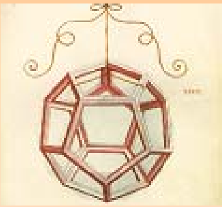
Material studies for CLIC RF-Cavities



M.Taborelli, TS-MME-SC

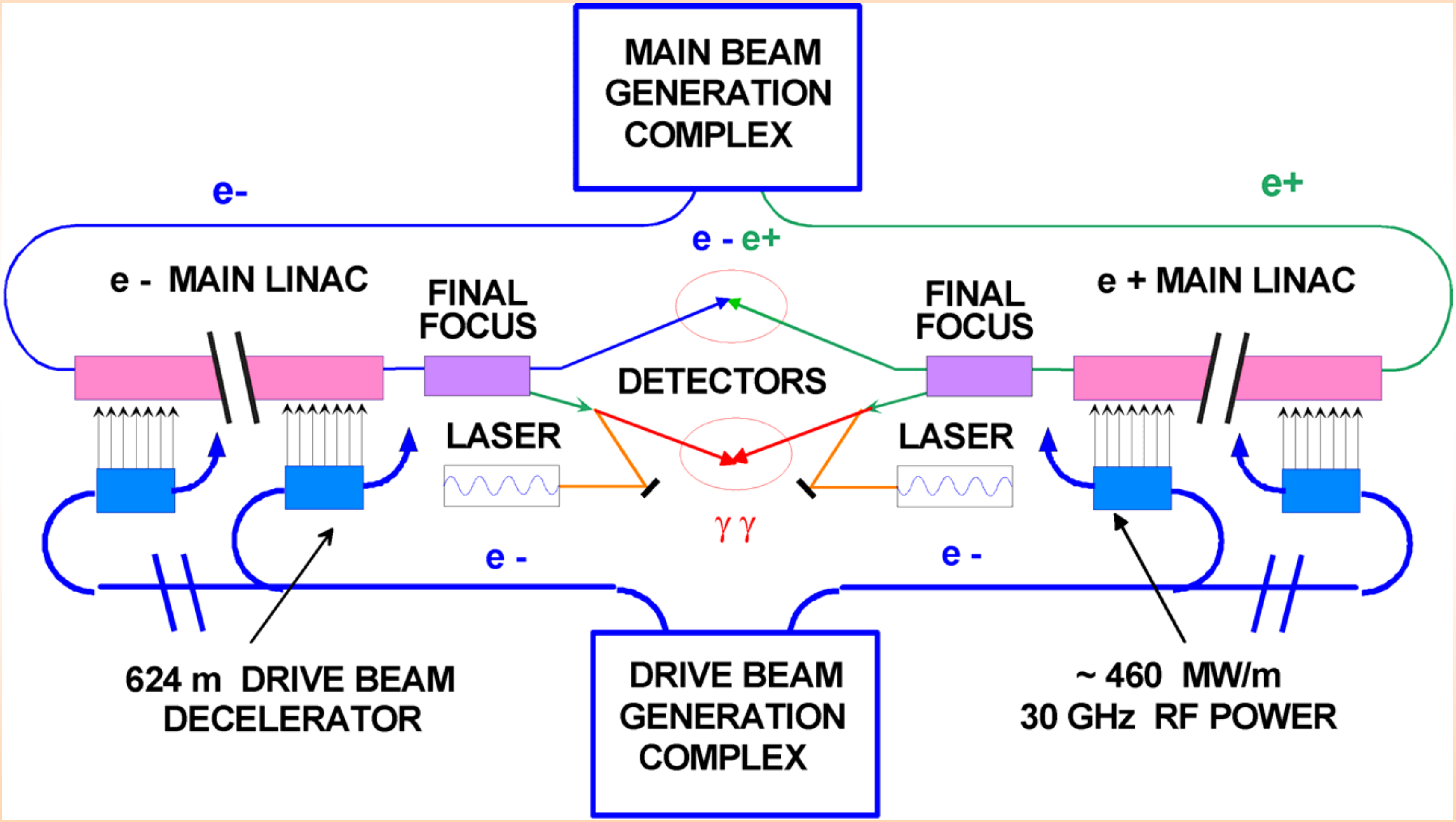
Summary:

I. Materials for high electric field regions of the main beam accelerating structures

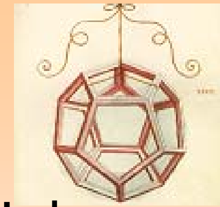
II. Fatigue tests for high current regions

III. The HDS prototype

CLIC main beam scheme



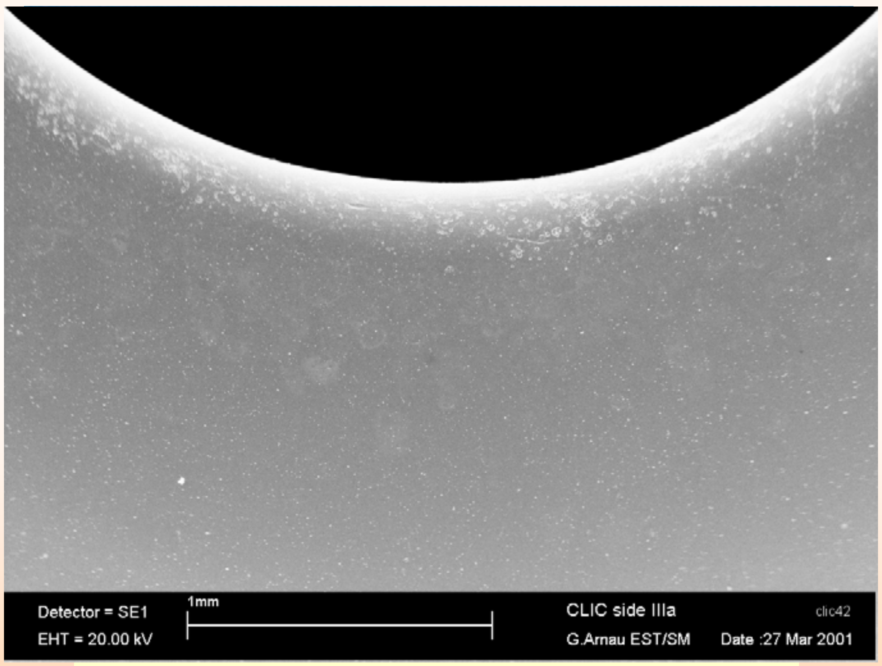
High E | Fatigue | HDS



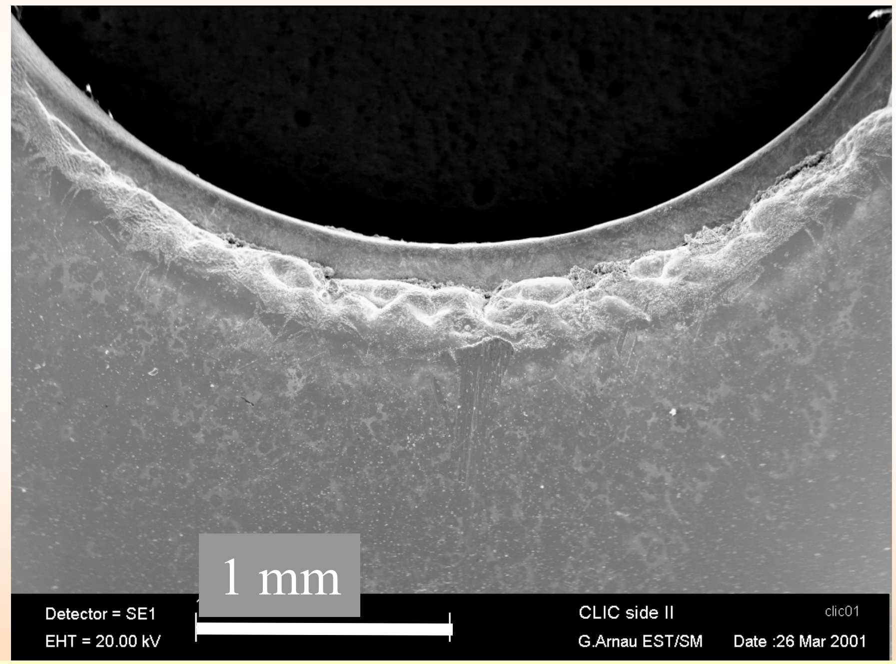
RF cavities: OFE Cu

Acceleration of main e^+/e^- beam 9 GeV ↗ 1.5 TeV : use high accelerating field to limit the machine length (15+15 km)

