Koç University

Laser Scanning 3D Display with Dynamic Exit Pupil

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Outline

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- Helium3D Project
- Specialties of the display
- Description of display hardware
  - Principle of operation
  - Light engine
  - Transfer screen
- Static Exit Pupil Prototype
- Summary

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Helium 3D Project – Partners

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- **De Montfort University**: Display design, construction, and project coordination.
- **Philips Electronics**: Commercial applications, interaction and human factors.
- **Barco**: Stereoscopic systems and commercial applications.
- **University College London (UCL)**: Optical design and simulation.
- **Heinrich Hertz Institute**: Far-and near field viewer tracking and interaction.
- **Eindhoven University of Technology**: Human factors and interaction.
- **Koç University**: Optical design of light engine.
- **Nanjing University**: Near-field viewer tracking and interaction.

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Taxonomy of 3D Displays

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- **Autostereoscopic**
  - **Holographic**
  - **Volumetric**
  - **Multiple Image**
    - **Holoform**
    - **Multiple view**
    - **Binocular**
      - **Fixed Viewing Zones**
      - **Head Tracking**

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Specialities of the System

- Laser-based display that uses reflective LCoS.
- High colour gamut.
- Rear projected display with horizontal scanning.
- Glasses free 3D viewing experience.
- Horizontal motion parallax to all viewers with no restriction on movement.
- Conventional 2D to all viewers providing backward compatibility when necessary.

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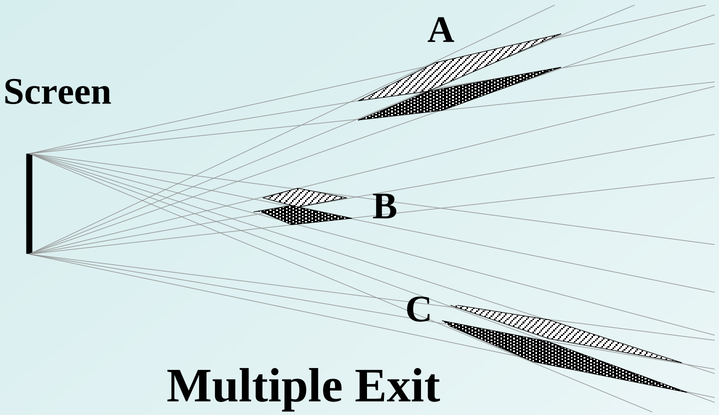
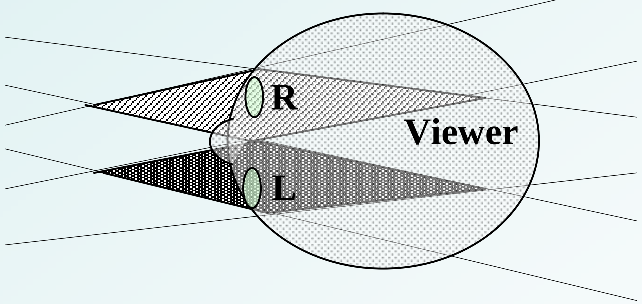
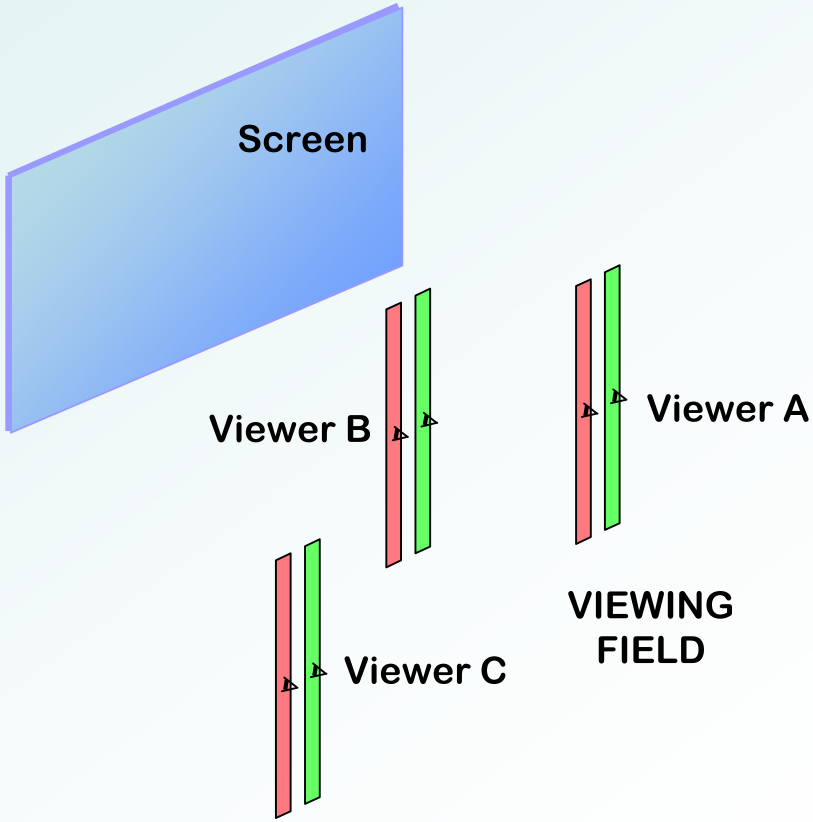
Dynamic Exit Pupils



Multiple Exit Pupils



Exit Pupil Pair



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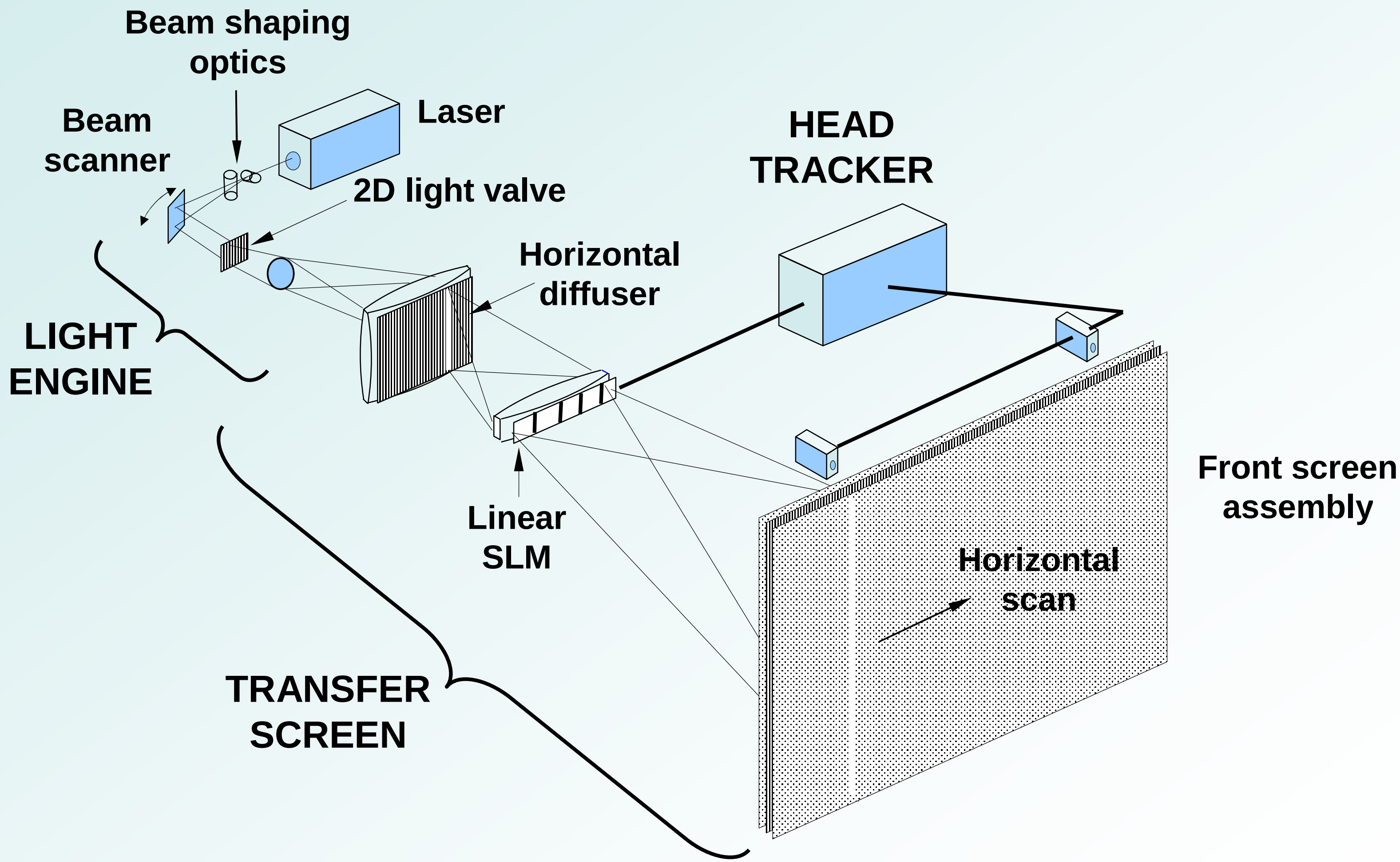
Display Simplified Schematic



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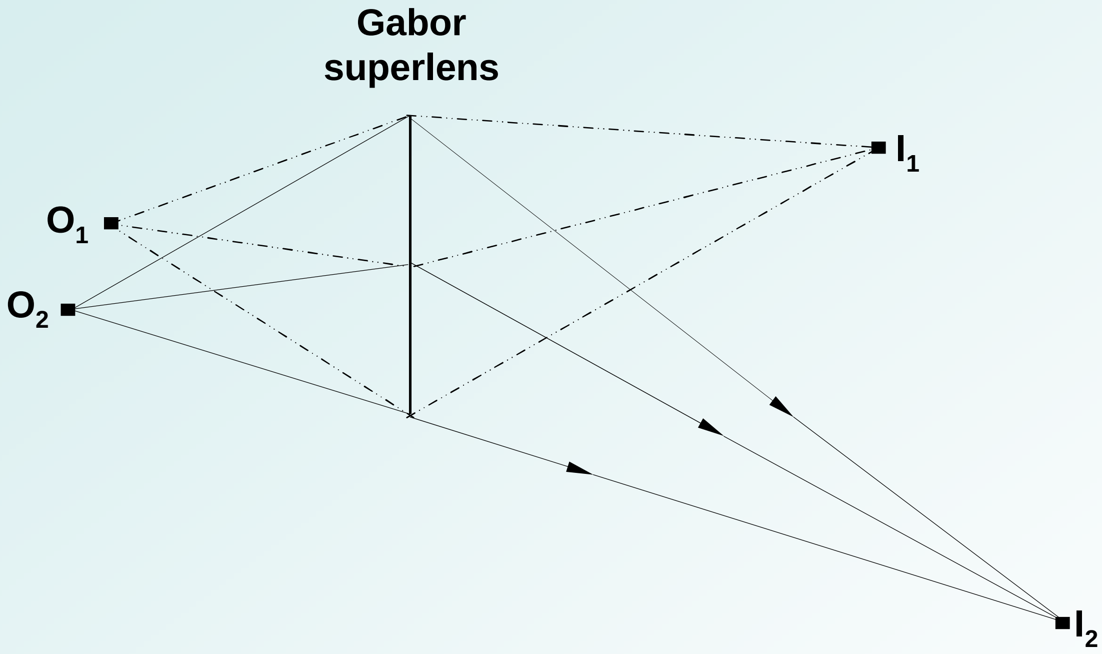
Gabor superlens



- Properties differ from conventional lens
- Object and image same side of axis
- Image distance increases with object distance

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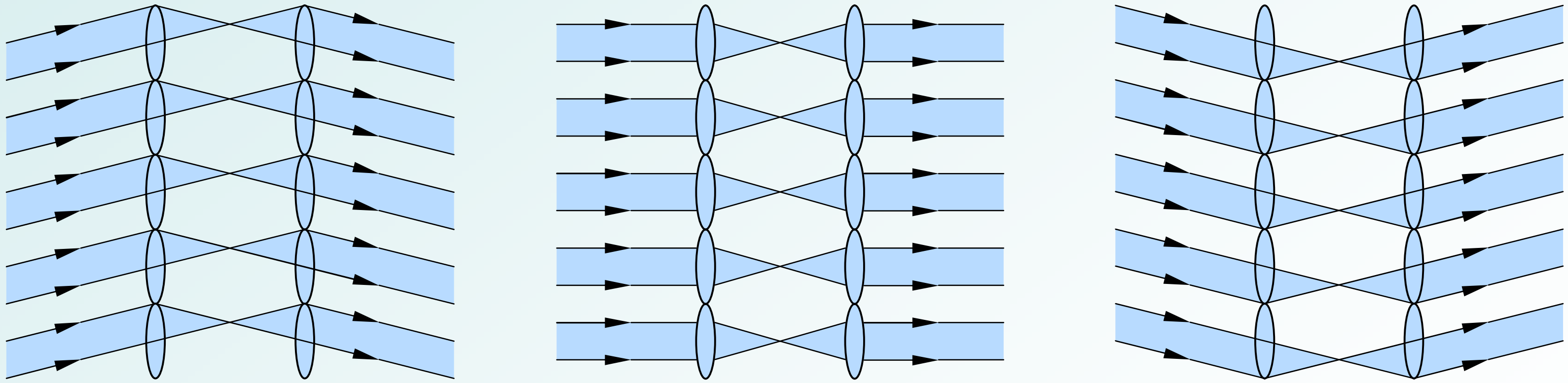
Gabor superlens

- Comprises two lenslet arrays
- Can be one or two-dimensional
- One-dimensional array used in HELIUM3D
- Figures below do not show field lens array



