PULSE GATING :

A new picosecond Laser pulse generation method.

Picosecond lasers can be found in many fields of applications from research to industry. These lasers are very common in bio-photonics, non-linear optics, chemistry, micro-machining or in very conservative markets, such as dermatology.

IRISIOME, a French startup company from Bordeaux, has released a product range based on a new picosecond pulse generation method. We propose in this white paper to give more details about this new technique as well as a comparative review of the main existing techniques for picosecond pulse generation.

Picosecond pulse generation methods and what's new in this field?

- Mode-locking: a well known technique

The mode-locking technique is an ultrashort pulse generation method theorized in 1964. The principle of this method is to impose a fix phase relationship between the longitudinal modes of a laser cavity. This fix phase relationship results in a periodically constructive interference of these modes and the generation of the pulse train.

The mode-locking technique can be applied to many types of lasers to produce picosecond or femtosecond pulses. These lasers can be dye lasers, fiber lasers, external cavity and monolithic diode lasers or bulk lasers.

For picosecond or sub-picosecond pulse generation, active mode-locking is often employed. An active component, usually an electro or acousto-optic modulator, is used inside the laser cavity and periodically modulates the resonator loss. To effectively "mode lock", the modulator frequency has to match the roundtrip travel time of the pulse within the cavity. There is also passive mode-locking techniques that doesn't require an active component inside the cavity. The most used technique needs saturable absorber inside the cavity, this is a device that exhibits an intensity dependent losses. Another technique uses the nonlinear polarization rotation and a couple of polarizing elements inside the cavity to produce ultrashort pulses. Both technique are difficult to stabilize and the reliability is a real challenge.

In general, formations and propagations of ultra-short pulses in a cavity or in medium amplifier is subject to the influence of the optical gain. Besides, amplification bandwidth of the active medium has a finite width, which must be taken into account. In the case of fiber lasers, the gain bandwidth is broad and is in the range of 10nm.

The different mechanisms of propagation in mode-locked fiber lasers are classified according to the total dispersion of the cavity. Indeed, formation of ultra-short pulses depends on the interaction between non-linear effects and dispersive effects. For example, if the total amount of dispersion inside the cavity is anormal, the mode-locking operation is in solitonic regime, with hyperbolic-secant pulses.

With mode-locking technique it's possible to get ultrashort pulses in the range of ten's femtosecond up to ten's of picosecond, but pulse duration and repetition rate is directly linked to the cavity parameters. There is no flexibility for this kind of lasers.

- Synchronization of passive mode-locked lasers

Within both chemistry and physics, there has been along-standing desire to pursue experiments using two independent ultrafast (picosecond or femtosecond) lasers.

Pulse synchronization requires independent lasers to be mode-locked at exactly the same repetition rate. As the repetition rate depends linearly on the effective cavity length, a feed-back locking system is essential for laser synchronization to compensate for the unavoidable cavity variations. In accordance with the feedback methods, laser synchronization scheme can be classified into active, passive and hybrid synchronization.

In the active synchronization scheme, the feedback is typically provided by electronic phase-locking-loop devices, which offer the advantage of long-term stability and independence on the oscillating wavelengths in laser operation. However, such a scheme suffers from limited bandwidth of electronic circuits and the time jitter among synchronized lasers is critically dependent on the control precision of the electronic circuits. Passive synchronization is typically achieved by using all-optical methods on the basis of nonlinear optical effects within the concerned laser cavities.

These techniques have been developed 15 years ago and are currently used in many fields of application such as difference frequency generation (DFG) to generate tunable, ultrafast pulses in the midinfrared (2–10 μm) wavelength region, coherent anti-Stokes Raman scattering microscopy, two-color pump–probe investigations, and coherent control of molecules. etc. Nevertheless, It appears these techniques are complicated to set-up and are expensive.

- Picosecond gain-switched diode: a compact and easy to use alternative to mode-locking

There is confusion in the laser technique field between gain switching and direct modulation diode operations.

Indeed, gain-switching is a method used to generate ultrashort pulses down to tens of picoseconds. When the gain of a semiconductor laser is switched by a short electrical pulse from a state below threshold into gain inversion, the light emitted from the laser exhibits relaxation oscillations. The standard gain switching arrangement is to drive a laser, biased below threshold, with an electrical RF generator. The basic principle is to catch the first spike of relaxation oscillation without exciting subsequent ones. The emitted optical pulses are shorter than the electrical drive pulse. It will result of an intense laser pulse emission that is shorter than the electrical pulse required to inject the carrier. The pulse duration and peak power depends on the semiconductor laser cavity and the duration and peak current used across the diode.

