

# Optoelectronics Research Centre at Tampere University of Technology

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**Optoelectronics Research Centre**  
Tampere University of Technology

# ORC – A cradle of photonics in Finland

ORC has two divisions (i) Semiconductor physics & technology  
(ii) Ultra-fast & intense laser optics  
+ Commercialization of research results

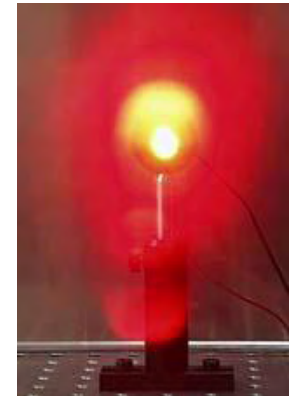
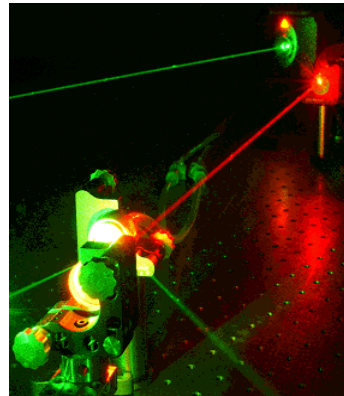
65 employees (December 2008)

Investments in scientific equipment: >€18 million

Total funding = €25M during 2000-2008

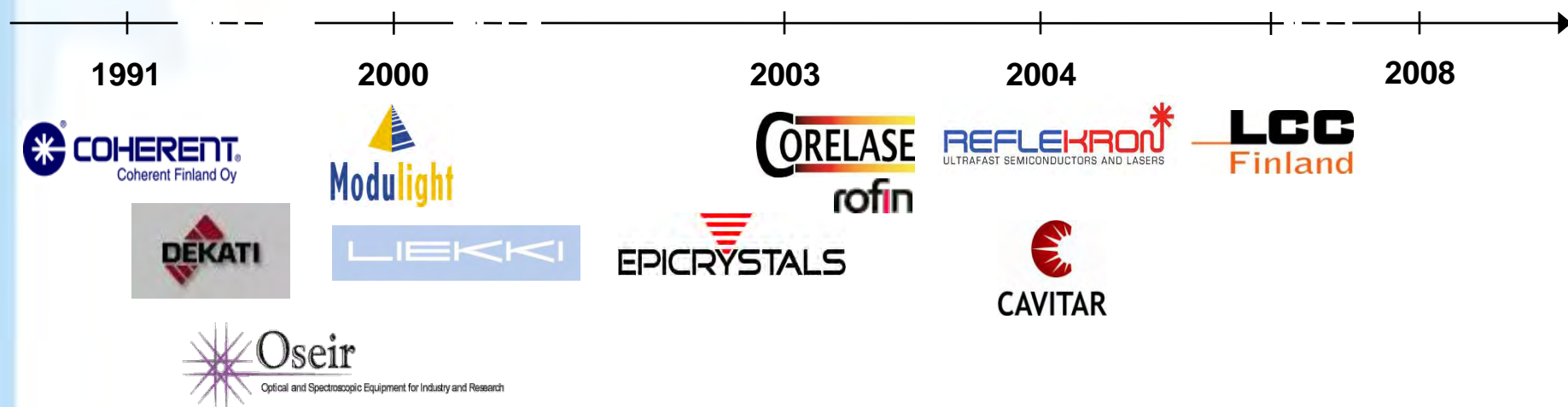
23 research projects in 2008, revenue ≈ €5.0 million (2008)

Co-operation with 40 international and 20 national partners



# Laser manufacturing industry has spun out from academic research

From Research to Business: Spin-off companies



# Laser manufacturing industry has spun out from academic research



  
**EPICRYSTALS**  
 Building a factory in 2008-2009

  
**REFLEKRON**  
 ULTRAFast SEMICONDUCTORS AND LASERS

## Recent EU FP6 (STREP) Projects

### **NATAL:**

Materials, equipment and processes for production of nano-phonic and nano-electronic devices. For development of OP-SDLs operating at 630 – 670 nm, 940 nm, 1040 nm and 1220 nm; development of frequency-doubled OP-SDLs emitting at 335 nm, 470 nm, 520 nm, and 615 nm (RGB light sources)

