OSA Fall Vision Meeting '07

Schepens Eye Research Institute — An affiliate of Harvard Medical School

Design and Implementations of In-the-Spectacle-Lens Bioptic Telescopes

Eli Peli and **Fernando Vargas-Martín***

Schepens Eye Research Institute, Harvard Medical School, Boston, MA

*Departamento de Física, Universidad de Murcia, Murcia, Spain

UNIVERSIDAD DE MURCIA — Departamento de Física — Lite2c

Abstract: Bioptic telescopes are the most effective visual aid available for distance vision, yet they are frequently rejected by people with low vision due to their appearance. We describe a novel design built completely inside the spectacle lens that uses embedded mirrors inside the carrier lens for optical pathway folding and conventional lenses or curved mirrors for power. A tilt of the ocular mirror enables the wearer to simultaneously view the magnified field above the unmagnified view of the uninterrupted horizontal field, which may be important for safety and aid in image navigation. This telescope can be produced as a commodity ophthalmic lens blank and surfaced to include the wearer's prescription. We have tested a family of possible designs for Galilean and Keplerian telescopes using laminated lenses, embedded curved mirrors, and polarizing converging beam splitters.

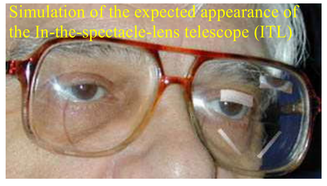
Bioptic telescopes

Head tilt = magnification on demand

- Mounted in the carrier lens
- Magnification on demand
- Useful in mobility & driving

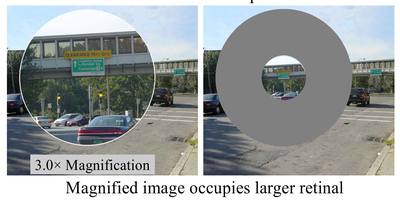
Aesthetics

- Main concern of patients
- Smaller telescopes developed
  - Loss of FOV, light, or eye relief



Ring Scotoma

Conventional Bioptic

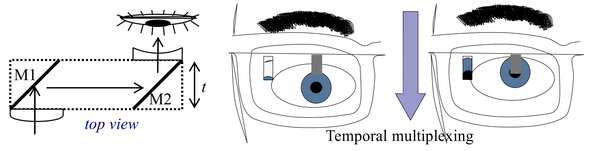


Magnified image occupies larger retinal area creating a ring scotoma

Proposed ITL

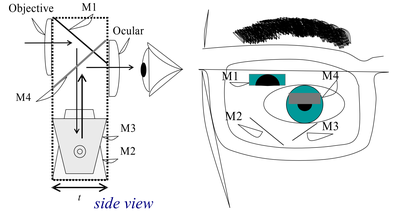
Spatial Multiplexing by shifting the image up

Laminated Lens Design (Galilean)



ITL novelty: Optical tube distance achieved along and within the carrier lens using folding mirrors

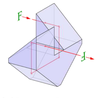
Laminated Lens Keplerian ITL



Carrier thickness only limits the vertical FOV

Keplerian vs. Galilean:

. Wider FOV
. Positive eye relief
. Better light efficiency



Folding mirrors in Porro's 2nd kind erecting arrangement

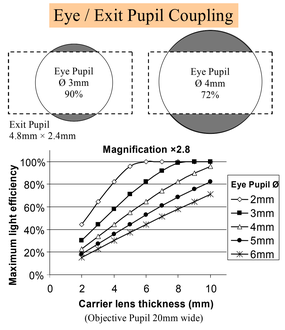
Light Economy

Entrance Pupil Height ≈ carrier thickness
Field window Height ≈ carrier thickness

Advantages of Rectangular Pupil

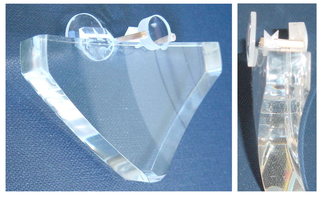
. Allows wider horizontal FOV
. Eye box for horizontal scanning
. Better Light Efficiency in eye/exit pupil coupling

