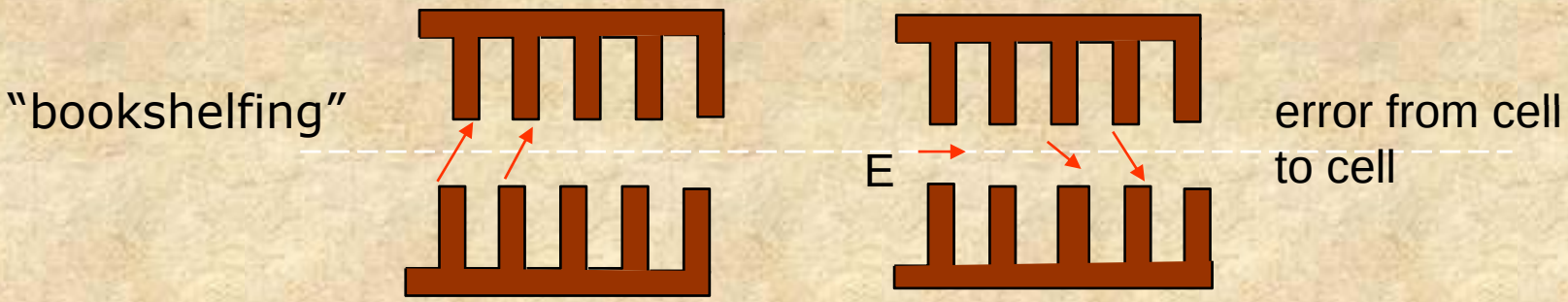
High precision machining and metrology for structures: achievements and open questions

M.Taborelli

Why + / - 1 micron precision?

0. Frequency matching (deviation of about 4MHz/μm on cavity radius at 30 GHz)

1. Longitudinal alignment precision : <5 μm
   alignment error of the irises induces transversal kick on the beam (depends on iris aperture)

