

AUGUST 2023



# Unleashing the Power of MicroOptics in Automotive Lighting

Reinhard Voelkel (CEO)

# SILICON VALLEY

Modern planar optics was invented here!

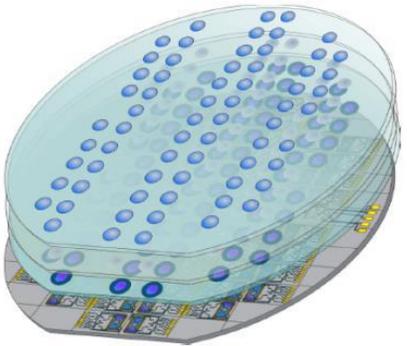
1963: Adolf W. Lohmann joined the IBM Development Lab in San Jose, CA, USA.

1966: Computer Generated Hologram (CGH)

Source: A. W. Lohmann



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



Source: FIG-IOF, Jena

Wafer-Level Packaging

1986: “The electronic computer is at the end. We need optical computers now” (A.W. Lohmann).

I had the chance to work for William (Bill) W. Hugle from 1994 to 1998.

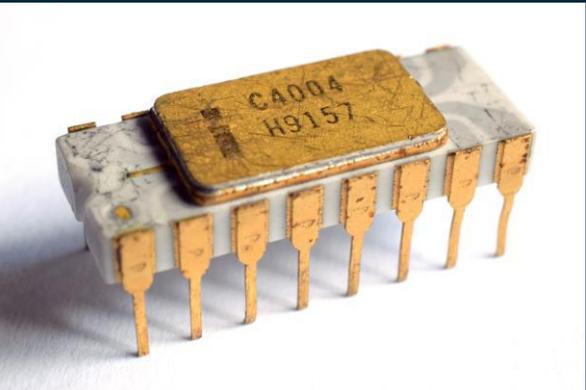
Bill Hugle founded more than 15 companies in Silicon Valley. He was the first president and founder of SEMI, the semiconductor industry association in 1971.



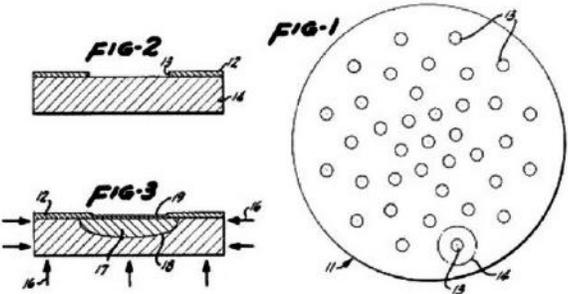
# SILICON VALLEY

- 1947:** Invention of the transistor by William B. Shockley et. al. (1956: Nobel Price)
- 1955:** Shockley Semiconductor Lab, Palo Alto
- 1957:** Fairchild Semiconductors: Robert Noyce, Gordon Moore, Jean Hoerni, Eugene Kleiner, Julius Blank, Sheldon Roberts, Jay Last, and Victor Grinich
- 1959:** Jean Hoerni invented the parallel process. **Wafer manufacturing** is the key to success for semiconductor industry!

- Vacuum tubes were replaced by microchips!
- Single unit manufacturing was replaced by parallel manufacturing on wafer-scale.



Jean Amédée Hoerni  
(1924-1997)



