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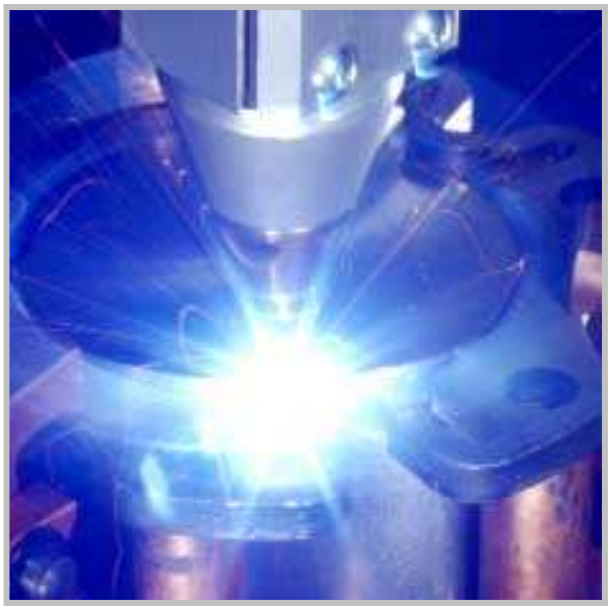
The Basics of Lasers and Laser Welding & Cutting



Tim Morris
Technical Sales Manager
TRUMPF Inc., Laser Technology Center

Agenda

1. **Basics of lasers**
2. **Basics of laser welding**
3. **Summary**

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Advantages of laser welding

- **Flexibility …**

  > beam manipulation (beam switching and sharing)

  > variety of product geometries and materials

  > ease of back-up (especially YAG)

- **Often faster than other techniques ...**

  > high power density weld process

  > high laser uptime (>98%)

- **Cost savings ...**

  > high productivity

  > reduction of scrap and re-work

  > reduction of manual labor

  > reduction of component material and weight

  > can eliminate secondary processes

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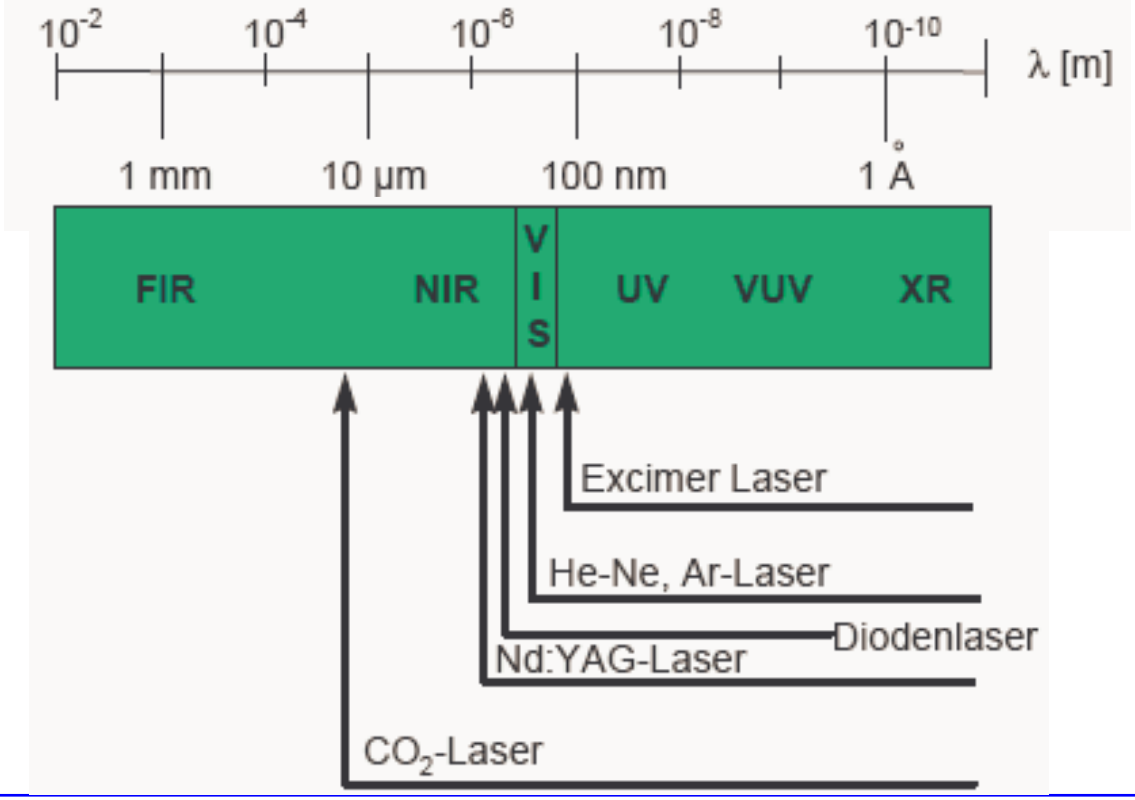
Laser basics

- LASER
  - **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

- Active Laser Media
  - **Nd:YAG (Rod Laser)**
    - **N**eo**d**ymium **Y**ttrium **A**luminum **G**arnet
  - **Yb:YAG (Disk Laser)**
    - **Y**tter**b**ium **Y**ttrium **A**luminum **G**arnet
  - **CO_2 (Gas Laser)**

Laser basics

- **Nd:YAG (Rod Laser) λ = 1064 nm**
- **Yb:YAG (Disc Laser) λ = 1030 nm**
- **CO_2 (Gas Laser) λ = 10600 nm**



