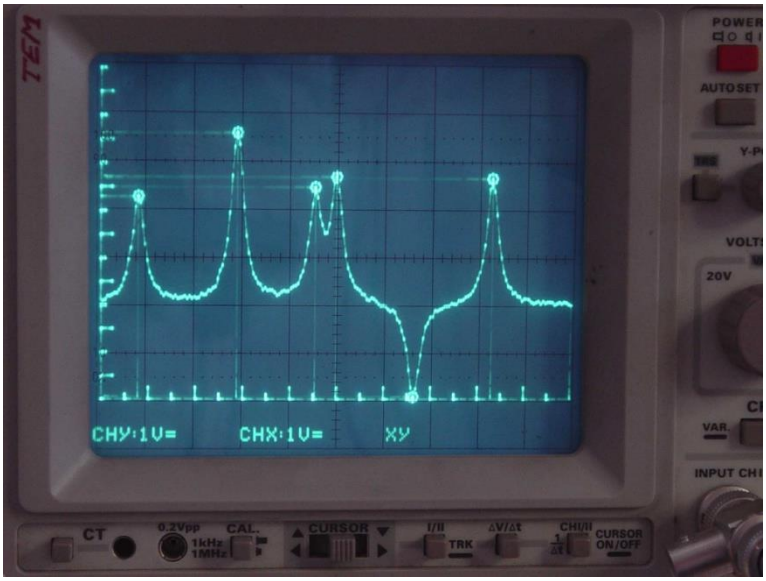
CoSy User Manual



CoSy User Manual

Compact Saturation Spectroscopy

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CoSy 6.0 Manual TEM en, Stand 20.02.2024 10:37:00

Contents

1 Product description

1.1 Principle of operation

The method of saturation spectroscopy allows to represent a wavelength exact enough to be used, e.g. for precise absolute stabilisation of tunable lasers.

To this end light from a tunable laser is led into a glass cell filled with a suitable gas, the particles of which absorb light of particular wavelengths.By the technique of Doppler-free saturation spectroscopy, a suitable optical setup consisting of several part beams compensates for the Doppler broadening of atomic lines to a large extent which highly increases the resolution of the measured absorption lines.

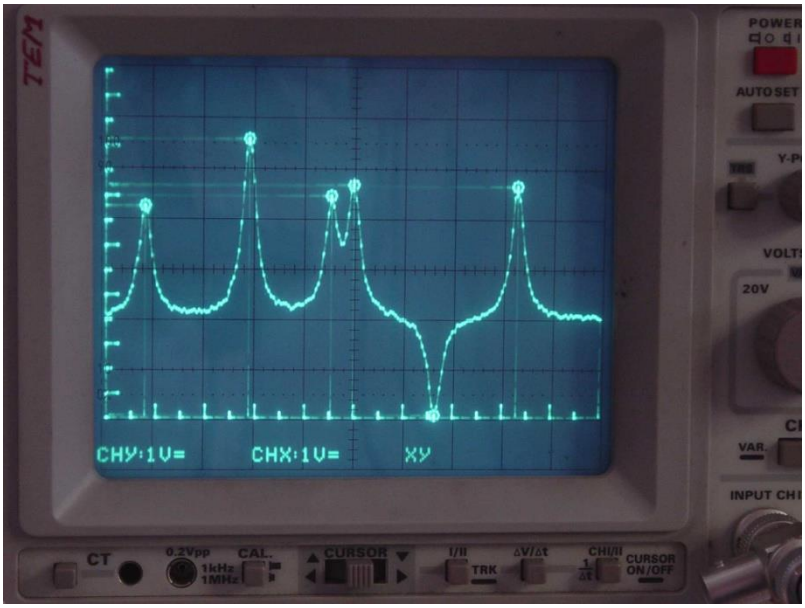


Fig. 1.1 Doppler-free saturation spectrum of the Cs-D_2-absorption line

Usually this is achieved by using a relatively complex opto-mechanical setup. The truly compact *CoSy* system contains this setup and also all the evaluation electronics needed to obtain a Doppler free saturation spectrum as an output voltage directly observable e.g. on an oscilloscope. The Laser irradiating the System can thus be stabilised to any of the detected lines. This may be done for example using TEM Messtechnik´s LaseLock or the Modules PID110 or LIR110 by TOPTICA Photonics.

In this way a frequency uncertainty below 1 MHz can be achieved , corresponding to a relative uncertainty of 10^{-9}.

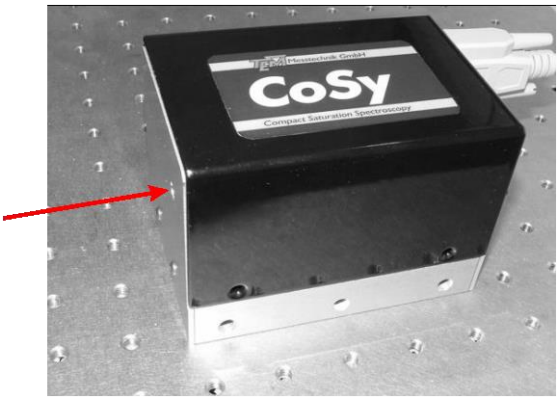


Fig.. 1.2 The *CoSy* measurement head

The complete optomechanical setup, consisting of beamsplitters, mirrors and the spectroscopy glass cell, is integrated in the *CoSy* measurement head.

