The CLIC accelerating structure development program

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CARE05
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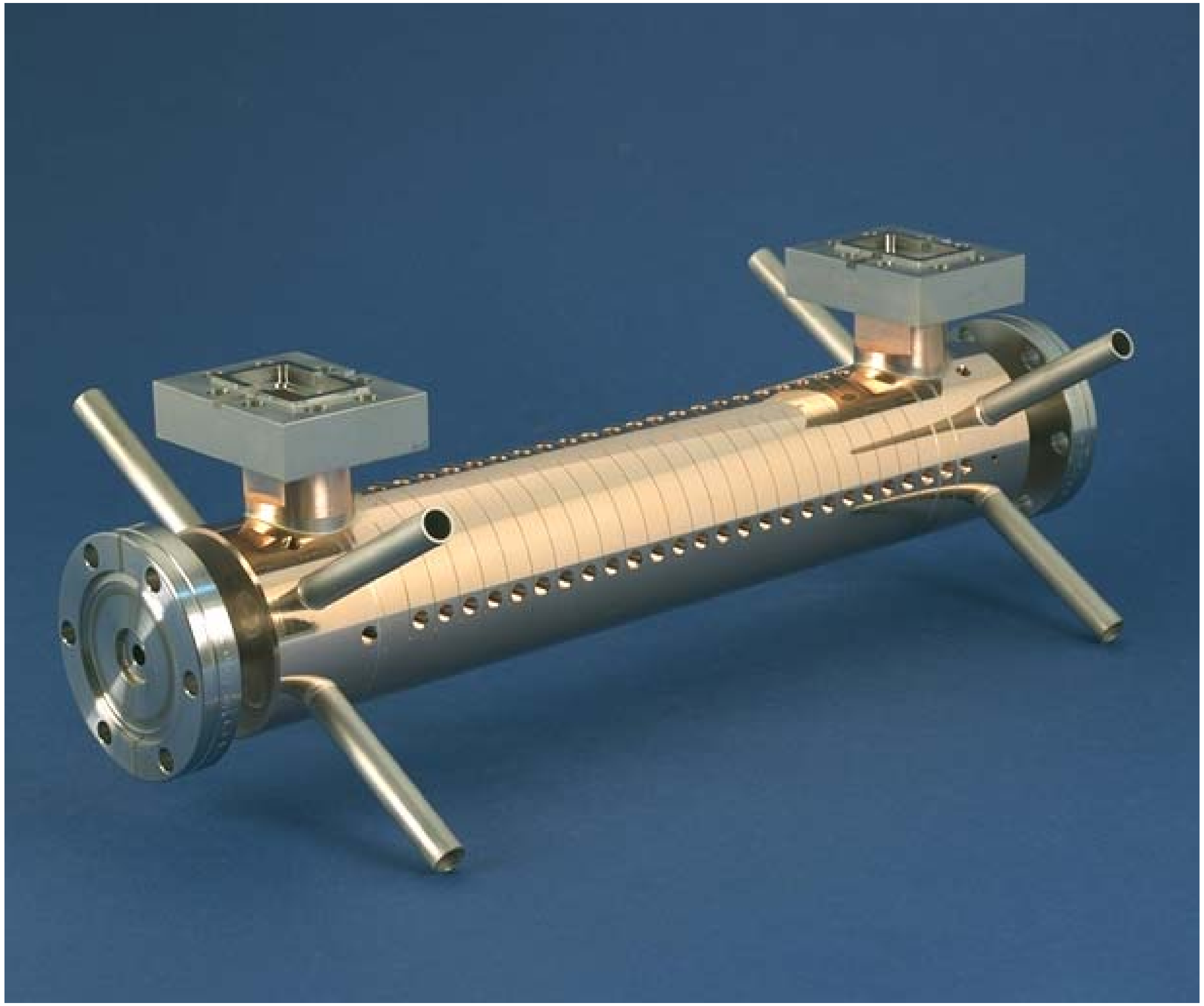
The CLIC design gradient of 150 MV/m was first achieved in a CLIC built structure tested at SLAC in 1994. Pulse length 150 ns.



11.424 GHz
0.114 a/λ
0.011 vg/c
Copper
Diamond turned
Vacuum brazed
Peak E_{acc} 153 MV/m
150 ns
69 MW
Peak E_s 326 MV/m
46 hr conditioning

So why does CLIC still have a high-gradient development program?

The $a/\lambda=0.114$ of this structure is low compared to
accelerating structures in linear collider parameter lists
so if you used it
you would expect to get
higher wakes, higher emittance growth and consequently an inefficient machine

but raising the a/λ immediately lowers achievable gradient (NLC structures)
on the other hand
shortening the pulse length increases achievable gradient (CTF2 structures)
but this again is inefficient

The other big high-gradient effect we face is pulsed surface heating:
Here again we face a compromise between gradient and efficiency
especially through damping features.

Our development program seeks to establish solutions for

high gradient

combined with

high efficiency

Our main lines of attack

New materials for higher gradient for fixed geometry and pulse parameters – for both rf breakdown and pulsed surface heating. We need to generate our own rf breakdown and fatigue data. Many many technological issues.

rf design for low surface field, E and H, structures – fully three dimensional geometries. Demanding computation and fully 3-d micron-precision machining.

rf design for short pulses – Very strong damping. Demanding time domain computation and fully 3-d micron-precision machining.

Fully integrated optimization procedure – optimization of structures and linac made together because the interplay of rf efficiency and emittance growth is not trivial.

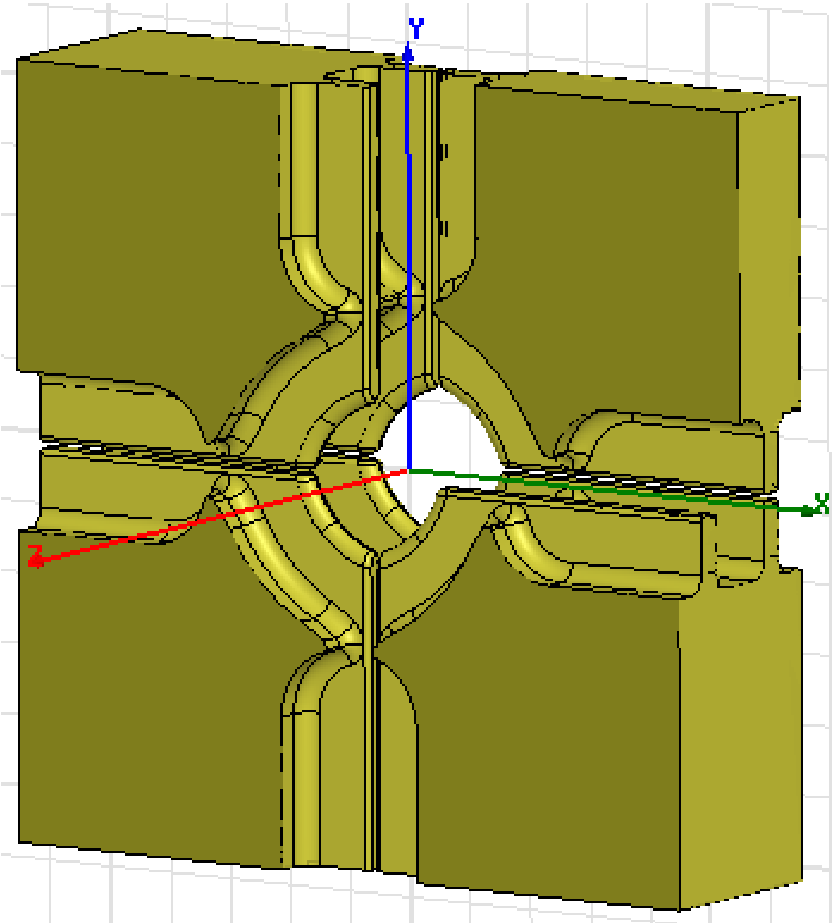
rf design for low surface field structures

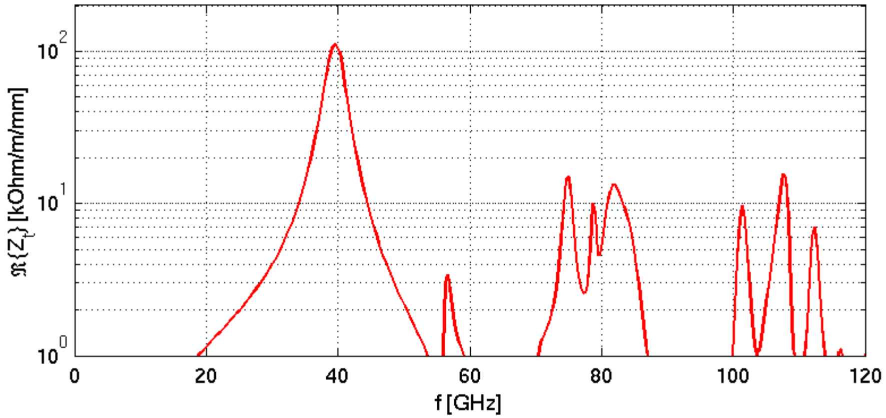
and

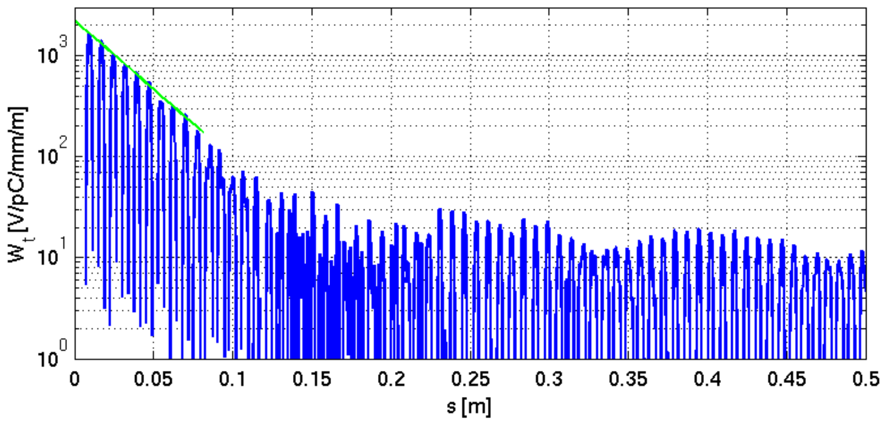
short pulses

Hybrid Damped Structure (HDS)

