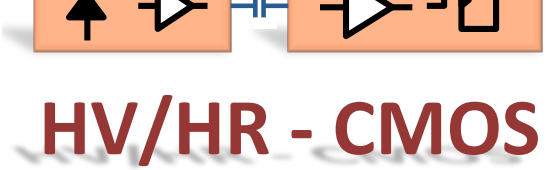
Update on HV-CMOS Hybridization Activities

Alessandro, Ettore, Giuseppe, Nanni

Genova, 19 June 2014



Design of masks for SU8 deposition

Flip-chip machine retune

KLA-Tencor profilometer

Action list from last meeting

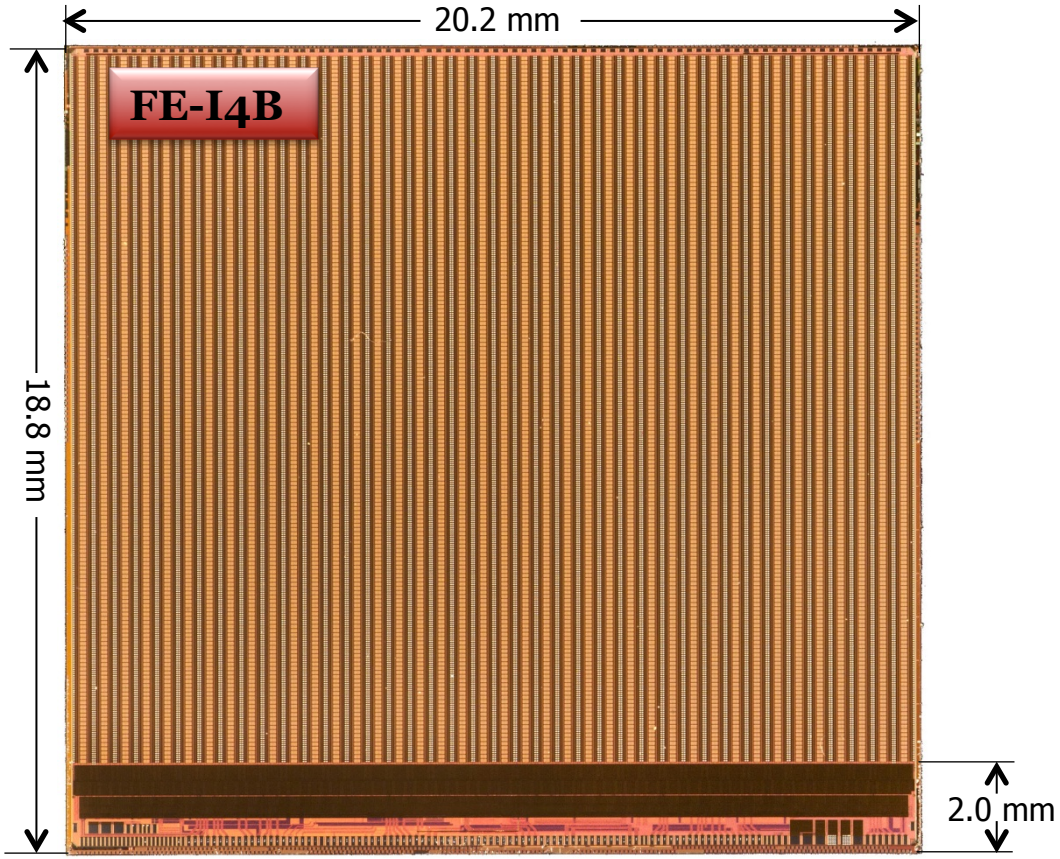
Indico agenda:

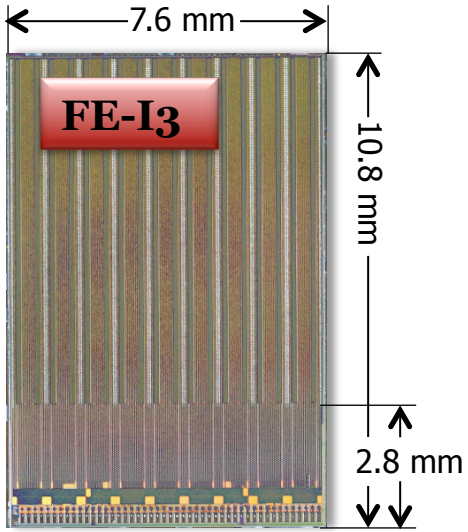
https://agenda.infn.it/conferenceDisplay.py?confId=8261

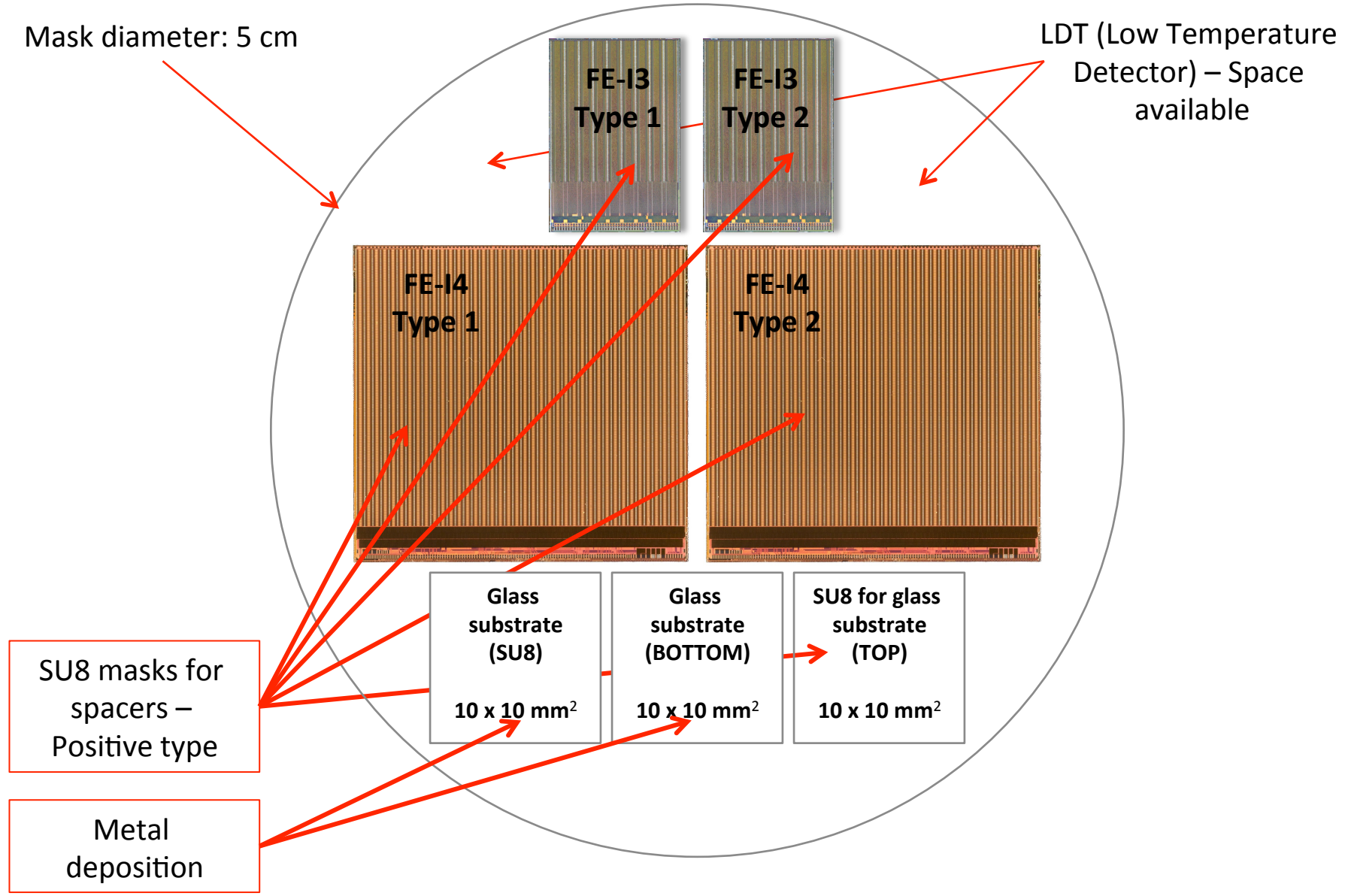
Alessandro

MASKS FOR SU8 AND METAL DEPOSITION

Chip Dimensions

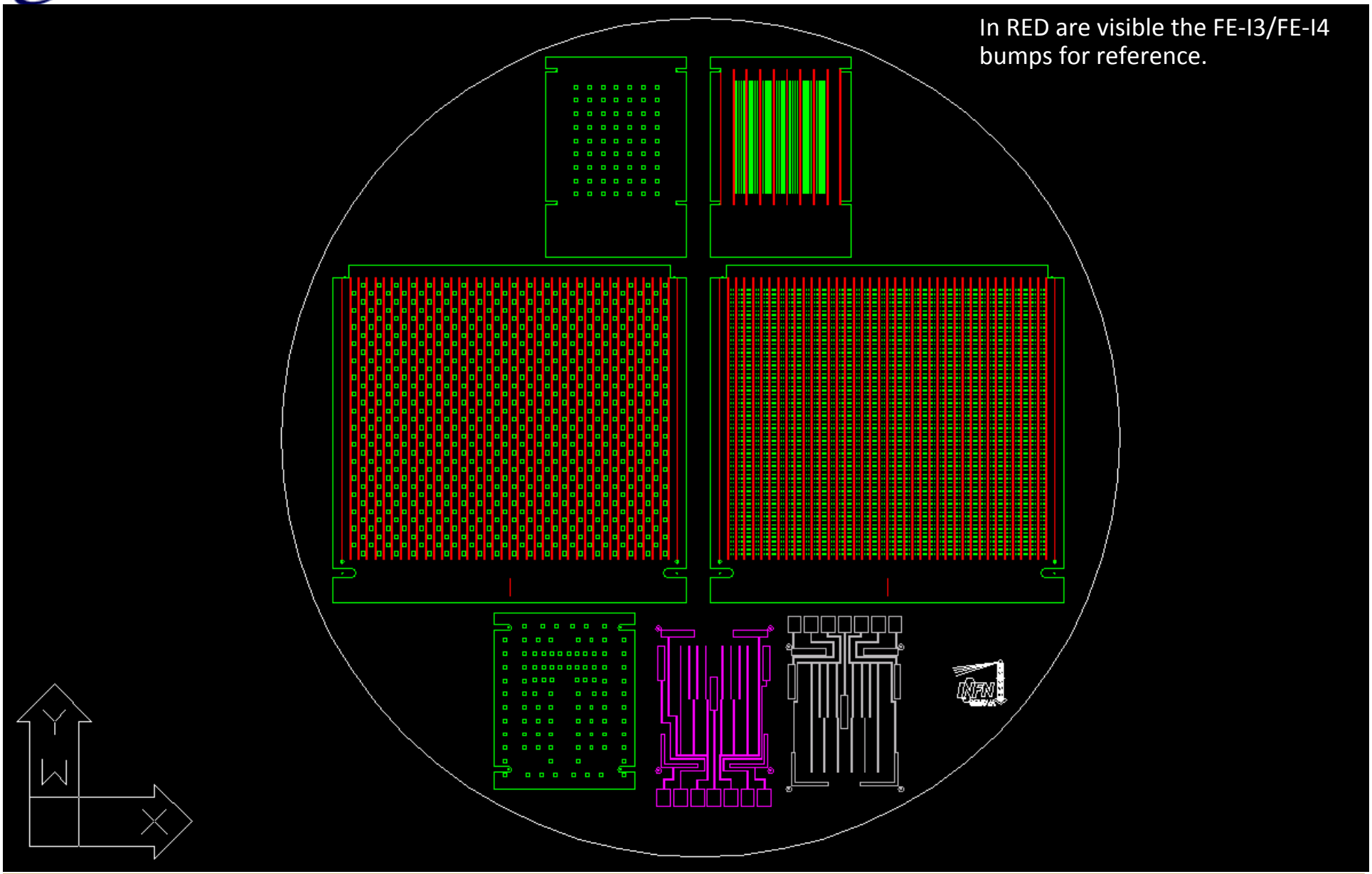




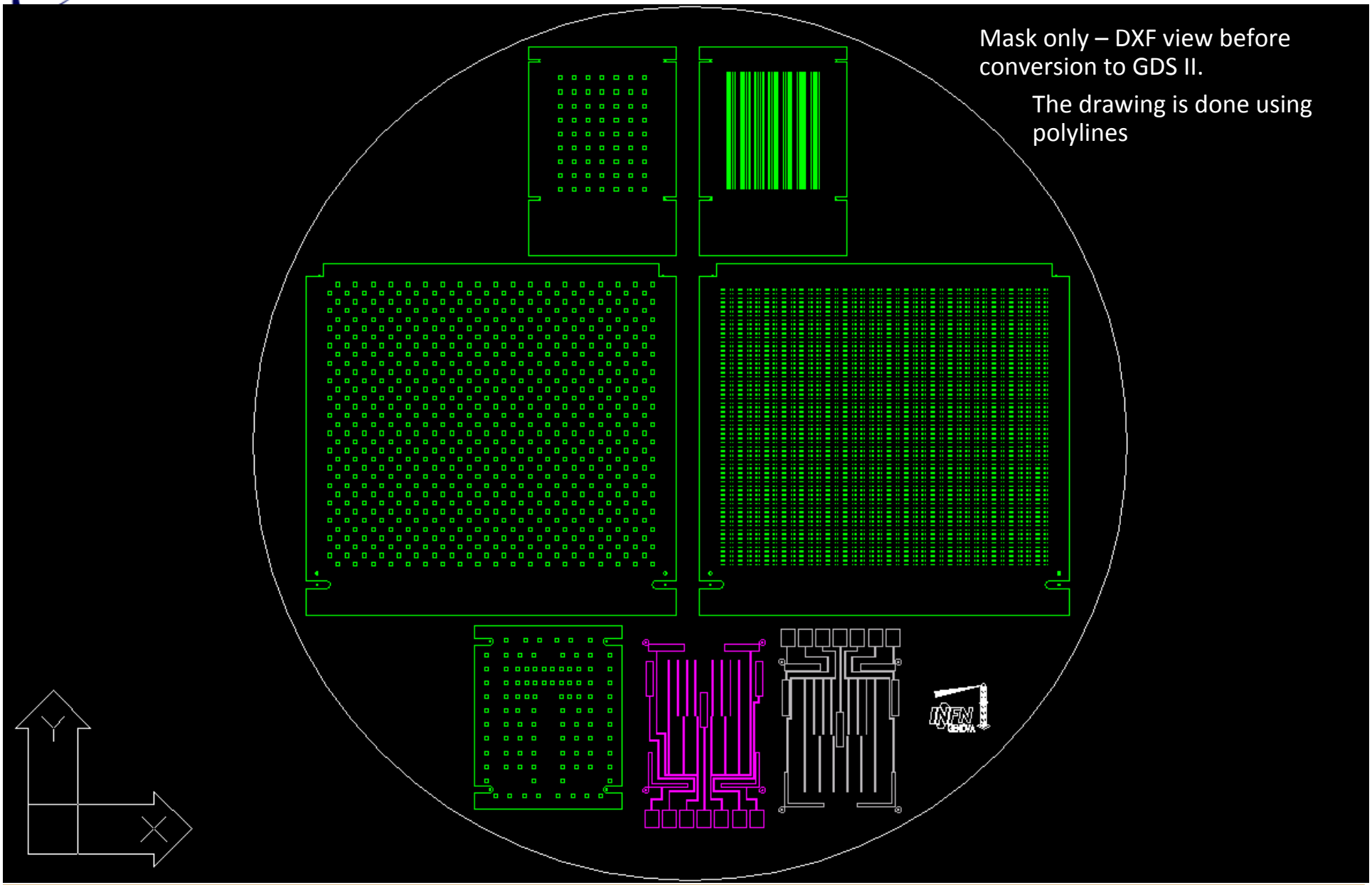

Mask diameter: 5 cm
LDT (Low Temperature Detector) – Space available
FE-I3 Type 1
FE-I3 Type 2
FE-I4 Type 1
FE-I4 Type 2
Glass substrate (SU8)
10 x 10 mm2
Glass substrate (BOTTOM)
10 x 10 mm2
SU8 for glass substrate (TOP)
10 x 10 mm2
SU8 masks for spacers – Positive type
Metal deposition

Quartz Mask Layout

In RED are visible the FE-I3/FE-I4 bumps for reference.



