



# Investment Opportunities

at the Jožef Stefan Institute



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## // Introduction

This brochure is aiming at matching the potential investors with the spin-out teams of Jožef Stefan Institute.

The teams and their technologies presented in this brochure have different levels. However, their common features are:

- Committed team with business ambition.
- Innovative technology with strong scientific background.
- In search of the effective business model.

## // Jožef Stefan Institute

Jožef Stefan Institute is the leading Slovenian scientific research institute. The Jozef Stefan Institute has been traditionally dedicated to applicative technology research with strong ambition to compete in the global scientific community. In 2014 the Jozef Stefan Institute has been on the 37th position at the European Research Ranking - out of more than 1000 research institutions in Europe.




## // Center for Technology Transfer and Innovation

Center for Technology Transfer and Innovation at the Jožef Stefan Institute is complementing the excellent research results with intellectual property protection, licencing and spin-out development.



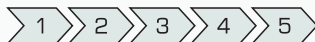
## // Technologies

The technology investment opportunities are divided into three categories:

- Electronics, IT and Telecommunications, 
- Nanotechnology and New Materials, 
- Physical Science. 

Investment readiness stage:

1. **Stand-up stage:** team in formulation, POC stage
2. **Stand-up stage:** Team formed, company not yet established, business plan in preparation phase, POC stage
3. **Stand-up stage:** Company established, establishing first contacts with VCs, not ready yet for investment, will be ready in 6, 12, 18 months
4. **Start-up stage:** Company established, looking for VC capital to market enter
5. **Scale-up stage:** Company established, increasing sale of products, looking for VC capital for market expansion



### **Investment (Financing) range**

- < 100k EUR
- 100k EUR - 250k EUR
- 250k EUR - 500k EUR
- 500k EUR - 1M EUR
- > 1M EUR

**In case you are interested in collaboration, write us at [tehnologije@ijs.si](mailto:tehnologije@ijs.si) and we will connect you with a suitable person at the relevant department.**

## // A powerful self-contained unit for autonomous predictive maintenance of a broad range of traditional industrial drives

Versatile, portable and low-cost system that can be used in most of the process and manufacturing industries.

### **Industrial field**

Industrial Systems and Control

### **Technology area**

Electronics, Computer Systems

### **Keywords**

Diagnostic and Prognostic Platform, Electronic Circuits, Components and Equipment

### **Stage of development**

TAL: 9

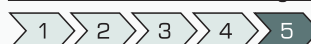
### **IPR status**

Secret know-how

### **Investment (Financing) range**

500k EUR - 1M EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

A powerful self-contained unit for autonomous predictive maintenance of a broad range of traditional industrial drives. Versatile, portable and low-cost system can be used in most of the process and manufacturing industries.

### **About the Department, Inventor**

Department of Systems and Control - E2.

The authors of the solution are founders of the spin-out company of Jožef Stefan Institute. The company is already installing first systems in the industrial facilities. The team is looking for strategic investment partner to support scale up of the technology in the global markets.

### **About the Technology**

The solution is a low-cost diagnostic and prognostic device capable of non-invasive automatic condition monitoring and predict the remaining useful life of a wide range of industrial drive components. The system is fully compliant with Industry 4.0 guidelines.

The solution combines innovative digital electronics with state of the art digital signal processor and innovative intelligent diagnostic algorithms, easily connectible to a variety of standard sensory equipment up to micro sensors and wireless sensors. The employed novel algorithms for condition monitoring and remaining useful life estimation are completely new to industry and provide a significant competitive advantage.

### Advantages

The main advantages of the system are:

- an order of magnitude lower investment costs,
- connectivity to a broad range of traditional sensors including wireless sensors and micro sensors,
- data driven prognosis as one the most important features,
- based on the latest signal processing algorithms that alleviate the non-stationarity in system dynamics,
- the system allows fusion of features from diverse measurement devices like vibrations sensors, online oil analyzers, noise sensors, thermal sensors and motor current and voltage, which greatly improve diagnostic precision,
- the system is fully compliant with guidelines from Industry 4.0.

### Goal

First year: to sign a deal with at least one OEMs - 500k EUR revenue; 5 closed deals with direct customers - 150k EUR revenue

Second year: turnover - 1 M EUR (OEMs and direct industrial customers).

