

Laser range finder

474 7113

Objects of the experiment

- Investigate the optical spectra of LED and laser light sources
- Investigate other properties of these sources like polarization and spatial emittance

Safety notes

This experiment uses a Laser. According to EN 60825 it is rated class 3B.

474 5428:

Laser Class 3B, invisible 905 nm, pulsed, <5 μ J; "Danger. Invisible Laser radiation. Avoid direct exposure to beam." Do not look into beam"

Safety precautions are necessary. Please check with local regulations. Typically the use requires a safety sign and maybe a warning lamp that is on when the laser is activated and it might also be necessary to do and document a risk assessment. In some places it might be necessary to apply for a license or notify the relevant authorities.

Germany: According to OStrV it is necessary to inform the "Gewerbeaufsichtsamt" and the workers' insurance "Berufsgenossenschaft" 14 days prior to startup for Lasers > class 2.

Misuse of lasers poses a health risk for the eyes.

Do not operate the devices outside parameters specified in the manual.

People using the laser must be properly trained and students must be supervised.

As a general guidance, the user is advised to:

- Check the laser and LEDs for damages before use
- Never to look into the laser beam
- Take necessary measures that no people or animals can accidentally enter the beam area
- Do not direct the beam on reflecting surfaces or into public areas
- Do not work close to the light path with reflecting tools
- Take off all jewelry and wristwatches when working with the laser to avoid reflections
- While placing or removing optical parts in the light path, switch off the laser or cover its exit
- Use laser protection glasses or laser adjustment glasses where necessary

- Supervise students by trained personnel when they work with the laser system

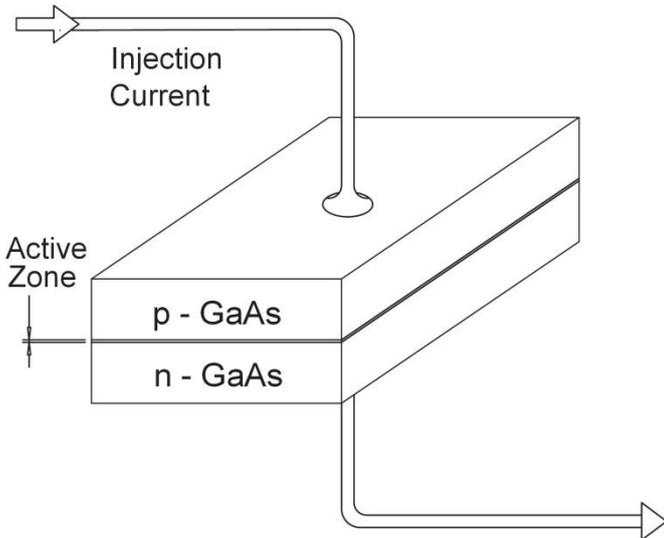
- Use the laser system only as described in the instruction manuals

Principles

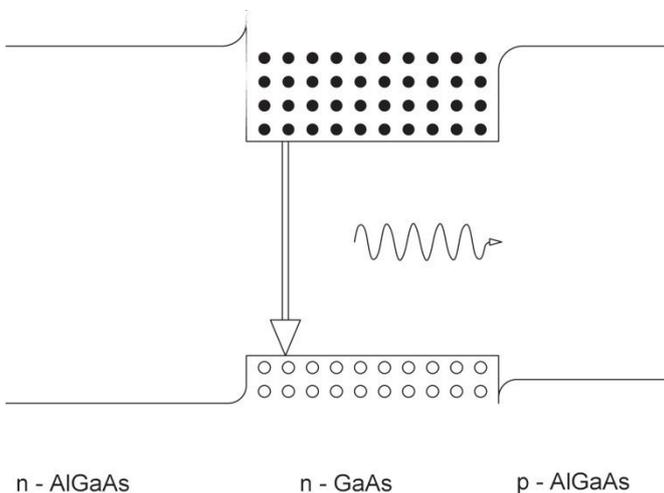
Light emitting diodes and Lasers are two modern ways to produce light. Both are devices where electrical current is used to push electrons and holes into differently doped areas of a semiconductor.

