

Ultrafast Laser Solutions for Microprocessing

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Lumentum Switzerland AG

- Founded in 1995 as Time-Bandwidth Products, a spinoff of the Ultrafast Laser Physics group from ETH Zurich
- Grew up in Technopark Zurich
- Specialized in development and manufacturing of high quality ultrafast lasers
- Moved to expanded and upgraded facility in Schlieren in July 2013
- Acquired in Jan 2014 by JDSU
- JDSU split into Lumentum and Viavi on 1-August-2015



By the numbers

\$815M in FY15 revenue*

~2,000 employees

8 offices around the globe

>1,000 patents

*As JDSU CCOP segment



Global operations



Focused on optical and photonic products

TELECOM



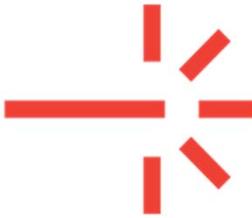
Broad portfolio of optical components and subsystems (that will be the basis of 100G metro builds)

DATAKOM



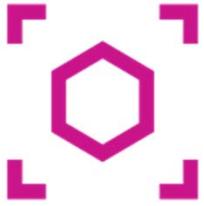
Optical transceivers with a focus on leading the 100G transition

COMMERCIAL LASERS



Laser solutions enabling high-value materials processing applications that are growing faster than the broad market

3D SENSING



Optical components for emerging PC and mobile device applications that leverage our telecom/datacom capabilities

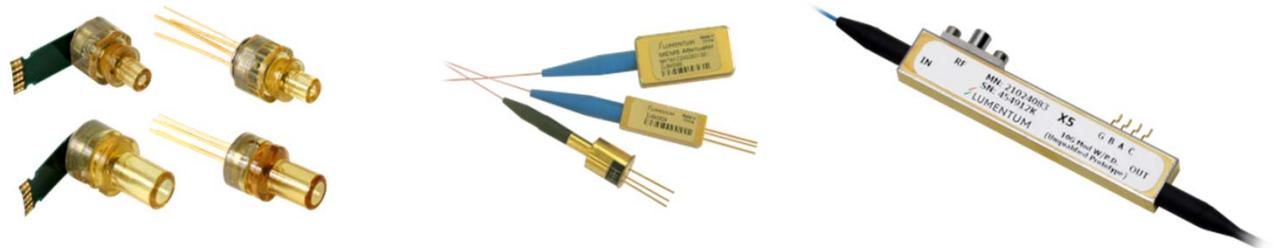
Telecom/Datacom operation

Vertical and functional integration core technology developed in-house with assembly and test at low cost CMs

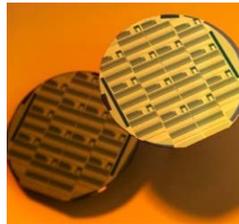
Modules and Circuit Packs



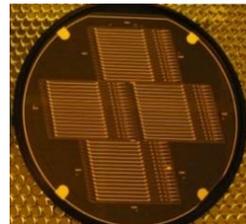
Sub-Assemblies and Components



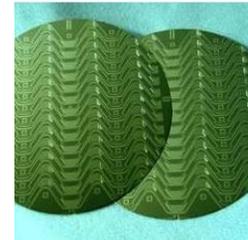
Internal Wafer Fabrication



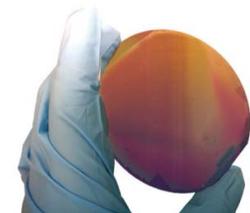
Indium Phosphide (InP)



Lithium Niobate (LiNbO₃)



Silica/Silicon (SiO₂/Si)



Gallium Arsenide (GaAs)

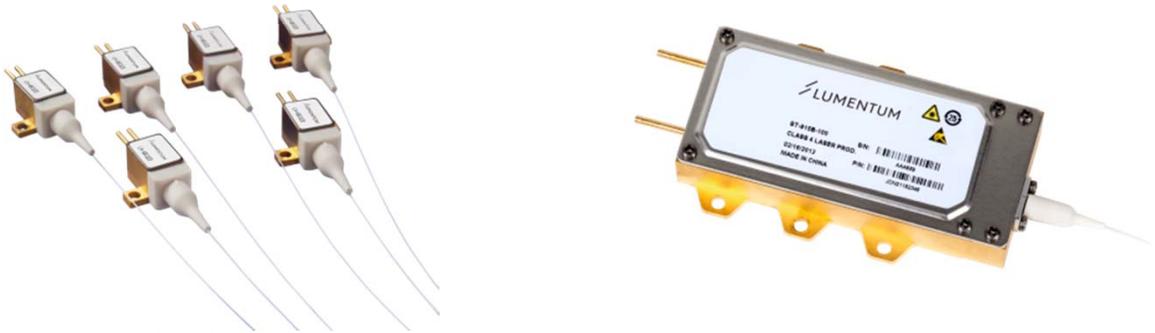
Commercial Lasers and 3D Sensing operation

Vertical and functional integration core technology developed in-house with assembly and test at low cost CMs

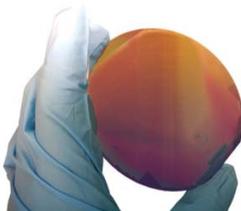
Commercial Lasers and Modules



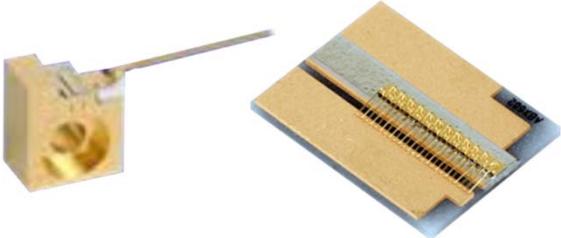
Pump Sources (industrial diodes)



