



# Amplitude

PRESS KIT / 2019

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Amplitude Laser,  
the world-leading manufacturer of ultrafast lasers.



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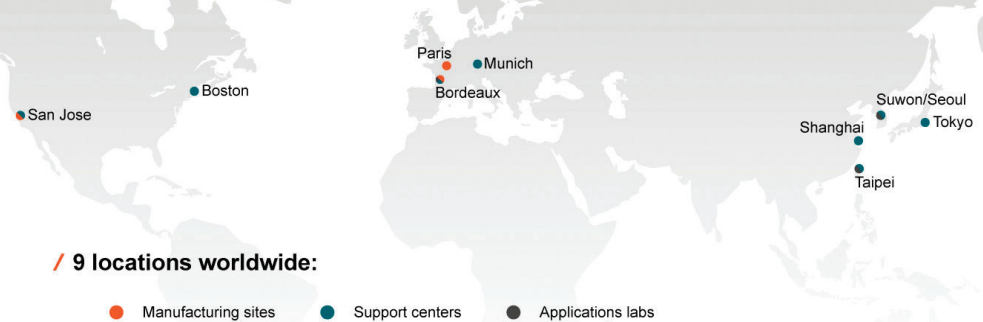
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# about AMPLITUDE



Since 2001, Amplitude has been the world-leading company in designing, manufacturing and commercializing ultrafast lasers.

Ultrafast laser technology, recognized by the 2018 Nobel Prize awarded to Donna Strickland and Gérard Mourou, revolutionizes scientific research, industrial manufacturing processes and health.

Dedicated to industrial, medical and scientific applications, Amplitude combines research and innovation, for the benefit of industrial, medical and scientific projects. Amplitude is the only international specialist to cover both ultrafast lasers technologies and their applications.



## OUR TEAM

Amplitude has more than 330 employees located in Pessac and Lisses in France, Milpitas in United States and Shanghai in China. All those sites form Amplitude Laser Group.

#MadeInFranceLasers  
#MulticulturalCompany

## OUR STORY / KEY DATES

**In 2001**, Éric MOTTAY and Gilles RIBOULET, two passionate engineers, created Amplitude Technologies.

**In 2002**, they raised Amplitude Systèmes, another part of Amplitude, specialized in smaller ultrafast lasers, for industrial application.

**In 2011**, Amplitude buys Continuum Inc., the American expert in nanoseconds lasers, and thus covers the American market.

**In 2017**, Amplitude reached 70 million euros of sales performance, including 90% from exports.

**In 2018**, Amplitude modernized its brand in a more sober style, more dynamic, expressing energy and control.



## / INNOVATION FROM THE VERY BEGINNING

Since its creation, Amplitude has been investing consistently in the design and manufacture of high performance, reliable and easy-to-use ultrafast lasers. Today, this laser manufacturer is a major actor in both the technological and scientific communities recognized with multiple awards:

2008

PhAST / Laser Focus World  
Innovation Award for  
Amplitude Laser

2012

Prism Award for our Satsuma  
laser for best industrial laser  
(San Francisco)

2013

Innovation award by I.N.P.I.  
- Institut National de la  
Propriété Intellectuelle

2016

"Croissance Internationale"  
award by Biznext/La Tribune

2017

EUREKA award as best  
project of the year  
  
Tangor laser nominated  
as best industrial laser at  
Prism Award (San Francisco)

## OUR VALUES

### / OUR HUMAN VALUES

Amplitude develops a social model in line with its development and innovation projects. It is based on a sustainable human policy built around values. Each collaborator's actions and behavior - with colleagues, hierarchy or in his/her external interactions - must be a guarantor of the following values :





## / QUALITY DEDICATED

With Amplitude, we collaborate with our international customers, industries and large scientific laboratories. For answering to their specific needs, Amplitude manufactures state-of-the-art lasers. Led by both honesty and an entrepreneurial spirit, Amplitude teams give all their best for the customers' satisfaction, especially by offering both high quality and reliable products.

Amplitude is in line with a dynamic to continually improve the quality of its products. Amplitude relies on international standards with ISO 9001 and ISO 13485. Our quality approach is to listen to our customers, meet the requirements and continually improve our products and processes to provide them with the best service.



## OUR AMBITION

### / TO BECOME OUR CUSTOMERS CHOSEN PARTNER

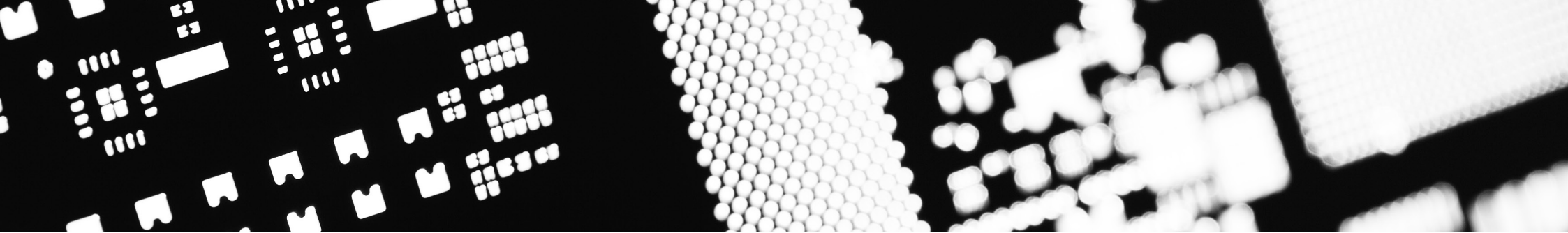
Amplitude has already implemented ultrafast laser technology in multiple sectors such as physics and chemistry research, applied research, ophthalmology, electronic components, semiconductors. But today, Amplitude is paving the way to become the chosen partner for our customers' projects, meaning predicting future uses of an ultrafast laser, for applications not yet imagined.

