TRUMPF

Sensitivity Studies for the Development of Laser Machines

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Agenda

- TRUMPF
- Challenges for the development of laser cutting machines
- Sensitivity studies
  - Laser & machine’s dynamic
  - Optical system
- Summary

About us

We are a high-tech company that focuses on manufacturing technology, laser technology and medical technology.

We offer our customers both innovative and high-quality products.

We are represented in all world markets,
close to our customers with 58 subsidiaries.

We are a family business established in 1923 and our goal is to stay economically independent.

At a glance

		2011/12	Change in percent
Sales	mil. EUR	2,328.2	+15.0
Income before Taxes	mil. EUR	210.9	+13.8
Expenditure on Fixed Assets	mil. EUR	152,5	+151.2
R+D Expenditures	mil. EUR	193.4	+ 22.4
Employees as of June 30	number	9,555	+11.8

TRUMPF Group Business Divisions

Machine Tools	Laser Technology/ Electronics		Medical Technology
Machine Tools	**Laser Technology**	**Electronics**	**Medical Technology**
 			
Machine tools for flexible sheet metal and tube processing, Power tools for sheet metal processing	Lasers for production technology	Power supplies for induction heating, plasma and CO_2 laser excitation	Surgical lights, operating tables, video solutions, supply systems
Sales (mil €) 1,890 Employees 5,918	Sales (mil €) 727 Employees 2,330		Sales (mil €) 184 Employees 713

End of fiscal year: June 30, 2012; consolidated within the business division; figures rounded

TRUMPF Historie – eine Innovationsgeschichte von der Komponente zum High-end System

1923

Christian TRUMPF acquires the mechanical shop Julius Geiger.
Flexible shafts for medical application and printers

TRUMPF – a success story from a single component to high-end systems

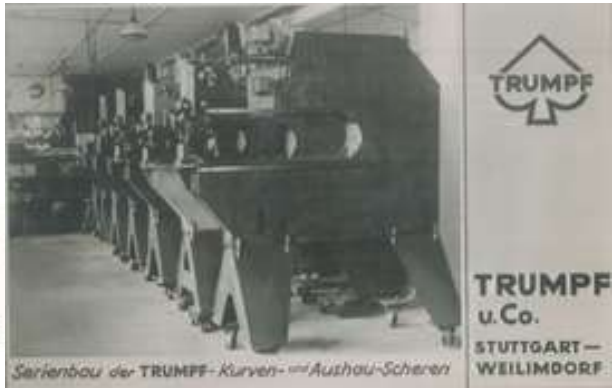
1923

70 Employees

1934

First manual operating **motor-driven scissor** for sheet metal cutting

TRUMPF – a success story from a single component to high-end systems



1923

70 Employees

1934

145 Employees

1957

Patent application for a **guide of coordinates** by the young **engineer Berthold Leibinger**.
First step towards **numerical controlled** motion

TRUMPF Historie – eine Innovationsgeschichte von der Komponente zum High-end System

1923 | 1934 | 1957 | 1968

Trumatic 20: **first numerically controlled sheet metal processing machine**. Pure automatic operation by „Lochstreifenspeicherung“.

70 Employees | 145 Employees | 325 Mitarbeiter

TRUMPF – a success story from a single component to high-end systems

1923 – 70 Employees

1934

1957 – 145 Employees

1968 – 325 Employees

1979 – **First steps into laser technology** - first punch and laser machine TRUMATIC 180 LASERPRESS

TRUMPF – a success story from a single component to high-end systems

1923 – 70 Employees

1934 – 145 Mitarbeiter

1957 – 325 Employees

1968 – 325 Employees

1979 – 1500 Employees

1985 – TRUMPF is **manufacturer of laser sources** (CO2-Laser).

