

White paper

A ready-to-teach Photon-Counting Educational Kit for single-photon physics, time-resolved measurements and photonic applications

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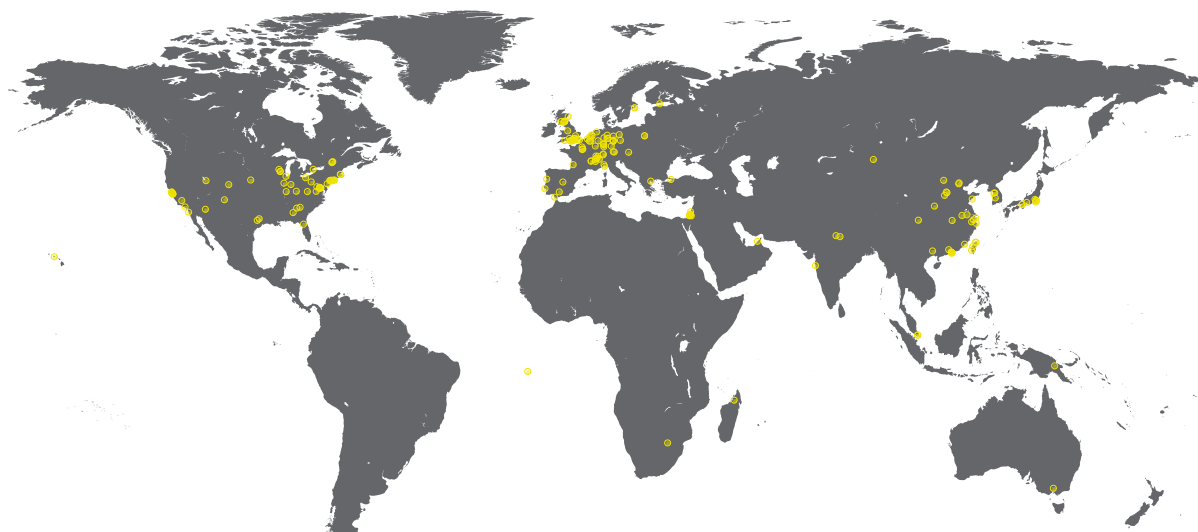
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Our Vision on Why Accessible Single-Photon Education Matters

The next breakthrough in noninvasive glucose detection or advanced brain mapping will likely depend on photon detection – yet many of these breakthroughs remain limited to groups with adequate residence. The world map below reveals a gap: we currently have no single-photon users in Latin America or Africa, and adoption remains limited across Eastern Europe and much of Asia.

This translates to most scientific and deep-tech equipment, out of reach for many. We are thus launching the Photon-Counting Educational Kit to help change that: to put single-photon detection into students' hands as early as their bachelor's studies, turning concepts from the classroom into experiments they can run themselves.

Our ambition goes beyond the classroom: we want single-photon technology to become part of the toolkit students carry into their careers. The model is straightforward—lower the barriers to learning and make the technology easy to integrate into university courses through hands-on labs, lecture slides, and hardware.



Single-photon detection underpins applications from biomedical imaging and autonomous vehicles to quantum communication and computing. Students study photon statistics, quantum randomness, fluorescence lifetimes, and time-of-flight sensing, but often only in theory: experimental instruments remain costly and complex.

Many therefore graduate with limited practical experience in the measurements and data processing used in modern photonic systems. As industry adopts single-photon and time-resolved technologies, hands-on teaching bridges this gap, deepening physical understanding while building skills in data acquisition, signal processing, and scientific programming.

Photon-Counting Educational Kit



The Photon-Counting Educational Kit gives students hands-on access to single-photon detection and time-resolved measurements in a compact platform. At its core is a 23-pixel Single-Photon Avalanche Diode (SPAD) array, sensitive from 400 nm to 1000 nm. It detects individual photons and records their arrival times with a temporal resolution of up to 20 ps. Students can investigate photon statistics, wavelength-dependent detection, and time-of-flight principles using real experimental data.

A dedicated optical cap integrates four LEDs—red, green, blue, and white—and a pulsed laser diode. The LEDs provide different wavelengths and illumination conditions, while the synchronized laser supports timing experiments and time-of-flight demonstrations.

All light sources are software-controlled. Students can adjust experimental parameters, automate measurements, and write their own acquisition routines. The same hardware supports introductory laboratory exercises and more advanced projects, combining photon-counting measurements with practical programming and data analysis.

Course Overview

The Photon-Counting Educational Kit is designed not only as a hardware platform, but as a complete teaching solution that enables instructors to introduce students to single-photon detection, time-resolved measurements, and their practical applications.

