

Nonconventional optical systems using varifocal lenses

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Abstract—We discuss the first order design of four optical devices, which use varifocal lenses for implementing the following optical systems: a single-lens zoom system, two-lens afocal system with tunable angular magnification, three-lens telephoto objective with an extremely low, tunable telephoto ratio (which does not require any axial displacement between its composing elements) and a telephoto objective that has a zero Petzval sum.

Several authors have proposed different techniques for implementing varifocal lenses. Some proposals follow the method that goes back to Kitajima [1–3]. Improvements to this proposal were presented independently and simultaneously by Lohmann [4–7] and by Alvarez [8–10]. This later method has inspired the use of two zone plates for generating varifocal Moiré fringes [11–14].

For implementing varifocal lenses, other authors have explored the use of liquid lenses [15, 16], and some others employ transparent membranes that can be acoustically controlled [17, 18]. Recently, based on the proposals in reference 7, we have suggested the use of vortex pairs for obtaining novel, tuneable focalizers [19, 20].

Related to the above research trends, it has been noted that varifocal lenses are useful for setting nonconventional telephoto objectives [21], as well as optical zoom systems [22–24].

Our aim here is to revisit the Gaussian optics design of the four optical systems that use varifocal lenses: a) a single-lens zoom system; b) two-lens afocal system with tunable angular magnification; c) three-lens telephoto objective that does not require any axial displacement between its composing elements, and that can be used for obtaining extremely low, tuneable magnifications; and d) improved version of the previous three-lens telephoto objective, which now has a zero Petzval sum.

As depicted in Fig. 1a), we indicate that by axially displacing a varifocal lens between a pair of conjugate planes, one can obtain the desired magnification. Then, at this specific position, one selects the optical power that is needed for mapping the input plane into the output plane. These planes are separated by the *fixed distance* T , which

is here denoted as the throw [25].

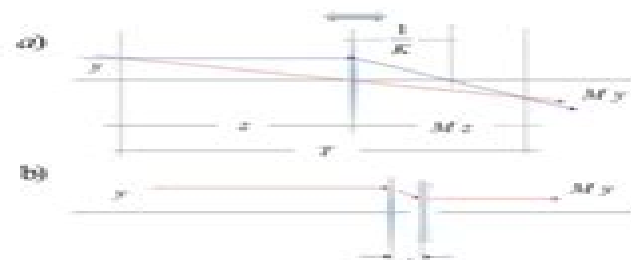


Fig. 1. Schematics of two optical systems using varifocal lenses.

In mathematical terms, if the desired magnification is M , then the distance from the lens to the input plane is

$$z = \frac{T}{M - 1}. \quad (1)$$

And the needed optical power is

$$K = -\frac{(1 - M)^2}{MT}. \quad (2)$$

The main advantage of this design is its simplicity. Didactically speaking, this example shows the usefulness of a varifocal lens. Next, we describe an afocal device with tuneable angular magnification.

As depicted in Fig. 1b), we employ now two composing elements that are separated by *fixed distance*, d , such that

$$d = \frac{1}{K_1} + \frac{1}{K_2}. \quad (3)$$

Next, we note that from the first lens to the second lens,

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Table of Contents Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie

1. Understanding the eBook Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - The Rise of Digital Reading Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Advantages of eBooks Over Traditional Books
2. Identifying Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals

3. Choosing the Right eBook Platform

- Popular eBook Platforms
- Features to Look for in an Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
- User-Friendly Interface

4. Exploring eBook Recommendations from Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie

- Personalized Recommendations
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie User Reviews and Ratings
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie and Bestseller Lists

5. Accessing Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie Free and Paid eBooks

- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie Public Domain eBooks
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie eBook Subscription Services
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie Budget-Friendly Options

6. Navigating Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie eBook Formats

- ePub, PDF, MOBI, and More
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie Compatibility with Devices
- Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie Enhanced eBook Features

7. Enhancing Your Reading Experience

- Adjustable Fonts and Text Sizes of Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie

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- ~~Highlighting and Note-Taking Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17~~
September 1993 Rokosowo Poland Spie
 - Interactive Elements Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
8. Staying Engaged with Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 9. Balancing eBooks and Physical Books Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
 11. Cultivating a Reading Routine Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Setting Reading Goals Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Carving Out Dedicated Reading Time
 12. Sourcing Reliable Information of Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Fact-Checking eBook Content of Nonconventional Optical Imaging Elements Proceedings Of Volume 2169 14 17 September 1993 Rokosowo Poland Spie
 - Distinguishing Credible Sources
 13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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