Innovate in Industrial and Optical Sensing Applications using award-winning DLP® Technology

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Agenda

- Introduction
- DLP Technology in Industrial Applications
- Optical sensing - 3D Machine Vision
  - DLP technology benefits
  - Development platforms
- Optical sensing - Spectroscopy
  - DLP technology benefits
  - Development platforms
- Q&A

TI DLP® Products: a History of Innovation

1987

Dr. Larry Hornbeck invents digital micromirror device (DMD), known as the DLP® chip

1996

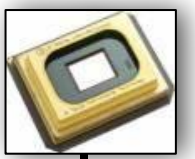
First commercial DLP system ships; enables **first ultra portable projector**

1998

DLP Products receives first **Emmy® Award** for Outstanding Achievement In Engineering Development

2004

DLP Products becomes **highest volume MEMS supplier** worldwide



2009

Consumer devices begin to ship worldwide featuring **DLP Pico™ technology based projectors**

2011

Half of all movie **theatres converted from film to digital** enabled by DLP Cinema® technology

2012

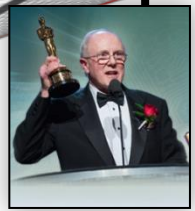
New DLP development kit launches allowing developers to use DLP technology in **new markets**

2013

Increasing adoption of **DLP Pico solutions**

2015

First **automotive**-qualified DLP chipset for head-up display (HUD) applications

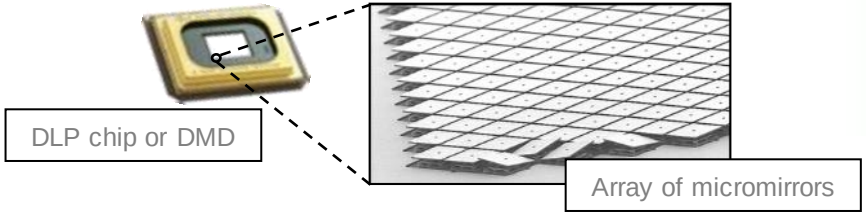


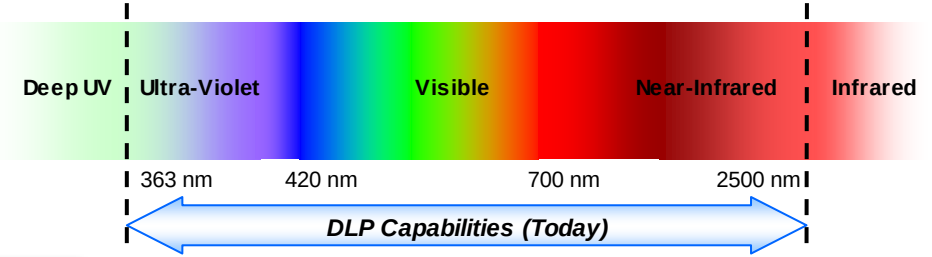
Dr. Hornbeck receives the **2014 Scientific and Technical Academy Award® of Merit (Oscar® statuette)** for the invention of the digital micromirror device (DMD) technology as used in DLP Cinema® projection.

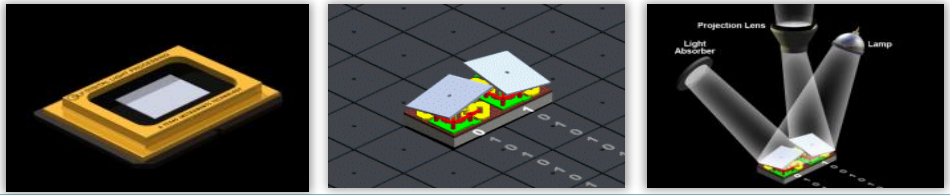
Photo credit: Michael Yada / ©A.M.P.A.S.

For more than two decades, award-winning DLP Product innovations have solved some of the world's most complex display and light control applications.

DLP MEMS technology enables many industrial non-display applications

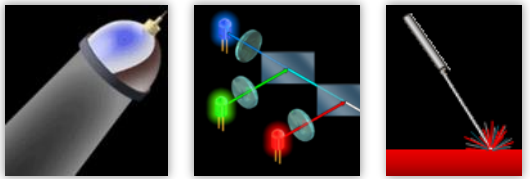






Array of micromirrors… …that digitally switch… …to steer light.

Works with lamps, LEDs, and Lasers



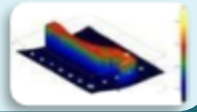
The DMD is a fast, efficient, and reliable spatial light modulator (SLM) offering:

1) High Speed Switching – Switching of the mirrors at up to 32kHz
2) Extended Wavelength – Supporting UV and near-infrared (NIR) in addition to Visual spectrum
3) Wavelength Selection – Direct and modulate specific wavelengths of light through programmable pixel mapping

“Hundreds” of Applications are possible

Industrial

Test & Measurement
- 3D Depth Measurement
- Spectrometers
- Food Inspection
- Fluid Analyzers



Lighting
- Stage Lighting
- Adaptive Illumination

Display & Digital Signage
- Advanced 3D Displays
- Planetariums

Medical, Healthcare & Fitness
- 3D Dental Scanners
- Pharmaceutical Controls
- Vascular Imaging
- Ophthalmology
- Hyperspectral Imaging
- Phototherapy
- Microscopes

Space, Avionics & Defense
- NIR Single Pixel Cameras
- 3D Biometrics
- Drug Identification

Other Industrial
- PCB Lithography
- Flat Panel Lithography
- LCD Repair
- Computer-to-Plate Printing
- 3D Printers
- Laser Marking

Factory Automation & Control
- 3D Machine Vision
- Inline Surface Inspection
- Pick & Place
- Inline Chemical Process Control

Communication Equipment

Telecom Infrastructure
- Reconfigurable Optical Add-Drop Multiplexers (ROADM)
- Wavelength Selective Switches (WSS)
- Variable Optical Attenuators (VOA)

Personal Electronics

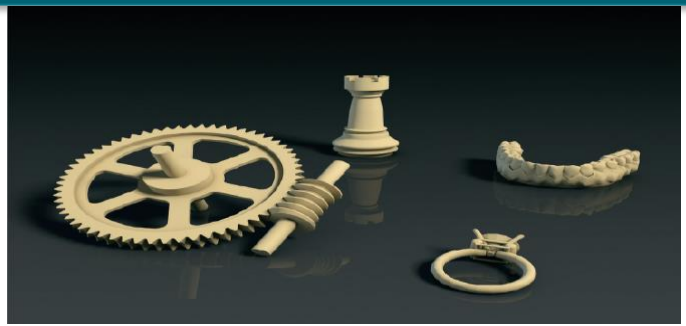
Printers & Other Peripherals
- 3D Printers