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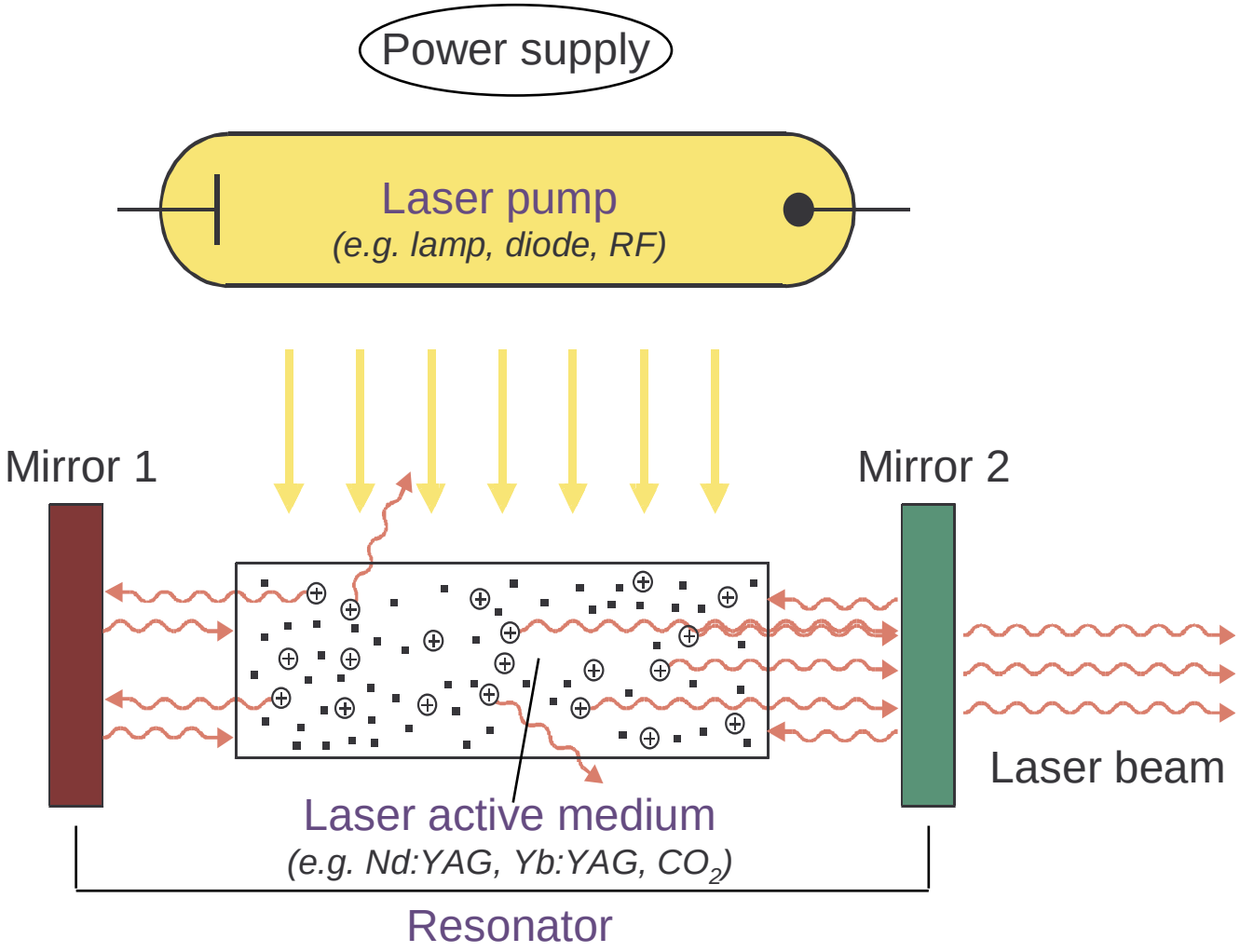
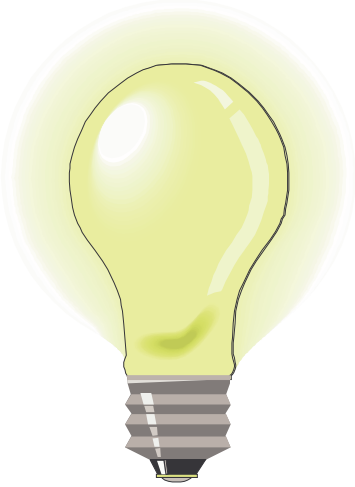
Laser basics

