

Quality assurance of pixel detectors for the CMS Phase I upgrade

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Who we are:

CMS Upgrade Group



Jaakko Härkönen, Project leader



Eija Tuominen, Senior scientist



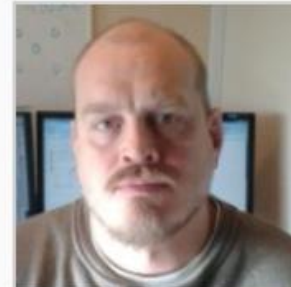
Ivan Kassamakov, Senior scientist



Panja Luukka, Senior scientist



Esa Tuovinen, Post-doc scientist



Timo Peltola, Graduate student



Aneliya Karadzhinova, Graduate student



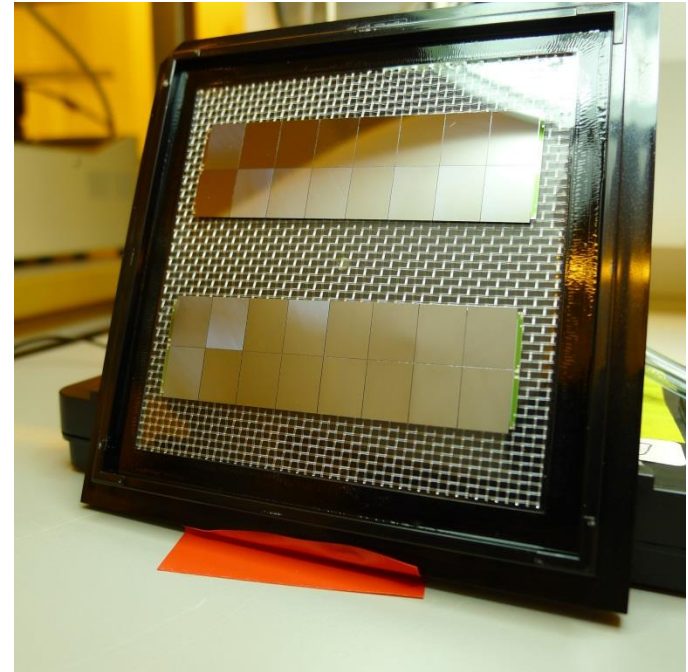
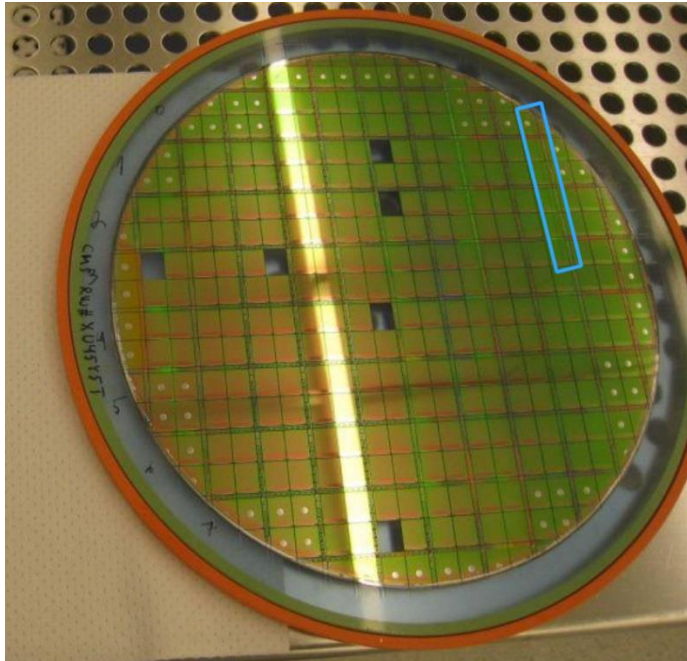
Tatyana Arsenovich, Graduate student



