LIMO
Lissotschenko Mikrooptik

1st international Workshop for project partners

Laser welding - a versatile process for the high performance production of polymeric components

15th March 2011, CRFI, Torino

POLY BRIGHT

SEVENTH FRAMEWORK PROGRAMME

Laser Sources for Laser Welding of Polymers – Technology of High Power Diode Lasers

LIMO Lissotschenko Mikrooptik GmbH
J. Meinschien

OUTLINE

LIMO – Company Overview

Principles of High Power Diode Lasers

Technology of Manufacturing High Power Diode Lasers

High Power Diode Lasers vs other Lasers

Applications of High Power Diode Lasers

High Power Diode Lasers for the POLYBRIGHT Project

LIMO
Lissotschenko Mikrooptik

www.limo.de

LIMO Lissotschenko Mikrooptik GmbH

1992
founded near Paderborn

1995
production launch at "Technologiezentrum Dortmund"

1998
market leadership: refractive micro optics

1999
new product line: diode laser systems

2001
facility expansion at Dortmund Wickede

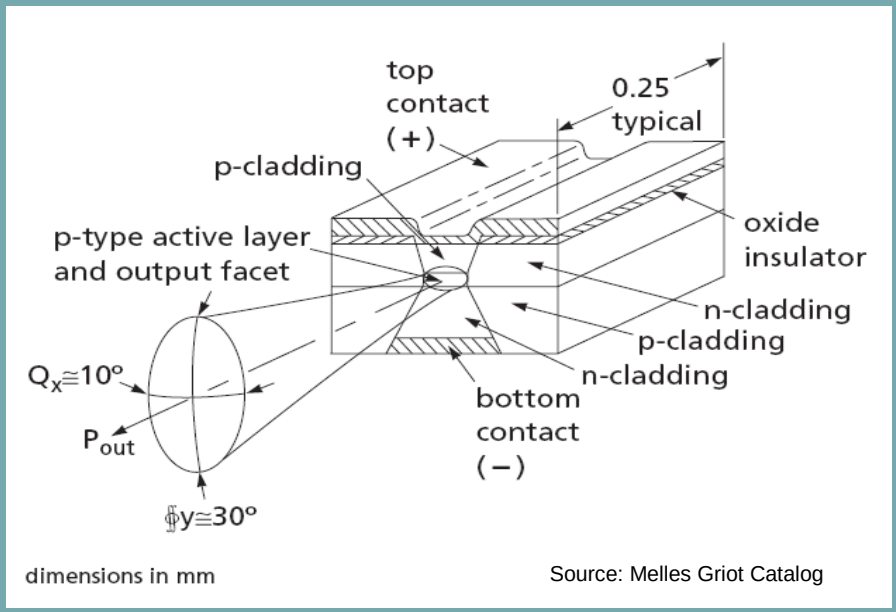
2004
- extension of laser and optics product lines: beam shaping systems, turn-key diode laser systems
- Applications Center

Innovationspreis ® der deutschen Wirtschaft
The World's First Innovation Award

TODAY
- 220 employees
- 10,000 m² co. owned floor space
- 2,000 m² clean room
- more than 300 patents
- profitable

Laser Diode Characteristics

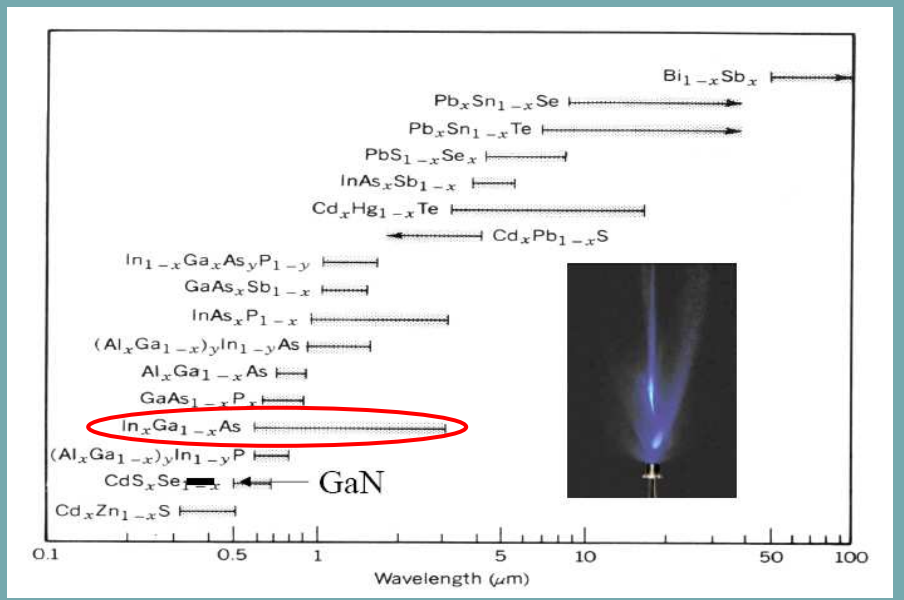
- Semiconductor as active medium, electrically pumped
- Light is emitted “fast” in vertical direction (FA) and “slow” in the horizontal direction (SA) for high power edge emitter



Source: Melles Griot Catalog

Typical values:
l=1µm, w=100µm, pitch=500µm
Divergence fast axis: 30°,
Divergence slow axis: 10°

