EUROPEAN COMMISSION

Horizon Europe Framework Programme (HORIZON)
HORIZON-EIC HORIZON EIC Grants
HORIZON Action Grant Budget-Based

GA No. 101070417

Computation Systems Based on Hybrid Spin-wave–CMOS Integrated Architectures

SPIDER - Deliverable report

D7.2- First communication, dissemination, and innovation activity report

Disclaimer/ Acknowledgment

Funded by the European Union (under grant agreement No. 101070417).

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About SPIDER

In the future, the miniaturisation of electronic devices– epitomised by Moore's law – will be progressively limited by increasing power densities and the associated chip heating. Moreover, autonomous microelectronic applications, for example for the Internet of Things, demand high performance at ultralow power. Therefore, much research has recently focused on disruptive computing technologies that limit power consumption and optimise performance per circuit area. Spin wave computing is a disruptive spintronic technology that uses the interference of spin waves for computation and has considerable potential for power and area reduction per computing throughput. Despite much recent progress in the realisation of spin wave logic gates, no concept for a complete computing system exists today that is based only on spin waves. Thus, to advance from devices to systems, spin wave devices need to be complemented by CMOS in a hybrid spin wave–CMOS system. Using an interdisciplinary approach joining partners with expertise in materials science, physics, device manufacturing, electrical engineering, circuit design, and packaging, SPIDER targets the demonstration of a complete operational hybrid spin wave–CMOS computing system. To date, complex spin wave circuits are yet to be realised. SPIDER targets to fill this gap by developing spin wave logic circuits based on majority gates. To embed these circuits into a CMOS environment, SPIDER will design mixed signal CMOS chips that can drive spin wave circuits and read out computation results. The spin wave and CMOS chips will then be combined on an interposer to obtain the final hybrid system. This work will pave the way towards viable spin wave chips and provide a first benchmark of spin wave computing at the system level. Based on the results, SPIDER will then develop a roadmap to advance spin wave technology to compete with CMOS in technology nodes below 1 nm.

SPIDER consortium members

imec THALES TU Delft Delft University of Technology Fraunhofer IZM RPTU IMT Akronic

Document information

Deliverable No.	D7.2
Related WP	WP7
Deliverable Title	First communication, dissemination, and innovation activity report
Deliverable Date	30 – November - 2023
Deliverable Type	Report
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Document history

Date	Revision	Prepared by	Approved by	Description
13/11/2023	1	Task Leader	WP leader	First draft
15/01/2024	2	WP Leader	Coordinator	Final

Dissemination level

PU	**Public**	
SEN	**Sensitive**	x

Publishable summary

This deliverable D7.2 - First communication, dissemination, and innovation activity report, covers the communication, dissemination, and innovation (exploitation) activities of the SPIDER project during the last 12 months.

This deliverable will be updated twice more during the project, in month 26 (D7.3) and at the end of the project, in month 42 (D7.4).

Contents

List of acronyms, abbreviations and definitions

Abbreviation	Definitions
EC	European Commission
GA	Grant Agreement
KER	Key Exploitable Result
WP	Work Package

1. Introduction

This deliverable describes the communication, dissemination and innovation activities carried out in the past 12 months under Work Package 7: "Dissemination, communication and exploitation". The main objective of this work package is to ensure the largest possible visibility, impact and uptake of the project - generated results and findings in support of the widest-possible adoption of delivered innovations in the broad electronics ecosystem. WP 7 aims at providing and executing communication, dissemination and exploitation strategy of the project and its development.

In this deliverable 7.2 we will describe the communication, dissemination and innovation activities carried out in the last 12 months.

Table 1: Overview of deliverable D7.2.

Deliverable Number	Short deliverable name	Lead beneficiary	Type	Dissemination level	Due date
D7.2	First communication, dissemination, and innovation activity report	RTPU	R	SEN	M12

1.1. Objectives of communication activities

The objectives of the communication plan are to:

- Create an identity to the project through graphically coherent material including the development of a website and logo.
- Define the communication activities and the responsible partners for the implementation.

1.2. Objectives of dissemination activities

The objectives of the dissemination plan are to:

- Identify the target groups, communication tools and distribution channels for the project dissemination and communication activities.
- Plan how to share the knowledge gained in the project, i.e. to which target groups each activity and results are relevant, as well as the adequate channels to address these.
- To communicate and disseminate results to regional, national and international channels.
- Define how to engage the community into adopting the results of the project.
- Interact with a wide audience through the internet, promotional materials and events.

1.3. Objectives of innovation activities

The objectives of the Innovation plan are:

- To systematic capture the exploitable results, related IPR and other exploitation, while monitoring intellectual property rights, regulations, and other exploitation related issues.

2. Communication activities

Communication is part of WP7 (Dissemination, exploitation and communication activities) and more specifically of T7.1 – "Dissemination, exploitation, and communication". As described in the Grant Agreement, the main objective of the communication is to identify all stakeholders and make them aware of the project. A communication plan (D7.1) was rapidly released (in January 2023) to identify target audiences/stakeholders and briefly list the planned dissemination channels/tools in use by the SPIDER project partners.

As described in the Grant Agreement and in the D7.1 report, these dissemination channels/tools include:

- Posts on the project website and in social media (LinkedIn)
- Participation to conferences, workshops, exhibitions, seminars, and networking events
- Publications in conference proceedings, journals, and specialized magazines

2.1. Communication results

2.1.1. Traffic on the project website

The SPIDER project website (Spider Horizon (spider-horizon.eu)) has been set up at the beginning of the project. It provides general information about the project including the technology objectives, SPIDER's concept and approach. It presents all project partners with the possibility to sort by R&D centers, universities, SMEs and larger companies. A direct link to the social media platform LinkedIn (see below) has been implemented.

Figure 1: Homepage of the SPIDER project website.

Google Analytics tool has been set active since December 2023, to monitor the website traffic and activities. Below is the report drawn on 15th Janurary 2024.

Analytics | Pure Communication
spider-horizon.eu

Go to report

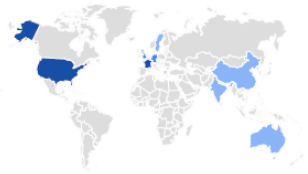
All Users | Add comparison

Last 90 days 17 Oct 2023 - 14 Jan 2024

Reports snapshot

Users	New users	Average engagement time	Total revenue
29	29	1m 06s	€0.00

Users by Country

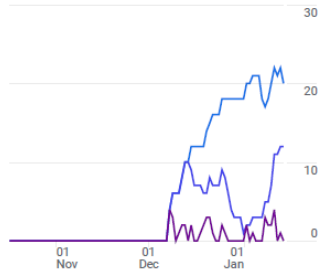


COUNTRY	USERS
Belgium	6
United States	6
France	5
Greece	4
Germany	2
United Kingdom	2
Australia	1

View countries →

HOW ARE ACTIVE USERS TRENDING?

User activity over time



30 DAYS 20
7 DAYS 12
1 DAY 0

WHICH PAGES AND SCREENS GET THE MOST VIEWS?

Views by Page title and screen class

PAGE TITLE AND SCREEN CLASS	VIEWS
Spider Horizon	61
Partners – Spider Horizon	16
Deliverables – Spider Horizon	11
Kick-off Meeting in imec (BE) – Spider Horiz...	11
Publications – Spider Horizon	11
News – Spider Horizon	6
Results – Spider Horizon	6

View pages and screens →

WHAT ARE YOUR TOP EVENTS?

Event count by Event name

EVENT NAME	EVENT COUNT
page_view	147
user_engagement	113
scroll	58
session_start	55
first_visit	29
click	4
file_download	3

View events →

WHAT ARE YOUR TOP CONVERSIONS?

Conversions by Event name

Is conver...

EVENT NAME	CONVERSIONS

No data available

View conversions →

HOW DOES ACTIVITY ON YOUR PLATFORMS COMPARE?

Conversions by Platform

View tech details →

©2024 Google | Analytics home | Terms of Service | Privacy policy | Send feedback

2.1.2. Traffic on social media (LinkedIn)

We started to place regular post on LinkedIn (https://www.linkedin.com/company/spider-horizon-project/) to provide the followers with information about the project progress, but also about presentations of the project and its results on international conferences and other scientific events.

By the end of December 2023, the total number of followers on SPIDER company LinkedIn page has reached 134. Below is the activity report generated on 15th January 2024.

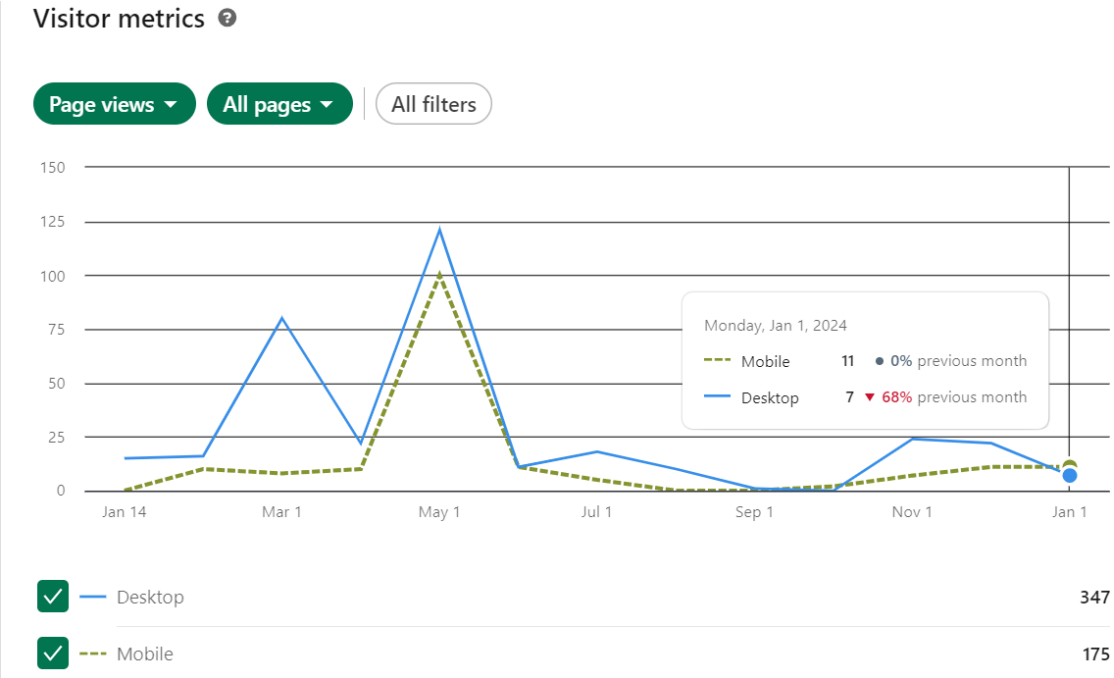


Figure 2: Visitor metrics of the SPIDER page on LinkedIn (from Jan.2023 to Jan.2024)