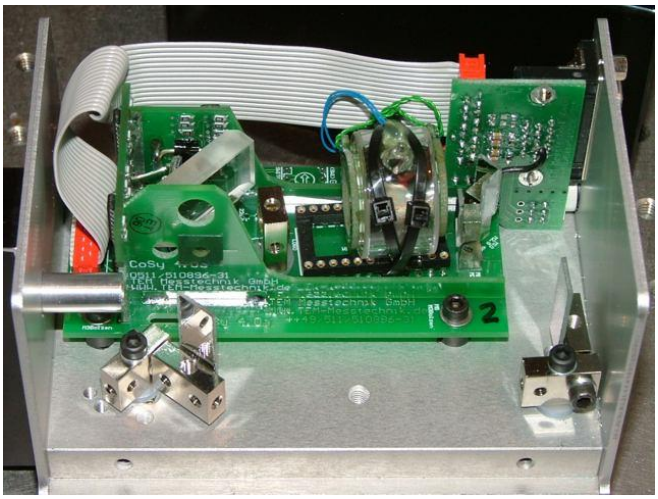


Fig. 1.3 The *CoSy* measurement head from the inside

For operation a free laser beam is directed into the *Cosy* measurement head where it is split several times in order to traverse the glass cell on different paths, falling onto three different photo diodes. From the resulting signals the doppler free saturation spectrum of the chosen chemical element is generated by amplification and electronic signal processing, to be monitored on an oscilloscope or to be used, e.g., for laser stabilisation.

The *CoSy* head is controlled and supplied by the electronic module *CoSyControl*. This contains the voltage supply unit and the connectors for the output signals A, B and I, as well as, the control elements for adjusting the cell temperature and optionally and thus not contained in the standard product, the longitudinal magnetic field.

1.2 Chemical elements available for spectroscopy cell

The standard version of *CoSy* is delivered with the glass cell containing the following alkali metals:

- „Cs“: Caesium (^{133}Cs)
- „Rb“: Rubidium (mixture of ^{85}Rb and ^{87}Rb)
- “K”: Potassium (^{39}K)

(other elements available on request).

1.3 Versions of the product

The following options, not contained in the standard product described in this manual, exist:

- „Coil“: For certain applications it is useful to generate an (AC- or DC-) magnetic field inside the cell. To this end, a coil around the cell is provided in this version of *CoSy*.
- „FC“ the measurement head may on request be delivered with a FC/APC single mode fiber coupler.

2 Safety instructions

Please read this manual carefully before operating any part of your *CoSy* system to avoid any damage to objects or persons

Warning!

The *CoSy* system is being used in Laser systems with partially invisible laser radiation. Do not look into the laser beam! Take precautions to avoid any direct or reflected laser radiation outside the experiment.

Warning!

The users are responsible for keeping the legal rules concerning laser safety that apply in their country. In germany this is the „Unfallverhütungsvorschrift BGV B2“ of the „Berufsgenossenschaft der Feinmechanik und Elektrotechnik“.

Warning!

Use only the supplied power cord and plugs or the corresponding ones for your country, as only this guarantees safe operation and grounding of the devices.

Warning!

Please ensure before operation that the proper supply voltage is chosen on the *CoSyControl* unit (see section 8.3 for details).

Warning!

The devices *CoSy* measurement head and *CoSyControl* are intended for indoor operation with a temperature range from +10 °C to +25 °C (please take into account that the spectroscopy cell has to have the right optical density and therefore the right temperature for proper operation.) Do not subject to heat, direct sunlight or the influence of other electric devices. Protect from humidity, dust, agressive liquids and vapors.

Warning!

CoSyControl should be opened only by trained technical personnel. Before opening the housing, the device must under all circumstances be disconnected from the supply voltage, for example by pulling the power plug.

Please keep this manual within easy reach to refer to if needed.

Give your *CoSy*-system to third parties only with this manual.

3 Shipping materials and system preconditions

3.1 Shipping materials

Please check first of all if you obtained all the parts listed below. If not please check your ordering form and refer to the manufacturer or distributor.

The *CoSy* system consists of the following parts:

- One *CoSy* measurement head
- One Control unit *CoSyControl* in 2 height units housing
- One HD15 cable to connect the measurement head to *CoSyControl*
- One power cord

Fig. 3.1 Shipping material for *CoSy* system

It is recommended to keep the original packaging for future transport or storage.

3.1.1 System preconditions

Use an optical setup with a tunable laser and two movable mirrors to adjust the beam position. Make sure the tuning range of the laser fits the resonance spectrum of the chosen chemical element. If needed, use a wavemeter to check this.

The scan generator used for detuning the laser should have its trigger signal available as output for triggering the oscilloscope on which the spectrum is to be displayed.

Tab. 3.1: Absorption wavelength of the relevant alkali metals

Element	line	Wavelength (vacuum)	Frequenz
Rubidium (^{87}Rb)	D1 ($5^2S_{1/2} – 5^2P_{1/2}$)	794,978 nm	377,107 THz
Rubidium (^{87}Rb)	D2 ($5^2S_{1/2} – 5^2P_{3/2}$)	780,241 nm	384,230 THz
Caesium (^{133}Cs)	D1 ($6^2S_{1/2} – 6^2P_{1/2}$)	894,592 nm	335,116 THz
Caesium (^{133}Cs)	D2 ($6^2S_{1/2} – 6^2P_{3/2}$)	852,347 nm	351,725 THz
Potassium (^{39}K)	D1 ($4^2S_{1/2} – 4^2P_{1/2}$)	770,108 nm	389,286 THz
Potassium (^{39}K)	D2 ($4^2S_{1/2} – 4^2P_{3/2}$)	766,701 nm	391,016 THz

The laser beam should have a diameter of 3mm and the laser power should be as given in Tab.7.1.The spectral resolution and the signal to noise ratio of the *CoSy* system depend on the laser power.

If the laser beam profile is elliptic,(e. g. by a laser diode) the large axis of the ellipse should be 3mm in diameter.

The laser beam must be polarized vertical to the tabletop plane.

To display the signal an oscilloscope with at least two channels and a trigger input is needed. Having a voltmeter switched to the range of 0 to 10 volts ready is recommended additionally.

3.2 Brief description of the control elements

3.2.1 Control elements situated on the *CoSy* measurement head

The gain of the photo diode amplifiers can be adjusted by range switches. These have 8 positions(0 to 7) with a factor of 3.3 between two neighboring positions.

