Funded by the HORIZON-JU-Chips and ROK NRF

Heterogeneously Integrated Multi-Material Photonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines

Deliverable D5.1.
Press Release and Communication Kit including Factsheet and website development

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Log of changes

Version	Organization	Changes
V1.0	AUTH	Document created
V1.1	DGIST	Document finalized

Table of Contents

List of Abbreviations

AI	Artificial Intelligence
DL	Deep Learning
LLM	Large Language Models
AiMC	Analog-in-Memory Computing
KPI	Key Performance Indicator
TL	Transfer Learning
NLAF	Non-Linear Activation Functions
MVM	Matrix Vector Multiplication
NN	Neural Network
DC	Data Center
MEMS	Micro Electro Mechanical systems

1 Executive Summary

This document summarizes the relevant information regarding the communication kit developed during the first months of the HAETAE project.

2 Introduction

2.1 Purpose of this document

The objective of this deliverable is to present the factsheet, the first press release, the brochure and the website development for the HAETAE project, which are a part of the media kit to be used for communicating the project vision, mission, objectives and targeted technological breakthroughs

2.2 Document structure

The present deliverable is split into following major chapters:

- HAETAE media kit
    - Factsheet
    - Brochure
    - 1st Press Release
- HAETEA online tools
    - Website
    - Social media accounts

2.3 Audience

This document is public.

3 HAETAE media kit

A set of project promotional material has been developed and will be distributed through various mass media channels for public use. This media kit, including **i)** a project factsheet and **iii)** a brochure, will allow the project Consortium to reach large audiences in a short period of time and communicate the mission, vision and objectives of the project.

- A project **factsheet** includes a clear overview of the project: the logo, the title of the project, general information about the project's duration, funding details and the Consortium. It summarizes the challenges the project is aiming to address as well as the mission statement detailing the aims of the project. The factsheet lists the objectives of the project and the targeted technological breakthroughs. Factsheets will be made available online at the HAETAE website, and will be promoted through its social media channels. Printed copies will be limited to the dissemination of information in external events where online promotion is neither possible nor sufficient.
- A project **brochure** includes clear and appealing info-graphics to be distributed on the web (social media, communities, partners' networks, external blogs, etc.), as well as in meetings, workshops, conferences, exhibitions and public events. It details the relevant project information, the Consortium, funding information, as well as the project's concept and vision, mission and aims, objectives and targeted neuromorphic photonic architectures. It will be shared online and printed only when necessary to be handed out at events.

3.1 HAETAE factsheet

See Pages 7-8

Chips JU

HAETAE

Heterogeneously Integrated Multi-Material Photonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines

Grant Agreement	101194393
Programme	HORIZON-JU-Chips-2024-3-RIA
Duration	01/10/2024 – 31/09/2027 (36 Months)
Budget	Overall Cost: 2,899,956.00 € EU Contribution: 1,499,956.00 €
Coordinator	Aristotle University of Thessaloniki, GR
Contact	**Prof. Nikolaos Pleros,** email: npleros@csd.auth.gr **Dr. Miltiadis Moralis-Pegios,** email: mmoralis@csd.auth.gr **Dr. Apostolos Tsakyridis,** email: atsakyrid@csd.auth.gr
Website	http://www.haetae.eu

Consortium

ARISTOTLE UNIVERSITY OF THESSALONIKI	Aristotle University of Thessaloniki	Greece
imec	Interuniversitair Micro-Elektronica Centrum	Belgium
AKHETONICS	Akhetonics	Germany
DGIST	Daegu Gyeongbuk Institute of Science & Technology	Republic of Korea
KAIST 1971	Korea Advanced Institute of Science and Technology	Republic of Korea

The challenge

Artificial Intelligence (AI) is booming and so does also its energy footprint. The exponentially increasing scale of Deep Learning (DL) models comes at the cost of high computational power and energy requirements, with the daily power consumed by highly acclaimed Large Language Models (LLMs) like ChatGPT-3 being already at 0.5 GWh. With current projections forecasting that the computational power requirements will double every 5-6 months , the way-to-the-rescue was initially being sought through innovative electronic AI hardware architectures, including neuromorphic and analog-in-Memory Computing (AiMC). Designing, however, an AI hardware roadmap around electronics implies inherent energy constraints due to the speed and power limits of the electronic interconnects inside the circuits. *Meeting the compute power requirements of next-generation AI applications without yielding an energy boom necessitates probably nothing less than a "tectonic shift" in the underlying computing hardware*. This deadlock has driven the emergence of neuromorphic photonics that were theoretically predicted to allow for orders of magnitude improvements in energy and size efficiencies compared to electronic AI platforms with the predictions relying on solid scientific principles and assumptions. Delving, however, deeper in the performance metrics of recent neuromorphic photonic demonstrations reveals a significant discrepancy between projected and achieved efficiencies: instead of the 10s of fJ/MAC expectations, computations with light can still not be offered at energy levels lower than a few pJ/MAC.

Mission statement / Objectives

This is where HAETAE steps in, aiming to overcome these shortcomings and release a versatile and energy-efficient photonic AI processor that can turn the promise of neuromorphic photonics into a tangible reality. To realize its ambitious goals, HAETAE will follow a holistic hardware/software co-design approach targeting the following objectives:

- **Develop a multi-material photonic integration platform that synergizes the best-in-class computational technologies**. HAETAE aims to rely on 3D Si/Si$_3$N$_4$ exploiting the low-loss interconnect and passive circuit substrate of Si$_3$N$_4$ and synergize it with i) SiGe/Ge for high-speed modulation, weighting functions and photodetection, ii) Si-based non-volatile Micro Electro Mechanical systems (MEMS) for zero-energy non-volatile weighting, iii) InP actives for on-chip amplification and non-linearities, providing analogue all-optical reconfigurable Non-Linear Activation Functions (NLAF) without requiring any digital interfaces between cascaded neural layers!

