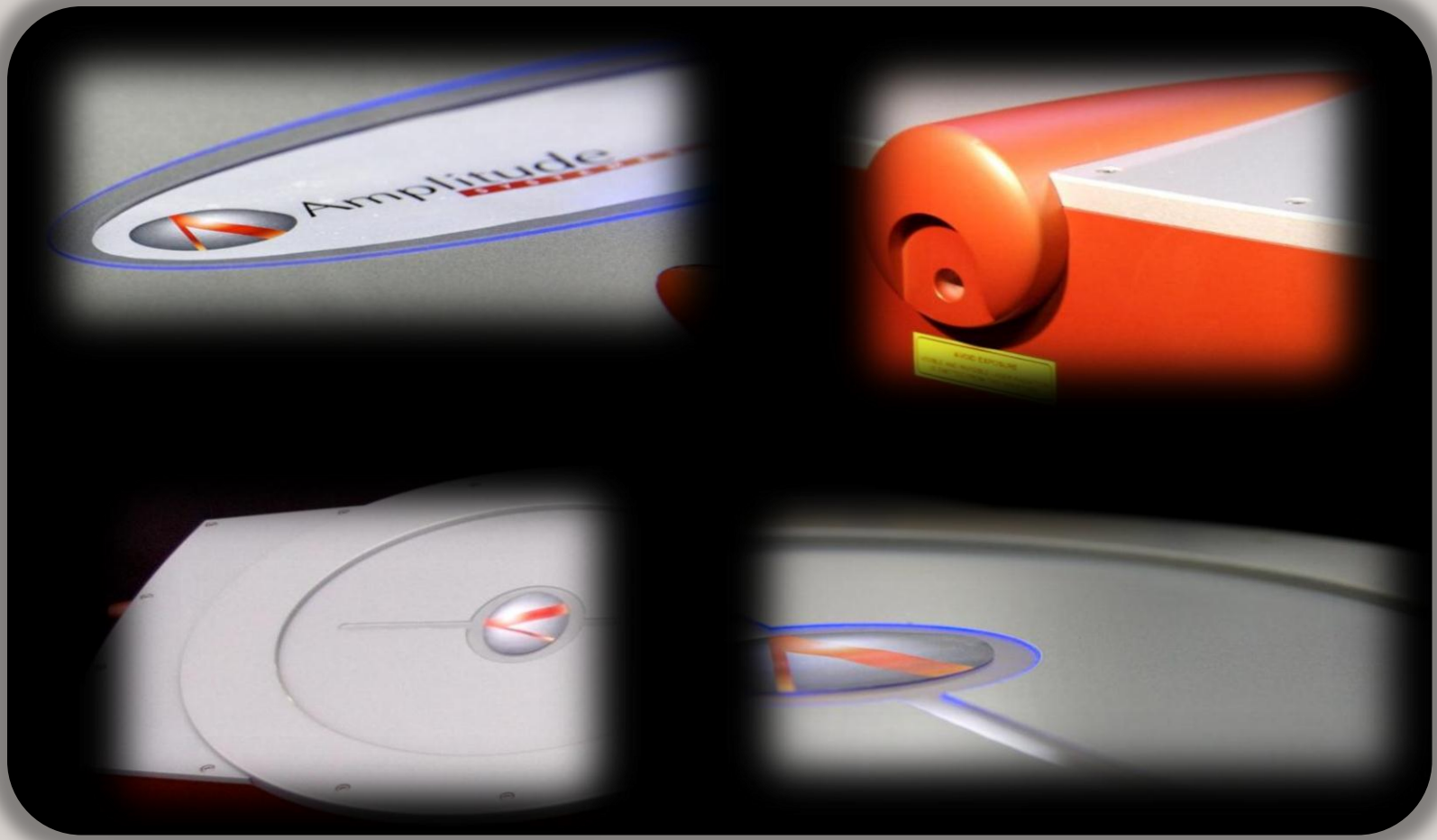
Amplitude SYSTEMES



nothing but ultrafast

www.amplitude-systemes.com

Current status and future of high-power ultrafast industrial lasers

Yoann Zaouter

R&D department

Amplitude Systemes, Pessac, France

Company

Company

Amplitude SYSTEMES

Amplitude Systemes - Bordeaux
Compact femtosecond lasers

Amplitude TECHNOLOGIES

Amplitude Technologies - Paris
High power femtosecond lasers

Amplitude LASER

Amplitude Laser - Boston
U.S. sales and support

Amplitude Systemes – Taipei
Asia sales and support

Company

- Created in 2000

- >150 employees only manufacturing ultrafast lasers

- Products sold in more than 20 countries

- Pionneer in diode-pumped ultrafast lasers

- R&D centers: Amplitude Systemes (Pessac), Bordeaux University (Talence), Institut d'Optique (Palaiseau), Amplitude Technologies (Evry), CEA (Saclay)

Amplitude SYSTEMES

First and only company

Amplitude Systemes

- Diode-pumped ultrafast **oscillators**
- Diode-pumped **solid state** ultrafast amplifiers
- Diode-pumped **fiber** ultrafast amplifiers

Amplitude Technologies

- Multi-PW Ti:Saphire laser chains

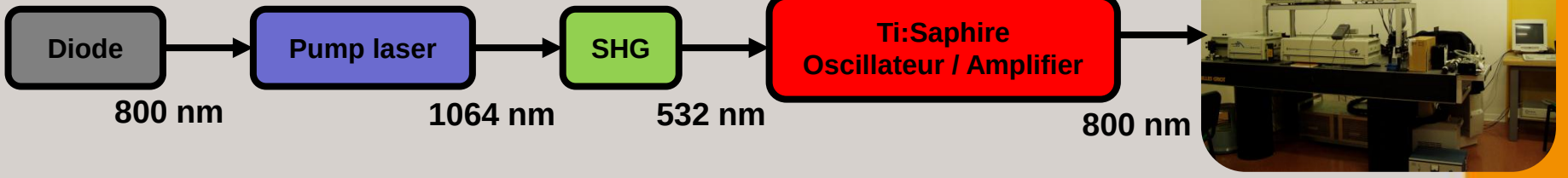
Amplitude SYSTEMES

TECHNOLOGY

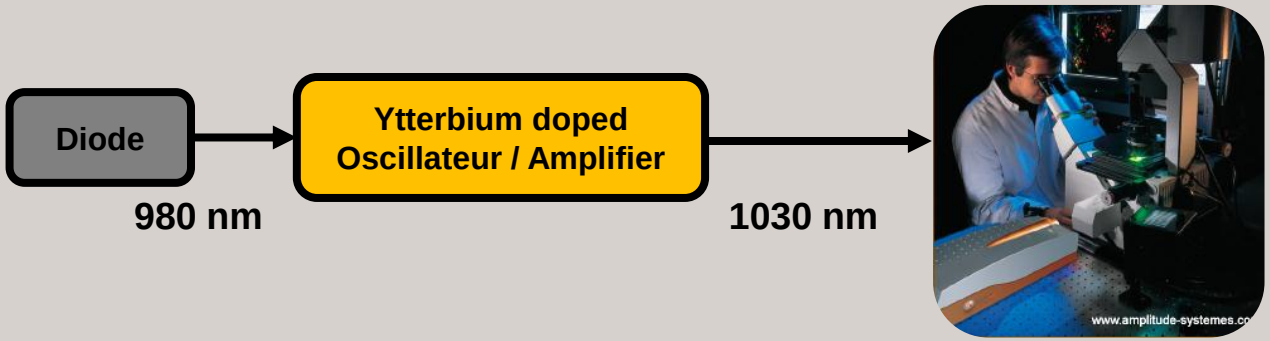
Directly diode-pumped Ytterbium lasers :

The new generation of industrial femtosecond lasers

Traditional femtosecond lasers :



Amplitude Systemes femtosecond lasers :



TECHNOLOGY

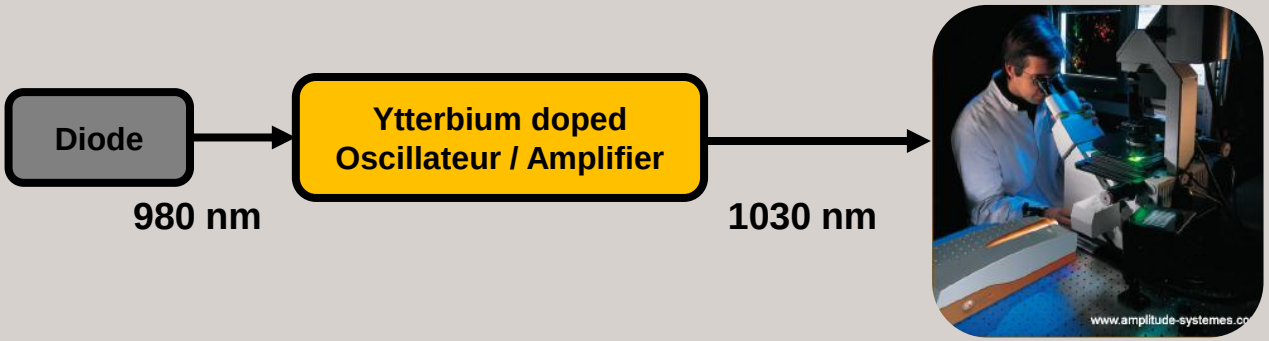
Directly diode-pumped Ytterbium lasers :

The new generation of industrial femtosecond lasers

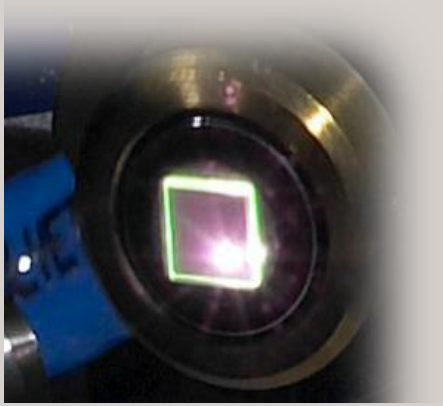
Advantages

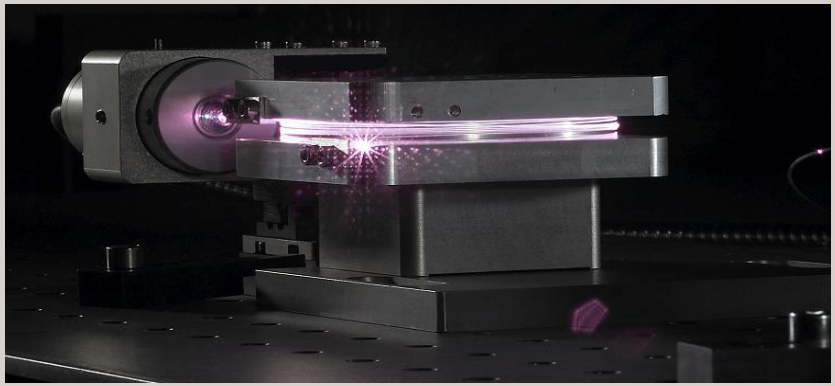
- *High wall plug efficiency*
- *Simple and robust design*
- *Maintenance-free*
- *High performances*

Amplitude Systemes femtosecond lasers :



Bulk and fiber solutions

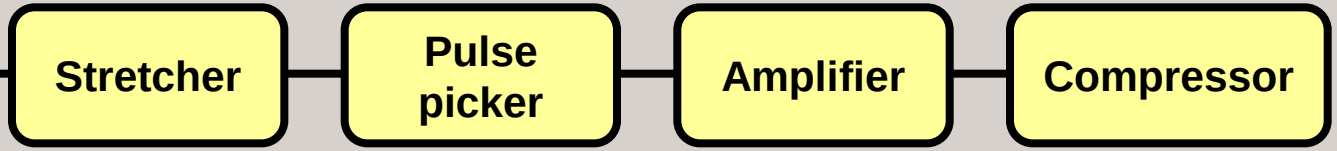




	Crystal solutions	Fiber solutions
Pulse energy	☺	😐
Average power	😐	☺
Stability reliability	Vibration > 5G Thermal test : 15°C – 35°C Long term stability < 0.5% rms	

