FIBER OPTICS

DEMONSTRATION KIT

(version 2)

Users guide

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Introduction

For several decades we have been aware of the ability to transfer information using light frequencies. Major expansion of and advancements in fibre optics began taking place after 1966, being signified by the use of new technology and materials.

The development is on-going and specifically related to optimising the refraction index profile of the fibre itself. Recently developed materials are utilised as carrier and protection elements. The development of tools related to fibre optics, such as semi-conducting lasers and sensors has also advanced significantly.

The main advantages of systems utilising optical fibres are the following:

- transfer capacity

- lower losses

- greater number of transfer channels

- lower overall cost per channel/km

- receiver and transmitter being galvanically separated

- robustness in terms of sustainability against outer electromagnetic fields

- larger span between amplifiers

- savings on use of non-ferrous metals , the prices of which constantly increase, and the production of which is high in energy consumption

The following are some disadvantages of optical transfer systems:

- more stringent requirements in following the technological procedures

- higher cost of inter-operation check-ups

These inadequacies are gradually being eliminated by increasing the share of automated manufacturing facilities at production level.

With regard to the practical use of systems with optical cables it is necessary to point out the increased precautions that need to be taken into account when installing cables. Attention should be paid to mechanical strain put on

the cables (it is essential not to exceed the maximum allowable forces, to maintain sufficient radius of curvature, and prevent damage to the coating of the cable), and to ensure appropriate cable connection quality.

The following mistakes should try to be avoided when connecting cables:

- mutual displacement of the axes of the cables
- tilt of the axes of the cables
- non-perpendicularity of the connecting ends with respect to the axis of the cable
- insufficient smoothness and cleanliness of the cable ends to be connected

Optical systems are capable of transferring signals in digital or in analogue form. Some of the main areas in which transfer systems with optical cables are used as follows:

- measuring equipment
- computer networks
- control of technological procedures
- communications links between telephone exchange offices
- industrial conglomerates
- remote data transfer

Development in this field is proceeding at a fast pace and it is anticipated that in the near future links between fibre optics and other related fields will expand and give rise to exciting new opportunities in the realms of science.

Set contents

Main panels (pic. 2)

The set consists of two main panels each with a 5 V stabiliser and detachable 9 V plug. These panels are mutually non-interchangeable: one of them serves as the assembly of the transmitter (`TX Board`) and the other one of the receiver (`RX Board`). They carry three plug-in slots for direct connectors, into which other components of the set can be plugged in. There are Measurement Points (`MP`) between the connectors that facilitate voltage monitoring at selected points of the chosen arrangement. Also located on the main panels are the optical transmitter connector and the receiver connector, to which the polymer optical fibre (1 mm diameter) can be attached.

Transmitter modules

Potentiometer (pic. 19) (`POT`)[*]

The potentiometer has a linear resistance range capable of setting the DC voltage from 0 V to 5 V. It is used to determine transmission path parameters and to adjust the reference signal level.

Low Frequency generator (pic. 20) (`LF GEN.`)

This generates a sine signal with a frequency of about 1 kHz and an amplitude swing of 1.4 V (i.e., $U_{ef} = 0.5$ V), which is super-imposed on the DC voltage of +2 V. The Wien cell is used within the positive feedback of the operation amplifier. The amplitude of the signal is stabilised by the diode gate within the circuit of the negative feedback.

Microphone amplifier (pic. 18) (`MIC.AMP`)

This facilitates acquiring the voice signal as input (microphone) and amplifying it to the appropriate level. It is possible to adjust amplification within the range of 1 – 1000 using the module's trimmer. The output signal is super-imposed on the DC voltage of +2V. This board also contains a mono 3,5 jack connector for the input of an external signal (except of microphone), but it is not amplified.

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[*] The abbreviations of the modules' names are written down in the parentheses. These abbreviations are printed on the rear sides of the modules.

Analogue transmitter (pic. 16) `(ANAL.TX)`

This module transforms the analogue voltage signal into the current signal, which feeds the optical transmitter on the main panel. The circuit is constructed by means of a controlled current source and the output current is linearly dependent on the input voltage. The level of signal is indicated on the module by the brightness of the red LED diode.

Digital transmitter (pic. 14) `(DIG.TX)`

This module consists of four Smith "drop-down" circuits, two of which shape the input signal, while the other two generate the testing signal with a frequency of about 1 kHz. Moving the sliding switch on the panel determines whether the input signal or the testing oscillator is selected as the modulation source. Input to the module is controlled by protection diodes. Output status is indicated by the red LED diode.

USB TX BOARD (pic. 11) `(USB-Tx BOARD)`

This module transforms the signal from the USB interface to TTL voltage level (0 – 5V). It is using FT232RL for the signal conversion.

VIDEO TX BOARD (pic. 22) `(VIDEO TX)`

This module converts analog video signal to signal suitable for transmitting LED diode (located on the main TX board) that converts the signal to optical signal. The procedure is done by amplitude modulation.

Receiver Modules

Analogue receiver (pic. 15) `(ANAL.RX)`

This module transforms the current from the optical receiver on the main panel into the analogue DC voltage. The level of signal is indicated by the brightness of the green LED diode. The sensitivity of the module can be modified by the input trimmer, so that the output voltage of the module is at the same level as the input voltage of the analogue transmitter. This ensures that attenuation changes along the transmission path are compensated for. These changes are caused by random damping of optical fibre connections and by using optical fibres of various lengths.

Digital receiver (pic. 13) (`DIG.RX`)

The signal from the optical receiver on the main panel is transmitted to the digital receiver. The decision level, which determines output status, can be altered by the trimmer. The digital receiver status is indicated by the green LED diode.

Low frequency amplifier + speaker (pic. 17) (`LF.AMP`)

This module processes the signal from the analogue receiver. It is used when the low frequency generator panel, the microphone amplifier or another source of sound signal is set up. The module contains a potentiometer for loudness (volume) regulation, an amplifier, a miniature speaker and a mono 3,5 jack connector for the output of an external signal. While using the microphone amplifier at the transmitter side and using the low frequency amplifier at the receiver side, it is important to position both set-ups sufficiently far apart from each other and to set the amplification level so that acoustic feedback is avoided.

USB RX BOARD (pic. 12) (`USB-Rx BOARD`)

This module transforms the signal from TTL (0 – 5V) to the USB interface. It is using FT232RL for the signal conversion.

VIDEO RX BOARD (pic. 21) (`VIDEO RX`)

This module amplifies weak analog signal and demodulates it to video signal suitable for display on TV or LCD screens. The procedure is done via photodiode located on the main RX board.

Other parts

Optical components (pic. 1)

The set consists of three 1 mm diameter polymer optical fibres 2 m, 3 m, 5 m long, one 2 mm outside-diameter jacketed optical fibre 3 m long, and one U-probe 1 m long. The fibres have a step profile of refractive index.

Power supply (pic. 4)

Power is supplied by two universal adaptors which are connected to the main boards. Feed voltage is 9 V.

Measuring device (pic. 3)

The universal Multimeter is included in the set. The Multimeter enables measurement of voltage tension between measuring points GND and MP1 or MP2 on the main boards.

Mechanical fibre holders (pic. 5)

The holders are fixed to the calliper. This combination is useful for demonstration of losses caused by an imperfect fibre-fibre bond.

Emeries (pic. 8)
Three fine emeries are included to file and smooth cut fibre ends.
Attention: the colours of the emeries could be various – always see the attached sticker at the front page of this manual.

Plastic tube (pic. 7)

The plastic tube is used in the Tyndall's experiment.

Force plates (pic. 6)

Two separate metal plates with 3 holes and holders. The force plates are used in the dynamometer experiment.

Bending cylinders (pic. 9)

The bending cylinders are used in the attenuation measurement.

USB cables (pic. 10)

Two USB cables are used to connect the USB RX and USB TX modules to the transmitter and receiver computer.

VIDEO cables (pic. 23)

Two video cables are used to connect the VIDEO RX and VIDEO TX modules with a camera and TV monitor.

CD medium - software

The CD contains instalation of the comunication software OptoSerial-RxD and TxD for the transfer of digital signal experiment. It also contains video manual form of some experiments with subtitles.

CD medium - driver

The CD contains a driver for USB to RS 232 converter in case of problems for the transfer of digital signal experiment.

**Important and warning text for the label WEEE**
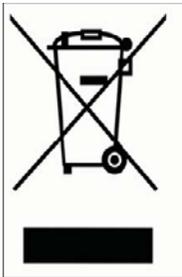
This symbol on the product or on its packaging indicates that this product must not be disposed of with your other household waste. Instead, it is your responsibility to dispose of your waste equipment by handing it over to a designated collection point for the recycling of waste electrical and electronic equipment (WEEE). For more information about where you can drop off your waste equipment for recycling, please contact your local city office, our household waste disposal service or the shop where you purchased the product.
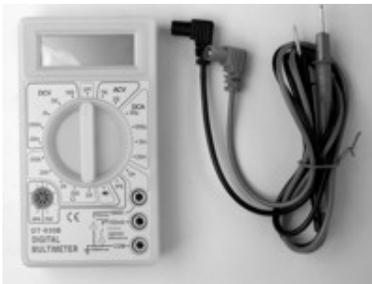
Photo of parts

Picture 1: Optical components (not jacketed, jacketed fibre, U-porbe)
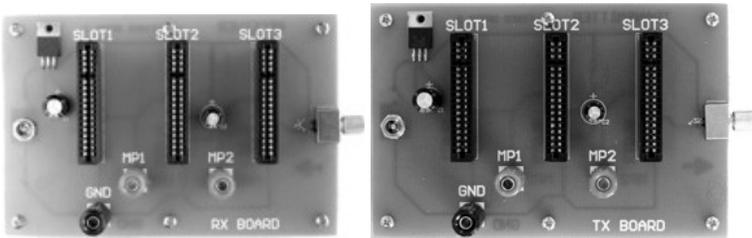
Picture 2: Main panels (RxD, TxD board)

