

Excellence in Imprint Lithography and Wafer-Stacking

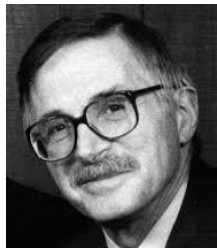
Reinhard Völkel

CEO SUSS MicroOptics SA

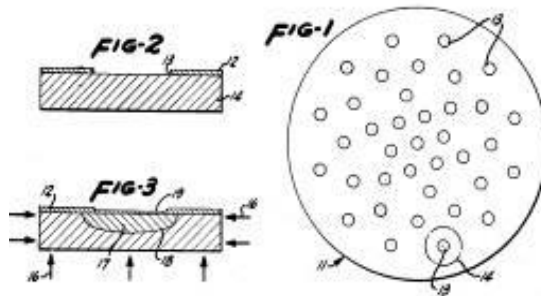
THE PARALLEL PROCESS – WAFER-LEVEL MANUFACTURING

SEMI: Key to Success is Wafer Manufacturing

- 1947:** Invention of the transistor by John Bardeen, William B. Shockley and Walter H. Brattain (1956: Nobel Price)
- 1955:** Shockley Semiconductor Laboratory
- 1957:** The “Traitorous Eight” split from Shockley and start Fairchild Semiconductor: Robert Noyce, Gordon Moore, Jean Hoerni, Eugene Kleiner, Julius Blank, Sheldon Roberts, Jay Last, and Victor Grinich.
- 1959:** Jean Hoerni invents the “parallel process”. Wafer manufacturing is the key to success for semiconductor industry!



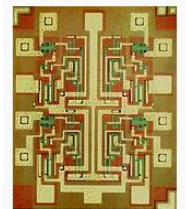
Jean Amédée Hoerni
(1924-1997)



"Wafer"



Semiconductor manufacturing processes



10 μm	– 1971
6 μm	– 1974
3 μm	– 1977
1.5 μm	– 1981
1 μm	– 1984
800 nm	– 1987
600 nm	– 1990
350 nm	– 1994
250 nm	– 1996
180 nm	– 1999
130 nm	– 2001
90 nm	– 2003
65 nm	– 2005
45 nm	– 2007
32 nm	– 2009
22 nm	– 2012
14 nm	– 2014
10 nm	– 2016
7 nm	– 2018
5 nm	– 2019
3 nm	– ~2021

https://en.wikipedia.org/wiki/Semiconductor_device_fabrication

Computer Generated Holograms (CGH)



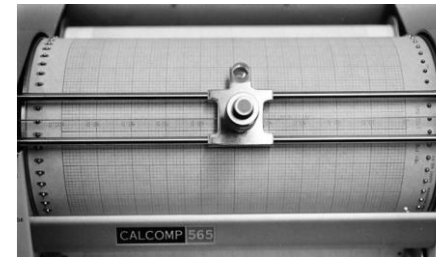
Fig. 7.7. Adolf Lohmann (centre) with Byron Brown and Ronald Kay of IBM, c.1966 (Lohmann collection)



Fig. 7.8. Computer-generated binary hologram and its reconstruction, Lohmann et al., 1967 (Lohmann collection)

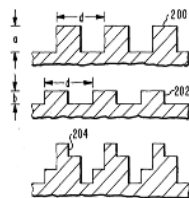


Source: A. W. Lohmann

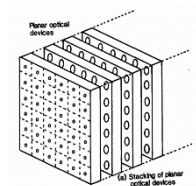


CALCOMP 565 Plotter

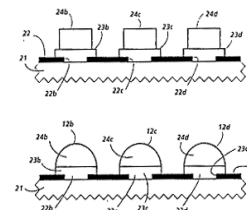
- + 1966 **Digital** or **Planar Optics**
- + 1977 Mike Gale: Multi-level **Diffraction Optics**
- + 1982 Kenichi Iga: **Stacked Planar Optics**
- + 1985 Zoran Popovich: Melting Resist **Microlenses**



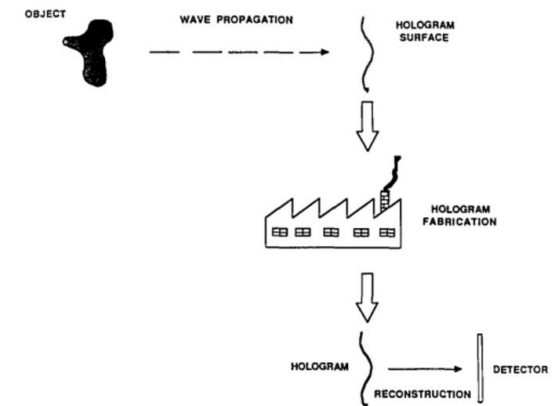
Multi-Level DOE



Stacked planar micro-optics



Melting resist microlenses



Lohmann's Hologram-Factory

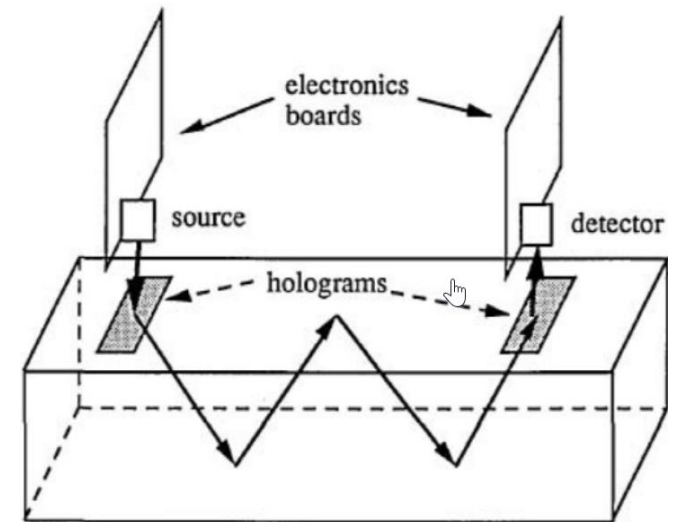
THE VISION: MICRO-OPTICS – FORMERLY CALLED DIGITAL OPTICS - COULD SAVE THE WORLD!

My first lecture from Adolf W. Lohmann (Nov 6th, 1986):

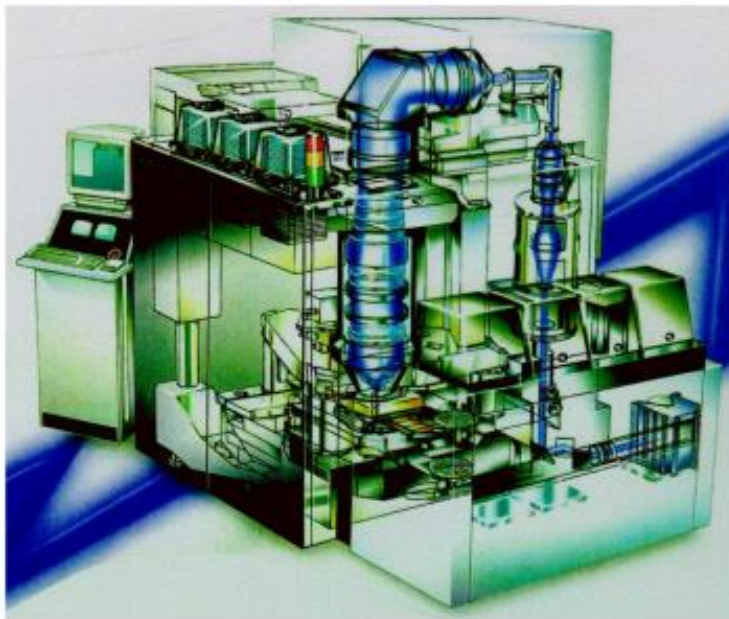
- + “We urgently need the **Digital Optical Computer** because electronic computing has reached the fundamental limits.”
- + 3D holographic memory
- + Planar optics replaces photo lenses
- + Optical backplanes for telecom
- + Microlens Arrays



1992: Mike Hutley in our cleanroom at the Optics Institute in Erlangen, Germany



Diffusers for DUV-lithography: a success story



- 1994 Feasibility study at IMT (Herzig/Dändliker)
- 1995 Manufacturing of diffractive optical elements (DOEs) for DUV-Lithography at CSEM
- 1997 Development of refractive microlens arrays for DUV-Lithography
- 1999 Free-form beam-shaping (CGH)
- 2009 MEMS mirror arrays (FlexRay™)

W. Singer, H. P. Herzig, M. Kuittinen, E. Piper, J. Wangler, "Diffractive beam-shaping elements at the fabrication limit," Opt. Engin. **35**, 2779-2787 (1996).