Combination of slotted iris and radial waveguide (hybrid) damping results in low Q-factor of the first dipole mode: ~ **10**

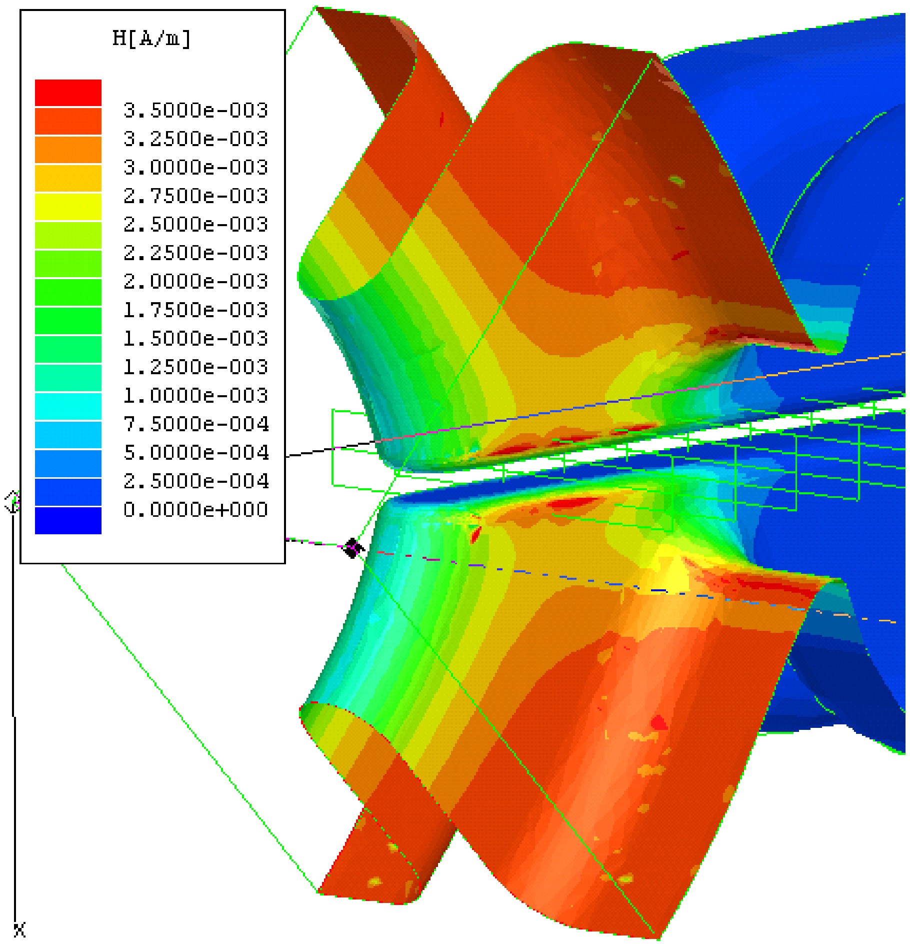




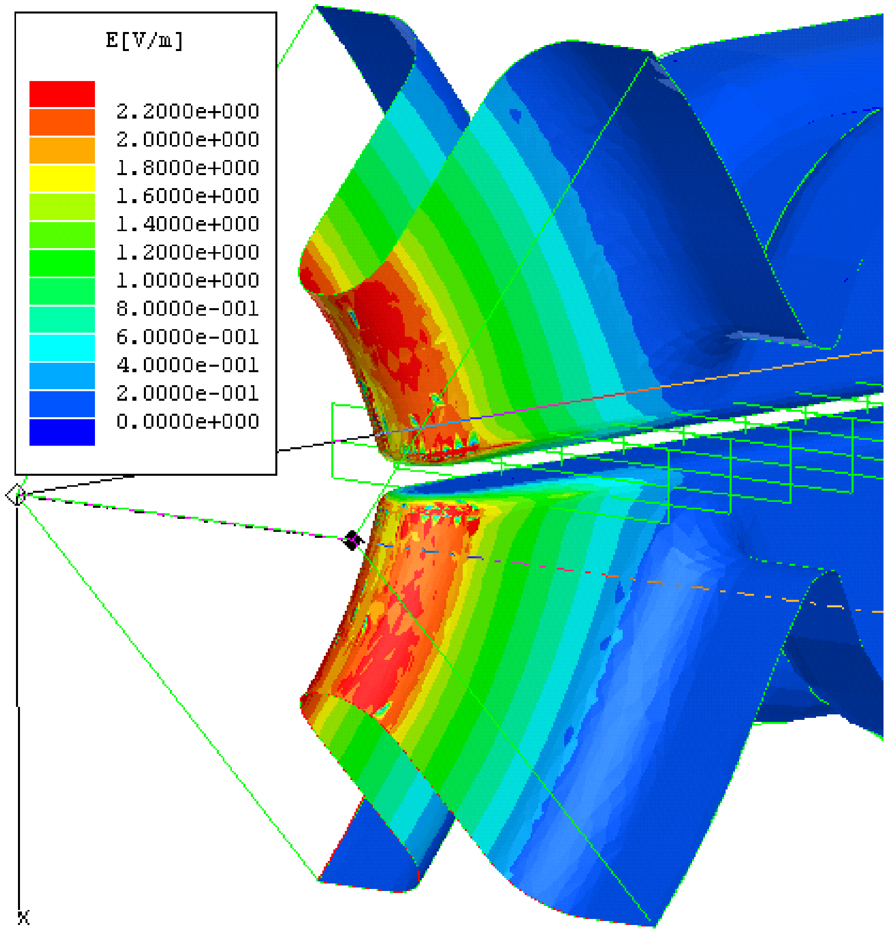


HDS cell design

Surface magnetic field

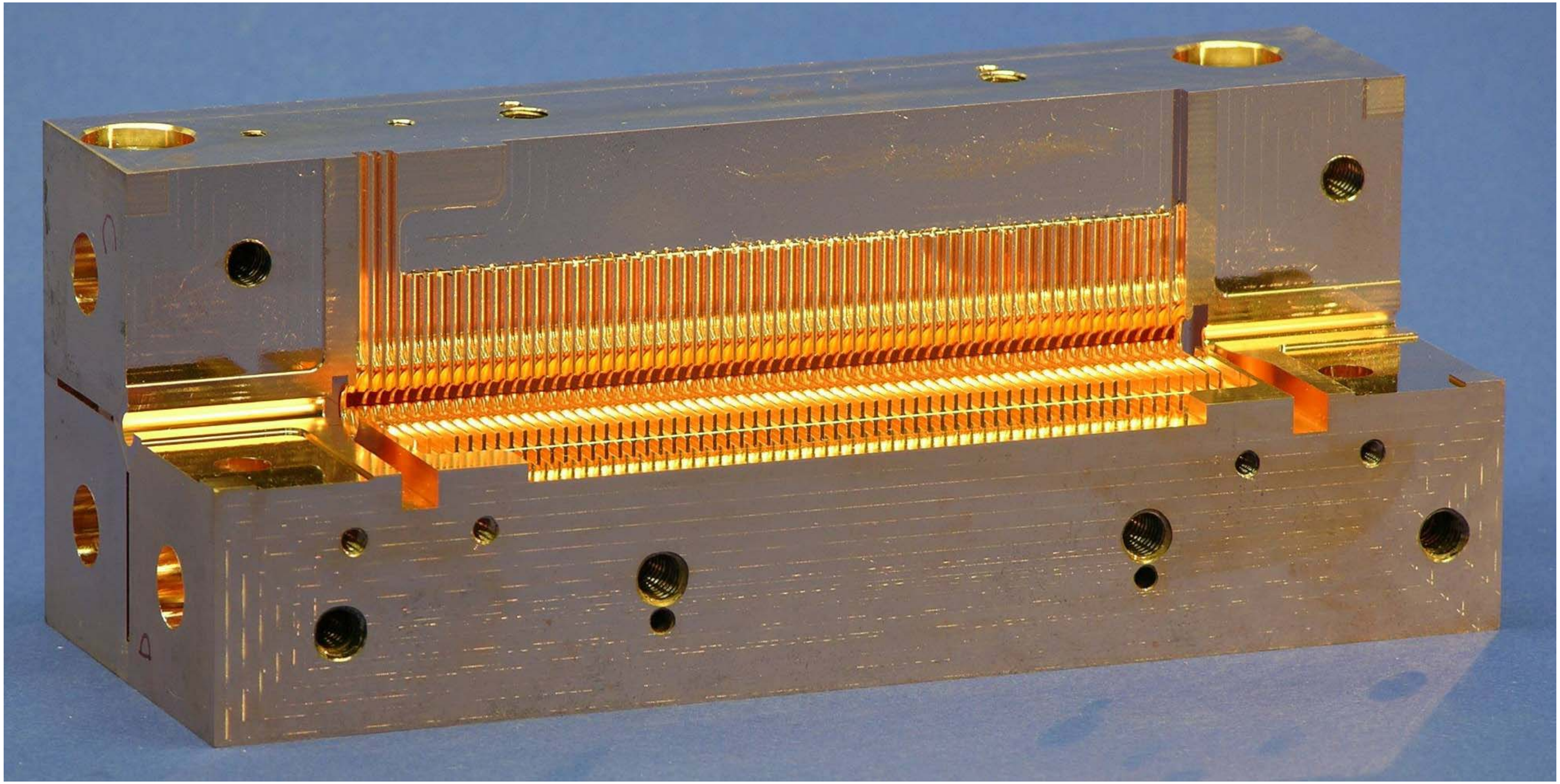


Surface electric field



HDS 60-cells Cu prototype

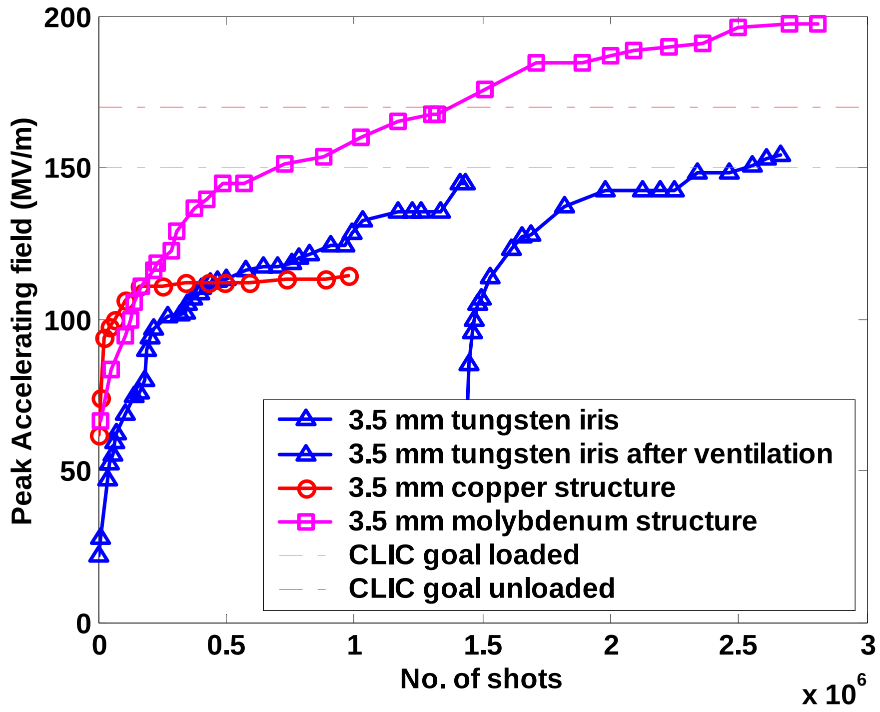
High speed 3D-milling with 10 μm precision