Problem: 150 MV/m acc. field ⇒ 400 MV/m peak surface field (LEP ~ 10 MV/m): breakdown and structure modification

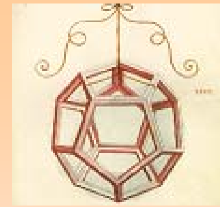


accelerating structures



OFE-Cu (cavity iris) after operation in CTF2 (~300MV/m)

High E | Fatigue | HDS

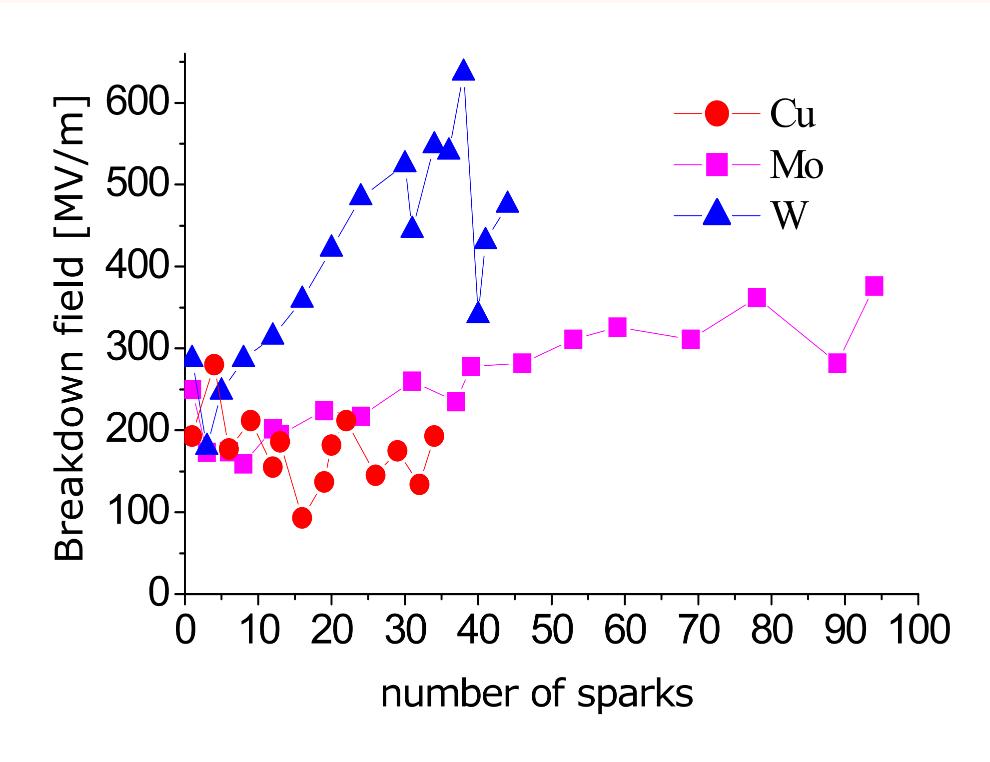


Material selection by DC spark

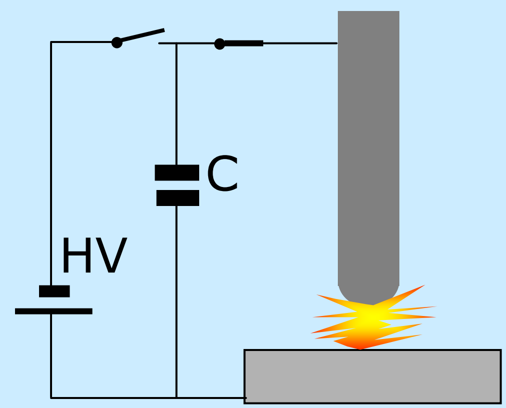
Idea: low vapour pressure material (Mo and W) in high field regions