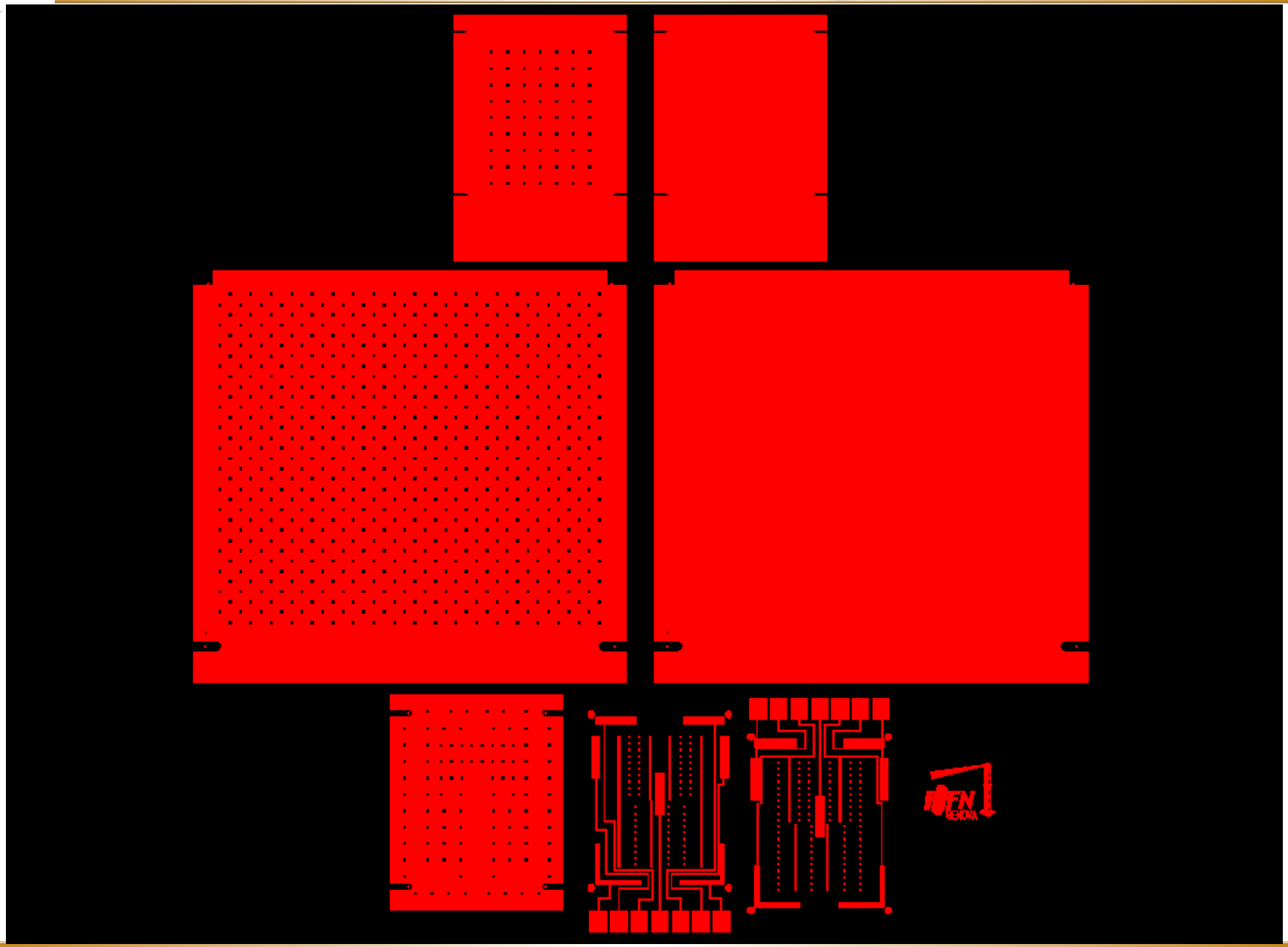
Layout in DXF



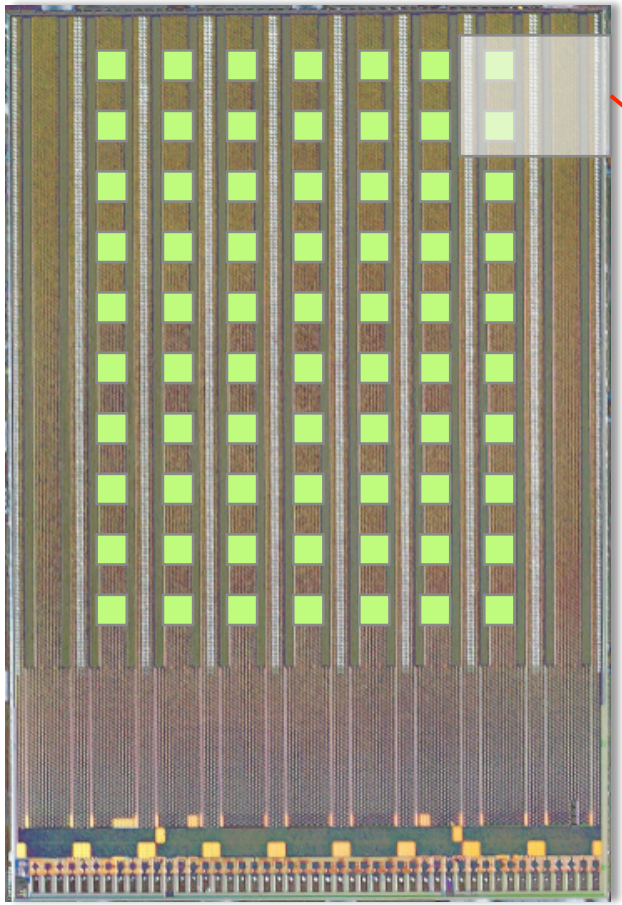
Mask only – DXF view before conversion to GDS II.

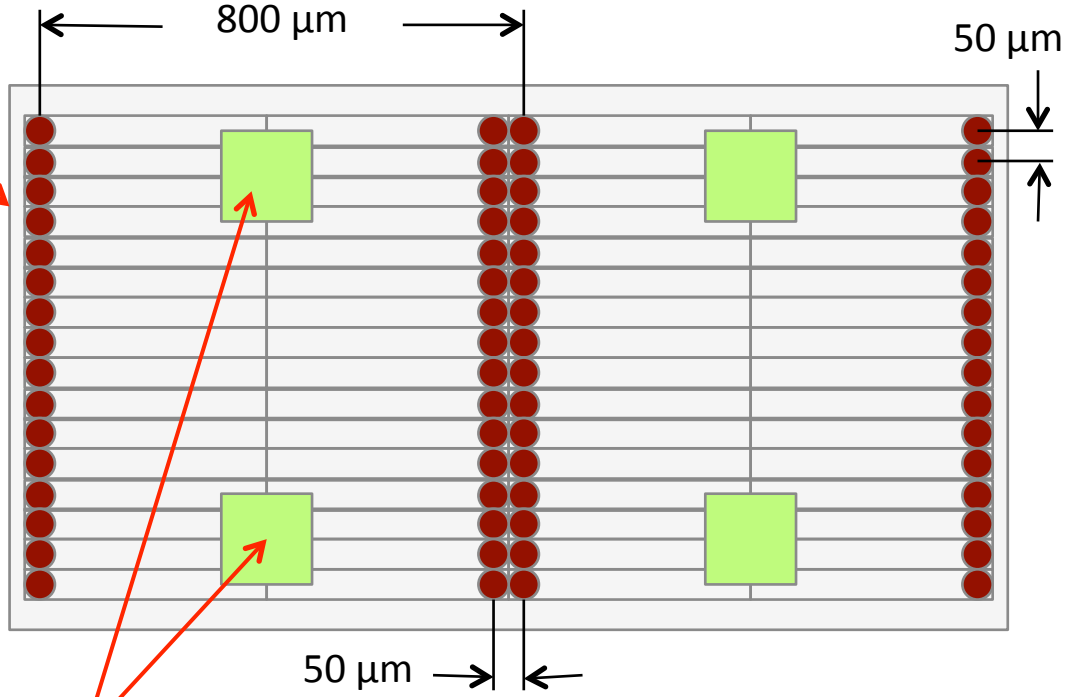
The drawing is done using polylines

Converted to GDS II by Photronix



FE-I3 - SU8 Spacers



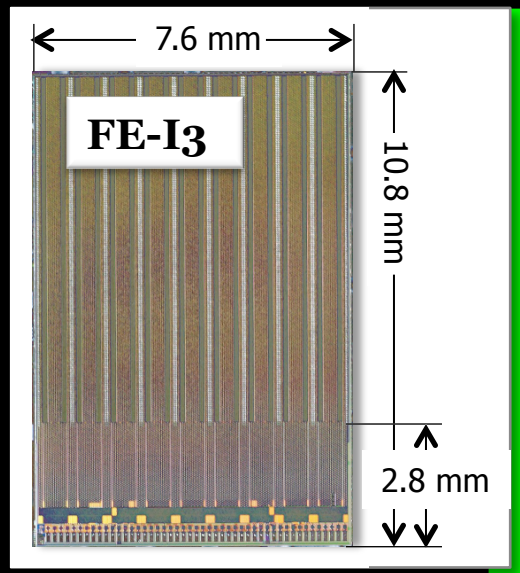


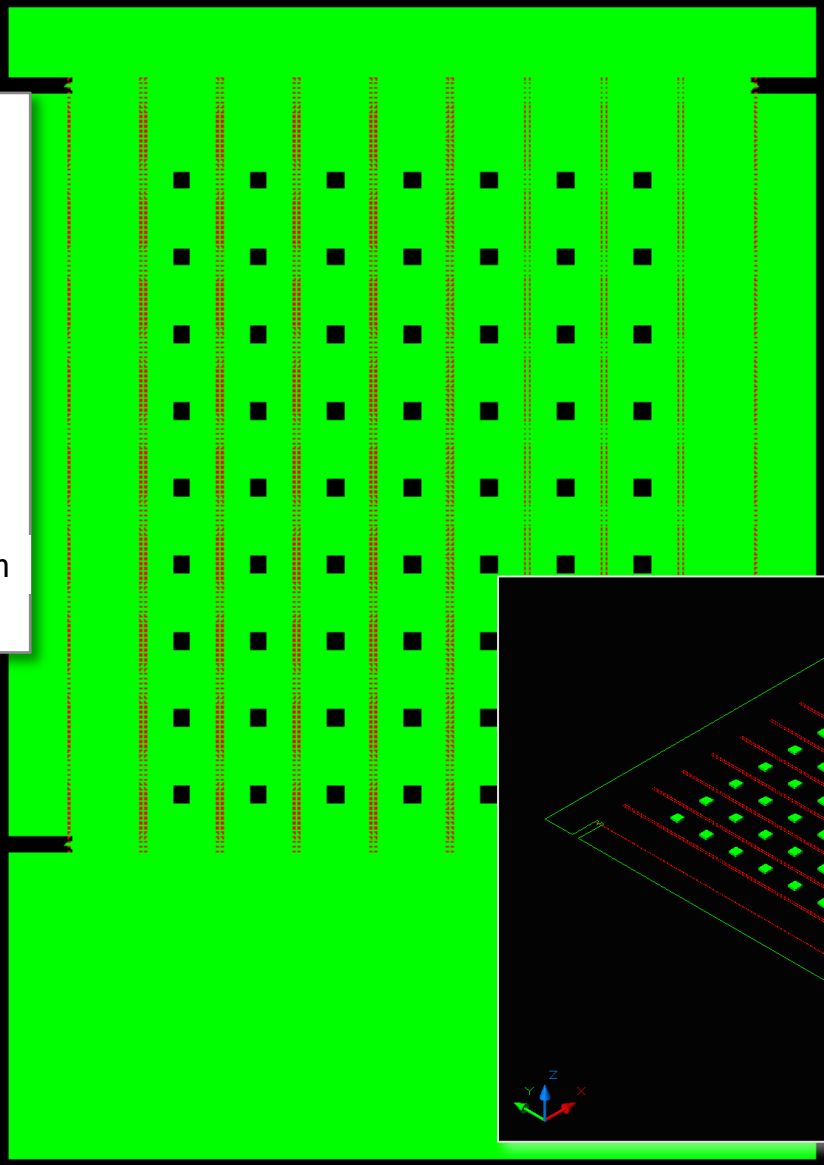
SU8 SPACERS

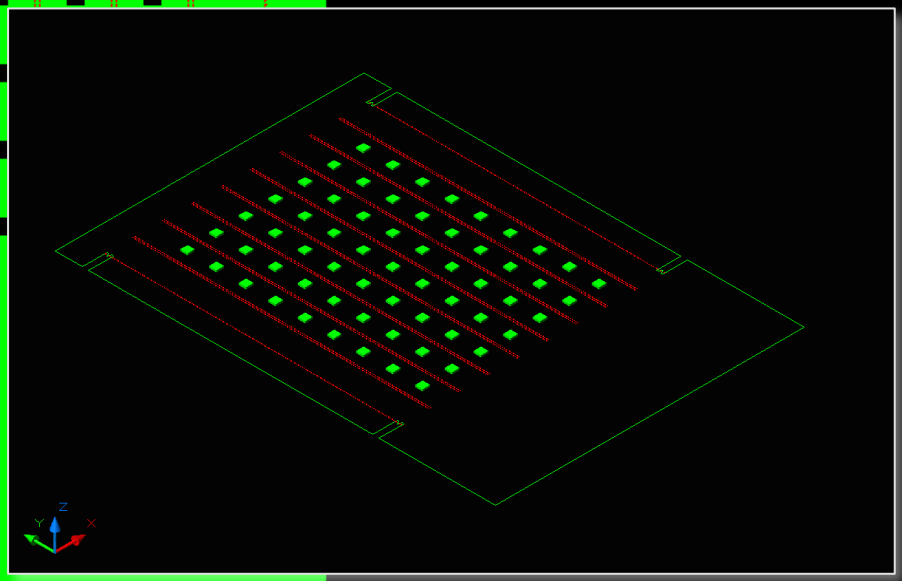
Matrix 800x800 µm pitch with 200 µm square spacers

