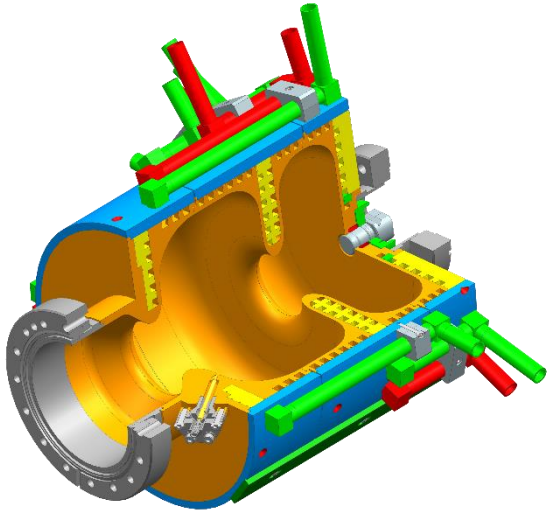
New RF-Contact spring for exchangeable cathodes in Gun5

Solution is compatible to all guns with the mechanical design “Watchband reloaded” and fully compatible to the existing cathode design, cathode load-lock systems, magazines a.s.o.



Frieder MÜLLER for PITZ
Hamburg 19.06.2025

HELMHOLTZ

DESY.

Original RF-Contact Spring

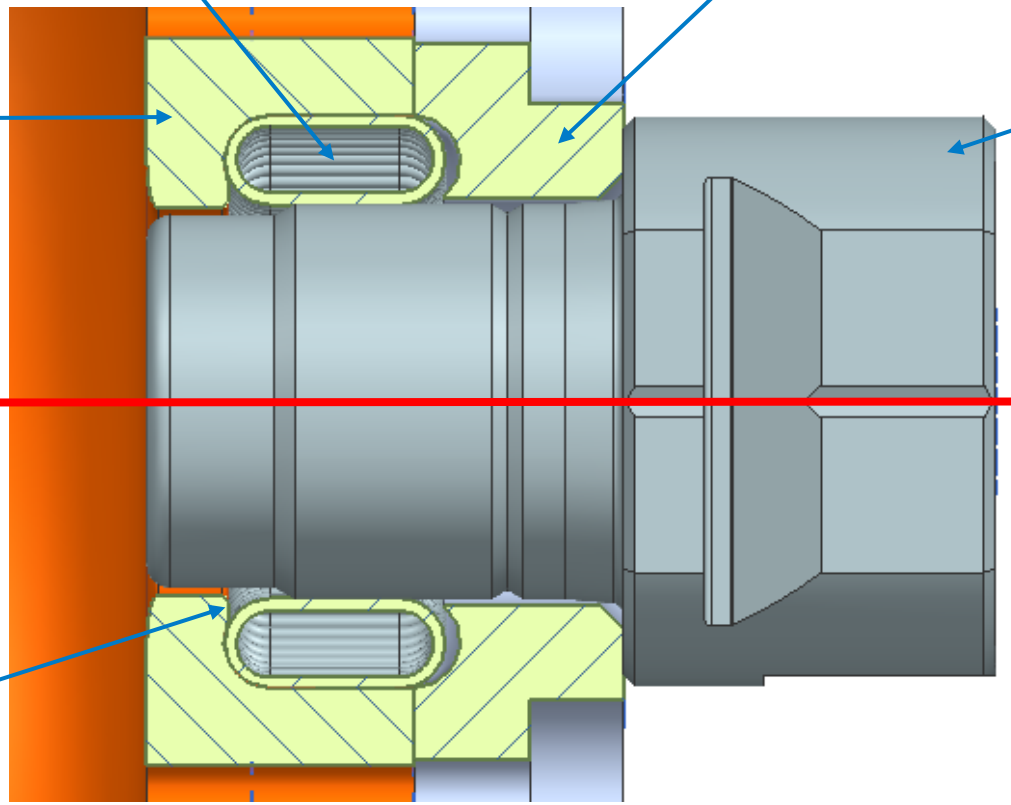
„Watchband reloaded“ design - taken over from previous Gun4 design

„Watchband“
Spring

„Spring holder“
(screw mounted)

Gun Backplane
with hole Ø16.6 mm

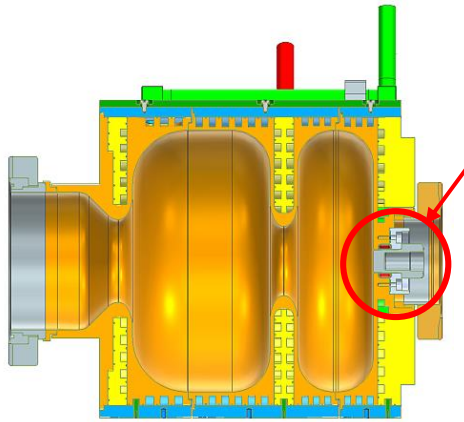
Cathode „Plug“
Spring contacts at the larger front diameter



Electron Beam Direction

Cathode insertion direction

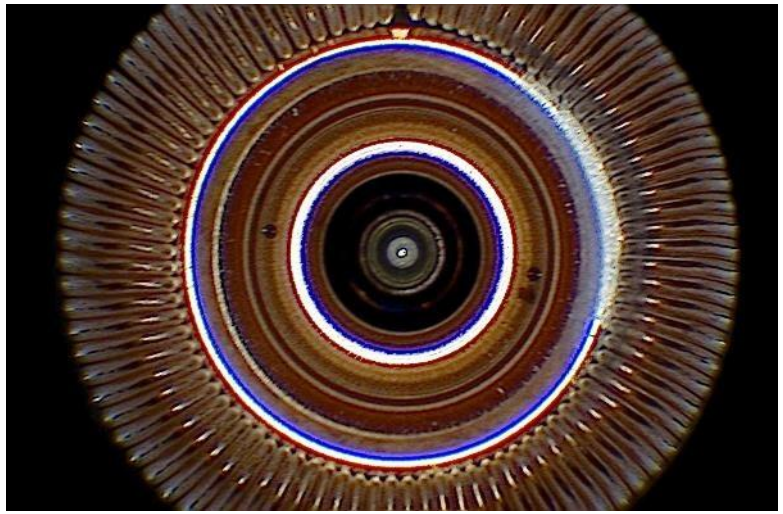
Small flat with radius
„reloaded“

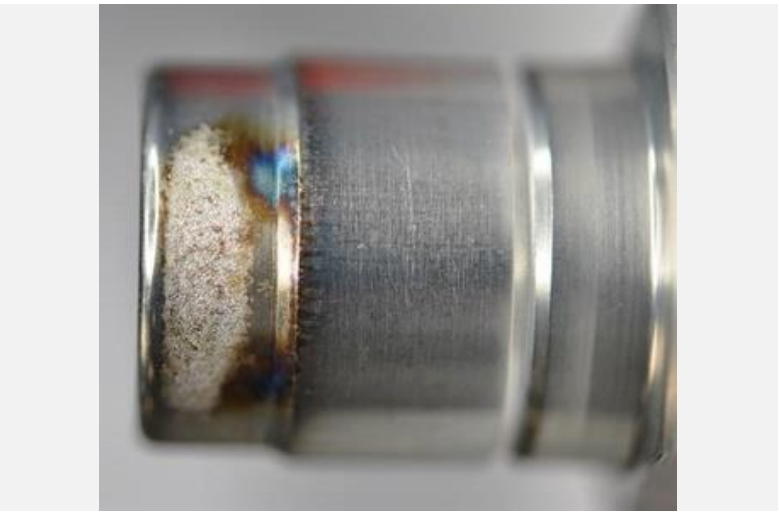


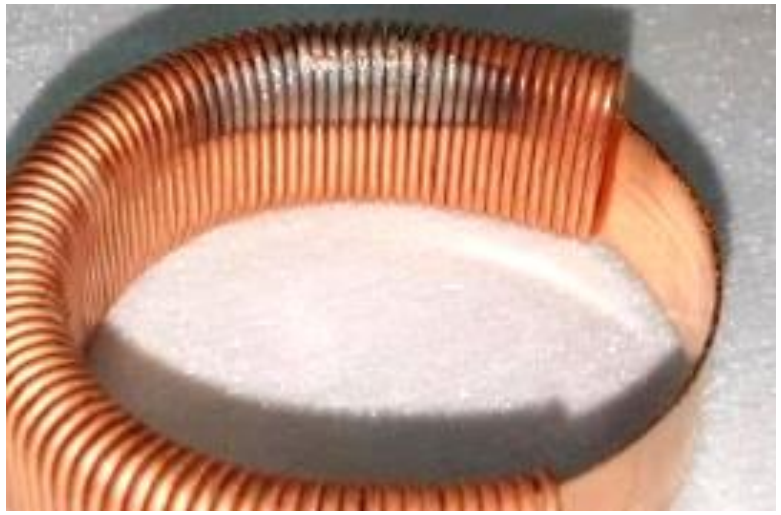
Detail

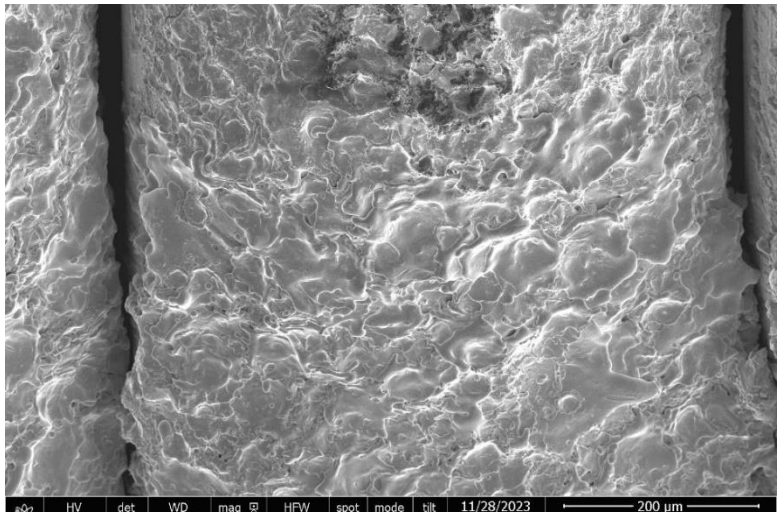
Motivation for a new RF-contact spring design

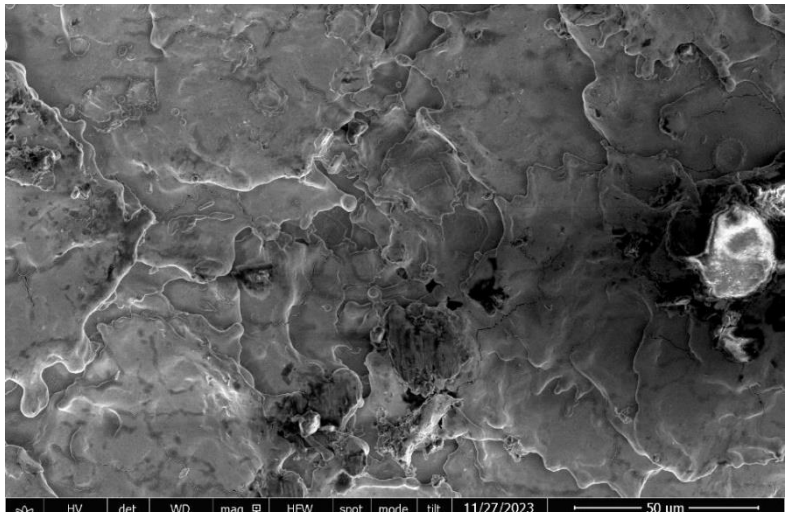
Instable operation and damages at Gun 5.1 at pulse durations >600µs @ ~60MV/m







