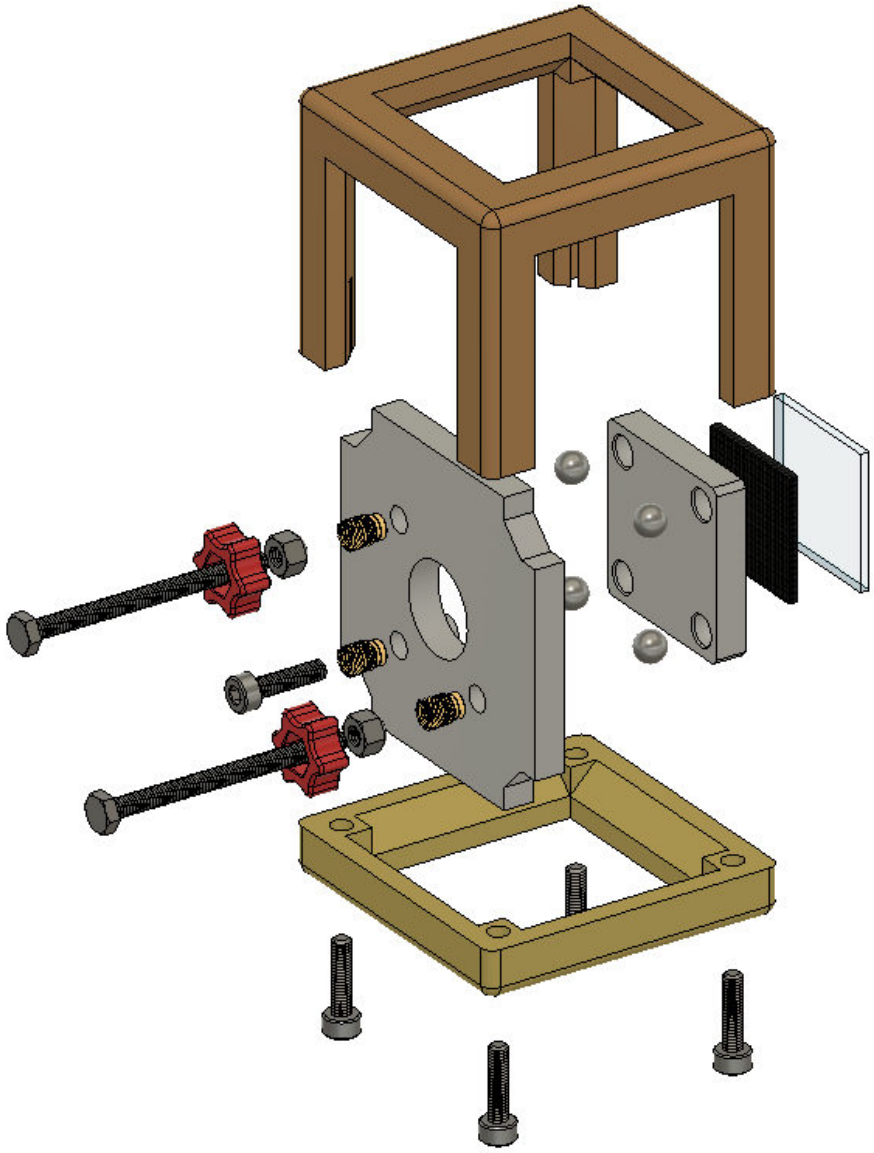
Institut für Didaktik der Physik

Open3 Quantum
Assembling the optical modules



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Preface

The optics modules of the Open3 Quantum (O3Q) project are an innovative way of making the physical phenomena of wave and quantum optics accessible and interactive for teaching purposes. These modules were developed at the Institute for Didactics of Physics at the University of Münster to convey complex topics in an engaging and practice-orientated way. By combining 3D printing technology, modular components and a didactic focus, they offer teachers a flexible basis for integrating exciting experiments into the classroom.

These instructions are designed to support teachers and students in assembling the O3Q modules independently. The modules cover a variety of physics experiments, including the demonstration of basic principles such as reflection, refraction, interference and polarisation. They enable both classic and modern applications, such as the simulation of quantum mechanical processes.

A particular advantage of the O3Q modules is their versatility: the components are designed in such a way that they can be easily adapted to different experimental requirements. At the same time, the modular design allows existing experiment sets to be expanded. This not only promotes an in-depth understanding of physical laws, but also the creativity and problem-solving skills of learners.

The development of these modules is in line with the aims of modern physics teaching: scientific knowledge should not only be taught, but should also be discovered independently. Through the use of resource-saving 3D printing technologies and the integration of interactive elements, the O3Q project offers a future-orientated platform for STEM education.

Further information can be found at www.O3Q.de.

Contents

Tools

Fig. 1: Tools for assembling the O3Q modules

Introduction

Only a limited selection of tools is required to set up and assemble the O3Q experiment cubes. The following overview contains both mandatory and optional tools, supplemented by handling instructions and specific examples from the assembly of the O3Q cubes.

Fig. 2: Wrench

I. 2,5mm Allen key

Standardized 2.5 mm Allen screws are used to connect the O3Q cubes and are essential. An ergonomically shaped screwdriver (Figure 2) and/or a cordless screwdriver with 2.5 mm hexagon socket head (Figure 3). The use of simple L-shaped wrenches is not recommended due to the limited handling.

Fig. 3: Cordless screwdriver (left) with 2.5 mm attachment (right)

II. Stripping tool

Fig. 4: Stripping tool

The stripping tool (Figure 4) is used to remove the insulation from cable ends in preparation for solder connections.

III. Lighter

Fig. 5: Lighter

A commercially available lighter (Figure 5) is used to shrink heat-shrink tubing, which is used to electrically insulate soldered connections.

IV. Baseplate tool

Fig. 6: Baseplate tool

The baseplate tool is required for assembling the baseplates in order to connect two base plates.

V. Hot glue gun

Fig. 7: Hot glue gun

The hot glue gun (Figure 7) is required when assembling the laser module to glue the laser diode into the strain relief.

VI. Lens tool

Fig. 8: Lens tool

The lens tool (Figure 8) can be helpful for inserting the lens into the corresponding insert.

VII. Knife

Fig. 9: Knife

A craft knife (Figure 9) is required for precise cutting work, e.g. to remove the corners from the freshly printed base plate.

VIII. Soldering iron

Fig. 10: Soldering iron

Fig. 11: Soldering tip (left) and tip for melting the thread inserts (right)

The soldering iron (Figure 10) is used for soldering. The soldering tip is used to solder cables together and the tip for melting threaded inserts (Figure 11) is used to melt threaded inserts.

IX. Tweezers

Fig. 12: Tweezers

Tweezers (Figure 12) can be used to handle sensitive or small components. For example, they can help to remove the protective films from optical components such as the beam splitter.

X. Ratchet

Fig. 13: Ratchet (left) with socket wrench attachment (right)

A ratchet with a suitable socket wrench attachment (Figure 13) can alternatively be used to assemble the set screws.

XI. PCB holder

Fig. 14: PCB holder

The PCB holder (Figure 14) is used to hold the components in place during soldering.

XII. Pipe wrench

Fig. 15: Pipe wrench

The pipe wrench (Figure 15) is required to press magnetic spheres into the corresponding components. The magnetic spheres must be aligned in such a way that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically if you press the spheres in with a ferromagnetic pipe wrench (Figure 16).

Fig. 16: Magnetic sphere sticks to ferromagnetic pliers

XIII. Scissors

Fig. 17: Scissors

The scissors (Figure 17) are required for cutting the polarizing filter foil and the adhesive label for the polarizing filter module.

XIV. Side cutter

Fig. 18: Side cutter

The side cutter (Figure 18) is used to shorten cables to the appropriate length.

XV. Pliers

Fig. 19: Pliers

The pliers (Figure 19) can be used to hold components, e.g. when making the set screws.

90° mirror

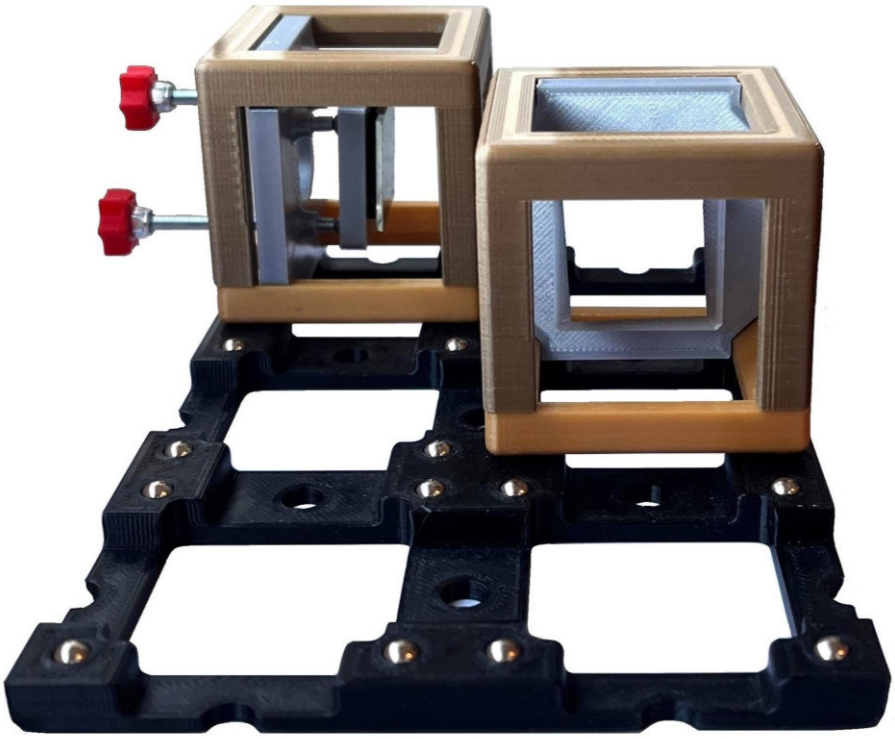

Fig. 1: Adjustable mirror cube - 90°

Introduction

In the 90° mirror module a mirror is held approximately vertically and at a 90° angle to the base plate (Figure 1). The tilt and angle of the mirror can be adjusted using the two screws with the red handles. This is necessary for example for adjusting the Michelson interferometer.

Experiments

- Michelson interferometer - 2 pcs.
- Michelson interferometer with piezoelement - 1 pc.

Material & Tools

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 10A_Si_V*_insert 90°
1x 11C_Si_V*_mirror_plate
2x 03A_Re_V*_adjusting_screw_head

Other components

1x Adhesive pad (20mm x 20mm)
1x Front surface mirror (22mm x 22mm)
4x Magnetic sphere, ø=5mm
3x Thread insert, M3
5x Allen cylinder head screw, M3x12
2x Nut, self-locking, M3
2x Hexagon head screw, M3x40

Tools

- Allen key - 2,5 mm
- Soldering iron (+ tip for threaded inserts)
- (Pipe) wrench
- (ratchet + socket spanner attachment 12 mm)
- (tweezers)

Exploded view

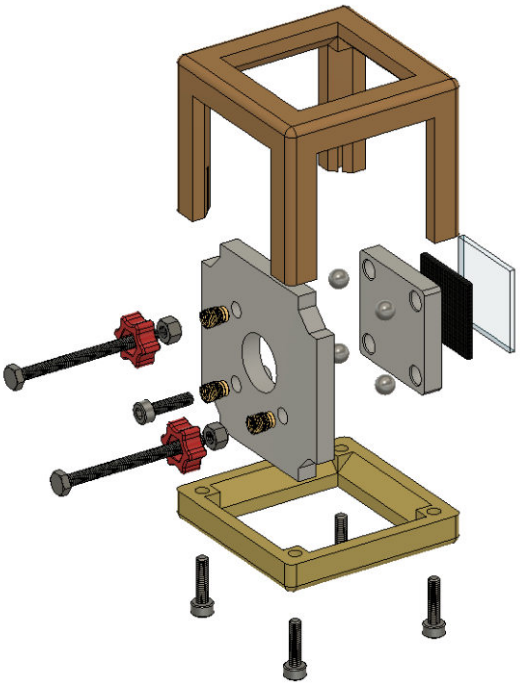

Fig. 3: Exploded view of the 90° mirror cube

I. Adjusting screw (2x)

Material

2x 03A_Re_V*_adjusting_screw_head
2x Hexagon head screw, M3x40
2x Nut, self-locking, M3

(1) Place the 03A_Re_V*_adjusting_screw_head onto a Hexagon head screw, M3x40 with the hexagonal opening facing the screw head.

(2) Then turn the Nut, self-locking, M3 onto the screw so that it holds the red screw head in place (Figure 4).

Note: *The red screw head fits 12 mm socket spanner attachments so that the nut can also be tightened with a cordless screwdriver or ratchet.*

(3) Repeat these steps for the second adjusting screw (Figure 4).

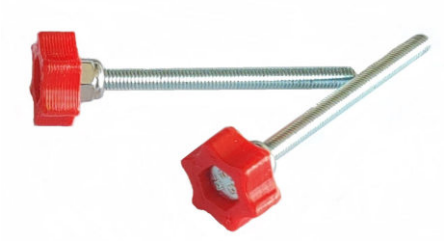

Fig. 4: Ready assembled screw

II. Adjusting plate

Material

2x Ready assembled screw
1x 10A_Si_V*_insert 90°
3x Thread insert, M3
1x Allen cylinder head screw, M3x12

(4) If necessary mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(5) Place the Thread insert, M3 in the designated openings of the 10A_Si_V*_insert 90° (Figure 5).

(6) Attention: Carefully melt the threaded inserts into the 90° insert with the soldering iron so that the inserts are flush with the surface. Ensure that the inserts are melted in as vertically as possible (Figure 5).

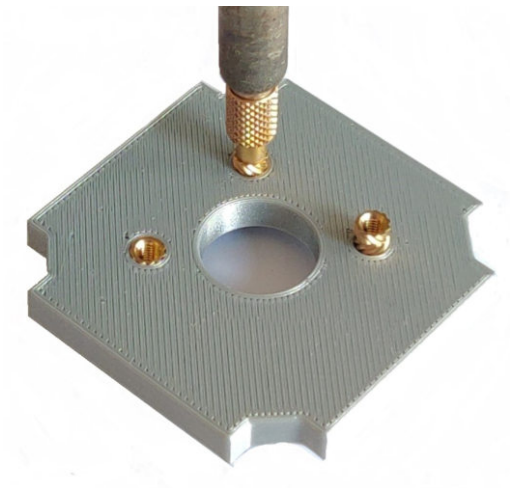

Fig. 5: Melting down the thread inserts

(7) Screw the Allen cylinder head screw, M3x12 completely into the centre of the three thread inserts (Figure 6).

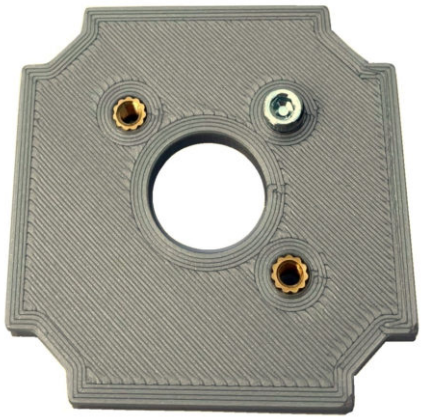

Fig. 6: Allen screw in the adjusting plate

(8) Screw the two Ready assembled screw into the other two threaded inserts so that they protrude approximately as far as the allen screw on the other side (Figure 7).

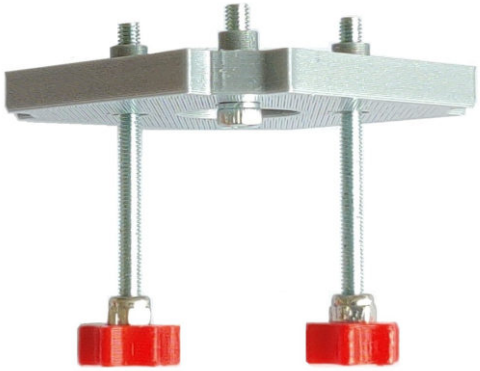

Fig. 7: Finished adjusting plate

III. Mirror plate

Material

1x 11C_Si_V*_mirror_plate
4x Magnetic sphere, ø=5mm
1x Adhesive pad (20mm x 20mm)
1x Front surface mirror (22mm x 22mm)

(9) Press the four Magnetic sphere, ø=5mm into the openings of the 11C_Si_V*_mirror_plate .

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically when you press the spheres in with a ferromagnetic pipe wrench.*

Fig. 8: The correct fit can be checked with another magnetic ball: The left-hand ball is well aligned. The ball on the right should be rotated slightly.

(10) Glue the adhesive pad (20mm x 20mm) to the centre of the mirror plate on the opposite side (Figure 9).

Fig. 9: Adhesive pad on mirror plate

(11) Stick the Front surface mirror (22mm x 22mm) in the centre of the adhesive pad so that the reflective side is facing upwards (Figure 10).

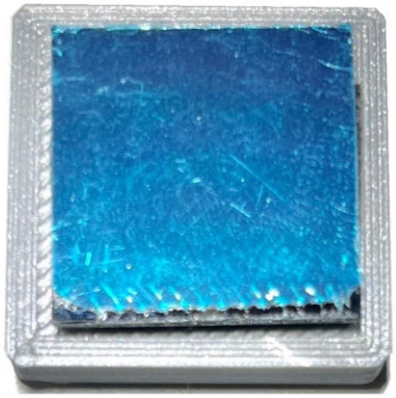

Fig. 10: Finished mirror plate

(12) Remove the blue protective film from the mirror (using tweezers if necessary).

Note: *The mirror is a front surface mirror. The reflective surface is therefore in front of the glass pane and not behind the glass pane as is usual with household mirrors. The glass plate is vapour-coated with a metallic layer and a thin protective layer on top. Despite the protective layer, the mirrors are not as easy to clean as standard household mirrors.*

IV. Last steps

Material

1x Finished mirror plate
1x Finished adjusting plate
1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
4x Allen cylinder head screw, M3x12

(13) Assemble the 02A_Br_V*_cube_cover 1x1 and the Finished adjusting plate (Figure 11).

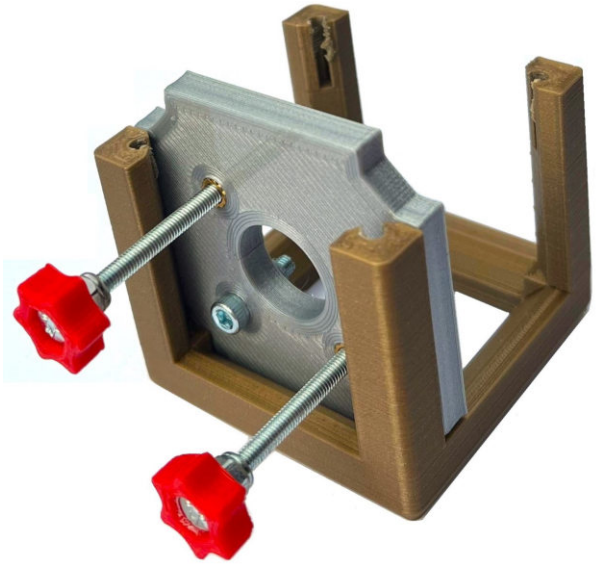

Fig. 11: Adjustment insert in the cube cover

(14) Place the 01A_Go_V*_cube_base 1x1 on top and secure it with the Allen cylinder head screw, M3x12 (Figure 12).

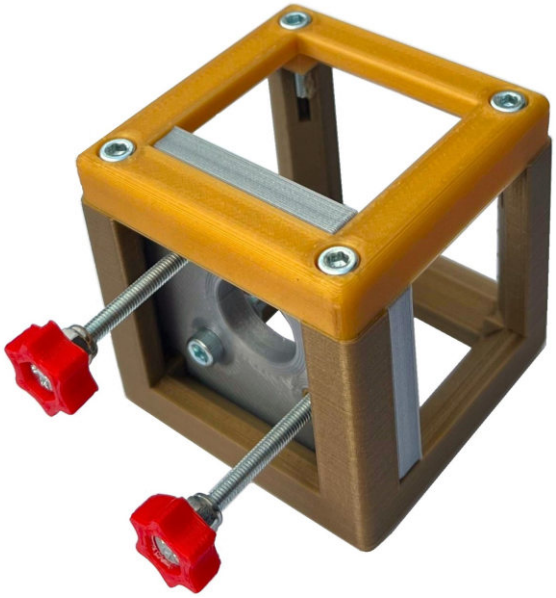

Fig. 12: Assembled cube

(15) Carefully place the Finished mirror plate on the 3 screws in the cube using the magnets (Figure 13).

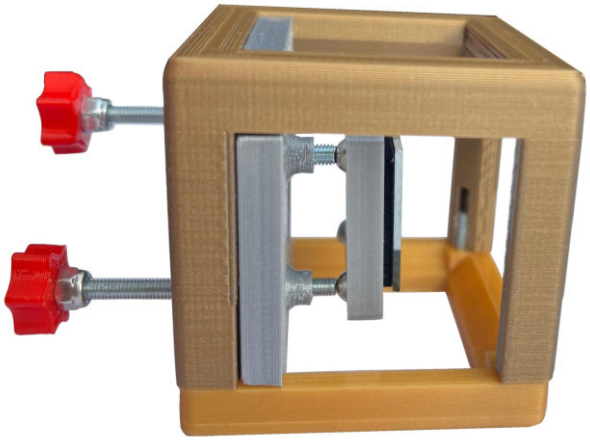

Fig. 13: Finished cube

45°-Mirror

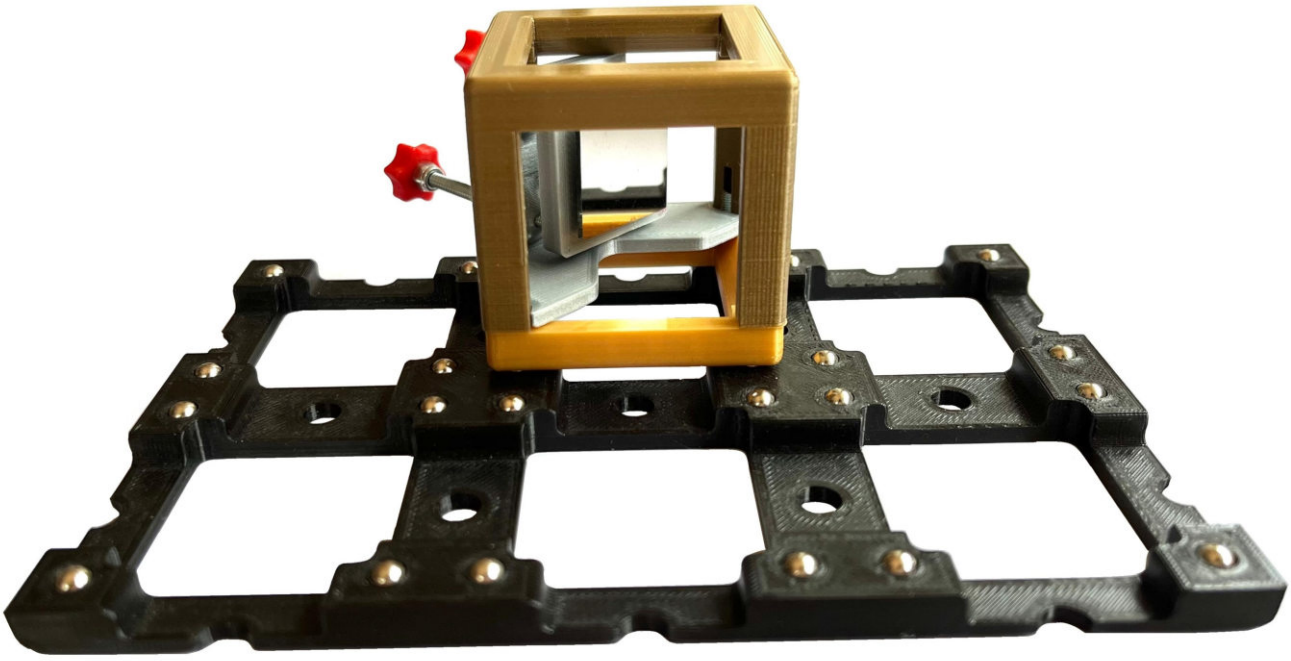

Fig. 1: Adjustable mirror cube - 45°

Introduction

In the 45° mirror module, a mirror is held approximately vertically and at a 45° angle to the cube (Figure 1).
The tilt and angle of the mirror can be adjusted using the two screws with the red handles. This is necessary, for example, for adjusting the Mach-Zehnder interferometer.

Experiments

- ▷ Mach-Zehnder interferometer - 2 pcs./3 pcs.
- ▷ Quanten eraser - 2 pcs./3 pcs.
- ▷ BB84 model experiment - 1 pc.