TRUMPF – a success story from a single component to high-end systems

1923 | 1934 | 1957 | 1968 | 1979 | 1985 | **1987**

First **2D-laser cutting machine**
TRUMATIC L3000

70 Employees | 145 Employees | 325 Employees | 1500 Employees

TRUMPF – a success story from a single component to high-end systems

1923 – 70 Employees

1934 – 145 Employees

1957 – 325 Employees

1968 – 325 Employees

1979 – 1500 Employees

1985 – 1500 Employees

1987 – 1500 Employees

2011 – 8500 Employees

20.000 TruFlow **CO_2-Lasers** sold

Cutting and laser technology define the performance progress

Performance

2000 Watt
9 m/min@1mm
4 mm

2600 Watt
11 m/min@1mm
10 mm

4000 Watt
11 m/min@1mm
15 mm

TruFlow CO2-Laser

6000 Watt
11 m/min@1mm
25 m/min@1mm
25 mm

3000 Watt
34 m/min@1mm
4 (12) mm

8000 Watt
11 m/min@1mm
32 m/min@1mm
50 mm

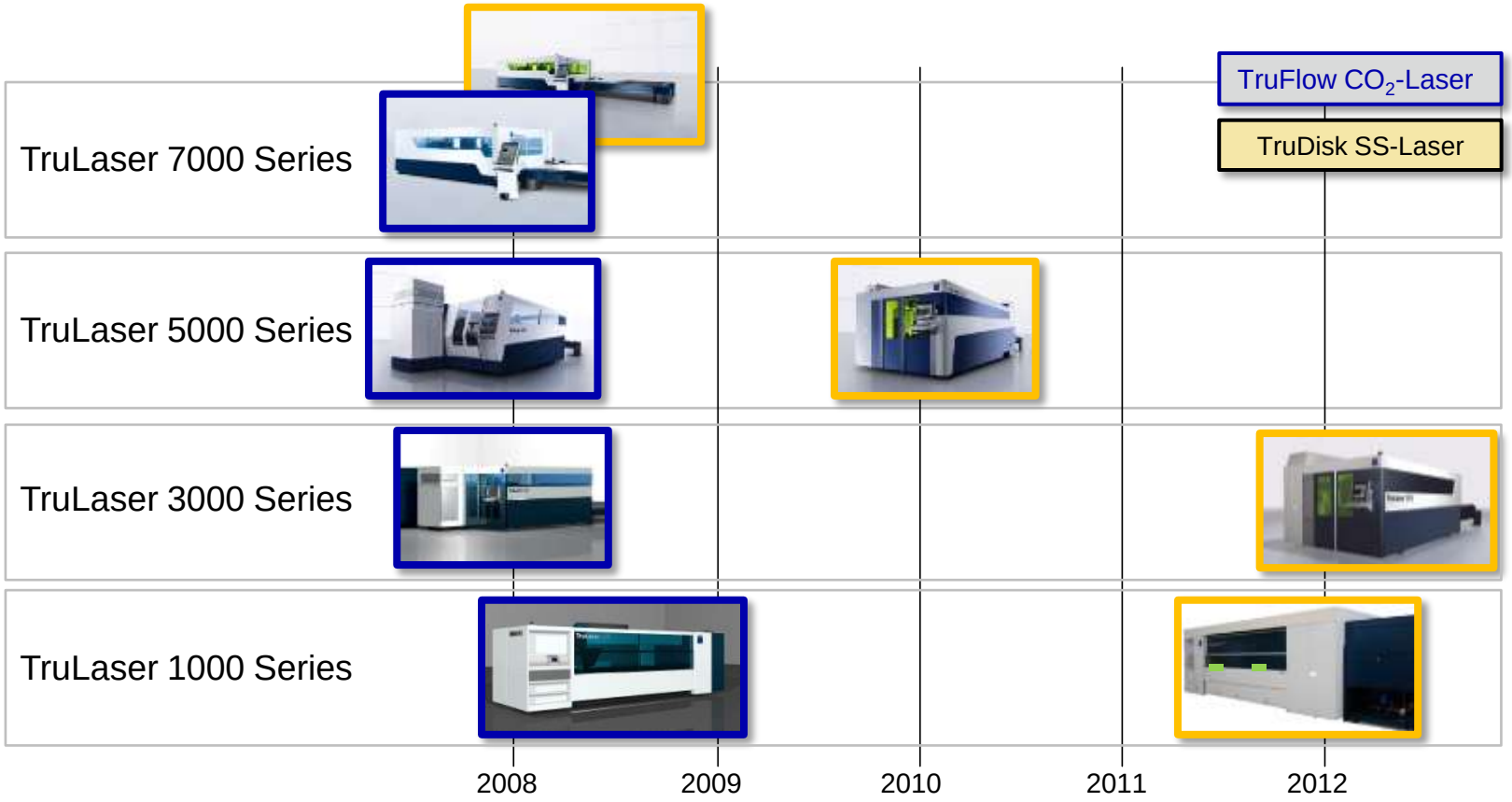
5000 Watt
50 m/min@1mm
5 (20) mm

TruDisk SS-Laser

stainless steel

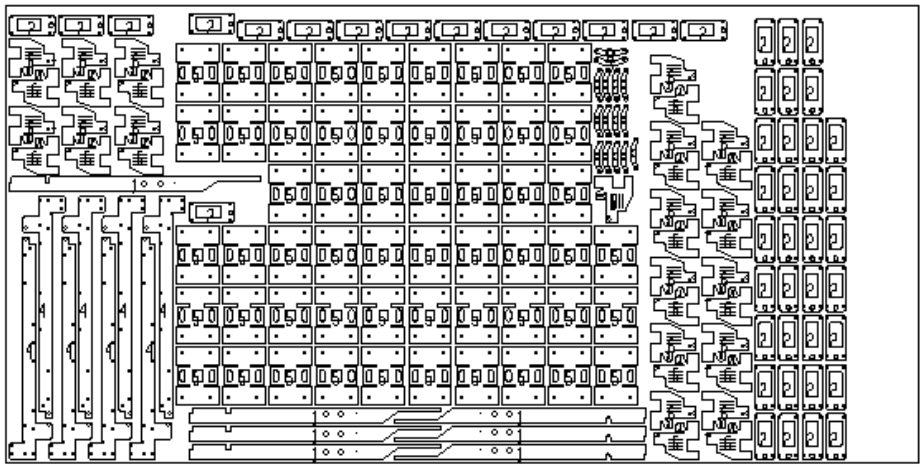
1990 2000 2010

Solid state lasers almost doubled the portfolio

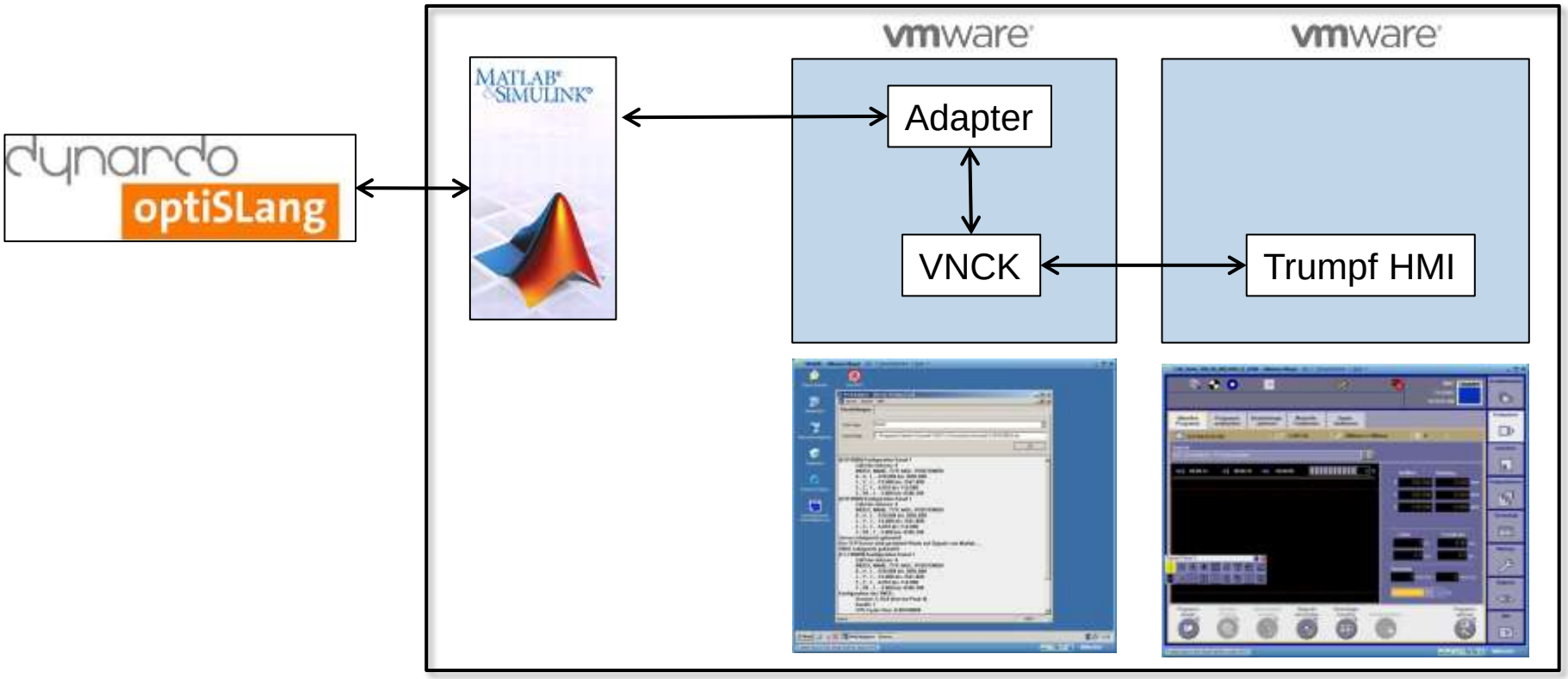


Sensitivity studies help to find efficient laser - machine combinations

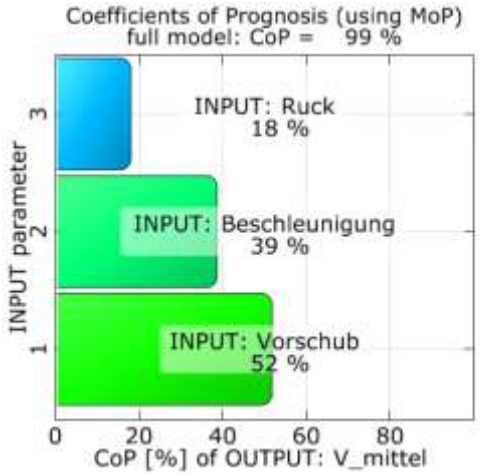
- Input parameter laser
  - Forward feed
- Input parameter of the machine's dynamic
  - Acceleration
  - Jerk
- Output
  - Average velocity
  - Duration of production
- Test case
  - Sheet metal 2.500x1.250 mm²
  - 169 parts
  - TruLaser 3030 → 33 minutes

