Anforderungen an Laserbearbeitungsköpfe beim Schweißen mit hoher Strahlqualität

HIGHYAG Lasertechnologie

Dr. Björn Wedel

LAF´06

Agenda

Introduction

Focusing Fibre Beam Delivered Laser Light

Specific Requirements for Focusing High Brightness Lasers

Examples for High Brightness Laser Processing Heads

Conclusion

Motivation - Products - Innovation

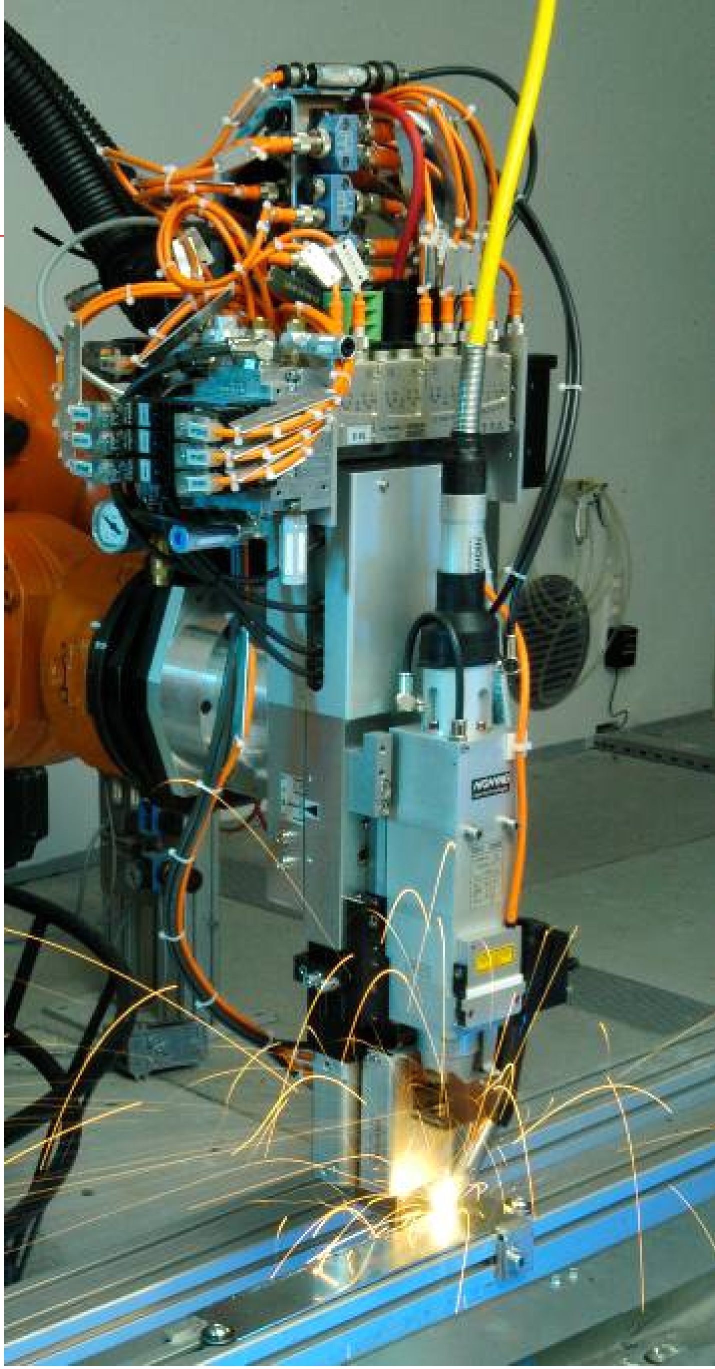
***HIGHYAG* is the interface between the laser and the user on the shop floor:**

„Tools for Laser Materials Processing“

- Laser processing heads
- Beam delivery systems
- Customized solutions

Product features:

- Up-time
- Simple Use
- Logical system integration
- Component access



HIGHYAG Lasertechnologie

HIGHYAG Lasertechnologie **GmbH (Headquarters) is located in Berlin (Germany)**

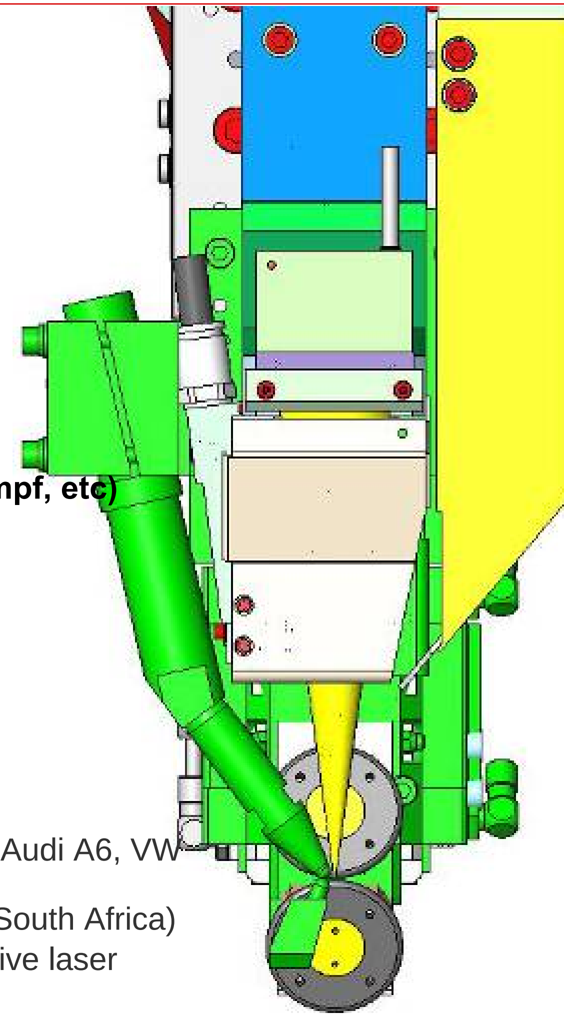
- 55 Employees
- Founded in 1995 with the **business idea of providing „Beam Delivery Systems and Tools for Laser Materials Processing “** for the increasing number of laser applications in the advanced manufacturing industry
- Installed base of more than 1000 laser processing heads in automotive production

International presence

- USA: *HIGHYAG* Laser Technology, Inc. and Abicor Binzel Corporation, Inc.
- Japan: Marubun
- Worldwide in cooperation with Abicor Binzel such as France, Spain, Mexico, Brazil, South Africa, China




HIGHYAG´s References (amongst others)



BMW (5er-series)

Bosch

DaimlerChrysler (E Class, Dodge Ram)

Dana

EADS

EWI

Ford

Fraunhofer Institute

GM

Hyundai Motor Company

Laser manufacturers (IPG Photonics, Jenoptik, Laserline, Lumonics, RofinSinar, Trumpf, etc)

Porsche

PSA

Renault

System integrators (ComauPico, EDAG, Thyssen Krupp, KUKA, etc)