Leave ~1.2 mm clearance from chip borders

Mask with 200 x200 μm^2 and 40 x 40 μm^2 spacers

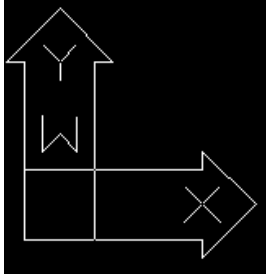




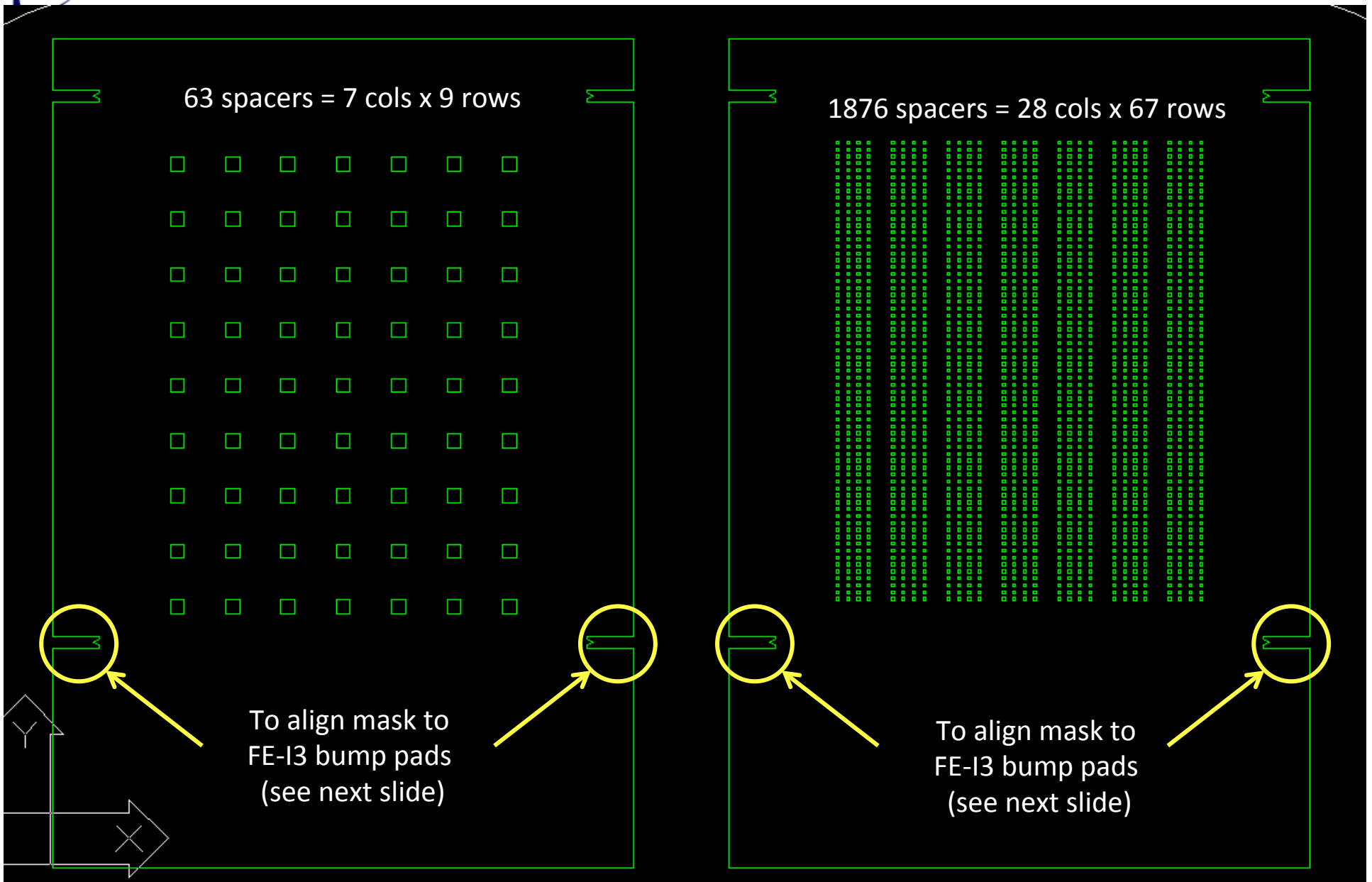


Mask for FE-I3 type of chip:

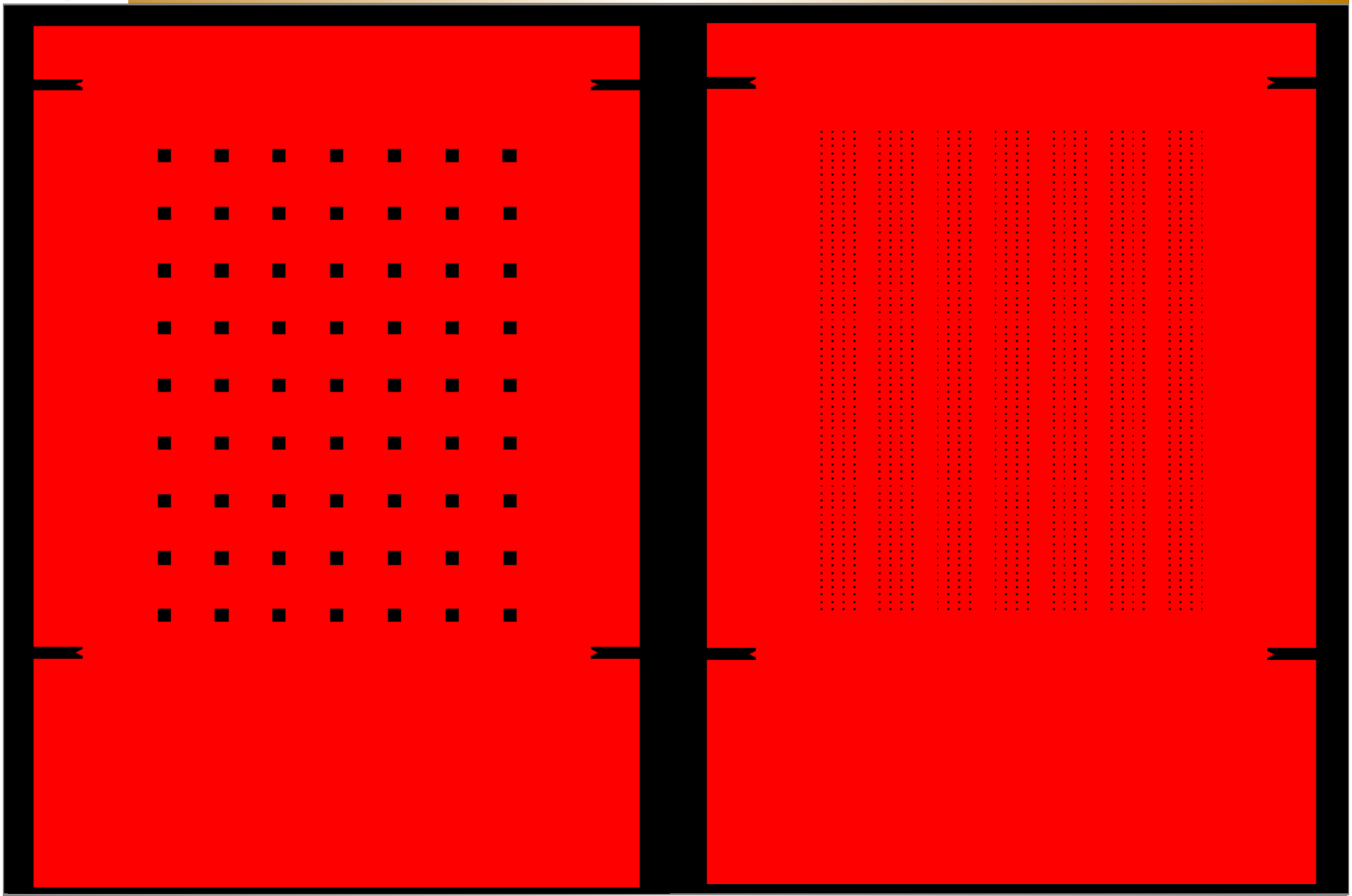
- *Column dimension:*
  200x200 µm^2 and 40x40 µm^2
- *Total column's area:*
  2.5 mm^2 (@ 200 µm column)
  3.0 mm^2 (@ 40 µm column)
- *Fraction covered by columns:*
  6.3 % (@ 200) ÷ 7.4 % (@ 40)
- Green = chromium , black = clean. Where is clean SU8 photoresist is polymerized.



FE-I3 Masks


63 spacers = 7 cols x 9 rows
To align mask to
FE-I3 bump pads
(see next slide)
1876 spacers = 28 cols x 67 rows
To align mask to
FE-I3 bump pads
(see next slide)

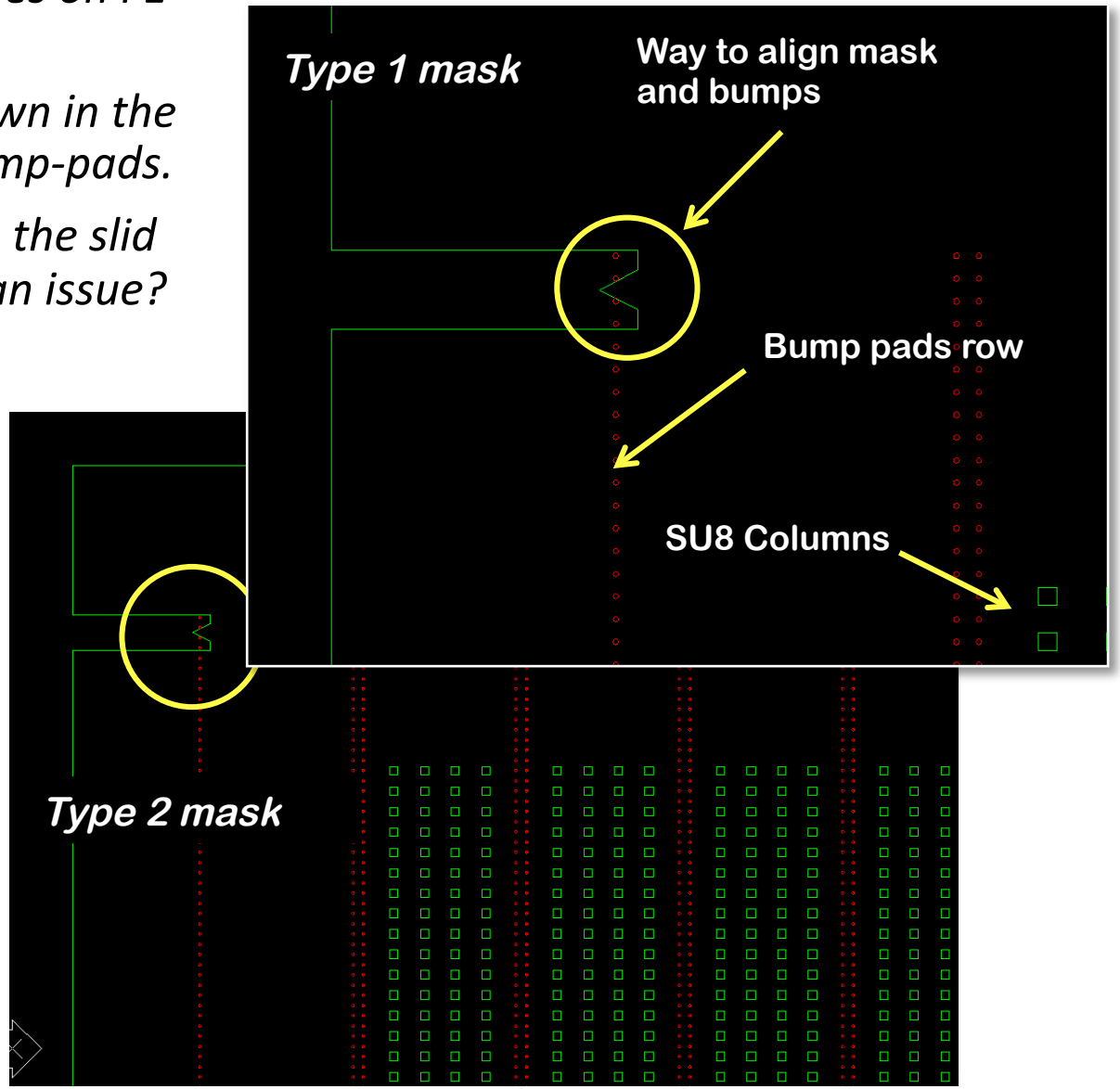
FE-I3 Masks in GDS II



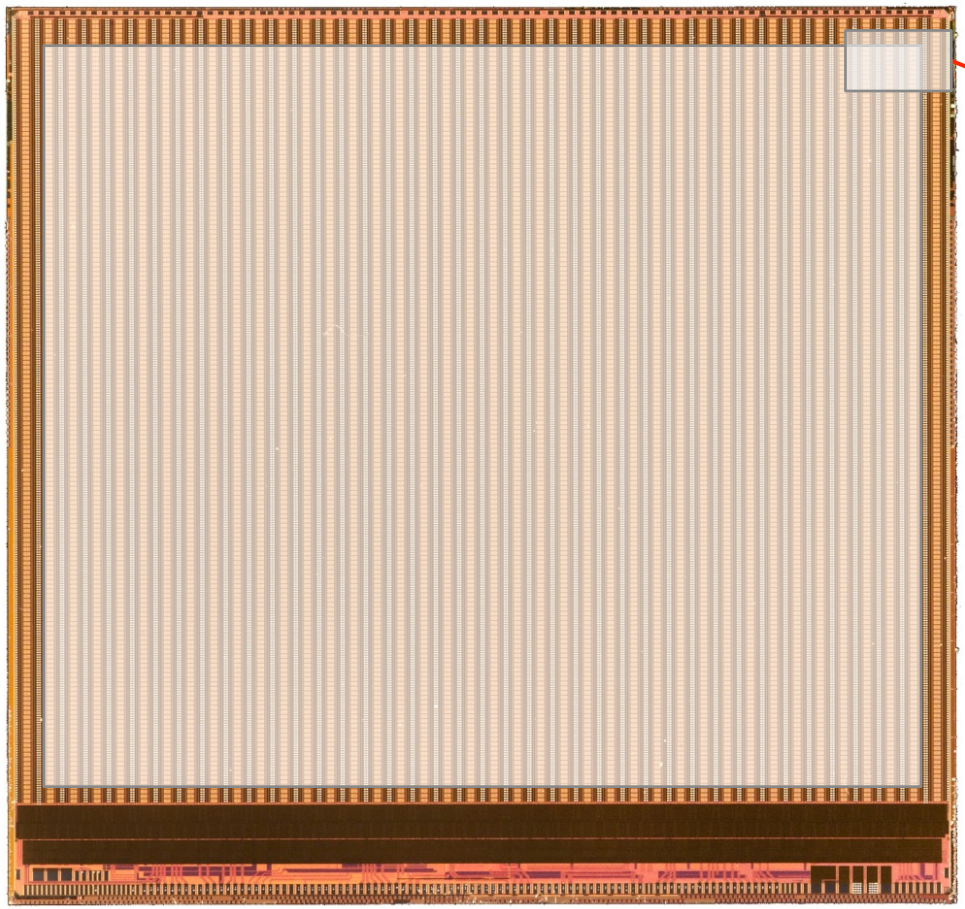
FE-I3: Mask Alignment

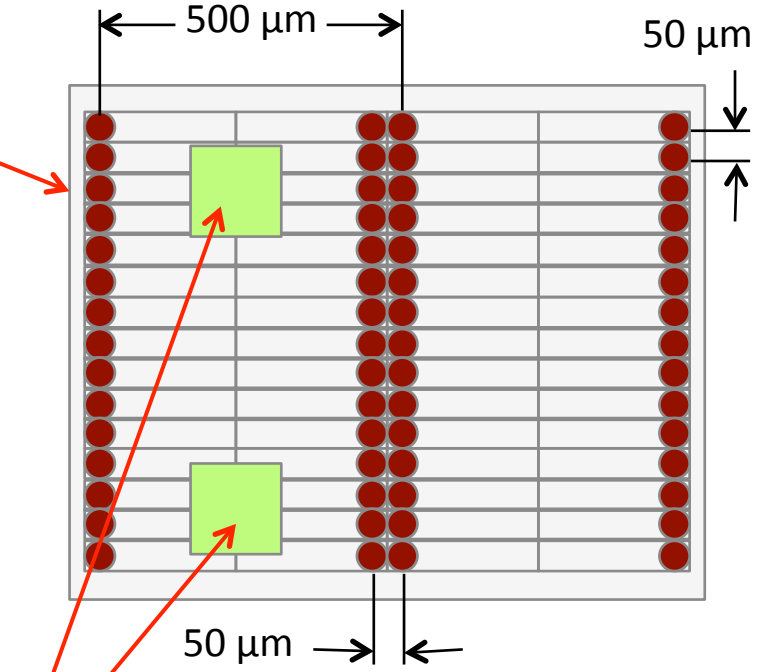
There are no reference crosses on FE-I3 to align to:

- *Alignment is done as shown in the figs on the left: slid to bump-pads.*
- *Photoresist will remain in the slid up to the chip edge. Is it an issue?*



FE-I4 - SU8 Spacers





SU8 SPACERS

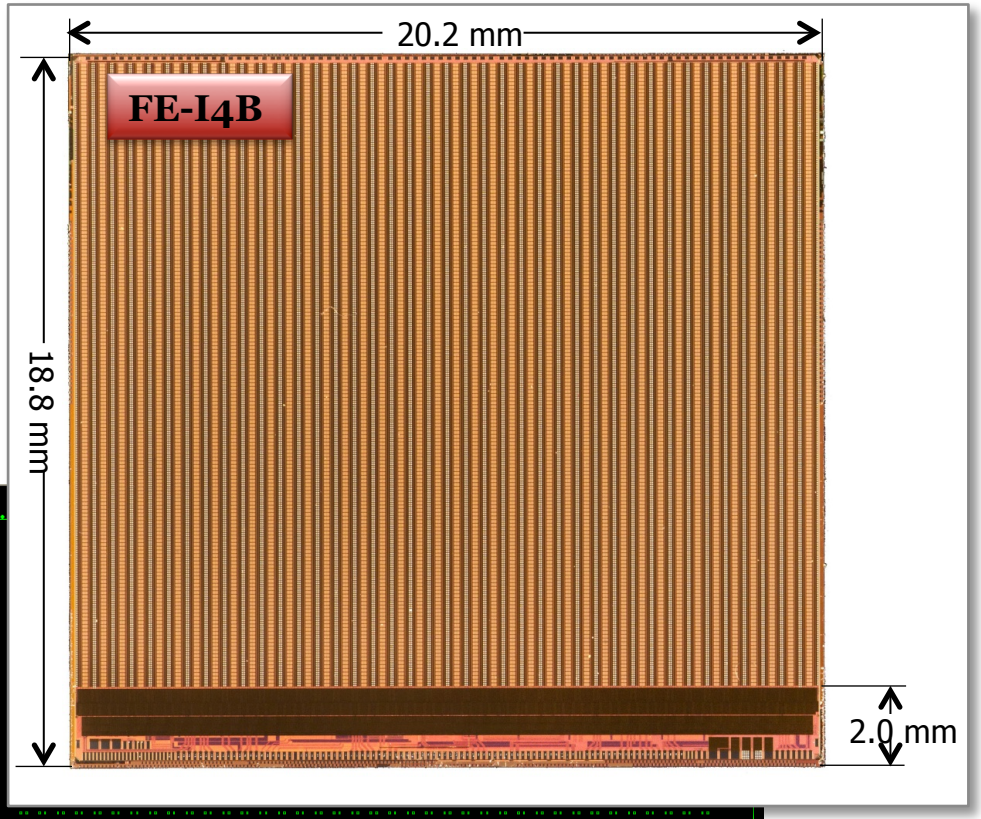
Matrix with 200x200 µm2 and 40x40 µm2 spacers.

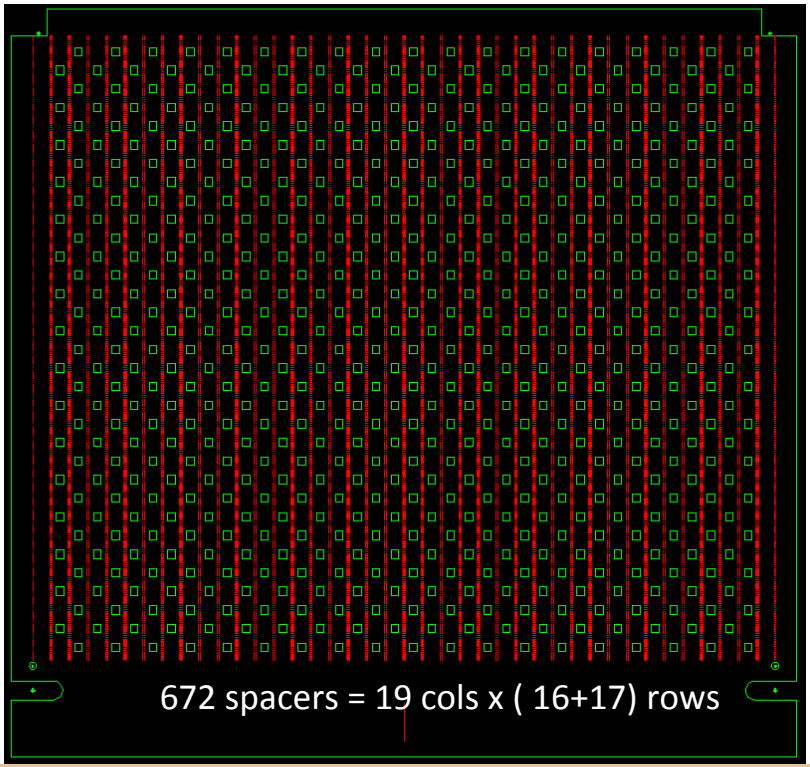
Left ~700 µm clearance from chip borders.

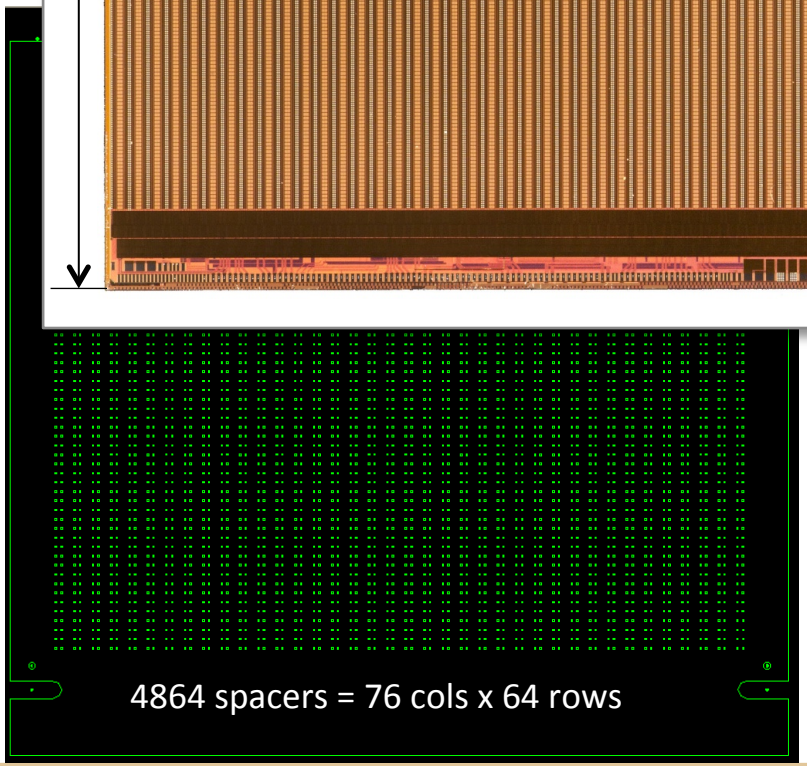
FE-I4B

Mask for FE-I4B type of chip:

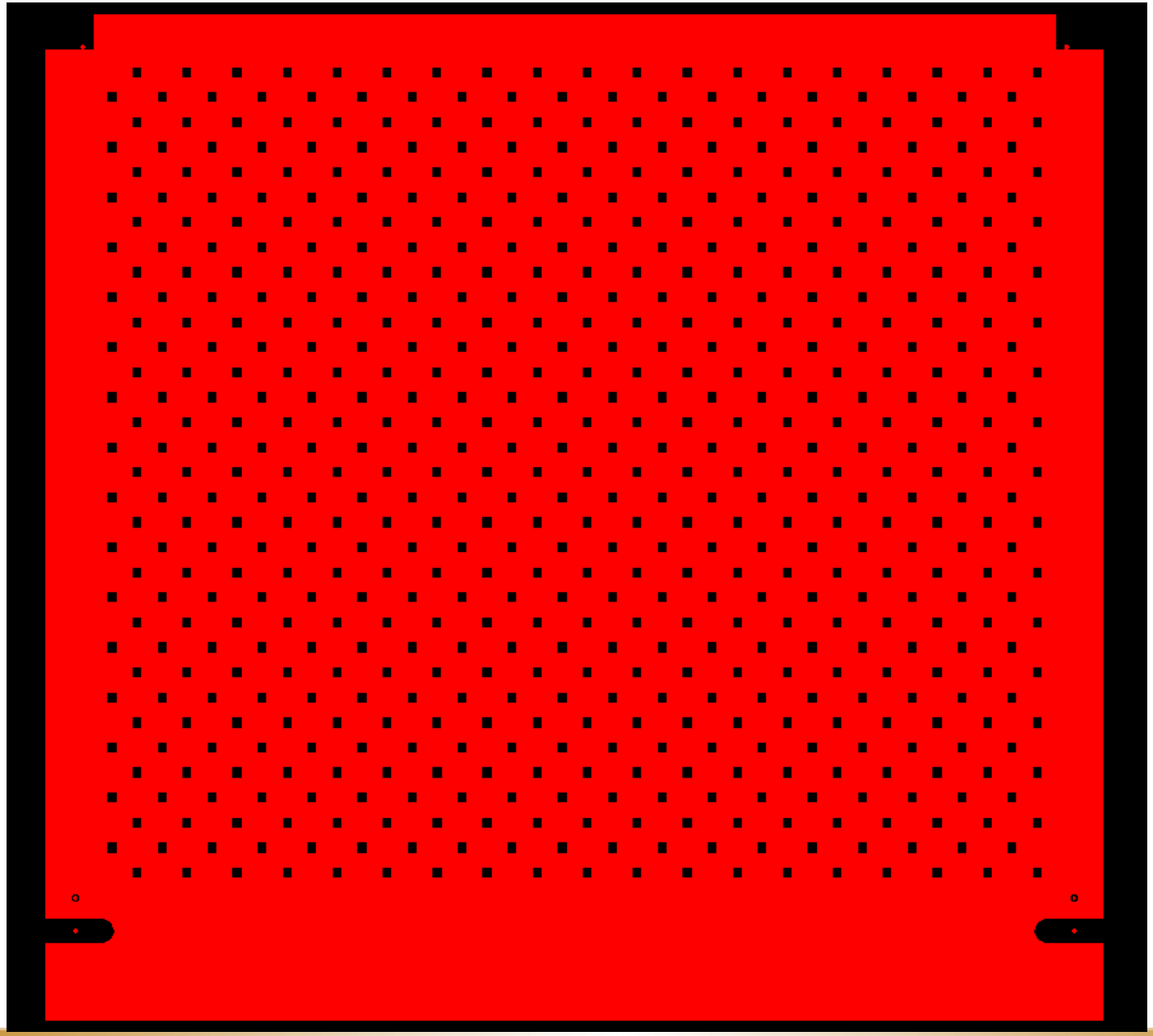
- *Column dimension:*
  200x200 µm^2 and 40x40 µm^2
- *Total column's area:*
  25.1 mm^2 (@ 200 µm column)
  7.8 mm^2 (@ 40 µm column)
- *Fraction covered by columns:*
  8.0 % (@ 200 µm)
  2.9 % (@40 µm)