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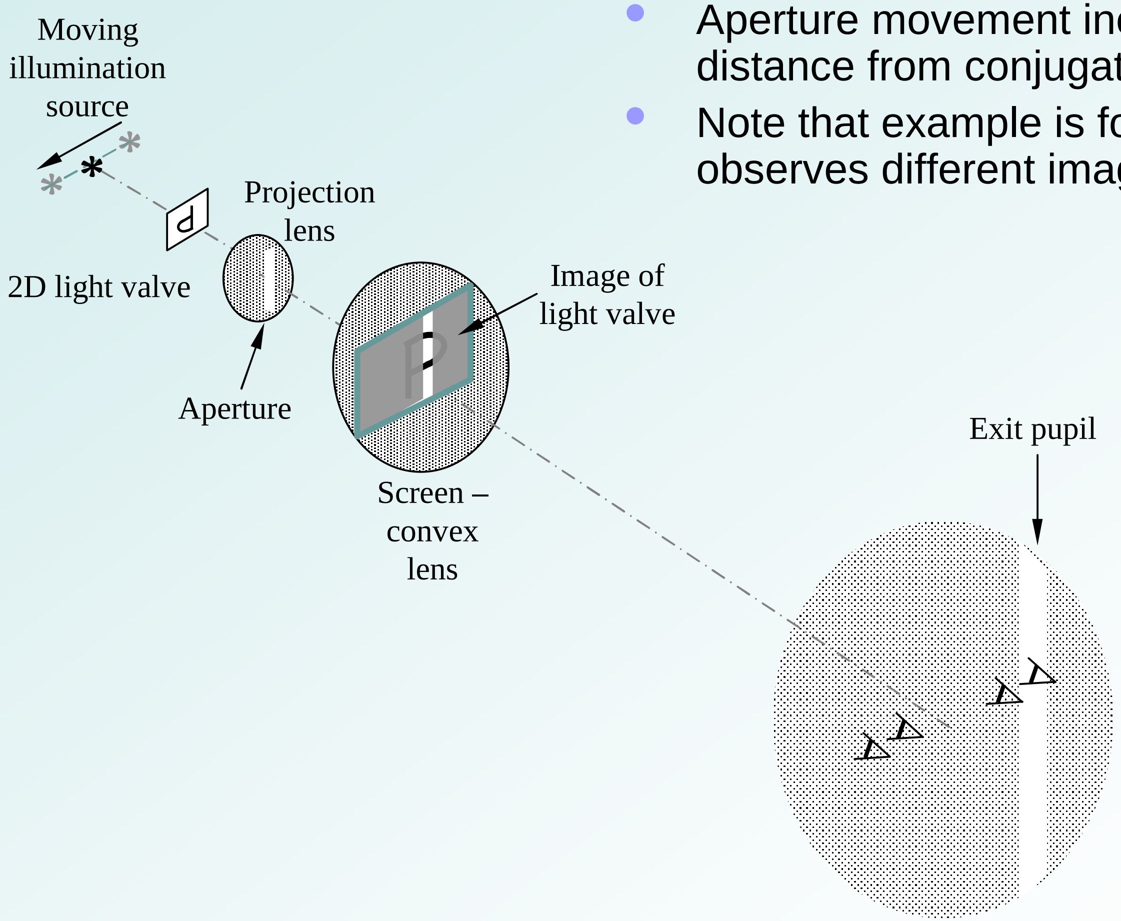
Principle of Operation



- Scanning with a light column produces raster scanned image column on screen.
- If exit pupil is away from the conjugate plane, the aperture moves laterally during scan.
- Aperture movement increases with increasing exit pupil distance from conjugate plane.
- Note that example is for single exit pupil – viewer B observes different image field in same frame.

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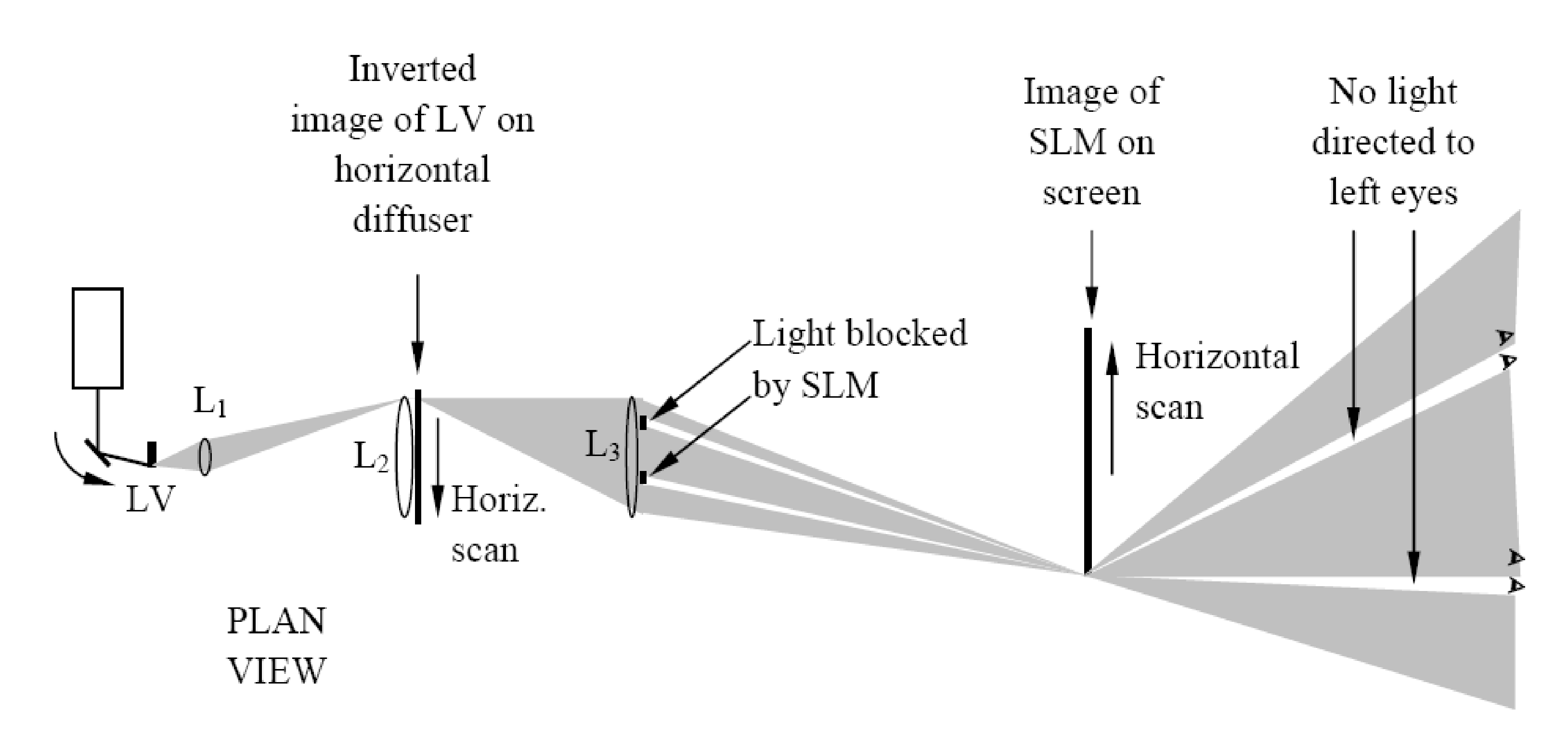
Functional Diagram of Display Optics



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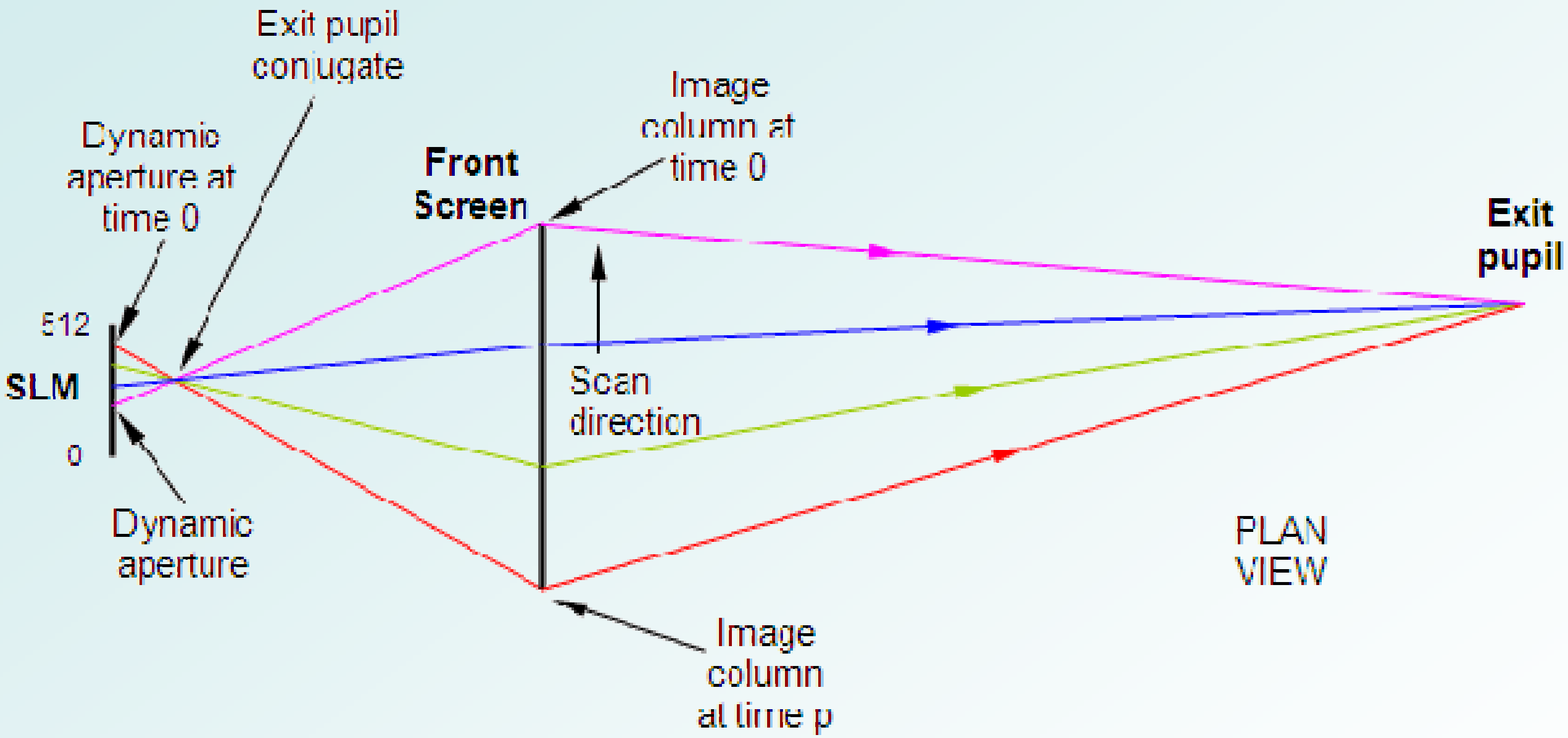

If the exit pupil is not in the conjugate plane of the SLM then the dynamic aperture region of the SLM must change its position during the horizontal scan

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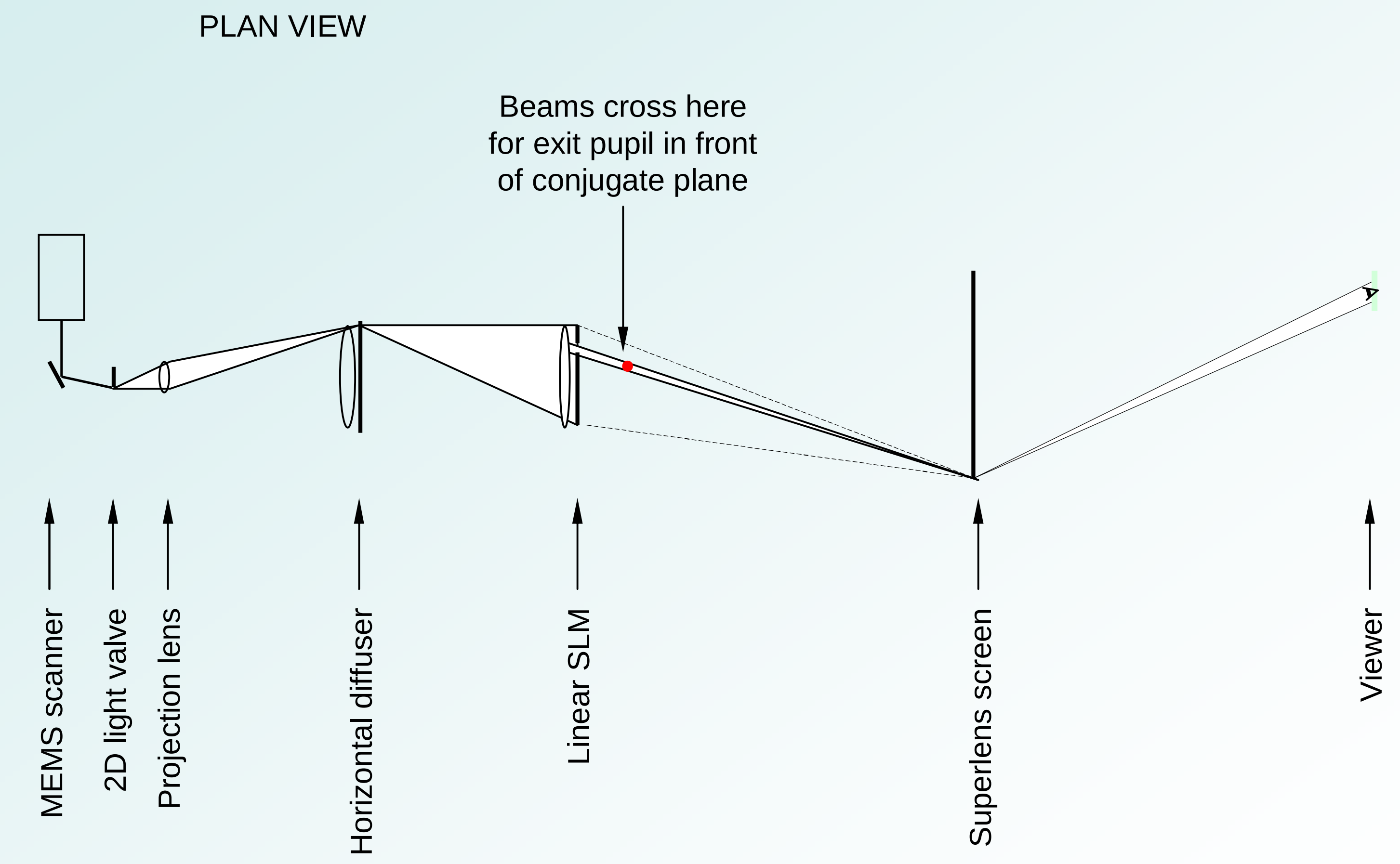
Dynamic Exit Pupil