Tower Automotive

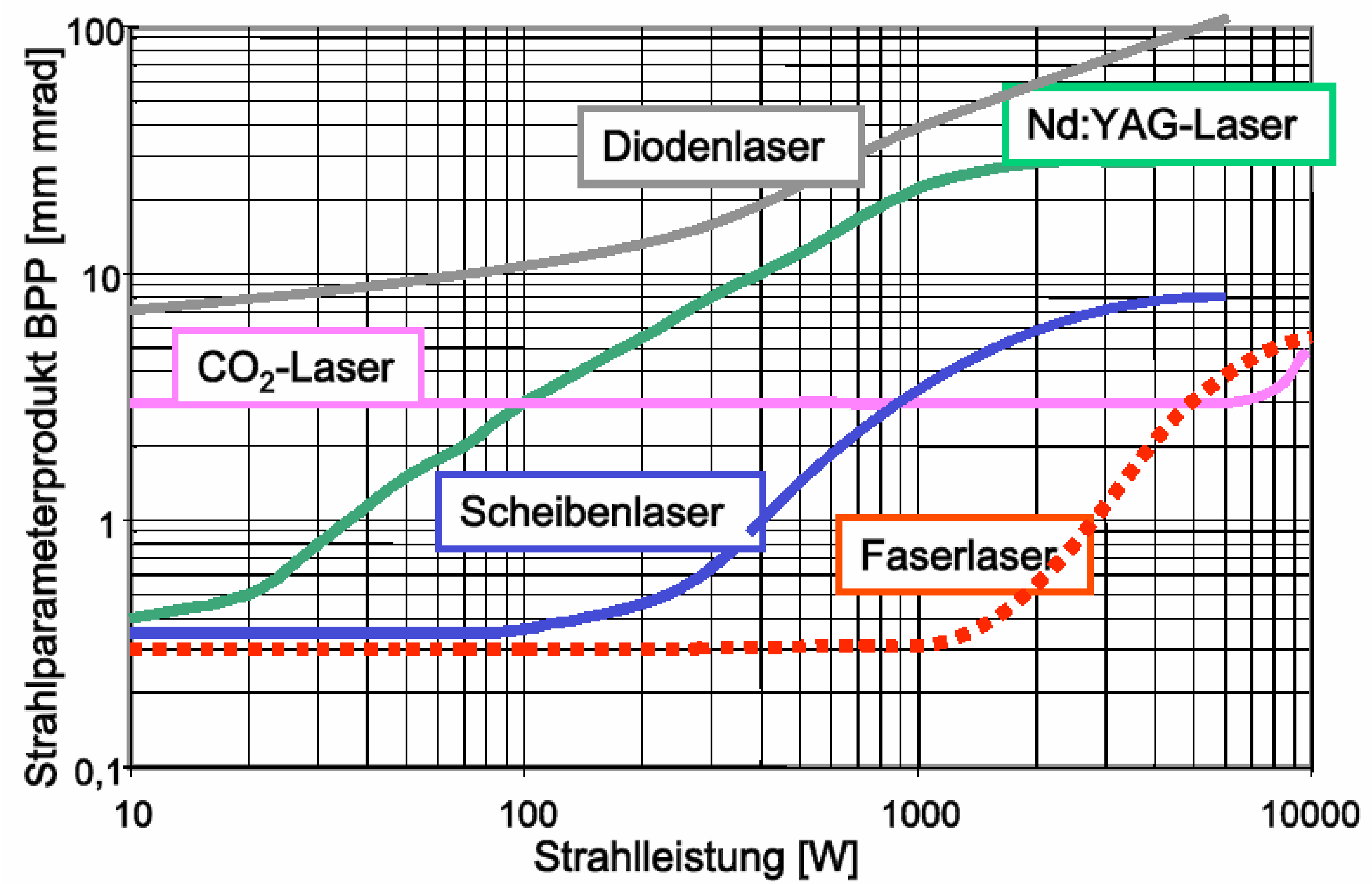
TWI

Volkswagen (Volkswagen, Audi, Skoda, SEAT)

- VW Jetta, VW Passat, Skoda Fabia, SEAT Ibiza, VW Polo, VW Phaeton, Audi A4, Audi A6, VW Touareg, VW Touran, VW Golf A5, VW Passat B6)
- Installations worldwide (Germany, Slovakia, Poland, Mexico, Brazil, Spain, China, South Africa)
- VOLKSWAGEN realized with his partner ***HIGHYAG*** the first mass volume automotive laser production

Volvo

Laser Output Power and Beam Quality



Quelle: Fraunhofer IWS, 2006

High Brightness Lasers

The fibre laser is a high brightness laser:

High average power

- Larger than 5 kW, up to 30 kW

(Very) good beam quality

- TEM 00 up to 1 kW
- Approx. 10 - 20 mm*mrad up to 20 kW

Applications

- Large working distances for remote laser welding
- Thick section welding with high laser power
- Welding / cutting fine structures

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Focusing Fibre Beam Delivered Laser Light

$Ø_{fib}$: Fibre core diameter

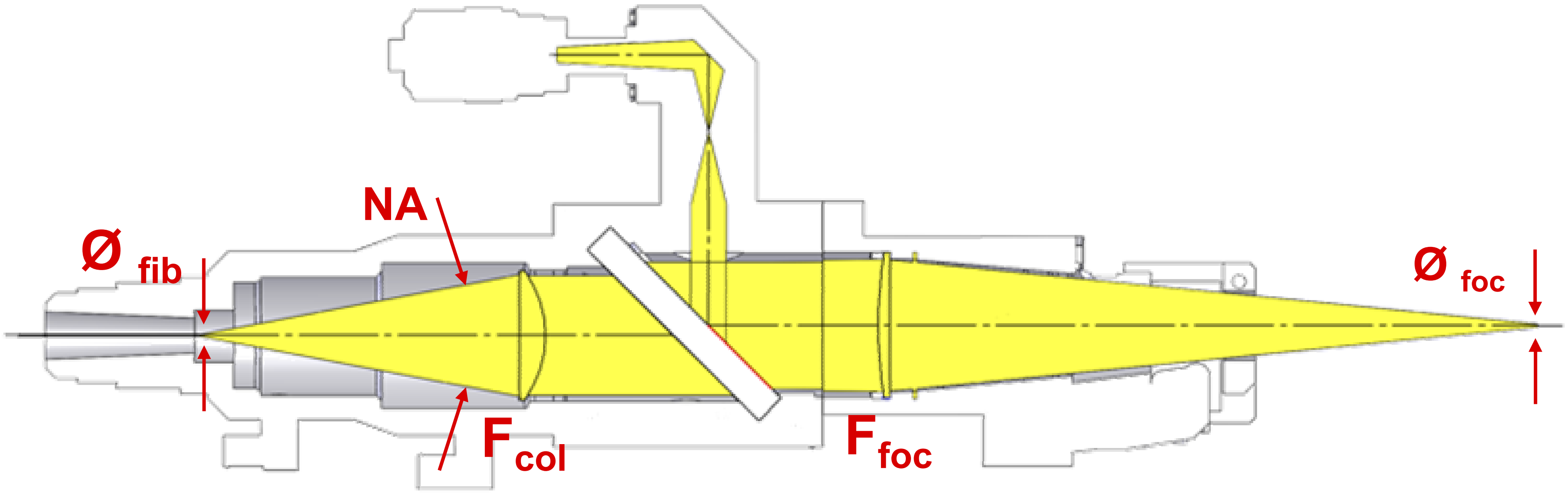
NA: Beam parameter acceptance (numerical aperture) of laser beam exiting the fibre

F_{col}: Focal length optical collimation system

F_{foc}: Focal length optical focusing system

$M = F_{foc} / F_{col}$: Magnification of overall optical system

$Ø_{foc} = M \times Ø_{fib}$: Focus diameter



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- Laser Power Induced Focus Shift
- Imaging Quality

Examples for High Brightness Laser Processing Heads

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High Brightness Laser Light

Major difference to conventional high power solid state lasers

- High laser power (up to 20 kW)
- Small fibre diameters require a large magnification of fibre diameter in the focus
- (Varying beam parameters exiting the fibre)

(Possible) side effects on the focusing head

- Interaction of the high power laser light with the imaging elements
- System tolerances are leveraged / multiplied by the large magnification

Laser Power Induced Focus Shift

Absorption of laser power alters the focusing properties of the imaging lens system

- dn/dT (temperature dependent refractive index)
- Radial temperature gradient in optical elements
- Deformation

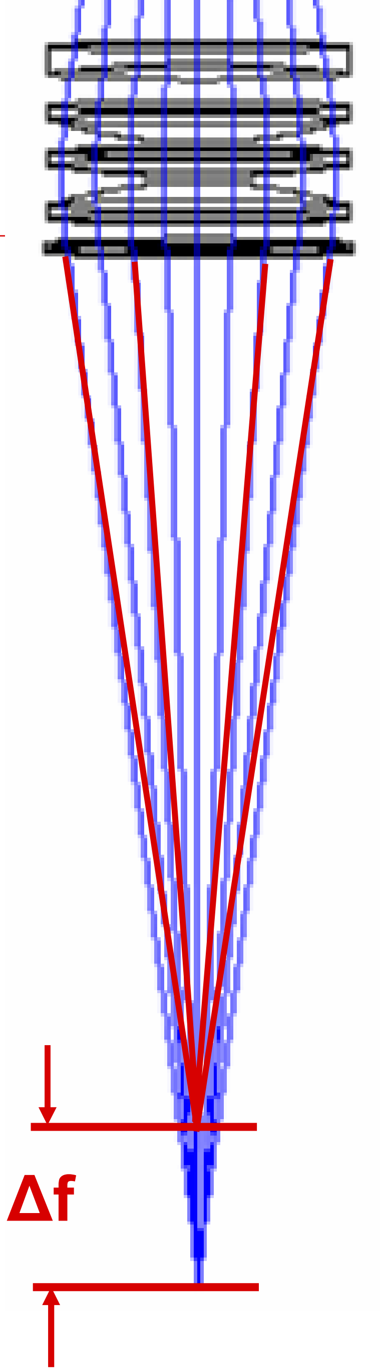
Laser Power Induced Shift of the focus position

