Lasers and Photonic Technologies for Environmental Challenges (SYEC)

jointly organized by
the Short Time-scale Physics and Applied Laser Physics Division (K) and
the Environmental Physics Division (UP)

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As one of the major issues facing the world, the ongoing climate crisis substantially threatens today's society. To mitigate this threat we need to increase the overall energy usage efficiency (greener industrial designs) and reduce CO_2, methane, black carbon and CFC emissions (avoid environmental pollution, safeguard human health and weaken greenhouse warming) by establishing low-carbon "clean" energy sources (renewables, nuclear fusion and others). At the same time, the current century is known as the age of the photon spawned through the invention of the laser and its continuous development. At this special symposium, current solutions to environmental challenges based on lasers and photonic technologies will be presented and discussed. These solutions will be as diverse as the environmental challenge they aim to solve and cover, e.g., optical fibre and waveguide technology, photonic sensing, photocatalysis, nanophotonics, (ultrashort pulsed) lasers, or photonic quantum technologies.

Overview of Invited Talks and Sessions

(Lecture hall ELP 6: HS 1 and ELP 6: HS 4)

Invited Talks

SYEC 1.1	Tue	11:10–11:40	ELP 6: HS 1	**Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications** — •Omar de Varona, Franzette Paz-Buclatin, Paul Santos, Pablo Molina, Leopoldo Martín, Airán Ródenas
SYEC 1.2	Tue	11:40–12:10	ELP 6: HS 1	**Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability** — •Max-Jonathan Kleefoot, Jens Sandherr, Jiri Martan, Volker Knoblauch, Harald Riegel
SYEC 2.1	Tue	14:00–14:30	ELP 6: HS 4	**Development of soft glass optical fibers based on 3D printed preforms** — •Ryszard Buczynski, Pawel Wiencław, Przemyslaw Golebiewski, Dariusz Pysz, Adam Filipkowski, Grzegorz Stepniewski, Olga Czerwinska, Andrzej Burgs
SYEC 2.2	Tue	14:30–15:00	ELP 6: HS 4	**Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials** — •Airán Ródenas, Omar de Varona, Franzette Paz-Buclatin
SYEC 2.3	Tue	15:00–15:30	ELP 6: HS 4	**Fibre-based plasmonic micro reactor CO2 reduction** — •Devin O'Neill, Patrick Spath, Wiebke Albrecht
SYEC 5.1	Tue	17:15–17:45	ELP 6: HS 4	**Studying atmospheric dynamics with lasers in remote places** — •Bernd Kaifler

Sessions

SYEC 1.1–1.3	Tue	11:00–12:25	ELP 6: HS 1	**Laser-Based Micro-/Nanostructuring for Environmental Challenges**
SYEC 2.1–2.3	Tue	14:00–15:30	ELP 6: HS 4	**Fiber-Based Plasmonic Microreactor for Flow Chemistry**
SYEC 3.1–3.2	Tue	15:30–16:00	ELP 6: HS 4	**Photonics-Assisted Green Energy Production I**
SYEC 4.1–4.3	Tue	16:30–17:15	ELP 6: HS 4	**Photonics-Assisted Green Energy Production II**
SYEC 5.1–5.4	Tue	17:15–18:30	ELP 6: HS 4	**Photonic Measurement Technology for the Environment**

SYEC 1: Laser-Based Micro-/Nanostructuring for Environmental Challenges

Time: Tuesday 11:00–12:25 Location: ELP 6: HS 1

Introduction to 'Lasers and Photonic Technologies for Environmental Challenges'

Invited Talk SYEC 1.1 Tue 11:10 ELP 6: HS 1
Nanostructured optical waveguides inside YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications — •Omar de Varona[1,2], Franzette Paz-Buclatin[1], Paul Santos[1], Pablo Molina[3], Leopoldo Martín[1,2], and Airán Ródenas[1,2] — [1]Department of Physics, University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [2]Instituto Universitario de Estudios Avanzados en Física Atómica, Molecular y Fotónica (IUDEA), University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [3]Departamento de Física de Materiales, Instituto de Materiales Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, 28049 Madrid, Spain

Nanophotonics stands as a pivotal technology to fight climate change, offering diverse solutions across multiple disciplines. Recent advancements in fabrication processes have enabled spectrum engineering, plasmonic nanoparticles techniques and miniaturization of light-trapping and guiding structures. These innovations equip researchers with novel tools for applications spanning from CO2 capture and enhancement of solar energy harvesting efficiency, to precise detection of pollutants for air and water monitoring. This presentation delves into the fabrication process of 3D nanostructures within crystalline materials tailored for photonic applications by means of femtosecond laser lithography. We report our latest results on the production of waveguides embedded in YAG crystals as a crucial step towards the development of microlasers for advanced sensing applications.