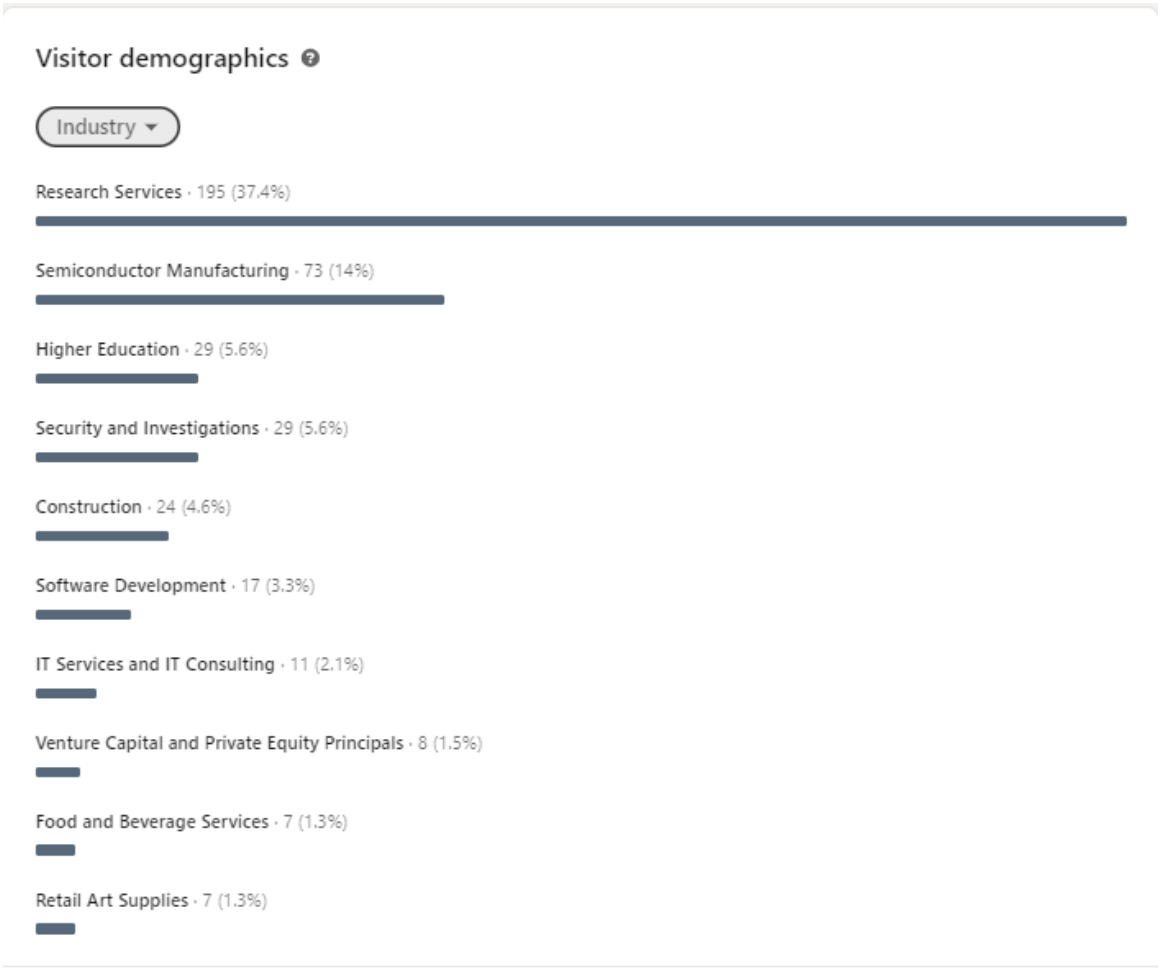


Figure 3:Visitor demographics per industry (from Jan. 2023 to Jan. 2024)

3. Dissemination activities

In this part, we give a brief overview of the dissemination activities that have been performed by the project partners in the last 12 months. This includes articles/proceedings/journals, participation to conferences/workshops and involvement in networking events.

As described in the GA and in the D7.1 delivery report, these dissemination channels/tools include:

- Posts on the project website and in social media (LinkedIn)
- Participation to conferences, workshops, exhibitions, seminars, and networking events
- Publications in conference proceedings, journals, and specialized magazines

3.1. Posts on the project website

As project coordinator and lead participant for WP7, IMEC has been setting up the SPIDER project website (www.spider-horizon.eu) with the following sections: Project, Technology, Partners, Results, News/Events (see Fig. 1). The Project and Partners sections contain static information that is not changed during the project, unless changes are required following an amendment to the Grant Agreement, that is accepted by the EU commission. The Results and News/Events contain information that is updated regularly by IMEC and RTPU depending on when the information becomes available. All the deliverable reports (or at least the publishable summary in case of confidential deliverables) are uploaded in the Results section as soon as they become available. Latest news (interviews with project participants, press releases, etc.) and events (upcoming conference/workshop, webinar, etc.) are the subject of short posts that are published in the News/Events section. Finally, publications in conference proceedings, journals, and specialized magazines are listed in the Publications section with the full details available (Authors, Journal, Publisher, Publication date, DOI) to ensure open access.

Overall, the project website is a key tool to disseminate the project results. It's also useful to increase the audience of the electronic newsletter and redirect visitors towards the project accounts on social media (LinkedIn) and vice-and-versa.

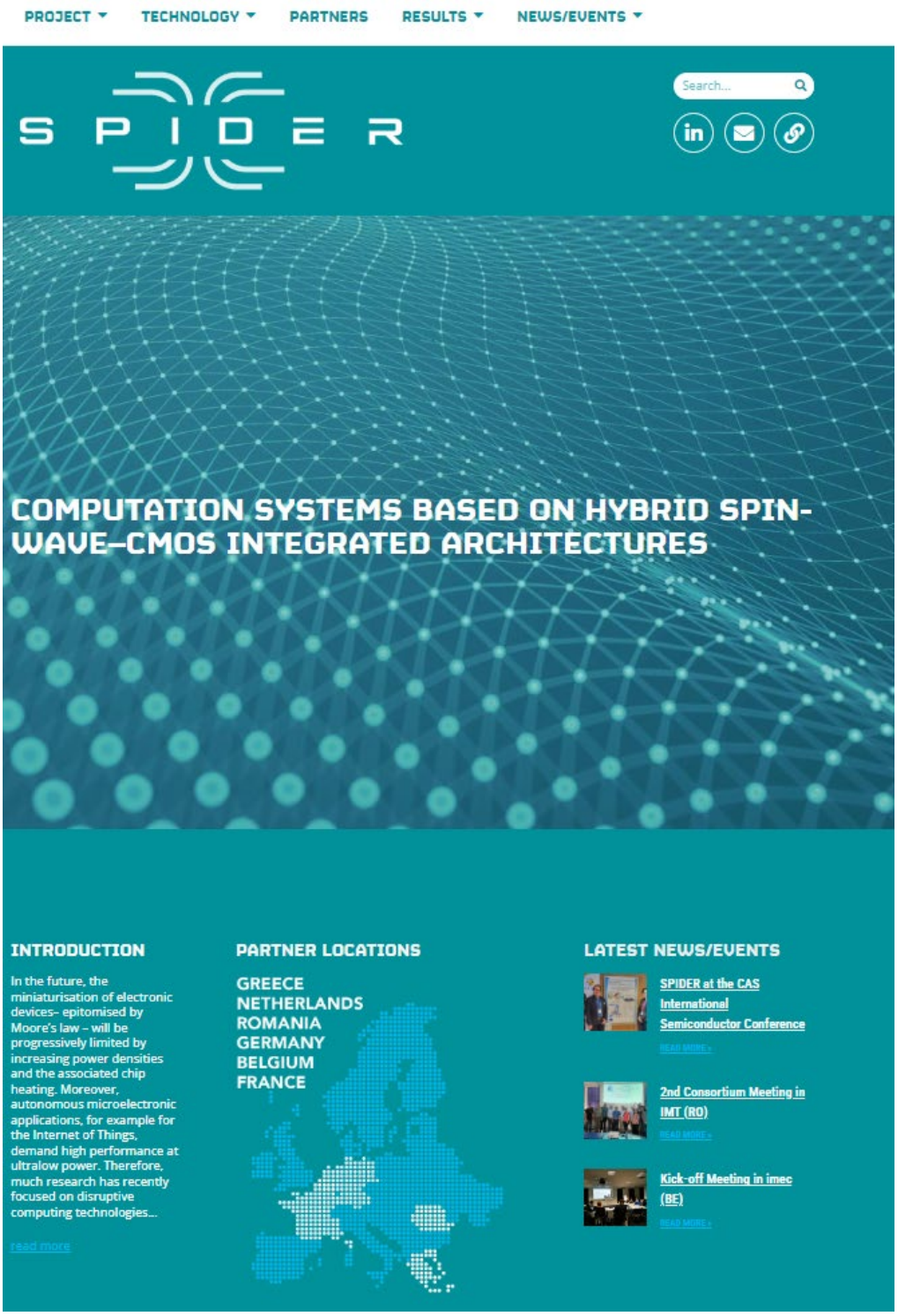


Figure 4: SPIDER project website - Latest News/Events

3.2. Posts on social medial

Social media platforms such as LinkedIn can be effective tools to increase the participation and awareness among the SPIDER project target audience/stakeholders (Members of the (EU) semiconductor and chip manufacturing industry, international electronic companies buying EU-made

technology, academic and industrial R&D communities, decision makers of the Member States and the European Commission, the general public). Therefore, SPIDER project account has been created on LinkedIn with all contributing partners as content admin. So far, the SPIDER project has gathered over 130 followers. Posts are made by all members.)

