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Light reflection-based system for spin measurement of table tennis balls

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Introduction & objectives

In table tennis, spin is one of the key to win matches. Therefore, it is crucial to measure performance.

However, spin measurement is difficult to perform under real match conditions because of the high speed conditions (± 800 rad/s) unless using a high-speed camera and image processing algorithms. Unfortunately, most clubs or non-aware users cannot develop or afford to buy these kinds of expensive tools.

We propose a new tool for spin measurement based on observation of light reflection on balls.

Objectives:

- Perform spin measurement
- Linear speed measurement
- Retrieve ball spin frequency numerically

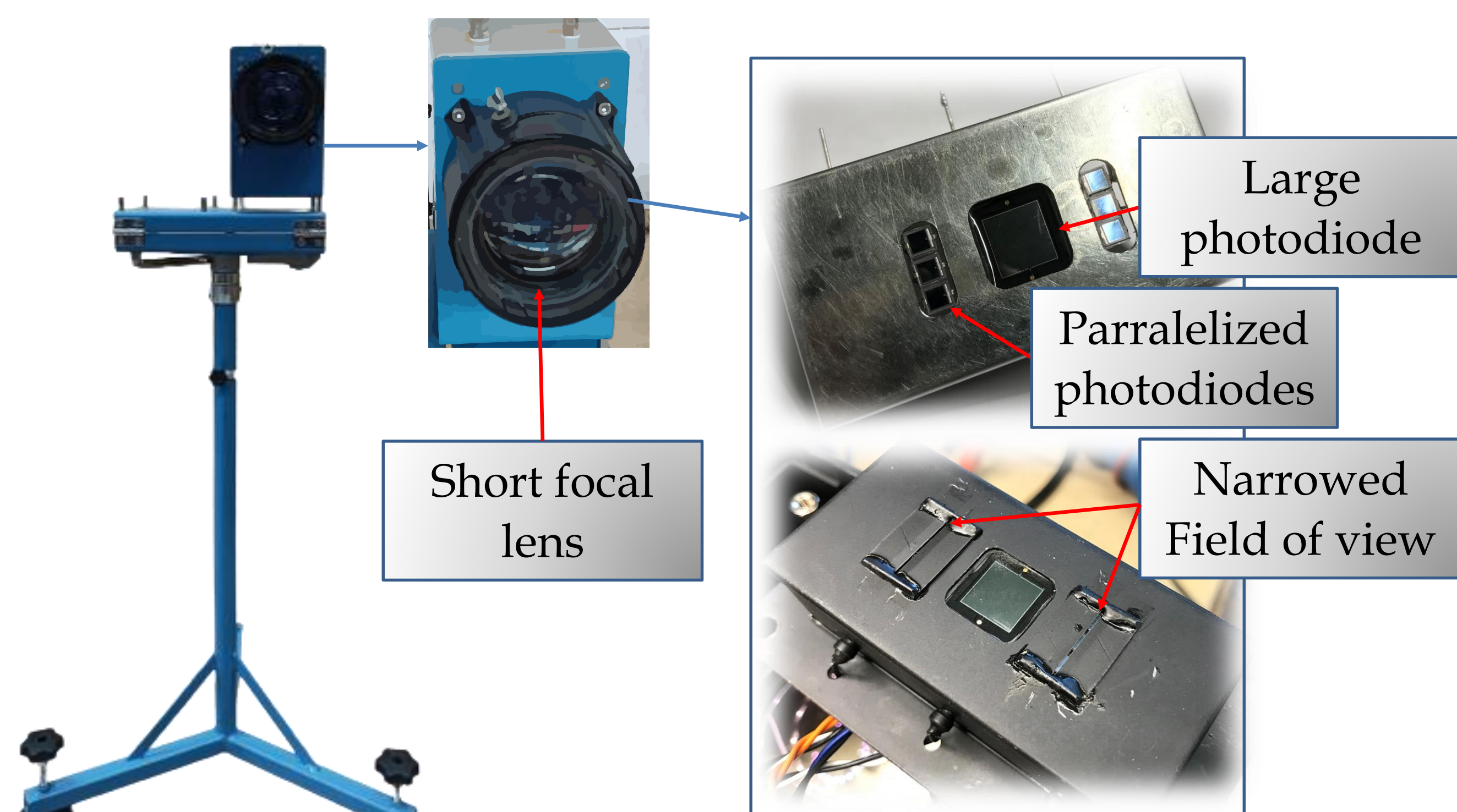


Fig 1. Rotation measurement system & zoom on inner components

Materials & Methods

We developed an optical system based on photodiodes and a short focal lens for light-reflection measurement (Fig 1) on balls (half painted in black). The system is inspired by the invention of Shaw [1], the difference is the use of external LEDs to enlighten the area of interest instead of laser projection.

