

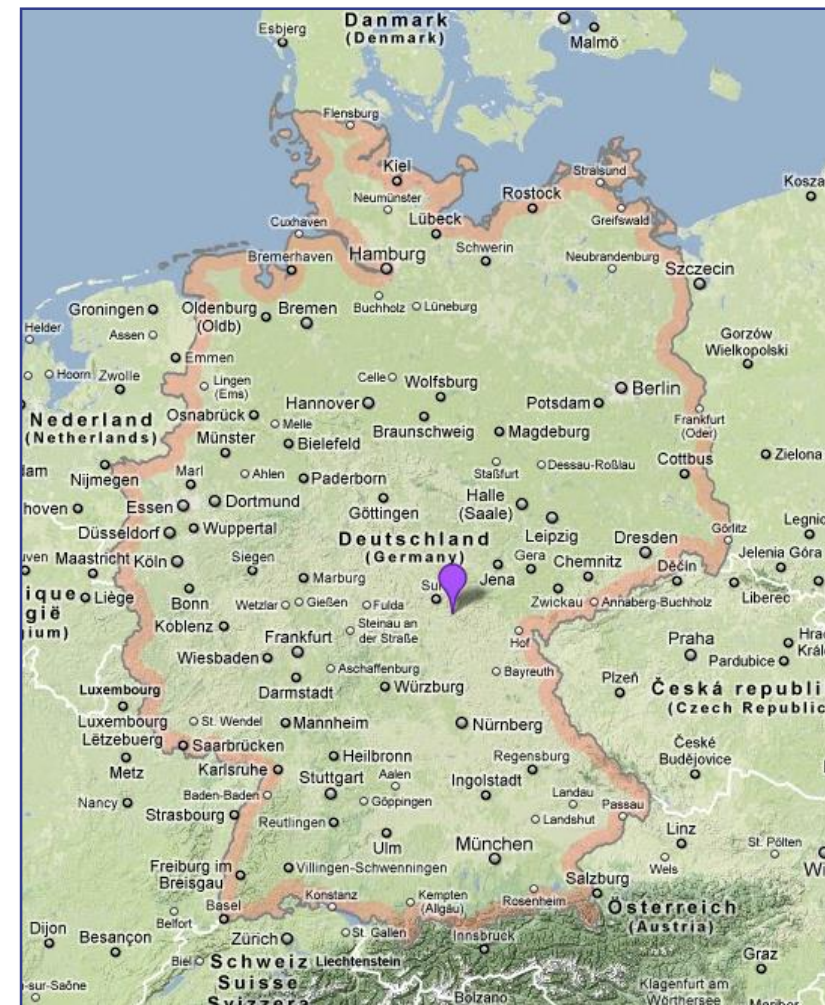
Hybrid Sintering – A New Trend for Innovative Material Solutions

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FCT Systeme GmbH, Rauenstein Frankenblick / Germany*



- ▶ **Company Profile of FCT Systeme GmbH**
- ▶ **What is „HYBRID SINTERING“ ?**
 - ▶ **FAST/Hybrid: The Trendsetter**
- ▶ **FCT ´s Hybrid Sintering Portfolio**
- ▶ **Future Prospects / Industrial Application of HYBRID SINTERING**

- **Location:** In the heart of Germany (Southern Thuringia).
- **Core Business:** High-temperature plants and systems for the production of high-performance sintering materials, including expert know-how and customized support.



- **Non-Oxide Engineering Ceramics**
Nitrides, Carbides, Borides, ...
- **Ceramic Matrix Composites CMC**
SiC-C_f, SiC-Graphene, BN/TiB₂, Al₂O₃-SiC_w, ZrO₂-Ti(C,N), ...
- **Powder-Metals**
W, Mo, Al-Si-Zr-..., Nd-Fe-B, Zr-Hf-Co-Sb-Sn-, NdFeB, ...
- **Metal Matrix Composites**
WC/Co, Al-SiC, Al-C_f, TZM, ...
- ...






- 6 original **FCT-furnaces** for lab use and pilot production
- Active and professional support from **FCT-specialists**

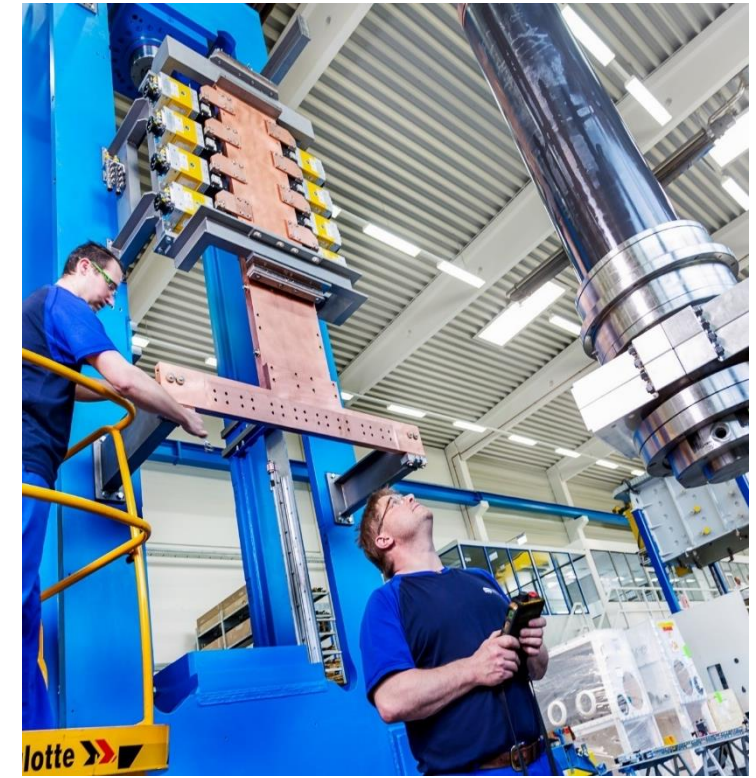
Our Services:

- ✓ Commission orders
- ✓ Technical training
- ✓ System solutions
- ✓ Development support for customized sintering concepts
- ✓ Basic tests and research support



Portfolio of FCT Systeme GmbH – High-Temperature Equipment and Technology

| | | | | |
|--|---|--|---|---|
|  |  |  |  |  |
| Hot Presses and mould technology HP W | FAST/SPS-Furnaces (Field Assisted Sintering/ Spark Plasma Sintering) HP D / H-HP D | Vacuum Sintering Furnaces FH W / FSW | Gas Pressure Sintering Furnaces FPW | Hybrid Systems CVD/CVI Customized Solutions |


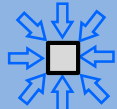
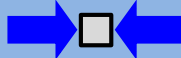


