Optoelectronic semiconductor devices come from the so called III-V semiconductors like Gallium Arsenide, GaAs. One element from the third column of the periodic table and one from the fifth are combined. The resulting material has semi-conducting properties and a direct energy gap. The maximum energy released by an electron-hole recombination process is determined by the so called Band-gap of such a material and the maximum energy of the released photons defines the color of the light source.

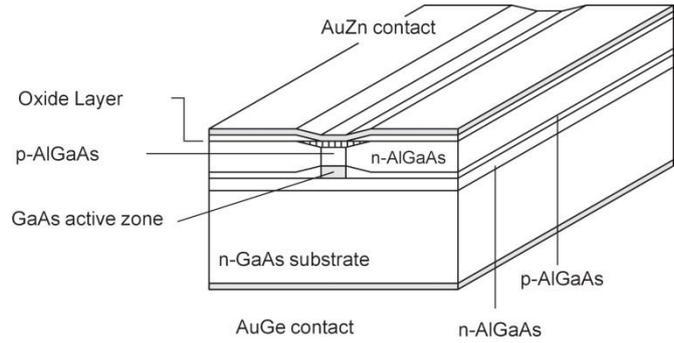
As simple as it may seem, it took about 20 years until people had acquired the necessary technology of coating under extremely pure conditions. It all began in 1962 with the first laser diode, just two years after Maiman had demonstrated the first functional ruby laser. In the course of 1962 three different groups reported more or less simultaneously the realisation of GaAs diode lasers.



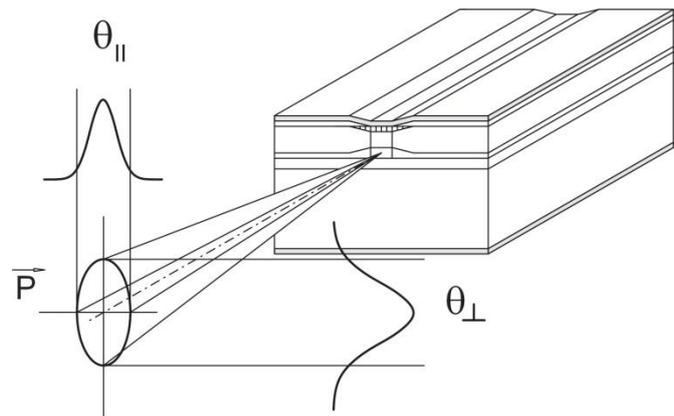
The first laser was basically made of highly doped GaAs. A threshold current of 100 kA/cm² was needed since the GaAs material of those days was not by far as good as it is today regarding the losses within the crystal. Because of thermal conditions the laser could only work at 70 K and in the pulsed mode. During the following years the threshold could be lowered to 60 kA/cm² by improving the crystals but then the use of a heterostructure (Bell Labs. and RCA-Labs.) brought the „breakthrough“ in 1968. The threshold could be lowered to 8 kA/cm² and working in the pulse mode at room temperature. A layer of p conducting AlGaAs is deposited on the p layer of the pn transition of GaAs. The slightly higher band gap of AlGaAs compared to GaAs ensures that a potential barrier is created between both materials in a way that charge carriers accumulate here and the population inversion is increased respectively.



The next step in development was the attachment of a similar layer on the n-side of the crystal. That way the threshold could be lowered once again in 1970. Now it amounted to about 1 kA/cm². Until today nearly all commercially sold laser diodes are built up on the double hetero structure principle.