DLP Technology – Industrial Focus Areas

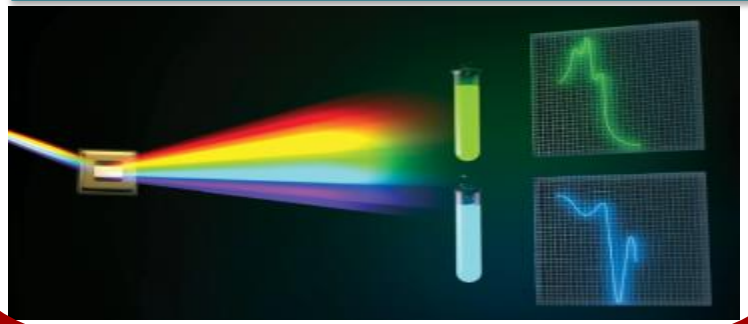
3D Machine Vision Sensing

Optical sensing

3D Printing



Spectroscopic sensing



Lithography

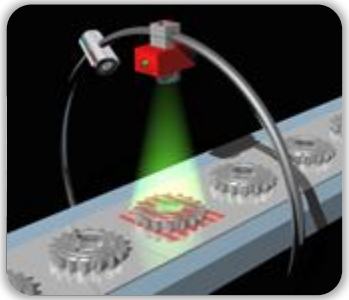
Optical sensing – 3D Machine Vision

Introduction to 3D Machine Vision

What is 3D Machine Vision?

3D measurement is a fast and accurate way of gathering physical measurements of an object onto a computer in an organized manner, resulting in 3D scan data.

Once the scan data is on the computer, all of the dimensions of the object can be taken, such as length, width, height, volume, feature size, feature location, surface area, etc.



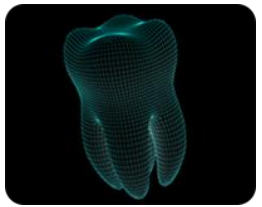
Where is 3D Machine Vision Used?

Location & Guidance

Measure & Inspect

Biometrics

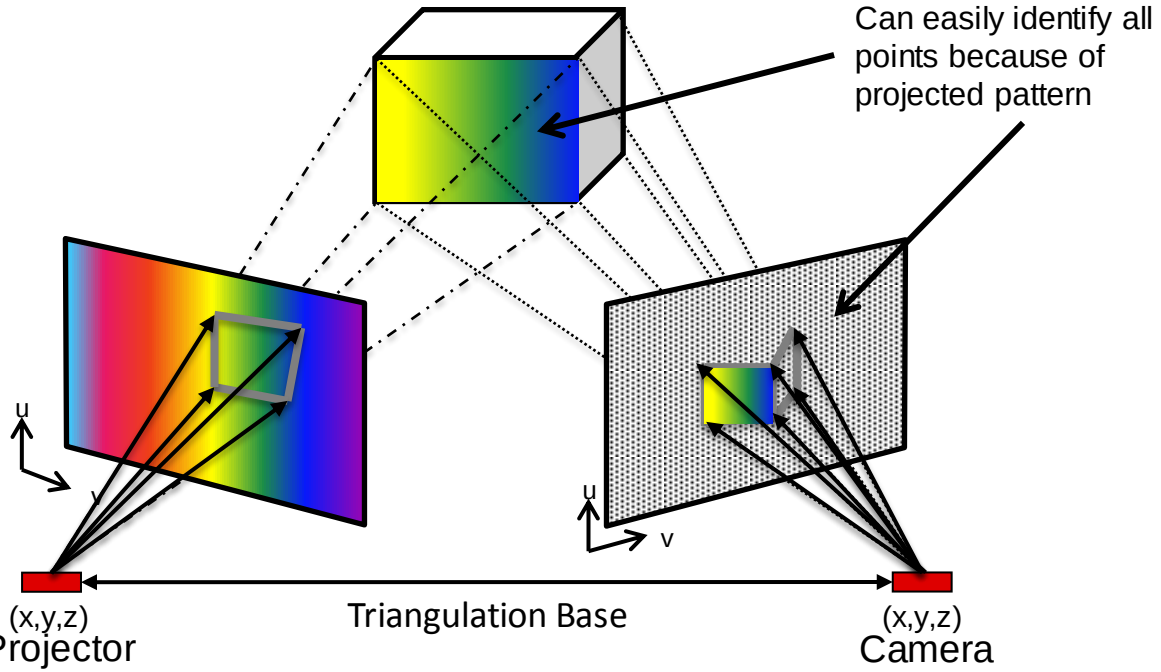
Automated Optical Inspection



Medical Imaging

3D Machine Vision with Structured Light

- Patterns projected on an object inherently create identifiable features
- A camera triggered to each pattern captures these features



DLP Programmable Patterns

*Programmable Patterns allow users to gain **full control** over the Structured Light System*

Multiple patterns

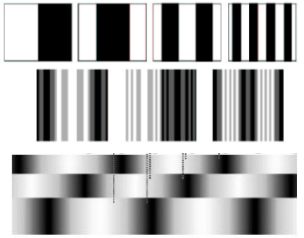
- Binary Code
- Gray Code or N-ary Codes
- Phase Shift