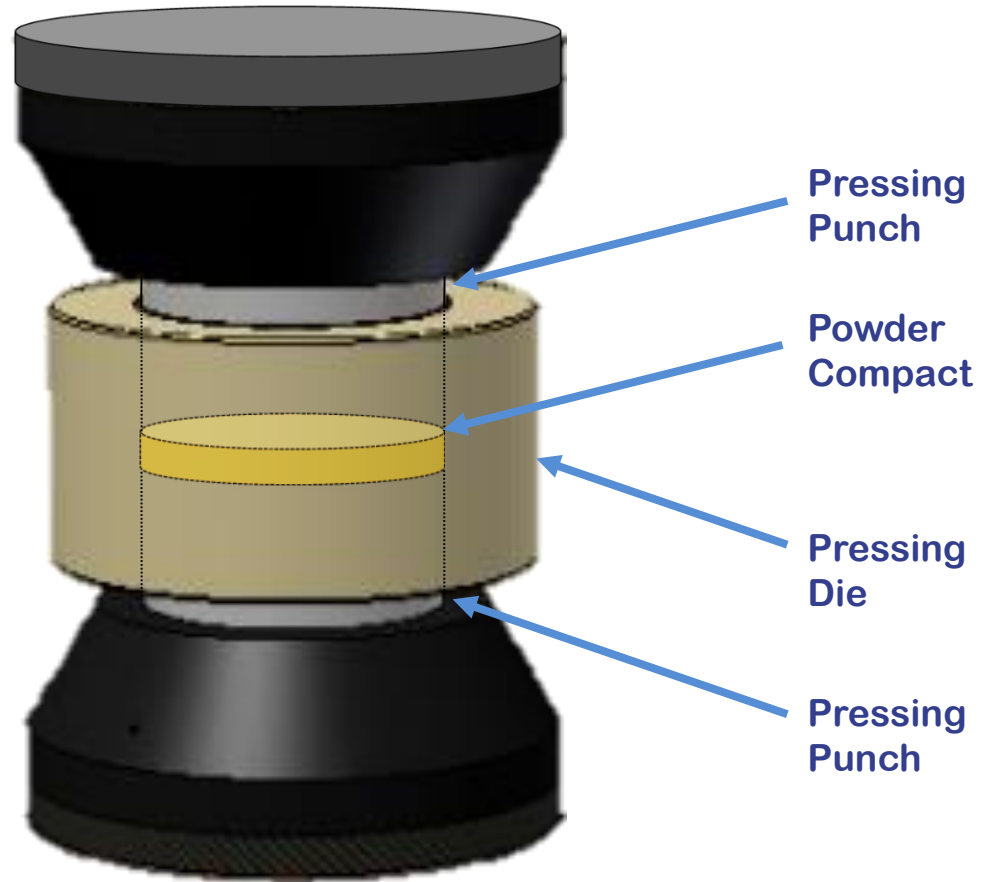
What is „Hybrid“ ?

Wikipedia: *(analogous translation of the german entry)*

„Hybrid“ in the technological context means a system, **combining** two **different technologies**.

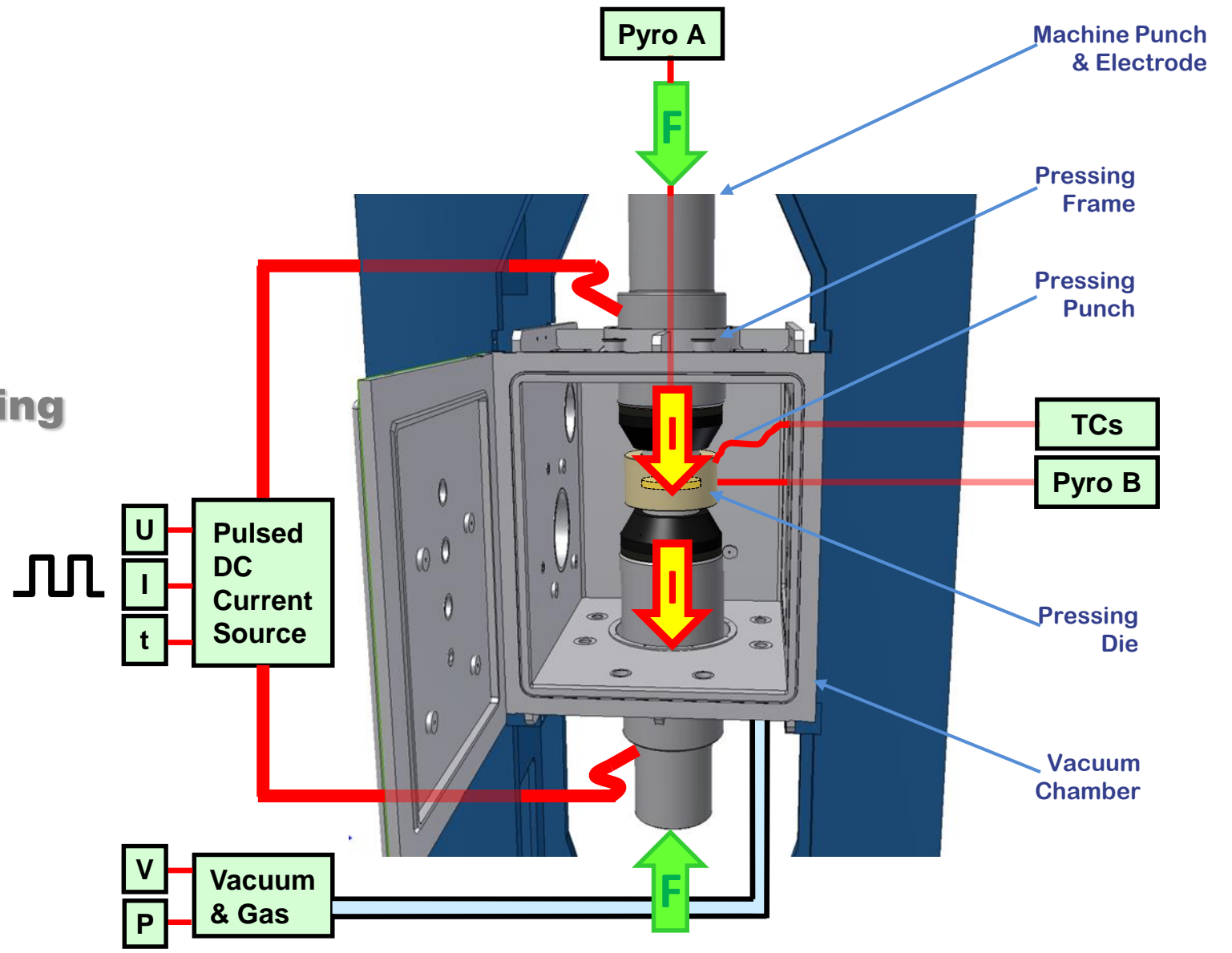
As a characteristic each of these technologies present a solution on its own, but the combination creates **new, beneficial properties**.

| FCT Sintering Technology | ACTIVE SINTERING PRINCIPLES | | | |
|-----------------------------------|--|--|--|---|
| |  HEAT |  GAS PRESSURE |  MECH. PRESSURE |  ELECTR. FIELD |
| PRESSURELESS |  | | | |
| GAS PRESSURE (SINTER)- HIP |  |  | | |
| HOT PRESSING |  | |  | |
| FAST/SPS |  | |  |  |
| FAST/Hybrid (FAST/Flash) |  | |  |  |
| Hybrid Sintering |  |  |  |  |

