

# LiDAR design and development

Optics, Virtual Testing, Signal Analysis, LiDAR-on-Chip



# Software Tools for LiDAR R&D

## CODE V

- Optimized imaging optics for emitter & detector
- Beam collimation
- Spot size control
- Beam widening
- Detector irradiation

## LightTools

- Source and detector setup
- Emitter and detector optics
- Gaussian ray propagation
- Time of flight simulations
- Test environment
- Weather effects

## RSoft

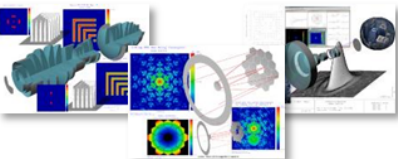
- Receiver physics
- Geiger mode / APD
- Integrated LiDAR CAD layout
- Photonics

## PIC Design Suite

- OptoDesigner & OptSim Circuit
- Photonic Integrated Circuit (PIC) layout
- Circuit verification
- PIC component library
- Process design kits (PDKs)

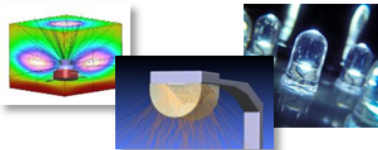
### CODE V - Imaging Design

Lens optimization, analysis, tolerancing and fabrication support



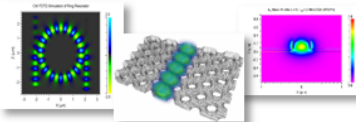
### LightTools - Illumination Design

Virtual prototyping, simulation, optimization and visualization of illumination optics



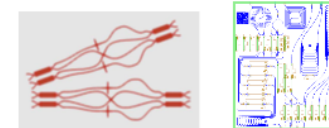
### RSoft - Photonics Design

Design and simulation of optical telecomm devices, nano-scale optical structures, circuits and systems



### PhoeniX OptoDesigner - Photonic Integrated Circuit Design

Physical layout and verification for photonic integrated circuits



### LucidShape - Automotive Lighting Design

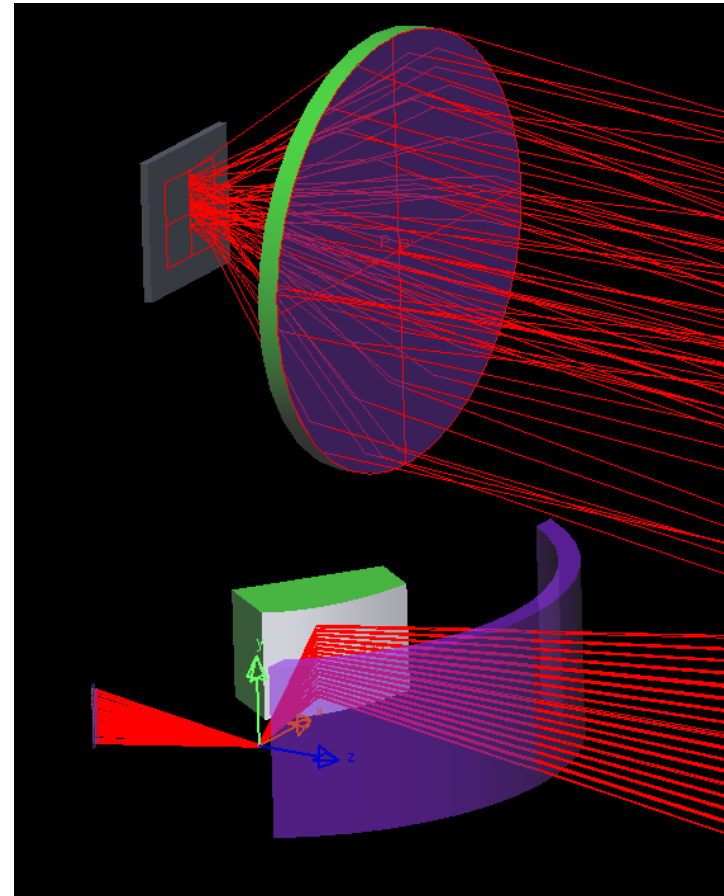
Design and real-time simulation of automotive forward, rear and signal lighting



