Chroma

Create Your Own Testing Innovation.

2019

Laser Diode used in 3D sensing Technologies Test Requirements/Concerns and Solutions

Jeff

2019.9.27

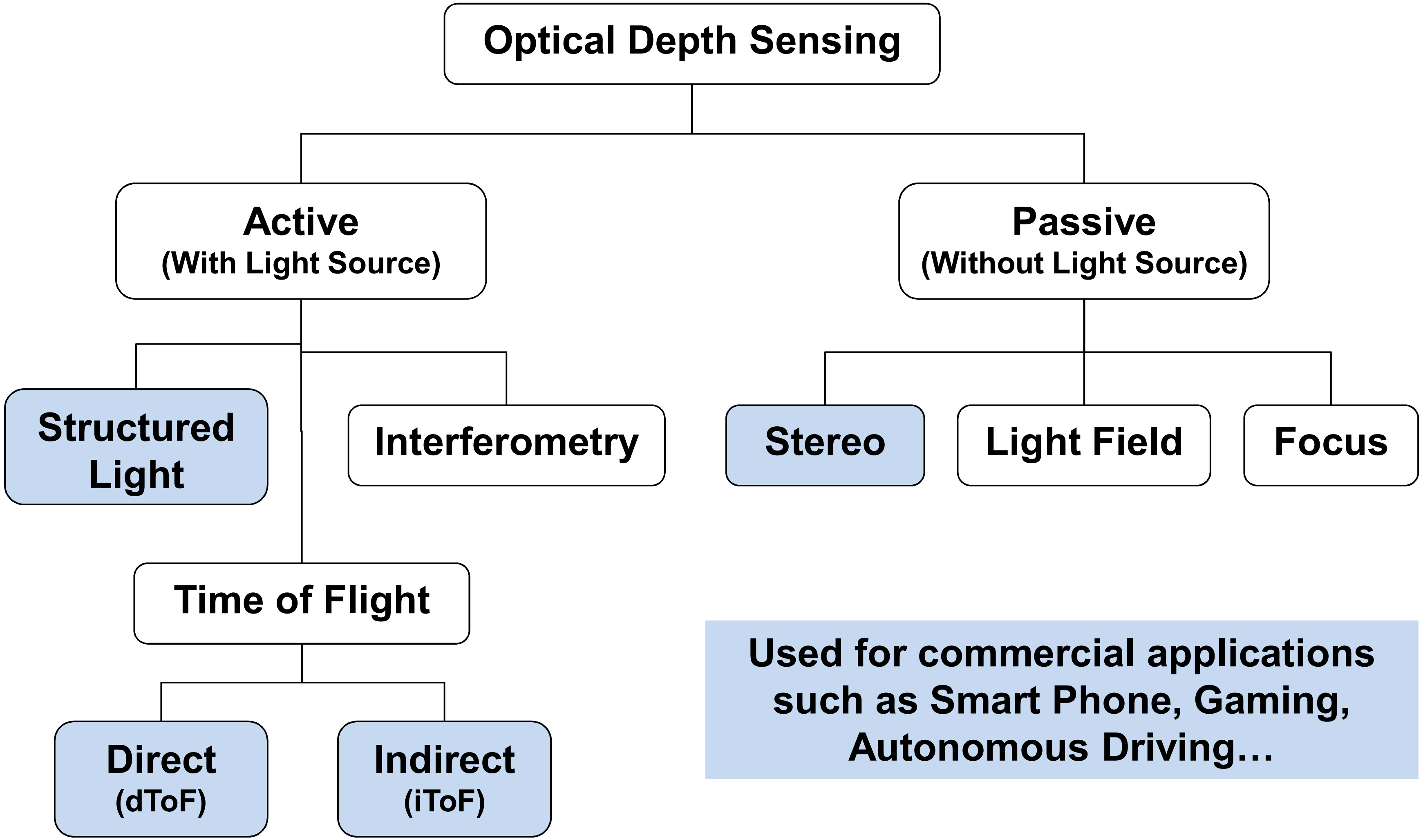
turnkey Test and Automation Solution provider

Content

- 3D Sensing Technologies
- Test Requirements per Technologies used
- MP test solutions

3D Sensing Technologies

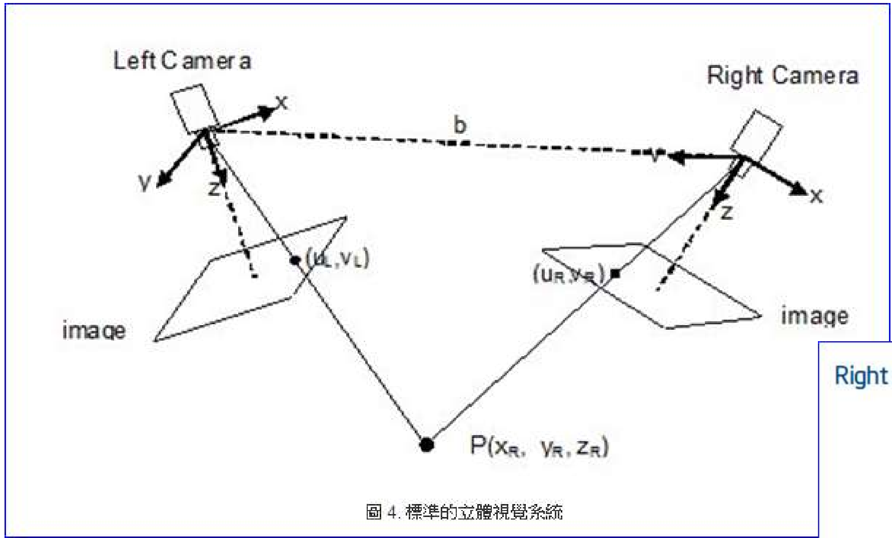
Depth Sensing Technologies



Used for commercial applications such as Smart Phone, Gaming, Autonomous Driving…

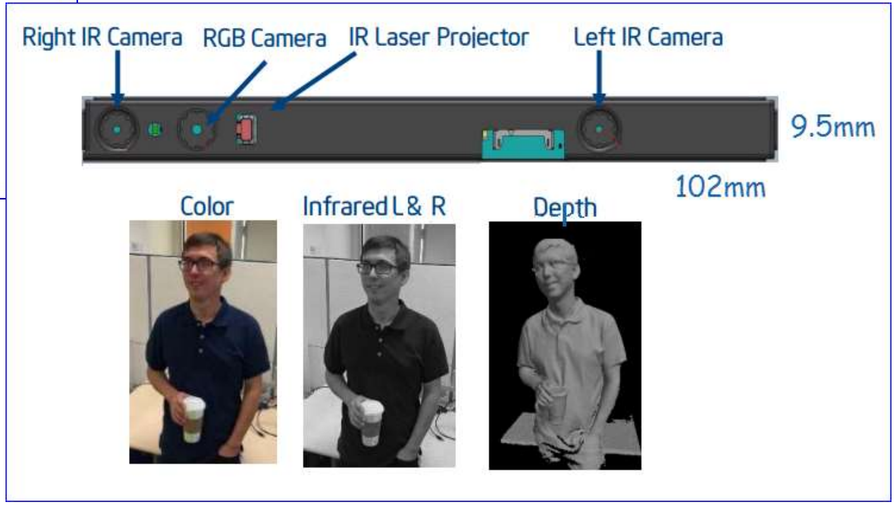
Source : D. Stoppa et al., SSCS Distinguished lecture 2018

Stereo



Pros:

1. Simplicity in Structure
2. Well established technology
3. Low power consumption (when no active light source)



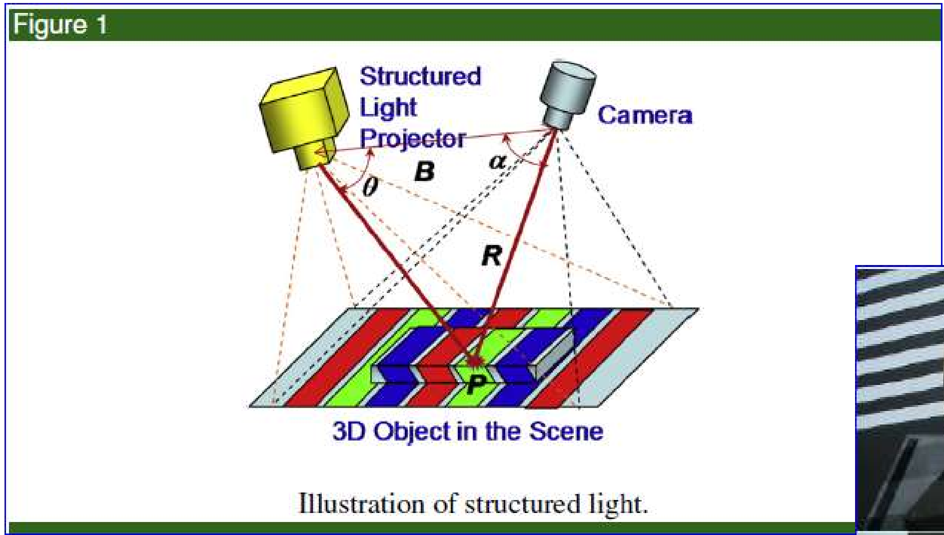
Cons:

1. Depth resolution related to size
2. Limited range
3. High computation requirement thus low update rate

Light Source Requirements (when equip):

1. **Driving :** uS Pulse driving
2. **Spectral :** Narrow spectrum / Immune to Sunlight / Low T shift
3. **Spatial :** Diffused cover detection area
4. **Eye safety :** Combination of driving, spectrum and spatial distribution

Structured Light



Pros:

