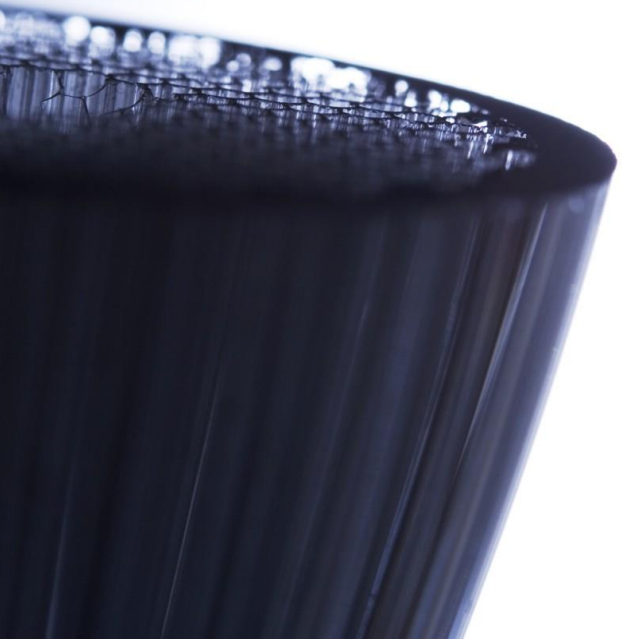
Ultrafast Laser Processing Workshop 2019

Advancing Ultrafast Lasers with PCF Technology

NKT Photonics



3. May, 2019

Crystal Fibre • Koheras • SuperK • LIOS • Fianium • Onefive

NKT Photonics

- Who are we?
- PCF Technology for Ultrafast Lasers
- Optocage Technology: Thermo-mechanical design
- NKTP Ultrafast Laser Products

NKT Photonics at a glance

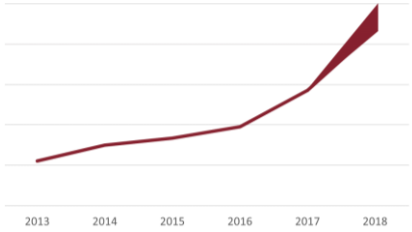
Overview

NKT Photonics

Supplier of fiber-based lasers and sensing systems for industrial and scientific applications

Founded in 1999

By the numbers



370 employees

390 patents and applications

2019 guidance:

15-20% EBITDA

15-20% revenue growth

Manufacturing

Manufacturing in
DK, GB, DE, CH and US

>15,000 m^2 total footprint

>6,000 m^2 production floor

>15,000 system install base

Revenue and EBITDA reported in EUR (2019 guidance is 15-20% growth in revenue and 15-20% EBITDA margin).
Exchange rate of 1.15 used to convert to USD

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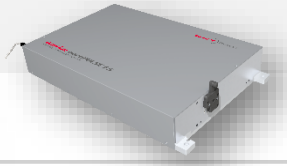
Site Strategy by product line

DK - Birkerød	GB - Southampton	CH - Zurich	DE - Berlin	DE - Cologne
Supercontinuum lasers Single-frequency lasers Fibers & Modules	Ultrafast fiber lasers	Solid state ultrafast lasers	Pulsed laser diode systems	Distributed sensing systems



Markets and products

Imaging & Metrology

Bio-imaging & medical
Semiconductor
Industrial metrology

Light sources and optical equipment to view microscopic details

Microscopes, medical, and industrial measuring instruments


SuperK & Fianium


Onefive


AeroPulse

Sensing & Energy

Energy
Security
Structural monitoring

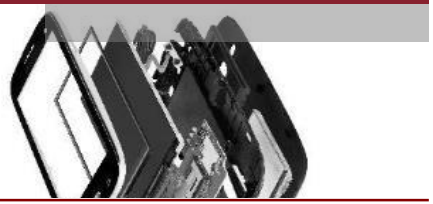
Temperature and disturbance detection

Optimisation of energy production, power cables, pipeline surveillance and fire detection


