

Hub of Application Laboratories for Equipment  
Assessment in Laser Based Manufacturing

## Editorial

**Dear APPOLO newsletter  
readers,**



The APPOLO project is coming to its end. Four years of fruitful work in establishing collaboration among laser application laboratories and companies, assessment of laser technologies and equipment for them have passed. In the last year, new experiments selected after the Open call, progressed significantly and provided excellent results to end-users and equipment suppliers. Paving a way for impact of the APPOLO project to competitiveness of European industry.

In this last APPOLO newsletter, we would like to overview outcomes of the experiments ready for commercialisation:

- Laser-induced forward transfer of metallic past for front contact printing in photovoltaics and electronics developed by UPM and implemented by Mondragon Assembly;
- Selective laser-induced metallisation of polymers developed by FTMC, CRF and other partners providing laser-based technology with significant cost savings on final product possessing integrated electronics on plastic components;
- Various approaches and techniques for surface texturing utilising ultrashort pulse lasers developed by Lightmotif, BUAS/DG, and IOM for applications in printing, embossing and machinery industries;
- Combined Perovskite/CIGS thin-film solar cells with laser-made monolithic interconnects as outcome of joint work of IOM, EMPA and FLISOM.
- Decorative texture of chromium layer for automotive industry as common work of UPM, Lasing and Maier;
- And many more ...

The APPOLO summer school this July was one of remarkable events which attracted new people to APPOLO project ideas and results. It was a final dissemination event with students from numerous countries and world-class lecturers.

FP7 project APPOLO was formally finished on the 31<sup>st</sup> of August. However, the future of APPOLO HUB as a “club” of laser application laboratories, or competence centres in laser technologies was and remains the main issue for partners involved. We are ready proceeding toward sustainable operation beyond the APPOLO project.

We hope you enjoy this edition of the APPOLO newsletter,  
Gediminas Račiukaitis, Project Coordinator

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[www.appolo-fp7.eu](http://www.appolo-fp7.eu)

# Focus Topic

## The future of the APPOLO HUB

The APPOLO Project has fruitfully been running for four years and can now proudly present an international HUB [of Laser Application Laboratories](#), which is integrating EU innovation with research activities and industry challenges. With partners located in Switzerland, Spain, Germany, Finland and Lithuania, the HUB is covering the European Union from East to West.

For a successful implementation of innovations from the field of research into the industry, the HUB has been tackling the issue of testing novel laser micromachining technologies in industrial environments. The outcome is the core product of the APPOLO HUB; **assessment services** for complex photonic equipment. The HUB offers high-quality assessments of new lasers, scanners, beams guiding equipment and laser workstations, in order to verify how they meet the customers' expectations. Companies and particularly SMEs, with manufacturing suitable for laser processing, can in this way get an assessment of the feasibility of the potential photonic technology.

The HUB does also offer service in the field of **laser processing verification**. Laser micromachining requires detailed knowledge of equipment and processing know-how. The HUB can help you to achieve the highest possible quality and reliability in production.

The third focus area of the HUB is **laser micro-machining Costs of Ownership & Benefits services**. Costs, process flow and alternatives for the processing will be evaluated in order to find hidden potentials and optimise costs and production.

With the vision to become a technology transfer centre for the laser micromachining manufacturing industry, the HUB is continuously exploring new laser processing concepts at the laboratories. The results will be exploited in two different forms:

- **Services:** HUB participants will be able to offer and perform individualised services for both, the industrial sector as well as for public customers.
- **New projects:** The HUB has the possibility to acquire new projects as a single entity and can then bring unparalleled depth and knowledge as one partner.

For an easy and efficient access to APPOLO's competences and equipment, a database has been created, and it is available on the website. The database allows an easy selection of desirable competences or equipment, fitting to actual projects and current needs.

**Do you want to explore the future of laser micro-machining manufacturing? The HUB is expanding:**

- In order to expand the APPOLO HUB, the HUB is looking for new outstanding **assessment lab partners**, in order to explore new thematic areas as well as new regional areas.
- The APPOLO HUB is in the search for engaged **system integrators**, which can match customers' requests with the best available technology on the market and build outstanding laser processing systems.

