SW Test Workshop
Semiconductor Wafer Test Workshop

Achieving higher speeds for CMOS Image Sensor Testing

FormFactor Inc.

Larry Levy

Minoru Mikami

Hitachi Chemical Co.,Ltd.

June 5-8, 2016

Abstract

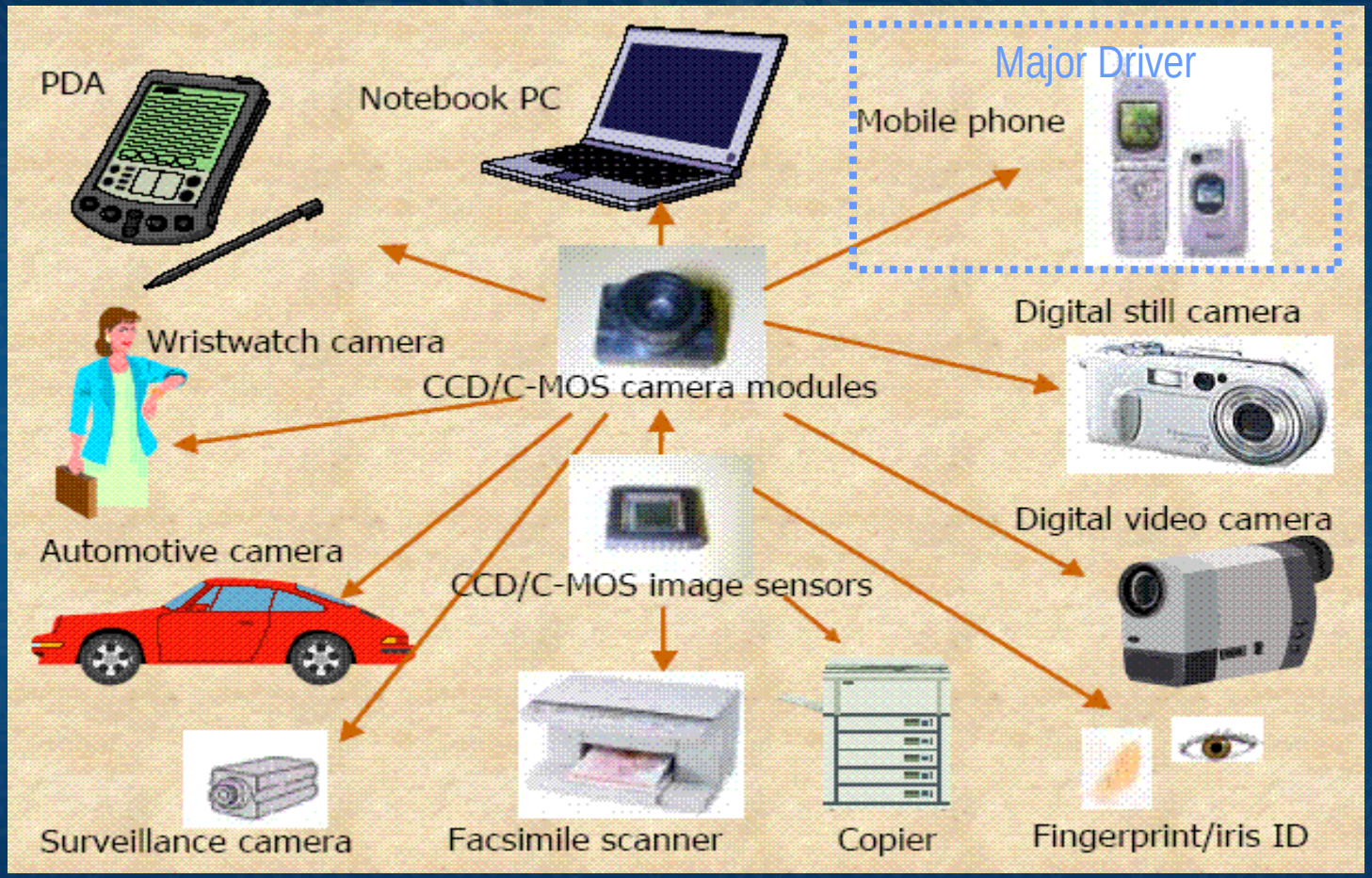
As CMOS Image Sensors continue to grow at ~10% CAGR, a part of that market is driven by the need for speed.
At SWTW in 2014 FormFactor and Advantest first presented the challenges of the test infrastructure keeping pace with the device speeds.
Since that time new requirements relating to the incorporation on lens modules in the probe card, have increased the difficulty of meeting this challenge.
Last year we produced several card designs requiring 2.5Gbps for the differential pair and clock speeds as called out by MIPI D-PHY V1.2. However, new M-PHY opportunities require 3Gbps speeds for several differential pairs.
In cooperation with Hitachi Chemical Co.,Ltd, using new PCB materials and design rules, we were able to achieve loss characteristics of the probe card that was comparable to traditional high speed CIS probe card performance without a lens module. An Eye pattern simulation that used actual S-parameter data indicated we finally have enough signal quality to meet 3Gbps.
However, as we look toward the future our next target of 5Gbps may require some structural changes.

Agenda

- **Need for speed the sequel**
- **How do we meet the testing needs?**
  - Tester + Probe card (system solution)
- **The bar has been raised**
  - Probe card design just became more difficult
- **New PCB material required**
- **S-Parameter and Eye Pattern Measurement**
- **Summary and Next Steps**

Need For Speed

Image sensor applications



Cell Phones

Peshkova/Shutterstock.com

Cell Phones

More Data Drives Need for Higher Speed

- **More Megapixels in cameras**
- **Display resolution increasing for video and still**
  - At least 21 models greater than 1080P resolution
  - At least 20 models with 4K video speeds
- **Need to take multiple pictures to get one good high resolution picture**
  - Apple video/picture feature

High Pixel Count Cell Phones

Microsoft Lumia 950
/ 950 XL
20 MP camera

4K video capture
5.2” Quad HD AMOLED Display with 564ppi

LG G5
16 MP camera

5.3" IPS Quantum QHD Display with 554 ppi

Samsung Galaxy S7
12 MP camera

5.5”/5.1” Quad HD super AMOLED display

Apple 6S 12 MP

List of Cell Phones with 1440P Resolution

Brand	Model	Release month	Operating system	Display type	Resolution (pixels)	Display size	Pixel density (ppi)
BBK	Vivo Xplay 3S	March 2014	Funtouch OS	IPS LCD	2560x1440	6.0 in (150 mm)	490
Fujitsu	ARROWS NX/F-02G	November 2014	Android 4.4	IPS LCD	2560x1440	5.2 in (130 mm)	570
Gionee	Elife E8	June 2015	Android 5.1	AMOLED	2560x1440	6.0 in (150 mm)	490
Huawei	Nexus 6P	September 2015	Android 6.0	AMOLED	2560x1440	5.7 in (140 mm)	518
Lenovo	Vibe Z2 Pro K920	September 2014	Android 4.4	IPS LCD	2560x1440	6.0 in (150 mm)	490
LG	G3	May 2014	Android 4.4	IPS LCD	2560x1440	5.5 in (140 mm)	538
LG	isai FL	July 2014	Android 4.4	IPS LCD	2560x1440	5.5 in (140 mm)	538
LG	isai VL	December 2014	Android 4.4	AH-IPS	2560x1440	5.5 in (140 mm)	538
Microsoft	Lumia 950	November 2015	Windows 10 Mobile	AMOLED	2560x1440	5.2 in (130 mm)	570
Microsoft	Lumia 950 XL	November 2015	Windows 10 Mobile	AMOLED	2560x1440	5.7 in (140 mm)	518
Motorola	Droid Turbo	October 2014	Android 4.4	AMOLED	2560x1440	5.2 in (130 mm)	570
Motorola	Nexus 6	November 2014	Android 5	AMOLED	2560x1440	5.96 in (151 mm)	493
OPPO	Find 7	May 2014	ColorOS	IPS LCD	2560x1440	5.5 in (140 mm)	538
Philips	i966 Aurora	October 2014	YunOS 3.0	IPS LCD	2560x1440	5.5 in (140 mm)	538
Samsung	Galaxy S5 LTE-A G906S	July 2014	TouchWiz Nature UX 3.5	Super AMOLED	2560x1440	5.1 in (130 mm)	577
Samsung	Galaxy Note 4	October 2014	Android 4.4	Super AMOLED	2560x1440	5.7 in (140 mm)	518
Samsung	Galaxy Note 5	August 2015	Android 5.1.1	Super AMOLED	2560x1440	5.7 in (140 mm)	518
Samsung	Galaxy S6	April 2015	Android 5.1.1	Super AMOLED	2560x1440	5.1 in (130 mm)	577
Samsung	Galaxy S6 Edge	April 2015	Android 5.1.1	Super AMOLED	2560x1440	5.1 in (130 mm)	577
Samsung	Galaxy S6 Edge+	August 2015	Android 5.1.1	Super AMOLED	2560x1440	5.7 in (140 mm)	518

- Apple 6S is 1080P
- Sony has an offering at 2160P

Wikipedia

There Are Over 20 Cell Phones that Shoot 4K Video

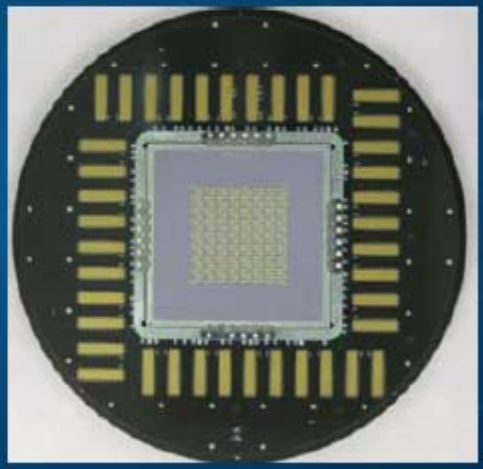
source: Phone Arena 2014

How Do We Meet the Testing Needs?

Presented in 2014 SW.

