1. Research outline diagram

Outline your research proposal using graphs, charts and colors which are easy to identify in the box below.

| Research Subject	Development of ultra-high-speed image sensors

The evolutions of ultra-high-speed image sensors

➢ Our group has developed ultra-high-speed image sensors since 1992.
➢ The highest speed of our camera (NanoSIS) achieved 100,000,000 fps in 2018.

The **drawbacks** of NanoSIS
- Spatial crosstalk → Noise in images
- Long travel time of electrons → Low speed
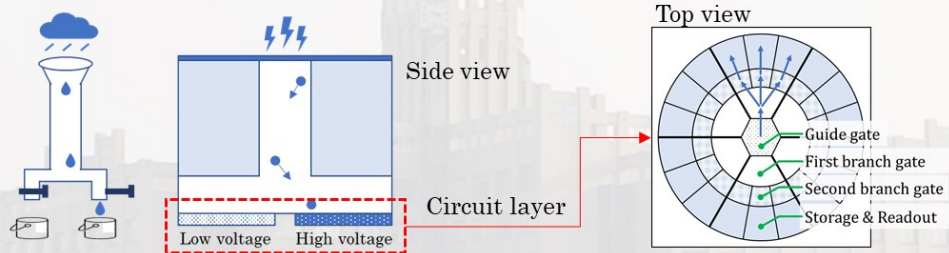- 5 in-pixel storages → Only 5 consecutive images

Goal
- Create a sensor that reaches beyond the highest theoretical frame rate of Si image sensors (90.1 Gfps). This will be the *Super Temporal Resolutions* (STR) image sensor

40 ns
30 ns
20 ns
10 ns
0 ns
Source
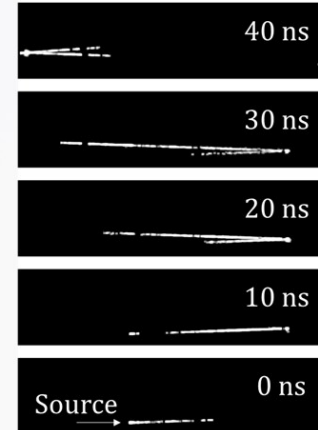
NanoSIS captured the flying light

Concept of the proposed image sensor (Hanabi image sensor)

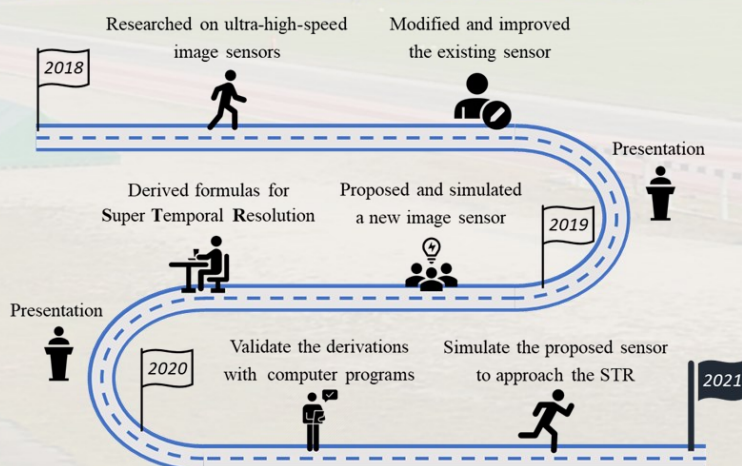The similar analogy between rainfall collection and our image sensor

Side view
Circuit layer
Low voltage High voltage
Top view
Guide gate
First branch gate
Second branch gate
Storage & Readout

Sensor operation:
1. Electrons are converted from photons and travel to the circuit layer.
2. Electrons are then transferred to in-pixel storage elements by furcating structure

This sensor can overcome the difficulties of the NanoSIS by:
1. Reducing the spatial crosstalk by using guide pipe (electrons travels within the pipe)
2. Removing the horizontal motions of electrons also by the guide pipe
3. Furcating the poly-gates so that the number of storage elements are multiplied to 18

The work done and plans during PhD course

2018 — Researched on ultra-high-speed image sensors
Modified and improved the existing sensor
Presentation
Derived formulas for **Super Temporal Resolution**
Proposed and simulated a new image sensor — 2019
Presentation
2020 — Validate the derivations with computer programs
Simulate the proposed sensor to approach the STR — 2021

During the PhD: Work on the feasibilities of the STR image sensors

After the PhD: The practical sensor is planned to be fabricated and evaluated in 2025

Potential applications:
- Lifetime Imaging (FLIM)
- Time-of-flight imaging (LiDAR)
- ToF Mass Spectrometry