TRUMPF Hüttinger GmbH + Co. KG

HIGHLY RELIABLE RF POWER SOURCES FOR IMPROVEMENT OF THE ACCELERATOR AVAILABILITY

Marcus Lau I Sector Management Electronics Emerging Markets

29th Aug 2023 FLS Lucerne

TRUMPF

A Company Gets 100 Years Old

2022

TRUMPF Hüttinger
generating confidence

becomes 100Years

May 2022

Celebrating in the new SC Freiburg stadium with all employees

PA² International Conference on Power Amplifier for Particle Accelerators

November 2022

Establishing the PA² Conference

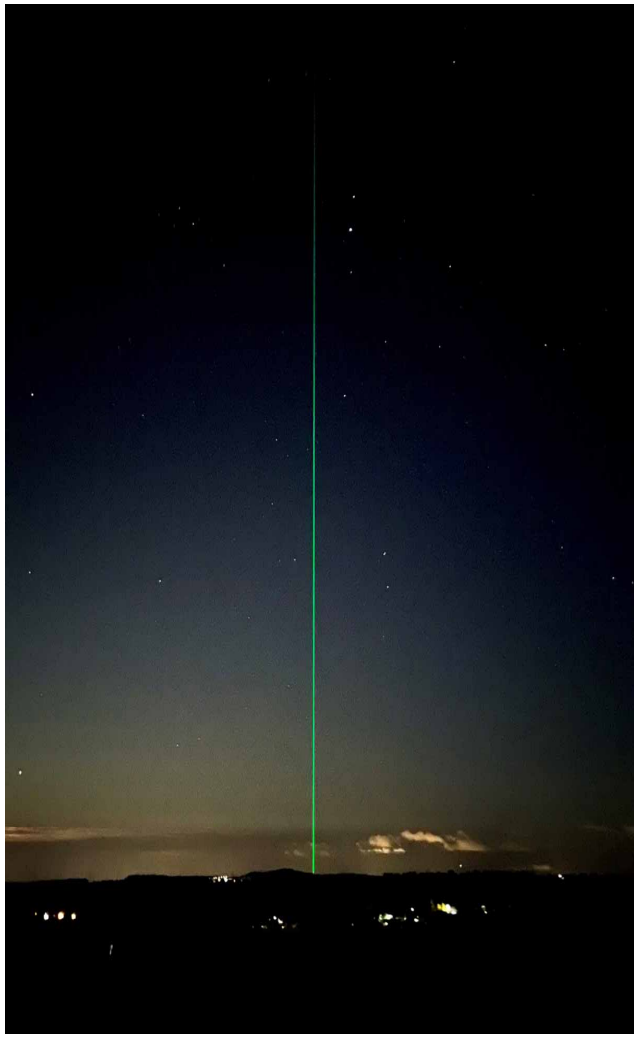
2023

TRUMPF 100 1923–2023

becomes 100Years

August 2023

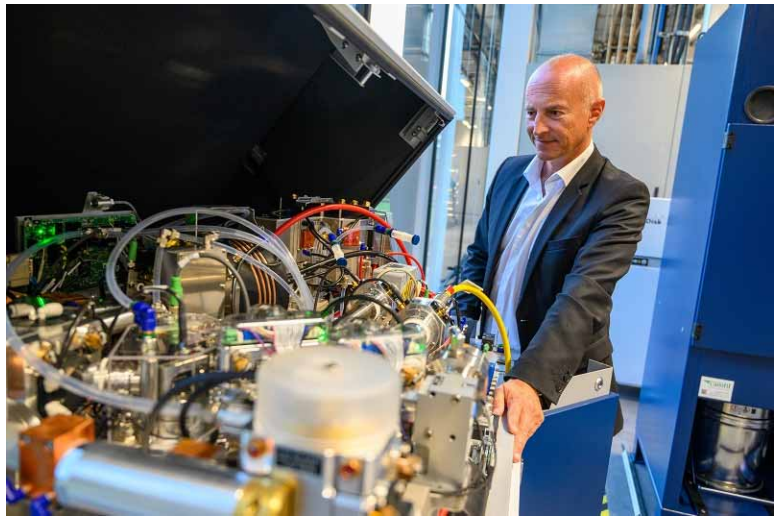
TRUMPF Birthday Candle: 3kW CW Laser at 515nm, visibility 80km radius, heigh approx. 10km

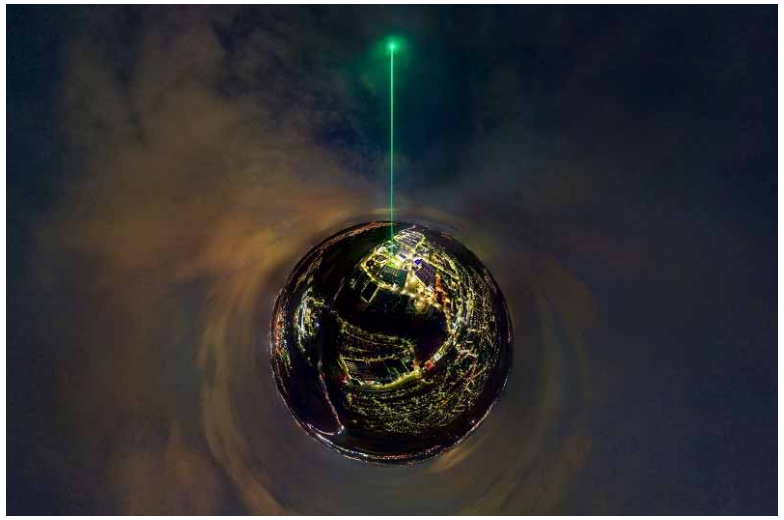


TRUMPF

From the Factory Hall into the World

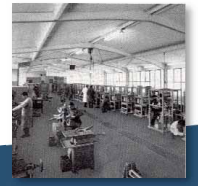
Visibility of laser technology





Milestones in the history of TRUMPF Hüttinger

100 years of experience in power electronics



1922

enterprise for the production of electr. apparatus by Fritz Hüttinger

1990

TRUMPF becomes partner of HÜTTINGER Electronic

2007

Acquisition of “Advanced Converters” as DC center of competence

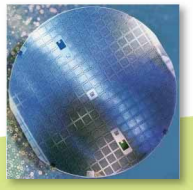
Turnover 2007: 2 M€

Turnover today: 150 M€

2009

Foundation of the international PE² Conference

(Power Electronics for Plasma Engineering)