Systematic Approach Required

+

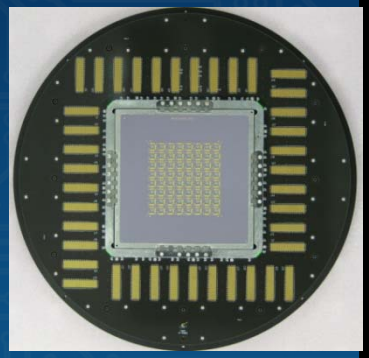


= 3Gbps

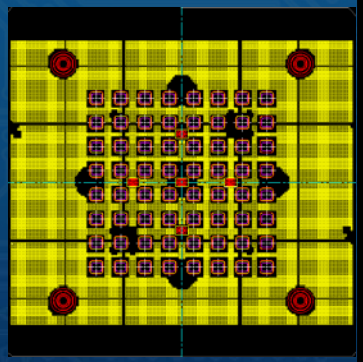
June 8-11, 2014 SWTW IEEE Workshop 12

Presented in 2014 SW.

Phase2 PC



Phase2 PH



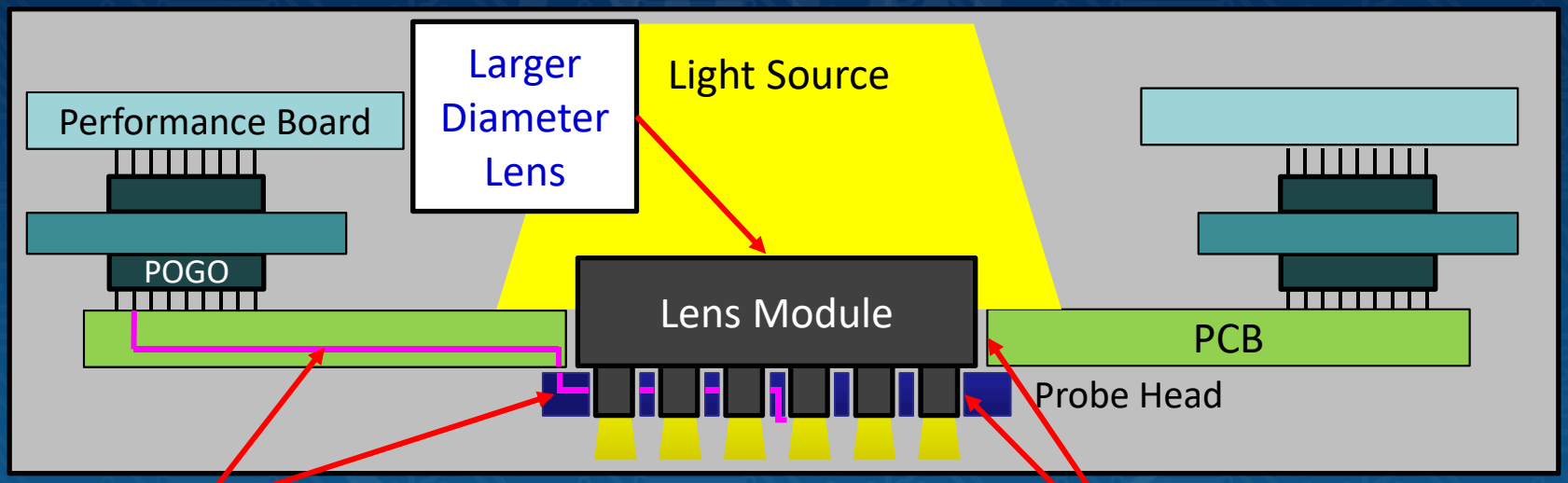
Probe Card Loss Phase 2 Results Summary

Loss @ F=1.5Ghz	1.2Gbps Design	3Gbps Design
Parallelism	64	64
Total Probe Card S21 Loss	-3db	1.72 to 2.32dB
3Gbps S21 Loss Goal	-2db	
Judgment	Fail	Acceptable with minor adjustments
Total Probe Card Impedance @ Tr100ps		Pogo: 45.2 to 49.4Ω PCB: 45.9 to 51.9Ω
3Gbps S21 Loss Goal	**47-53Ω**	
Judgment	Fail	Acceptable

June 8-11, 2014 SWTW IEEE Workshop 21

The Bar Has Been Raised

CIS Probe Card with Lens Module



Longer Trace Length

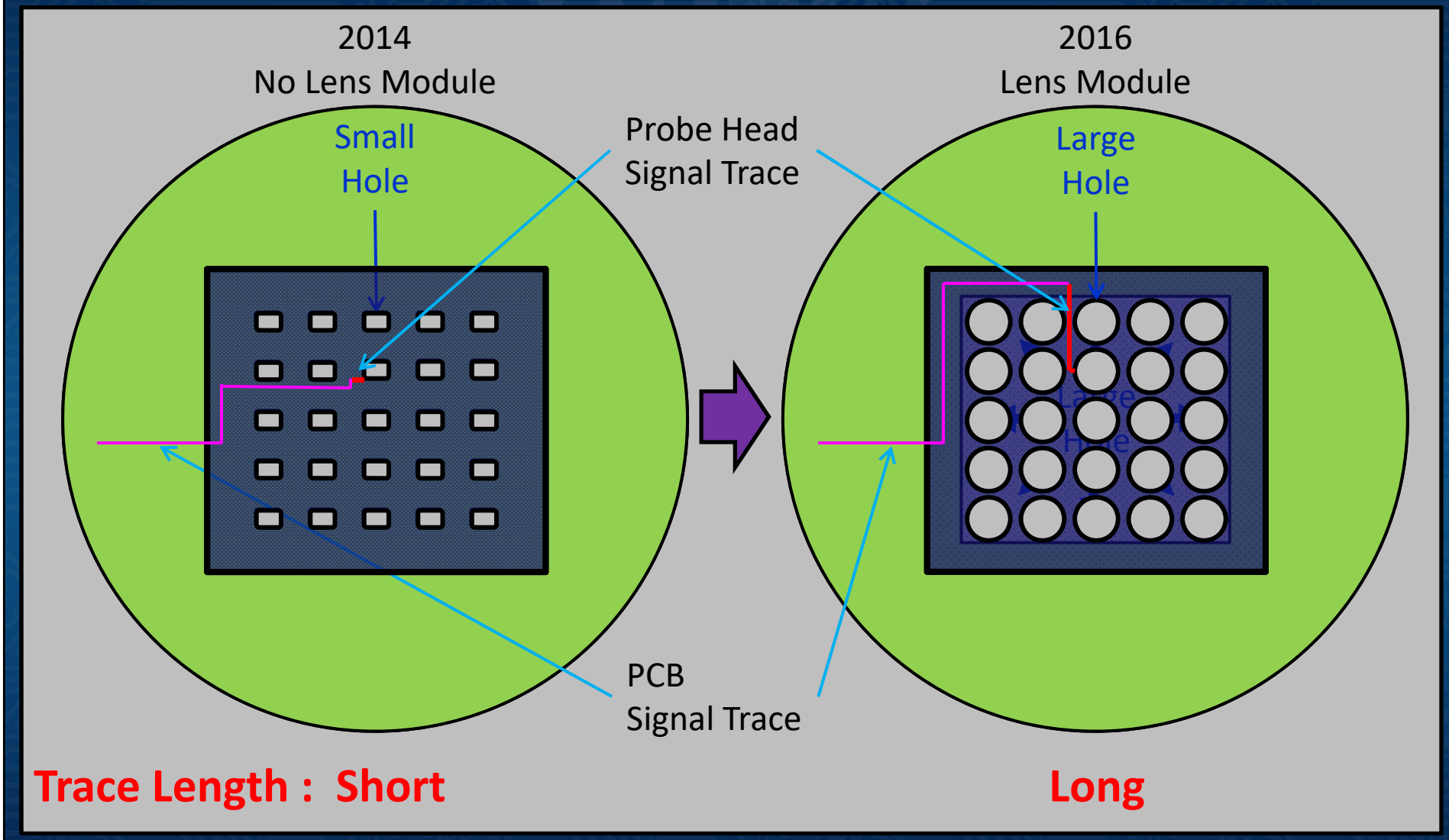
Large Loss

Require

Low Loss Technology

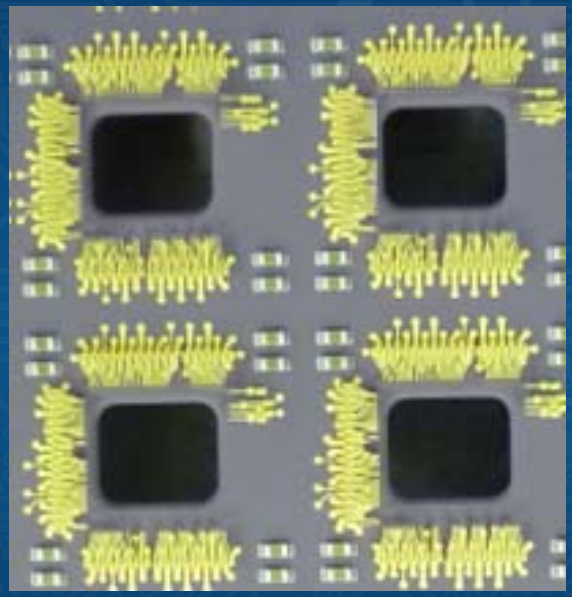
Larger Hole (PCB, Probe Head)