Invited Talk SYEC 1.2 Tue 11:40 ELP 6: HS 1
Laser surface modification of graphite anodes for lithium-ion batteries with improved fast-charging capability — •Max-Jonathan Kleefoot[1,3], Jens Sandherr[1], Jiri Martan[2], Volker Knoblauch[1], and Harald Riegel[1] — [1]LaserApplicationCenter (LAZ), Aalen University, Beethovenstraße 1, 73430 Aalen, Germany — [2]New Technologies Research Centre (NTC), University of West Bohemia, Plzen, Czech Republic — [3]Department of Machining Technology, Faculty of Mechanical Engineering (FST), University of West Bohemia, Pilsen, Czech Republic

In order to fulfil the high energy density requirements of lithium-ion batteries used in battery electric vehicles, electrodes with high active mass loading and low porosity or high compaction are required. However, such high-energy electrodes have a significantly lower rate capability, which is mainly a consequence of the limited lithium-ion diffusion. Laser-based microstructure adaptations can help to partially overcome the conflict of objectives between energy and power density. Various approaches such as the selective removal of binder components on the surface or the perforation of the electrode layer as deep structuring were investigated for this purpose. The aim of the work was to gain a better understanding of the machining processes but also to investigate the resulting performance of the electrode. It could be shown that the investigated processes lead to an significantly improved electrode performance in the fields of fast charging capability, wetting and lifetime compared to unprocessed electrodes.

SYEC 1.3 Tue 12:10 ELP 6: HS 1
Ultrashort pulse laser surface nanostructuring and its application — •Pierre Lorenz, Joachim Zajadacz, Martin Ehrhardt, and Klaus Zimmer — Leibniz-Institut für Oberflächenmodifizierung, Leipzig, Deutschland

Ultrashort pulse laser radiation can be used to irradiate metal surfaces and create self-organized micrometer and nanostructured surfaces. The surface morphologies depend on various laser parameters, including laser power, scan speed, wavelength, and repetition rate. In addition, the nanostructures can be transferred to an arylate surface using UV nanoimprint lithography (UV-NIL). The directly lasered or molded surfaces exhibit interesting optical, electrical, and fluidic properties. For example, laser-assisted nanostructuring of copper surfaces allows the fabrication of Cu surfaces with adjustable secondary electron yield. Similarly, laser-assisted nanostructuring of stainless steel surfaces allows the water contact angle to be adjusted from superhydrophobic to superhydrophilic. In addition, the forming of nanostructured surfaces allows the production of surfaces with adjustable optical reflectance. This presentation provides an overview of laser-assisted nanostructuring of surfaces and its applications.

SYEC 2: Fiber-Based Plasmonic Microreactor for Flow Chemistry

Time: Tuesday 14:00–15:30 Location: ELP 6: HS 4

Invited Talk SYEC 2.1 Tue 14:00 ELP 6: HS 4
Development of soft glass optical fibers based on 3D printed preforms — •Ryszard Buczynski[1,2], Pawel Wienclaw[2,3], Przemyslaw Golebiewski[1,2], Dariusz Pysz[1], Adam Filipkowski[1], Grzegorz Stepniewski[1], Olga Czerwinska[3], and Andrzej Burgs[3] — [1]Lukasiewicz Research Network, Institute of Microelectronics and Photonics, Al. Lotnikow 32/46, 02-668 Warsaw, Poland — [2]Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland — [3]Sygnis S.A., Al. Grunwaldzka 472, 80-309 Gdansk, Poland