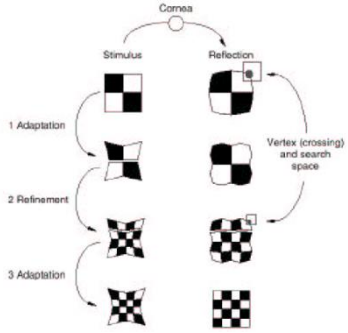
Adaptive Patterns

- Varying Color/Light and Pattern depending on object response and movement

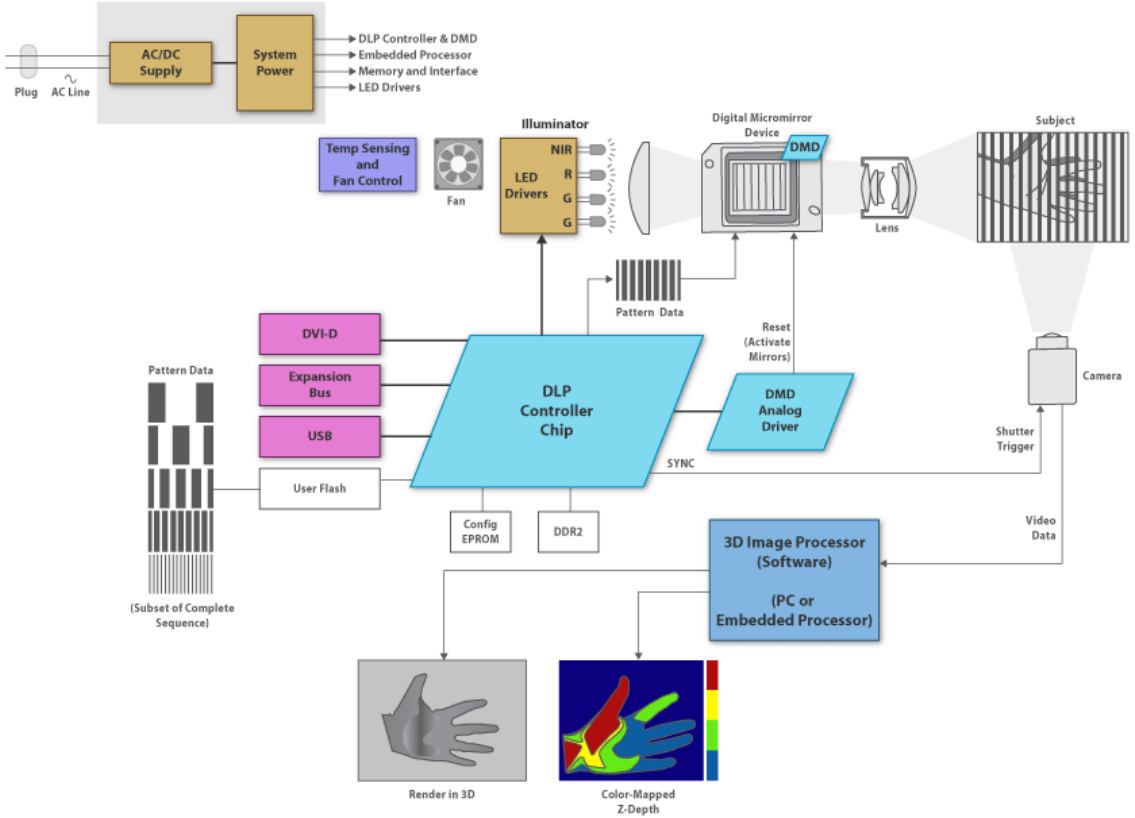
Hybrid Patterns

- Combination of several patterns



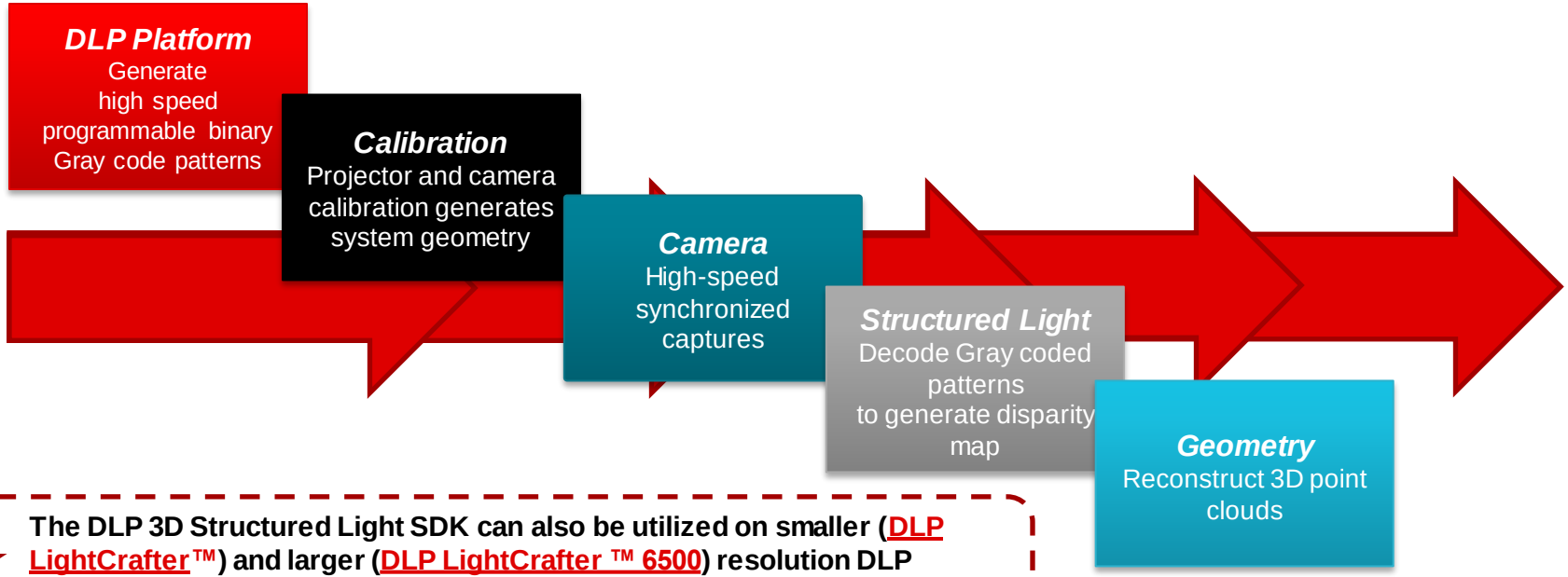


3D Machine Vision System Block Diagram



DLP Structured Light SDK

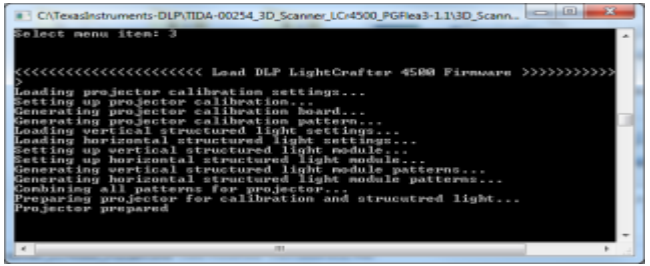
A Complete 3D Machine Vision Development Software Solution



The DLP 3D Structured Light SDK can also be utilized on smaller (DLP LightCrafter™) and larger (DLP LightCrafter ™ 6500) resolution DLP Evaluation Modules (EVMs) for portable and high resolution 3D scanning applications.

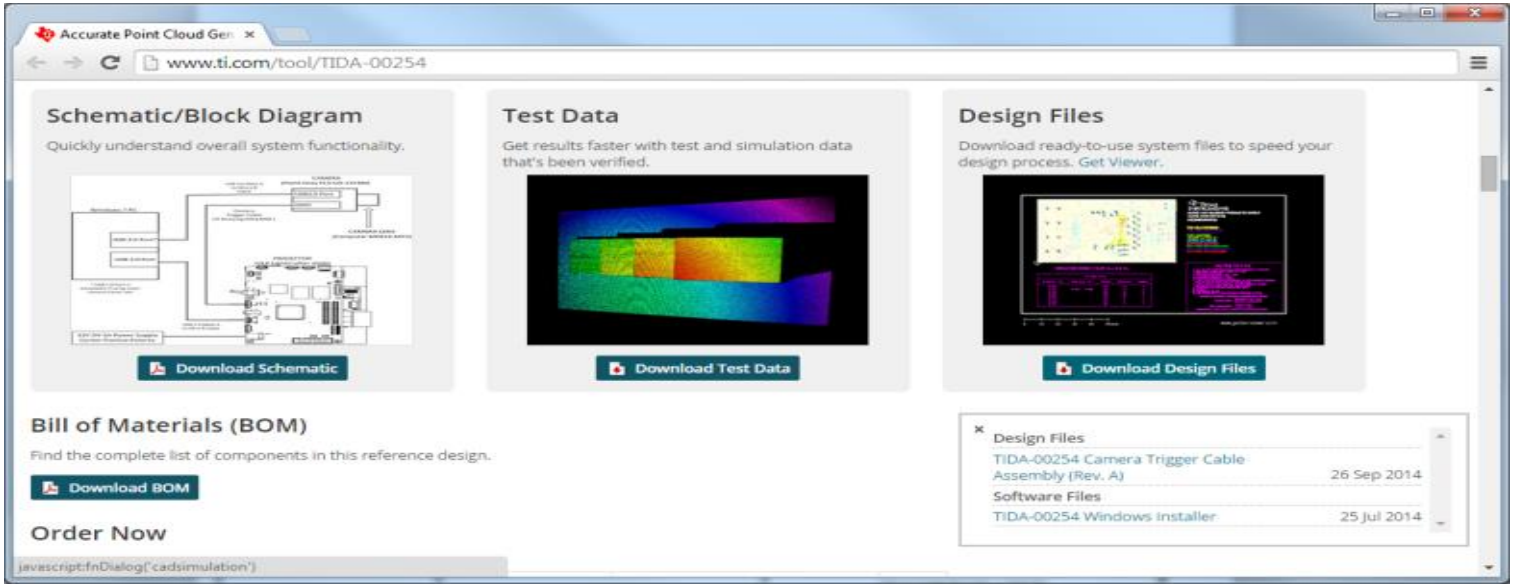
Accurate Point Cloud Generation for 3D Machine Vision Applications using DLP Technology