3.2.2 *CoSyControl* control elements

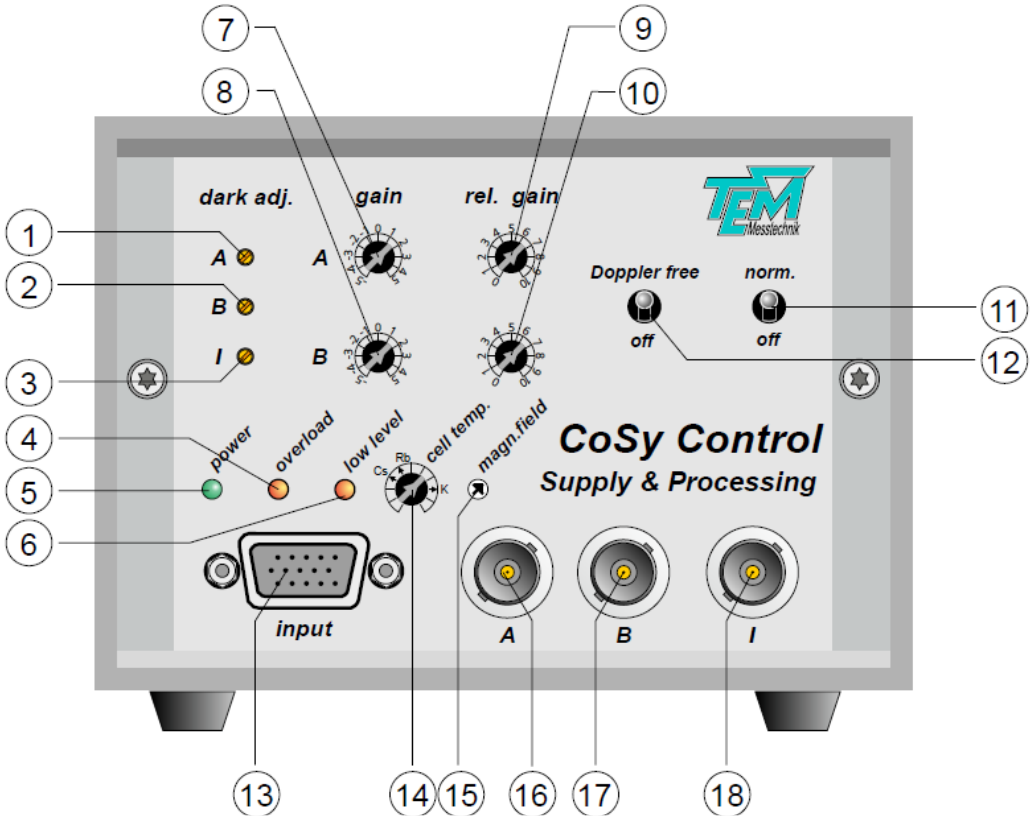


Fig. 3.2.2.1 Control elements on *CoSyControl* front panel

1	Offset for A channel
2	Offset for B channel
3	Offset for I channel
4	Indicator for too a high optical input power level
5	Power indicator
6	Indicator for too little input power (only if switch 11 is on „norm.“)
7	Gain adjustment for channel A
8	Gain adjustment for channel B
9	Elimination of Doppler background in the hyperfine structure
10	Elimination of hyperfine structure in Doppler background
11	On/off switch for division by signal I („normalisation“)
12	On/off switch for the weighted subtraction of A and B channels
13	Connector outlet to *CoSy* measurement head
14	Trim potentiometer for cell temperature
15	Trim potentiometer for longitudinal magnetic field in cell
16	Outlet for signal A
17	Outlet for signal B
18	Outlet for signal I (indicating the optical input power)

table 3.2.2.1: description of *CoSyControl* front panel elements

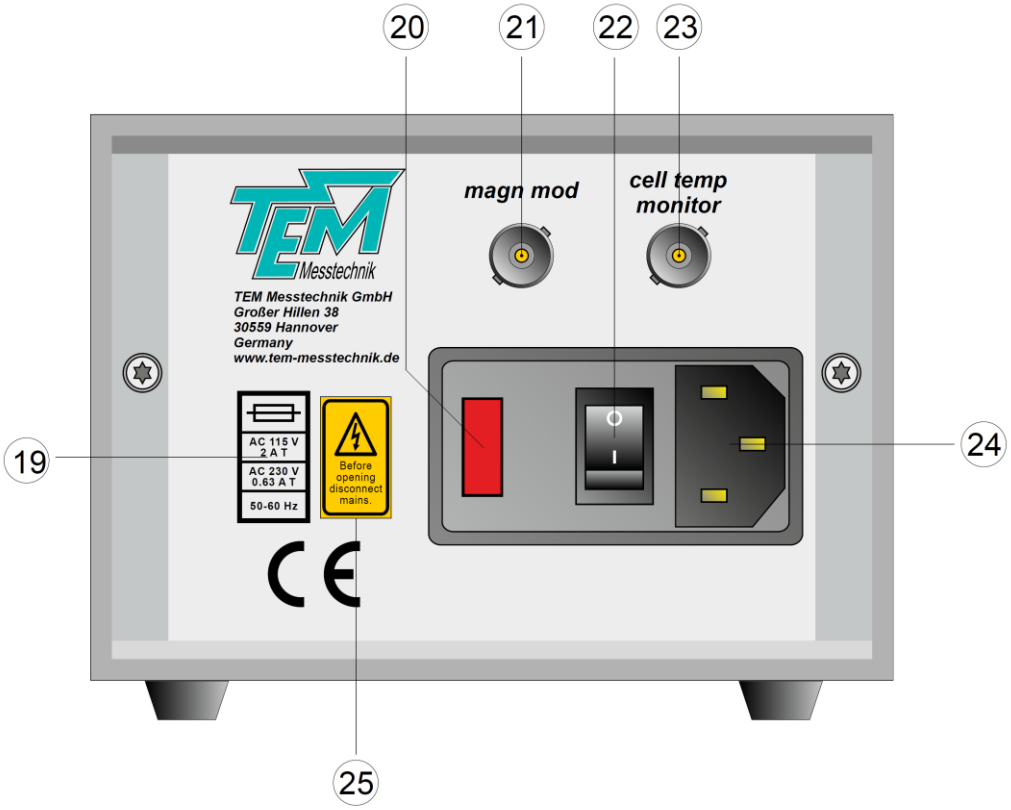


Fig. 3.3.2.2 Control elements on *CoSyControl* rear panel

19	informations regarding fuse and supply voltages
20	Fuse holder (inside the power switch housing)
21	Input connector for option „Coil“
22	Power switch
23	Outlet for cell temperature monitor
24	Outlet for power cord
25	Safety warning

