Symposium New Trends in Laser Systems and their Applications for Photonic Quantum Systems and Emerging Technologies (SYLA)

jointly organised by
the Short Time-scale Physics and Applied Laser Physics Division (K) and
the Wissenschaftliche Gesellschaft für Lasertechnik (WLT)

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The first part of the Symposium will present production technologies for integrated photonic (quantum-) systems. As quantum and photonic technologies transit from laboratory research to real-world applications, scalable and robust production processes are becoming critical. This session focuses on advanced manufacturing technologies enabling the industrialization of integrated photonic and quantum systems. The second part will present laser sources for emerging technologies. Laser sources are essential enablers of disruptive technologies that are set to shape the future across multiple high-impact fields. This session highlights advancements and specific requirements for laser systems in groundbreaking areas like quantum systems, photonic chips, nuclear fusion, and EUV lithography.

Overview of Invited Talks and Sessions

(Lecture halls P1 and HS 20)

Invited Talks

SYLA 1.1	Tue	11:00–11:30	P 1	**3D printing of integrated optics on thin-film lithium niobate for quantum photonic applications** — •Moritz Hinkelmann, Alexandra Rittmeier, Elisavet Chatzizyrli, Philipp Gehrke, Muhamed A. Sewidan, Andreas Wienke, Dietmar Kracht, Michael Kues
SYLA 1.2	Tue	11:30–12:00	P 1	**Photonic Quantum Sensors and Their Fabrication Using Femtosecond Laser Micromachining** — •Tobias Menold
SYLA 1.3	Tue	12:00–12:30	P 1	**3D printed micro-optics: Novel fabrication enabling innovative designs** — •Michael Schmid, Simon Thiele, Nils Fahrbach
SYLA 2.1	Wed	14:30–15:00	HS 20	**Low-Noise Quantum Frequency Conversion for NV-Based Quantum Network Nodes** — •Bernd Jungbluth, Fabian Geus, Ludwig Hollstein, Hans Huber, Florian Elsen
SYLA 2.2	Wed	15:00–15:30	HS 20	**ZEISS Innovation: EUV lithography, a European Success story** — •Dirk Heinrich Ehm
SYLA 2.3	Wed	15:30–16:00	HS 20	**Advancements in Infrared Spectroscopy with Undetected Photons** — •Chiara Lindner, Frank Kühnemann
SYLA 2.4	Wed	16:00–16:30	HS 20	**Ultrafast 2μm fiber lasers for scientific and industrial applications** — Tobias Heuermann, Christian Kern, Ziyao Wang, Evgeny Shestaev, •Oliver Herrfurth, Christian Gaida, Tino Eidam

Sessions

SYLA 1.1–1.3	Tue	11:00–12:30	P 1	**Production Technologies for Integrated Photonic (Quantum) Systems**
SYLA 2.1–2.4	Wed	14:30–16:30	HS 20	**Laser Sources for Emerging Technologies – Enabling the Future**

SYLA 1: Production Technologies for Integrated Photonic (Quantum) Systems

Time: Tuesday 11:00–12:30 Location: P 1

Invited Talk SYLA 1.1 Tue 11:00 P 1

3D printing of integrated optics on thin-film lithium niobate for quantum photonic applications — •Moritz Hinkelmann[1,2], Alexandra Rittmeier[1,2], Elisavet Chatzizyrli[1,2], Philipp Gehrke[1,2], Muhamed A. Sewidan[2,3], Andreas Wienke[1,2], Dietmar Kracht[1,2,3], and Michael Kues[1,2,3] — [1]Laser Zentrum Hannover e.V., Hannover, Germany — [2]Cluster of Excellence PhoenixD, Leibniz University Hannover, Hannover, Germany — [3]Institute of Photonics, Leibniz University Hannover, Hannover, Germany

In this contribution, we will review cutting-edge progress in 3D printing of integrated optics, emphasizing high-resolution techniques that enable rapid and sustainable photonic chip production, such as multi-photon lithography. Particular focus will be placed on thin-film lithium niobate, whose exceptional electro-optic and second-order nonlinear optical properties make this material one of the most promising candidates for quantum photonic applications. We highlight advances in fabricating low-loss optical waveguides - especially etchless, strip-loaded concepts that mitigate sidewall roughness while maintaining strong modal confinement. We discuss how these developments are accelerating the realization of compact, scalable quantum photonic integrated circuits. Initial results demonstrate that this approach can facilitate the production of a high-performance integrated device capable of generating entangled photon pairs through spontaneous parametric down conversion.

Invited Talk SYLA 1.2 Tue 11:30 P 1

Photonic Quantum Sensors and Their Fabrication Using Femtosecond Laser Micromachining — •Tobias Menold — Institut für Strahlwerkzeuge, Universität Stuttgart, Pfaffenwaldring 43, 70569 Stuttgart

Ultrafast lasers are an extremely versatile tool for fabricating integrated devices in transparent materials, particularly in the fields of microelectronics, advanced packaging, and integrated photonics. Their potential is especially relevant in the emerging field of quantum sensing, which is currently transitioning toward industrialization and practical applications. By leveraging ultrafast lasers, it is possible to fabricate nearly all passive components of integrated photonic circuits on glass-based substrates. Furthermore, these circuits can be coupled with quantum sensors, such as vapor-cell-based devices, providing a scalable manufacturing route for miniaturized architectures of quantum sensors. This talk presents an overview of possible manufacturing techniques, illustrated through a demonstrator of a quantum-based gyroscope. Such a device represents a breakthrough in navigation, with transformative applications in autonomous driving, navigation of small aerial vehicles such as drones, and defense-related Positioning, Navigation, and Timing (PNT) capabilities particularly in scenarios where Global Navigation Satellite Systems (GNSS) may be compromised through jamming or spoofing.