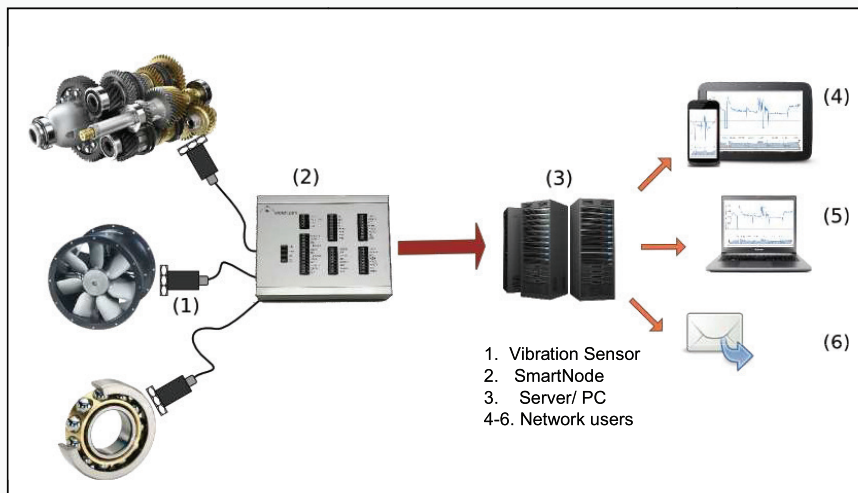
### Time to reach the goal

2 years

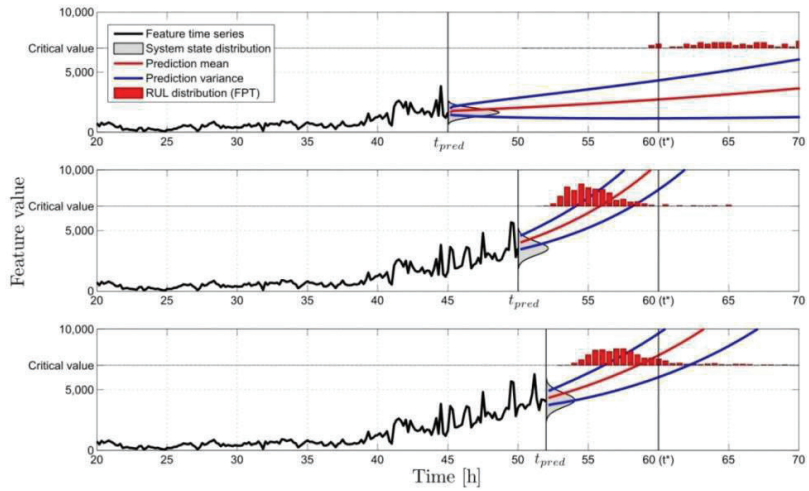
### Previewed amount of financing to reach the goal

In 1st year: 100k EUR investment;

in 2nd year 250k EUR investment needed (to scale up with OEMs).



On-line (24/7) vibration monitoring system.



Estimation of remaining useful life (RUL) of system.



## // Smart kitchen scale for people with special nutritional needs

### **Industrial field**

Smart Appliances, Applications for Health, Household Goods & Appliances, Care and Health Services, Nutrition and Health Market, Medical/health

### **Technology area**

Electronics, Embedded Computer Systems, Nutrition, Dietetics & Food Science

### **Keywords**

Wireless kitchen scale, Dietary solutions for food intolerances and allergies

### **Stage of development**

TRL: 7. A prototype in a form of a smartphone has been developed and it is being tested in hospitals and elderly homes.

### **IPR status**

Patent application, secret know-how

### **Investment (Financing) range**

100k EUR - 250k EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

A lite, pocket-sized, wireless kitchen scale that is used for assisting people with special nutritional needs by analyzing the content of any food portions.

The team is ready to fully support the licensing out the technology to the industrial scale producers or to collaborate with a strategic partner to develop a viable business model for scaling up the technology. Joint venture agreement or technical collaboration agreements are possible options.

### **About the Department, Inventor**

Department of Computer Systems - E7.

The inventors have been involved in several national projects on clinical nutrition, in which they have developed a web application for personalized diet menu planning based on evolutionary computation and food composition data from various national and European resources. The leading inventor is an associate member of the leading European network of excellence on food composition databank systems EuroFIR (European Food Information Resource Network). Their areas of research of the proposer cover real-time and embedded computer systems, real-time executives and operating systems, task scheduling for real-time systems, hardware/software co-design, multi-objective and multi-constraint evolutionary optimization and public and clinical nutrition.

### **About the Technology**

A lite, pocket-sized, wireless kitchen scale that is used for assisting people with special nutritional needs by analyzing the content of any food portions. The main advantage of the technology is that is smart and adaptable to personal needs. The

technology enables simple and economically-priced wireless connection of a kitchen scale with a mobile phone, a tablet or a personal computer. In this way, the scale can be a lite, pocket-sized device that is used in a connection with a mobile phone. A user can carry the scale out of home and use it as a reliable source of food composition data (FCD). The complementary mobile/web application provides complex FCD as well as tools for individual recipe calculation, barcode recognition etc. FCD are not limited to nutrients but may be also other constituents, like toxins, E-numbers etc. Such a portable kitchen scale is aimed for people with special nutritional needs, i.e., chronic patients, people with food allergies or intolerances, as well as athletes, and pregnant and lactating women. It can be used not only by an individual but also by hospitals and elderly homes, where patients need nutritional treatment.

The team is ready to fully support the licensing out the technology to the industrial scale producers or to collaborate with a strategic partner to develop a viable business model for scaling up the technology. Joint venture agreement or technical collaboration agreements are possible options.

