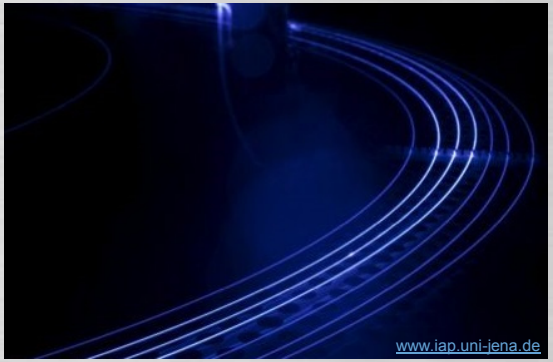
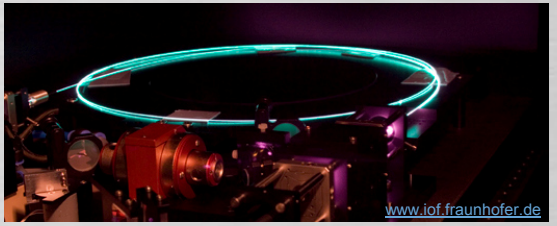
Optical Fiber Delivery of Ultrashort Pulses for Machining: Wishes, Progress, Status

EWAG AG, 15.11.2017


www.iap.uni-jena.de


www.iof.fraunhofer.de


www.nktphotonics.com

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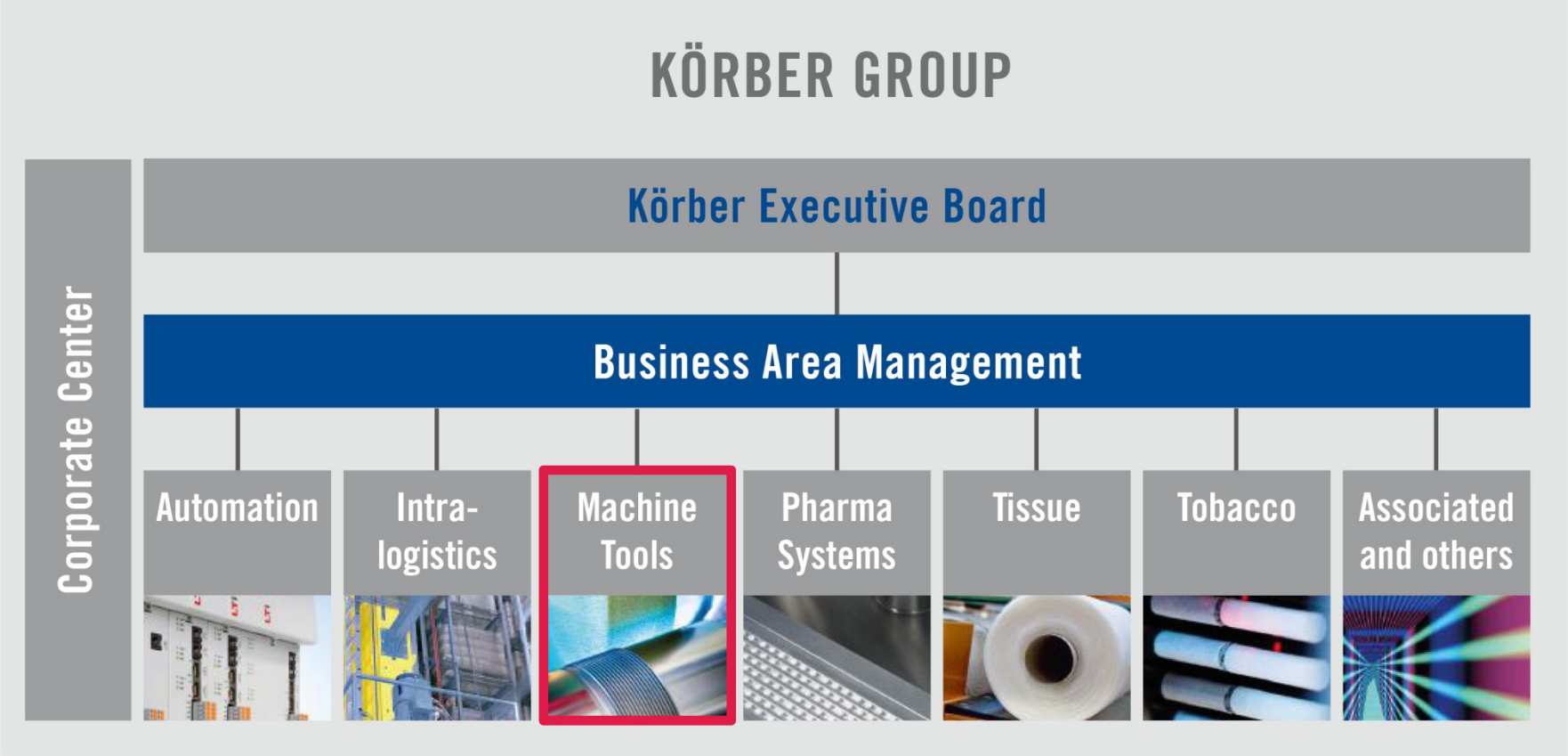
Körber and UGG: The structure of the Körber group