Picture 3: Measuring device

Picture 4: Power supply
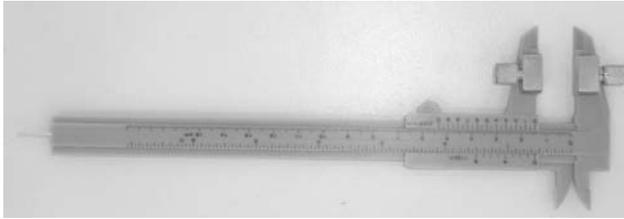
Picture 5: Mechanical fibre holders
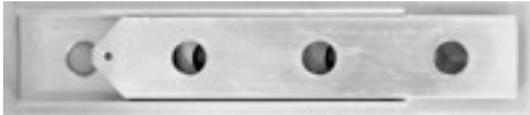
Picture 6: Force plates

Picture 7: Plastic tube

Picture 8: Emeries

Picture 9: Bending cylinders

Picture 10: USB cable

Picture 23 :Video cable

Picture 11, 12: USB – Rx and Tx BOARD

Picture 13, 14: Digital receiver and transmitter

Picture 15, 16: Analogue receiver and transmitter

Picture 17, 18: Low frequency amplifier and Microphone amplifier

Picture 19, 20: Potentiometer and Low Frequency generator
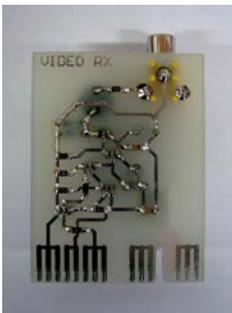
Picture 21, 22: Video RX and Video TX

Recommendations

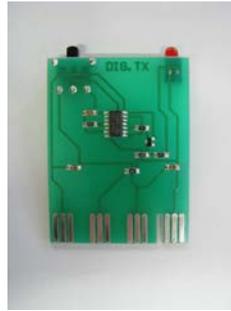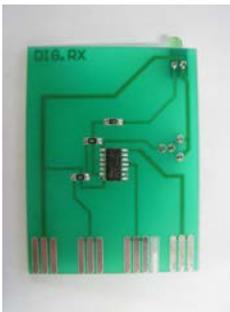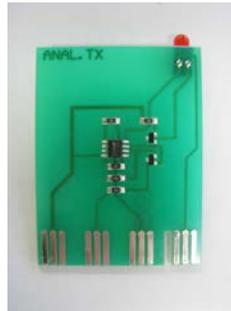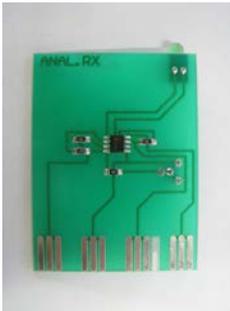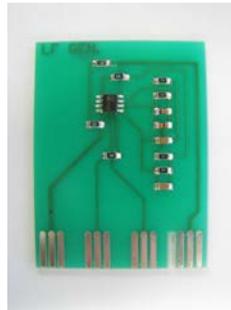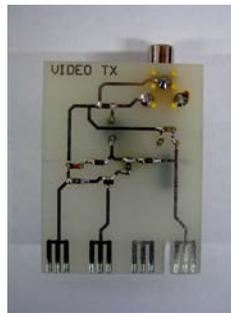Some general principles are valid during experiments, to ensure that devices function properly. It is advised that they are remembered and adhered to.

1. The laboratory where experiments take place should be dark. Background light could damage the photodiode of the receiver or cause its saturation.

2. Never touch unprotected conductive metal parts of modules. This could cause a discharge and the fine electrical parts could be damaged.

3. Adapters should be first inserted into the electricity socket after being connected to the main panel.

4. The black connector of the Multimeter should be connected to GND point first.

5. The U-probe must be and clean and dry when changing the liquid.

6. The reference voltage level can be adjusted by the potentiometer. Be careful not to set it to the extreme position.

7. Do not cause undue stress to the optical fibres by excessive mechanical force. The shape changes are mostly irreversible.

8. Upon completion of the experiment return all components to the portable case.

The following set of experiments should help you to acquaint yourself with the basics of fibre optics. There are, of course, many more experiments which can be undertaken with our set. We welcome any ideas and suggestions that you might have which could help us to refine our fibre optics set. In the meantime, we hope that you enjoy using this set.

Your company

Basic overview of fibre optic cables

Fibre optic cable functions as a "light guide," guiding the light introduced at one end of the cable through to the other end. The light source can either be a light-emitting diode (LED) or a laser. The light source is pulsed on and off, and a light-sensitive receiver on the other end of the cable converts the pulses back into the digital ones and zeros of the original signal.

Even laser light shining through a fibre optic cable is subject to loss of strength, primarily through dispersion and scattering of the light, within the cable itself. The faster the laser fluctuates, the greater is the risk of dispersion. Light strengtheners, called repeaters, may be necessary to refresh the signal in certain applications.

While fibre optic cable itself has become cheaper over time - an equivalent length of copper cable cost less per foot but not in capacity. Fibre optic cable connectors and the equipment needed to install them are still more expensive than their copper counterparts.

There are two types of fibre optic cable commonly used:
- single mode
- multi mode and plastic optical fibre (POF)

Single Mode (Figure 1) cable is a single stand of glass fibre with a diameter of 8.3 to 10 microns that has one mode of transmission. Single Mode Fibre with a relatively narrow diameter, through which only one mode can propagate typically 1310 or 1550nm. Carries higher bandwidth than multimode fibre, but requires a light source with a narrow spectral width. Single-mode fibre gives you a higher transmission rate and up to 50 times more distance than multimode, but it also costs more. Single-mode fibre has a much smaller core than multimode. The small core and single light-wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fibre cable type. Single-mode optical fibre is an optical fibre in which only the lowest order bound mode can propagate at the wavelength of interest typically 1300 to 1320nm.

"Single mode fiber"
single path through the fiber
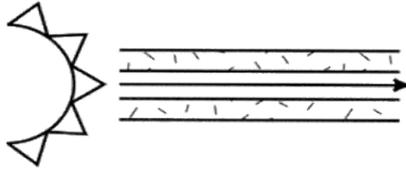
Figure 1: Single mode fibre

Multimode cable and plastic optical fibres (POF) (Figure 2) are made of glass fibres, with common diameters in from 50 to 100 micron for the light carry component (the most common size is 62.5). POF is a newer plastic-based cable which promises performance similar to glass cable on very short runs, but at a lower cost. Multimode fibre gives you broad bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300nm. Typical multimode fibre core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (longer than 3000 feet [914.4 m]), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

"Multimode fiber"
multiple paths through the fiber
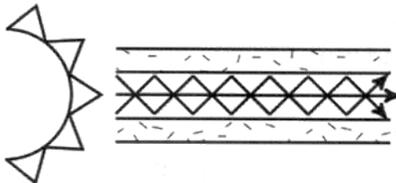
Figure 2: Multimode fibre

NOTICE:

1. Prepare the optic fibre fairly following instructions in experiment #1 before each of experiments.

2. For each experiment use only neccessary long piece of fibre, because the longer it is, the bigger the loss is.

3. Remember that the fibre gets worn off or destroyed while performing some of experiments e.g. #3 & #4. So take care to not destroy whole fibre for the first time.

4. Values measured in the experiments are only approximate and they should vary for each repeating of experiment. It depends on a number of circumstances like preparing of the fibre, its length, deflection etc.

Plastic Optical Fibre (POF) – technical specifications:

- Type: step-index PMMA fibre
- Core diameter: 980µm
- Cladding diameter: 1000µm ± 40µm
- Attenuation: <150dB/km at 650nm
- Attenuation: <80dB/km at 570nm
- Length x Bandwidth: >100m/30Mhz
- Core refraction index: 1,49
- Numerical Aperture: 0,46 ± 0,025
- Cladding non-circularity: 1% max
- Weight: 1g/m with no sheath
- Operating temperature: -40°C ~ +85°C
- Max tensile strength at Yield Point: 65N

Experiment No.1: Preparation of optical fibres

Introduction

As it was mentioned before, careful attention has to be paid to the fibres bond during optical transmission system building. Imperfect worked fibres bonds are responsible for large losses in the whole system. This is the reason why fibres must be prepared before starting experiments. In this experiment the proper cutting of fibre will be demonstrated (Figure 3).

Objective

Preparing the fibres before experiments so any losses after connecting connectors will be as low as possible.

Principle of light propagation in optical fibres

Optical fibres consist of a core, a cladding and a protective coating. The core diameter is usually about 5 to 50 μm. The cladding can be of a diameter up to hundreds of μm. The core and the cladding are necessary for light propagation, whereas the coating has a protective function against mechanical and chemical damage.

The Snell Law of refraction controls propagation inside a fibre. Light is subject to total reflection on the core-cladding border. The refractive index of the core n_1 is higher then that of the cladding, n_2. Light is propagated, in terms of geometrical optics, only through the core of the fibre. The cladding has an important role in this process, because through the division of the two indices one of the main parameters of the fibre can be defined as the *numerical aperture* (Figure 3)

$$\mathrm{NA} = \sin\alpha = \sqrt{n_1^2 - n_2^2}$$

The numerical aperture is a sine of the maximum incidence light angle entering the fibre and fulfilling total reflection requisites. It is also the maximum angle of the light cone leaving the fibre at the other end, until the output cut is planar and perpendicular to the fibre axis.

Equipment

Optical fibres, scalpel or sharp knife[*], mechanical holders of fibres (fixed on the calliper), emery papers

Procedure

1. Cut the end of the fibre accurately by applying steady pressure to the knife.

2. Fix the end of the fibre to the mechanical holder (fixed on the calliper). Let about 0.1 mm of the end overhang the plane of the holder.

3. Lay down the emery on flat and solid field and keep trying to grind the fiber only vertically. Grinding not uprightly should cause creation of a number of various fields at the end of fibre.

4. Resurface the end of the fibre with an emery with the most thickness, then polish it with an emery with the lower thickness and finally with an emery with the lowest thickness.

5. Repeat the procedure for every fibre.

The fibres are prepared to be used for light transmission with lower losses.