We report on the development of a 3D printing system dedicated to the development of soft glass optical fiber preforms. In contrast to previous studies on 3D printing of optical fiber preforms, the proposed process is based on the deposition of straight, horizontally oriented lines to replace the manual stack-and-draw fiber assembly process. The printer consists of a miniaturized crucible for melting glass blocks and a pneumatic extrusion head. Developed in-house heavy metal oxide glass was used to print the preform. The proposed 3D glass printing system is recognized as green technology, as it significantly reduces glass waste compared to standard stack-and-draw methods, and does not use difficult-to-recycle polishing powders in the fabrication process. As a proof-of-concept, a microstructured fiber preform with a solid core and 3 rings of air holes was printed. The fiber preform was composed of 2500 microrods. The total dimensions of the preform were 60x25x25 mm. Next, the final fibers are drawn at the fiber drawing tower and further characterized. The optical quality of the glass is maintained during the process and no crystallization is observed. The proposed 3D printing method is very promising for automating development process of microstructured fibres and free-form optical components. Since there are no restrictions related to the symmetry or circular shape of the printed fiber preform, this method can be applied to develop new types of fiber optic sensors and flow-through micro-optofluidic systems.

Invited Talk SYEC 2.2 Tue 14:30 ELP 6: HS 4
Three-dimensional Ultrashort-Pulse Laser Nanolithography of Optical Materials — •Airán Ródenas[1,2], Omar de Varona[1,2], and Franzette Paz-Buclatin[1,2] — [1]Department of Physics, University of La Laguna, 38200 Santa Cruz de Tenerife, Spain — [2]Instituto Universitario de Estudios Avanzados en Física Atómica, Molecular y Fotónica (IUDEA), University of La Laguna, 38200 Santa Cruz de Tenerife, Spain

In this talk we will discuss our recent results on 3D ultrashort pulse laser nanolithography of optical materials towards novel optical instrumentation for harsh-environments. We will present recent results on the understanding of the photomodification processes in optical crystals on different irradiation dose accumulation regimes. We will also discuss the microstructuring of hollow optical fibers towards novel optofluidic micro-reactor systems.

Invited Talk SYEC 2.3 Tue 15:00 ELP 6: HS 4
Fibre-based plasmonic micro reactor CO2 reduction — •Devin O'Neill, Patrick Spath, and Wiebke Albrecht — AMOLF, Amsterdam, The Netherlands

As part of a bid to achieve carbon neutrality or even atmospheric remediation of CO2 levels new, sustainable, and efficient technologies are needed. The EU "reaCtor" project aims to combine the chemical selectivity of a flow microreactor with plasmon-induced photocatalysis in a highly efficient light guiding system - a hollow core optical fibre with annular light propagation; capitalizing on short lived (0.1-1 ps)[1] hot-electrons generated with plasmon relaxation to drive CO2 reduction to useful products[2]. We strive to unify disparate literature in a highly photon-efficient photocatalytic system. Here, we show work on surface enhanced Raman scattering from a single nanoparticle for CO2 reduction where the hot electron is extracted by imidazolium[2] binding CO2 and driving the chemical reaction[3] with the restrictions of the optofluidic environment.

[1] Nature Nanotech (2015), 25-34, 10(1), [2] Nature Comm (2019), 1-7, 10(1), [3] J. Phys Chem. C (2021), 17734-17741, 125(32)

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SYEC 3: Photonics-Assisted Green Energy Production I

Time: Tuesday 15:30–16:00 Location: ELP 6: HS 4

SYEC 3.1 Tue 15:30 ELP 6: HS 4

Upconversion Nanoparticles Towards Sensing in Hydrogen Electrolysis Cells — •Rajesh Komban[1], Simon Spelthann[2], Lea Kötters[2], Michael Steinke[2,3], and Christoph Gimmler[1] — [1]Fraunhofer Center for Applied Nanotechnology CAN, D-20146 Hamburg, Germany — [2]Institute of Quantum Optics, Leibniz University Hannover, D-30167 Hannover, Germany — [3]QUEST-Leibniz-Research School, Leibniz University Hannover, D-30167 Hannover, Germany

With its potential to address environmental concerns and energy security, hydrogen is gaining prominence in various energy sectors. In this scenario, the proton exchange membrane (PEM) electrolysis cell emerges as a significant tool for generating green hydrogen from water. The temperature inside these cells is crucial, as it directly correlates with their efficiency. To monitor the temperature in situ, a specialized technique needs to be developed.

