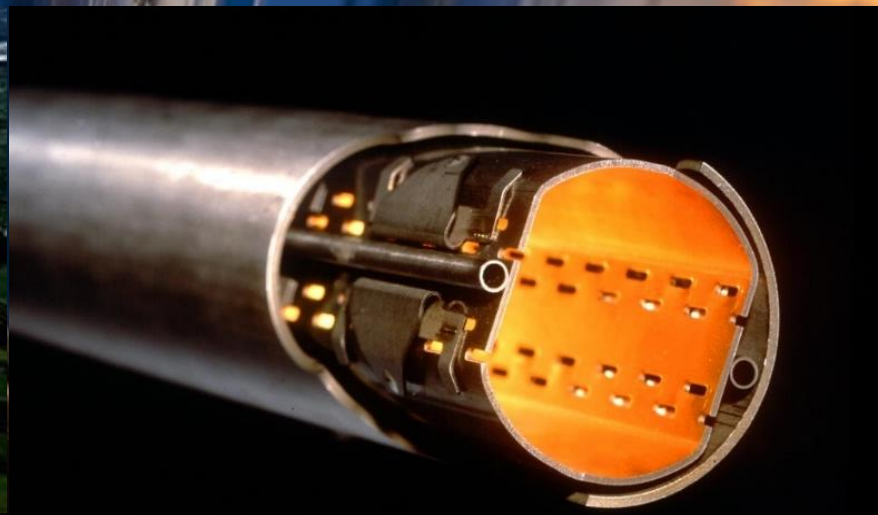
GE Inspection Robotics

Robotics in Nuclear

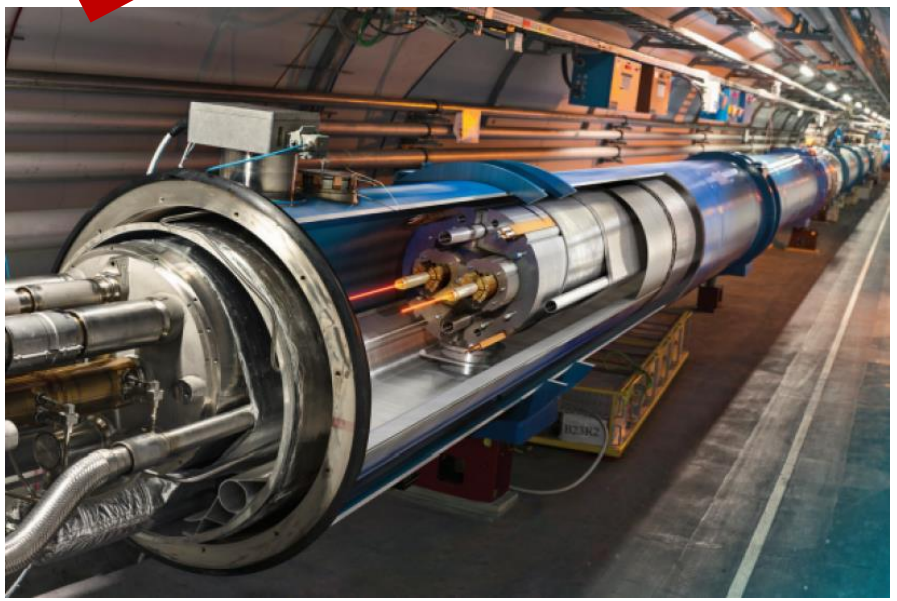
Successful “commercial” deployments and future developments

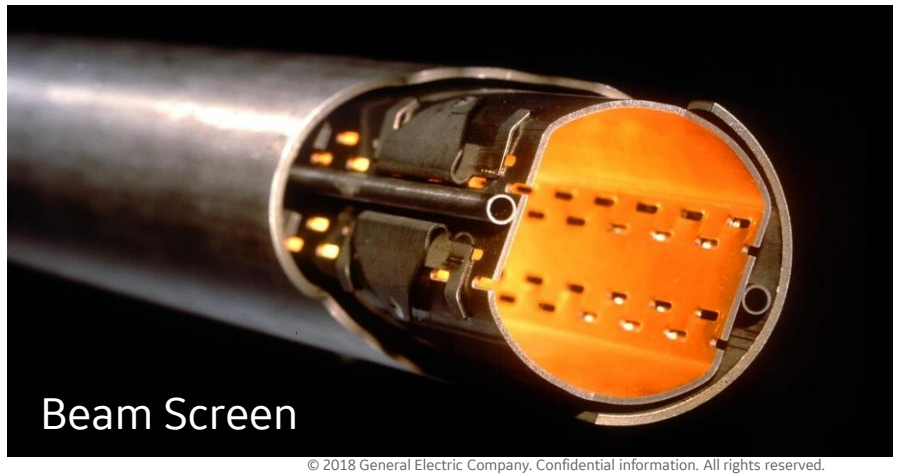
Robotics for Laser Engineered Surface Structures in the CERN Large Hadron Collider (LHC)



The Large Hadron Collider (LHC)

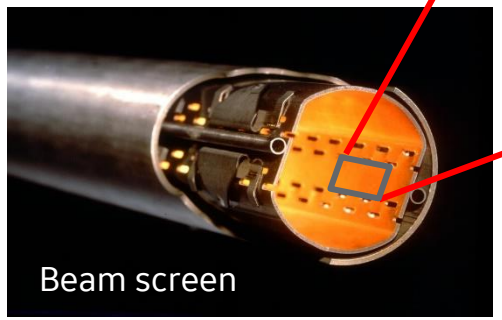
- The world's largest and most powerful particle accelerator.
- It first started up on 10 September 2008, and remains the latest addition to CERN's accelerator complex.
- The LHC is located in a 27-kilometre long ring tunnel about 100 meters underground. Superconducting magnets ensure the steering of two counter-rotating hadron beams;
- A number of accelerating structures boost the energy of the particles up to 7 TeV along the way.
- Four gigantic detectors analyze the results of the collisions of the two colliding beams.