Invited Talk SYLA 1.3 Tue 12:00 P 1

3D printed micro-optics: Novel fabrication enabling innovative designs — •Michael Schmid, Simon Thiele, and Nils Fahrbach — Printoptix GmbH, Nobelstraße 15, 70569 Stuttgart, Germany

In recent years, 3D direct laser writing (also known as 2pp), has established itself as an irreplacable tool to fabricate complex micro-optical systems.

From the initial prototype fabrication in the academic field, the fabrication method has established itself on the commercial field, offering annual production in the 100.000s of complex, user defined micro-optical parts.

The design possibilities of 3D printed optics on the μm up to mm scale are unmatched, enabling unique optical designs with outstanding performance. This includes monolithic free-form aspheric multi-lens systems, the combination of refractive, diffractive and reflective optics, as well as different lens materials with varying dispersion, and the integration of apertures. Both, illuminating and imaging optics, as well as holographic optics, can be 3d printed. These possibilities offer innovative optical designs in various fields such as endoscopy, beam shaping, and microscopy.

SYLA 2: Laser Sources for Emerging Technologies – Enabling the Future

Time: Wednesday 14:30–16:30 Location: HS 20

Invited Talk SYLA 2.1 Wed 14:30 HS 20

Low-Noise Quantum Frequency Conversion for NV-Based Quantum Network Nodes — •Bernd Jungbluth[1], Fabian Geus[1], Ludwig Hollstein[1], Hans Huber[1], and Florian Elsen[1,2] — [1]Fraunhofer-Institute for Laser Technology ILT, Aachen, Germany — [2]RWTH Aachen University, Aachen, Germany

We present two low-noise quantum frequency converters enabling telecom-band photon emission from NV centers. The NORA-QFC, deployed in the Q.Link demonstrator (Delft-The Hague), achieves >48% efficiency with less than 2 noise counts per second and per picometer filter bandwidth. A second, compact two-stage converter developed in the BMBF-funded HIFI project was implemented in Aachen for integration into a local NV-center node for scalable photonic interface testing.

Invited Talk SYLA 2.2 Wed 15:00 HS 20

ZEISS Innovation: EUV lithography, a European Success story — •Dirk Heinrich Ehm — Rudolf-Eber-Strasse 2 73447 Oberkochen; Germany

More than 80% of all microchips manufactured worldwide today are produced with ASML lithography systems with ZEISS optics as their central core. In the field of EUV lithography the share is even 100%, together with a strong growth expectation in the coming years driven e.g. by artificial intelligence applications. Already in 2020 ZEISS, together with TRUMPF, and Fraunhofer IOF, have been awarded with the *Deutscher Zukunftspreis* for their contributions in the field of EUV lithography.

Invited Talk SYLA 2.3 Wed 15:30 HS 20

Advancements in Infrared Spectroscopy with Undetected Photons — •Chiara Lindner and Frank Kühnemann — Fraunhofer Institute for Physical Measurement Techniques IPM, Freiburg, Germany

Correlated photon pairs offer innovative approaches to infrared spectroscopy, allowing for high-resolution measurements using only visible light detection. This technique addresses the limitations of traditional infrared detectors, such as speed, cost, and noise. Key element is the quantum interference effects of correlated photon pairs created by spontaneous parametric down-conversion (SPDC) within a nonlinear interferometer. Combining this quantum technology with established Fourier-Transform Infrared Spectroscopy methods (then referred to as Q-FTIR) enables high-performance infrared spectroscopy. This research paves the way for future applications and new research fields such as quantum hyperspectral imaging. In this talk, we will cover the fundamentals of measurements with undetected photons, discuss recent implementations for infrared spectroscopy and take an outlook.

Invited Talk SYLA 2.4 Wed 16:00 HS 20

Ultrafast 2μm fiber lasers for scientific and industrial applications — Tobias Heuermann, Christian Kern, Ziyao Wang, Evgeny Shestaev, •Oliver Herrfurth, Christian Gaida, and Tino Eidam — Active Fiber Systems GmbH

Tm-based fiber lasers have emerged as compelling ultrafast sources in the 2-μm spectral region. We report recent progress on a thulium-doped fiber chirped-pulse amplification system aiming to deliver 200 W average power, 2 mJ pulse energy, and 150 fs pulse duration at 2μm. Key challenges, including atmospheric water absorption, high thermal load and nonlinear effects in fiber amplifiers, are mitigated through a novel fiber module design and a sealed system enclosure enabling dry or vacuum operation. Further peak-power scaling is achieved via

spectral phase and amplitude optimization of the seed pulses.

Furthermore, we present results on a >500W / 5mJ source featuring between 10ns to 500ns pulse duration. A potential application can be EUV plasma generation, but also other applications seem feasible. In summary, we show different system architectures in the ultrafast and ns-regime that represent record values in the commercial sector.