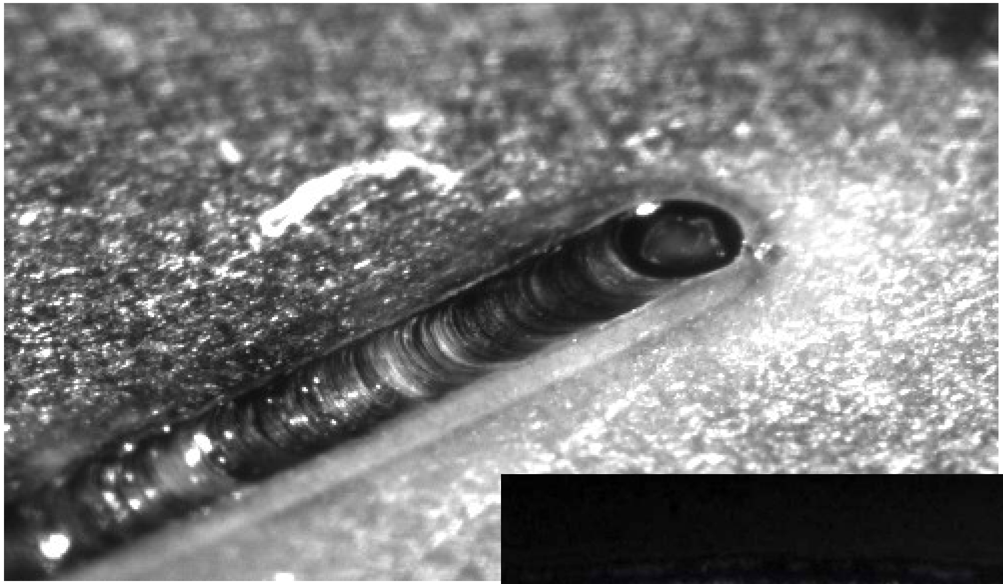
Laser Processing of Materials

Applications: Bending and Welding

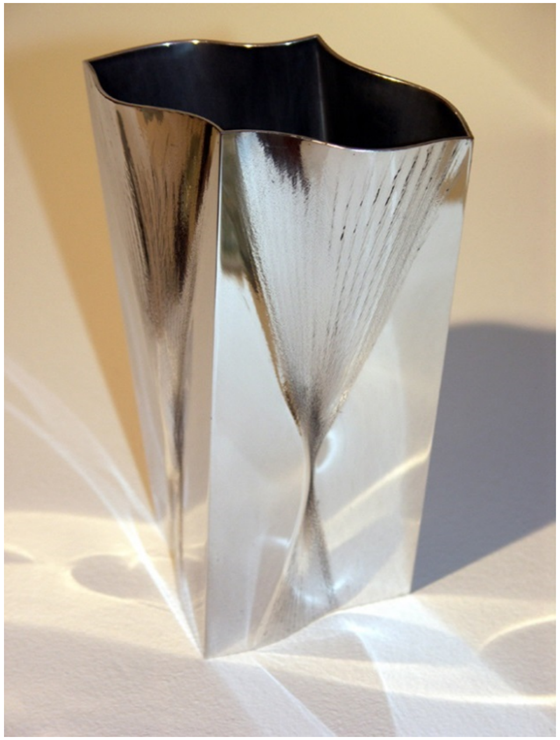
Patrik Hoffmann

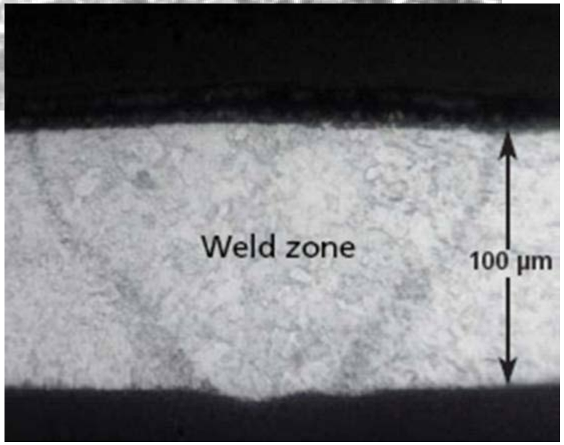
Bending and Welding

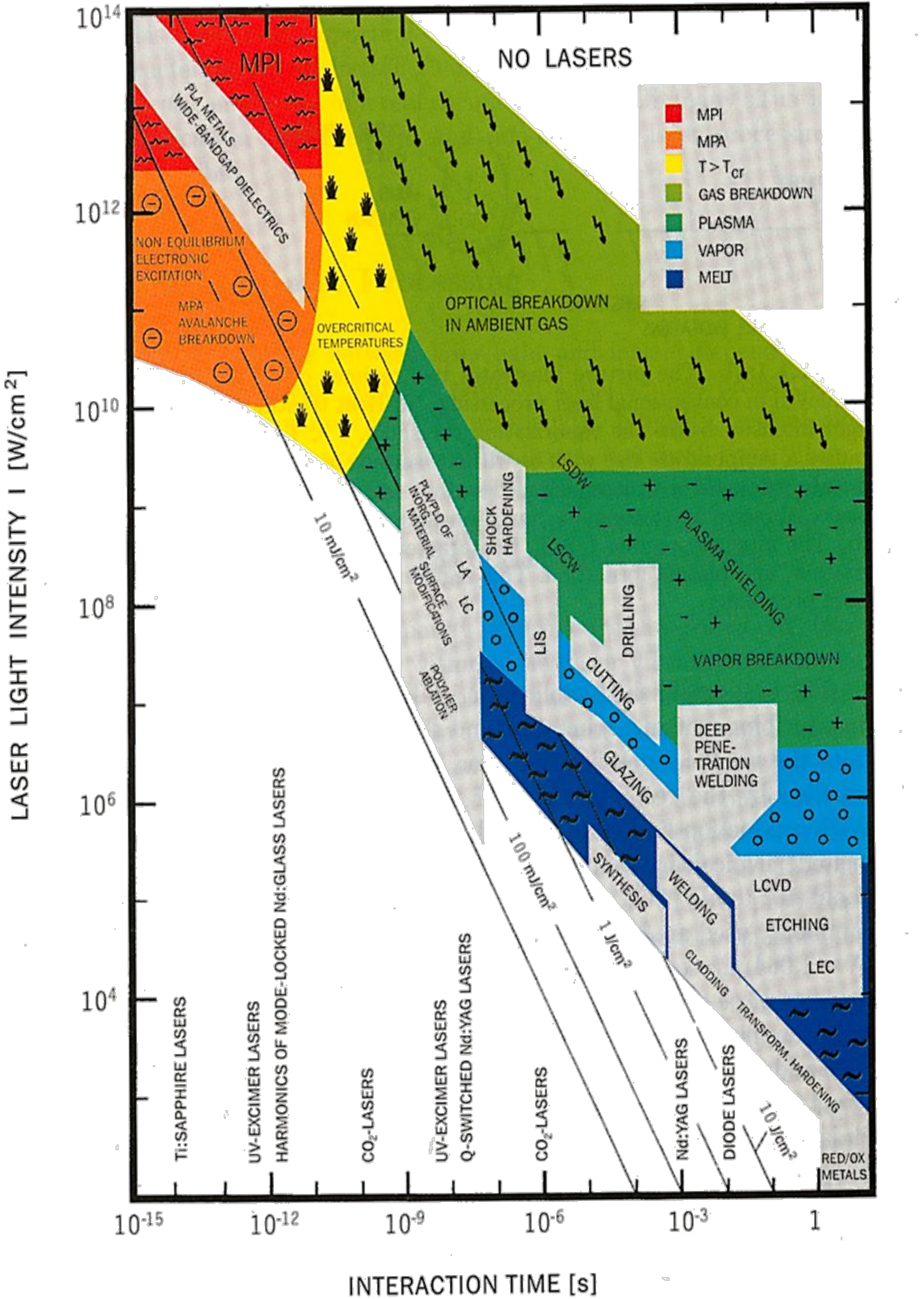
welding



bending







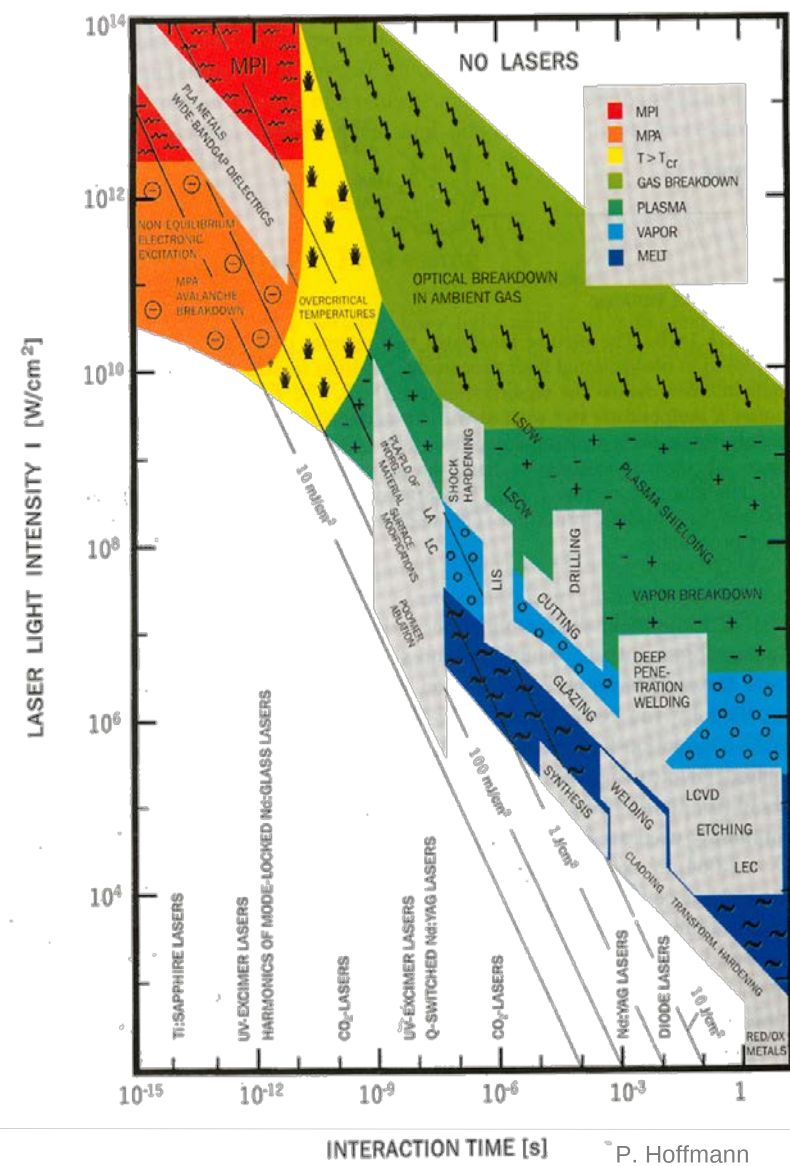
D. Bäuerle;
Laser Processing and Chemistry, 3rd ed.
Springer, Berlin, 2000

What kind of laser do you propose for bending / welding?

Application of lasers in materials processing:
Intensity-Time Diagram

- PLA/PLD – pulsed laser ablation/ deposition
- LA – laser annealing
- LC – laser cleaning
- LIS – laser induced isotope separation/IR – laser photochemistry
- MPA/MPI – multiphoton absorption ionization
- LSDW/LSCW – laser supported detonation/combustion waves
- LCVD – laser induced chemical vapour deposition
- LEC – laser induced electrochemical plating/etching
- RED/OX – long pulse or cw CO_2-laser induced reduction/oxidation