One large photodiode is placed alongside two arrays of small photodiodes with a narrowed field of view.

Each group of diodes is dedicated to one measure:

- The big photodiode is dedicated to spin rotation on zone 2 (Fig 2)
- The 2 arrays of photodiodes are dedicated to observe the ball crossing the table border and the net respectively (linear speed computation possible).

A second system is added to get the rotation on the second half table.

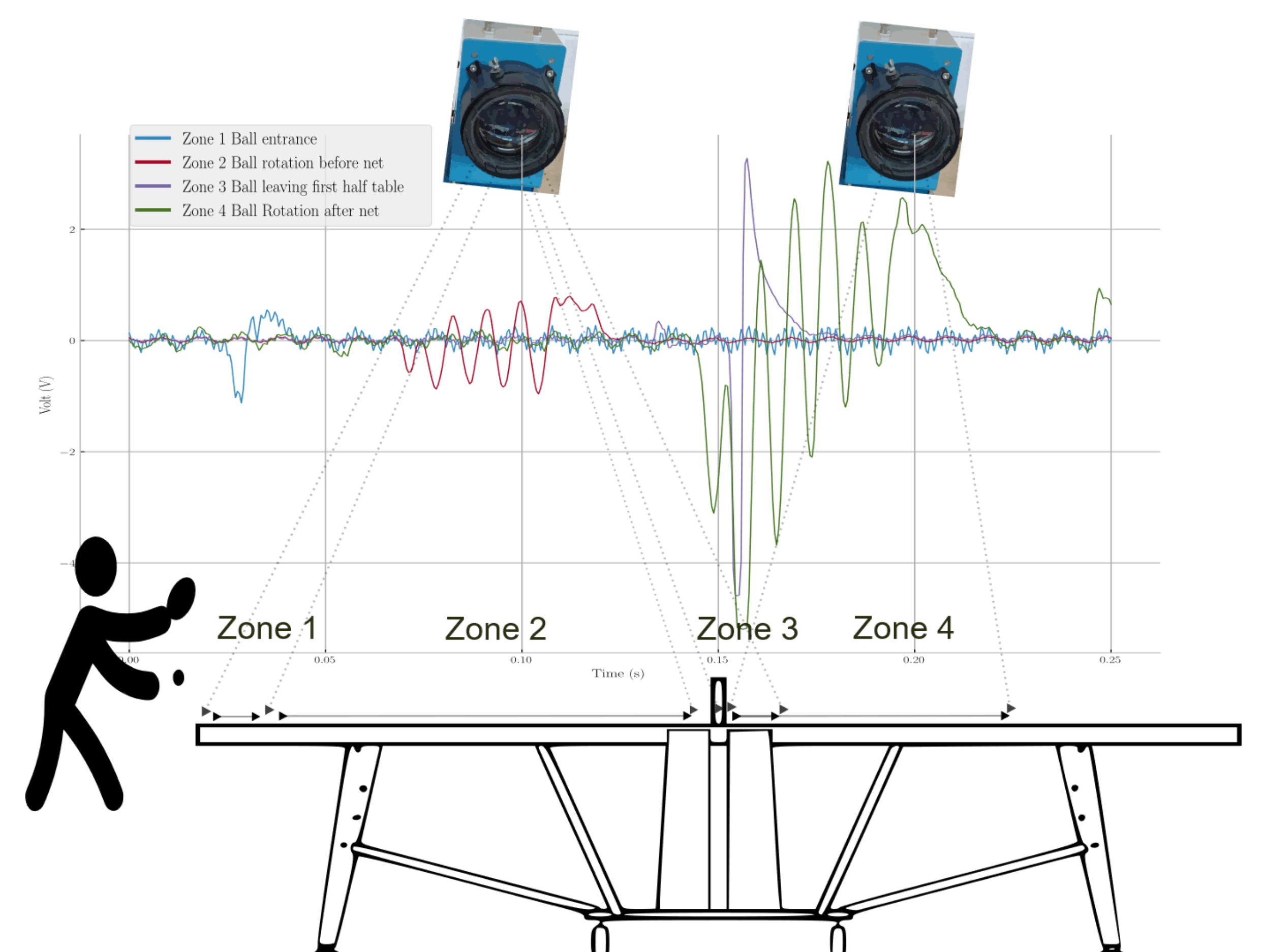


Fig 2. Optical signals through the different areas

Results & Discussion

Frequency extraction is done by computing **Power Spectrum Density (PSD)** on the time signal of rotation (Fig 3 A) using Welch's method and retrieve the maximum value.

