EIC PATHFINDER

EIC Pathfinder (Research and Innovation Action)

Bio-Photonic Reservoir Computing in Engineered Living Tissue

BIOPHOTON

Field	Value
Call Identifier	HORIZON-EIC-2026-PATHFINDEROPEN-01
Type of Action	EIC Pathfinder Open
Duration	48 months
TRL Range	TRL 1 to TRL 3
Total Budget	EUR 3,000,000
EU Contribution	EUR 3,000,000

Abstract

BIOPHOTON pursues a radical long-term vision: optogenetically engineered living tissue deployed as the physical substrate of a reservoir computing system, interrogated and driven entirely through photonic means. For the first time, we will demonstrate that a bio-hybrid system comprising hiPSC-derived neural tissue expressing spectrally orthogonal channelrhodopsins can perform reservoir computing benchmark tasks - including spoken-digit recognition and non-linear time-series prediction - with classification accuracy exceeding 90%, advancing the field from TRL 1 to TRL 3. The science-towards-technology breakthrough lies in the deliberate coupling of synthetic biology and reservoir computing theory through a custom photonic read-write interface, creating a computational substrate with no silicon analogue: one that self-organises, adapts metabolically, and exploits the intrinsic complexity of living neural networks as a computational resource. Beyond the immediate state of the art in both neuromorphic hardware and unconventional computing, success would lay the scientific foundations for a new class of ultra-low-power bio-hybrid computing devices, directly addressing the energy crisis of digital infrastructure and simultaneously opening transformative new paradigms in neurological disease modelling and drug screening. The consortium unites four highly complementary institutions across Spain, Switzerland, Germany, and the Netherlands - IBEC (coordinator), EPFL, the Max Planck Institute for Intelligent Systems, and a photonics SME - combining hiPSC tissue engineering, integrated photonics, reservoir computing theory, and industrial technology translation in a genuinely interdisciplinary structure. Over 48 months and with a total budget of EUR 3,000,000, BIOPHOTON will deliver: stable, reproducible optogenetic tissue platforms; a validated high-resolution photonic read-write interface; proof-of-principle reservoir computing demonstrations on established benchmarks; a formally validated biophysical computational theory; and a publicly available roadmap for the transition toward commercial bio-hybrid devices, including regulatory pathway analysis and a societal impact assessment.

Keywords: reservoir computing, optogenetics, bio-hybrid computing, neuromorphic photonics, synthetic biology, tissue engineering, hiPSC, unconventional computing, deep tech, EIC Pathfinder

SECTION 1 - EXCELLENCE

1.1 Objectives and Ambition

BIOPHOTON pursues a radical long-term vision: a living, self-organising computing substrate in which optogenetically engineered tissue performs neuromorphic information processing through light-mediated dynamics. If realised, this vision would establish an entirely new class of bio-hybrid computer - one that operates at the thermodynamic efficiency of biological neural networks, consumes orders of magnitude less energy than silicon architectures, and exploits the intrinsic complexity of living matter as a computational resource. This is not an incremental improvement on existing neuromorphic hardware; it is a foundational departure from the very substrate of computation, replacing lithographically defined circuits with genetically encoded, self-assembling biological networks.

The concrete scientific and technological objectives of BIOPHOTON are: (O1) Engineer a three-dimensional optogenetic tissue platform with defined network topology and stable, reproducible light-responsive dynamics over timescales relevant to computation (target: >72 h of continuous stable activity; months 1–24); (O2) Design and validate a photonic read-write interface capable of sub-millisecond optical stimulation and spatially resolved fluorescence readout of tissue state at single-cell resolution (targets: <1 ms stimulation latency; >500 independently addressable nodes; months 6–30); (O3) Demonstrate reservoir computing functionality - including spoken-digit recognition and non-linear time-series prediction - using the bio-photonic system as the physical reservoir, achieving classification accuracy exceeding 90% on established benchmark tasks (months 24–42); (O4) Develop and experimentally validate a computational model of tissue reservoir dynamics that predicts information-processing capacity as a function of network connectivity and optogenetic gain (months 12–36); (O5) Produce a technology and ethics roadmap for the transition toward TRL 4–6 bio-hybrid computing devices, encompassing regulatory, biosafety, and broader societal considerations (months 36–48). These objectives are ambitious yet scientifically plausible given the complementary expertise assembled in the consortium. They are explicitly designed to advance the field from TRL 1 (theoretical foundations) to TRL 3 (experimental proof of principle in the laboratory), in full alignment with the EIC Pathfinder Open scope.

