PHOTONICS PUBLIC PRIVATE PARTNERSHIP

Advantages of Phase Modulating MEMS for Full 3D Hologram Scene Reconstruction

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Digital Holography and Three-Dimensional Imaging

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Hybrid Event - Greenwich Mean Daylight/Summer Time (UTC + 01:00)

Cambridge University, Cambridge, UK

SeeReal Technologies

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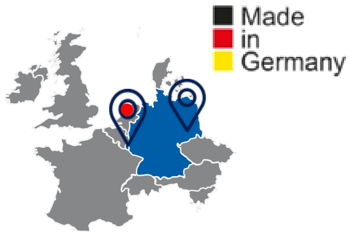


Based in Luxembourg and Dresden

TECHNISCHE UNIVERSITÄT DRESDEN

Span out of Dresden Universiy

30 FTEs

150

Yrs. of experience in holography

600+

Patents and Patent Applications globally

Partnership with since 2018

Since 2019 Investor

JDAs with long term partners/suppliers

Why Holography ?

Common stereoscopic 3D displays cannot provide all 3D depth cues

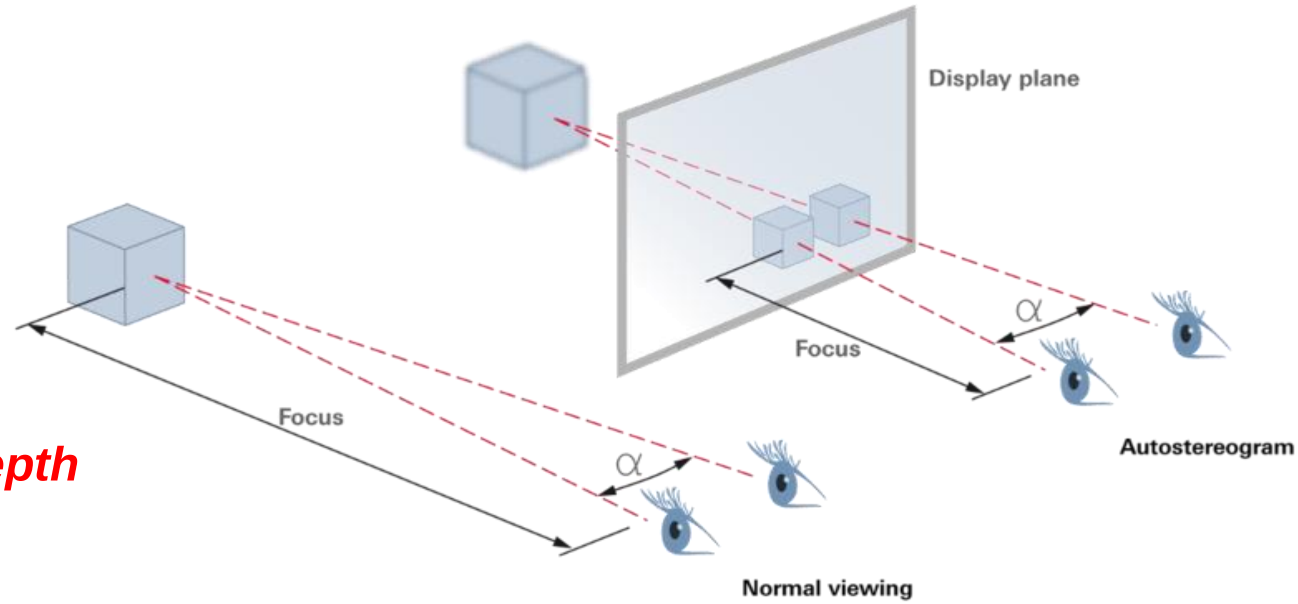
- Binocular images create 3D effect and stimulate vergence of eyes
- Actual eye focus (accommodation) remains always on the 2D display

