Optical Instrumentation development:
Plenoptic cameras for denoising and optical systems for biology

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Outline

INFRARED PLENOPTICS CAMERAS

1A. Motivation 1: Plenoptic imaging systems (IR)
2A. Introduction: Plenoptic cameras
3A. Denoising by an Infrared plenoptic camera

OPTICAL TWEEZERS AND TRMFS

1A. Motivation 2: Measurement challenges in biology
2A. Introduction: Optical instrumentation for biology
3.A Dual Optical Trapping and TRMFS for RBC membrane fluctuation

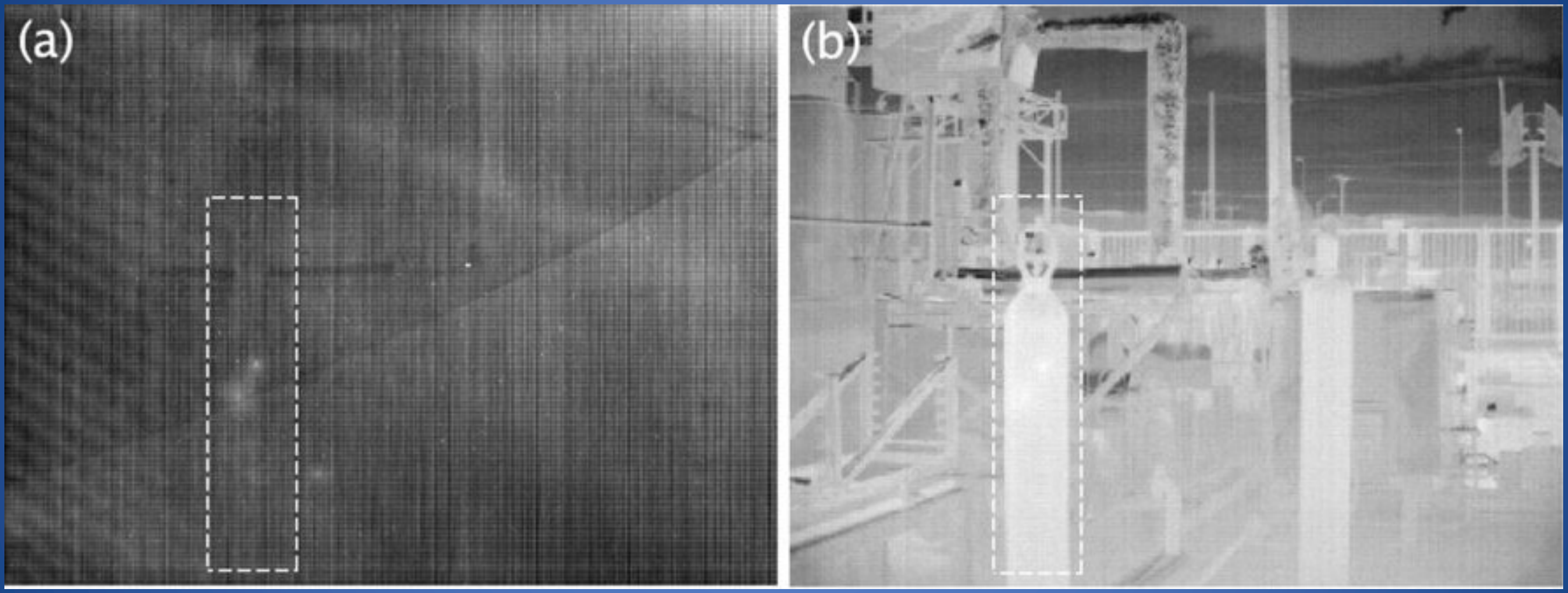
4. Conclusions and perspectives

INFRARED PLENOPTIC CAMERAS

1A. Motivation : Plenoptic imaging systems (IR)

Infrared image : Raw data

Corrected infrared image by traditional methods (linear correction)



Noisy infrared images:

- Low energy photons
- Defects in sensor manufacturing

Linear correction

We need precalibrate camera
We need to know response of sensor previously

2A. Introduction: Plenoptic cameras

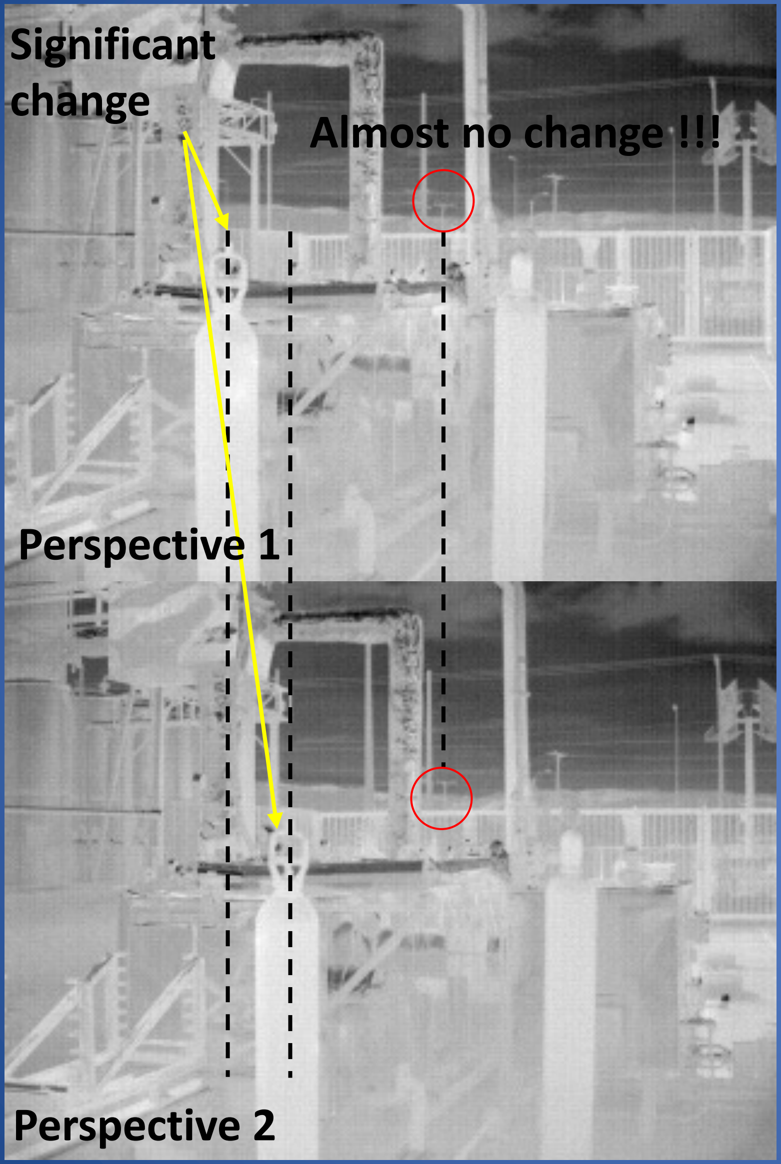
Matrix of images (L_f): Plenoptic Data or Light Field

Fourier Slice Photography Operator: Plenoptic algortihm

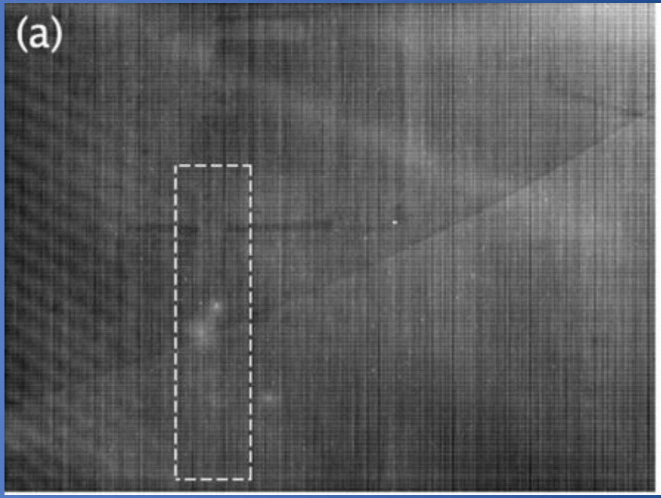
$$\mathcal{P}_\alpha[L_f] = \mathcal{F}^{-2} \circ \mathfrak{B}_\alpha \circ \mathcal{F}^{4}[L_f]$$

2A. Expected Result: Different objects plane in focus

3A. Denoising by an Infrared plenoptic camera



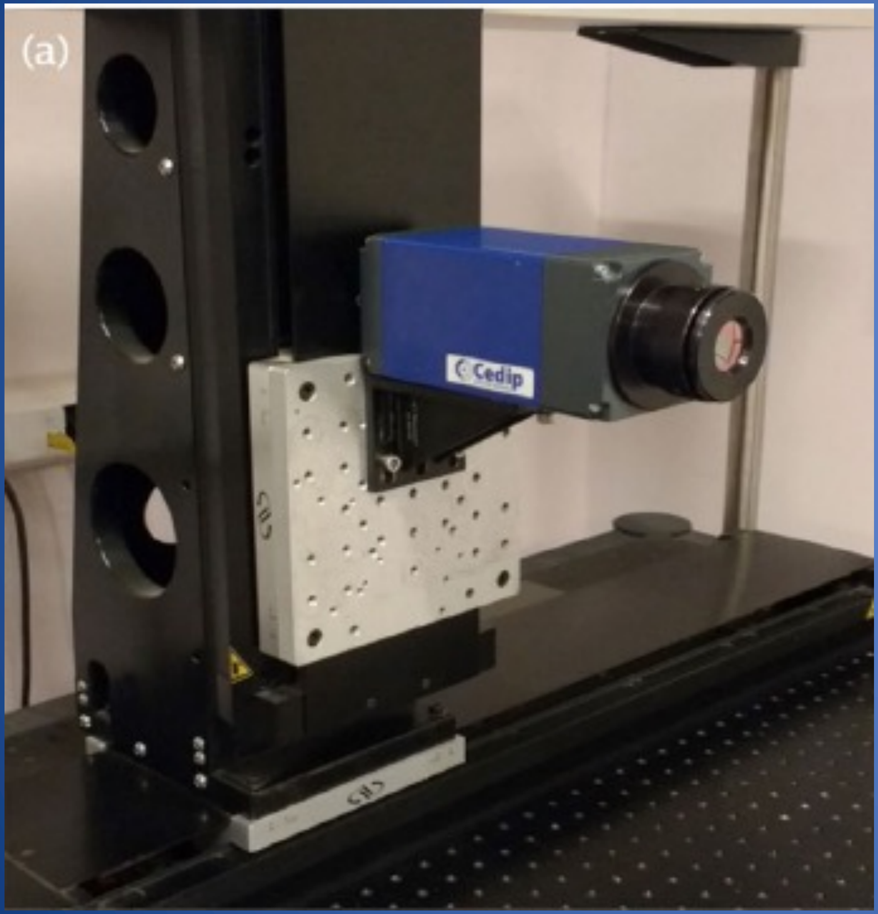
FPN no change from any perspective as object at infinity