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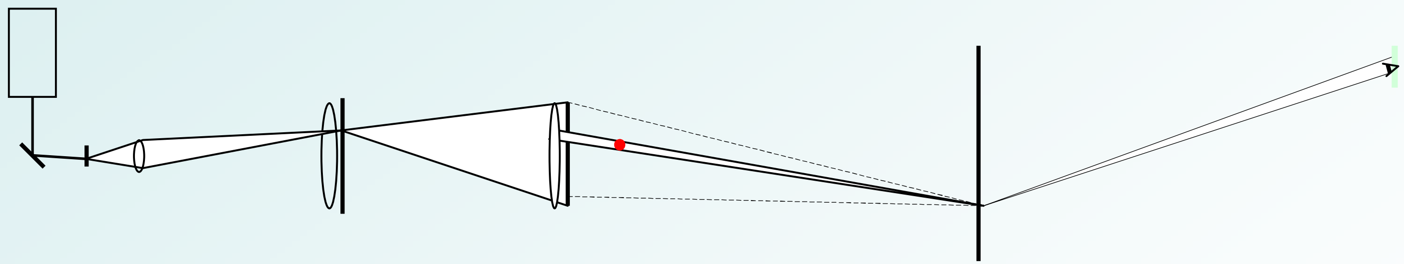
Dynamic Exit Pupil



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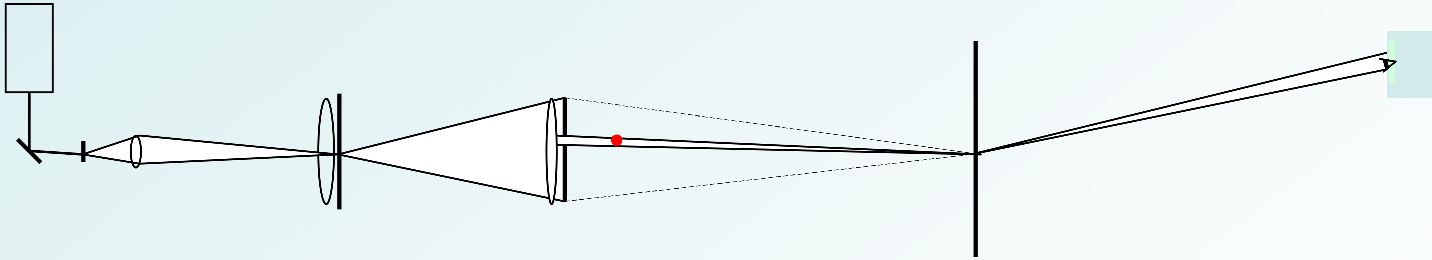
Dynamic Exit Pupil



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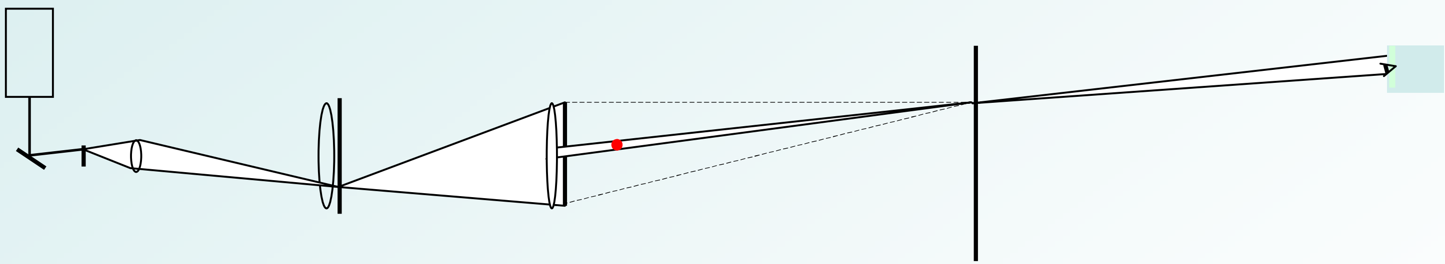
Dynamic Exit Pupil



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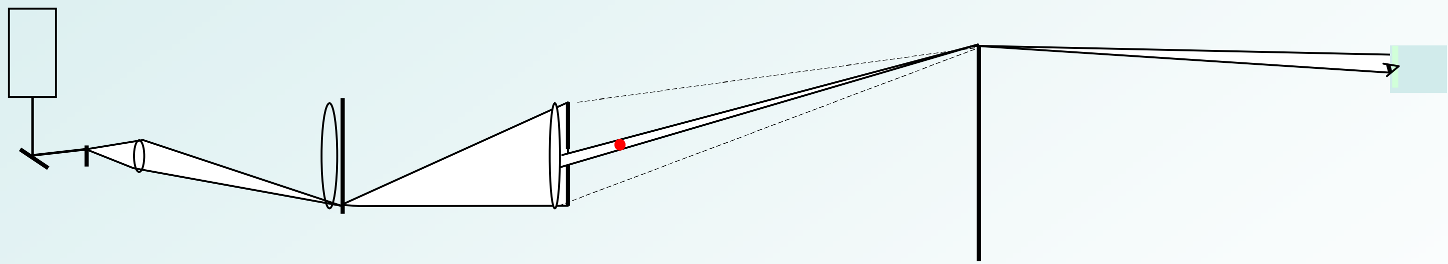
Dynamic Exit Pupil



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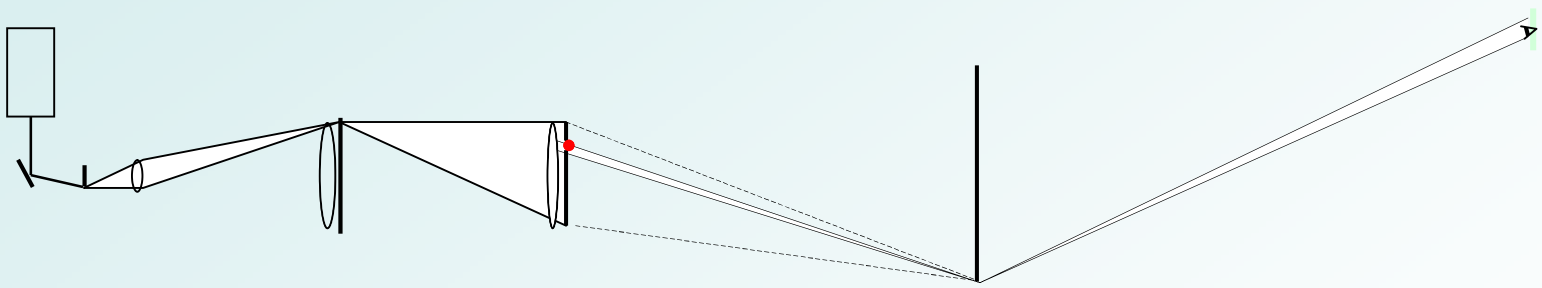

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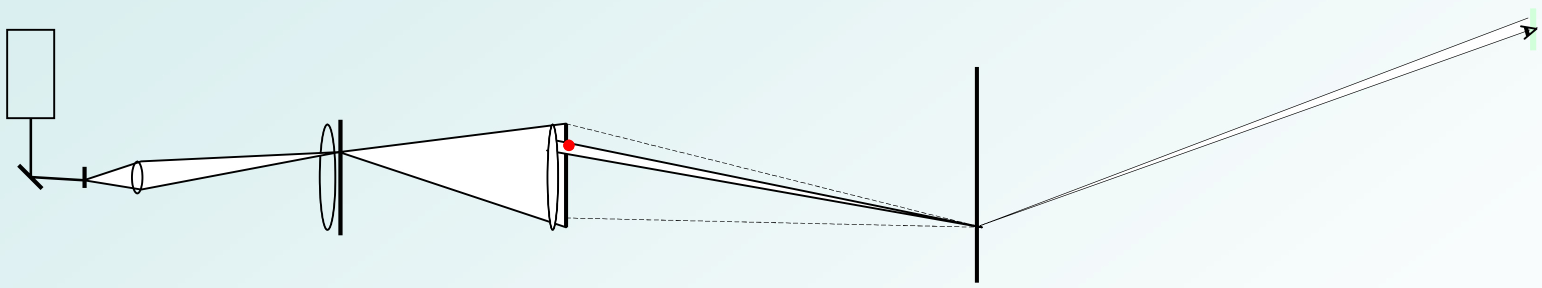

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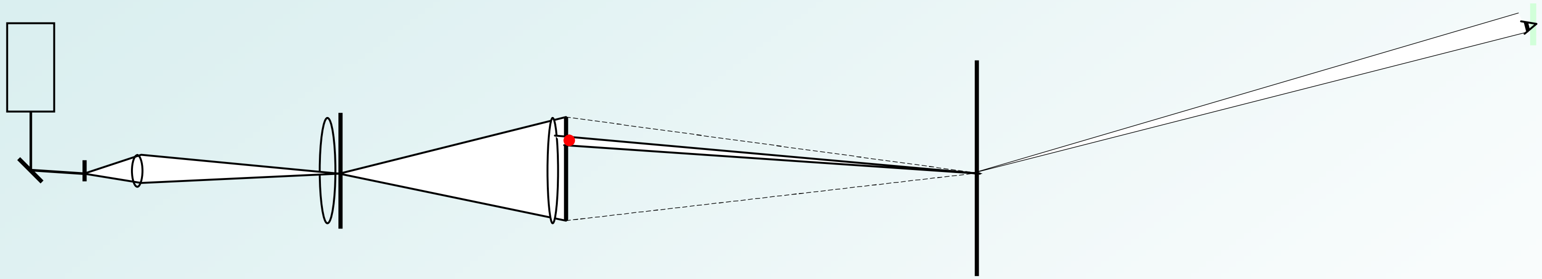

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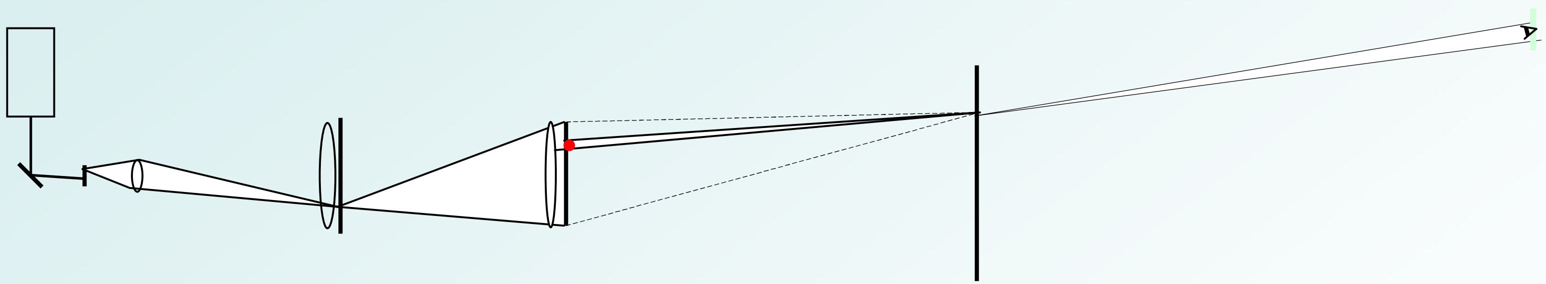

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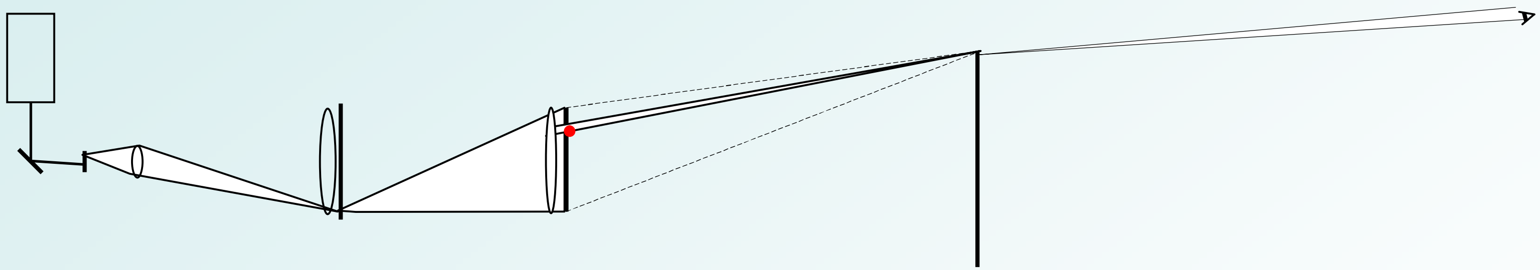

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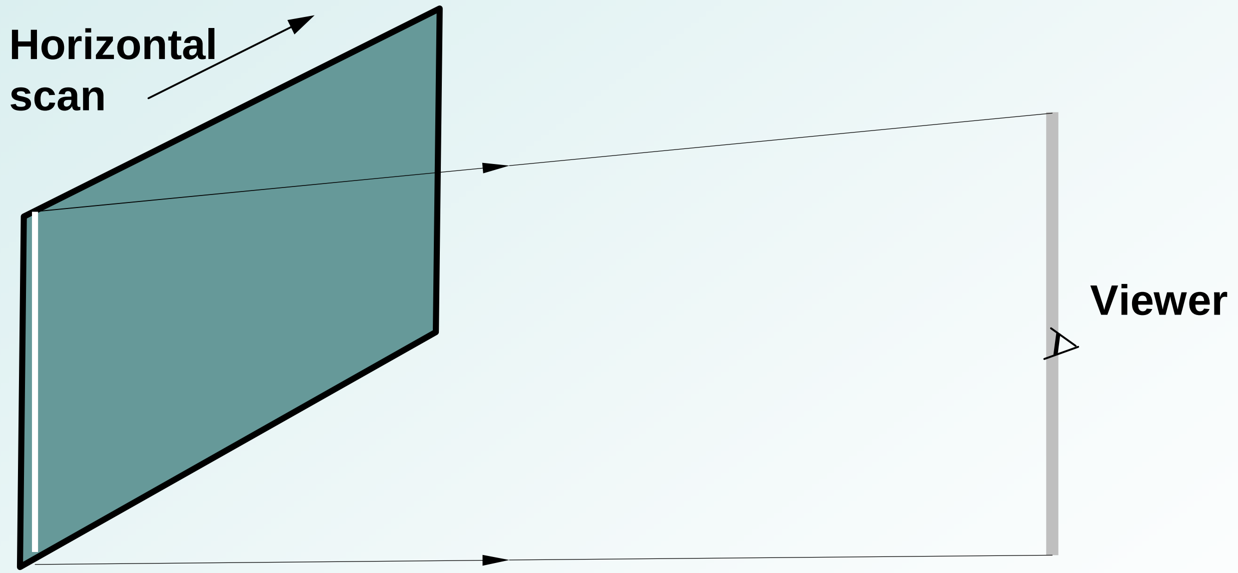
Dynamic Exit Pupil Formation



