Digital Optics for Immersive Displays

Bernard C. Kress
Wolfgang Osten
Hagen Stolle
Editors

24–25 April 2018
Strasbourg, France

Sponsored by
SPIE

Cosponsored by
Strasbourg the Eurooptimist (France)
CNRS (France)
Investissements d'Avenir (France)
iCube (France)
Université de Strasbourg (France)

Cooperating Organisations
Photonics 21 (Germany)
EOS—European Optical Society (Germany)
Photonics Public Private Partnership (Belgium)
Comité National d’Optique et de Photonique (France)

Published by
SPIE

Volume 10676
Contents

Authors ix
Conference Committee xi
Conference Sponsors

SESSION 1  OPTICAL CHALLENGES FOR NEXT-GENERATION AR/VR HEADSETS

10676 04  Field of view: not just a number [10676-3]
10676 05  Optical design challenges from satellite imaging to augmented reality displays [10676-4]
10676 06  Viewing optics for immersive near-eye displays: pupil swim/size and weight/stray light [10676-5]

SESSION 2  DESIGN, FABRICATION AND TESTING OF NOVEL OPTICS FOR AR/VR SYSTEMS

10676 07  Ultra-compact multichannel freeform optics for 4xWUXGA OLED microdisplays (Invited Paper) [10676-6]
10676 09  Casting technology for embedding optical elements into prescription spectacle lenses [10676-8]
10676 0B  Optical metrology for immersive display components and subsystems [10676-10]
10676 0C  HMD quality evaluation of projected image: hardware assessment and software evaluation for distortions correction [10676-11]

SESSION 3  HOLOGRAPHIC OPTICS FOR AR/VR SYSTEMS

10676 0D  Curved wedges and shearing gratings for augmented reality (Invited Paper) [10676-12]
10676 0E  Characterisation and optimisation of Volume Holographic Optical Elements (VHOEs) in AR combiners for ghost reduction [10676-13]
10676 0F  Bragg polarization gratings used as switchable elements in AR/VR holographic displays [10676-14]
DigiLens switchable Bragg grating waveguide optics for augmented reality applications [10676-15]

Wavelength multiplexing recording of vHOEs in Bayfol HX photopolymer film [10676-16]

SESSION 4  IMPROVING VISUAL COMFORT IN AR/VR SYSTEMS

Varifocal technologies providing prescription and VAC mitigation in HMDs using Alvarez lenses (Invited Paper) [10676-18]
Computationally efficient and antialiased dual-layer light-field displays [10676-19]
Experimental evaluation of self-focusing image formation in unconventional near-eye display [10676-22]

DOID STUDENT OPTICAL DESIGN CHALLENGE FOR VR/AR AND MR: POSTER PRESENTATIONS

Improving image quality of 360-degree viewable holographic display system by applying a speckle reduction technique and a spatial filtering [10676-20]
Design of a freeform gradient-index prism for mixed reality head mounted display [10676-101]
Optical design, assembly, and characterization of a holographic head mounted display [10676-103]
Mitigating vergence-accommodation conflict for near-eye displays via deformable beamsplitters (1st Place, DOID Student Optical Design Challenge) [10676-104]
Designing of a monocular see-through smart glass imaging system [10676-105]
A reflective prism for augmented reality with large field of view [10676-109]
Design of a spatially multiplexed light field display on curved surfaces for VR HMD applications [10676-110]
See-through smart glass with adjustable focus [10676-111]
Ultrathin full color visor with large field of view based on multilayered metasurface design (1st Place, DOID Student Optical Design Challenge) [10676-117]
A vergence accommodation conflict-free virtual reality wearable headset [10676-119]
Ultrathin optical combiner with microstructure mirrors in augmented reality (2nd Place, DOID Student Optical Design Challenge) [10676-120]
Wide field-of-view waveguide displays enabled by polarization-dependent metagratings (1st Place, DOID Student Optical Design Challenge) [10676-121]

Over-designed and under-performing: design and analysis of a freeform prism via careful use of orthogonal surface descriptions [10676-122]

Shape scanning displays: tomographic decomposition of 3D scenes [10676-124]

Polarization-dependent metasurfaces for 2D/3D switchable displays [10676-125]

High-performance integral-imaging-based light field augmented reality display [10676-126]

Design and stray light analysis of a lenslet-array-based see-through light-field near-eye display [10676-127]

High-resolution head mounted display using stacked LCDs and birefringent lens (2nd Place, DOID Student Optical Design Challenge) [10676-128]

A retinal-projection-based near-eye display for virtual reality [10676-129]

Understanding waveguide-based architecture and ways to robust monolithic optical combiner for smart glasses [10676-131]

Compact see-through AR system using buried imaging fiber bundles (2nd Place, DOID Student Optical Design Challenge) [10676-132]

Design of an immersive head mounted display with coaxial catadioptric optics [10676-133]

Ultra-compact pancake optics based on ThinEyes super-resolution technology for virtual reality headsets (3rd Place, DOID Student Optical Design Challenge) [10676-134]