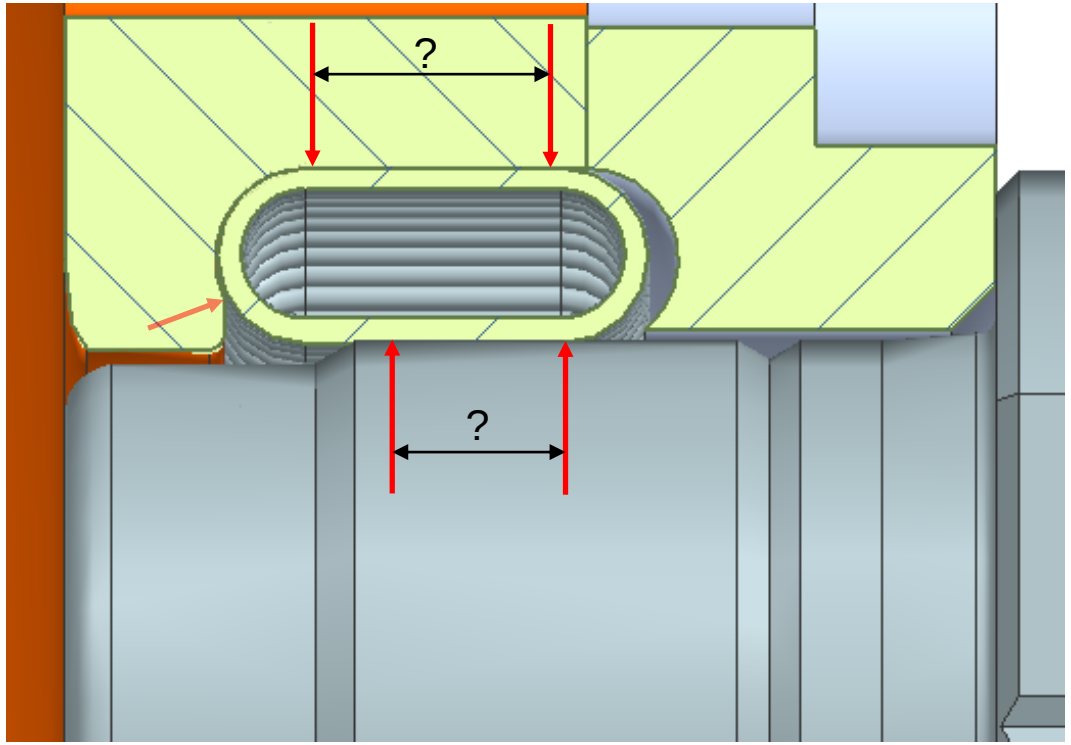




Reasons of the observed damages

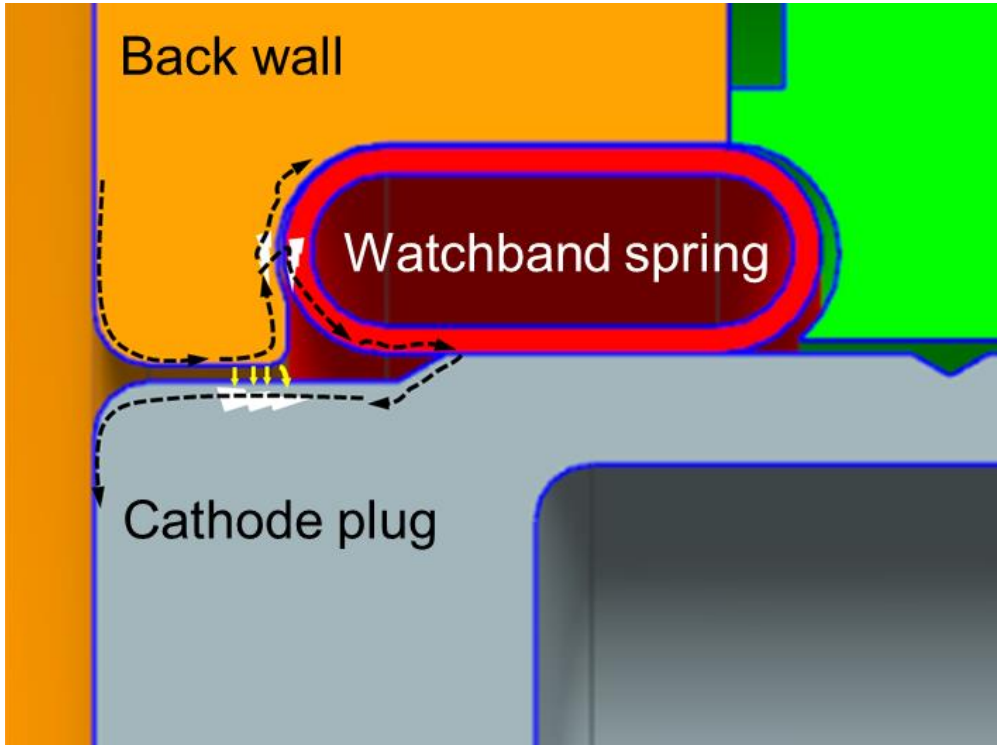
Arcing was observed in Gun5.1 at elevated fields ~ 60MV/m and longer pulse lengths ≥600µs

Spring contact point(s) to the larger cathode diameter (Ø17)



There is no „ideal“ line contaxt in praxi …
→ therefore the contact point(s) may be
somewhere in between the red arrows

Path for high surface currents too long?

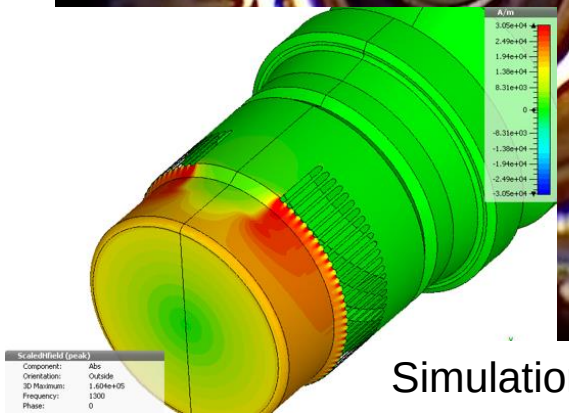


Traces of arcing including material transfer between gun, spring & cathode have been observed

Open Watchband → Geometrical Problem

Gap in Gun 5.1 evolved over time → unequally distributed RF-contacts

07/2023

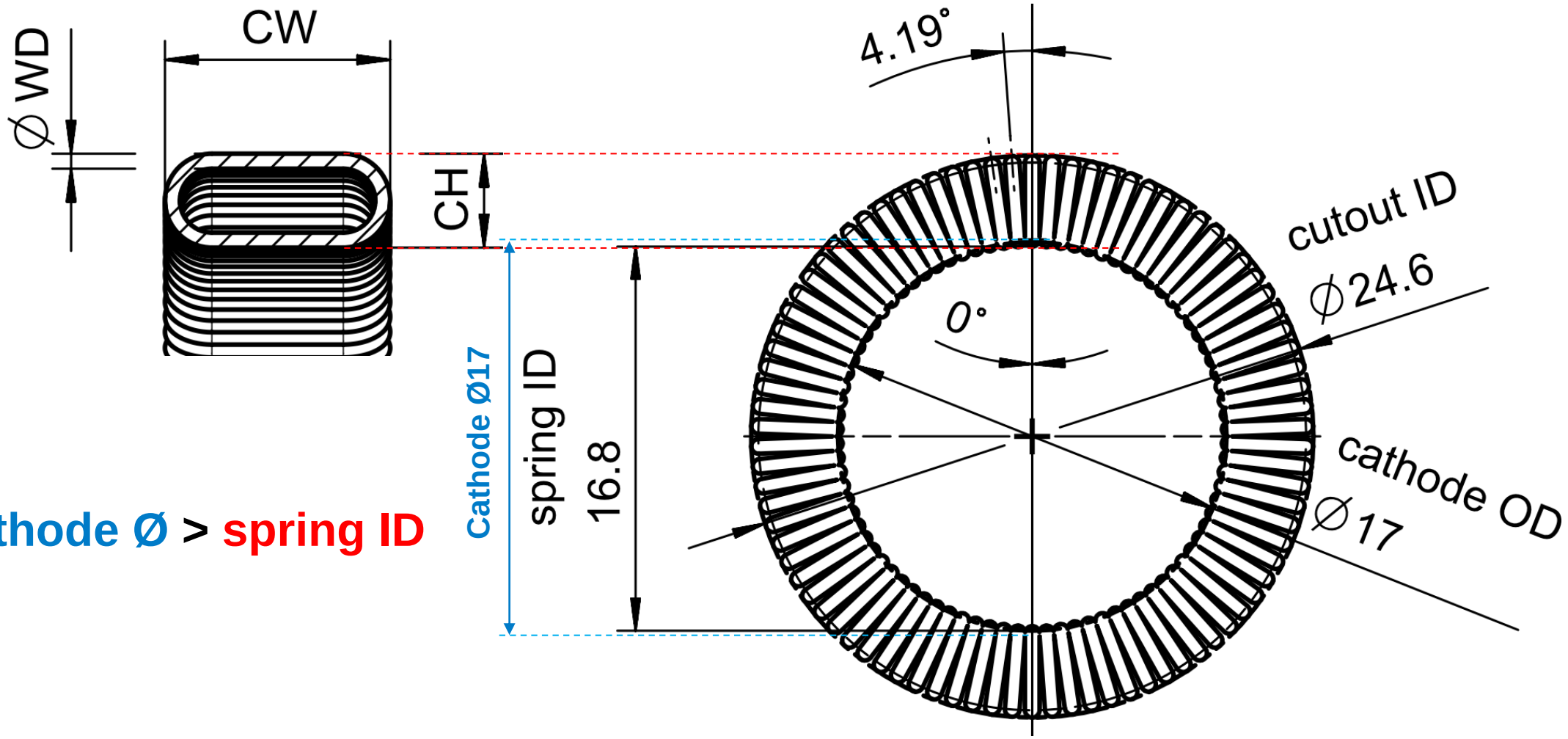


Simulation by D. Lipka (MDI)

08/2024

Watchband → uncompressed (idealized)

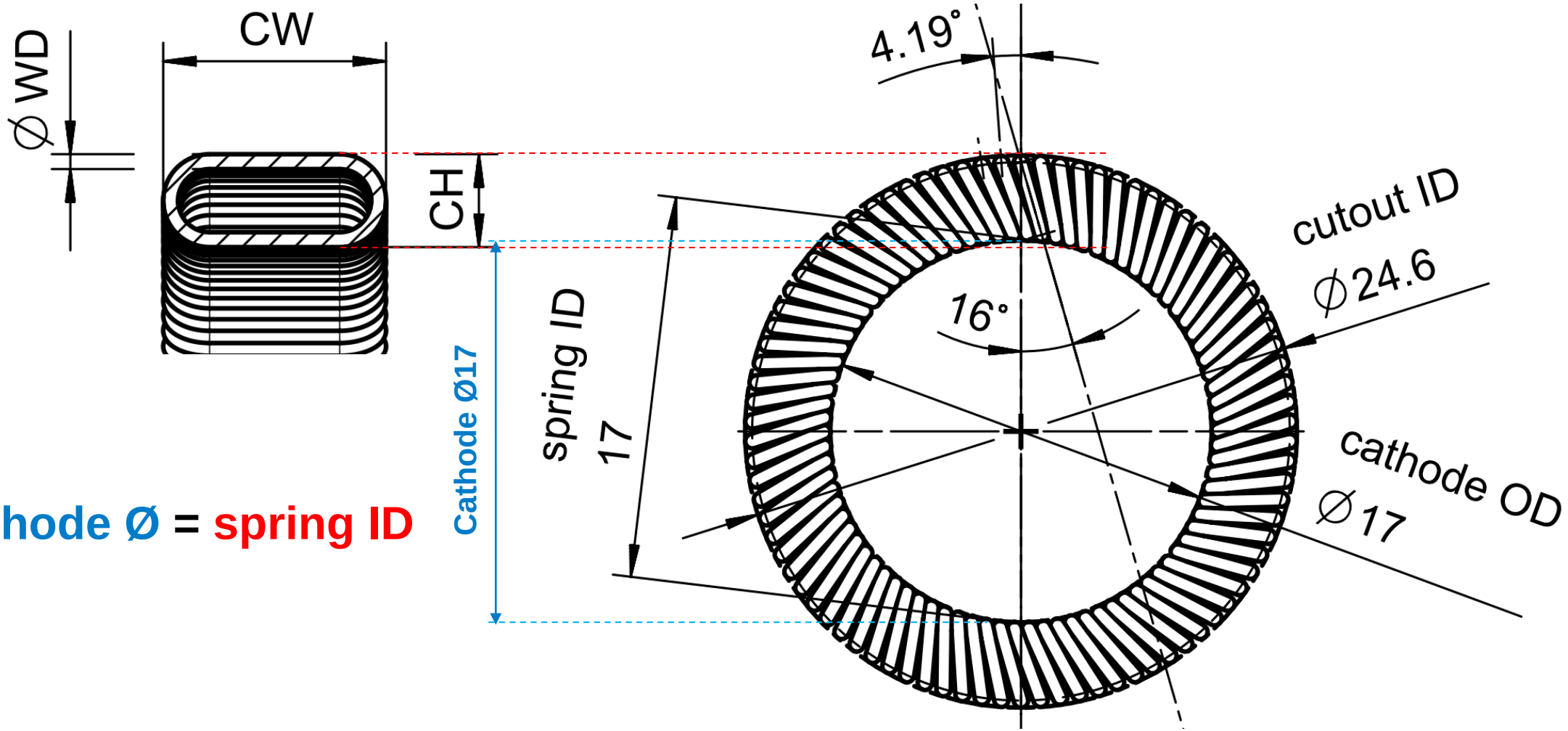
Dimension of the Watchband is slightly oversized in Coil Height (CH”)



cathode Ø > spring ID

Watchband → with cathode inserted (idealized)

Canted situation → less contact force than compressing the Coil Height (CH) of the racetrack



cathode Ø = spring ID

Open Watchband Problems

Gap & canting → irregular contact distribution and contact force around the circumference

