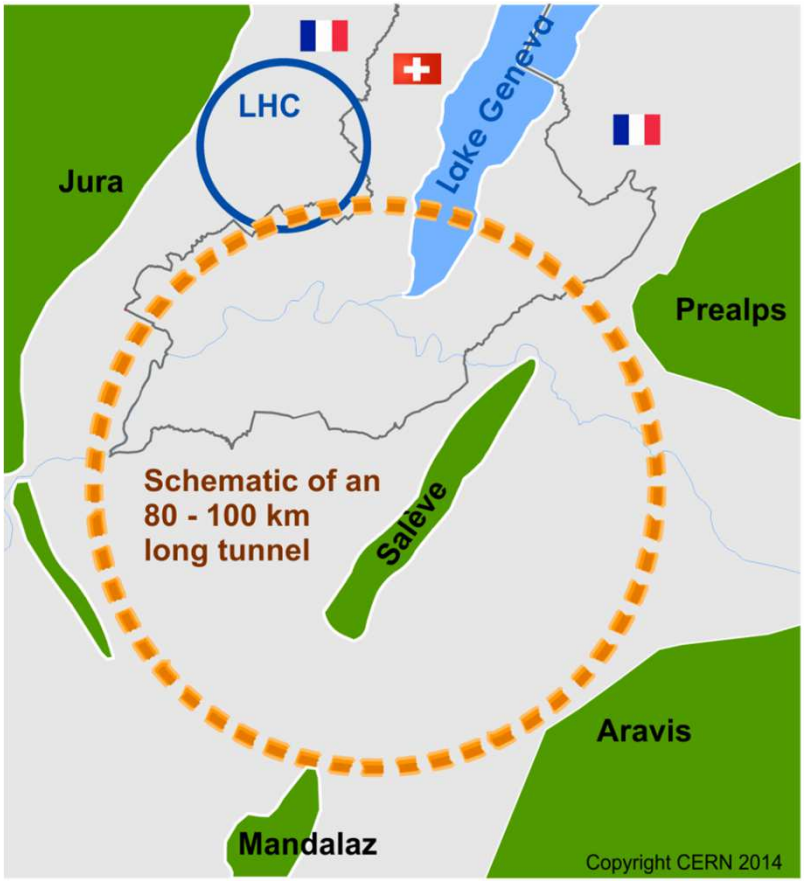
Concept of in-situ repair using laser based additive manufacturing techniques

Prof. Toms TORIMS
Riga Technical University, Latvia

FCC Week 2016, Rome



- **80-100 km** infrastructure
- Unprecedented **powers**
- Unprecedented **fields**
- pp-collider (FCC-hh)
- e+e- collider (FCC-ee)
- p-e (FCC-he) option
- HE-LHC with FCC-hh technology

What challenges we can expect for repairs and maintenance?

Challenges

- Due to its nature, size, scale, complexity and environment, **conventional repair methods** and technologies simply **will not work**
- **Human intervention** will be limited or even impossible - too time consuming and too costly
- FCC will be so **large and complex** – possibility "that something goes wrong" increases exponentially
- There will be unprecedented amount of tech. faults and problems to be fixed/repaired

Challenges - repairs

Environmental:

- Radiation
- Supper high magnetic fields
- High voltage
- Oxygen deficiency
- **Fire safety**
- Recycling

Challenges - repairs

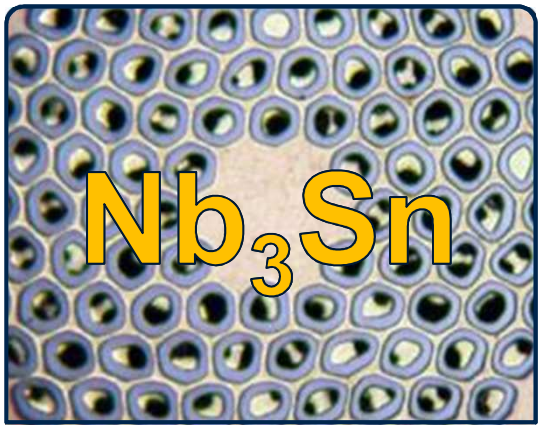
Operational:

- Difficult to access
- Very limited space
- Distance from the access points
- Time to access and solution to the problem
- Time schedule – recovery
- Reliability of technology

Challenges - repairs

Technological:

- Very delicate equipment, high precision and fine tolerances
- Complex assemblies
- Magnitude from micro to macro levels
- Variety of materials, often difficult to process and repair
- Novel and "unknown" materials
- Designed for manual repairs?