MICRO-OPTICS

Digital optics, planar optics

Gratings

Diffractive Optical Elements (DOEs)

Holographic Optical Elements (HOEs)

Computer Generated Holograms (CGHs)

Fresnel lenses, zone plates

Binary optics

Microlens arrays

Kinoforms

Micro-Optics

Sub-wavelength elements (SWL)

Hybrid optics

Waveguides

Planar optics

Metasurfaces

Phase masks

MOEMs

Digital holograms

Courtesy of Bernard Kress

Manufacturing Technologies

- + Resist & Plasma Etching (RIE)
- + Greyscale Lithography
- + Imprint Technology
- + Laser Ablation
- + Injection Molding
- + Ion Diffusion (GRIN)
- + E-Beam & Etching
- + Direct Laser Writing
- + Wet Etching (HF)
- + Holography
- + Diamond Turning
- + Imbossing or Mold Pressing
- + Lapping/Grinding & Polishing
- + ...

Companies



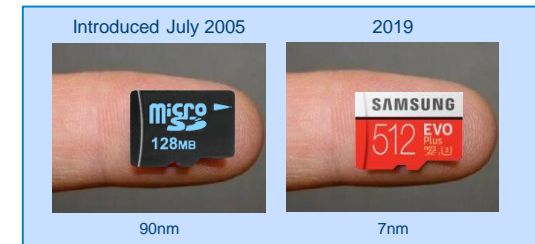
What are the big differences between Photonics and Semiconductor Industry?

SEMI

- + Wafer-based manufacturing using Ø200mm and Ø300mm wafers
- + High degree of standardization and automatization
- + Highly parallel manufacturing processes
- + Standardized manufacturing equipment (\$65 billion annual spending)
- + Price reduction of 30% per year since 1960 for logic and memory

PHOTONICS

- + Mostly manual processes and one-piece flow manufacturing
- + Fewer standardization and high diversity
- + Wafer-based manufacturing is < 15% of the global Photonics revenue
- + Often low automatization makes up-scaling a challenge



SUSS MICROOPTICS

SUSS MICROOPTICS: SPIN-OFF FROM IMT NEUCHÂTEL IN 1999

SUSS + MicroOptics

+ Joint venture



85%
SUSS MicroTec AG
Garching, FRG



5%
Reinhard Völkel
CEO



5%
Martin Eisner
CTO



5%
Kenneth J. Weible
COO

Good choice, because

- + Customer
- + Investor
- + Equipment supplier
- + Business angel
- + 550 km away

Hugle Litho, Microlens Projection Lithography

SUSS MicroTec IPO 1999

Semiconductor Industry

Support, worldwide network

...

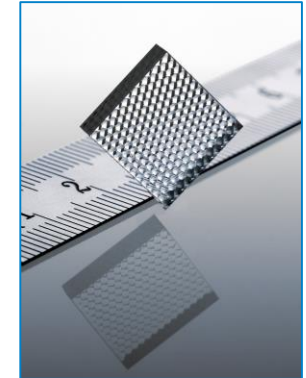
SUSS MICROOPTICS – WE SET THE STANDARDS

SUSS MicroOptics

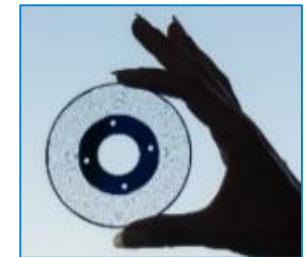
- + World leading supplier of high-quality Micro-Optics
- + More than 200 active customers worldwide
- + We are part of **SUSS MicroTec** group

20Years
of Micro-Optics FAB Experience

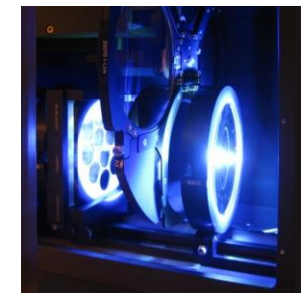
IATF 16949
Automotive Qualified



Microlens Array



Nipkow Disk



MO Exposure Optics



Neuchâtel, Switzerland



8" Wafer Cleanroom Fab

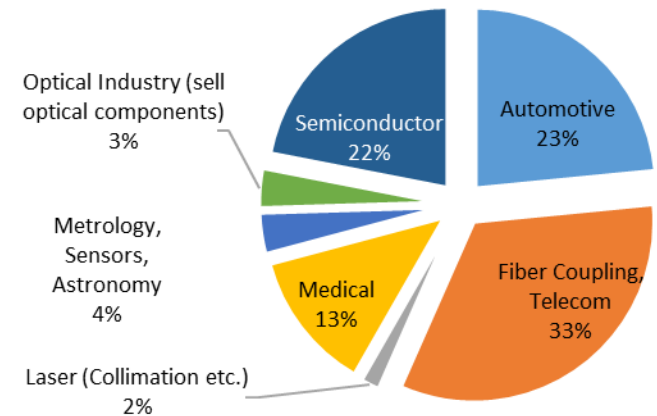
BUSINESS DEVELOPMENT

- + Strong growth in Niche Markets
- + 2012: New Cleanroom Fab @Innoparc I
- + 2018: New production line for Automotive Lighting
- + 2019: 2nd Cleanroom Fab @Innoparc IV

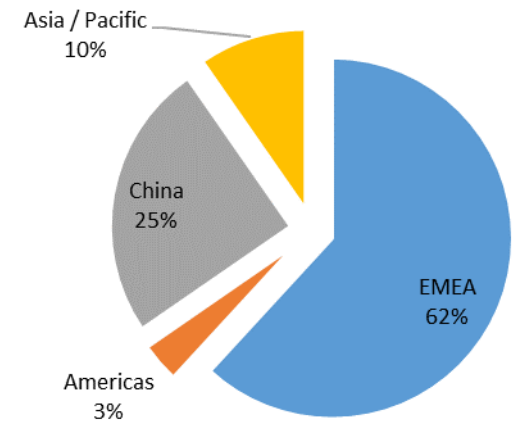
20 Years
of Micro-Optics FAB Experience

IATF 16949
Automotive Qualified Imprint Production

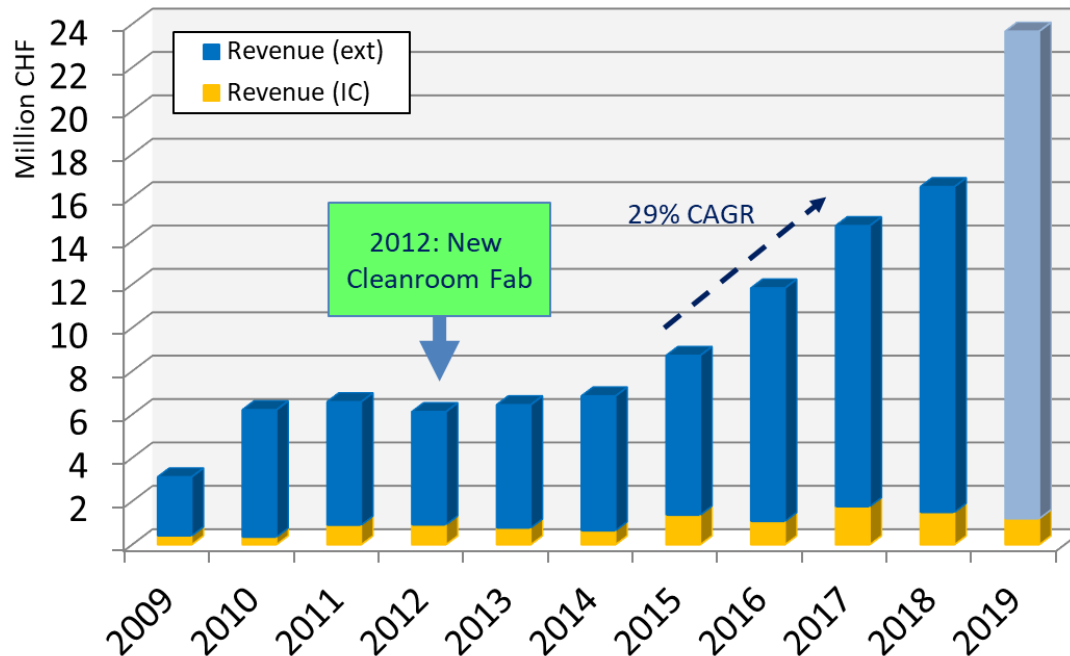
Revenue by Market 2018



Revenue by Region 2018



REVENUE [CHF]