Solving the vergence-accommodation conflict in head mounted displays with a magnifier system [10676-135]

Augmented reality display system for smart glasses with streamlined form factor [10676-139]

High-resolution optical see-through vari-focal-plane head-mounted display using freeform Alvarez lenses (3rd Place, DOID Student Optical Design Challenge) [10676-140]

Super multi-view augmented reality glasses [10676-142]

PARA: experimental device for virtual and augmented reality (3rd Place, DOID Student Optical Design Challenge) [10676-143]
Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Avayu, Ori, 12
Benítez, Pablo, 07
Bentley, Julie L., 0S, 0Y, 16, 11
Bodei, S., Yvonne, 05
Bolotova, A., 1K
Brac de la Pemière, Vincent, 1D
Bruder, Friedrich-Karl, 0H
Byars, Brett, 06
Buljan, Marina, 07
Capasso, Federico, 15, 18
Cardenas, Nelson, 06
Casan, Julien, 1L
Chakravarthula, Praneeth, 0U
Chan, Ning, 06
Charrière, S., 13
Chen, Bo, 0X
Chen, Chao Ping, 1C
Chen, Wei Ting, 15
Cheng, Dewen, 1A, 1F
Cho, Jaebum, 17
Choi, Stephen, 04
Chu, Jiaqi, 0D
Deck, Leslie L., 0B
de Groot, Peter J., 08
Ditcovski, Rani, 12
Dong, Qian, 0U
Druzhin, V., 1K
Dunn, David, 0U
Duveau, L., 13
Ellenbogen, Tom, 12
Fix, Alexander, 06
Fleck, B., 0T
Francardi, Marco, 0C, 0E
Francesca, Enzo, 0C, 0E
Fu, Yijing, 06
Fuchs, Henry, 0U
Gantes-Nuñez, Francisco Javier, 1H
Gao, Liang, 1B
Gao, Weichuan, 04
Gärtner, A., 0T
Geng, Ying, 04, 06
Georgiou, Andreas, 0D
Geser, P., 1E
Giartosio, Francesco, 0C, 0E
Gissens, H., 1E
Gollier, Jacques, 04, 06
González, Juan Carlos, 07
Gorospe, Jorge, 07
Grabovičkić, Dejan, 07
Grant, Alastair J., 0G
Gritsai, Yuri, 0F
Gu, Luo, 1F
Gurabardhi, Entela, 0C
Gurganos, Dustin, 0Z
Haeberlé, Olivier, 0N
Hansen, Sven, 0H
Hasnain, A., 0J
Häussler, R., 0T
Herkommer, Alois M., 1E
Hong, Keehoon, 0Q
Horvath, Nicholas, 0Z
Hovis, Clark, 02
Hua, Hong, 14, 19, 1J
Huang, Hekun, 19
Jin, Peng, 18
Jo, Youngjin, 17
Kim, Hayan, 0Q
Kim, Jinwoong, 0Q
Kochan, Nicholas S., 0Y
Kolchin, Konstantin, 0L
Koneva, Tatiana A., 0V
Körner, L., 09
Krotov, Vladimir, 0N
Kurilin, Ilya, 0L
Laffont, P.-Y., 0J
Lam, Wai Sze Tiffany, 06
Lanman, Douglas, 06
Larroque, Stan, 1L
Lee, Byoungho, 17
Lee, Dukho, 17
Lee, Seunghae, 17
Lewis, Brant, 06
Li, Yang, 1C
Lim, Yongjun, 0Q
López, Jesús, 07
Luana, Selo, 04
Matilo, Nizamuddin, 1C
Malacara-Hernández, Daniel, 1H
Malacara-Hernández, Zacarías, 1H
Mantecke, Christel, 0H
Martínez, Christophe, 0N
McEldowney, Scott, 06
Mi, Liantian, 1C
Miletli, Thomas, 0C, 0E
Milyukov, Gleb, 0L
Miñano, Juan Carlos, 07
Mohedano, Rubén, 07
Moore, Duncan T., 0S, 0Y, 16, 11
Muff, D., 09
Narasimhan, Bharathwaj Appan, 07, 1G
Ni, Yunhui, 0S
Nikolić, Milena, 07
Noste, Todd, 0Z
Noui, Louahab, 05
Orselli, Enrico, 0H
Park, Minsik, 0Q
Peng, Fenglin, 06
Pérez, Eduardo, 07
Popov, Mikhail, 0L
Popovich, Milan M., 0G
Putlin, A., 1K
Qiao, Wei, 1B
Rewitz, Christian, 0H
Rhodes, D. P., 0J
Rolland, Jannick P., 0S, 16
Rölle, Thomas, 0H
Romanova, Galina E., 0V
Rychagov, Mikhail, 0L
Ryu, Jaeyeol, 0L
Sahm, Hagen, 0F
Sakhno, Oksana, 0F
Sanchez, Eduardo, 07
Schmidt, Greg, 0Y, 1I
Shahinian, Hossein, 02
Shanmugam, Prithiviraj, 0Z
Shi, Zhujuin, 15, 18
Shtykov, Stanislav, 0L
Sizemore, Nicholas, 0Z
Sohn, Alexander, 06
Song, Wanyue, 0S, 16
Steven, Samuel J., 0Y, 1I
Stevens, R. E., 0J
Stolle, H., 0T
Stumpe, Joachim, 0F
Sulai, Yusufu, 04, 06
Takaki, Nicholas, 0S, 16
Thiele, S., 1E
Travis, A. R. L., 0D
Truant, Nicola, 0C, 0E
Turko, Sergey, 0L
Waldern, Jonathan D., 0G
Wang, Yongtian, 1A, 1F
Wegener, Michael, 0F
Wewer, Brita, 0H
Wheelwright, Brian, 04, 06
Wilson, Austin, 1J
Xu, Miaomiao, 14
Yang, Tianyi, 0S, 0Y
Yao, Cheng, 1A
Yee, Anthony J., 0S, 16
Yoo, Dongheon, 17
Yoon, Youngshik, 06
Yu, Bing, 1C
Zamora, Pablo, 07
Zhang, Wenbo, 1C
Zhao, Yang, 0S, 1I
Zhou, Yuanchao, 1C
Zhu, Shuaishuai, 1B
Conference Committee