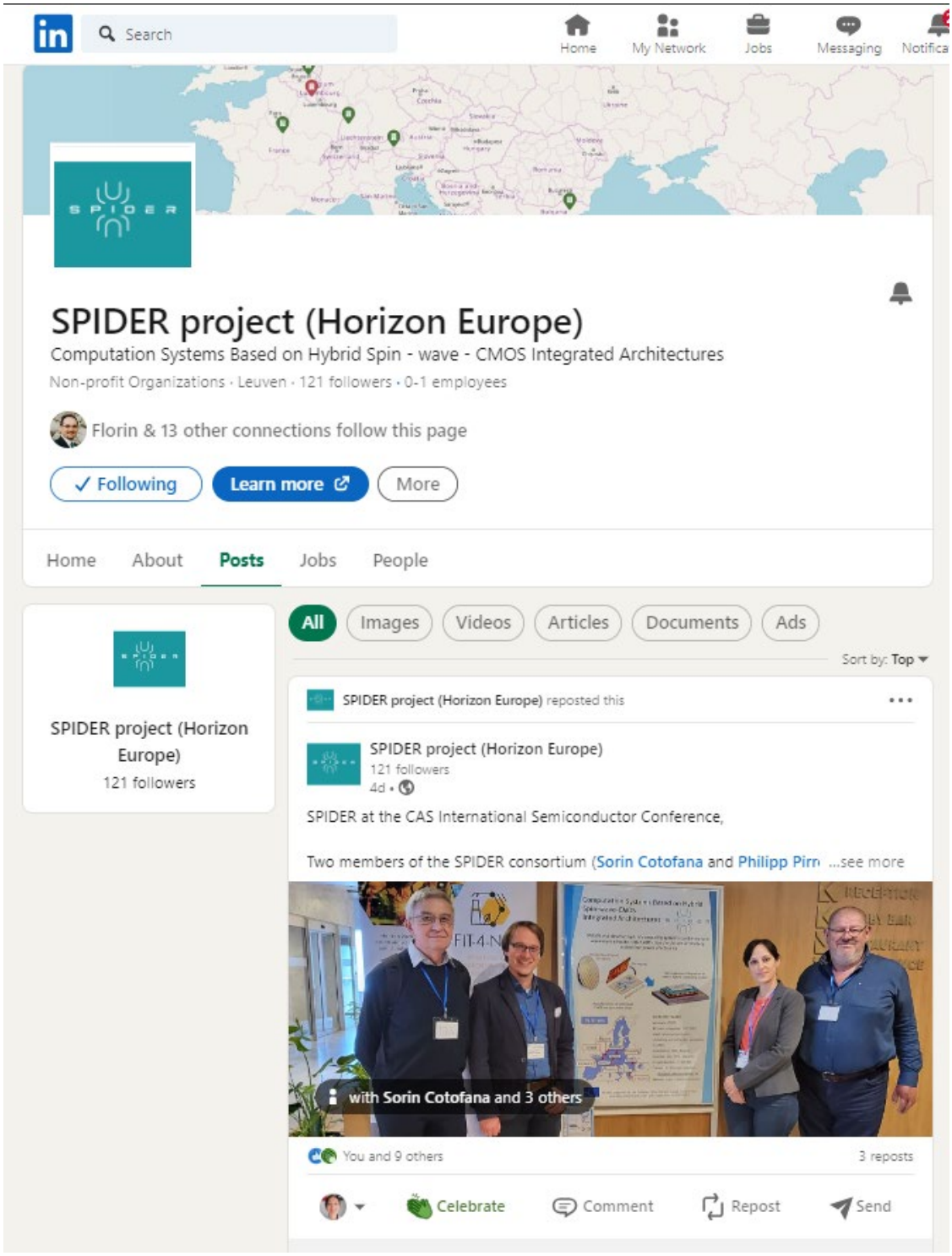


Figure 5: Post made by contributing member on LinkedIn company page

3.3. Participation at conferences, workshops, exhibitions, seminars, and networking events

Participating to conferences, workshops, exhibitions, seminars and networking events is an excellent way for SPIDER project partners to communicate about the project results and exchange with the different target audiences (specialists, material and equipment suppliers, potential customers and end-users, general public, policymakers, etc.). The SPIDER project partners were able to communicate about the SPIDER project at multiple conferences, workshops, webinars, and exhibitions as can be seen from the overview in Table 2 on the next page.

Table 2: Dissemination activities by SPIDER members by the end of Dec.2023

Type of Dissemination	Event name	Dates	Venue	Title	Author (Affiliation)
Invited Talk	SPEAR Workshop on Spintronics for beyond-CMOS	20.-22.03.2023	Gothenburg, (Sweden)	Boolean spintronic logic gates and circuit benchmarking	Florin Ciubotaru (imec)
Invited Talk	Intermag 2023	15.-19.05.2023	Sendai (Japan)	Spintronic logic: from transducers to logic gates and circuits	Christoph Adelmann (imec)
Plenary Discussion	Intermag 2023	15.-19.05.2023	Sendai (Japan)	Magnetics for tomorrow's chips	Martin Hempel (Fraunhofer IZM)
Social Media	Different platforms	15.08.2023	Online	Future Chips	PR (Fraunhofer IZM)
Invited Talk	2023 IEEE 13th International Conference "Nanomaterials: Applications & Properties"	10.-15.09.2023	Bratislava, (Slovakia)	Spin Wave Based Computing: Promises and Hurdles on the Road	Sorin Cotofana (TUD)
Invited Talk	46th International Semiconductor Conference (CAS) IEEE	11.-13.10.2023	Sinaia (Romania)	Magnon Spintronics – Processing data with Spin Waves	P. Pirro (RPTU)
Invited Talk	46th International Semiconductor Conference (CAS) IEEE	11.-13.10.2023	Sinaia (Romania)	Spin Wave Based Threshold Logic	S. Cotofana (TUD)
Oral presentation	15th International Conference on Physics of Advanced Materials (ICPAM-15)	19-26.11.2023	Egypt	Horizon Europe SPIDER (grant nr. 101070417) – Romanian participation in the development of beyond CMOS computing systems	A.C. Bunea, D. Neculoiu, A. Cismaru (IMT)
Oral presentation	18th ACM International Symposium on Nanoscale Architecture (NANOARCH)	18-20.12, 2023	Dresden, Germany	Spin Wave Threshold Logic Gates	A. Van Zegbroeck, P.Anagnostou, S. Hamdioui, C. Adelmann, F. Ciubotaru and S.Cotofana (TUD, imec)

3.4. Publications in conference proceedings, journals, and specialized magazines

Publications in conference proceedings, journals and specialized magazines are an effective to reach to the R&D and academic communities and members of the semiconductor industry.

By the end of project month 12, there has been two publications:

- C. Adelmann, F. Ciubotaru, F. Meng, S. Cotofana and S. Couet, "Spintronic logic: from transducers to logic gates and circuits", *2023 IEEE International Magnetic Conference - Short Papers (INTERMAG Short Papers)*, Sendai, Japan, 2023, pp. 1-2, doi: 10.1109/INTERMAGShortPapers58606.2023.10228488.
  Open access version at https://arxiv.org/abs/2401.10007
- Arne Van Zegbroeck, Pantazis Anagnostou, Said Hamdioui, Christoph Adelmann, Florin Ciubotaru and Sorin Cotofana, "Spin Wave Threshold Logic Gates", proceedings of the *18th ACM International Symposium on Nanoscale Architecture (NANOARCH)*, Dresden, Germany, 18.-20.12, 2023, *in press*.
  Open access version at https://arxiv.org/abs/2401.12136

In the future, all publication will be made available in an open access public repository, as required by the EC. In addition, the details of each publication will also be listed on the SPIDER project website.

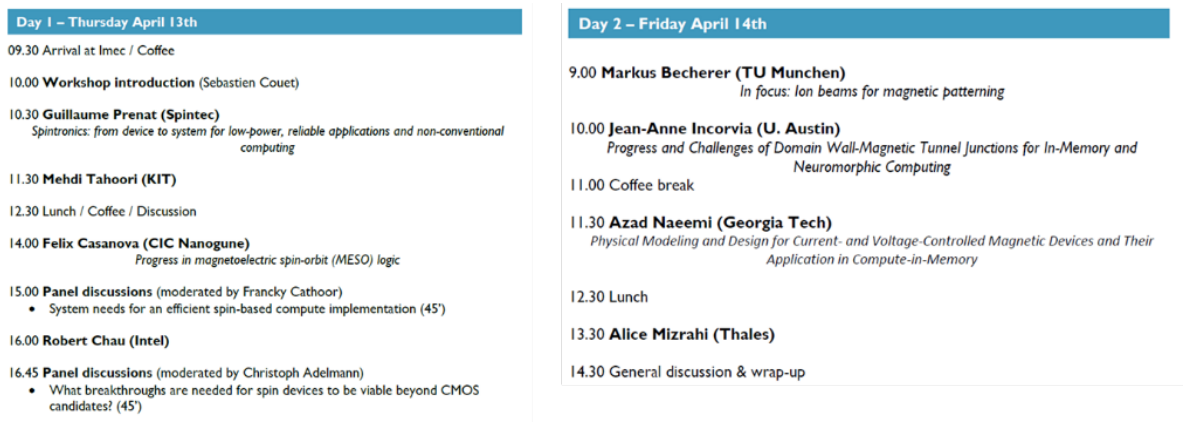
3.5. Dissemination activities per partner

3.5.1. IMEC

A central goal of IMEC's dissemination activities is the communication of SPIDER's concept and results to the semiconductor industry. IMEC's activities within SPIDER are embedded in the Industrial Affiliate Programs on beyond CMOS logic and on MRAM. These programs have numerous partners from the entire supply chain of the semiconductor industry, including all major integrated device manufacturers and foundries. In the first 12 months, SPIDER's concept and ideas have been presented to the semiconductor industry via dedicated teleconferences (e.g. most recently, a dedicated teleconference with Intel in January 2024) as well as to a broader audience at IMEC's semiannual Partner Technical Week (PTW), where more than 500 people meet onsite (and many more online) for an update of IMEC's recent progress. Dedicated presentations on SPIDER's results will be planned when system-level data become available.

A second goal of IMEC's dissemination and communication activities is the creation of a scientific and industrial community that addresses the understanding of spintronic computation at the system level. Research on spintronic computation today is focused very much on the device level with little to no insight into circuits and systems. However, commercial applications can only occur when spintronics becomes competitive at the system level. Community building was supported by a workshop at IMEC in April 2023 with participants from both academia and industry. Although the workshop did not focus on spin-wave approaches only, concepts such as SPIDER's were very much on topic for the workshop. The program of the workshop including speakers is shown in the figure below. Discussions to continue by organizing additional workshops with a similar audience are ongoing. The groundbreaking results of

SPIDER will then become of great interest to discuss future directions of microelectronic applications based on spin waves.



Day 1 – Thursday April 13th

09.30 Arrival at Imec / Coffee

10.00 **Workshop introduction** (Sebastien Couet)

10.30 **Guillaume Prenat (Spintec)**
Spintronics: from device to system for low-power, reliable applications and non-conventional computing

11.30 **Mehdi Tahoori (KIT)**

12.30 Lunch / Coffee / Discussion

14.00 **Felix Casanova (CIC Nanogune)**
Progress in magnetoelectric spin-orbit (MESO) logic

15.00 **Panel discussions** (moderated by Francky Cathoor)
- System needs for an efficient spin-based compute implementation (45')

16.00 **Robert Chau (Intel)**

16.45 **Panel discussions** (moderated by Christoph Adelmann)
- What breakthroughs are needed for spin devices to be viable beyond CMOS candidates? (45')

Day 2 – Friday April 14th

9.00 **Markus Becherer (TU Munchen)**
In focus: Ion beams for magnetic patterning

10.00 **Jean-Anne Incorvia (U. Austin)**
Progress and Challenges of Domain Wall-Magnetic Tunnel Junctions for In-Memory and Neuromorphic Computing

11.00 Coffee break

11.30 **Azad Naeemi (Georgia Tech)**
Physical Modeling and Design for Current- and Voltage-Controlled Magnetic Devices and Their Application in Compute-in-Memory

12.30 Lunch

13.30 **Alice Mizrahi (Thales)**

14.30 General discussion & wrap-up

Figure 6: Program of IMEC workshop on spintronic systems in April 2023.