Laser diodes cover a wide spectral range



LIMO
Lissotschenko Mikrooptik

www.limo.de

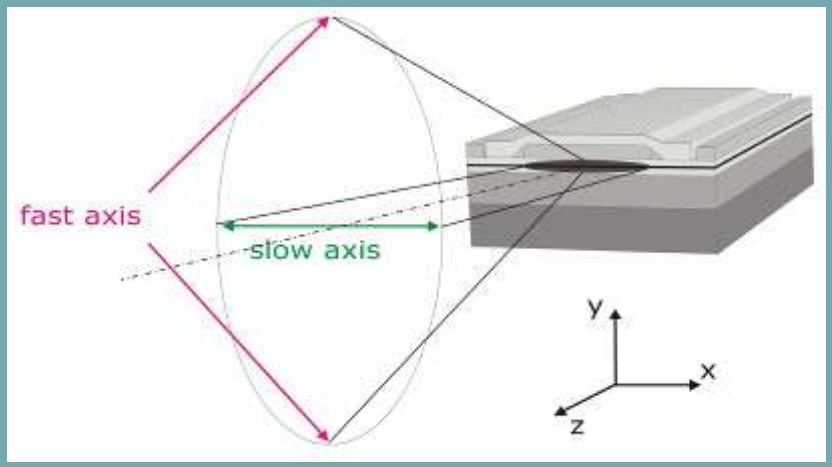
Beam Shaping for High Power Diode Laser

refractive micro lens (arrays)

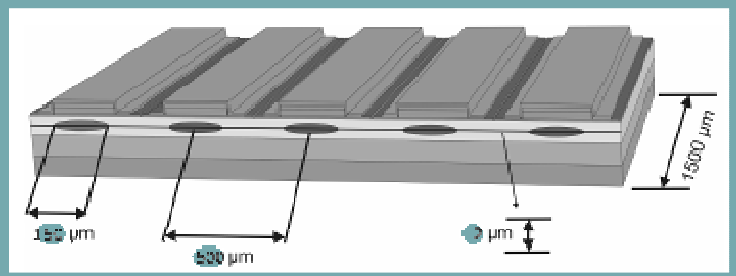
→ high efficiency , high transmission

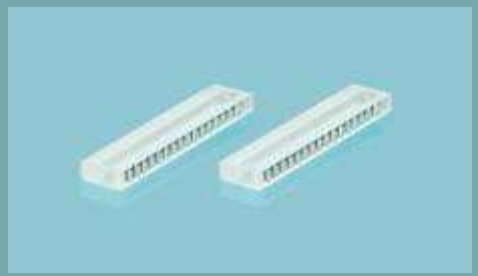
diffraction limited beam shaping for optimum brightness

→ conservation of beam parameter product



crossed
acylindrical lenses
for
asymmetric beam
of single emitter

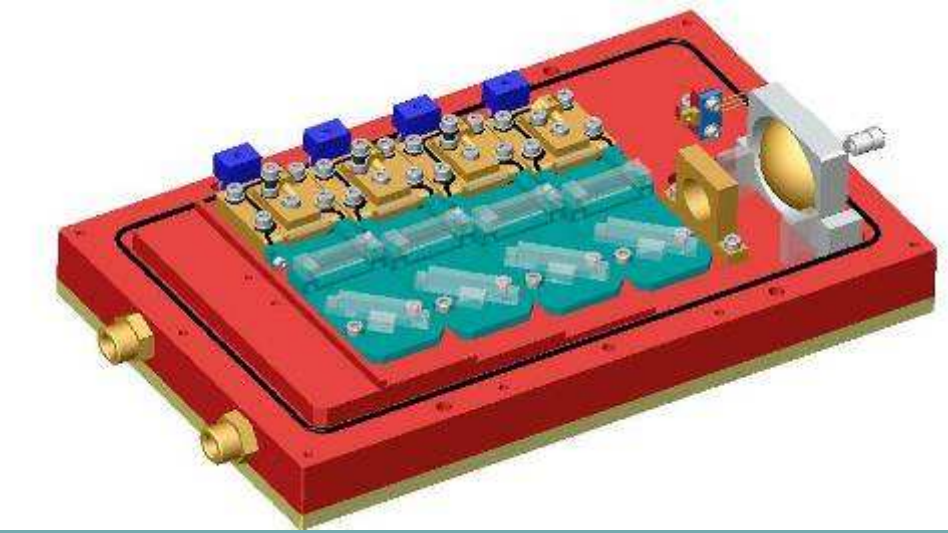


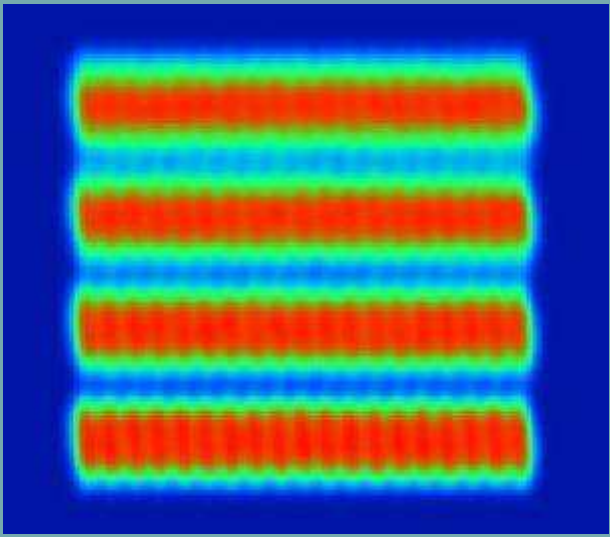


lens arrays
for
arrays of emitters

Power Scaling for High Power Diode Laser

- Geometric Arrangement of Emitters
  - Singe Emitters, Multi-Single-Emitters
  - Bars, Stacks
- Geometric Arrangement of Beams
- Polarization Coupling, Wavelength Coupling