➢ **Adopt the best-in-class linear optical circuit architecture for versatile, loss- and fidelity-optimized photonic Matrix Vector Multiplication (MVM) engines**: HAETAE adopts a newly designed and loss-optimized linear optical Xbar circuit architecture based on a 3D Si/Si_3N_4 layer, following the principles of the conventional Xbar, for its photonic MVM chiplets in order to take advantage of its lowest insertion-loss performance and highest circuit-size scalability perspectives, its error-tolerant design that safeguards 100% accuracy in targeted computations, and its WDM-compatible credentials for boosting computational performance through wavelength parallelism.

➢ **Align photonic Neural Network (NN) technology with Transfer Learning DL models and architectures**. HAETAE aims to repaint the optical computing landscape by aligning its photonic NN technology along the powerful transfer learning (TL) paradigm that seems to perfectly fit the idiosyncrasy of photonic NN hardware. TL extends along the use of pre-trained backbone NNs that are followed by a shallow retrainable layer for task-adaptation purposes, suggesting that its synergy with photonics can i) maximize energy gains through the use of energy-efficient statically-weighted photonic MVM chiplets as its pre-trained photonic backbone NNs, ii) adapt to different applications through the use of a limited number of photonic TMM engines as its shallow photonic retrainable NN layer. The transition into a Photonic TL era will align with the development of an optics-informed NN training model library, designed to optimally streamline DL models for photonic hardware.

➢ **Translate its photonic-based innovations into tangible market opportunities by validating its technology platform along a set of communication and computing application areas**: i) in the Data Centre (DC) communication sector, demonstrating a photonic TL-enabled compute engine as the AI-enhanced DSP module in inter- and intra-DC optical interconnections applications, ii) in the large language models sector, efficiently processing physical languages showcasing the capabilities of its re-trainable photonic MVM chiplet to allow for real-time language translation, sentiment analysis and content filtering tasks, iii) in the inter-DC security sector, achieving line-rate cybersecurity threat detection.

Target technology breakthroughs

HAETAE's cross-cutting workplan, extending from material technology to photonic accelerator architectures and related applications, aims to enable impressive beyond-the-state-of-the-art advancements in multiple fronts. Specifically, HAETAE envisions to develop:

➢ **MEMS phase and amplitude modulators** projected to (i) achieve nearly zero power consumption by migrating from volatile to non-volatile designs, transforming photonic MEMS to electronic memristor equivalents (ii) offer more than 50x higher dynamic range compared to alternative photonic amplitude modulation components, reaching 50 dB.

➢ **All-optical NLA modules** projected to leapfrog current SotA by offering (i) a 5x higher operating frequency reaching 50 GHz, (ii) 80x in area efficiency reaching 1100 GSymbols/s/mm^2 (iii) 6x in energy efficiency reaching 2.5 pJ/NOP.

➢ **A converged PTL engine** projected to surpass current SotA NN hardware accelerators by: (i) 20x in operating frequency reaching 50 Gbaud, (ii) 15x in energy efficiency reaching 18 fJ/MAC, (iii) 20% higher footprint efficiency reaching 2450 GMAC/s/mm2.

➢ **An all-optical DSP module replacement** is expected to offer 50% lower power consumption than currently available electronic counterparts, reaching ~2W, when targeting 800G OSFP modules.

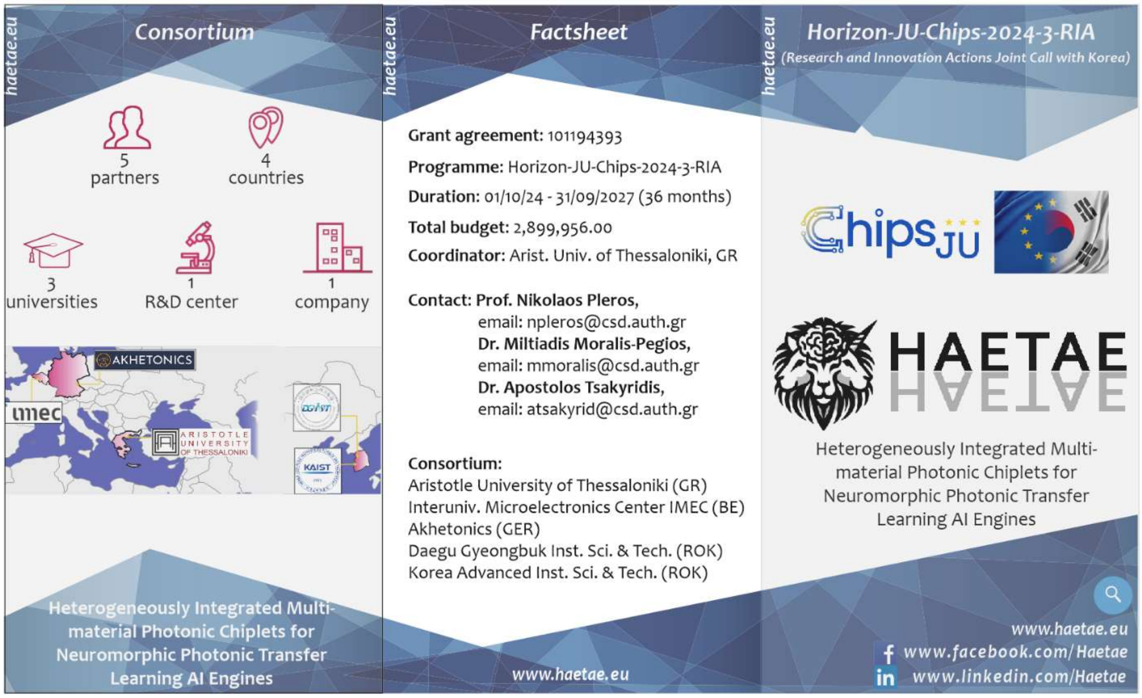
Consortium

HAETAE's consortium is strategically assembled to include the entire technology development chain, comprising a high-quality blend of industrial and academic partners which will work complementary towards satisfying all possible technological requirements and exploitation paths. *HAETAE's team has been built for success by bringing together, across the Republic of Korea and the European Union* :

- Three leading universities (AUTH, KAIST, DGIST) with pioneering outcomes in the area of neuromorphic photonics, combining expertise along all critical integration platforms employed in HAETAE – KAIST and DGIST on MEMS-based and AUTH on silicon-based PNNs,
- A renowned R&D centre (IMEC) with a track-record on developing cutting-edge Silicon Photonic technology, and finally
- An established SME (AKHETONICS) with strong R&D in the fields of all-optical computing.