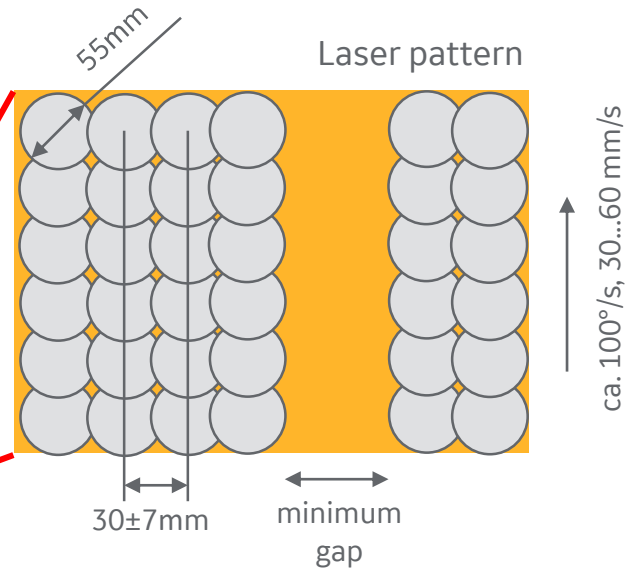


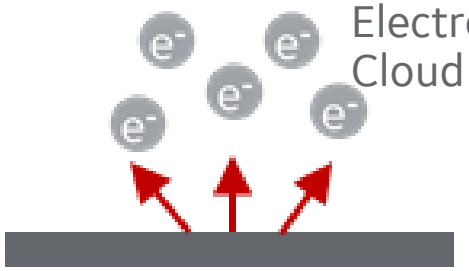


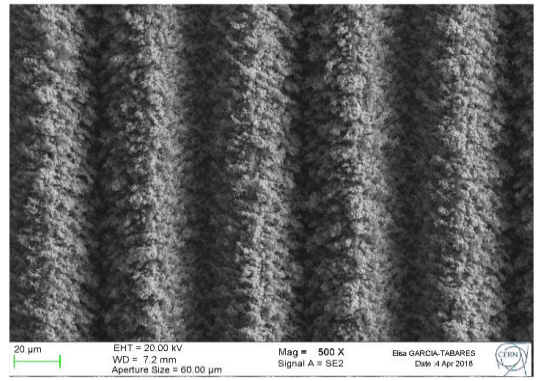
Laser Engineered Surface Structures, LESS

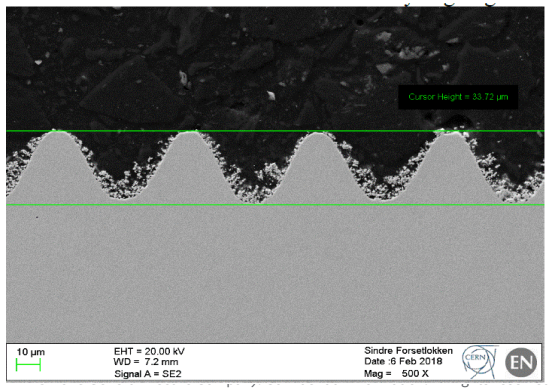
- Generation of secondary electrons at the material surfaces creates a so called “Electron Cloud”
- The secondary electron cloud facing the bunched proton beam that circulates in the accelerator limits the range experiments
- Laser Engineered Surface Structures (LESS) help to mitigate this “electron cloud” (by of “absorbing” the secondary electrons)
- LESS was jointly developed by researchers from the University of Dundee and the Science and Technology Facilities Council (STFC)











The Robotic Challenge

Deployment of a rotating a laser beam

- Deployment of a optical fiber with the beam delivery system
- Control system that manages the whole process

Length: 15 m

- This in-situ surface treatment needs to be carried out in relatively long (up to 15 meters) and narrow pipes
- The laser light must be delivered over long distances in a very limited space.

Diameter: ID 35 mm

- The LHC beam screen LESS treatment needs to be in racetrack shape
- Internal radius of the beam screen is variable,

Access: 150 mm

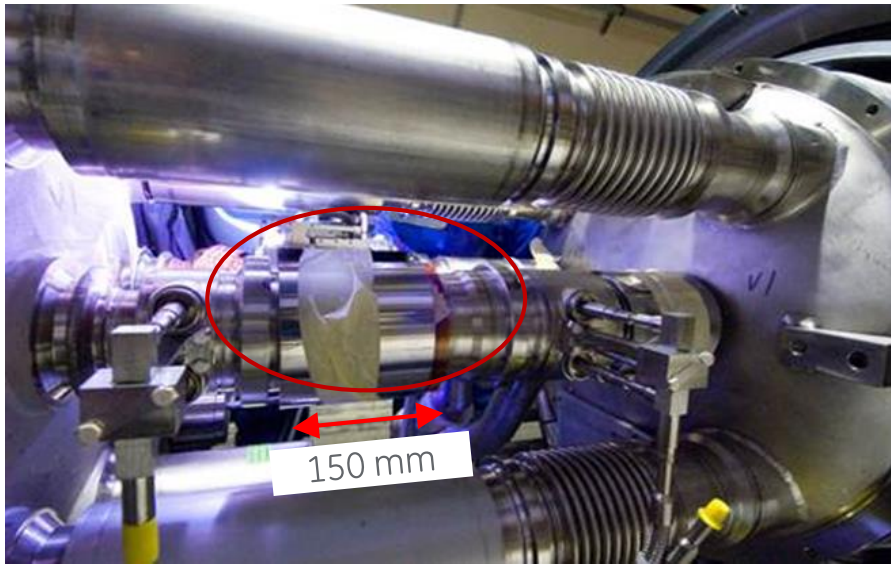
- The access to the beam screens is limited to a 15-cm long access slot available after dismantling the removable interconnection unit called plug-in module.

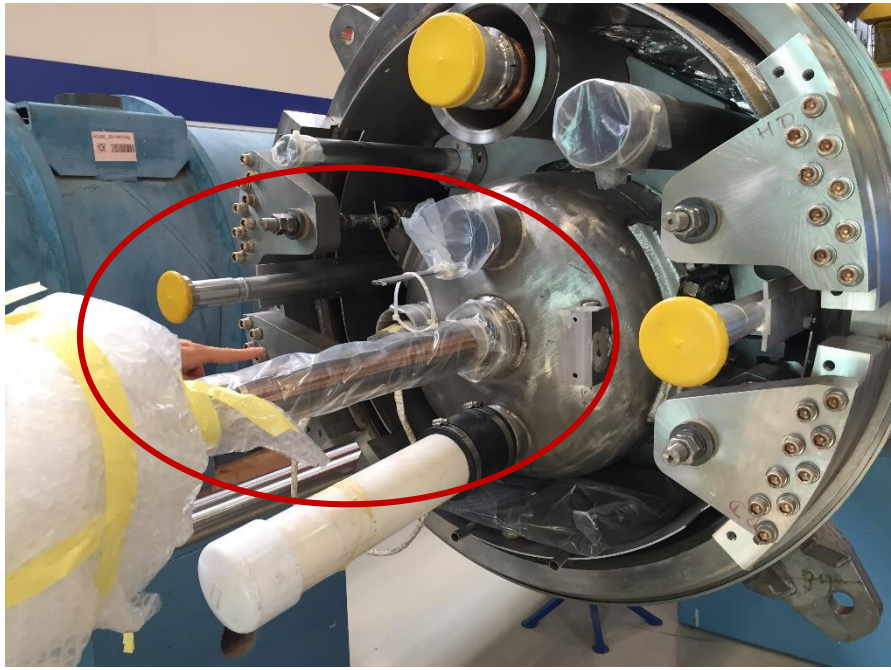
Accuracy: 10 micro meters

- To ensure functionality of the LESS treatment a high precision in laser transmitted via mechanic movement (10 micrometer's) is mandatory.