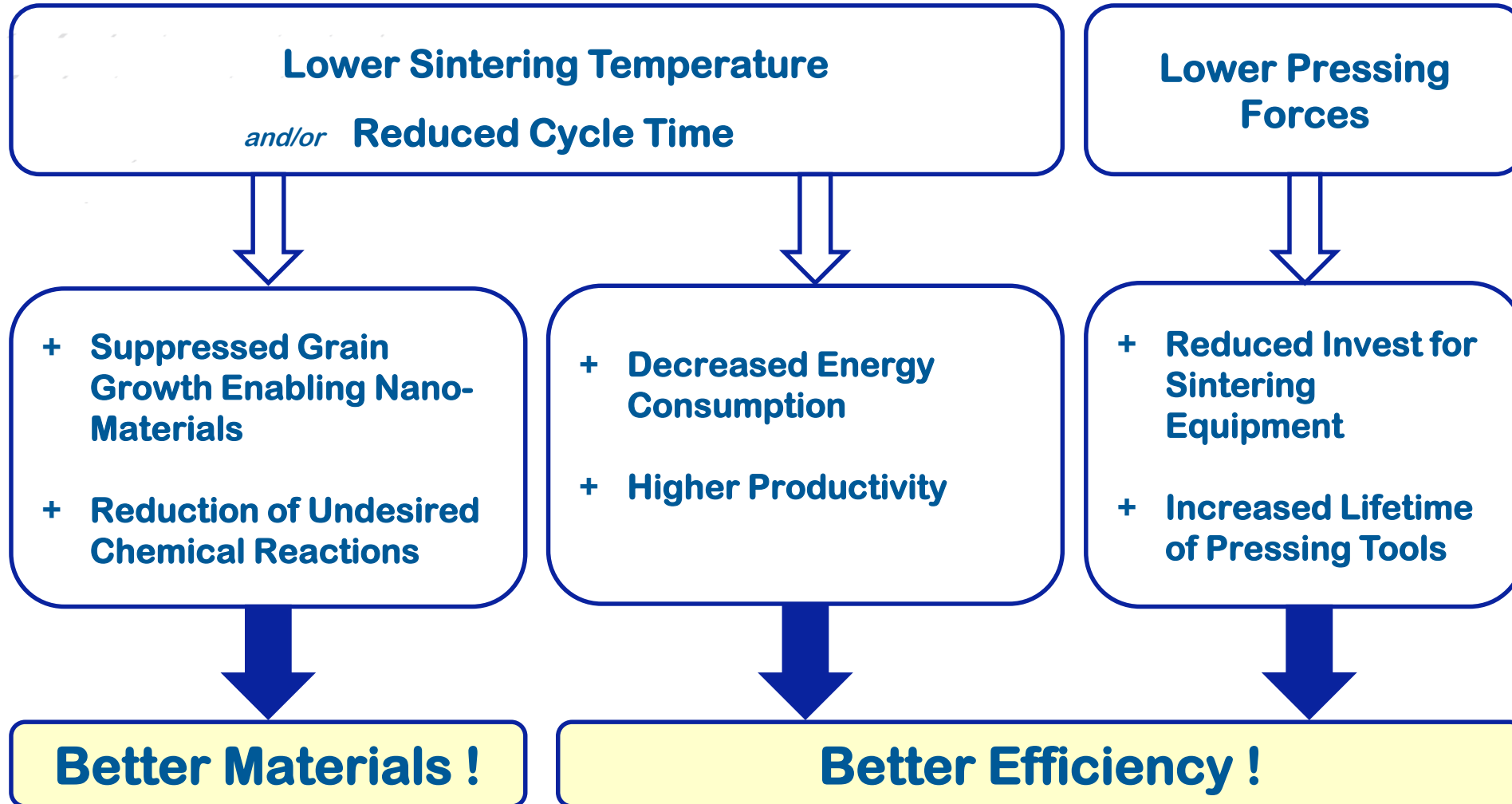


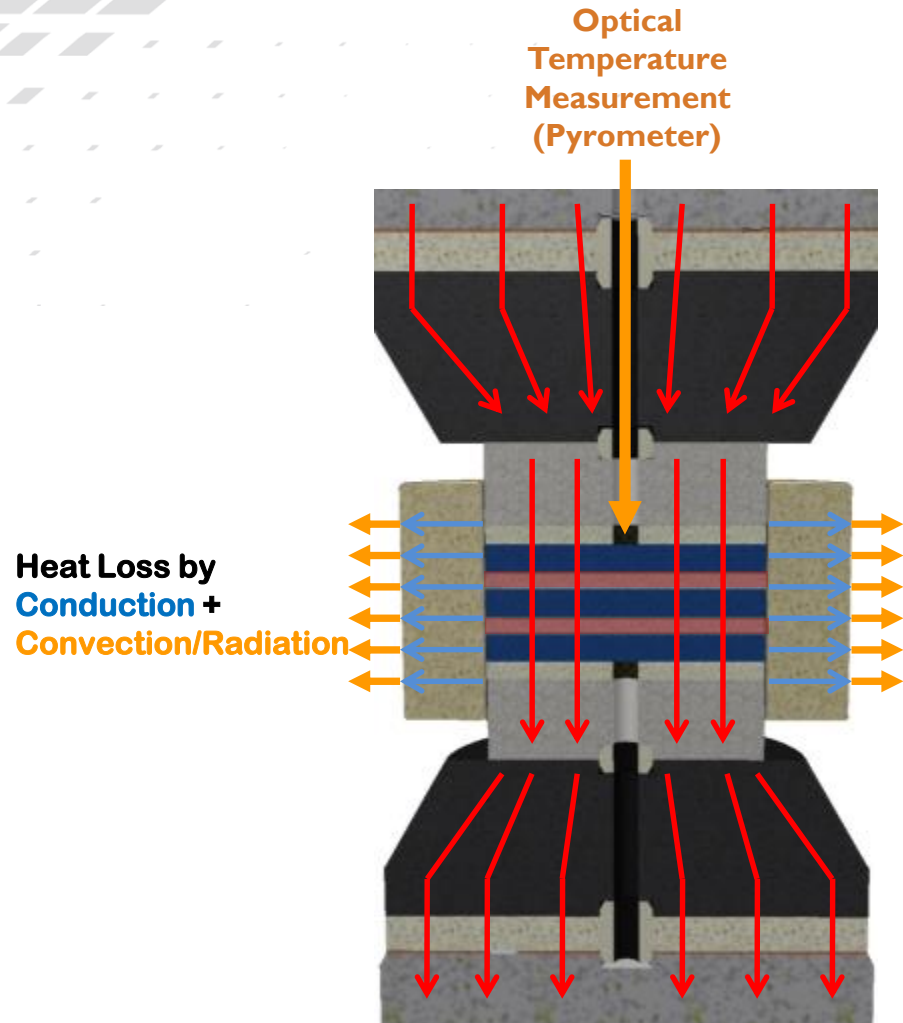
FAST SPS

Field Assisted Sintering Technology
Spark Plasma Sintering

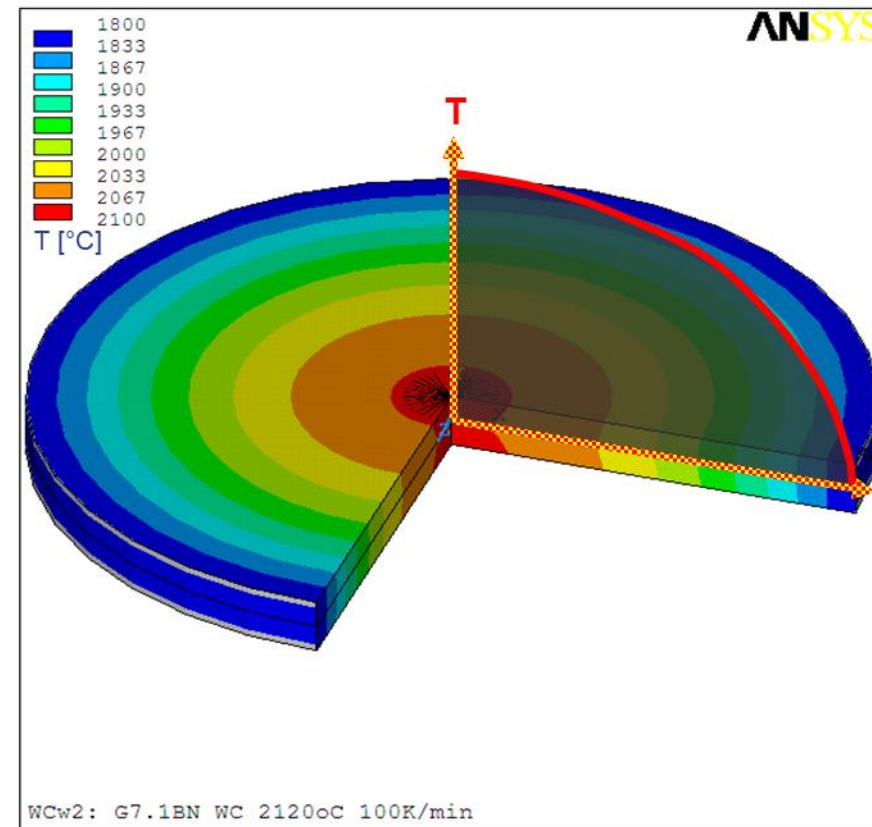