### **Advantages**

Main advantages of the solution as opposed to existing nutrition scales on the market:

- Portable scale that enables weighing of realistic food portions.
- Provides up-to-date food composition data (FCD) and allows FCD for any dish with known recipe.
- User can select data he is interested in and adapt the system to his personal needs.
- FCD may include also other constituents (toxins, E-numbers etc.).
- The scale can have a form of a smart phone, a plate, or even a wristband.

### **Goal**

Establish strategic partnership with large manufacturers of food scales for mass production and marketing. Finalize the clinical testing with at least 3 hospitals in Europe. Goal is 10.000 scales sold by the end of year 3.

### **Time to reach the goal**

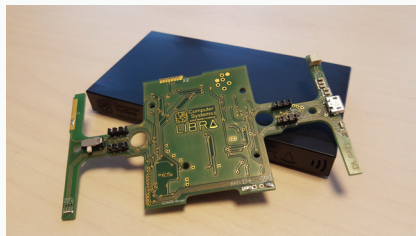
3 years

### **Previewed amount of financing to reach the goal**

200k EUR



Pocket-size wireless kitchen scale can be easily connected (via Bluetooth) with a smartphone to read, store and interpret the weigh of food.



Printed circuit board of Libra - developed at the Computer Systems Department, JSI.

## // Device for monitoring of a person's movement and her 3D position

### **Industrial field**

Leisure and Recreational Products and Services, Satellite Microwave Communications

### **Technology area**

Telecommunications, Networking: Satellite Technology / Systems / Positioning / Communication / GPS - Global Positioning System, IT and Telematics Applications, Information Processing, Information System, Workflow Management

### **Keywords**

Monitoring of a person's movement, 3D position, Satellite technology, GPS, Tennis tracker

### **Stage of development**

TRL: 6. Prototype available for demonstration.

### **IPR status**

Secret know-how

### **Investment (Financing) range**

100k EUR - 250k EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

Tennis tracker is a wearable sensor worn on the body during practice and competitive matches. It tracks detailed player movement, measures its effort in combination with numerous other tennis specific metrics. TT combines various sensor readings with advanced artificial intelligent methods to improve player's physical preparation, optimize training sessions and produce objective tennis relevant metrics to reach player's potential.

### **About the Department, Inventor**

The main inventor is a former tennis player, who also represented Slovenia in national team. Due to injuries, he focused his career on research in the field of artificial intelligence and finished his Ph.D. in 2015.

Helping him with the design of algorithms is the team of Ambient Intelligence Group of Department of Intelligent systems at the Jožef Stefan Institute. This team achieved much acclaimed results like the first place on the world tournament for activity recognition and finished many different projects containing sensor analysis.

On the tennis side, the closely involved in the design and also the prospective investor and partner is the first Slovenian player among the best 100 in the world. In addition to him, also other players and coaches are involved with consulting and testing.

We are still looking for a partner for helping us with the precise player positioning technology. We are in contact with several business partners to join us and help us with business decisions and first marketing moves with possible collaboration as a strategic selling support.

### **About the Technology**

Tennis is a sport where players are competing directly against each other. Depending on the type of your opponent, playing conditions and chosen tactics, every match is different. To be able to constantly win matches, player needs (i) to be physically in their best shape and (ii) to tactically approach a match in the right way to exploit advantages and limit weaknesses.

Nowadays the players' preparation (volume and type of training) is mostly influenced on subjective players' feelings of fatigue, his subjective feelings between last matches and some general rules like what and how much are others usually practicing in such situations. However, it is scientifically proven that every athlete is different. Therefore, to achieve his maximum potential he has to practice in a way adapted to his needs and predispositions. Thus, to find optimal personalized training regime, avoid injuries and raise long-term physical preparation, general rules and subjective opinions are not enough.

To be able to measure and analyze all physical components in tennis, we developed Tennis tracker, a wearable sensor worn on matches and practices. It includes various sensors that combination with intelligent software enables us to detect moving patterns, efforts, sprints, forces working on the body, shots characteristics and other tennis specific metrics to help tennis players improve their game. Due to the continuously measurements, the system is able to detect not just when an athlete is tired and needs a break to decrease the possibility of injury, but also how to train to prepare the player's body for the effort that the matches will bring.

The precise player movement tracking combined with automatic shot detection algorithm allows to break down (trainings) matches and focus on tennis specific metrics like average shot court position and direction of movement before and after each type of shot. This information is essential when preparing tactics or trying to improve weak parts of your game.

The ability to objectively compare different matches or tactical approaches is extremely important since players' subjective opinion of match can often be incorrect due to lots of emotions that are always involved during tennis matches. Also by tracking player efforts for a longer time, you can find optimal physical state for each player and thus prepare him to be at his best for the most important tournaments.

### **Advantages**

Currently there are no similar tennis specific sensors on the market. Some are used of other sports, but our advantage over competition is in the unique combination of skills and knowledge. The team consists of top AI scientists that are proven to be one of the world's best in the field of activity recognition and some of the best tennis players and coaches home and abroad that are helping them with their expertise. Together with their expertise they believe the team has the right technology, knowledge, skills, experience and resources for development of the product which will be extremely useful from the first day of use.