LIOS DTS


Koheras

Material Processing

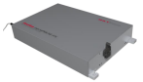


Micromachining
Medical
R&D

Highly accurate laser-based manufacturing

Mobile phone components, high-precision eye surgery


Onefive


AeroPulse

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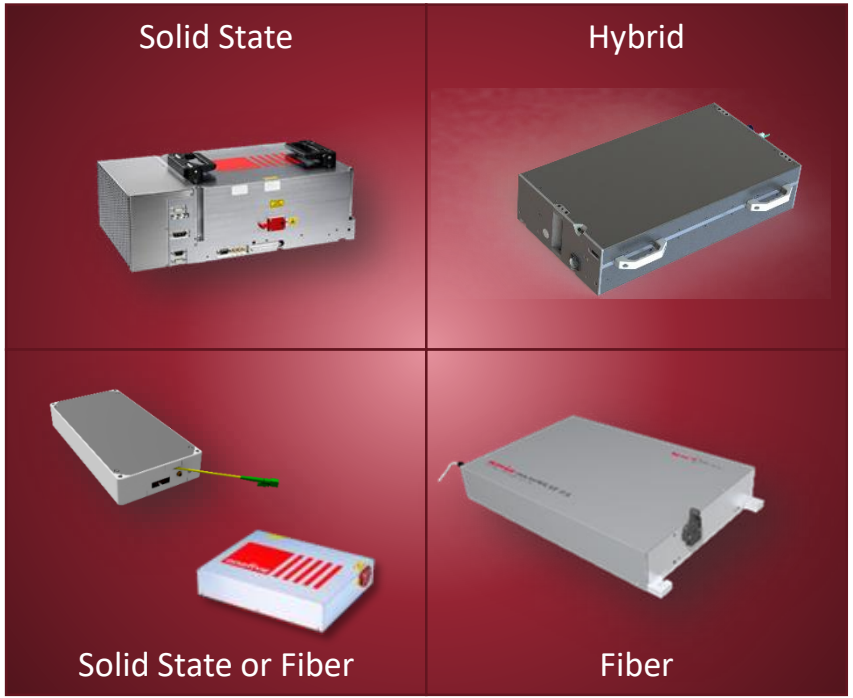
Parameter space of ultrafast lasers



Pulse Energy

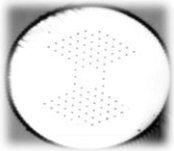
Pulse Repetition Rate
Average Power

Ultrafast Laser Technology

- Application determines technology
- NKT expertise in fiber & solid state technology
- Allows for flexible laser design and performance

Our strength in Ultrafast lasers

Proprietary (PCF) fiber technology



- Perfect beam quality
- High gain (per length)
- Peak power – large MFD
- Excellent reliability
- Scalable cost with volume

Proprietary optomechanical OptoCage™

- Very compact design
- Excellent beam quality
- Excellent pointing stability
- High pulse stability
- High environmental stability

Ultrafast laser markets

- Industrial
- Medical
- High-end scientific

NKT – Technology integration

Vast range of ultrafast laser technologies in house

- Mode-locking
  - SESAM design, characterization, sourcing, handling
  - Soliton mode-locking
- Gain switching
- Fibers
  - PCF leader
  - From preform to gain modules
  - Fiber laser design
- Solid-state technology
  - OptoCage™

Complete technology set inhouse
Application driven

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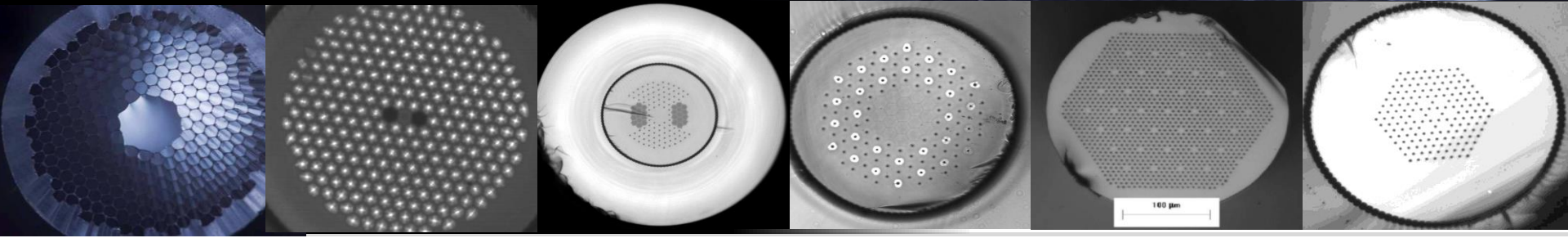
PCF – a fiber technology platform