- Provides a 3D scanner software solution to shorten development time with DLP technology
- No software or optical development required for evaluating DLP technology for generating 3D point clouds!
  - Generates and decodes structured light patterns
  - Calibrates camera and projector
- Available design files
  - Schematic (http://www.ti.com/lit/pdf/tidr157)
  - Bill of Materials (http://www.ti.com/lit/pdf/tidr958)
  - Command-line 3D Scanner with DLP Structured Light SDK (http://www.ti.com/lit/zip/tidc535)
  - Camera Trigger Cable Assembly Guide (http://www.ti.com/lit/df/tidu457a/tidu457a.pdf)
- Available from TI Designs
  - http://www.ti.com/tool/TIDA-00254



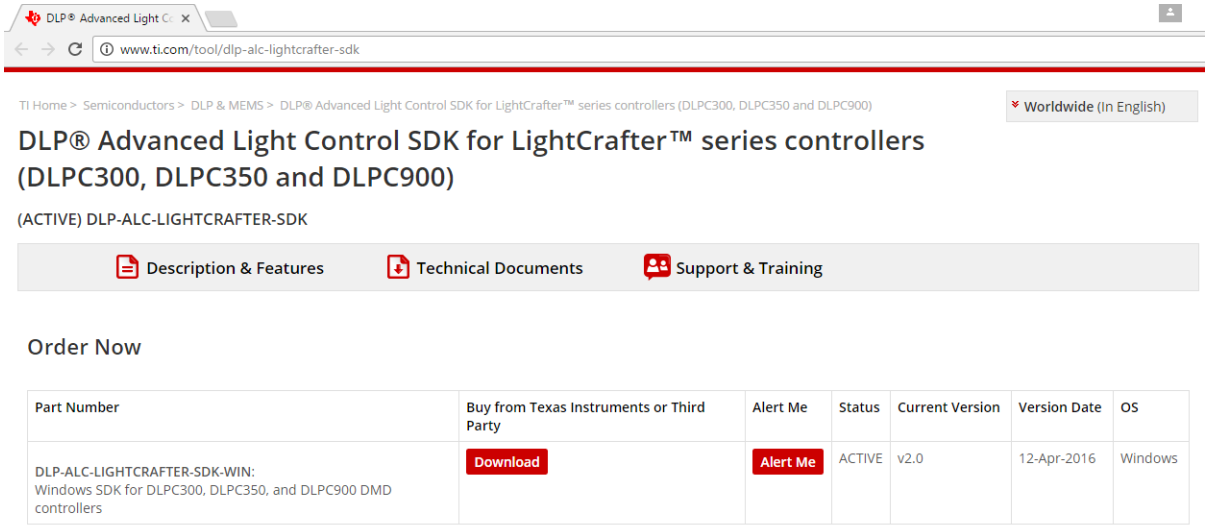
Where to Find Software, the BOM, and the Trigger Cable Assembly Guide?

1. Go to the TIDA-00254 tool page (http://www.ti.com/tool/TIDA-00254)
2. Software installer listed under Download Design Files button (executable for SDK)
3. Schematic and BOM listed under their respective buttons



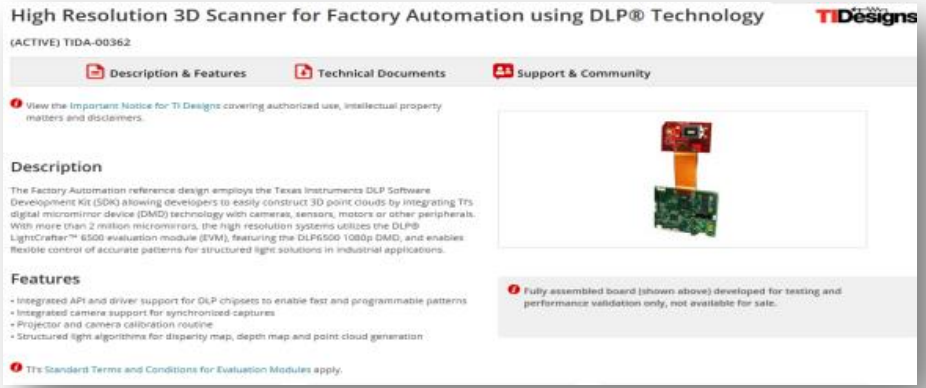
Where is the 3D Scanner Application and DLP Structured Light SDK source code?

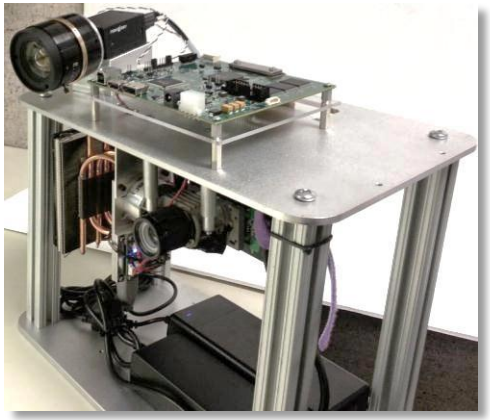
1. One tool page on ti.com for three DLP Lightcrafter EVM and controller platforms: (http://www.ti.com/tool/dlp-alc-lightcrafter-sdk)
2. User's guide for the Windows SDK: http://www.ti.com/lit/ug/dlpu042/dlpu042.pdf



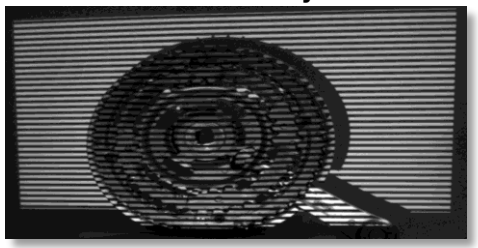
DLP6500 1080p 3D Scanner TI Design (TIDA-00362)