Configurations of High Power Diode Lasers

	Emitter Brightness	Overall power per device	Reliability	Relative size	Power per linear length of device	Costs ($/W)
Single Emitter	++	-	++	o	-	-
Bars passively cooled	o	o	+(+)	-	-…o	o…+
Bars MCC standard	o	+	-	+	+	+
Bars MCC improved	+	++	-….+	++	++	-

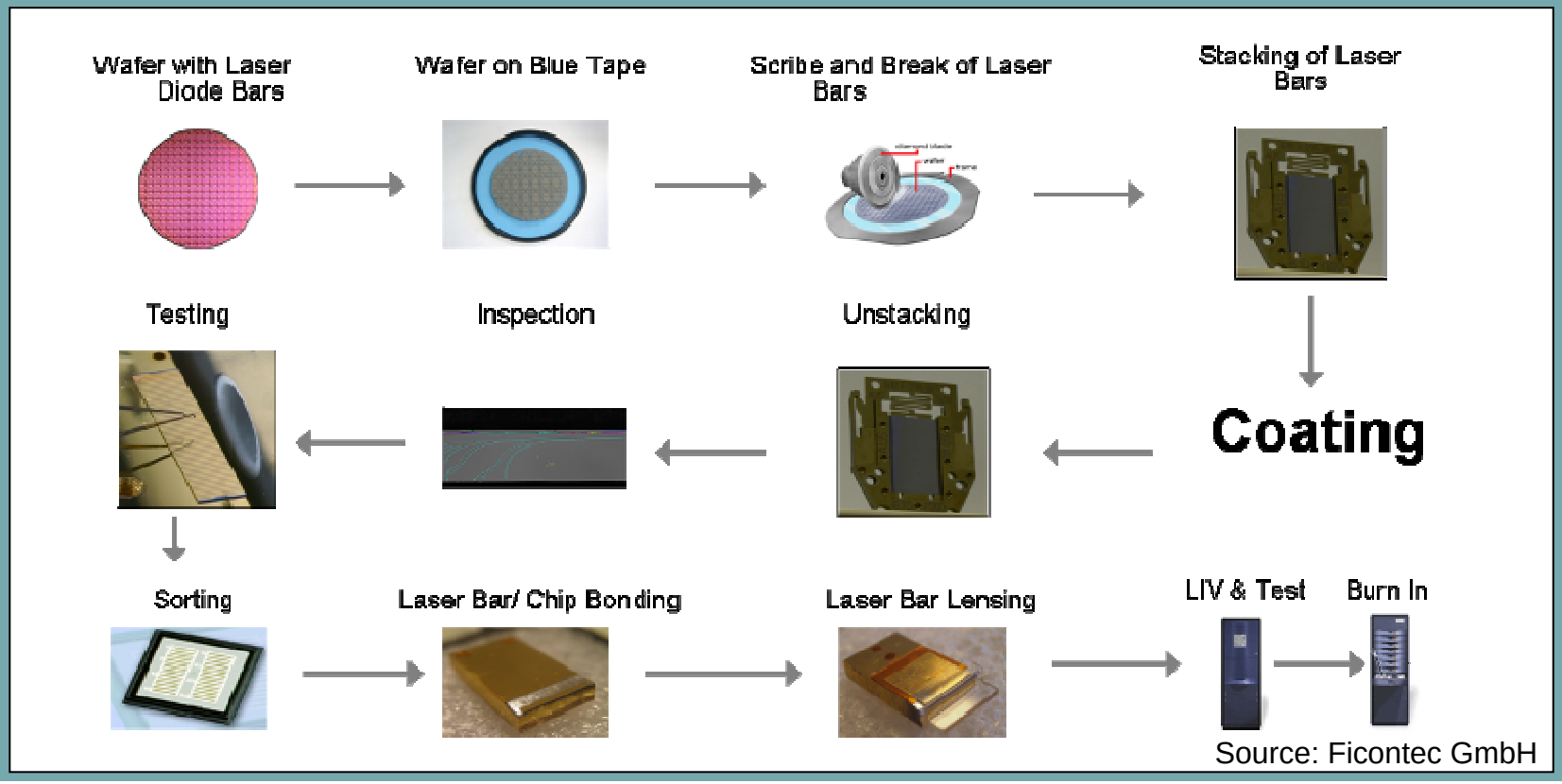
No all over superior, especially if costs and size are critical

First choice varies with applications and boundary conditions

Manufacturing of High Power Diode Laser

highly automated production steps enable

- large number of units
- high and uniform quality
- competitive cost structure



Source: Ficontec GmbH

LIMO
Lissotschenko Mikrooptik

www.limo.de

Manufacturing of Laser Diode Modules at LIMO

Proprietary process for producing refractive micro optics

Accurate alignment and mounting of beam shaping elements (lenses, mirrors)
for high efficient and high brightness laser beams (fibre coupled or free beam)

High Power Diode Lasers vs other Lasers

No brightness converter
- + cost
- + electro-optical efficiency
- - brightness and beam quality

Directly eletrically pumped
- + easy modulation

Relatively simple and rugged resonator design (Fabry-Pérot)
- + no mirror alignment
- - low coherence
- - large spectral width

LIMO
Lissotschenko Mikrooptik

www.limo.de

Advantages of High Power Diode Lasers

High electro-optical efficiency
- up to 60% on emitter level
- 25-50% on system level (wall plug efficiency)

Wide range of available wavelengths
- UV – VIS – IR – NIR
- e.g. 405 nm, 640 nm, 790-1060 nm, 1450-1550 nm, 1800-2000 nm

Feasible operation modes by current control
- Pulsed (ps … ms) – modulated – cw

Application matched beam shapes
- fibre coupled, collimated, homogenous lines (1D) or fields (2D)

Easy handling, commercially attractive
- maintenance free
- lifetime can exceed 20.000 hrs and more
- competetive cost structure

Limitations of High Power Diode Lasers

Limited Brightness, Moderate Beam Parameter Product
multi mode beam (M^2: 1 … 10.000)
→ limited spot size and/or short working distance

!!! however: no brightness converter is required !!!