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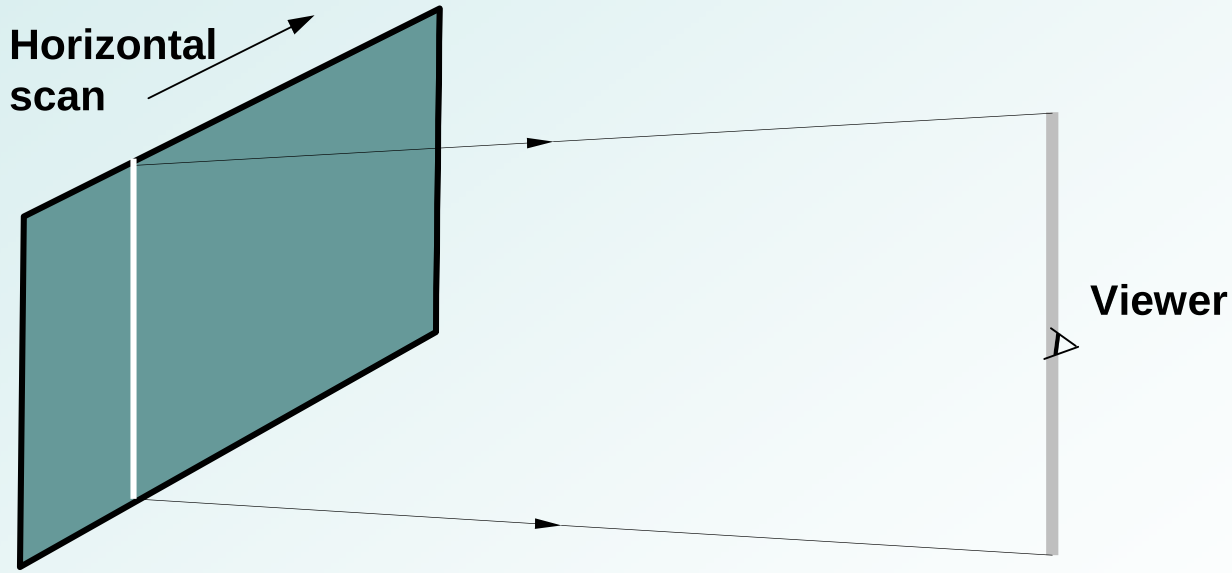
Dynamic Exit Pupil Formation



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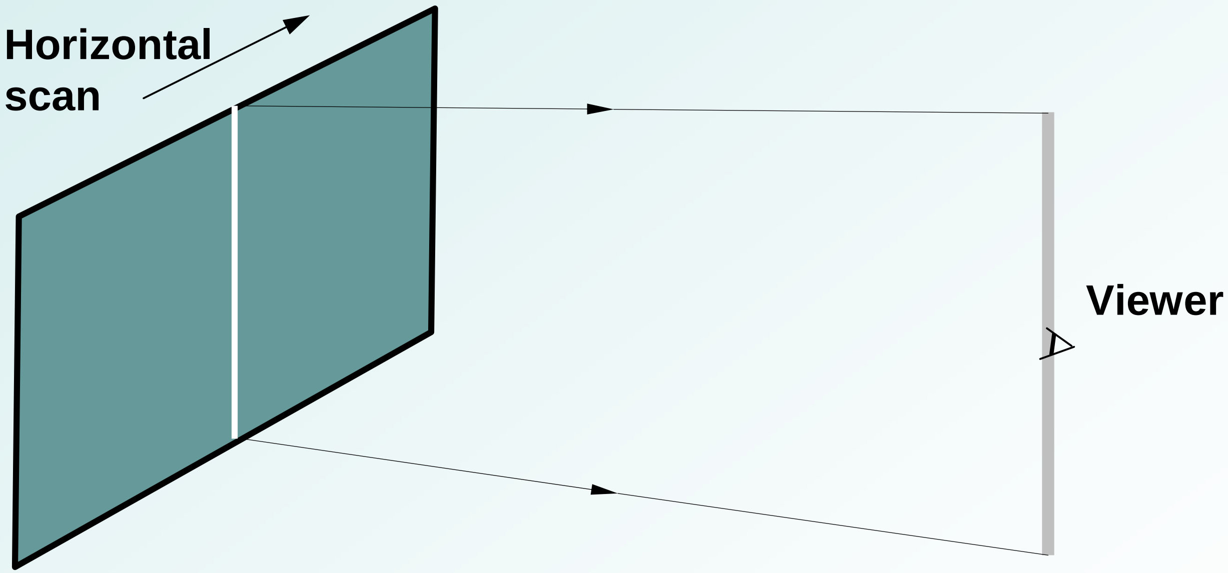
Dynamic Exit Pupil Formation



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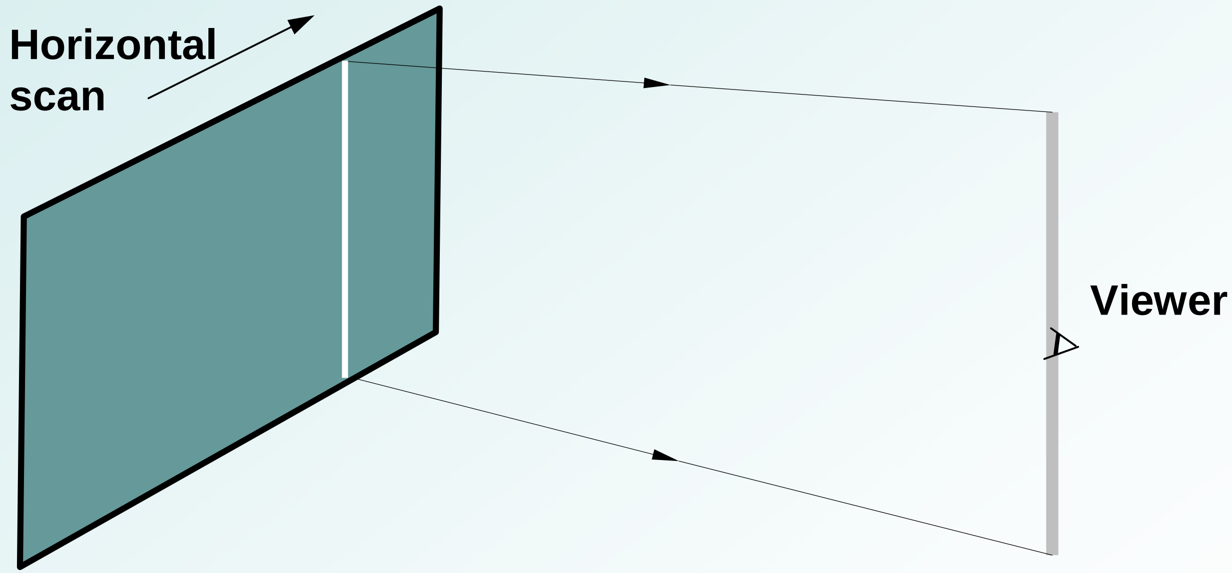
Dynamic Exit Pupil Formation



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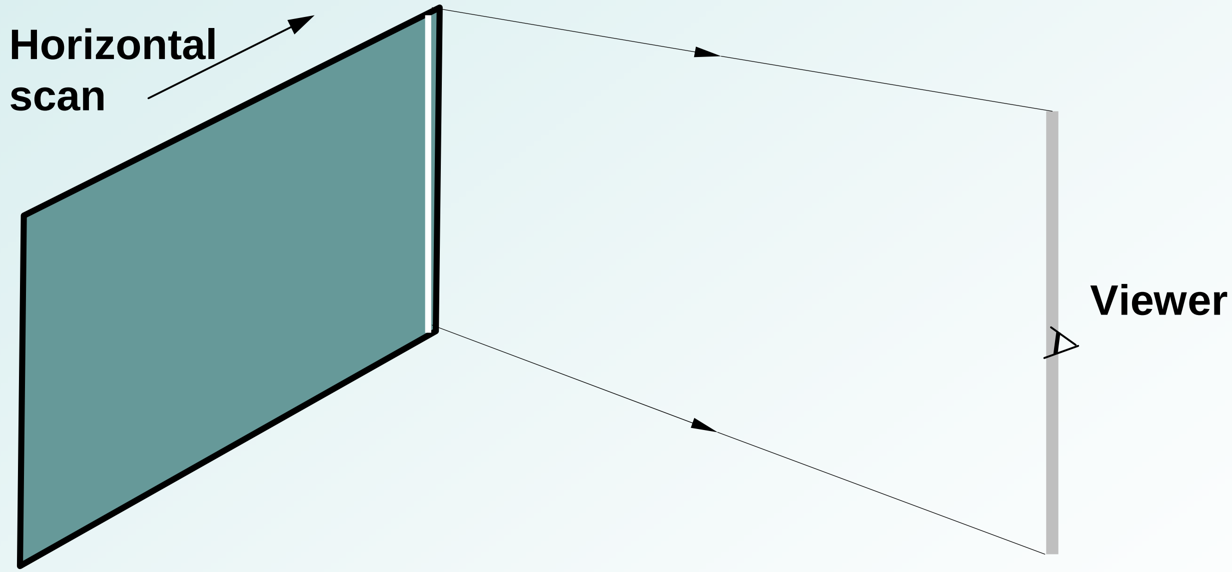
Dynamic Exit Pupil Formation



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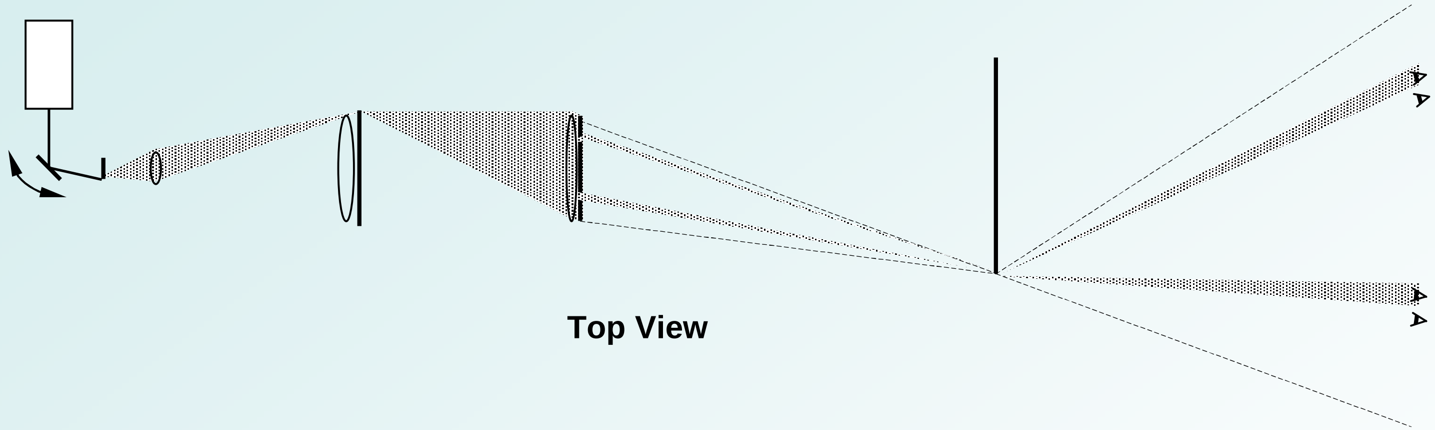
Display with multiple viewers



Temporal multiplexing is employed for R & L images for 3D.