# Emitter/Detector Optics and Radiation Propagation

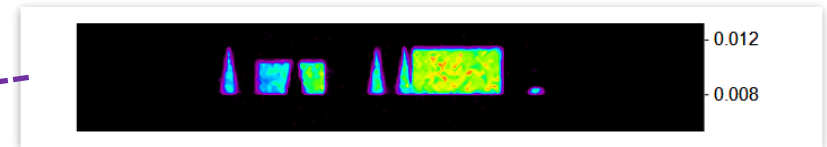
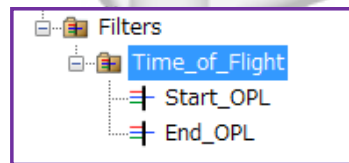
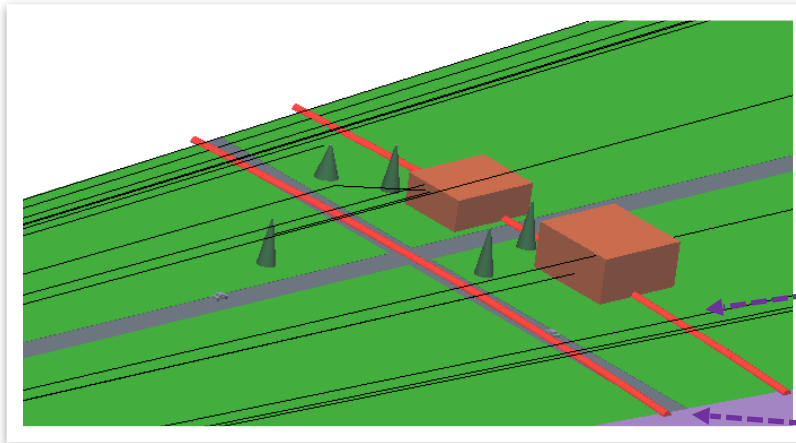
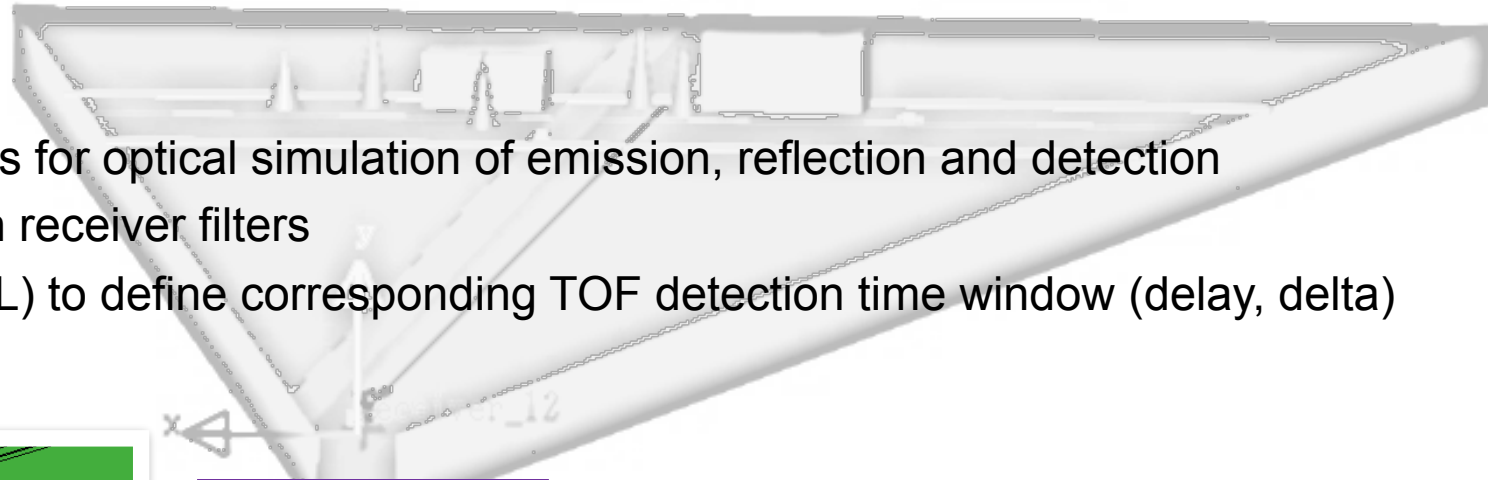
Propagation is simulated with Gaussian beam physics in LightTools

- Source engine simulation: housing, optics, stray light analysis
- Beam steering, e.g., scanning systems with rotating mirrors
- Detector image data display
- Static test scene setup for LiDAR simulation
- Time-of-flight (TOF) investigations
- Weather modeling

