



160 W 800 fs Laser System without CPA for High Speed Surface Texturing

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Introduction

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 - Minimum surface roughness is achieved with a spatial overlap of two consecutive pulses of 50-75 % [1] → **high marking speeds (several 100 m/s)** are needed
 - Provided by novel **polygon line scanners**
 - For a given material, there is an **optimum fluence (pulse energy)** at which maximum specific removal rate (removal rate per average power) is achieved [2,3]
 - $P_{\text{average}} = E_{\text{pulse}} * f_{\text{rep}}$ → **to work at high rep rates high average power is needed**
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- **Appolo** project <http://www.appolo-fp7.eu/>
 - Collaboration between the end-users, research labs and laser manufacturers (21 partners, 8 countries)
 - **Laser system for high speed surface texturing**
 - high rep rate > 3 MHz,
 - high average power ~ 100 W,
 - ultrashort pulses ≤ 500 fs,
 - compact foot print,
 - low cost,
 - robust system,
 - ...

APPOLO - Validation of Process Feasibility and Adaptation of Innovative Laser Technology and Equipment
Gediminas Raciukaitis, today, 11:20 h
Forum A2 - Optical Metrology and Imaging

1. Jaeggi, B. et al. Proc. of SPIE 8243-20, 2012
2. Raciukaitis, G. et al. JLMN 4, 186, 2009
3. Neuenschwander, B. et al. Proc. of SPIE 7584, 2010

Laser System Design: Oscillator

- **MOPA:** YBIX oscillator + 2-stage SCF amplifier

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



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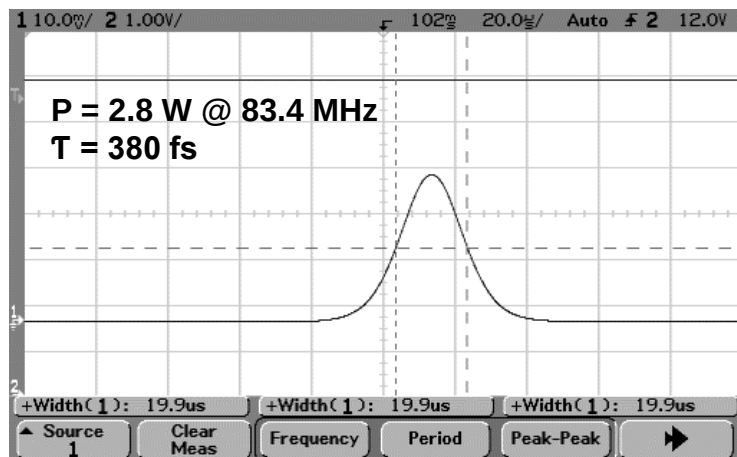
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- Customized **YBIX** oscillator parameters:

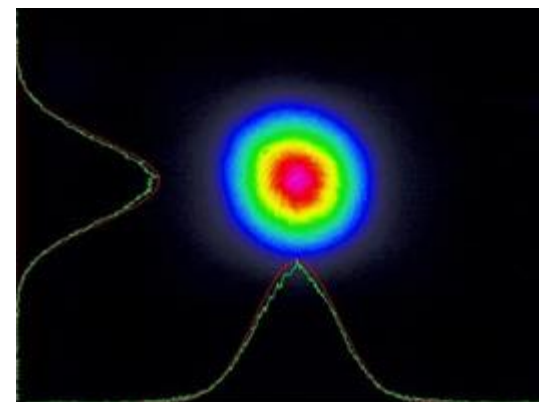
- **2.8 W, 83.4 MHz, 1030.3 nm, FWHM = 2.4 nm, < 400 fs, M2<1.1**



YBIX Compact, High Power, Femtosecond Laser
1040 nm Wavelength with SESAM[®] Technology*