### **URANUS:**

Ultra-fast technology for multicolor compact high-power fibre systems. For development of high power ultra-fast fibre lasers and SESAMs and PCFs; development of super-continuum fibre lasers

# New EU FP7 & National Projects

**Fast-Dot ([www.fast-dot.eu](http://www.fast-dot.eu)):**

Compact Ultrafast Laser Sources Based On Novel Quantum Dot Structures

**Lamp (TEKES):**

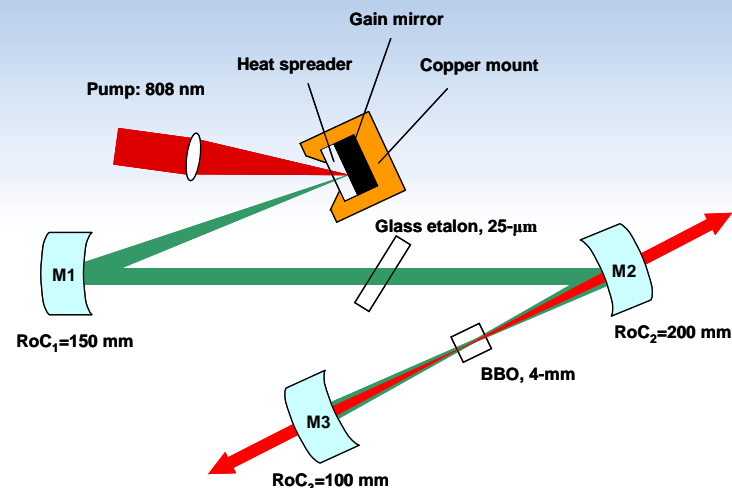
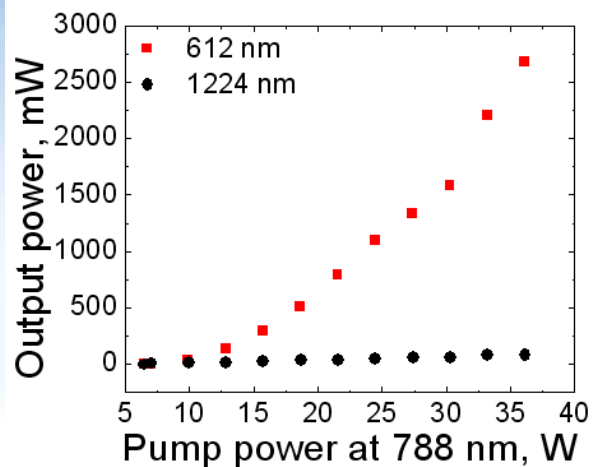
Cost-effective Fiber Lasers for Material Processing

**WIT (Academy):**

Nonlinear Optics of Photonic Nanowires and  
Microstructured Nanotapers

# EU FP6 NATAL

An example: GaInNAs 615 nm OP-VECSEL with 2.7 W output (world record)



ORC (coordinator), Technical Univ. of Berlin, CTH (Sweden), IoP (Strathclyde), OSRAM (Germany), TOPTICA (Germany), OPTOCAP (UK), EpiCrystals (Finland)

July 2005 – June 2008



# EU FP6 NATAL - summary

## Fundamental, cw

940 nm – 3 W

1050 nm – 5 W

1220 nm – >3 W (GaInNAs)

2030 nm – >1 W (GaSb)

