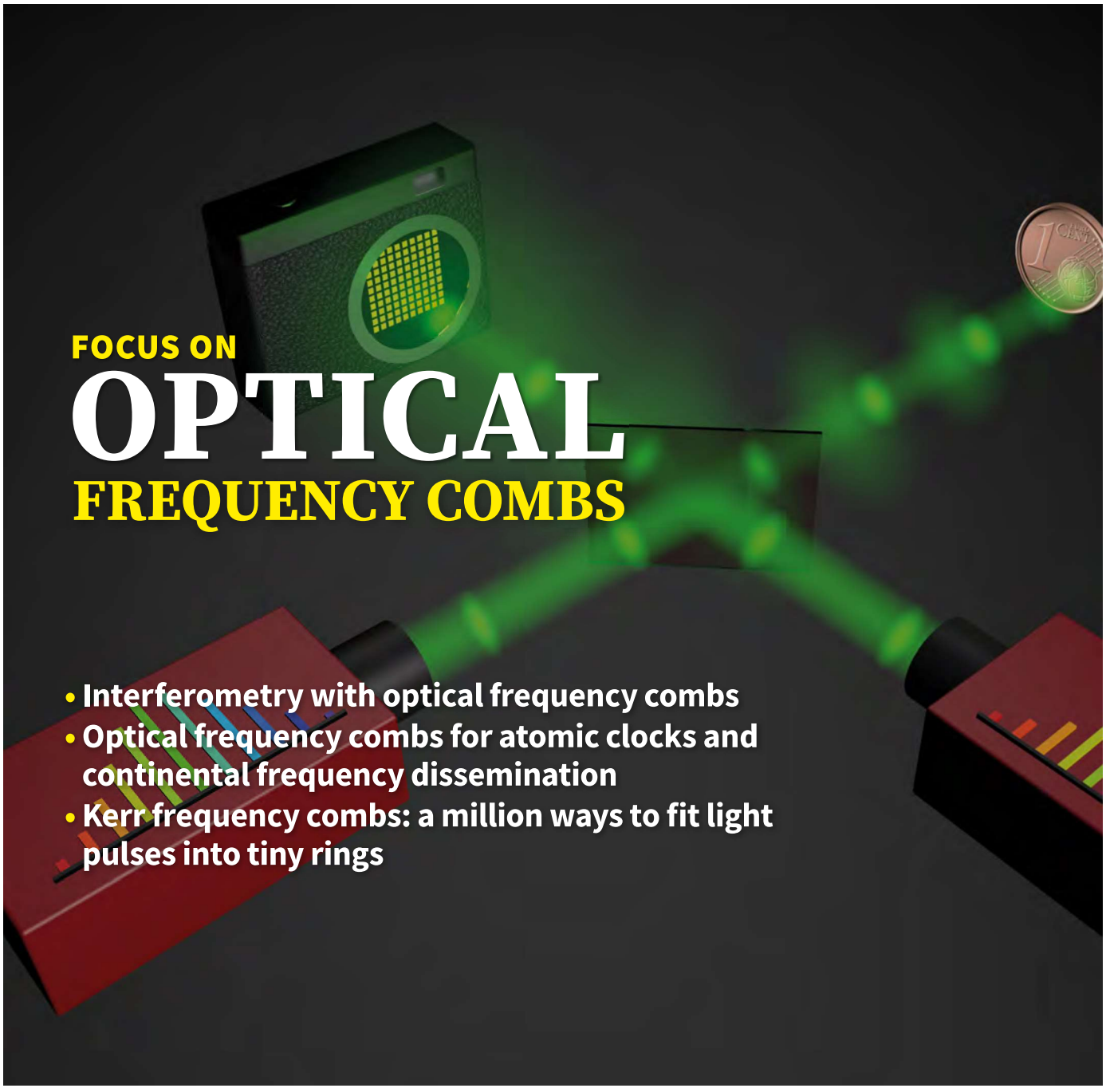
N°113

Photoniques

LIGHT AND APPLICATIONS | EOS & SFO JOINT ISSUE



FOCUS ON

OPTICAL FREQUENCY COMBS

- Interferometry with optical frequency combs
- Optical frequency combs for atomic clocks and continental frequency dissemination
- Kerr frequency combs: a million ways to fit light pulses into tiny rings