Thanks to both its technological research and its geographical reach, Amplitude can respond to an even wider field of applications in industrial, medical and scientific fields.



# AMPLITUDE LAUNCHES **TANGOR 300**, THE MOST POWERFUL ULTRAFAST LASER IN THE MARKET FOR ALL TYPES OF MATERIALS





**Tangor 300**, the fastest, most versatile and powerful ultrafast laser in the market, offers high quality results with high productivity.

Manufacturer Amplitude will demonstrate its high performance live on June 26 at Laser World of Photonics in Munich, Hall B3 / Booth 325.

## PESSAC, FRANCE - MONDAY, JUNE 24, 2019

Amplitude reveals the **Tangor 300**, its brand-new high performance laser - the most powerful in its field, with average power reaching 300W and pulse width less than 500 femtoseconds. In addition, **Tangor 300** is capable of supplying energy of up to 1000µJ per pulse and a repetition rate of up to 40MHz. The combination ensures continuous quality, combined with high productivity for manufacturers and researchers.



Vincent Rouffiange,  
Sales and Marketing Director



**Tangor 300** is capable of handling all types of materials, covering a surface of 100mm<sup>2</sup> per second. This new ultrafast laser will enable our clients to multiply machining strategies via the perfect quality and productivity combination."

- Vincent Rouffiange, Sales and Marketing  
Director at Amplitude Laser Group.

**Tangor 300** is ideal for texturization, and its performance will be demonstrated in this application.

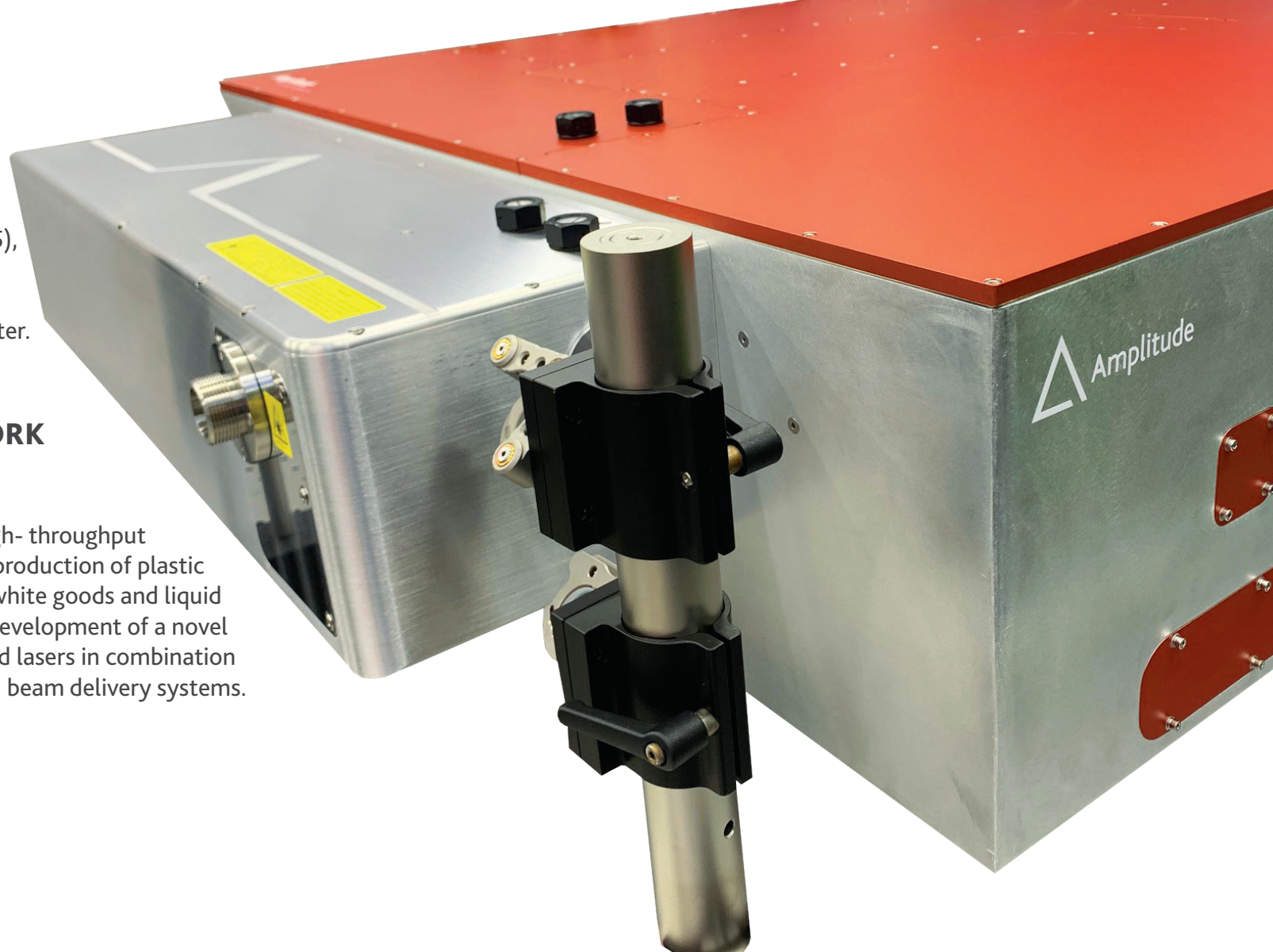
Amplitude is organizing a live demonstration on its booth (Hall B3, #325), June 26 at 11am CET, broadcast live from the laboratory of its partner AlphaNov, a technology optic and lasers research center.