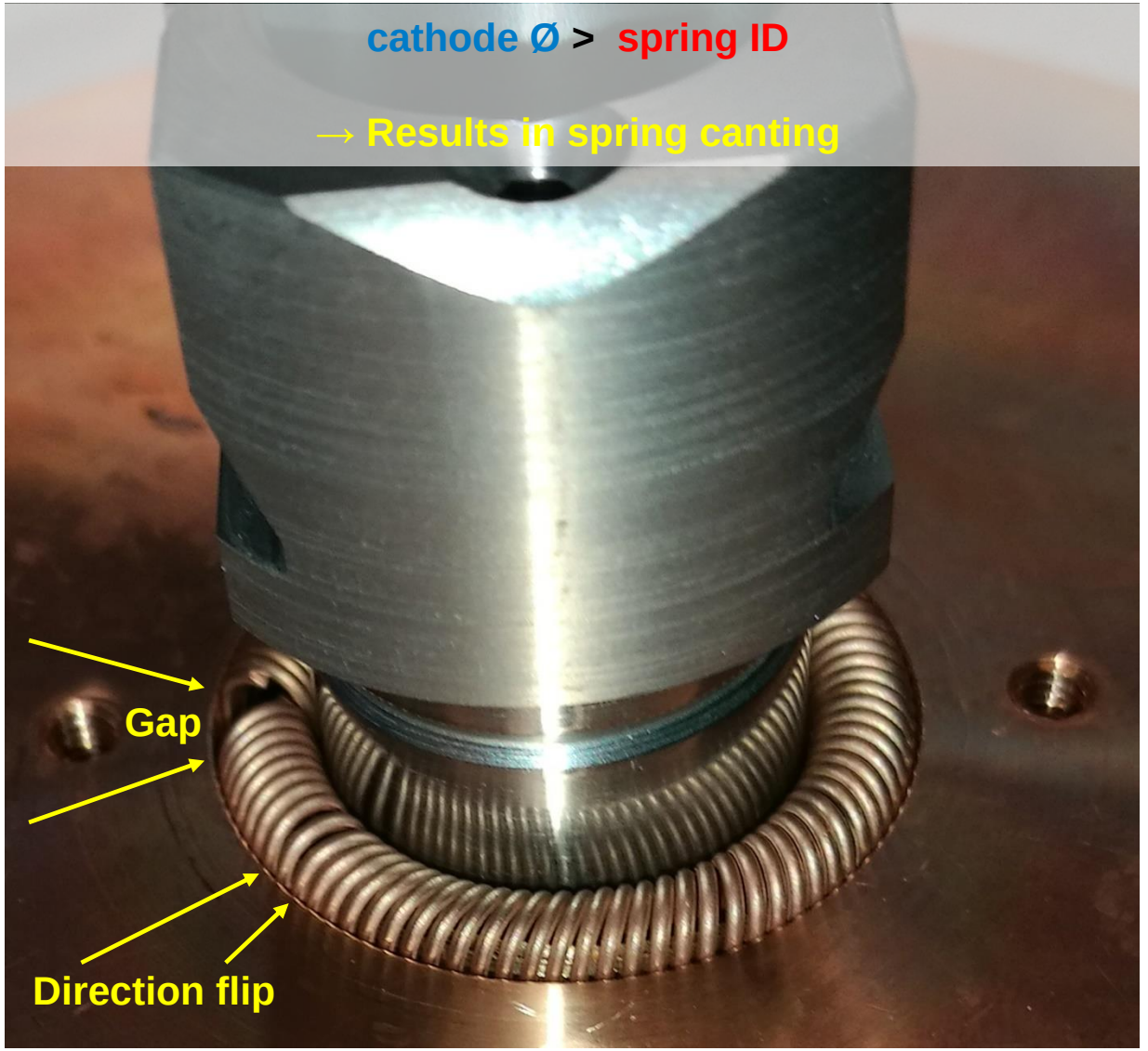
→ Open ring results in gap and therefore last windings on both sides of the gap do not take part at the contact anymore

→ Gap causes windings to flip the end-windings in opposite direction

→ Canting of windings must therefore flip its direction somewhere around the circumference

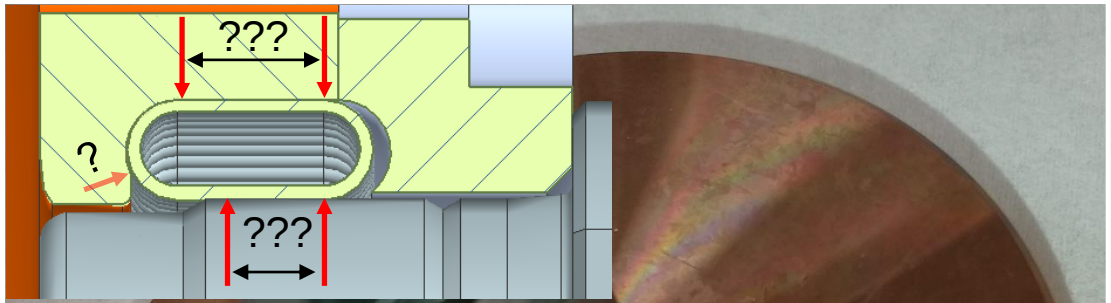
→ No equidistant contact points over the full circumference

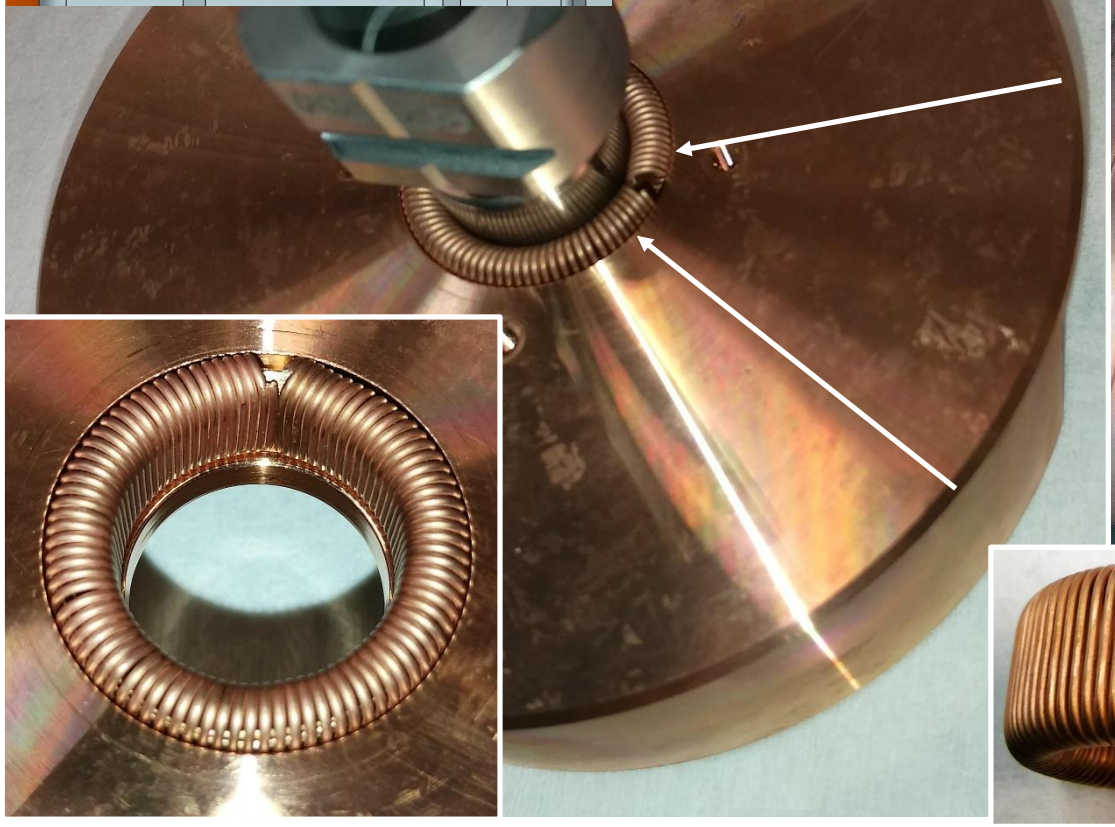
→ Canting force is lower than racetrack compression force
(racetrack compression might have been the original idea, this would result in quite strong contact forces)

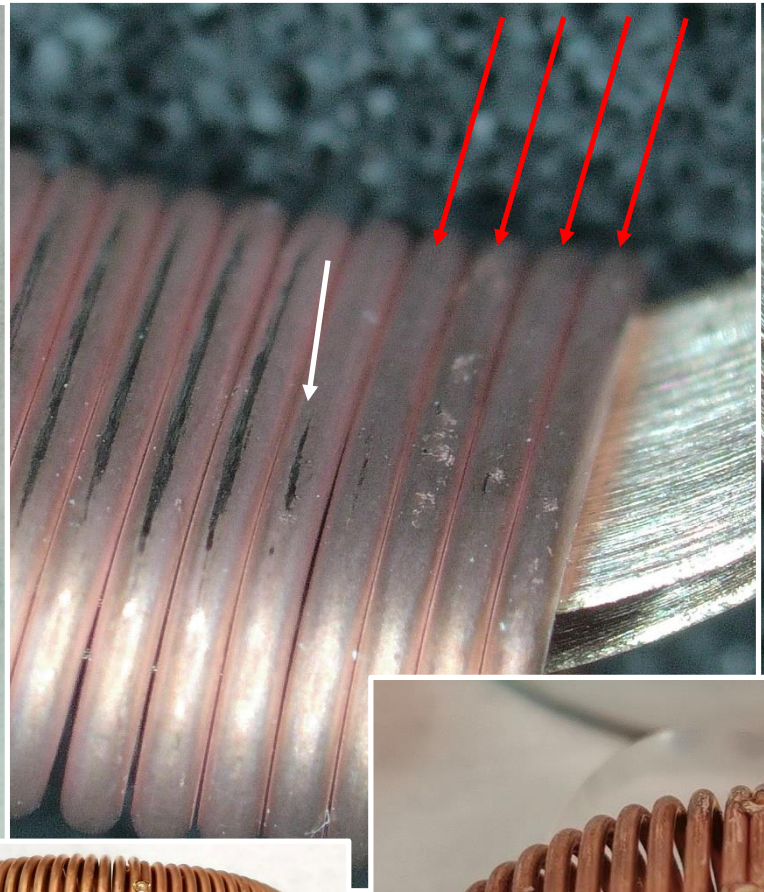


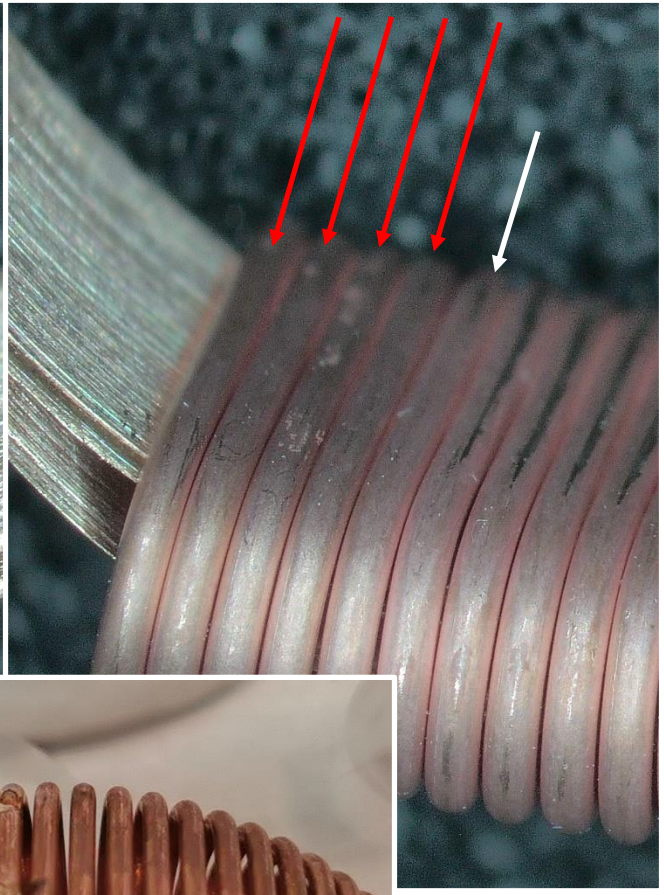
Watchband improvement

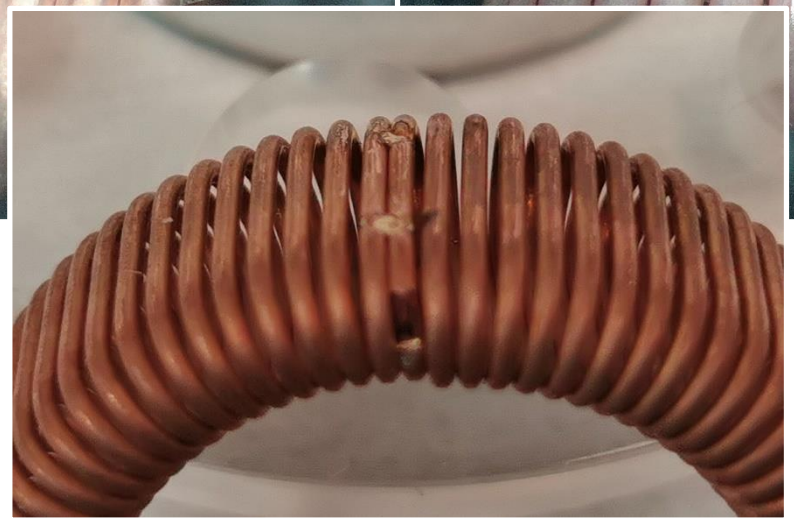
Laser-welded, closed Watchband ring → better, but does not solve all problems





