bias
Bremer Institut für
angewandte Strahltechnik GmbH

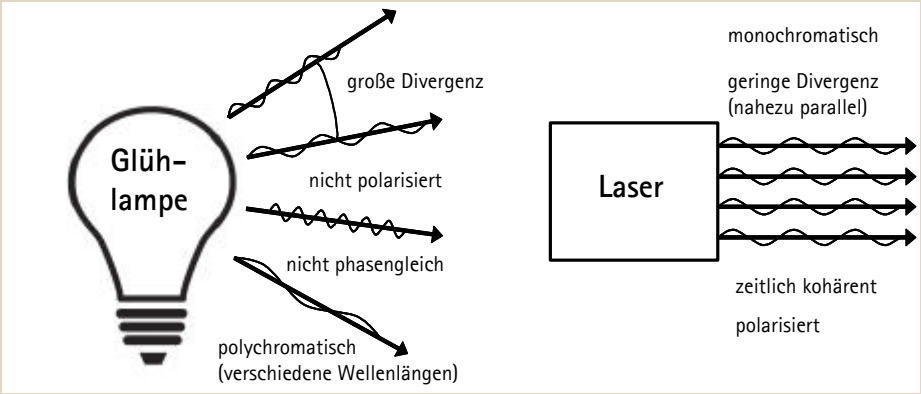
Laserstrahlschweißen
Anwendungsbeispiele und Entwicklungen

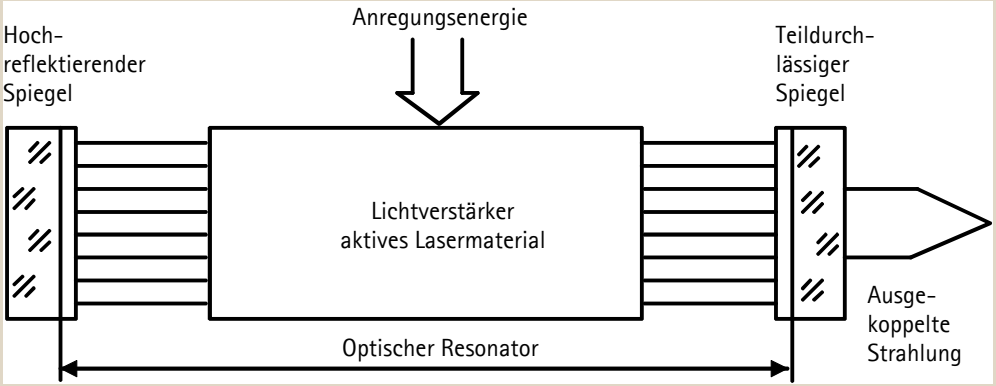
Claus Thomy

Graepel InForm, Löningen, 15. März 2006

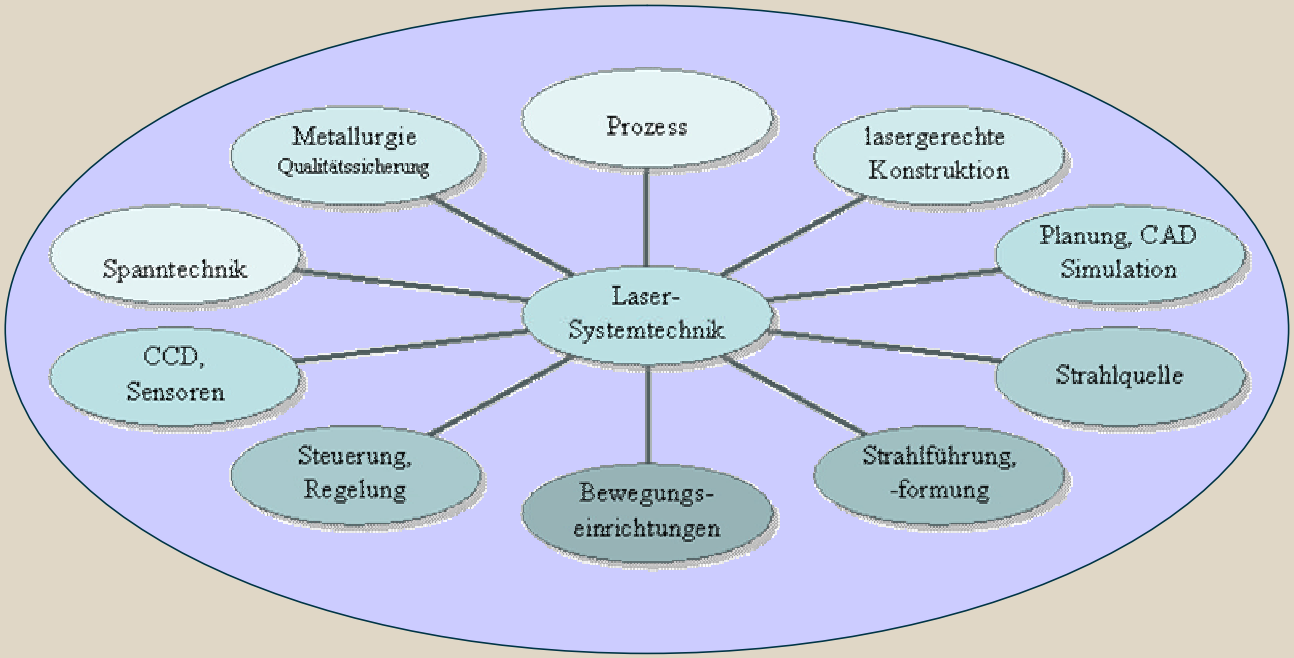
Grundprinzip des Lasers

LASER = Light Amplification by Stimulated Emission of Radiation





Lasersystemtechnik



„Herkömmliche“ Laser

Quelle: Trumpf

CO_2-Laser:

- Strahlleistung: bis ca. 40 kW
- Wirkungsgrad: ca. 10%
- Strahlführung: Spiegeloptik

Quelle: Laserline

Diodenlaser:

- Strahlleistung: bis ca. 6 kW
- Wirkungsgrad: ca. 35 .. 50%
- Strahlführung: Faseroptik oder direktstrahlend

Quelle: Trumpf

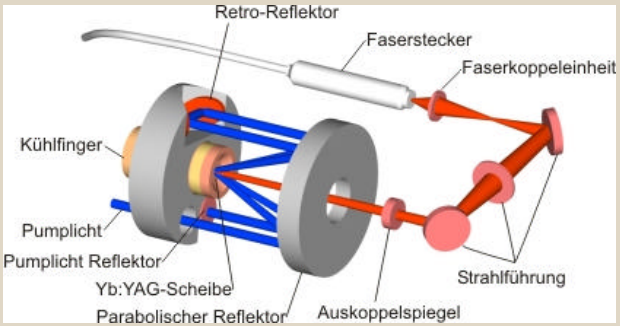
Nd:YAG-Laser:

- Strahlleistung: bis ca. 5 kW gebräuchlich
- Wirkungsgrad: ca. 3 .. 10%
- Strahlführung: Faseroptik

Neuartige Laser

Scheibenlaser:

- Strahlleistung: bis ca. 6 kW im Versuchsbetrieb
- Wirkungsgrad: ca. 20%
- Strahlführung: Faseroptik

