

Agenda

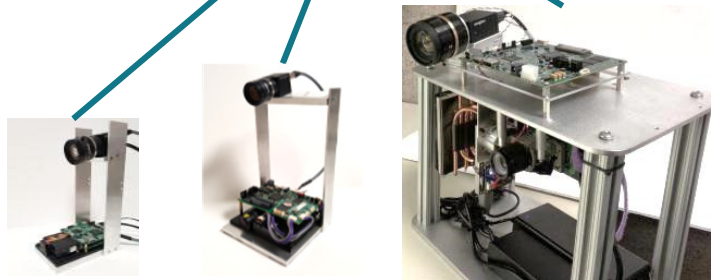
- DLP 3D scanning Introduction
- **DLP 3D scanning SDK Introduction**
- Advance features for existing SDK
 - Increasing scanning speed from 20Hz to 400Hz
 - Improve the lost point cloud
- 3D Machine Vision Applications: Performance of adaptive patterns
- DMD Performance and Stability for 3D Machine Vision Applications

TI Designs for Targeted Applications

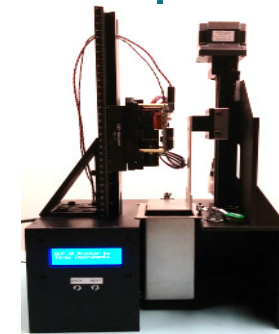
Spectroscopy



3D Machine Vision



3D Printing & Stereo-lithography



Programmable Patterns by using DLP® Technology

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

Multiple patterns

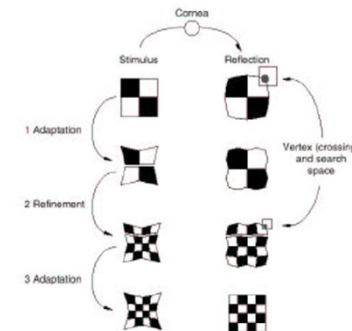
- Binary Code
- Gray Code or N-ary Codes
- Phase Shift
- Hybrid:
 - Gray Code + Phase Shift

Adaptive Patterns

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

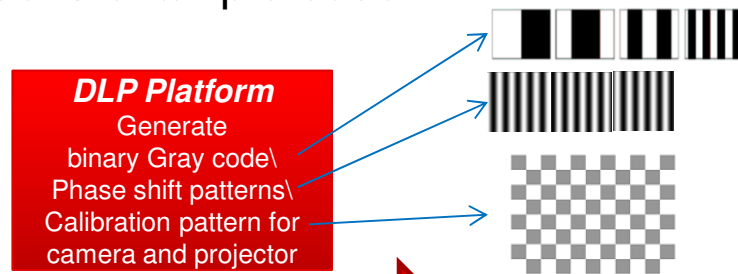
Hybrid Patterns

- Combination of several patterns



DLP® Structured Light SDK- Generate Pattern

TI code is example code



How to calculate the pattern numbers(Hybrid Patterns):

THREE_PHASE_PARAMETERS_PIXELS_PER_PERIOD = 32

Three phase pattern = 3 =>Vertical + Horizontal=3*2=6

For DLP4500(912x1140):

Gray Code pattern=

Vertical phase shift period: $912/32=28.5=>29$;

$29*8=232=>2^8=>8$ patterns=> $8*2(\text{invert})=16$

Horizontal phase shift period: $1140/32=35.625=>36$;

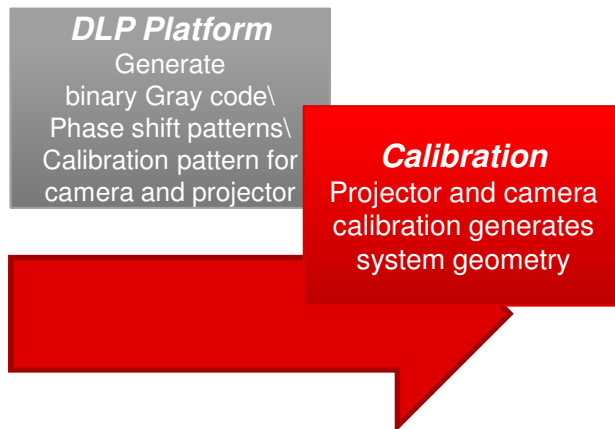
$36*8=288=>2^9=>9$ patterns => $9*2(\text{invert})=18$