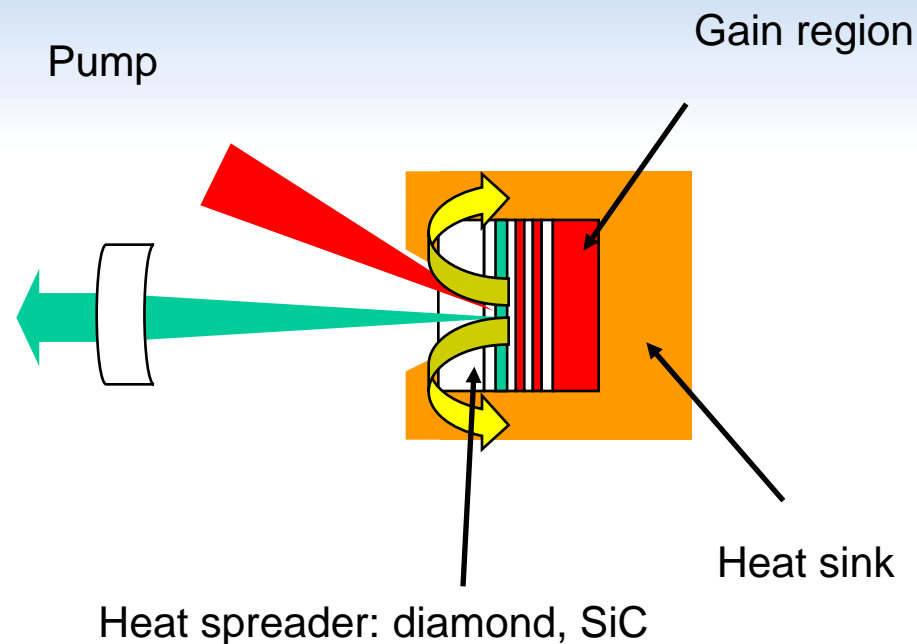
## Mode-locked by SESAMs

2 GHz, ps, 100 mW

## Frequency doubled, cw

615 nm, 2.7 W

470 nm, 700 mW



# EU FP6 URANUS

*Table 1: URANUS project goals pertaining to high power ultrafast fibre lasers.*

| Operation wavelength, nm | Average Power | Pulse duration | Peak Power | Development stage  |
|--------------------------|---------------|----------------|------------|--|
| 980                      | 1 W           | < 10ps         | >20 kW     | Prototype demonstration (Fianium, TTY)   |
| 1064                     | 5 W           | < 300 fs       | >200 kW    | Commercial product (Fianium)   |
| 1064                     | 20 W          | < 15 ps        | >15 kW     | Commercial products (Fianium, Corelase)  |
| 1064                     | 100 W         | < 30 ps        | > 200 kW   | Laboratory demonstration NKT<br>Laboratory demonstration (Fianium)                                     |
| 1550                     | 0.5 W         | 100 fs         | 100 kW     | Master oscillator developed commercially<br>Laboratory demonstration of the amplified system (Fianium) |

FIANIUM's high power MOPA



ORC (coordinator, Finland), INESC Porto, FIANIUM (UK), NKT (Denmark), STRATOPHASE (UK), CORELASE (FINLAND)

## EU FP6 URANUS (continued...)

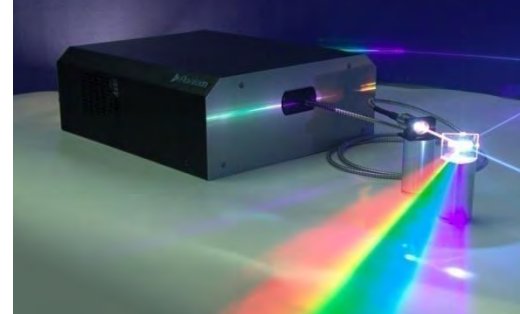
*Table 2: URANUS project goals pertaining to broad spectrum and multicolour sources.*

| Wavelength, nm | Technology Employed  | Average Power                         | Development stage  |
|----------------|--|---------------------------------------|--|
| 266            | Frequency quadrupled 1064 nm fibre lasers  | 2 W                                   | Initial target exceeded<br>Commercial product (Fianium)      |
| 355            | Sum-frequency using 1064 nm fibre lasers   | 8 W                                   | Initial target exceeded<br>Commercial product (Fianium)      |
| 530            | Frequency doubled 1064 nm fibre lasers   | 10 W                                  | Initial target exceeded<br>Commercial product (Fianium)      |
| 775            | Frequency doubled 1550 nm fibre lasers   | 150 mW                                | Initial target exceeded<br>Laboratory demonstration          |
| 400–1800       | SC generation using 1064 nm and 1550 nm fibre lasers and photonic crystal fibres | 8W<br>Spectral brightness<br>>5 mW/nm | Initial target exceeded<br>Commercial product (Fianium, NKT) |