New materials for rf breakdown and pulsed surface heating

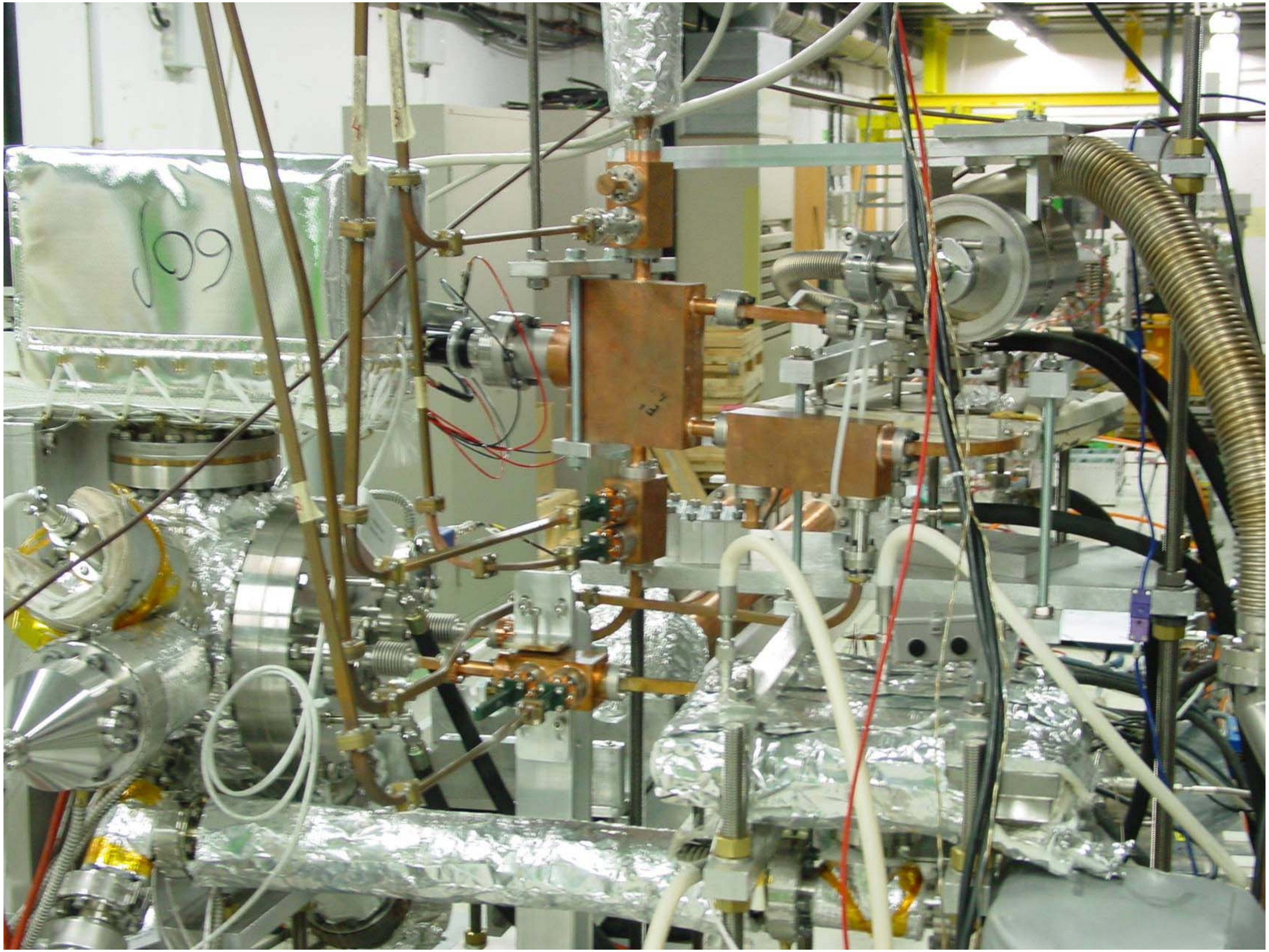
30 GHz testing results: Cu, Mo and W iris

16 ns pulse length in CTF2

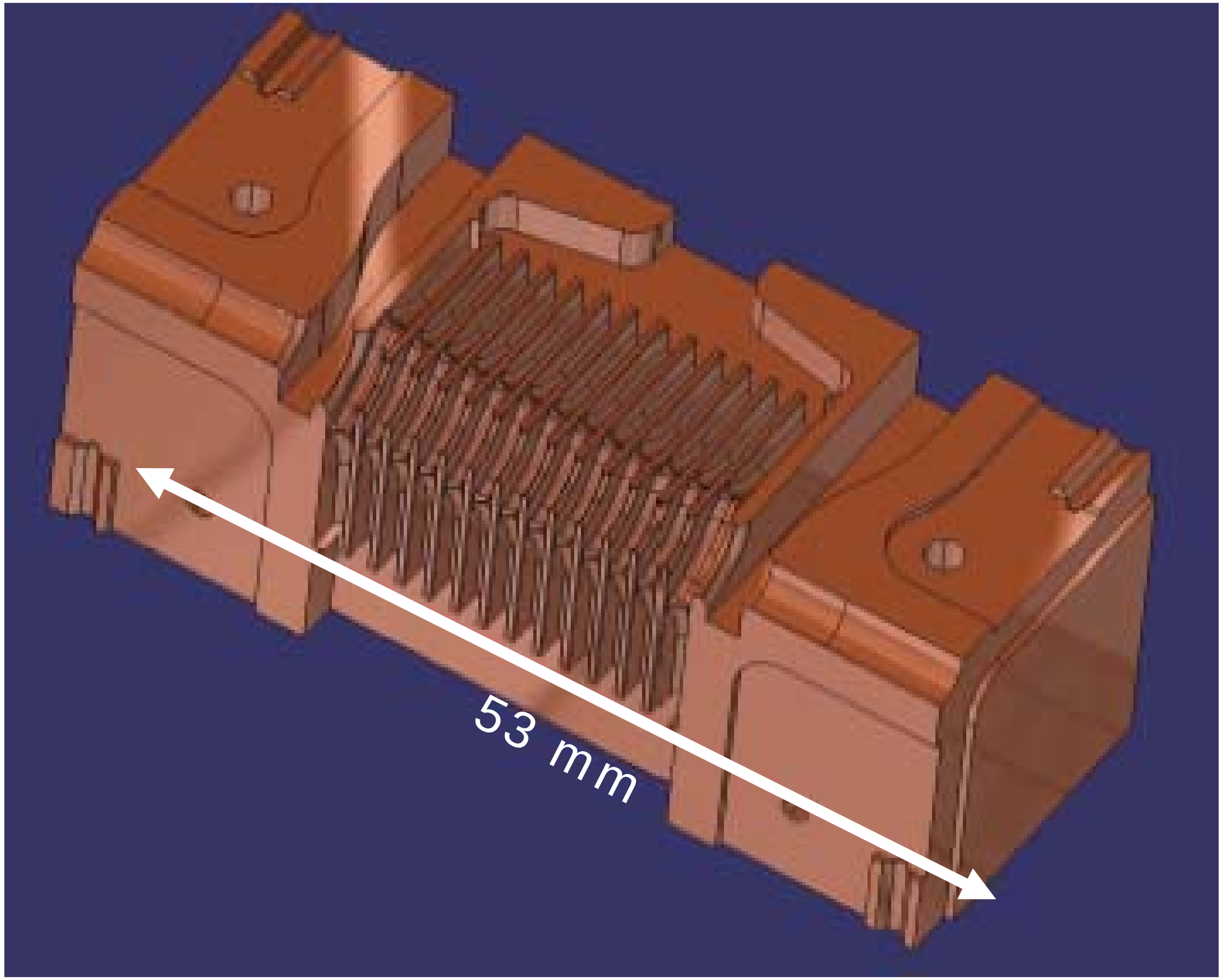


Breaking news! Longer pulses are being achieved in a new Mo iris test! Progress report next week in the CTF3 collaboration meeting!