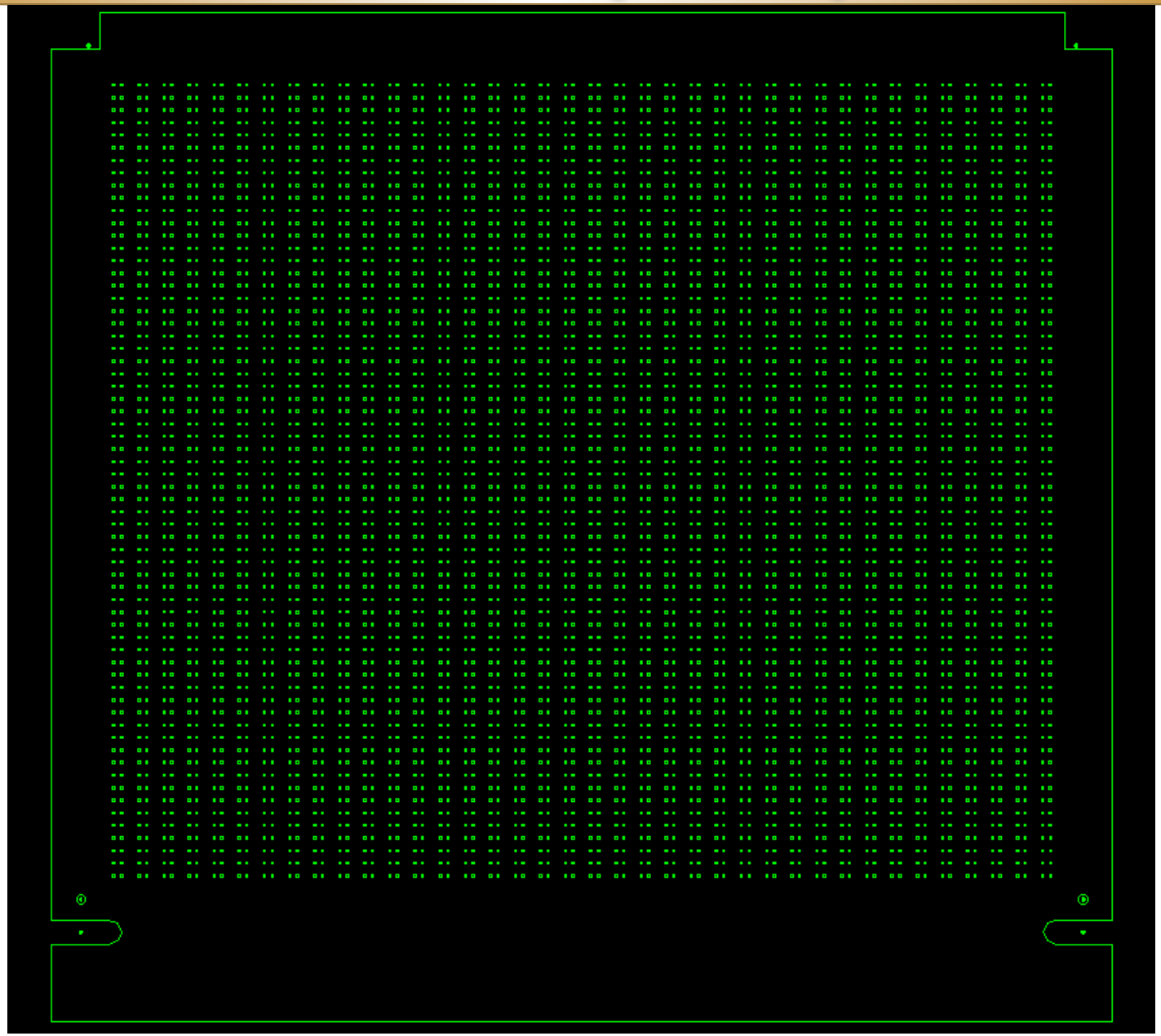




FE-I4B: 200 x 200 μm^2 Spacers



FE-I4B: 40 x 40 μm^2 Spacers

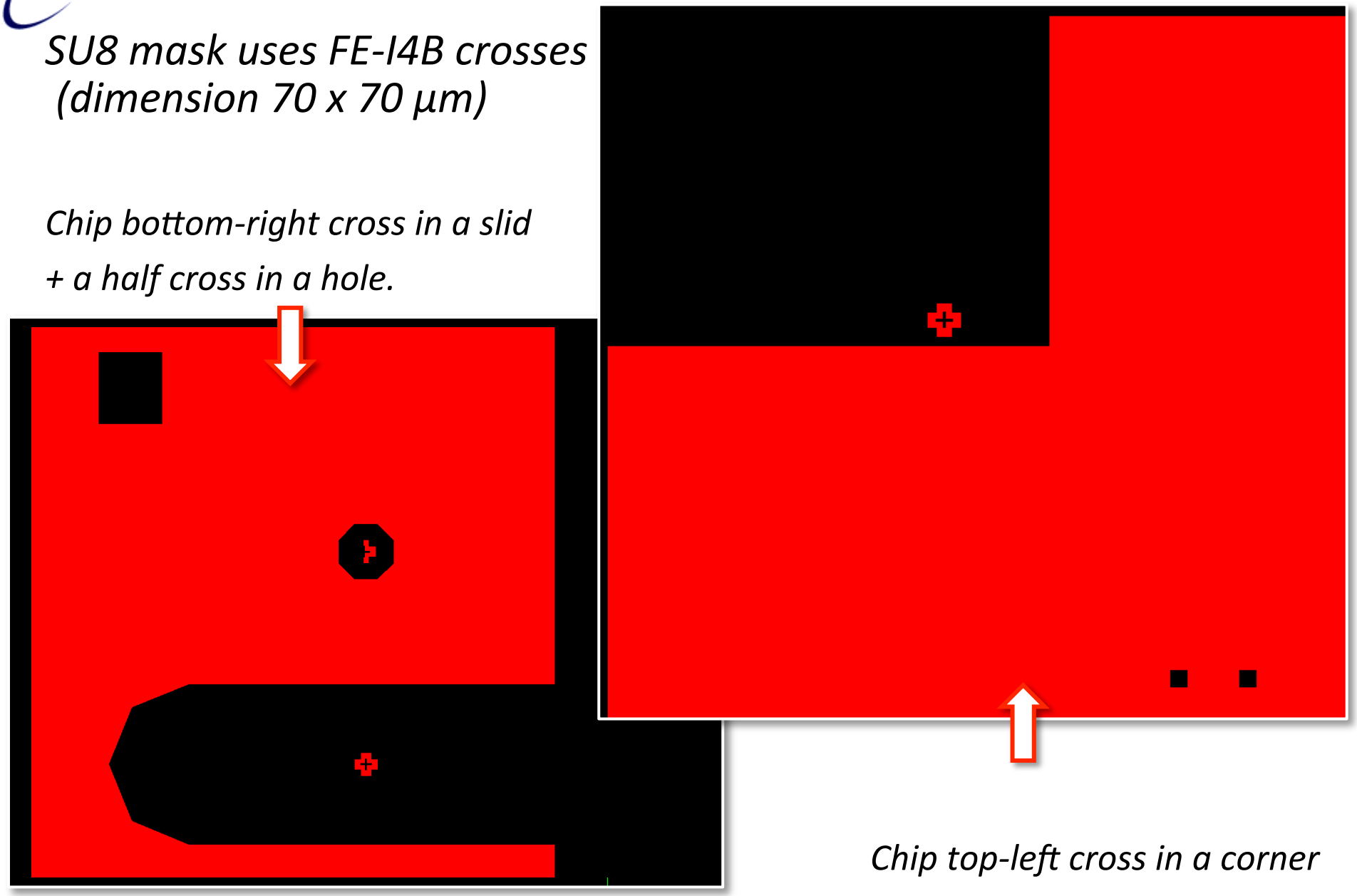


FE-I4 Alignment Crosses

SU8 mask uses FE-I4B crosses (dimension 70 x 70 µm)

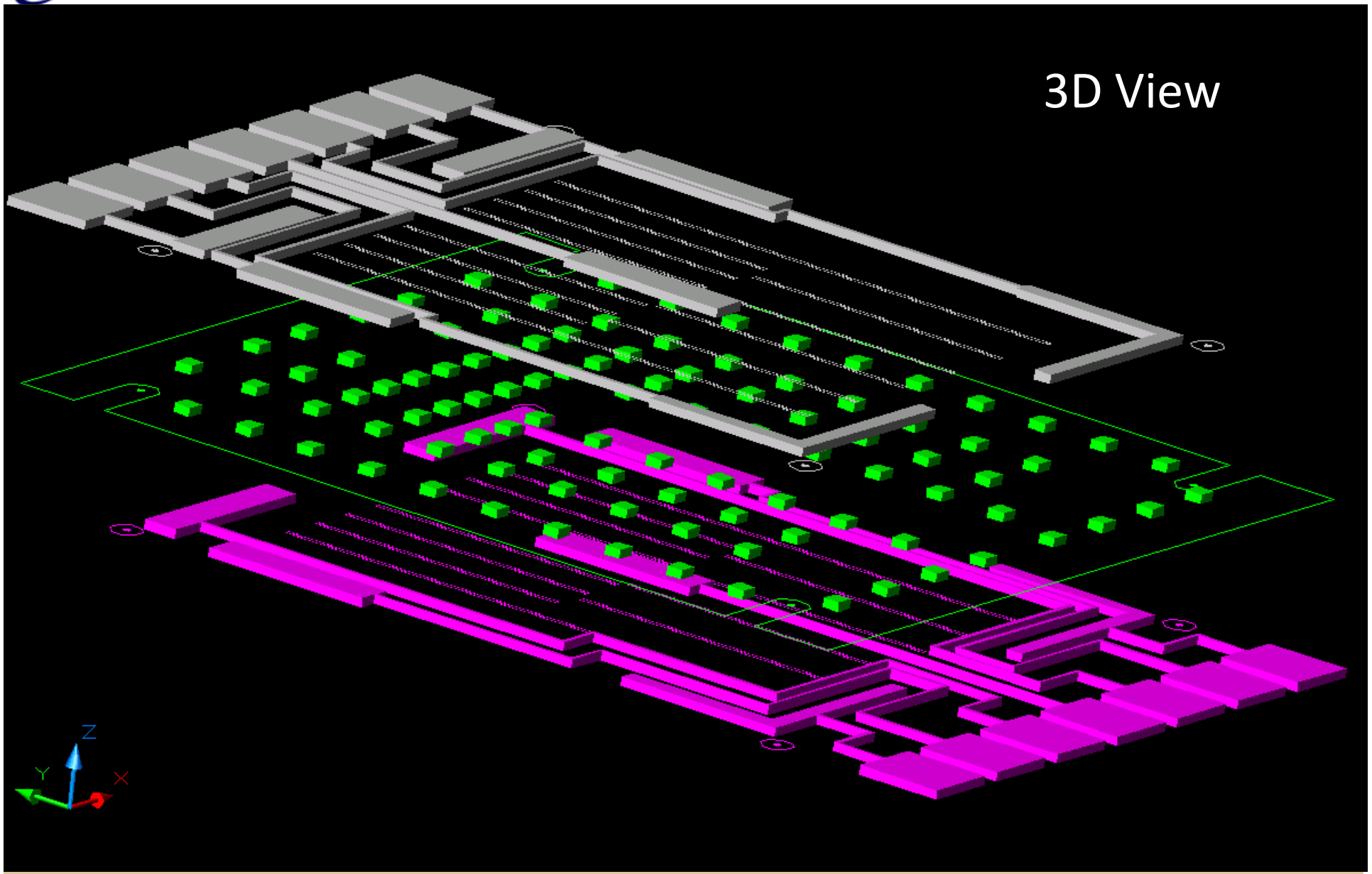
Chip bottom-right cross in a slid

+ a half cross in a hole.