table 3.2.2.2: description of *CoSyControl* rear panel elements

3.2.3 *CoSyControl* block diagram

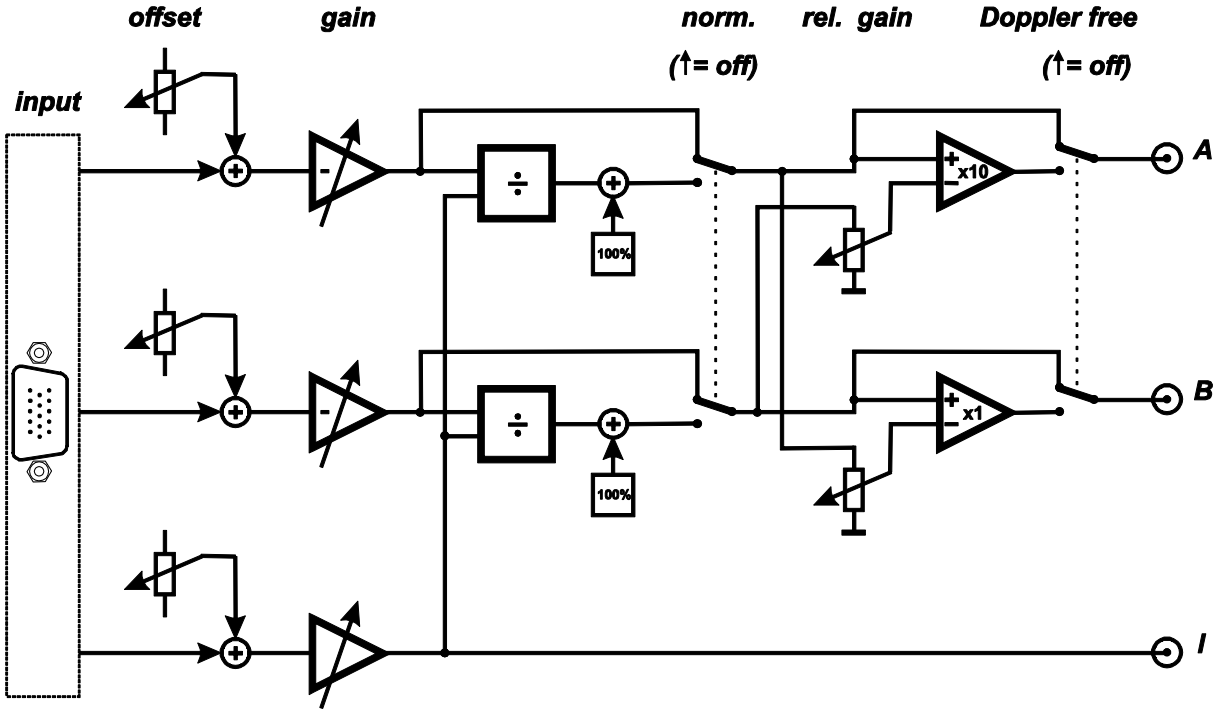


Fig. 3.4 Block diagram of *CoSyControl*

4 Mechanical setup and electrical connections

4.1 Setup

Place the *CoSyControl* suitably, taking into account the safety warnings in chapter 2.

Caution!

If the red window at the back of your *CoSyControl* shows a voltage value (230 V or 115 V), you have the version where this value must be adjusted manually to the supply voltage of your country. If the shown value is the wrong one proceed as is described in 7.4/7.5 .

Insert the *CoSy*-measurement head suitably into the free laser beam of your experiment. The input power has to be less than 1 mW. The beam must enter the aperture at normal incidence. The polarisation must be oriented perpendicular to the tabletop.

If you wish, see chapter 5 first for easy optical adjustment.

As the signals generated in the *CoSy* measurement head depend on the local magnetic flux density, the head must be positioned far enough from magnetised objects such as magnets, optical isolators, etc.

4.2 Connections

Use the power cord and plugs delivered with your system if possible. If the power plug does not fit your country´s mains power socket, use the corresponding plug and cable of your country .

Connect the *CoSy* measurement head to *CoSyControl* by the HD15-cable delivered with your system.

Connect the BNC outlets „A“ and „B“ of *CoSyControl* to the vertical-coordinate (Y-) inputs of an oscilloscope and adjust the sensitivity of these to 1V/cm.

Connect the BNC outlet „I“ of *CoSyControl* to a free Y input of an oscilloscope or alternatively to a voltmeter switched to a range of 0 to 10 volts.

Synchronise the trigger for the oscilloscope´s horizontal coordinate with the frequency modulation of your laser. (If this is TOPTICA´s DL100 diode laser, connect the trigger output of the scan generator SC110 to the oscilloscopes trigger input.)