3.5.2. TUD

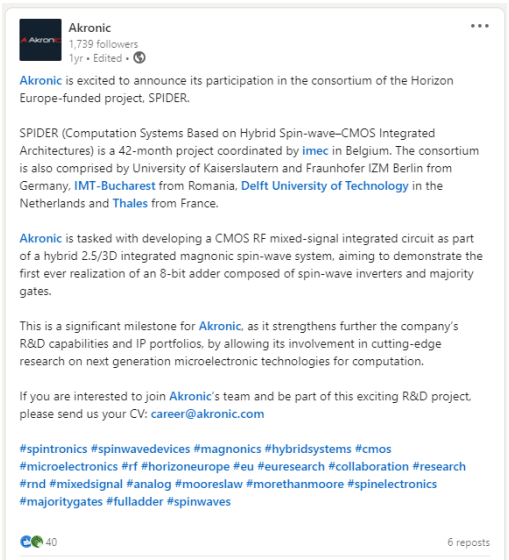
TUD strategy is to make known SPIDER's theoretical and experimental results within the academic environment. Specifically, our target is the further spread of knowledge on spin wave devices, circuits, and computation paradigms within similar fields and to future professionals. To achieve that, we plan to publish our results and conclusions in collaboration with the other SPIDER partners in conferences who mainly focus on magnonics and spintronics. The goal is to increase the interest and research in the field of spin waves by showing their true potential. These publications will mostly materialize from the start of the second year of the project when our results will be thoroughly examined and analyzed, but the first TUD lead scientific paper has been already presented at 18th ACM International Symposium on Nanoscale Architecture (NANOARCH), Dresden, Germany, 18.-20.12, 2023 and uploaded in arXiv. Apart from publications, preprints of publications will be uploaded to arXiv enhancing in that way the accessibility to a wider public. Invited talks and keynote addresses within domain related conferences and/or other public events are also envisaged, as they constitute a very effective dissemination avenue. During 2023 TUD members gave invited talks at 13th IEEE International Conference "Nanomaterials: Applications & Properties", 10.-15.09.2023, Bratislava, (Slovakia) and 46th IEEE International Semiconductor Conference (CAS), 11.-13.10.2023, Sinaia (Romania), and, as SPIDER project evolves we plan to continue following this dissemination thread. Last, but not least, we also plan to expose Electrical and Computer Engineering (ECE) students to the Spin Wave technology by including its fundamental concepts within the graduate level ECE curriculum.

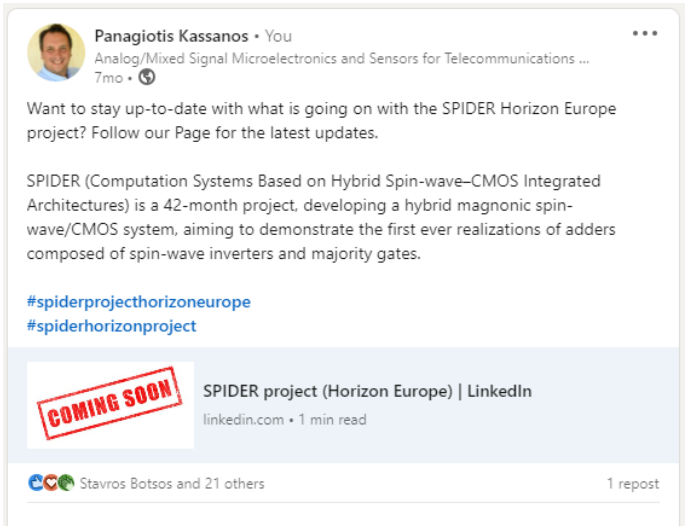
3.5.3. AKRONIC

Akronic is exploiting two parallel paths with regards to dissemination and communication. One is to exploit LinkedIn, where through posts of individual Akronic members or through the company's LinkedIn page or the project's LinkedIn page, we communicate the progress of the project and various developments. The second is through publication of papers in scientific journals as open access articles and in peer-reviewed conference proceedings. In this way, we will target both industrial and academic communities in the fields of future computing systems and RF/mm-wave microelectronics. We aim to participate in conferences in the field of microelectronics and circuit design. These conferences, in

addition to a publication that can be referenced by others, will allow Akronic to receive valuable feedback from experts in the field, share knowledge and meet others working in relevant fields. They also give the opportunity for more people to become familiar with Akronic, its services and products, as well as with the SPIDER project. The latter will be of great value to the microelectronics community, as magnonics is a growing field that is not yet attracted much attention from this community. Following experimental validation of the microchips we will design and fabricate we will aim towards journal papers, focused on the microelectronics we will develop, while other papers will follow through the combined work with our SPIDER partners when the different project elements come together to form a complete system.

Examples of social media posts (LinkedIn) can be seen below:





3.5.4. RTPU

We want to show that European research and industry is developing disruptive technologies that lead to more energy efficient integrated circuits. RPTU's interest to exploit the results generated within SPIDER is mainly on the side of fundamental research. Hence the target audience is the scientific community in spintronics and magnonics. These will be addressed by publication of our results in scientific journals. By publishing the results as open access articles or by making them available on well-known repositories, such as arXiv, we want to make them accessible to the largest possible audience. Further we will participate in various international spintronics and magnonics conferences to present our research outcomes. These conferences are an excellent platform to meet experts in the field, share knowledge, and receive valuable feedback. We aim to participate in at least two major conferences every year.

In addition to disseminating the results to the scientific community, we want to make the ideas and results available to a broader public. As a first start, we could attract a lot of attention for the topic of spin-wave computing by contributing to an article in the science section of the renowned German newspaper "Frankfurter Allgemeine Sonntagszeitung" (15.10.2023). In this article, the Spider-Project is explicitly mentioned and the concept of a CMOS-magnon hybrid is presented to the public including the principle of a wave-based majority gate. In general, spin-wave computing is presented as one of the technologies relevant to decrease the carbon footprint of a digitalized word.

FRANKFURTER ALLGEMEINE SONNTAGSZEITUNG

WISSENSCHAFT

15. OKTOBER 2023 NR. 41 SEITE 55

Trommeln für die grüne Zukunft

Die heutige Computer-Hardware hat ein Problem: Sie ist ineffizient. Eine Lösung versprechen unkonventionelle Rechnerarchitekturen.

Von Roland Wengenmayr

Es ist kein geringer Beitrag, den die Digitalisierung zum Klimawandel leistet: Schon heute erreicht ihr globaler CO_2-Fußabdruck das Niveau des internationalen Flugverkehrs. Vor diesem Hintergrund könnte man fast ein „Heizungsgesetz" für Computer fordern, denn heutige Mikroprozessoren und Elektroheizungen mit Datenverarbeitung als Nebenprodukt. Da die winzigen Transistoren die Zwischenergebnisse ihrer Rechnungen nicht speichern können, muss der Prozessor permanent Daten zwischen dem zentralen Rechenwerk, der CPU, und dem Arbeitsspeicher RAM hin und her schieben. Das sorgt für regen elektrischen Verkehr der Bits durch die mikro- und nanometergroßen Strukturen und für hormende Reibungsverluste und dadurch erzeugte Wärme.

„Neunzig Prozent der Energie, die man in einen Computer hineinsteckt, wird in Hitze verbraten", erklärt Helmut Schultheiß in seinem Büro im Helmholtz-Zentrum Dresden-Rossendorf. Der Physiker forscht auf dem Gebiet der sogenannten Magnonik, das die fließenden Elektronen heutiger Bits durch einen radikal neuen Informationsträger ersetzen will: den Elektronenspin. Gelänge dies, so wäre das eine Wende hin zu einer grüneren Informationsverarbeitung.

Der Spin ist ein quantenmechanische Drehimpuls hier des Elektrons und macht den Ladungsträger zu einem winzigen Elementarmagneten. In geeigneten Materialien formen freie Elektronenspins ein System, durch das magnetische Wellen laufen können – die Spinwellen, auch Magnonen genannt. Vereinfacht kann man sich Magnonen wie die Wellen vorstellen, die der Wind über ein Kornfeld treibt, wobei die schwankenden Halme fest verwurzelt bleiben. Ganz ähnlich verhalten die Elektronen in einer Spinwelle an ihren jeweiligen Atomen und wackeln wie kleine Kompassnadeln hin und her.

Im Labor werden schon magnonische Logikbauelemente und Transistoren gefertigt und deren besondere Funktionsweise demonstriert. Allerdings ist es eine enorme Herausforderung, die bestehende Halbleiterindustrie für die Fertigung neuer Chiparchitekturen zu gewinnen. Die erste Hürde heiße daria, die etablierte CMOS-Technologie mit Magnonik-Bauteilen zu verbinden, die zweite Hürde ist die Halbleiterindustrie selbst. Sie hat Milliarden in ihre Fabriken investiert und muss vom Sprung in ein komplett neues Materialsystem überzeugt werden, welches die Magnonik erfordert. Hier droht das berüchtigte „Tal des Todes", das in der Akzeptanzkurve neuer Technologien zwischen der Laborelemonstration und der breiten Anwendung lauert.

Um der Magnonik zum Durchbruch zu verhelfen, haben Katrin und Helmut Schultheiß gemeinsam das Projekt „Nanoficia" initiiert, das großzügig von der EU gefördert wird. Entscheidend für die Förderzusage war der Einstieg zweier großer Chiphersteller: der amerikanischen Firma GlobalFoundries, die auch in Dresden produziert, sowie der deutschen Infineon. Bei Nanficia geht es nicht allein um Magnonen, sondern auch um ein alternatives Computerkonzept, den „Reservoir-Computer". Ein solcher Rechner besteht grundsätzlich nicht aus Transistoren, sondern aus einem physikalischen System mit einer entscheidenden Eigenschaft: Es muss stark „nichtlinear" sein. Dieses Kriterium erfüllen Spinwellen perfekt. Nichtlinearität ist uns zum Beispiel als verzerrter Sound einer Rockgitarre vertraut. Darin sind viel mehr Frequenzanteile enthalten als in der ursprünglichen Saitenschwingung. Dies ist auch bei Spinwellen der Fall.

Helmut Schultheiß erklärt das Prinzip eines Reservoir-Computers anhand einer Pionierstat. Vor zwanzig Jahren bauten Chrisantha Fernando und Sampsa Sojakka von der University of Sussex einen frühen Reservoir-Computer aus einem transparenten Wasserbecken, das auf einem Overhead-Projektor stand. Eine Reihe von Lego-Technik-Armen verwirrte die Wasseroberfläche in Schwingungen, und der Projektor warf das wabernde Schattenbild auf eine Fläche mit kleinen Photodetektoren. Deren elektrische Signale verarbeitete ein sehr einfaches künstliches neuronales Netz. Entscheidend war nun, dass die Wasserwellen sich für verschiedene Eingangssignale, in deren Takt die Lego-Arme wackelten, stark nichtlinear überlagerten. Das Ergebnis waren charakteristische Muster, die Informationen über dieses Eingangssignal enthielten und von der KI nach etwas Training erkannt wurden. Der simple Reservoir-Computer war sogar in der Lage, die von einem Mikrofon auf die Legomeeren übertragenen Wörter „Zero" und „One" zuverlässig zu unterscheiden.