$$s(f) = \left| \int_0^{\infty} x(t)e^{-i2\pi ft} dt \right|^2$$

With $s(f)$ the Power spectrum density

Butterworth bandpass filter of 5th order was applied to smooth the PSD (Fig 3 B) (Low cut frequency = 10Hz, High-cut frequency= 250Hz)

The numerical frequency value was compared with frame by frame analysis performed on a high speed camera Miro C210 from Phantom at 2000 fps.

Estimated error between High speed camera and our system is $\pm 5.6\%$.

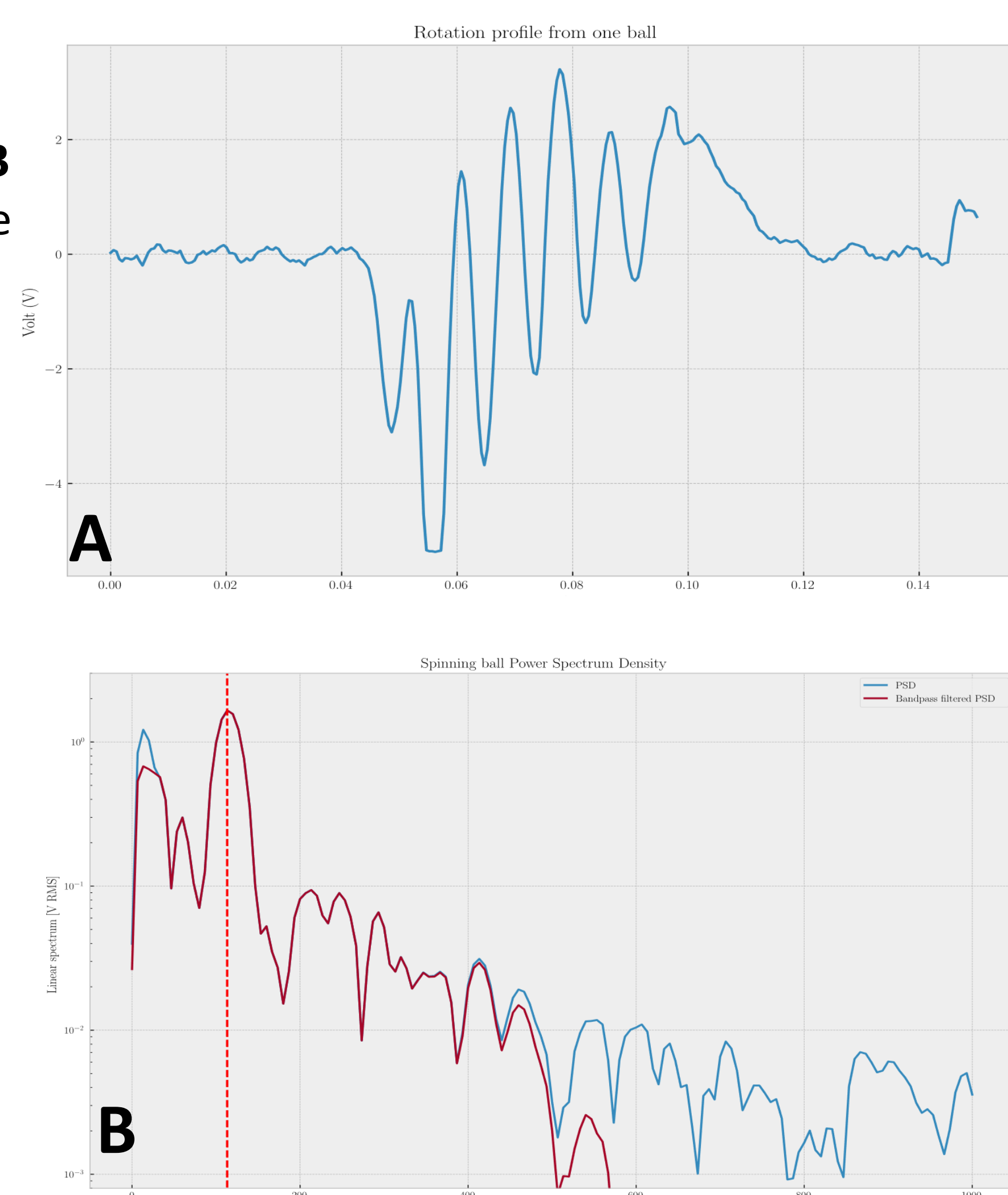


Fig 3. A Rotation profile from one ball
B. Power Spectrum Density of the spinning ball