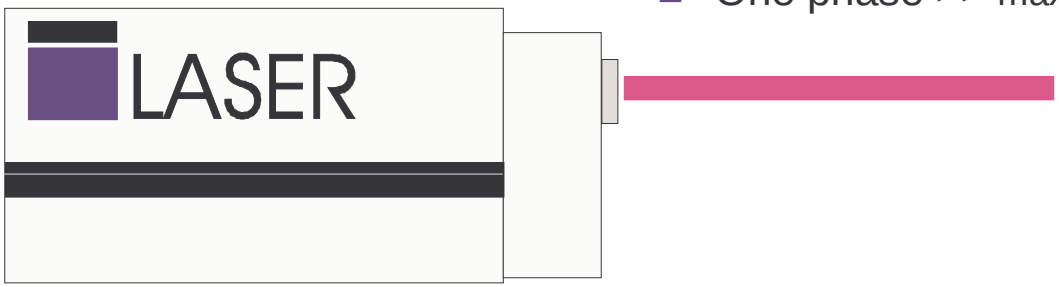


Characteristics of laser light

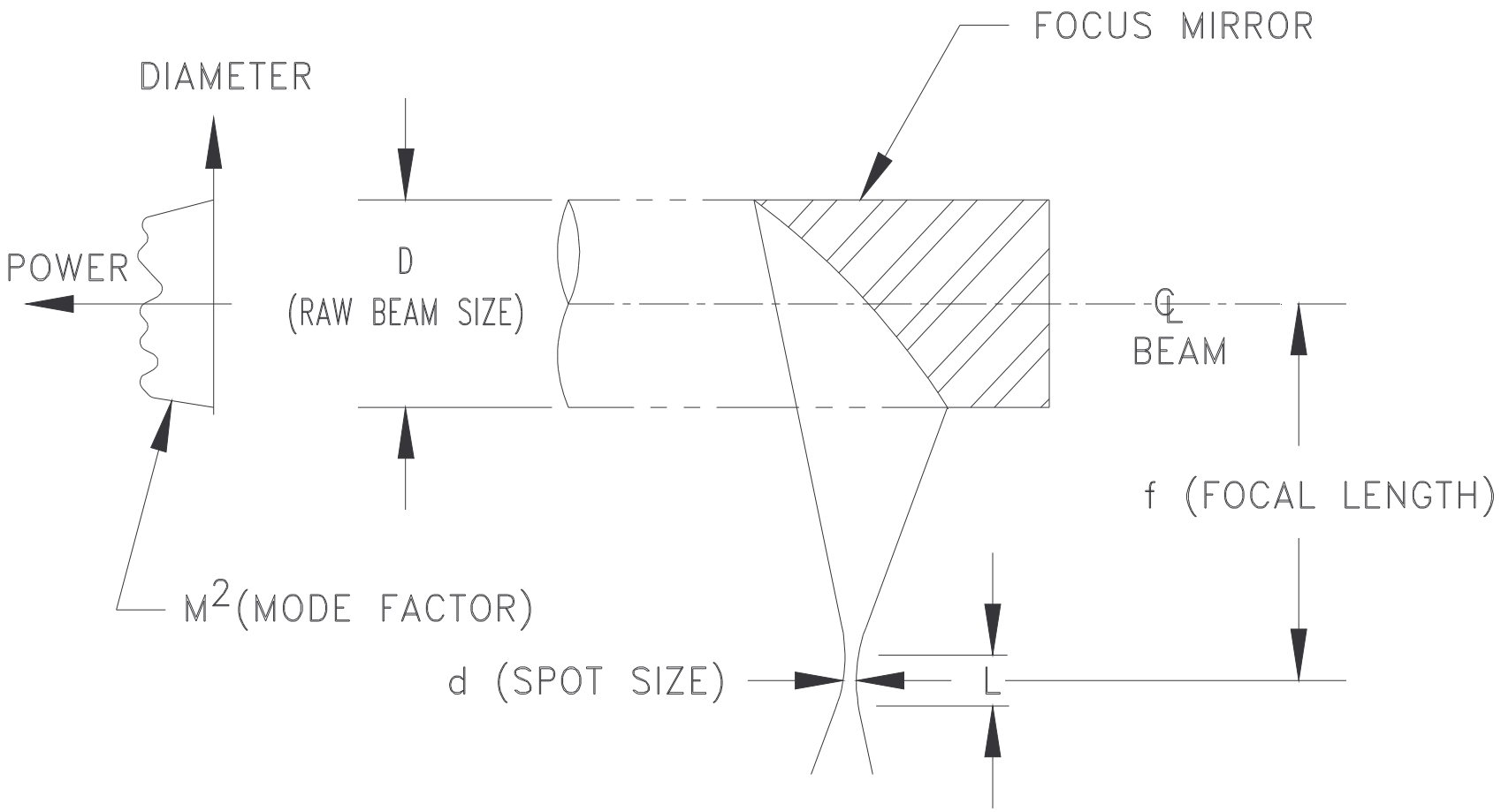


- Many colors
- Many directions
- Many phases

- One color >> select laser for application
- One direction >> can capture all the beam energy
- One phase >> maximum energy at workpiece



Spot size – CO_2



$$d_f = M^2(4\lambda f/\pi D)$$

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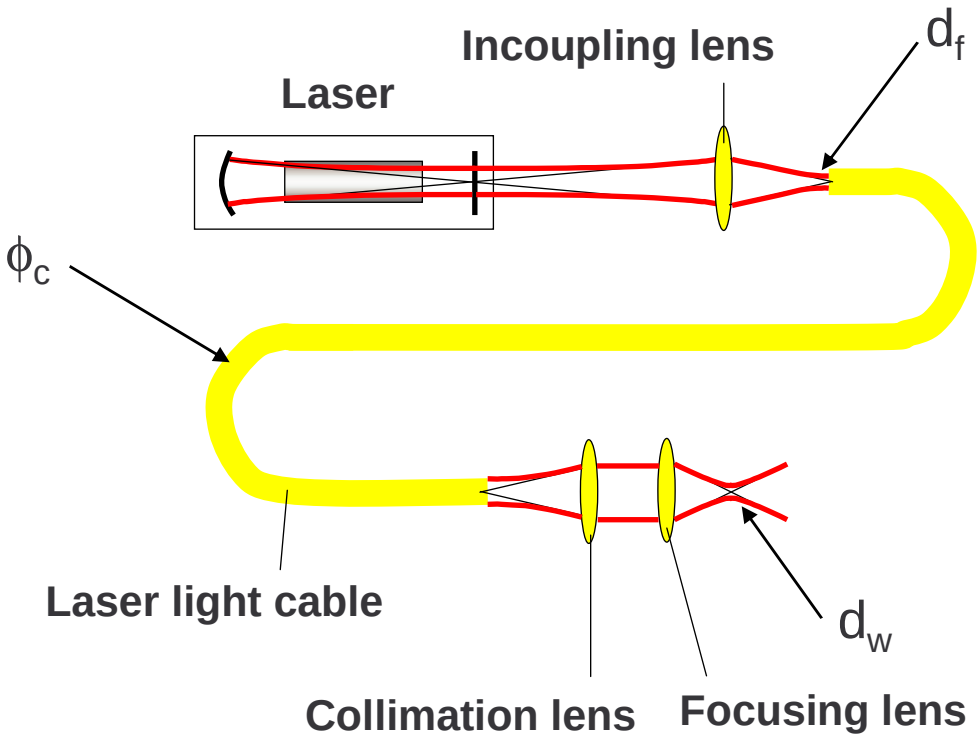
Spot size - YAG