The synergy between all partners ensures that the development work always remains along the right direction: system design, modelling, testing and evaluation on the basis of valid market application scenarios are indispensable activities to enable HAETAE to maximize its exploitation potential, providing a credible path for breeding innovation into tangible outcomes.

3.2 HAETAE brochure



haetae.eu

Consortium

5 partners

4 countries

3 universities

1 R&D center

1 company

Heterogeneously Integrated Multi-material Photonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines

haetae.eu

Factsheet

Grant agreement: 101194393

Programme: Horizon-JU-Chips-2024-3-RIA

Duration: 01/10/24 - 31/09/2027 (36 months)

Total budget: 2,899,956.00

Coordinator: Arist. Univ. of Thessaloniki, GR

Contact: Prof. Nikolaos Pleros,
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Dr. Miltiadis Moralis-Pegios,
email: mmoralis@csd.auth.gr
Dr. Apostolos Tsakyridis,
email: atsakyrid@csd.auth.gr

Consortium:
Aristotle University of Thessaloniki (GR)
Interuniv. Microelectronics Center IMEC (BE)
Akhetonics (GER)
Daegu Gyeongbuk Inst. Sci. & Tech. (ROK)
Korea Advanced Inst. Sci. & Tech. (ROK)

www.haetae.eu

haetae.eu

Horizon-JU-Chips-2024-3-RIA
(Research and Innovation Actions Joint Call with Korea)

Chips JU

HAETAE

Heterogeneously Integrated Multi-material Photonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines

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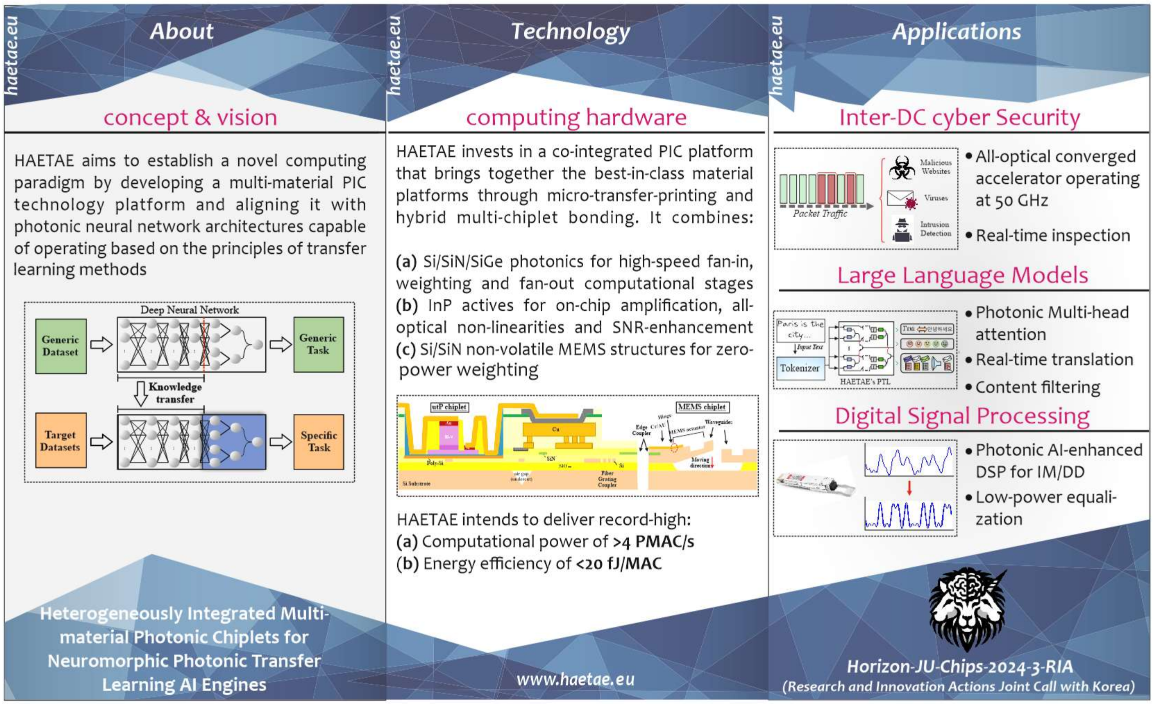

haetae.eu

About

concept & vision

HAETAE aims to establish a novel computing paradigm by developing a multi-material PIC technology platform and aligning it with photonic neural network architectures capable of operating based on the principles of transfer learning methods

Heterogeneously Integrated Multi-material Photonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines

haetae.eu

Technology

computing hardware

HAETAE invests in a co-integrated PIC platform that brings together the best-in-class material platforms through micro-transfer-printing and hybrid multi-chiplet bonding. It combines:

(a) Si/SiN/SiGe photonics for high-speed fan-in, weighting and fan-out computational stages
(b) InP actives for on-chip amplification, all-optical non-linearities and SNR-enhancement
(c) Si/SiN non-volatile MEMS structures for zero-power weighting