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Editorial

NICOLAS BONOD
Editor-in-Chief

Photonics, a Science of Precision and Accuracy

The history of science teaches us how numerous scientific breakthroughs were achieved by increased precision and accuracy. It also highlights how pushing forward the limits of precision and accuracy opens the way to novel research fields and applications.

The story of optical frequency combs is the story of an optical spectroscopy method, which was developed to overcome the limits that were reached by conventional methods in atomic spectroscopy. This technique based on phase-locked lasers, initiated in the 1970's, turned out to be a major scientific breakthrough. Its importance was highlighted in 2005 when the Nobel Prize in Physics was awarded to J. L. Hall and T. W. Hänsch "for their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique". Articles of this special feature unveil the richness of this method and its huge potential for pushing forward measurement limits in terms of precision and accuracy. The fast development of this technology also benefited from the remarkable work of photonic companies, which managed to implement the most advanced lasers and optical techniques into ergonomic devices providing reliable and commercial sources of optical frequency combs.

Another field associated with excellence and precision is that of optical glass, whose development revolutionized optics. 2022 was declared on May 18th 2021 a United Nations International Year of Glass, and the zoom of this issue is dedicated to this event. Optical glass has deeply broadened our horizons, from the solar system and beyond with the development of telescopes, to the nano/micro world, in the solid state and in life sciences, with the constant progress achieved in optical microscopy. It has also brought communications to a new era by connecting billions of peoples with optical fibers. All these technologies have pushed the efficiency of optical glass to new standards with extremely precise polishing, structuring and transparency. The long and rich history of optical glass is far from being concluded since the soar of micro and nanotechnologies, a science of precision and accuracy, is spurring exciting and original concepts for tailoring light propagation through meta-optics.

This international issue inaugurates the publication of the section "Lab work" devoted to original optical set-ups aimed at learning optics and photonics though experiments. And what better topic than the emblematic experiment on the violation of Bell's inequalities to inaugurate this section? The authors explain how the EPR paradox, long considered a "Gedankenexperiment", has now become a very exciting lab work in order to introduce quantum concepts and related technologies to students.

The preparation of this issue was marked by the invasion of Ukraine by Russia. The international scientific community has been deeply saddened by this attack on a sovereign country, which severely violates international laws. I warmly thank all the scientific societies that clearly and promptly condemned the invasion of Ukraine by Russia, and in particular our partners SFO, SFP, EOS and EDP Sciences.



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SFO forewords

ARIEL LEVENSON
President of the French Optical Society

"Morally as well as physically, the first of human rights is the right to light."
"Au moral comme au physique, le premier des droits de l'homme, est le droit à la lumière"
Proses philosophiques, Victor Hugo

The United Nations International Year of Light in 2015 was a global success in celebrating the many ways that light impacts society. The desire to ensure its legacy led UNESCO to proclaim a permanent annual International Day of Light, and this coming edition in 2022 will also be an occasion to remember our dear friend and colleague Costel Subran who passed away in January. Costel was a passionate organizer of International Day of Light activities in France, and as he would say, Light must go on!

Among the many International Day of Light events in France, I wish to highlight the development of laser teaching kits by the SFO Education Commission intended for outreach, especially at secondary schools. These will be freely distributed to accompany dissemination projects, and please contact the Education Commission for details. Let the light penetrate everywhere!