2014

Market launch in the field of semiconductor

2017

Market leader in the segment solar

2020

Acquisition of “HBH Microwave” as microwave technology center of competence

2022

Foundation of the international PA² Conference

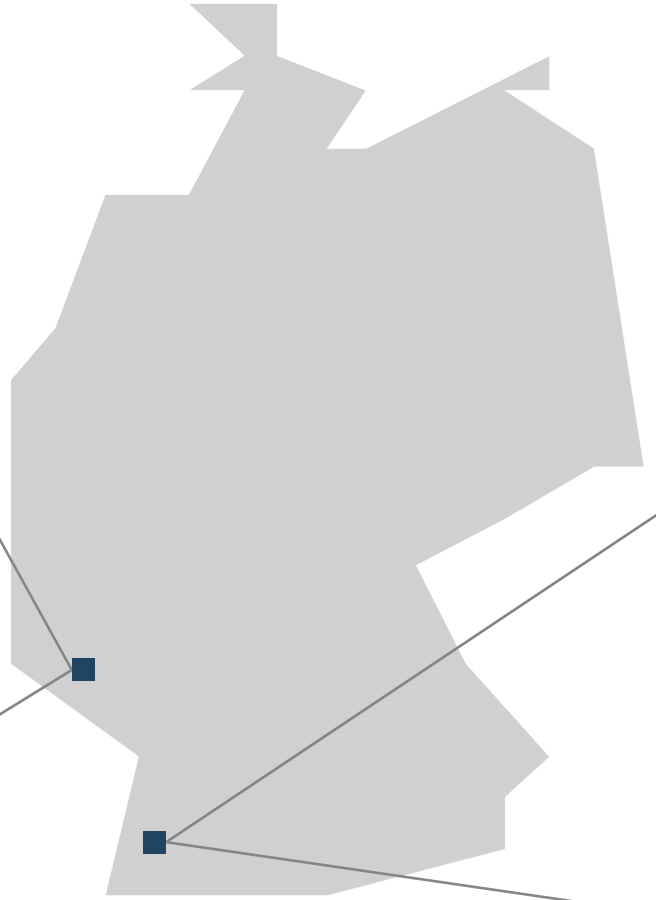
TRUMPF Huettinger celebrated its 100 year anniversary in 2022 with big plans for the future

TRUMPF Hüttinger
generating confidence

Our Facilities in Karlsruhe and Freiburg

The synergy of microwave amplifier development and industrial production at two sites

Microwave Development Expertise



Industrial Production and Service

Flexible Product Design

Scientific users requiring individual solutions

Available Amplifier Unit Power Level:
2 kW
3 kW
5 kW

Available Rack Power Level:
8 kW – 36 kW

Integration to Higher System Power with Multiple Racks:
50 – 200 kW

Important Features:

Reliability
(MTBF, Redundancy, MTTR, De-rating, System Design)

Efficiency
(Transistor, Drain Voltage, System Design, De-rating)

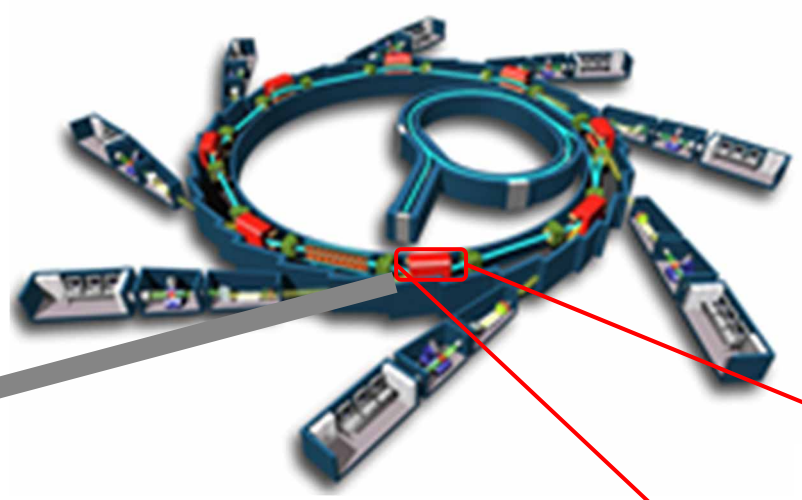
Challenge

Identification of the ideal design for industrialization with highest flexibility in terms of frequency and total power

Where are our SSPAs used in Particle Accelerators

Microwave solid state power amplifiers (SSPA) for cavities in accelerator systems