1.2 Relation to the Work Programme

The state of the art in unconventional computing encompasses physical reservoir computing implementations in soft matter, memristive networks, and photonic integrated circuits. While silicon-photonic reservoirs have demonstrated high-speed processing and spintronic systems have shown rich nonlinear dynamics, no existing substrate combines self-organisation, metabolic adaptability, and the architectural richness of biological neural networks with optical addressability. In parallel, synthetic biology has produced optogenetic tools of extraordinary precision - channelrhodopsins, calcium indicators, and engineered gene-regulatory elements - yet these have never been deployed as the physical substrate of a computing paradigm. Neuromorphic computing remains anchored to CMOS hardware, despite biological tissue already performing exactly the kind of high-dimensional, fading-memory, nonlinear transformations that reservoir computing theory requires.

BIOPHOTON's science-towards-technology breakthrough lies precisely in coupling these two frontiers: the deliberate engineering of living tissue as a reservoir computing medium, interrogated and driven exclusively through photonic means. This constitutes a clear advance beyond the state of the art, for three compounding reasons that simultaneously define the project's high-risk character. First, it is unknown whether engineered optogenetic tissue can maintain the degree of network-state diversity required for high-rank reservoir matrices over experimentally useful timescales, as biological variability may preclude the reproducibility demanded by a computing application. Second, the optical interface must simultaneously stimulate and read out a three-dimensional scattering

medium without cross-talk - a problem that remains unsolved at the required spatial and temporal scale. Third, reservoir computing theory has not been extended to substrates exhibiting metabolically driven plasticity and stochastic cell turnover, meaning the theoretical framework itself must be co-developed as an integral part of the research. The high-gain potential is proportional to these risks: success would provide the scientific foundation for a computing paradigm with no silicon analogue, directly advancing the European Green Deal's goal of sustainable digital infrastructure and positioning Europe at the frontier of deep-tech convergence between life sciences and information technology. The project therefore aligns strongly with the EIC Pathfinder Open call's mandate to support visionary, high-risk research that opens fundamentally new technological directions.

1.3 Concept and Methodology

The conceptual core of BIOPHOTON rests on three interlocking pillars. First, living tissue engineered from human induced pluripotent stem cell (hiPSC)-derived neurons and astrocytes - transfected with spectrally orthogonal channelrhodopsins and genetically encoded calcium indicators (GECIs) - will serve as the physical reservoir. This tissue will be grown in microfluidic scaffolds designed at IBEC to enforce controllable connectivity graphs, bridging the gap between biological self-organisation and engineering-grade reproducibility. Second, a custom photonic interface developed at EPFL will provide wavelength-multiplexed optical stimulation (input encoding) and wide-field two-photon fluorescence readout (state observation) through a single optical path, eliminating electrical artefacts and enabling operation in a scattering three-dimensional medium. Third, computational models developed at the Max Planck Institute for Intelligent Systems will formalise the reservoir's kernel quality and generalisation capacity as functions of measurable biophysical parameters, creating a tightly coupled feedback loop between theory and experiment that guides tissue and interface design throughout the project.

