Compressive fluorescence microscopy for biological and hyperspectral imaging

Vincent Studer et al.

PNAS. (2012.12)

Presenter : Eunseok Jung

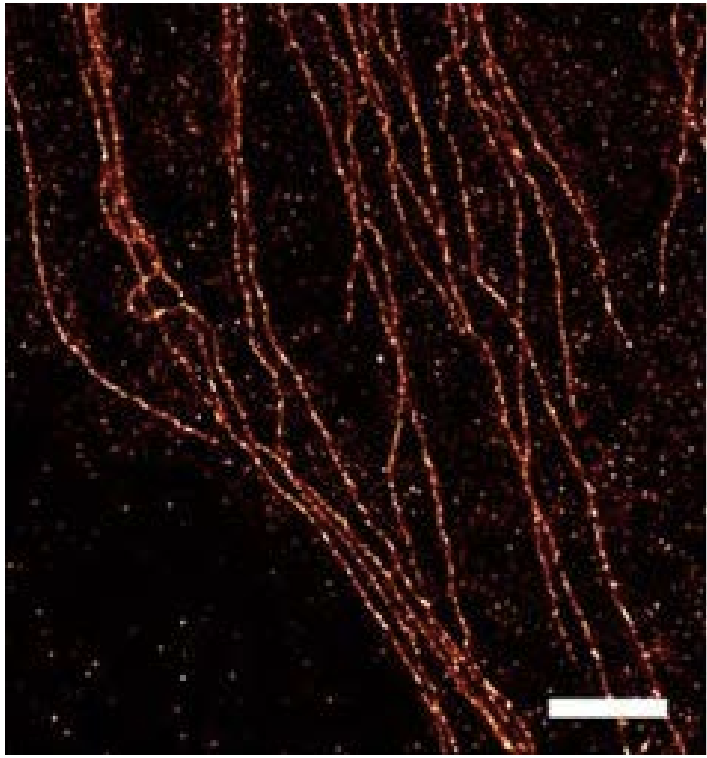
GIST, Dept. of Mechatronics , BiO-scopy Lab.

Gwangju Institute of Science and Technology

Background

- Fluorescence protein

  - Fluorescence microscopy use fluorescence protein.
  - Fluorescence protein can help to see molecule structure or phenomenon.



Cited form : http://huanglab.ucsf.edu, Wikipedia, http://www.microscopyu.com, http://smb.snu.ac.kr/tools_updating.htm