Challenges - repairs

Conclusion:

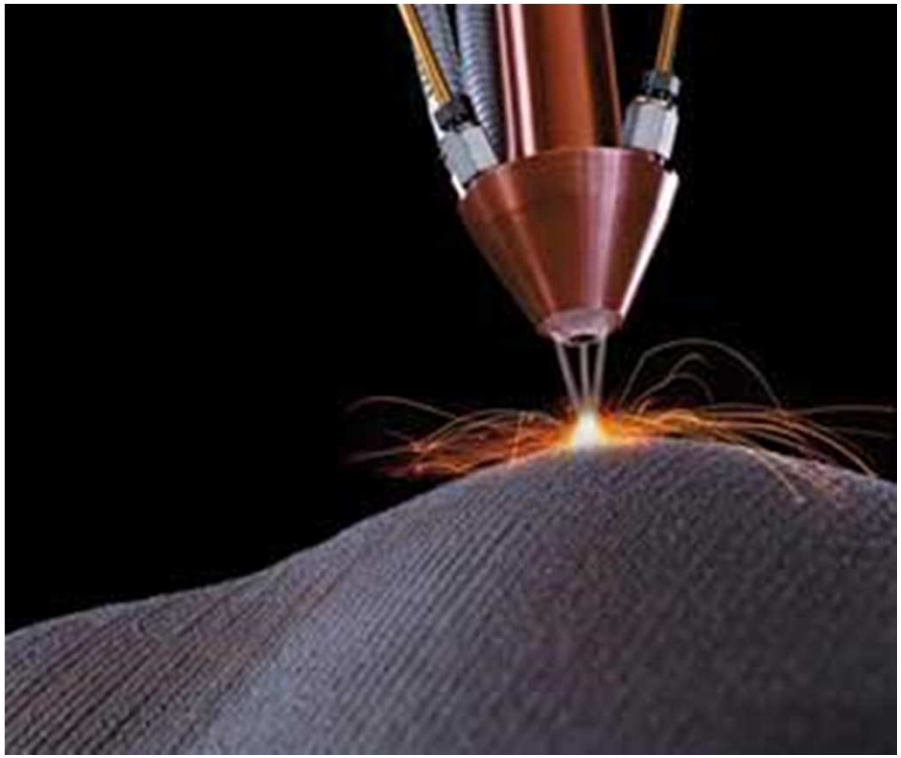
- Conventional repair might be not sufficient and difficult to apply
- There is no industrial off-shelf "ready-to-use" solution for these challenges
- **New concepts and different philosophy is needed for any repairs in FCC**

Laser cladding

What it is and why for FCC?