Low Peak Power for Short Pulses
not (yet) feasible for ablation processes

Low Coherence (compared to other lasers)

Large Spectral Width (compared to other lasers)
0.1 nm … 4 nm (… 300 nm)

LIMO
Lissotschenko Mikrooptik

www.limo.de

Prospects and Future Trends of High Power Diode Lasers

Increase of Power per Emitter and/or Bar
- e.g. for passively cooled laser diode bars, 980 nm
  - year 2000: ~20 W
  - year 2011: ~120 W

Increase in Brightness
- e.g. for 100 µm fibre NA =0.12, single wavelength
  - year 2000: ~ 2 W
  - year 2011: ~ 100 W

Extended Wavelength Range
- e.g. 405 nm, 25 W out of 1.000 µm fibre (LIMO, year 2011)
- e.g. 1550 nm from telecom application to material processing

Decrease of Costs (per Watt)
- through scale of economy
- target is to process MW power per year

LIMO
Lissotschenko Mikrooptik

www.limo.de

Some Current Targets for High Power Diode Lasers

Metall Sheet Cutting with Diode Lasers
- 2.5 to 4 kW with beam parameter product of 10 - 20 mm mrad
- (several wavelength 800nm to 1100 nm)

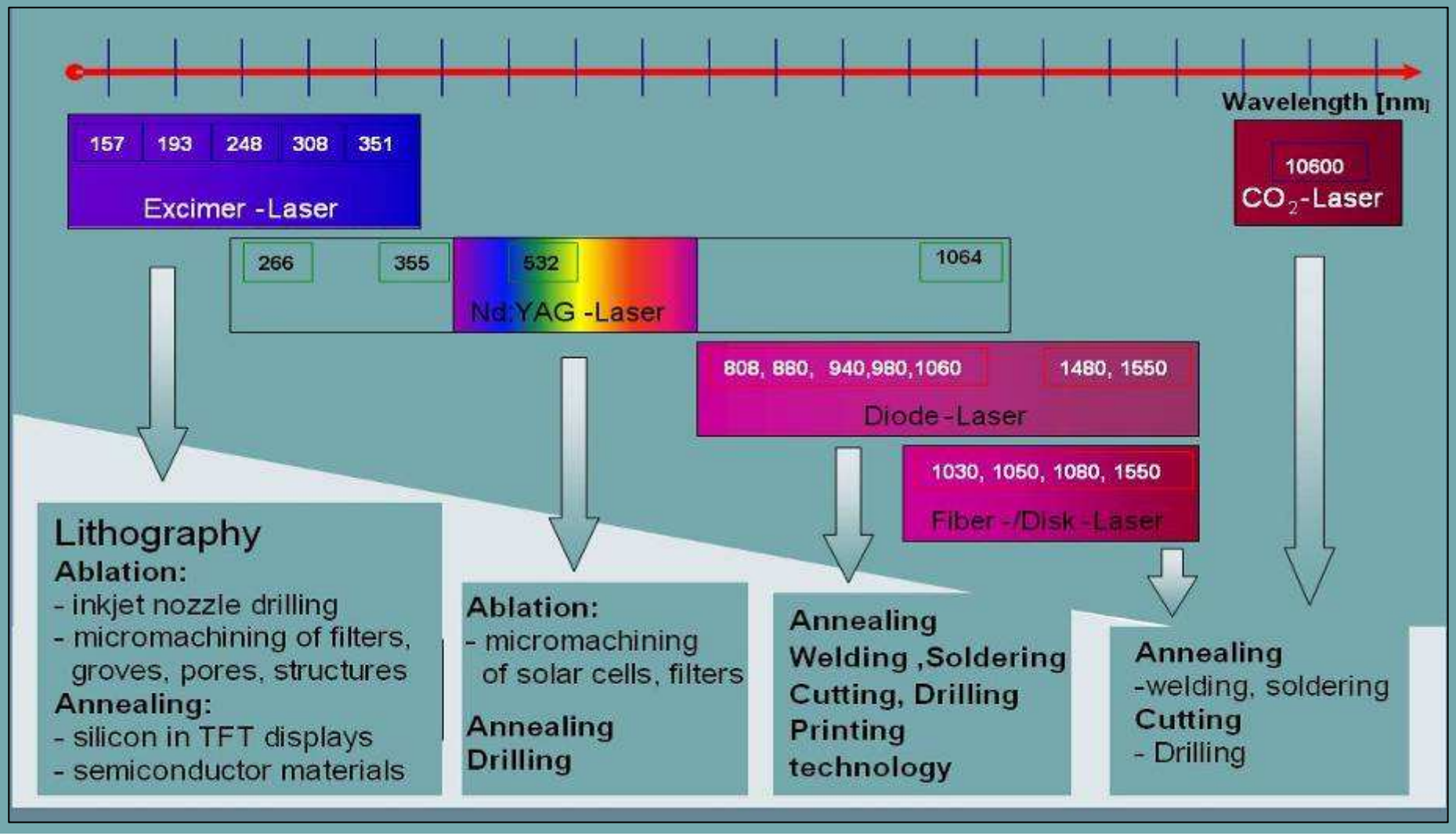
Aircooled Diode Lasers (no water, no TEC)
- > 100 W (cw) at room temperature ambient

