

Field-Injection Grating Light Valves - Quantum Apertures -

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AMPB/RD

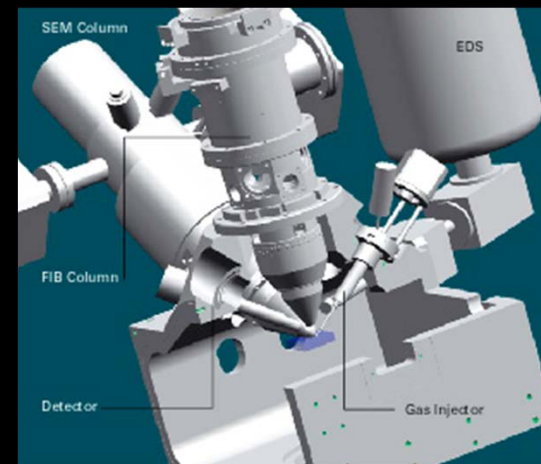
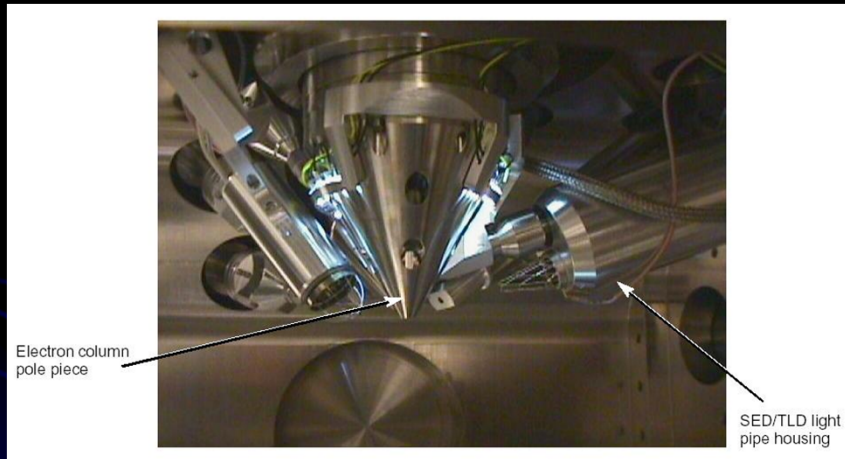
NASA Langley Research Center

May 24, 2011

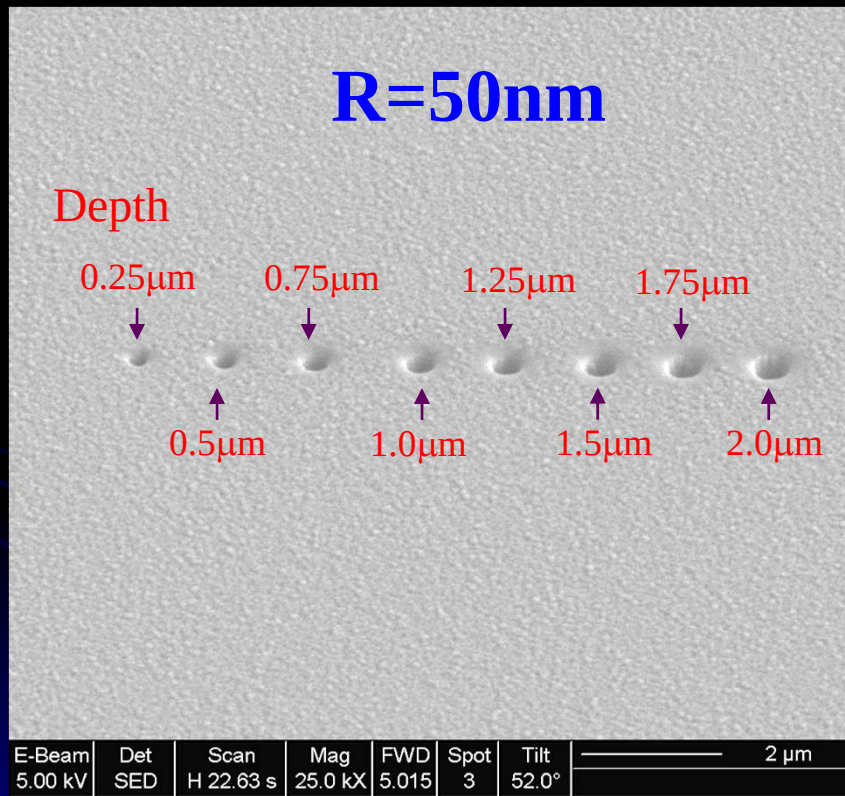


Equipment used for Quantum Aperture Fab

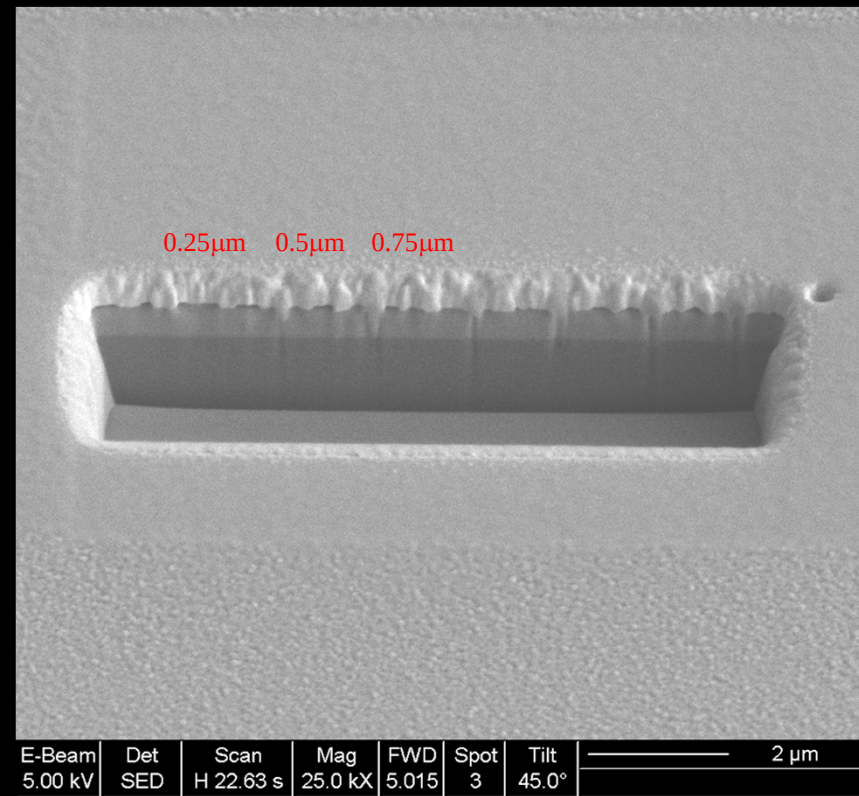
Dual Column Focused Ion Beam at LBNL



FIB & Nano-Fabrication



Tilted View after FIB etching

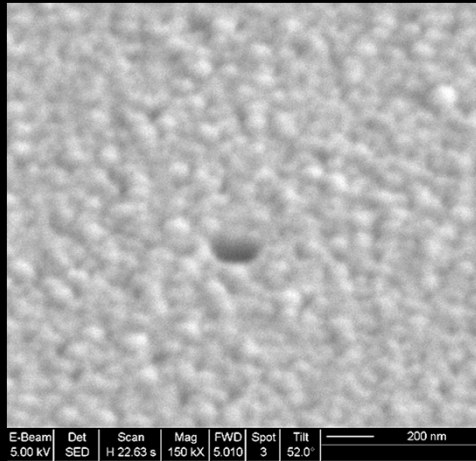
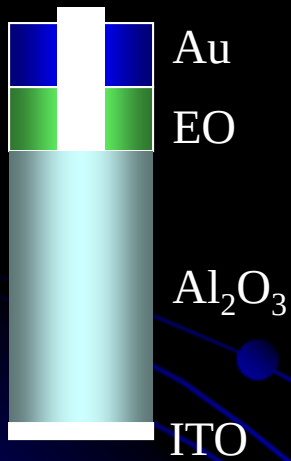


Cross-section Analysis

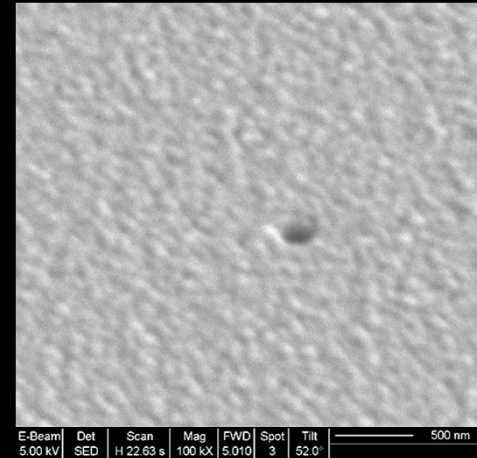


Single Aperture

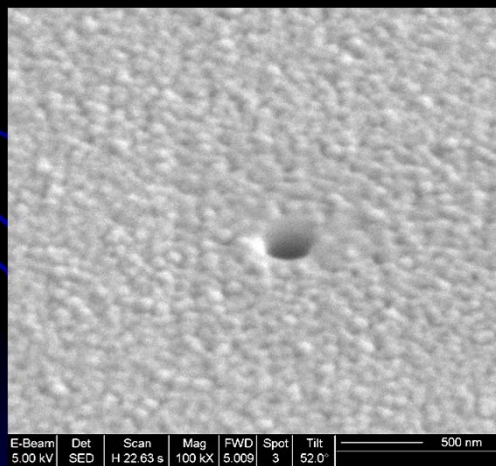
Diameter=100nm, Depth=0.6 μ m



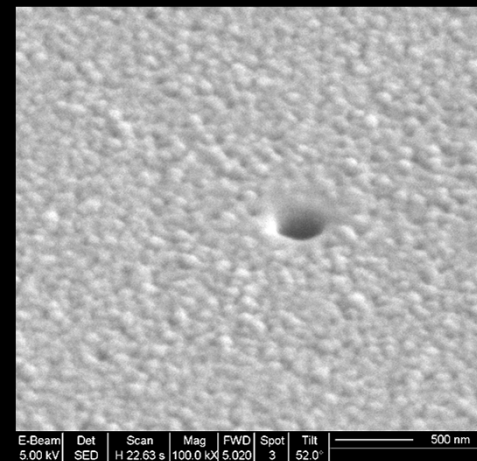
$\phi = 60\text{nm}$



$\phi = 100\text{nm}$



$\phi = 150\text{nm}$

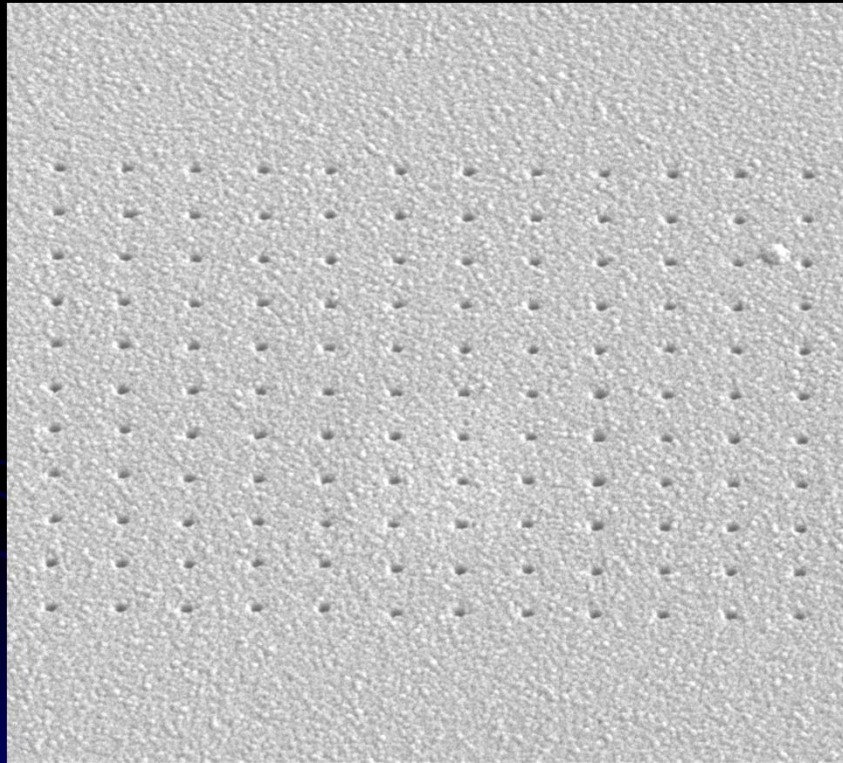


$\phi = 200\text{nm}$

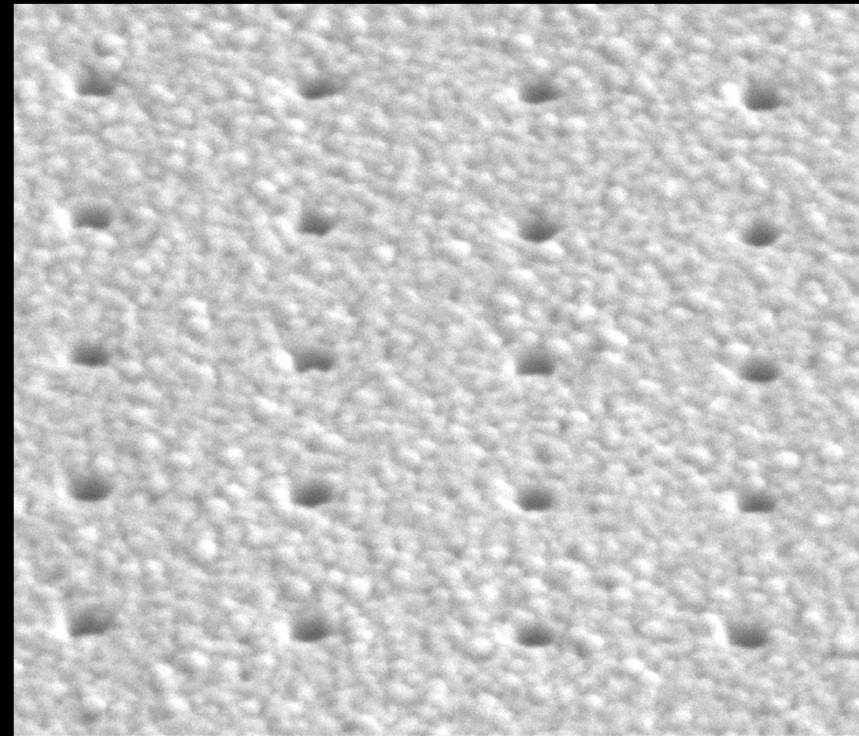


Array Pattern (12 x 11)