- Caused by a temperature increase of a few degree Kelvin
- Even using fused silica with very low laser power absorption coefficient
- Typical time constants of a few 10 sec to a minute

System stabilises during the application process

- Influence on the processing results

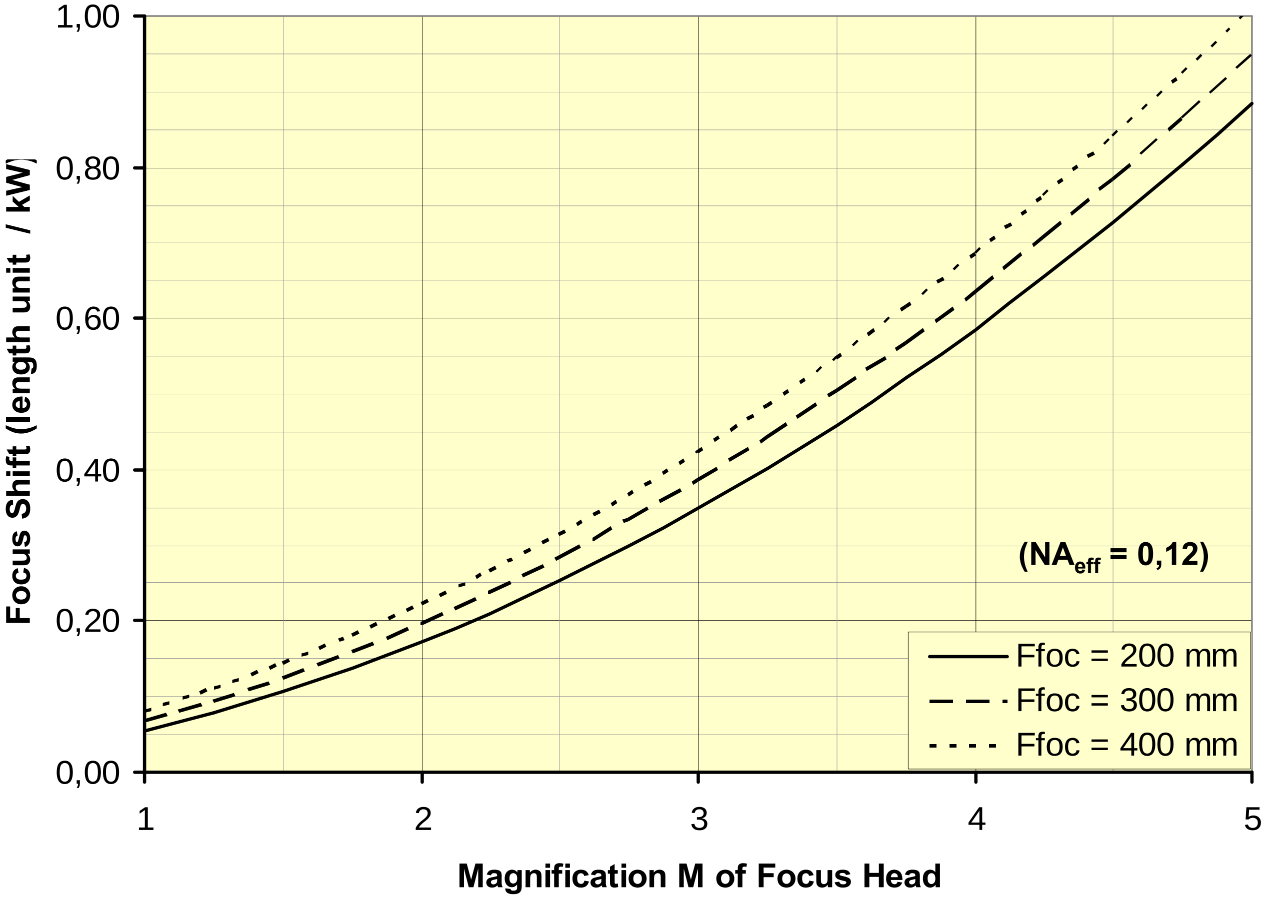
Physics is the limiting factor!



Magnification and Laser Power Induced Focus Shift

Focus Shift

- Squared dependency on magnification
- Small influence of focal length
- Offsets the advantage of the long Rayleigh length



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Reduction of
Laser Power Induced Focus Shift

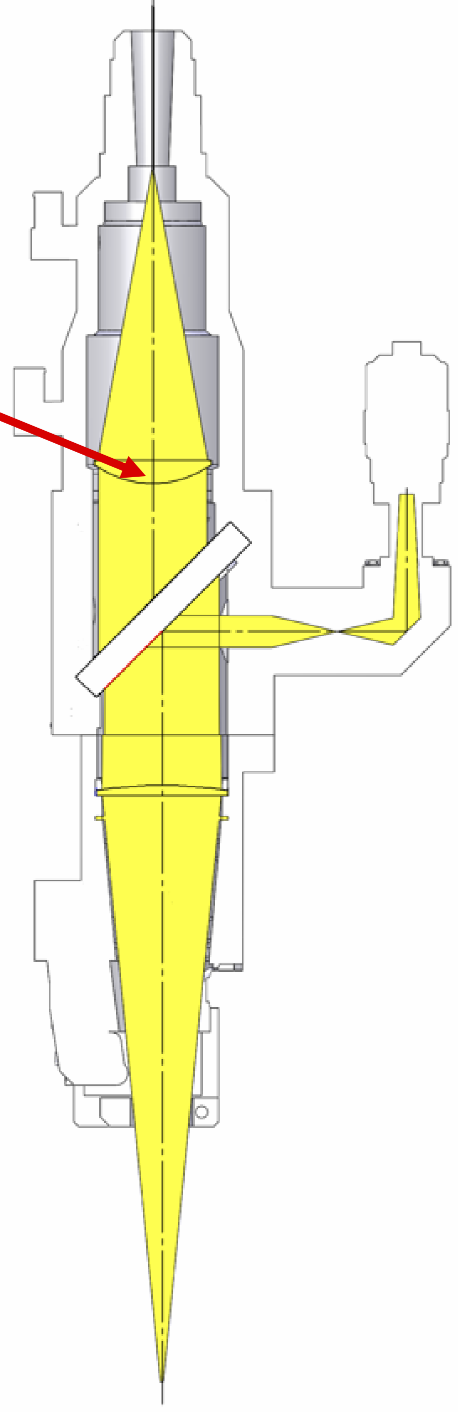
Preventing the absorption of laser light in the material

- Choose the best possible material for optical components
- Reduce additional absorption by dirt and dust on optical surfaces
  - Less interfaces
  - Additional protection of all interfaces and open surfaces
  - Monitoring of components

Reducing the number of optical elements

Best possible adaptation of the focus head to the laser beam

Alternative approaches



Reduction of Laser Power Induced Focus Shift

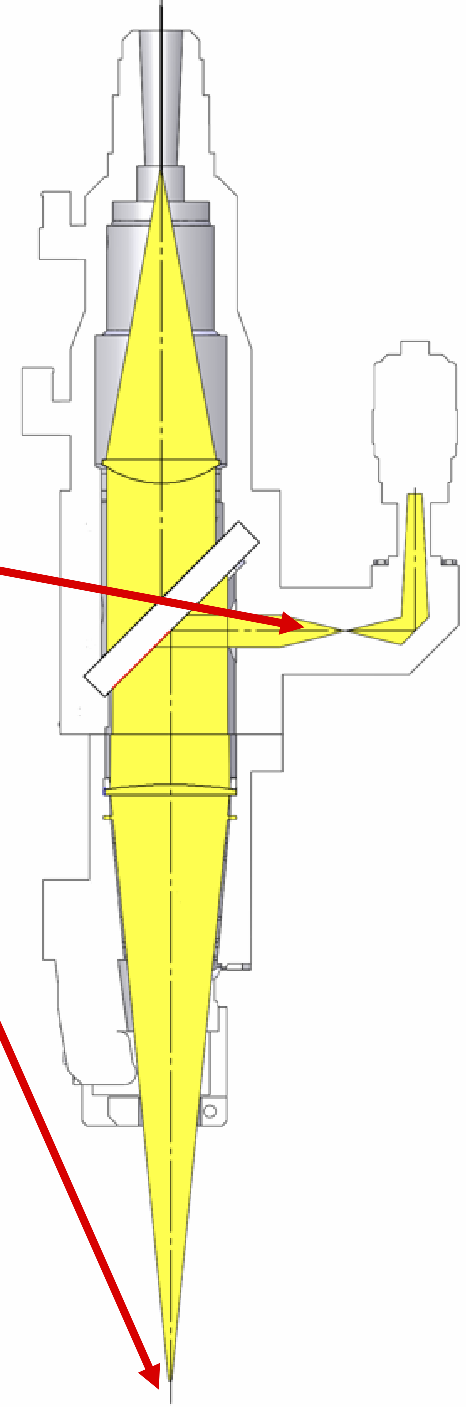
Preventing the absorption of laser light in the material