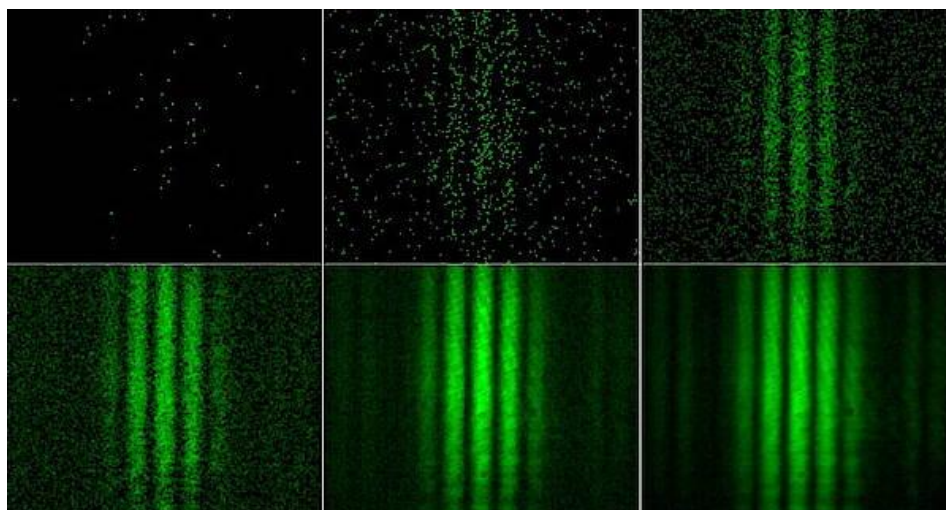
To facilitate course deployment, the kit is accompanied by educational resources. These include lecture slides covering both theoretical concepts and practical applications, as well as Python scripts for data acquisition, simulation, and analysis. Complete reference scripts are provided for instructors, while student versions contain guided exercises and partially completed code sections that encourage active learning and problem-solving.

This dual approach allows students to compare theoretical predictions with real experimental measurements acquired directly from the SPAD array system. By combining simulation and experimentation, students gain a deeper understanding of detector operation, photon statistics, and data analysis techniques while developing practical programming skills.

The educational material is organized into eight progressive chapters, allowing instructors to adapt the content to different academic levels and course objectives.

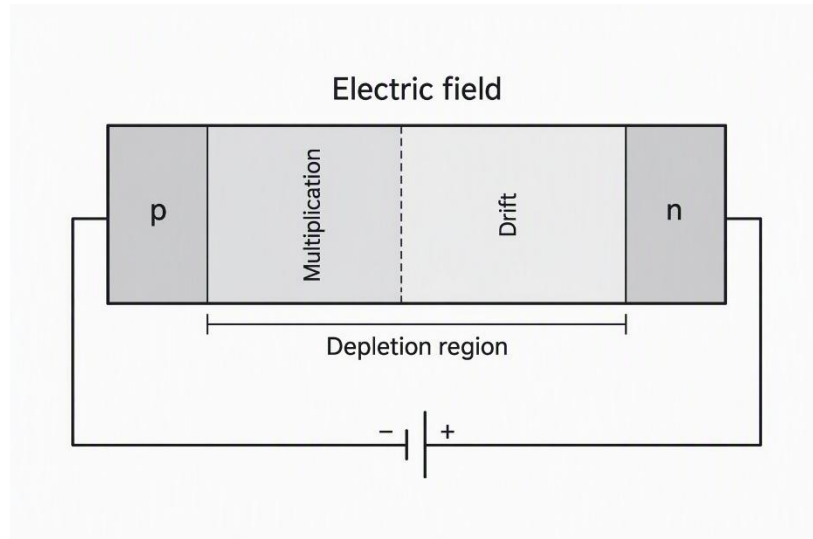
Chapter I – Light Detection

This introductory chapter presents the fundamental concepts of light detection and photonic measurements. Students are introduced to the wave-particle duality of light, the interaction between photons and matter, and the challenges associated with detecting extremely weak optical signals. Main families of light detectors and basic detector characteristics such as sensitivity and noise are also discussed.