Internal Wafer Fabrication



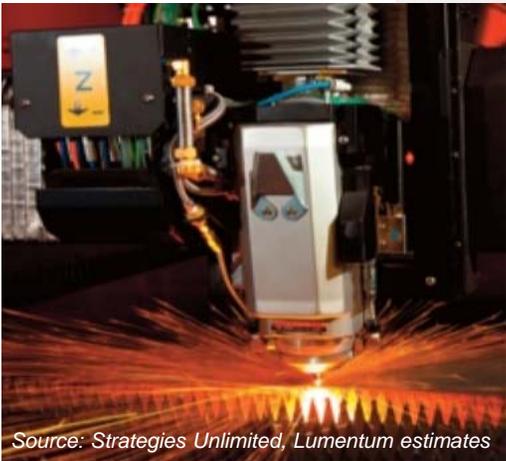
GaAs Wafer



Gallium Arsenide (GaAs)

Commercial Lasers Trends

\$2.5B SAM Opportunity Lumentum Served Market



Source: Strategies Unlimited, Lumentum estimates

Macro (kW) Materials Processing (CO₂ Replacement)

\$1,500M

Cutting Welding/other

Micro-Materials Processing (Mechanical Tool Replacement)

\$600M

Biomedical and Analytics Instrumentation (Long Lifecycle)