Das inspirierte die Dresdner Forscher zum Bau eines magnonischen Reservoir-Computers. Kernstück ist eine fünf Mikrometer große und 50 Nanometer dicke Scheibe aus einer magnetischen Nickel-Eisen-Legierung. Umgeben ist sie von einer omegaförmigen Antenne (siehe Abbildung rechts unten). Diese sendet Mikrowellen aus und regt in der Scheibe wirbelförmige Spinwellen an. Die Form dieser Magnonen erinnert an kreisförmige Schwingungen auf dem Fell einer in *der Mitte* angeschlagenen Trommel.

In das magnetische Scheibchen lassen sich auch zwei Magnonen mit leicht unterschiedlicher Schwingungsfrequenz einspeisen. Sie repräsentieren zwei Signale A und B. Geschieht dies schnell hintereinander, dann überlagern sie sich nichtlinear zu komplexeren Schwingungsmustern, wie auf einem entsprechend angeschlagenen Pankenfell. Die Muster erinnern an die Chladnischen Klangfiguren, die sich akustisch in einer Sandschicht auf einer schwingenden Metallplatte erzeugen lassen. Jedes Muster repräsentiert nun eine bestimmte Folge von Eingangssignalen, zum Beispiel „ABAB". Setzt man die Scheibe der Dresdner Forscher auf einen sogenannten MRAM-Speicherchip, dann wirken dessen magnetische Speicherzellen im Prinzip wie die Trommelnehmer unter den Saiten einer E-Gitarre.

MRAMs sind magnetische Schreib-Lese-Speicher, sie speichern Bits in Form von Elektronenspins – und GlobalFoundries stellt genau solche Speicherbausteine industriell in Dresden her. So ein MRAM-Chip lässt sich relativ einfach mit dem magnetischen Scheibchen kombinieren, und so kann dann der Speicher die verschiedenen Magnon-Überlagerungsmuster erkennen. Ein daran angeschlossenes, einfaches künstliches neuronales Netz ist dann in der Lage, diese Muster zu „lesen" und nach ihrem Informationsgehalt zu sortieren.

Es geht also um Mustererkennung, wie beim Fingerabdrucksensor eines Smartphones. Das Dresdner Bauteil bildet einen Reservoir-Computer, der Eingangsmuster in Echtzeit analysieren kann. Das könnten in Zukunft die vom Sensor einer Kamera ausgelesenen Daten sein oder ein Elektrokardiogramm, in dem der Reservoir-Computer sofort krankhafte Abweichungen im Herzschlag erkennen kann. Das Potential ist nach Ansicht des Dresdner Forscherpaars enorm: Theoretisch erreicht ein solcher magnonischer Computer die Rechenleistung eines größeren künstlichen neuronalen Netzes, das heute üblicherweise zur Mustererkennung eingesetzt wird und aus rund 20.000 Transistoren besteht. Schon wenige dieser Scheibenstrukturen, die auf einem MRAM-Chip aufgebracht sind, würden eine gewaltige Rechenleistung für Mustererkennungs-anwendungen in Echtzeit ermöglichen. Das habe die anfangs skeptischen Ingenieure der Halbleiterhersteller überzeugt, sagt Schultheiß.

Ein entscheidender Vorteil des Dresdener Konzepts: Das magnetische Scheibchen arbeitet ausschließlich mit ortsfest schwingenden Magnonen. Die Spinwellen wandern nicht durch feine Strukturen, wie es bei anderen Ansätzen in der Magnonik der Fall ist, bei denen die Funktionsweise etwa eines klassischen Transistors imitiert werden soll. Hier verliert das Magnon auf seinem Weg durch die feinen Strukturen an Schwingungsenergie. Diese Dämpfung ensprieht dem Ohmschen Widerstand in elektronischen Bauteilen. Genau dieses Grundproblem soll ausbreitender Spinwellen hat das Dresdner Forscherpaar vermeiden können.

Forschergruppen, die mit wandernden Spinwellen arbeiten, versuchen mit smart designten „Zwischenverstärkern" die unvermeidlichen Dämpfungsverluste auszugleichen. Um die Transportverluste der Magnonen im technisch relevanten Mikrowellenbereich zu senken, sollte der Querschnitt der Wellenleiter im Bereich von zehn bis hundert Nanometer Durchmesser liegen. Diese winzigen Strukturen ernsthaften komplexe Bauelemente, erklärt Philipp Pirro, Juniorprofessor an der Universität Kaiserslautern. Er ist ebenfalls an einem von der EU geförderten Projekt beteiligt, das Spider-Konsortium. Neben mehreren Forschungsinstituten und Universitäten sind Industrieunternehmen wie Thales mit an Bord. Pirros Gruppe ist für das Design des Magnonik-Bauteils mitverantwortlich, das dann auf einen CMOS-Chip aufgebracht wird. Die Auftragsfertigung einer Kleinserie von Chips für die Forschung übernimmt die Taiwan Semiconductor Manufacturing Company (TSMC).

Auf dem Chip sollen mehrere Magnonik-Logikbausteine zusammen einen sogenannten Volladdierer bilden: Dieser kann binäre Zahlen, die aus acht Bits bestehen, addieren. Solche Volladdierer sind zentrale Bauteile in den CPUs von Prozessoren. Wissenschaftlich interessant sind hier die Magnonik-Bauteile selbst: Es sind sogenannte Majoritäts-Gatter. Diese logischen Schaltungen besitzen drei Eingänge und einen Ausgang. Wie ihr Name besagt, wird das Ergebnis am Ausgang durch die Mehrheit der Eingangssignale bestimmt. Zum Beispiel sorgt die Kombination von Binärzahlen an den drei Eingängen 0, 1, 1 für eine 1 am Ausgang. In CMOS-Technik benötigt so ein Baustein ein Dutzend Transistoren – mindestens. Theoretisch kann dies ein rein magnonisches Majoritätsgatter aus drei parallelen Eingangswellenleitern übernehmen, zwischen denen ein Ausgangswellenleiter liegt. Darin überlagern sich die Wellen der Eingangssignale so, dass am Ausgang ohne weitere Zwischenschritte immer ein Signal erscheint, welches der Mehrheit der Eingangsmagnon-Bits entspricht. Ein solches rein magnonisches Majoritätsgatter wäre bestechend einfach und elegant, mehrere davon können einen Volladdierer bilden.

Pirro erklärt, dass es jedoch ein wesentliches Problem bei einer Kombination von CMOS-Technologie mit magnonischen Bauelementen gibt – die Kopplung zwischen beiden. Im Grunde passiert dasselbe wie bei einem schlechten Anschluss einer Antennenleitung: Es kommt kaum ein Signal im TV-Gerät an. „Gerade bei den ganz kleinen Systemen wird 99,5 Prozent der Signale einfach zurückreflektiert", sagt Pirro. Dieses Problem muss die Magnonik auf dem Weg zum grüneren Computer lösen. Allerdings könnte der steigende Druck nachhaltiger zu machen. Am Ende werden es vielleicht CO_2-Zertifikate sein, die der Magnonik helfen, durch das „Tal des Todes" der Technologieentwicklung zu kommen.

Der Dresdener Reservoir-Computer verarbeitet wirbelförmige Spinwellen (grün und blau dargestellt), die von Mikrowellen in einer Magnetscheibe (unten) angeregt werden. Überlagern sich diese Wellen (darüber dargestellt) entstehen komplexe Schwingungsmuster. Ein neuronales Netz kann die darin codierten Informationen lesen.

Grafik: IFW/Schultheiß

WOCHENSCHAU

Wein und Winter

Das Wetter beeinflusst die Qualität eines Weines auch außerhalb der Wachstumsphase. Demnach profitiert der Geschmack nicht nur vom warmen, trockenen Sommer, sondern auch vom nassen Winter. Dies haben Forscher der Universität Oxford jetzt in *iScience* veröffentlicht. Die Biologen korrelierten die Weintrinken aus der Region Bordeaux mit geographisch hochaufgelösten Klimadaten von 1950 bis 2020. Dabei bewegen sie erstmals das Winter in den Jahreszeiten mit ein, in denen die Weinstöcke ihre Ruhephase haben. Die Weinschaffer haben die Region im Südwesten Frankreichs für ihre Studie ausgewählt, da die Winzer dort die Reben nicht bewässern und Bewertungen der Weinhändler zurück bis ins Jahr 1950 verfügbar sind. Durch den Klimawandel werden die Sommer in Europa tendenziell heißer und die Winter nasser, demnach müssten die Weine aus dem Bordeaux also besser werden. Allerdings, so schränken die Autoren ein, gilt das nur so lange, wie die Weinstöcke ausreichend mit Wasser versorgt sind. Langanhaltende Dürren, wie sie laut den Klimamodellen in Europa häufiger vorkommen werden, ruinieren die Weinernte. *zbi*

Kein Entkommen

Können große, mobile Tiere den klimatischen Veränderungen an den Polen einfach ausweichen? Offenbar nicht. Zumindest zeigt eine Studie in *Science*, dass ihre Populationsgröße mit Meereisbedeckung und Nahrungsangebot in der Arktis korrelliert. Seit dem Wälfangmoratorium, das 1982 aufgrund eingebrochener Bestände verhandelnden wurde und 1986 in Kraft trat, erholen sich die Grauwal-Bestände gut. Es kommt aber immer wieder zu Einbrüchen, bei den drei größten waren jeweils 15 bis 20 Prozent der Tiere gestorben. Die Studie zeigt, dass in den betreffenden Jahren die Biomassenproduktion in den Sommermonaten, in denen sich die Wale zum Fressen in der Arktis aufhalten, infolge des Klimawandels sehr gering war. Offenbar schwächte das die Tiere, ihre Populationen schrumpften. *pb*

Kleine überall

In der Diskussion um die Ewigkeitschemikalien PFAS lag der Schwerpunkt oft auf Perfluoroktansäure, PFOA, mit acht Kohlenstoffatomen. In der EU ist PFOA seit 2020 verboten, da sie persistent und gesundheitsschädlich ist. Nun haben Wissenschaftler in den USA in Haushaltsstaub, Trinkwasser und Blutserum höhere Gehalte an kurzkettigen PFAS – Substanzen mit nur zwei Kohlenstoffatomen im Molekül – gefunden. Diese könnten teilweise aus langkettigen PFAS-Vorläufersubstanzen entstanden und noch giftiger als PFOA sein, wie sie in *Environmental Science und Technology* berichten. Bei der EU liegt ein Antrag von fünf Mitgliedstaaten vor, alle PFAS zu verbieten. *zbi*