Exercises

1. Try to derive the formula for numeric aperture.

2. What should be the maximum value of the refractive index of the core if the index of the cladding equalled to 1? (in the case of a fibre without cladding, it consists of a core only)

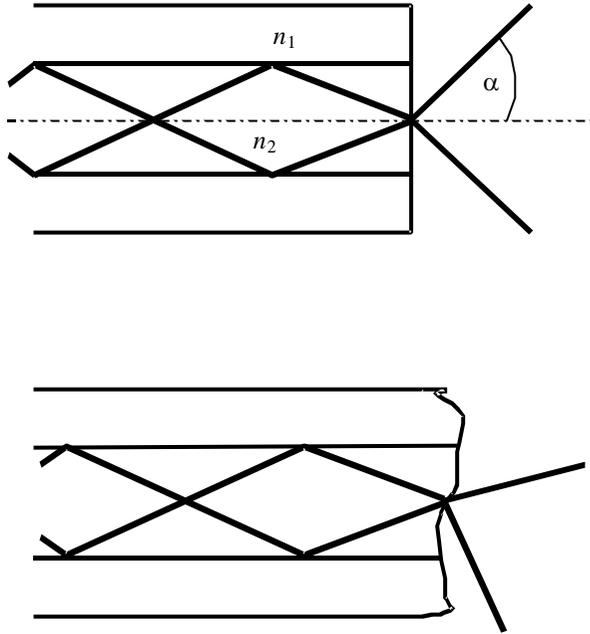[*] Not contained in this kit

Figure 3: Well and badly cut fibre. The radiation angle is limited by the numerical aperture, therefore when the fibre is cut badly, the angle is unlimited.

Experiment No.2: Tyndall's Light Guiding Experiment

Introduction

The modern-day technology of fibre optics starts back in the days when inventors and scientists were trying their best to bend the light around corners. It isn't exactly clear why anyone would want to do that, but a lot of people, even a hundred years ago, were unwilling to accept that light travel was confined to straight lines. They tried many different devices like mirrors and special tubes, but none received much attention until John Tyndall came along. In 1870, before members of the prestigious British Royal Society, Tyndall demonstrated how to guide a light beam through a falling stream of water. His method is shown in Figure 4. The tank of water had a horizontal pipe extending out one side which allowed water to flow out in an arc to a collection pan on the floor. A bright light was directed into the pipe and the light rays traveled within the water until they were broken up by the turbulence of the water hitting the collection pan.
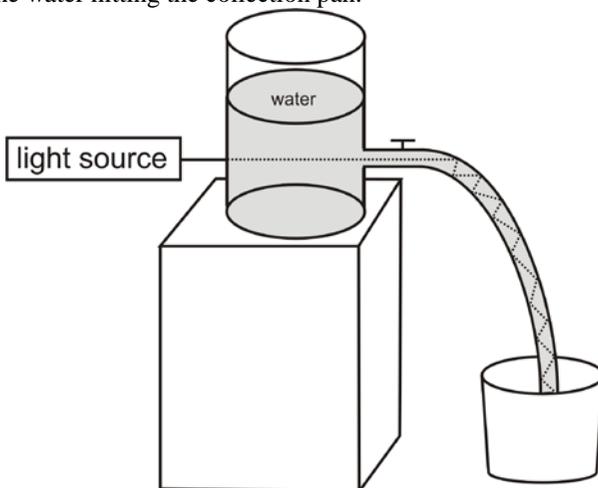

Figure 4: John Tyndall's light guiding experiment

Objective

Demonstration of the Tyndall's light guiding experiment.

Equipment

Main transmitter panel, analogue transmitter, optical fibre, plastic tube, 2x empty plastic bottle (min. size 1,5 liter or 0,5 galon)[*], sticking plaster[*], scalpel or sharp knife[*], bucket[*], water

THIS EXPERIMENT CAN BE REALIZED IN MANY WAYS. THE FOLLOWING METHOD IS ONLY PRINCIPIAL AND YOU SHOULD TAKE IT LIKE A TIP FOR THE REALIZATION. IT DEPENDS ONLY ON YOUR POSSIBILITIES AND EQUIPMENT.

Procedure

1. Fill up one empty plastic bottle with water.

2. Insert the analogue transmitter into `Slot 3`, as given in Figure 7.

3. Connect the prepared optical fibre to the transmitter.

4. Take other empty bottle and using knife cut a hole (approximately twice of the size of the optical fibre diameter) on the plastic bottle and cover it with a sticking plaster.

5. Using knife make a hole on the opposite side of the sticking plaster. The hole should be so big, that you can stick the plastic tube through it.

6. Stick the plastic tube in to the bottle (you can tighten it with plaster). Push the optical fibre from the transmitter through the other sticking plaster to the bottle.

7. Guide the optical fibre through the bottle to the plastic tube.

8. Put down the bucket in front of the table, and place the plastic bottle at the edge of the table so the plastic tube is over the table and bucket is under the tube Figure 5.

9. Darken the room and connect the power sources of the main transmitter panels to the power.

10. Start pouring water carefully from one bottle to the other one (try not to pour water on the electronics). Observe the light beam after it leaves the end of the plastic tube end and the stream of water. Do you see the light

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[*] Not contained in this kit

in the water stream? The light will leave the plastic tube and follow, or be guided by the stream of water to the bottom of the bucket. For better effect you can to the water few drops of milk.

Advices for better effect

- choose a tube with smaller diameter
- take care to have appropriate strong water stream
- the angle of deflection have to be sufficient
- the bucket shouldn't be too deep; for better efect you can insert an object to see the light beam better
- on supplied CD medium you can find video which shows another tip for the experiment demonstration
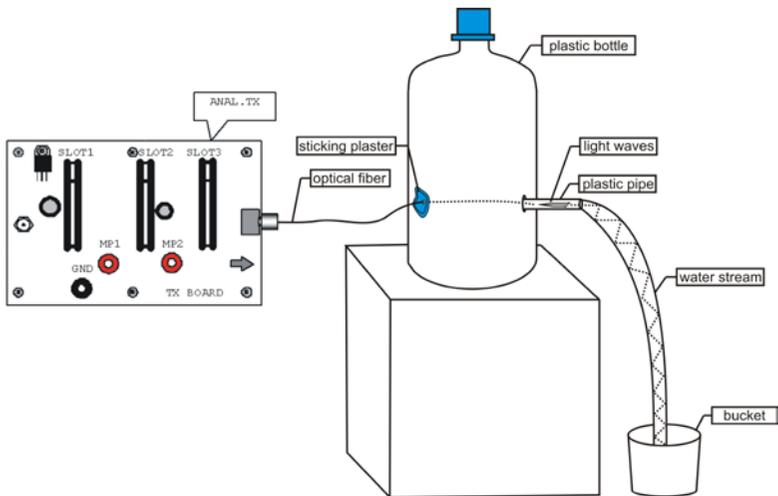
Figure 5: The set-up diagram of the Tyndall's experiment

Questions

1. Describe where do you see the light, once the stream of water is in motion?

2. How does the light get down to the bottom of the bucket?

3. Where is visible the majority of the light?

Experiment No.3: Measurement of attenuation caused by the bend of a fibre

Introduction

When bending a fibre, the incidence angles of beams at the boundary between the core and the cladding of a fibre changes, consequently some beams get emitted from the fibre. A bent fibre results in losses caused by emittance and an increase in attenuation, because the angle of incidence decreases at the points with a too small curvature radius and the condition of total reflection is not achieved (Figure 6). It is therefore necessary to maintain a sufficiently large curvature radius of a fibre when installing the cable nets.

Figure 6: The losses caused by a bent fibre.

Objective

Demonstration of the attenuation of transmitted light power increase caused by a bent fibre.

Equipment

Main transmitter panel, main receiver panel, analogue receiver, analogue transmitter, potentiometer, optical fibre, Multimeter, bending cylinders
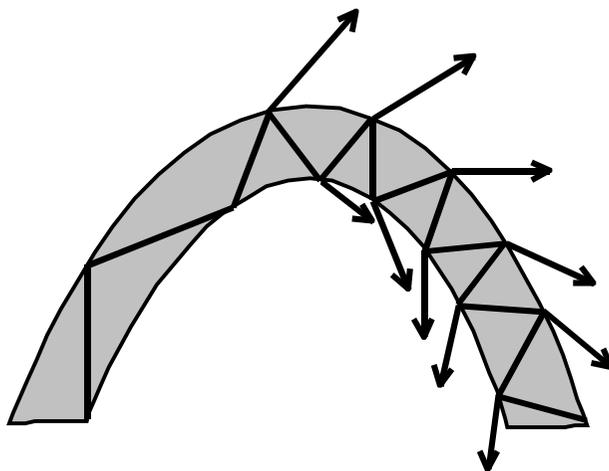
Procedure

1. Insert the analogue transmitter into `Slot 3` and the potentiometer into `Slot 2` of the main transmitter panel, following the order as given in Figure 7.

2. Connect the main transmitter panel to the main receiver panel by using the optical fibre.

3. Insert the analogue receiver into `Slot 3` of the main receiver panel.

4. Connect the Multimeter to the main receiver panel; plug it into the ground (`GND`) and to the measuring point `MP2`.

5. Connect the power sources of both the main receiver and the main transmitter panels to the power.

6. Measure the emitted power P_0. (Set the reference level by the potentiometer to appropriate level)

7. Coil one turn onto the bending cylinder of a diameter 1 cm, 1.5 cm, 2 cm and 2.5 cm and measure the transferred power P_x.

