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

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CLEO Europe, 25.06.2015

# Introduction

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  - **High repetition rate** lasers operating at **> 1 MHz** deliver > 1 million pulses per second
  - 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]
  - $P_{average} = E_{pulse} * f_{rep}$ ➔ **to work at high rep rates high average power is needed**
  - **Demand for laser systems with high average power and high repetition rate**

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

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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*


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  - High peak power
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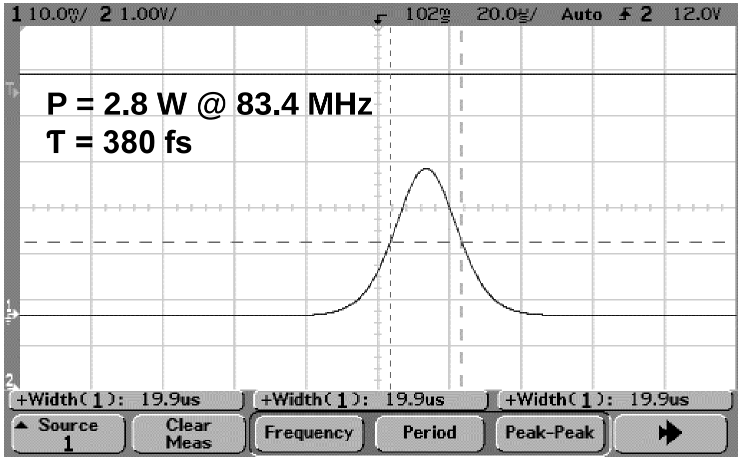
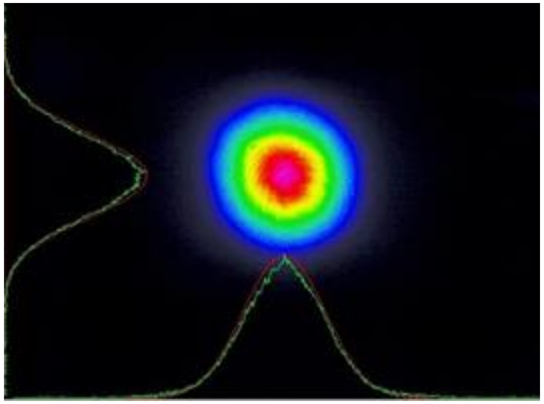
- Customized **YBIX** oscillator parameters:
  - **2.8 W, 83.4 MHz, 1030.3 nm, FWHM = 2.4 nm, < 400 fs, M2<1.1**



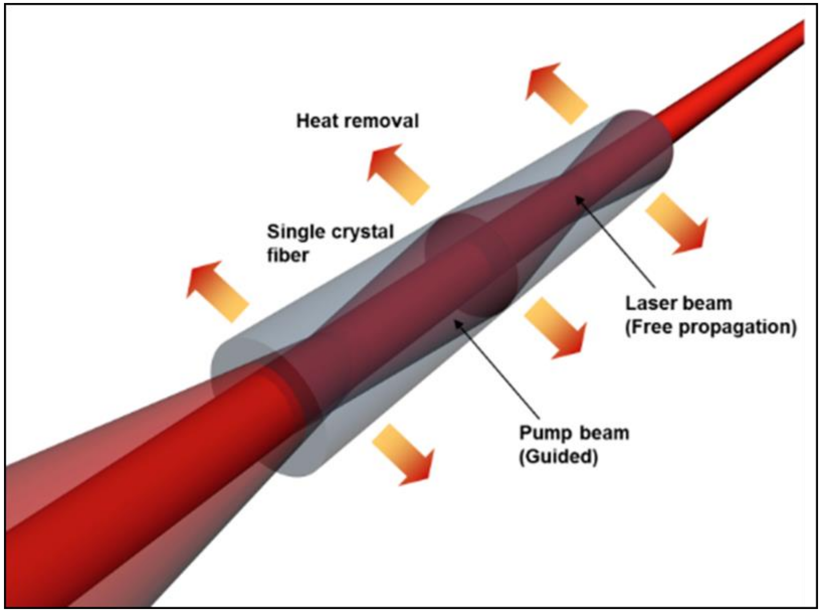
Autocorrelation trace of 380 fs at 2.8 W.


