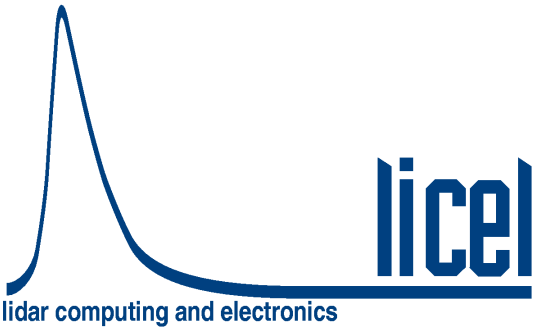


Licel Polarotor

Licel GmbH

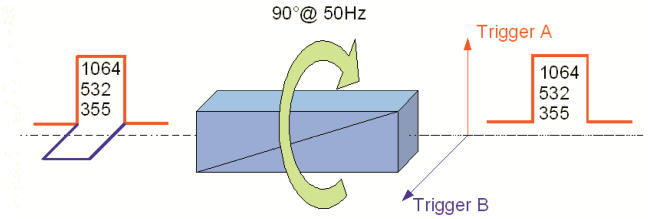
April 29, 2019

Contents

Chapter 1

Introduction

The Licel Polarotor adds (de-)polarization measurements to multispectral detection systems. A rotating Glan Thompson prism is used to separate p- and s-polarized signal contributions. The integrated trigger generator synchronizes the laser flashlamp and Q-switch pulses. A laser repetition rate of up to 50 Hz is supported. The free aperture is 20 mm.



The rotation of the Glan Thompson prism is driven by a bipolar stepper motor. The housing of the Polarotor is made of CNC machined anodized aluminum. Fig. 1.1 displays a photograph of the polarotor.
The Licel Polarotor can easily be integrated into existing systems. Breadboard mounting and in line mounting into tubed optics setups is supported. The supplied Licel Polarotor and the integrated pulse generator are controlled controlled via TCP/IP by the acquisition computer. LabVIEW software (including source code) is provided.

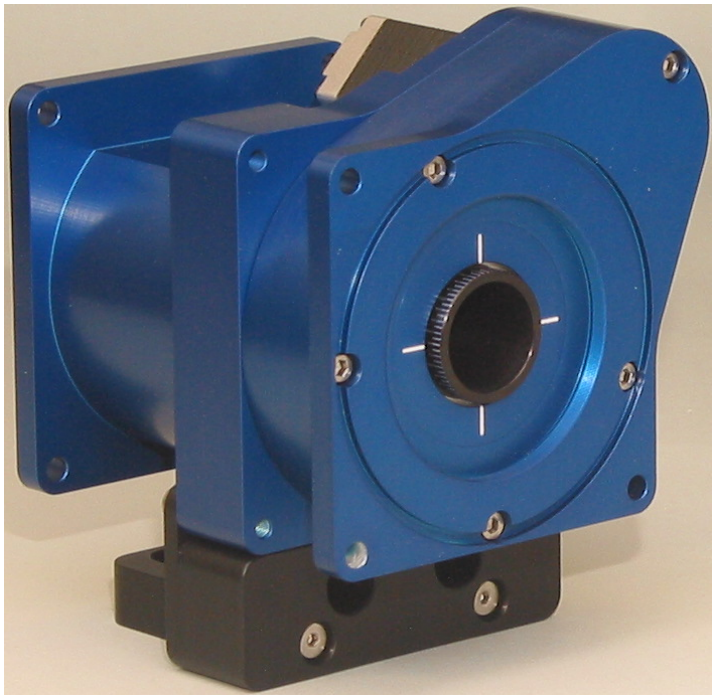


Figure 1.1: Licel Polarotor with breadboard mount seen from the drive cover side

Chapter 2

Dimensions and Mounting Opportunities

2.1 Mechanical Dimensions

The Polarotor is designed as a compact instrument for easy integration into existing experiments. Fig. 2.1 displays a side cut of the Polarotor.

