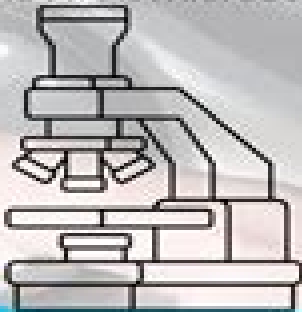


# Optical super resolution techniques

- Optical super-resolution techniques surpass the traditional limits of light microscopes, allowing scientists to view details at the nanoscale
- These methods, such as STED and PALM, employ specialized fluorescent molecules and precise light control to enhance resolution
- This breakthrough is crucial for advancements in biology and medicine, enabling detailed study of cellular structures and disease processes
- As technology progresses, these techniques continue to evolve, promising even greater insights into the microscopic world

## Practical example: Microscopy

- Optical super-resolution techniques break traditional microscopy limits, allowing scientists to view details smaller than 200 nanometers
- These methods, such as STED and PALM, use laser light manipulation to enhance resolution
- This advancement is crucial in biology and medicine, helping researchers observe finer details in cells and molecules than ever before, leading to breakthroughs in understanding diseases at a molecular level
- Super-resolution microscopy thus bridges the gap between conventional microscopy and electron microscopy



# Optical Super Resolution

**Alice Sandmeyer**



## **Optical Super Resolution:**

*Super Resolution Optical Imaging and Microscopy* Junle Qu, Zhigang Yang, 2023-12-15 Super Resolution Optical Imaging and Microscopy Extremely comprehensive resource containing cutting edge and practical knowledge of super resolution optical imaging This book covers both the basic principles and specific technical details of super resolution microscopy techniques It covers the criteria to choose different fluorophores for various SRM methods and critically assesses the nitty gritty of associated problems that are often encountered in practical applications A progressive guide to designing the next generation of advanced fluorophores to meet the goal of advanced SR imaging studies is also put forward Written by two well qualified authors the book contains exclusive content to enhance readers understanding on innovation of newer SRM technologies Sample topics covered in the book include Optical techniques fluorescent probe design and algorithm development Recent highlight and breakthroughs in biology using SRM methods The overall success of SRM in biological inventions The future direction and scope of the field This book is an invaluable resource for chemists and researchers scientists involved in designing newer fluorescent materials for SRM studies It can also assist biologists engaged in advanced biological studies using SRM by guiding them through sample preparation image processing and precautions to be taken in practical imaging studies

*Superresolution Optical Microscopy* Barry R. Masters, 2020-03-21 This book presents a comprehensive and coherent summary of techniques for enhancing the resolution and image contrast provided by far field optical microscopes It takes a critical look at the body of knowledge that comprises optical microscopy compares and contrasts the various instruments provides a clear discussion of the physical principles that underpin these techniques and describes advances in science and medicine for which superresolution microscopes are required and are making major contributions The text fills significant gaps that exist in other works on superresolution imaging firstly by placing a new emphasis on the specimen a critical component of the microscope setup giving equal importance to the enhancement of both resolution and contrast Secondly it covers several topics not typically discussed in depth such as Bessel and Airy beams the physics of the spiral phase plate vortex beams and singular optics photoactivated localization microscopy PALM stochastic optical reconstruction microscopy STORM structured illumination microscopy SIM and light sheet fluorescence microscopy LSFM Several variants of these techniques are critically discussed Noise optical aberrations specimen damage and artifacts in microscopy are also covered The importance of validation of superresolution images with electron microscopy is stressed Additionally the book includes translations and discussion of seminal papers by Abbe and Helmholtz that proved to be pedagogically relevant as well as historically significant This book is written for students researchers and engineers in the life sciences medicine biological engineering and materials science who plan to work with or already are working with superresolution light microscopes The volume can serve as a reference for these areas while a selected set of individual chapters can be used as a textbook for a one semester undergraduate or first year graduate course on superresolution

microscopy Moreover the text provides a captivating account of curiosity skepticism risk taking innovation and creativity in science and technology Good scientific practice is emphasized throughout and the author s lecture slides on responsible conduct of research are included as an online resource which will be of interest to students course instructors and scientists alike