Improved Spectral Properties
- stabilized centre wavelength, spectral width < 0.1 nm
- for pumping or spectroscopy

Large Scale Surface Modifications
- up to several meters line length
- 10 … 200 kW (cw)

Production Technology, Decrease of Costs
- < 20 USD per Watt for laser system incl. periphery

High Power Laser Sources & Applications in Materials Processing

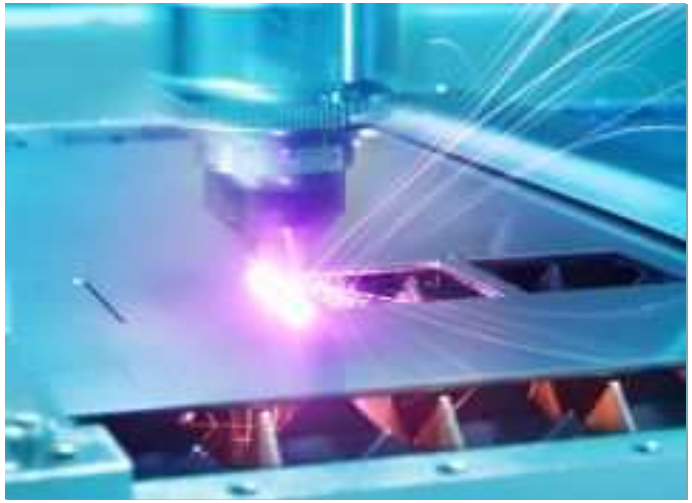


LIMO
Lissotschenko Mikrooptik

www.limo.de

Huge Range of Applications of High Power Diode Lasers

- Pumping of Solid State Lasers (incl. Fibre Laser)
- Illumination for Vision Inspection
- Printing - CtP-Technology
- Medical
  - Soft Tissue Treatment
  - Hair Removal
- Metall Processing
  - Micro – Macro: Marking, Cutting, Welding

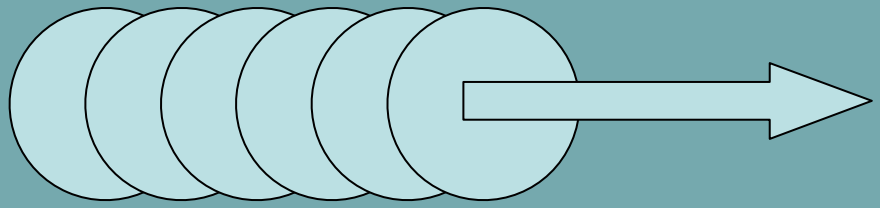


LIMO
Lissotschenko Mikrooptik

www.limo.de

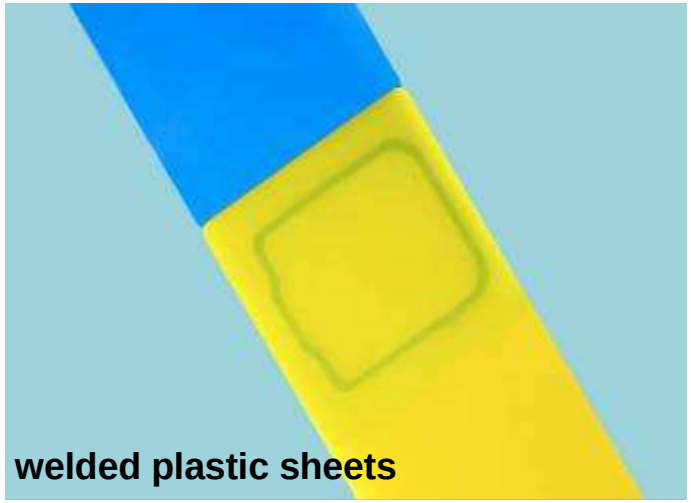
Plastics Processing with High Power Diode Lasers

Scanning of circular spot with typically
rotational symmetric intensity distribution

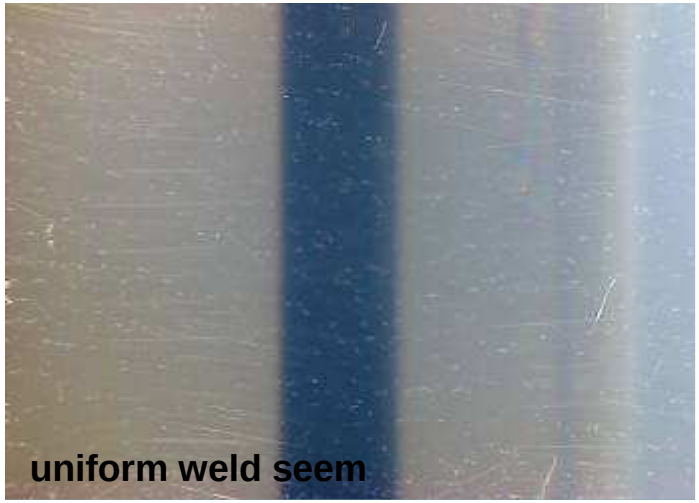


Target: smooth and uniform weld seem with tolerant parameter set
(width, penetration depth, strength, visual appearance etc.)