Advantages of FAST/SPS



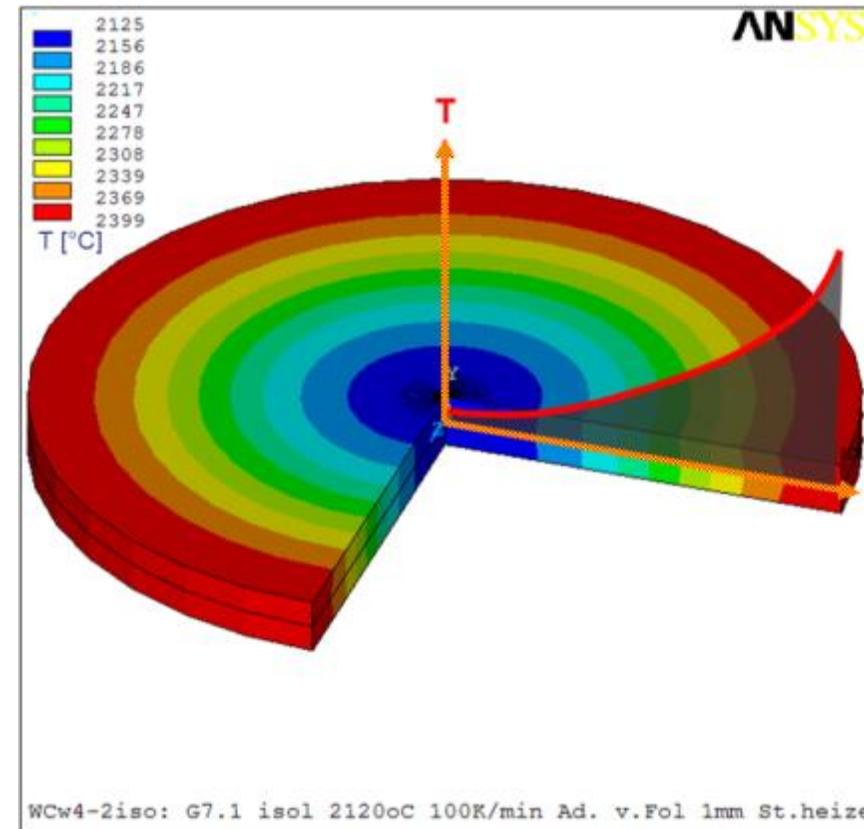
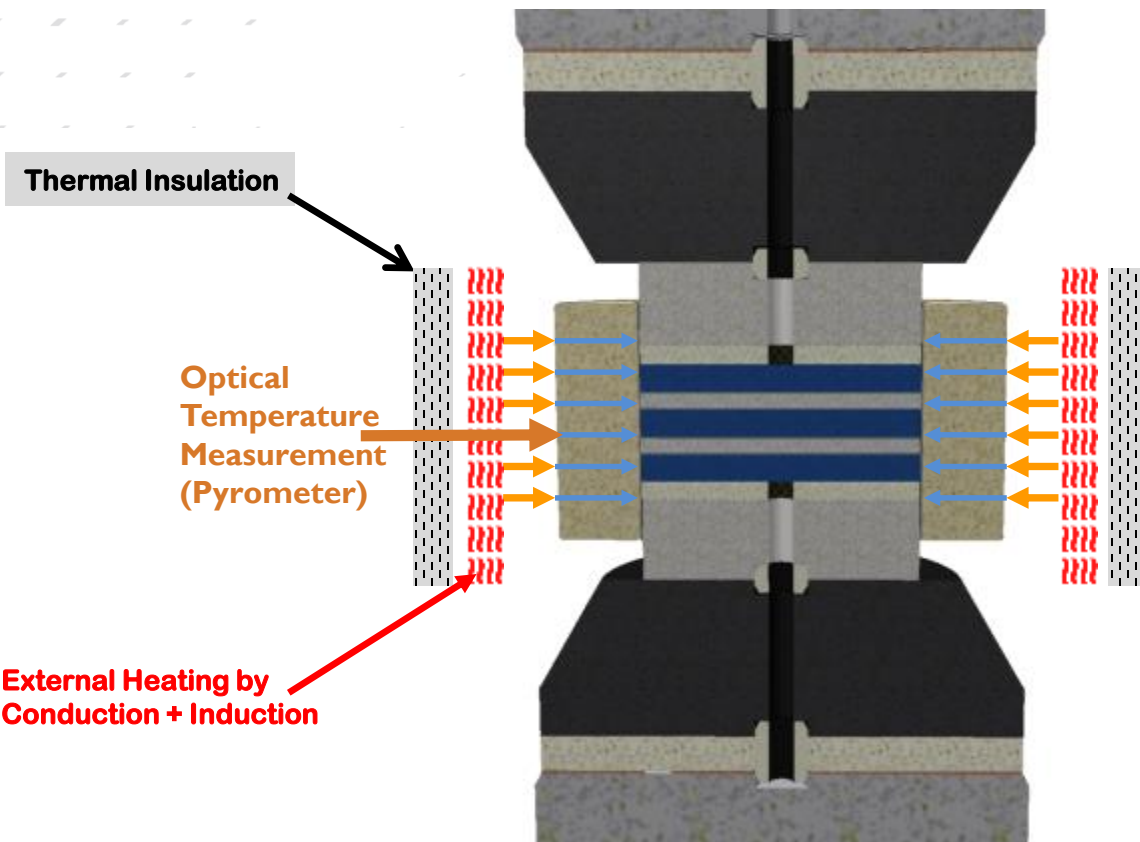


CHALLENGE:
Thermal Gradients are Growing if Heating Rate, Part Size and **Temperature** are Increasing!



