Test setup for SiPM areal homogeneity studies

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AIDA 1st Annual Meeting 29.3.2012

Outline

Is useful for:

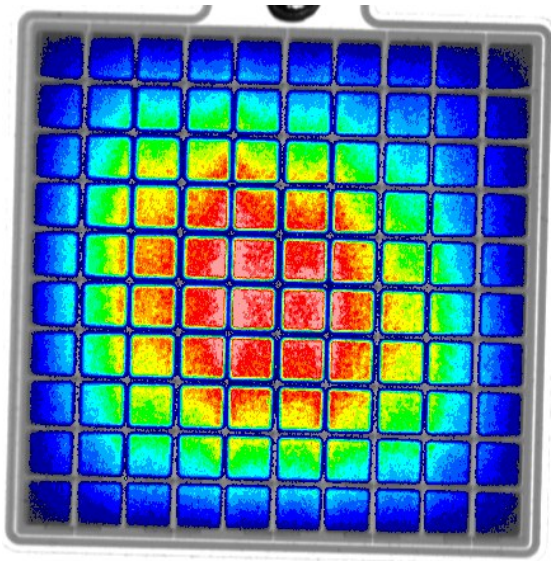
- studying of SiPM detection efficiency uniformity
- quick feedback in the MPI Semiconductor Lab
- comparing different commercial and non-commercial sensors
- studying of properties of different design
- getting precise information of shape of active area
- determination of geometrical fill-factor

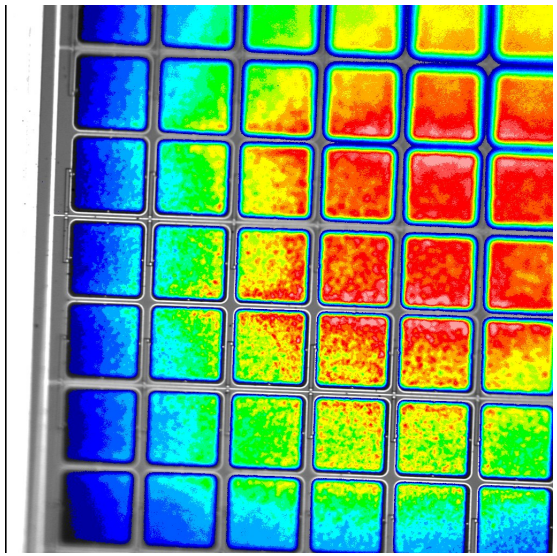
Goal of the measurement

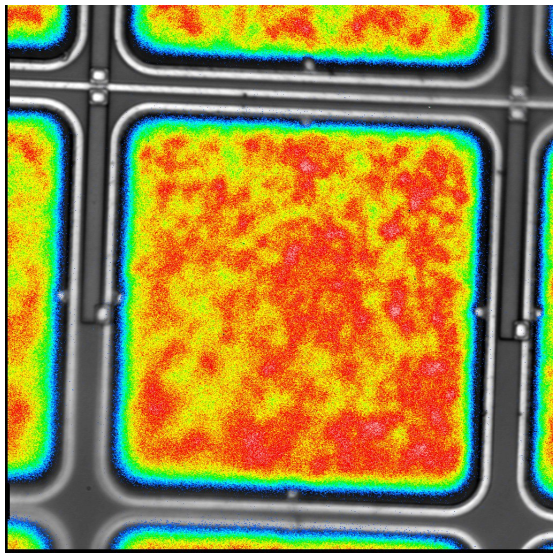
Ultimate goal

Measuring the sensitivity distribution of a SiPM over its area

- separating signal from dark count and leakage current
- photon emission measurement in not capable of providing that information
- the measurement has to be done with sub-microcell resolution



