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Laser Beam Scanning for Near-to-Eye Display Applications: Synopsis of Architectural, Optical, Photonic and System Considerations

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Chair LaSAR Alliance

EPIC Meeting on Photonics for AR/VR/MR: From Design to System Integration and Mass Production at Jabil Optics

11 May 2023
Jena, Germany

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

Agenda

1. Principles behind, and benefits of LBS
2. Optical Light Engine Design
3. Optical Light Engine Architectures
4. Combiner Optics
5. Diffractive Waveguides
6. LaSAR Alliance
7. Summary

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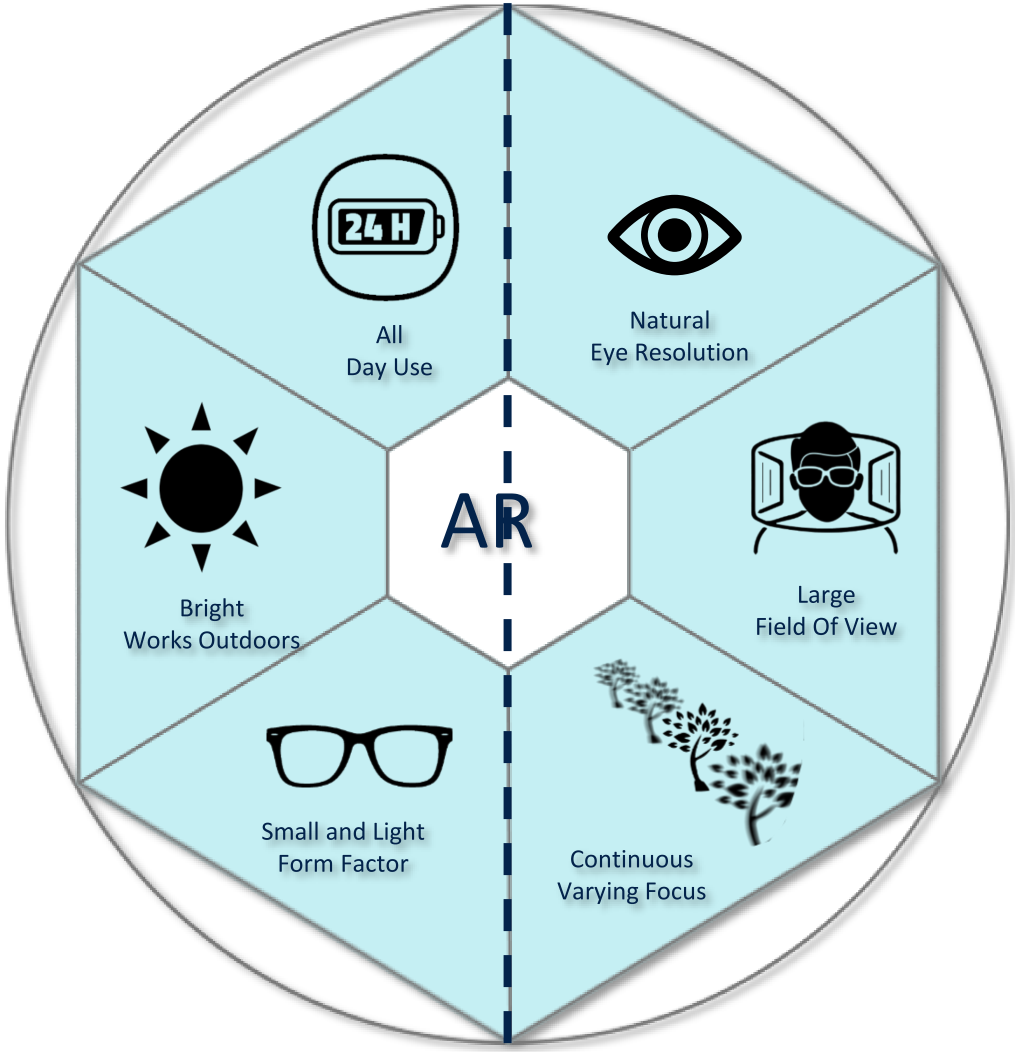
Challenges and Opportunities for AR Wearables

Practical and Useful



Immersive and Niche

Image (adapted) courtesy of Nikhil Balram, Eyeway Vision, https://www.youtube.com/watch?v=Rt6zWDYI_dk

LBS technology can address the display needs and challenges of both markets
BUT immersive have many more challenges beyond just the display

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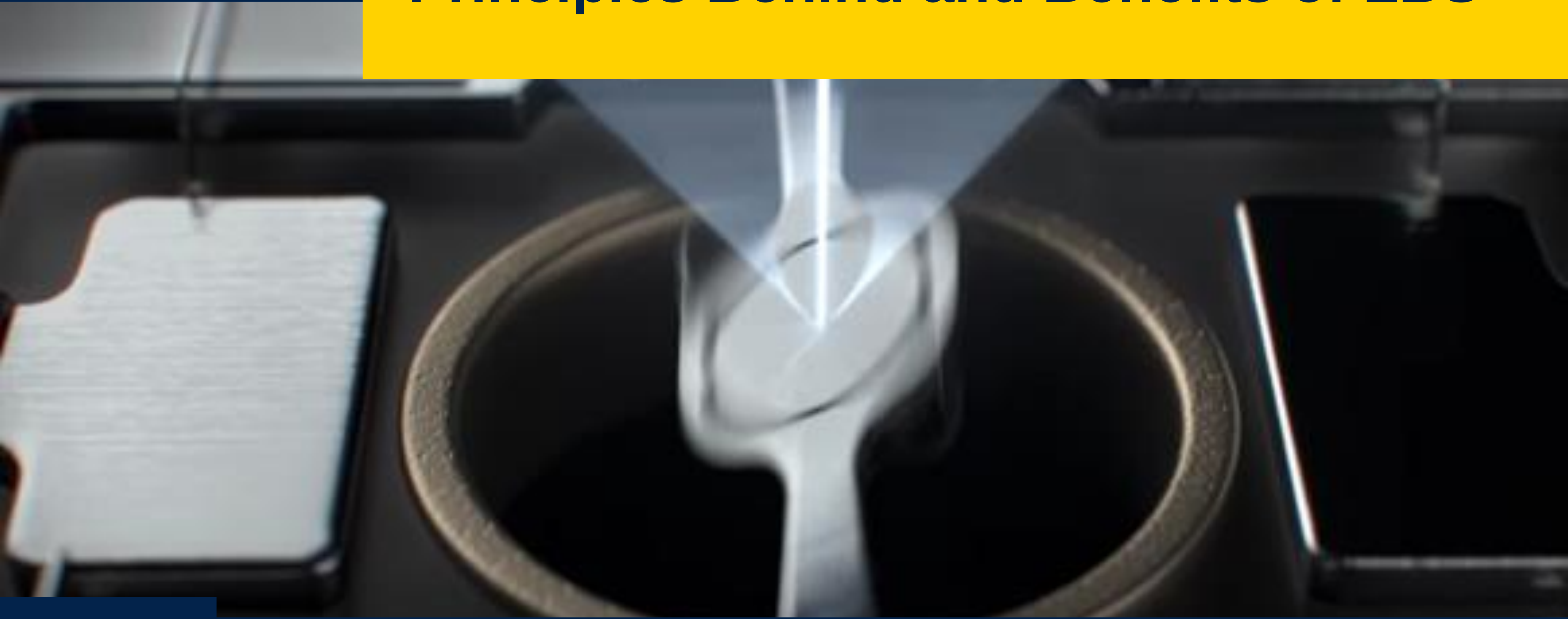
Principles Behind and Benefits of LBS



Benefits of LBS

- High brightness
- Low power
- Small form factor
- Scalable FoV
- Scalable resolution

