



南京理工大学

NANJING UNIVERSITY OF SCIENCE & TECHNOLOGY

# 计算光学成像与 光信息处理技术前沿

(第14讲)

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Nanjing University of Science and Technology,

Nanjing, Jiangsu Province 210094, China



电子工程与光电技术学院

School of Electronic and Optical Engineering



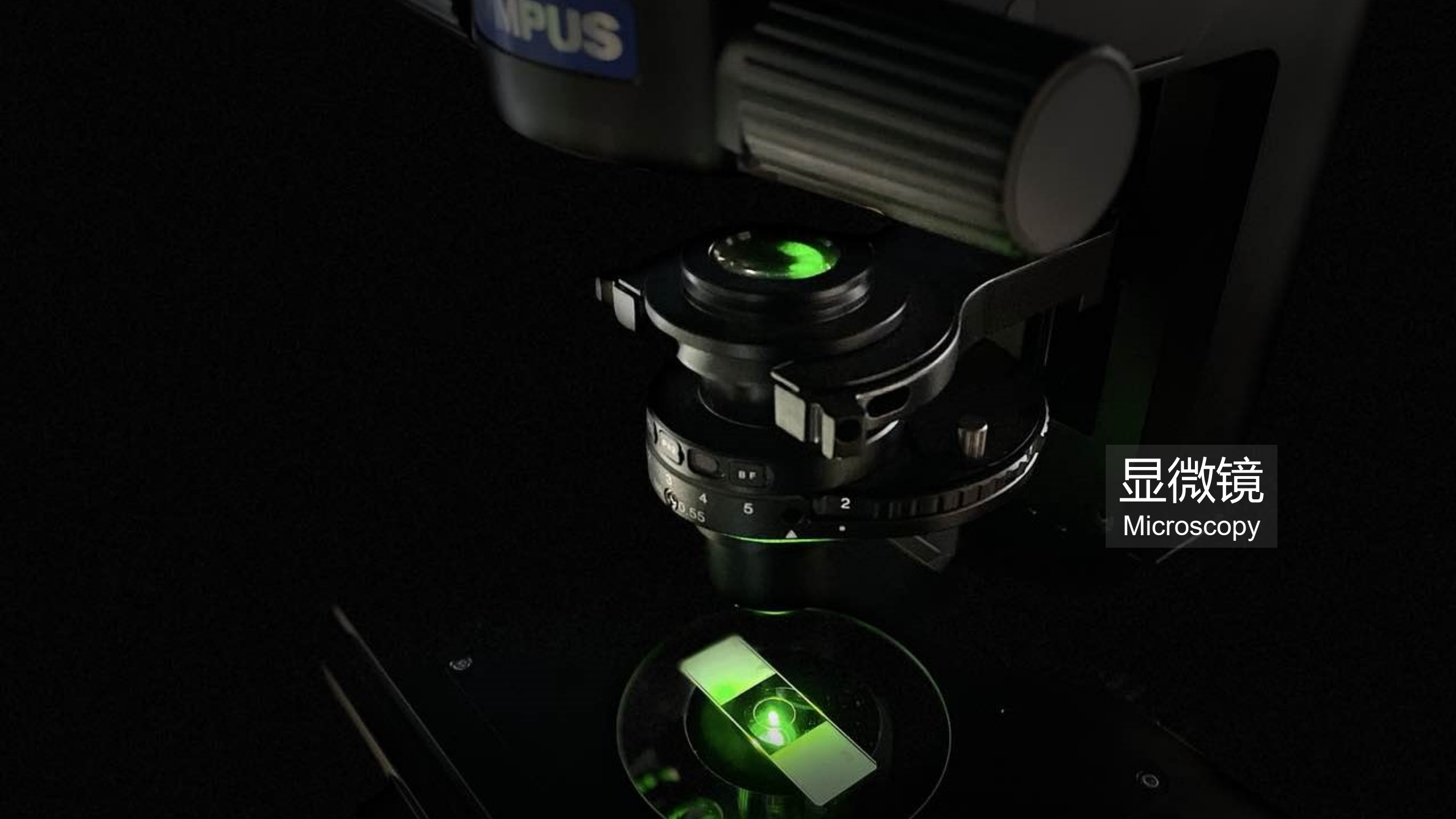
江苏省光谱成像与智能感知重点实验室

Jiangsu Key Laboratory of Spectral Imaging & Intelligent Sense

A detailed view of a super-resolution microscope setup. The image shows a complex arrangement of optical components, including lenses, mirrors, and a camera, all illuminated with a bright green laser light. The setup is mounted on a black metal base with a grid of holes. The text "超分辨显微成像技术" and "Super-resolution microscopy" is overlaid on the image. The background is dark, making the green light stand out prominently. The text is in white, with the Chinese characters on top and the English translation below. The overall scene is technical and scientific in nature.

# 超分辨显微成像技术

## Super-resolution microscopy



MPUS

显微镜  
Microscopy



亚斯·詹森 | 荷兰 1590

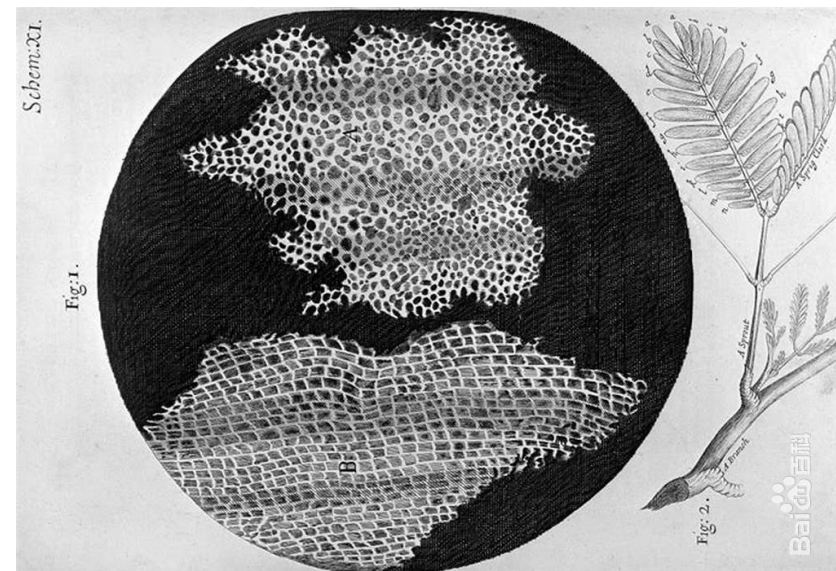
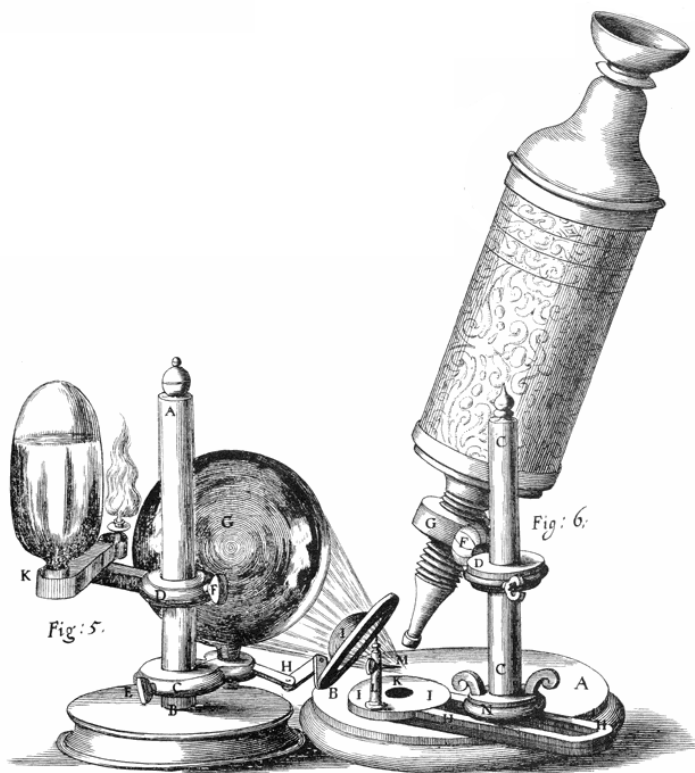


米德尔堡科学协会 | 1604

# cell

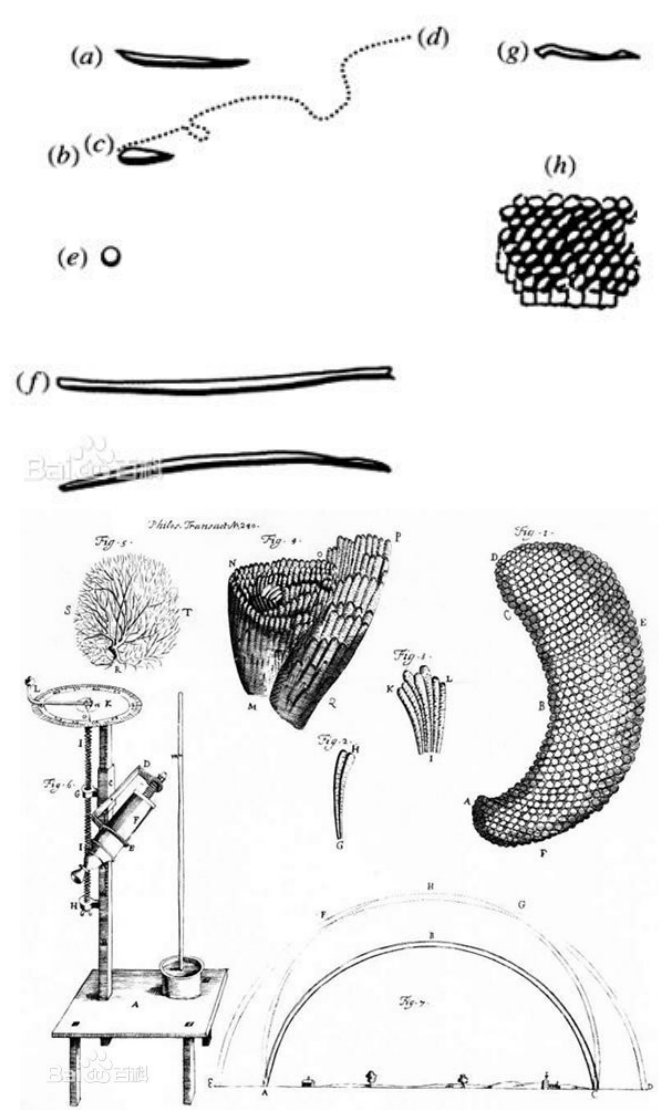


罗伯特·胡克 | 英国 1665

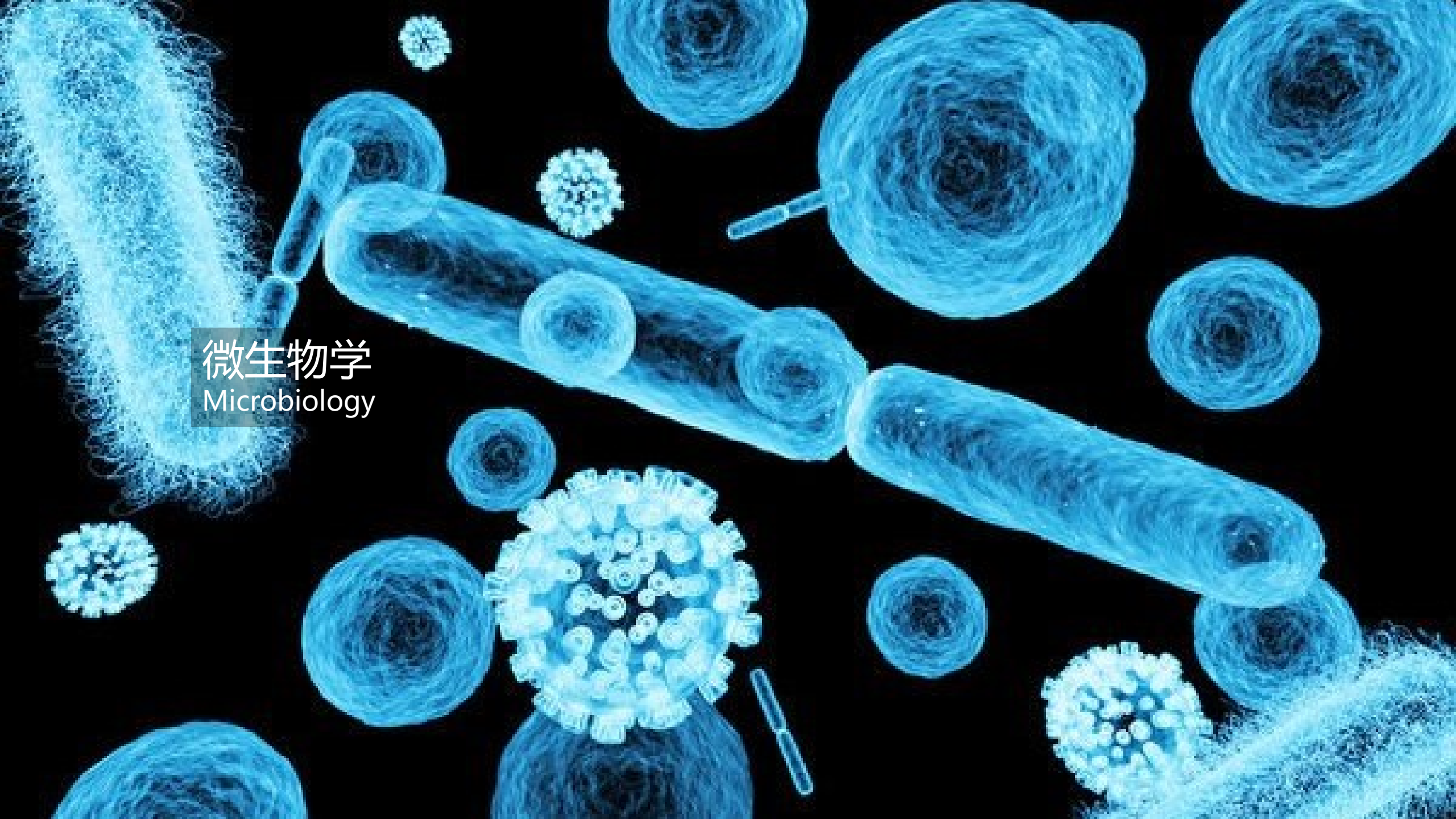





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微生物学  
Microbiology

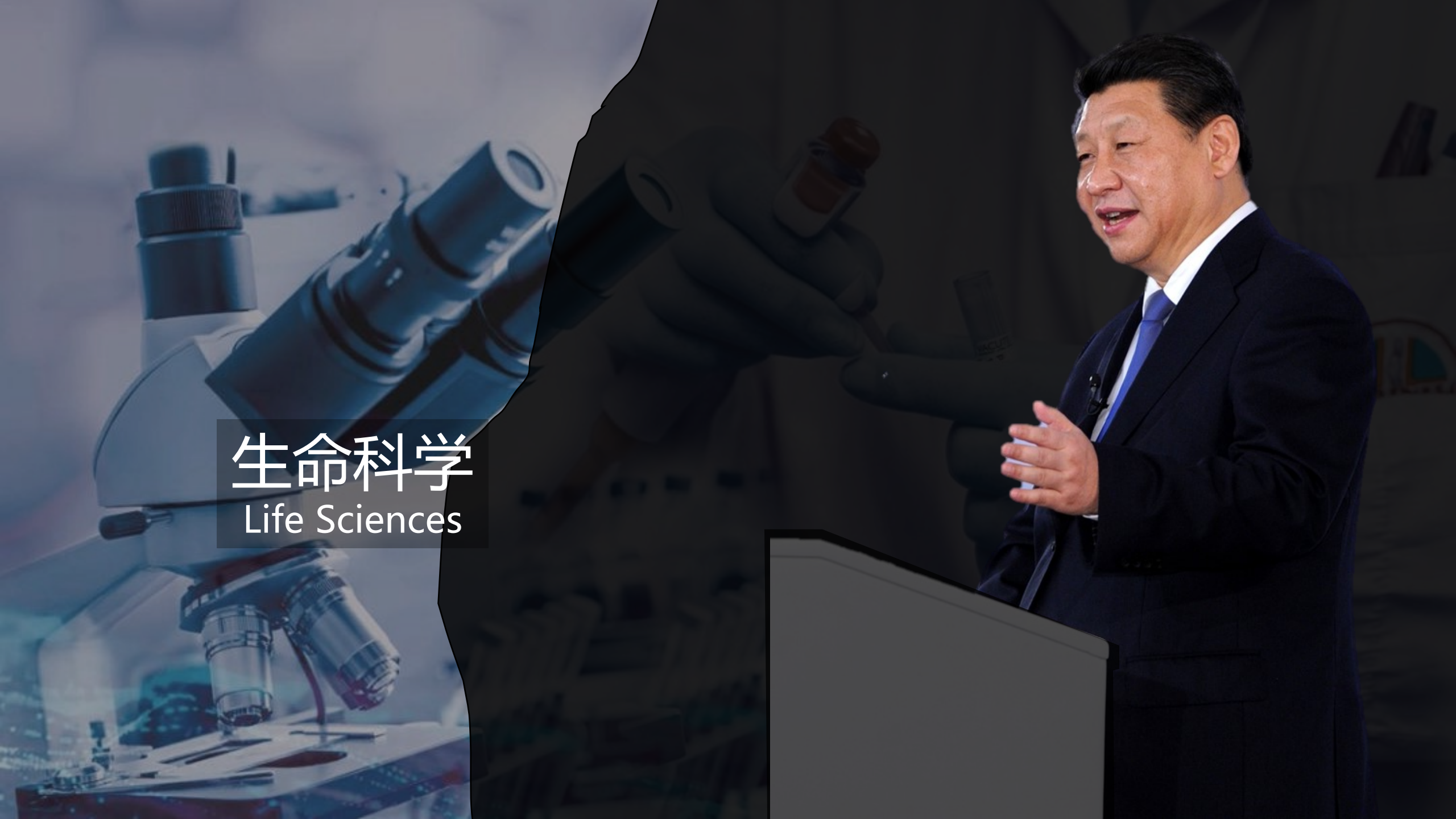




IN the year 1675. I discover'd living creatures in Rain water  
which had stood but few days in a new earthen pot, glased  
new within. This invited me to view this water with great at-  
tention, especially those little animals appearing to me ten thou-  
sands times less than those represented by Monsieur Sprenghel.

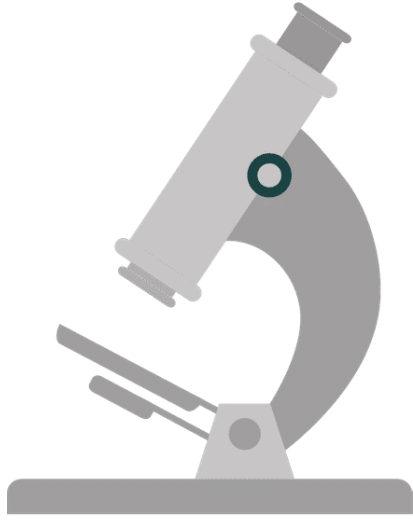
Leeuwenhoek, 1675





# 生命科学

Life Sciences



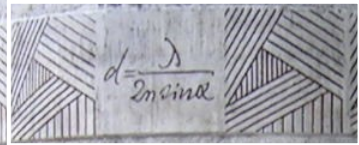
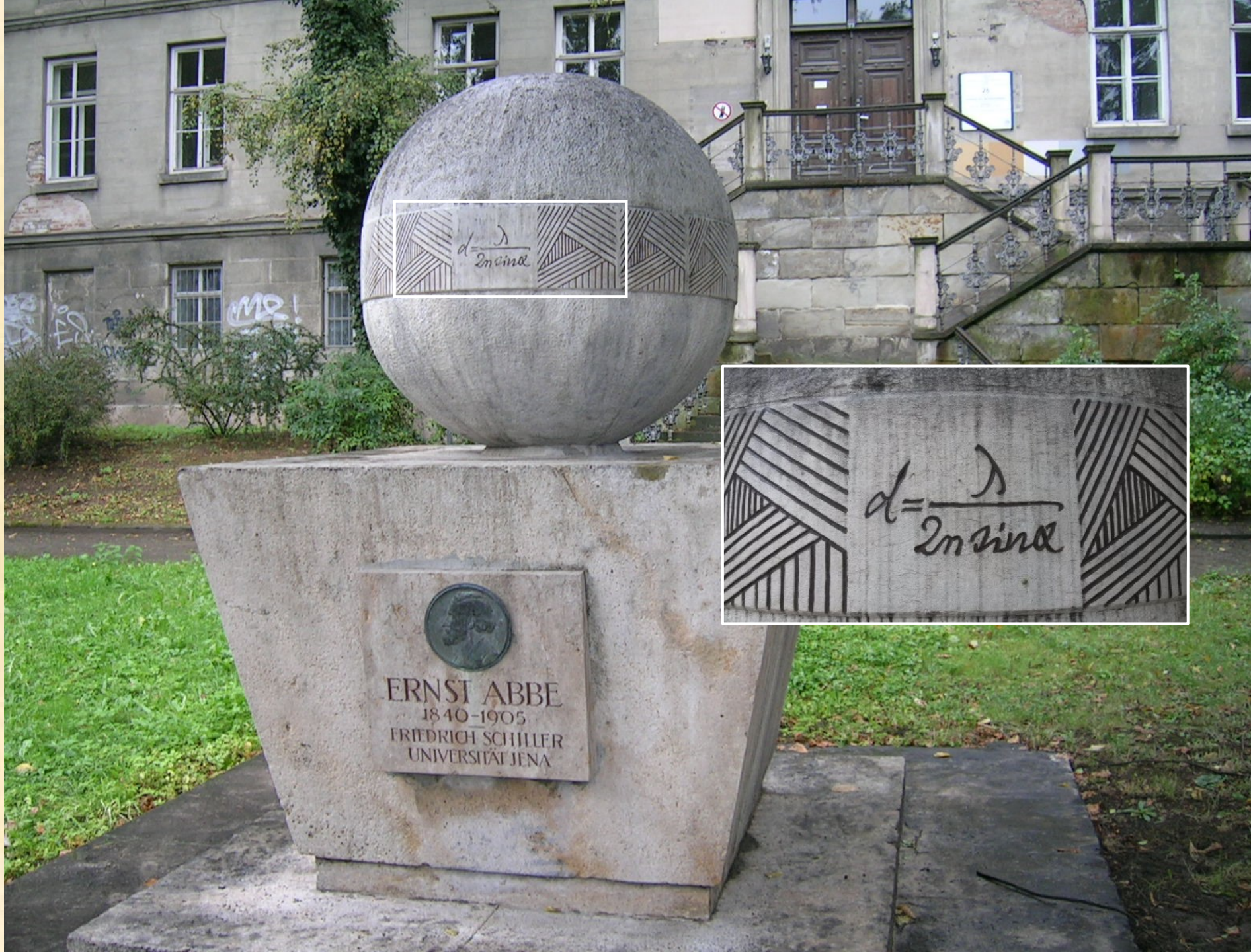
A dark, textured spherical particle is centered within a glass petri dish. The particle has a rough, porous appearance. The petri dish is set against a background of a repeating pattern of similar dark, textured spheres. The text "200nm?" is overlaid in white on the particle.

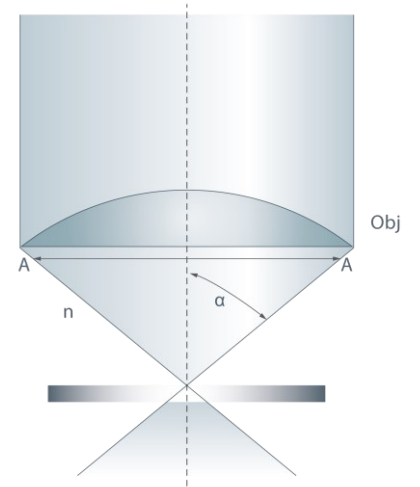
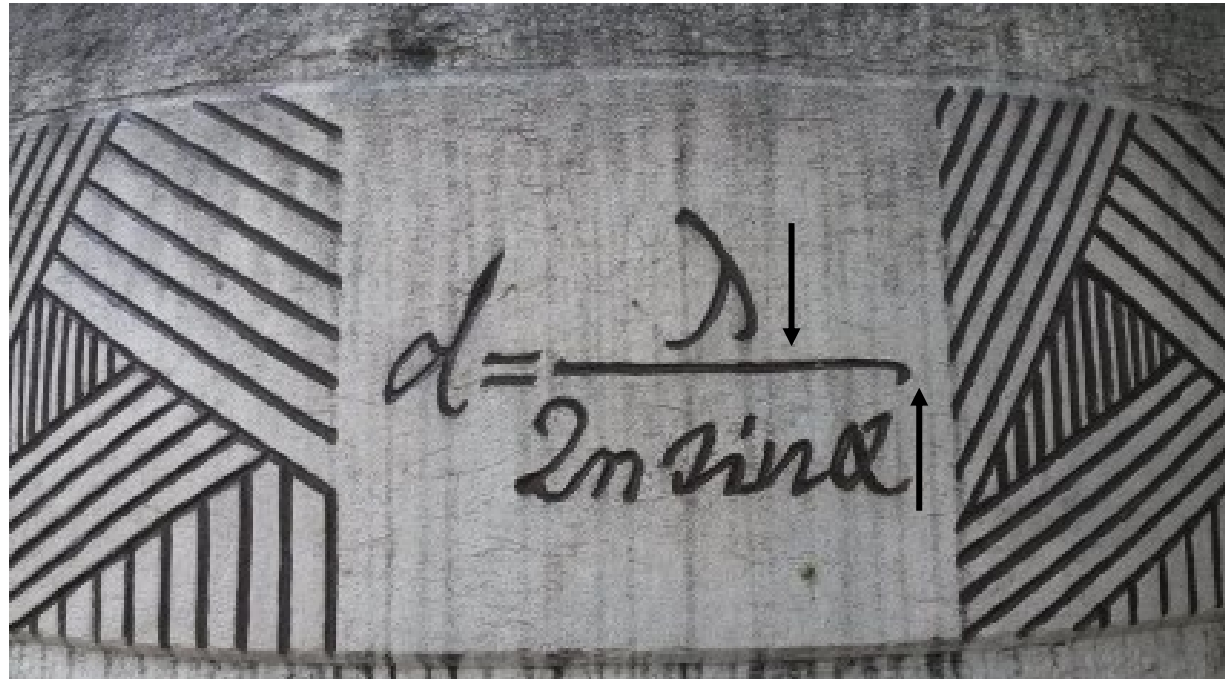
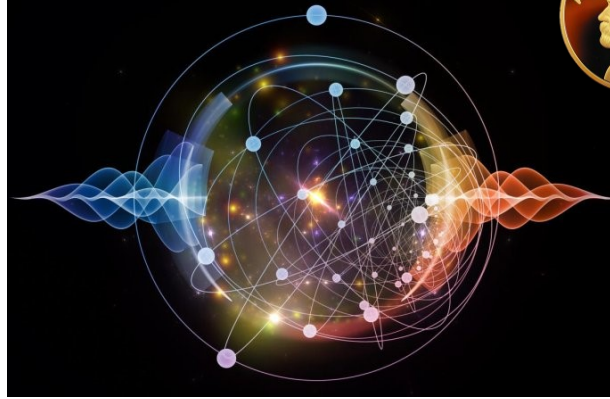
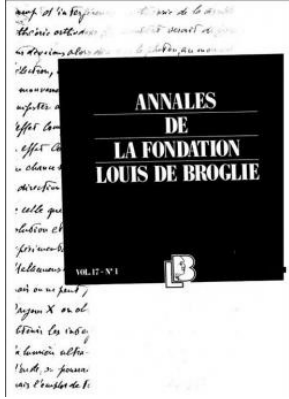
200nm?

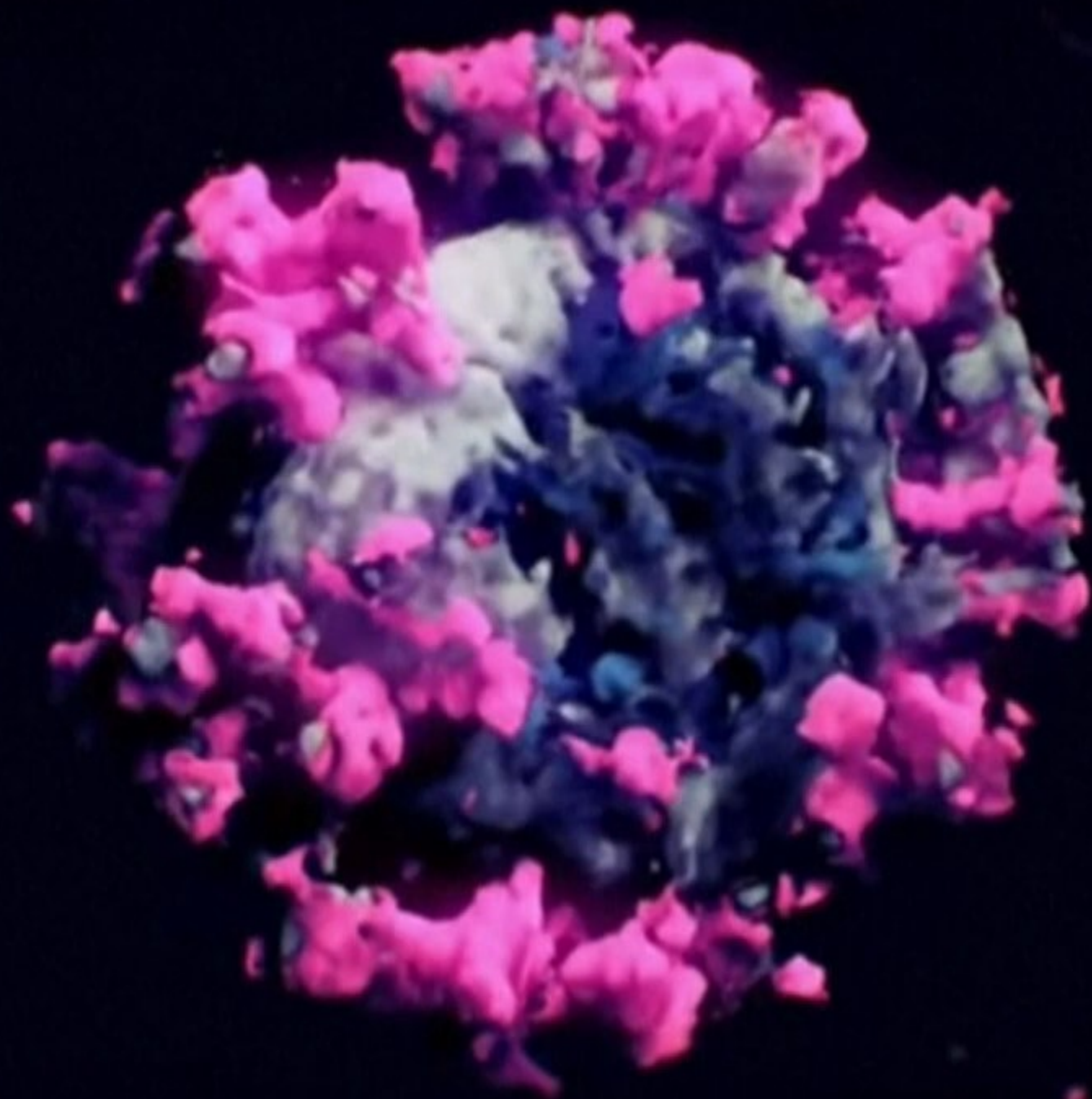
ERNST ABBE.