CORELASE ps fiber laser



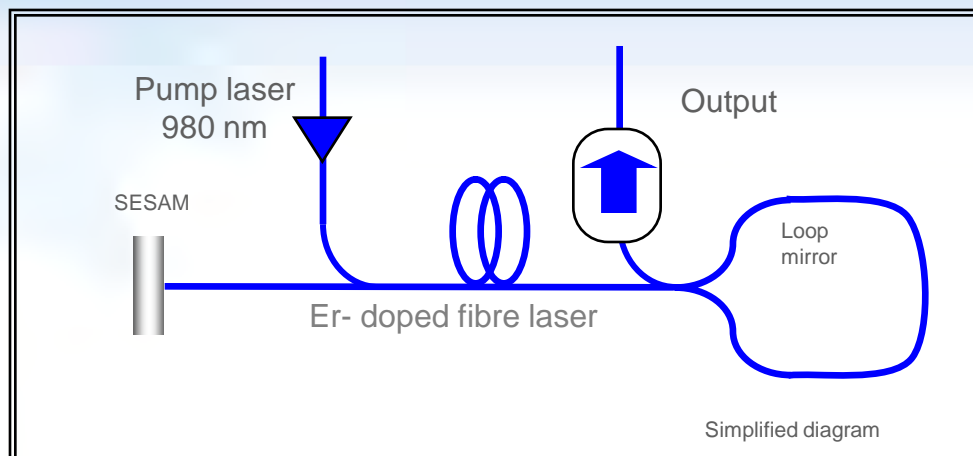
Fianium's SC laser



# EU FP6 URANUS:

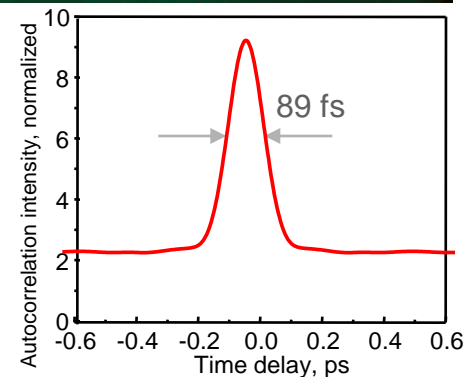
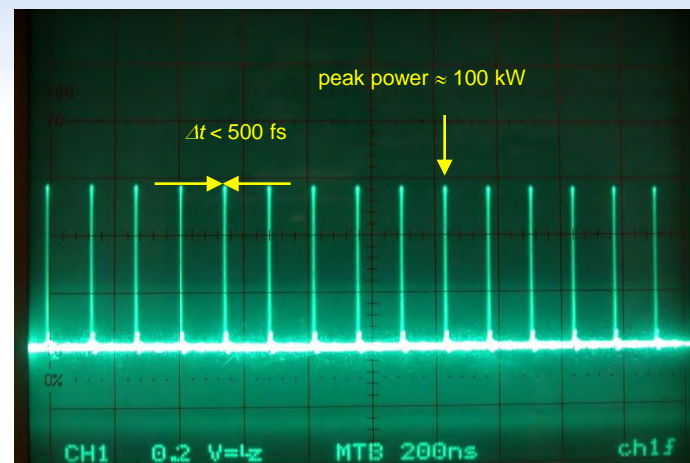
Ultra-fast optical pulses from fibre lasers using a SESAM as a cavity end-mirrors

An example of using SESAM in a glass fibre laser



Ultra-short-pulse train (SESAM inside).

$\lambda \approx 1.55 \mu\text{m}$ ,  $P_{\text{out}} \approx 0.5 \text{ W}$  (average)