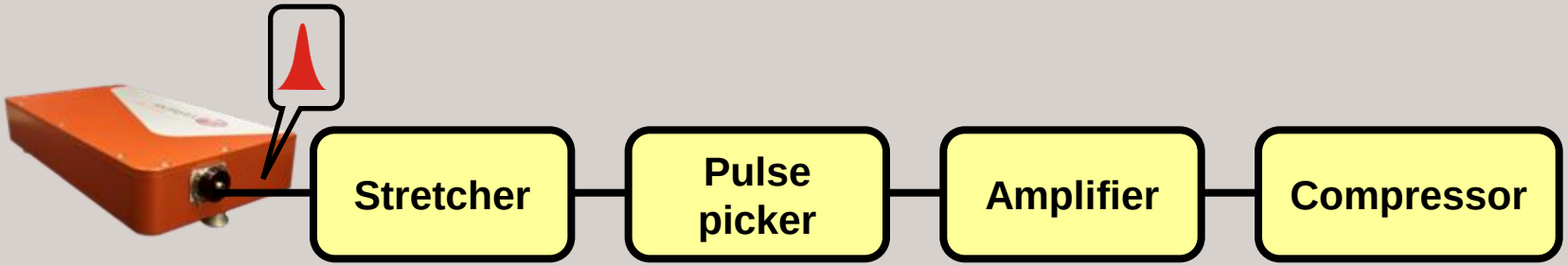
Chirped pulse amplifier

1. **Bulk amplifier**



Chirped pulse amplifier

1. Bulk amplifier

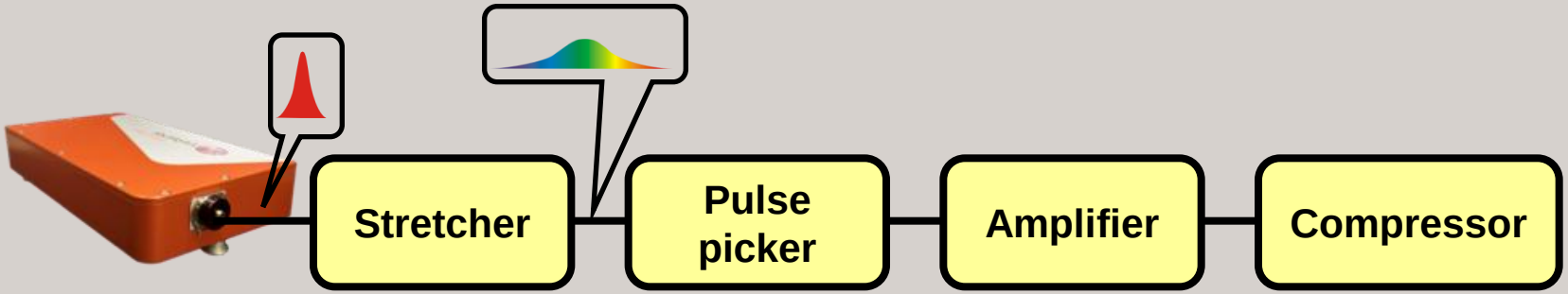


Oscillator

Generate the ultrashort pulses
f = Tens of MHz
P = W-level
t = sub-200 fs

Chirped pulse amplifier

1. Bulk amplifier

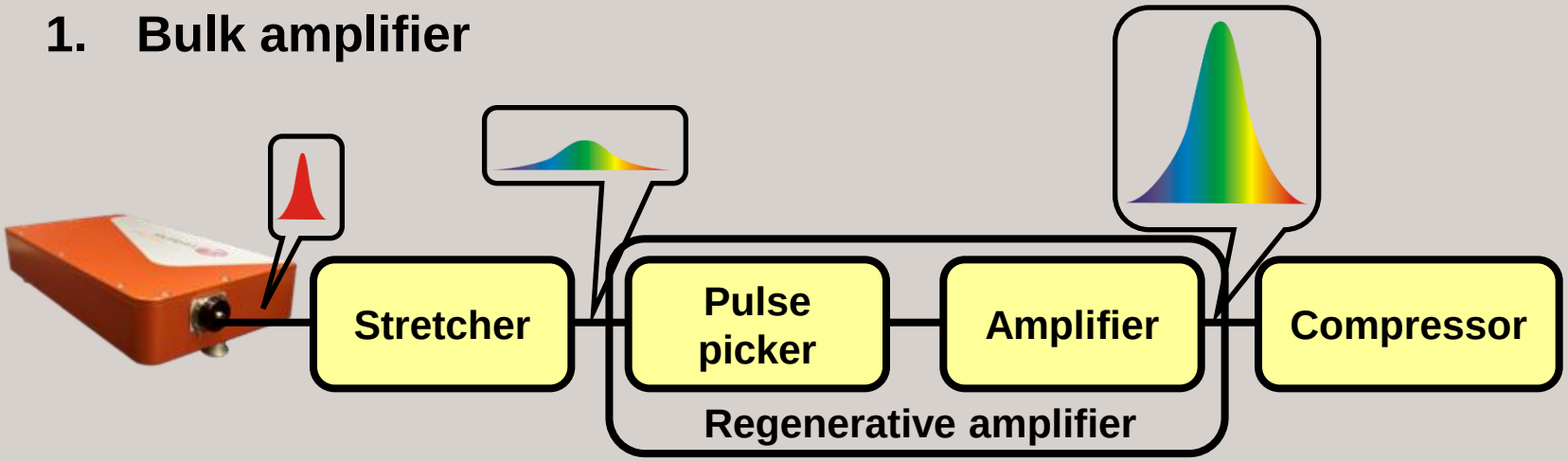


Stretcher

- Decrease the peak intensity
- Reduce accumulated NL

Chirped pulse amplifier

1. Bulk amplifier

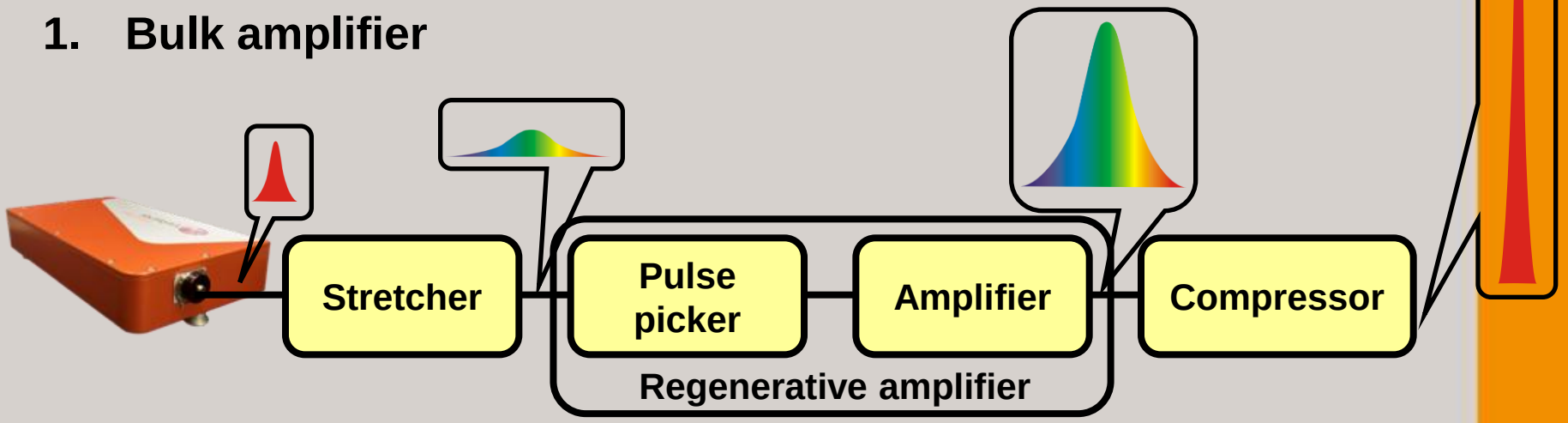


Regenerative amplifier

- Pulse picking with EOM
  → From Single shot to few 100's kHz
- Amplification with a bulk media