Particle Accelerator

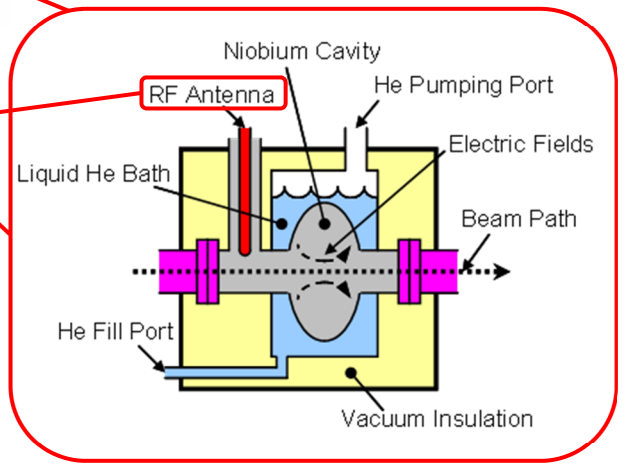


Waveguide

SSPA Rack system powering the accelerator

Connection to our SSPA products via waveguide

Cavity



Introduction: Tube Technology and Transistor Based Amplifier

Move to new technology state for particle accelerators

Tube Technology

- High voltage power supplies needed
- Continuous degradation during operation
- Strong dependency on single tubes

Transistor Technology

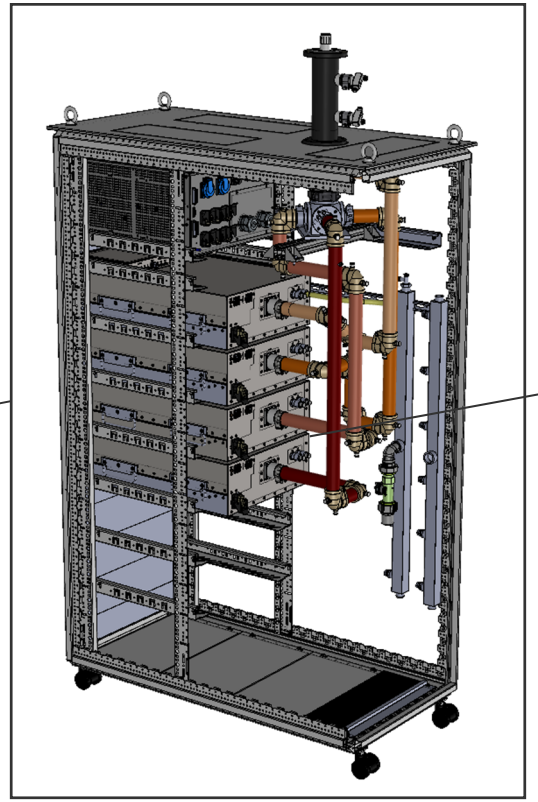
- Integrated standard power supply units
- Stable in total efficiency over time
- Modular at low power level

Overall System Design

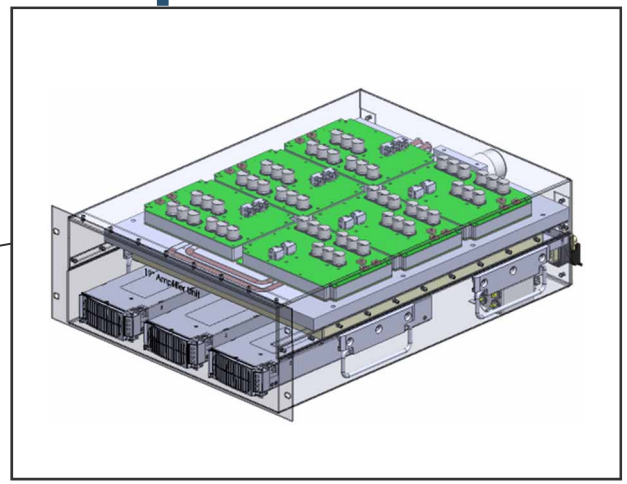
Detailed view into the construction for understanding the factors affecting the efficiency

System

Rack



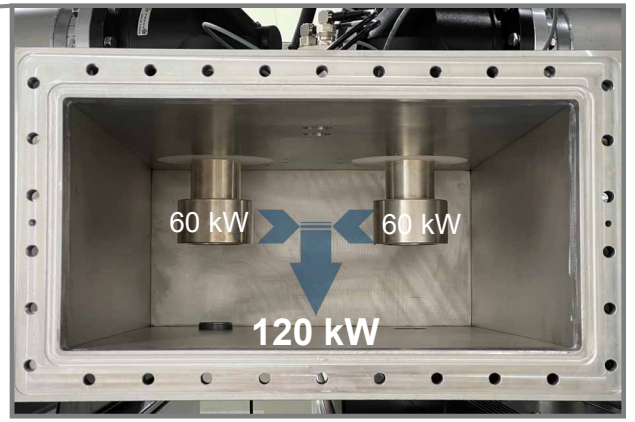
Amplifier Unit

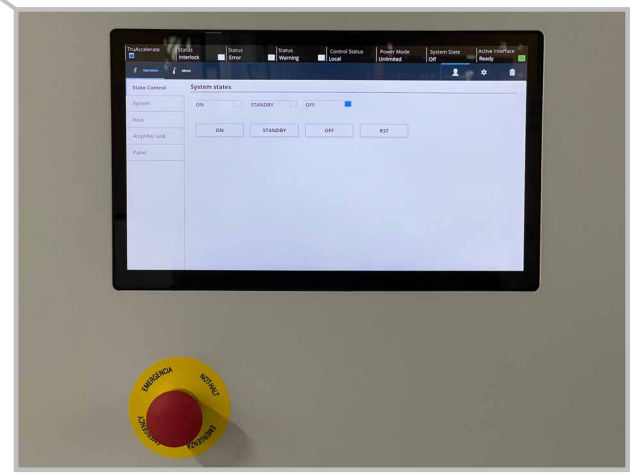


TruAccelerate

120kW System architecture at 500MHz for Synchrotron Light Sources

2:1 Combining step from coaxial to waveguide





HMI displaying the amplifier status down to the pallet level

Features Crucial for Customers

Most important aspects we need to consider as technology provider

Reliability

MTBF

MTTR

Performance

Overall Efficiency

Footprint

Control

Service

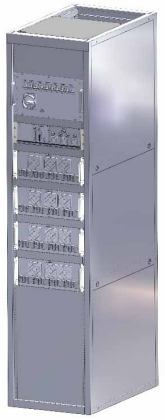
Spare Parts

Service Contact

Obsolescence Management

Field Data

Proof of exceptional performance in operation



Integrated:

2kW PA Units

Power Distribution Unit (PDU)

Driver Control Unit (DCU)

Combiner

250 X

250
each 4 x 2kW,
2 x 4kW, or 1 x 8kW
output power (3,400 amplifier pallets in total).