- Complete set of design files
- Mechanical schematic of metal frame
- Preliminary calibration for quick evaluation
- Executable calibration and scanning program
- TI test results using this exact design
- Access to SDK

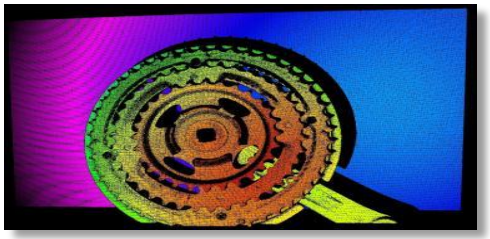




Scanned Object



3D Point Cloud of Object



Structured Light for PCB AOI Inline Inspection

How it Works

Example system with four projectors to capture micron scale features on a PCB

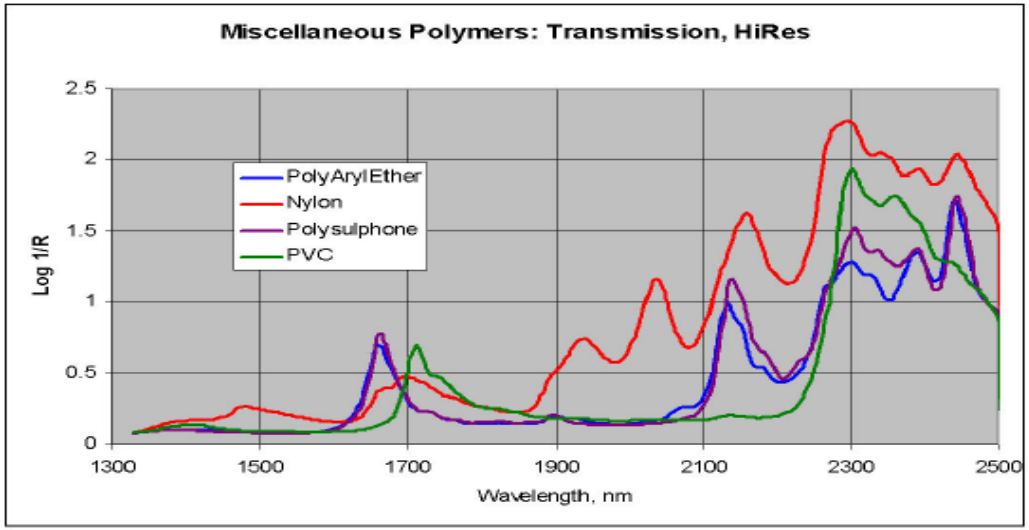
Why choose DLP technology?

DLP Feature	System Benefits
High speed programmable patterns up to 1KHz with 8-bits grayscale pre-stored patterns	• Area based measurement • Short scanning time • Extreme flexibility in generating patterns
Customized DLP hardware and software reference design	• High system lumen efficiency without the need of polarizer • Compact solution for size/cost reduction • Reduced R&D effort
Optical MEMS with product longevity	• Great pattern quality with high on/off contrast ratio • Uniform mirrors providing excellent grayscale linearity and repeatability • Proven technology with shipment in millions
Strong DLP ecosystem	• Quicker time-to-market with support from DLP Design Network partners • Lower R&D Investment

Optical sensing - Spectroscopy

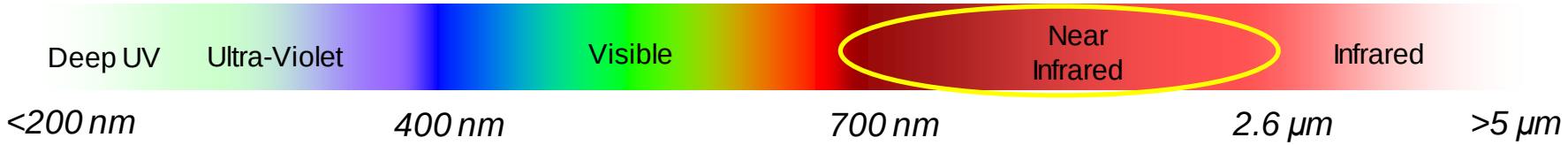
Spectroscopy

- Spectroscopy is a powerful technique for recognizing and characterizing physical materials. It measures variations in absorption or emission for different wavelengths of light. Spectroscopy determines the degree of light interacting with the material and produces a signature known as a spectrum; the variation of light intensity as a function of wavelength.
- Example of a spectra for various plastics/polymers showing their spectral differences
- Spectrometers are used in:
  - Pharmaceuticals
  - Food
  - Agriculture
  - Petrochemical
  - Automotive Fluids
  - Manufacturing: QA/QC
  - Medical diagnostics
  - Security/counterfeit detection
  - Law Enforcement and forensics



Electromagnetic/Light Spectrum

- Spectroscopy utilizes the light from the ultraviolet (UV) to the near-infrared (NIR):



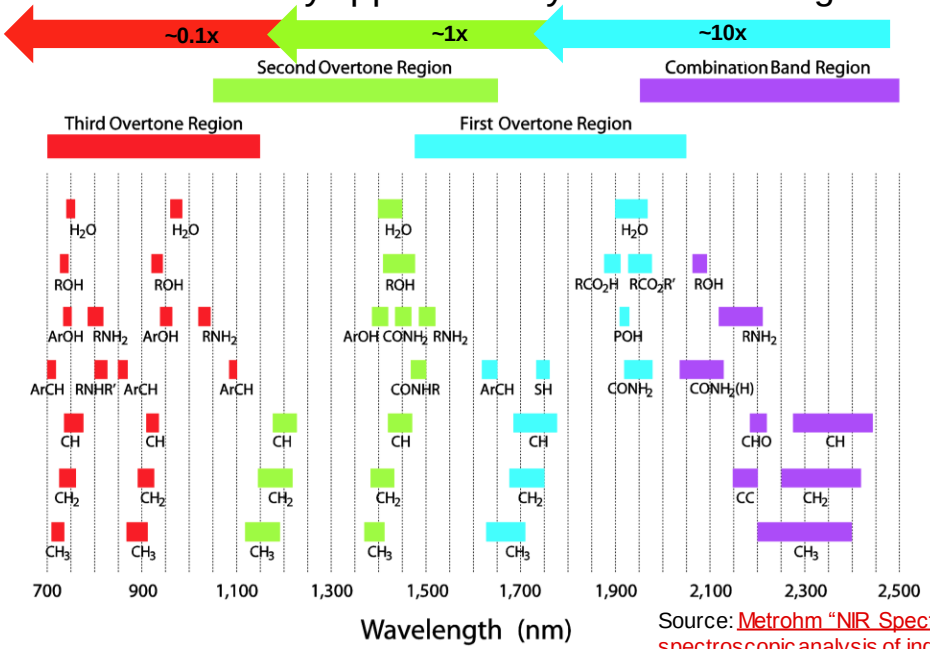
- Light energy in the near infrared region causes molecular chemical bonds to vibrate at specific frequencies. Overtones of those frequencies are observed from 650nm to 2600nm.