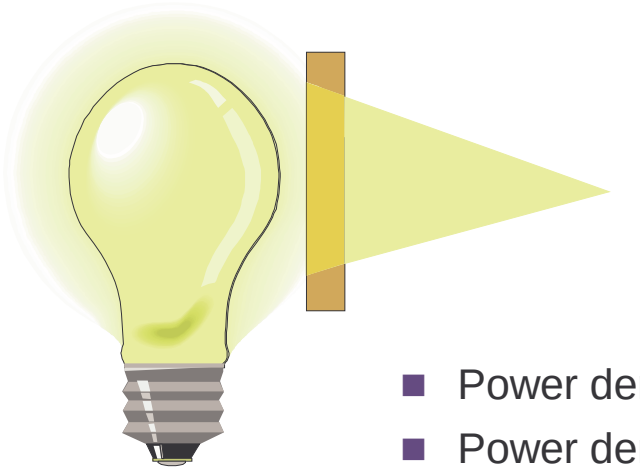


$$d_f = M^2(4\lambda f/\pi D)$$

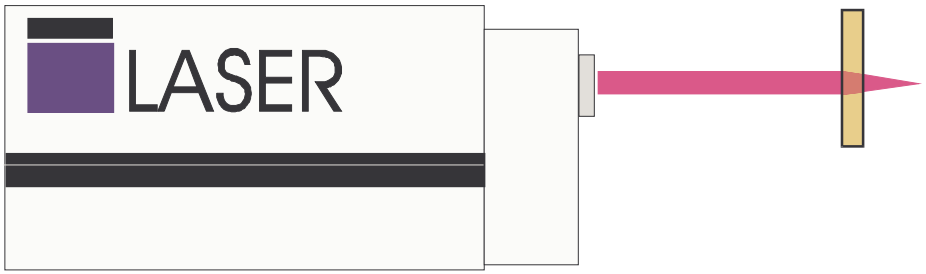
$$d_f = 3BQ(4\lambda f/\pi D)$$

$$d_w = \phi_c(f/ f_c)$$

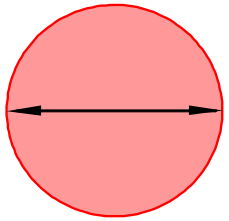
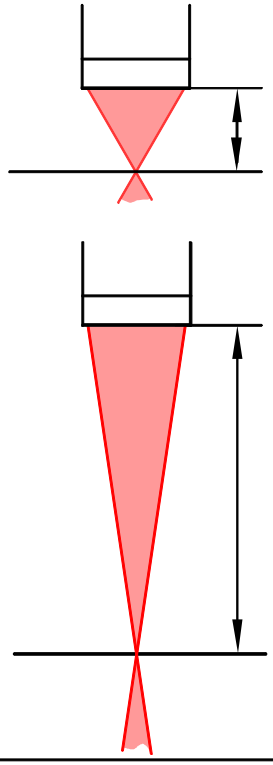
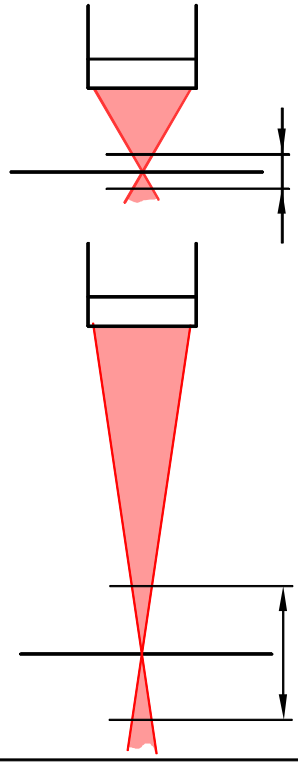
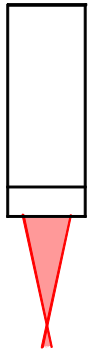
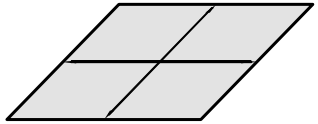
Power density



- Power density = power per unit area
- Power density of an unfocused 6 kW CO_2 HQ laser is about 1,000 W/cm^2
- Power density of a focused 6 kW CO_2 laser (f200mm) is about 50,000,000 W/cm^2



Effects of Beam Quality

Beam-quality	Spot-diameter	Working distance	Depth of focus	Optics	Working area of a scanner optics
25 mm*mrad (LP rod)					
4-8 mm*mrad (DP disk)					
	With same Focussing optics	With same Spot diameter			

Focal length

Key advantages of short focal length:

- Faster weld speed
- Less heat input

Key advantages of long focal length:

- Longer depth of focus
- Further from weld spatter & smoke

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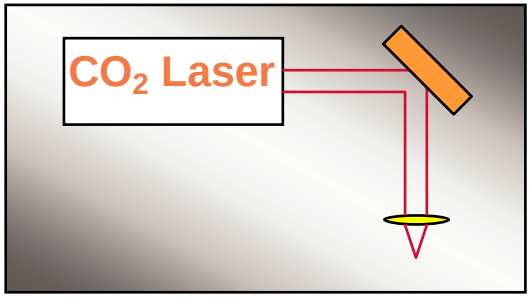
CO_2 vs. YAG

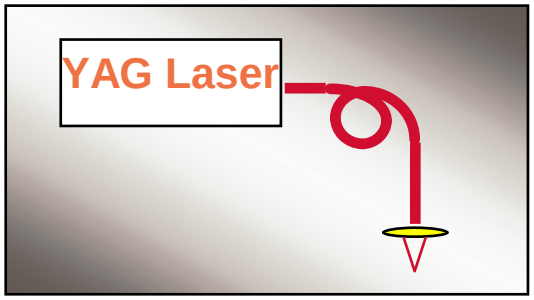
CO_2 considerations ...



- Higher powers
- Better focusability
- Higher weld speeds on materials non-reflective to CO_2 wavelength
- Deeper weld penetration on materials non-reflective to CO_2 wavelength
- Lower capital and operating costs
- Less expensive safety precautions

CO_2 vs. YAG

YAG considerations ...