1. Good depth Resolution
2. Active light, work in dark
3. Compact size

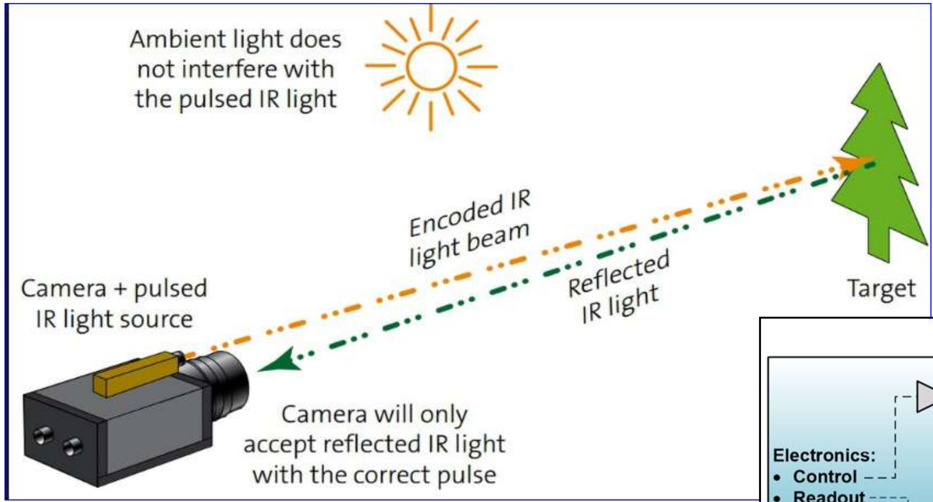
Cons:

1. Complex optics thus higher in cost
2. IP issues

Light Source Requirements:

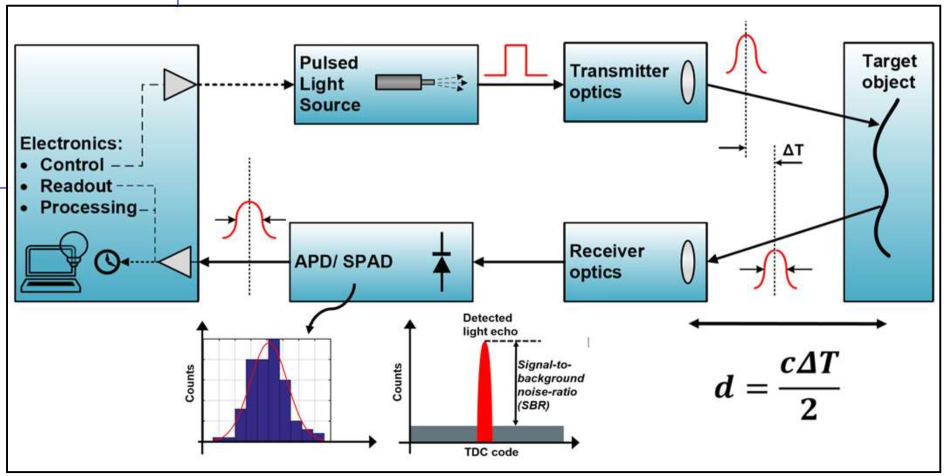
1. **Driving :** uS Pulse driving
2. **Spectral :** Narrow spectrum / Immune to Sunlight / Low T shift
3. **Spatial :** Multiple collimated light beams cover detection area
4. **Eye safety :** Combination of driving, spectrum and spatial distribution

Direct Time of Flight - dToF



Pros:

1. Simplest in S/W
2. Good depth resolution
3. Low power consumption
4. Good for Autonomous



Ref : EPFL Advance Quantum Achitecture Lab

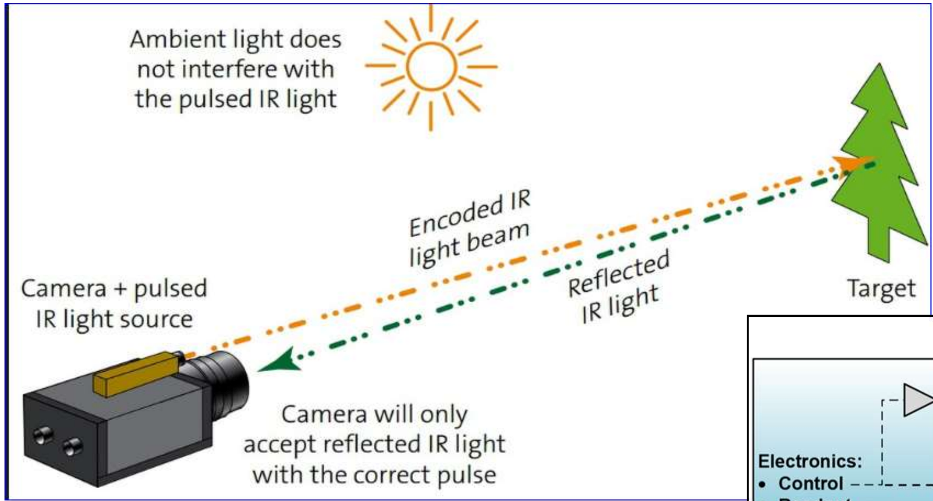
Cons:

1. Very challenge in testing (nS pulse to Laser)
2. Poorer lateral resolution because use of SPAD/APD

Light Source Requirements:

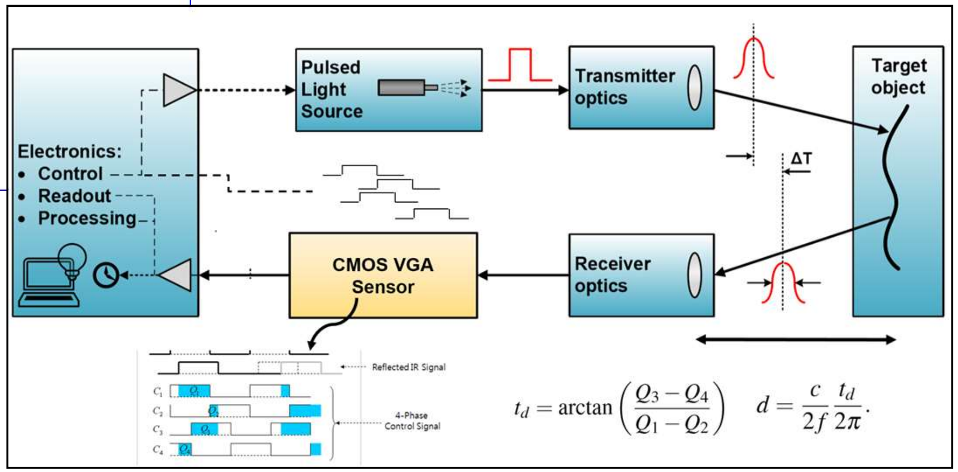
1. **Driving :** Super short nS Pulse driving
2. **Spectral :** Narrow spectrum / Immune to Sunlight / Low T shift
3. **Spatial :** Diffused cover detection area
4. **Eye safety :** Combination of driving, spectrum and spatial distribution

Indirect Time of Flight - iToF



Pros:

1. Simple in S/W
2. Good lateral resolution
3. Lower in cost
4. Good for Smart Phone



Ref : EPFL Advance Quantum Achitecture Lab

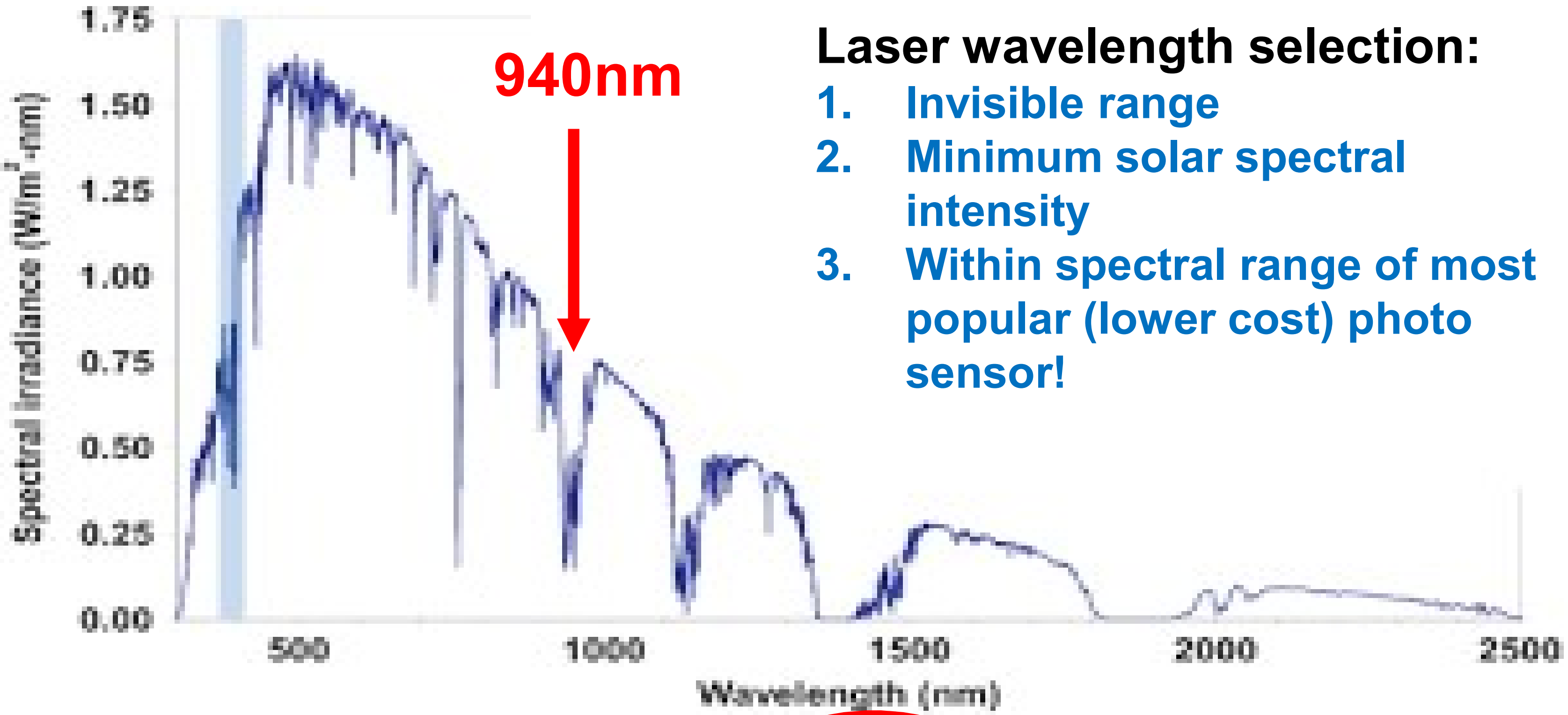
Cons:

1. Average depth resolution because of integration time
2. Higher power consumption

Light Source Requirements:

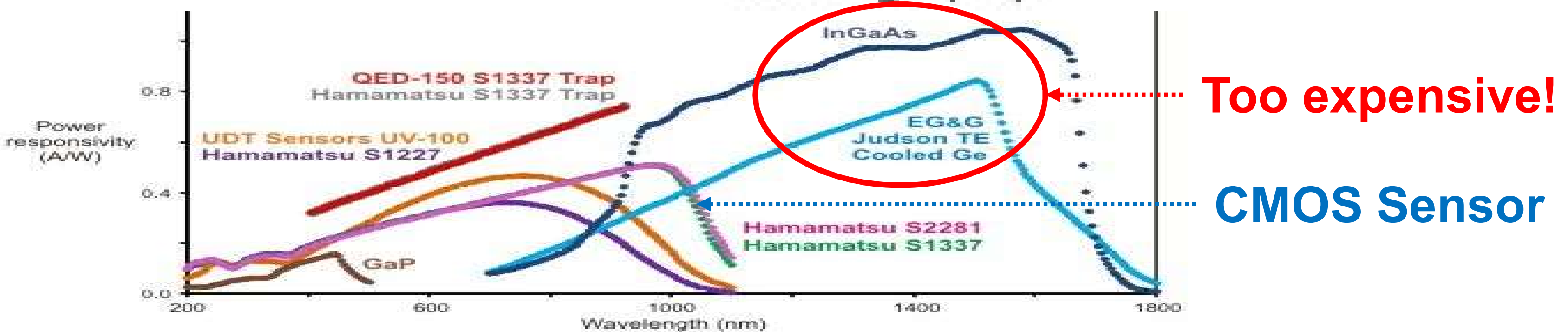
1. **Driving :** Tens to hundreds nS pulse or modulated Sinewave driving
2. **Spectral :** Narrow spectrum / Immune to Sunlight / Low T shift
3. **Spatial :** Diffused cover detection area
4. **Eye safety :** Combination of driving, spectrum and spatial distribution

Why 940nm? – Smart Phone

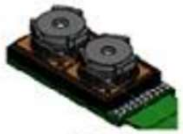


Laser wavelength selection:

1. **Invisible range**
2. **Minimum solar spectral intensity**
3. **Within spectral range of most popular (lower cost) photo sensor!**



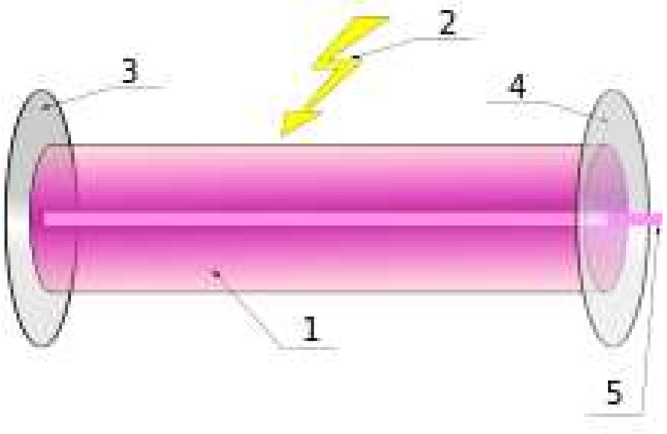
3D Sensing Technologies – Wrap up

YOLE Développement	Stereo vision	Structured light	Time of Flight
Image resolution	Several Mpix	Max. 1–3 Mpix	Max.VGA
Hardware	Simple cameras Complex system	Demanding illumination Complex system	Simple illumination Complex sensors
Computation power	High	Medium	Low
Limitations	May require illumination in low light	Best indoors Need power	Best indoors Low resolution
Picture (example)	 *Courtesy of ams*	 *Courtesy of Apple*	 *Courtesy of PMD Tech*
Best suited for	Robotic navigation	3D mapping	Short-range gesture capture
Maturity	High	Medium	Low
Players	SONY, ams, STEREOLABS, SAMSUNG, OmniVision	Himax, ams, ST, NAMUGA, intel	Infineon, pmd, SONY, ST, epc, LIPS

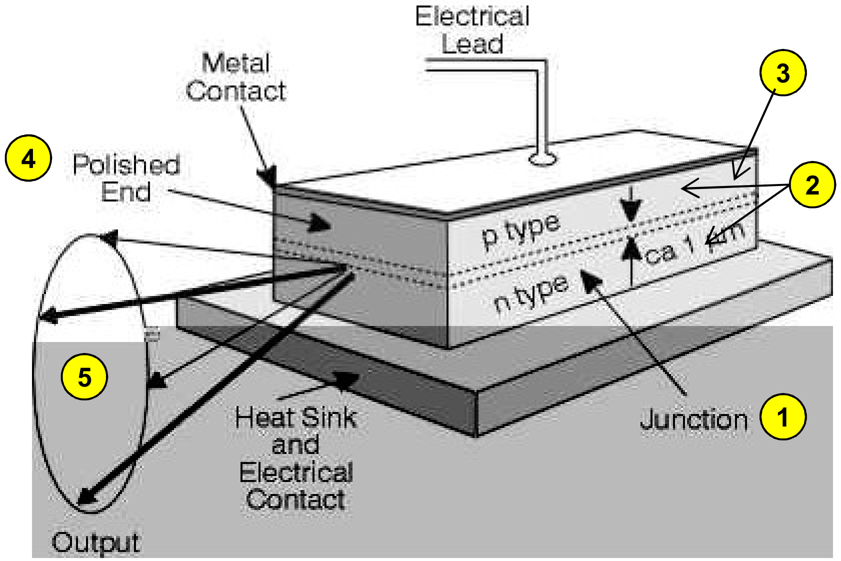
Source : Yole Development

Test Requirements per Technologies Used

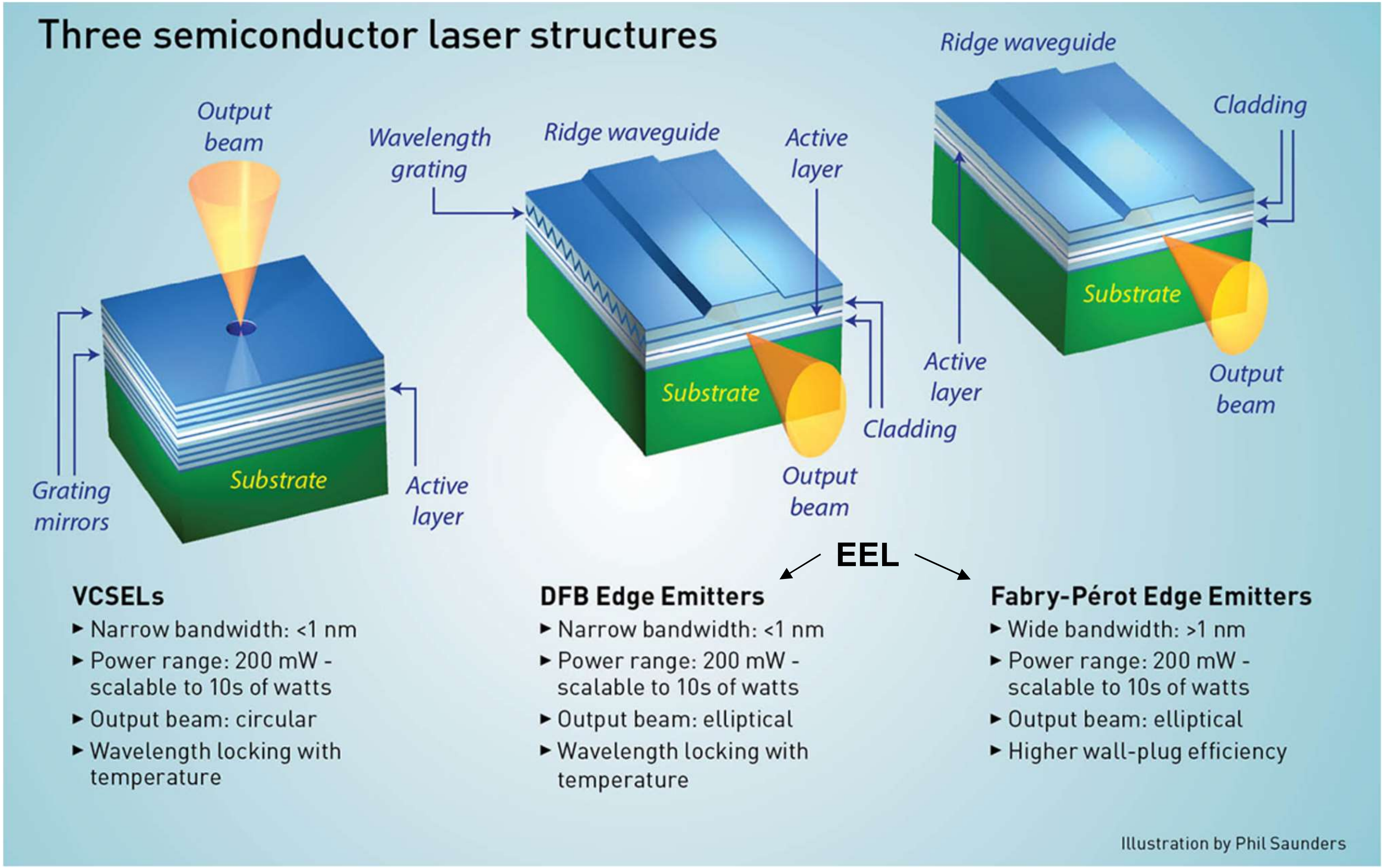
LASER = **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation



Components of a typical laser:
1. Gain medium
2. Laser pumping energy
3. High reflector
4. Output coupler
5. Laser beam