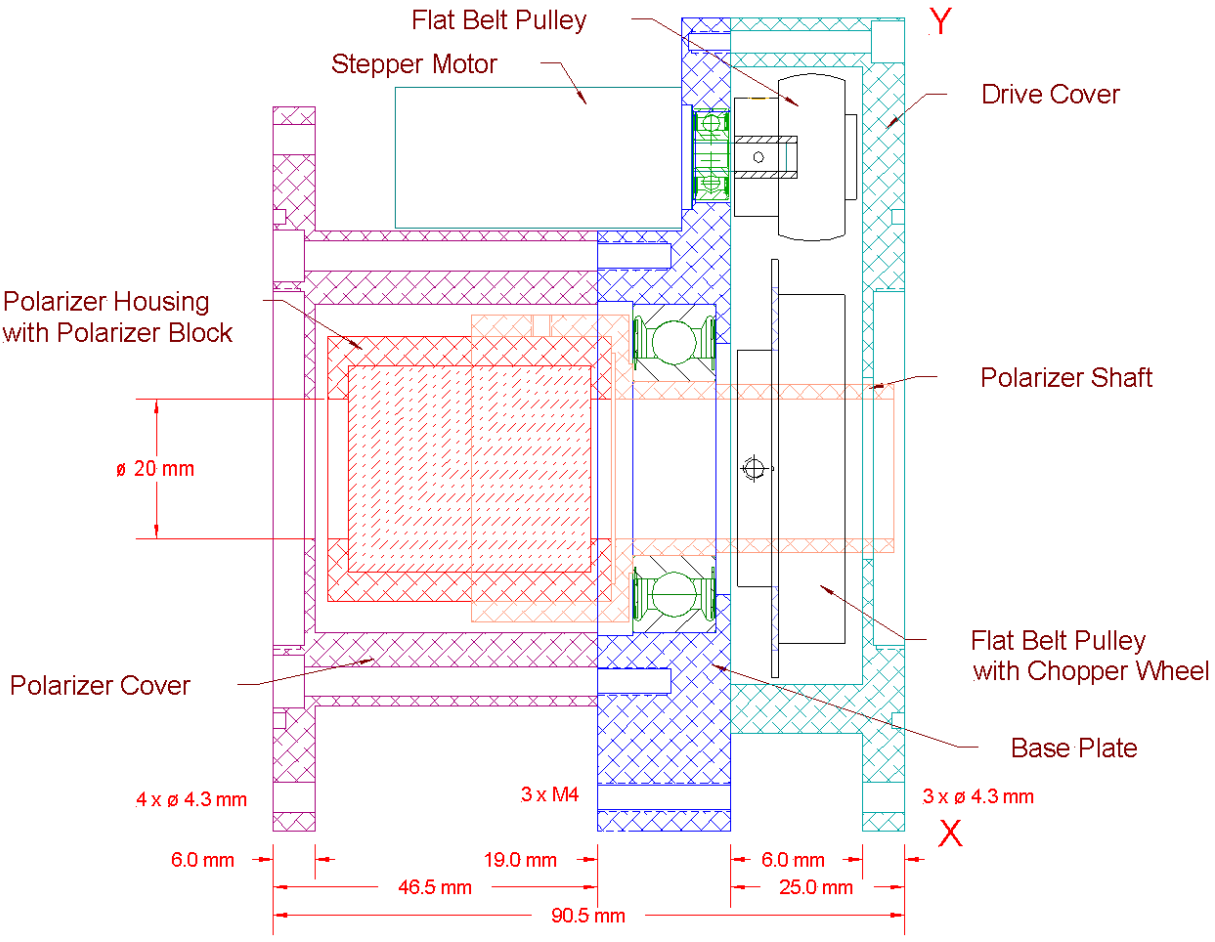


Figure 2.1: Sectional drawing along the XY diagonal in fig 2.2.

2.2 Mounting Opportunities

The following mounting opportunities are available (refer to fig. 2.2):

- 2.035”-40 threads at both sides, compatible to Thorlabs Ø 2” Lens Tubes
- Ø 4.3 mm drillings at both sides
- M4 threads in the base plate at the same positions as the drillings in the cover.
- the Polarotor is supplied with an optional breadboard mount.

O-ring seals 70 mm $\times$ 2 mm may be used at both sides.

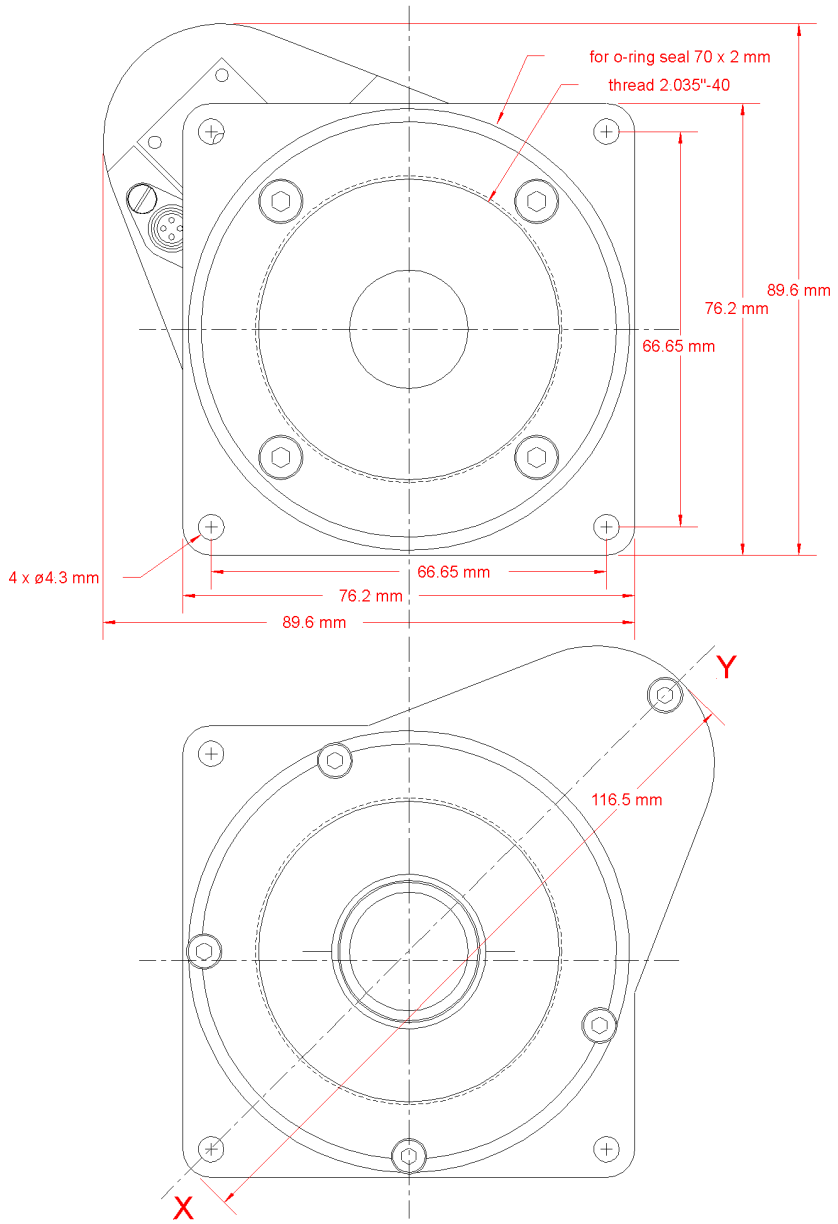


Figure 2.2: Top: front view of the rotating polarizer (left side in fig. 2.1).
Bottom: cover view of the rotating polarizer (right side in fig. 2.1). For the dimensions refer to the top of this figure.

Chapter 3

Operation

3.1 Polarization Control

An α-BBO Glan-Thompson Polarizer is mounted in a hollow shaft with a free aperture of 20 mm. The shaft is rotated by a flat belt driven by a stepper motor. The stepper motor is controlled by the Licel Polarotor Controller.
The current rotation angle is monitored by a photoelectric sensor. For this purpose a chopper wheel with four grooves at the angular positions 0, 90, 180, and 270 degrees is mounted on the hollow shaft. As a groove is sensed 4 times during one revolution these grooves are referred to as *1234 hole* in the software chapter. The corresponding signals are used to generate the Acquis || and Acquis + triggers of the Polarotor Controller.
An additional photoelectric sensor monitors one single hole on a smaller radius. The corresponding signal detected once per revolution is used as a synchronization signal for the acquisition triggers, i.e. it is used to correlate the transmitted polarization with the individual *1234 hole* signals. Thus the Polarotor Controller is capable to individually switch on and off the triggers corresponding to the four angles. The synchronization hole is referred to as *sync hole* in the software chapter.