# SEMI: WAFER MANUFACTURING

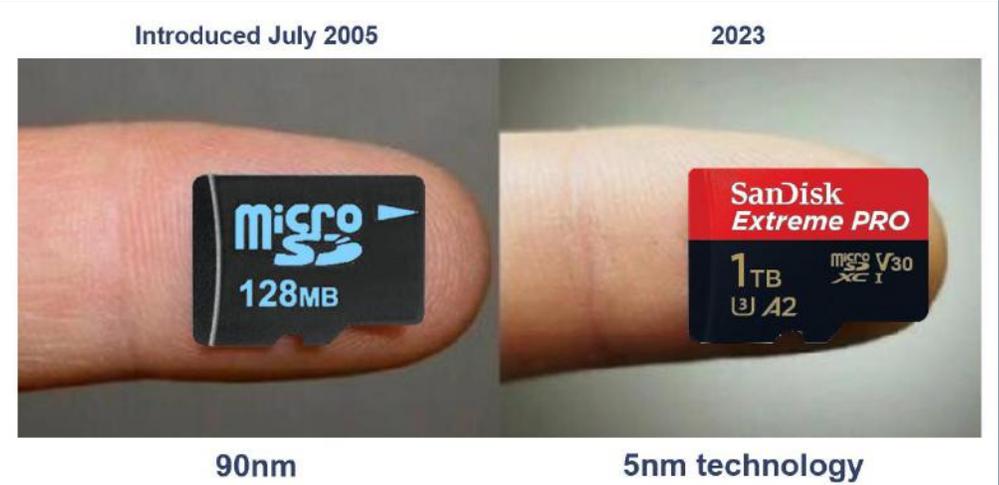
- Semiconductor industry has grown to \$550 billion revenue today.
- Semiconductor industry has also dramatically changed the automotive industry!

**Figure: Global Semiconductor Industry Market Size, 2020-2025**



Data source : Mordor Intelligence

- Semiconductor Industry has changed our life significantly!
- Wafer manufacturing using the parallel process is the key enabling technology.
- Dramatic cost reduction by 20% to 30% per year for a transistor on a wafer (logic).
- Example MicroSD (memory): 8000x more for same price in less than 20 years.

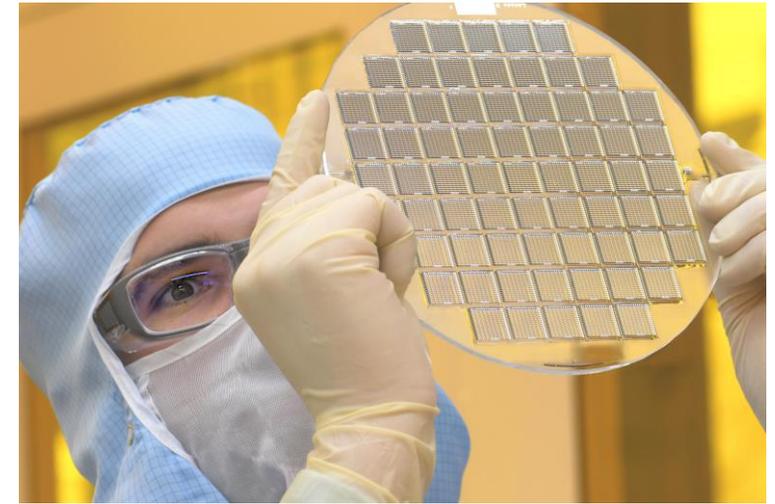


# OPTICS FOR AUTOMOTIVE LIGHTING

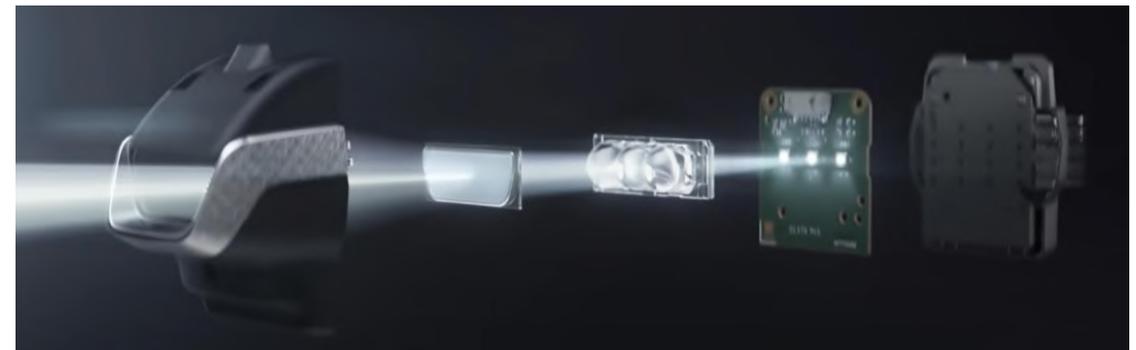
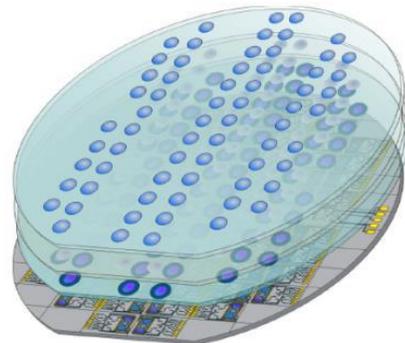
The **parallel process** was a total game changer for semiconductor industry.