Diameter = 100nm, Depth = 0.4 μ m



E-Beam	Det	Scan	Mag	FWD	Spot	Tilt	
5.00 kV	SED	H 45.26 s	25.0 kX	5.018	3	52.0°	2 μ m



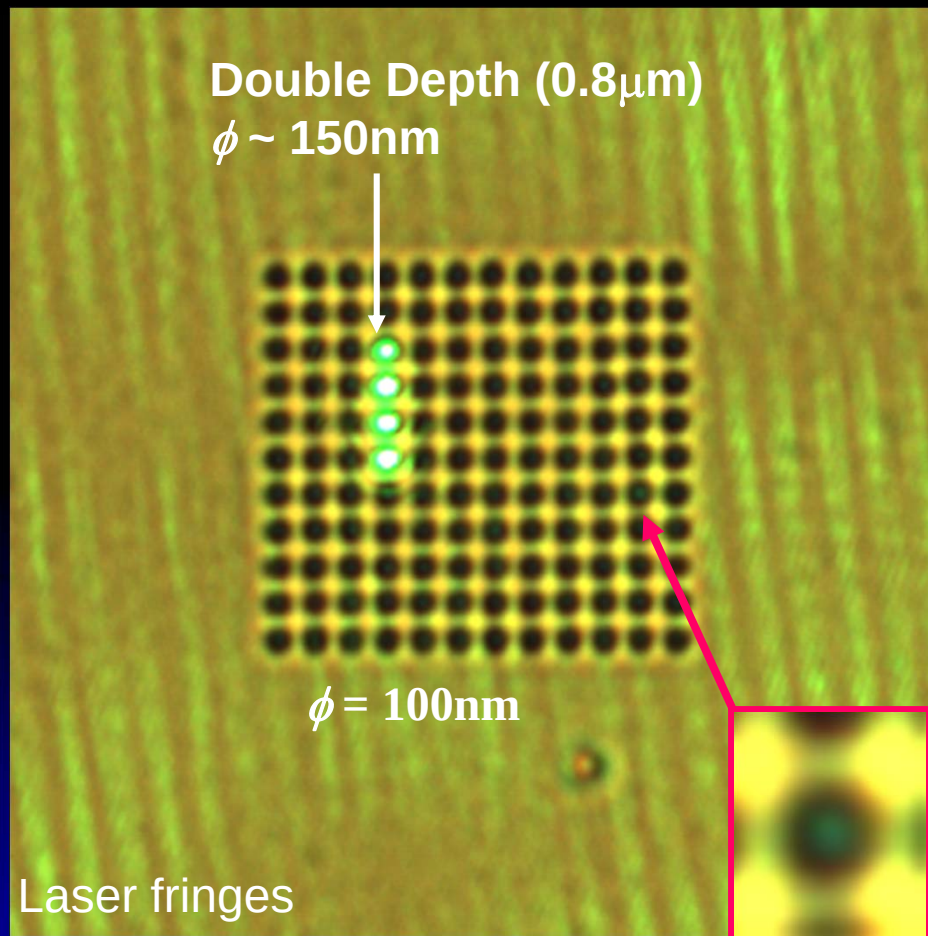
E-Beam	Det	Scan	Mag	FWD	Spot	Tilt	
5.00 kV	SED	H 45.26 s	80.0 kX	5.018	3	52.0°	500 nm

$\phi = 100\text{nm}$

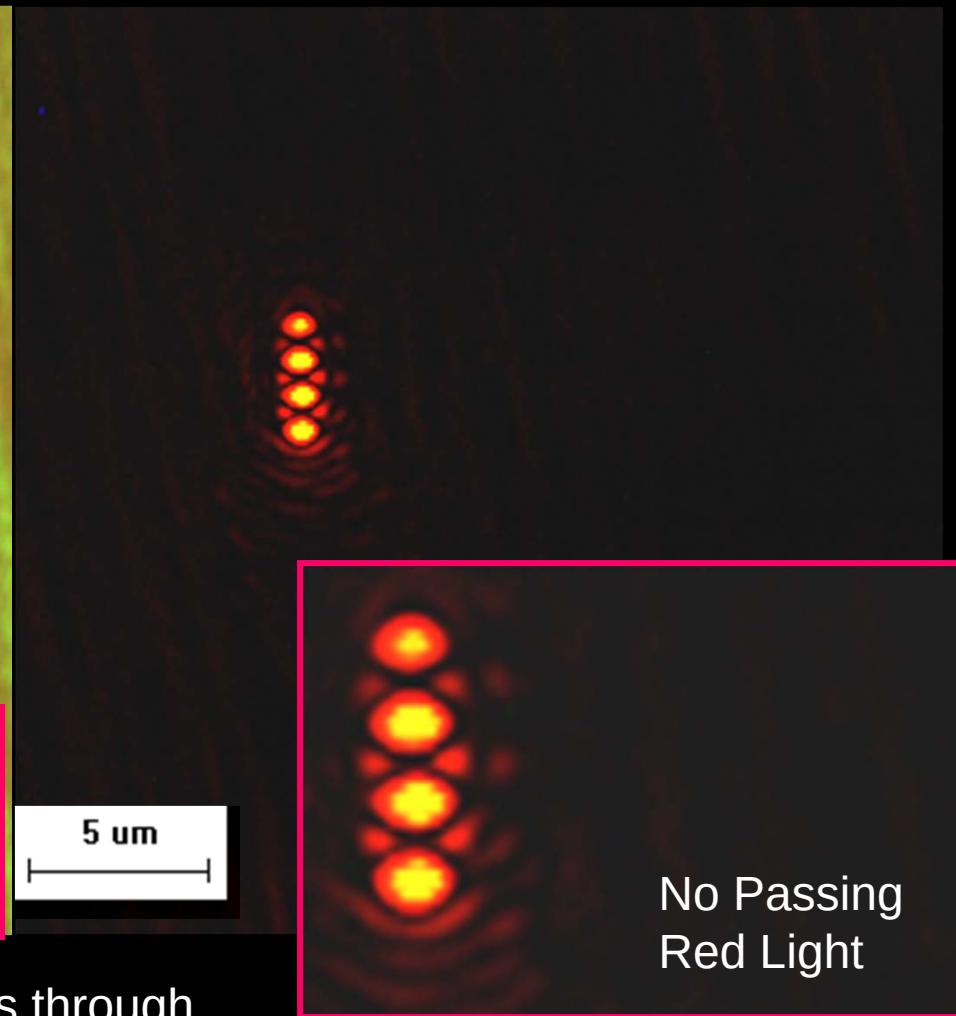


Selected Light Transmission

Laser (532nm) + Front side illumination

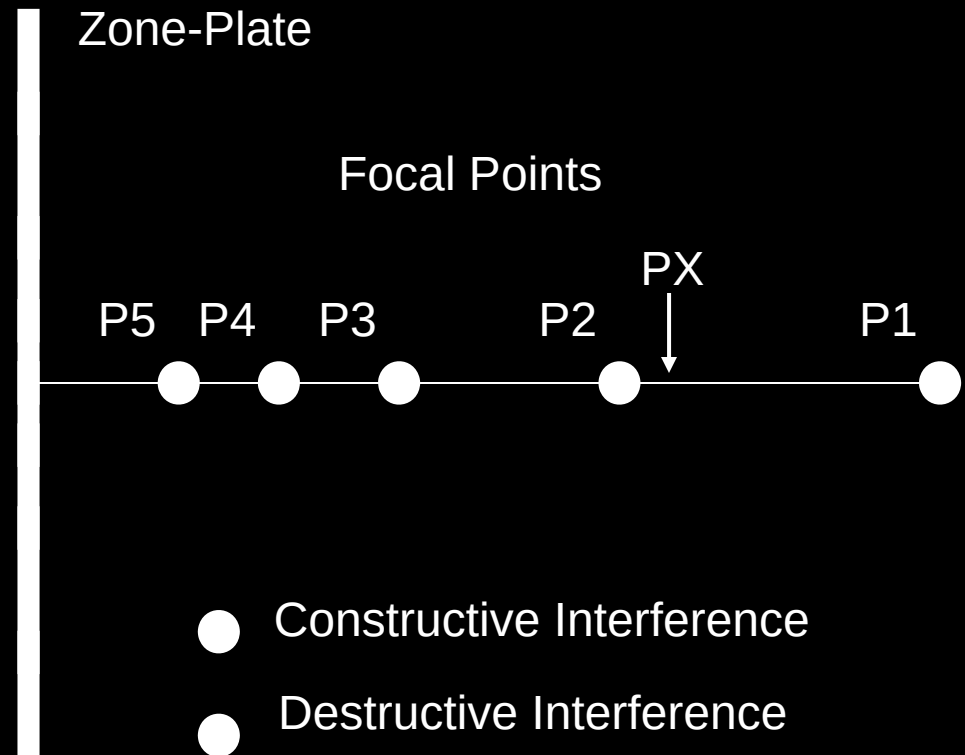


Laser (630nm) backside illumination only

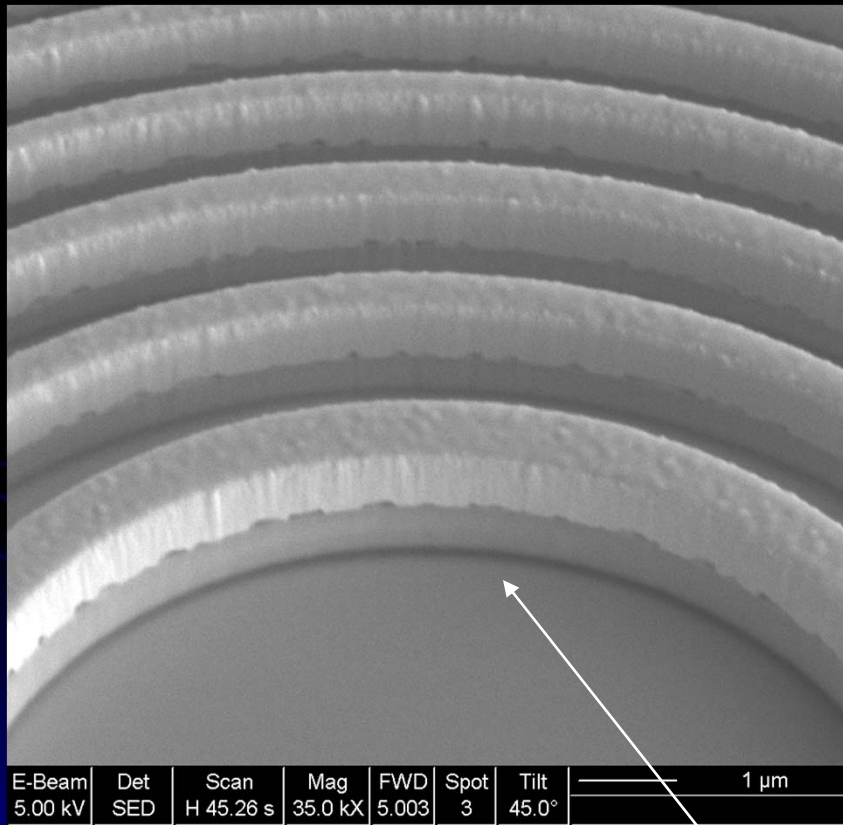


Green light passes through.