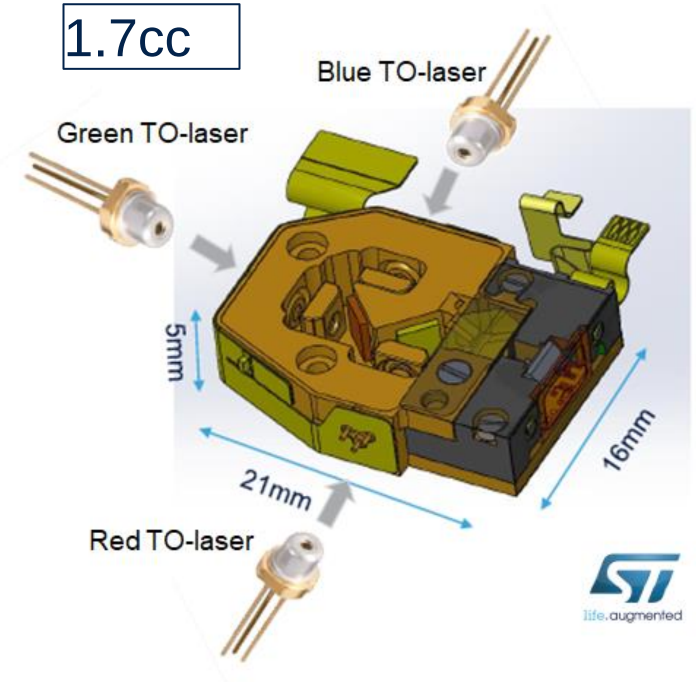
Optical Light Engine Design

Miniaturization with Advanced Laser Diode Designs

Traditional Design: Discrete Laser Diodes

Optical engine size: L-21mm, W-16mm, H-5mm

1.7cc

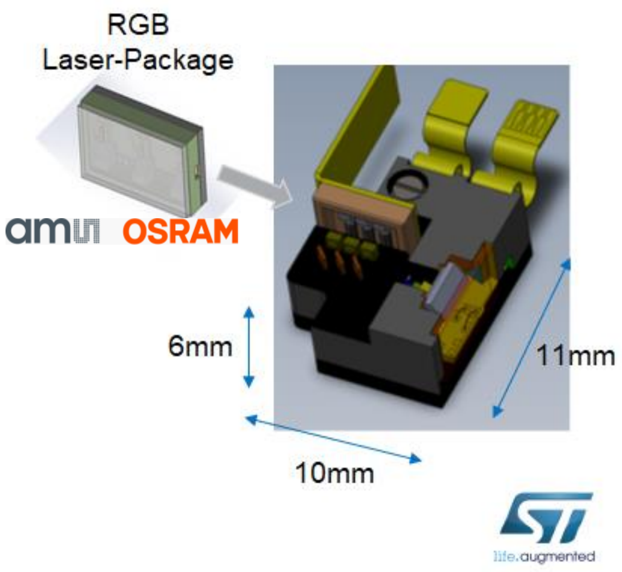


significant size reduction

Advanced Design-Single RGB Laser Module

Optical engine size: L-10mm, W-11mm, H-6mm

0.7cc



Enabling small form-factor wearable devices – e.g., AR glasses

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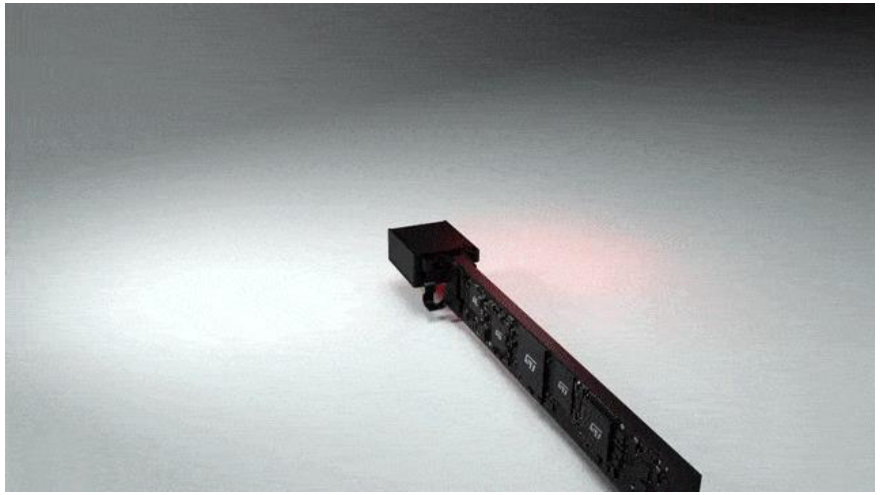
ST Platform for LBS

Combining ST advanced technologies for µ-mirrors and laser / mirror drivers to enable XR applications



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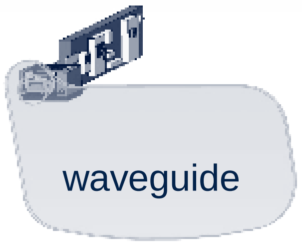

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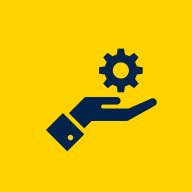
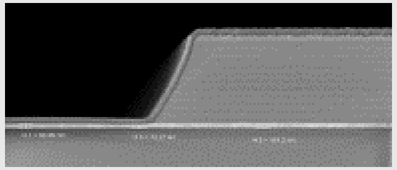
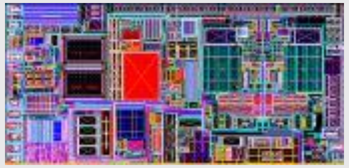


Technology

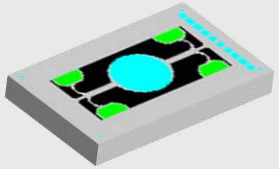


Piezoelectric

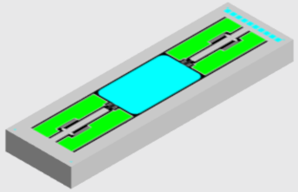


BCD

Mirrors



Resonant mirror



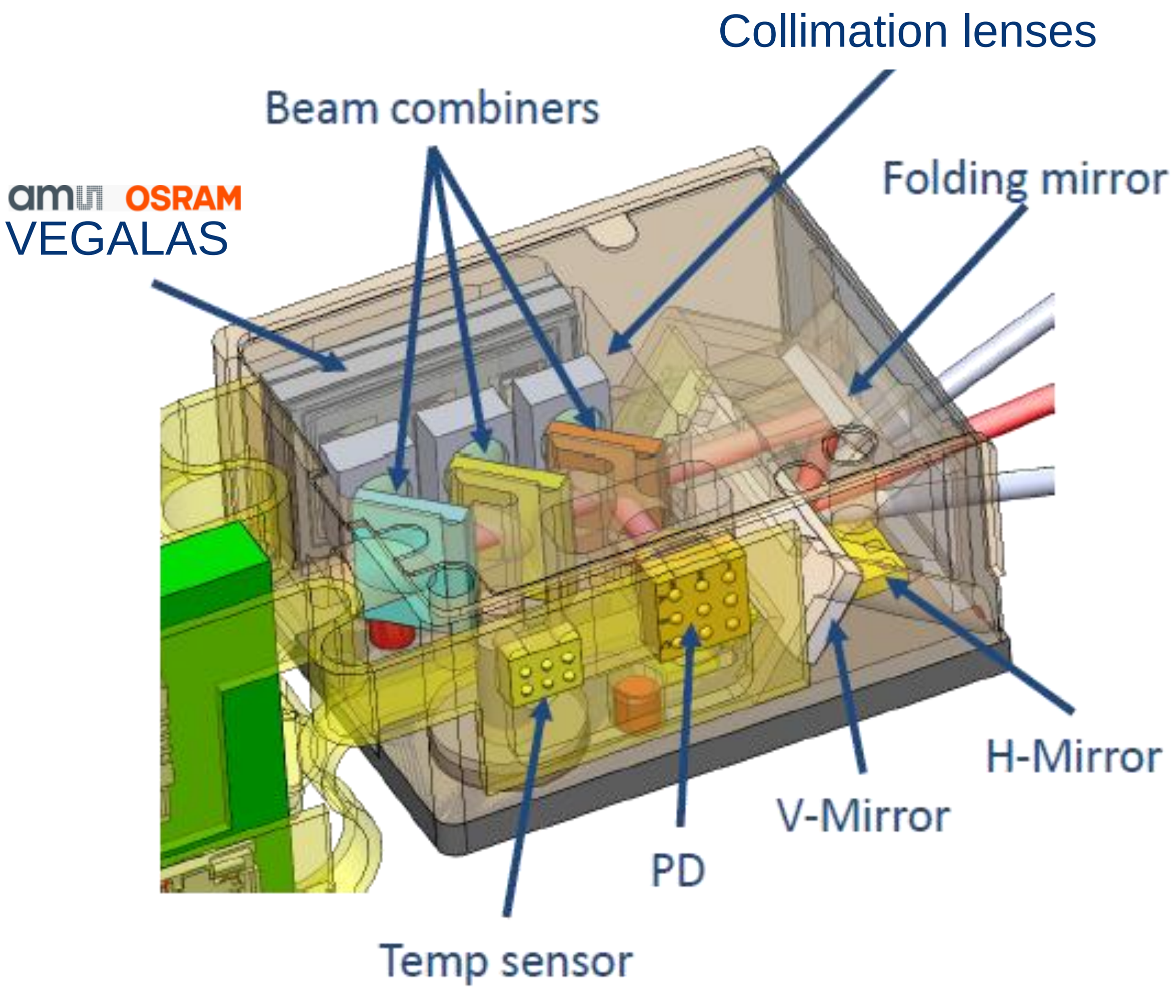
Linear mirror

Drivers

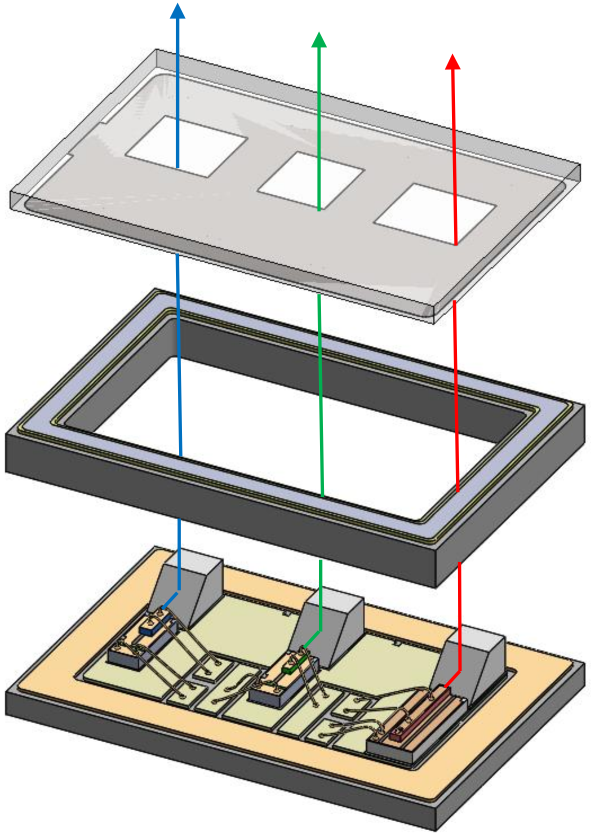
Mirror driver

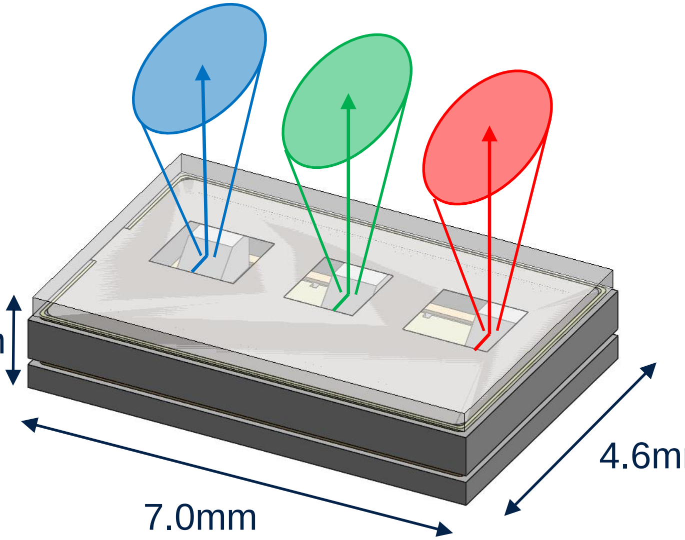
Laser diode driver

Optical Light Engine Details



VEGALAS™ RGB - Laser Module Characteristics





Parameter	Specification
Package Type	SMD Top-looker Hermetically sealed
Dimensions	7.0 x 4.6 x 1.2 mm
Laser diodes	1 Chip-on-Submount per color
Wavelength for R/G/B	640nm / 520nm / 450nm
Optical power for R/G/B	100mW / 50mW / 80mW
Laser diode spacing	2.3mm
Beam divergence (FWHM)	7° x 22° per color
Optics	• Prisms to reflect beams to the top • AR-coated glass lid • Beam collimation & combination outside of module

Slide courtesy of ams OSRAM

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Optical Light Engine Architectures