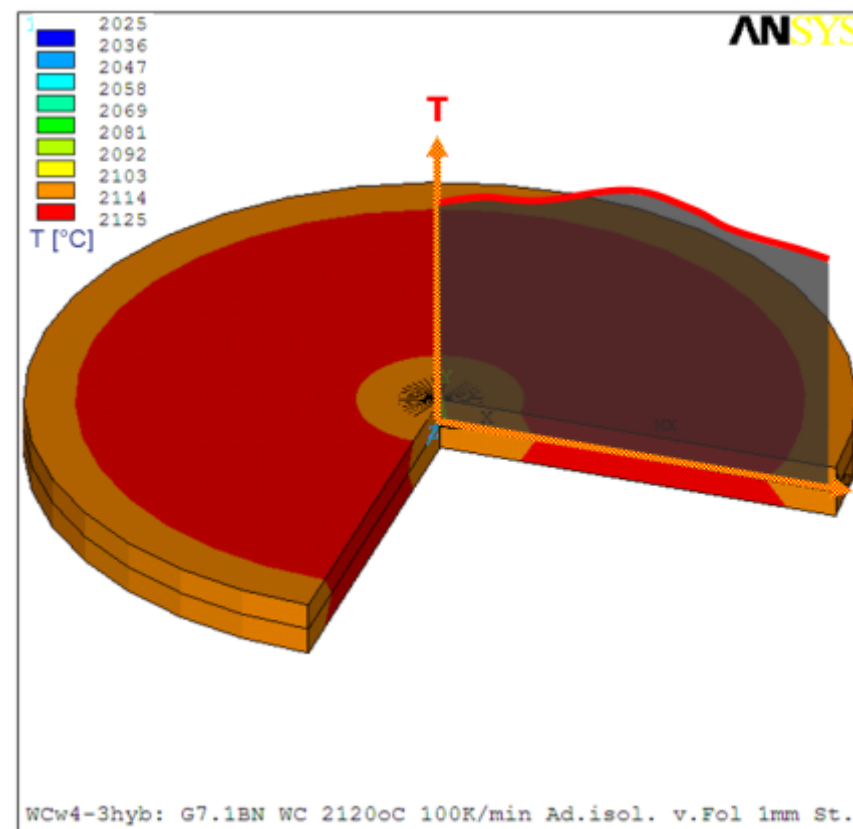
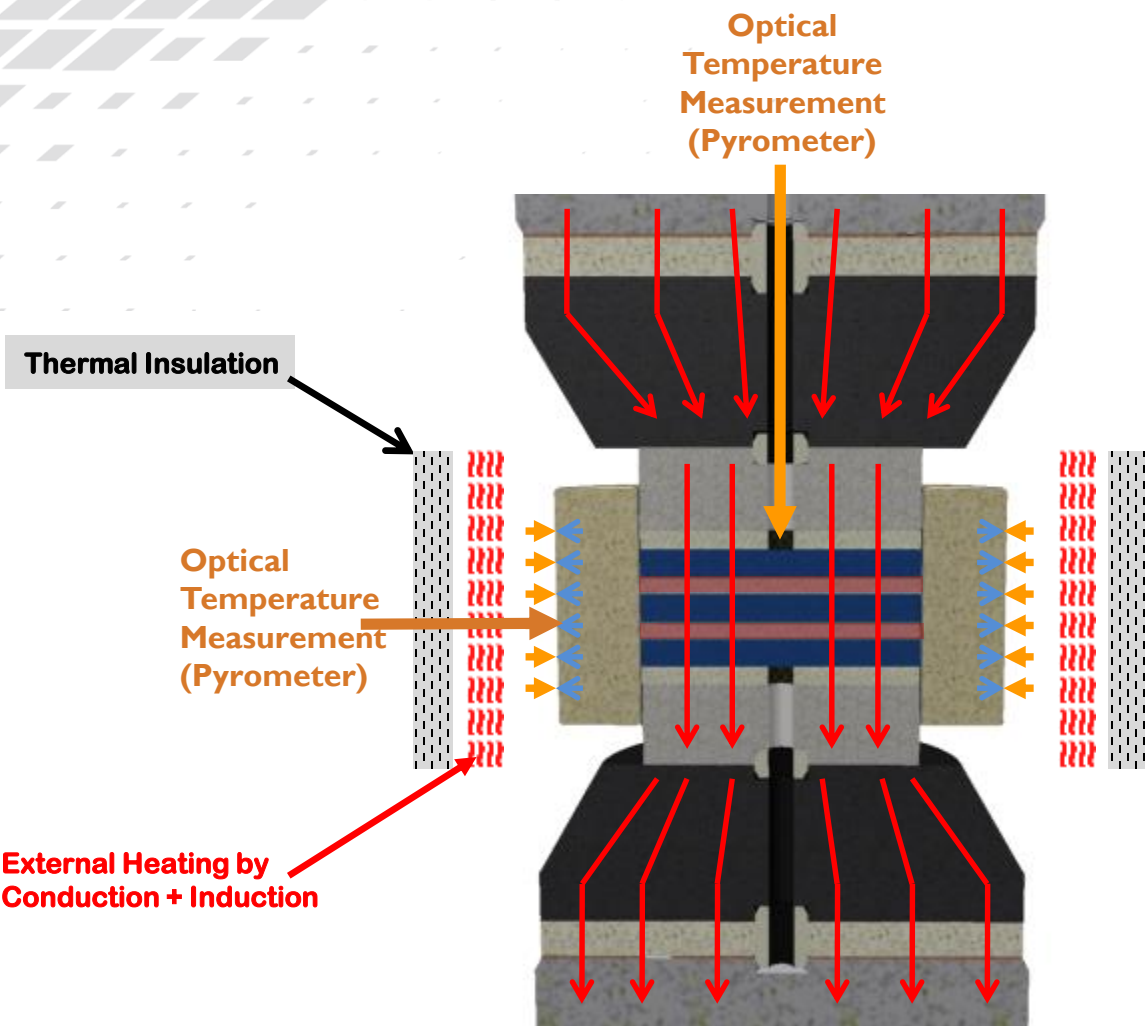
(electrical conducting powder)

Direction of Thermal Gradients
Opposite to FAST/SPS Gradients



FAST/Hybrid HEATING

Combination of **Two Independently Controlled Heaters**
Allows Compensation of Thermal Gradients



(electrical conducting powder)

FAST/Hybrid from Lab to Industrial Scale



Lab Scale FAST/Hybrid

Industrial Scale FAST/Hybrid



| | | | | | |
|-----------------------|-------------------------|-------------------------|--------------------------|--------------------------|--------------------------|
| 25 kN 30 mm | 250 kN 120 mm | 600 kN 150 mm | 1250 kN 200 mm | 2500 kN 350 mm | 4000 kN 450 mm |
|-----------------------|-------------------------|-------------------------|--------------------------|--------------------------|--------------------------|

Main specifications

| | |
|----------------------------------|--------------------|
| Max. pressing force | 25 kN |
| Max. component diameter | 40 mm |
| Max. sintering temperature | 2200°C |
| Max. heating rate | up to 1000 K/min |
| Final vacuum in the cold furnace | 5×10^{-1} |
| Max. continuous output | 20 kW |
| Max. FAST/SPS voltage | 8V |

Options

| | |
|--|---|
| Max. operating temperature 2400°C | ● |
| Dilatometer | ● |
| Rate Controlled Sintering | ● |
| FAST/SPS (high current density) AC/pulsed AC | ● |
| FAST/Flash (high electric field) DC | ● |
| FAST/Flash (high electric field) AC | ● |

Operation Modes:

- ▶ FAST/SPS
- ▶ Hot Pressing
- ▶ FAST/Hybrid



Main specifications

| | |
|----------------------------------|--------------------|
| Max. pressing force | 250 kN |
| Max. component diameter | 100 mm |
| Max. sintering temperature | 2200°C |
| Max. heating rate | up to 1000 K/min |
| Final vacuum in the cold furnace | 5×10^{-1} |
| Max. continuous output | 80 kW |
| Max. FAST/SPS voltage | 8V |

Options

| | |
|--|---|
| Max. operating temperature 2400°C | ● |
| Dilatometer | ● |
| Rate Controlled Sintering | ● |
| FAST/SPS (high current density) AC/pulsed AC | ● |
| FAST/Flash (high electric field) DC | ● |
| FAST/Flash (high electric field) AC | ● |



Main specifications

| | |
|----------------------------------|--------------------|
| Max. pressing force | 3200 kN |
| Max. component diameter | 400 mm |
| Max. sintering temperature | 2200°C |
| Max. heating rate | up to 600 K/min |
| Final vacuum in the cold furnace | 5×10^{-2} |
| Max. continuous output | 350 kW |
| Max. SPS continuous output | 350 kW |