- There are three important and diagnostic functional groups of NIR overtones:
  1. **Hydroxy functional group: -OH**
     - Found in Water/Moisture, Carbohydrates, Sugars, Alcohols, Glycols, etc.
  2. **Amino functional group: -NH_2**
     - Found in Proteins, Polymers (Nylons, Urethanes, etc.), Dyes, Pharmaceuticals, etc.
  3. **Alkyl/Aryl functional group: C-H aliphatic and aromatic hydrocarbons**
     - Found in Fats/Lipids, Fuels, Plastics and Polymers, etc.

NIR Spectroscopy

- The following major overtones or harmonics observed in the NIR spectral region result from compounds featuring these functional groups

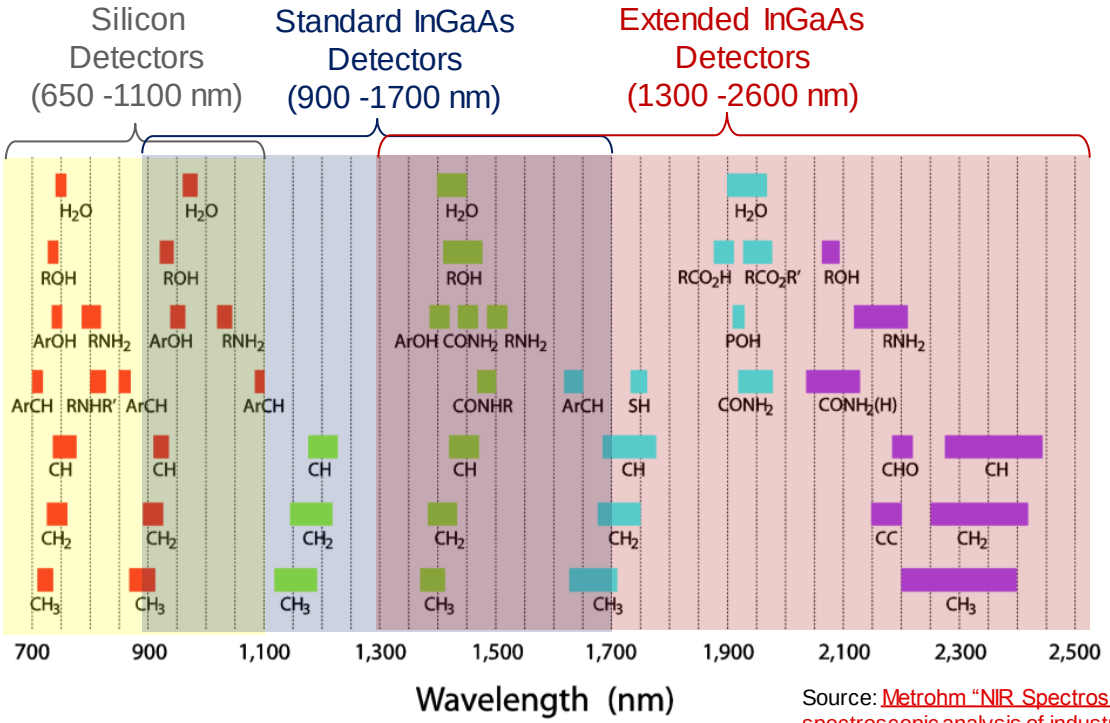
  Relative absorbance decreases by approximately an order of magnitude with each overtone



Source: Metrohm "NIR Spectroscopy: A guide to near-infrared spectroscopic analysis of industrial manufacturing processes"

NIR Photodetectors

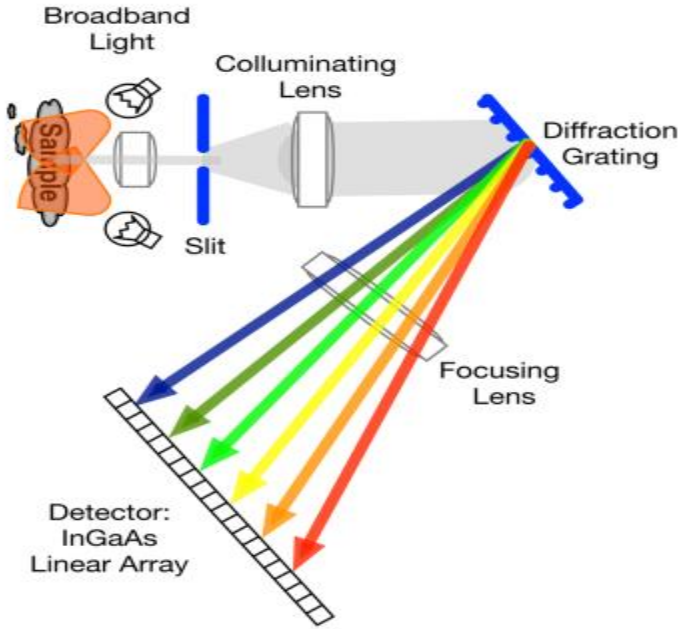
- Detection of these major overtones depends on photodetector technology:



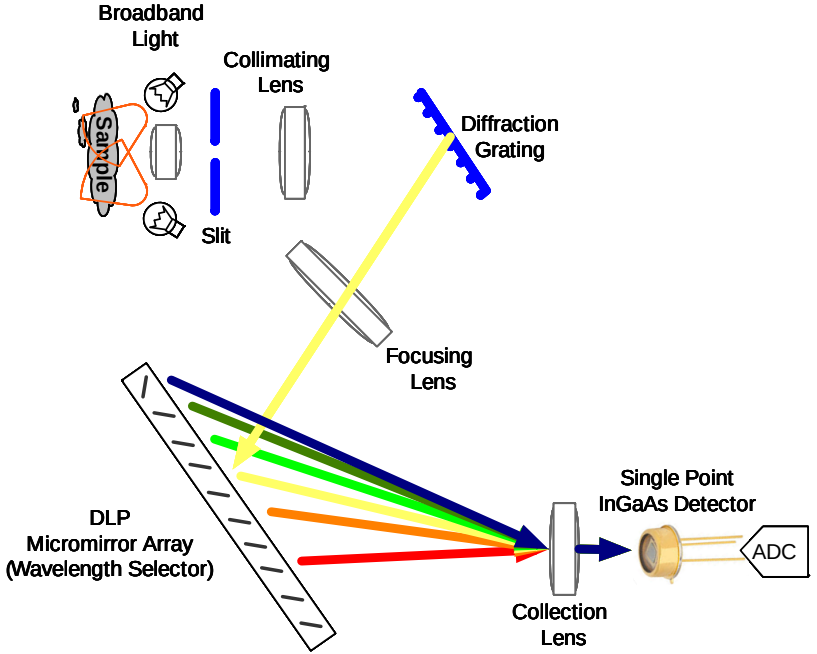
Source: Metrohm "NIR Spectroscopy: A guide to near-infrared spectroscopic analysis of industrial manufacturing processes"