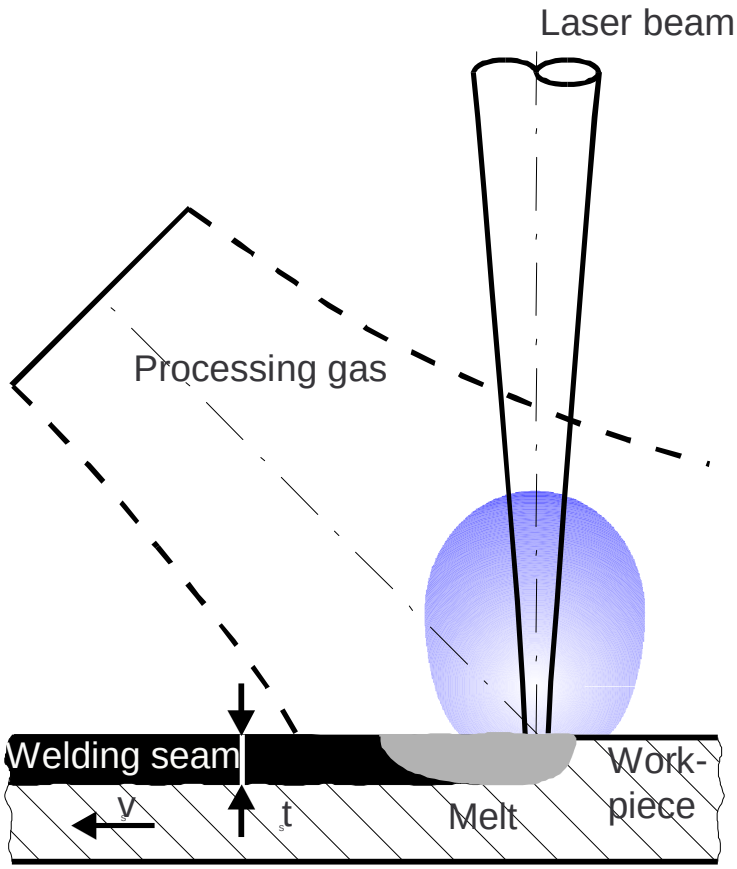
- Fiber optic beam delivery
  (esp. robotic applications)
- Materials reflective to CO_2 wavelength can often be welded
- Easy beam alignment, beam switching and beam sharing
- Argon can be used for shield gas (plasma suppression not required)
- Long and varied fiber lengths with no effect on process
- High peak powers with high energy per pulse

Heat conduction welding

Description
Heating the workpiece above the melting temperature without vaporizing

Characteristics
- Low welding depth
- Small aspect ratio
- Low coupling efficiency
- Very smooth, highly aesthetic weld bead

Applications
Laser welding of thin workpieces like foils, wires, thin tubes, enclosures, etc.



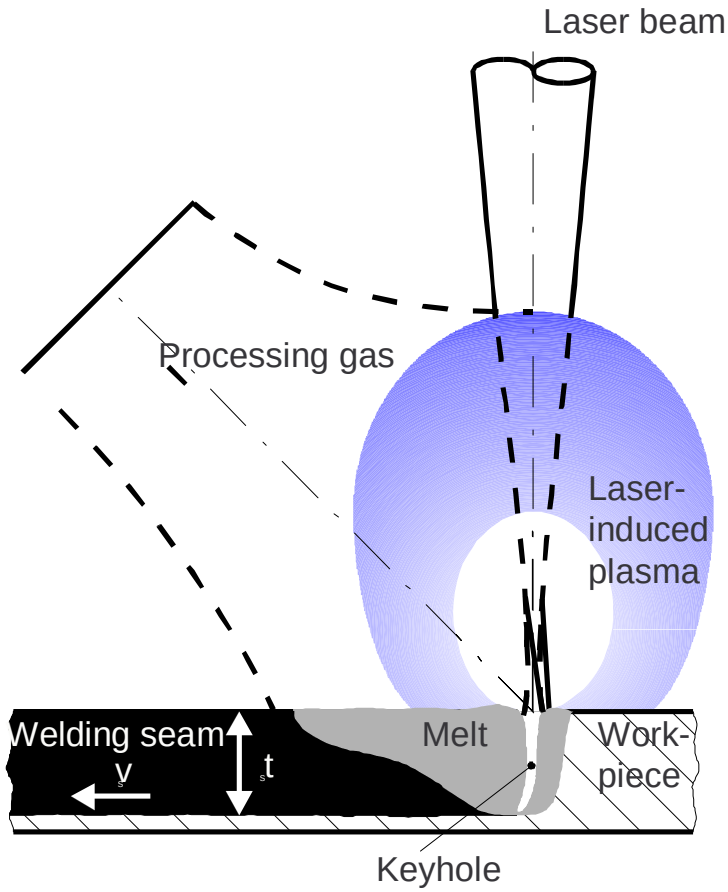
Keyhole welding

Description

Heating of the workpiece above the vaporization temperature and forming of a keyhole

Characteristics

- High welding depth
- High aspect ratio
- High coupling efficiency



Cutting

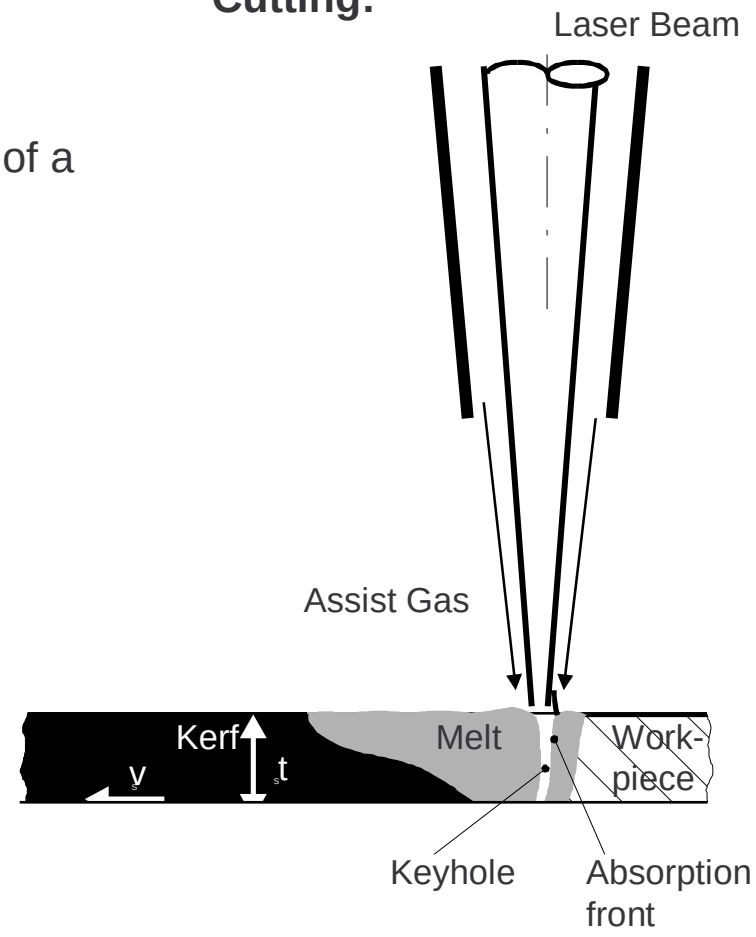
Description

Heating of the workpiece above
the evaporating temperature and creation of a
keyhole because of the ablation pressure
of the flowing metal vapor,
power density of 10^5 - 10^6 W/cm^2