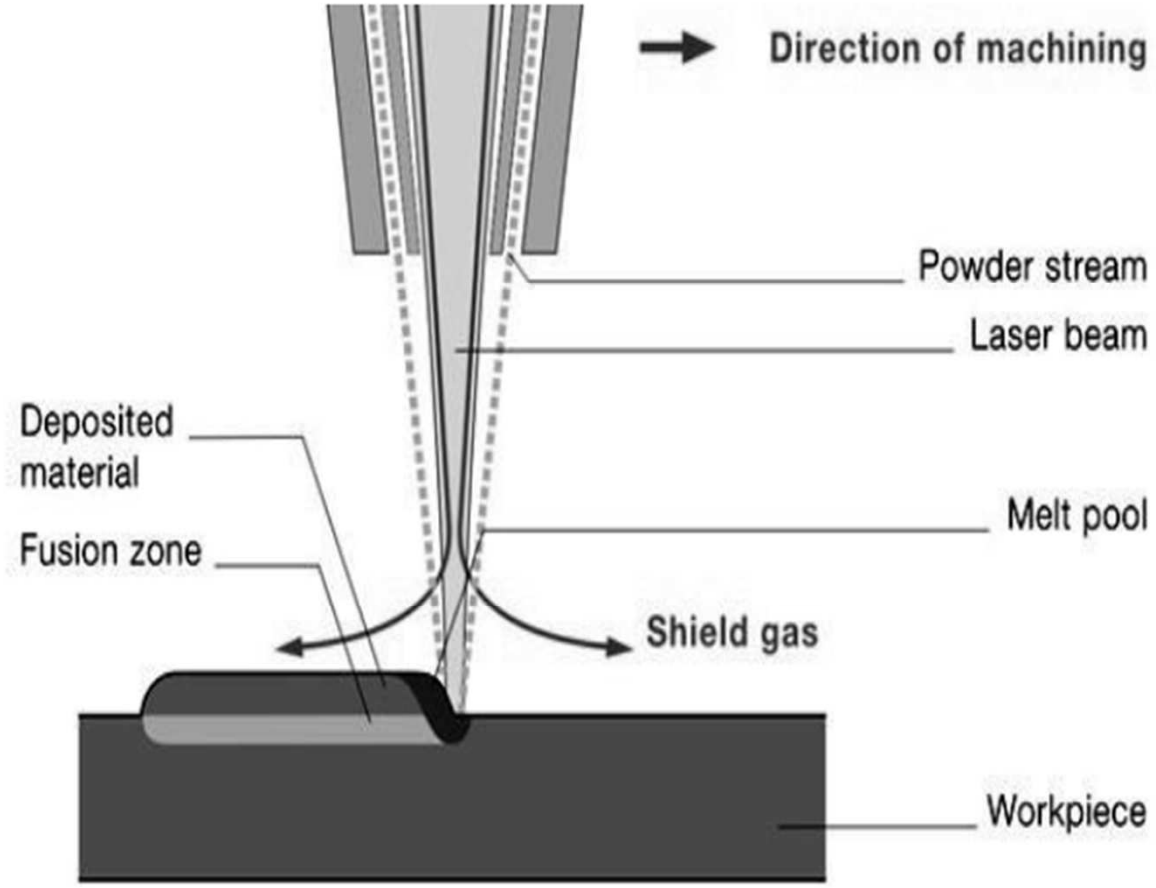
Laser cladding

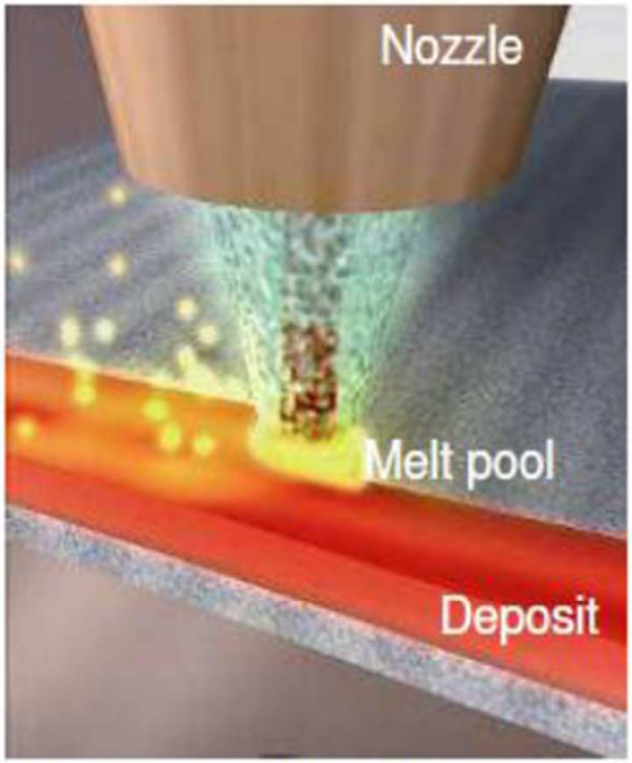
Fraunhofer



source: Laser focus world

Laser cladding



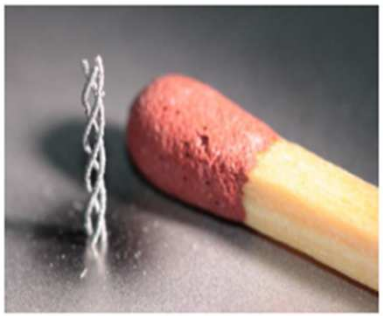


3D representation of the laser cladding process

Courtesy of TRUMPH

Laser cladding

- Surface cladding
  - 100 μm to 2 mm thickness
  - 100 μm to 2 mm single truck with cladding area range of sq/m
- Repairs
  - 100 μm to 2 mm single truck with
  - Multi-layer build-up
  - Exact material delivery
- Additive manufacturing
  - 3D material build-up
  - 30 μm to 1 mm lateral resolution