8. Repeat point 7 for up to five turns. The optical fibre must fit the bending cylinder tightly.

9. Calculate the additional attenuation from the formula

$$A = 10 \log \frac{P_0}{P_x}$$

10. Make a graph of the dependence of the attenuation on the radius of the cylinders at five coiled turns.

Questions

1. What is the influence of the number of turns on the losses caused by bending?

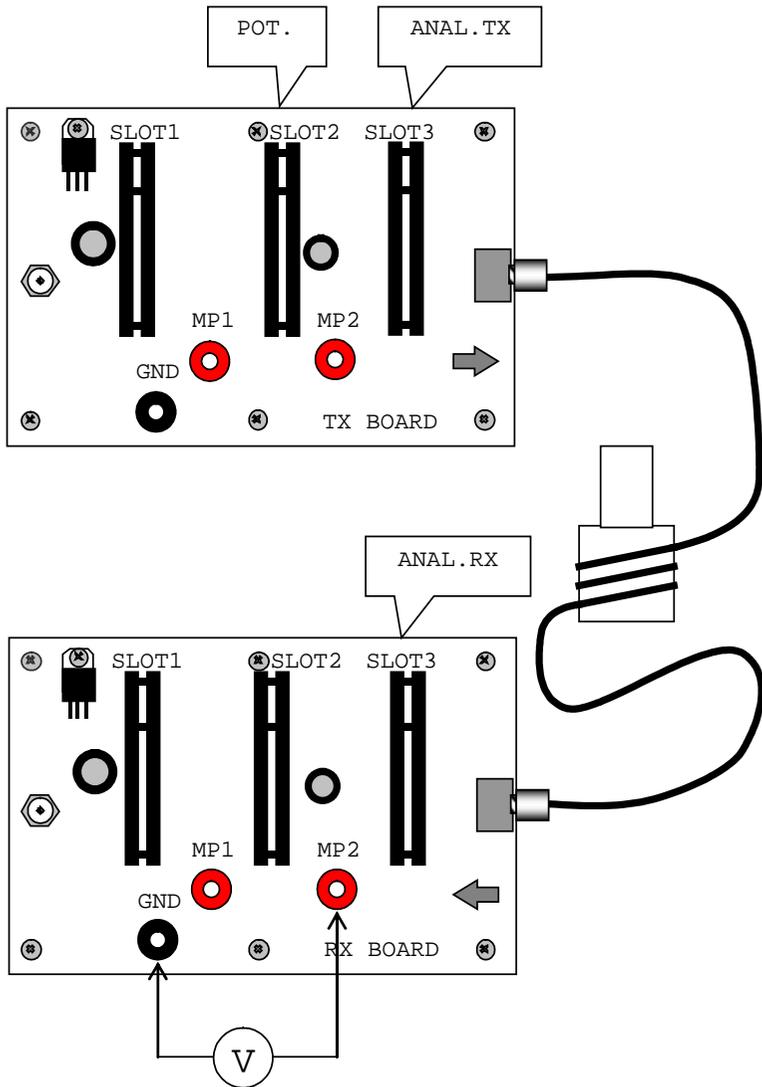2. What is the influence of the radius of a cylinder on the losses caused by bending?

Figure 7: The set-up diagram of the experiment of attenuation caused by a bend.

Experiment No.4: Optical fibre based dynamometer

Introduction

In the previous experiment you verified the fact that the attenuation of a fibre is dependent on its deformation. This effect can be used in the construction of a dynamometer. Such device could measure the force applied on the fibre cable or it can be used for measurement of the heaviness.

Objective

Demonstration of the dynamometer based on bent fibre.

Equipment

Main transmitter panel, main receiver panel, analogue receiver, analogue transmitter, potentiometer, jacket optical fibre, Multimeter, force plates, weights[*]

Procedure

1. Insert the analogue transmitter into Slot 3 and the potentiometer into Slot 2 of the main transmitter panel, following the order as given in Figure 8.

2. Insert the analogue receiver into Slot 3 of the main receiver panel.

3. Tow the optical fibre thorough the force plate holes as shown in Figure 8.

4. Connect the main transmitter panel to the main receiver panel by using the optical fibre.

5. Connect the Multimeter to the main receiver panel; plug it into the ground (GND) and to the measuring point MP2.

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[*] Not contained in this kit. You can use a bottle filled with water instead of weights.

6. Connect the power sources of both the main receiver and the main transmitter panels to the power.

7. Measure the emitted power P_0. (Set the reference level by the potentiometer card to appropriate level.)

8. Hang up one side of the first force plate and put a weight to the other side of the second plate. Check the emitted power P_x .

9. Calculate the power difference between P_x and P_0. Try this experiment with different weights. Always adjust the power to the same level as the first measured P_0 was when switching the weights. Avoid using weights that are too heavy or too light. Use weights which voltage difference is between 0.1 V – 0.5 V. Try not to change the position and the bending level of the optical fibres between measurements.

NOTE:

The fibre can get worn off during the experiment and you may not reach the initial reference level if you set the potentiometer at maximal level at the beginning of the experiment. To avoid this, begin with lower weights. You can   destroy   the   fibre   using   too   heavy   weights.
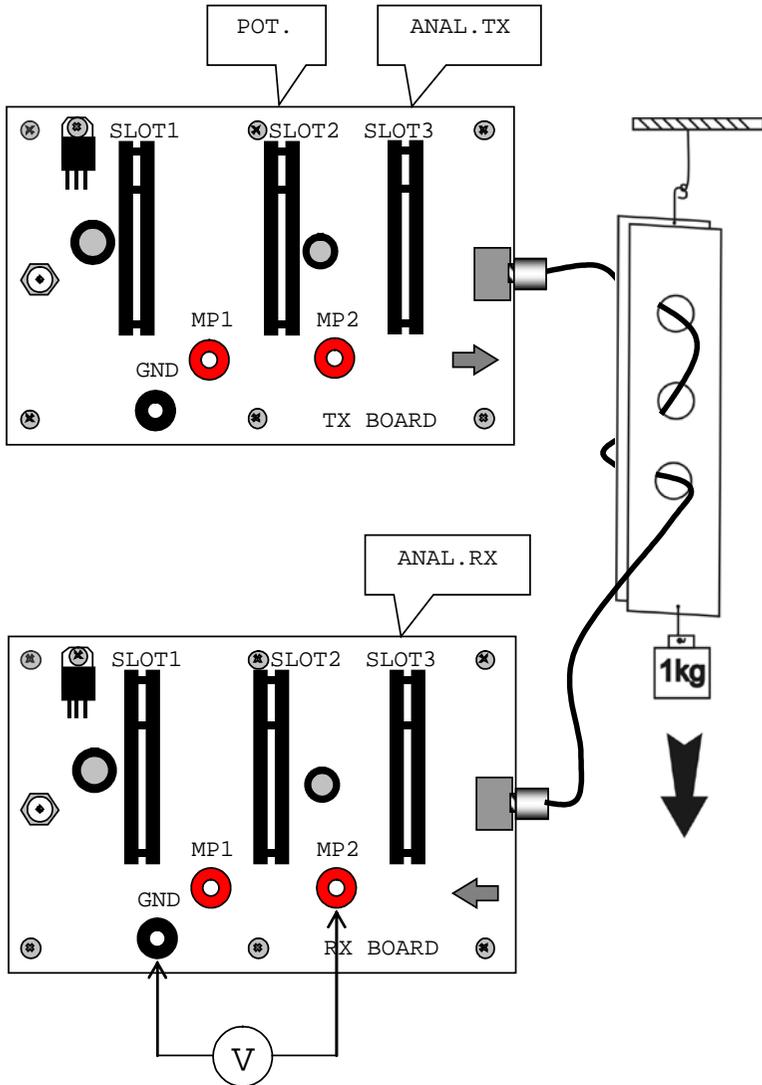
Figure 8 : The set-up diagram of the dynamometer experiment

Questions

1. Calculate the size of the force applied to the optical fibre using different weights. Compare your calculation results with a mechanical dynamometer.

2. How would you calculate the weight of an unknown sample (X kg) using 1 kg weight and the optical fibre dynamometer?
    Hint: $1:d_1 = X:d_2$, where $d_1=abs(PX_1 - P0_1)$, $d2=abs(PX_2-P0_2)$

3. Try to check the linearity of the system, by calibration with different weight standards and suggest an optimal calibration equation.

4. It's also possible to measure weight with the method shown on the picture Figure 9? Try this experiment.

Figure 9: Weight measurement

Experiment No.5: Sensor of a liquid surface

Introduction

Using the optical fibre bent in 180 degrees (U-shaped) on a very small radius of curvature, it is possible to vividly demonstrate the tie-out of an optical wave by submersing it in a liquid matter with the refraction index having a value c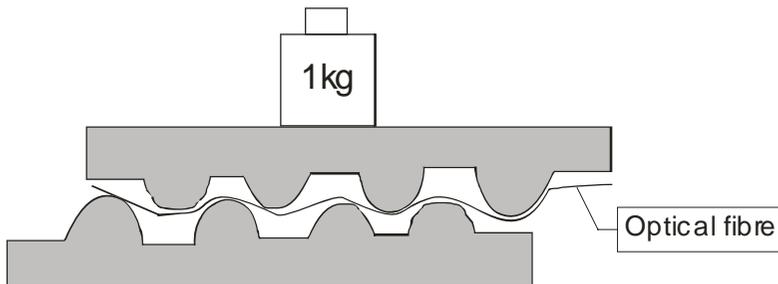lose to the refraction index of the fibre itself. Light is emitted through the fibre at the point of the bend, because the condition for total reflection is not satisfied (Figure 6). The loss increases when the refraction index of the surrounding environment approaches the refraction index of the fibre. If the power of transferred light is measured, the type of environment in the vicinity of the sensor can be determined.

Equipment

U-shaped fibre (so-called 'U-probe'), main receiver panel, main transmitter panel, potentiometer, analogue transmitter, analogue receiver, beak[*], water and sugared water, ehtylalcohol.

Objective

Demonstration of the operation of the water liquid sensor.

Procedure

1. Insert the analogue transmitter into Slot 3 and the potentiometer into Slot 2 of the main transmitter panel (Figure 10).

2. Connect the main transmitter panel to the main receiver panel by the U-shaped fibre.

3. Insert the analogue receiver into Slot 3 of the main receiver panel.

4. Connect the Multimeter to the main receiver panel; plug it into the ground (GND) and into the measuring point MP2.

---

[*] Not contained in this kit

5. Connect the power sources of both the main receiver and the main transmitter panels to the power.

6. The reference level has to be set by the potentiometer at appropriate level.

7. Measure the emitted power, which is proportional to the voltage in MP2, using the Multimeter, when the U-probe is

   a) not submersed (power P_0)

   b) submersed in water (power P_w)

   c) submersed in ethylacohole (power P_e)

   d) when sensor is submersed in a water-sugar solution (power P_s)

   Ensure that the U-probe is dry before changing the liquid.

