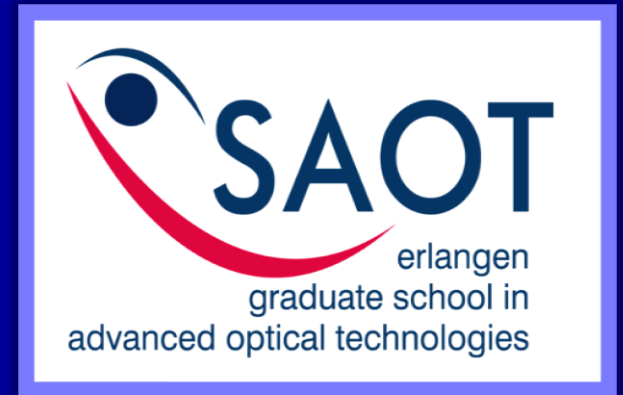


# Time-of-Flight Imaging

## And Its Applications

24.07.2008



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Friedrich-Alexander-University Erlangen-Nuremberg**

SAOT Summer Academy 2008

# Outline



- What is Time-of-Flight?
- The Time-of-Flight Principle
- Constraints in ToF imaging
- Fields of application for ToF imaging
- Current Work

# What is Time-of-Flight?



## ■ Data from MESA-camera/SR3100 (2)



Amplitudes



Distances

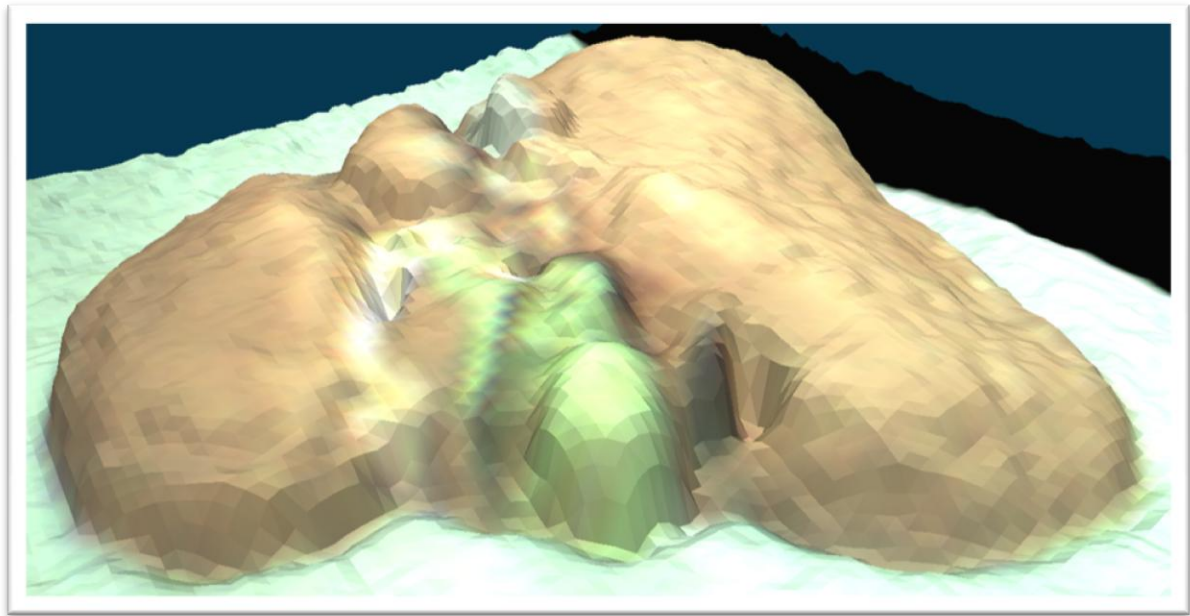
# What is Time-of-Flight?