welded parts of fuel filter



welded plastic sheets



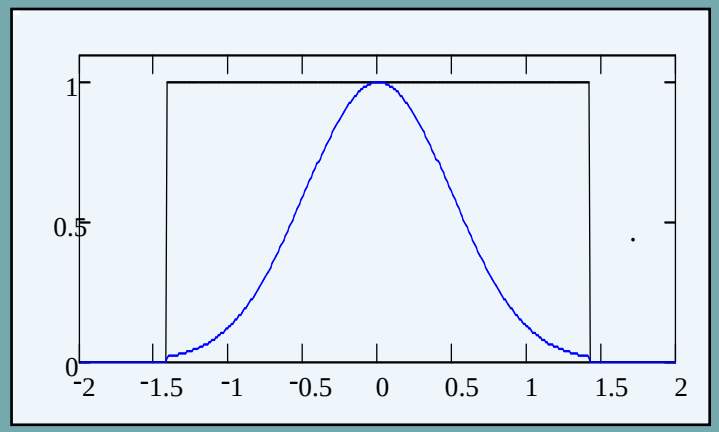
uniform weld seem

Plastics Processing with High Power Diode Lasers

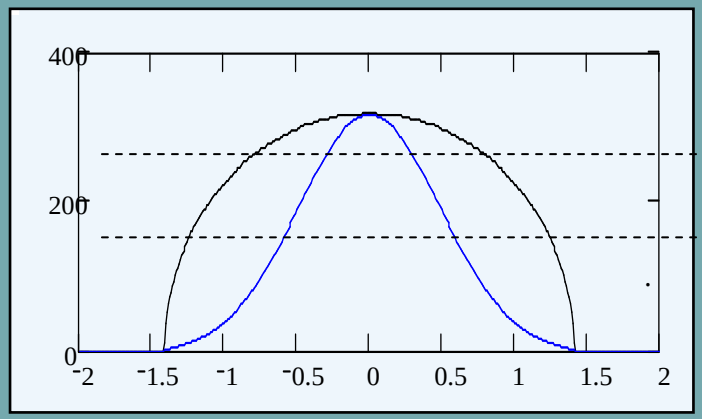
Oberservation:
- small range of parameter sets for satisfying results
- weld seem with deterioration in the centre of the seem

Background:
- effective interaction (heat impact) exceed threshold for damaging in the center of the seem

Radiale Intensity Distribution
(Top Hat, Gaussian)



Effective Interaction/Heat Impact
(Parabolic, Gaussian)

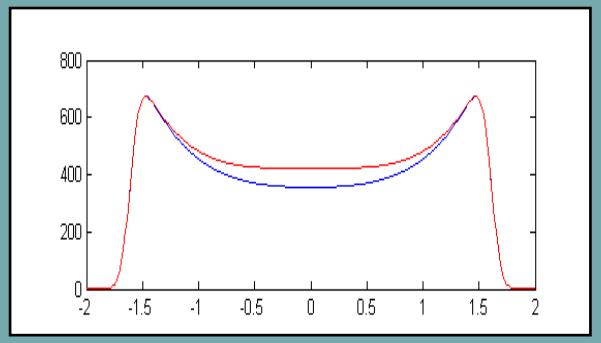


process window

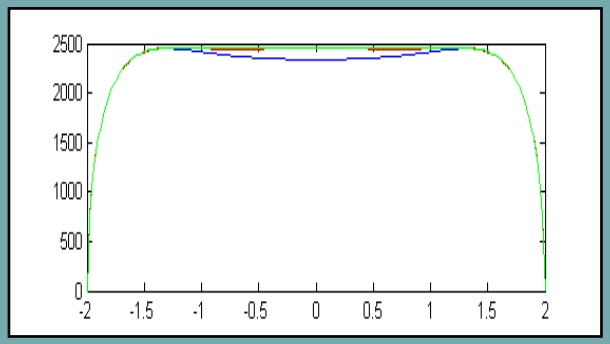
Plastics Processing with High Power Diode Lasers

Solution:
Ideally M-shaped intensity profile (near field on appliction surface, radial symmetric) for processing low heat conducting materials

Radiale Intensity Distribution



Effective Interaction/Heat Impact



Approaches

1) **beam shaping with refractive optics (this presentation)**
2) diffractive optical elements (DOE)
3) axicon for beam manipulation
4) pattern by masks