⇒ improvement verified in simple DC-spark test (tip-sample geometry) and field emission behaviour

⇒ prototype accelerating structure

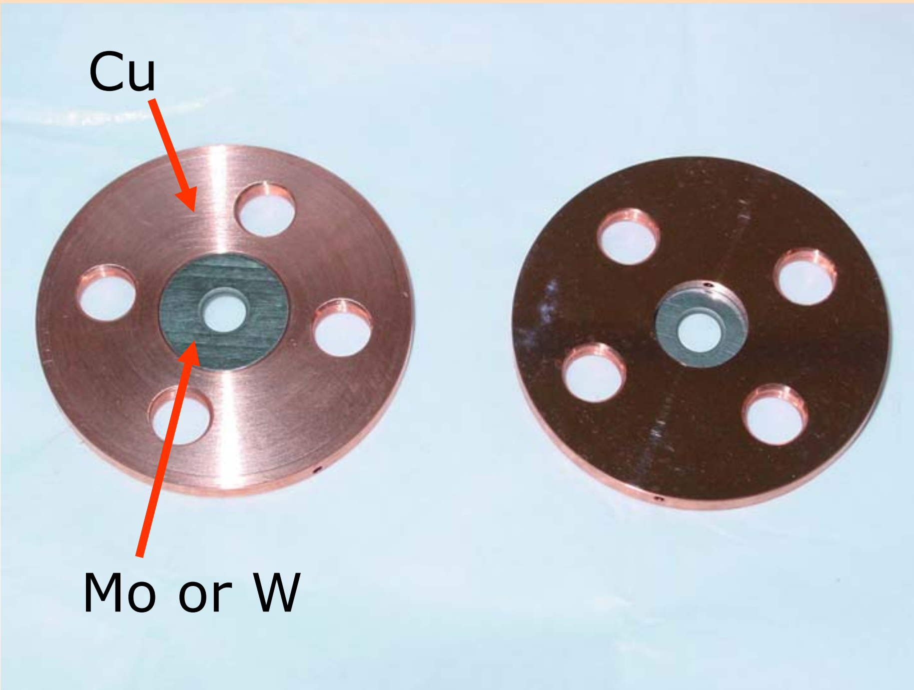


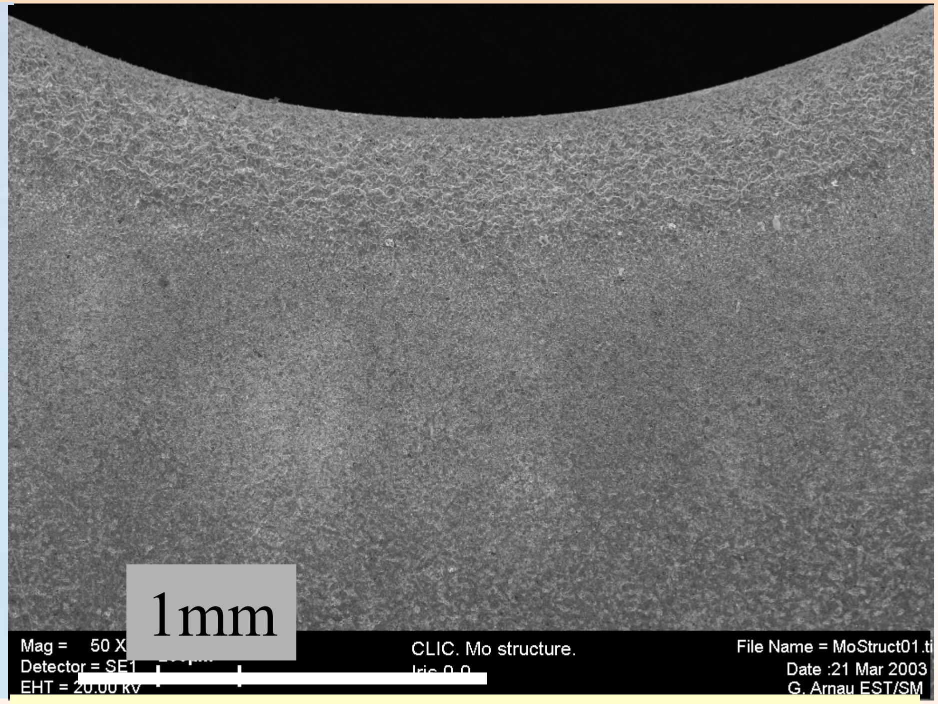
DC spark test in vacuum:



High E | Fatigue | HDS

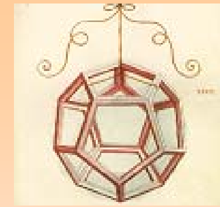
RF cavities, second generation: W and Mo





Mo iris after testing in CTF2 up to 420 MV/m : only minor modifications

Use Mo or W in high E regions
Solve machining issues and improve conditioning speed



Fatigue testing by laser irradiation

High intensity RF magnetic field pulses induce high currents on the surface of the cavity periphery (Cu region)
$\Rightarrow$ pulsed heating and local thermal “expansion”
$\Rightarrow$ resulting mechanical stress and fatigue

10^{11} pulses, 100 ns long, during accelerator lifetime: no available material data

Simulate with pulsed laser irradiation:

UV laser (308 nm, 50 ns, 20 Hz repetition rate)

induces ΔT pulse

exponential T decay in depth (1/e at 400 nm)

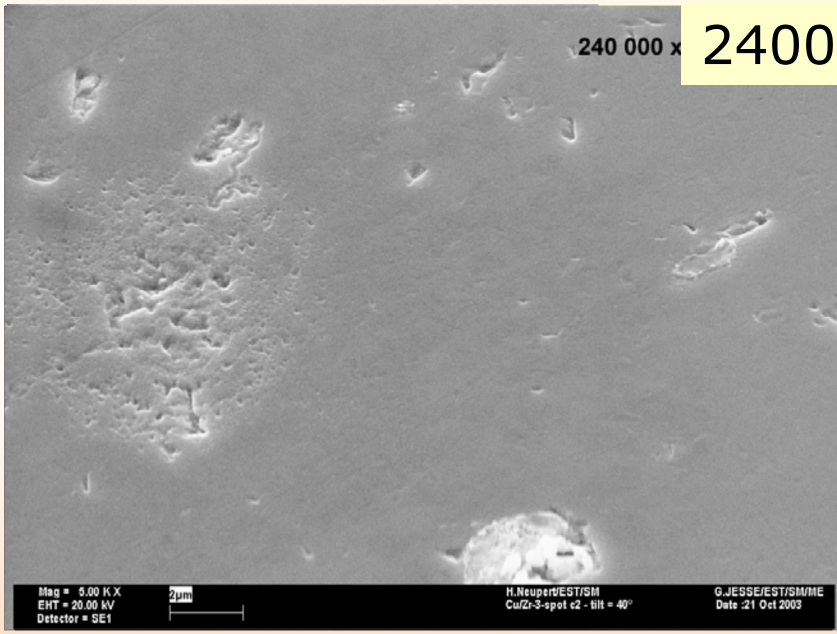
ΔT at surface proportional to incident power density