HAETAE intends to deliver record-high:
(a) Computational power of **>4 PMAC/s**
(b) Energy efficiency of **<20 fJ/MAC**

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Applications

Inter-DC cyber Security

- All-optical converged accelerator operating at 50 GHz
- Real-time inspection

Large Language Models

- Photonic Multi-head attention
- Real-time translation
- Content filtering

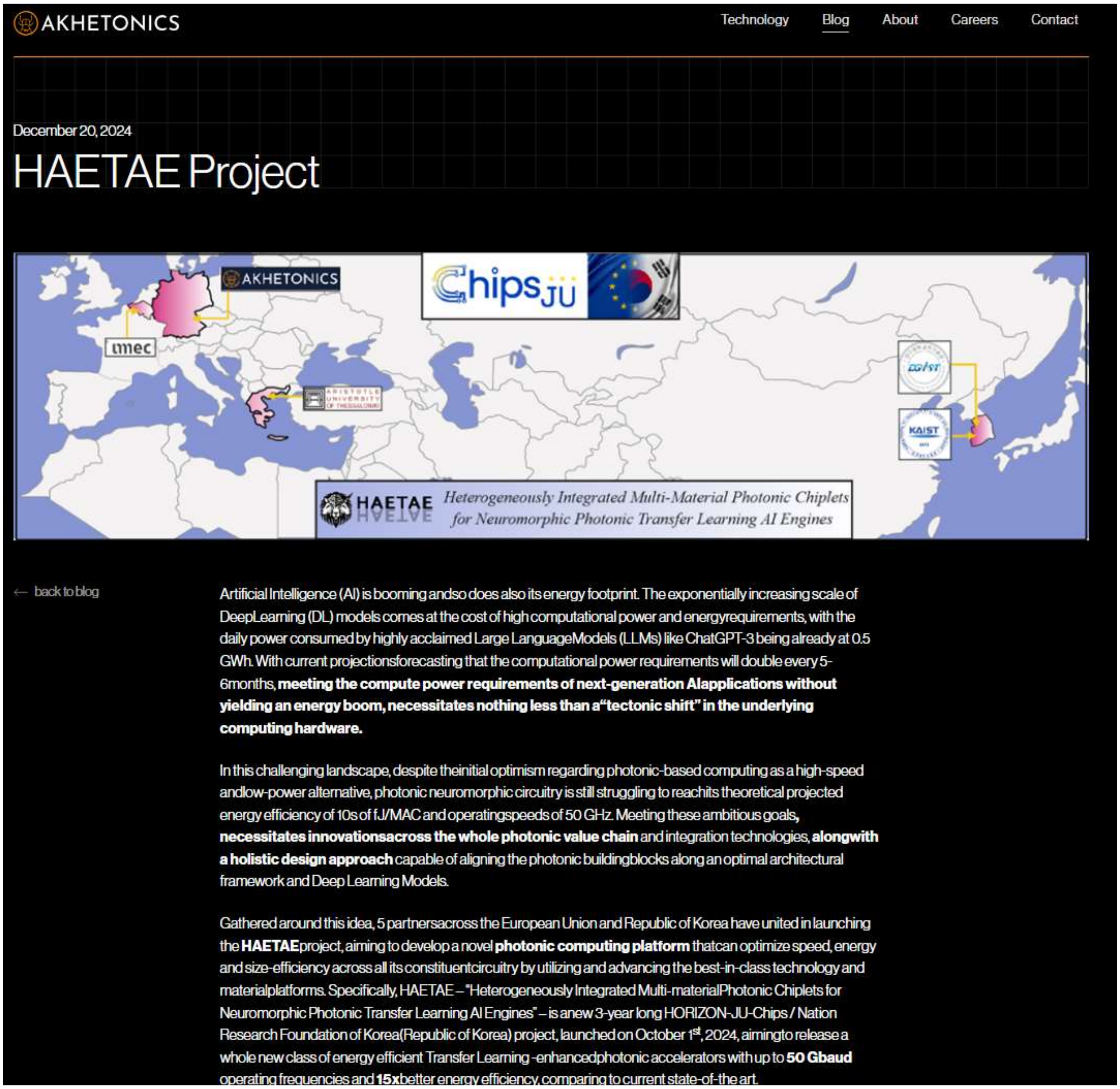
Digital Signal Processing

- Photonic AI-enhanced DSP for IM/DD
- Low-power equalization

Horizon-JU-Chips-2024-3-RIA
(Research and Innovation Actions Joint Call with Korea)

3.3 HAETAE Press Release

HAETAE's 1st Press Release was published by AKHETONICS, while it is also available on-line in HAETAE's social media and website.



December 20, 2024

HAETAE Project

Artificial Intelligence (AI) is booming andso does also its energy footprint. The exponentially increasing scale of DeepLearning (DL) models comes at the cost of high computational power and energyrequirements, with the daily power consumed by highly acclaimed Large LanguageModels (LLMs) like ChatGPT-3 being already at 0.5 GWh. With current projectionsforecasting that the computational power requirements will double every 5-6months, **meeting the compute power requirements of next-generation AIapplications without yielding an energy boom, necessitates nothing less than a"tectonic shift" in the underlying computing hardware.**

In this challenging landscape, despite theinitial optimism regarding photonic-based computing as a high-speed andlow-power alternative, photonic neuromorphic circuitry is still struggling to reachits theoretical projected energy efficiency of 10s of fJ/MAC and operatingspeeds of 50 GHz. Meeting these ambitious goals, **necessitates innovationsacross the whole photonic value chain** and integration technologies, **alongwith a holistic design approach** capable of aligning the photonic buildingblocks along an optimal architectural framework and Deep Learning Models.