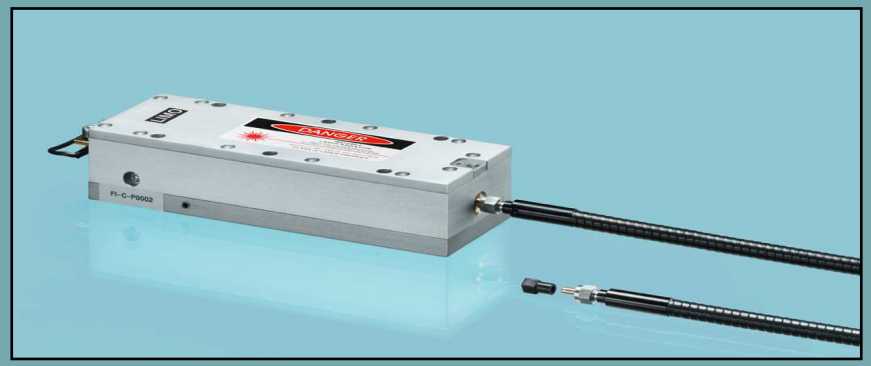
LIMO
Lissotschenko Mikrooptik

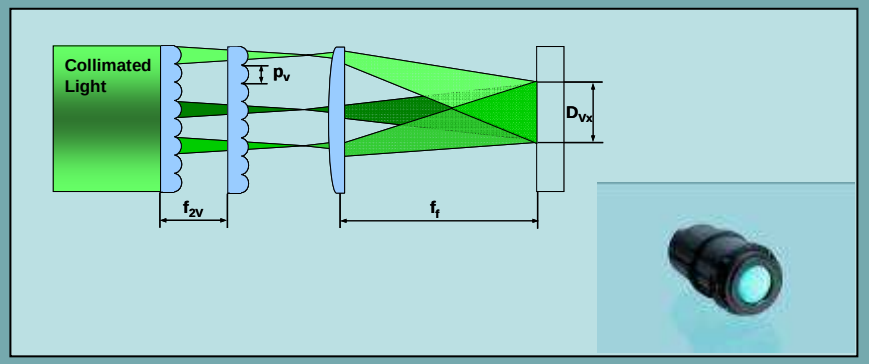
www.limo.de

Generation of M-Shaped Intensity Distribution

A) Near field at Fiber tip
with M-shaped intensity distrubution *
→ Imaging of Fiber tip by
refocussing unit or scanner etc.

B) Beam Mixing *
(Radial lens array, field lens)
→ M-Module as refocussing unit
or integrated in scanner





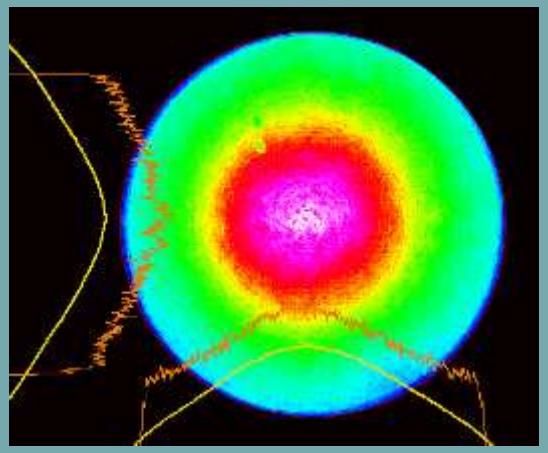
Advantages of refractive optics
- high transmission (potential > 99%)
- high damage threshold
- versatile use in application (imaging, scanner etc.)

* approaches are patent pending: A) 2010, A. Mikhailov B) 2010, Y. Mikliaev et al,

Generation of M-Shaped Intensity Distribution

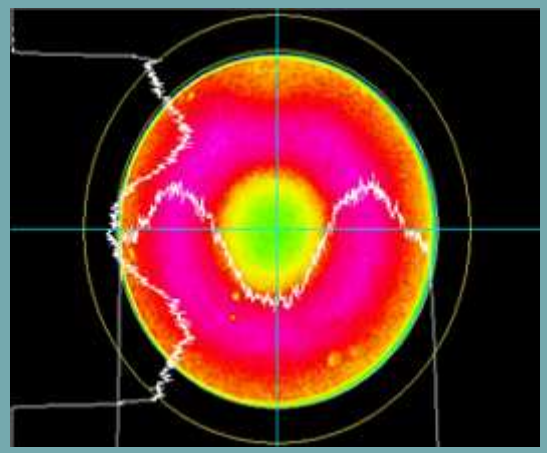
Near Field at Fiber Output

Standard Configuration (LIMO)