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Flexibility and Scalability

Lissajous Scanning

after 1.66ms
1 / 600 s

after 8.33ms
1 / 120 s

after 16.66ms
1 / 60 s

Image courtesy of OQMENTED

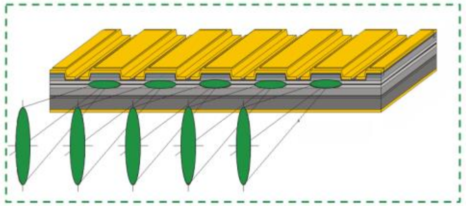
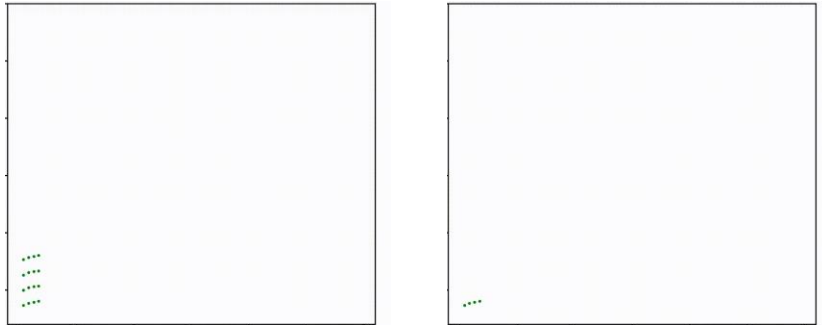


Image courtesy of ams OSRAM

MBS *vs.* Standard LBS



Much higher **resolution** and **uniformity** for a given MEMS and framerate

Direct Retinal Scanning

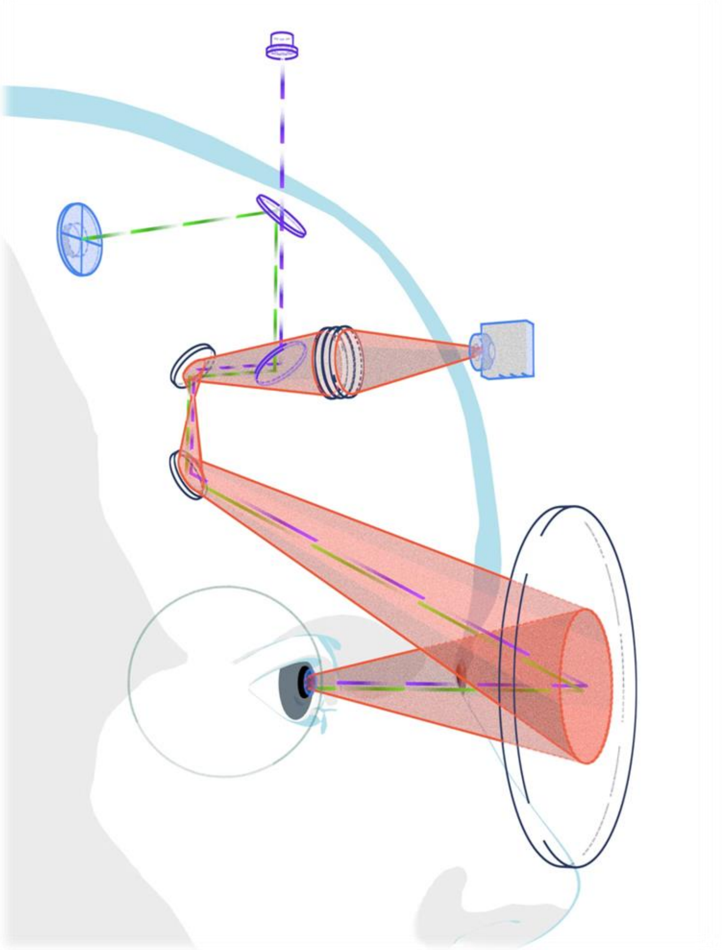


Image courtesy of EYEWAY
ALL IS ILLUMINATED

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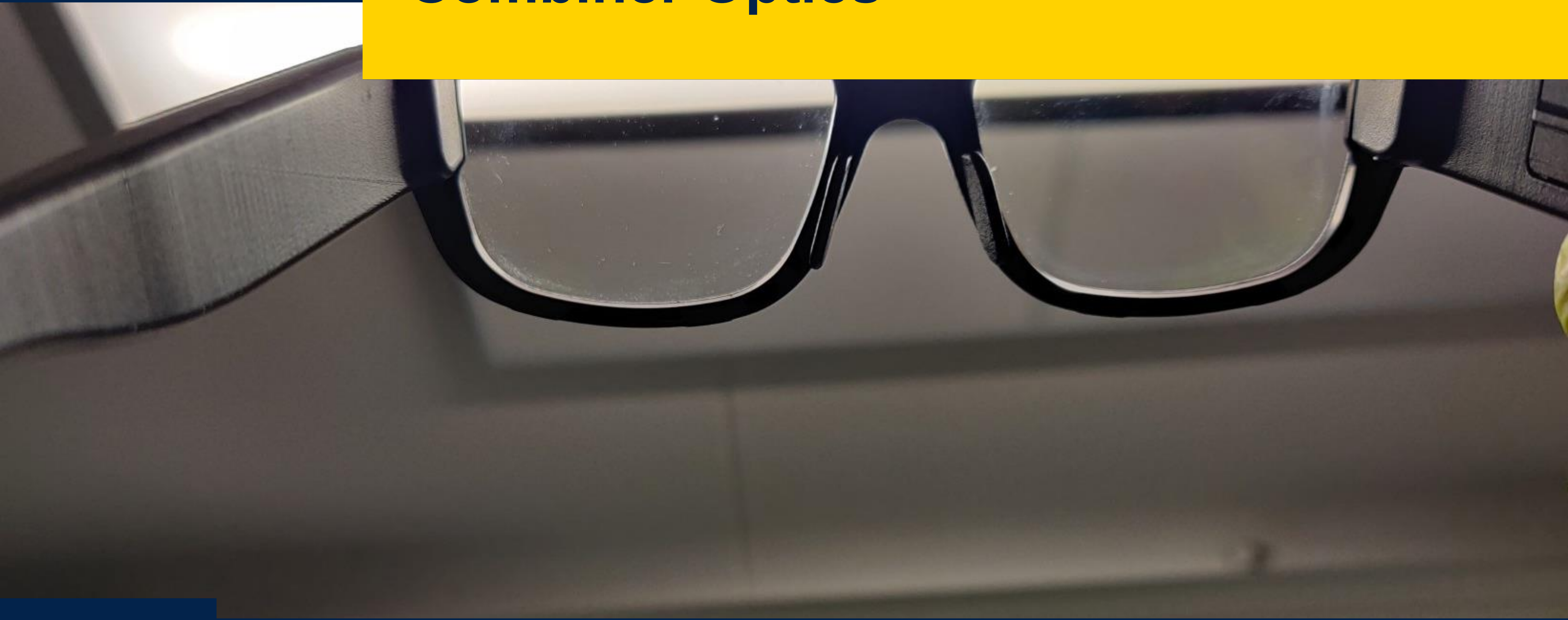
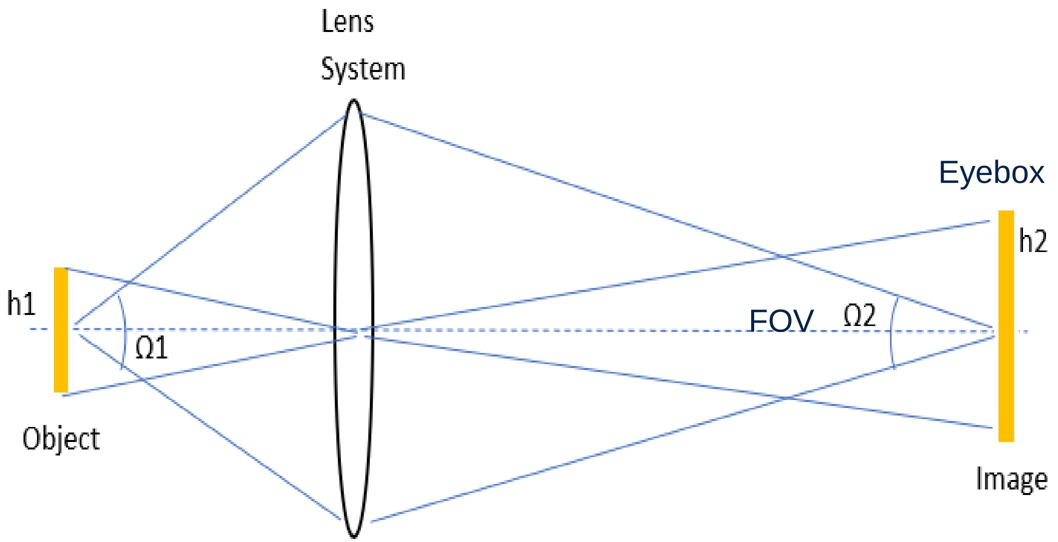
Combiner Optics



Key Optics Challenge: FOV vs. Eyebox



$h1$, $\Omega 1$ generally fixed

$h2$, $\Omega 2$ to be optimized (FOV vs. Eyebox tradeoff)

Etendue or Lagrange Invariant:

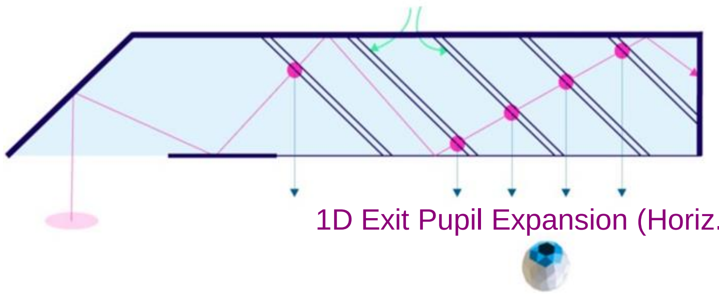
- Product of solid angle of light with a surface must be conserved in the optical system
- Rule of thumb:

$$h1 * \Omega 1 = h2 * \Omega 2$$

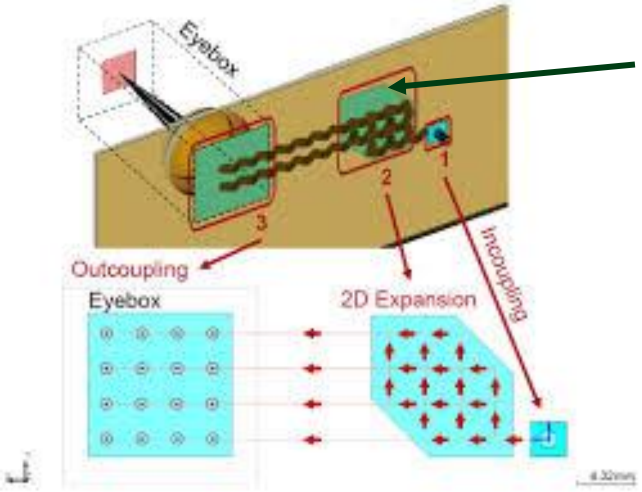
Example, 1 mm MEMS mirror with HSCAN angle 48º, FOV 40º diagonal (~35º horizontal at 16:9 aspect ratio)

$$h2 = 1.4 \text{ mm (horizontal eyebox width)}$$

Since the display is usually fixed then either optical design must expand the exit pupil or eyebox through additional optical elements or using waveguides for eyebox expansion or make performance tradeoffs