Label-Free Super-Resolution Microscopy Vasily Astratov,2019-08-31 This book presents the advances in super resolution microscopy in physics and biomedical optics for nanoscale imaging In the last decade super resolved fluorescence imaging has opened new horizons in improving the resolution of optical microscopes far beyond the classical diffraction limit leading to the Nobel Prize in Chemistry in 2014 This book represents the first comprehensive review of a different type of super resolved microscopy which does not rely on using fluorescent markers Such label free super resolution microscopy enables potentially even broader applications in life sciences and nanoscale imaging but is much more challenging and it is based on different physical concepts and approaches A unique feature of this book is that it combines insights into mechanisms of label free super resolution with a vast range of applications from fast imaging of living cells to inorganic nanostructures This book can be used by researchers in biological and medical physics Due to its logically organizational structure it can be also used as a teaching tool in graduate and upper division undergraduate level courses devoted to super resolved microscopy nanoscale imaging microscopy instrumentation and biomedical imaging

**Optical Superresolution** David Mendlovic,2012-08-07 The authors explore the ways to improve the classical resolution limits of an imaging system and provide novel approaches for achieving better results than would otherwise be possible with current imaging technology The book begins by presenting the theoretical foundations background information and terminology of super resolution and then discusses methods and systems used to achieve the super resolution effect Various approaches to dealing with and exceeding the limitations of the lens aperture the pixel size of the camera and the noise generated at the detector are presented and analyzed The last chapter illustrates several industry related examples and potential applications to real industrial electro optical systems This book is intended for graduate students or researchers in academia or industry and anyone else looking to improve the performance of their electro optical system design

Super-Resolution Microscopy Udo J. Birk,2017-12-04 This unique book on super resolution microscopy techniques presents comparative in depth analyses of the strengths and weaknesses of the individual approaches It was written for non experts who need to understand the principles of super resolution or who wish to use recently commercialized instruments as well as for professionals who plan to realize novel microscopic devices Explaining the practical requirements in terms of hardware software and sample preparation the book offers a wealth of hands on tips and practical tricks to get a setup running provides invaluable help and support for successful data acquisition and specific advice in the context of data analysis and visualization Furthermore it addresses a wide array of transdisciplinary fields of applications The author begins by outlining the joint efforts that have led to achieving super resolution microscopy combining advances in single molecule photo physics fluorophore design and

fluorescent labeling instrument design and software development The following chapters depict and compare current main standard techniques such as structured illumination microscopy single molecule localization stimulated emission depletion microscopy and multi scale imaging including light sheet and expansion microscopy For each individual approach the experimental setups are introduced the imaging protocols are provided and the various applications illustrated The book concludes with a discussion of future challenges addressing issues of routine applications and further commercialization of the available methods Guiding users in how to make choices for the design of their own experiments from scratch to promising application this one stop resource is intended for researchers in the applied sciences from chemistry to biology and medicine to physics and engineering

*Single-Molecule Super-Resolution Optical Microscopy* Partha Pratim Mondal, Samuel Hess, 2026-02-22 This book provides a comprehensive introduction to the field of single molecular super resolution microscopy It covers the behavior of light as it propagates through optical elements and specially designed optical systems the wave nature of light and its interaction with single molecules the photophysics of single molecules the instrumentation and dedicated single photon detectors necessary for single molecule detection and the future of quantum aspects of light in super resolution microscopy With its gradual progression from the basics of light to the most advanced techniques in single molecule based super resolution microscopy this book's easy to understand language and focus on the interdisciplinary nature of single molecule science make it ideal for students from a wide range of research disciplines across physics chemistry biology medicine and engineering Written in a way that is accessible to everyone from undergraduates to experts this book does not require a strong background in physics or optics and deliberately avoids the use of extreme mathematics in favor of logical arguments and simple reasoning to explain complex concepts Chapter end questions and worked examples round out this entirely self contained textbook making it the ideal accompaniment to courses on imaging optics and single molecule science

**Plasmonics and Super-Resolution Imaging** Zhaowei Liu, 2017-06-26 Plasmonics is an emerging field mainly developed within the past two decades Due to its unique capabilities to manipulate light at deep subwavelength scales plasmonics has been commonly treated as the most important part of nanophotonics Plasmonic assisted optical microscopy techniques especially super resolution microscopy have shown tremendous potential and attracted much attention This book aims to collect cutting edge studies in various optical imaging technologies with advanced performances that are enabled or enhanced by plasmonics The basic working principles development details and potential future direction and perspectives are discussed Edited by Zhaowei Liu a prominent researcher in the field of super resolution microscopy this book will be an excellent reference for anyone in the field of nanophotonics plasmonics and optical microscopy