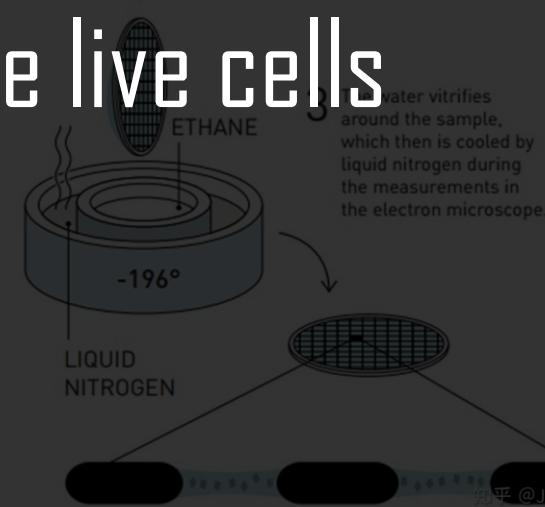
*Dr. Ernst Abbe*







## DUBOCHET'S VITRIFICATION METHOD



无法对**活细胞**进行成像

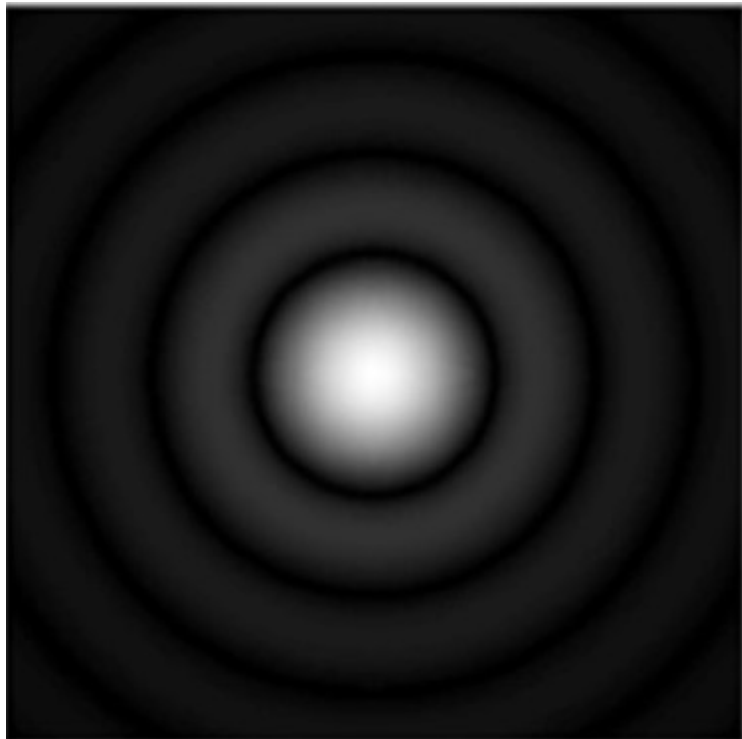
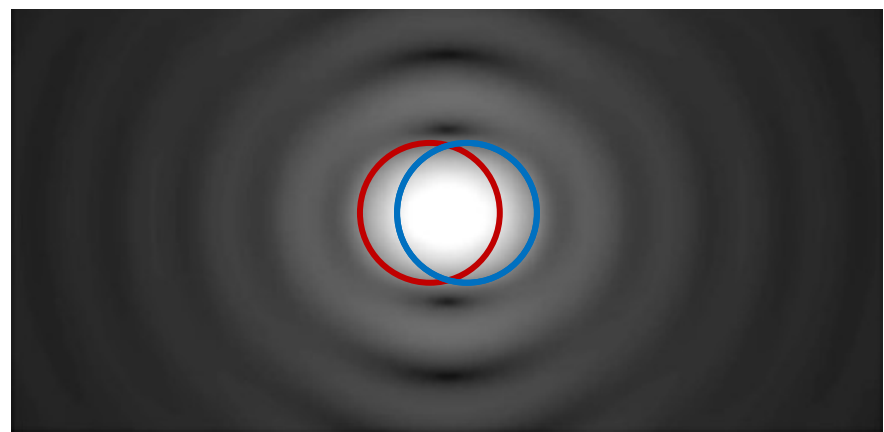
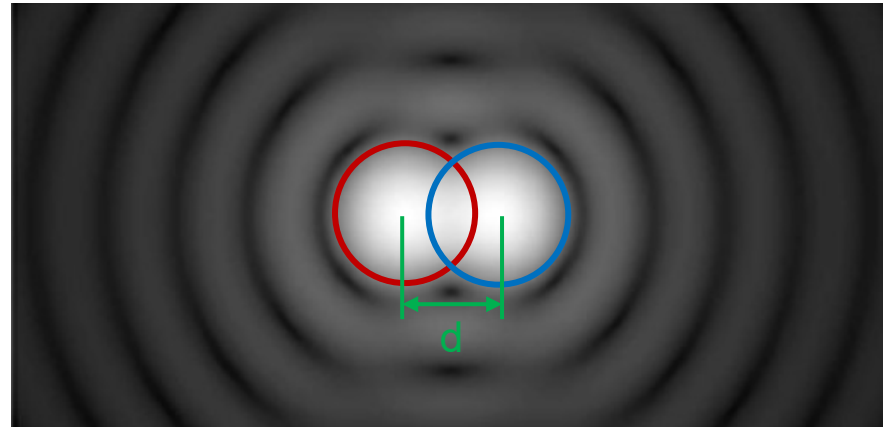
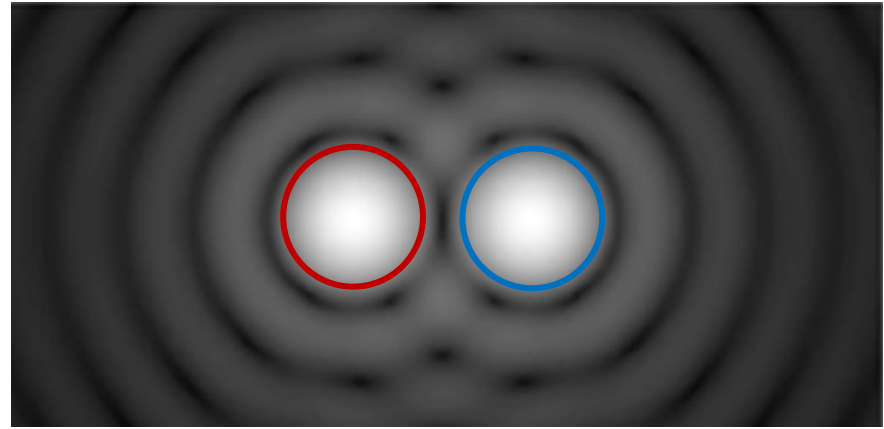
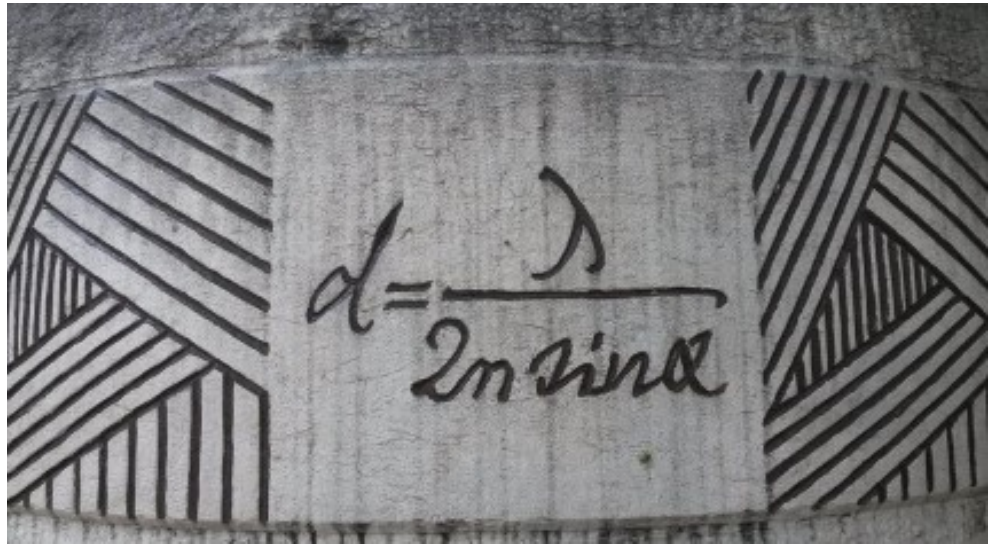
Inability to image live cells

# 光学显微镜

Optical microscopy

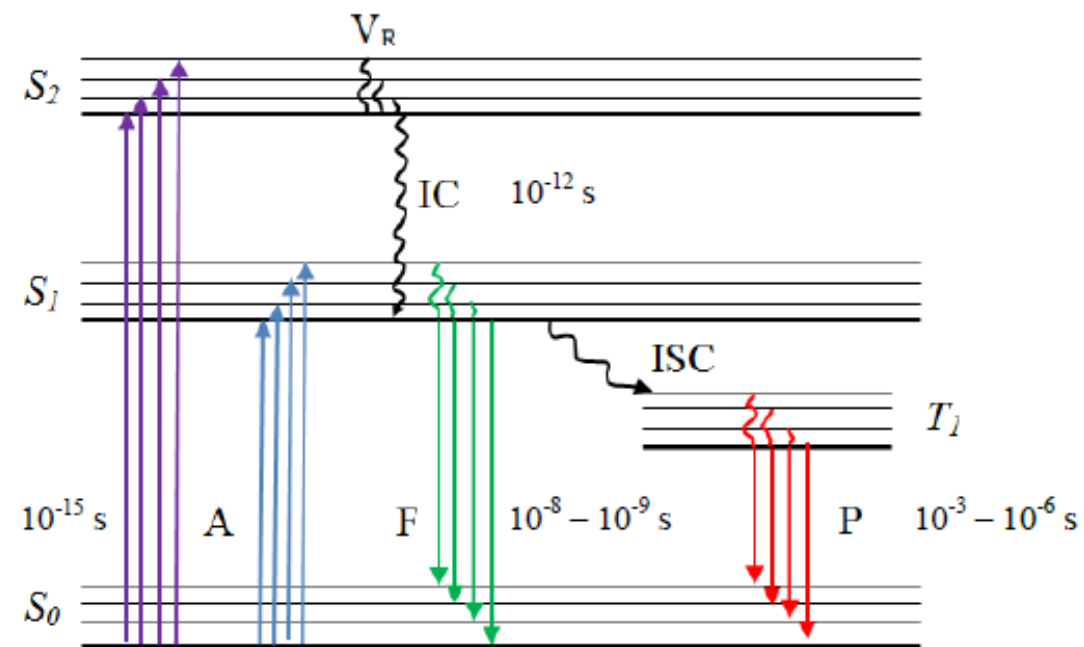
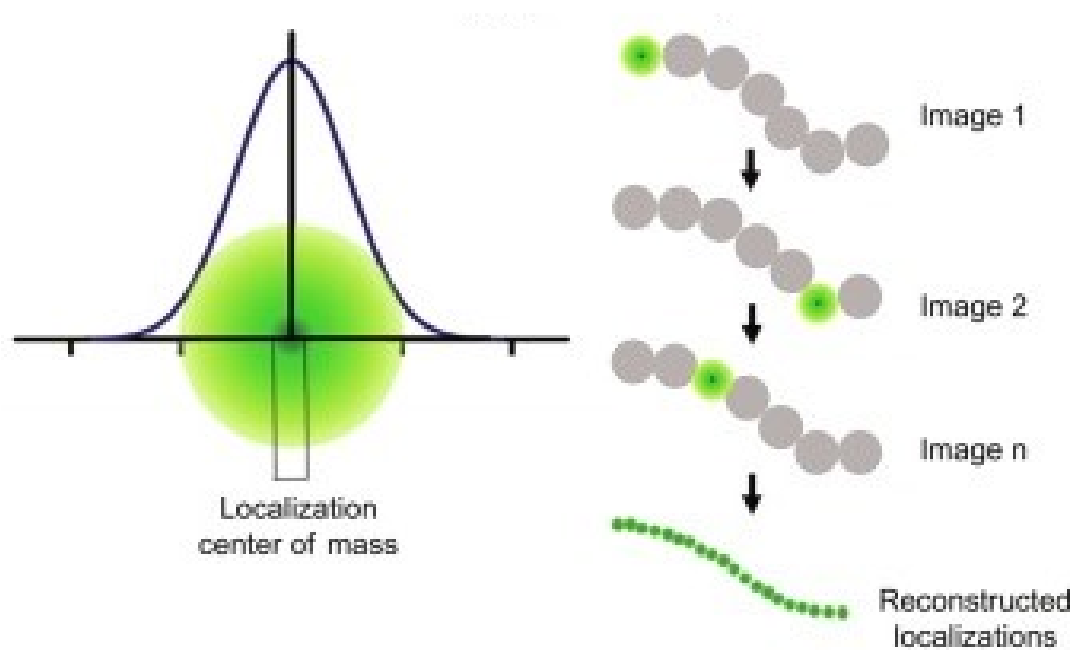


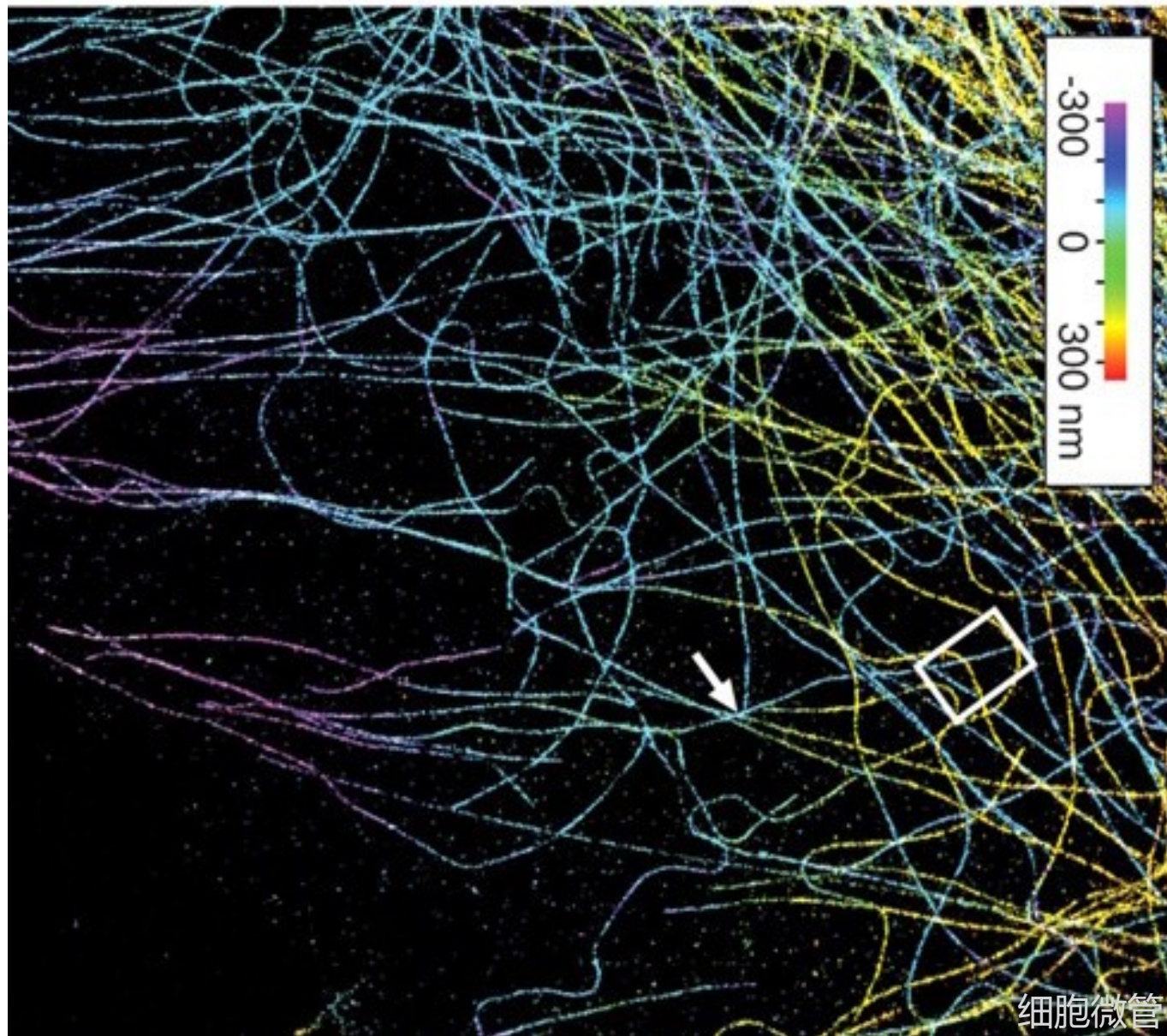
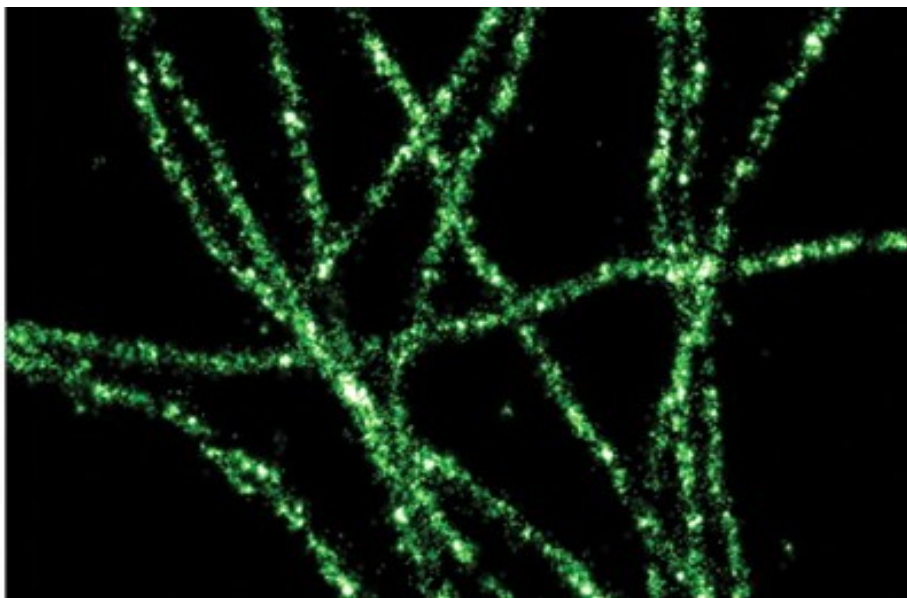
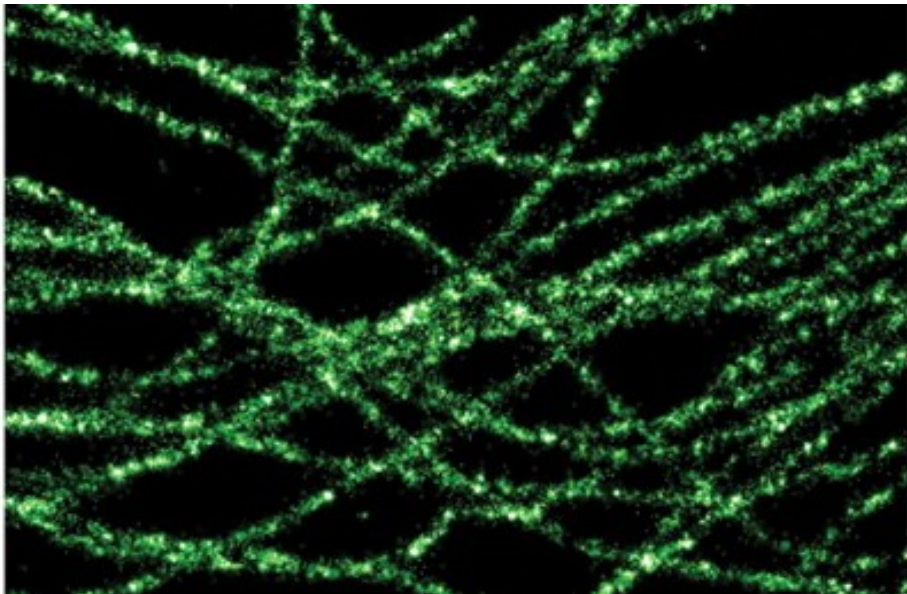




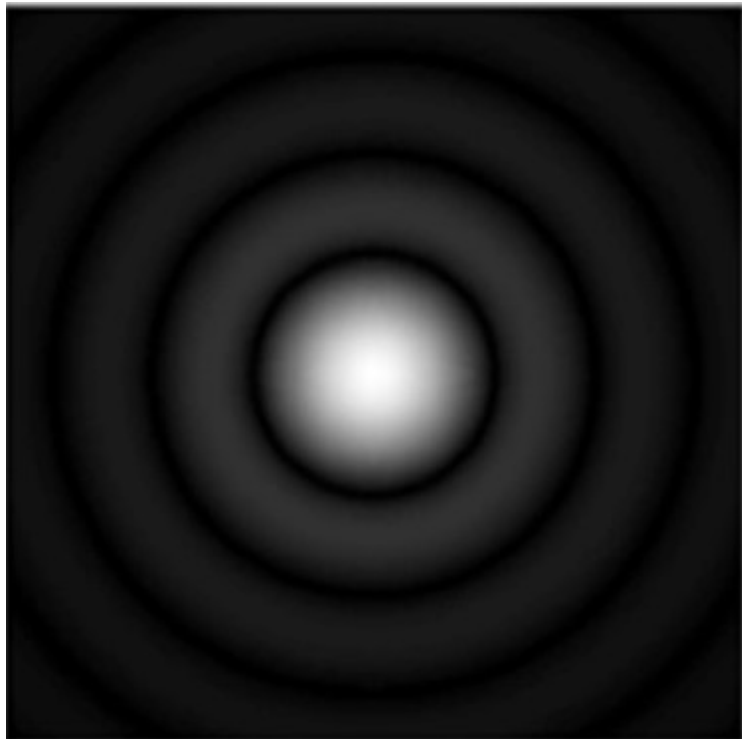
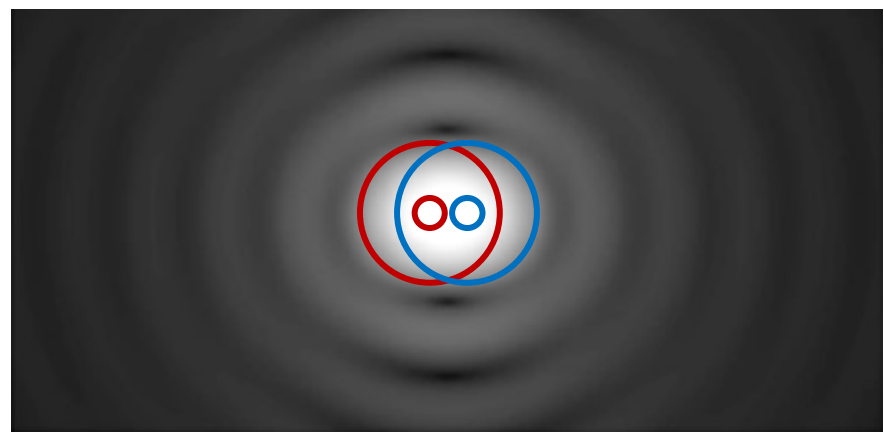
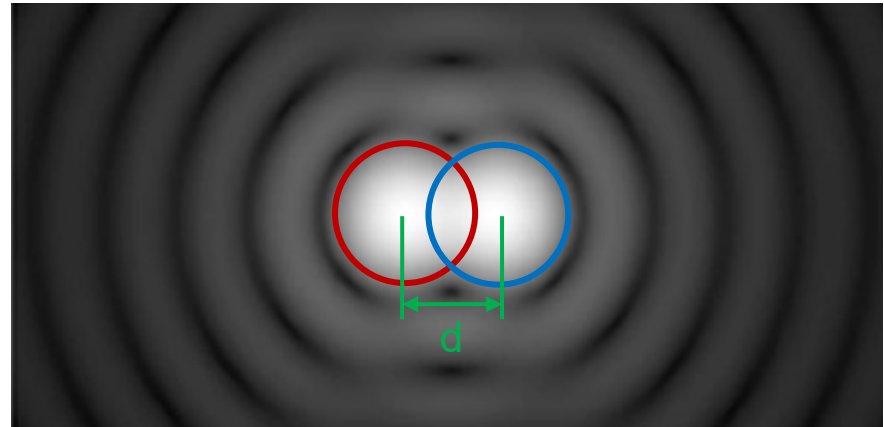
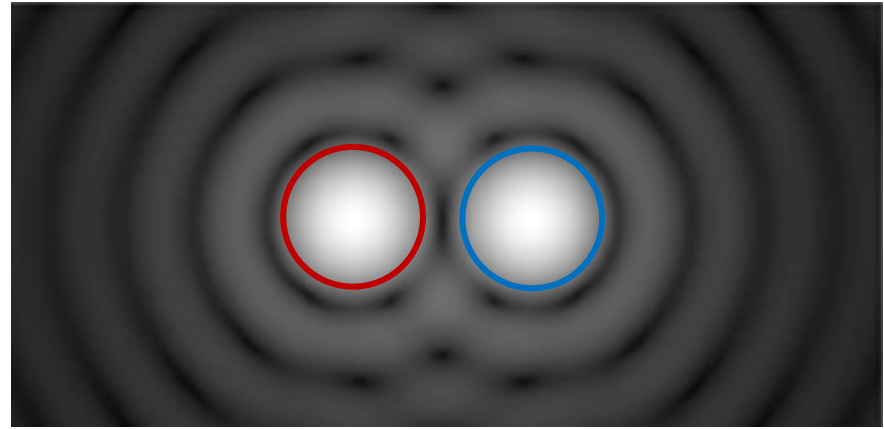
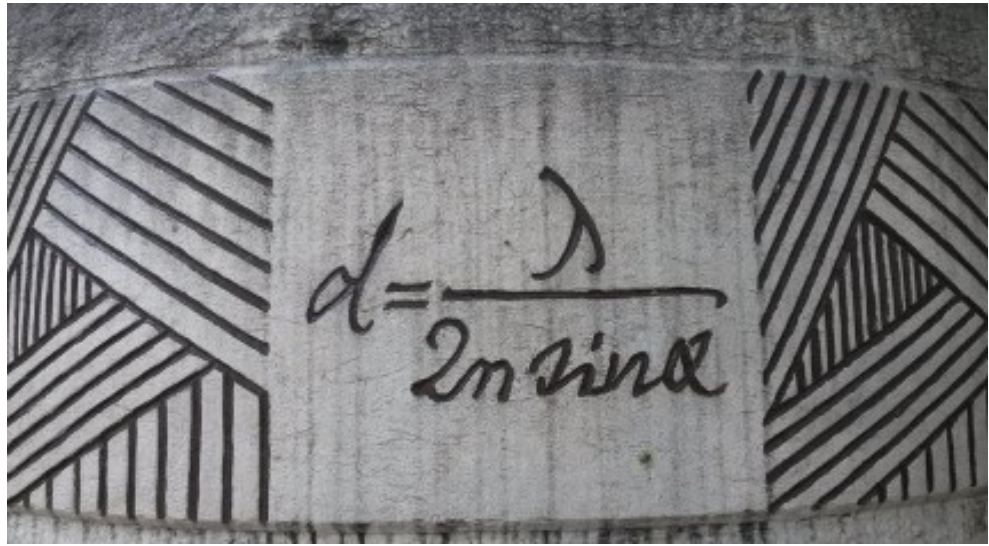
PALM (光活化定位显微术)  
 STORM (随机光学重构显微术)