The **parallel process** might also be a radical game changer for automotive lighting.

- Microlens arrays (MLAs) combine different optical functions like collimation, focusing, imaging, and beam shaping and are manufactured on wafer-level.
- Wafer-level packaging (WLP) becomes a valid option.
- Micro-LED matrix solutions become mature and might be the next game changer for automotive lighting.



BMW



Lucid Motors

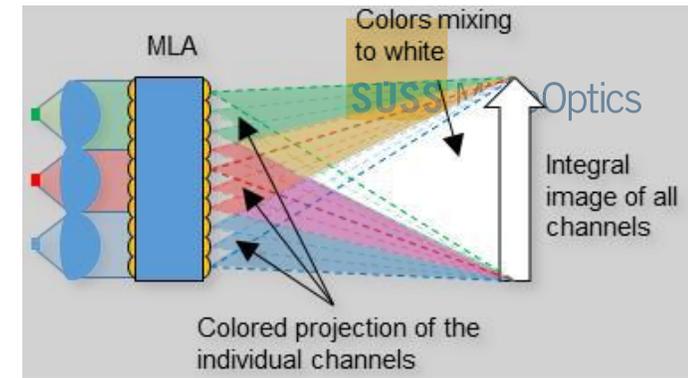
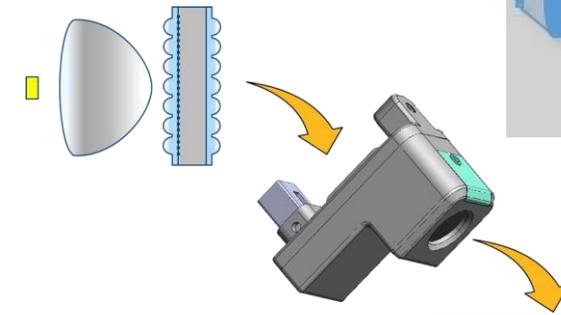
# MICRO-OPTICS FOR AUTOMOTIVE LIGHTING

Microlens arrays (MLAs) combines different optical functions like

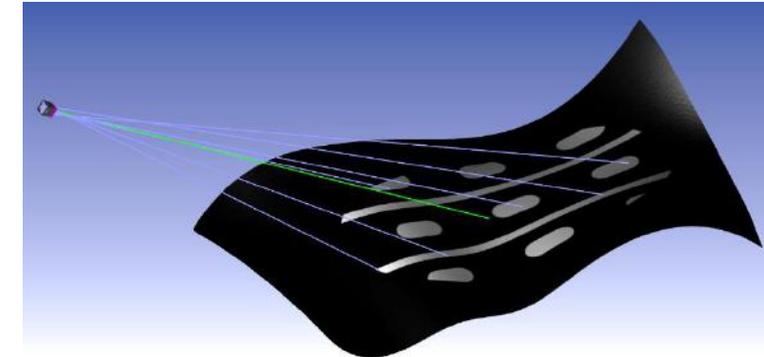
- **Collimation** micro-LED array
- **Homogenizing, mixing** all light sources
- **Projection** light carpet, safety
- **Beam shaping** head light
- **Beam splitting** LiDAR, LiFi

MLAs allow to reduce

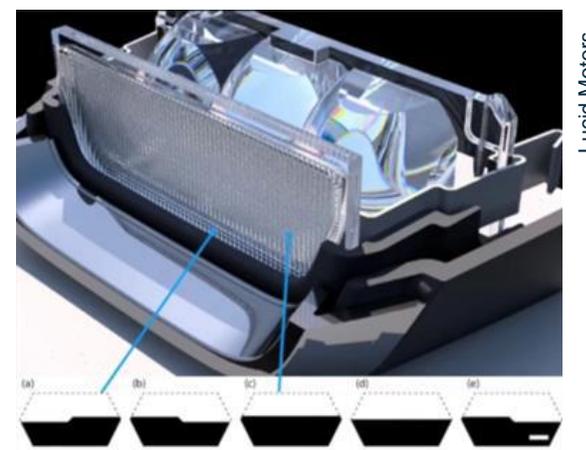
- the **complexity** (number of parts)
- the **size** (volume, weight),
- and, in the future,
- the **costs** per unit significantly.