Options

| | |
|--|---|
| Max. operating temperature 2400°C | ● |
| Digitally controlled servo-hydraulics | ● |
| Dilatometer | ● |
| Rate Controlled Sintering | ● |
| Semi-continuous/Separate cooling chamber | ● |
| Resistance heating | ● |



- *Material Development*
- *Prototype Production*
- *Ultrafast Sintering Process for „Non-conducting“ Materials (Ionic Conductors, Semiconductors e.g. Oxides, SiC, B₄C etc.)*
- *Prevention of Grain Growth*

Main specifications

| | |
|----------------------------------|----------------------|
| Max. pressing force | 100 kN |
| Max. component diameter | 60 mm |
| Max. sintering temperature | 2200°C |
| Max. radial heater power | 27 kW |
| Final vacuum in the cold furnace | 5 × 10 ⁻² |
| Max. FLASH voltage | 180 V |

Options

| | |
|-------------------------------------|---|
| Max. operating temperature 2400°C | ● |
| Dilatometer | ● |
| Rate Controlled Sintering | ● |
| FAST/Flash (high electric field) AC | ● |



* Material Development * Prototype Production

Main specifications

| | |
|----------------------------------|--------------------|
| Max. pressing force | 250 kN |
| Max. component diameter | 100 mm |
| Max. sintering temperature | 2200°C |
| Max. heating rate | up to 1000 K/min |
| Final vacuum in the cold furnace | 5×10^{-1} |
| Max. continuous output | 80 kW |
| Max. FLASH voltage | 180 V |
| Max. FAST/SPS voltage | 8 V |

Options

| | |
|--|---|
| Max. operating temperature 2400°C | ● |
| Dilatometer | ● |
| Rate Controlled Sintering | ● |
| FAST/SPS (high current density) AC/pulsed AC | ● |
| FAST/Flash (high electric field) DC | ● |
| FAST/Flash (high electric field) AC | ● |

Operation Modes:

- ▶ FAST/SPS
- ▶ Hot Pressing
- ▶ FAST/Hybrid
- ▶ **FAST/Flash**



**AVAILABLE
AT OUR
TECHNICAL
CENTER**

- *Material Development*
- *Prototype Production*
- *High Grade Si_3N_4 , SiC, ...*

Main specifications

| | |
|----------------------------------|--------------------|
| Useful volume | 4 dm ³ |
| Max. sintering temperature | 2200°C |
| Max. pressing force | 125 kN |
| Gas pressure | 10 bar (1 Mpa) |
| Dilatometer | |
| Max. component diameter | 60 mm |
| Final vacuum in the cold furnace | 5×10^{-2} |

Options

| | |
|-----------------------------------|---|
| Max. operating temperature 2400°C | ● |
| Rate Controlled Sintering | ● |
| Air/oxygen atmosphere | ● |
| Debinding (thermal oxidation) | ● |
| Gas supply in retort | ● |
| Induction heating | ● |

Operation Modes:

- ▶ Hot Pressing
- ▶ Gas Pressure Sintering
- ▶ **HP + GPS**



- *Material Development*
- *Prototype Production*
- *Synthesis for LED ...*

Main specifications

| | |
|----------------------------------|----------------------|
| Useful volume | 6 dm ³ |
| Max. sintering temperature | 2200°C |
| Max. pressing force | 125 kN |
| Gas pressure | 100 bar (10 Mpa) |
| Max. component diameter | 70 mm |
| Final vacuum in the cold furnace | 5 x 10 ⁻² |

Options

| | |
|-----------------------------------|---|
| Max. operating temperature 2400°C | ● |
| Dilatometer | ● |
| Rate controlled Sintering | ● |
| Debinding (thermal oxidation) | ● |
| Gas supply in retort | ● |
| Induction heating | ● |

+ Hot Pressing

- ▶ **Operation Modes:**
 - ▶ Gas Pressure Sintering
 - ▶ Hot Pressing
 - ▶ **GPS + HP**



➤ Currently: Production Lines with Medium and Large Scale Systems



Large Hybrid/FAST-Unit
Pressing Force 400 tons max.

| Properties | |
|----------------|--|
| Pressing force | max. 4000 kN |
| Temperature | RT – 2400°C |
| Sample size | Ø150 – 450 mm |
| Heating power | FAST/SPS: 500 kW Induction: 500 kW |
| Gas pressure | ABS: < 5*10 ⁻² mbar REL: up to 60 mbar |
| Working gases | Ar/N ₂ /Other |

➤ Currently: Production Lines with Medium and Large Scale Systems

Pure Tungsten Carbide 400 mm Diameter FAST/Hybrid sintered **at 2100°C**

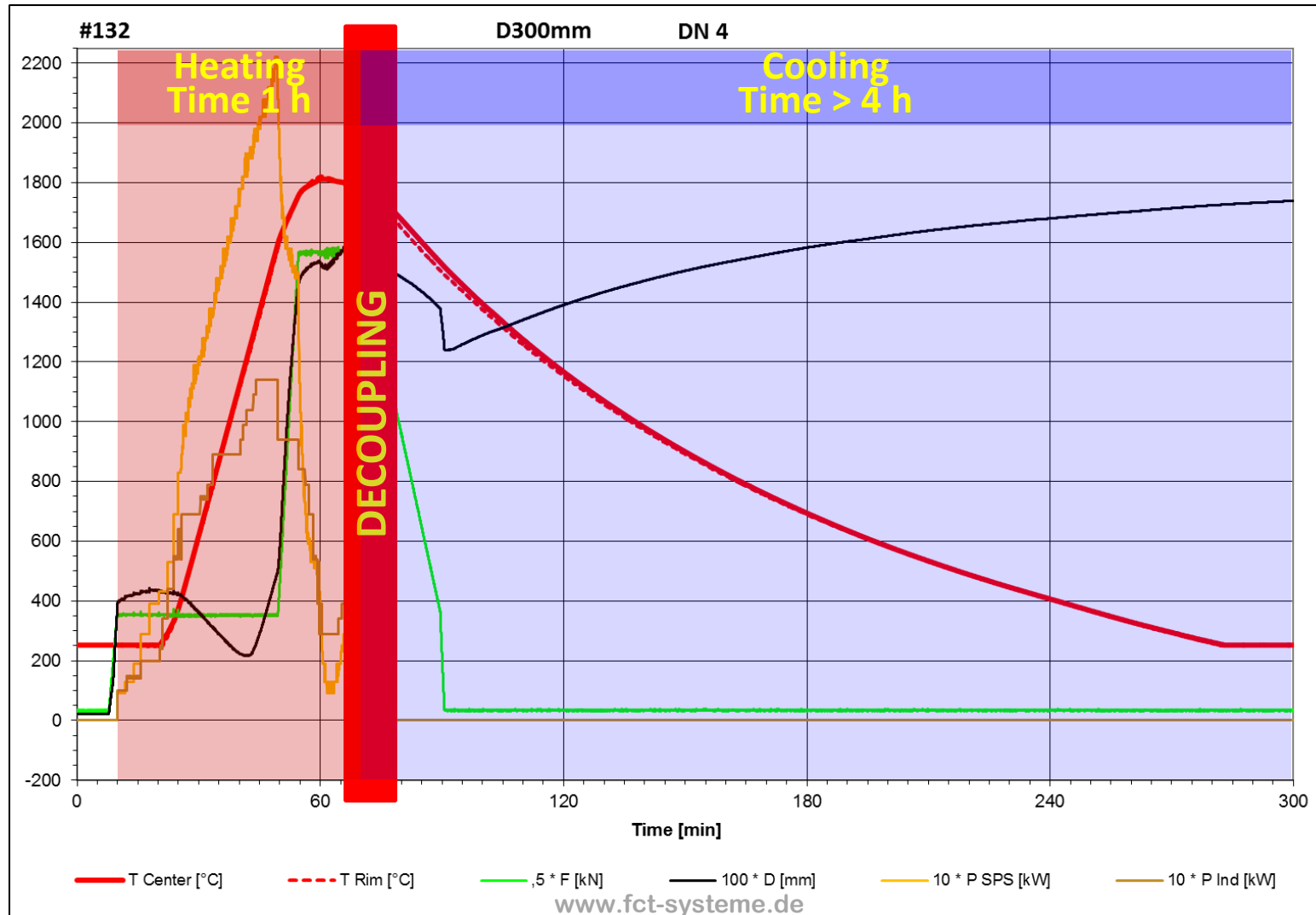


Posted by CINN / in Blog Industry, Featured News /
No comments yet March 9th, 2015