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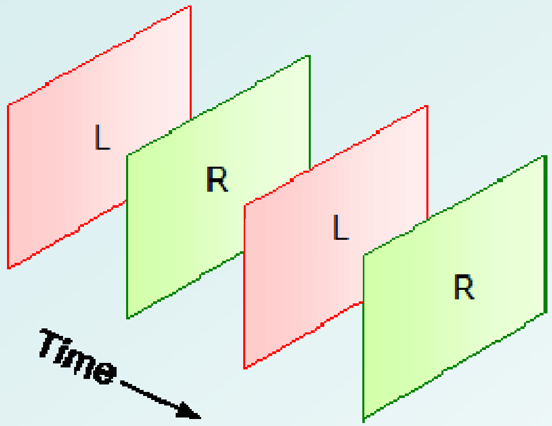
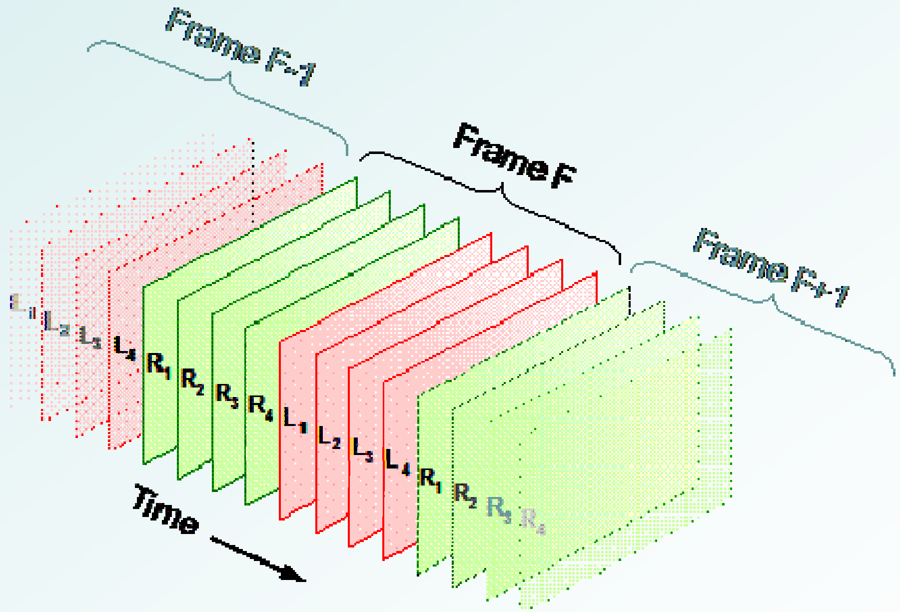
Temporal MUX for 3D



STEREO
(2 fields per frame)



MOTION PARALLAX ETC.
(2xN fields per frame – N is the number of viewers)

RGB Laser based Light Engine

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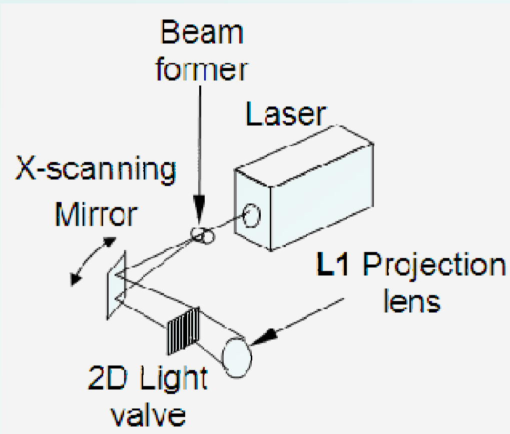
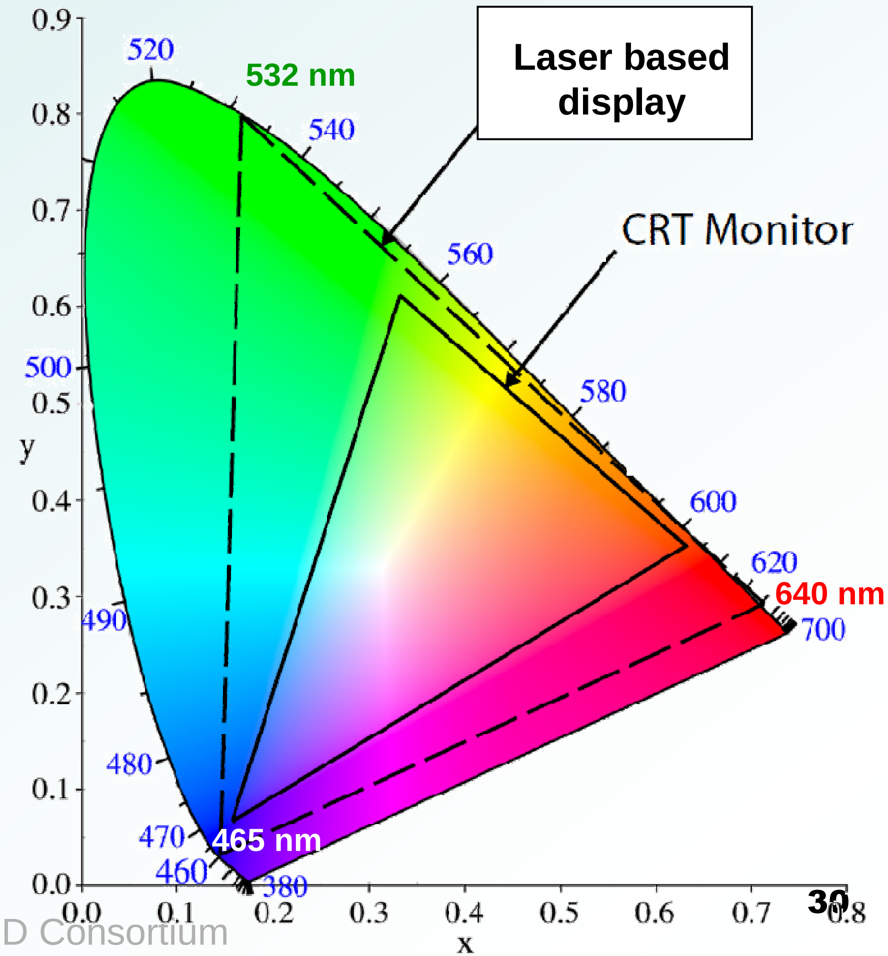
- Red, Green and Blue lasers are being used
- High color gamut

Two prototypes

- Low power single emitter lasers
- High power laser arrays



Conceptual diagram of Light Engine



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RGB lasers

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- Green and Blue lasers are from Arasor
  - Surface emitting – circular beams
  - 532 nm and 465 nm.
  - High power (~3 W)
  - Array (possibility of lower speckle contrast)
- Red laser from DILAS
  - Edge emitting diode array
  - High power (~4 W)
  - 640 nm

All these lasers require beam shaping/homogenizing with special optics.

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Power Budgeting of the display

Koç University

	Arasor Lasers		
	Red	Green	Blue
Power (mw)	**4000**	**3000**	**3000**
Wavelength	640.00	532.00	465.00
Photopic lumious efficiency - V(lambda)	0.18	0.89	0.06
System efficiency	0.00416254	0.00256	0.00216
Lumens	1.99	4.65	0.27
Screen width (cm)	**40.60**	**40.60**	**40.60**
Screen height (cm)	**30.50**	**30.50**	**30.50**
Screen area (m^2)	**0.12**	**0.12**	**0.12**
Viewing angle (horizontal)	**22.50**	22.50	**22.50**
Viewing angle (vertical)	**22.50**	22.50	**22.50**
Solid Angle (sr)	0.12	0.12	0.12
Screen Efficiency (% light within viewing a	1.00	1.00	1.00
Luminance (nit=Cd/m^2)	133.12	310.80	17.80
Luminance (ft-L)	**38.85**	**90.71**	**5.19**
POWER RATIO FOR 6500 Kelvin using F	1.00	0.57	0.50
Required power from each color (based o	4000.00	2279.20	1984.00
Excess power from each color	0.00	720.80	1016.00
Luminance based on limited color	38.85	68.91	3.44
Total luminance of display (fL)	**111.2**		
		Red limited	

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Green array laser characterization

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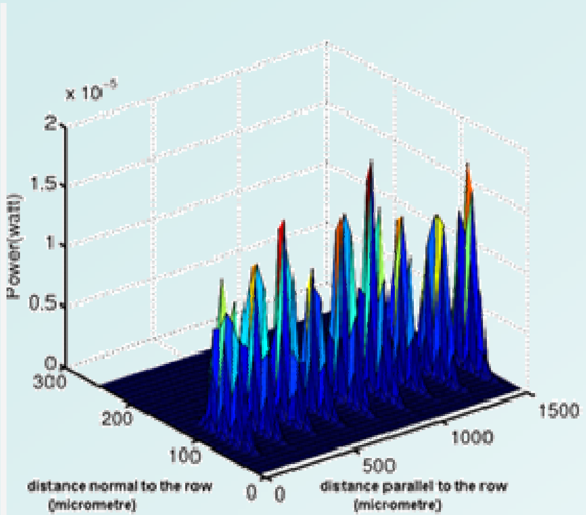
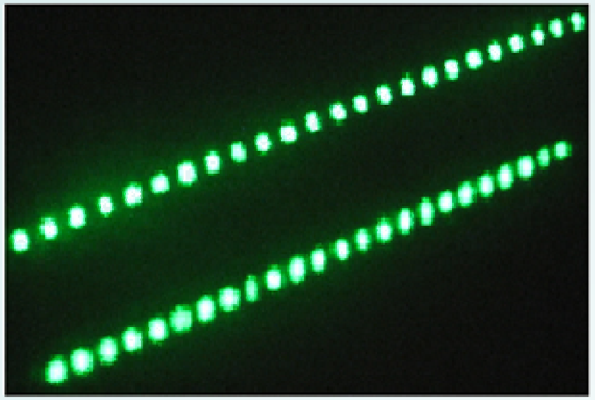
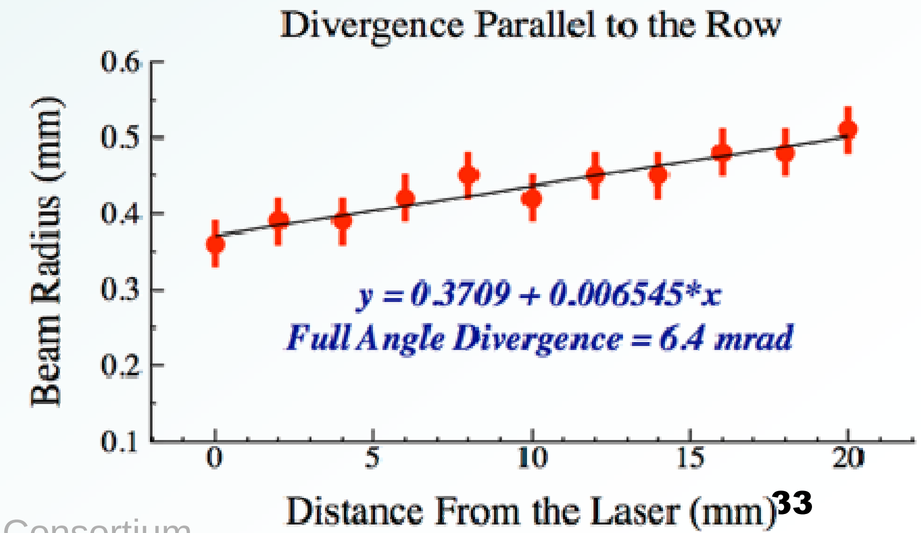




- Beam Divergence, Full Angle→ 6.5 mrad
- Emitter Intra-row Spacing → 0.32 mm



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Optical layout of the Fly's Eye 1D Laser Array Homogenizer

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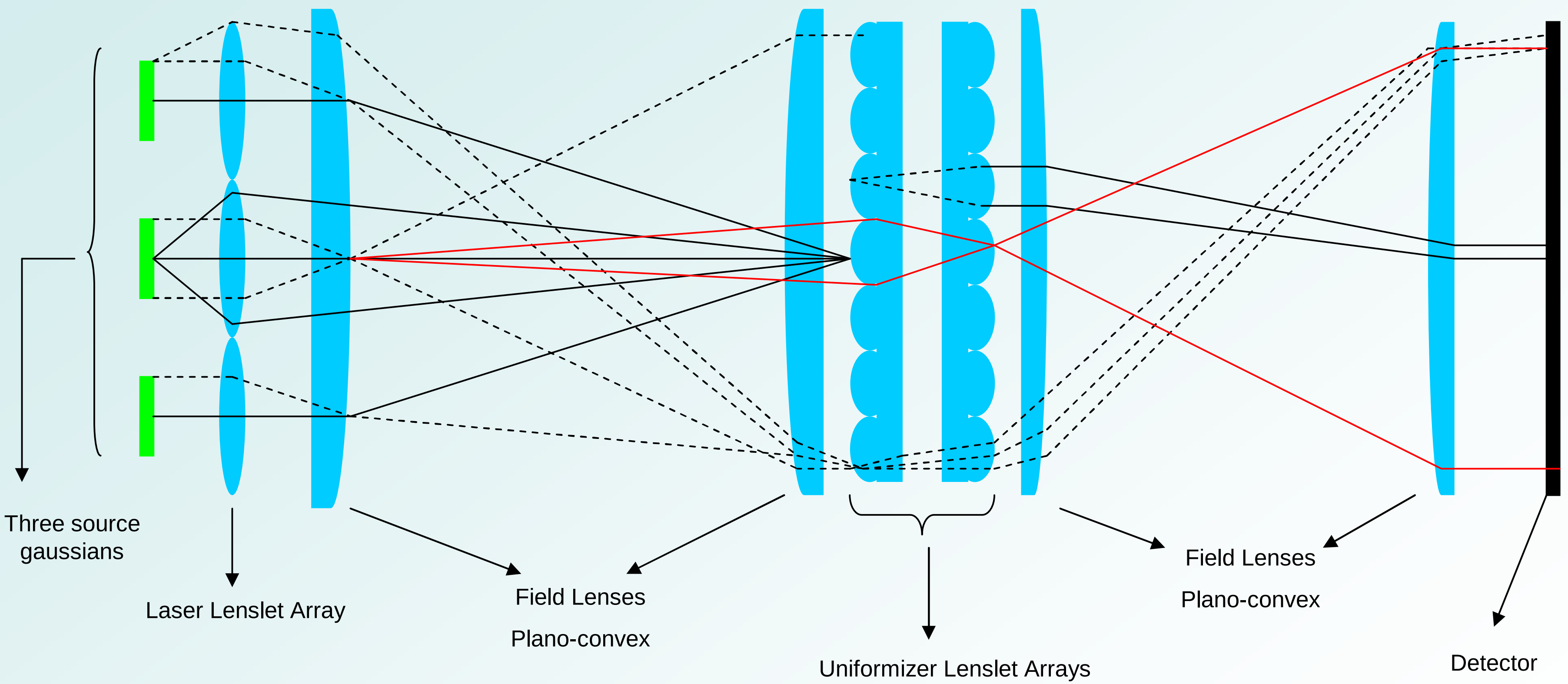