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

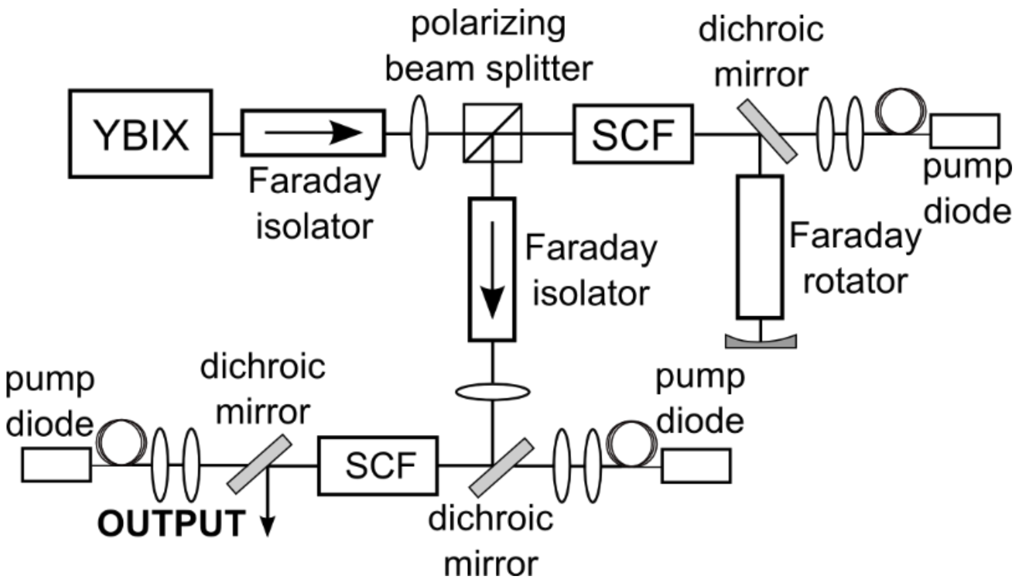
# Laser System Design: Amplifier

- 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*

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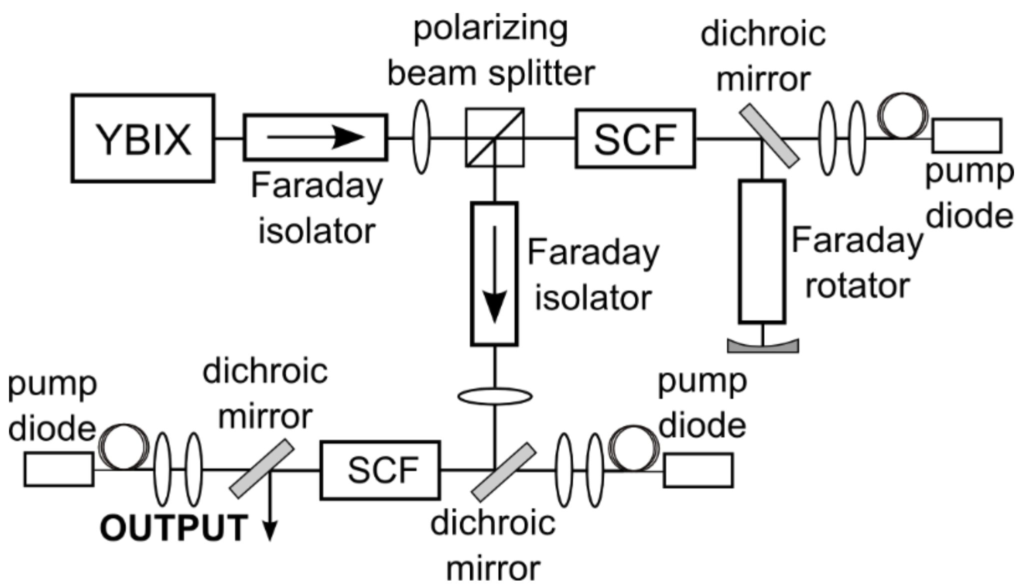


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- **1st stage amplifier:**
  - Double-pass signal configuration using the retro-reflective mirror and Faraday rotator
  - **High brightness 105-µm fiber-coupled pump diode, 140 W, 940 nm**

