SH-ToF: Micro Resolution Time-of-flight Imaging with Super-heterodyne Interferometry

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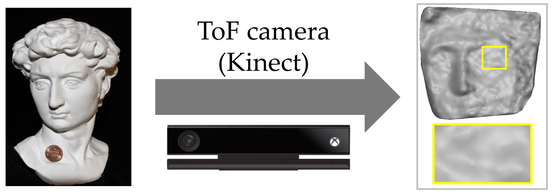
MOTIVATION

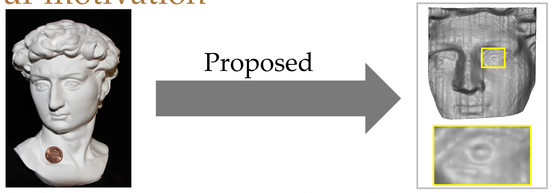
Why ToF cameras for 3D imaging?

- ❑ Large baseline for comparable depth resolution (Triangulation based 3D imaging e.g. structure light camera)
- ❑ ToF camera's compact size

Problem with current ToF cameras



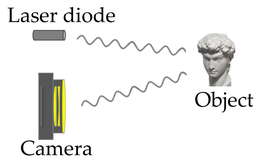
Our motivation

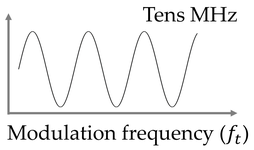


- ❑ Build a depth camera with micro resolution

BACKGROUND & PROPOSED

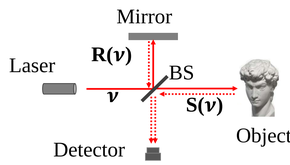
ToF camera

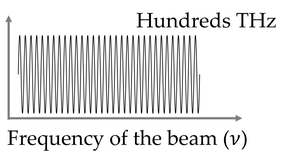




- ❑ Meters image range but centimeters depth resolution

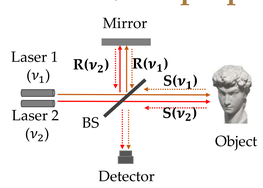
Michelson Interferometry (MI)

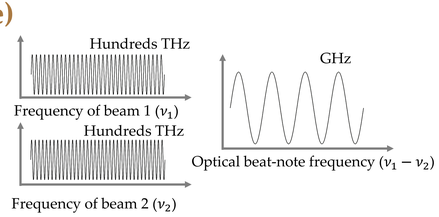




- ❑ Micro depth resolution but micro image range
- ❑ **Not** able to image optical rough surface (laser speckle)

SH-ToF (Our propose)

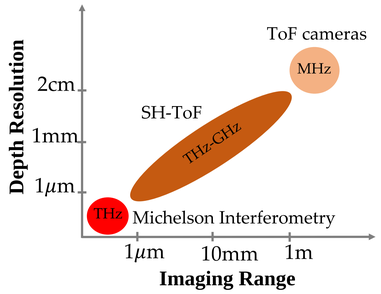




- ❑ Micro depth resolution but tunable image range (micro to meters)
- ❑ **Able** to image optical rough surface (laser speckle)

COMPARISON & CONTRIBUTIONS

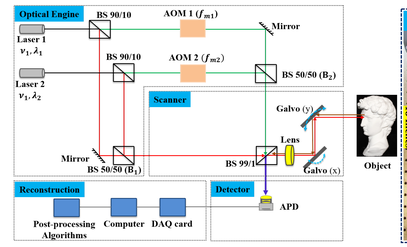
ToF camera	MI	SH-ToF
$z = \frac{1}{2}\cdot\frac{c}{f_t}\cdot\frac{\phi_p}{2\pi}$	$z = \frac{1}{2}\cdot\frac{c}{\nu}\cdot\frac{\phi}{2\pi}$	$z = \frac{1}{2}\cdot\frac{c}{(\nu_1-\nu_2)}\cdot\frac{\phi}{2\pi}$
100 MHz	100 THz	1GHz~1THz

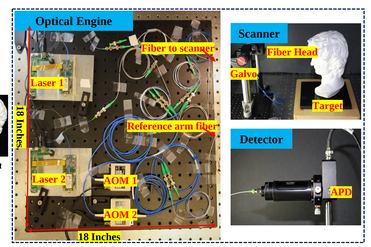


Our Contributions

- ❑ Micro resolution
- ❑ Tunability between depth resolution and depth range
- ❑ 3D scanning on rough surface