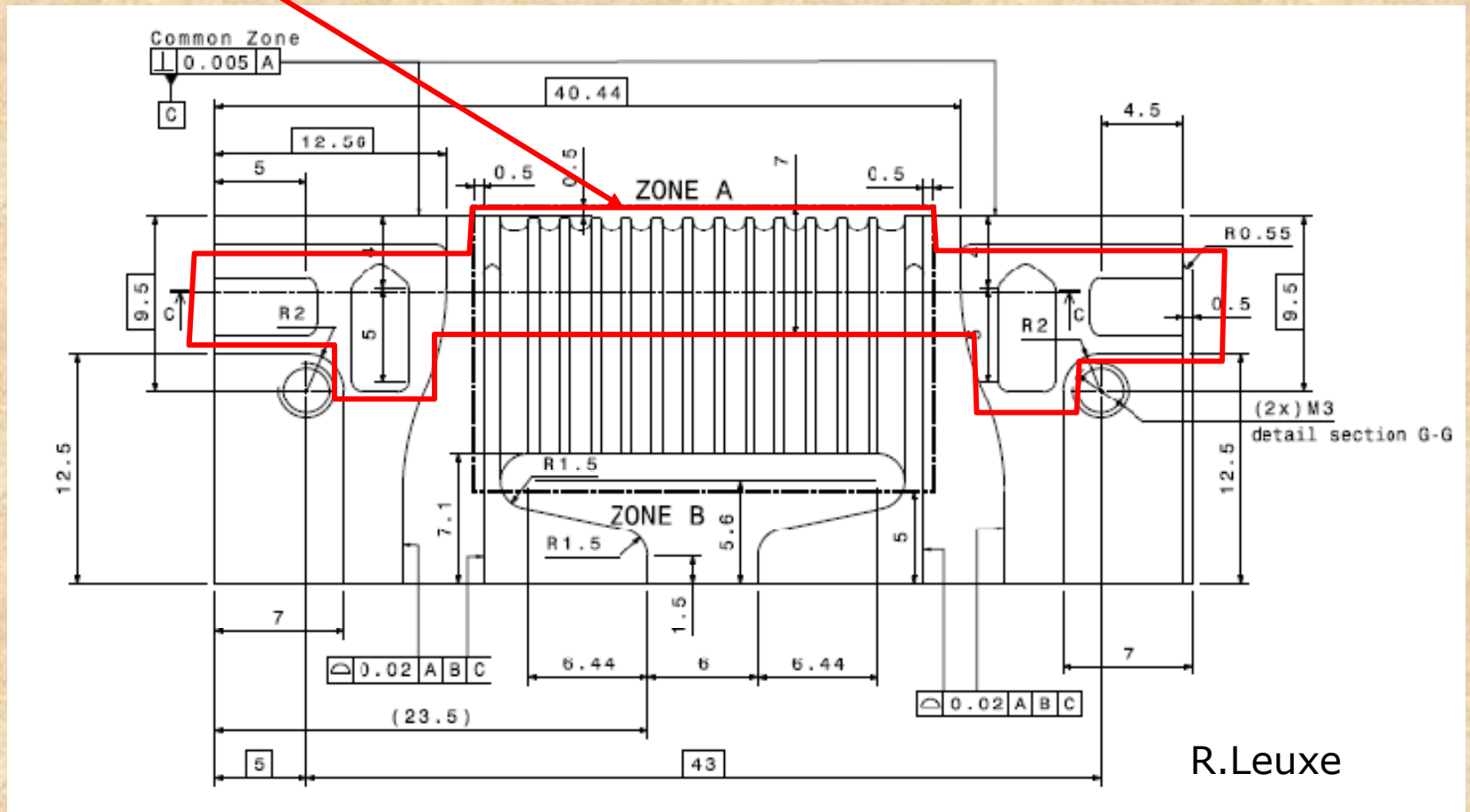


2. Avoid steps and kinks on the surfaces (field enhancement β)

3. Ra should be around ¼ of the skin depth to preserve electrical conductivity (0.1 μm)

Tolerances:

5 μm shape tolerance



Ways to approach target accuracy:

1. Production of structures at "acceptable" precision for CTF3/SLAC high power RF-testing (target +/- 0.01 mm on the shape) and exploit the learning curve of firms (Greenfox, Imtec, VDL….)

2. R&D Projects:
   KERN, μ-2010 project, EIG, Fraunhofer Inst. ?

Ongoing projects

KERN Feinwerktechnik (D): (CERN order June 2006)

- -Machine tool manufacturer (best accurate commercial milling centers in Europe)
- -Produced a first prototype (now at CERN metrology), second improved version will follow
- -CERN investment: 15K€ + materials

µ-2010: (start March 2007)

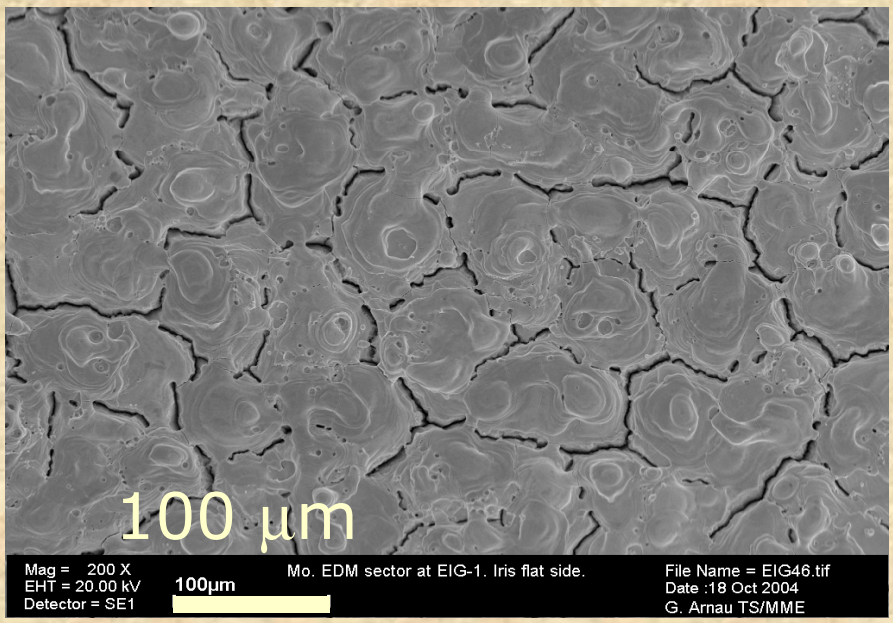
- group of French firms/institutes including ENSAM-Cluny and Mikron-France (machine tool manufacturer)
- will deliver a prototype end of July
- CERN investment: materials, investments for further phase to be discussed

HES-SO Genève: (start Feb 2007, 1y)