On the other hand, diodes modulation operation consists in directly modulating the electrical pump power of a semiconductor laser with high power electrical pulses. Thanks to this modulation, if the current across the semiconductor laser is higher than the threshold, it's possible to directly modulate the instantaneous power emitted from the semiconductor laser. It's possible to get pulses from 1ns to tens of ns with this technique. Rise and fall-times for generated pulses will depend on the cavity length and also the rise and fall-time of the pump current used across the semiconductor laser.

Gain switching of single longitudinal mode laser diodes, such as distributed feedback laser diodes (DFB-LD), has proven to be a simple method of generating picosecond pulses and is a good candidate for seed sources in master oscillator power fiber amplifier architecture. However, spectral broadening occurs under the generation of picosecond pulses with single-mode laser diodes due to significant frequency chirp. This could be a limitation for frequency conversion with nonlinear crystals.

IRISIOME Solutions is providing laser solutions using gain-switching of single-mode laser diodes at 1um and 1.5um with our SID Lasers series.

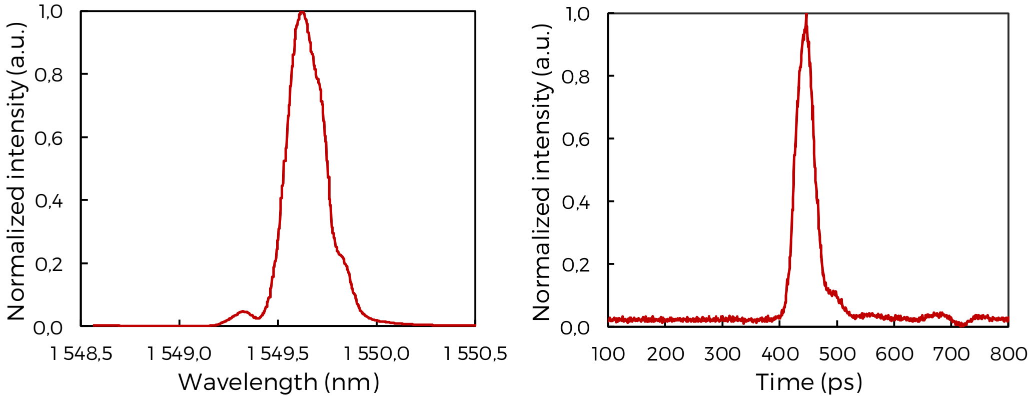

Fig. 1 – Left: Typical Optical spectrum of the SID Laser: a gain-switch based laser with fiber amplification at 1550 nm. Right: Typical pulse profile at the laser output, pulse duration is in the range of 35 ps.

Unlike mode-locked laser, the repetition rate of a gain-switched laser does not depend on the cavity length and is widely tunable. It is possible with a single system to reach a wide range of repetition rate from single pulse operation to several GHz.

- Picosecond pulse gating: toward frequency and pulse duration tunability

Owing to the improvement in modulation bandwidth, the decrease in driving voltage, and the new ultrashort electrical pulse generators developed by Irisiome, short pulses and agile generation using electro-optic modulators (EOM) can be attracting renewed attention.

Externally modulated lasers have operational flexibility with respect to pulse widths and repetition rate, and require modulators such as electro-optic modulators (EOM). This method presents also the advantage to be achromatic and can be extend to various wavelengths as long as EOM can work at the desired wavelength.

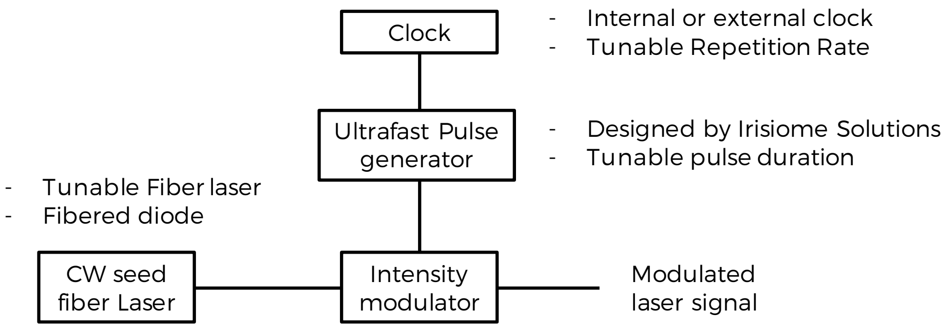

Fig. 2 – Ultrafast pulse gating diagram developed by Irisiome

This technique is than the most user-friendly/easier and versatile picosecond pulse generation. It is based on the gating of pulses by an optical intensity modulator seeded by a continuous wave laser. Such lasers are highly flexible because the repetition rate and the pulse duration do not depend on the cavity length or the cavity design of the laser but they are controlled and can be synchronized by electrical signals. Therefore it is possible to change the pulse duration from few tens of picoseconds to any pulse duration with optical spectra limited by Fourier Transform (keeping very long coherence length) and the repetition rate can be adjusted very precisely and in a very wide range up to few GHz. External synchronization to a RF signal or another laser is easy since pulses are controlled electronically.