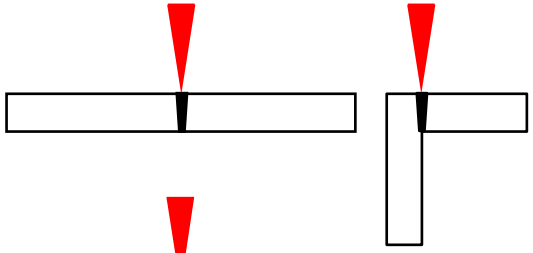
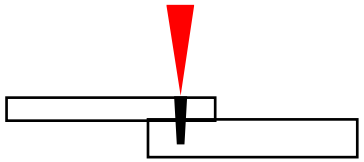
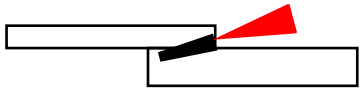
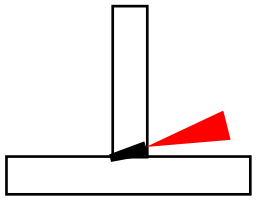
Characteristics

- High cutting depth
- Fine cutting precision
- Very low heat input

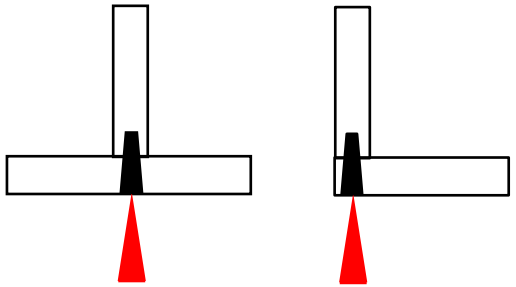
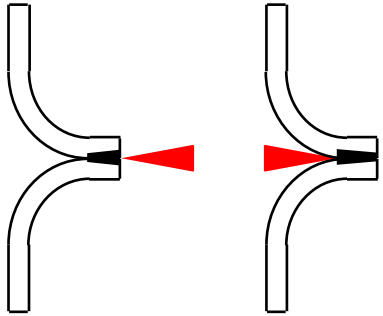
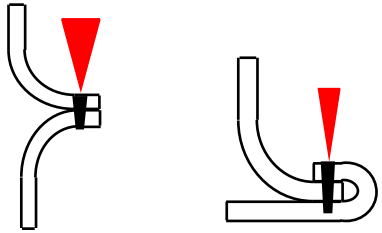
Cutting:



Seam and joint types

Name	Example	Characteristics
Seam weld on butt joint		+ weld fusion area - positioning tolerance
Lap weld on lap joint		+ positioning tolerance - weld fusion area
Fillet weld on lap joint		+ weld fusion area - positioning tolerance
Fillet weld on T-joint		+ weld fusion area - positioning tolerance

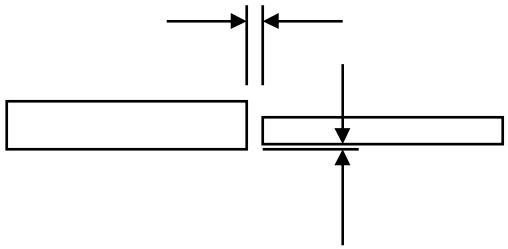
Seam and joint types

Name	Example	Characteristics
Lap weld on T / border joint		+ positioning tolerance - weld fusion area
Seam weld on flange		+ weld fusion area - positioning tolerance
Lap weld on formed seam		+ positioning tolerance - weld fusion area

Seam and joint tolerances

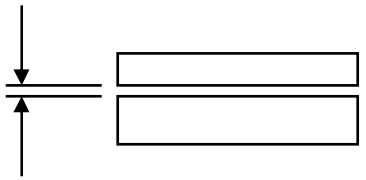
Butt joint configuration:

- Gap: 3-5% thickness of thinnest sheet
- Offset: 5-12% thickness of thinnest sheet



Overlap joint configuration:

- Gap: 5-10% thickness of thinnest sheet



Why is this general guideline not absolute?

(What influences the amount of gap that can be bridged?)