The utilization of luminescent intensity ratio-based thermometry coupled with a fiber sensor would be an optimal choice for such an application. As lanthanide ions excited energy levels enable such correlation, we develop lanthanide doped green emitting upconversion nanoparticles (UCNP) for this purpose. Highly efficient submicron range $NaYF_4$:Er^{3+},Yb^{3+} UCNP core particles are developed and further modified their surface with silicon dioxide shell to enable them to stick on surface of the fiber. We assume that these functionalized UCNP can be used in different fiber based temperature sensors not only in PEM cells, but also in battery technology.

SYEC 3.2 Tue 15:45 ELP 6: HS 4

Nanothermometers on Fiber Tip for Temperature Measurements in Water Electrolysis Cells — •Lea Koetters[1], Simon Spelthann[1], Lena Bühre[2], Mareike Benecke[2], Rajesh Komban[3], Patrick Späth[4], Wiebke Albrecht[4], Boris Bensmann[2], Christoph Gimmler[3], Richard Hanke-Rauschenbach[2], and Michael Steinke[1] — [1]Leibniz University Hannover, Institute of Quantum Optics, Hannover, Germany — [2]Leibniz University Hannover, Institute for Electric Power Systems, Hannover, Germany — [3]Fraunhofer-Institut für Angewandte Polymerforschung IAP, Hamburg, Germany — [4]AMOLF, Amsterdam, Netherlands

Hydrogen from Proton Exchange Membrane Water Electrolysis (PEMWE) cells enables the storage of sustainably generated energy. The efficiency and longevity of these cells depend on operating conditions such as the temperature of the membrane. We set up a fiber sensor using lanthanide-doped nanoparticles as nanothermometers and employed it to measure the temperature at the cell's membrane for different operational conditions. The results will help us to optimize the cell's operational parameters. The sensor is also applicable in strong electromagnetic fields, for example in battery technology or magnetic resonance tomography.

SYEC 4: Photonics-Assisted Green Energy Production II

Time: Tuesday 16:30–17:15 Location: ELP 6: HS 4

SYEC 4.1 Tue 16:30 ELP 6: HS 4

Laser-based diagnostics in nuclear fusion research at Wendelstein 7-X — •Jannik Wagner[1], Golo Fuchert[1], Ekkehard Pasch[1], Jens Knauer[1], Kai Jakob Brunner[1], Marcus Beurskens[1], Sergey A. Bozhenkov[1], Matthias Hirsch[1], Petra Kornejew[1], Maciej Krychowiak[1], Miklos Porkolab[2], Adrian v. Stechow[1], Thomas Wegner[1], Robert C. Wolf[1], and W7-X Team[1] — [1]Max-Planck-Institut für Plasmaphysik, Greifswald, Germany — [2]Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA

Thermonuclear fusion offers the potential of unlimited, carbon-free and safe energy production with little or no long living radioactive waste, compared to nuclear fission. At Wendelstein 7-X (W7-X), one of the world's largest fusion experiments, several laser-based diagnostic methods are employed. Using various wavelengths, they obtain information on plasma parameters, which are important to determine the performance of the W7-X plasma. These diagnostics evaluate for example the light scattered by plasma electrons (Thomson scattering), phase shifts of the laser beam due to plasma density fluctuations (phase contrast imaging), changes in the refractive index (interferometry) or the light emitted by laser-induced electronic transitions in spectroscopic measurements. Lasers are also used for targeted material injection into the plasma edge in order to investigate the transport of impurities (laser blow-off).

In this talk, we will give a short introduction to nuclear fusion and an overview of the laser-based diagnostics at W7-X as an example of diagnostics commonly used in fusion research.

SYEC 4.2 Tue 16:45 ELP 6: HS 4

Making ultra-thin silicon solar cells competitive through hyperuniform disordered light trapping. — •Alexander Lambertz[1,2], Esther Alarcon-Llado[1], and Jorik van de Groep[2] — [1]NWO-i AMOLF, Amsterdam, Netherlands — [2]University of Amsterdam, Amsterdam, Netherlands

Current industrys crystalline silicon solar cells rely on fossil fuels for wafer production and require too much high-quality silicon per watt-peak and are thus unsuitable to meet climate goals. Substantially reducing the absorber thicknesses will not only allow to save silicon, but also to avoid the wasteful Czoralski process, use lower quality poly-silicon, expand the application of c-Si cells to light-weight, semi-transparent, flexible, and wearable photovoltaics.

