Fibre laser
A revolution in materials processing???

Flemming Olsen

Technical University of Denmark
DK 2800 Kongens Lyngby, Denmark

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  - Fibre laser development
  - System integrators
  - Technology development

Introduction

- The history of industrial lasers:
  - Market segments:
  - Major laser sources

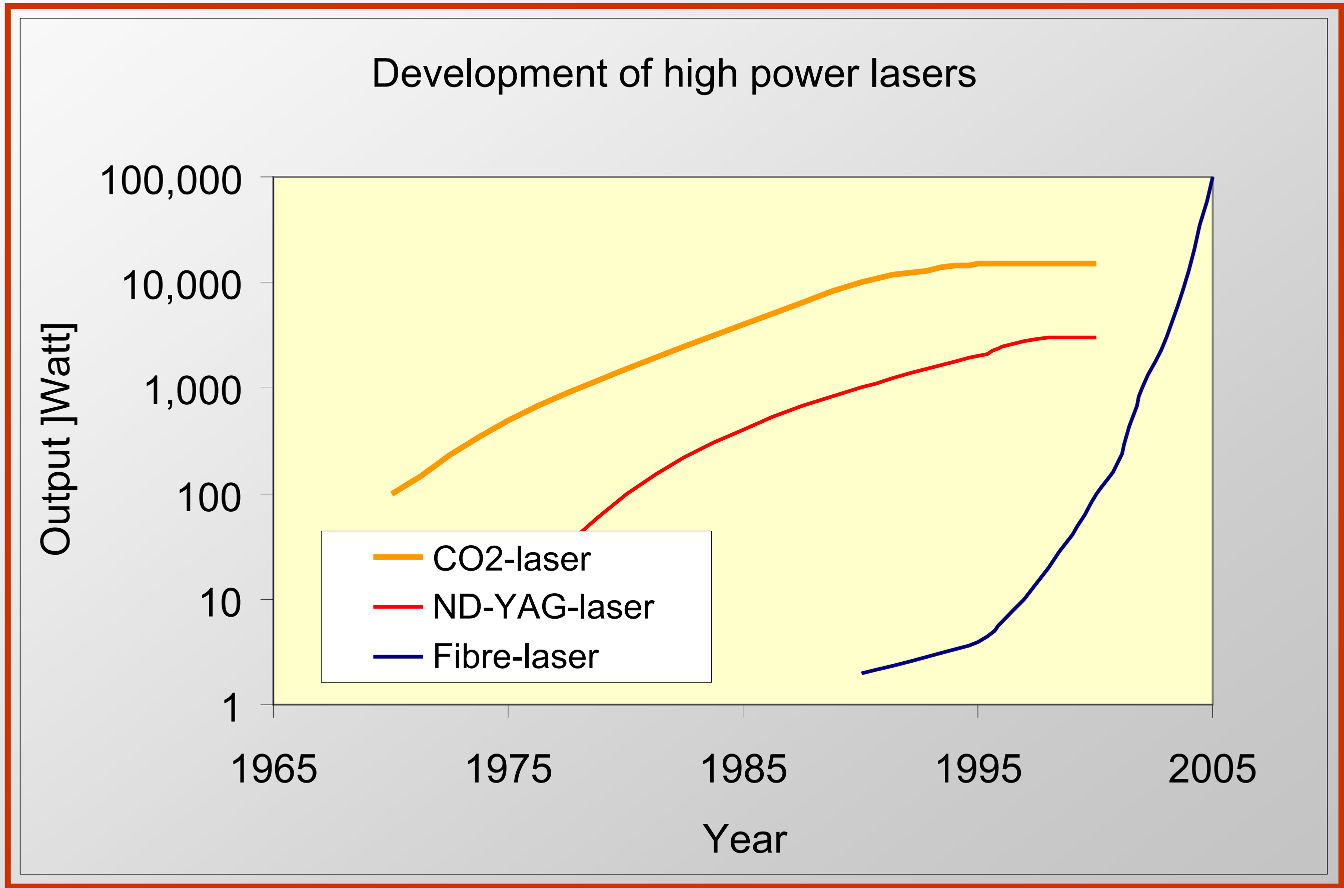
Introduction

- The history of industrial lasers:
  - Market segments:
    - Drilling – the first application
    - Welding – a major application from the beginning
    - Hardening – an early process – together with other surfacing applications
    - Cutting - the biggest market
    - Engraving – also a large market