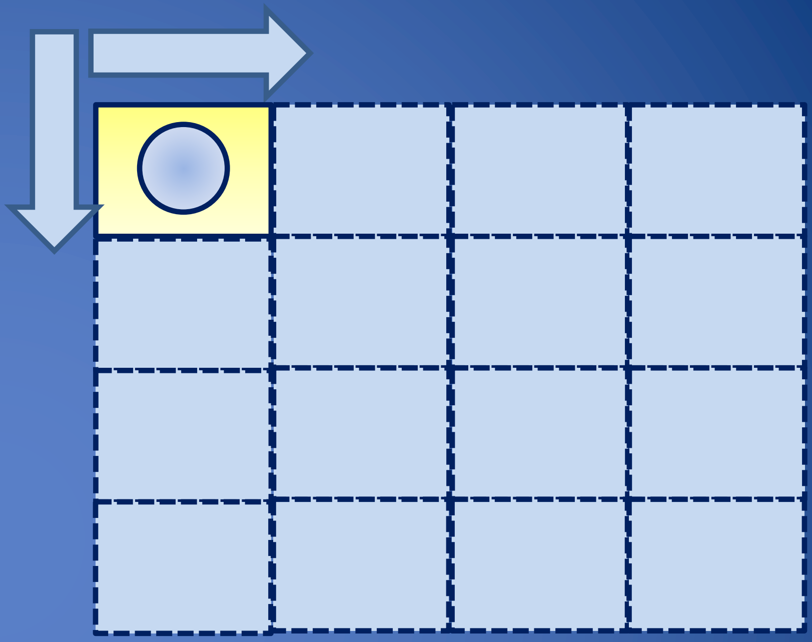


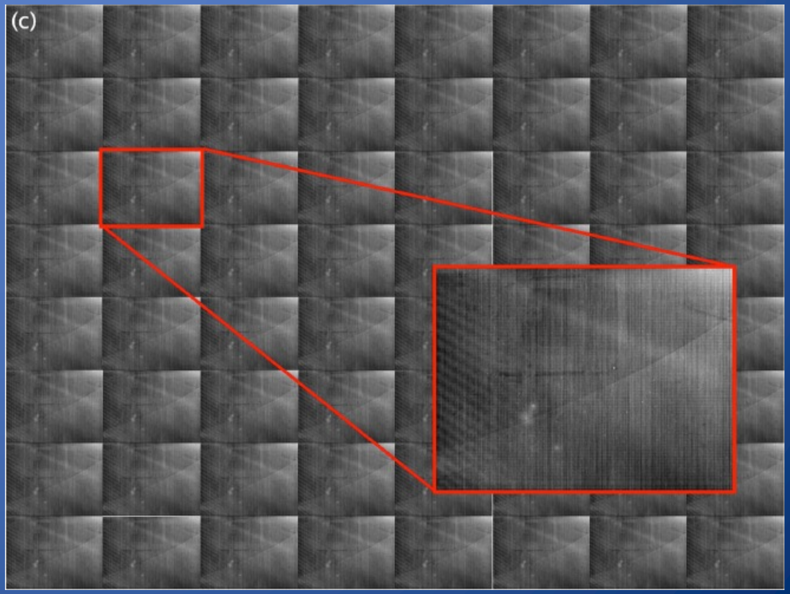
Under different perspectives, fixed pattern noise doesn't move between different perspectives ,hence, it behaves like an object in infinity

