<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
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<tbody>
<tr>
<td>μTAS</td>
<td>micro total analysis system</td>
</tr>
<tr>
<td>1D</td>
<td>one-dimensional</td>
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<tr>
<td>2D</td>
<td>two-dimensional</td>
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<tr>
<td>3D</td>
<td>three-dimensional</td>
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<tr>
<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>AFM</td>
<td>atomic force microscopy</td>
</tr>
<tr>
<td>ALE</td>
<td>arbitrary lagrangian eulerian</td>
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<tr>
<td>AlN</td>
<td>aluminum nitride</td>
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<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>AO</td>
<td>adaptive optics</td>
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<tr>
<td>AOM</td>
<td>acousto-optical modulator</td>
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<tr>
<td>AR</td>
<td>anti-reflective</td>
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<tr>
<td>ASIC</td>
<td>application-specific integrated circuit</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>AWG</td>
<td>arrayed waveguides</td>
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<tr>
<td>AWN</td>
<td>acid waste neutralization</td>
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<tr>
<td>BEM</td>
<td>boundary element method</td>
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<tr>
<td>BPM</td>
<td>beam propagation method</td>
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<tr>
<td>BPSG</td>
<td>boron phosphorus doped silicate glass</td>
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<tr>
<td>CAD</td>
<td>computer-aided design</td>
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<tr>
<td>CAIBE</td>
<td>chemically assisted ion-beam etching</td>
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<tr>
<td>CEM</td>
<td>contactless embossing microlenses</td>
</tr>
<tr>
<td>CGH</td>
<td>computer-generated hologram</td>
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<tr>
<td>CMOS</td>
<td>complementary metal-oxide semiconductor</td>
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<tr>
<td>CMP</td>
<td>chemical mechanic polishing</td>
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<tr>
<td>CMS</td>
<td>ciliary motion system</td>
</tr>
<tr>
<td>CTE</td>
<td>coefficient of thermal expansion</td>
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<tr>
<td>CVD</td>
<td>chemical vapor deposition</td>
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<tr>
<td>DC</td>
<td>direct current</td>
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<tr>
<td>DDR</td>
<td>double data rate</td>
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<tr>
<td>DEMUX</td>
<td>demultiplexing</td>
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<tr>
<td>DMD</td>
<td>digital micromirror device</td>
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<tr>
<td>DOE</td>
<td>diffractive optical element</td>
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<tr>
<td>DOF</td>
<td>degrees of freedom</td>
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<tr>
<td>DRAM</td>
<td>digital random access memory</td>
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</table>
DRIE deep reactive ion etching
DSC differential scanning calorimetry
DUV deep ultraviolet
DWDM dense wavelength division multiplexing
DXRL deep X-ray lithography
EC electric circuit
EDFA erbium-doped fiber amplifier
ELT extremely large telescope
ETV electrothermal vibromotor
EUV extreme ultraviolet
ExAO extreme adaptive optics
FP or F-P Fabry-Perot
FD finite difference
FHD flame hydrolysis deposition
FIB focused ion beam
FPA focal plane array
FSMOS free-space micro-optical system
FS face shear
FWHM full width half maximum
GLV grating light valve
GRIN gradient index
HEBS high-energy beam sensitive (glass)
HOE holographic optical element
I/O input/output
IBE ion beam etching
IC integrated circuit
ICP inductive coupled plasma (etching)
IR infrared
LC liquid crystal
LIGA lithography, electroplating, and molding
LPCVD low-pressure chemical vapor deposition
LVCMOS low-voltage CMOS
LVDS low-voltage differential signal
MARS modulated antireflecting surface
MC magnetic circuit
MCM multichip module
MDOF master degrees of freedom
MEMS micro-electro-mechanical-systems
MHz megahertz
MMIC monolithic microwave integrated circuit
MOEMS micro-opto-electro-mechanical-systems
MOSMOD micromachined optical shutter modulation
MUMPS multi-user MEMS process service
MUX multiplexing
NA numerical aperture
<table>
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<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>OXC</td>
