

# ***“Advanced Fiducial Alignment for Photolithographic Probe Cards”***

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## **Acknowledgements**

- Electroglas Inc. for the use and proper time for development and testing
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- Southwest Test Conference Committee for the opportunity to present this paper

## Introduction

- Fiducial alignment objective
- Drivers for Fiducial alignment
- Why Fiducial alignment?
- Advantages of photolithographic probe cards for Fiducial alignment

### **Fiducial Based Alignment Objective**

- **Develop a new method for accurately aligning the probe card to the device pads for tight pitch applications.**
- **Increase the overall test cell reliability, capability and productivity for production applications. (OEE)**
- **Develop a method of communicating detailed probe card information based on a simple file format.**

## Drivers for Fiducial alignment?

- Device technology shrinking to the sub 0.13  $\mu\text{m}$  technology level and specialized devices require small bond pad technology - 30  $\mu\text{m}$  pad sizes.
- Consumer applications also require small pads and tight pitches - 40  $\mu\text{m}$  pitches.
- Advancing probe card technology with tight pin pitch require advance probe to pad alignment process
- Probe to pad alignment on small pad devices

## Why Fiducial Alignment?

- Provides high accuracy reference points.
- Offers a fast file download method to the prober for each probe tip location to increase productivity.
- Decreases the time needed for the prober to accurately locate the probe card pins.
- Extremely accurate and fast solution!

# Photolithographic Probe Card Advantages for Fiducial Alignment

- Photolithography offers 0.5  $\mu\text{m}$  accuracy resolution enabling solutions for probing small pads and fine pitch applications.
- Fiducials have the same high accuracy as that of the mask.
- Extremely low card to card variation in pin position due to photolithography.
- Photolithographic based Fiducials do not change location or accuracy over time or with wear.
- No additional cost to implement Fiducials in the design.



## **Fiducial Alignment Program**

### Probe Card

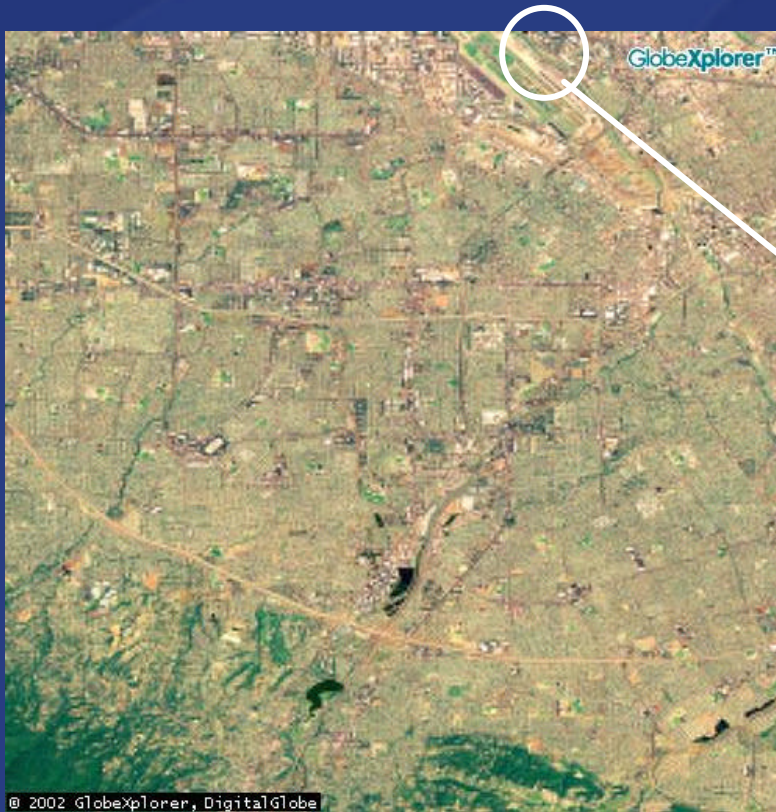
- Develop a photolithography based probe card
- Develop a fiducial design for pin location
- Develop a fiducial structure
- Build a photolithographic probe card with Fiducials

### Wafer Prober

- Develop the prober software to recognize and find Fiducials
- Use Fiducials to calculate pin locations
- Develop a standard file format for downloading probe card information
- Test Automatic Probe To Pad Alignment (APTPA) using Fiducial alignment

# Design and Fabrication of Photolithography Probe Cards with Fiducials

## Fiducial Theory – Image Identification



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Image from:  
[www.mapquest.com](http://www.mapquest.com)

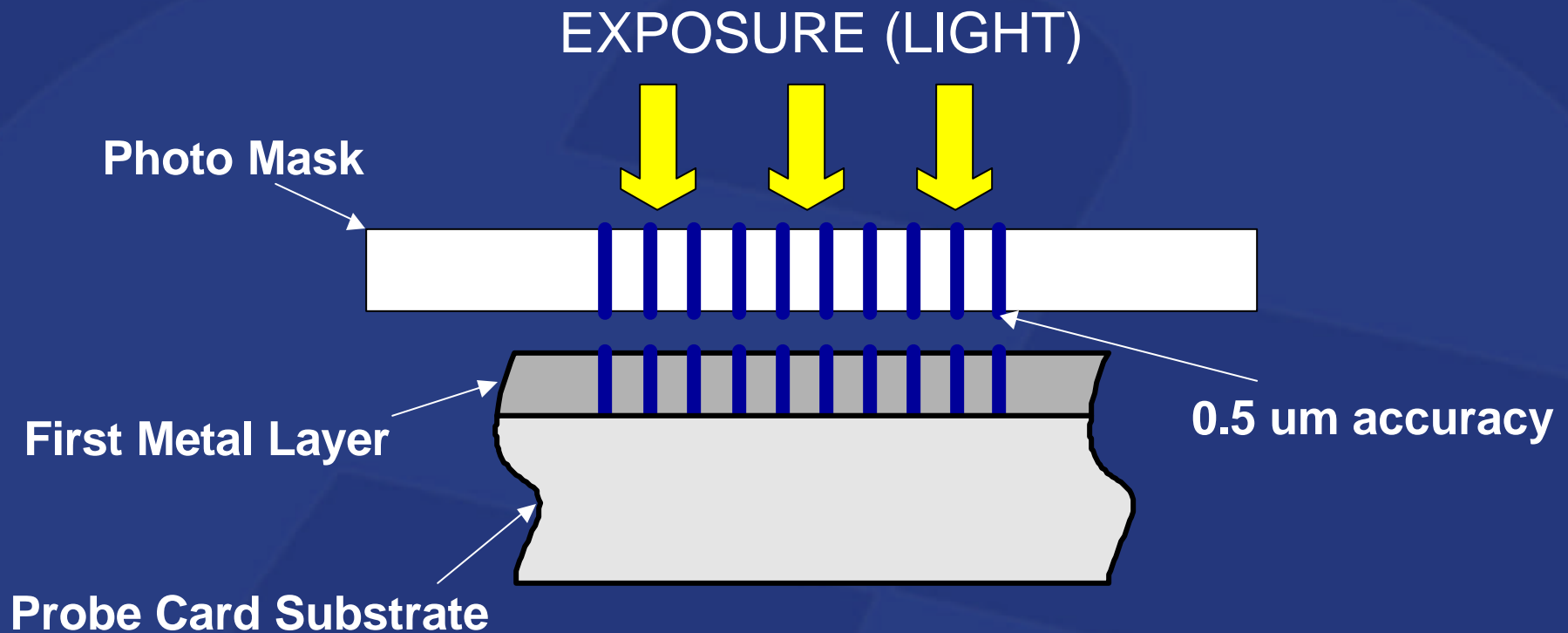
With a known image, you can find a location based upon “geography”

Or you can find a given shape/feature then relate it to the desired location.