30 GHz accelerating structure testing area in CTF



30 GHz testing program in CTF3

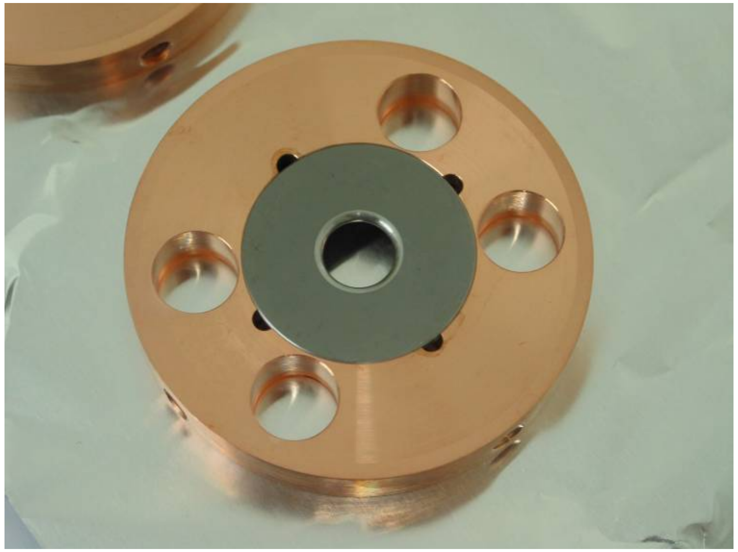


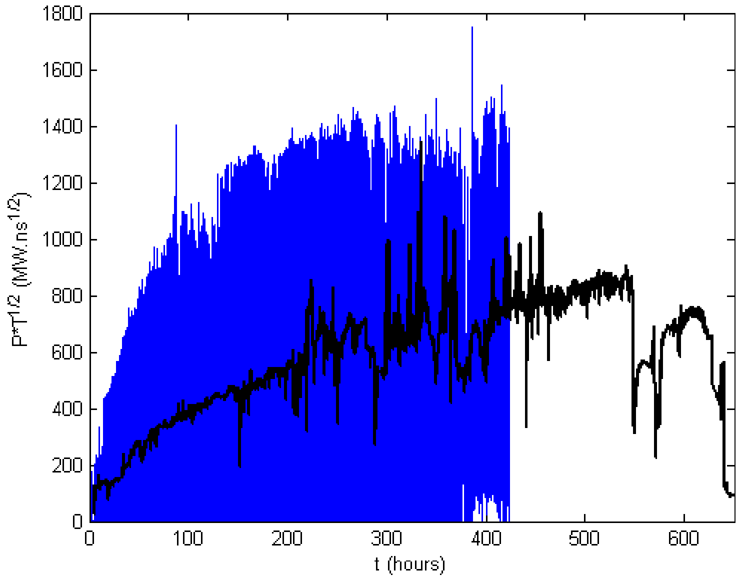
Circular structures:
Mo iris – under test
Cu 2π/3
Cu π/2
W iris

HDS60, 60°, Cu

HDS11, 60°:
Cu,
Mo,
stainless steel,
Ti,
Al

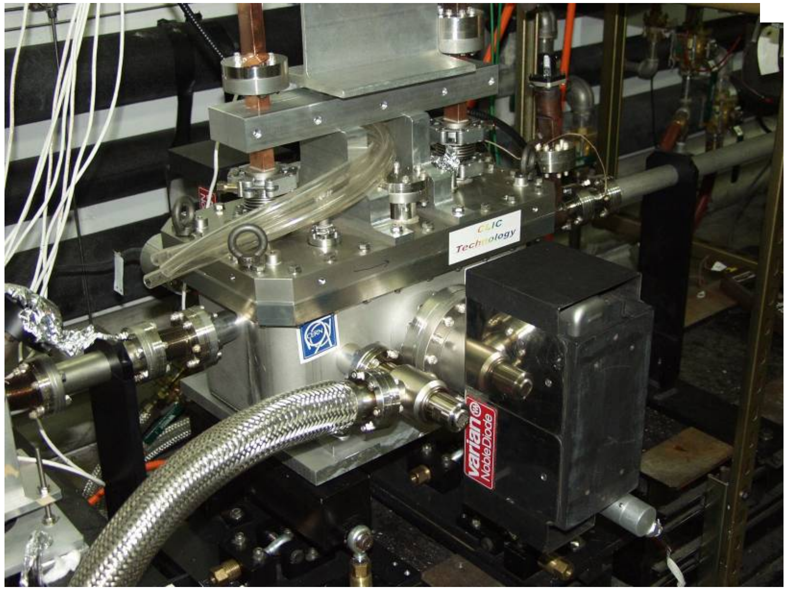
CLIC X-band testing at NLCTA



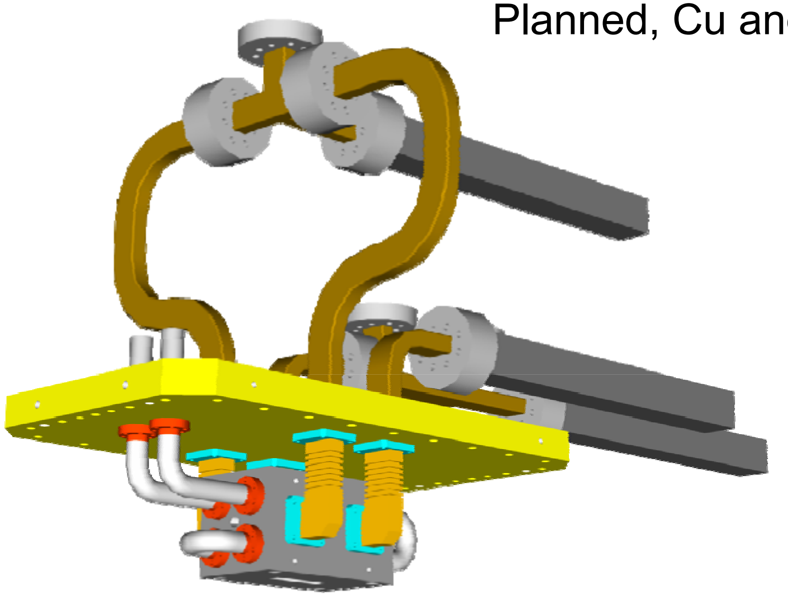


W, 93 MV/m 70 ns, ongoing

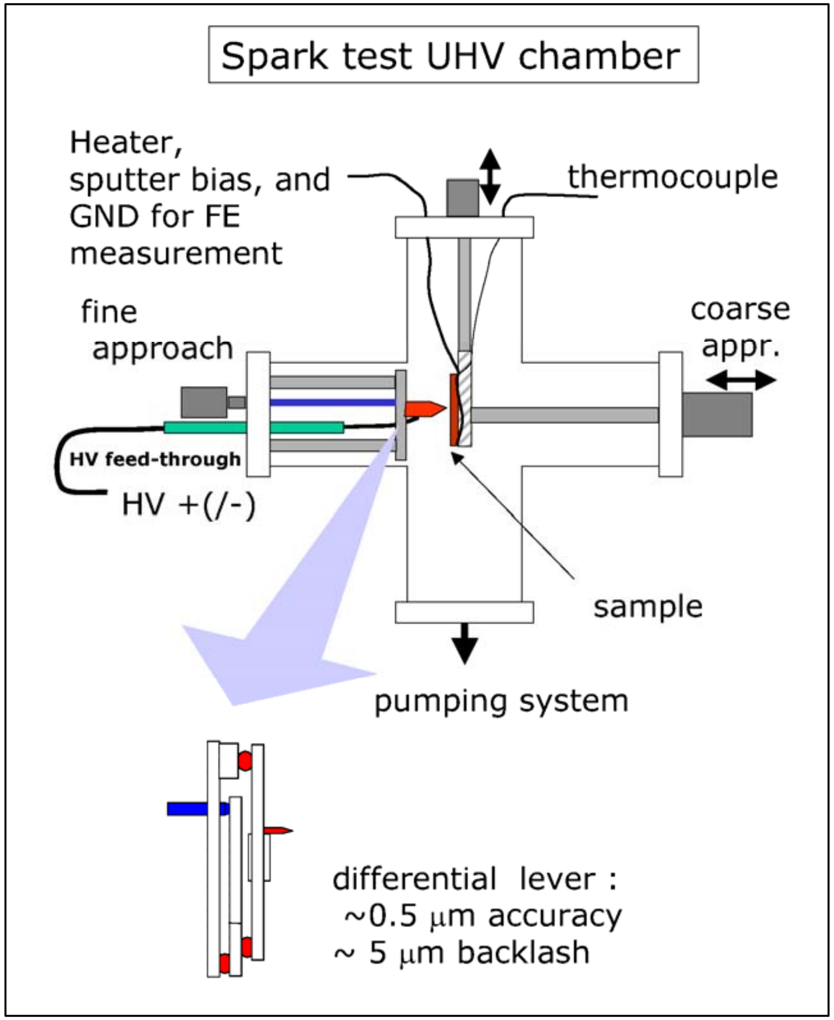
Mo, 87 MV/m, 30 ns, conditioning strategy?