Eye / Exit Pupil Coupling

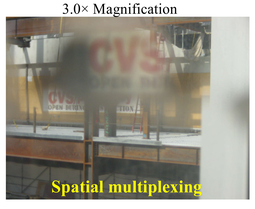


ITL prototype-I

- Ophthalmic carrier lens blank (cut at right angle)
- Total internal reflection in right angle prism
- Conventional meniscus lenses



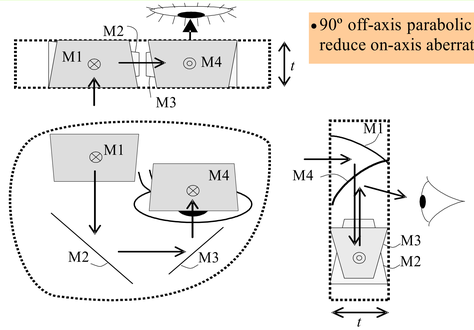
3.0× Magnification



Embedded Folding Curved Mirrors

- Curved mirrors provide required power instead of lenses
- Elements completely embedded
- Reduce chromatic aberration
- Less curvature needed compared to lenses
- Standard ophthalmic surfacing for user refraction

Embedded Off-axis Parabolic Mirrors ITL Design

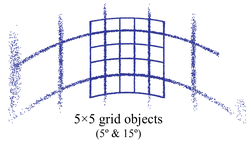


- 90º off-axis parabolic mirrors reduce on-axis aberrations

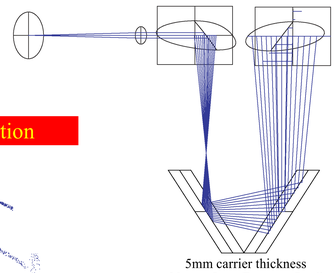
Simulated Ray Tracing Model

- 3.0× magnification
- Wide FOV (15º×7º)
- 15mm eye relief

Non rotational Distortion

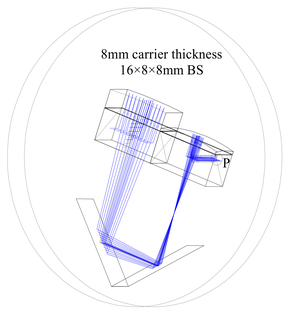


5×5 grid objects
(5º & 15º)

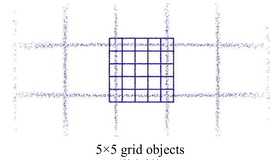


5mm carrier thickness
20mm×5mm Entrance Pupil

Simulated Ray Tracing Model



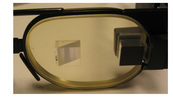
- 3.3× magnification
- Wide FOV (20º×10º)
- 10mm eye relief
- No distortion



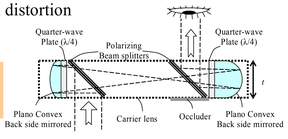
5×5 grid objects
(5º & 20º)

On-axis Spherical Mirrors with Beam Splitters

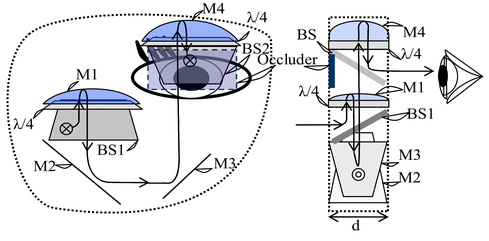
- BS allow on-axis spherical mirrors to avoid distortion
- 50% light loss ideally with Polarizing BS



- Existing technology (MicroOptical HMD)



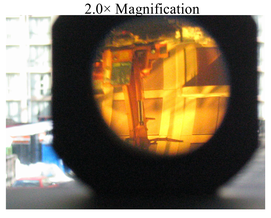
Polarizing Beam Splitter Design



ITL prototype-II

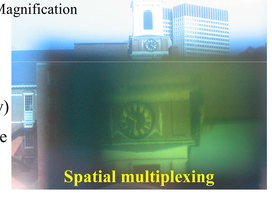
- 90º off-axis parabolic Mirrors
- Up-down reversing mirrors not included

2.0× Magnification



ITL prototype-III

2.8× Magnification



- MicroOptical's EyeGlasses (removed display)
- Polarizing Beam Splitter + quarter wave plate
- Conventional PCX lens (mirrored)