荧光成像

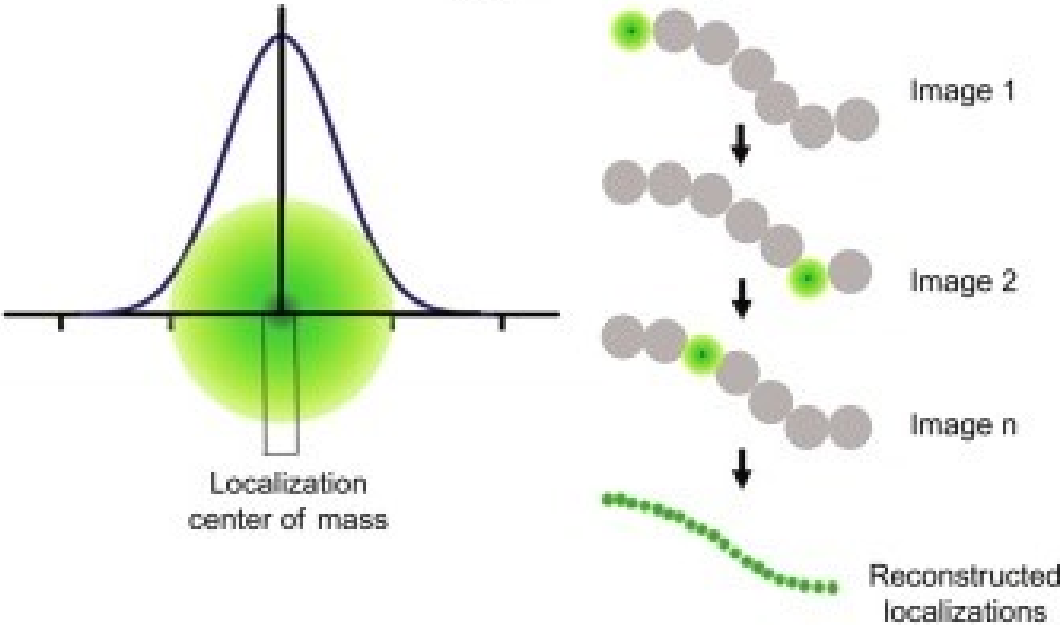




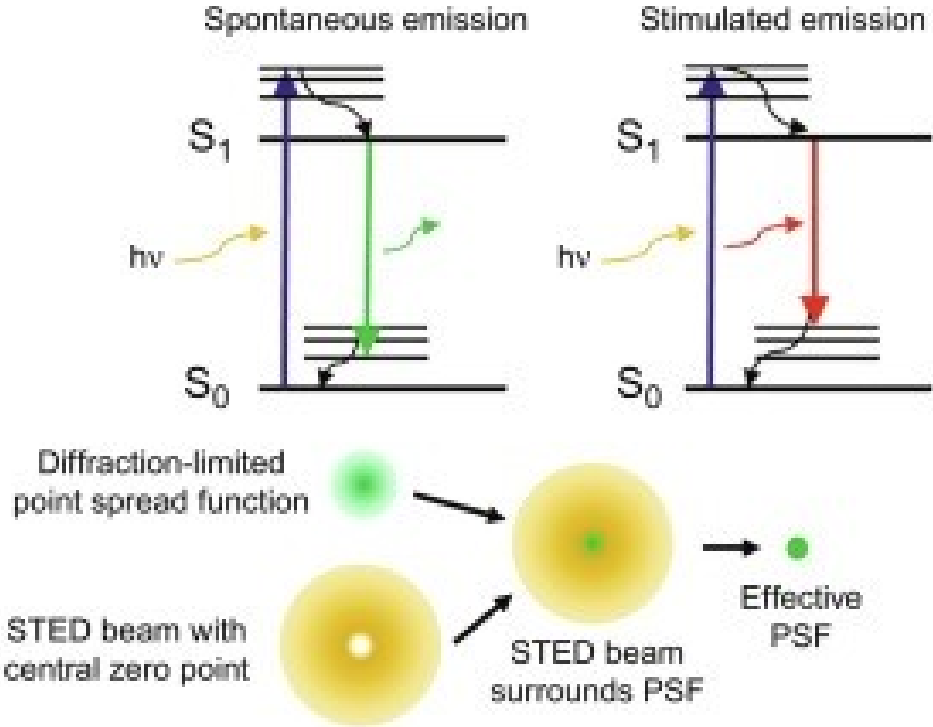
细胞微管

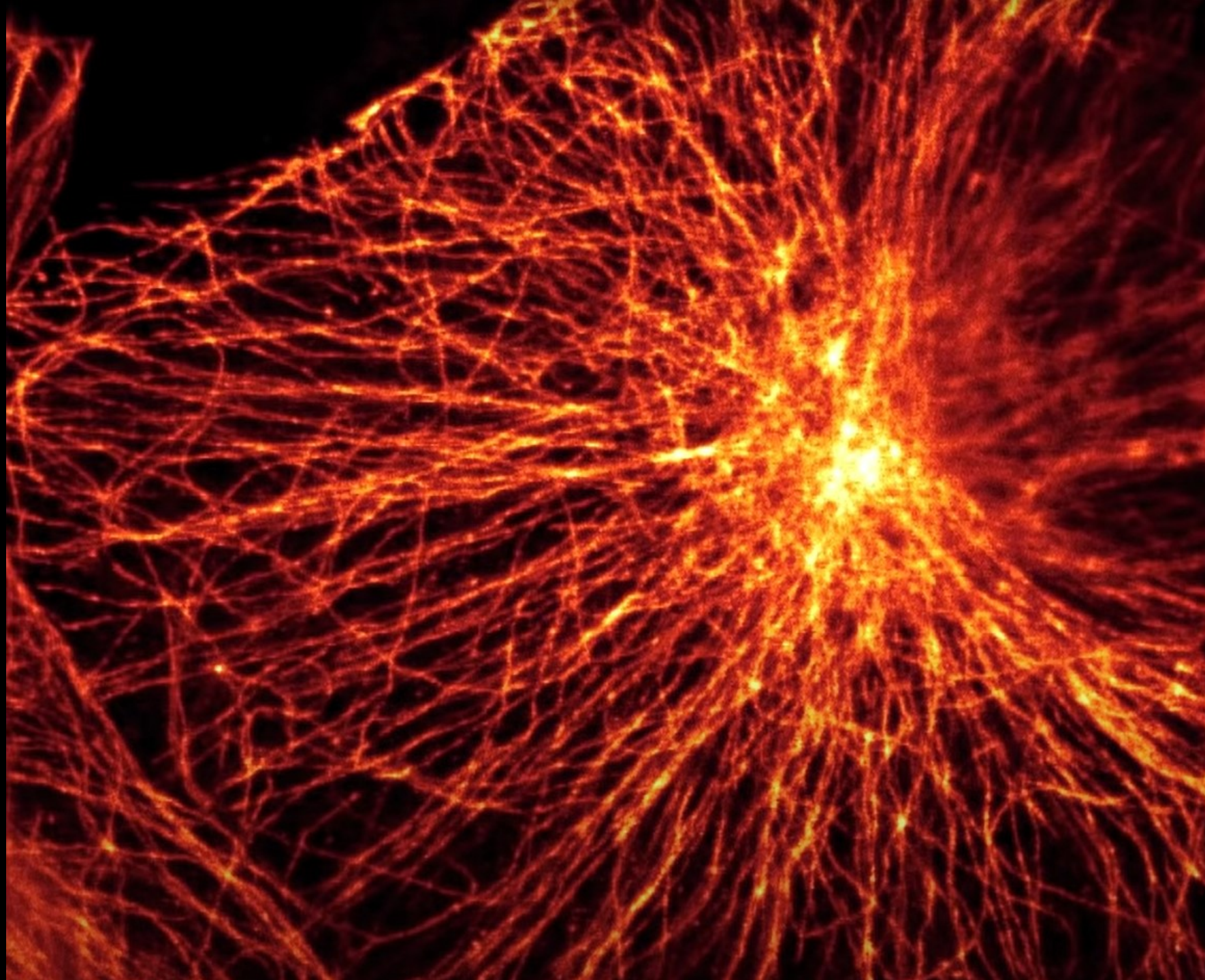


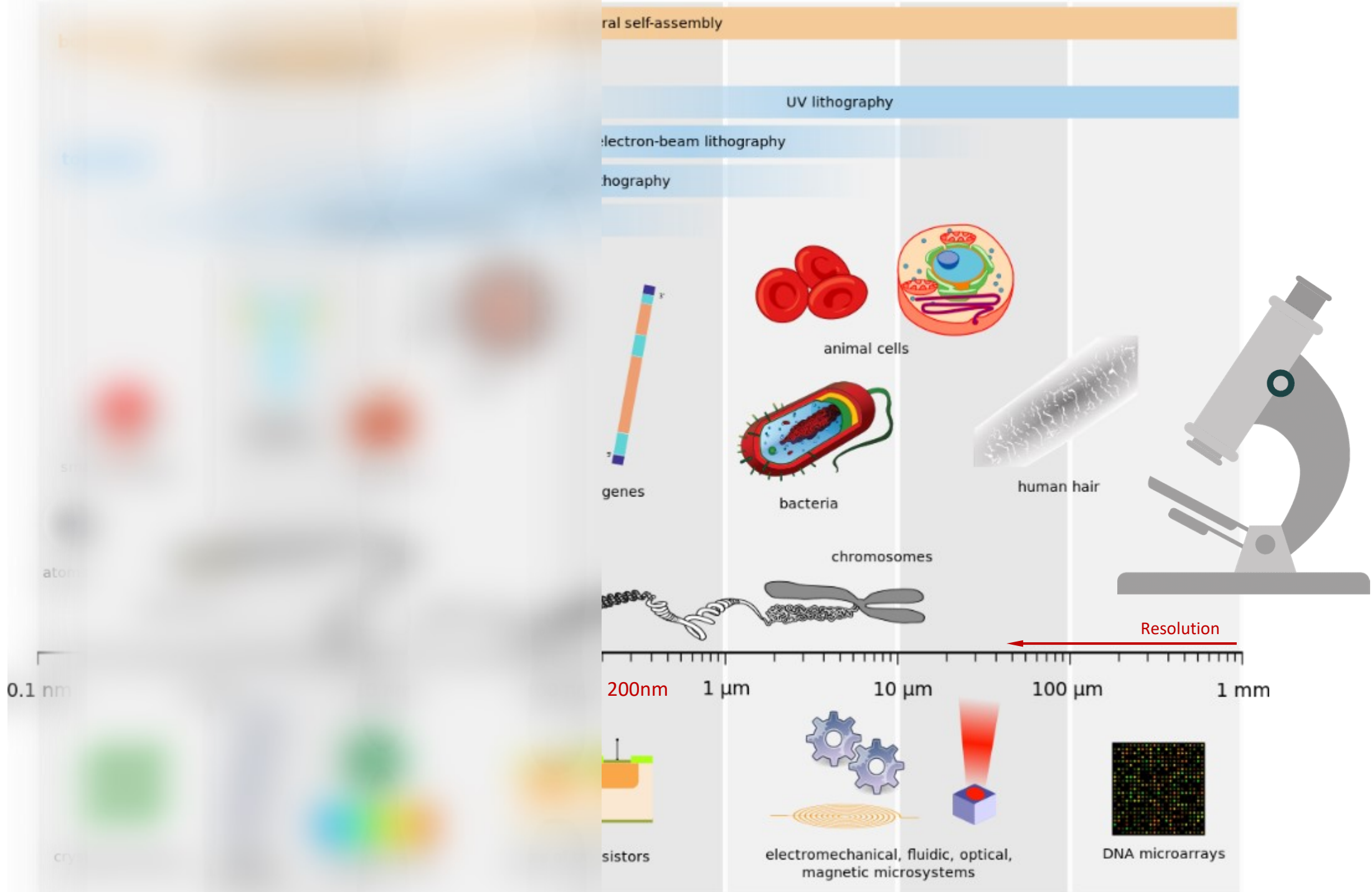
PALM (光活化定位显微术)  
STORM (随机光学重构显微术)



STED (受激发射损耗显微术)









# 2014年·诺贝尔奖

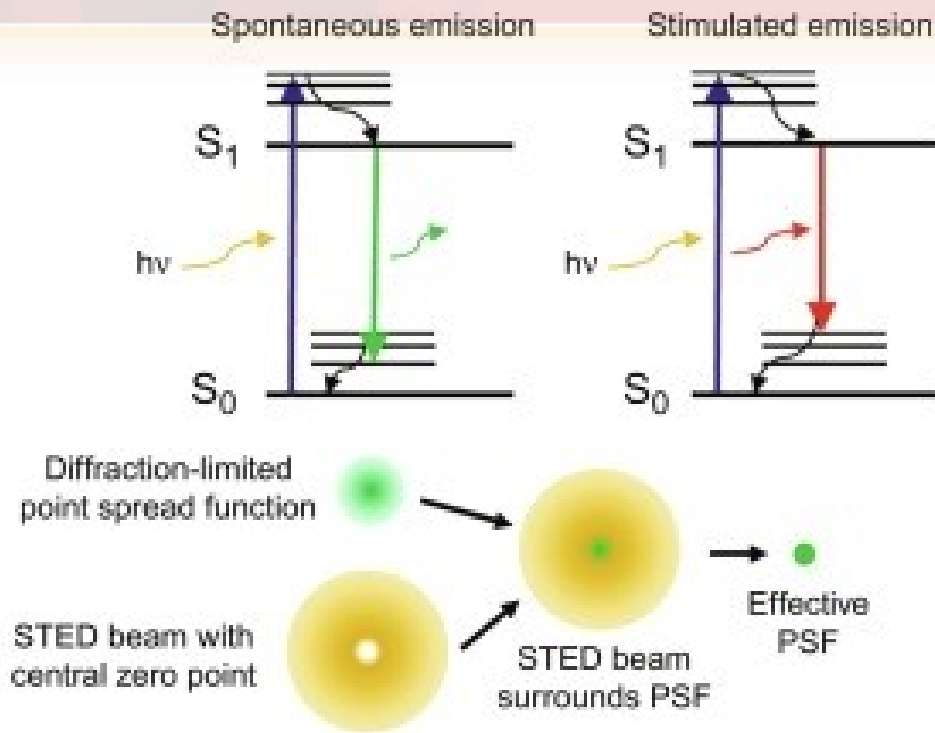
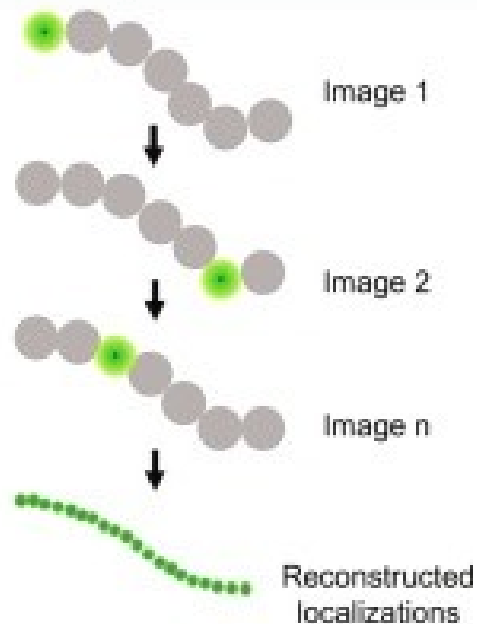
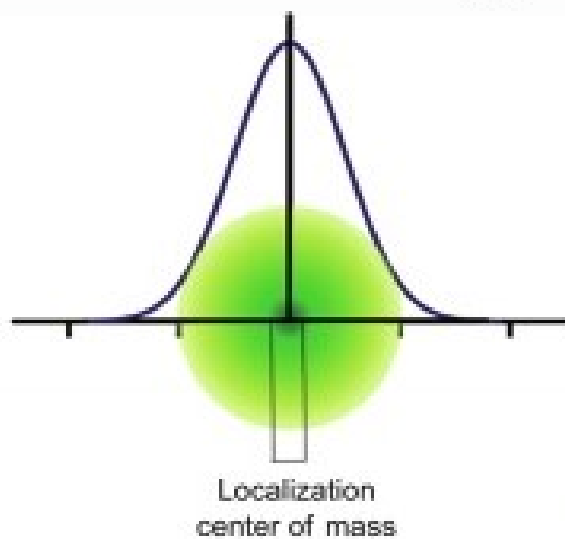


PALM (光活化定位显微术)

STORM (随机光学重构显微术)



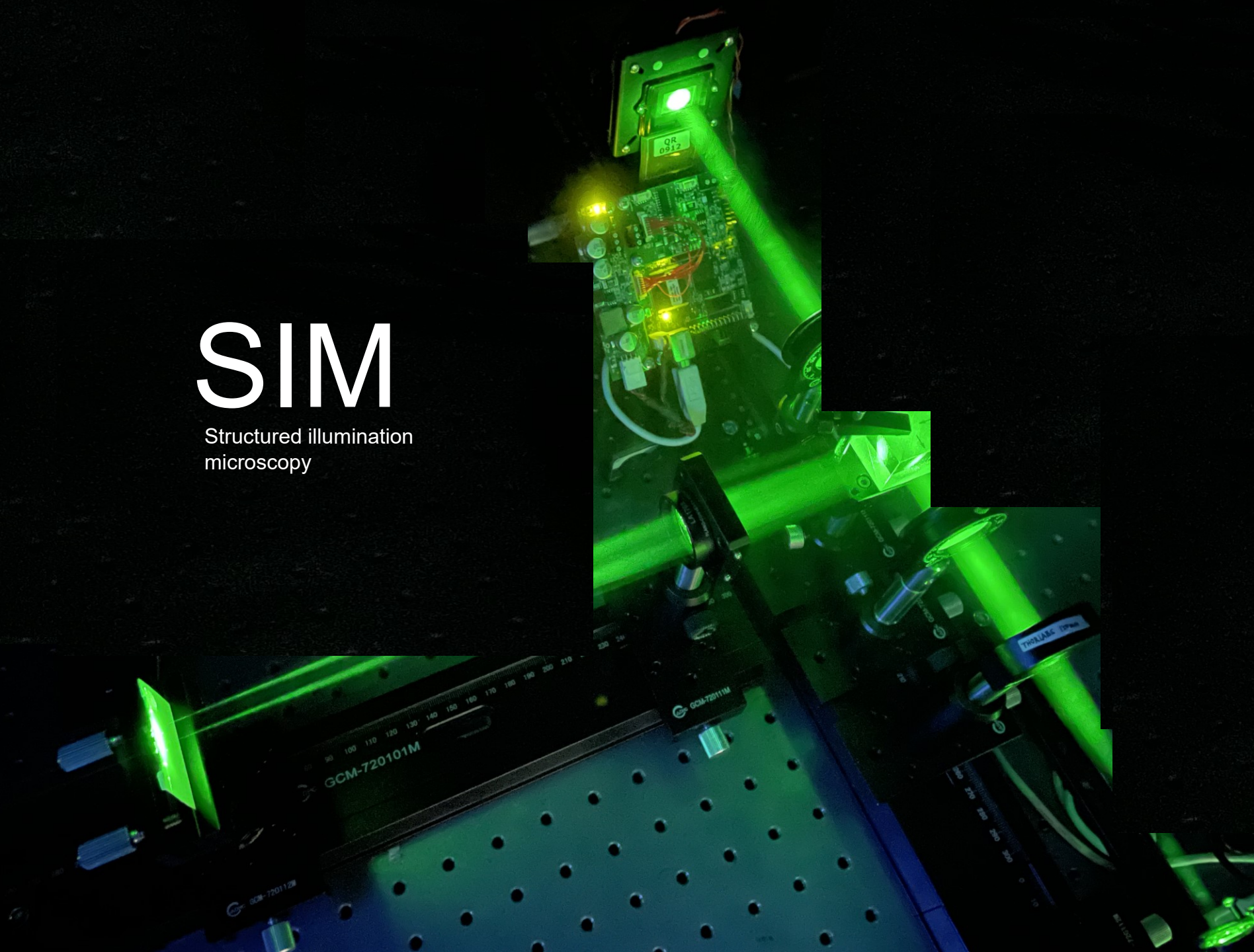
STED (受激发射损耗显微术)



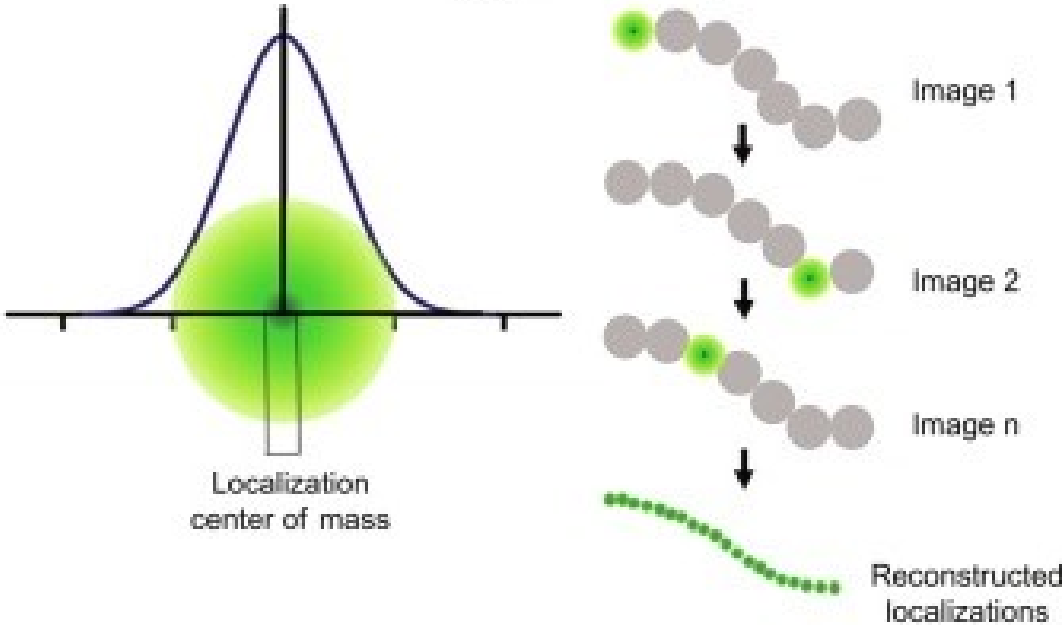


# SIM

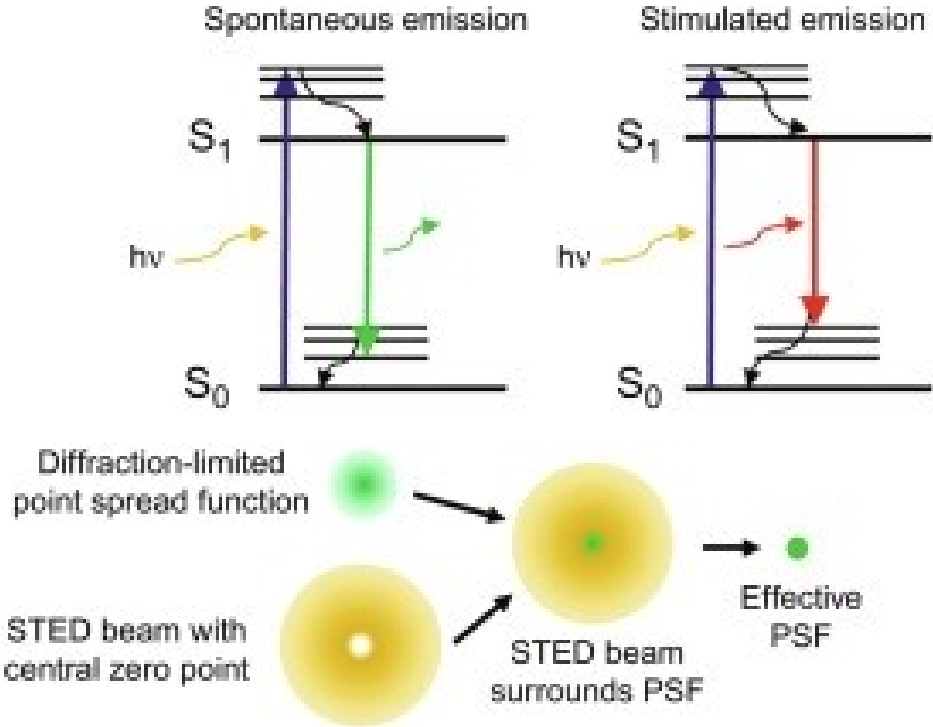
Structured illumination  
microscopy



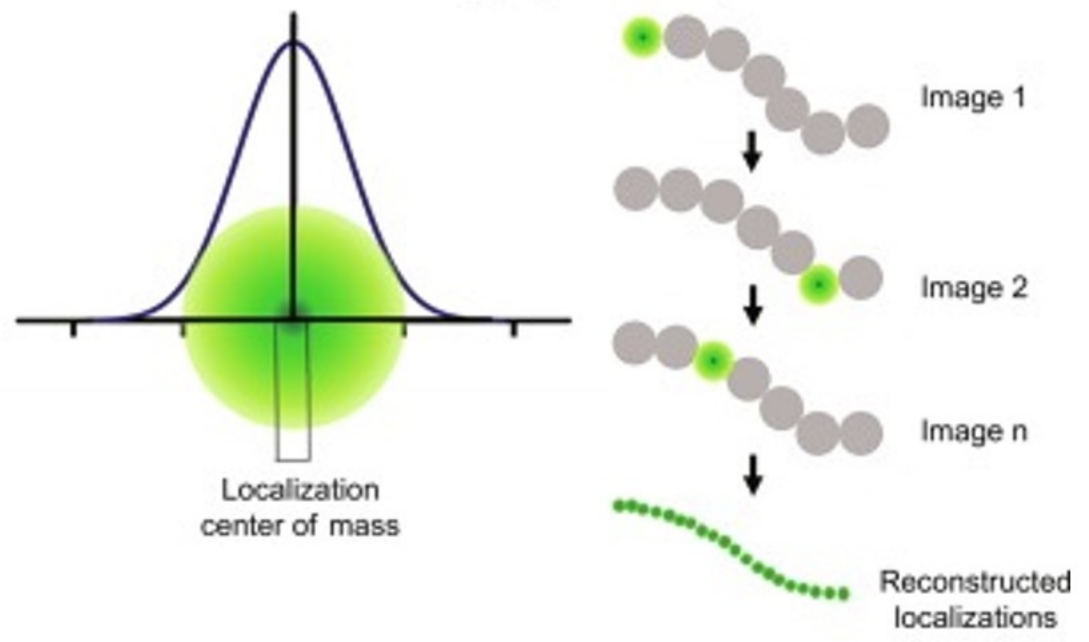
PALM (光活化定位显微术)  
STORM (随机光学重构显微术)



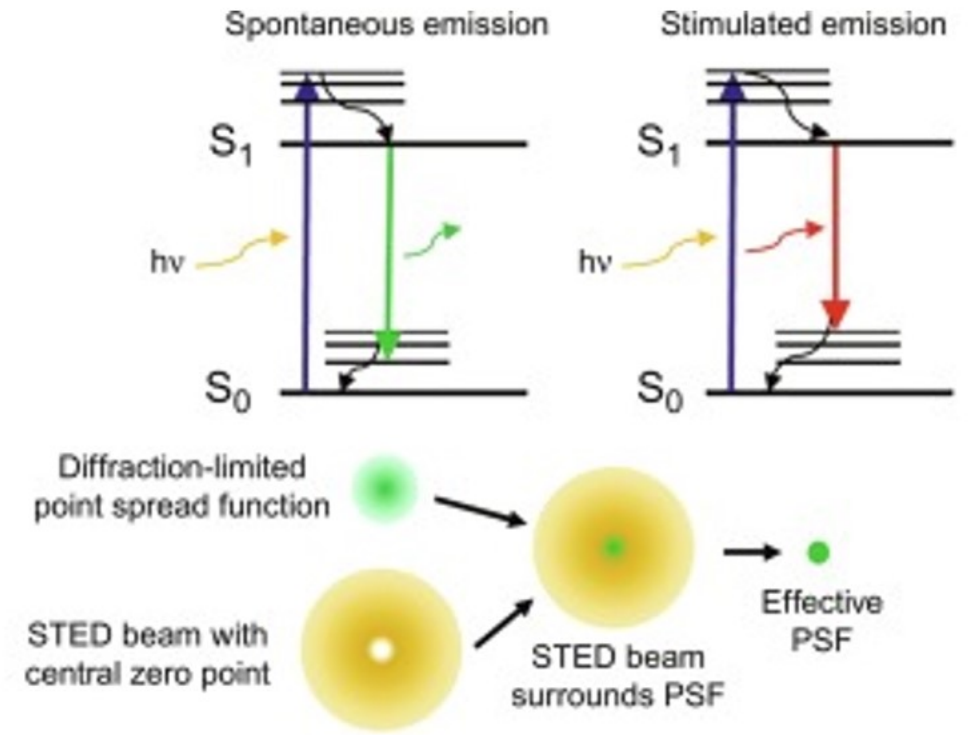
STED (受激发射损耗显微术)



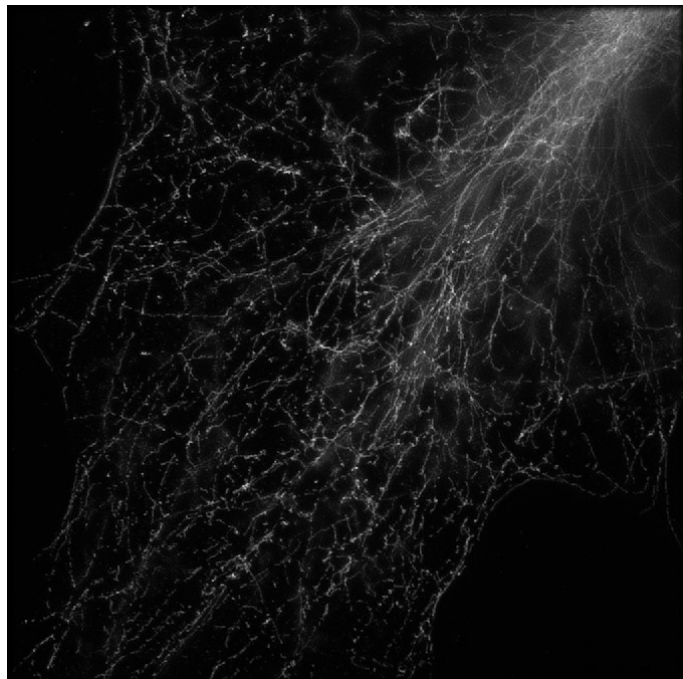
PALM (光活化定位显微术)  
STORM (随机光学重构显微术)



STED (受激发射损耗显微术)



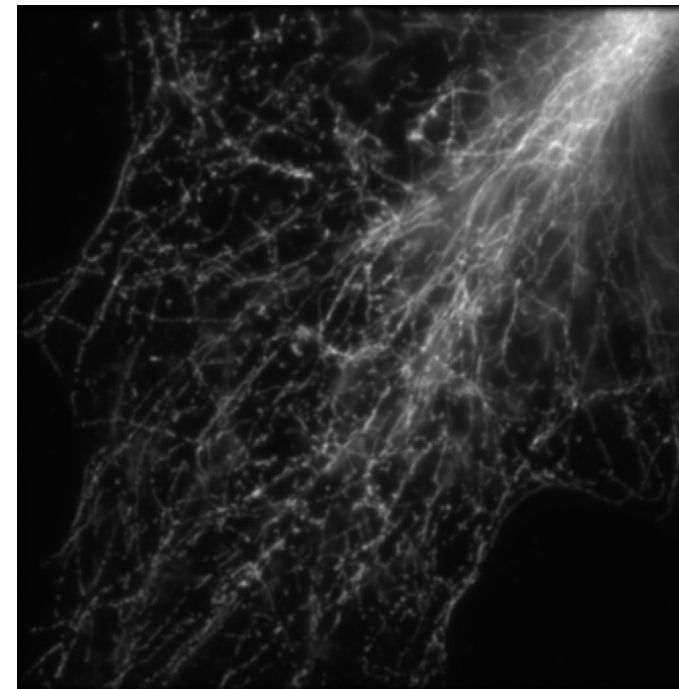
$S(r)$



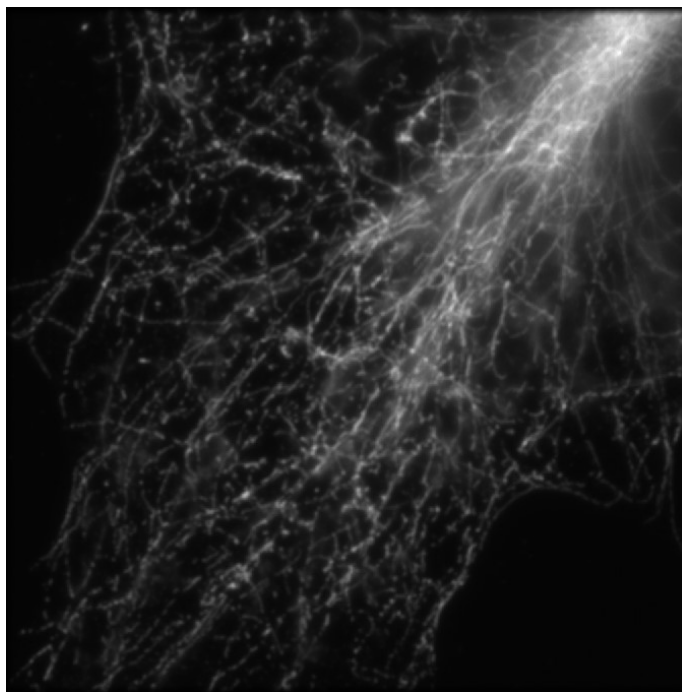
$PSF(r)$



$D(r)=S(r)\otimes PSF(r)$

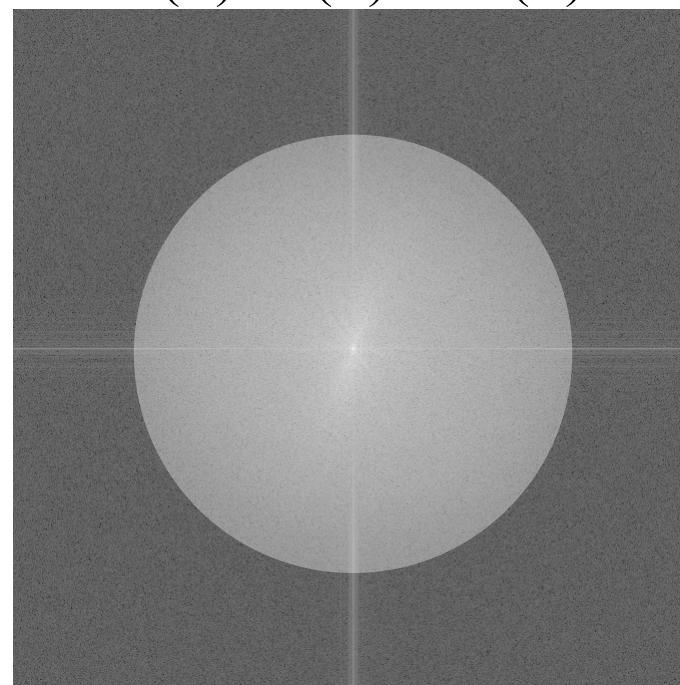


$$D(r) = S(r) \otimes \text{PSF}(r)$$

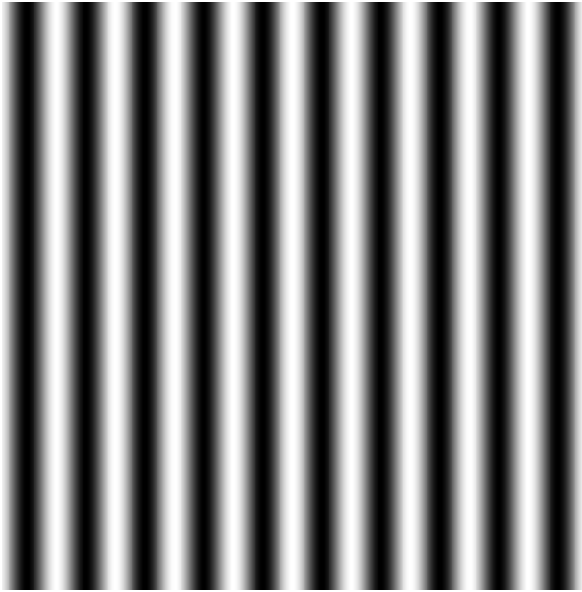


FFT  
→

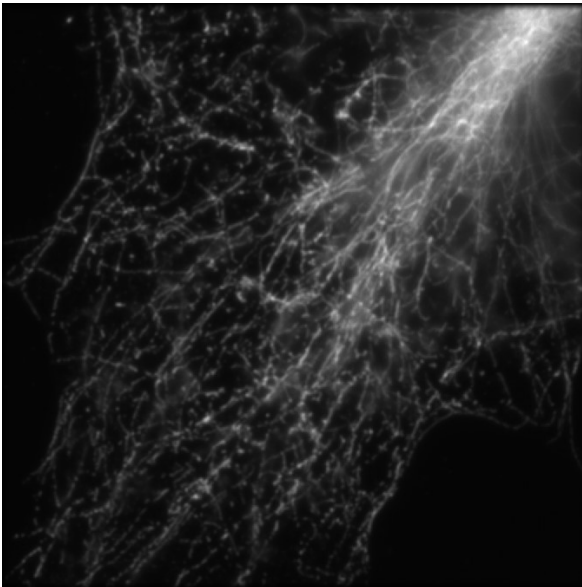
$$\tilde{D}(k) = \tilde{S}(k) \text{OTF}(k)$$