Reducing the number of optical elements

- Less accessories e.g. CCTV viewing, integrated illumation
- (by decreasing the imaging quality?)
- **Beam quality preservation is more important than focus shift !**

Best possible adaptation to laser beam

Alternative approaches



Imaging Quality vs. Focus Shift
Comparison Beam Propagation and Focus Shift

Simple system

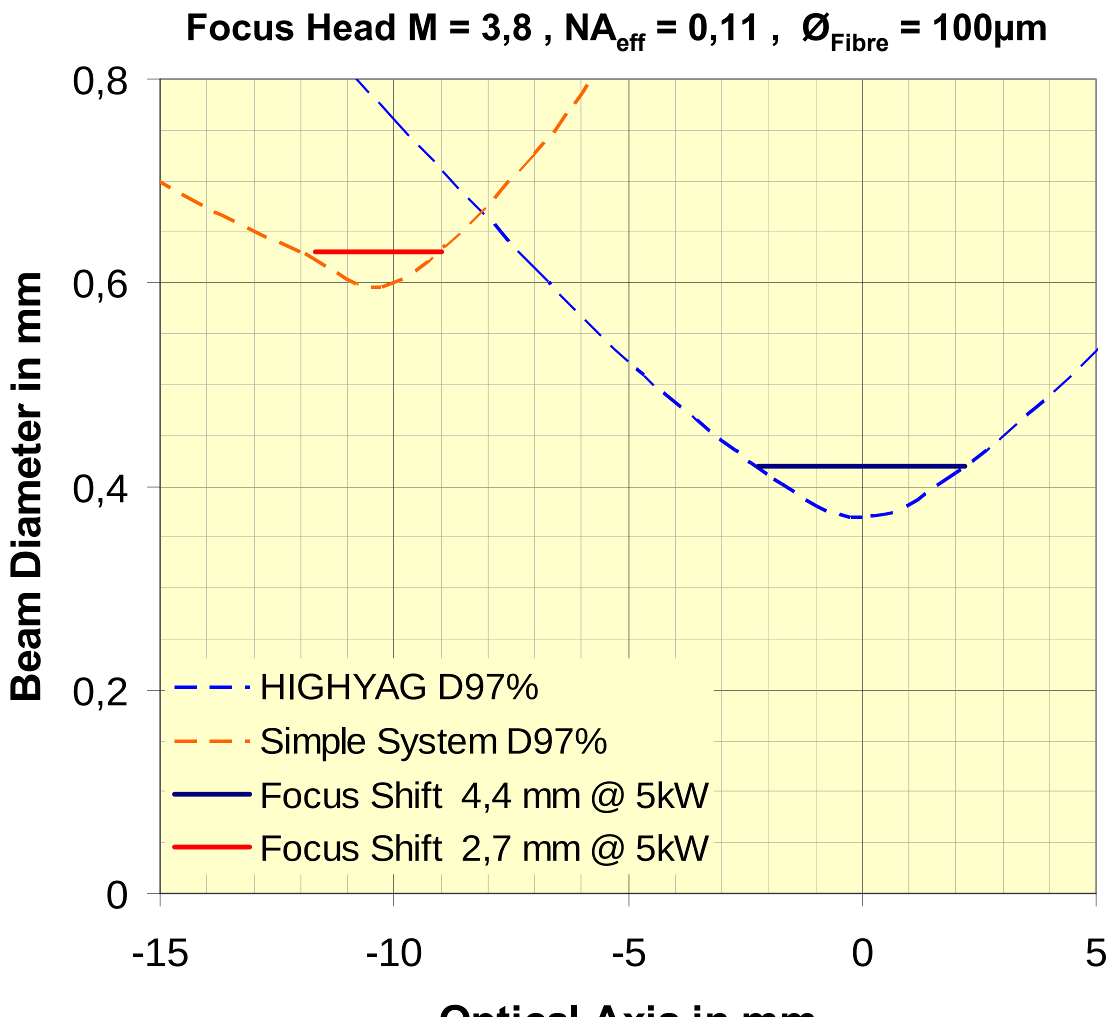
- Beam diameter 0,6 mm
- Total shift @ 5 kW 2,7 mm

Corrected system

- Beam diameter 0,4 mm
- Total shift @ 5 kW 4,4 mm

Although the focus shift is approx. 50 % higher the corrected system still gives the smaller focus!

Beam quality preservation is more important than focus shift!



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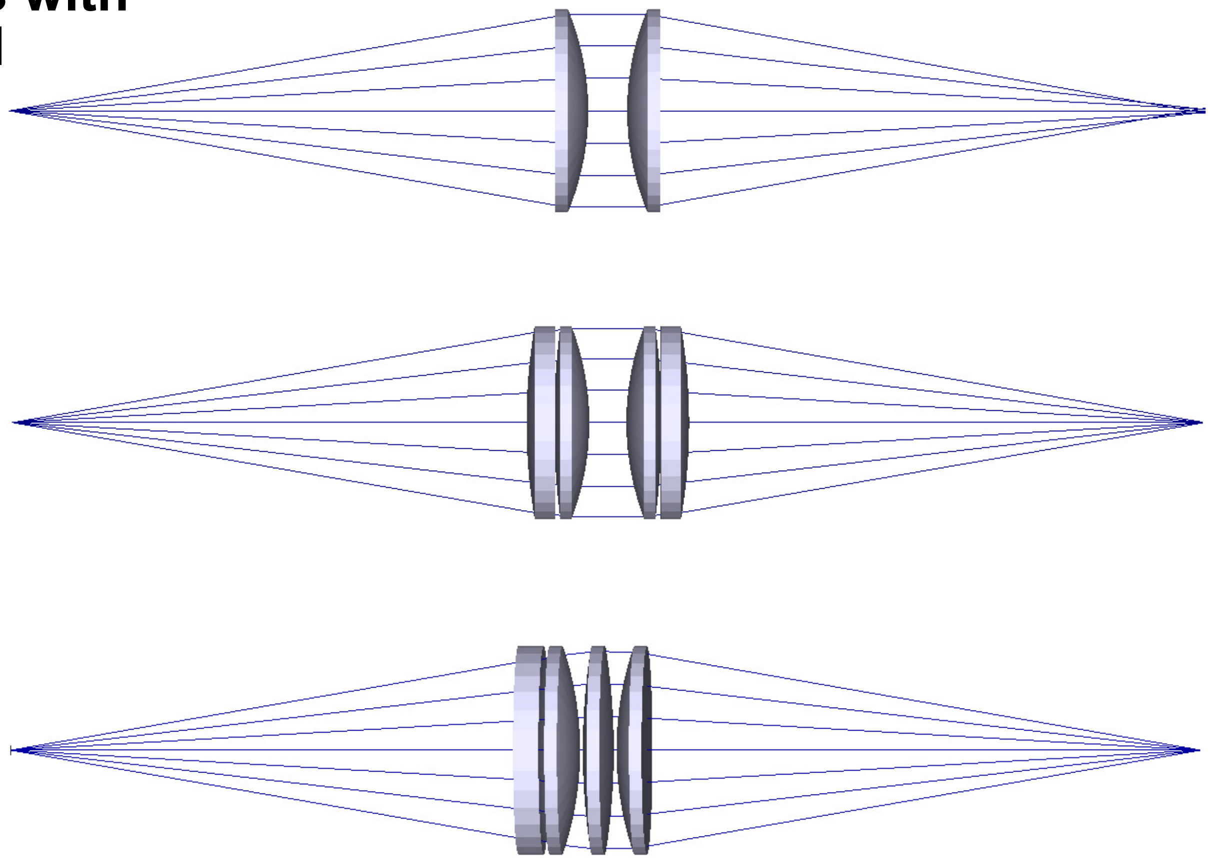
Focusing High Brightness Laser Light
Optimised Optical Design

Comparison ot three different optical design approaches with reduced number of optical elements