Material & Tools

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 10B_Si_V*_insert 45°
1x 11C_Si_V*_mirror_plate
2x 03A_Re_V*_adjusting_screw_head

Other components

1x Adhesive pad (20mm x 20mm)
1x Front surface mirror (22mm x 22mm)
4x Magnetic sphere, ø=5mm
3x Thread insert, M3
5x Allen cylinder head screw, M3x12
2x Nut, self-locking, M3
2x Hexagon head screw, M3x40

Tools

- ▷ Allen key - 2,5 mm
- ▷ Soldering iron (+ tip for threaded inserts)
- ▷ (Pipe) wrench
- ▷ (ratchet + socket spanner attachment 12 mm)
- ▷ (tweezers)

Exploded view

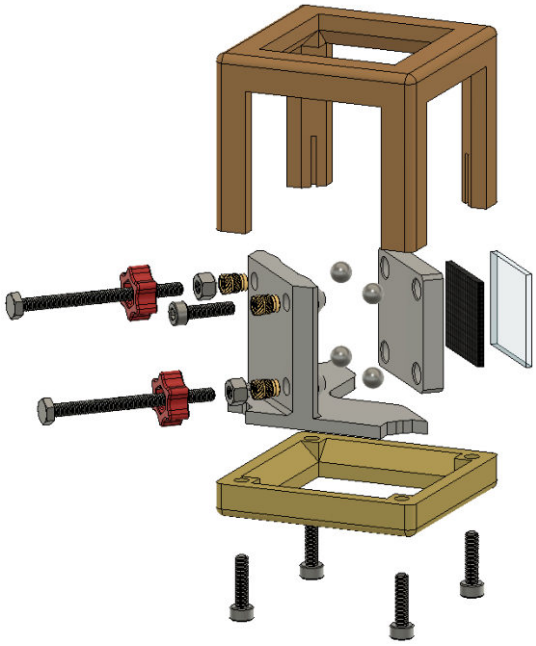

Fig. 3: Exploded view of the 45° mirror cube

I. Adjusting screw (2x)

Material

2x 03A_Re_V*_adjusting_screw_head
2x Hexagon head screw, M3x40
2x Nut, self-locking, M3

(1) Place the 03A_Re_V*_adjusting_screw_head onto a Hexagon head screw, M3x40 with the hexagonal opening facing the screw head.

(2) Then turn the Nut, self-locking, M3 onto the screw so that it holds the red screw head in place (Figure 4).

Note: *The red screw head fits 12 mm socket spanner attachments so that the nut can also be tightened with a cordless screwdriver or ratchet.*

(3) Repeat these steps for the second adjusting screw (Figure 4).

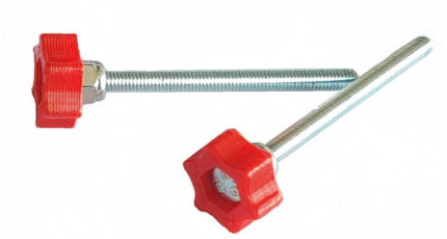

Fig. 4: Ready assembled screw

II. Adjusting plate

Material

2x Ready assembled screw
1x 10B_Si_V*_insert 45°
3x Thread insert, M3
1x Allen cylinder head screw, M3x12

(4) If necessary, mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(5) Place the Thread insert, M3 in the designated openings of the 10B_Si_V*_insert 45° (Figure 5).

(6) Carefully melt the thread inserts into the 45° insert with the soldering iron so that the inserts are flush with the surface. Ensure that the inserts are melted in as vertically as possible (Figure 5).

Fig. 5: Melting down the thread inserts

(7) Screw the Allen cylinder head screw, M3x12 completely into the centre of the three thread inserts (Figure 6).

(8) Screw the two ready assembled screws into the other two thread inserts so that they protrude roughly as far as the Allen screw on the other side (Figure 6).

Fig. 6: Finished adjusting plate

III. Mirror plate

Material

1x 11C_Si_V*_mirror_plate
4x Magnetic sphere, ø=5mm
1x Adhesive pad (20mm x 20mm)
1x Front surface mirror (22mm x 22mm)

(9) Press the four Magnetic sphere, ø=5mm into the openings of the 11C_Si_V*_mirror_plate .

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically when you press the spheres in with a ferromagnetic pipe wrench.*

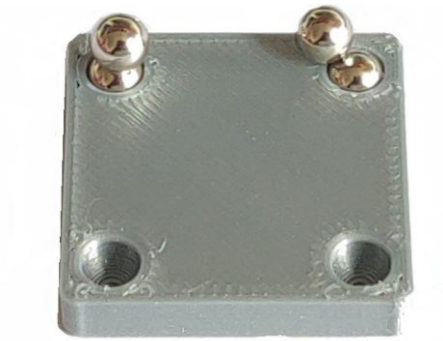

Fig. 7: The correct fit can be checked with another magnetic ball: The left-hand ball is well aligned. The ball on the right should be rotated slightly.

(10) Glue the Adhesive pad (20mm x 20mm) to the centre of the mirror plate on the opposite side (Figure 8).

Fig. 8: Adhesive pad on mirror plate

(11) Stick the Front surface mirror (22mm x 22mm) in the centre of the adhesive pad so that the reflective side is facing upwards (Figure 9).

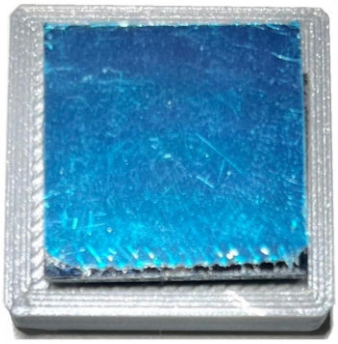

Fig. 9: Finished mirror plate

(12) Remove the blue protective film from the mirror (using tweezers if necessary).

Note: *The mirror is a front surface mirror. The reflective surface is therefore in front of the glass pane and not behind the glass pane as is usual with household mirrors. The glass plate is vapour-coated with a metallic layer and a thin protective layer on top. Despite the protective layer, the mirrors are not as easy to clean as standard household mirrors.*

IV. Last steps

Material

1x Finished mirror plate
1x Finished adjusting plate
1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
4x Allen cylinder head screw, M3x12

(13) Assemble the 01A_Go_V*_cube_base 1x1 , the 02A_Br_V*_cube_cover 1x1 and the Finished adjusting plate (Figure 10).

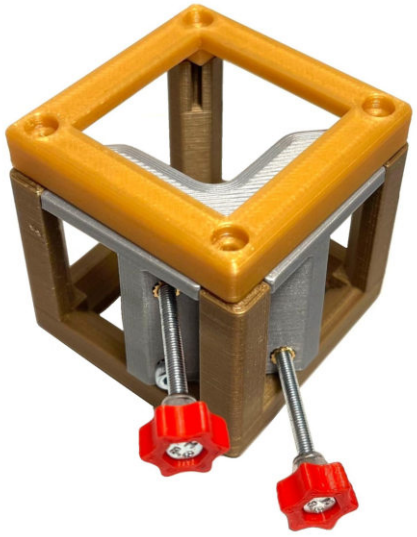

Fig. 10: Assembled cube

(14) Fasten the cube with the four ALLEN CYLINDER HEAD-SCREW, M3X12 .

(15) Carefully place the FINISHED MIRROR PLATE on the 3 screws in the cube using the magnets (Figure 11).

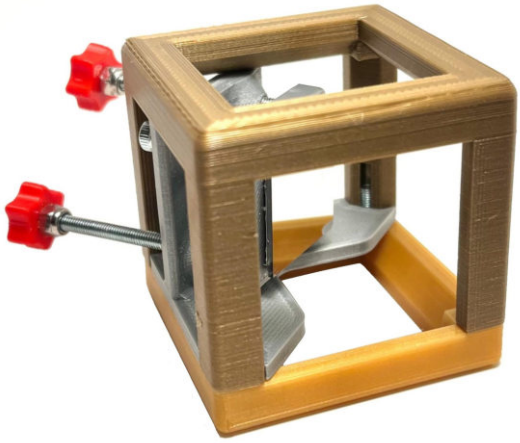

Fig. 11: Finished cube

Beamsplitter

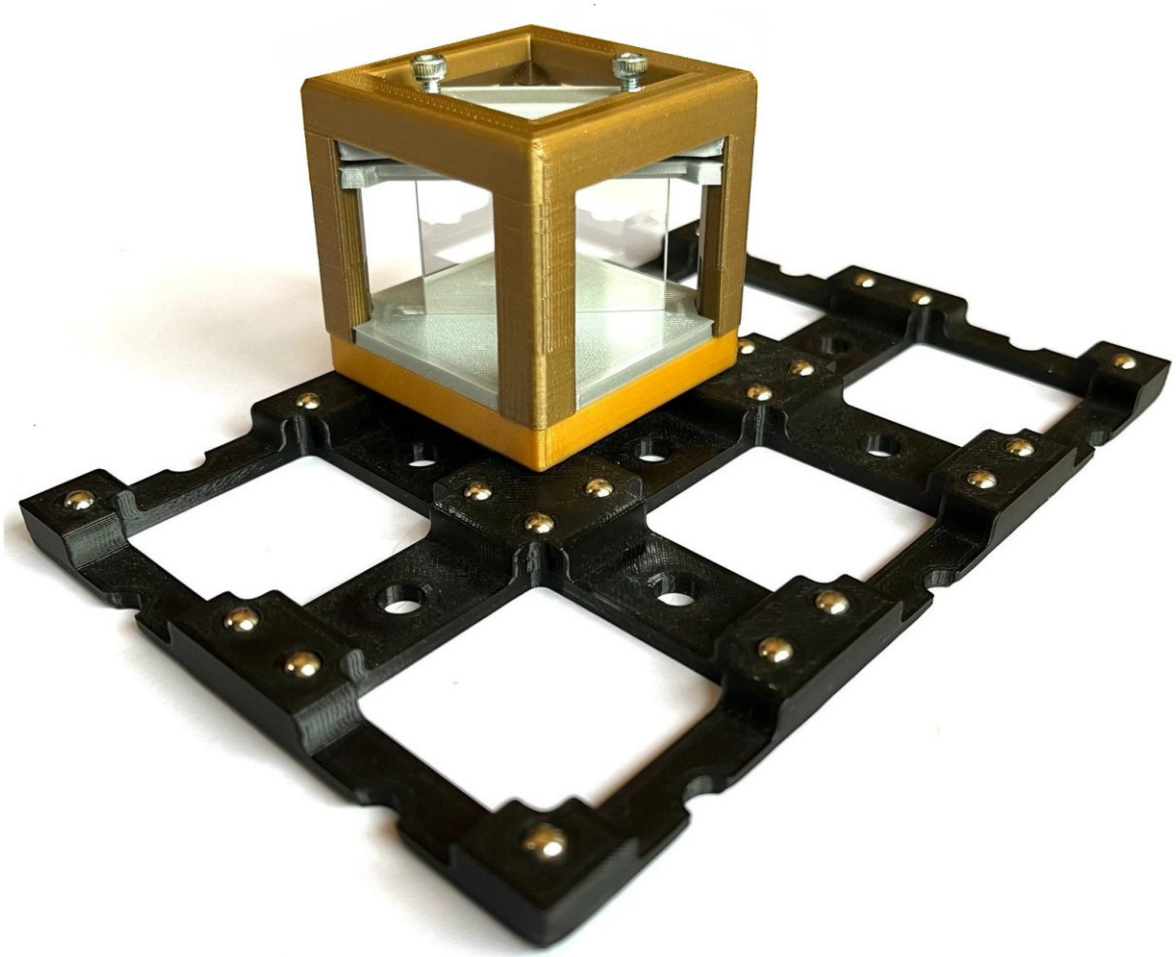

Fig. 1: Beamsplitter

Introduction

In the beamsplitter module a vapourised mirror is held at an angle of approximately 90° to the base plate and 45° to the cube (Figure 1). The vapour-coated mirror reflects and transmits approximately half of the incident light and thus acts as a beamsplitter.

Experiments

- Michelson interferometer - 1 pc.
- Michelson interferometer with piezo element - 1 pc.
- Mach-Zehnder interferometer - 2 pcs.
- Quantum eraser - 2 pcs.
- BB84 model experiment - 1 pc.

Material & Tools

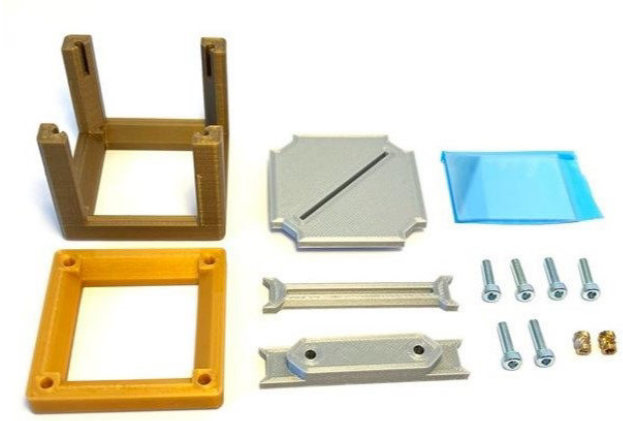

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 12A_Si_V*_beamsplitter_clamp
1x 12A_Si_V*_beamsplitter_top
2x 12A_Si_V*_beamsplitter_bottom

Other components

1x Semi-transparent front surface mirror (40mm x 30mm)
2x Thread insert, M3
6x Allen cylinder head screw, M3x12

Tools

- Allen key - 2.5mm
- Soldering iron (+ tip for threaded inserts)
- (Pipe) wrench
- (Tweezers)

Exploded view

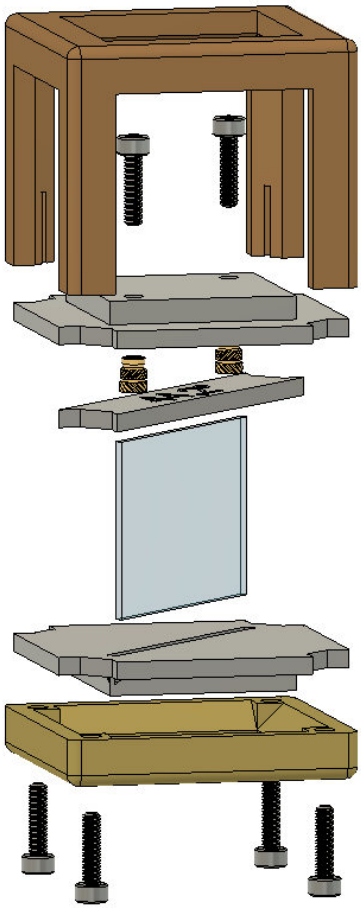

Fig. 3: Exploded view of the beamsplitter cube

I. Melting down thread inserts

Material

1x 12A_Si_V*_beamsplitter_top
2x Thread insert, M3

(1) If necessary mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(2) Place the two `Thread insert, M3` in the openings provided in the `12A_Si_V*_beamsplitter_top` (Figure 4).

Fig. 4: Correctly positioned thread inserts

(3) Carefully melt the thread inserts into the insert with the soldering iron so that the inserts are flush with the surface.

Note: *Make sure to melt the inserts as vertically as possible (Figure 5).*

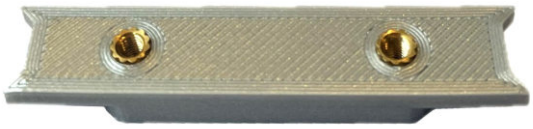

Fig. 5: Fully melted thread inserts

II. Insert beamsplitter

Material

1x Beamsplitter insert with thread inserts
1x 02A_Br_V*_cube_cover 1x1
1x 12A_Si_V*_beamsplitter_clamp
2x 12A_Si_V*_beamsplitter_bottom
1x Semi-transparent front surface mirror (40mm x 30mm)

(4) Place the Beamsplitter insert with thread inserts in the 02A_Br_V*_cube_cover 1x1 so that the thread inserts are facing upwards (Figure 6).

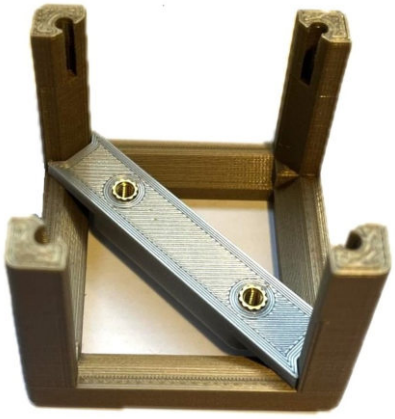

Fig. 6: Correctly inserted upper part

(5) Place the 12A_Si_V*_beamsplitter_clamp with the slot facing upwards over the beam splitter insert in the cube cover so that the two thread inserts are covered (Figure 7).

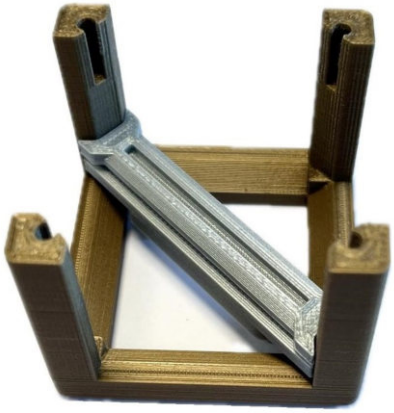

Fig. 7: Used beamsplitter clamp

(6) Carefully remove (with tweezers if necessary) the protective film on both sides of the Semi-transparent front surface mirror (40mm x 30mm) .

Attention: *From now on, take care not to leave any fingerprints on the reflective surfaces!*

(7) Place the semi-transparent front surface mirror with one of the long edges in the slot (Figure 8).

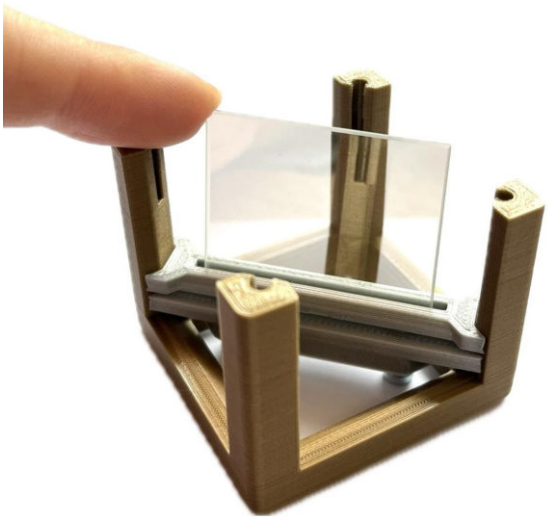

Fig. 8: Front surface mirror in the correct position

(8) Now carefully insert the 12A_Si_V*_beamsplitter_bottom into the lid with the slot facing downwards so that the partially transparent front surface mirror is held in the two slots. To do this, it may need to be tilted slightly into the correct position (Figure 9).

Fig. 9: Front surface mirror clamped between the two components

III. Last steps

Material

1x 01A_Go_V*_cube_base 1x1

6x Allen cylinder head screw, M3x12

(9) Place the 01A_Go_V*_cube_base 1x1 on the cube as shown in Figure 10.

Fig. 10: Composite cube

(10) Fasten the cube with four Allen cylinder head screw, M3x12 (Figure 11).

Fig. 11: Screwed together beam splitter

(11) Now turn the cube over (Figure 12).

Fig. 12: Assembled beamsplitter without fixing screws

(12) Carefully screw two Allen cylinder head screw, M3x12 into the thread inserts from above until the clamp is firmly seated on the front surface mirror. Take care not to damage the front surface mirror (Figure 13).

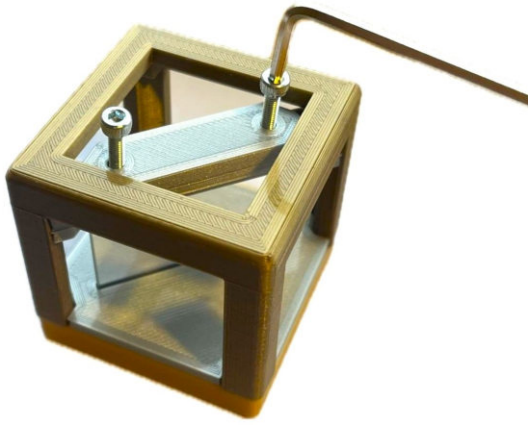

Fig. 13: Fastening the semi-transparent front surface mirror

Lens

Fig. 1: Lens module

Introduction

In the lens module, a lens is held approximately perpendicular to the base plate. The lens can have different focal lengths (Figure 1).

Experiments

- Michelson interferometer - 1 pc. (15 mm)
- Michelson interferometer with piezoelement - 1 pc.(15 mm)
- Mach-Zehnder interferometer - 1 pc. (26,5 mm)
- Polarisation - 1 pc. (65 mm)
- BB84 - 1 pc. (65 mm)

Material & Tools

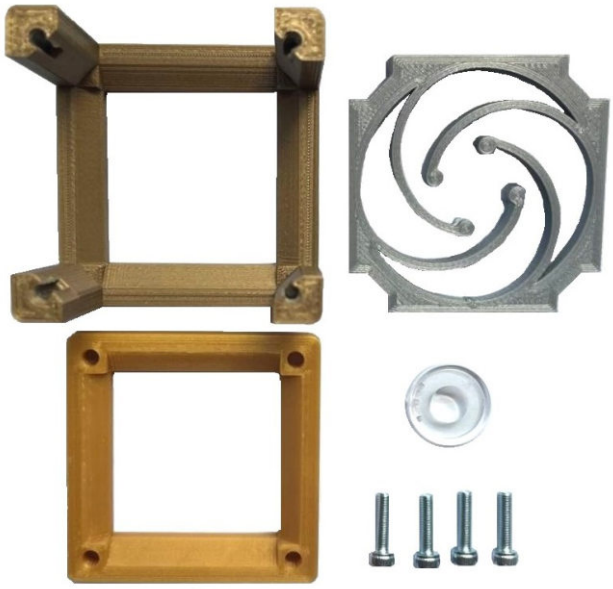

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1

1x 02A_Br_V*_cube_cover 1x1

1x 13A_Si_V*_lens_holder *oder*
13B_Si_V*_lens_holder_f=15mm *oder*
13C_Si_V*_lens_holder_f=26,5mm *oder*
13D_Si_V*_lens_holder_f=65mm

Other components

1x Lens, f=15 mm, ø=16,5mm *oder*
Lens, f=26,5 mm, ø=15mm *oder*
Lens, f=65 mm, ø=16,5mm

4x Allen cylinder head screw, M3x12

Tools

▷ Allen key - 2,5 mm

▷ (3D printing tool to insert lenses (Figure 3))

Fig. 3: Lens tool

Exploded view

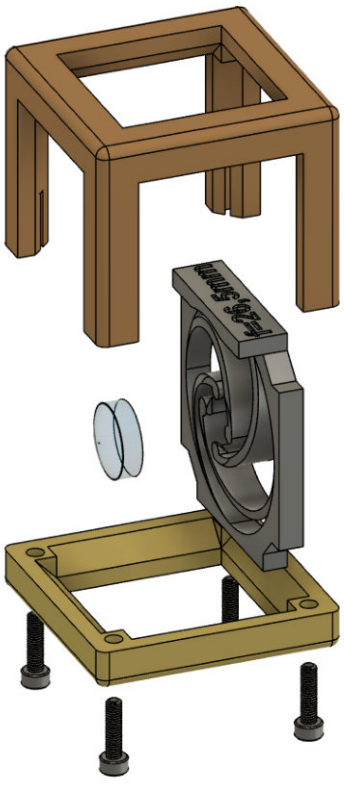

Fig. 4: Exploded view of the lens cube

I. Assembly

Material

1x 13A_Si_V*_lens_holder *oder*
13B_Si_V*_lens_holder_f=15mm *oder*
13C_Si_V*_lens_holder_f=26,5mm *oder*
13D_Si_V*_lens_holder_f=65mm

1x Lens, f=15 mm, ø=16,5mm *oder*
Lens, f=26,5 mm, ø=15mm *oder*
Lens, f=65 mm, ø=16,5mm

1x 01A_Go_V*_cube_base 1x1

1x 02A_Br_V*_cube_cover 1x1

4x Allen cylinder head screw, M3x12

(1) Place the `LENS, F=* Ø=*` in the `13*_SI_V*_LENS_HOLDER_F=*` (Figure 5).

Tip: *You can use the lens tool to keep the arms apart.*

Fig. 5: Lens in lens holder

(2) Place the lens holder with the lettering facing downwards in the `02A_BR_V*_CUBE_COVER 1X1` (Figure 6).

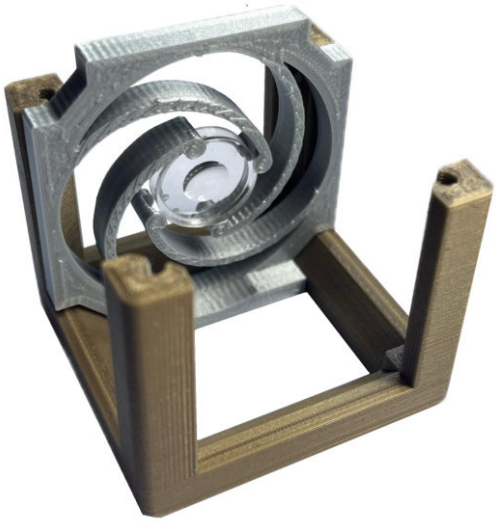

Fig. 6: Lens holder in the cube cover

(3) Place the `01A_GO_V*_CUBE_BASE 1X1` on the cover (Figure 7).

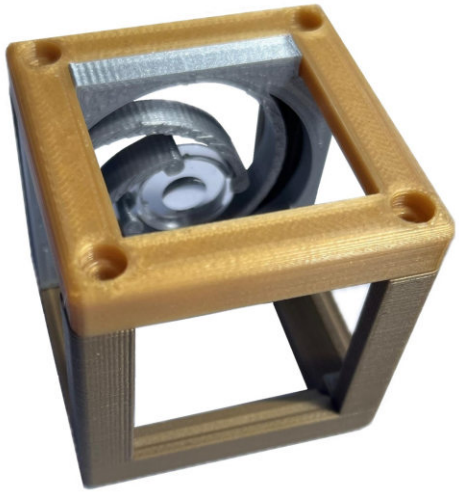

Fig. 7: Composite cube

(4) Attach the cube base to the cube cover using the four Allen cylinder head screw, M3x12 (Figure 8).