DLP Technology-Based Spectroscopy

Current technology: InGaAs linear array



DLP technology-based: DLP chip + single point InGaAs

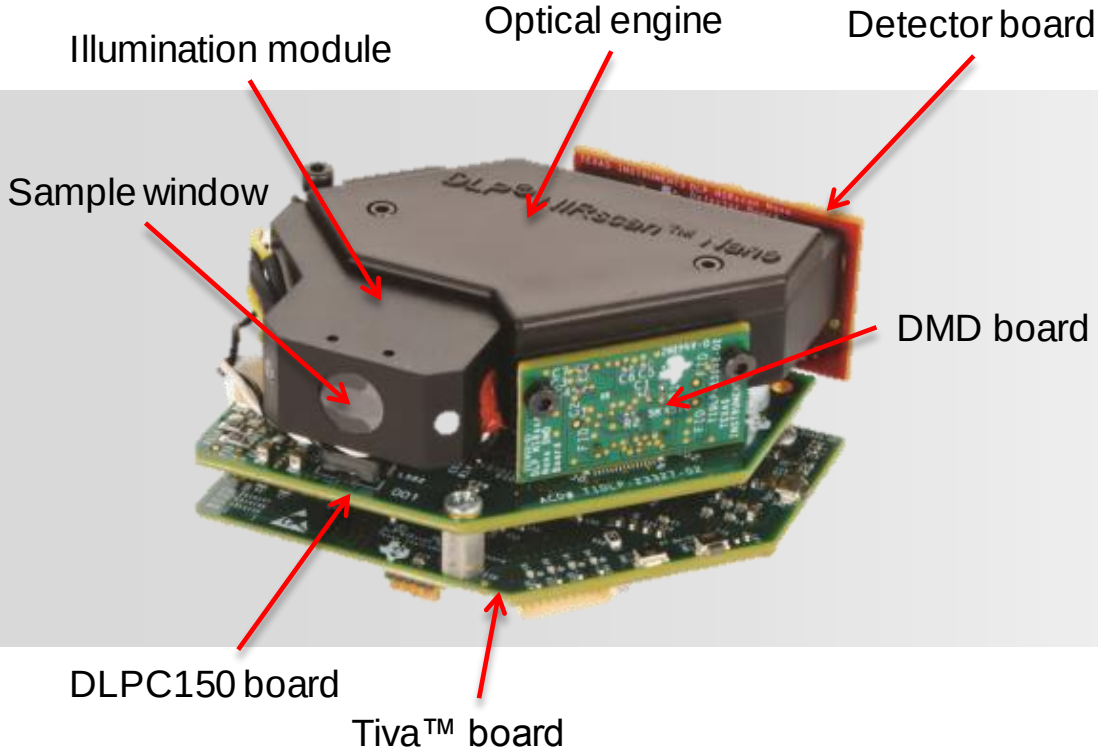


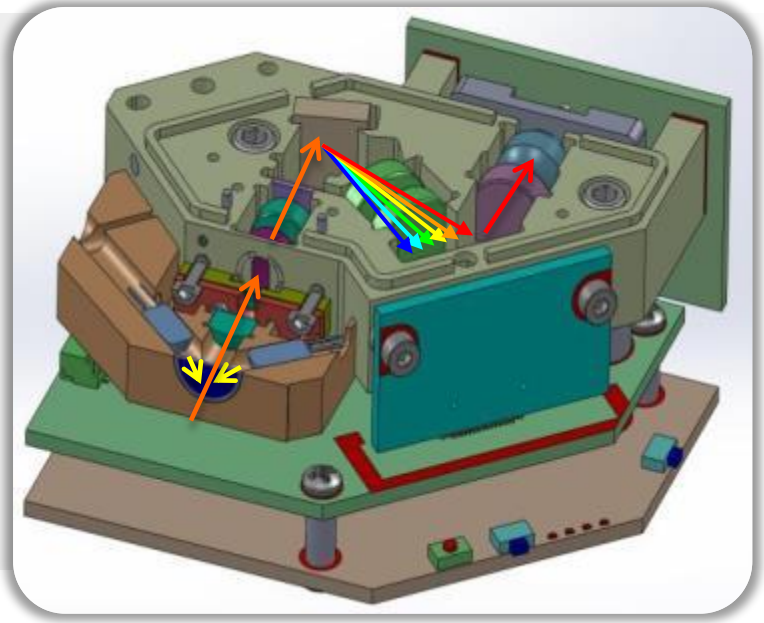
DLP Technology-Based Advantages

Linear Array Technology	DLP Technology-Based	Advantage
Linear InGaAs array detector have small pixels: 7.8 - 30 um wide x 125 - 500 um tall	Large InGaAs detector pixel: 1 - 2 mm diameter	**Higher Performance**
Linear InGaAs array detector with limited pixels: 128, 256, 512, or 1024	Pixels limited by DLP micromirror array size: • 854 x 480 on DLP2010NIR • 912 x 1140 on DLP4500NIR	**Higher Performance**
Not programmable	Programmable: • Variable Intensity • Variable Integration Time • Resolution • Complex Hadamard Patterns • Custom Spectral Filters • Compensate Optical Distortion and Physical Misalignment	**Higher Performance**
Linear InGas photodetecor cost: $1500 - $5000	DLP micromirror + single pixel InGaAs cost: $200 - $700	**Lower Cost**