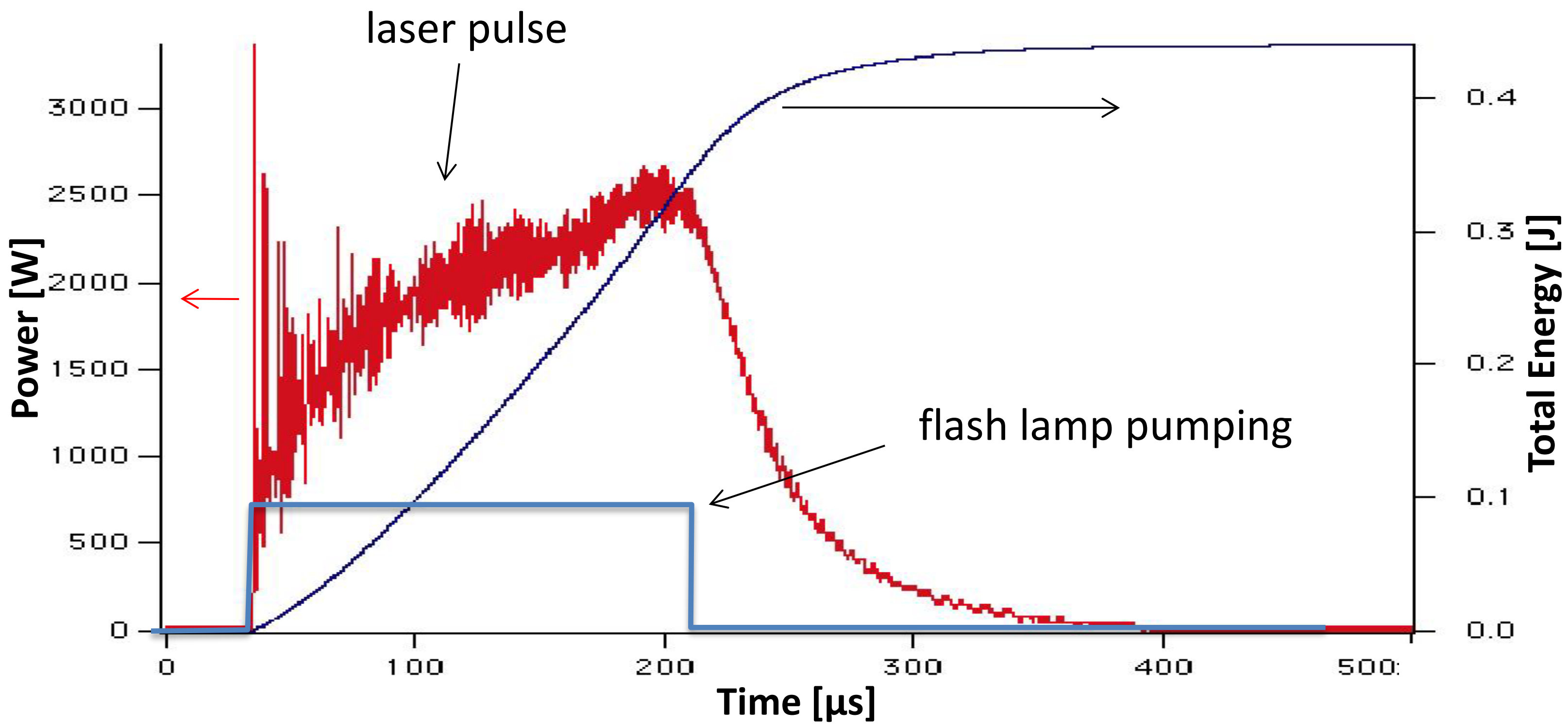
D. Bäuerle; Laser Processing and Chemistry, 3rd ed. Springer, Berlin, 2000



Laser Types: Pulsed & CW

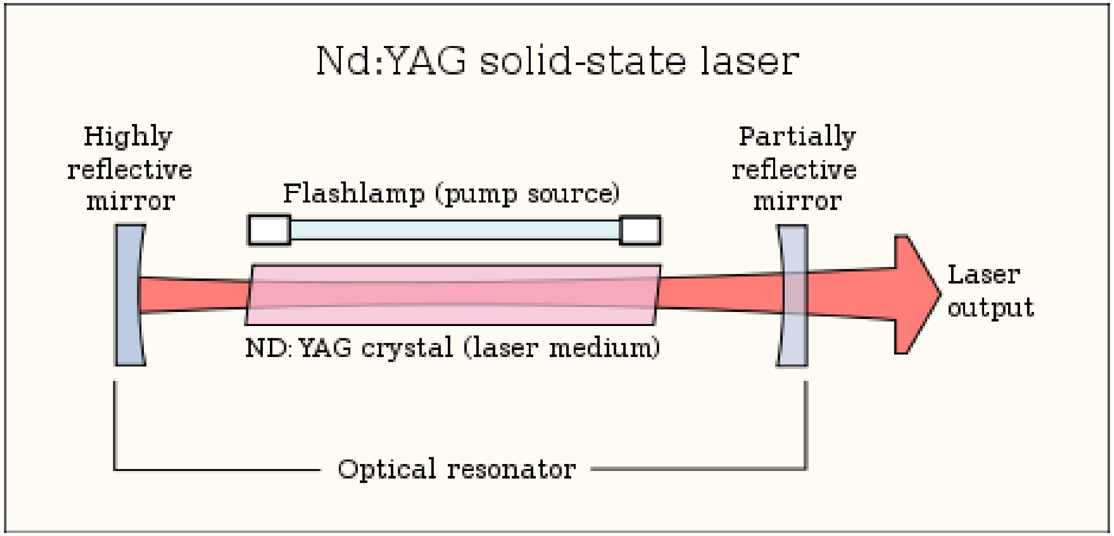
Type of laser	Pulse length determined by	Typical pulse length	Characteristic pulse peak power
Continuous wave (cw)	-	∞	Ws – kWs
Free running laser	Pump pulse length (flash lamp)	100 µs – 1ms	kWs
Q-switched laser	Time constants of active material and modulating element	1 ns – 100 ns	MWs
Mode-locked laser	Number of coupled modes, pulse compression	10 fs – 10 ps	GWs

Free-running Lasers

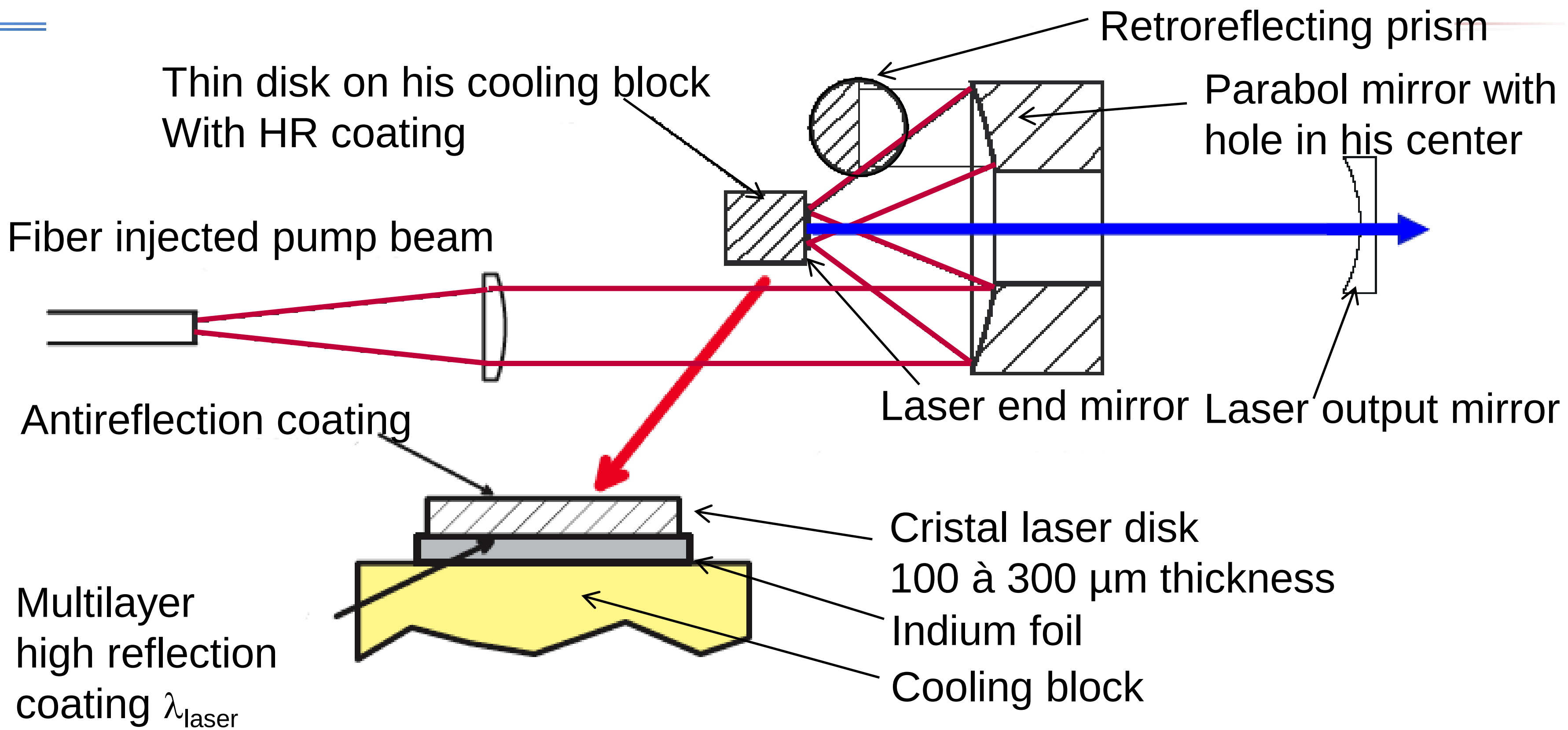


- „Free-running“ = no special pulse duration regulation
- pulse duration determined by pump duration, typically 10 µs – 1 ms
- peak power is relatively low
- total pulse energy can be quite high

Nd:YAG Laser- Flash Lamp Pumped



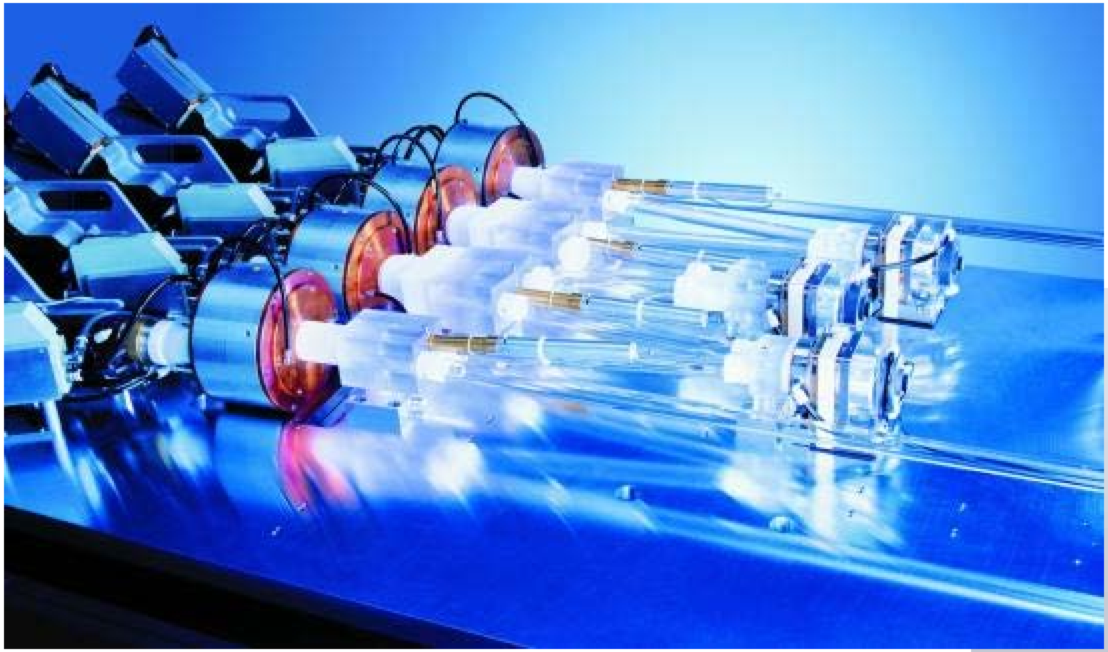
Yb:YAG Thin Disc Laser



Avantages:

High power
High beam quality
Very efficient cooling and longitudinal thermal gradient only.

Thin Disk Laser



four laser head combined give 8kW optical power at 1030 nm (IR)

TRUMPF

Fiber Lasers

Single mode

Multimode

(Courtesy of IPG Photonics Corp.   Bill Shiner)

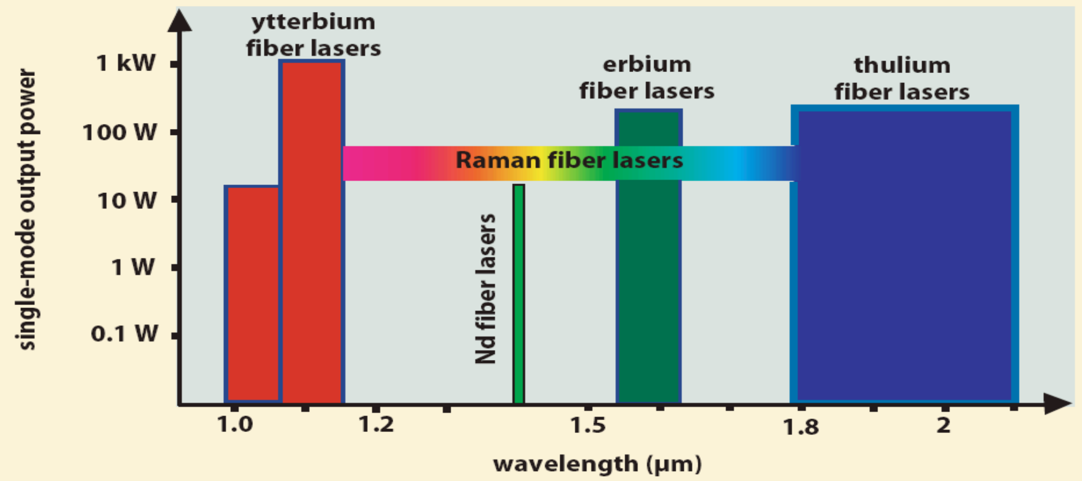


Figure 2. *Wavelengths available with single-mode fiber lasers.*

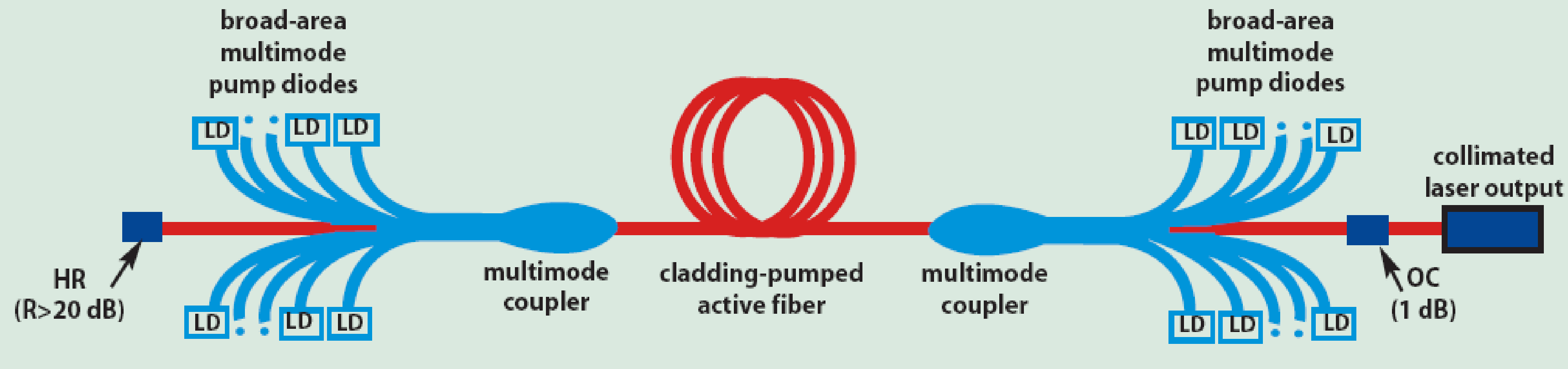


Figure 1. *Schematic of a typical single-mode fiber laser utilizing single-emitter diodes.*