## **TANGOR 300 HAS BEEN DEVELOPED IN THE FRAMEWORK OF TresClean Project\***

The aim of TresClean is to demonstrate high- throughput laser-based manufacturing applied to the production of plastic and metal component parts of consumer white goods and liquid filling machines respectively through the development of a novel industrial use of high-average power pulsed lasers in combination with high-performance optical devices and beam delivery systems.



See the video: <https://youtu.be/C5iYoP9lFGo>



PHOTONICS PUBLIC PRIVATE PARTNERSHIP

**PHOTONICS<sup>21</sup>**

\* The TresClean project is an initiative of the Photonics Public Private Partnership and has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 687613



# AMPLITUDE COVERS THE WIDEST RANGE OF LASER TECHNOLOGY

## ULTRAFAST LASERS

### / AMPLITUDE IS SPECIALIZED IN HIGH ENERGY ULTRAFAST LASERS USING $\text{Ti}:\text{Sapphire}$ AND $\text{Yb}$ TECHNOLOGIES

Based on unique laser engineering capabilities, Amplitude offers Petawatt class  $\text{Ti}:\text{Sapphire}$  lasers associating performance with flexibility. It guarantees specifications as measured by our de facto standard proprietary metrology tools. Leveraging the advantage of the Amplitude leading  $\text{Yb}$  core technologies, Amplitude also offers high repetition lasers for researchers in the fields of accelerators, material science and life science.

#### **SATSUMA**

Versatile, full-featured and compact femtosecond laser

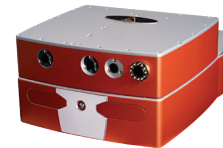
The Satsuma family of femtosecond laser offers versatility in the most compact aircooled laser platform on the market. Satsuma is a cost-efficient solution providing high repetition rate and high energy, up to 150  $\mu\text{J}$ .



#### **SATSUMA DISPLAY**

The most compact air-cooled femtosecond laser on the market

Satsuma Display is based on the well-known Satsuma platform – benefiting from 10 years of product improvements and feedback from installation of 1500 units in the field. The Satsuma platform's reliability and stability are internationally recognized.



#### **TANGOR**

Powerful, full-featured and versatile femtosecond laser

Tangor is a powerful femtosecond laser combining both high repetition rate (going up to 40 MHz adjustable) and high energy per pulse (going up to 500  $\mu\text{J}$  that can be splitted in several beams).



#### **TANGOR UV**

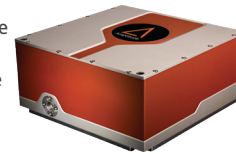
Tangor UV is a state-of-the-art high-power UV femtosecond laser, up to 30W-500fs. It combines high repetition rate, up to 2MHz and high UV pulse energy, up to 150 $\mu\text{J}$ . Tangor UV is compact and lightweight, making the integration smooth for in-line display equipment.



#### **GOJI**

High precision and compact femtosecond laser

The Goji benefits from our 15 years' experience in laser surgical applications. It has been specifically engineered and tested to meet the requirements of today's most demanding medical and industrial markets.



#### **YUJA**

Ultra-compact and high energy femtosecond laser

Yuja is a powerful femtosecond laser offering a high repetition rate (going up to 40 MHz and adjustable according to your needs). Thanks to its small dimensions, it can be implemented in all production configuration.



#### **MIKAN**

Air-cooled high power ultrafast oscillator

Mikan is an ultra-compact, reliable and turn-key femtosecond laser oscillator with high average power. Mikan offers a unique optional fiber output for easy set-up and integration to the user's experiments. Optional green light output allows users to extend the scope of potential applications.



#### **TANGERINE**

Femtosecond laser for research and development in micro processing and scientific applications

Tangerine is a powerful femtosecond laser combining both high repetition rate (going up to 40 MHz and adjustable according to your needs) and high energy per pulse going up to 250  $\mu\text{J}$ .



#### **MAGMA**

Magma is the world's first industrial-grade ultrafast laser with up to 300 mJ pulse energy. The system offers both high energy and high repetition rate together with higher peak power capabilities than the norm.



## HIGH PEAK POWER LASERS

The design and manufacturing of robust and reliable high peak power ultra-intense femtosecond laser systems is a cornerstone of Amplitude's research and development program.

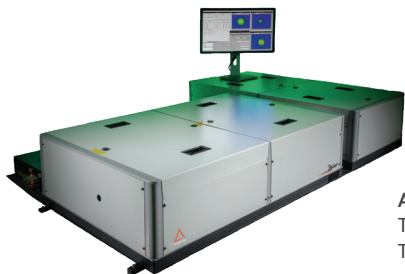
ARCO and PULSAR are Titanium: Sapphire based laser systems considered as the worldwide reference in terms of specifications, reliability, and ergonomics.

PULSAR delivers high energy and reproducible ultra-short pulses with enhanced ultra-high temporal contrast. With more than 35 units installed, including Petawatt scale amplifiers, major scientific group around the world have relied on PULSAR model for large table-top accelerators projects.



**PULSAR PW:**  
Ultra intense  
ultrafast laser

The Titanium: Sapphire product line is completed by the ARCO lasers, designed for experiments which do not require enhanced contrast. ARCO is the perfect tool for reliable, day-to-day operations with the best specifications offered by modern laser amplifiers.