\$400M

Gen2 4kW Fiber Laser Engine



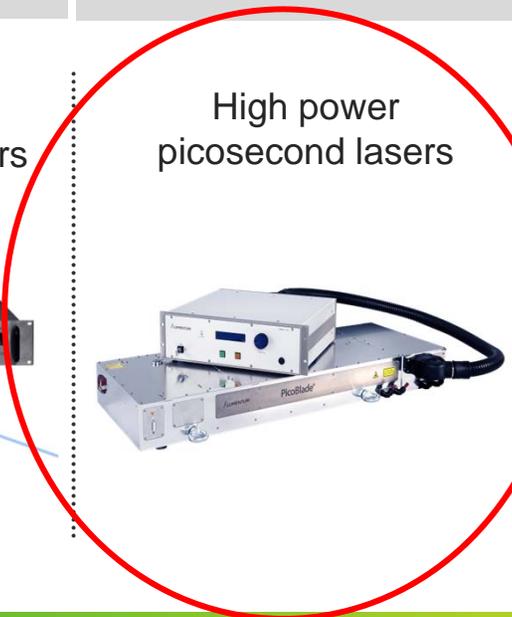
Gen1 4kW Fiber Laser Engine



High power nanosecond UV lasers



High power picosecond lasers



Laser Micro Materials Processing of Consumer Electronics

>1B Smartphones and Tablets in 2014

Si IC singulation

MEMS, RF and power devices

PCB via holes

Si/glass/other interposers

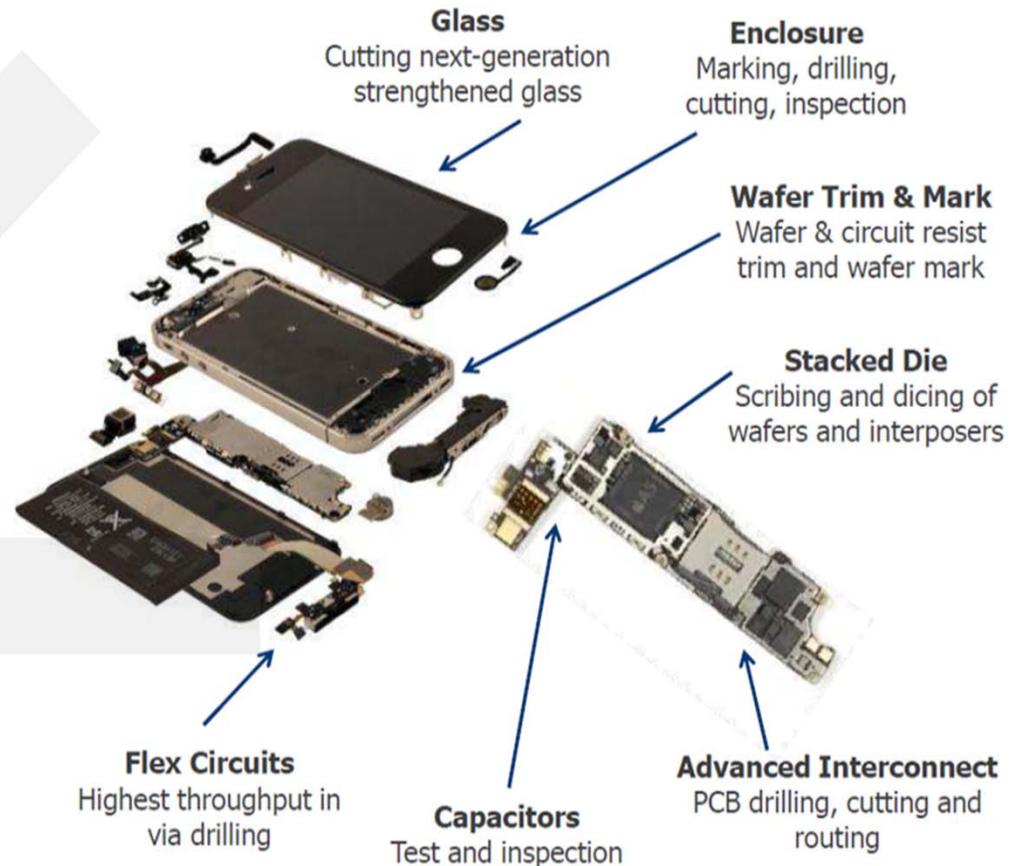
LED flash singulation

Ceramics cutting

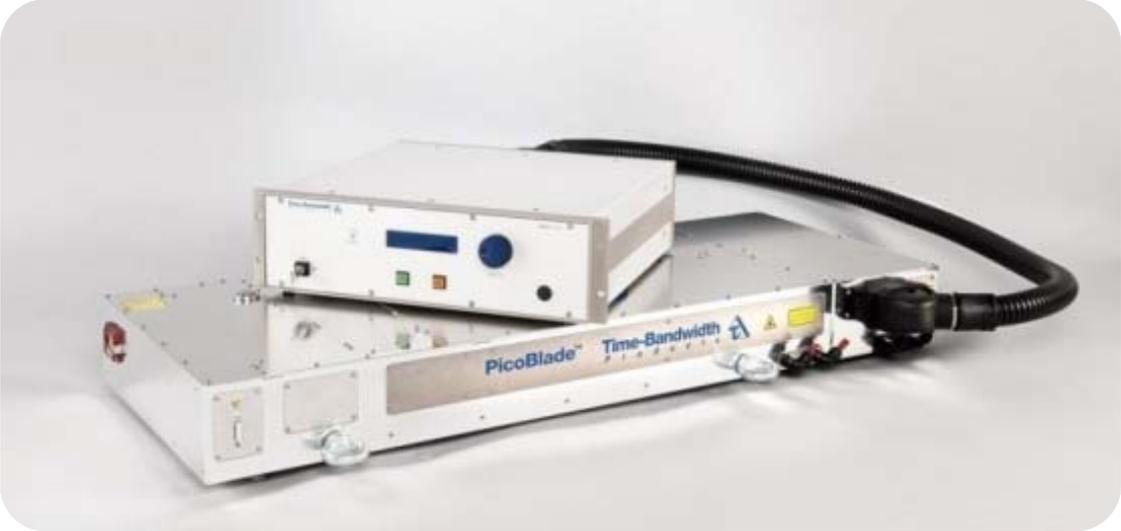
Marking, cutting, drilling, welding

TFT annealing, AMOLED

Hydro/oleo-phobic surfaces



PicoBlade™ Industrial Picosecond Micromachining platform



OEM Laser for micro-material processing

PicoBlade™

fully integrated picosecond laser



Average power	up to 50 W
Pulse-frequency	single-pulse to 8 MHz
Pulse-energy	up to 200 μ J
Pulsewidth	10 ps
Peakpower	up to 20 MW
Wavelength	355, 532, 1064 nm
M ²	< 1.3

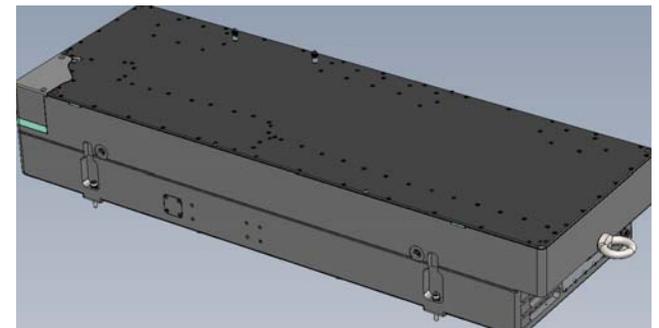
Advantages of Lumentum's PicoBlade



- Most flexible architecture on the market in terms of power, wavelength, and pulse modulation formats
- FlexBurst
 - Highest available burst envelope energy
 - Fully “flexible” burst patterns offer ability to further optimize a process
- Highly Reliable
 - Passively mode-locked “heart” using SESAM technology
 - Conservative and proven design throughout system
- Lumentum manufacturing - agility with scalability
 - Network of world-class photonics contract manufacturing for rapid, high-volume product ramps

APPOLO Project

- Simple architecture for high-repetition rate sub-picosecond high-average power pulses (e.g. target applications use high-speed line scanners)
- YBIX femtosecond seed laser plus multi-stage non-fiber amplifiers w/ Lumentum pumps
- No stretcher or compressor components
- Achieved $>100\text{W}$, $M^2 = 1.3$, 800 fs pulses at 5-16 MHz and 1030 nm on benchtop
- Building on PicoBlade OEM platform
- Prototype delivered to Burgdorf application labs



Laser System Design: Oscillator

- **MOPA:** YBIX oscillator + 2-stage Yb:YAG amplifiers

- Why **YBIX**?
 - Robust SESAM[®] mode-locking
 - High peak power
 - Ultrashort pulses, 200 fs