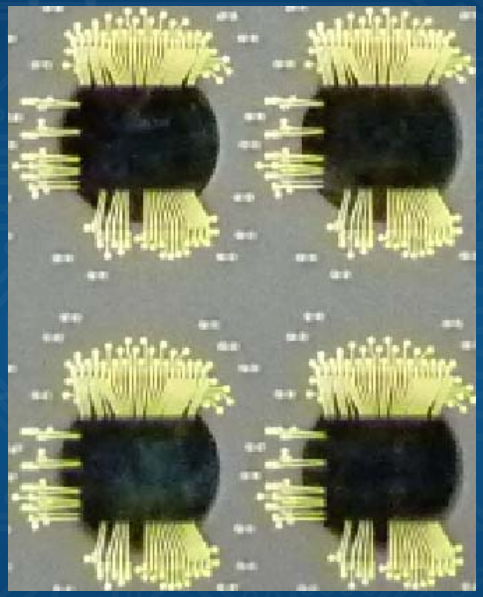
PCB & Probe Head Signal Trace



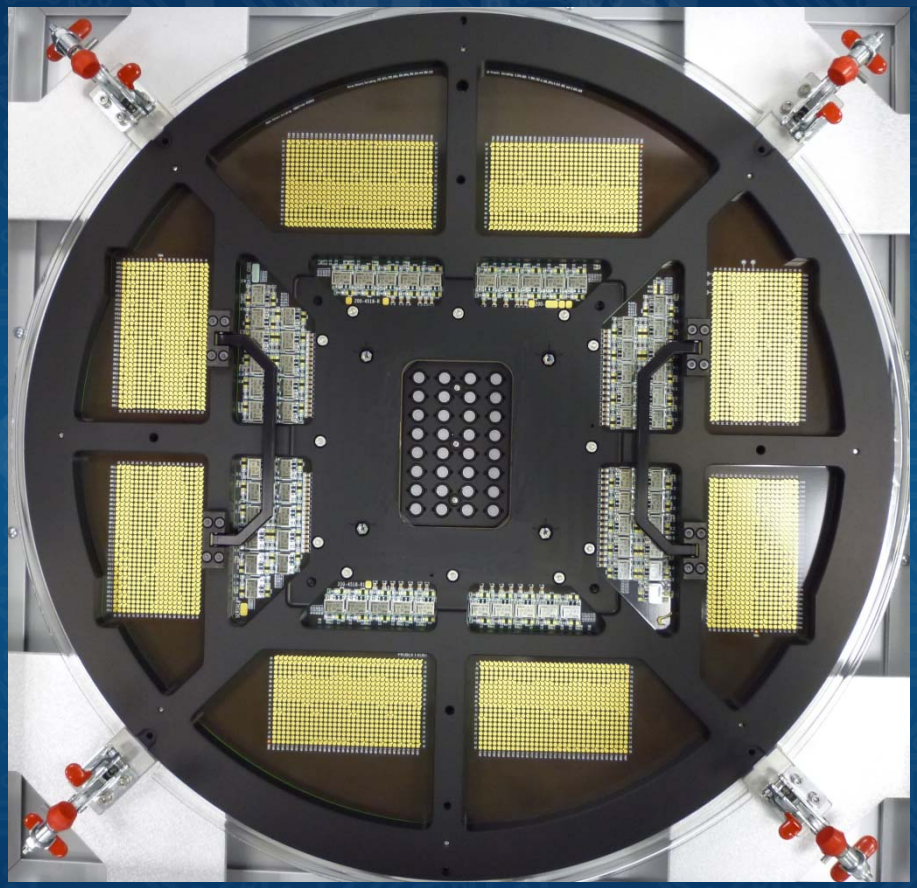
Larger Lens Drives Complexity

- **Springs now overhang opening**

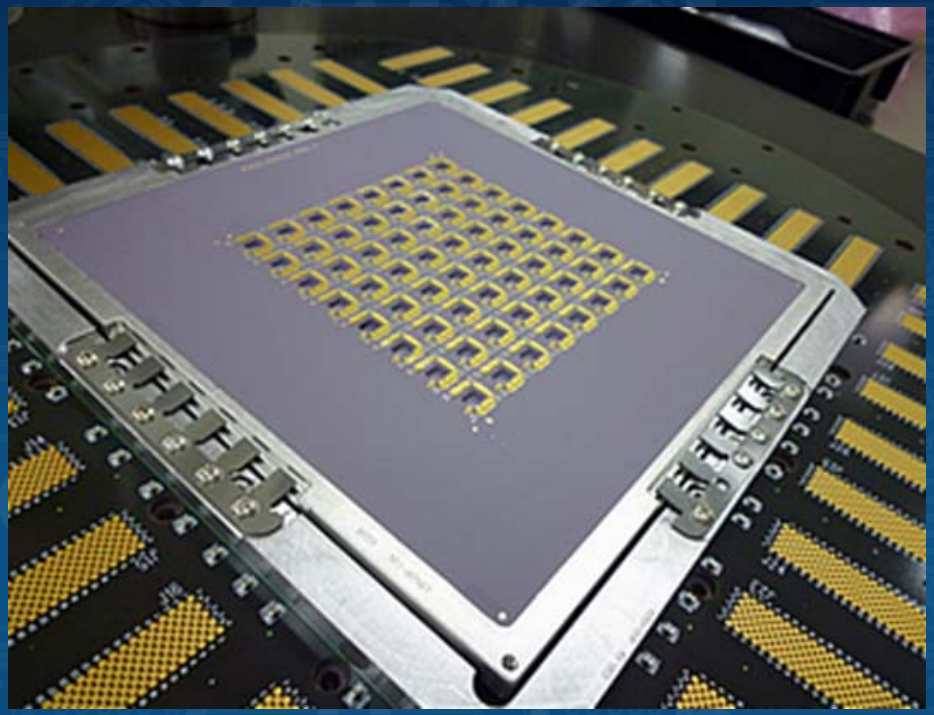




Lens Module



PCB and Probe Head



Optimized FormFactor Design rules

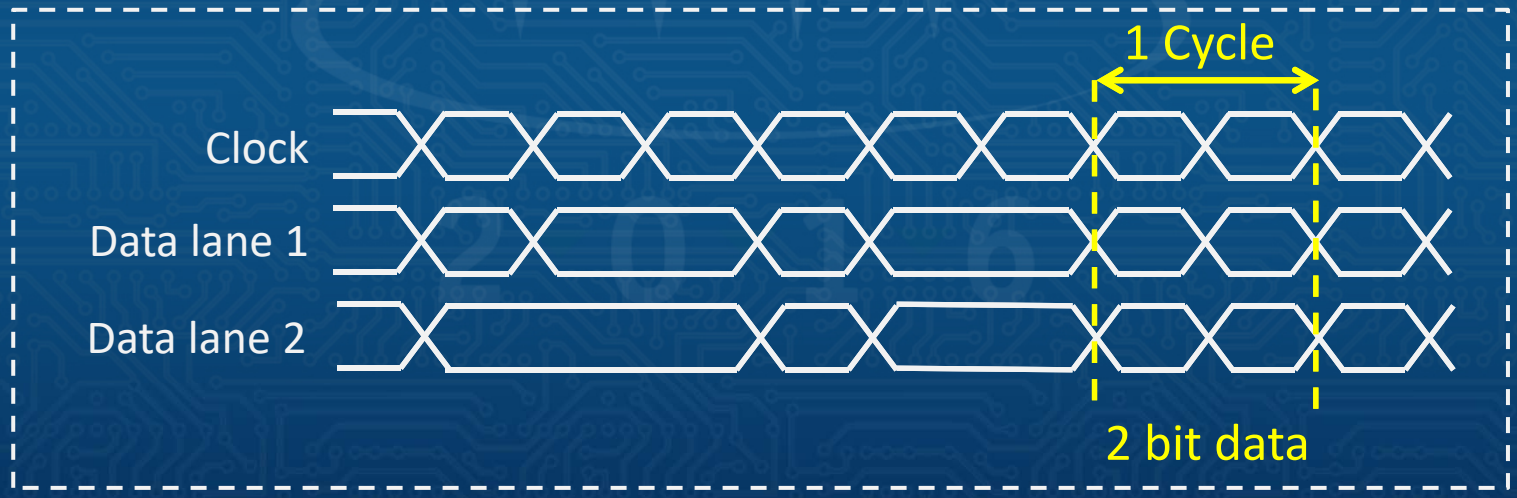
- **Tight trace length adjustment**
- **Tight impedance control**
- **Optimal signal trace spacing**

New PCB material required

Target

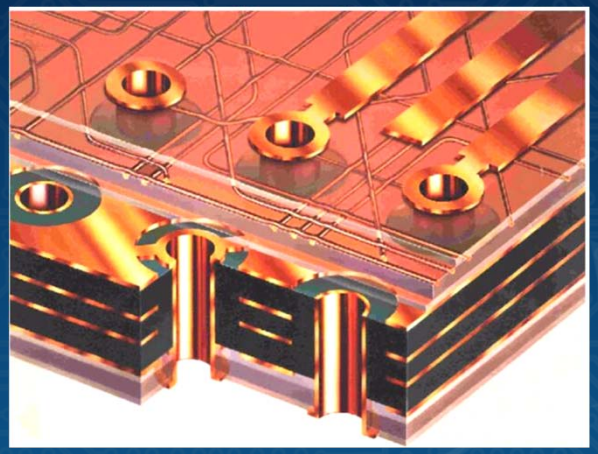
Probe Card : High// CIS with Lens Module

Signal Speed : MIPI D-PHY 3Gbps



MIPI D-PHY outline

Multi Wire Board (MWB)



Crossover Wiring

Provided by Hitachi Chemical Co.,Ltd.