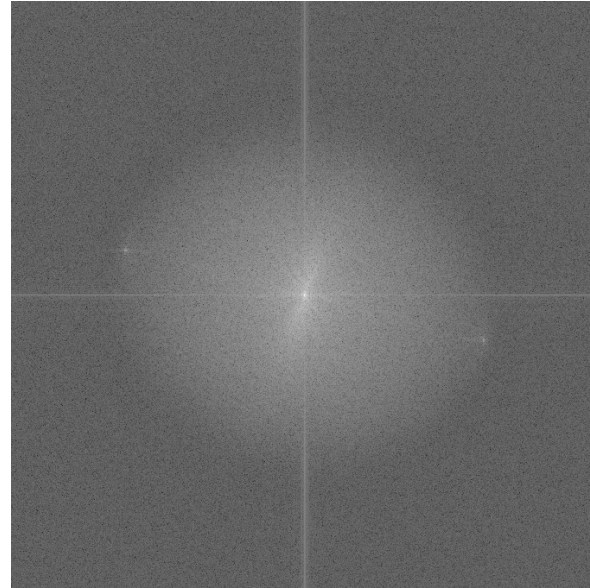
$$1 + m \cos(2\pi k_{ex} r + \phi)$$



$$D(r) = S(r) \otimes PSF(r)$$



FFT  
→

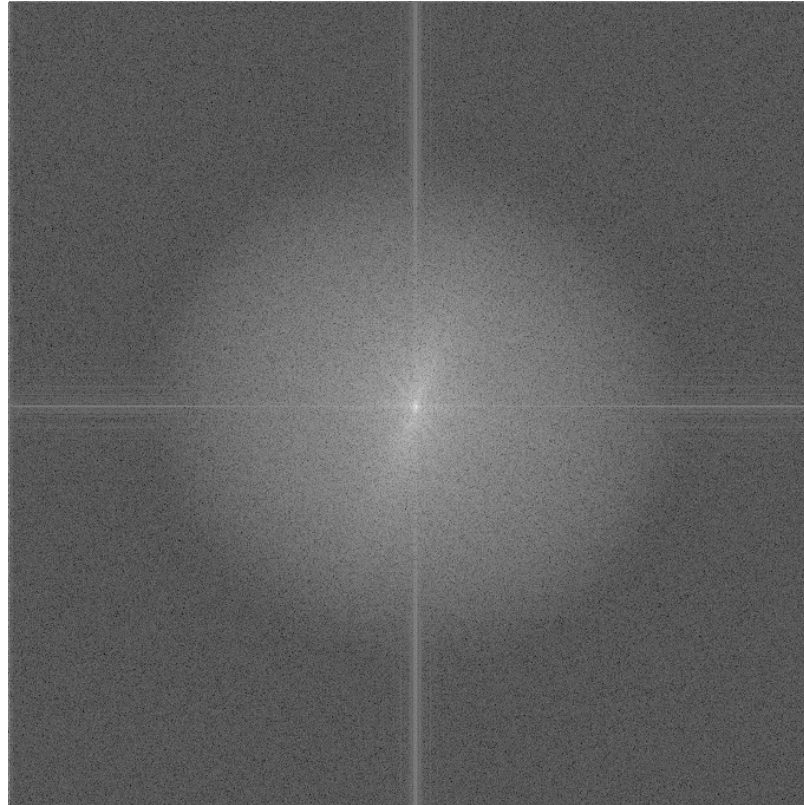


$$\tilde{D}(k) = \left[ \frac{m}{2} \tilde{S}_{+1}(k - k_{ex}) e^{j\phi} + \tilde{S}_0(k) + \frac{m}{2} \tilde{S}_{-1}(k + k_{ex}) e^{-j\phi} \right] OTF(k)$$

$$OTF(k)\tilde{S}_{-1}(k+k_{ex})$$

$$OTF(k)\tilde{S}_0(k)$$

$$OTF(k)\tilde{S}_{+1}(k-k_{ex})$$



$$OTF(k)\tilde{S}_{-1}(k+k_{ex})$$

$$OTF(k)\tilde{S}_0(k)$$

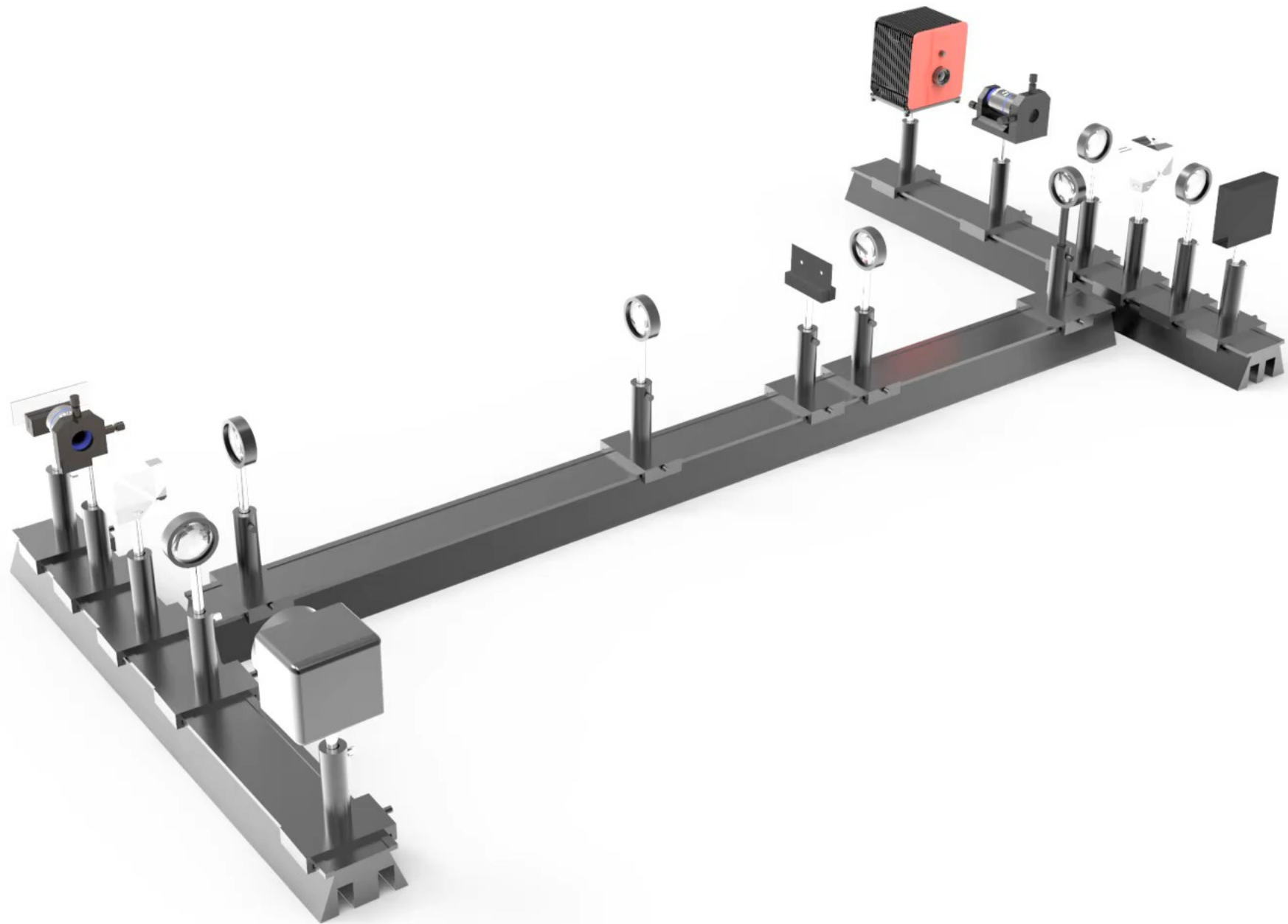
$$OTF(k)\tilde{S}_{+1}(k-k_{ex})$$

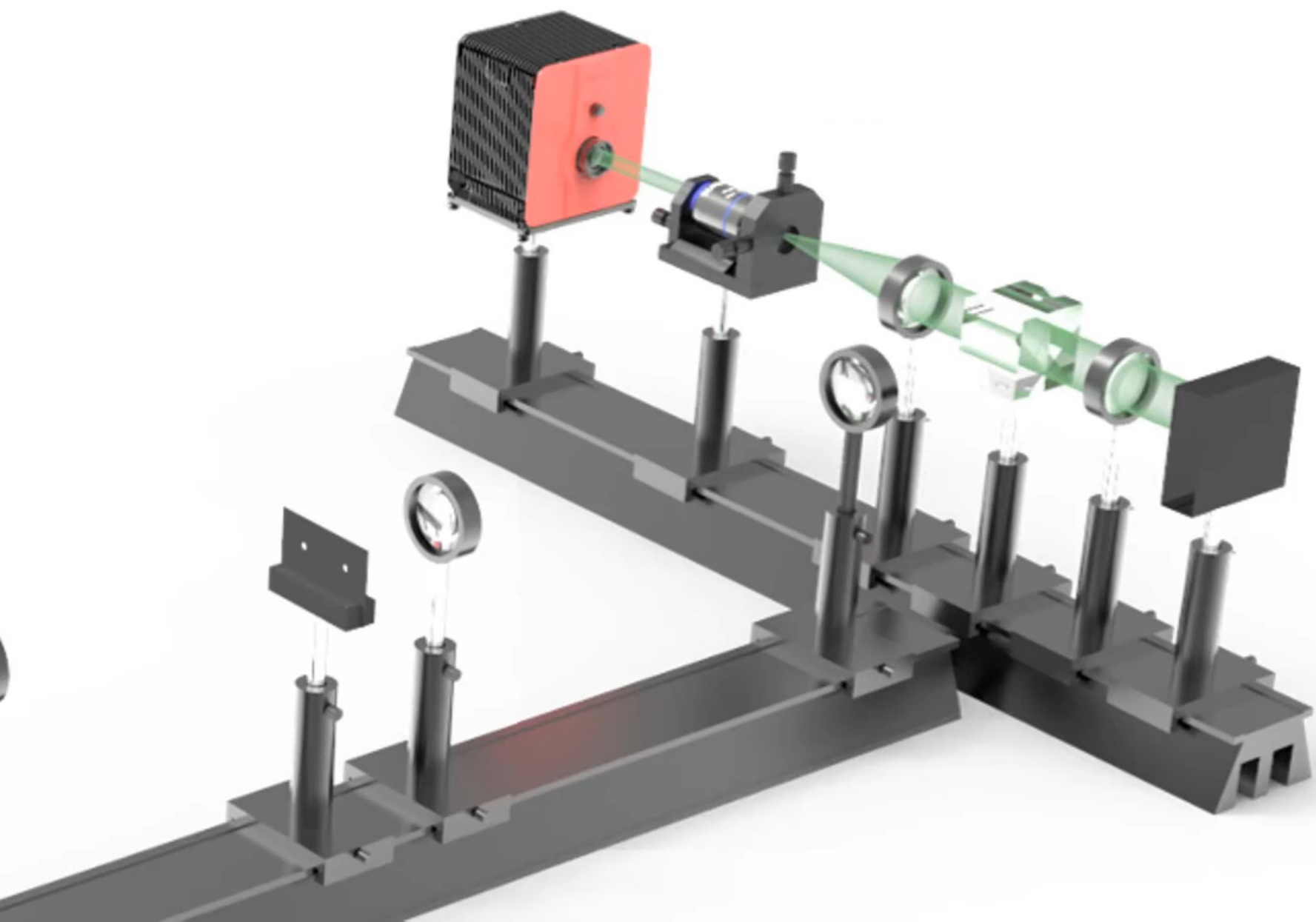
$$OTF(k+k_{ex})\tilde{S}_{+1}(k)$$

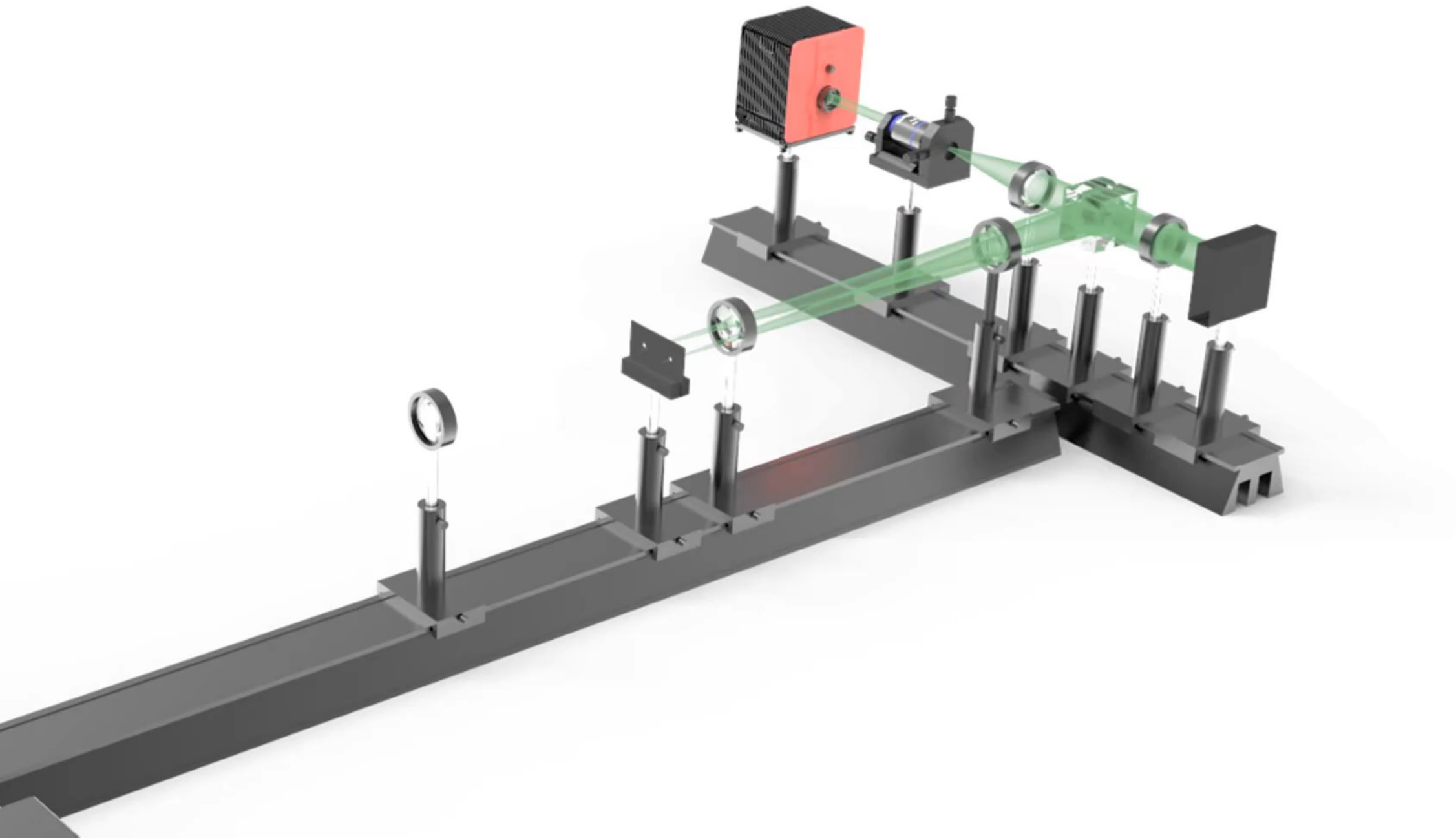
$$OTF(k)\tilde{S}_0(k)$$

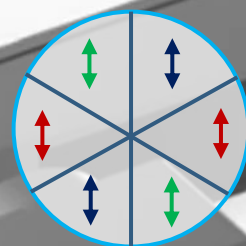
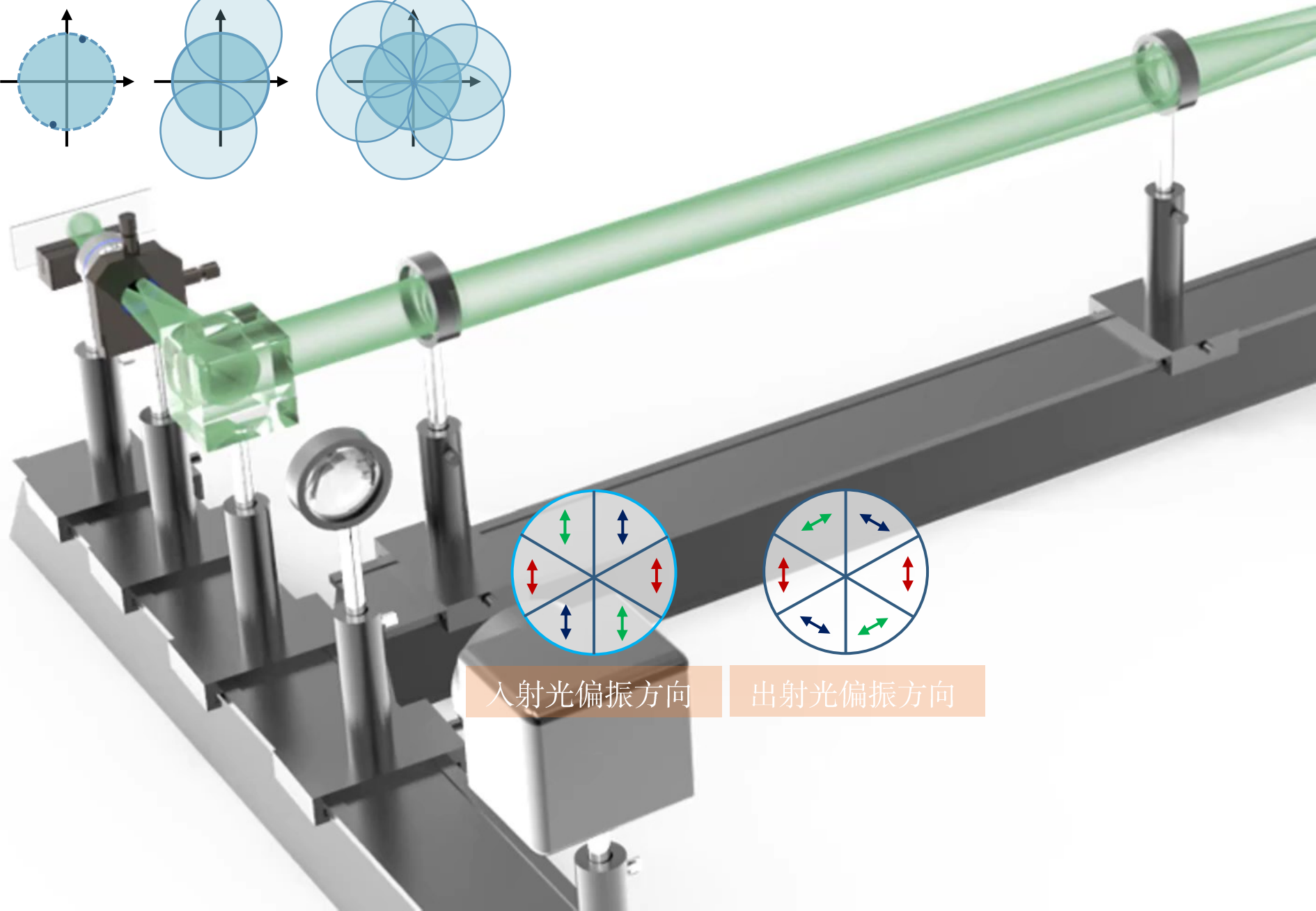
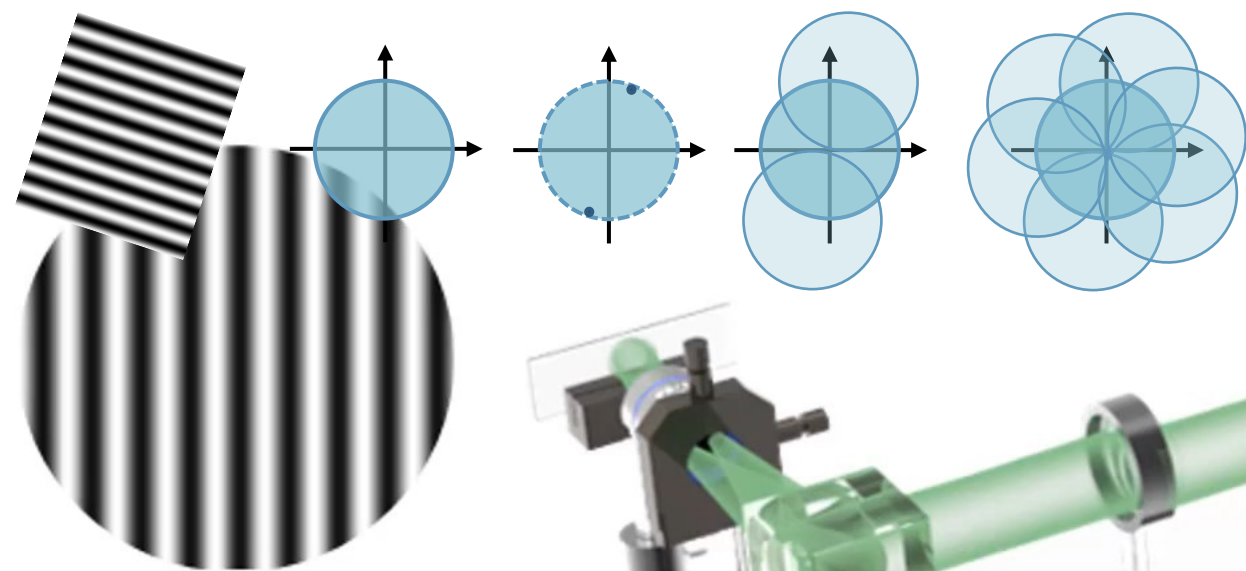
$$OTF(k-k_{ex})\tilde{S}_{+1}(k)$$



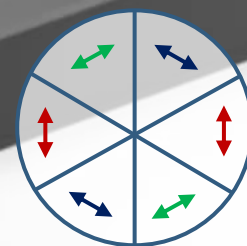








入射光偏振方向



出射光偏振方向

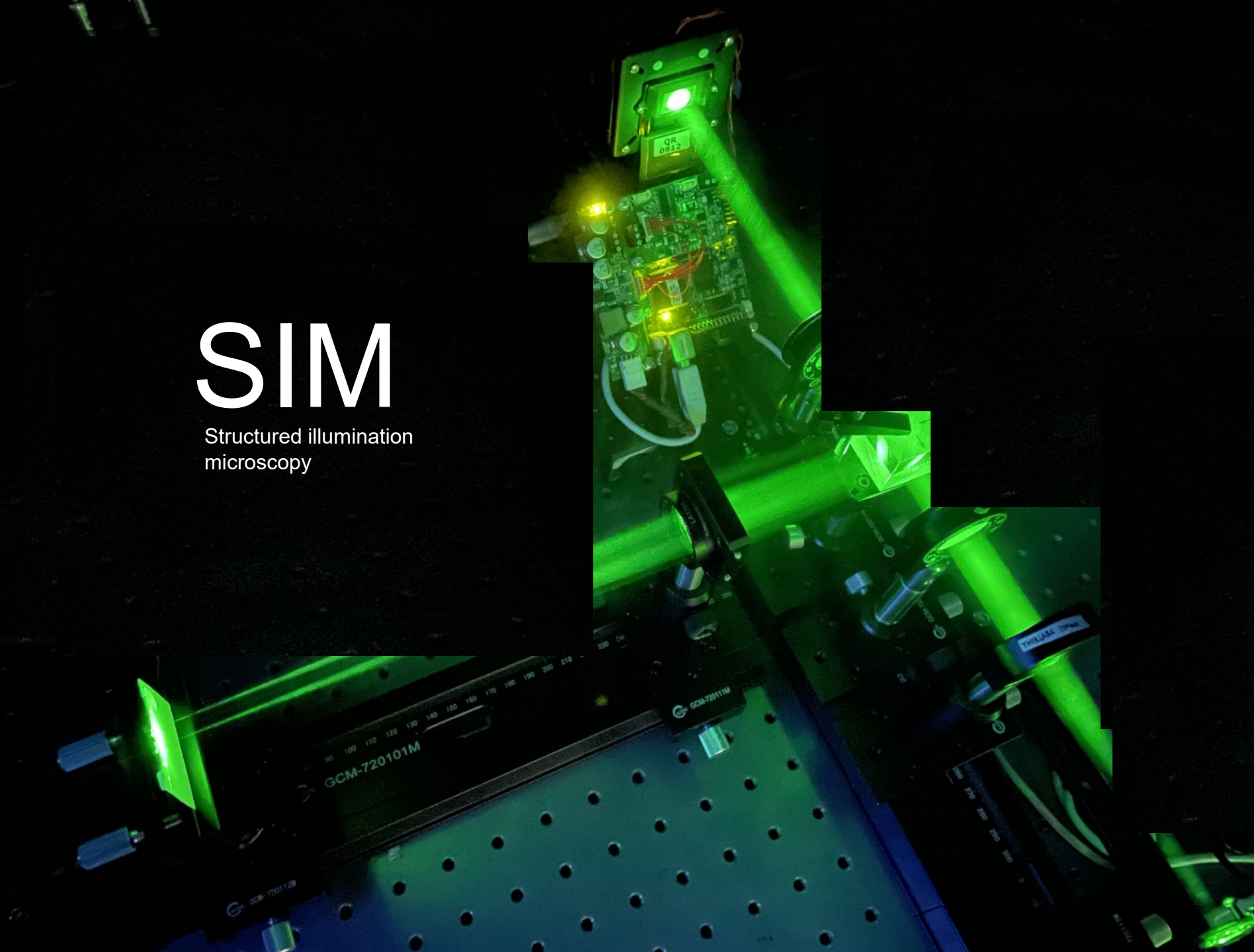
A photograph of a Structured Illumination Microscopy (SIM) setup. A bright green laser beam is visible, originating from the left and passing through a series of optical components including mirrors, lenses, and a beam splitter. The beam is directed towards a microscope objective lens. The setup is mounted on a black perforated metal plate. In the background, there is a white and black piece of equipment, possibly a laser source or detector. The overall scene is dimly lit, with the green laser providing the primary light source.

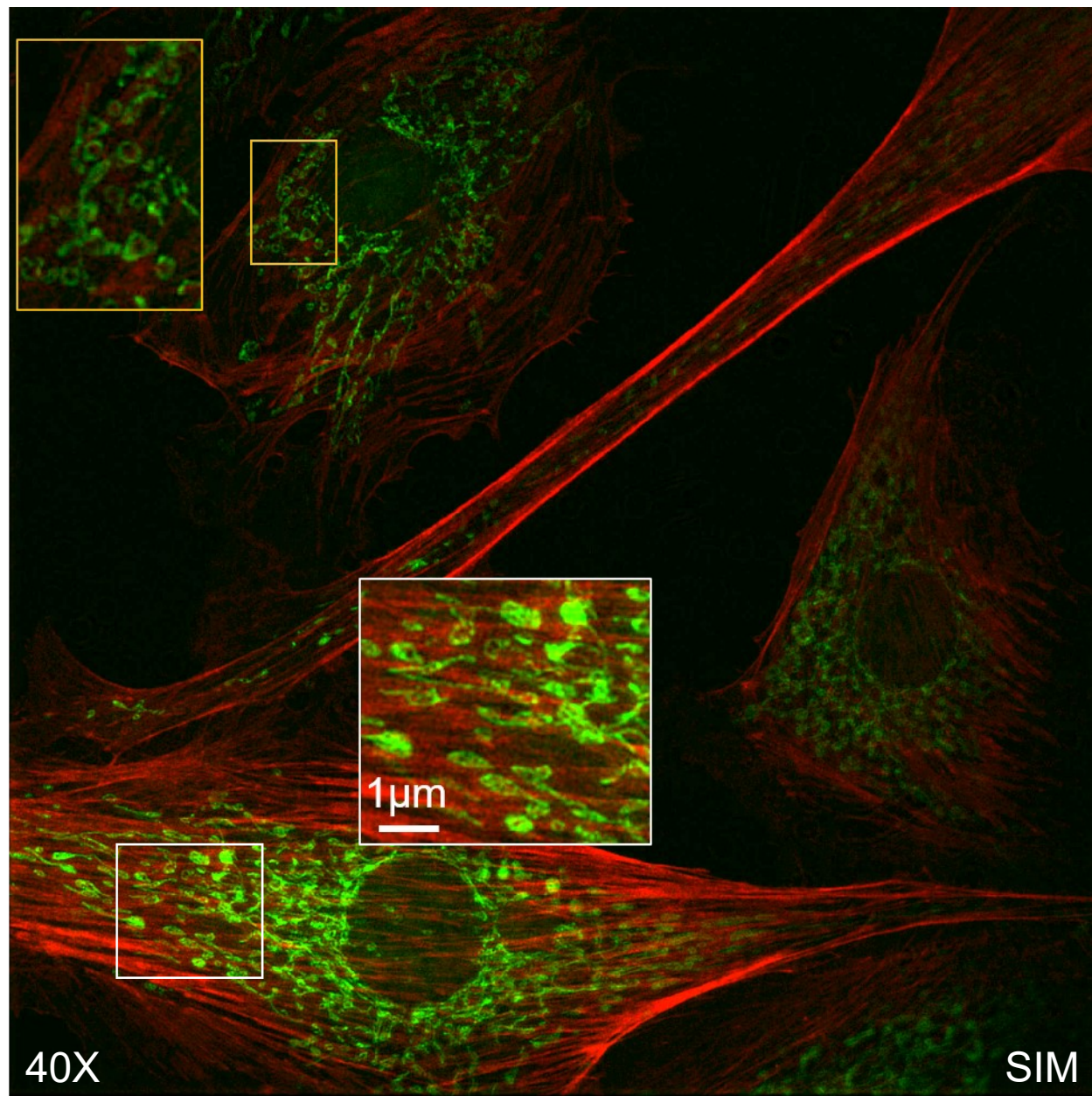
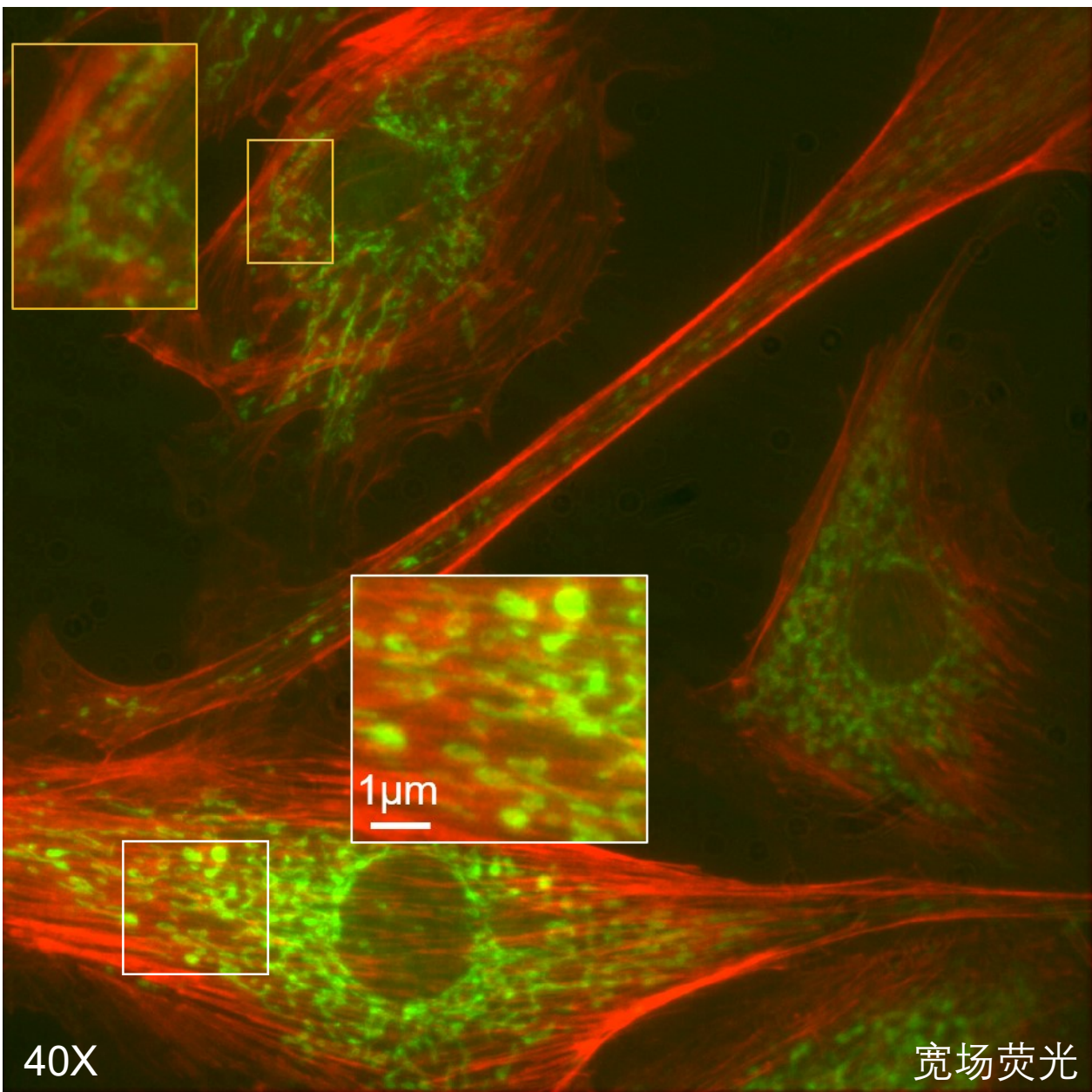
# SIM