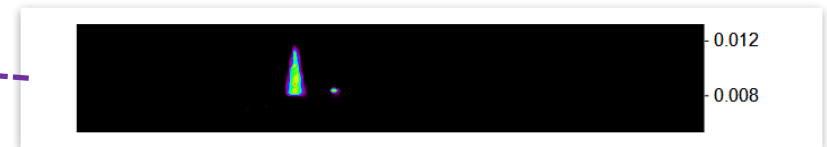


# Custom Scene Setups for TOF Simulation (LightTools)

- Manage physical test scenes for optical simulation of emission, reflection and detection
- Binning for time of flight with receiver filters
- Use optical path length (OPL) to define corresponding TOF detection time window (delay, delta)



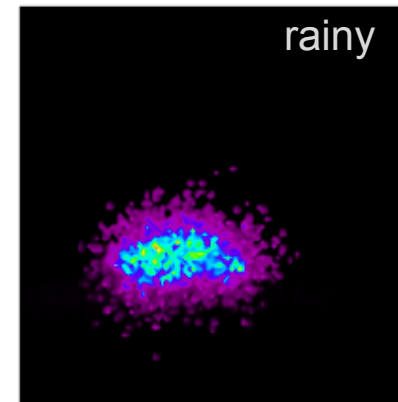
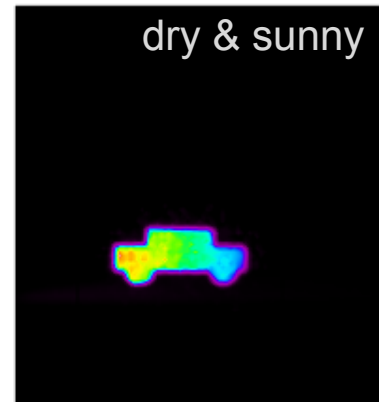
Range detection: imaging signal at different TOF bins



# Weather Effects

- Fog and rain, dust or atmospheric disturbances in general massively affect radiation propagation and reduce signal quality
- Physical volume scattering simulations provide a reliable base for water-based effect predictions
- Simulate, investigate, and analyze sensor signal deterioration as a function of fog or raindrop density

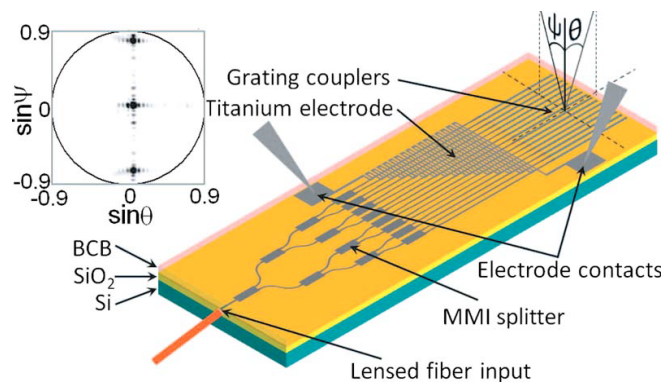
- Rain volume when  $X$ mm rain falls in 1 mm square
  - $1 \cdot 1 \cdot X = X(\text{mm}^3)$
- Volume of raindrop of diameter  $R$ 
  - $\frac{4}{3} \cdot \pi \cdot (R/2)^3 = \frac{\pi}{6} \cdot R^3(\text{mm}^3)$
- $\therefore$  Number of raindrops =  $6X / (\pi R^3)(\text{pcs})$
- Rain fall speed =  $V(\text{m/sec}) = V_e3(\text{mm/sec})$
- One hour = Height falling at  $60 \cdot 60(\text{sec}) = V_e3 \cdot 3600 = V \cdot 36e5(\text{mm})$
- Because there are  $6X / (\pi R^3)$  raindrops in volume  $S \cdot 36e5(\text{mm}^3)$ 
  - Raindrop number density =  $6X / (\pi R^3) \cdot (S \cdot 36e5) = X / (6e5 \cdot \pi \cdot SR^3)(\text{pcs/mm}^3)$
  - Rainfall amount 20 mm, raindrop diameter 2 mm, falling speed 7 m/sec
    - Raindrop number density:  $1.895e-7(\text{pcs/mm}^3)$ ,  $MFP: 5.28e6(\text{mm})$
    - $MFP \ll \lambda$  - When light propagates, the distance that all rays hit the rain and scatter is less than directly



Evaluation of detector results for a vehicle at  $\sim 0.5 \mu\text{s}$  within weather effect scenario