- Real-Time acquisition of dense 3D-Data
- For every pixel the distance of the scene is measured



2D Camera



3D ToF Camera (with overlay)

# Manufacturers and their cameras



**3DV Systems**

image: [www.3dvsystems.com](http://www.3dvsystems.com)



**PMDTec**

image: [www.pmdtec.com](http://www.pmdtec.com)



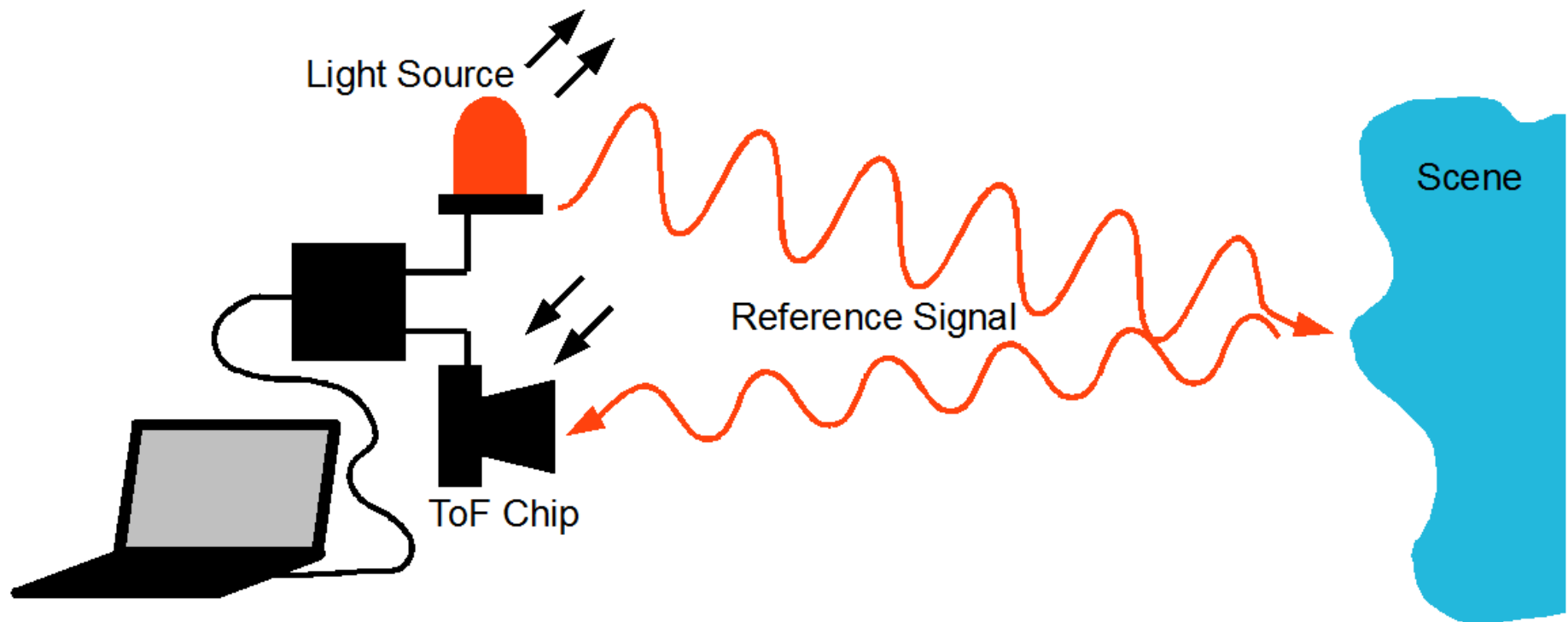
**MESA**

image: [www.mesa-imaging.ch](http://www.mesa-imaging.ch)