- PCFs are microstructured fibers
- Provides unique design flexibility
- Facilitates large single-mode cores superior to step-index
- Can provide tight confinement of light
- ***Commercially*** established amplifier platform



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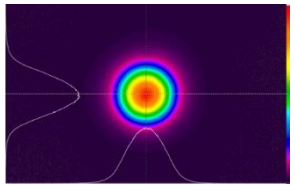
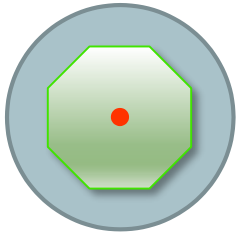
PCF advantages

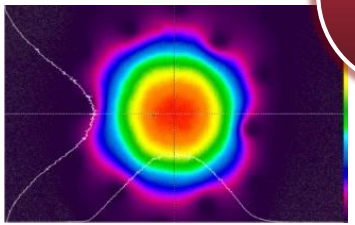
Ultrafast lasers



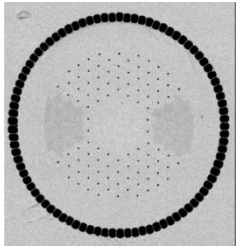
MCVD core



- Single-mode operation
  - Diffraction limited beam quality
  - Clean pulse amplification
  - Efficient frequency conversion
- Superior index control
  - Large mode-field diameters
  - Handling of high peak power
  - Excellent length homogeneity
- All glass fiber
  - High pump guide NA from air clad
  - High pump absorption – short fibre length
  - Reliable high power handling



PCF core



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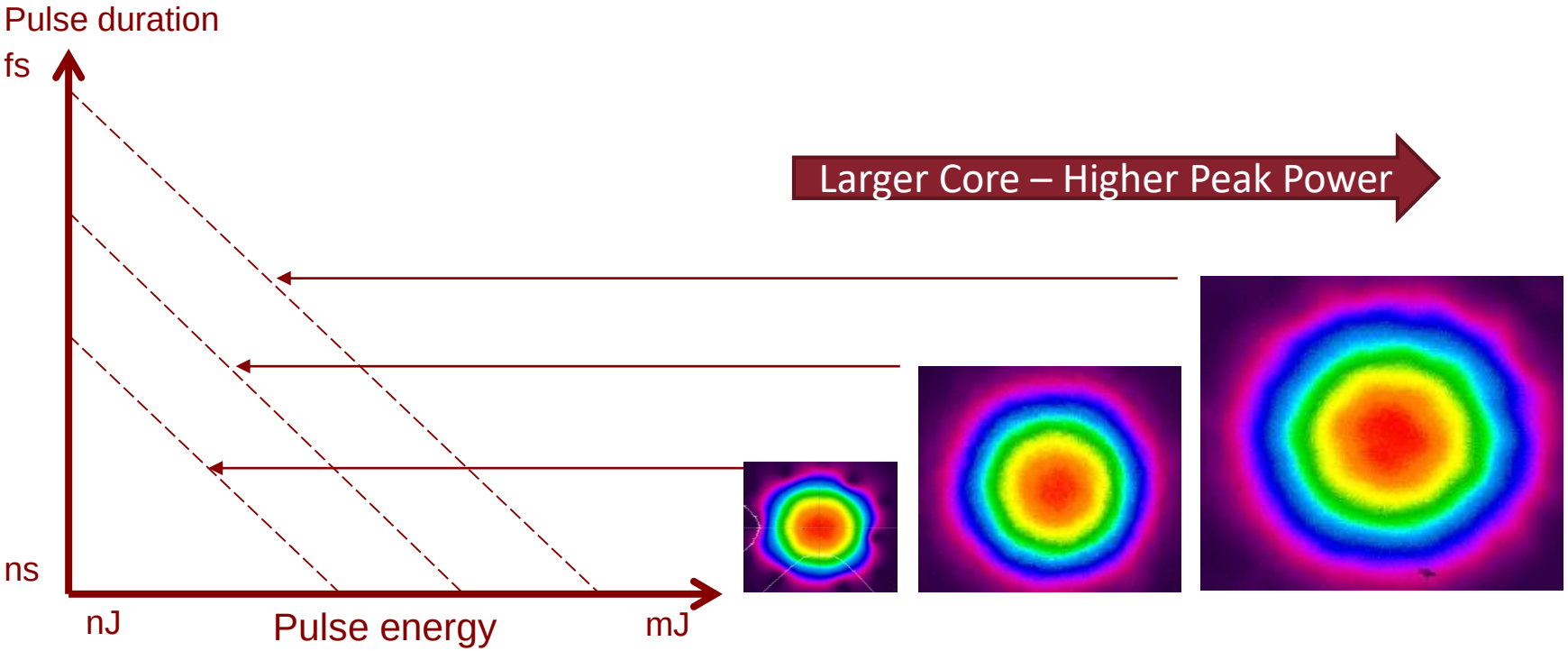
Peak Power scaling by changing amplifiers