Introduction

Körber and UGG: Brands of the United Grinding Group

Surface and Profile

MÄGERLE KÖRBER SOLUTIONS

BLOHM KÖRBER SOLUTIONS

JUNG KÖRBER SOLUTIONS

Cylindrical

STUDER KÖRBER SOLUTIONS

SCHAUDT KÖRBER SOLUTIONS

MIKROSA KÖRBER SOLUTIONS

Tools

WALTER KÖRBER SOLUTIONS

EWAG KÖRBER SOLUTIONS

Introduction

WALTER / EWAG – complete solution partner for tools

- GRINDING TECHNOLOGY
- EDM TECHNOLOGY
- LASER TECHNOLOGY
- MEASURING TECHNOLOGY
- SOFTWARE & PROCESS DEVELOPMENT
- CUSTOMER CARE

Contents

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Laser machining centers (LASER LINE series)

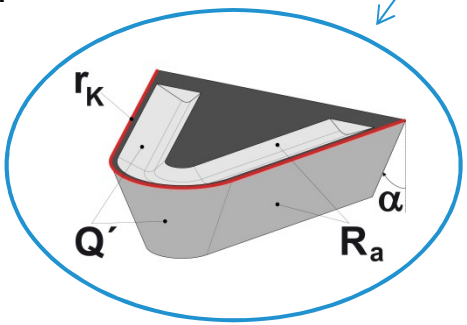
- 5 CNC- + 3 optical axes
- Free-space laser system & beam delivery (IR)
- t_P = 10 ps, P = 50/100 W, f_P < 2 MHz
- Water cooling (+- 0.1 K)
- On-site servicing challenging
- High laser system costs

- 5 CNC- + 2 optical axes
- Compact solid state laser (green)
- t_P = 30 ns, P = 50 W, f_P < 0.6 MHz
- Water cooling (+- 0.1 K)
- Laser system easily exchangable
- Low laser system costs

EWAG AG

Laser machining centers (LASER LINE series)

- **Accuracy**
  - Tool dimensions d < 200 mm, l < 250 mm
  - Typical tolerances (e.g. automotive industry)
    - Profile form (entire tool) < 3 µm
    - Diameter < 2 µm
    - Runout < 2 µm
- **Operating environment**
  - Climate control highly recommended
- **Machine base**
  - Massive vibration damping required



-> Machine design & environmental issues critical

-> Fiber lasers & fiber delivery systems help reduce complexity & enable high accuracy

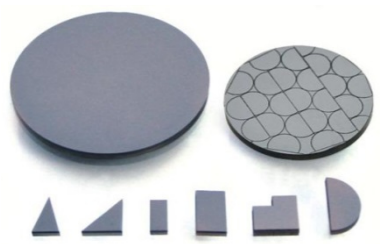
EWAG AG

Materials, standard applications, research

- **Ultrahard materials**
  - Polycrystalline diamond (PCD)
  - Chemical vapor deposition diamond (CVD-D)
  - Cubic boron nitride (cBN)
  - Monocrystalline diamond (MCD)
- **Application**
  - Plate based(e.g. milling or drilling tools)
  - Grain based (e.g. dressing wheels)
  - Combinations (e.g. full PCD on carbide base)