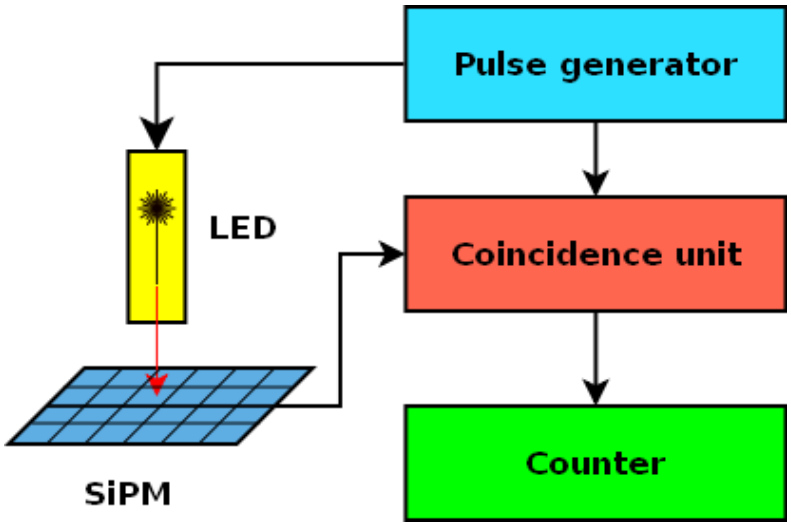




Photoemission images: Hamamatsu MPPC (100 μm pitch)

Basic idea of the measurement

- light from an LED is focused to a small point ($\phi \sim 1.5\ \mu$m)



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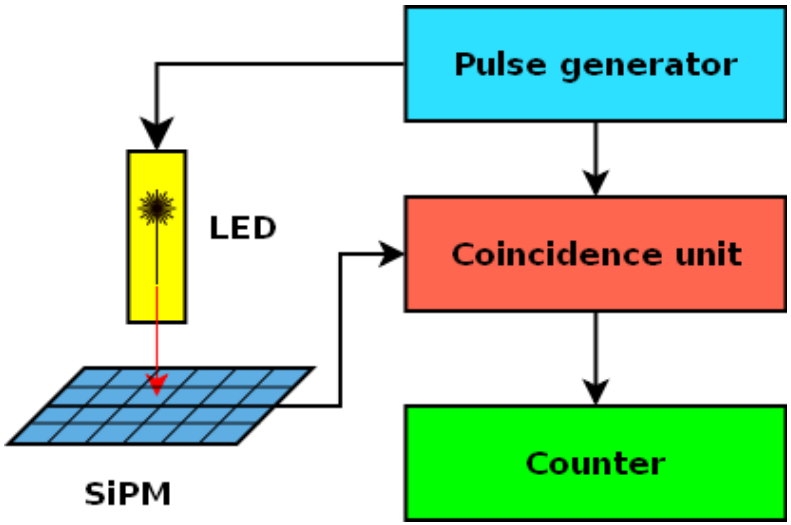

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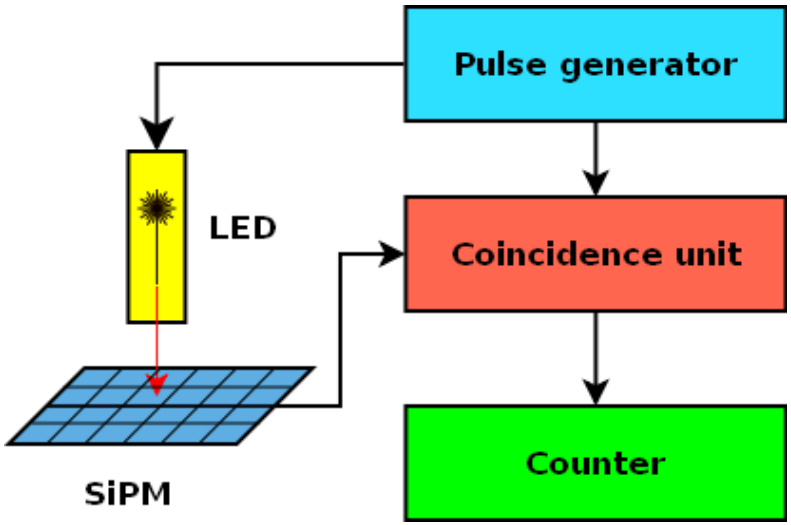