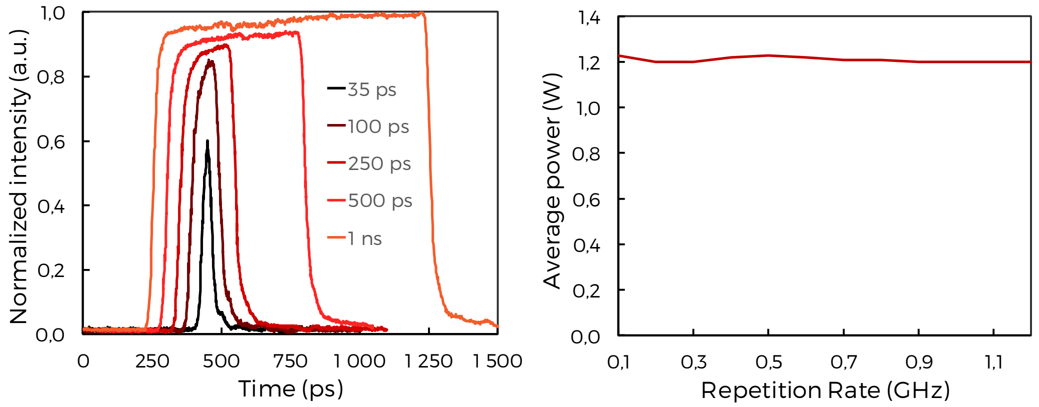

Fig. 4 – Left: Pulse duration measurement from a MANNY laser at 35 ps, 100 ps, 250 ps, 500 ps and 1 ns
Right: Average power from a MANNY versus pulse repetition rate.

Usually an electro-optic modulator is used as optical intensity modulator which limits the possible output power but here again, it is possible to amplify the signal with fiber based amplifiers.

This method is still undisclosed because of the difficulty to reach pulse durations under hundreds of picoseconds. Besides industrial solutions are still scarce and it is more usual to find only pulse gating modules without seeder and with or without amplification, but recently, all integrated and turnkey solutions are commercially available. The MANNY turnkey laser from the company Irisiome Solutions based on picosecond pulse gating allows a fine tuning of the pulse parameters (peak power, pulse energy, pulse duration, repetition rate) with possible external synchronization and fiber amplification up to 30W. Irisiome Solutions also managed to get pulse duration down to 30 ps by developing the adapted fast response electronics.

Why does this method bring something new?

In ultrafast laser field, mode locking is one of the most common methods because of the ability to generate pulses from femtoseconds to picoseconds with a very low noise level and a low timing jitter. In picosecond regime, our method is suitable for applications requiring high peak power and short pulse durations. For such applications, as micro machining or multi-photon microscopy, picosecond lasers are used as a compact and robust alternative to femtosecond lasers. Besides, thanks to their low noise level, they are also used in advanced applications such as time resolved spectroscopy or frequency comb generation.

On the other hand, for less demanding applications, gain switched diodes are very attractive and present an alternative to mode locking. They are much more compact, cheaper and user friendly. Besides, since the repetition rate of the optical pulses depends on the repetition rate of the electrical pulses, it is widely adjustable and therefore easily synchronizable to another system.

Picosecond pulse gating, unlike the two previous methods, is the only technique that allows flexibility on both pulse duration and repetition rate but the pulse duration cannot be as short as the one from a mode locked laser. This extreme flexibility turns out to be a real benefit for laser matter (living or not) interactions and biophotonics since it is very important to be able to manage the amount of energy deposited and thermal effect. Moreover, since pulses generated by pulse gating are driven by electrical signal, the laser system is really user-friendly and can easily be synchronized to another system as master or slave.

For efficient harmonic generation, the fundamental laser beam should have good beam quality, high polarization extinction, sufficient peak power, and narrow line width.

Polarization maintaining large-mode-area (LMA) fibers can support good beam quality with high peak power and high polarization extinction in the fiber MOPA architecture. The spectral property of the fundamental beam, such as the line width, is basically attributed to the seed source.

For additional information, do not hesitate to contact us (contact@irisiome-solutions.com) or visit our website http://www.irisiome-solutions.com.

About IRISIOME

IRISIOME is a French startup company from Bordeaux, in France founded in 2015, The company is the result of a project valorization led by the CELIA Laboratory (CEntre Lasers Intenses et Applications) which was aiming at developing a user friendly and simple laser source for medical applications. Since the beginning of the project our team has strengthen its expertise by developing an innovative laser architecture which would be easily integrated in any experiment or system.

Willing to widen its offer and confront its laser sources to challenging applications, IRISIOME has created a new brand, IRISIOME Solutions, fully dedicated to the scientific and R&D markets. To be able to fulfill our users' specific requirements, we are making ourselves available to take up any challenge and new developments that will push our systems to the highest level of performance.