THE SPEED OF LIGHT – SF-7203

The speed of light in a vacuum (c) is a fundamental constant in physics.

To measure the speed of light, pulsed light is reflected off a retroreflector and the time between the pulse and the received reflection is measured with an oscilloscope. The progressive delaying of light pulses is observed as the pulses travel farther and farther.

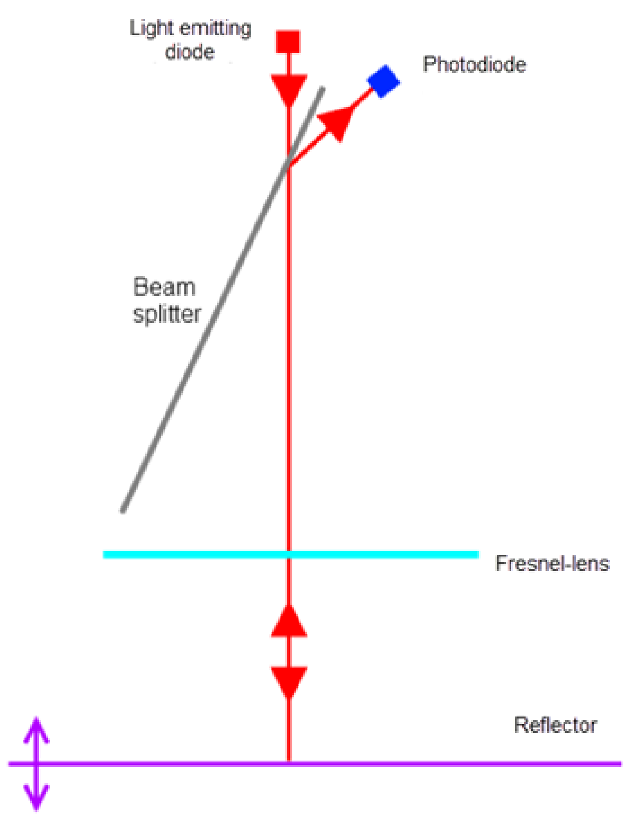
The equipment must be used in conjunction with an oscilloscope.

Principle

Very short but powerful pulses of light (10-15 ns) are emitted from the box. (With a frequency of around 300kHz). A fresnel lens gathers the light into a reasonable well-focused beam. (See figure)

In other words, when the light pulses hit the special retro-reflective foil of the reflector, they are directed back toward the source with no need for tedious adjustments The returning light pulses pass through a beam-splitter and strike a high-speed photodiode, converting the light pulses into electric pulses that are displayed on an oscilloscope. A separate synchronization signal marks the time of pulse emission, so time between emission and return can be timed.

The distance to the retroreflector is increased by a known distance and the resulting increase in return time allows the speed of light to be calculated by simply dividing the distance by the change in time.



Conducting the measurements

The device is supplied from the included 12 V adapter. Although the individual flashes of light are quite powerful, the average power of the emitted light is low enough that there is no danger to the eyes. Connect the oscilloscope as shown using the included 50 coaxial cables. Place the reflector immediately in front of the lens, while setting the oscilloscope.

For a quick demonstration of how it works the raw input signal is used. To achieve more precise measurements, it is recommended to charge the digital oscilloscope from an average value over several impulses. For the pictures in this guide, the oscilloscope is averaged over 32 measurements.
The following parameters are a reasonable starting point for the experiments:

Time axis: 10 to 25 ns/unit

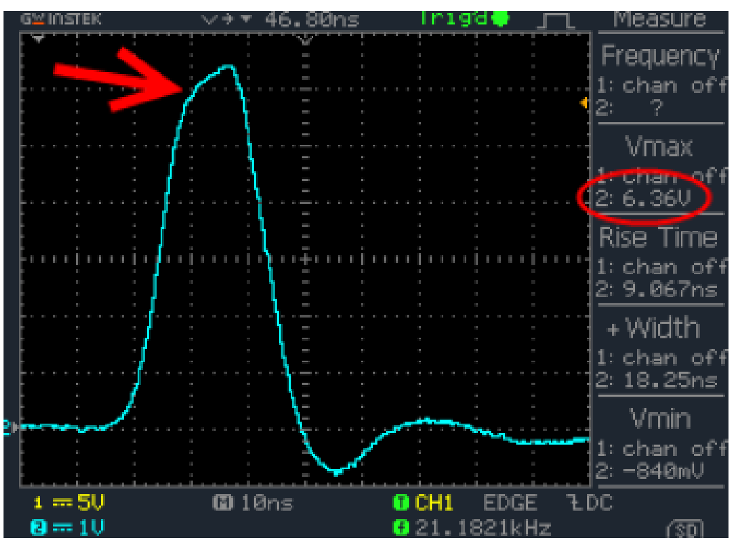
Channel 1 (Sync.): 5 V/unit

Channel 2 (Rec.): 0.5 to 1 V/unit

Trigger Source: Channel 1

Adjusting the trigger level may be the easiest thing to do by trying to produce a stagnant image of the synchronization signal with the time axis set at 0.5 µs / unit. Then switch to the desired time resolution.

It is possible to reflect so much light into the reception that the circuit goes into saturation, (i.e., cuts the peak of the signal). The device does not incur damaged from this, but accurate measurements are obtained only if the recipient works with undistorted impulses. This is ensured when the peak voltage is a maximum of 5 V (4.5 V for a 20 MHz oscilloscope) – either found on the y-axis or read directly using the oscilloscope built-in measurement functions.