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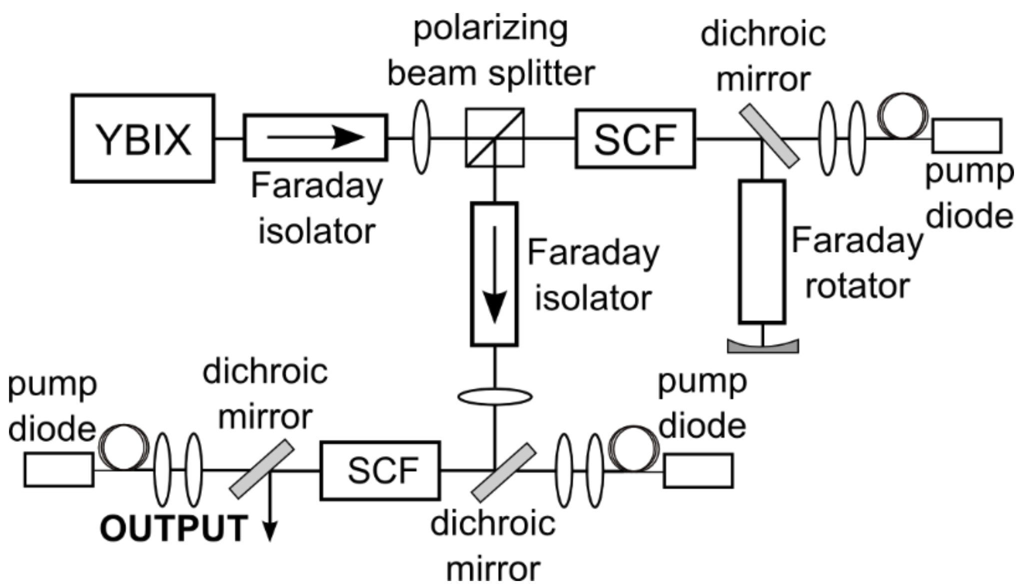


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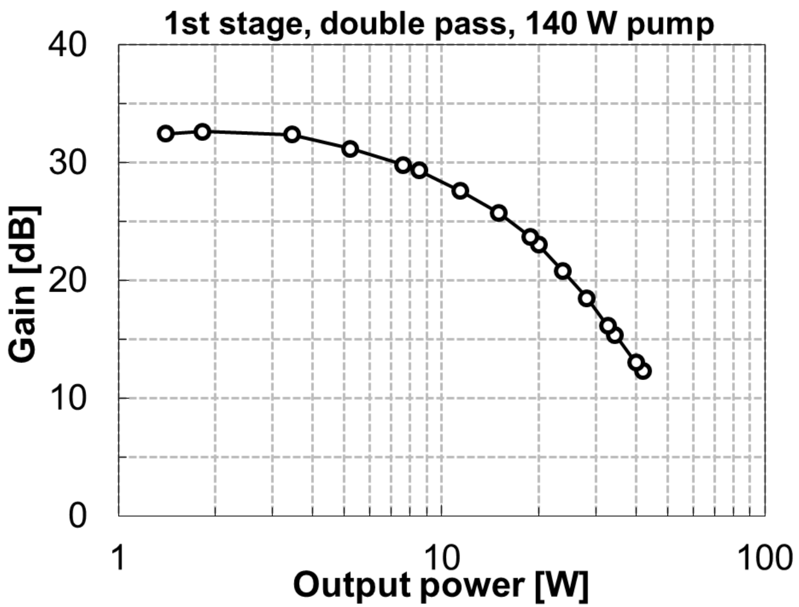
- **2nd stage amplifier:**
  - Single-pass signal configuration
  - **Bidirectional pumping**: 105-µm fiber-coupled diode, 140 W, 940 nm and 200-µm fiber-coupled diode, 200 W, 940 nm

# 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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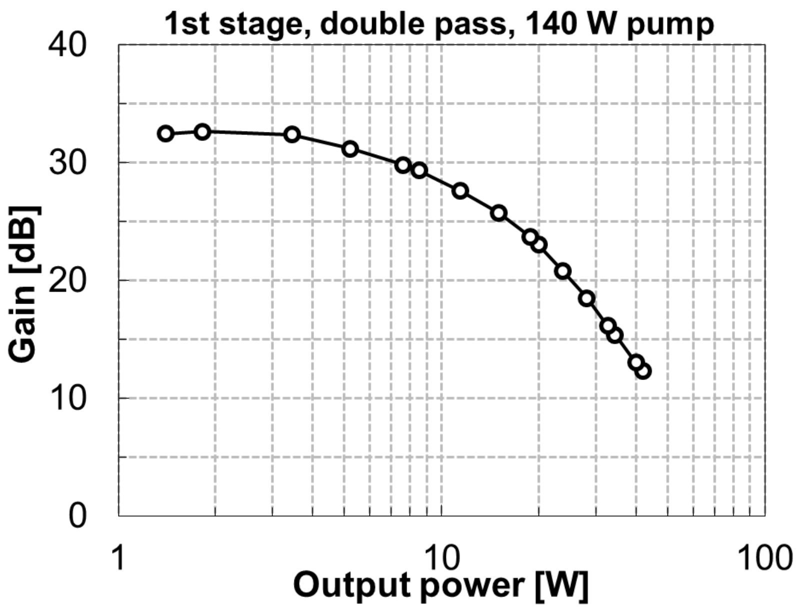