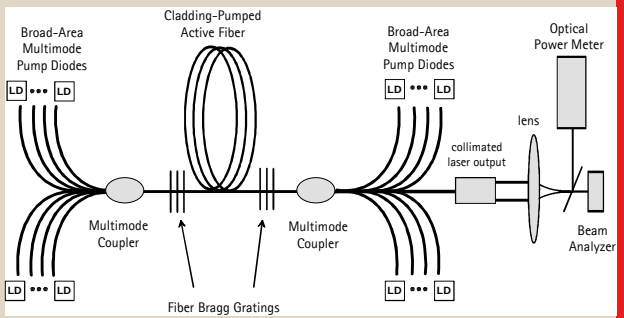


Quelle: Rofin

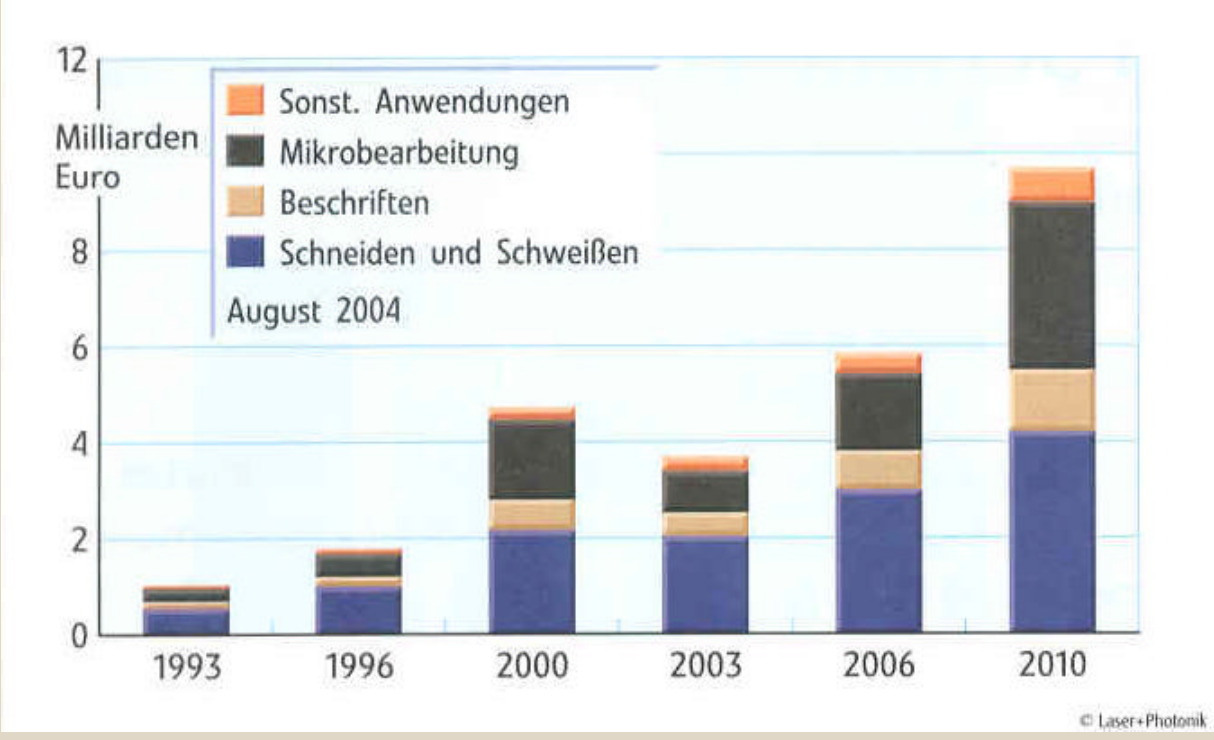
Quelle: Trumpf

Hochleistungs-Faserlaser:

- Strahlleistung: 20 kW und mehr im Einsatz
- Wirkungsgrad: bis zu 30 %
- Strahlführung: Faseroptik

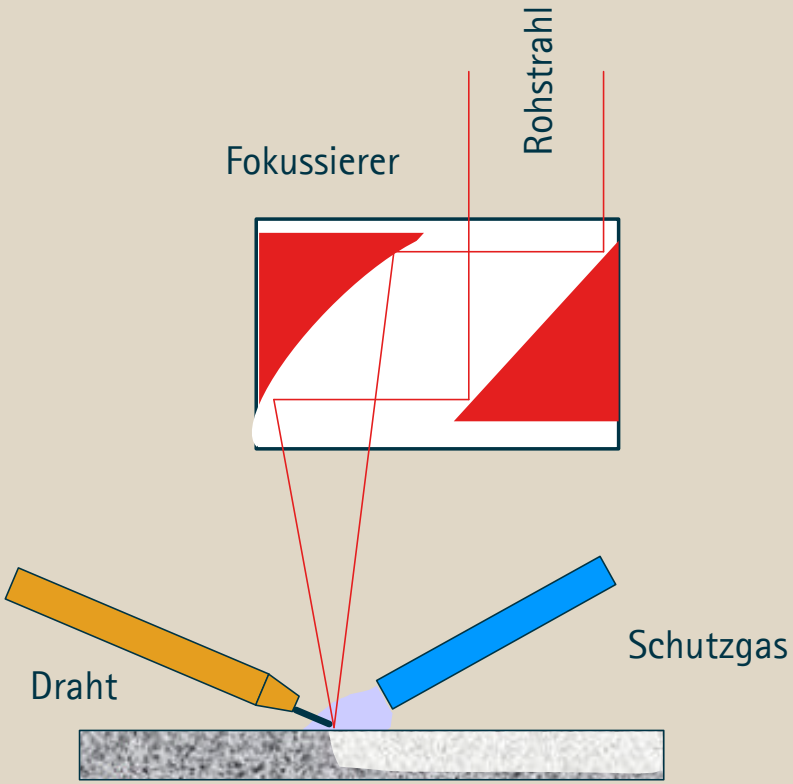


Lasersysteme für die Materialbearbeitung

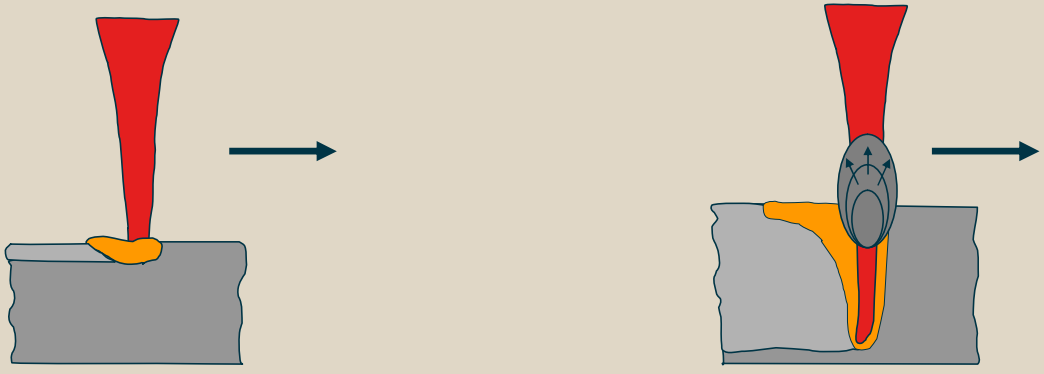


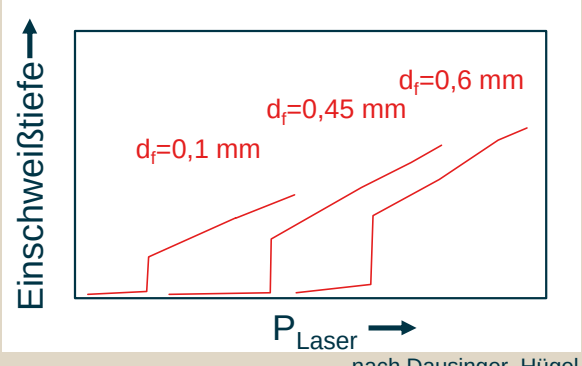
Quelle: Optech Consulting AG, in: Laser + Photonik, April 2005