From ~1000 PA Units and over 6500 operational hours of each Unit

Determination of field meantime between failure (MTBF) and annual failure rate (AFR)

$$MTBF = \frac{cumulative\ operational\ time}{\#\ Incidents} \qquad AFR = 1 - e^{-\frac{8760}{MTBF}}$$

According to standard SEMI E10-0221

M. Lau et al., FIELD MTBF of SOLID STATE POWER AMPLIFIERS - HIGHLY RELIABLE RF POWER SOURCES, SRF Conference Grand Rapids 2023

MTBF and AFR values

for the complete Rack and individual PA Units, DCUs and PDUs

$$MTBF_{Rack} = 166,750 \; [h] \qquad AFR_{Rack} = 5.12\%$$

$$MTBF_{PA\ Unit} = 952,857 \; [h] \qquad AFR_{PA\ Unit} = 0.92\%$$

$$MTBF_{DCU} = 833,750 \; [h] \qquad AFR_{DCU} = 1.05\%$$

$$MTBF_{PDU} = 1,667,500 \; [h] \qquad AFR_{PDU} = 0.52\%$$

$$MTBF_{Rack} = 555,833 \; [h] \qquad AFR_{Rack} = 1.56\%$$

$$MTBF_{PA\ Unit} = 6,670,000 \; [h] \; * \qquad AFR_{PA\ Unit} = 0.13\%$$

*** We assumed that a PA Unit could fail in any coming time. This value is 0 at the moment for data taken**

TRUMPF

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Obsolescence Management

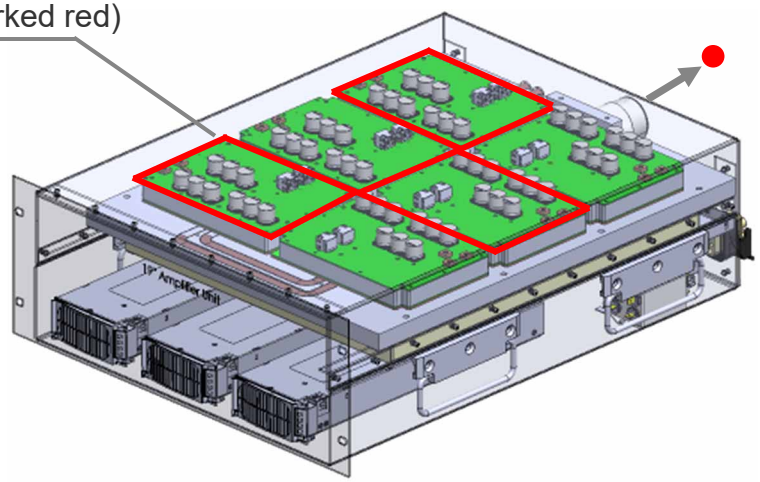
Influence of Misalignment

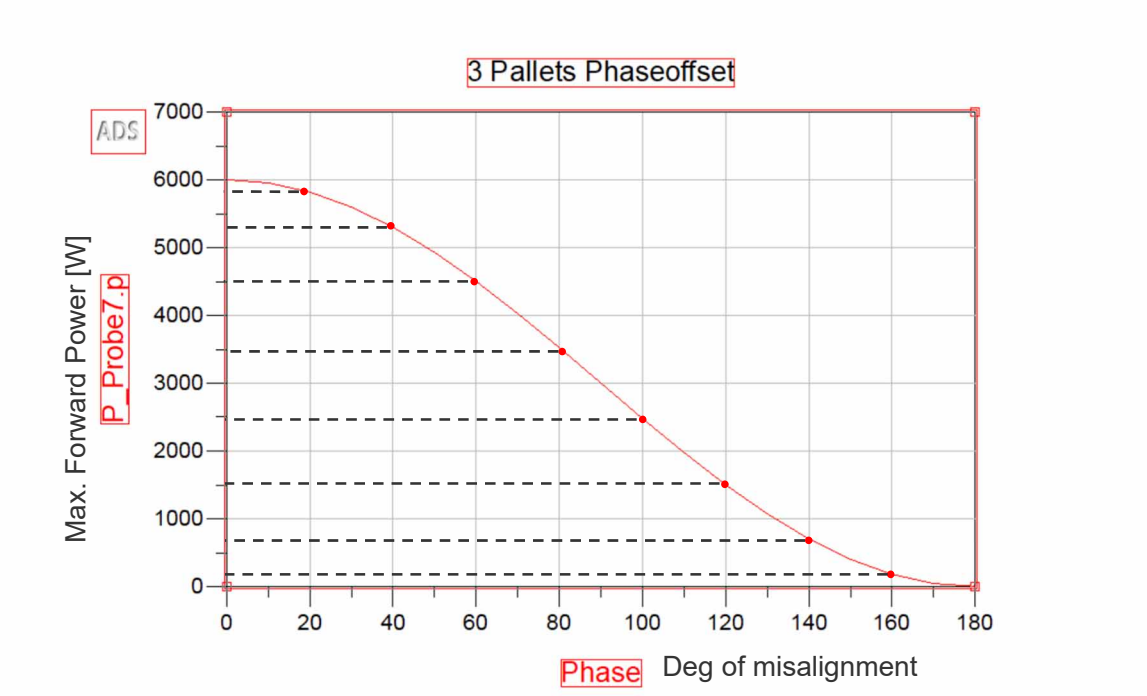
From best to worst case possible

Performance

PA Unit Top View

Coherently misaligned Pallets
(marked red)