In a laser, we have to have a population inversion for stimulated emission. In the pn junction, this is done by a large current density to create lots of electrons and holes, which can take part in the process of stimulated emission to amplify light. The semiconductor is put inside a resonator made of two mirrors and the light amplification when it is reflected back and forth is the laser process. Usually, the “mirrors” are just the end facets of the semiconductor crystal where the Fresnel reflection due to the change in index of refraction will act like a semitransparent mirror. Usually some layers of dielectric mirrors are evaporated onto the end facets of the semiconductor.



Not only the beam guidance but also the size of the laser mirrors influences the beam geometry. Conventional lasers use very large mirrors compared to the beam diameter. In a laser diode the laser mirror (crystal gap area of the active zone) has a size of about 10 μm x 2 μm, through which the laser beam has „to squeeze“ itself. Diffraction effects will be the consequence and lead to elliptical beam profiles. The polarization is parallel to the "junction plane", that is the plane which is passed by the injection current perpendicularly. Light generated by spontaneous emission will be more or less unpolarized and so the ratio of polarization, P_⊥ to P_∥, depends on the output power since for higher laser power the ratio of spontaneous to stimulated emission is changing.

The divergence angles θ_⊥ and θ_∥ differ by about 10-30° depending on the type of laser diode. If the beams are extended geometrically into the active medium the horizontal beams will have another apparent point of origin as the vertical beams. The difference between the points of origin is called astigmatic difference. It amounts to about 10 μm for the so called index guided diodes. For the so called gain guided diodes these values are appreciably higher. Modern diodes are mostly index guided diodes. This means that the laser beam is forced not to leave the resonator laterally by attaching lateral layers of higher refractive index to the active zone. At the gain guided diodes the current is forced to pass along a small path (about 2-3 μm width). In this way the direction of the amplification (which is proportional to the current flux) and

the laser radiation are determined. At the gain guided diodes the formation of curved wave fronts within the resonator is disadvantageous since they simulate spherical mirrors. In this case higher injection currents provoke transversal modes which will not appear in index guided diodes because of the plane wave fronts. Laser diodes with intensity profiles following a Gauss curve and a beam profile which is only limited by diffraction are called Diffraction Limited Lasers (DFL). They represent the most „civilized“ diode lasers. For the time being they are only available for powers up to 200 mW. High power diode lasers have very fissured nearly rectangular intensity profiles.

Pulsed diode Laser

In this experiment a hybrid pulsed laser diode is used strained with InAlGaAs/GaAs QW-structures. This guarantees a high power large-optical-cavity laser structure and a Laser aperture $200\ \mu\text{m} \times 2\ \mu\text{m}$. The typical pulse width is around 30 ns.

The pulsed laser driver consists of a capacitor and a switch which discharges the charge of the capacitor to the laser. The charging of the capacitor is done between two laser pulses.

This way we can generate short high current pulses (several 10 Ampere for 10 nanoseconds) without a bulky power supply. To maintain a small inductance, the capacitor is built into the laser housing.

Electrical energy is stored in the capacitor at an adjustable voltage up to 20 Volts. In regular intervals (up to 3 kHz repetition frequency) the capacitor is discharged into a laser diode. The discharge can be stopped after a selectable time from 10 to 200 nanoseconds. As the capacitor is discharged, the emitted laser power decreases. So we have a bright laser pulse in the first nanoseconds with decreasing intensity over time, repeated in regular intervals.

The control unit of the laser allows the user to set these three parameters:

- Charge voltage of the capacitor
- Discharge pulse duration
- Repetition frequency

The supply box is powered by a 12 Volt DC power supply connected to mains. During power up, the supply asks for a PIN code, which is supplied on a separate paper.

Dial in the PIN, a short press of the button changes between digits and a long press of the button enters the pin value and unlocks the device when the PIN is correct.



To set the three values, turn the knob until the value to be set is highlighted by a thick white frame (Pulse Width in the image above), press the button for a few seconds, now the value starts to blink. Turning the knob changes the value immediately and another long press of the knob leaves the value setting and changes to the selection of the white frame.