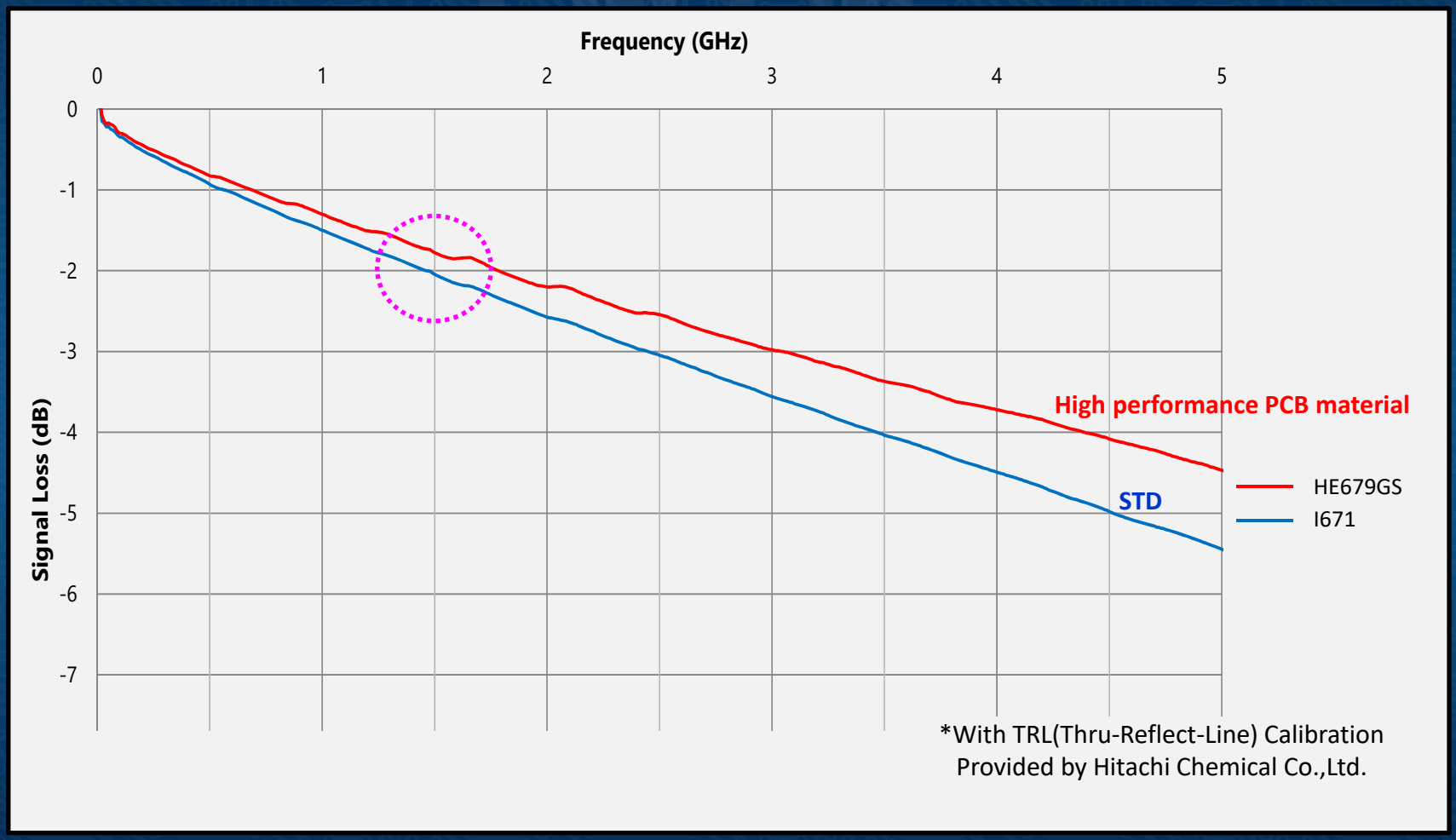
- Crossover wiring within one layer
- Two to three times as much wiring capacity as that of etching method boards
- Uniform copper wire diameter
- Provides stable electrical characteristics even if long wiring on big size board

PCB Material Dielectric Constant (DK) and Dissipation Factor (Df)

PCB Material		Dk @ 1GHz	Df @ 1GHz
STD (Polyimide)	I-671	4.2 – 4.3	0.013 – 0.015
High Performance	HE-679G(S)	3.7 – 3.9	0.006 – 0.008

PCB Material Characteristics

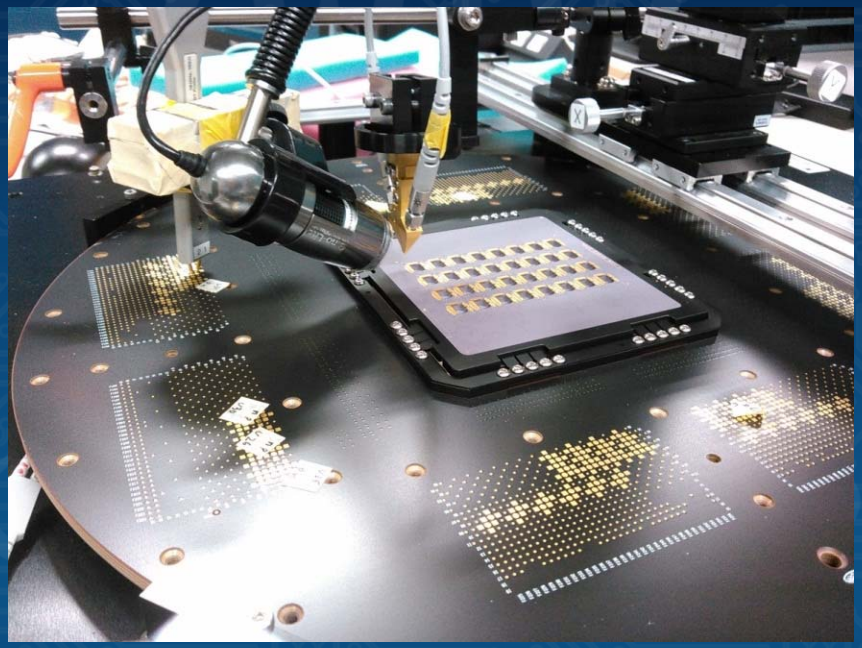
Loss at 1.5GHz: -1.7dB HE-679G(S), -2.0dB I671



Comparison of Sdd21 (Signal Loss), in 250mm length of differential pair path

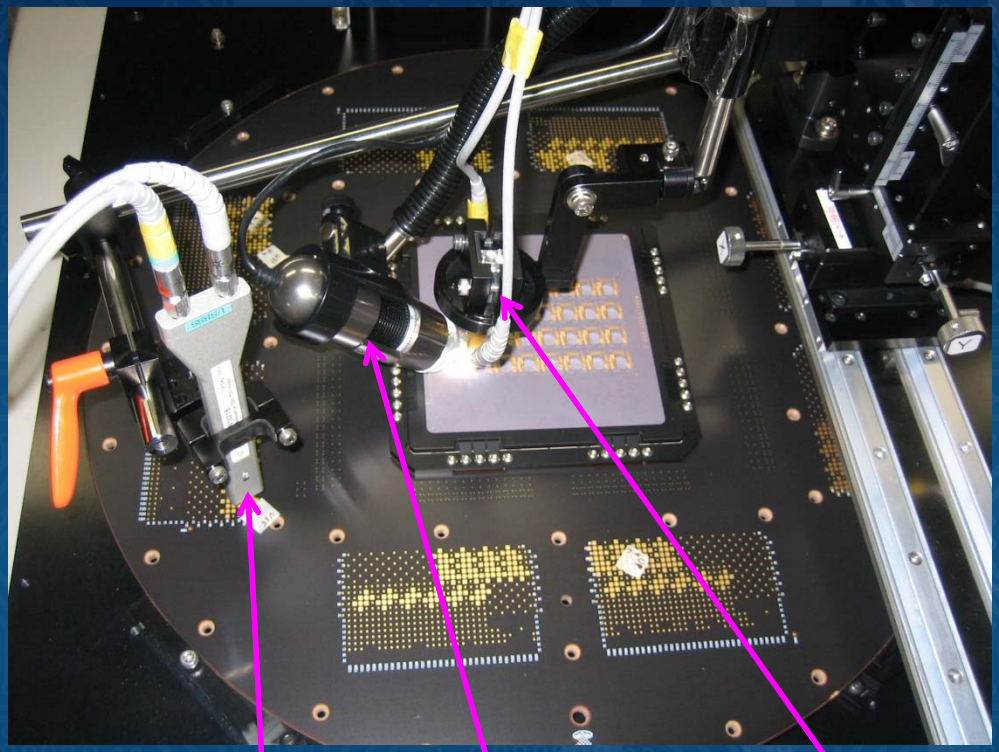
S-Parameter and Eye Pattern Measurement

Probe Card Specifications



- PCB type : Multi Wire Board
- PCB material : High performance PCB material HE-679G(S)
- Array configuration : 4x8, 1 Skip Column and 1 Skip Row
- Probe Head : Standard FormFactor Ceramic PH100

Measurement Apparatus



Differential Probe:
Agilent N1021B
for PCB POGO

USB Camera

Differential Probe:
Yokowo FCP-VPDF
for Probe Head Spring

Network Analyzer:
Agilent E5071C

Measurement & Simulation Method

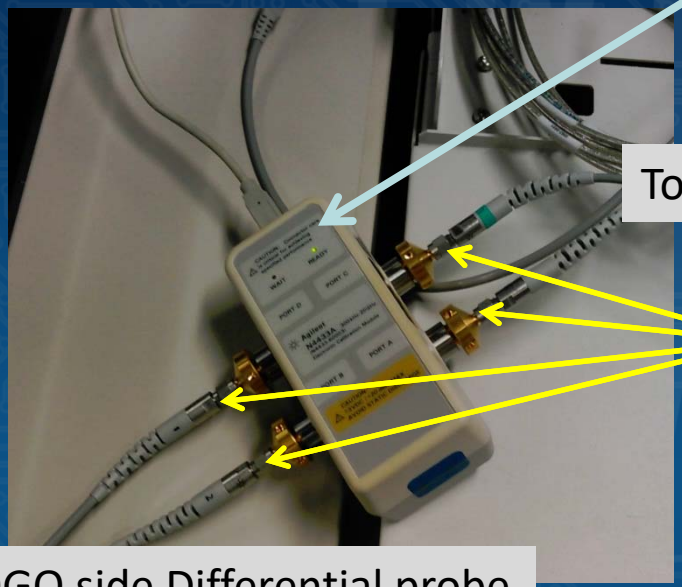
1. **Calibrated Network Analyzer**
2. **Measured Differential probe loss**
   - Agilent N1021B
   - Yokowo FCP-VPDF

3. **Measured S-Parameter**
   - 5 site (1 pair / site)
   - Stimulation Amplitude 360mV (P-P)
   - Rise Time 100psec
4. **Calculated Probe Card loss**
5. **Simulated Eye pattern from measured S-Parameter**

Site Map

1		2		3		4
5		6		7		8
9		10		11		12
13		14		15		16
17		18		19		20
21		22		23		24
25		26		27		28
29		30		31		32