- **Metals**
  - Iron
  - Steel
  - Tungsten carbide
- **Application**
  - Tool body
  - Substrate material for plating

- **Ceramics**
  - Individual material mostly unkown
  - Parameter range needs to be found on every trial
- **Application**
  - Tooling industry
  - IT industry



www.langescheid.de

www.eibtron.com

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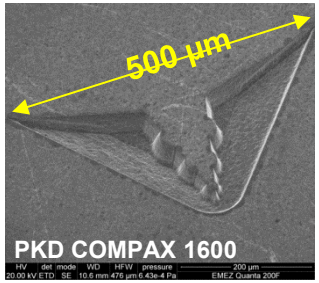
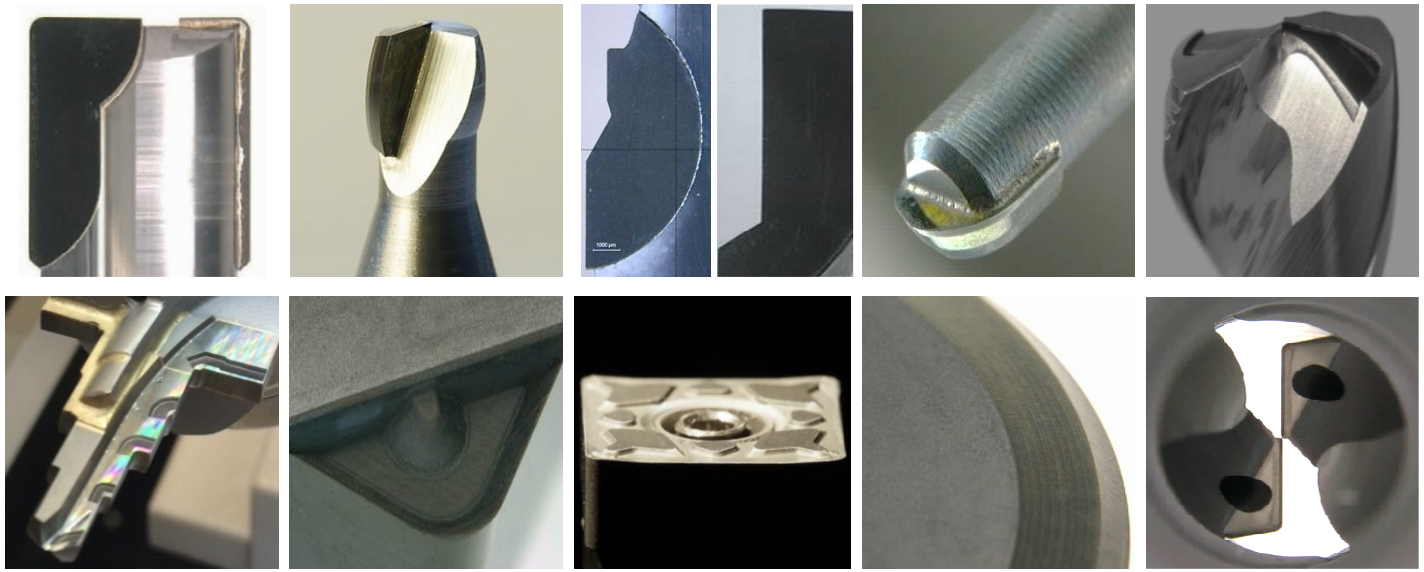
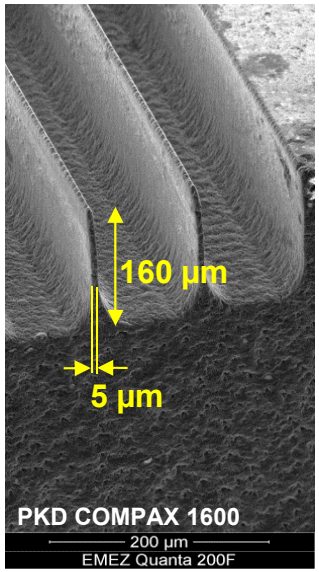
Materials, standard applications, research