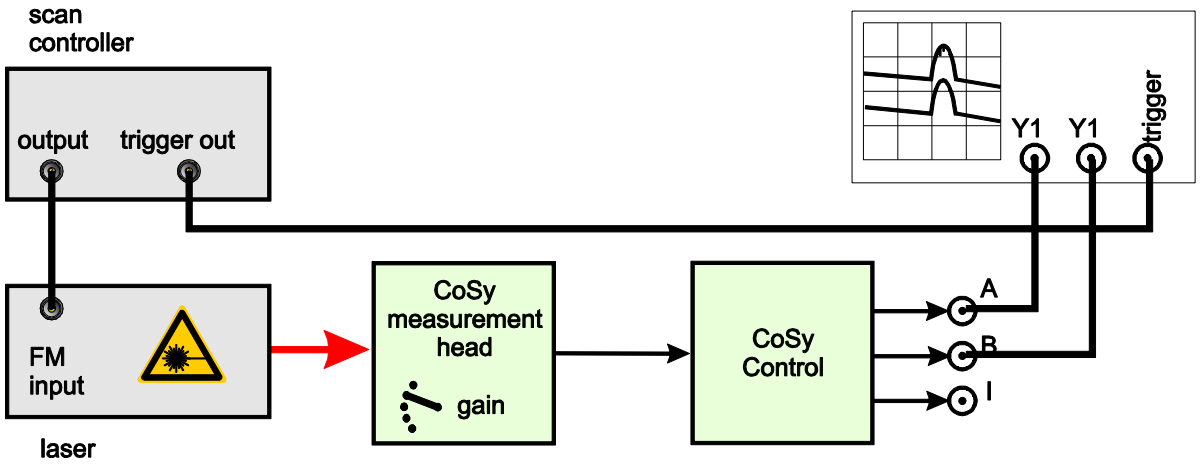
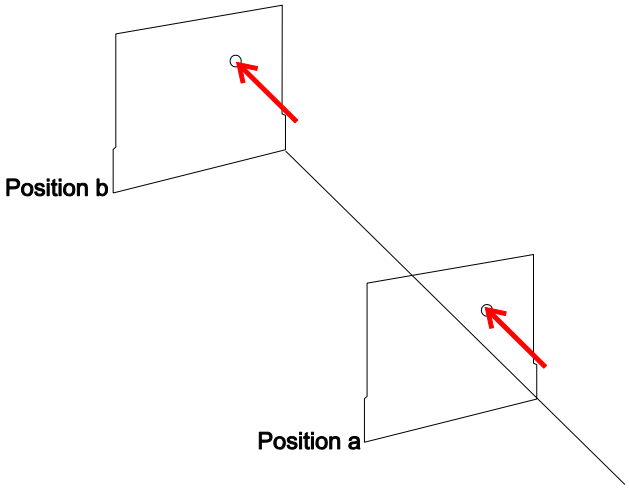


Fig. 4.1: diagram of connections

5 Optical adjustment of *CoSy* measurement head

5.1 free beam version



The *CoSy* head has to be positioned such that the laser beam falls into the input aperture exactly vertically. The laser beam must be polarized vertical to the tabletop plane.

For precise adjustment we recommend to proceed as follows:

- Fix a straight metal bar with rectangular cross-section to the table for a physical reference line.
- Put the *CoSy* head flat on the table, the lower edge of one of the long sides coinciding with the reference line (position a).
- Adjust the beam position such that the beam hits the middle of the input hole
- Move the *CoSy* head along the reference line (position b).
- Adjust the beam position such that the beam hits the middle of the input hole also in this position.

In this way the beam runs parallel to the reference line and the long edges of the measurement head.
Now fix the measurement head to the table and remove the metal bar.

5.2 fibercoupled versions

Only polarization maintained fibers (PM) are applicable.

The laser beam must be polarized vertical to the tabletop plane (normally, slow axis of most PM-fibers).

6 Operating the *CoSy* system

6.1 Switching on

Connect *CoSyControl* to the power supply by the power switch on the device´ back, beside the supply socket.The green LED “power”should then be on.

Remark: Before the first run, the switches “Doppler free” and “norm.” should be in “off” position. Also, bring all range switches and trim potentiometers approximately to middle position. Bring the gain switch on the measurement head to position 5.

Make sure the laser is being frequency modulated in a range where absorption from the atomic lines in question is expected. (see Tab. 3.1: absorption wavelength of certain alkali metals). Synchronise the trigger for the oscilloscope´s horizontal coordinate with the frequency modulation of your laser. (If this is TOPTICA´s DL100 diode laser, connect the trigger output of the scan generator SC110 to the oscilloscopes trigger input.)

6.2 Dark current adjustment

Block the laser beam. Adjust the signals A,B and I to zero by turning the three *CoSyControl* knobs “offset”. This compensates for the photo diode dark currents and any photo currents caused by stray light.

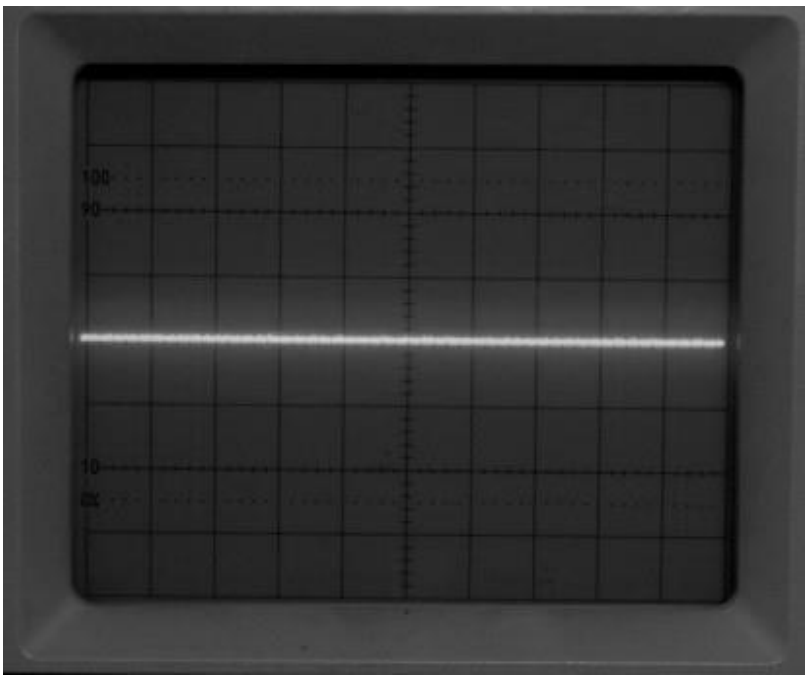


Fig. 6.1 Oscilloscope screen after dark current adjustment

6.3 Sensitivity adjustment

Now unblock the laser beam. The “I” output of *CoSyControl* should now show a constant voltage well between +1V and +10V. If not, change the gain by the range switch on the *CoSy* measurement head such that the voltage is in this range. (By turning the switch clockwise, the sensitivity of the measurement head and thus the “I” voltage is increased. Please note that positions 8 and 9 are not defined.)