Chirped pulse amplifier

1. **Bulk amplifier**

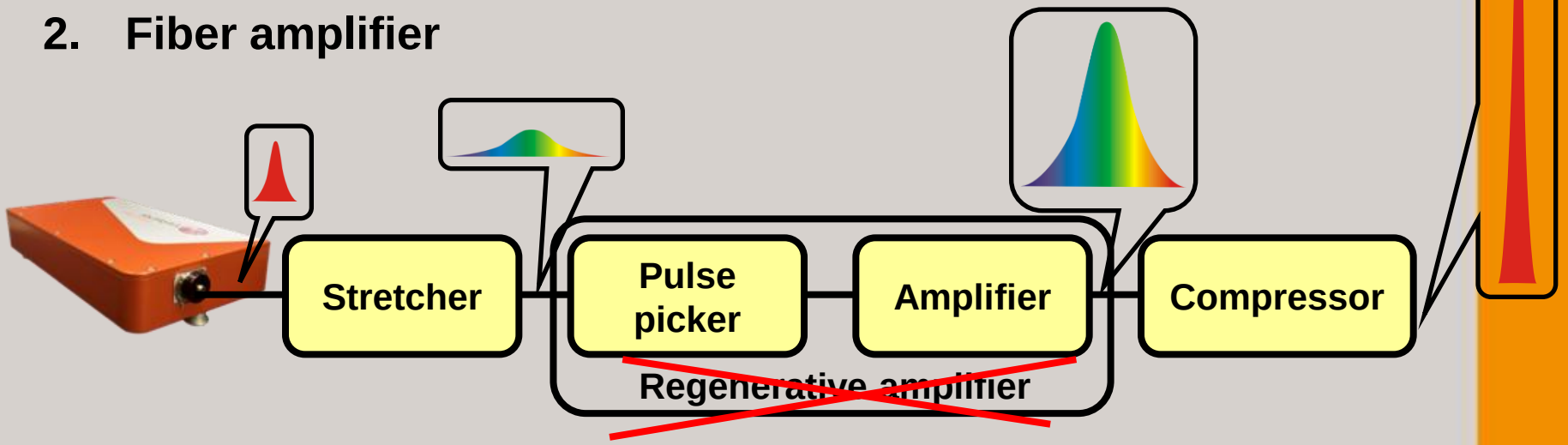


Compressor

- Reveal the final peak power

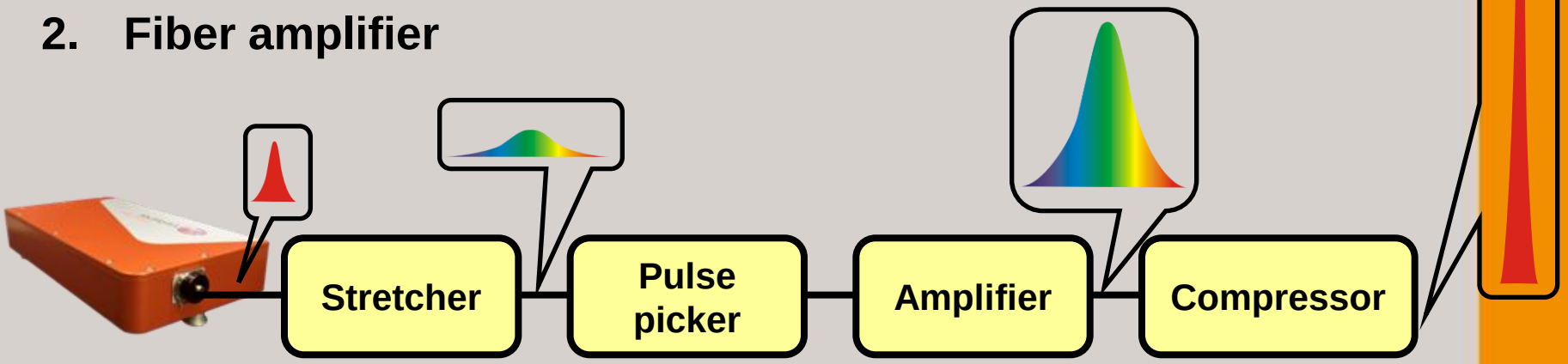
Chirped pulse amplifier

2. Fiber amplifier



Chirped pulse amplifier

2. Fiber amplifier

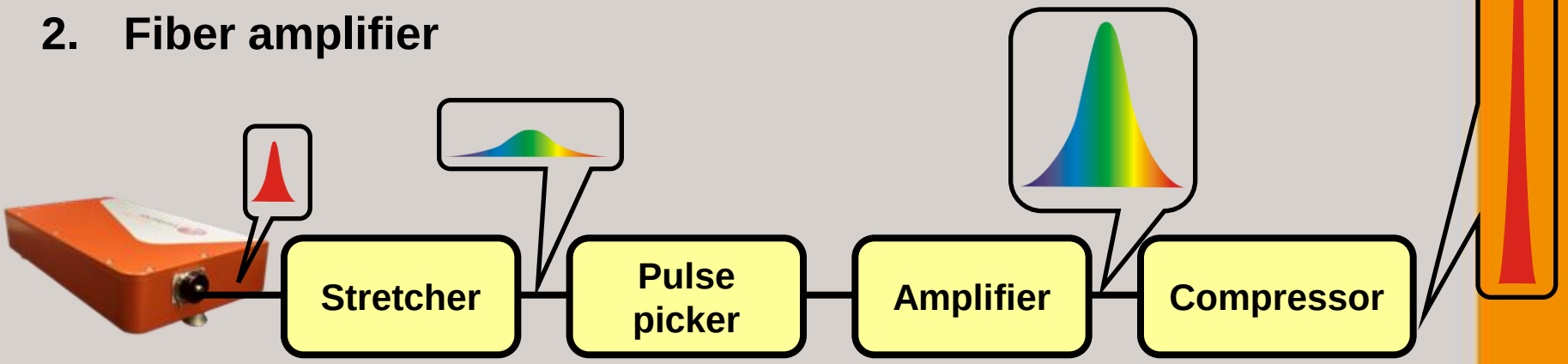


Pulse picker

- Decrease the repetition rate
  → From Single shot to few GHz

Chirped pulse amplifier

2. Fiber amplifier

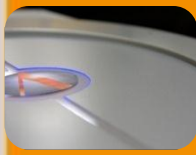


Fiber amplifiers

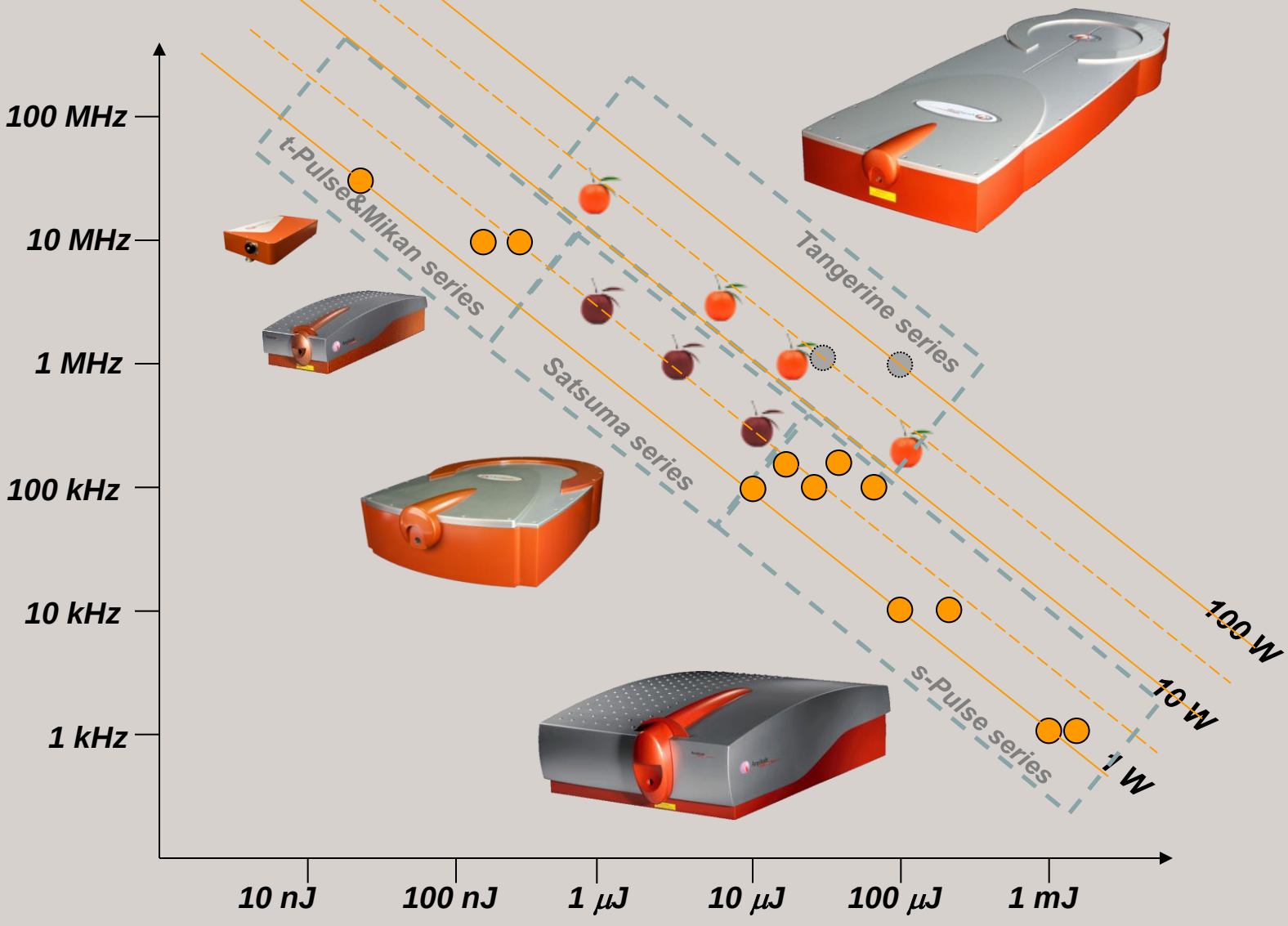
- Large mode area µ-structured fibers
- Very high gain
- Low NL
- High beam profile quality