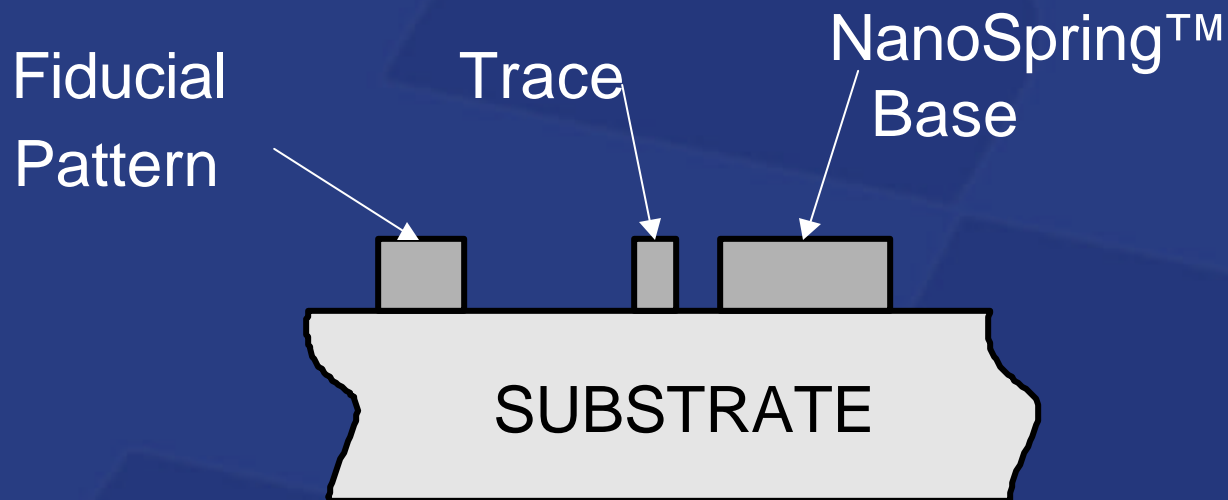


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## Fabrication - Photolithography



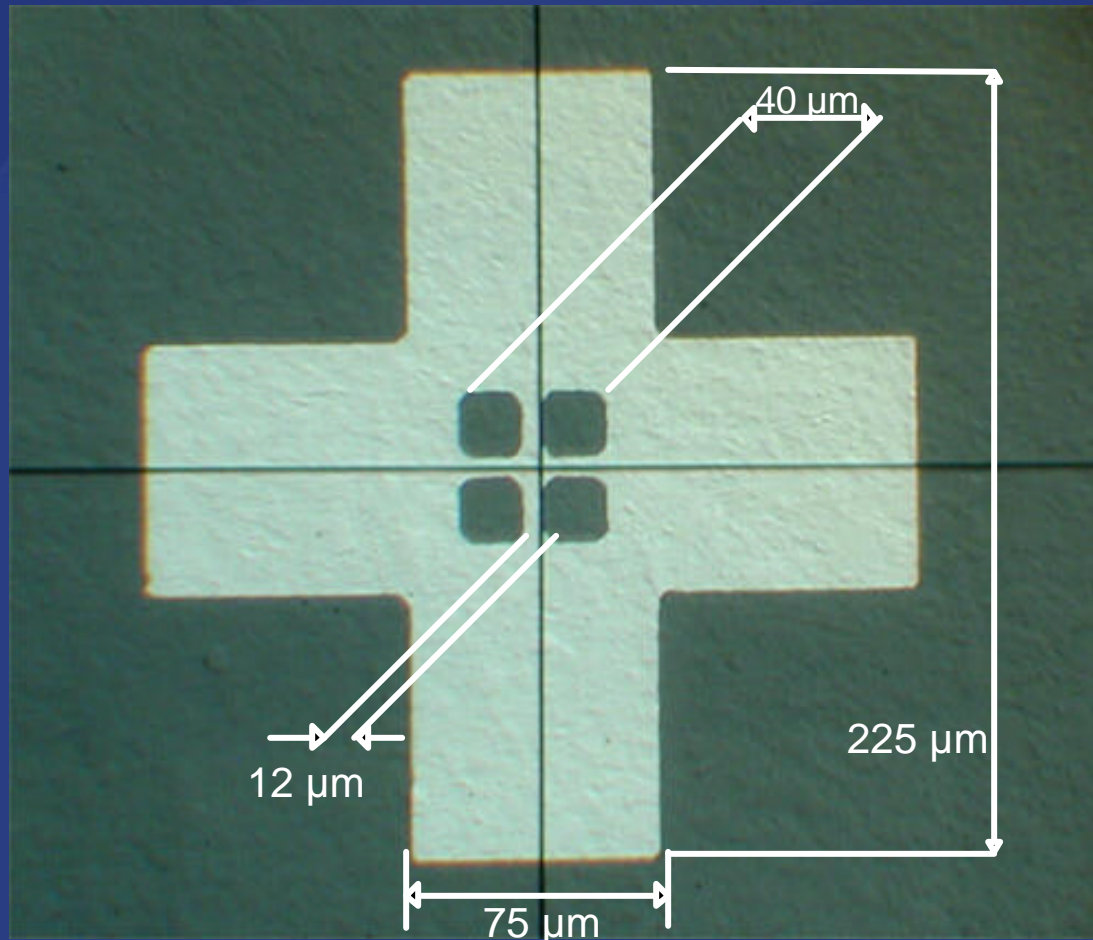
## Fabrication - Etch



- Fiducial formed with the same accuracy as the probe base.
- Fiducial kept clear of passivation for additional accuracy.