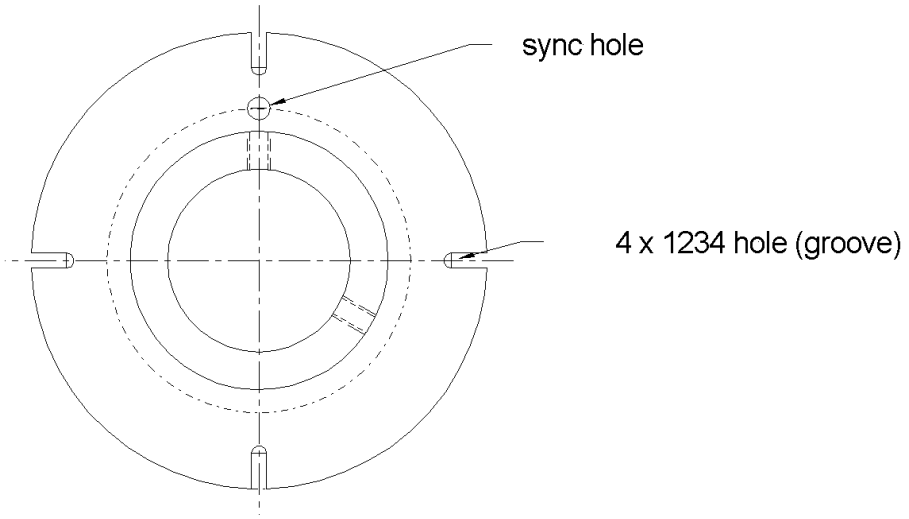
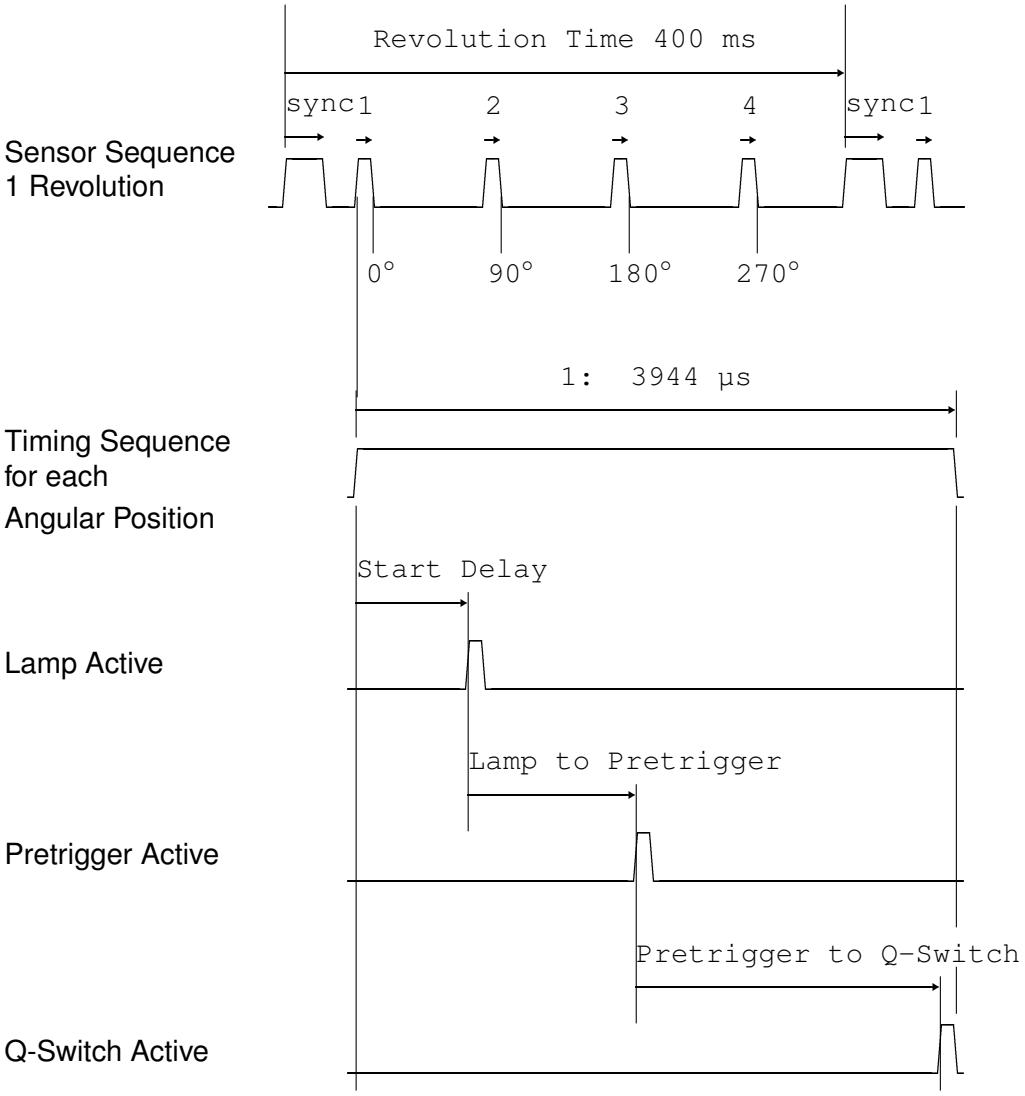


Figure 3.1: Sketch of the chopper wheel with 4 *1234 holes* (grooves) and the sync hole.