**Does this sound interesting to you?  
Then contact:**

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## APPOLO summer school

APPOLO Summer School on Ultra-short Pulse Lasers Applications in Material Processing (UPLAMP), organised by FTMC took place in Vilnius (Lithuania) from July 3<sup>rd</sup> – July 7<sup>th</sup>. The school was held at Center for Physical Sciences and Technology and Laser and Engineering Technologies Cluster.

23 Students from Lithuania, Switzerland, Germany, Greece, France, Ukraine and Russia participated at the Summer School. Lectures were presented by invited speakers and APPOLO partners. Students presented their experiments in various ultra-short pulse lasers applications during oral talks and poster presentations. All summer school participants visited Lithuanian laser companies Light Conversion and Ekspla, ELAS and laboratories of the Department of Laser Technologies (FTMC). Next school will be organised 2019, in two years.



Students from APPOLO summer school July 2017

## BUAS attends @ EPMT Fair & Swissphonics Workshop

The Bern University of Applied Science (BUAS) attended the EPMT fair last week in Geneva. In a separate booth technologies and samples were presented, which were generated within the APPOLO project. Additionally BUAS was able to participate in a talk on "Photonics for Luxury Coatings" at the Swissphonics workshop, which was also taking place during the fair.

For further Information visit:

- <https://www.swissphonics.net/workshops/workshop-datenbank?3066>
- <http://www.ephj.ch/>

## Successful Finalization of DECOUL-Cr experiment within APPOLO Project

DECOUL-Cr experiment in FP7 APPOLO Project focused on using ultrafast lasers combined with a specifically designed and constructed beam guiding and irradiation systems to improve the quality of special decorative finishing in chrome plated parts for the automotive industry.

Three partners were involved in the task:

- MAIER, as leading supplier for chrome plated parts within the automotive sector in Europe
- LASING, as laser machinery supplier and integrator, with the particular goal of assessing a new tool for intelligent laser beam guiding and control
- UNIVERSIDAD POLITÉCNICA DE MADRID, as reference lab of APPOLO HUB applying all its experience in laser process development

Using a ps-laser provided by EKSPLA – and working with different laser parameters – the obtaining of desired effects for the automotive customers in terms of aesthetics on two different chrome surfaces has been achieved. In addition, a smart tool for laser parameters control, the Beam Guiding Box (BGB) designed by LASING, has been assessed and is has proven itself as a basis element of a final industrial machine concept developed for this particular application during the project.



Cosmetic finished obtained in chromed parts for automotive industry; ©UPM & Maier

Final process results, working directly on real parts, fulfilled the selected aesthetics and the promising results of the tests that the automotive sector requires, especially in the particularly strict CASS corrosion resistance tests.



## BUAS successfully combined LASE-170STD, Roller and Lumentum fs-Laser

In the laboratories of the Bern University of Applied Science researchers were able to combine a LASE-170STD polygon lines scanner, the roller and a Lumentum fs-Laser in one set-up and to machine first patterns. Currently Deatwyler Graphics (DG) is working with that set-up at the BUAS facility in order to test out sleeves for SWG.

About 900 people work at its three sites in Dübendorf, St. Gallen and Thun. There are between 100 and 150 PhD candidates and undergraduates each. EMPA also offers training to 100 interns and trainees. The EMPA Academy provides a forum for lively information sharing. Congresses, lecture series, seminars and teaching events cater to scientists seeking a dialogue, specialists looking to improve their knowledge and laypeople who want to find out about current technological developments.

The Laboratory for Thin Films and Photovoltaics at EMPA is known for excellence in the field of CIGS, CdTe, and perovskite thin film solar cell and tandem device research and development on various substrate materials and the technology transfer to industry.

# Meet the Consortium



**Empa** © EMPA

Materials Science and Technology

EMPA is an interdisciplinary research and service institution for materials science and technology development. It is part of the ETH domain and as such is an important element in science, technology and education in Switzerland. It specialises in applications-focused research and development and provides high-level services in the field of sustainable materials science and technology. Its core tasks are an innovative collaboration with industry and public institutions, ensuring the safety of people and the environment, knowledge propagation and university-level teaching.

EMPA engages in interdisciplinary work in a large number of specialised disciplines. Its key areas of research are grouped in five «Focus Areas» entitled Nanostructured Materials, Sustainable Built Environment, Health and Performance, Materials for Energy Technologies and Natural Resources and Pollutants.