- 2 single lenses
- Symmetric design
- Asymmetric design



Basic design data

- Lens diameter 50 mm
- Magnification M=1
- F_{col} = 150 mm
- F_{foc} = 150 mm

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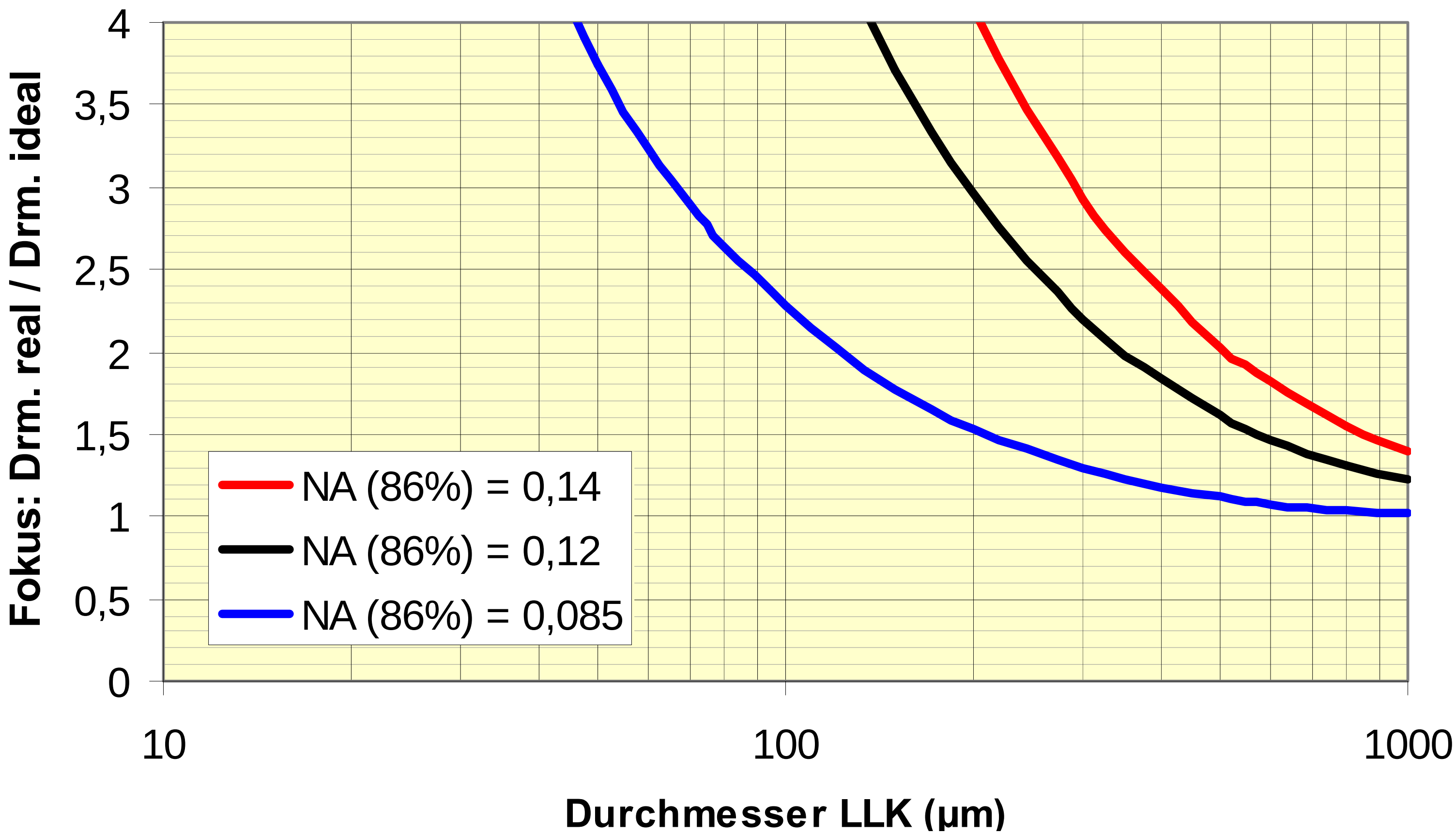
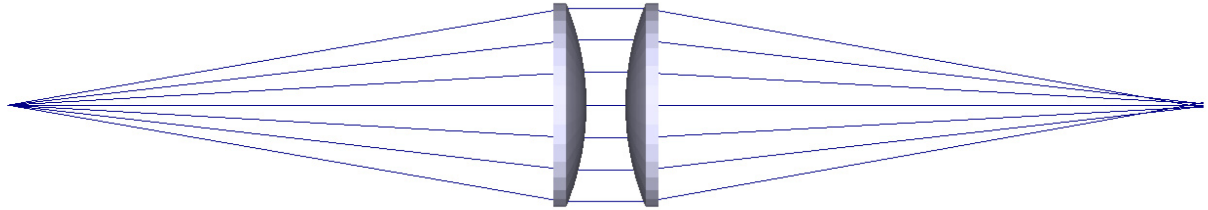
Focusing High Brightness Laser Light
Imaging Quality 2-Lens-System





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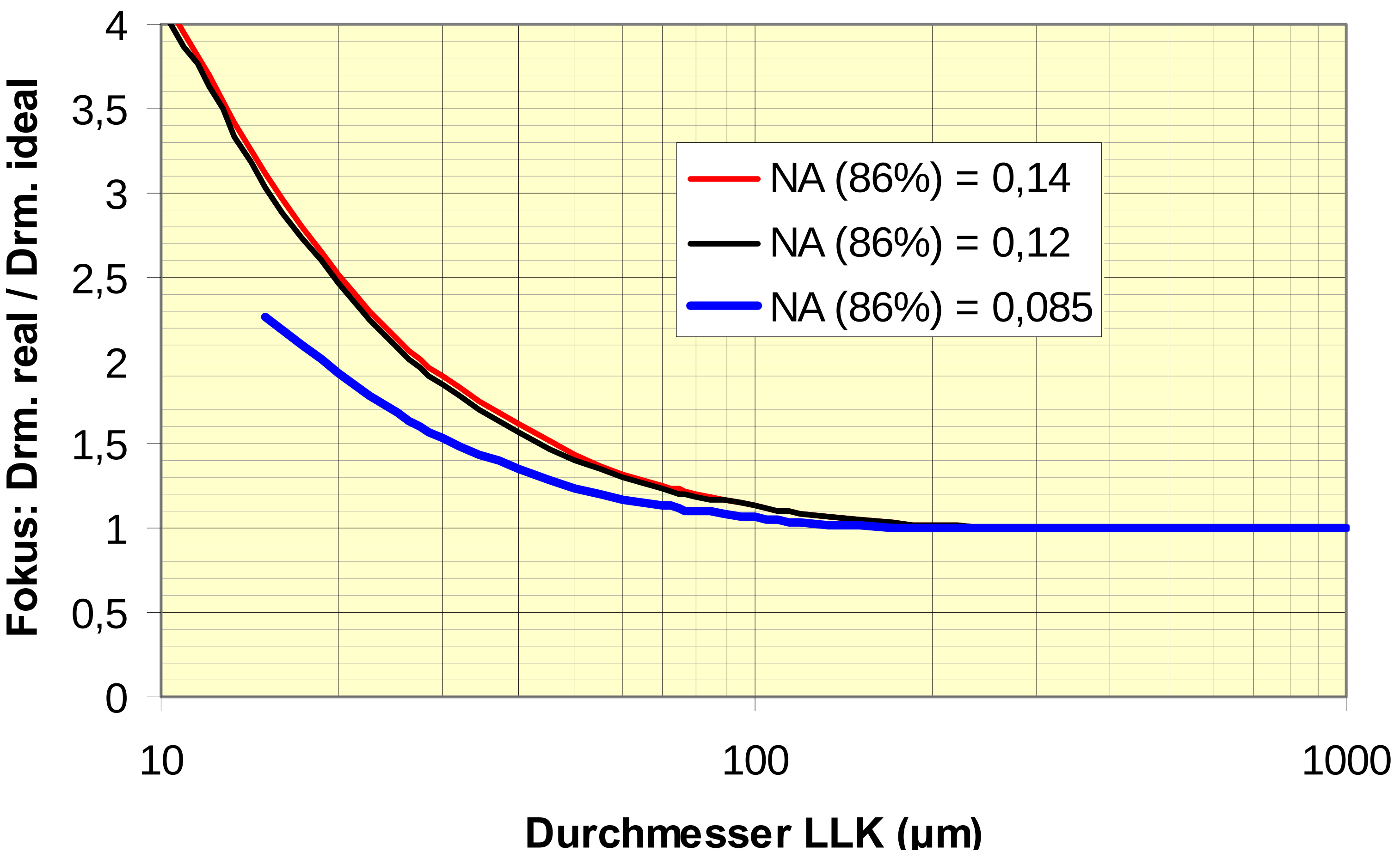
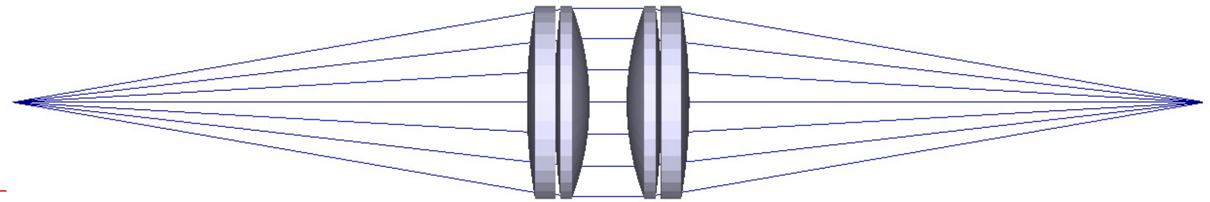
Focusing High Brightness Laser Light
Imaging Quality Symmetric System