Materials

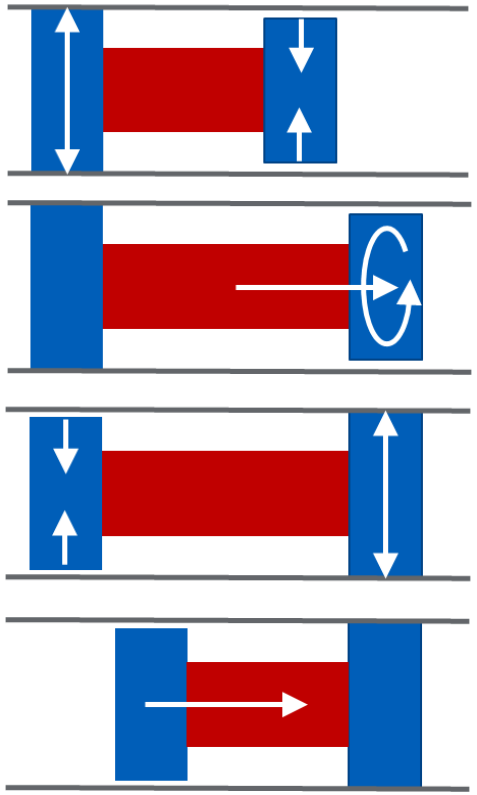
- Avoid/minimize organic materials
- NO oil, grease or other contaminating substances; All parts to be cleaned before assembly





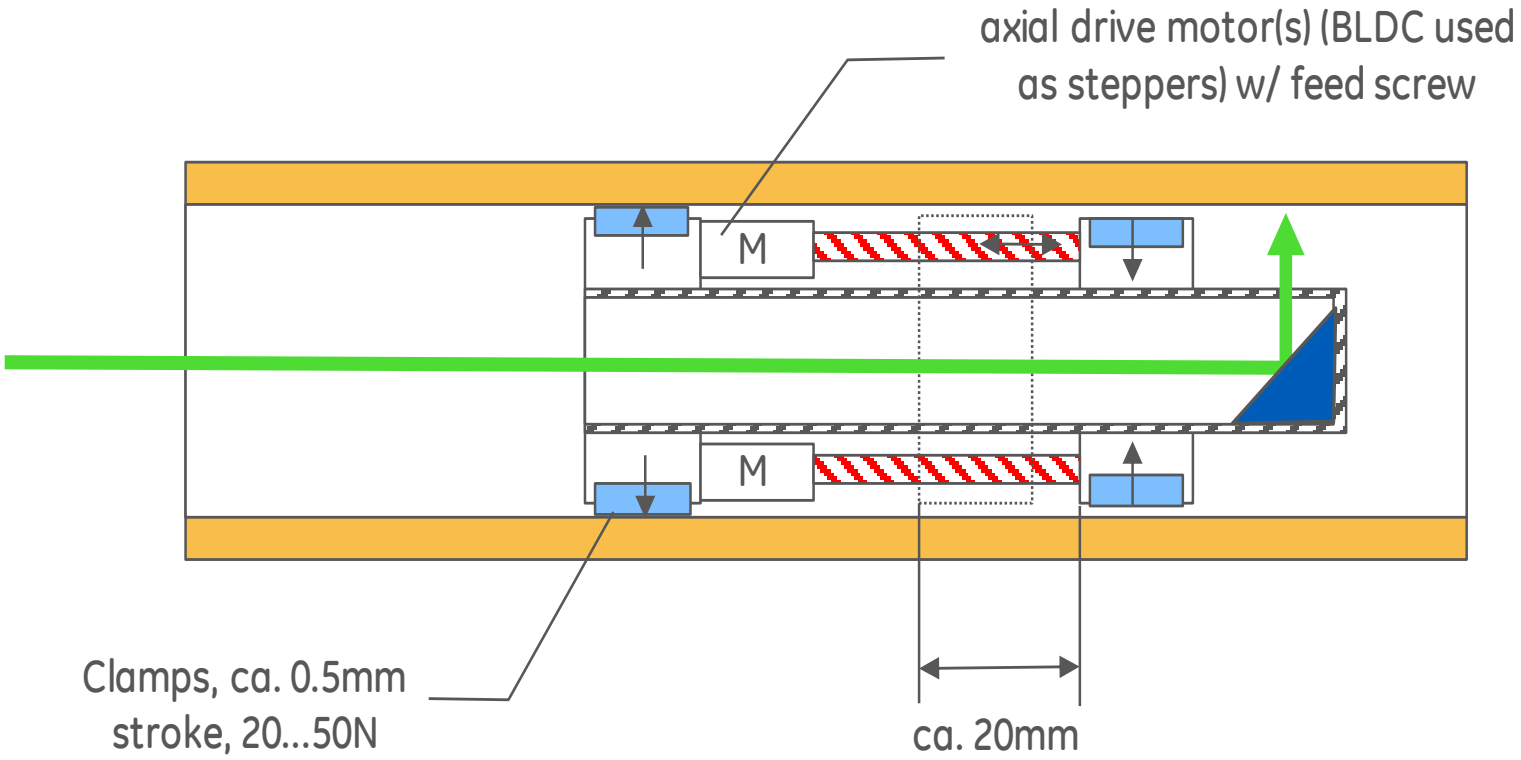
Robotic Principle Chosen: Inchworm / Conceptual Design