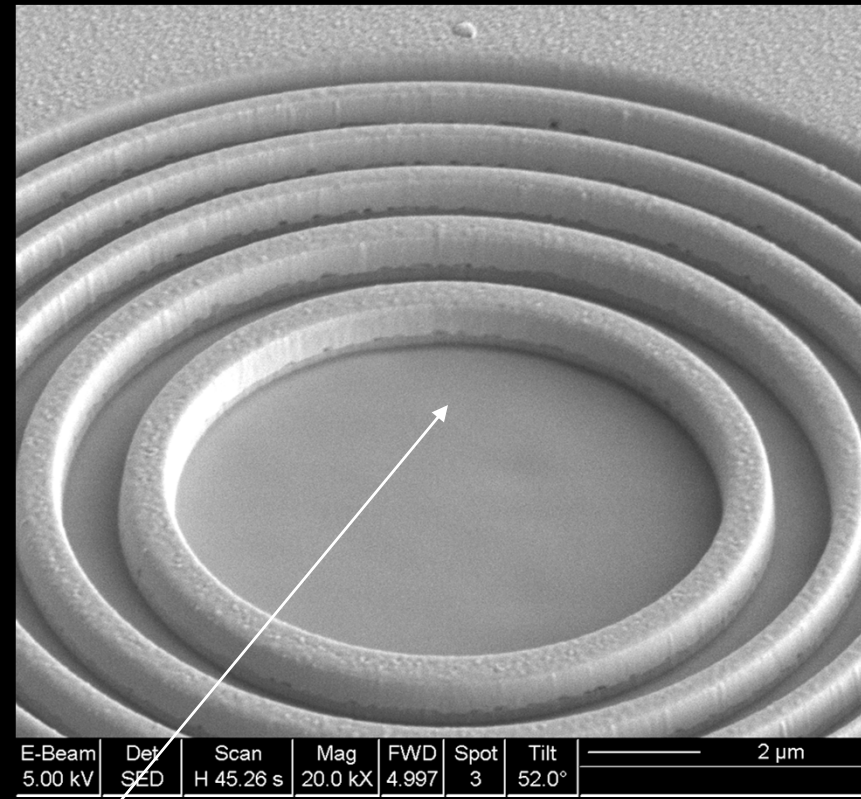
[1] Micro Zone Plate (MZP)



Ion-Etching of Metal & Electro-Optic Layer



Pattern #A

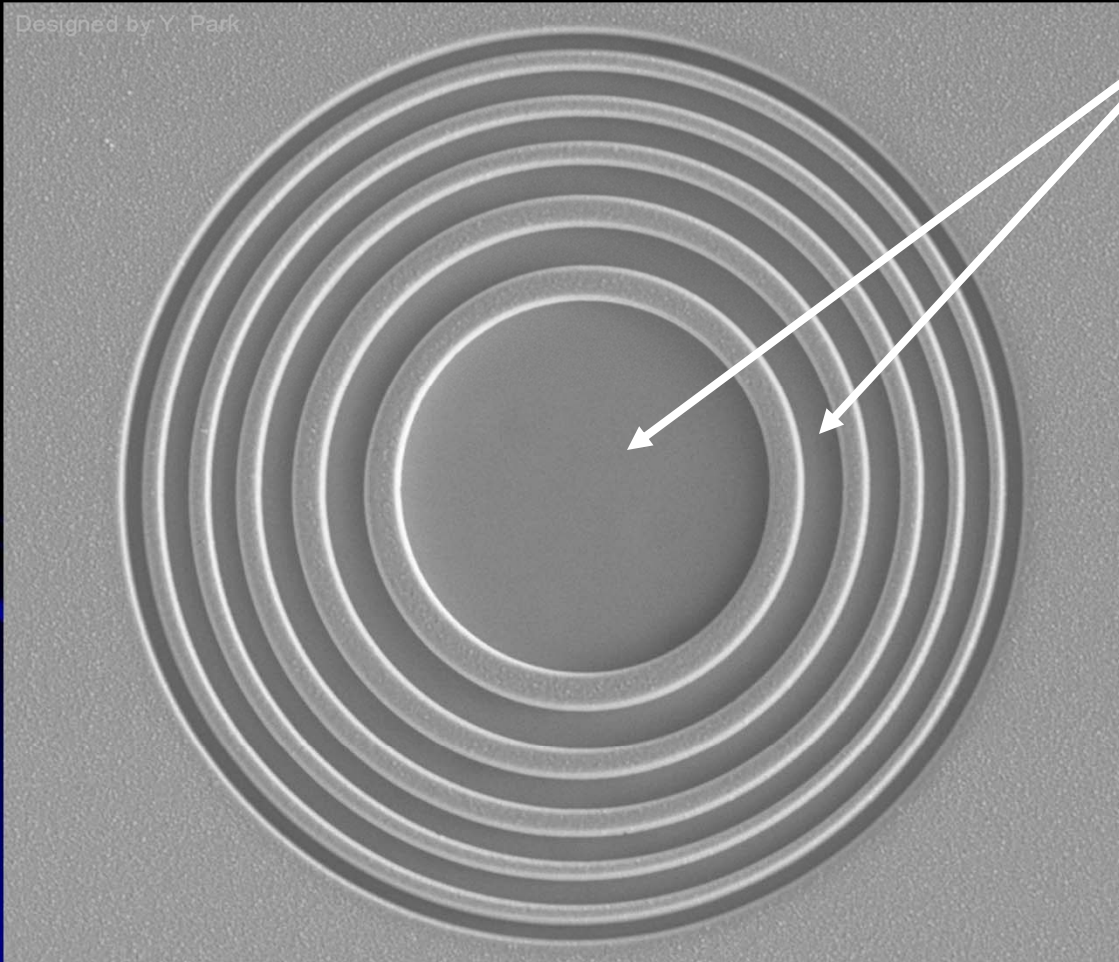


Pattern #C

Electro-Optic Layer



The World's Smallest Programmable Micro-Lens + Ring-Grating



Electro Optic Layer

Estimated Focal Points

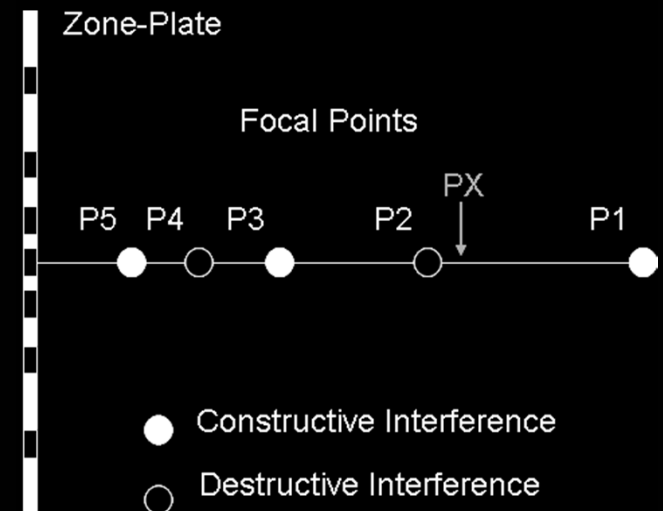
P1 = 46.99 μm, Constructive

P2 = 15.66 μm, Destructive

P3 = 9.40 μm, Constructive

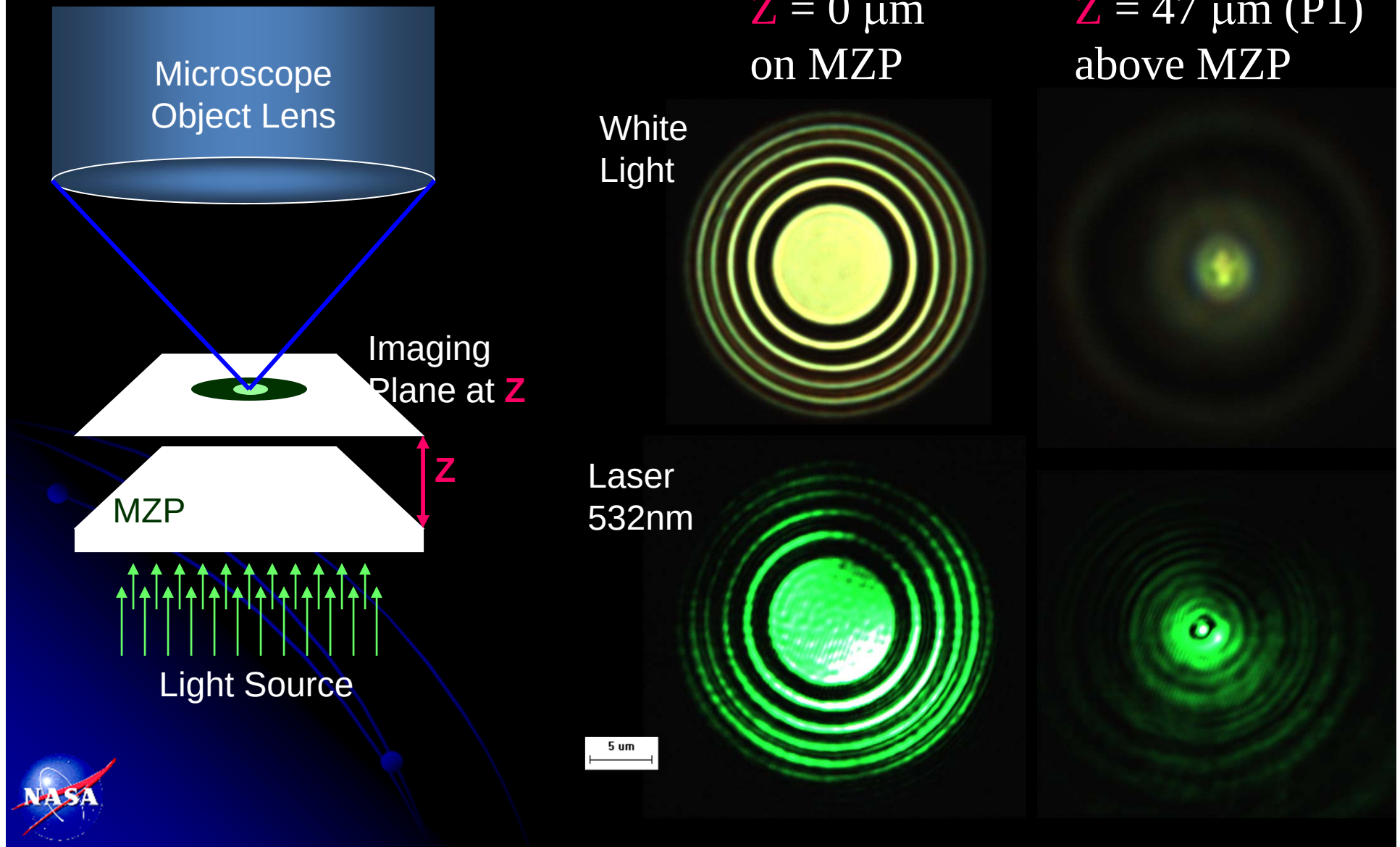
P4 = 6.71 μm, Destructive

P5 = 5.22 μm, Constructive



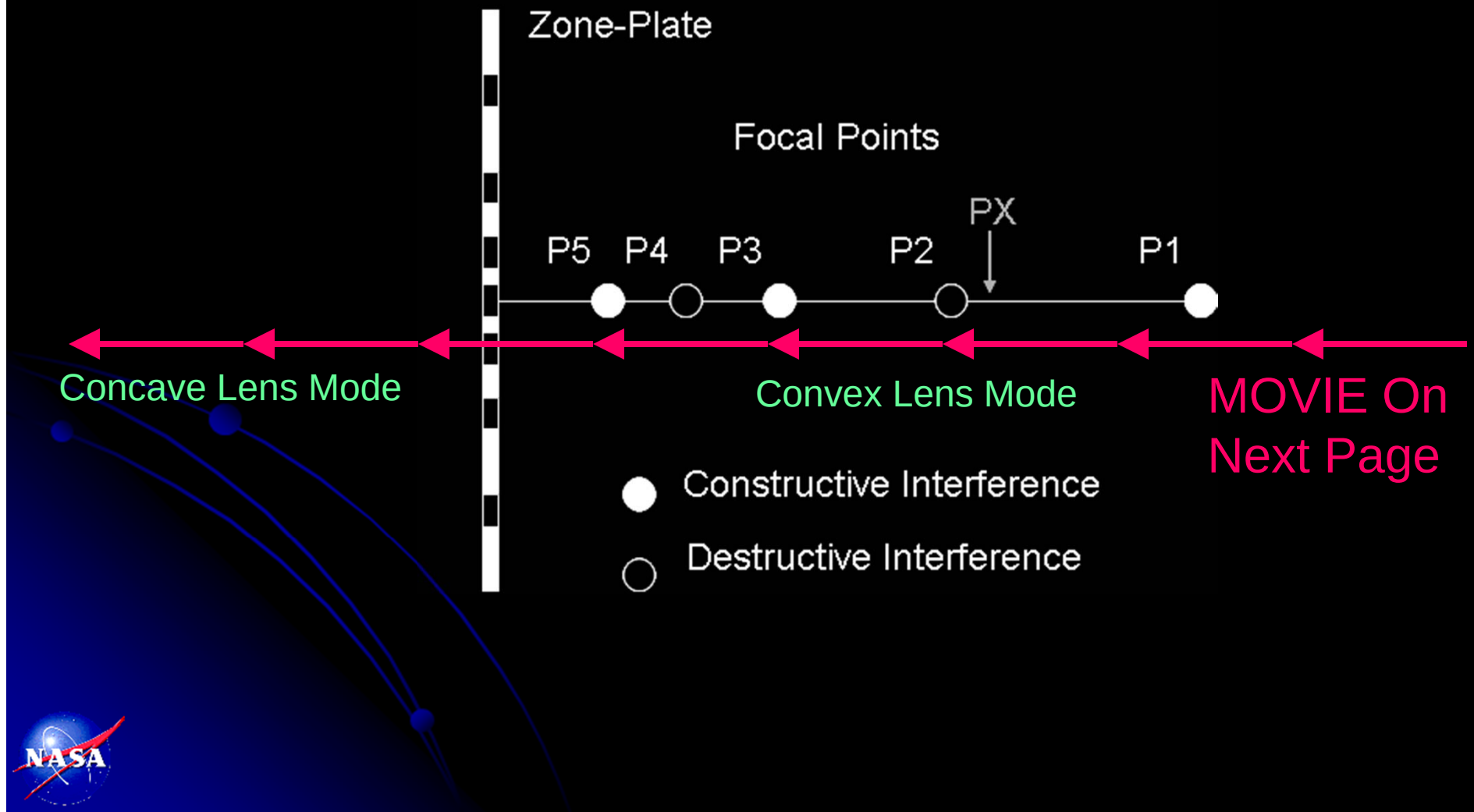
E-Beam	Det	Scan	Mag	FWD	Spot	Tilt	
5.00 kV	SED	H 45.26 s	10.0 kX	5.001	3	0.0°	5 μm

