# Pixel-level 3D nanophotonic structures for multi-modality image sensors. Regular single-investigator grant, EECS-1807590

Euan McLeod, College of Optical Sciences, University of Arizona, Tucson, AZ. December 6 & 7, 2018

euanmc@optics.arizona.edu, https://wp.optics.arizona.edu/emcleod

## Soft Nano-Photonic Systems Laboratory

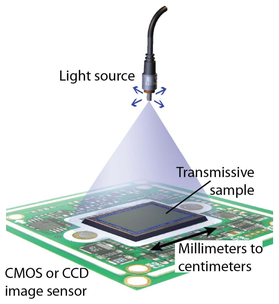
### Broad areas of research

- Soft Matter
  - Liquids
  - Polymers
  - Biological materials
  - Surface forces
  - Biochemical interactions
  - Material transport
- Nano-photonics
  - Resolution beyond $\lambda/2$
  - Optical sensing of nano-objects
  - Optical nanofabrication
  - Optical properties of subwavelength structures
- Systems of nanoparticles
  - Coordinated interaction of many components
  - Self assembly
  - Directed assembly
  - Stochastic interactions

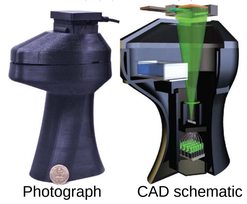
### Lensfree holographic microscopy

#### Environmental sensing

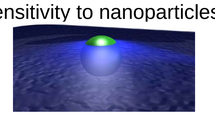
Computational reconstruction of diffraction patterns for ultra-large field of view imaging with sub-micron resolution:



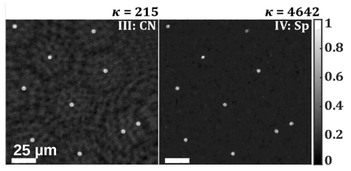

Field-portable nanosensing devices:




Liquid nanolenses boost sensitivity to nanoparticles:



Specialized algorithms for reconstructing sparse samples with high signal-to-noise ratio:

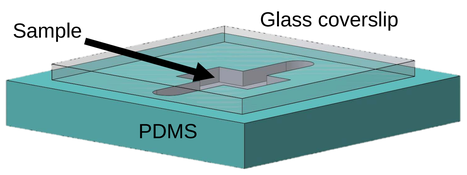



E. McLeod, T. U. Dincer, M. Veli, Y. N. Ertas, C. Nguyen, W. Luo, A. Greenbaum, A. Feizi, and A. Ozcan, *ACS Nano*, **9** (3), 3265-3273 (2015).

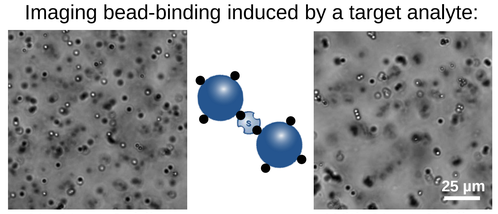
Z. Xiong, J. E. Melzer, J. Garan, and E. McLeod, *Opt. Express,* **26**, 25676- 25692 (2018).

#### Quantitative Large-Area Biosensing

Lensfree imaging of microfluidic chips:



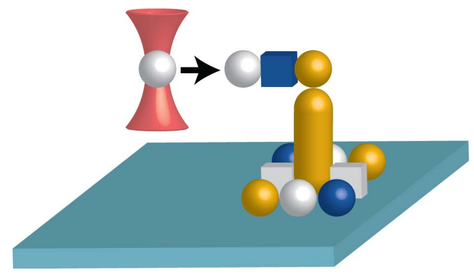

Imaging bead-binding induced by a target analyte:



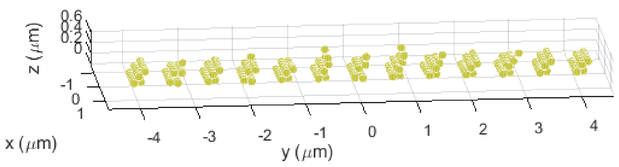

No NeutrAvidin | With NeutrAvidin

### Optical positioning and linking

#### 3D multi-material nanofabrication



#### Design through optimal positioning




## High-speed optical tweezers

Particles are lost from the trap once the Stokes' drag force exceeds the maximum optical force.