Amplitude
SYSTEMES

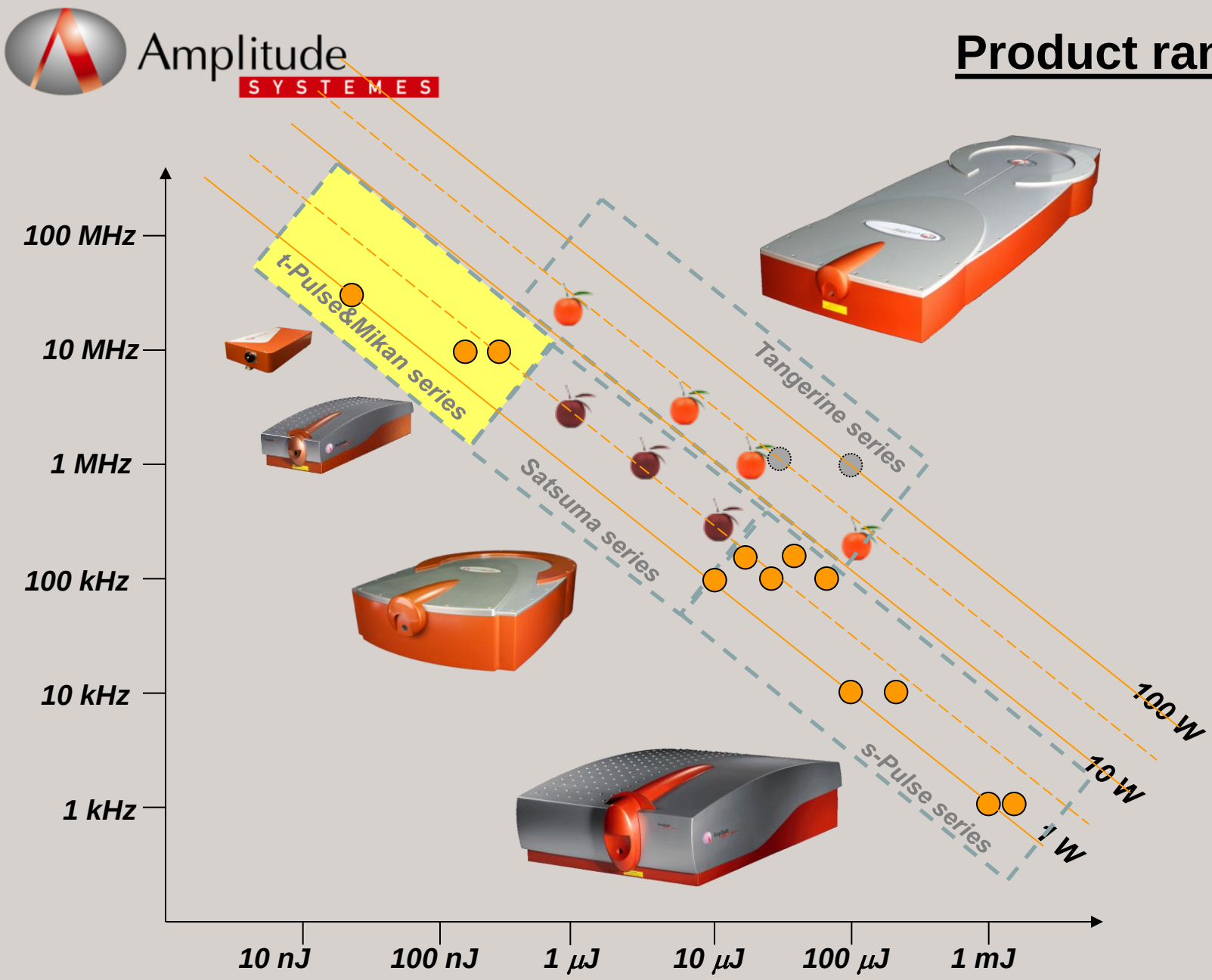


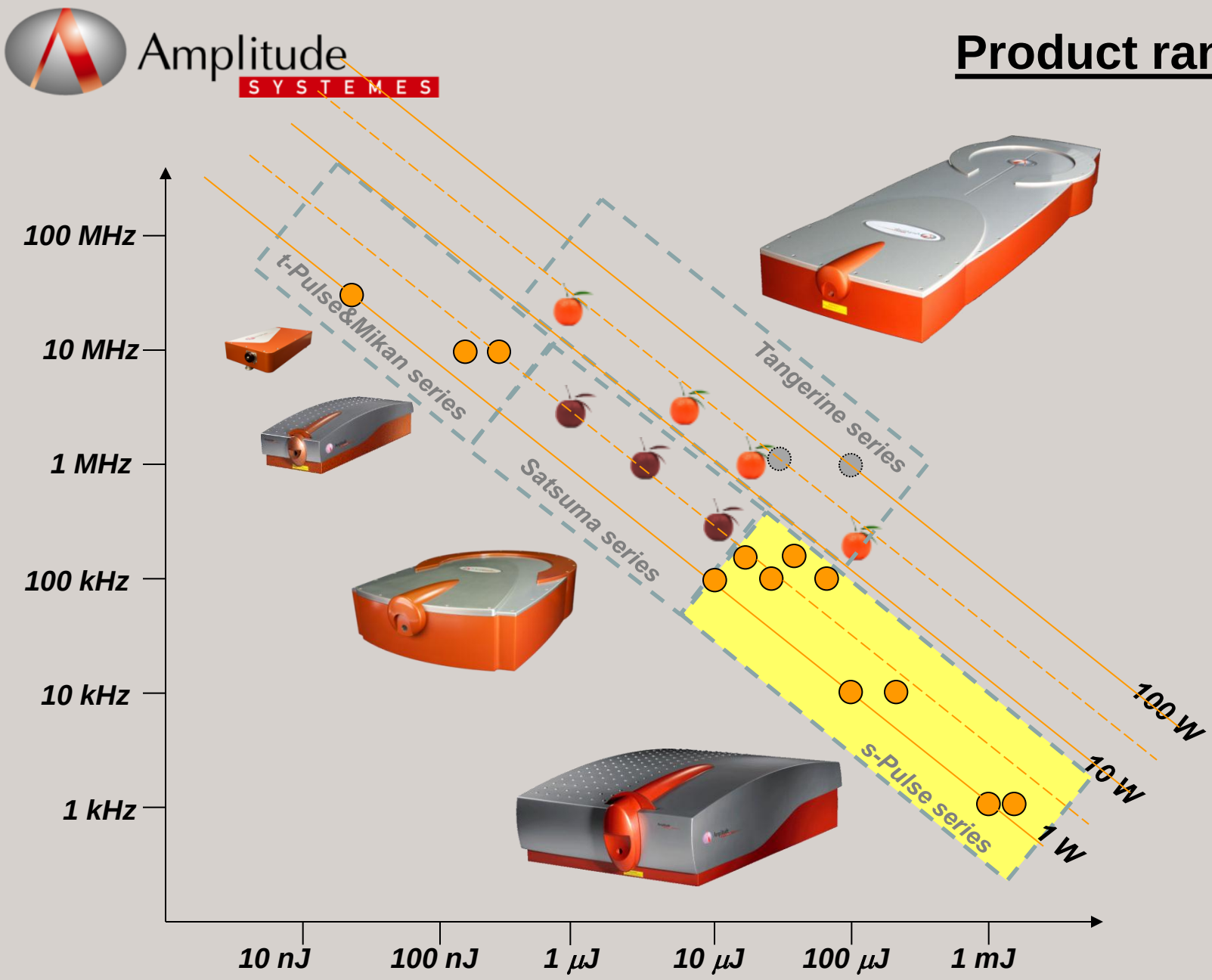
Product range



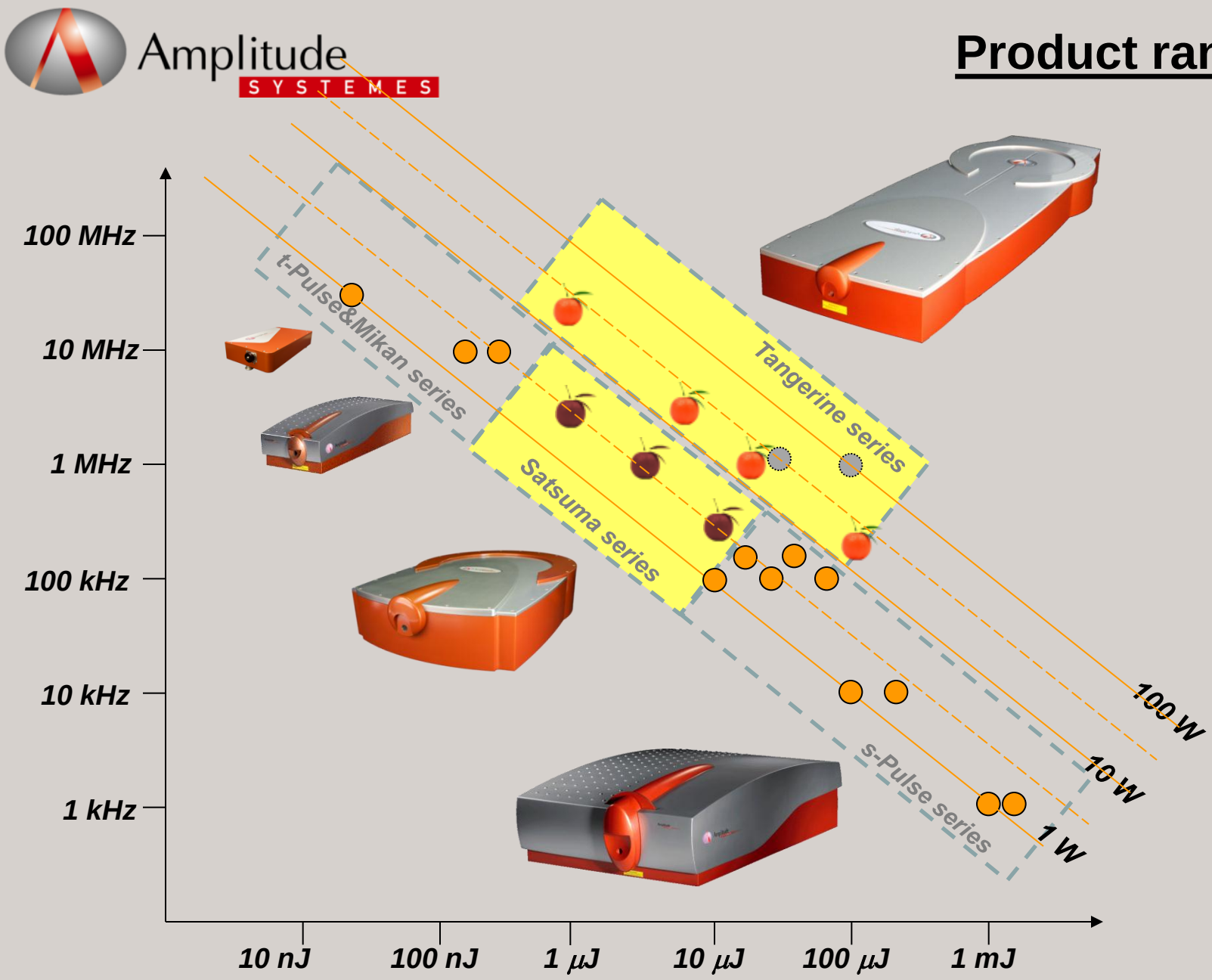
Product range



Product range



Product range



Femtosecond fiber lasers

Satsuma

Compact high repetition rate ultrafast fiber laser

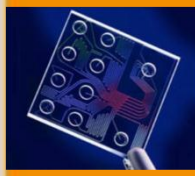
Features:

- Air cooled

Applications:

- Refractive surgery
- Ultrafast SEM
- OPA Pumping

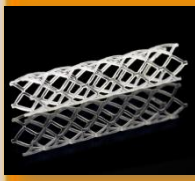
	Satsuma	Satsuma HP	Satsuma HP²
Pulse duration	< 400 fs	< 400 fs	< 400 fs
Average power	Up to 5 W	Up to 10 W	Up to 20 W
Pulse energy	Up to 10 µJ	Up to 20 µJ	Up to 40 µJ
Repetition rate	From 0 up to 2 MHz	From 0 up to 2 MHz	From 0 up to 2 MHz
Wavelenght	1030 nm	1030 nm	1030 nm
Beam quality	TEM_{00}	TEM_{00}	TEM_{00}
Footprint	50 x 33 cm	50 x 33 cm	50 x 33 cm

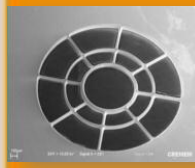


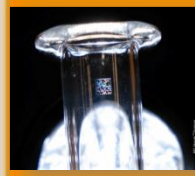
Femtosecond fiber lasers

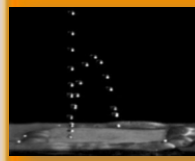
Tangerine

High power ultrafast fiber laser









Features:

	Tangerine	Tangerine HP
Pulse duration	From < 300 fs up to 10 ps	From < 300 fs up to 10 ps
Average power	20 W	50 W
Pulse energy	100 µJ	150 µJ
Repetition rate	From 0 up to 2 MHz	From 0 up to 2 MHz
Wavelenght	1030 nm	1030 nm
Beam quality	TEM_{00}	TEM_{00}
Footprint	120 x 42 cm	120 x 42 cm

- *D*
- *H*
- *H*
- *E*

Applications:

ng

ngraving

ng

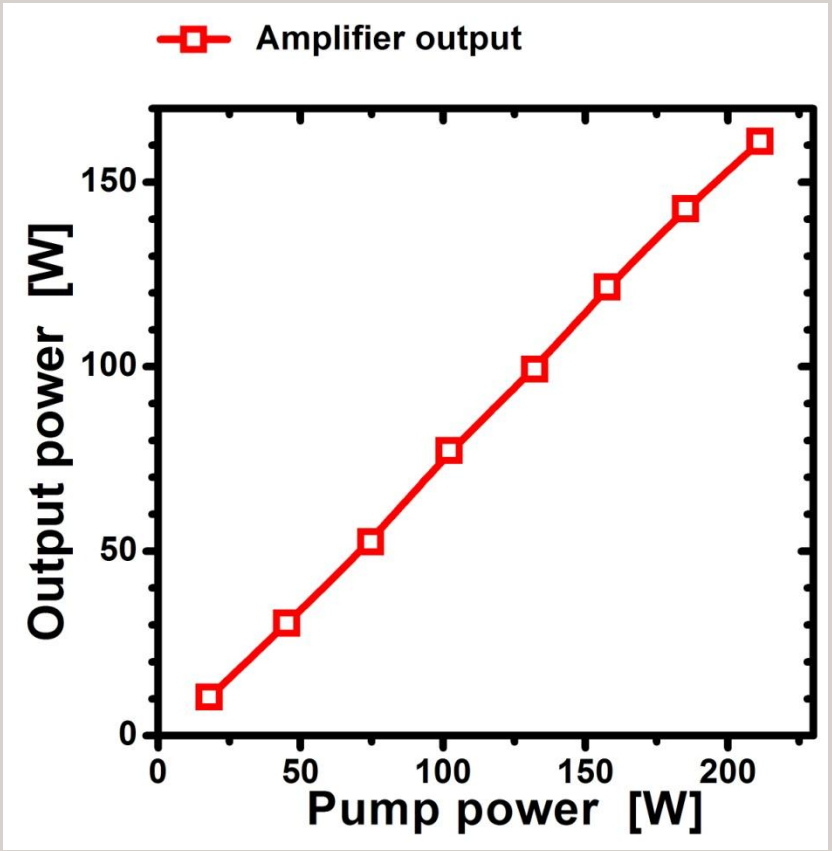
erator

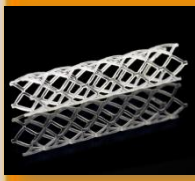
on

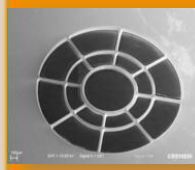
- *OPA Pumping*

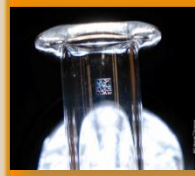
Tangerine & Satsuma

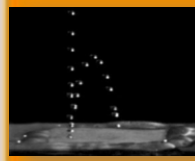
Very high efficiency
High power laser











s-Pulse

Diode pumped femtosecond amplifier

Features:

- *Desig*
- *High a*
- *High e*
- *Excell*

	s-Pulse HR	s-Pulse HP	s-Pulse HP²
Pulse duration	< 500 fs	< 500 fs	< 500 fs
Average power	> 2.5 W	> 4 W	> 8 W
Pulse energy	> 40 µJ	> 1 mJ	> 2 mJ
Repetition rate	0 to 300 kHz	0 to 300 kHz	0 to 300 kHz
Wavelenght	1030 nm	1030 nm	1030 nm
Beam quality	TEM_{00}	TEM_{00}	TEM_{00}
Dimensions	75 x 50 cm	75 x 50 cm	75 x 50 cm

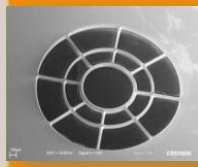
Applications:

graving

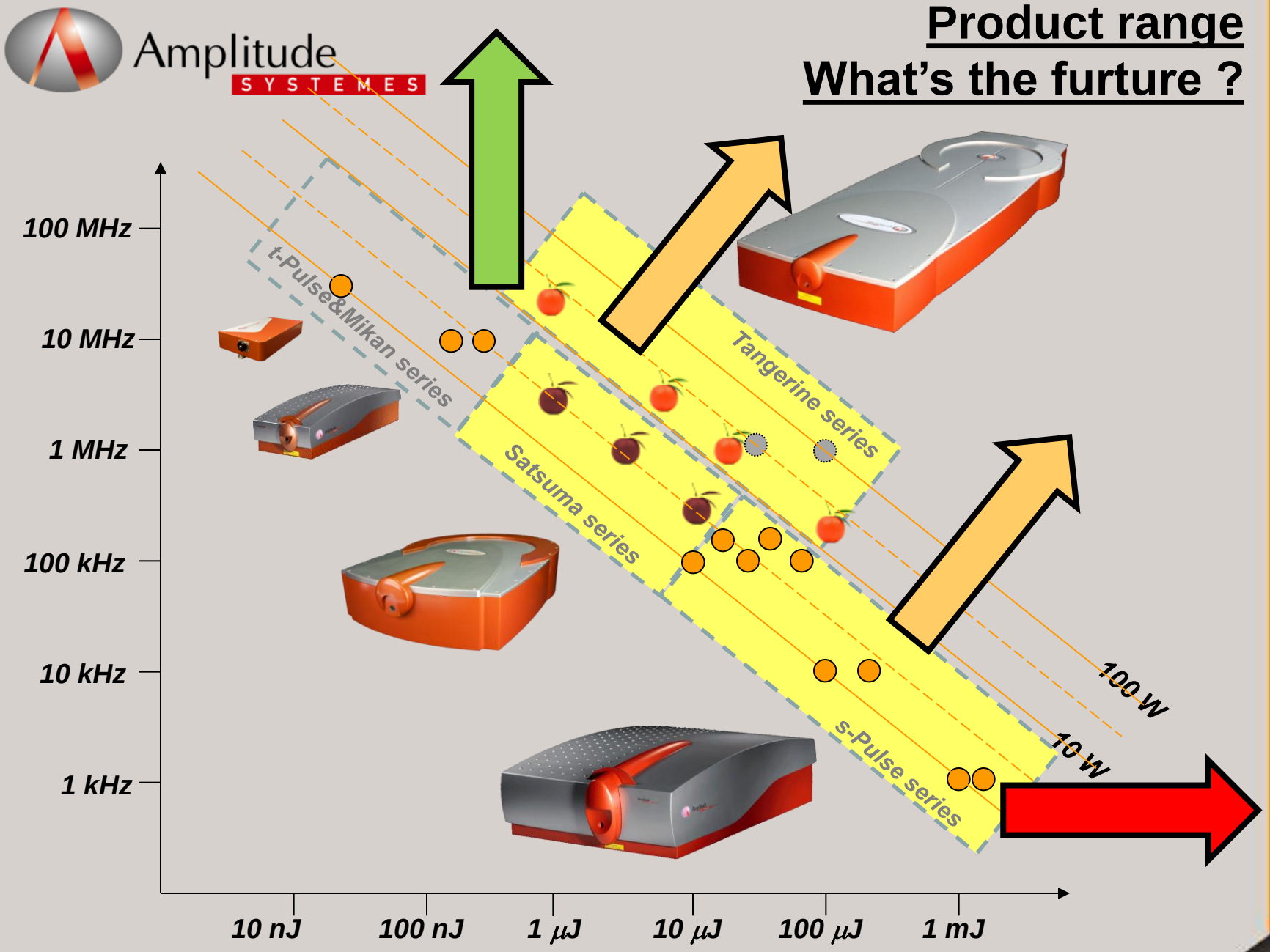
stry

rator

- *High harmonics generation*



Product range
What's the furture ?