Akiko Gädä, Graduate student

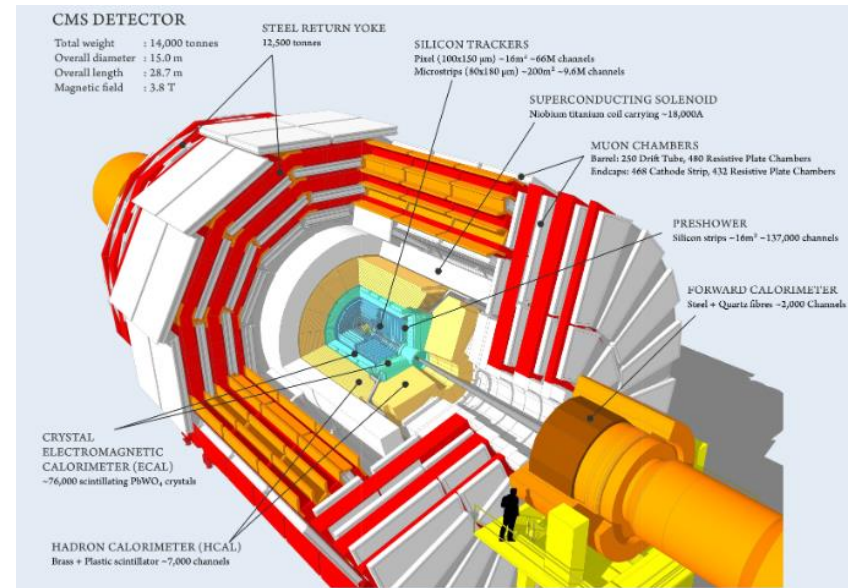
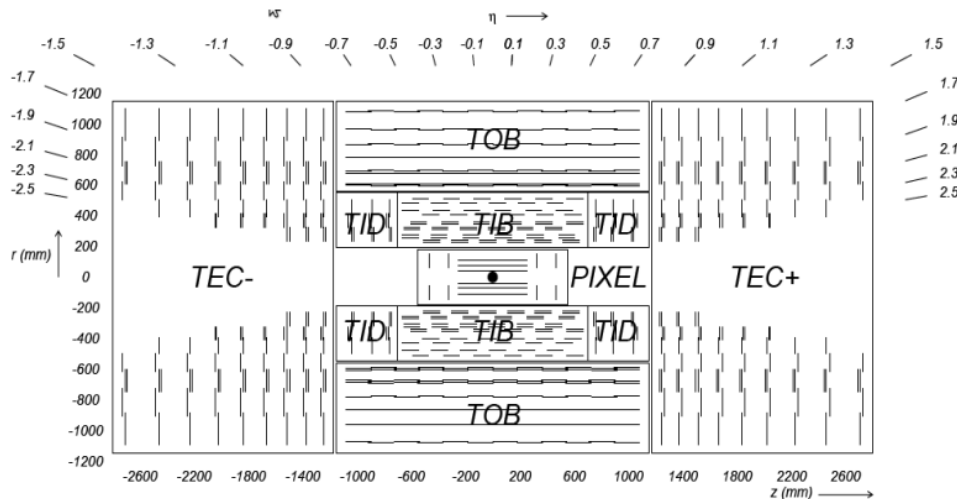
CMS Phase I Upgrade in Finland

- Finland has committed to deliver in-kind 50% on pixel modules of CMS Layer3.
- 4000 read-out ASICs will be flip-chip bonded in Micronova (Espoo, Finland) by Advacam Oy resulting in 240 silicon pixel detector modules with >16M channels.
- The responsibility of the Helsinki Institute of Physics CMS Upgrade group is the quality assurance of these pixel detector modules.



Why CMS pixel detector needs to be upgraded?