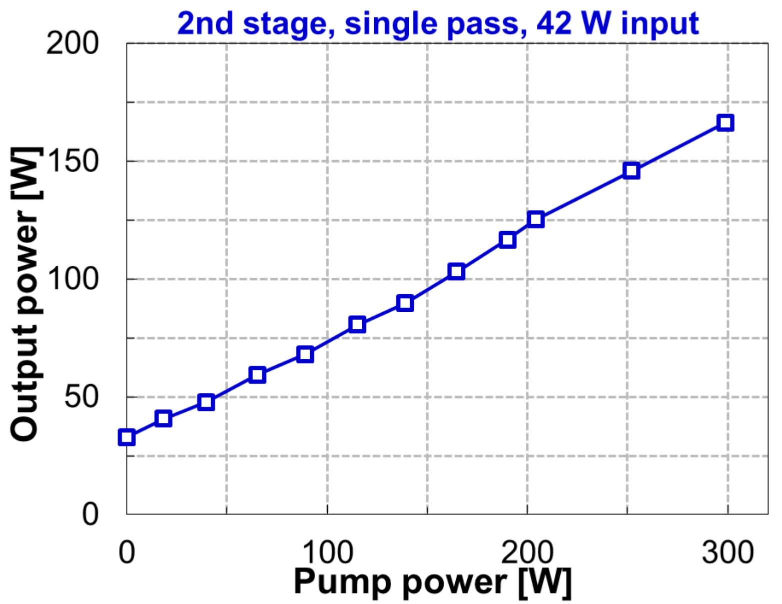


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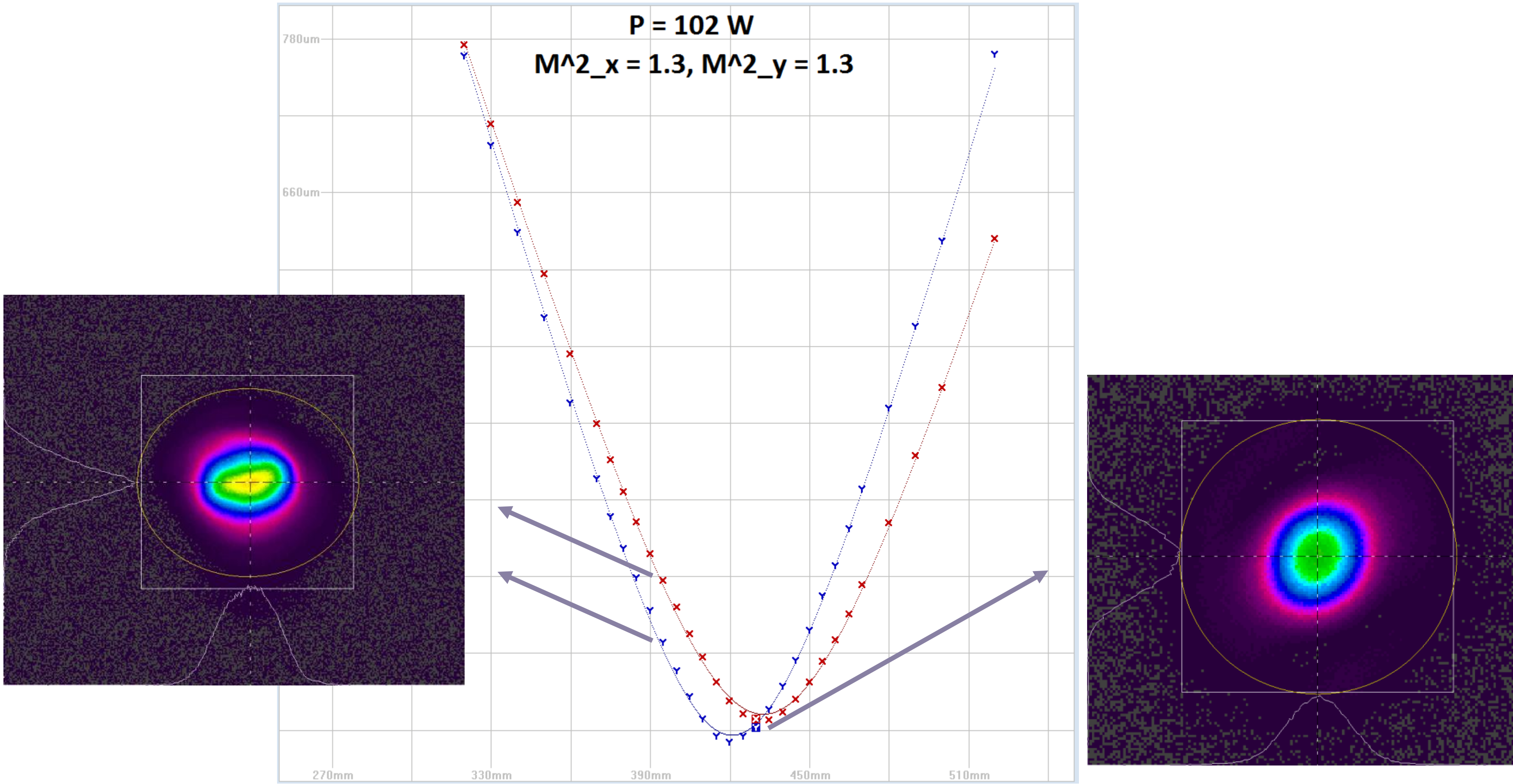
- **2nd stage amplifier**:
  - Maximum output power: **162 W**
  