3.2 Polarotor Timing Diagram

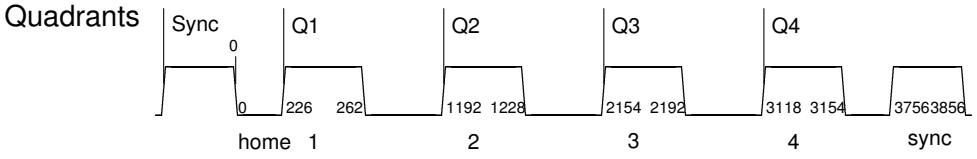
A start trigger is generated when one of the *1234 holes* is detected while the polarotor is running. The delay times between this start trigger and the trigger outputs are generated by the Polarotor and

Trigger Controller.
If the Polarotor is not running the start signal can be generated by the Polarotor and Trigger Controller.
Please refer to the next two chapters for more details.
The time values are for a laser repetition rate of 10 Hz (polarotor 2.5 Hz).



3.3 Stepping Sequence

The following Diagram displays the polarotor steps during one rotation.



Chapter 4

Licel Polarotor and Trigger Controller

The Licel Polarotor is driven by the Licel Polarotor and Trigger Controller. The front panel of the controller is shown in fig. 4.1. It is controlled via TCP/IP at 10/100 MB/s. The ethernet cable connector islocated at the front panel on the left. Please refer to the *Licel Ethernet Controller – Installation and Reference Manual*, chapter *Setting up the Network* to set up the network connection .
The Licel Polarotor and Trigger Controller is capable to

- control the stepper motor (speed and position)
- detect the polarizer angular position
- generate the trigger pulses dependent on the polarization
- generate the trigger and timing pulses (flash lamp, Q-switch, acquisition, gate) for 2 lasers

The front panel connectors are organized as follows:

Polarotor

The connectors to the polarotor and the corresponding trigger outputs are placed here:

Laser

- **Lamp** Laser lamp output
- **Q-Switch** Q-Switch output

The corresponding timing settings can be controlled on the tab **Polarization Timing** of the LabVIEW software described in the next chapter.

Acquisition

- || **Pol.** Acquisition (pretrigger) output corresponding to the parallel polarization
- **+ Pol.** Acquisition (pretrigger) output corresponding to the perpendicular polarization

The related timing settings can be controlled on the tab **Polarization Timing** of the LabVIEW software described in the next chapter.

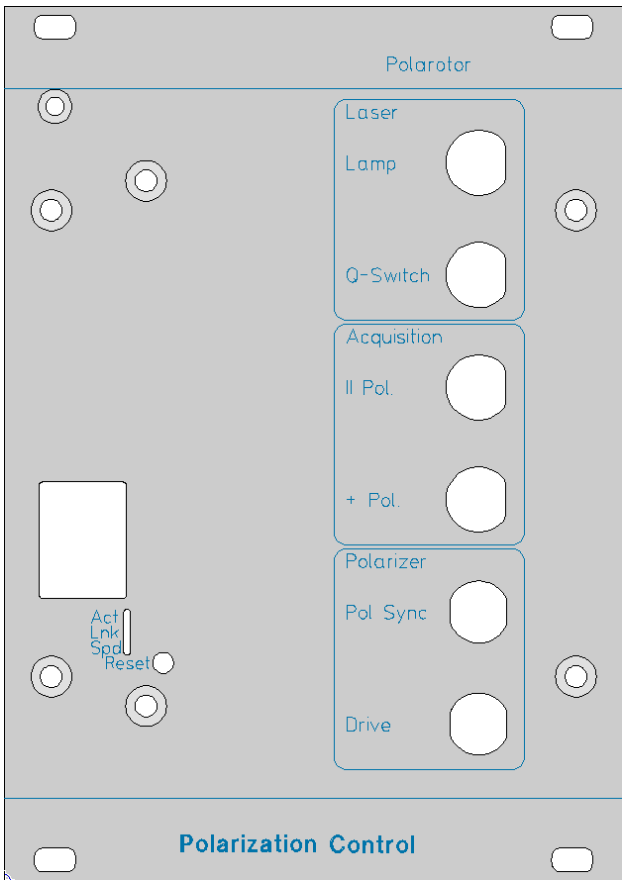


Figure 4.1: Licel Polarotor Controller with trigger in- and outputs, and the Polarotor connectors.

Polarizer

- **Pol Sync** Synchronization input from the Polarotor
- **Drive** Motor control output.

The stepper motor can be controlled on the tab **Drive** of the LabVIEW software described in the next chapter.

Chapter 5

LabVIEW Software Modules

5.1 Installation

Basic LabVIEW 7.0 software modules are provided with the Licel Polarotor. For use on computers without a LabVIEW installation an optional Windows Installer is available to install executable Windows applications together with a LabVIEW runtime engine. Please refer to the *Licel Ethernet Controller – Installation and Reference Manual*, chapter *Software Installation* for installation instructions. The application `Polarotor.exe` will be installed additionally to the package described there.
To use the LabVIEW software copy the following LabVIEW library files and vis from the CD to a directory of your choice:

```
ControlTiming.llb
DriveControl.llb
Licel Module.llb
Licel TCPIP.llb
Licel Util.llb
Polarotor.vi
```

Please copy the following initialization files, as well.

```
LicelTCPIP.ini
Polarotor.ini
Timing.ini
```

The Licel Ethernet Controller is shipped with the default IP address `10.49.234.234`. This value is preset as default for the software modules, as well. If you need to change the IP address please refer to the Network Setup section in the Installation and Reference manual. Note that a hardware reset will set the IP address to the Licel default value. Do not forget to set the new IP address as default value in the corresponding control fields of the LabVIEW vis. If you are using the Windows executable application `Polarotor.exe` please change these settings in the initialization file `Polarotor.ini`, as well.

5.2 Getting Started

The Polarotor is driven by the LabVIEW vi `Polarotor.vi` or by the corresponding Windows application `Polarotor.exe`. Both are referred to `Polarotor.vi` in the following text.
`Polarotor.vi` may be used to control all available timing and stepper drive control capabilities of the Licel Controller. When running `Polarotor.vi` it will load `DriveControl.llb`
`Drive Control.vi` and 3 copies of `ControlTiming.llb`
`ControlTiming.vi` on it's four tab pages. `DriveControl.llb`
`Drive Control.vi` is the vi to control stepper motor relevant functions, and `ControlTiming.llb`

ControlTiming.vi is responsible for controlling the timing generators. The order of the tab pages is similar to the alignment at the front panel of the Controller.