- + International High Tech Equipment provider for the SEMIconductor industry
- + Focus on growth segments: Advanced Packaging, MEMS, 2.5D / 3D and Imprint
- + Global customer base with biggest business volume in Asia (>12'000 tools installed)
- + Production at four major sites in Germany, USA, and Switzerland



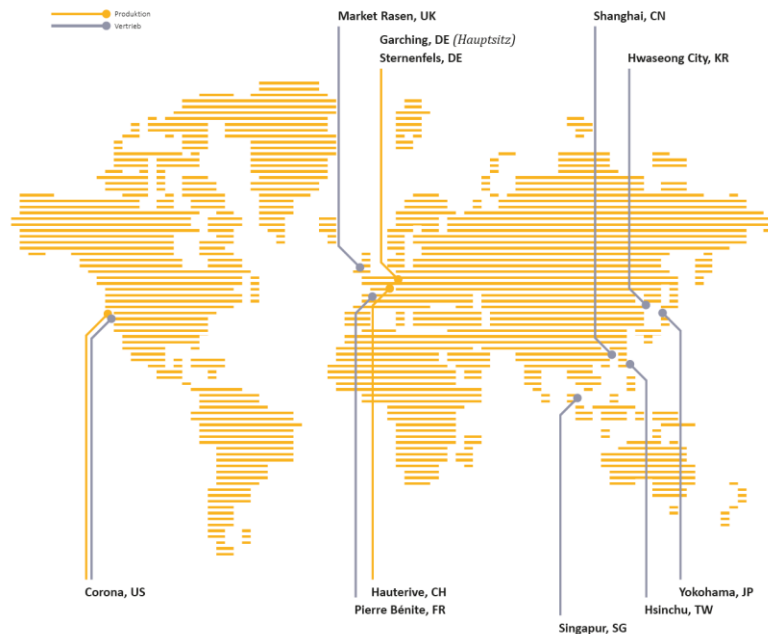
Mask Cleaning



Lithography
Wafer Bonder



Coating Cluster



Highlights FY 2018

+ Order entry	190 Mio€
+ Sales	210 Mio€
+ EBIT	15 Mio€
+ Employees	>900



Equipment for Wafer-Based Manufacturing: SEMI, Photonics, MEMS, ...

Frontend

Mid- und Backend

Photomask-Equipment

Photomask
Processing



MaskTrackPro

Lithography

Laser Equipment



ELP300 Gen2

Exposure-
systems



Mask Aligner
MA200 / MA300



Projection Scanner
DSC300 Gen2

Coater and
Developer



ACS300 Gen3

Bonder

Wafer Bonder



XBC300 Gen2

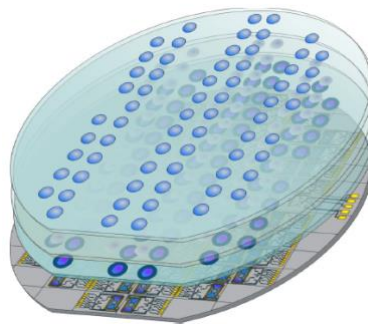
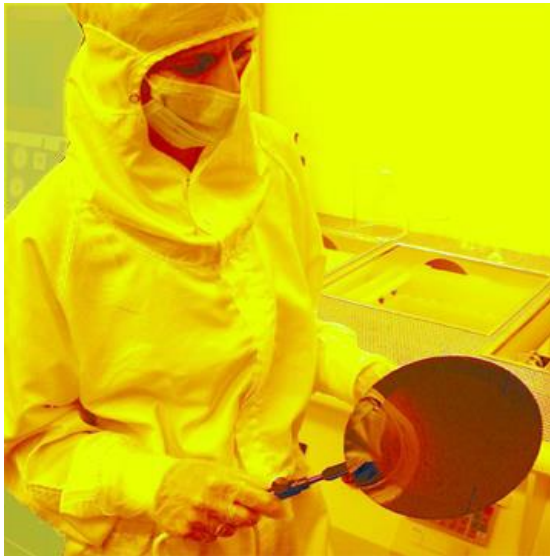


XBS200

APPLICATIONS AND MARKETS

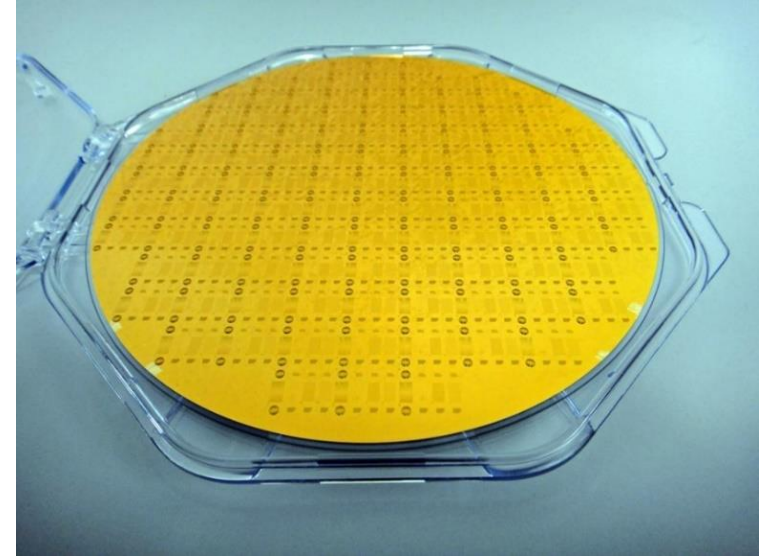
WAFER-LEVEL OPTICS (WLO)

- + Wafer-based microstructuring technology from SEMI and MEMS industry is used for the manufacturing of **Refractive**, **Diffractive** and **Hybrid** Micro-Optics on wafers
- + Wafers: **Fused Silica**, **Silicon** and **Polymer-on-Glass** (Imprint)
- + Commercial tools for Optical Design, Simulation, Metrology and Process Control
- + Wafer-Level Packaging (WLP), Stacking, Sorting



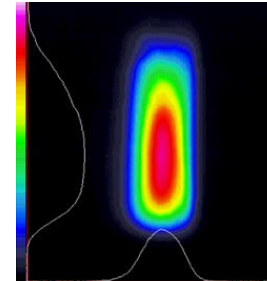
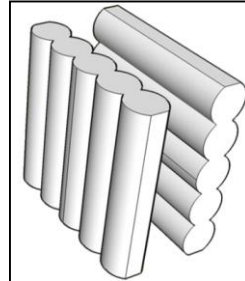
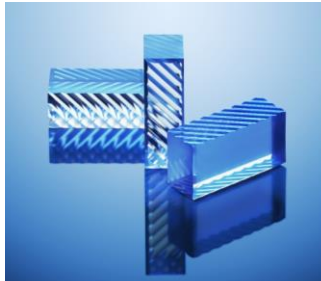
Source: FHG-IOF, Jena

Wafer-Level Packaging

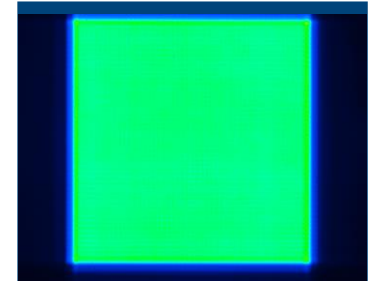


KILLER APPLICATION: (LASER) BEAM SHAPING

Microlens Arrays (ROE)

