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# Large-scale achromatic flat lens by light frequency-domain coherence optimization

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## Abstract

Flat lenses, including metalens and diffractive lens, have attracted increasing attention due to their ability to miniaturize the imaging devices. However, realizing a large scale achromatic flat lens with high performance still remains a big challenge. Here, we developed a new framework in designing achromatic multi-level diffractive lenses by light coherence optimization, which enables the implementation of large-scale flat lenses under non-ideal conditions. As results, a series achromatic polymer lenses with diameter from 1 to 10 mm are successfully designed and fabricated. The subsequent optical characterizations substantially validate our theoretical framework and show relatively good performance of the centimeter-scale achromatic multi-level diffractive lenses with a super broad bandwidth in optical wavelengths (400–1100 nm). After comparing with conventional refractive lens, this achromatic lens shows significant advantages in white-light imaging performance, implying a new strategy in developing practical planar optical devices.

## Introduction

Conventional refractive lens has achieved great success in the area of imaging, metrology, detection, etc.<sup>1–2</sup>, but its bulky and heavy characteristics prevent the systems from being compact, lightweight, and miniaturized, which is in high demand for portable and convenient applications<sup>3</sup>. Metalenses, made of subwavelength nano-unit cells with ultrathin, lightweight, and flat architecture, do provide possible solutions that to some extent overcome the shortcomings of conventional diffractive lens with higher focusing efficiency and weak shadow-effect<sup>4–7</sup>. However, metalenses still severely suffer from poor imaging quality under broadband illumination due to serious chromatic aberration<sup>10–13</sup>. Several pioneering works have demonstrated achromatic metalens operating over a broad wavelength range<sup>14–21</sup>. However, according to the

fundamental limitations of the achromatic flat lens, the diameter of an ideal achromatic metalens (under the diffraction limit) is restricted by its thickness (the max height each nano-unit can achieve)<sup>18–20,32–34</sup>. As results, the diameters of reported achromatic metalenses with NA  $\geq 0.1$  in the visible do not exceed 200  $\mu\text{m}$  due to their relatively small thicknesses ( $<4\mu\text{m}$ ) up to date. Such miniaturized metalenses are useful in the micro-nano optics or integrated optics (for example, endoscope<sup>7</sup>). However, millimeter- or centimeter-scale metalenses are necessary when it comes to other fields, such as augmented reality, lens modules in cell phones, landscape cameras and telescopes<sup>1,15</sup>. Under theoretical estimation, hundred-micron thickness is needed to access the ideal centimeter scale (5–10 mm) achromatic metalens, which requires a very large aspect ratio ( $>1000:1$ ) for the constructing nano-units, while the reported largest one is only about 50:1<sup>28,34,35</sup>. Therefore, to access an ideal large-scale achromatic metalens based on the common meta-designs seems to be unachievably difficult.

Fortunately, the multi-level diffractive lens provides an alternative strategy to reach the achromatism by

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# On The Construction Of Large Achromatic

**Thomas Dick**



## **On The Construction Of Large Achromatic:**

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*The Practical Astronomer: Comprising Illustrations of Light and Colours* Practical Descriptions of All Kinds of Telescopes etc, etc. Thomas Dick, 2020-09-28 Light is that invisible ethereal matter which renders objects perceptible by the visual organs It appears to be distributed throughout the immensity of the universe and is essentially requisite to the enjoyment of every rank of perceptive existence It is by the agency of this mysterious substance that we become acquainted with the beauties and sublimities of the universe and the wonderful operations of the Almighty Creator Without its universal influence an impenetrable veil would be thrown over the distant scenes of creation the sun the moon the planets and the starry orbs would be shrouded in the deepest darkness and the variegated surface of the globe on which we dwell would be almost unnoticed and unknown Creation would disappear a mysterious gloom would surround the mind of every intelligence all around would appear a dismal waste and an undistinguished chaos To whatever quarter we might turn no form nor comeliness would be seen and scarcely a trace of the perfections and agency of an All Wise and Almighty Being could be perceived throughout the universal gloom In short without the influence of light no world could be inhabited no animated being could subsist in the manner it now does no knowledge could be acquired of the works of God and happiness even in the lowest degree could scarcely be enjoyed by any organized intelligence We have never yet known what it is to live in a world deprived of this delightful visitant for in the darkest night we enjoy a share of its beneficial agency and even in the deepest dungeon its influence is not altogether unfelt 1 The blind indeed do not directly enjoy the advantages of light but its influence is reflected upon them and their knowledge is promoted through the medium of those who enjoy the use of their visual organs Were all the inhabitants of the world deprived of their eye sight neither knowledge nor happiness such as we now possess could possibly be enjoyed

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### **Table of Contents On The Construction Of Large Achromatic**

1. Understanding the eBook On The Construction Of Large Achromatic
  - The Rise of Digital Reading On The Construction Of Large Achromatic
  - Advantages of eBooks Over Traditional Books
2. Identifying On The Construction Of Large Achromatic
  - 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 On The Construction Of Large Achromatic
  - User-Friendly Interface
4. Exploring eBook Recommendations from On The Construction Of Large Achromatic
  - Personalized Recommendations
  - On The Construction Of Large Achromatic User Reviews and Ratings

- On The Construction Of Large Achromatic and Bestseller Lists
- 5. Accessing On The Construction Of Large Achromatic Free and Paid eBooks
  - On The Construction Of Large Achromatic Public Domain eBooks
  - On The Construction Of Large Achromatic eBook Subscription Services
  - On The Construction Of Large Achromatic Budget-Friendly Options
- 6. Navigating On The Construction Of Large Achromatic eBook Formats
  - ePub, PDF, MOBI, and More
  - On The Construction Of Large Achromatic Compatibility with Devices
  - On The Construction Of Large Achromatic Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of On The Construction Of Large Achromatic
  - Highlighting and Note-Taking On The Construction Of Large Achromatic
  - Interactive Elements On The Construction Of Large Achromatic
- 8. Staying Engaged with On The Construction Of Large Achromatic
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers On The Construction Of Large Achromatic
- 9. Balancing eBooks and Physical Books On The Construction Of Large Achromatic
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection On The Construction Of Large Achromatic
- 10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
- 11. Cultivating a Reading Routine On The Construction Of Large Achromatic
  - Setting Reading Goals On The Construction Of Large Achromatic
  - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of On The Construction Of Large Achromatic
  - Fact-Checking eBook Content of On The Construction Of Large Achromatic
  - 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

### **On The Construction Of Large Achromatic Introduction**

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