Gathered around this idea, 5 partnersacross the European Union and Republic of Korea have united in launching the **HAETAE**project, aiming to develop a novel **photonic computing platform** thatcan optimize speed, energy and size-efficiency across all its constituentcircuitry by utilizing and advancing the best-in-class technology and materialplatforms. Specifically, HAETAE – "Heterogeneously Integrated Multi-materialPhotonic Chiplets for Neuromorphic Photonic Transfer Learning AI Engines" – is anew 3-year long HORIZON-JU-Chips / Nation Research Foundation of Korea(Republic of Korea) project, launched on October 1st, 2024, aimingto release a whole new class of energy efficient Transfer Learning -enhancedphotonic accelerators with up to **50 Gbaud** operating frequencies and **15x**better energy efficiency, comparing to current state-of-the art.

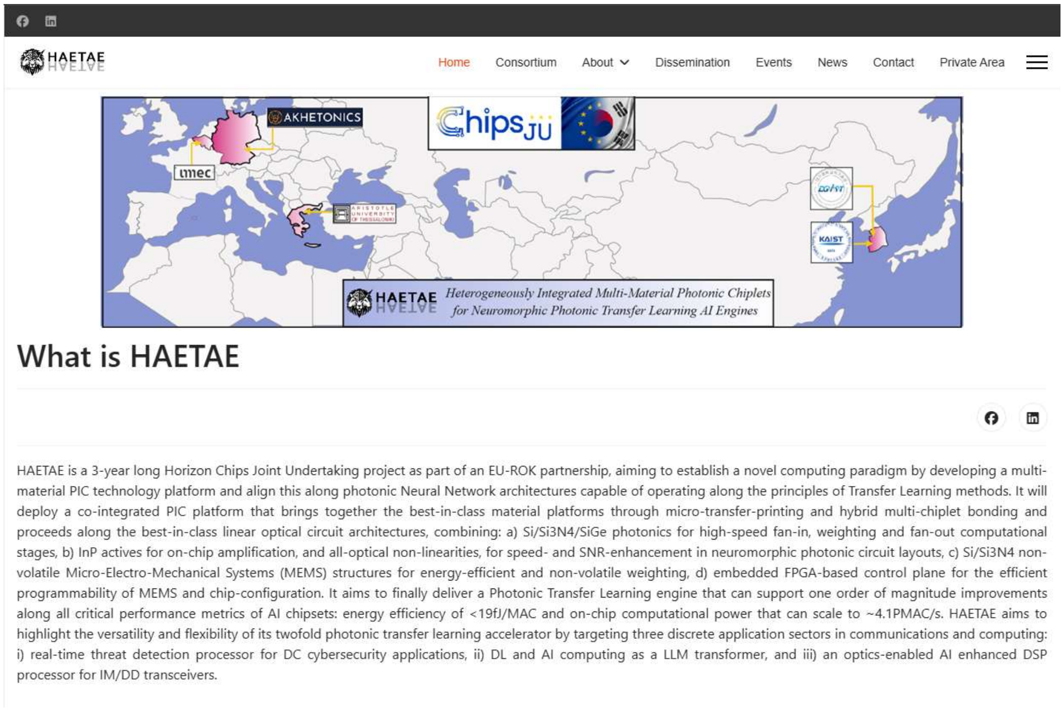
4 HAETAE online tools

4.1 HAETAE website

The official HAETAE website, accessible at http://haetae.eu/, is structured to host all current and future project-related information. It includes a dedicated section for secure access to the project's restricted area, facilitating internal data sharing and workflow management. This section links to the ownCloud repository, which has been approved by the Consortium as the platform for information exchange. All partners have been provided with credentials to access the restricted area.

The website serves as a comprehensive platform for disseminating HAETAE-related materials to a wide audience. Developed with a focus on accessibility, it aims to provide an overview of the project's objectives, an introduction to the HAETAE consortium, and a forum for discussing HAETAE -related topics. Recognized as one of the most effective channels for global dissemination, the website is accessible at any time to interested parties worldwide.

The HAETAE website features general information about the project, including its rationale, progress, expected outcomes, and details about the Consortium and its partners' contributions. As a promotional tool, it will be continuously updated throughout the project's duration with engaging content such as anticipated benefits, relevant references (e.g., studies, news, and publications), and additional promotional materials like brochures, factsheets, infographics, and posters.