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Laser Line Profiles

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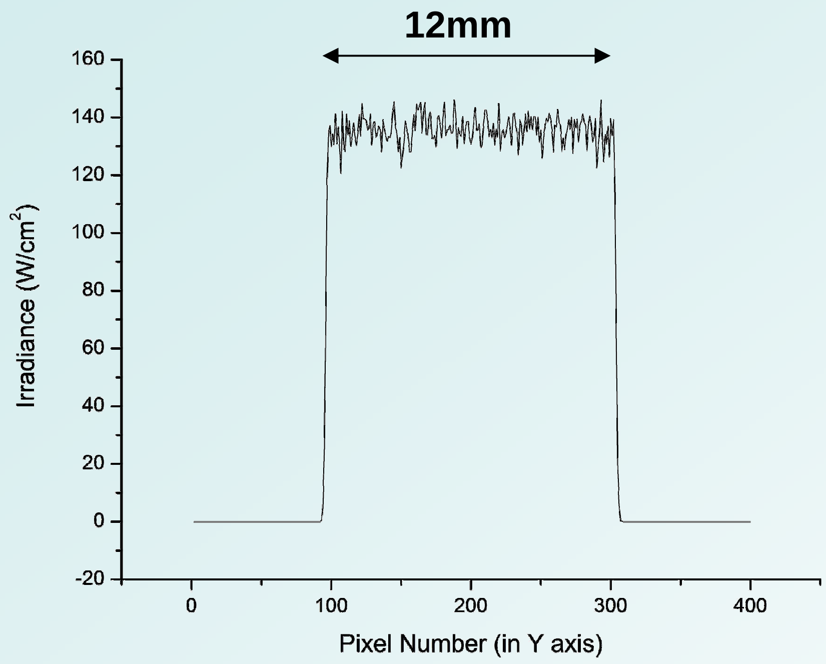
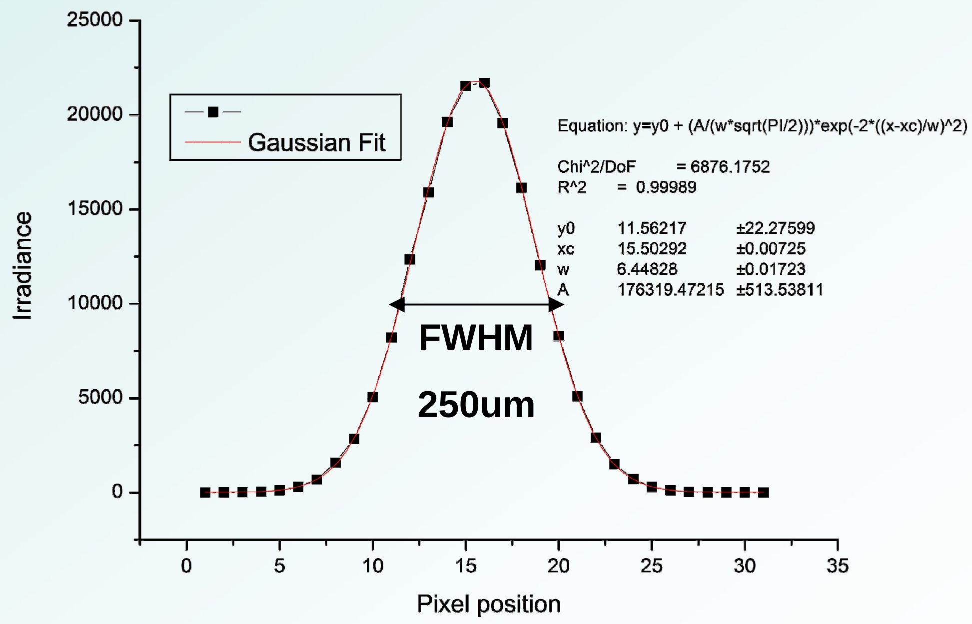


Intensity Distribution Along the Line



Intensity Distribution Along the Cross Section of the Line

Length of the line can be adjusted by changing the focal length of field lenses 3 and 4.

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Zemax model of LCOS Unit

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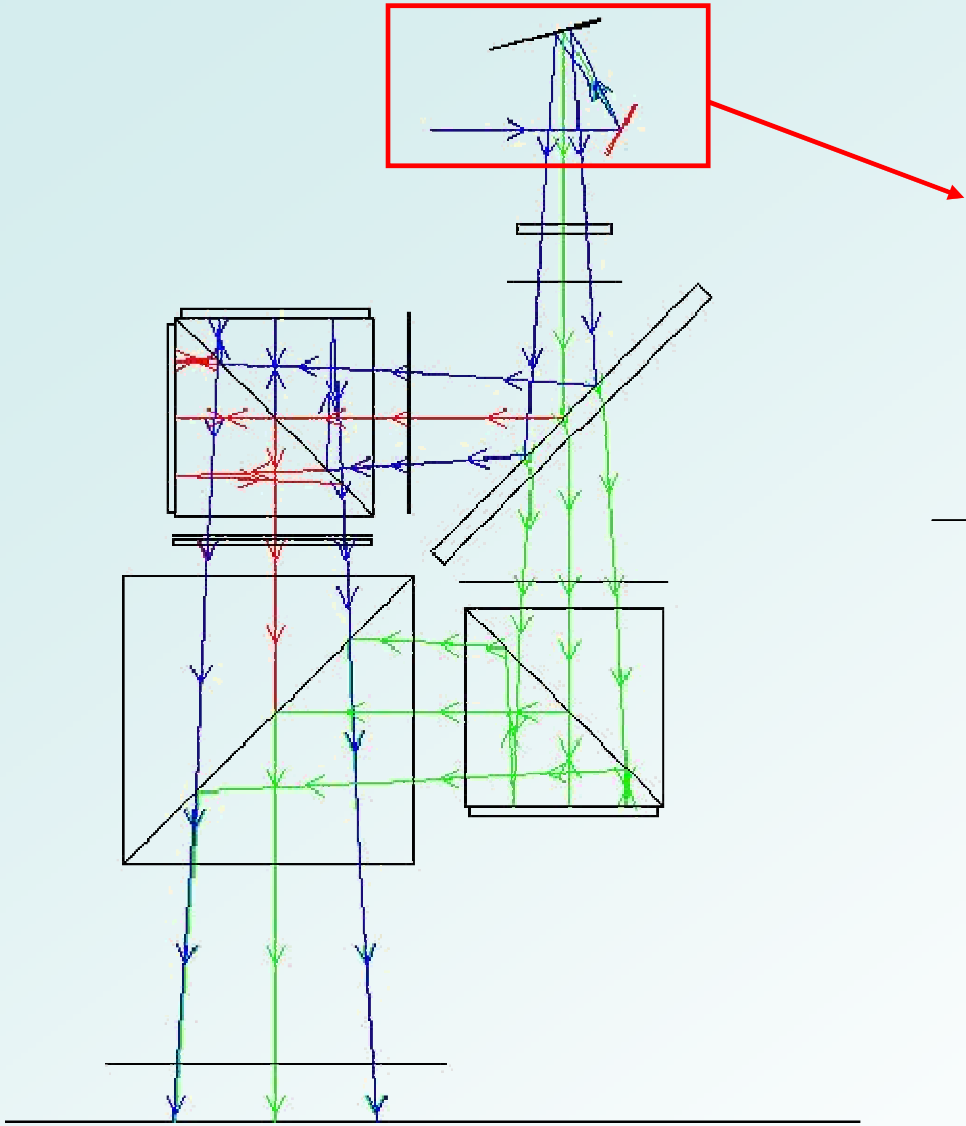

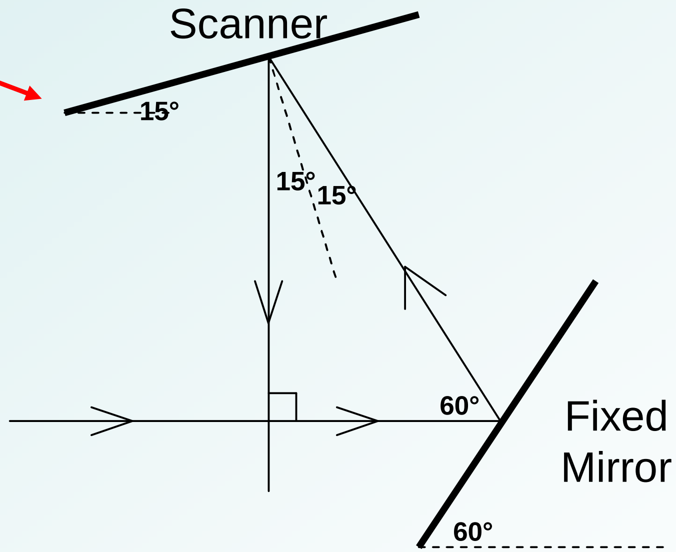

Color manipulation using dichroic coatings, polarizers and wave plates.

Three scanner positions are shown with red, green and blue.

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The Light Engine – Zemax Model

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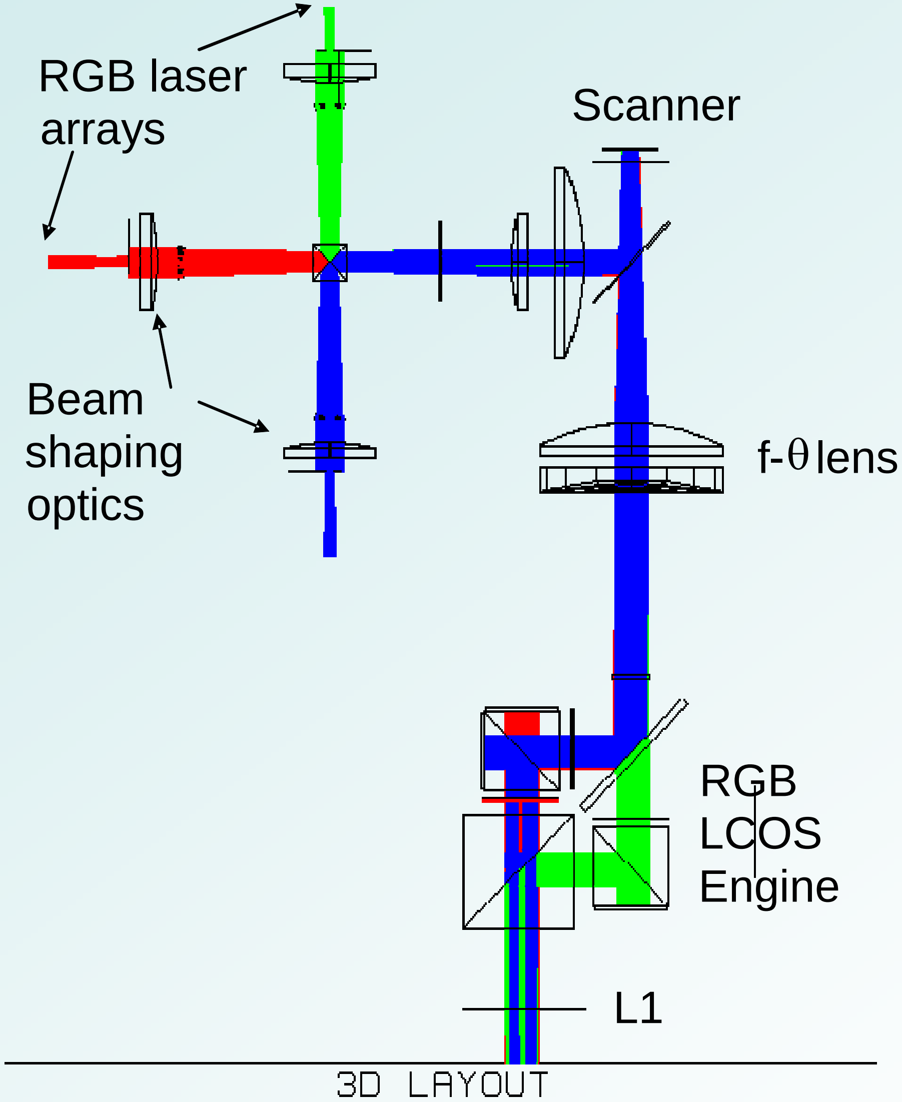

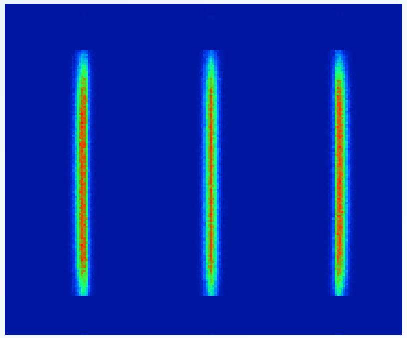

Detector view of scanned lines

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ZEMAX Model of the Projection Lens (L1)

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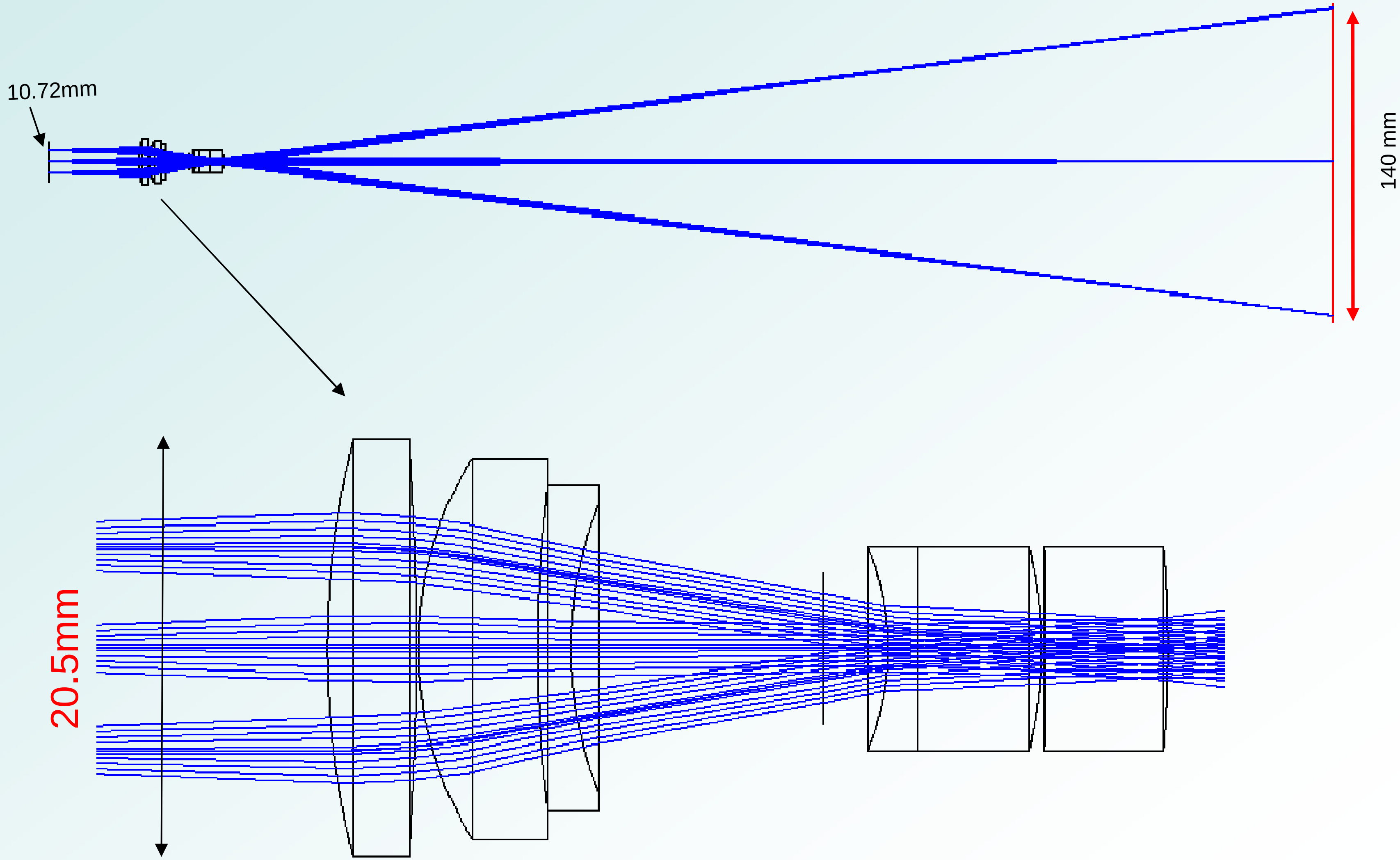