The Principle

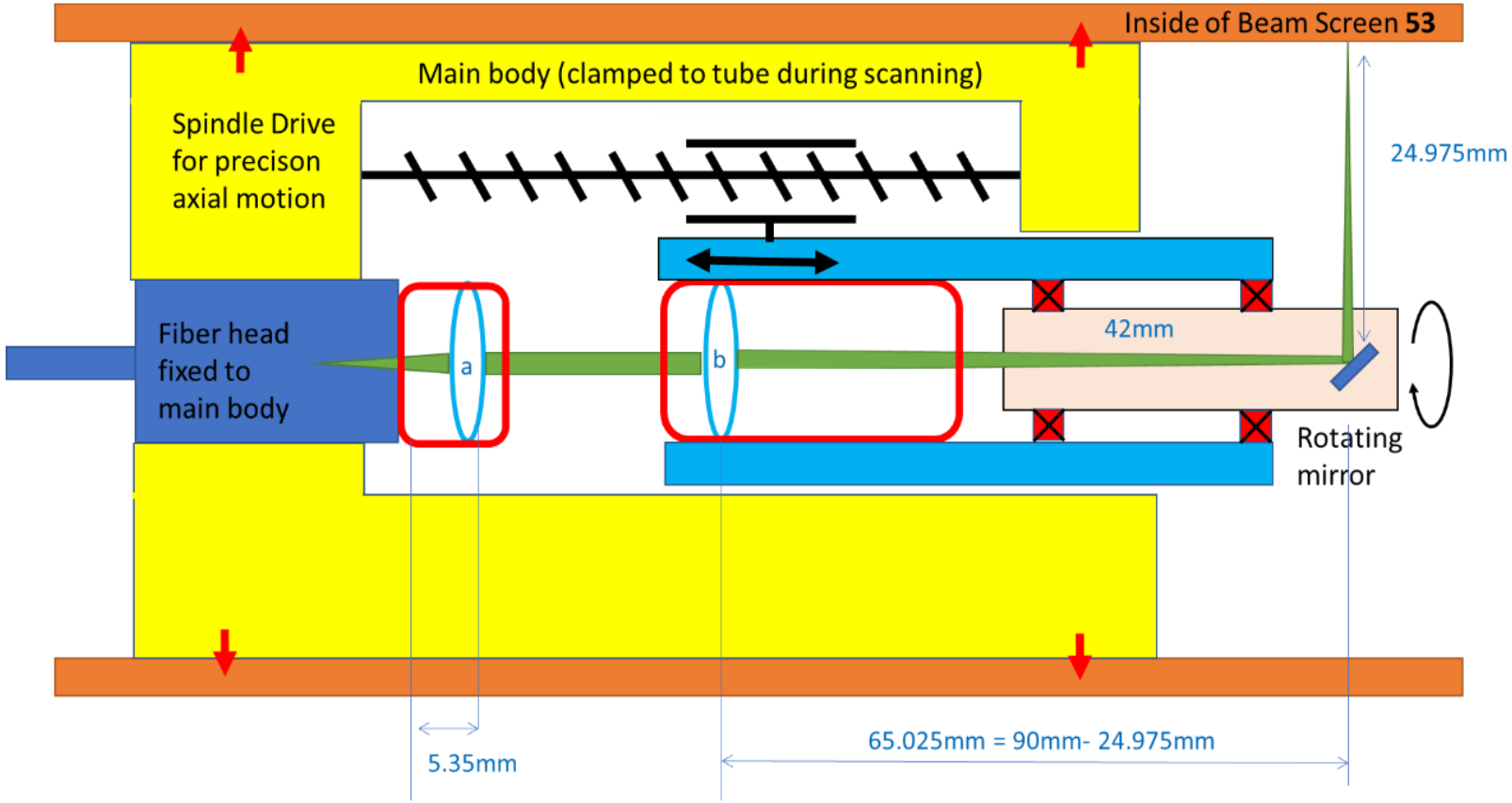


- Precision feed screw preloaded w/ spring to eliminate play
- Very little wear (not contamination by particles)

Conceptual Design

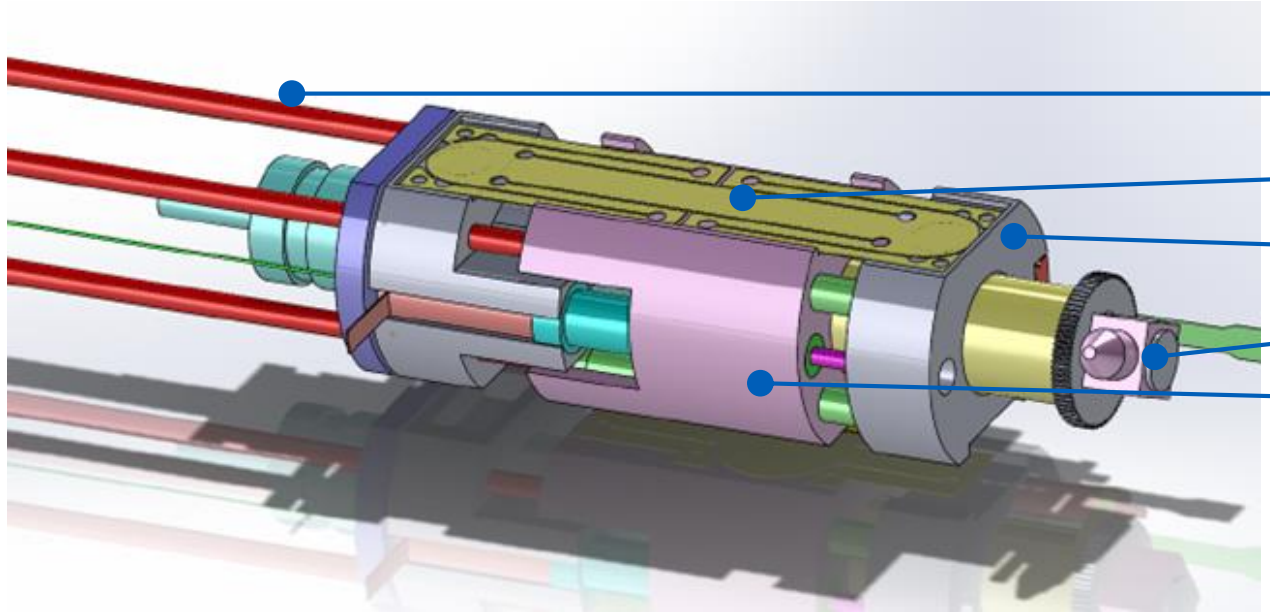


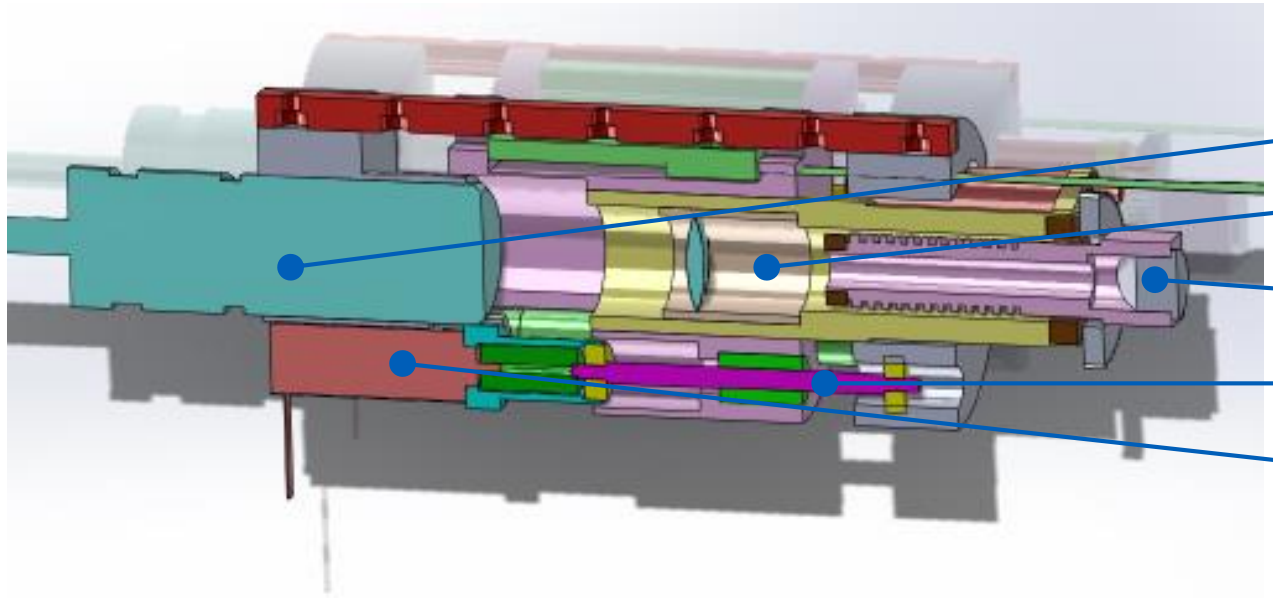
Challenge: How to integrate the Laser Beam