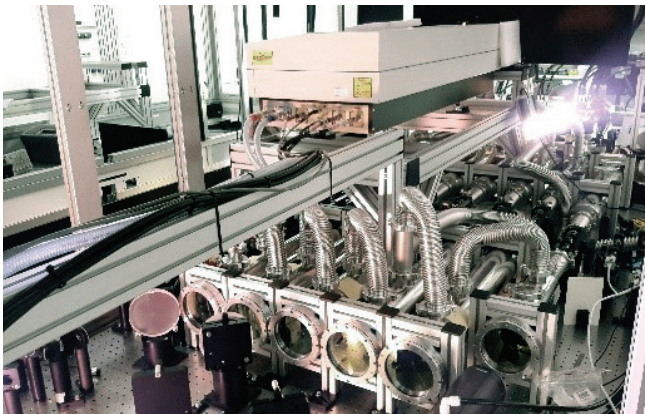


**ARCO:**  
The best of the  
Ti:Sapphire technology

## NANOSECOND LASERS

Amplitude has a strong experience in design of Nano-second lasers based on a wide range of material: Nd:YAG, Nd:YLF, Nd:Phosphate, Nd:Silicate glasses... At the heart of each our standard nanosecond laser systems is a very high efficiency pump chamber to couple the flashlamp light into the Nd:YAG rod. Through the use of a diffuse reflector concept, we are able to produce high gain with low heat buildup in the overall system. The result is superior beam quality and excellent passive beam pointing stability without the use of the costly active locking technology used by other companies.

Amplitude also offers a broad spectrum of diode-pumped solid-state lasers designed for use in scientific and commercial applications such as ultrafast amplifier pumping, Particle Image Velocimetry (PIV), laser micromachining, and laser marking/deep engraving. Our diode-pumped solid-state lasers offer choices in repetition rates, pulse energy, power, pulse duration, and wavelength (including IR, Green, and UV).



## LASER 4.0 SERVICE

Laser 4.0® Program is a helpful suite of digital services to accompany our clients throughout the laser's life cycle.



Thanks to numerous sensors and a state-of-the-art electronic system, laser data mining enables our customers to optimize the use of their laser: access to the full list of your installed lasers, to manuals and other technical documents, to Amplitude hotline, to our femtosecond laser process simulation application, to our secured files repository for sharing data with us, and to our production tracking application (coming soon).

With Laser 4.0 Program, Amplitude guarantees data security and confidentiality. Multiple benefits for both controlling laser and increasing productivity:

- Access to '4.0 Installation Checkup' service: guaranteeing that the installed system is matching factory performance
- Access to '4.0 Health Check' service: detecting anomalies and acting to avoid unexpected failures
- Access to '4.0 Fast Diagnosis': in case of an anomaly, reducing downtime thanks to faster and more accurate diagnosis
- Access to '4.0 Remote Maintenance' service: reducing downtime by repairing remotely (only in applicable cases)
- Access to '4.0 Laser Dashboard' service: real time dashboard & adjustable smart alerts



# APPLICATIONS

Specialist in ultrafast lasers for industrial, medical and scientific applications, Amplitude is the only international laser manufacturer to cover both ultrafast lasers technologies and their applications.

## FOR INDUSTRIES

### / CONSUMER ELECTRONICS



Thinner and more difficult to cut, consumer electronics require new methods of mass production, and optical technology is the solution.

Amplitude's femtosecond lasers, which include optical technology, are the new standard in terms of quality driven results. Thanks to both their high repetition rates and their peak to average power ratio, Amplitude's lasers can perform on any materials with an unparalleled precision, whether: PCB, operations on semiconductors and/or flexible electronic materials, glass-cutting, and many others.

Amplitude's femtosecond lasers process an average peak power, offering increased productivity for industrial applications. All Amplitude's femtosecond lasers can be combined with optional modules.

### / FLAT PANEL DISPLAY



We live in a world revolutionized by screens. New display technologies such as organic LED (OLED and AMOLED) or more recently micro-LED have meant improved display performance (definition, contrast, colors, etc.), and development of new features (screens that are flexible, foldable, transparent).

With such a rise in screen use, Amplitude's ultrafast lasers have become essential tools in the manufacturing process. With high precision and processing capacities on all types of materials, Amplitude ultrafast lasers are recognized internationally for their reliability and efficiency.

With more than 10 years of experience and expertise in the screen industry, the Amplitude know-how is undisputed by leading screen manufacturers.

Main display applications using ultrafast lasers:

- OLED array/cell repair
- OLED cell/module film cutting
- Cutting glass and sapphire
- Mask repair
- Structured glass cutting

## / MICRO-PROCESSING

Laser micro processing is based on a light-matter interaction process at a micro or submicron scale i.e. a removal of matter by laser focalization on a very small surface area (laser spot of few hundreds of  $\mu\text{m}^2$ ). The femtosecond lasers developed by Amplitude for more than 10 years have made real progress in this field. Indeed, the matter is ablated without going through the liquid state. The thermal effects during this operation are then reduced and the area affected by the heat remains negligible in front of the size of the laser spot on the sample. Thanks to our technology, we achieve the highest precision and the highest available quality in micro-machining. Hence, the initial matter's properties are not altered (no mechanical stresses induced, no electrical nor chemical modifications).

For example: luxury products, automotive and aeronautics.