The high-risk nature of the research is actively managed through a staged go/no-go strategy embedded in the work plan. At month 18, an internal scientific review panel will assess whether tissue stability and optical readout fidelity meet the minimum quantitative thresholds defined in O1 and O2. Should these thresholds not be met, contingency protocols specify the immediate adoption of alternative cell lines (cortical organoids from validated commercial sources) and alternative readout modalities (structured illumination microscopy with time-gated detection). At month 30, computational benchmarking against a silicon photonic reservoir baseline will validate whether the biological system provides competitive or superior information-processing capacity; the predictive model from O4 will be used to guide targeted re-engineering of the tissue if performance is insufficient. These decision points are defined with explicit, quantitative criteria to ensure that scientific and managerial responses are evidence-based and timely.

Open Science practices are observed throughout the project. All experimental protocols are deposited in protocols.io upon validation; raw datasets are archived in a FAIR-compliant repository under CC-BY licences; and all software tools are released in public version-controlled repositories under the Apache 2.0 licence. The gender dimension is integrated into the research design itself: all network dynamics analyses systematically assess whether results obtained with cell lines derived from donors of different biological sexes show statistically significant differences, and any such differences are reported and interpreted in publications. This approach ensures that biological sex is treated as a scientific variable rather than a confound.

1.4 Interdisciplinary Considerations

BIOPHOTON is irreducibly interdisciplinary. No single discipline possesses the conceptual vocabulary or technical toolkit required to address the project's core challenge in its entirety. Synthetic biology provides the genetic engineering frameworks for optogenetic tissue construction; neuroscience provides the understanding of network dynamics and synaptic plasticity; photonics engineering provides the interface hardware; and computational neuroscience together with reservoir computing

theory provide the mathematical framework for interpreting and optimising the biological system's information-processing capacity. The project's central hypothesis - that a living tissue can function as a high-performance computational reservoir when appropriately engineered and optically interfaced - can only be tested, and its implications fully understood, by integrating all four disciplines simultaneously.

The consortium is deliberately structured to instantiate this interdisciplinarity at the level of individual work packages, rather than confining each discipline to an isolated task. Cross-disciplinary dependencies are explicit in the work plan: the computational models of WP4 directly constrain tissue design decisions in WP1 and optical specifications in WP2, while experimental data from WP1 and WP3 continuously calibrate and validate the theoretical framework. Joint experimental campaigns, shared FAIR data standards, and formal co-supervision of early-career researchers across partner institutions are embedded in the project governance, ensuring genuine disciplinary integration rather than parallel monodisciplinary execution. IBEC (Spain) leads tissue engineering and project coordination, contributing expertise in hiPSC differentiation, microfluidic scaffold fabrication, and three-dimensional bioprinting. EPFL (Switzerland) leads photonic interface design, contributing internationally recognised competence in integrated photonics and two-photon microscopy. The Max Planck Institute for Intelligent Systems (Germany) leads computational modelling and reservoir computing theory, providing the mathematical backbone that unifies the experimental activities. The photonics SME partner (Netherlands) leads technology translation and industry-facing dissemination, contributing expertise in photonic component miniaturisation and industrial prototyping, and ensuring that the research trajectory is oriented toward commercially realisable devices from project inception.

SECTION 2 - IMPACT

2.1 Pathways Towards Impact

In the long term, a successful BIOPHOTON project would lay the scientific foundations for a new category of computing device: a bio-hybrid processor in which living tissue, maintained in a microfluidic bioreactor and addressed by photonic hardware, performs cognitive-scale inference tasks at metabolic power levels fundamentally inaccessible to silicon. The transformative potential spans multiple high-value domains. In artificial intelligence hardware, bio-photonic reservoirs could underpin edge-AI devices performing pattern recognition at nanowatt power budgets, directly addressing the accelerating energy crisis in data-centre infrastructure. In the life sciences, the engineered tissue platform simultaneously constitutes a high-fidelity model system for studying pathological changes in network dynamics associated with epilepsy and neurodegeneration, creating immediate scientific value independent of the computing application. In environmental monitoring and remote or space-based sensing, ultra-low-power bio-hybrid processors could enable in-situ data analysis without the need for transmission to ground stations.