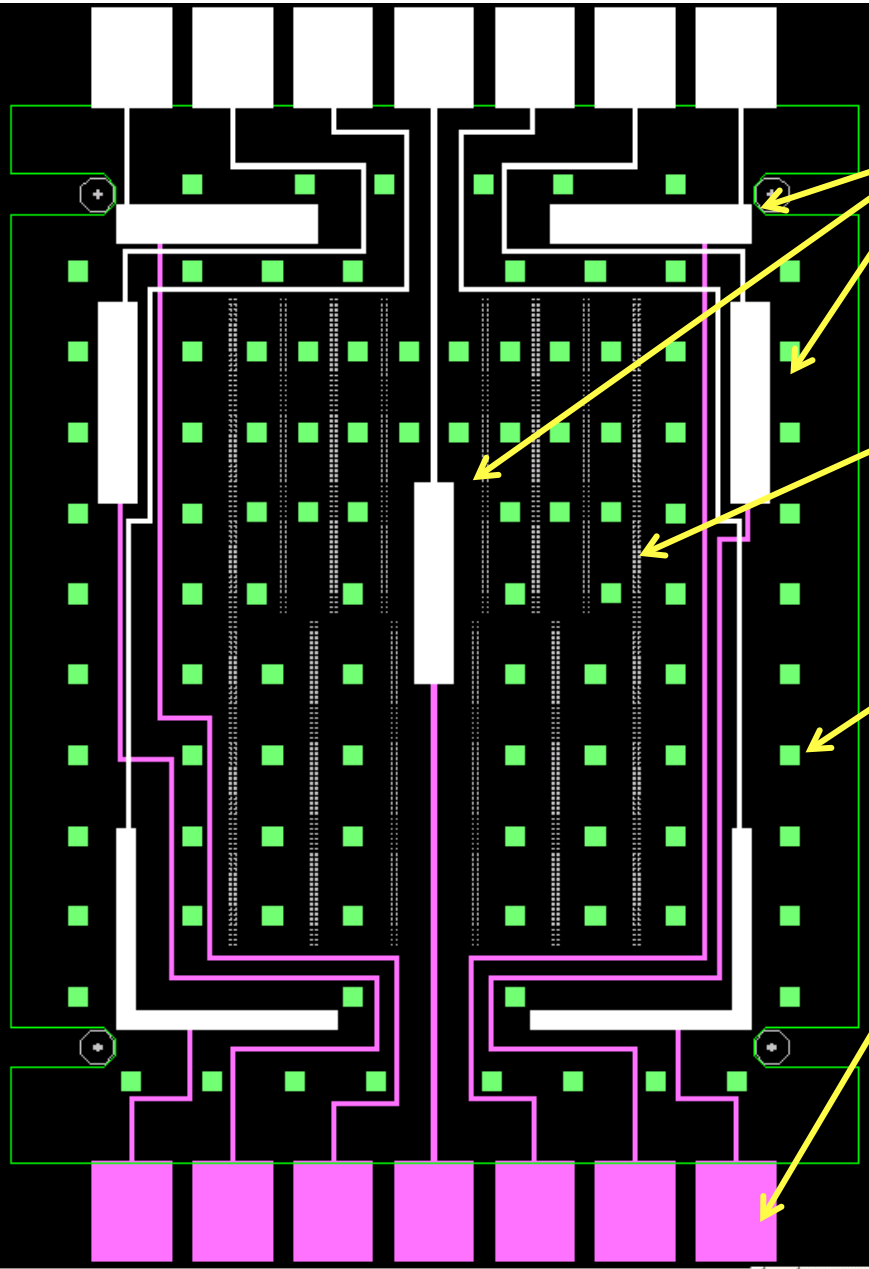


Chip top-left cross in a corner

Structure to test with Glass chips



Overlaid bottom/ top glasses with spacers interposer



7 capacitors to evaluate thickness of the glue layer

Rows of bump-pads to visually align top/bottom

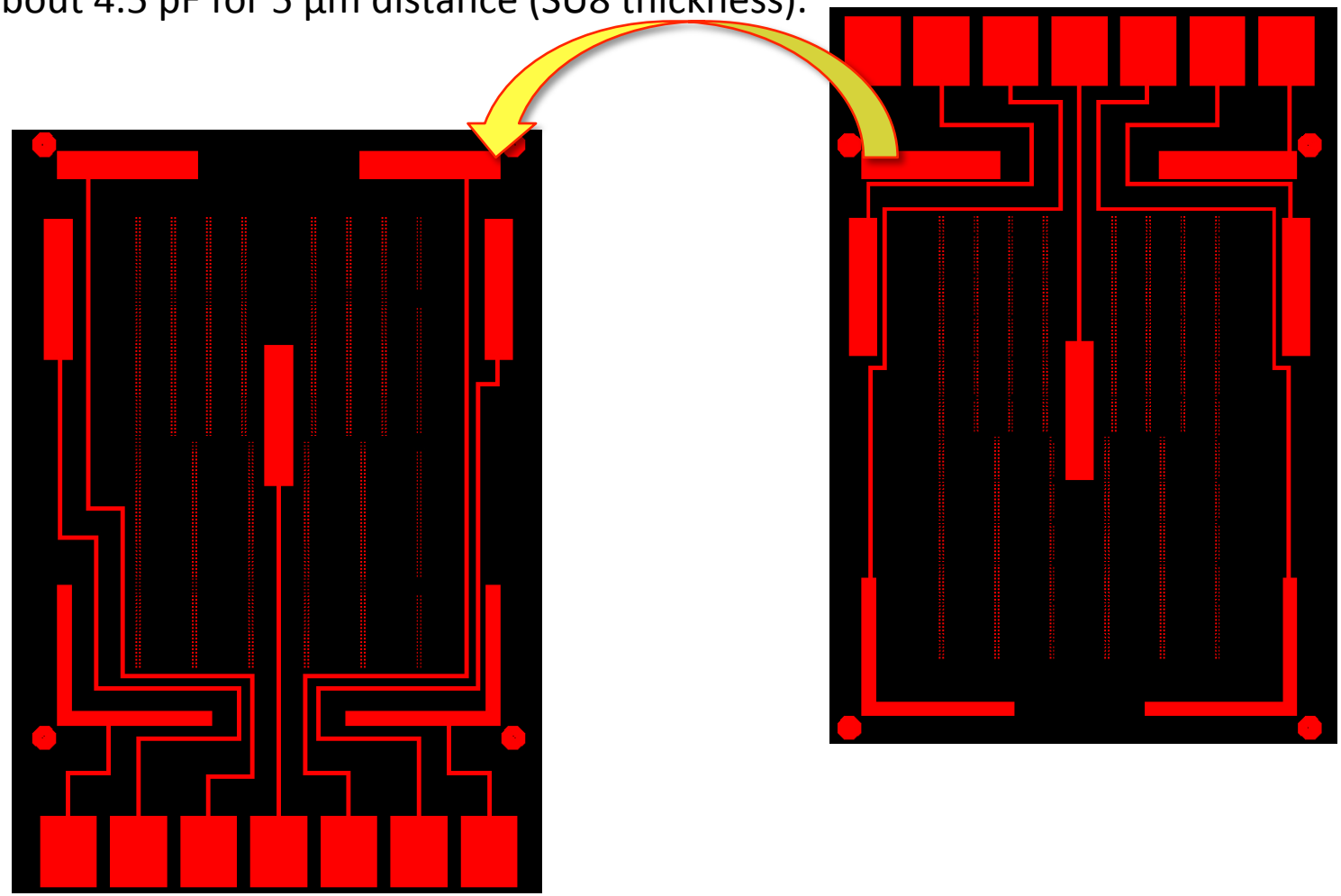
SU8 spacers

Capacity-meter probe pads

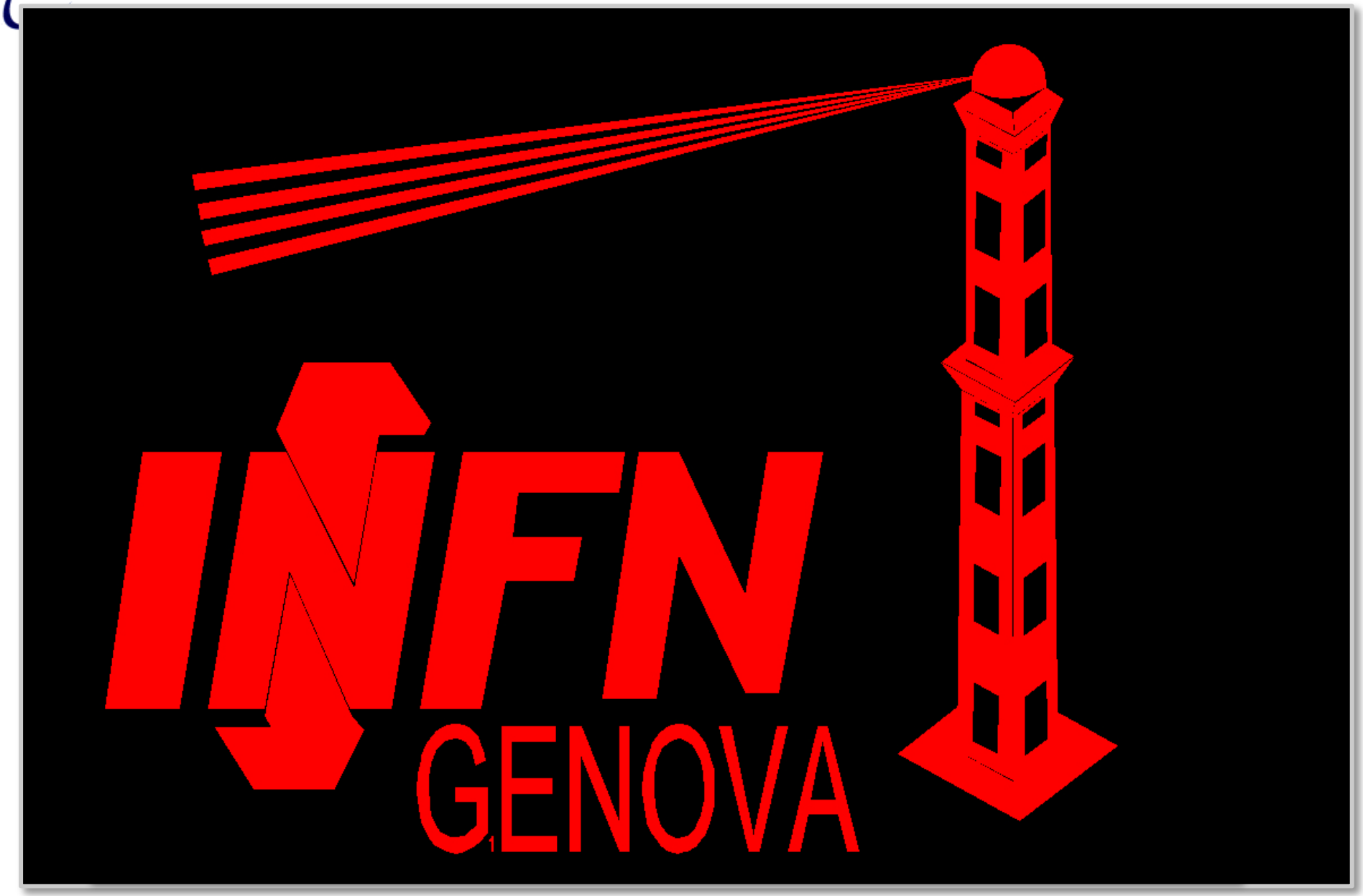
Metal Patterns Deposited on Glass

On the two facing glasses matching metal structures:

- Pads simulating FE-I3/FE-I4B bump pattern (for visual alignment).
- Strips of 0.4 x 2.0 mm2. There is one in each corner and one in the centre. Capacity is about 4.5 pF for 5 µm distance (SU8 thickness).

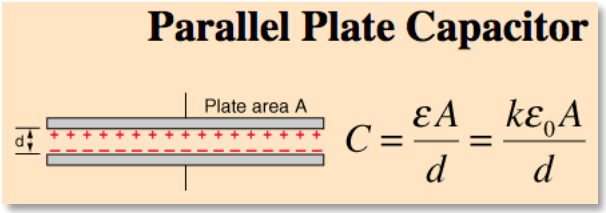


Mask Logo © Alessandro



Capacitance Evaluation

- *The formula for evaluating the capacitance is:*



- *The C using the FE-I4B bump-pads:*
  - Metal pad diameter = 18μm
  - For d = 5 μm and Ɛr = 3.2, C = 1.4 fF

- *Some C values for strip/pad structures are in the table*

Structure	W or D (um)	L (um)	D (um)	C (fF)
Pad (circ.)	D = 18		1	7.21
	D = 18		3	2.40
Pad (circ.)	D =18		5	1.44
Strip	400	2 000	1	22 666.72
Strip	400	2 000	5	4 533.34

Parameters:

Relative dielectric constant (εr)	3.2	
Vacuum dielectic constant (ε0)	8.854 E-12	$C \cdot V^{-1} \cdot m^{-1}$

Definition

W = Width (diameter for circular pads)
L = Length
D = distance between plates
C = Capacity

- *Signal needed by FE-I4*
  - Typical charge for a MIP in 200μm sensor 15ke, typical V at the HV-CMOS output 1 V:

    C = Q/V = 1.5 x 104 * 1.602 x 10^{-19} [Q]/ 1 [V] = 2.4 fF i.e 3μm of SU8

Note: considering that FE-I4B can operate well with 10ke **5 μm of SU8** is a good value to start.

SU8 Physical Properties

We have procured:

- *SU-8 photoresist: 2005, 2002, 2000.5 + developer from Microchem*
- *- stripper: mr Rem 660 (Microresist Technology)*

- *http://www.microresist.de/produkte/mcc/pdf/su_8_2000_2000_5_bis_2015.pdf*

Physical Properties
(Approximate values)

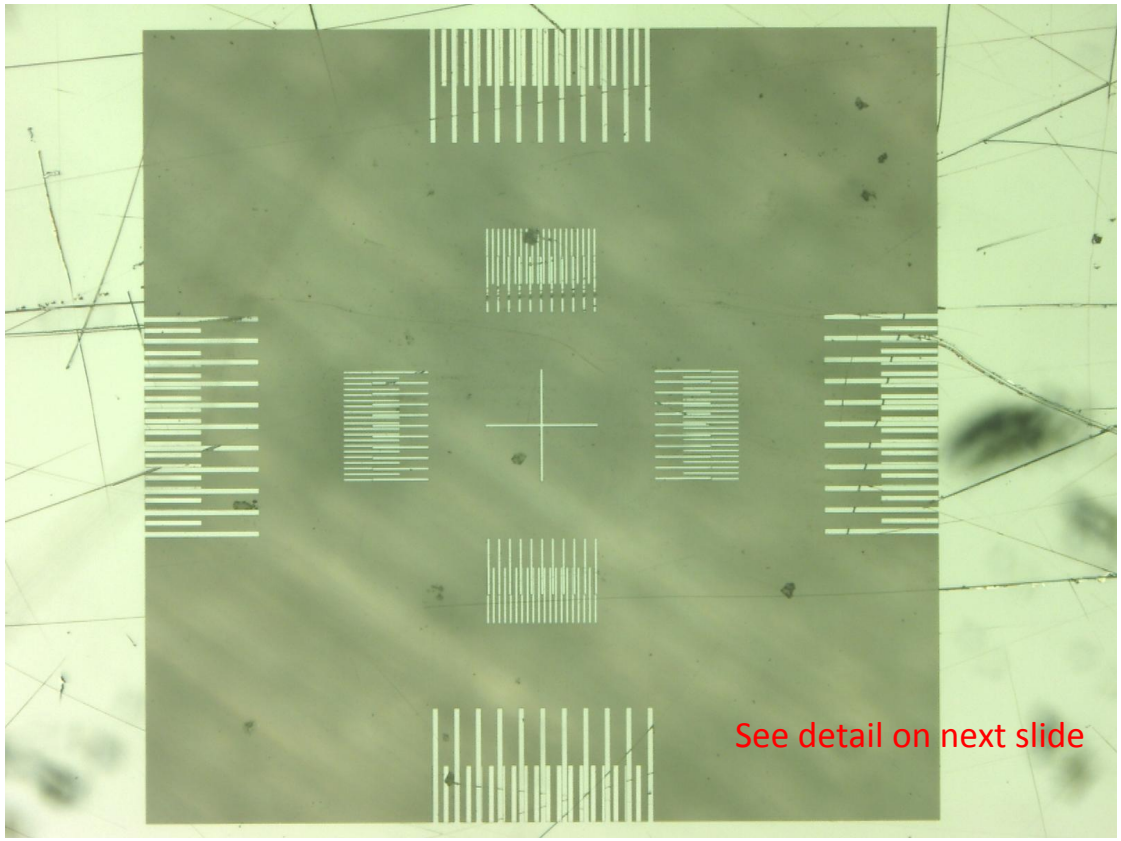
Adhesion Strength (mPa) Silicon/Glass/Glass & HMDS	38/35/35
Glass Transition Temperature (Tg °C), tan δ peak	210
Thermal Stability (°C @ 5% wt. loss)	315
Thermal Conductivity (W/mK)	0.3
Coeff. of Thermal Expansion (CTE ppm)	52
Tensile Strength (Mpa)	60
Elongation at break (εb %)	6.5
Young's Modulus (Gpa)	2.0
Dielectric Constant @ 10MHz	3.2
Water Absorption (% 85°C/85 RH)	0.65