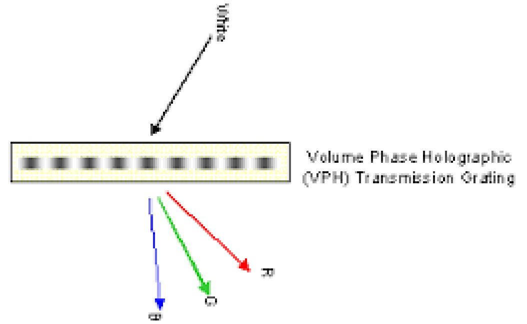


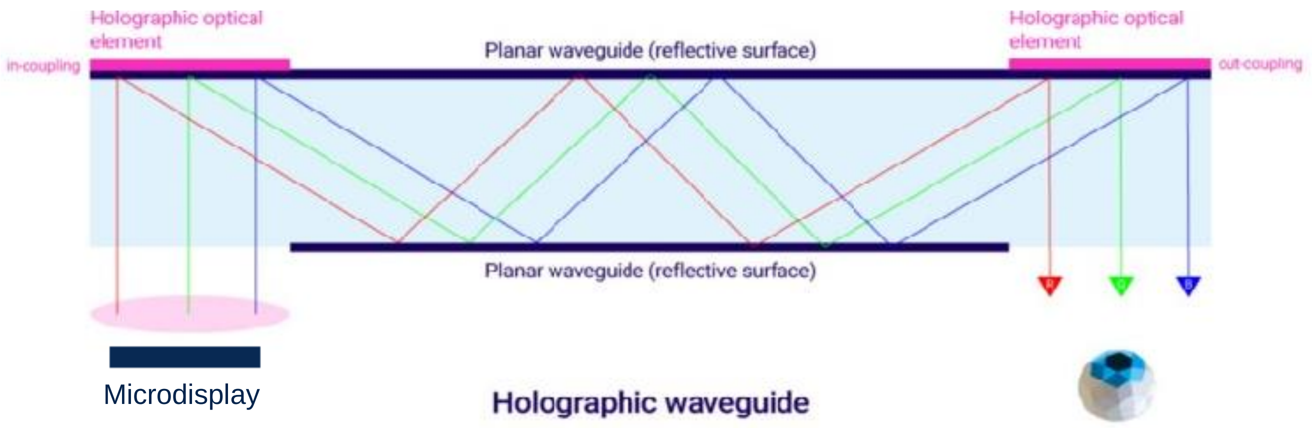
Source: www.hackernoon.com/fundamentals-of-display-technologies-for-augmented-and-virtual-reality

