A new picosecond laser pulse generation methods: the pulse gating.

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 or machining and even a very conservative market, such as dermatology is becoming aware of the benefits of picosecond pulses for laser treatments[i].

Irisiome Solutions a Startup Company will soon release a new laser system based on a new picosecond pulse generation method. On this occasion, this paper will give more details about this new technique as well as a comparative review of the main existing techniques.

What are the most common picosecond pulse generation methods and what's new in this field?

- **Mode-locking: the short and clean pulses**

The mode-locking technique is an ultrashort pulse generation method theorized in 1964[ii]. 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 an ultrashort pulse.

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 based lasers, external cavity and monolithic diode lasers or bulk lasers.

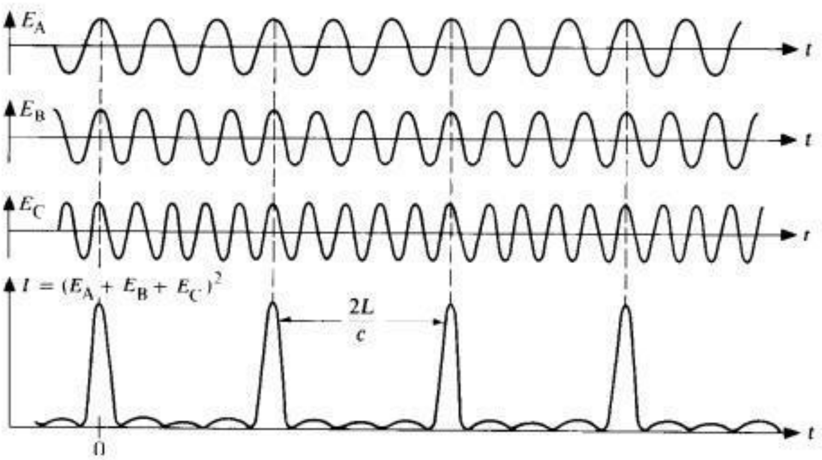

Figure 1 - Mode-lock pulse generation principle[iii]

For picosecond or sub-picosecond pulse generation, active mode-locking is often employed. An active component, usually an electro or acousto-optic modulator, is placed within 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.

The active mode-locking can generate pulses shorter than 10 ps close to Fourier transform limit with low noise level.

- **Picosecond gain-switched diode: compact and easy to use**

The gain-switching is a method used to generate ultrashort pulses down to few tens of picoseconds by modulating the electrical pump power of a semiconductor laser. The principle is to inject carriers into the active region of the semiconductor until the excitation level reach the lasing threshold. It will result of an intense laser pulse emission that is shorter than the electrical pulse required to inject the carrier.

The average power of a pulse train emission using gain switched diode do not usually exceed few hundreds of milliwatts. Increasing the pumping power will result of an increase of the optical power but also a deterioration of the pulse profile and a widening of the pulse duration. However it is possible to amplify the signal at some wavelengths with fiber amplifier up to tens of watts and keep a Gaussian pulse profile.

a.

b.

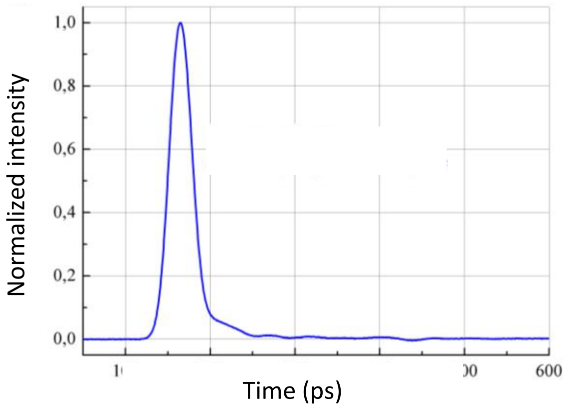

Figure 2 – (a) The SID laser from the company Irisiome Solutions is a gain switch based laser with fiber amplification for a high quality pulse at high power. (b) The laser delivers up to 30W average power with a pulse duration of 35 ps with a Gaussian temporal profile.

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.

- **Picosecond pulse gating: a new highly flexible solution**

This technique is the most 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 spectrum bandwidth but they are controlled and synchronized by an electrical signal. Therefore it is possible to change the pulse duration from few tens of picoseconds to any pulse duration with a narrow bandwidth emission spectrum and the repetition rate can be adjust on a very wide range up to few GHz. External synchronization to a RF signal or another laser is easy since the pulses are controlled electronically.

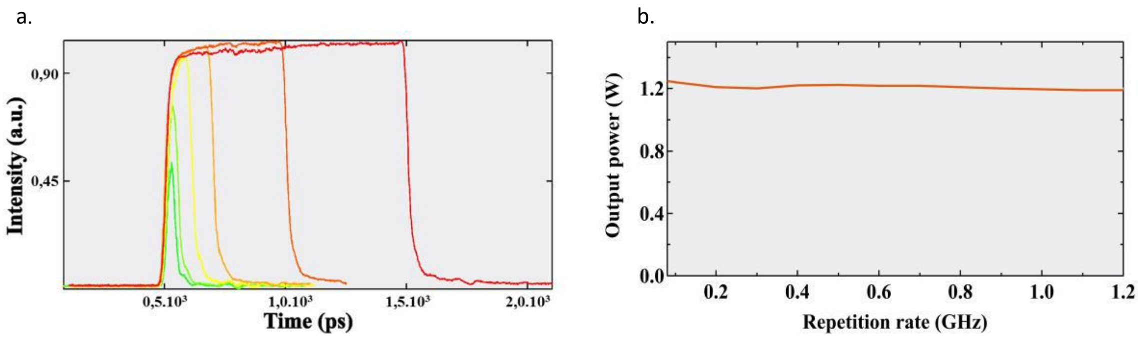

Figure 3 – (a) Pulse duration measurement made on a MANNY laser at 32ps, 50 ps, 100 ps, 250 ps, 500 ps and 1 ns (b) Measurement of the output power of a MANNY 1.2W laser at repetition rates from 5 MHz up to 1.2 GHz.

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[iv]. 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 the ultrafast laser field, the mode locking is one of the most common method because it can generate pulses with durations from femtoseconds to picoseconds with a good pulse quality, that is to say with a very low noise level and a low timing jitter. In picosecond regime, this method is suitable for applications requiring high peak power and short pulse durations. For these applications, such 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 considered as a very attractive 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. However gain switched diodes will not replace mode locked laser yet due, to their higher timing jitter, typically few picoseconds, and lower shot to shot stability.

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.

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About Irisiome

Irisiome was founded in 2015 and is aiming at developing a very versatile laser system for various dermatological treatment. In this process, the company has partnered with researchers from the French national research center to develop a high end and all integrated picosecond fiber laser source based on pulse gating technique.

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[i] www.irisiome.com
[ii] W. E. Lamb Jr., "Theory of an optical laser"
[iii] Tarek Ennejah and Rabah Attia (2013). Mode Locked Fiber Lasers, Current Developments in Optical Fiber Technology, Dr. Sulaiman Wadi Harun (Ed.), InTech, DOI: 10.5772/52214. Available from: https://www.intechopen.com/books/current-developments-in-optical-fiber-technology/mode-locked-fiber-lasers
[iv] www.irisiome-solutions.com