Affe mit Fremdorgan

Bis zu zwei Jahre lebten Javaneraffen mit an gespenden Schweinenieren, berichten Forscher der US-Firma eGenesis in *Nature*. Zwar überlebten einige Tiere nur Tage oder Wochen, mehrere jedoch viele Monate. Das Team nutzte umfassender als bei ähnlichen Versuchen zuvor Möglichkeiten, die Spendertschweine gentechnisch zu verändern: Bei einer Gruppe von Schweinen wurden 69 Gene verändert. Dies betraf neben solchen, die zu Abstoßungsreaktionen beim Menschen führen, insbesondere in diesen Erbgut verbundene Viren – damit diese bei Affen oder auch Menschen nicht zu Infektionen führen können. Den Schweinen wurden zudem einige menschliche Gene „implantiert". Dies könnte einen erheblichen Vorteil der Xenotransplantationen darstellen, denn bei der Übertragung menschlicher Organe müssen die Empfänger lebenslang immunsuppressive Mittel nehmen. Der weltweit erste bekannte Fall einer Xenotransplantation eines Herzens von einem gentmodifizierten Schwein zum Menschen erfolgte Anfang 2022 in den USA – der Empfänger lebte nach der Übertragung rund zwei Monate. Ein zweiter Patient erhielt diesen September ein Schweineherz. *kjd*

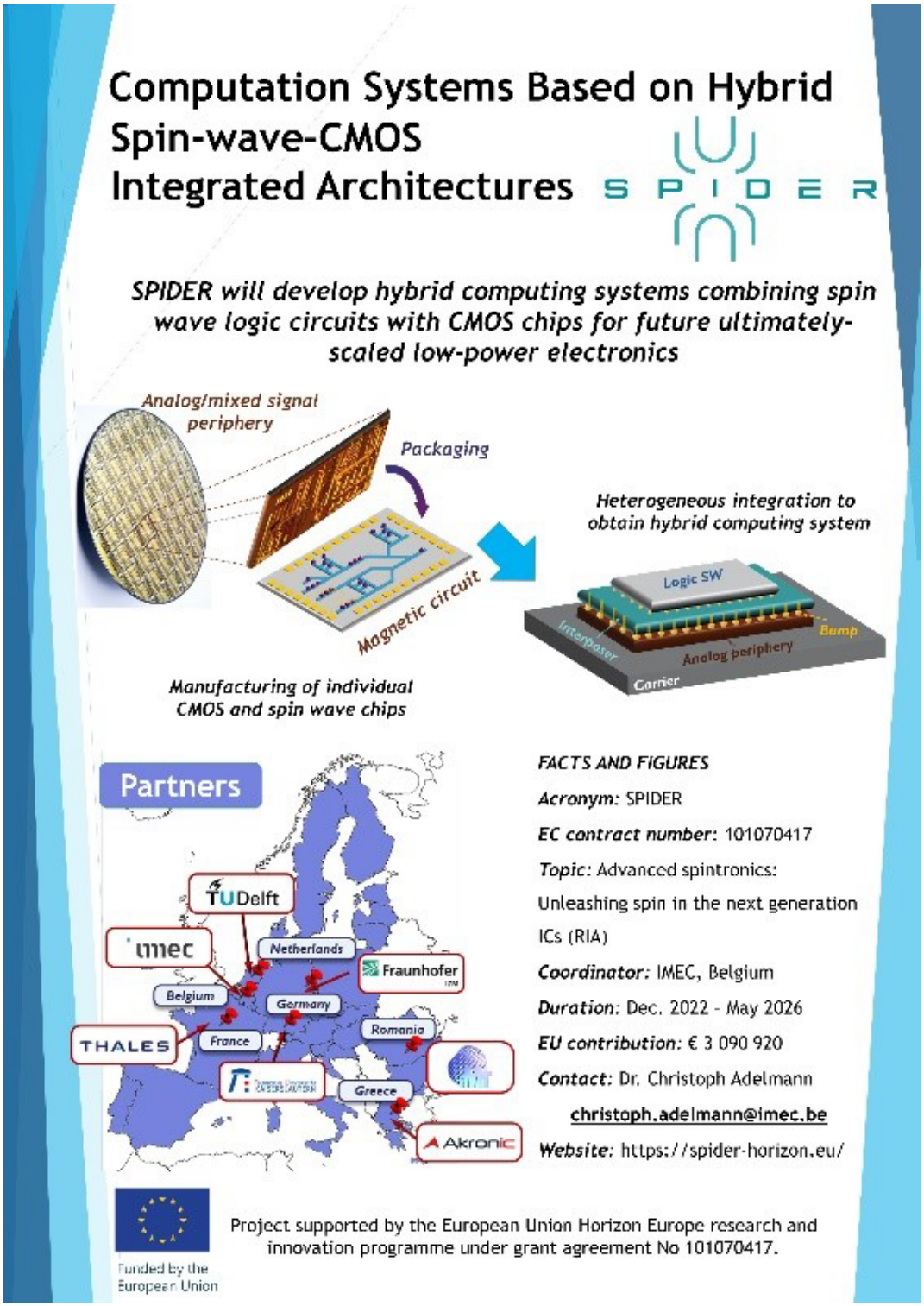
On the one hand, we plan to use the results of the project in teaching, for example in lectures for university students. On the other hand, we have and will continue to present the project to the public at local events for the public, such as the "Tag der Physik" (Day of Physics, took place on the 03.12.2023), “Nacht, die Wissen schafft (“Night that creates knowledge”, which will take place summer 2024) and other scientific fairs.

3.5.5. IMT

IMT will mainly focus on disseminating the results of the project in the academic environment and towards the education of future professionals in the field. We plan to participate in one to two IEEE conferences per year, mainly in the microwave and microelectronics areas (e.g., IEEE European Microwave Week, IEEE International Microwave Symposium, IEEE Asia-Pacific Microwave Conference, IEEE International Semiconductor Conference – CAS). Our dissemination actions will start to materialize in the second year of the project, when the first experimental results of the system circuit blocks will become available. The scientific community we target has limited contact with the spin-wave computing field, which will lead to interesting inter-disciplinary approaches and discussions and a better understanding on how to reconcile microwave engineering with spintronics. We aim to publish the results, in collaboration with other SPIDER partners, in high-ranking journals in full open-access format. Alternatively, pre-prints will be uploaded to online repositories such as arXiv. The publications will be highlighted on platforms such as ResearchGate or LinkedIn. We plan to organize a dedicated workshop as a satellite event to the IEEE International Semiconductor Conference in either the second or third year of the project. One additional dissemination direction is related to graduate and post-graduate lectures taught to students attending the University "Politechnica" of Bucharest.

During the IEEE International Semiconductor Conference – CAS organized by IMT Bucharest in Sinaia, Romania in October 2023, a poster showcasing the SPIDER project was placed in the exhibition area. CAS 2023 was co-located with the 2023 International Conference on Analog VLSI Circuits - AVIC 2023, offering wider exposure to an interdisciplinary audience. Around 200 professionals from public research institutions as well as private companies were present at the event.

The Abstract entitled "Horizon Europe SPIDER (grant nr. 101070417) – Romanian participation in the development of beyond CMOS computing systems", authors Alina Cristina Bunea, Dan Neculoiu and Alina Maria Cismaru, was presented orally at 15th International Conference on Physics of Advanced Materials (ICPAM-15) (19-26 November 2023, Egypt). The expenses were partially covered by a national support action associated with the Horizon Europe projects. Flyers based on the SPIDER presentation poster from CAS 2023 were distributed to interested parties.

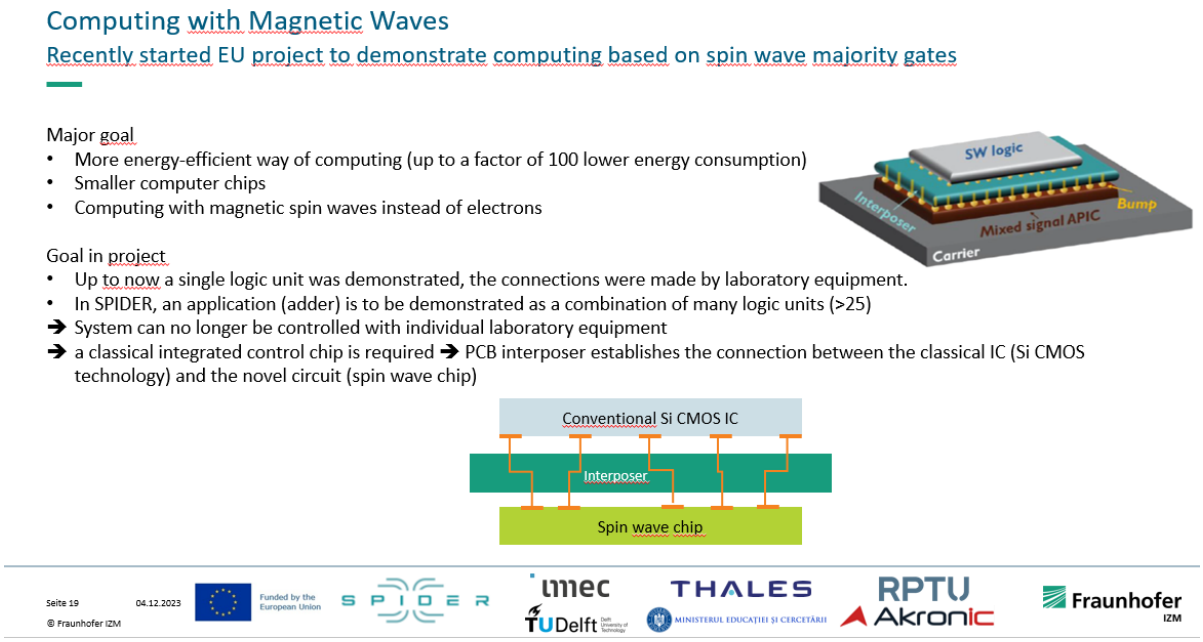

Computation Systems Based on Hybrid Spin-wave-CMOS Integrated Architectures
SPIDER
SPIDER will develop hybrid computing systems combining spin wave logic circuits with CMOS chips for future ultimately-scaled low-power electronics
Analog/mixed signal periphery
Packaging
Magnetic circuit
Heterogeneous integration to obtain hybrid computing system
Logic SW
Interposer
Bump
Analog periphery
Carrier
Manufacturing of individual CMOS and spin wave chips
Partners
TUDelft
imec
Netherlands
Fraunhofer
Belgium
Germany
Romania
THALES
France
Greece
Akronic
FACTS AND FIGURES
Acronym: SPIDER
EC contract number: 101070417
Topic: Advanced spintronics: Unleashing spin in the next generation ICs (RIA)
Coordinator: IMEC, Belgium
Duration: Dec. 2022 - May 2026
EU contribution: € 3 090 920
Contact: Dr. Christoph Adelmann
christoph.adelmann@imec.be
Website: https://spider-horizon.eu/
Funded by the European Union
Project supported by the European Union Horizon Europe research and innovation programme under grant agreement No 101070417.