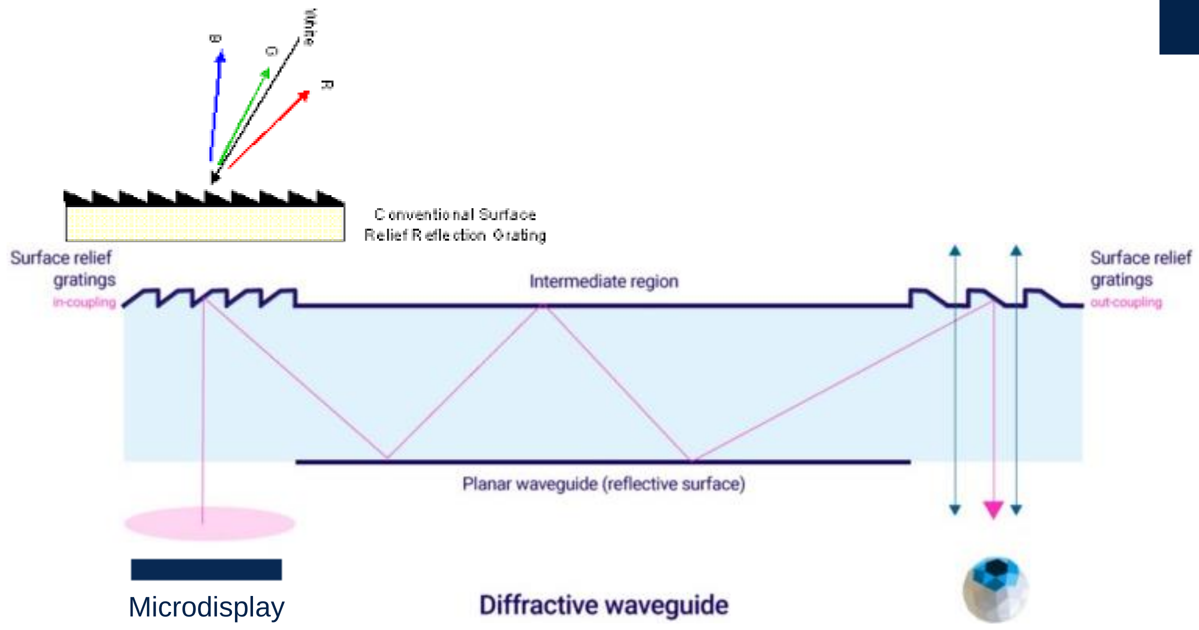


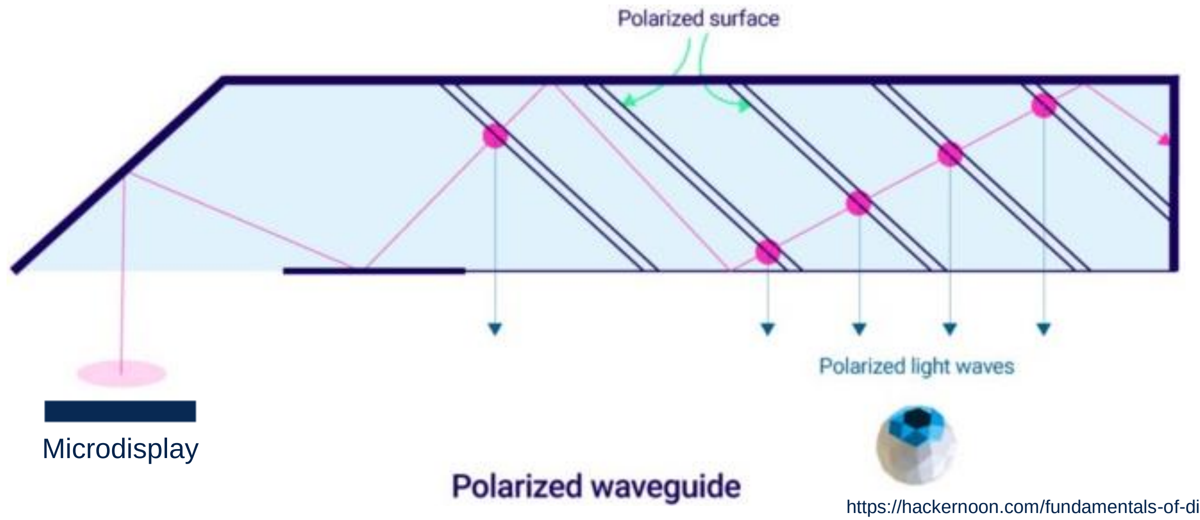
Source: www.LightTrans.com

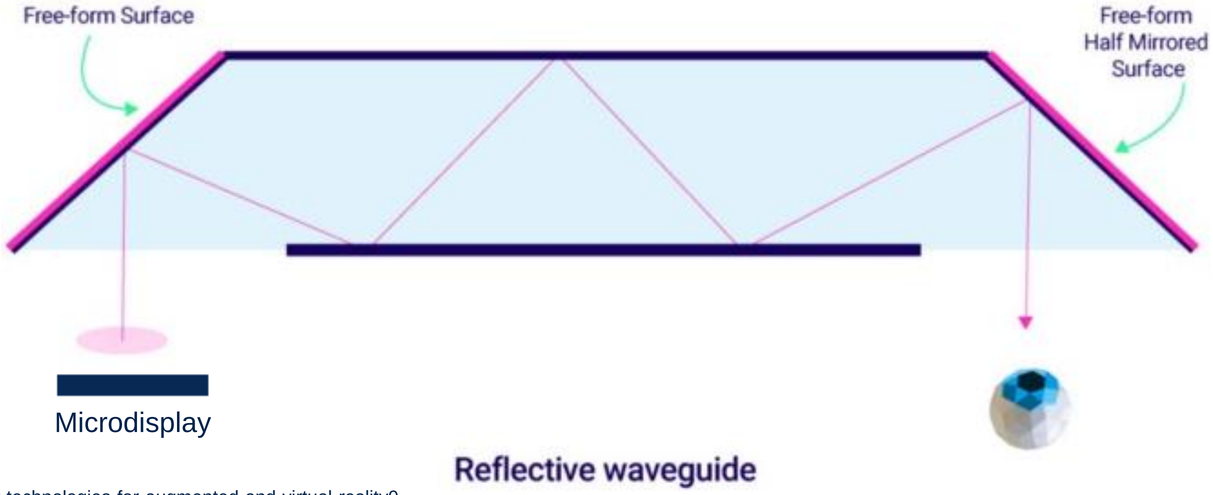
Waveguides: Diffractive vs. Reflective





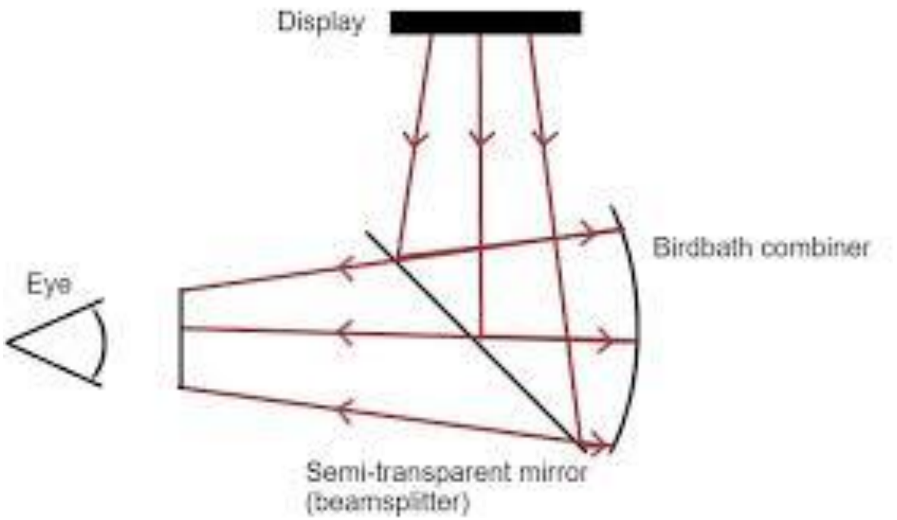




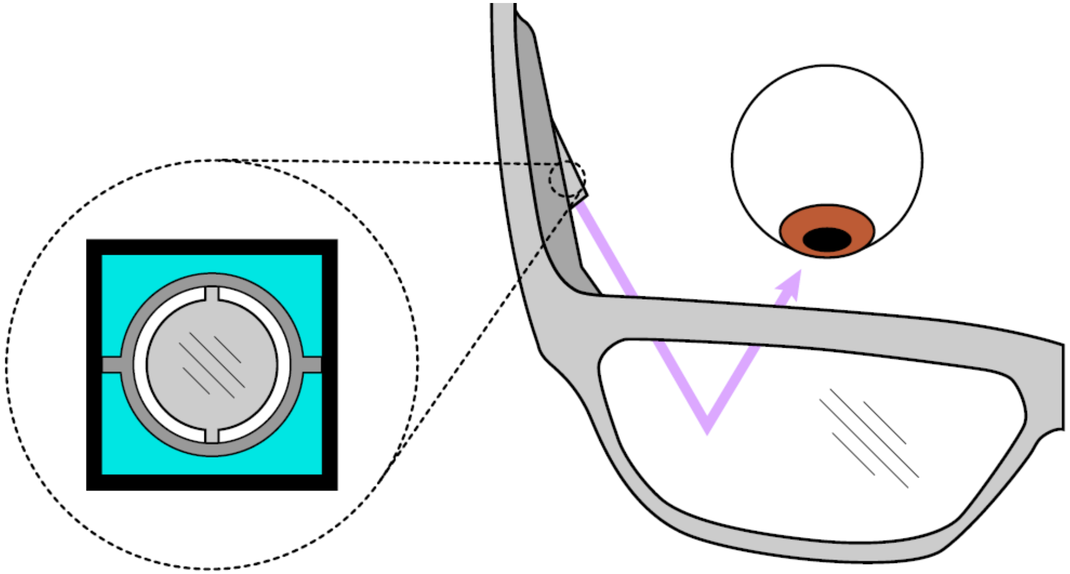


https://hackernoon.com/fundamentals-of-display-technologies-for-augmented-and-virtual-reality0

Non-Guided Wave Optics



Beam Splitter Combiners
("Bird Bath Optics")

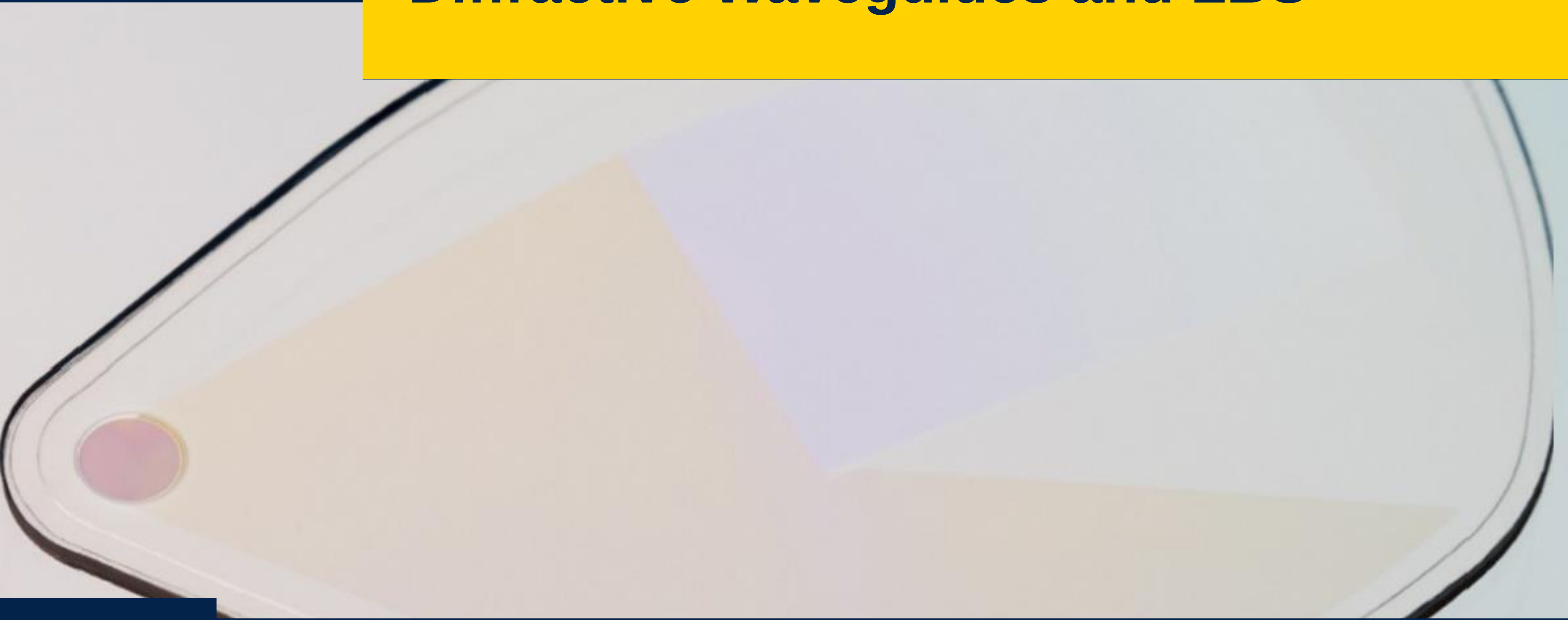


Holographic Combiner
(Reflector/Mirror)

Source: www.altexsoft.com/blog/engineering/augmented-reality-check-get-ready-to-ditch-your-smartphone-for-goggles/

Source: Chris Grayson, 2019 Consumer Smart Glasses Report

Diffractive Waveguides and LBS



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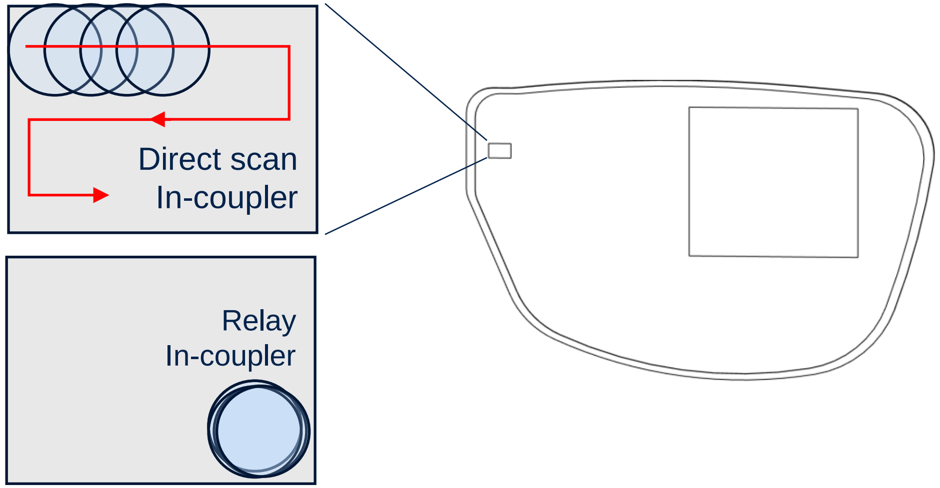
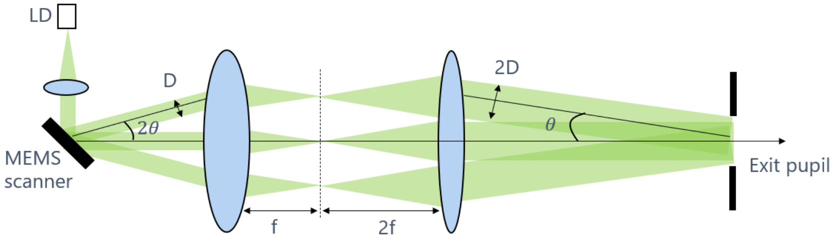
LBS Projector to Waveguide Coupling

Direct scan coupling
- Scan laser beam at the in-coupling grating, raster or Lissajous scan

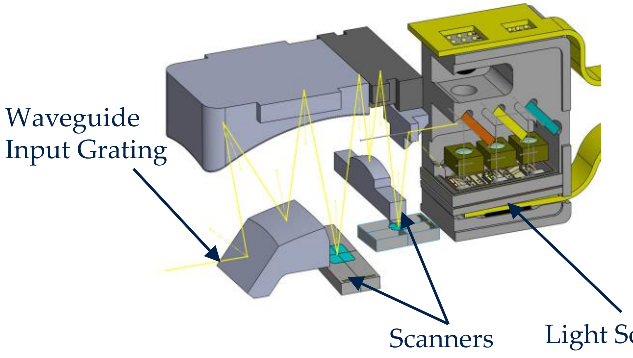
Relay coupling
- Relay lens used to reduce projector exit pupil dimension
- Relay lens for the beam expansion

Choice depends on
- FOV target
- MEMS mirror size
- Beam size
- Spectral selection
- Weight and size targets





A simple relay optics configuration for 2X beam magnification



Source: Seattle Photonics – SPIE AR.MR.VR 2021

Courtesy of dispelix

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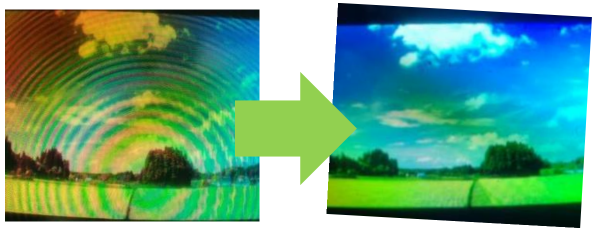
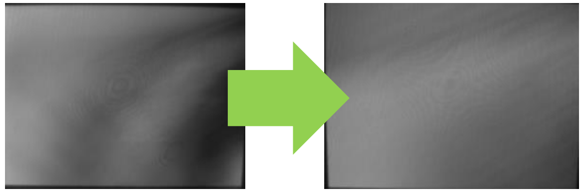
Challenges And Solutions for LBS Compatible Waveguide Displays