<td>optical crossconnect</td>
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<tr>
<td>PCR</td>
<td>polymerase chain reaction</td>
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<tr>
<td>PDE</td>
<td>partial differential equation</td>
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<tr>
<td>PE</td>
<td>planar expansion</td>
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<tr>
<td>PECVD</td>
<td>plasma-enhanced chemical vapor deposition</td>
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<tr>
<td>PLC</td>
<td>planar lightwave circuit</td>
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<tr>
<td>PLE</td>
<td>parallel length expansion</td>
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<tr>
<td>PMMA</td>
<td>polymethyl methacrylate</td>
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<tr>
<td>PSF</td>
<td>point spread function</td>
</tr>
<tr>
<td>PVdF</td>
<td>polyvinylidene fluoride</td>
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<tr>
<td>REM</td>
<td>raster electron microscope</td>
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<tr>
<td>REPM</td>
<td>rare earth permanent magnet</td>
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<tr>
<td>RF MEMS</td>
<td>radio-frequency MEMS</td>
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<tr>
<td>RIBE</td>
<td>reactive ion beam etching</td>
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<tr>
<td>RIE</td>
<td>reactive ion etching</td>
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<tr>
<td>rms</td>
<td>root-mean-square</td>
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<tr>
<td>ROM</td>
<td>reduced order modeling</td>
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<tr>
<td>RSD</td>
<td>retinal scanning display</td>
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<tr>
<td>SAM</td>
<td>self-assembled monolayer</td>
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<tr>
<td>SCREAM</td>
<td>single crystalline reactive etching and metallization</td>
</tr>
<tr>
<td>SDA</td>
<td>scratch drive actuator</td>
</tr>
<tr>
<td>SDR</td>
<td>single data rate</td>
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<tr>
<td>SEM</td>
<td>scanning electron microscope</td>
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<tr>
<td>SLM</td>
<td>spatial light modulator</td>
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<td>SMA</td>
<td>shape memory alloy</td>
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<td>SME</td>
<td>shape memory effect</td>
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<tr>
<td>SOAC</td>
<td>systems on-a-chip</td>
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<tr>
<td>SOAP</td>
<td>systems on-a-package</td>
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<tr>
<td>SOI</td>
<td>silicon-on-insulator</td>
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<tr>
<td>SRAM</td>
<td>static random access memory</td>
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<tr>
<td>SUMMiT</td>
<td>Sandia’s ultraplanar multilevel MEMS technology</td>
</tr>
<tr>
<td>SVG A</td>
<td>super video graphics adapter</td>
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<tr>
<td>SWIR</td>
<td>short-wave infrared</td>
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<tr>
<td>SXGA</td>
<td>super-extended graphics adapter</td>
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<tr>
<td>TCR</td>
<td>temperature coefficient of resistance</td>
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<tr>
<td>TE</td>
<td>transverse electric</td>
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<tr>
<td>TE</td>
<td>thickness expansion</td>
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<tr>
<td>TEOS</td>
<td>tetra ethyl orthosilicate</td>
</tr>
<tr>
<td>TFAMA</td>
<td>thin-film-actuated mirror array</td>
</tr>
<tr>
<td>TLE</td>
<td>transverse length expansion</td>
</tr>
<tr>
<td>TM</td>
<td>transverse magnetic</td>
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<tr>
<td>TS</td>
<td>thickness shear</td>
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<tr>
<td>TTD</td>
<td>true time delay</td>
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<tr>
<td>UV</td>
<td>ultraviolet</td>
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<tr>
<td>VCM</td>
<td>variable-capacitance motor</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<tr>
<td>VCSEL</td>
<td>vertical cavity surface emitting laser</td>
</tr>
<tr>
<td>VLSI</td>
<td>very large scale integration</td>
</tr>
<tr>
<td>VOA</td>
<td>variable optical attenuator</td>
</tr>
<tr>
<td>WDM</td>
<td>wavelength division multiplexing</td>
</tr>
<tr>
<td>WLP</td>
<td>wafer-level packaging</td>
</tr>
<tr>
<td>XGA</td>
<td>extended graphics adapter</td>
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ABOUT THE EDITOR