In order to overcome the shortcoming of poor absorption in thin silicon layers, we present light-trapping patterns based on hyperspectral uniformity to achieve unprecedented absorptance values. We experimentally demonstrated beyond 65% sunlight absorption in one micron thick free-standing silicon membranes and developed an analytical model based on temporal coupled-mode theory to find optimum Fourier-space profiles.

We recently fabricated ultra-thin silicon solar cells of less than five micron thickness by molecular beam epitaxy that have shown over 15 % power conversion efficiencies when our patterns were applied, where flat silicon-nitride-coated references only achieved about 10%. We furthermore give reasonable indication that efficiencies beyond 20 % are achievable already below 10 micron silicon thicknesses.

SYEC 4.3 Tue 17:00 ELP 6: HS 4

Search for ferromagnetism in Mn-doped lead halide perovskites — •Maryam Sajedi[1], Chen Luo[1], Konrad Siemensmeyer[1], Maxim Krivenkov[1], Kai Chen[1,2], James M. Taylor[1,3], Marion A. Flatken[1], Florin Radu[1], and Oliver Rader[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie

— [2]National Synchrotron Radiation Laboratory, university of Science and Technology of China, — [3]Fakultät für Physik, Technische Universität München,

Lead halide perovskites are new key materials in various application areas such as high efficiency photovoltaics, lighting, and photodetectors. Doping with Mn, which is known to enhance the stability, has recently been reported to lead to ferromagnetism below 25 K in methylammonium lead iodide (MAPbI3) mediated by superexchange. Two most recent reports confirm ferromagnetism up to room temperature but mediated by double exchange between Mn2+ and Mn3+ ions. Here we investigate a wide concentration range of MAMnxPb1*xI3 and Mn-doped triple-cation thin films by soft X-ray absorption, X-ray magnetic circular dichroism, and quantum interference device magnetometry. The X-ray absorption lineshape shows clearly an almost pure Mn2+ configuration, confirmed by a sum-rule analysis of the dichroism spectra. A remanent magnetization is not observed down to 2 K. Curie-Weiss fits to the magnetization yield negative Curie temperatures. All data show consistently that significant double exchange and ferromagnetism do not occur. Our results show that Mn is not suitable for creating ferromagnetism in lead halide perovskites.

SYEC 5: Photonic Measurement Technology for the Environment

Time: Tuesday 17:15–18:30 Location: ELP 6: HS 4

Invited Talk SYEC 5.1 Tue 17:15 ELP 6: HS 4

Studying atmospheric dynamics with lasers in remote places — •Bernd Kaifler — Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, Germany

Light detection and Ranging (LiDAR) is so far the only active remote sensing technology which allows almost continuous profiling of the atmosphere from ground to space. LiDAR systems provide measurements of key variables related to atmospheric dynamics such as air density, temperature and wind speed. As numerical weather prediction and climate models are extended to higher altitudes, observations in the middle atmosphere (approximately 15-90 km altitude) have become increasingly important for process studies and the validation of these models, and in the last decade a new generation of automatic LiDAR systems has been developed and the instruments deployed to locations around the world. Driven by the desire to probe regions of particular scientific interest, such as hotspots of atmospheric gravity waves, the instruments are often set up in remote places that could be described as “the world’s end”: from a small town above the Arctic Circle in Finland, the southern tip of the Andes Mountains in South America, to South Pole Station high on the Antarctic Plateau. This presentation highlights these places and the scientific results that were obtained by observing atmospheric gravity waves using LiDAR instruments operated on the ground, on aircrafts and on long duration stratospheric balloons.