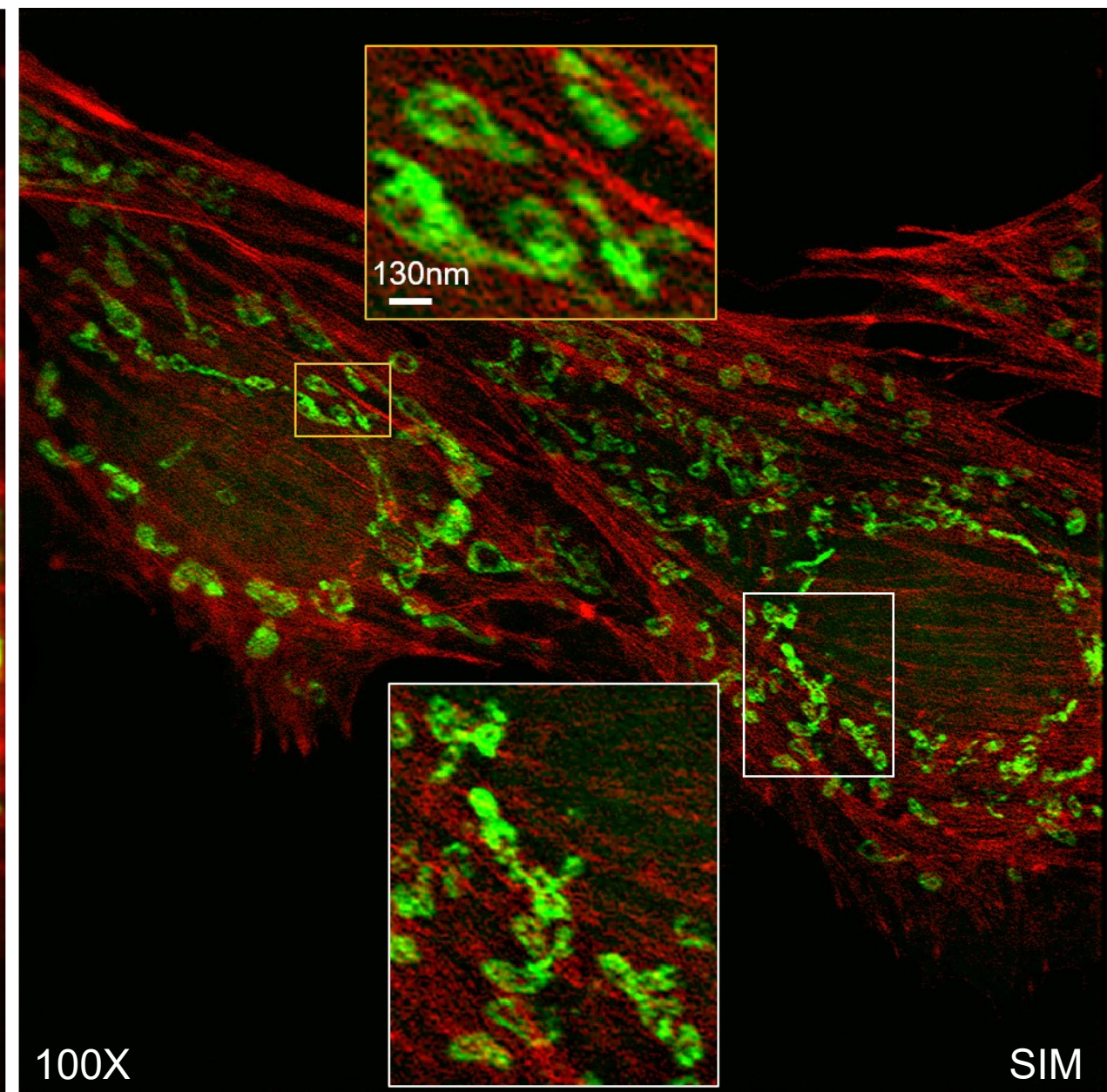
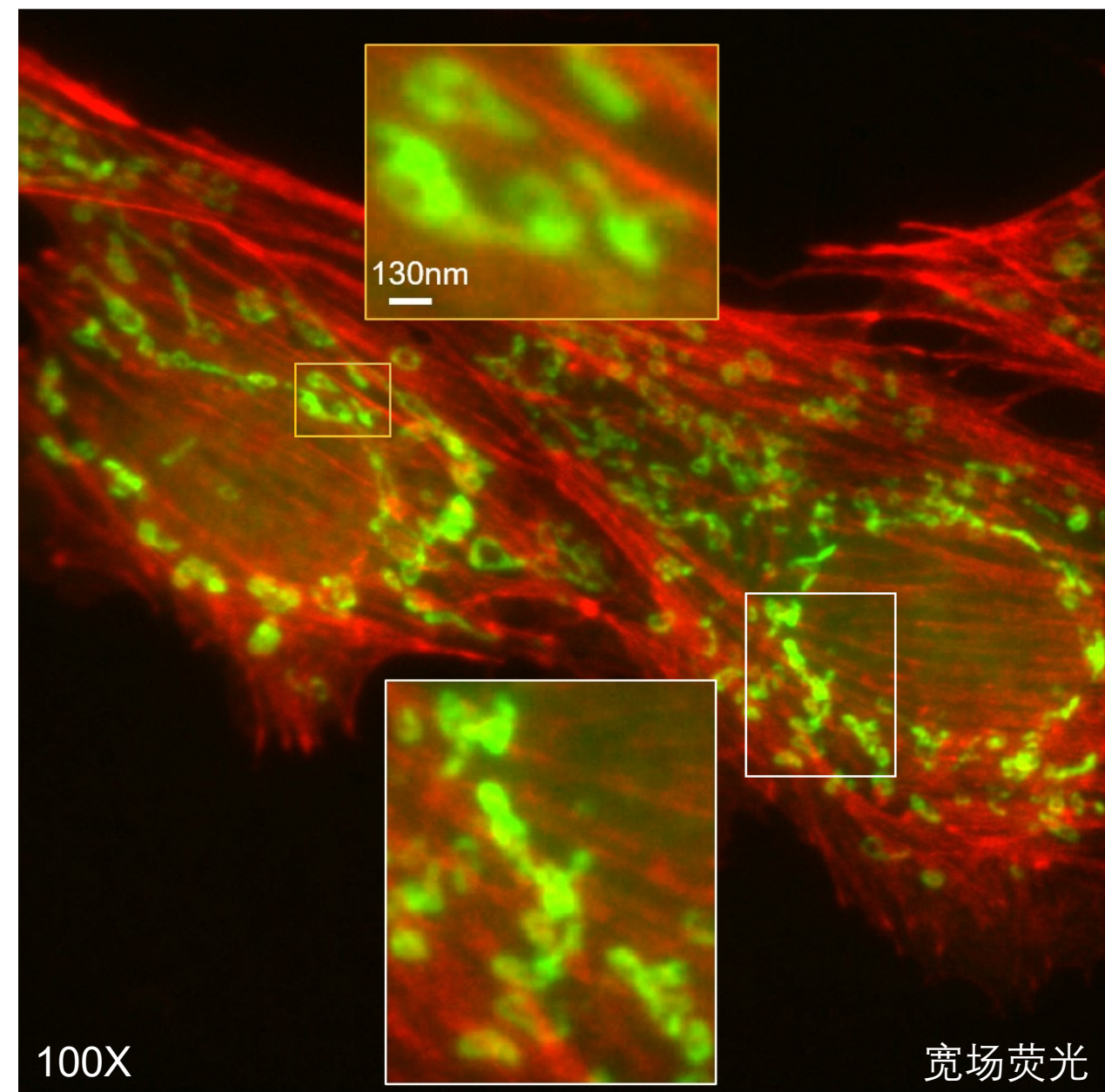
Structured illumination  
microscopy

# SIM

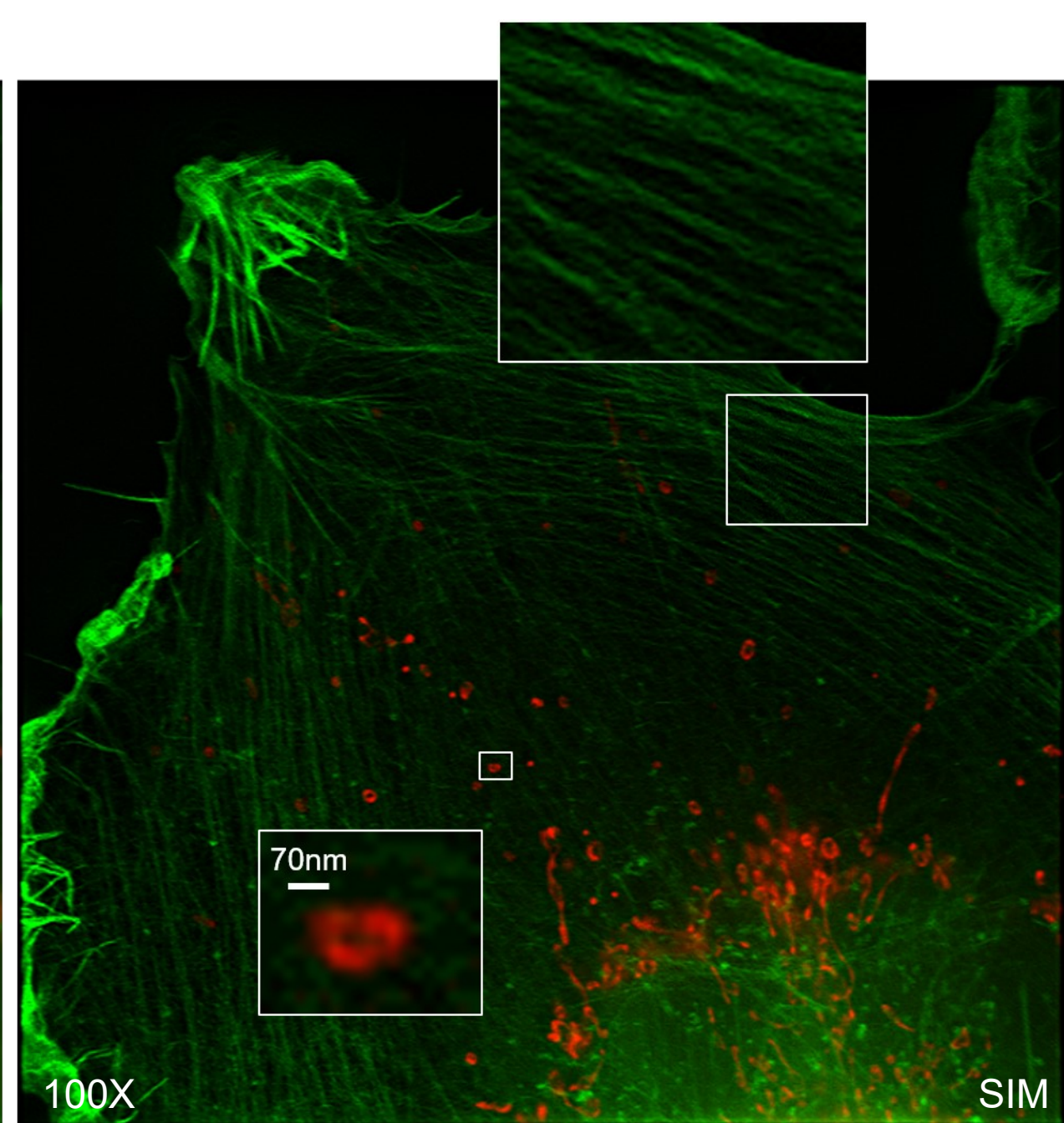
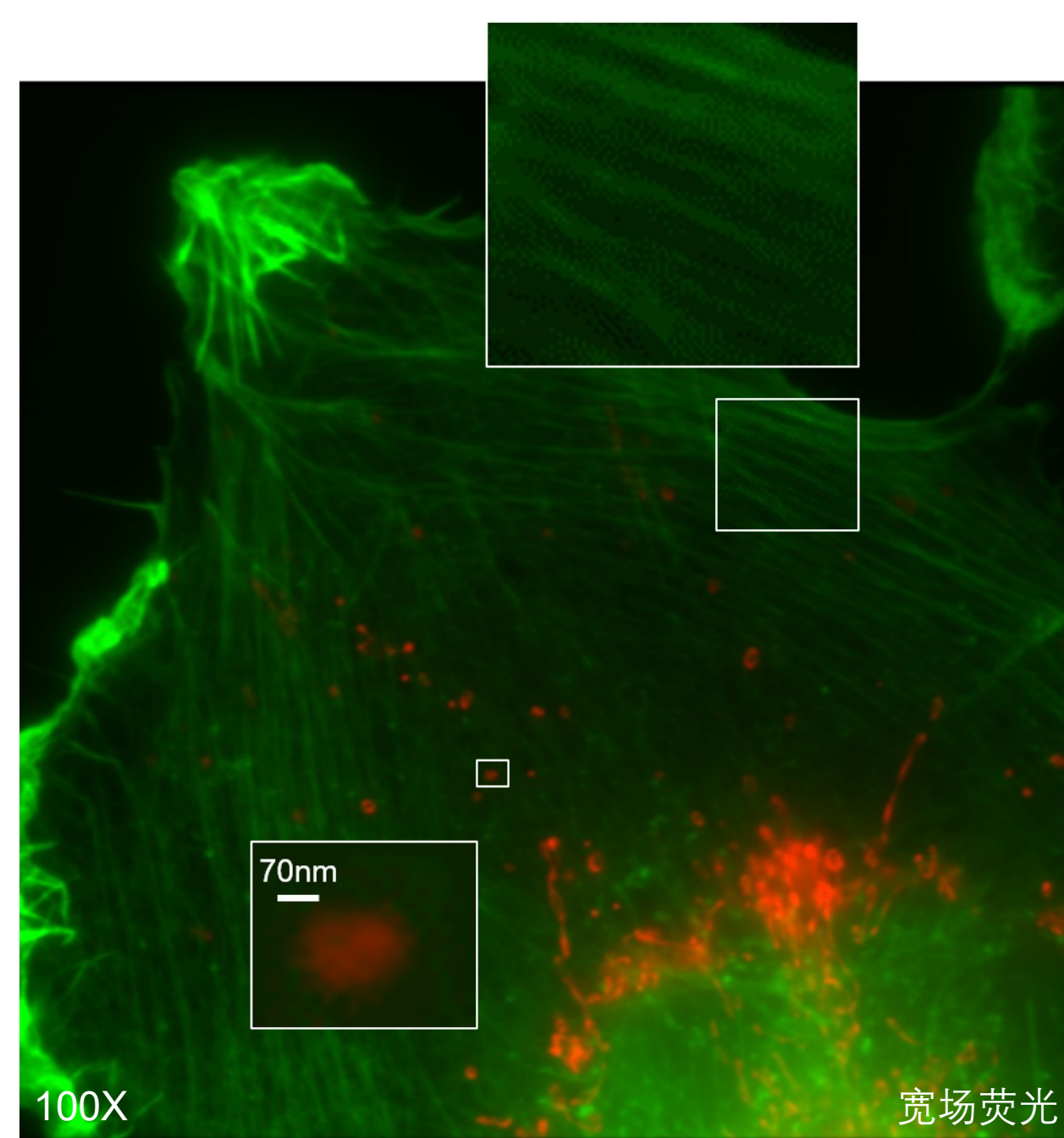
Structured illumination  
microscopy







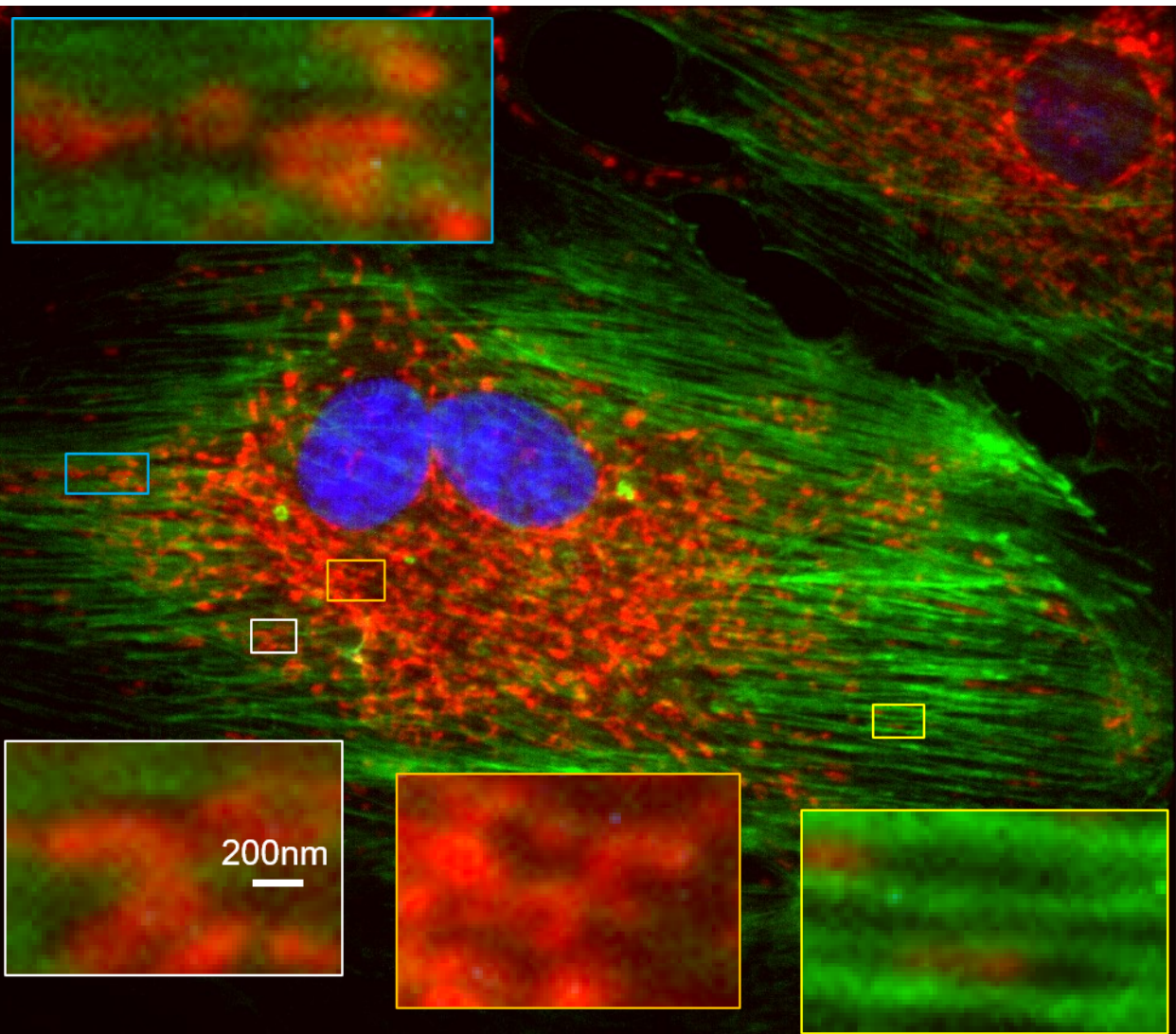






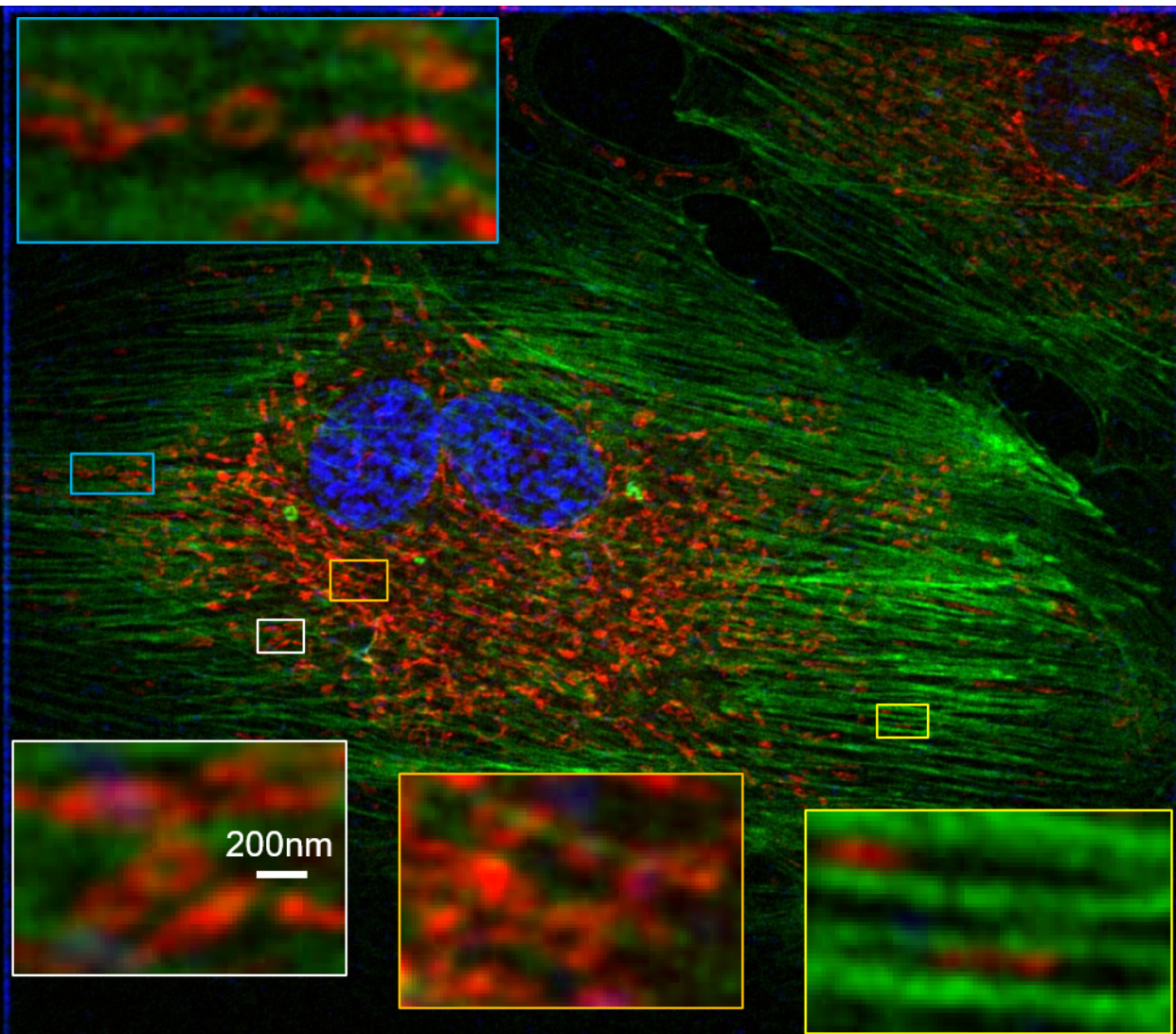
# SIM

Structured illumination  
microscopy



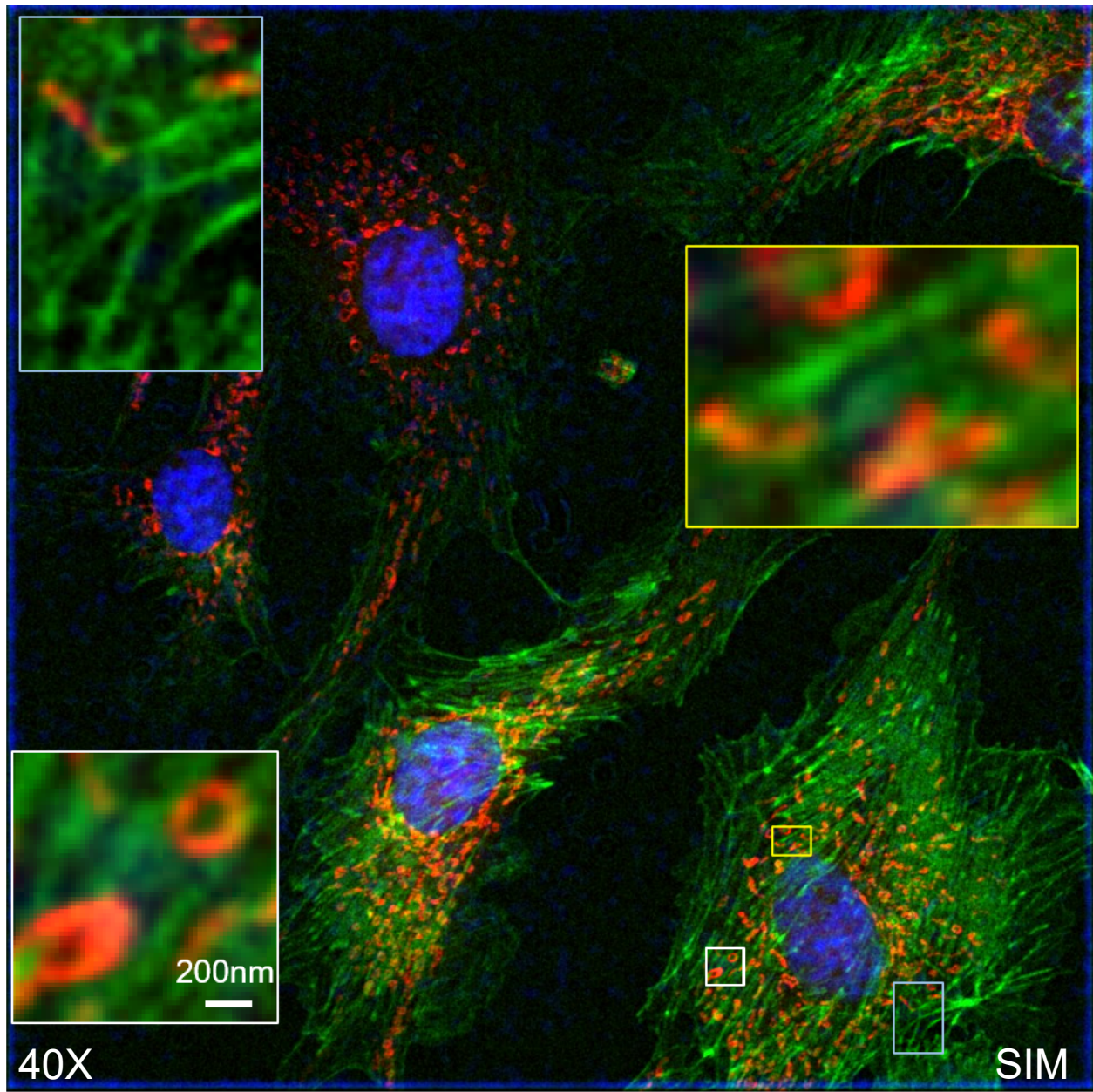
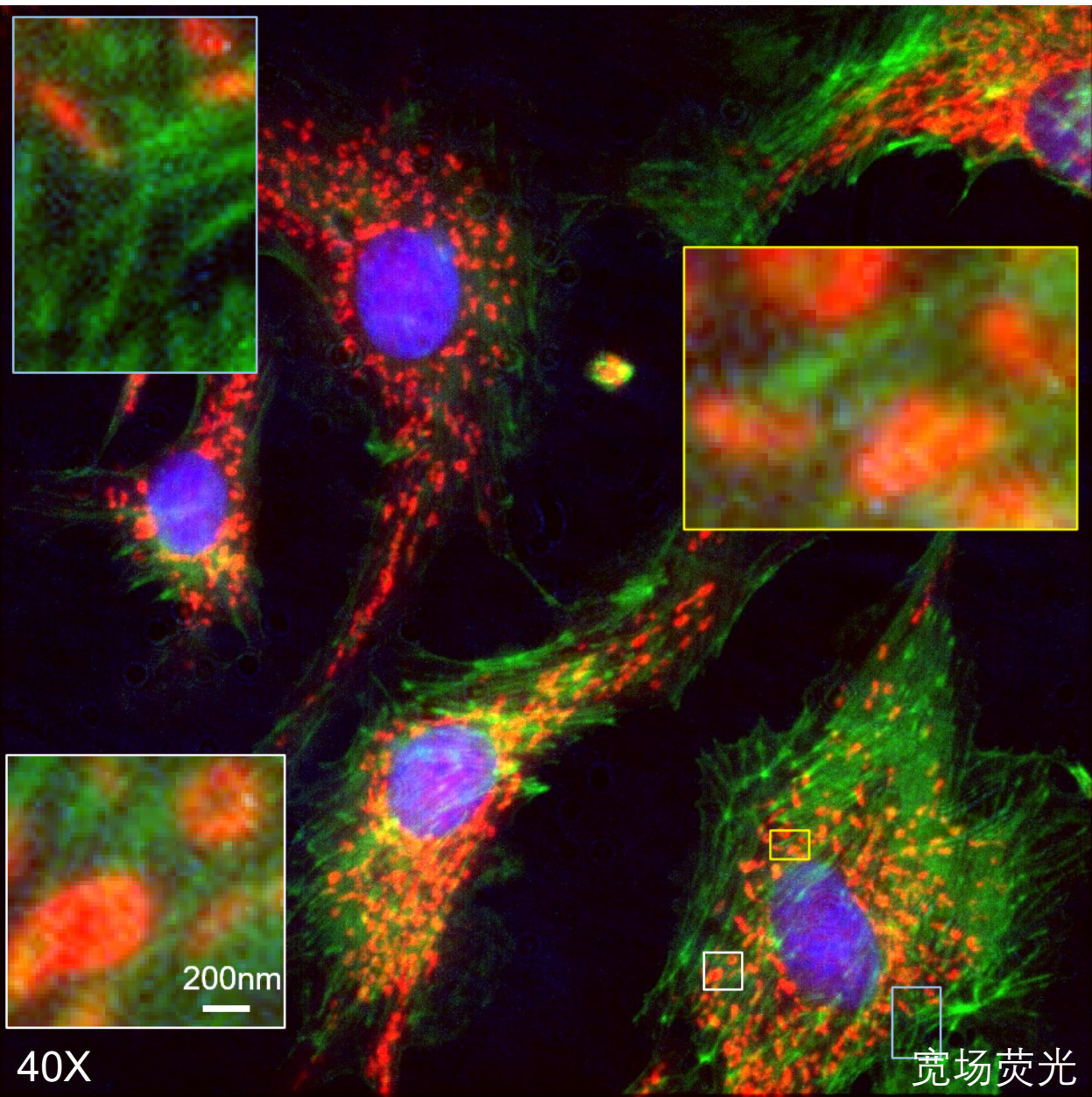
40X