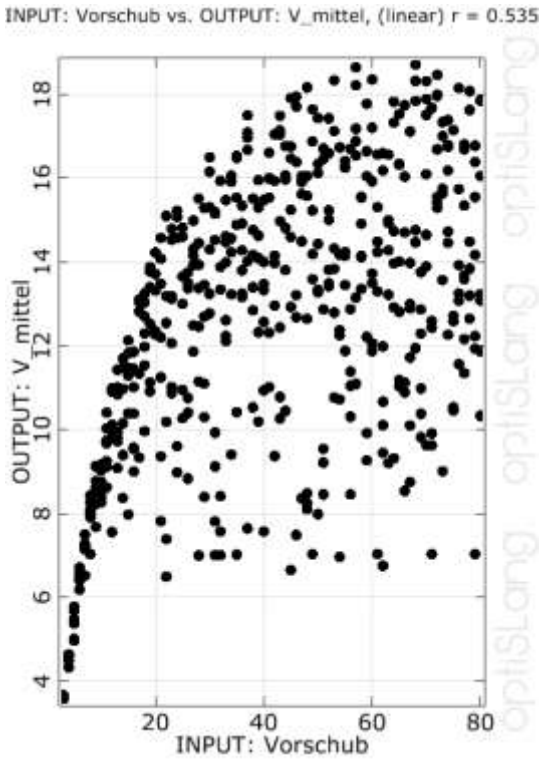


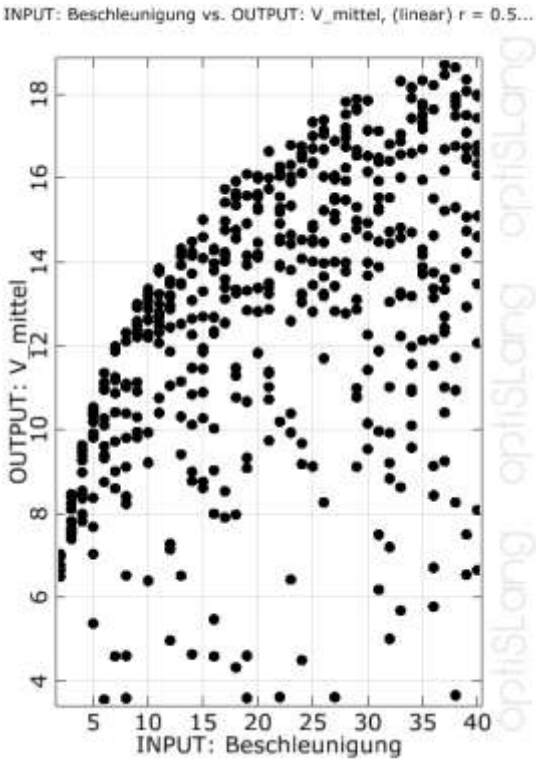
Virtual control unit as basic model
VNCK “virtueller NC-Kern” by Siemens



Results (1)


Coefficients of Prognosis (using MoP)
full model: CoP = 99 %
INPUT: Ruck
18 %
INPUT: Beschleunigung
39 %
INPUT: Vorschub
52 %
INPUT parameter
1
2
3
0
20
40
60
80
CoP [%] of OUTPUT: V_mittel

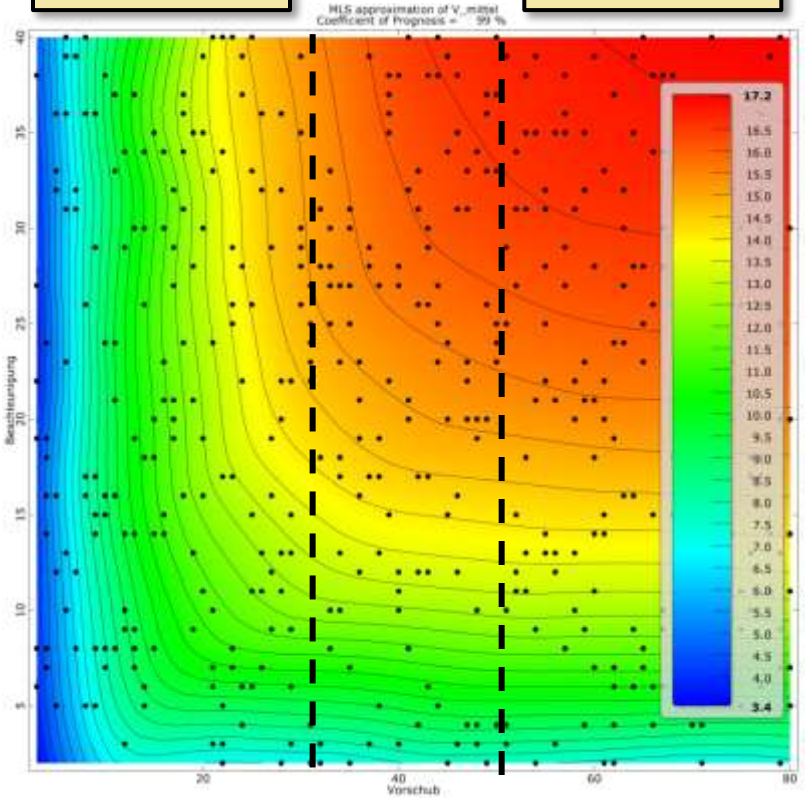

INPUT: Vorschub vs. OUTPUT: V_mittel, (linear) r = 0.535
OUTPUT: V_mittel
4
6
8
10
12
14
16
18
20
40
60
80
INPUT: Vorschub