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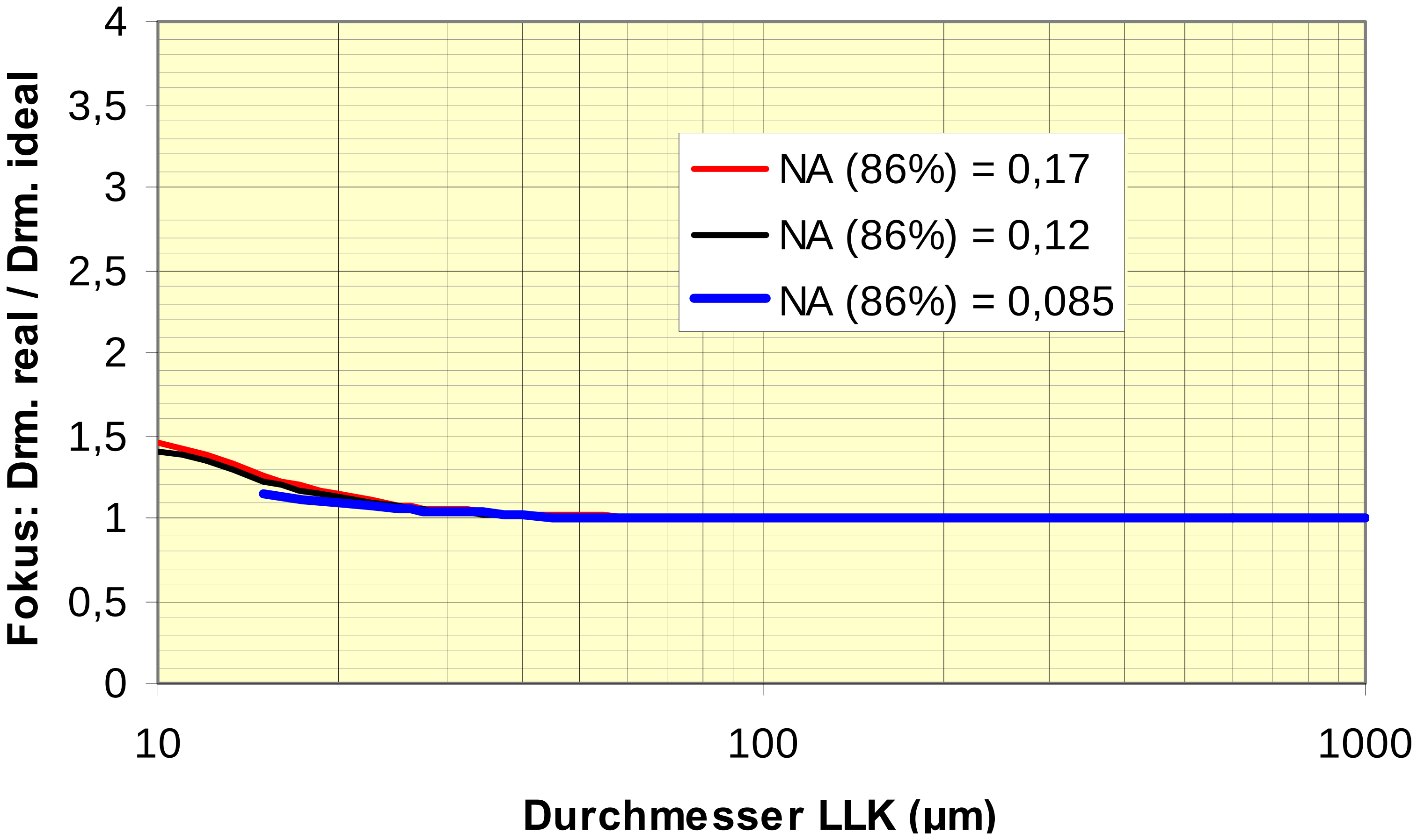
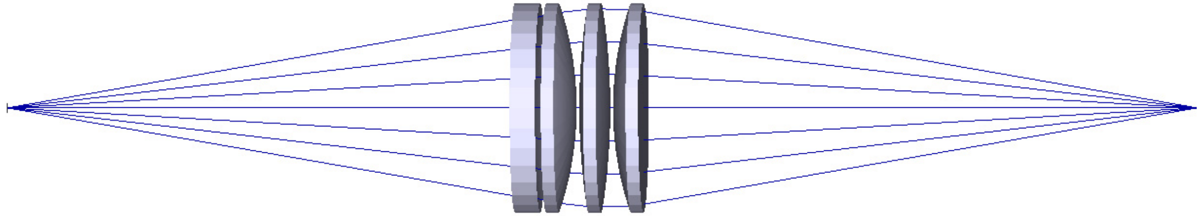
Focusing High Brightness Laser Light
Imaging Quality Asymmetric System





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Focusing High Brightness Laser Light
Comparison Optical Designs

2 single lenses

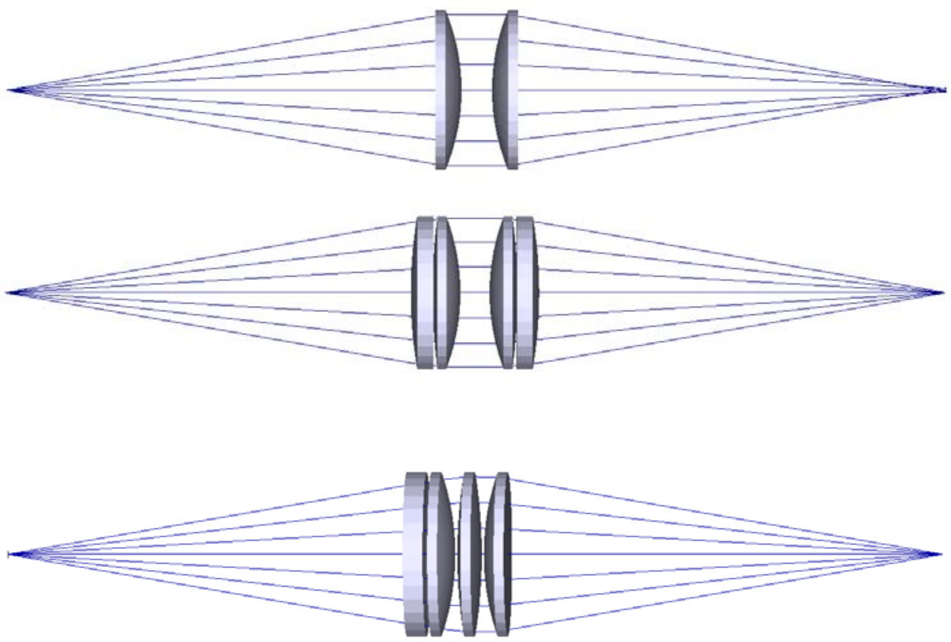
- Acceptable image quality for focus diameters > 1000 µm and low NA

Symmetric design

- Acceptable image quality for focus diameters > 100 µm and NA < 0.17
- Modularity

Asymmetric design

- Acceptable (diffraction limited“) image quality for focus diameters > 10 µm and NA < 0.17
- Limited modularity



Reducing the number of optical elements while maintaining diffraction limited imaging quality is possible!