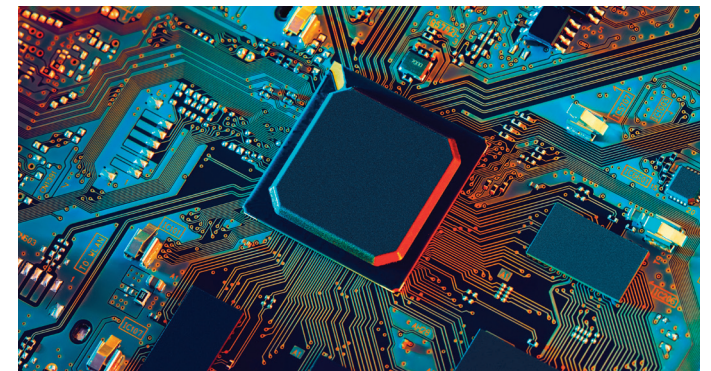


## / SEMI-CONDUCTOR

The semiconductor industry tends towards ever smaller and more complex microchips, making the standard production tools of limited use, if not obsolete. The rapid development of new materials and structures linked to advanced packaging of semiconductor devices presents new challenges, leading to the use of increasingly fine laser systems. Offering unrivalled precision, Amplitude's femtosecond lasers are perfectly-adapted to meet the needs of these new issues.

These lasers are mainly used for:

- 
- Metrology: Wafer thickness measurement and characterization of thin layers
  - Selective Ablation: Removal of thin layers from micron to nanometer – without impacting adjacent layers
  - Dicing: Dicing of microchips with accuracy and quality, incomparable to current methods (diamond saw and traditional lasers)
  - High Precision Drilling: Micrometric drilling for a large range of materials (hard ceramics, polymers or transparent materials)
- 





## FOR MEDICAL

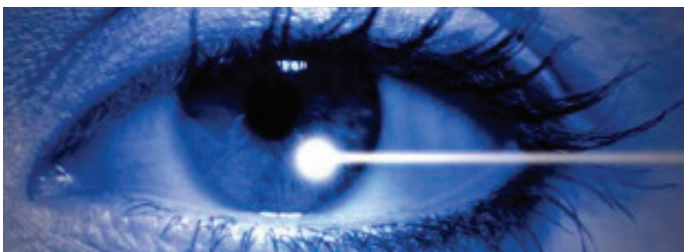
### / OPHTHALMOLOGY

Application in the field of ophthalmology has been part of Amplitude since the beginning of the company. We created and sold our first femtosecond lasers designed for eye surgery applications back in 2003.

Through safe, painless and effective procedures, femtosecond lasers have helped millions of patients regain perfect vision. Femtosecond lasers are used to correct myopia and other vision impairments, for corneal grafts and other complex treatments against cataracts.

Current research undertaken on glaucoma surgery and presbyopia correction is constantly ensuring new advances for this technology. With thousands of lasers installed across 5 continents and with 15 years of experience, Amplitude is the uncontested leader in this field. With their compact, robust, reliable and flexible nature, our lasers meet the most difficult needs of surgeons and medical systems manufacturers.

With its ISO 13485 medical certification, Amplitude offers a guarantee to clients, to supply comprehensive management systems for the design and manufacture of medical equipment. This includes rigorous quality assurance processes at every step of product development and manufacture.



With our proven industry experience and culture of innovation, Amplitude is the partner of choice for all ultrafast laser eye procedures and operations.

### / PROTON THERAPY



Proton therapy is the treatment of cancerous tissues using protons or beams charged with heavy ions. Unlike X-rays or electrons, which tend to deposit energy over a large region of the tissue, protons deposit most of their energy at a very specific depth. The actual depth depends on the initial energy of the protons. As a result, proton beams can be used to remove tumors without collateral damage.

Proton therapy is currently used in about 30 facilities around the world, using large and expensive accelerators. This technology poses a clear limitation to access this treatment.

As an alternative, physicists are looking at how compact femtosecond lasers could be used to develop smaller and less-costly proton sources. The basic principle consists of shooting an intense, short laser pulse at a thin solid target. The protons and other ions are pushed out of the target by the electrons and subsequently accelerated into the laser electric field, over distances as small as a few microns.

Amplitude manufactures table-top intense lasers to generate heavy ions and protons beams. We help researchers around the world study how to generate the proton beams and how these beams interact with living cells.

The Pulsar product line has been designed to provide certain important features required by physicians in this domain, such as contrast ratio, beam quality, and stability.

### / X-RAY IMAGING



X-ray technology has the incredible ability to penetrate almost any material and tissue, allowing the production of 2D or 3D images of human beings or objects. Both techniques are well-established and widespread, for instance in hospitals or airports, and are based on a mature but proven technology, of X-ray tubes. Unfortunately, this technology faces physical limitations that have until now restricted high-resolution X-ray imaging to large synchrotron facilities. Hence the interest in ultrafast laser technology.

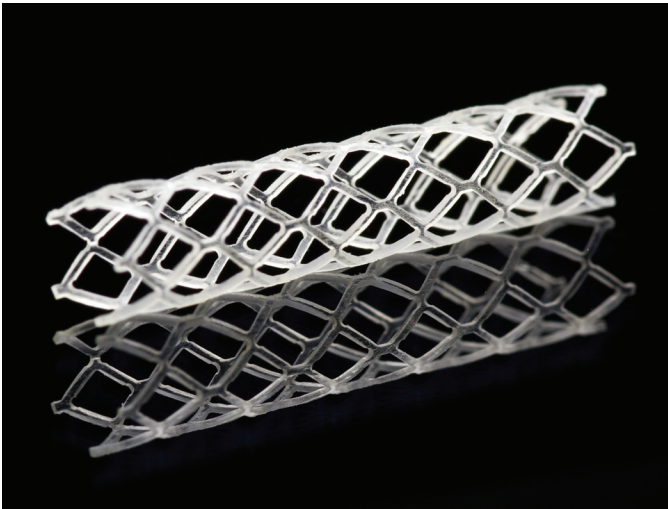
It has been rapidly identified in laboratories that ultrafast lasers can overcome those limitations thanks to a new physical process. A high intensity beam focused on a solid target produces a hot plasma in a very confined space. The electrons present in the plasma are then converted into X-rays when they hit the target, like in conventional tubes, but with a much higher intensity when the correct laser parameters are selected.