5.3 Polarotor.vi

After loading and starting Drive Control Interface.vi the following screen appears:

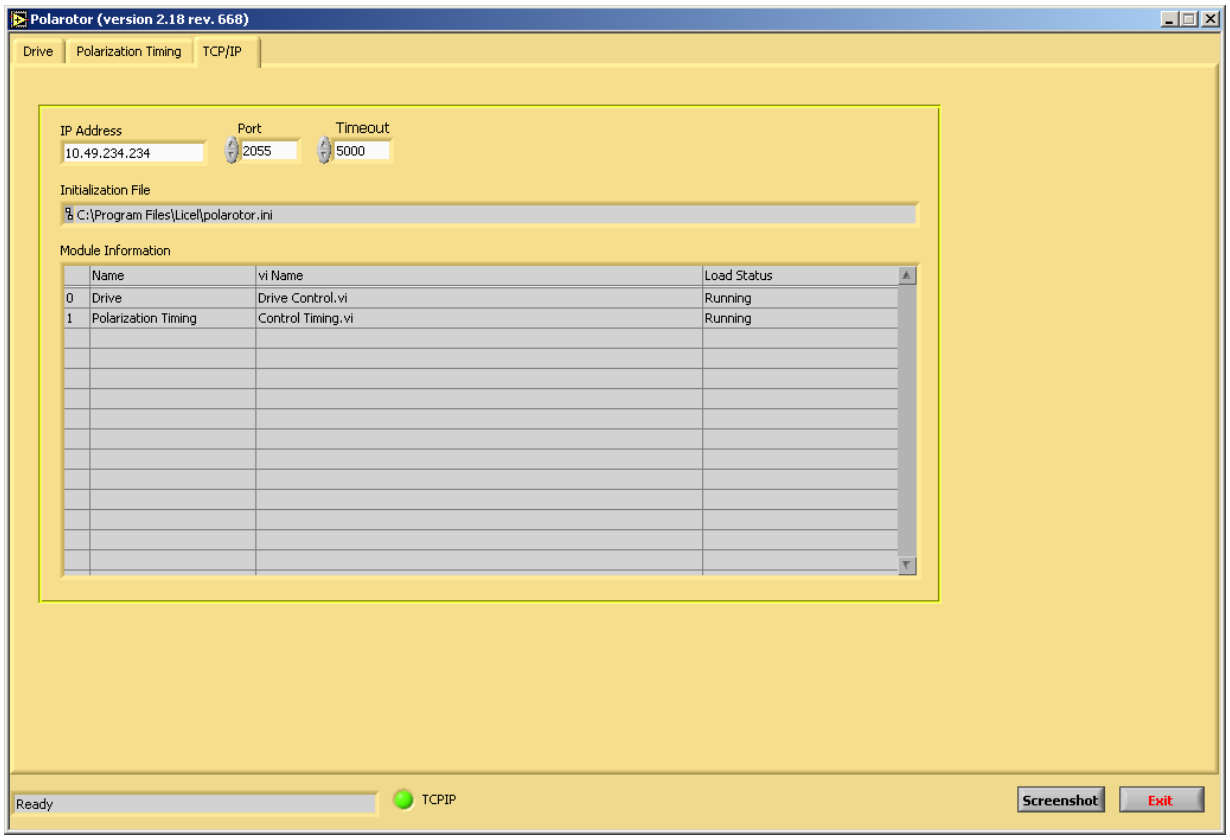


Figure 5.1: Polarotor.vi

The following tab pages are available:

1. **Drive** to control the Polarotor stepper motor
2. **Polarization Timing** to control the Polarotor timings
3. **TCP/IP** TCP/IP and other settings

The application starts on the last (settings) page.

- **The text** field on the **bottom left** is an indicator to inform about the program's current status.
- The **TCPIP** indicatior shows the status of the TCPIP connection.
- **Screenshot** opens a dialog to choose a png file to save a screenshot.
- **Exit** is used to stop the program .
- **Module Information** is a table containing information about the software (sub-) modules loaded by Polarotor.vi
- **The IP parameters** (**IP Address** and **Port**) may be changed in the top left controls.

The program will initialize the tab pages, and after successfully finishing the tab pages **Drive**, and **Polarization Timing** will be accessible.

5.4 Drive

5.4.1 Alignment

Change to the tab page **Drive**. The vi `DriveControl.llb` `Drive Control.vi` will automatically be loaded into the subpanel of the page. When changing to the page for the first time an initialization procedure will be started which may take some ten seconds. After the initialization all controls on the sub page **Alignment** will be accessible.