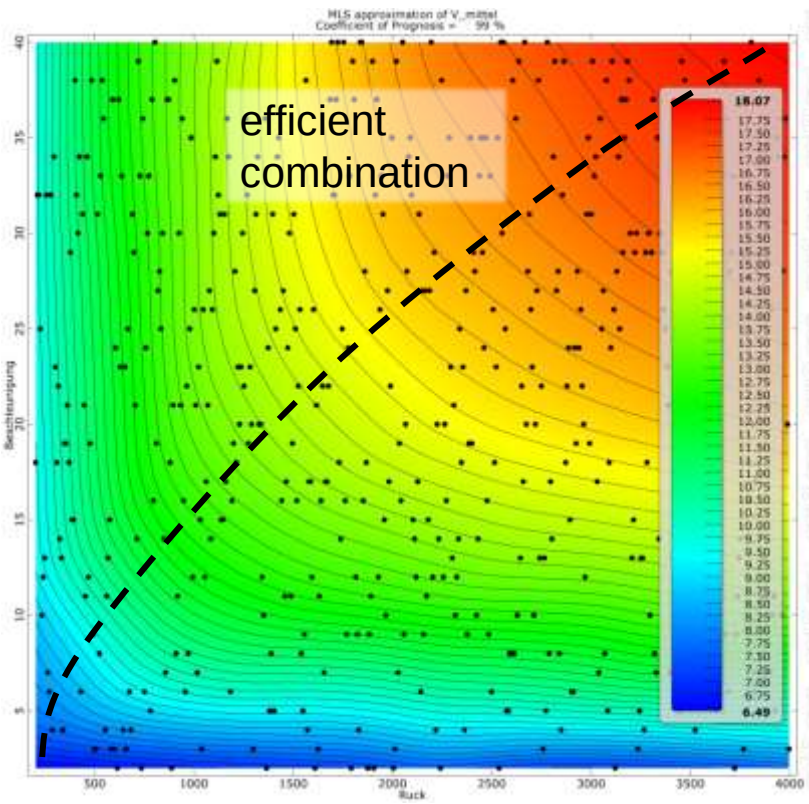

INPUT: Beschleunigung vs. OUTPUT: V_mittel, (linear) r = 0.5...
OUTPUT: V_mittel
4
6
8
10
12
14
16
18
5
10
15
20
25
30
35
40
INPUT: Beschleunigung

Results (2)