The innovation pathway beyond BIOPHOTON is clearly mapped through EIC Transition and EIC Accelerator instruments. The roadmap deliverable (O5) will identify the most commercially mature application vertical - anticipated to be neurological disease modelling and drug screening, given the considerably shorter regulatory pathway relative to implantable computing devices - and define the specific TRL 4–6 milestones required to reach market entry. The photonics SME partner is strategically positioned to lead this transition, converting the custom optical interface into a manufacturable, commercially deployable product. European added value is substantial and multi-layered: the project creates a unique transnational research infrastructure, trains a cohort of at least six early-career researchers at the intersection of synthetic biology and photonics, and strengthens EU strategic autonomy in deep-tech computing at a time when global competition in neuromorphic hardware is intensifying. The project is fully aligned with the European Green Deal's digital strategy, the EU's ambitions for energy-efficient computing infrastructure, and the European Research Area's priority on convergent and enabling technologies.

2.2 Dissemination, Exploitation and Communication

BIOPHOTON will pursue an integrated dissemination, exploitation, and communication strategy, managed by the SME partner in close coordination with the project coordinator, ensuring that scientific excellence and societal relevance are communicated effectively to all relevant audiences throughout the project lifetime.

Scientific dissemination targets a minimum of 12 peer-reviewed publications in high-impact, open-access journals (including venues such as Nature Electronics, Advanced Materials, and PLOS Computational Biology), with all manuscripts deposited in EuropePMC and Zenodo no later than the date of submission to the journal, in compliance with the EIC's open-access mandate. Three international workshops will be co-organised in collaboration with relevant IEEE and EMBO communities at months 18, 36, and 46, providing structured opportunities for external scientific feedback at critical project junctures. All software tools, tissue protocols, and datasets will be released under open licences (CC-BY 4.0 for data and documents; Apache 2.0 for software) through a dedicated BIOPHOTON open-science portal, maintained for a minimum of five years beyond the project end date.

For intellectual property protection, a joint IP agreement signed at project inception will govern ownership and licensing of the photonic interface architecture and the engineered cell-line variants, ensuring that IP rights are clarified before any public disclosure. Patent applications will be filed before publication where appropriate; a dedicated IP committee - comprising technology transfer

offices from IBEC and EPFL, with the SME partner holding a right of first refusal for exclusive licensing in defined application fields - will conduct a formal exploitability assessment of all results at month 30. Public communication will address three distinct audiences in a differentiated manner: the scientific community (workshops, peer-reviewed publications, and preprints); technology stakeholders and investors (EIC Community events, Photonics21 forums, and synthetic biology industry conferences); and the general public (a multilingual project website, accessible policy briefs, and participation in European Researchers' Night events). The ethical, legal, and societal implications of living computing substrates will be addressed in a dedicated white paper at month 40, co-authored with external bioethics experts, ensuring that the project's societal licence to operate is proactively secured and publicly communicated.

2.3 Summary of Impact Indicators

Indicator	Target	Measurement
Peer-reviewed open-access publications	12 publications by month 48	Count of accepted/published manuscripts deposited in open repositories
Patent applications filed	At least 2 patent applications by month 42	Filing records maintained by IP committee
Reservoir computing task accuracy	>90% classification accuracy on NIST spoken-digit benchmark	Blind test set evaluation documented in scientific publication
Tissue platform stability	Stable optogenetic response over >72 consecutive hours	Fluorescence time-series coefficient of variation <15% across 3 independent experiments
Early-career researchers trained	At least 6 PhD students or postdocs with cross-disciplinary co-supervision	HR records and co-supervision agreements
Stakeholder engagement events	3 international workshops and 2 industry forum presentations	Attendance records and post-event reports

SECTION 3 - QUALITY AND EFFICIENCY OF THE IMPLEMENTATION

3.1 Work Plan and Work Packages

WP	Title	Lead	PM	Duration
WP1	Optogenetic Tissue Platform Engineering	IBEC	36	M1-M30
WP2	Photonic Read-Write Interface	EPFL	34	M3-M36
WP3	Reservoir Computing Demonstration	IBEC	28	M18-M44
WP4	Computational Modelling and Theory	Max Planck Institute for Intelligent Systems	30	M1-M42
WP5	Roadmap, Dissemination, and Project Management	IBEC	22	M1-M48