Rayleigh regime:

$$\langle \vec{F} \rangle = \varepsilon_b \frac{\alpha'}{2} \sum_i \mathrm{Re}\{E_i^* \nabla E_i\} + \varepsilon_b \frac{\alpha''}{2} \sum_i \mathrm{Im}\{E_i^* \nabla E_i\}$$

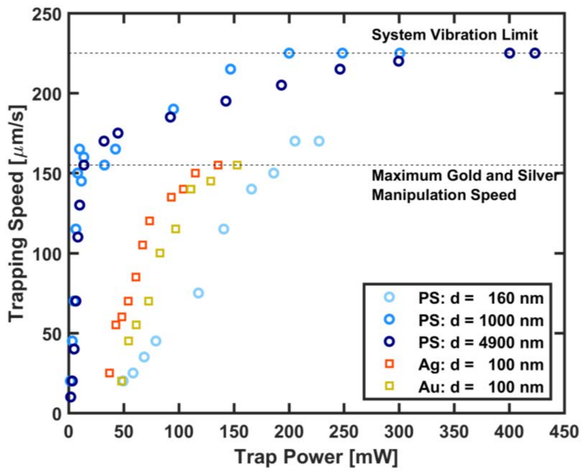
$\alpha = \alpha' + i\,\alpha''$ = Particle polarizability

Gradient force

Scattering force

$$F_{drag} = 3\pi\eta d v$$

Viscosity, Particle diameter, Velocity




- **Long distance manipulation (0.1–1 mm)**
- **Particularly high nanoparticle optical trapping speeds**
- **Speeds competitive for nanofabrication**

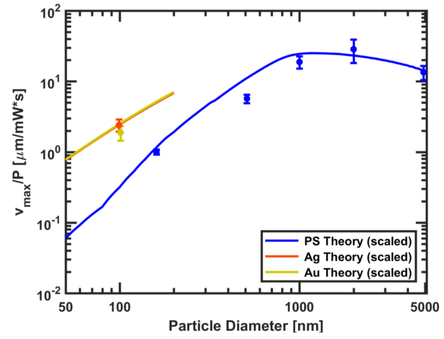
For nanoparticles:

- Stable trapping disappears at power levels >150-250 mW.
- Based on estimates of absorption cross sections of the nanoparticles, and heat transfer to the liquid, we attribute this to water vaporization and microbubble formation.

For microparticles:

- We attribute the upper limit to stage vibrations when run at high speed.

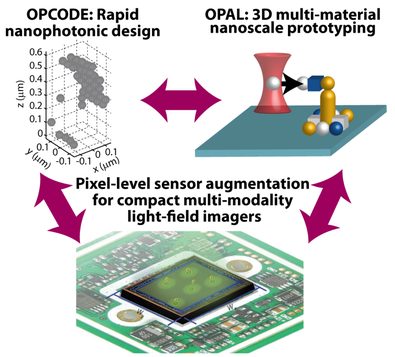
Within the low-power linear regime, observed dependence on laser power matches theoretical functional form:



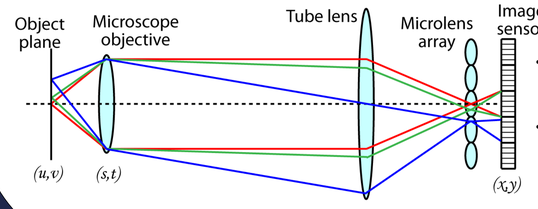

J. E. Melzer and E. McLeod, *ACS Nano*, **12** (3), 2440-2447 (2018).

## Pixel-level 3D nanophotonic structures for multi-modality image sensors. EECS-1807590

- Period of performance: August 2018 – July 2021
- Nanophotonic structures can be used to generate functional pixels for angle and polarization sensitivity
- This can lead to smaller advanced imaging devices




Conventional light-field microscope:
(also called plenoptic or integral imaging)




- Each block of pixels images a different region of the object
- Individual pixels correspond to different points of view

E. McLeod and A. Ozcan, *Rep. Prog. Phys.,* **79**, 076001 (2016).