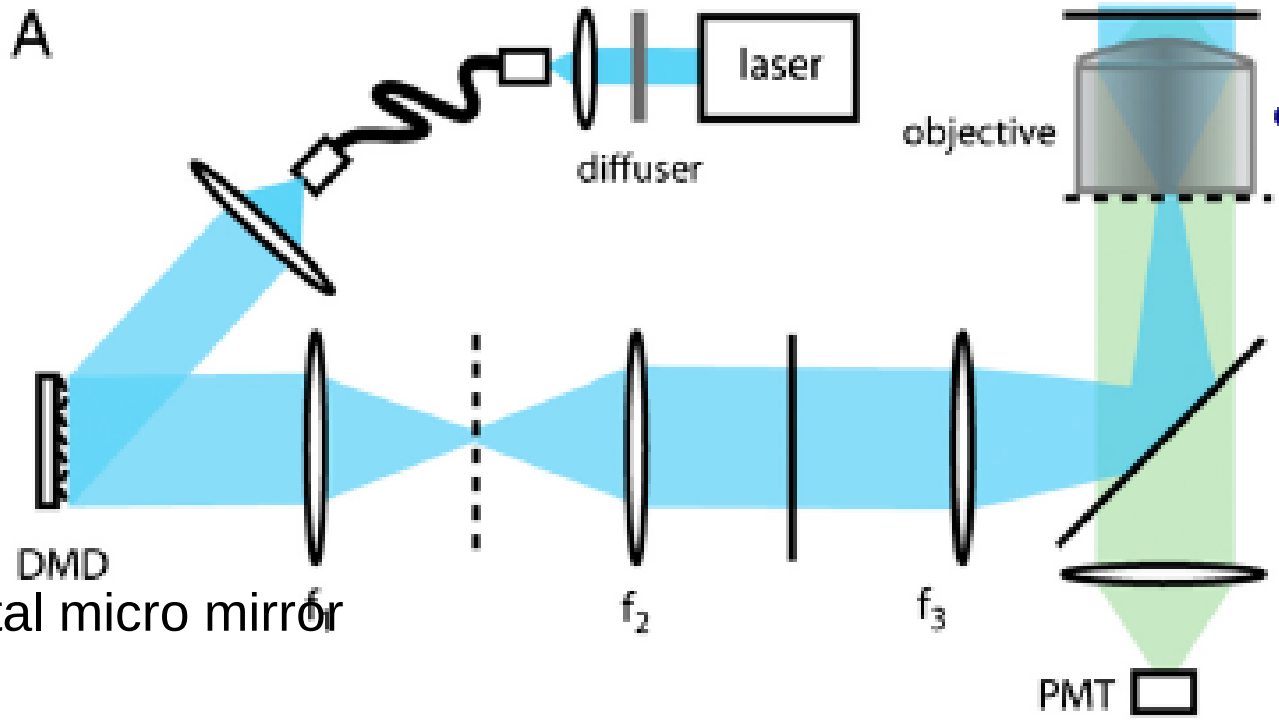
Introduction & Motivation

- CS algorithm make up fluorescence microscope major drawback

1. CS help to imaging in diffusing media.
2. CS can decrease experiment time.
3. If we use CS algorithm, it doesn't need expensive CCD camera.

From : Imaging Intracellular Fluorescent Proteins at Nanometer Resolution, E. Beitzig, science, 2006