SYEC 5.2 Tue 17:45 ELP 6: HS 4

A portable OCT system to investigate the influence of environmental factors on plants under field conditions — •Miroslav Zabic[1,2], Mohamad Bsata[1], Akshay Solleti[1], Timm Landes[1,2,3], Hans Bethge[1,2], and Dag Heinemann[1,2,3] — [1]Hannover Centre for Optical Technologies (HOT), Leibniz University Hannover, Germany — [2]Institute of Horticultural Production Systems, Leibniz University Hannover, Germany — [3]PhoenixD Cluster of Excellence, Leibniz University Hannover, Germany

Optical coherence tomography (OCT), a non-destructive imaging technique, is increasingly recognized in the field of plant biology for its potential in addressing environmental challenges in agriculture. The conventional stationary setup of OCT systems limits their application for on-site use, often necessitating plant dissection for laboratory analysis. Here we present a portable OCT system, enabling direct observation of plants in their natural environments. A possible application of this system is the monitoring of russeting in apple skin. Russeting in apples, which manifests as brown, rough patches on the skin, is promoted by several environmental factors and leads to significant economic losses, as affected apples often fail to meet market standards for sale. This not only affects profitability but also raises concerns about sustainability, as it results in increased food waste and resource inefficiency. By enabling OCT imaging on apples still on the tree, our system could offer new insights in russeting development and its dynamic interplay with environmental factors such as humidity. We detail technical aspects of our system and present preliminary results.

SYEC 5.3 Tue 18:00 ELP 6: HS 4

Characterization of PFAS transport in groundwater via laser-based ^{85}Kr and ^{39}Ar age dating — •Florian Meienburg[1,2,3,4], David Wachs[1,2], Axel Suckow[3], Christoph Gerber[3], Alec Deslandes[3], Punjehl Craine[3], Rohan Glover[4], Thomas Chambers[4], Ivan Herrera[4], Hue T. Nguyen[5], Jochen Müller[5], Markus Oberthaler[1], and Werner Aeschbach[2] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Institute of Environmental Physics, Heidelberg, Germany — [3]CSIRO, Adelaide, Australia — [4]University of Adelaide, Adelaide Australia — [5]University of Queensland, Brisbane, Australia

Radioisotopes are a widely used and important tool for dating environmental systems. Due to their chemical inertness and their well-understood input functions, the radioisotopes of argon and krypton are especially valuable tracers. Furthermore, their half-lives of 10.8 years (^{85}Kr), 269 years (^{39}Ar) and 229,000 years (^{81}Kr) cover a wide range of timescales and are therefore of interest for various tracer-based water studies. However, a very small abundance as small as 10^{-16}, requires an ultra-sensitive and highly isotopically selective detection method which is achieved by the quantum technology Atom Trap Trace Analysis (ATTA).

The presented study makes use of this unique measurement technique to investigate a per- and polyfluoroalkyl substance (PFAS) plume in groundwater at a site in Queensland, Australia. Age dating tracers combined with PFAS concentration measurements give insights into the transport characteristics of these forever chemicals.

SYEC 5.4 Tue 18:15 ELP 6: HS 4

ArTTA - Dating of environmental samples with ^{39}Ar — •David Wachs[1,2], Joshua Marks[1], Pascal Bohleber[3,4], Andrea Fischer[3], Yannis Arck[1], Martin Stocker-Waldhuber[3], Julian Robertz[2], Markus Oberthaler[2], and Werner Aeschbach[1] — [1]Institute of Environmental Physics, Heidelberg — [2]Kirchhoff-Institute for Physics, Heidelberg — [3]Institute for Interdisciplinary Mountain Research, Innsbruck, Austria — [4]Ca* Foscari University of Venice, Venice, Italy

Argon Trap Trace Analysis (ArTTA) for measuring ^{39}Ar concentrations represents an applied quantum technology to perform age dating of environmental samples. The isotope ^{39}Ar with its half life of 268 years uniquely enables dating in the age range between 50 and 1000 years. The very low isotopic abundance of about 10^{-15} however sets high demands on the measurement method. ArTTA has reduced the required sample sizes to routinely applicable amounts and thus enables ^{39}Ar age measurements in various settings from oceans over groundwater to glaciers. This work aims at presenting the technical concept of the ArTTA analytical method, from the initial excitation of the atoms by plasma discharge to the trapping by laser cooling methods and the current challenges and upgrades of the system. Furthermore, environmental applications will be discussed with a focus on the dating of Alpine glaciers. In this environmental archive, the age itself can provide information about environmental changes and processes.