Both red LEDs “overload” and “low level” should be off.

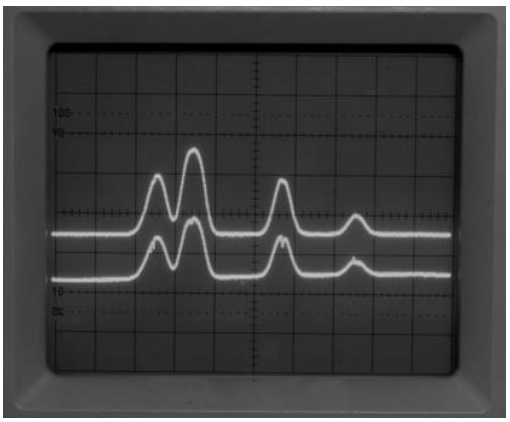


Fig. 6.2 Oscilloscope screen with laser on (here: rubidium D2 lines)

There should be signals different from zero on the oscilloscope screen now (Fig. 6.2).

Remark: The signals are not level from left to right because a diode laser is used here the laser power of which is modulated with the frequency automatically. Other lasers have different features.

6.4 Choosing the correct laser wavelength range

If there are no absorption lines visible on the oscilloscope screen, the wavelength range of the laser does not match the atomic lines. Detune the laser until you see absorption signals (Fig.6.2 or similar). (If you use TOPTICA´s DL100, change the offset of the scan controller SC110 by switching on “offset” and turning the offset potentiometer knob, and possibly change the current of the current controller DCC110.)

6.5 Relative gain adjustment

Adjust the „gain“ potentiometers of *CoSyControl* such that the signals are zero outside the absorption bands (Fig. 6.3.) The signal’s amplitudes may differ.

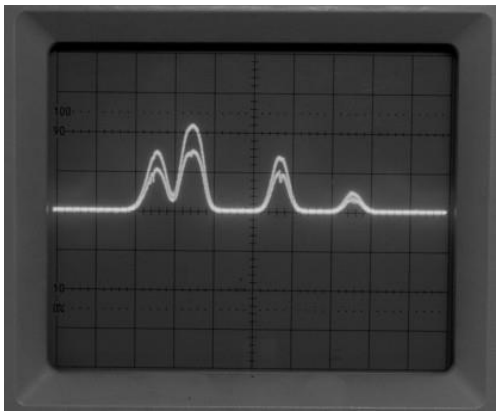


Fig. 6.3: Signals A and B without offset after gain adjustment

6.6 Doppler free absorption signal

Bring the "Doppler free" switch into upper position. On the oscilloscope you see a weighted difference of the previously shown signals now (Fig. 6.6).

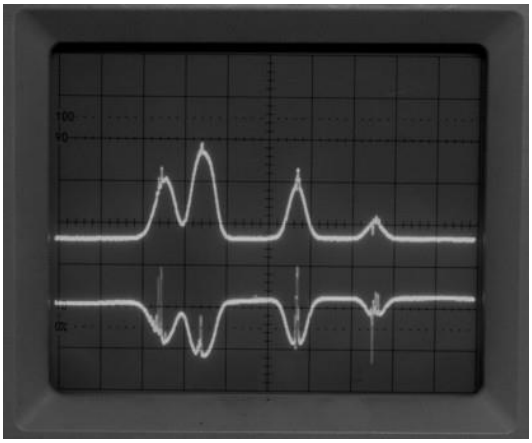


Fig. 6.4: Absorption signals with clearly visible hyperfine structure

Adjust the weighting by turning the potentiometers "rel.gain" such that the signal "A" is free of Doppler broadening and the signal "B" has no hyperfine structure.

It may be necessary to readjust the „gain" potentiometers of *CoSyControl* such that the signals are zero outside the absorption bands.

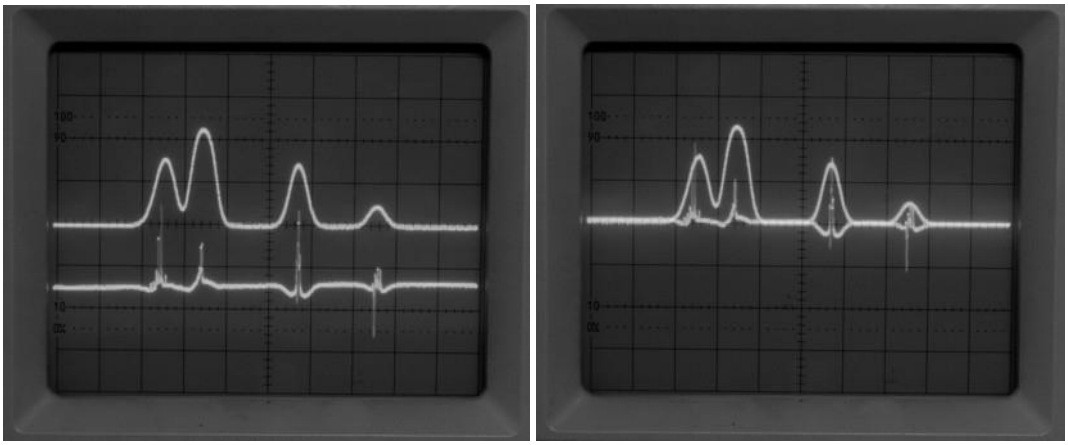


Fig. 6,7: Absorption signals with the weighting adjusted correctly (left), and after slight correction of the gain (right)

6.7 Normalisation

Now bring the “norm.” switch into the upper position.On the oscilloscope you see signals the amplitude of which is independent of input laser power for a large range of the latter. If the signal level is out of the normalization range, this will be indicated by the LEDs “overload” or “low level”, respectively.