  ➔ **Highest average power of femtosecond pulses achieved with SCF so far**
  - Extraction efficiency: **42 %**
  
  ➔ **Highest value achieved with SCF so far**

# 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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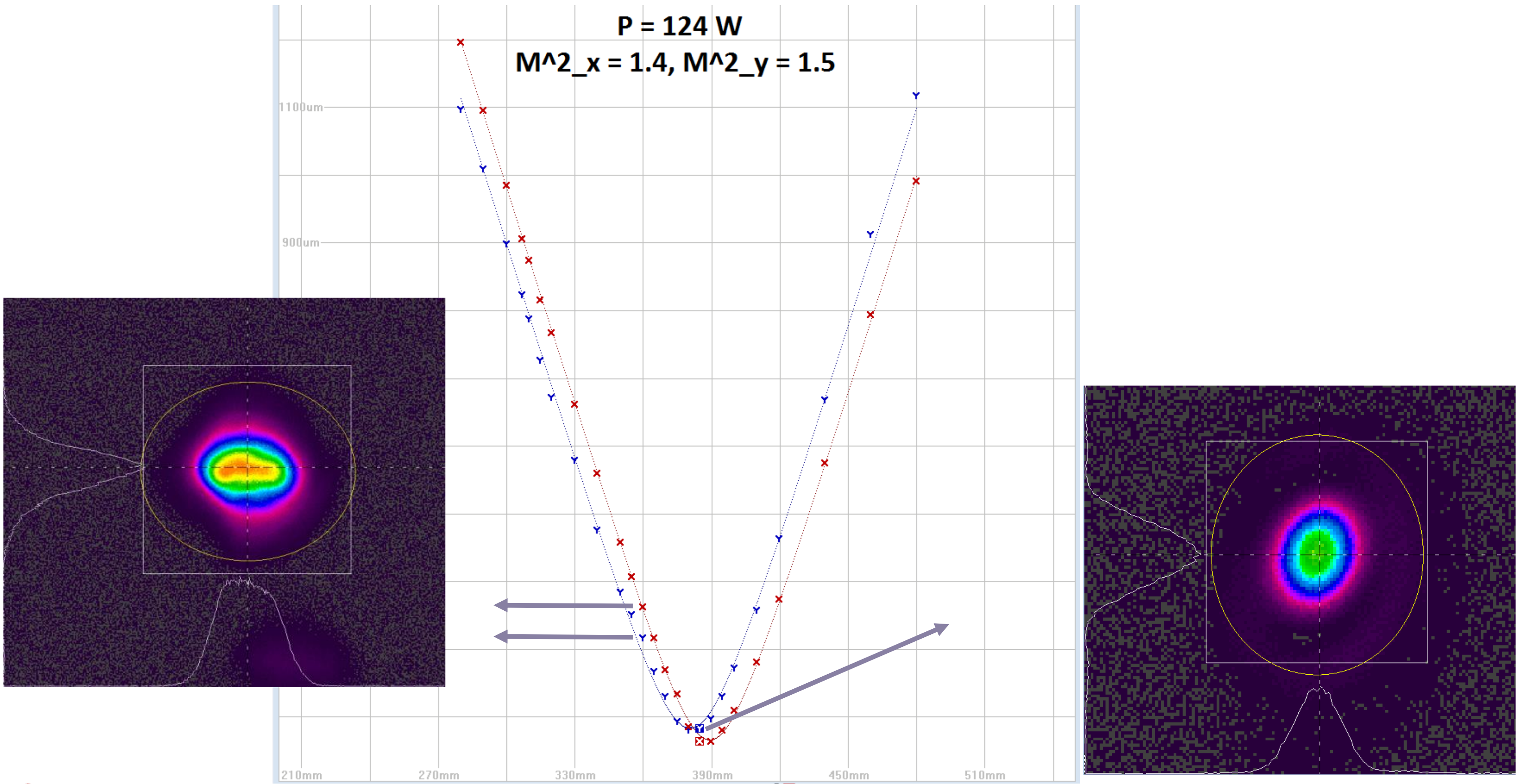