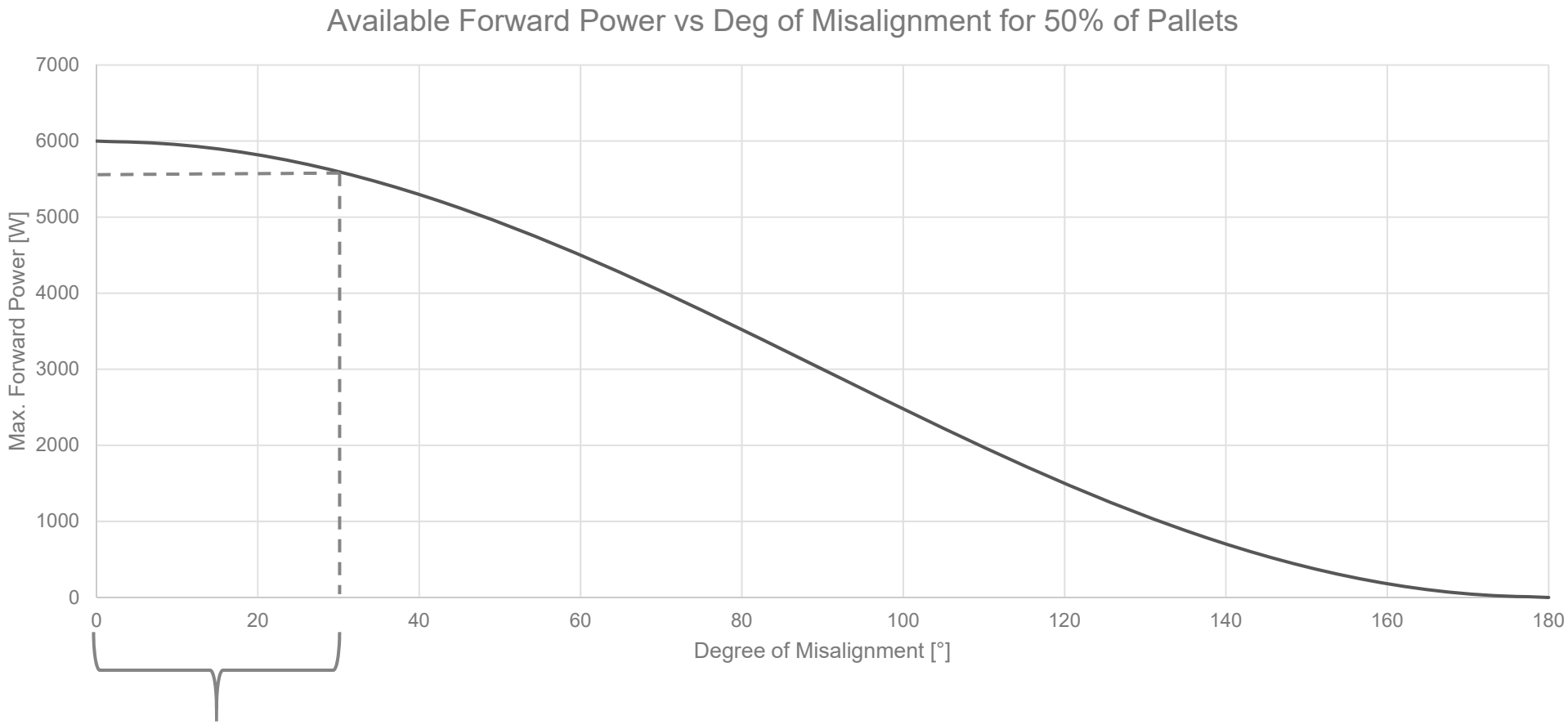




TRUMPF

Misalignment for three Pallets at different Degrees

Influence of phase shift on the output power

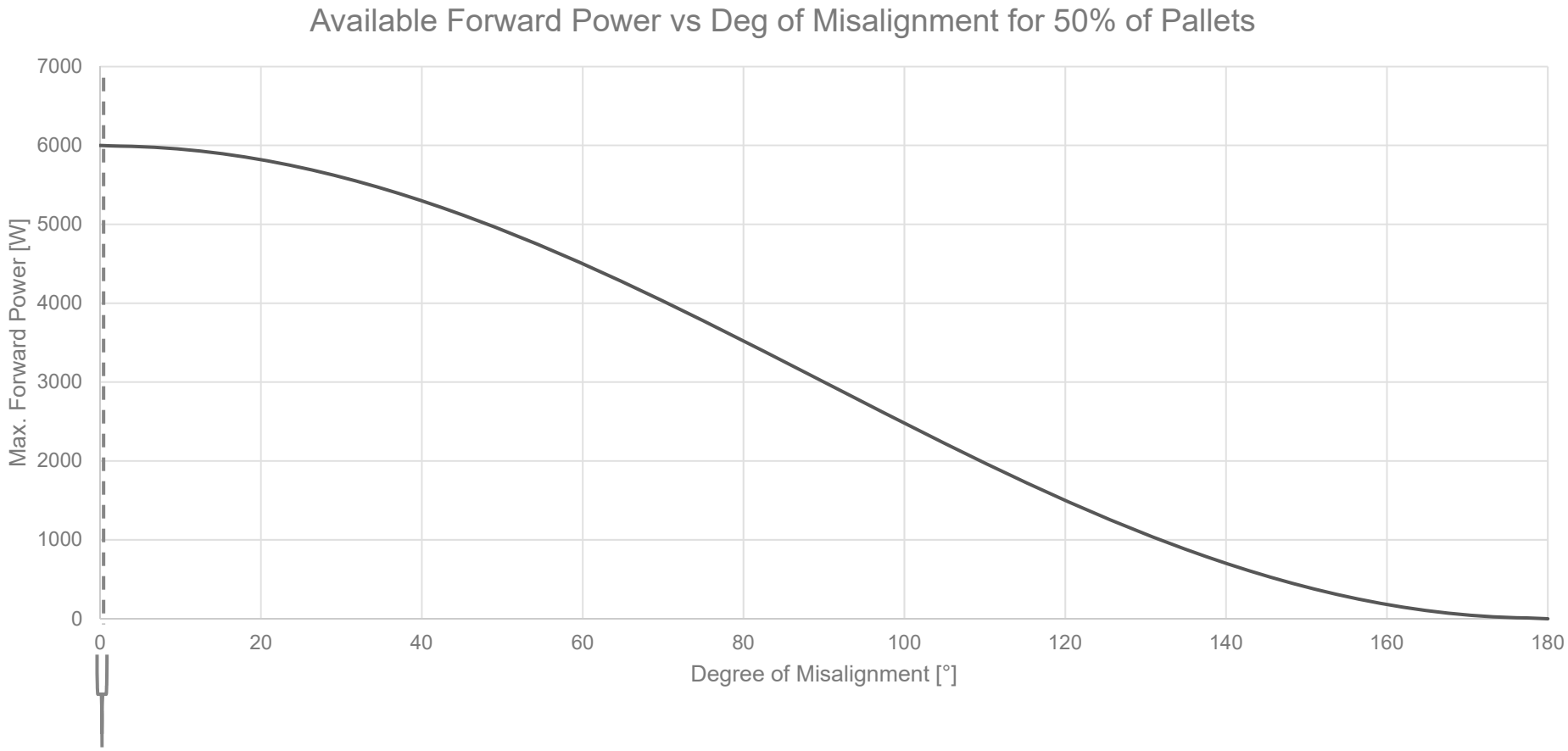


Deviation after pallet series production (±15°) → max pot. loss of ~400W (6.6%)

→ factory calibration

Misalignment for three Pallets at different Degrees

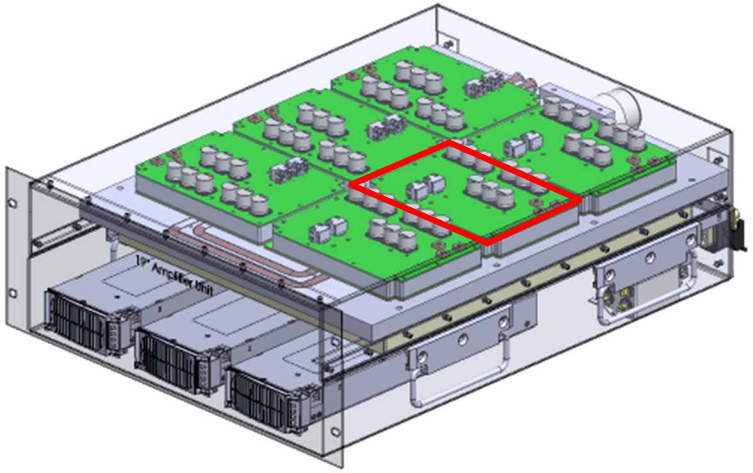
Improvement of loss to neglectable values after factory calibration