Fiber Lasers

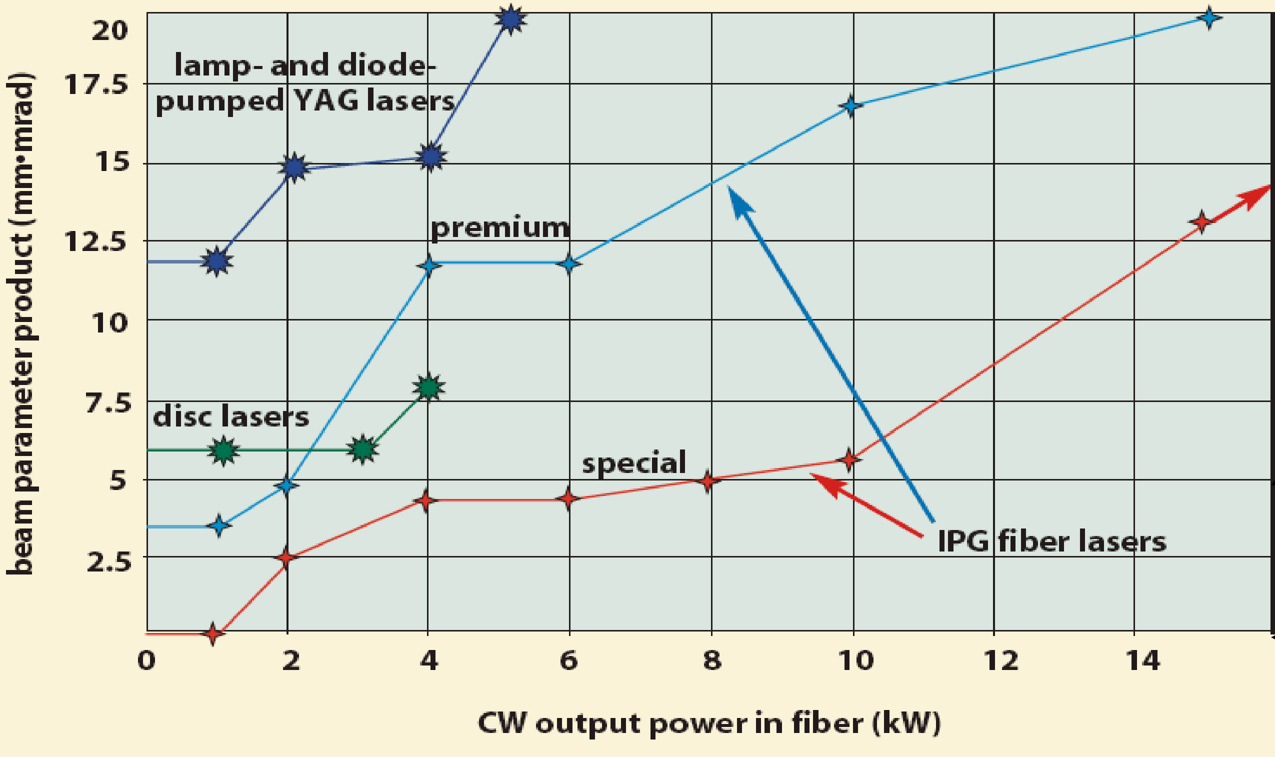


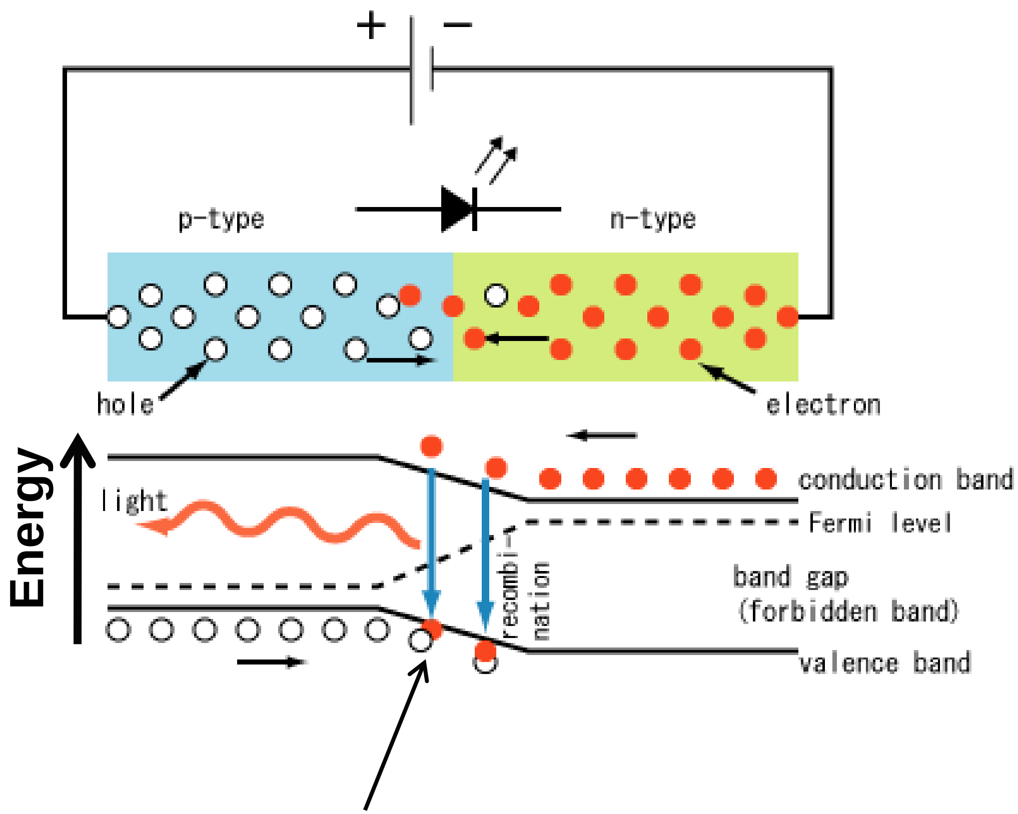
Figure 3. *Beam quality of kilowatt-class fiber lasers.*

$M^2 \approx 15$
$BPP = \lambda/\pi$
$=5$ mm*mrad

$M^2 = 1$
$BPP = \lambda/\pi$
$=0.34$ mm*mrad

(Courtesy of IPG Photonics Corp)

Light Emitting Diodes



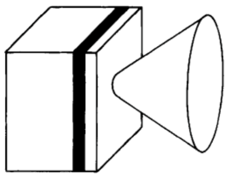
Recombination of electrons and holes in the p-n junction liberates energy, emitted as light.

Differences between LED and LD (laser diode):

- LED devices do not reach light amplification condition
- LD have designed resonator (feedback) to promote stimulated emittion
- LED are spontanous emission devices
- LD emission is more directed

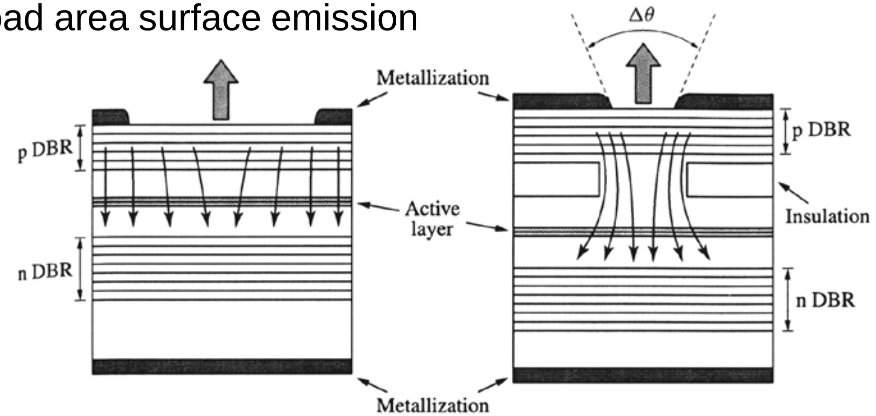
Light Emitting Diodes

Surface emitting LEDs

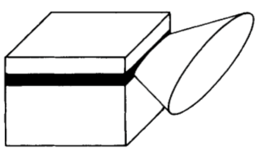


Broad area surface emission

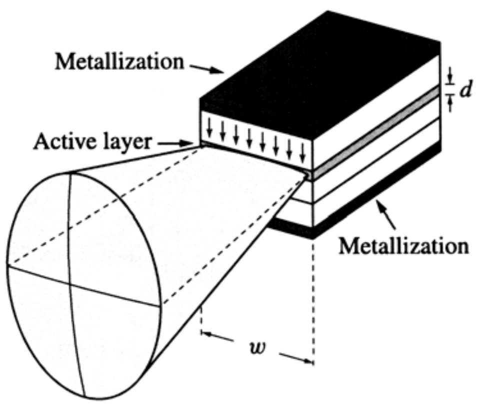
small area surface emission



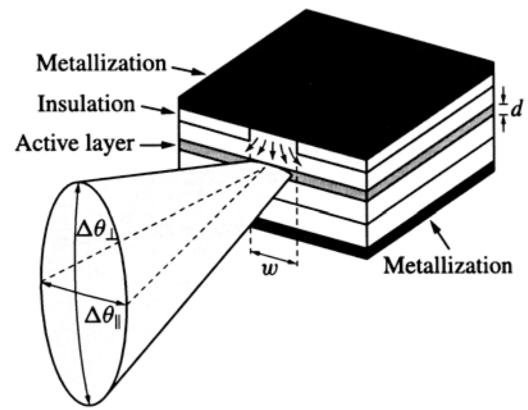
Edge emitting LEDs



Broad area edge emission



Strip geometry edge emission



Emitting surface of the LED can be quite small:

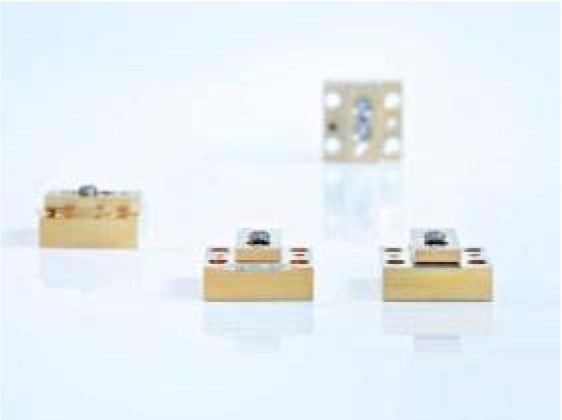
dia.~10 µm – for surface emission

1 µm x 10 µm – for egde emitting LED

Laser Diodes: Production Chain

Epitaxialy grown semiconductor thin films

Individual emitters or emmiter bars by lithography process



single emmiters mounted on passive cooler

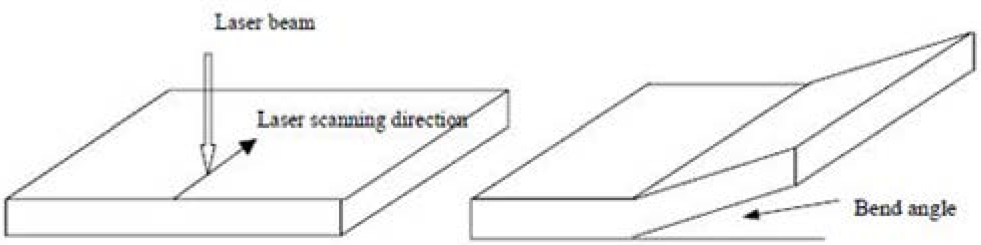
vertical stack (high power) of laser diode bars