OptoCage™

Rugged implementation of free space optics

- ❑ Complete absence of mirror mounts
- ❑ Precision positioning of optics
- ❑ Closed loop thermal control OptoCage™
- ❑ Kinematic mounting to housing

Free space optical design

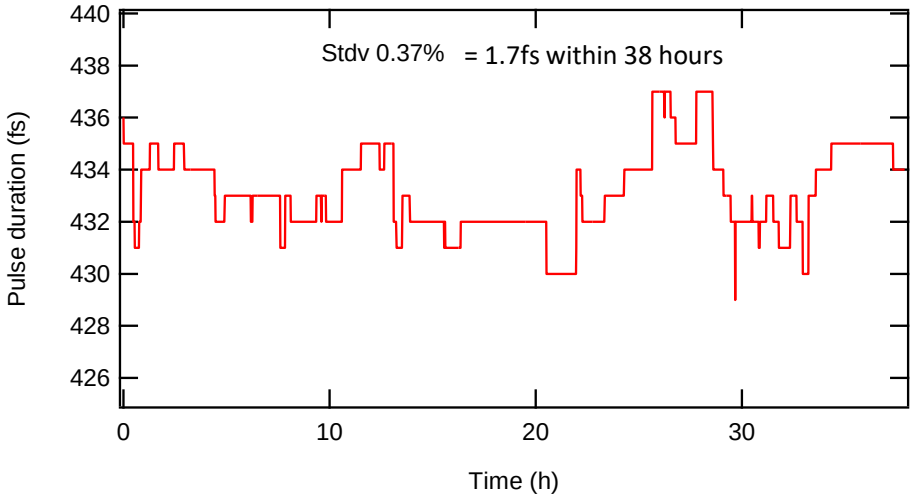
- Solid-state laser technology needed for extreme pulse energies
- Chirped pulse amplification
  - Compressor design always in **free space** technology due to peak power
- Fiber amplifier with extreme mode sizes
  - Backwards pumping
  - **Free space** pumping to limit nonlinearities
- Output shutter/processor
  - **Free space** acousto optic modulator