This laser-based technique allows, among other things:

- Achievement of significantly greater brightness sources than X-ray tubes,
- Much higher spatial resolution together with a reduced deposited dose,
- Greater access for all to trustworthy results from synchrotron sources.

We are convinced that this new X-ray source will revolutionize the world of medical imaging, by giving access to high resolution images in hospitals in the coming years.

## / MEDICAL DEVICES MANUFACTURING

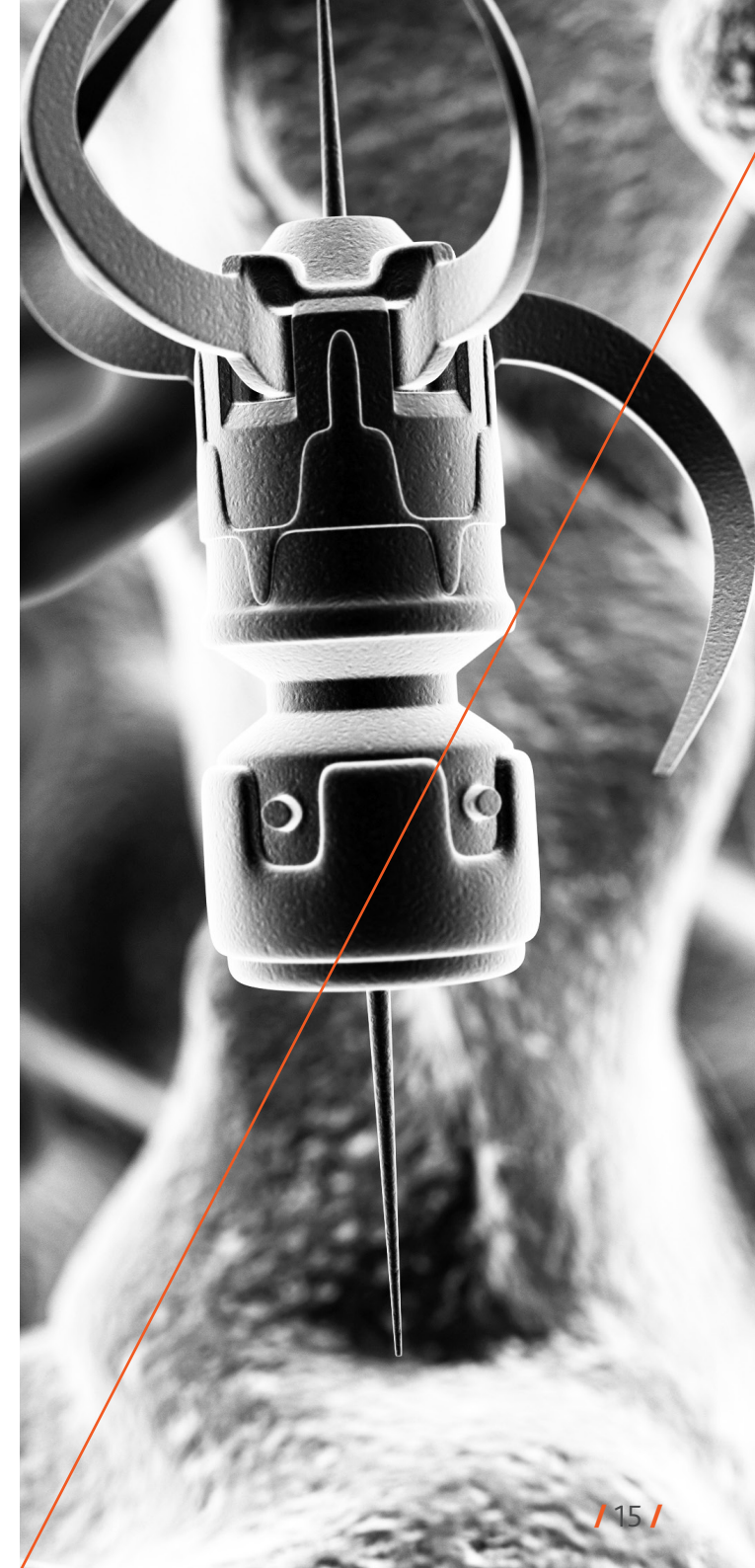


Medical components such as implants and surgical tools require perfected manufacturing processes: the slightest alteration of the surface, the dimensions, or the form may have a significant impact on their performance.

For these sophisticated and demanding applications, ultrafast lasers (femtosecond or picosecond) offer unique advantages: they can work on any type of material (ceramic, glass, polymer, metals) without emitting heat, and with both remarkable precision and exceptional quality. They are of a higher average strength and therefore increased industrial productivity and accuracy.

Among the typical applications, we can cite the production of new generation bio-absorbable stents, catheter treatment, or texturing the surfaces of biocompatible implants. New applications are currently under active development, notably in the area of nano-technologies and manufacture of advanced additives.

Amplitude's femtosecond lasers solve this problem. With their extremely high repetition rates, our lasers prevent any change in the integrity of the biomaterial, such as corrosion resistance, making femtosecond technology the best option to use. Operating at this precision height, Amplitude-femtosecond lasers are the most in tune with the expectations of our customers manufacturing medical devices.