after 1.5 m
length of fiber

Modified Configuration with M-Shape Optic

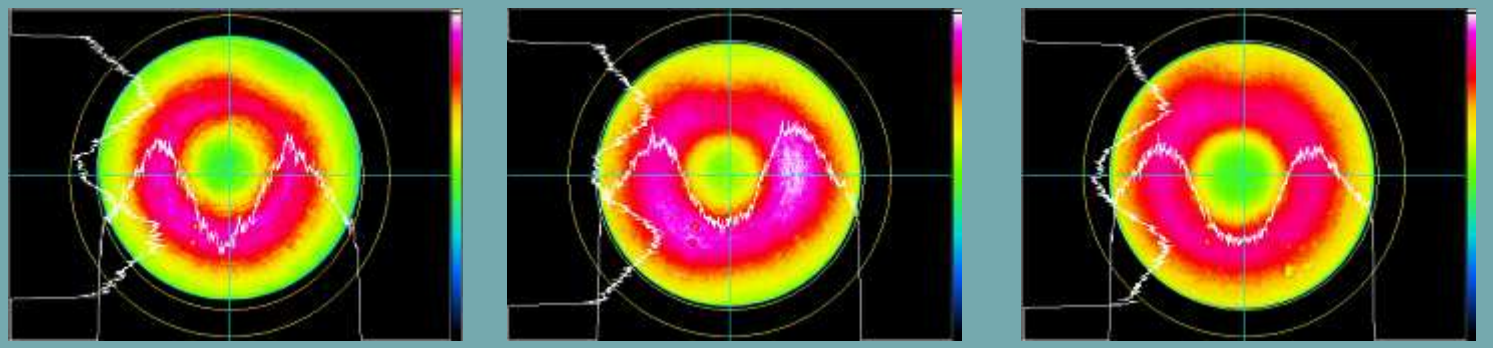


bi shaped lens
aperture: 1mm

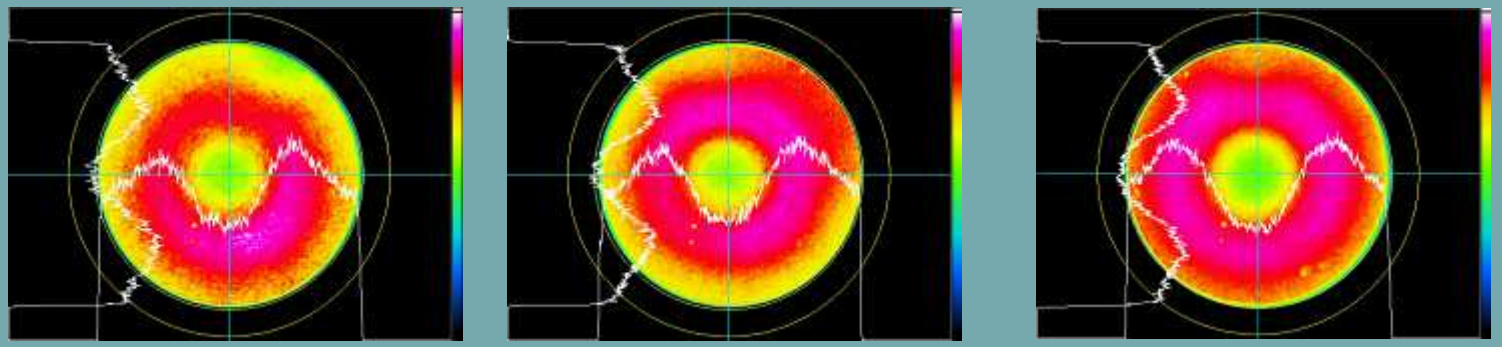
60 W
980 nm
400 µm NA: 0.22

Generation of M-Shaped Intensity Distribution

straight fiber



fiber coil



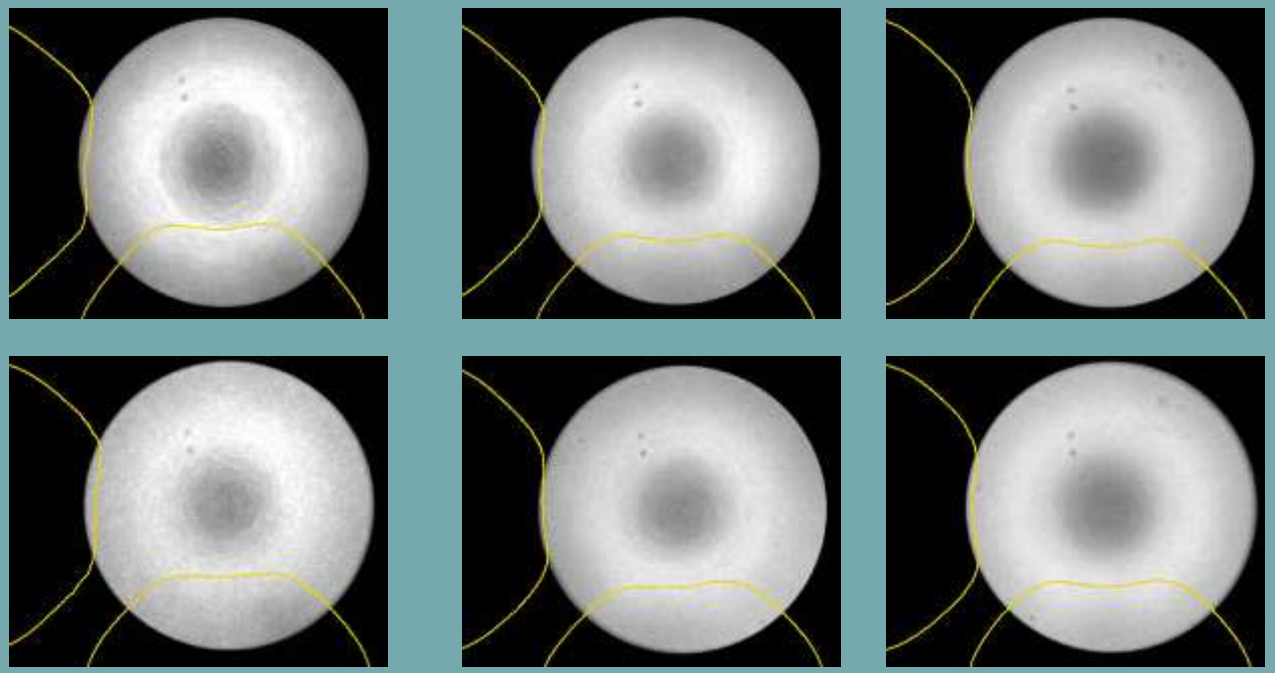
Fiber Length (1-10 m)

Handling of fiber without impact on m-shape

Generation of M-Shaped Intensity Distribution of Fibre Coupled Diode Laser

straight fiber

fiber coil



yellow curves are integrated intensities

Fiber Length (1-10 m)

Handling of fiber without impact on effective interaction / heat impact

LIMO
Lissotschenko Mikrooptik

www.limo.de

Summary

High Power Diode Lasers are:

- high efficent light sources
- compact, robust and easy to handle
- emitting in many wavelenght (UV – VIS – IR)
- available in wide power range (up to multiple kW)
- applicable for cw, modulated and pulsed operation (ps … s)
- available in application matched beam form
  - fibre coupled (100µm … 1.000 µm fibre diameter)
  - collimated, spots, line (1D), fields (2D)
- versatile for many applications

With Potentially High Impact for Polybright Project

- high absorption of polymer (low optical power required)
- processing of visual transparent material

Thank you for your attention!

Dr. Jens Meinschien
VP Research & Development
E-mail: jens@meinschien.de
Phone: +49-231-22241-130