WP1: Optogenetic Tissue Platform Engineering

Lead: IBEC | Person-months: 36 | Duration: M1 - M30

WP1 develops the living tissue substrate that constitutes the bio-photonic reservoir. Activities encompass the differentiation of hiPSC lines into mixed neuron-astrocyte cultures, transfection with spectrally orthogonal channelrhodopsins (ChR2 and ChrimsonR) and genetically encoded calcium indicators (GCaMP7 and jRCaMP1b), three-dimensional scaffold fabrication by two-photon polymerisation, and iterative optimisation of network connectivity topology. Stability assays and reproducibility benchmarking are conducted throughout, culminating in a validated tissue platform that meets the quantitative criteria required to proceed to WP3. All protocols are released publicly on protocols.io upon validation, contributing to Open Science and enabling independent replication by the broader community.

T1.1: hiPSC differentiation and optogenetic transfection - Establish and validate reproducible protocols for differentiating hiPSC lines - sourced from donors of both biological sexes to enable the gender-dimension analysis required by the research design - into mixed neuron-astrocyte cultures stably expressing dual-wavelength optogenetic constructs. Transfection efficiency, construct expression stability, and spectral orthogonality are characterised across multiple independent cell lines.

T1.2: 3D scaffold design and microfluidic integration - Design, fabricate, and test microfluidic scaffolds that enforce defined connectivity graphs - informed by the theoretical optimal topologies identified in WP4 - while maintaining long-term tissue viability. Scaffold geometry is iteratively refined based on live-imaging feedback, and perfusion parameters are optimised to ensure nutrient delivery and waste removal over extended culture periods.

T1.3: Stability and reproducibility characterisation - Quantify network activity statistics - including firing rate distributions, pairwise correlations, and fluorescence signal coefficient of variation - across a minimum of five independent biological replicates and over culture periods extending to at least 72 h. Results are used to define and validate the quantitative go/no-go criteria for WP3 and to calibrate the computational model in WP4.

WP2: Photonic Read-Write Interface

Lead: EPFL | Person-months: 34 | Duration: M3 - M36

WP2 designs, constructs, and validates a photonic instrument for the simultaneous optical stimulation and spatially resolved fluorescence readout of the tissue reservoir. The system employs wavelength-multiplexed structured illumination for input encoding and wide-field two-photon imaging for state readout, engineered through extensive Monte Carlo light-propagation modelling to minimise cross-talk in the scattering three-dimensional tissue medium. The SME partner co-develops a ruggedised, miniaturised prototype of the interface, ensuring that the instrument architecture is compatible with eventual commercial manufacturing. The photonic interface design specifications are released as a technical deliverable, with the level of confidentiality reviewed by the IP committee prior to publication.

T2.1: Optical system architecture and simulation - Develop detailed Monte Carlo models of light propagation and stimulation-readout cross-talk in tissue-mimicking scattering phantoms parameterised to match the optical properties of the hiPSC-derived tissue. Use simulation results to define optical specifications - including wavelength

bands, numerical aperture, illumination geometry, and detection gating - for both the stimulation and readout channels.
T2.2: Instrument construction and calibration - Construct the integrated photonic interface according to the specifications derived in T2.1. Calibrate spatial addressability (target: >500 independently addressable nodes), temporal resolution (target: <1 ms stimulation latency), and cross-talk rejection ratio against tissue-phantom models. Validate performance against the criteria defined in O2 prior to integration with WP1 tissue samples.
T2.3: Ruggedised prototype development - The SME partner leads co-development of a compact, manufacturable version of the optical interface suitable for deployment in standard cell-culture laboratory environments. The ruggedised prototype incorporates commercially available photonic components selected for scalability and cost-effectiveness, and serves as the basis for the post-project commercialisation pathway defined in the WP5 roadmap.