need for

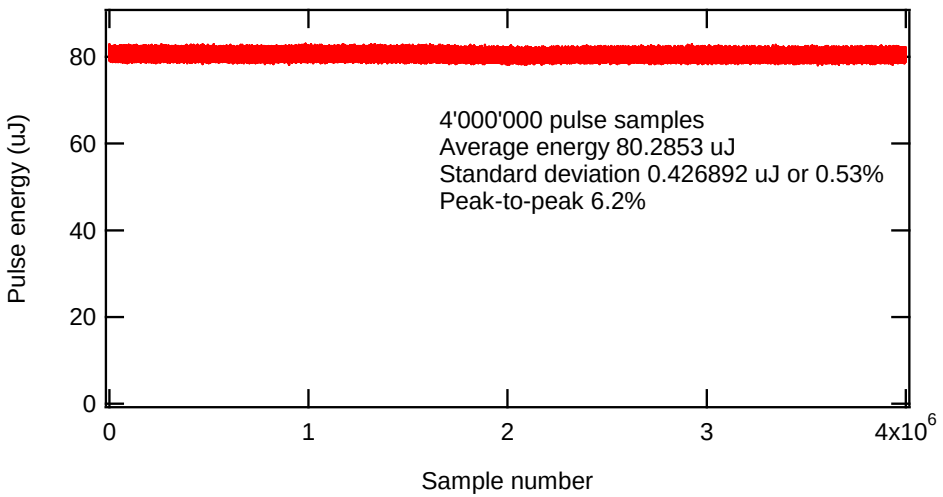
- **stable free space optical implementation**
- **stable thermo-mechanical implementation**

High Stability / Low drift

Pulse duration stability of high energy laser



Pulse energy stability of high energy laser

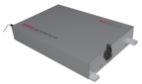


Chirped pulse amplification system

- Stable seed
- Stable stretching
- Stable compressing

Commercially Established Technologies

Shipped +4000 Ultrafast lasers – inside Supercontinuum



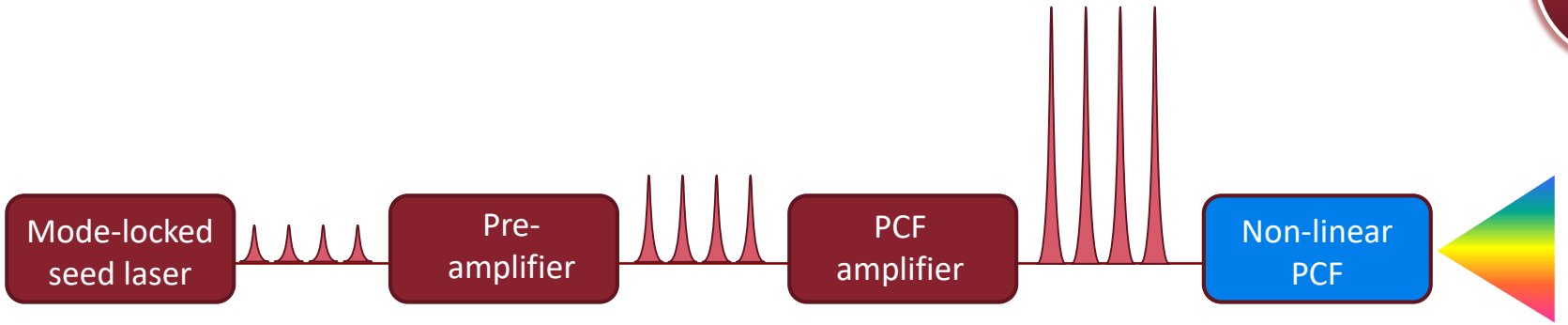
Shipped +2500 OneFive Ultrafast lasers in eye surgery

Shipped +1000 AeroGain modules for Ultrafast lasers

NKTP has significant experience to be an important supplier in Ultrafast lasers

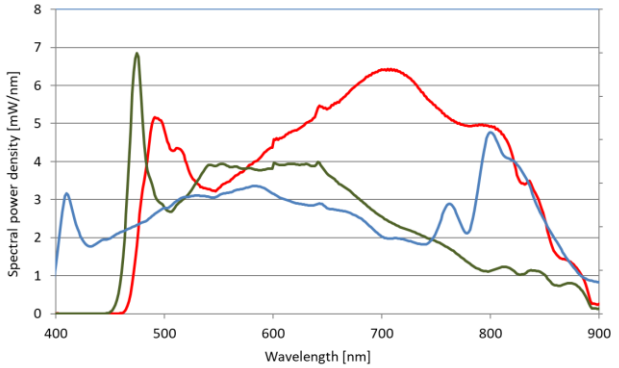
PCF platform for Super Continuum

Ultrafast laser



- Ultrafast ps laser
  - MHz repetition rate
  - > 10 W average power
  - > 20 kW peak power