DLP Mobile Spectroscopy EVM

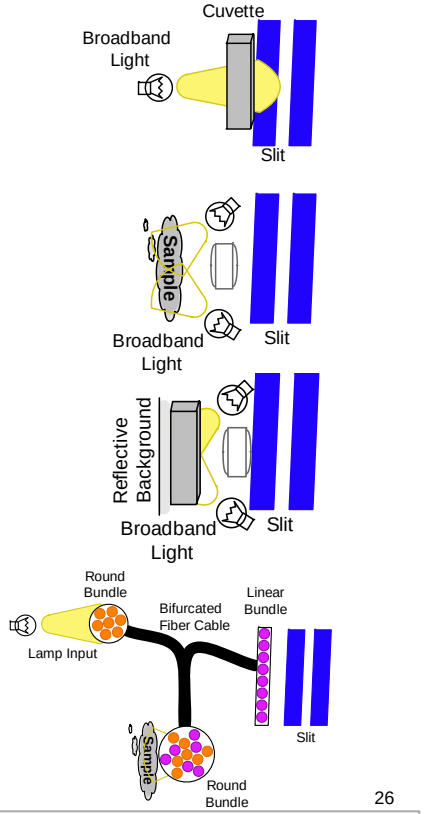
DLP® NIRscan™ Nano



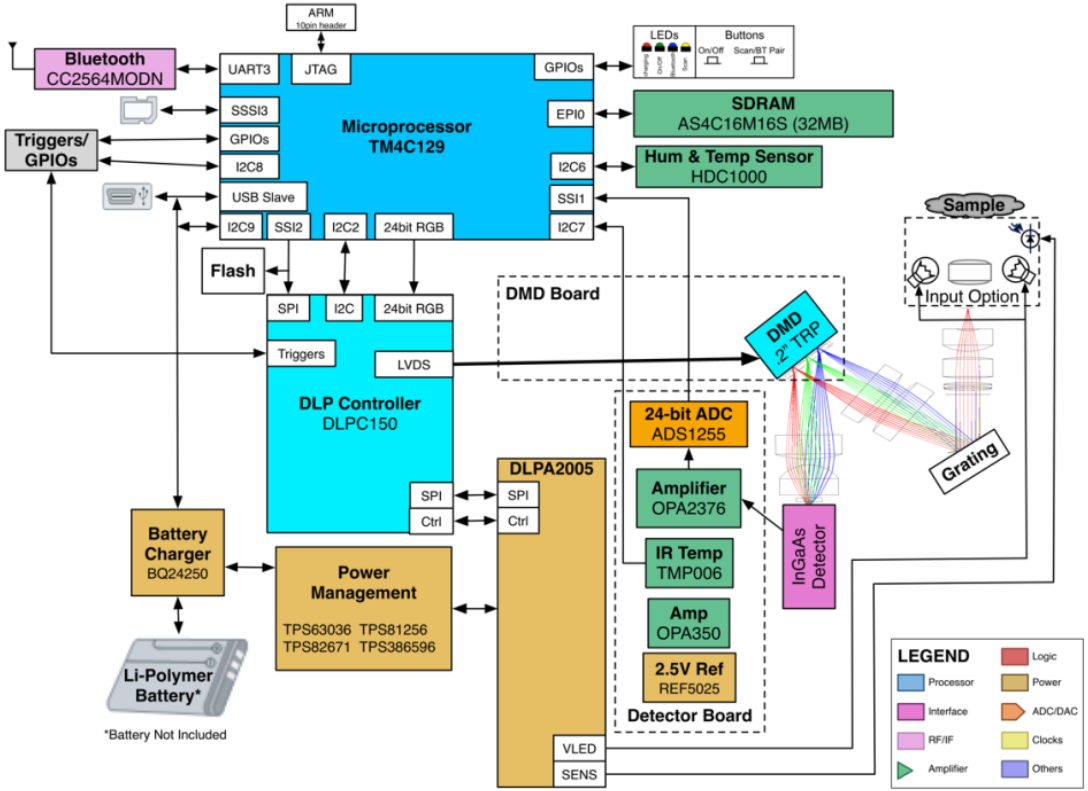


Sampling Methods

- **Transmission/Transmittance**
  - Used for liquids, films, transparent, and translucent materials
    - Oils, fuels, solvents, polymers/plastics, solutions, etc.
  - Light directed through the sample and then captured by the system
- **Reflection/Reflectance**
  - Used for solids, powders, and polymers
  - Light directed onto the surface of the solid and then the reflected light is captured by system
- **Transflectance**
  - Used for liquids, slurries, gels, pastes, polymers, and thin coatings on metals
  - Used in dip-probe configuration with a fiber optic cable
  - Light directed through the sample and reflected by the background material, passing through the sample twice
- **Fiber Optic Interfacing**
  - Used for remote sampling
  - Combines a light source and sample capture in one fiber bundle
  - Transfers the light from the sample back into the system



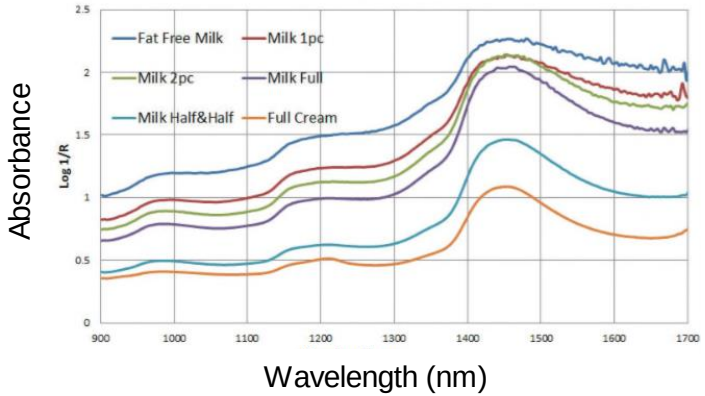
DLP NIRscan™ Nano Block Diagram



The DLP NIRscan™ Nano EVM functions as a mobile NIR spectrometer!

Spectroscopy Applications: Food

- NIR Spectroscopy can perform many measurement tasks in the food industry
- Examples of these tasks are:
  - ***Quality assessment*** of food by reporting:
    - Moisture
    - Carbohydrates, Sugar content (BRIX)
    - Proteins
    - Fat
    - Alcohol content for alcoholic beverages
  - ***Confirmation*** of the authenticity of oils and syrups
  - ***Detection*** of counterfeits or adulterations in food
    - Detection of unexpected flavor components in high value samples, such as olive oil, honey, and maple syrup
    - Measurement of saturation and trans-unsaturation in oil products
    - Detection of toxic or non-nutrient materials, such as melamine as a protein enhancer or "nitrogen booster" in food products (cereals, pet foods, dairy products, etc.)



Example NIR Spectral Signatures in Food

Food	Sampling Method	Signature	Wavelength Range
Milk	Dip Probe	Fats, Melamine, Fillers	1400 - 1700 nm
Butter, Cheese, and Yogurt	Contact	Sugars, Proteins, Fats/Lactose	1100 - 1600 nm
White, Milk, and Dark Chocolate		Sugars, Fats	
Meat Products		Water, Proteins, Fat	1100 - 1700 nm
Fish		Proteins, Fats, Oils	
Soft Drinks	Dip Probe	Sugar, CO_2	
Juices		Sugars	
Syrups		Sugars, Water	
Wine Fermentation Process		Sugars, Acid, Alcohols	
Beer Brewing Process		Sugars, Alcohols	
Oils		Poly/Transunsaturated Fats	
Produce Inspection	Contact and Non-Contact	Water, Sugars, Proteins, Fats/Lactose	

Development Platforms and Reference Designs for Faster Development

Development Resources and links

Silicon – Extensive portfolio

13 DMD chips for non-display optical sensing applications

Featured Applications

http://www.ti.com/lsds/ti/dlp/advanced-light-control/applications-featured-applications.page

Development Platforms and Software

Several EVMs starting at $599

http://www.ti.com/lsds/ti/dlp/advanced-light-control/tools.page

TI Designs and reference designs

http://www.ti.com/tool/TIDA-00362

http://www.ti.com/tool/TIDA-00554

Extensive 3P network **worldwide** 20+ companies with 40+ solutions

http://www.ti.com/lsds/ti/dlp/advanced-light-control/solutions-services.page

Innovate in Industrial and Optical Sensing Applications using award-winning DLP® Technology

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Marketing Manager,

Texas Instruments, Inc

Matt Soucek

Engineering Manager,

Texas Instruments, Inc