Types of Laser Diode – Structures



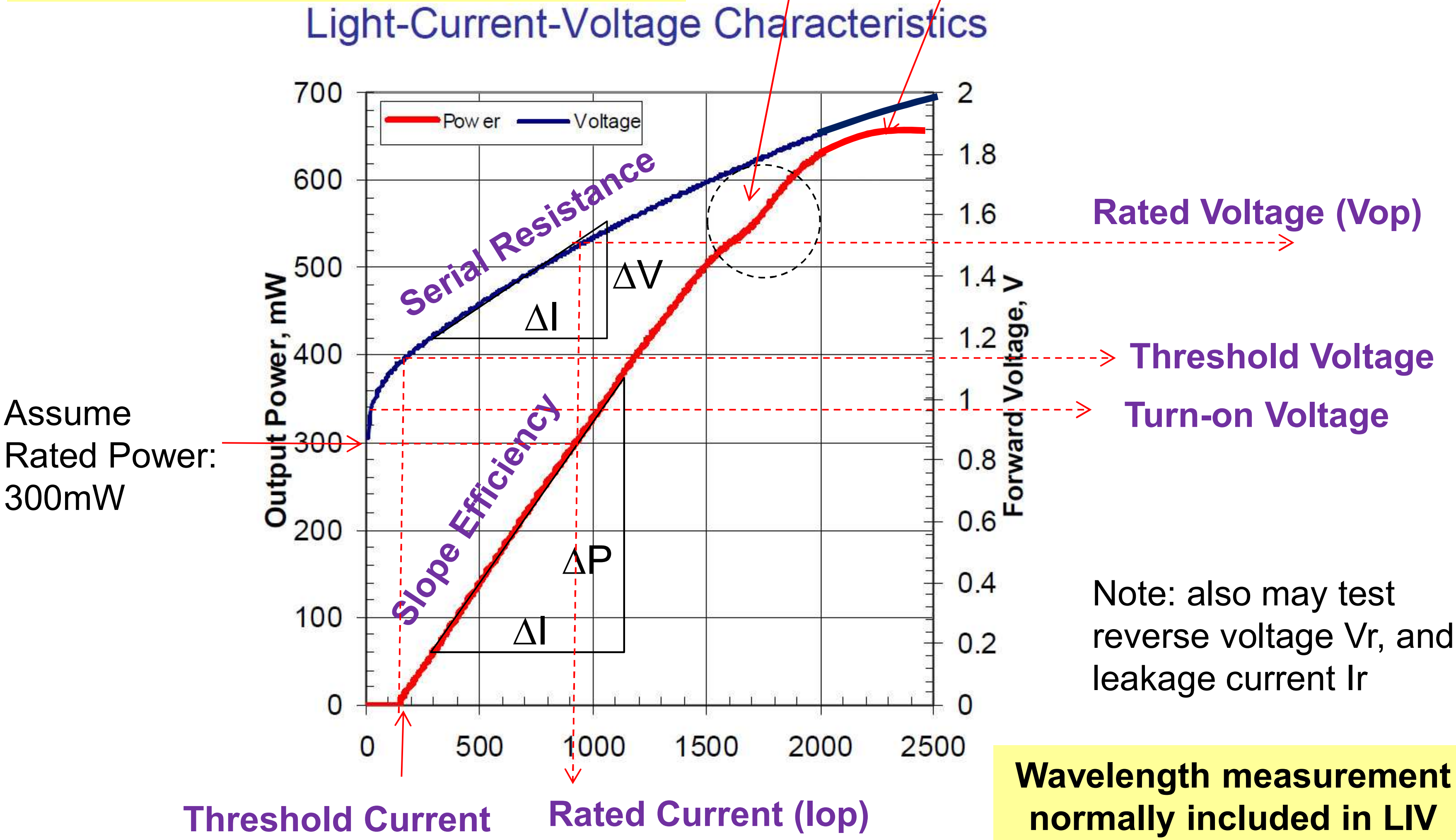
Source : Optics & Photonics

Laser Diode vs LED per Technologies

Requirements /Verdict	Stereo	Structured Light	dToF	iToF	LED	Laser Diode
Eye Safety	High	Very High	High	High		👑
Narrow λ (Immune to Sunlight)	High	High	High	High		👑
Small λ Temp-co	High	High	High	High		👑
Fast Modulation	Low	High	Very High	High		👑
Multi-Emitters	Low	High	Low	Low		👑
Individual Emitter Reliability	Low	High	Low	Low		👑
Power Overdrive (Short pulse with high driving current)	Low	Medium	Very high	High		👑
Collimation Requirement	No	High	No	No		👑
Beam Quality Requirement	Low	High	Low	Low		👑
Cost	Low	Very High	High	High	👑	
Suitable Applications	**Gaming**	**Face ID**	**3D sensing for Portable, Autonomous**	**3D sensing for Portable**		
Champion Device	**VCSEL/LED**	**VCSEL**	**VCSEL/EEL**	**VCSEL**		

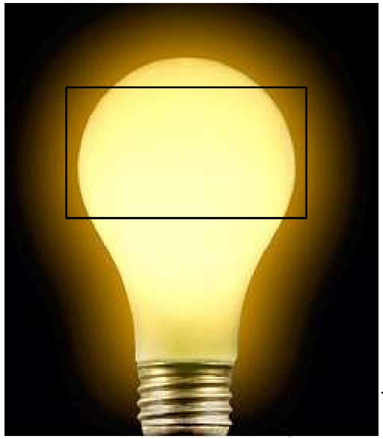
LIV + λ Test

LIV Test: Source current, measure light power & voltage



Wavelength measurement normally included in LIV

Near Field & Far Field



Near Field Image

Far Field Image

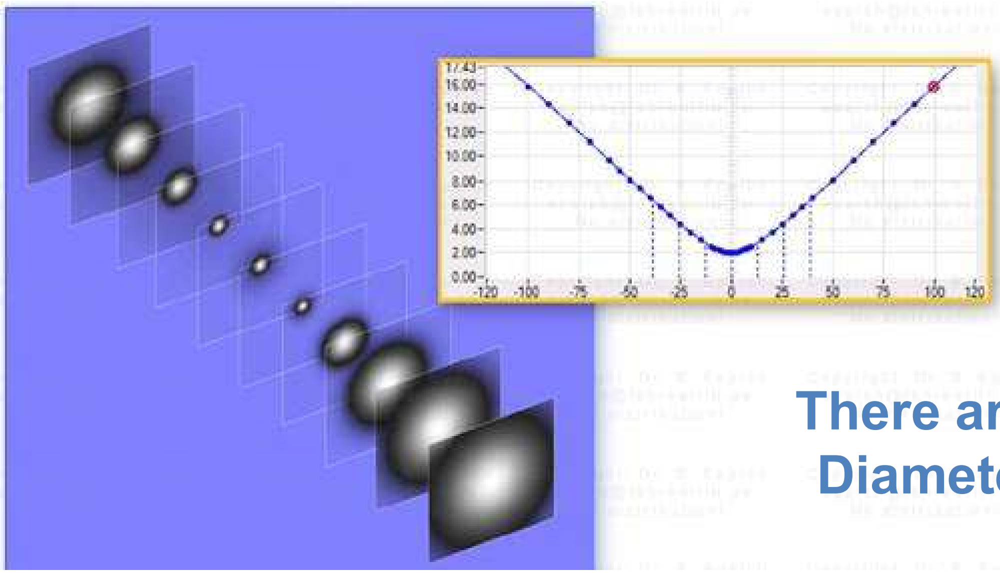
Near Field Image:

Image taken (focused) at where the light comes out of a light source.

Far Field Image:

Image taken (observed) at a distance of a light source

Laser Beam Quality (NF)



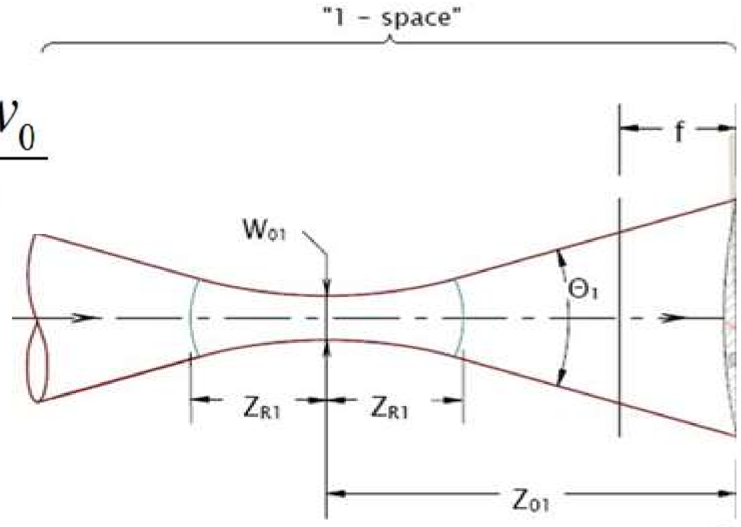
ISO 11146

Lasers and laser-related equipment - Test methods for laser beam widths, divergence angles and beam propagation ratios

There are different Beam Waist Diameter definitions, such as D86, D4S

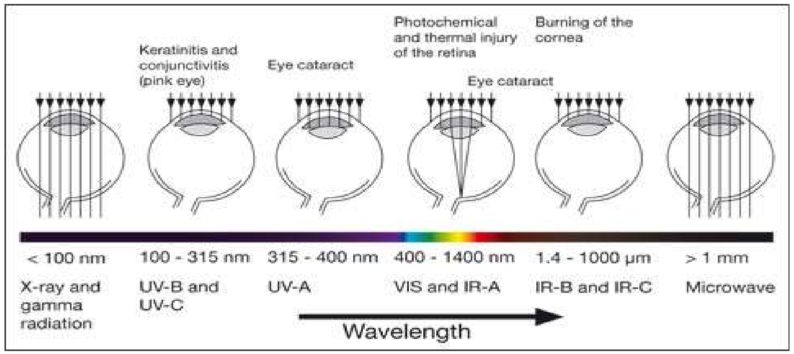
M^2 : Beam Quality Factor, ideal = 1; Means how close the actual beam profile compares to ideal Gaussian profile

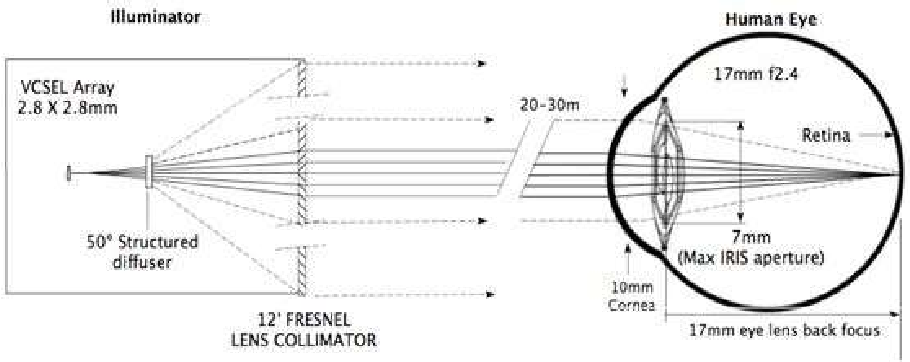
$$M^2 = \frac{\theta \pi w_0}{\lambda}$$