### **Goal**

1st year: to have the first minimum viable product ready to approach the professional and semi-professional players

2nd year: to sell 20 - 30 units

3rd year: product adjustment and to scale up to the mass tennis market

**Time to reach the goal**

3 years

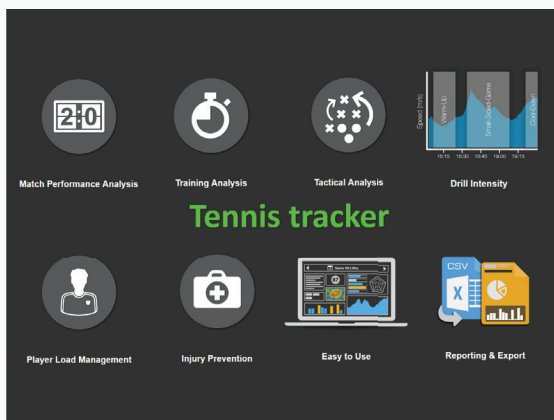
**Previewed amount of financing to reach the goal**

1st year: 50k EUR

2nd to 3rd year: 100k EUR



Tennis Tracker:



Tennis Tracker tracks detailed player movement, measures its effort in combination with numerous other tennis specific metrics.

## // Flex Hex IVC, flexible passive hexapod

### **Industrial field**

Industrial Automation, Automotive, Airplane, Railway and Mechanical Engineering

### **Technology area**

Manufacturing (assembly, welding), Others (drilling, grinding, polishing, painting)

### **Keywords**

Reconfigurable tooling, Robotics, Off-line programming, Adjustable fixturing

### **Stage of development**

TRL: 8

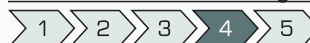
### **IPR status**

Patent application

### **Investment (Financing) range**

100k EUR - 250k EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

Passive hexapod delivers reconfigurable or adaptive tooling, which is a concept that allows for the rapid reconfiguration of fixtures, either automatically (robot aided) or manually. Its passivity and simplicity provides an affordable solution.

### **About the Department, Inventor**

Department of Automation, Biocybernetics and Robotics - E1.

Researcher's personal focus is on coordinate measuring arms, robot-aided reconfiguration, sustainable machinery integration, automation in construction and factories of the future (FoF). His career started at the Jožef Stefan Institute, Slovenia, continued at the University of Maribor, Slovenia, Graz University of Technology, Austria and Vienna University of Technology, Austria.

Collaborating Danish company develops and introduces new innovative market-ready robots for a broad range of branches from industry, healthcare and education to agriculture, construction and offshore etc. They provide complete solutions including design, concept, development, installation, implementation, ramp-up, training, test, documentation, dissemination, support, maintenance and more – all in a life-cycle perspective. Focus is on commercializing robotics R&D.

Slovenian manufacturing company is a company with a 40-year tradition in manufacturing. They provide integral high quality solutions in design, development, production and assembly of injection products and metal processing.

All parties will be involved in research and development of the Hexapod product and public funding. Danish company will provide strategic and user partners, international network and distribution channels and PR and Marketing. In regards to manufacturing and assembly of Hexapods, Slovenian company will be in charge of production, assembly and furthermore delivery and service of sold Hexapods. Moreover there is a need of a financial investor.

### **About the Technology**

Hexapod can be used in several processes due to no need of power supply. Production lines in the automotive, railway or airplane industry are cases, where the Hexapod could be optimal solution, but several other processes have also the opportunity to use such a passive Hexapod.

### **Advantages:**

There are many benefits to the use of these flexible systems; some of these are as follows:

- Increases cost efficiency through the re-use of fixture components on multiple projects
- Reduces fixture design lead times due to the use of dedicated design apps
- Removes the limitations of traditional fixture design, which requires component geometry and datum's to be locked months in advance of manufacturing
- Cuts fixture build lead times due to the use of off the shelf modular components
- Facilitates single piece flow on multi product processes Hexapod utilize a number of different reconfigurable tooling systems independently and in conjunction with each other in order to provide the optimum solution to meet clients' needs.

### **Goal**

Development of final product, Production of Hexapod (preparation and implementation)

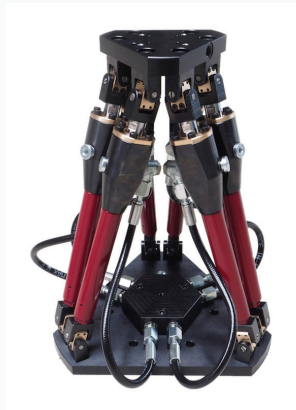
To build sales channels and to sell 2300 hexapods in 4 years

### **Time to reach the goal**

4 years

### **Previewed amount of financing to reach the goal**

1M EUR



The individual Hexapod is a robot fixture which can be featured with passive reconfigurable and adaptive tooling on the base plate. It can be reconfigured either automatically by a robot or manually.