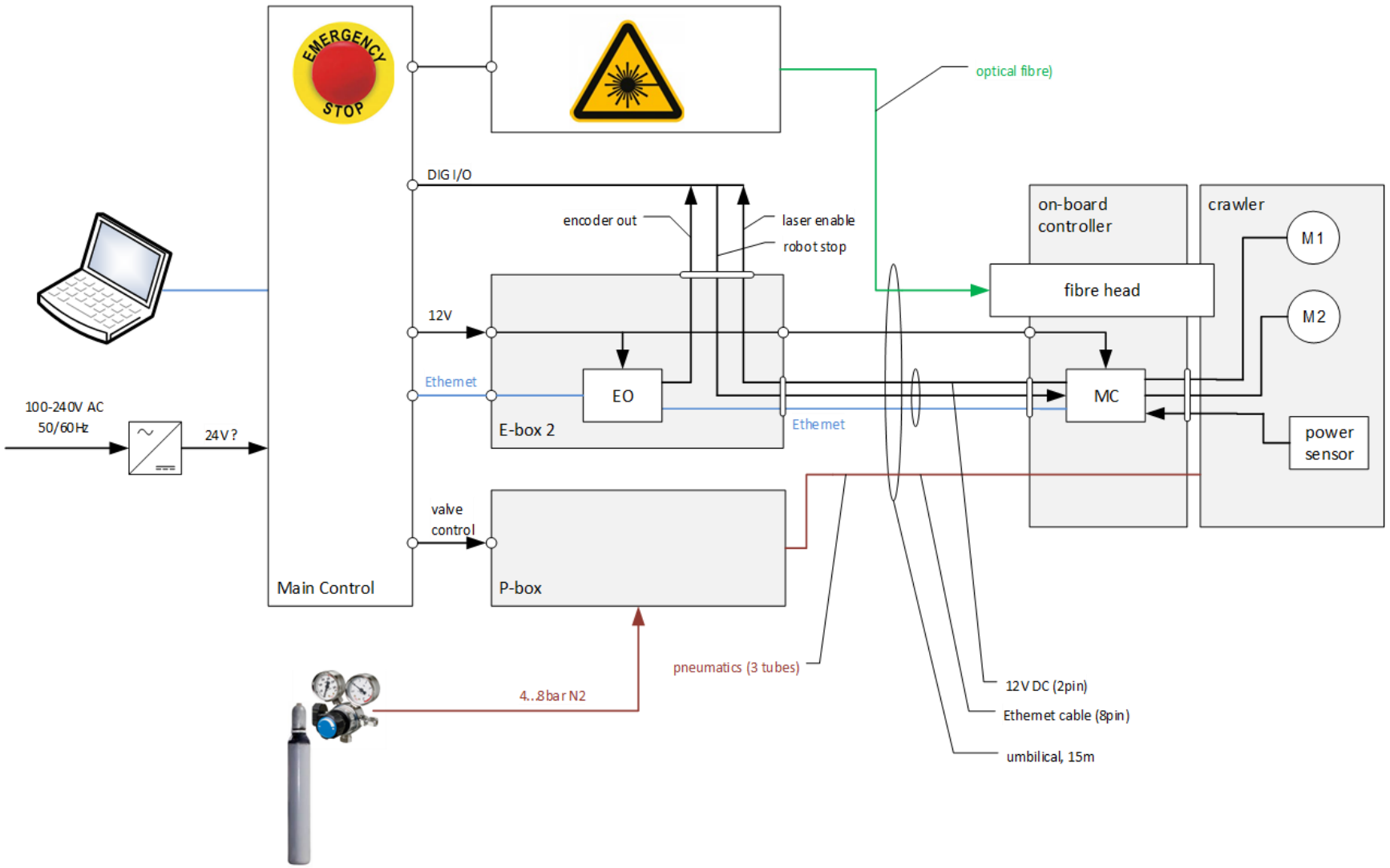
- Lens a and b in separate parts that can move axial up to 20mm relative to each other on axial direction to decouple stiff fiber from laser head
- Combine fiber head and lens a into ONE unit, to simplify integration and mounting in TCS; lens can be adjusted to a create parallel beam
- OD of optical system 16mm
- Challenge: axial alignment of optics