Eye Safety (FF)

	Condition 1 *applied to collimated beam where e.g. telescope or binoculars may increase the hazard*[a]		Condition 2 *Applicable to optical fibre communication systems, see IEC 60825-2*	Condition 3 *applied to determine irradiation relevant for the unaided eye, for low power magnifiers and for scanning beams*	
Wavelength nm	Aperture stop mm	Distance mm		Aperture stop/ limiting aperture mm	Distance mm
< 302,5	–	–		1	0
≥ 302,5 to 400	7	2 000		1	100
≥ 400 to 1 400	50	2 000	See Note 1 under 5.4.1	7	100





IEC-60825

VCSEL Test Requirements

Device Phase /Technologies	Test Requirements	Structured Light	dToF	iToF
Wafer Level	LIV + λ Related	Optical power, Pop, Ith, Slope Eff. Vf, Ir, Wp, PCE	Optical power, Pop*, Ith*, Slope Eff*. Vf*,PCE*, Ir, Wp,	Optical power, Pop, Ith, Slope Eff. Vf, Ir, Wp, PCE
	Near Field Related	Emitter Power, Emitter N.A. W0, W0 Uniformity, M^2	Dead Emitter (VCSEL)	Dead Emitter (VCSEL)
	Far Field Related	Die N.A., 7mm diameter power	Die N.A., 7mm diameter power	Die N.A., 7mm diameter power
	Burn-In	LAT/WAT	LAT/WAT	LAT/WAT
Module Level	LIV + λ Related	Pop, Vf, Ir, Wp, PCE	Pop, Vf, Ir, Wp, PCE (w/Driver)	Pop, Vf, Ir, Wp, PCE
	Near Field Related	Nil	Nil	Nil
	Far Field Related	Beam Pattern, Eye Safety	Spatial Profile, Eye Safety	Spatial Profile, Eye Safety

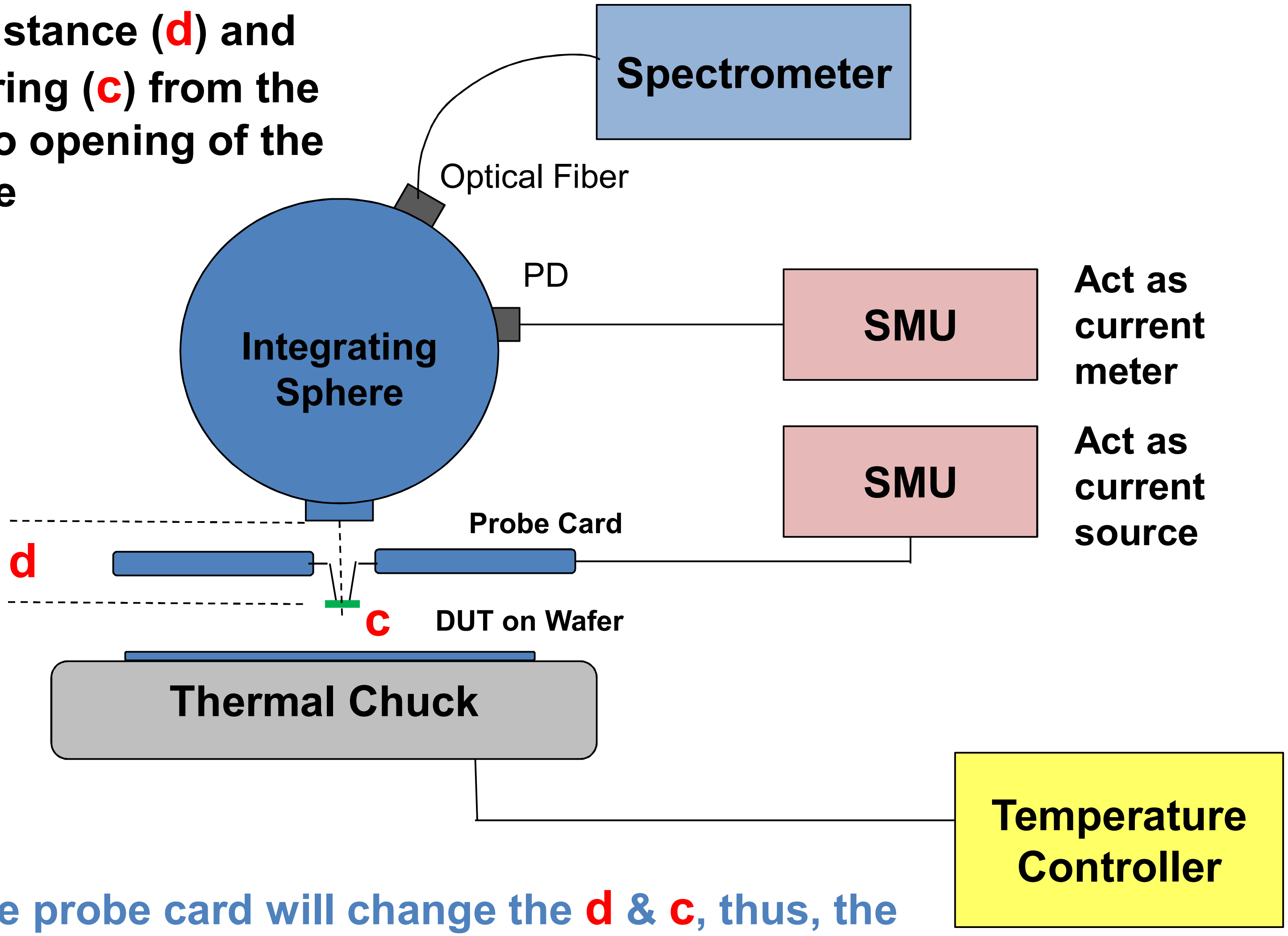
* Require relaxed pulse width

MP Test Solutions

LIV + λ Test Setup

Chroma

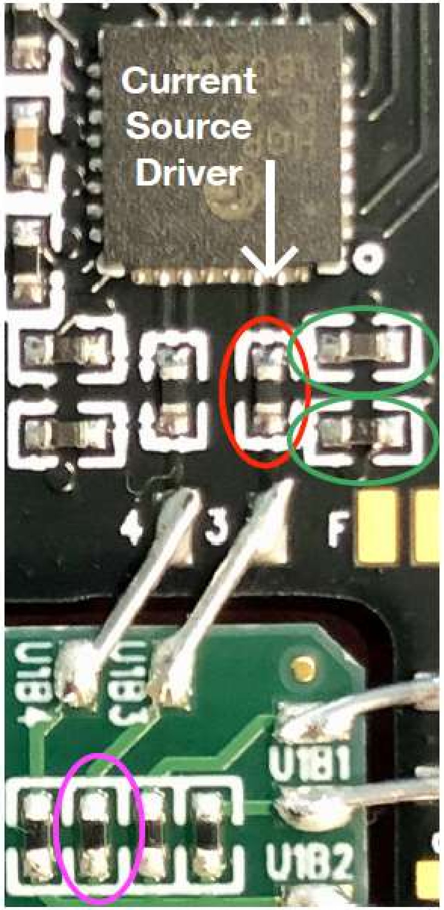
The distance (d) and centering (c) from the DUT to opening of the sphere



Change probe card will change the d & c, thus, the Sphere may need to adjust to secure same test result

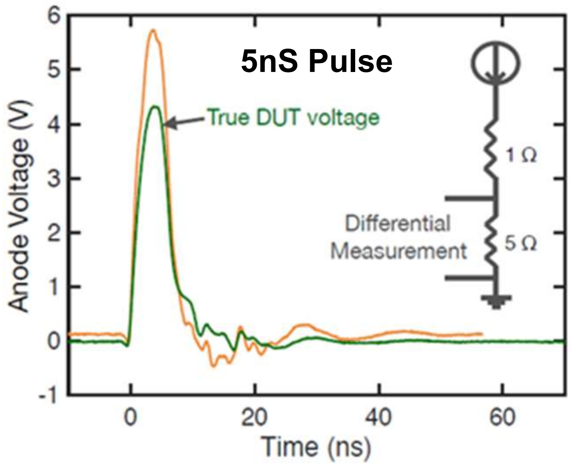
Short Pulse Driver – for ToF

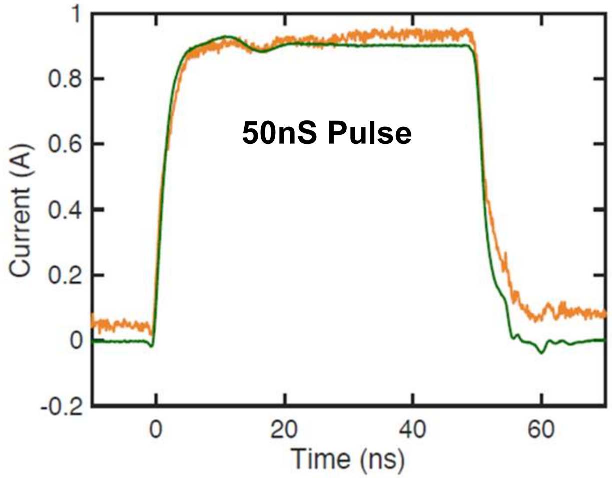
Driver embedded on Probe Card



Chroma Programmable ToF Driver

- **0-5A/ Min. Pulse width : 5nS** (at O/P terminal)
- **Embedded design -> shortest path to DUT**
- **FPGA control**
- **Sense output to connect to O'Scope**