PROTOTYPE





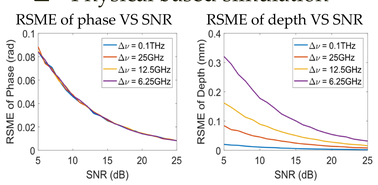
QUANTITATIVE EVALUATION

Pixel-point measurement

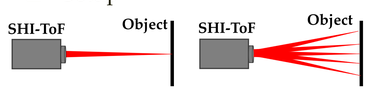
- ❑ Prototype measure

$\Delta\nu$[GHz]	100	25	12.5	6.25
$\delta\Phi$[rad]	0.041	0.049	0.059	0.047
δz[mm]	0.009	0.047	0.114	0.179

- ❑ Physical based simulation

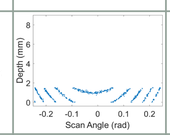
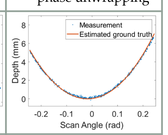
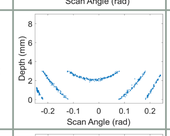
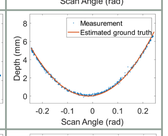
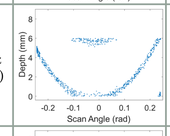
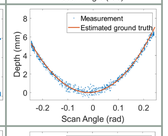
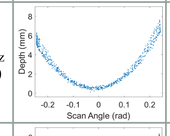
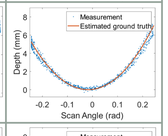
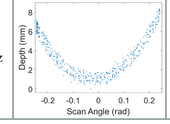
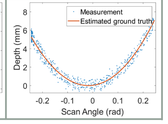


- ❑ Setup



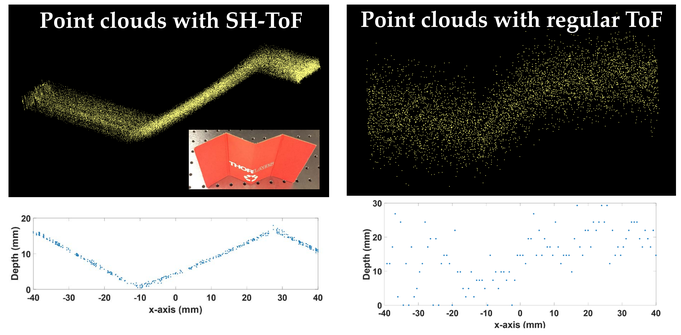
Line-scan measurement

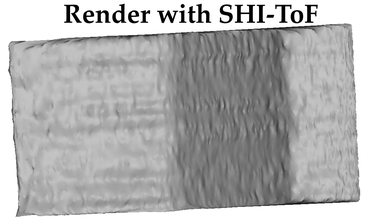
$\Delta\nu$[GHz]	100	50	25	12.5	6.25
δz[mm]	0.070	0.093	0.221	0.274	0.437

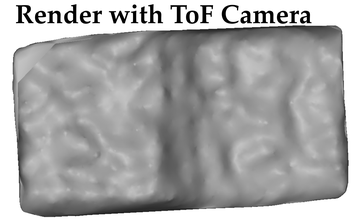
$\Delta\nu$ (Λ)	Depth estimated	Depth estimated with phase unwrapping
0.1 THz (3 mm)		
50 GHz (6 mm)		
25 GHz (12 mm)		
12.5 GHz (24 mm)		
6.25 GHz (48 mm)		

3D SCANNING

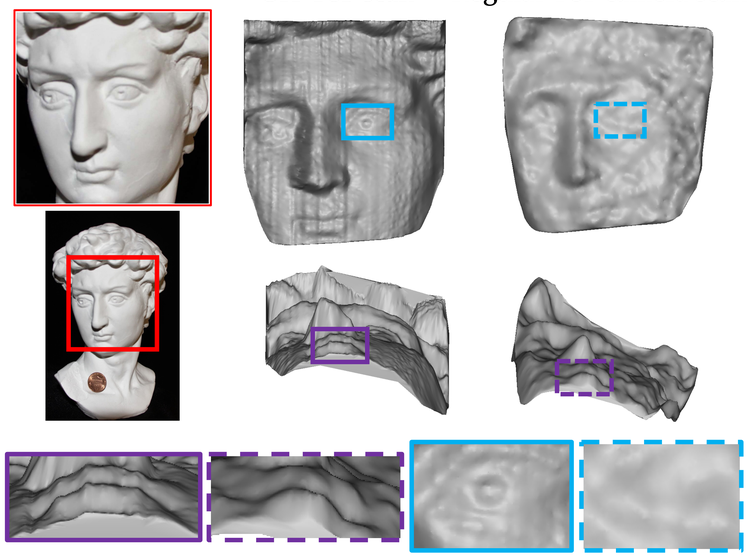
Folded cardboard







Plaster bust



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