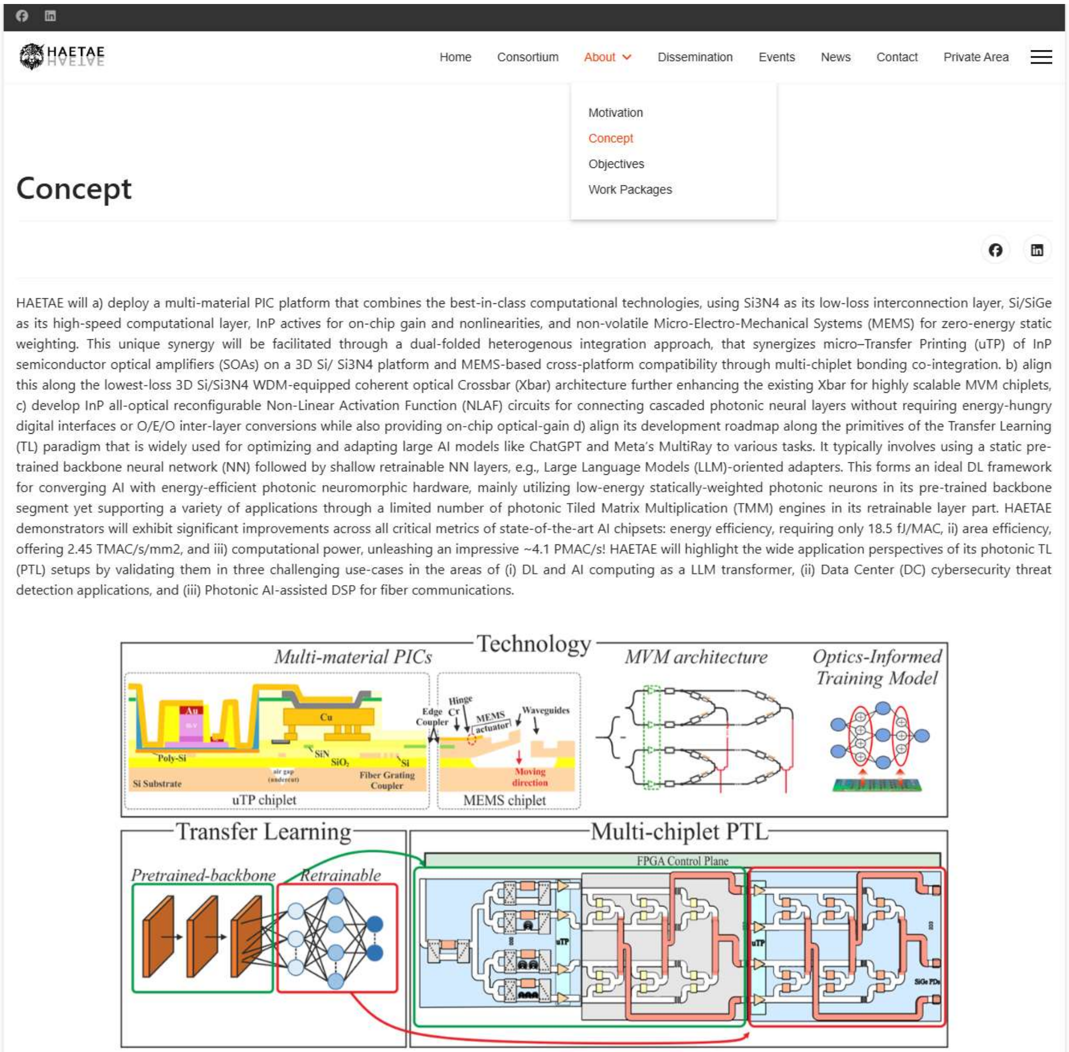
What is HAETAE

HAETAE is a 3-year long Horizon Chips Joint Undertaking project as part of an EU-ROK partnership, aiming to establish a novel computing paradigm by developing a multi-material PIC technology platform and align this along photonic Neural Network architectures capable of operating along the principles of Transfer Learning methods. It will deploy a co-integrated PIC platform that brings together the best-in-class material platforms through micro-transfer-printing and hybrid multi-chiplet bonding and proceeds along the best-in-class linear optical circuit architectures, combining: a) Si/Si3N4/SiGe photonics for high-speed fan-in, weighting and fan-out computational stages, b) InP actives for on-chip amplification, and all-optical non-linearities, for speed- and SNR-enhancement in neuromorphic photonic circuit layouts, c) Si/Si3N4 non-volatile Micro-Electro-Mechanical Systems (MEMS) structures for energy-efficient and non-volatile weighting, d) embedded FPGA-based control plane for the efficient programmability of MEMS and chip-configuration. It aims to finally deliver a Photonic Transfer Learning engine that can support one order of magnitude improvements along all critical performance metrics of AI chipsets: energy efficiency of <19fJ/MAC and on-chip computational power that can scale to ~4.1PMAC/s. HAETAE aims to highlight the versatility and flexibility of its twofold photonic transfer learning accelerator by targeting three discrete application sectors in communications and computing: i) real-time threat detection processor for DC cybersecurity applications, ii) DL and AI computing as a LLM transformer, and iii) an optics-enabled AI enhanced DSP processor for IM/DD transceivers.

The HAETAE website contains the project identity (e.g. logo, media-kit) developed as part of the WP5 and has been designed in order to provide both the general public and the project partners with useful information concerning HAETAE.

The idea behind the site is twofold. Firstly, to provide a point of reference for people interested in learning more about the project (with information such as HAETAE objectives, the expected benefits, participating partners, etc.) and secondly as a place from which to distribute documents and information addressed strictly to the partners. For this to happen the overall HAETAE site is divided to two sectors, one for the public and another for authorized-only users.

In the picture below, we present the main menu of the site and an indicative sub-menu :



Concept

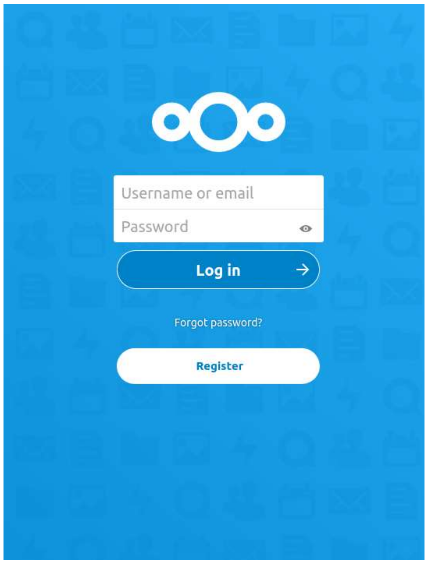
HAETAE will a) deploy a multi-material PIC platform that combines the best-in-class computational technologies, using Si3N4 as its low-loss interconnection layer, Si/SiGe as its high-speed computational layer, InP actives for on-chip gain and nonlinearities, and non-volatile Micro-Electro-Mechanical Systems (MEMS) for zero-energy static weighting. This unique synergy will be facilitated through a dual-folded heterogenous integration approach, that synergizes micro–Transfer Printing (uTP) of InP semiconductor optical amplifiers (SOAs) on a 3D Si/ Si3N4 platform and MEMS-based cross-platform compatibility through multi-chiplet bonding co-integration. b) align this along the lowest-loss 3D Si/Si3N4 WDM-equipped coherent optical Crossbar (Xbar) architecture further enhancing the existing Xbar for highly scalable MVM chiplets, c) develop InP all-optical reconfigurable Non-Linear Activation Function (NLAF) circuits for connecting cascaded photonic neural layers without requiring energy-hungry digital interfaces or O/E/O inter-layer conversions while also providing on-chip optical-gain d) align its development roadmap along the primitives of the Transfer Learning (TL) paradigm that is widely used for optimizing and adapting large AI models like ChatGPT and Meta's MultiRay to various tasks. It typically involves using a static pre-trained backbone neural network (NN) followed by shallow retrainable NN layers, e.g., Large Language Models (LLM)-oriented adapters. This forms an ideal DL framework for converging AI with energy-efficient photonic neuromorphic hardware, mainly utilizing low-energy statically-weighted photonic neurons in its pre-trained backbone segment yet supporting a variety of applications through a limited number of photonic Tiled Matrix Multiplication (TMM) engines in its retrainable layer part. HAETAE demonstrators will exhibit significant improvements across all critical metrics of state-of-the-art AI chipsets: energy efficiency, requiring only 18.5 fJ/MAC, ii) area efficiency, offering 2.45 TMAC/s/mm2, and iii) computational power, unleashing an impressive ~4.1 PMAC/s! HAETAE will highlight the wide application perspectives of its photonic TL (PTL) setups by validating them in three challenging use-cases in the areas of (i) DL and AI computing as a LLM transformer, (ii) Data Center (DC) cybersecurity threat detection applications, and (iii) Photonic AI-assisted DSP for fiber communications.