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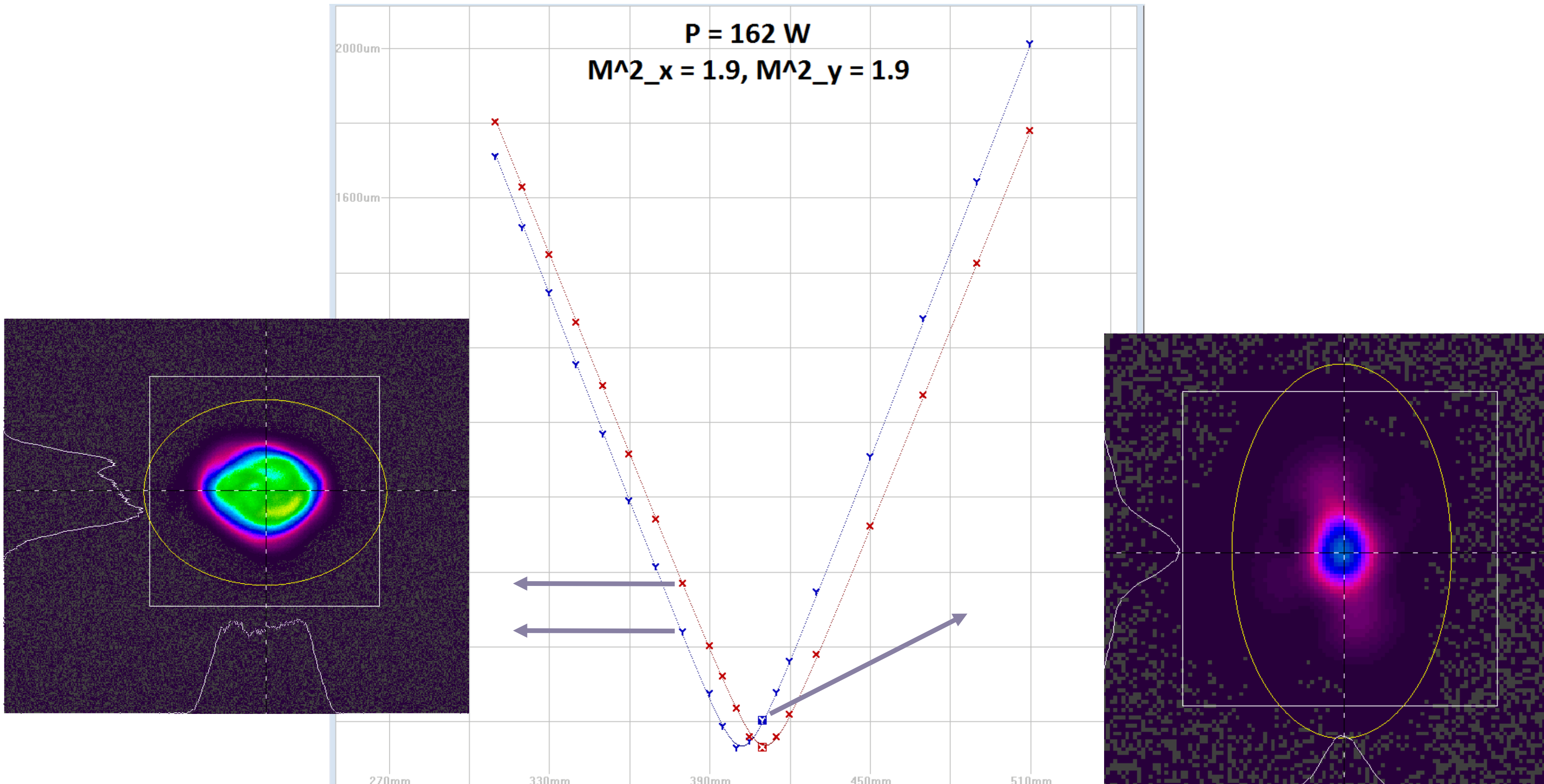
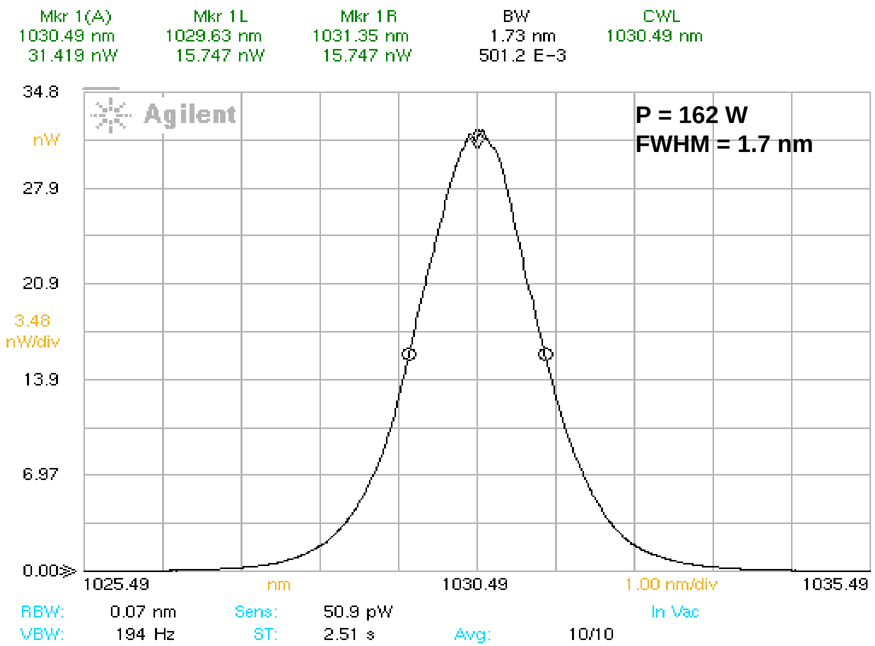
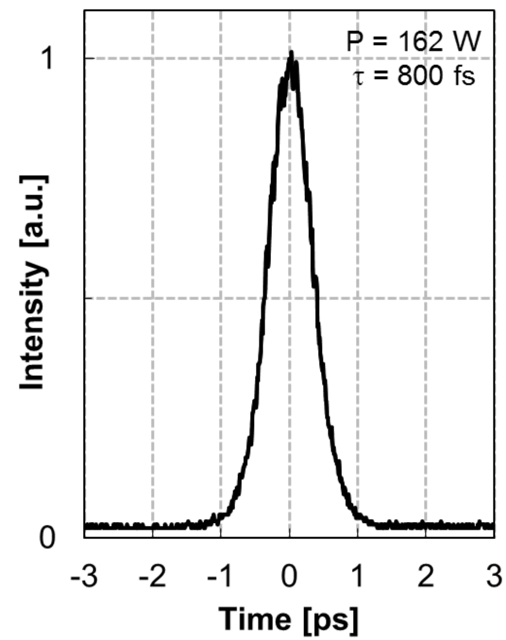


# Spectrum and Pulse Duration




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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- Working on **beam quality improvement of 160 W beam**

# 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 number 609355.

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