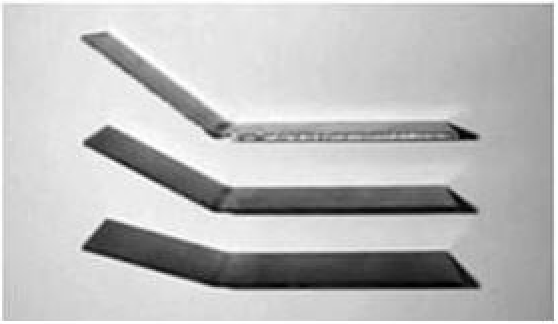
fibre coupled and water cooled laser diode modules

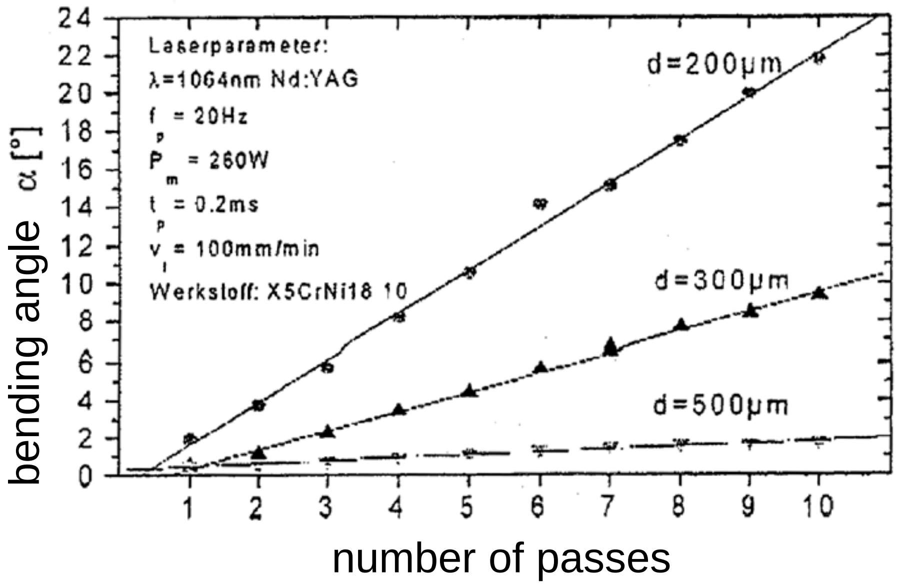
JENOPTIK

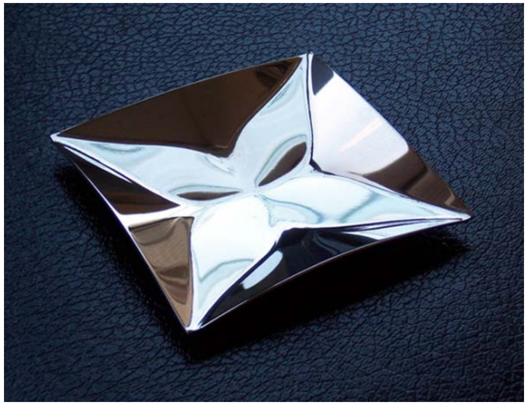
http://www.jenoptik.com/en-diode-laser

Laser Bending

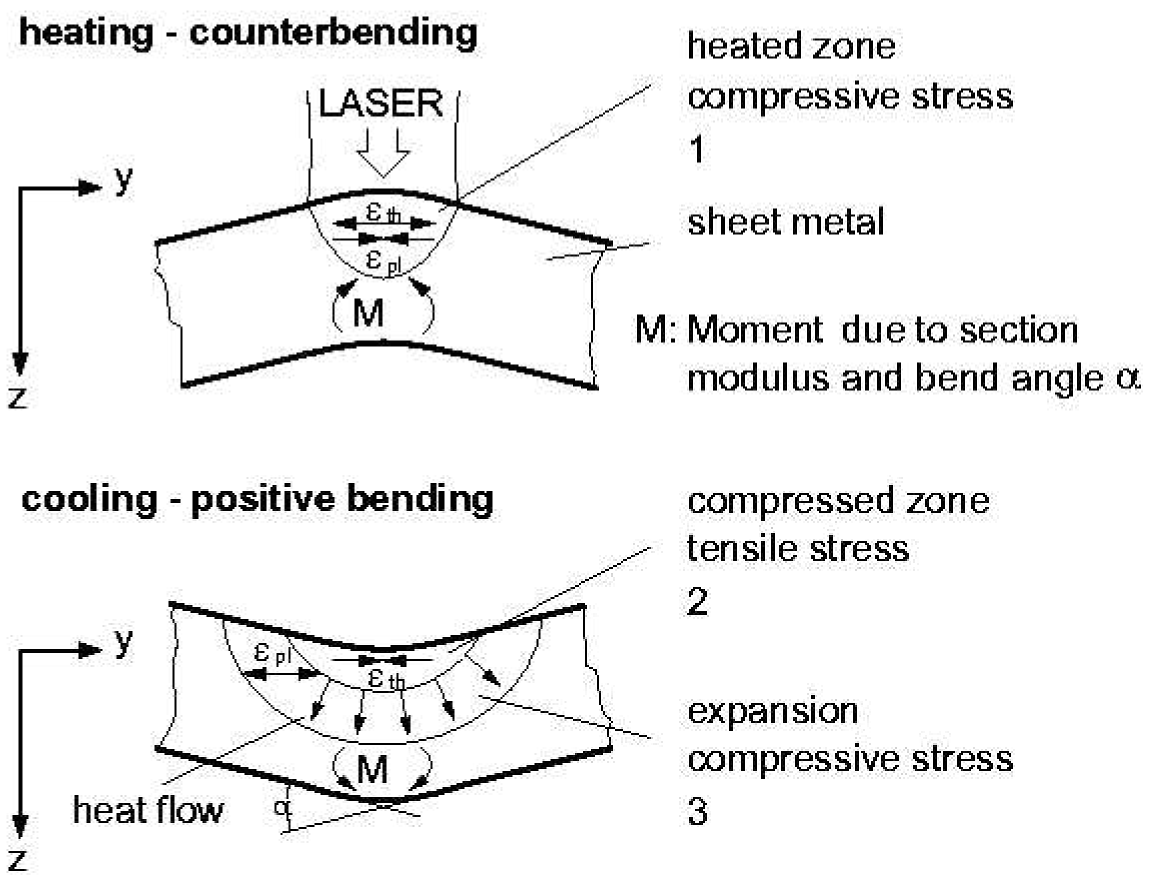




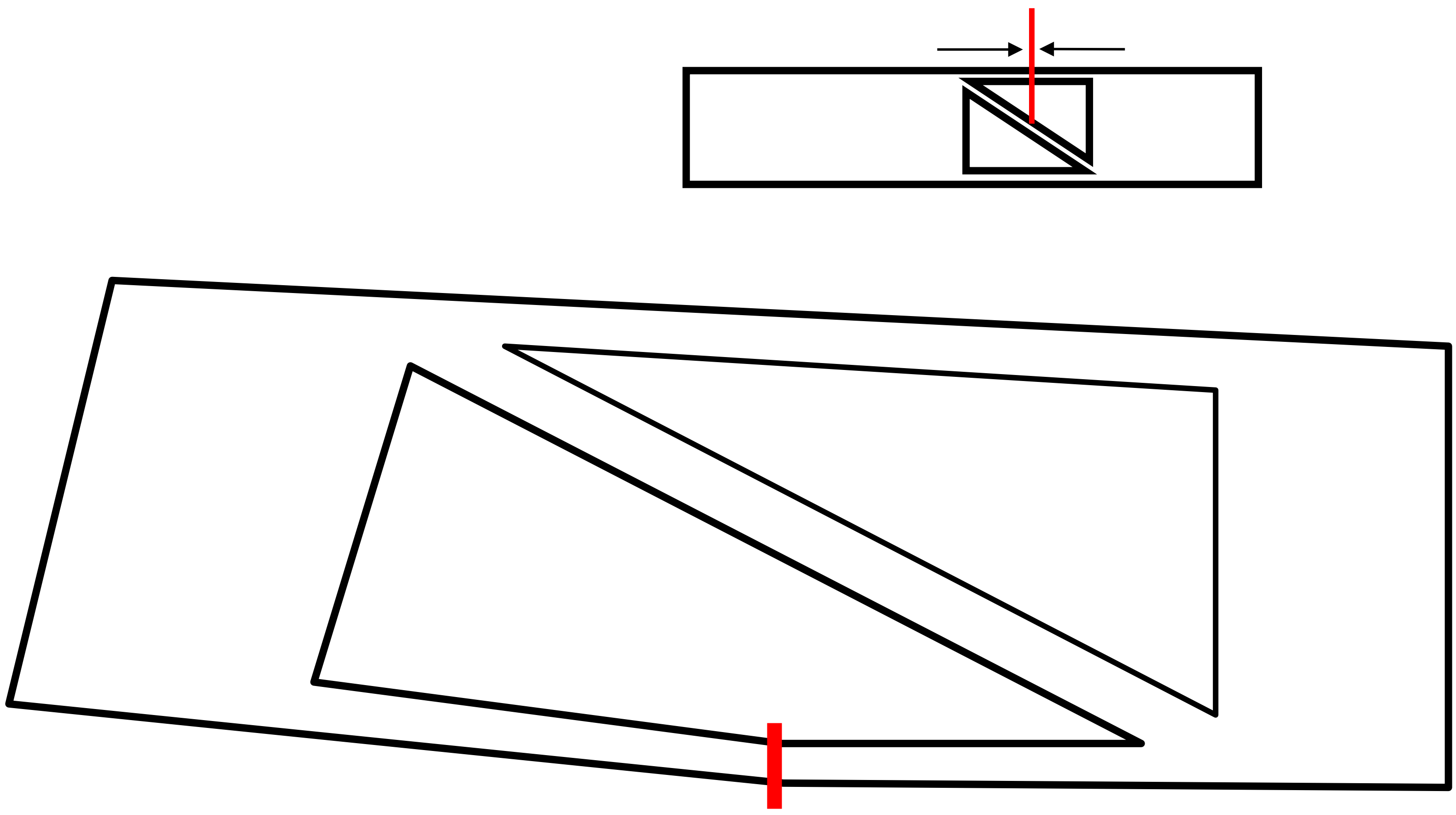




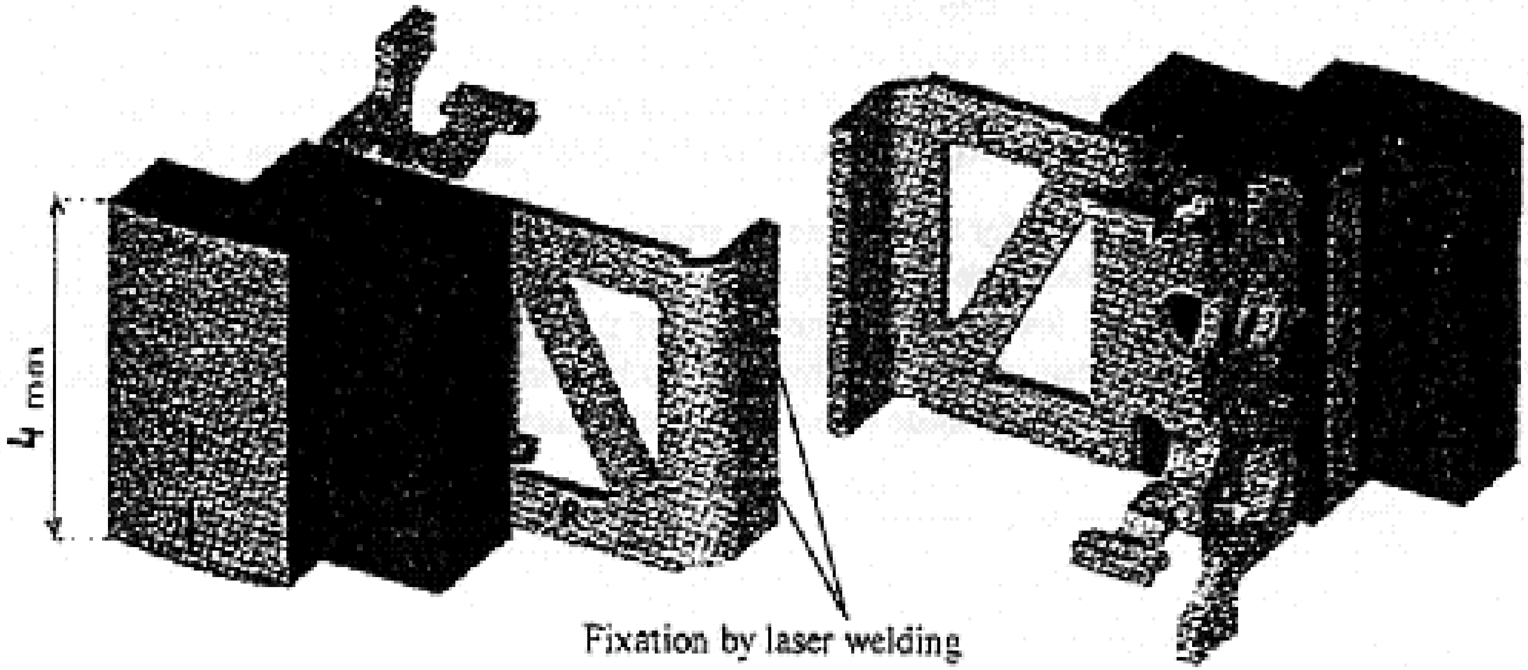
Laser Bending



Laser Bending



Laser Welding

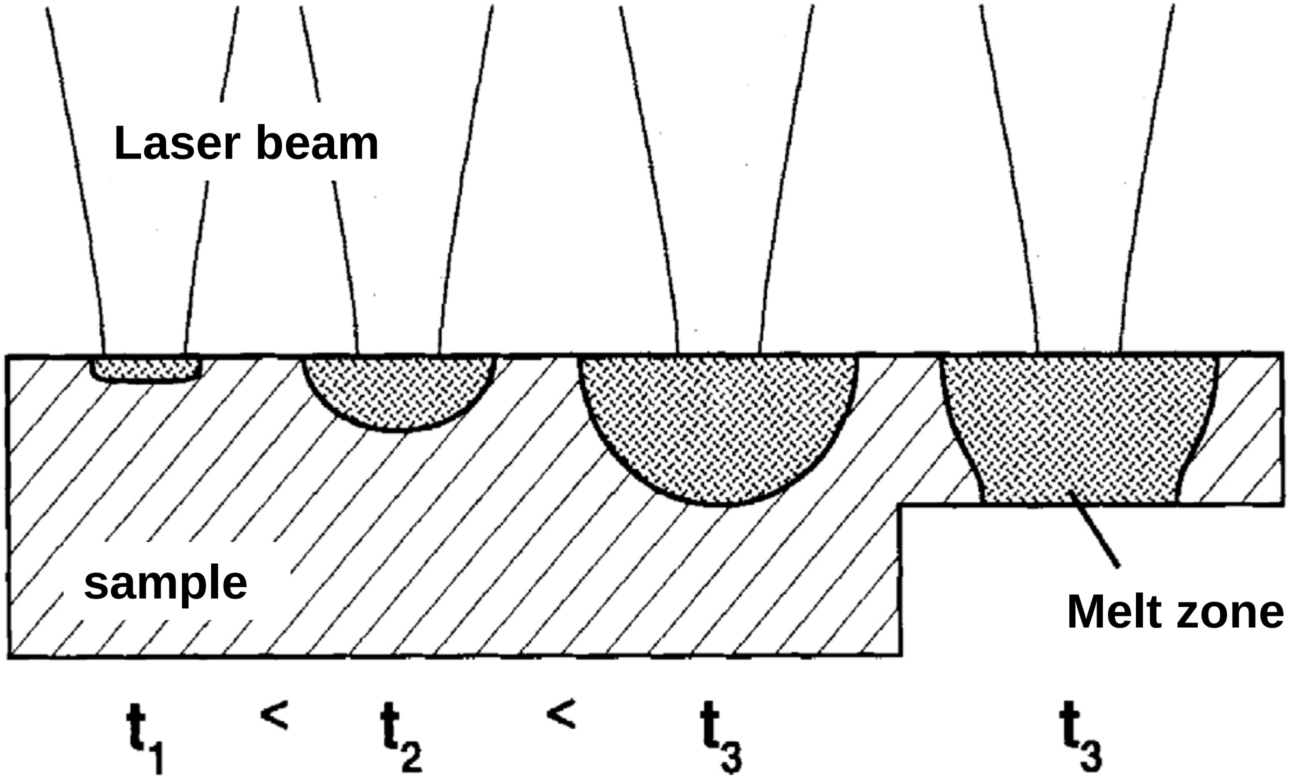


The audio chip for the DCC (Digital Compact Cassette) mounted onto a special carrier for laser-adjustment. After 'rough' fixation by laser welding, the carrier allows an accurate adjustment of two important degrees of freedom of the chip: the track-height and the azimuth of the thin film heads. If the parts L, R and M are irradiated by short intense laser