The image above shows an impulse which is distorted from too strong a signal.

The signal strength is most easily regulated by covering part of the reflector. For example: one piece of black cardboard.

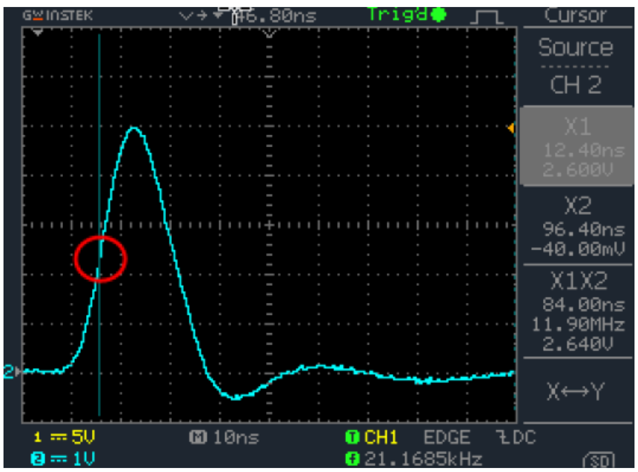
The position of the impulse on the time axis is defined as where the rising edge passes half of the peak voltage.

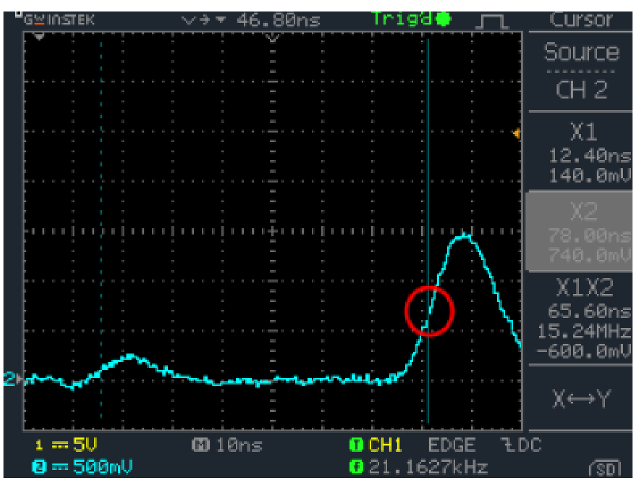
On an analog oscilloscope, this time can be read on the time axis. On a digital oscilloscope it usually has, a cursor function which can facilitate this reading.

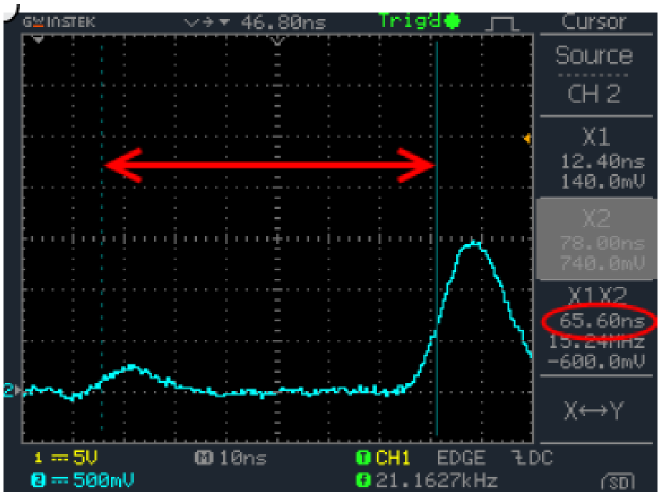
First, the time t0 is determined for the distance s = 0 m: With the reflector directly up against the lens and with the intensity regulated down as previously mentioned, the position of the reflection is the measurement of the impulse.

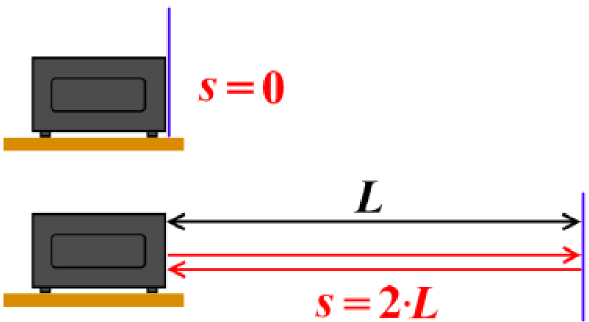
After this, the time axis must not be changed. Now take one or more measurements with the reflector further away from the device (up to 10 m). To be able to see with your eyes, hit the reflector, a few centimeters above the top of the device.

Measure the distance L between the front edge of the device and reflector as accurately as possible.









For each position, the arrival time is determined from the reflected light pulses.

All time measurements are converted to flashes of light flight time by subtracting t0 – this gives the time 0 to correspond to the distance 0. As stated before, the digital oscilloscope's cursor function can make this easier to determine.

Data Analysis

All distance measurements are converted to distances traveled by multiplying them by 2.

The distance traveled is displayed as a function of the flight time. From the graph, the velocity of light is determined in atmospheric air.

The refractive index of air at room temperature is approximately 1.00028. With this, the speed of light in a vacuum (**c**) is determined and compared to the table value.

Consider the magnitude of the measurement uncertainty on the value of the speed of light and whether it is relevant to distinguish between the speeds in air and the speeds in a vacuum.