Fig. 8: Lens cube screwed together

Laser module

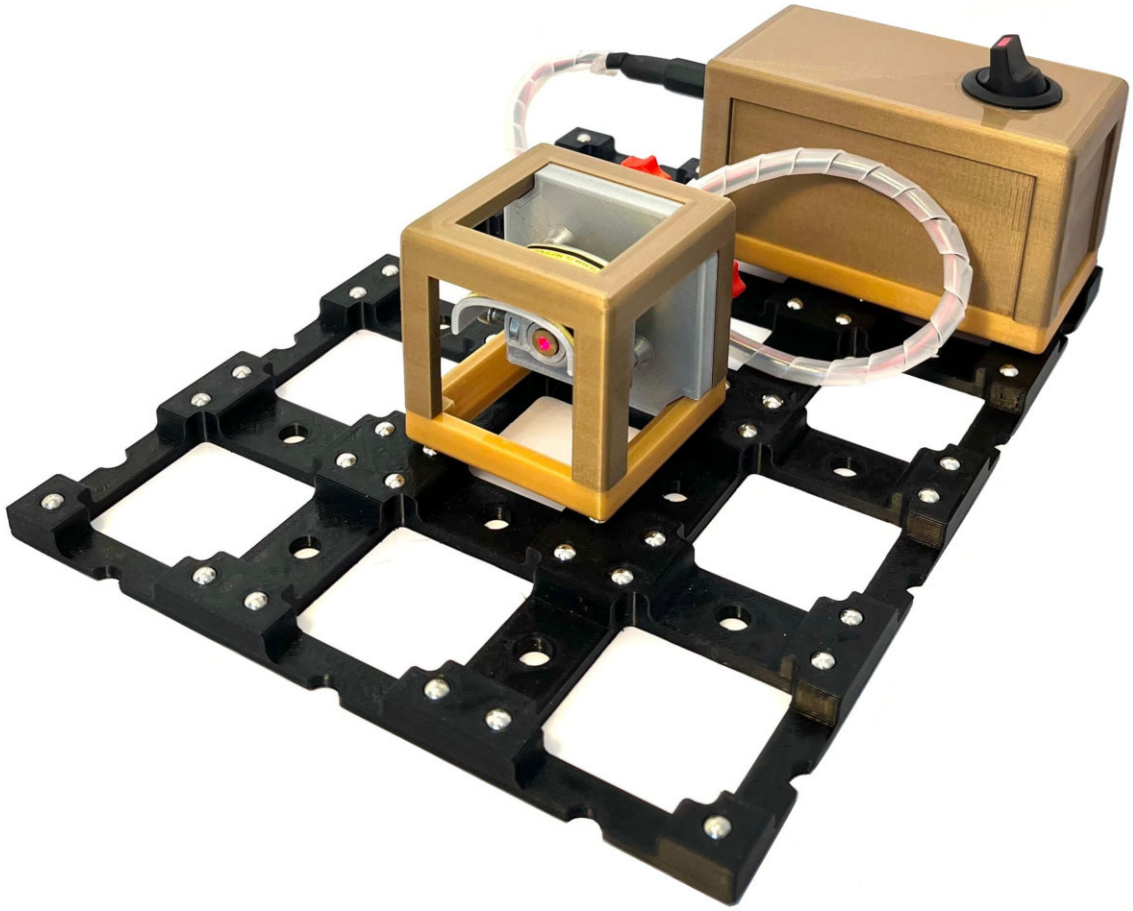

Fig. 1: Connected laser diode

Introduction

A laser diode is held approximately perpendicular to the base plate in the laser module (Figure 1). This is connected to the battery box module via a cable so that the laser diode can be switched on and off.

Experiments

- Michelson interferometer - 1 pc.
- Michelson interferometer with piezoelement - 1 pc.
- Mach-Zehnder interferometer - 1 pc.
- Slits & diffraction grating - 1 pc.
- Polarisation - 1 pc.
- BB84 model experiment - 1 pc.

Material & Tools

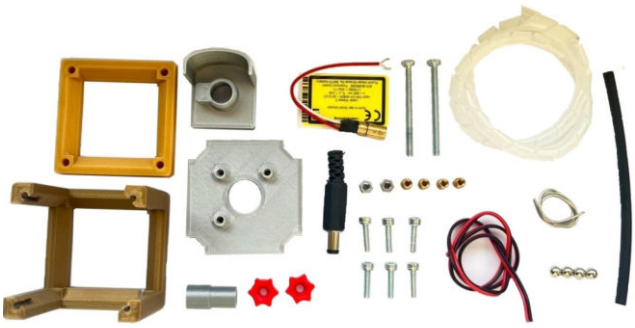

Fig. 2: Benötigtes Material

3D-Druck

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 10A_Si_V*_insert 90°
1x 11A_Si_V*_laser_plate
1x 11A_Si_V*_laser_strain_relief
2x 03A_Re_V*_adjusting_screw_head
1x XX3_Sign_laser_warning

Other components

1x Laserdiode 3V
1x Barrel connector
4x Thread insert, M3
4x Magnetic sphere, ø=5mm
8x Allen cylinder head screw, M3x12
2x Nut, self-locking, M3
2x Hexagon head screw, M3x40
▷ Spiral hose
▷ Shrink tubing
▷ Twin strand
▷ Solder tin
▷ Superglue

Tools

▷ Allen key - 2.5mm
▷ Soldering iron (+ tip for thread inserts)
▷ (pipe) wrench
▷ (ratchet + socket spanner attachment 12 mm)
▷ Side cutter
▷ PCB holder for soldering
▷ Lighter
▷ Stripping tool
▷ Hot glue applicator

Exploded view

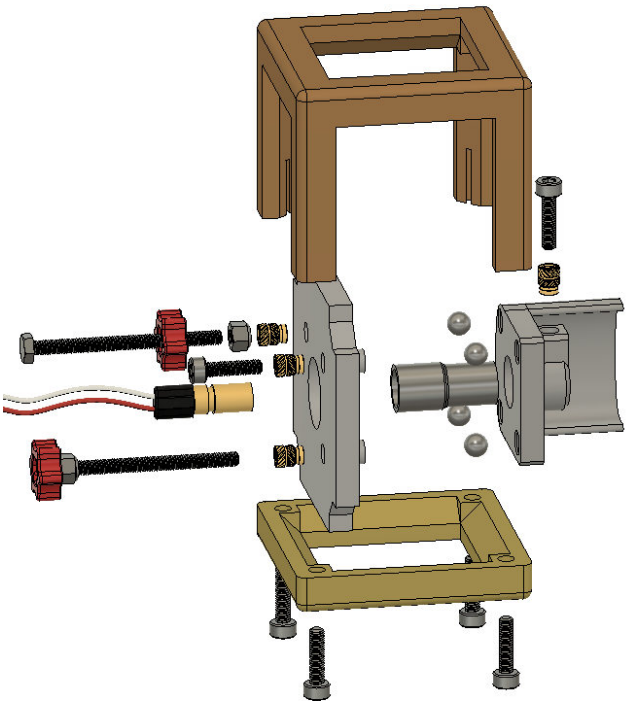

Fig. 3: Exploded view of the laser diode cube

I. Adjusting screw (2x)

Material

2x 03A_Ro_V1_Adjusting screw_Head
2x Hexagon head screw, M3x40
2x Nut, self-locking, M3

(1) Slide the 03A_Re_V*_adjusting screw_head with the hexagonal opening first onto a Hexagon head screw, M3x40 .

(2) Then turn the Nut, self-locking, M3 onto the screw so that it holds the red screw head in place (Figure 4).

Note: *The red screw head fits 12 mm socket spanner attachments so that the nut can also be tightened with a cordless screwdriver or ratchet.*

(3) Repeat these steps for the second adjusting screw (Figure 4).

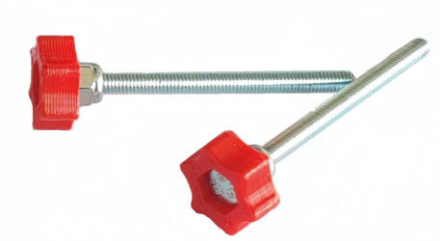

Fig. 4: Ready assembled screws

II. Adjusting plate

Material

2x Ready assembled screws
1x 10A_Si_V*_insert 90°
3x Nut, M3
1x Allen cylinder head screw, M3x12

(4) If necessary, mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(5) Place the Thread insert, M3 in the designated openings of the 10A_Si_V*_insert 90° (Figure 5).

(6) Carefully melt the thread inserts into the 90° insert with the soldering iron so that the thread inserts are flush with the surface. Ensure that the inserts are melted in as vertically as possible (Figure 5).

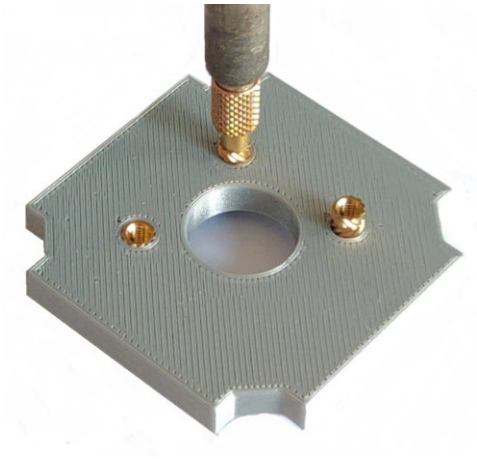

Fig. 5: Melting down the thread inserts

(7) Screw the Allen cylinder head screw, M3x12 completely into the centre of the three thread inserts (Figure 6).

(8) Screw the two ready assembled screws into the other two thread inserts so that they protrude roughly as far as the Allen screw on the other side (Figure 6).

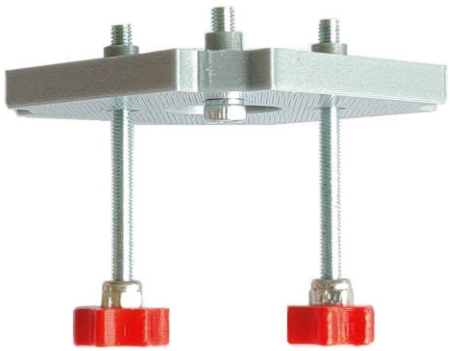

Fig. 6: Finished adjusting plate

III. Laserplatte

Material

1x 11A_Si_V*_laser_plate
4x Magnetic sphere, ø=5mm
1x Thread insert, M3

(9) Press the four Magnetic sphere, ø=5mm into the openings of the 11A_Si_V*_laser_plate (Figure 7).

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically when you press the spheres in with a ferromagnetic pipe wrench.*

Fig. 7: Magnetic spheres pressed into the plate

(10) Affix the laser warning label supplied with the laser diode to the top of the laser plate (Figure 8).

Tip: *A small drop of liquid adhesive improves the adhesion of the laser warning sign to the laser plate.*

Fig. 8: Laser warning sign glued to the laser plate

(11) Melt the Thread insert, M3 into the opening on the side of the laser plate so that the insert is flush with the surface

(Figure 9). Ensure that the insert is melted in as vertically as possible.

Fig. 9: Thread insert melted into the laser plate

IV. Laserdiode

Material

1x 11A_Si_V*_laser_strain_relief
1x Laserdiode 3V
1x Barrel connector
▷ Shrink tubing
▷ Twin strand
▷ Solder tin
▷ Super glue

(12) Take a piece of the TWIN STRAND (approx. 25 cm), strip one end and pull the two cables slightly apart.

(13) Repeat the process with the cable on the LASERDIODE 3V .

(14) Pull a piece of the SHRINK TUBING over each cable of the laser diode (Figure 10).

Fig. 10: shrink tubing over the cables on the laser diode

(15) Fit the soldering tip to the soldering iron and heat it to 350°C.

(16) Solder the red cable of the laser diode to the red cable of the twin strand and the white cable of the laser diode to the black cable of the twin strand (Figure 11).

Note: *A clamp for clamping the cables can be helpful for soldering. Also make sure to push the shrink tubing as far away from the soldering point as possible before soldering to prevent it from shrinking during soldering.*

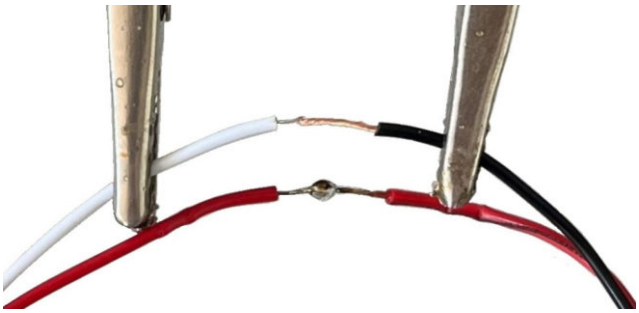

Fig. 11: Soldering the cables together

Fig. 12: Soldered cable with the laser diode

(17) Pull the shrink tubing over the soldered joints and heat it carefully with a lighter or similar so that it shrinks together (Figure 13).

Fig. 13: Shrink tubing over the solder joints

(18) Unscrew the BARREL CONNECTOR and pull the sleeve over the other end of the cable. Strip this too and pull the cables apart slightly.

(19) Pull a piece of shrink tubing over the red cable. Now solder the red cable to the short part of the connector (Figure 14).

Note: *A clamp for clamping the cables can be helpful for soldering. Also make sure to push the shrink tubing as far away from the soldering point as possible before soldering to prevent it from shrinking during soldering.*

Fig. 14: Soldering the hollow connector to the cable

(20) Pull the shrink tubing over the solder joint and heat it carefully with a lighter or similar so that it shrinks together and completely encloses the solder joint.

(21) Solder the black end of the cable to the long part of the connector. To do this, pull the stripped piece through the hole and fold it over slightly so that the solder can bond with the materials (Figure 15).

Fig. 15: Soldering the connector to the cable

(22) Carefully press the cables and then the connector holder together (Figure 16).

Fig. 16: Completely soldered connector

(23) Now pull the black cap over the connector and screw it tight (Figure 17).

Fig. 17: Finished connector

(24) Rotate the SPIRAL HOSE around the twin strand so that it is completely encased (Figure 18).

Fig. 18: Finished laserdiode

(25) Use hot SUPERGLUE to glue the laser diode into the 11A_SI_V*_LASER_STRAIN_RELIEF (Figure 19).

Note: *Make sure that the laser diode is glued straight into the strain relief so that it is not restricted in its function. Also press it into the strain relief as far as possible. The strain relief serves to protect the driver board soldered to the rear part of the laser diode from breaking off.*

Fig. 19: Laser diode glued into the strain relief

V. Last steps

Material

1x Finished adjusting plate
1x Finshed laser plate
1x Soldered laserdiode
1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
5x Allen cylinder head screw, M3x12

(26) Push the SOLDERED LASERDIODE as far as possible through the back of the FINISHED LASERPLATE and carefully screw a ALLEN CYLINDER HEAD SCREW, M3X12 through the thread insert until the laserdiode is firmly seated (Figure 20).

Fig. 20: Laser diode inserted into the laser plate

(27) Assemble the 02A_BR_V*_CUBE_COVER 1X1 and the FINISHED ADJUSTING PLATE (Figure 21).

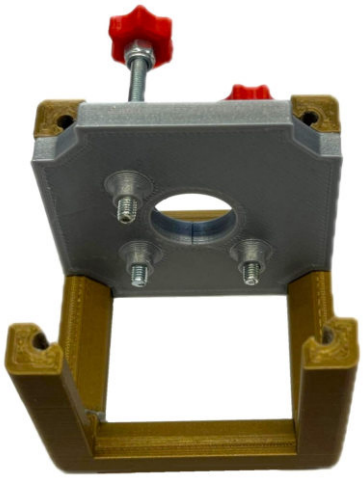

Fig. 21: Composite cube

(28) Pull the laser diode cable out of the cube from the inside through the hole provided and attach the laser plate with the balls on the screws (Figure 22).

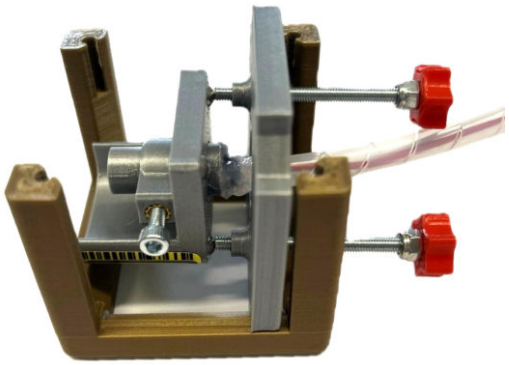

Fig. 22: Laser module inserted into the cube cover

(29) Place the 01A_GO_V*_CUBE_BASE 1X1 on the base of the cube and secure it with the four ALLEN CYLINDER HEAD SCREW, M3X12 (Figure 23).

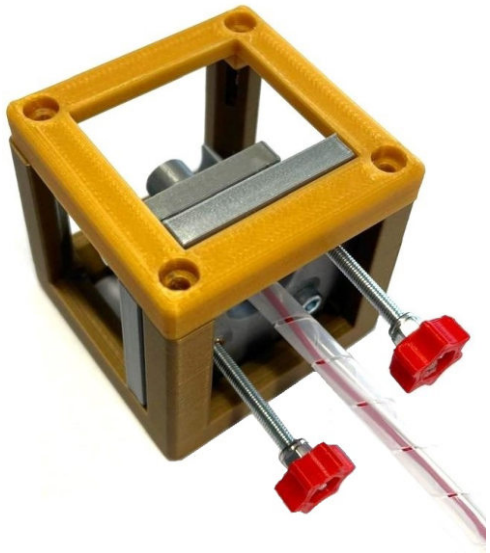

Fig. 23: Assembled laser module

VI. Laser warning sign

Fig. 24: Laser warning sign

Material

1x XX3_Sign_laser_warning_sign

2x Allen cylinder head screw, M3x12

Fig. 25: Material

(1) Screw the Allen cylinder head screw, M3x12 into the back of the XX3_Sign_laser_warning (Figure 26).

Fig. 26: Finished laser warning sign

LED module

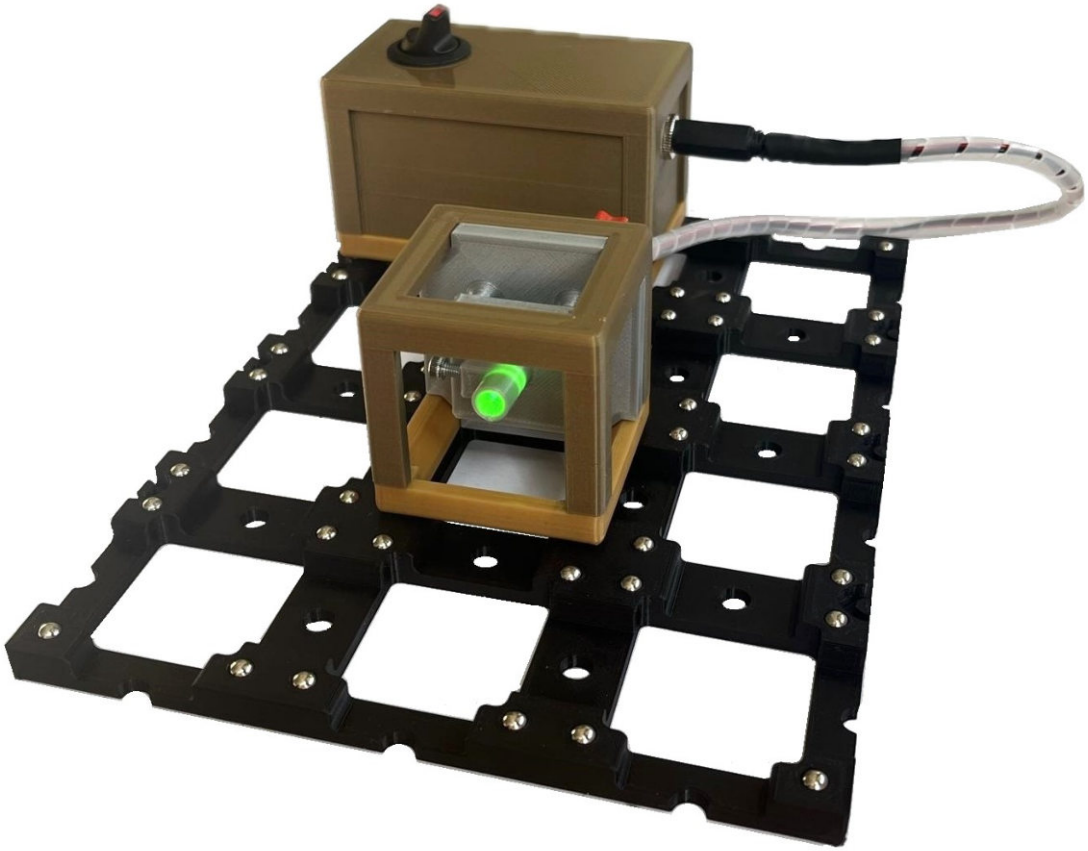

Fig. 1: Connected LED module

Introduction

In the LED module, an LED is held approximately vertically and at a 90° angle to the base plate (Figure 1). This is connected to the battery box module with a cable so that the LED can be switched on and off.

Experiments

▷ BB84 Model experiment

Material & Tools

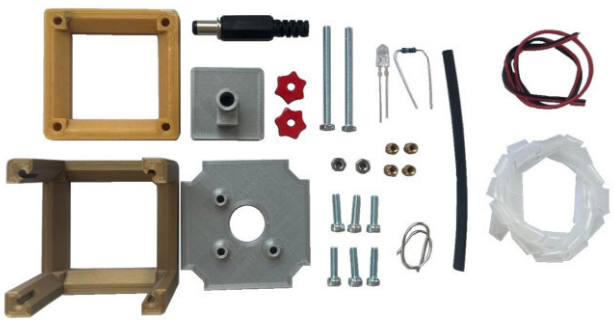

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 10A_Si_V*_insert 90°
1x 11B_Si_V*_led_plate
2x 03A_Re_V*_adjusting_screw_head

Other components

1x LED
1x Resistor 10 Ohm
1x Barrel connector
4x Thread insert, M3
4x Magnetic sphere, ø=5mm
6x Allen cylinder head screw, M3x12
2x Nut, self-locking, M3
2x Hexagon head screw, M3x40
▷ Spiral hose
▷ Shrink tubing
▷ Twin strand
▷ Solder tin

Tools

▷ Allen key - 2.5mm
▷ Soldering iron (+ tip for threaded inserts)
▷ (Pipe) wrench
▷ (Ratchet + socket spanner attachment 12 mm)
▷ Side cutter
▷ PCB holder for soldering
▷ Lighter or similar
▷ Stripping tool

Exploded view

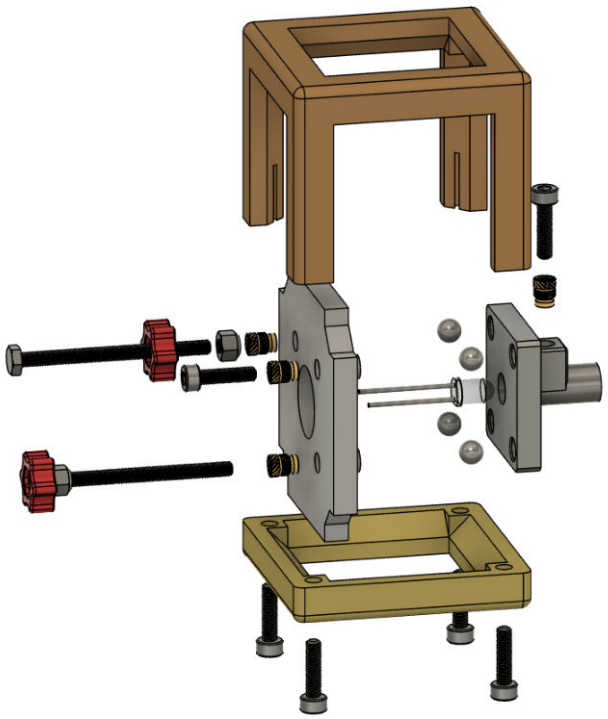

Fig. 3: Exploded view of the LED cube

I. Adjusting screw (2x)

Material

2x 03A_Re_V*_adjusting_screw_head
2x Hexagon head screw, M3x40
2x Nut, self-locking, M3

(1) Slide the 03A_Re_V*_adjusting_screw_head with the hexagonal opening first onto a Hexagon head screw, M3x40 .

(2) Then turn the Nut, self-locking, M3 onto the screw so that it holds the red screw head in place (Figure 4).

Note: *The red screw head fits 12 mm socket spanner attachments so that the nut can also be tightened with a cordless screwdriver or ratchet.*

(3) Repeat these steps for the second adjusting screw (Figure 4).

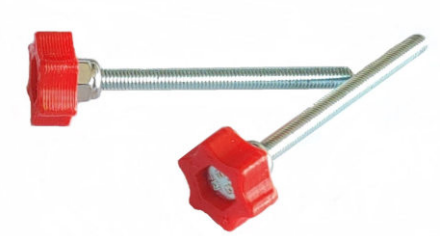

Fig. 4: Ready assembled screws

II. Adjusting plate

Material

2x Ready assembled screws
1x 10A_Si_V*_insert 90°
3x Thread insert, M3
1x Allen cylinder head screw, M3x12

(4) If necessary, mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(5) Place the Thread insert, M3 in the designated openings of the 10A_Si_V*_insert 90° (Figure 5).

(6) Carefully melt the thread inserts into the 90° insert with the soldering iron so that the thread inserts are flush with the surface. Ensure that the inserts are melted in as vertically as possible (Figure 5).

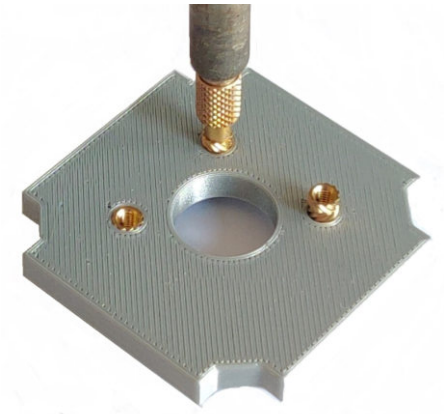

Fig. 5: Melting down the thread inserts

(7) Screw the Allen cylinder head screw, M3x12 completely into the centre of the three threaded inserts (Figure 6).