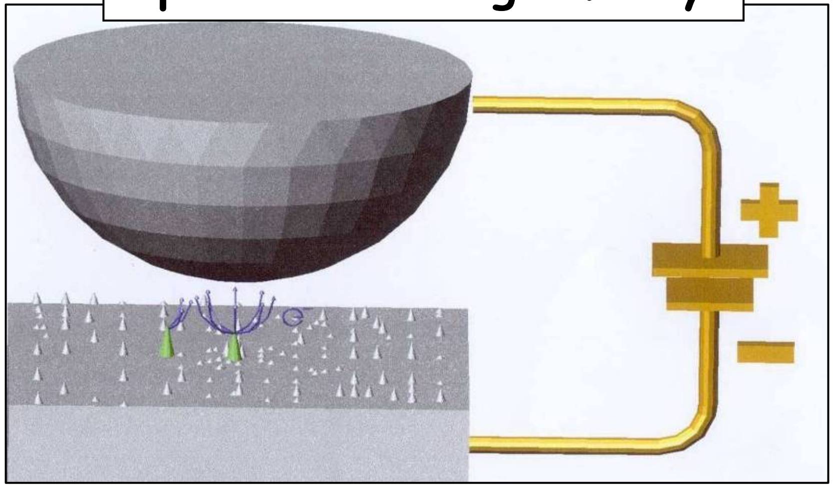
Planned, Cu and Mo HDS

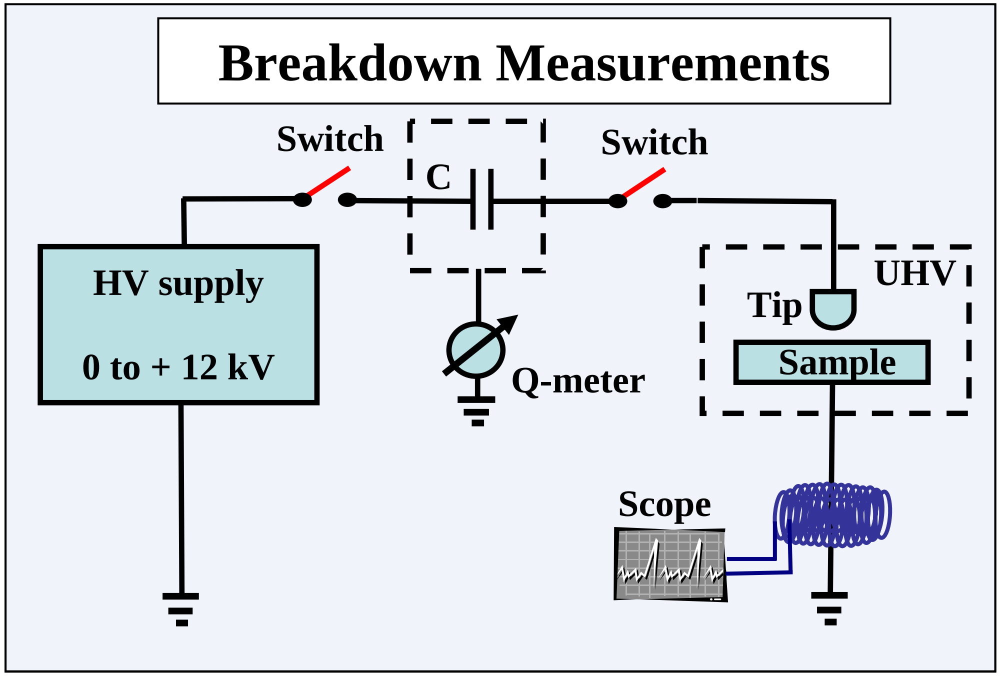


dc spark: materials, preparation techniques, breakdown physics

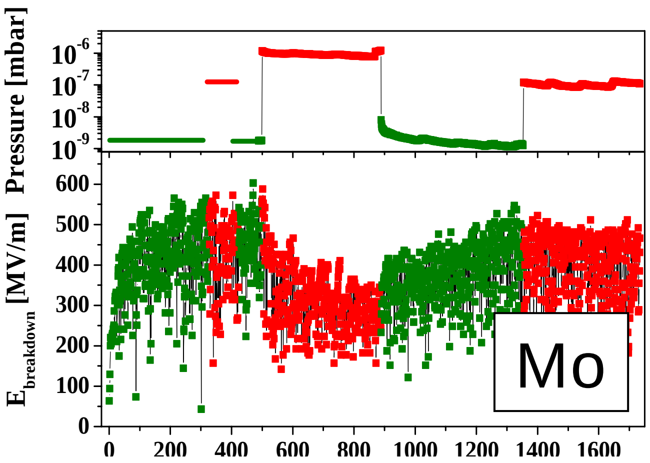


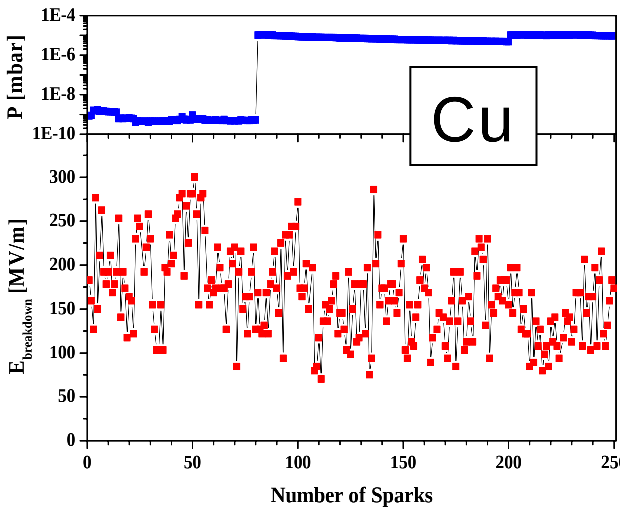
Sphere / Plane geometry

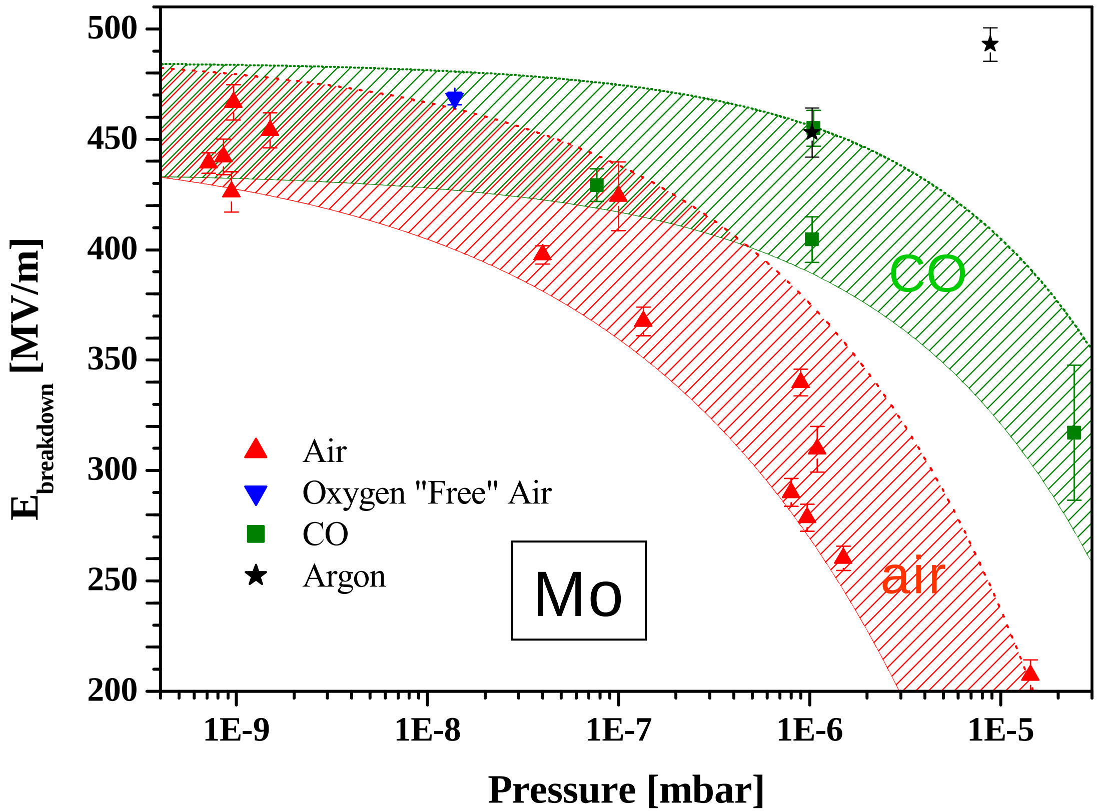




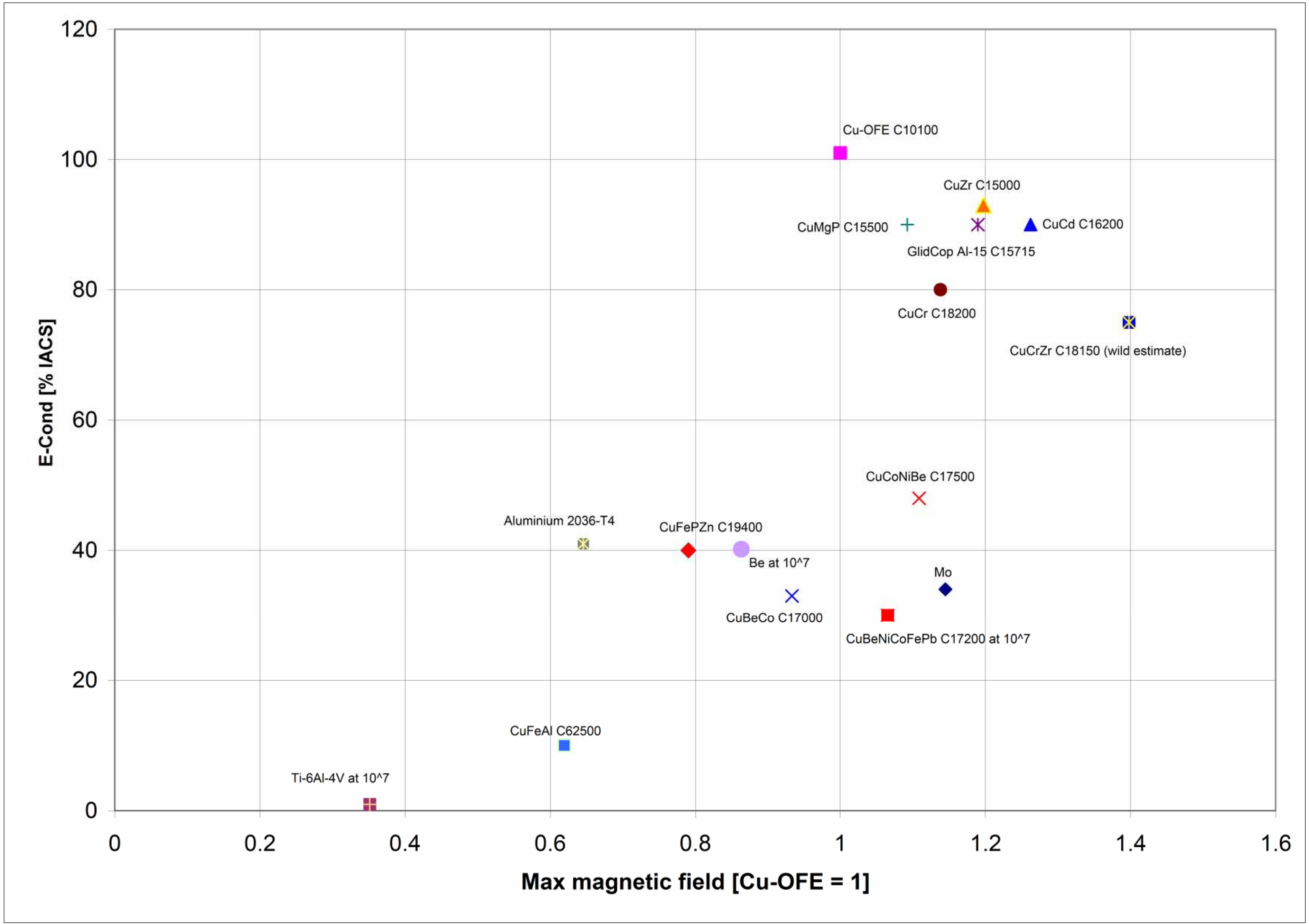
dc spark example: effect of vacuum level on breakdown level