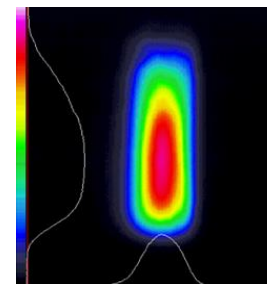
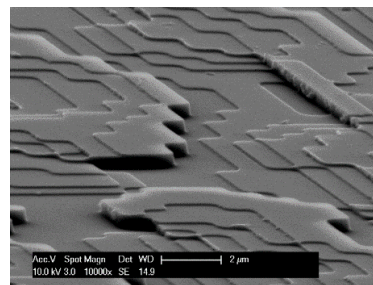
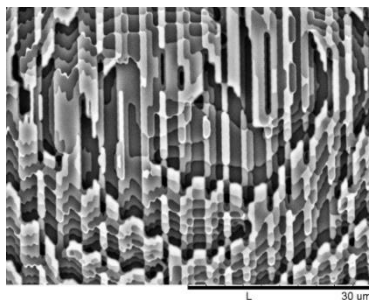
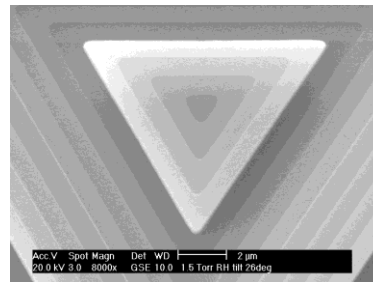
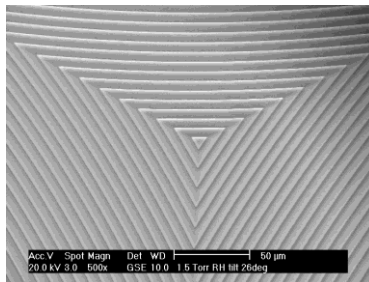


Excimer

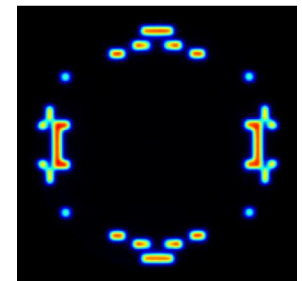


Flat-Top

Diffractive Optical Elements (DOE)

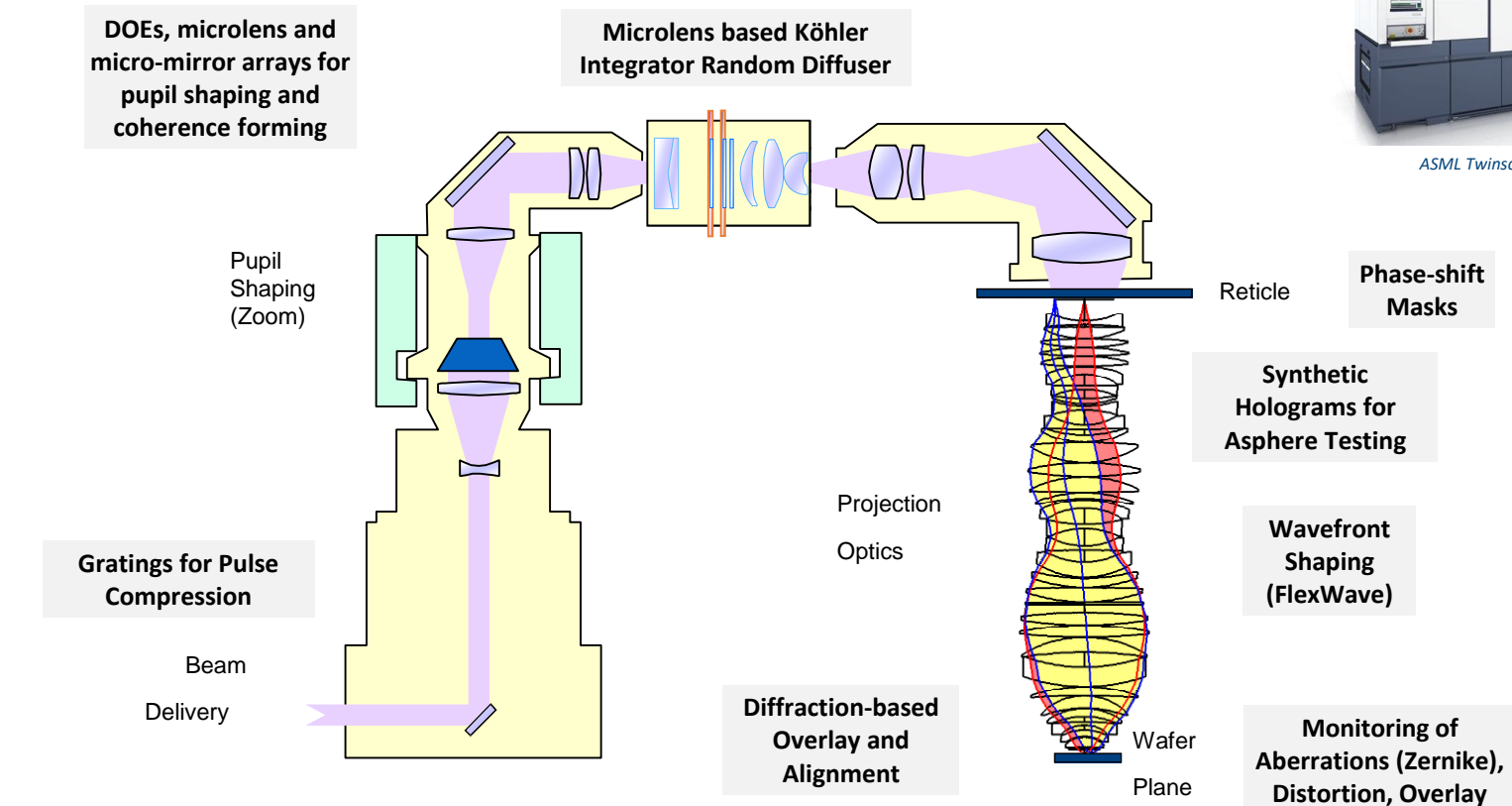


Excimer



Sources: www.blz.org, Johannes Wangler (CZ SMT)

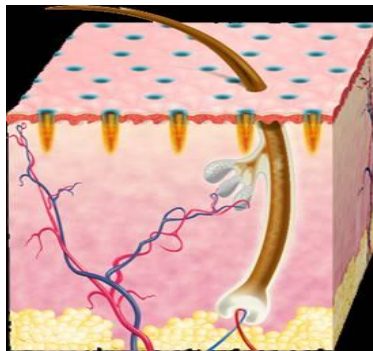
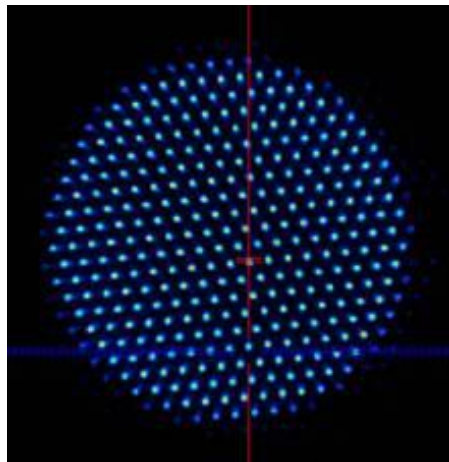
KILLER APPLICATION: SEMICONDUCTOR INDUSTRY