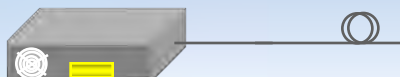


Fiber laser record in 2007

# EU FP6 URANUS:

## Photonic crystal (PC) fibre laser: 8 W supercontinuum spectrum

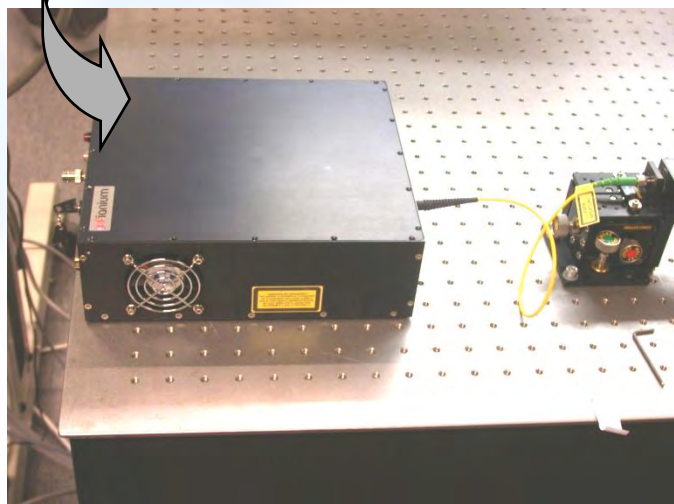
Laser source & amplifier + a PC fibre with zero dispersion at 1  $\mu\text{m}$



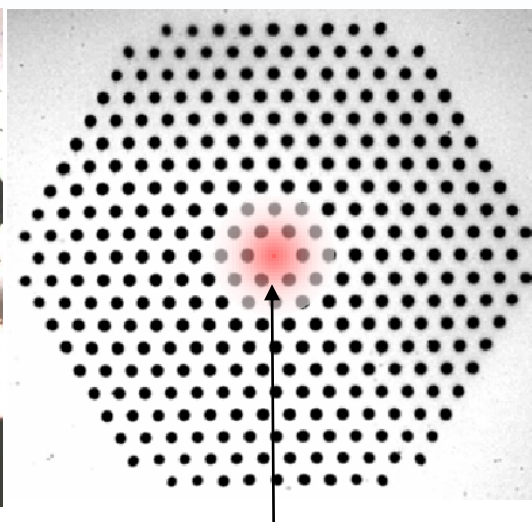
Fibre laser (ORC / Fianium Ltd., UK)