(8) Screw the two ready assembled screws into the other two threaded inserts so that they protrude roughly as far as the allen screw on the other side (Figure 6).

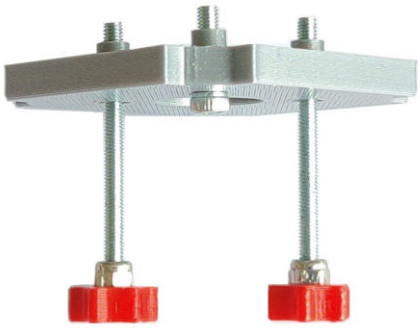

Fig. 6: Finished adjusting plate

III. LED-Plate

Material

1x 11B_Si_V*_led_plate
4x Magnetic sphere, ø=5mm
1x Nut, M3

(9) Press the four magnetic spheres into the openings of the 11B_Si_V*_led_plate (Figure 7).

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically when you press the spheres in with a ferromagnetic pipe wrench.*

Fig. 7: Magnetic spheres pressed into the plate

(10) Melt the Thread insert, M3 into the opening on the inside of the LED plate so that the insert is flush with the surface. Ensure that the insert is melted in as vertically as possible (Figure 8).

Fig. 8: Threaded insert melted into the LED plate

IV. LED soldering

Material

1x LED
1x Resistor 10 Ohm
1x Barrel connector
▷ Twin strand
▷ Shrink tubing
▷ Solder tin

(11) Shorten the leg at the anode from the LED (Figure 9).

Fig. 9: Unshortened LED, the red marking shows the corresponding point at which the LED is to be shortened.

(12) Shorten one side of the Resistor 10 Ohm (Figure 10).

Fig. 10: Shortened resistor

(13) Solder the short end of the resistor to the short side of the LED (Figure 11).

Fig. 11: Resistor soldered to the LED

(14) Pull a piece of Shrink tubing over the resistor to the soldering point and heat it carefully with a lighter or similar (Figure 12).

Fig. 12: LED soldered together with resistor

(15) Take a piece of the Twin strand (approx. 25 cm), strip one end and pull the two cables slightly apart.

(16) Fit the soldering tip to the soldering iron and heat it to 350° C.

(17) Pull a sufficiently long piece of shrink tubing over the black cable and solder it to the other end of the resistor (Figure 13).

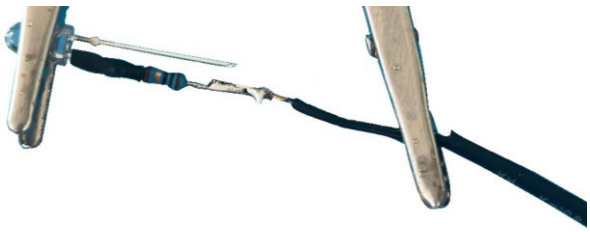

Fig. 13: Black cable soldered to the resistor

(18) Pull the shrink tubing over the soldering point and heat it carefully with a lighter or similar.

(19) Pull a piece of shrink tubing over the red cable and solder it to the other side of the LED (Figure 14).

Fig. 14: Cables soldered to the LED

(20) Unscrew the Barrel connector and pull the sleeve over the other end of the cable. Insulate this too and pull the cables apart slightly. Pull a piece of shrink tubing over the red cable.

(21) Solder the red cable to the short end of the barrel connector (Figure 15)

Note: *A clamp for clamping the cables can be helpful for soldering. Also make sure to push the shrink tubing as far away from the soldering point as possible before soldering to prevent it from shrinking during soldering.*

Fig. 15: Red cable soldered to the barrel connector

(22) Pull the shrink tubing over the solder joint and heat it carefully with a lighter or similar so that it shrinks together and completely encloses the solder joint.

(23) Solder the black end of the cable to the long part of the connector. To do this, pull the stripped piece through the hole and fold it over slightly so that the solder can bond with the materials (Figure 16).

Fig. 16: Soldering the connector to the cable

(24) Carefully press the cables and then the connector holder together slightly (Figure 17).

Fig. 17: Completely soldered connector

(25) Now pull the black cap over the connector and screw it tight (Figure 18).

Fig. 18: Finished connector

(26) Now pull a piece of shrink tubing over the LED so that the resistor and soldering points are covered and heat it carefully with a lighter or similar. (Figure 19).

Fig. 19: Completely soldered LED module

(27) Twist a suitably long piece of SPIRAL HOSE around the twin braid so that it is completely encased (Figure 20).

Fig. 20: Finished LED

V. LAST STEPS

Material

1x Finished adjusting plate
1x Finished LEDplate
1x Finished LED
1x 01A_Go_V*_cube base 1x1
1x 02A_Br_V*_cube cover 1x1
5x Allen cylinder head screw, M3x12

(28) Push the FINISHED LED as far as possible through the back of the FINISHED LEDPLATE and carefully screw a ALLEN CYLINDER HEAD SCREW, M3X12 through the thread insert until the LED is firmly seated (Figure 21).

Fig. 21: LED inserted in the LEDplate

(29) Assemble the 02A_BR_V*_CUBE_COVER 1X1 and the FINISHED

ADJUSTING PLATE (Figure 22).

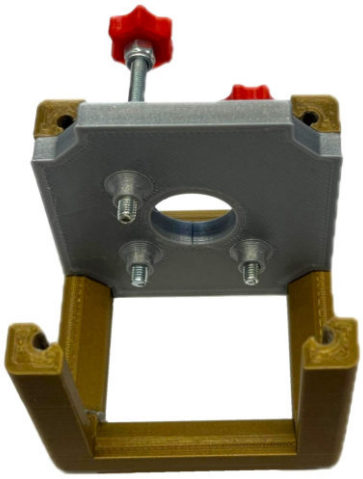

Fig. 22: Adjusting plate inserted into the cube cover

(30) Pull the LED cable out of the cube from the inside through the hole provided and attach the LED plate with the balls to the screws (Figure 23).

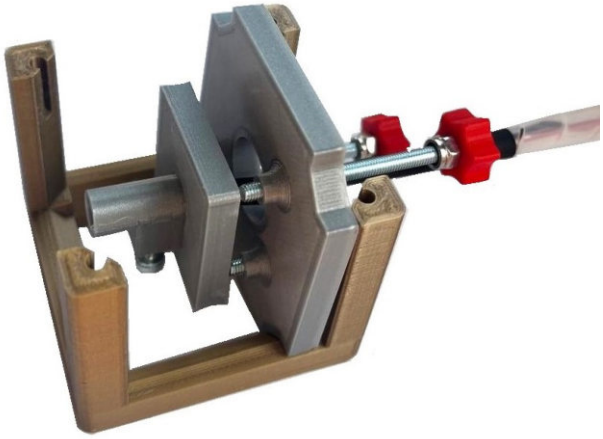

Fig. 23: Adjustment insert with LED inserted in the cube cover

(31) Place the 01A_Go_V*_cube_base 1x1 on the cube cover and secure it with four Allen cylinder head screw, M3x12 (Figure 24).

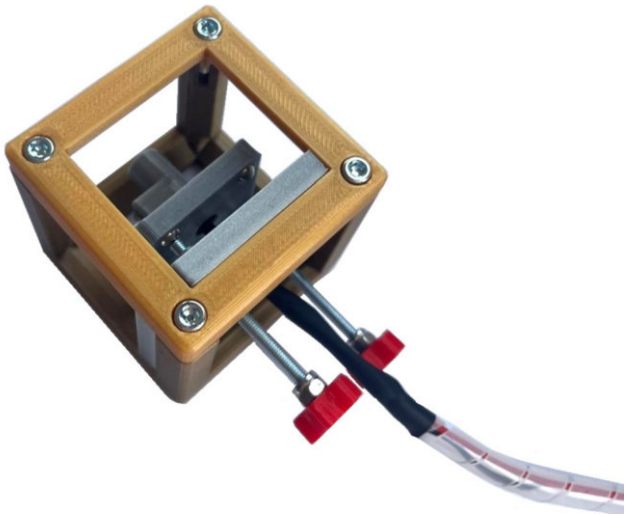

Fig. 24: Assembled LED cube

Battery box

Fig. 1: Battery box

Introduction

The battery box module is used for the power supply and contains two AA batteries. It has an on/off switch with an integrated LED display that can be used to easily switch connected modules such as the laser diode or LED module on and off. It can be soldered together in the modular O3Q system and enables independent experimental setups without an external power source (Figure 1).

Note: *The battery box does not fit on the base plate. Although the battery box is also held together with screws, the dimensions are not suitable for holding it firmly on the grid. Especially when setting up sensitive experiments such as interferometers, the battery box should be positioned next to the grid so that the interference behaviour is not disturbed by vibrations of the grid.*

Experiments

- Michelson interferometer - 1 pc.
- Michelson interferometer with piezoelement - 1 pc.
- Mach-Zehnder interferometer - 1 pc.
- Slits & diffraction grating - 1 pc.
- Polarisation - 1 pc.
- BB84 - 1 pc.

Material & Tools

Fig. 2: Material

3D-printing

1x 01D_Go_V*_battery_box_base

1x 02D_Br_V*_battery_box_cover

Other components

1x DC-Socket

1x Switch illuminated

1x Battery holder AA

1x Resistor 47 Ohm

2x Battery AA

4x Allen cylinder head screw, M3x12

2x Cable tie (min. 15cm long and max. 4mm wide)

▷ Twin strand

▷ Heat-shrink tubing

▷ Solder tin

Tools

▷ Allen key - 2.5mm

▷ Soldering iron (+ tip for threaded inserts)

▷ (Pipe) wrench

▷ (Ratchet + socket spanner attachment 12 mm)

▷ (Tweezers)

Circuit diagram

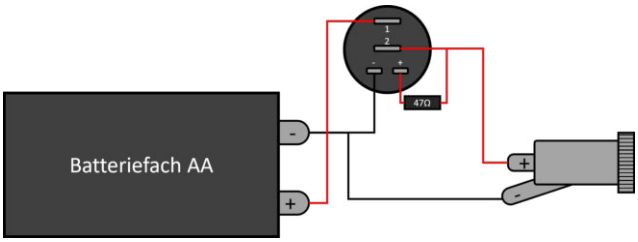

Fig. 3: Circuit diagram of the battery box

I. Soldering the changeover switch

Material

1x Switch illuminated

1x Resistor 47 Ohm

▷ Twin strand

▷ Solder tin

▷ Heat-shrink tubing

(1) Pull a piece of Twin strand (approx. 10 cm) completely apart and insulate one end of the red cable.

(2) Shorten the Resistor 47 Ohm slightly on one side and twist it with the end of the red cable (Figure 4).

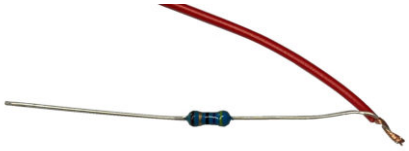

Fig. 4: Resistor twisted with the cable

(3) Heat the soldering iron to 220°C.

(4) Solder the cable with the resistor to the centre part of the Switch illuminated (Figure 5).

Note: *Take a close look at the circuit diagram provided (Figure 2) before you start soldering.*

Fig. 5: Cable and resistor soldered to the changeover switch

(5) Pull a piece of Shrink tubing over the soldered area and heat it carefully with a lighter or similar so that it shrinks.

(6) Pull another piece of Shrink tubing over the resistor and solder the still open end to the narrow left connection of the switch, as shown in Figure 6.

Note: *If you are unsure, refer to the wiring diagram (Figure 2).*

Fig. 6: Correctly connected resistor

(7) Pull the heat-shrink tubing over the solder joint and heat it carefully with a lighter or similar (Figure 7).

Fig. 7: Soldered resistor with heat-shrink tubing

(8) Pull a piece of Heat-shrink tubing over the black cable and solder it to the connection next to the soldered resistor

(Figure 8).

Note: *If you are unsure, refer to the wiring diagram (Figure 2).*

Fig. 8: Correctly soldered black cable

(9) Pull the shrink tubing over the soldered area and heat it carefully with a lighter or similar so that it shrinks together (Figure 9).

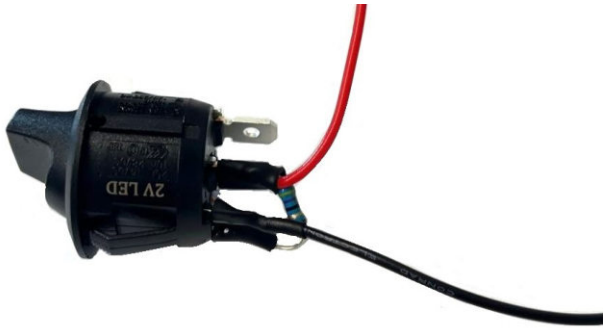

Fig. 9: Shrink tubing over the solder joint

(10) Pull the other piece of twin stranded wire completely apart and solder the red cable to the remaining connection of the changeover switch (Figure 10).

Note: *If you are unsure, refer to the wiring diagram (Figure 2).*

Fig. 10: Correctly soldered cable

(11) Pull a piece of SHRINK TUBING over the solder joint and heat it carefully with a lighter or similar so that it shrinks together (Figure 11).

Fig. 11: Ready soldered switch

II. Soldering the battery holder

Material

1x Ready soldered switch
1x 02D_Br_V*_battery_box_cover
1x Battery holder AA
▷ Short black cable
▷ Solder tin
▷ Heat-shrink tubing

(1) Press the READY SOLDERED SWITCH into the opening of the 02D_BR_V*_BATTERY_BOX_COVER so that the switch is facing outwards (Figure 12).

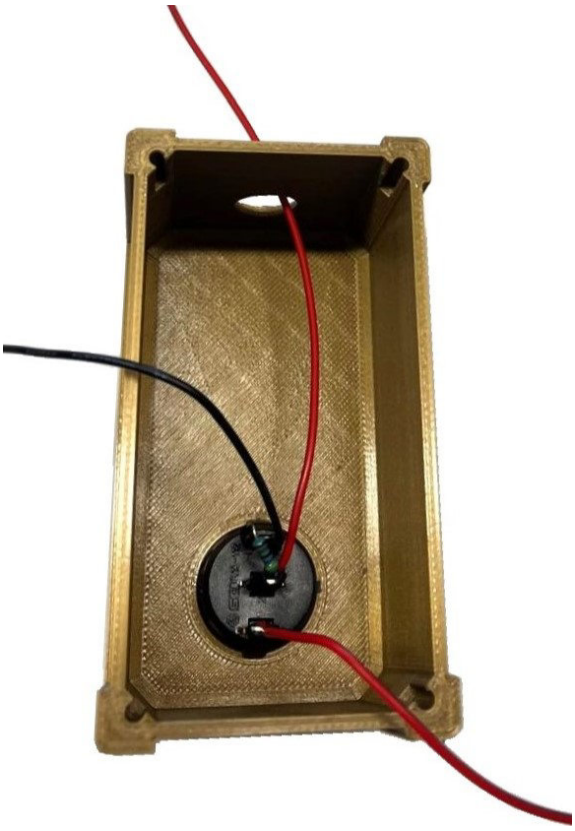

Fig. 12: Correctly inserted changeover switch

(2) Strip the insulation from the black cable, twist the end with the end of the black cable that is soldered to the switch and pull a piece of HEAT-SHRINK TUBING over the two cables

(Figure 13).

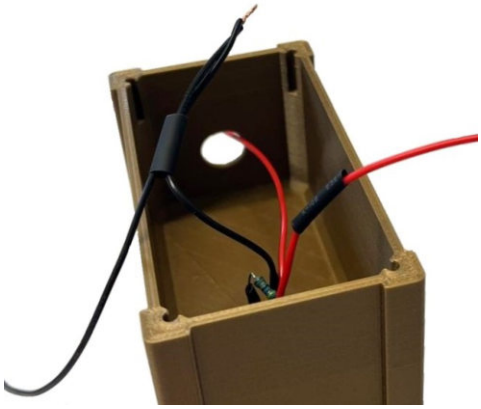

Fig. 13: Twisted cables

(3) Pull a piece of heat-shrink tubing over the shorter red cable and solder it to the positive pole of the BATTERY HOLDER AA (Figure 14).

Note: *If you are unsure about the correct wiring, please refer to the wiring diagram (Figure 2).*

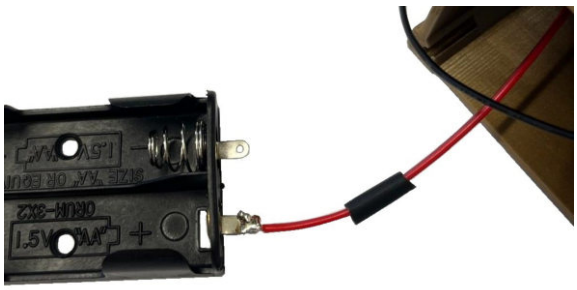

Fig. 14: Correctly soldered cable

(4) Solder the twisted black cables to the other pole of the battery holder (Figure 15).

Note: *If you are unsure about the correct wiring, please refer to the wiring diagram (Figure 2).*

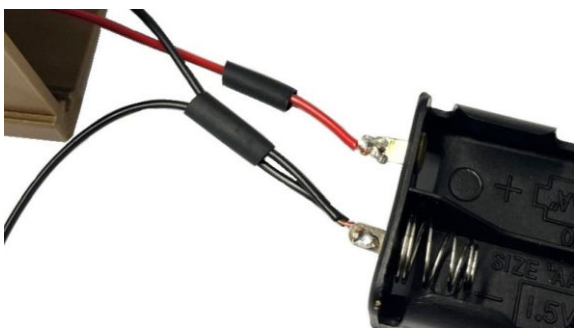

Fig. 15: Correctly soldered cables

(5) Pull the shrink tubing over the solder joints and heat them carefully with a lighter or similar (Figure 16).

Fig. 16: Ready connected battery holder

III. Soldering the DC-Socket

Material

1x Soldered battery box
1x DC-Socket
▷ Shrink tubing
▷ Spiral hose
▷ Solder tin

(1) Unscrew the DC-SOCKET (Figure 17).

Fig. 17: Unscrewed DC-Socket

(2) Pull the nut of the hollow socket over the red cable on the switch and the black cable on the battery holder, the ends of which are still left. The nut should now be inside the cover and can therefore be screwed back onto the hollow socket from the inside later.

(3) Then lay the two cables through the opening of the SOLDERED BATTERY BOX (Figure 18).

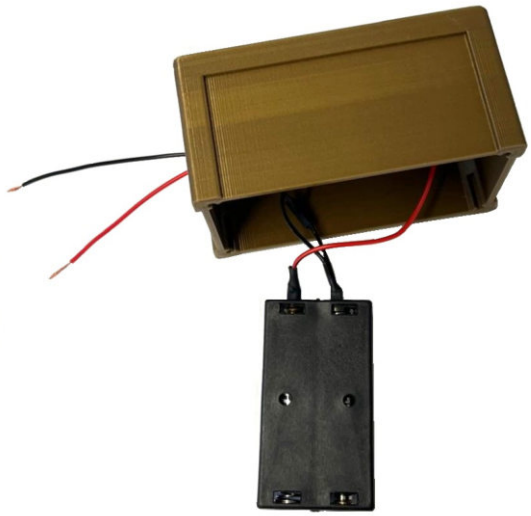

Fig. 18: Correctly positioned cables

(4) Pull a piece of HEAT-SHRINK TUBING over the red cable and solder it to the round short end of the hollow socket (Figure 19).

Note: *If you are unsure about the correct wiring, please refer to the wiring diagram (Figure 2).*

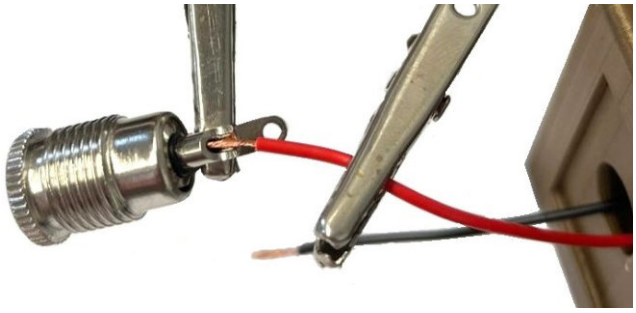

Fig. 19: Soldering the red cable to the hollow socket

(5) Pull a piece of heat-shrink tubing over the black cable and solder it to the other connection of the hollow socket, then pull the heat-shrink tubing over the soldering points and heat them carefully with a lighter or similar (Figure 20).

Note: *If your are unsure about the correct wiring, please refer to the wiring diagram (Figure 2).*

Fig. 20: Correctly connected DC-Socket

(6) Press the DC-Socket from the outside through the opening of the soldered battery box (Figure 21).

Fig. 21: DC-Socket in the cover

(7) Screw the DC-Socket together so that it is firmly seated in the opening (Figure 22).

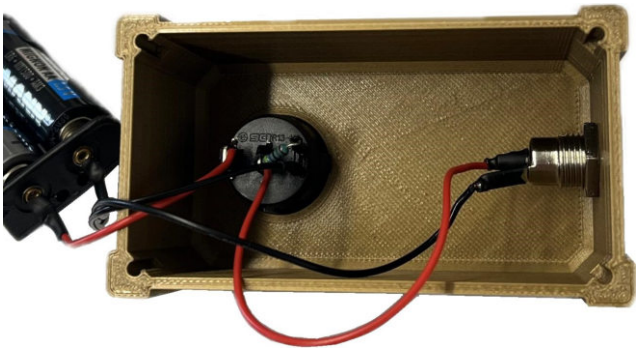

Fig. 22: Completely soldered battery box

IV. Assembling

Material

1x Completely soldered battery box
1x 01D_Go_V*_battery_box_base
4x Allen cylinder head screw, M3x12
2x Cable tie (min. 15cm long and max 4mm wide)
2x Battery AA

(1) Pull the two Cable tie (min. 15cm long and max. 4mm wide) through the openings in 01D_Go_V*_battery_base (Figure 23).

Fig. 23: Cable ties in the openings provided in the base

(2) Place the Battery AA in the battery holder and position it approximately in the centre of the floor (Figure 24).

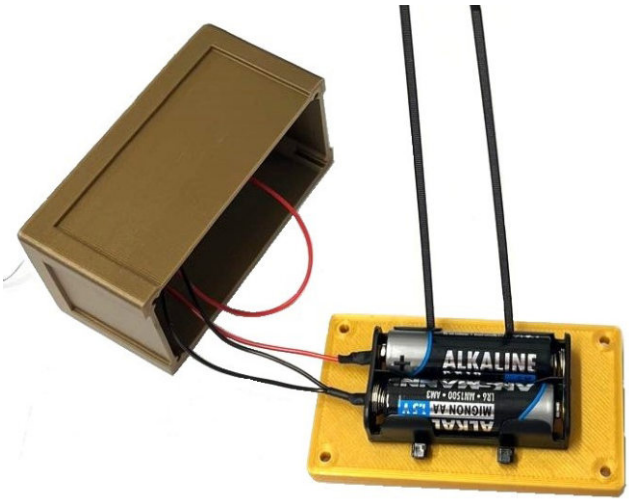

Fig. 24: Correctly positioned battery holder

(3) Tighten the cable ties and cut off the protruding ends (Figure 25).

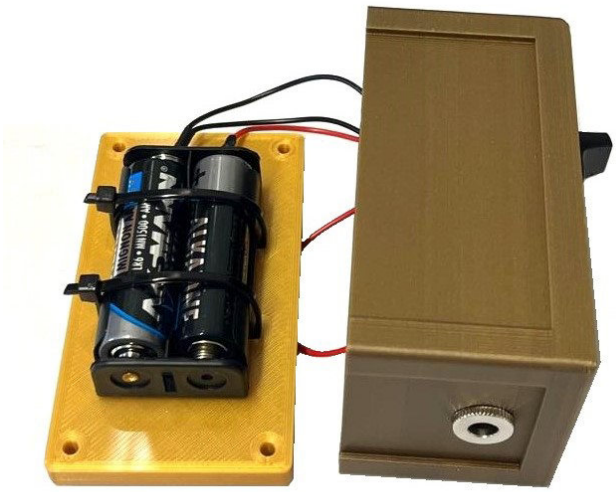

Fig. 25: Battery holder fixed to the floor

(4) Carefully place the base on the cover of the battery box so that all cables are inside and screw it tight with the Allen cylinder head screw, M3x12 (Figure 26).