## FOR SCIENCE

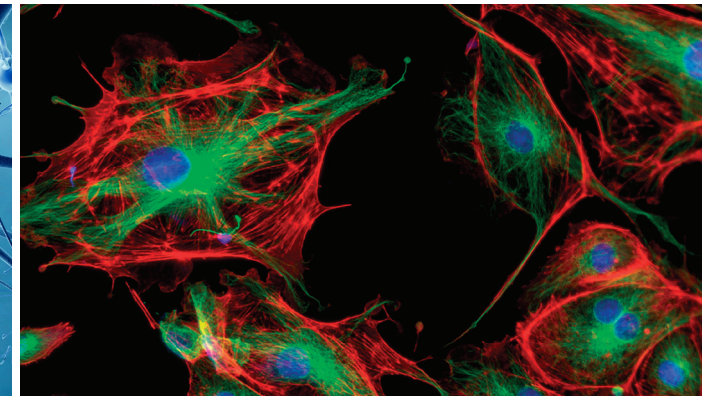
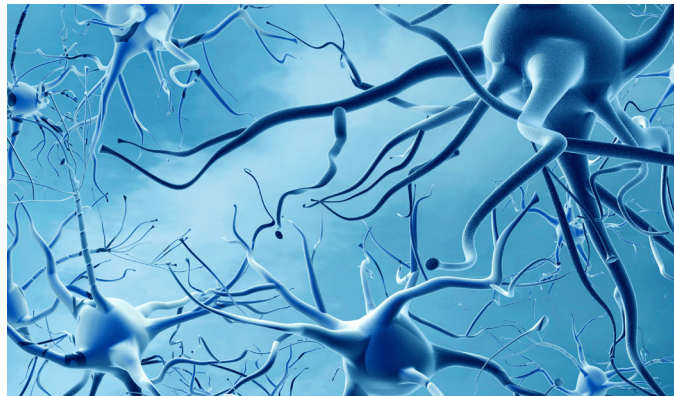
### / LIFE SCIENCES

Amplitude offers innovative laser solutions for life science-related applications, combining state-of-the-art laser specifications required for cutting-edge scientific applications, with the robustness and ease of use required by the most demanding medical and industrial applications.

Our vocation is to allow scientists to work at the forefront of research in multiphoton imaging (cellular imaging, embryology, immunology), nano-surgery / ablation, as well as neuroscience / optogenetics for which Amplitude has developed a range of high-performance lasers.

Applications related:

- Neuroscience
- Cellular Imaging

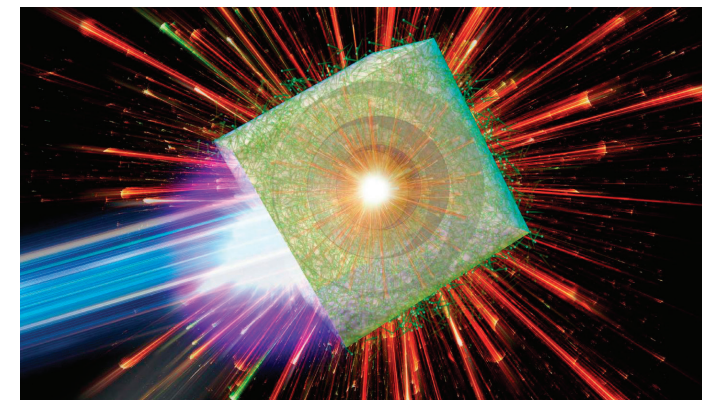


### / CELLULAR IMAGING

Modern laser sources routinely achieve intensities as high as  $10^{22}$  W/cm<sup>2</sup>. With such intensities, Ultra-intense laser systems have accelerated the advent of new physics with significant applications in fundamental science, medical research and industry. By focusing ultrashort intense laser beams onto targets, extremely high electric fields with strength higher than 1 TV/m have been produced. Hence, energetic particles (electrons, protons, ions...), as well as radiation ranging from X-ray to  $\gamma$ -ray, can be delivered using the appropriate targets (gas jets, thin metallic foils, capillaries...). Thanks to their outstanding properties, such as pulse width or brightness, Laser-driven particles and radiations have demonstrated their uniqueness compared to conventional sources.

New applications have already been addressed with these sources, for instance, the generation of quasi-monoenergetic electron beam at several GeV for fast chemistry, radiotherapy, and material science, or for the development of the future generation of colliders. The availability of inexpensive and compact accelerators, covering a wide range of electron (multi- GeV) or proton energies of (10-100 MeV), makes them accessible to universities and industries.

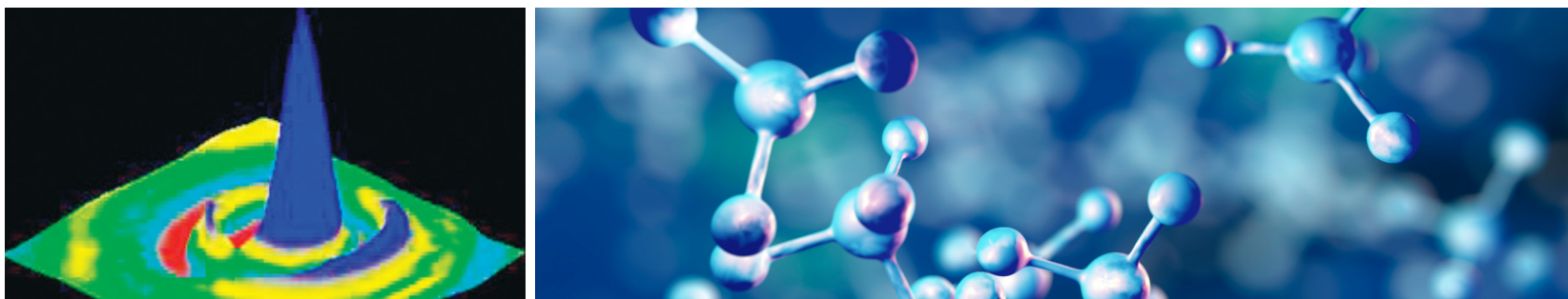
Amplitude manufactures intense lasers designed to serve the needs of the most challenging applications. These lines of product are characterized by their unprecedented set of performance, their vast list of options as well as a robust, flexible and upgradable monitoring system which greatly enhance the user experience.