Total patterns= $6+16+18=40$

DLP® Structured Light SDK - Calibration

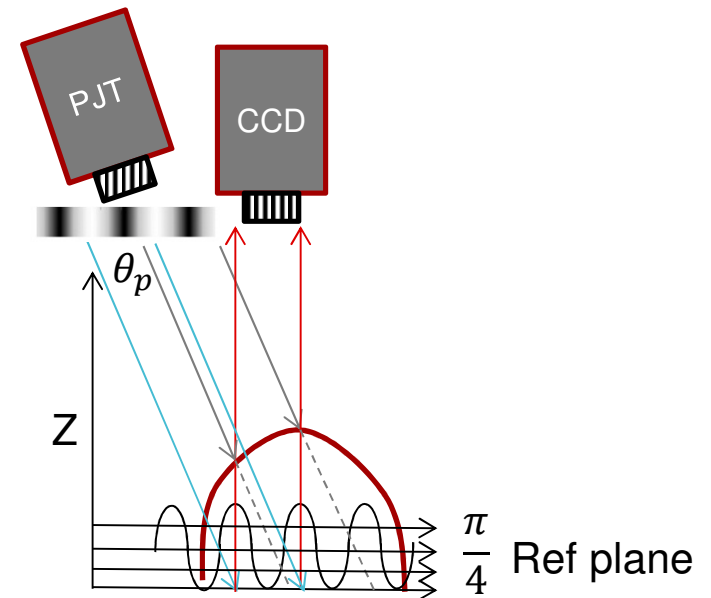
TI code is example code

SDK can share the same calibration data for Gray code and Hybrid(Gray code + Phase shift) alg.. No need unwrapping alg. for phase shift.



Formula to calculate the phase for 3 steps phase shift.
It cannot tell if object is over $\pm \pi$ or not.

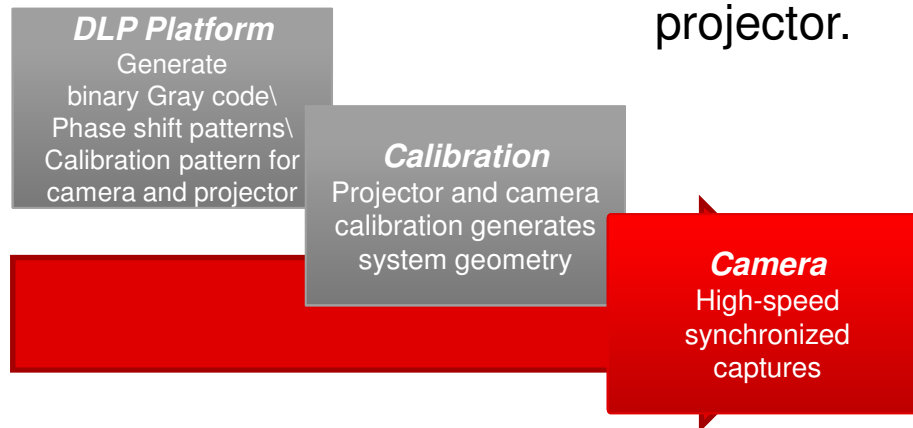
$$\phi(x, y) = \tan^{-1} \left[\sqrt{3} \frac{I_1(x, y) - I_3(x, y)}{2 * I_2(x, y) - I_1(x, y) - I_3(x, y)} \right]$$



DLP® Structured Light SDK - Synchronization

TI code is example code

In standard SDK, camera sends trigger to projector. SDK can find first pattern from projector.



Camera trigger projector:

-need to make sure buffer size is enough for scanning

CAMERA_PARAMETERS_FRAME_BUFFER_SIZE

= 72

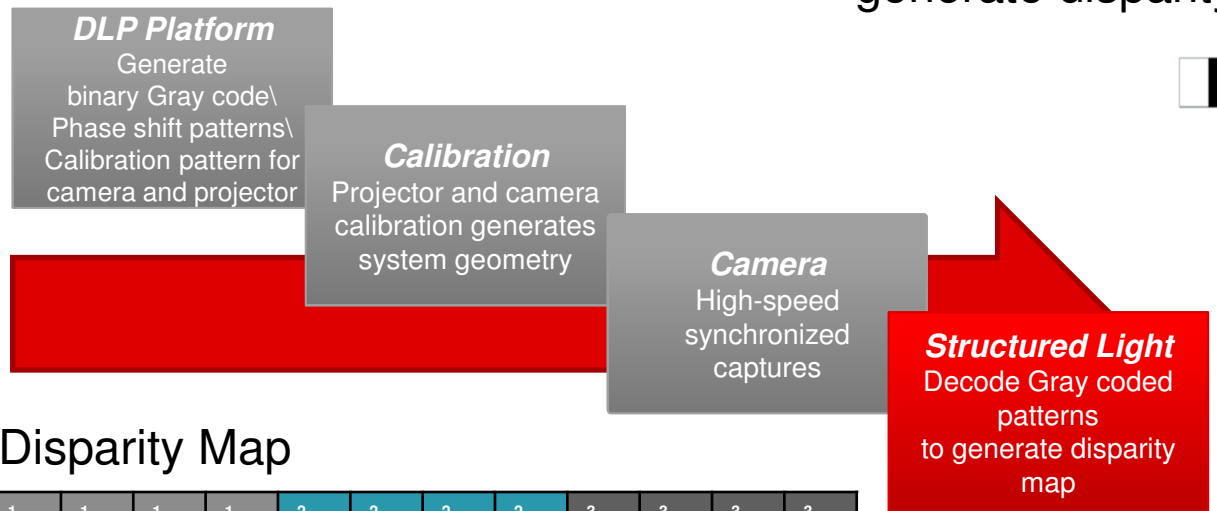
Projector trigger camera:

-need to make sure no overflow in camera

DLP® Structured Light SDK - Gray Code Pattern Decoding

TI code is example code

Gray code: Decode Gray Code to generate disparity map



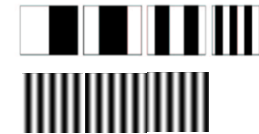
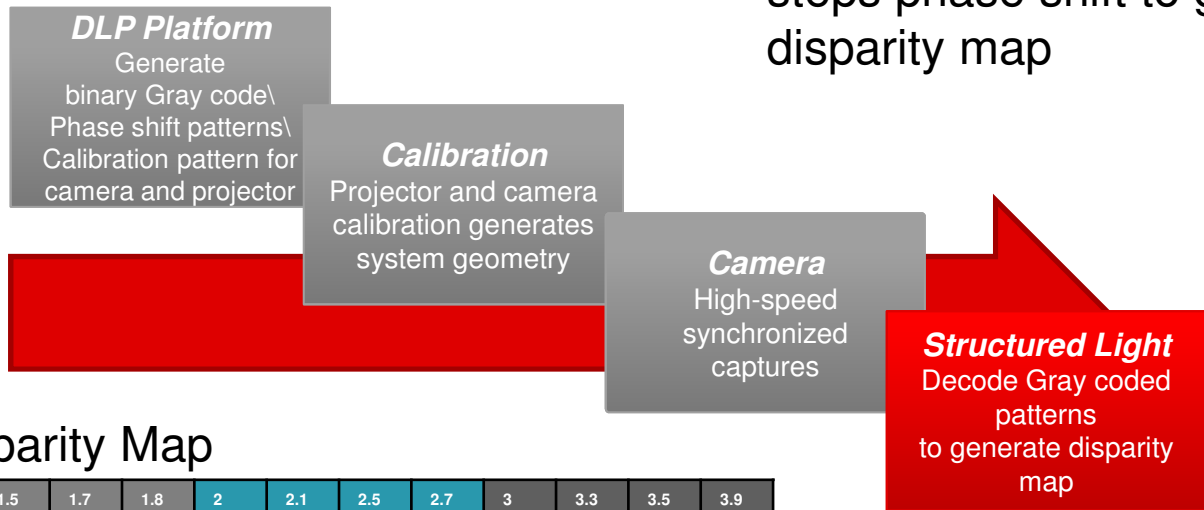
Disparity Map

1	1	1	1	2	2	2	2	3	3	3	3
1	1	1	1	2	2	2	2	3	3	3	3
1	1	1	1	2	2	2	3	3	3	3	3
1	1	1	2	2	2	2	3	3	3	3	3
1	1	1	2	2	2	3	3	3	3	3	4