## // Photoelectrocatalytic micro-reactor for wastewater treatment, gas treatment, determination of chemical oxygen demand, or selective synthesis of organic molecules

### **Industrial field**

Industrial (and domestic) wastewater (and gas) treatment

### **Technology area**

Chemistry, Physics, Nanotechnology

### **Keywords**

Wastewater treatment, Gas treatment, Synthesis of organic molecules

### **Stage of development**

TRL: 3. The technology is developed to the level of experimental proof of concept.

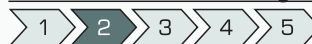
### **IPR status**

Secret know-how

### **Investment (Financing) range**

100k EUR - 250k EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

The researchers at Slovenian research institute have developed an inventive design of the photo-electro-catalytic reactor for wastewater treatment, gas treatment, determination of chemical oxygen demand, or selective synthesis of organic molecules. The invention enables cheaper fabrication and higher photocatalytic activity.

The researchers are in the phase of establishing a spin-out company and are looking for an early stage investment partners able to contribute in the proof of concept stage of the technology.

### **About the Department, Inventor**

Department of Nanostructured Materials - K7.

The inventors are internationally recognized experts in the area of nanostructured materials focused on inorganic materials with specific physical properties that are a consequence of their structural and chemical phenomena at the nano-structural and atomic levels. Their fields of research involve natural and manufactured ceramic materials as well as metals and intermetallic compounds. In the past few years, they have focused on development and characterization of photocatalytic and photo-electro-catalytic reactors for use in water and air purification.

### **About the Technology**

The technology is an efficient system for degradation of organic pollutants, micro-pollutants and also some inorganic pollutants that are present in water. Photo-electro-catalytic reactor is a necessary contributor for solving the critical environmental issue of purifying drinking water. Many countries in the world struggle without safe drinking water as conventional purifying technologies ineffectively remove some organic pollutants from water and wastewater. The most important polluters come from industries that treat their wastewater with their own



purification systems or pay a sewage treatment plant to do this job for them. In either case, production managers face many problems like: treatment cost, different types of pollutants require different treatments, and quality. There are also higher and higher restrictions regarding the use of certain chemicals in treatment processes. Another issue with many conventional treatments is their unsuccessful or incomplete removal of some pollutants. Therefore, different industries seek new wastewater purification solutions that can reduce the treatment cost and maintain a clean environment. PurBox was designed to meet all of the above mentioned requirements. It is able to completely degrade organic pollutants and does not use any potentially hazardous oxidants. It is an inexpensive sustainable solution that can be also used for air purification.

#### **Advantages:**

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- High photocatalytic surface-to-volume ratio enables very fast, continuous oxidation of organics
- Cheap and fast fabrication; all the components are made separately and in the end assembled into the final device
- Photo-catalytically active anode coil constitutes of rigidly attached titania nanotubes that are grown by industrially known anodic oxidation process
- There is no need for post-separation and recovery of the photo-catalyst as it is immobilized
- Photo-electro-catalytic device can be easily scaled-out, scaled-up, or numbered-up
- Device can be optimized in a research laboratory for a specific use
- Low treatment cost compared to other advanced oxidation processes; electricity consumption during the operation is low and can be supplied from the renewable sources
- No addition of harmful chemicals and no harmful products, what makes the technology a green one

#### **Goal**

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Stable technology and team capability for selling turnkey solutions to industrial facilities.

Install at least 10 devices in industrial plants taking over at least 75% of the industrial water cleaning capacity in those plants.

#### **Time to reach the goal**

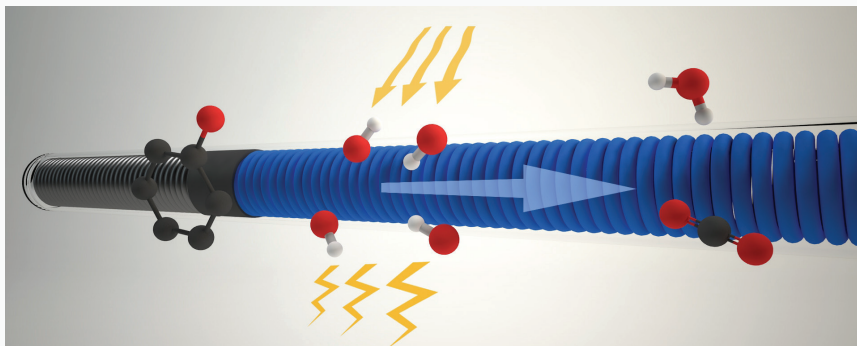
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3 years