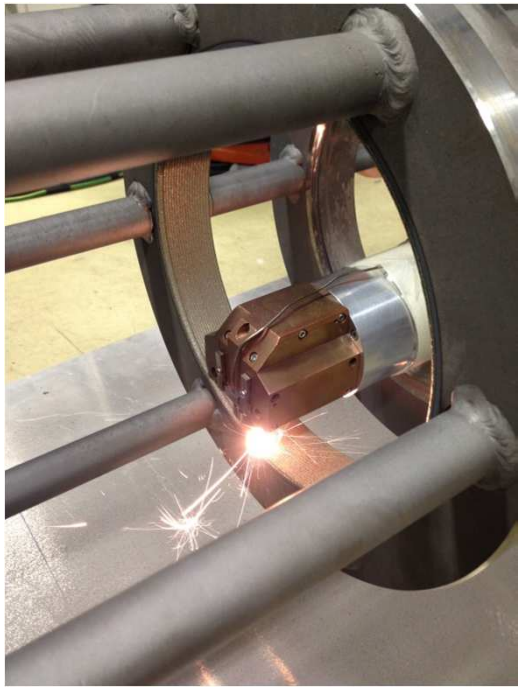


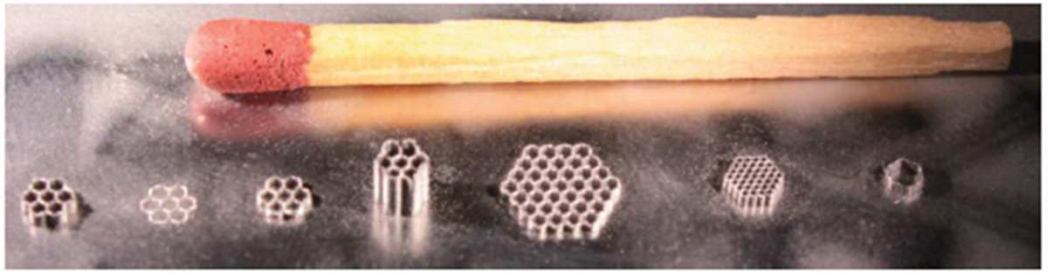
Fraunhofer

Laser cladding

Provides for:

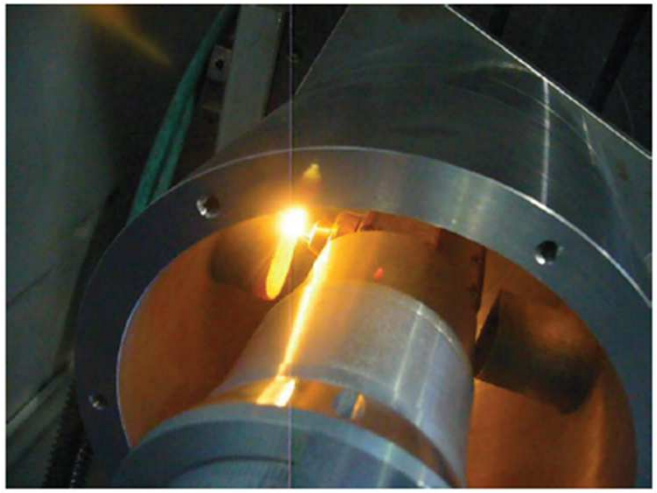
- rapid design changes – very flexible
- **direct generation of complex parts made from eventually any material**





Fraunhofer

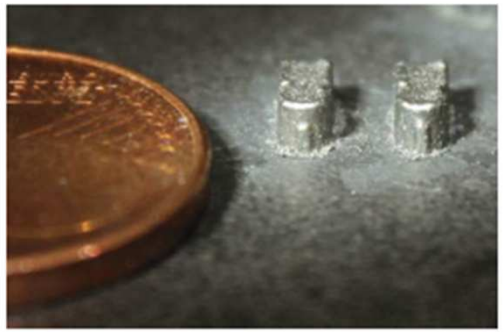
Comparative advantages



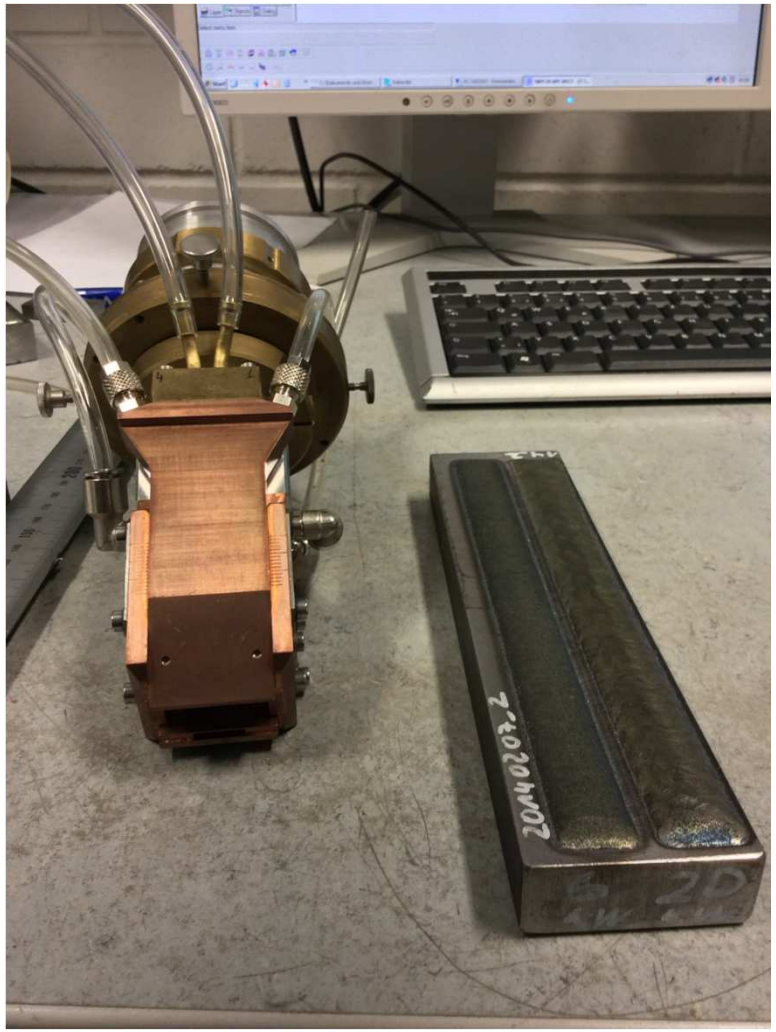
- minimal dilution and distortion
- enhanced thermal control
- Heat Affected Zone is reduced
- customised surface parameters
- low porosity and few imperfections
- high precision and **surface quality** parameters
- the resulting surface material has characteristics similar to or even better than the original