To toggle the on/off setting of the laser a short press of the button is required.

Speed of light

The limited speed of light is the key concept of special relativity. Einstein introduced it in 1905 and since then it is a keystone of modern physics.

But the knowledge that light travels rather slow is much older; Ole Rømer found out in 1676 that the apparent motion of Jupiter's moon Io was best understood by assuming a finite speed of light.

In 1850, Foucault created his rotary mirror setup for a rather precise measurement of c . In 1865 Maxwell proposed that light was just another electromagnetic wave.

In 1983, the unit meter was redefined and now the speed of light is a constant.

With modern electronics getting faster and faster, there are numerous applications where speed of light is used or even a limiting factor. Examples range from GPS / GLONASS / GALILEO navigation to data transmission.

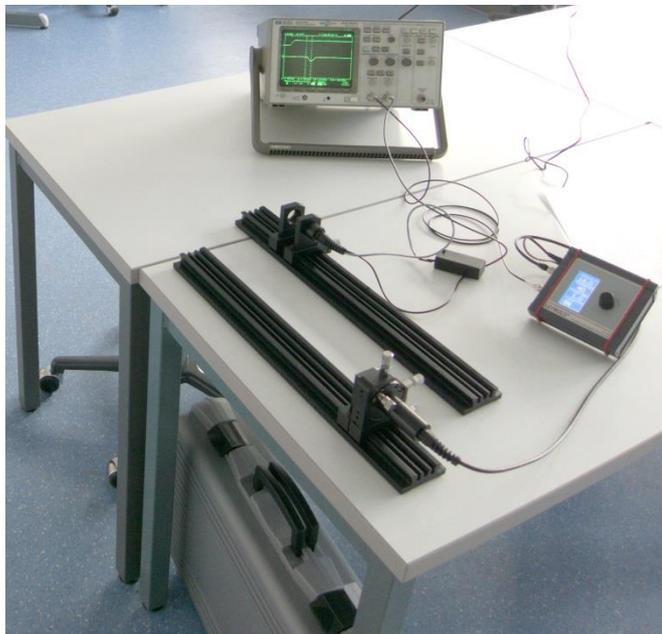
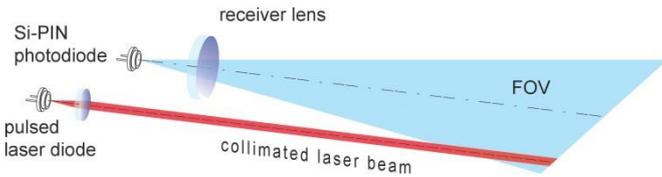
In the early days, measuring the speed of light required either astronomic observations or huge effort in the lab, like setting up a rotary mirror.

Nowadays, fast electronics make the experiment rather simple. Just send out a nanosecond wide pulse, let it bounce off somewhere and take a fast receiver and a fast scope and that is it.

Experiments

Material required:

- 1 Pulsed Diode Laser Module 908 nm474 5428
- 1 Module B - Collimating optics on carrier474 1031
- 1 Adjustment holder, 4 axes, carrier 20 mm474 211
- 1 Controller for Pulsed Laser Diode474 309
- 1 IR converter screen 0.8 - 1.6 μm 474 4025
- 1 Focussing Optics, $f = 60\text{ mm}$ 474 104
- 1 Photodetector, Ultrafast with Amplifier474 331
- 1 Mounting Plate C25 with Carrier 20 mm474 209
- 1 Oscilloscope, Dual Channel, Digital474 5464
- 1 HF-Cable, BNC-Mini BNC, 1.5 m501 061
- 2 Profile rail, 500 mm474 5442



For this experiment, we use two optical benches in parallel. One bench carries the transmitter, while the other bench holds the receiver. The transmitter sends out a more or less focused beam of light with a pulse intensity of 20 watt. This bright pulse is reflected somewhere, say by a white painted wall. Do not use a mirror. The reflected light is collected by a lens and focused onto a fast photodetector, amplified and brought to the oscilloscope.