Fig. 26: Assembled battery box

Polarizing filter

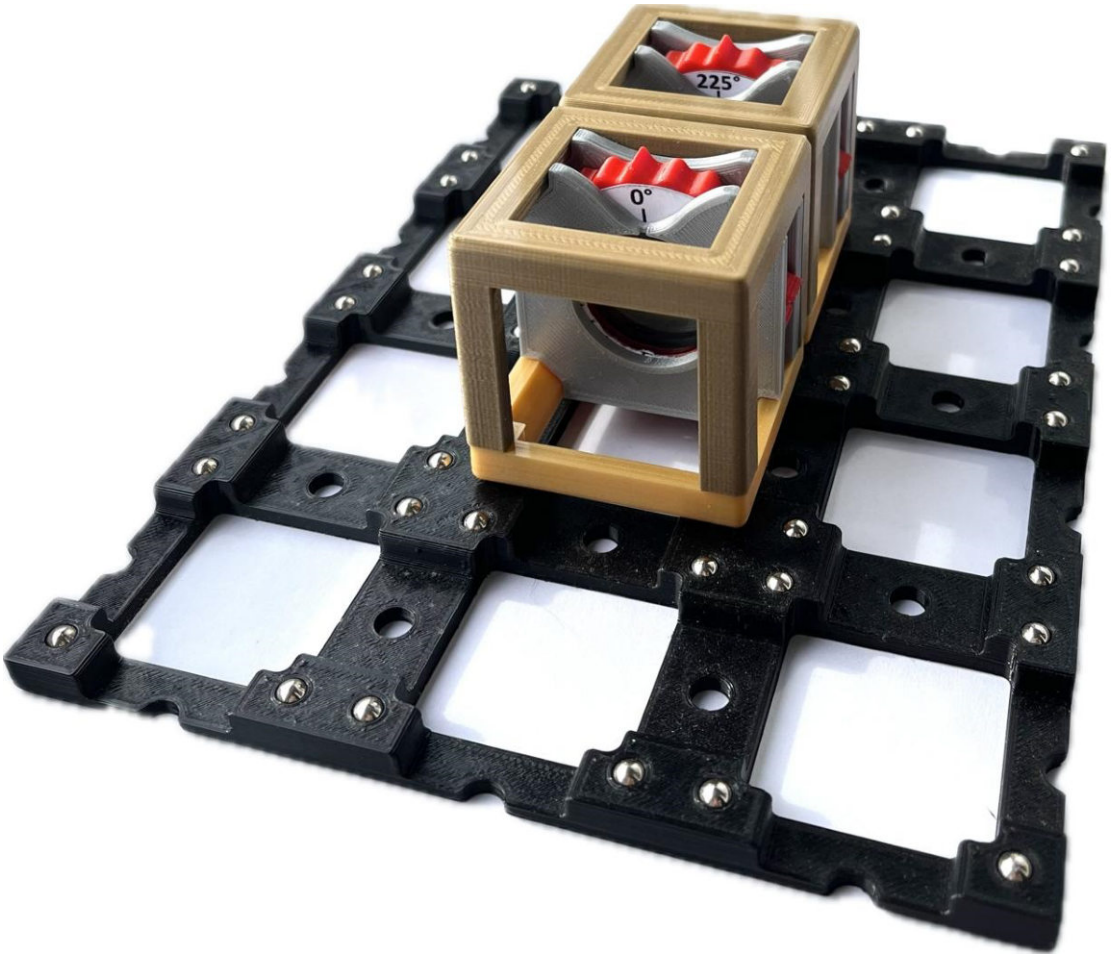

Fig. 1: polarizing filter

Introduction

A rotary wheel is used in the polarizing filter module to hold a polarizing filter foil in alignment (Figure 1). The rotary wheel allows the polarization direction to be set. This is necessary, for example, for adjusting the quantum eraser.

Experiments

- Quantum eraser - 5 pcs.
- Polarization of a laser diode - 1 pc.
- Malus' law - 2 pcs.
- Rotate polarization with polarizing filters - min. 3 pcs.

Material & Tools

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 14A_Re_V*_polarizing_filter_cover
1x 14A_Re_V*_polarizing_filter_wheel
1x 14A_Si_V*_polarizing_filter_frontplate
1x 14A_Si_V*_polarizing_filter_retaining_plate
1x 14A_Si_V*_polarizing_filter_intermediate_plate

Other components

4x Allen cylinder head screw, M3x12
1x Polarizing filter foil 30 mm x 30 mm
1x Adhesive label - Scale

Tools

▷ Allen key - 2,5 mm
▷ Scissors / knife

Exploded view

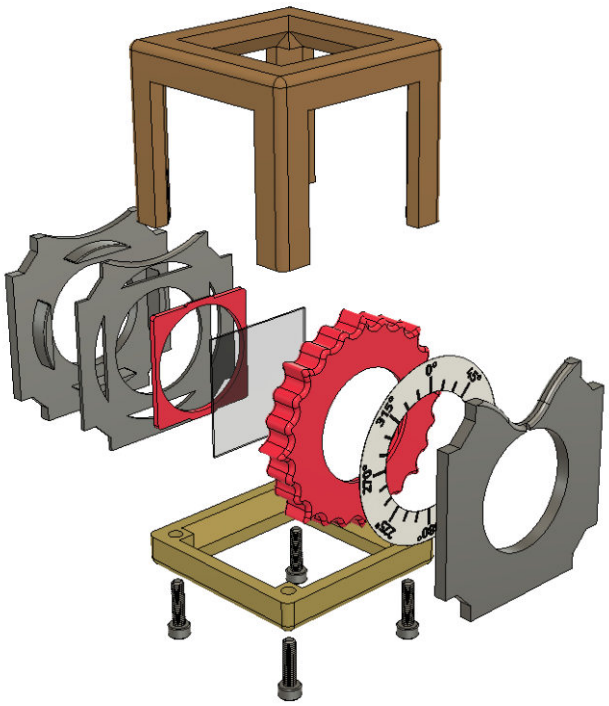

Fig. 3: Exploded view of the polarizing filter

I. Polarizing filter wheel

Material

1x 14A_Re_V*_polarizing_filter_cover
1x 14A_Re_V*_polarizing_filter_wheel
1x Polarizing filter foil 30 mm x 30 mm
1x Adhesive lable - Scale

(1) Stick the Adhesive lable - Scale to the front of the thick edge of the 14A_Re_V*_polarizing_filter_wheel so that the angle markings are on the long prongs of the wheel. Make sure that the 45°, 135°, 225° and 315° markings are located at the corners of the square on the back of the polarizing filter wheel (Figure 4).

(2) Carefully cut out the inner circle using scissors.

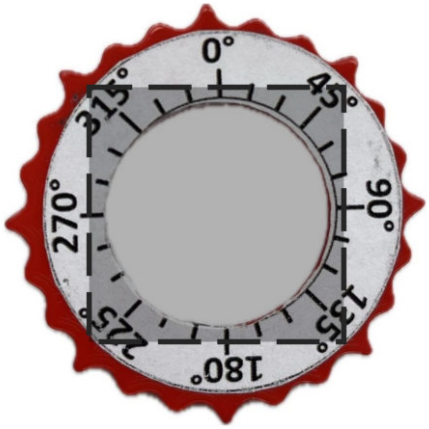

Fig. 4: Label with angle information glued to the rotating wheel. The square on the back is marked with a dotted line.

(3) Pull the foil from the polarizing filter foil 30 mm x 30 mm and place it in the opening provided in the wheel from behind (Figure 5).

Fig. 5: Polarizing filter film inserted in the rotary wheel

Note: *Ensure that the polarizing filter foil is correctly aligned. To do this, first determine the alignment of the polarizing foil. Use the effect of the Brewster angle, e.g. on a glass plate (smartphone) as shown in Figure 6. Hold the foil in front of the reflected polarized light. The orientation of the polarizing film is 0° when the reflected light is absorbed.*

Fig. 6: Polarization on a glass plate (Brewster angle). The reflected light is absorbed on the left and transmitted on the right.

(4) Press the `14A_Re_V*_polarizing_filter_cover` over the inserted polarizing filter into the openings provided in the wheel (Figure 7).

Tip: *If you apply a thin layer of graphite (pencil abrasion) to the outer edge of the back, the polarizing filter will be easier to turn later.*

Fig. 7: Filter cover attached to the rotary wheel

Fig. 8: Finished polarizing filter wheel

II. Assembling cube

Material

1x Finished polarizing filter wheel
1x 02A_Br_V*_cube_cover 1x1
1x 01A_Go_V*_cube_base 1x1
1x 14A_Si_V*_polarizing_filter_frontplate
1x 14A_Si_V*_polarizing_filter_retaining_plate
1x 14A_Si_V*_polarizing filter_intermediate_plate
4x Allen cylinder head screw, M3x12

(5) Place the `14A_Si_V*_polarizing filter_intermediate_plate` with the smooth side facing up on the `14A_Si_V*_polarizing_filter_retaining_plate` (Figure 9).

Note: *Make sure that the smooth side of the intermediate plate is facing away from the retaining plate to make it easier to turn the polarizing filter wheel later.*

Fig. 9: Intermediate polarizing filter plate on the polarizing filter retaining plate

(6) Place the assembled holding plate with the intermediate plate in the `02A_Br_V*_cube_cover 1x1` with the rounding facing downwards (Figure 10).

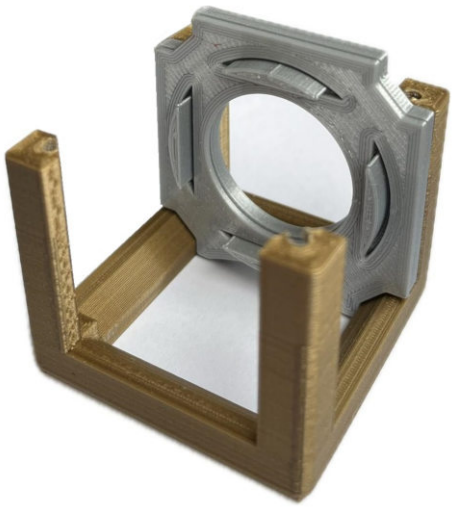

Fig. 10: Retaining and intermediate plate in the cube cover

(7) Place the Finished polarizing filter wheel in front of it with the back facing the retaining plate (Figure 11).

Fig. 11: Retaining and intermediate plate with the rotary wheel in the cube cover

(8) Finally, place the 14A_Si_V*_polarizing_filter_frontplate in front of it, also with the rounding facing downwards (Figure 12).

Note: *Make sure that the smooth side of the front plate is facing the polarizing filter wheel to make it easier to turn later.*

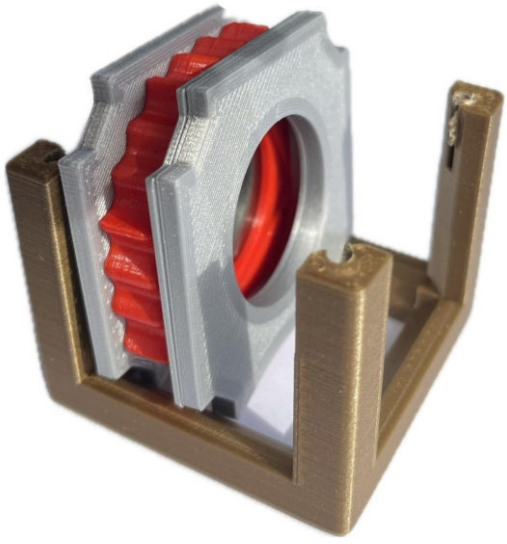

Fig. 12: All necessary components inserted into the cube cover

(9) Place the 01A_Go_V*_cube_base 1x1 on the cube cover and secure it with the Allen cylinder head screws (Figure 13).

Fig. 13: Assembled cube

Piezoelectric mirror

Fig. 1: Piezoelectric mirror

Introduciton

In the piezoelectric mirror module, a mirror mounted on a piezo element is held approximately perpendicular to the base plate (Figure 1). The mirror can be moved forwards or backwards a few nm by connecting it to a voltage source. This is necessary, for example, to observe the effect on the interference pattern caused by the smallest changes in distance in the interferometer arms of the Michelson interferometer.

Experiments

- Michelson interferometer with piezoelectric element - 1 pc.

Material & Tools

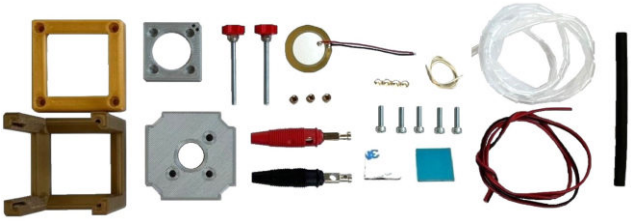

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 10A_Si_V*_insert 90°
1x 11D_Si_V*_mirror_plate_piezo
2x 03A_Re_V*_adjusting_screw_head

Other components

1x Piezoelectric element
1x Banana plug
1x Banana jack
3x Threaded insert, M3
1x Adhesive pad (~ 20mm x 20mm)
1x Front surface mirror (22mm x 22mm)
4x Magnetic sphere, ø=5mm
5x Allen cylinder head screw, M3x12
2x Nut, M3, self-locking
2x Hexagon head screw, M3x40
▷ Superglue
▷ Solder tin
▷ Head-shrink tubing
▷ Twin stranded wire

Tools

▷ Allen key - 2,5 mm
▷ Soldering iron (+ tip for threaded inserts)
▷ (Pipe) wrench
▷ (Ratchet + socket spanner attachment 12 mm)

Exploded view

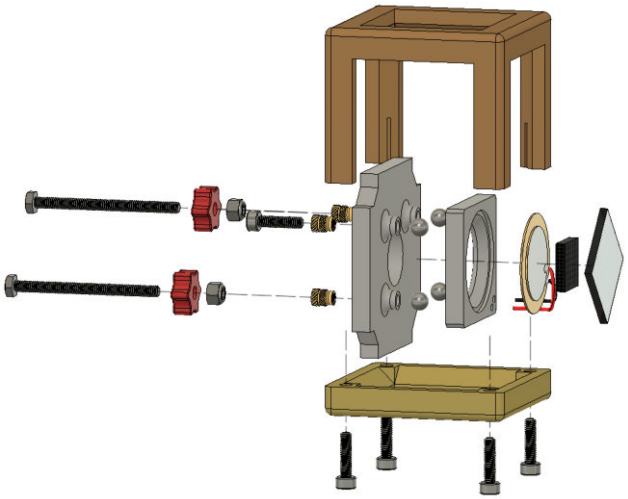

Fig. 3: Exploded view of the piezo cube

I. Adjusting screw (2x)

Material

2x 03A_Re_V*_adjusting_screw_head
2x Hexagon head screw, M3x40
2x Nut, M3, self-locking

(1) Slide the 03A_Re_V*_adjusting_screw_head with the hexagonal opening first onto the Hexagon head screw, M3x40 .

(2) Then turn the Nut, M3, self-locking onto the screw so that it holds the red screw head in place (Figure 4).

Note: *The red screw head fits 12 mm socket spanner attachments so that the nut can also be tightened with a cordless screwdriver or ratchet.*

(3) Repeat these steps again to create a second adjusting screw (Figure 4).

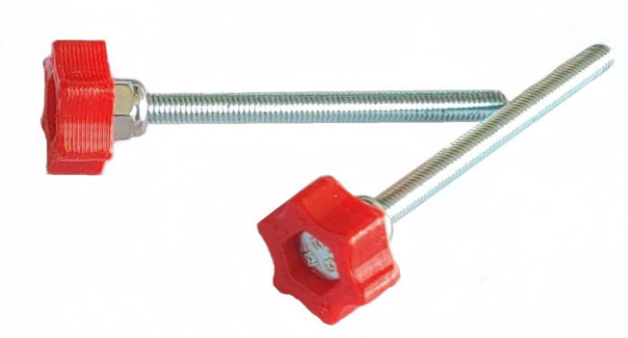

Fig. 4: Ready assembled screw

II. Adjusting plate

Material

2x Ready assembled screw
1x 10A_Si_V*_insert 90°
3x Threaded insert, M3
1x Allen cylinder head screw, M3x12

(4) If necessary, mount the tip for melting the threaded inserts on the soldering iron and heat the soldering iron to 220°C.

(5) Place the THREADED INSERT, M3 in the designated openings of the 10A_SI_V*_INSERT 90° (Figure 5).

(6) Carefully melt the threaded inserts into the 90° insert with the soldering iron so that the inserts are flush with the surface. Ensure that the inserts are melted in as vertically as possible (Figure 5).

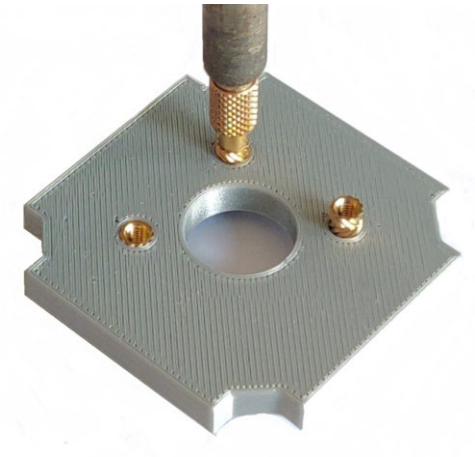

Fig. 5: Melting down the threaded inserts

(7) Screw the ALLEN CYLINDER HEAD SCREW, M3X12 fully into the middle of the three threaded inserts (Figure 6).

(8) Screw the two READY ASSEMBLED SCREWS into the other two threaded inserts so that they protrude from the other side approximately as far as the allen screw (Figure 6).

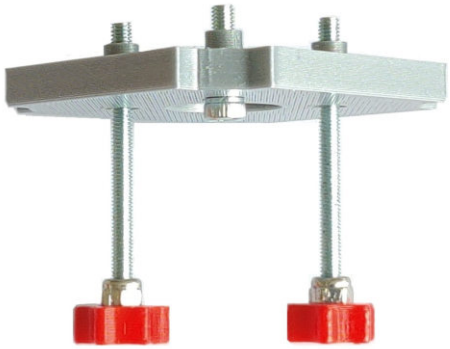

Fig. 6: Finished adjusting plate

III. Piezo plate

Material

1x 11D_Si_V*_mirror_plate_piezo
4x Magnetic sphere, ø=5mm
1x Piezoelectric element
1x Banana plug
1x Banana jack
1x Adhesive pad (~ 20mm x 20mm)
1x Front surface mirror (22mm x 22mm)
▷ Superglue
▷ Twin stranded wire
▷ Heat-shrink tubing
▷ Spiral hose

(9) Press the four MAGNETIC SPHERES, Ø=5MM into the openings of the 11D_SI_V*_MIRROR_PLATE_PIEZO .

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically when you press in the spheres with a ferromagnetic pipe wrench.*

Fig. 7: Magnetic spheres pressed into the disc

(10) Pull a piece of HEAT-SHRINK TUBING as far as possible over the cables to the PIEZOELECTRIC ELEMENT and heat this carefully with a lighter or similar so that the tube shrinks together.

(11) Pull the ends of the cables through a hole in the plate (Figure 8).

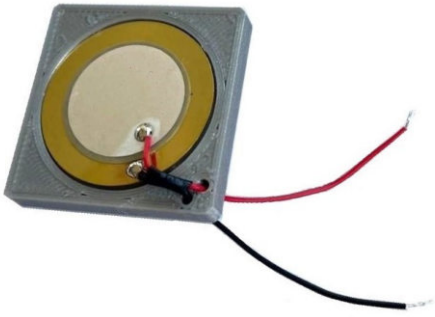

Fig. 8: Cable through piezo plate

(12) Attach the back of the piezo element to the piezo plate with a little SUPERGLUE .

(13) Take a piece of TWIN STRANDED WIRE and pull the two cables

slightly apart on one side. Strip the ends and pull a piece of HEAT-SHRINK TUBING over each end.

(14) Fit the soldering tip to the soldering iron and heat it to 350°C.

(15) Solder the black end of the twin stranded wire to the black cable of the piezoelectric element (Figure 9).

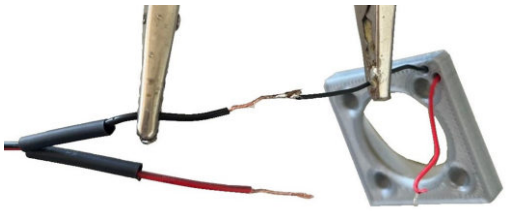

Fig. 9: Black cables soldered together

(16) Pull the heat-shrink tubing over the solder joint and heat it carefully with a lighter or similar so that it shrinks completely.

(17) Solder the red end of the twin stranded wire to the red cable of the piezoelectric element (Figure 10).

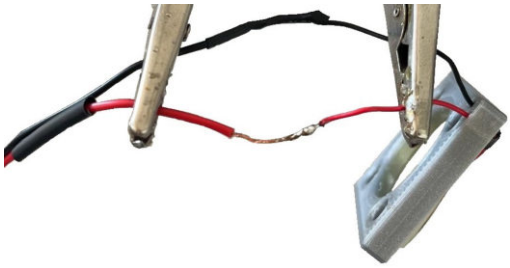

Fig. 10: Red soldered cables

(18) Pull the heat-shrink tubing over the solder joint and heat it carefully with a lighter or similar so that it shrinks completely.

(19) Pull two thick pieces of HEAT-SHRINK TUBING over the twin stranded wires (Figure 11).

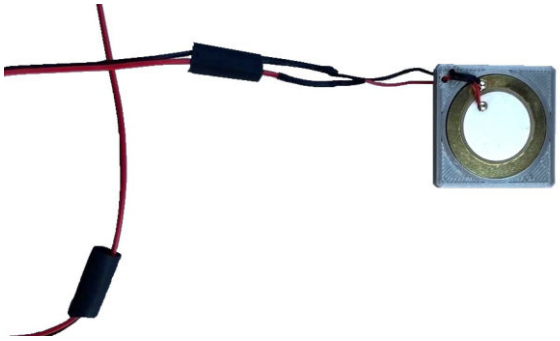

Fig. 11: Heat-shrink tubing over cables

(20) Pull the two cables slightly apart at the end of the twin stranded wire and insulate the ends.

(21) Pull off the cap of the BANANA PLUG and pull it over the black end of the twin stranded wires.

Note: *Ensure correct alignment so that the plug can be pushed back together after soldering.*

(22) Solder the black cable to the banana plug (Figure 12).

Fig. 12: Soldering the black cable to the banana black plug

(23) Repeat the steps with the red cable and the BANANA JACK (Figure 13).

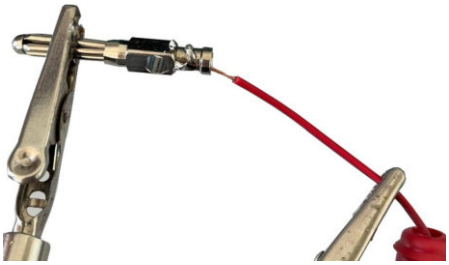

Fig. 13: Soldering the red cable to the banana jack

(24) Pull the caps over each of the soldered plugs (Figure 14).

Fig. 14: Finished plugs

(25) Wrap a suitable piece of SPIRAL HOSE around each of the two cables up to the fork (Figure 15).

Fig. 15: Ready plug with spiral hose

(26) Wrap another piece of SPIRAL HOSE around the rest of the cable, insert the ends into the piece of heat-shrink tubing and then heat them carefully with a lighter or similar until they are completely shrunk together (Figure 16).

Fig. 16: Completely soldered piezo element

(27) Glue the ADHESIVE PAD (~ 20MM X 20MM) in the centre of the piezo element and then glue the FRONT SURFACE MIRROR (22MM X 22MM) in the centre and offset on the adhesive pad (Figure 17).

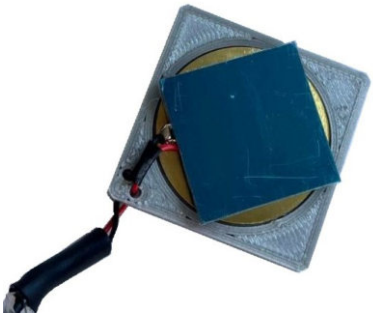

Fig. 17: Mirror plate glued onto the piezo element

(28) Then remove the blue protective film from the mirror (using tweezers if necessary).

Note: *The mirror is a front surface mirror. The reflective surface is therefore in front of the glass panel and not behind the panel as is usual with household mirrors. The glass plate is vapour-coated with a metallic layer and a thin protective layer on top. Despite the protective layer, the mirrors are not as easy to clean as standard household mirrors.*

IV. Assembling

Material

- ▷ Finished adjusting plate
- ▷ Finished piezo element
- 1x 01A_Go_V*_cube_base 1x1
- 1x 02A_Br_V*_cube_cover 1x1
- 4x Allen cylinder head screw, M3x12

(29) Place the FINISHED ADJUSTING PLATE in the 02A_BR_V*_CUBE_COVER 1X1 (Figure 18).

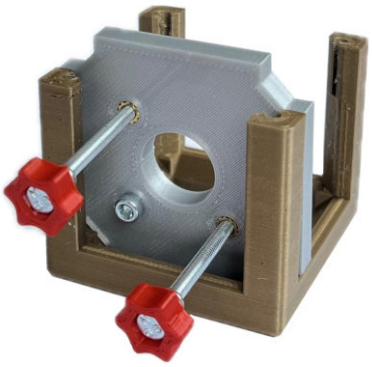

Fig. 18: In den Würfeldeckel eingesetzte Justageplatte

(30) Pull the cable of the FINISHED PIEZO ELEMENT from the inside to the outside towards the screws through the hole in the adjustment plate. Place the plate with the piezo element on the screws of the adjustment plate (Figure 19).

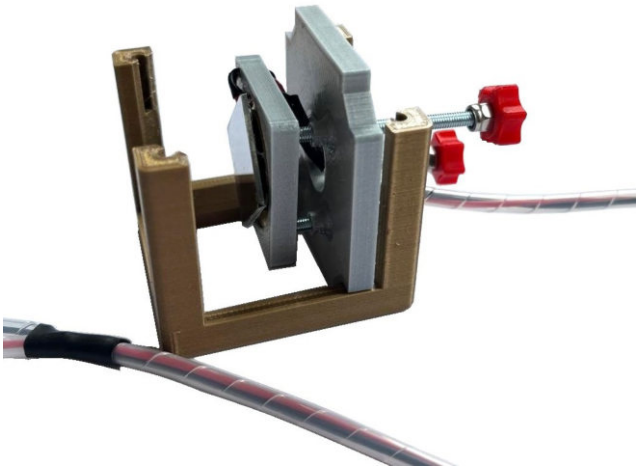

Fig. 19: Adjustment plate with piezo element in the cube cover

(31) Place the 02A_BR_V1_CUBE_BASE 1X1 on top of the cube cover and secure it with the ALLEN CYLINDER HEAD SCREWS, M3X12 (Figure 20).