**Super-resolution Optical Lithography with DNA.** Shi Ho Kim, 2021 Super resolution optical microscopy offers powerful imaging methods that use sub diffraction imaging techniques and have been employed widely to investigate subcellular biological processes While super resolution optical microscopy can reveal structures whose size is below the

diffraction limit of visible light it has never been developed to construct structures at an optical super resolution Such a method will offer efficient ways to construct nanoparticle assemblies whose properties can be tuned with a precisely designed shape and internal structure at a resolution of a few tens of nanometers nm Nanoparticle assemblies can be useful for various applications such as novel optoelectronic devices based on metal nanoparticles DNA has been utilized as a building material for macro molecular assemblies due to its programmability and reversibility based on double strand hybridization Previously a photolithographic technique utilizing UV cross linkable DNA has been reported to chemically pattern a surface in micrometer resolution By taking advantage of super resolution microscopy and DNA photolithography I have developed a method with the name of Super resolution Optical Lithography with DNA SOLiD with which one can construct nanoparticle assemblies below the optical diffraction limit The method utilizes a DNA hairpin and single molecule fluorescence resonance energy transfer smFRET To understand SOLiD it is crucial to understand super resolution microscopy techniques along with the physical and mechanical properties of a DNA hairpin that render its folding and unfolding kinetics In this dissertation I present my research on developing an optical super resolution microscopy method using a DNA hairpin and smFRET and on investigating the kinetics of single stranded DNA folding and unfolding to understand the conformational dynamics of a DNA hairpin In Chapter 1 super resolution optical microscopy and FRET are reviewed In Chapter 2 single molecule fluorescent microscopy and the measurement method are presented in detail In Chapter 3 I present Super resolution Optical Lithography with DNA SOLiD which is the super resolution microscopy method that I developed to construct a nanoparticle assembly In Chapter 4 the kinetics of single stranded DNA folding and unfolding is discussed Finally in Chapter 5 the dissertation is concluded with future directions of this research

**Super-Resolution Microscopy for Material Science** Lorenzo Albertazzi, Peter Zijlstra, 2024-03-26 Optical microscopy is one of the most frequently used tools in chemistry and the life sciences However its limited resolution hampers the use of optical imaging to many other relevant problems in different disciplines Super Resolution Microscopy SRM is a new technique that allows the resolution of objects down to a few billionth of meters nanometers ten times better than classical microscopes opening up opportunities to use this tool in new fields This book describes the theory principles and practice of super resolution microscopy in the field of materials science and nanotechnology There is a growing interest in the applications of SRM beyond biology as new synthetic materials such as nanoscale sensors and catalysts nanostructured materials functional polymers and nanoparticles have nanoscopic features that are challenging to visualize with traditional imaging methods SRM has the potential to be used to image and understand these cutting edge man made objects and guide the design of materials for novel applications This book is an ideal guide for researchers in the fields of microscopy and materials science and chemistry as well as graduate students studying physics materials science biomedical engineering and chemistry Key Features Contains practical guidance on Super Resolution Microscopy SRM an exciting and growing tool that was awarded