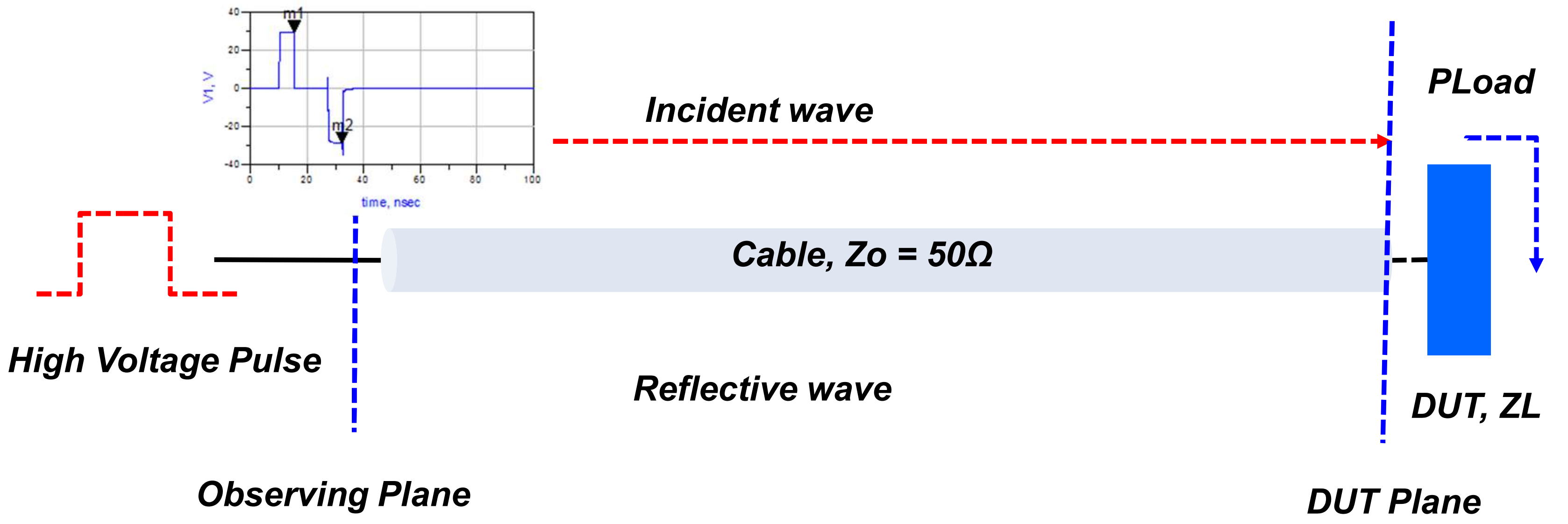




- **Multiple pulse train is normally used to achieve optical power needed**
- **Electrical power is hard to measure for pulse width <10nS**

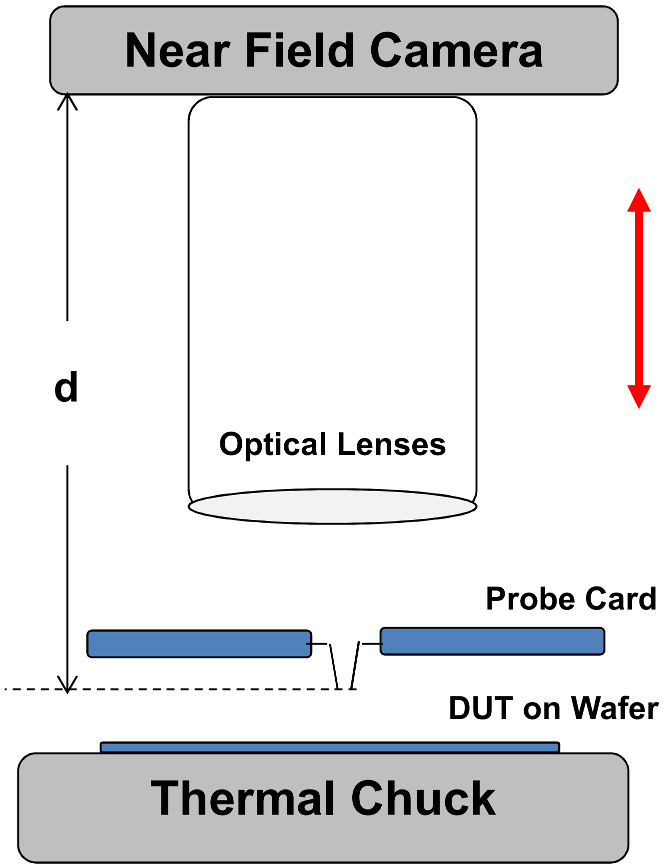
Time Domain Reflectometer (TDR)

1. *Send a sub-nsec with 1 A peak current to DUT, Laser Diode, on wafer.*
2. *Measure the current, voltage, and power delivered to DUT.*
3. *Sourcing the pulse by voltage wave traveling the cable down to DUT.*
4. *Simultaneously measuring the incident/reflective voltage waves on observing plane to determine the information on DUT*

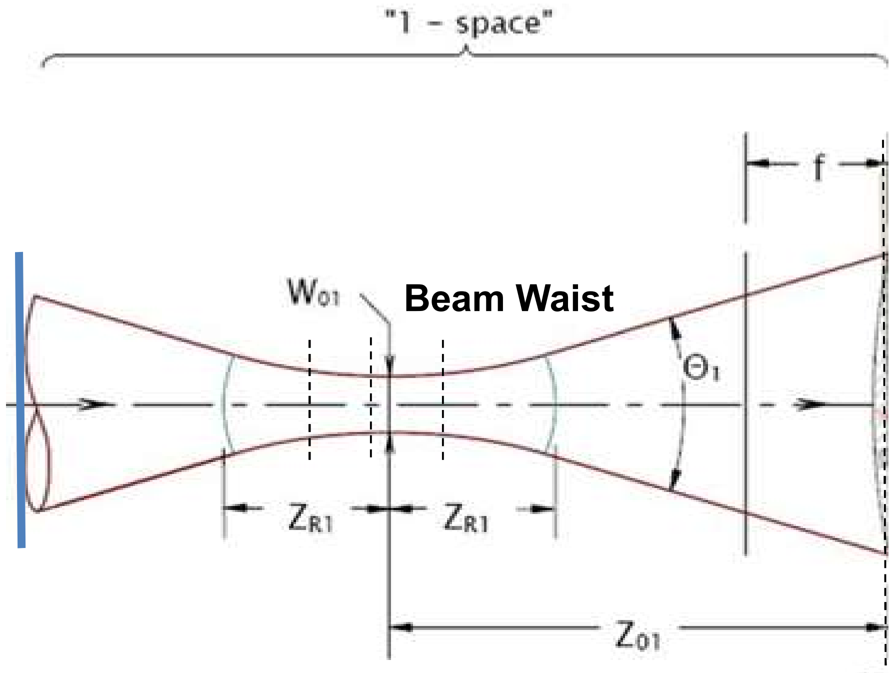


TDR approach is not good for high current (>1A) because the well established 50Ω system will cause non-realistic voltage/power requirement

Near Field MP Test Method

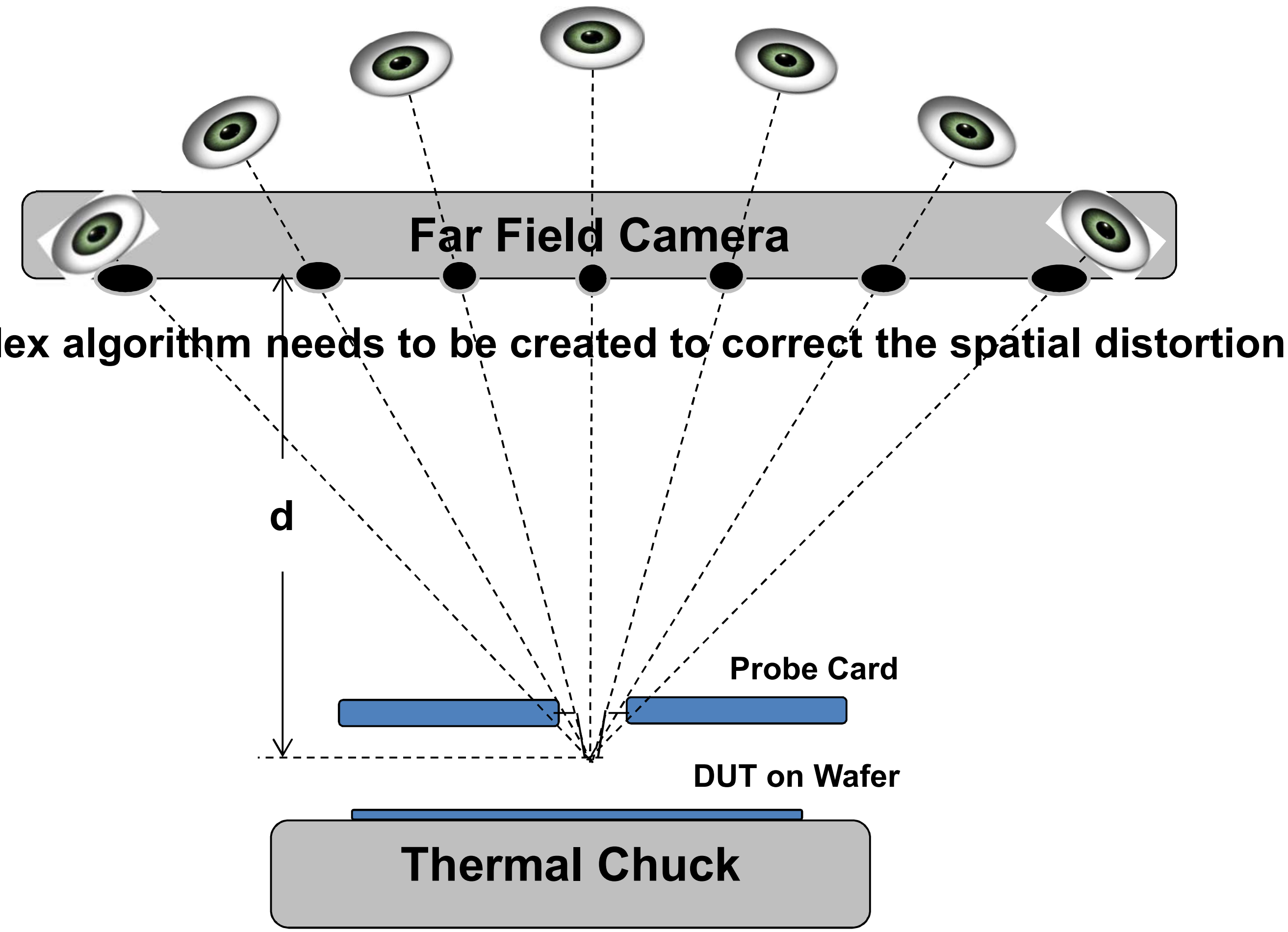


M^2 measurement requires very accurate Beam Waist diameter (W_0), therefore needs multiple points to interpolate the most accurate W_0



The DUT z-position is determined by probe tip position, therefore alignment is needed every time when changing probe card.