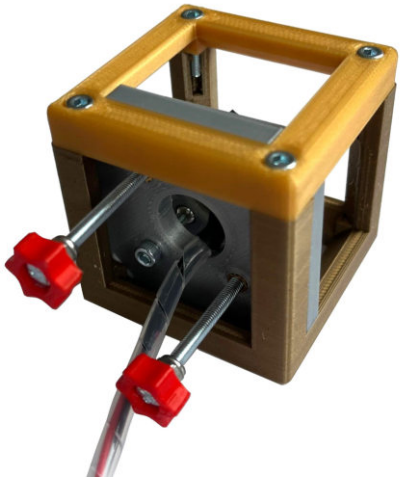

Fig. 20: Assembled cube

Screens

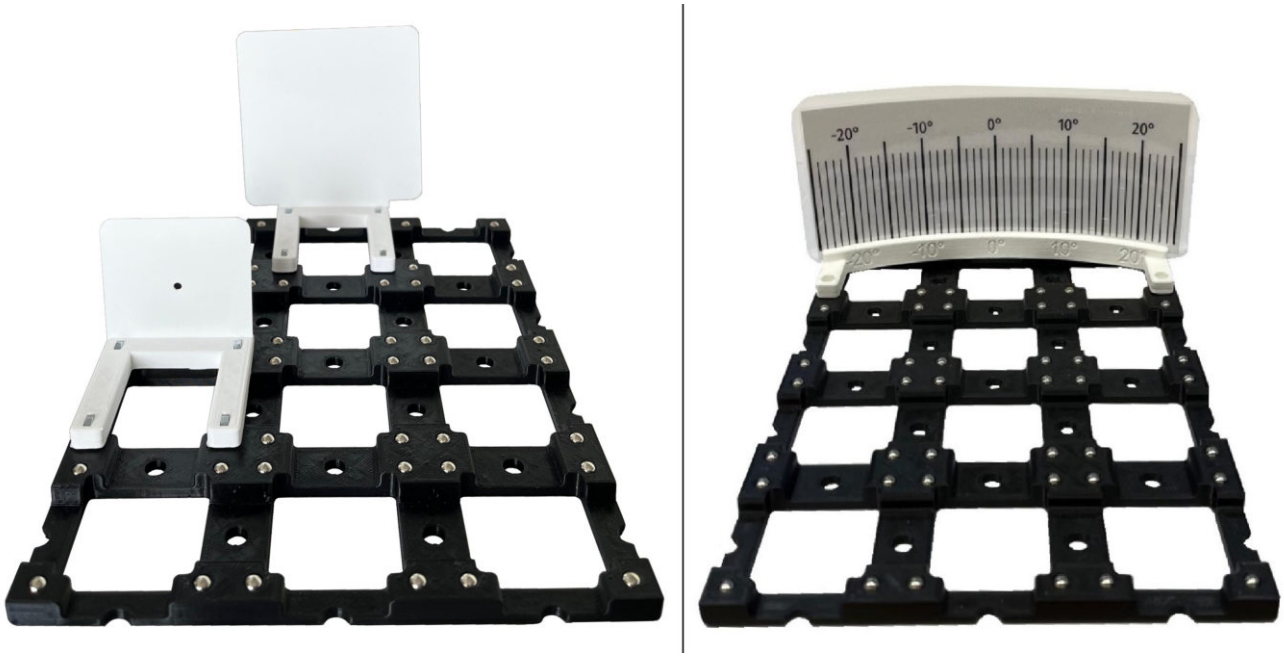

Fig. 1: Screen and pinhole (left), angular scale screen (right)

Introduction

In this module, a screen or pinhole is held approximately perpendicular to the base plate (Figure 1). The interference pattern can be observed on the screen when adjusting the Michelson interferometer, for example. With the help of the pinhole aperture, the beam path of a laser or similar can be adjusted more precisely. This is helpful, for example, when adjusting the Mach-Zehnder interferometer. Alternatively, the angular scale screen can be used to quantify the deflection or interference angles of diffracted or interfered light beams.

Experiments

- Michelson interferometer - 1 screen
- Michelson interferometer with piezo element - 1 screen
- Mach-Zehnder interferometer - 2 screens, 1 pinhole
- Slits & diffraction grating - 1 screen, 1 pinhole / 1 angular scale screen
- Polarisation - 2 screens, 1 pinhole
- BB84 Model experiment - 2 screens

Material & Tools

Fig. 2: Material required for the screen

Fig. 3: Material required for the pinhole

Fig. 4: Material required for the angular scale screen

3D printing
2x 04A_Wh_V*_base
1x 04B_Wh_V*_screen
1x 04C_Wh_V*_pinhole
1x 04A_Wh_V*_scalefoot

Other components
8x Nut, M3
1x Angular scale screen

Tools
▷ (Pipe) wrench

Exploded view

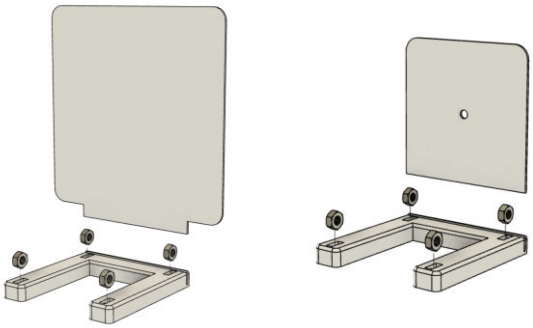

Fig. 5: Exploded view of the screen (left) and the pinhole (right)

I. Screen

Material
1x 04A_Wh_V*_base
1x 04B_Wh_V*_screen
4x Nut, M3

(1) Press the four `Nut, M3` into the holes provided in the `04A _Wh_V*_base` (Figure 6).

Tip: *Use the (pipe) wrench to press in the nuts if necessary.*

Fig. 6: Nuts in the base

(2) Slide the `04B_Wh_V*_screen` into the base from the side (Figure 7).

Fig. 7: Fully assembled screen

II. Pinhole

Material

1x 04A_Wh_V*_base
1x 04C_Wh_V*_pinhole
4x Nut, M3

(1) Press the Nuts, M3 into the holes provided in the 04A_Wh_V*_base (Figure 8).

Tip: *Use the (pipe) wrench to press in the nuts if necessary.*

Fig. 8: Nuts in the base

(2) Slide the 04C_Wh_V*_pinhole into the base from the side (Figure 9).

Fig. 9: Fully assembled pinhole

III. Angel scale

Material

1x 04A_Wh_V*_scalefoot
1x Angular scale screen

(1) Laminate the angular scale screen and slide it sideways into the 04A_Wh_V*_scalefoot .

Push-button

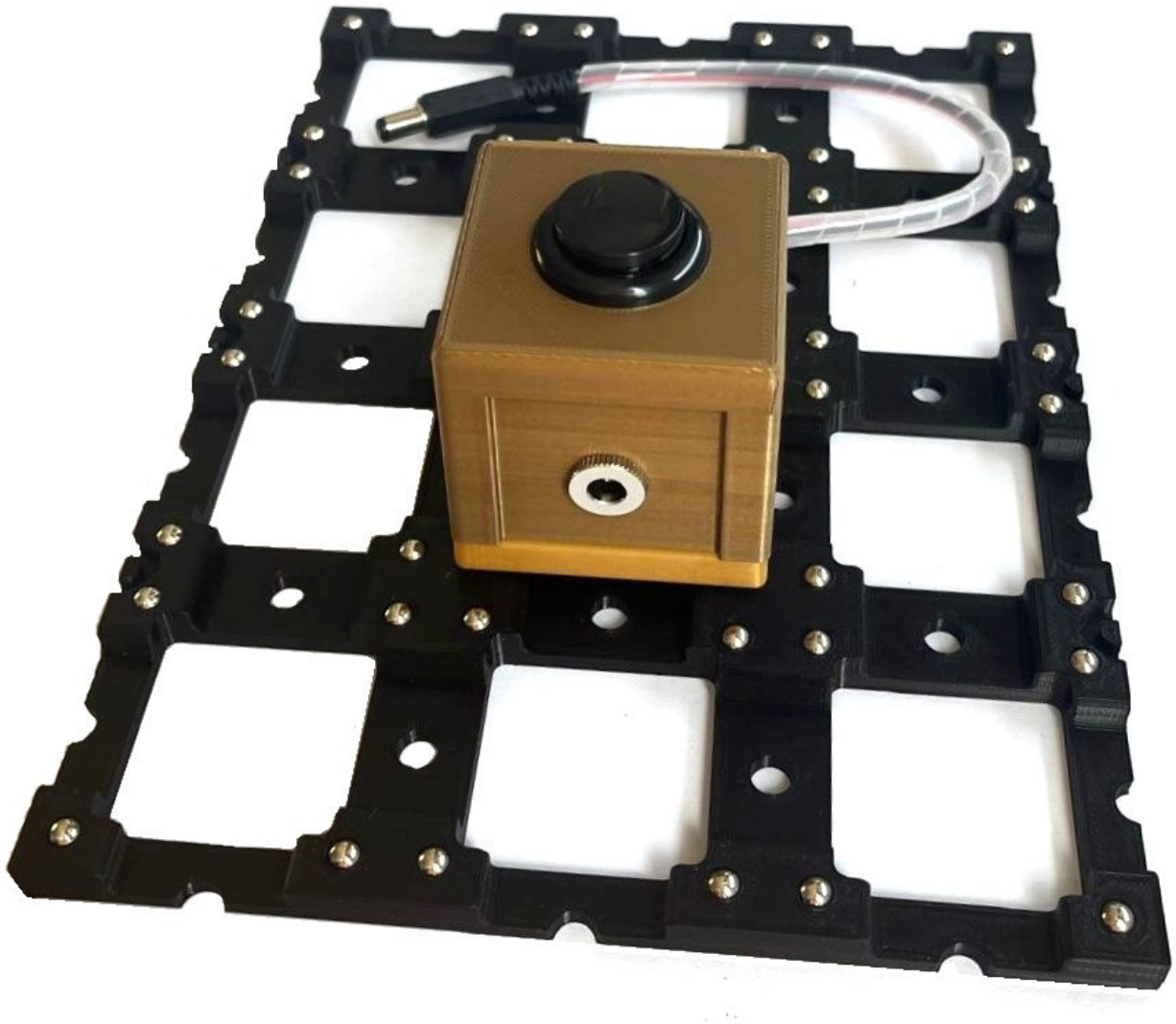

Fig. 1: Push-button

Introduction

In the push-button module, a push-button can be connected between the laser diode or LED module and the battery box module so that the laser diode or LED only lights up as long as the push-button is held down. This is necessary, for example, when carrying out the BB84 model experiment (Figure 1).

Experiments

▷ BB84 model experiment

Material & Tools

Fig. 2: Material

3D printing

1x 01B_Go_V*_cube_base 1x1_closed

1x 02B_Br_V*_cube_cover 1x1_button

Other components

1x Barrel connector

1x DC-Socket

1x Push-button

4x Allen cylinder head screw, M3x12

▷ Heat-shrink tubing

▷ Twin stranded wire

▷ Spiral hose

▷ Soldering tin

Tools

▷ Allen key - 2,5 mm

▷ Soldering iron (+ tip for thread inserts)

▷ (pipe) wrench

Circuit diagram

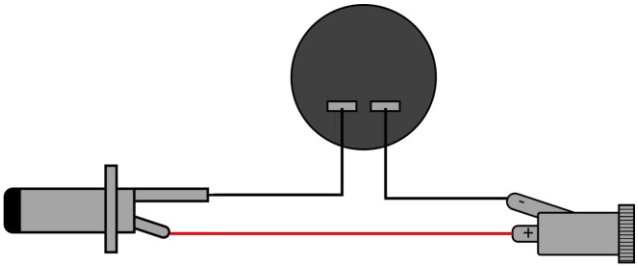

Fig. 3: Circuit diagram of the push-button module

I. Soldering DC-Socket

Material

1x DC-Socket

▷ Twin stranded wire

▷ Heat-shrink tubing

▷ Soldering tin

(1) Take a piece of TWIN STRANDED WIRE (approx. 15 cm) and insulate one end.

(2) Pull the two cables slightly apart and pull a piece of the HEAT-SHRINK TUBING over the red cable.

(3) Heat the soldering iron to 350°.

(4) Solder the red cable to the short end of the DC-Socket (Figure 4).

Note: *Take a close look at the circuit diagram provided (Figure 3) before you start soldering.*

Fig. 4: Soldering the cable to the DC-Socket

(5) Pull the heat-shrink tubing over the soldered area and heat it carefully with a lighter or similar so that it shrinks together (Figure 5). .

Fig. 5: Soldered DC-Socket

II. Push-button

Material

1x Soldered DC-Socket

1x 02B_Br_V*_cube_cover 1x1_button

1x Push-button

▷ Soldering tin

(1) Unscrew the SOLDERED DC SOCKET and remove the nut from the cable.

(2) Pull the twin stranded wire from the outside inwards through the hole on the side of the 02B_Br_V*_cube_cover 1x1_button so that the opening of the socket is facing outwards.

(3) Then pull the nut back over the twin wire and screw it tight so that the hollow bushing is firmly seated in the opening (Figure 6).

(4) Insert the PUSH-BUTTON into the opening of the 02B_Br_V*_cube_cover 1x1_button from below so that the push button is outside the cube cover (Figure 6).

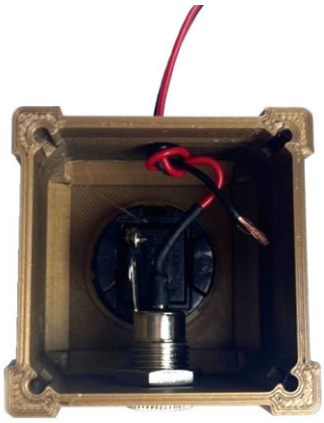

Fig. 6: Correctly assembled button

(5) Pull the twin stranded wire through the opening on the opposite side of the cube cover (Figure 6).

Not: *Knot the cable before pulling it through to provide strain relief.*

(6) Solder the black cable to the button (Figure 7).

Note: *If you are unsure, refer to the wiring diagram (Figure 3)*

Fig. 7: Cable soldered to the button

(7) Solder the long part of the DC-Socket to the button (Figure 8).

Note: *If you are unsure, refer to the wiring diagram (Figure 3)*

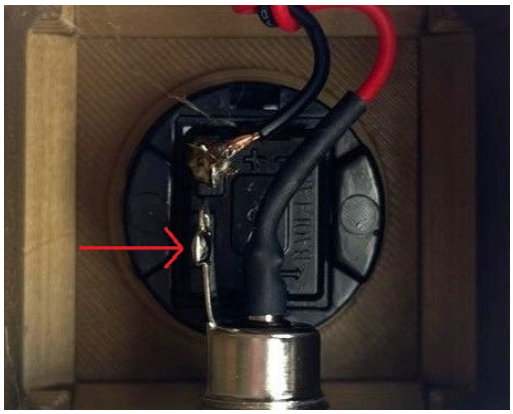

Fig. 8: DC-Socket soldered to the button

III. Soldering barrel connector

Material

1x Soldered button
1x Barrel connector
▷ Heat-shrink tubing
▷ Soldering tin

(1) Unscrew the BARREL CONNECTOR and pull the sleeve over the other end of the cable. Strip this too and pull the cables apart slightly.

(2) Pull a piece of HEAT-SHRING TUBING over the red cable. Now solder the red cable to the short part of the connector (Figure 9).

Note: *A clamp for clamping the cables can be helpful for soldering. Also make sure to push the heat-shrink tubing as far away from the soldering point as possible before soldering to prevent it from shrinking during soldering.*

Fig. 9: Soldering the barrel connector to the cable

(3) Pull the heat-shrink tubing over the solder joint and heat it carefully with a lighter or similar so that it shrinks together and completely encloses the solder joint.

(4) Solder the black end of the cable to the long part of the connector. To do this, pull the stripped piece through the hole in the connector and fold it over slightly so that the solder can bond with the materials (Figure 10).

Fig. 10: Soldering the connector to the cable

(5) Carefully press the cables and then the connector holder together slightly (Figure 11).

Fig. 11: Fully soldered connector

(6) Now pull the black cap over the connector and screw it tight (Figure 12).

Fig. 12: Finished connector

Fig. 13: Fully soldered button

IV. Last steps

Material

1x Soldered button
1x 01B_Go_V*_cube_base 1x1_closed
4x Allen cylinder head screw, M3x12
▷ Spiral hose

(1) Wrap the Spiral hose around the cable (Figure 14).

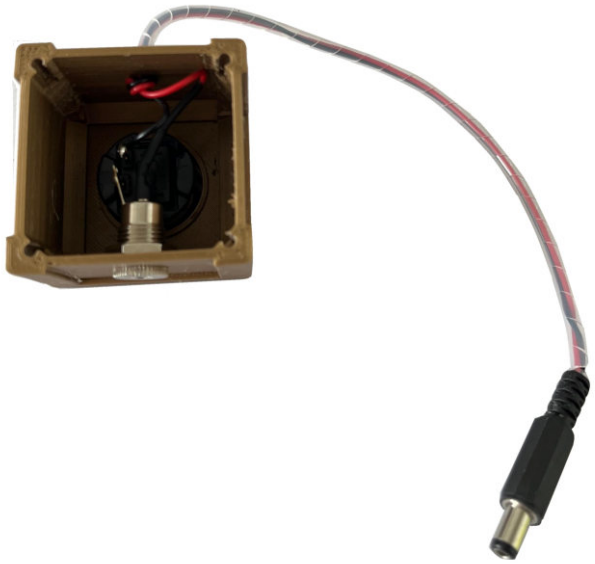

Fig. 14: Spiral hose around the cable

(2) Place the 01B_Go_V*_cube_base 1x1_closed on the soldered button and fasten it with the four allen cylinder head screw, M3x12 (Figure 15).

Fig. 15: Assembled button module

Grating holder

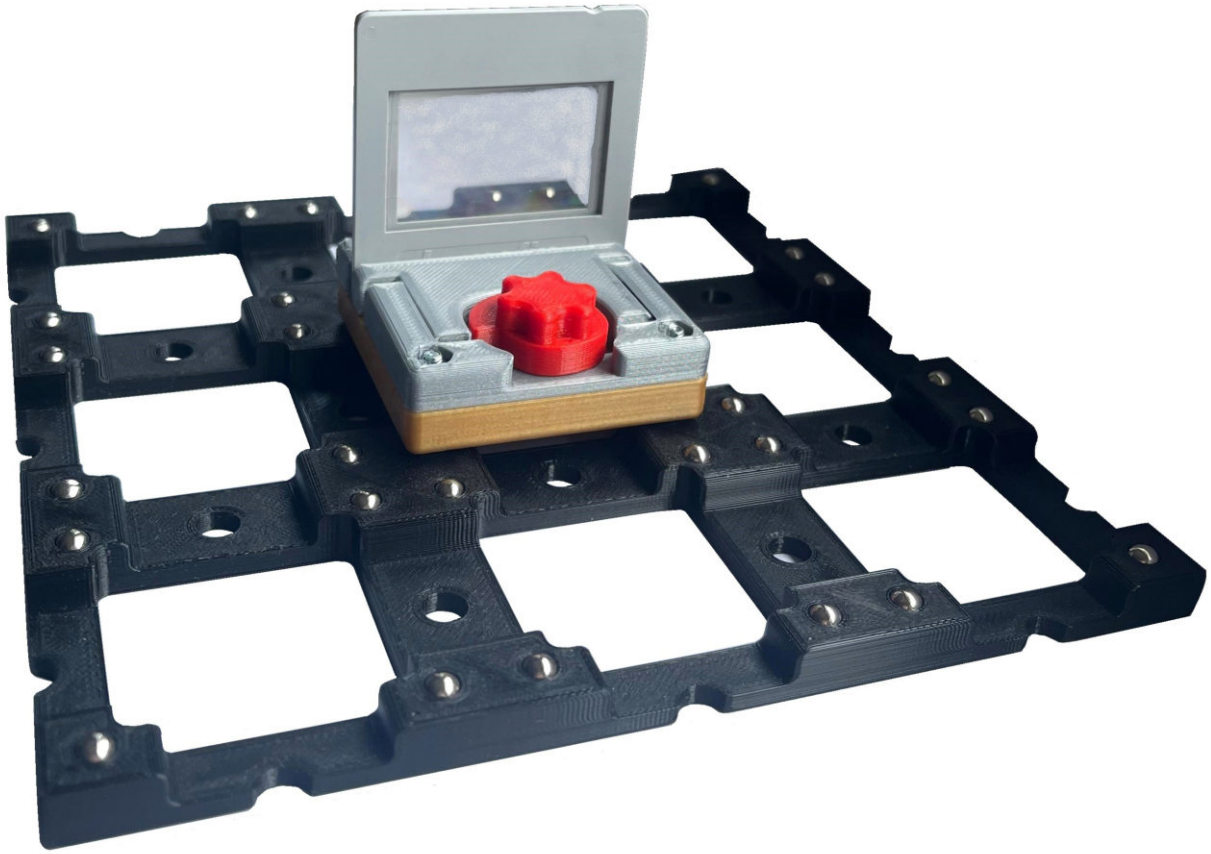

Fig. 1: Grating holder

Introduction

In the grating holder module, a grating can be clamped in the gap provided using the red rotary knob so that experiments with optical gratings, for example, can be carried out with the module box (Figure 1).

Experiments

▷ Experiments with slits and diffraction grating

Material & Tools

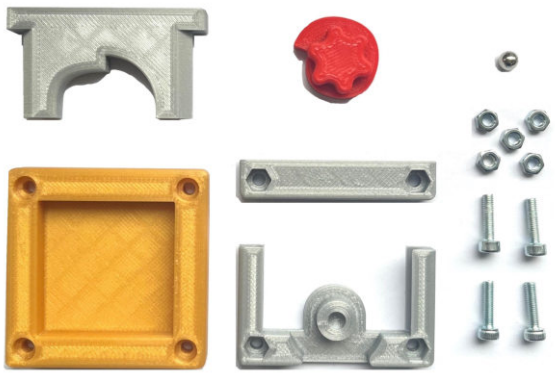

Fig. 2: Material

3D printing
1x 01B_Go_V*_cube_base 1x1_closed
1x 05A_Si_V*_grating_holder_frame
1x 05A_Si_V*_grating_holder_stopper
1x 05A_Si_V*_grating_holder_sledge
1x 05A_Re_V*_grating_holder_rotary_button

Other components
1x Magnetic sphere, ø=5mm
4x Allen cylinder head screw, M3x12
5x Nut, M3
▷ Superglue

Tools
▷ Allen key - 2,5 mm

Exploded view

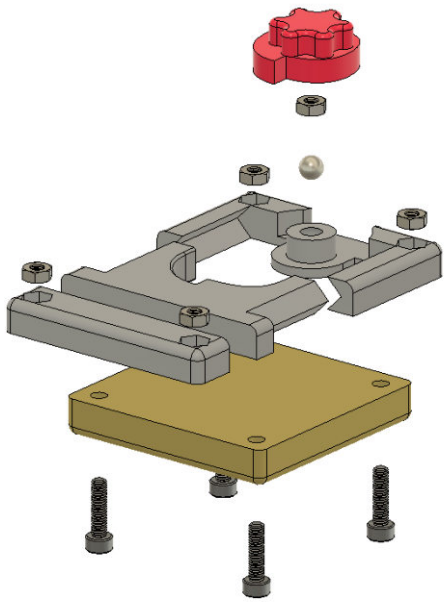

Fig. 3: Exploded view of the grating holder

I. Assembling

Material
1x 01B_Go_V*_cube_base 1x1_closed
1x 05A_Si_V*_grating_holder_frame
1x 05A_Si_V*_grating_holder_stopper
1x 05A_Si_V*_grating_holder_sledge
1x Magnetic sphere, ø=5mm
4x Nut, M3
4x Allen cylinder head screw, M3x12

(1) Press the MAGNETIC SPHERE, Ø=5MM into the 05A_SI_V*_GRATING_HOLDER_FRAME (Figure 4).

Fig. 4: Magnetic sphere pressed into the grating holder frame

(2) Place the frame on the 01B_GO_V*_CUBE_BASE 1X1_CLOSED and press a NUT, M3 into each of the openings provided for this purpose (Figure 5).

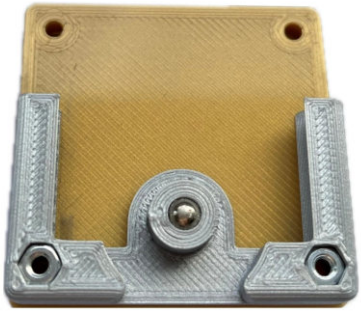

Fig. 5: Grating holder frame on the cube base

(3) Screw the frame to the base from below using two ALLEN CYLINDER HEAD SCREWS, M3X12 (Figure 6).

Tip: *Make sure that the nuts do not fall out of the openings when screwing them on. Hold the openings closed with a finger when turning the grating holder.*

Fig. 6: Frame screwed to the cube base

(4) Place the 05A_SI_V*_GRATING_HOLDER_SLEDGE with the straight side facing up on the base of the cube (Figure 7).

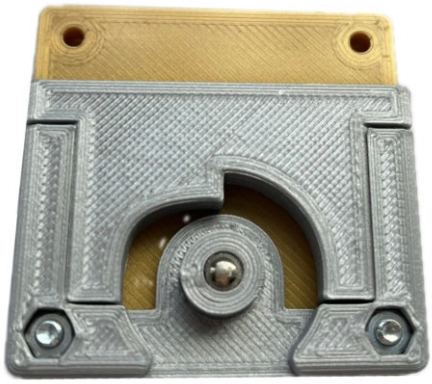

Fig. 7: Sledge on the cube base

(5) Insert a NUT, M3 into each of the openings provided in the 05A_Si_V*_grating_holder_stopper (Figure 8).