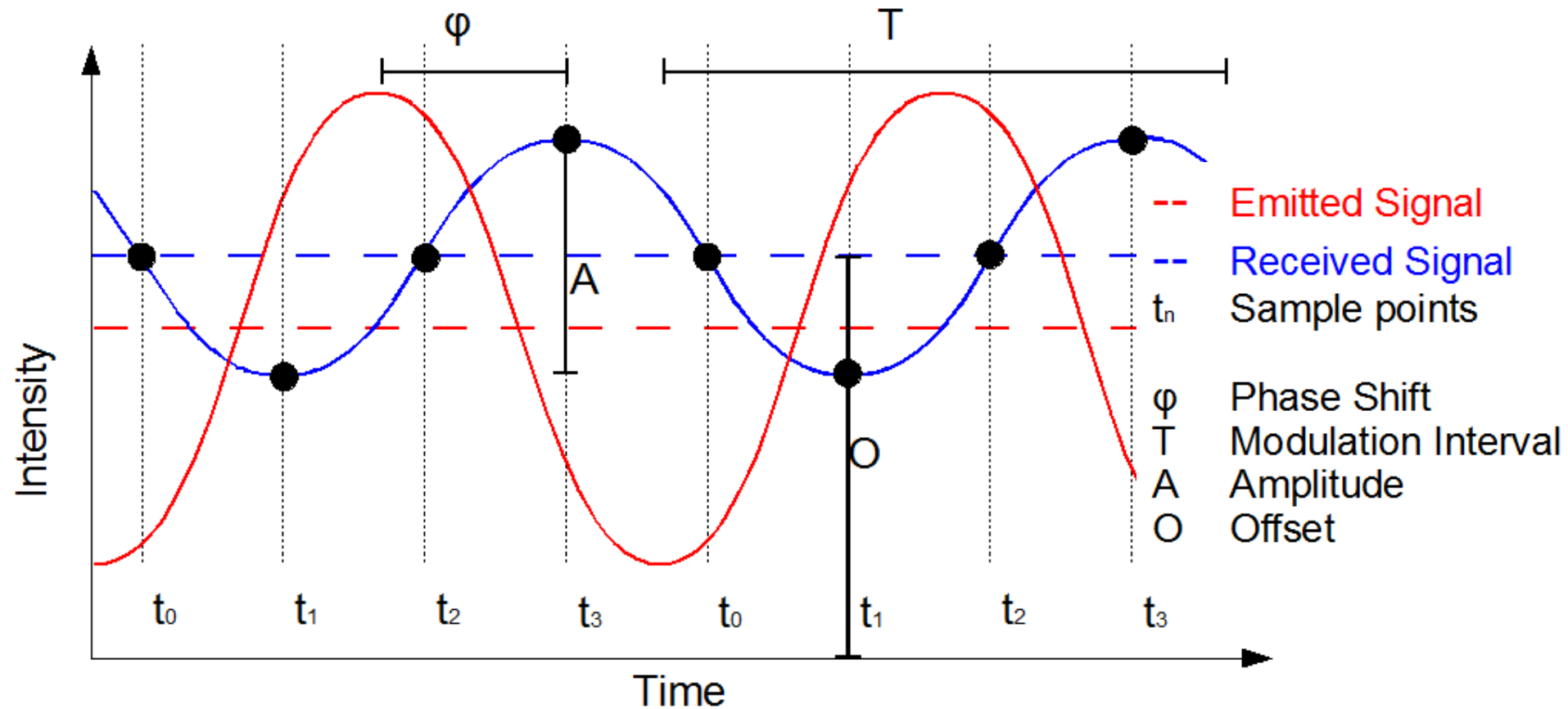


**Canesta**

# Principle of Time-of-Flight cameras



# Principle of Time-of-Flight cameras



# Determining the distance



$$d = \frac{c}{4\pi \cdot f_m} \cdot \varphi$$

$d$	distance
$c$	speed of light
$f_m$	modulation frequency



# Restrictions in ToF imaging



- Limited maximum range.
- Depth resolution depends on modulation frequency/maximum range.
- Interference when using multiple cameras.
- Interreflections using bad geometries/materials.
- Materials with low albedo lead to bad distance values.
- Oversaturation of CCD and specular reflections make distance data invalid.

# Fields of application



## ■ Automotive

- Obstacle detection
- Parking aid

## ■ Robot Navigation

- Collision avoidance
- Orientation in arbitrary scenes
- Reconstruction of static scenes

## ■ Human Pose estimation

- Gesture navigation
- Holistic body pose estimation

# Time of Flight at the LME

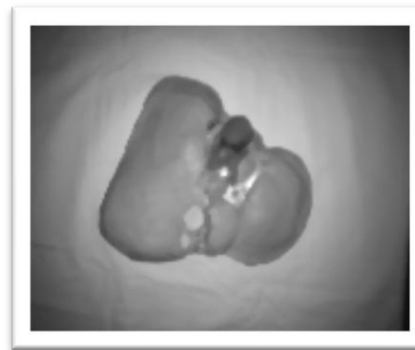


- At the Chair of Pattern Recognition (LME)  
5 Researchers are working on different Projects:
  - Gesture navigation
  - Human pose estimation
  - Patient positioning
  - Respiratory motion

# Current Work



- Development of a general purpose ToF-software-framework.
- Standardization of Amplitude-Values with respect to integration time and distances.
  - Amplitudes are biased
    - Integration Time
    - Distance Values