Coherence induced Newton rings

→ Control by laser coherence manipulation and waveguide architecture



Coherence induced nonuniformity

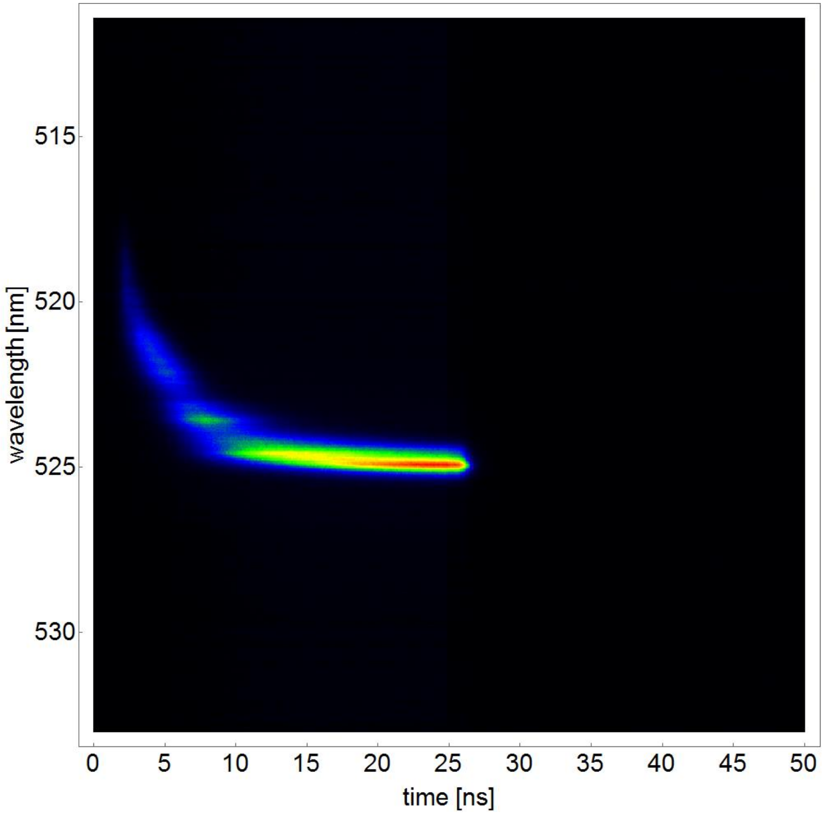
→ Control by waveguide architecture

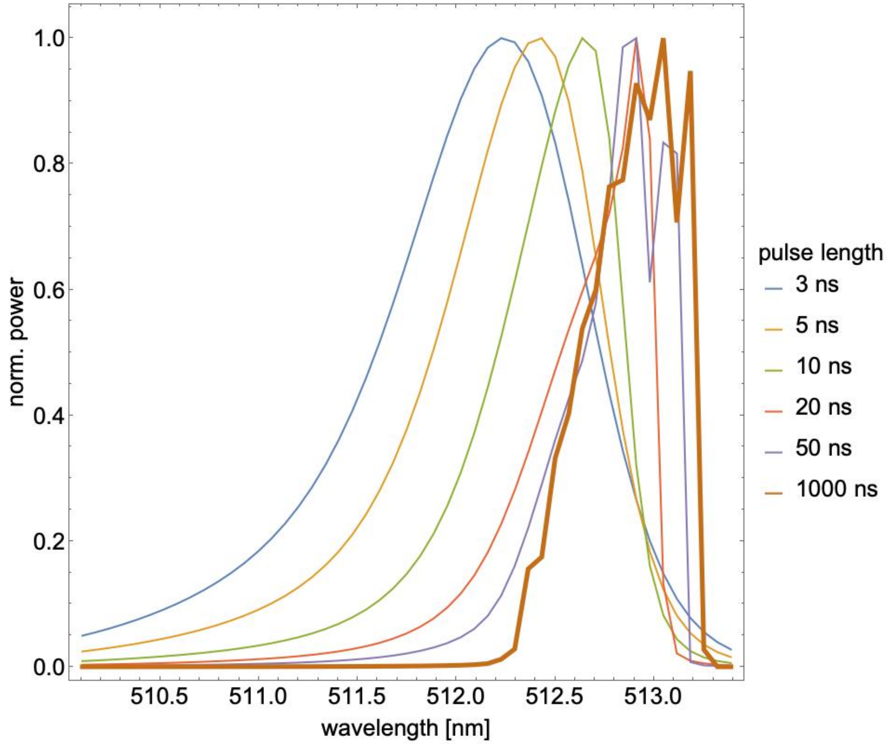
Component match within a full electro-optical integration is critical for a good virtual image performance, including factors such as uniformity and MTF

→ Control by laser properties, in-coupling methods, waveguide architecture, MEMS mirrors

Ultra Short Pulses for Suppressing Coherence Artifacts

Temporal coherence can be significantly reduced by short pulses of <5ns



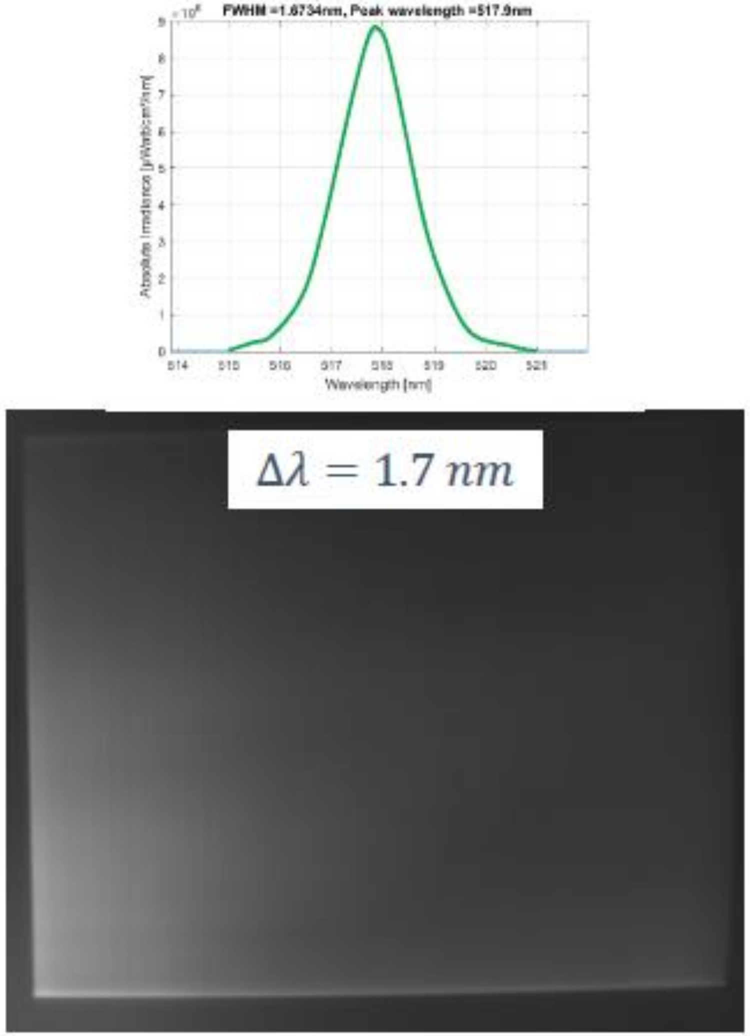


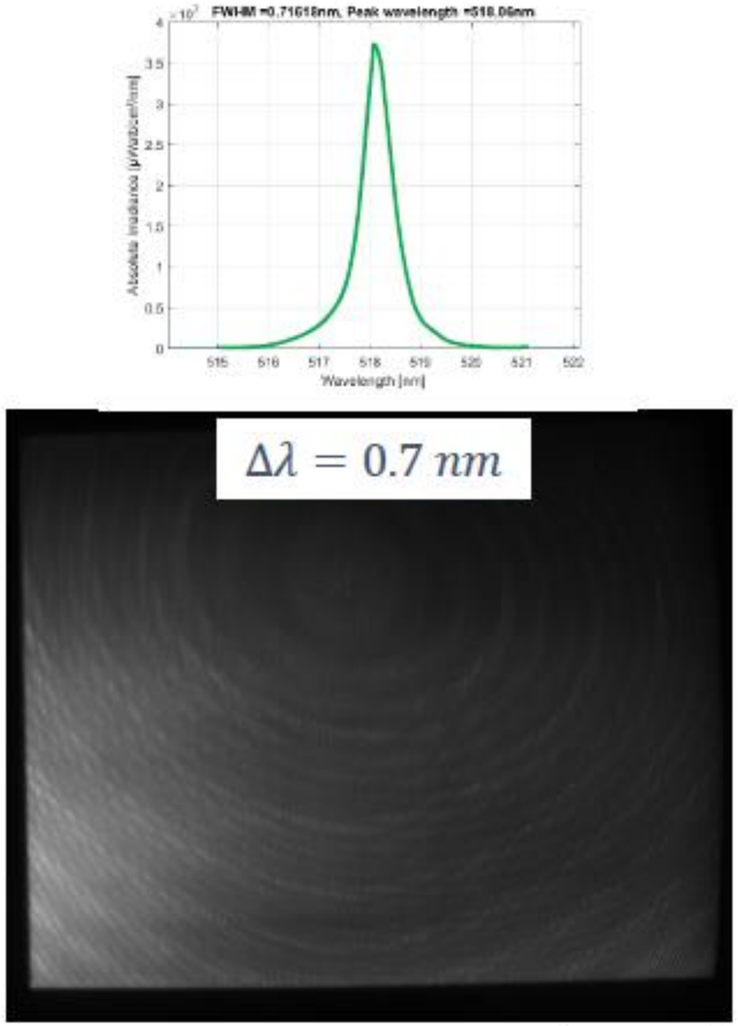
- Bandwidth broadening with shorter pulses: FWHM 1nm => 2nm
- Broader spectrum reduces coherence artifacts by diffractive waveguide combiners

Source: Ulrich Schwarz, Institute of Physics, Chemnitz University of Technology, Chemnitz 09126, Germany

Slide courtesy of ams OSRAM

Newton Ring Mitigation with Laser Drive Modulation





Source: Juuso Olkkonen, SPIE AR.MR.VR 2021 Conference (Virtual)

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The LaSAR Alliance

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It Take a Village: The LaSAR Alliance Ecosystem of Companies

Founding Members

Quanta Computer, OSRAM, ST life.augmented, dispelix, MEGA1, APPLIED MATERIALS make possible

Regular Members

CORNING, INKRON, Lochn Opti, oomii, SCHOTT, OQMENTED, evatec, META Go Beyond., HENSOLDT, OPTOFIDELITY, Greatar 至格