pulses, their lengths change by the thermo-mechanical shrinkage: the parts become shorter by a few microns. The carrier fulfils the function of an actuator for fine-adjustment of the audio chip. The carrier also acts as a support for mounting the audio chip into the DCC-player: 'the actuator is part of the product'. It can be mass-produced by simple stamping from thin metal sheet.

Laser Welding

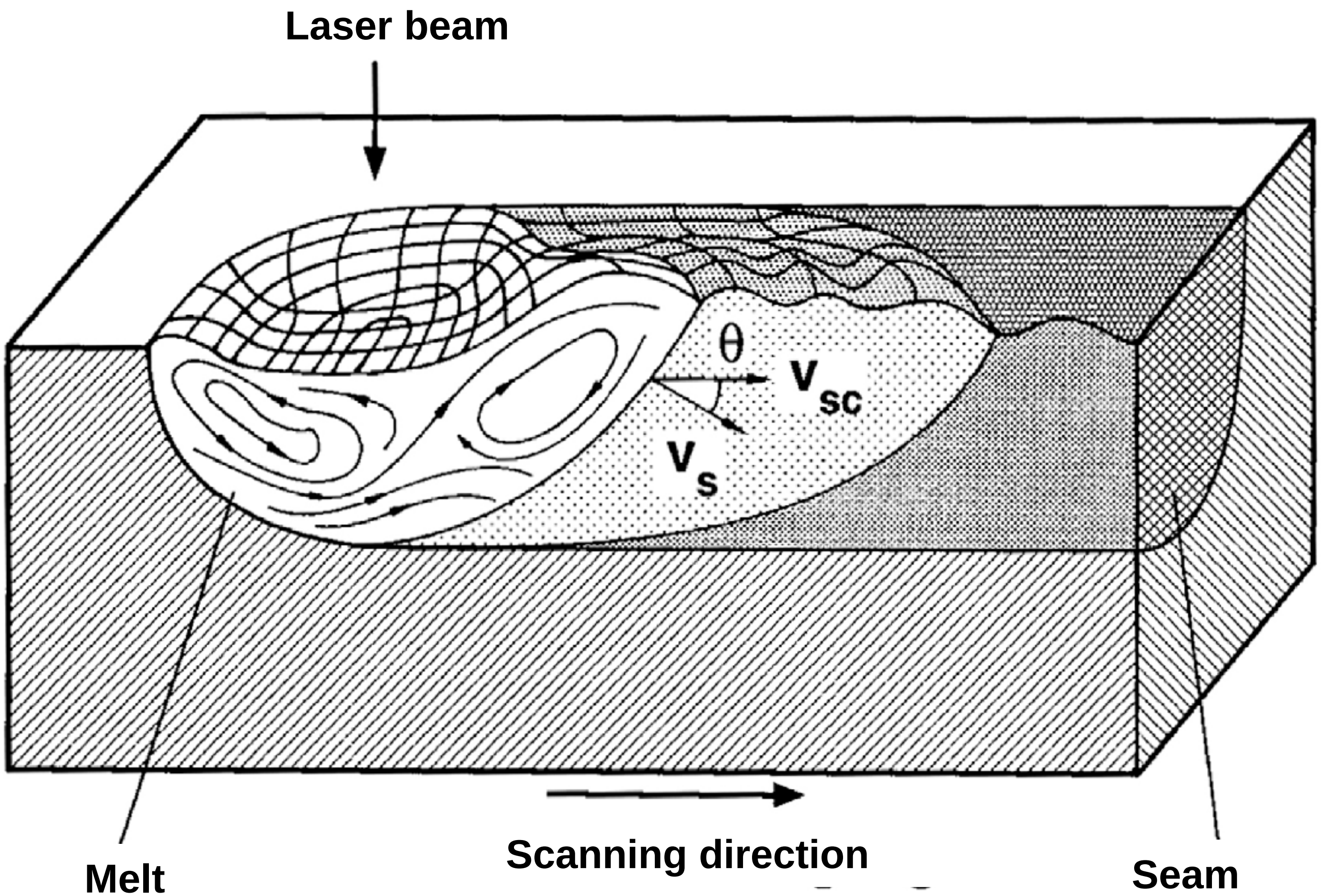
- conduction welding
- deep welding

Laser Welding



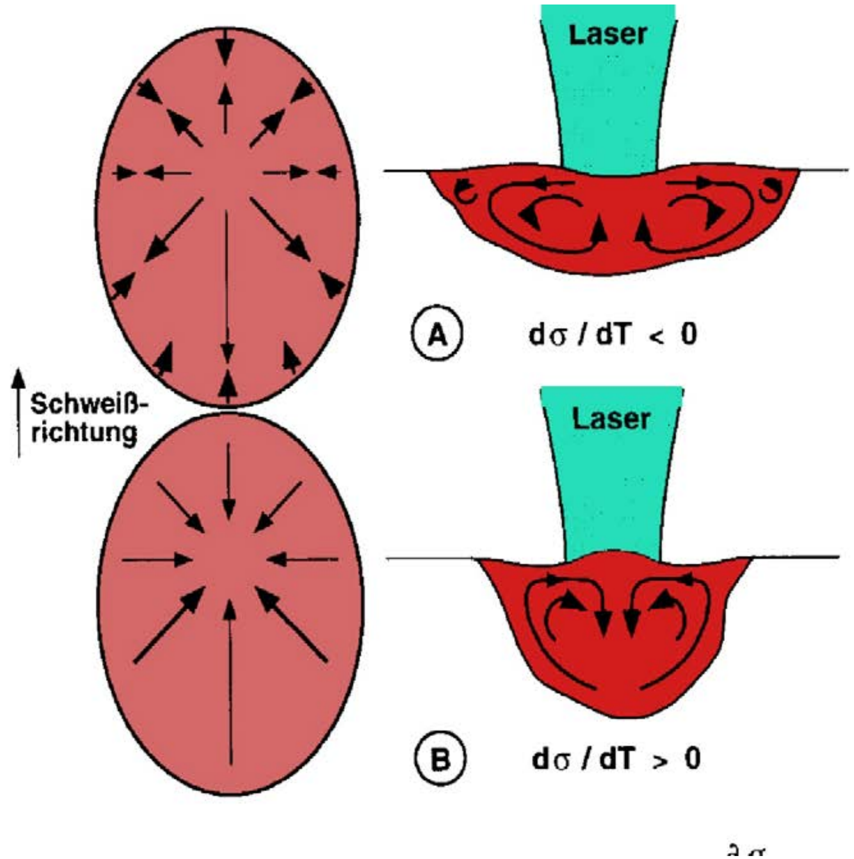
Principle of conduction welding

Laser Welding – Melt Dynamics



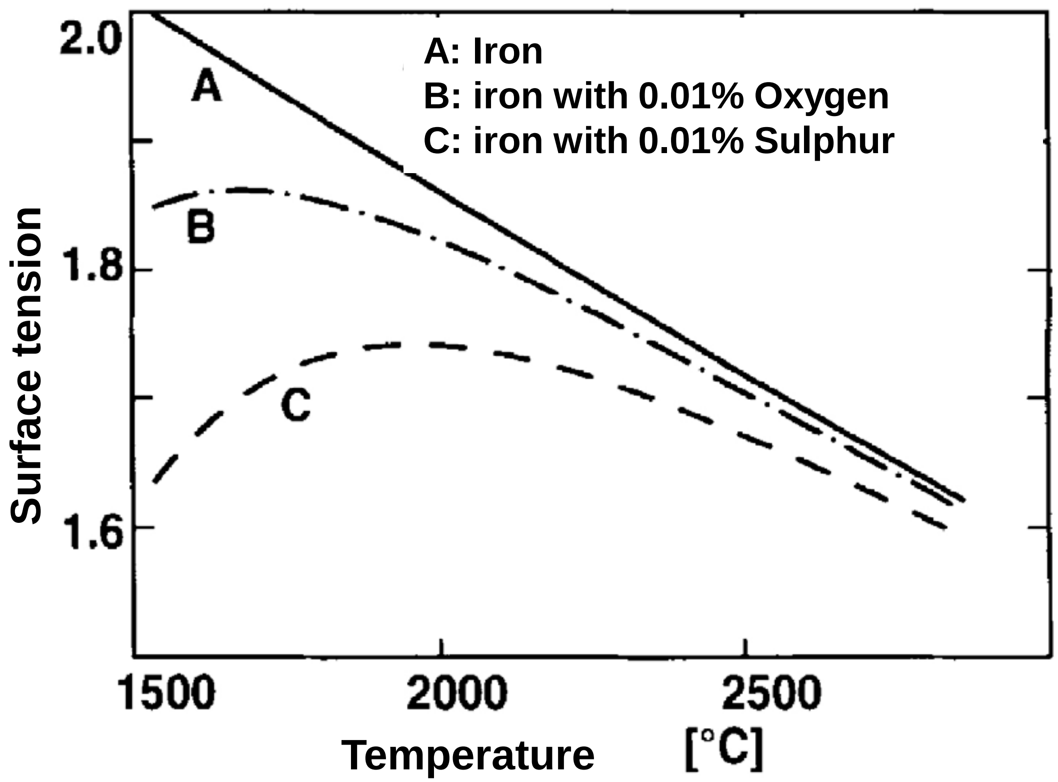
Melt bath dynamics and deformed surface

Laser Welding – Marangoni Effect



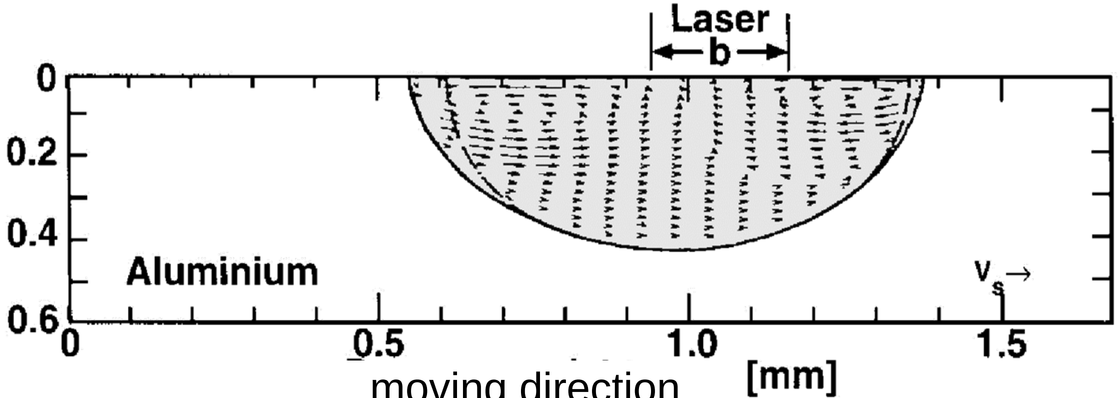
Melt zone for different surface tension on temperature dependencies