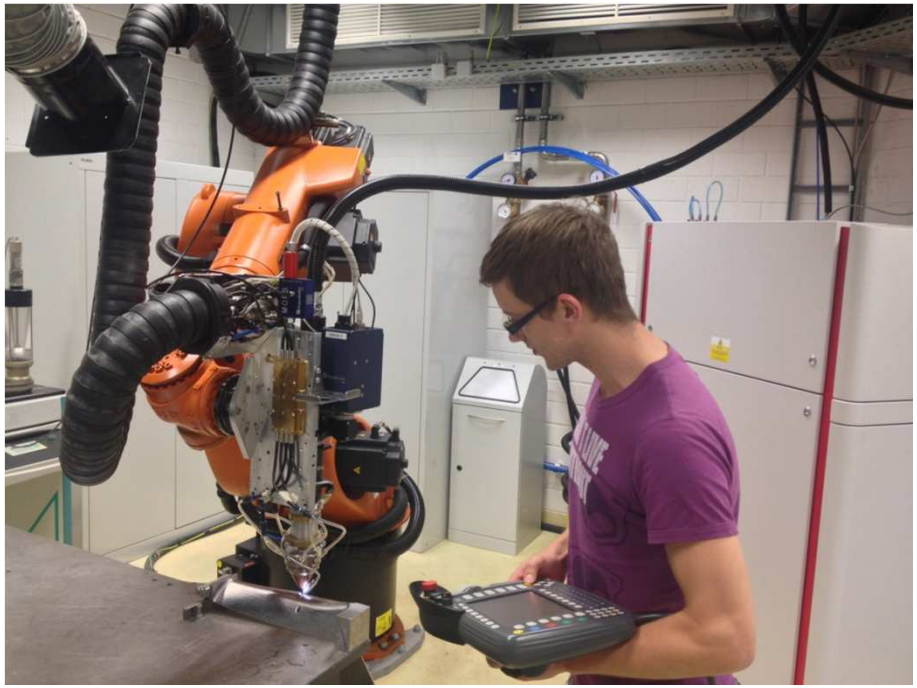
Comparative advantages

- reduced production time (compared e.g. with welding)
- highly satisfactory repair of parts
- production of a functionally graded parts
- production of smart structures
- **Perfect technology for in-situ repairs**
- Suitable for automation