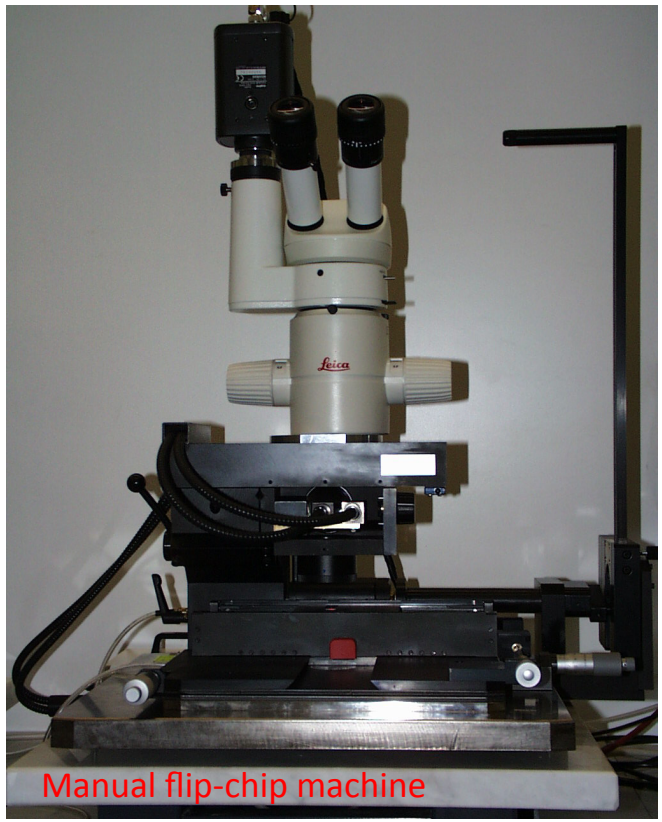
Ettore

ASSEMBLY & FLIP-CHIP MACHINE

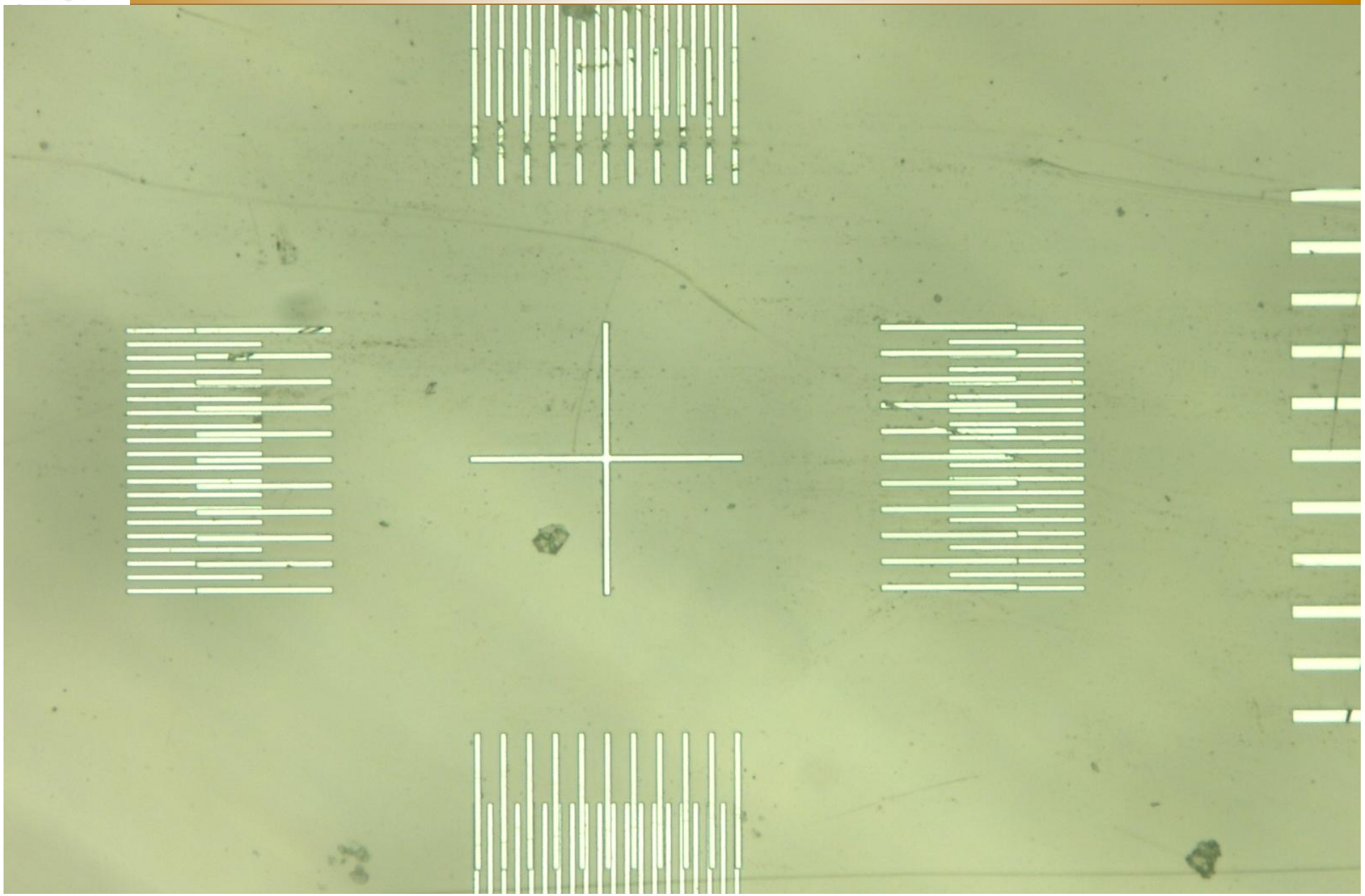
Flip-chip Machine Calibration

- *Flip chip machine calibrated with 200µm thick glasses*
  - Used calibrated patterns on glass (from flip-chip machine vendors) and old bump pad arrays available from Selex.
  - Better than 7µm is obtained over a distance of 8 mm (see next slides)

