A249: Laser Gyroscope

April 4, 2022

In here we will present the tasks that we have to complete before conducting the lab.

1 Getting Started with Gyroscopes

We downloaded the `phyphox` app made by RWTH Aachen University, and we played around with the Gyroscope function. We rotated the phone in several directions to observe the relationship between the orientation of the phone and the corresponding coordinates used in the application. This is shown in Fig. 1. Fig. 2 - 4 show the corresponding time series for the x, y, z coordinates for each rotation that we performed.

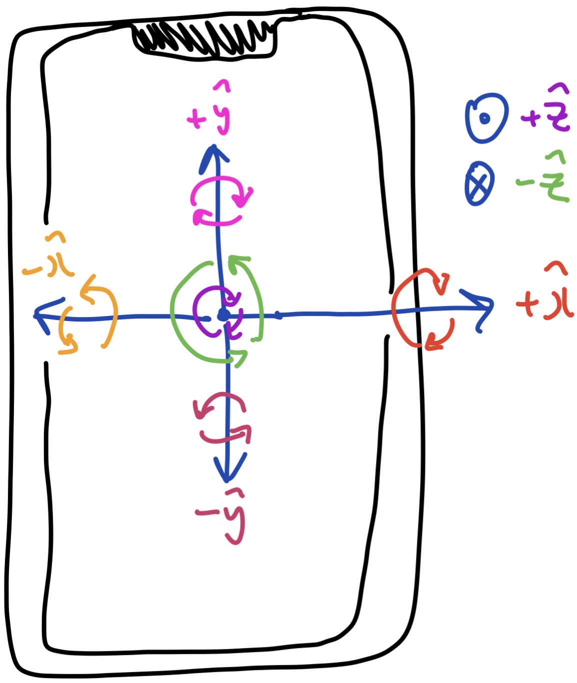
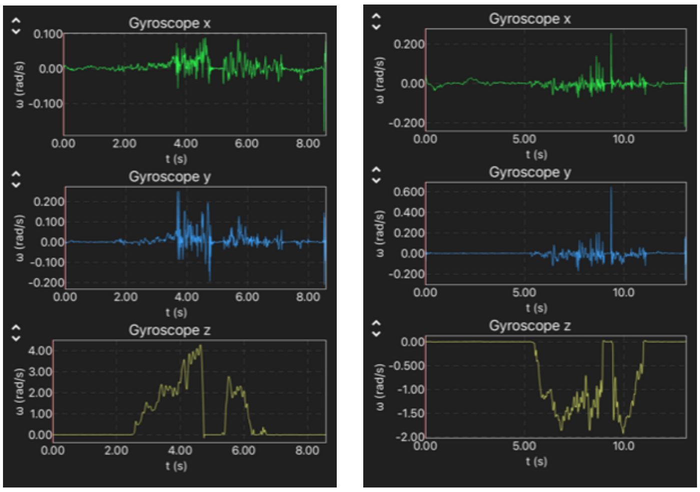
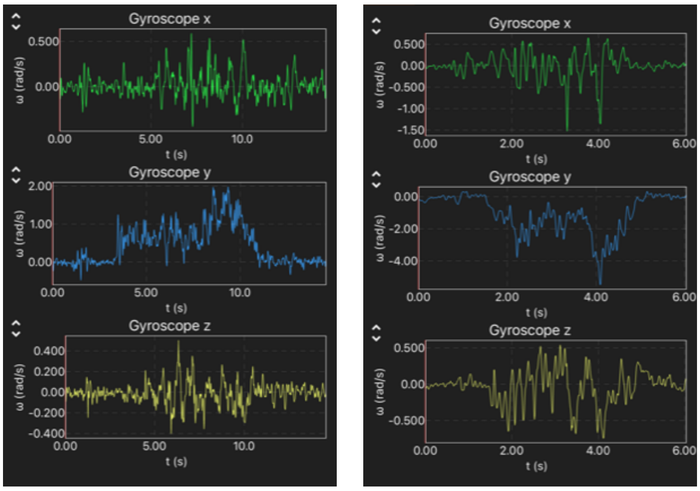


Figure 1: Sketch of the phone used to measure the gyroscope with its relevant x, y, z coordinates and sense of rotation. The sense of rotation is color coded with each rotation axis, and the direction of the axis is indicated by the blue arrows.



(a) $+z$ direction, anti-clockwise (b) $-z$ direction, clockwise

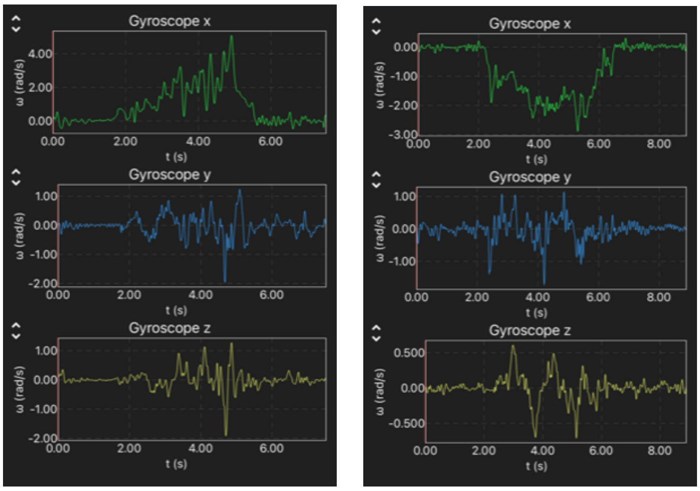
Figure 2: The time series of the x, y, z coordinates shown from the `phyphox` application when the phone was rotated parallel to the surface. This corresponds to rotations in the z-direction. Note the large amplitudes in the time series, which indicates rotations in the relevant axis.