Manufacturing

Production environment

- 20000 ft² clean room production area

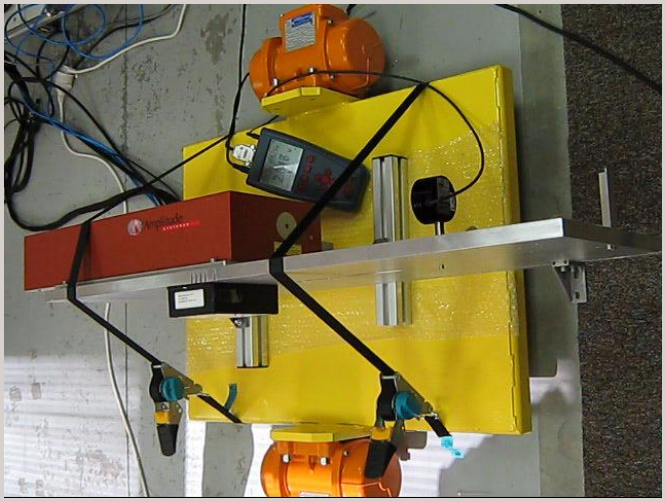
- Production capacity > 400 lasers / year

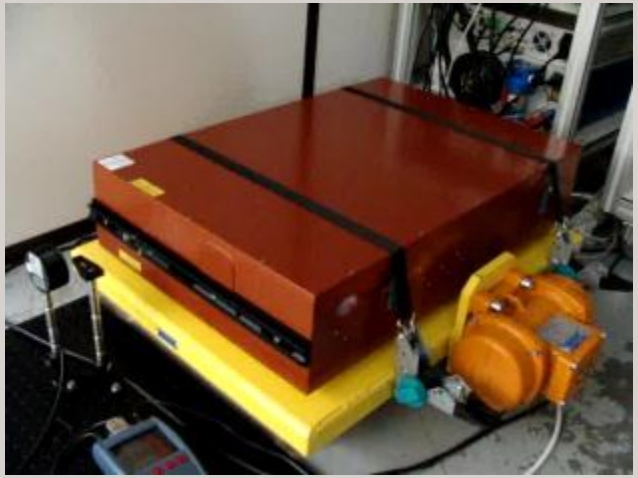
- ISO 9001 certified

- ISO 13485 certified

Production process

- Clean room from mechanical assembly to quality control
- Over 700 individual check points
- >3G vibration tests on all products





A true expertise on large scale project

- Complete management of large scale project

1. Oscillator
2. Booster
3. Stretcher
4. Regenerative + MP amplifiers
5. First HE Amplifier
6. Pump lasers
7. Cryogenic cooling

PULSAR - 200 TW class	
Rep. rate	10 Hz
Wavelength	800 nm
ASE contrast	> 10^9
Pulse duration	< 25 fs
Stability	< 1% RMS

Upgrade possibilities with the **SUPER BOOSTER**
> Contrast **10^{12}**
> Pulse duration **< 20 fs**

> PULSAR PW

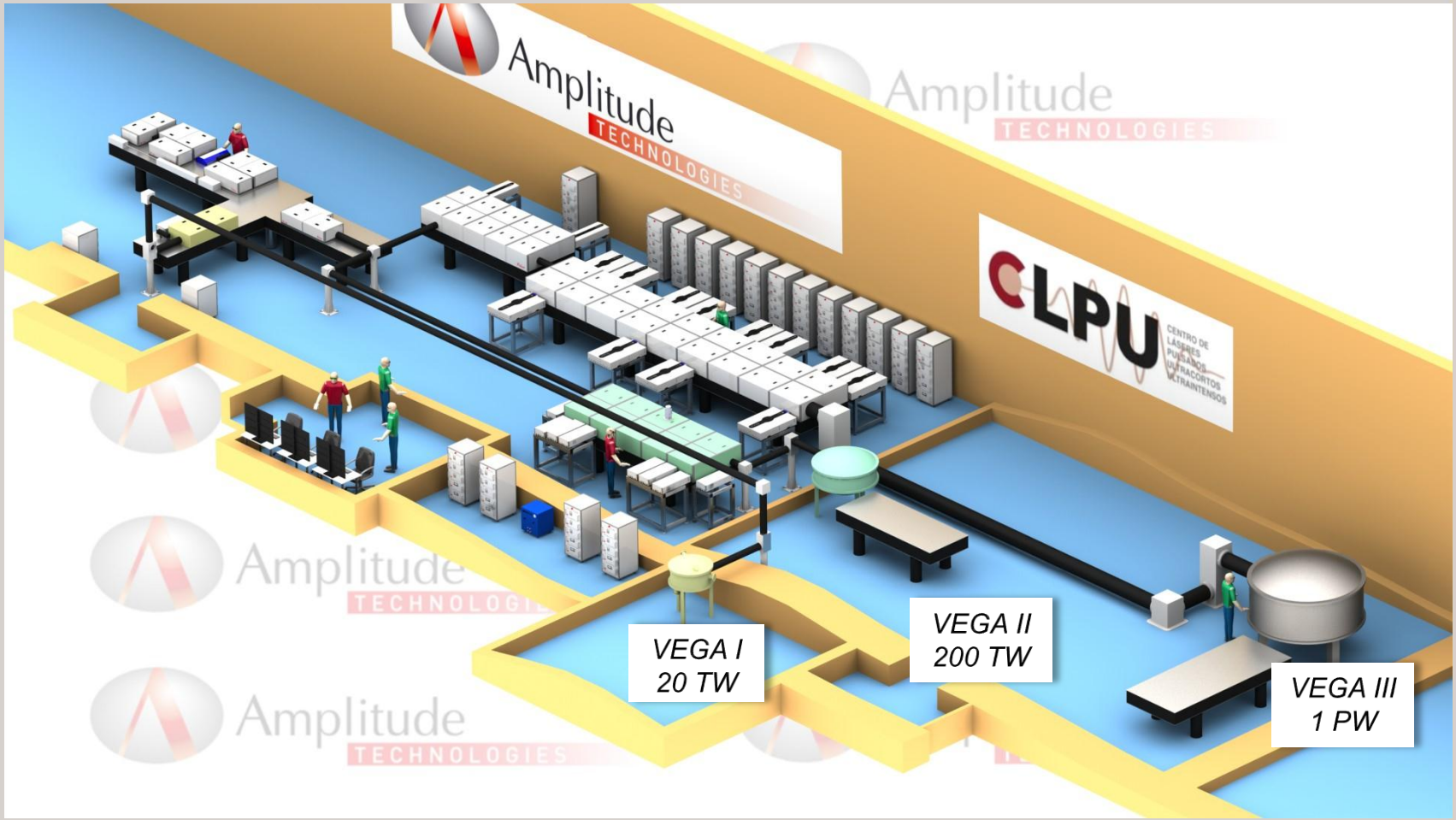
PW UPGRADE

4 UNDER CONSTRUCTION !

Front-end TW

Performances	
Rep. rate	1 Hz
Pulse duration	< 25 fs
Temporal contrast	> 10^{12}
PW output energy after compression	≈ 1 PW