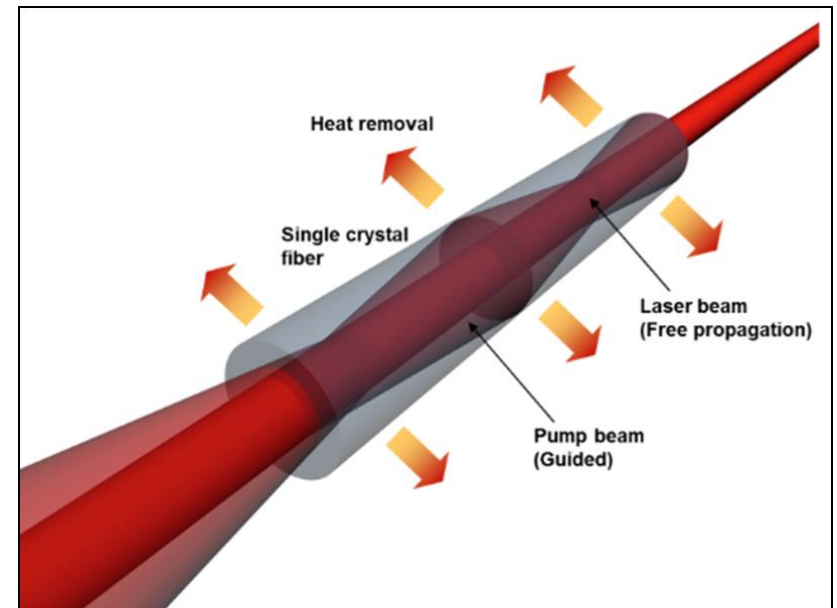
Autocorrelation trace of 380 fs at 2.8 W.



Beam profile measured at 200 mm distance from the housing at 2.8 W.

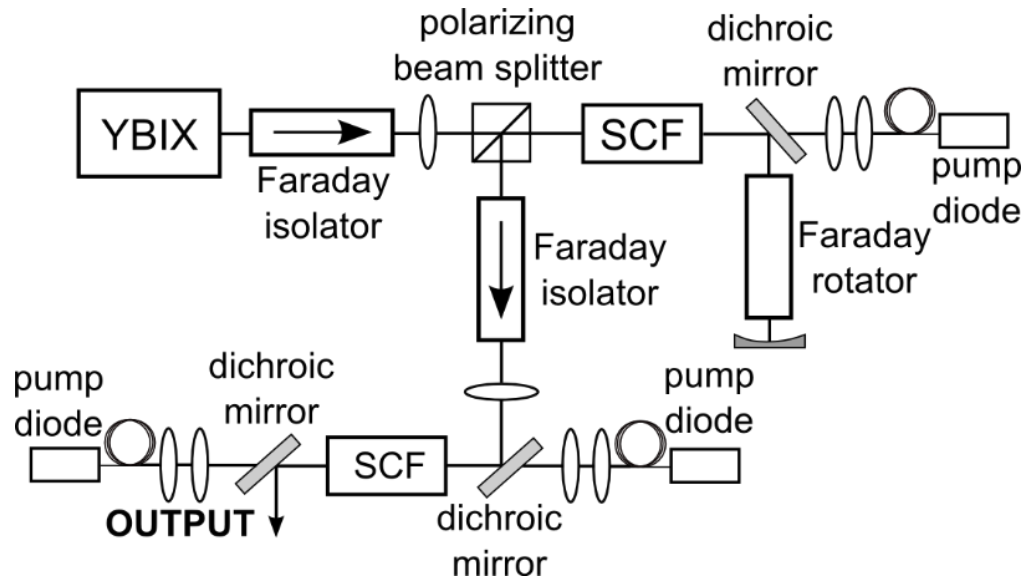
Laser System Design: Amplifier

- Why **single crystal fiber (SCF)**?
 - A short rod fiber or a thin and long crystal
 - Direct amplification of femtosecond pulses avoiding the standard CPA technique
 - Designed for a pump light guidance and a free-space propagation of a laser signal
- **SCF:** 1 mm diameter Yb:YAG rod