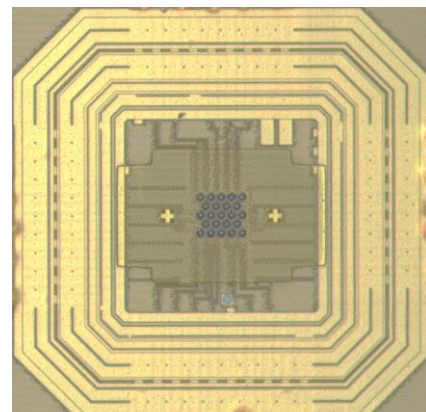
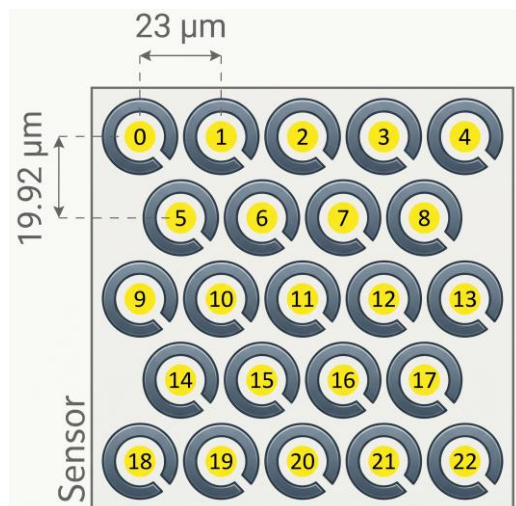
Chapter II – Single-Photon Avalanche Diodes

The second chapter focuses on the operating principles of Single-Photon Avalanche Diodes (SPADs). Topics include avalanche multiplication, Geiger-mode operation, photon detection efficiency, dark counts, afterpulsing, and timing jitter. Students learn how SPADs differ from conventional photodetectors and why they have become key components in modern photonic systems.



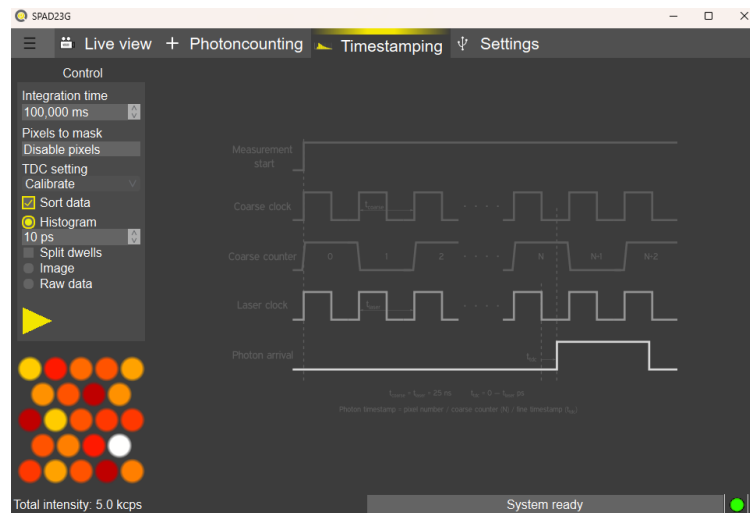
Chapter III – SPAD Array Presentation and Specifications

This chapter introduces the SPAD 23 sensor. Characteristics and specifications such as photon detection probability, microlenses, timing jitter, and dynamic range of the SPAD array are discussed.



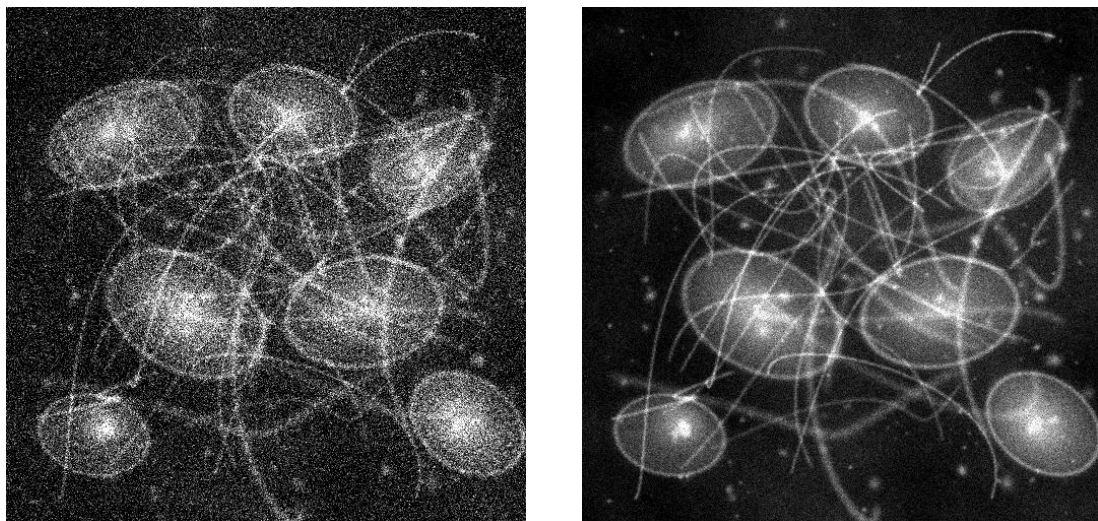
Chapter IV – Scripting and Data Acquisition

Modern photonics increasingly relies on software-controlled instrumentation and automated data analysis. This chapter introduces students to Python-based acquisition and control of the SPAD system. Through guided examples, students learn how to configure measurements, acquire data, visualize results, and build their own analysis routines.