8. Calculate the attenuation for the U-shaped fibre in the case of submersion in water and in ethylalcohol according to the formula :

$$A = 10 \log \frac{P_0}{P_e}$$

Questions

1. How and why is the attenuation for water different from the one for ethylalcohol?

2. Why does the power of emittance decrease when the U-probe is submersed in liquid?

3. What is the relationship between the sensitivity of the U-probe and the value of the refraction index of the environment in which the sensor is submersed?
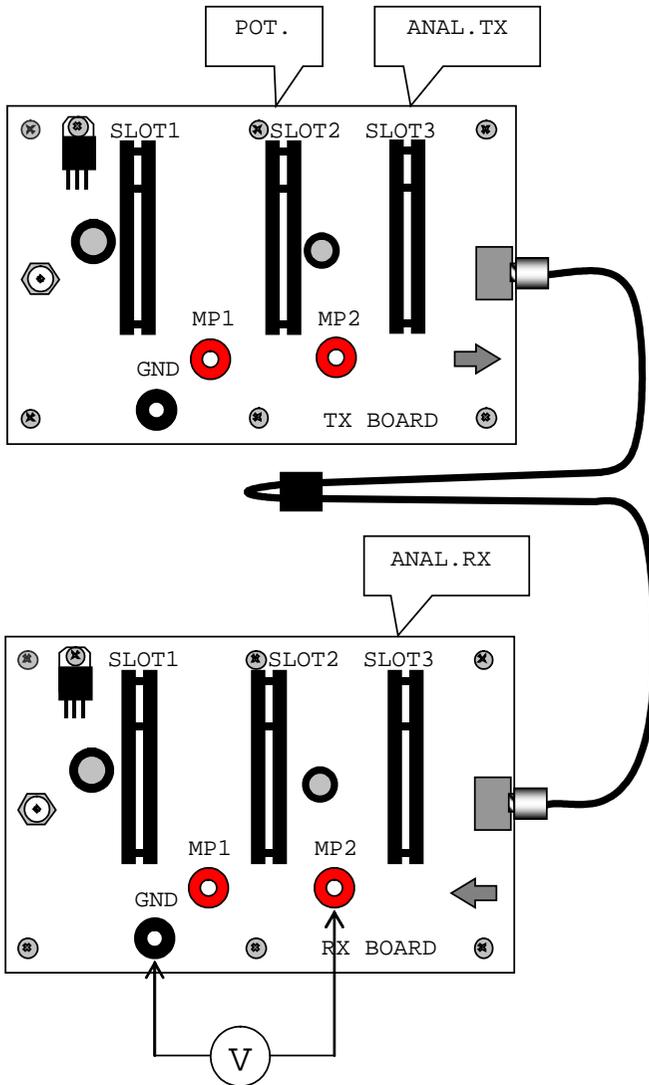
Figure 10: The set-up diagram of the U-probe experiment

Experiment No.6: Transmission sensor

Introduction

The transmission sensor facilitates detection of changes in the optical signal between two separate optical ends. Sometimes we refer to it as an optical gate. It is used as a counter of the amount of transferred objects, as a detector of speed and movement.

Objective

Demonstration of the principle of a transmission sensor.

Means

Main transmitter panel, main receiver panel, analogue receiver, analogue transmitter, digital receiver, potentiometer, jacketed optical fibre, mechanical holder of the optical fibres with a calliper, Multimeter.

Procedure

1. Insert the analogue transmitter into `Slot 3` and the potentiometer into `Slot 2` of the main transmitter panel (Figure 11).

2. Insert the analogue receiver into `Slot 3` of the main receiver panel.

3. Connect the main transmitter panel to the main receiver panel by the optical fibres, the other ends of which are fitted into the mechanical holders of optical fibres which are in turn fitted into the calliper.

4. Connect the Multimeter to the main receiver panel; plug it into the ground (`GND`) and into the measuring point `MP2`.

5. Connect the power sources of both the main receiver and the main transmitter panels to the power.

6. Set the ends of fibres 5 mm apart in the mechanical holder and set the appropriate signal level by the potentiometer on the main transmitter panel.

7. Pass a diaphragm through the space between the separated ends of fibres while observing the change in the transferred power.

8. Switch off the power on the main receiver panel. Replace the analogue receiver in the main receiver panel with the digital receiver.

9. Set the signal level by the potentiometer of the main transmitter panel to get "zero" (the green diode lights) when the diaphragm is between the ends of the fibres, and to get "one" when the diaphragm is absent. By doing so we have set up a counter which records the number of objects passing through the space between the fibres.

Questions

1. In what manner could the transmission sensor be used for measuring speed, or alternate movement (the investigated object may be provided with ticks)?

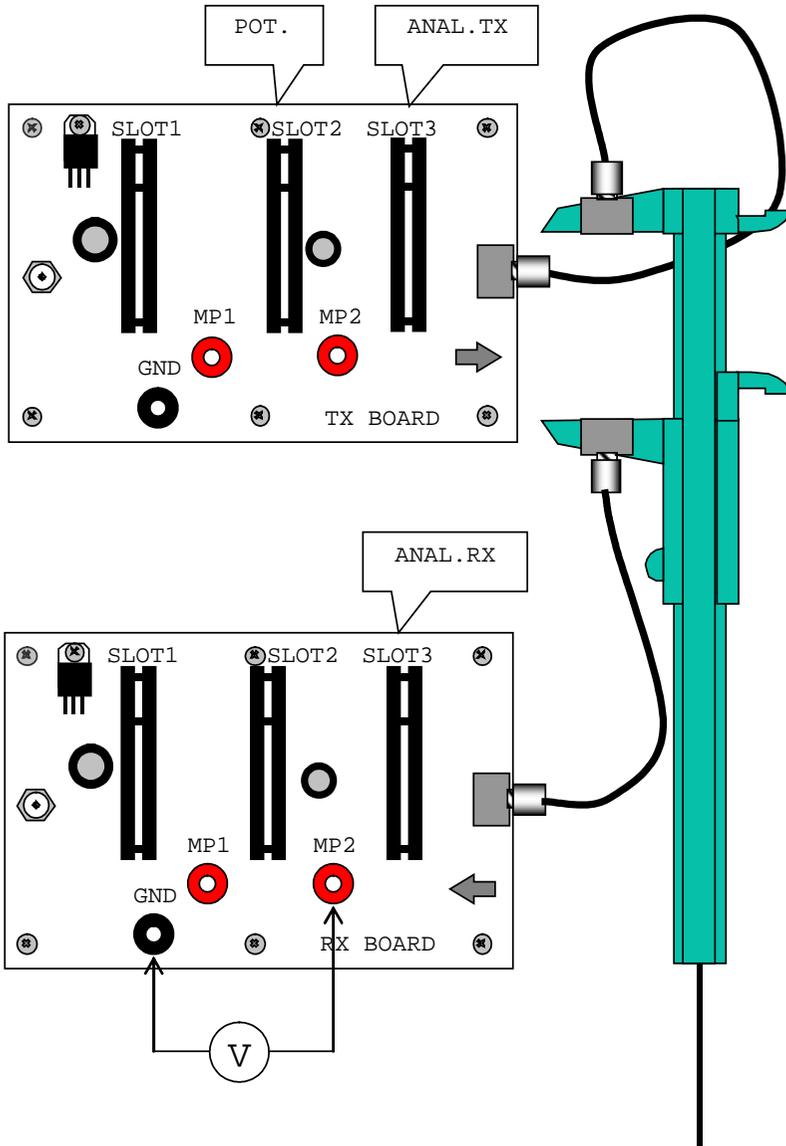2. How could the transmission sensor be used as a passing objects counter?

Figure 11: The set-up diagram of the transmission sensor.

Experiment No.7: Measurement of attenuation caused by an imperfect fibre-fibre bond

Introduction

The optical signal is attenuated along its entire path during the transfer. The losses which arise in the optical cable depend on the type of cable and on its length. The unit for evaluating losses in the cable is dB/m; it represents the attenuation of a 1 m long cable. Optical connectors and connections are additional sources of losses during transfer of an optical signal. When connecting optical cables, it is important that the axes of the fibres are aligned, and that the front sides fit each other well in longitudinal as well as latitudinal direction.

Objective

The demonstration of the influence of an insufficient fibre-fibre bond on attenuation, when increasing the separation of the fibres.

Equipment

Main transmitter panel, main receiver panel, analogue receiver, analogue transmitter, potentiometer, jacketed optical fibres, mechanical holder of the optical fibres with a calliper, Multimeter.

Procedure

1. Insert the analogue transmitter into `Slot 3` and the potentiometer into `Slot 2` of the main transmitter panel (Figure 13).

2. Insert the analogue receiver into `Slot 3` of the main receiver panel.

3. Connect the main transmitter panel to the main receiver panel using the optical fibres, the other ends of which are fitted into the mechanical holders of optical fibres which are in turn fitted into the calliper.

4. Connect the Multimeter to the main receiver panel; plug it into the ground (`GND`) and into the measuring point `MP2`.

5. Connect the power sources of both the main receiver and the main transmitter panels to the power.

6. Position the ends of fibres fitted in the mechanical holder to a distance until you still have signal and set the appropriate signal level by the potentiometer on the main transmitter panel.

7. Gradually bring the fibres towards each other measuring the level of transferred power P_x at each 1 mm interval. Make an effort to prevent crosswise shift of the fibres during the measurement.

8. Denote the measured transferred power at zero separation of fibres as P_0.

9. Calculate the attenuation from the formula:

$$A = 10 \log \frac{P_0}{P_x}$$

10. Make a graph of the dependence of the transferred power on the distance between the ends of the fibres and the dependence of the attenuation on the same distance.