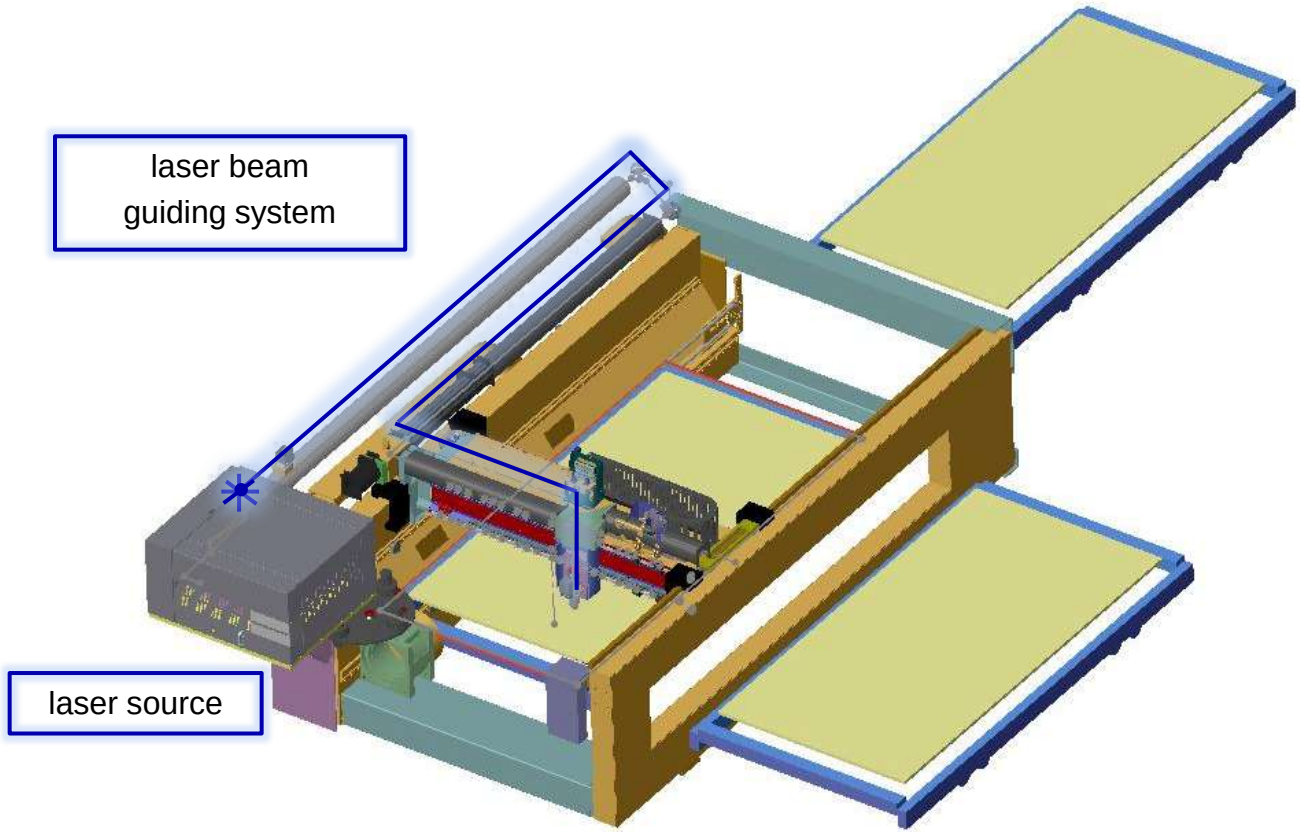
3000 Watt
34 m/min@1mm

5000 Watt
50 m/min@1mm

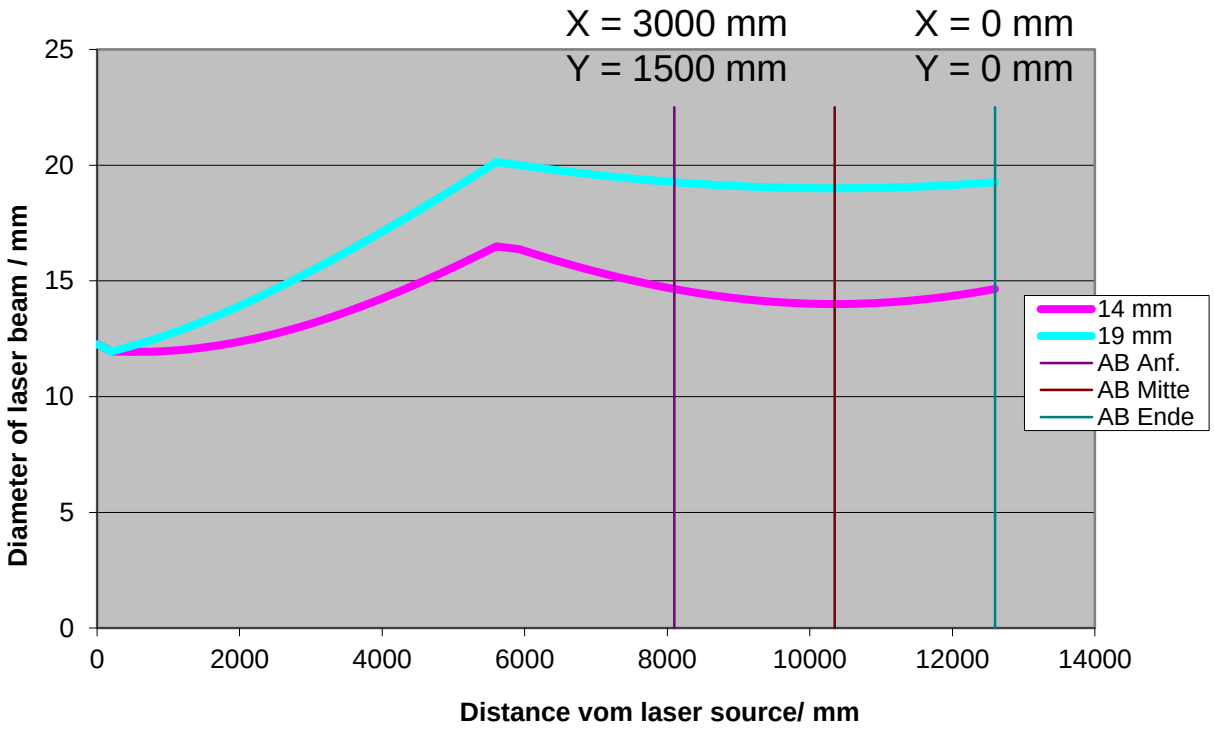




High quality laser cutting requires several parameters in a certain range

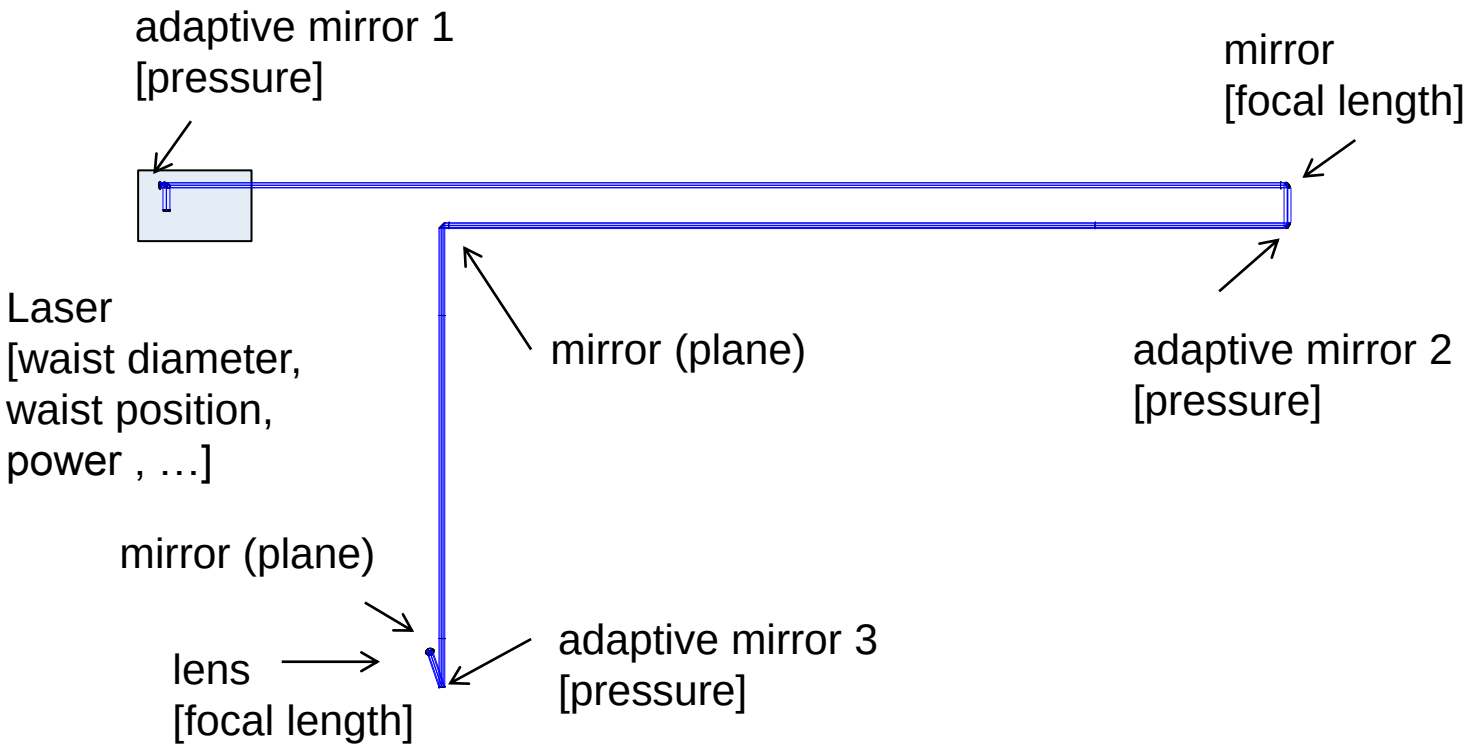