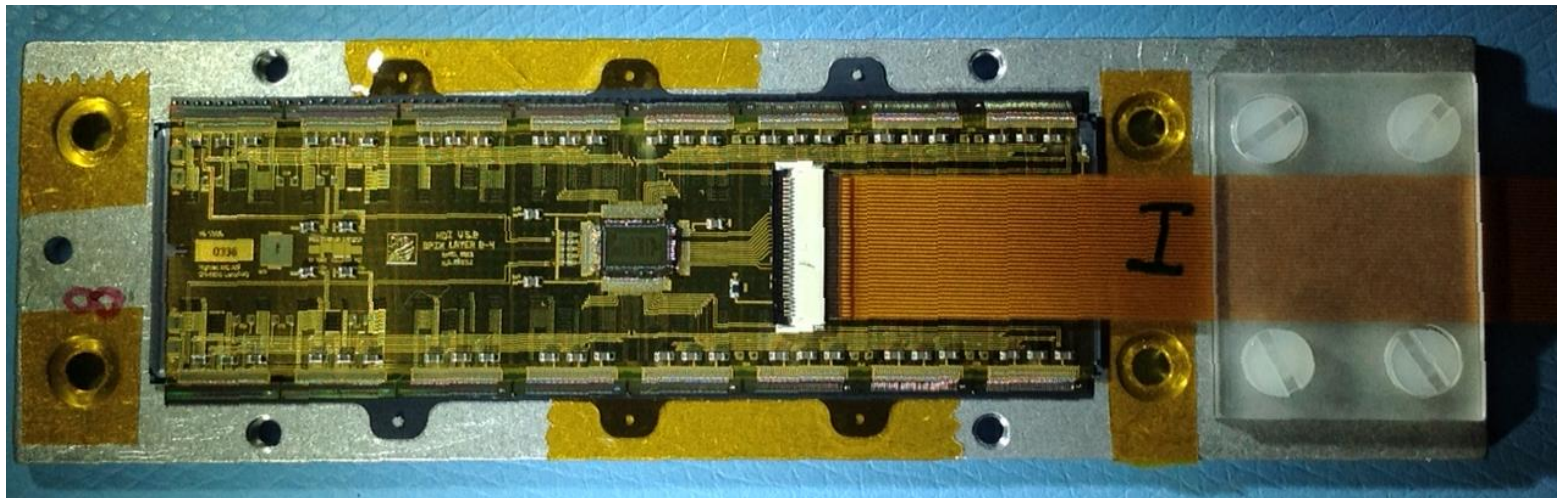
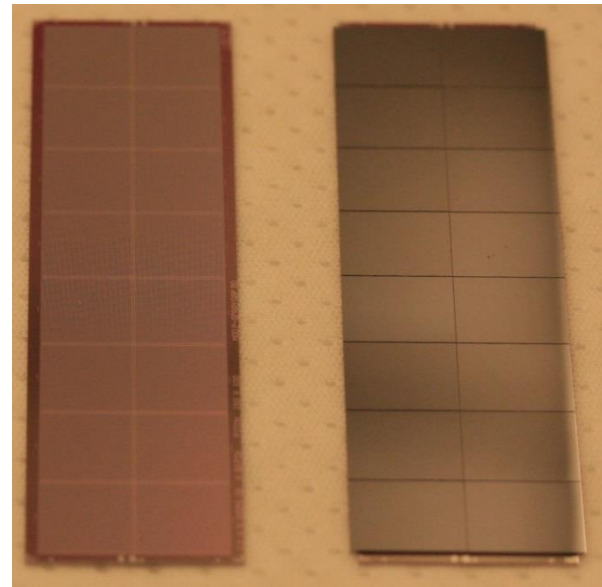
- Pixel detector is the innermost detector in CMS experiment
- Considerable increase of data rates requires modifications in the readout chip (ROC) in order to minimize data losses
- Other improvements:
 - +1 innermost layer into Barrel Pixel (BPIX)
 - Number of channels $48\text{ M} > 79\text{ M}$