## Interview

**Prof. Ayodhya N. Tiwari, Laboratory for Thin Films and Photovoltaics**



© EMPA

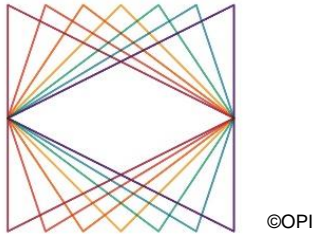
**What are the biggest challenges in the field of laser-based manufacturing today?**

In the Laboratory for Thin Films and Photovoltaics at EMPA we are developing multilayer device structures for various applications including photovoltaics and batteries. Laser based structuring is a key production step to realize highly efficient thin film solar modules. The main challenge is to realize fast selective ablation on moving substrates without damaging adjacent layers.

**To which extent can APPOLO help to face those challenges?**

The APPOLO project serves as unique platform to explore and assess various laser sources and light guiding optics for laser structuring application in CIGS and perovskite solar module production.

## OPI Photonics



## OPIPHOTONICS

OPI Photonics s.r.l. (OPI) is an Italian SME based in Turin and established at the end of 2012 targeting cutting-edge industrial solutions in high power photonics. OPI produces high power multi-emitter laser diode sources, innovative devices for kilowatt laser beam management (combining, coupling, collimating and switching) and laser pulse delivery systems.

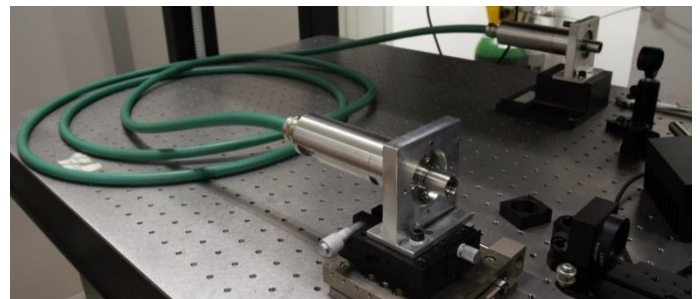
OPI was born from an idea of Prof. Ing. Guido Perrone and Dr.-Ing. Andrea Braglia. Prof. Perrone has 20 years of experience in photonics, he is founder and manager of the research group "Fiber and Optical Components" of the Department of Electronics and Telecommunications of Politecnico di Torino University; Dr. Andrea Braglia has a degree in Physic Engineering from Politecnico di Milano and a PhD in Electronics from Politecnico di Torino, he has almost 10 years of experience in high power lasers. OPI exploits to industrial level the remarkable know-how gained during 25 years of photonics research - one of the key enabling technologies (KET) according to the The European Union and hence with enormous growth potential for numerous applications and cross-cutting approaches that are expected in the near future.

OPI Photonics develops cutting-edge industrial solutions in high power photonics, focusing on laser beams managing for material processing, whereas main products and services are related to High power laser diodes (multi-emitter fibre-pigtailed modules from 100W to 500W), kW laser beam delivery systems (Couplers, Switches, Combiners, Splitters, and Collimators) and Ultra-short laser pulses fiber delivery.

OPI Photonics high power **BrighteX** laser modules combine **multiple-single emitters** into a delivery

fiber exploiting different optical architectures. Each architecture is implemented on a common platform, which constitutes the base of OPI Photonics standard products while enabling to tailor the product to specific needs, whenever required. Thanks to this unique, innovative approach, OPI's customers are given the power to either choose from a standard product portfolio or to identify the combination of platform, single emitter properties and output fiber characteristics best matching their application, without the high costs and long timescales of a new product development. Currently, the BrighteX series is made up of three common platforms:

- BrighteX-P1 features a rugged and reliable design based on beam stacking, allowing up to 140W of fiber coupled power;
- BrighteX-P2 platform adds polarisation multiplexing to beam stacking, doubling the brightness of the P1 platform;
- BrighteX-D1 further exploits coarse wavelength division multiplexing to deliver up to 500 W in a compact and reliable package footprint.