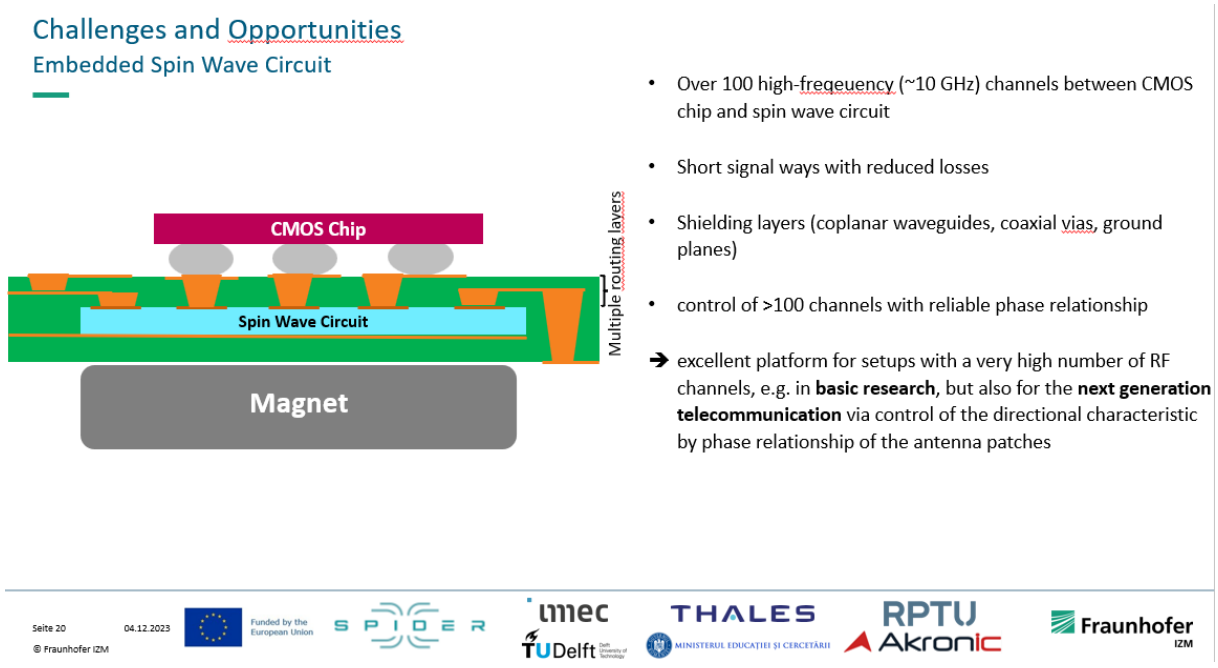
3.5.6. Fraunhofer

Fraunhofer IZM aims a dissemination of the results through multiple channels and tailored for different target groups. Initially, the results of SPIDER subsystems and the planned SPIDER overall demonstrator will be presented in cooperation with the project partners in appropriate journals and at conferences. Here, we strongly follow the suggestions of journals and conferences made by the partners, who are already involved for decades in expert circles on magnetic spin waves. Furthermore, Fraunhofer IZM will publish further technical papers on sub-aspects of packaging. Here too - together with partners from the consortium - corresponding publications and conference papers will be prepared. In particular, the specifically developed packaging methods for the phase-correct control (essentially through precisely controlled lengths) of a large set of channels promises to be of great importance for applications in wireless telecommunications (5G/6G, WiFi) and radar sensor technology. Since with such techniques the transmit beam can be precisely controlled by driving different antenna elements with a defined phase offset. This is presented in technical papers on packaging (e.g. IMPAS, IMPACT) and on radar conferences (e.g. EuRAD and RadConf). In addition to providing highly technical information about the project and sub-technologies, Fraunhofer IZM will use its established social media channels to present the main project content in a comprehensible way, even for laypersons in this field, and to highlight the potential added value of the targeted developments. Likewise, the knowledge generated in the SPIDER project will be incorporated into university knowledge transfer, as Fraunhofer IZM will take on teaching activities there in cooperation with universities and colleges. The same applies to the transfer of knowledge in the context of qualification theses, which are prepared directly at Fraunhofer IZM or are supervised at corresponding institutions. Following this general concept, the following dissemination activities have been carried out.

3.5.6.1. Conference contributions

At the Intermag 2023 conference in Sendai (Japan) a special session was organized by Paolo Bortolotti (THALES) a podium discussion started by the presentation of a slide set was given. The title was “Magnetics for Tomorrows’s Chips”. The panelists were Andrii Chumak, University of Vienna, Austria; Martin Hempel, Fraunhofer, Germany; Guohan Hu, IBM, USA; and Nian Sun, Northeastern University, USA. (https://2023.intermag.org/program/program/special-sessions). In the slide set the project SPIDER was present as a milestone and proto-typical example for future architectures of integration of CMOS-based with magnetics-based systems. The slides are shown below.





3.5.6.2. Social media channels

In order to make the results of the project accessible to the widest possible audience, IZM has endeavored to present the intended developments and also more concrete short-term effects of the developed technologies in a form that is as generally understandable as possible. These presentations were disseminated via IZM's social media channels in parallel to SPIDER's own channels (with reference to these). On the one hand, this is intended to arouse the interest of the wider public in the research topics. On the other hand, it was also important for us to inform interested parties from related areas of research and industry about developments in the SPIDER project. In particular, we consider interposer technology with phase-locked control of a large number of channels to be an interesting topic for this community.

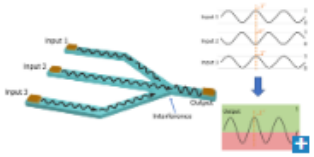
The following is an overview of the published content:

- Fraunhofer IZM website: same article in a German version and an English version : https://www.izm.fraunhofer.de/de/news_events/tech_news/chips-der-zukunft-koennten-100-mal-weniger-energie-verbrauchen.html ; https://www.izm.fraunhofer.de/en/news_events/tech_news/hundredfold-reduction-in-the-power-consumption-of-future-chips.html

Using magnetic effects in electrons for a hundredfold reduction in the power consumption of future chips

August 15, 2023

Electronic devices are shrinking all the time. At the same time, the computer chips inside them are getting more and more powerful, but they are also using more energy, and running hotter. This makes it essential to find new ways toreduce the power consumption of high-performance computers. A new EU-funded project has brought together a high-profile consortium from science and industry to investigate how changes to the magnetic properties of semiconductors could achieve a hundredfold reduction in the power consumption of computer chips. Researchers at Fraunhofer IZM are on the team to investigate how the semiconductors' tiny contacts could be connected.



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Logic element using spin waves: Compared to traditional logic gates with their two inputs, spinwave logic gates can handle multiple inputs and allow new combinations for the computing system.

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Spin waves can help future computer chips solve complex calculations with a hundredfold reduction in the power they need.

Laptops, smartphones, even smart watches: In our digital world, we expect more and more functions to be taken over by devices that are getting smaller and smaller, but also hungrier and hungrier for energy. New insights from research suggest that it can help reduce the size and energy consumption of electronic devices by a massive margin, if spinwave technologies are used in microchips.

What are spin waves? Spin waves refer to the collective excitation of magnetic material. The "spin" is the angular momentum of a quantum particle, like an electron or a neutron. That momentum is responsible for all magnetic phenomena. The quantum particles making up spin waves are called magnons, and researchers have seized on these magnons, because they can be used to carry more information while using less energy than conventional microchips or semiconductor chips.

Putting the insights from spin and magnon research into practical use needs new technological solutions. The researchers at the Fraunhofer Institute for Reliability and Microintegration IZM and their science and industry partners from across Europe have developed a computer system that combines magnonics with conventional computing technology with its standard semiconductor systems. The team put their sights on CMOS circuits to achieve the necessary compatibility. CMOS or Complementary Metal Oxide Semiconductors are used in all modern computers to process digital or analogue data. For their project, the group working at Fraunhofer IZM produced an interface between the conventional computer and a spinwave circuit made from saphire or gardolinium gallium garnet (GGG). It operates at frequencies of up to 16 GHz with more than a hundred channels using almost identical wiring lengths.

One particular challenge for the project was the sheer density of the spinwave logic gates on a chip. Logic gates run the logical operations that turn binary input into output signals.

"Current spinwave chips have only one logic gate, but we are planning for more than a hundred gates on a single chip", says Dr Martin Hempel, project leader at Fraunhofer IZM, banking on the Institute's unique expertise with embedding high-frequency chips with multiple interfaces. The project will be the first to use spin waves for more complex calculations in a computer chip, potentially making it possible to reduce the energy consumption of future computers by a factor of a hundred. The technology to access multiple high-frequency channels that IZM- scientists developed for the project will also be useful for many other applications in other areas, such as RF and communication systems like those needed by self-driving cars to avoid collisions.

As a HORIZON project, "SPIDER" (Spin Wave Computing for Ultimately-Scaled Hybrid Low-Power Electronics) is supported with €3 million in European funding (funding ID 801055). The project is scheduled to run from 1 December 2022 to 31 May 2026 and includes Fraunhofer IZM, the Technical University of Delft, the Rhineland-Palatinate Technical University of Kaiserslautern-Landau, the Bucharest-based National Microtechnology Research and Development Institute IMT and the companies Thales and Akronic as project partners, coordinated by the Interuniversity Microelectronics Centre (IMEC) of Leuven.

(Text: Niklas Goll)

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- idw online, a portal for scientific press releases (German: https://idw-online.de/de/news819148 ; English: https://idw-online.de/en/news819147)

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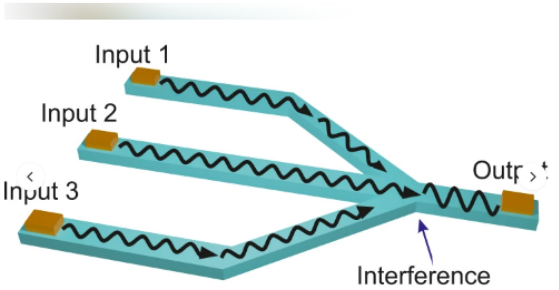
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM 15.08.2023

Chips der Zukunft könnten durch Magneteffekt in Elektronen 100-mal weniger Energie verbrauchen



Logikelement mit Spinwellen: Im Gegensatz zu klassischen Logikgattern mit zwei Eingängen können Spinwellen-Logikgatter mehr...

(PresseBox) (Berlin, 15.08.2023) **Elektronische Geräte und Computer werden immer kleiner. Die in den Geräten verbauten Chips benötigen bei wachsenden Anwendungswünschen hingegen immer mehr Leistungsdichte, erwärmen sich stärker und verbrauchen somit mehr Energie. Deshalb werden Technologien für Hochleistungscomputer mit extrem niedrigem Stromverbrauch immer relevanter. In einem von der EU geförderten Projekt will ein Konsortium aus Forschung und Industrie Änderungen der magnetischen Eigenschaften in Halbleitern nutzen, um den Energieverbrauch von Computern um das 100-Fache zu verringern. Forschende des Fraunhofer IZM klären dabei, wie die winzigen Kontakte der Halbleiter angeschlossen werden.**

atches – im Zuge der voranschreitenden Digitalisierung sollen
men und gleichzeitig kleiner werden. Das geht oft mit einem

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Using magnetic effects in electrons for a hundredfold reduction in the power consumption of future chips

Susann Thoma *Presse- und Öffentlichkeitsarbeit*
Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration IZM

Electronic devices are shrinking all the time. At the same time, the computer chips inside them are getting more and more powerful, but they are also using more energy, and running hotter. This makes it essential to find new ways to reduce the power consumption of high-performance computers. A new EU-funded project has brought together a high-profile consortium from science and industry to investigate how changes to the magnetic properties of semiconductors could achieve a hundredfold reduction in the power consumption of computer chips. Researchers at Fraunhofer IZM are on the team to investigate how the semiconductors' tiny contacts could be connected.