Laser Welding

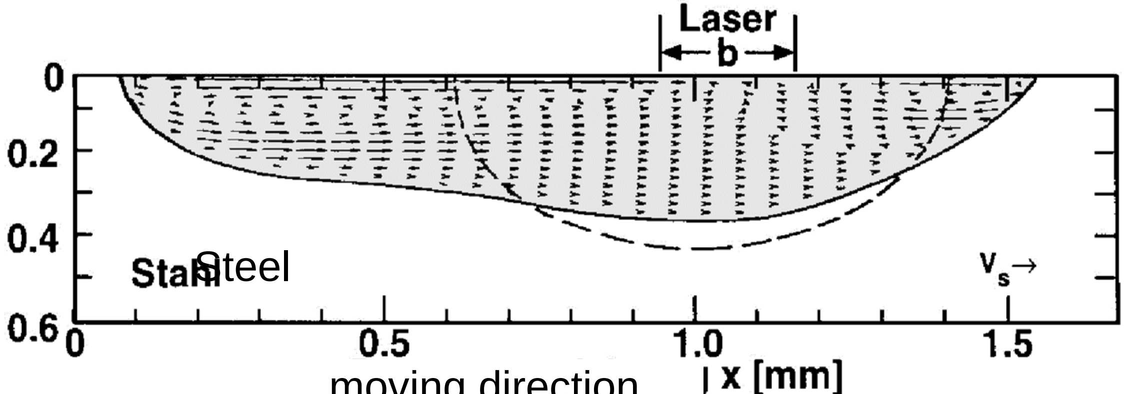


Melt zone for different surface tension on temperature dependencies

Laser Welding



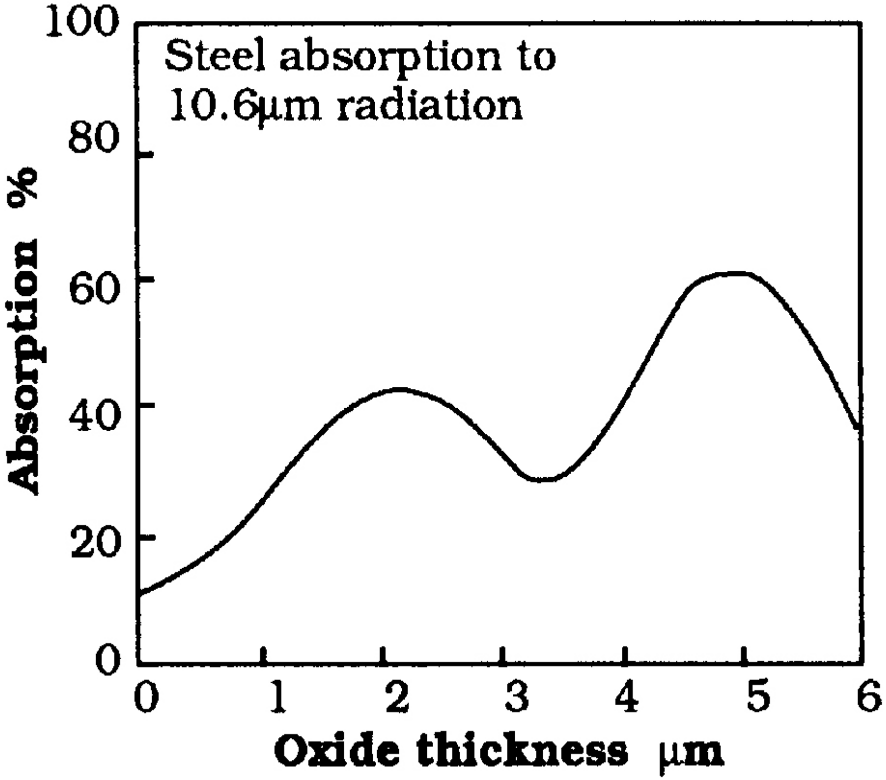
moving direction

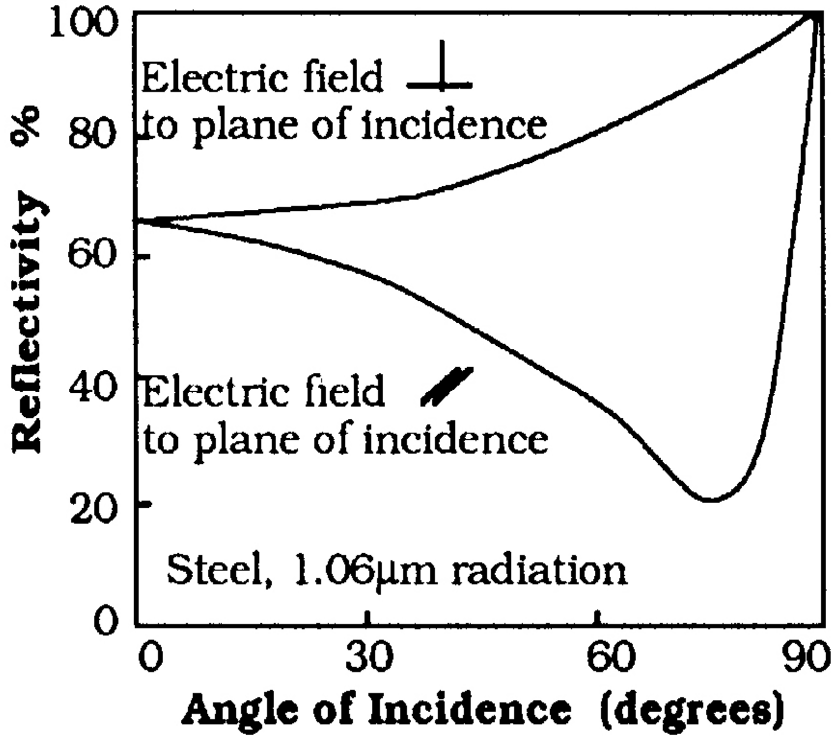


moving direction

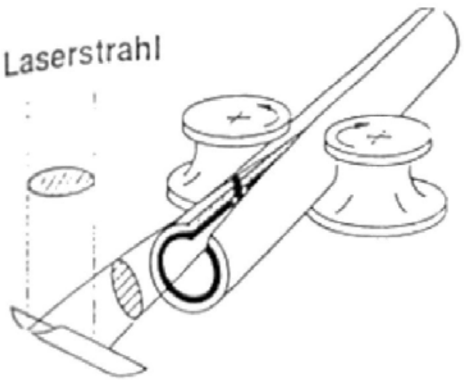
Numerically simulated melt isotherm for steel and aluminium
at 6 mm/s scanning speed
(the dashed line marks the melt zone if convention is not taken into account)

