On Femtosecond Laser

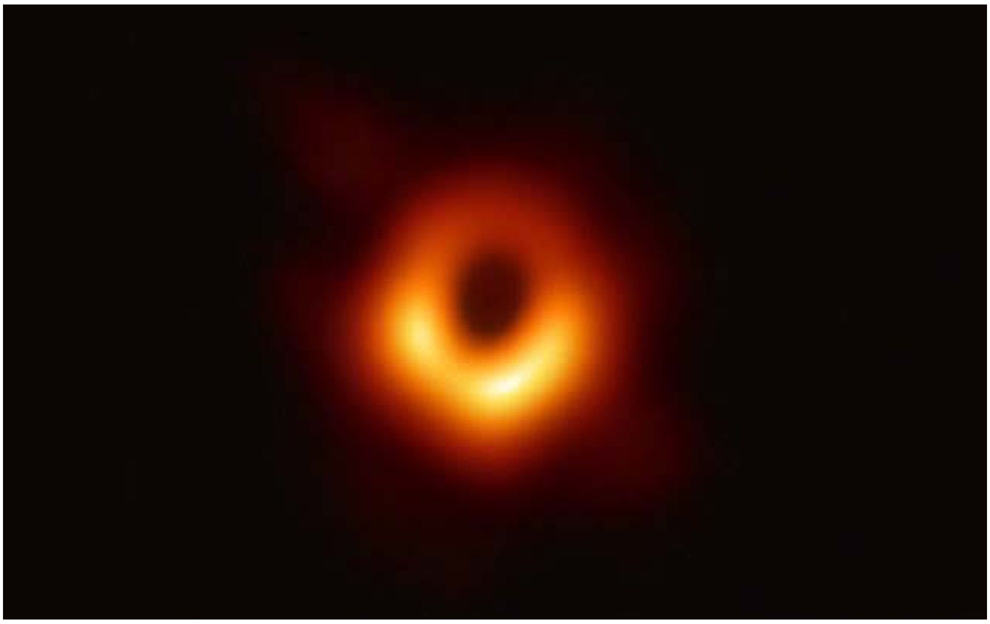
As the saying goes, time flies. Time passes swiftly in the blink of eye, as if it has a pair of magic wings. Some might associate the idea with the term femtosecond, as the pronunciation of “fem” sounds similar with that of “fly”. But wait, don't go astray!

Femtosecond, or *fs* for short, is a unit measuring time length. 1 femtosecond is equal to 10^{-15} second. Femtosecond laser has a pulse width of a femtosecond magnitude. By far it is the commercially available laser with the shortest pulse. Compared with ordinary laser, femtosecond laser has the following features:

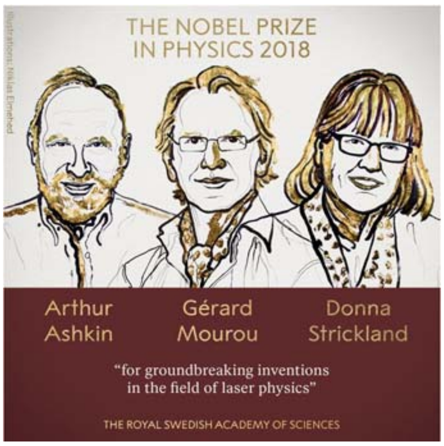
First, the pulse of femtosecond laser is extremely short, i.e, only a few femtoseconds. This is several thousand times shorter than the shortest pulse that can be obtained by electronic methods, and the shortest pulse that humans can produce under current experimental conditions. How short is a femtosecond? The fastest light on earth travels only 0.3 micron in 1 femtosecond. In the fastest H+H2 reaction, the duration of the transition state is tens of femtoseconds.

Second, femtosecond laser has an extremely high peak power, which can reach one hundred trillion watts. Let me put it this way: The peak power of femtosecond laser within a short time is several hundred times more than the current total power generation of the entire world.

Third, femtosecond laser can concentrate in a space smaller than the diameter of a hair, making the intensity of the electromagnetic field several times higher than the force of the nucleus on the surrounding electrons. However, many of these extreme physical conditions do not exist on the earth, nor can they be obtained by other methods. How powerful is femtosecond laser? We can use it to simulate, in laboratory, the environment surrounding the black hole.



It is these advantages that make femtosecond laser a rising super star in the laser industry. In recent years, femtosecond laser has been associated with the Nobel Prize twice.



In 2018, the Nobel Prize in Physics was awarded to Arthur Ashkin, Gérard Mourou, and Donna Strickland. Gérard Mourou and Donna Strickland became laureates for their joint invention of the "Chirped Pulse Amplification technology (CPA)", which is exactly the core of femtosecond laser amplification technology.