Far Field MP Test Method



The DUT z-position is determined by probe tip position, therefore alignment is needed every time when changing probe card.

Chroma 58635 VCSEL Probe/Tester

58635-L : for LIV test
58635-N : for Near Field test
58635-F : for Far Field test

Key features:

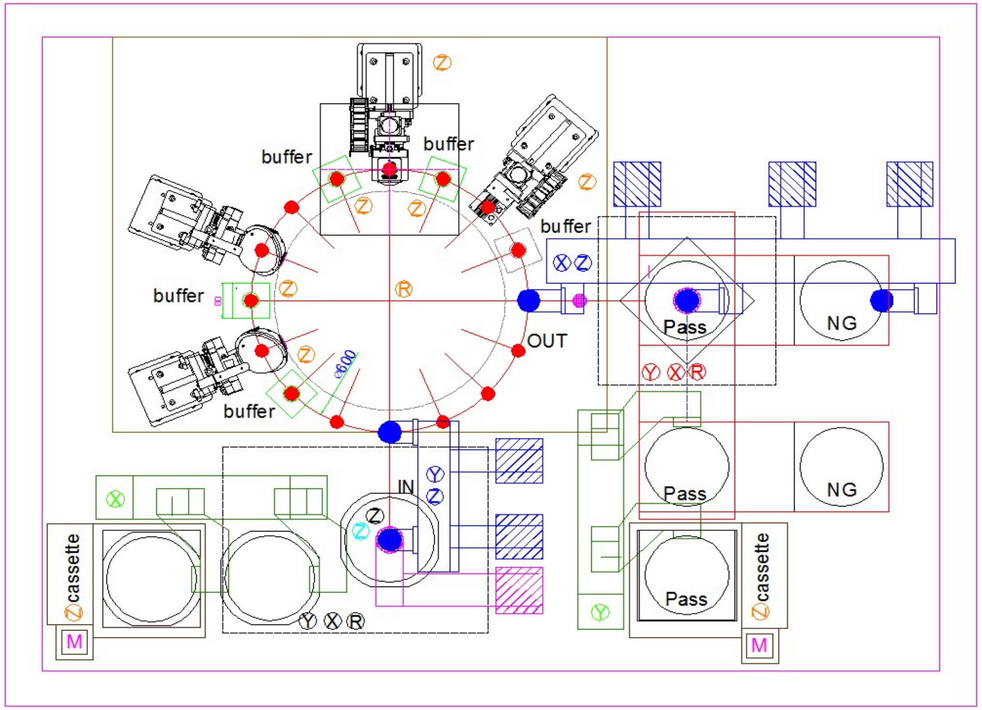
- Referencing ISO/IEC standards
- Wide range and precise temperature control
- Support both pulse and CW operation

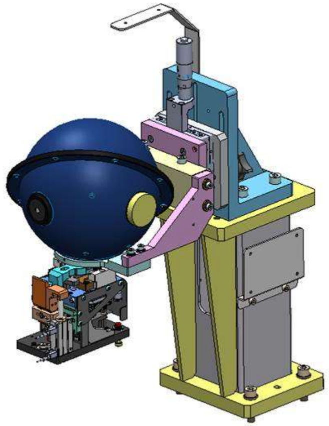
Chroma 58622 VCSEL Module Tester/Sorter

Key features:

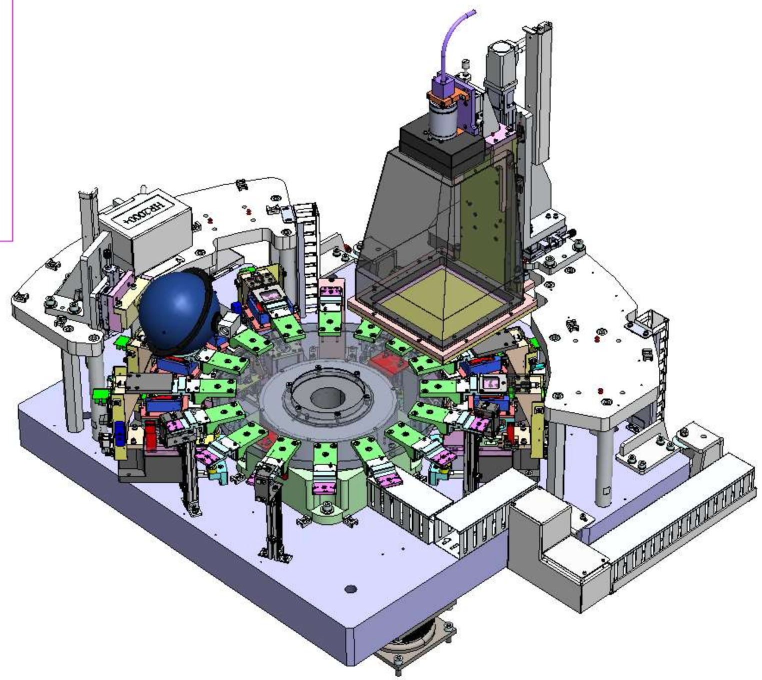
- Turret based system
- DUT: 3D sensing applications; VCSEL sub-module, illuminator, TOF module
- UPH:1200 *
- Max. 4 test stations. Flexible test stations arrangement upon requirements.
- Precise temperature control for each socket
- High speed SMU
- Auto-binning after test

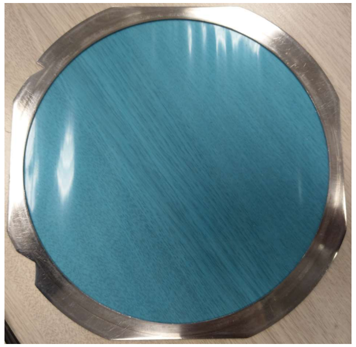
Chroma 58622 System Layout





LIV
Test
Station



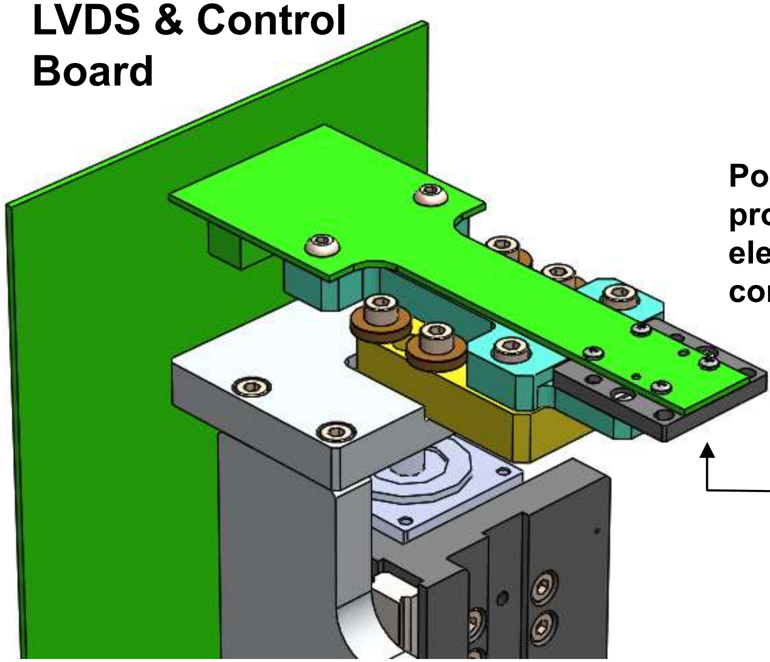


DISCO Frame input/output (Optional Tray input/output)

Active ToF module

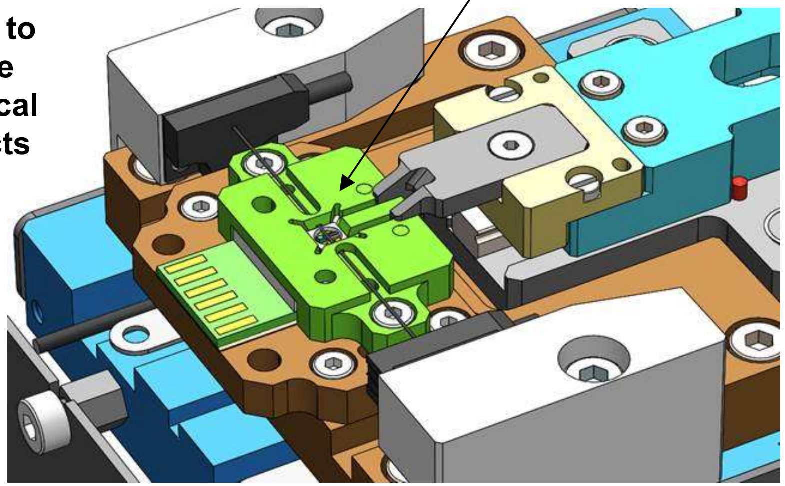
- VCSEL is die/wire bonded on module
- Optics (normally diffuser lens) is mounted
- Driver and control circuit on board
- The pulse width is normally controlled through LVDS signal