Reduction of
Laser Power Induced Focus Shift

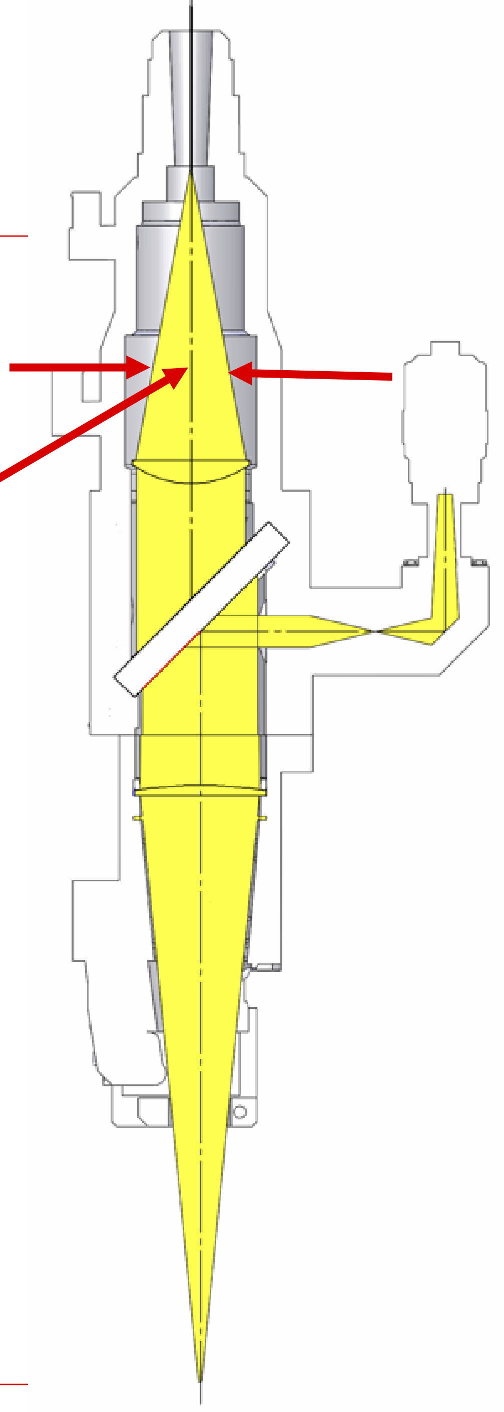
Preventing the absorption of laser light in the material

Reducing the number of optical elements

Best possible adaptation of the focus head to the laser beam

- Matching the focus head to required application
- Standardisation of high power laser beam output parameters

Alternative approaches



Adaptation of Focus Head on Beam Parameters
Laser Beam Diameter in Optical System

Matching the optics to the laser beam diameter (fill factor)

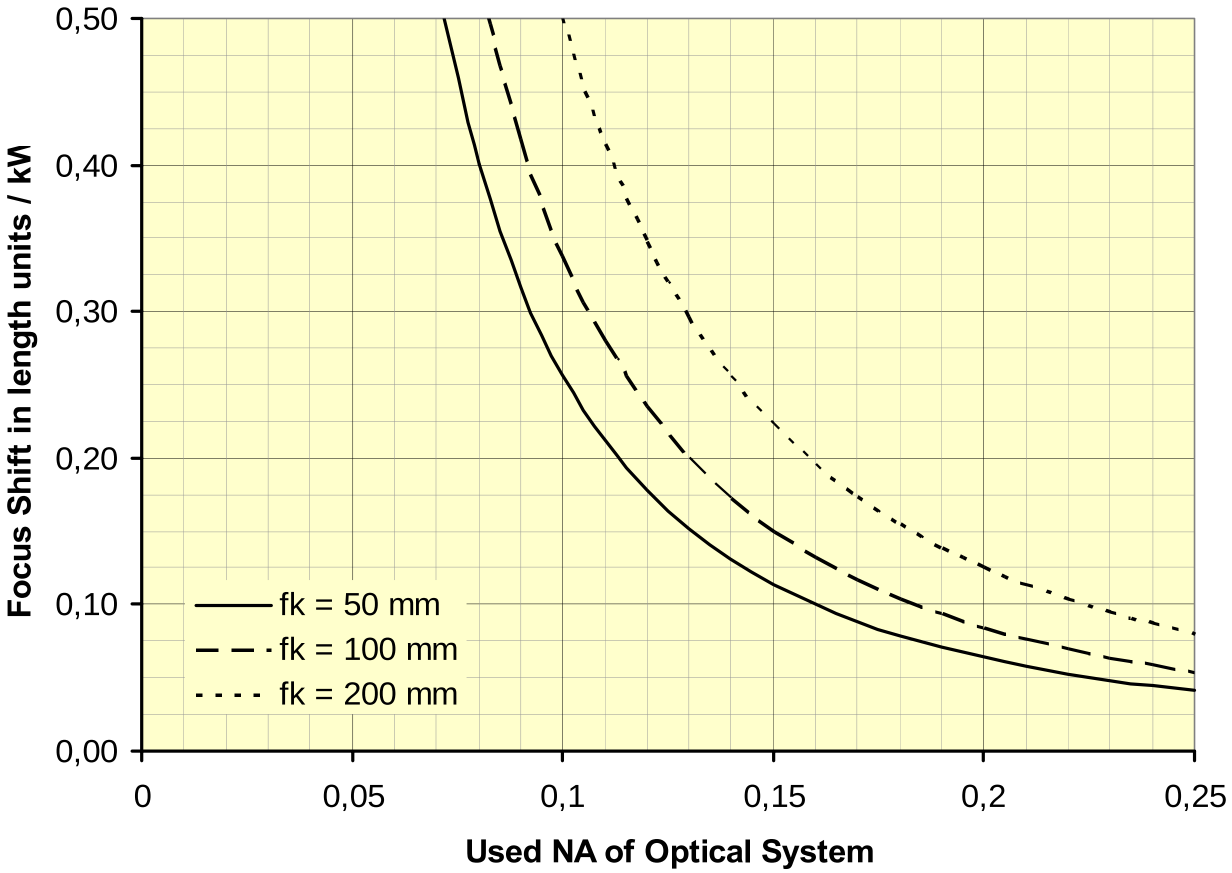
- Reducing the tolerances

Smooth beam profile

- No intensity peak in the center

Standardisation of laser beam exiting the fibre

- Power contents in an defined aperture for all lasers



Reduction of
Laser Power Induced Focus Shift

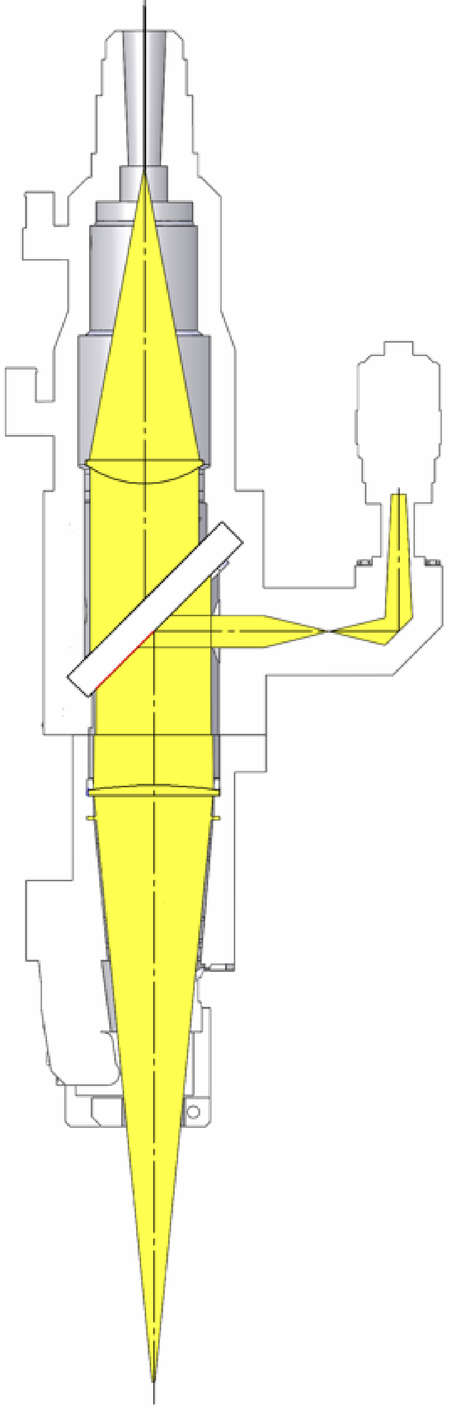
Preventing the absorption of laser light in the material