Range of nozzles

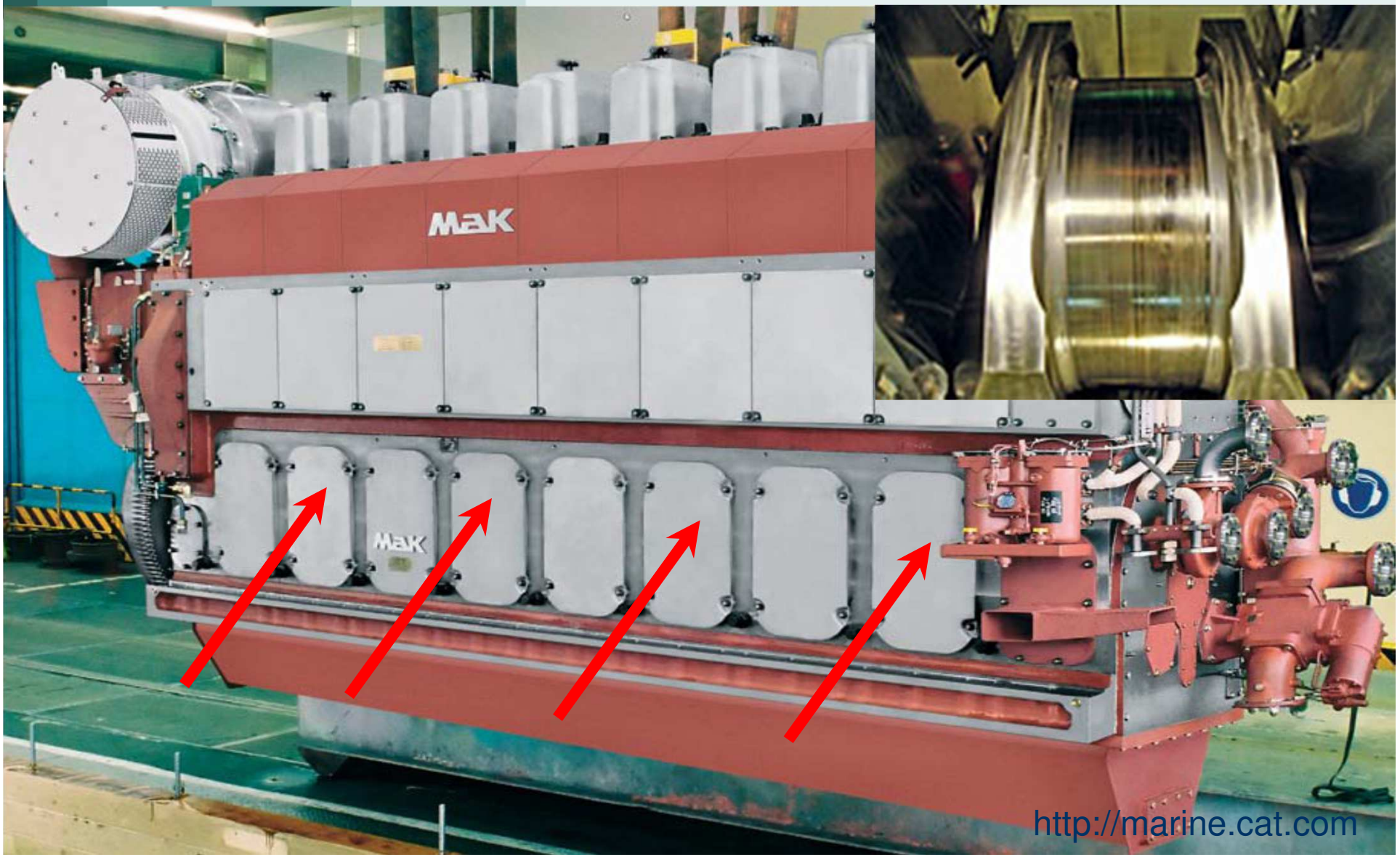




Current applications

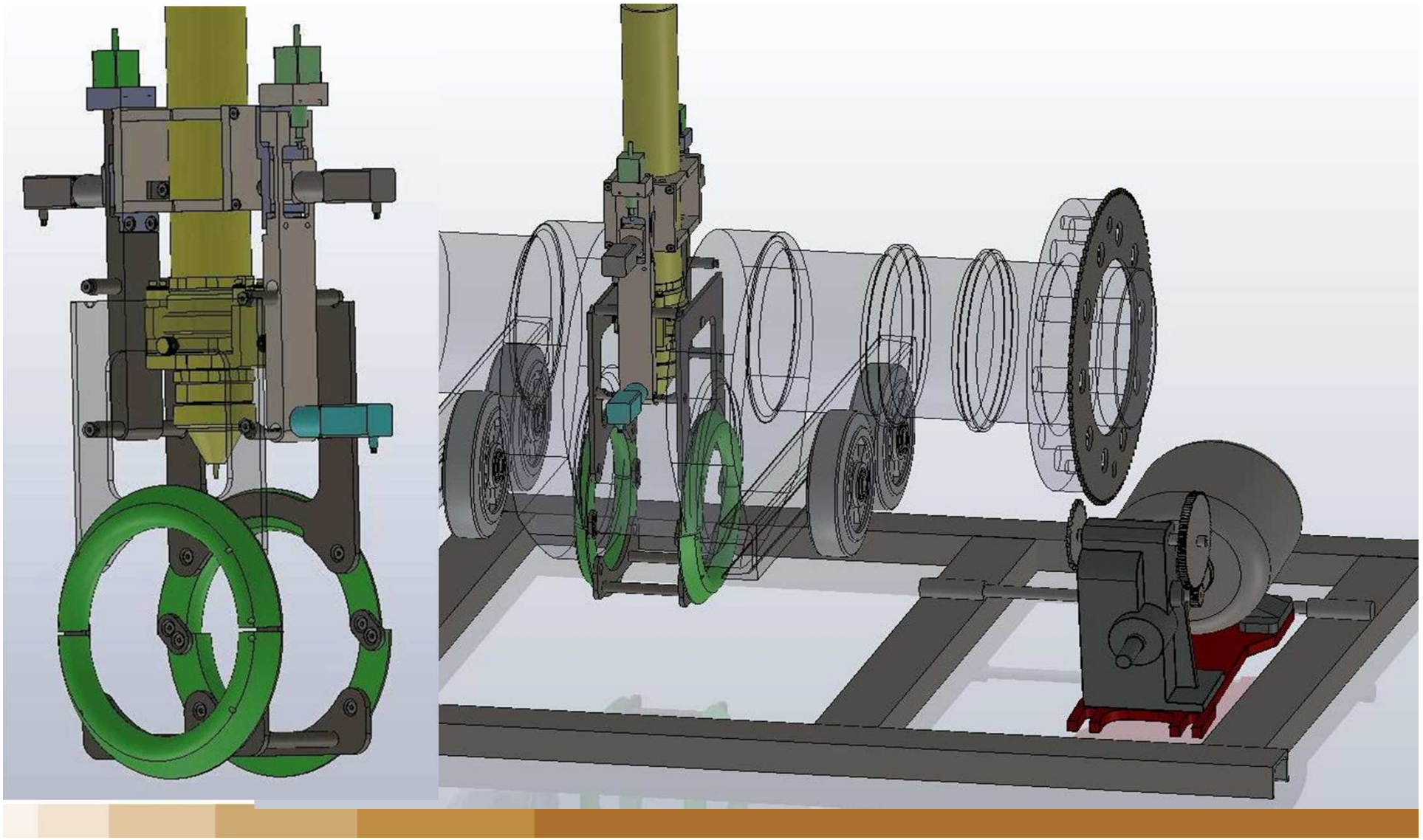
- Repair and refurbishment of high value components (e.g. tools, turbine blades, gas turbine and engine parts)
- Metallic coatings, rapid prototyping, layered metal deposition and nano-scale manufacturing
- Three main fields of application:
  - surface cladding
  - repair welding
  - generative manufacturing