Questions

1. What are the main sources of attenuation during the transfer of an optical signal?

2. What is the contribution of an imperfect treatment of the fibre end to the losses?
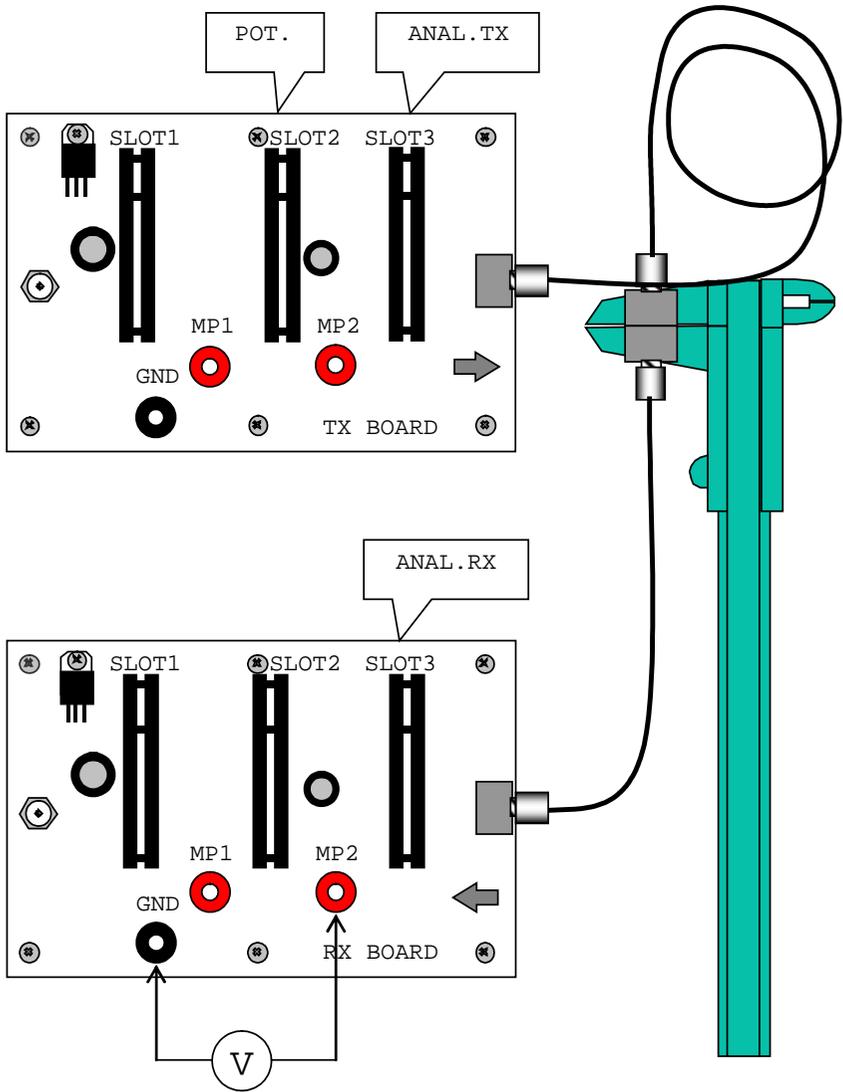
3. Why do we need to bond fibres?

Figure 12: The set-up diagram of the measurement of attenuation caused by an imperfect fibre-fibre bond.

Experiment No.8: Distance sensor

Introduction

In the previous experiment you verified the fact that the attenuation of a divided fibre depended on the distance between the two ends. This effect can be used in the construction of a distance sensor. A sensor of this kind could cause another device to turn on or off when the fibre ends reach a certain distance.

Objective

Demonstration of the distance detector principle.

Equipment

Main transmitter panel, main receiver panel, digital receiver, transmitter, module with the potentiometer, jacketed optical fibre, mechanical holder of the optical fibres with a calliper, Multimeter.

Procedure

1. Insert the analogue transmitter into `Slot 3` and the potentiometer into `Slot 2` of the main transmitter panel (Figure 14).

2. Insert the digital receiver into `Slot 3` of the main receiver panel.

3. Connect the main transmitter panel with the main receiver panel by the optical fibres, the other ends of which are fitted into the mechanical holders of optical fibres which are in turn fitted into the calliper.

4. Connect the Multimeter to the main receiver panel; plug it into the ground (`GND`) and into the measuring point `MP2`.

5. Connect the power sources of both the main receiver and the main transmitter panels to the power.

6. Position the ends of fibres 10 mm apart in the mechanical holders.

7. Adjust the power on the transmitter side by the potentiometer so that the digital receiver shows "zero" (the green LED diode light shows) for dis-

tances shorter than 10 mm and "one" (the green LED diode light does not show) for distances longer than 10 mm.

8. You have created a distance sensor, which is able to turn off or on another device in the event of the calliper arms approaching.

Questions

1. What is the practical use of distance sensor?

2. Try to calculate the most convenient switch distance of fibres in accordance with your previous measurement.
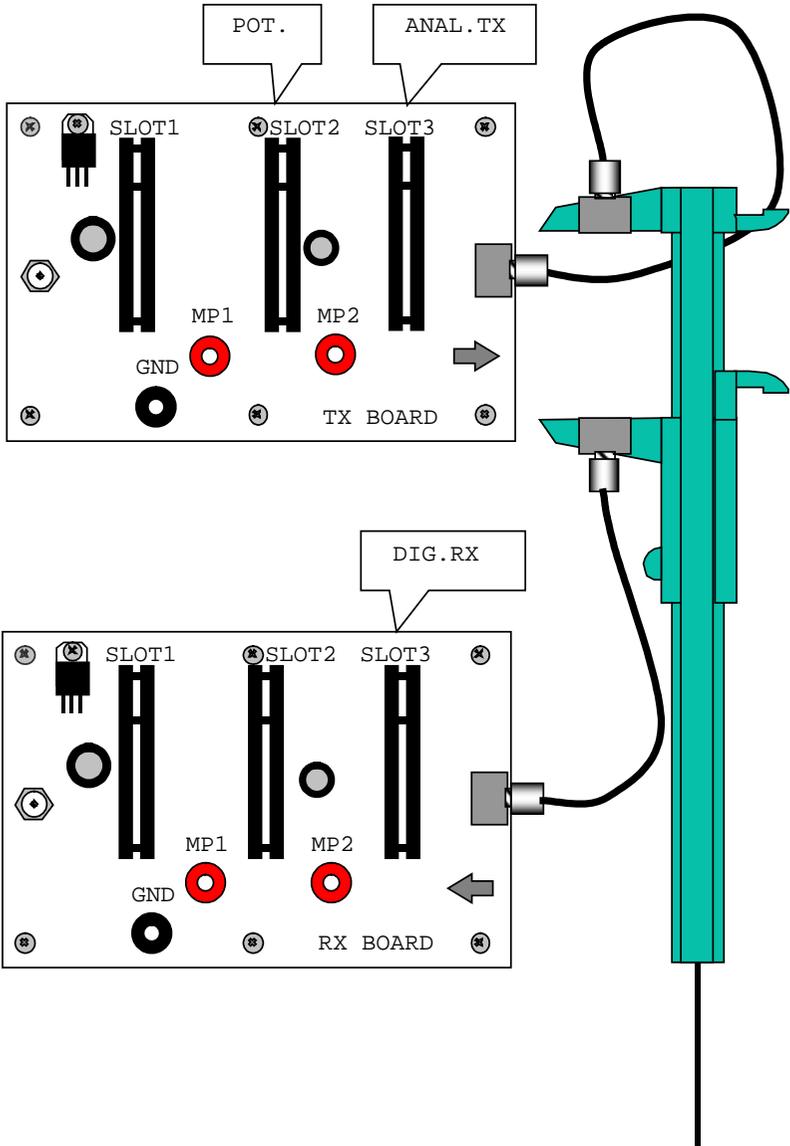
Figure 13: The setup diagram of a distance sensor.

Experiment No.9: The transfer of an audio signal (sound) by an optical cable

Introduction

Signals of frequencies within the range of 15 Hz to 20 kHz are audible to people and they are referred to as audio signals. In order to transfer sound via optical cable we must provide a microphone for the transformation of the audio signal into an electrical signal. This electrical signal is transformed further into an optical signal. After the signal is transferred via the optical cable, it is transformed in a receiver through the electrical signal back into sound using a speaker.

Objective

The demonstration of the principle of sound transfer by an optical fibre and the use of this principle in practise.

Equipment

Main transmitter panel, main receiver panel, analogue receiver, analogue transmitter, low frequency generator, microphone amplifier, potentiometer, optical fibre, oscilloscope[*]

Procedure

1. Insert the analogue transmitter into `Slot 3`, the potentiometer into `Slot 1`, and the low frequency generator into `Slot 2` of the main transmitter panel (Figure 15).

2. Insert the analogue receiver into `Slot 3` of the main receiver panel.

3. Connect the main transmitter pannel and main receiver pannel with optic fibre.

---

[*] Not contained in this kit

4. Connect the input of the oscilloscope to GND and MP 2 on the main receiver panel. (Set the sensitivity to 1 V/tick, set the time frame to approximately 2,5 ms/tick.)

5. Plug the power sources of both the main receiver and the main transmitter panels to the power.

6. Monitor the time variations of the signal coming from the receiver module on the oscilloscope.

7. By adjusting the potentiometer the range of output voltage can be determined. Set the signal to be in the middle of the linear range using the potentiometer.

Demonstration of the transfer of sound

1. Replace the low frequency generator with the microphone amplifier on the main transmitter panel.

2. Insert the low frequency amplifier into Slot 2 on the main receiver panel.

3. Position both the set-ups as far as possible from each other to prevent acoustic feedback.

4. Set the volume (loudness) using the potentiometer on the LF.AMP. slightly below the level of the origin of the acoustic feedback (high-pitched sound).