7 Option „Coil“ for magnetic stray field compensation

7.1 Perturbation by external magnetic fields

Magnetic stray field in the experimental setup will influence the shape of the Doppler free saturation spectrum (compare Fig. 7.1 left and right hand side). E.g., the spectrum depends on the orientation of the CoSy head relative to the magnetic field of the earth. If you wish to see the undisturbed spectrum, remove the magnetic elements causing the field or else compensate for it. The version “Coil” of the *CoSy*-system is useful here.

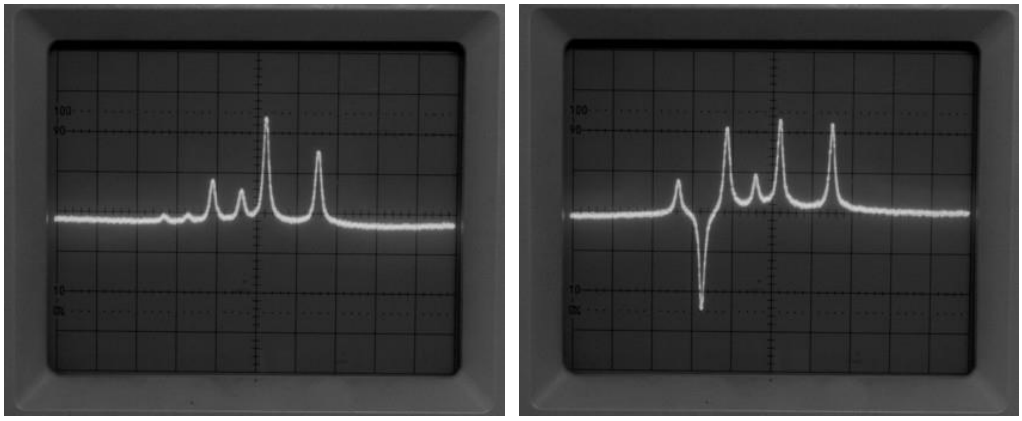
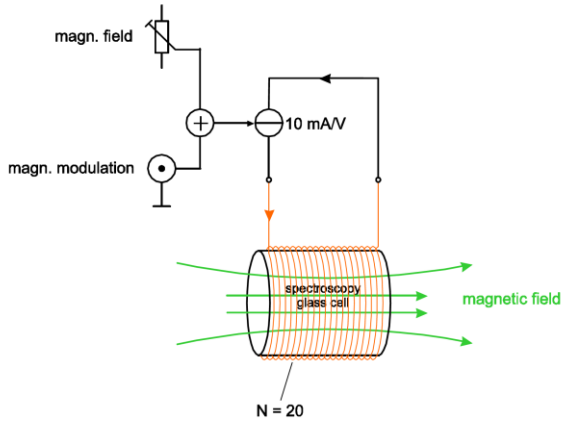


Fig. 7.1: The same doppler-free saturation spectrum of Rb with and without a magnetic field at the location of the glass cell.

7.2 Description of the coil setup

In order to compensate magnetic stray fields, a coil is positioned coaxial to the absorption cell. The magnetic flux is parallel to the beam path in the cell. The coil has 20 turns. The static current through the coil is adjusted by the trim pot “magn. field” (15). There is also the option to modulate the magnetic field in addition to the static current (fig. 7.2). For this application there is a BNC input “magn mod” at the rear panel of the *CoSyControl*.



Technical data for „magn mod“ (21)	
voltage input range	±10 V
amplification	10 mA/V
input impedance	10 kΩ
cut-off frequency	> 1 MHz

Fig. 7.2: Block diagram of the current source and the coil

8 Further hints

8.1 Better resolution through less optical power

To resolve the atomic lines better, the input laser intensity must be weakened, e.g. by a filter.

Please note that the signal-to-noise-ratio (SNR) is lowered by this. To obtain an acceptable SNR, one might for example average the signal over some scans with a sampling oscilloscope.

Element	Line	recommended optical input power
Cs	D1, D2	0,1 mW – 3 mW
Rb	D1, D2	0,5 mW – 3 mW
K	D1, D2	0,5 mW – 3 mW

Tab. 8.1: Recommended optical input power

8.2 Spectroscopy cell temperature

The degree of absorption depends on the vapor pressure of the chemical element in the glass cell and therefore on its temperature. To achieve a good long term stability, the spectrosopy cell is equipped with an temperature regulation. Choose the cell temperature such that the degree of absorption is less than 60% by turning trim pot 14 (see recommended temperature adjustment in Tab. 8.2). The trim-pot “cell temp” (14) at the front panel of the *CoSyControl* covers a range of 20°C…75°C (left to right stop). The center position corresponds to temperature of 45°C. Please note that the CoSy head is equipped with a cell heater, which will not be able to reduce the temperature to a value below room temperature. If the degree of absorption is already higher than 60% at the given room temperature, ask for a *CoSy*-system containing a shorter cell.

alkali Element	Line	Recommended cell temperature
Cs	D1, D2	~33 °C
Rb	D1, D2	~40 °C
K	D1, D2	~70 °C

Tab. 8.2: recommended cell temperatures

The trim-pot positions for the recommended cell temperatures are marked at the front panel.

Please note that the temperature settling time after switching on will last up to 15 minutes. The actual cell temperature can be monitored at the connector “cell temp monitor” at the rear panel of the *CoSyControl* (see fig. 8.2.1).

