author: Gerrit van Dalfsen
tel.: +31 10 458 4816
email: gerrit@tijdteam.nl
web: www. tijdteam.nl

Date	Version	Change
30Jul2009	0.1	First draft

Slalom timing accuracy with photobeams

1. Introduction

Electronic time measurement with photobeams is of common usage for timing slalom events. For top events, timing with photobeams is insufficient for the required accuracy of 1/100 second. This paper explains why for canoe events photobeams are not fit to deliver the required accuracy.

In top events, the difference between the best competitors can be no more than 0.02 sec. The best five rank sometimes in a one second time slot. When these times are measured by photobeam interruption, the accuracy of this measuring method does not support such a ranking to be reliable.

2. The slalom rules

The slalom rules for international slalom events (2009) state:

- 33.1 The time of a run is measured from the time that the competitor's body first breaks the starting line to the time when the finish line is broken by the competitor's body.
- 33.2 Timing of each run must be accurate to at least 1/100th of a second
- 41.12.1 Timing at World Championships must be carried out both by a photoelectric system and stopwatch. In any case, the body of the competitor must be used to both start and stop the clock

The photoelectric system is in most cases interpreted as a photoelectronic beam, that when interrupted, triggers a timer for a timestamp.

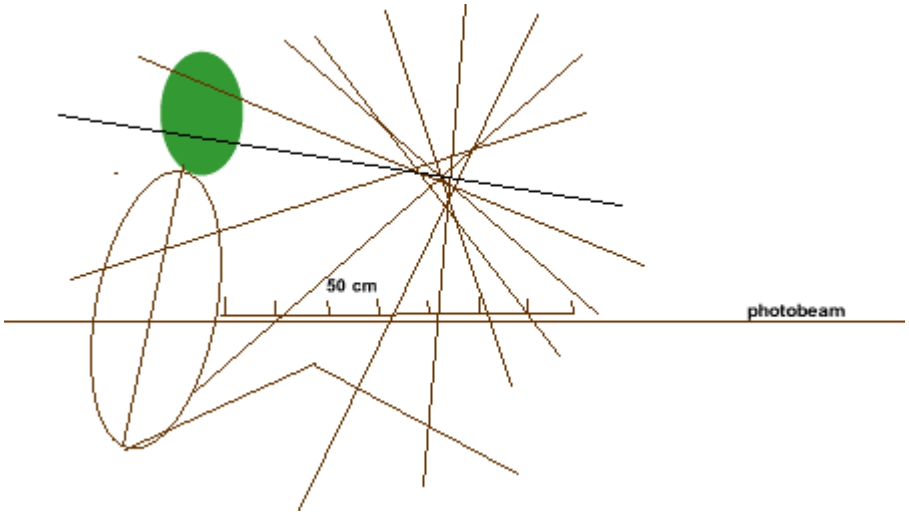
With the photoelectric beam measuring method the required accuracy for the runtime of 1/100 second cannot be obtained. This is inherently to the measuring method of beam interruption by a paddling competitor.

The Slalom rules state that the measurement of the runtime must start and end on the body breaking the start line resp. the finish line. In many cases the photobeam is not interrupted by the body of the competitor, but by the paddle, arm or splashing water. The measurement method of photobeam interruption introduces an unreliability of the measurement of at least 0.2 seconds, which makes the accuracy of the timing as bad as that.

3. The paddlers movement

The figure below shows the movement of the paddle during a paddling cycle. This stick figure derives from a video of a paddler on an ergometer.

In one position the paddle is almost horizontally. In this phase the photobeam is interrupted by the competitors body (as required by the rules). Half a cycle later the paddle is vertically and in this phase it is the paddle or the arm that interrupts the photo beam. This is about 50 cm before the body interrupts the beam. As the photobeam may be interrupted in any phase of the paddling cycle,



The paddle positions during a paddle cycle

the photobeam will be interrupted 0 - 50 cm before the body interrupts the photobeam. And this happens on both start and finish line.

Below some photographs that shows clearly the premature interruption of the photobeam and consequently firing of the timer.



4. Inaccuracy of the photobeam method for canoe timing

By paddle, arm of watersplash the photobeam can be interrupted before the body crosses the start or finish line. This premature interruption can be at least 50 cm before the body crosses the photobeam. Calculating with a velocity of the competitor of 4 to 6 m/sec (as measured on the course), a 50 cm early interruption of the photobeam decreases the runtime with 0.1 sec. As this can happen both at start and finish, the total inaccuracy of the photobeam measuring method is at least 0.2 sec.

Explanation:
Suppose two runs, with exactly the same time T, counted from the body crossing the start line to the body crossing the finishline. With premature interruption of the photobeam at start and finish we get the following table of runtimes:

		Finish	
	Runtime	paddle horizontally	paddle vertically
Start	paddle horizontally	T	T - 0.1
	paddle vertically	T + 0.1	T

So two competitors which have exactly the same run time when counted from body crossing the startline to body crossing the finishline, may end up with a runtime difference of 0.2 second, when measured with photobeams. Caculating with 4 m/s and 70 cm premature beam interruption (which is not unreasonable) delivers an inaccuracy of 0.35 sec.

Looking at the ranking of the EC Seniors 2009:

Rank	**Name**	**Total**	**Behind**	**Difference**
1	MOLMENTI Daniele	92.49		
2	NEVEU Boris	92.93	+0.44	+0.44
3	BILLAUT Julien	93.43	+0.94	+0.50
4	KAUZER Peter	95.46	+2.97	+2.03
5	WALSH Campbell	96.13	+3.64	+0.67
6	POPIELA Dariusz	96.34	+3.85	+0.21
7	HRADILEK Vavrinec	96.38	+3.89	+0.04

Given the inaccuracy of the photobeam method, differences between the rankings of 5, 6 and 7 are within the inaccuracy of the measurements. Based on the measurements you cannot say that this ranking is correct. In this case there is a ranking problem with 5,6,7. But this could equally have happened with ranking 1,2,3. And on these positions big stakes are involved.

5. Accuracy, Precision and Reliability

In measurement theory three concepts are used:

Accuracy: the deviation of the measured value of the real value
Precision : the divisions of the measurement scale (e.g. measuring in seconds or in milliseconds)
Reliability: the variation in measured values with repeated measurements

The precision of the timing measurements is OK. The electronic clocks can deliver timestamps into 1/10,000 seconds

The precision and reliability of the photocells themselves are OK to. The rising of the flanks of the electronic pulse is fast enough en highly repeatable.

The problem of photobeam measurement is due to that you cannot discriminate with photocells between the body or other parts of the competitor crossing the start and finish line. This creates an unreliability in this measurement method that adds to an inaccuracy of photobeam timing of +/- 0.1 second.

6. Solutions

Efforts to improve the accuracy with double beams provide only marginal improvements. Ideas to inspect and select the right timing impulse does not work out without a video picture.

That hints to a solution: using a start and a finish camera. With these camera's you can determine the crossing of the startline and finishline by the competitors body with better than 1/100 accuracy.

Another solution is to use RFID's with antenna amplifiers. With this technique you can fairly good determine the crossing of the competitors body of the start resp. finishline.

A work around for the problem can be that the competitors train to keep the paddle horizontally at start and vertically at finish.

7. Conclusion

For top events, a timing accuracy of at least 1/100 is definitely a requirement. Photobeams are not fit for this as this measuring method has an inccuracy of at least 0.2 sec. And photobeams do not fulfil the rules requirement that the measurements must use the body of the competitor to measure the start and finish time.

For local competitions photobeams will do, as differences between competitors are way larger as the inaccuracy of the photobeam measuring method.