3A. Set-up: Infrared plenoptic camera

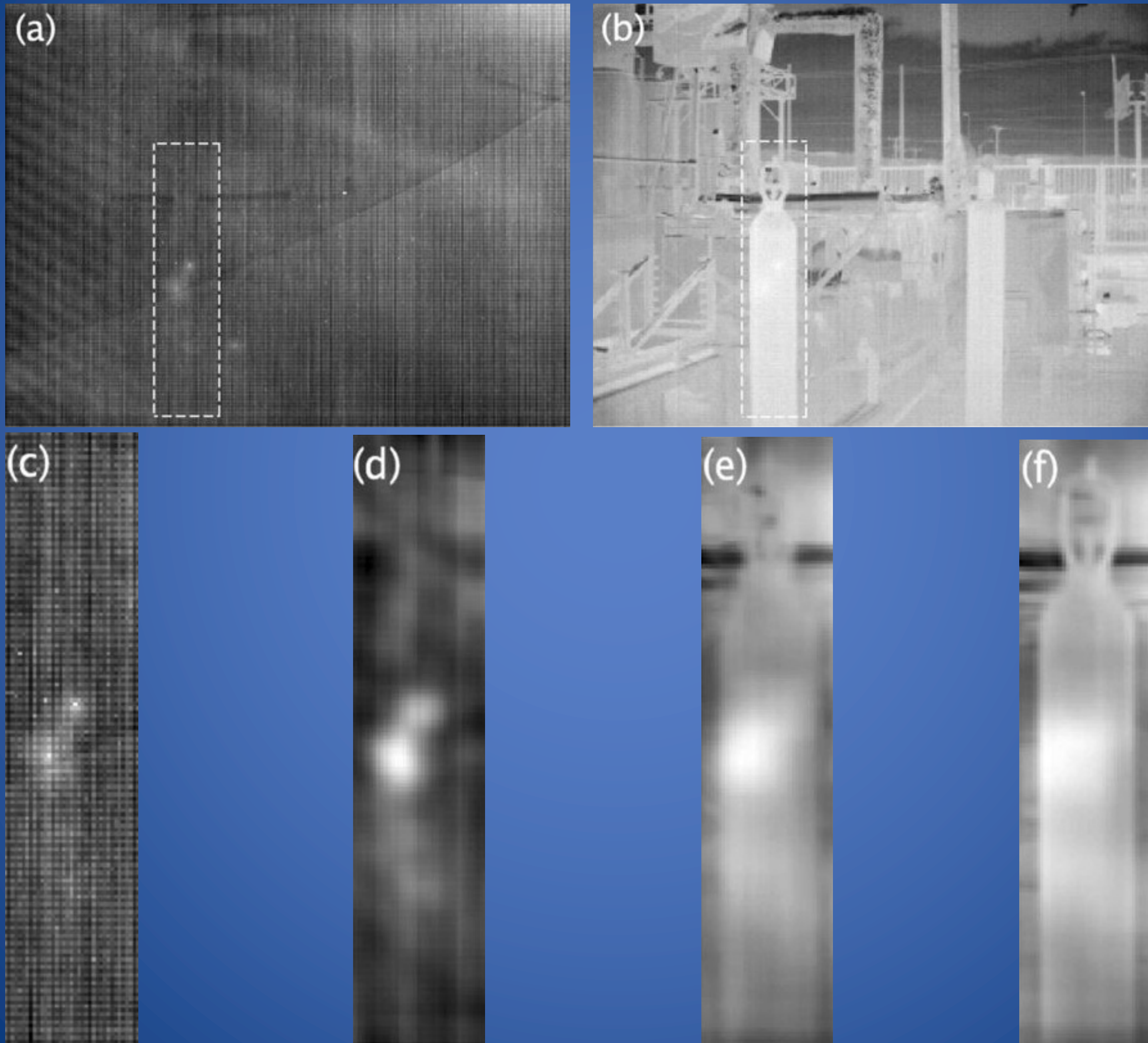
Acquisition Method







3A. RESULTS:

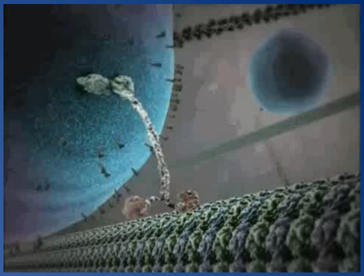


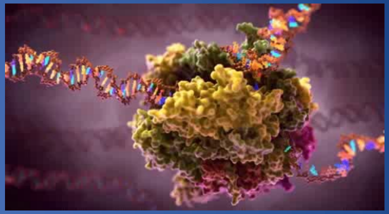
BIOLOGY

- Optical Tweezers
- Time resolve membrane fluctuation Spectroscopy

1B. Motivation: Measurement in biological systems

Proceso	Δx_{step} (nm)	Instrumentation	Ref.
Kinesin moves along microtubules	8.3 ± 0.2	Single OT	[1]
RNA polymerase (RNAP) moving in DNA transcription	0.37 ± 0.06	Dual OT	[2]
Red blood cells Membrane Fluctuation	34.0 ± 0.7	Single TRMFS	[3]





We need instrumentation with resolution as high as possible

- **Optical Tweezers**
  - **(OT)**

Time resolve membrane fluctution spectrocopy (TRMFS)