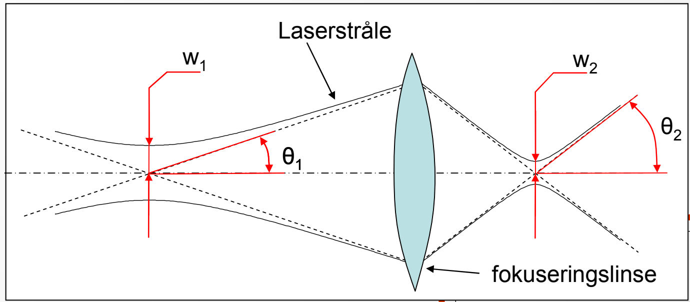
Introduction

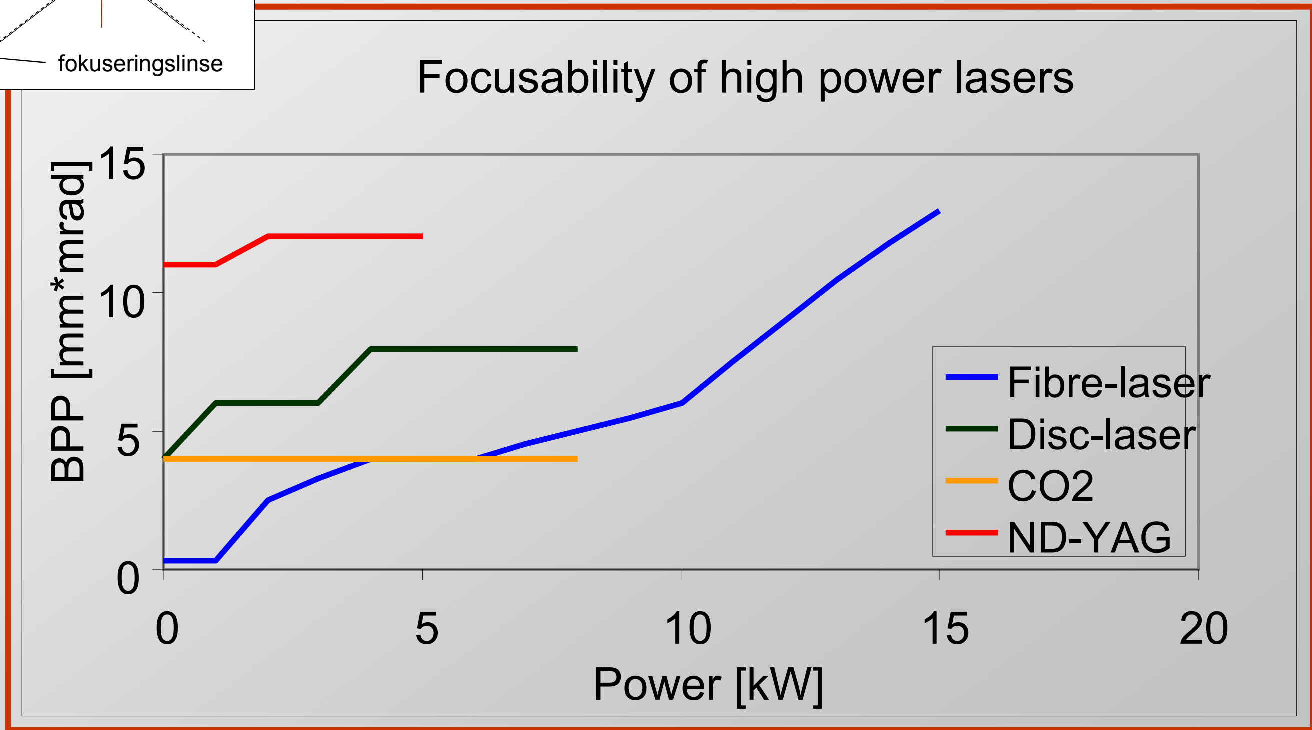
- The history of industrial lasers:
  - Major laser sources
    - CO_2
    - Nd-YAG (lamp pumped)
    - Excimer
    - Copper Vapour
    - Short puls lasers
    - Nd-YAG new pump sources
    - Fibre laser

The potential og high brightness lasers



The potential og high brightness lasers





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The potential og high brightness lasers

Fibre laser versus disc-laser:

Fibre-laser: Direct transmission from laser to processing head ➔ Ultimate solution for maintaining the BPP

Fibre-laser: Doesn’t require high quality electromechanical design

The potential og high brightness lasers

Fibre laser in welding:

Do we need the high beam quality?

- Welding looks most of all like EB-welding.
- The high brigthness and the short wavelength ensure stable beam coupling into the keyhole.
- Plasma formation has been seen at high intensities, but not problematic as with CO_2-lasers

The potential og high brightness lasers

Fibre laser in cutting:

Do we need the high beam quality?

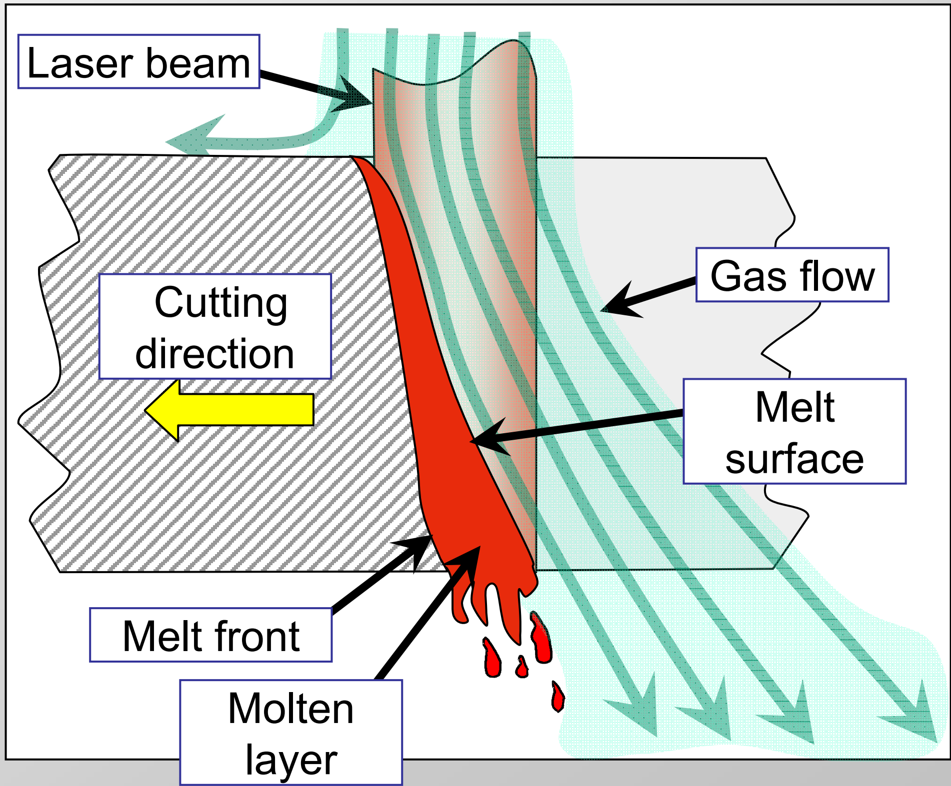
We see eigther high speed cutting or high quality cutting.