To set up the transmitter, put the laser module 474 5428 into the holder 474 211 and place the lens 474 1031 close to it.

Connect the laser to the supply 474 309. Switch it on and set it to an intermediate value like 20 Volt, 20 ns, 1 kHz. Using the IR detector card optimize the position of the laser (screws of 474 211) and the distance between laser and collimator to get a small spot on the IR detector card, which does not change much with distance.

The laser beam is now collimated.

Please take care, this laser beam can be class 3B depending on the settings of the power supply and is definitely not eyesafe.

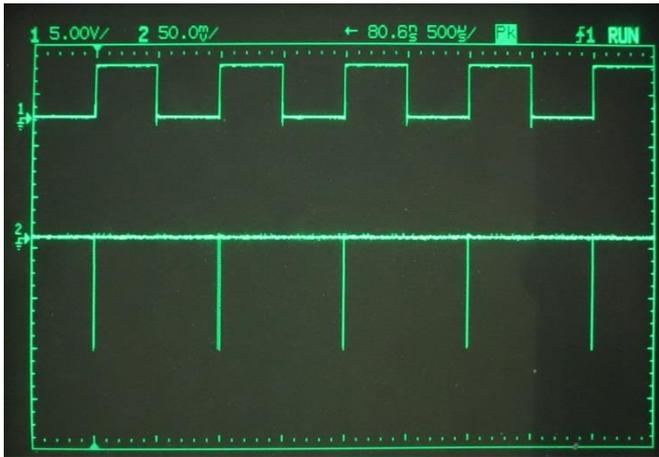
Connect the trigger output of the supply box 474 309 to the first channel of the oscilloscope.



The receiver is built from the detector 474 331 held by a 474 209 together with a biconcave lens 474 104. Connect the BNC output to the second channel of the oscilloscope. The battery box contains a 9V block battery and a switch. Switch on the detector and put the lens a few cm in front of the detector.



On the oscilloscope, press the “Auto Set” button or similar.

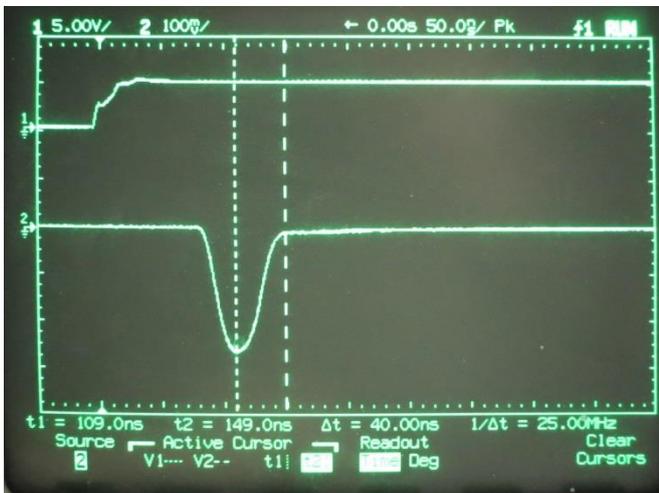


An image like this will occur. The upper trace, channel 1, is the output of the transmitters supply box, 50% duty cycle at 1 kHz repetition frequency. At each rising edge, the laser fires a very short pulse. The lower trace shows the detector signal, a negative Peak whenever light hits the detector.

Please note the detector will output a negative voltage when the light intensity is higher

Pointing the transmitter to a target adjust everything for a maximum in signal amplitude, distances of the lenses and direction of the rails.

Zoom into the image by decreasing the timescale until there is a clear view of one single pulse like this.