CMS pixel module

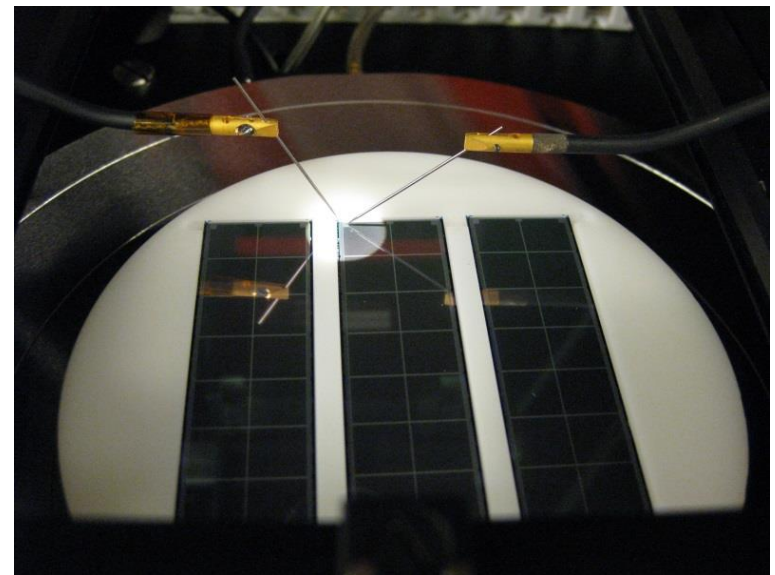
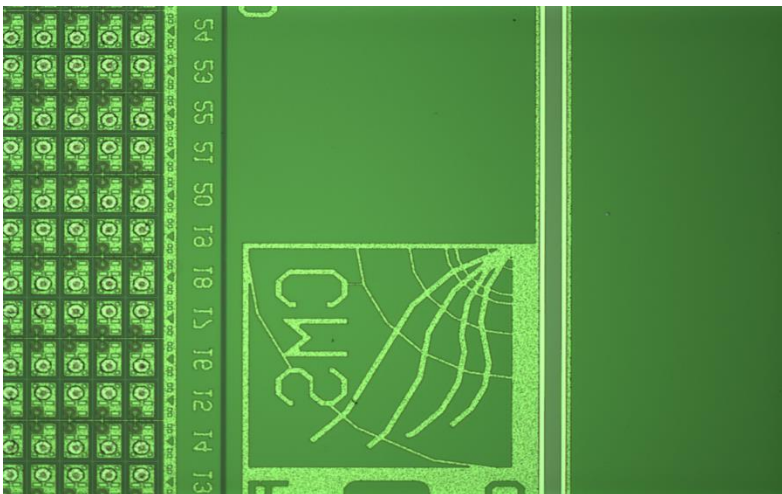
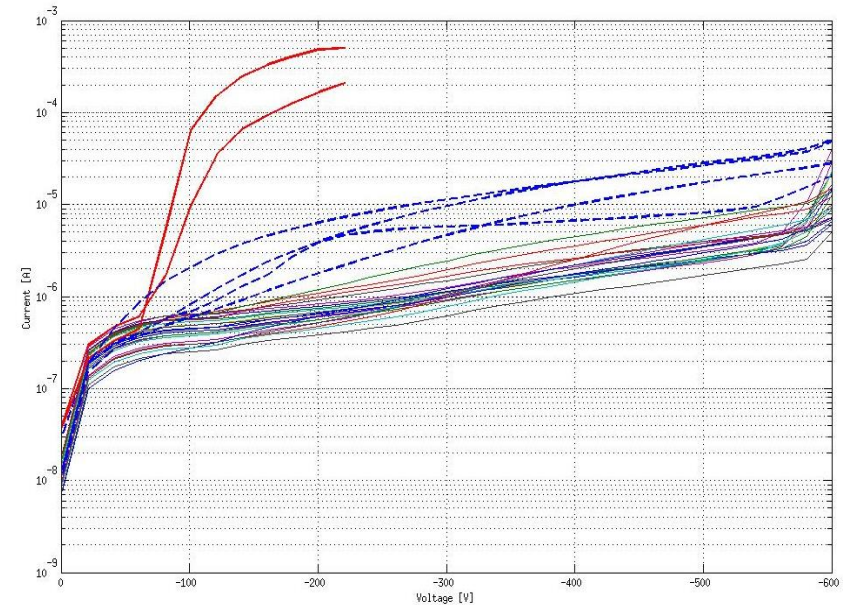
- The CMS pixel detector module consist of a sensor and 16 Read Out Chips (ROC) flip-chip bonded together.
- Total number of pixels in one module is $16 \times 80 \times 52 = 66560$.