WP3: Reservoir Computing Demonstration

Lead: IBEC | Person-months: 28 | Duration: M18 - M44

WP3 integrates the validated tissue platform from WP1 and the photonic interface from WP2 to deliver experimental proof-of-principle demonstrations of reservoir computing functionality. Benchmark tasks - non-linear time-series prediction (NARMA-10) and spoken-digit recognition (NIST TI-46) - are implemented by encoding task inputs as spatiotemporal optical stimulation patterns and training a linear ridge-regression readout layer on fluorescence-derived tissue state vectors. The biological reservoir's performance is rigorously compared against a silicon photonic reservoir baseline evaluated under identical readout conditions, providing a clear, quantitative measure of the bio-photonic system's competitive information-processing capacity. WP3 begins after the go/no-go review at month 18 confirms that WP1 and WP2 outputs meet the minimum thresholds defined in O1 and O2.
T3.1: Input encoding and readout layer design - Define and optimise optical encoding schemes that map benchmark task inputs onto spatiotemporal stimulation patterns compatible with the photonic interface's addressable-node architecture. Train and cross-validate ridge-regression readout layers on tissue state observations, with hyperparameter selection guided by the capacity metrics predicted by the WP4 computational model.
T3.2: Benchmark task execution and performance evaluation - Execute systematic reservoir computing experiments across a minimum of three independent tissue preparations per benchmark task. Quantify classification accuracy, memory capacity, and kernel quality metrics for each preparation; assess cross-preparation variability; and determine whether the >90% accuracy target of O3 is achieved. All raw data are archived in the FAIR-compliant open repository.
T3.3: Comparative benchmarking - Evaluate a silicon photonic reservoir baseline on the same benchmark tasks using identical readout procedures and readout training protocols to enable a fair, controlled comparison. Document performance differences quantitatively and analyse them in the context of the WP4 theoretical framework, providing a scientifically rigorous assessment of the bio-photonic system's advantages and current limitations.

WP4: Computational Modelling and Theory

Lead: Max Planck Institute for Intelligent Systems | Person-months: 30 | Duration: M1 - M42

WP4 develops and experimentally validates a biophysically grounded computational model of the tissue reservoir that predicts information-processing capacity as a function of network connectivity, optogenetic gain, and metabolic state. The model serves a dual role: it provides actionable theoretical guidance for tissue and interface design decisions in WP1 and WP2 throughout the project, and it constitutes a generalisable predictive framework for future engineering of bio-hybrid computing devices beyond the project's scope. Running from month 1 to month 42, WP4 is the project's longitudinal theoretical backbone, ensuring that experimental activities are continuously informed by quantitative predictions. All model code is released as open-source software.
T4.1: Mean-field model of optogenetic network dynamics - Derive and parameterise a mean-field model capturing the collective dynamics of the optogenetic tissue network, including channelrhodopsin photocycle kinetics, synaptic transmission, and astrocytic modulation. The model is calibrated against time-series data provided by WP1 and refined iteratively as experimental data accumulate, with all parameter values and fitting procedures documented in a reproducible computational notebook.
T4.2: Reservoir computing capacity analysis - Compute kernel quality, generalisation rank, and fading memory capacity metrics as functions of the model's biophysical parameters. Construct phase diagrams identifying the operating regimes - in terms of connectivity density, optogenetic gain, and stimulation frequency - that maximise reservoir computing performance. These results are directly used to guide tissue engineering and protocol choices in WP1 and WP3.

T4.3: Metabolic plasticity integration - Extend the base model to incorporate metabolically driven synaptic plasticity and stochastic cell turnover - biological phenomena absent from classical reservoir computing theory - and derive their predicted effects on long-term reservoir stability and computational capacity. Generate falsifiable experimental predictions to be tested in WP3, thereby closing the theory-experiment loop that is central to the project's methodology.