Reducing the number of optical elements

Best possible adaptation to laser beam

Alternative Approaches

- Use of reflective optical elements
  - Metallic materials absorb and deform as well
  - Complex shapes in non metallic materials are very difficult to generate
- Active / adaptive compensation of focus shift



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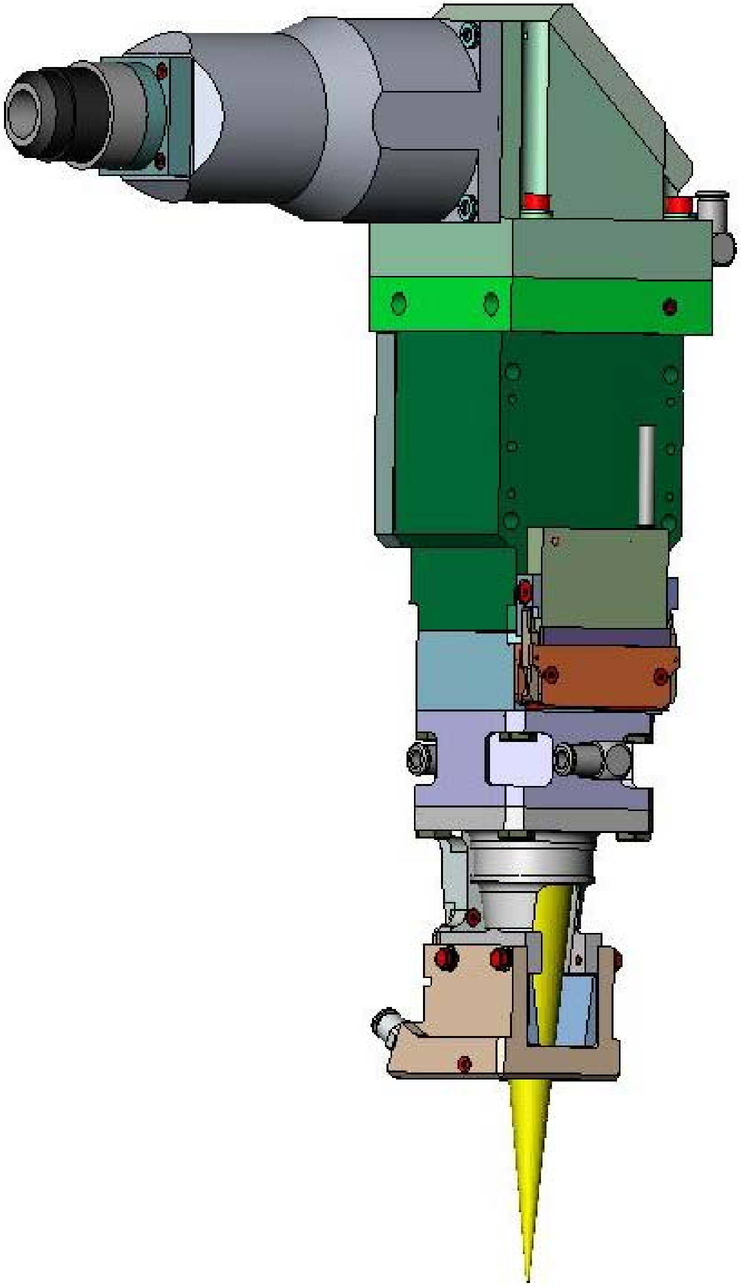
Laser Focus Head BIMO HP

Main design objective

- Transferring of laser power in the range of 20 kW
  - Large beam diameter at the optical elements
- Beam parameter acceptance (NA) typically 0,2
- Magnification range 1 – 3 by exchanging the focusing system

Additional features

- Added cooling for thermal management of backreflection from work piece
- Cover slide drawer and crossjet
- Cover slide monitoring system



Laser Focus Head BIMO HQ

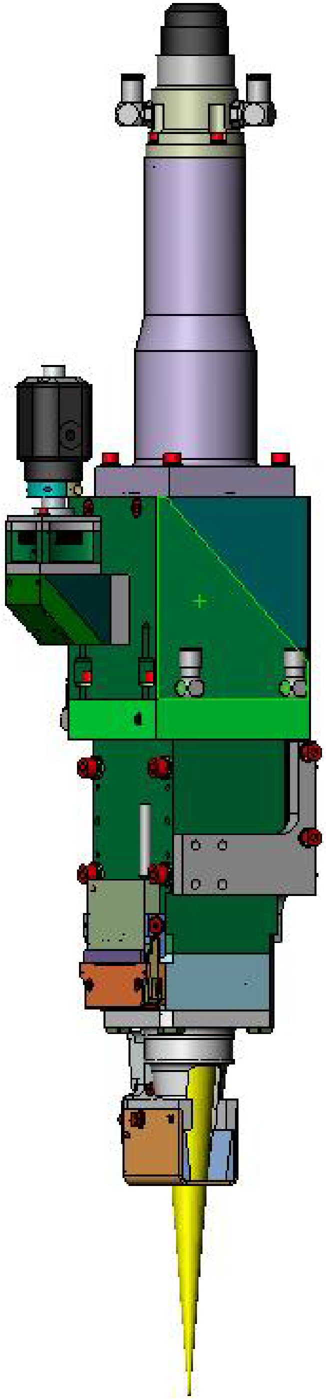
Primary design objective

- Preservation of fundamental mode beam quality at the work piece
  - Confirmed by „Primes“ measurement
- Beam parameter acceptance (NA) 125 mrad
- Laser power up to 1 kW

Additional design objectives

- Magnification range 1 – 5 by exchange of collimation and focusing modules
- Cctv viewing system

How to measure TEM 00 beam quality @ 1 kW laser power?



Conclusion

High power and very good beam quality are the advantage of fibre lasers.

Laser power induced focus shift

- Absorption of laser power in optical elements
- Large magnification leverages the effect
- Physics is the limiting factor!

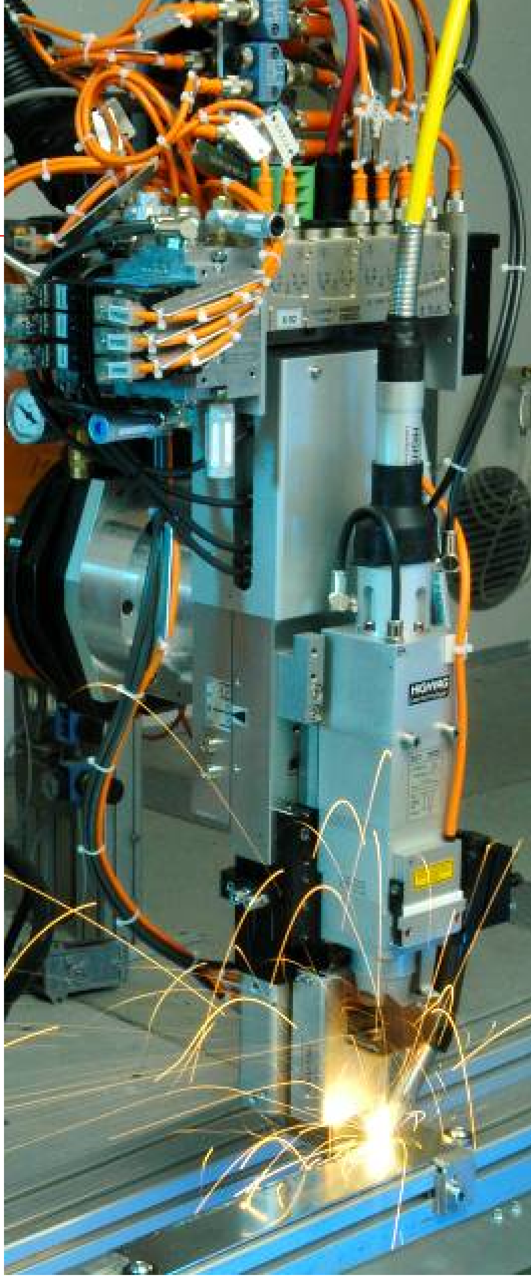
Reduction of focus shift

- Benefit of optical correction is more important
- Adapt focus heads to laser beam parameters

Use of optimised optical systems

- Reducing the number of optical elements while maintaining diffraction limited imaging quality is possible
- Diffraction limited imaging quality is required for achieving focus diameters in the sub 100 µm range

Adapted solutions to specific applications will give the best performance



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Thank You

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