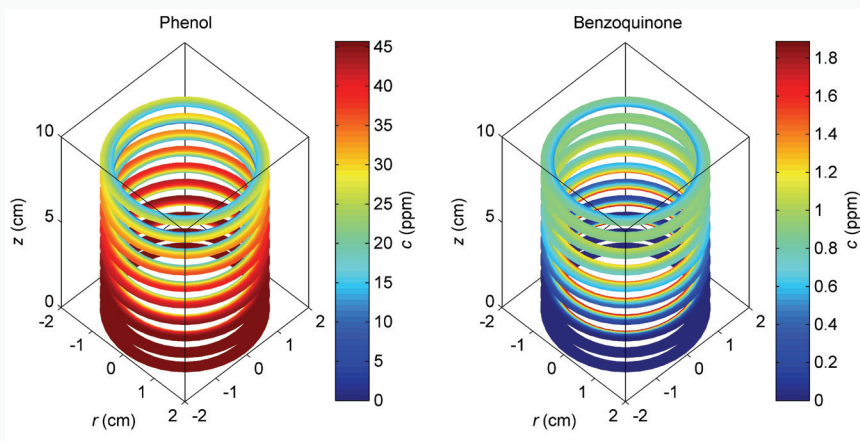
#### **Previewed amount of financing to reach the goal**

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250k EUR



Degradation of a model degradation compound (phenol) in a photoelectrocatalytic microreactor.



The concentration profiles of phenol and benzoquinone in a photoelectrocatalytic microreactor that can efficiently remove organic and some inorganic pollutants from water and air.

## // Biodegradable therapeutic protein patches for healing of chronic wounds

### **Industrial field**

Regenerative medicine, Biomaterials, Tissue engineering, Wounds treatment, Veterinary market, Human medicine

### **Technology area**

Medical Biomaterials, Micro- and Nanotechnology related to Biological sciences, Veterinary medicine, Human medicine

### **Keywords**

Regenerative medicine, Wound healing, Protein patch, Silk fibroin, Scaffold, Biodegradable, Tissue engineering, Natural material

### **Stage of development**

TRL: 7. Available for demonstration and use in animals (experimental proof of concept, validated in laboratory, tested on animals). In vitro cell tests on biocompatibility, larger animal study and clinical trials would have to be conducted to expand the product to human medical market. The researchers have knowledge for developing the technology to higher TRLs.

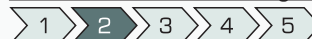
### **IPR status**

Secret know-how

### **Investment (Financing) range**

500k EUR - 1M EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

Slovenian research institute developed the patch for treating chronic skin wounds. The basic goal of research was to improve the procedures of healing the severely painful chronic wounds that may, in case of serious conditions, result in the amputation of extremities. Patches are biodegradable – disappearing in the wound, leaving no residue and no scars behind, also enabling a targeted and controlled release of therapeutic substances.

### **About the Department, Inventor**

Department of Nanostructured Materials - K7.

The team has many experiences of working in field of biomaterials, where members expertise complement on the whole, due to which the group can work in this challenging field.

Members have extensive experiences in research project applications, management and consultancy in the field of science.

### **About the Technology**

The protein patch developed by the team of Slovenian researchers is a combination of three-dimensional highly porous scaffold and a film, both made of protein obtained from silk. The scaffold is capable of withholding the active substances or stem cells in the target area, while the film prevents the scaffold to stick to the bandage. The silk protein patch is also biodegradable. The team of Slovenian researchers is capable of pilot fabrication up to 100 pieces a month.

Main know-how is related to the procedure of preparation of the material, more precisely a protein network as a base for construction of the scaffolds and films, having suitable physical and chemical properties resulting in ability to withhold and release therapeutic substances simultaneously during its biodegradation in a controlled manner. By manipulating the quantity of material applied to the skin (e.g. thickness of the individual patch), it is possible to control the rate of biodegradation of these patches and the release of the therapeutic substances simultaneously. Therefore, there is no need to exchange the patches on a daily basis (e.g. conventional therapies). If needed the treatment can be prolonged with another application of the patch containing therapeutic substance and/or stem cells.

The protein patch was already used for preliminary treatment of animals (with consent of their owners), combined with animal stem cells that were provided by collaborator - a Slovenian company performing animal stem cells treatments. The test, on cell lines and on large animals, provided crucial information for improvement of the patches regarding the material processing and scaffold design.

### **Advantages**

The natural silk-protein patches are biodegradable, disappearing in the wound, leaving no residue and no scars behind. They can be infused with therapeutic substances – medicine or stem cells – enabling targeted and controlled release of the substances into the wound simultaneously during the biodegradation.

Although the medical personnel must apply the patches, there is no need for daily bandage and the time of healing is proved to be shortened resulting in lower costs comparing to the conventional therapies.

### **Goal**

1st year: Collaboration with one Slovenian partner and sell 10-15 protein silk patch on veterinary market.

R&D: Preparation of medical patches samples for the experimental skin wound treatments, Development of 3D scaffolds for toxicological tests

2nd year: Collaboration with SLO partner and at least two partners from abroad, sale increase on veterinary market, preparation of custom-made scaffolds, pre-clinical and clinical tests in human medical market

3rd year: setting up an own laboratory, scaling up of the production of protein silkpatch for veterinary market

4th year: to expand product on human medical market, continuously selling products on veterinary market

**Time to reach the goal**

4 years

**Previewed amount of financing to reach the goal**

1st year: 50k EUR (for staff costs, laboratory, in-vitro tests, certifications)

2nd year: 150k EUR (pre-clinical and clinical tests in human medical market)

3rd year: 250k EUR (setting up an own laboratory)

4th year: 110k EUR (marketing, to expand product on human medical market)



Silk fibroin film - protection of 3D cells scaffolds.