DLP® Structured Light SDK – Hybrid pattern Decoding

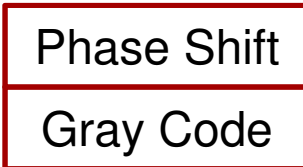
TI code is example code

Hybrid: Based on Gray code and three steps phase shift to generate subpixels disparity map



Disparity Map

1	1.5	1.7	1.8	2	2.1	2.5	2.7	3	3.3	3.5	3.9
1	1.5	1.7	1.8	2	2.1	2.5	2.7	3	3.3	3.5	3.9
1	1.5	1.7	1.8	2	2.1	2.5	3	3.3	3.3	3.5	3.9
1.5	1.7	1.8	2	2.1	2.5	2.7	3	3.3	3.5	3.6	3.9
1.5	1.7	1.8	2	2.1	2.5	3	3.3	3.5	3.6	3.9	4

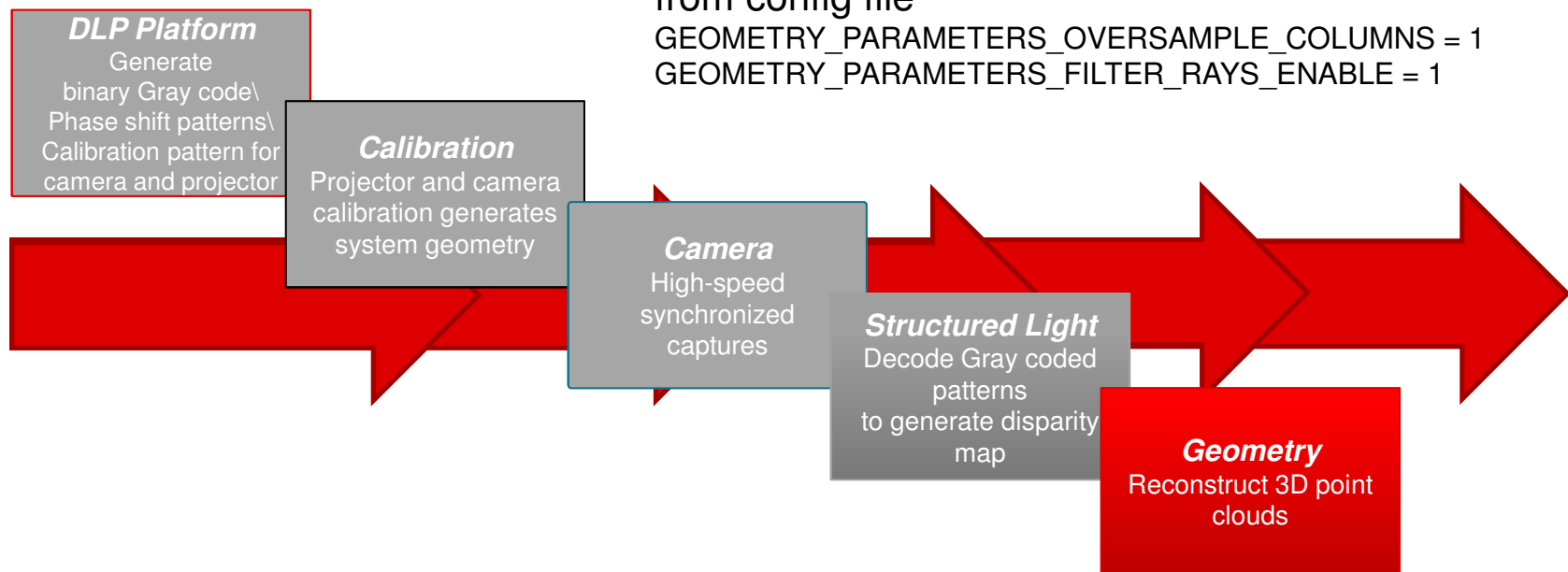


DLP® Structured Light SDK - Reconstruction

TI code is example code

Easy to fine tune the reconstruction performance from config file

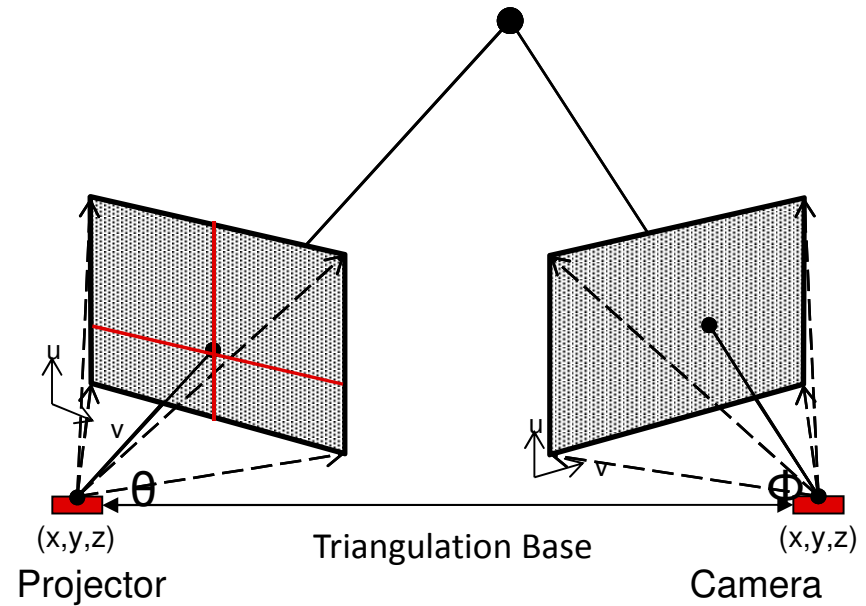
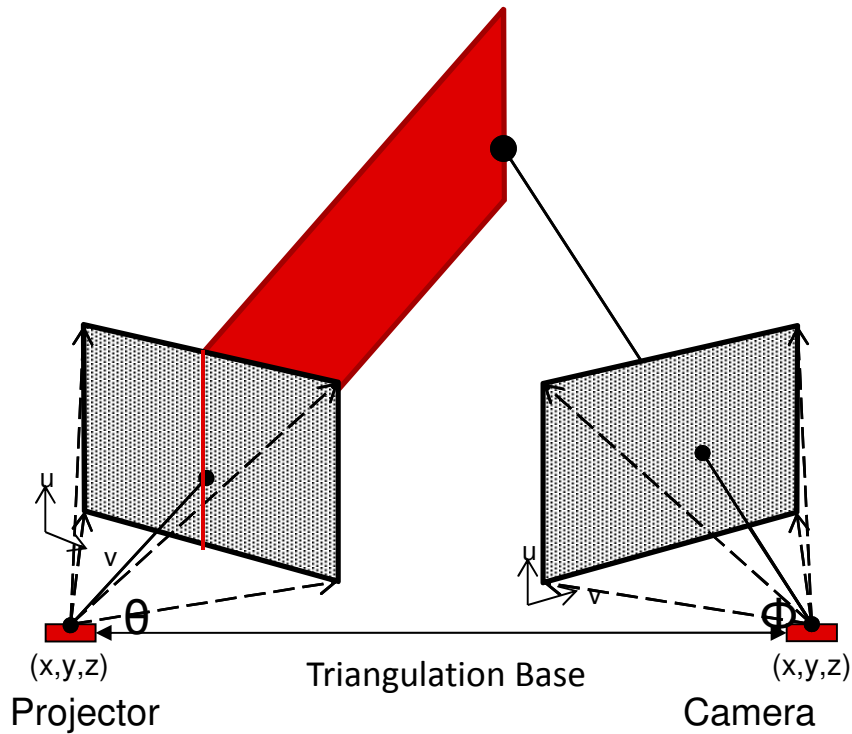
```
GEOMETRY_PARAMETERS_OVERSAMPLE_COLUMNS = 1  
GEOMETRY_PARAMETERS_FILTER_RAYS_ENABLE = 1
```



DLP® Structured Light SDK- Supports Two Reconstruction Method

Plane\ Line intersection(V or H scan)