Photonic crystal fibre

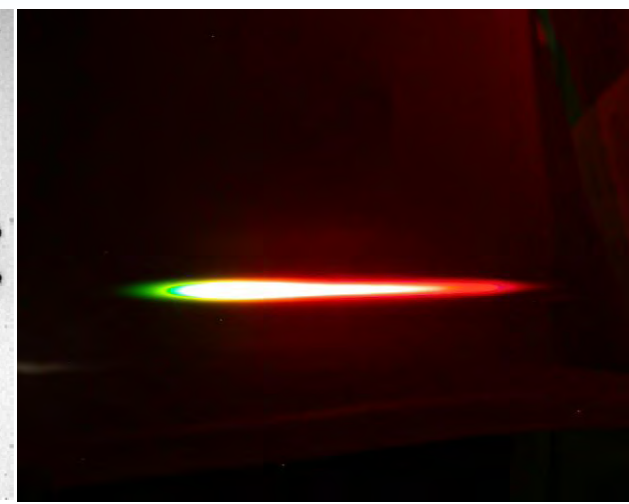
Supercontinuum output



Supercontinuum PC fibre laser



Light is effectively confined in the core of a PC fibre

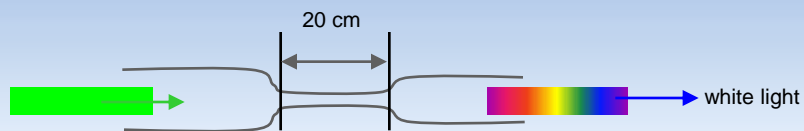


Width of the spectral range of 1  $\mu\text{m}$

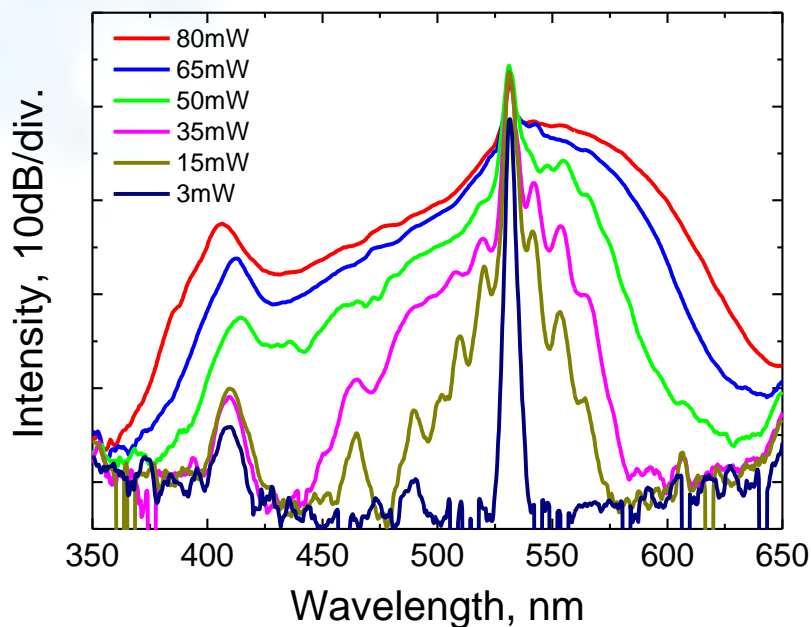
Cooperation between ORC and NKT (Denmark) within EU FP6 **URANUS**, 2006

# EU FP6 URANUS:

## Tapered fibre laser: Concentration on visible light



0.9  $\mu\text{m}$  waist diameter of a tapered fibre



(Cover page of *Optics Express*, Oct. 2005)

EU FP6 URANUS, 2006

Spectral width  $\approx 200$  nm, total power  $\approx 40$  mW, concentrated on the **visible** range

(a)

# New materials for photonics at ORC

(b)

Semiconductor Quantum Dots

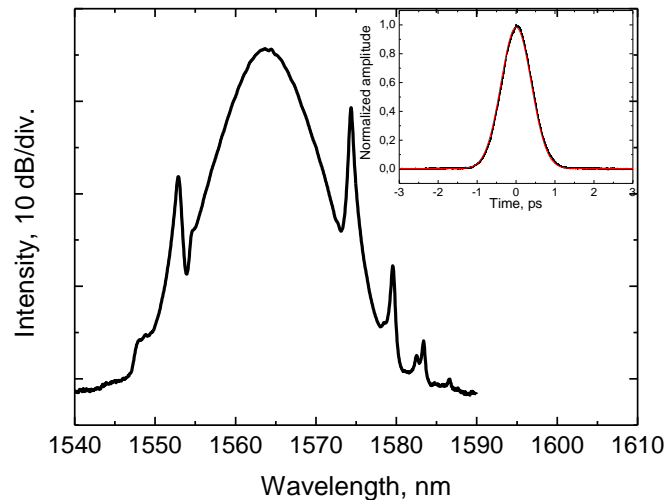
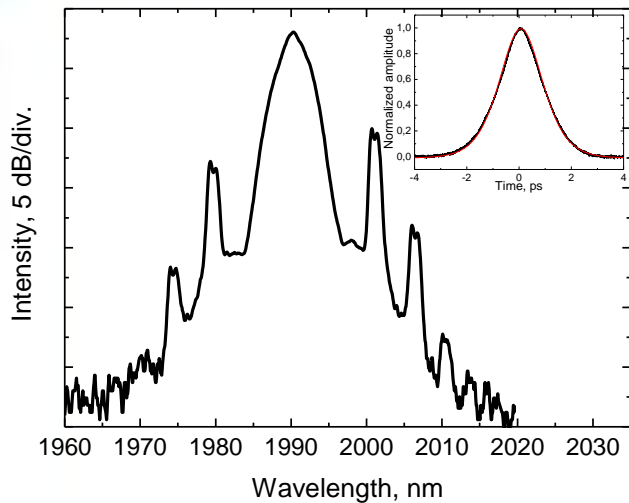
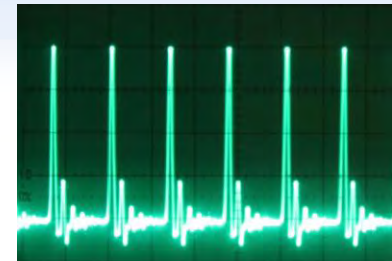
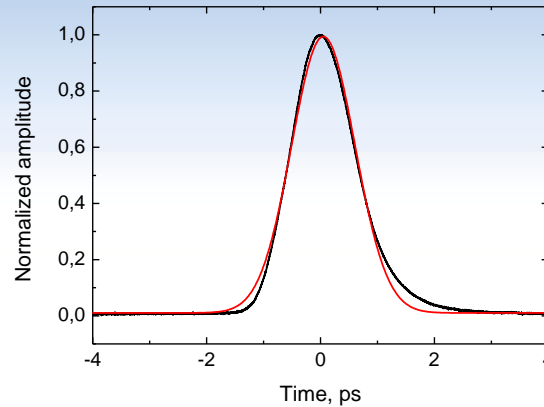
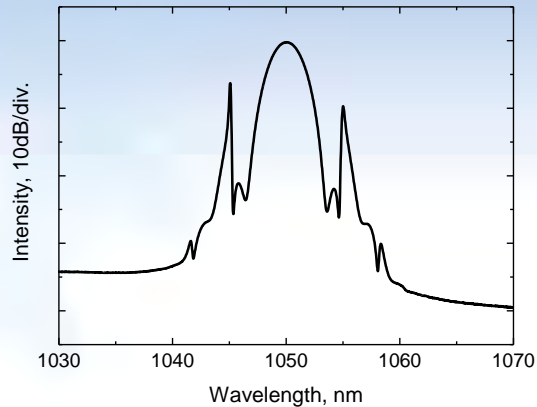
Carbon Nanotubes