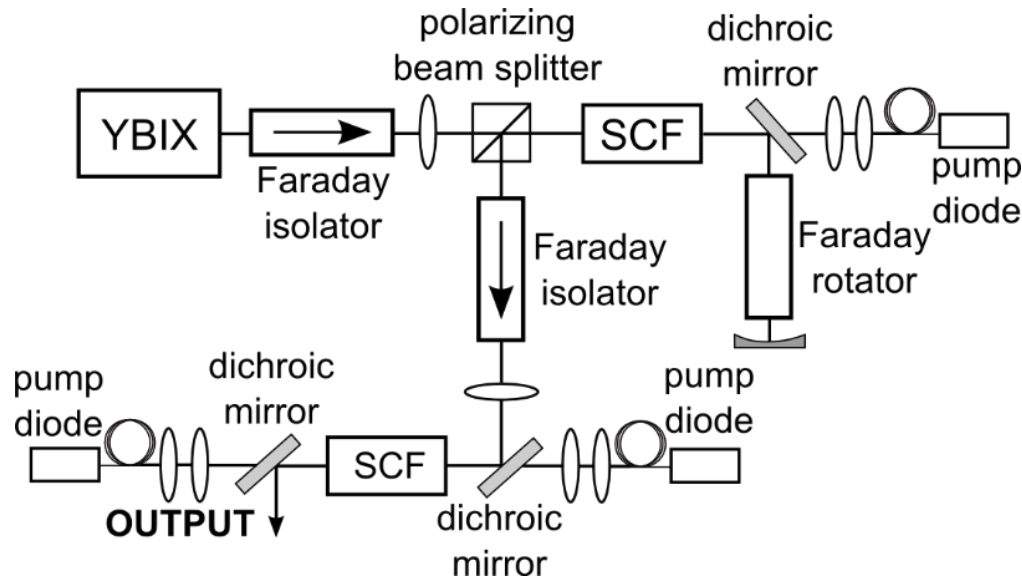
picture credits : property of Fibercryst SAS

Laser System Design



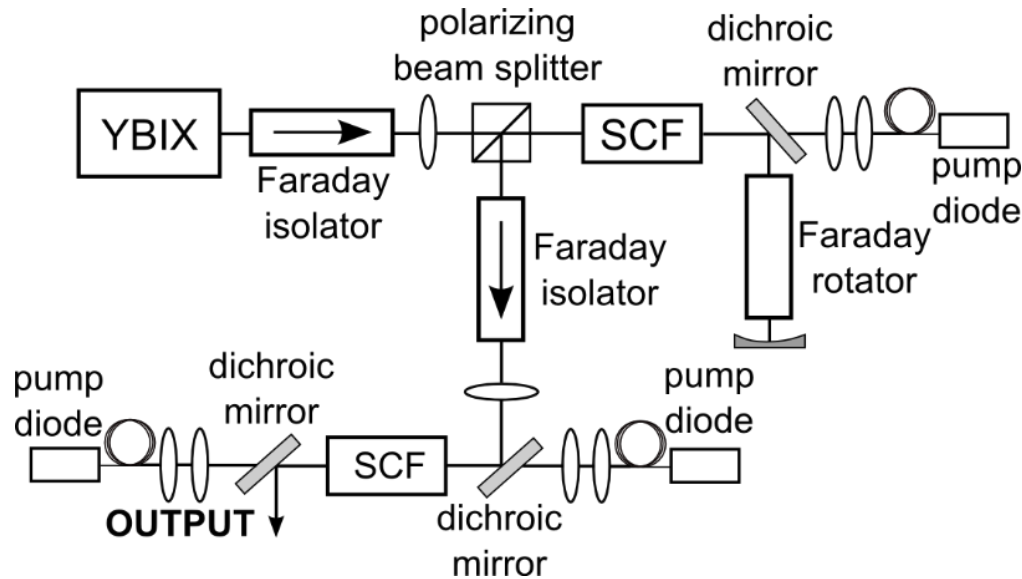
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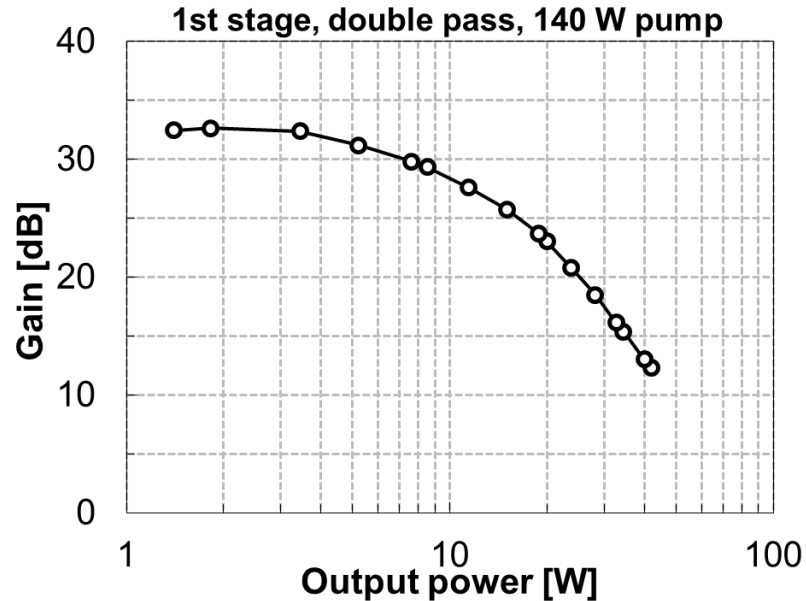
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- **1st stage amplifier:**
 - Double-pass signal configuration using the retro-reflective mirror and Faraday rotator
 - **High brightness 105- μ m fiber-coupled pump diode, 140 W, 940 nm**