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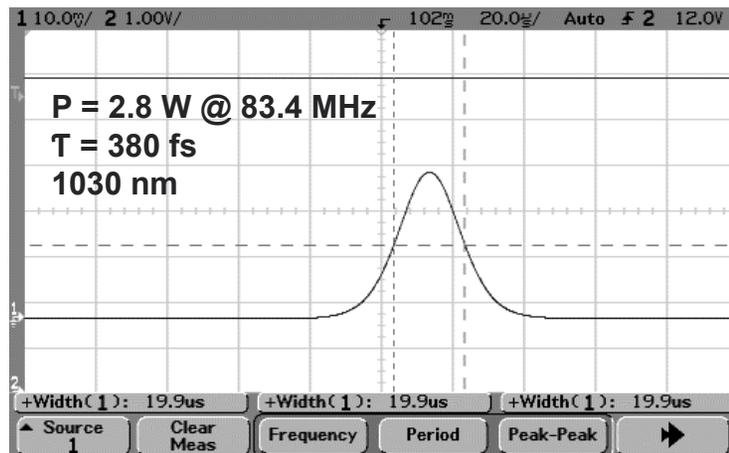
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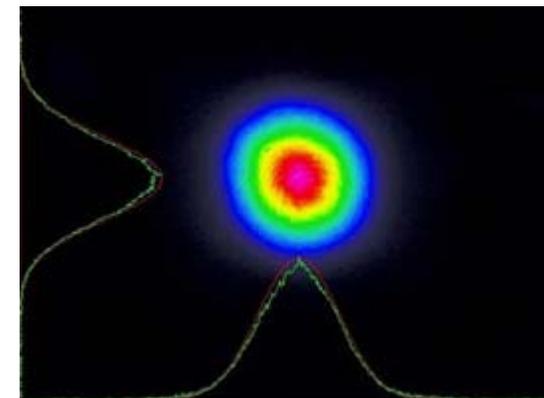
- Customized **YBIX** oscillator parameters:

-



Autocorrelation trace

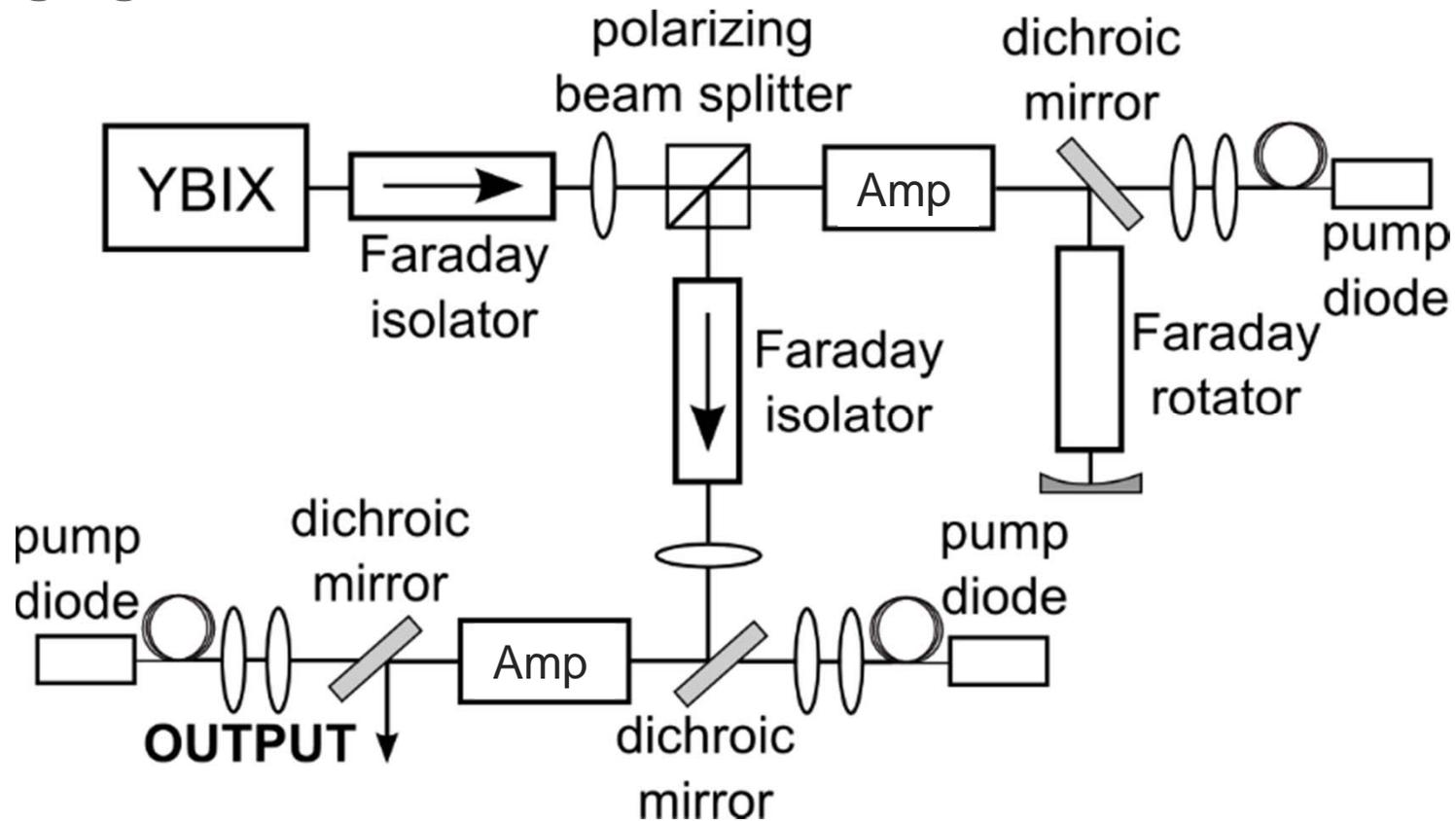
M2<1.1



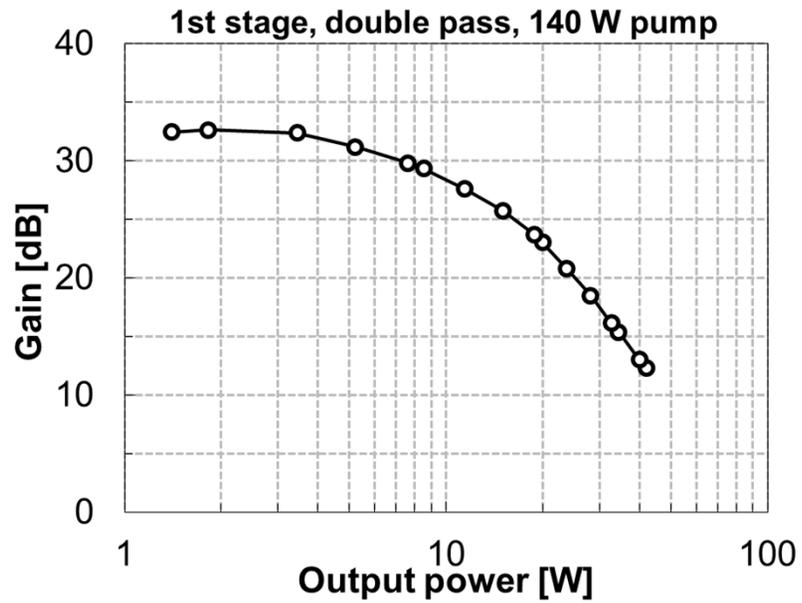
Beam profile

Laser System Overview

- No CPA
- High brightness 105- μm fiber-coupled pump diode, 140 W, 940 nm
- High gain!

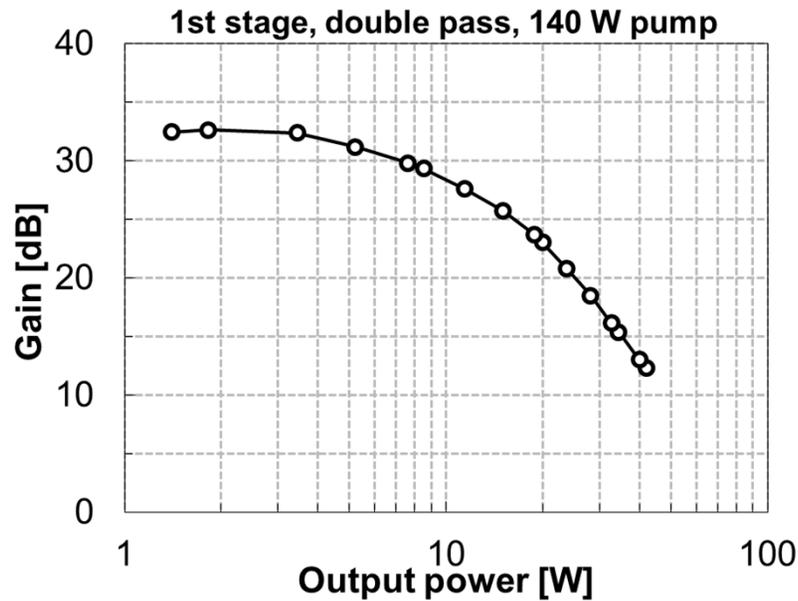


Gain Curves



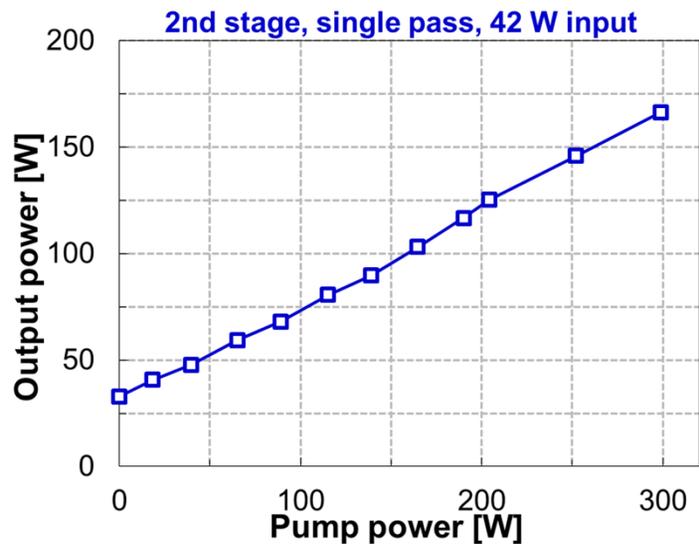
- 1st stage amplifier:
 - Small signal gain: **>32 dB**
 - Maximum output power: **42 W**
 - Extraction efficiency: **28 %**