the Nobel Prize for chemistry in 2014 Provides a new perspective targeting materials science unlike existing books which target readers in chemistry life science and biology Targets students in its core chapters while offering more advanced material for professionals and researchers in later chapters     High-Aperture Optical Microscopy Methods for Super-Resolution Deep Imaging and Quantitative Phase Imaging Jeongmin Kim, 2016 Optical microscopy thanks to the noninvasive nature of its measurement takes a crucial role across science and engineering and is particularly important in biological and medical fields To meet ever increasing needs on its capability for advanced scientific research even more diverse microscopic imaging techniques and their upgraded versions have been intensively developed over the past two decades However advanced microscopy development faces major challenges including super resolution beating the diffraction limit imaging penetration depth imaging speed and label free imaging This dissertation aims to study high numerical aperture NA imaging methods proposed to tackle these imaging challenges The dissertation first details advanced optical imaging theory needed to analyze the proposed high NA imaging methods Starting from the classical scalar theory of optical diffraction and partially coherent image formation the rigorous vectorial theory that handles the vector nature of light i e polarization is introduced New sign conventions for polarization ray tracing based on a generalized Jones matrix formalism are established to facilitate the vectorial light propagation with physically consistent outcomes The first high NA microscopic imaging of interest is wide field oblique plane microscopy OPM for high speed deep imaging It is a simple real time imaging technique recently developed to access any inclined cross section of a thick sample Despite its experimental demonstration implemented by tilted remote focusing the optical resolution of the method has not been fully understood The anisotropic resolving power in high NA OPM is rigorously investigated and interpreted by deriving the vectorial point spread function PSF and vectorial optical transfer function OTF Next OPM is combined with stochastic optical reconstruction microscopy STORM to achieve super resolution deep imaging The proposed method termed obliqueSTORM together with oblique lightsheet illumination paves the way for deeper penetration readily available in localization based super resolution microscopy The key performance metrics of obliqueSTORM quantitative super resolution and axial depth of field are studied obliqueSTORM could achieve sub 50 nm resolution with a penetration depth of tens of microns for biological samples The last part of the thesis covers the development of nonparaxial imaging theory of high NA differential phase contrast DPC microscopy for high resolution quantitative phase imaging The phase retrieval in conventional optical DPC microscopy relies on the paraxial transmission cross coefficient TCC model However this paraxial model becomes invalid in high NA DPC imaging Formulated here is a more advanced nonparaxial TCC model that considers the nonparaxial nature of light propagation apodization in high NA imaging systems and illumination source properties The derived nonparaxial TCC is numerically compared with the paraxial TCC to demonstrate its added features The practical forms of the TCC for high resolution phase reconstruction are discussed for two special types of objects weak objects and slowly varying phase objects

The theoretical studies conducted here can help to bring such high NA microscopy techniques into the real world to solve imaging challenges

**Plasmonics and Super-Resolution Imaging** Zhaowei Liu, 2017-06-26 Plasmonics is an emerging field mainly developed within the past two decades. Due to its unique capabilities to manipulate light at deep subwavelength scales, plasmonics has been commonly treated as the most important part of nanophotonics. Plasmonic assisted optical microscopy techniques, especially super resolution microscopy, have shown tremendous potential and attracted much attention. This book aims to collect cutting edge studies in various optical imaging technologies with advanced performances that are enabled or enhanced by plasmonics. The basic working principles, development details, and potential future direction and perspectives are discussed. Edited by Zhaowei Liu, a prominent researcher in the field of super resolution microscopy, this book will be an excellent reference for anyone in the field of nanophotonics, plasmonics, and optical microscopy.

Plasmonics for Super Resolution Optical Imaging Joseph Ponsetto, 2016 Imaging with resolution beyond the diffraction limit has attracted great interest in recent years. In this work, new tools for super resolution optical imaging using plasmonics are developed and demonstrated theoretically and/or experimentally. Localized Plasmonic Structured Illumination Microscopy (LPSIM) and the hyperlens. The LPSIM technique offers a significant improvement in resolution performance over existing structured illumination microscopy (SIM) methods. An array of plasmonic nano antennas provides dynamically tunable near field excitations which result in a finely structured illumination pattern for a given fluorescent object of interest. The illumination pattern feature sizes are limited only by the antenna geometry, and reconstruction from simple far field images yields deeply subwavelength resolution. In the initial theoretical and experimental demonstrations shown, resolution is improved 3 fold relative to the diffraction limit. LPSIM is attractive among competing tools due to its wide field of view, bio compatibility, and video rate speed capability. Imaging applications of the hyperlens are also shown in this work. A spherical metal dielectric multilayer geometry is used to numerically demonstrate unprecedented radial resolution at 5 nm scale for both imaging and lithography applications. Accuracy far beyond the diffraction limit in the radial direction indicates potential for three dimensional imaging and lithography applications. Design optimization with regards to several important hyperlens parameters is explored in detail.