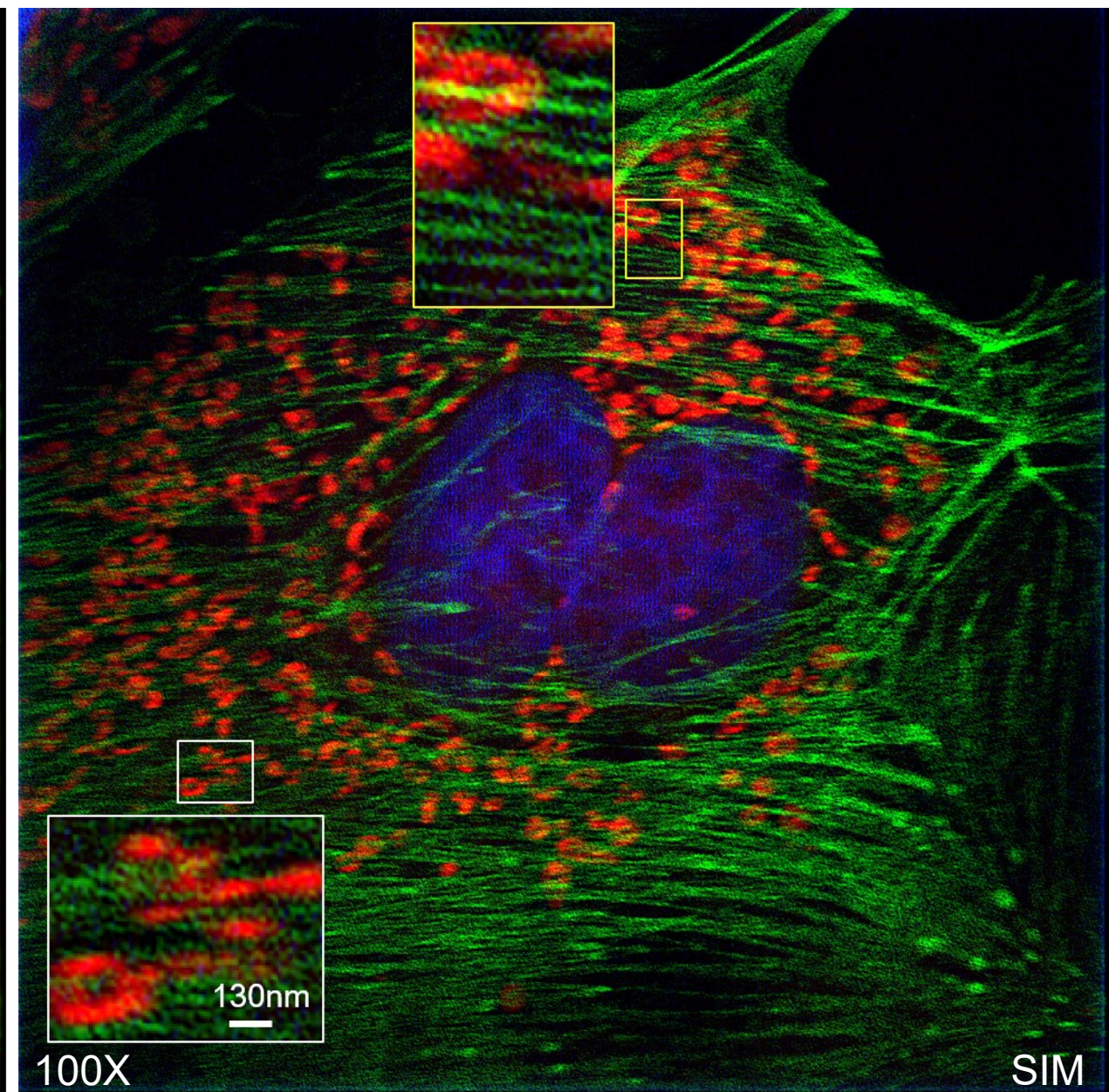
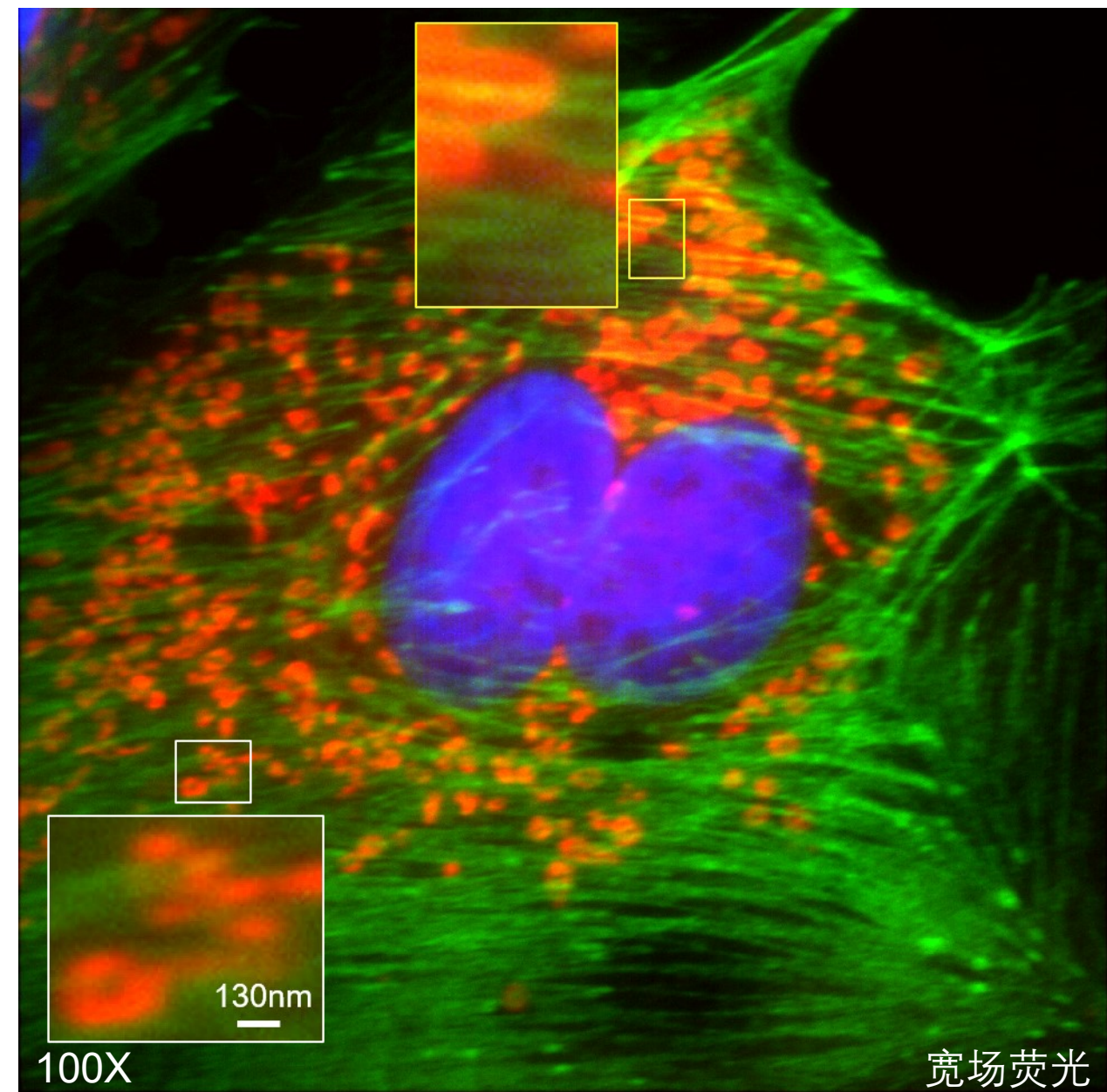
宽场荧光

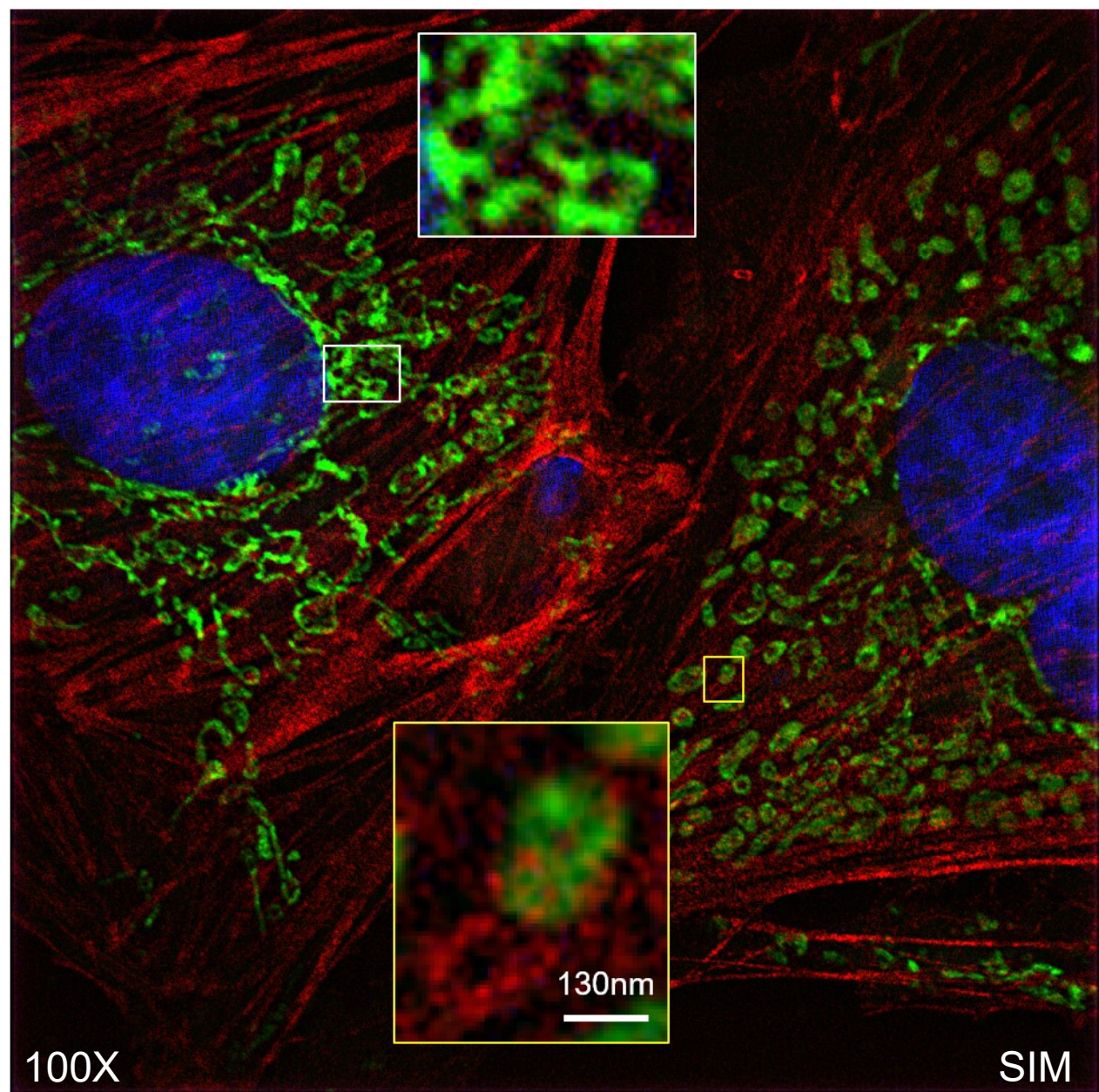
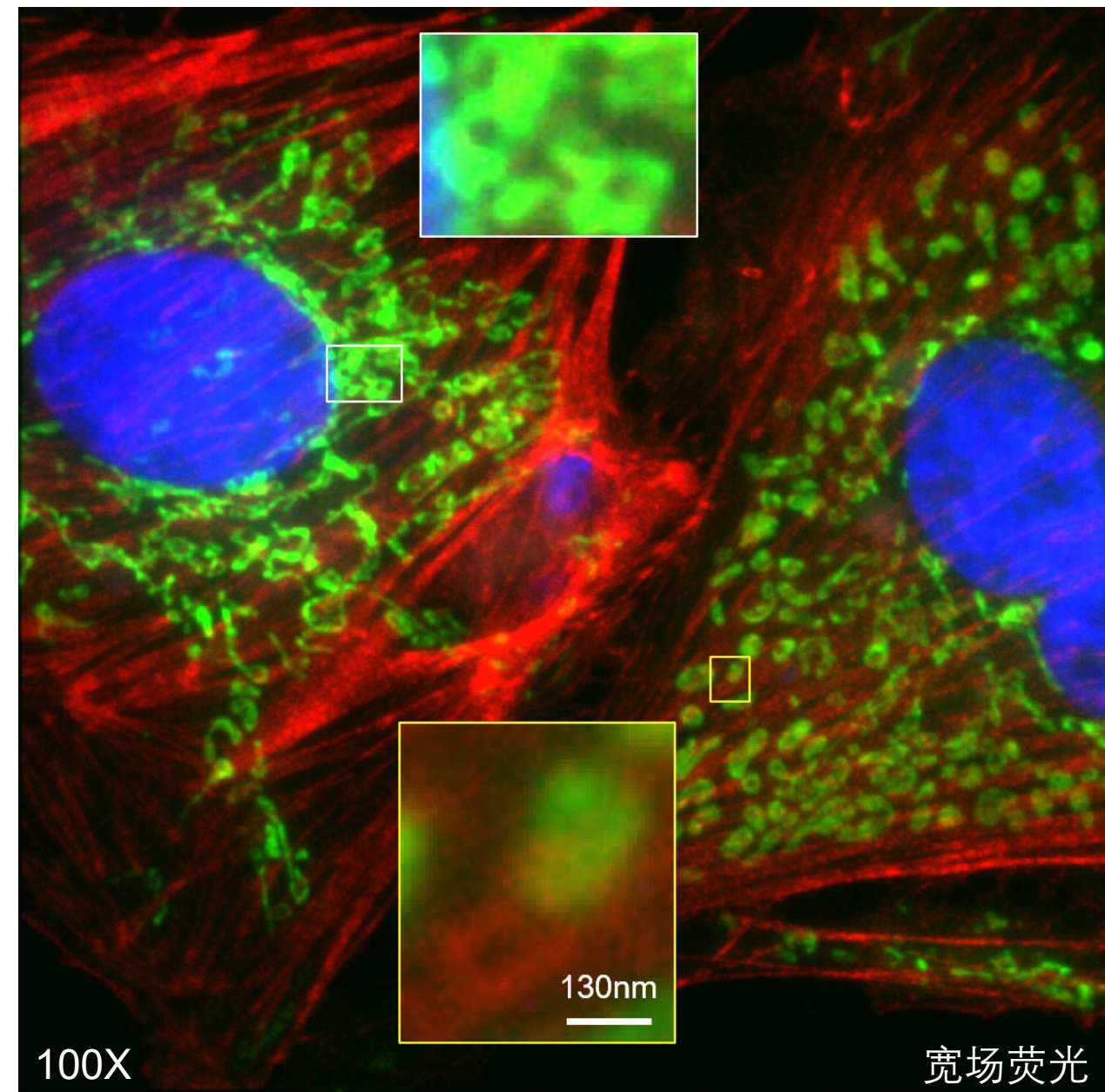


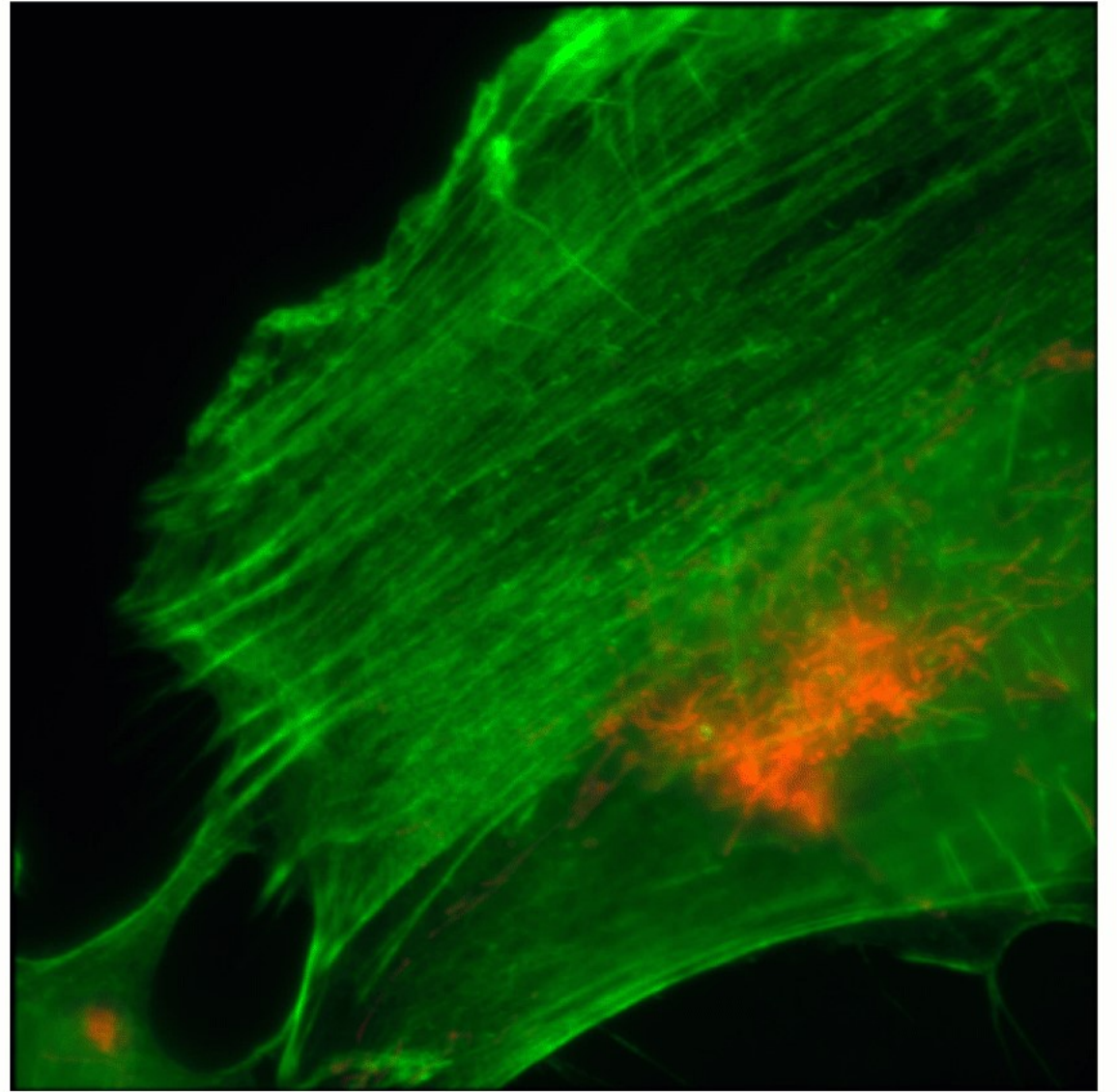
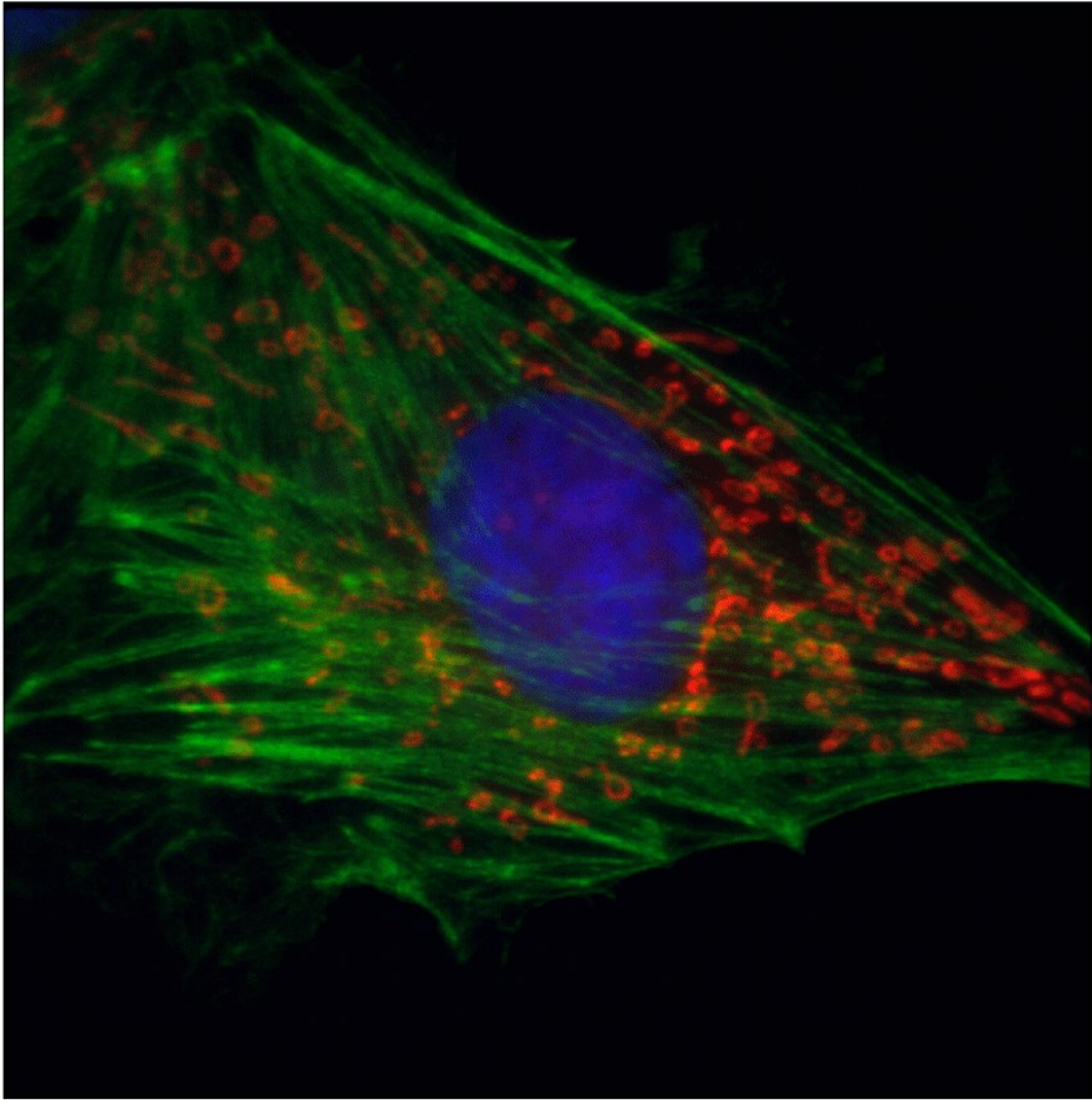
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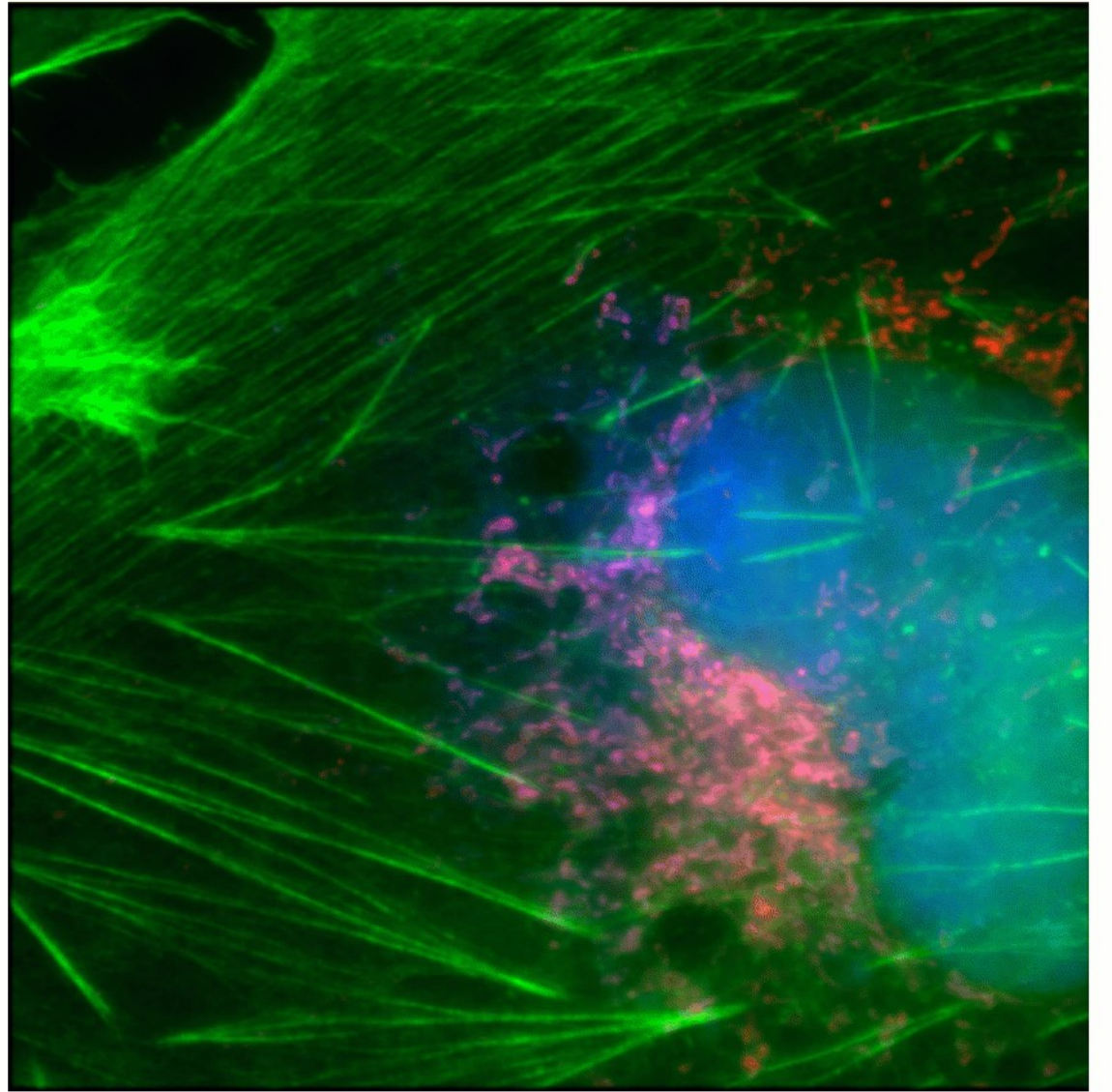
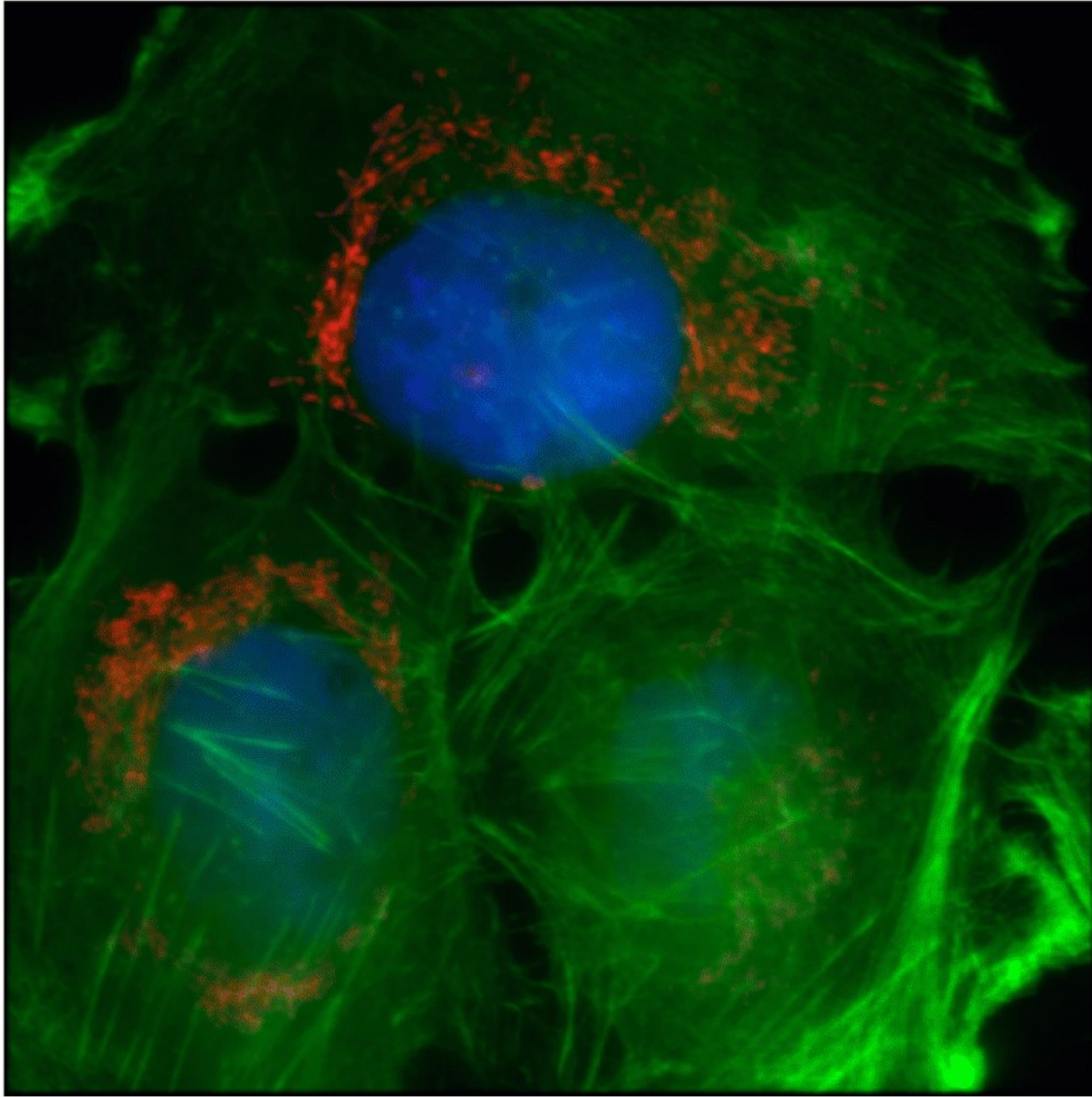
SIM