Gain Curves



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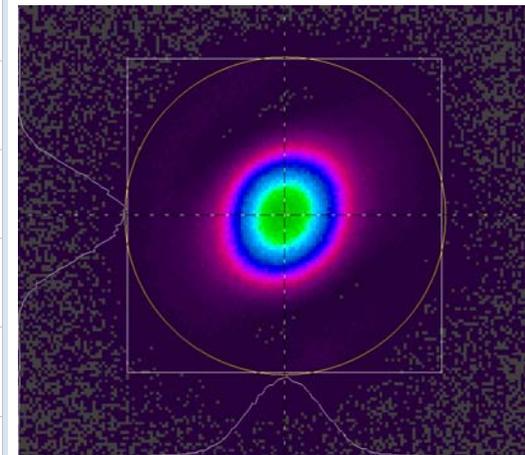
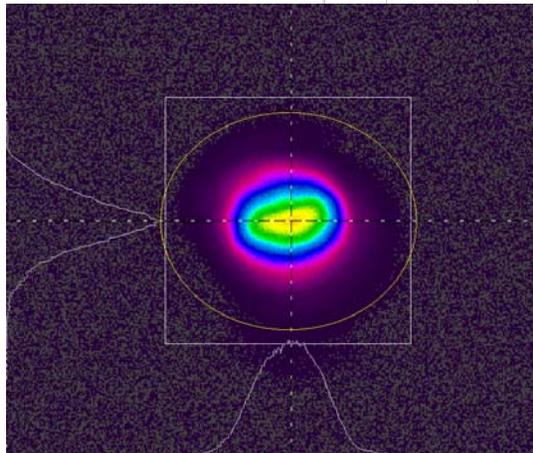
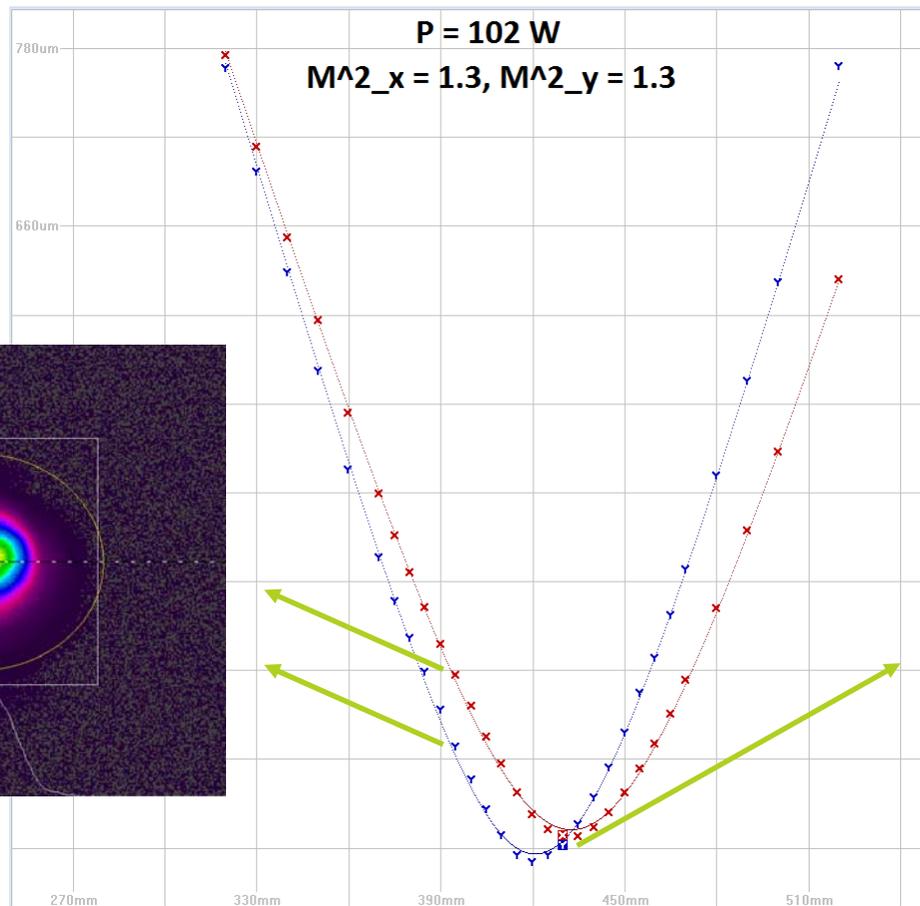