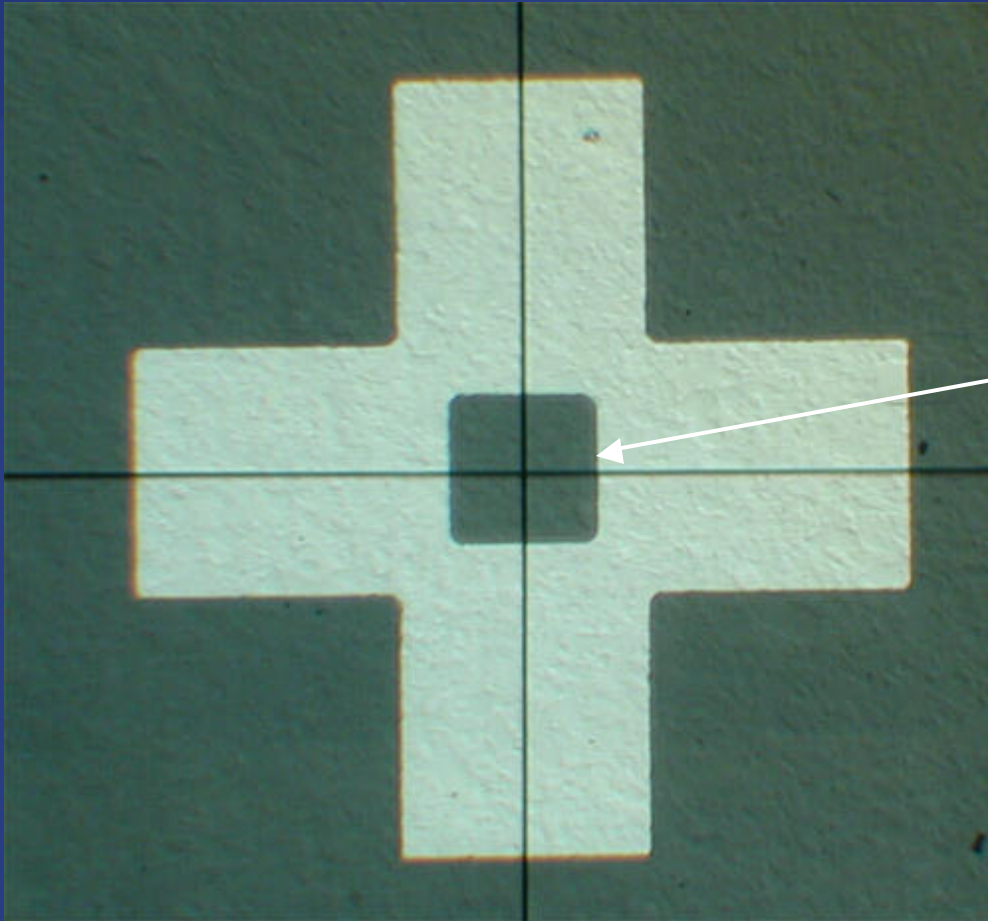


# Fiducial Target Specifications



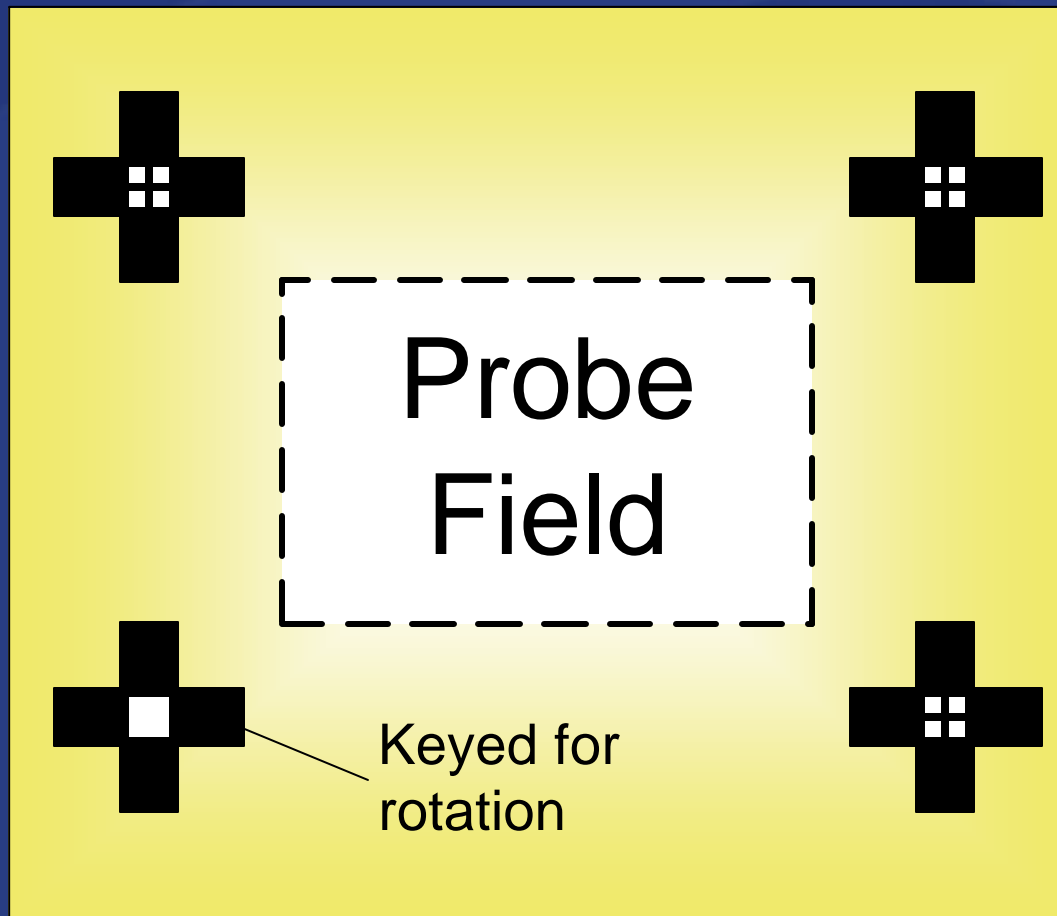
- Four targets total
- Large structure for low magnification
- Small structure (center) for high magnification

## Rotation Fiducial Design



One Fiducial with blank center to indicate rotation.

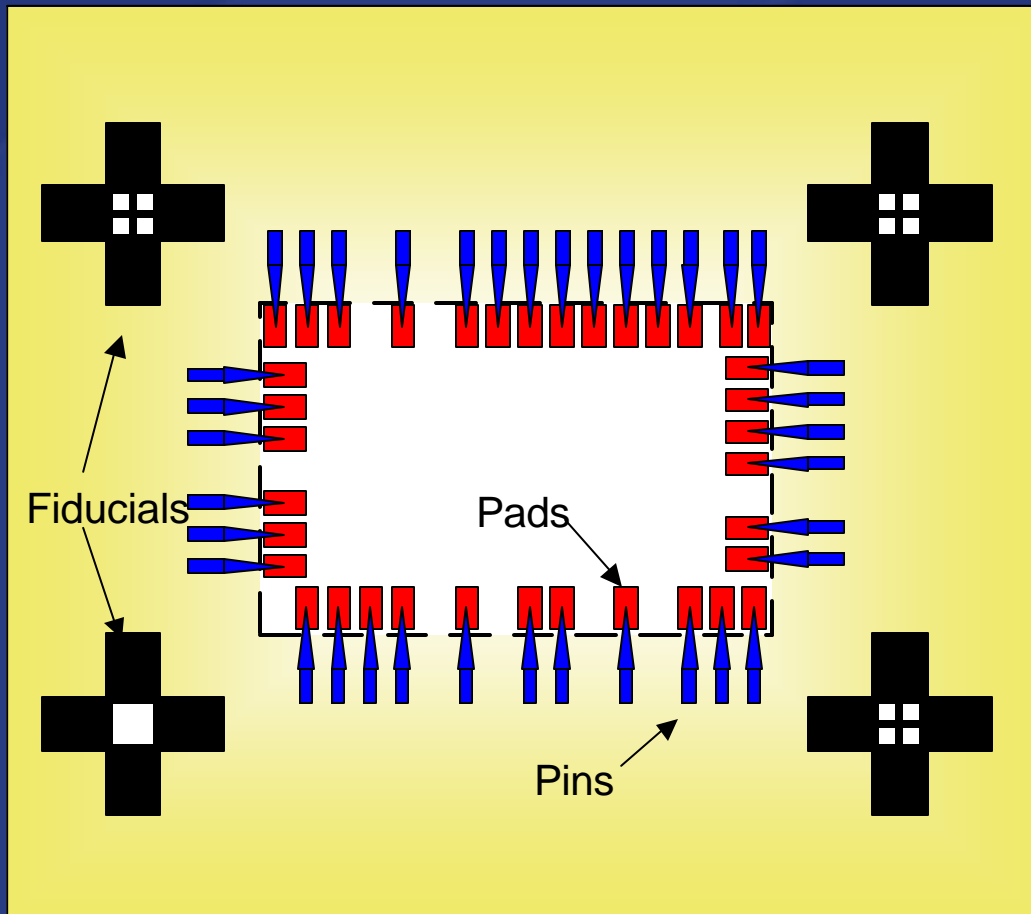
## Layout of the Fiducials on the Probe Card



