Optics

Velocity of Light

PHYSICS EXPERIMENT

Determination of the velocity of light

DETERMINE THE VELOCITY OF LIGHT FROM THE TRANSIT TIME OF SHORT LIGHT PULSES.

- Measuring the transit time of a short pulse of light across a known distance, by using an oscilloscope to compare it with a reference signal.
- Determining the velocity of light in air as a quotient of the distance travelled and the transit time.

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BASIC PRINCIPLES

The fact that light is propagated at a finite speed can be demonstrated by a simple transit time measurement using modern measurement techniques. This is achieved by using very short light pulses of only a few nanoseconds duration and determining the time for them to travel out and back over a distance of several metres, which is measured by an oscilloscope.

In the experiment, the short light pulses from a pulsed LED are passed via a beam-splitter onto two photoelectric cells whose amplified signals are recorded as voltage pulses by the oscilloscope. Photocell A receives light pulses reflected back by a triple-prism reflector at a large distance, whereas photocell B records the locally generated light pulse as a reference pulse that is not delayed by transit. The oscilloscope trace is triggered by a voltage pulse from output C, which precedes the reference pulse by 60 ns.

Using a two-channel oscilloscope, one measures the transit time as the difference t between the two pulses. From this and the distance s from the transmitter to the triple-prism reflector, we can calculate the velocity of light as:

$$(1) \quad c = \frac{2 \cdot s}{t}$$

The experiment can be made more impressive by varying the distance to the reflector and observing the resulting change of the pulse separation on the oscilloscope. This can be done very easily, as careful and precise adjustments in re-positioning the triple-prism reflector are not required, rather, an approximate adjustment will suffice.

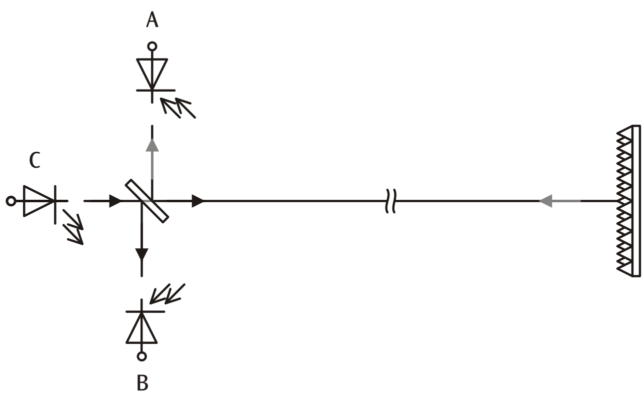

Fig. 1: Measurement principle

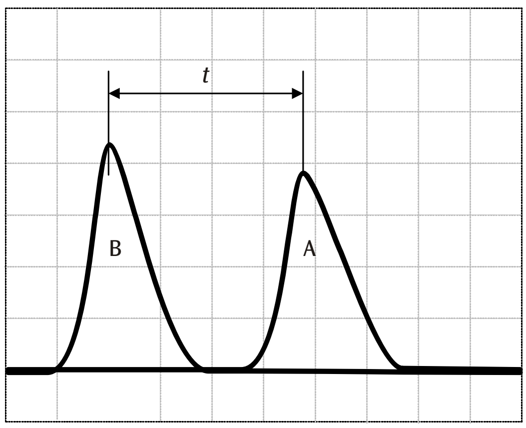

Fig. 2: Measuring the transit time with the oscilloscope

LIST OF APPARATUS

1	Speed of Light Meter	U8476460
1	Analogue Oscilloscope 2x150 MHz	U11177
1	Optical Bench U, 600 mm	U17151
2	Optical Rider U, 75 mm	U17160
1	Tripod Stand 185 mm	U13271
1	Stainless Steel Rod 1500 mm	U15005
1	Multiclamp	U13255
1	Pocket Measuring Tape, 2 m	U10073

SET-UP

- Place the optical bench on a table and level it horizontally.
- Mount the light transmitter/receiver unit and the Fresnel lens on the optical bench and adjust the Fresnel lens so that its plane is exactly perpendicular to the beam path.
- Connect the outputs A and B from the light transmitter/receiver unit to the inputs I and II of the oscilloscope, and output C to the external trigger input.
- Mount the triple-prism reflector on a stand and adjust its height to that of the beam path.

EXPERIMENT PROCEDURE

- Connect the light transmitter/receiver unit to the mains supply.
- Switch on the oscilloscope and set the time base at 50 ns/div.
- Set up the triple-prism reflector at a distance of at least 10 m from the light transmitter/receiver, and position it so that the red light spot from the transmitter is at the centre of the reflector.
- Adjust the position and orientation of the Fresnel lens on the optical bench so that the spot of light on the triple-prism reflector is sharp and the reflected light signal on the oscilloscope is as high as possible.
- Make further adjustments to the orientations of the Fresnel lens and the triple-prism reflector to maximise the reflected light signal on the oscilloscope.
- Adjust the oscilloscope display so that both signals have the same height.
- Read off the time interval *t* between the two signals.
- Measure the distance *s* between the light transmitter/receiver and the triple-prism reflector.

SAMPLE MEASUREMENTS

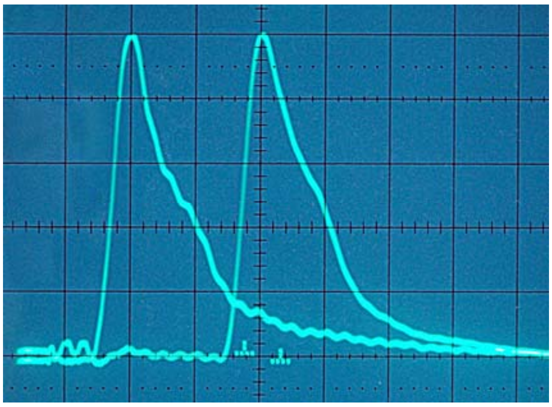

Fig. 3: Oscilloscope signals obtained with $s = (15.0 \pm 0.1)$ m; time base 50 ns/div.

Transit time of the light signal: $t = (100 \pm 1)$ ns

EVALUATION

Applying Equation 1 to the above experimental data we obtain:

$$c = \frac{2s}{t} = (3.00 \pm 0.04) \cdot 10^8 \frac{\text{m}}{\text{s}}$$

Fig. 4: Experiment set-up