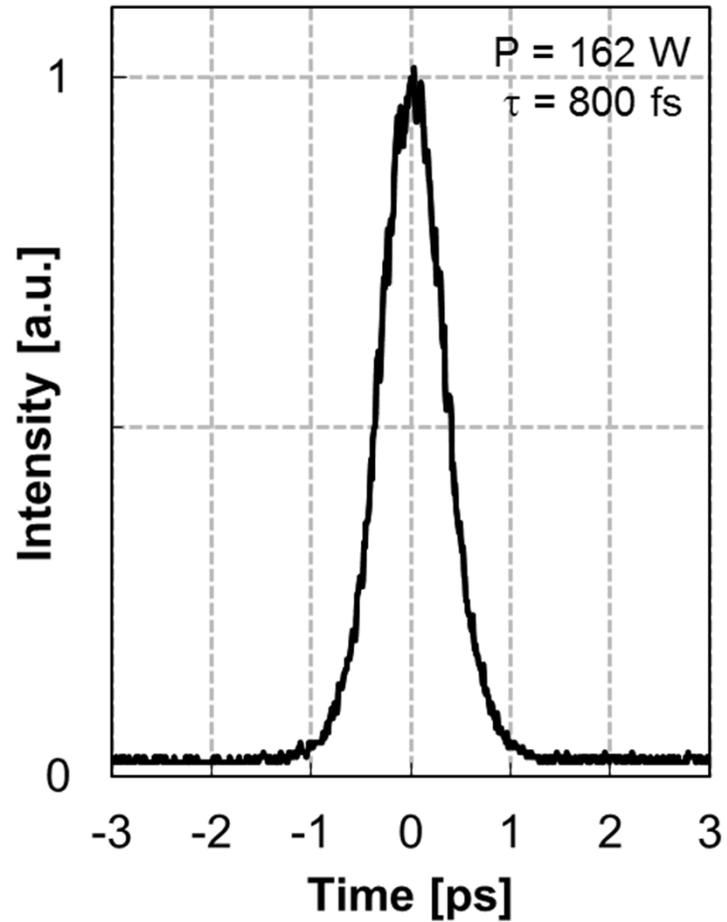
- **2nd stage amplifier:**

- Maximum output power: **162 W**
- Extraction efficiency: **42 %**

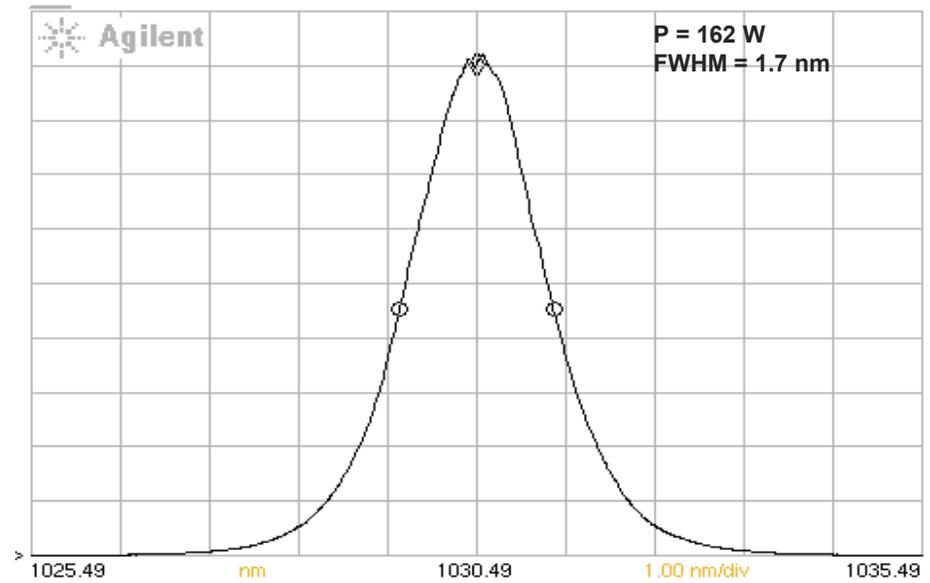
Beam quality

Beam quality factor, M^2			
Oscillator	@ 102 W output	@ 124 W output	@ 162 W output
< 1.1, 1.1	1.3, 1.3	1.4, 1.5	1.9, 1.9





Autocorrelation
800 fs at 160 W output



Optical spectrum centered at 1030.5 nm
1.7 nm FWHM at 160 W output

Summary and Outlook

- **Compact laser system that delivers >100 W femtosecond pulses** with only 2 amplifier stages
- High brightness pumping results in the **highest small signal gain (>30 dB dB)** achieved
- A **bidirectional pumping scheme of the second amplifier** allowed us to reach 160 W with 2 amplifier stages

Acknowledgment



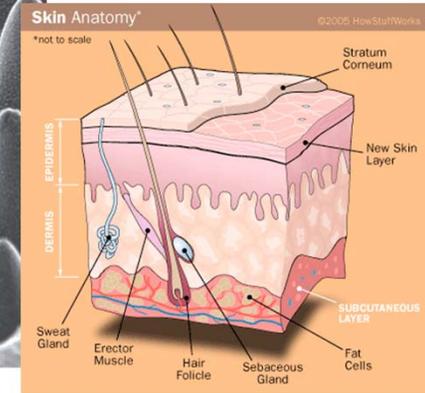
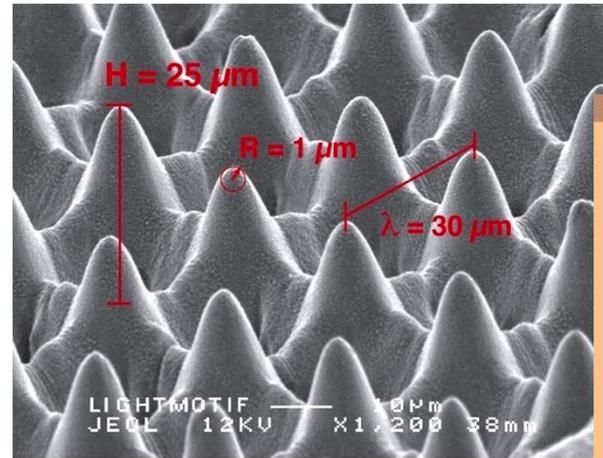
Hub of Application Laboratories for Equipment
Assessment in Laser Based Manufacturing

This work was partially financially supported by EU FP7 project Appolo
Grant Agreement 609355