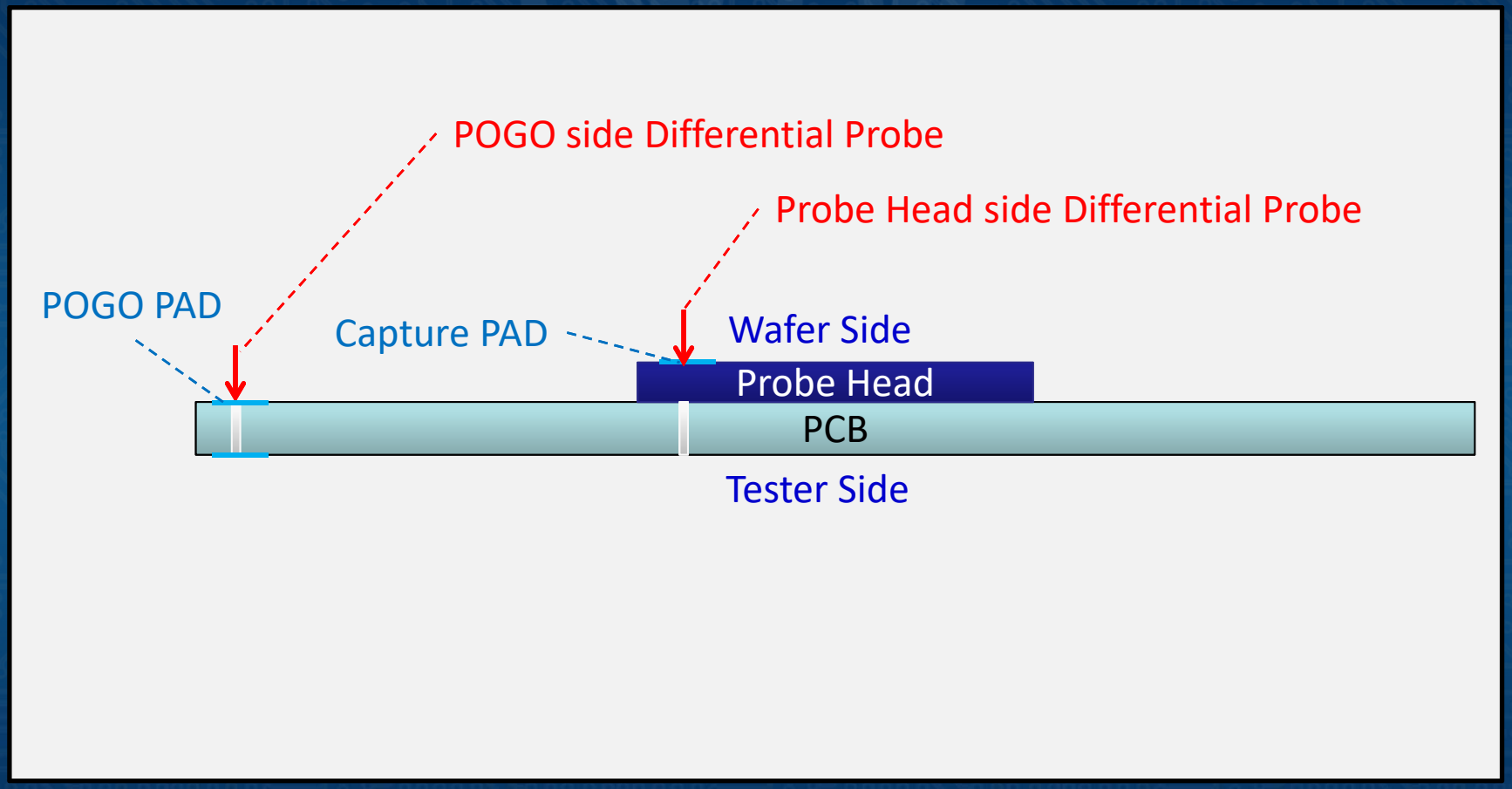
Calibration Method for Cable loss



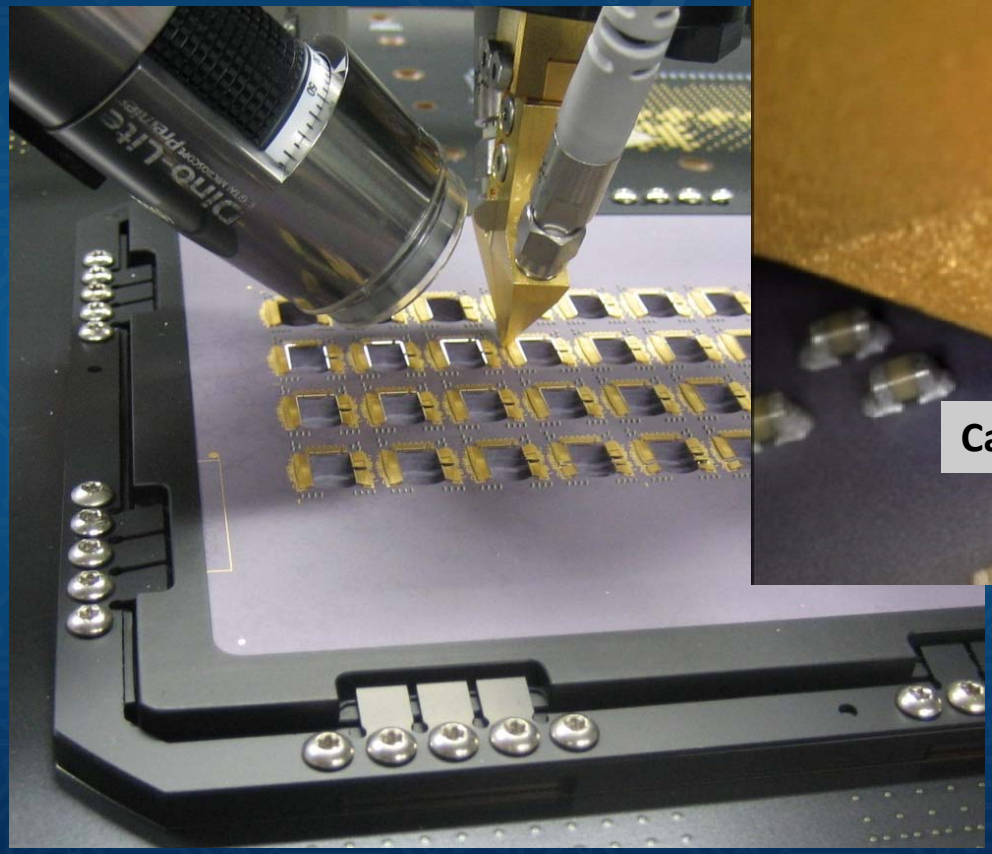
- Calibrator : Agilent N4433A
- Calibration point: End of the cable