Laserschweißen



Tiefschweißeffekt

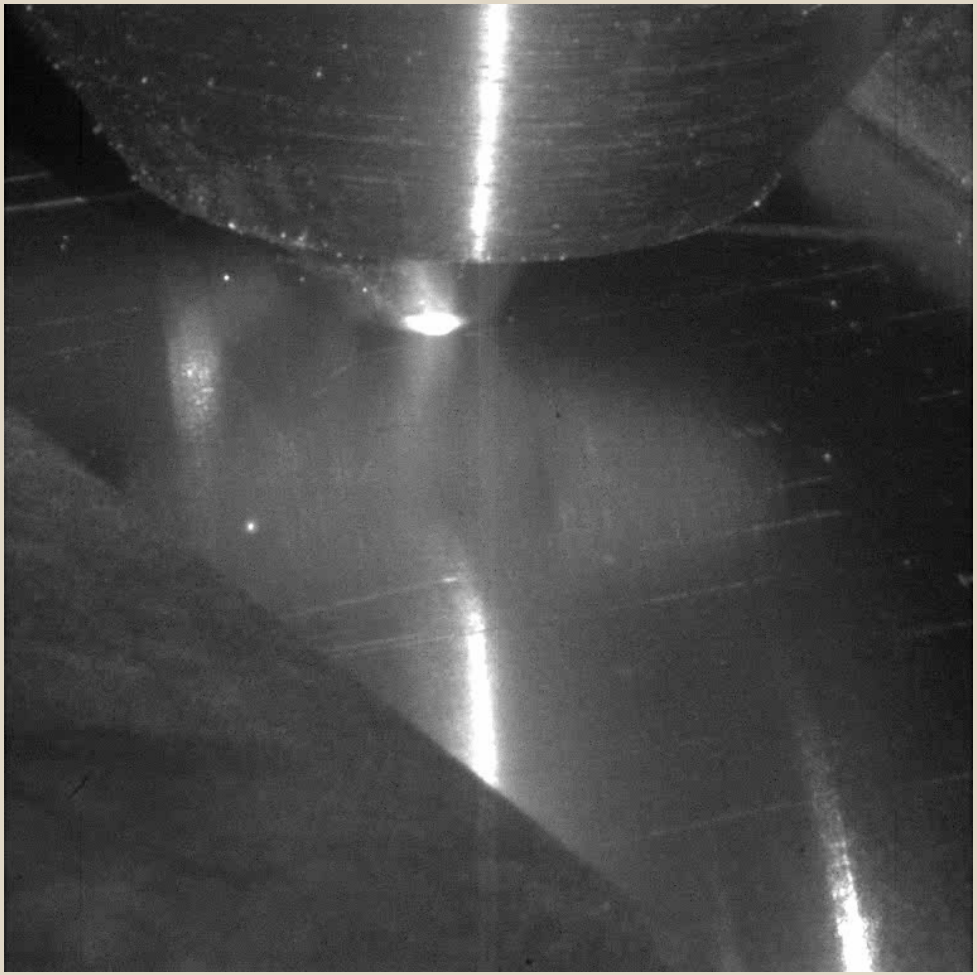




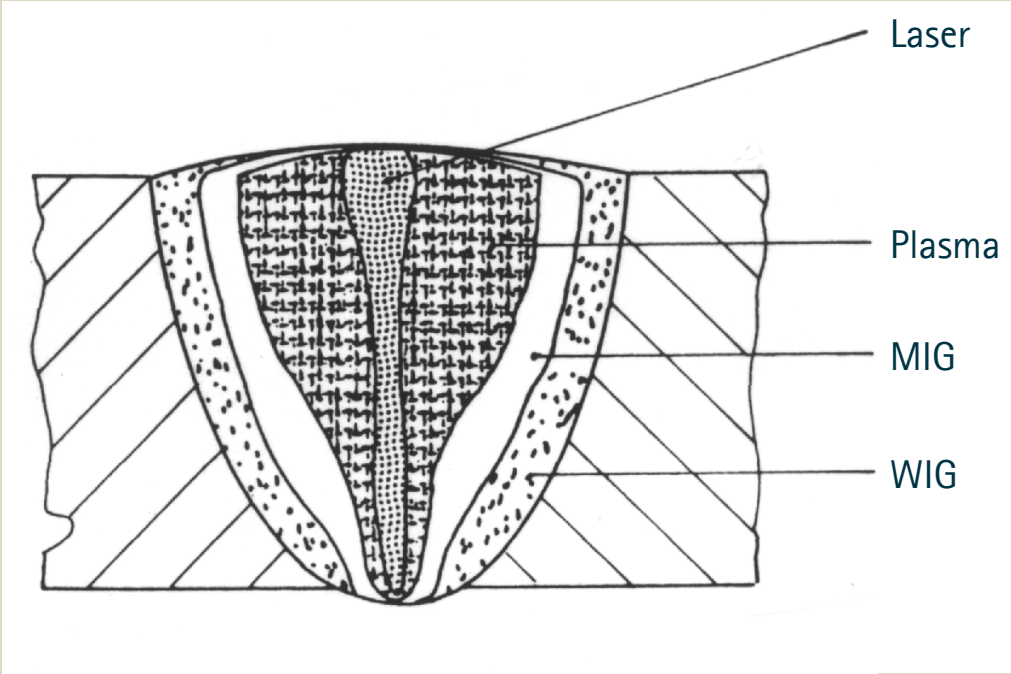
nach Dausinger, Hügel

Besonderheit Sprungartiges Ansteigen des Einbrandes beim Übergang vom Wärmeleitungsschweißen zum Tiefschweißen

Laserschweißen



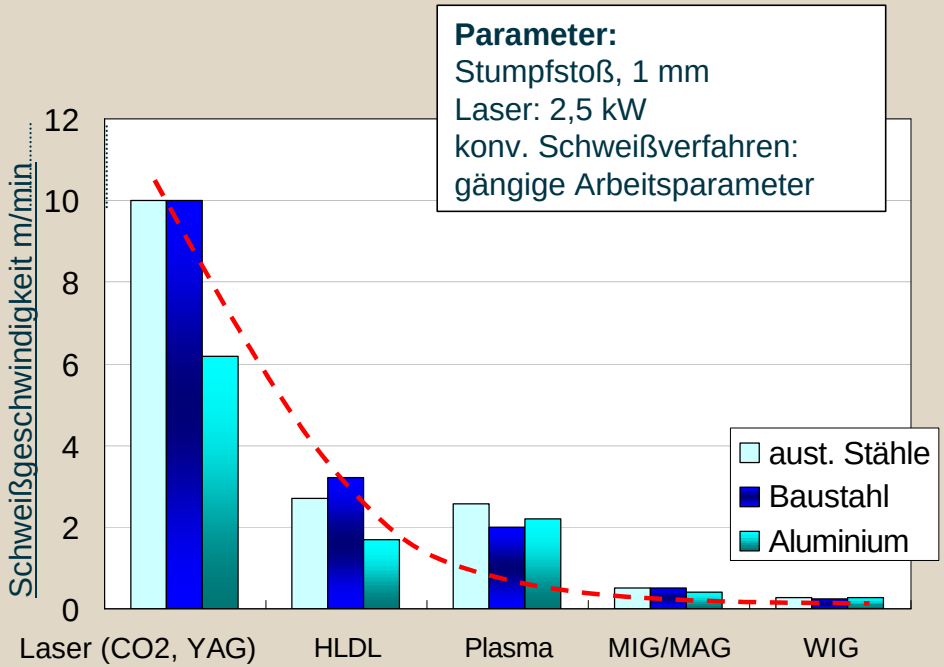
Vergleich von Schweißnahtflächen



nach Hügel

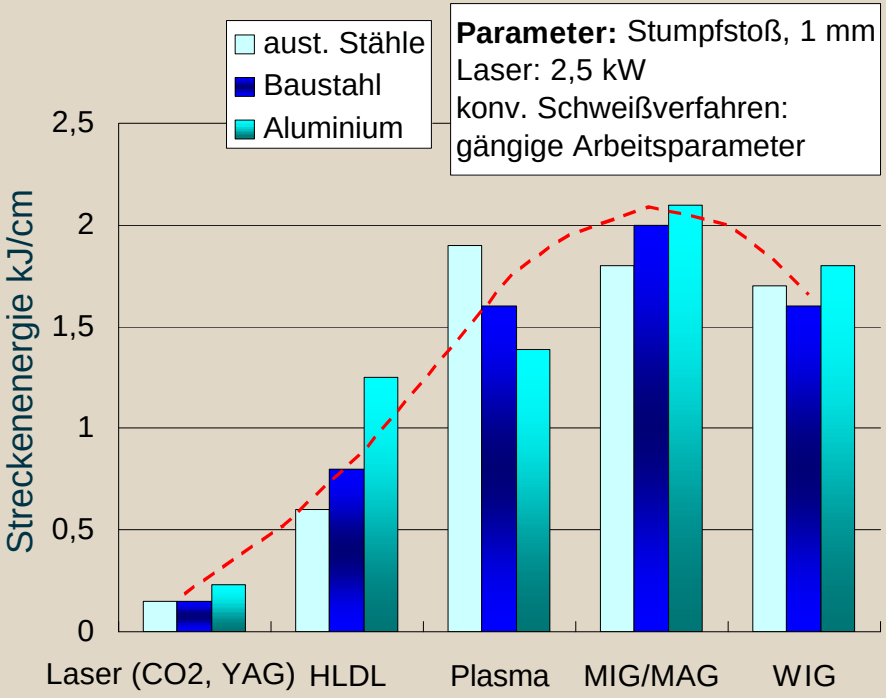
Parameter
je Verfahren zum Erreichen einer Durchschweißung