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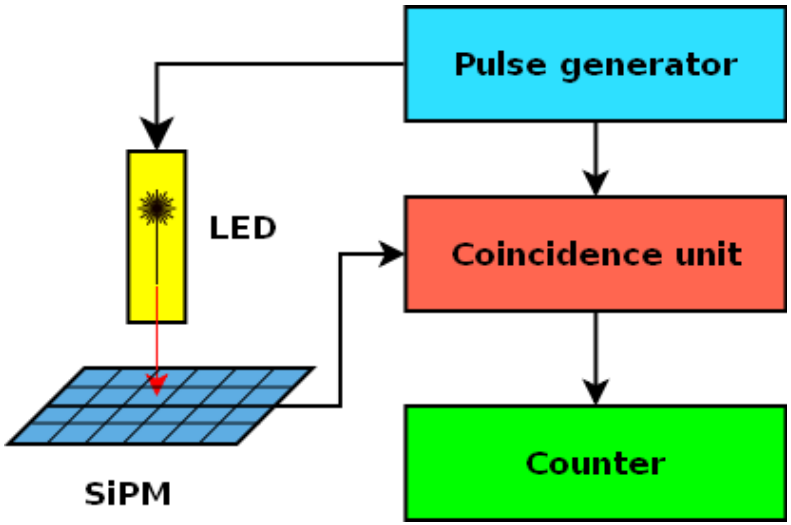

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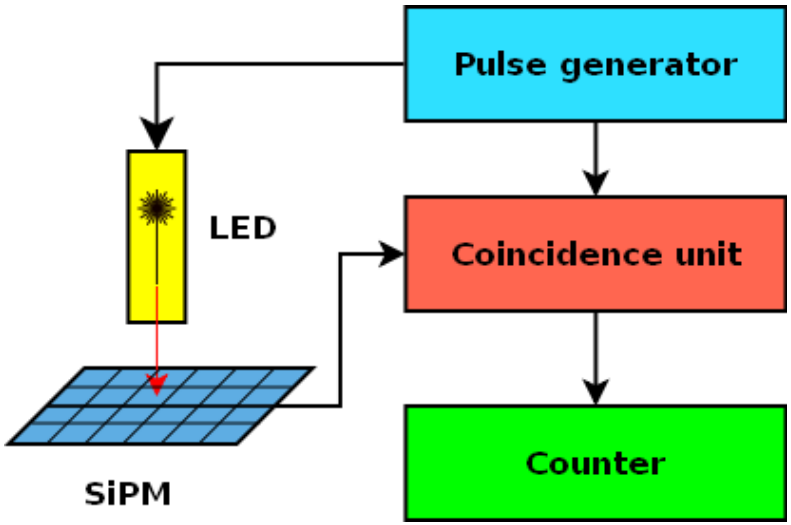

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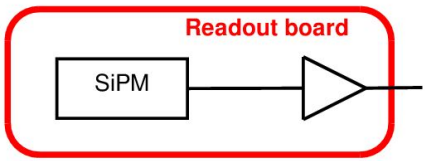
- SiPM response is measured in coincidence with LED pulses
- the light beam is driven through any part a SiPM matrix in discrete steps ($\geq 2\ \mu$m)
- a sensitivity scan of a 1×1 mm^2 device with 1 μm step size can be completed in $\sim$ 42 hours

Block scheme

& Measurement process



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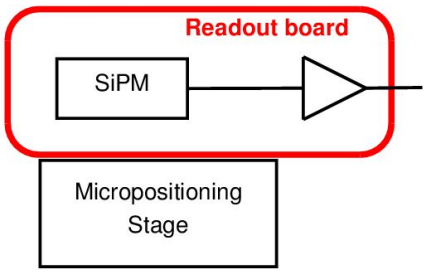