The potential og high brightness lasers

- Fibre laser cutting potential:
  - Looking on the cut front mechanisms
    - Classical thermal cutting including laser cutting
    - Keyhole laser cutting – ho does it work and what is the potential?
  - Comparing theory with available cutting results
  - Discussing the potential

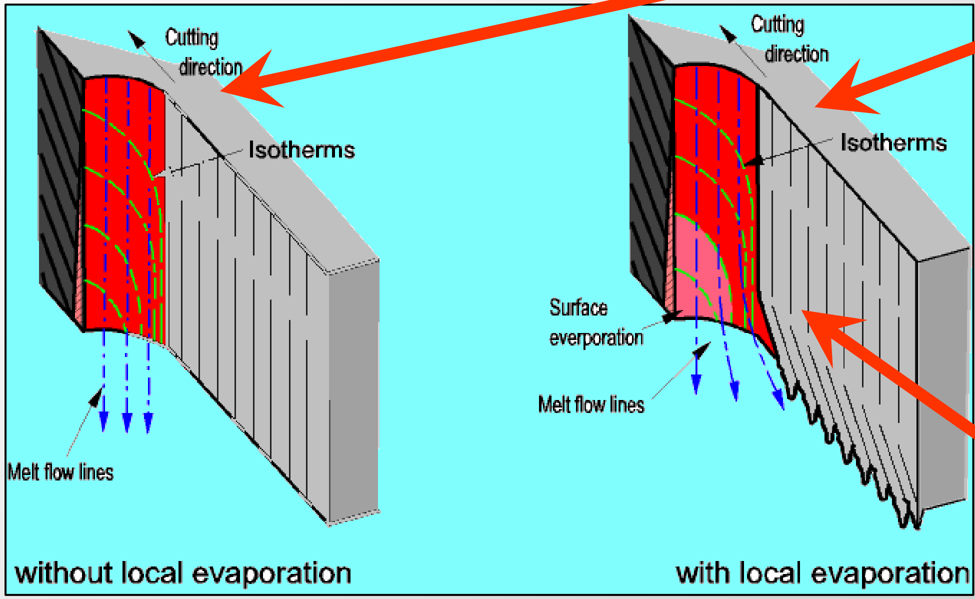
Cut front theory

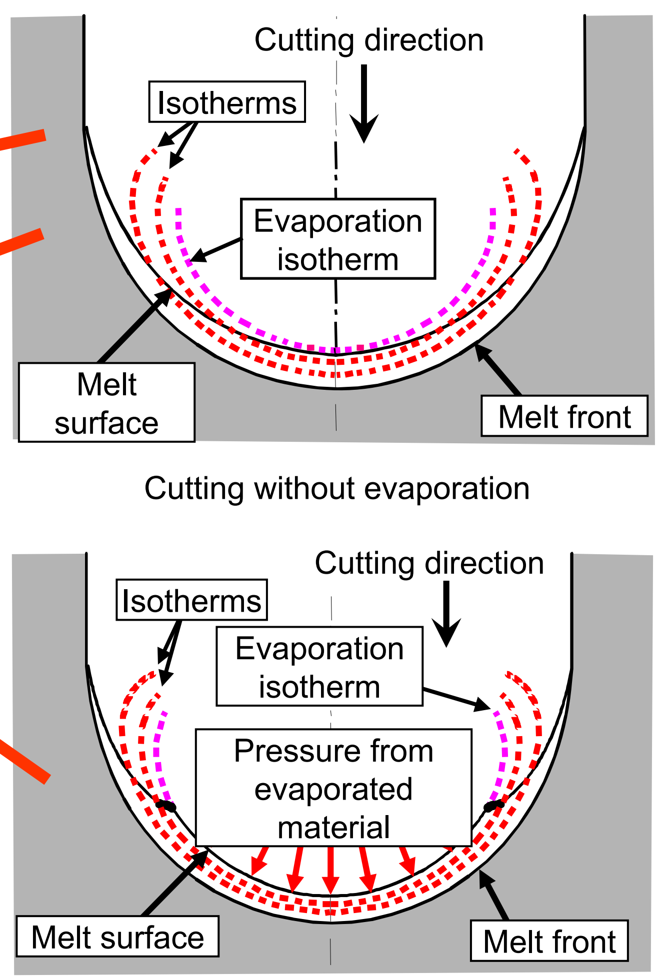
- Laser cutting:
  - melting
  - removal