And…Let the sunshine in! From 4-8 July, the SFO Congress will take place in the Côte d'Azur. OPTIQUE Nice 2022 will bridge the academic and industrial communities, with outstanding plenary speakers including: Alain Aspect, Sophie Brasselet, Rémi Carminati, Jean Dalibard, Frédérique de Fornel, Jérôme Faist, Philippe Goldner, Aurélie Jullien, Sophia Kazamias and Philip Russell. The congress also includes tutorials, SFO Club thematic sessions, and 50 industrial and pedagogical exhibition stands. In addition, to celebrate the International Day of Light several events are planned:

- an exhibition of Low Cost Innovation in Optics organized by the SFO Optics and Physics without Borders Commission, targeted to help promote optics in countries and regions where access to science and technology can be difficult
- a workshop on gender equality organized by the SFO Gender Equality Commission, which aims to develop realistic and efficient actions to address this important issue
- a Scientibus hosted by the SFO Education Commission and the REOD Network, which will showcase a range of exciting experiments to school students

2022 is also the International Year of Glass, and Glass and Light marry well in the SFO Club for Guided Optics (JNOG) that recently joined with the Optical Fibers and Networks Club to better combine the academic and industrial communities in a reinforced JNOG.

In this Photoniques issue celebrating Bell's Inequality experiments, I would like to warmly congratulate our colleague Alain Aspect for his nomination as Honorary Member of OPTICA, a highly deserved and prestigious recognition.

It is a pleasure to share this international edition of Photoniques with the European Optical Society, and I would like here to affirm SFO's full support of EOS's declaration against military intervention in Ukraine. Our thoughts go out to our Ukrainian colleagues and their families, and all whose safety has been jeopardized. They can be assured of our solidarity: нехай вони будуть впевнені в нашій солідарності. At the same time, we know that our many Russian colleagues are equally concerned, and we look forward to the time in the hopefully near future where international science can once again show the way towards peace.

Photoniquement vôtre
Ariel Levenson
Directeur de recherche CNRS
Président de la SFO

The next Laser-Induced Breakdown Spectroscopy France Days, organized by the SFO LIBS Club will take place in Marseille on June 1 and 2, 2022 (France), on the Luminy campus of Aix-Marseille University. The LIBS 2022 Days will be a unique opportunity to bring together the entire chain of specialists in this increasingly developed instrumentation, from academics to manufacturers and instrumentation vendors.

https://www.sfoptique.org/agenda

THE SECOND WAVINAIRE: METASURFACES – JUNE 2022

After the great success of the first edition, the SFO, the GDR Complexe and the GDR Ondes are pleased to announce the second Wavinaire – open questions which will be held on June. The wavinaires are intended for students, post-docs, engineers and researchers. This second edition is organized around an emblematic publication:

"Light Propagation with Phase Discontinuities: Generalized Laws of Reflection and Refraction", N. Yu, P. Genevet, M. A. Kats, F. Aieta, J.-P. Tetienne, F. Capasso, and Z. Gaburro, Science 334, pp. 333-337 (2011)

An introductory mini course on a basic concept necessary for understanding the article, as well as a brief presentation of its main results, given by a post-doctoral fellow, will be followed by a critical perspective vision proposed by two internationally recognized experts, Pierre Chavel from Institut d'Optique Graduate School and Bernard Kress Director, Optical Engineering - AR hardware - Google, who will discuss the industrial and academic impacts. The Wavinaire will end with questions and a free discussion.

https://www.sfoptique.org/pages/sfo/wavinaire.html

WELCOME TO OPTIQUE NICE 2022

You are cordially invited to participate in the 9th Congress of the French Optical Society SFO, which will take place in Nice, France from July 4 to July 8. This congress provides fertile ground for beneficial exchanges between academic and industrial actors of optics and photonics.

Plenary session : Alain Aspect, Sophie Brasselet, Jean Dalibard, Frédérique De Fornel, Rémi Carminati, Jérôme Faist, Philippe Goldner, Sophie Kazamias, Aurélie Jullien and Philip Russell.