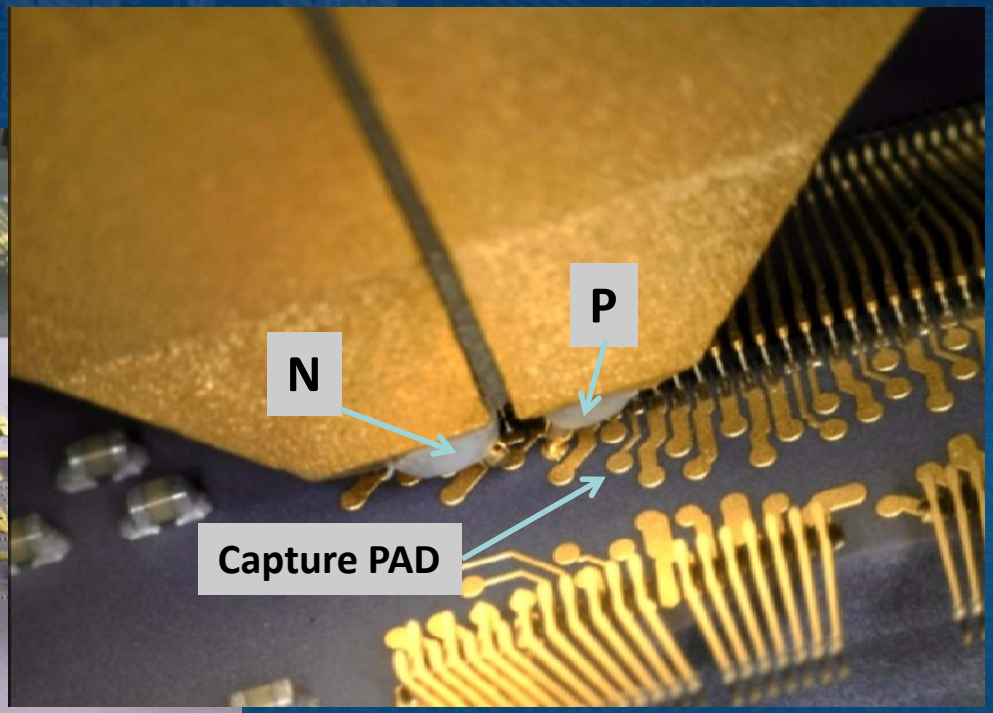
  Cancelled Network Analyzer cable loss

Probe Card Measurement Point



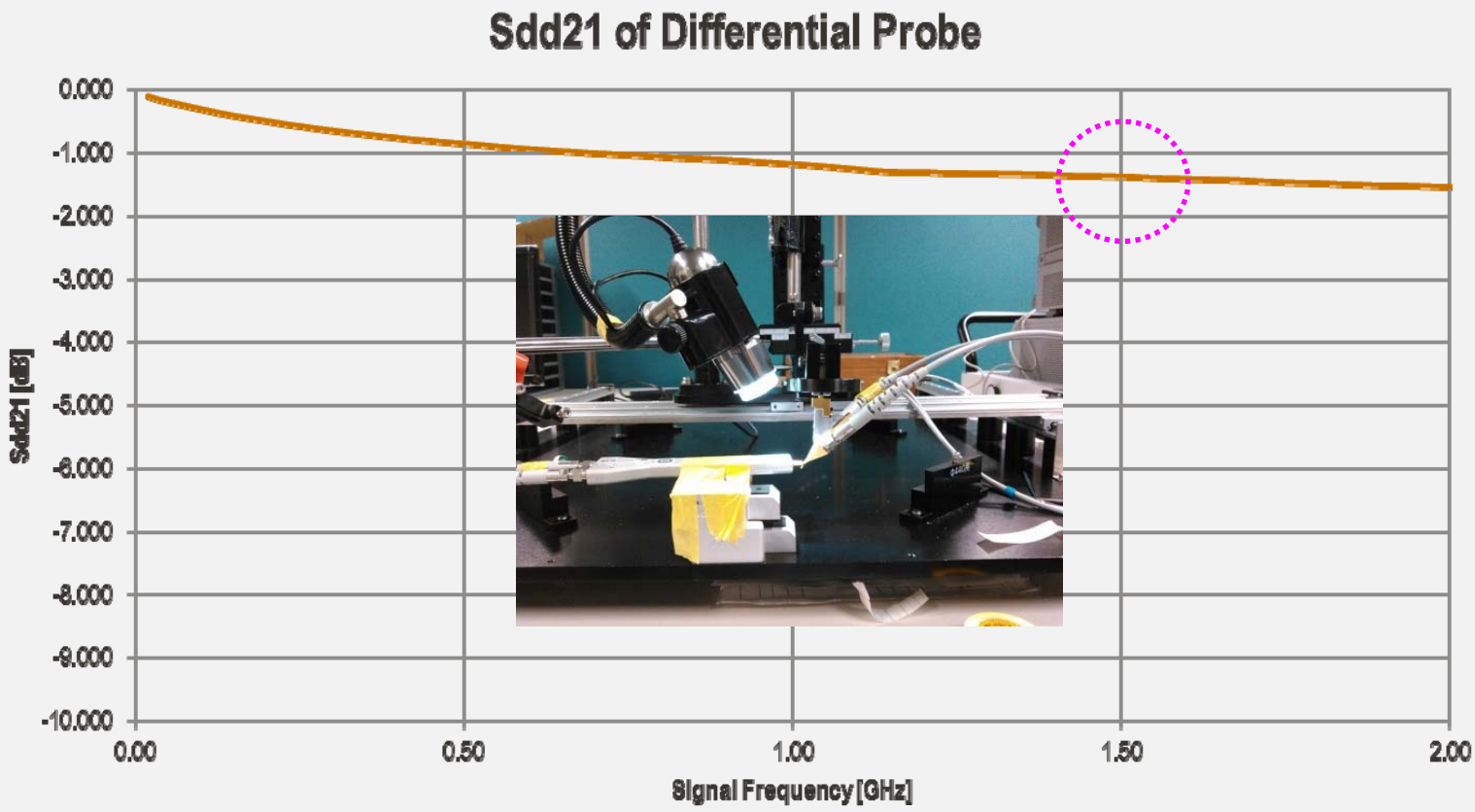
Probe Head Measurement point





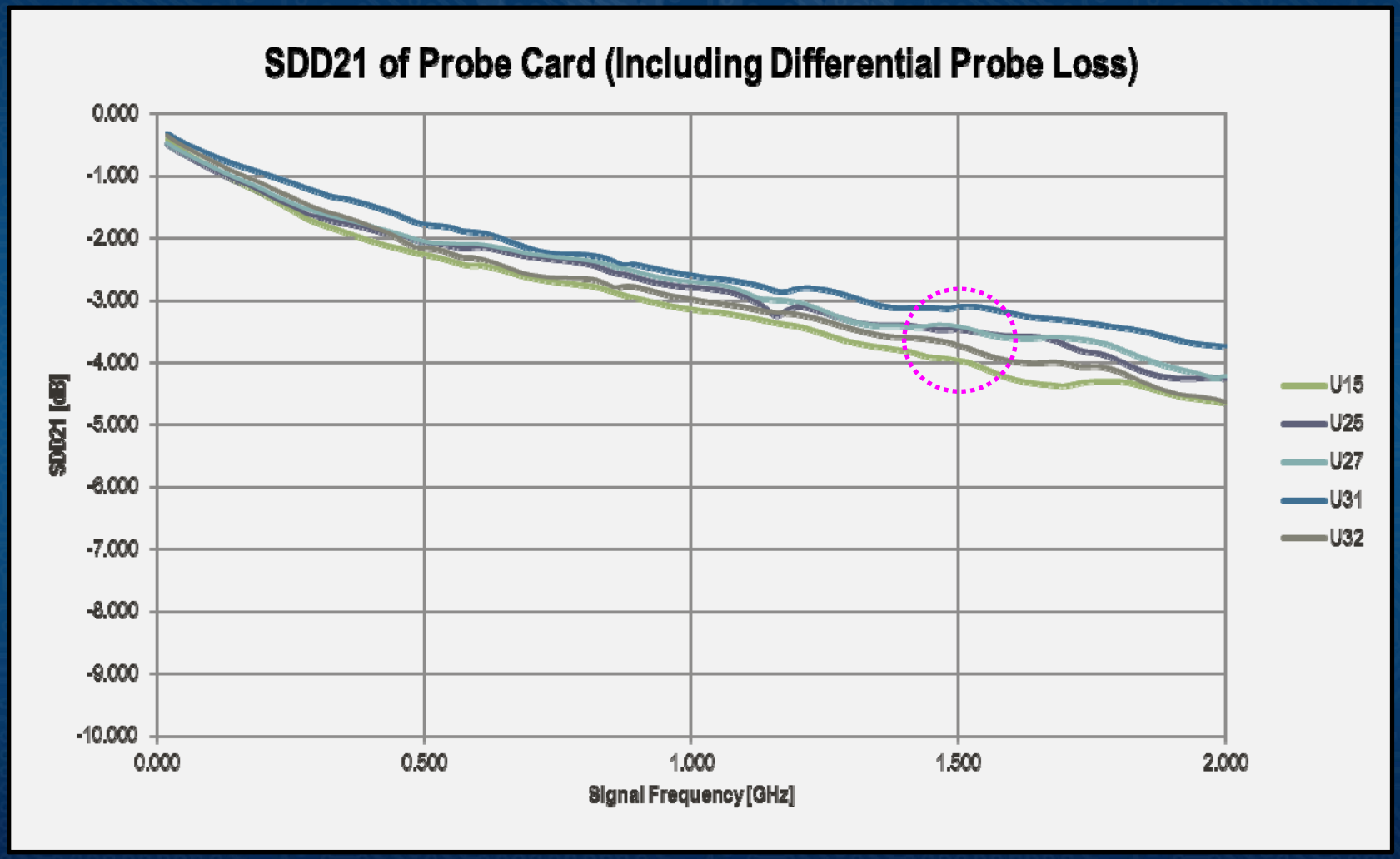
Differential Probe Loss

Loss at 1.5GHz: -1.4dB



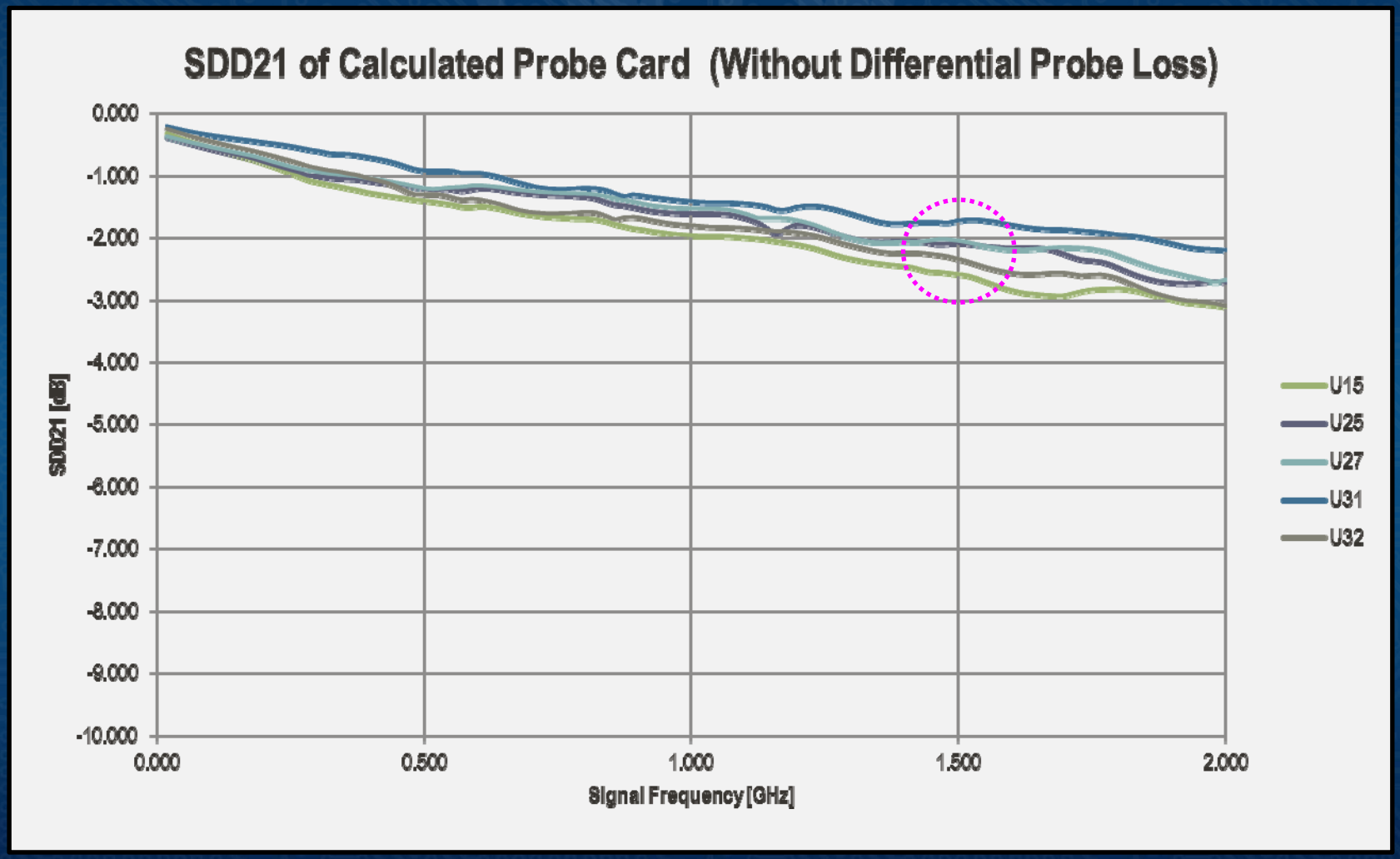
Probe Card Loss

Loss at 1.5GHz: -3.1dB (U31) ~ -4.0dB (U15)