In situ laser cladding



http://marine.cat.com

Prototype device



Drawbacks

Mostly technological:

- Powder v/s wire
- Metallurgical challenges (e.g. cracks)
- Complex technological system
- High equipment and running costs
- Lack of maturity in industrial application

Concept of in-situ repairs in FCC

How can it be done?

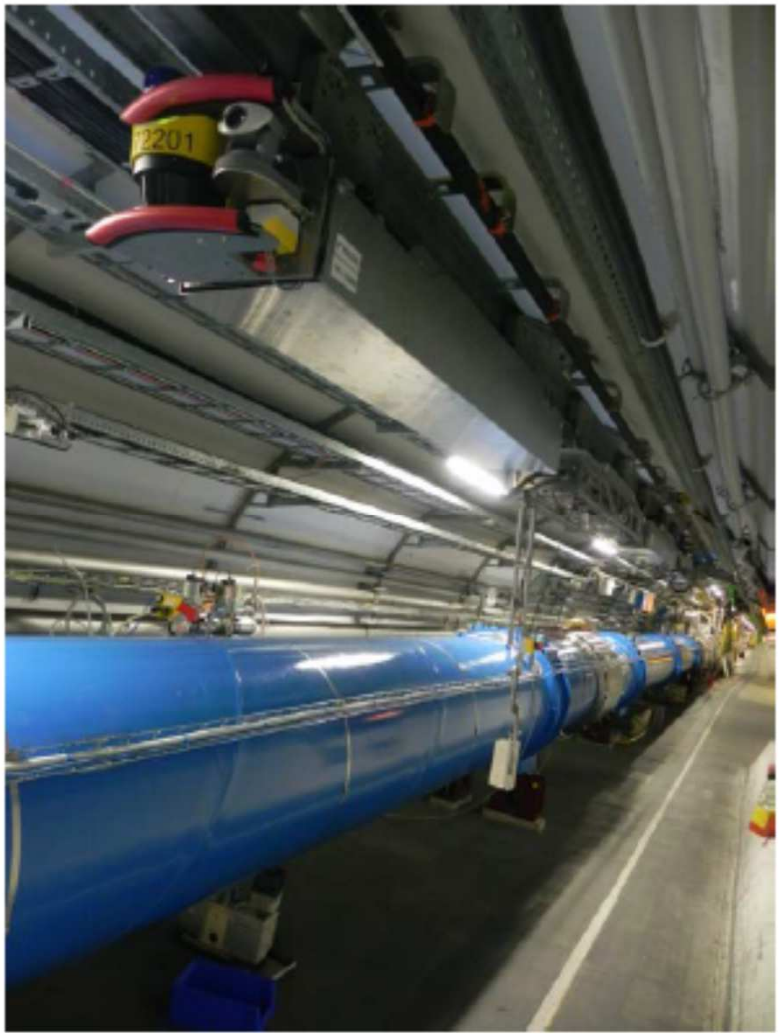
Potential for FCC

- Fire safety – is different from welding – less heat and very local impact
- Flexibility – type and material
- Large variety of materials, including composite - everything that tolerates laser melting
- Could be applied to unknown and novel materials
- From nano to macro

Potential for FCC

- No post-processing is needed
- Fast reaction – time-to-action
- No human intervention – automation and remote manipulation
- Reliable technology
- Can work in hazardous environment
- Offers a new concept/philosophy