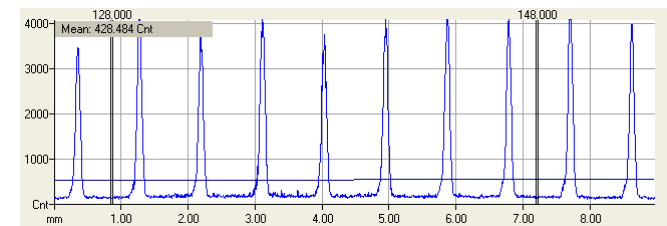
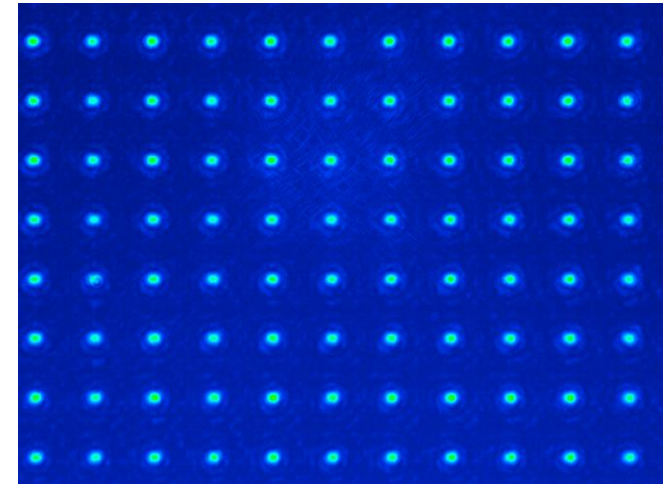
ASML Twinscan NXT 1970 Ci

Dermatology

- + Hair Removal
- + Tattoo Removal
- + Pigment Treatment
- + Skin Rejuvenation



Source: www.palomarmedical.com



FIBER COLLIMATOR AND REFOCUSING FOR DATACOM & TELECOM



www.anguerde.com

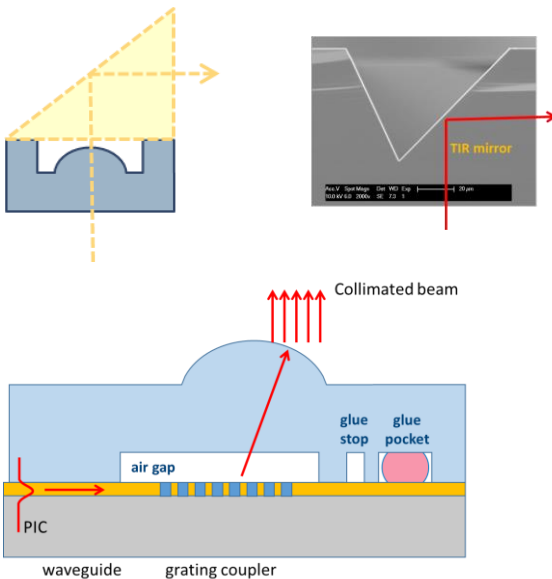
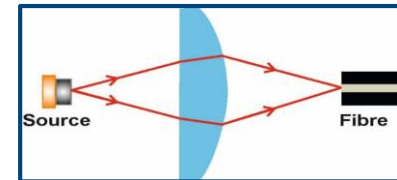
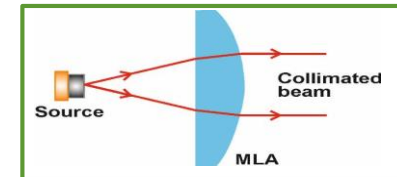
FTTX: Fiber to the X

FTTN: Fiber to the Neighborhood

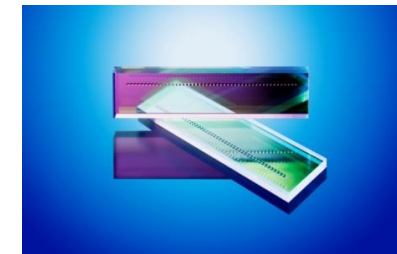
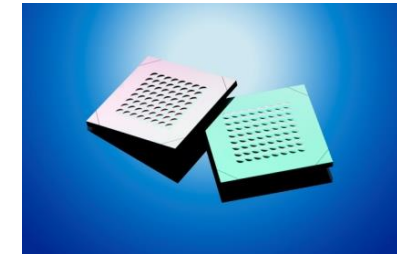
FTTC: Fiber to the Cabinet

FTTB: Fiber to the Building

FTTH: Fiber to the Home

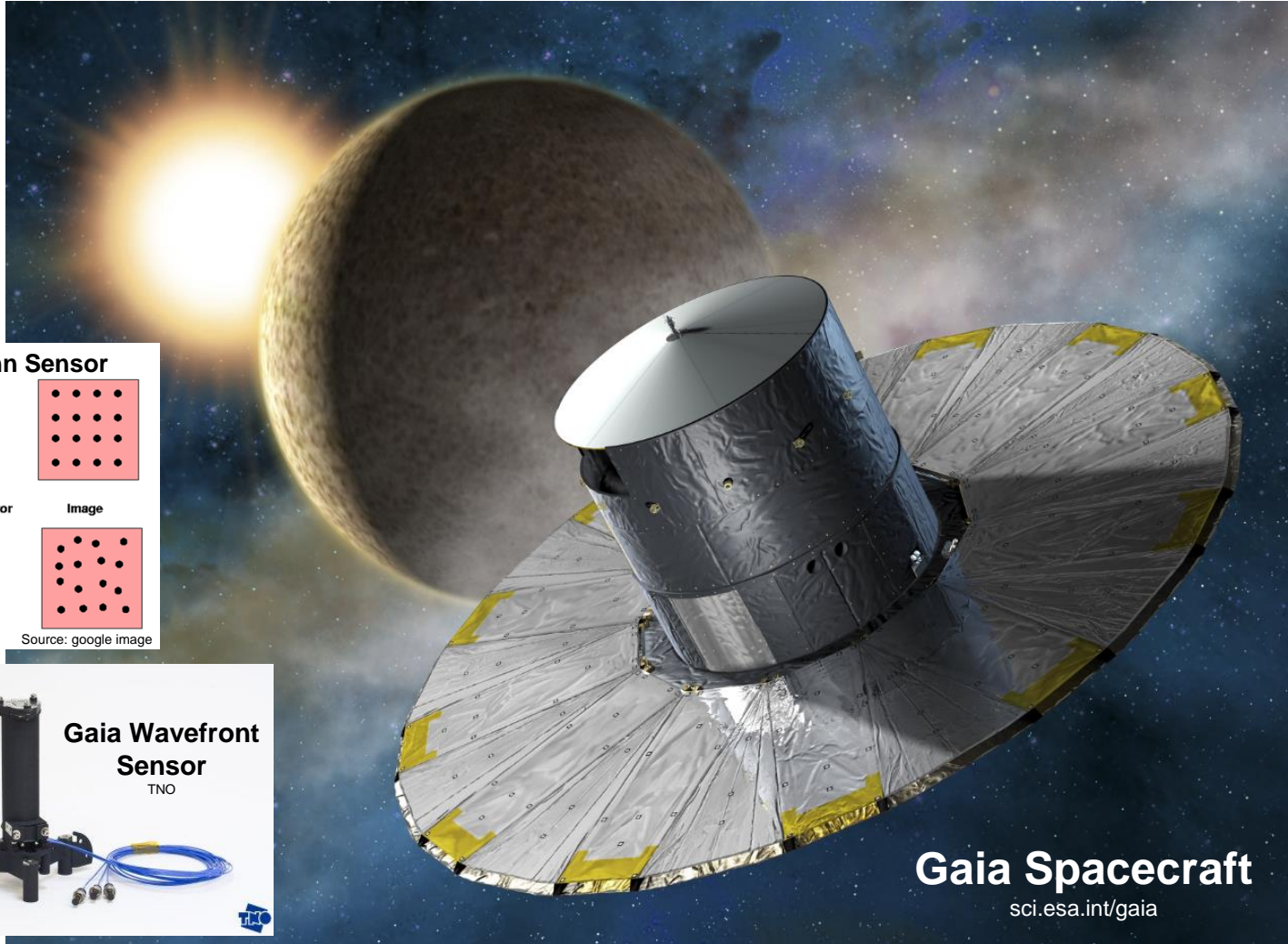
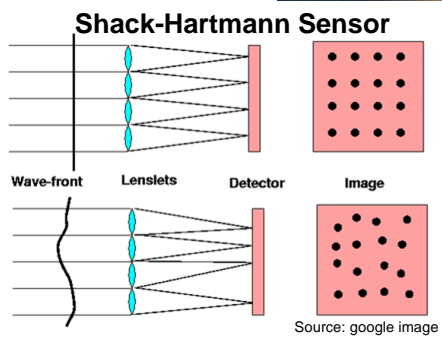