➔ 3D scenes with large depth cause *Vergence Accommodation Conflict (VAC)*

► Visual discomfort

► Fatigue

► Headache

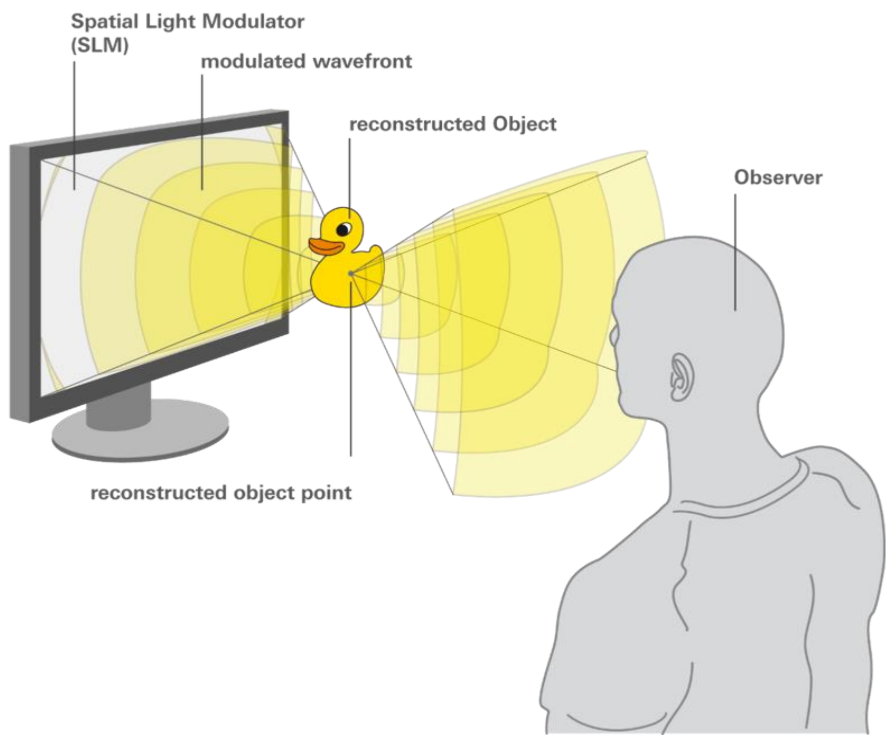


Stereoscopic 3D depth has to be limited

Holographic 3D Technology

Holographic displays synthesize the wave field of a real 3D scene

- Objects are created in space not only on the display
- Provides all depth cues that are essential for a **natural 3D perception**
- ► Binocular vision without 3D glasses
- ► Free eye focus determined by observer – as in real life
- ► Motion parallax depending on observer position

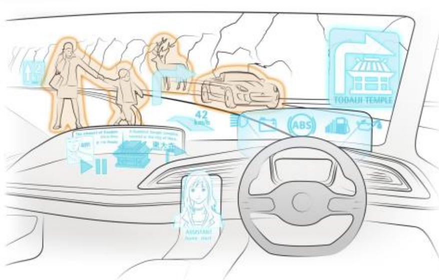


*No Vergence Accommodation Conflict → **unlimited scene depth***

Display Technology

Variety of display formats

- Direct view **flat panel** display - Scalable from mobile use to TV-size
- **Head Mounted** Displays (HMD) for Virtual and Augmented Reality
- **Heads Up** Displays (HUD) for automotive use



Liquid-crystal-on-silicon (LCOS)

- prevalent technology
- limited switching speed
- fringe-field effects induce optical crosstalk and reduce holographic reconstruction quality

Microelectromechanical Systems (MEMS)

- in development
- high switching speeds
- no optical crosstalk due to fringe-field effects

Fringe-Field Effects in Micro Displays

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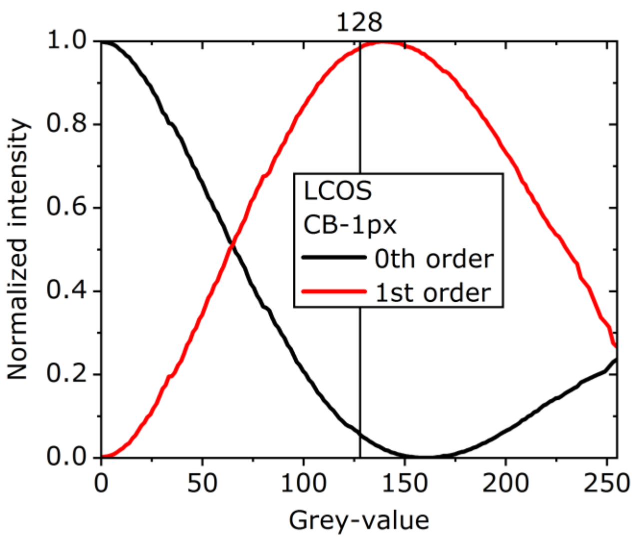
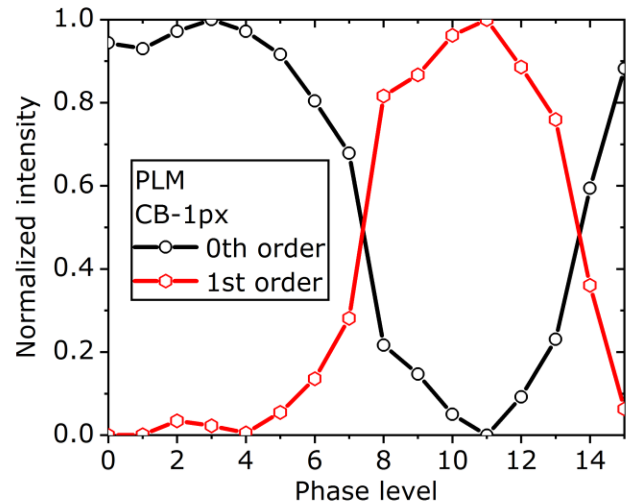
LCOS diffraction [1]