Basic optical design calculated with ZEMAX

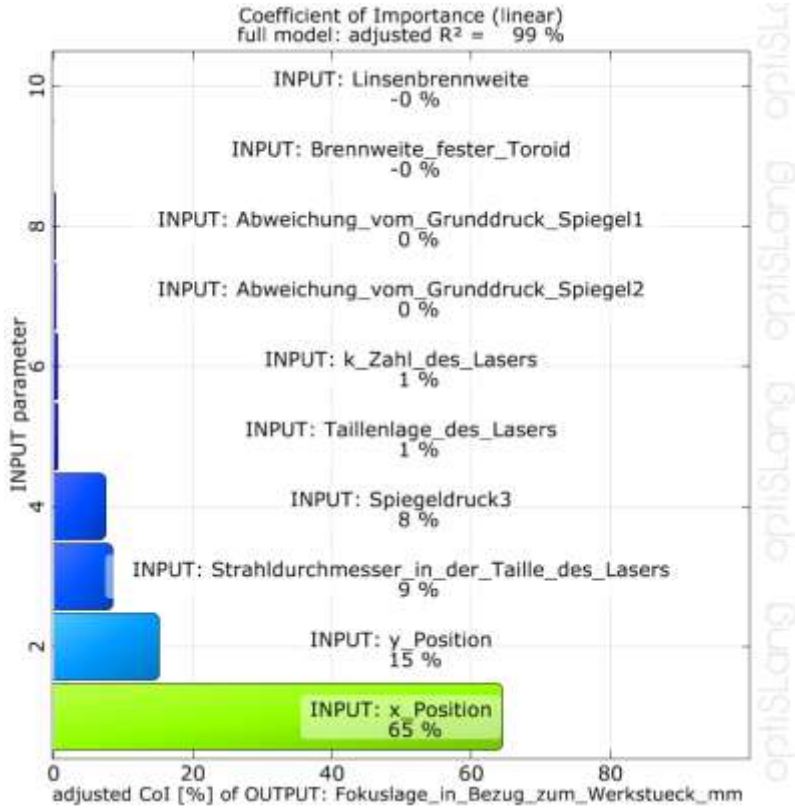


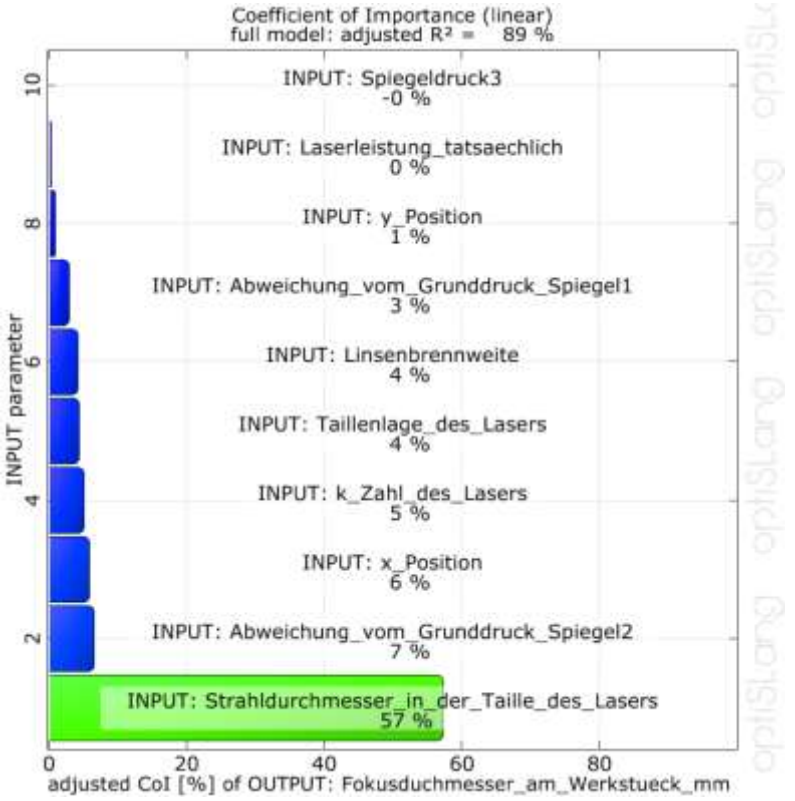
For both beam diameters, the beam waist is placed be in the centre of the machine