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Technology and Science. He also served on the steering and technical program committees for the IEEE International Conference on MEMS, and served as a general co-chair for this meeting in 2002.

Rolf Göring received his Diploma in Physics from Lomonossov State University in Moscow and his Ph.D. in Nuclear Magnetic Resonance Spectroscopy in 1981 from Friedrich-Schiller University in Jena, Germany. He started at the Fraunhofer Institute for Applied Optics and Precision Engineering, in Jena, Germany, where he worked in the field of optical waveguides and fibers, including the development of a range of micro-optical devices. In 1992, he became the head of the micro-optics section in the Fraunhofer Institute focusing mainly on beam-shaping systems for high-power laser diodes. Dr. Goering’s interest was redirected to “moving micro-optics,” leading to novel solutions for MOEMS scanners and switches. In 1999, he joined Piezosystem Jena as a Manager of micro-optics where he developed and commercialized a series of both single-mode and multimode optical fiber switches. In 2001, he joined Pyramid Optics Company as an R&D manager, offering high-quality fiber optic MOEMS switches, shutters, and couplers for the entire VIS/NIR wavelength range. Dr. Goering has contributed to SPIE by chairing and organizing several conferences. He has published numerous papers and is the editor of several SPIE proceedings.

Ridha Hamza graduated from the University of Grenoble in 1998 with a degree in Electrical Engineering. His graduate work was in the area of interface electronics for sensors. He joined MEMSCAP in 1999, where he was in charge of cooperative programs on CAD. He then took over the management of the development of MEMSCAP’s UNIX based MEMS Design Platform MEMS Xplorer and MEMSCAP’s foundry design kits. After two years as a Marketing Manager for CAD tools at MEMSCAP, he is now VP of European and Asian Operations at SoftMEMS. His main interests are in MEMS design methodologies.

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Jean-Michel Karam holds a Ph.D. in Microelectronics from the French Institut National Polytechnique de Grenoble, a Masters from Paris VII University, and an Engineering degree from the French ESIEE. After having started and developed the MEMS applied research group at TIMA Laboratory, he founded MEMSCAP in November 1997. In less than three years, he took the company public for half a billion dollars. He grew his organization to be the first independent and listed MEMS group in the world. MEMSCAP today is present in 5 countries with over 200 employees. MEMSCAP acquired Capto (Norway), Cronos from JDS Uniphase (USA), and GalayOr (Israel), and is widely recognized as the MEMS leader. Jean Michel Karam holds more than 25 patents, is author or co-author of more than two hundred publications, is the guest Editor of many scientific magazines and chairman or co-chairman of several conferences.

Ernst-Bernhard Kley received his diploma and Ph.D. in physics from the Friedrich-Schiller University Jena in 1974 and 1987 respectively. After he received his diploma in physics and before he started his doctoral work, he earned three years of industrial experience. Dr. Kley’s general fields of research are micro- and nanolithography, various e-beam writers, and scanning electron microscopes applied to micro-optics, integrated optics, and cryogenic electronics. He made essential contributions to the physics of the proximity effect and the development of variable-dose writing in e-beam lithography, including the combination of e-beam and gray-tone lithography. Currently he is the head of the Microlithography and Micro-optics Group at the Institute of Applied Physics of Friedrich-Schiller-University Jena. This group is well known for long-term experience with the ZRM 12, ZBA 21P, ZBA 23H, and LION LV1 e-beam systems. Dr. Kley is author and co-author of more than 80 scientific papers and was involved in the organization of several conferences. Since the beginning of the 1990s, he was a partner of more than 30 European and national projects and established the cooperation of many international partners.

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Seethambal S. Mani received her Ph.D. from the Materials Engineering Department of Rensselear Polytechnic Institute. Since graduating, she has worked at Westinghouse, Northrop Grumman, and more recently, Sandia National Laboratories. She has been involved in processing devices in both Si and compound semiconductor areas. At Sandia National Laboratories, she started as a process engineer in the chemical vapor deposition area and currently is a technology engineer in the MEMS technology group. She has more than 30 conference proceedings and journal publications. Dr. Mani is a member of SPIE and MRS. She has experience in the area of process integration and has contributed to numerous programs.

Philippe Nachtergaele was born on April 1969 in Charleroi, Belgium. He studied Applied Sciences and obtained an Electro-Mechanical Engineering diploma from the University of Liège, Belgium in 1992. In 1994, he acquired finite elements analysis experience at SAMTECH S.A., Liège. In 1996, he joined the Laboratoire des Techniques Aéronautiques et Spatiales (L.T.A.S.). During 1996 to 1999, he took part in a three year R&D project in aeroelasticity. In 1999, he joined the CAD Development Group of MEMSCAP to focus on MEMS design and is now responsible for the modeling activity inside the Business Unit.