<0.1% of dead channels is acceptable



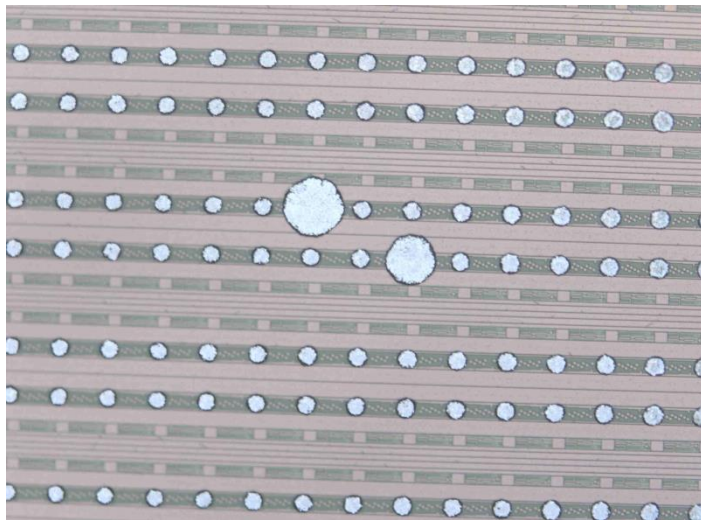
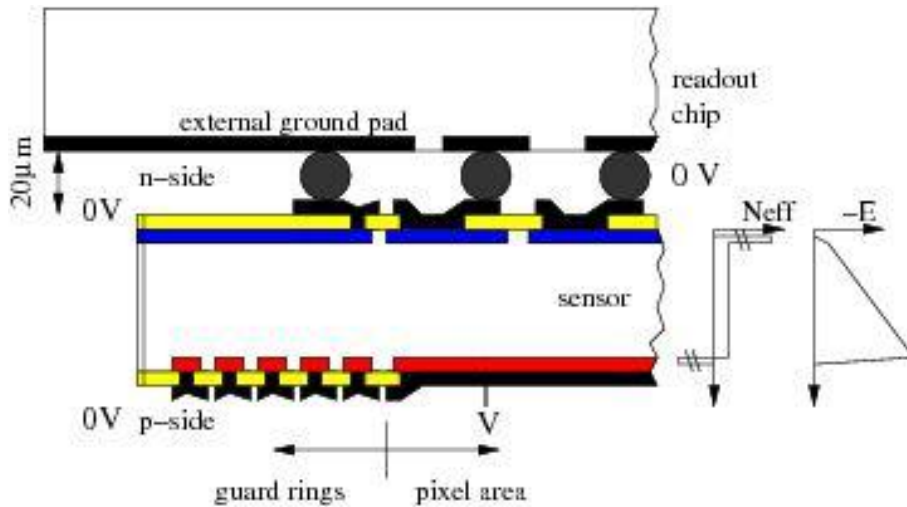
Quality Assurance before flip-chip bonding

- Flip chip bonding and assembled components are **expensive**.
- Sensor and ROC quality must be assured prior the flip-chip bonding.
- Each ROC is electrically tested after receiving the wafer from the manufacturer.
- IV measurements of sensors are performed before dicing the wafer, after the dicing and once more after the flip-chip bonding.

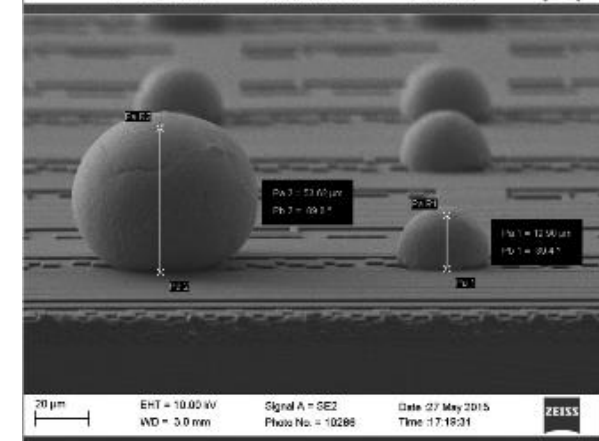
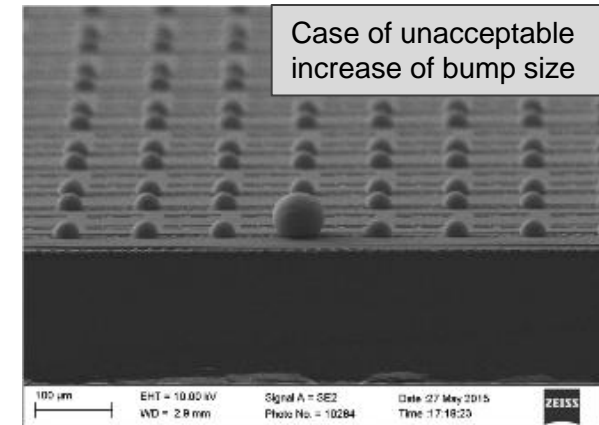
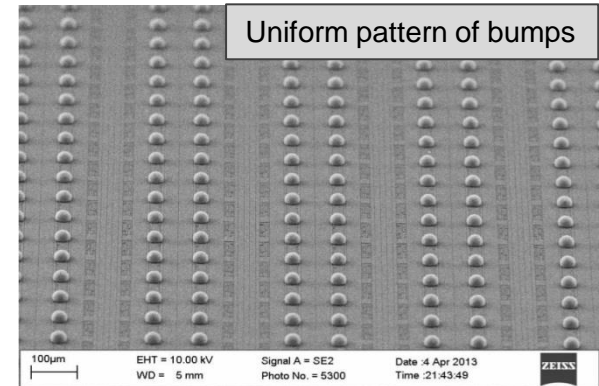