- fringe-field effect with 1px CB pattern where 1st order is shifted against zero order
- reduction of image quality due to optical crosstalk of adjacent pixels

MEMS diffraction [1]



- diffraction measurements of nonlinear 4-bit MEMS show no displacement of diffraction orders
- no optical crosstalk due to absence of fringe-field effects

[1] Teich, M., et al. "Real-time, large-depth holographic 3D head-up display: selected aspects." *Applied Optics* 61.5 (2022): B156-B163

Simulation Methods

Synthesis of Complex Hologram

- Sub-Hologram encoding, where small encoded lenses are assigned to individual scene points in 3D space

Phase-Only Encoding

- iterative optimization based on Gerchberg-Saxton algorithm

Introduction of Phase Distortions

- supersampling of individual kinoform pixels to model detailed deviations from the perfect system

Reconstruction of Scene Intensity

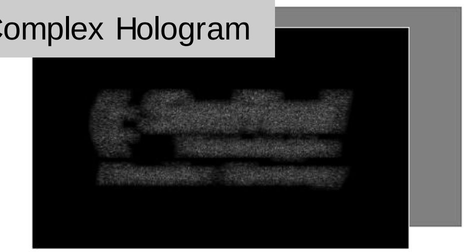
- Fraunhofer propagation
- angular-spectrum method

Quality Assessment

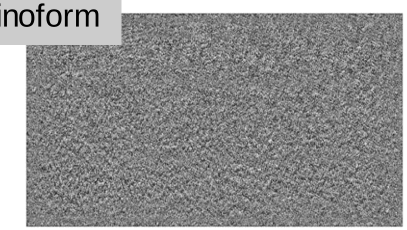
- intensity contrast (critical for AR use cases)
- PSNR, SSIM