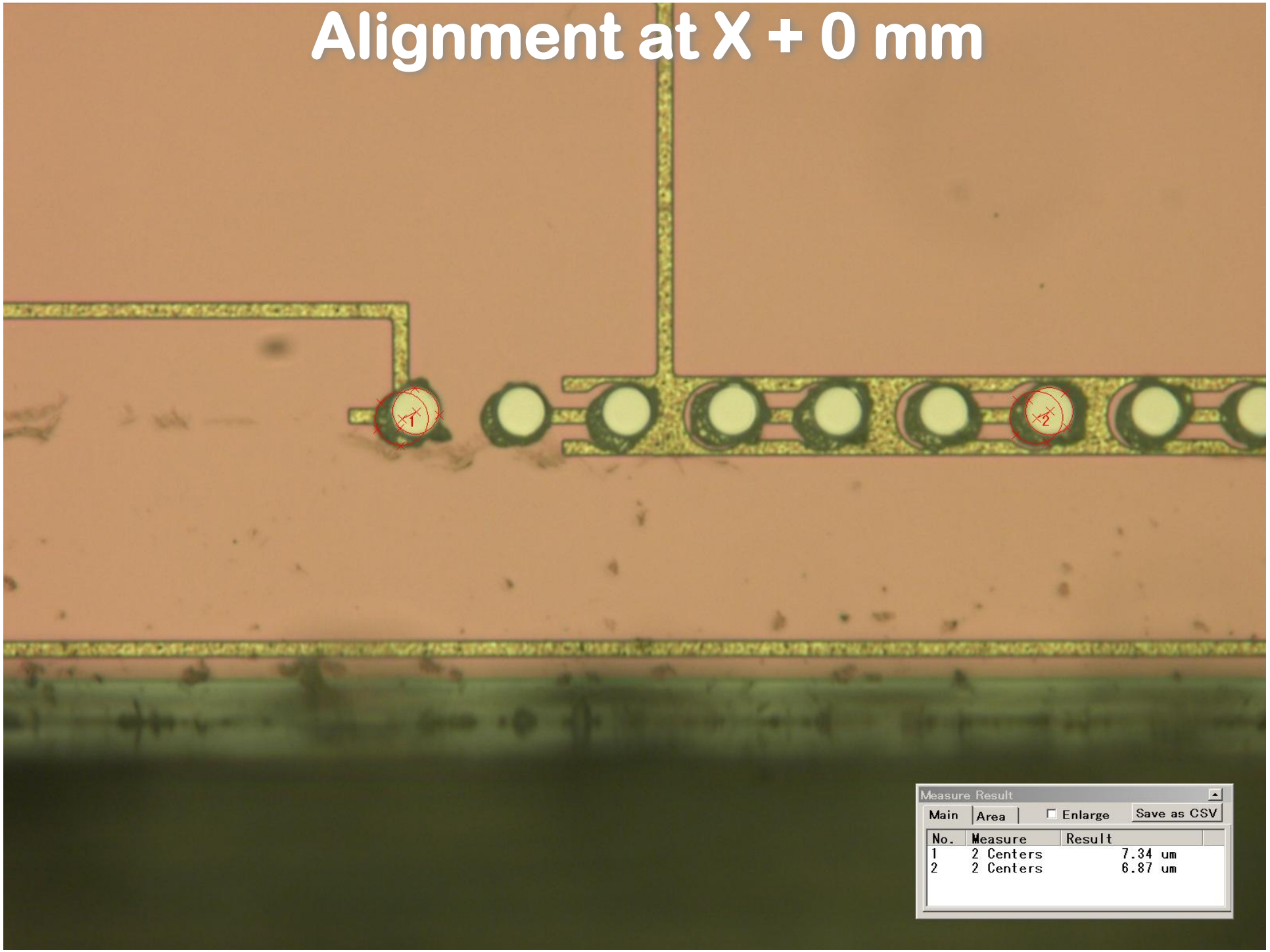




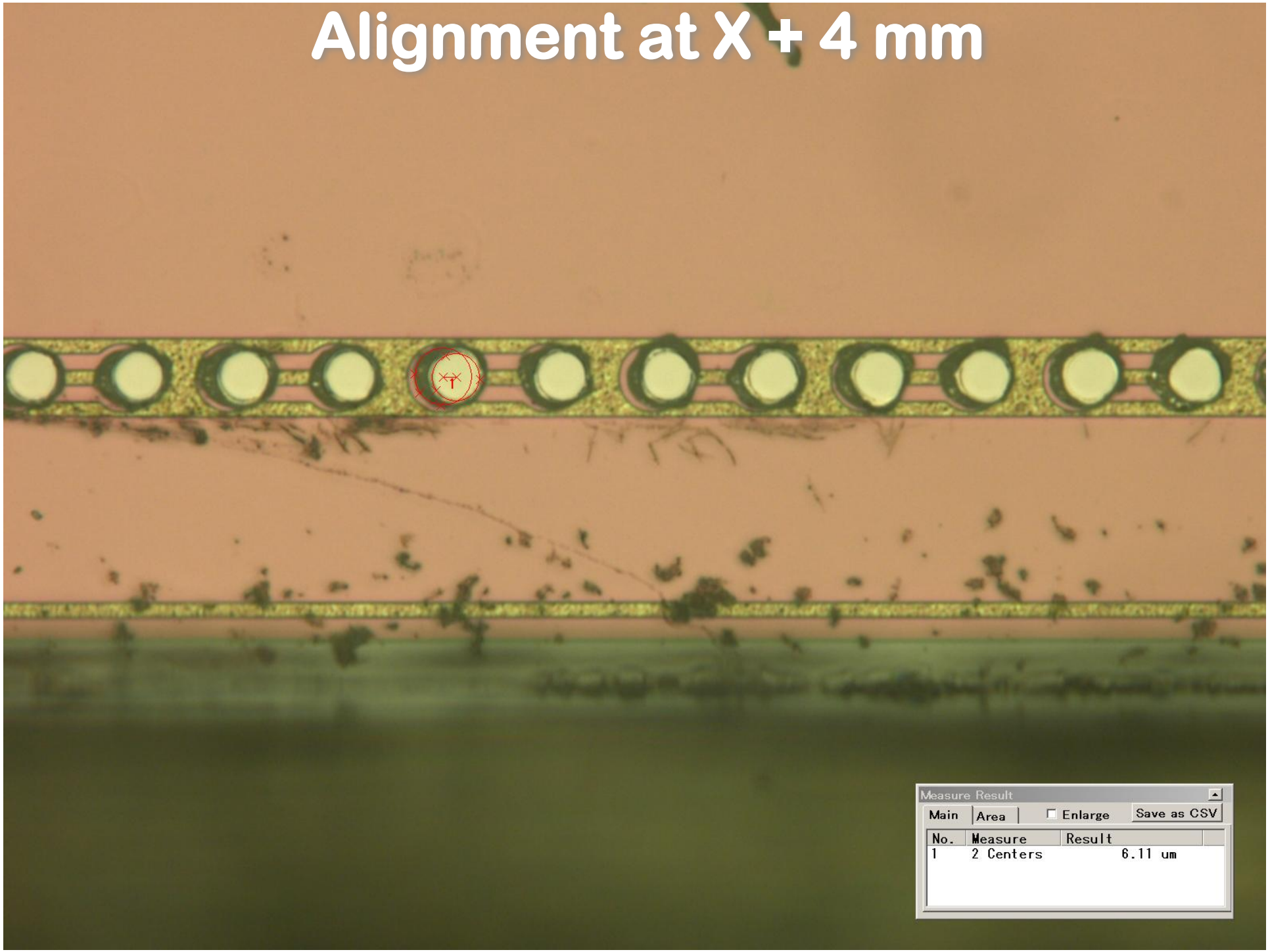
Bottom to Top glass Alignment - Detail



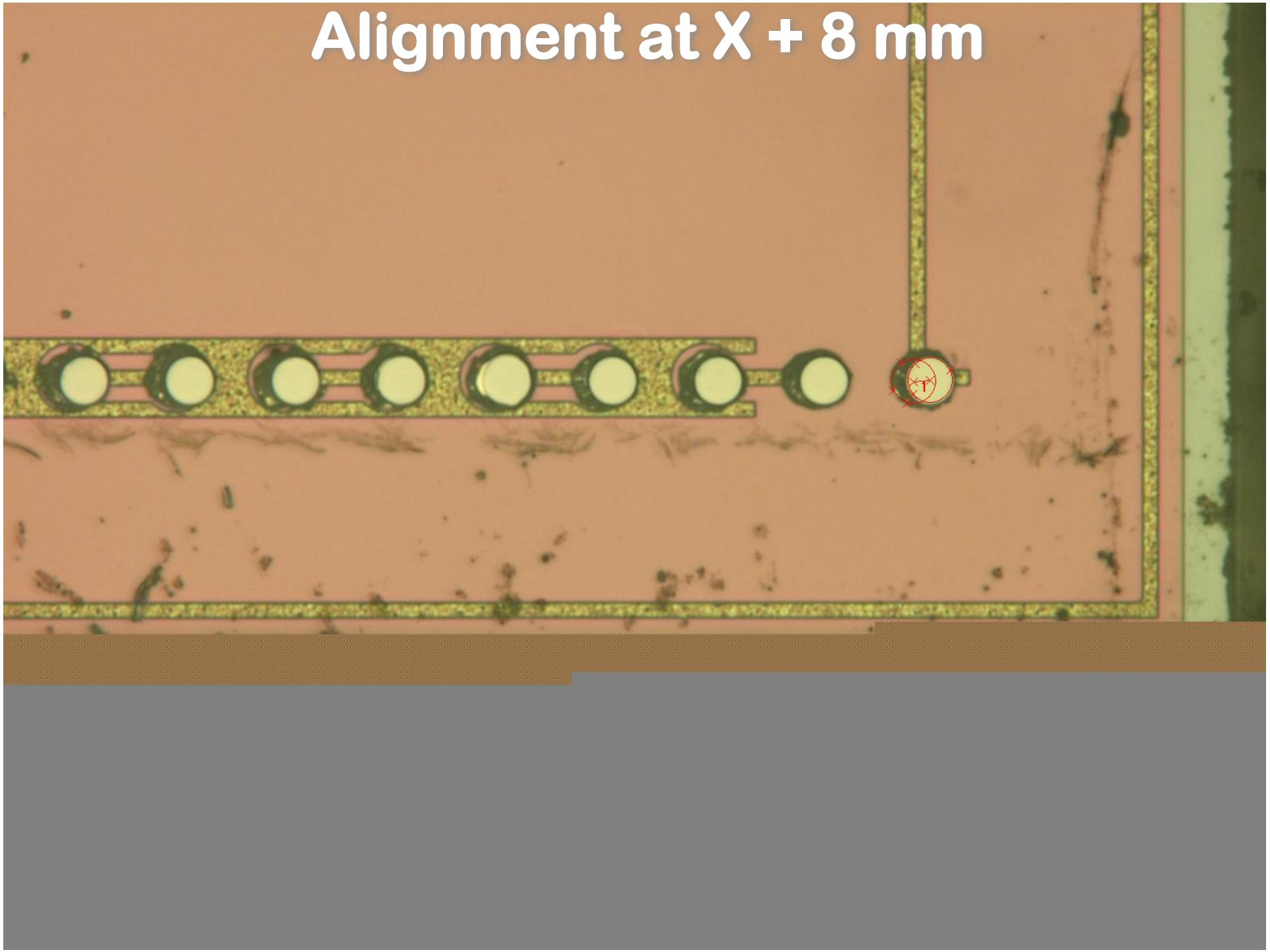
Alignment at X + 0 mm



Alignment at X + 4 mm



Alignment at X + 8 mm



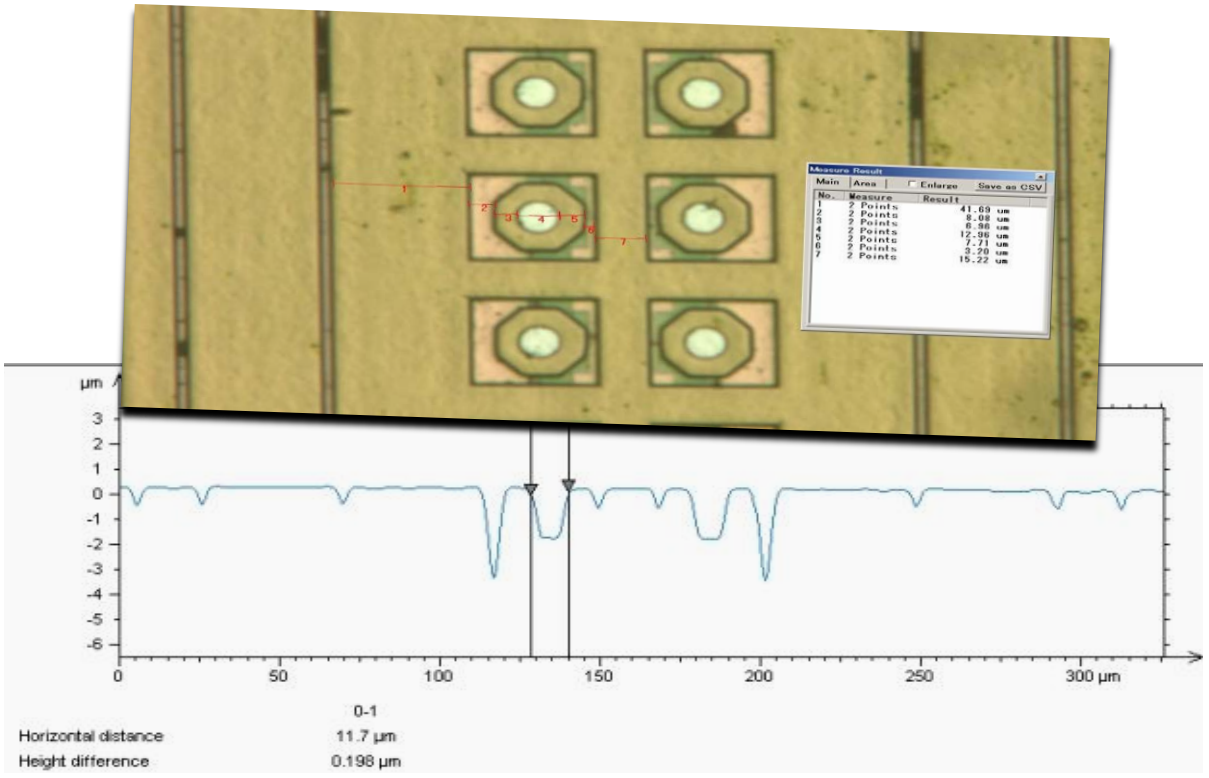
Alessandro, Ettore & Giuseppe

PROFILOMETER TESTS KLA-TENCOR

Indium BB: Next Steps

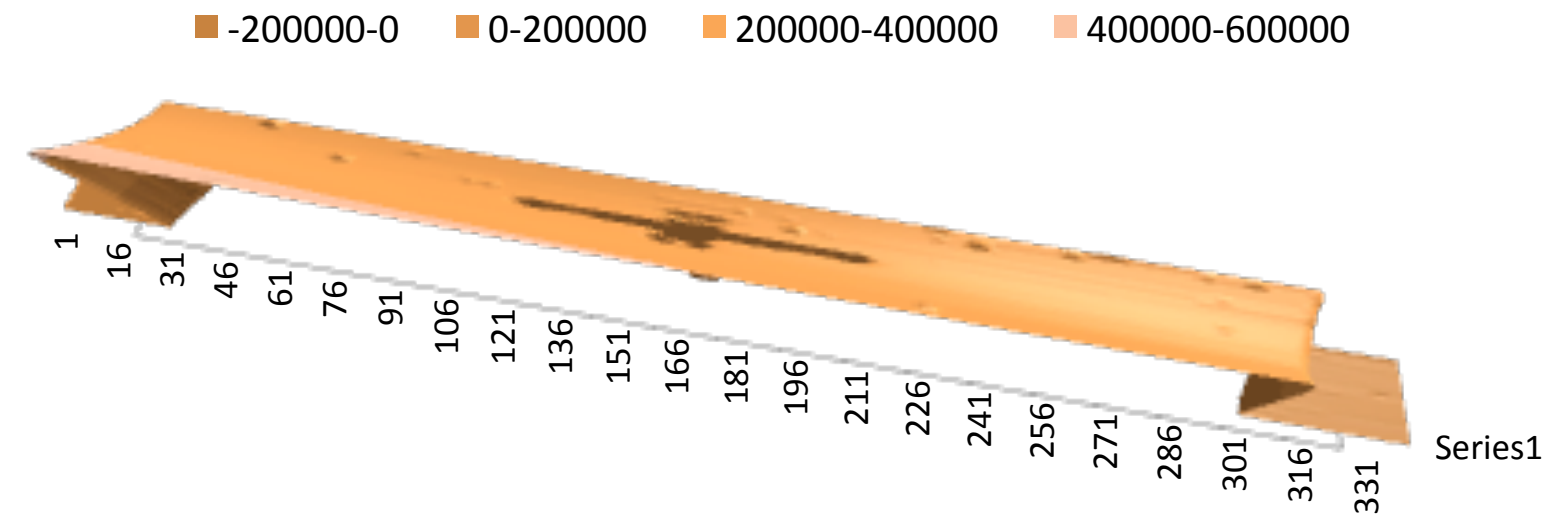
- *On-going upgrade at Selex of the mask aligner to deal with 6" wafers (in the past only 8" for electronics and 4" for sensors where available). Expected operation after summer.*
  - We will test with the 6" wafers from FBK (3D sensors of IBL-like type and planar devices from batch2)
- *Develop high density/high number of of bumps BB with dummy sensors:*
  - 130k-bumps, 50µm x 50µm pitch, 2 x 2 cm2

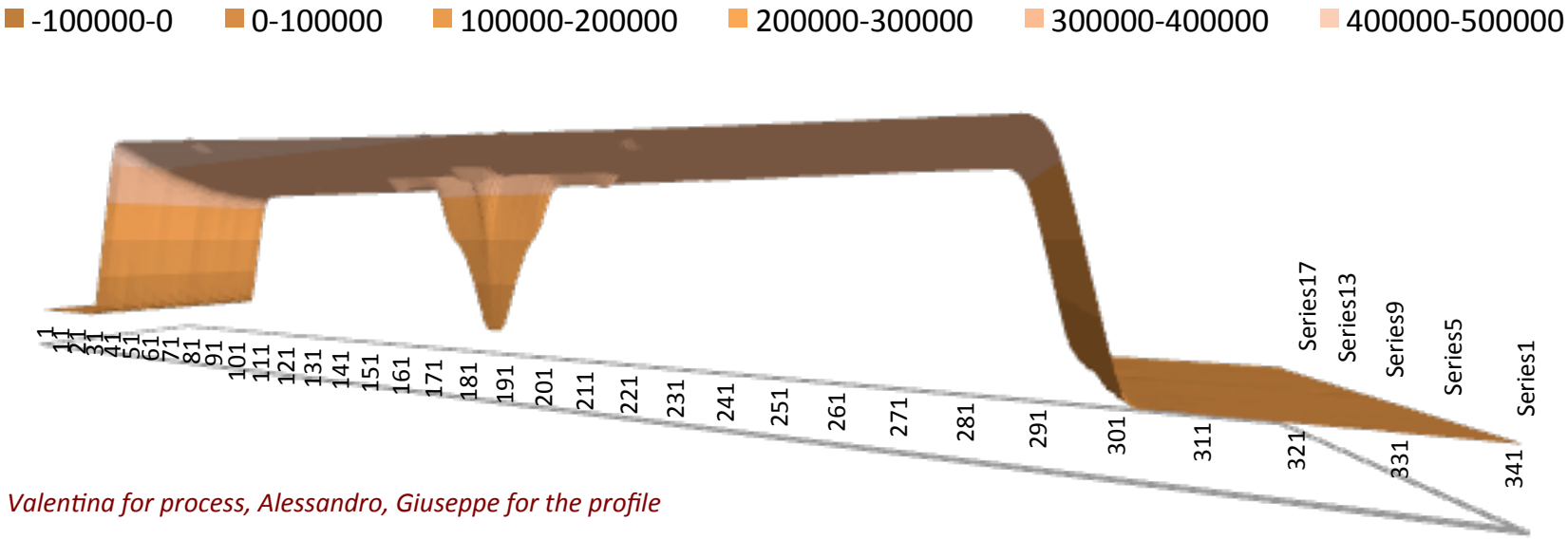
Figure: bump pad profile of FE-I4B chip made with KLA-Tencor P7 in Genova.



Credits:
E. Ruscino, G. Gariano – INFN/Genova

3D Tower in SU8





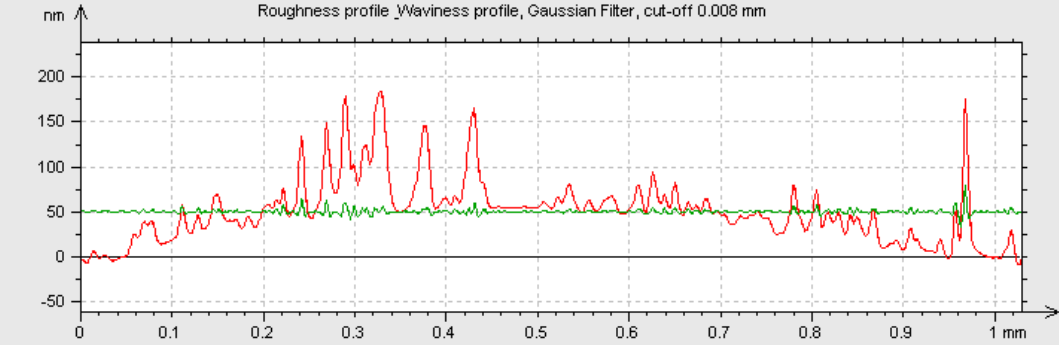
Credits: Valentina for process, Alessandro, Giuseppe for the profile

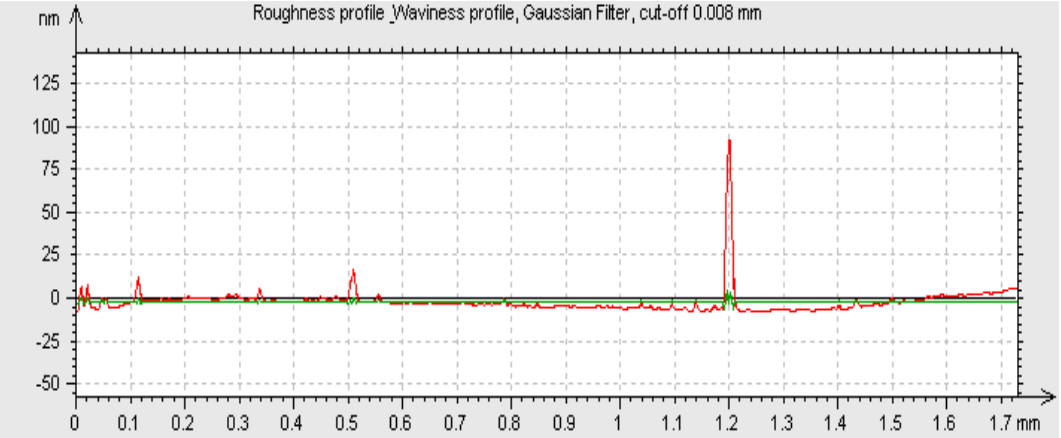
Tools for Hybridization Developments

Mechanical Profilometer (Genova ATLAS)

- Useful for BB and HV/HR-CMOS hybridization

Roughness study of a glass substrate (to test hybridization with glue):
Top cleaned with alcohol isopropyl
Bottom cleaned with plasma cleaner





Credits: E. Ruscino, G. Gariano – INFN / Genova

KLA-TENCOR P7 stylus profiler
Scan length: 200mm - 8" wafer
Repeatability/reproducibility: 4/15 Å
Vertical resolution: 0.01/0.60 Å

ACTION LIST: Where are we?

- *Valutare capacità necessaria per accoppiare HV/HR-CMOS con FE-I4: done*
- *Procurare SU-8 2005, adatto per spessori dell'ordine di 5µm → done*
- *Maschere →* ***done***
- *Spinning photoresist, test spessore deposizione mediante misure con profilometro ottico, impressione e sviluppo photoresist mediante mascere, misura altezza colonne (con profilometro meccanico/ottico). Test iniziali su vetrini e poi su chip →* ***in progress***
- *Deposizione del photoresist (usato come colla) in forma di "paddle" e come velo sottile per bagnare l'altra superficie d'incollaggio →* ***To be done***
- *Messa a punto della macchina di flip-chip e verifica se utilizzabile per incollaggio di 2 parti della dimensione FE-I3 e di un FE-I4 con un componente delle dimensioni del FE-I3 →* ***done***
- *Prove d'incollaggio (processo completo) e verifica allineamento e uniformità spessore e assenza di bolle. La procedura andrà finalizzata in base ai risultati dei passi precedenti. →* ***To be done***
- *Utilizzo e-log. Messa a punto di e-log e informazioni su come usarlo →* ***done***
- *Valutare la possibilità di misure di uniformità spessore e allineamento mediante vetrini con pattern metallizzati e misure di capacità: implemented in the mask →* ***done*** *(mask)*

Action list from 3/4/2014

SPARES

Assembly of HV-CMOS/FE-I4

Procedure (idea to fully workout)

- Deposit US-8 photoresist by spinning → ~5 µm thick
- Use mask to pattern the photoresist → make spacer columns
- Deposit glue amongst columns
- Align FE-I4 to HV-CMOS → with old flip-chip machine?
- Apply pressure until columns are in contact
- Is feasible?

Let's discuss !

Spin SU-8 photoresist
Pattern pillars by mask

Glue deposition

Align & pressure

2x2 pillar height test:
- distance 4 mm
- height in µm

Pillar 1	5.92
Pillar 2	6.07
Pillar 3	5.92
Pillar 4	5.92

Low Tempreature Detector facility – LTD Genova
Ref.: M. Biasotti et al., 9th "Trento" Workshop – Genova 26-28/2/2014

SU-8 2000

Permanent Epoxy Negative Photoresist

PROCESSING GUIDELINES FOR:

SU-8 2000.5, SU-8 2002, SU-8 2005, SU-8 2007, SU-8 2010 and SU-8 2015

SU-8 2000 is a high contrast, epoxy based photoresist designed for micromachining and other microelectronic applications, where a thick, chemically and thermally stable image is desired. SU-8 2000 is an improved formulation of SU-8, which has been widely used by MEMS producers for many years. The use of a faster drying, more polar solvent system results in improved coating quality and increases process throughput. SU-8 2000 is available in twelve standard viscosities. Film thicknesses of 0.5 to >200 microns can be achieved with a single coat process. The exposed and subsequently thermally cross-linked portions of the film are rendered insoluble to liquid developers. SU-8 2000 has excellent imaging characteristics and is capable of producing very high aspect ratio structures. SU-8 2000 has very high optical transmission above 360 nm, which makes it ideally suited for imaging near vertical sidewalls in very thick films. SU-8 2000 is best suited for permanent applications where it is imaged, cured and left on the device.

SU-8 2000 Features

- High aspect ratio imaging
- 0.5 to > 200 μm film thickness in a single coat
- Improved coating properties
- Faster drying for increased throughput
- Near UV (350-400 nm) processing
- Vertical sidewalls