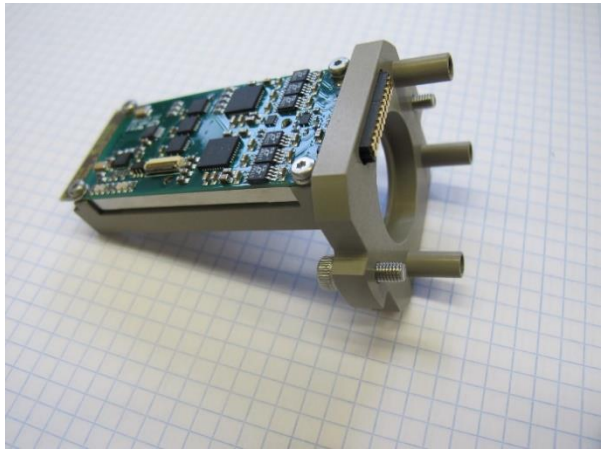
Detailed Design



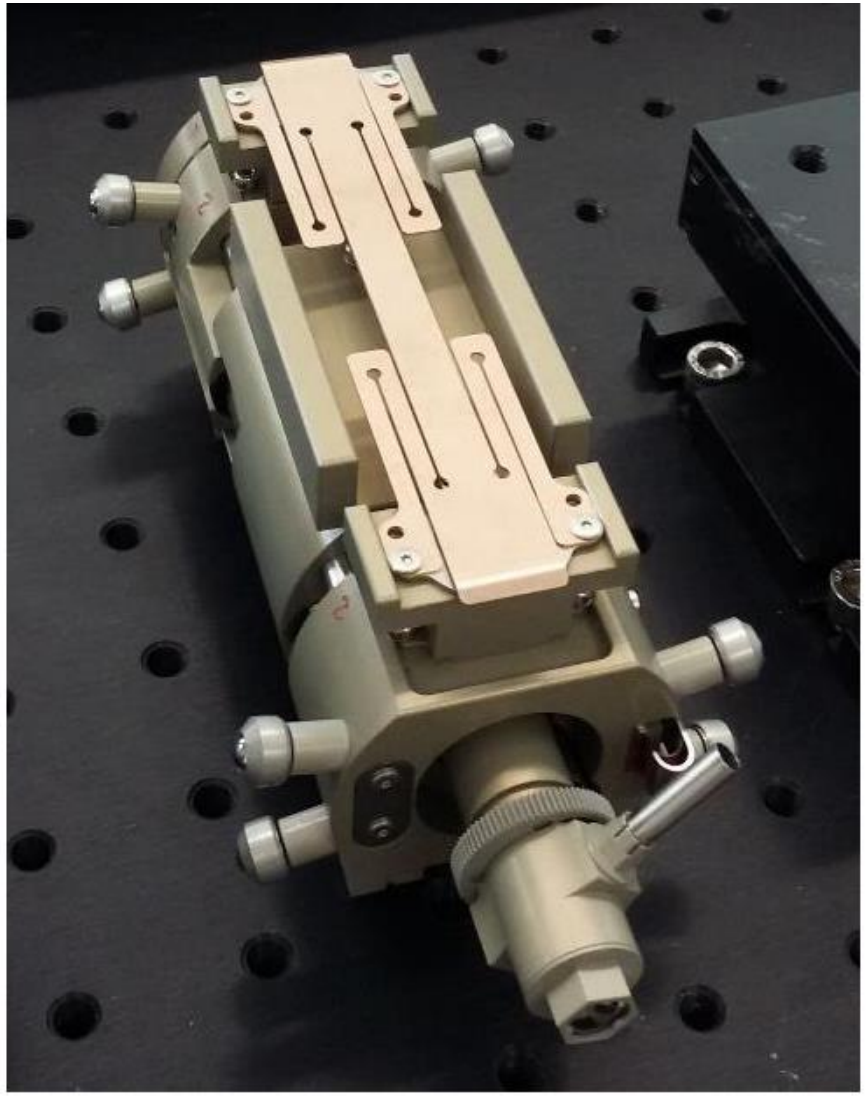


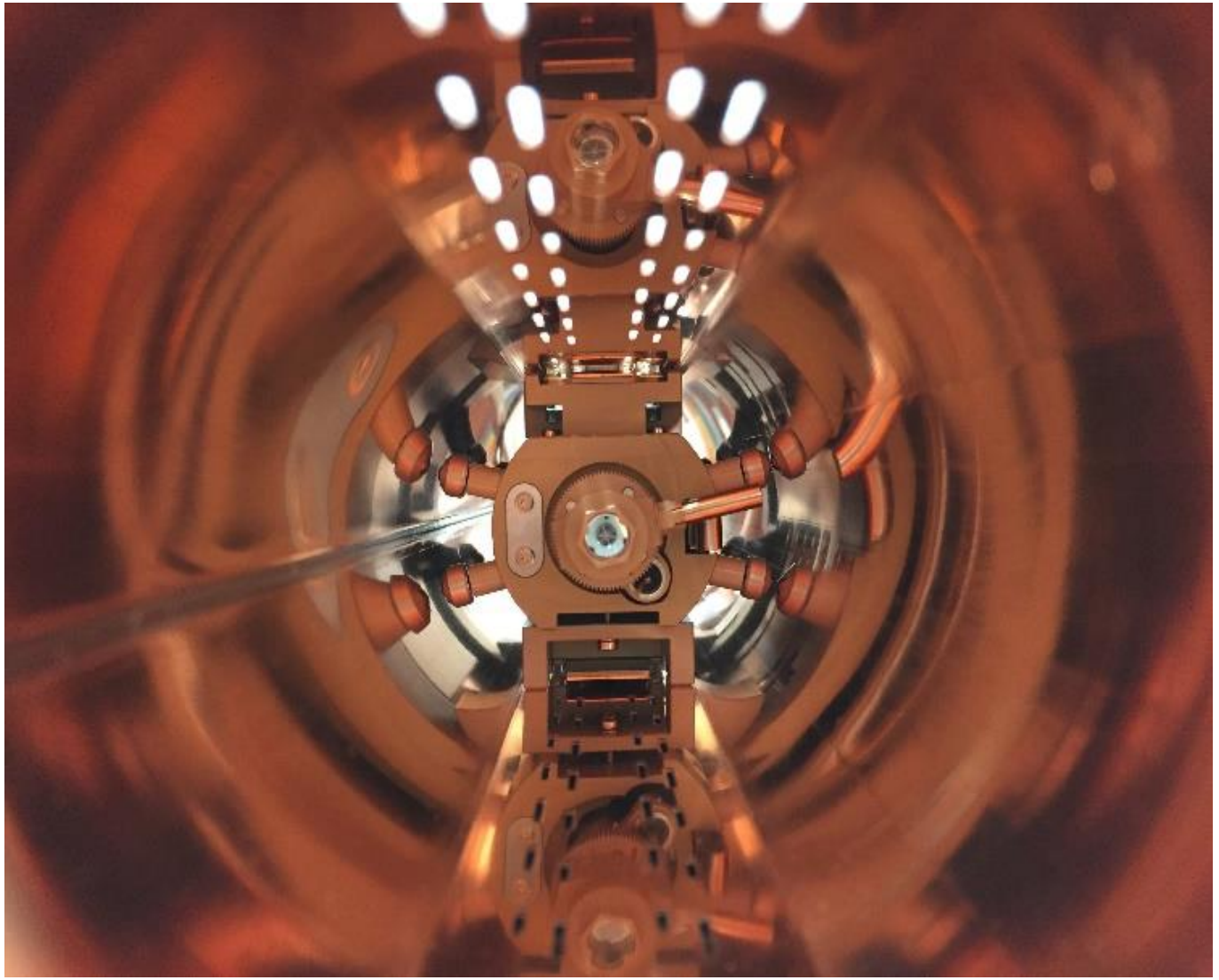
Control



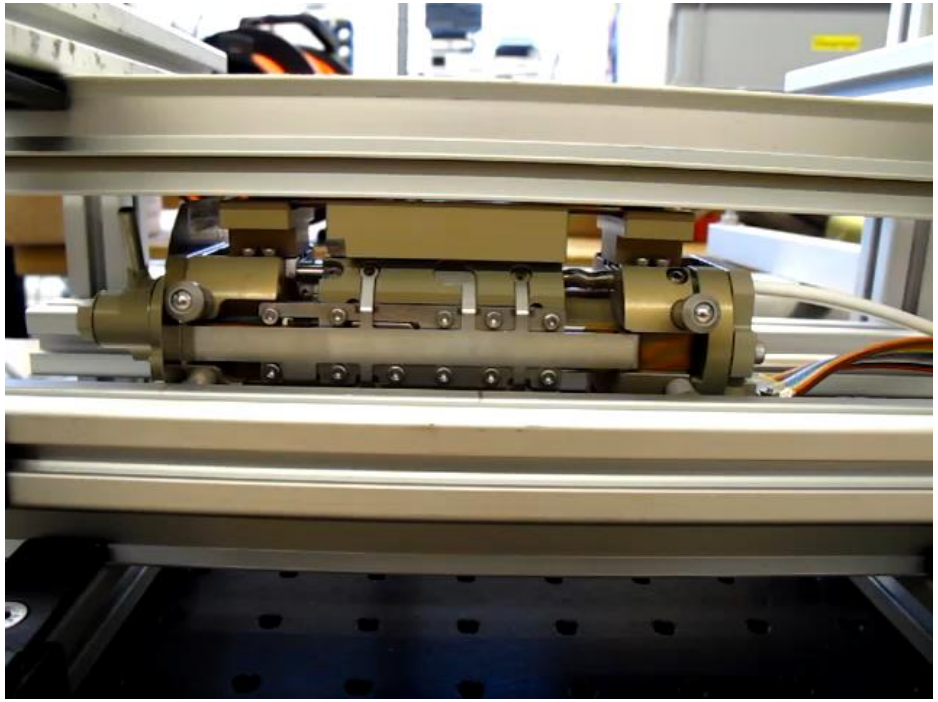


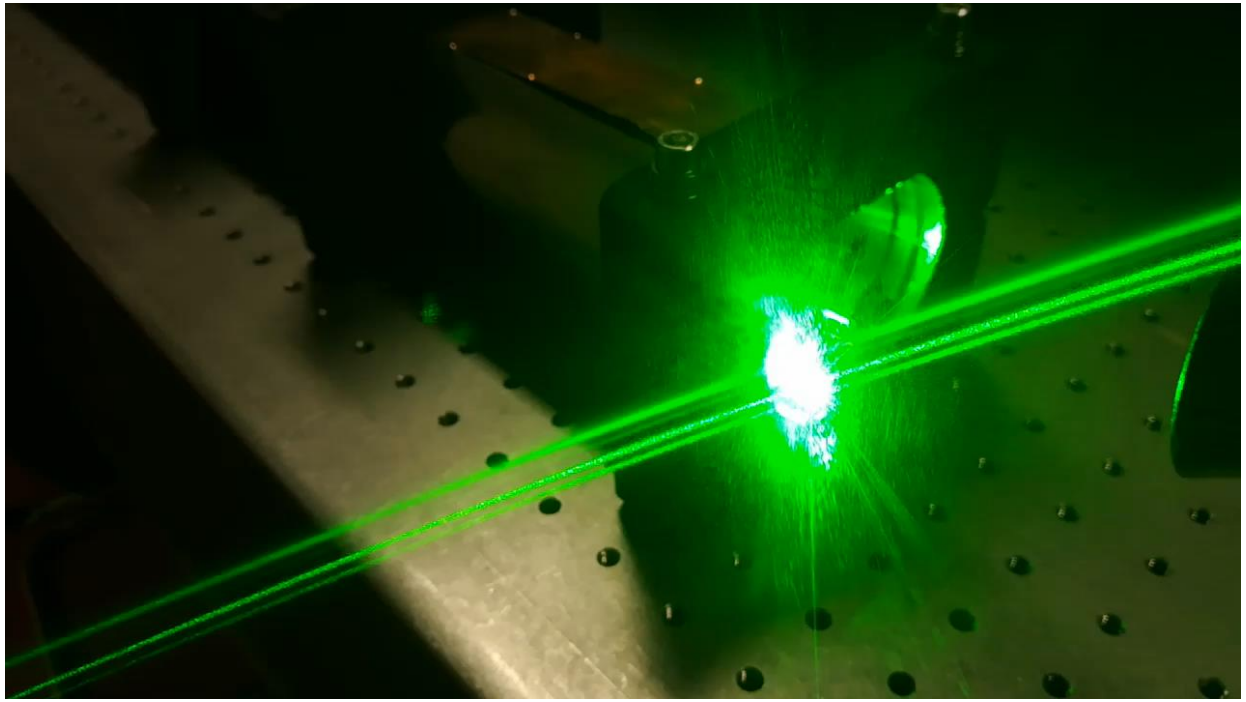
Assembled System





Lab System Testing & System Commissioning





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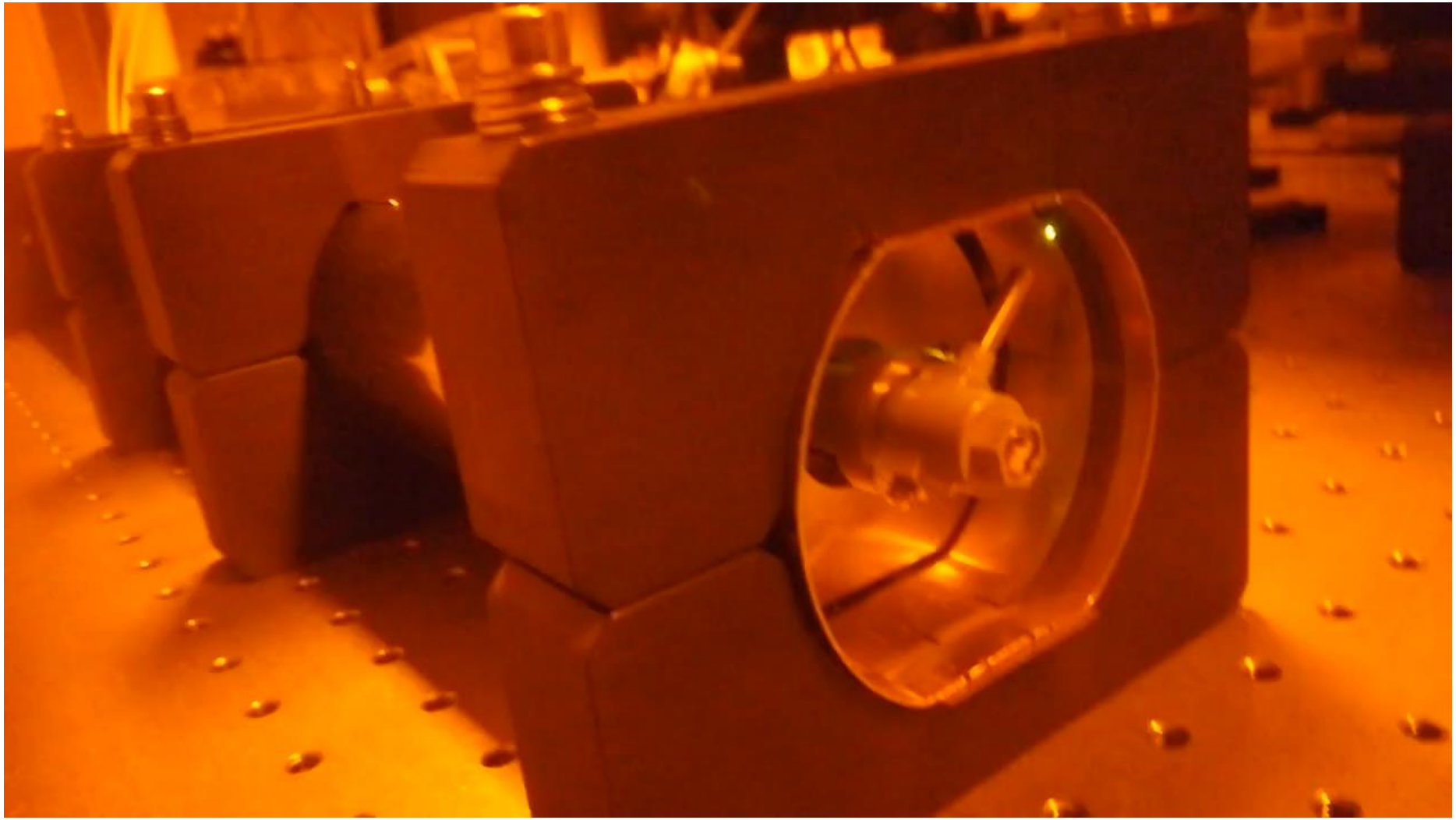