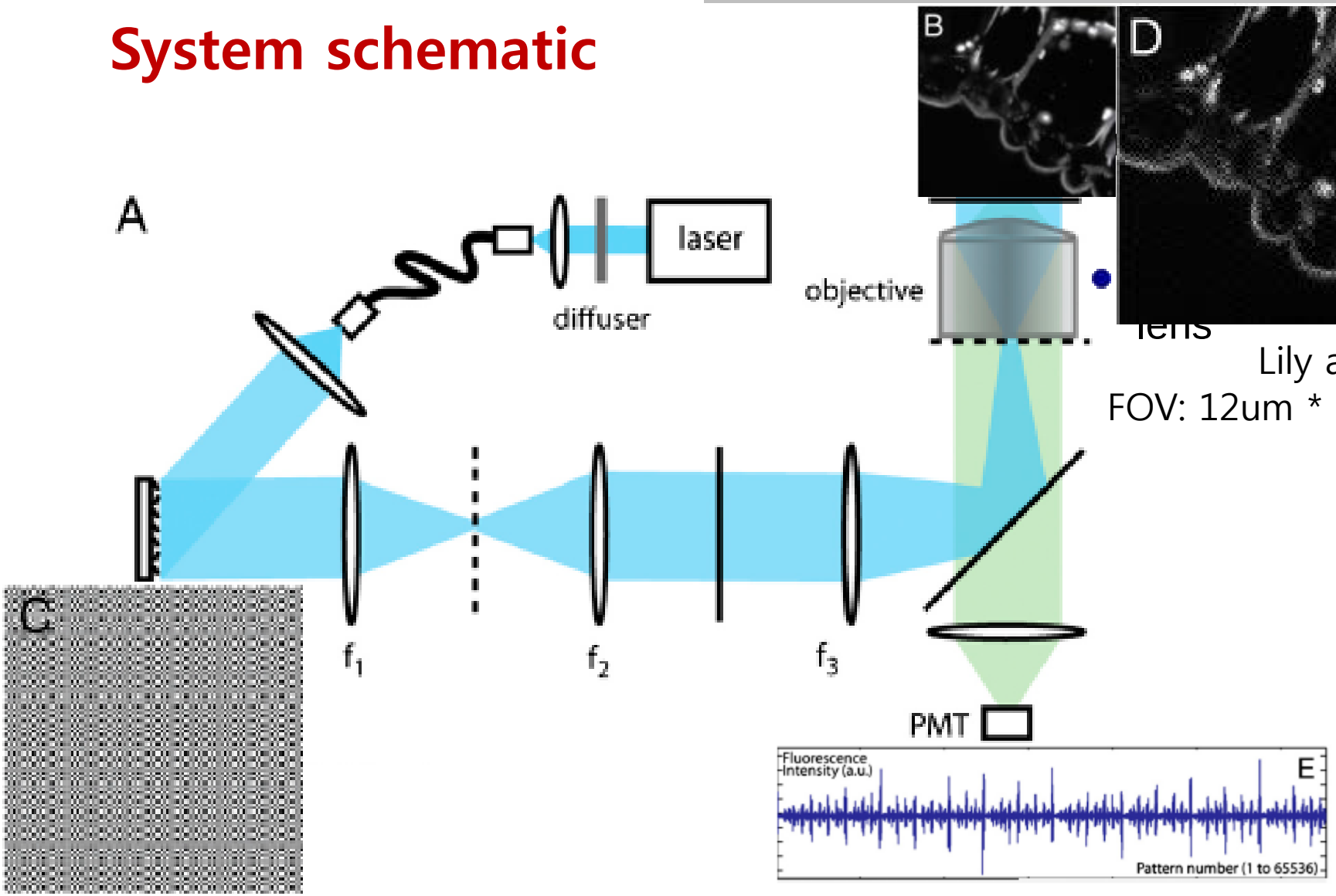
System schematic



- Sample plane
- 60x objective lens
- Digital micro mirror
- Photo multiplier tube(Detector)

From : Imaging Intracellular Fluorescent Proteins at Nanometer Resolution, E. Beitzig, science, 2006

System schematic



From : Imaging Intracellular Fluorescent Proteins at Nanometer Resolution, E. Beitzig, science, 2006

Reconstruction

$$\min_{\mathbf{x}\in\mathbb{R}^N} \|\mathbf{W}^T\mathbf{x}\|_{\ell_1} \text{ subject to } \|\mathbf{y}-\mathbf{\Phi}\mathbf{x}\|_{\ell_2} \leq \epsilon$$

- Recovering the signal x from acquired signal by solving the optimization problem.
- The acquired signal is noisy, it is better to relax the constraints into

$$\min_{\mathbf{x}\in\mathbb{R}^N} \|\mathbf{W}^T\mathbf{x}\|_{\ell_1} + \frac{\alpha}{2}\|\mathbf{y}-\mathbf{\Phi}\mathbf{x}\|_{\ell_2}^2$$