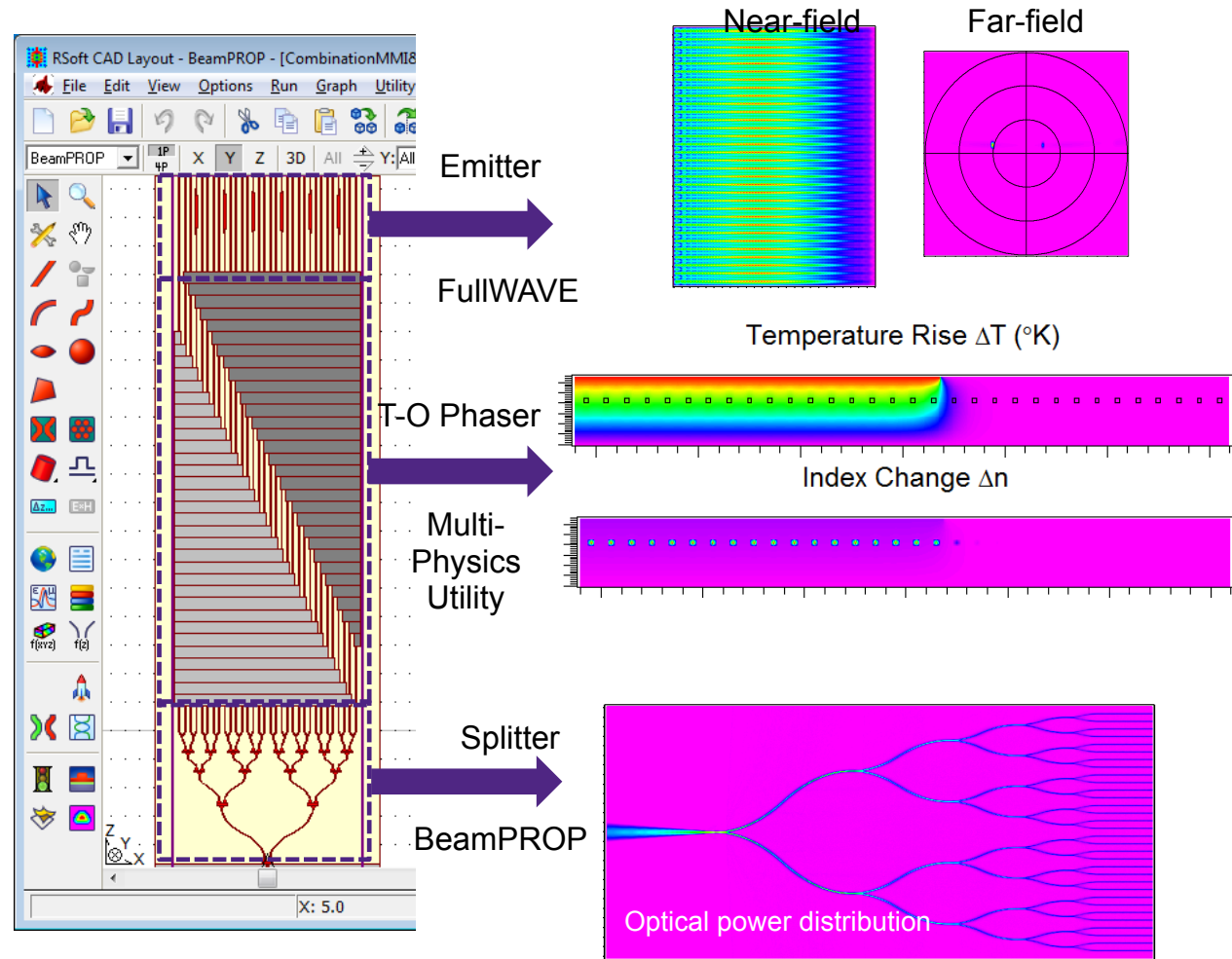
# PIC LiDAR R&D (RSoft)

- Example structure by Ghent University and IMEC



Van Acoleyen, Karel, et al. "Off-chip beam steering with a one-dimensional optical phased array on silicon-on-insulator." *Optics letters* 34.9 (2009): 1477-1479.

- Layout in RSoft CAD
- No single simulation tool can solve this complex problem; tools must be combined to simulate different elements of the device
- Design photonic power splitters, thermo-optical phase shifters, emitter gratings





**SYNOPSYS**<sup>®</sup>  
*Silicon to Software*<sup>™</sup>