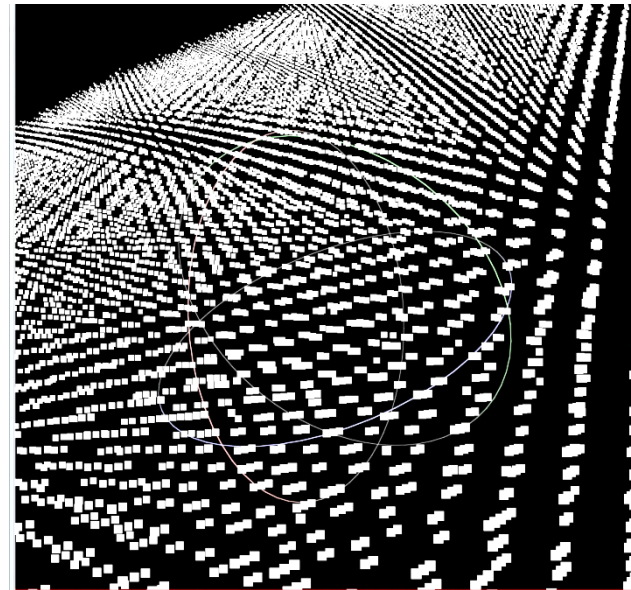
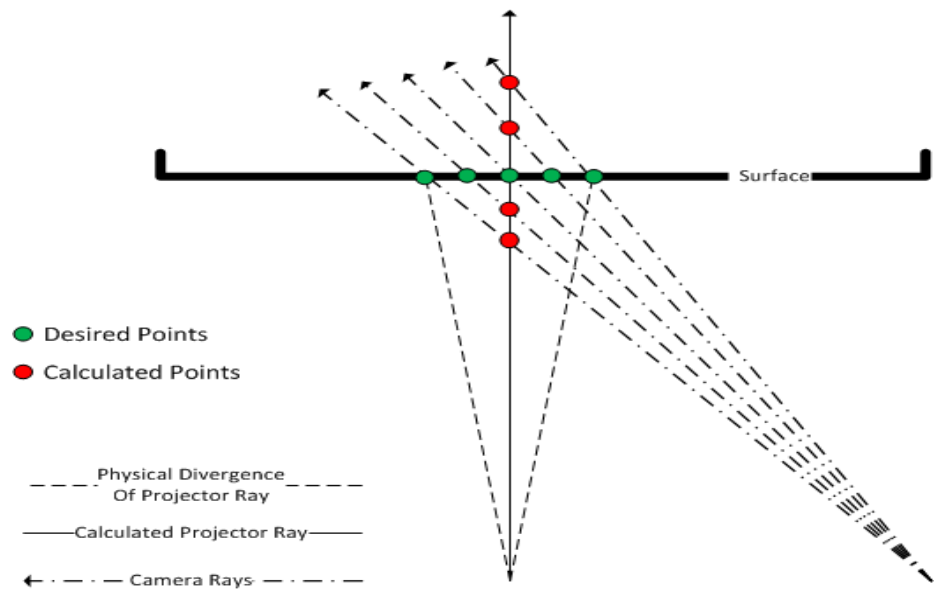
Line\ Line intersection(V+H scan)



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DLP® Structured Light SDK- Effects of Pixel Over-Sampling

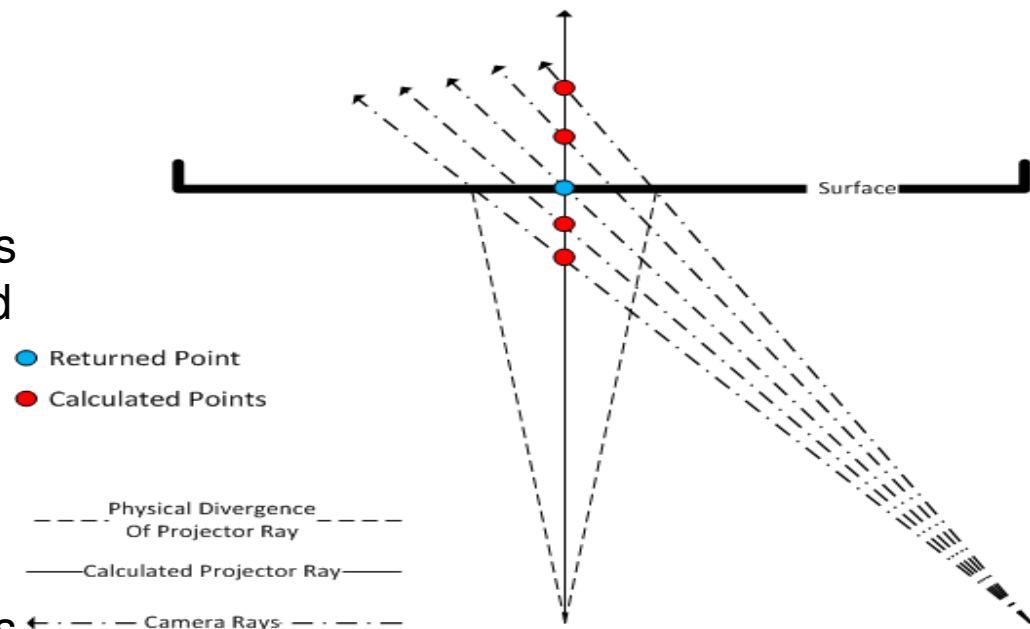
- Decreased point cloud accuracy from divergent beams
 - Projector rays are straight lines rather than divergent beams
 - Over-sampling the projector rays leads to incorrect point reconstructions