CINN is proud to announce the fabrication of the first 400 mm pure tungsten carbide blank on March 3rd, 2015 by hybrid SPS-HP sintering, a sintering technique that take advantages of the combination of two heating systems: induction and joule heating.

The fabrication of the of this 400mm blank at the facilities of the Multifunctional Materials Development Unit marks the first important milestone in the development of the Spark Plasma Sintering (SPS) technology towards its implementation in the industrial scale fabrication of large components.

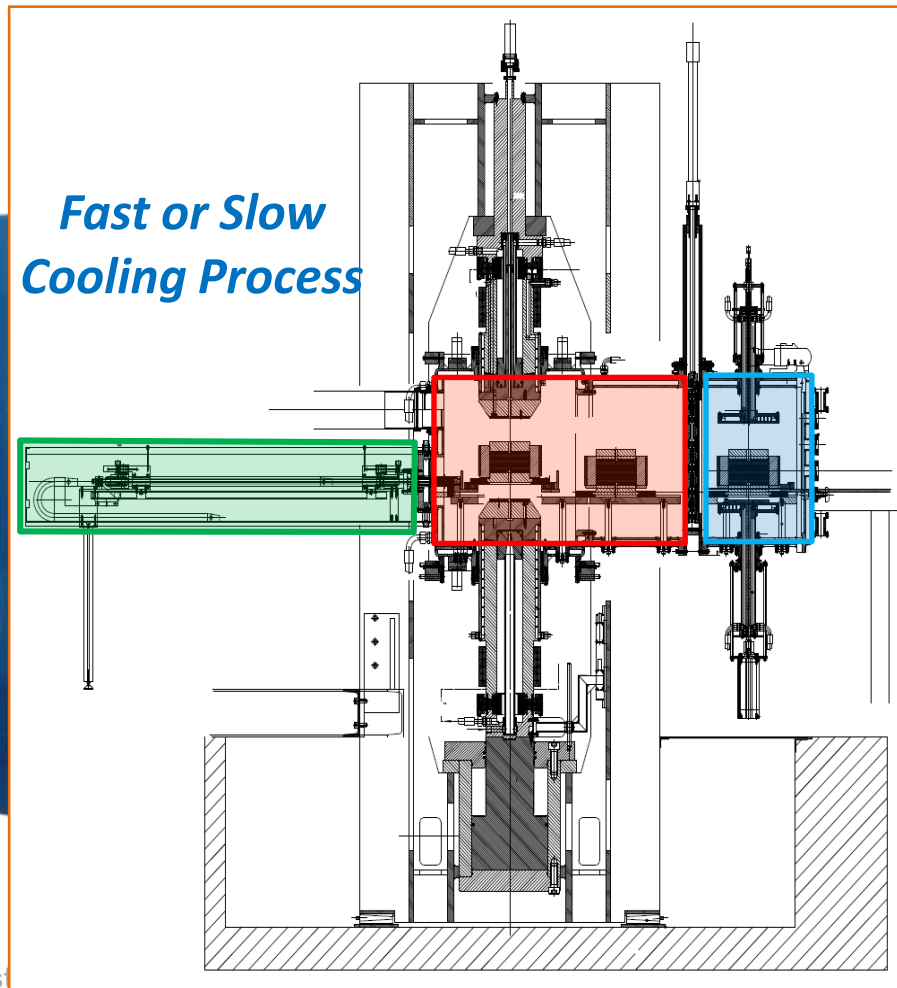
FAST/Hybrid Sintering Cycle - D = 300 mm - Binderless Tungsten Carbide



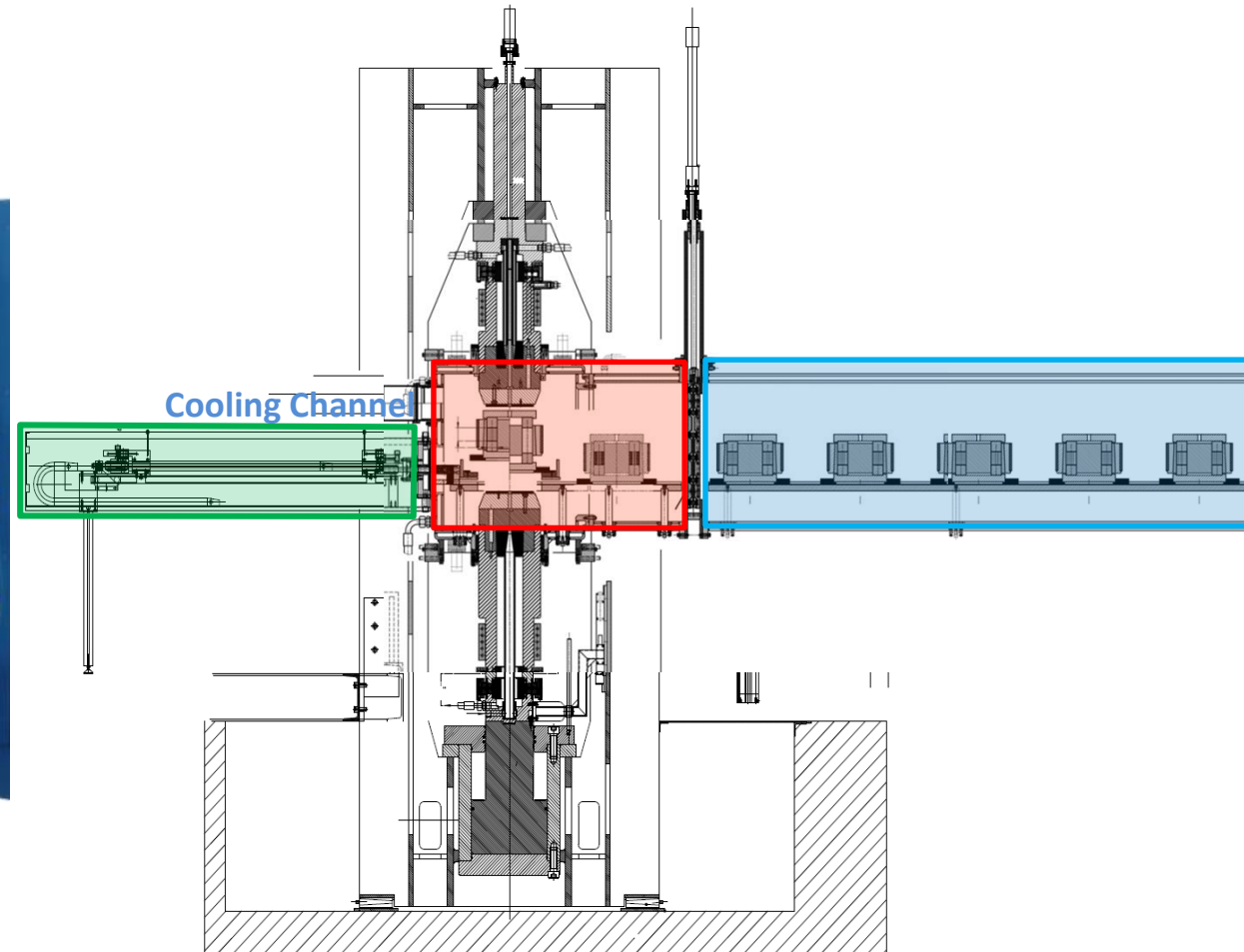
Improved Productivity by Decoupling of Process Steps