Optical Measurements



Photon Distribution vs. Vertical Height

Light Source: Broad White Light (Light Bulb)



Photon Distribution vs. Vertical Height

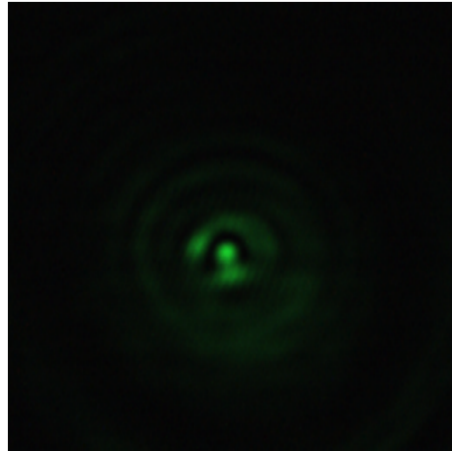
Light Source: Broad White Light (Light Bulb)



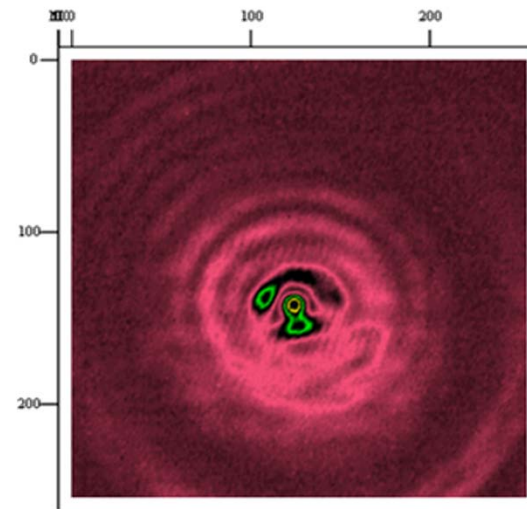
Photon distribution at P1 ($Z = 47 \mu\text{m}$)

Light Source = Green Laser (532nm)

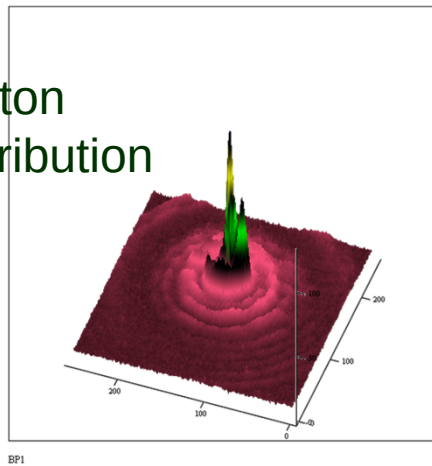
CCD
Image



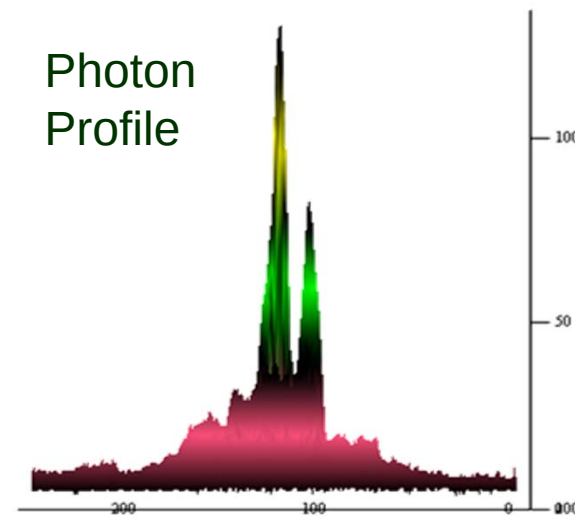
Numeric
Data



Photon
Distribution

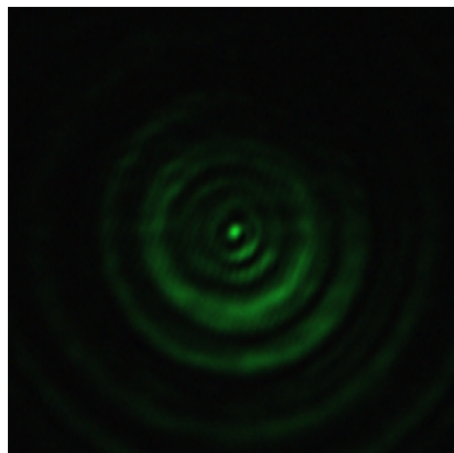


Photon
Profile

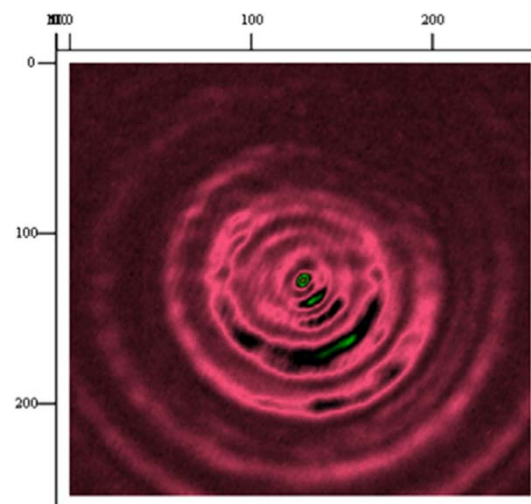


Photon Distribution at PX ($Z = 18 \mu\text{m}$)

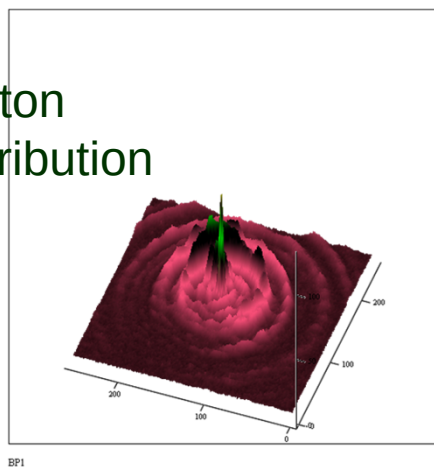
CCD
Image



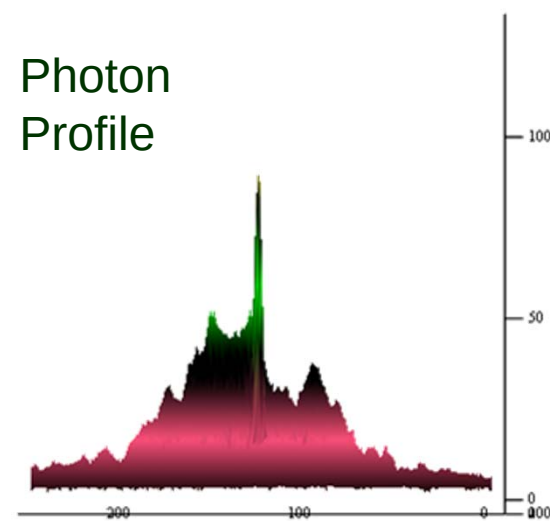
Numeric
Data



Photon
Distribution



Photon
Profile



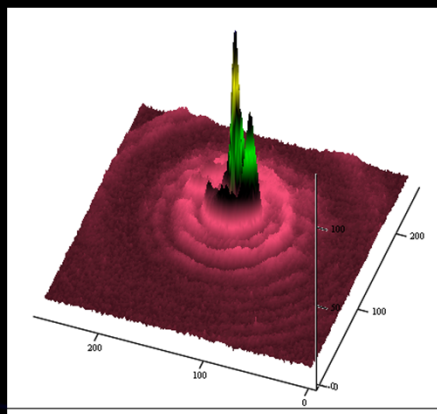


MZP ($Z=0\mu\text{m}$)

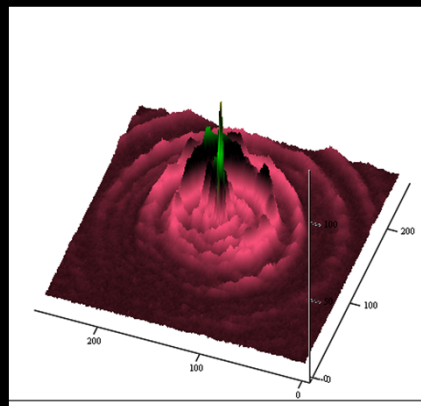
Photon distribution at each focal point

Focal points: Constructive (P1, PX, P3)

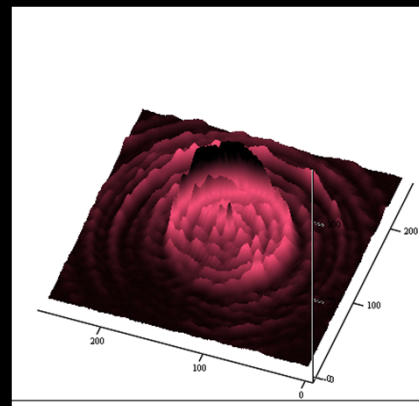
Destructive (P2)



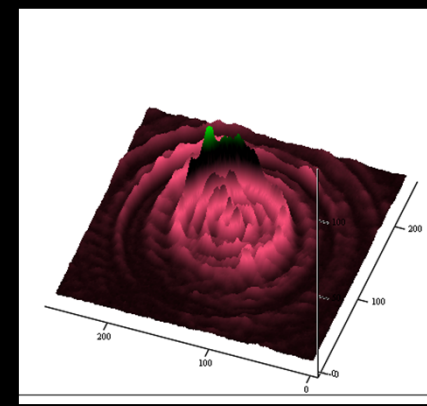
P1 ($Z=47\mu\text{m}$)



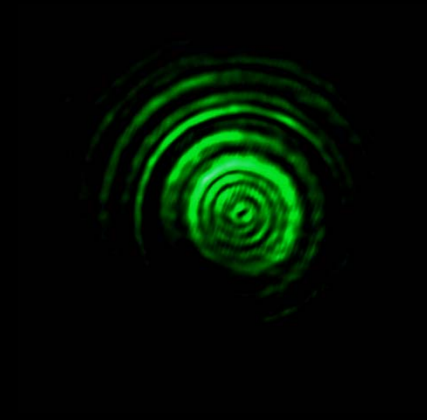
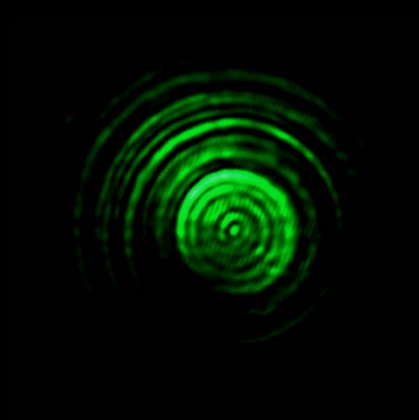
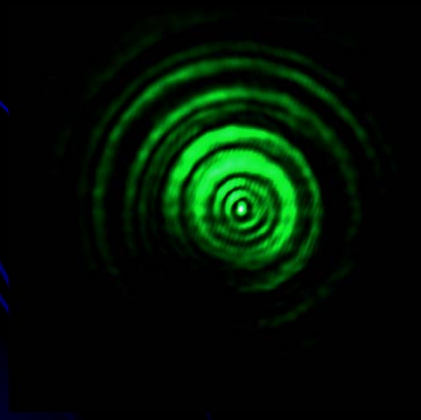
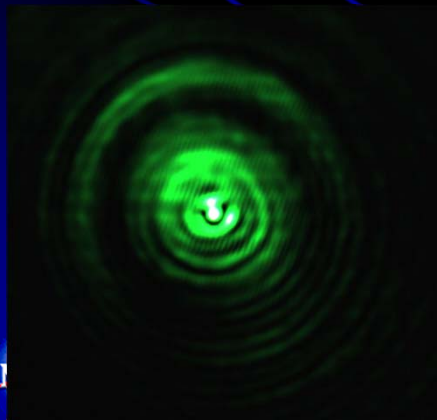
PX ($Z=18\mu\text{m}$)

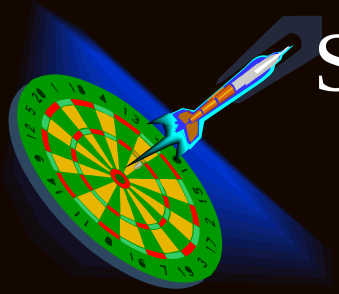


P3 ($Z=9.4\mu\text{m}$)



P2 ($Z=16\mu\text{m}$)