- The closer the fiber comes to the your home/office, the more switches are needed
- Switches are getting smaller, need to be cheaper and higher volume



www.intelfreepress.com/news/revolutionizing-computing-with-lasers/57/

Micro-Optics in Space



Low Volume High Quality (LVHQ)

- + Core business with strong growth (CAGR >15%) in niche markets
- + Key is a unique feature, high excellence requirements or other unique sales proposition (USP)

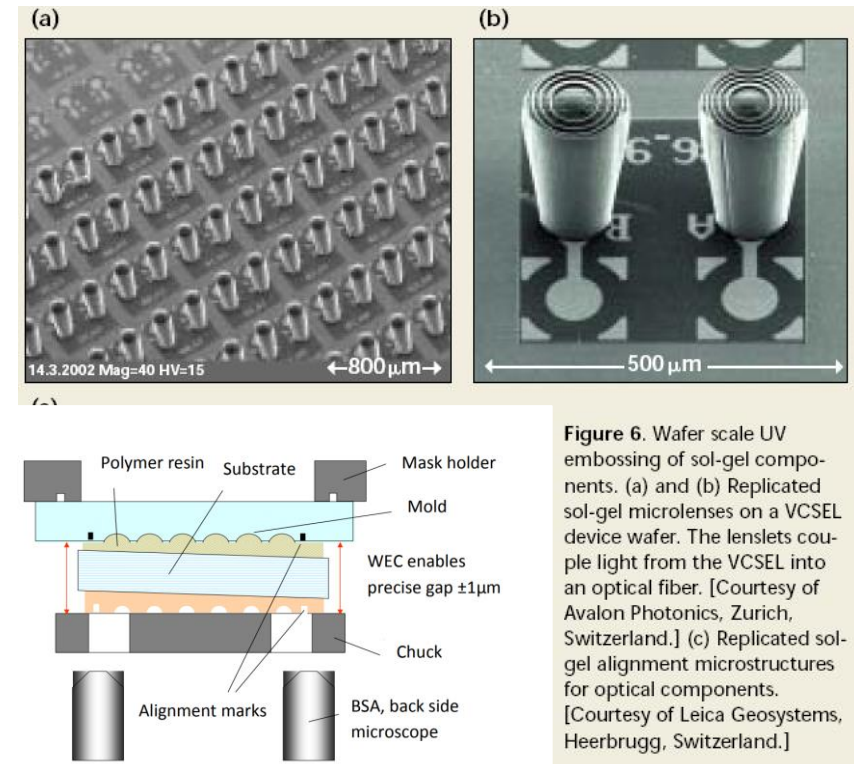


MICROLENS IMPRINT LITHOGRAPHY (SMILE)

Wafer-Level Photonics

1997 MICROLENS IMPRINT - SUSS MASK ALIGNER

+ CSEM Zurich (Mike Gale) former RCA Lab



M.T. Gale, "Replication," Chapter 6 in Micro-Optics: Elements, Systems and Applications, H.P. Herzig, Ed., Taylor and Francis, London (1997).

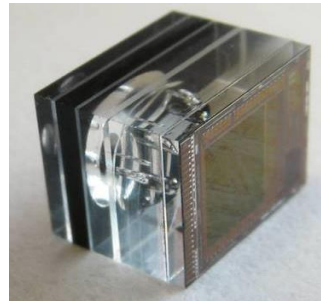
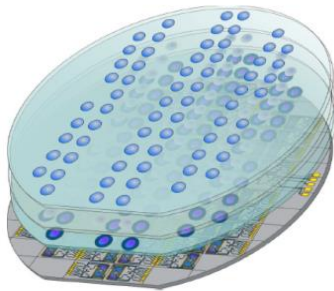
Brite-Euram Project BE97-464 1, DONDODEM, Development of new dielectric and optical materials and process-technologies for low cost electrical and/or optical packaging and testing of precompetitive demonstrators, (1998-2001).

MICROLENS IMPRINT LITHOGRAPHY (SMILE)

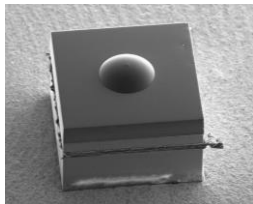
WAFER-LEVEL CAMERA (WLC)

WAFER-LEVEL PACKAGING (WLP)

- + EU-Project WALORI (2002 -2005)
- Backside (see-through) CMOS Viewer

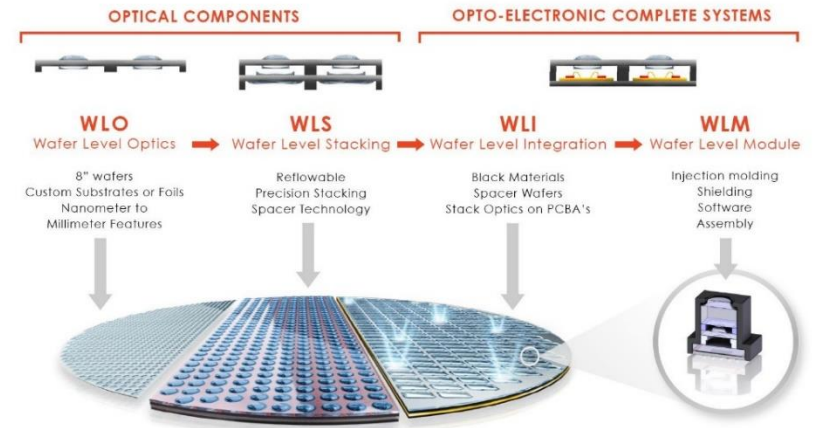


- + WLO Endoscope Camera NanEye (Awaiba)



ams AG

- + Heptagon acquired CSEM (RCA) in Zurich in 2002
- + Wafer-Level Camera (WLC) hype 10y ago

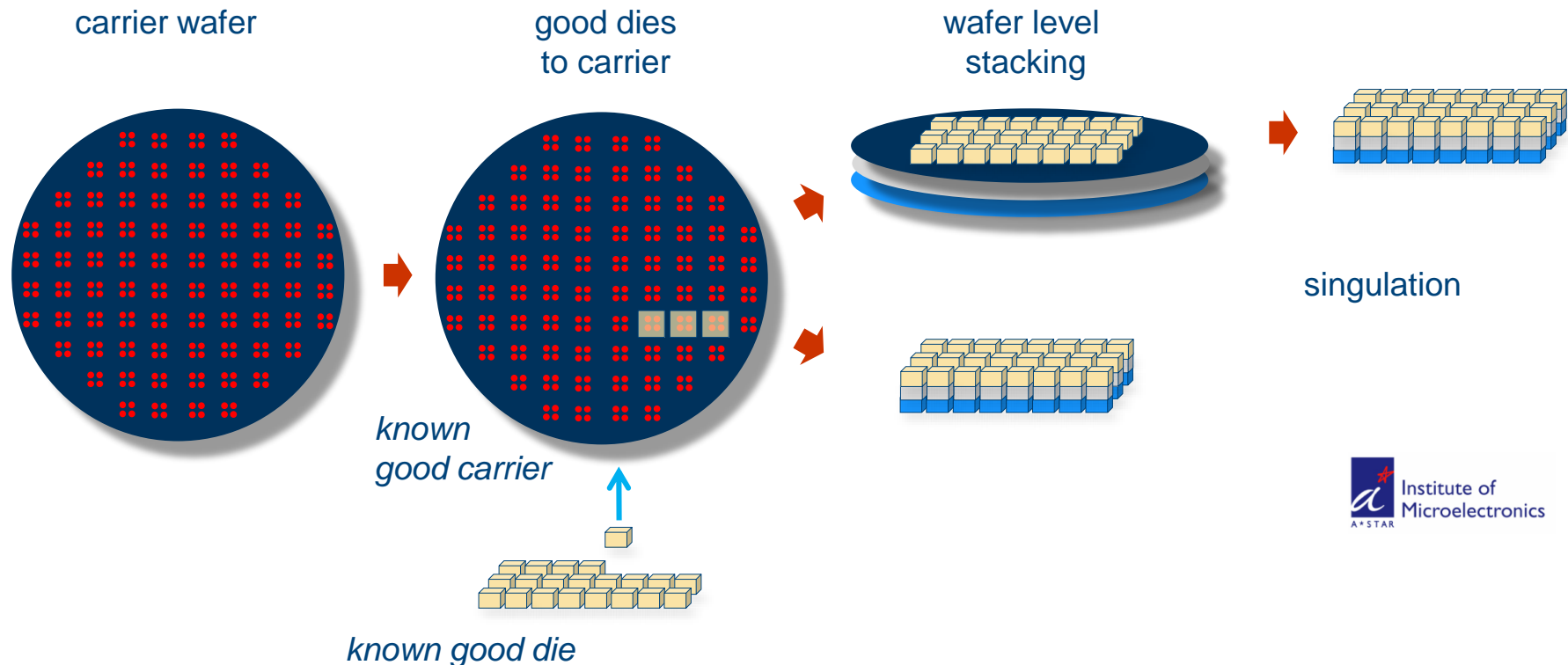


ams AG

- + Heptagon's incredible success story

YIELD – THE KILLER ISSUE FOR WAFER-LEVEL CAMERAS (WLC) AND WAFER-LEVEL PACKAGING (WLP)