Target Scene

Complex Hologram

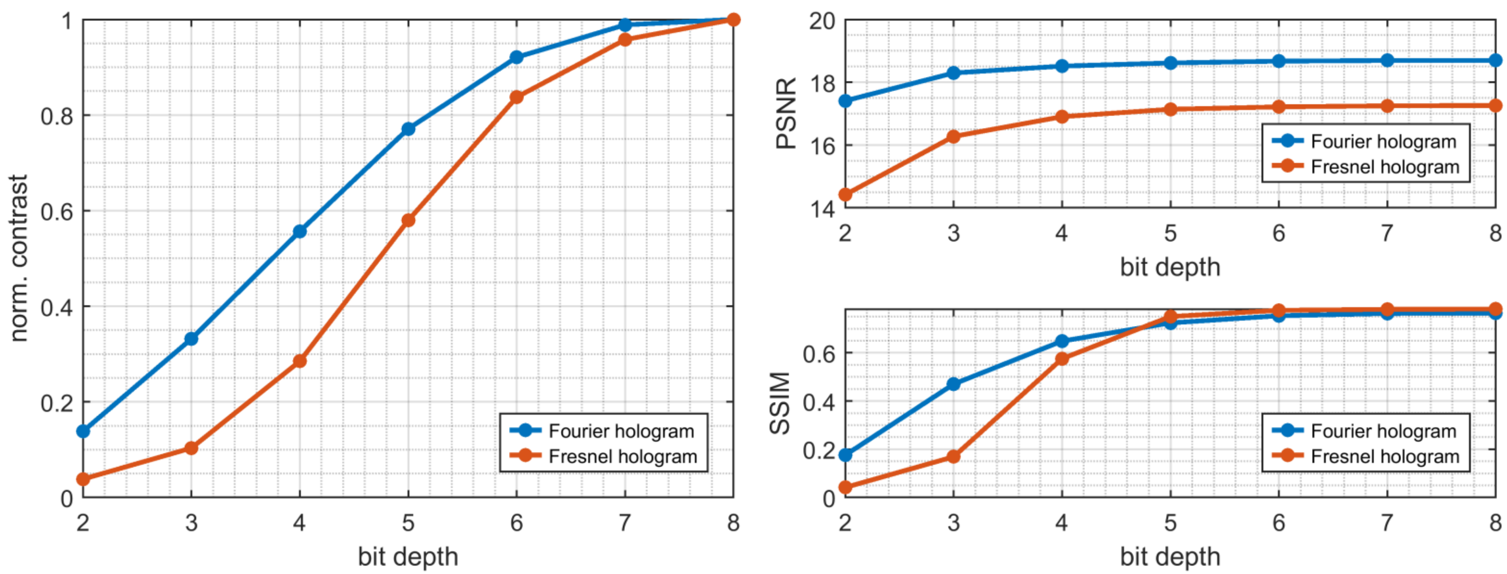


Kinoform



Reconstructed Scene

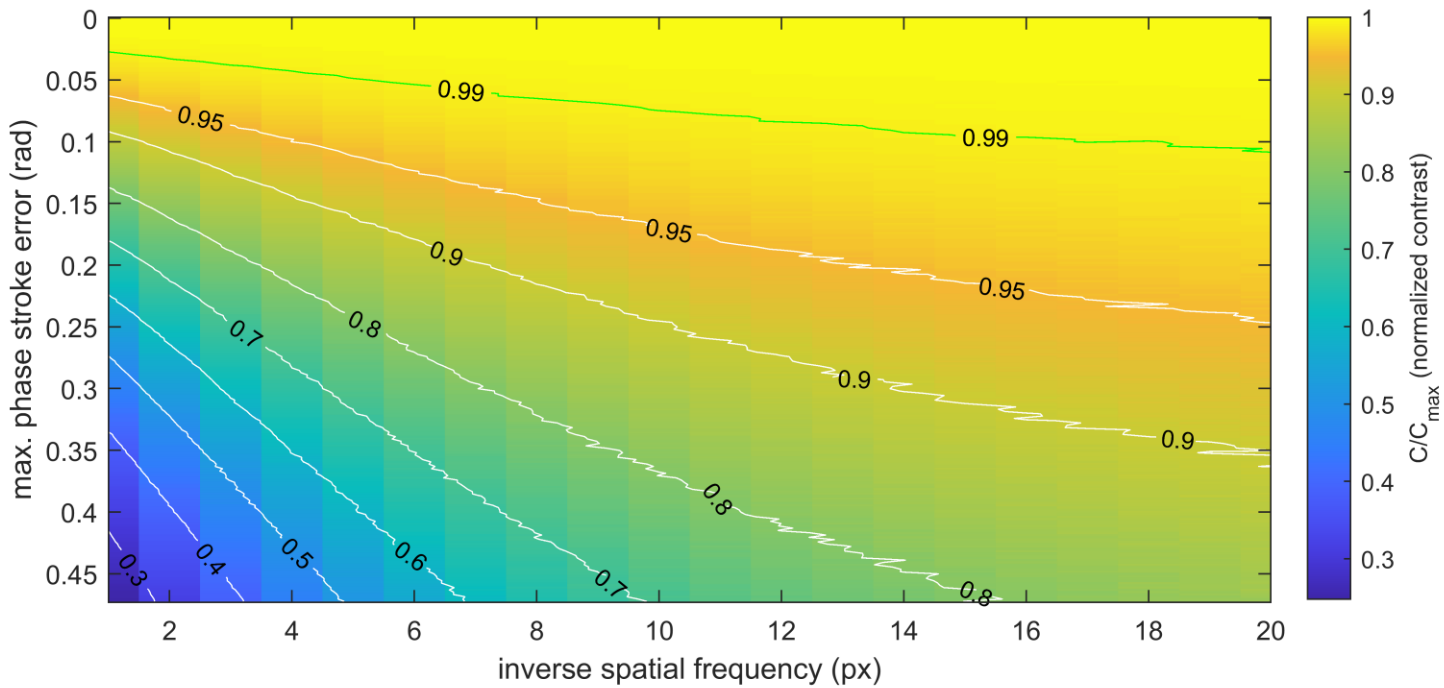
Number of Phase Levels – Bit Depth



- phase-only optimization, where constraints of the phase-only modulator are combined with a defined number of phase levels
- quality parameters with identical tendencies
- quality improvement least noticeable in view of PSNR
- drastic improvement of intensity contrast above 4 bits, especially in case of Fresnel holograms