- EDM machining and surface finishing of refractory metals
- CERN investment: 20 KFr+ materials

EDM :

-Electro discharge machining of refractory metals
(micro-cracks on molybdenum), development in progress



HES-SO Geneva

-Parameters to avoid cracks on W are already determined
-Difficult to work in water (black layer); verify the possibility to get clean surfaces when working in oil

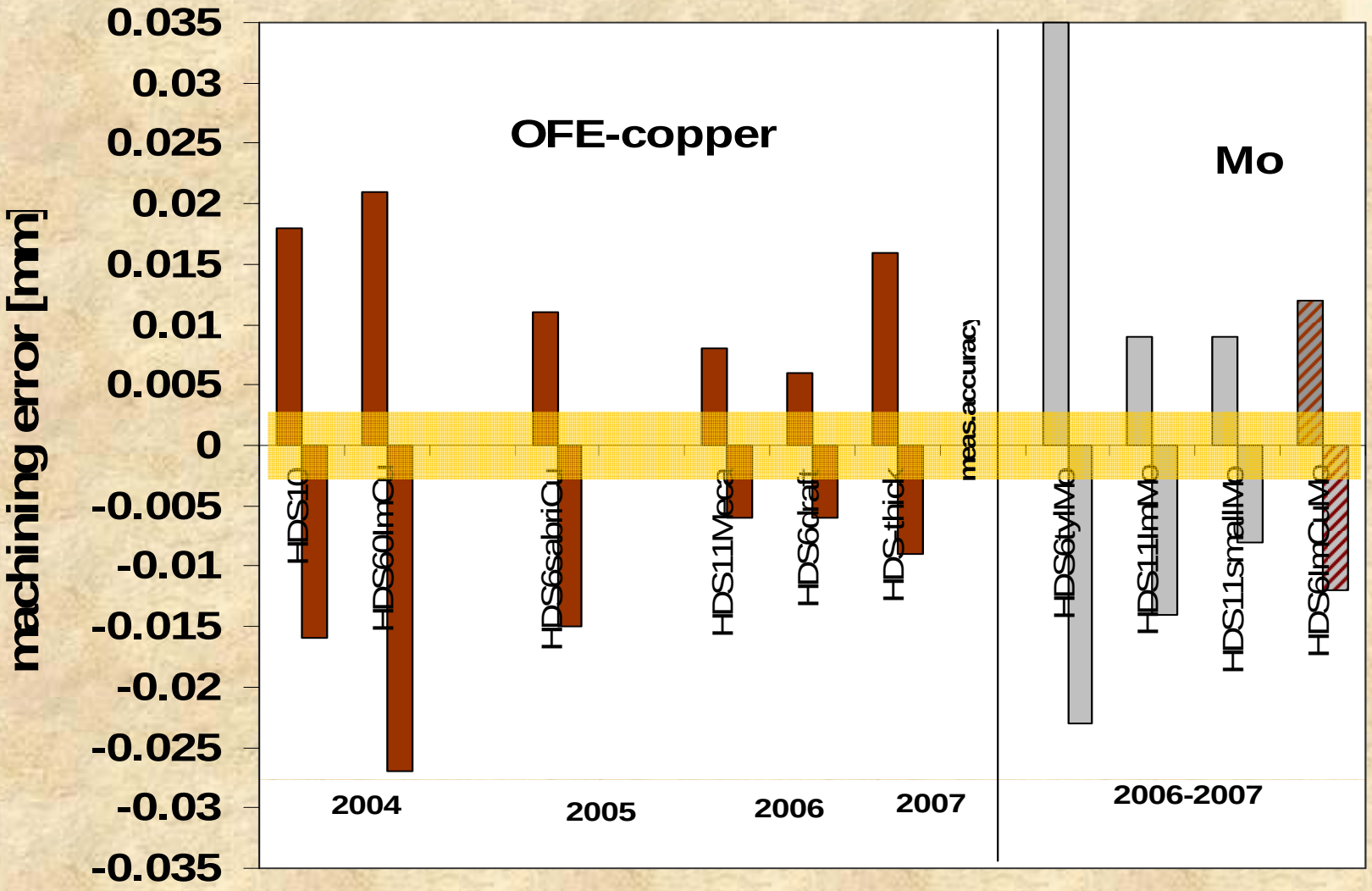
Machining technology applied so far to manufacture structures