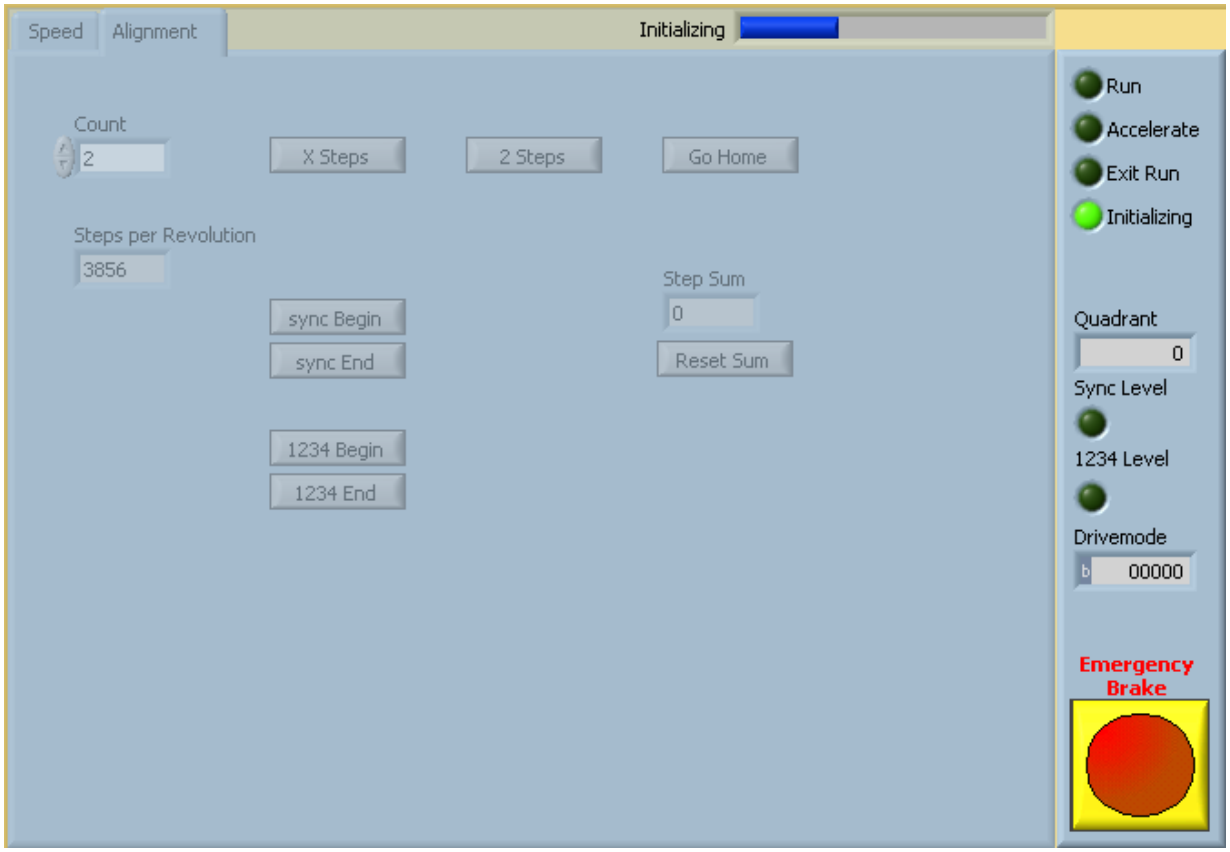


Figure 5.2: On the page **Drive** the stepper motor may be controlled. On the sub page **Alignment** some alignment utilities are available. When calling the page for the first time the initialization will run.

After the initialization the position of the chopper wheel of the rotating polarizer will be at the end of the sync hole (first position after the hole where the sync level is low).
Functionality of the button controls:

Steps per Revolution Number of motor steps needed for one revolution of the polarizer.

X Steps Move the motor **Count** number of steps. The number of steps will be added to the current value of **Step Sum**.

2 Steps Move the motor 2 steps — this is the minimum rotation.

Go Home Initialize and go back to the sync hole end position.

sync Begin Move the motor until the *sync hole* is detected. Available only if the current position is outside the *sync hole* position range.

sync End Move the motor until the *sync hole* is no longer detected. Available only if the current position is inside the *sync hole* position range.

1234 Begin Move until the next *1234 hole* is detected. Available only if the current position is outside the *1234 hole*s position ranges.

1234 End Move the motor until a *1234 hole* is no longer detected. Available only if the current position is inside one of the *1234 hole*s position ranges.

Reset Sum Resets the value of **Step Sum** to 0.

The following indicators display the status of the rotation polarizer. These values are read every 500 ms. Note that while the polarotor is rotating fast, not all changes can be monitored.

Quadrant Current quadrant. A quadrant begins at the beginning of a 1234 hole and ends at the beginning of the next 1234 hole.

Sync Level Indicates whether the sync hole level is high or low.

1234 Level Indicates whether the 1234 hole level is high or low.

Drivemode Current drive mode:

- 00000 stopped
- 01000 free running
- 11001 run *as long as* the angular position detector (*1234 hole*) is active
- 11010 run *until* the angular position detector (*1234 hole*) is active
- 11011 run *as long as* the synchronization detector (*sync hole*) is active
- 11100 run *until* the synchronization detector (*sync hole*) is active
- 11101 go x steps

Example

To find the positions of the holes follow these steps:

1. Press the **Reset Sum** button. **Step Sum** will be reset to 0.
2. Press **Go Home**. The motor will move the polarizer to the position corresponding to the end of the sync hole. This will be your reference point. **Quadrant** should be 1, the level indicators should be off.
3. Enter a value of 870 to **Count**.
4. Press **X Steps**. The motor will move 870 steps, the value has been set to the **Step Sum** indicator. Both level indicators should be off.
5. Enter a value of 2 to **Count**.
6. Press **X Steps**. The motor will move 2 steps, the value is added to **Step Sum** indicator. Wait approximately 2 seconds. Repeat this step until **1234 Level** turns to green. Now **Step Sum** indicates the position of the beginning of the hole corresponding to the quadrant 2.
7. Enter a value of 50 to **Count**.
8. Press **X Steps**. The motor will move 50 steps, the value is added to the **Step Sum** indicator.
9. Enter a value of 2 to **Count**.

10. Press **X Steps**. The motor will move 2 steps, the value is added to **Step Sum** indicator. Wait approximately 2 seconds. Repeat this step until **1234 Level** turns off. Now **Step Sum** indicates the position of the end of the hole corresponding to the quadrant 2.

11. repeat the last 8 steps for the other 3 1234 holes.

Of course you will be able to find the position of the sync hole with a similar procedure.

5.4.2 Emergency Brake

Figure 5.3: Emergency brake for immediately stopping the motor.

To operate the motor use the Start/Stop button (see below). The Emergency Brake button should not be used during normal operation. Use this button only, if you need to stop the motor immediately. Pressing the button at high rotational speed may cause damage of the mechanics of the polarotor.

5.4.3 Drive Control

Change to the tab **Speed** of the sub page on the main tab **Drive**. Here, you can choose the rotation speed of the polarizer and start and stop the motor.