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 - **High brightness 105- μ m fiber-coupled pump diode, 140 W, 940 nm**
- **2nd stage amplifier:**
 - Single-pass signal configuration
 - **Bidirectional pumping:** 105- μ m fiber-coupled diode, 140 W, 940 nm and 200- μ m fiber-coupled diode, 200 W, 940 nm

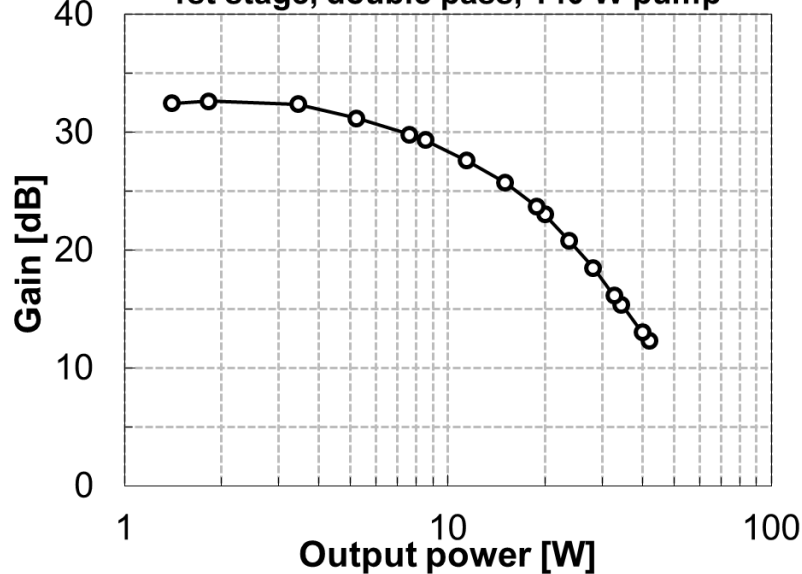
Gain Curves



- **1st stage amplifier:**
 - Small signal gain: **>32 dB**
➔ **Highest small signal gain with SCF so far**
 - Maximum output power: **42 W**
 - Extraction efficiency: **28 %**