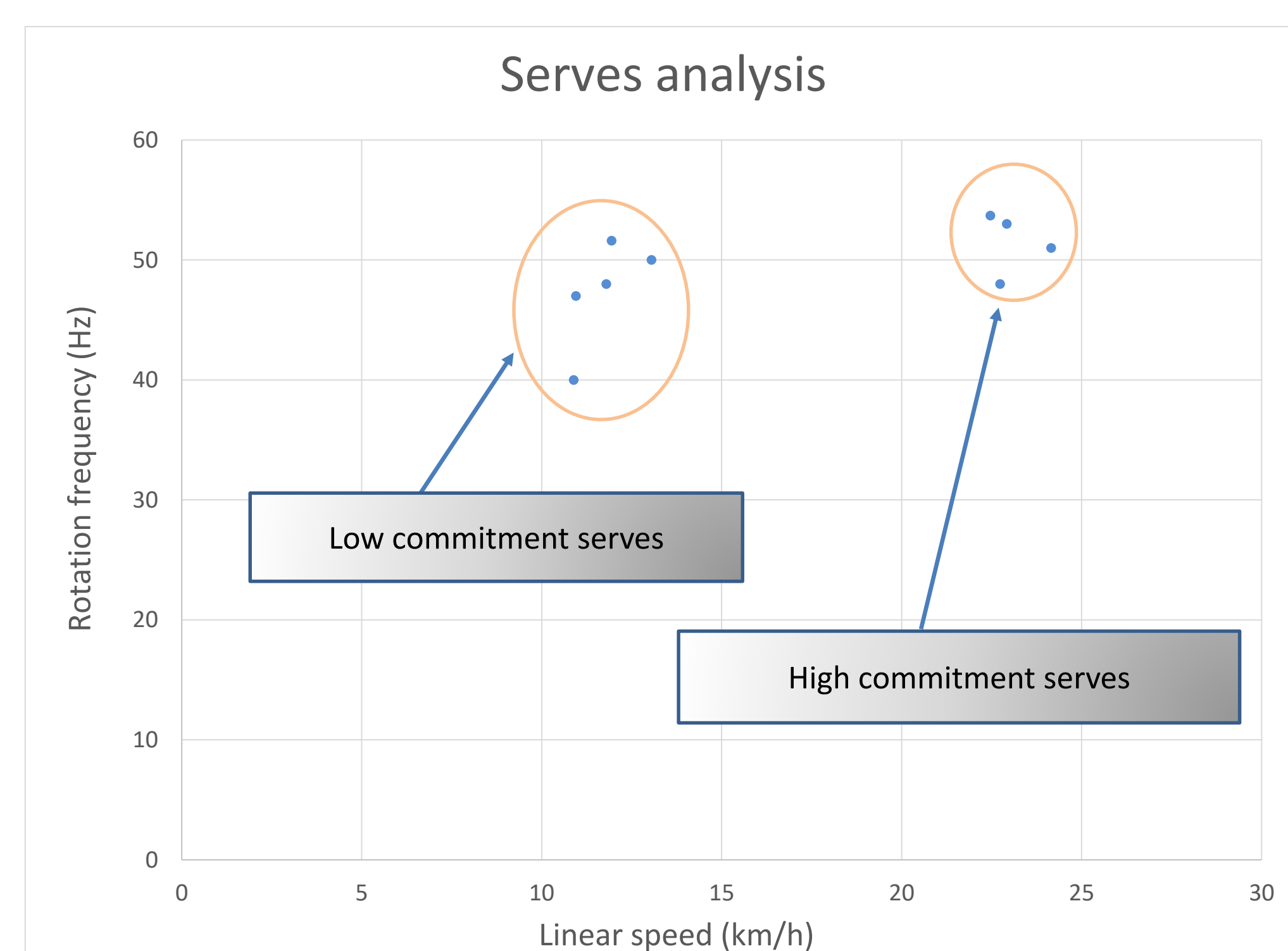


Fig 4. Real strokes spin/speed relation

Case study on player's serves, observation of the spin frequency / linear speed relation. (Fig 4)

Conclusions

1. Developpement of a spin measurement tool dedicated to table tennis
2. System show strong accordance to a High speed camera
3. The system allows the observation of speed/spin relation