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Performance of the Projection lens

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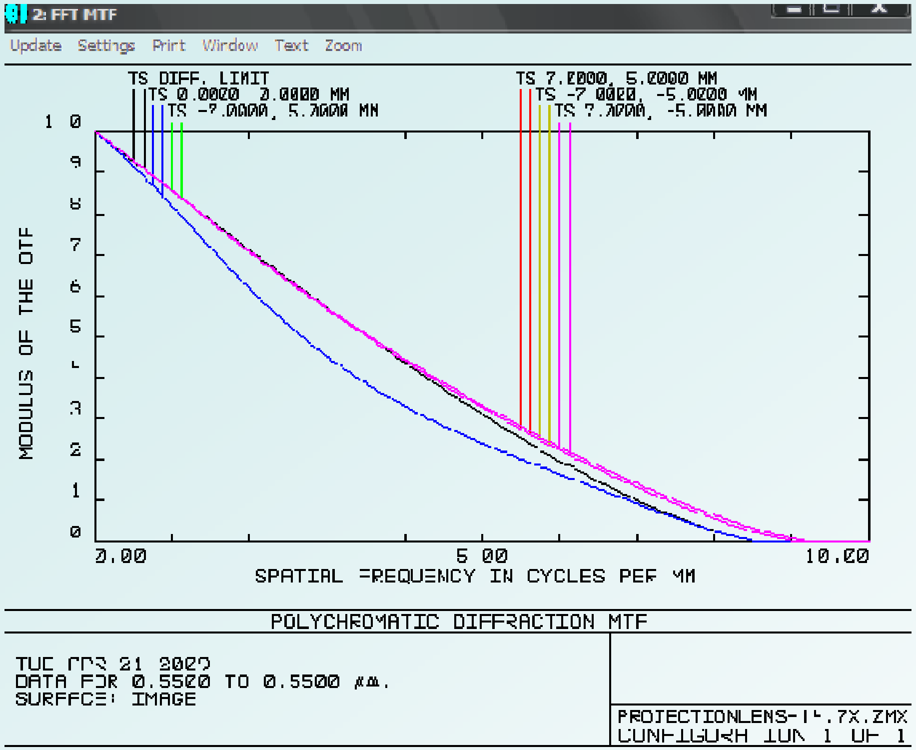
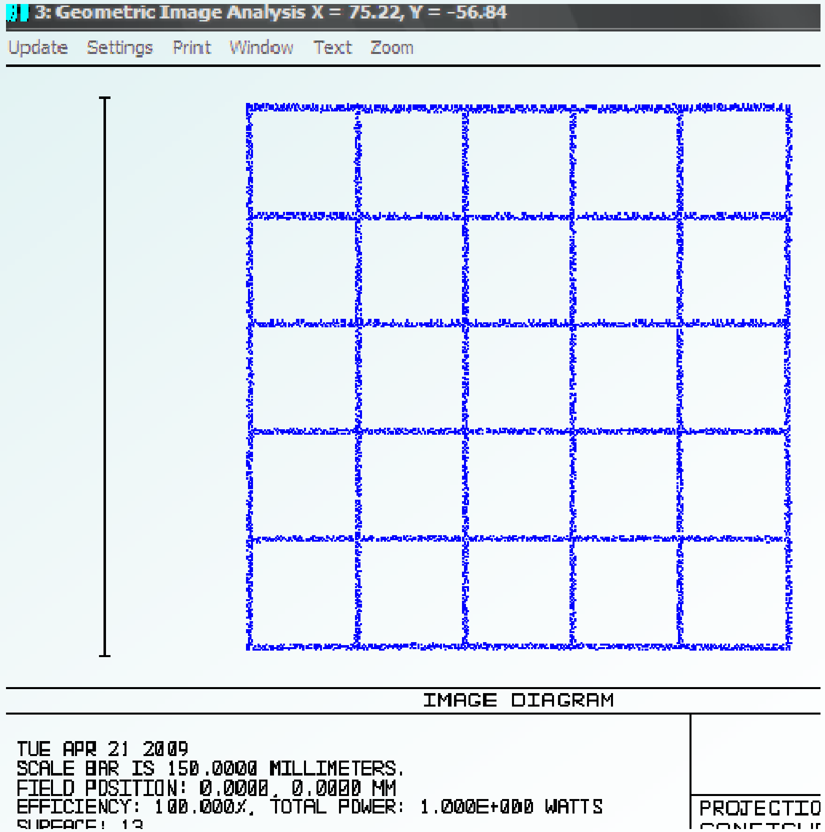


MTF Curves



Geometric Image Analysis – projected image – 14x

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Monochrome Light Engine

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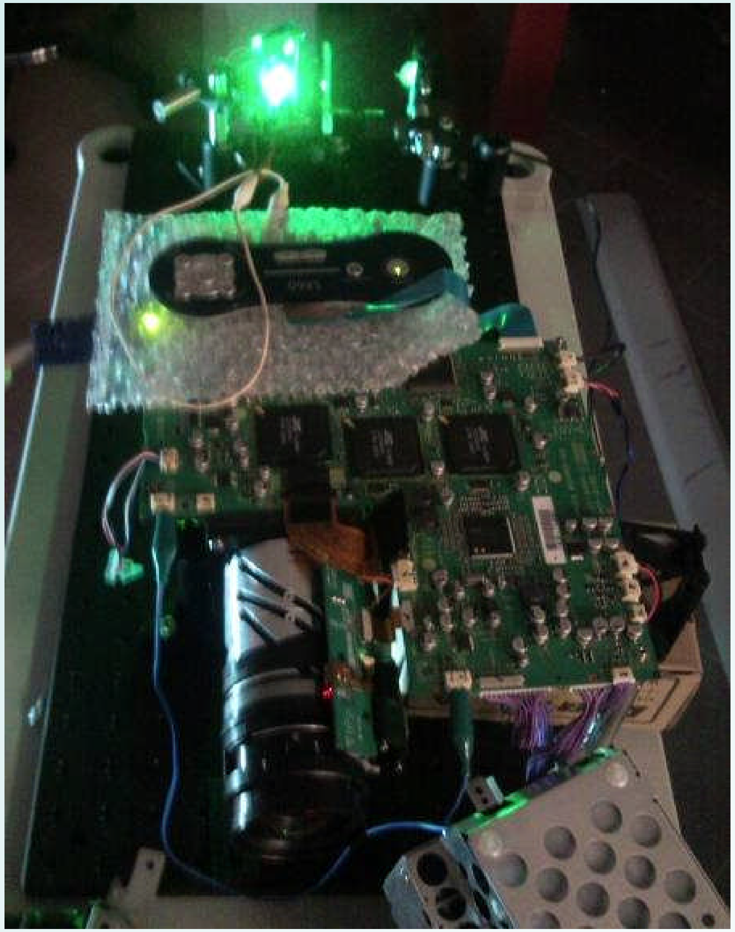

- With 250mW single emitter green laser and FR4 Scanner*

**Compact Fourier transform spectrometers using FR4 platform, Caglar Ataman and Hakan Urey, Sensors and Actuators A (2009).*

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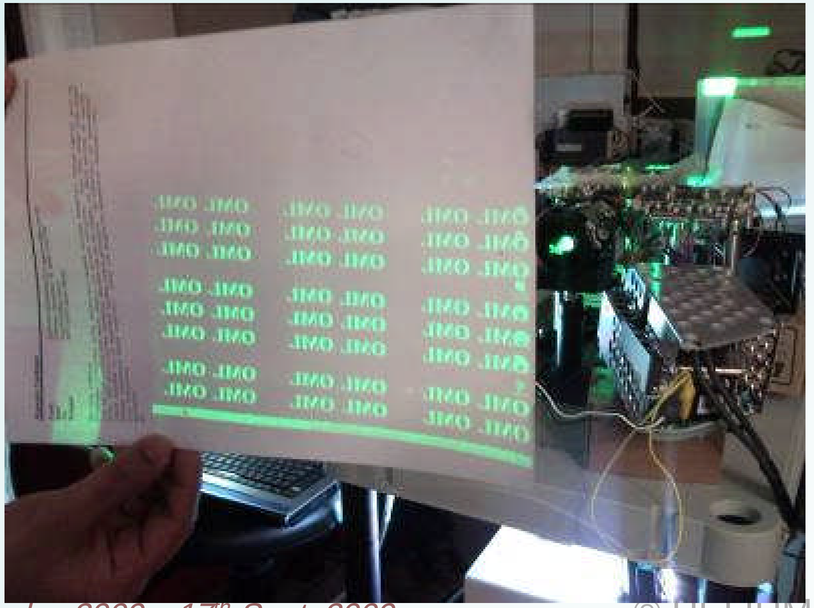
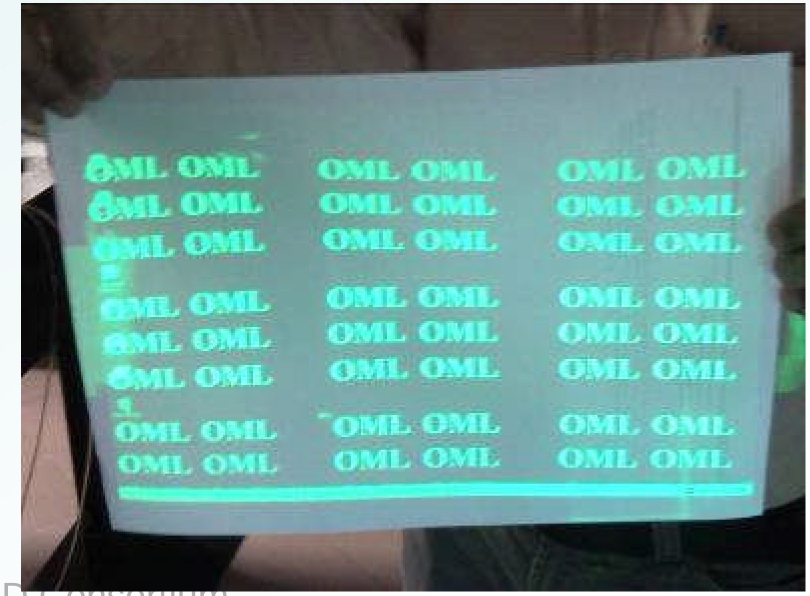
Image on Computer Screen

Back projected on paper



Front projected on paper



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Full Colour Light Engine

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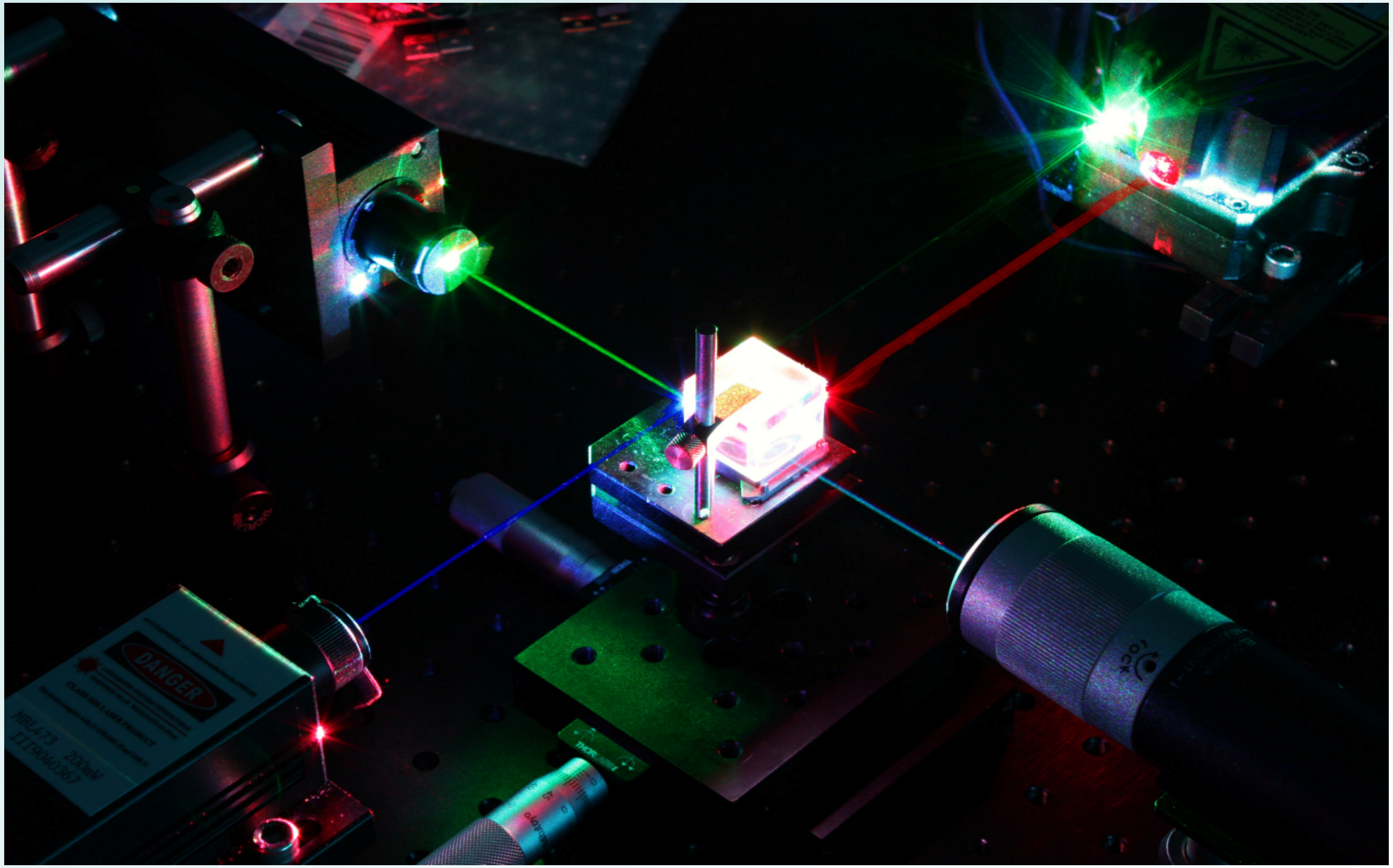