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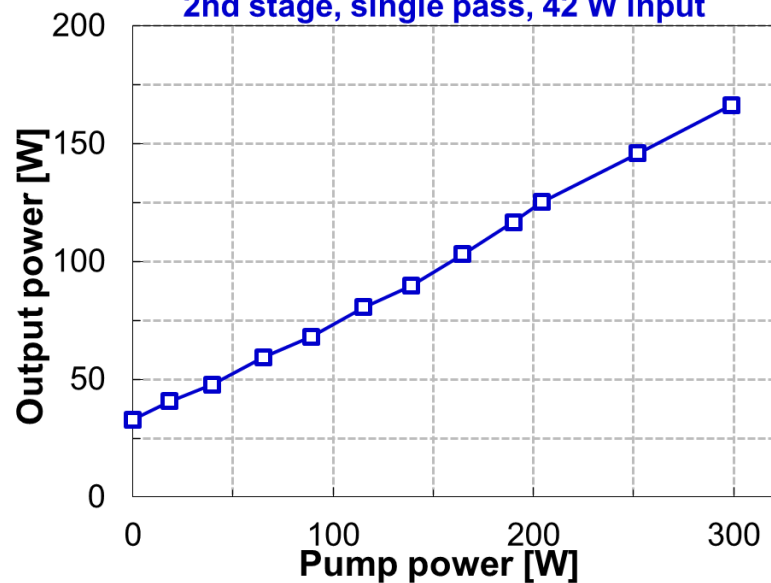
1st stage, double pass, 140 W pump



1st stage amplifier:

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2nd stage, single pass, 42 W input