- Targets are outside the area of the probe “field”.
- Ideal location on the diagonals.
- One fiducial keyed to indicate rotation.
- Spacing can provide identification.

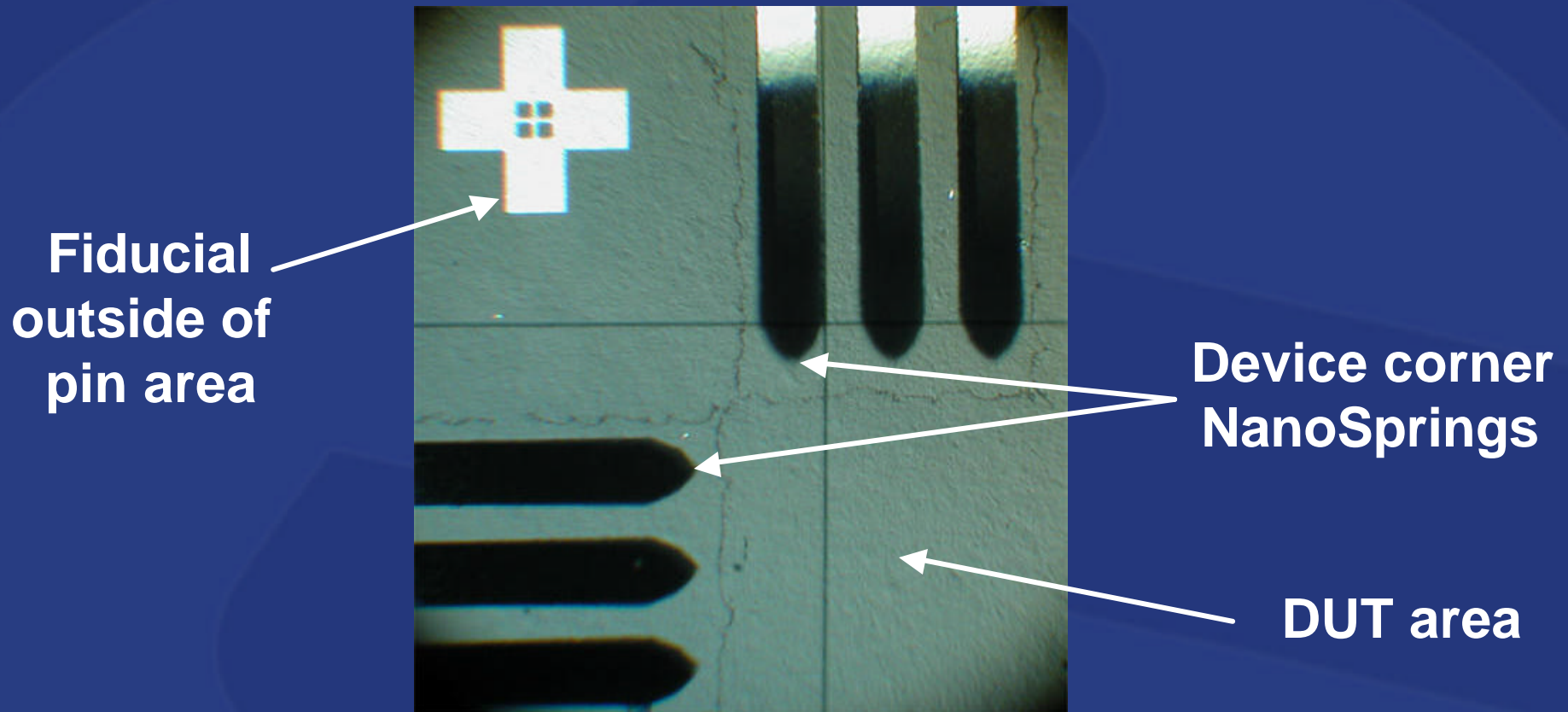


## Probe Field Construction

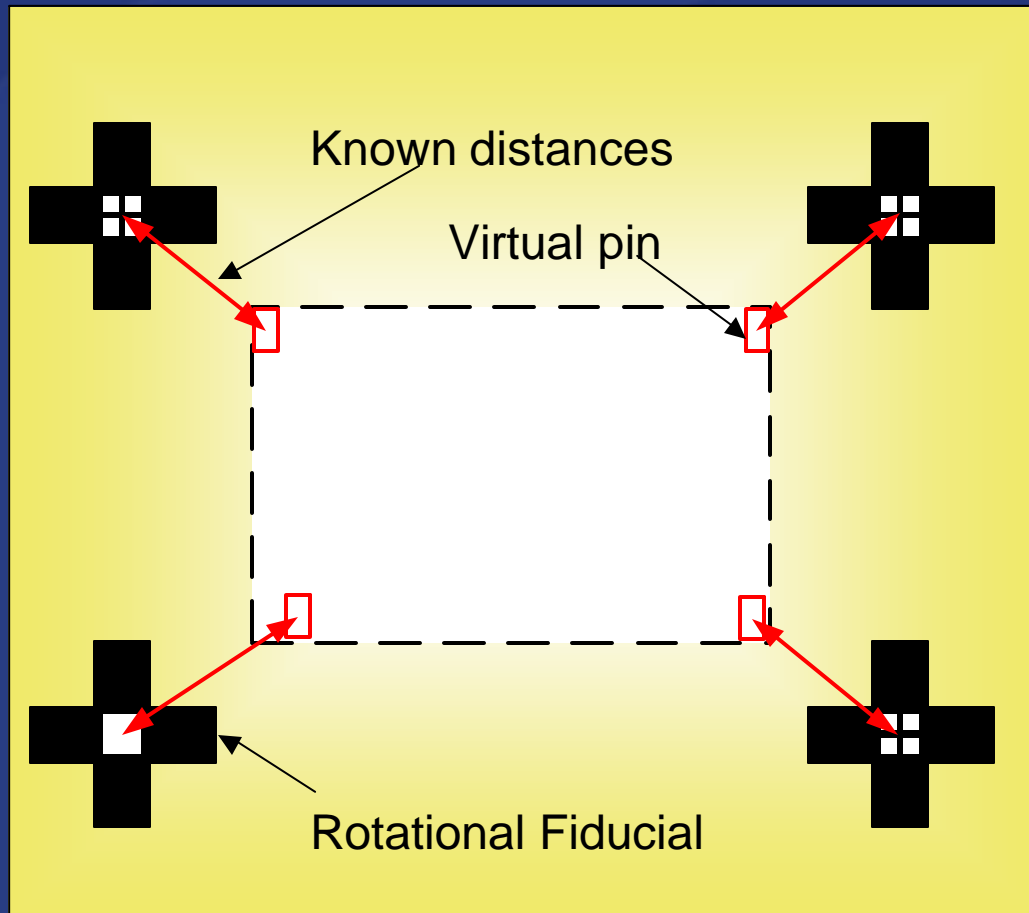


- Pins located within probe field as required by application.
- Probe field need only contain probe / pin tips (not entire structure).
- Need only data of X-Y location of pins with respect to fiducials.

## Actual Fiducial of NanoSpring Probe Card



## Known Distances



- By knowing the Fiducial locations it is possible to determine the virtual pin locations using downloaded data.
- Centroid of the probe card can be calculated directly from the Fiducial locations or from the nominal corner pin locations (current method)

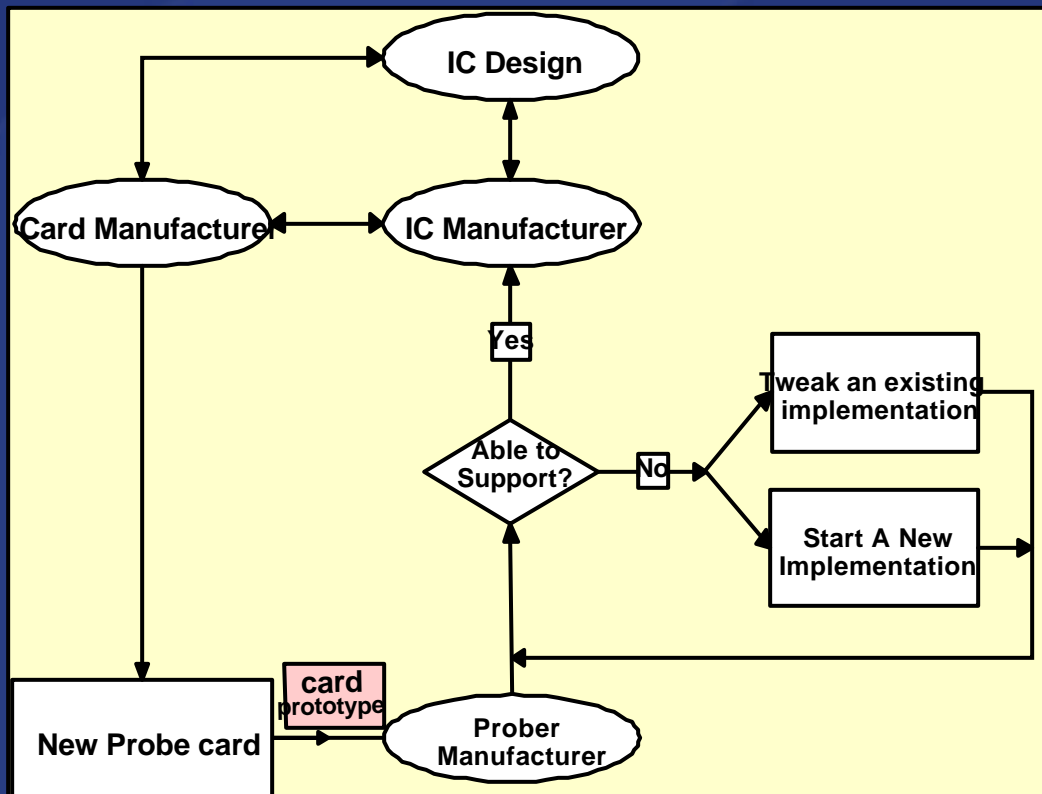
# Requirements for Fiducial Alignment on Wafer Prober Systems

## **Considerations of Probe Card Support on Probers**

- **Significant variations in tip appearance for prober vision systems**
  - Probers provides only card specific solutions
  - Add a new probe card support to a prober is very time consuming
- **Communication between probe card and prober manufacturers**
  - Probers have no knowledge on what to expect
  - Long probe card support cycle
- **No portability of support between probers from different vendors**
- **Difficult to track physical properties of individual probe card.**

# Advanced Fiducial Alignment

## Typical Process Flow for Probe Card Delivery



**Trial and error approach: time consuming and complicated**

- No prior knowledge of the probe card appearance
- Card support is very complicated due to the appearances of the tips of different probe cards
- Only communication is at the time of probe card prototyping
- Not sure if the prototype will be the same as the final product