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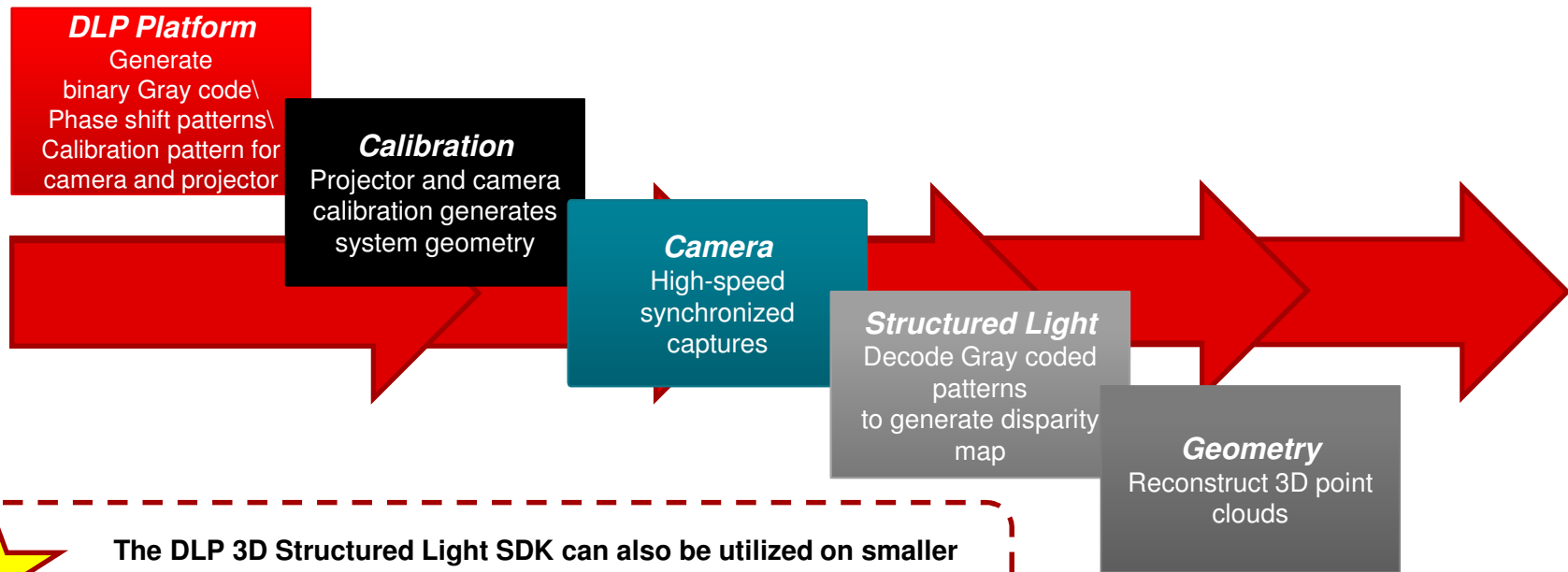
DLP® Structured Light SDK- Overcoming Pixel Over-Sampling

- When both vertical and horizontal patterns are used every camera ray is associated to a specific projector ray
- During reconstruction, group points according to their projector ray and filter!
- This method limits the number of points to the number of projector pixels
- This method will not work for scans with a single orientation of patterns



DLP® Structured Light SDK- Cross Platform Support

TI code is example code



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