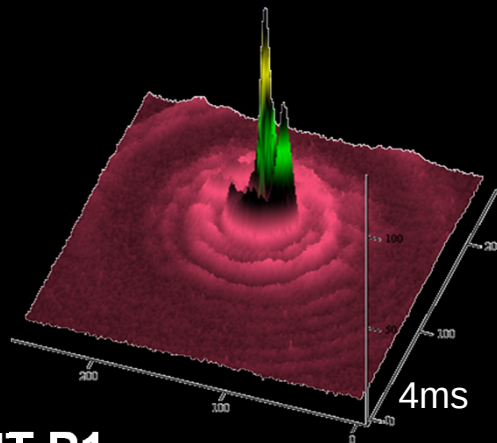




Sharpness of focal point P1 and PX with a green laser ($\lambda=532\text{nm}$)

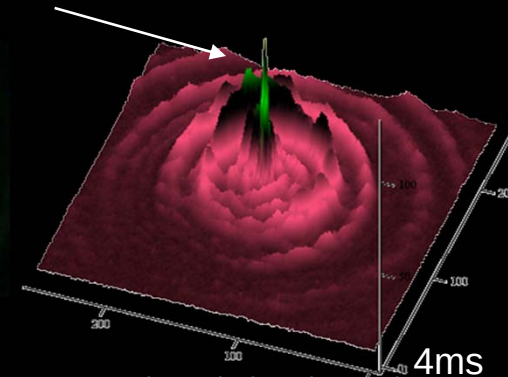
10 mW Laser in 2mm diameter (0.3 W/cm^2) can have a focused power density = 10^5 Watt/cm^2

1 μm 4ms



FOCAL POINT P1

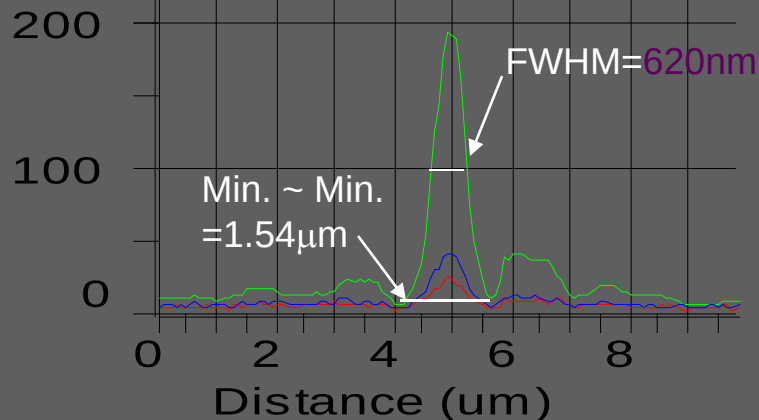
1 μm 6ms



FOCAL POINT PX (2 μm before destructive interference height)

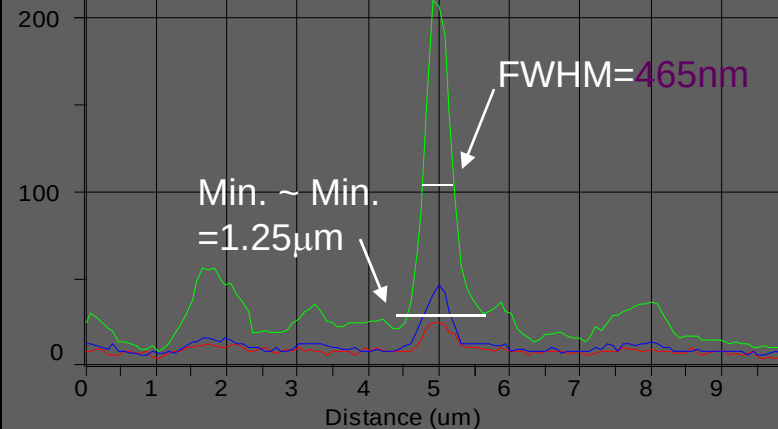
Line Profile

Photon Collection Time = 4ms



Line Profile

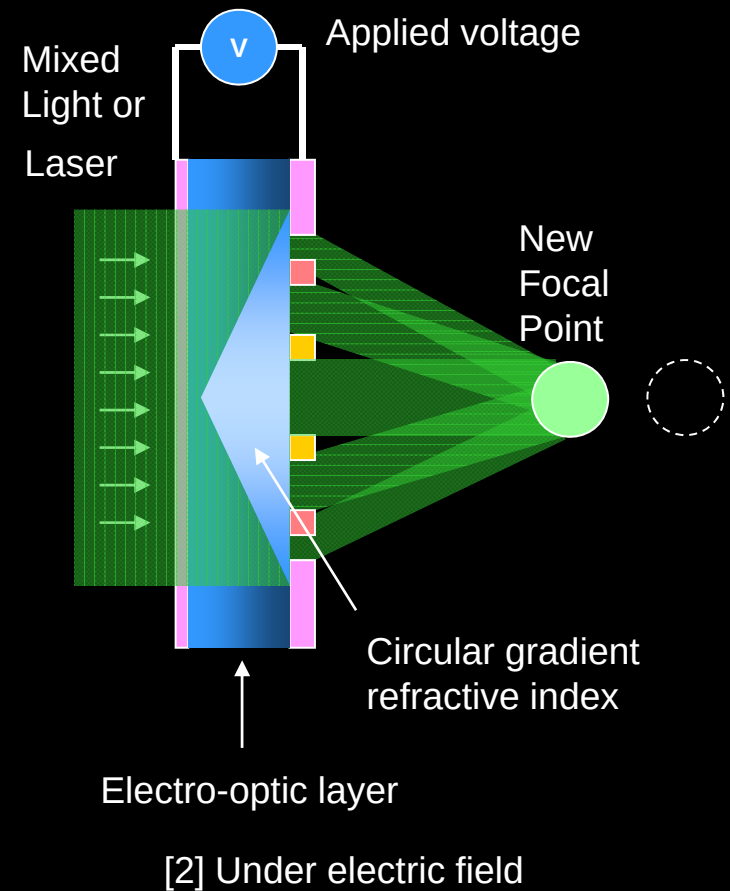
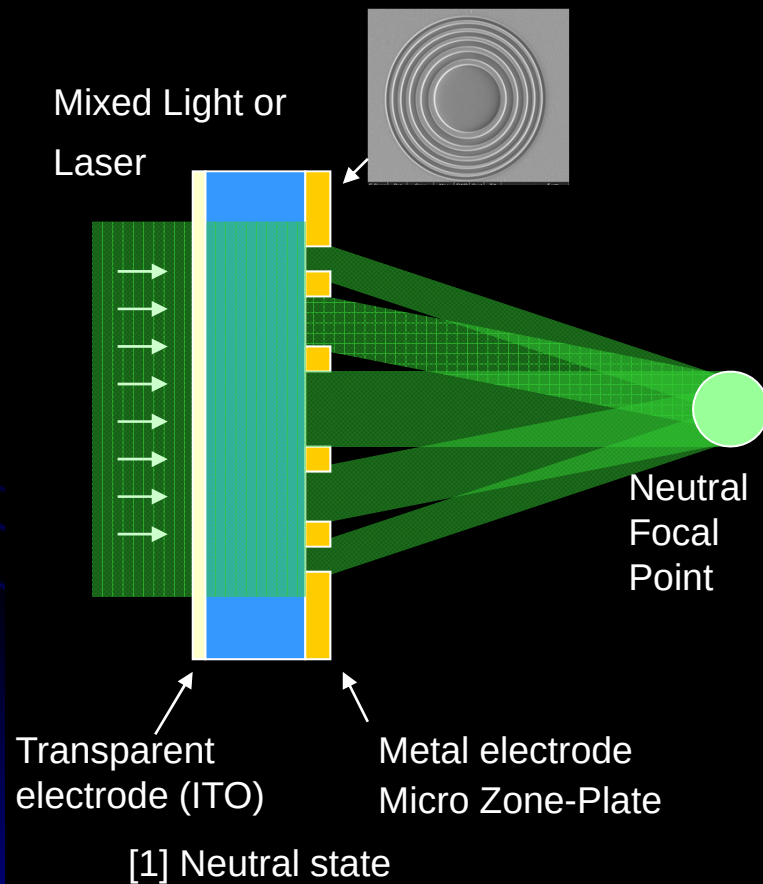
Photon Collection Time = 6ms



Photonic DART Technology
(Densely Accumulated Ray-point by micro-zone-plaTe)