WP5: Roadmap, Dissemination, and Project Management

Lead: IBEC | Person-months: 22 | Duration: M1 - M48

WP5 provides overarching project coordination and management, ensures continuous ethics compliance and Open Science practice, drives dissemination and communication to all target audiences, and produces the technology and ethics roadmap that defines BIOPHOTON's legacy beyond the project's operational lifetime. The SME partner leads dissemination activities targeting industry and investor audiences, leveraging its established networks in the European photonics and deep-tech ecosystems. WP5 also oversees IP management, monitors the implementation of gender-inclusive research practices across all work packages, and coordinates the production of the final public white paper on the societal implications of living computing substrates.

T5.1: Project coordination and risk monitoring - Maintain project governance structures - including the Steering Committee, Scientific Advisory Board, and Ethics Advisory Board - oversee the go/no-go decision points at months 18 and 30, manage consortium communication, and ensure timely and complete reporting to the EIC. Monitor risks against the risk register and activate contingency protocols when trigger conditions are met.

T5.2: Dissemination, communication, and IP management - Execute the full dissemination and communication plan, including the organisation of three international workshops, management of the open-science portal, coordination of patent filings through the IP committee, and delivery of public communication materials for general, scientific, and industry audiences. Monitor open-access compliance for all publications and ensure that all data and software releases conform to FAIR principles and open-licence requirements.

T5.3: Technology and ethics roadmap - Produce the BIOPHOTON roadmap document, integrating inputs from all partners and from external stakeholders engaged through the workshops. The roadmap defines TRL 4–6 transition milestones for the most viable application vertical, analyses the regulatory pathway for bio-hybrid computing devices, and provides a societal impact assessment co-authored with external bioethics experts. The roadmap is published as an open-access document and presented at a dedicated stakeholder event at month 48.

3.2 Consortium Composition

Organisation	Country	Type	Role	Description
Institute for Bioengineering of Catalonia (IBEC)	Spain	Research Organisation	Coordinator	Project coordinator; leads WP1 (tissue platform) and WP3 (computing demonstration); responsible for overall scientific and administrative management
Ecole Polytechnique Federale de Lausanne (EPFL)	Switzerland	University	Partner	Leads WP2 (photonic interface); contributes to WP3 and WP4 modelling validation; co-supervision of PhD researchers
Max Planck Institute for Intelligent Systems	Germany	Research Organisation	Partner	Leads WP4 (computational modelling and theory); provides theoretical framework guiding WP1 and WP2 design; leads benchmark analysis in WP3

Photonics SME (Netherlands)	Netherlands	SME	Partner	Leads ruggedised prototype development in WP2 (T2.3); leads industry dissemination and IP commercialisation in WP5; contributes technology translation expertise

The BIOPHOTON consortium combines four complementary and non-overlapping competences, each individually necessary and collectively sufficient for achieving the project's breakthrough objectives. IBEC contributes EU-leading expertise in hiPSC-based tissue engineering, microfluidic scaffold fabrication, and three-dimensional bioprinting, making it the natural leader for the tissue platform and computing demonstration work packages. EPFL contributes world-class capabilities in integrated photonics instrumentation and two-photon microscopy, providing the optical interface hardware that is the essential coupling element between the biological substrate and the information-processing domain. The Max Planck Institute for Intelligent Systems provides unparalleled depth in reservoir computing theory and computational neuroscience, supplying the mathematical framework that unifies and guides the experimental activities. The Dutch SME partner grounds the consortium in industrial photonic manufacturing realities, ensuring that the research pathway is oriented toward devices that are realisable and commercially deployable from the outset, and providing the industry-facing networks needed for effective exploitation and dissemination.

The four institutions span four different European Member States and Associated Countries - Spain, Switzerland, Germany, and the Netherlands - maximising geographic diversity and engaging a broad range of national research ecosystems and innovation networks in the project's activities. This geographic spread also reduces single-point-of-failure risks to project continuity. Gender balance among work package leaders is actively sought as part of the project's commitment to inclusive research practice, with a target of at least two of the five WP leadership positions held by female researchers. Early-career researchers are formally co-supervised across at least two partner institutions, ensuring that the next generation of scientists trained by BIOPHOTON is itself interdisciplinary and internationally networked.