Associate Members

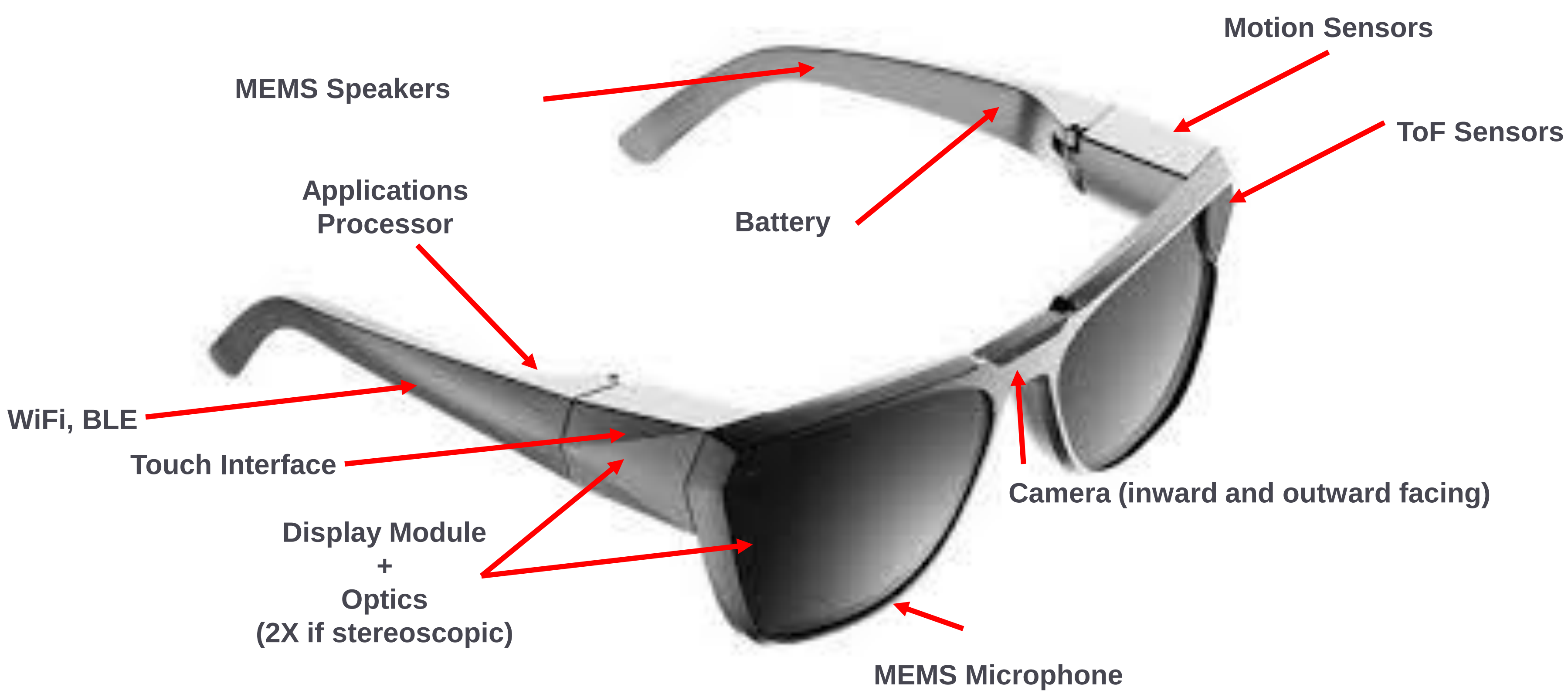
EXALOS The bright light source company, b com, KST World Corp.

LaSAR Alliance Synopsis

- Enable, facilitate and promote development of technologies, devices and solutions around LBS for near-to-eye display products
- Establish ecosystem making available to ODMs and OEMs commercially viable and available components and solutions towards the design, development and manufacturing of augmented reality wearable products
- Create a forum for discussion on key challenges around LBS, including complementary technologies and solutions
- Longer term, develop standardization for technologies, devices & solutions around LBS
- Announced in October 2019 and launched in March 2020 with six Founding Members
- 3 current working groups/committees (Content, Image Quality Methods, Metrics and Measurements, Marketing)

Alliance mission accomplished: Will be significantly expanding scope – STAY TUNED!

Enabling Compelling AR Experiences



Focus on display is necessary, but many more technology challenges exist. Delivering compelling experiences: low latency, low power, light weight, right specification (e.g. FoV, resolution etc.) and an intuitive user interface

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Our technology starts with You

Contact info: bharath.rajagopalan@st.com

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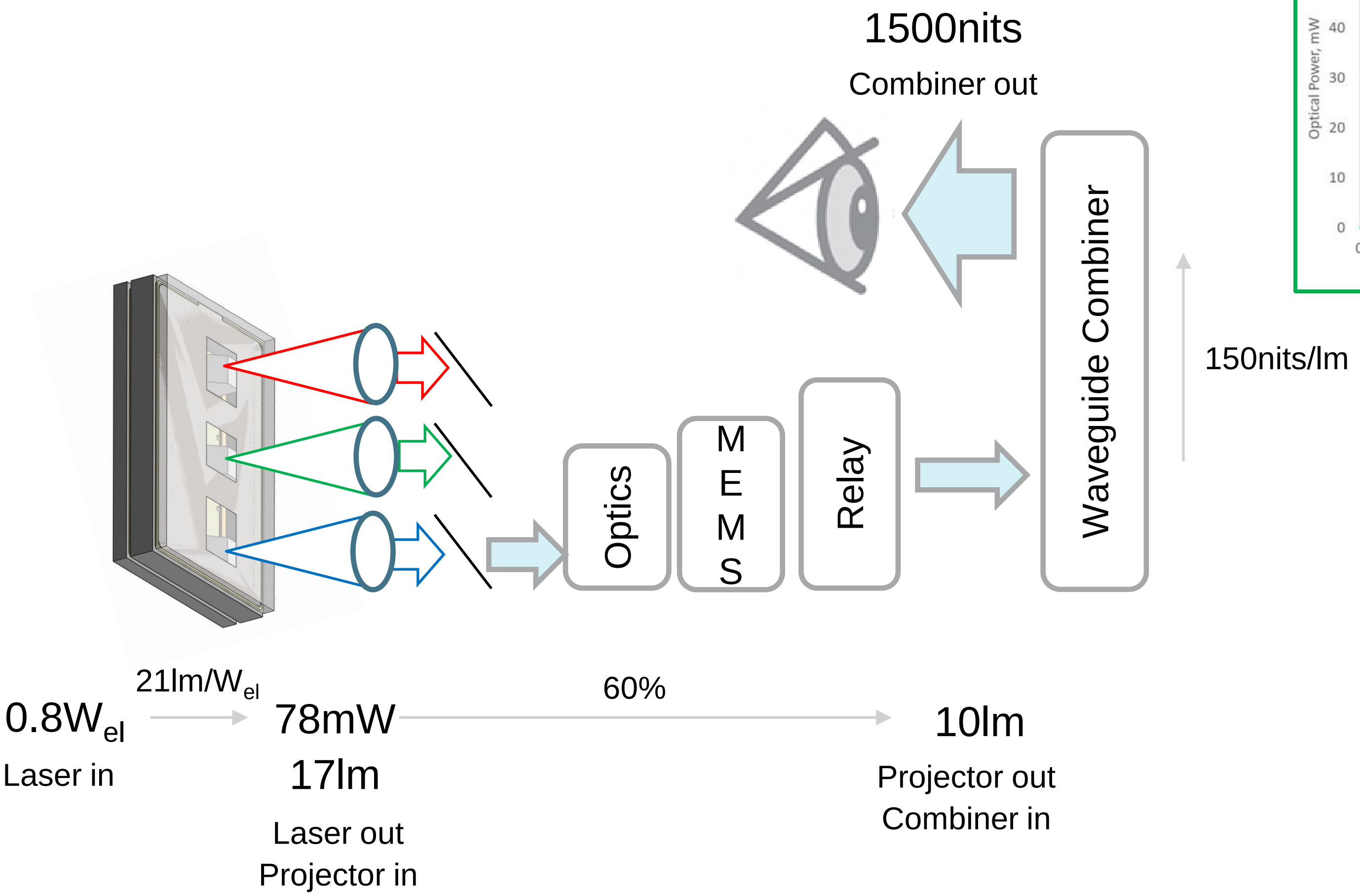
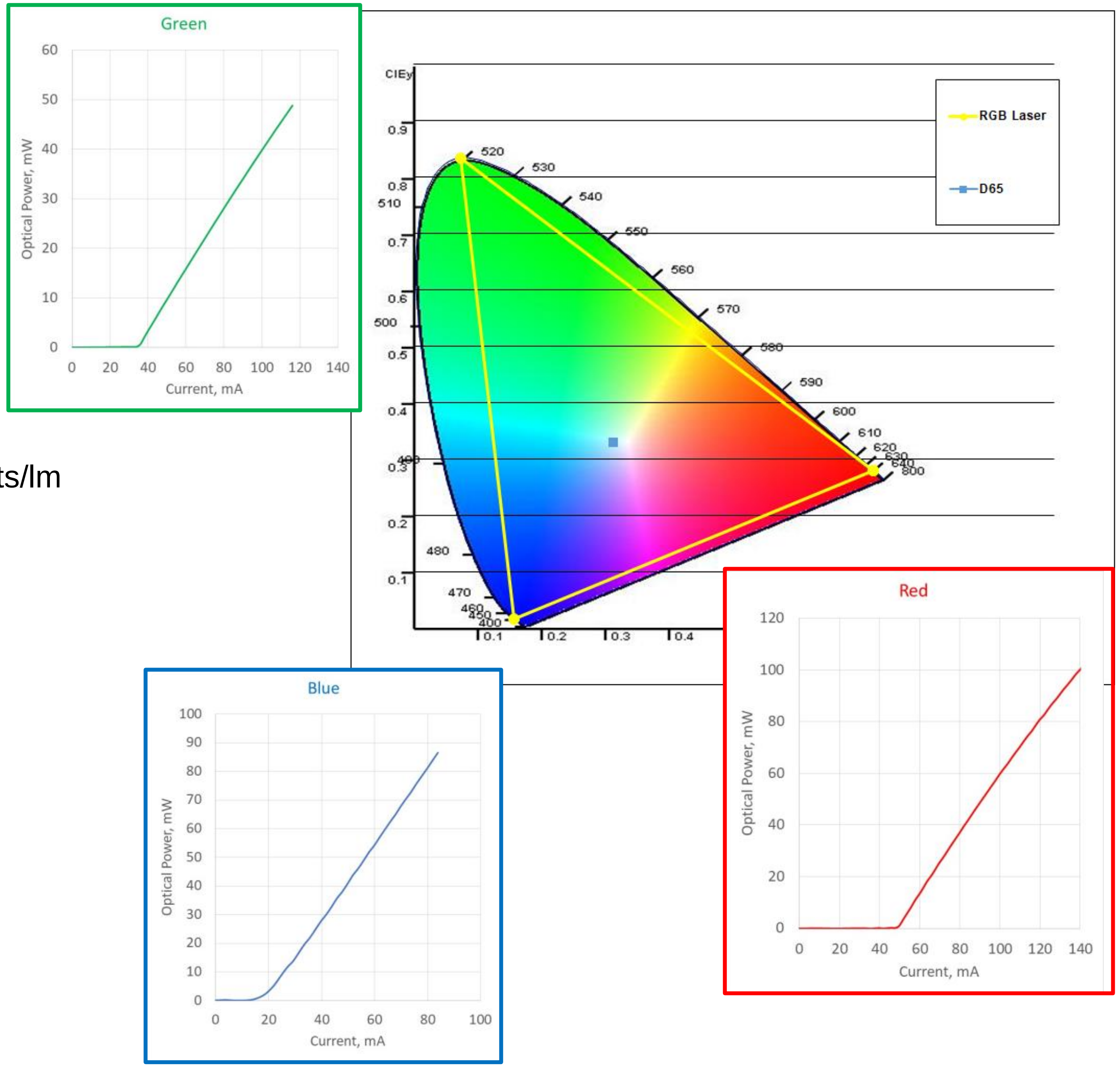
Appendix