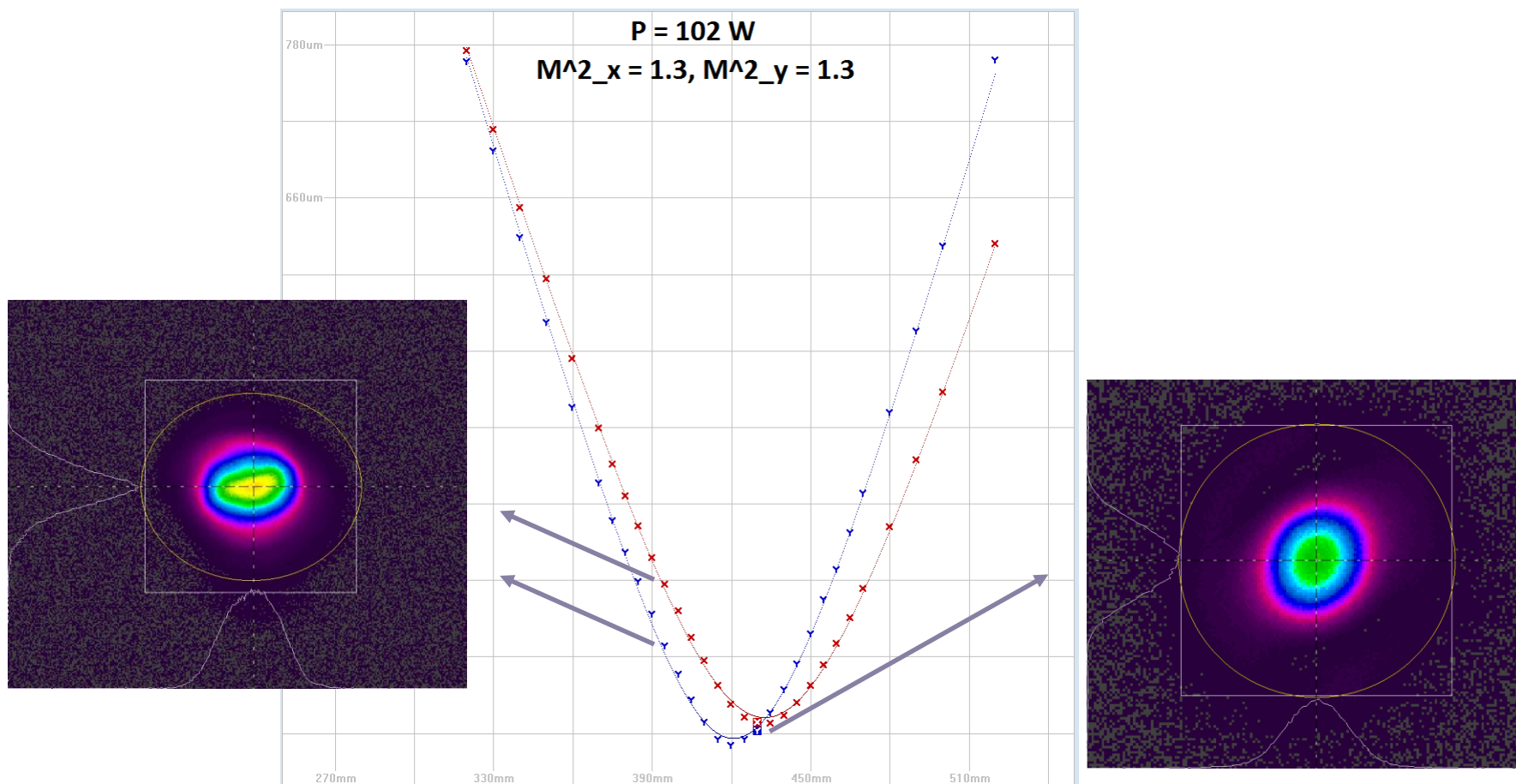


2nd stage amplifier:

- Maximum output power: **162 W**
➔ **Highest average power of femtosecond pulses achieved with SCF so far**
- Extraction efficiency: **42 %**
➔ **Highest value achieved with SCF so far**