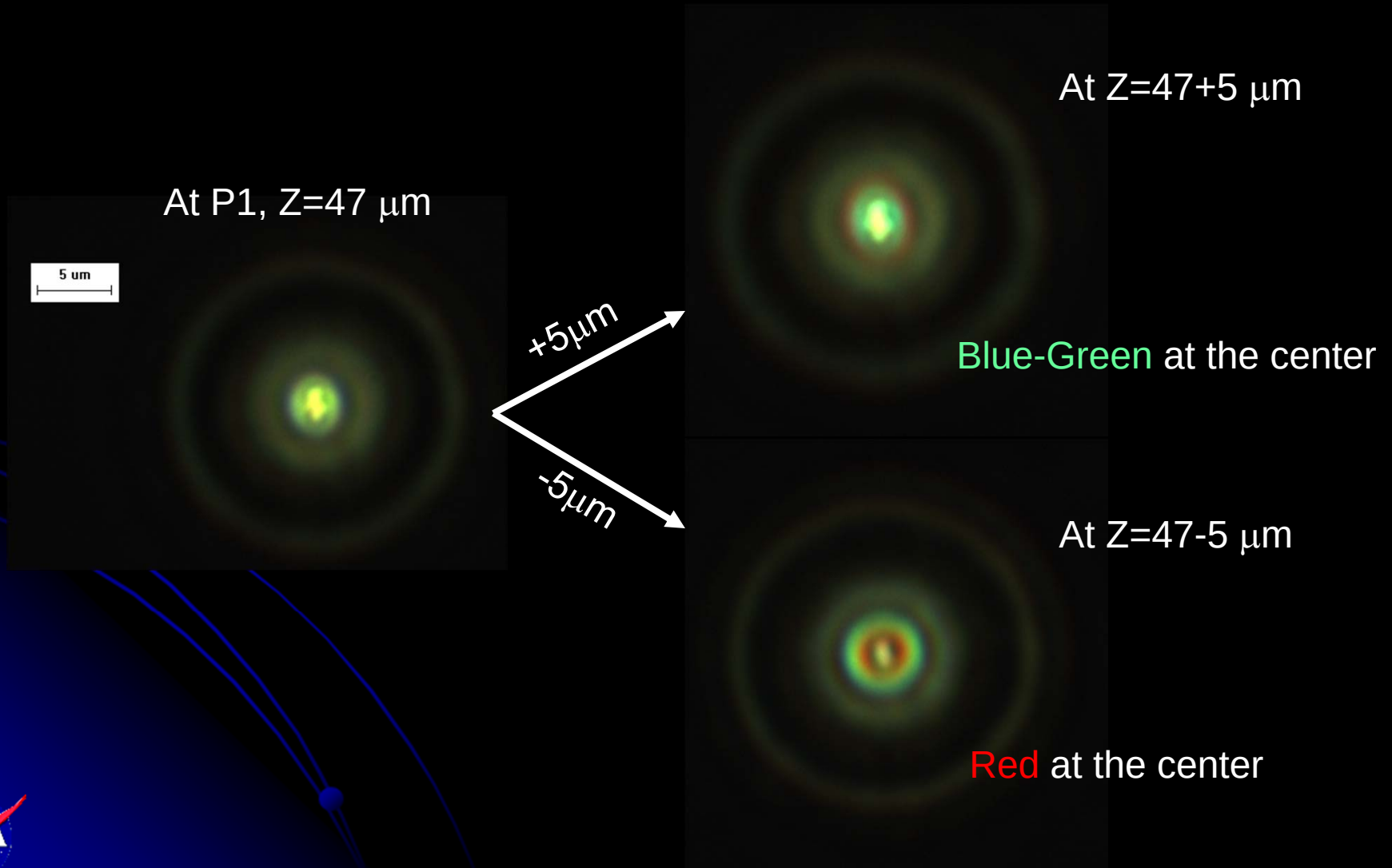
NASA Invention Disclosure

[2] Programmable Micro-Lens



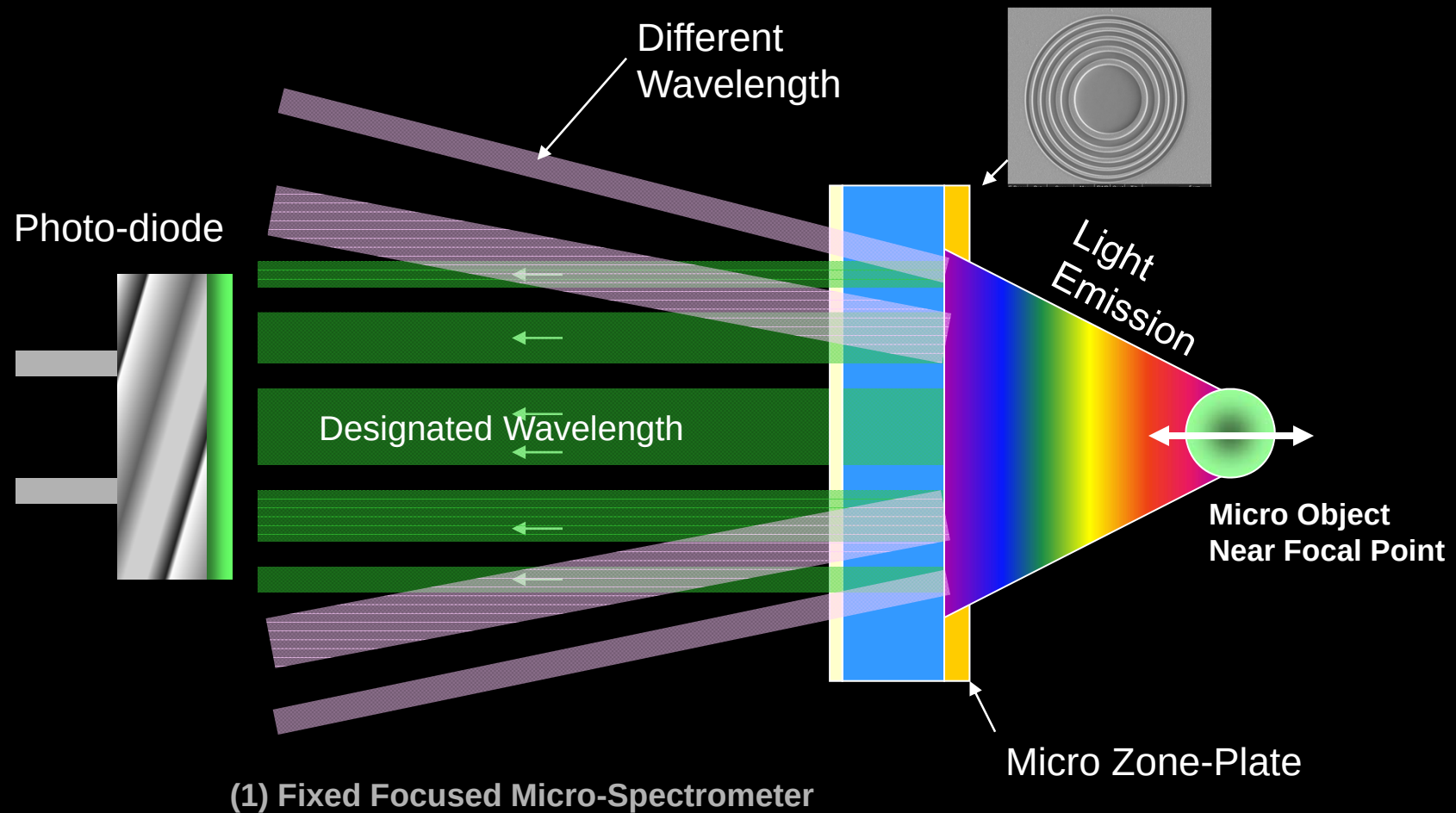
Dispersion Relation with White Light

- Dependence on Wavelengths -



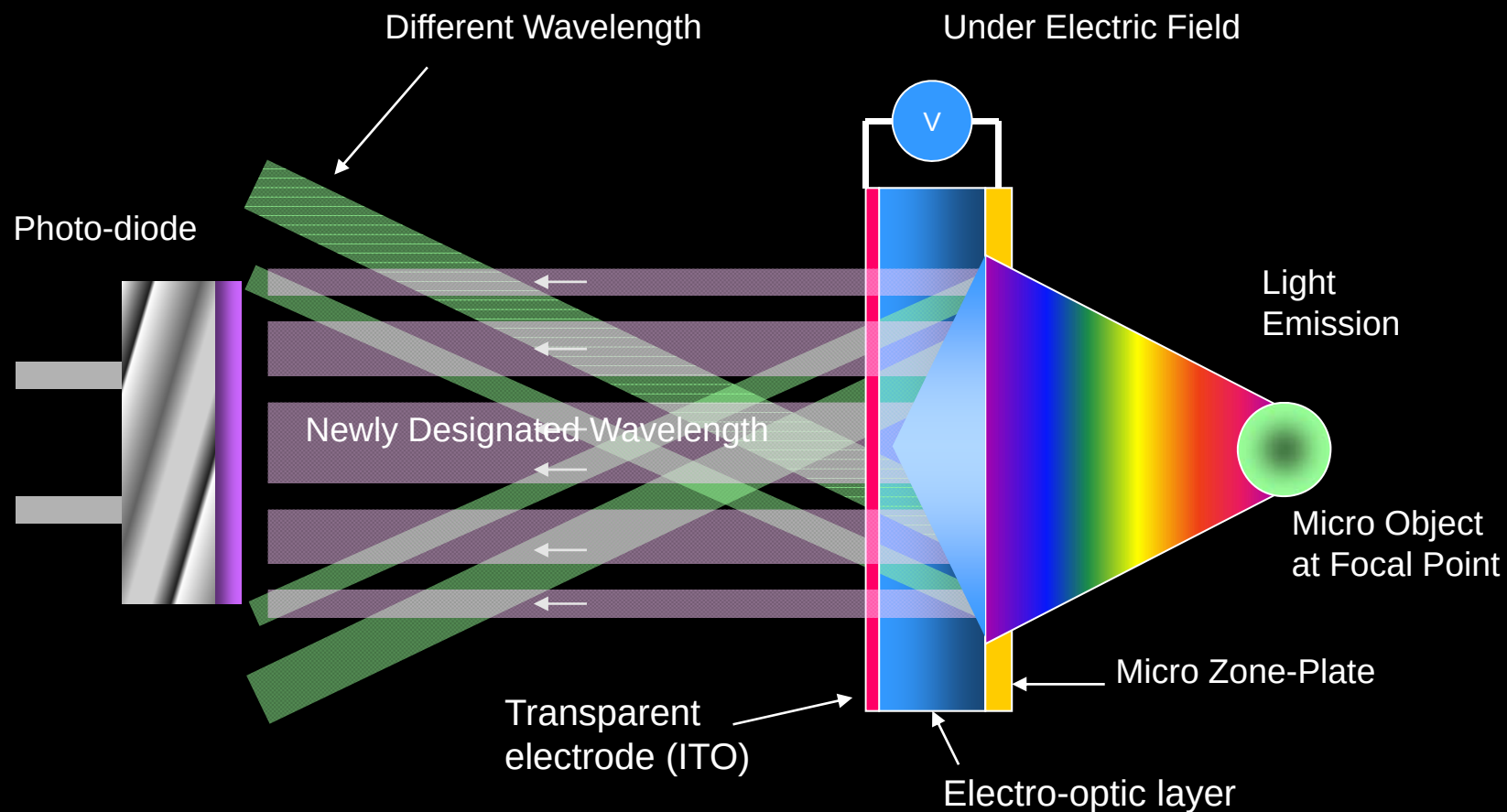
NASA Invention Disclosure

[3] MZP as a Fixed Ring-Grating



NASA Invention Disclosure

[4] Electro-Optic MZP as a Programmable Ring-Grating



(2) Programmable Focused Spectrometer

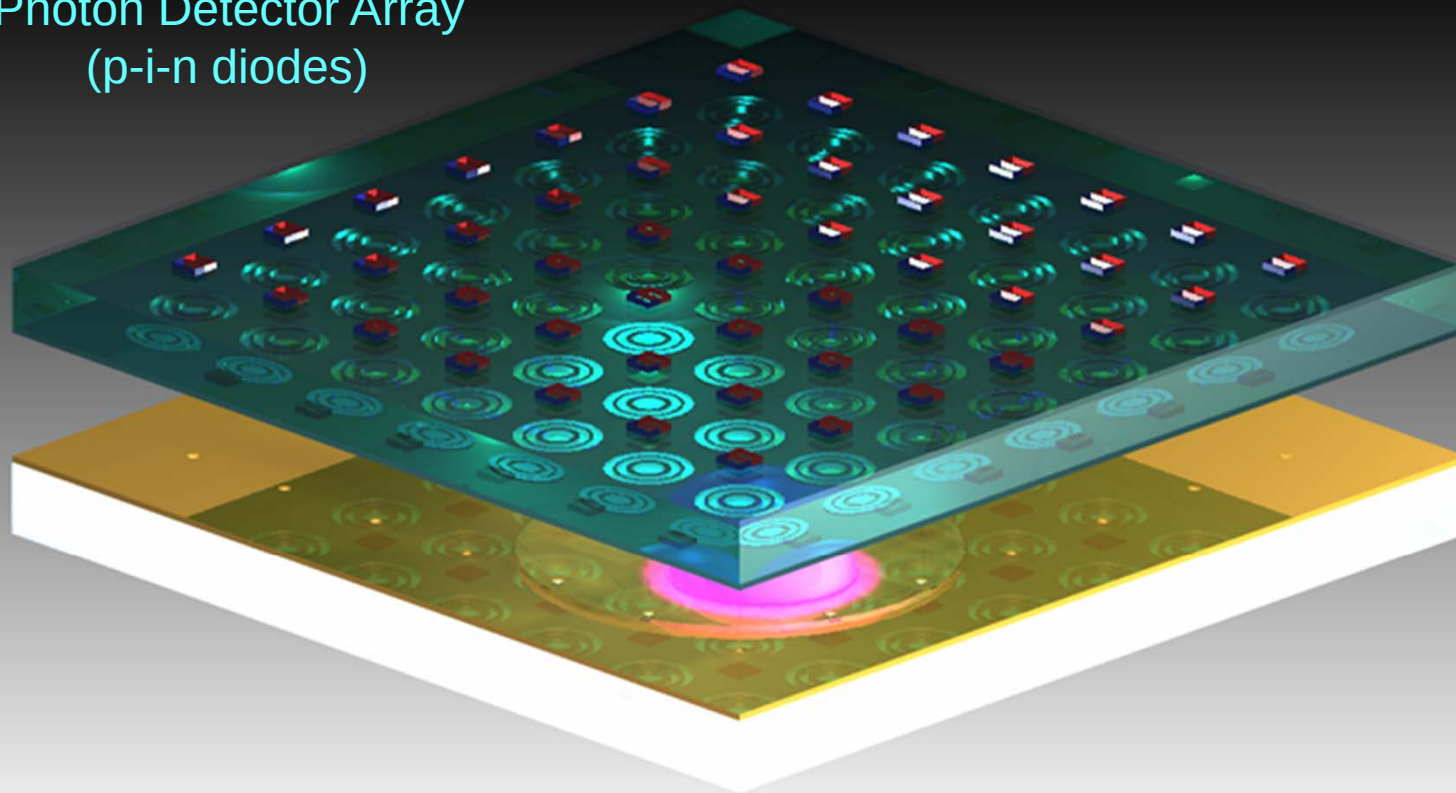


NASA Invention Disclosure

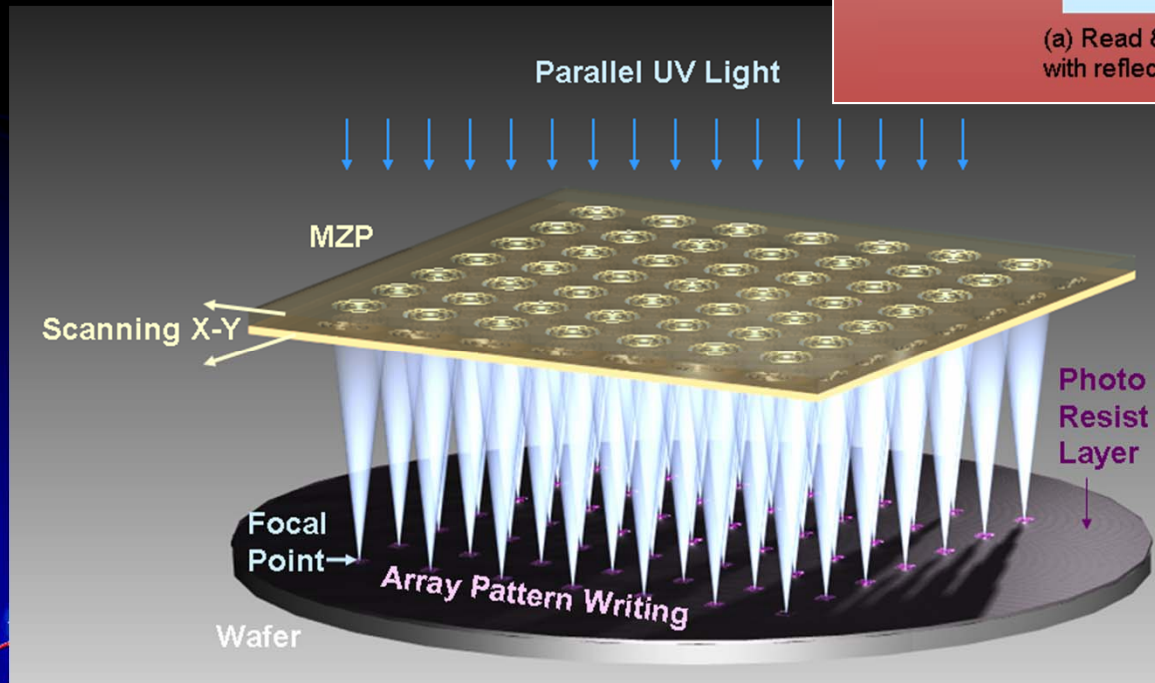
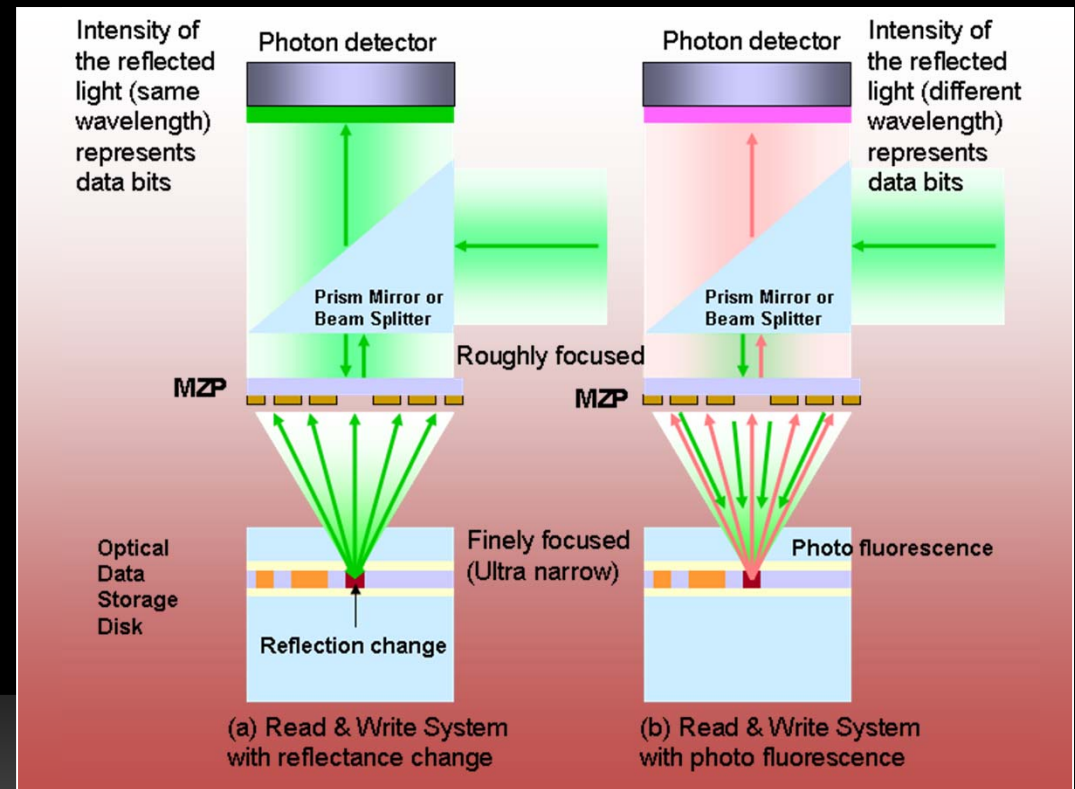
[5] Thin-film Spectrometer Array