Cut front theory

- Melt flow patterns



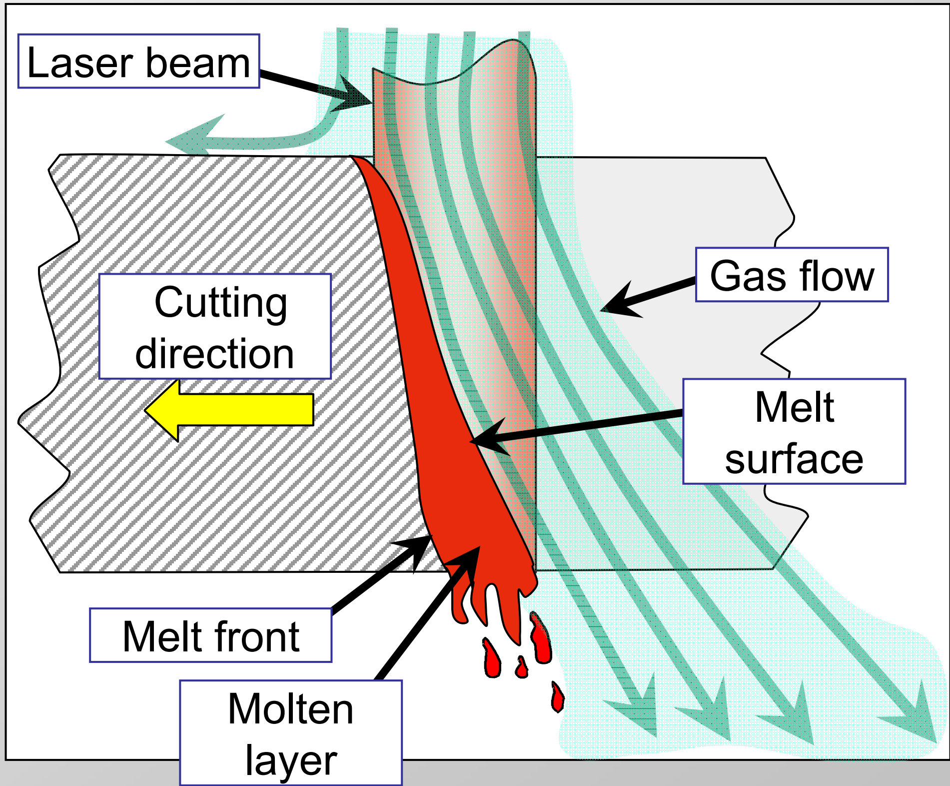


Cutting without evaporation

Cutting with evaporation

Cut front theory

- Limitation of cutting rate in classical laser cutting:
  - Heat input?
  - Melt removal?

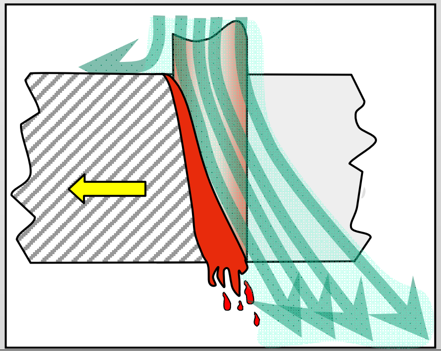


Cut front theory

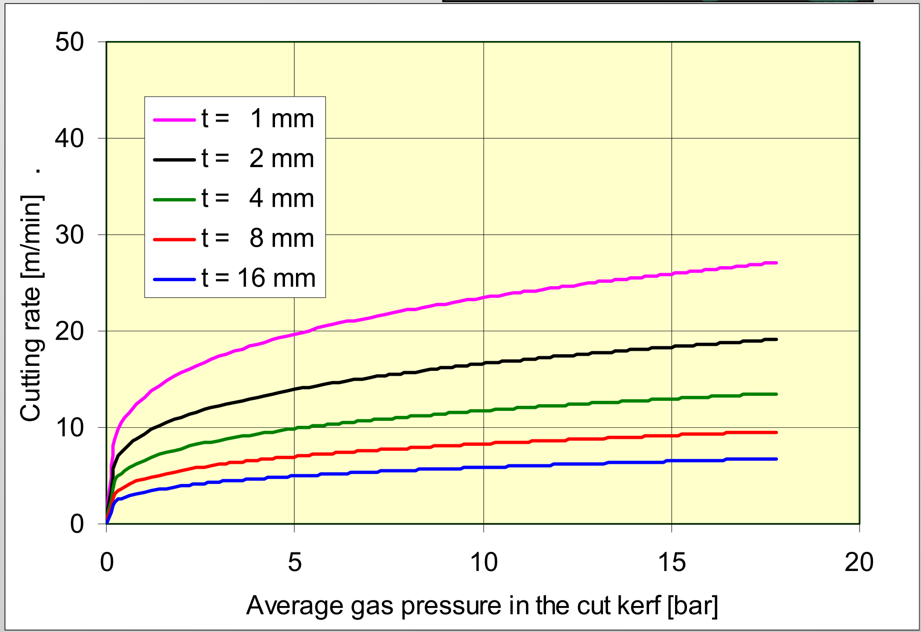
- Melt flow limitation

  Simple calculation:

$$V_{MELT} = \sqrt{\frac{(T_E - T_M)K_M\sqrt{P}}{((T_M - T_0)C_p + L_M)\sqrt{\rho^3}h\beta_B}}$$



T_0 is the room temperature
T_M is the melting temperature
T_E is the evaporation temperature
K_M is the thermal conductivity of the melt
C_p is the heat capacity of the solid metal
L_M is the latent heat of fusion
ρ is the density of the metal
β_B is the cut front angle in the bottom of the cut front
P is the average cutting gas pres-sure in the cut kerf
h is the material thickness



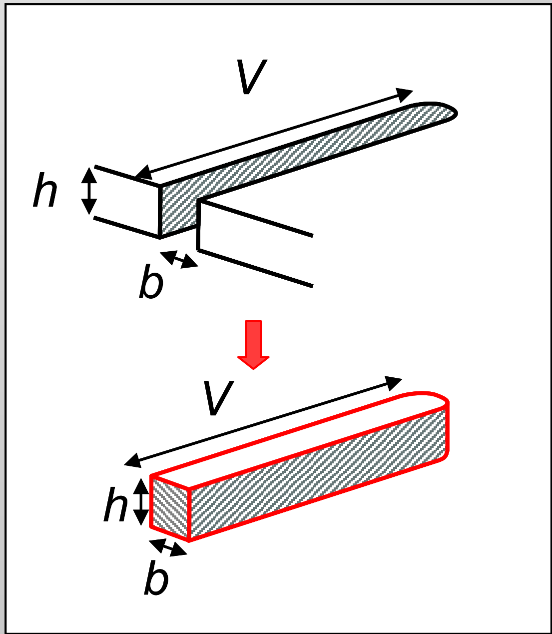
Cut front theory

- Power limitation

Energy balance:

$$V_I = \frac{\zeta\, \eta\, W}{h\, b\, \rho\left(\left(T_M - T_0\right)C_p + L_M + (1-\xi)\left(T_A - T_M\right)C_L + \xi\left(\left(T_E - T_M\right)C_L + L_E\right)\right)}$$