Vergleich Schweißgeschwindigkeit



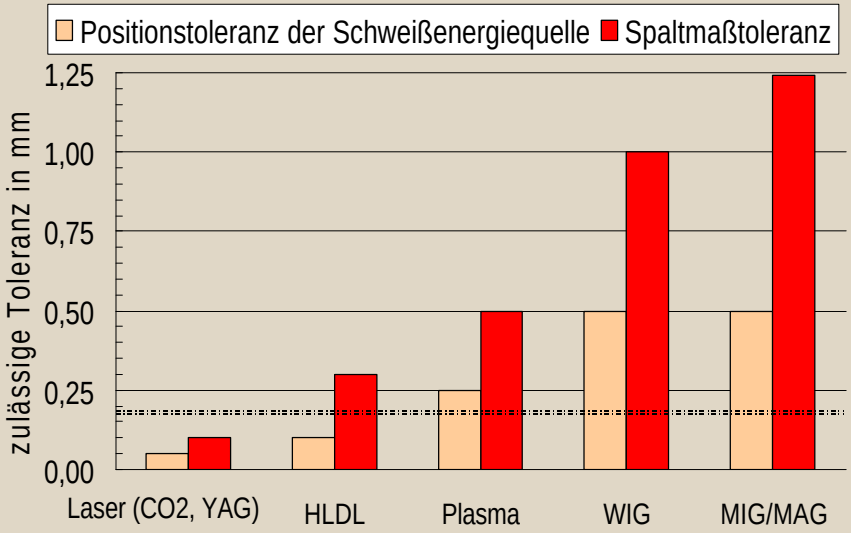
Quelle: IWS Dresden

Vergleich Streckenenergie



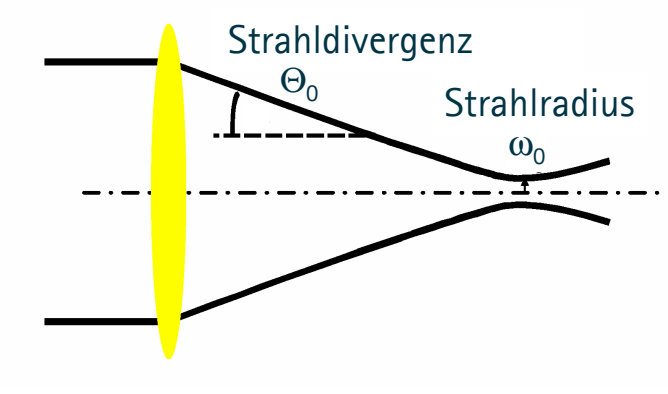
Quelle: IWS Dresden

Vergleich Toleranzen



Quelle: IWS Dresden

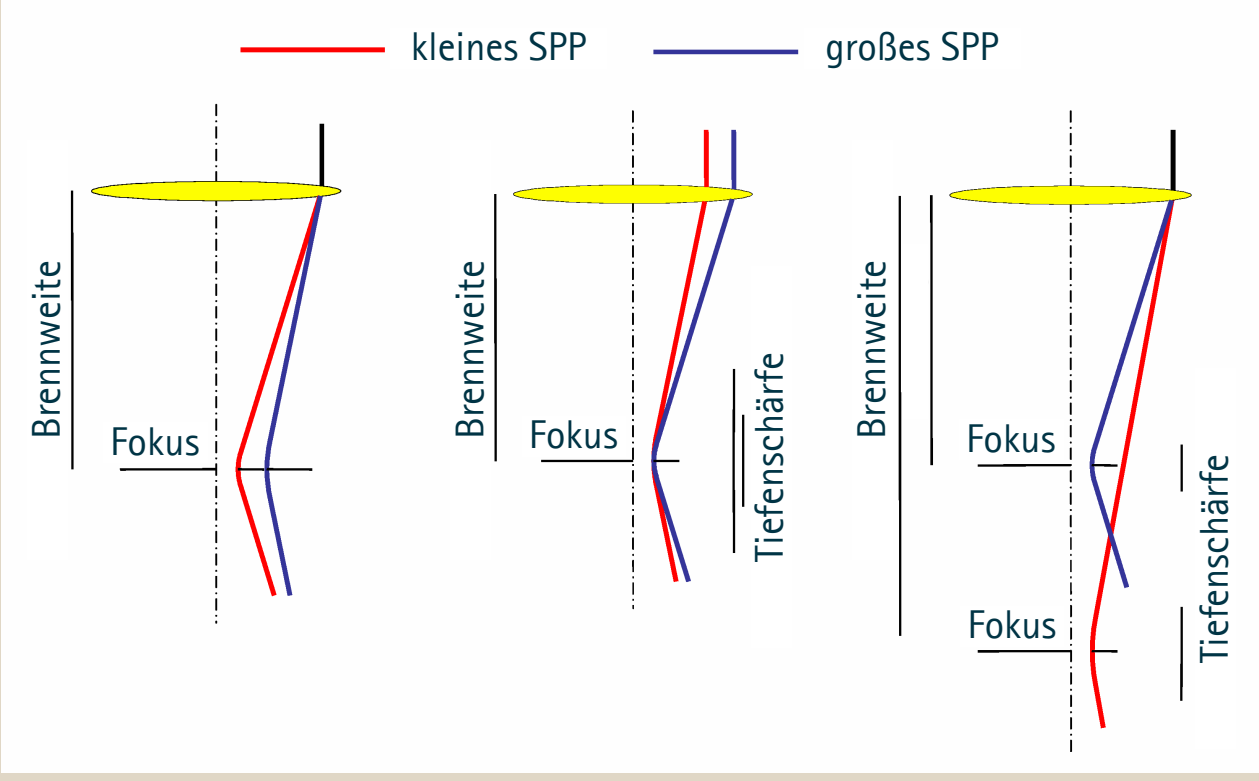
Definition der Strahlqualität



Strahlparameterprodukt: $\Theta_0\ \omega_0 = M^2\ \lambda\ /\pi$

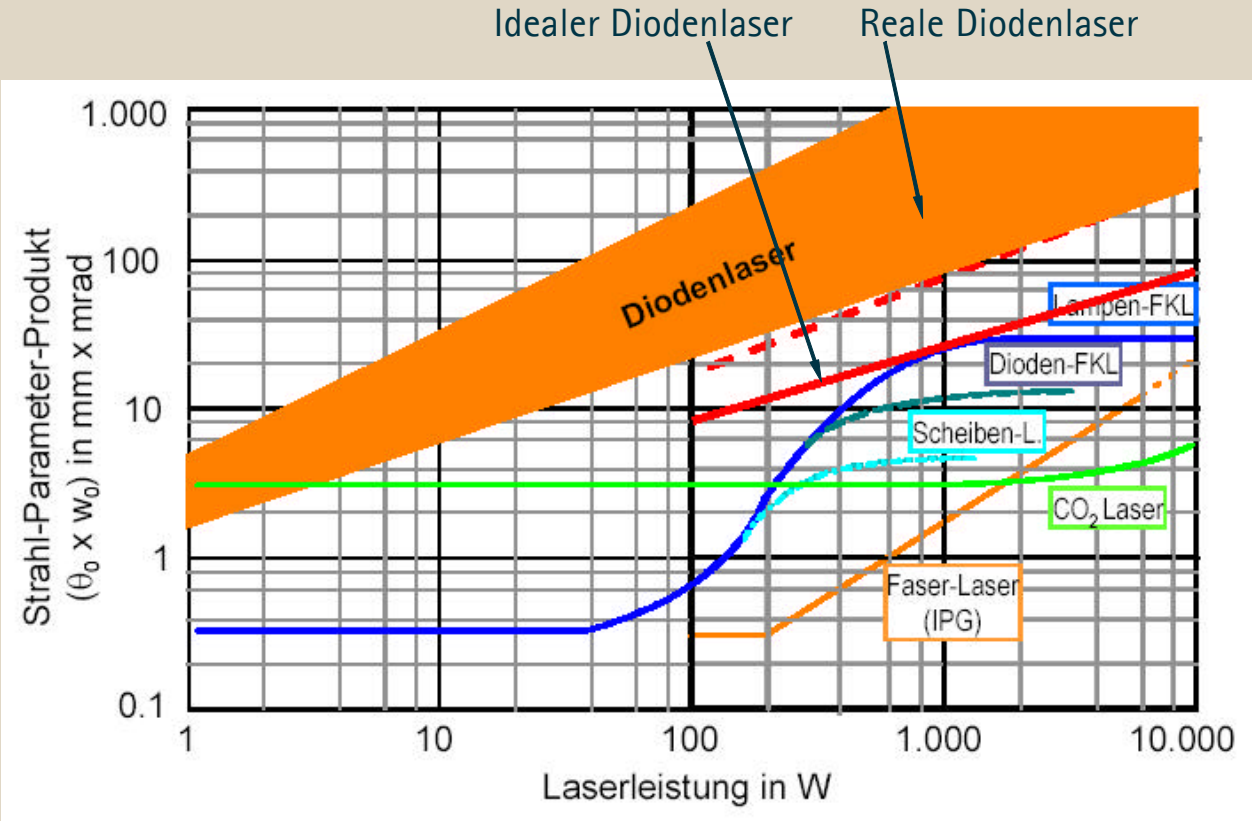
Strahlkennzahl: $M^2 = \Theta_0\ \omega_0\ \pi/\lambda > 1$