Laptops, smartphones, even smart watches: In our digital world, we expect more and more functions to be taken over by devices that are getting smaller and smaller, but also hungrier and hungrier for

Spin waves can help future computer chips solve complex calculations with a hundredfold reduction in ...

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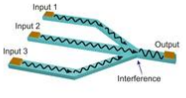
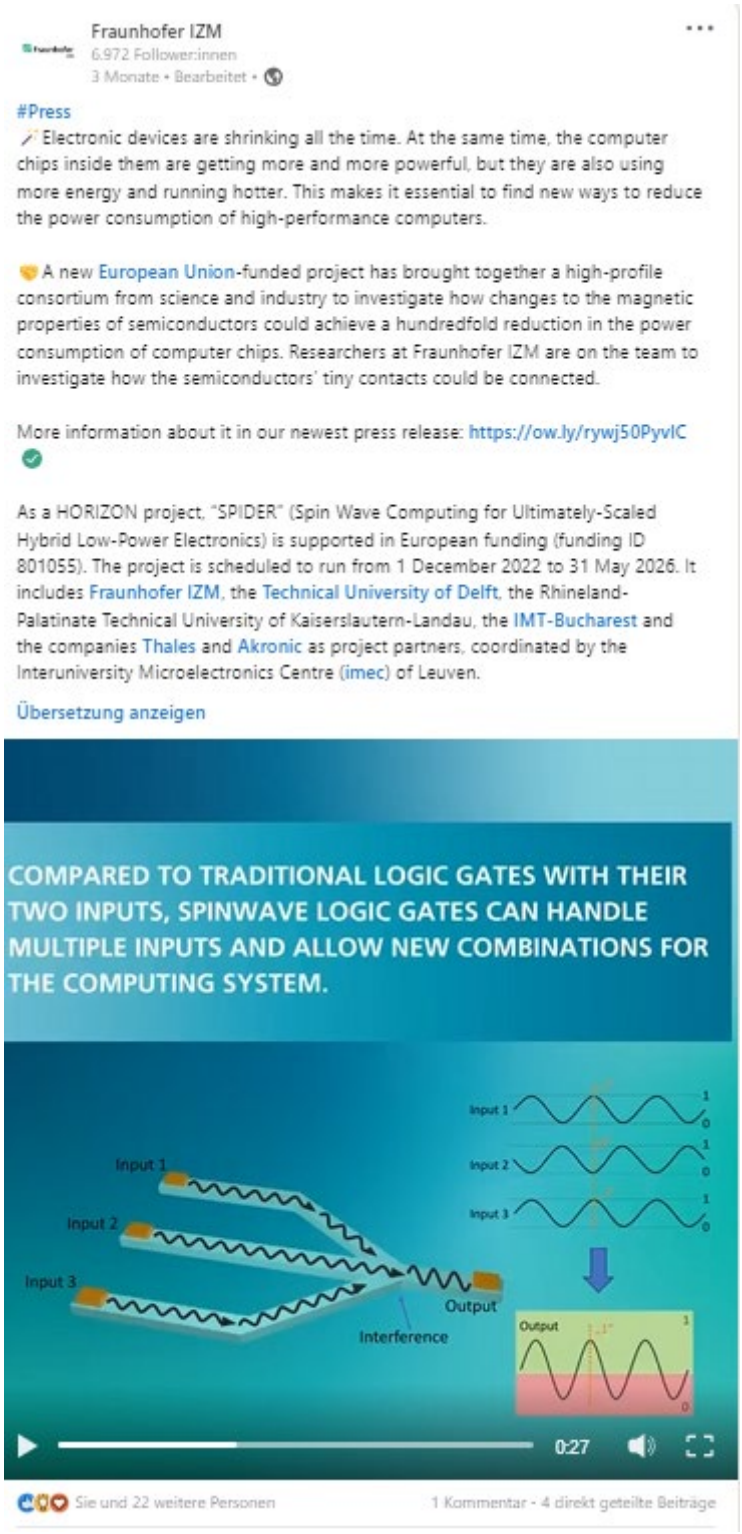


Logic element using spin waves: Compared to traditional logic gates with their two inputs, spinwave

- LinkedIn including a small video clip and links to the relevant info websites (via Fraunhofer IZM channel; https://www.linkedin.com/feed/update/urn:li:activity:7097155042486403072)



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How could you achieve changes to the magnetic properties of semiconductors, a hundredfold reduction in the power consumption of computer chips? Our Researchers are on the team to investigate how the semiconductors' tiny contacts could be connected.
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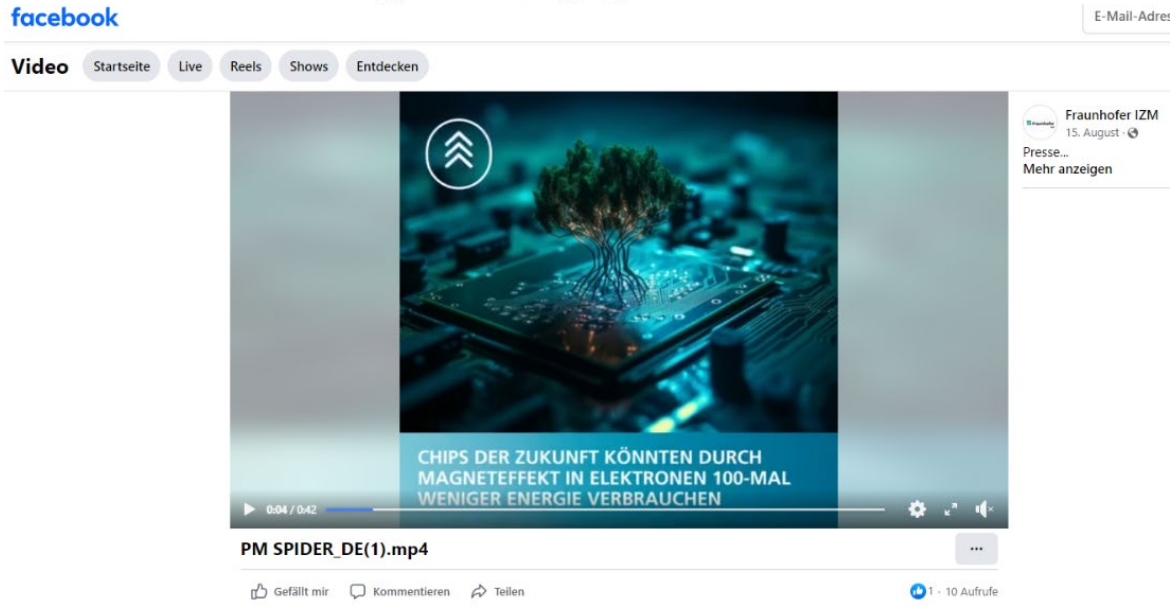

3.5.7. Thales

The dissemination activities pushed by Thales are two-fold. On one side, we are monitoring the latest results of the partners of SPIDER involved in the integration of spintronic devices with CMOS in order to present these results to Thales Global Business Units (GBUs) and make them aware of the progress of the SPIDER technology. Secondly, Paolo Bortolotti (Thales) organized two events during the INTERMAG meeting in Sendai, Japan in May 2023. The first one was a symposium related to spintronics applications (see figure below) where 5 different partners (including the coordinator of SPIDER) presented their recent results on the field of integration of spintronic devices with CMOS; furthermore, a special panel (with participation from FHG) was also organized to discuss the implication of industrial partners in those activities.

Onsite Session FA

Symposium SG: What is the Place of Magnetic Materials in Tomorrow's Chips?

Thursday, May 18, 2:00pm - 5:00pm, Main Hall (Conference Building)

Magnetic materials were always considered "dirty & risky" for integration in production lines. The emergence of Spintronics as an Emerging Technology is breaking this myth and several example of integration of magnetic materials with other technologies are now possible. In this special symposium, we invite representatives from industry and big R&D centers to highlight different type of integrations and clarify the place of magnetic materials in the Roadmaps of future chips. This symposium is linked to an Evening Event to further discuss with the main stakeholders.

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International Iberian Nanotechnology Laboratory

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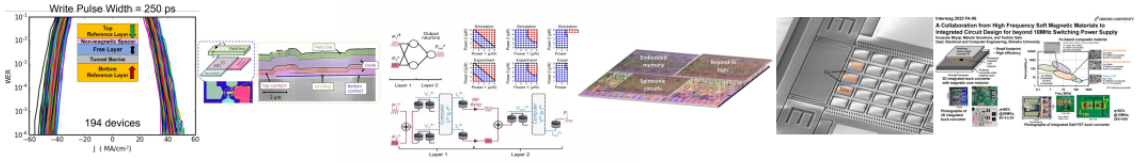

4. Innovation Activities

Since the SPIDER project is still in an early stage, no IP has been generated yet. Nevertheless, the SPIDER partners are working to identify the results that could lead to potential patents/IP generation, new products and technologies. This will be the focus of the exploitation of the results in a later stage of the project.

IMEC possesses background IP that is relevant for spin-wave computing as well as for SPIDER and/or longer-term successor projects:

Granted patents:

1. *Wave based majority gate device*, US patent 2018175863, European patent EP3339871, Odysseas Zografos, Florin Ciubotaru, Christoph Adelmann, Bart Sorée, Granted in October 2019.
2. *System and method for applying a magnonic-vector-multiplier arrangement*, US 11,599,138 B2, EP 3 632 840 A1, Christoph Adelmann, Jose Diogo Costa, Florin Ciubotaru. Granted in June 2023.

Pending patent applications:

1. *Logic gates based on phase shifters*, US 2022/0392683 Al, EP 4 099 571 A1, Florin Ciubotaru, Christoph Adelmann. Published in December 2022.
2. *Magnetoelectric device*, US 2023/0012461 Al, EP 4 120 372 A1, Christoph Adelmann, Florin Ciubotaru. Published in January 2023.

A list of identified key exploitable results is planned to be included in the upcoming report: D7.3 in month 26 and D7.4 at the end of the project, in month 42.

5. Conclusions

This deliverable covers the communication, dissemination and innovation activities of the SPIDER project in the past 12 months.

Here, we present an overview on:

- Report the number of people that were addressed in our dissemination activities.
- Dissemination activities carried out by all partners.

It is a living document that will be adapted during the project to reflect the status of the actions undertaken and planned. A second communication, dissemination and innovation activity report will be submitted in January 2025.