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Swiss Federal Institute of Technology Zurich

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LASER ZENTRUM NORD

The University of Nottingham
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SEVENTH FRAMEWORK PROGRAMME

Sources: G. Eberle, C. Dold, K. Wegener (2015) Picosecond laser fabrication of micro cutting tool geometries on polycrystalline diamond composites usinng a high-numerical aperture micro scanning system. Lase – Spie Photonics West, USA, 935103/1-9.

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Beam delivery

Requirements for industrial machining

- **Free space systems**
  - Bulky
  - Complex
  - Expensive
- **Fiber based systems**
  - Compact
  - Reliable
  - Reduced maintenance

- **Transport challenging (free-space system)**
  - Laser mounted into machine bed /no vibration isolation possible
    - Laser system
    - Beam path
    - All optical components
  - Machine weight approx. 4.5 t
  - Machine transported via ship / airplane
    - Shock events up to 10g

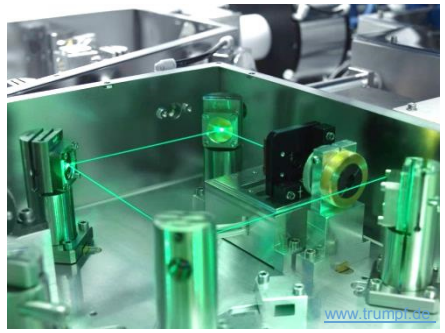
-> Fiber based beam path is ideal

Fig. 1: Example of an ultrashort pulse free-space system.

Fig. 2: Delivery of a machine with installed ultrashort pulsed laser system. Shock events up to 10g when handling system.

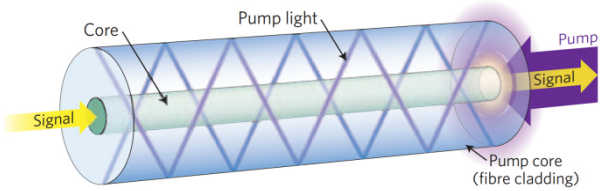
Beam delivery

Requirements for industrial machining



- **Laser system architecture not as important for industrial use**
  - Free-space or fiber laser as system design is not primarily important
  - Machine can be designed for ideal
    - Vibration damping of system, isolators for system protection
    - Cooling (Water / air, climate control)

- **But beam delivery systems are highly important**
  - **Free-space** beam delivery highly challenging
    - Micrometer precision of entire beam path
    - 8 axes kinematics -> tolerances
    - Vibration damping not possible
  - **Fiber based** beam delivery
    - Fiber integration is simple and fast
    - Fiber length up to 5 m sufficient
    - Laser pulse properties (esp. ultrafast) must keep
      - Pulse shape (temporal, spatial)
      - Wave properties (e.g. no chromatic dispersion)



Source (2nd from bottom): C. Jauregui, J. Limpert, A. Tünnermann (2013) High-power fibre lasers. Nature Photonics, 7:861-867.

Beam delivery

Wishes 2015

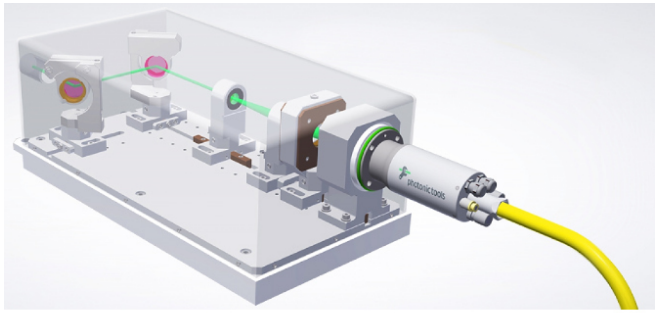
- **Ideal parameter range for processing**
  - Large pulse energy range (µJ-mJ)
  - Large repetition rate range (kHz – MHz)
  - Average power 50 – 100 W
  - Wavelength IR and green
  - Pulse duration ns -> fs