3.3 Milestones

ID	Title	WP	Due	Verification
MS1	Stable optogenetic tissue prototype validated	WP1	M18	Fluorescence time-series data showing CV <15% across 3 independent preparations over 72 h, reviewed by internal scientific board
MS2	Photonic interface integrated and calibrated	WP2	M24	Characterisation report demonstrating <1 ms stimulation latency and >500 independently addressable nodes
MS3	First reservoir computing benchmark achieved	WP3	M36	Blind evaluation report demonstrating >85% accuracy on NARMA-10 task using biological reservoir
MS4	Computational model validated against experiment	WP4	M36	Peer-reviewed preprint or publication; model

				predictions within 10% of experimental capacity metrics
MS5	Full benchmark suite completed; >90% accuracy demonstrated	WP3	M42	Independent evaluation on NIST TI-46 spoken-digit task; results submitted for peer review
MS6	Technology and ethics roadmap published	WP5	M48	Public roadmap document and white paper deposited in open repository and presented at final stakeholder event

3.4 Deliverables

ID	Title	WP	Due	Type	Dissemination
D1.1	Optogenetic tissue fabrication protocol v1.0	WP1	M12	Open dataset / protocol	Public
D1.2	Tissue stability and reproducibility report	WP1	M24	Report	Public
D2.1	Photonic interface design specifications	WP2	M18	Technical report	Confidential
D2.2	Ruggedised prototype and characterisation report	WP2	M36	Prototype + report	Confidential
D3.1	Reservoir computing benchmark evaluation report	WP3	M42	Scientific report	Public
D4.1	Computational model software release v1.0	WP4	M36	Software (open source)	Public
D4.2	Theoretical capacity analysis publication	WP4	M40	Peer-reviewed journal article	Public
D5.1	Data Management Plan v1.0	WP5	M6	Plan	Public
D5.2	Dissemination and Exploitation Plan	WP5	M6	Plan	Public
D5.3	Technology and ethics roadmap	WP5	M48	Roadmap / white paper	Public

3.5 Resources and Budget Summary

Cost Category	Amount (EUR)
Personnel Costs	2100000
Subcontracting	60000
Travel & Subsistence	90000
Equipment	420000
Other Direct Costs	90000

Indirect Costs (25%)	240000
TOTAL	3000000

3.6 Risk Management

ID	Risk	Likelihood	Impact	Mitigation
R1	Engineered tissue fails to maintain stable, reproducible optogenetic dynamics over >72 h due to biological variability or cell death	High	High	Contingency cell lines (cortical organoids, commercial hiPSC lines) pre-validated in parallel; scaffold optimisation protocols prepared; go/no-go review at M18 triggers contingency switch if primary line underperforms
R2	Optical cross-talk between stimulation and readout channels degrades state observation fidelity in scattering tissue	Medium	High	Extensive Monte Carlo simulation of light propagation prior to instrument construction; structured illumination and time-gated detection as backup readout modality; contingency protocol uses structured illumination microscopy
R3	Bio-photonic reservoir fails to achieve >90% classification accuracy on benchmark tasks, indicating insufficient computational capacity	Medium	High	Computational model (WP4) used to identify parameter regimes with higher kernel quality; tissue re-engineering guided by model predictions; definition of scientifically valuable partial results (characterisation of capacity limits) as alternative success criterion
R4	Key personnel departure at a lead institution disrupts work package delivery	Low	Medium	Co-supervision structures and shared protocols ensure knowledge redundancy; consortium agreement includes personnel replacement clauses; early-career researcher pool provides pipeline of trained staff
R5	Regulatory or biosafety constraints	Low	Medium	Ethics advisory board engaged from M1;

	on use of hiPSC-derived tissue in computing applications delay or restrict dissemination			white paper on regulatory pathway (D5.3) initiated at M36; all biological work conducted under existing institutional biosafety approvals renewed annually