BrighteX Series; © OPI

OPI Photonics range of laser beam **Couplers, Switches, Combiners, Splitters, and Collimators** are the high-power *beam management* solutions for multi-kilowatt fiber and direct diode lasers, ready for "industry 4.0". OPI offers both off-the-shelf and custom products to satisfy specific needs regarding optical fiber cable and connectors (QBH, QD, PT-F etc.) and laser beam specifications. Each system is equipped with embedded safety and control boards which monitor both the operative conditions of the optical, electrical, and internal mechanical elements, and the feeding and process fibers.

Beyond that, OPI has most recently developed an innovative fiber delivery cable specifically designed for high energy and/or high peak power ultra-short laser

pulses targeting industrial applications. The product qualification has strongly benefited from the APPOLO project, which enabled the possibility of testing the cable at the Bern University of Applied Science, where proper equipment and know-how was provided.

OPI skills and facilities include design and simulation, high power laser characterisation, a 1.000 – 10.000 class (ISO 6 – 7) clean room for component assembly, fiber processing machines, access to dielectric and metal deposition, wet and dry etching, nanoscale lithography (EBL) and diode chip assembly.

Building on these capabilities, OPI Photonics has been successfully managing innovative projects, such as high power diode lasers for special applications (e.g. 300 W fiber-coupled modules for additive manufacturing) or smart free space systems for breakthrough production optimization (e.g. automotive material processing).

OPI Photonics is an **SME** open to innovation: its flexible technology makes OPI Photonics the ideal partner for research projects, both as a technology provider and end user. OPI Photonics expertise has already been recognised in several projects funded by the European Commission (FP7 and H2020).

In the Appolo project OPI is coordinating the experiment NEW-DELI, including two SMEs, a technology provider (OPI) and an end-user (IRIS), and a lab belonging to the Appolo hub (BUAS) to experimentally assess a cutting edge ultra-short pulse fibre delivery system in a practical use case with a definitely relevant potential market since it targets the next generation of additive-subtractive manufacturing machines as well as all the possible application of USP lasers that can benefit from a flexible delivery system. So far the delivery of these ultra-short pulses has been through free-space systems, the approach that poses many limitations to machine designers. Very recently, however, innovative fibre-based delivery solutions have been reported exploiting a new type of photonic crystal fibre able to route high peak power pulses with minimal distortion and, especially, no fibre damage. OPI has prototyped an industrial grade cable system based on the above-mentioned fibres. BUAS has validated the cable performance, and IRIS owns, processes and machines for the cable testing in a real industrial environment focusing on advanced laser-based manufacturing processing.

## Interview

with, **Dr.-Ing. Andrea Braglia, CEO of OPI Photonics SRL**



©OPI

**What are the biggest challenges in the field of laser-based manufacturing today?**

Ultra-short pulse laser-based manufacturing is definitely fast growing and double digit CAGR till 2020 is foreseen, thus its outstanding market penetration is unstoppable. Nevertheless such laser sources are expensive (e.g. compared to traditional nano-seconds lasers) and especially SME cannot afford the investment. On the other hand, USP lasers enable impressive applications (e.g., surface functionalization), hence end-users will gradually not be able to live without. Finally, the number of laser source suppliers is increasing (with big player interested in such technology), leading to hard competition but also price reduction.

**To which extent can APPOLO help to face those challenges?**

The APPOLO HUB will help USP laser technology diffusion, reducing the initial investment for processing assessment; expertise and equipment are shared, laser source manufacturers are set in contact with end users through universities and research centers exploiting the hub concept.



## Quick, Precise but not Cold

On April 26 and 27, 2017, 150 experts from research and industry met in Aachen for the 4<sup>th</sup> UKP-Workshop: Ultrafast Laser Technology. Once again, the workshop – organized by the Fraunhofer Institute for Laser Technology ILT – focused on the industrial use of ultrashort laser pulses. However, it was basic researchers that caused a stir. Using relatively simple formulas, they demonstrated how the much-lauded “cold ablation” of picosecond and femtosecond lasers is by no means cold when the parameters and systems chosen are not matching the physical limitations and conditions of beam-material interactions.

Researches like Prof. Beat Neuenschwander have been studying thermal effects and the efficiency of high-power ultrafast lasers. He demonstrated that when operating at high output, they in fact deposit heat on the workpiece, significantly impacting the ablation process.