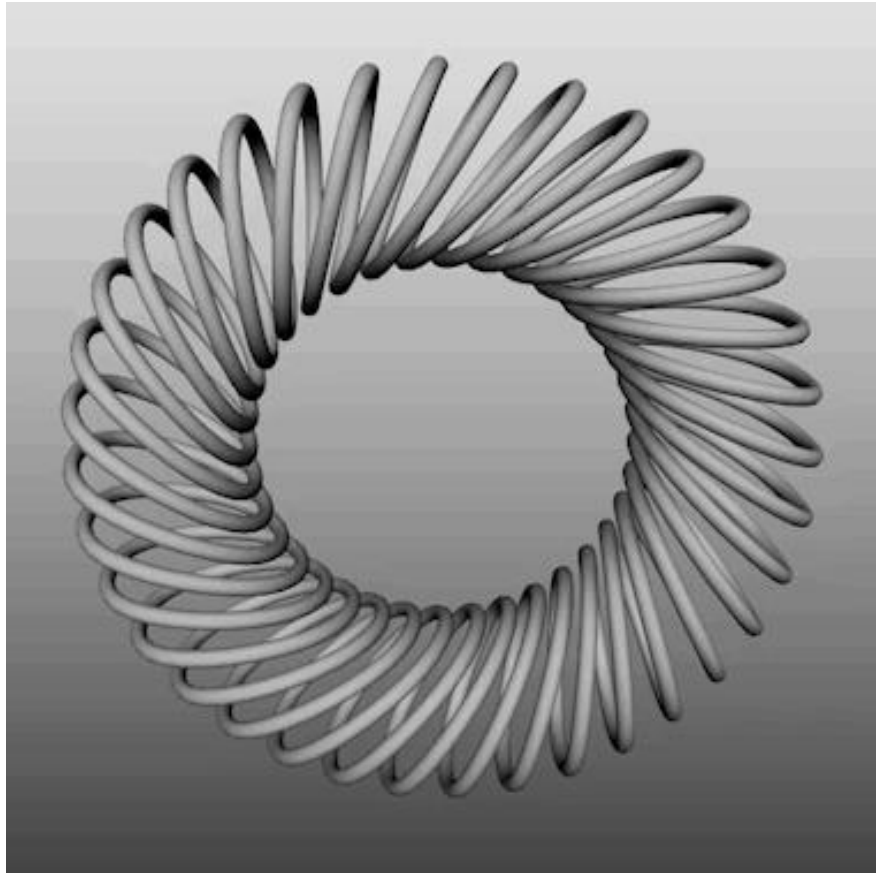






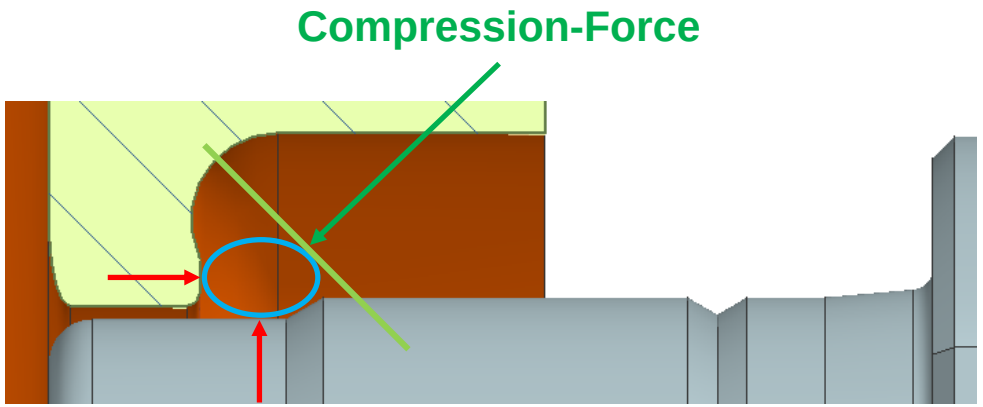
Idea & location for a new RF-Contact spring

Canted helical „BalSeal-Spring“



Source: https://www.balseal.com/spring/
Download: 06.12.2023

→ Uses canting by purpose
→ Allows small crossection
→ Allows **more windings and contact points**
→ Contact points are **locally defined** very precisely
→ Can shorten the path for surface currents



Spring contact points to the smaller cathode diameter (Ø16)

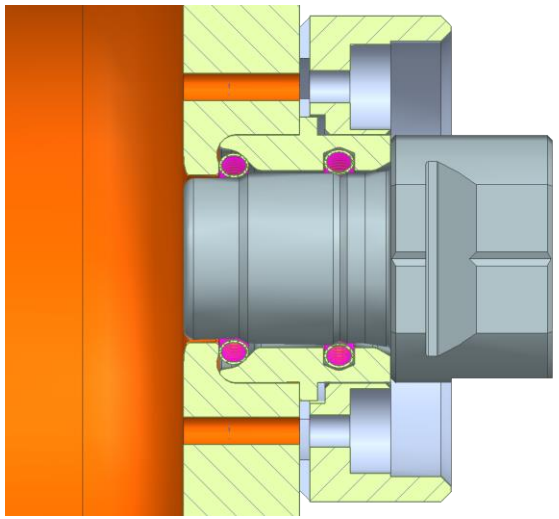
How can we hold the spring safely in this location?

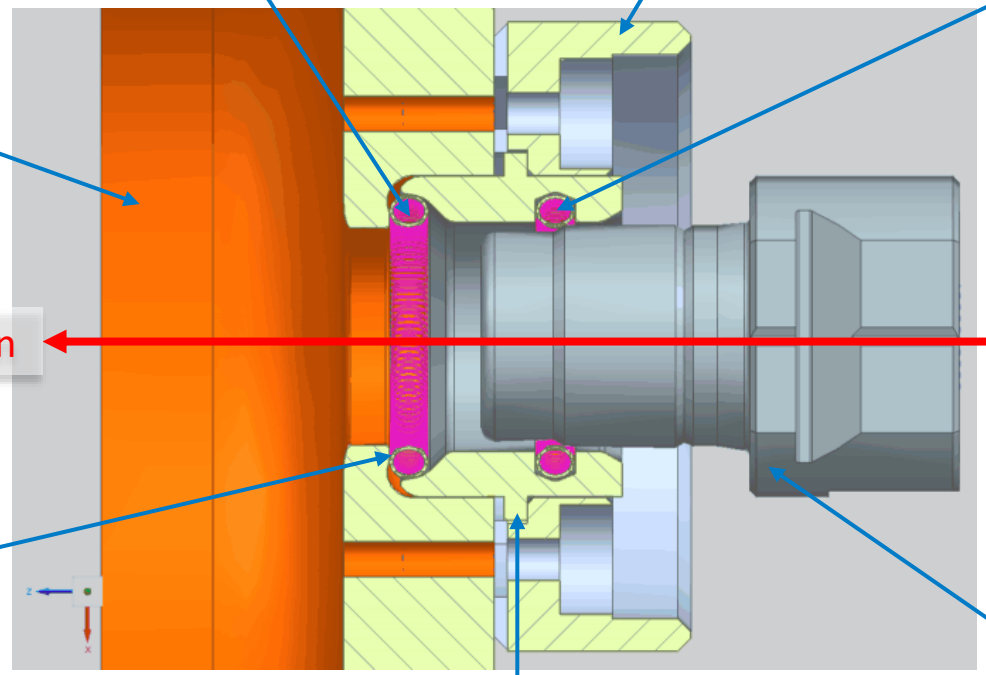
How can we preload it with the magnetic coupled linear actuator used in the existing load lock?

New RF-Contact spring mechanism

Canted helical spring(s) – front spring with loading / unloading mechanism

Fully compatible with existing
Gun5, cathodes & loadlock systems





Available spring & PMMA-model

Test setup for kinematic test

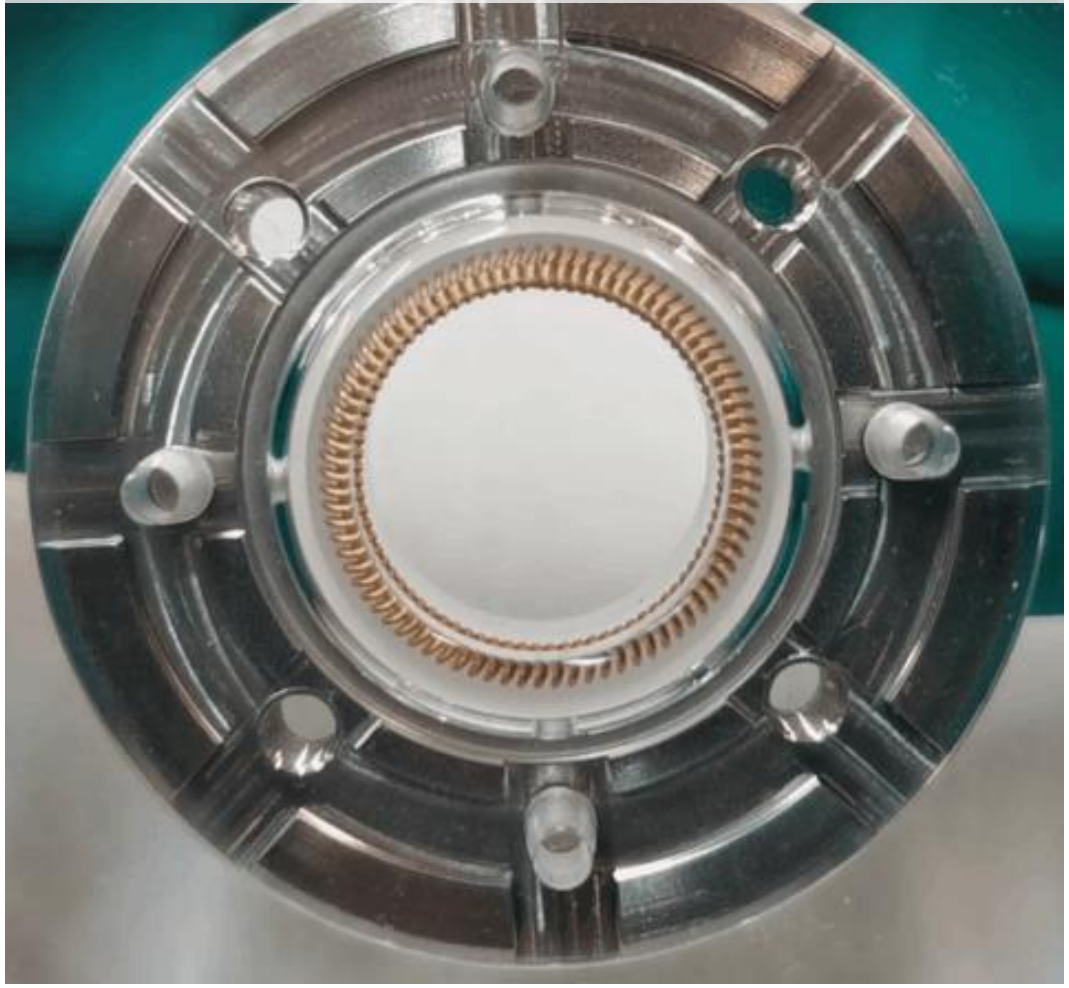
PMMA model → for observation of mechanism kinematic

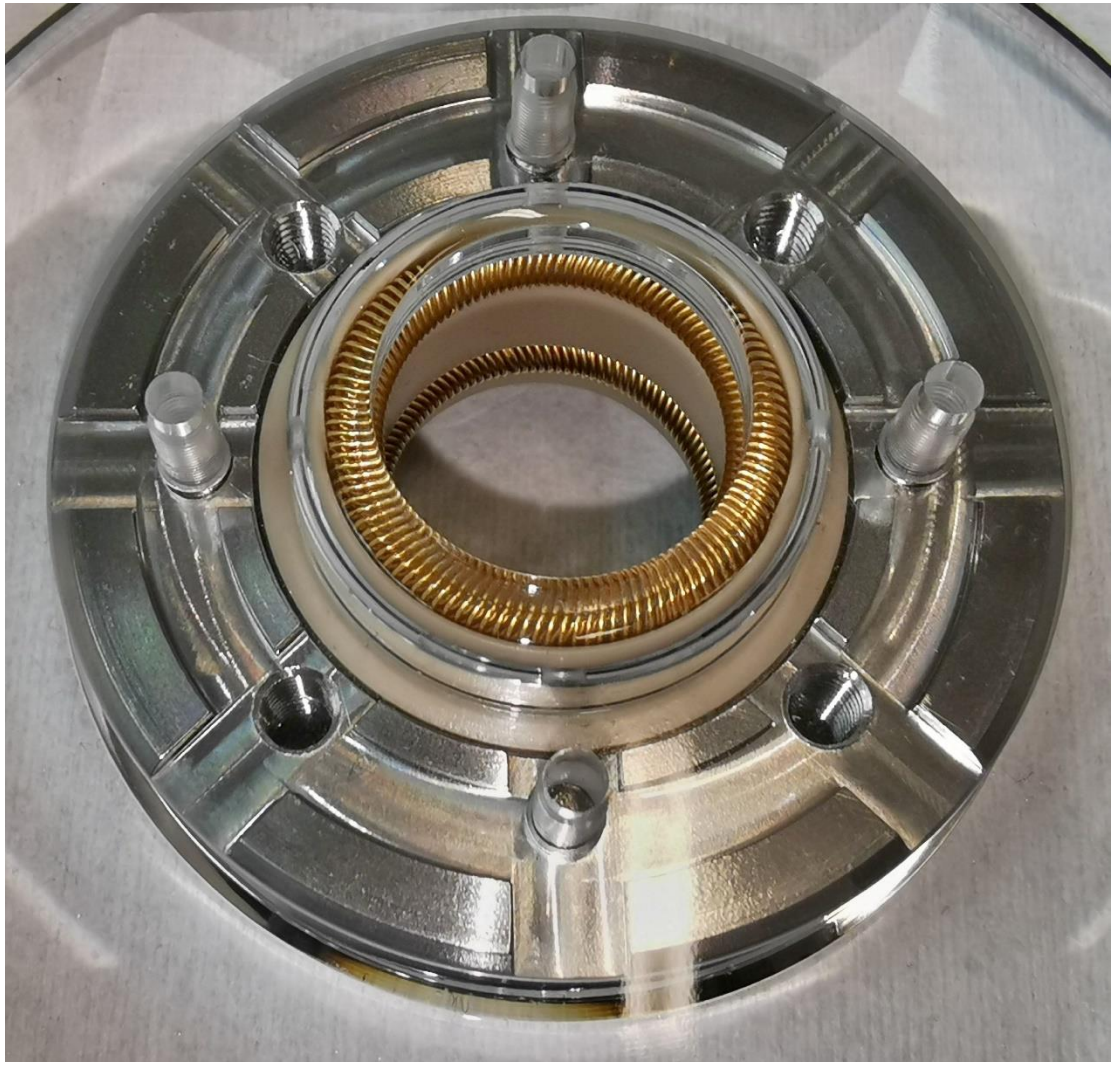
Spring (Stainless steel + Au-coating) purchased for another project → provided by Silke Vilcins for testing