Designed by Y. Park

Photon Detector Array
(p-i-n diodes)



[6] MZP Optical
Data Storage System
(for > 25GB in DVD disc,
currently 4.7GB per disc)

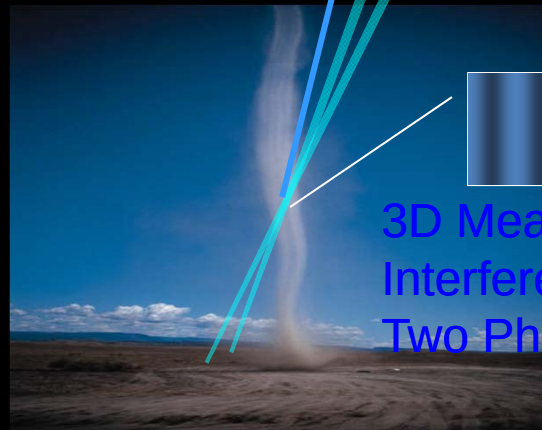
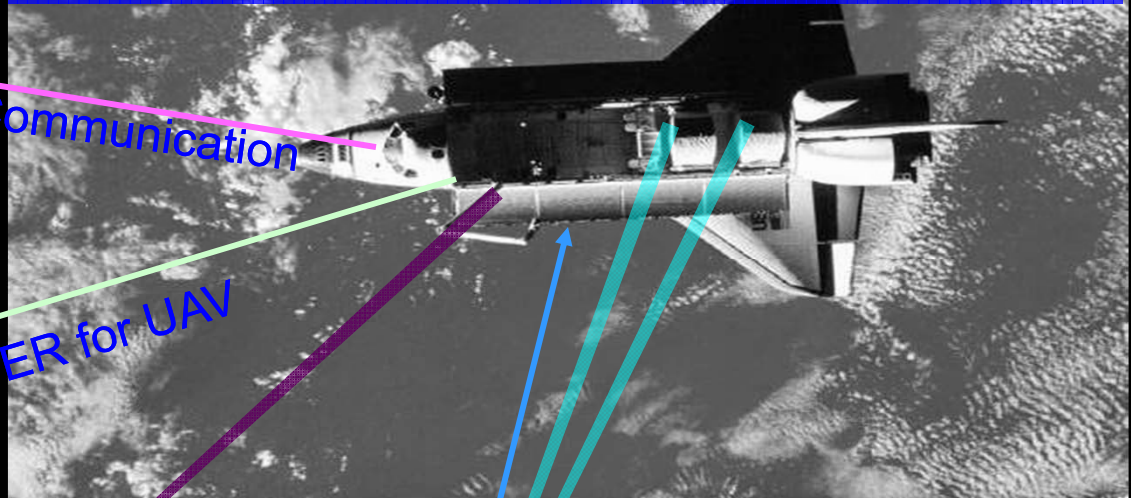


[7] Maskless Phase-Contrast
Photolithography with MZP

III. Light Scanning Control Device Aero-Space Application



Typical Mechanical Vibration: 0.1Hz ~ 100kHz
Beam scanner has to be faster than a few MHz!
We need **Fast Solid State Optical Components!**



3D Measurement
Interference Fringe
Two Photon Excitation



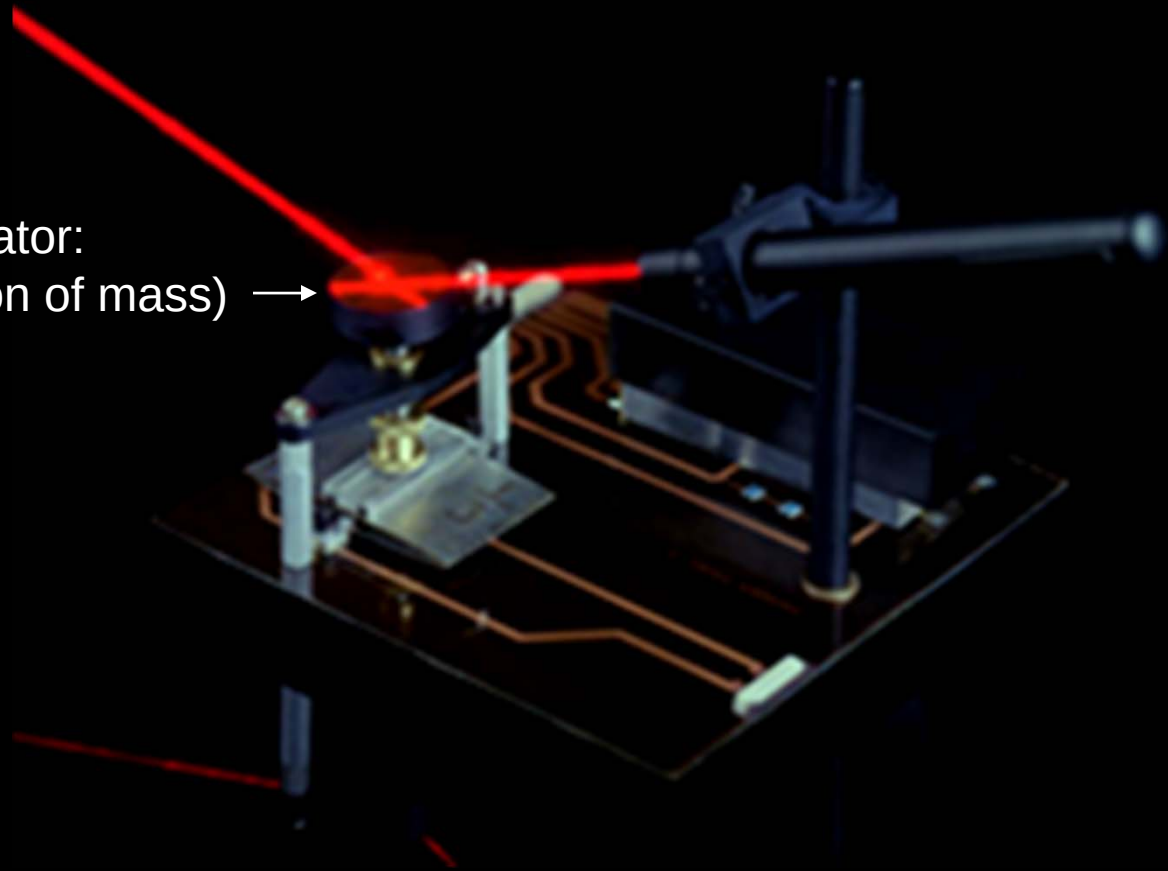
Laser Communication

POWER for UAV

2D Measurement

Limit of Mechanical Actuator

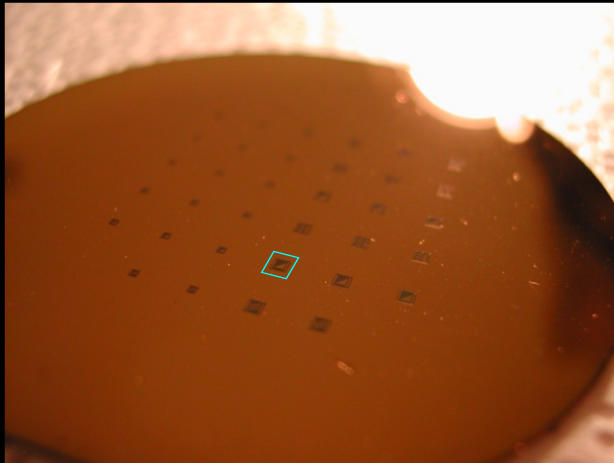
Limit of Mechanical Actuator:
< 10kHz (due to its motion of mass) →



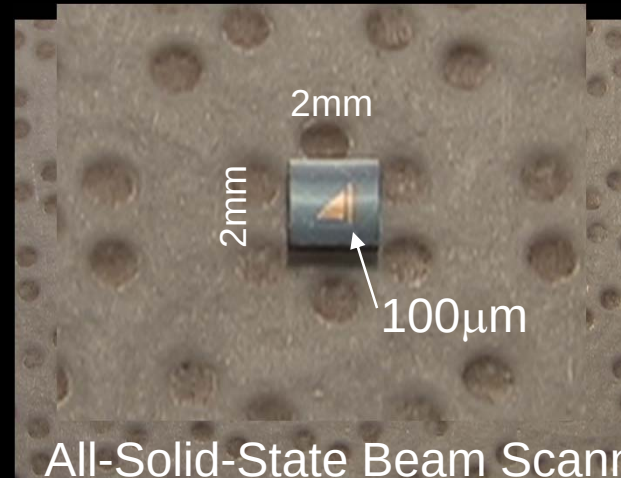
Thin-Layer Composite-Unimorph Piezoelectric Driver and Sensor,
i.e. "THUNDER" by Richard Hellbaum, Robert Bryant, Robert Fox,
Antony Jalink, Wayne Rohrbach, and Joycelyn Simpson in 1996



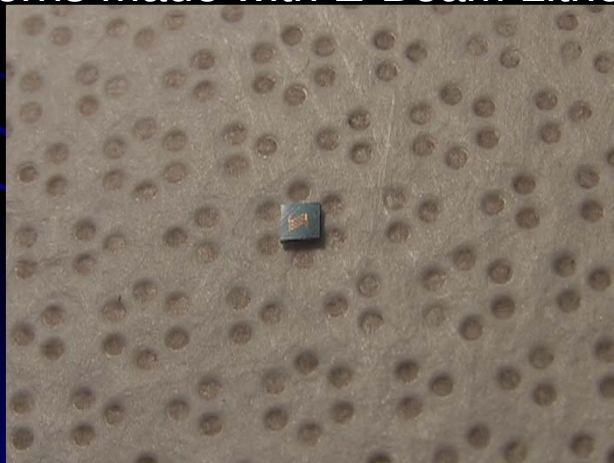
Light Scanning Control Device



Patterns made with E-Beam Lithography



All-Solid-State Beam Scanner



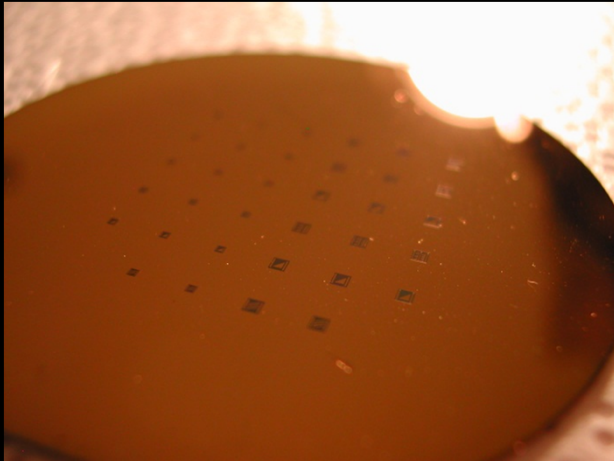
All S.S. Beam Scanner Array

Solid State Beam Displacer

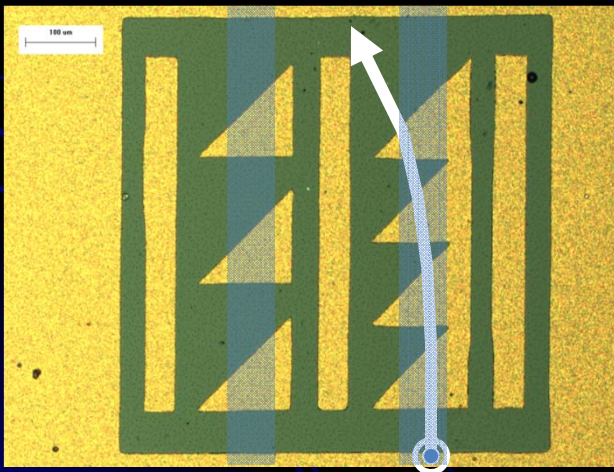
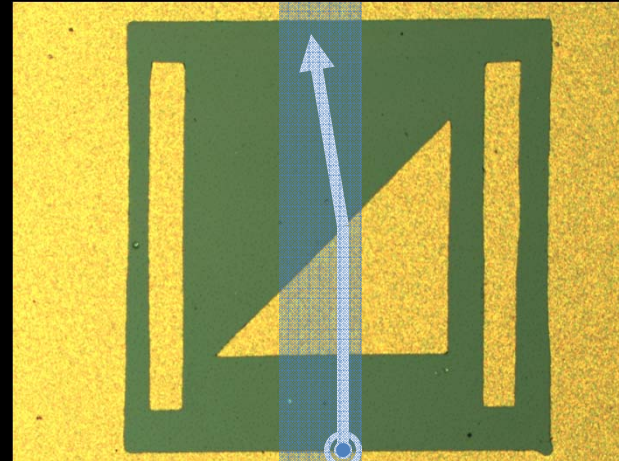