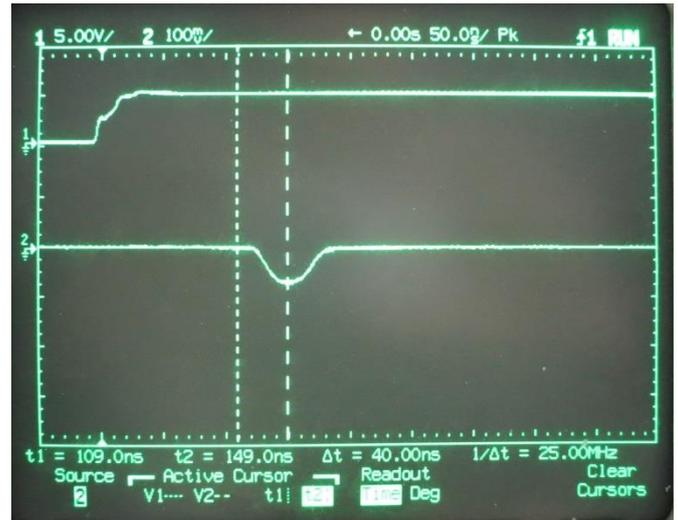


The image was done using a rather close reflector, a white sheet of paper right in front of both optical rails.

The upper trace again shows the trigger edge from the electronics. The detector pulse on the lower trace is several (~50) nanoseconds behind, this is not only the optical delay the light needs for a short way,

But there is also a lot of electrical delay from the pulse output to the laser firing and then from photons reaching the detector until maximum amplitude at the oscilloscope.

Now point the laser and detector to something further away.



In this example the wall was 6 m away from the end of the optical rails. The position of the cursors on the screen is the same, but the position of the reflex was delayed by 40 nano-seconds.

Of course the light has travelled 6 m to the reflector and 6 m back, so there is a path length of 12 m.

Taking $12 \text{ m} / 40 \times 10^{-9} \text{ s} = 3 \times 10^8$ we get the speed of light.

Using a short pulse time, say 15 ns, how long is the light pulse then? Light travels 30 cm in 1 ns, so a 15 ns pulse is just 4.5 m long.

Use different settings of the optics and for example defocus the laser transmitter. The pulse will first get weaker, but not much, since even a defocused laser will illuminate the area of the detectors field of view.

But when the defocused laser “spot” is wider then the detectors FOV, peak intensity will rapidly decrease.

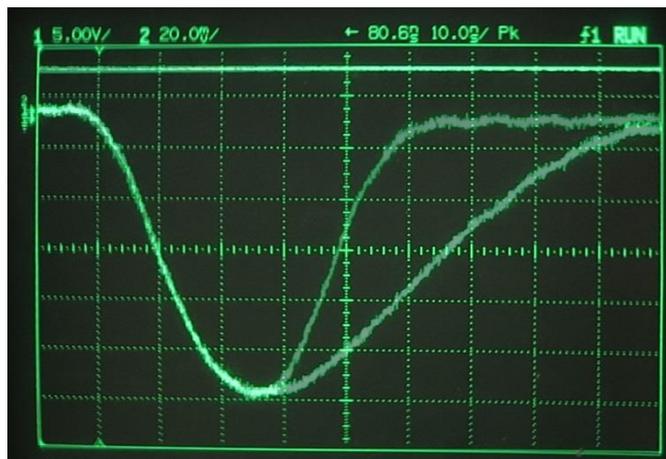
Additional tasks

The basic use is to demonstrate the working of a laser range-finder.

Additionally, some other experiments can be done:

Take a fixed mechanical setup and vary the electrical parameters of the laser.

For example comparing two Pulses of 40 and 80 ns length, we get a result like this:



At the end of the short pulse, the laser is obviously switched off.

But when the capacitor discharge switch inside the laser is left on for a longer time, the light output decreases by itself as the capacitor empties. Opening the switch after another 40 ns is not visible at all, because the light output already decreased to zero.

The peak power output can be recorded with respect to the different voltage settings of the capacitor. The more charge inside the capacitor, the longer and the brighter the laser will radiate.