(a) $+y$ direction, into surface (anti-clockwise) (b) $-y$ direction, out of surface (clockwise)

Figure 3: Same as Fig. 2 but for rotations into / out of the surface, corresponding to rotations in y-direction.

To save the rotation rates and import it into the computer for further analysis, the `Export Data` feature can be utilized. This will save the data as a `.zip` file that contains the raw data, the software and specifics regarding the device used, and the system time in which the experiment was started and finished. All such files are saved as `.csv` formats. An example for the raw data is shown in the Appendix section.

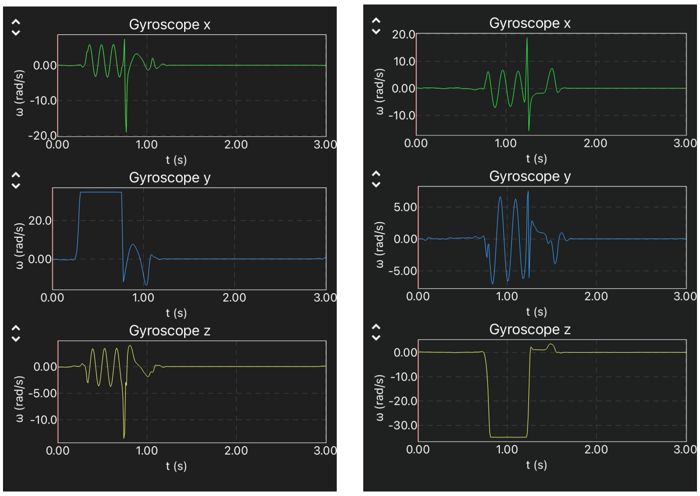


(a) $+x$ direction, rotation towards user (anti-clockwise)

(b) $-x$ direction, rotation away from user (clockwise)

Figure 4: Same as Fig. 2 but for rotations towards / away the user, corresponding to rotations in x-direction.

To obtain a faster rotation rate, we applied maximal torque on each end of the phone such that the rotation at each axis was maximal. This was done at an adequate height to ensure the rotation rate was properly measured. Several cushions were placed on top of a bed to ensure that the phone does not break. Fig. 5 show the time series of the x, y, z coordinates in the $+y$ and $-z$ directions. Performing the measurement in such a way yields a more notable and stable measurement of the rotation rate



(a) $+y$ direction

(b) $-z$ direction

Figure 5: Same as Fig. 2 but for fast rotations in the (a) $+y$ and (b) $-z$ direction.

2 Allan Deviation

We start off by keeping the phone flat on the ground for the duration of an hour and record the accelerometer of the phone. In Fig. 6, we see the raw data for individual axis of rotation.

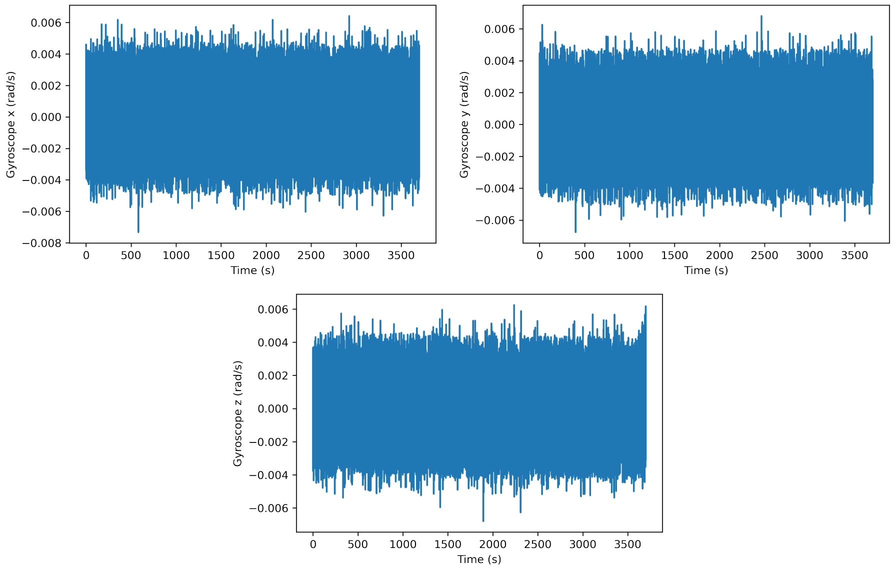


Figure 6: Raw data of all the three axes of gyroscope from phone.