Three-dimensional silk fibroin cell scaffolds of various shapes.

## // Compact/Educational Transient Current Technique and Scanning - Transient Current Technique measurement systems

### **Industrial field**

Electronic Components (Semiconductors, Customized semiconductors, Standard semiconductors, other semiconductors)

### **Technology area**

Electronics, Microelectronics, (Electronic Circuits, Components and Equipment), Photovoltaics, Electronic measurement Systems

### **Keywords**

Transient Currents, Semiconductor characterization, Radiation detectors, Carrier excitation

### **Stage of development**

Already on the market

### **IPR status**

Secret know-how

### **Investment (Financing) range**

< 100k EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

Slovenian research institute has developed a sophisticated and cost effective system for measurements of transient signals in different semiconductor devices for determination of their properties. The system uses fast (few 100 ps) laser pulses of different wavelengths to excite non-equilibrium carriers in semiconductors. Transient currents that are measured during relaxation allow for sophisticated semiconductor characterization. The nature of the technique has a large educational potential. Partners for technical cooperation interested in adaptation of the system to the specific needs of the end users are sought.

### **About the Department, Inventor**

Department of Experimental Particle Physics - F9.

The authors of the system are experts in solid-state particle detectors. They have broad range of experiences and their research is conducted within large collaborative programs at international centers for particle physics at CERN near Geneva and at KEK in Tsukuba. They are engaged in developing and applying the technologically advanced particle detectors systems for high-energy physics experiments.

### **About the Technology**

One of the major challenges in the field of semiconductor detectors is the adjustment of silicon detectors to operate in a highly radioactive environment. The radiation reduces the lifetime of the semiconductor devices and influences the quality of measurements. In order to address the above-mentioned challenges the Transient Current Technique (TCT) is being used for characterization of different device technologies. The conventional TCT is a well known and established principle which is

used in the research of different semiconductor devices. The technique exploits generation of non-equilibrium carriers in semiconductor by laser light (or particle) and follows the response of the device as the carriers drift/diffuse/recombine.

Slovenian research institute has developed two different systems. A Compact/Educational Transient Current Technique System is a portable/table system is intended for use at educational institutions (basics of semiconductors) and at research institutions for state-of-the-art studies of semiconductor material properties. It is used in elementary particle physics and all other applications where semiconductor changes after exposure to different types of radiation is followed, such as dosimetry, photovoltaic, nuclear medicine and radiology. A more elaborate and larger system, called Scanning-TCT, uses focusing optics (beam spot of few microns) and a full 3D translation stages to move the laser beam with sub-micron precision across the device for studies of position resolved response.

Both systems encompass fast pulsed laser (FWHM~350 ps) of different wavelengths, full readout electronics chain (HV filters, Bias-T, wideband amplifiers), temperature controlled mounting plane (Peltier element), DAQ software and a software package for signal analysis. The Scanning-TCT includes in addition also the computer controlled stages and complex focusing optics. There are several adds on to the system such as multielectrode readout, beam monitors, beam locators etc. Due to the good results obtained with this system, ease of use and because of the long experience and reputation of the research group in this area, several research institutions have already acquired TCT systems.

### **Advantages**

Different innovative measurement procedures supported in the analysis package: such as Edge-TCT (polished device edge illumination), Top-TCT or Single Event Upsets configuration. The main advantages over custom made systems are:

- ease of use, standardized mounts, user support;
- high quality results of the TCT measurements;
- cost effective and cheaper than currently available solutions.

The system contains the following innovative solutions for basic elements needed for good TCT measurements:

1. fast laser pulses (FWHM~350 ps)
2. high bandwidth amplifiers (>3 GHz)
3. Bias-T enabling high voltage (2 kV) connection to DUT
4. focused laser beam and precise positioning of DUT allowing studies of response of the device depending on the place of laser light impact. DUT is mounted on a < 1  $\mu\text{m}$  resolution x-y-z moving stages with range of 10 cm.
5. Temperature control of DUT is provided by liquid cooled Peltier element.

### **Goal**

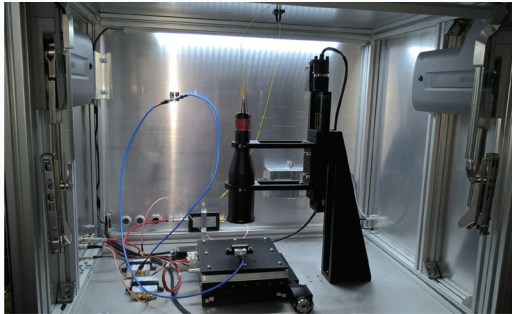
To sell 50 systems (in the scientific market) per year and enter large scale educational equipment market.

