenge of studying perovskite solar cells' stability with machine learning."
- Adv. Funct. Mat. 2023: Liu et al., "Machine Learning for Perovskite Solar Cells and Component Materials: Key Technologies and Prospects."

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- J. Opt. 2024: Mammeri et al., "Stability forecasting of perovskite solar cells utilizing various machine learning and deep learning techniques."
- Emerg. Mat. 2024: Velez et al., "Measurement of information content of Perovskite solar cell's synthesis descriptors related to performance parameters."
- Neural Computing and Applications 2024: Touati et al., "Predictive Machine Learning approaches for perovskite properties using their chemical formula."
- Adv. En. Mat. 2024: Suchan et al., "Rationalizing Performance Losses of Wide Bandgap Perovskite Solar Cells Evident from the Perovskite Database."
- Patterns 2024, 5: Xie et al., "Creation of a structured solar cell material dataset and performance prediction using large language models."
- APL Energy 2023: Baumann et al., "Monitoring the stability and degradation mechanisms of perovskite solar cells by in situ and operando characterization."
- Nat Comm. 2023: Hartono et al., "Stability follows efficiency based on the analysis of a large perovskite solar cells ageing dataset."
- Energy Adv 2024: Fukasawa et al., "Effectiveness and limitation of the performance prediction of perovskite solar cells by process informatics."
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- J. Electron. Mater. 53: El Arfaoui, Y., Khenfouch, M. & Habiballah, N. "A DFT and Time-dependent DFT Investigation of the Structural, Electronic and Optical Properties of Lead-free FAMgI3 Perovskite for Photovoltaic Applications.
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5. CONCLUSION

The VIPERLAB project showed how effective it can be when countries work together to improve perovskite photovoltaic research and development. By giving researchers fair access to top research facilities and offering online tools for sharing and analyzing data, VIPERLAB helped strengthen Europe's role as a leader in sustainable energy.

The project's success can be seen in the high number of projects completed, the variety of users involved, and the valuable research results produced. Important progress was made in key areas of photovoltaic technology, such as making materials more stable, developing lead-free alternatives, and improving the scalability of the technology, setting the stage for future breakthroughs.

Although there were some challenges like delays and unexpected disruptions, VIPERLAB met its goals, encouraging inclusivity and helping bridge the gap between academic research and industry. The project also showed a strong commitment to gender equality, global

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teamwork, and sharing knowledge, further highlighting its importance in the photovoltaic research community.

Looking to the future, VIPERLAB's work will continue to have a big impact on the field. Its shared databases and new methods will remain useful for both current and future research, showing how important international collaboration is in solving global energy challenges.

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