Light mixing, uniform illumination



Sharp projection on curved surfaces



Different aperture shapes in each channel

Micro-LED arrays are the next game changer!  
 MLAs for collimation and beam shaping allows to build ultra-flat and ultra-slim light engines.  
 Cost saving by using standardized building blocks in automotive lighting.

# THE SUCCESS STORY OF SEMI

The 8 founders of Fairchild Semiconductor generated more than 90 new companies.

- A. Half of these new companies were manufacturing micro-chips.
- B. Half of these new companies were providing dedicated manufacturing tools for SEMI!

From the beginning, these companies all agreed to common standards, the SEMI standards.

In the first years, micro-chip production was not profitable at all. SEMI only became profitable after they have fully automated production avoiding any human interaction.

Today, semiconductor industry typically achieves yield levels of >90% for more than 160 subsequent process steps.



Fairchild Semiconductor:

Robert Noyce, Gordon Moore, Jean Hoerni, Eugene Kleiner, Julius Blank, Sheldon Roberts, Jay Last, and Victor Grinich

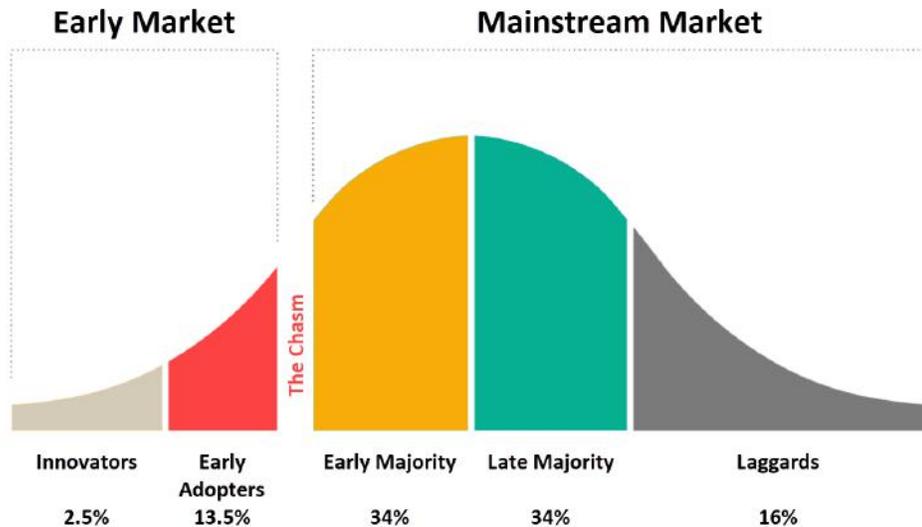
# MLA FOR AUTOMOTIVE LIGHTING

First microlens arrays (MLA) manufactured on wafer-level were introduced 7 years ago (light carpets).

More than 10 million cars with MLA light carpets are on the road today.

Safety applications will follow soon.

First MLA headlamps were introduced last year.



# MLA MANUFACTURING 2023



Wafer-level manufacturing of MLAs is based on old semiconductor tools like mask aligners.

No dedicated tools are available today.

Production is still based on human operators.