Over 3000 lasers globally deployed



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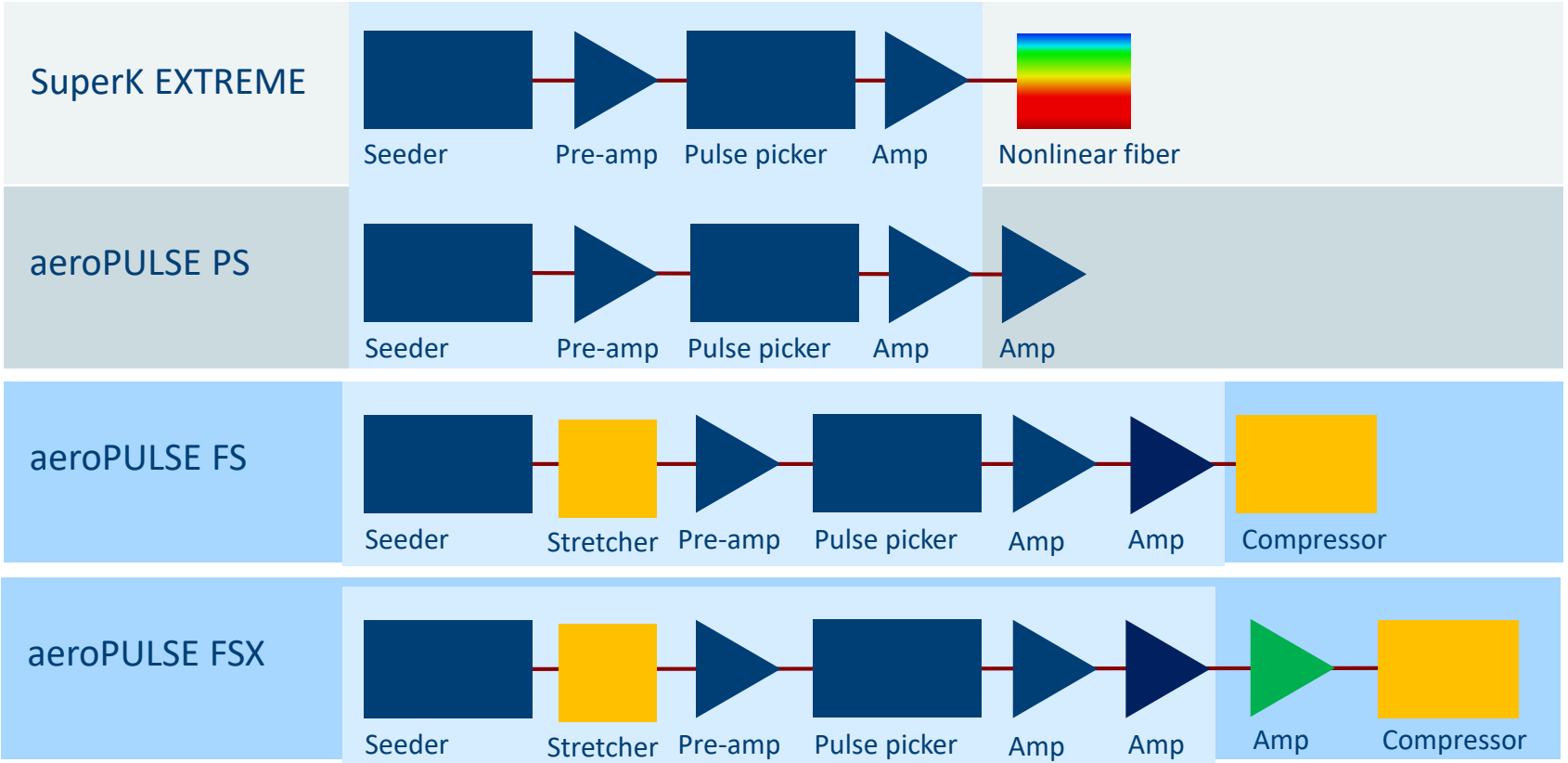
Ultrafast and supercontinuum: modularity