- + Yield [Process #1] x Yield [Process #2] x Yield [Process #3] x ... =
- + Work around solution: Die-to-Wafer, reconstitute wafers
- + Carrier based integration

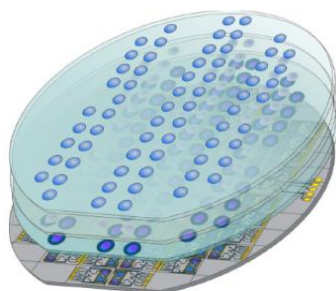


MICROLENS IMPRINT LITHOGRAPHY (SMILE)

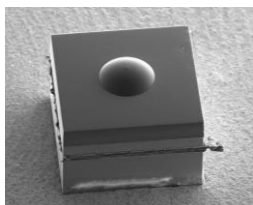
WAFER-LEVEL CAMERA (WLC)

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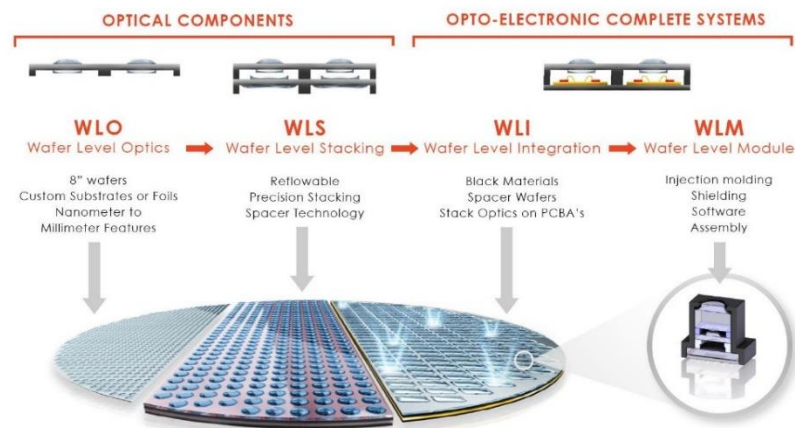


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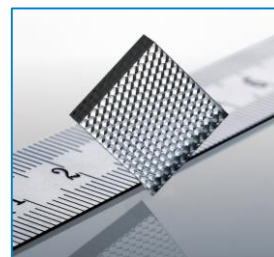
ams AG

- + Heptagon acquired CSEM (RCA) in Zurich in 2002
- + Wafer-Level Camera (WLC) hype 10y ago



ams AG

- + Heptagon's incredible success story
- + BMW Welcome Lightcarpets



SUSS MICROOPTICS – OUR PRODUCTS AND SERVICES

Low Volume High Quality (LVHQ)

- + Core business with strong growth (CAGR >25%) in niche markets

Mid Volume High Quality (MVHQ)

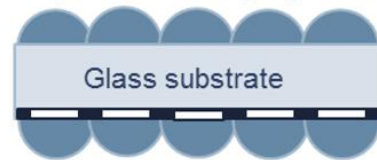
- + Key is a unique feature, high excellence requirements or other unique sales proposition (USP)
- + A close co-operation with SUSS MicroTec ensures top-notch production equipment
- + Excellence Center with mid volume production and 1st class support for high volume customers

SMO's Products	<div></div> <div>Microlens Array 13x13mm²</div> <div></div> <div>Nipkow or Pinhole Disk</div> <div></div> <div></div> <div>ROE + DOE 40x50mm²</div>	<div></div> <div></div> <div>Polymer-on-Glass/Silicon Wafer-Level Optics (WLO)</div>
Customer's Products	<div></div> <div>Tattoo Removal Laser</div> <div></div> <div>Confocal Microscope</div> <div></div> <div>Photolithography Stepper</div>	<div></div> <div></div> <div>Automotive Lighting, Wafer-Level-Optics (WLO)</div>
SMO'LVHQ		SMO'MVHQ

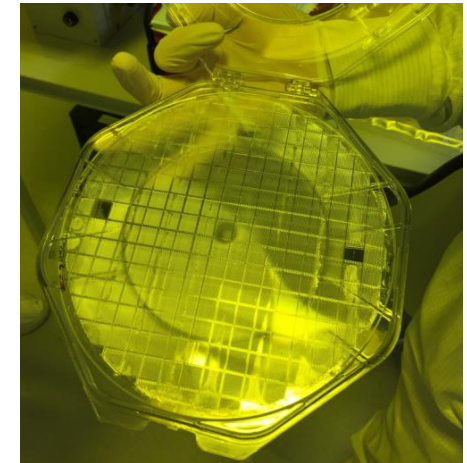
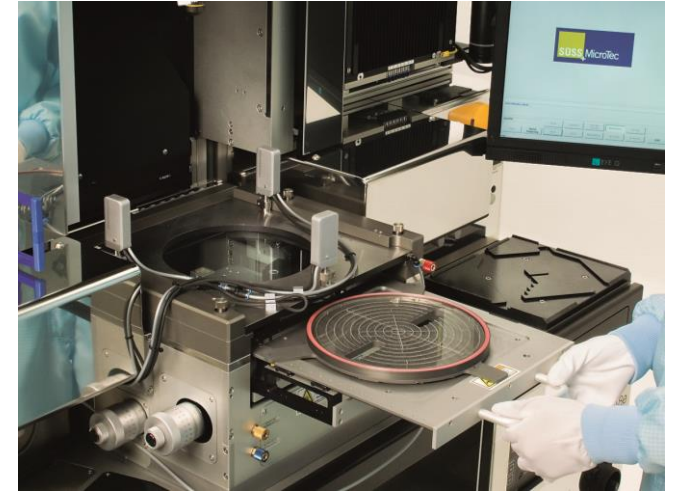
WELCOME LIGHT CARPET FOR CARS



Replicated Imaging lens

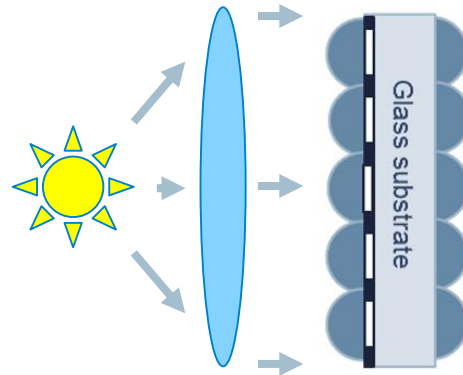


Replicated Illumination
(condenser) lens

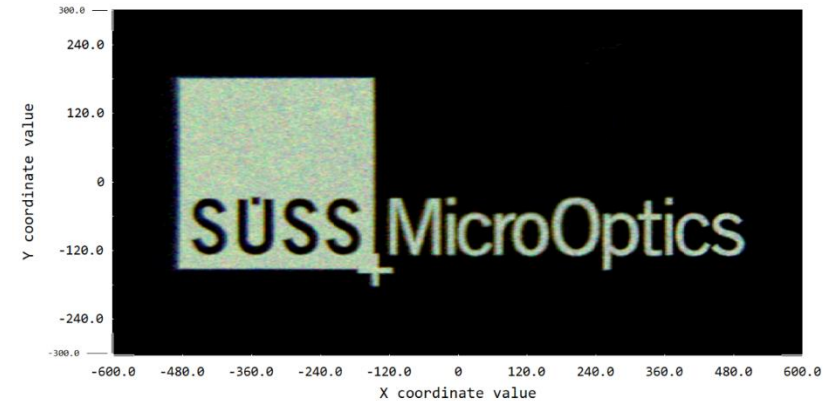


MICROLENS IMPRINT LITHO FOR LIGHT CARPETS

IATF 16949
Automotive Qualified Imprint Production



Array Projector (Moiré Magnifier)