Einfluß der Strahlqualität



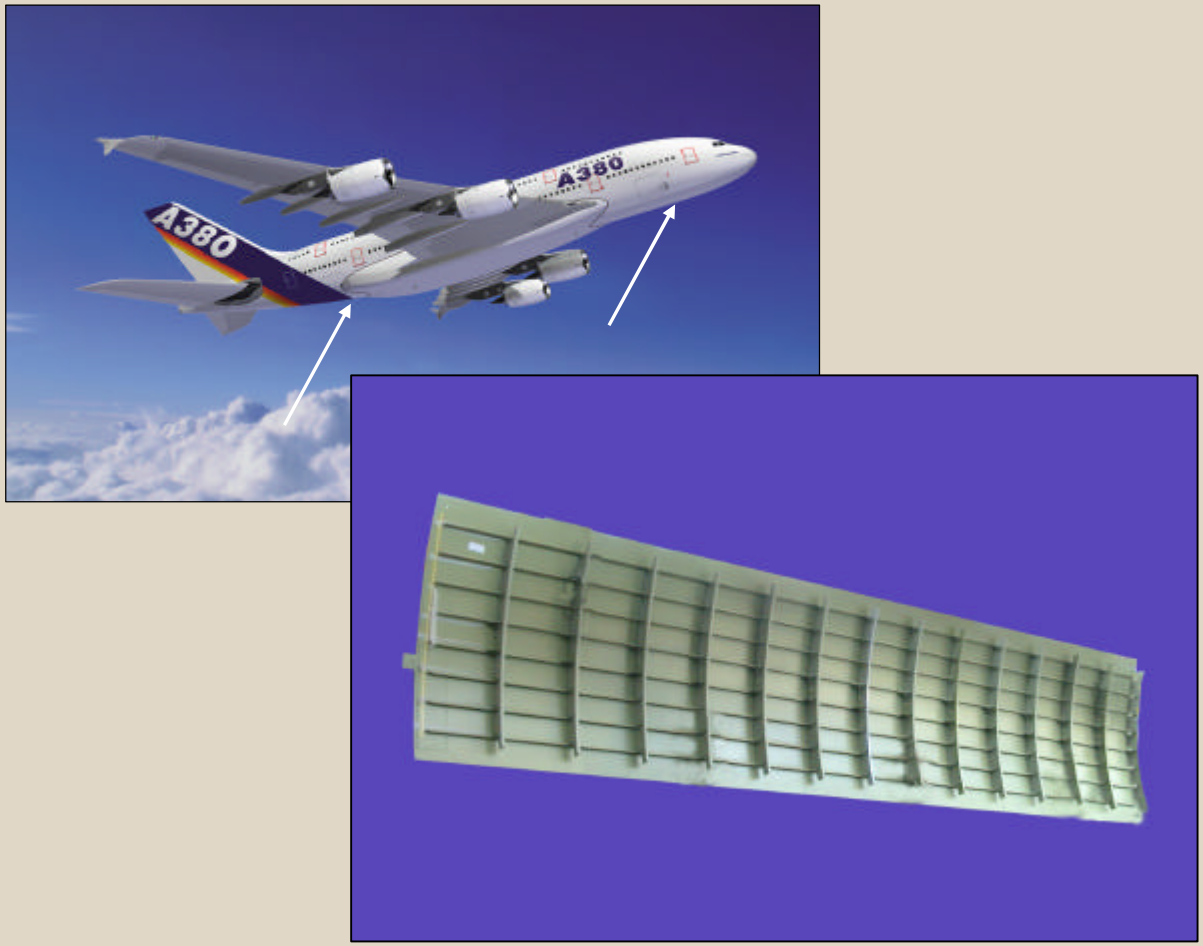
Quelle: W. O'Neill, ICALEO 2004

Strahlqualität von Hochleistungslasern

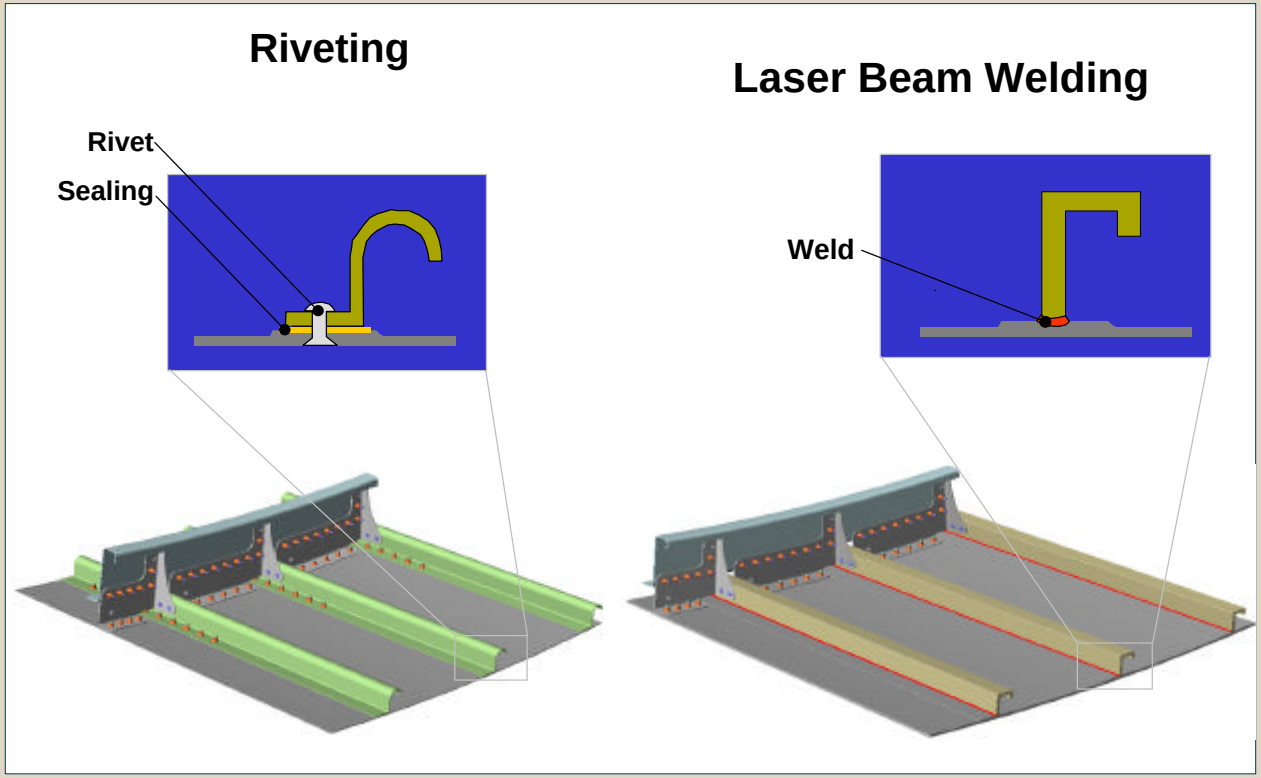


Quelle: Rofin 2003

Lower fuselage panels

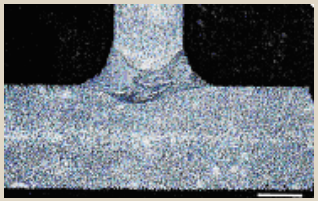


Skin-stringer joining technologies



Welding for Aviation Industry

- Simultaneous T-joint welding of Skin-Stringer-Panels
  → minimal distortion



- Qualified technique for serial application

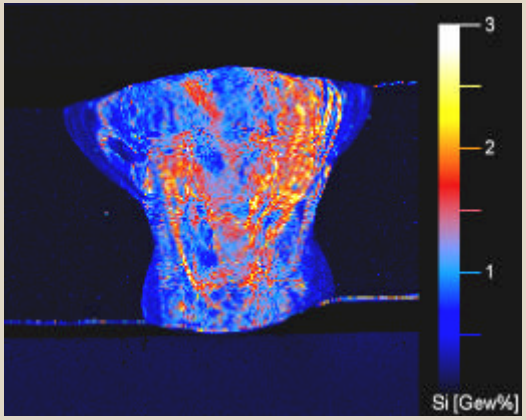
- First-time appliction of welded structures in Airbus A318
- Future application in Airbus A380 and A340

CO_2 laser welding gantry at Nordenham

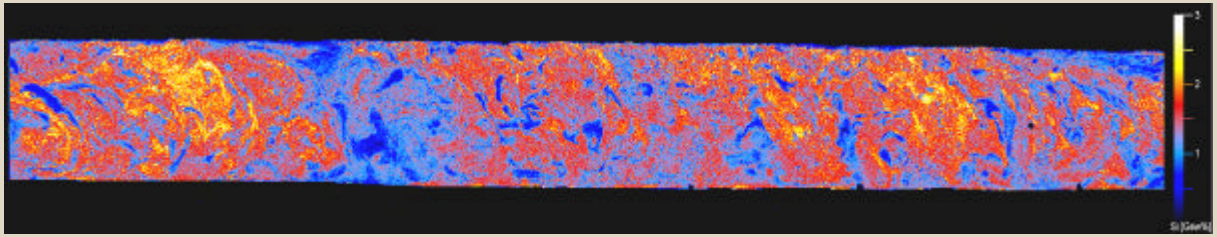
Metallurgy of Welding

Questions under investigation:

- High hot cracking susceptibility alloys
- Optimized filler for maximum strength
- Homogeneous distribution of alloing elements in bead
- Delivery of filler material at beginning and end of weld seam