Photonic crystal nanowire fibers

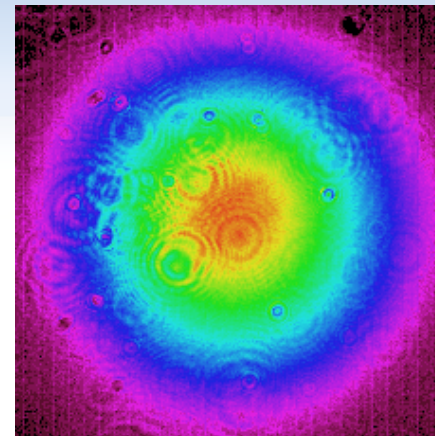
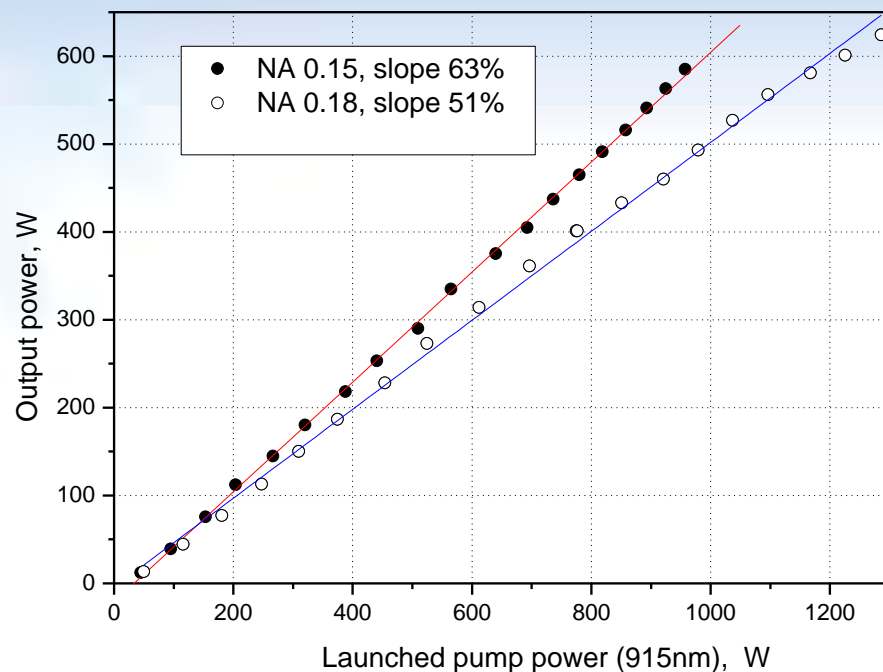
(a) (a)