η is the fraction of the laser power absorbed in the cut kerf
ς is the melting efficiency
W is the laser power
ξ is the fraction of material removed as vapour
T_A is the average temperature of the ejected melt
T_0 is the room temperature
T_M is the melting temperature
T_E is the evaporation temperature
C_p is the heat capacity of the solid metal
L_M is the latent heat of fusion
ρ is the density of the metal
C_L is the heat capacity of the molten material
L_E is the latent heat of evaporation

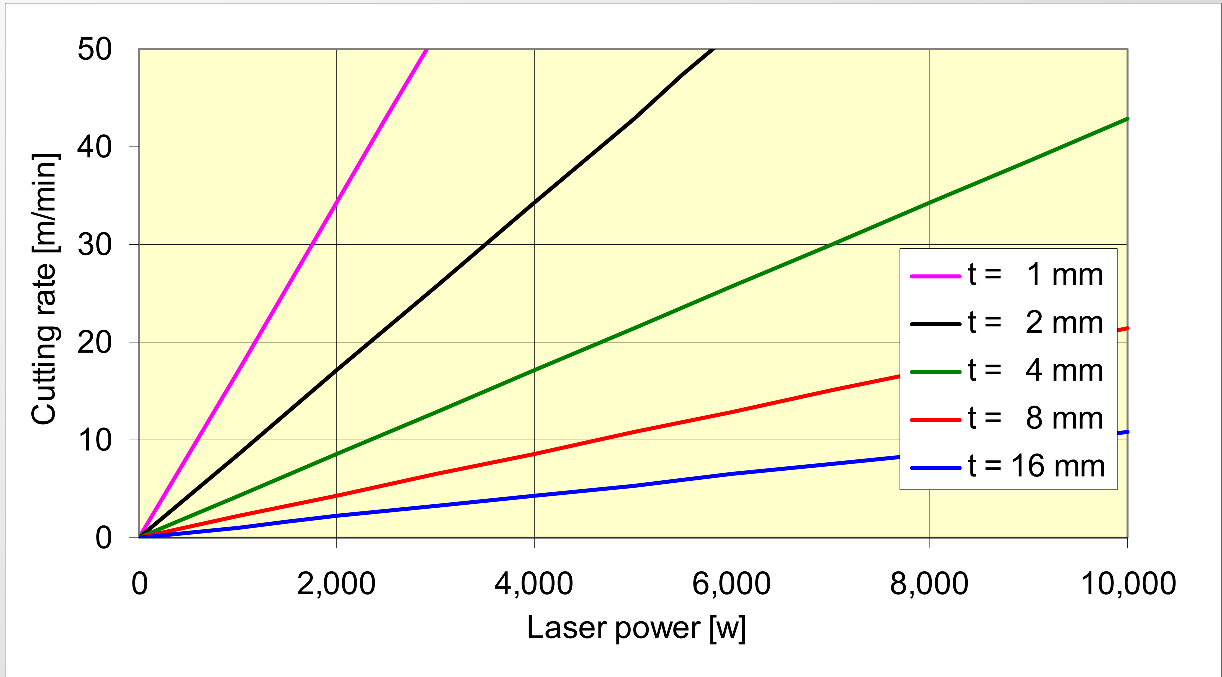


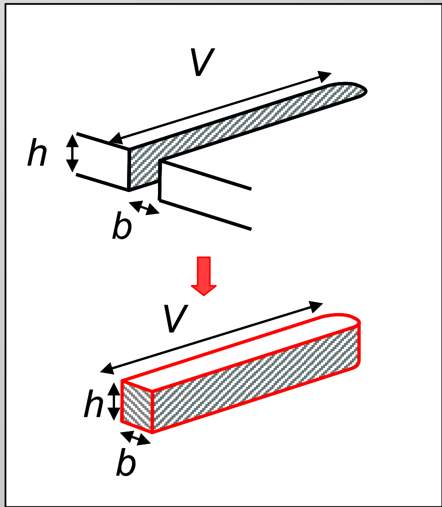
Cut front theory

- Power limitation

Energy balance:

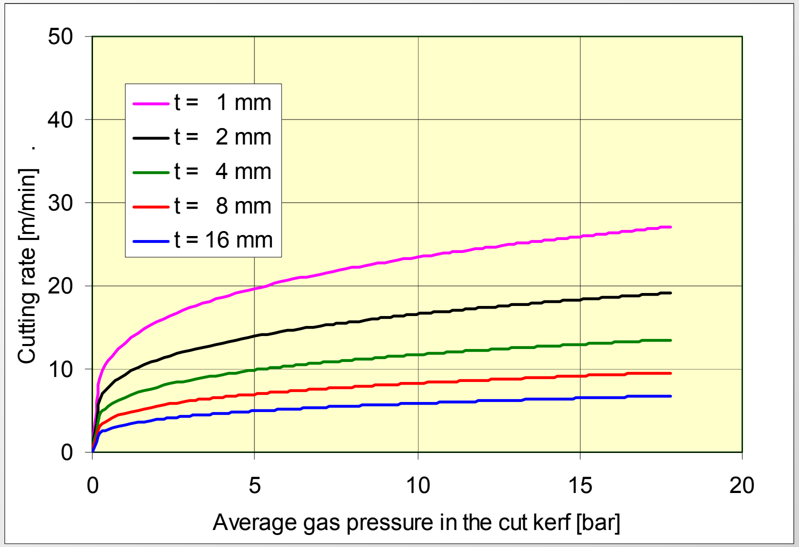
$$V_I = \frac{\zeta \eta W}{h\, b\, \rho((T_M - T_0)C_p + L_M + (1-\xi)(T_A - T_M)C_L + \xi((T_E - T_M)C_L + L_E))}$$