Effect of laser pulse on Cu and CuZr

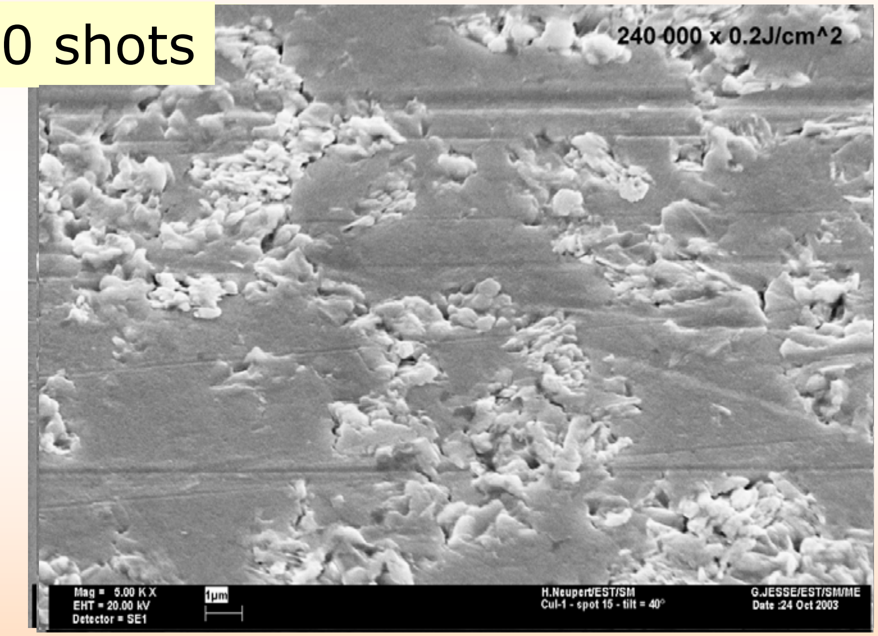
Compare Cu and Cu-Zr (precipitation hardened alloy C15000, 0.15% wt Zr) , diamond machined surfaces