2B. Introduction: Optical instrumentation for biology

DUAL OPTICAL TRAP

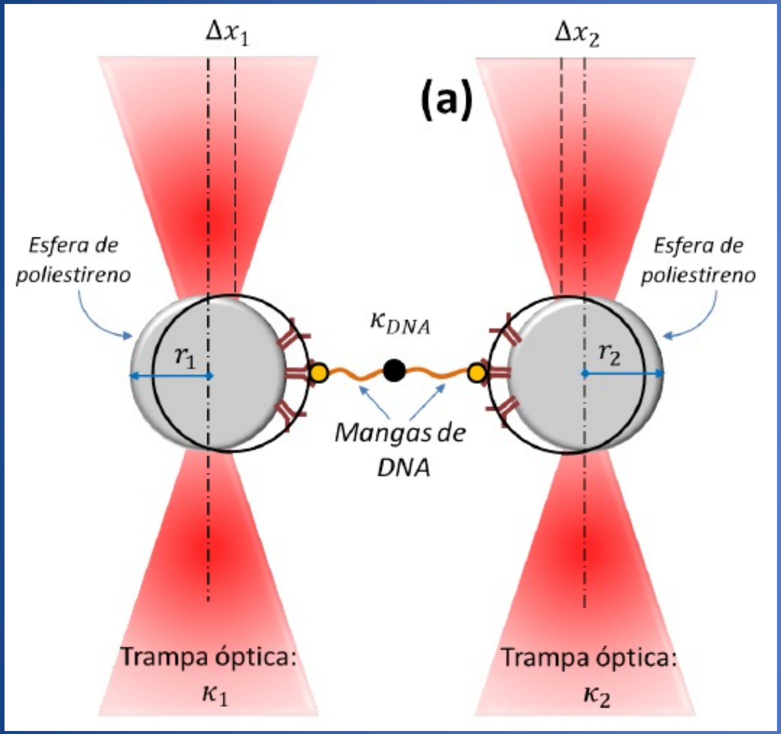


Figura 4. Dual Optical Trap.

$x_- = x_1 - x_2$ **Differential coordinate**

***SNR* de coordenada diferencial**

$$SNR_{diff} = \frac{\langle \Delta x_- \rangle}{\langle x_-^2 \rangle_B}$$

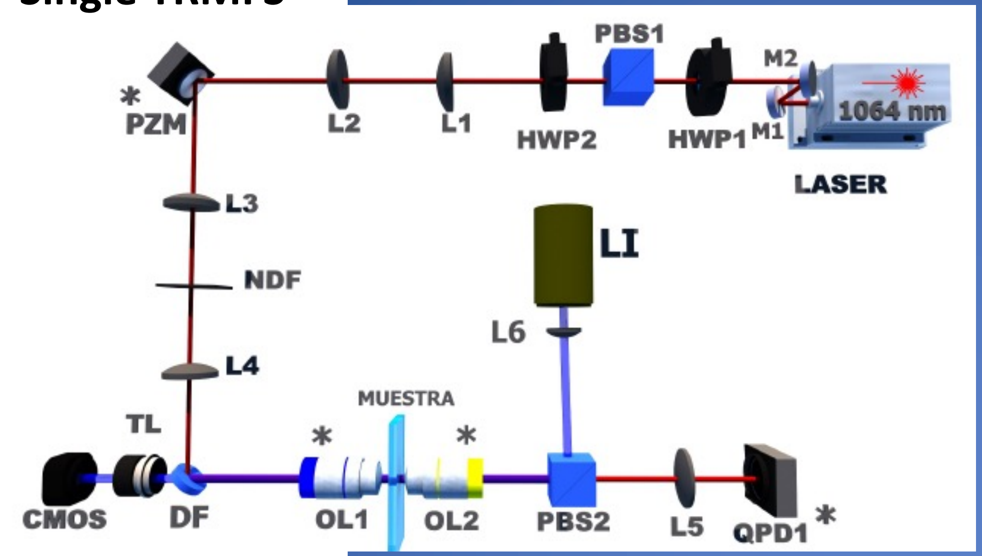
$$\langle \Delta x_- \rangle = \langle \Delta x_1 \rangle - \langle \Delta x_2 \rangle$$

$$\langle x_-^2 \rangle_B = \langle x_1^2 \rangle_B + \langle x_2^2 \rangle_B - 2\langle x_1 x_2 \rangle_B$$