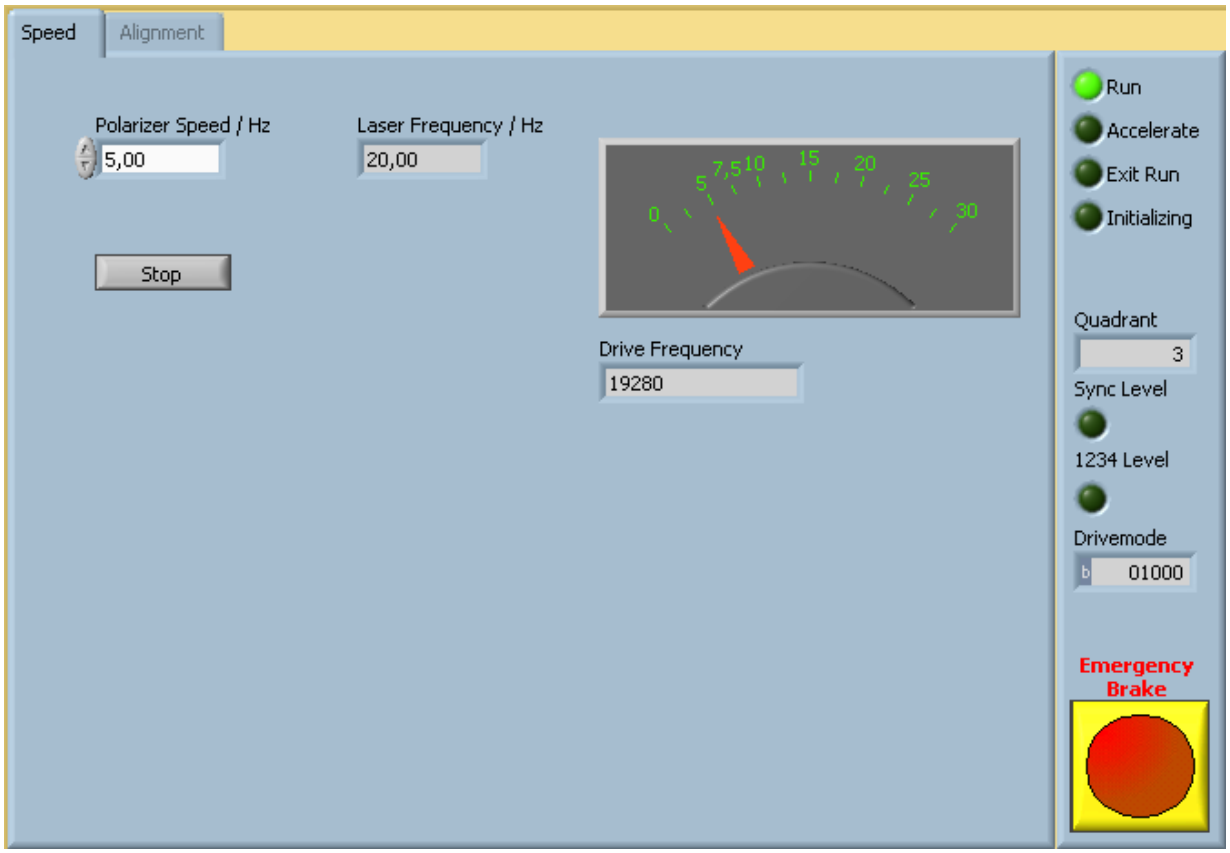


Figure 5.4: **Speed** control.

Polarizer Speed / Hz Revolutions per second of the polarizer. Choose this value before pressing the **Start/Stop** button. The current speed is indicated on tachometer on the right.

Laser Frequency Corresponding Laser Frequency $= 4 \times$ **Polarizer Speed**.

Stop Start / Stop button. When the polarizer is not rotating, the label of this button is **Start**.

Drive Frequency Stepping transferred to the motor controller.

During an acceleration / deceleration the main pages of `Polarotor.vi` cannot be changed.
When pressing the **Exit** button while the motor is running, a deceleration ramp will be executed before the program stops. When the motor has reached its target velocity, the main tab pages may be changed.

5.5 Polarization Timing

On the page **Polarization Timing** the trigger outputs for the *Polarotor* timings *Laser* and *Acquisition* will be defined. Whenever a button on this page is switched, or a control value is changed, the corresponding command will be sent to the controller.

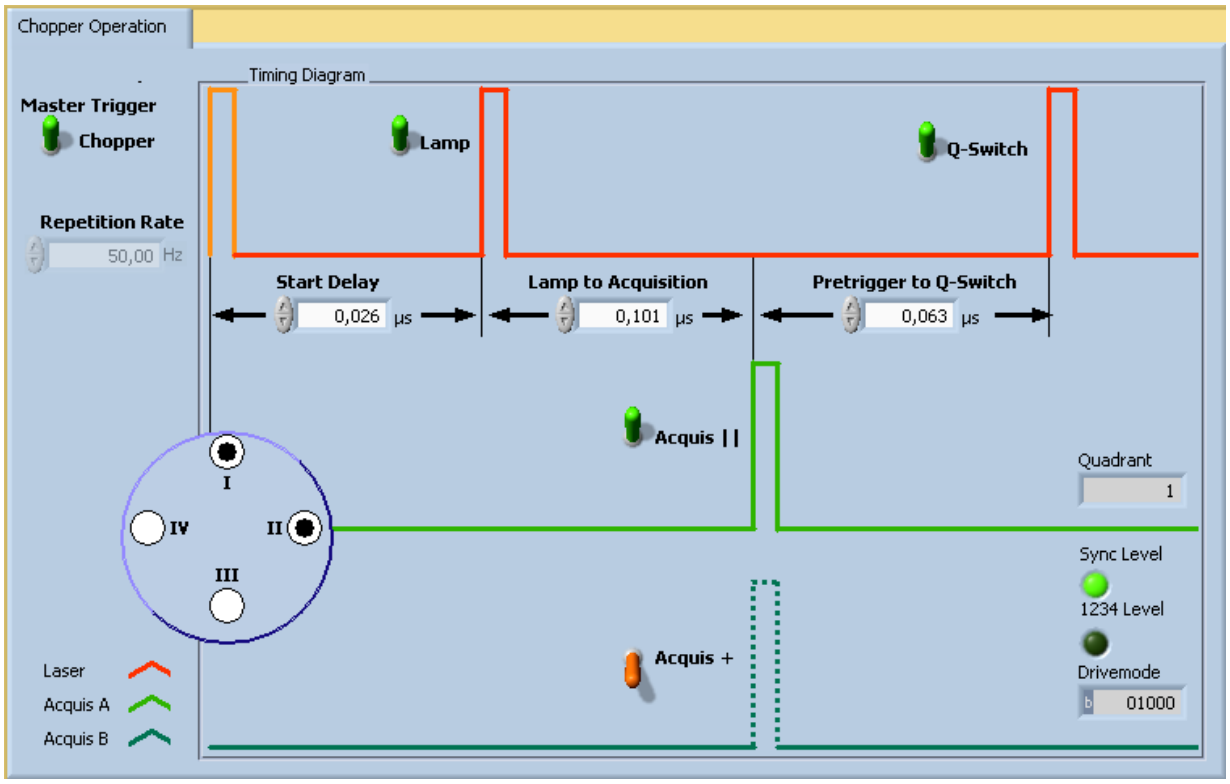


Figure 5.5: On the page **Polarization Timing** (sub page **Chopper Operation**) the behavior of the polarotor timings is determined.