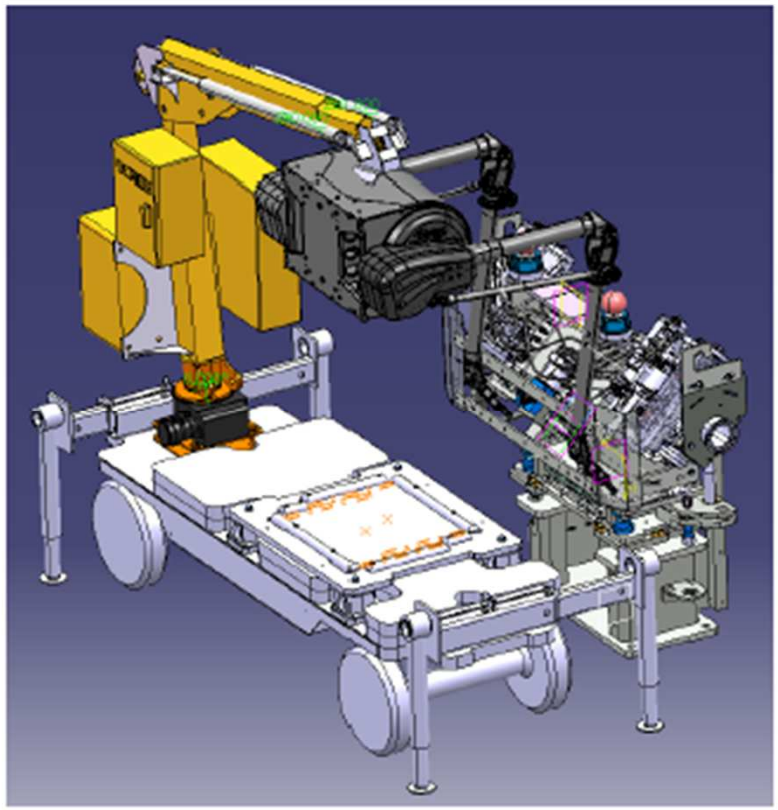
Monorail train

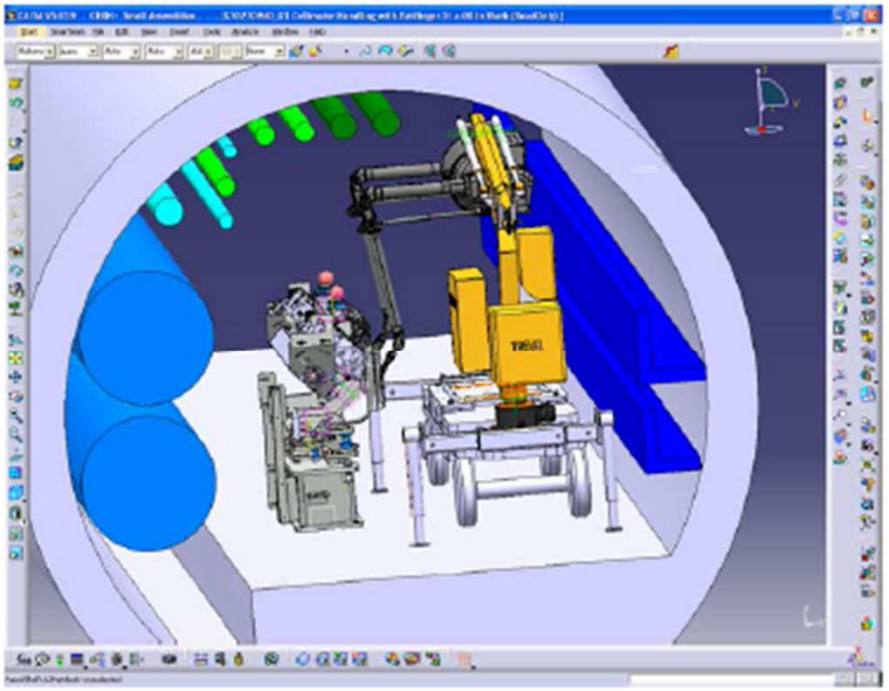


Components

- Laser power source unit – e.g. diode laser
- Powder or wire deposit and supply unit
- Control and guidance unit
- Robotic arm unit
- Fire safety unit

Remote manipulation





Courtesy of Dr. Mario Di Castro (CERN)

Challenges

- Size and space limitations
- Accessibility
- How to fit all parts in to mobile delivery systems
- Operational and automation issues
- Control and positioning
- Fire safety

Closing remarks

- Very promising technology – e.g. Canadian Space Agency
- Laser cladding is not only for repairs
- Certain FCC repair challenges could be addressed
- RTU is ready to establish a collaboration and to run a feasibility study on how to deploy laser cladding technology for in-situ repairs. Not only for FCC, also for LHC and other projects

Thank you for your attention!