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Laser Welding & Cutting

Examples

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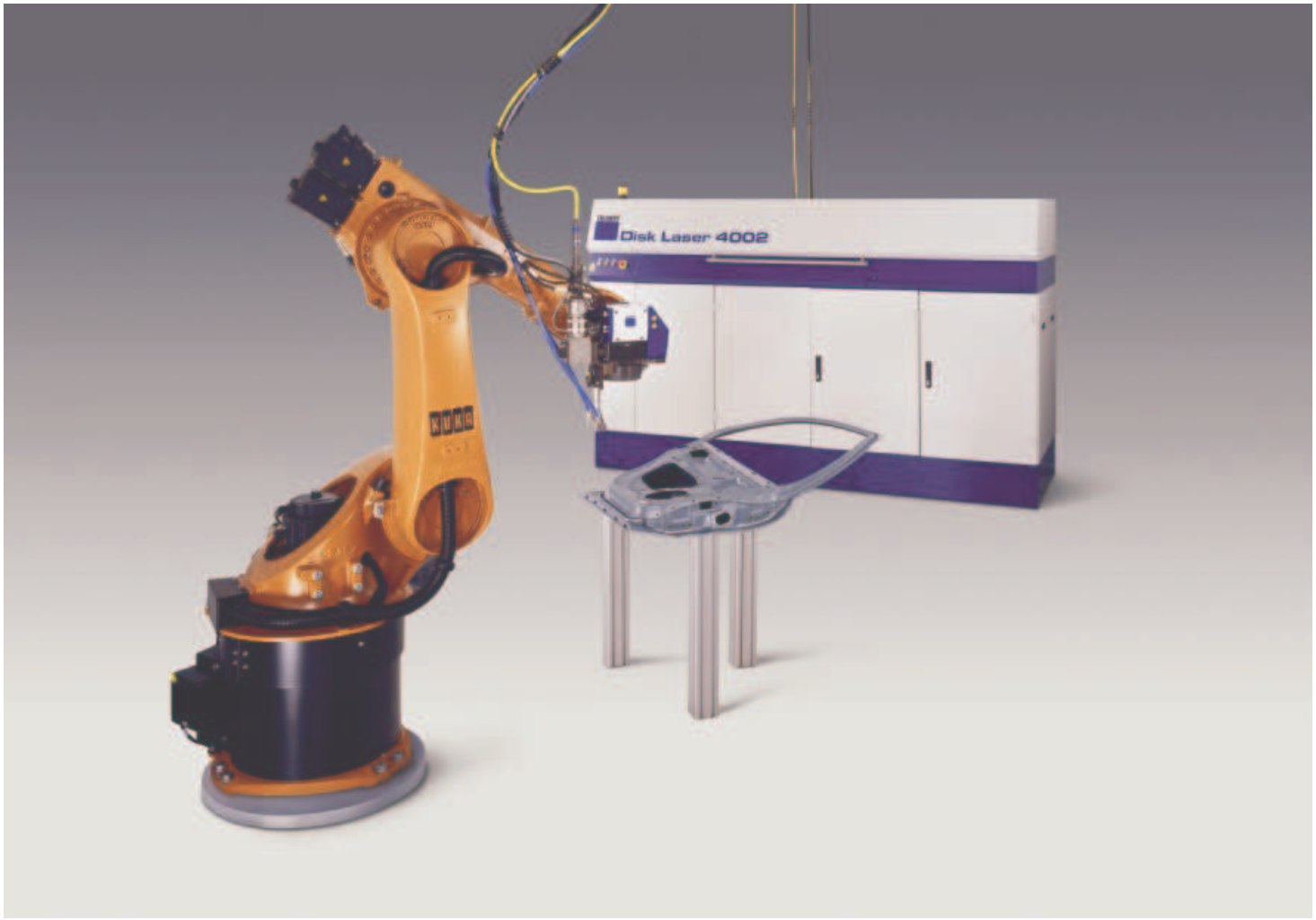
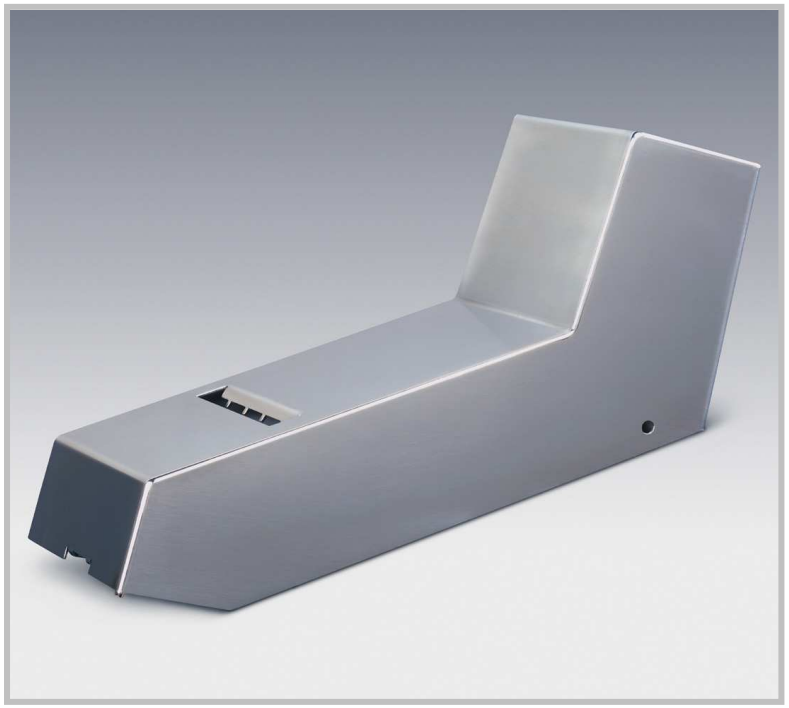
Remote welding with Disk Laser