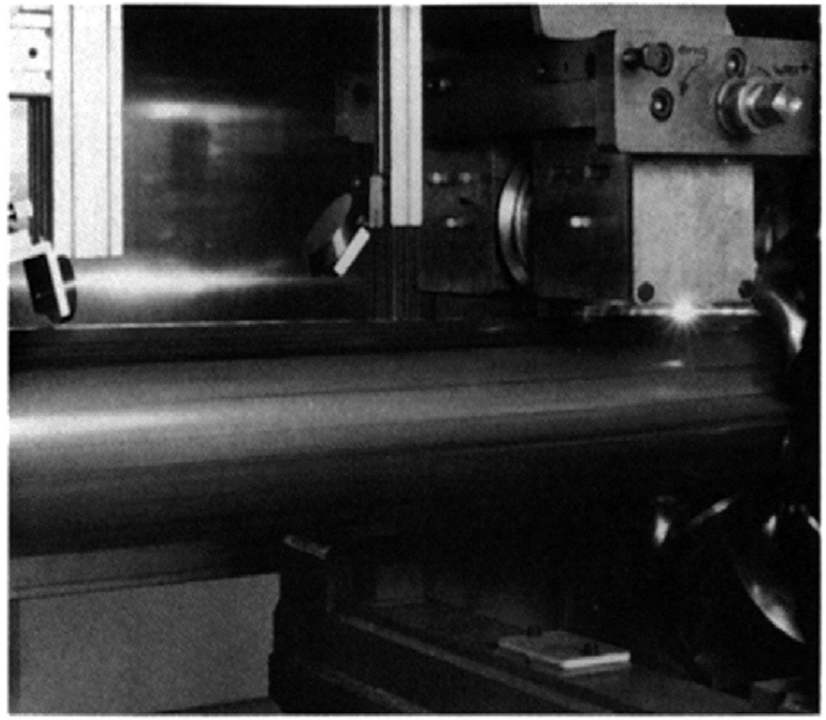
Laser soldering





Laser Welding

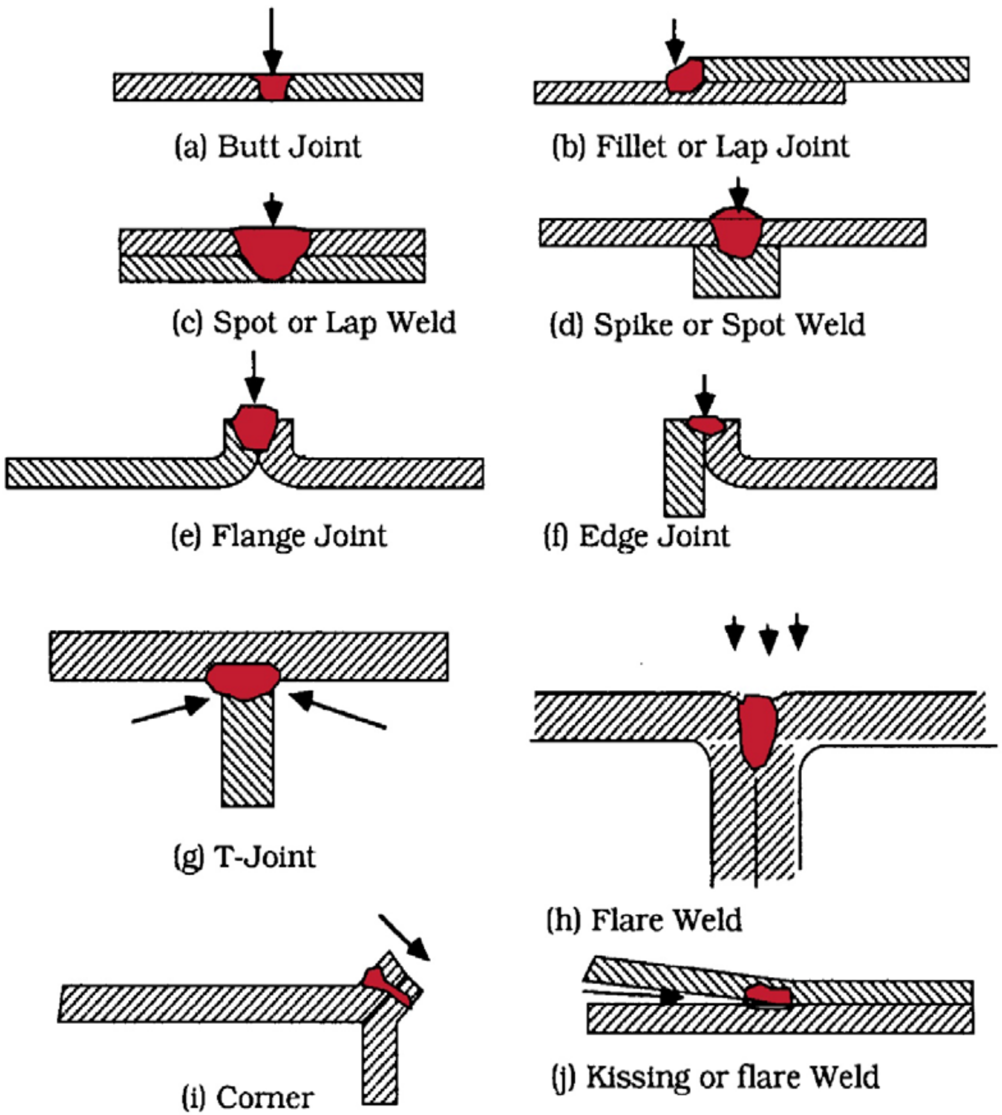




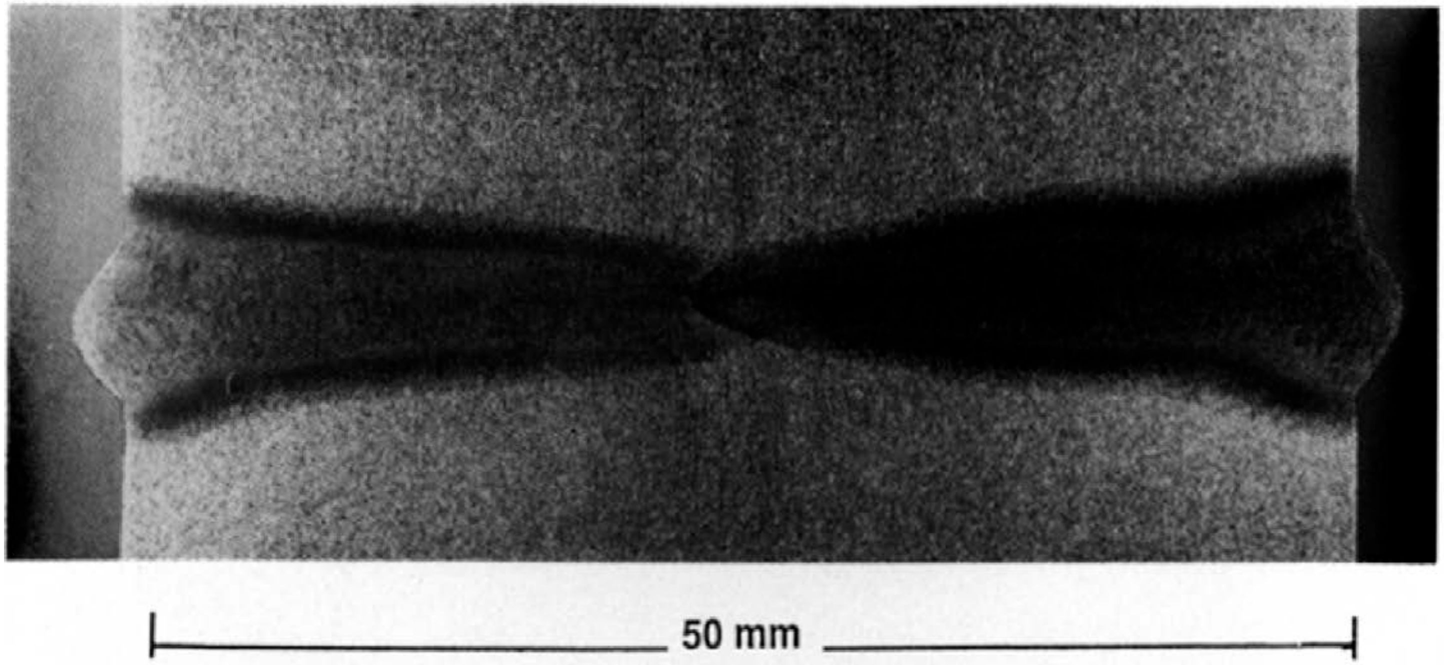
$P_L = 20$ kW
6 mm < s < 12 mm
20 m/min > v_s > 5 m/min

Polarisation welding of tubes
polarisation is cosen to increase the reflectivity on the walls to guide the light deeper

Laser Welding



Laser Welding

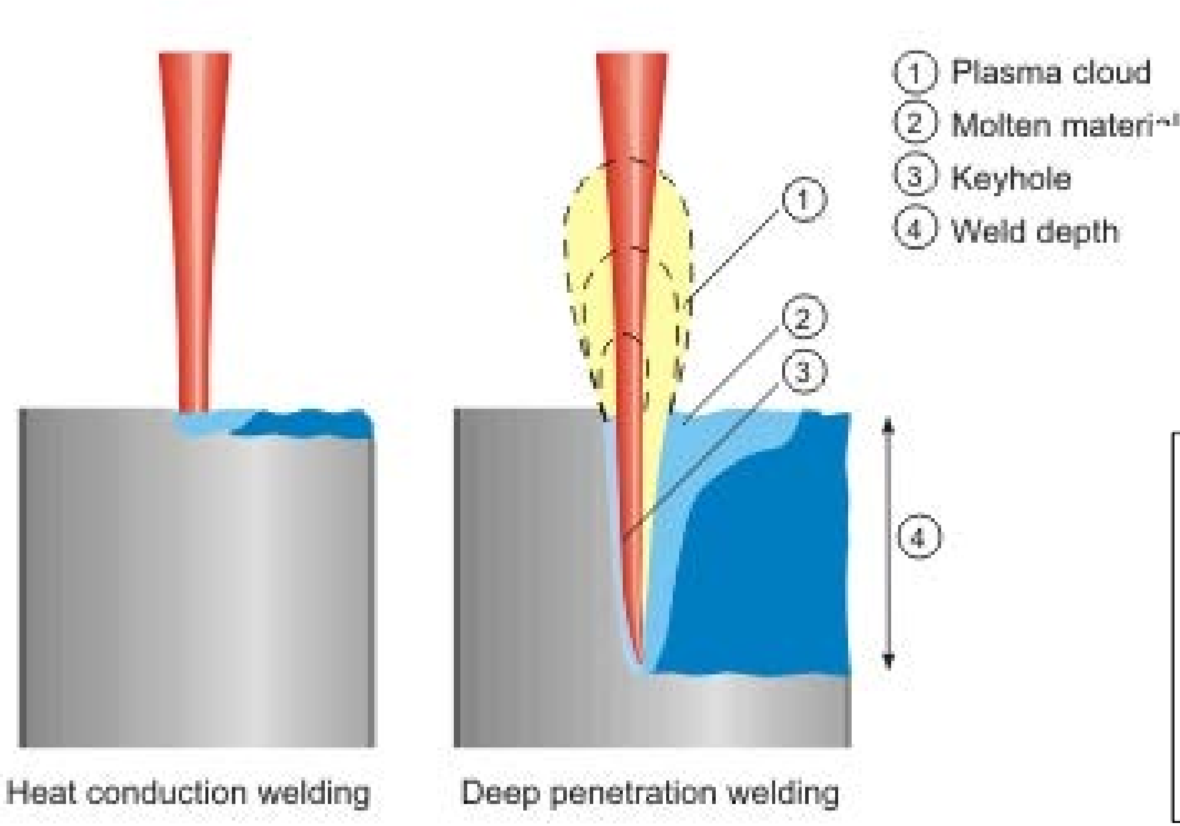


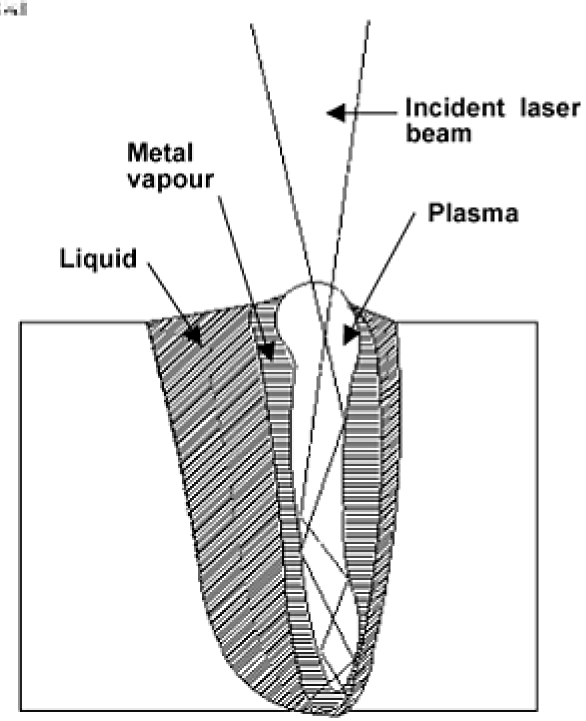
v_{s1} = 0.6 m/min F = 10 P_L = 20 kW

v_{s2} = 0.6 m/min r_F = 330 µm

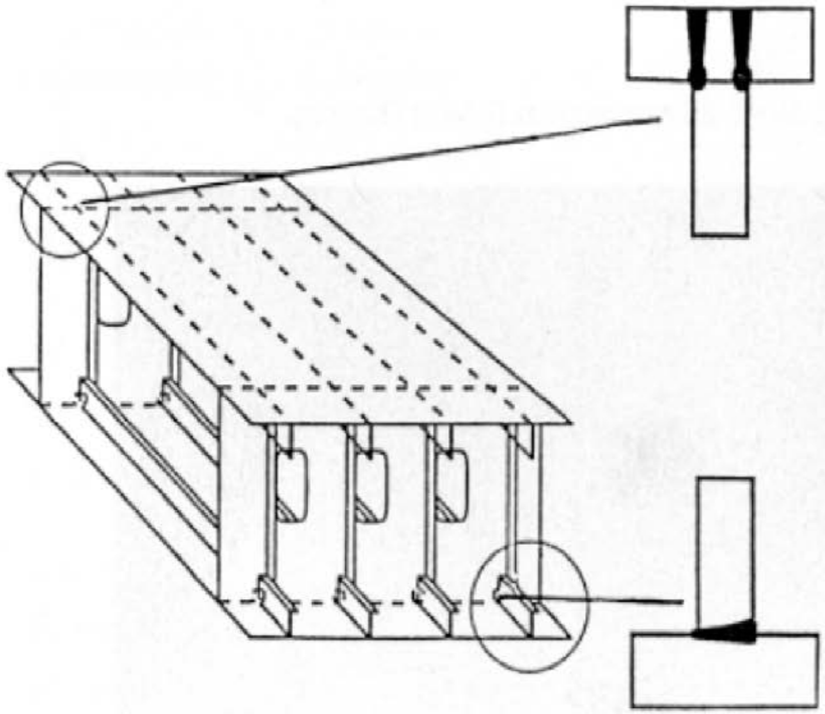
Double side welded seam of 50mm thick steel