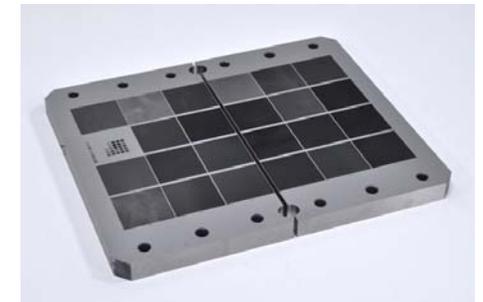
FP7 Project APPOLO

appolo

Lightmotif

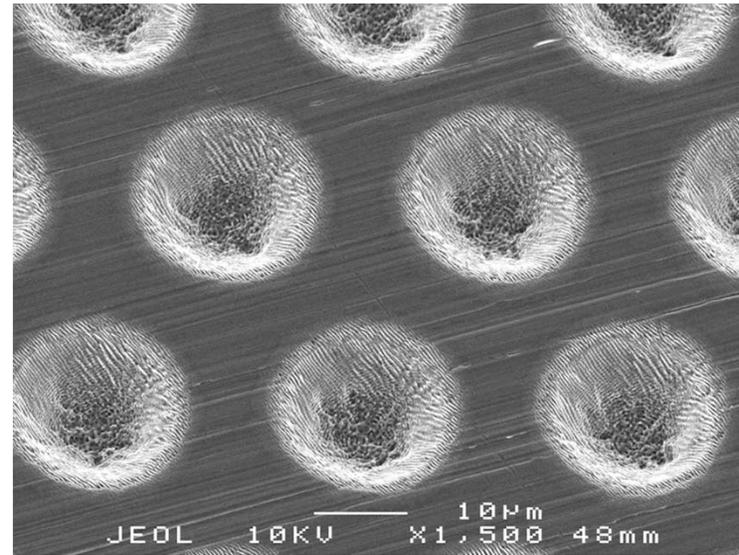
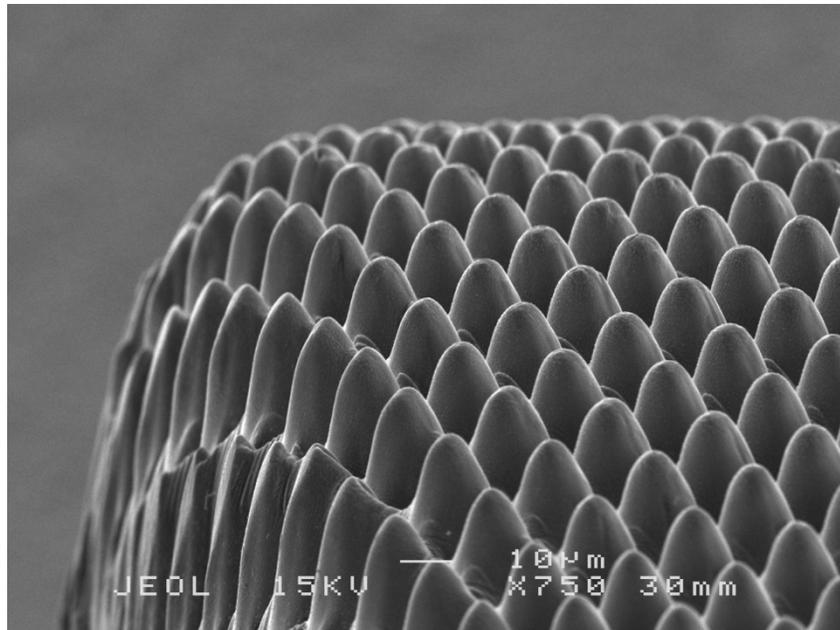
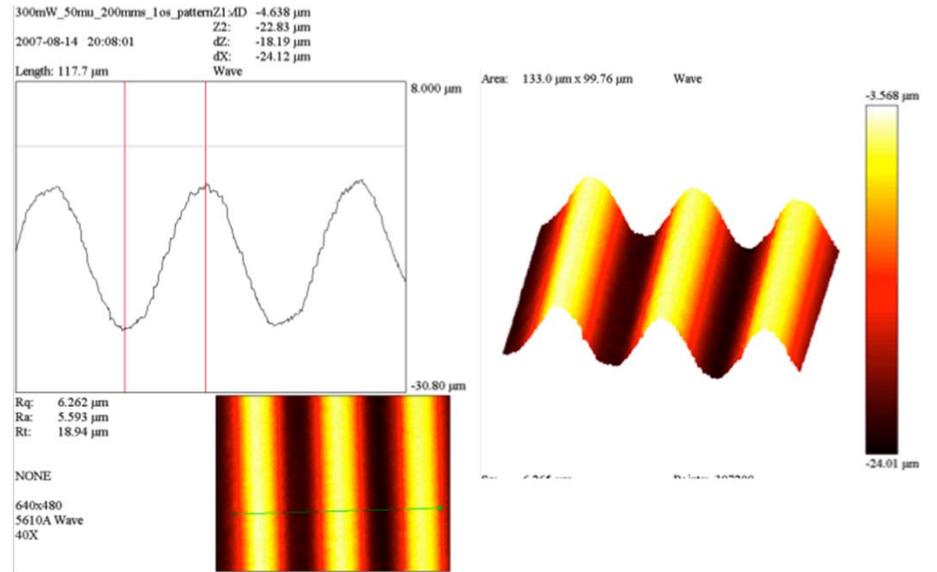
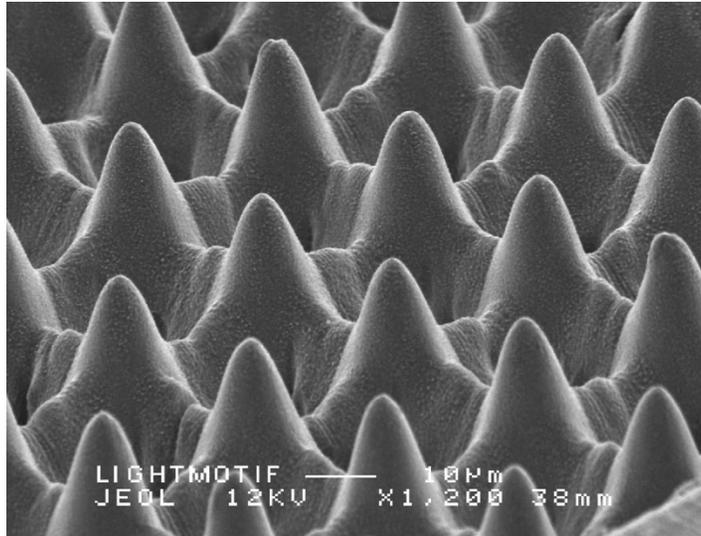


- Development of technology for soft-touch and anti-glare surfaces in car interiors
- 'Soft-touch' effect by reduced skin friction,
- Precisely 'engineered' skin contact surface
- Anti-glare effect by dense and highly diffusing microtextures
- Optimization of texture, process and machine
- Further development towards industrial use of technology



Direct-Write Textures

Lightmotif



Thank you



www.lumentum.com