Chapter V – Light Statistics

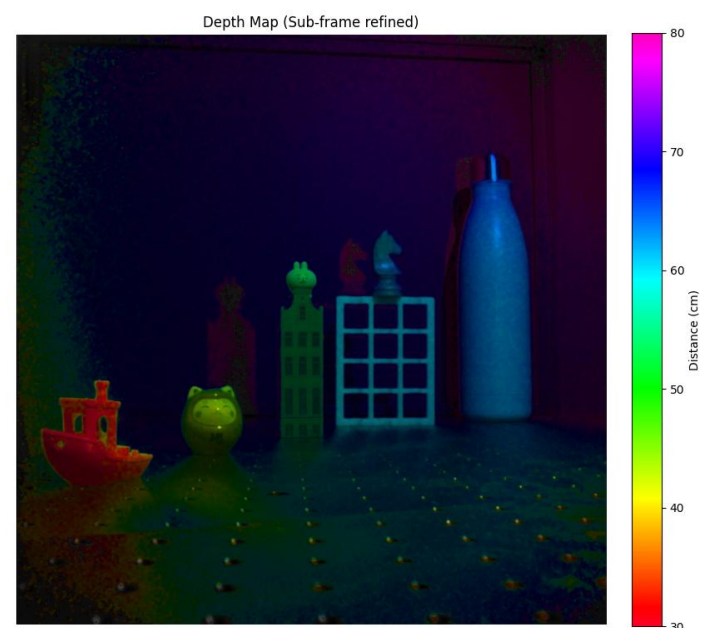
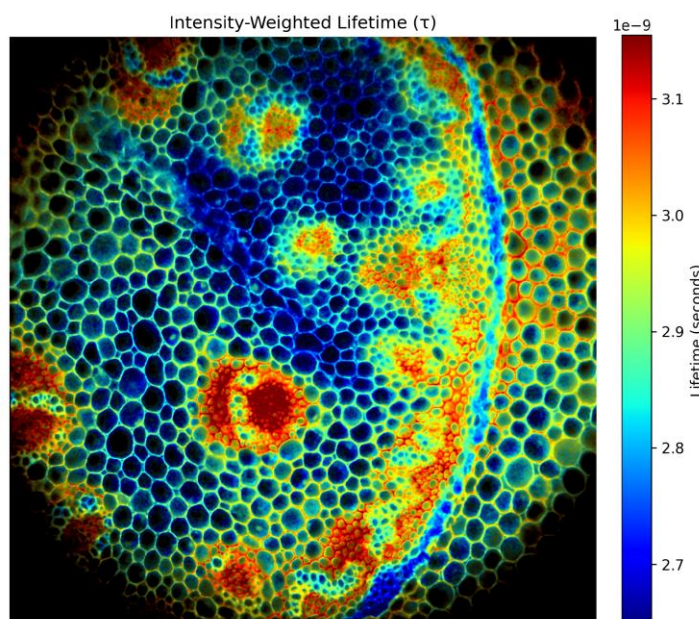
Photon detection is inherently governed by statistical processes. This chapter explores Poisson statistics, photon counting distributions, signal fluctuations, and the relationship between photon arrival events and probability theory. Students compare simulated datasets with experimental measurements acquired using the integrated LEDs and laser source.



Emulated images with a maximum signal of 16 (left) and 81 (right) photons with a background of 4 photons.