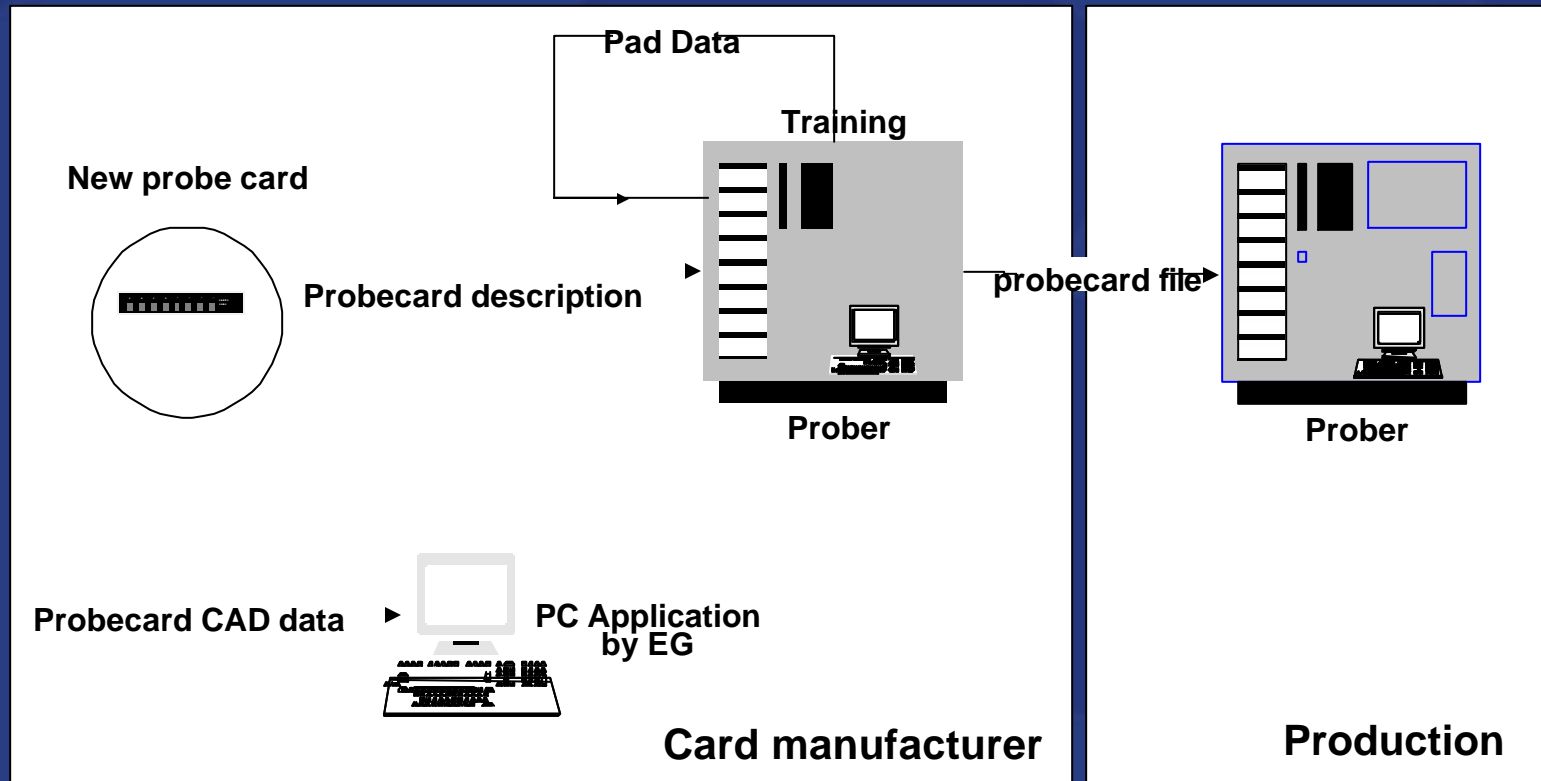
## **Fiducial Alignment as the Solution**

- **Fiducials:**
  - Less variation under different optics/cameras
  - No wear and tear in the testing process
- **Potential for standardization of PC description file:**
  - Provide an effective way of communication between probe card and prober manufacturers
  - Probers know what to expect of a probe card
  - Provide portability of probe card support between different probers
  - All probe card data in one place for easy tracking of probe cards
  - Can archive data to be used on other probers
- **Potential to use any identifiable image as Fiducials**



# Advanced Fiducial Alignment

## With Fiducials Probe Card Delivery Process is Simplified





# ***Advanced Fiducial Alignment***

## **With Fiducials Probe Card Delivery Process is Simplified**

- **Probe card and prober manufacturer support is simplified**
  - Probe card manufacturer provides a detailed description of the probe card through a file
  - Prober manufacturer works on a solution in the card design stage.
- **Simplified test floor production activity**
  - Most of the data is generated off-line with less interruption of production
  - The file is portable between probers.
  - Minimum amount of training is needed on individual probers
- **Easy to add future enhancements**
  - Large amount of data may be embedded in the file
  - Easy probe card tracking

## Probe Card Description File Requirements

- **File Structure**
  - Mandatory sections for probe card auto align process
  - Optional sections for functional enhancements
- **File Format**
  - Editable and readable by plain text editors
  - Plain text for mandatory sections
  - Plain text or Base64 encoded data for optional sections
  - Optional sections may be encrypted by the provider
- **File Error checking**
  - MD5 or SHA256 based data integrity checking

## Content of the Probe Card Description File

- **Mandatory file sections**
  - File version and probe card ID section
  - Global Probe Card Data - units, reference frame....
  - Fiducial Section: reference and validation fiducials
  - Die Section – how many, layout....
  - Tip Section – where, name, how many....
  - Data integrity checking sections
- **Optional file sections**
  - Card usage information - may be machine and time stamped
  - Card manufacturer data section – private data
  - Metrology data section - measurements
  - Prober data section – Private data to support probe card align
  - Other data sections – extension data

## Design Goal: Probe Card Description File

- **Simplicity**
  - Support the necessary probe card information only
- **Portability**
  - Mandatory section provide sufficient data to support auto align
  - Different probers may have their own private data sections to support portability.
- **File Tracing**
  - Each file may be associated with the serial number of the card
- **Flexibility**
  - Customer may add their own private data sections for various purposes
  - A data field may present or absent for different cards

# Advanced Fiducial Alignment

## Probe Card Description File: An Example

```
PRDFVersion:: 0.01
ProbeCardName: nanonexus-Test1
ProbeCardIDType: Manual
ProbeCardID: testprbcard
SerialNumber: 01234567
ReservedField:
DateCreated: 03/07/2002
DateLastModified: 03/07/2002
IntegrityChecking: MD5
Manufacturer: NanoNexus
CoordinateSystem: BottomView
Units: mils
CenterLocation: 0.000000 0.000000
Angle: 0.000000
RecommendedOverDrive: 4.000000 3.000 5.000
RecommendedCleanMethod: Scrub
RecommendedCleanInterval: 3000 2000 5000
ProbecardIDLocation: none
ProbecardIDFieldSize: 0 0
ProbecardIDFieldParameter: 0
FiducialLighting: Coaxial; 200 200 0
NumberOfReferenceFiducials: 4
ReferenceFiducialName: first-low-resolution-reference
ReferenceFiducialResolution: COARSE
ReferenceFiducialLocation: 3389.17 2599.3 152.000000
ReferenceFiducialPatternType: 1
ReferenceFiducialParameters: 290.000000 290.000000 3 4
ReferenceFiducialName: first-high-resolution-reference
ReferenceFiducialResolution: FINE
ReferenceFiducialLocation: 3389.170000 2599.300000
152.000000
ReferenceFiducialPatternType: 1
ReferenceFiducialParameters: 80.000000 80.000000 3 4
ReferenceFiducialName: second-low-resolution-reference
ReferenceFiducialResolution: COARSE
ReferenceFiducialLocation: -3352.6500 -2599.300000
152.000000
ReferenceFiducialPatternType: 0
ReferenceFiducialParameters: 290.000000 290.000000 9 10
```

```
ReferenceFiducialName: second-high-resolution-reference
ReferenceFiducialResolution: FINE
ReferenceFiducialLocation: -3352.6500 -2599.300000
152.000000
ReferenceFiducialPatternType: 0
ReferenceFiducialParameters: 80.000000 80.000000 9 10
NumberOfValidationFiducials: 2
ValidationFiducialName: validation
ValidationFiducialResolution: COARSE
ValidationFiducialLocation: -3352.650000 2599.350000
0.000000
ValidationFiducialPatternType: 2
ValidationFiducialParameters: 290.000000 290.000000 5 6
ValidationFiducialName: validation-fine
ValidationFiducialResolution: FINE
ValidationFiducialLocation: -3352.650000 2599.350000
0.000000
ValidationFiducialPatternType: 2
ValidationFiducialParameters: 80.000000 80.000000 5 6
MaxValidationErrorBound: -200.0, 200.0, -200.0, 200.0
NumberOfDiesOnCard: 1
DieOrientation: 0
DiesInaRow: 1
DieMatrix:
NumberOfTips: 48
TipLighting: Oblique; 200 200 0
TipType: 1
TipParameters: 4.000000 5.000000 6.000000
FirstTipLocation: 2939.000000 2149.000000
TipSteps: 2
TipRange: 0 22 4 2939.000000 2149.000000 186.0
TipRange: 23 47 3 -2903.000000 -2149.000000 186.0
MD5HashValue:
```