Phase-Stroke Errors

Randomized phase deviations with varyingly spatial rate of change

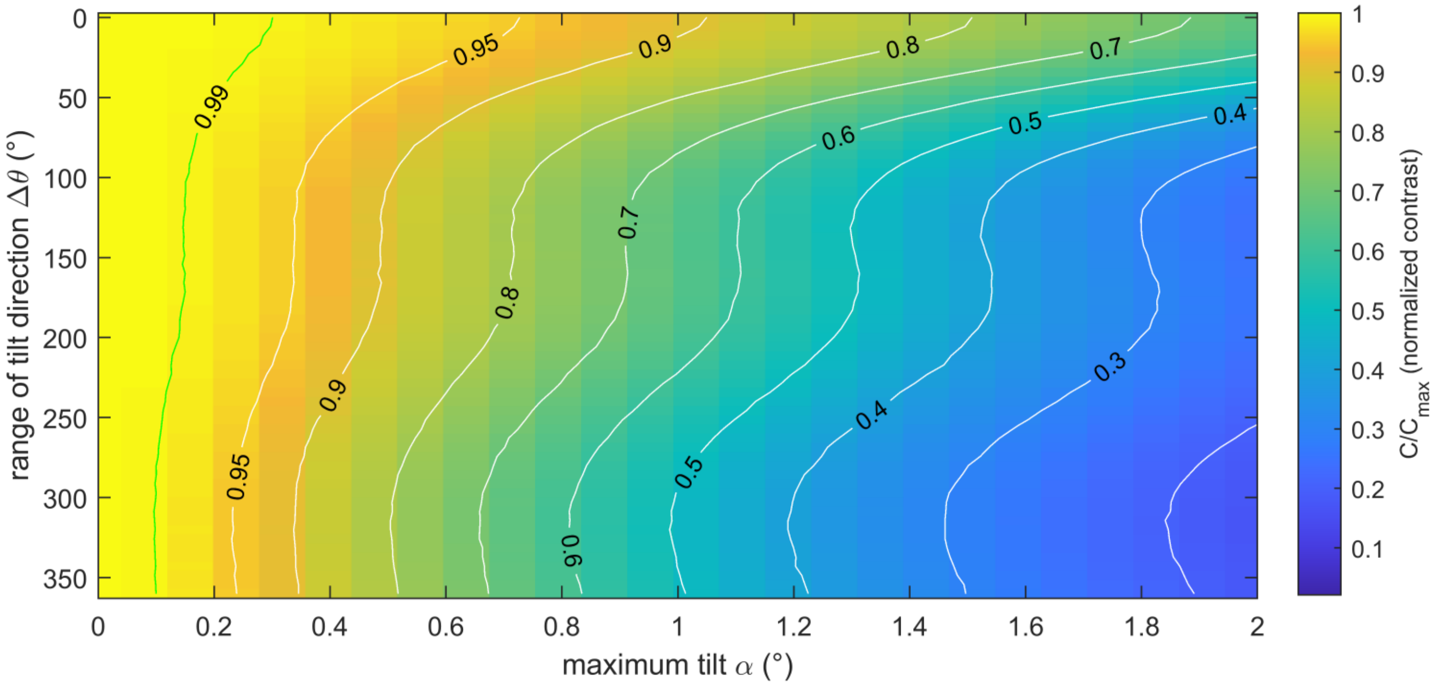


- hologram quality more affected when error sources affect pixels more independently
- image quality almost preserved with a phase stroke error of ±0.03 rad
- tolerance above the 8-bit precision range of novel micro-mirror designs [2]

[2] Duerr, Peter, et al. "MEMS Spatial Light Modulators for Real Holographic 3D Displays." *MikroSystemTechnik Congress 2021; Congress*. VDE, 2021.