# Single-walled Carbon Nanotube films for ultrafast ultrabroadband technology

(b)(b)

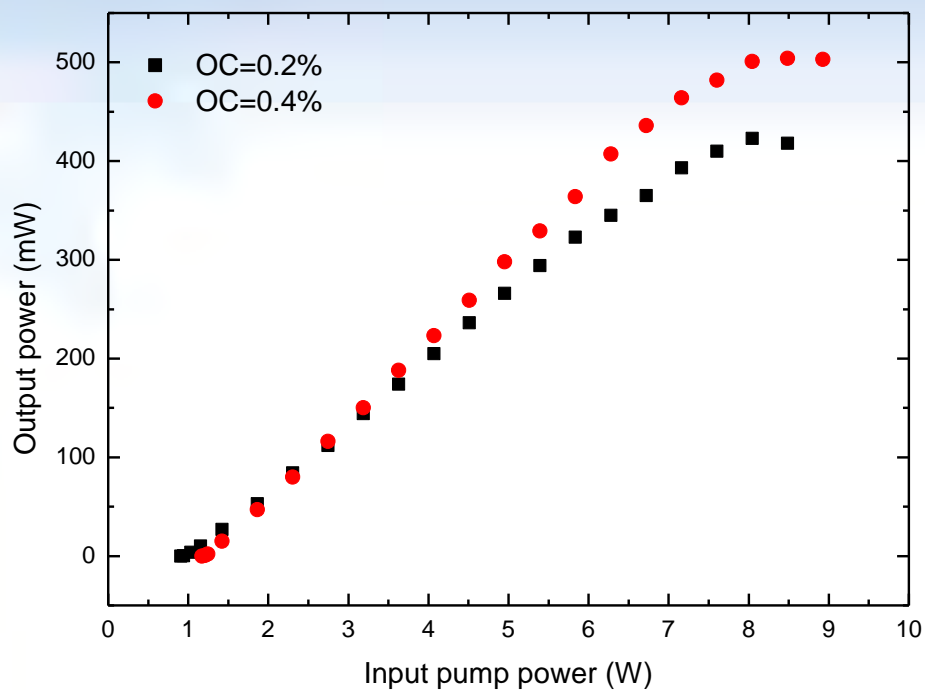


# 600 W Power Scalable Single Mode Tapered Double Clad Fiber Laser

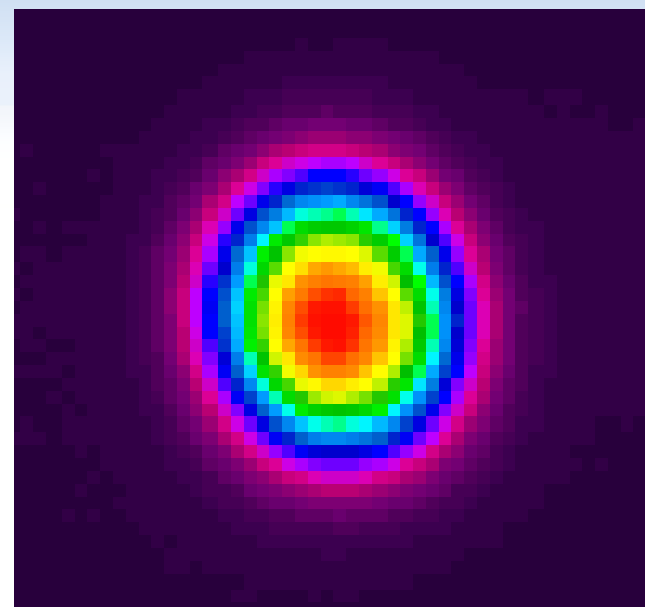


## Now over 750 W!

# FAST-DOT EU Project



Output characteristics. The curved mirror is used as an output coupler with different transmissions.  
With 1 % transmission the laser did not start lasing.



Typical beam profile of the laser. (OC=0.4 %,  $P_{out}=364$  mW).  
In vertical direction the  $M^2$  was below 1.1 and in horizontal direction it was  $\sim 1.2$ .

# THANK YOU!

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