Optical components and it's parameters for sensitivity study

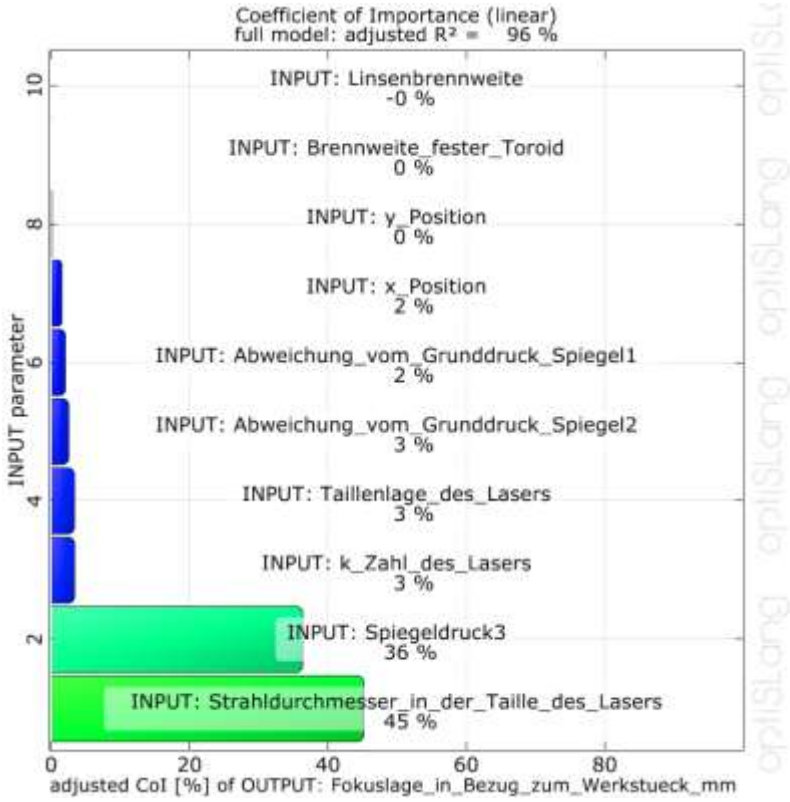


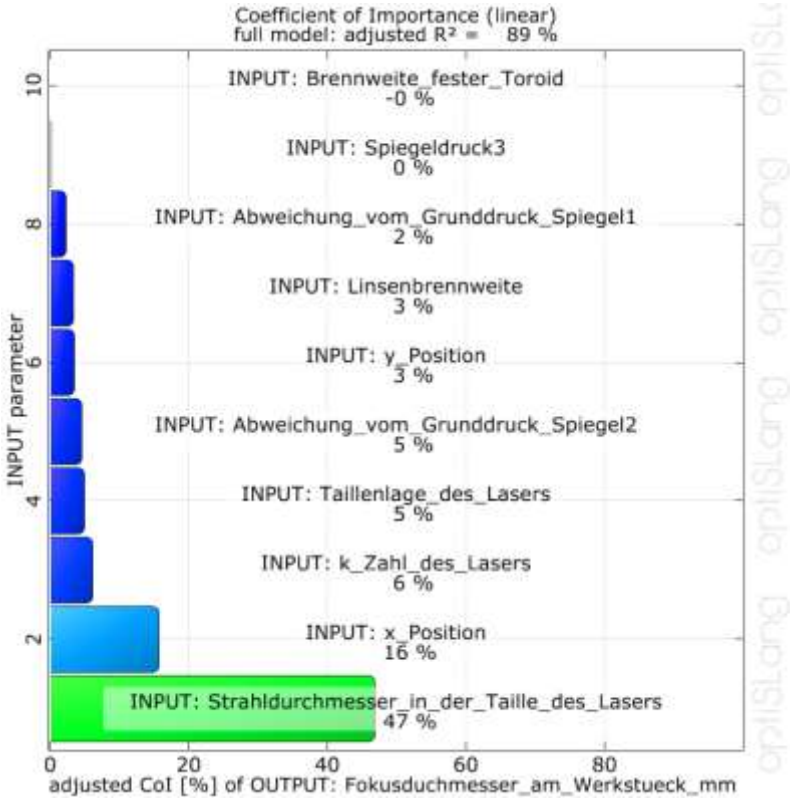
Results


Coefficient of Importance (linear)
full model: adjusted R² = 99 %
INPUT: Linsenbrennweite
-0 %
INPUT: Brennweite_fester_Toroid
-0 %
INPUT: Abweichung_vom_Grunddruck_Spiegel1
0 %
INPUT: Abweichung_vom_Grunddruck_Spiegel2
0 %
INPUT: k_Zahl_des_Lasers
1 %
INPUT: Taillenlage_des_Lasers
1 %
INPUT: Spiegeldruck3
8 %
INPUT: Strahldurchmesser_in_der_Taille_des_Lasers
9 %
INPUT: y_Position
15 %
INPUT: x_Position
65 %
INPUT parameter
0
20
40
60
80
adjusted CoI [%] of OUTPUT: Fokuslage_in_Bezug_zum_Werkstueck_mm


Coefficient of Importance (linear)
full model: adjusted R² = 89 %
INPUT: Spiegeldruck3
-0 %
INPUT: Laserleistung_tatsaechlich
0 %
INPUT: y_Position
1 %
INPUT: Abweichung_vom_Grunddruck_Spiegel1
3 %
INPUT: Linsenbrennweite
4 %
INPUT: Taillenlage_des_Lasers
4 %
INPUT: k_Zahl_des_Lasers
5 %
INPUT: x_Position
6 %
INPUT: Abweichung_vom_Grunddruck_Spiegel2
7 %
INPUT: Strahldurchmesser_in_der_Taille_des_Lasers
57 %
INPUT parameter
0
20
40
60
80
adjusted CoI [%] of OUTPUT: Fokusduchmesser_am_Werkstueck_mm

Results with active compensation (mirror 3)





Summary

- First steps towards the field of CAE based robust design
- Sensitivity analysis are already helpful
- For simple models only a minor improvements can be achieved
- Knowing the technology and the simulation model is a huge benefit