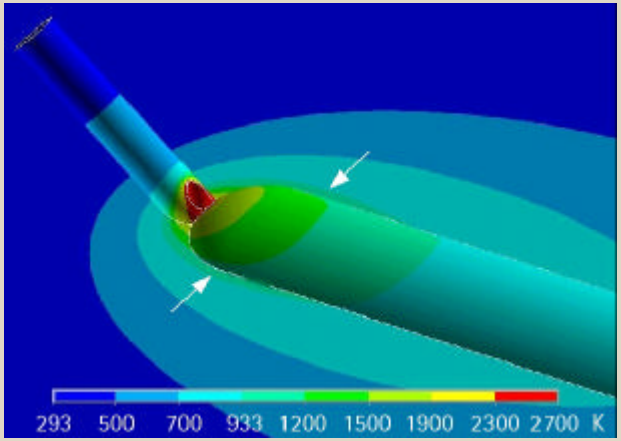


Si distribution in cross section



Si-distribution in longitudinal section

Simulation Durchmischung beim Schweißen

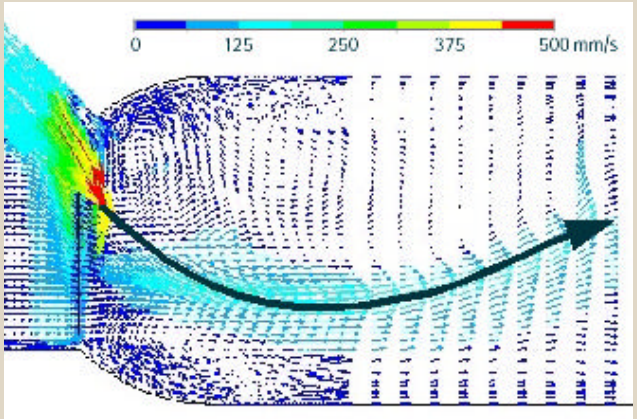


Temperaturverteilung

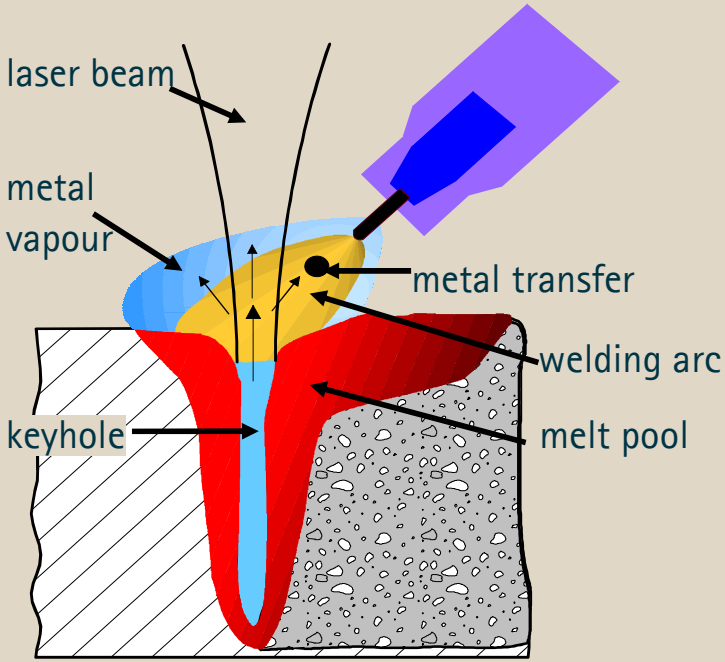
Laserleistung:	9.2 kW
Vorschubgeschwindigkeit:	50 mm/s
Drahtvorschubgeschw.:	170 mm/s
Drahtdurchmesser:	1 mm
Blechdicke:	2.5 mm

Blech:	Al99.5
Draht:	AlSi12

Geschwindigkeit der Si-Zugabe



Laser GMA Hybrid Welding



Advantages due to the process combination:

- process stabilization
- higher welding speeds
- lower tolerance requirements
- improved weld properties
- ...

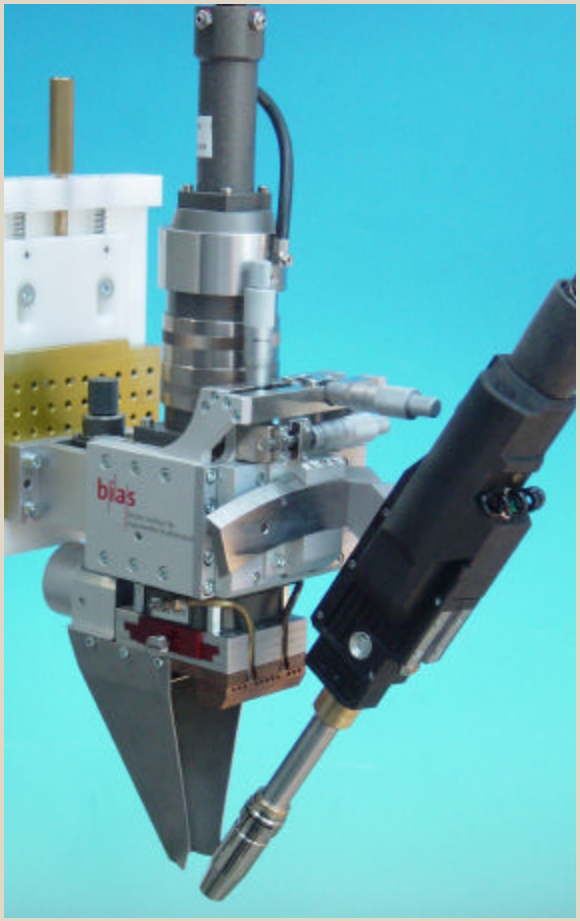
Fields of application

- shipbuilding
- offshore
- automotive
- ...
- railway

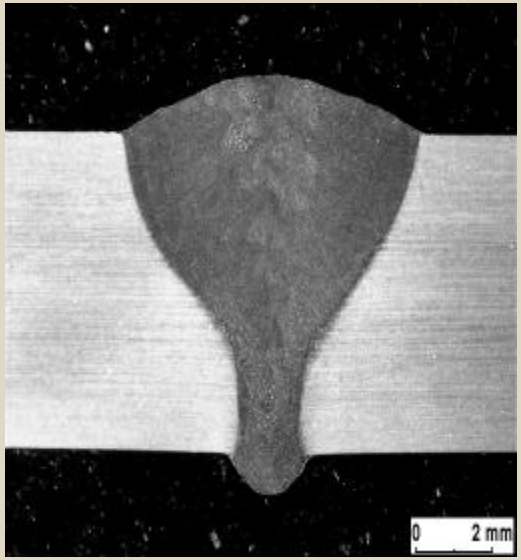
Application potentials

- increase in welding speed
- pure laser beam welding not feasible (e.g. tolerances)

Hybrid Welding

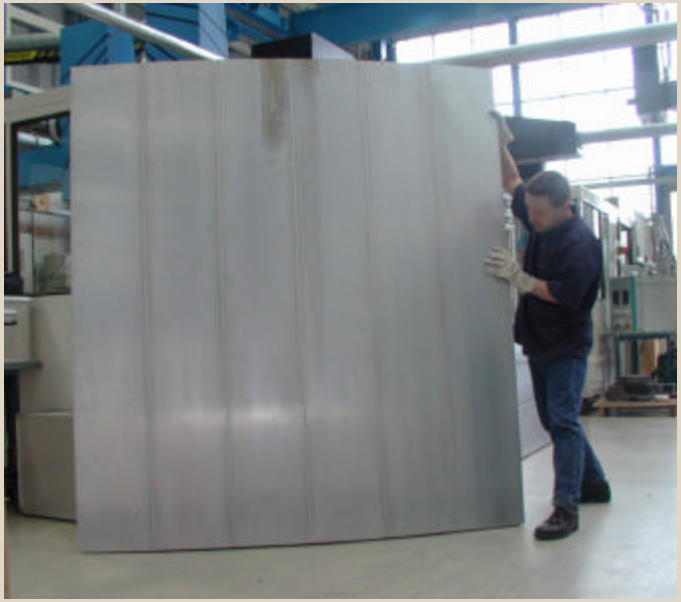


Nd:YAG-MIG Welding head

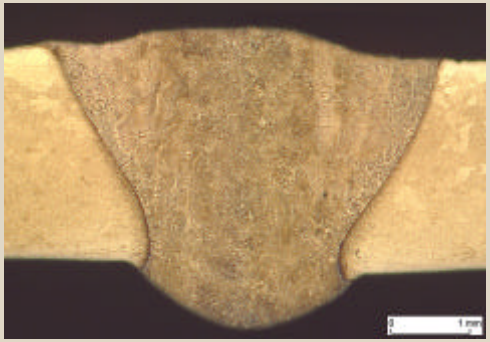


Hybrid weld seam

Hybrid Welding of extruded Aluminium Profiles



AlMgSi0.7 + filler wire AlSi12, t = 3 mm



P_L = 4 kW

P_{GMA} = 3.65 kW pulse arc

v_w = 4 m/min

Results:

- high welding speeds (4 m/min)
- low distortion due to a reduction of heat input of up to 85%
- no excessive tolerance requirements