VEGALAS™ RGB - Display Brightness & Laser power





Slide courtesy of ams OSRAM

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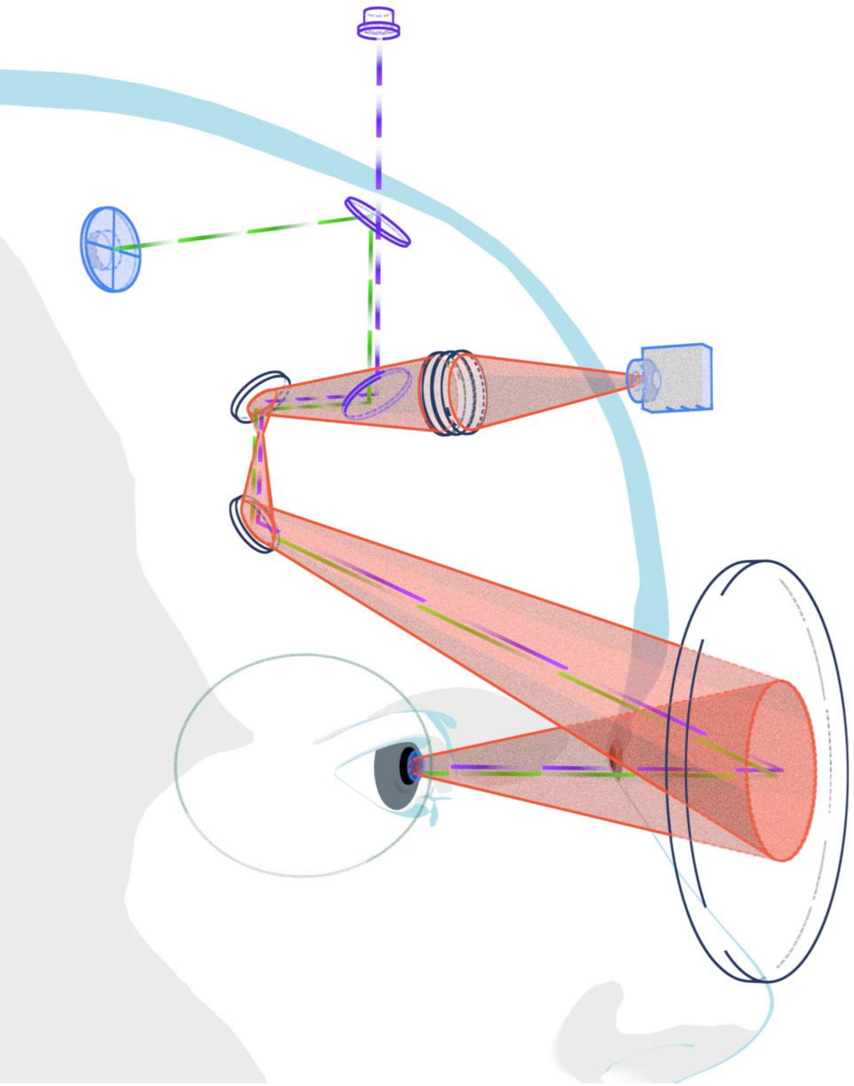
Principles of Direct Retinal Scanning with Eye Tracking



Optical path sharing:

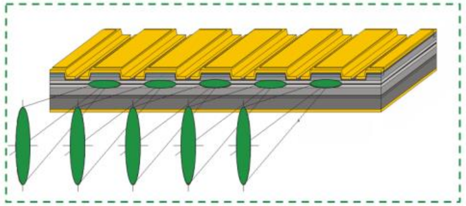
When MEMS move to correct the tracking,
it also moves the projected image accordingly!

Patents:
"Image Projection System" - WO2018220608A1
"MEMS based light deflecting device and method" - WO2020212984

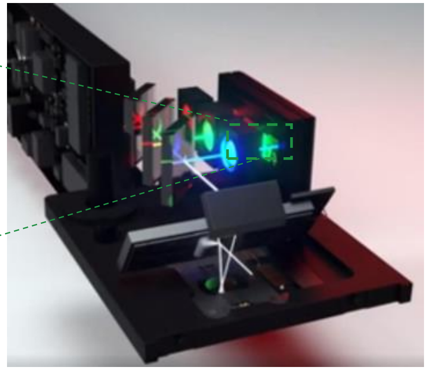
Multi-Beam Scanning (MBS)

Laser beam scanning with dramatically better resolution, frame rate and image quality

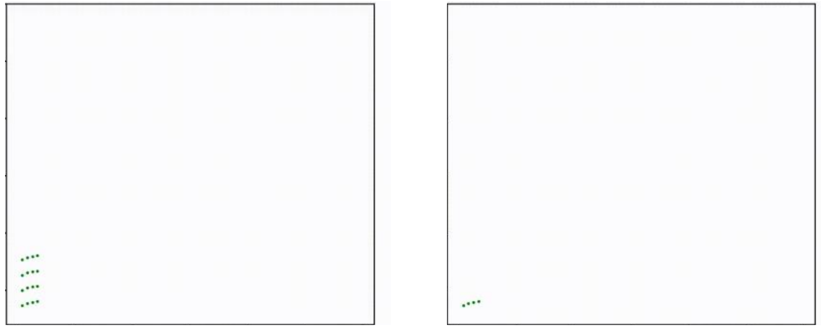
Multi-ridge lasers



MBS light engine for AR eyewear



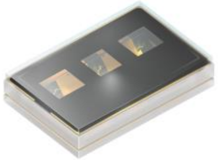
MBS *vs.* **Standard LBS**



Much higher **resolution** and **uniformity** for a given MEMS and framerate

MBS enables advanced display performance

System target specifications	
Resolution	2100 x 2100
Field of view (Diag. degrees)	70
Brightness (nits)	1500
Frame rate (Hz)	90
Power consumption (mW)	500



OSRAM
Multi-ridge laser module

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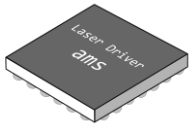

ams
Laser Driver ASIC

Co-design & integration are key

Performance depends on the driver, the lasers and their connection

Slide courtesy of ams OSRAM

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Summary: LBS Solutions Enable Holistic Design Philosophy

AR Devices – Design Tradeoff Considerations

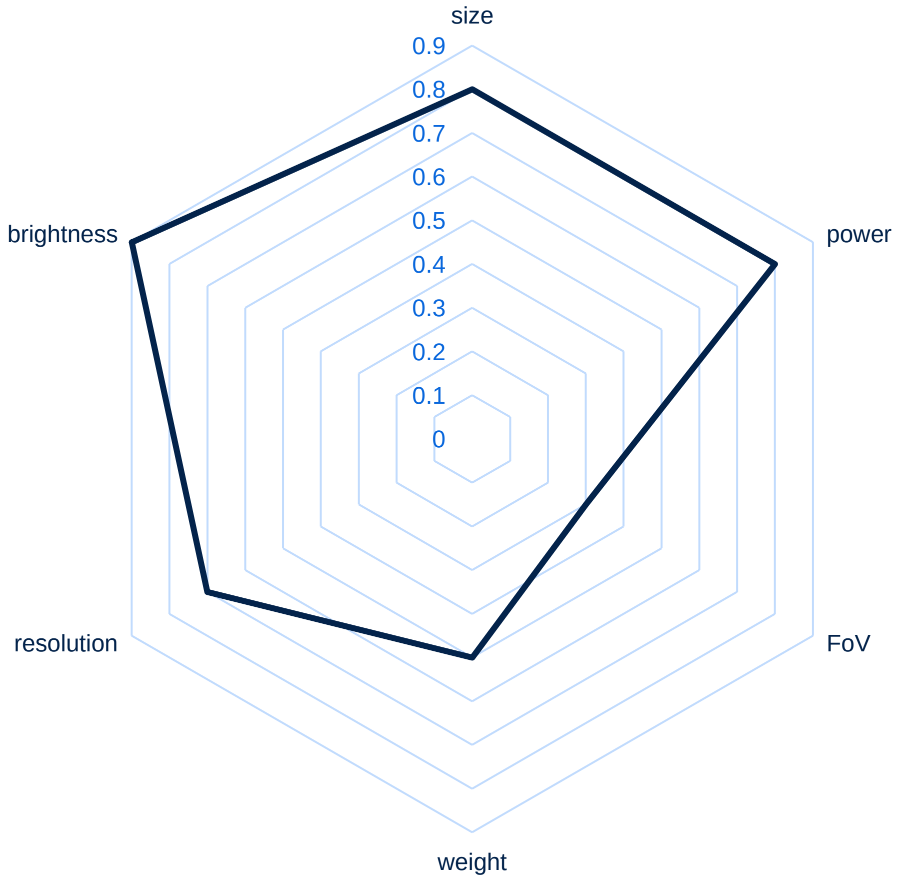

Illustration only

- Unlike fixed-pixel display architectures, LBs provides significant architectural and system design flexibility
- Depending on the design requirements, appropriate tradeoffs can be made to achieve desired level of performance
- As an example:
  - Keep performance (e.g. resolution, FoV) and benefit from lower power
  - Increase resolution at same FoV, or keep resolution at increased FoV
  - Optimize between FoV and resolution and power consumption
  - Consider alternative optical light engine designs
- These tradeoffs can be made with relation to other system parameters such as brightness, size, weight, battery source etc.
- These tradeoffs can also be made with respect to combiner optical choices, illumination sources/types, materials, applications etc.