From these figures, it is difficult to come to any conclusion because all we see in random noise. To analyze it further, we will take the Fourier Transoform. For plotting the data in the frequency domain, we use the `numpy` tool from the `Python`.

In Fig. 8, we see that in the x-axis Fourier transform, there is a noticeable peak at approximately 0.19 Hz. This could be a small disturbance that might have been caused by some random movement. But it would have to be periodic enough to be noticeable. It also could be because of the rotation of earth but we would have to investigate this further.

For computing the Allan deviation for all of these plots, the function `adev()` was used from the Python package, `allantools`.

We notice that around 700s, the drift becomes larger than the stability. We also do a fit with a slope of -0.5 in order to see this better. Since the Allan deviation is used to quantify the stability of the system over a period of time, we use the value of 700s for doing the measurements for the next part of the homework. To calculate the shot noise limited sensitivity, A, we use the formula:

$$\sigma_{ad}(\tau) = \frac{A}{\tau} \tag{1}$$

Using the fact that we plot the Allan deviation with log scale, we solve the Eqn. 1 to find out that the exponential of the y-intercept should give us the value of A. Because we do not have any readings at the y-intercept, we take the average of the errors for all values of τ and calculate the error. The results are summarized in the table 1.

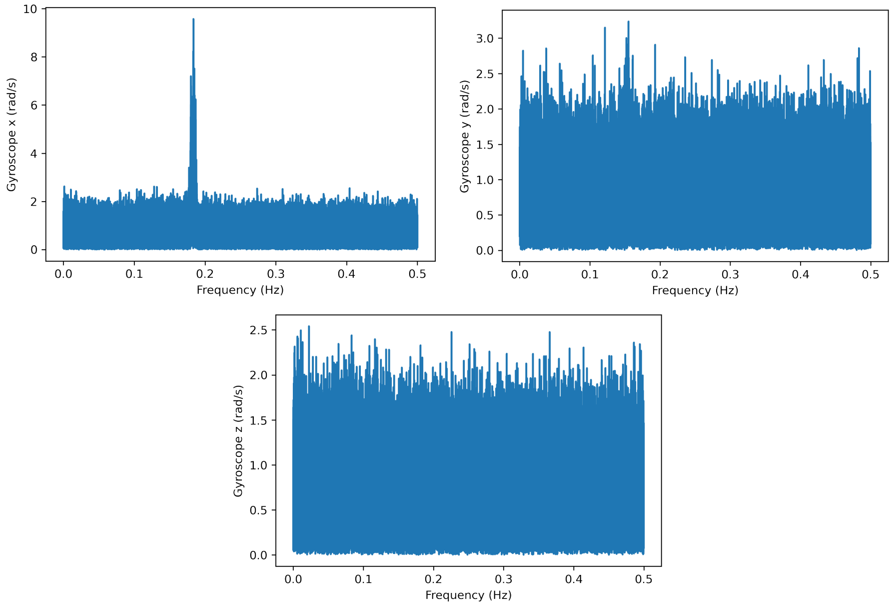


Figure 7: Fourier Transform of all 3 axes of the raw data.

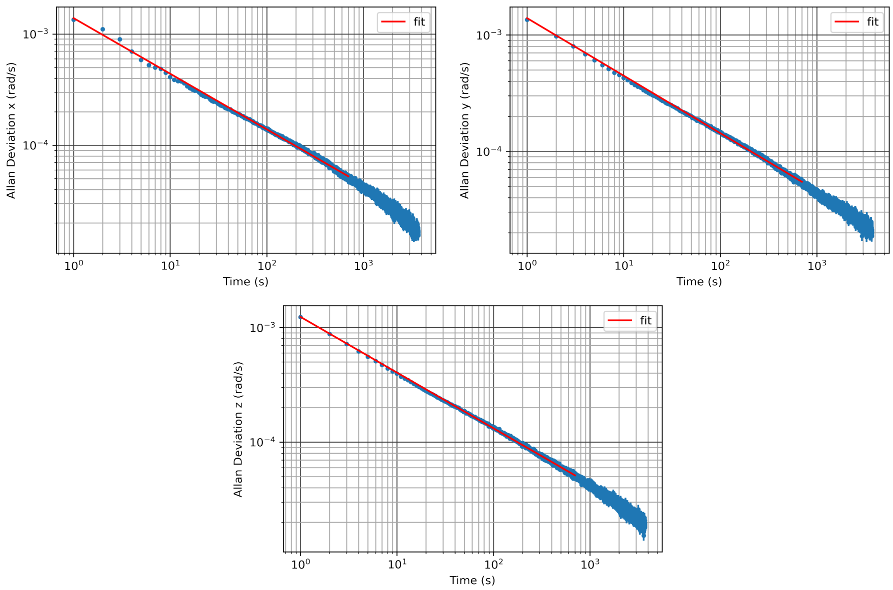


Figure 8: Allan deviation of 3 axes of rotation.

3 Earth Rotation Rate

A_x	0.001389 ± 0.000004047
A_y	0.001394 ± 0.000004203
A_z	0.001238 ± 0.000003919

Table 1: Shot noise limited sensitivity for different components