5. The system is now ready to transfer acoustic signals (voice, music, etc).
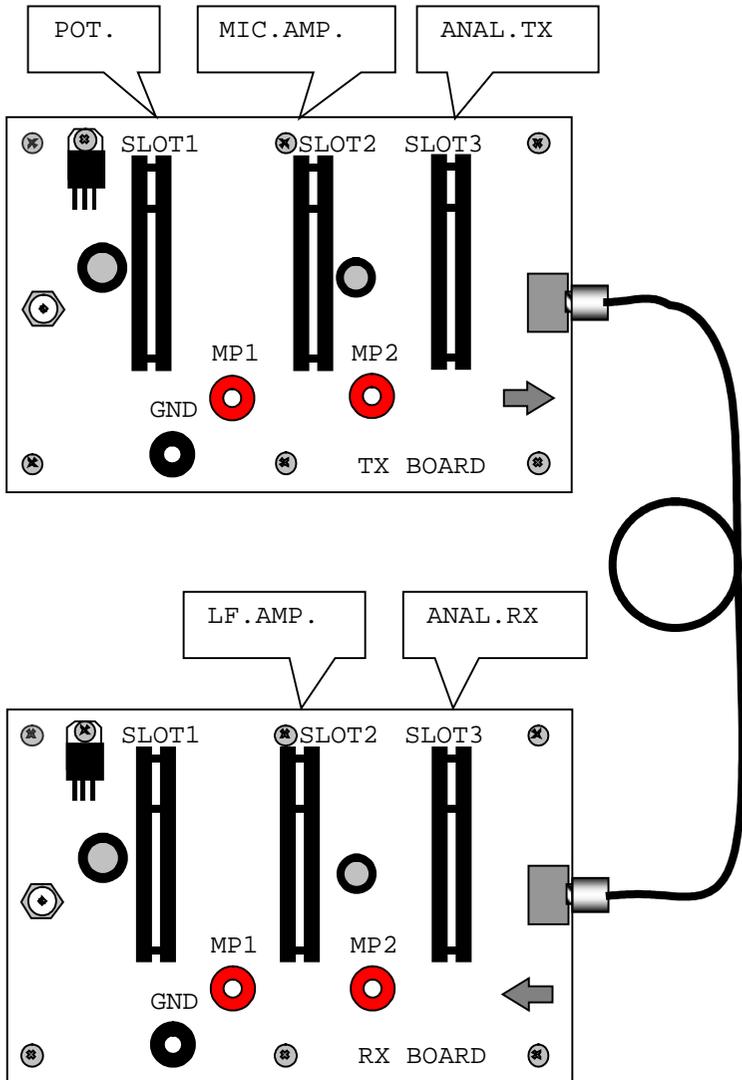
Figure 14: A set-up diagram of a device for sound transmission.

Experiment No.10: The transfer of a digital signal (data) by an optical fibre

Introduction

Optical fibres are a key component of modern communications network, largely because of the high speed of communications and virtually error-free transmission they offer. In many cases the data is in digital form already - such as the output from the readout system of a CD (compact disc) player or a network card. In order to transfer digital signal via optical cable we must provide a transformation further into an optical signal. After the signal is transferred via the optical cable, it is transformed in a receiver through the electrical signal back into digital signal. With the next experiment we will demonstrate how can be data transferred from one computer to another with the help of optical cable. For this experiment you will need two computers with CD-ROM and USB2 ports. The experiment is using as asynchronous serial transmission through USB ports with no flow control.

Objective

Demonstration of digital communication by an optical fibre.

Equipment

Main transmitter panel, main receiver panel, digital receiver, digital transmitter, USB Rx BOARD, USB Tx BOARD, jacketed optical fibre, USB data cables (2pcs), CD medium-software, CD medium-driver, PC or notebook supplied with CD drive and USB2 ports (2pcs – not included in kit) equipped with one of the following operating systems: Windows 9x/NT/2000/XP/Vista/7

Procedure

Setting up the hardware

1. Insert the digital transmitter into `Slot 3` and the USB Tx BOARD into `Slot 2` of the main transmitter panel. Set the switch on the digital

transmitter to the left position (the black part should be further from the red diode, Figure 16).

2. Insert the digital receiver into `Slot 3` and the USB Rx BOARD into `Slot 2` of the main receiver panel.

3. Connect the main transmitter panel to the main receiver panel by using the jacketed optical fibre.

4. Connect the power sources of both the main receiver and the main transmitter panels to the power.

5. Adjust the trimmer on the digital receiver so that the receiver shows "zero" (the green LED diode light is off). Than start turning slowly the trimmer to the opposite position till the receiver shows "one" (the green LED diode light is on). Stop turning immediately after the diode flashes on.

6. With the data USB cable connect the transmitter computer's USB port and the USB Tx module.

7. With the data USB cable connect the receiver computer's USB port and the USB Rx module.

Setting up the software

Installation of the driver:

1. Insert installation disc with the driver into CD-ROM drive of a transmitting/receiving computer.
2. The window *Found new hardware* should appear.
3. While asking to search for a new driver online, click on *No, not this time* and then *Next*.
4. Pick the option *Install from a list or specific location* and click *Next*.
5. Pick the option *Search removable media* and click *Next*.
6. The computer will search for the driver on the CD drive.
7. The pop-up window *Installation of hardware* will appear. Click *Continue*.
8. The computer will install the driver from CD, then click *Finish*.
9. In case the device was not recognized, so no *USB Serial Port* option appeared in the *Device manager* under the option *Ports Com and LPT*

(continue at **Identifying COM port number**), it is necessary to repeat whole installation procedure once again, therefore install the driver twice. It is not necessary to restart the computer in between these two installations.

Installation of the Opto Serial RxD a TxD software:

1. Insert installation disc with the software into CD-ROM drive of a transmitting/receiving computer.
2. Depending on the autostart setup of your computer, Flashplayer window may appear automatically. In case it will not appear, open it up manually (double-click on the CD-ROM drive icon in the *My Computer* folder). Continue in the bottom right corner under *Opto Fiber Demonstration Kit* by clicking on *Enter*. Another window should open up. In the right menu of this window pick *Opto Serial Com* option.
3. Software installation wizard window of the will open up. On the *Welcome to the Opto Serial COM Setup Wizard* window click *Next*. In the following window *Select Installation Folder* choose the final destination where do you wish to install the software. Click *Next* again. In the following window pick *Transmitter PC (Opto-Serial TxD)* option for transmitting computer. For receiving computer pick *Receiver PC (Opto-Serial RxD)* option. Click *Next*. In the following *Confirm Installation* window click *Next* again. The installation process will begin. When the installation is finished, *Installation Complete* window will pop-up. Click *Close* to finish the installation. On your desktop, the new Opto Serial Txd / Opto Serial Rxd software icon will appear.
4. In case the Flashplayer window will not open up even after manual method, right-click on the CD-ROM drive icon in the *My Computer* folder a then click on *Open* option. Open *fscommand* folder and double-click on the *OptoInstall.msi* file to run the installation. Then continue according to the steps stated above (Step 3).

Setup of the Opto Serial RxD a TxD software:

1. Run Opto Serial Rxd / Opto Serial Txd software by double-click on the desktop icon.
2. In the window, choose *COM Port* with the number that the computer assigned to *USB Serial Port* device. The information about assigned

number of the port can be searched via *Device manager* (continue at **Identifying COM port number**).

3. Choose the transfer rate 300 or 1200 baud/s (WARNING: Transfer rate has to be set at the same value on transmitting as well as receiving computer! When the transfer rate has been changed, the software on both computers must be closed and restarted again.)

4. Press *Connect* button in Opto Serial Rxd window, at first. The *Connection Status* information should change from *Not Connected* to *Waiting for connection*.... If the *Waiting for connection...* status will not appear and *Failed to open com port* will emerge instead, it is necessary to check whether the correct *COM Port* is set up. After correction, keep pressing *Connect* until the *Connection Status* will change to *Waiting for connection...*

5. Subsequently, press *Connect* button in Opto Serial Txd window. The *Connection Status* information should change from *Not Connected* to *Ready to send*. If this is not the case and *Failed to open com port* notice emerge instead, it is necessary to check whether the correct *COM Port* is set up. Then keep pressing *Connect* until the *Connection Status* will change to *Ready to send*. At the same time, the *Connection Status* in Opto Serial Rxd window should change to *Ready to receive*.

6. In Opto Serial Txd window (the receiving computer), write random text into *Message* box and press *Send* button. Sent text should appear in the Opto Serial Rxd window on receiving computer.

7. Transfer time will be shown next to received message. The time will change according to the lengths of the message (amount of data to be transferred) as well as the transfer rate (300 or 1200 baud/s).

Troubleshooting

Fixing the problems with Opto Serial RxD a TxD software setup:

1. In case any of the programs reports *Failed to open com port* error for all COM ports, check setup of all serial ports of the computer (continue at **Identifying COM port number**). It the problem persists, close all other running programs that might be using any of the serial ports.

2. In case the transfer of text messages does not work, check the transfer rate. Transfer rate has to be set at the same value on transmitting as well as receiving computer. While connecting, make sure to click *Connect* button on receiving computer as first.
3. It may happen that the computer will assign a higher number than 6 to port after connection. But, the software has only ability to offer the COM port number within the range from 1 to 6. In such case, it is necessary to change the COM port number (continue at **Changing the COM port number**).

Identifying COM port number:

Windows Vista and Windows 7:

Start with right-click on the *Computer* icon. From the pop-up menu choose *Properties*. In the following window, go to *Device Manager* on the left side. When the *Device Manager* opens up, unroll *Ports (COM & LPT)* option. Search for *USB Serial Port (COM_X)* where X stands for the COM port number, which the computer assigned *to USB Serial Port*. If this number is higher than 6, it is necessary to change the *COM port number*, hence the Opto Serial Rxd / Opto Serial Txd software is only able to communicate within the *COM port number* ranging from 1 to 6 (continue at **Changing the COM port number**).

Windows XP:

Start with right-click on the *Computer* icon. From the pop-up menu choose *Properties*. In the following window go to shutter menu *Hardware* and then click on *Device Manager*. The next steps are identical with Windows Vista and Windows 7.

Changing the COM port number:

Windows Vista and Windows 7:

In the *Device Manager* right-click on the *USB Serial Port (COM_X)*, where X stands for the *COM port number*, which the computer assigned *to USB Serial Port*. Click on *Properties*, then go to *Port Settings* and click *Advanced*. Then, go to *COM port number* and change the COM port number to

any number ranging from 1 to 6. Subsequently, it is necessary to confirm all the changes and steps by clicking *OK* on every option and close them down by so.

<u>Windows XP:</u>

Changing the COM port number under Windows XP operating system is identical to previous steps dedicated to Windows Vista and Windows 7.

Note: Changing the COM port number is only allowed to users of the computer with administrator rights.