The structure of the web site is quite standard and at the onset of its operation contains the following basic sections

- Home page, which is the main page of the website and shows its structure, the summary of the project, and in the top left corner provides links to related social media accounts.
- Consortium, which lists the HAETAE Consortium members and provides more details about their expertise and contribution to the project.
- About, which gives a general overview of the HAETAE project, including Grant details, and has 4 submenus:
    - Motivation, detailing the challenges that HAETAE is addressing;
    - Concept, providing a general overview of the project and its targets;
    - Objectives, which provides a main description of each of the project's objectives (*to be updated*);
    - Work Packages, which provides a brief description of each of the project's work package (*to be updated*).
- Dissemination, which includes three submenus:

  - Communication kit, currently composed of four tabs:
    - Documents, which includes the links to factsheet, project presentation and brochure, and will host any other relevant document developed during project's duration;
    - Media, which will host video presentation, as well as other relevant media files, including presentations, interviews, news articles, etc.
    - Gallery, which will host photos from meetings, other organized events, conferences, exhibitions, etc.
    - Logo, which offers selection of HAETAE logos, as well as the QR codes for accessing HAETAE social media accounts, all of which can be downloaded in vector and image form.
  - Publications, which contains all the journal and conferences publications carried out within HAETAE.
  - Public reports, where all non-confidential reports/newsletters regarding the milestones that are achieved within HAETAE project will be made available.
- Events, which will provide information to users regarding events that will take place within the project.
- News, which will host all the non-confidential news related to the HAETAE project, in an easy to comprehend form, as they will be targeted primarily at general public.
- Contact, which holds all the relevant information for contacting the project coordinator, including electronic and physical addresses and phone numbers.

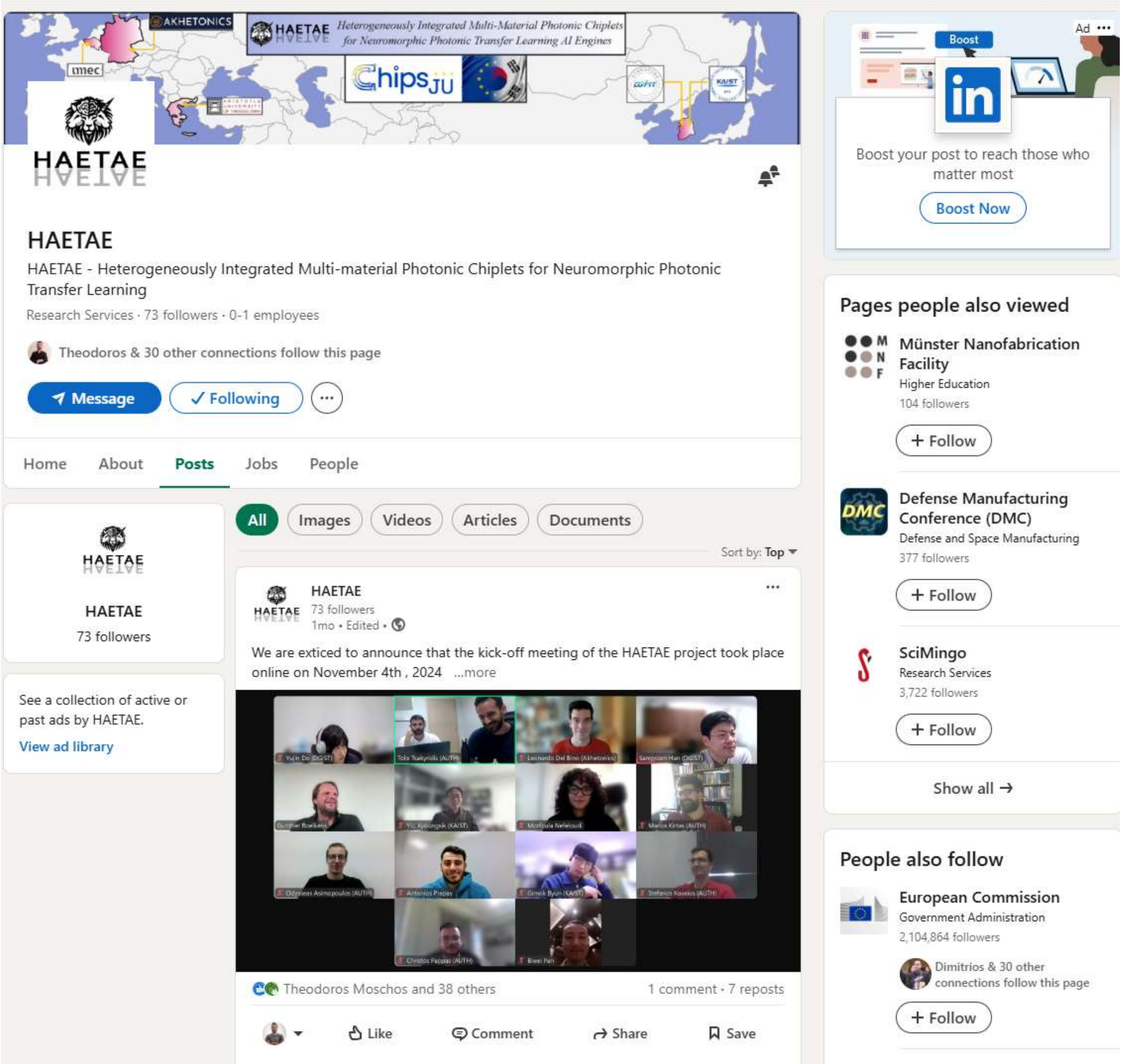
The following picture shows the access to the Private area of HAETAE website