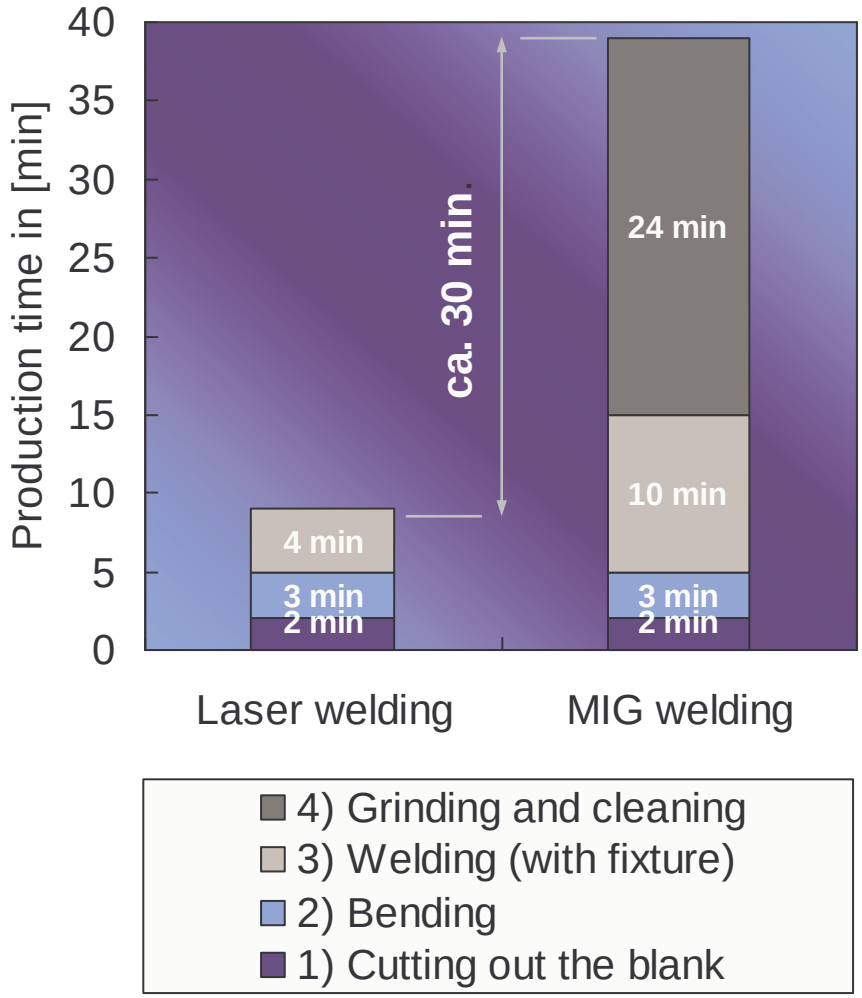


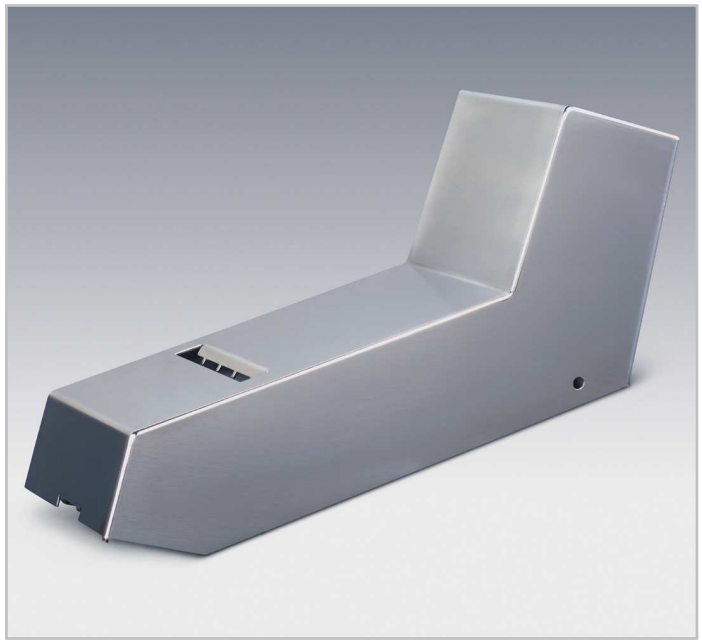
Register Enclosure



- Material
  - Stainless Steel
  - Thickness 0.040”
- Laser Welding Strategy
  - Heat Conduction Welding
  - Shield Gas He

Register Enclosure





- Example:
  Housing 16“x24“x10“

2. Elimination of Post Processing : OLYMPUS – Display Enclosure

Manual welding			
Welding time (manual 56 €/hour)		10 Min	9.33 €
Grinding (manual 48 €/hour)		24 Min	19.20 €
Sum			**28.53 €**
Laser welding			
Welding time (automated 140 €/hour)		4 Min	**9.33 €**
Incl. Load and un-load			
Straightening			Non
Grinding			Non
Savings			**19.20 €**
in %			**67%**

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Laser Welding in Sheet Metal Manufacturing

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3-D Laser Cutting

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Laser Welding

Keys to Success

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Outline

- Early involvement from production personnel
- Creating a laser champion
- Selecting partners for success
- Considering the ambient environment
- Design for maintenance and service
- The making of exceptional operators and maintenance personnel
- Commitment to training
- Not sparing the spares
- Conclusion

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Early involvement from production personnel

Include plant personnel early in the process

> relational and philosophical disconnect between engineering and plant personnel can result in implementation delays and reduced system operational efficiency

> Early involvement is the key to ...

- *ownership*
- *technology transfer*
- *acceptance*
- *integrating suggestions based on plant experience*

> In summary ...

- *involve*
- *lead*
- *listen*
- *expect great things*

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Creating a laser champion

Appoint plant laser champion

> not having a laser champion at the using plant can increase system downtime and reduce system operational efficiency

- **appointing a champion**

- **characteristics of a champion**
  - > *ideally a welding or mechanical engineer*
  - > *has an interest in laser technology*
  - > *will be around for awhile*
  - > *is teachable/trainable*
  - > *can teach others*

- **shepherding the champion**
  - > *instilling the vision*
  - > *provide and support key training*
  - > *enablement - authority and focus*

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The making of exceptional operators and maintenance personnel

Selecting and mentoring operators and maintenance personnel

> inappropriate selection of operators and maintenance personnel can increase system downtime and reduce system operational efficiency

- **selecting** (when allowed)
  - > *attitude*
  - > *aptitude*

- **training**
  - > *need to know how to safely operate and maintain the system in all "modes"*
  - > *need to know how components function*
  - > *need to know when the system is not operating at optimal performance*
  - > *laser training at using site vs. TRUMPF*
  - > *supplemented by laser champion and LSO (on-going)*

- **empowering**
  - > *proportional to mentoring and training*
  - > *proportional to attitude and aptitude*

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Commitment to training

Training of laser personnel

> inadequate and improper training of key laser personnel can increase system downtime and reduce system operational efficiency

- **commitment to training = commitment to quality**
- **training requires investment (time and money)**
- **it's more than just cranking out parts** *(safety, operator, maintenance, application, LSO, technology transfer, etc.)*

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Not sparing the spares

In-house spares

> inadequate appropriation of spare parts can increase system downtime and reduce system operational efficiency

- **“We’ll take care of that later.”**
- **the role of tele-diagnostics**

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Advantages of laser welding

- **Flexibility …**

  > beam manipulation (beam switching and sharing)

  > variety of product geometries and materials

  > ease of back-up (especially YAG)

- **Often faster than other techniques ...**

  > high power density weld process

  > high laser uptime (>98%)

- **Cost savings ...**

  > high productivity

  > reduction of scrap and re-work

  > reduction of manual labor

  > reduction of component material and weight

  > can eliminate secondary processes

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Conclusion

What I am NOT saying ...

- ignore economics and cost justification
- forget about the details of laser physics
- don’t bother with prototype parts and DOE’s
- underestimate the mechanical & electrical engineering considerations
- tooling and part fit-up are no big deal
- part cleanliness doesn’t matter

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Conclusion

What I am saying ...

- **continue to do all these things better than ever before**

- **re-emphasize and strongly consider these items …**
  - *involve key people from production personnel early in the process*
  - *create a laser champion at the using plant*
  - *select partners that have proved themselves – over and over again*
  - *consider the ambient environment*
  - *insure the issues of maintenance and service are not overlooked in the system design*
  - *be truly committed to training and mentoring operators and maintenance personnel*
  - *procure key spare parts before you need them*

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Thank you

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