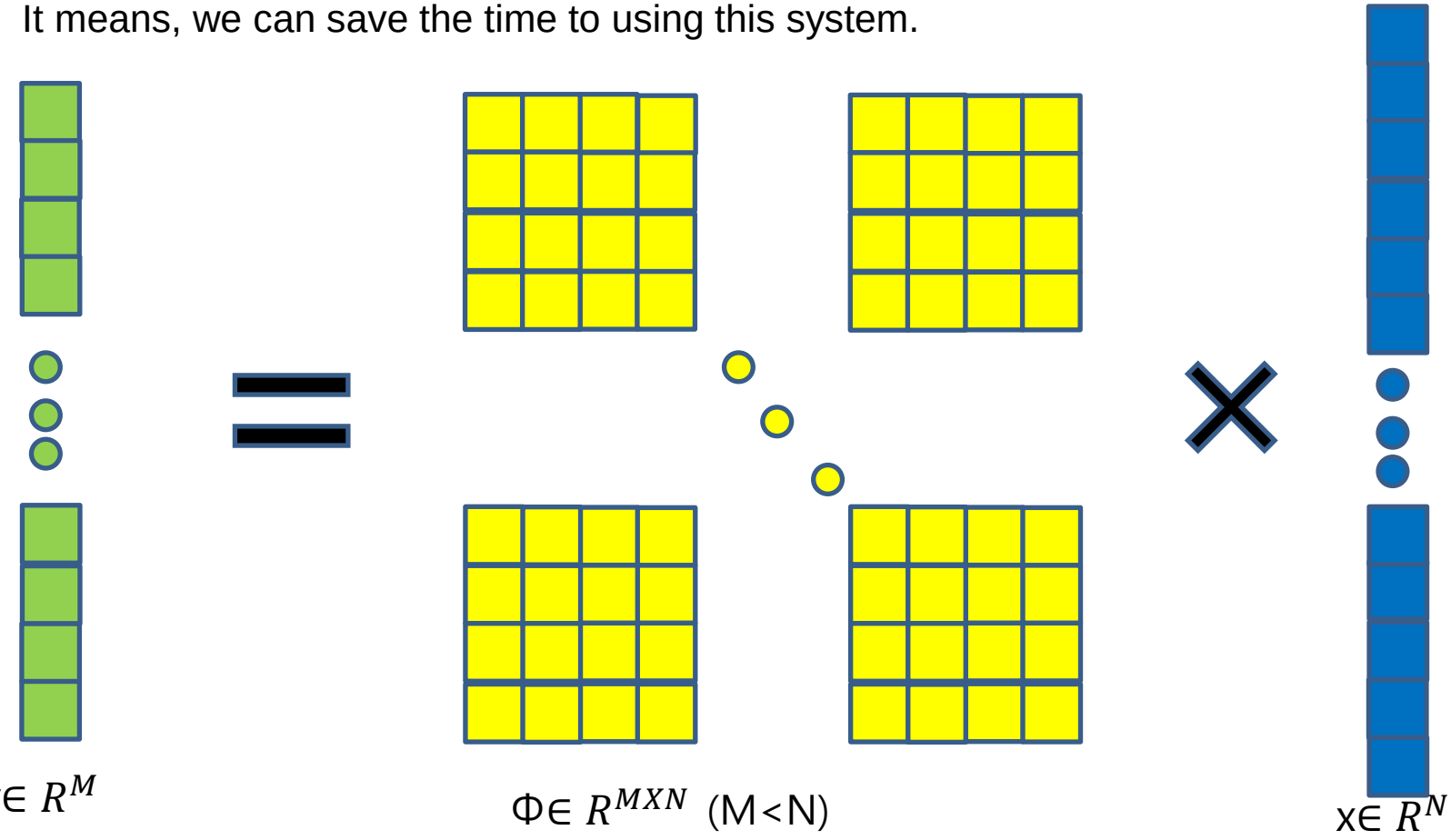
- **W** will be either an orthonormal basis(e.g., Dirac basis) or an overcomplete signal representation(e.g., undecimated wavelet frame or curvelet frame).
- $\alpha(\epsilon)$ is chosen empirically depending on the noise level.

Reconstruction

- M=N/Under sampling-ratio.
- Under sampling ratio = 8, 16, 32, 64,...

  => M=8192, 4096, 2048,…
- It means, we can save the time to using this system.