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Amplifier technology for ultrafast lasers

Robustness

Ease of use

Beam quality

Efficiency

Single-mode operation

Effective area

Reliability

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Ultrafast laser portfolio

Selected products from NKT's fs and ps product portfolio

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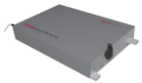
Ultrafast Laser Platforms

aeroPULSE

aeroPULSE PS



aeroPULSE
FS-20

aeroPULSE
FS-60

PCF Fiber + OPTOcage

Onefive

Origami LP (fs)

Origami XP (fs)

Genki XP (ps)

OPTOcage Solid State

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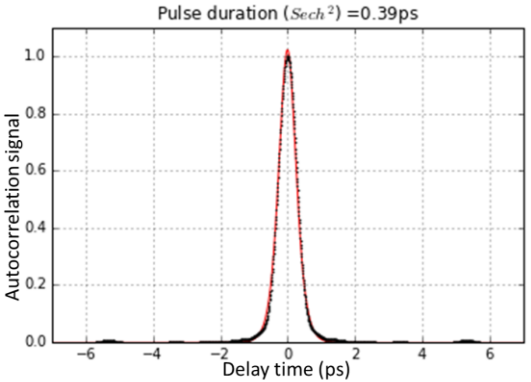
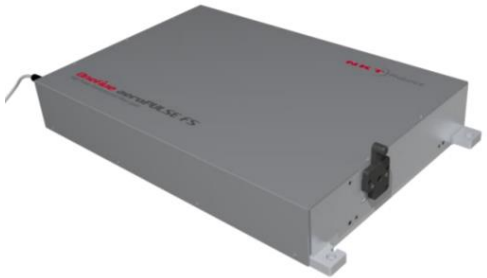
aeroPULSE FS Lasers - Key Features

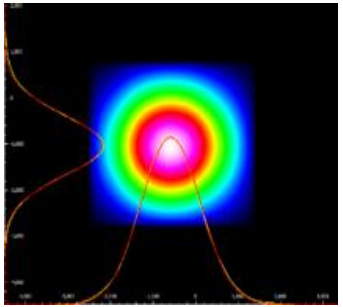
- Simple all-fiber design, high reliability
- Modular, scalable platform
- Short warm-up time
- Stable and reliable performance over full operational range in 18-30 degree C environments
  - **> 20,000 hours lifetime expected**
- Low cost of ownership
- Remote laser diagnostics – simple servicing
- Two box solution – 1.5m umbilical (detachable)

aeroPULSE FS-20 Specification

- Low nonlinearity design → no pulse pedestals
- Pulse duration **< 500 fs** – 3ps – adjustable pulse length
- Pulse energy up to **20uJ**/pulse – adjustable pulse energy
- Average power up to **20W** – adjustable output power
- Center wavelength 1030-1050nm operation
- Pulse repetition rate 200Khz – 50MHz – adjustable
- Water cooling
- No output AOM & Burst Mode yet