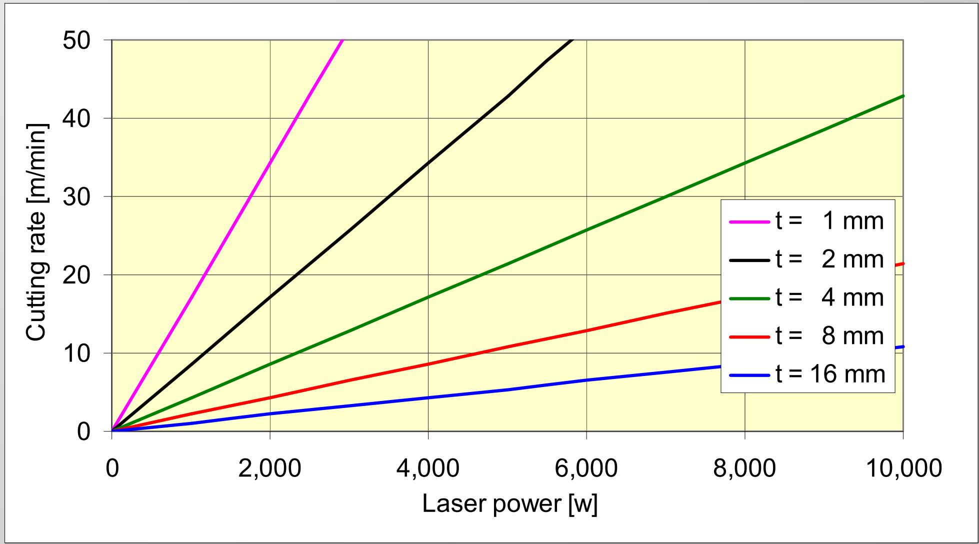


Cut front theory

- Classical laser cutting is normally limited by melt flow and not by power



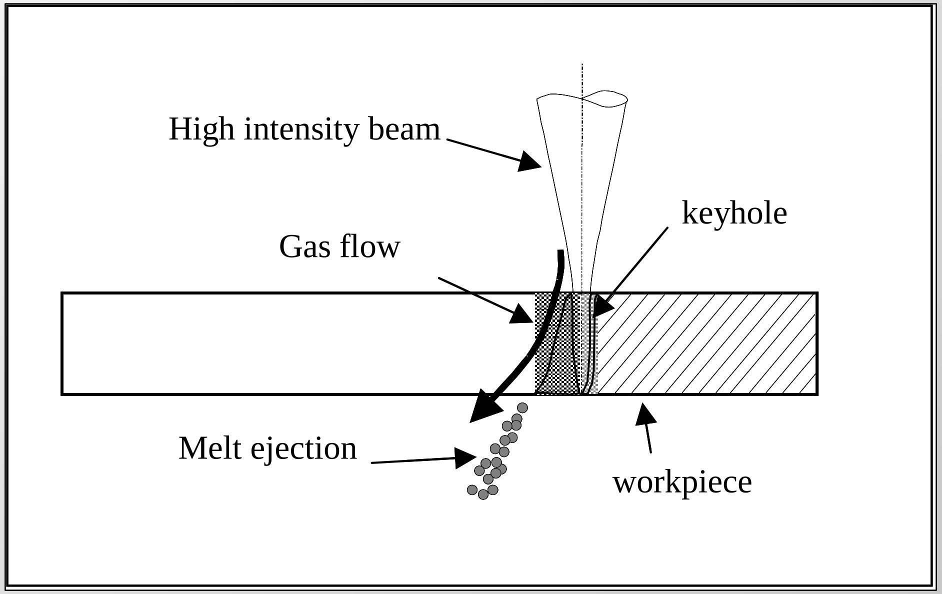
Melt flow limitation



Power limitation

Cut front theory

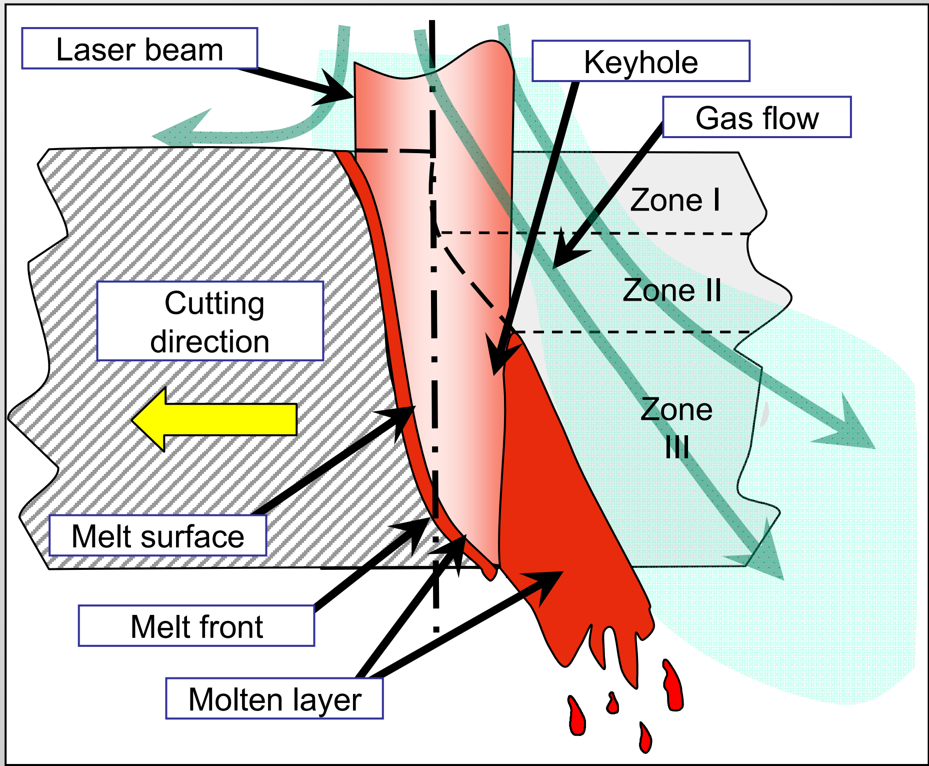
- Keyhole laser cutting



  - First demonstrated by Petring et al. in sheet metal CO_2-laser cutting
  - Requires high intensity through the keyhole
  - For CO_2-laser cutting – plasma shielding is limiting the application to thin sheets