Mechanical tests of spring

Kinematic tests → motion range, friction, compression forces

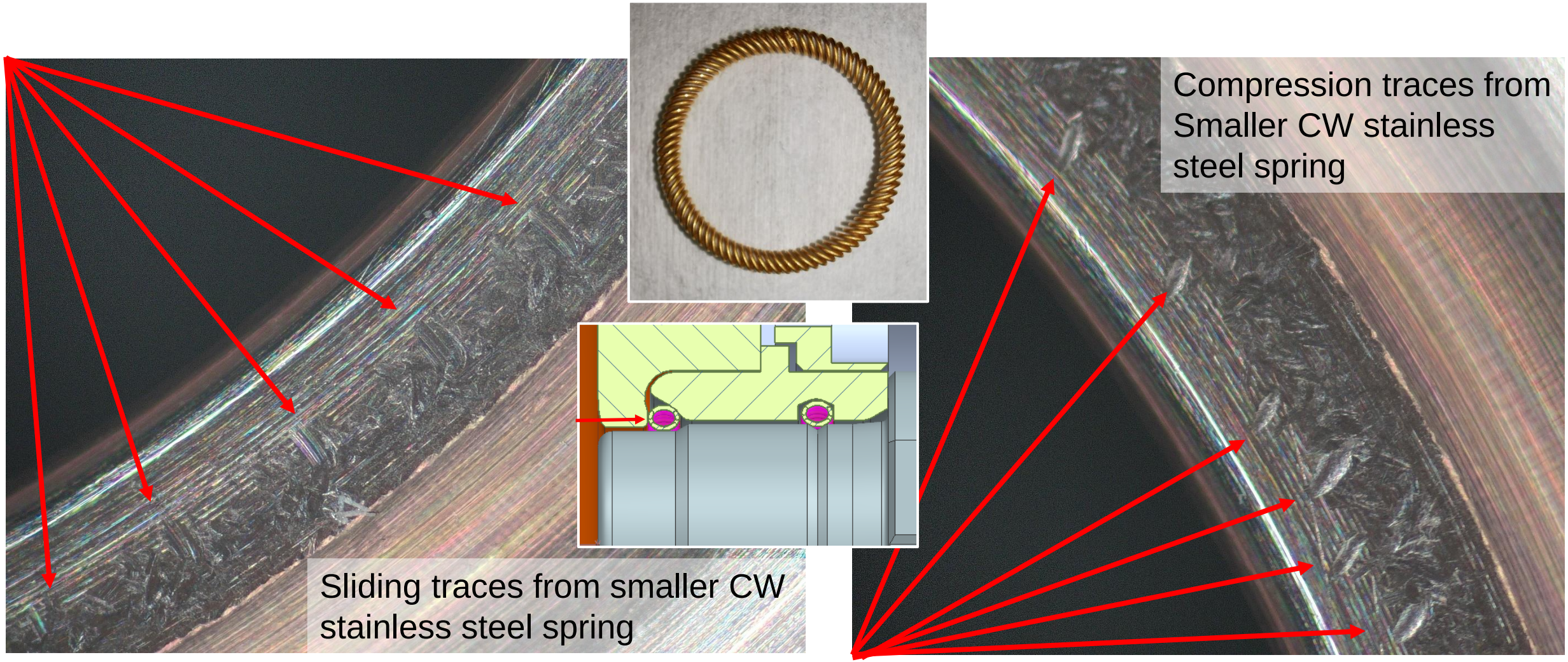
Spring compresses by less than 1mm!





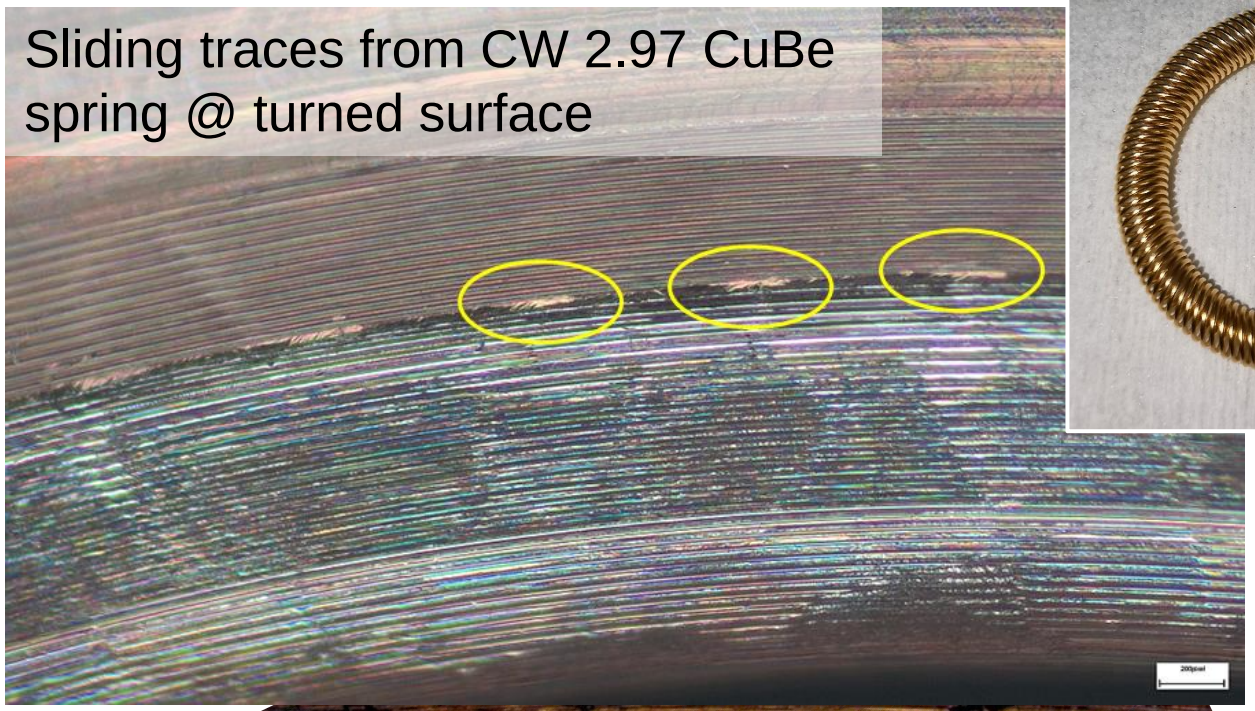
Traces from 1st spring in the soft copper surface

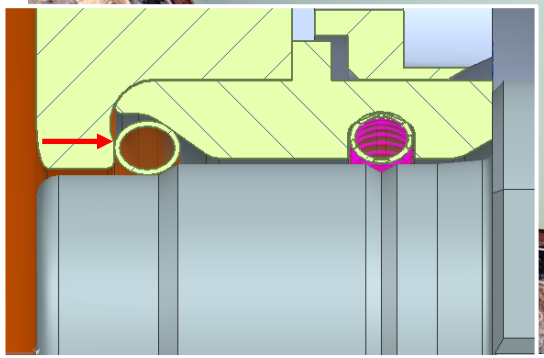
1st spring: CW 2.3 / BSE3 (SS+Au) → clearly visible sliding and compression traces on the small plane surface → force too strong for the soft copper surface inside the gun



Traces from 2nd spring

2nd spring: CW 2.97 / 114 windings / BSE9 (BeCu2 + 15µm Au) → very faint traces at the edge of the plane from sliding





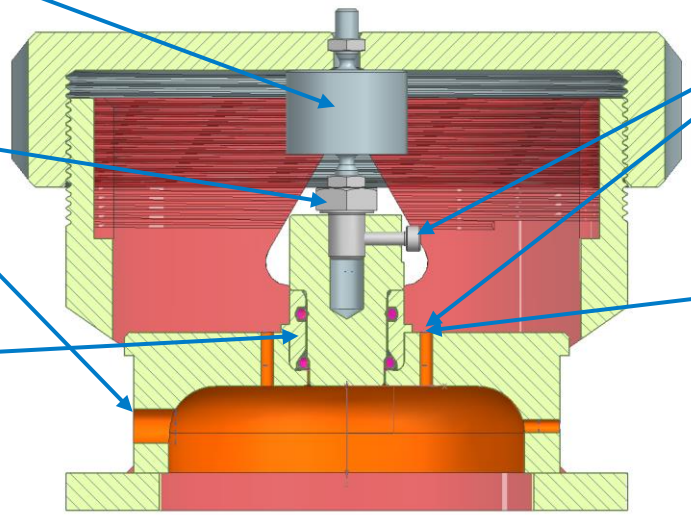
Setup for high current pulse testing

Cu-backplane model, test-plugs, non-conductive bushing, only front spring mounted

Preload via Load Cell (F_Z)

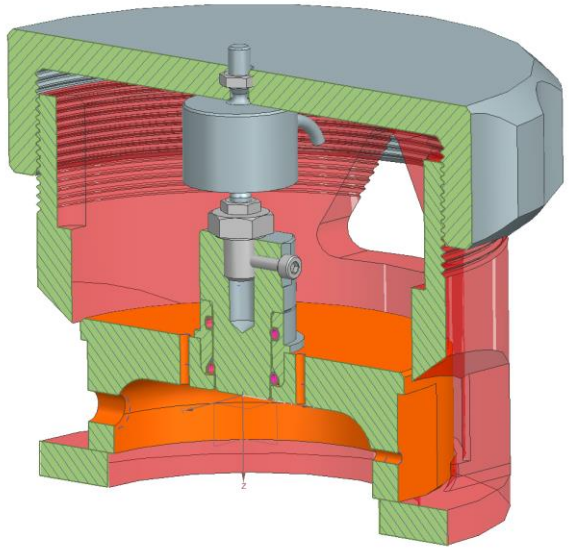
DC-Pulse (U_{Meas})

Non- conductive bushing



Voltage Measurement (U_{Meas})

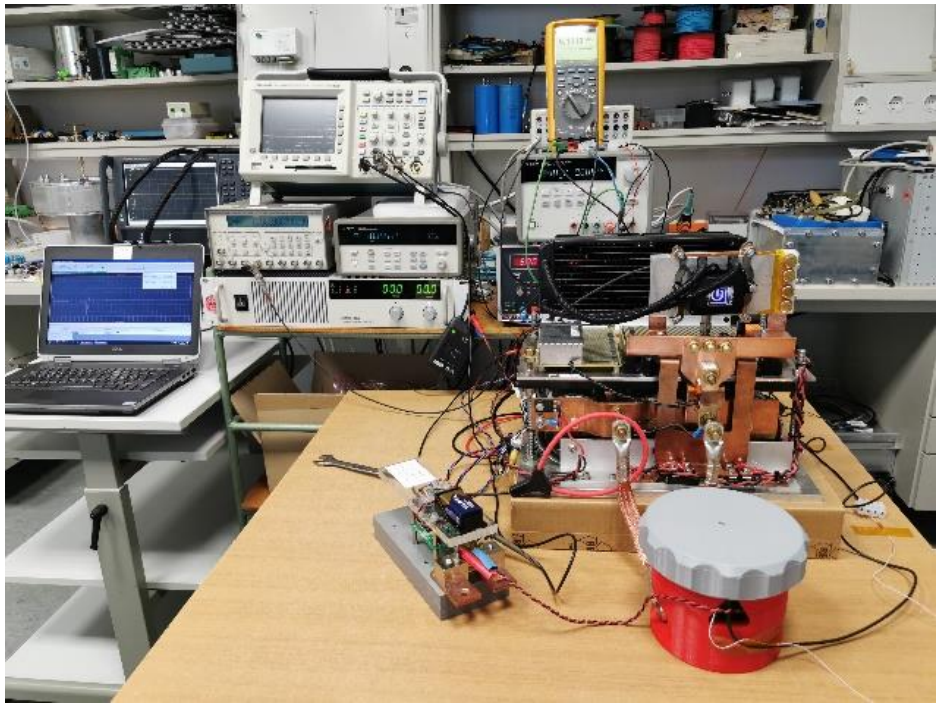
Temp. Measurement PT100 (T)



PMMA spring holder for test with Watchband

Pulse current tests in Zeuthen and Hamburg

Different springs, bushing geometries, cathode-plug materials and different peak currents