- technology used so far: CNC milling, at high cutting speed (spindles at 20000-50000 rpm)

- positioning accuracy of the machine tools is 5 μm, two machines below 1 μm (range ~300 mm-500 mm)

-carbide or diamond (on copper only) tools (ball nose mills)

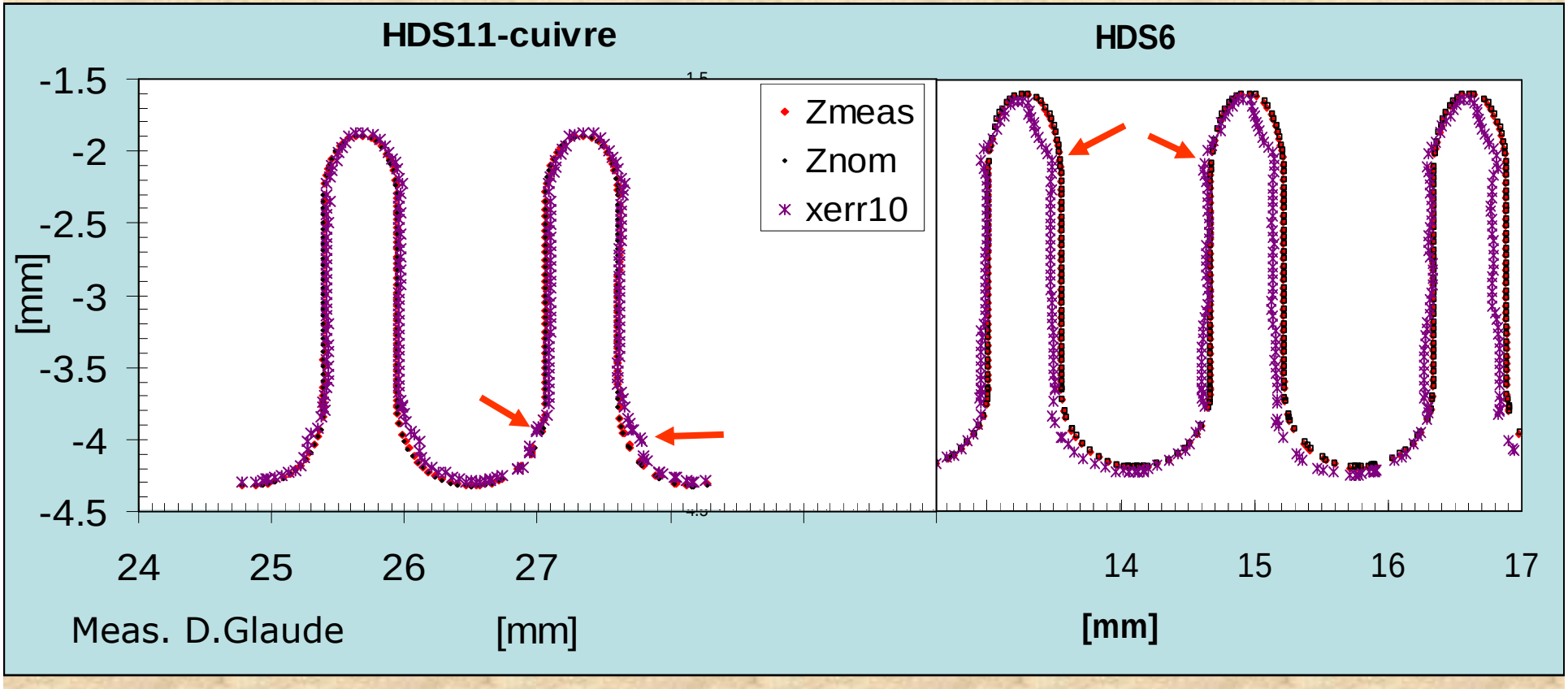
Achieved shape accuracy



Surface finishing on copper, Ra=0.1-0.4 µm

Metrology on copper quadrants

Measurement: coordinate measuring machine, contact with 0.1N force, accuracy **+/-3 µm** (at CERN), scan pt. by pt. on the surface ……in parallel with RF low power control