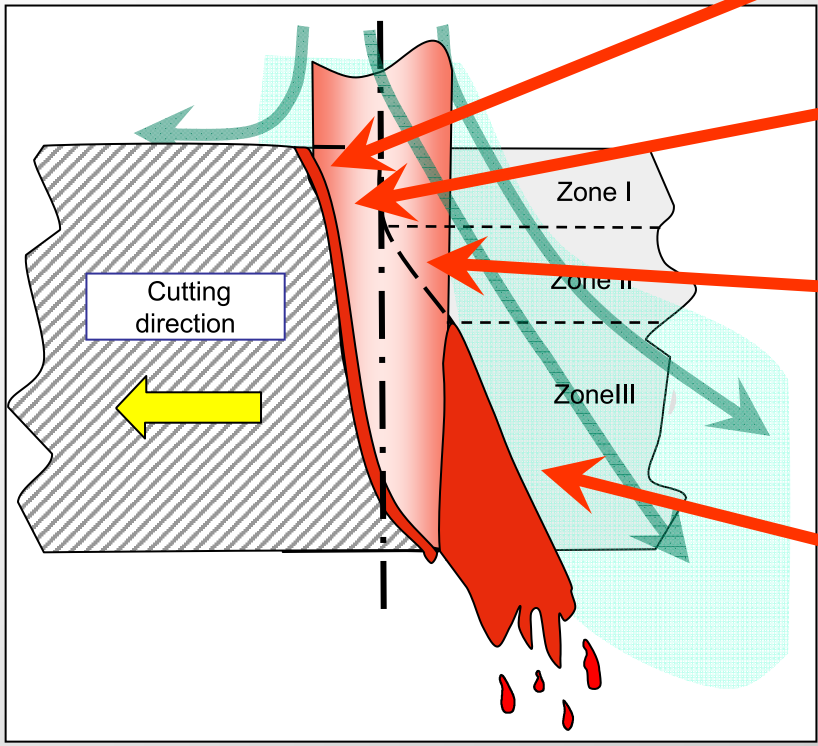
Cut front theory

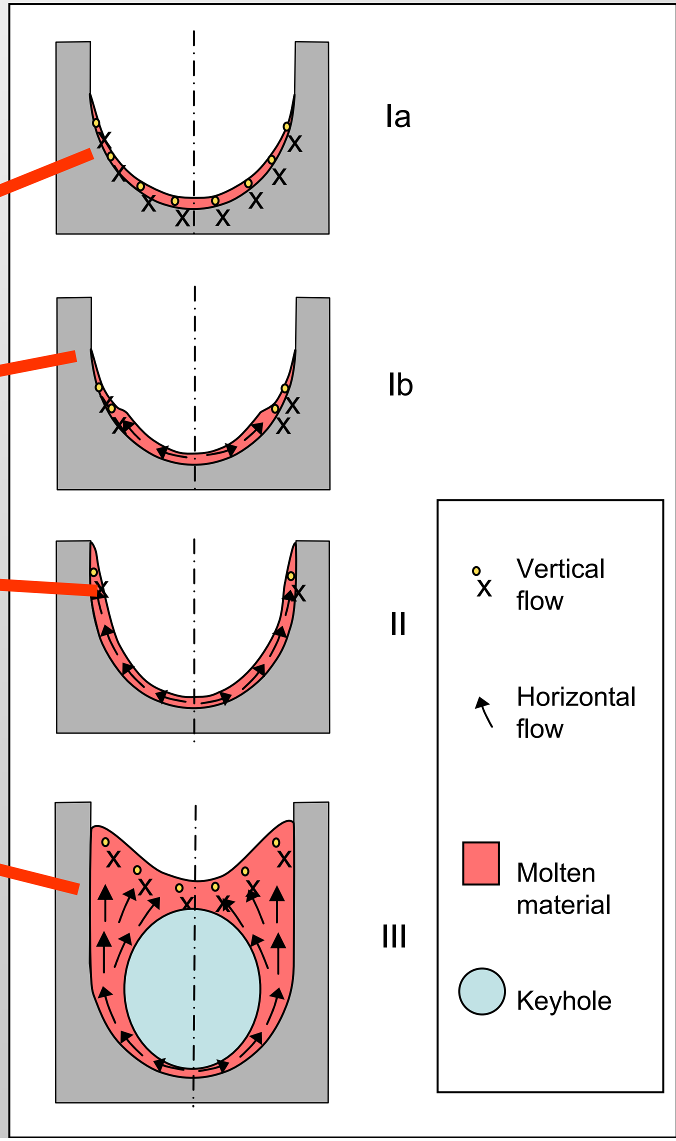
- Keyhole laser cutting
  - High intensity
  - Suitable wavelength
    - Fibre laser
    - Disc-laser