N=256*256,
It was fixed by pixel

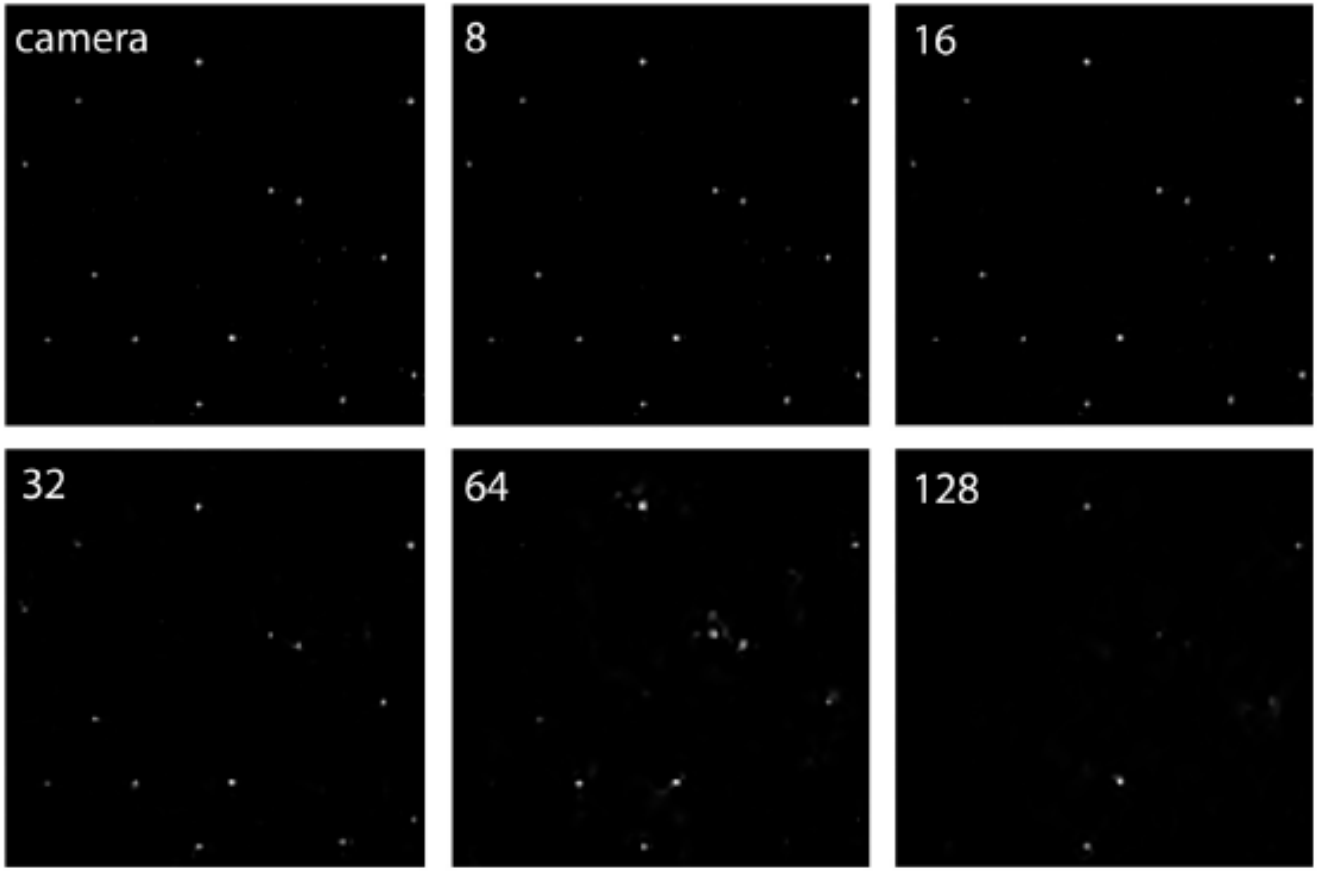


y∈ R^M

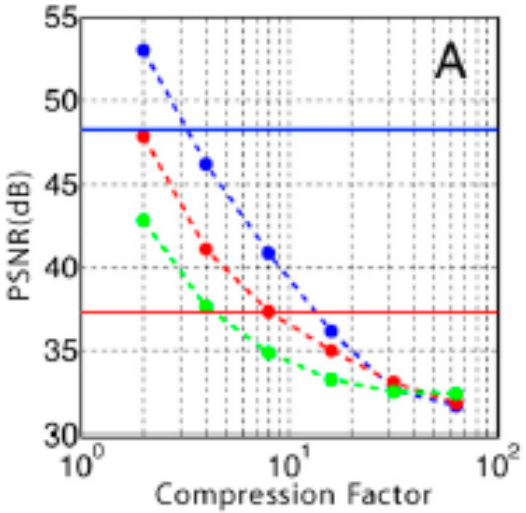
Φ∈ R^{MXN} (M<N)