Tutorials sessions will introduce different hot topics: Thermal emission at the nanoscale by Jean-Jacques Greffet and Yannick De Wilde, Single spin detection by Vincent Jacques, Multiphoton microscopy by Emmanuel Beaurepaire, Earth-space telemetry by Clément Courde and we will even go to Mars with Supercam on the Rove Perseverance by Pernelle Bernardi.

OPTIQUE Nice Prizes, to promote optics and photonics research

To recognize excellence, the SFO awards two Scientific Prizes during this congress: Grand Prix SFO Léon Brillouin and the Young researcher Fabry-de Gramont prize. OPTIQUE SFO Congress welcomes for the second time the Jean Jerphagnon Prize, a prestigious award for outstanding scientific contributions with high potential industrial impact.

Women in Optics and Physics commission, to promote parity in Optics

The congress pays a special attention to the number of women working in optics, at all responsibility levels and tends to parity on invited conferences.

PhD students and young researchers are welcome in OPTIQUE Nice

Our goal is to allow all PhD students to participate once in the congress during their thesis. More than 200 students are expected. OPTIQUE Nice 2022 will provide a dedicated and friendly space to initiate a "Youth" action...

Nice hosts the 9th edition of SFO biennial congress

The members of local organizing committee orchestrated by Sébastien Tanzilli do their utmost efforts to accommodate hundreds of participants in a friendly atmosphere. During our networking program you will get to know this exciting city in all its aspects.

OPTIQUE Nice 2022 is an International Day of Light event
https://www.sfoptique.org/

2ND COLLOQUIUM ON THE PHYSICS AND APPLICATIONS OF METASURFACES

Fortezza da Basso, Florence, Italie, July 18-22, 2022

This 2nd colloquium is organized by the Nanophotonics Club of the French Optical Society (SFO) in collaboration with the Italian Society for Optics and Photonics (SIOF). The attendees will benefit from outstanding international keynote speakers, Andrea Alù (CUNY), Shanui Fan (Stanford University), Federico Capasso (Harvard University), Philippe Lalanne (CNRS Bordeaux), Anatoly Zayats (King's College London) will present the latest developments in all areas of Metasurfaces.
https://www.sfoptique.org/pages/sfo/colloque-metasurface.html

Research in applied optics
at IOGS together with industrial partners

The Institute of Optics Graduate School (IOGS) has been strengthening its applied research activity with industrial partners, both French and foreign, for a few years now, notably with the creation in early 2019 of a dedicated Industrial Photonics team at the Charles Fabry Laboratory (LCF, CNRS Joint Research Unit 8501) in Palaiseau (Ile de France), headed by Yvan Sortais.

Like any team of a laboratory under the supervision of the CNRS, this one does not aim at competing with private offices, nor to interfere in the competition between companies. It responds to requests from industrials which contain at least one original and innovative point in terms of research, which can be developed in the form of a patent or scientific communication, and when it is free to do so without interfering with the interests of another industrial with whom it is already working on a similar or related subject.

IOGS intends to offer the industry a response adapted to its needs: services, collaboration, supervision of doctoral theses (with industrial funding in particular), and funding applications for shared projects. IOGS status as a higher education and research institution allows industrials to benefit from the Research Tax Credit.

In all cases, whether or not the initial request from the industrial is ultimately translated into a contract, technical exchanges are governed by a confidentiality agreement signed by both parties. When it continues beyond the initial exchanges, the interaction can last from a few weeks for the shortest services, to several years for research projects such as a PhD thesis.

The Industrial Photonics team deals in particular with requests related to the design, prototyping and metrology of optical systems, components or surfaces, in particular freeform optics, or optronic systems, for lighting or imaging. The studies concern many fields (defense, automotive, pharmaceutical, cosmetics, etc.).

The Industrial Photonics team works closely with the French Freeform Optics Association (Freeform Optics - Research and Solutions), of which IOGS is a founding member (see Refs. [1,2]).