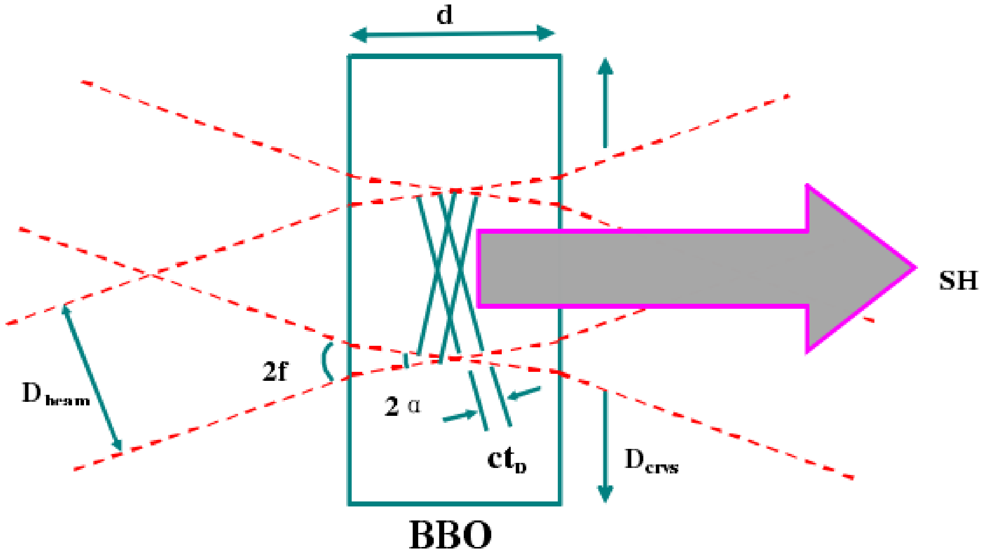
In 1999, the Nobel Prize in Chemistry was awarded to Ahmed H. Zewail, a scientist born in Egypt in recognition of his application of femtosecond time resolved imaging in observing the movement of atoms of molecules in chemical reactions. His achievement facilitates our understanding and anticipation of important chemical reactions and brings a revolution to the entire chemistry and related sciences.

See that? Both the invention of femtosecond laser and its application are awarded with the Nobel Prize. It is high time that we apply it in our scientific research. What are the issues that require our particular attention in using femtosecond laser? Now I would like to give you a brief introduction.

1. Femtosecond laser operates in pulse form in very brief period of time, i.e., a few femtoseconds.

Wait, you mentioned the pulse width at a femtosecond magnitude. But how do you prove it? The most high-end oscilloscope and photodiode function at a magnitude of picoseconds. Since the pulse width of femtosecond laser beyond the detection of the electronic means, how is it measured? Is that made up?

Of course not! A time-to-space conversion method is adopted in measuring the pulse width of femtosecond laser. At present, autocorrelator is a common device for this purpose. Single-shot autocorrelator measures the pulse width of femtosecond laser through the quadratic correlation method. The basic idea is like this: when plane parallel waves passes through a beam splitter, the incident light pulse is divided into two beams which intersect in the SHG crystal after passing the same optical path. Under the condition of equal optical path, the two pulses overlap at a certain angle in the SHG crystal to generate a frequency-doubled signal. At this point, the two pulses have different delays at different positions on the cross-section of the multiplied frequency beam generated. In this way, the signal with respect to pulse delay τ is converted into the light intensity distribution with respect to the spatial position x, as shown in the following diagram:



The Everfsmeter autocorrelator of Daheng Optics adopts the quadratic correlation method to measure ultrashort pulse. It consists of an optical module and a data acquisition module. The femtosecond laser passes through the optical module of the autocorrelator and multiplied frequency signal is generated in the BBO crystal. The data acquisition module records the width of the multiplied frequency signal and gives the pulse width of the femtosecond laser after some calibration.

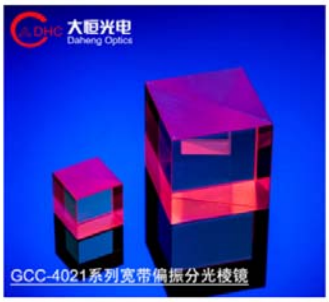
Isn’t that amazing? Come and measure pulse width with our autocorrelator!

2. Corresponding to its short pulse, the spectrum of femtosecond laser is relatively wide. But wait…As we all know, laser is monochromatic and directional, so how can laser has a wide spectrum?

Wideness and narrowness are relative concepts. The spectrum of femtosecond lasers is relatively wide compared with that of ordinary laser. Generally, the spectral width of ordinary laser is less than one nanometer, and that of semiconductor laser is a few nanometers. The spectral width of femtosecond laser is generally more than ten to tens of nanometers, that’s why we describe it as wide.

Because of the above feature, we should pay attention when choosing femtosecond laser-related devices. The single-wavelength reflection, transmission, wave plate, and Polarizer we are familiar with are no longer applicable. We must choose coating devices with board band wavelength.

The GCCH-101512 series reflectors, GCC-4021 series polarizing beam splitters and GCL-0608 series achromatic waveplates of Daheng Optics are ideal for debugging femtosecond laser.



Considering the spectral width, apart from applying broad-band coating devices, dispersion is another issue that requires special attention. (If you are not familiar with the term, watching a fish tank in front of sun might help you gain some insight of it.) For example, when femtosecond laser passes an optical lens, the pulse width increases from10 fs to 100 fs. What can be done to solve the problem? How to focus the femtosecond laser?

Off-axis parabolic mirror is the answer. It can not only completely solve the dispersion problem, but also eliminate the influence of chromatic aberration. An off-axis parabolic reflector can focus femtosecond laser into a quite compact light spot. It is the most ideal device for femtosecond laser focusing.

Apart from the devices related to the ultra-fast laser, Daheng Optics has femtosecond laser products, too, including the Ti: Sapphire femtosecond laser oscillator. Besides, we offer femtosecond laser amplifiers of various magnitudes (from TW to PW), as well as a complete set of femtosecond laser application solutions. If you do not have much idea about how to choose or use femtosecond laser, we will be glad to be of any help.

Ti:Sapphire Femtosecond Laser Oscillator