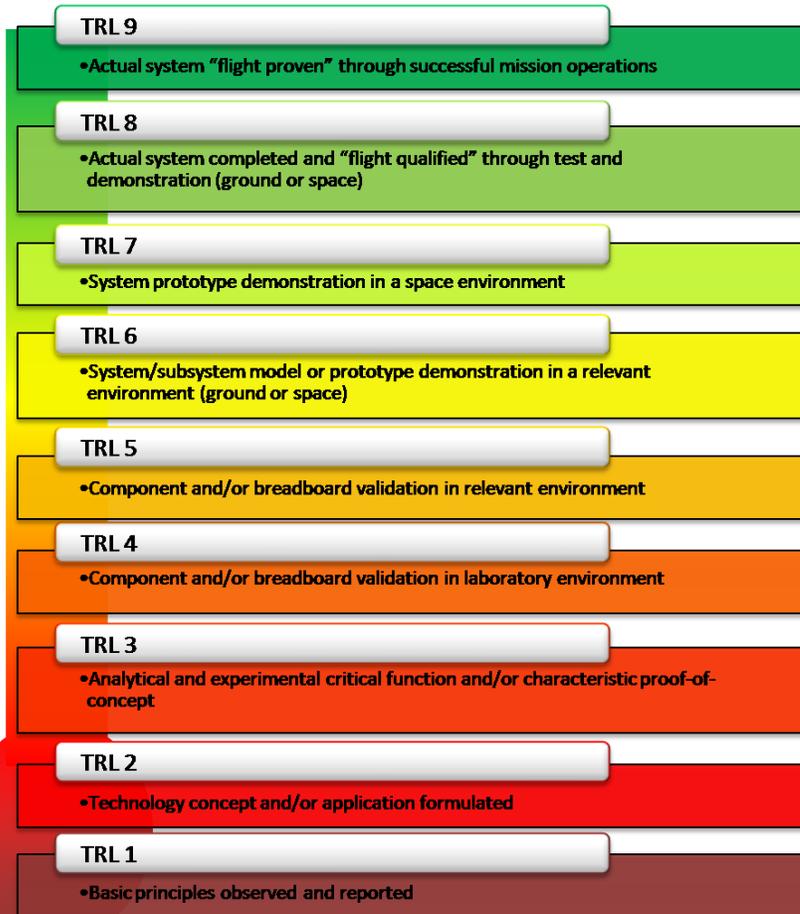
The major issue with the parallel process is yield:

- $\text{Yield}_1 \times \text{Yield}_2 \times \text{Yield}_3 \times \dots = \text{Yield}_{\text{total}}$
- **Example:  $0.8 \times 0.8 \times 0.8 = 0.5 !!!$  50%**

Very similar to semiconductor industry in the 1970, MLA manufacturers need to get fully industrialized, automated and optimized manufacturing equipment!

# MLA FOR AUTOMOTIVE LIGHTING

Technology Readiness Level: TRL 9  
MLAs are "flight proven"



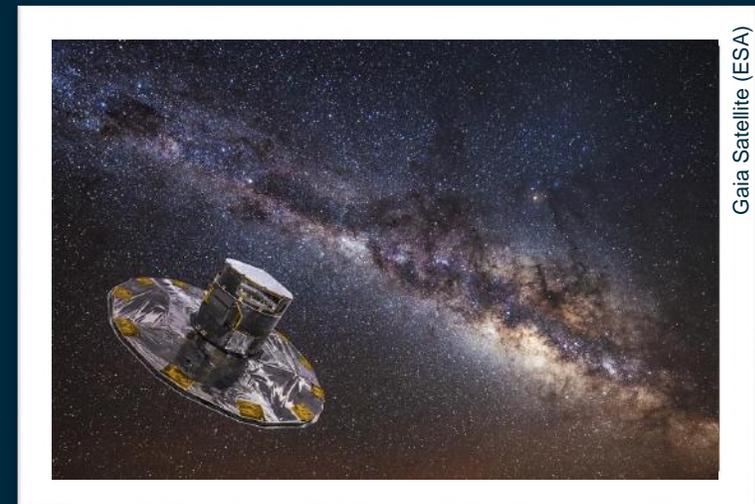
# MLA MANUFACTURING 2023



The current lack of dedicated production equipment and related yield issues introduced by human operators severely increase costs per MLA today.

## Manufacturing Readiness Level: MRL 6 to 7

This is only a temporary issue which will be solved within the next 2 to 3 years.



# THE MICROLENS REVOLUTION

Classical electronics manufacturers were not taking the semiconductor industry for serious in the 1970s, but ...

Yes, still you can buy radios and amplifiers with vacuum tubes, but ...

Micro-LED arrays in combination with Microlens Arrays (MLA) will allow significant cost savings in automotive lighting industry.

The current lack of dedicated manufacturing equipment for MLAs is an issue, but not unsolvable. No rocket science!

The microlens revolution has a high potential to significantly change today's automotive lighting landscape.

Happy to team up with you to make it happen!



Thank you!