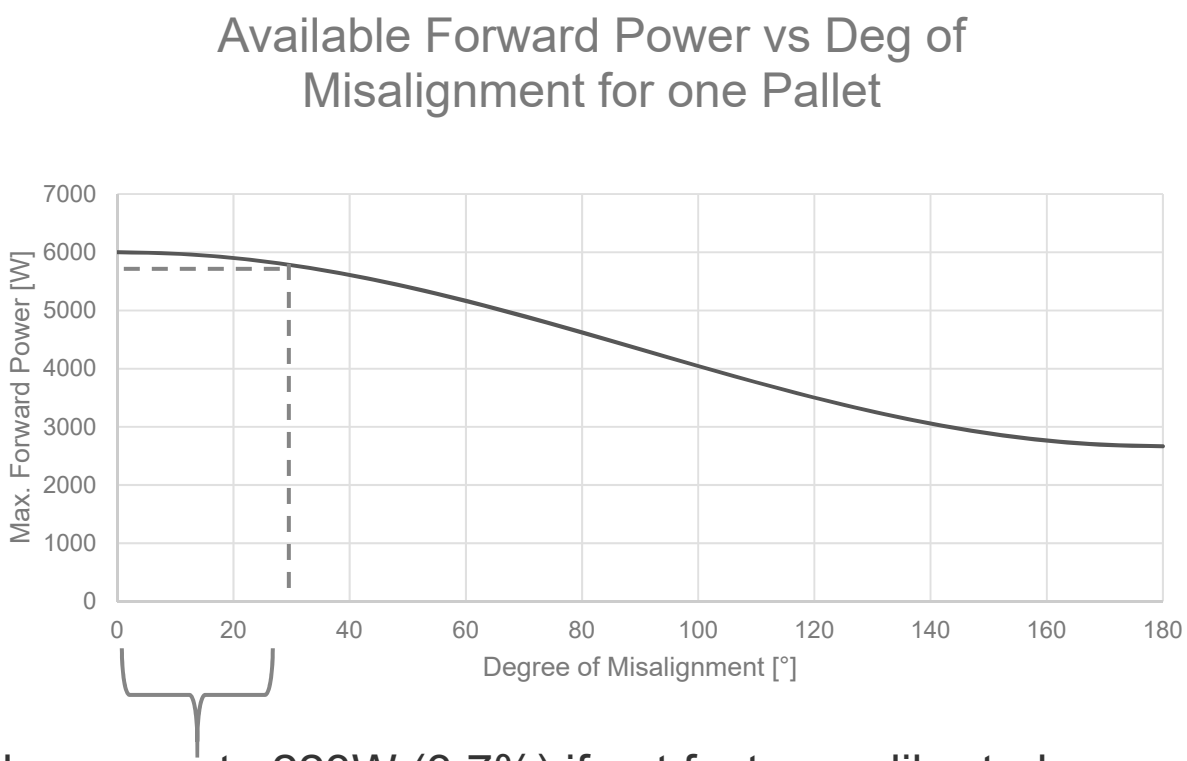


Max. deviation after factory calibration by internal protocol (±0.5%) → max pot. loss of ~0.457W (0,0076%)

Misalignment of one Pallet at different Degrees

We need to take care of every pallet



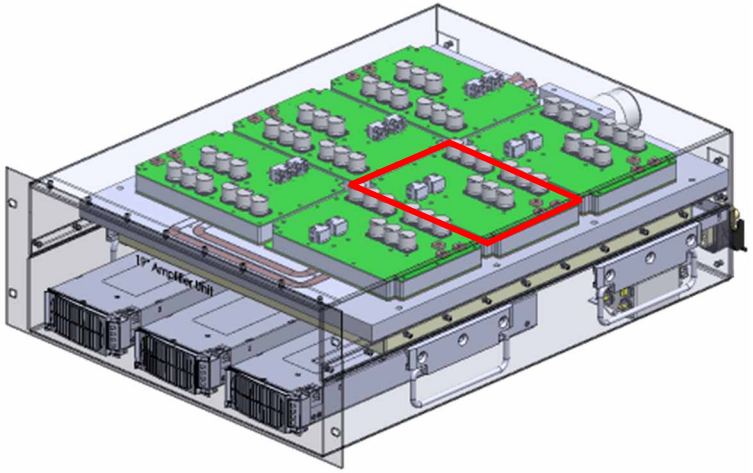


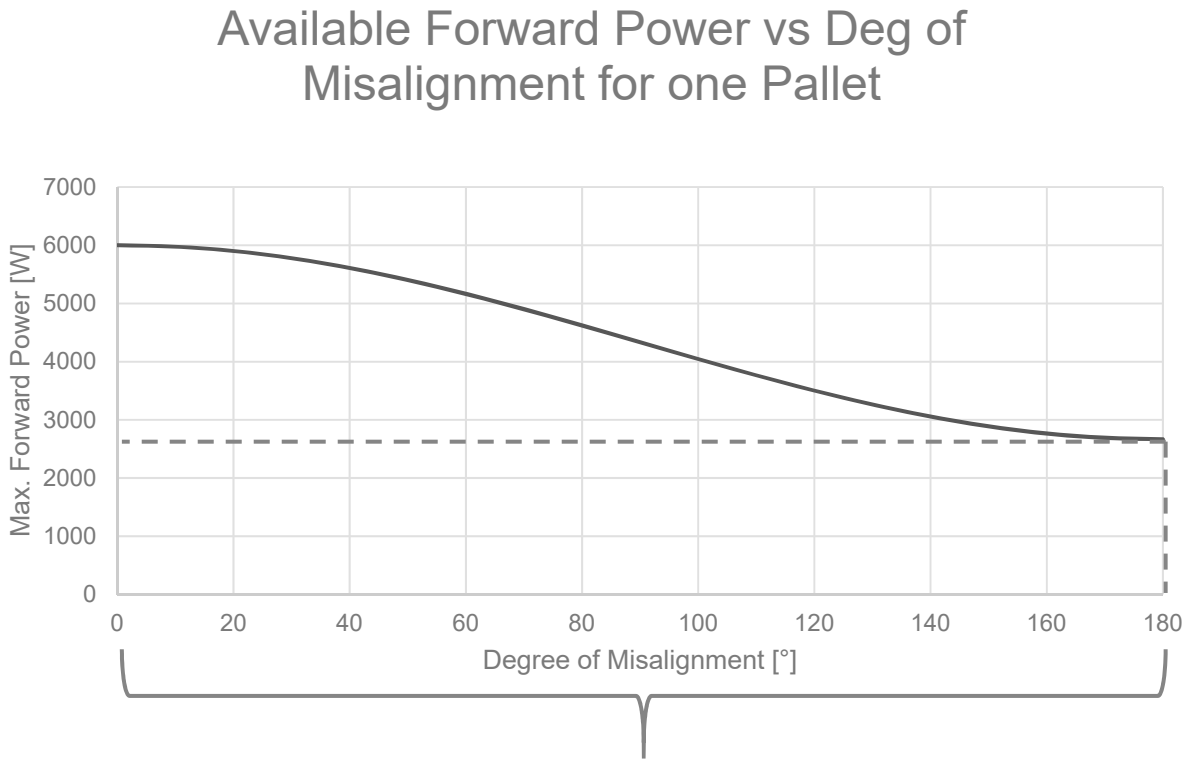
A single Pallet can cause losses up to 223W (3.7%) if not factory calibrated

Calibration of every single pallet is crucial

Misalignment of one Pallet at different Degrees

We need to take care of every pallet





A faulty Pallet can cause losses up to 3200W (53.3%)