## **Set Up of Fiducial Probe Card**

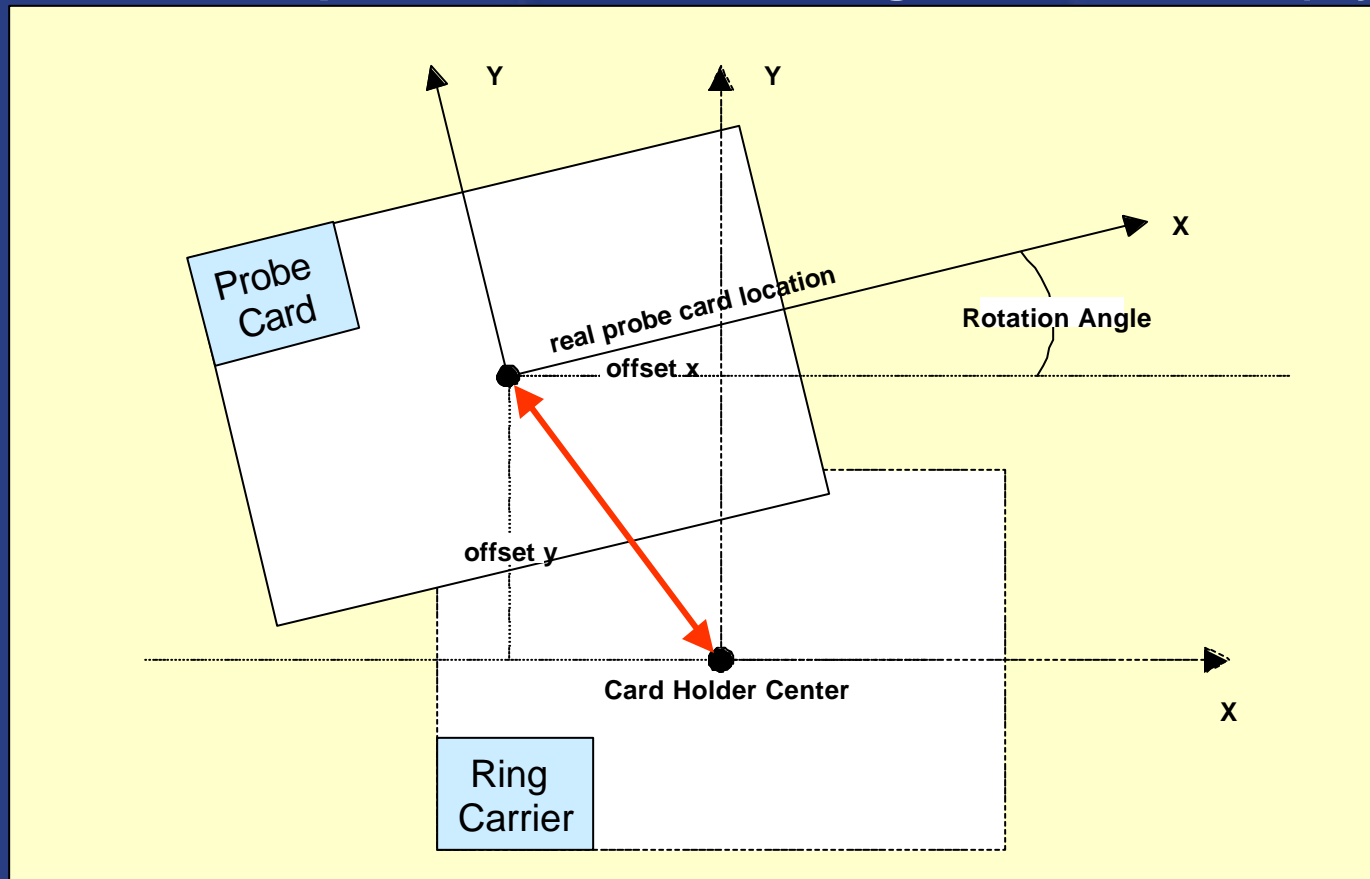
- **Obtain or build the probe card description file**
  - File normally provided by the card manufacturer
  - Or a text file description can be built
- **Load the probe card description file on the prober**
- **Select appropriate probe card file from the prober**
  - Through EGComander UI as any other probe cards
- **Train the Fiducials if required**
  - You will be prompt to start training if the fiducial are not trained yet.
  - A Probe card manufacturer may have done this already. In this case you may directly run auto align using the Fiducials
- **Auto align using the Fiducials at any time**



# Advanced Fiducial Alignment

## Fiducial Align Offset and Rotation Calculation

Determine probe card rotation angle  $\alpha$  and offset (x,y)



## Fiducial Align Error Analysis

- Fiducial Location Error

$$d_r = d_{\text{motion}} + d_{\text{training}} + d_{\text{pattern-search}} + d_{\text{fiducial}} = d_{\text{systematic}} + d_{\text{random}}$$

- Angular error use the fiducials (assume Gaussian error)

$$d_a \approx d_{\text{a-systematic}} + \frac{\sqrt{2} d_{\text{random}}}{(N-1)} \sqrt{\sum \frac{1}{R_{k,l}^2}}$$

- Offset error use all fiducials

$$\Delta_r = d_{\text{systematic}} + \frac{1}{\sqrt{N}} d_{\text{r-random}}$$



## Fiducial Align Error Analysis

- Assume systematic error is small (Prober is calibrated and the fiducials are produced and trained accurately) we have:

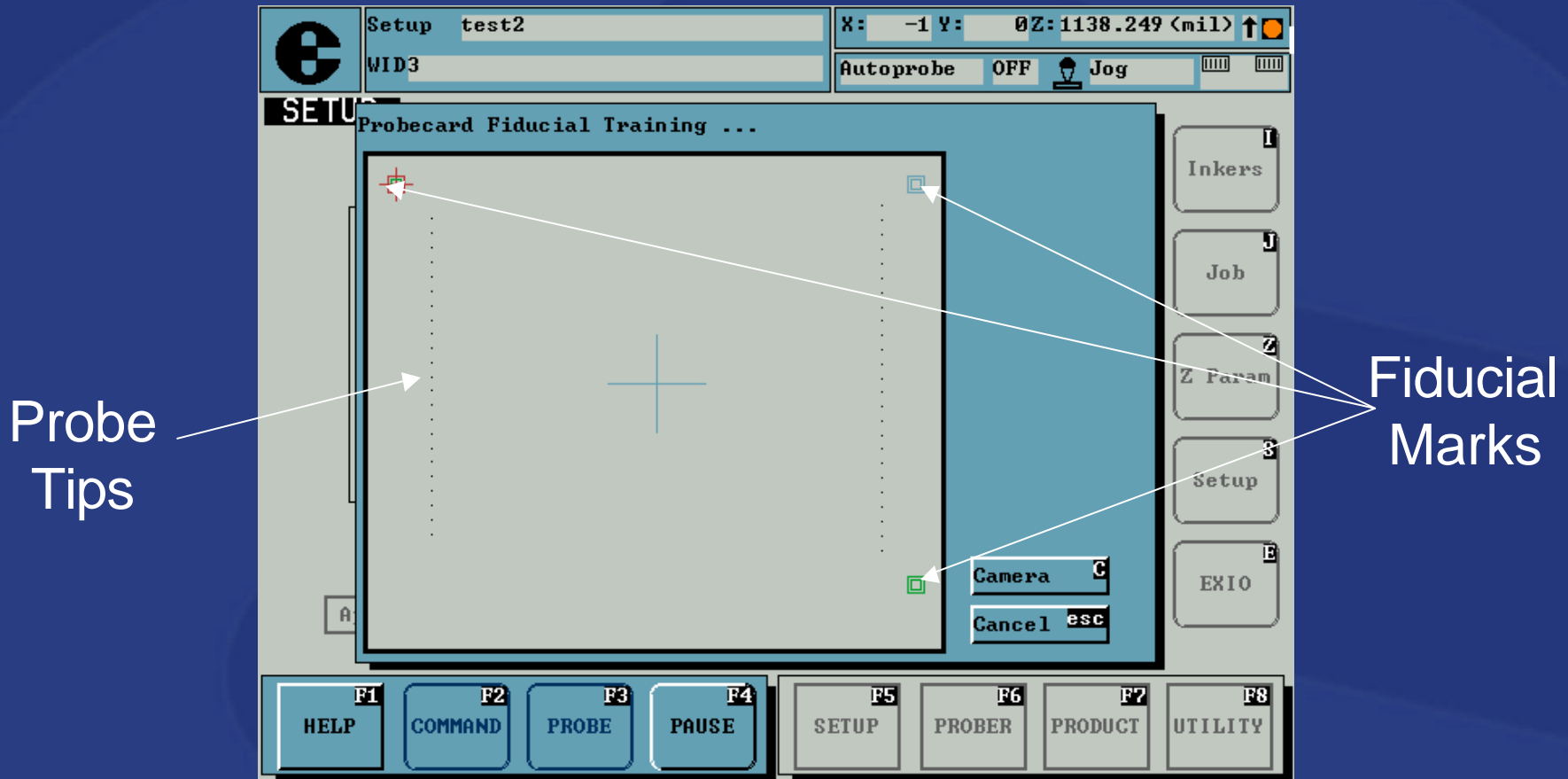
$$d_a \approx \frac{\sqrt{2} d_{r-random}}{\sqrt{N-1} \cdot \bar{R}}$$

Where  $\bar{R}$  is the average distance between the fiducials

$$\Delta_r = \frac{1}{\sqrt{N}} d_{r-random}$$

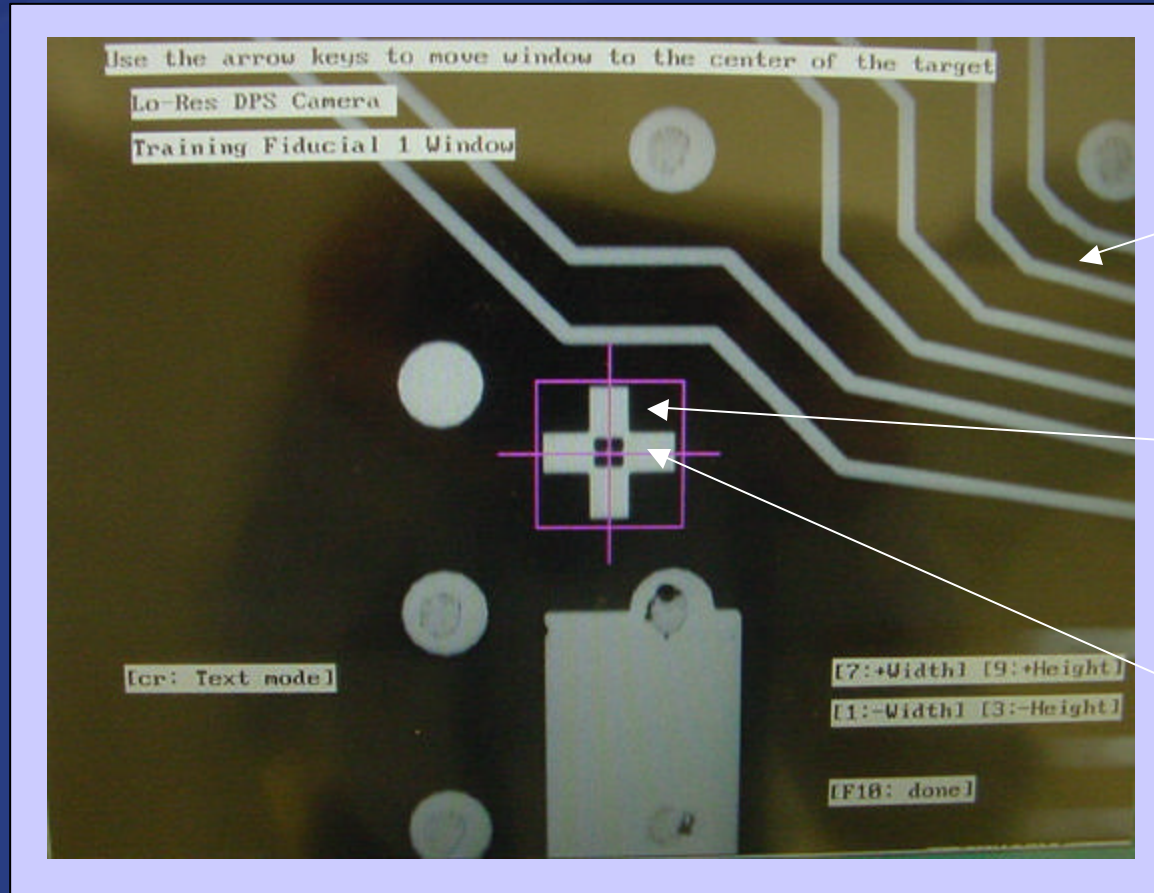
The greater number of fiducials, the better the accuracy

## Actual Fiducial Screen Electrogas 4090 $\mu$ Prober



# Advanced Fiducial Alignment

## Actual Fiducial Mark on EG4090 $\mu$ prober



Lithography  
Probe  
Card

Fiducial  
Mark

Prober  
Vision  
Target

## **Fiducial Alignment Conclusions**

### **Elegant solution:**

- Solves challenges of fine pitch and small pad probing
- Enables high accuracy probe card technology
- Automates prober setup:
  - Easy pin identification and location
  - Greater operational flexibility
- Increases performance of test cell

### **Results:**

- Concept demonstrated
- Open industry standard proposed