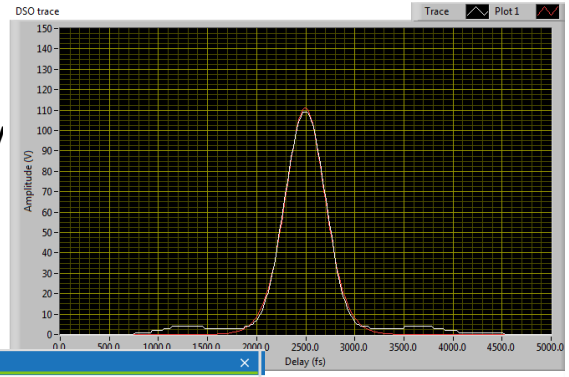


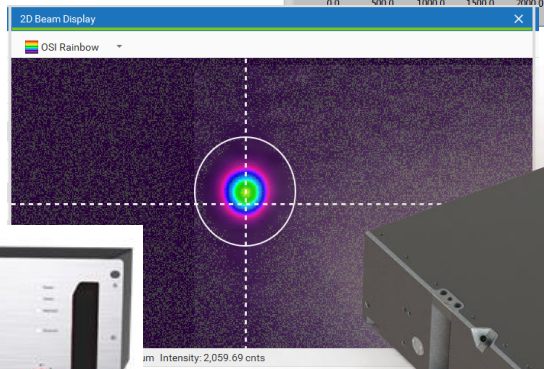


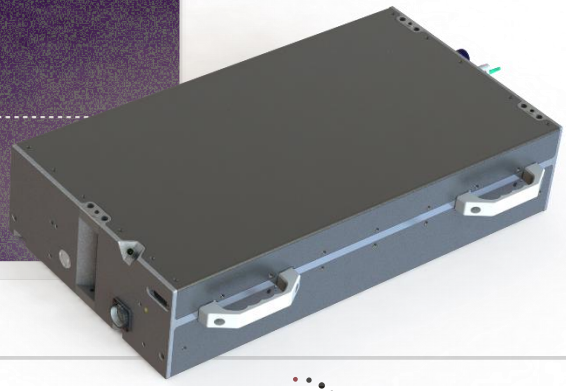


NEW: aeroPULSE FS-60

- Low nonlinearity design → weak pulse pedestals
- Pulse duration **< 500 fs** – 3ps – adjustable pulse length
- Pulse energy up to **40uJ**/pulse – adjustable pulse energy
- Average power up to **60W** – adjustable output power
- Center wavelength 1030-1050nm operation
- Pulse repetition rate single shot – 50MHz – adjustable
- Two box solution – detachable umbilical
- Water cooled
- Output AOM & Burst Mode capability







ORIGAMI – 10 XP High Energy fs Laser

High-energy fs laser

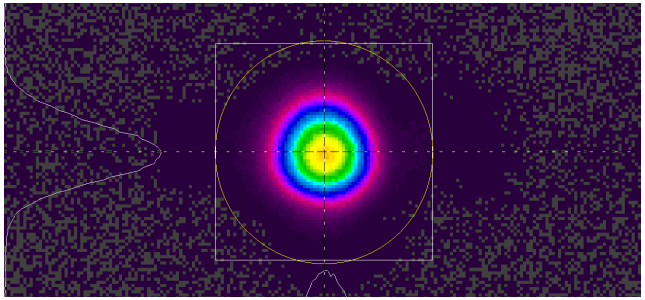
- All-in-one design, turn-key, ease of use
- Compact, industrial package – smallest of its class
- Water-cooled or air-cooled available
- 23 kg
- 24V/25A supply
- Simple 4 top-down through hole mounting
- Mounting in any direction

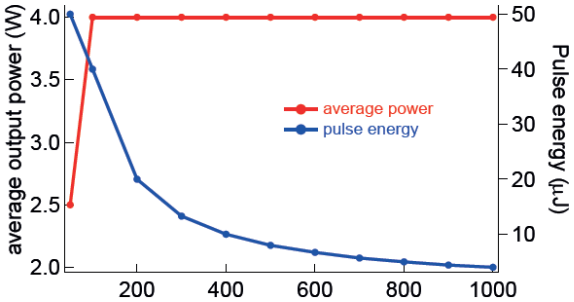
Ideal for gantry mounting

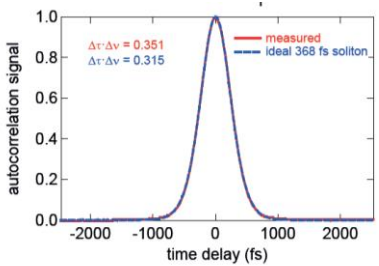
ORIGAMI - 10 XP – High energy

- Standard version Origami – 10 XP
  - 40uJ pulse energy
  - 4W average power
  - 100 MW peak power

- High energy version Origami – 10 XP
  - 75uJ pulse energy
  - 5W average power
  - 165 MW peak power







Genki – 10 XP High Energy ps Laser

High energy ps laser

- All-in-one design, turn-key, ease of use
- Compact, industrial package
- Water-cooled
- 72 kg
- 24V+48V 1.2kW supply
- Simple 3 top-down through hole mounting
- > 250uJ pulse energy
- > 100W average power
- 10 ps pulses