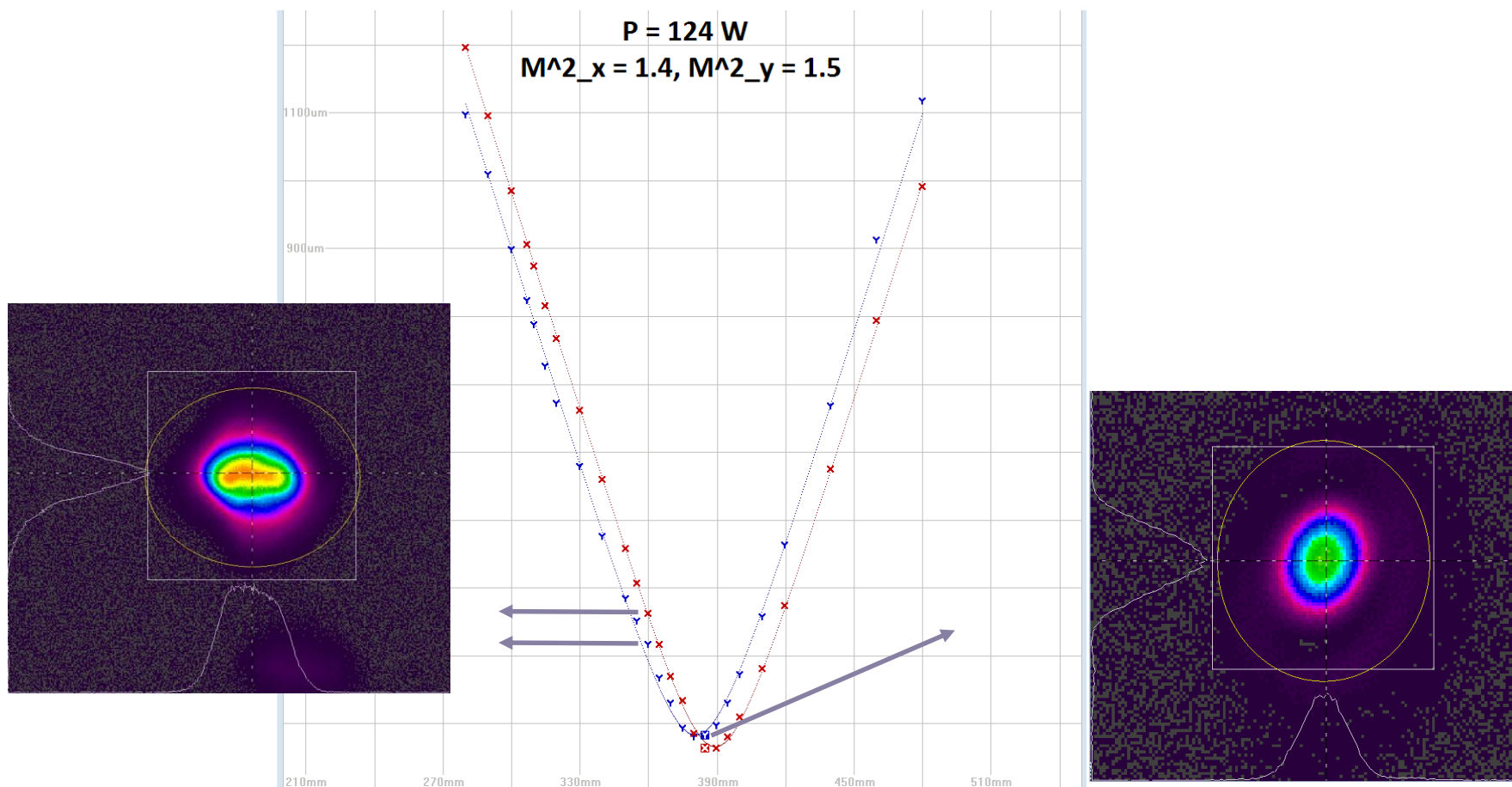
Beam quality

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



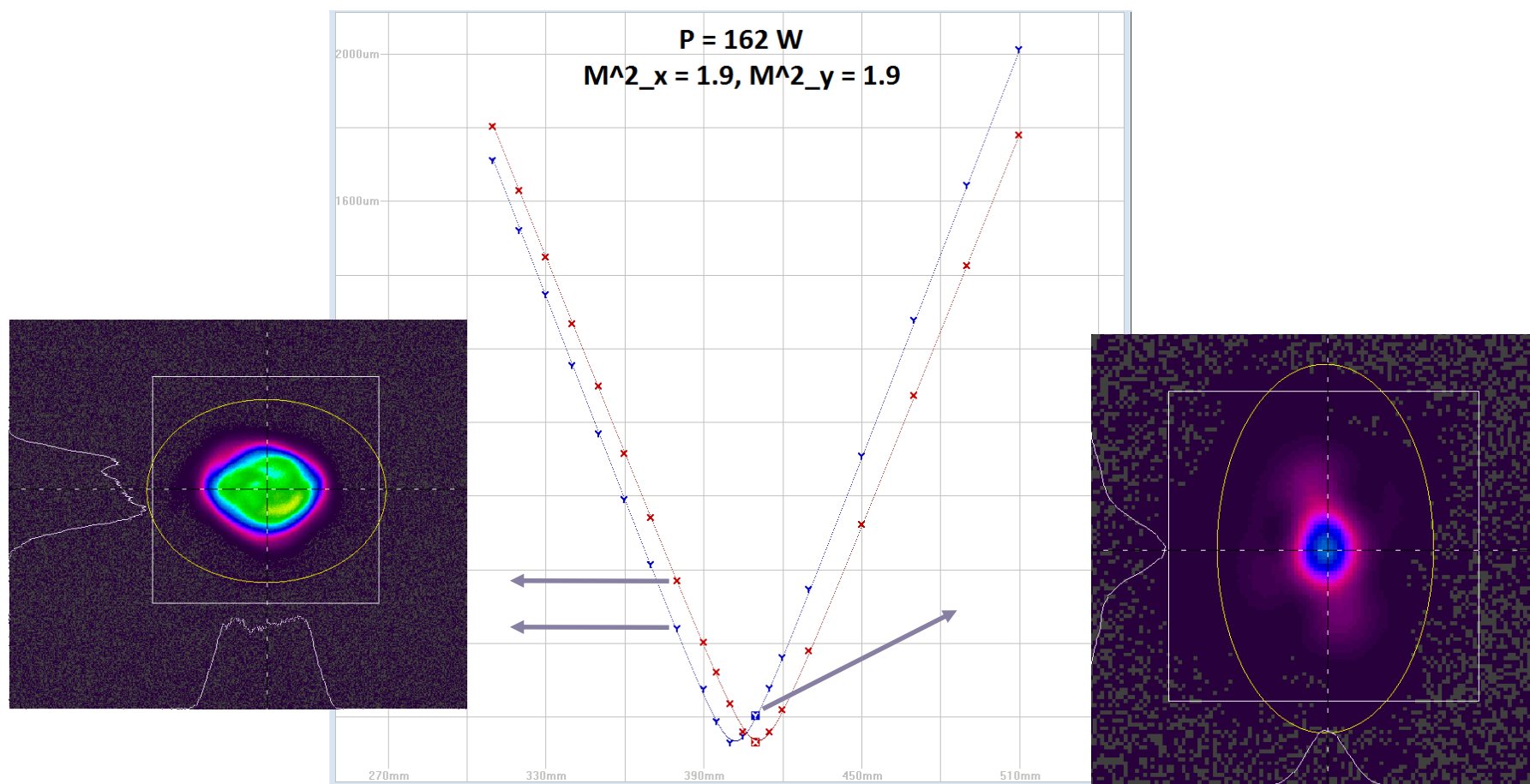
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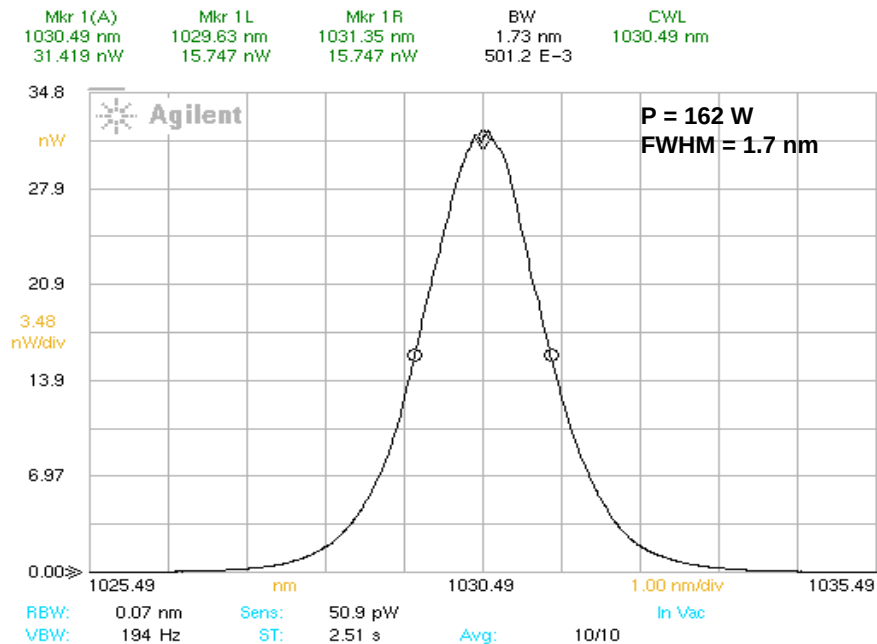