*Prof. Thomas Graf on thermal effect during ablation © ILT*

Prof. Thomas Graf from the IFSW of the University of Stuttgart summed up the theory of thermal effects using a few simple formulas. He identified the limits, too, using equally clear words: “We still don’t fully understand how much heat ultrashort pulses leave behind,” he said. “We are currently working on simulations at a molecular level to better understand the processes at play.” [Read More](http://www.innovations-report.com/html/reports/process-engineering/quick-precise-but-not-cold.html)

Source:

<http://www.innovations-report.com/html/reports/process-engineering/quick-precise-but-not-cold.html>

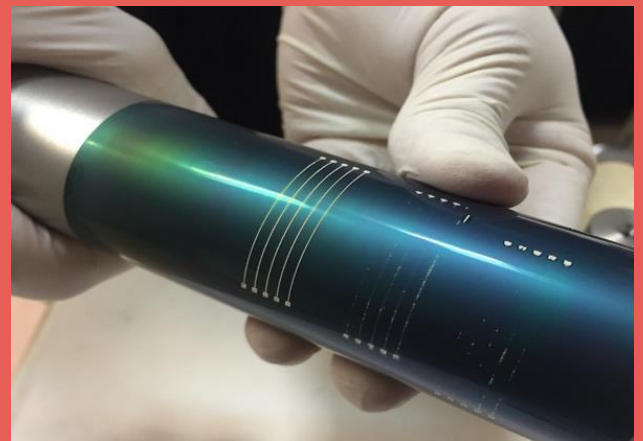
<https://www.ilt.fraunhofer.de/de/presse/pressemitteilungen/pm/2017/pressemitteilung-16-05-2017.html>

## Laser-Based Metalization Process for Screen Printing Applications

One of the fundamental targets of APPOLO project (WP7) was the development of a full laser-based metallization process, ready to be integrated into industrial lines and competitive with the standard screen printing process widely adopted by PV industry.

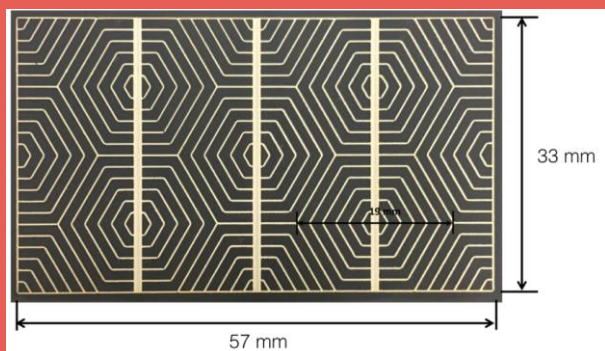
Using a Laser-Induced Forward Transfer (LIFT) approach to deposit fully commercial high density silver-based pastes in free geometries with high aspect ratios, and after a sintering approach using CW laser sources, a new metallization approach is ready to be used with flexible substrates, standard PV technologies or even with low-temperature approaches as those used many high efficiency approaches.

In FP7 APPOLO, three partners (Mondragón Assembly, Abengoa Solar and Universidad Politécnica de Madrid), have collaborated to reach a level of maturity of this technology high enough to envisage first attempts of industrialisation. Currently, Mondragon Assembly has different machine concepts in its portfolio, ready to be adapted and customised to produce complex metallization patterns with higher aspect ratios (reducing then shadowing losses) than standard screen printing approaches in a number of different PV technologies.



*Printed fingers onto a CIGS on flexible substrate with optimum adherence properties; © UPM & ABENGOA*

In addition, Universidad Politécnica de Madrid has used part of the knowledge generated in the project to incorporate Innofluence ([www.innofluence.es](http://www.innofluence.es)), a spin-off that is currently developing customised machines to apply LIFT techniques in the new, and strategical, field of laser bioprinting for tissue engineering and regenerative medicine.