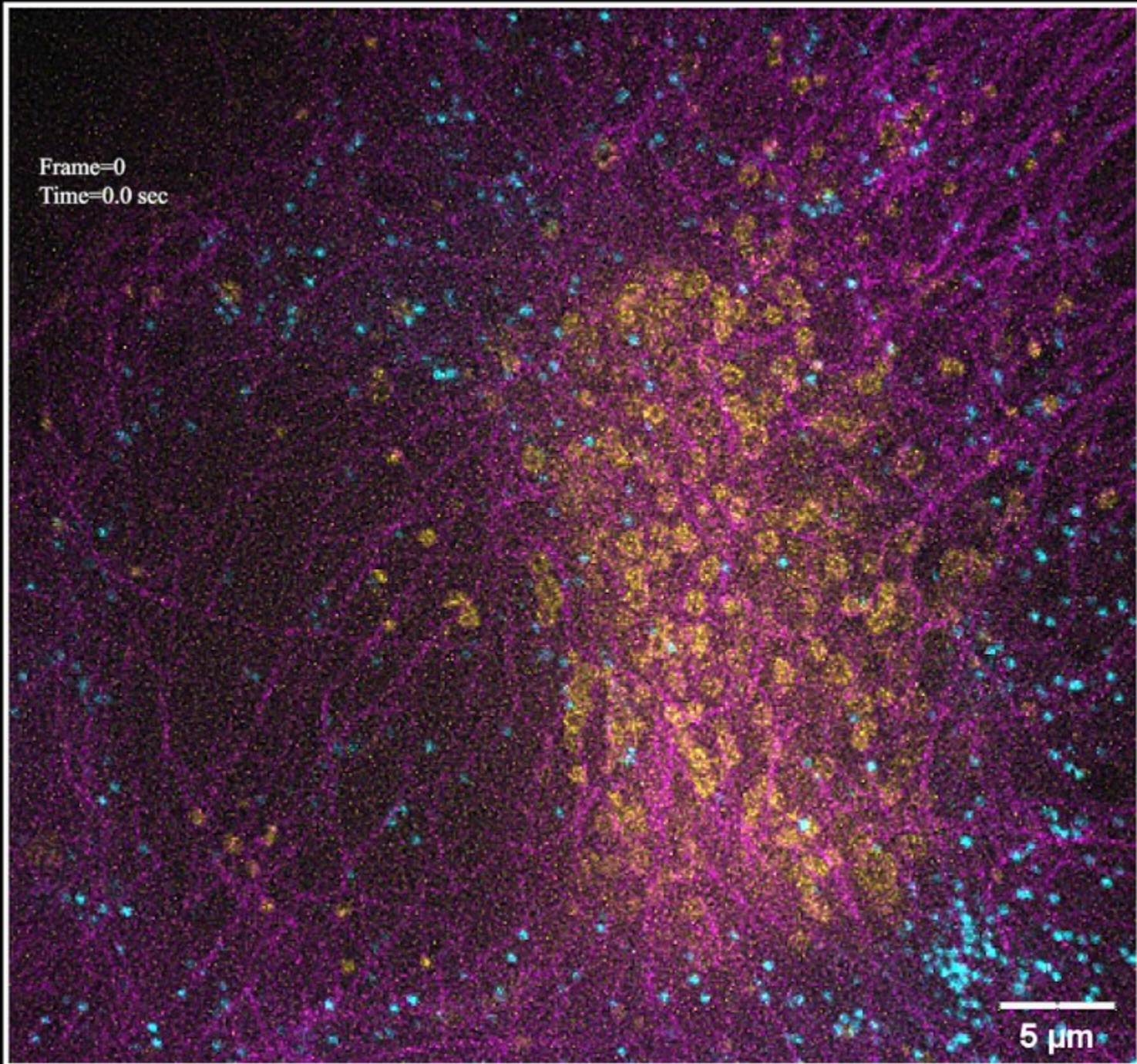






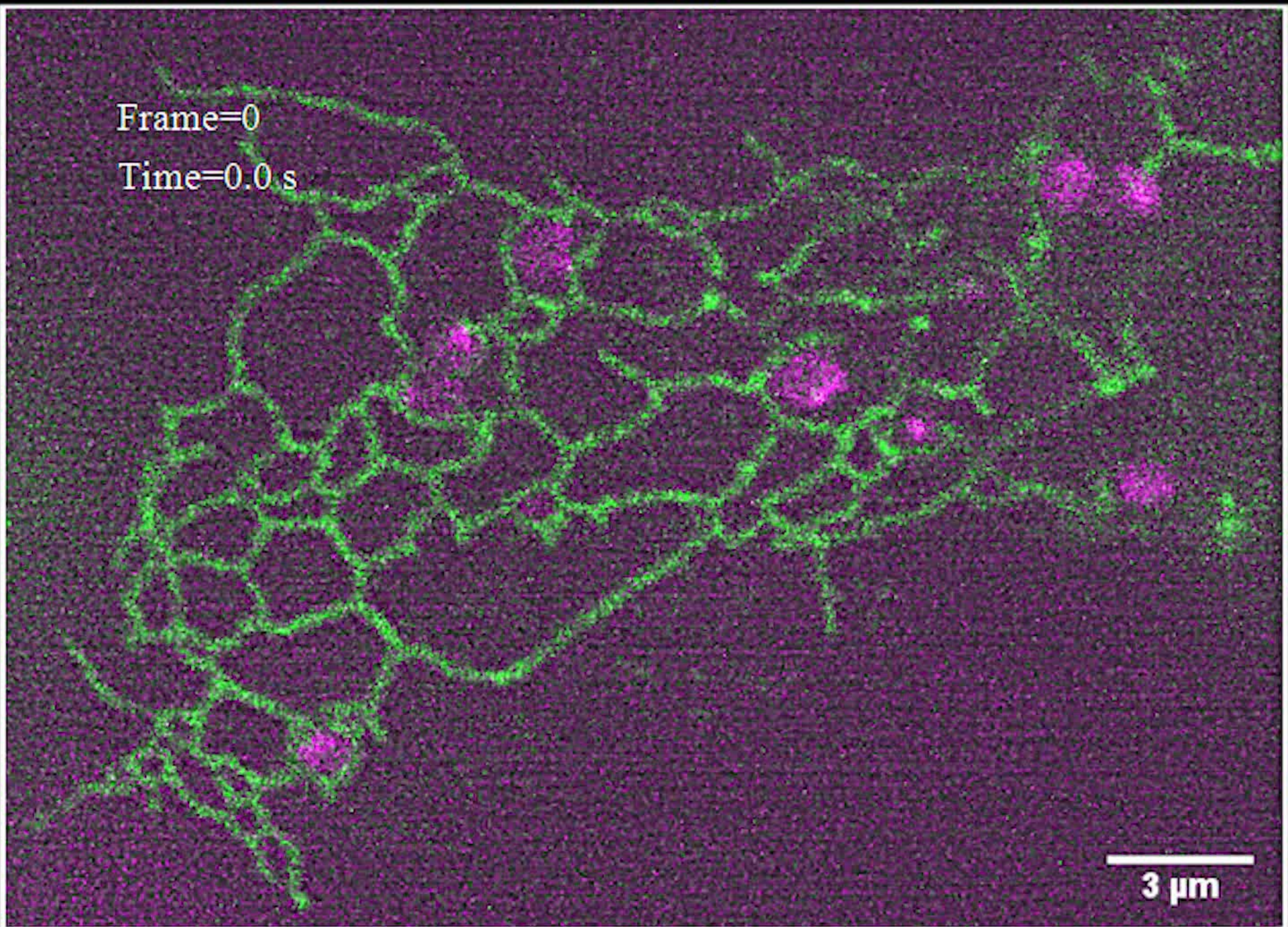
Frame=0  
Time=0.0 sec

5  $\mu\text{m}$



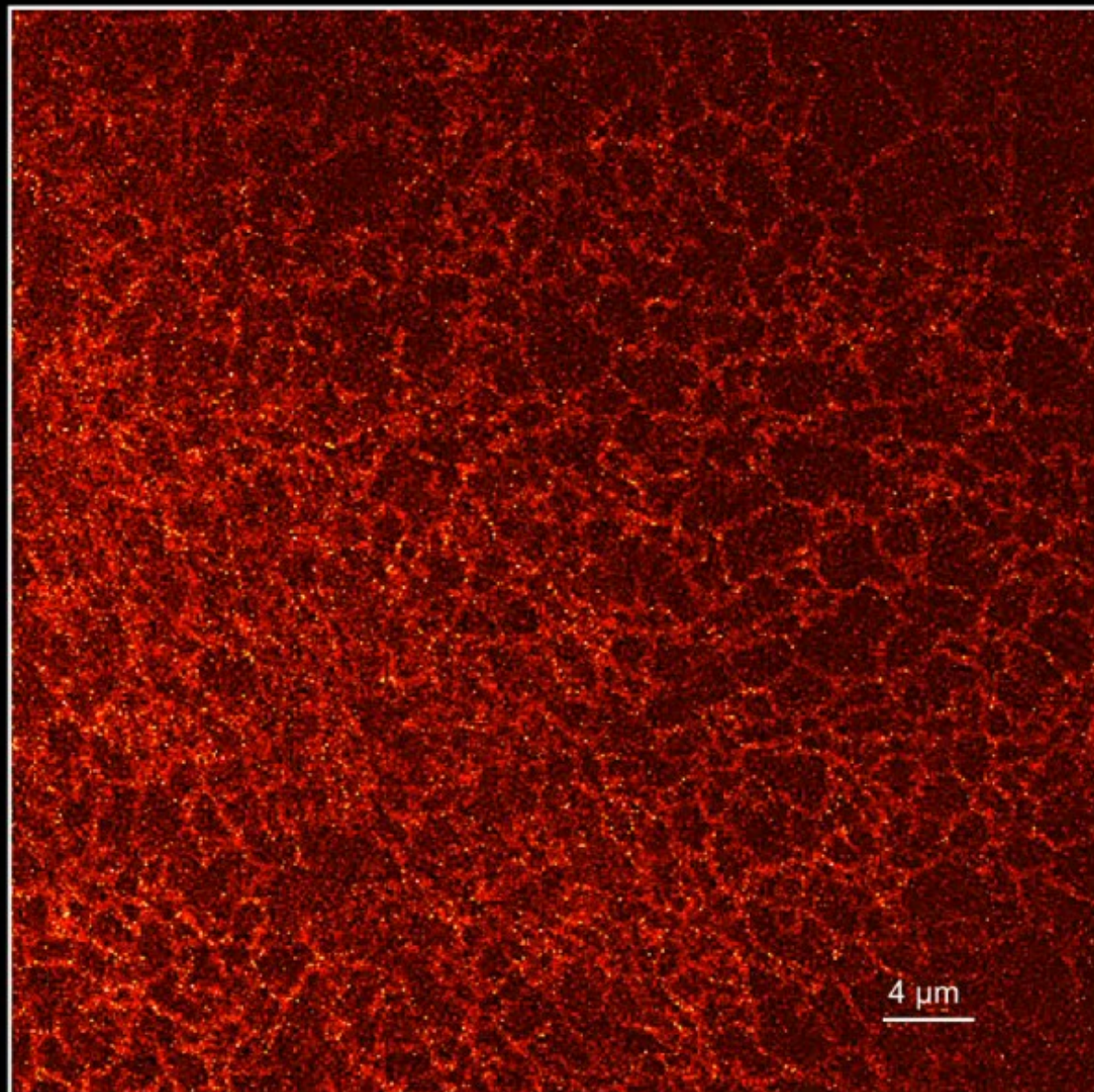
Frame=0

Time=0.0 s



3 μm

Frame = 1  
Time = 0.2 (s)



4  $\mu$ m

SD-SIM

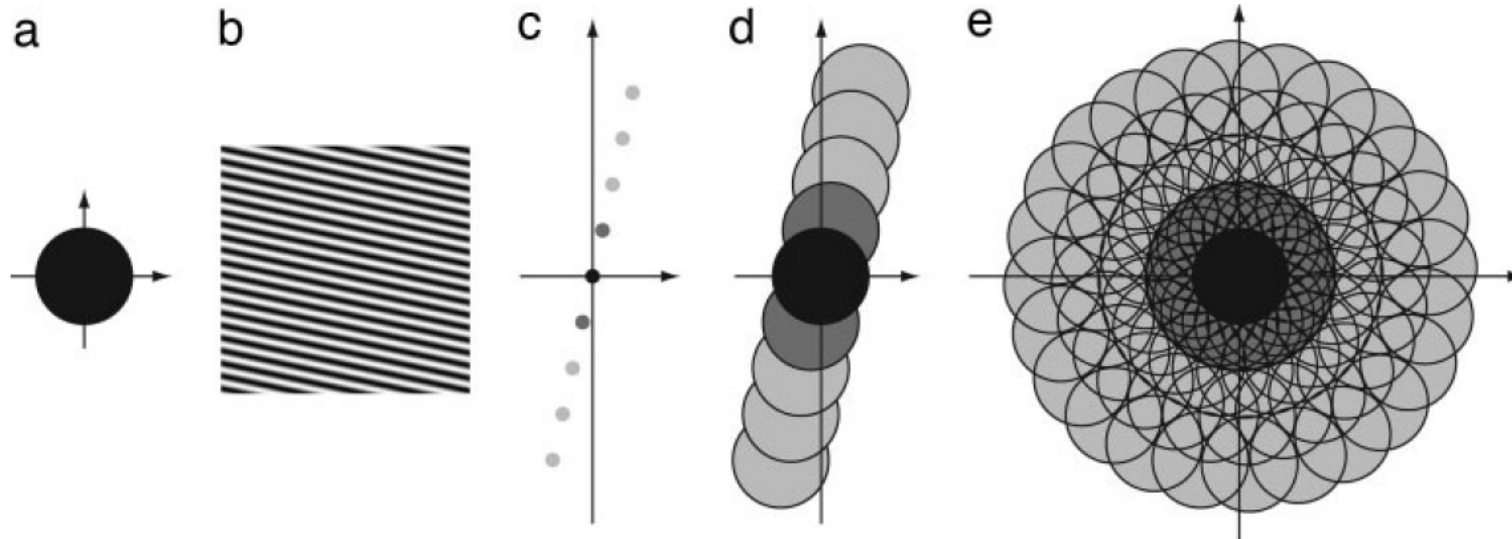
细胞外围的管状内质网

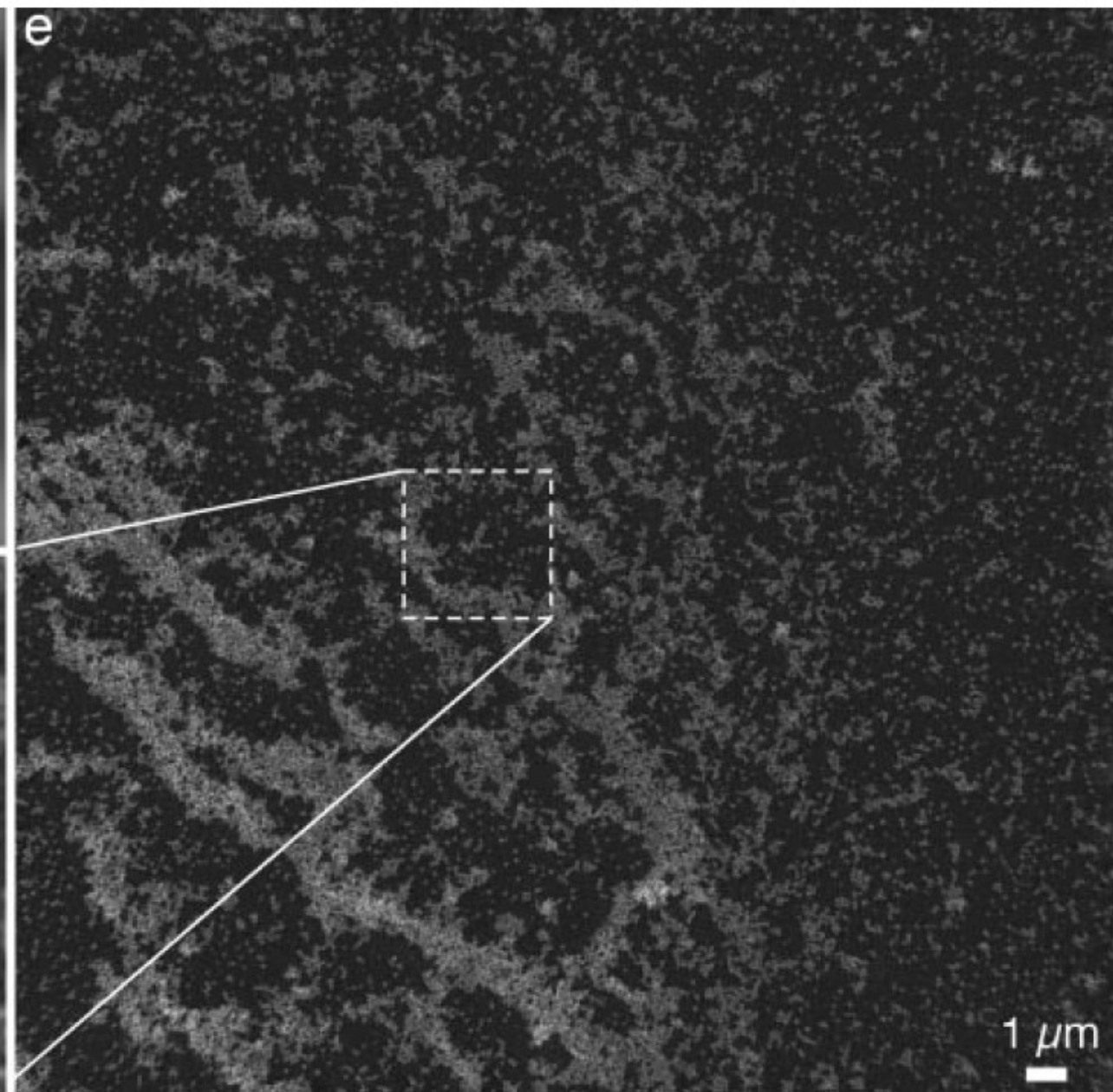
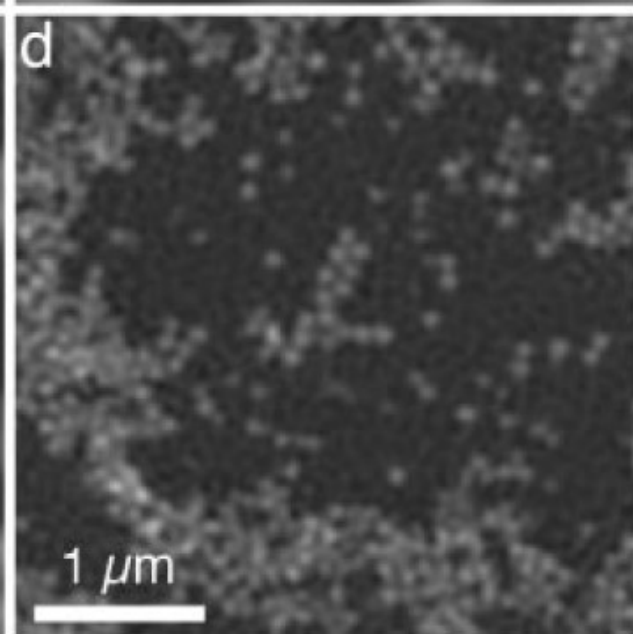
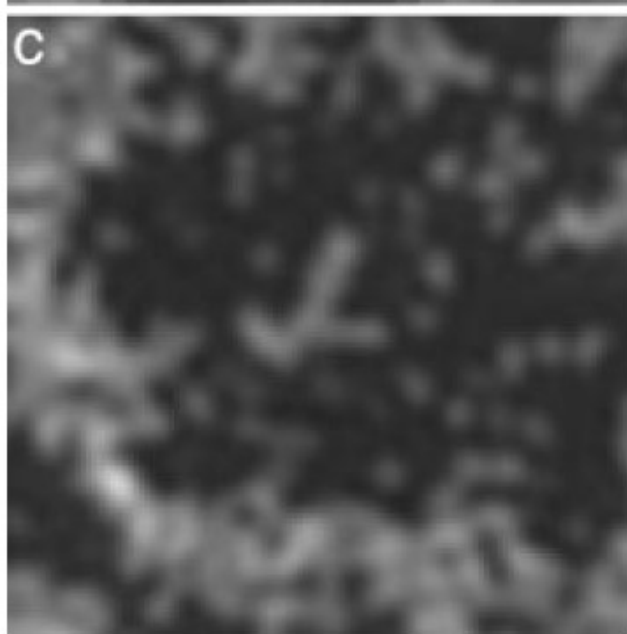
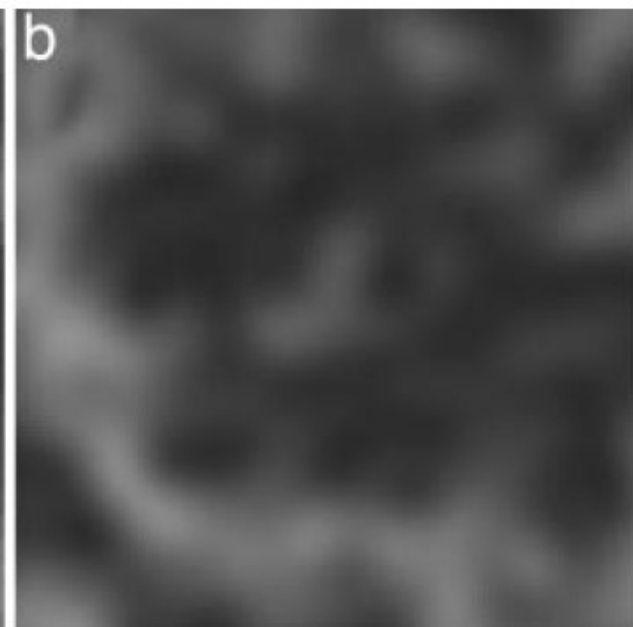
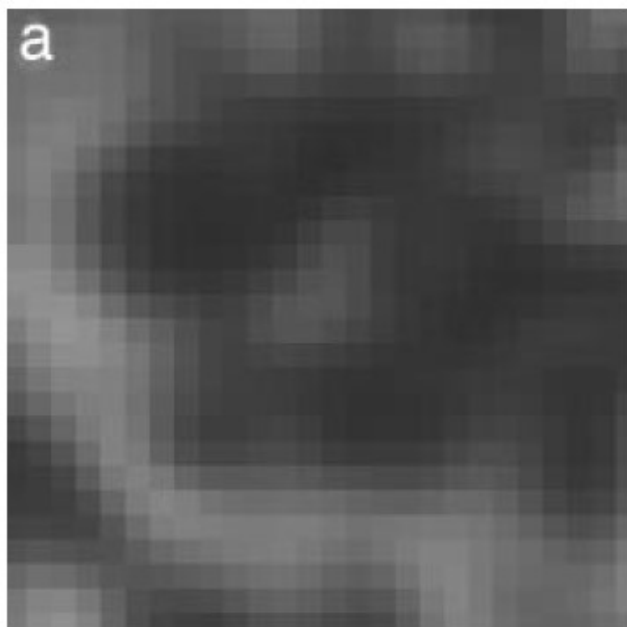
# Nonlinear structured-illumination microscopy: Wide-field fluorescence imaging with theoretically unlimited resolution

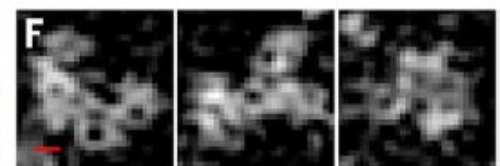
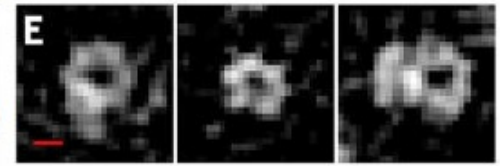
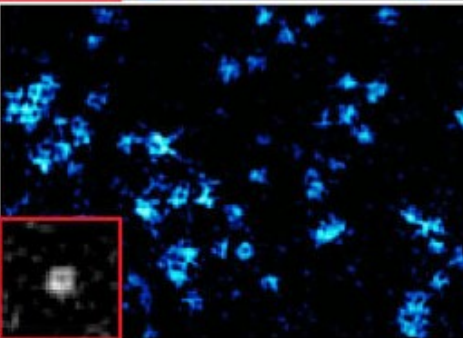
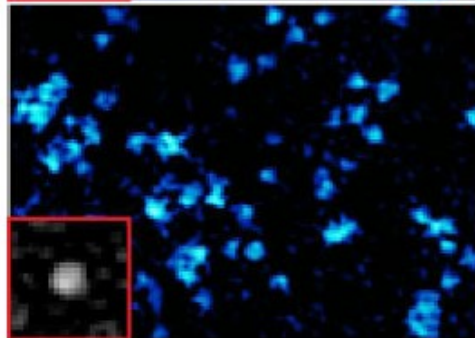
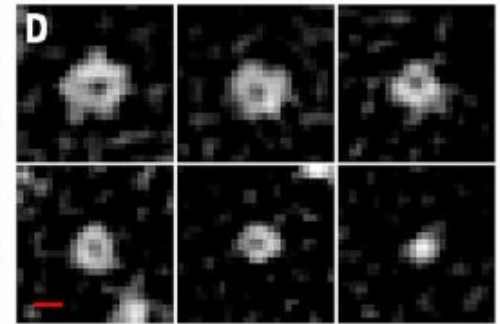
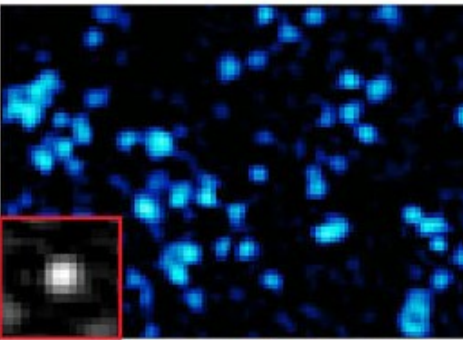
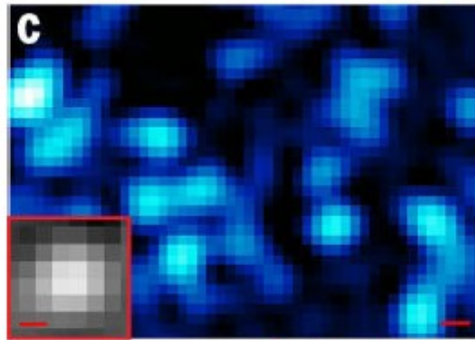
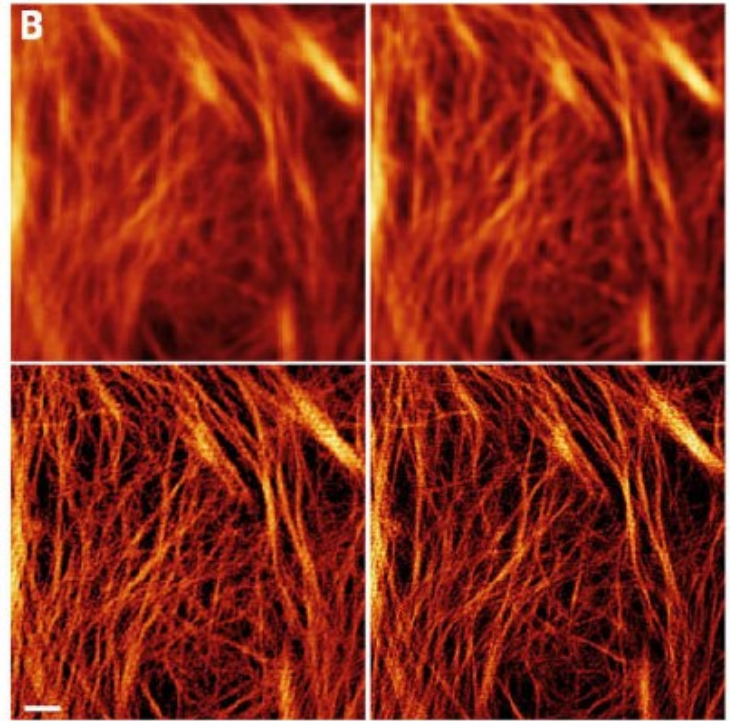
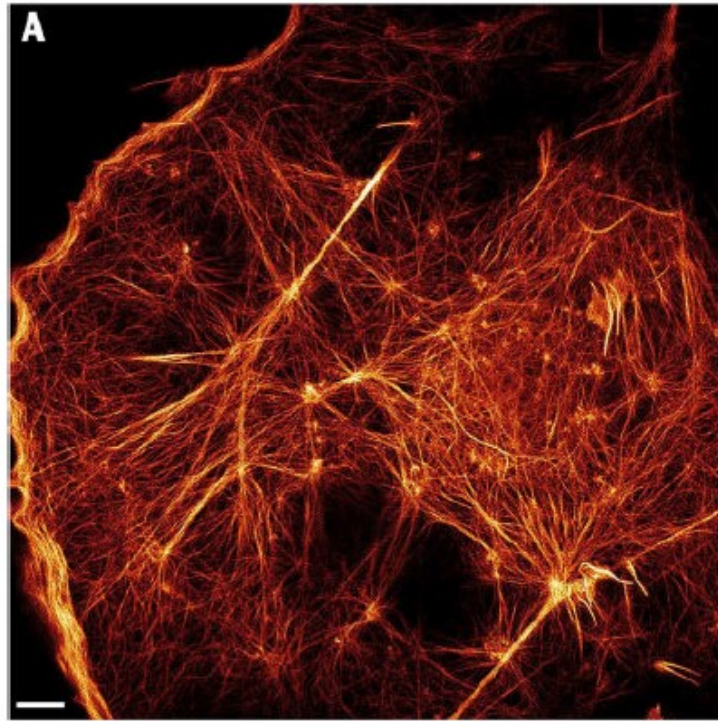
Mats G. L. Gustafsson\*

Department of Physiology and Program in Bioengineering, University of California, San Francisco, CA 94143-2532

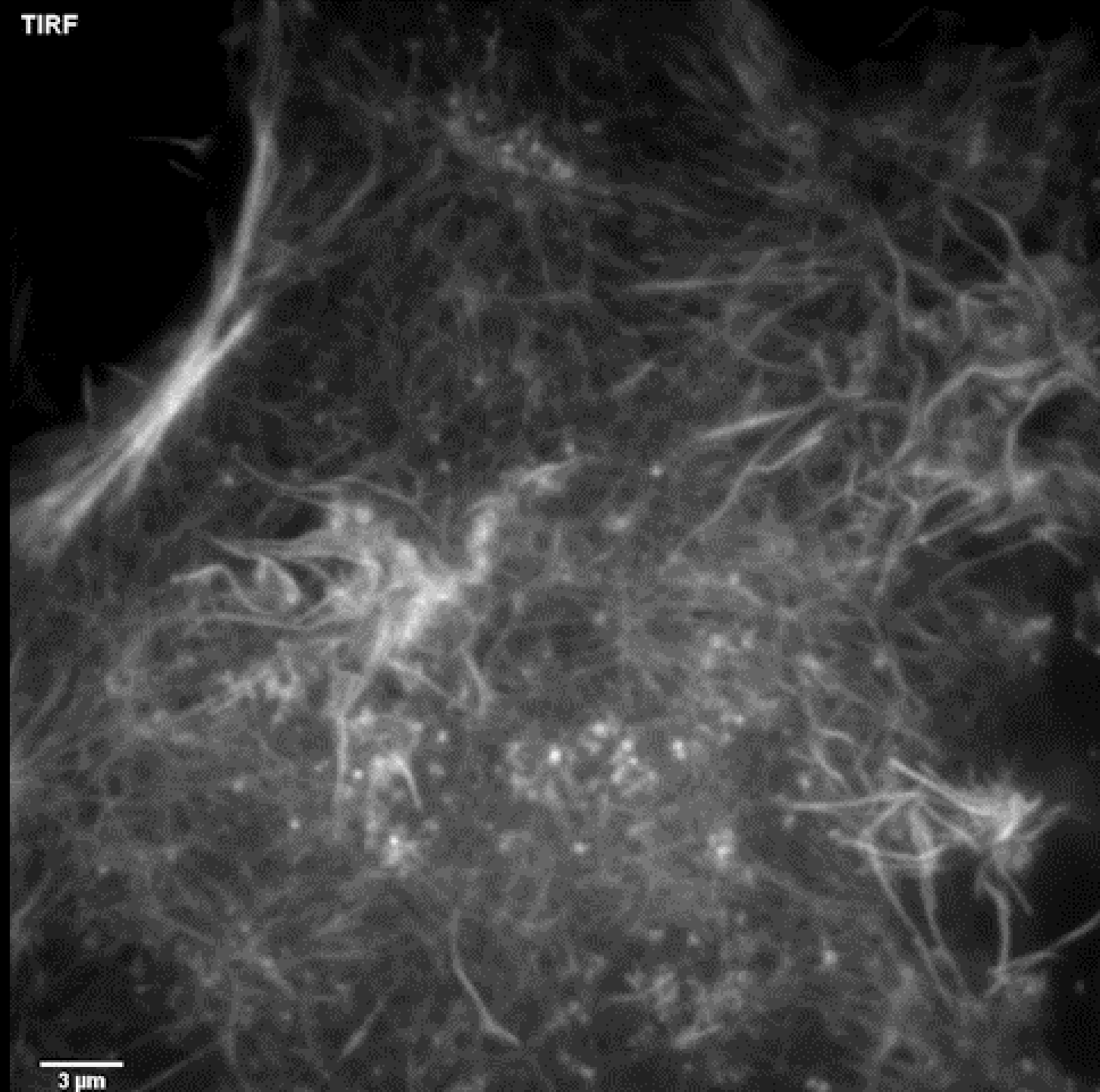
Edited by Watt W. Webb, Cornell University, Ithaca, NY, and approved July 29, 2005 (received for review September 16, 2004)