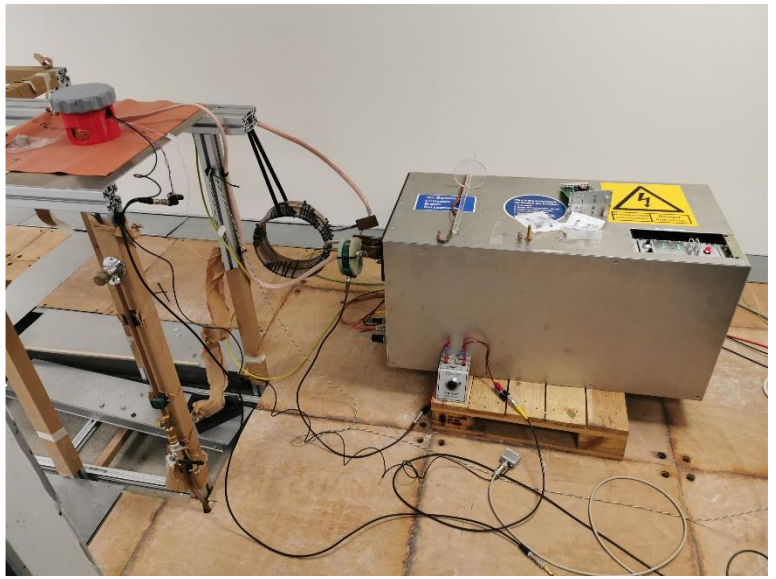


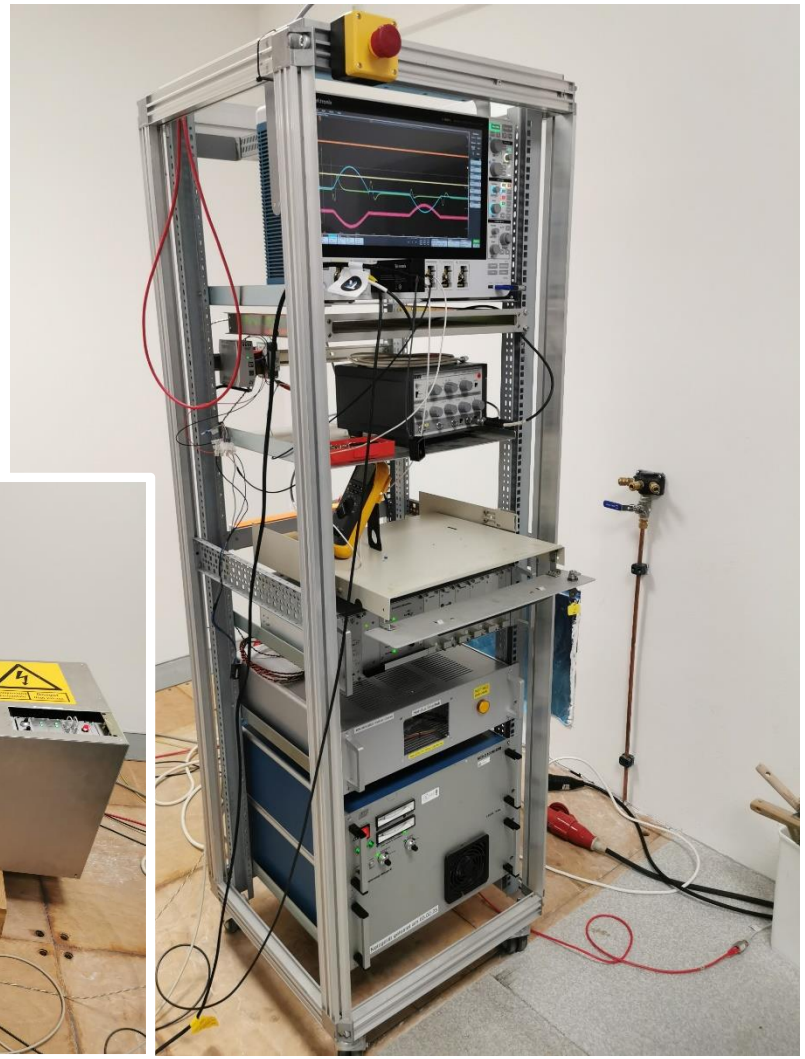
Pulser in Zeuthen → DC pulse
by several large electrolyte condensators
tests **up to 1700A**
10Hz / 1 sqare pulse 800µs

Courtesy:
Winfried Köhler,
Lutz Jachmann

Pulser in HH → pulse
tests **up to 3500A**
10Hz / 2 half sine waves
each ~870µs

Courtesy:
Hans-Hinrich Sahling
Mario Lengkeit

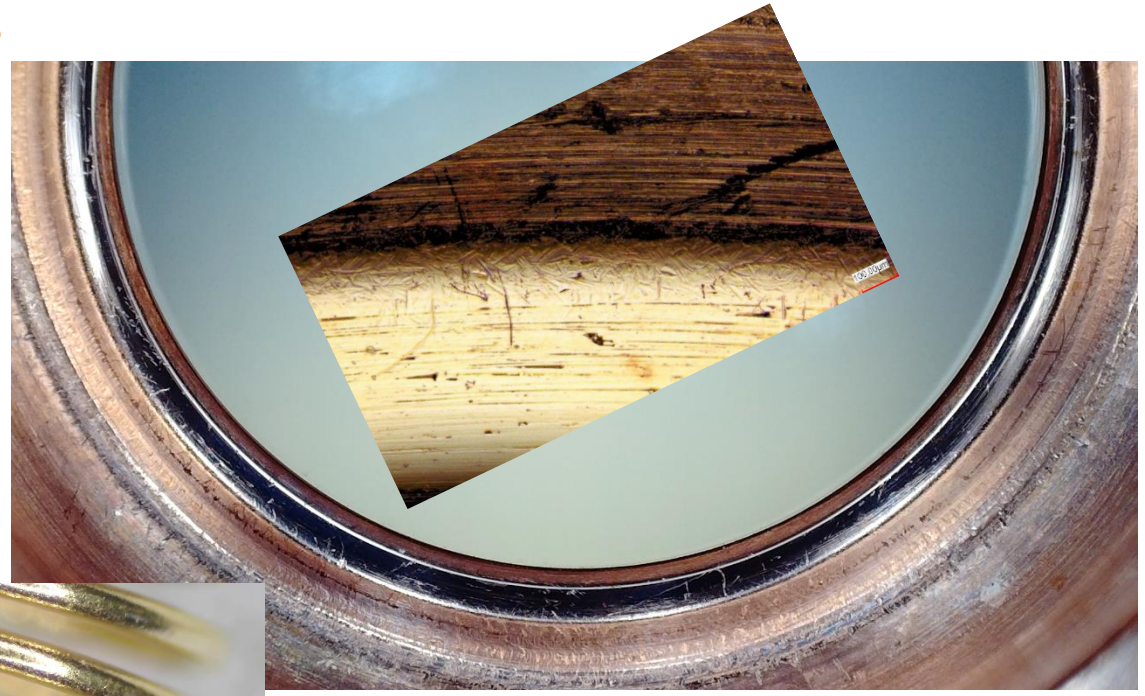


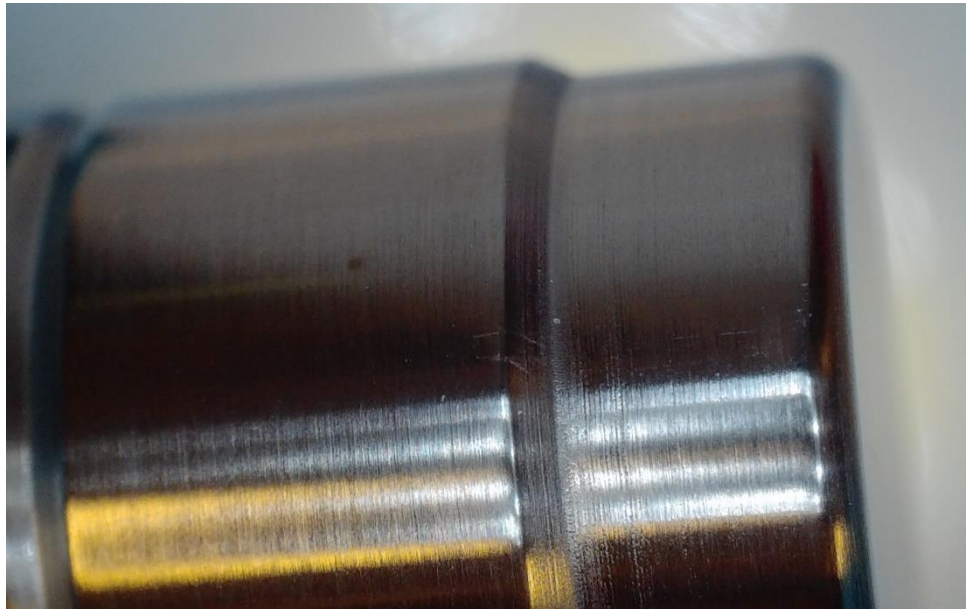


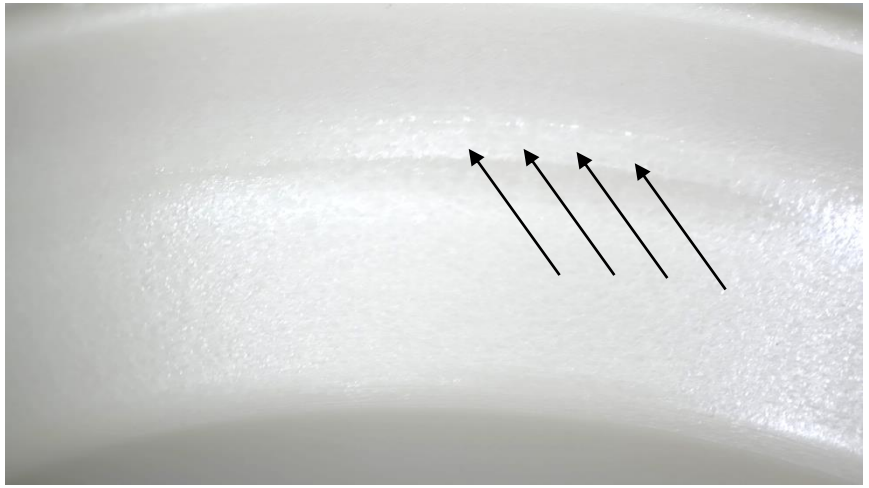
Visual surface inspection after pulse tests

No traces of high currents visible at the contact partners

- Molybdenum-Cathode plug → no visible traces at all
- Spring → no visible traces at all
- Backplane → faint sliding traces, visible only under microscope
- PEEK bushing → only a few barely visible imprints from the spring