Questions

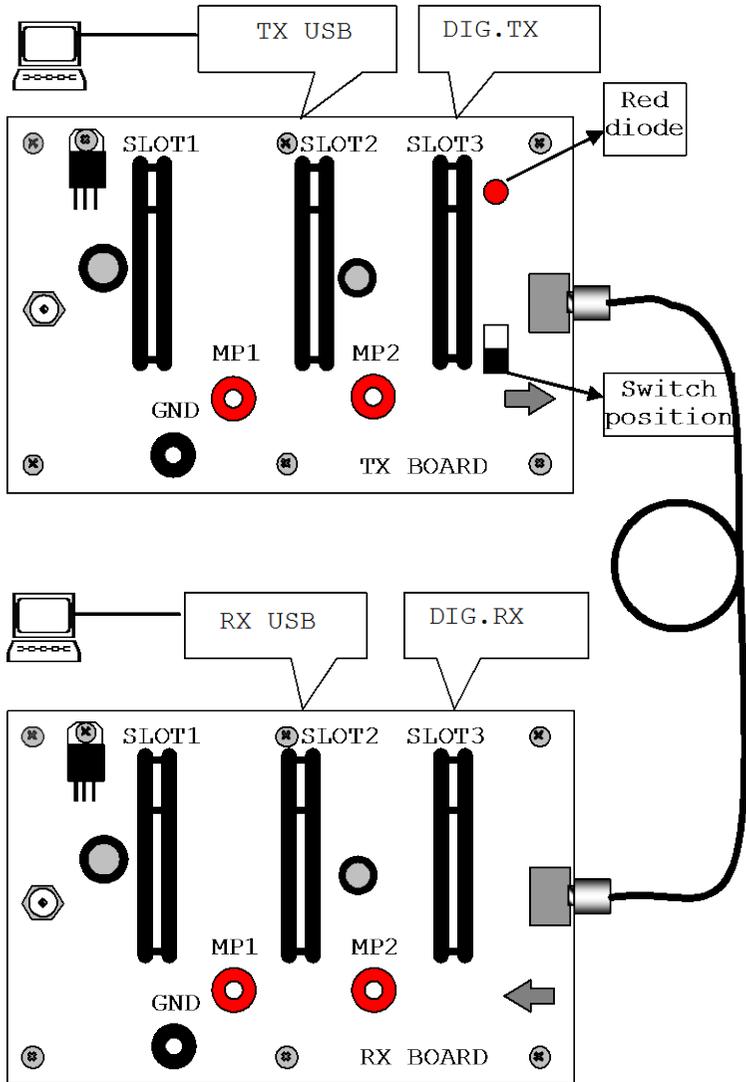1. How is the asynchronous serial transmission working through USB interfaces?

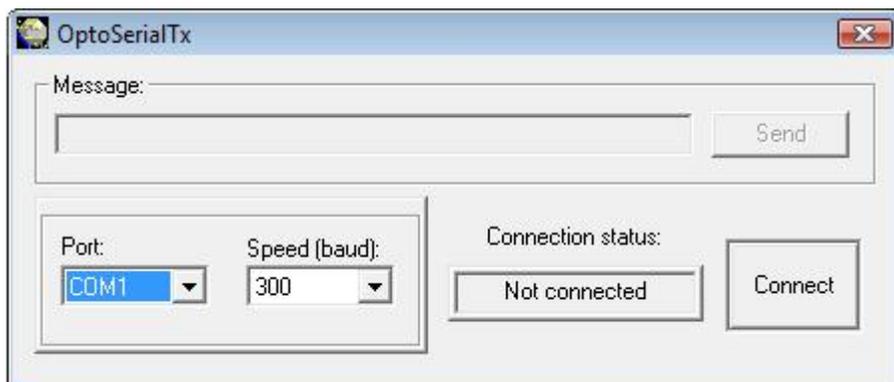Figure 15: A set-up diagram of device for data transmission.

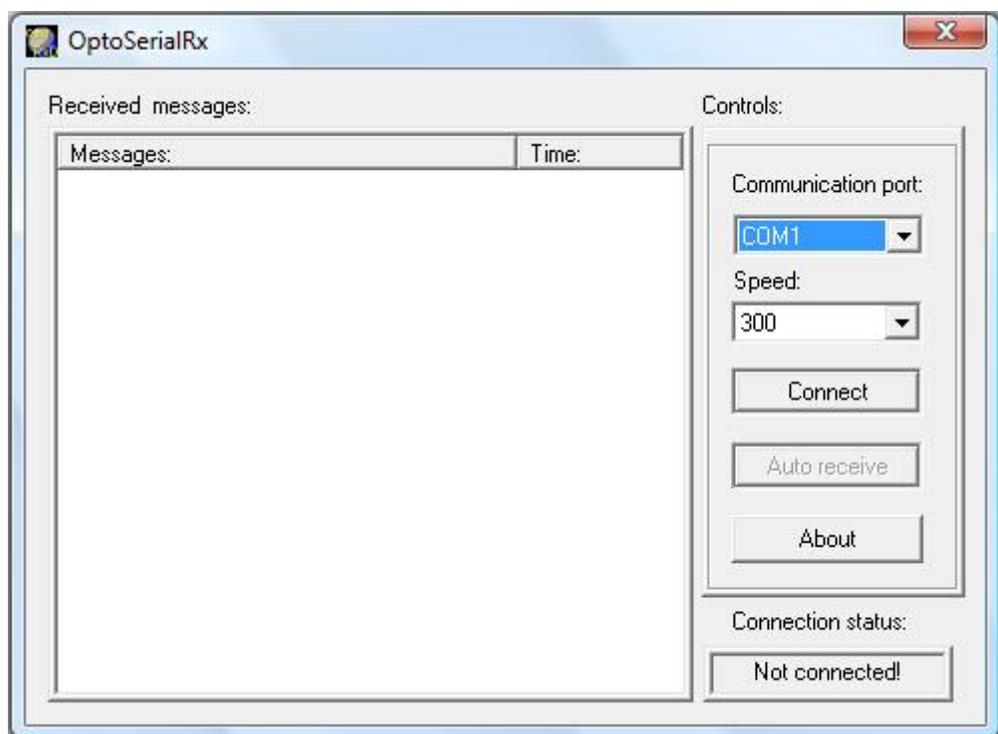Figure 16: OptoSerial-TxD program (on the transmitter computer)

Figure 17: OptoSerial-RxD program (on the receiver computer)

Experiment No.11: The transfer of a video signal (screen) by an optical fibre

Introduction

The composite video signal is a signal that contains all the components required to generate the video signal.

There are three following major components forming a composite signal:

• Luminance component - contains the intensity (brightness) of the screen - video

• Chrominance component - contains the information about the color of the screen - video

• The synchronization component - manages the synchronization on the screen (monitor)

The frequency of this signal is in the MHz range. This task demonstrates the rate of change that the optical fiber is able to pass to the receiving side with the use of amplitude modulation of light.

Objective

Demonstrate the principle of video transmission by an optical fiber and its use in practice.

Equipment

Main transmitter panel, main receiver panel, Video TX module, Video RX module, optical fiber, connecting cables (for camera and TV): video cable RCA/CINCH-RCA/CINCH (2pcs), color CCD video camera PAL/NTSC (not included in kit), TV or LCD monitor with AV input (not included in kit).

Procedure

1. Insert the VIDEO TX module to the slot no.3 of the transmitting panel TX.
2. Insert the VIDEO RX module to the slot no.3 of the receiving panel RX.
3. Cut off and precisely polish the both ends of the uncoated optical fiber with a length of about 20 cm.
4. Connect the transmitting board TX via uncoated optical fiber to the receiving board RX.
5. Connect the VIDEO TX module to the video camera with the video cable and turn on the camera.
6. Connect the VIDEO RX module to the TV or LCD screen with the video cable and set the TV input to AV mode.
7. Connect the 9V DC power supplies to electricity network at first, and then to the main TX and RX panels..
8. You can observe the transmitted video signal from the video camera on TV or LCD screen. The signal is transmitted via optical fiber.

Troubleshooting

1. If the TV screen does not display an image from the camera, make sure the camera is turned on and TV set to AV mode.
2. Try to connect the camera to the TV screen or LCD monitor directly and check connecting video cables.
3. If the picture is poor or unclear, check and, if necessary, polish the optical fiber so the fiber transmits as much light as possible.
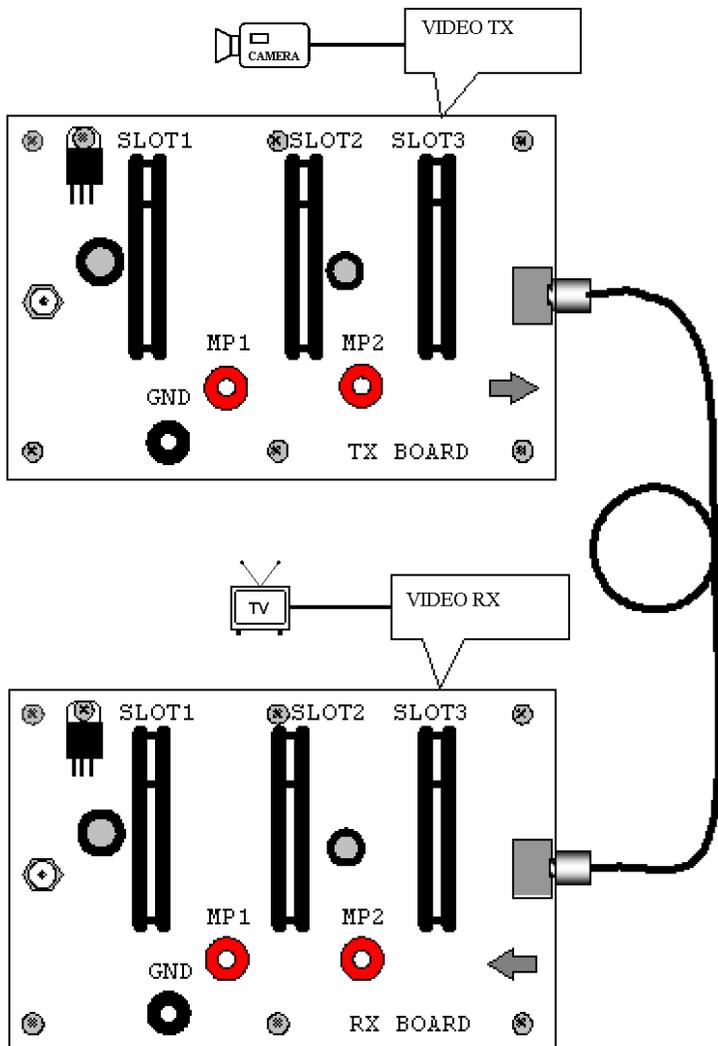4. If the picture is poor or absent at all, mechanically (by blowing) clean the optical fiber holder on the main panels TX and RX.

Figure 19: A set-up diagram of device for video transmission.