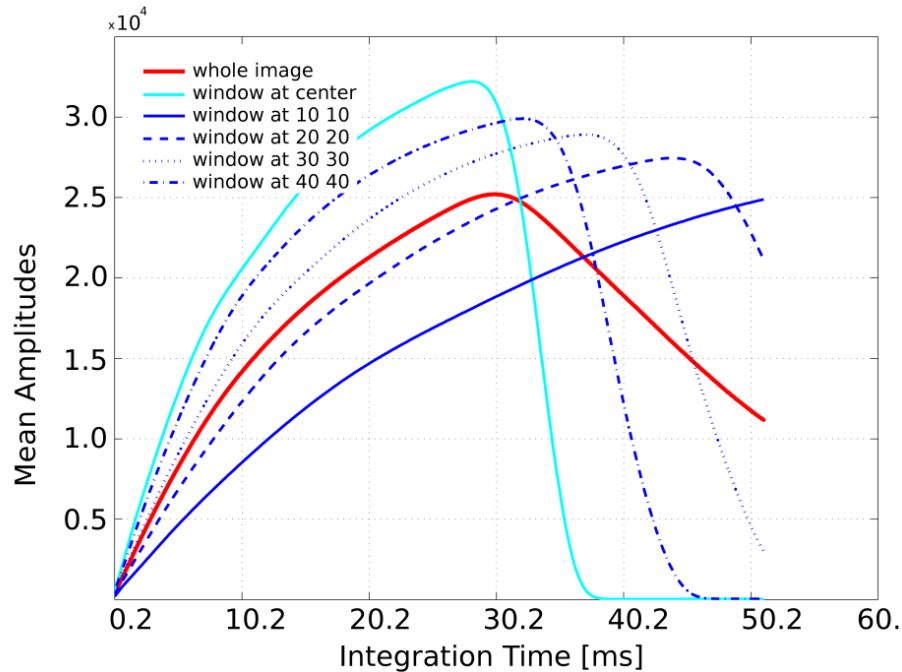


Amplitudes

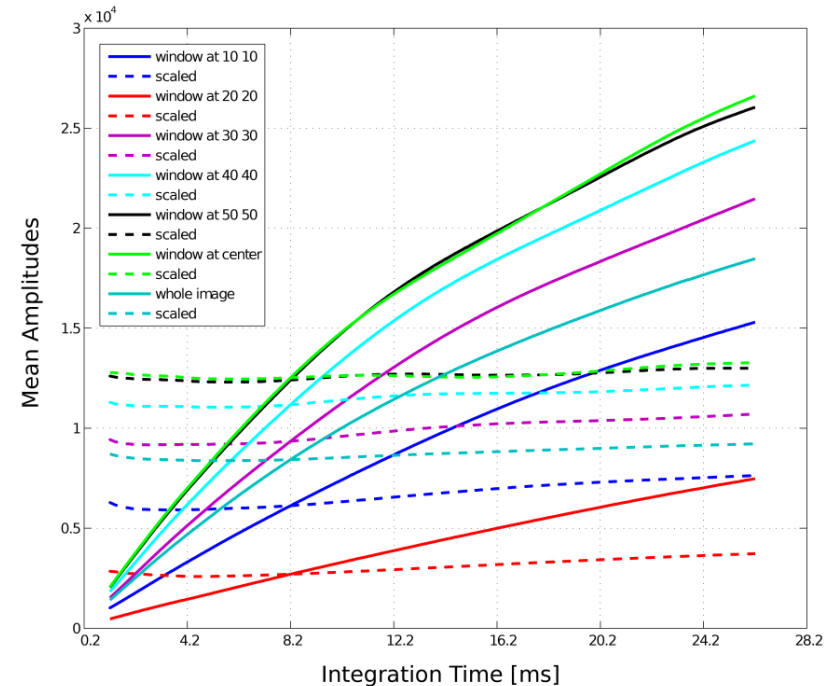


Distances

# Integration Time-Scaling

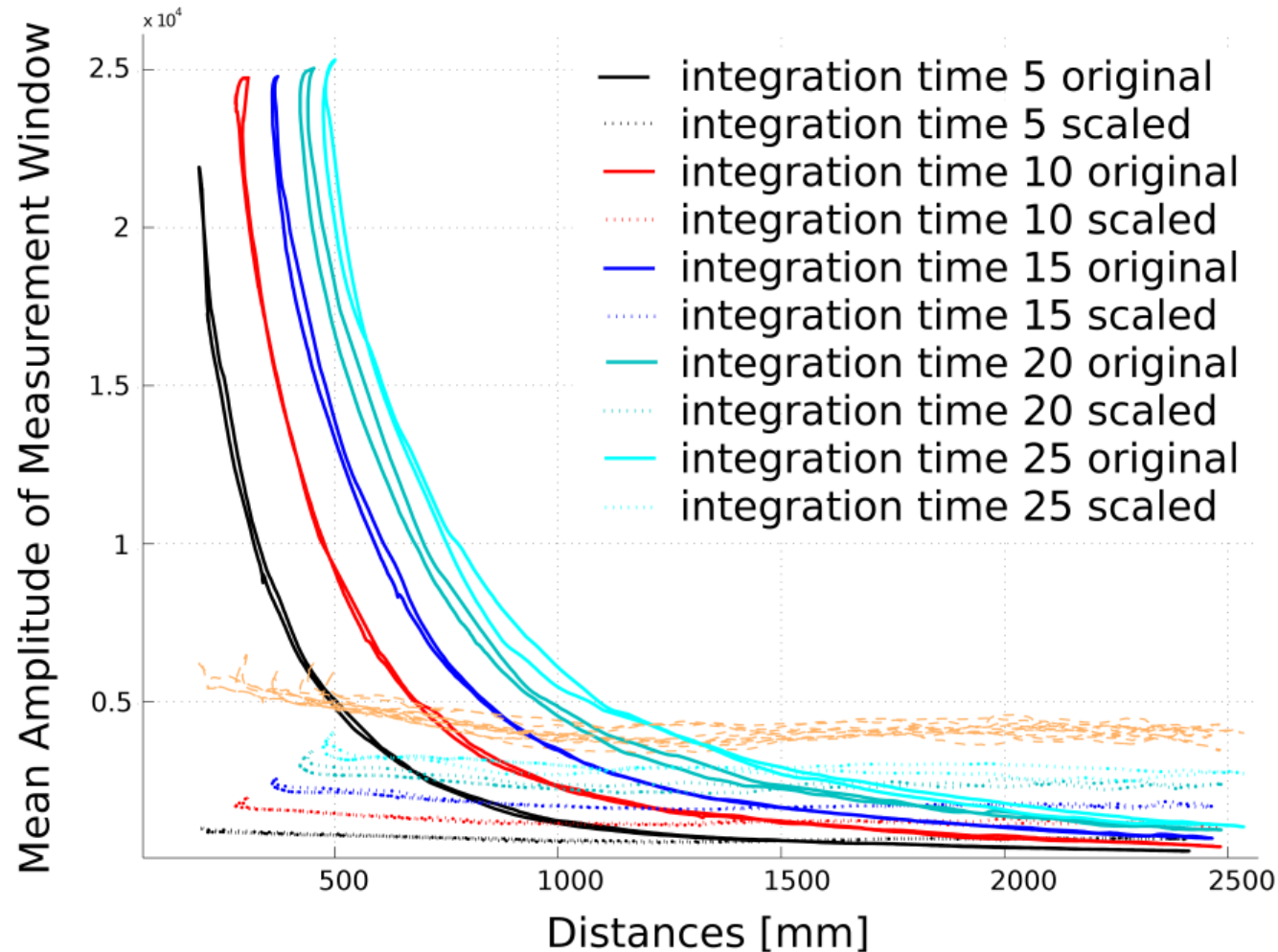


Mean Intensities over  
Integration Time



Unscaled (solid) and  
Scaled Intensities (dashed)

# Distance-Scaling of Amplitudes



## Decay of Mean Amplitudes depending on Distance

Michael Stürmer

24.07.2008

Time-of-Flight imaging

# Distance-Scaling of Amplitudes



Unscaled



Scaled

# Conclusion



- ToF starts to establish itself as a fairly known modality.
- Quality of cameras is high enough to be used in products.
- Both processing methods and hardware development still undergo a rapid evolution.
- Software development puts more and more focus on application of ToF cameras within products.



# Thank you for Your attention.