Anwendung des Lasers beim Längsnahtschweißen – Systemtechnik

Einformung

↓

Schweißung

↓

Weiterverarbeitung:
- Wärmebehandlung
- Kalibrierung
- zerstörungsfreie Prüfung

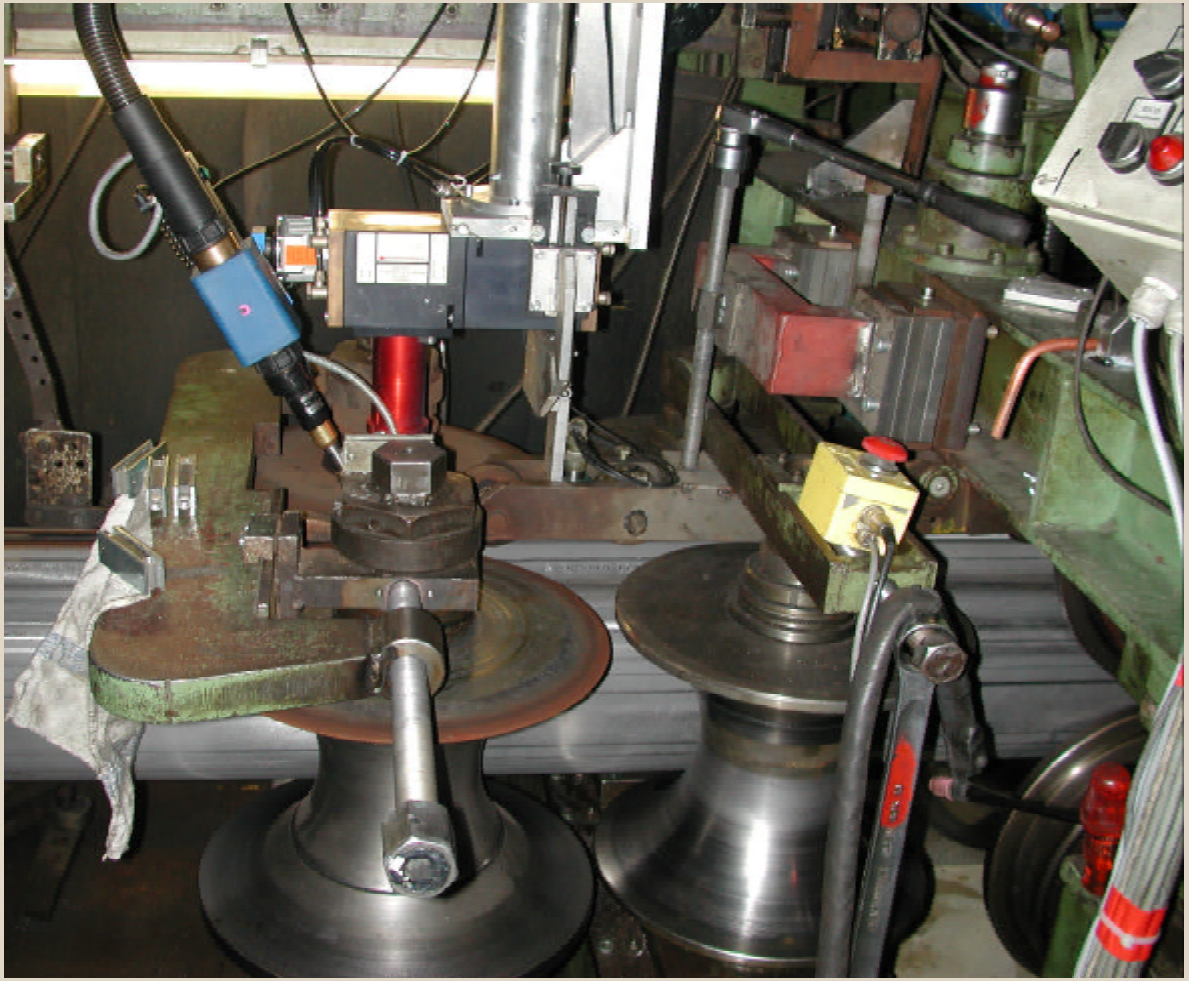
↓

Ablängen

CO_2-Laserstrahlschweiß-kopf mit Kaltdrahtzufuhr

CO_2-Laser-MSG-Hybridschweißkopf

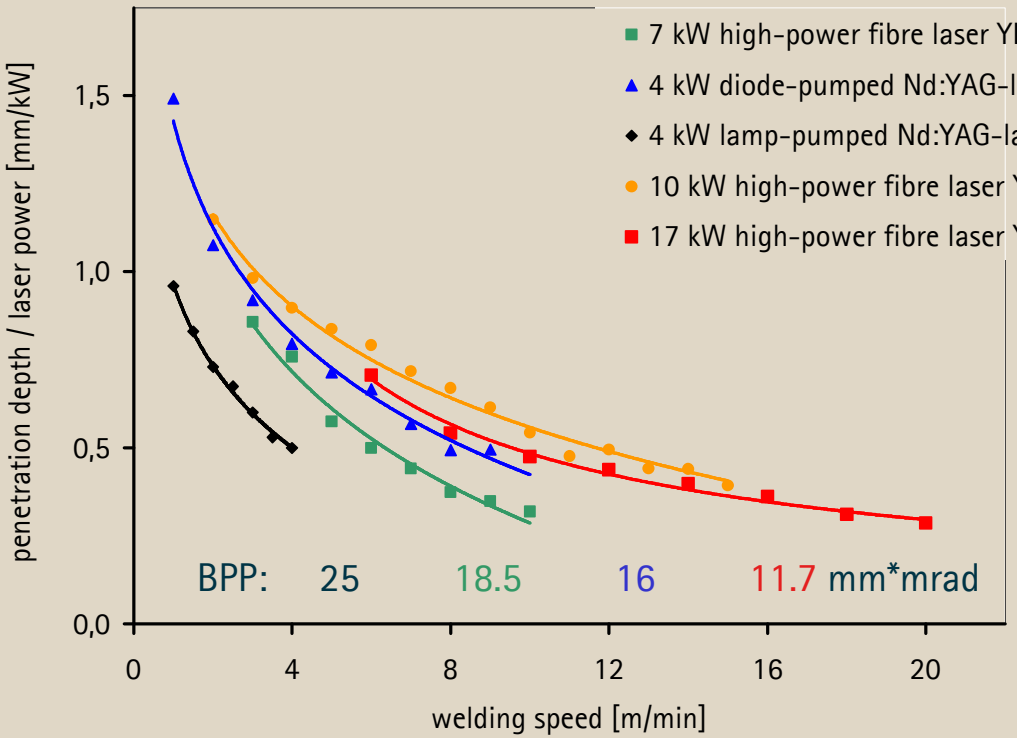
Hybridschweißen von Edelstahlrohren



Hochleistungs-Faserlaser

IPG YLR-7000	IPG YLR-10000	IPG YLR-17000
2003	2004	2005
6.9 kW	10.5 kW	16.7 kW
18.5 mm*mrad	11.6 mm*mrad	11.7 mm*mrad

Comparison of Penetration / Laser Power



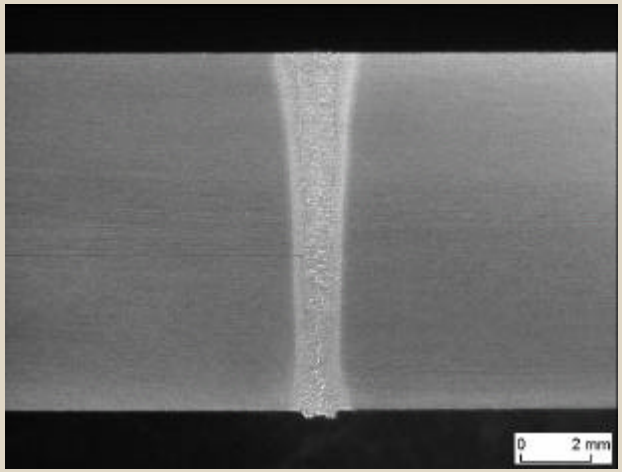
AlSi1 MgMn
P_L = max.
z = 0 mm
f = 200 mm;
f = 250 mm

Comparison of CO_2 Laser and Fiber Laser

TLF 15000 turbo

X70, t = 11.2 mm

IPG YLR-10000



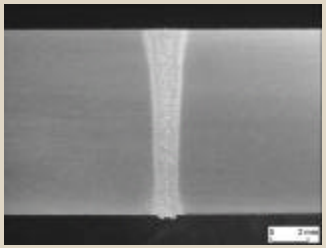
X70, t = 11.2 mm

P_L = 13.5 kW —— - 24 % ——→ P_L = 10.2 kW

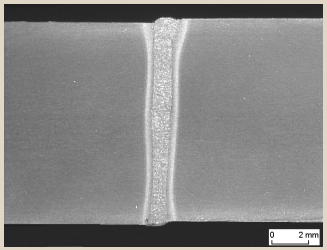
v_w = 1.8 m/min —— + 22 % ——→ v_w = 2.2 m/min

E = 4.5 kJ/cm —— - 38 % ——→ E = 2.8 kJ/cm

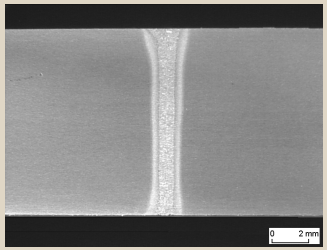
Laser Welding of Pipe Steel



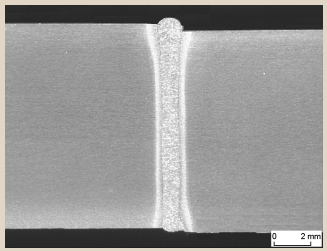
Position PA (0°)



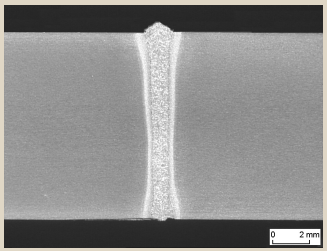
Position PB (45°)



Position PC (90°)



Position PD (135°)