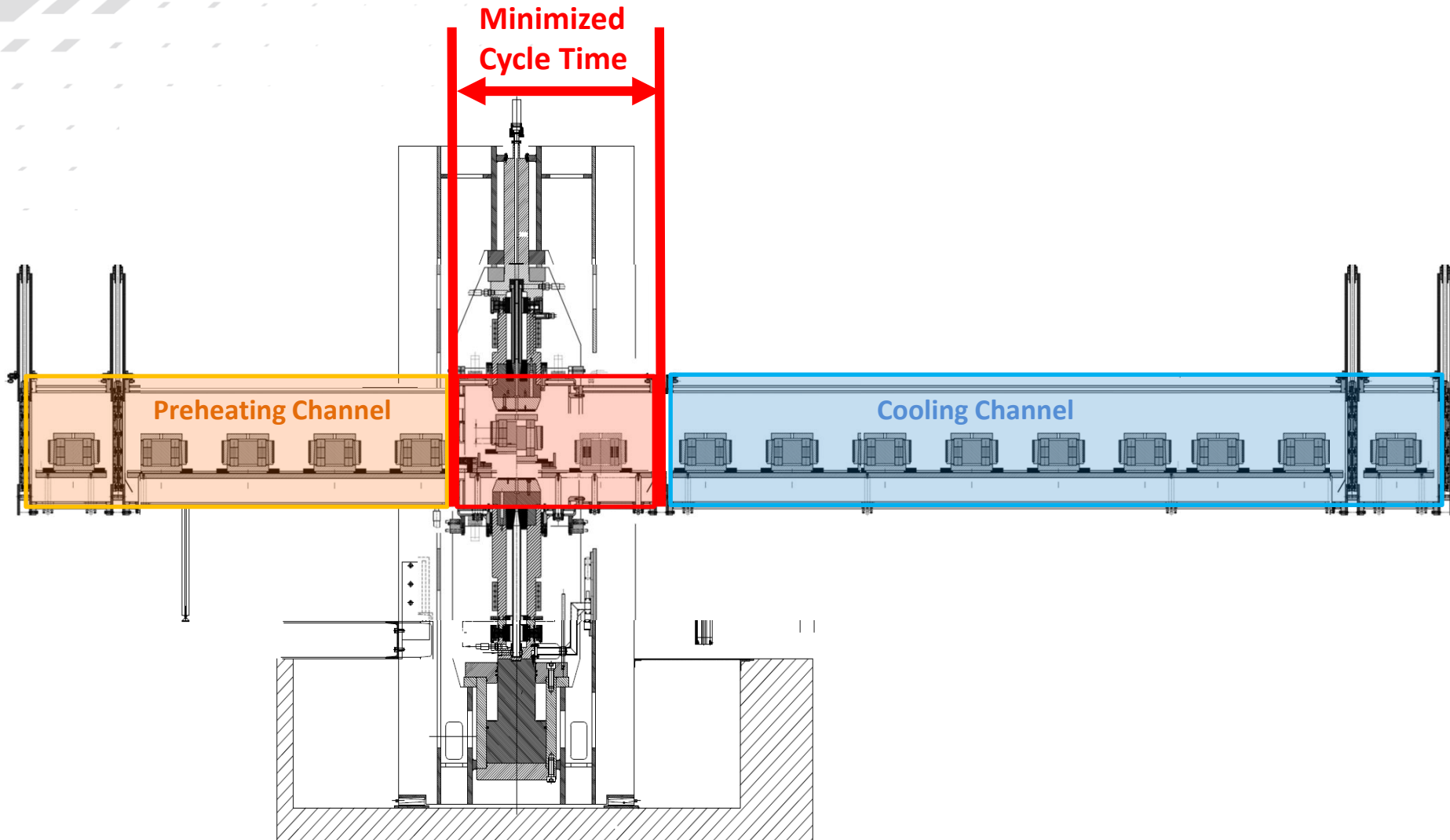
Double Chamber: Decoupling of **Sintering** Step and **Cooling** Step



Improved Productivity by Decoupling of Process Steps

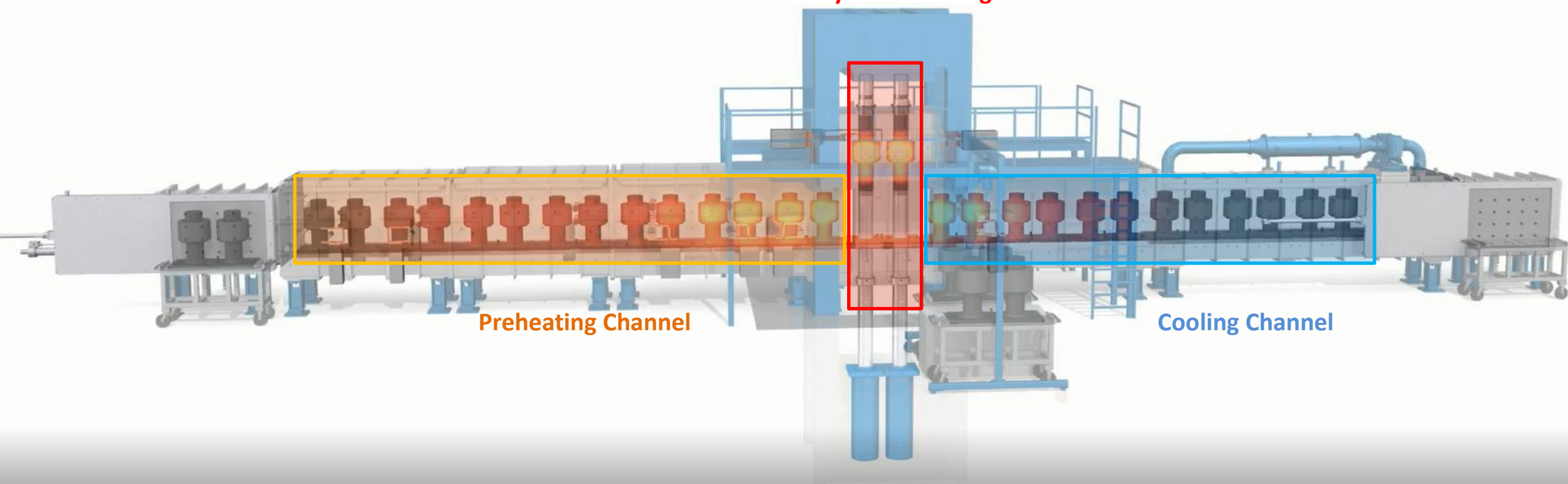


High Throughput Systems under Construction



High Throughput Systems under Construction

Hot Pressing
FAST/SPS
FAST/Hybrid
other Hybrid Sintering



HYBRID SINTERING: High Throughput Production Line

Thank you for your attention!

*For more Details
visit us at B6.431*