Fig. 8: Nuts in the stopper

(6) Place the stopper on the base (Figure 9).

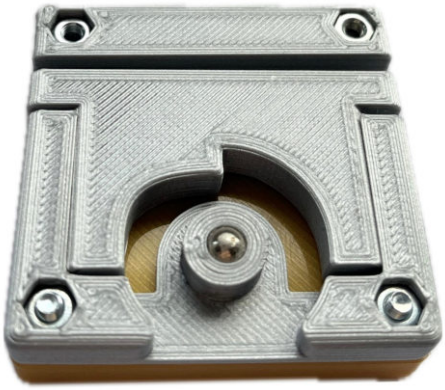

Fig. 9: Stopper on the cube base

(7) Screw the stopper to the base of the cube using two ALLEN CYLINDER HEAD SCREWS, M3X12 (Figure 10).

Tip: *Make sure that the screw nuts do not fall out of the openings when screwing them on. Hold the openings closed with a finger when turning the grating holder.*

Fig. 10: Screwed stopper

II. Last steps

Material

1x Assembled frame
1x 05A_Re_V*_grating_holder_rotary_button
1x Nut, M3
▷ Superglue

(8) Using SUPERGLUE and glue a NUT, M3 into the back of the 05A_Re_V*_grating_holder_rotary_button (Figure 11). This allows the rotary button to be easily fixed to the magnetic sphere.

Fig. 11: Nut glued into the rotary button

(9) Place the rotary button on the ASSEMBLED FRAME (Figure 12).

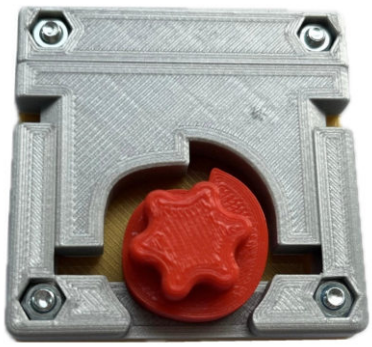

Fig. 12: Finished grating holder

Pair of basis polarizing filter BB84

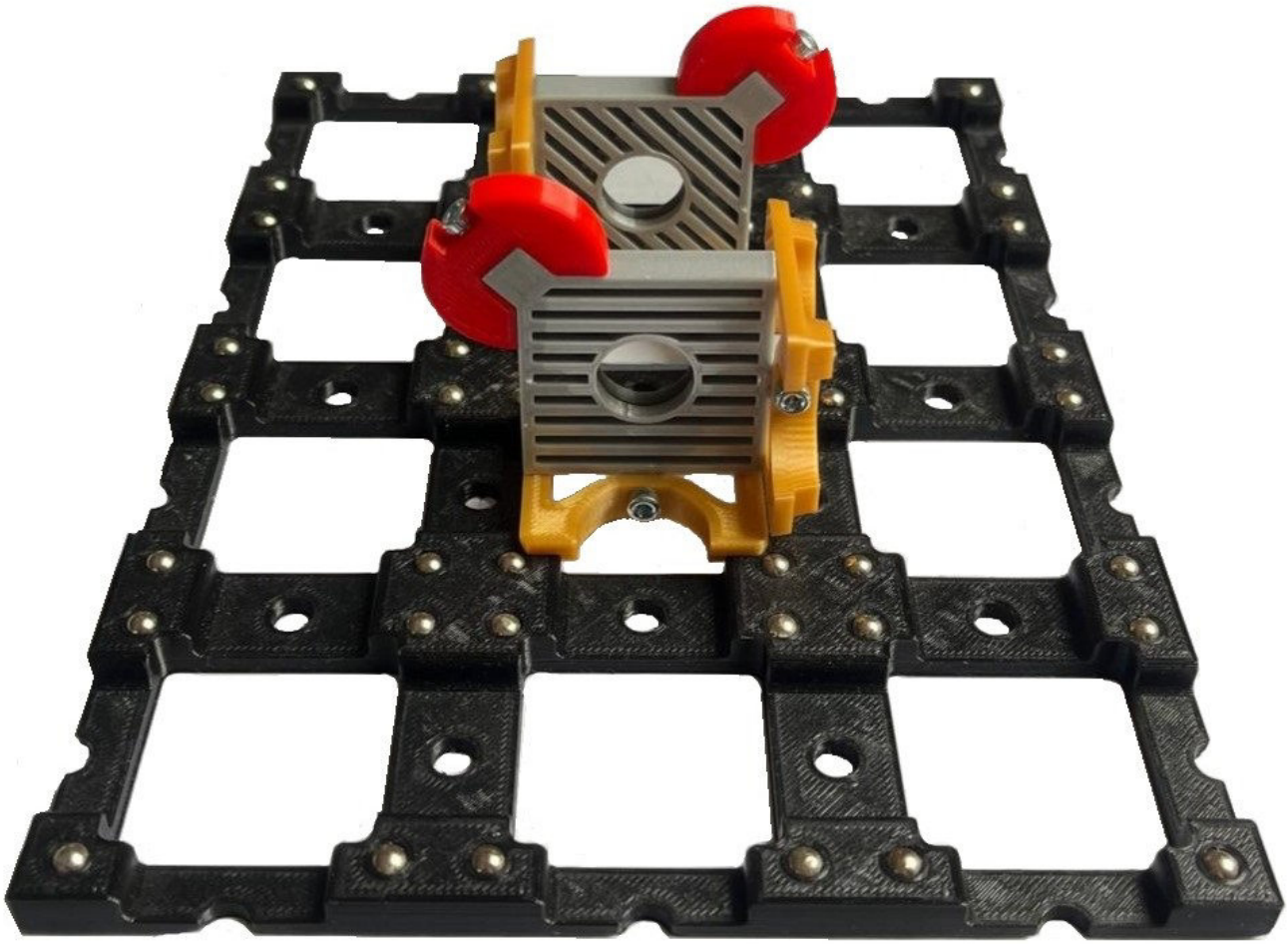

Fig. 1: Pair of basis polarizing filters for the BB84 experiment

Introduction

In this module two polarizing filters are held perpendicular to the base plate rotated 45° to each other. These can each be rotated by 90° using the red handle. This is necessary for the BB84 experiment.

Experiments

▷ BB84 model experiment - 1 pair

Material & Tools

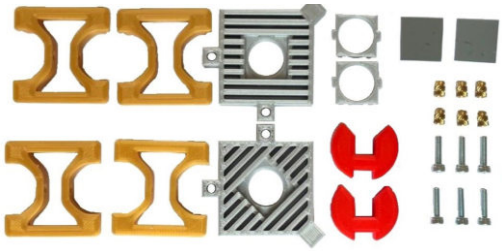

Fig. 2: Material

3D printing

4x 01E_Go_V*_basis_polarizing_filter_base
2x 06A_Si_V*_basis_polarizing_filter_cover
1x 06B_Si_V*_+basis_polarizing_filter_centre
1x 06C_Si_V*_xbasis_polarizing_filter_centre
2x 06A_Re_V*_basis_polarizing_filter_handle

Other components

6x Threaded insert, M3
6x Allen cylinder head screw, M3x12
2x Polarizing filter foil 17 mm x 17 mm

Tools

▷ Allen key - 2,5 mm
▷ Soldering iron (with melting tip)
▷ Scissors (for cutting the polarizing filters to size)

Exploded view

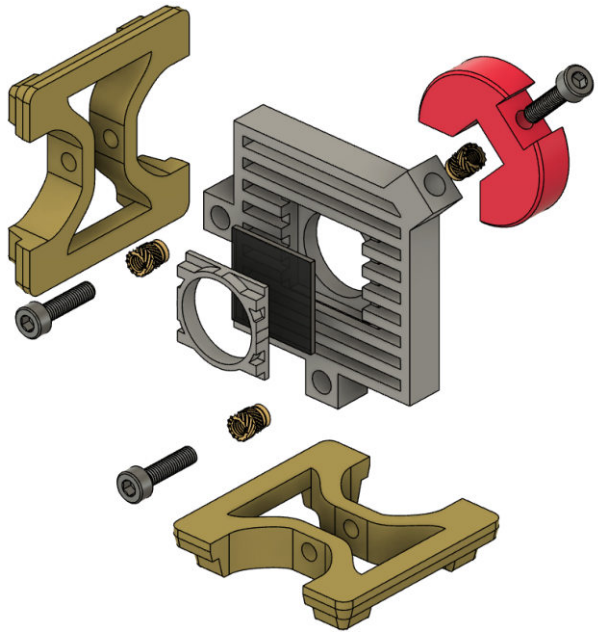

Fig. 3: Exploded view of the polarizing filter

I. Polarizing filter holder

Material

2x 06A_Si_V*_basis_polarizing_filter_cover
1x 06B_Si_V*_+basis_polarizing_filter_centre
1x 06C_Si_V*_xbasis_polarizing_filter_centre
6x Threaded insert, M3
2x Polarizing filter foil (17 mm x 17 mm)

(1) If necessary mount the tip for melting the thread inserts on the soldering iron and heat the soldering iron to 220°C.

(2) Melt two of the Threaded insert, M3 with the soldering iron into the flat side of the 06C_Si_V*_xbasis_polarizing_filter_centre (Figure 4).

Fig. 4: Correctly positioned threaded inserts

(3) Melt the third Threaded insert, M3 into the opening provided on the side of the xbasis polarizing filter (Figure 5).

Fig. 5: Correctly positioned threaded inserts

Fig. 6: Melted threaded inserts

(4) Pull the foil from the polarizing filter foil (17 mm x 17 mm) and place it in the opening of the xbasis polarizing filter (Figure 7).

Fig. 7: Polarizing filter foil inserted in the holder

Note: *Ensure that the polarizing filter foil is correctly aligned. To do this, first determine the alignment of the polarizing foil. Use the effect of the Brewster angle, e.g. on a glass plate (smartphone) as shown in Figure 8. Hold the foil in front of the reflected polarised light. The orientation of the polarizing foil is 0° when the reflected light is absorbed. The orientation of the polarizing filter holder will help you with this: if the slots in the holder are aligned vertically, the reflected light*

should be absorbed, if they are aligned horizontally, it should be transmitted (Figure 8).

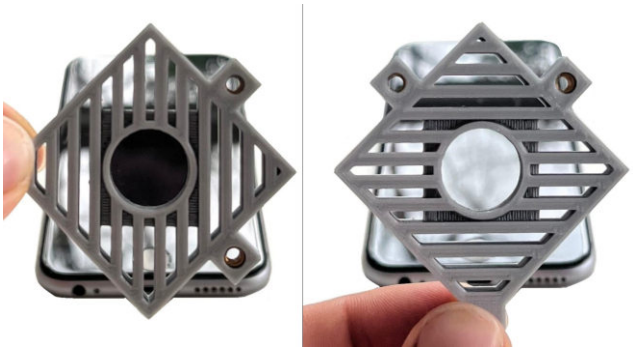

Fig. 8: Polarisation on a glass plate (Brewster angle). The reflected light is absorbed on the left and transmitted on the right.

(5) Press the 06A_SI_V*_BASIS_POLARIZING_FILTER_COVER over the inserted polarizing filter with the openings provided into the holder (Figure 9).

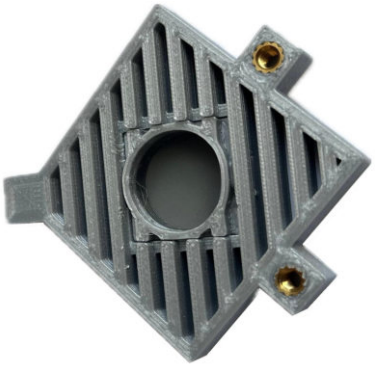

Fig. 9: Filter cover pressed into the holder

(6) Repeat the steps with the 06B_SI_V*_+BASIC_POLARIZING_FILTER_CENTRE .

Note: *Ensure that the polarizing filter foil is correctly aligned. To do this, first determine the alignment of the polarizing foil. Use the effect of the Brewster angle, e.g. on a glass plate (smartphone) as shown in Figure 10. Hold the foil in front of the reflected polarised light. The orientation of the polarizing foil is 0° when the reflected light is absorbed. The orientation of the polarizing filter holder will help you: if the slits of the holder are aligned vertically, the reflected light should be absorbed, if horizontally, it should be transmitted (Figure 10).*

Fig. 10: Polarisation on a glass plate (Brewster angle). The reflected light is absorbed on the left and transmitted on the right.

II. Assembling

Material

1x Finished xbasis polarizing filter holder
1x Finished +basis polarizing filter holder
2x 06A_Re_V*_basis_polarizing_filter_handle
4x 01E_Go_V*_basis_polarizing_filter_base
6x Allen cylinder head screw, M3x12

(1) Place a 01E_GO_V*_BASIS_POLARIZING_FILTER_BASE on one side of a FINISHED XBASIS POLARIZING FILTER HOLDER so that the edges are on top of each other and secure it with a ALLEN CYLINDER HEAD SCREW, M3X12 (Figure 11).

Fig. 11: Correctly positioned base on the polarizing filter holder

(2) Repeat the previous step with the second `01E_Go_V*_basis_polarizing_filter_base` on the other side of the finished polarizing filter holder (Figure 12).

Fig. 12: Correctly positioned base on the polarizing filter holder

Fig. 13: Attached bases on the polarizing filter holder

(3) Place the `06A_Re_V*_basis_polarizing_filter_handle` over the edge on the corner of the polarizing filter holder and secure it with a `Allen cylinder head screw, M3x12` (Figure 14).

Fig. 14: Ready assembled polarizing filter

(4) Repeat the steps with the `Finished +base polarizing filter holder` to create the second polarizing filter (Figure 15).

Fig. 15: Ready assembled polarizing filter

Coupled polarizing filter BB84

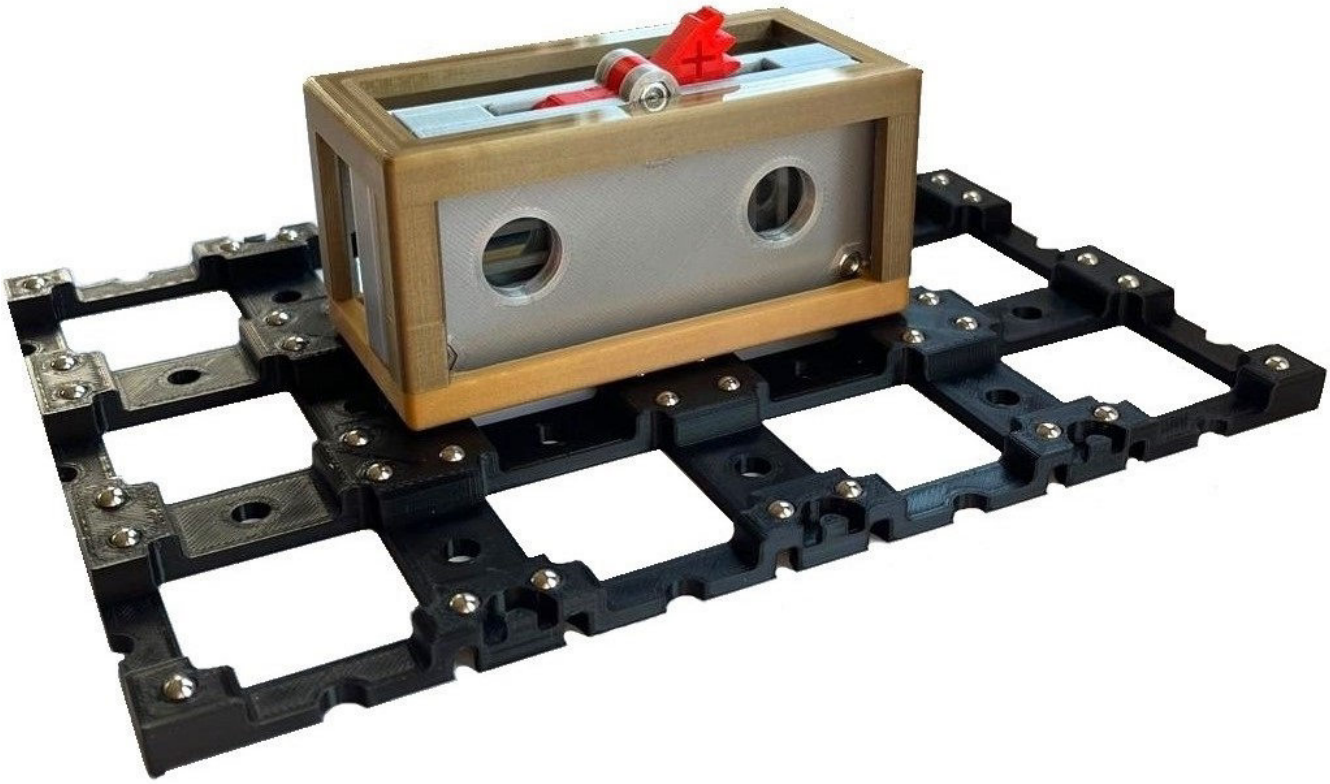

Fig. 1: Coupled polarizing filter BB84

Introduction

In the coupled polarizing filter module, two polarizing filters are held in a cube offset by 45° to each other and connected to each other with a switch so that they can be rotated in a coupled manner. This is necessary, for example, for the BB84 model experiment.

Experiments

▷ BB84 model experiment - 1 pc.

Material & Tools

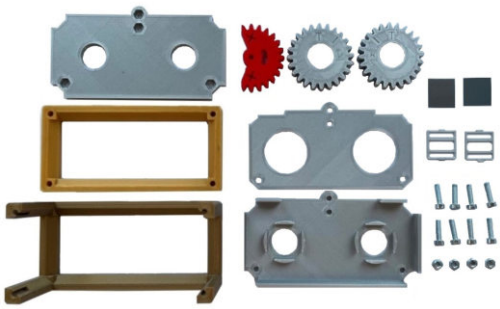

Fig. 2: Material

3D printing

1x 01C_Go_V*_cube_base 1x2
1x 02C_Br_V*_cube_cover 1x2
1x 21A_Si_V*_coupled_polarizing_filter_front_plate
1x 21A_Si_V*_coupled_polarizing_filter_retaining_plate
1x 21A_Si_V*_coupled_polarizing_filter_intermediate_plate
1x 21A_Si_V*_coupled_polarizing_filter_gearwheel_left
1x 21A_Si_V*_coupled_polarizing_filter_gearwheel_right
2x 21A_Si_V*_coupled_polarizing_filter_grid_insert
1x 21A_Re_V*_coupled_polarizing_filter_switch

Other components

8x Allen cylinder head screw, M3x12
4x Nut, M3
2x Polarizing filter foil (17 mm x 17 mm)

Tools

▷ Allen key - 2,5 mm
▷ Scissors / knife

Exploded view

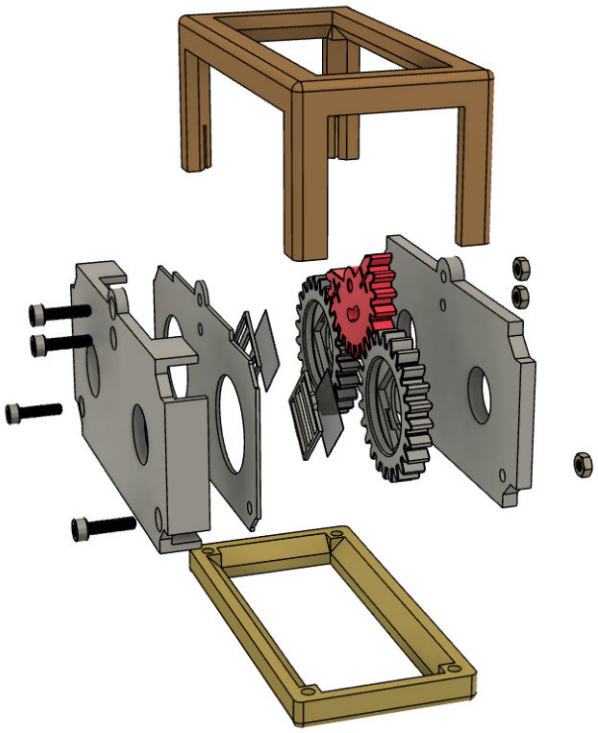

Fig. 3: Exploded view of the coupled polarizing filter

I. Rotary wheels

Material

1x 21A_Si_V*_coupled_polarizing_filter_gearwheel_left
1x 21A_Si_V*_coupled_polarizing_filter_gearwheel_right
2x 21A_Si_V*_coupled_polarizing_filter_grid_insert
2x Polarizing filter foil (17 mm x 17 mm)

(1) Pull the foil from the polarizing filter foil (17 mm x 17 mm) and place it from behind in the opening provided in the 21A_Si_V*_coupled_polarizing_filter_gearwheel_left (Figure 4).

Fig. 4: Polarizing filter foil inserted in the wheel

Note: *Ensure that the polarizing filter foil is correctly aligned. To do this, first determine the alignment of the polarizing film. Use the effect of the Brewster angle, e.g. on a glass plate (smartphone) as shown in Figure 5. Hold the film in front of the reflected polarised light. The alignment of the polarization film is correct if the reflected light is transmitted when the struts are aligned horizontally in the holder and the light is absorbed when the struts are aligned vertically (Figure 5).*

Fig. 5: Polarization on a glass plate (Brewster angle). The reflected light is transmitted on the left and absorbed on the right.

(2) Press the 21A_Si_V*_Coupled_polarizing_filter_grid_insert over the inserted polarizing filter with the openings provided in the wheel (Figure 6).

Fig. 6: Correctly inserted grid insert

(3) Repeat these steps for the 21A_Si_V*_coupled_polarizing_filter_gearwheel_right (Figure 8).

Note: *Ensure that the polarizing filter foil is correctly aligned. To do this, first determine the alignment of the polarizing film. Use the effect of the Brewster angle, e.g. on a glass plate (smartphone) as shown in Figure 7. Hold the film in front of the reflected polarised light. The alignment of the polarization film is correct if the reflected light is transmitted when the struts are aligned horizontally in the holder and the light is absorbed when the struts are aligned vertically (Figure 7).*

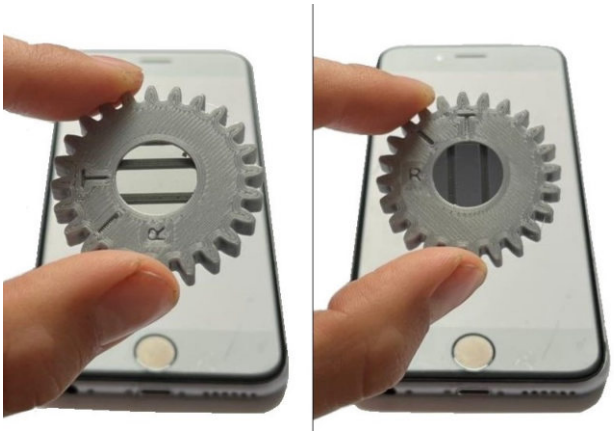

Fig. 7: Polarization on a glass plate (Brewster angle). The reflected light is transmitted on the left and absorbed on the right.

Fig. 8: Finished rotary wheels

II. Coupled polarizing filter holder

Material

2x Finished rotary wheels
1x 21A_Si_V*_coupled_polarizing_filter_front_plate
1x 21A_Si_V*_coupled_polarizing_filter_retaining_plate
1x 21A_Si_V*_coupled_polarizing_filter_intermediate_plate
1x 21A_Re_V*_coupled_polarizing_filter_switch
4x Allen cylinder head screw, M3x12
4x Nut, M3

(1) Place the 21A_Si_V*_coupled_polarizing_filter_intermediate_plate with the smooth side facing up on the 21A_Si_V*_coupled_polarizing_filter_retaining_plate (Figure 9).

Note: *Make sure that the smooth side of the intermediate plate is facing away from the retaining plate to make it easier to turn the Coupled pole filter wheels later.*

Fig. 9: Coupled polarizing filter intermediate plate on the retaining plate

(2) Push four of the Allen cylinder head screws, M3x12 from behind into the retaining plate and the intermediate plate through the openings provided for this purpose (Figure 10).

Fig. 10: Allen cylinder head screws pushed through the openings in the retaining and intermediate plate

(3) Then place the Finished rotary wheels on the holders provided. Place the left rotary wheel (L) on the left and the right rotary wheel (R) on the right so that the letters are legible (Figure 11).

Note: *When the wheels are correctly positioned, the upper line of the T is exactly horizontal and the letters (L and R) are legible.*

Fig. 11: Correctly positioned rotary wheels

(4) Place the 21A_Re_V*_Coupled_polarizing_filter_switch on the intermediate plate. Make sure that the switch is positioned so that both the left-hand line is in line with the line on the left-hand dial and the right-hand line is in line with the line on the right-hand dial (Figure 12).

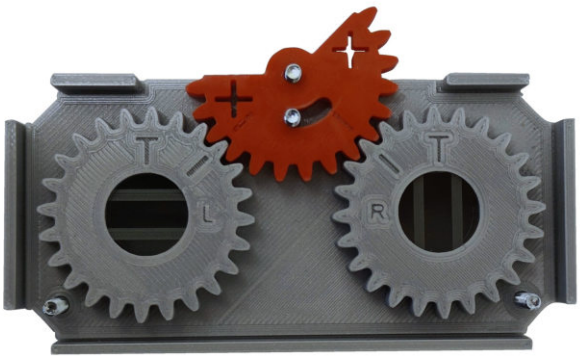

Fig. 12: Correctly positioned switch

(5) Place the 21A_Si_V*_Coupled_polarizing_filter_front_plate on top (Figure 13).