## / SPECTROSCOPY ET IMAGING

In spectroscopy, the process of acquiring data usually takes from several hours to several days depending on the repetition rate of the laser used. Thanks to our Ultra-fast Ytterbium technology, scientists can overcome this issue. Indeed, with an extremely high repetition rate, femtosecond lasers can drastically increase the quality of the measurement done as well as multiply the received data and reduce the time taken to make the measurement, improving therefore the end users' productivity.

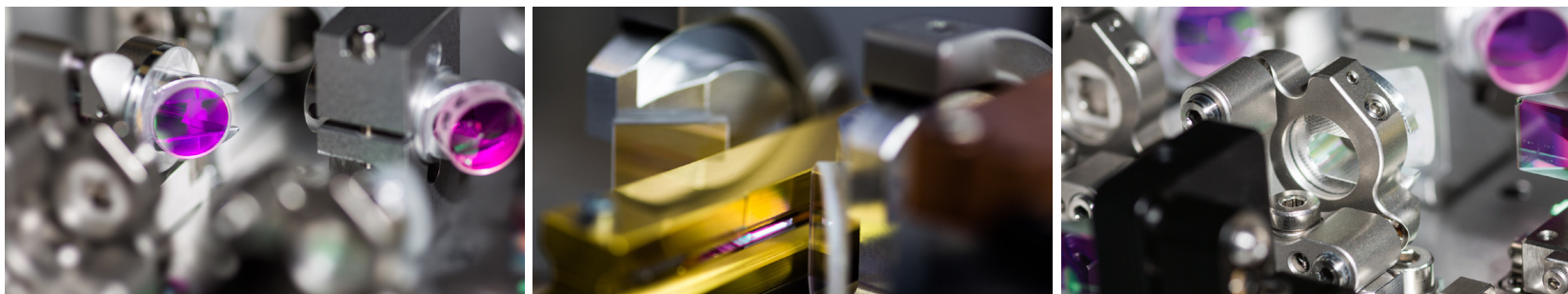
Our lasers are manufactured under a well-defined and controlled industrial process. They are taking advantage of our experience on both the scientific and industrial market. Performances are at the edge of the technology while maintaining a high reliability and easiness of use. Options are available to answer the different needs of the final user. This allows to cover more applications and gives enough flexibility to adapt to the different experiments required by the users. Our Mango OPA option can be coupled to all our Yb systems in order to generate the required wavelengths whenever the end users wish.



## / INSTRUMENTATION

Beyond simply selling cutting-edge laser solutions, we propose to our clients the possibility of acquiring instruments, modules or additional systems which can be installed around our lasers. This allows, for example, the expansion regarding the possibilities of our platforms, the customization of spatial and temporal characteristics of the laser beam, but also the daily simplification of the use of our laser systems with the introduction of a control and embedded intelligence software.

Clients wishing to develop or improve their own femtosecond systems will also find an answer to their needs in our product catalogue. A complete line of lasers for pumping based on Neodyme and Ytterbium YAG technologies is also available. The many different combinations possibles in those cases have us envision a wide range of pumping configurations, going from the Ti :Saphir system to the OPCPA.







*Nothing but ultrafast*

[amplitude.com](http://amplitude.com)

# where to MEET US

EVENT	WHEN	WHERE
<b>CSNDIS 2019</b> - 2019 Cross Strait (Chengdu) New Display Industry Summit Forum	28 - 30 May 2019	Chengdu / China
<b>11-TH INTERNATIONAL YMPOSIUM ON ULTRAFAST SURFACE DYNAMICS, USD11</b>	8 - 12 June 2019	Qiandao Lake, Zhejiang / China
<b>SCULPTED LIGHT IN BRAIN</b>	20 - 21 June 2019	London / UK
<b>LASER WORLD OF PHOTONICS MUNICH</b>	24 - 27 June 2019	Munich / Germany
<b>ATTO</b>	1 - 5 July 2019	Szeged / Hungary
<b>LASER KOREA SHOW</b>	3 - 6 July 2019	Gyeonggi-do / South Korea
<b>XXXIst INTERN. CONF. ON PHOTONIC, ELECTRONIC AND ATOMIC COLISIONS</b>	23 - 30 July 2019	Deauville / France
<b>FEMTO 14</b>	28 July - 2 August 2019	Shanghai / China
<b>ISUILS 2019</b>	4 - 8 August 2019	Kushiro / Japan
<b>CIOP2019</b>	6 - 9 August 2019	Xi'an / China
<b>44th INTERNATIONAL CONF. ON INFRARED, MILLIMETER AND TERAHERZ WAVES</b>	6 - 9 August 2019	Paris / France
<b>COLA</b>	8 - 12 September 2019	Maui / Hawaii
<b>3nd LASER MANO-MICRO PROCESSING</b>	19 - 20 September 2019	Suzhou / China
<b>SEMICON TAIWAN</b>	18 - 20 September 2019	Taiwan
<b>INTERN. SYMP. OPTICS &amp; ITS APPLICATIONS 2019</b>	20 - 24 September 2019	Yerevan / Armenia
<b>OSA's LASER CONGRESS : ASSL + LAC</b>	29 September - 3 October 2019	Vienna / Austria





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Mother knows best...right? The Big Bang Theory is all new Thursday at 8/7c, and this one's a family affair!



Saatsuma - Amplitude's Laser on  
*Big Bang Theory* - S12E20 - May 9<sup>th</sup> 2019