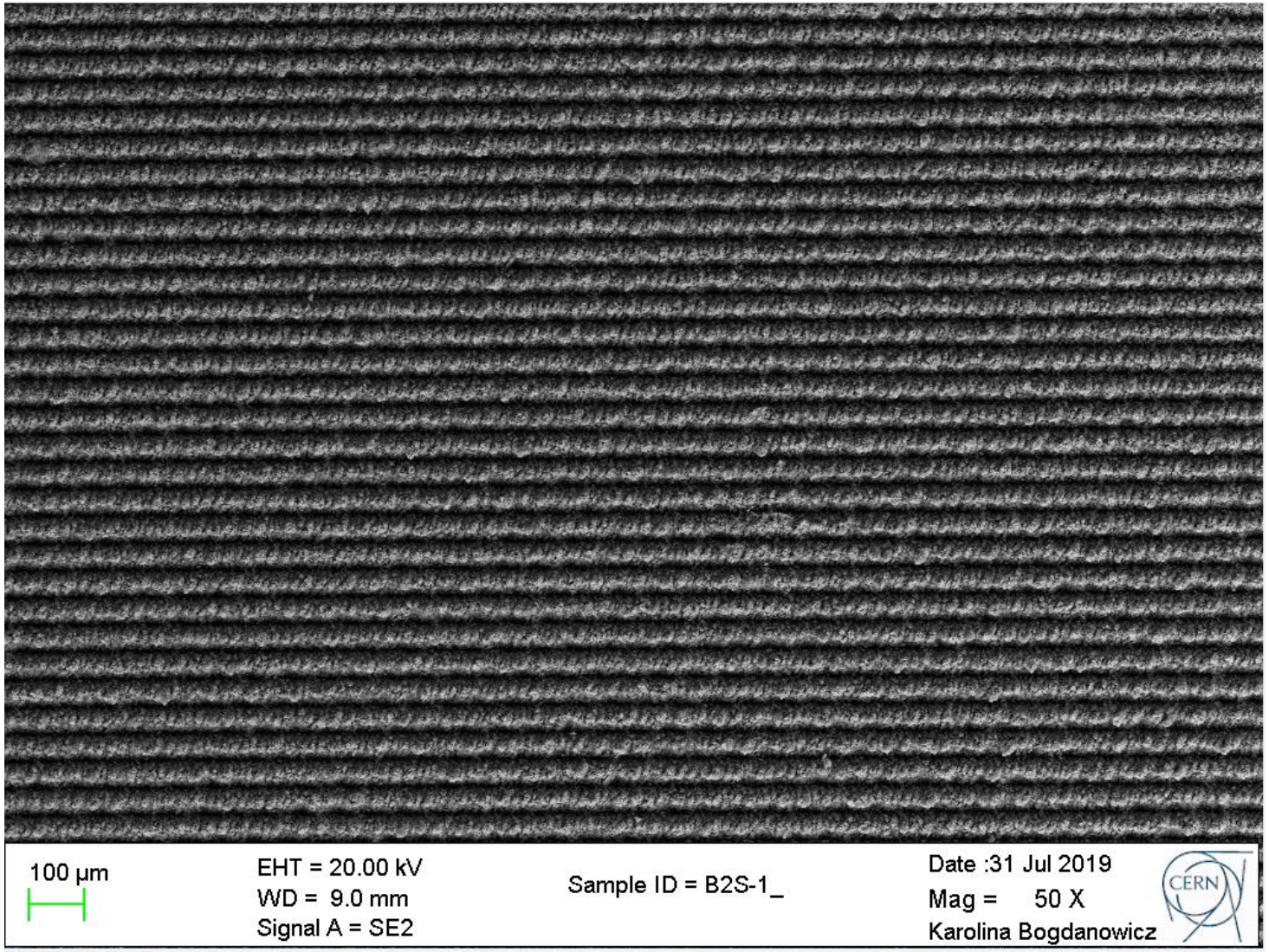
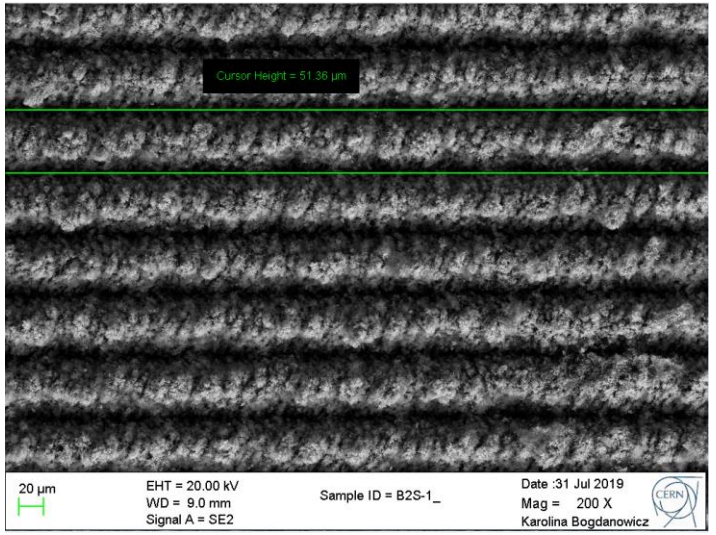
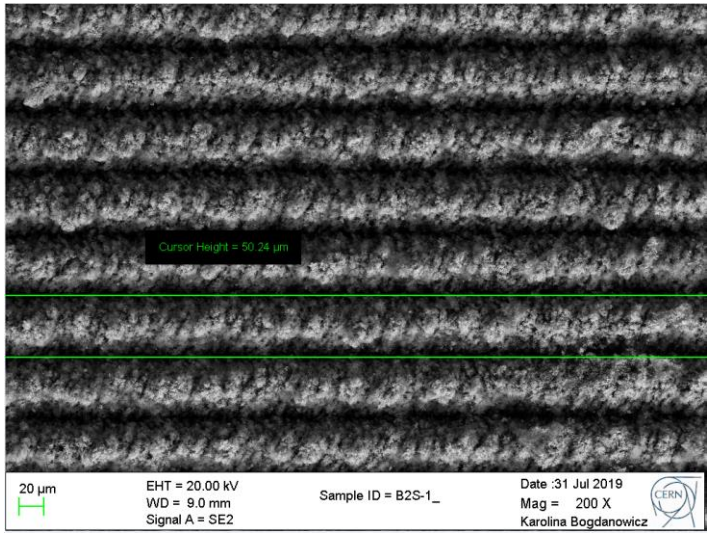


LESS – Surface Results







Status & The Way Forward

System Commissioning & Optimization

- The whole LESS treatment system was commissioned at the University of Dundee
- Several trial treatments were performed in LHC beam screens
- The resulting surface structure was analyzed in an electron microscope
- The robotic approach was successfully proven
- Currently the laser settings are optimized (Energy)

The way forward

- Full implementation of the system control (by CERN) aiming to operate the system easily
- Further experiments to optimize the surface structure (Laser settings)
- Application in the planned HL-LHC upgrade

Inspection Robotics