John Patrick O’Connor received his BSAE from the University of Texas at Austin in 1986 and his MSME and Ph.D. degrees from the University of Texas at Arlington in 1991 and 1994, respectively. Dr. O’Connor worked for five years at General Dynamics, Aircraft Division integrating propulsion systems into fighter aircraft. In 1991, he joined Texas Instruments, where he designed thermal management systems for missile and aircraft avionics systems. In 1999, he joined the DLP products division of Texas Instruments where he is currently serving as the DMD Package Development Manager. Dr. O’Connor is an active member of ASME and IMAPS, has authored or co-authored over twenty papers on phase
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**Long Que** received his undergraduate and graduate education in physics and communication in Peking University, Beijing, China. He received his Ph.D. in electrical engineering from the University of Wisconsin-Madison in 2000. He has held various positions in industry, research institutes, and academia. Currently he is a visiting research scientist at the Department of Electrical Engineering and Computer Science at the University of Michigan at Ann Arbor. His research interests are in BioMEMS, MOEMS, nano-MEMS and nanotechnology. He has published about 20 papers in journals and conferences, has been awarded three US patents and has four patents pending. He is a member of IEEE and SPIE.

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**Johannes Schwider** was born in Gleiwitz, Silesia in 1938. He received his Diploma in physics from TU (Technical University) Dresden in 1961 and his *Dr. rer. nat.* (Ph.D. equivalent in the US) from Humboldt University, Berlin in 1966. In 1978, he received a Doctoral degree in Science and Technology from TH Ilmenau, which was supplemented by the Habilitation at the University Erlangen-Nürnberg in 1987. During 1962 to 1987, Dr. Schwider was with the Academy of Sciences in Berlin, Central Institute for Optics and Spectroscopy. From 1988 to 1990, he was with Heinrich Hertz Institute, GmbH in Berlin and since 1990, has been with the Lehrstuhl für Optik University Erlangen-Nürnberg. Dr. Schwider’s expertise is in physical optics, wave optics, diffraction, and interferometry. He has more than 30 years of experience in interferometry, including 10 years of experience in micro-optics and micro-optical elements—both diffractive as well as refractive—and for 10 years has engaged in optical interconnects for computers and LANs. Dr. Schwider received two major awards for his work on interferometry. The first award was the Abbe-Prize of the Carl Zeiss Foundation in Jena in 1979. His second award was a national prize second class of the GDR in 1986. Dr. Schwider is a member of the German Society for Applied Optics (DgAO) and the Optical Society of America (OSA).

**Olga Blum Spahn** received her B.S. from the University of Illinois, Champaign-Urbana in 1987, and her M.S. and Ph.D. from the University of California, Berkeley in 1990 and 1992, all in Electrical Engineering. In 1993, she joined Sandia National Laboratories in Albuquerque, NM. Her research interests include micro-optical component fabrication, oxidation of compound semiconductors, 1.3-1.55 μm VCSELs, integration of VCSELs with microsystems, and compound semiconductor MEMS and MOEMS applications. Dr. Blum has over one hundred publications and conference presentations, including several invited talks and book chapters.

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as a Research Engineer and was a member of the research team developing the Retinal Scanning Display technology. He was the Principal System Engineer when he left Microvision to join the faculty of Engineering at Koç University. His research interests are in the area of information optics and microsystems, including micro-optics, optical system design, micro-electro-mechanical systems (MEMS), micro-opto-electro-mechanical systems (MOEMS), and display and imaging systems. He is a member of SPIE, IEEE, and OSA.

**Lars-Christian Wittig** received his diploma in Physics in 1999 from the Friedrich Schiller University of Jena. During his graduate work, he investigated a lithographic pre-form technology for the fabrication of continuous surface profiles. Since that time, he has worked in the microstructure technology and micro-optics group of Dr. Ernst-Bernhard Kley at the University of Jena. His main field of his interest is micro-optics with focus on continuous surface profiles, especially refractive beam shaping elements. His work focuses on the design of micro-optical elements and the technologies for its fabrication with analogue lithography like grey-tone lithography and variable-dose writing. Mr. Wittig is the author and co-author of many scientific papers in this area of technology. He is a member of the Deutsche Physikalische Gesellschaft, the German society for physics.
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