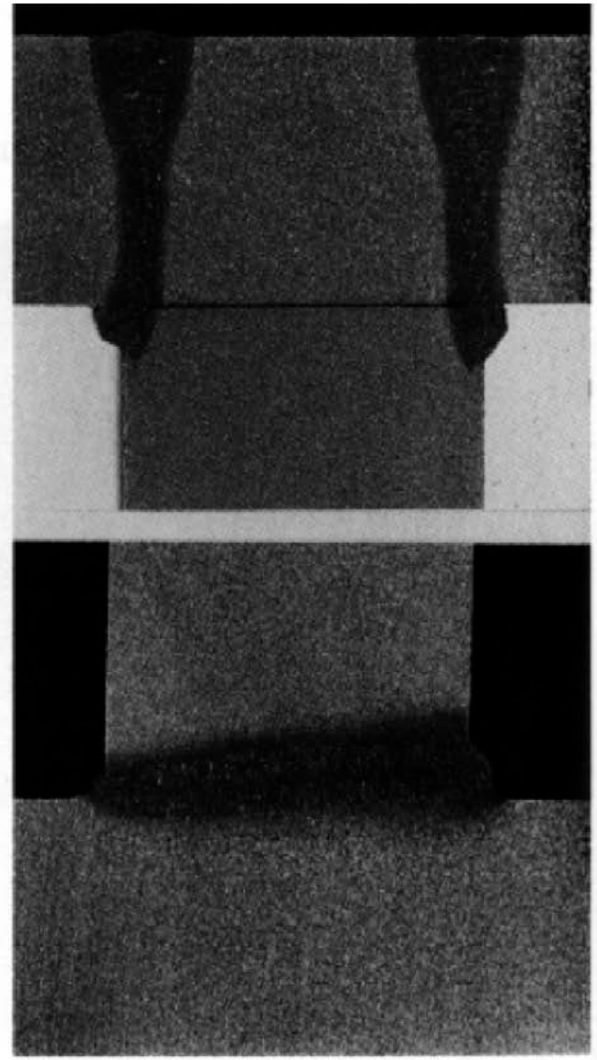
Deep Laser Welding





Laser Welding





Material St 52-3

Stegdicke = 15 mm

v_s = 1,5 m/min

r_F = 320 µm

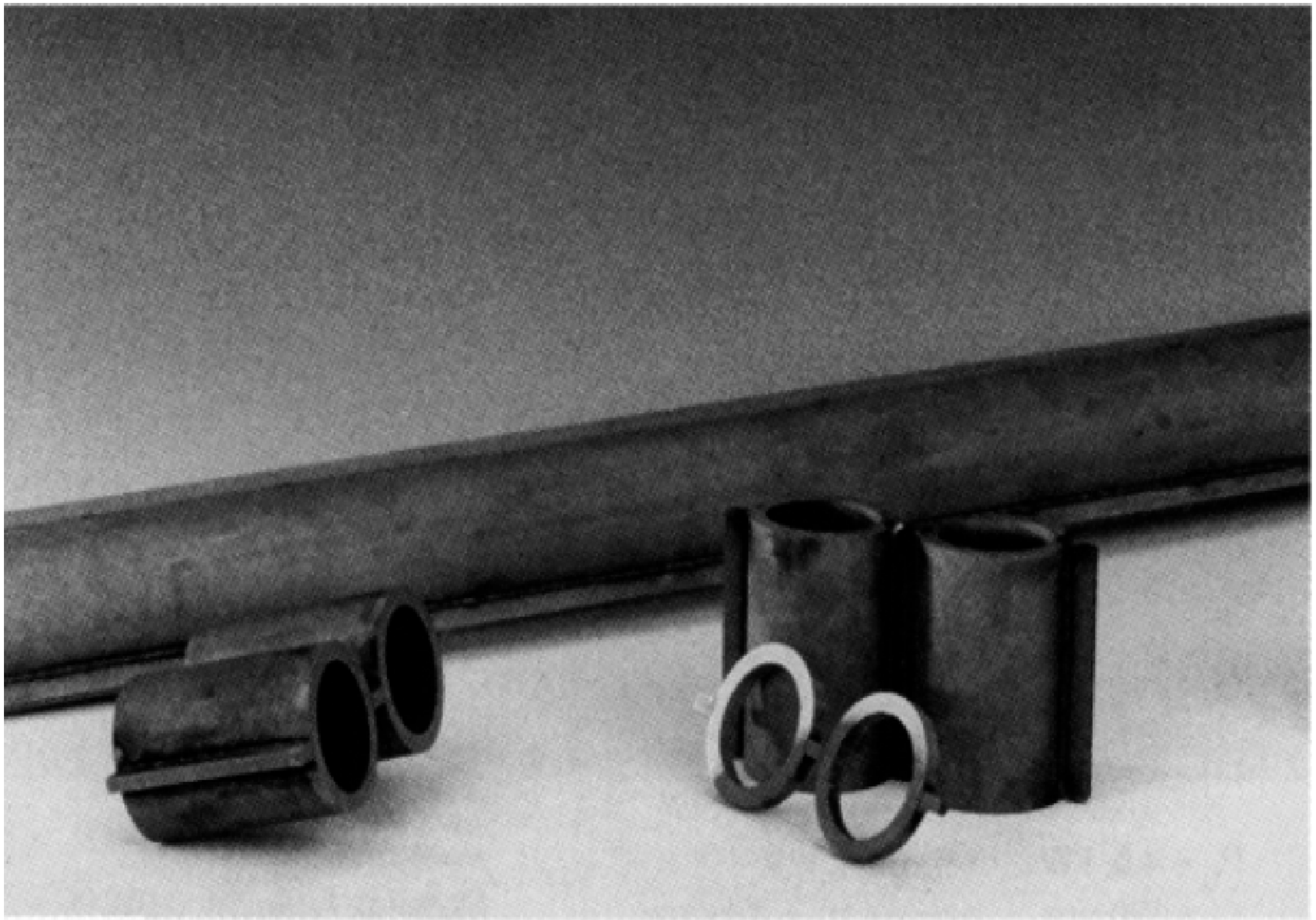
P_L = 10 kW

Bodendicke s = 10 mm

F = 13

Abb. 2.3.4 Laserstrahlschweißungen an Doppelböden

Laser Welding



$P_L = 10$ kW $F = 13{,}5$ $s = 6$ mm
$r_F = 320\ \mu m$ $v_s = 2{,}7$ m/min

Laser Welding

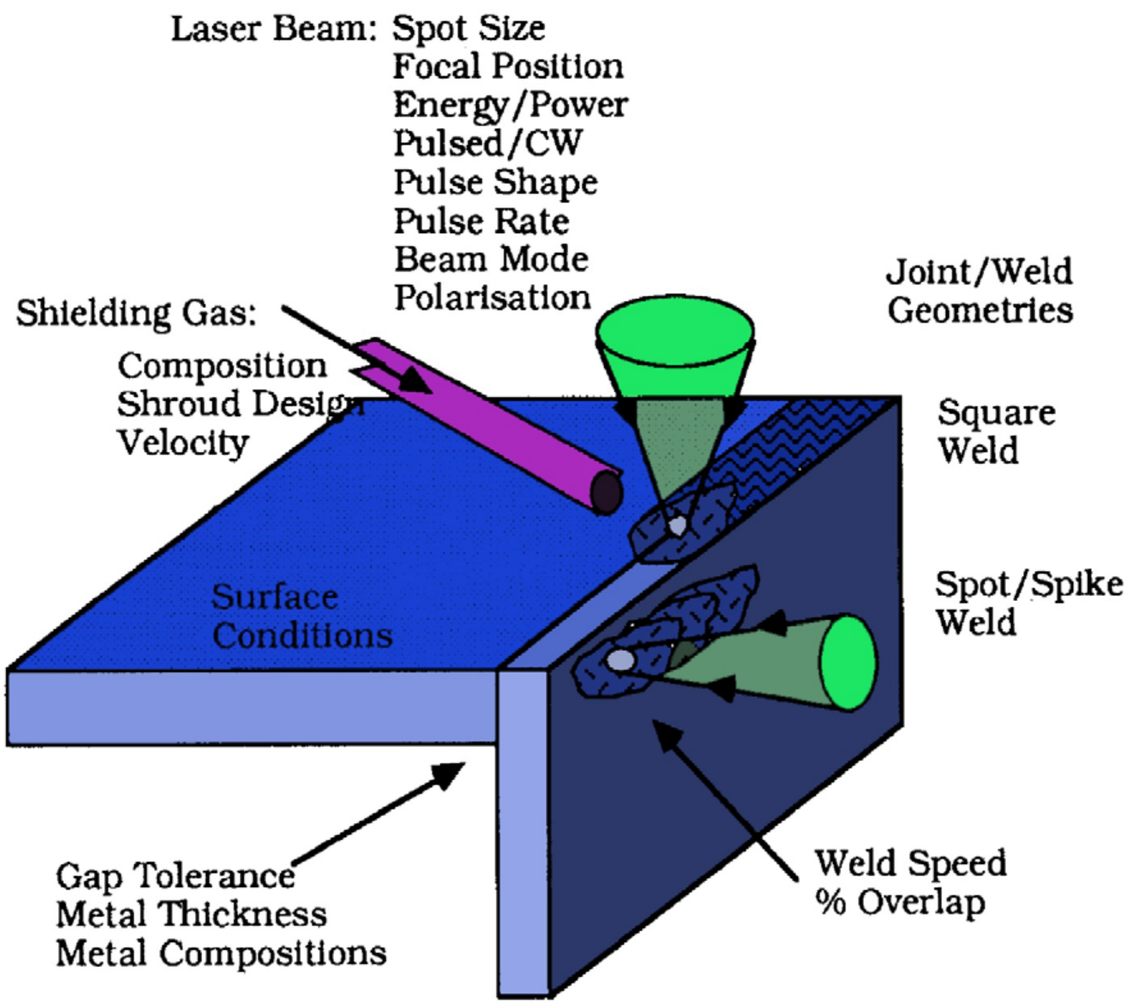
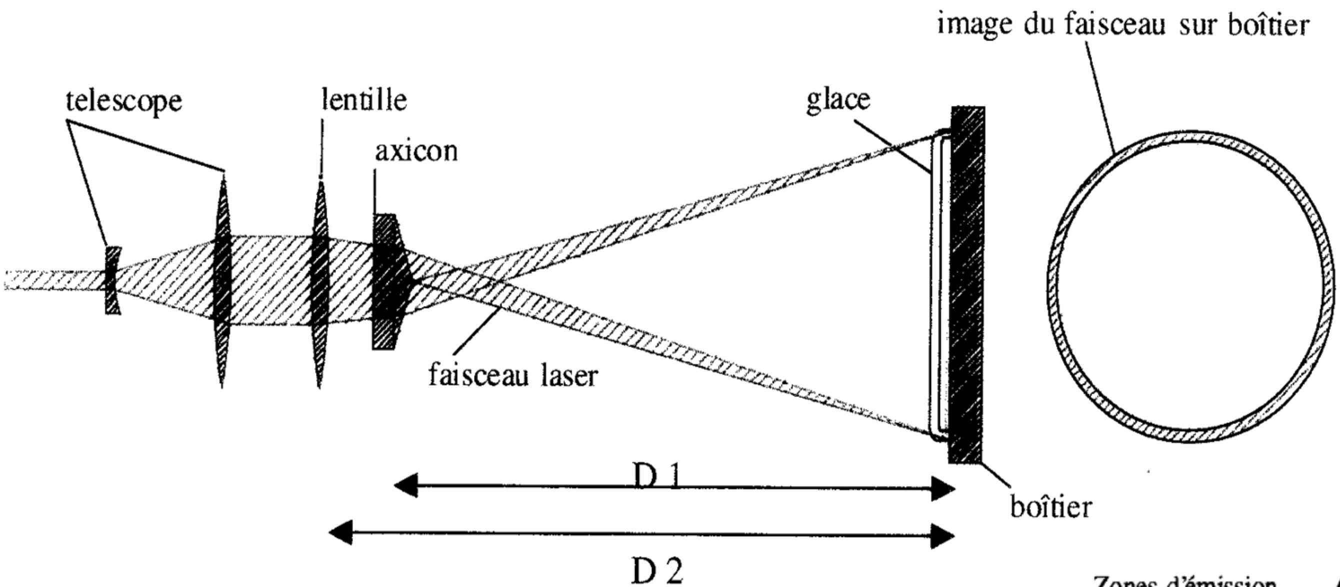
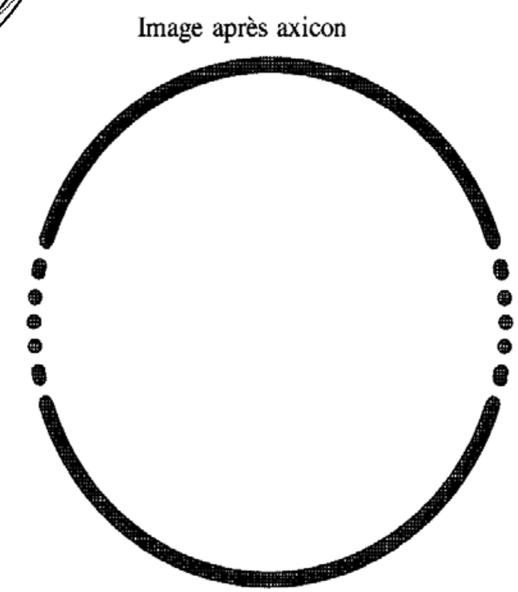


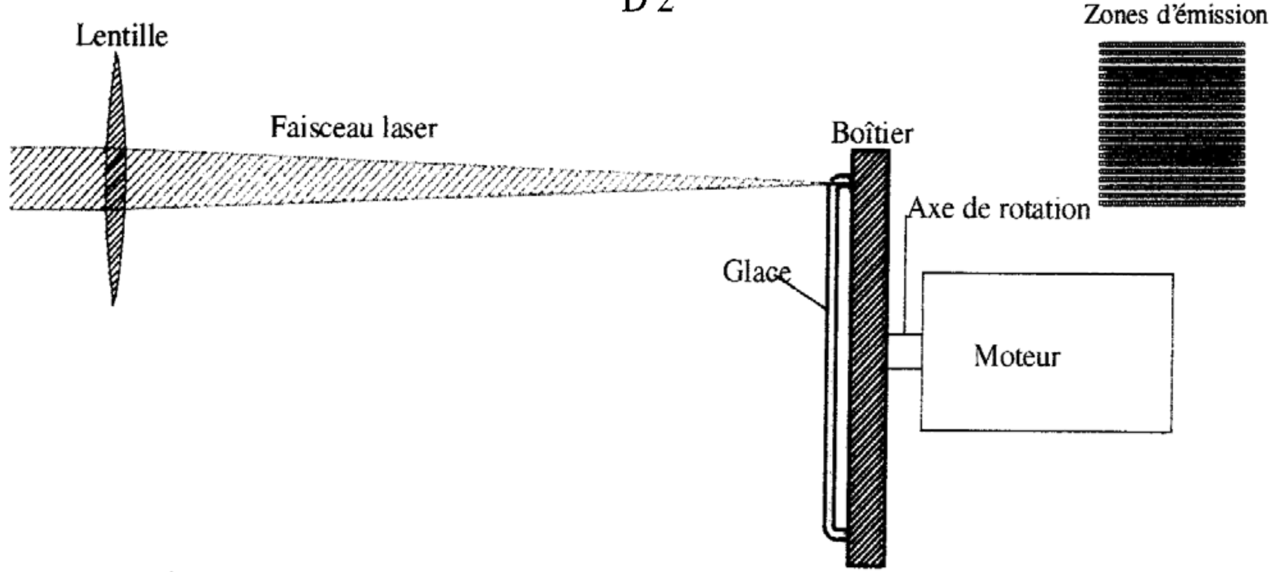
Fig. 4.10. The main process parameters.

Laser Welding of Plastic



Ring soldering using axicone





Ring soldering using rotaion of the object