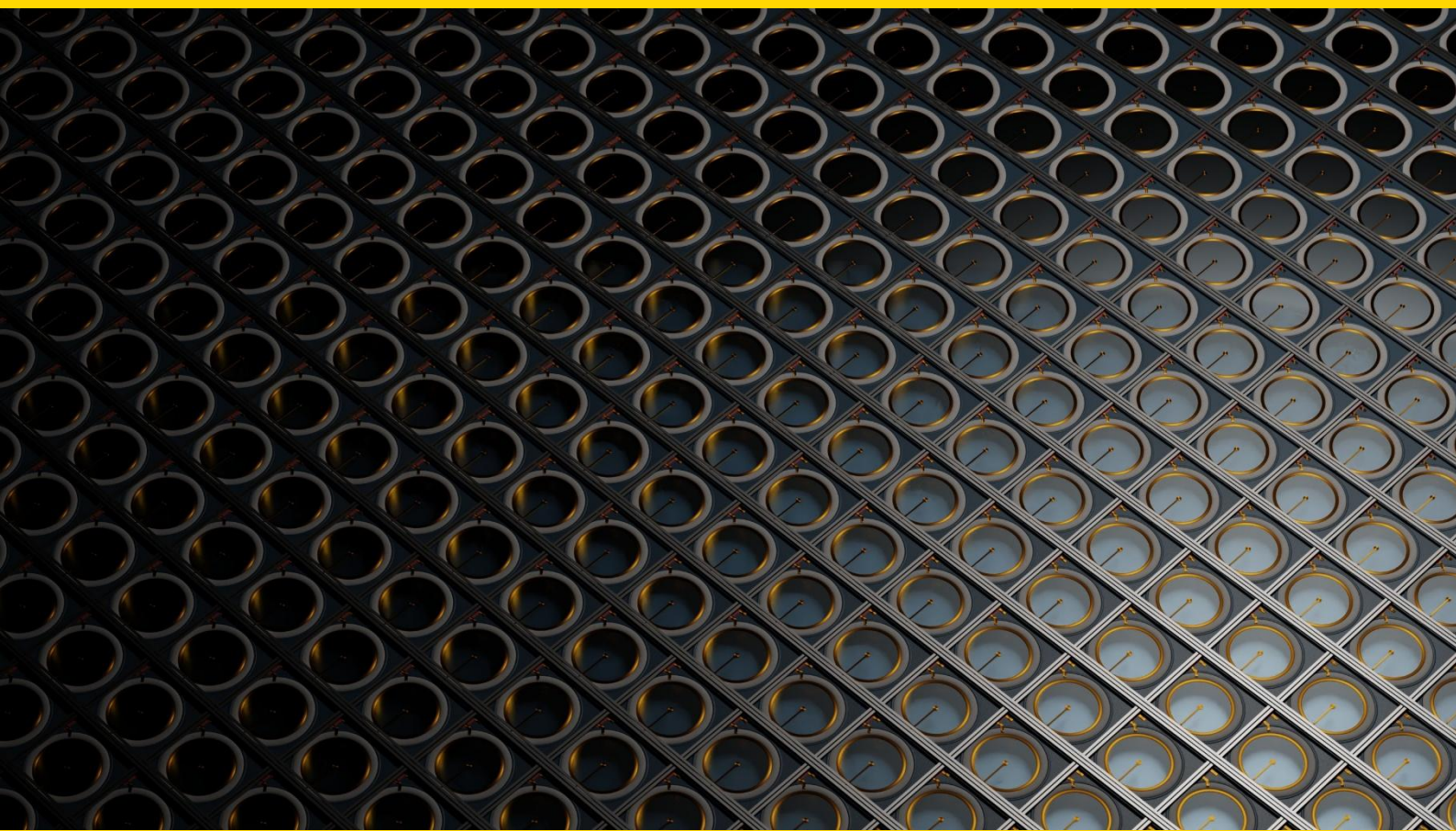
Chapters VI–VIII – Applications: Random Number Generation, Fluorescence Lifetime Imaging (FLIM), and LiDAR

To conclude the course, three different applications are studied and discussed. The first application-oriented chapter demonstrates how quantum randomness can be extracted from photon detection events. The second introduces the principles of time-resolved fluorescence measurements, and the third focuses on time-of-flight measurements and LiDAR principles using the integrated pulsed laser source and the detector's high timing resolution.



The Photon-Counting Educational Kit provides a complete learning environment that combines modern single-photon detection hardware, programmable data acquisition, and structured educational content. By integrating theory, simulation, and real-world experimentation, the platform enables students to gain practical experience with technologies that underpin many of today's most advanced photonic applications.

From fundamental concepts such as photon detection and statistical analysis to advanced topics including random number generation, fluorescence lifetime measurements, and LiDAR, the kit offers a scalable and engaging pathway into the rapidly growing field of single-photon photonics.



About Pi Imaging Technology

Pi Imaging Technology is fundamentally changing the way light is detected by creating photon-counting arrays with the highest sensitivity and lowest noise.

We enable our partners to introduce innovative products. The end users of these products perform cutting-edge science and develop better products and services.

Pi Imaging Technology builds on 11 years of dedicated work at TU Delft and EPFL. At its core is a single-photon avalanche diode designed in standard semiconductor technology. This enables our photon-counting arrays to support an unlimited number of pixels and adaptable architectures.

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