Calculated Probe Card Loss

Loss at 1.5GHz: -1.7dB (U31) ~ -2.6dB (U15)



Eye Pattern Simulation Setting

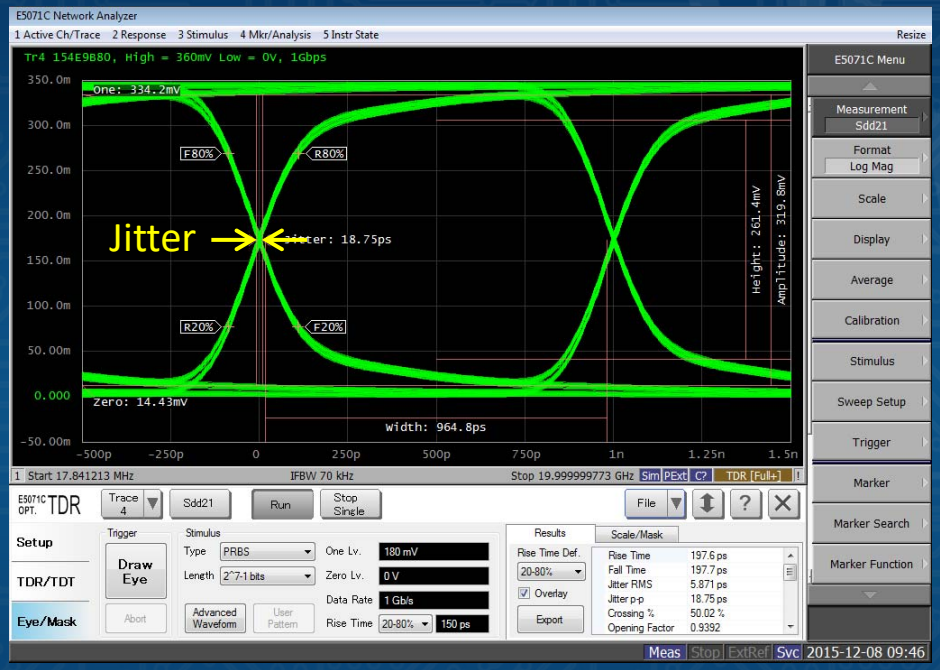
- **Input Signal setting:**
  - Type: PRBS (Pseudo random bit sequence)
  - Length: 127bit
  - High Voltage: 360mV (P-P)
  - Low Voltage: 0V
  - Data Rate: 1.0Gbps ~ 3.5Gbps
  - Rise Time: 15% of Half cycle time (20-80%)
- **Eye parameter calculation setting:**
  - Rise Time: 20-80%

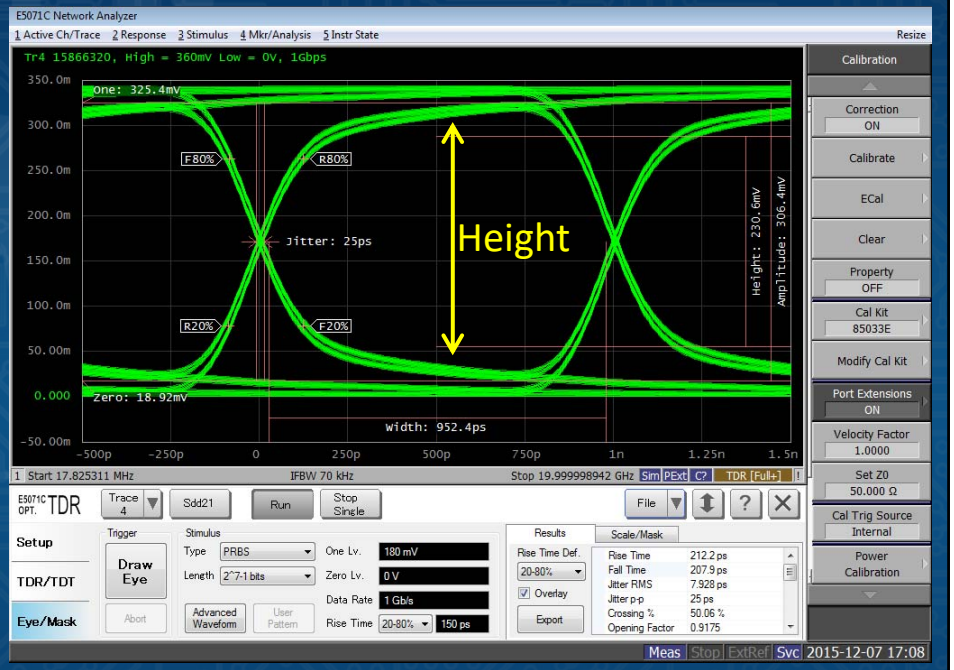
1.0Gbps

Loss(Sdd21):

Best
U31

Worst
U15





Probe Card Loss (Including Differential Probe Loss)

1.5Gbps

Loss(Sdd21):

Best
U31

-2.3dB @0.75GHz

Worst
U15

-2.3dB @0.75GHz

2.0Gbps

Loss(Sdd21): Best U31 Worst U15

-2.6dB @1.0GHz

-2.8dB @1.0GHz

2.5Gbps

Loss(Sdd21):

Best
U31

-2.8dB @1.25GHz

Worst
U15

-3.2dB @1.25GHz

3.0Gbps

Loss(Sdd21):

Best
U31

-3.1dB @1.5GHz

Worst
U15

-3.5dB @1.5GHz

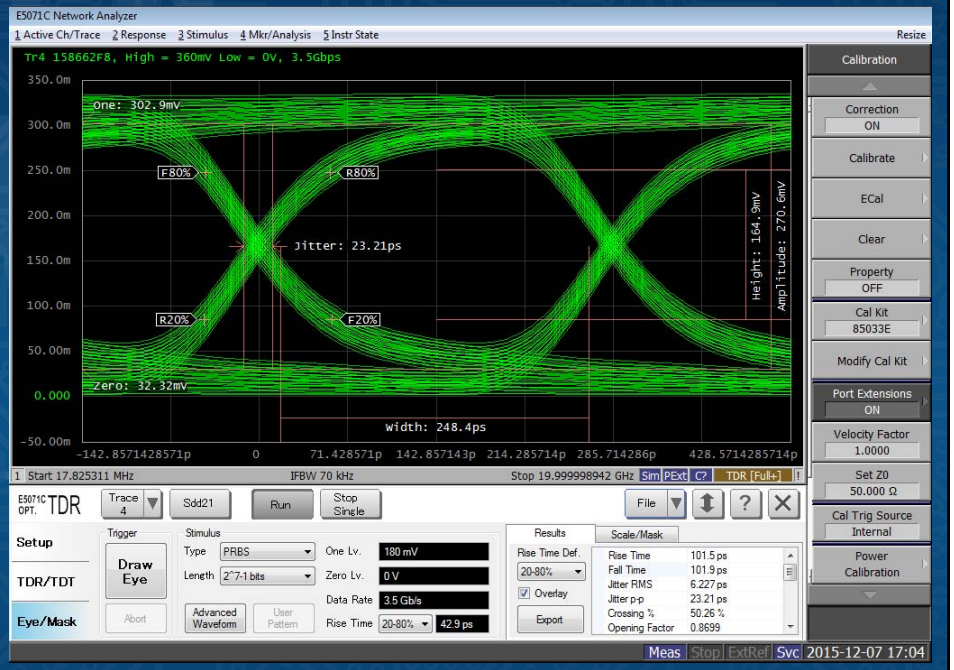
3.5Gbps

Loss(Sdd21):