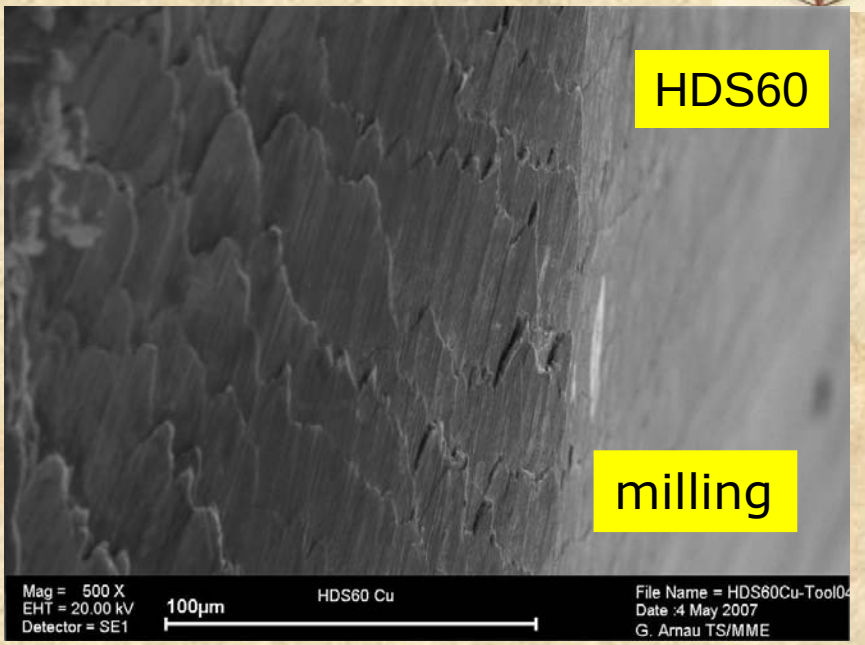


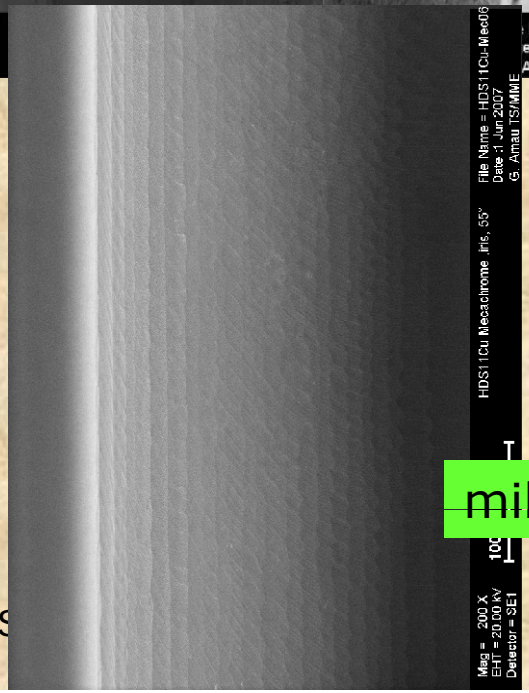
Possible sources of the error in 3D milling

-**Most important:** Error on tool diameter, tool length, tool run-out (dynamic dimensions)
-Error on tool shape
-Tool flexure (larger tools at 12GHz should be favourable)
-Tool consumption during machining

-Temperature stability and dynamics of the machine tool
-Positioning accuracy of the machine tool (machine tools with higher nominal accuracy have given better surface finish)