Master Trigger Up – *Chopper*: The start trigger is received from the polarotor's chopper wheel
Down – *Internal*: The start trigger is generated by the controller (should be set when the polarotor is not running).

Lamp Enable / disable the lamp output.

Q-Switch Enable / disable the Q-switch output.

Acquis || Enable / disable the ||Pol output (one or both hole switches I or III must be enabled, as well).

Acquis + Enable / disable the + Pol output (one or both hole switches II or IV must be enabled, as well).

Hole Switches Enable / disable the acquisition triggers for each angular position. In fig. 5.4 the hole switches I and II are enabled.

Repetition Rate Repetition rate when the master trigger is generated by the controller (**Master Trigger** down).

Start Delay Time between the master trigger and the lamp pulse.

Lamp to Acquisition Time between the lamp pulse and the acquisition (pretrigger) pulse (||Pol and + Pol) outputs.

Acquisition to Q-Switch Time between the acquisition pulse outputs and the Q-switch.

Status Indicaters The indicators on the right hand side are the same as on the **Stepper Motor** page. Note that when the polarizer is rotating fast, not all changes can be monitored.

5.6 Finding the Start Delay

To operate the system it is necessary to find the appropriate **Start Delay** to trigger the laser lamp. The **Start Delay** should be aligned in a way that one polarization has a maximum transmission and as a consequence the other polarization has a maximum blocking.
We recommend to align the **Start Delay** when the Polarotor is mounted and the whole detection system is set up.

1. Enable a signal monitor to inspect the strongest scattering channel during the alignment procedure. Use e.g. Licel's **Live Display**.
2. Run `Polarotor.vi` and change to the tab page **Polarization Timing**
3. Switch **Master Trigger** to the *Internal* mode
4. Change to the main tab page **Drive**, sub page **Alignment**
5. Move the polarotor to the beginning of the next 1234 hole (button **1234 Begin**)
6. Press **Reset Sum** to reset the **Step Sum** to 0
7. Move the Polarotor using the **2 Steps** button. Watch the signals for maximum blocking after each step
8. When the maximum suppression of the signal is reached you have found the **Step Sum** corresponding to the **start Delay** you will want to use in your acquisitions.
9. Calculate the delay time using

$$t_{\textit{Start Delay}(\mu s)} = \frac{sum}{Nf} \qquad 1 \times 10^6$$

with

sum	the **Step Sum** found at the maximum signal suppression
N	number of steps per revolution ($N = 3856$)
f	the **Polarizer Speed** you will use ($f = \frac{1}{4} f_{\text{Laser}}$)

Chapter 6

Appendix

Timing Ranges

Timing parameters for Polarotor and Trigger Outputs:

	Timing	min	step	max
Polarotor				
	0, 90, 180, 270 degree to Lamp	20 µs	6.4 µs	419ms
	Lamp to Acquisition (|| or + pol)	1 µs	200 ns	13.1 ms
	Acquisition to Q-switch	62 ns	12.5 ns	819.2 µs

Mechanical Parameters

The Polarotor stepper driver makes 3856 steps per revolution.
One Polarotor revolution corresponds to 4 laser shots.
The following table lists the velocity limits.

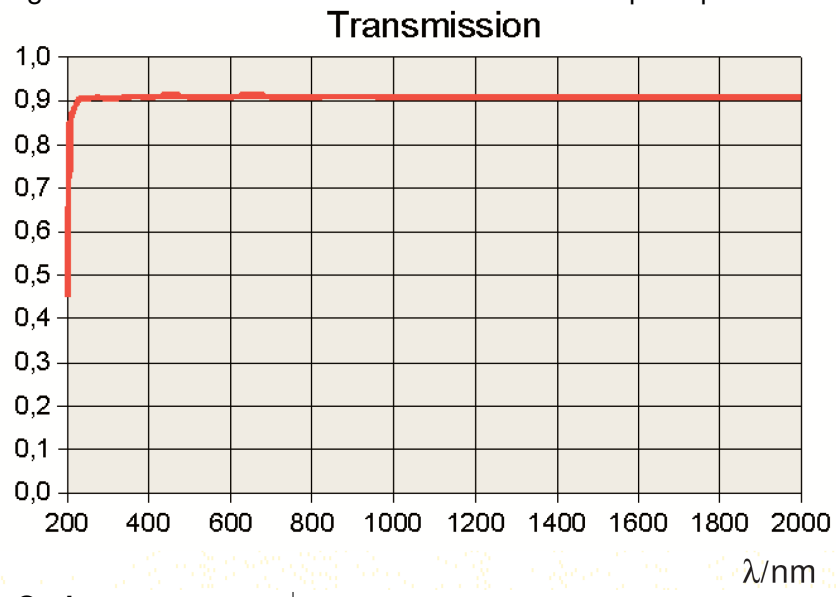
		steps/sec	Polarotor rev./sec	Laser frequency (Hz)
Velocity Limits	Min. Velocity	320	0.08	0.32
	Max. Velocity	48200	12.5	50

Max. Acceleration/Deceleration: $1000 \frac{\text{steps}}{\text{sec}^2}$.

Max. Speed Increment: $160 \frac{\text{steps}}{\text{sec}}$.

Optics

The figure shows the transmission of the Glan-Thompson prism at 0° incidence .



Optics	
Polarizing material	α-BBO
Coating	AR355/532
Optical transmission	200 nm - 2µm
Extinction	5×10^{-6} @$220 \ldots 900$ nm
Acceptance angle	$> 15°$ (full angle)
clear aperture	20 mm