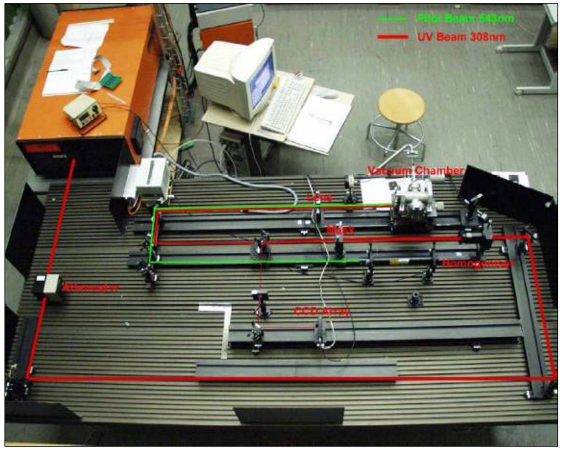


Fatigue strength of materials

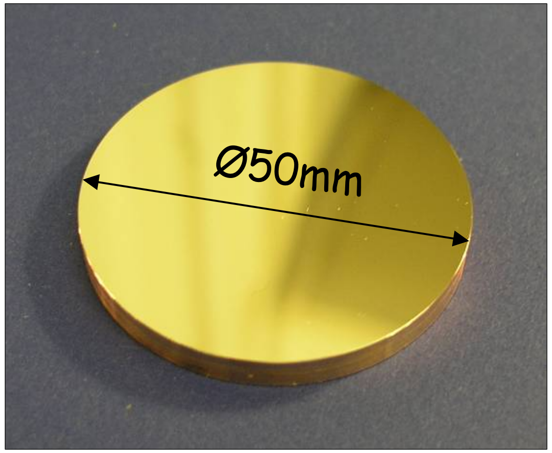


Pulsed Laser Fatigue Tests

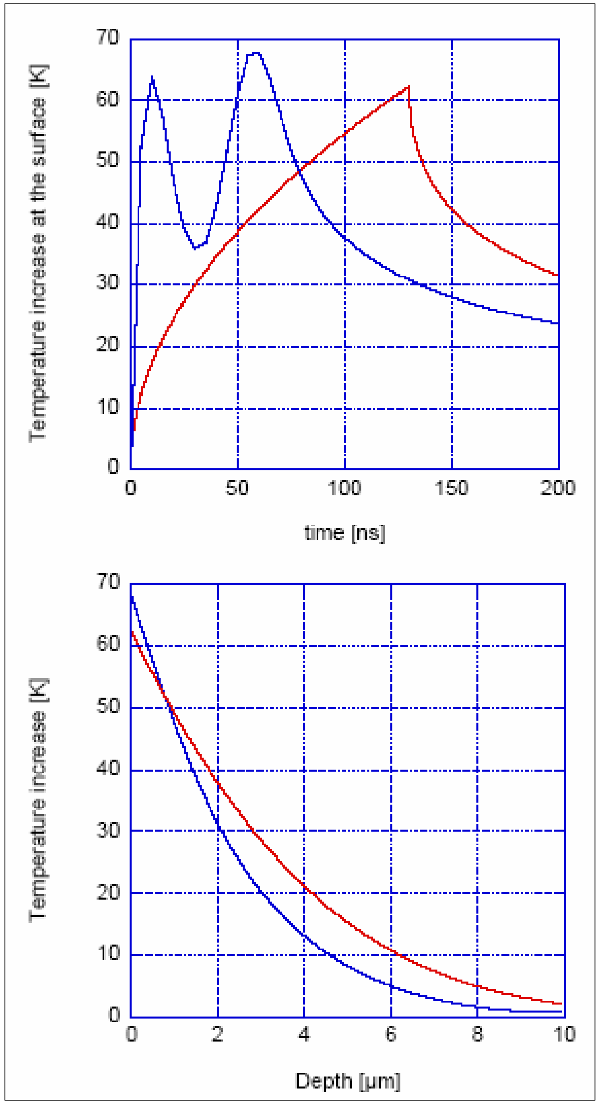
- **Surface of test sample is heated with pulsed laser. Between the pulses the heat will be conducted into the bulk.**
- **The Laser fatigue phenomenon is close to RF fatigue.**
- **The operating frequency of the pulsed laser is 20 Hz -> low cycle tests.**
- **Observation of surface damage with electron microscope and by measuring the change in surface roughness.**
- **Tests for CuZr & GlidCop in different states under way.**



Laser test setup

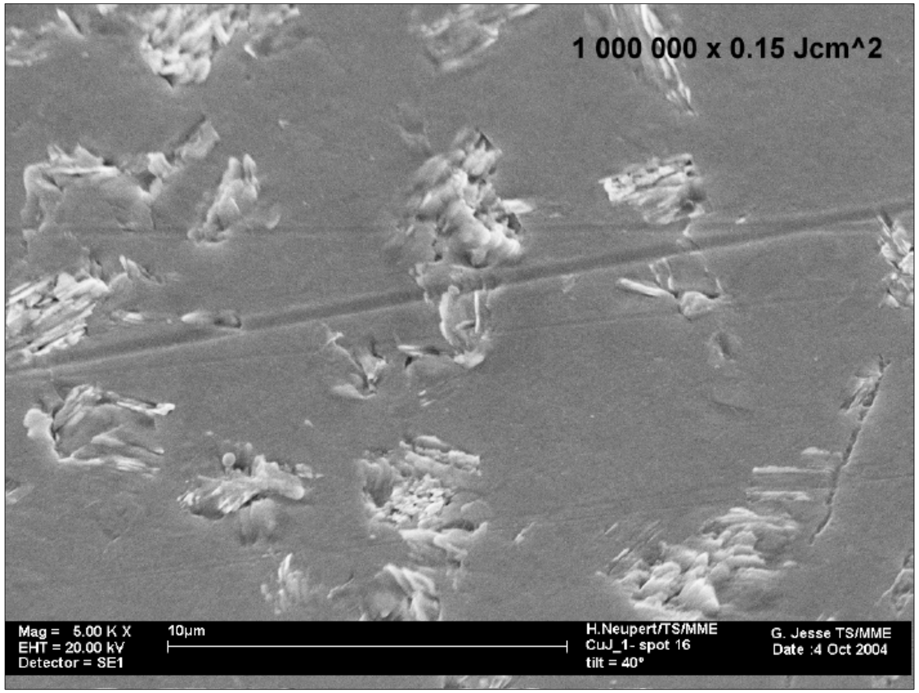


Diamond turned test sample, Ra 0.025μm

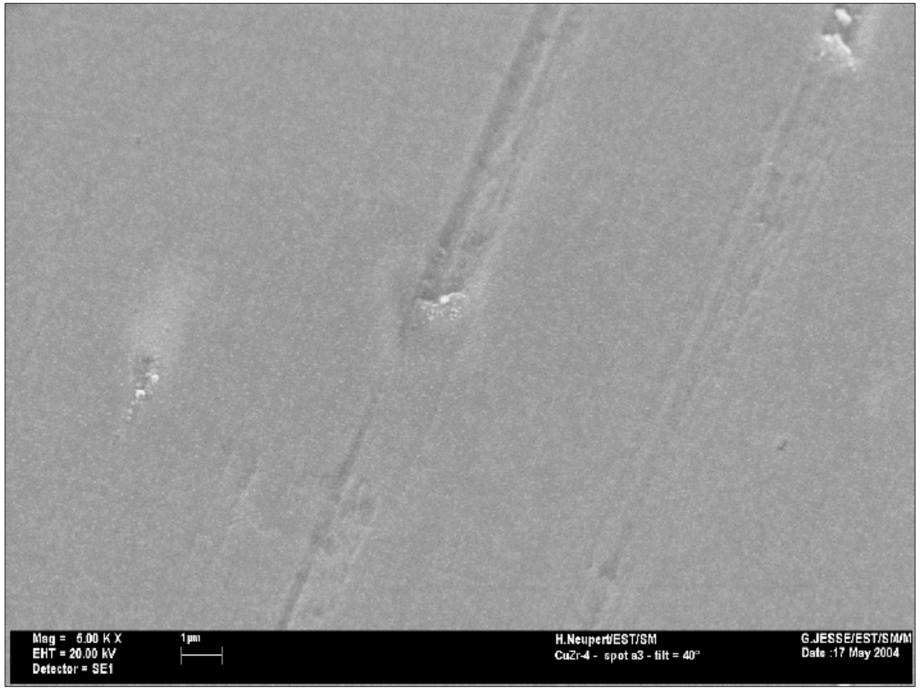


Red curve – CLIC RF pulse
Blue curve – Laser pulse

Pulsed Laser Fatigue Tests



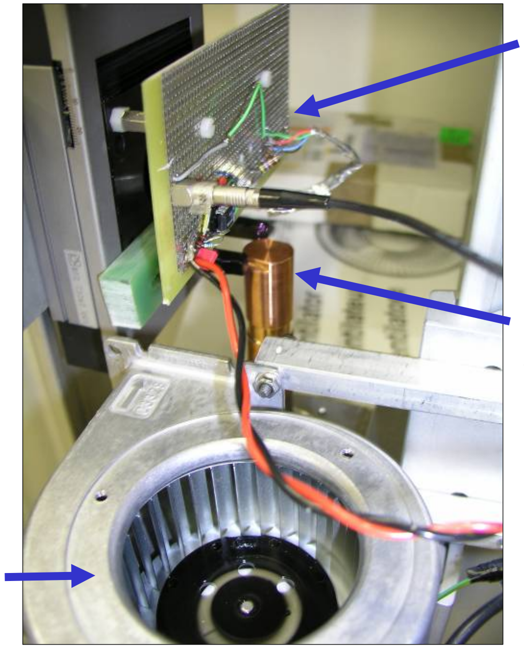
Cu-OFE at 10^6 cycles, ΔT=90°C
Fatigued surface

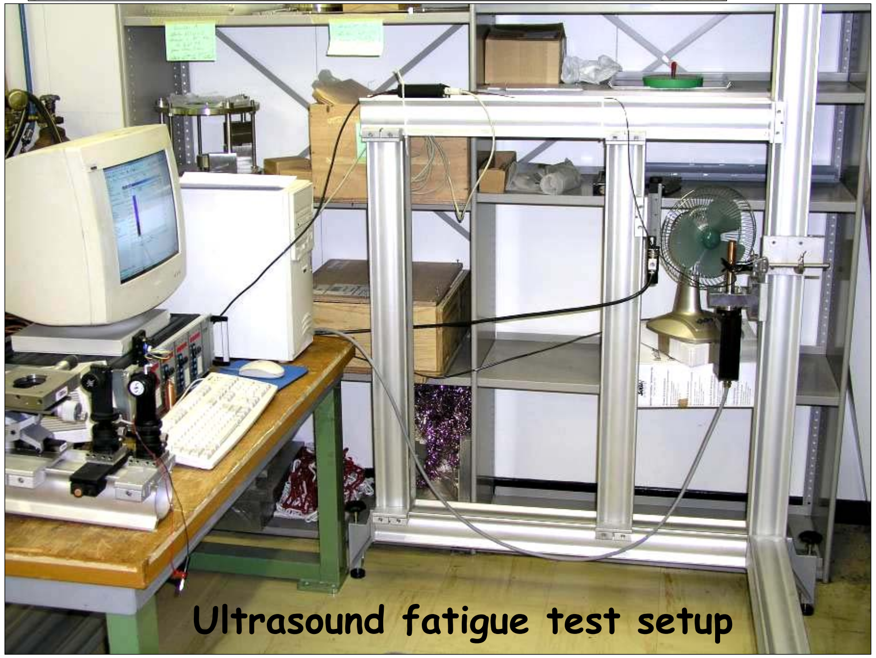


CuZr at 10^6 cycles, ΔT=90°C
No fatigue.