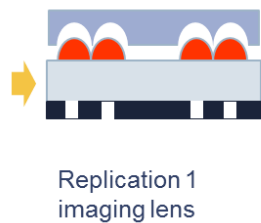


Superposition of Microlens Array Projection on Target (Simulation SMO)

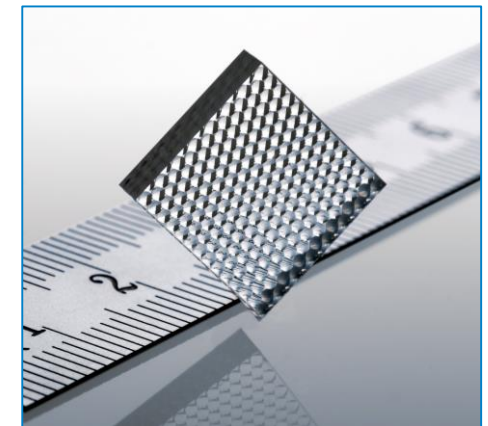
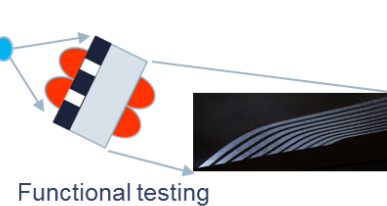
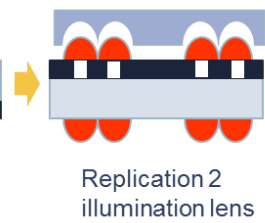
Cr pattern lithography



Replication



Back end



Microlens Array (MLA) for Light Carpets

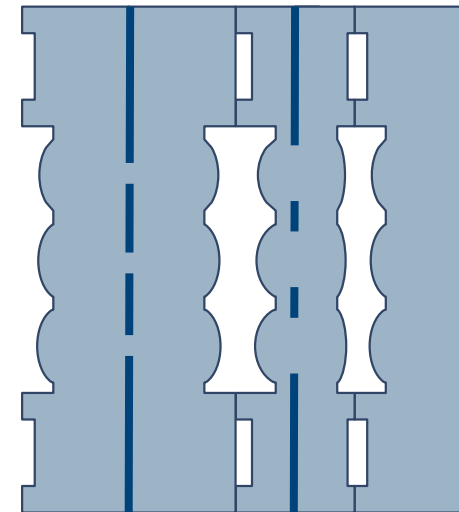
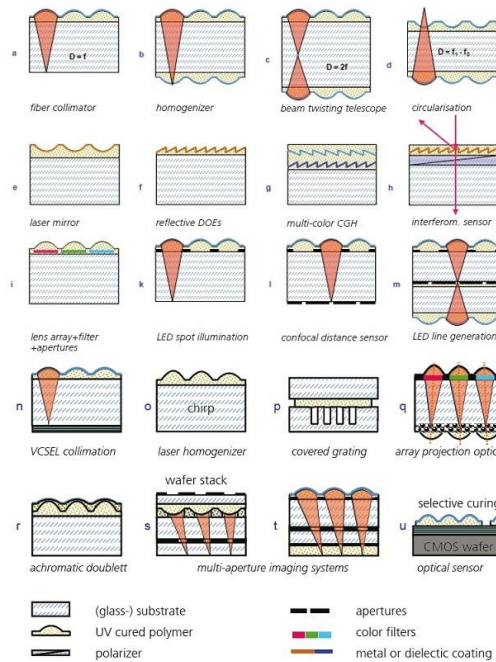
THE FUTURE: MICRO-OPTICS FOR AUTOMOTIVE LIGHTING?

+ Light Carpet

- External
- Internal

+ Front Lights

- LED Matrix
- Laser Light



installed customer base

190

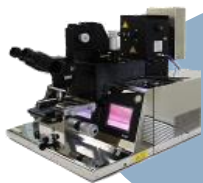
tools worldwide

- + Global service infrastructure
- + Complete semi-automatic product portfolio
- + Complete process development infrastructure
- + Decades of imprinting process experience

EVOLUTION OF SUSS IMPRINT EQUIPMENT



MA/BA6



MJB4



MA/BA8 Gen4



MA/BA8 Gen4 Pro



MA12



XLC200

**Mask & Bond
Alignment**

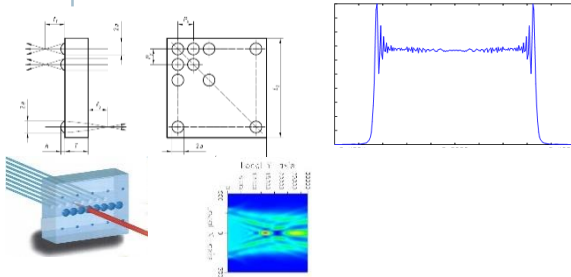
**Nano-Imprint
Lithography**

**Micro-Imprint
Lithography**

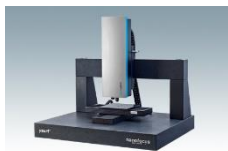
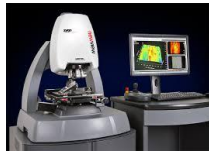
**WLO
Stacking**

IMPRINT EXCELLENCE CENTER AT SMO IN 2019

"You can't supply top-notch production equipment without have a production line in place"



**Optical Design, System Design,
Micro-Optics Simulation**



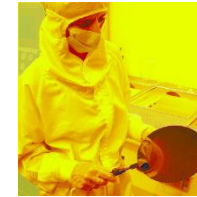
**Fully equipped metrology lab for inspection
and sorting of micro-optical components.
(ISO 9001, IATF 16949, SixSigma)**

**Optical
System
Design**

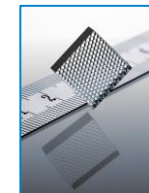
**8" (6") Wafer
Fab**

**Metrology,
Wafer-Level
Packaging,
Inspection**

**8" & 12"
Process
Development
and Customer
Demos**



**Production Line high-quality
refractive & diffractive micro-optics
(Fused Silica, Silicon)**



**Production Line for Microlens Imprint (Polymer),
Wafer-Level Packaging, Dicing
Excellence Center for SUSS Customers**

SUSS MicroTec Lithography

- Imprint Equipment
- Demonstrations
- Application support

Supply chain

- Resist supplier
- Stamp material supplier
- Master supplier



SUSS MicroOptics

- 6"/8"/12"
WLO imprint FAB
- Design & Prototyping
- WLO Metrology
- Automotive qualification

SUSS Imprint Excellence Center

Services for

- Design & Prototyping
- Mastering
- Process Development
- Transfer to HV production

SUSS MicroTec's Complete Imprint Solution:
Leading edge equipment technology combined with
our imprint production experience to ensure our customer success!

NEW CLEANROOM FAB FOR WAFER-LEVEL OPTICS SUSS IMPRINT EXCELLENCE CENTER



7-8 November 2019

EPIC Meeting on Wafer Level Optics at
SUSS MicroOptics

Neuchatel, Switzerland

Registration open



IATF 16949
Automotive Qualified

20Years
of Micro-Optics FAB Experience

A close-up photograph of a hand holding a black marker, writing the words "Thank you!" in a cursive script on a white surface. The hand is positioned on the right side of the frame, and the marker is in the process of finishing the exclamation mark. The background is a plain, light-colored surface.

Thank you!

This presentation was presented at EPIC Meeting on Wafer Level Optics 2019

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