Flip-chip bonding

In flip-chip bonding technology the ROC and the sensors are connected with solder bumps

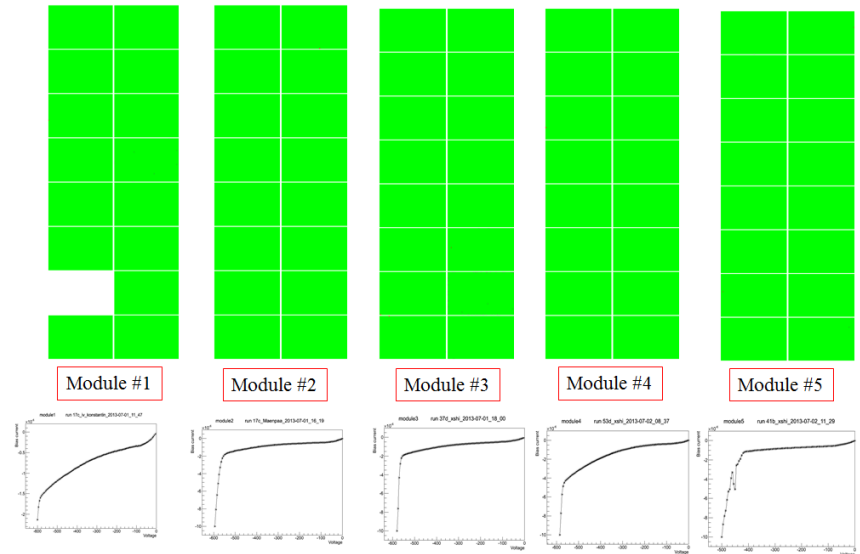
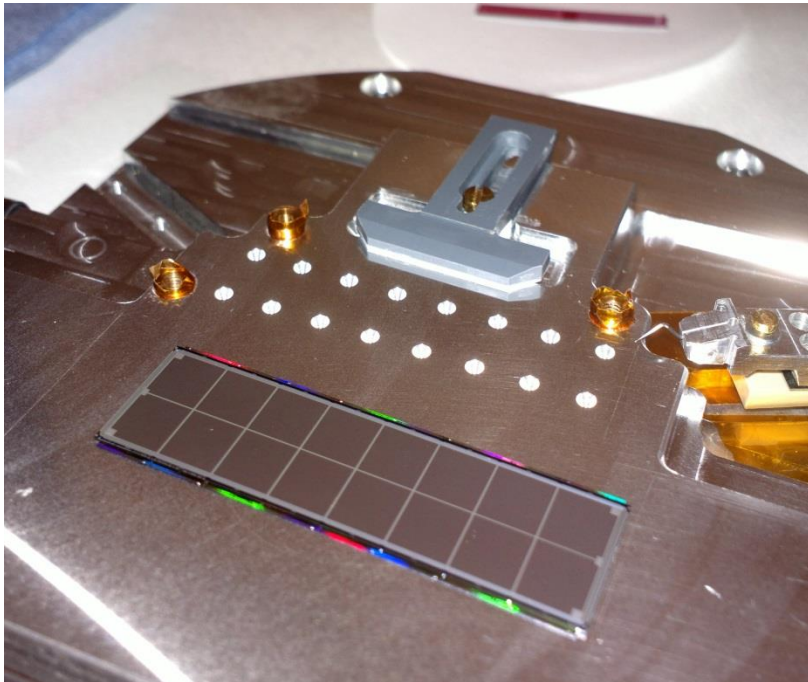