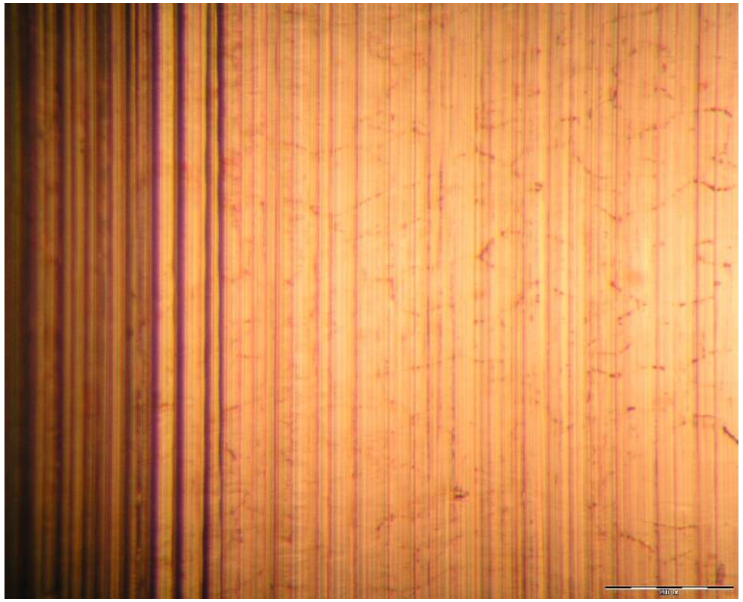
Ultrasound Fatigue Tests

- Cyclic mechanical stressing of material at frequency of 24 kHz.
- High cycle fatigue data within a reasonable testing time. 10^{10} cycles in 5 days.
- Will be used to extend the laser fatigue data up to high cycle region.
- Tests for Cu-OFE, CuZr & GlidCop under way.

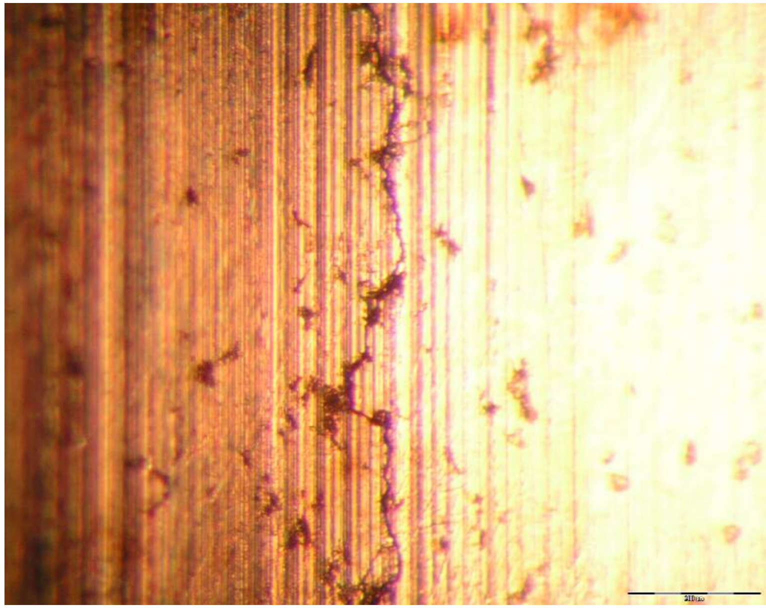




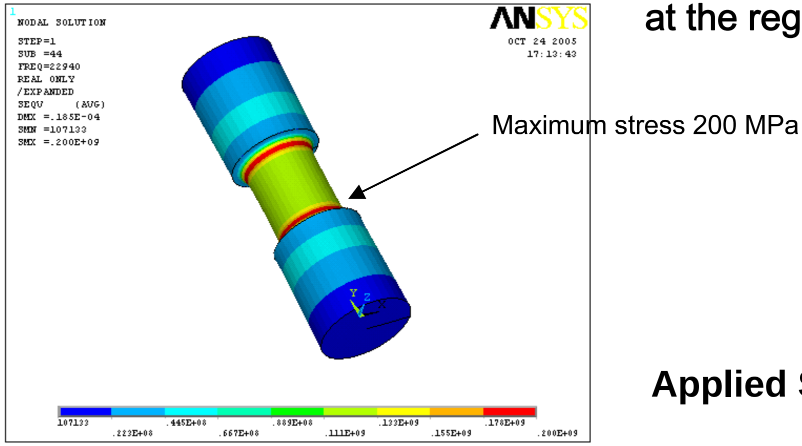
Ultrasound Fatigue Tests



Diamond turned specimen before cyclic loading

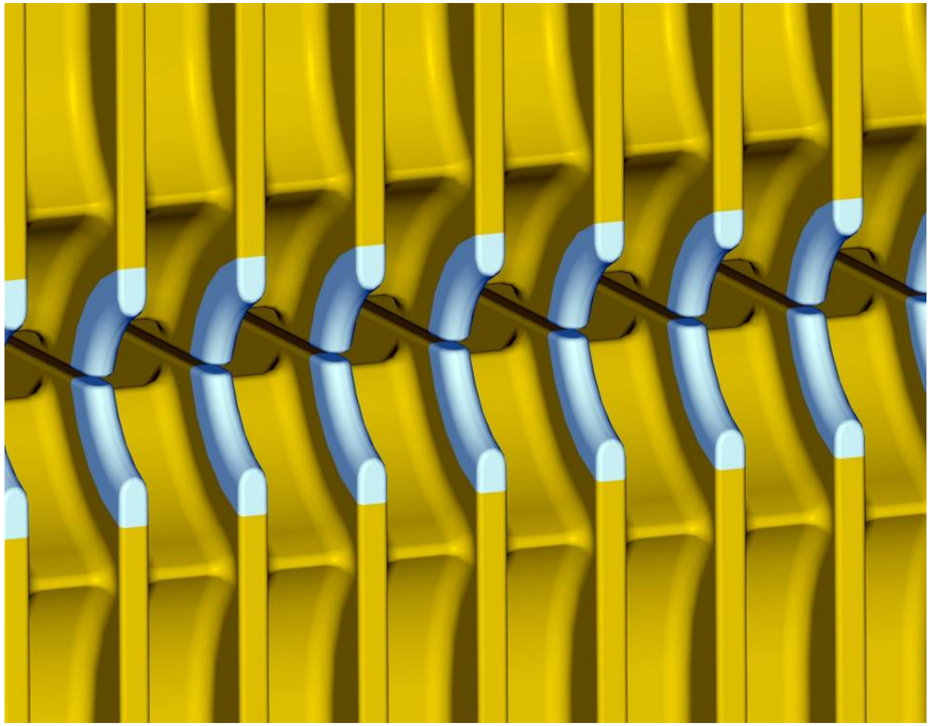


The same specimen after $3*10^6$ cycles, crack initiated
at the region of the maximum stress



Applied Stress is calculated in Ansys

Putting it all together: investigation of HIP, Hot Isostatic Pressing of Mo with CuZr



Fully integrated optimization procedure

Optimization

Accelerating structure parameters:

fixed: $\langle E_{acc} \rangle$= 150MV/m, f= 30GHz,

varied: $\delta\varphi$ = 50° - 130°,

a/λ= 0.1 - 0.25,

d/λ = 0.025 - 0.1,

N_b, N_{cells}, N_{cycles}

Optimization criterion

Luminosity per linac input power:

$$\int L \mathrm{d}t / \int P \mathrm{d}t \sim L_{b\times} \eta / N$$

Beam dynamics input:

$W_{t,2}$ = 20V/pC/mm/m for $N=4\times10^9$

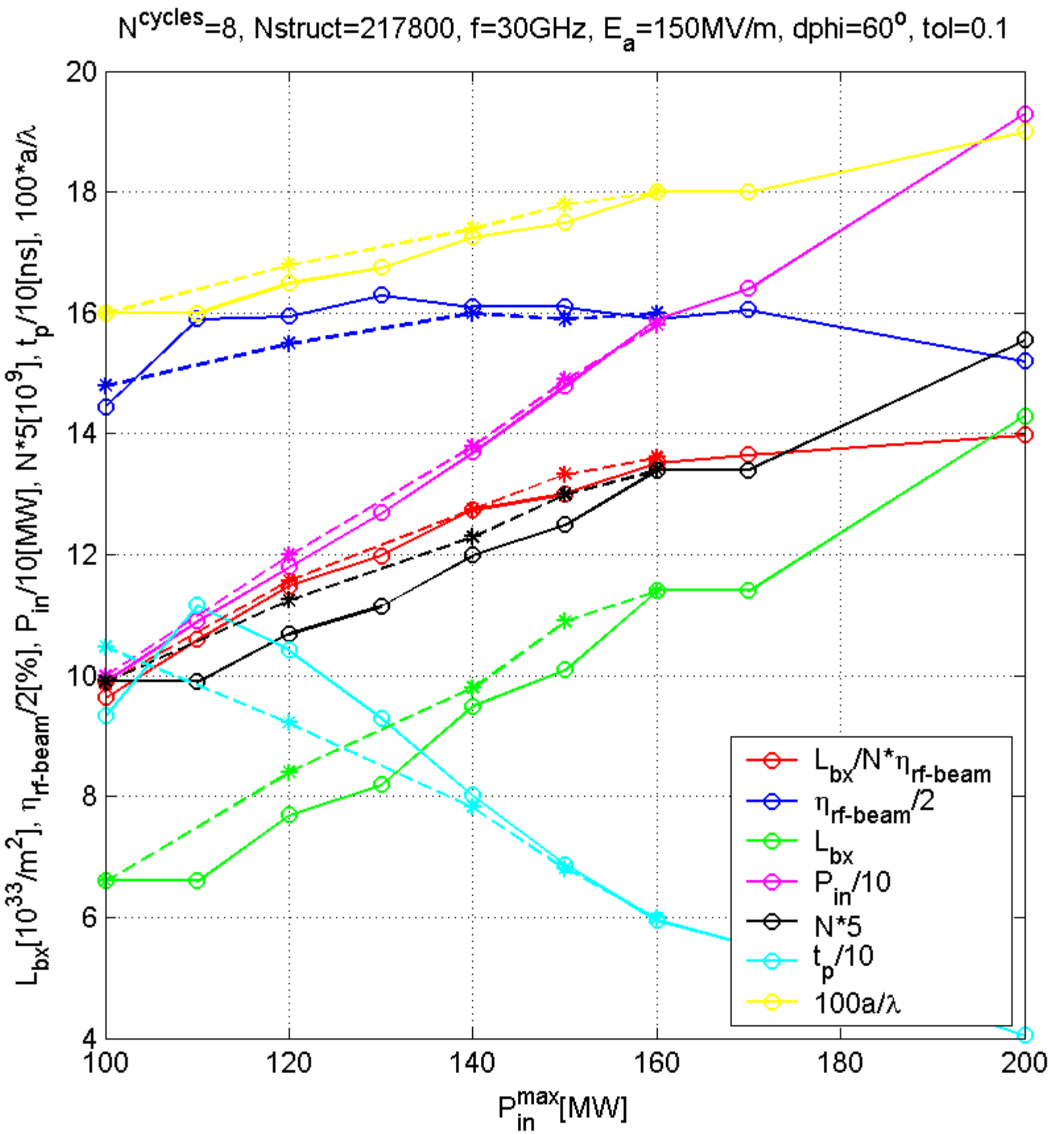
N, L_{bx} dependencies of a/λ

rf breakdown and pulsed surface heating (rf) constrains:

E_{surf} < 378 MV/m, ΔT < 56 K, $P_{in} t_p^{1/2}$ < 1225 MWns$^{1/2}$

Several million structures considered in the optimization

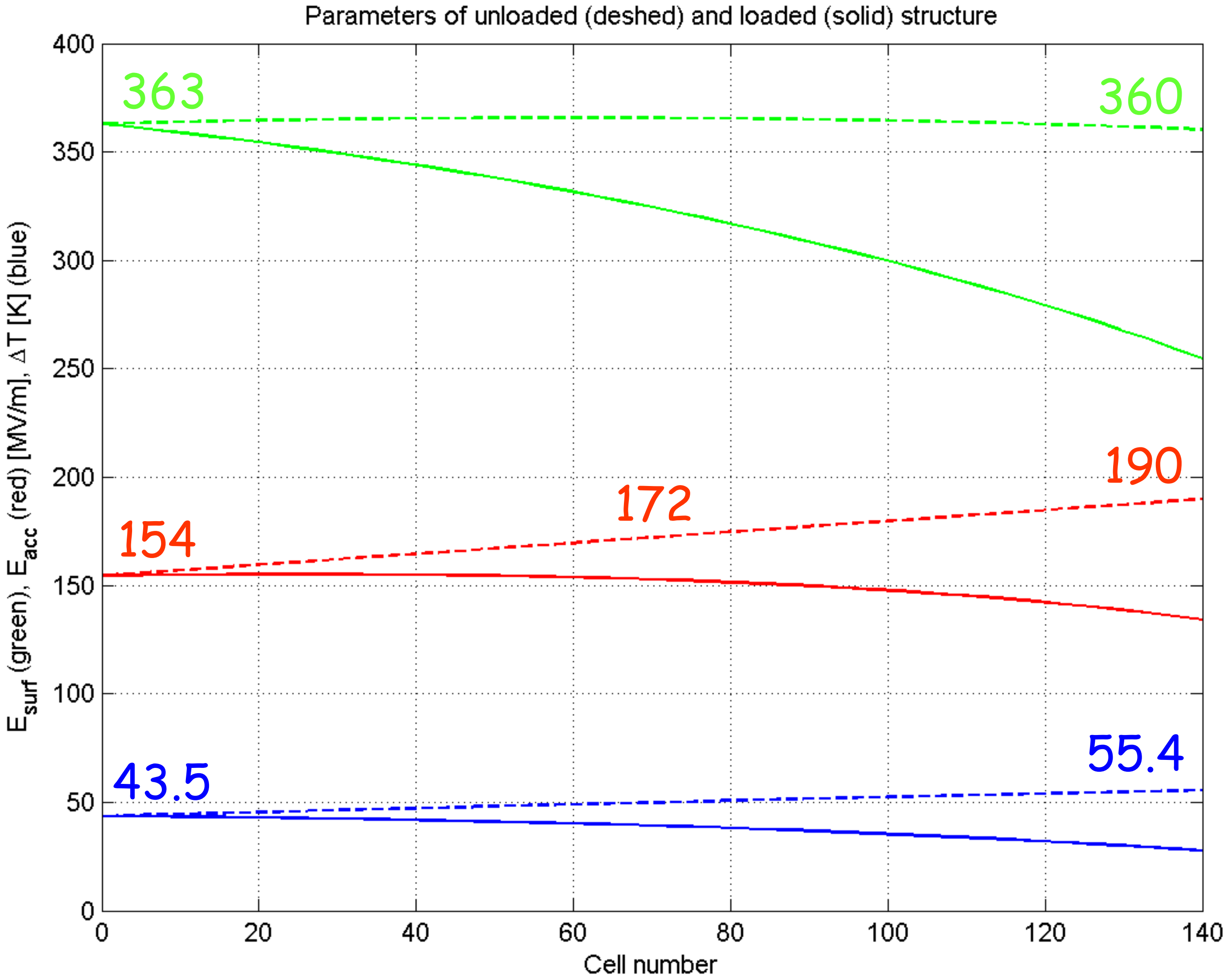
Parameters versus maximum P_{in}



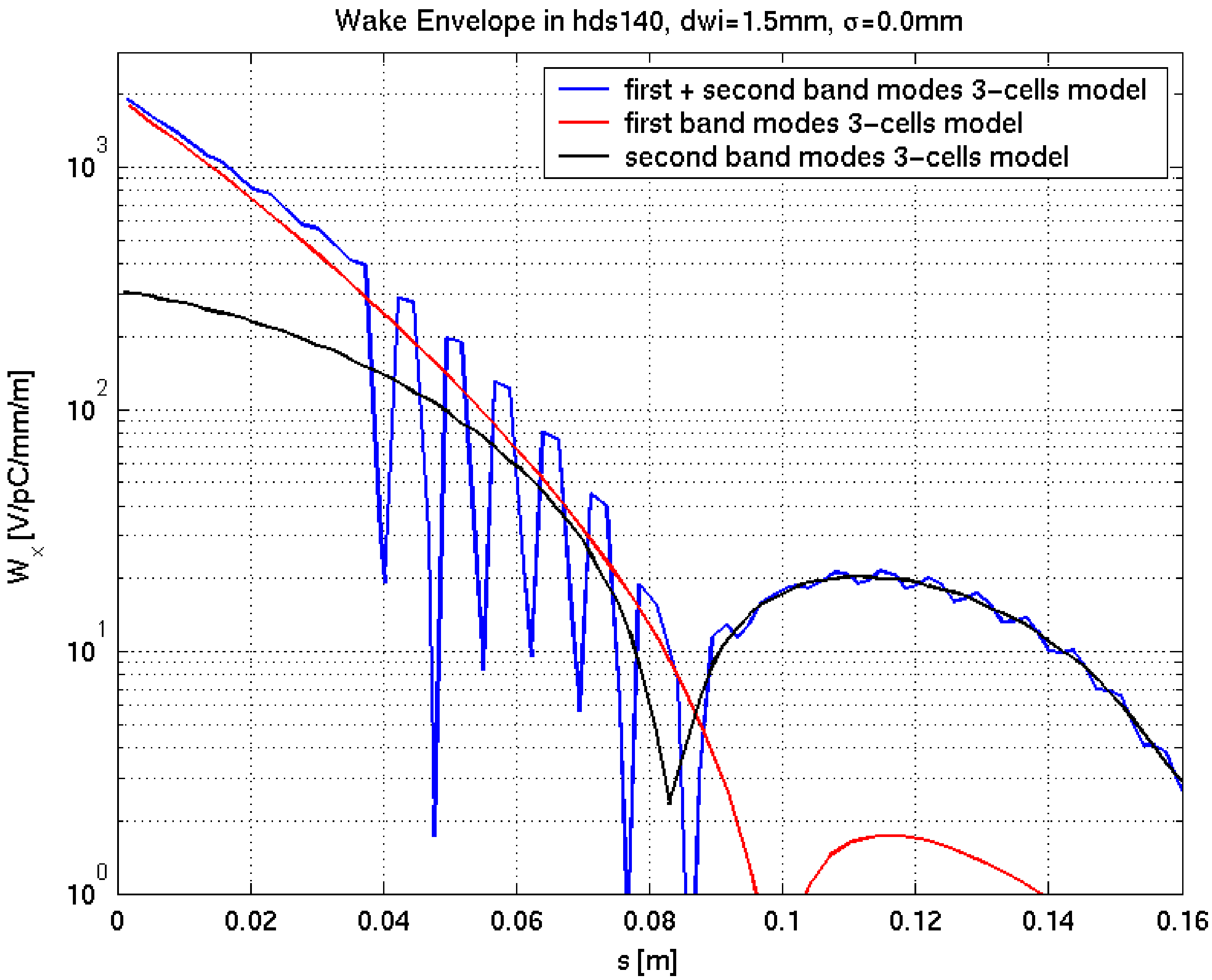
$\Delta\varphi = 60^o$

$N_{cycles} = 8$

Parameters of HDS140-Mo



Dipole mode wakes in hds140



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