- **Beam delivery challenges**
  - Delivery fibers need stable beam profile and highest pointing stability
  - Laser beam alignment through machine requires short beam paths and very stiff, vibration isolated, optical elements
  - Compact lasers to be built in close to the focussing optics
  - Beam coupling to a fiber is very critical: needs to be provided by the laser manufacturer

Beam delivery

Progress during the past two years

- **Photonic Tools**
  - 500W, 500µJ, IR
  - Coupling module
  - No complete solution for integrators



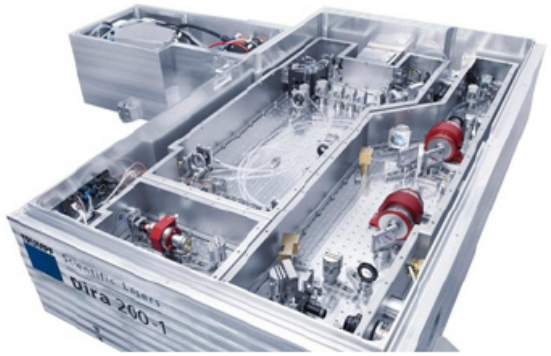
- **GLO Photonics**
  - 50W, 500µJ, IR and green
  - Coupling module
  - No complete solution for integrators

Beam delivery

Progress during the past two years

- **Amplitude**
  - Provide fiber coupled laser
  - 50W, <400fs
  - Robot applications possible
  - Processing during movement is not possible

- **Trumpf**
  - 30W, 400fs in fiber
  - Not stable enough for robot applications
  - Not yet for sale



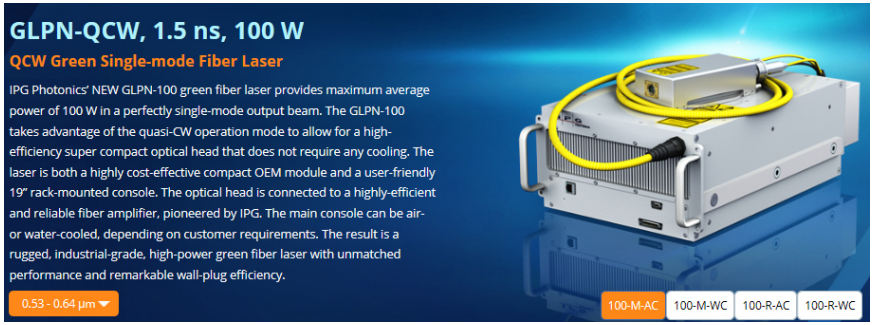
Trumpf's Dira-branded scientific lasers

Combine ultrashort pulses with fiber delivery
World of Photonics 2017

Beam delivery

Progress during the past two years

- **IPG**
  - No progress with green fiber laser
  - Power still at 20W



- **Coherent**
  - Are working on fiber coupling for solid state lasers
  - No solution up to now

Beam delivery

Status 2017

- No fiber laser found that fits EWAG needs for high productivity in micromachining
- No fiber lasers in products
- No fiber delivered laser
- Compact solid state lasers give new oportunities

EWAG AG

Status 2017

- LLU ps – product: no progress
- Free-space laser system & beam delivery (IR)
- t_P = 10 ps, P = 50/100 W, f_P < 2 MHz
- On-site servicing challenging

- LLP ns – product: Laser exchanged
- Compact solid state laser (green)
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Conclusions

- Fiber laser technology is the optimal base for all in fiber solutions in material processing.
- High average power combined with high pulse energy is hard to reach for fiber lasers and beam delivery fibers.
- Solid state lasers become more and more compact.
- For high processing speed EWAG made a step back to solid state laser technology.
- Laser manufacturer recognize the need to provide a fiber delivery solution to integrators.
- Delivery fibers are not yet stable enough (beam profile, pointing stability).

Thank you.

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