x∈ R^N

Results

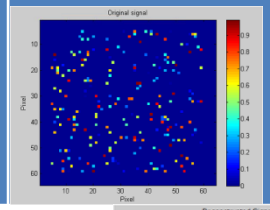
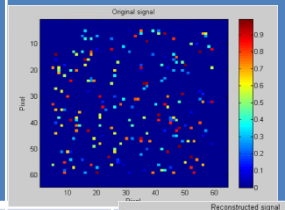
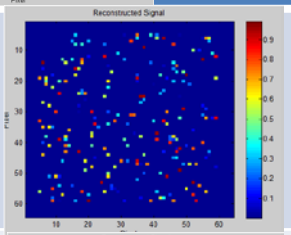
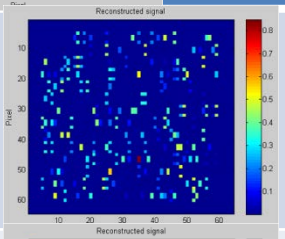
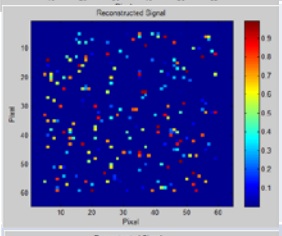
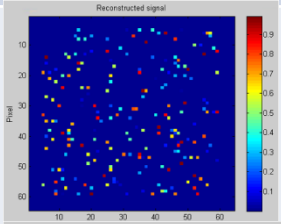
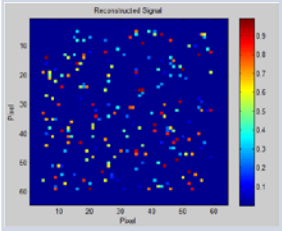
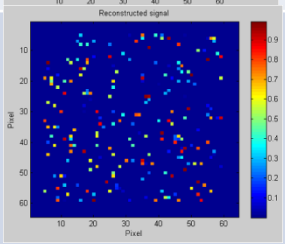
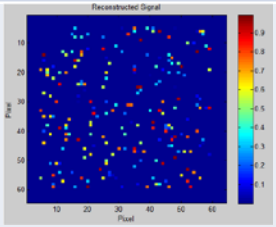
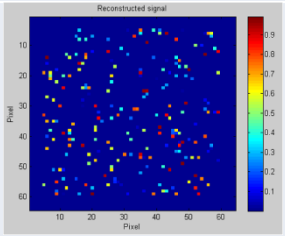


- Top left to bottom right: camera snapshot and reconstructed 256-by-256 bead images for values of the undersampling ratio equal to 8, 16, 32, 64, and 128.
- FOV: 6um * 6um



- Nominal illumination level(blue) and for the same level reduced by a factor 10(red) and a factor of 100(green). Solid lines correspond to the PSNR in raster scan for the same surfacic illumination(Blue: I, Red: I/10).

Simulation

		Random matrix		Hadamard matrix	
					
Rank : 1000	PSNR(dB)	78		20	
Rank : 2000	PSNR(dB)	87		31	
Rank : 3000	PSNR(dB)	88		96	
Rank : 4000	PSNR(dB)	90		96	

Discussion

- Conclusion

1. Reconstruct result is affected by measurement matrix.
   =>If we can make measurement matrix well, the reconstructed image will get high resolution image.

2. Fluorescence microscopy imaging is possible in diffusing media.

Thank you