An example of a partnership study between the LCF and industry : Design and implementation of benches for characterizing the optical properties of vials for the pharmaceutical industry (Credit: SGD Pharma)

It relies on the human and material resources of the LCF: computational resources, modeling (optical, mechanical, photometric, thermal, thin films, radiation, etc.), prototyping (precision optics, mechanics, electronics, 3D printing, etc.), and metrology (deformation and roughness of surfaces, transmission and spectral reflection, radiometric and photometric fluxes, color and visual appearance of materials).

More generally, IOGS offers industry the expertise of the teams from the three laboratories it oversees with the CNRS: the LCF, the Laboratoire de Photonique Numérique et Nanophotonique (LP2N, UMR CNRS 5298) and the Laboratoire Hubert Curien (UMR CNRS 5516). IOGS' response to industrial requests is coordinated by the Innovation and Industrial Relations Department.

Contact: dire@institutoptique.fr.

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[1] R. Geyl, F. Houbre, Y. Cornil, Th. Lépine and Y. Sortais, Optiques freeform : défis et perspectives, Photoniques 106, p. 17 (2021).

[2] Y. Sortais, Th. Lépine, J.-J. Greffet, Des formes libres dans notre champ de vision, La Recherche 568, p. 54 (2022).

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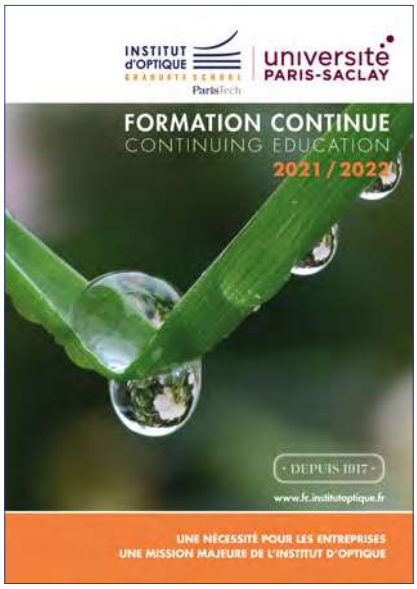
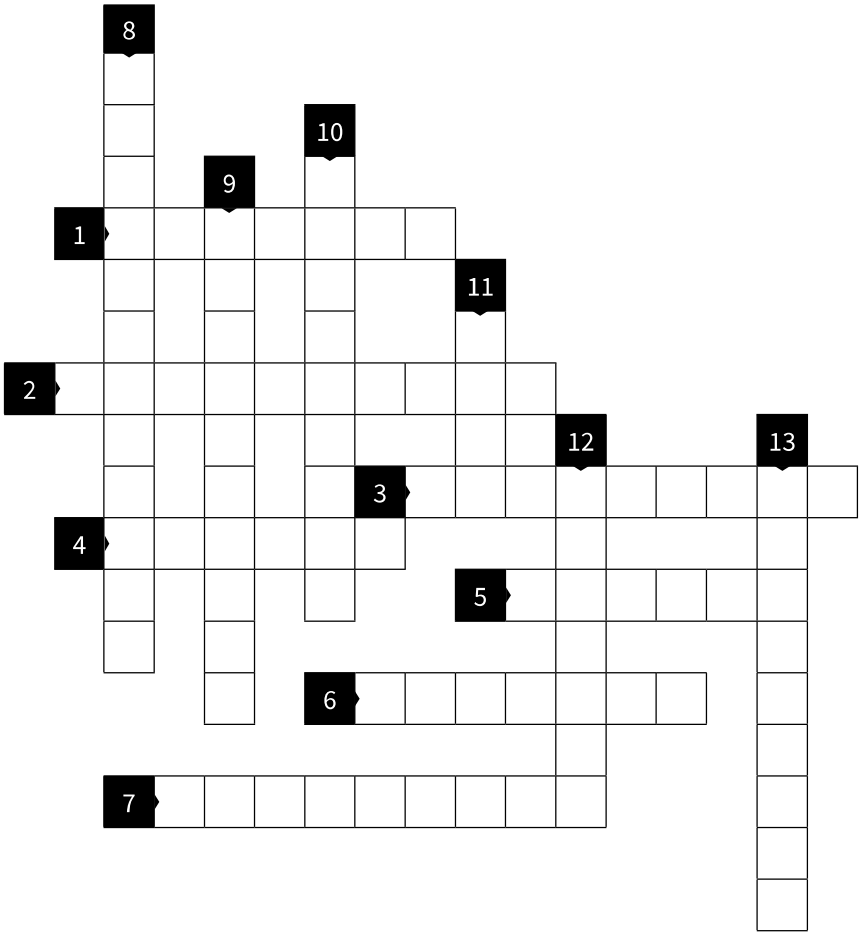