$0.2\ J/cm^2 \Leftrightarrow \Delta T=120K$

240000 shots



Cu-Zr

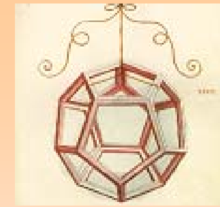


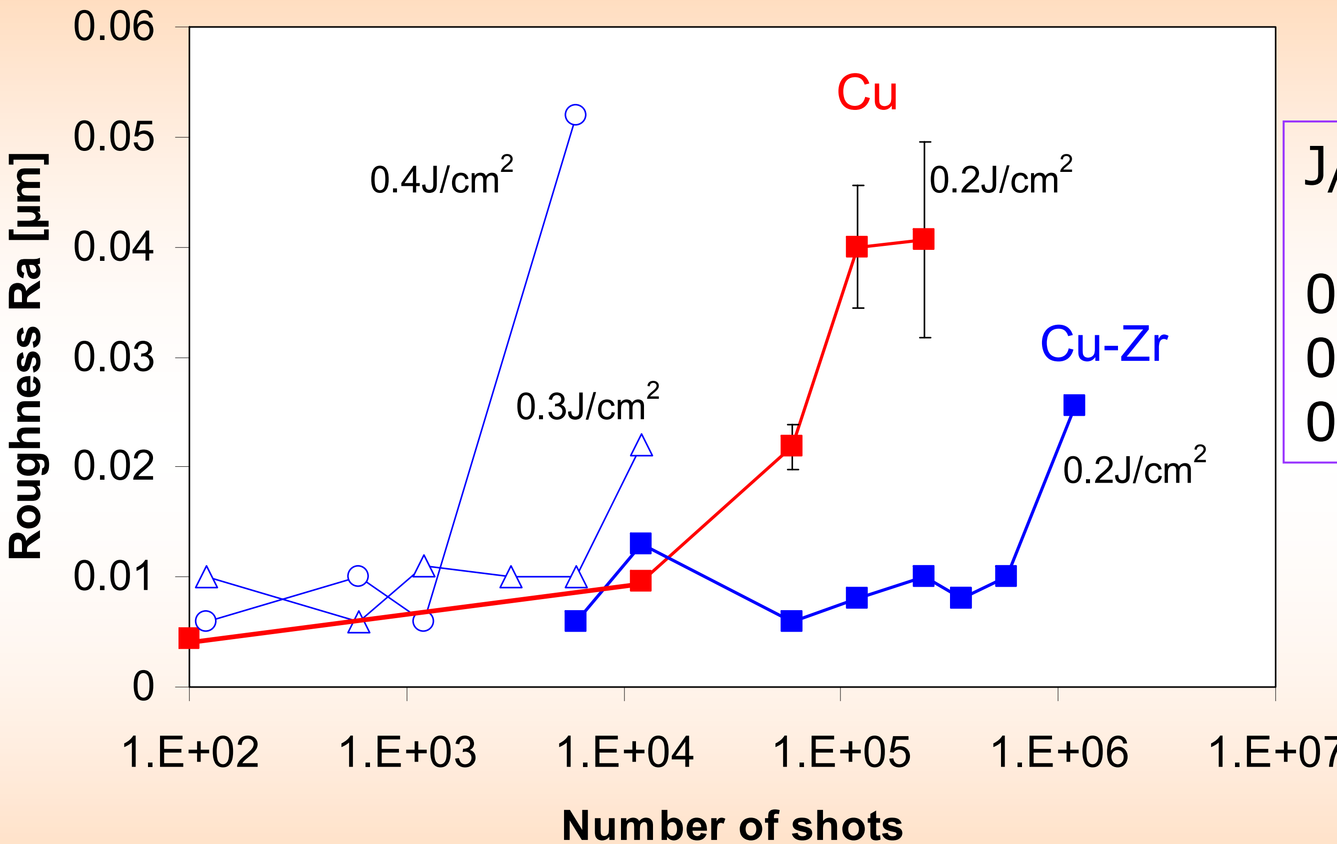
Cu-OFE

2 µm

High E | **Fatigue** | HDS

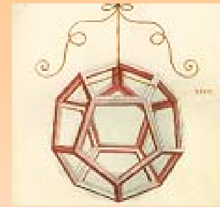
Quantitative effect:





J/cm^2	ΔT
0.2	120K
0.3	180K
0.4	240K

Cu-Zr can withstand about 50 times more pulses before reaching the same level of damages



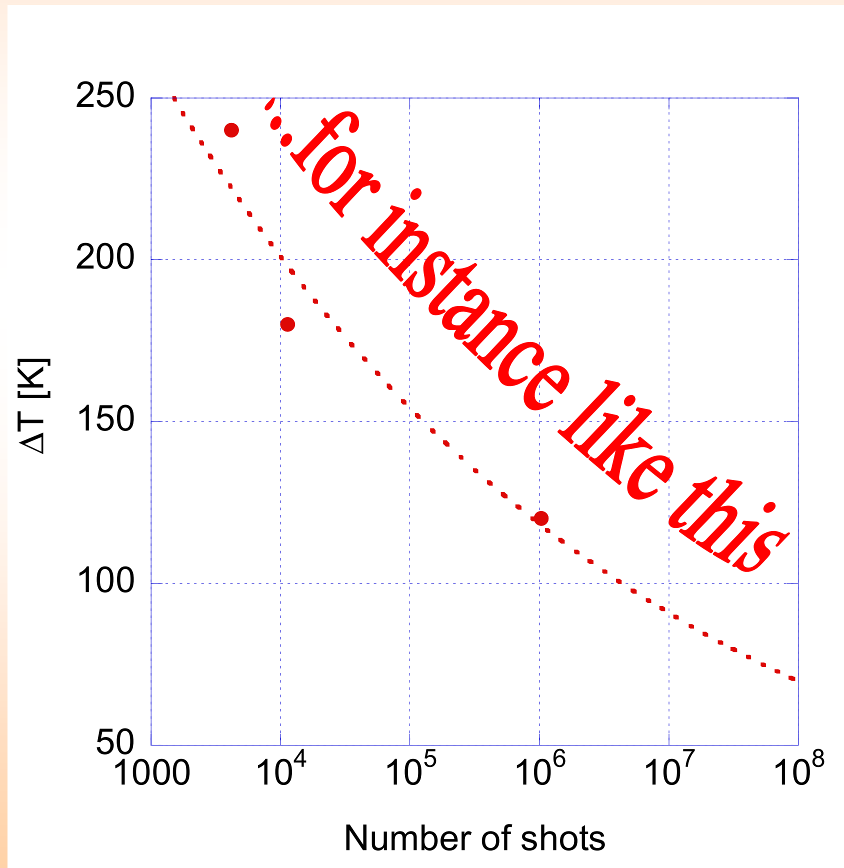
Quantitative: extrapolation

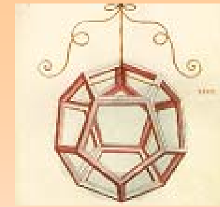
Nominal (and possible) local ΔT set at 56K for CLIC