Best
U31

-3.4dB @1.75GHz

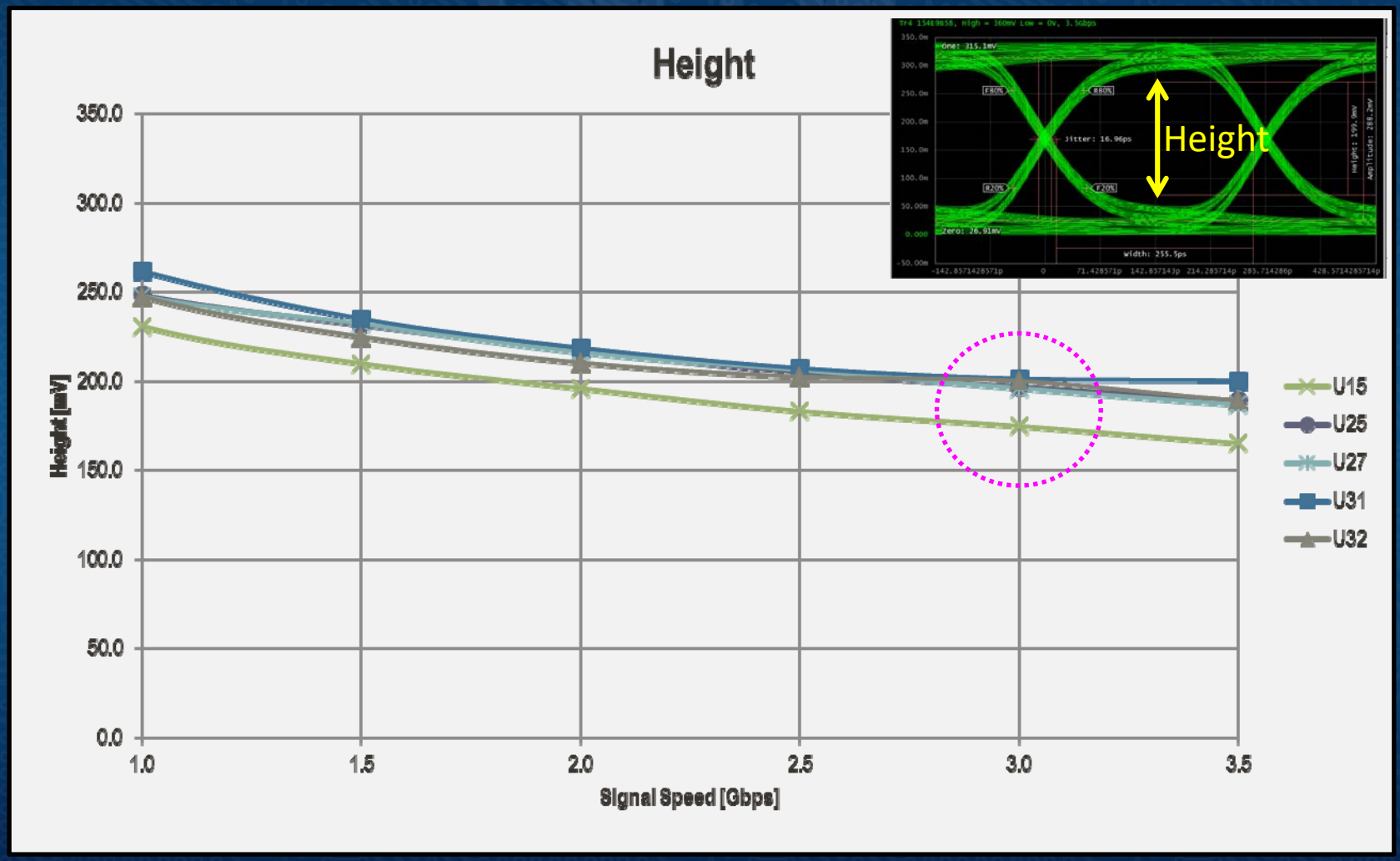
Worst
U15



-3.8dB @1.75GHz

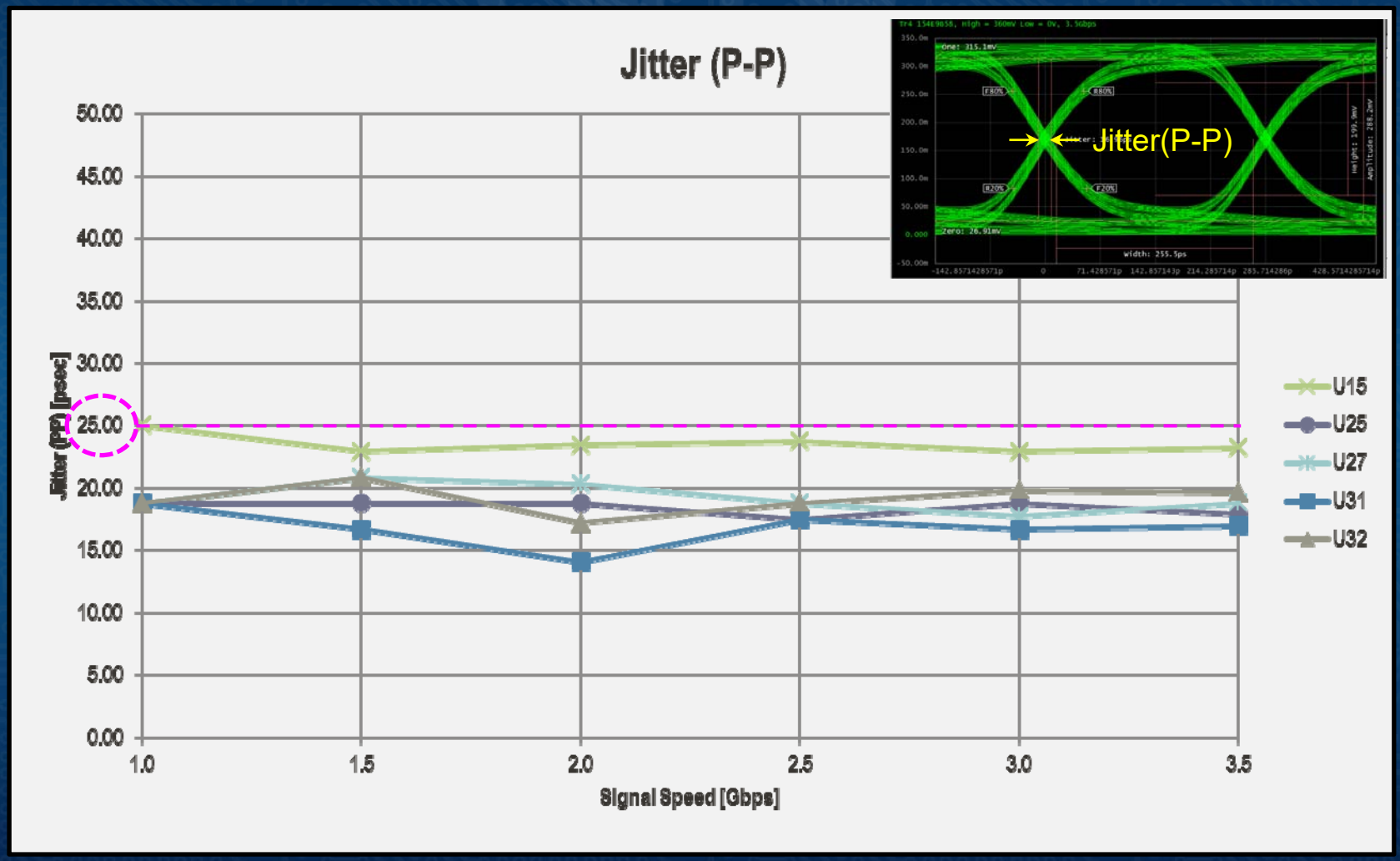
Eye Height

Height at 3.0Gbps: 190mv ~ 201mV (Input Signal 360mV)



Jitter (P-P)

Jitter: Less than 25psec



Summary and Next Steps

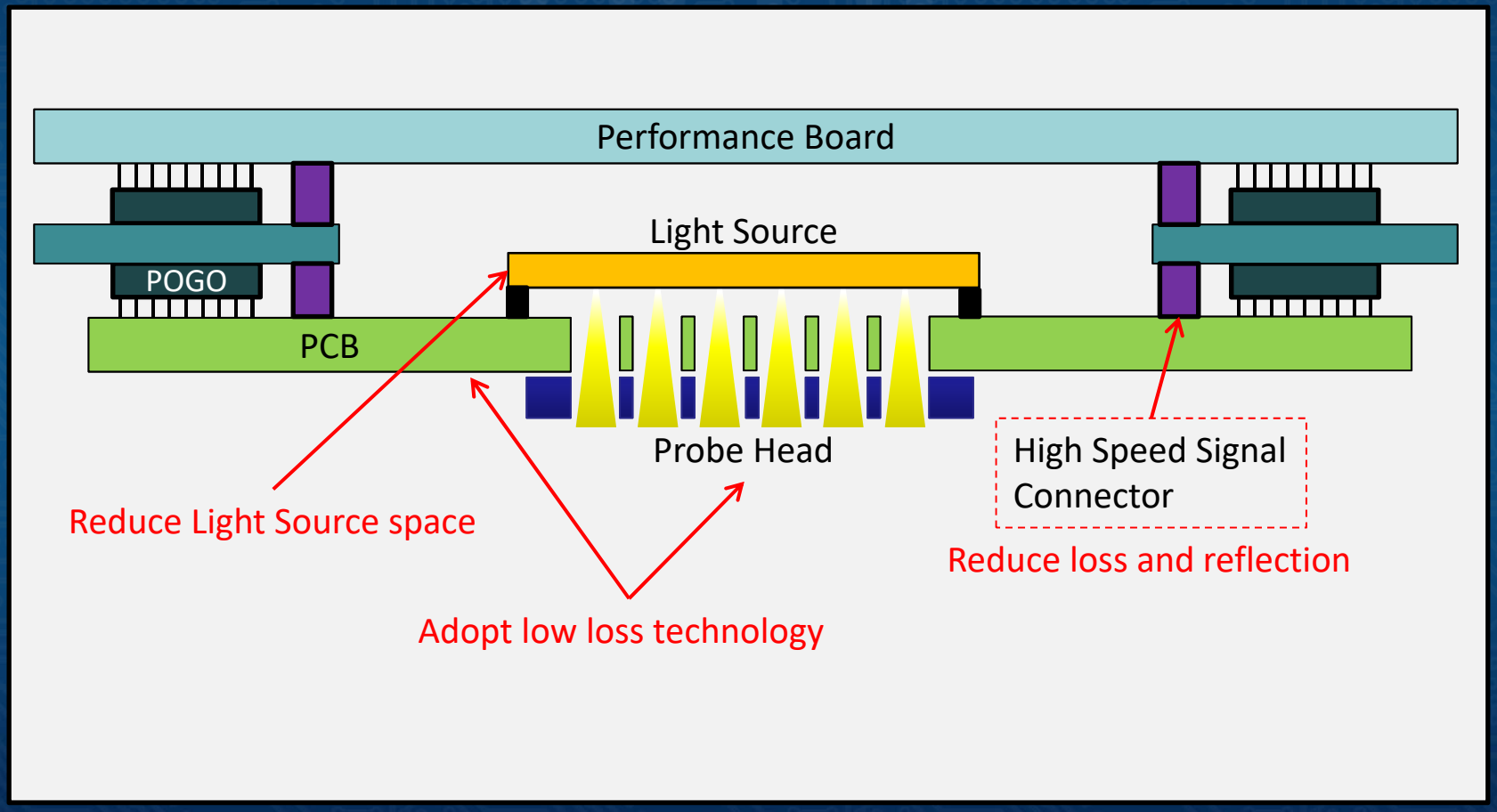
Summary
3Gbps Achieved

- Probe card loss (Sdd21)
  - Probe card loss was less than -2.6dB @1.5GHz
- Eye Pattern
  - Eye Height was more than 190mV @ 3Gbps
  - Jitter was shorter than 25psec regardless of the signal speed

3Gbps achieved with optimized FormFactor Design rules and high performance PCB material HE-679G(S)

Next Step

- **High// 5Gbps Probe Card Concept**



Acknowledgements

- Team Member
  - Hitachi Chemical Co.,Ltd.
    - Seiichi Kurihara
    - Noriaki Watanabe
    - Hiroyuki Mukouyama
  - FormFactor Japan
    - Nobuhiro Kawamata
    - Hiromitsu Sasanami
    - Yoichi Funatoko