4.2 HAETAE Social Media

Two social media accounts have been already established in order to further promote the HAETAE project. These two accounts will be maintained by making information related to HAETAE available to the wide audience for dissemination of the project. Considered as powerful interactive media tool, they will serve as a platform to disseminate, communicate, discuss, comment, consult and suggest research and policy topics with different target groups at different levels.

4.2.1 LinkedIn



HAETAE

HAETAE - Heterogeneously Integrated Multi-material Photonic Chiplets for Neuromorphic Photonic Transfer Learning

Research Services · 73 followers · 0-1 employees

Theodoros & 30 other connections follow this page

HAETAE
73 followers

See a collection of active or past ads by HAETAE.
View ad library

HAETAE
73 followers
1mo • Edited •

We are exticed to announce that the kick-off meeting of the HAETAE project took place online on November 4th , 2024 ...more

Theodoros Moschos and 38 others · 1 comment · 7 reposts

Boost your post to reach those who matter most

Pages people also viewed

Münster Nanofabrication Facility
Higher Education
104 followers

Defense Manufacturing Conference (DMC)
Defense and Space Manufacturing
377 followers

SciMingo
Research Services
3,722 followers

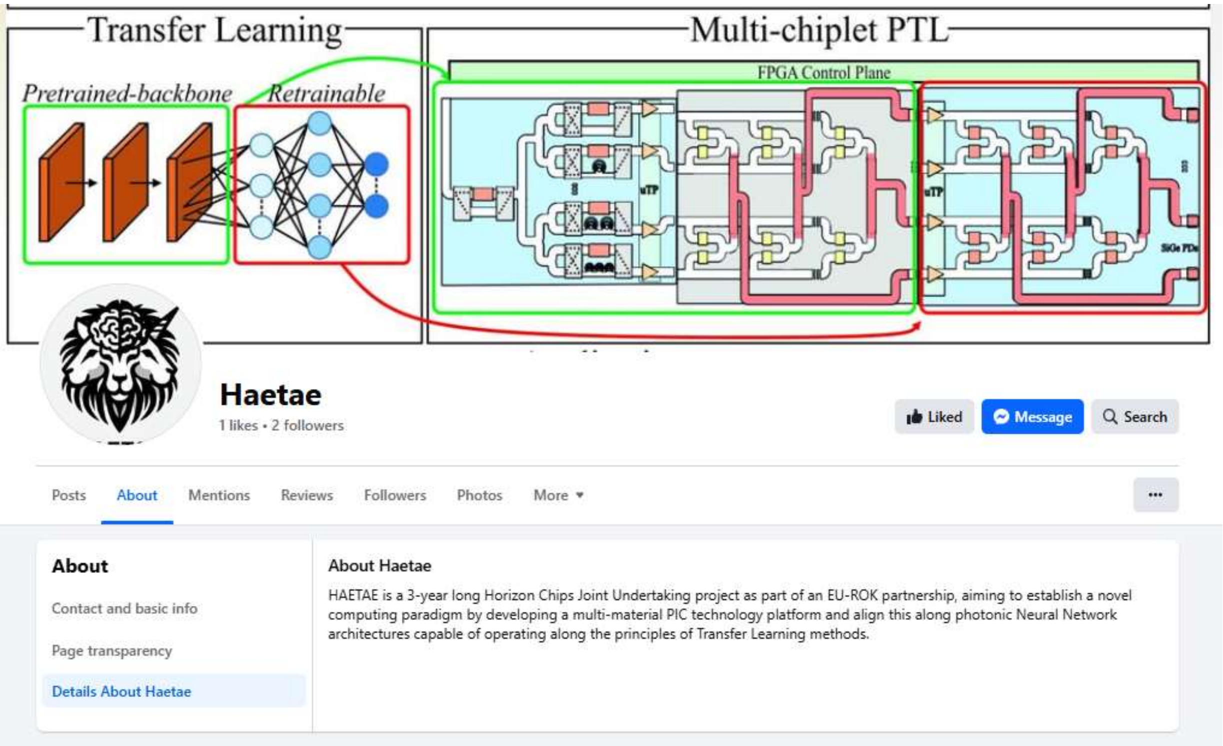
People also follow

European Commission
Government Administration
2,104,864 followers
Dimitrios & 30 other connections follow this page

The group has **73** followers as of 19/12/2024, which is **48%** from the KPI goal set out in the Grant Agreement, Annex 1, Part B.

4.2.2 Facebook

The group has **2** followers as of 19/12/2024



About Haetae

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