Tilt Errors

Randomized tilt with varying direction and maximum extent

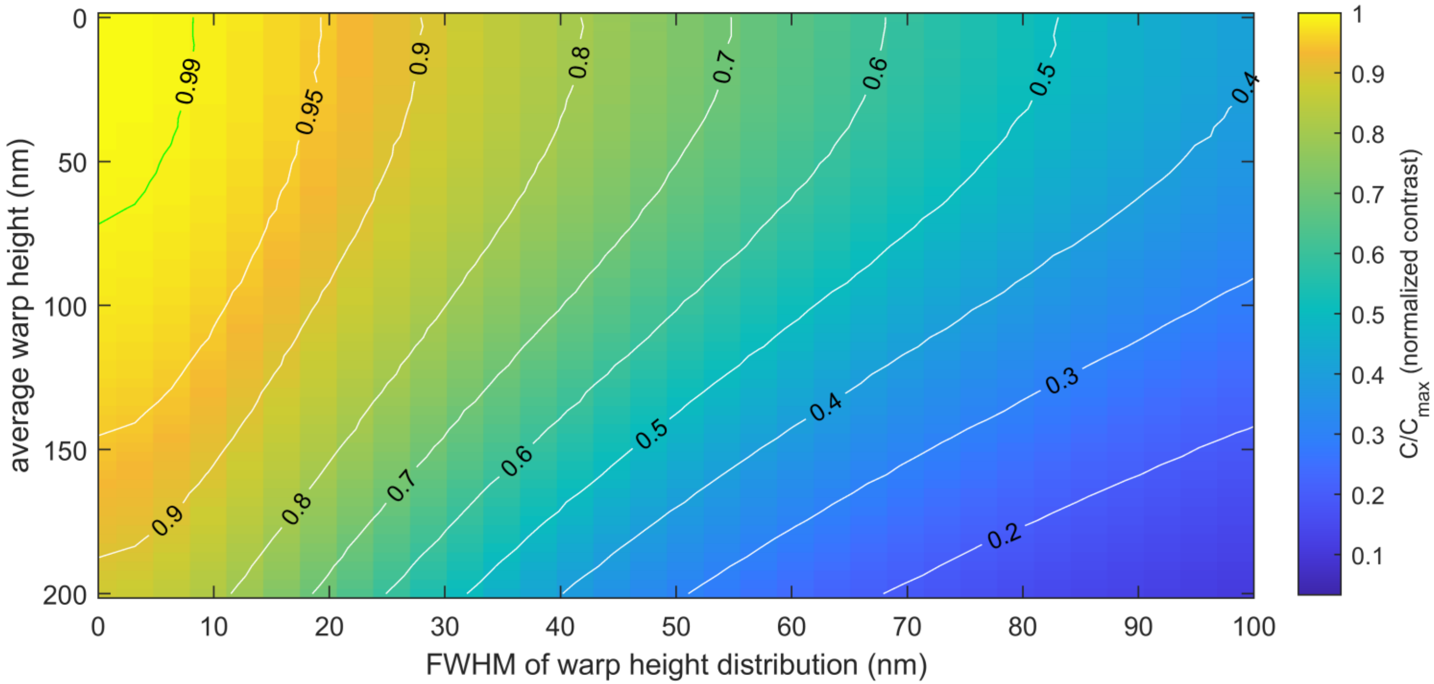


- reduced variation in tilt direction less critical
- contrast of holographic reconstruction almost preserved below a tilt angle of 0.1°
- novel micro-mirror designs within the required tolerance values [2,3]

[2] Dürr, P., et al. "MEMS Spatial Light Modulators for Real Holographic 3D Displays." *MikroSystemTechnik Congress 2021; Congress*. VDE, 2021.
[3] Dürr, P., et al. "MEMS piston mirror arrays for computer generated holography." *MOEMS and Miniaturized Systems XXI*. Vol. 12013. SPIE, 2022.

Warp Errors

Randomized warp with varying average and fluctuating height



- reconstruction quality not severely affected with average mirror warp beneath 100 nm and a random deviation (FWHM) below 20 nm

Conclusions

- simulated holographic reconstructions in the Fresnel regime show similar tendencies and lead to identical tolerances
- novel micro-mirror architectures allow for high quality of full 3D holography
- results obtained contribute to design standards and device tolerances for the development of advanced MEMS technology by the REALHOLO consortium

parameter	value
pixel count	4000 x 2400
pixel size	4µm x 6µm
deflection precision	8 bit
mirror tilt	< 0.1°
frame rate	> 1kHz

Acknowledgements

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