**Compact Realizations of Optical Super-resolution Microscopy for the Life Sciences** Alice Sandmeyer, 2019

**Far-field Linear Optical Super-resolution Imaging Via Hermite-Gaussian Microscopy** Anastasiia Pushkina, 2021

*Super-resolution Wide-field Optical Microscopy by Use of Evanescent Standing Waves* Euiheon Chung, Harvard University--MIT Division of Health Sciences and Technology, 2007 cont. The super resolution has been realized with the effective point spread function providing better than a fifth of the emission wavelength or approximately 100 nm, which is better than twice that of conventional microscopy. In addition, imaging biological specimens with SW TIRF demonstrated the performance revealing the fine actin cytoskeleton structures of fibroblasts. On the other hand, the surface plasmons induced by evanescent fields at a specific angle can generate an enhanced electric field which can



effectively excite fluorophores near a metal coated surface We observed a unique doughnut shaped point spread function of surface plasmon coupled emission and explained it with theoretical modeling using vector field theory The combination of surface plasmon resonance fluorescence imaging and SW TIRF resulted in a novel high resolution microscopy the standing wave surface plasmon resonance fluorescence SW SPRF microscopy These findings may allow super resolution imaging with even higher sensitivity and signal to noise ratio at high imaging speed

### **Nanophotonics with Surface Plasmons**

,2006-12-18 Current developments in optical technologies are being directed toward nanoscale devices with subwavelength dimensions in which photons are manipulated on the nanoscale Although light is clearly the fastest means to send information to and from the nanoscale there is a fundamental incompatibility between light at the microscale and devices and processes at the nanoscale Nanostructured metals which support surface plasmon modes can concentrate electromagnetic EM fields to a small fraction of a wavelength while enhancing local field strengths by several orders of magnitude For this reason plasmonic nanostructures can serve as optical couplers across the nano micro interface metal dielectric and metal semiconductor nanostructures can act as optical nanoantennae and enhance light matter coupling in nanoscale devices This book describes how one can fully integrate plasmonic nanostructures into dielectric semiconductor and molecular photonic devices for guiding photons across the nano micro interface and for detecting molecules with unsurpassed sensitivity Nanophotonics and Nanoplasmonics Metamaterials and negative index materials Plasmon enhanced sensing and spectroscopy Imaging and sensing on the nanoscale Metal Optics

### **Super-Resolution Imaging** Subhasis

Chaudhuri,2006-04-18 Super Resolution Imaging serves as an essential reference for both academicians and practicing engineers It can be used both as a text for advanced courses in imaging and as a desk reference for those working in multimedia electrical engineering computer science and mathematics The first book to cover the new research area of super resolution imaging this text includes work on the following groundbreaking topics Image zooming based on wavelets and generalized interpolation Super resolution from sub pixel shifts Use of blur as a cue Use of warping in super resolution Resolution enhancement using multiple apertures Super resolution from motion data Super resolution from compressed video Limits in super resolution imaging Written by the leading experts in the field Super Resolution Imaging presents a comprehensive analysis of current technology along with new research findings and directions for future work

### **Quantum**

**Imaging** Mikhail I. Kolobov,2007-11-03 Quantum Imaging is a newly born branch of quantum optics that investigates the ultimate performance limits of optical imaging allowed by the laws of quantum mechanics Using the methods and techniques from quantum optics quantum imaging addresses the questions of image formation processing and detection with sensitivity and resolution exceeding the limits of classical imaging This book contains the most important theoretical and experimental results achieved by the researchers of the Quantum Imaging network a research programme of the European Community

**Super-resolution Optical Imaging Using Microsphere Nanoscopy** Seoungjun Lee,2013 **Nonlinear**

**Super-Resolution Nano-Optics and Applications** Jingsong Wei, 2014-10-09 This book covers many advances in the subjects of nano optics and nano photonics The author describes the principle and technical schematics of common methods for breaking through the optical diffraction limit and focuses on realizing optical super resolution with nonlinear effects of thin film materials The applications of nonlinear optical super resolution effects in nano data storage nanolithography and nano imaging are also presented This book is useful to graduate students majoring in optics and nano science and also serves as a reference book for academic researchers engineers technical professionals in the fields of super resolution optics and laser techniques nano optics and nano photonics nano data storage nano imaging micro nanofabrication and nanolithography and nonlinear optics

## Reviewing **Optical Super Resolution**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is truly astonishing. Within the pages of "**Optical Super Resolution**," an enthralling opus penned by a very acclaimed wordsmith, readers set about an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve into the book's central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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## Optical Super Resolution Introduction

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