Implies a huge number of laser pulses to see an effect

Idea:

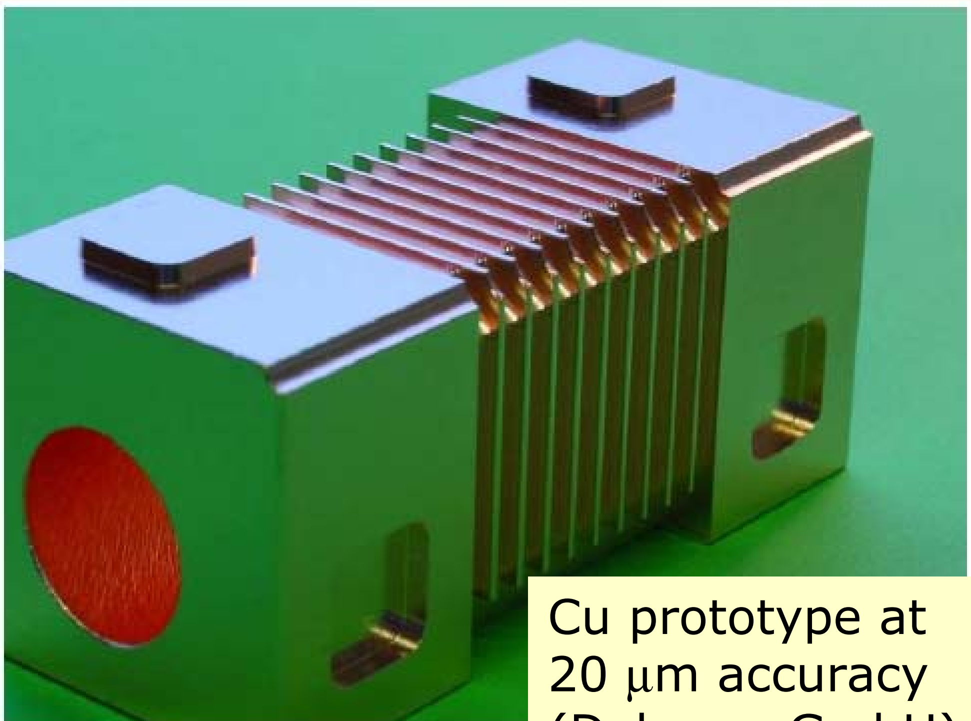
- Measure at lower and lower ΔT (0.15 J/cm^2 ⇔ 90K is in progress)
- set a maximum tolerated level of induced roughness
- extrapolate the number of shots to get the same roughness at ΔT=56K





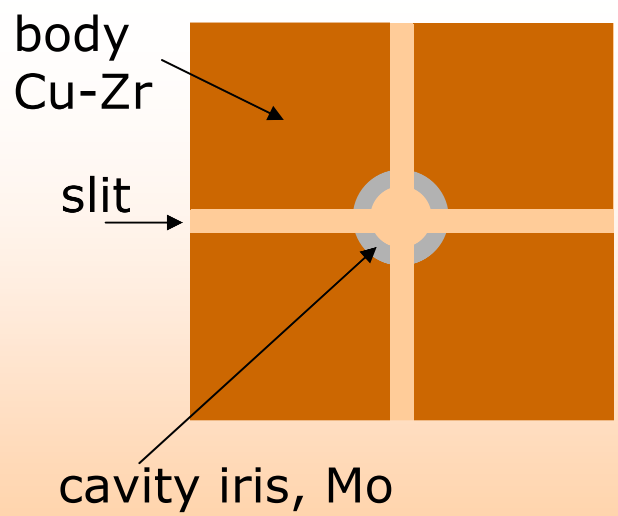
Conclusion: Hybrid damped structure

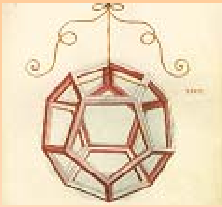
- Cu-Zr body with Mo iris tips
- accelerating structure build of 4 assembled blocks
- TS-MME in charge of fabrication of prototype at 5 μm accuracy



Cu prototype at 20 μm accuracy (Dahmen GmbH)

Final assembly





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