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

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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 unmagified 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.

Biometric 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

Proposed ITL

ITL prototype-I

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

ITL prototype-II

- 3.0× Magnification
- Spatial Multiplexing
- 3.0× Magnification
- Spatial Multiplexing
- +90° off-axis parabolic Mirrors
- Up-down reversing mirrors not included

ITL prototype-III

- Microscopic eyecups (removed display)
- Polarizing Beam Splitter + quarter wave plate
- Conventional PCX lens (mirrored)

Light Economy

Eye / Exit Pupil Coupling

- Entrance Pupil Height = carrier thickness
- Wide FOV (15º×7º)
- 15mm eye relief

Simulated Ray Tracing Model

Non-rotational Distortion

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

ITL prototype-I

100% Eye / Exit Pupil Coupling

ITL prototype-II

ITL prototype-III

On-axis Spherical Mirrors with Beam Splitters

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

Polarizing Beam Splitter Design

- Existing technology (Micro-Optical HSMD)

Simulated Ray Tracing Model

5×5 grid objects (5º & 20º)
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Polarizing Beam Splitter Design

Polarizing Beam Splitter Design

Advantages of Rectangular Pupil

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

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 suracing for user refraction

Embedded Off-axis Parabolic Mirrors ITL Design

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

Laminated Lens Design (Galilean)

- Conventional PCX lens (mirrored)

Laminated Lens Keplerian ITL

- Folding mirrors in Porro’s 2nd kind erecting arrangement

Laminated Lens Keplerian ITL

Embedded Folding Curved Mirrors

- Less curvature needed compared to lenses
- Reduce chromatic aberration

Polarizing Beam Splitter Design

- Polarizing Beam Splitter Design

Ring Scotoma

- Magnified image occupies larger retinal area creating a ring scotoma
- Spatial Multiplexing by shifting the image up

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

ITL prototype-I

ITL prototype-II

ITL prototype-III