CROSSWORDS
ON OPTICAL FREQUENCY COMBS

By Philippe Adam



1 Its phase has to be compared with envelope
2 Needed mode to generate frequency combs
3 Interval precisely equal to the repetition rate
4 Spanning music
5 2005 Nobel Prize in Physics
6 Used to measure unknown frequencies
7 Straightforward application of FC
8 Very straightforward application of FC
9 Separation frequency between two modes
10 Long wavelength today produced by photonic chips
11 Nonlinear effect which could induce FC in micro-resonators
12 Efficient (or finesse) factor
13 Transmitted from pulse to pulse

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HOW TO SELECT A NANOPOSITIONER SOLUTION?

Emmanuel Pascal[1]*, Scott Jordan[2]
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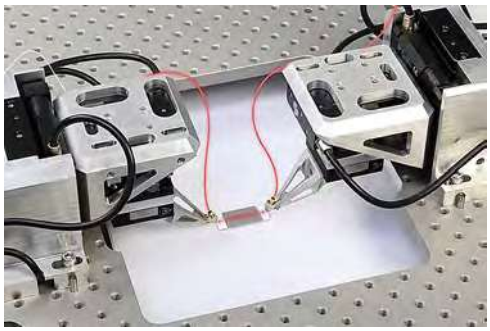

https://doi.org/10.1051/photon/202211360

Many recent innovations have been enabled by high precision positioning devices operating at a nanometer level or below. Developments in this field have been very fast over the last years supported by applications in material sciences, genomics, photonics, defense, biophysics, and semiconductors creating challenges for the scientists and engineers in need of precise and yet robust positioning systems. The critical point is: how should you select your nano positioning solution?

NANOPOSITIONING SYSTEM: A NEW DEFINITION?

By its original definition, a nanopositioning device is a mechanism capable of repeatedly delivering motion in increments as small as one nanometer. Lately, demands from industry and research have pushed requirements to the picometer range. While electroceramics such as piezo materials with flexure guides remain the gold standard for breaking the resolution nanometer barrier, there are several other solutions available today providing repeatable single-digit nanometer step resolution including linear motors, voice-coil drives, and frictionless guides such as air bearings and magnetic bearings.

Emmanuel Pascal: Country Director, PI France
Scott Jordan: Head of Photonics Market Segment, PI Group

Dynamic issues dominate many applications and can be addressed by novel approaches that benefit real-time/high-dynamic applications. They present new opportunities for optimizing process economics.

Rapid testing and packaging of the latest silicon photonics (SiPh) devices — starting at the wafer level — is the perfect example. In these applications, optical elements and probes must be brought into perfect coupling with devices in various stages of manufacture from wafer to final package. With thousands of optical elements on a single wafer, coupling time becomes the most critical cost factor in testing. The same applies to all further process steps up to assembly and packaging, where active and passive optical elements (e.g., LEDs, laser diodes, photodiodes and optical fibers and waveguides) must be precisely positioned

Figure 1. A double-sided test and alignment system for silicon photonics wafers based on hexapods and piezo nanopositioning stages to combine the fastest alignment speeds with the highest flexibility.