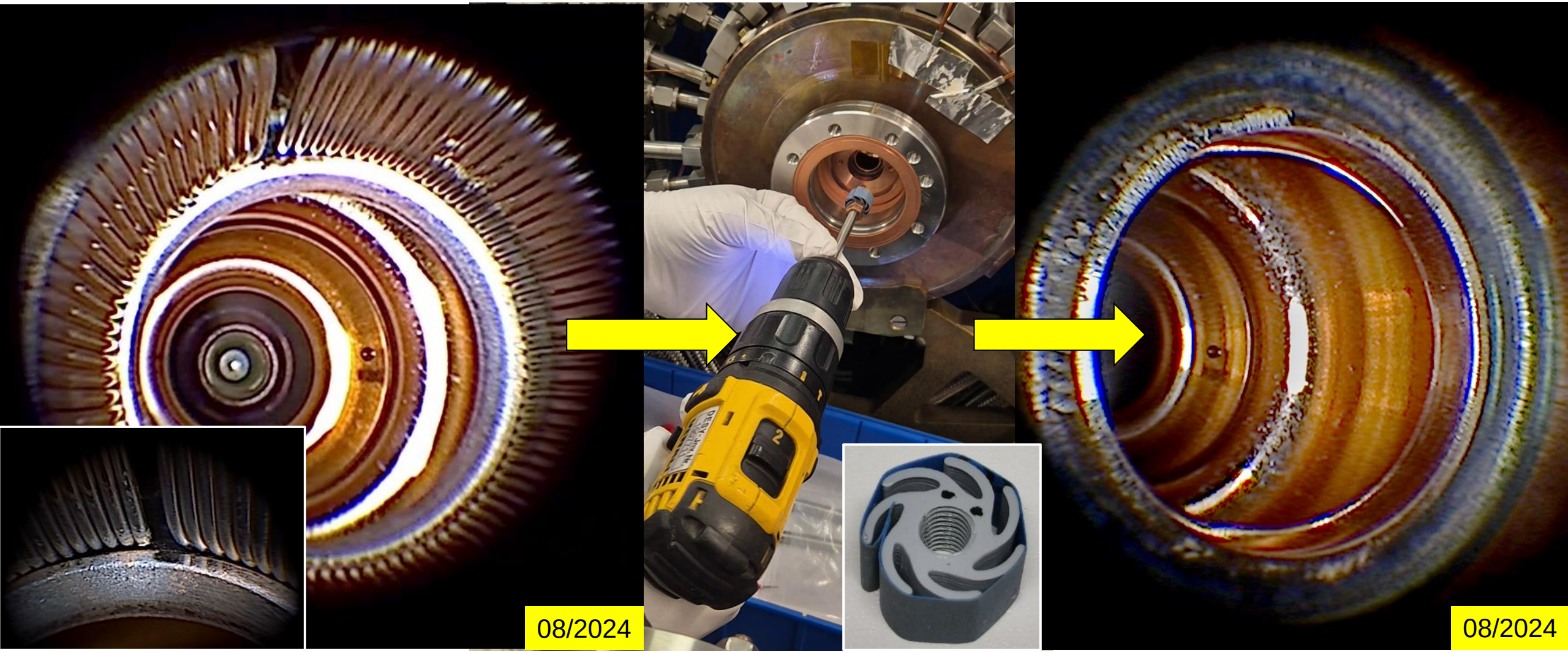






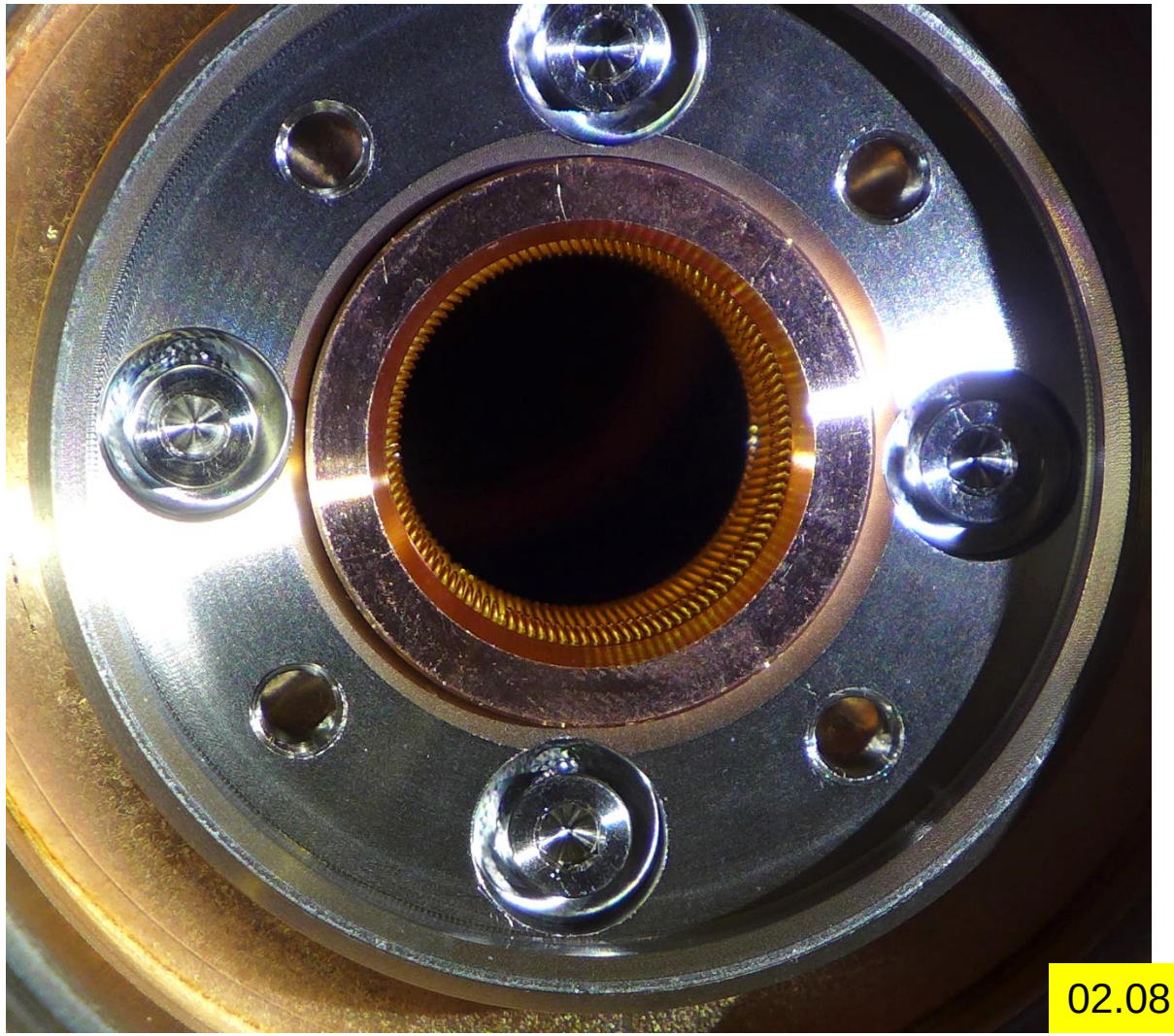
Gun 5.1 – „particle free“ in-situ polishing

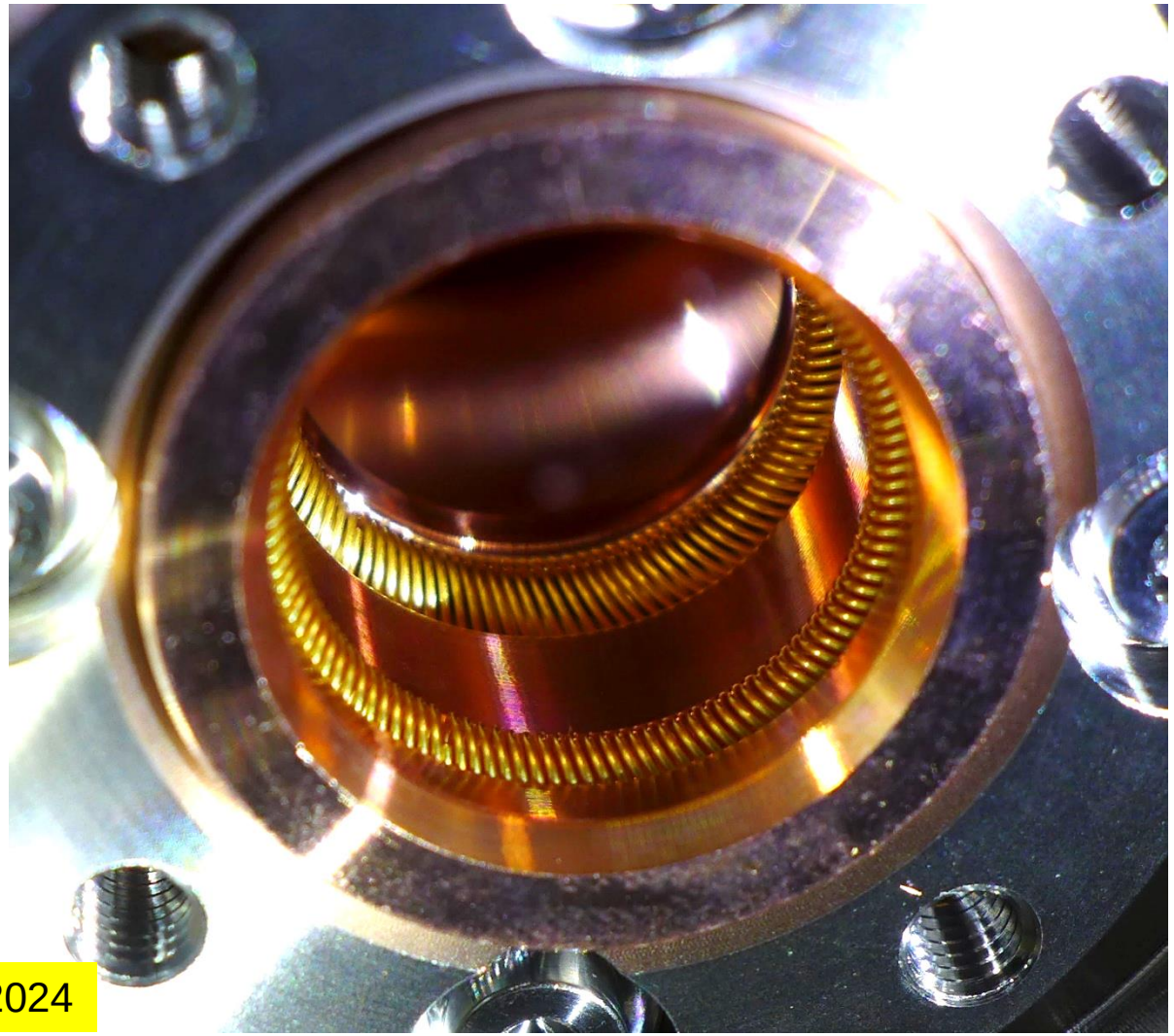
Up to MicroMesh 6000 under N_2-flow through the gun



Gun 5.1 with new RF-Spring mechanism

Operated for approx. 2 month → achieved max: pulse length 900us x 6.3 MW (~60MV/m)





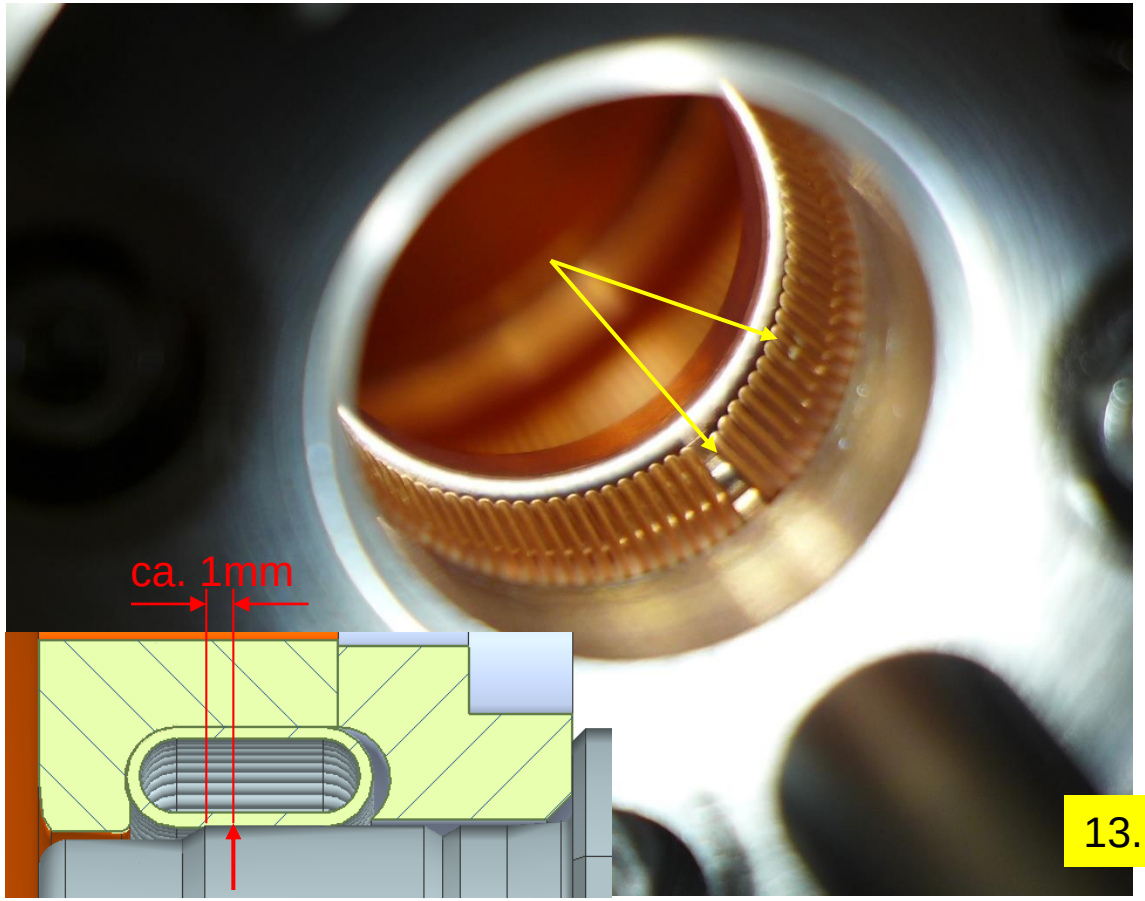
02.08.2024

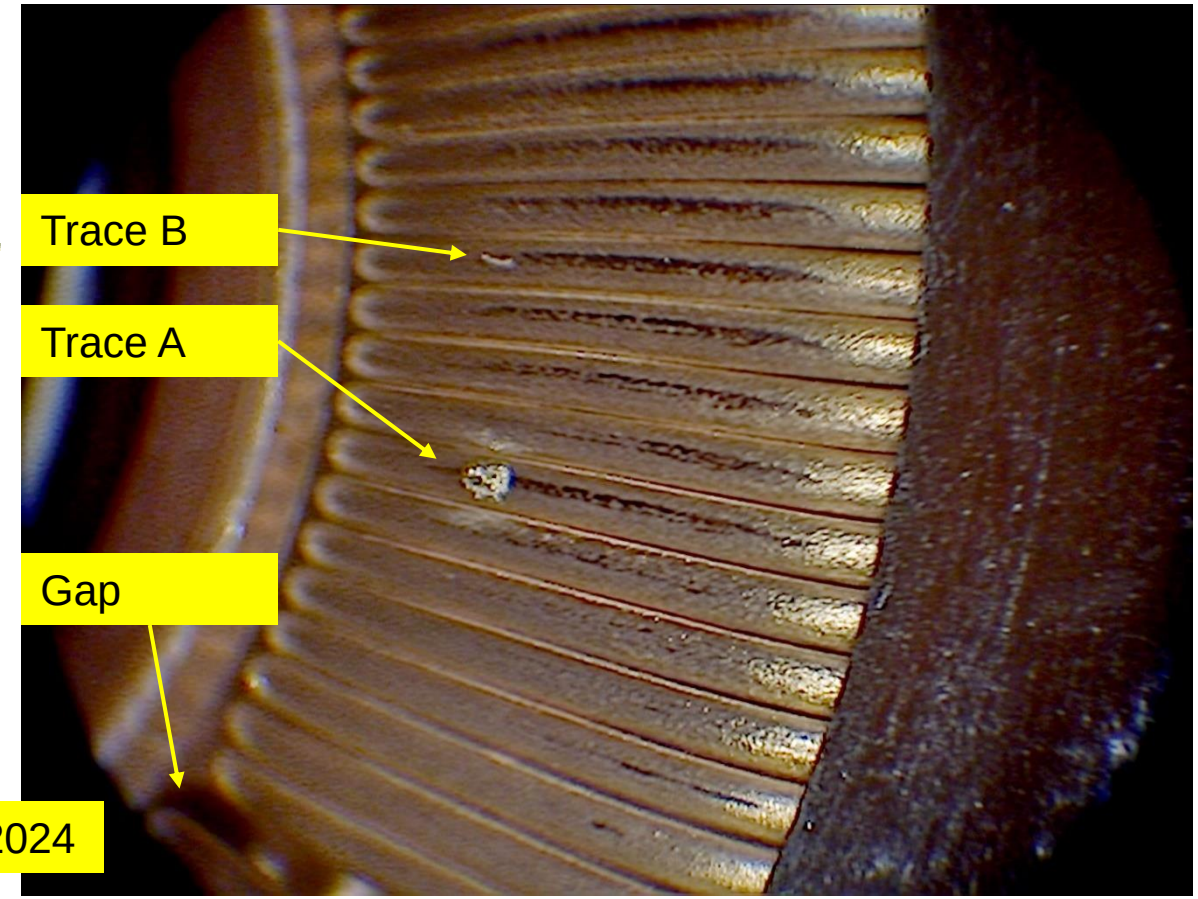
Gun 5.2 – conditioned @ FALCO

with „Watchband reloaded“

Gap at 5 o‘clock although spring quite nicely fixed
Mark at 4 o‘clock at the top of one winding