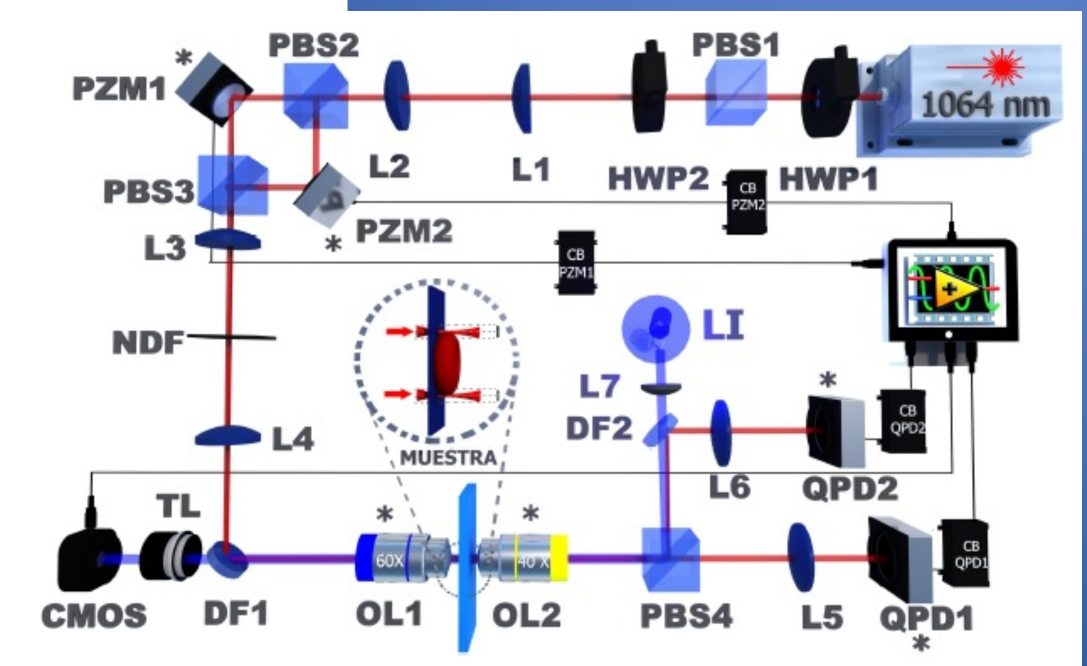
Positive correlation

2B. TIME RESOLVE MEMBRANE FLUCTUATION SPETROSCOPY (TRMFS)