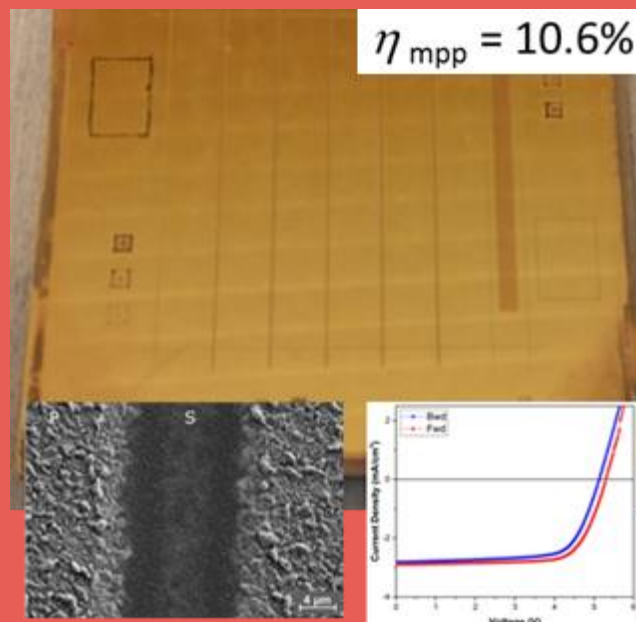


Free form printed pattern onto crystalline silicon substrates; © UPM

## Demonstration of all-laser scribed perovskite mini-modules

Efficient energy harvesting by thin film photovoltaic technology requires serial interconnection of solar cells stripes to modules with minimum loss of active area. Laser scribing is the key technology to perform the three required scribes with high speed, micron scale precision and reliability for industrial applications.

Within WP3 laser scribing of halide-based hybrid organic-inorganic perovskite solar cells was investigated in cooperation between EMPA and IOM. High repetition rate ps-laser sources were used to realize the P1, P2 and the P3 scribes for the development of a process for all-laser scribed perovskite mini-modules. One major challenge that was solved during the APPOLO project was the P2 scribing of the perovskite film that has to be selectively removed from the transparent front contact coated with proper charge extraction layers without destroying the underlying layer and substrate.



SEM micrograph of the P2 scribe line, module photograph and current voltage characteristics of the all-laser scribed perovskite mini-module on glass with stabilized efficiency of 10.6%. © Leibniz Institute of Surface Modification

Our investigations of the interaction between laser light and the perovskite film revealed the two major scribing mechanisms that are laser ablation and film lift-off depending on the laser wavelength, the pulse duration and the irradiation direction. After optimization of the laser scribing processes the 355 nm output of the Atlantic ps-laser was utilized together with high speed scanning for all the three scribes.

All-laser scribed perovskite mini-modules on glass with efficiency of 10.6% show, in a proof of concept, the benefits of laser scribing with ps-sources, allowing small dead areas, low material modification and high scribing speeds.

The feasibility of all-laser scribed mini-modules as demonstrated on glass in this project is of great interest for the industry side. As member of the consortium, FLISOM closely monitors the developments, because NIR-transparent perovskite modules could potentially be used as top cell together with CIGS and lead to further increase of cell efficiency. Successful implementation of the all-laser scribing of perovskite solar modules on flexible substrates would pave the way towards fabrication of all thin film flexible tandem modules.



# Upcoming Events 2017

|                 |                        |  |
|-----------------|------------------------|--|
| 25.09. – 29.09. | Amsterdam, Netherlands | European Photovoltaic Solar Energy Conference and Exhibition |
| 24.10. – 26.10. | Munich, Germany        | Euromold   |
| 15.11. – 16.11. | Veldhoven, Netherlands | Precision Fair   |
| 30.11. – 01.12. | Berlin, Germany        | Automotive Surface Conference                                |

***We invite you to meet us at these events and to get to know more about  
APPOLO and the partners!***



The **32<sup>nd</sup> European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)** will take place from September 25<sup>th</sup> to 29<sup>th</sup>, 2017 at RAI Convention and Exhibition Centre in Amsterdam, the Netherlands.

The EU PVSEC is held annually at changing European locations. This unique PV solar event constitutes the world's leading science-to-science, business-to-business and science-to-industry platform for the entire PV value chain.

Experts of the PV solar branch meet on that occasion to discuss new concepts, trends and developments in science and industry. Therefore the conference program will be structured in plenary, oral and visual presentations and cover the entire range of PV research, technologies and applications, focusing on the latest scientific, technological and market-related trends.