> PULSAR PW

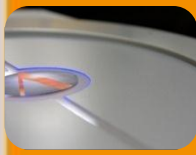


CLPU Salamanca: PW

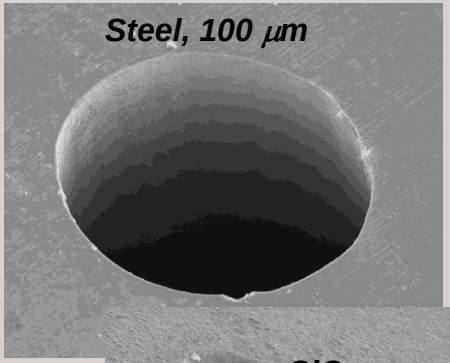
Amplitude
SYSTEMES

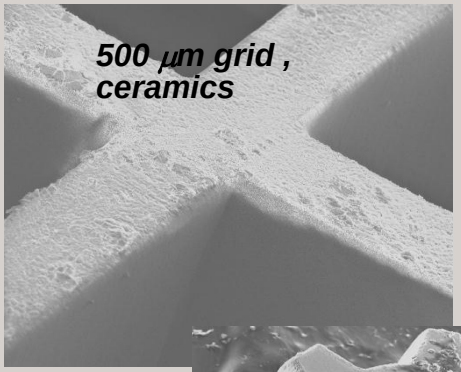
Applications

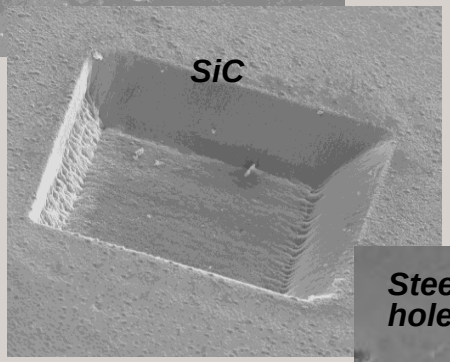


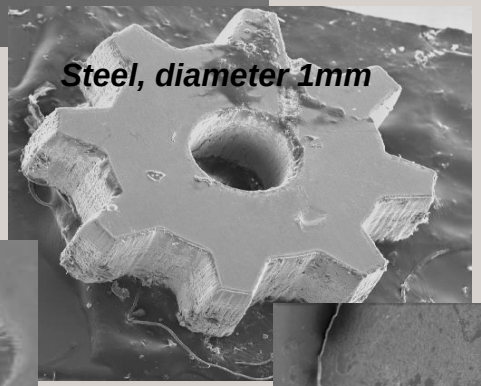



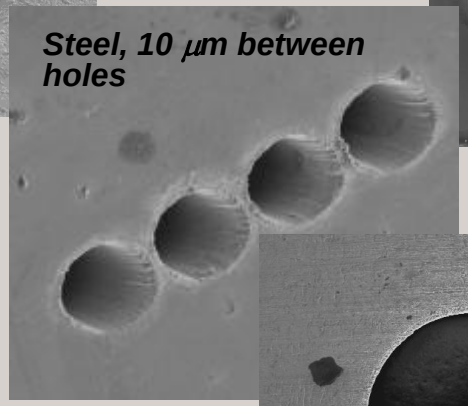
Micromachining

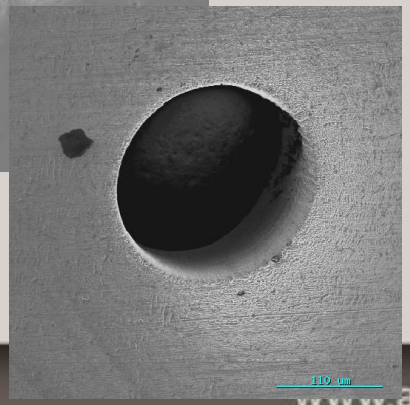


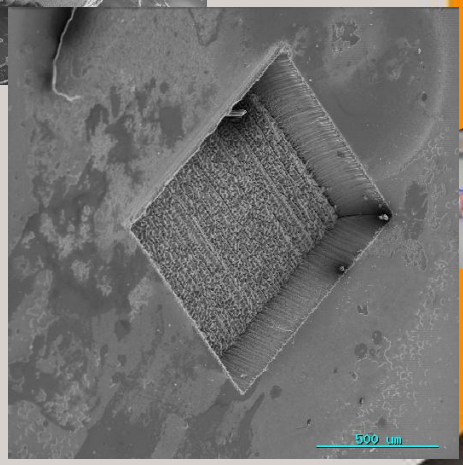


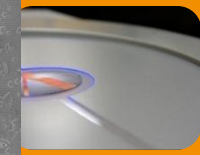




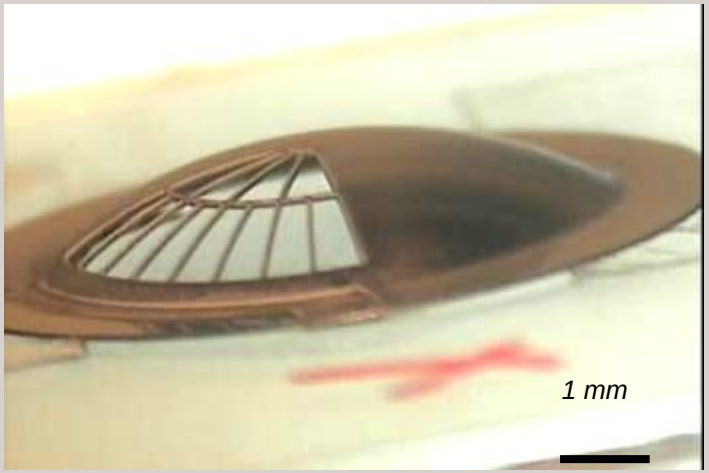




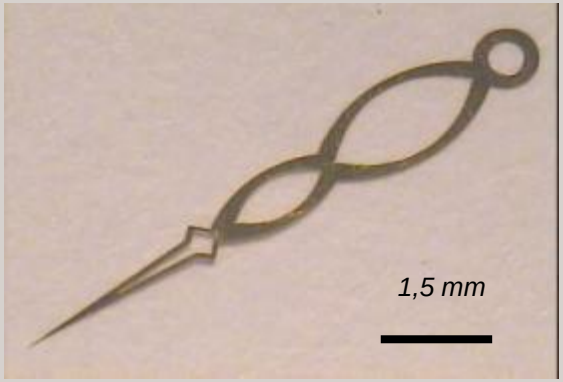




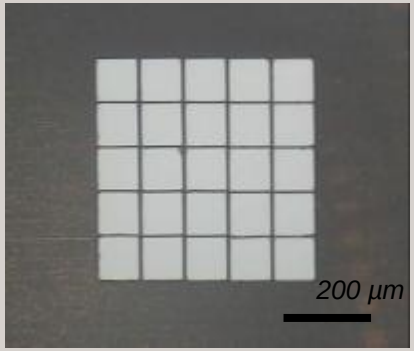
Micromachining



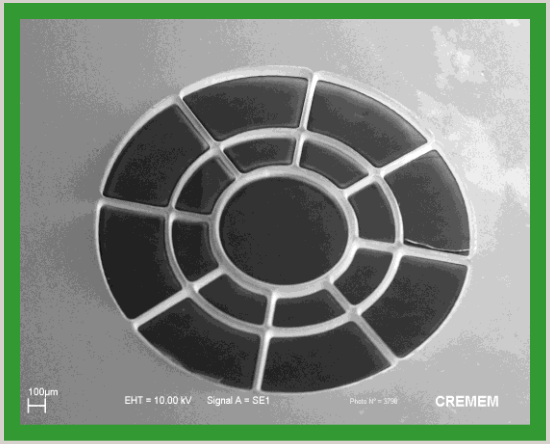
Metal - thickness.50µm
Bars width 90µm



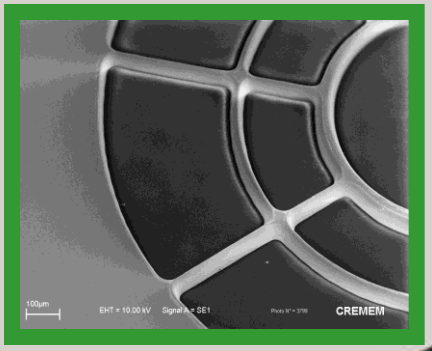
Gold - thickness.25µm

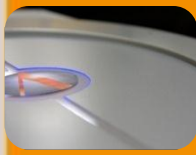


Platin - thickness.10µm
Bars width 10µm



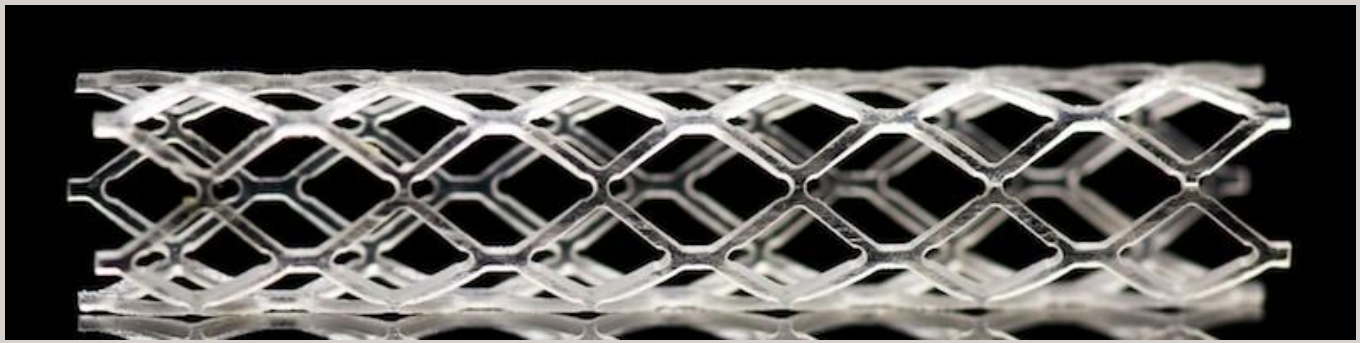
Tungsten - thickness. 100µm
Bars : 100µm