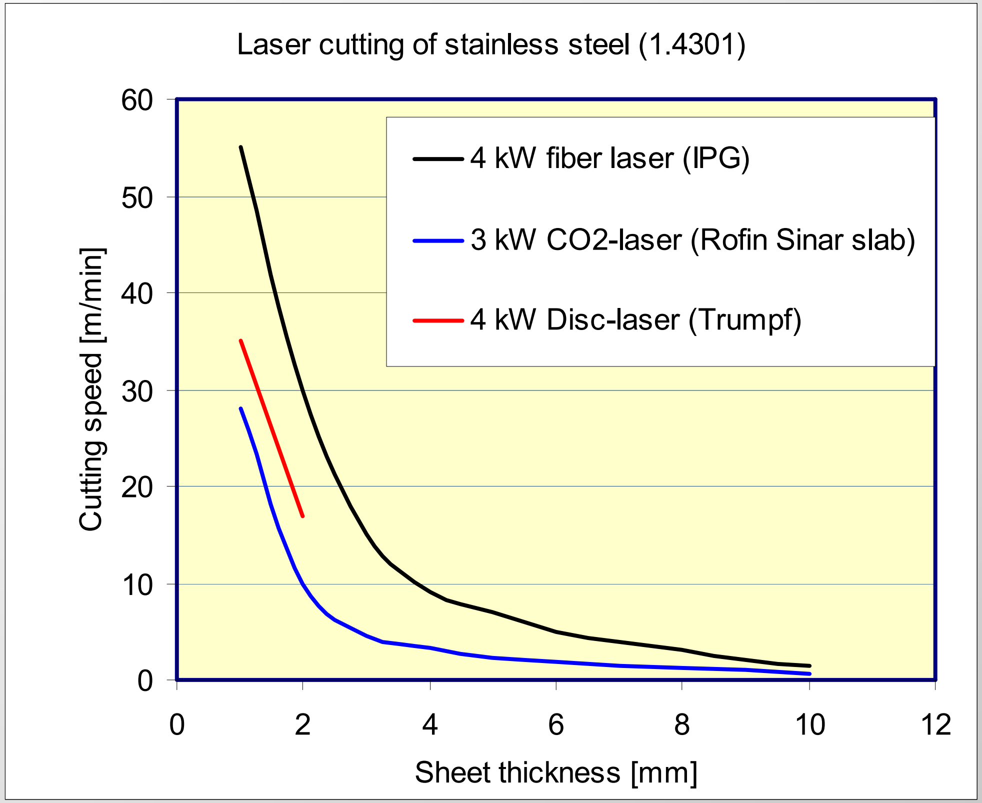
Cut front theory

- Flow patterns in keyhole laser cutting



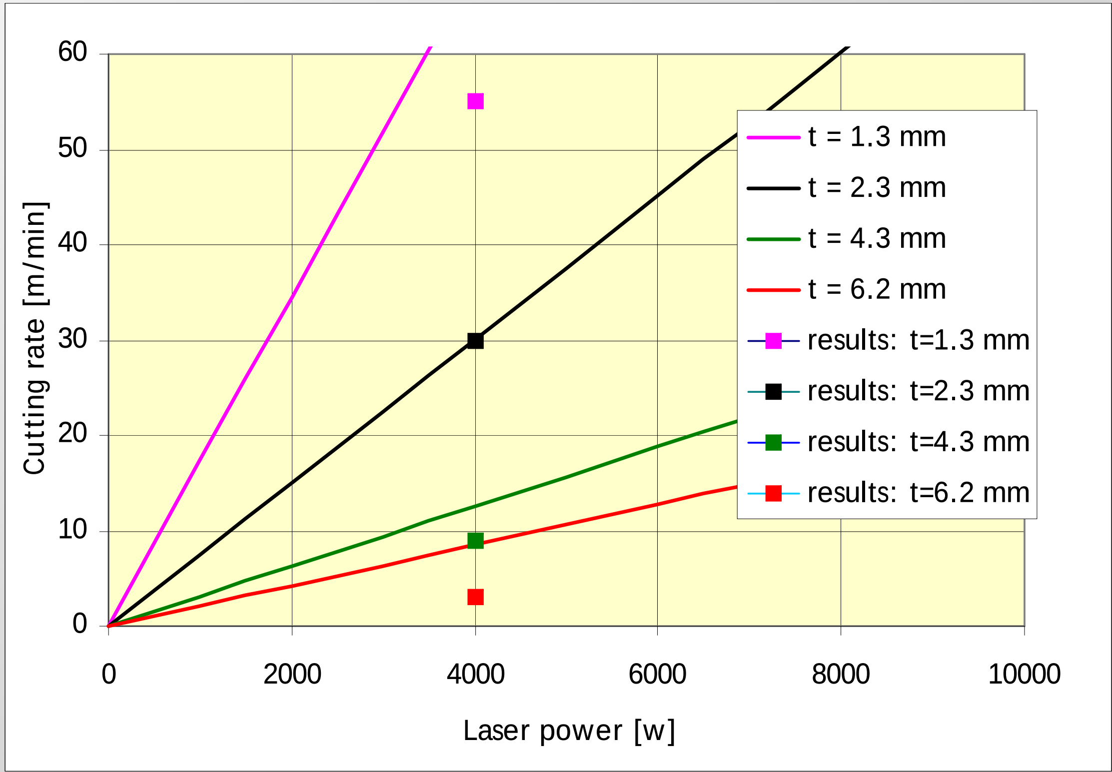


Cutting results



Cutting results

- Fiber laser results close to energy input limit.
  - Stainless steel
  - Graphs:
    Theoretical calculations
  - Points:
    Experimental results



Cutting results

- Fibre laser fine cutting:

- Single mode laser beams might be too narrow
- Process optimization critical with single mod beams

What next??

- Fibre laser development
- System integrators
- Technology development

What next??

- Fibre laser development:
  - Now: Only one supplier of kW-lasers
  - The future: Lets see what the Laser fair in Munich will show!

What next??

- System integrators
  - Welding:
    - ”One-of-the-kind” market
  - Cutting:
    - Mass produced standard systems

Systems integrators have the key to market

What next??

- Technology development
  - Throughout the world, laser scientists and application engineers are running.
  - Attractive results are allready demonstrated – further technological developments are certainly possible.