Symposium Chairs

Francis Berghmans, Vrije Universiteit Brussel (Belgium)
Thierry Georges, Oxxius SA (France)
Harald Giessen, Universität Stuttgart (Germany)
Paul Montgomery, Université de Strasbourg (France)

Conference Chairs

Bernard C. Kress, Microsoft Corporation (United States)
Wolfgang Osten, Institut für Technische Optik (Germany)
Hagen Stolle, SeeReal Technologies GmbH (Germany)

Conference Program Committee

Tibor Balogh, Holografika Kft. (Hungary)
Christian Bosshard, Centre Suisse d'Electronique et de Microtechnique SA (Switzerland)
Federico Capasso, Harvard School of Engineering and Applied Sciences (United States)
Jerome Carollo, Google, Inc. (United States)
Arie den Boef, ASML Netherlands B.V. (Netherlands)
Andreas Hermerschmidt, HOLOEYE Photonics AG (Germany)
Hans Peter Herzig, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
Tobias Haist, Institut für Technische Optik (Germany)
Marc D. Himel, JENOPTIK Optical Systems, LLC (United States)
Hong Hua, College of Optical Sciences, The University of Arizona (United States)
Fu-Chung Huang, NVIDIA Corporation (United States)
Norbert Kerwien, Carl Zeiss AG (Germany)
Lutz Körner, INTERGLASS Technology AG (Switzerland)
Byoungho Lee, Seoul National University (Korea, Republic of)
Cindy Lee, KHD Ltd. (China)
Scott McEldowney, Oculus VR, LLC (United States)
Juan C. Miñano, Limbak 4PI S.L. (Spain)
Ilmars Osmanis, Lightspace Technologies, SIA (Latvia)
Silvania F. Pereira, Technische Universität Delft (Netherlands)
Christophe Peroz, Magic Leap, Inc. (United States)
Pascal Picart, Université du Maine (France)
Demetri Psaltis, Ecole Polytechnique Fédérale de Lausanne (Switzerland)
Monika Ritsch-Marte, Medizinische Universität Innsbruck (Austria)
Khaled Sarayeddine, Optinvent (France)
Robert Stevens, Adlens Ltd. (United Kingdom)
Hagen Stolle, SeeReal Technologies GmbH (Germany)
Adrian Travis, Microsoft Corporation (United States)
Reinhard Voelkel, SUSS MicroOptics SA (Switzerland)
Angus Wu, Huawei Technologies Company, Ltd. (United States)
Frank Wyrowski, Friedrich-Schiller-Universität Jena (Germany)

Session Chairs
1 Optical Challenges for Next-generation AR/VR headsets
   Bernard C. Kress, Microsoft Corporation (United States)
2 Design, Fabrication and Testing of Novel Optics for AR/VR systems
   Lutz Körner, INTERGLASS Technology AG (Switzerland)
3 Holographic Optics for AR/VR Systems
   Friedrich-Karl Bruder, Covestro AG (Germany)
4 Improving visual comfort in AR/VR systems
   Hong Hua, College of Optical Sciences, The University of Arizona (United States)
Conference Sponsors

GOLD
Google, Inc. (United States)
LightTrans GmbH (Germany)
Microsoft Corporation (United States)
Oculus VR, LLC (United States)
Zemax, LLC (United States)
Huawei Technologies Company, Ltd. (China)
Jenoptik GmbH (Germany)

SILVER
Leia Inc. (United States)
Amazon.com, Inc. (United States)
Zeiss GmbH (Germany)
Synopsys Inc. (United States)
Applied Materials, Inc. (United States)

EQUIPMENT AND SOFTWARE
Lambda Research Corporation (United States)
NVIDIA Corporation (United States)
Zemax, LLC (United States)
LightTrans (Germany)