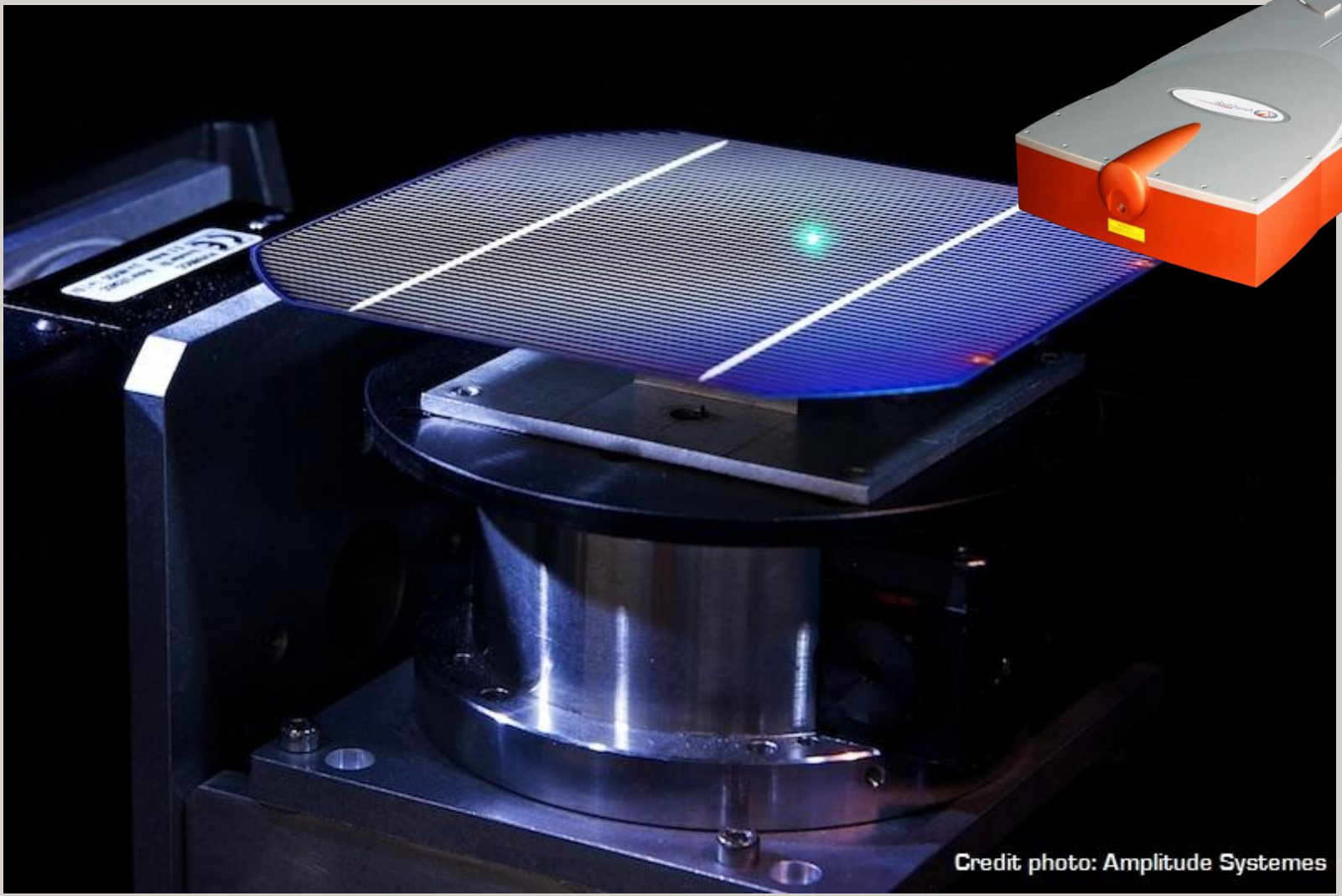
Medical device manufacturing

Metal or bio-polymer machining



Processed with Tangerine

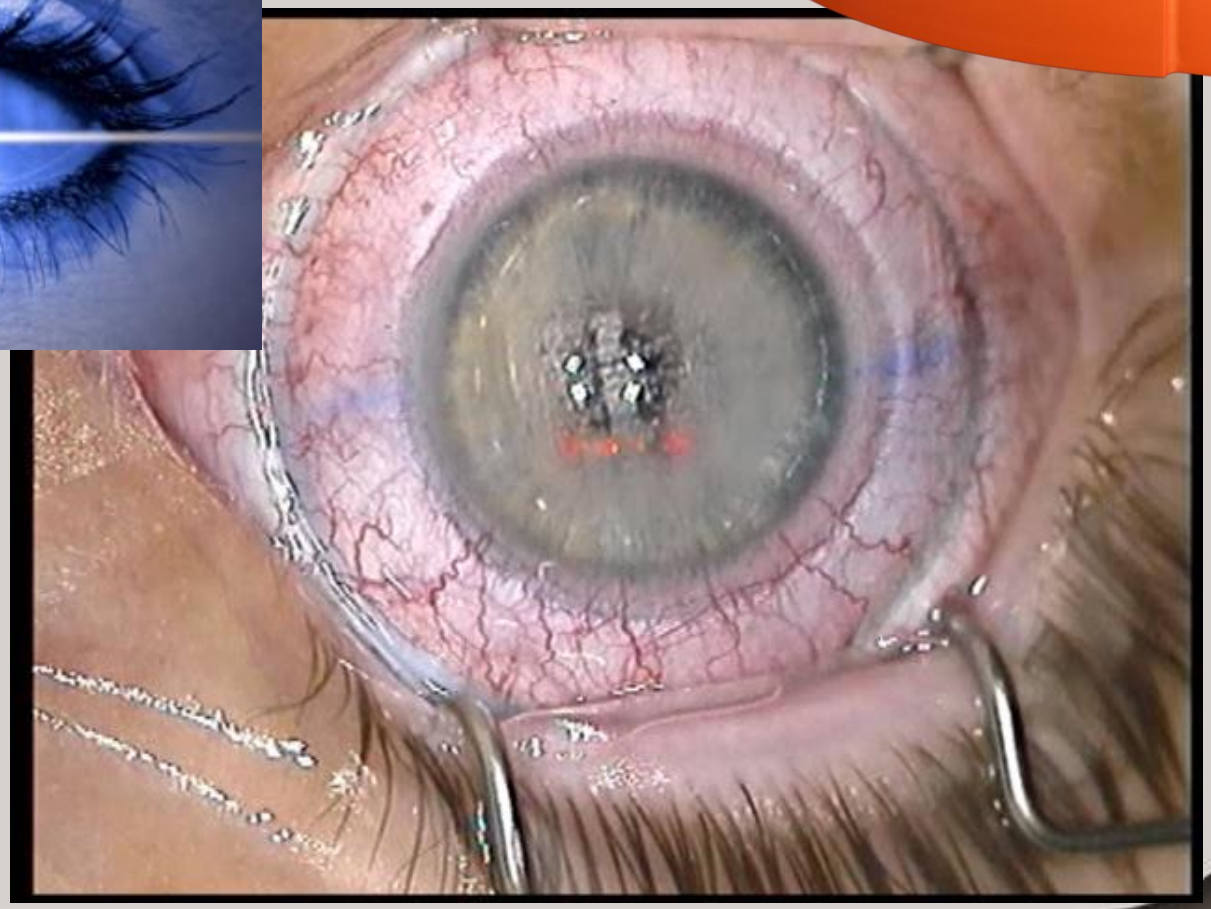
Photovoltaics



Processed with Tangerine

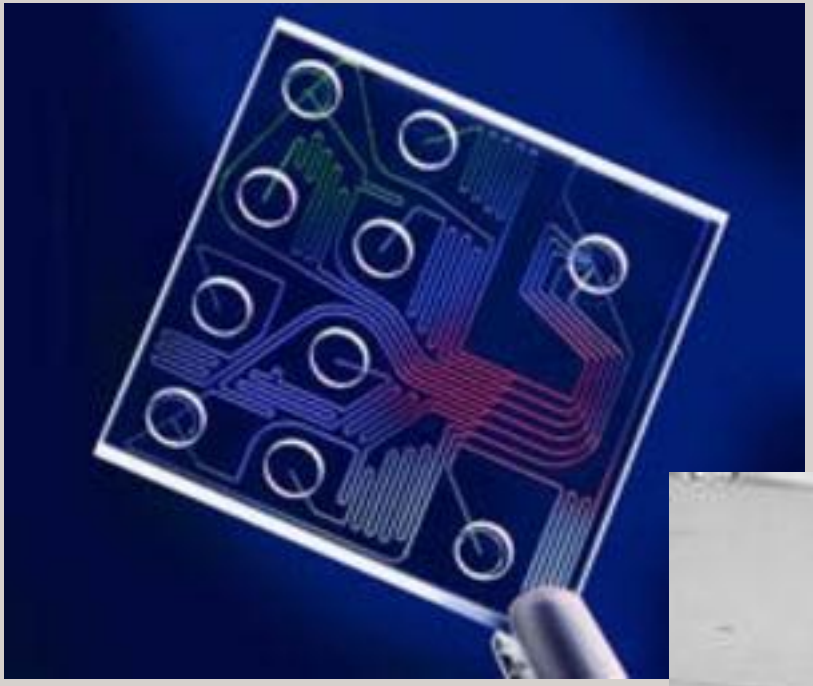
Eye surgery

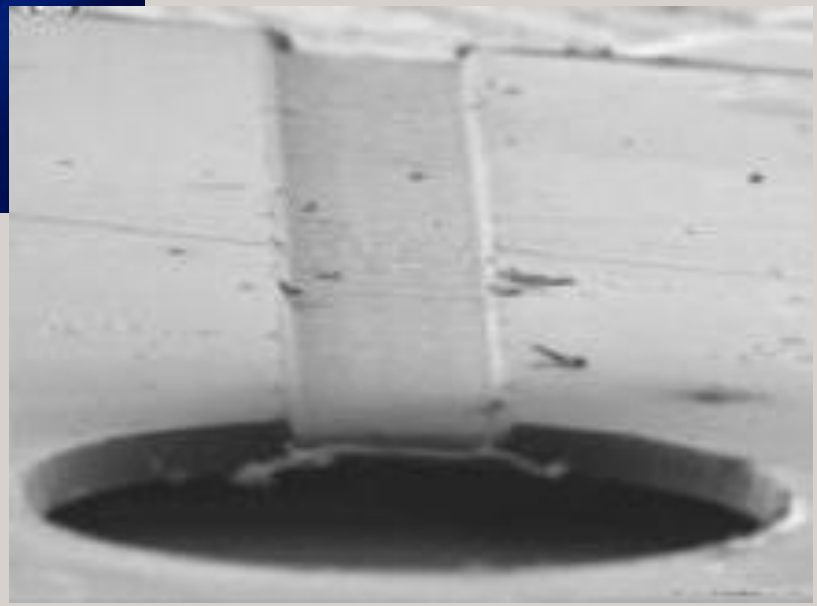
Leader in ultrafast eye surgery



Processed with Satsuma

Lab-On-Chip

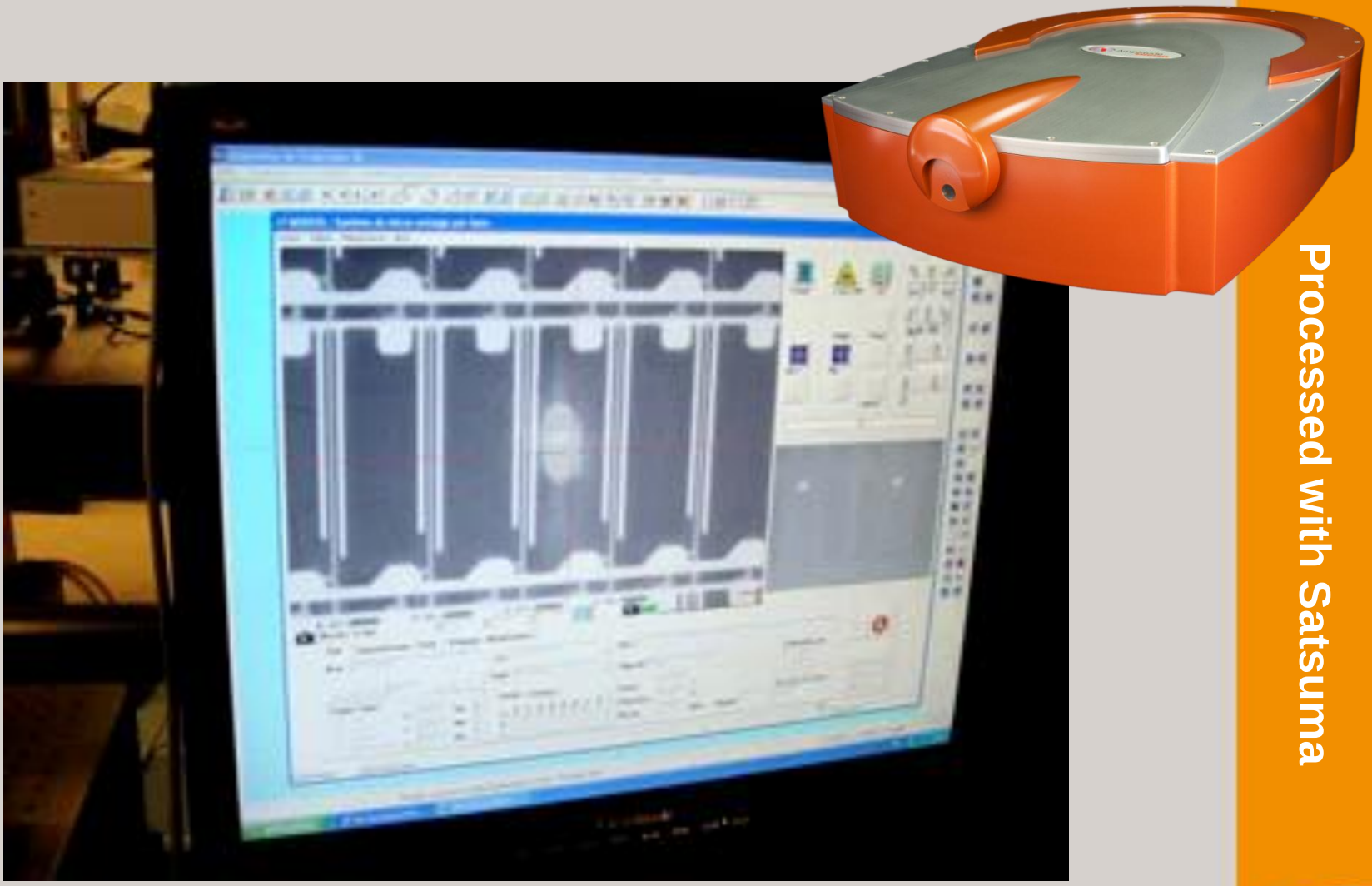




Processed with Satsuma

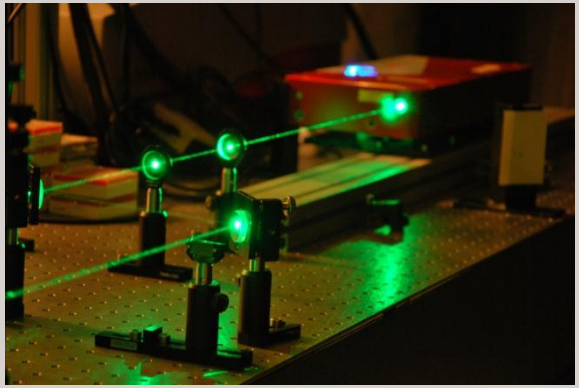
Amplitude SYSTEMES

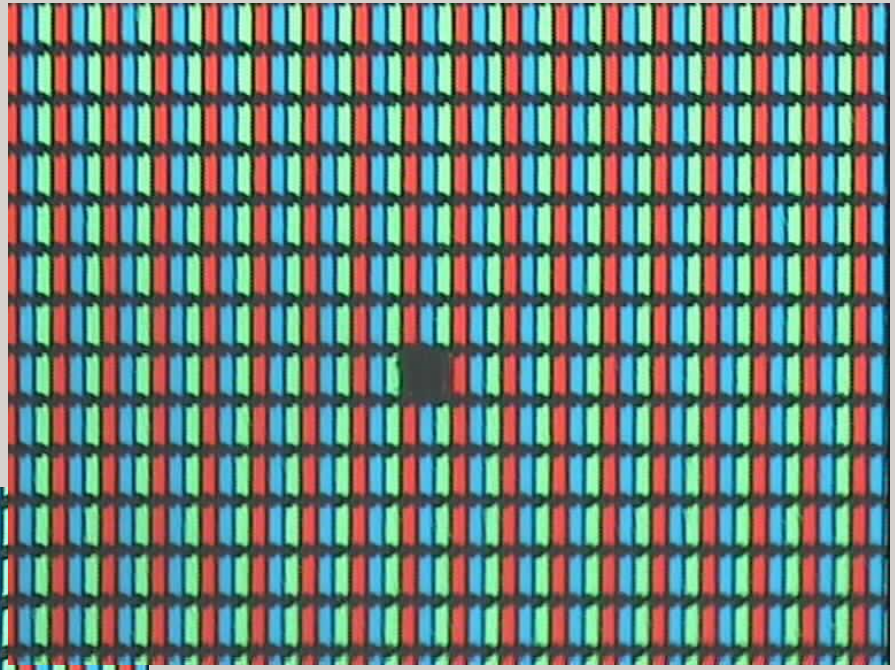
Display

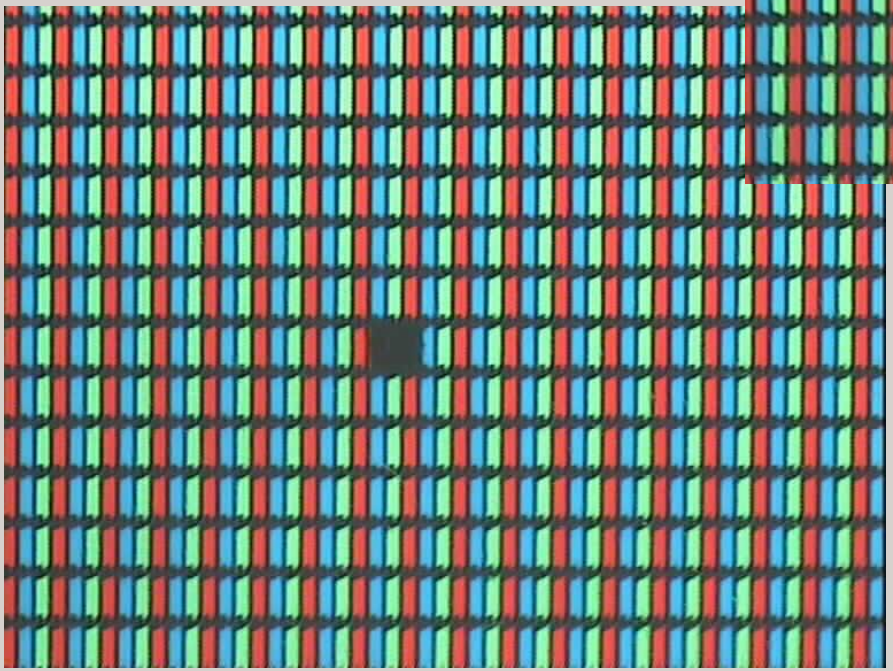


Processed with Satsuma

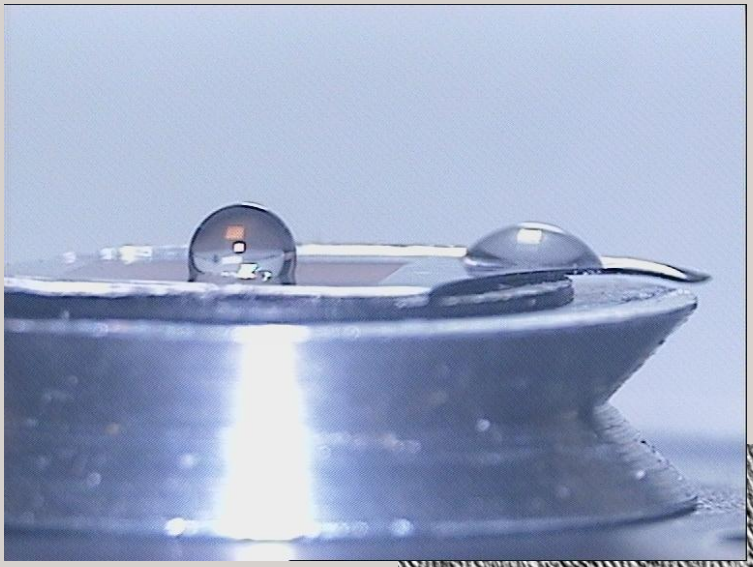
Pixels carbonization

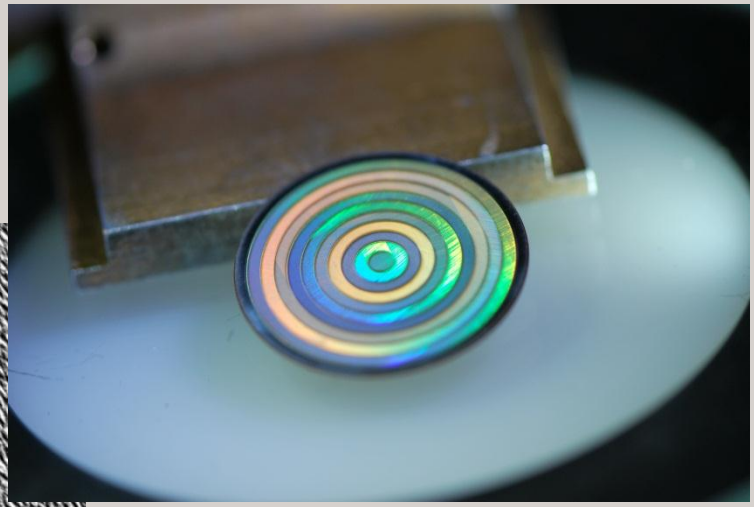




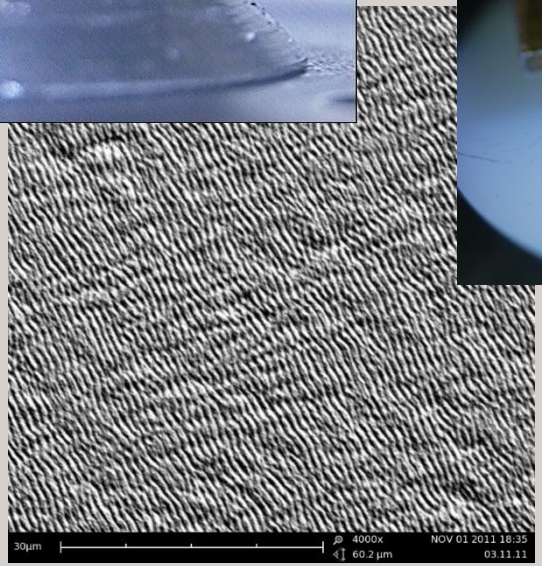


Surface structuring





Courtesy Alphanov

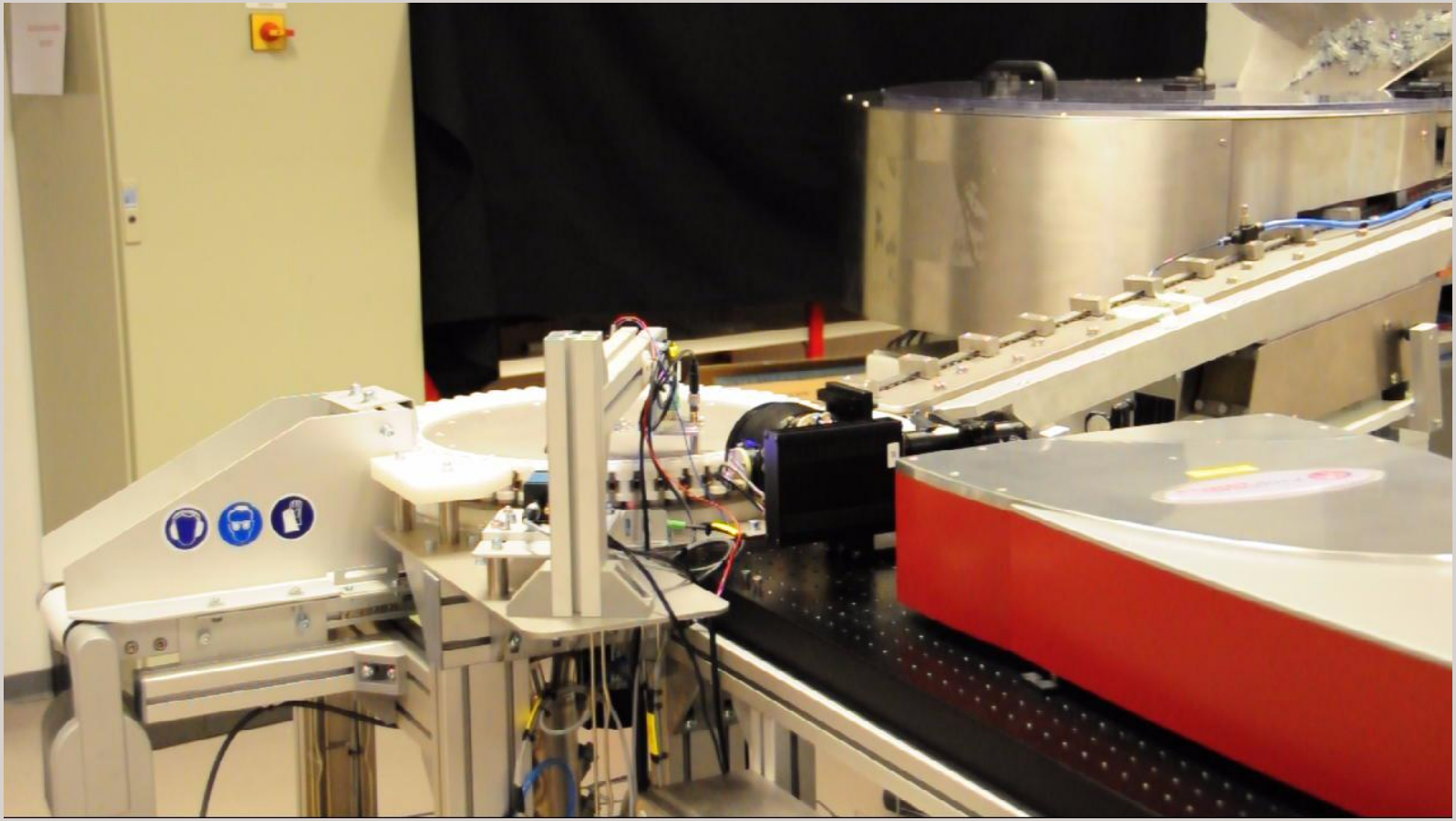


Processed with s-Pulse HP

Internal marking

Processed with Tangerine

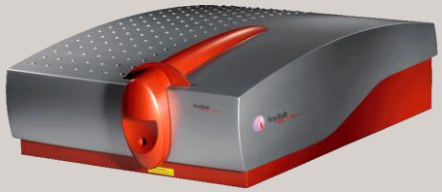
Internal marking



Particule accelerators

Satsuma

Tangerine



S-pulse

- Photocathode
- Laser heater
- Laser wire
- Experiments in beam lines
- Slicing
- e^- acceleration
- Proton acceleration

SOLEIL SYNCHROTRON

UNIVERSITY OF OXFORD

John Adams Institute for Accelerator Science

SLAC

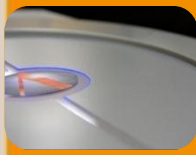
INFN Istituto Nazionale di Fisica Nucleare

European XFEL

PAUL SCHERRER INSTITUT PSI

Lawrence Livermore National Laboratory

Amplitude SYSTEMES



SAPPHiRE requirements

- 5 J, 200 kHz, 1MW @ 351 nm
  - Not achievable with a single amplifier

Coherent combining + **Cavity enhancement**

SAPPHiRE laser

Risk : High
Medium
Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

...

Amplifier

Compressor

THG

Cavity enhancement

SAPPHiRE laser

Risk : High
Medium
Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

...

Amplifier

Compressor

THG

Cavity enhancement

SAPPHiRE laser

Risk :
- High
- Medium
- Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

...

Amplifier

Compressor

THG

Cavity enhancement

Amplifiers

50 – 150 amps
Few 100's µJ each
Few 100's W each
Total = 10 – 30 kW
= 5 – 15 mJ

SAPPHiRE laser

Risk :
- High
- Medium
- Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

...

Amplifier

Compressor

Cavity enhancement

THG

Compressor

- Highly efficient MLD gratings
- Can sustain 50 kW