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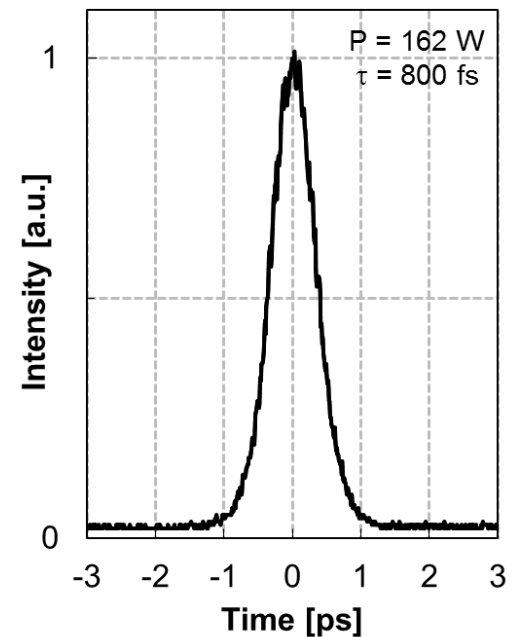
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Spectrum and Pulse Duration



Optical spectrum centered at 1030.5 nm with 1.7 nm full width half-maximum at maximum output power of 160 W.



Autocorrelation trace of 800 fs at maximum output power of 160 W.

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 (close to 33 dB)** achieved so far
- We implemented **bidirectional pumping scheme of SCF amplifier** for the first time, and this allowed us to reach 160 W with 2 amplifier stages
- **Highest average power of femtosecond pulses achieved with SCF**

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Acknowledgment



Hub of Application Laboratories for Equipment
Assessment in Laser Based Manufacturing

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