Now, that Photovoltaic Solar Energy is becoming a major electricity source, the EU PVSEC extended its focus to applied and policy-oriented topics. The EU PVSEC thus strengthens its established leading role in science and technology among the players of the global PV sector

<https://www.photovoltaic-conference.com/>

## euromold.

**Euromold 2017** will take place from November 24<sup>th</sup> to 26<sup>th</sup> of October, 2017 at the Expopark close to the Munich Airport, Germany.

For more than 20 years, Euromold is the world's leading trade fair in product development. Product Managers, Developers, Executives and anybody seeking to launch new products or innovative solutions within the broad range „from idea to series production“ will find an ideal space for the direct exchange with experts and professionals from around the globe.

One of Euromold's unique characteristics is the intersectoral exhibition that offers solutions for a variety of branches. In contrast to similar fairs, Euromold keeps the focus on holistic thinking with exhibitors that demonstrate how products from different departments perfectly fit together to create innovative opportunities and perspectives. Consequently, enterprises from totally different industries are lined up at Euromold and exhibit their ideas in combination.

Along the whole process chain of „Product Development“ our exhibitors present new trends in Design, Engineering, Molding and Toolmaking, Production as well as in Additive Manufacturing / 3D Printing. An exceptional position is awarded to the sector of Additive Manufacturing / 3D Printing, as it can be implemented in developing models and prototypes as well as in manufacturing processes for make-to-order and series production. Furthermore it's becoming a substantial part in classic mold-making and tooling.

Euromold is the unequalled No. 1 Trade show in the world for Additive Manufacturing / 3D Printing. It is our task and major issue to offer the perfect stage for these new technologies in a generative context with classic moldmaking and tooling.

<http://www.decorativeautomotiveplastics.com/>

## Precision Fair 2017

The **17th Precision Fairs** will take place from November 15<sup>th</sup> to 16<sup>th</sup>, 2017 at the NH Conference Centre Koningshof in Veldhoven, Netherlands.

Partly due to free access, the Precision Fair has grown to become the meeting point for precision technology and has now built international reputation.

<http://lasertechnologyconference.blogspot.de/>

## Automotive Surface 2017

The **Automotive Surfaces Conference** will take place from November 30<sup>th</sup> to 1<sup>st</sup> of December, 2017 at the Hotel Palace in Berlin, Germany.

The Automotive Surfaces Conference 2017 is focusing on vehicle interior fixings, applications and developments. At the conference the latest automotive interior and electronics innovations will be displayed and new materials, innovative technology and manufacturing techniques will be shown.

Since smart surfaces, both interior and exterior, are being developed rapidly to reflect consumer need for functionality, style and feel, smart coatings have been the focal point to produce desired surface properties and create added value for the user. New market trends in smart surfaces and technology are developing, which look to capitalise on the recent success of smart coatings. In order to face such

rapid developments the conference will act as a platform for industry experts to showcase new interior feature enhancements and explore smart surfaces.

<http://www.decorativeautomotiveplastics.com/>

## NextScan receives EPI Phoenix Award 2017

Next Scan Technology, polygon scanner expert and an associated company with SCANLAB GmbH, was presented the prestigious EPIC Phoenix Award 2017 that recognizes exemplary entrepreneurship in photonics.



The European Photonics Industry Consortium (EPIC) presented Next Scan Technology's management as the winner during its annual general meeting in Eindhoven, the Netherlands in May 2017.

**Source:**

<http://www.appolo-fp7.eu/news.html>; <https://www.pressebox.com/pressrelease/scanlab-gmbh/Polygon-Scanners-Represent-Award-Winning-Technology/boxid/847430>

## APPOLO @ LASER World of Photonics

The European commission, Photonics 21 and LASHARE invited to a forum at Laser World of Photonics in Munich. Under the headline "Digitization of laser-based manufacturing in Europe" the program intended to identify topics and activities that support digitization in the photonics sector. In that context the APPOLO project provided an overview on its innovation scheme. The following workshop was able to involve the audience and discuss future research and innovation programs connected to digitization.



**Source:**

[https://www.lashare.eu/content/dam/lashare/en/documents/2017-laser-world-of-photonics/LASHARE\\_Laser-M%C3%BCnchen\\_Abstract\\_v0201.pdf](https://www.lashare.eu/content/dam/lashare/en/documents/2017-laser-world-of-photonics/LASHARE_Laser-M%C3%BCnchen_Abstract_v0201.pdf)



# Consortium



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