LVDS & Control Board



Pogos to provide electrical contacts

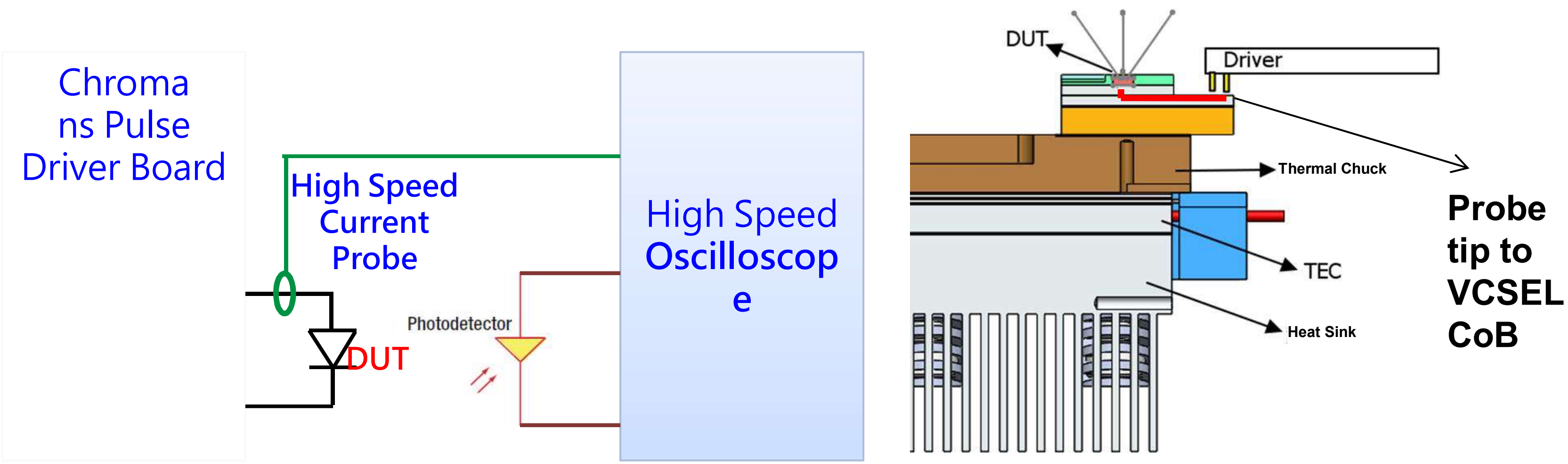
DUT Socket & DUT



DUT Stage Design – Passive ToF module

Passive ToF module

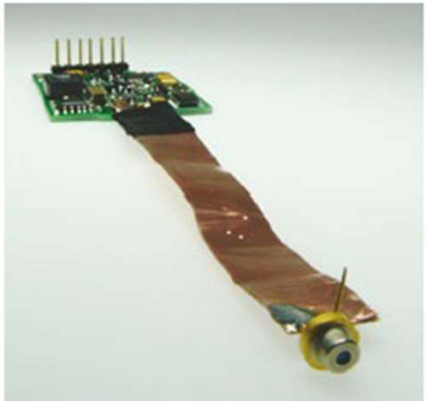
- **VCSEL is die/wire bonded on module**
- **Optics (normally diffuser lens) is mounted**
- **No driver nor control is included, thus external super short pulse driver is needed in test setup**



- **Path impedance needs to be reduced down to minimum**
- **High speed optical output can only be measured by low caps PD, no integrating sphere can be used.**

Impact of Path Impedance

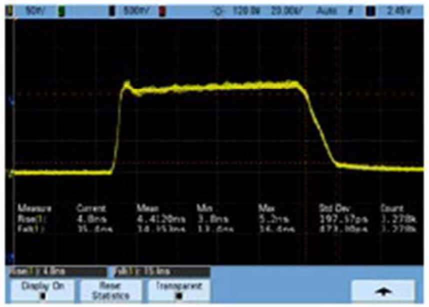
PLD directly connected to the driver
Current rise time approx. 3.5 ns

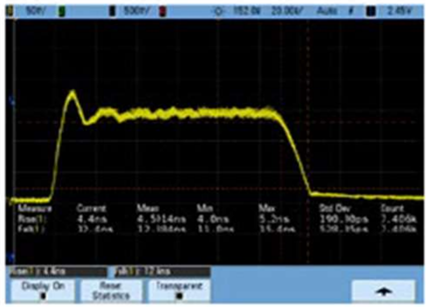


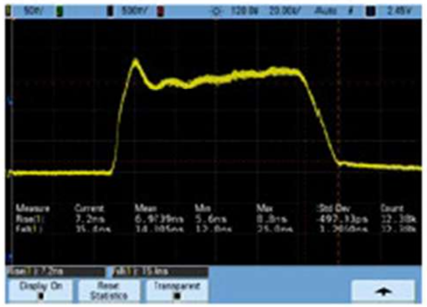
PLD connected by ribbon cable
Current rise time approx. 7 ns

PLD in plastic housing and long pins
Current rise time approx. 12 ns

PLD connected by braided wires (lenth: 100 mm)
Current rise time approx. >130 ns







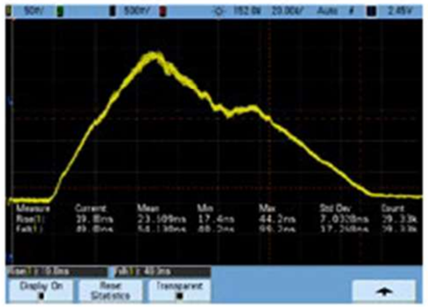
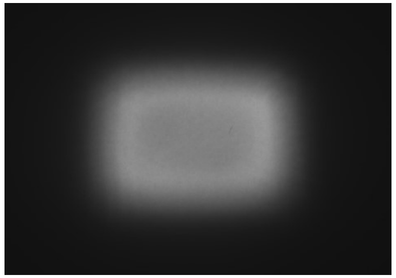


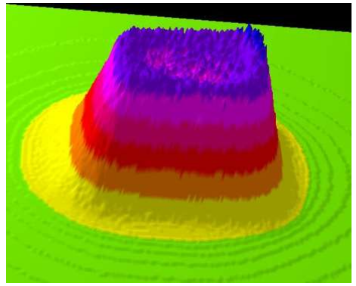
Figure 4:
Typical pulse shapes depending on the type of connection between driver and PLD (V_{op}= 100 V, I_{op}= 50 A)

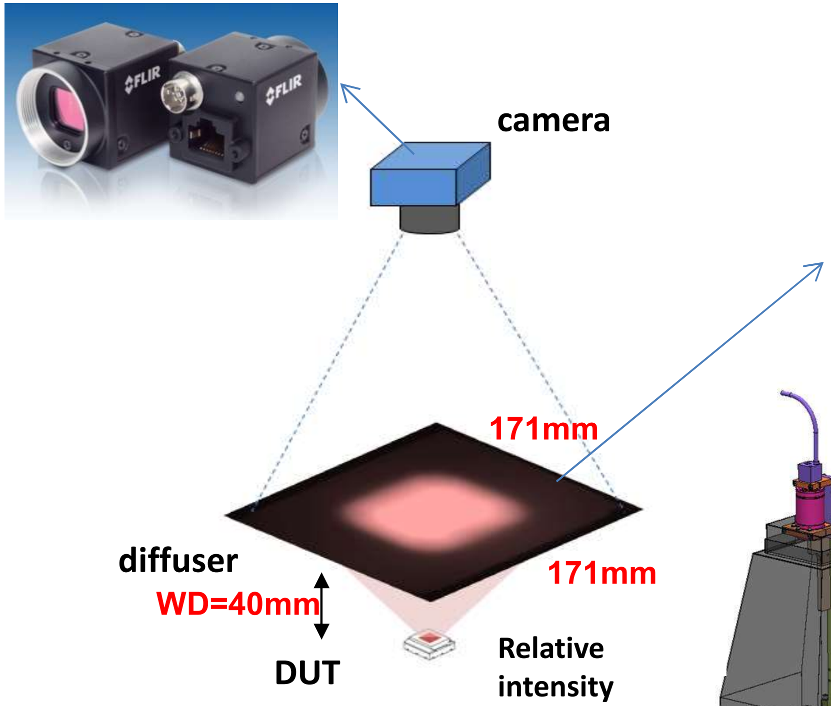
Source : Laser Components

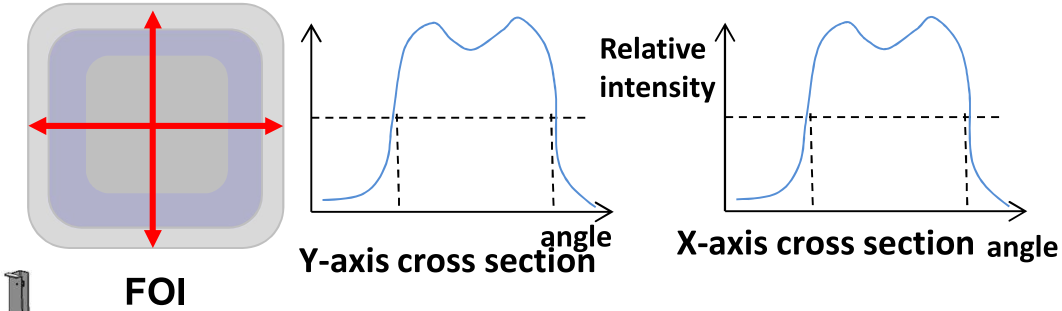
Far-Field/Eye Safety Test

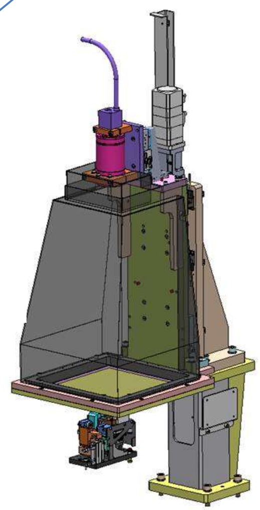
- **Projection**
  - Carefully correlated
  - Cover wider angle

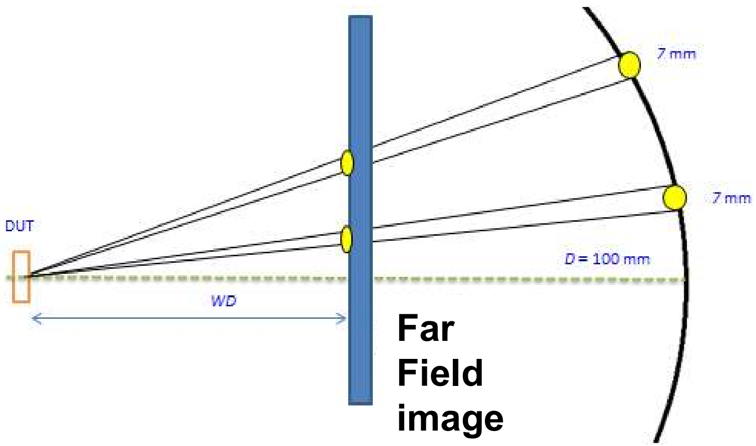












Thank you very much