### **Time to reach the goal**

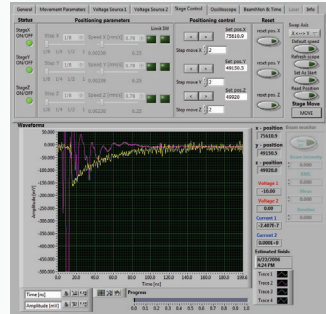
3 years

### **Previewed amount of financing to reach the goal**

250k EUR - 500k EUR



Large-Scanning TCT setup with Low Gain Avalanche Detector during tests.



Software controlling the setup and data acquisition.



## // Small-sized electro-absorption modulator enabling improved optical communications inside electronic devices

### **Industrial field**

Microelectronics, Integrated photonics

### **Technology area**

Optics, Nanomaterials

### **Keywords**

Optical Networks and Systems, Semiconductors, Data Processing/Data Interchange, Middleware, Signal Processing, Optics

### **Stage of development**

TRL: 3-4. Under development, lab tested. Currently, the technology has a low technology readiness level (TRL 3-4 – experimental proof of concept, validated in laboratory). The researchers have the knowledge for developing the technology to higher TRLs. Further development and investments by industrial partners are desired to increase the stage of development of this technology.

### **IPR status**

Patent application

### **Investment (Financing) range**

500k EUR - 1M EUR

### **Investment readiness stage**



### **Summary (content, partner sought)**

A Slovenian – Swiss – Italian R&D organization consortium has developed an electro-absorption modulator (EAM) for use in telecommunications and optical/photonics integrated circuits. Due to its radically smaller size the device allows for improved signal transmission, is cheaper to produce compared to known EAMs, and bears the potential to drastically reduce the switching energy per bit to the fJ/bit-1 range. Industrial partners interested in license agreements, technical cooperation agreements, and/or research cooperation agreements, are sought.

### **About the Department, Inventor**

Department of Complex Matter - F7.

The inventors are internationally recognized experts on the optical properties of nanomaterials and the electronic processes these depend on. Their expertise covers a broad range of materials, with particular emphasis on two-dimensional semiconductors, and a broad range of techniques of both characterization and fabrication of Nano devices.

### **About the Technology**

Electro-absorption modulators (EAMs) are candidates for use in external modulation links in telecommunications and internal links on integrated circuits of photonic and electronic devices. Compared to existing modulation systems, EAMs operate at 10-times lower voltages, generate less heat, and enable faster signal transmission.

Slovenian, Swiss and Italian researchers have developed an EAM based on a semiconductor material with exceptionally strong light-matter interaction. The device consists of an ultrathin (few nm) semiconductor film that is sandwiched between two transparent electrodes and whose transmission is modulated by the applied voltage between the two electrodes. A transverse electric field is applied via the electrodes. The device may be inserted directly into the light path (preferentially with the semiconductor film perpendicular to the light path) or cladding a waveguide (as in current electro absorption modulator technology) to modulate the evanescent wave. Various embodiments and geometries were developed that achieve a significant light modulation on an unprecedentedly short optical path.

EAMs presented here are due to their small size more applicable in future electronic devices (e.g. desktops, mobile phones, modems, routers etc.) in which conventional electronic integrated circuits will be replaced by photonic circuits capable of faster, more energy efficient data transmission.

Since the technology aims to reach its full potential in an industrial setting wherever precise EAMs are needed, industrial partners are sought. The technology requires micro/nanofabrication, therefore technical cooperation is sought in order to facilitate continuous development rather than just routine production, and to validate the technology in an industrial setting. License agreements and / or agreements for research / technical cooperation will enable the researchers to maintain their focus on the research behind the technology whereas validation will be carried out in the industrial partner's setting. Joint applications to EU calls are actively pursued.

### **Advantages**

In addition to known advantages of EAMs (lower energy consumption, lower heat generation and faster signal transmission) the device presented here achieves a significant light modulation on an unprecedentedly short optical path. Hence, the size of device is drastically reduced and with it both the consumption of semiconductor material for its production and the switching energy per bit.

Due to the reduced size, the device is envisaged as the enabling step for integrating EAMs into on-chip photonic circuits.

### **Goal**

1st Year: demonstrator integrated into optical fiber (personnel and equipment)

2nd Year: demonstrator for on-board optical communication,

3rd Year: demonstrate competitive speed and energy consumption, licensing contract with manufacturer, start production,

4th Year: Break point, production and selling.

### **Time to reach the goal**

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4 years

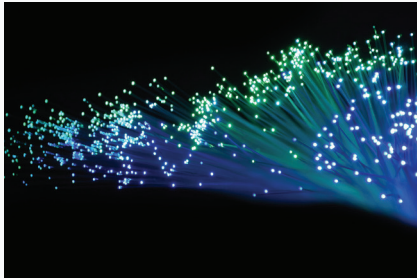
### **Previewed amount of financing to reach goal**

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1st Year: 125k EUR,

2nd Year: 250k EUR,

3rd Year: 400k EUR.



The rapid spread of optical communications requires low-cost, energy efficient electroabsorption modulators.



Data centers have a pressing need for reducing their energy consumption.





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