Gun hole ø16.6 was fine, rear surface also but ist edge to spring quite sharp -> to be polished

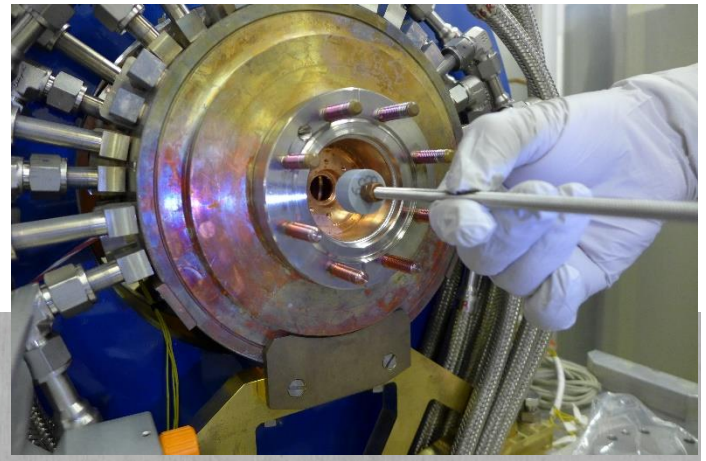


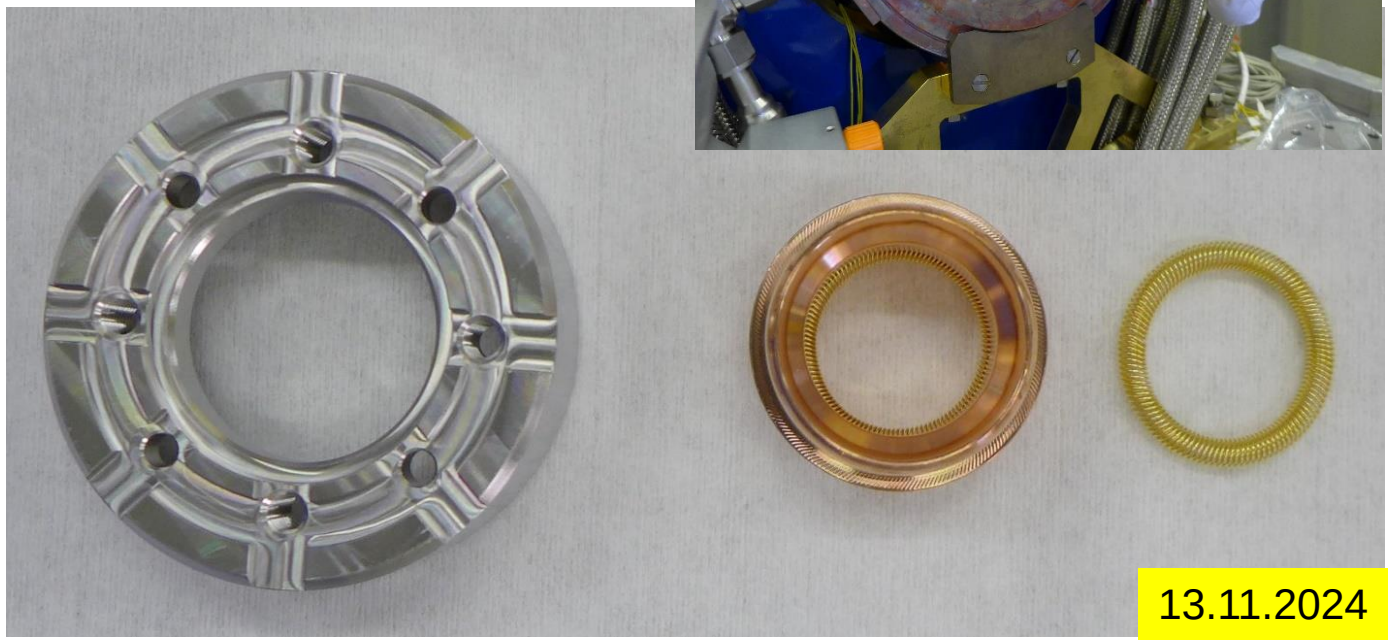


Gun 5.2 – before insertion to PITZ

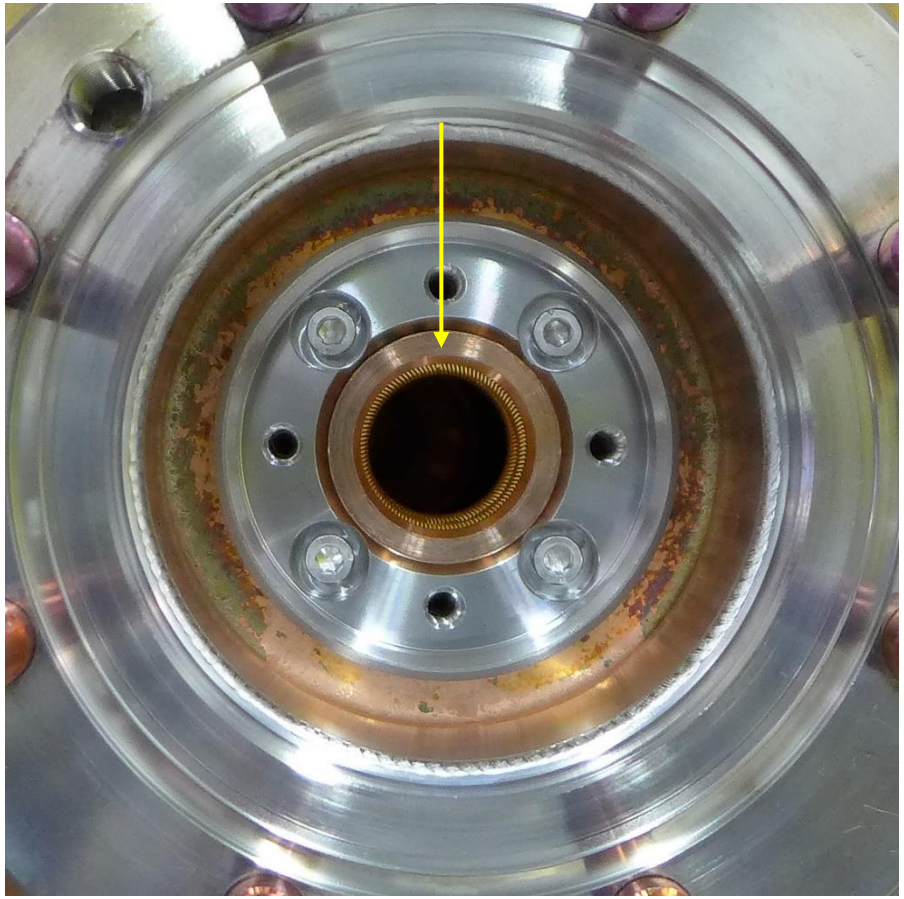
Gun 5.2 tiny plane repolished 6000-8000-12000 and BalSeal Springs installed

Front view of new contact springs before insertion.





With Watchband the 0° bolt pattern (X) was used.
Now the 45° bolt pattern was used.



New spring operated in Gun 5.1 and Gun 5.2

Summary

Gun5.1

- Hole ø16.6mm polished in situ
  to remove damages from arcing
- **Operation with new spring 12.08.2024-11.10.2024**
- Achieved max: pulse length 900µs x 6.3 MW (~60MV/m)
  → 3.5 hours
- ~1000 hours of operation, ~74GJ deposited in the cavity
  2024-11-05 00:00
- Average power → up to >45kW
  → no damages at spring & bushing and cathodes

Gun5.2

- small plane contact surface in Gun repolished before the new RF-spring was inserted
- New spring **operates since 16.11.2024** in Gun5.2
- Reliably running also at higher RF gradients and pulse longer pulses
- Milestone for conditioning reached (60MV/m @610µs) in spring 2025
- No new damages observed at the cathodes so far
- Several cathode exchanges done already

Thank you for your attention.
Vielen Dank für ihre Aufmerksamkeit.

AND
Many thanks to all colleagues involved!

PITZ Group; Sebastian Philipp (ME); Mechanical Workshop (Z_ME1); Winfried Köhler & Lutz Jachmann (RF);
Silke Vilcins & Dirk Lipka (MDI); Michael Bousonville (MHF); Alexej Ermakov (ZM) & Arno Jeromin (CXNS);
Matthias Schacht (ZM2); Hans-Hinrich Sahling & Mario Lengkeit (MIN); Ye Chen (MXL);
Robert Riegen (BalSeal); Jens Kruse (ABELCO)
and more …

Contact

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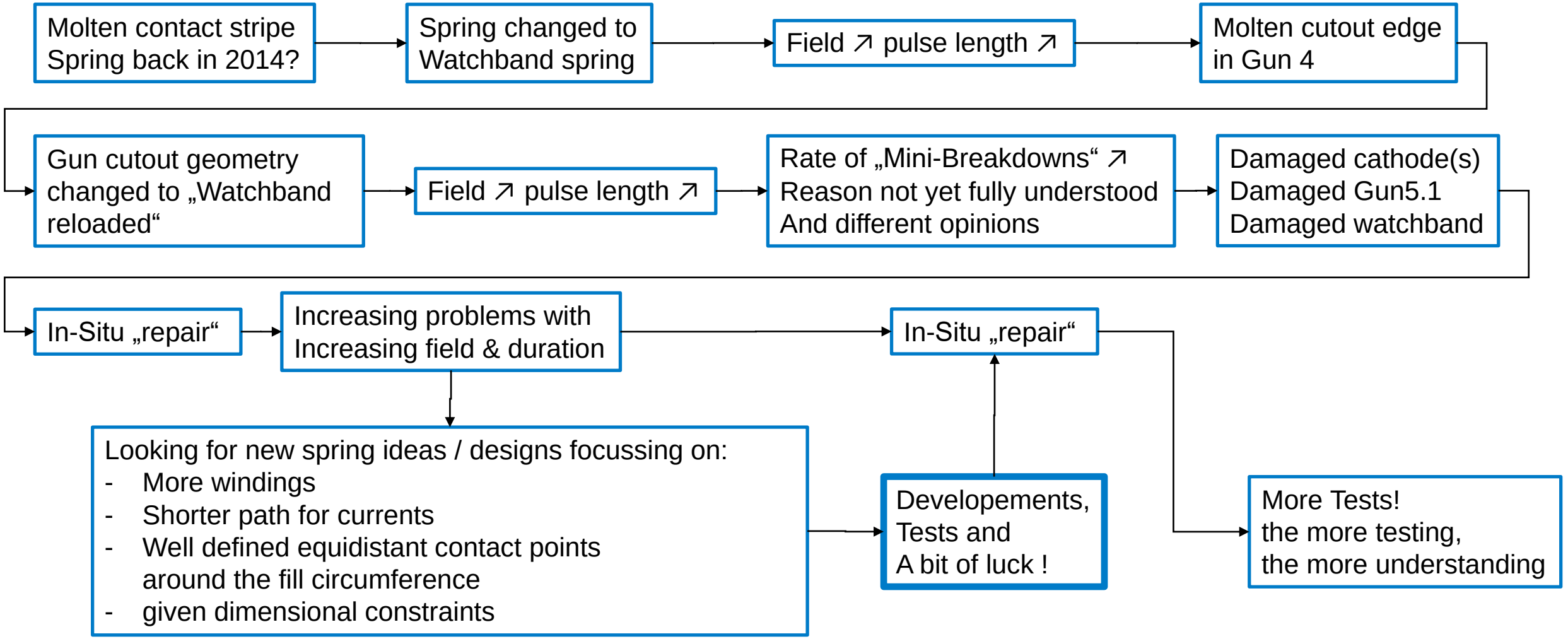
From problem to developement

… takes time …



From developement to new solution

… takes time and several (meander) ways to go

Increasing problems with
Increasing field & duration

Understanding and
common sense about
possible reasons

Looking for new spring ideas / designs focussing on:
- More windings
- Shorter path for currents
- Well defined equidistant contact points
  around the fill circumference
- given dimensional constraints

BalSeal on cathode

BalSeal(s) inside gun

Self manufactured
Sliced spring

Clamp bushing

Kinematic tests

Force tests

Watchband welding tests

Ring-welded Watchband

Pulse current tests

More understanding
of the problem(s)

Already broken Gun5.1
improved willingness to take more risk
no other choice

Successful test in Gun5.1
Under real conditions

Freshly conditioned Gun5.2
improved willingness to take
even more risk

Found initial damages on
Watchband in Gun5.2

More Tests