SAPPHiRE laser

Risk :
- High
- Medium
- Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

...

Amplifier

Compressor

THG

Cavity enhancement

Third harmonic generation

- Large aperture NL crystals
- Lifetime issues to be considered

SAPPHiRE laser

Risk :
- High
- Medium
- Low

Stretcher

Pulse picker

Amplifier + Compressor

THG

Amplifier + Compressor

THG

Amplifier + Compressor

THG

Amplifier + Compressor

THG

. . .

Amplifier + Compressor

THG

Cavity enhancement

Third harmonic generation

- Large aperture NL crystals
- Lifetime issues to be considered

SAPPHiRE laser

Risk : High
Medium
Low

Stretcher

Pulse picker

Amplifier

Amplifier

Amplifier

Amplifier

. . .

Amplifier

Compressor

THG

Cavity enhancement

Cavity enhancement

- Q = 1000
- 5 J, 10 MW circulating

SAPPHiRE laser

Risk :
- High
- Medium
- Low

Stretcher

Pulse picker

Amplifier + Compressor

THG

Amplifier + Compressor

THG

Amplifier + Compressor

THG

Amplifier + Compressor

THG

. . .

Amplifier + Compressor

THG

Cavity enhancement

Cavity enhancement

- Q = 1000
- 5 J, 10 MW circulating

Conclusion

- **Amplitude is committed to work with researchers from the particle / accelerator physic communities**
  - Develop state-of-the-art laser systems

- **Amplitude has a unique position as it is able to provide both :**

- Industrial lasers
  - Mass production
  - Proven in-the-field reliability
  - Low MTBF
  - Industrial leader for ultrafast fiber lasers

- Produce the most advanced laser systems available today
  - Complete management of the project from conceptual design to delivery and training
  - Risk management
  - Leader in ultrashort high energy laser systems

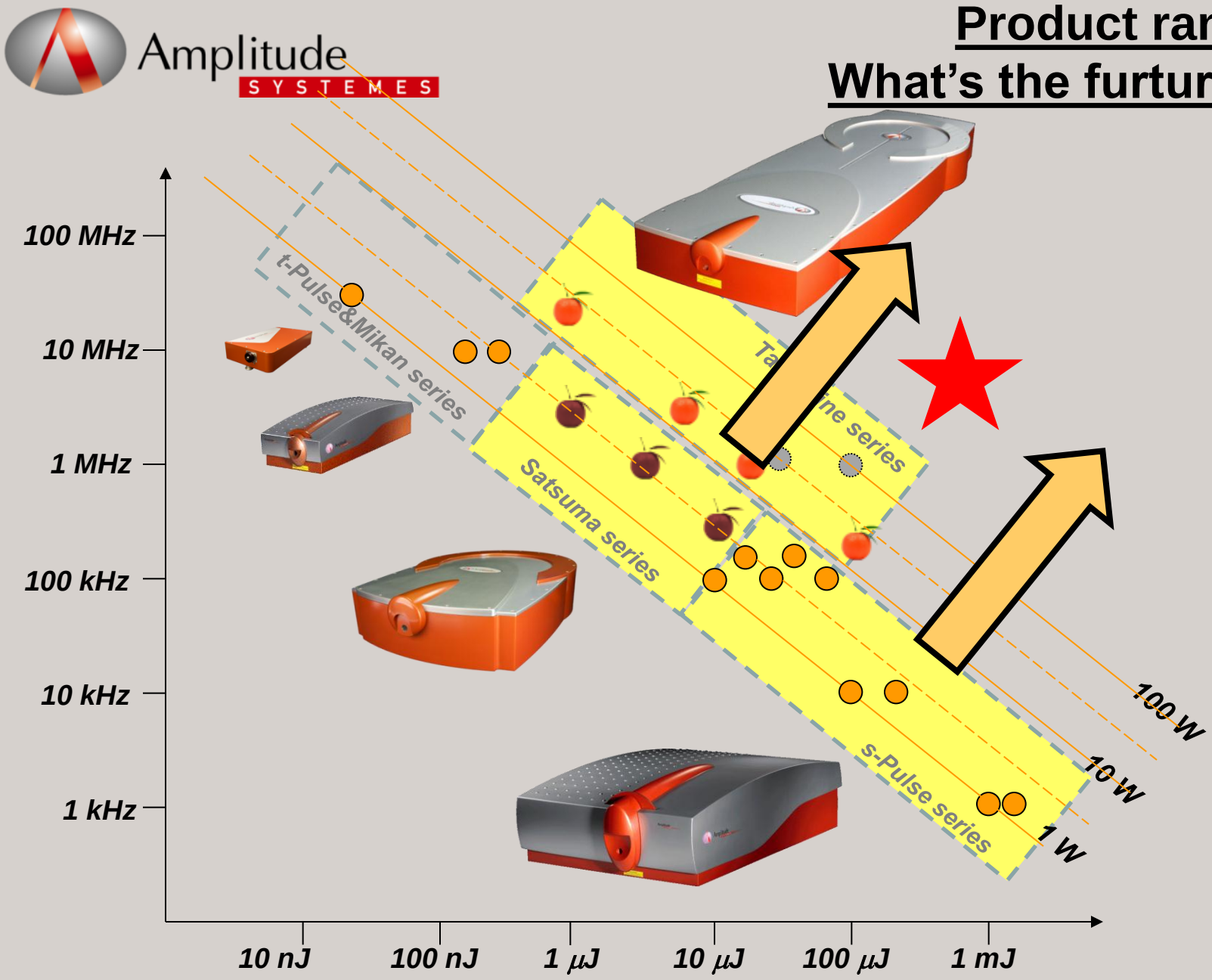
Conclusion

- **Amplitude has a unique technological expertise**

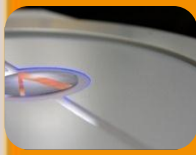
  - Ultrafast amplifiers
    - 10 years of experience in high power technology
    - State-of-the-art performances
    - Design of oscillator, stretcher / compressor, amplifiers
    - Patented technologies and concepts

  - Coherent combining of ultrashort pulses
    - Active coherent combining
    - Passive coherent combining
    - Divided pulse amplification
    - Patented architectures

Product range
What's the furture ?



Amplitude SYSTEMES



nothing but ultrafast

www.amplitude-systemes.com