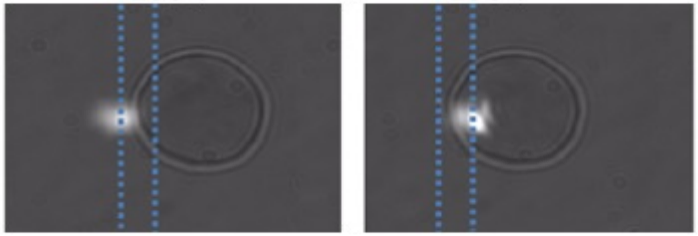
Single TRMFS



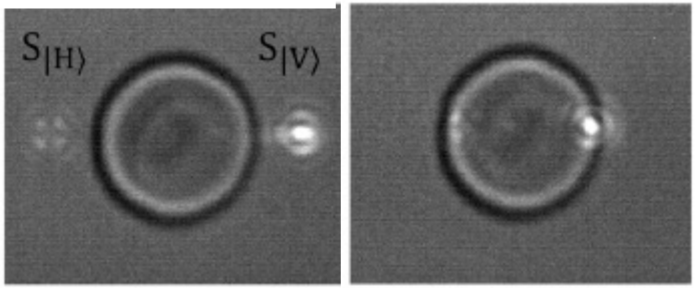
Dual TRMFS



Single TRMFS



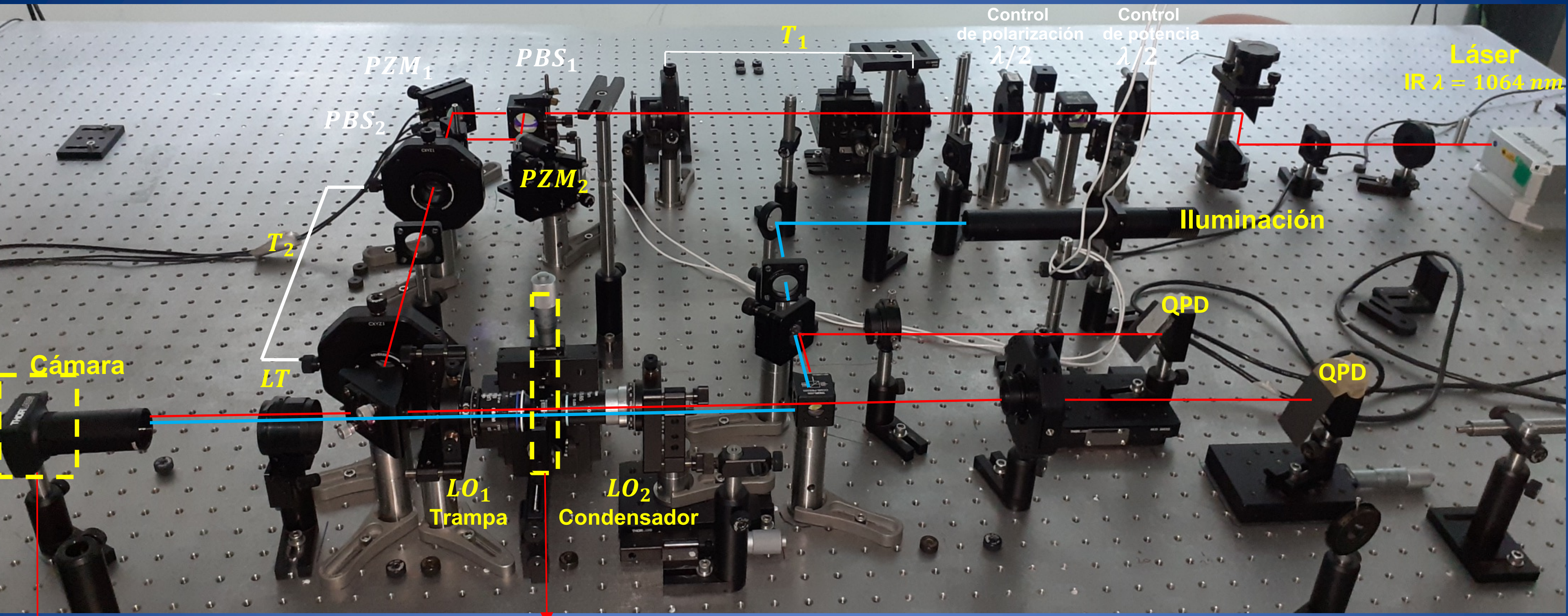
Dual TRMFS

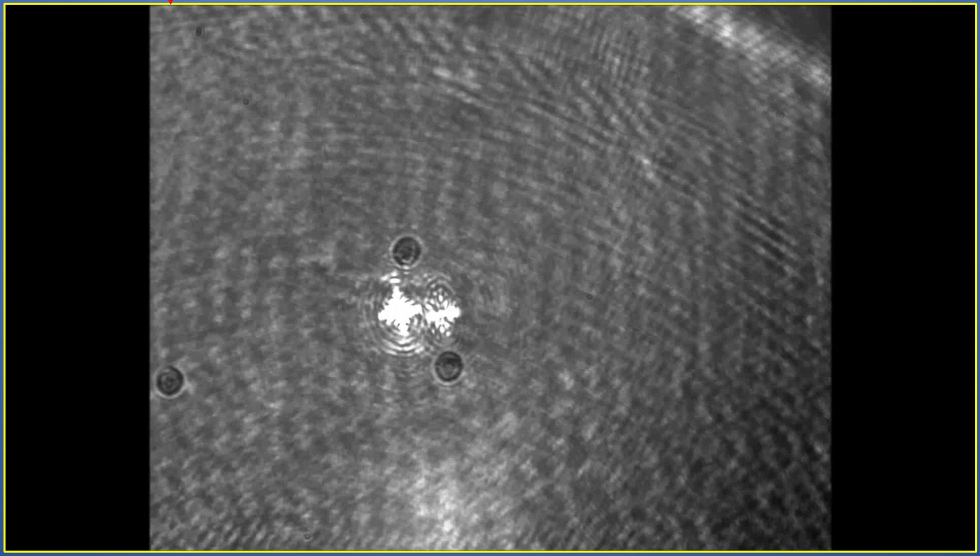


$$\mathrm{PSD}_{\omega\to 0} = \frac{k_B T}{2\sigma\omega} = \frac{k_B T}{2\sigma(2\pi f)},$$

$$\mathrm{PSD}_{\omega\to\infty} = \frac{k_B T}{6\pi(2\eta^2\kappa)^{1/3}\omega^{5/3}} = \frac{k_B T}{6\pi(2\eta^2\kappa)^{1/3}(2\pi f)^{5/3}}.$$

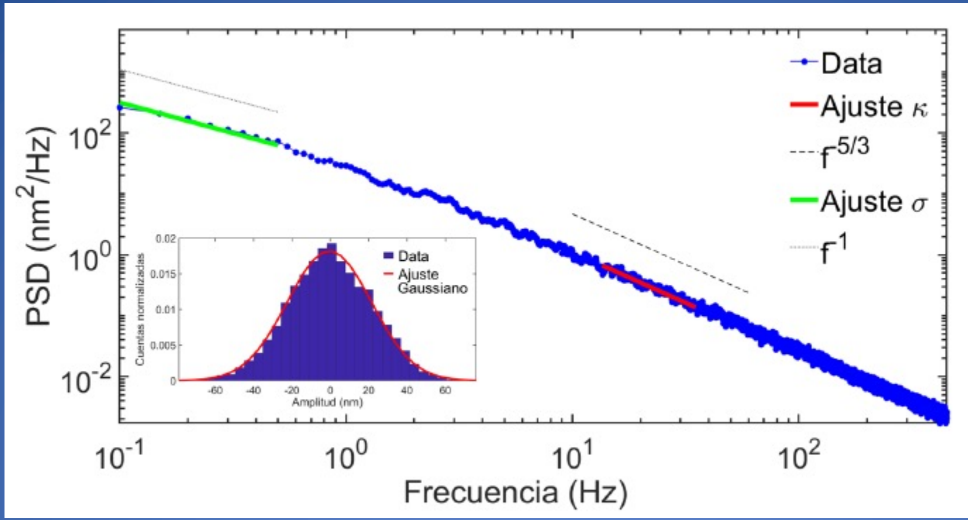
3B. RESULTS: DUAL OPTICAL TWEEZERS:





Sample plane

3B. RESULTS: Single and dual TRMFS:



Research on **resveratrol** protective effects

	Control	HClO	RV	RV + HClO
STD (nm)	28.6 ± 2.6	18.6 ± 1.7	29.6 ± 2.5	21.7 ± 1.4
κ (10^{-19} J)	2.2 ± 0.4	3.6 ± 0.5	1.2 ± 0.3	2.9 ± 0.6
η_{eff} (10^{-3} Pa $\times$ s)	86.3 ± 0.8	85.1 ± 0.9	85.9 ± 1.0	83.1 ± 1.1

Research on Different **Glucose** Concentratios

Señal	Parámetro	5.5 mM	12.5 mM	25 mM
$S_{\vert V\rangle}$	Amplitud (nm)	24.66 ± 0.38	27.50 ± 0.49	27.68 ± 0.55
	κ (10^{-19} J)	9.79 ± 0.78	6.75 ± 0.59	5.87 ± 0.63
	σ (10^{-6} N/m)	11.85 ± 0.55	9.05 ± 0.39	9.35 ± 0.50
$S_{\vert H\rangle}$	Amplitud (nm)	26.81 ± 0.35	28.69 ± 0.46	28.25 ± 0.52
	κ(10^{-19} J)	7.07 ± 0.52	6.40 ± 0.61	5.33 ± 0.44
	σ (10^{-6} N/m)	9.89 ± 0.51	8.36 ± 0.39	9.11 ± 0.50

Related publications and productivity

Publication 1

Coelho, P. A., Tapia, J. E., Perez, F., Torres, S. N., & Saavedra, C. (2017). Infrared light field imaging system free of fixed-pattern noise. Scientific reports, 7(1), 13040. doi.org/10.1038/s41598-017-13595-7

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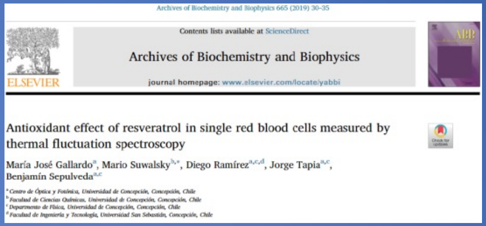
SCIENTIFIC REPORTS

OPEN **Infrared light field imaging system free of fixed-pattern noise**

Pablo A. Coelho[1,2], Jorge E. Tapia[2,3], Francisco Pérez[1], Sergio N. Torres[1,2] & Carlos Saavedra[2,3]

Publication 2

Gallardo, M. J., Suwalsky, M., Ramírez, D., Tapia, J., & Sepulveda, B. (2019). Antioxidant effect of resveratrol in single red blood cells measured by thermal fluctuation spectroscopy. *Archives of biochemistry and biophysics*, *665*, 30-35. doi.org/10.1016/j.abb.2019.02.011



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Antioxidant effect of resveratrol in single red blood cells measured by thermal fluctuation spectroscopy

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Publication 3

Tapia, J., Vera, N., Aguilar, J., González, M., Sánchez, S. A., Coelho, P., ... & Staforelli, J. (2021). Correlated flickering of erythrocytes membrane observed with dual time resolved membrane fluctuation spectroscopy under different D-glucose concentrations. Scientific reports, 11(1), 1-12.

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Correlated flickering of erythrocytes membrane observed with dual time resolved membrane fluctuation spectroscopy under different D-glucose concentrations

J. Tapia, N. Vera, Joao Aguilar, M. González, S. A. Sánchez, P. Coelho, C. Saavedra & J. Staforelli

Scientific Reports **11**, Article number: 2429 (2021) | Cite this article

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Patent 1: US

RUBILAR, C. S., INOSTROZA, S. N. T., CARO, P. A. C., FARIAS, J. E. T., & VENEGAS, F. G. P. (2021). *U.S. Patent No. 10,891,716*. Washington, DC: U.S. Patent and Trademark Office.

Patent 2: INAPI, Chile

Saavedra, C., Torres, S., Coelho, P., Tapia, J., & Pérez, F. (2018). Un proceso que permite eliminar el ruido de patrón fijo en imágenes efectivas formadas por arreglos de sensores electromagnéticos en un campo de luz mediante un reenfoque digital. N° de Patente: 55615. Chile; Instituto Nacional de Propiedad Industrial (INAPI).

4. Conclusions and perspectives

IR Plenoptics cameras could be an relevant alternative to decrease its cost of calibration and make easier this process

Dual TRMFS must to be studied deeper in terms of correlation and the possible improvements of spatial resolution applied to fluctuation measurements.

THANKS
TO EVERYONE