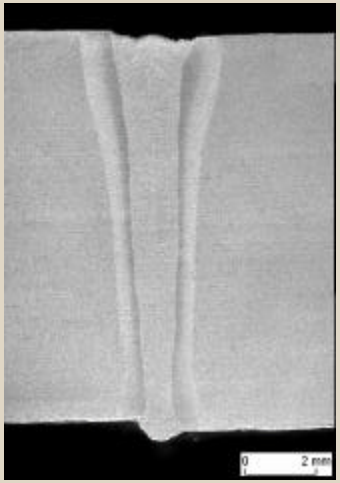


Position PE (180°)

P_L = 10.2 kW v_w = 2.2 m/min E = 2.8 kJ/cm

X70, t = 11.2 mm

Laser Welding of Pipe Steel



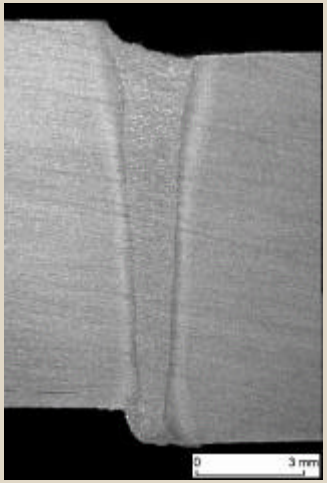
IPG YLR 17000
f = 500 mm

P = 15 kW

v = 2.8 m/min

E_s = 3.2 kJ/cm

Edge mis
alignment: 0.3 mm



IPG YLR 17000
f = 500 mm

P = 15 kW

v = 2.9 m/min

E_s = 3.1 kJ/cm

Edge mis
alignment: 1.0 mm

IPG YLR 17000
f = 500 mm

P = 15 kW

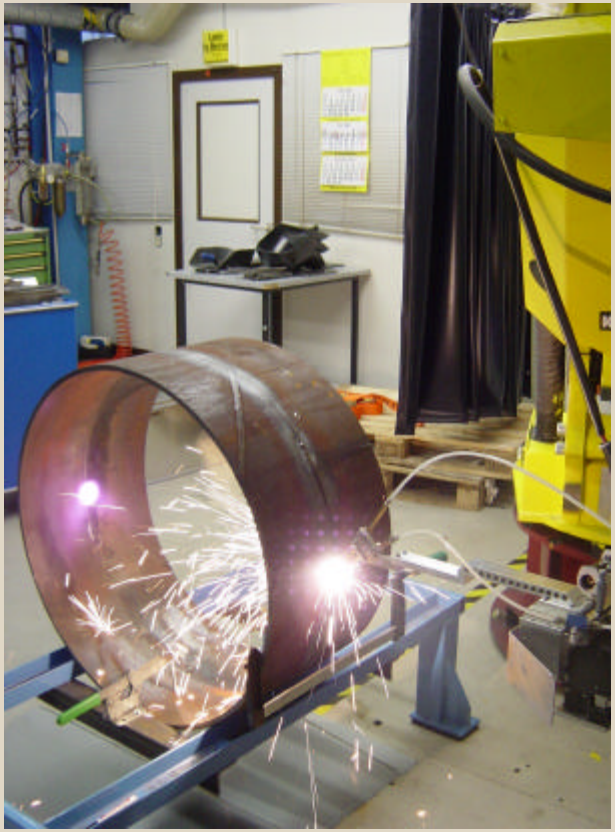
v = 2.9 m/min

E_s = 3.1 kJ/cm

Edge mis
alignment: 1.4 mm

X70, t = 11.2 mm

Pipe Welding Trials



X70, t = 12 mm

Essen Welding Show

Pipeline Welding Today

capping pass

filler passes (up to 5 stations)

root and hot pass

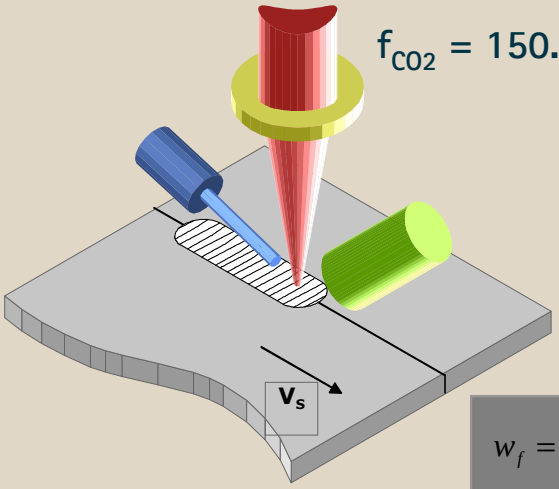
seam preparation + pre-heating (if appl.)

Source: Vietz GmbH

Welding Unit with VPL-System

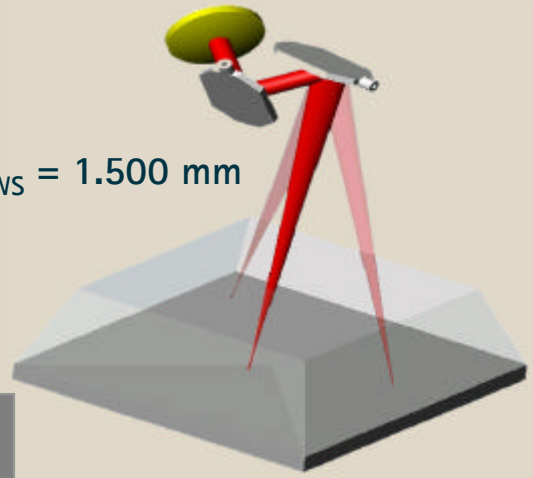
Source: Vietz GmbH

Remote Welding



f_{CO2} = 150...350 mm

f_{RWS} = 1.500 mm



$$w_f = \frac{2 \cdot l}{p} \cdot \frac{f}{D} \cdot \frac{1}{K}$$

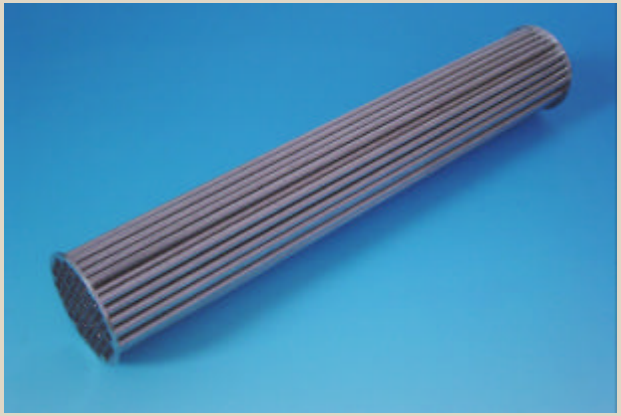
- **Conventional welding**
- Movement of optic or workpiece
- Short distance / focal length
- High intensity / small focus
- Short Rayleigh length
- Perpendicular incident

- **Remote-/Scanner-Welding**
- Movement of laserbeam
- Long focal length, large F-number
- Laser with high beam quality
- High dynamic / low masses
- Inclination angle

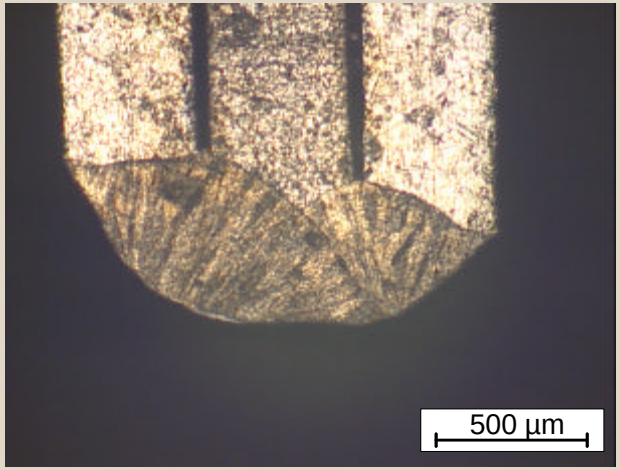
Car Bumper

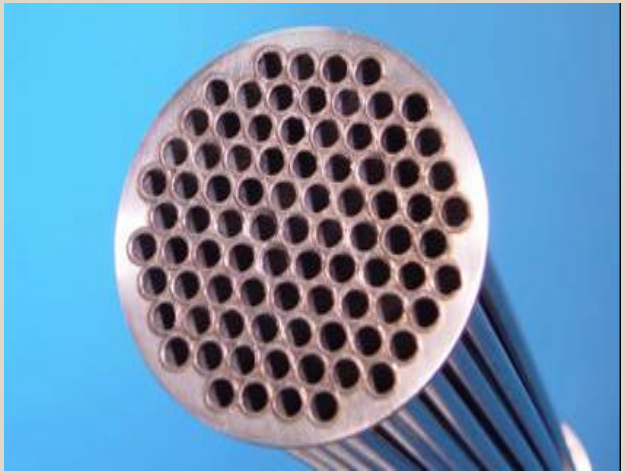
- Replacement of 56 resistance spots
- 20 – 25 mm stitch replace one resistance spot (equivalent fusion area)
- Processing time 27 seconds

Heat Exchanger



- 85 stainless steel tubes welded to the top and bottom plate
- Processing time t= 20s (single side)





3D-Hochgeschwindigkeitsbearbeitung

Quelle: KUKA Schweißanlagen GmbH