Variance in size of bump may result in bonding failures and short-circuiting after the bonding

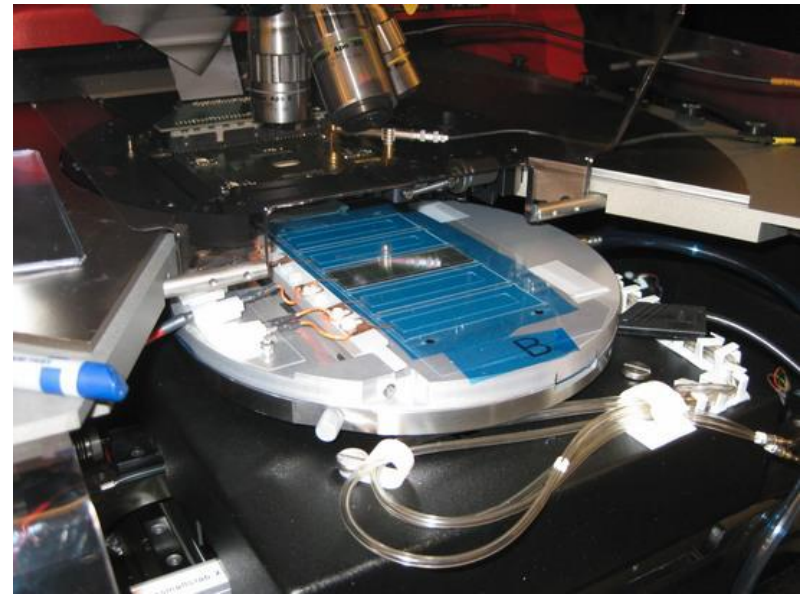
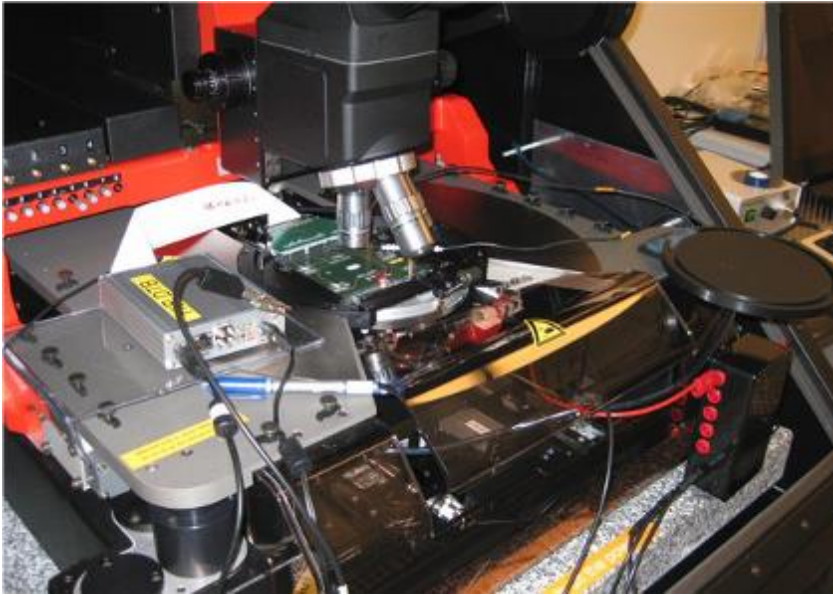


Quality Assurance after flip-chip bonding

- Replacement of disqualified sensors is very complicated
- One problematic ROC per module means the whole module with 16 ROC chips has to be discarded and replaced



Test setup for the flip-chip bonded modules



Summary

- Advacam has produced 88 flip-chip bonded modules of the 240 modules required from Finland for the CMS Phase I pixel upgrade.
- 71 of these modules are classified as class A
- 2 are classified as class C [failed] due to the high leakage current on sensor
- 15 have problematic ROC which can be replaced

The first quality assurance step after producing the flip chip bonded module is extremely important as at this phase a possibly malfunctioning readout circuit can still be replaced.