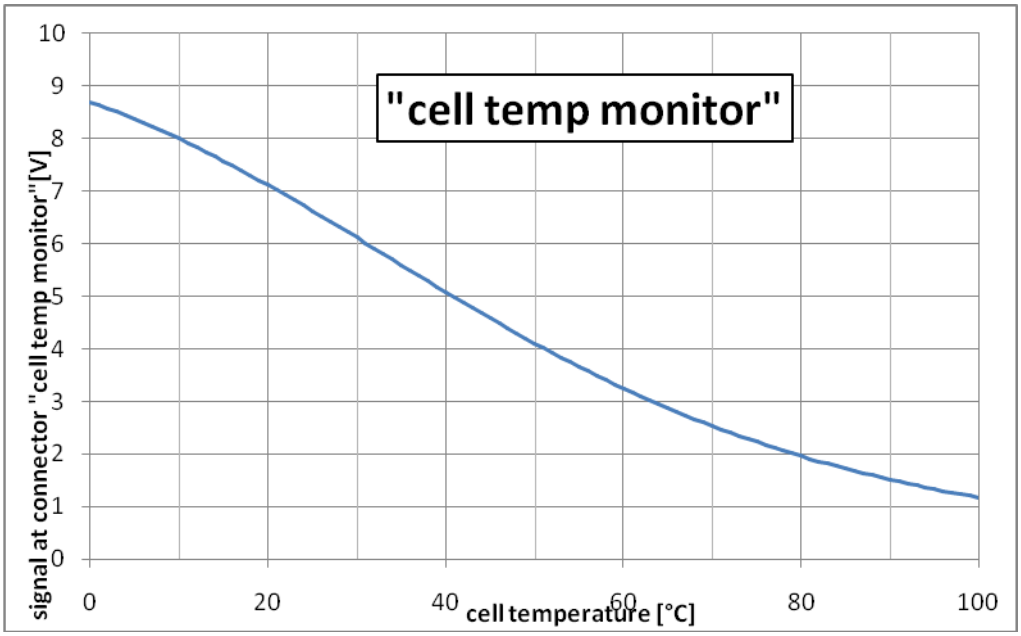


Fig. 8.2.1: signal at connector cell temp monitor vs. cell temperature

8.3 Adapting CoSyControl to a given supply voltage

The *CoSy Control* is equipped with an automatic line voltage switch. The CoSy can operate at supply voltages of 115V and 230V 50-60Hz.

8.4 Changing the CoSyControl fuse

The power cord must be removed. The flap around the power switch opens by use of a small standard screwdriver. Now lift the fuse block from its anchoring with the screwdriver. Please note that there are two fuses. Only fuses of the type 250 V/0.63 A, FLINK (for 110Volt: 250V/2A) are suitable.

9 Troubleshooting

Problem	Possible cause	Possible solution
No function/ power-LED is off	a) *CoSyControl* is not connected to net supply power or is not switched on	a) Connect *CoSyControl* to the net power socket by the power cord. Switch the *CoSyControl* on by the power switch at ist back directly beside the supply outlet
	b) fuse is defect	b) Check the fuse and replace it by a fuse 250 V, 0,63 A, FLINK(for 110 V:250 V/2A).
Neither signal A nor signal B resembles an absorption spectrum	a)Optical adjustment of *CoSy*-measurement head is wrong	a) Adjust position of *CoSy* measurement head.
	b) Laser is out of resonance with the element used for spectroscopy.	b) Use a wavemeter to find the right laser frequency
	c) The laser beam has the wrong polarisation	c) Change the polarisation with a lambda/2 plate such that it is then vertical to the tabletop plane
After all adjustments are done, the signal on the oscilloscope screen moves up or down.	a)Non-constant cell temperature.	a) Keep temperature constant around the measurement head.
	b) Input beam position not stable	Mount the *CoSy* measurement head near the laser source and avoid air turbulences, or use a *CoSy* system with fiber coupling (option „FC“ or „FC-APC“)
Too much Doppler background in the Doppler free absorption spectrum	signal B has the wrong amplitude.	a) Realign the laser beam with the *CoSy* measurement head.
		b)Adjust the amplitude of signal “B”(lower potentiometer”gain”).

10 Appendix

10.1 Technical specifications

Glas cell dimensions (diameter x length): 25 mm x 25 mm (25 mm x 15 mm on request)

Glas cell contains the following elements: (other elements on request):

- Rubidium (Rb),
- Potassium (K) and
- Caesium (Cs).

Input aperture: ∅ 3mm

Photo diode amplifier gain range:

Switch position	gain [10^3 V/A]
0	10
1	30
2	100
3	300
4	1000
5	3000
6	10000
7	33000

Set temperature of glas cell: 20 °C to 75 °C
Coil current for AC- or DC-magnetic field (optional): maximal ±100mA

Supply voltage for *CoSyControl*: 115 V / 230 V, 50 to 60 Hz

Housing dimensions:

*CoSy m*easurement head 55 mm x 65 mm x 100 mm

CoSyControl 87.2 mm x 125 mm x 209 mm (2 height units)

10.2 Connectors and cables

10.2.1 Power plug and cord

The power cord delivered with the system serves to connect *CoSyControl* to the mains. It has a three-pole outlet matching the corresponding plug at the back of *CoSyControl*. On the other end is a Schutzkontakt plug to go into a grounded wall socket. Use the corresponding cable for your country if you have different mains power wall sockets.

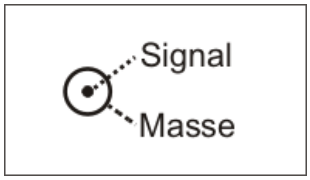
HD15-connector and HD15-cable

The HD15-cable for connecting the *CoSy*-measurement head to *CoSyControl* has the following pin out:

Nr	
1	signal a
2	signal b
3	signal I
4	(TEC +)
5	(Rth+)
6	+ 15V
7	– 15 V
8	(TEC –)
9	no pin
10	SG
11	n. c.
12	(APD supply)
13	Coil +
14	Coil –
15	n.c.

BNC-connector and BNC-cable

The BNC outlets at the *CoSyControl*-front panel guide the signal in the center contact. The outside ring of the BNC outlet is connected to system ground.



10.3 Maintenance and care

No maintenance is needed.

Caution!

Never use cleaning agents such as solvents, petrol,sprays or mechanical cleaning agents as these may damage the surfaces.

Clean external surfaces with a damp cloth and then dry with a clean dry cloth. Do not clean the inside of the devices.

In case of contact with liquids the devices may by no means be switched on. Instead, keep them in a dry, warm place for at least 72 hours. In many cases the systems work again after such treatment.

10.4 Customer service

In case of nessecary repairs or warranty claims you will obtain fast and reliable help under the address given on page 2.

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