Surface quality: on copper





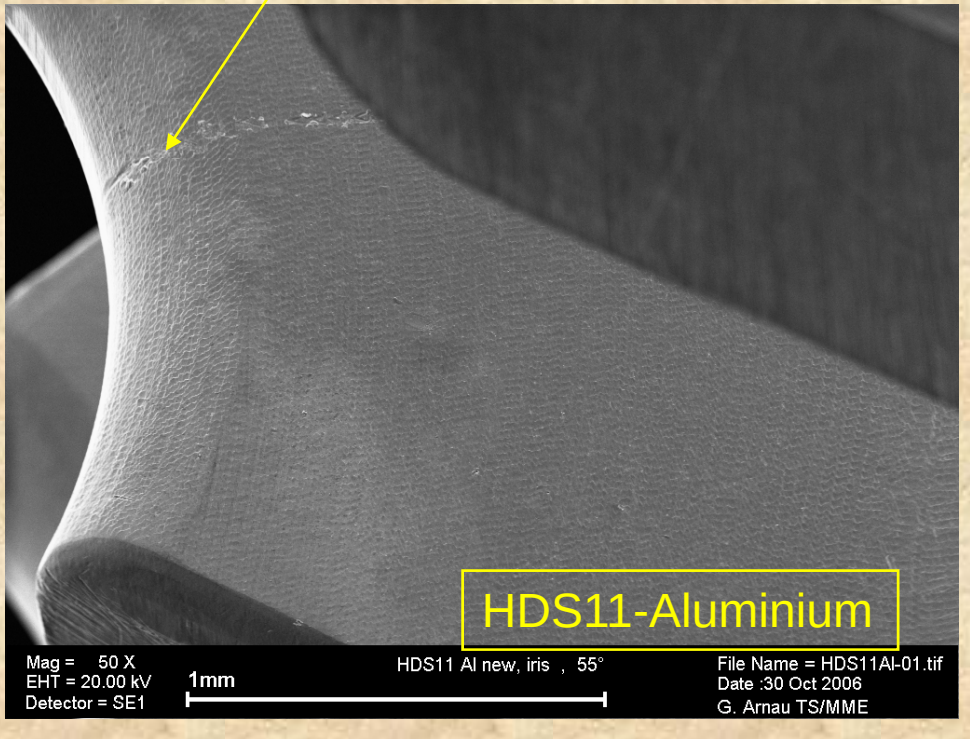
Surface quality still worse than diamond turning

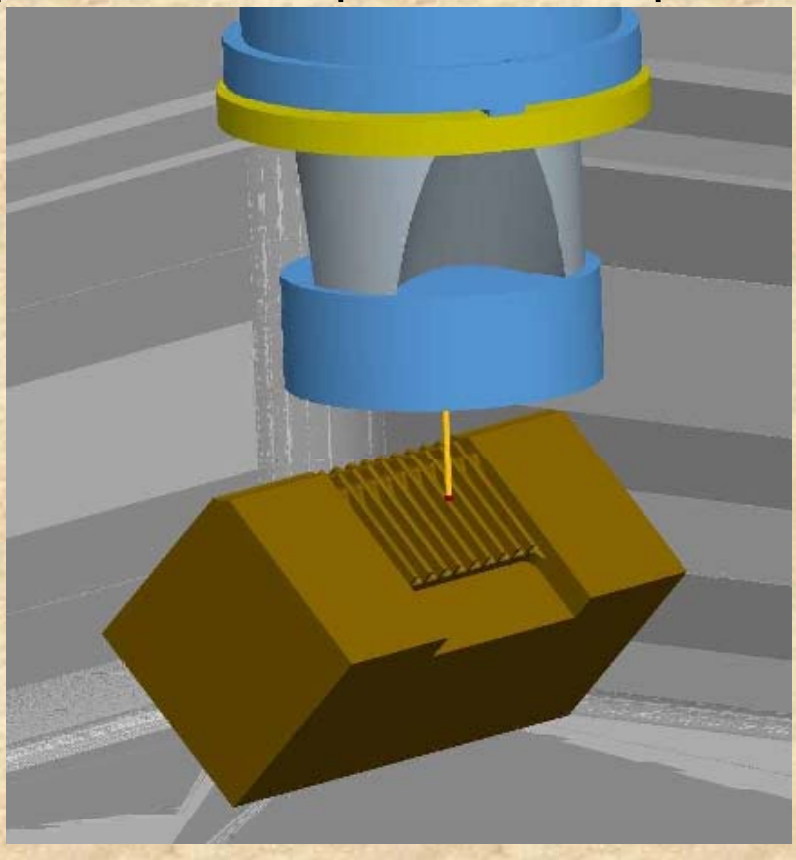
Image: G.Arnau-Izquierdo

Metrology

Requires high accuracy, ideally 0.1 μm to control at 1 μm level
Force of the sensor should be low (0.1 N leaves marks)
Available optical methods are not adapted for complex 3D shapes

Trace of sensor contact





Conclusions:

-Realistic goal for 2010 should be to demonstrate +/- 3-5 µm on a copper structure of 250-300 mm (CLIC size)

- +/- 1 µm needs major R&D investment and the market is still marginal for parts of this size

-Improving internal competence for high precision machining is necessary: through follow up, training or doing

-Internally we do not have a metrology equipment to control reliably below +/- 5-10 µm accuracy: needs better sensor (lower forces) and better CMM (higher positioning accuracy)

-Manpower for metrology is limited and feedback cannot be given fast to firms