TIRF

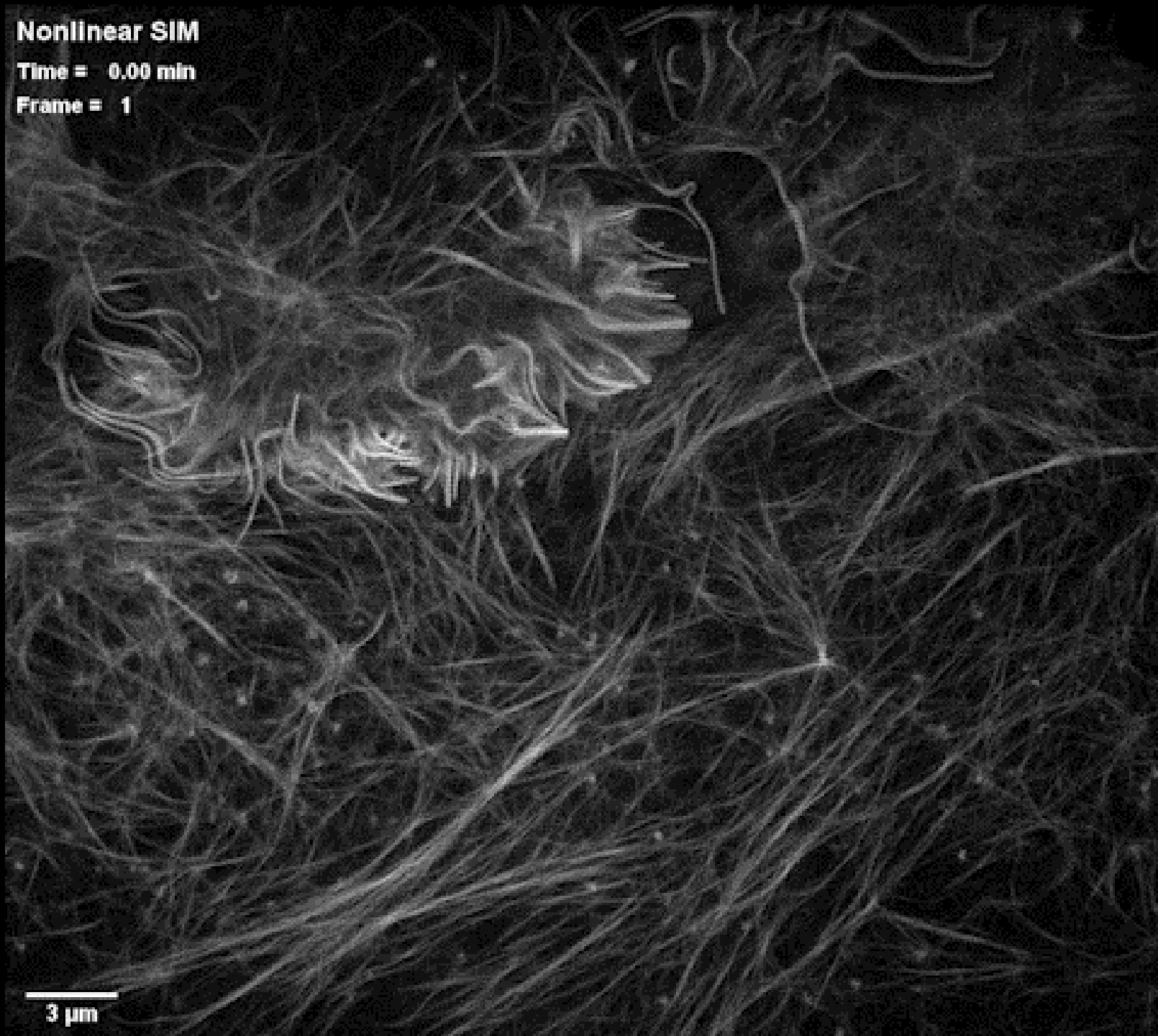


3  $\mu$ m

Nonlinear SIM

Time = 0.00 min

Frame = 1

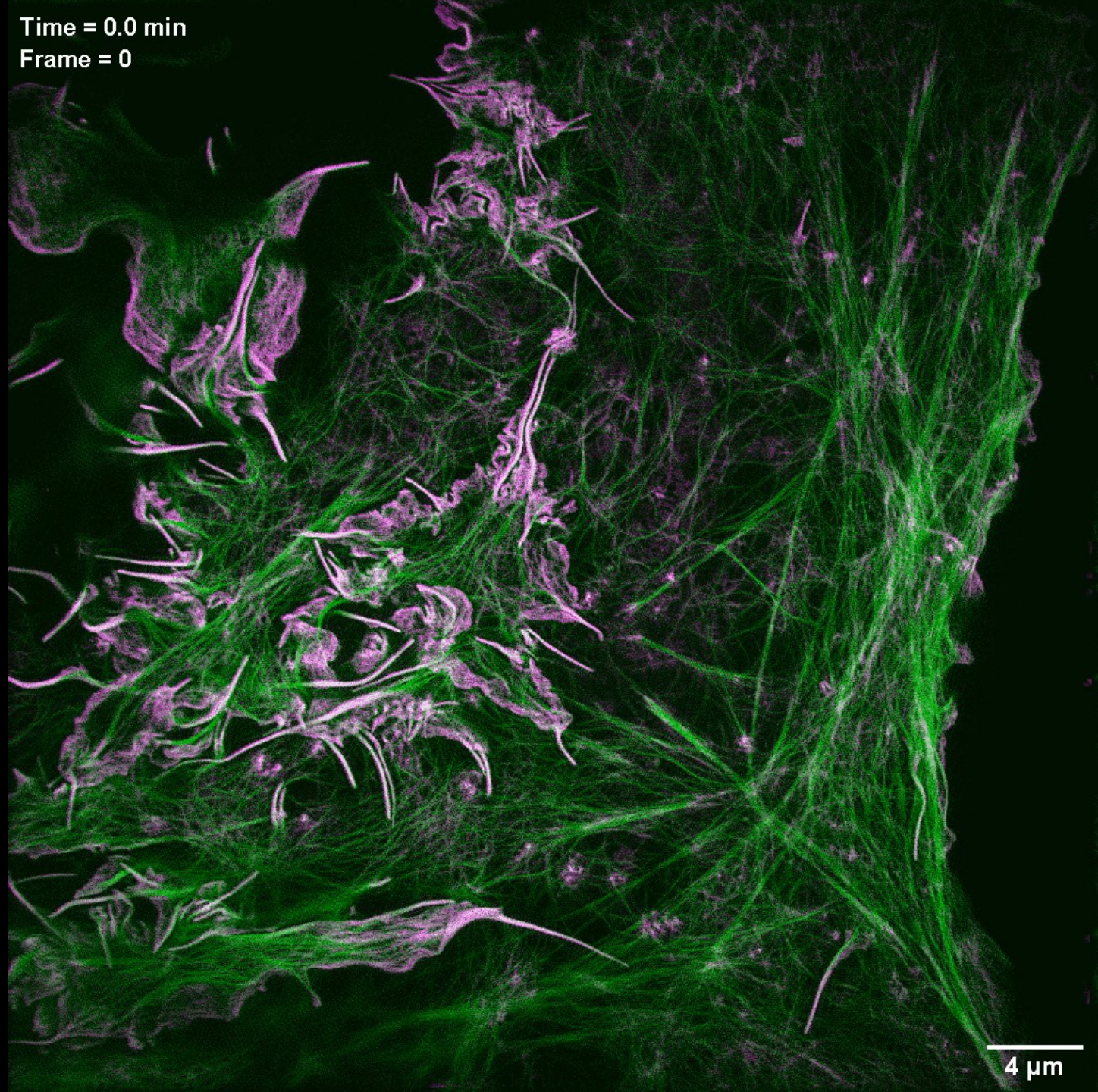


3  $\mu$ m

COS-7细胞肌动蛋白



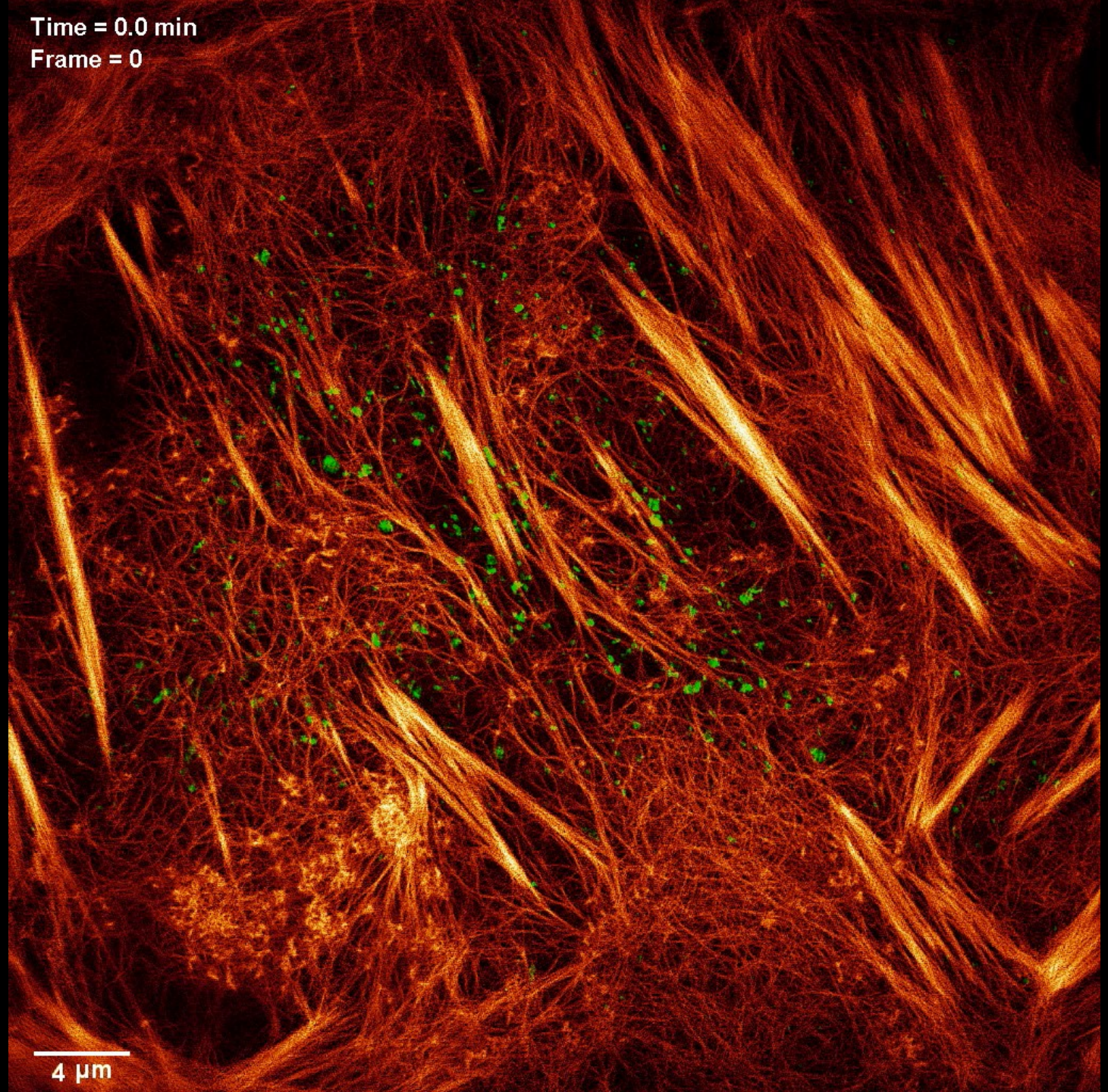
Time = 0.0 min  
Frame = 0



4 μm

Time = 0.0 min

Frame = 0

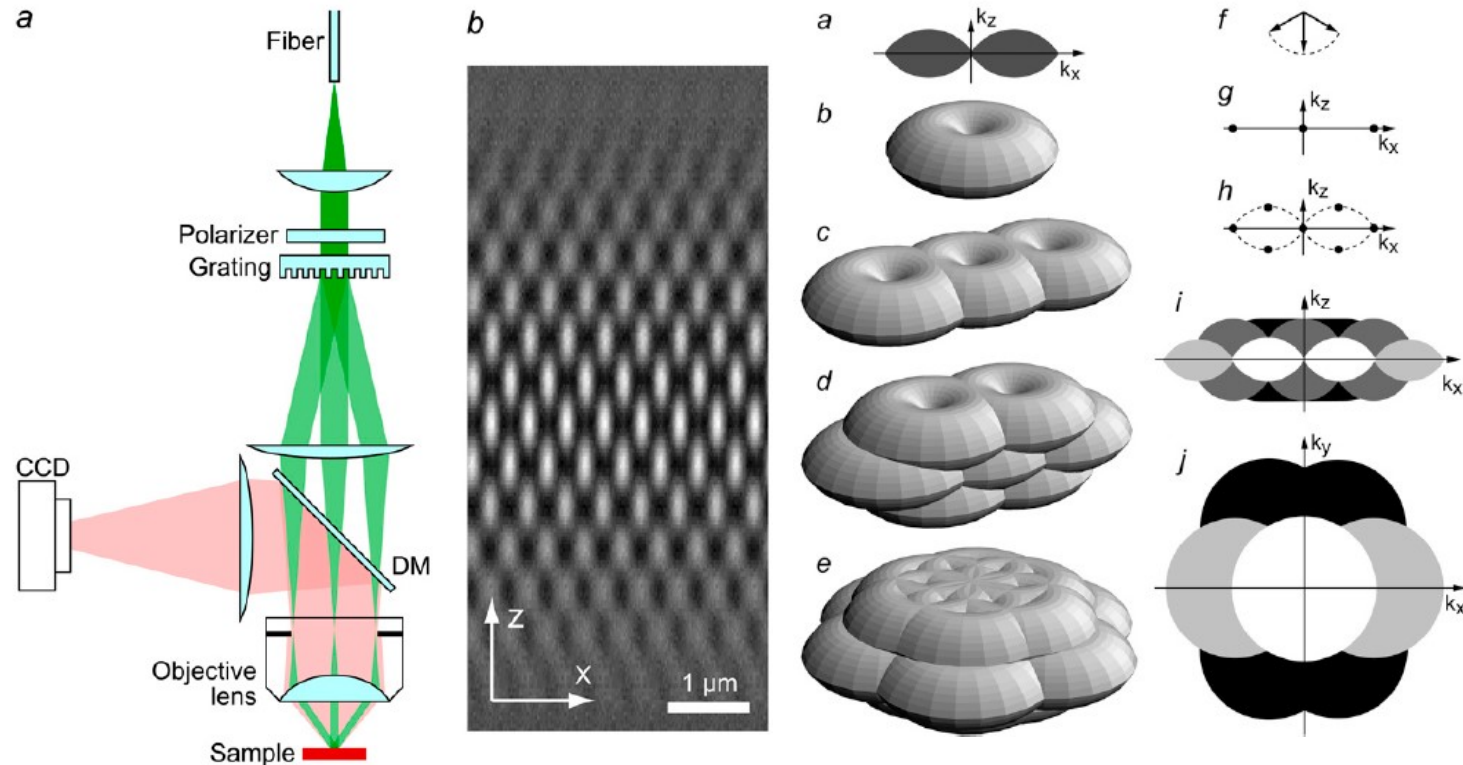


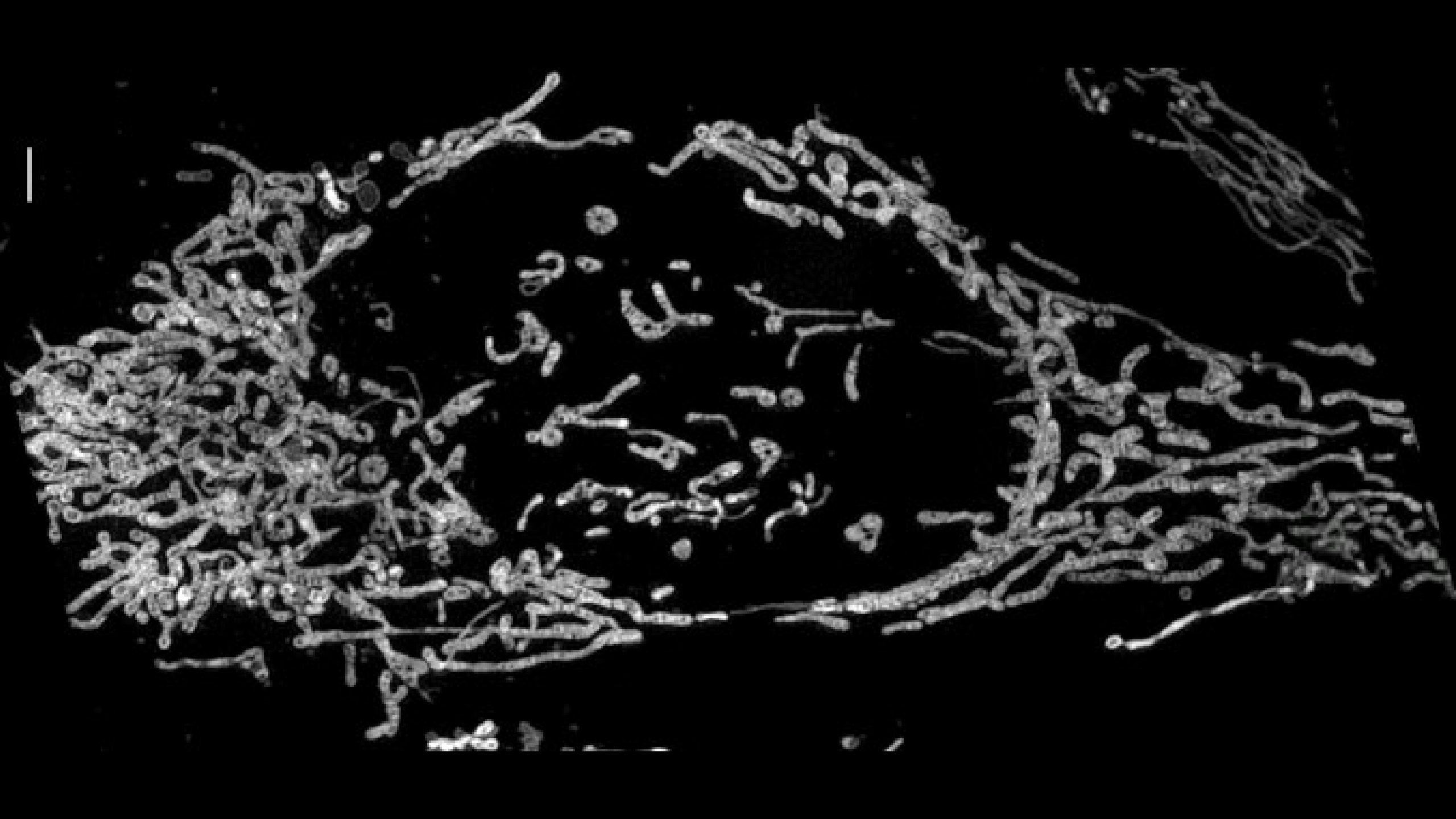
4  $\mu\text{m}$

## Three-Dimensional Resolution Doubling in Wide-Field Fluorescence Microscopy by Structured Illumination

Mats G. L. Gustafsson,<sup>\*</sup> Lin Shao,<sup>†</sup> Peter M. Carlton,<sup>†</sup> C. J. Rachel Wang,<sup>‡</sup> Inna N. Golubovskaya,<sup>‡</sup> W. Zacheus Cande,<sup>‡</sup> David A. Agard,<sup>†¶</sup> and John W. Sedat<sup>†</sup>

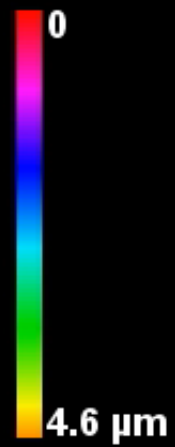
<sup>\*</sup>Department of Physiology and Program in Bioengineering, <sup>†</sup>The Keck Advanced Microscopy Laboratory and the Department of Biochemistry and Biophysics, University of California, San Francisco, California; <sup>‡</sup>Department of Molecular & Cell Biology, University of California, Berkeley, California; and <sup>¶</sup>Howard Hughes Medical Institute





Depth = 4.27  $\mu\text{m}$

3  $\mu\text{m}$



SD-SIM

*Z* axial position 0 ~ 0 ( $\mu\text{m}$ )

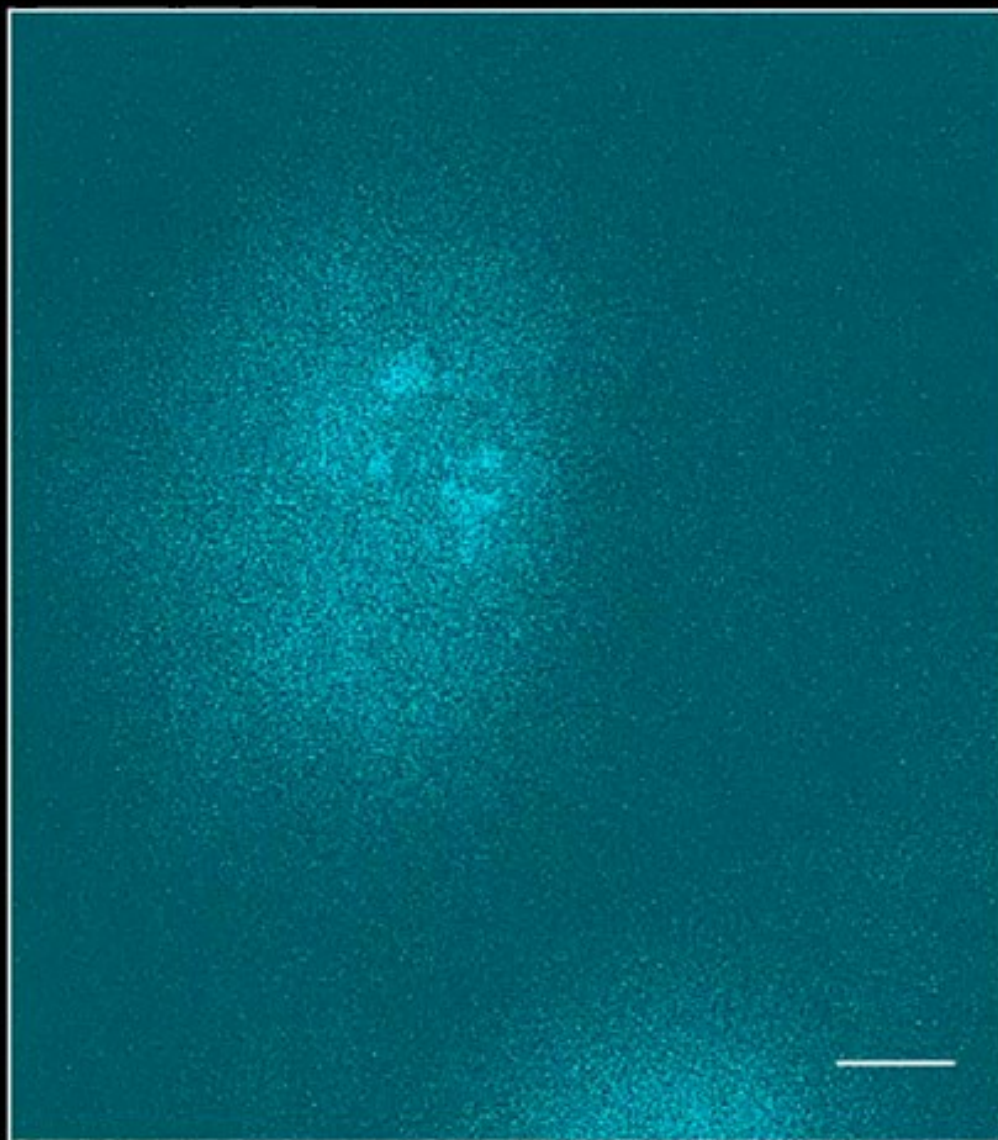
Sparse SD-SIM



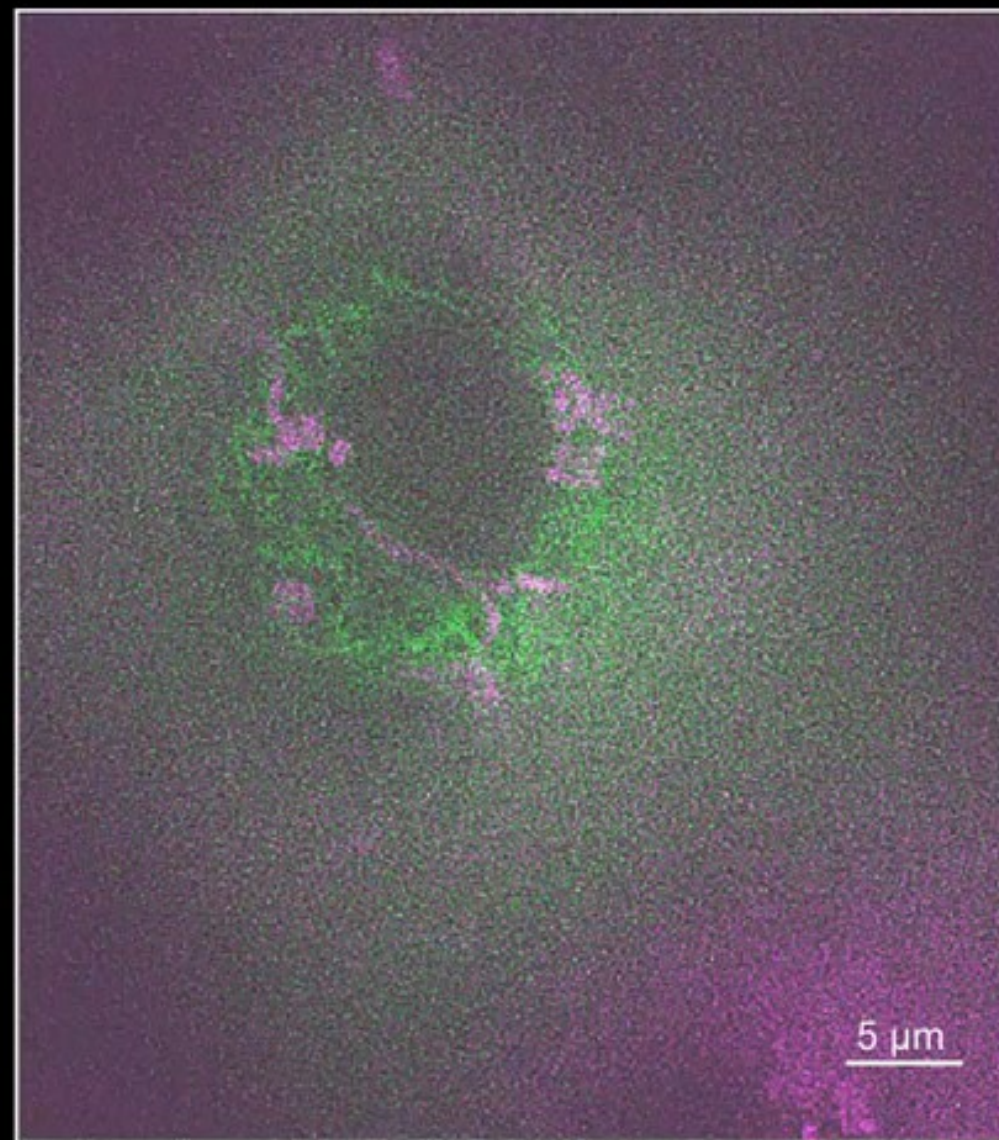
4  $\mu\text{m}$

分裂细胞

*Z axial position = 0 ( $\mu\text{m}$ )*

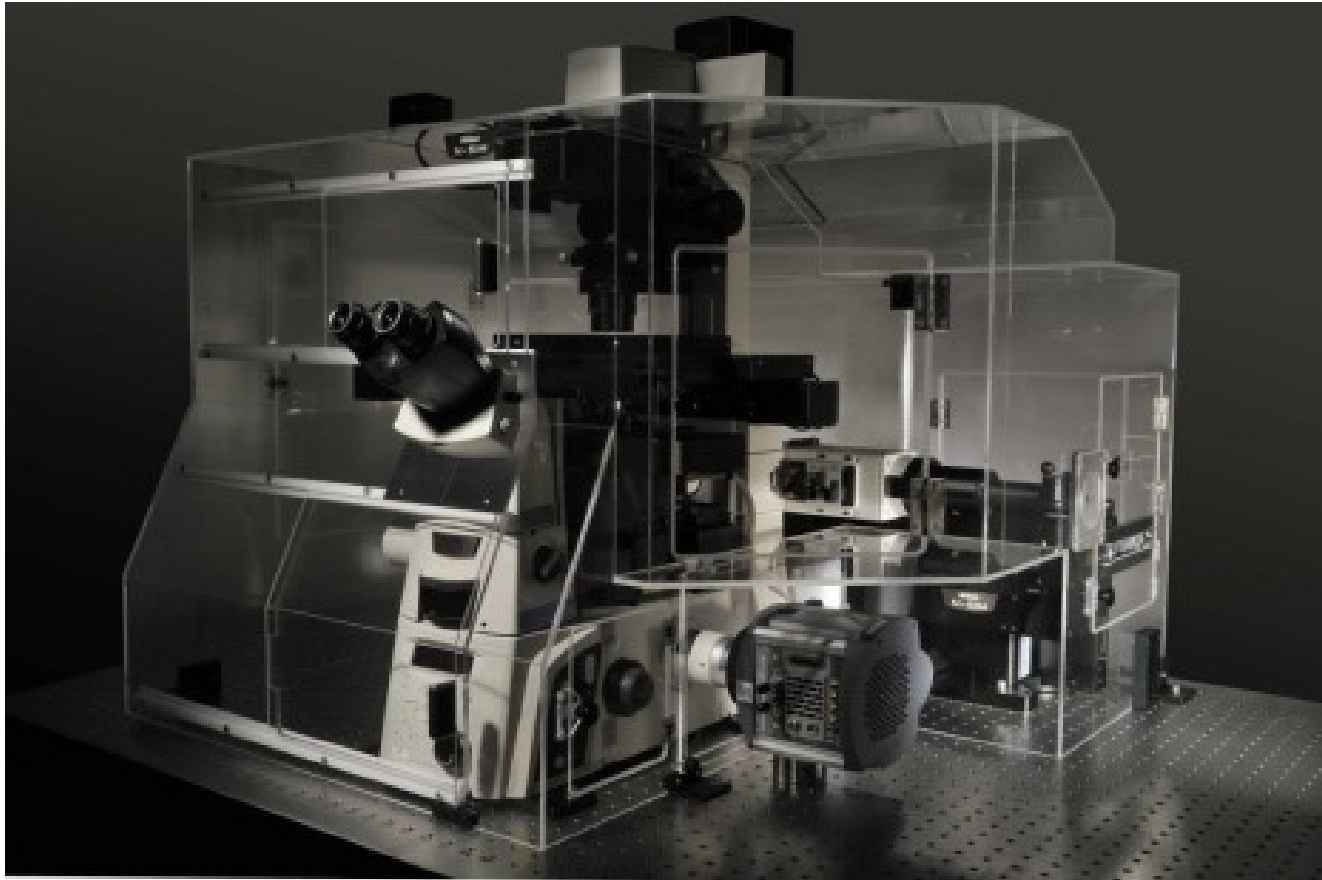


Nucleus



Mitochondria + Tubulin

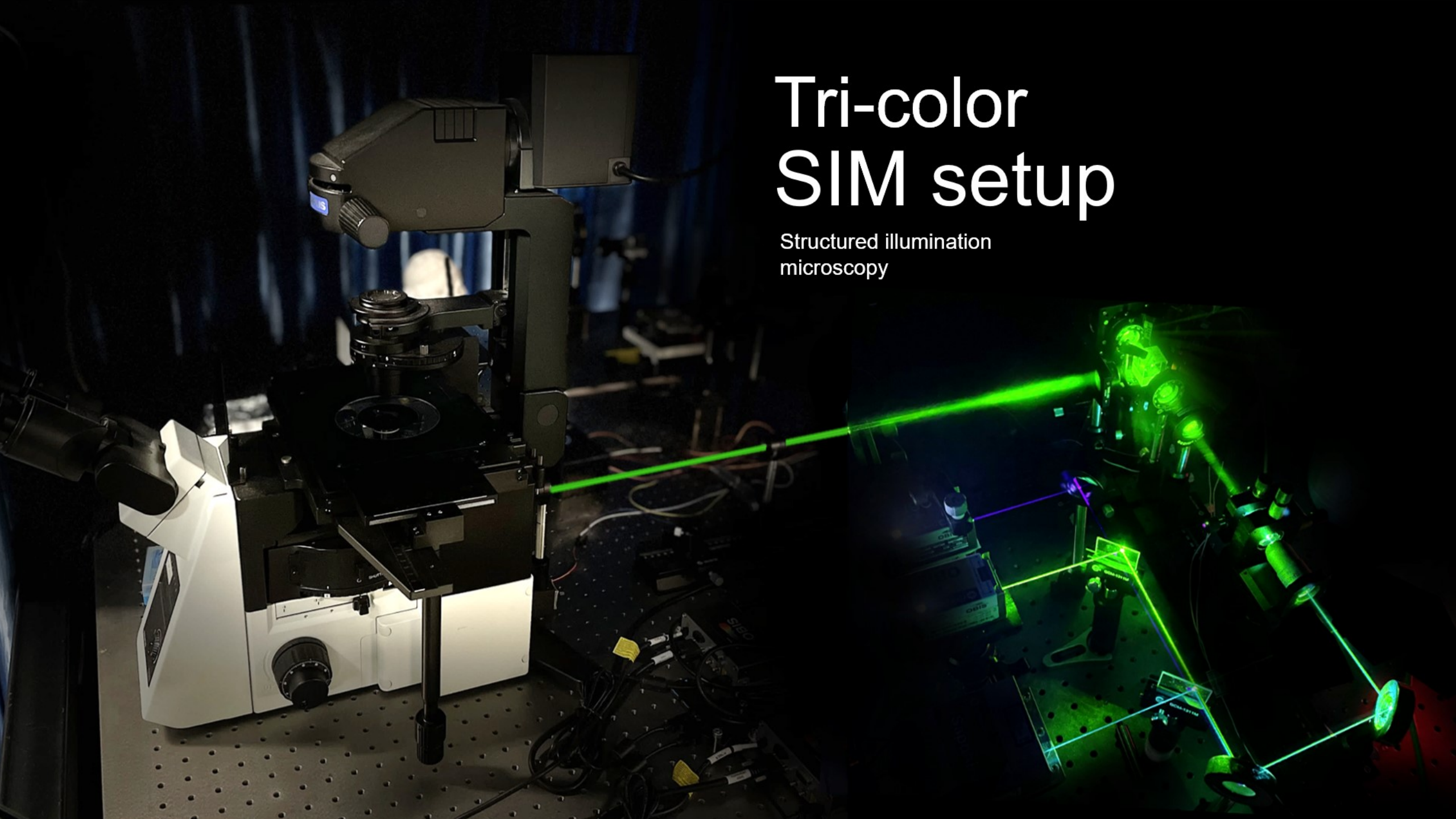
SD-SIM





# Tri-color SIM setup

Structured illumination  
microscopy

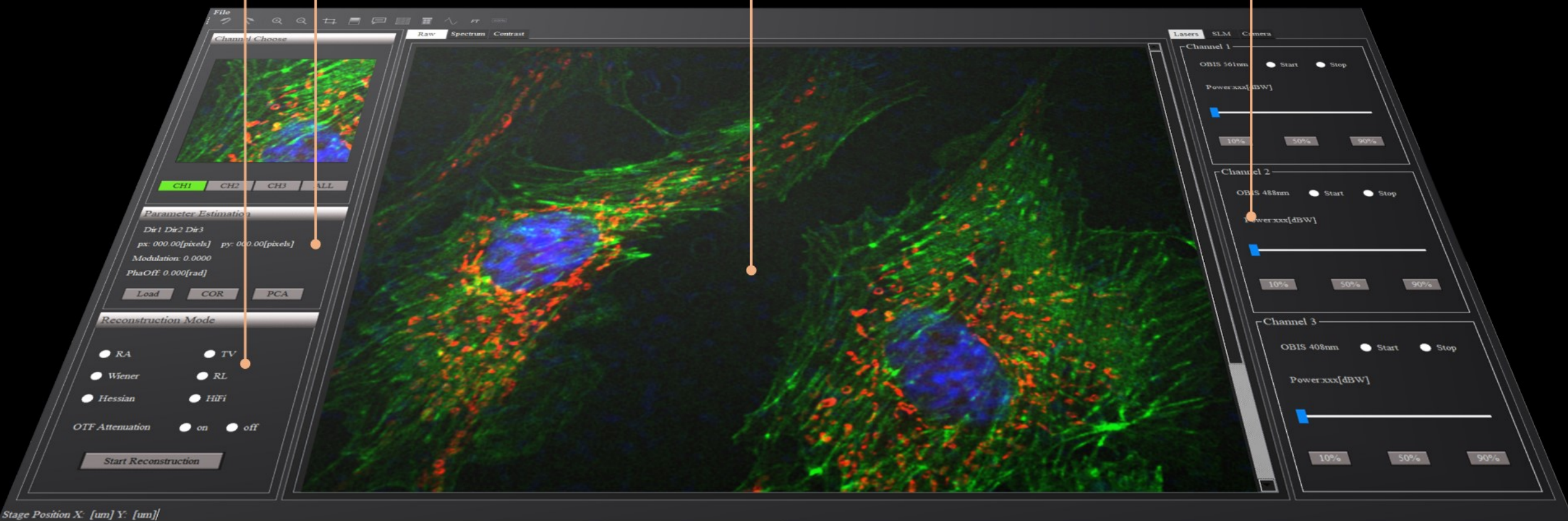


成像操作区

数据重建区

采集显示区

照明控制区



谢谢