Tests for every single manufactured pallet is crucial

Features Crucial for Customers

Most important aspects we need to consider as technology provider

Reliability

MTBF

MTTR

Performance

Overall Efficiency

Footprint

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Service

Spare Parts

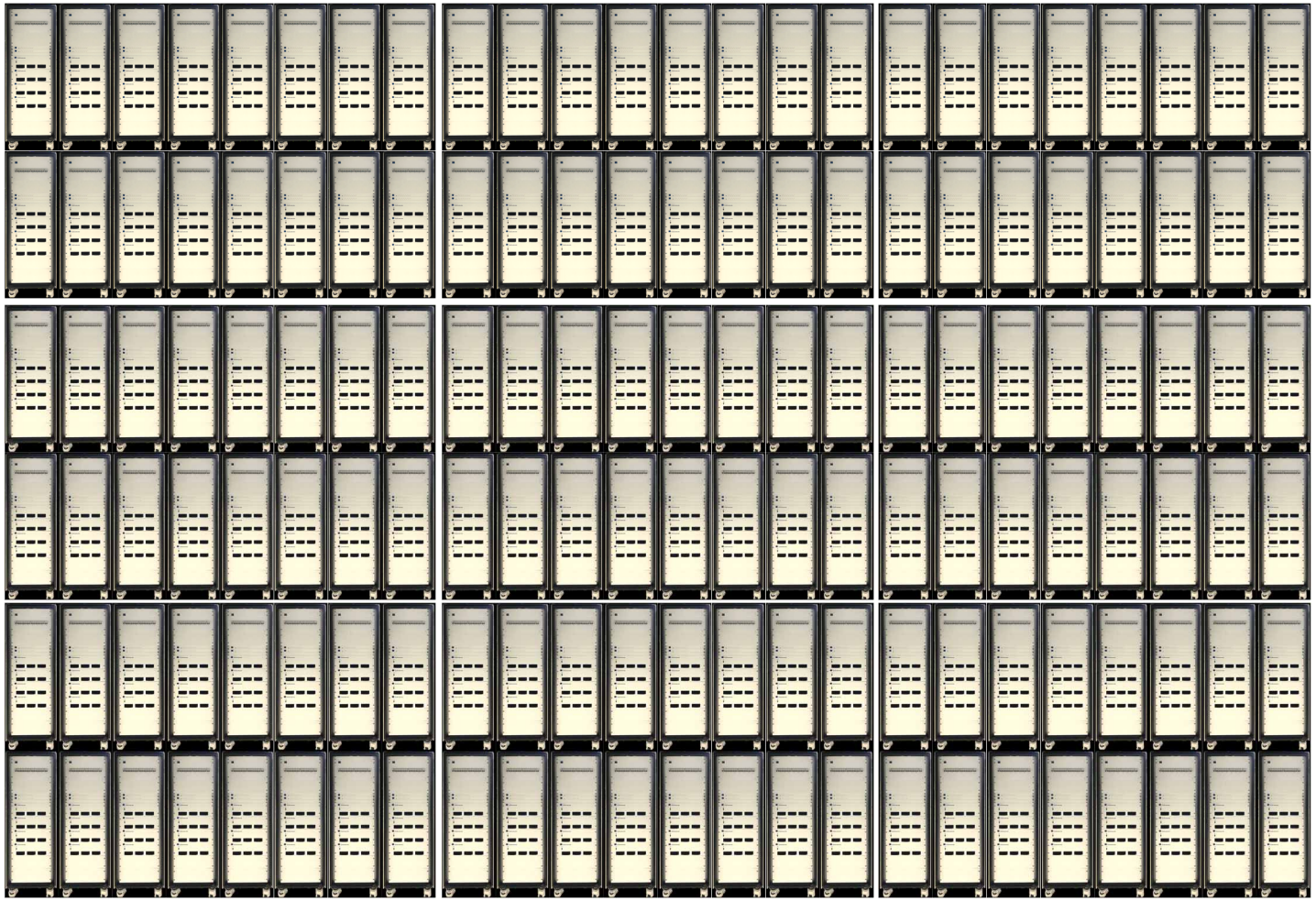
Service Contact

Obsolescence Management

Large Quantity Installation

Suggested Service and Spare Parts

144
x



Spare Parts and Service Concept

Suggested Service and Spare Parts

144 x

- 144 PDUs
- 144 DCUs
- **576 PA Units**

PDU

AFR: 0.52%

144 x 0.0052 = 0.7488 pcs

1 year delivery time and factor 2 safety level

2 PDUs suggested

DCU

AFR: 1.05%

144 x 0.0105 = 1.512 pcs

1 year delivery time and factor 2 safety level

4 DCUs suggested

PA Unit

AFR: 0.13% - 0.92%

576 x 0.0092 = 5.2992 pcs

1.5 years delivery time and factor 2 safety level

16 PA Units suggested

PA Unit

Reduction of deliver time to 0.5 years and improved repair time

6 PA Units suggested

Reduction by TRUMPF Hüttinger Service Concept

Conclusion

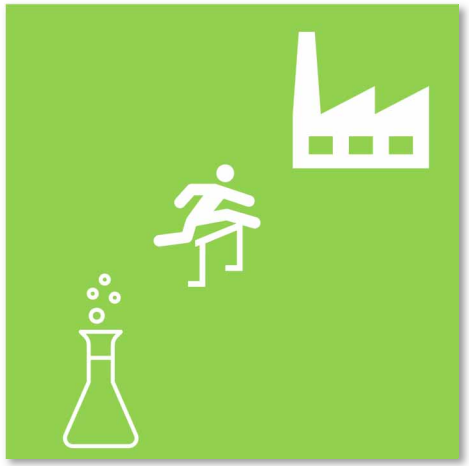
HIGHLY RELIABLE RF POWER SOURCES FOR IMPROVEMENT OF THE ACCELERATOR AVAILABILITY

It is an

Emerging Technology

Due to the advantages

We take the



Industrialization Challenge

By our flexible system design

Proven

High performance of the systems

Assured by high quality manufacturing and outstanding operational data