Operation of Light Scanning Control Device

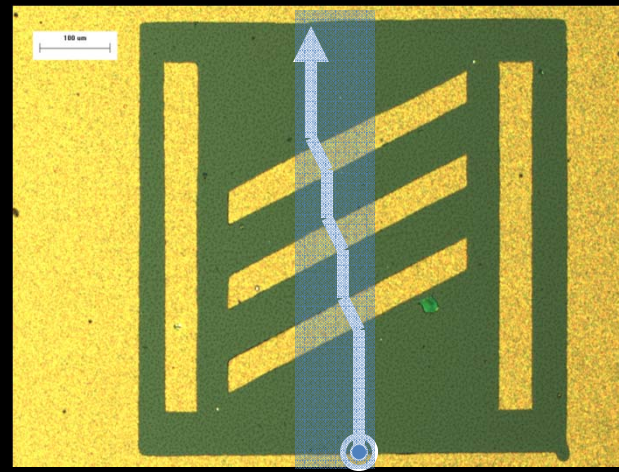
E-Beam Lithography



Single Beam Scanner



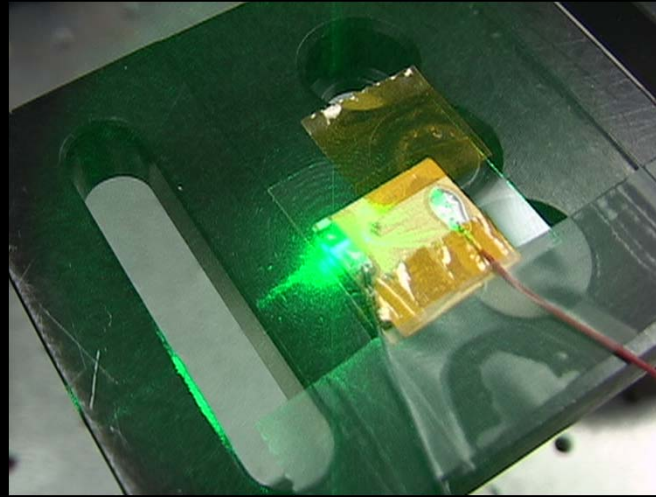
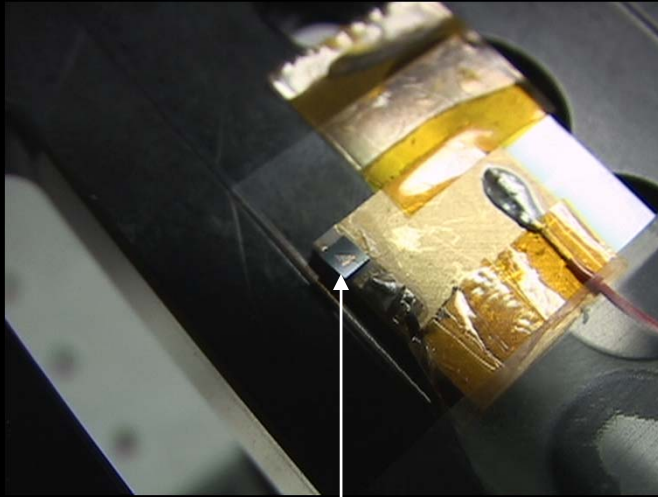
Beam Scanner Array



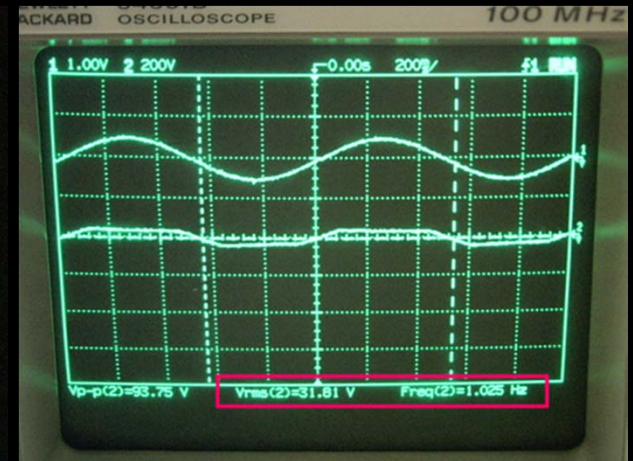
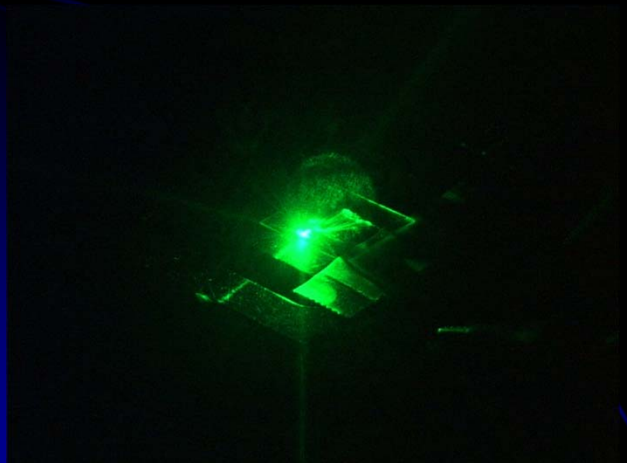
Beam Displacer



Device Under Beam-Steering Test



Light Scanning Control Device



Bending the light with E-field

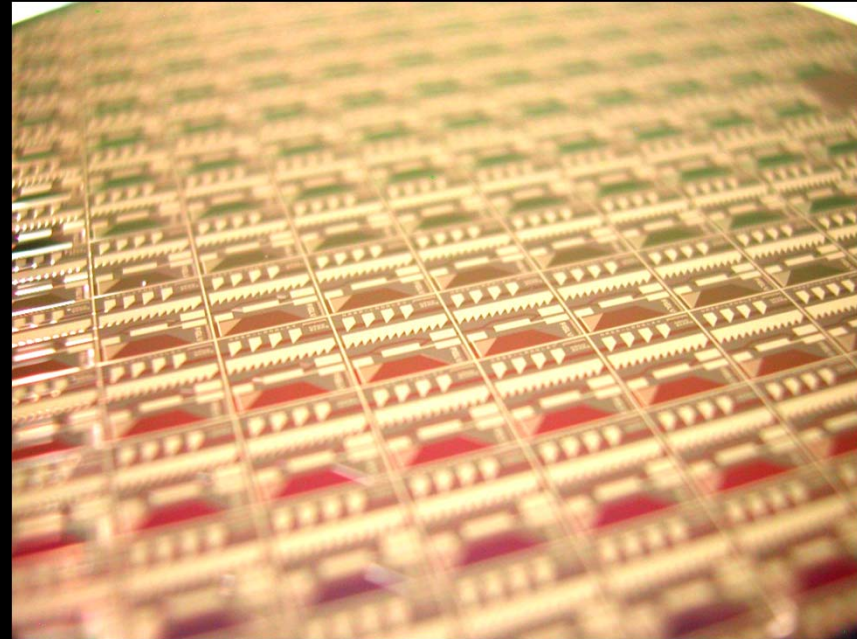
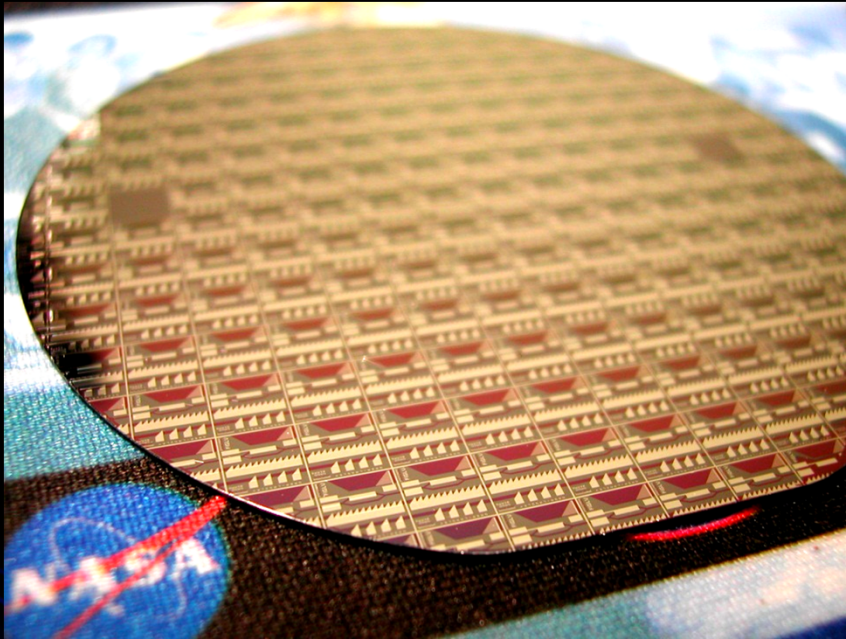


There is **No Mechanical Motion** in device!
Theoretically, it can approach 1GHz operating speed.

Field Injection Grating Light Valve



Field Injection Grating Light Valve (1-D) Made in NASA Langley Research Center



Our UV Lithography Capability: 200 Wafers/day
153 Devices/Wafer x 200 Wafer/Day
= 30,600 Devices / Day

RESEARCH IS THE MASS-PRODUCTION IN OUR LAB.



Inventions & Publications

Invention Disclosures:

1. NASA Case No. LAR 16512-1, "Field Injection Grating Light Valves", July 29, 2002.
2. NASA Case No. LAR 16601-1, "Adaptive Diffraction Optical Grating (ADOG)", March 3, 2003.
3. NASA Case No. LAR 16640-1, "Programmable Smart Grating Device with Quantum Aperture Array", May 22, 2003.
4. NASA Case No. LAR 16761-1, "Thin-Film Spectrometer with Tunable-Wavelength Real-Time 2D Imaging Device", September 2, 2003.
5. NASA Case No. LAR 16763-1, "Tunable Distributed Bragg Reflector & Etalon with Smart Optics Materials", September 3, 2003.
6. NASA Case No. LAR 16826-1, "[Pockels cell and its array made with semi-metallic semiconductor](#)", October 6, 2003.
7. NASA Case No. LAR 16886-1, "[Dual Sensing Capable Germ or Toxic Chemical \(GTC\) Sensor using Quantum Aperture Array with Surface Plasmon Polariton \(SPP\)](#)", March 26, 2004.
8. NASA Case No. LAR 16950-1, "[Ferroelectric](#) Light Control Device", July 2, 2004.
9. NASA Case No. LAR 17231-1, "Electro-Optic Micro-Zone-Plate as a Programmable Lenses and Micro-Spectrometer", September 12, 2005.
10. NASA Case No. LAR 17237-1, "Photonic DART (Densely Accumulated Ray-point by micro-zone-plaTe)", September 28, 2005.
11. NASA Case No. LAR 17239-1, "Micro-Ring Thin-Film Spectrometer", Track #5019871, October 3, 2005.
12. NASA Case No. LAR 17240-1, "Optical Data Storage System with Micro Zone Plate", [Track #5019873, October 3, 2005](#).

Publications:

1. "XRD Characterization of Ultra-Thin Electro-Optic Material Layers," 2nd World Congress of Biomimetics, Artificial Muscles and Nano-Bio, NB-02-05, Albuquerque, NM, Dec. 6-8, 2004.
2. "Photoluminescence Study of Ferroelectric BaTiO₃ Film under Electric Field", SPIE Proceedings of Integrated Optics: Devices, Materials, and Technologies IX (OE07), Vol. 5728, pp68-73, March, 2005.
3. "Diffraction Analysis for Periodic Nano-scale Apertures, Scatterers and Absorbers", IOP Measurement Science and Technology, Vol. 16, pp2208-2212, 2005.
4. "Ultra-flat GaN surface made by lateral milling with Ga⁺ focused ion beam", submitted to Physics Review Letters.