Note: *Make sure that the smooth side of the front plate is facing the rotary wheels to make it easier to turn the rotary wheels later.*

Fig. 13: Attached front plate

(6) Insert the four Nuts, M3 into the holes provided and tighten the screws (Figure 14).

Note: *Take care not to overtighten the screws so that the switch can still be operated easily.*

Fig. 14: Finished coupled polarizing filter holder

III. Last steps

Material

▷ Finished coupled polarizing filter holder
1x 01C_Go_V*_cube_base 1x2
1x 02C_Br_V*_cube_cover 1x2
4x Allen cylinder head screw, M3x12

(1) Insert the finished coupled polarizing filter holders into the 01C_Go_V*_cube_base 1x2 (Figure 15).

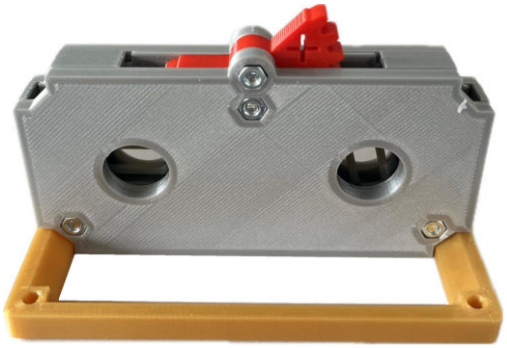

Fig. 15: Coupled polarizing filter holder in the base of the cube

(2) Place the 02C_Br_V*_cube_cover 1x2 on the base (Figure 16).

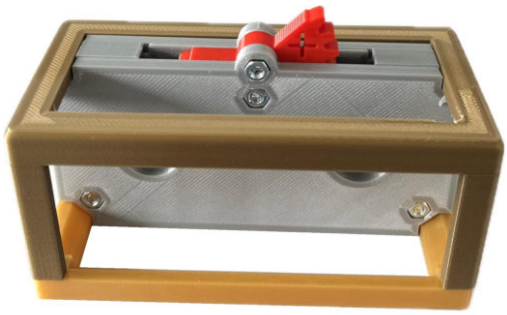

Fig. 16: Assembled cube

(3) Turn the cube over and screw the base in place using the Allen cylinder head screws, M3x12 (Figure 17).

Fig. 17: Screwed cube

Light sensor

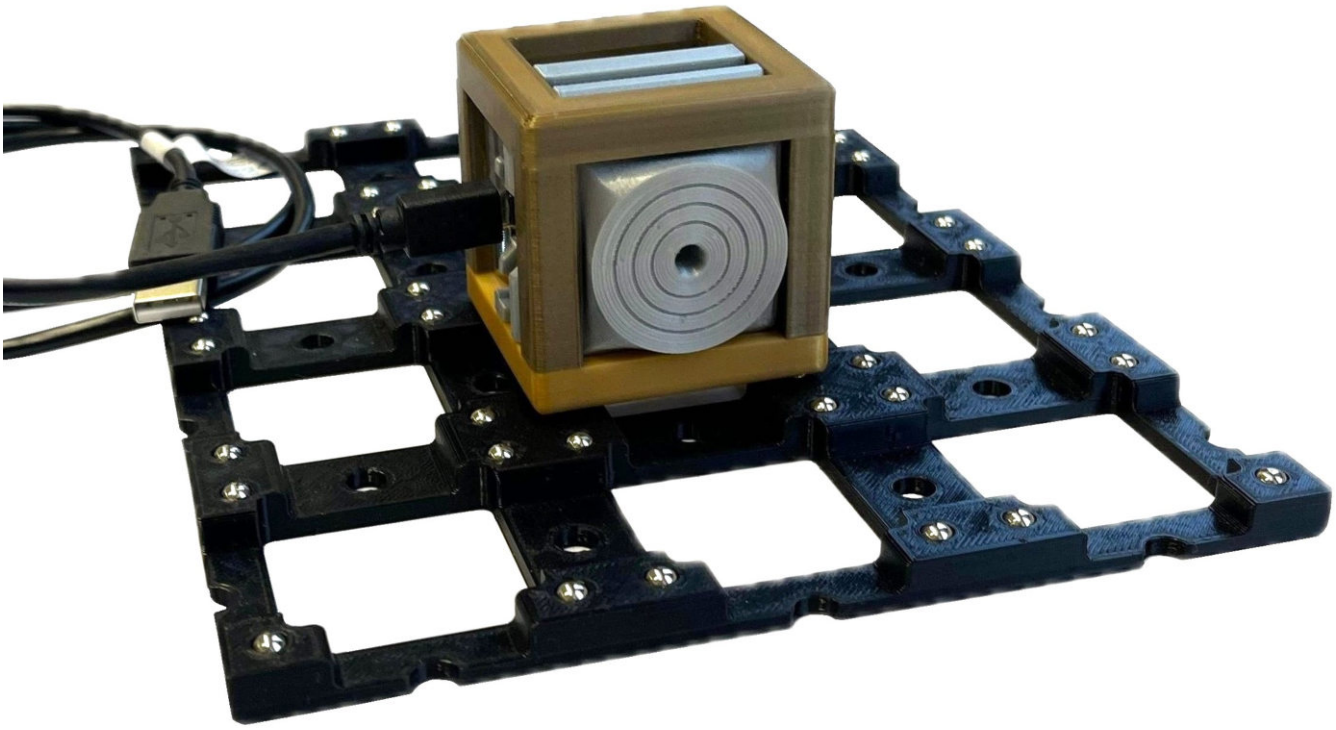

Fig. 1: Light sensor

Introduction

In the light sensor module, a light-sensitive sensor is used to measure and analyze the intensity of incoming light. The module consists of a BH1750 light sensor operated in conjunction with an ESP32 microcontroller. Due to its precise detection of light intensity, this module is suitable for a wide range of physics experiments, including investigations of light absorption, reflection, and attenuation (Figure 1).

Experiments

▷ Law of Malus

Material & Tools

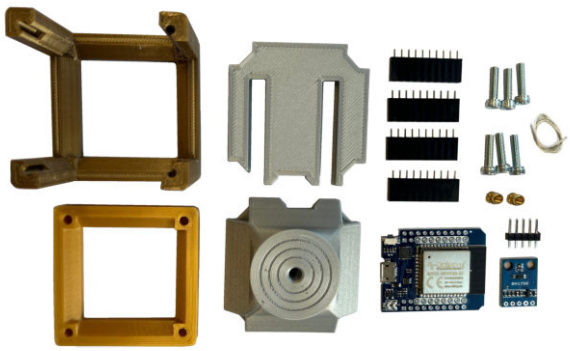

Fig. 2: Material

3D printing

1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
1x 15A_Si_V*_light_sensor_BH1750
1x 15A_Si_V*_light_sensor_ESP32Mini

Other components

1x Light Sensor BH1750
1x ESP32 Mini
6x Allen cylinder head screw, M3x12
2x Threaded, M3
▷ Soldering tin

Tools

▷ Allen key - 2,5 mm
▷ Soldering iron (with tip for threaded inserts)

Exploded view

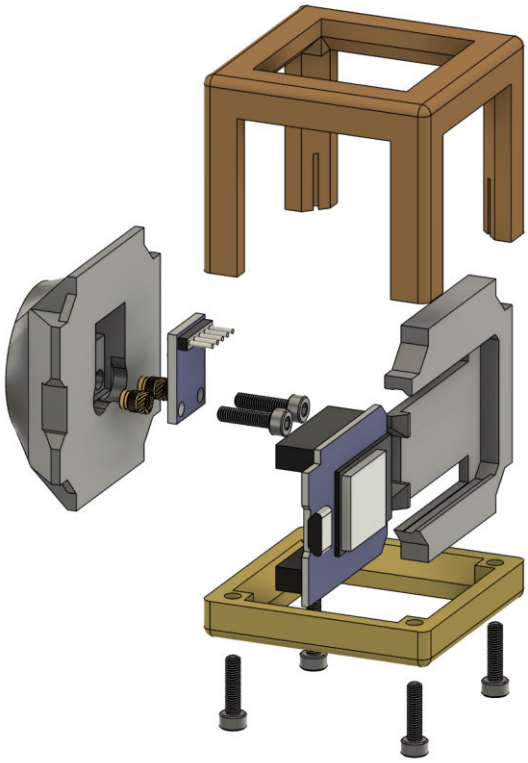

Fig. 3: Exploded view of the light sensor

I. PCB holder

Material

1x ESP32 Mini
1x 15A_Si_V*_light_sensor_ESP32Mini
▷ Soldering tin

(1) Heat the soldering iron to approximately 350 °C.

(2) Solder the short pin headers to the ESP32 Mini (Figure 4).

Fig. 4: Pin headers soldered to the PCB

(3) Slide the PCB into the 15A_Si_V*_light_sensor_ESP32Mini (Figure 5).

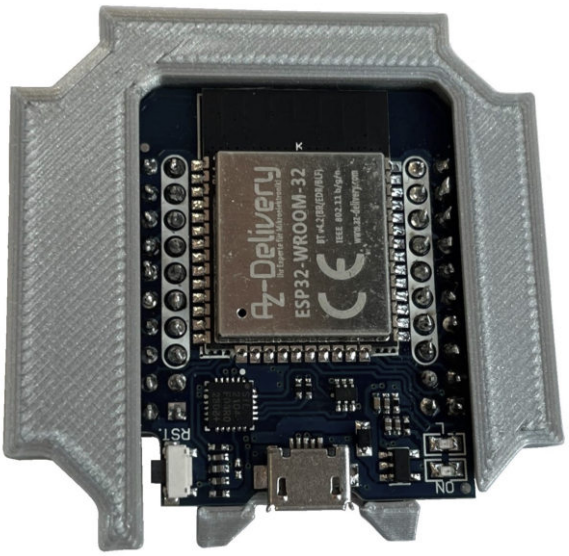

Fig. 5: PCB in the insert

II. Sensor holder

Material

1x Light Sensor BH1750
1x 15A_Si_V*_light_sensor_BH1750
2x Gewindeeinsatz, M3

(4) Solder the pin header to the Light Sensor BH1750 (Figure 6).

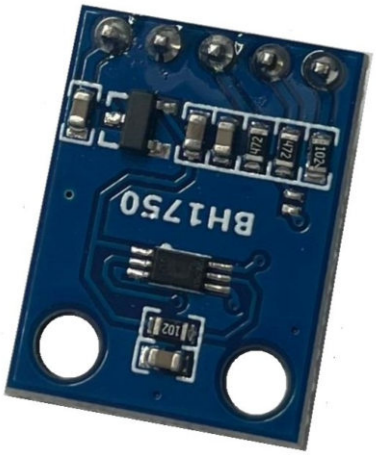

Fig. 6: Pin header soldered to the sensor

(5) Attach the tip for inserting threaded inserts and heat the soldering iron to approximately 220 °C.

(6) Heat-set the two threaded insert, M3 into the 15A_Si_V*_light_sensor_BH1750 (Figure 7).

Note: *Make sure to heat-set the inserts as vertically as possible.*

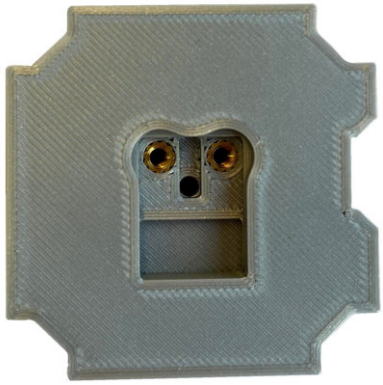

Fig. 7: Threaded inserts heat-set into the insert

(7) Place the sensor into the insert (Figure 8).

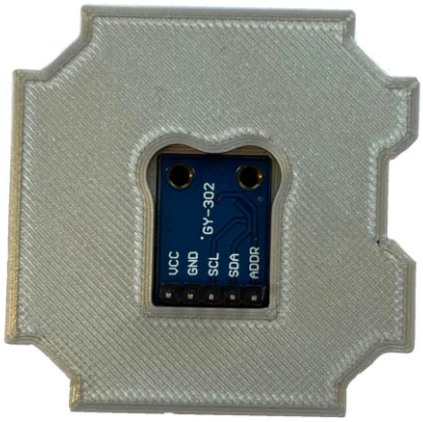

Fig. 8: Sensor in insert

(8) Fasten the sensor using two Allen cylinder head screw, M3x12 (Figure 9).

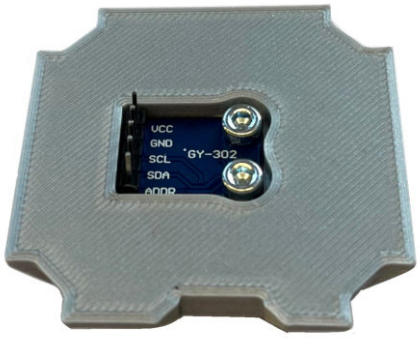

Fig. 9: Fastened sensor

III. Last steps

Material

1x Assembled PCB holder
1x Asemmbled sensor holder
1x 01A_Go_V*_cube_base 1x1
1x 02A_Br_V*_cube_cover 1x1
4x Allen cylinder head screw, M3x12

(9) Insert the ASSEMBLED PCB HOLDER and the ASSEMBLED SENSOR HOLDER into the 02A_Br_V*_CUBE_COVER 1x1. Make sure that the open sides of both holders face the same direction, while the three smooth sides are aligned. Place the 01A_Go_V*_CUBE_BASE 1x1 on top (Figure 10).

Fig. 10: Assembled components

(10) Fasten the cube base using the ALLEN CYLINDER HEAD SCREWS. Then connect the PCB holder and the sensor holder by sliding the pin headers together. Make sure to align and insert them as straight as possible (Figure 11).

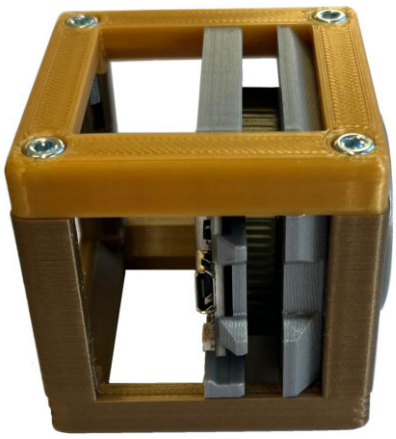

Fig. 11: Finished light sensor

IV. Upload program code

Material

1x Finished light sensor
1x Program code
1x Arduino IDE
1x Laptop/Computer
1x USB to USB-C cable

(11) If you have not yet installed the Arduino IDE, follow the link https://www.arduino.cc/en/software/ and install it for the operating system of your choice.

(12) Open the program code in the Arduino IDE. Here you can find the program code https://o3q.de/en/light-sensor/#Features

(13) Add the board in the Arduino IDE, here https://cdn.shopify.com/s/files/1/1509/1638/files/AZ279_A_20-2_EN_B08BTRQNB3_5bbfc25f-6964-44b5-9ff2-dc872d3abc0b.pdf?v=1721128718 you will find the relevant instructions on pages 26 and 27.

(14) Install the following libraries:
- ▷ Async TCP from ESP32Async
- ▷ ESP Async Webserver from ESP32Async

(15) Connect the ESP32 Mini to your laptop/computer and upload the program code.

Baseplate 4x6

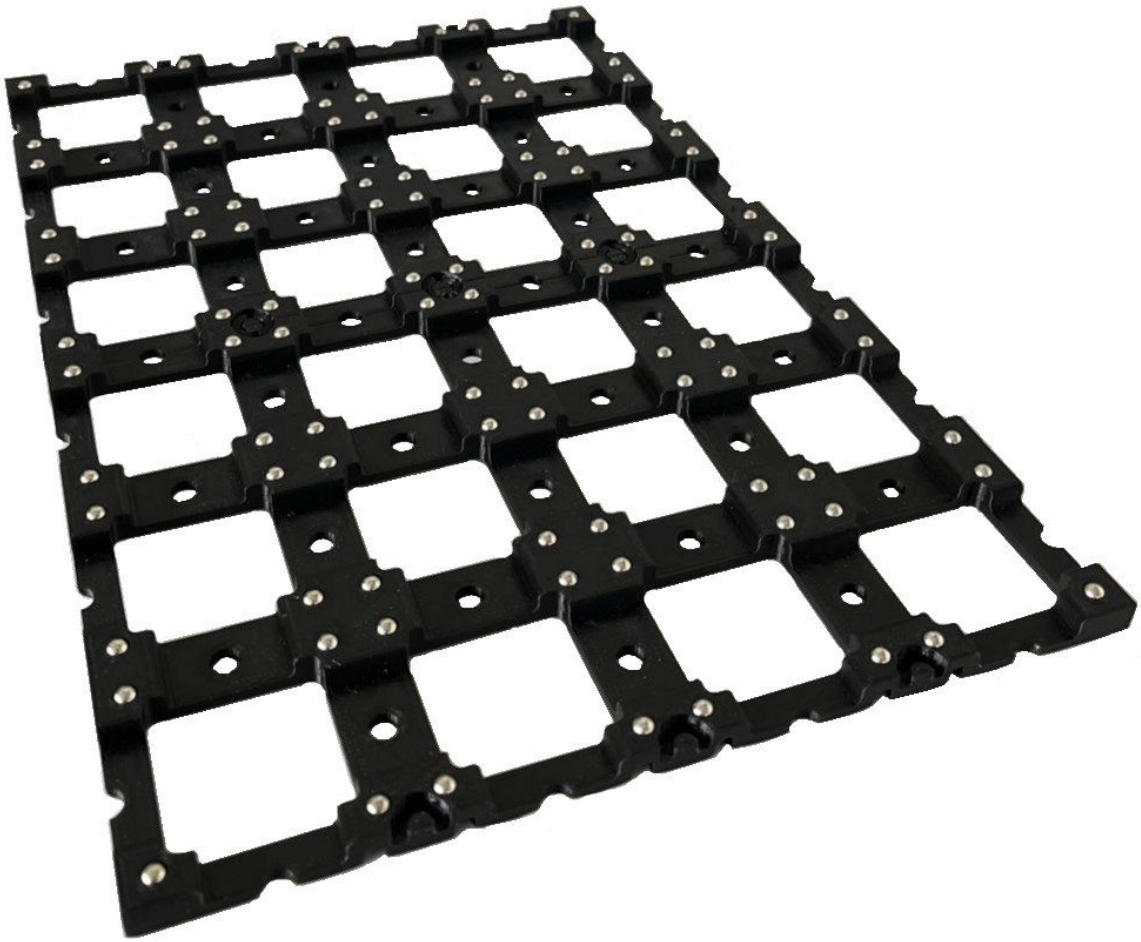

Fig. 1: Baseplate 4x6

Introduction

In these instructions, you will create the baseplate, which serves as a base and magnetic holder for the modular construction kit. It allows you to adjust various experiments and can be printed in different sizes as required. Connectors can be used to join several baseplates together.

Experiments

- Michelson interferometer - 1 pc.
- Michelson with piezo - 1 pc.
- Mach-Zehnder interferometer - 1 pc.
- Slits & diffraction grating - 1 pc.
- Polarization - 1 pc.
- BB84 model experiment - 1 pc.

Material & Tools

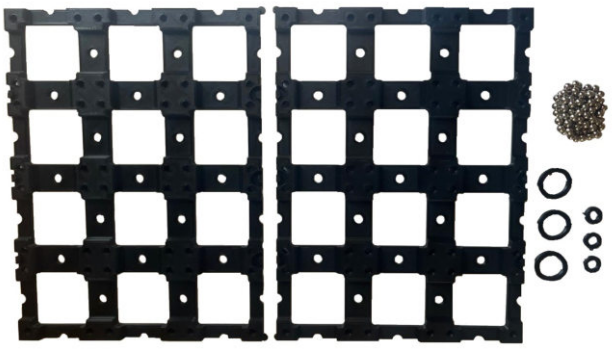

Fig. 2: Material

3D printing
1x 00A_Bl_V*_baseplate 4x6

or

2x 00B_Bl_V*_baseplate_con. 4x3
3x 00B_Bl_V*_connector_basepl.

Other components
96x Magnetic sphere, ø=5mm

Tools
▷ Pipe wrench
▷ Knife
▷ XX1_TOOL_connect_baseplates (Figure 3)

Fig. 3: Tool for assembling the baseplates

Exploded view

Fig. 4: Exploded view of the baseplate

I. Inserting the magnetic spheres

Material
1x 00A_Bl_V*_baseplate 4x6

or

2x 00B_BL_V*_baseplate_con. 4x3
96x Magnetic spheres, ø=5mm

(1) Take a knife and remove the print residue from the corners of the `00A_Bl_V*_baseplate 4x6` or the `00B_Bl_V*_baseplate_con. 4x3` the print residues.

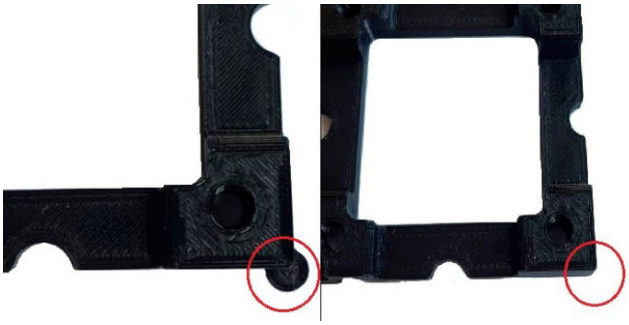

Fig. 5: Corner of the baseplate left before, right after removing the print residue, the red circles marks the corresponding areas

(2) Press the `magnetic spheres, ø=5mm` into the baseplate (Figure 6).

Fig. 6: Pressing in the magnetic spheres using a pipe wrench

Attention: *The magnetic spheres must be aligned so that the north or south pole protrudes vertically from the plate so that the spheres later hold well on the set screws. Ideally, this will happen automatically if you press the spheres in with a ferromagnetic pipe wrench (Figure 7)*

Fig. 7: Due to the ferromagnetic properties of the pipe wrench, the magnetic sphere adheres to it in the desired orientation

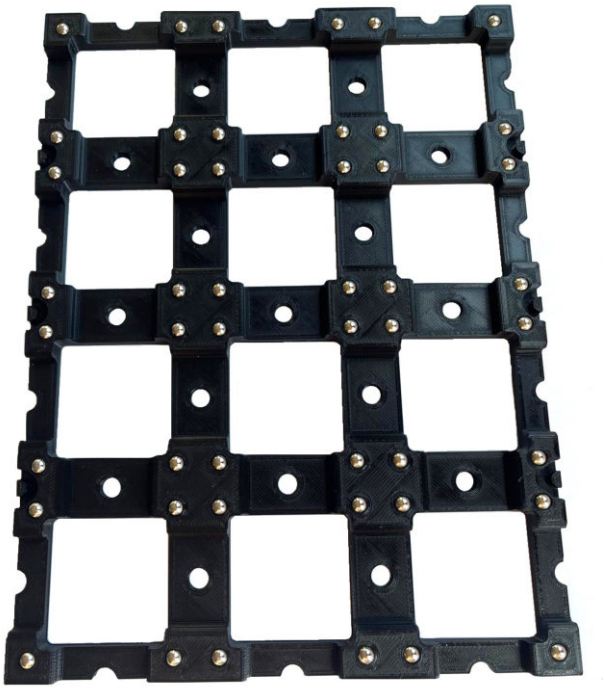

Fig. 8: Finished baseplate

II. Optional: Assembling the two 4x3 baseplates

Material

2x 00B_Bl_V*_baseplate_con. 4x3

3x 00B_Bl_V*_connector_basepl.

▷ XX1_TOOL_connect_baseplates

(1) Turn the two 00B_Bl_V*_baseplate_con. 4x3 and place them next to each other accordingly (Figure 9).

Fig. 9: Correctly placed 4x3 baseplates

(2) Push the 00B_Bl_V*_connector_basepl. apart so that they have 3 large and 3 small connectors.

(3) Place the 3 large connectors in the openings provided (Figure 10).

Fig. 10: Inserting the connectors

(4) Rotate them by 90° using the XX1_TOOL_connect_baseplates so that they hold the baseplates firmly together.

(5) Turn the now assembled 4x6 large baseplate over and repeat the last step with the 3 small connectors (Figure 11).

Fig. 11: Inserting the connectors

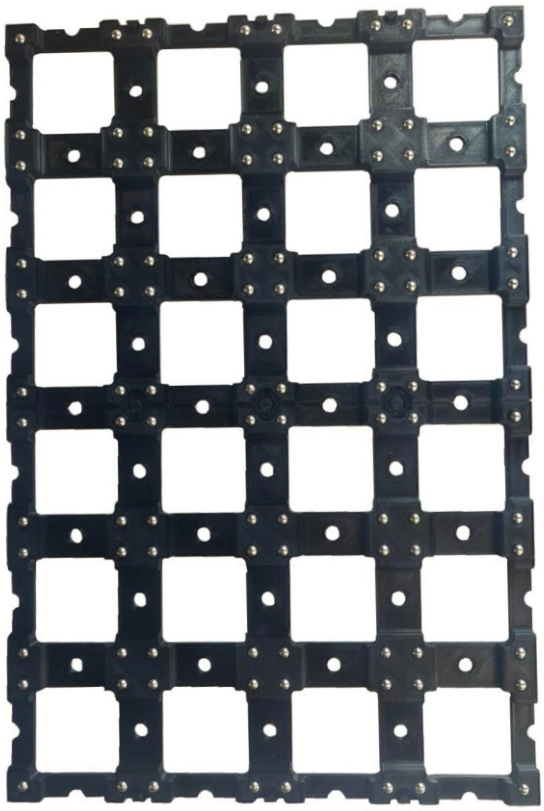

Fig. 12: Finished 4x6 baseplate