RGB Colour combining section of the light engine under development

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Transfer Screen

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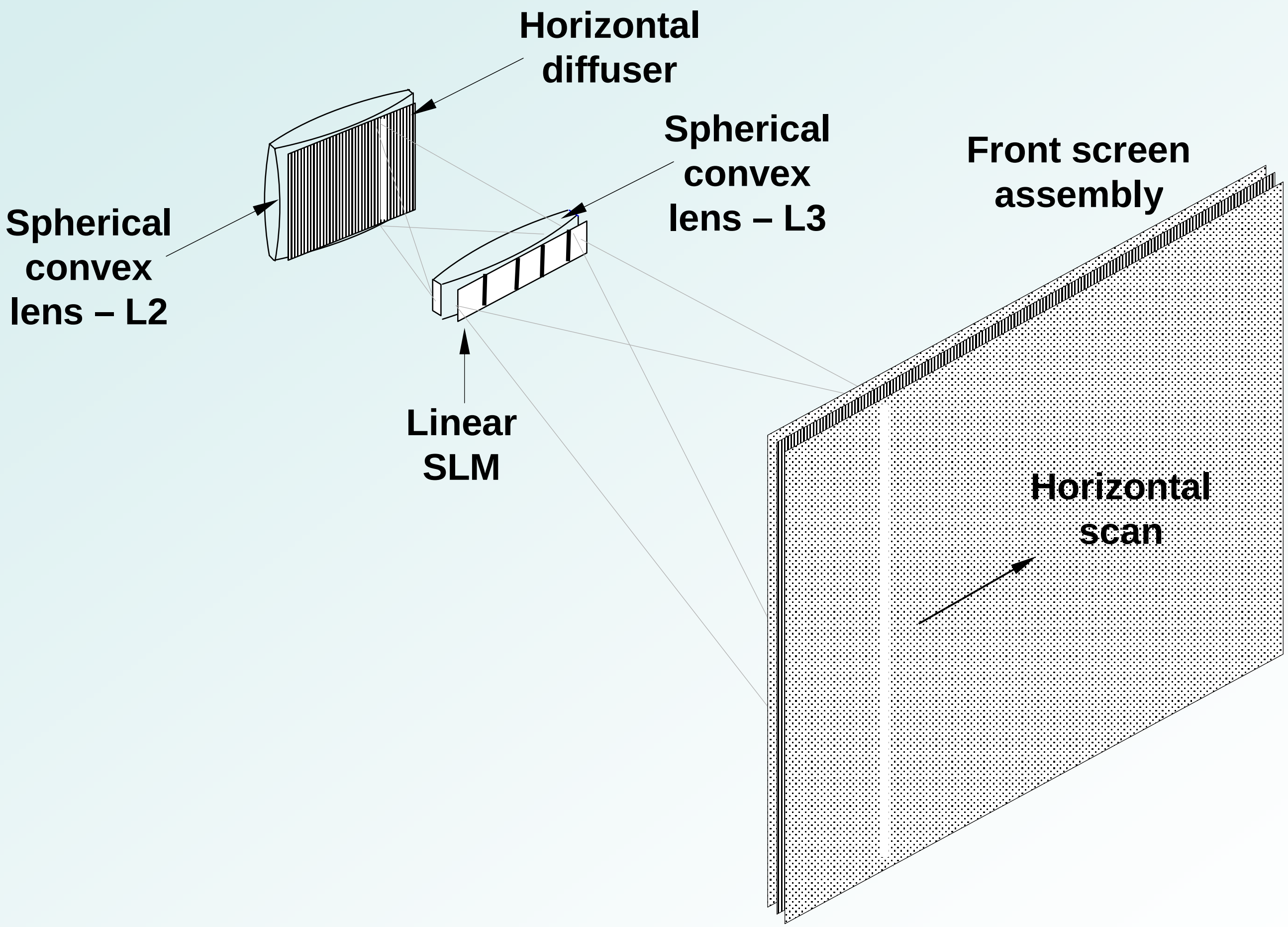

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Linear SLM

- Length ~ 260 mm
- Operates in bistable mode.
- Can be transmissive or reflective.
- Switching time < 20 microseconds (dependent on distance from conjugate.
- Contrast ratio > 100:1 (lower contrast ratio gives increased crosstalk).
- Continuous array with no gaps.
- A ferroelectric liquid crystal based SLM can perform according to the system requirements.

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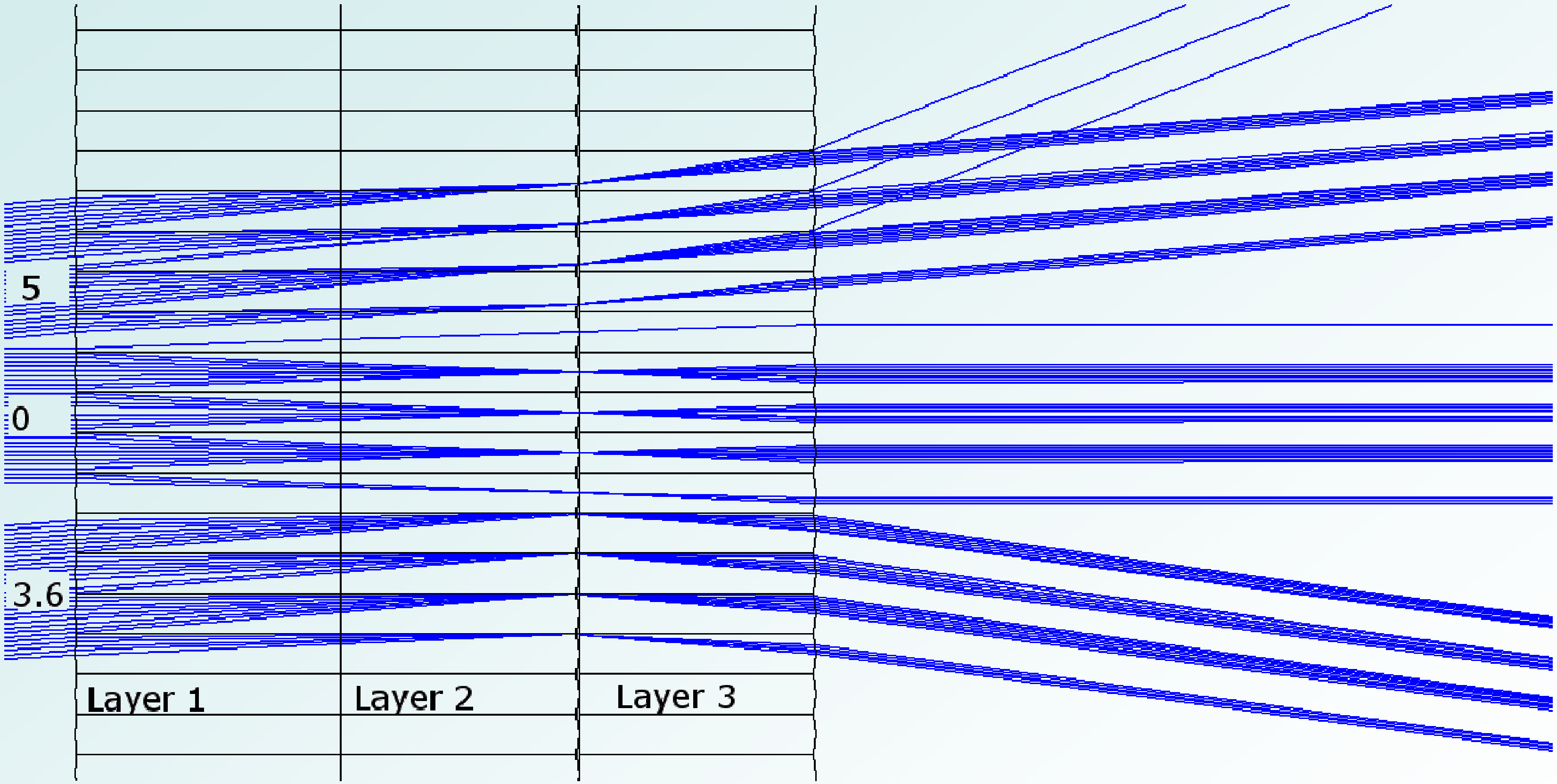
Zemax Model of the Gabor Superlens

UCL



Ray tracing showing the operation of the Gabor superlens. Collimated rays at three different angles are incident from left and transmitted to the right.

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Display: Near Field Tracking

- **Requires low tracker latency – high latency will affect task performance and could cause nausea**
- **Requires high tracker accuracy (more than for just locating exit pupils)**
- **Head tracking in x, y and z directions**
- **Images rendered in accordance with head co-ordinates**

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Eye Tracking & User Interaction

- **High-speed tracking (3D eye position @ 120 Hz)**
- **Stereo-camera version for exact distance measurements**
- **High-precision pupil detection (error range < 3x3x10 mm3)**
- **Fully automatic initialization**

Fraunhofer
Heinrich Hertz Institute

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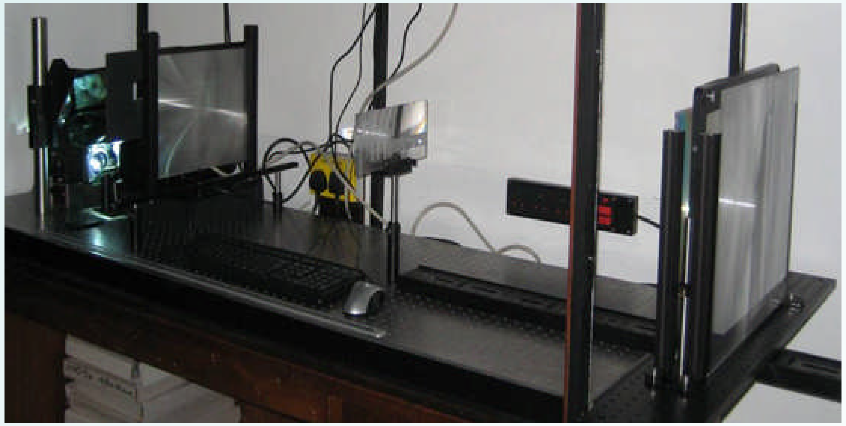
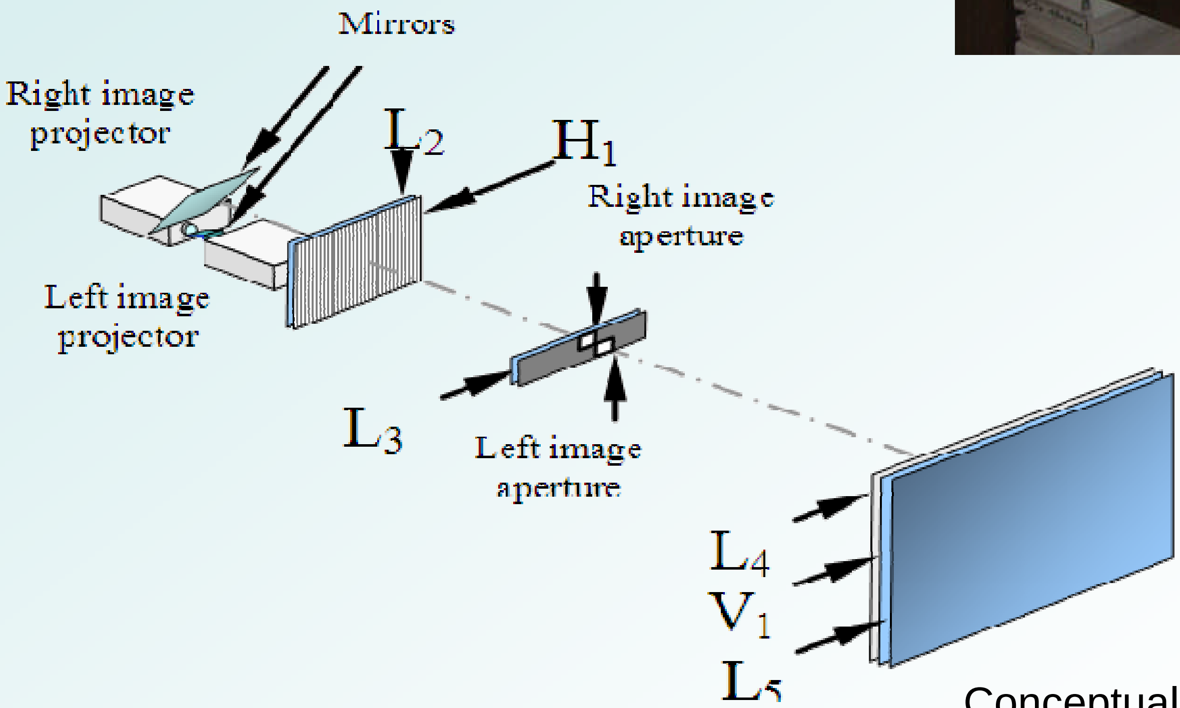
Static Exit Pupil prototype

- Two digital projectors were used for L&R image generation.
- Fixed aperture for fixed exit pupil location.
- One viewer.



Built system



Conceptual diagram

© HELIUM3D Consortium

Summary and Conclusions

- A 3D display system with dynamic exit pupil formation according to viewer location is presented.
- Number of viewers not restricted by optics.
- Light engine and a working static exit pupil prototype were successfully built.
- Full system is expected by December 2009.

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Acknowledgements

Financial support for this project is provided by the EC within FP7 under grant 215280 HELIUM3D project. Help from all the members of the HELIUM3D is gratefully acknowledged.

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Thank You

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