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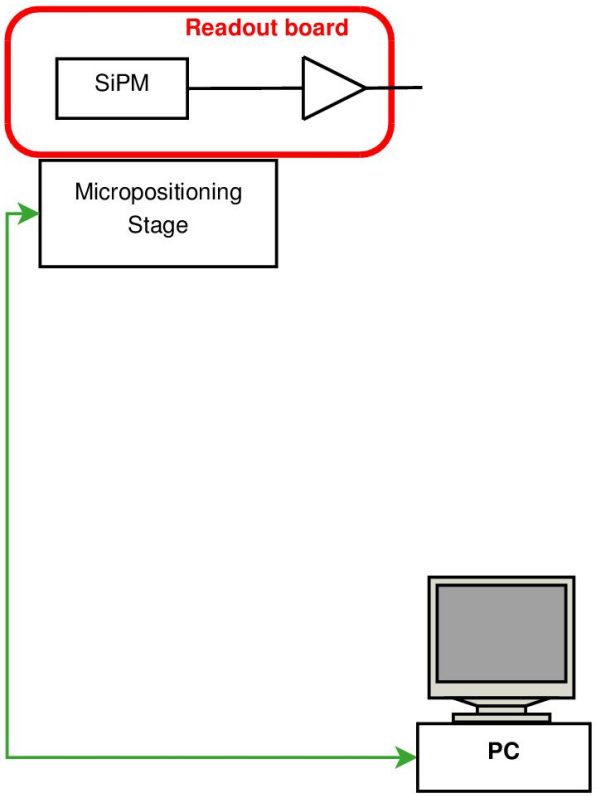

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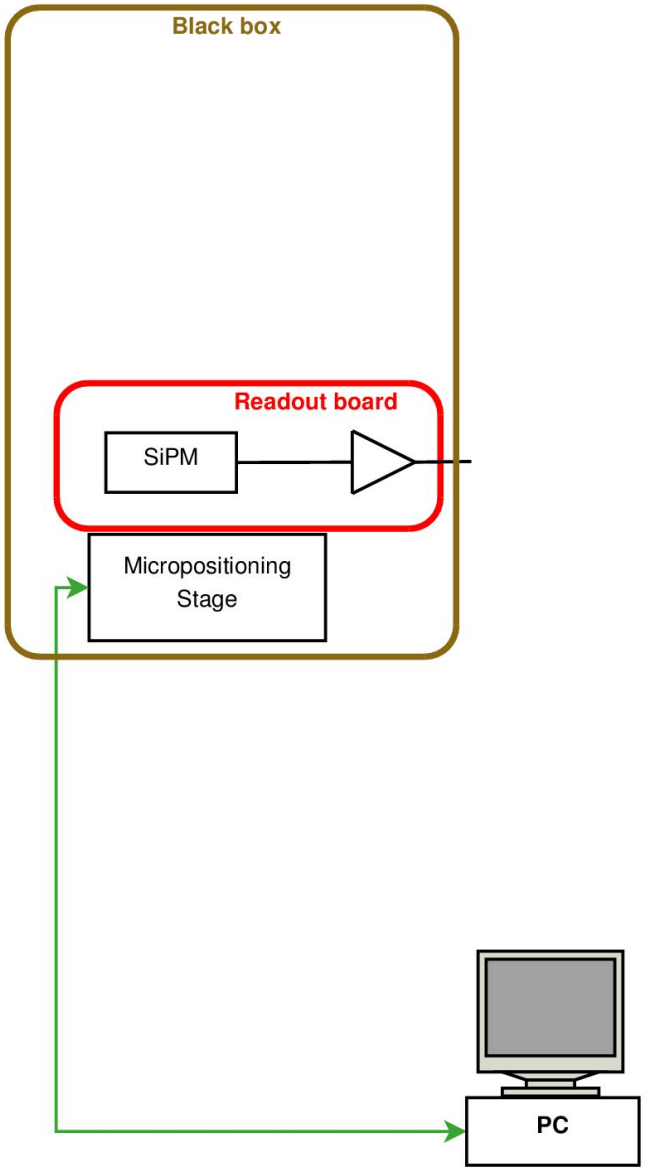

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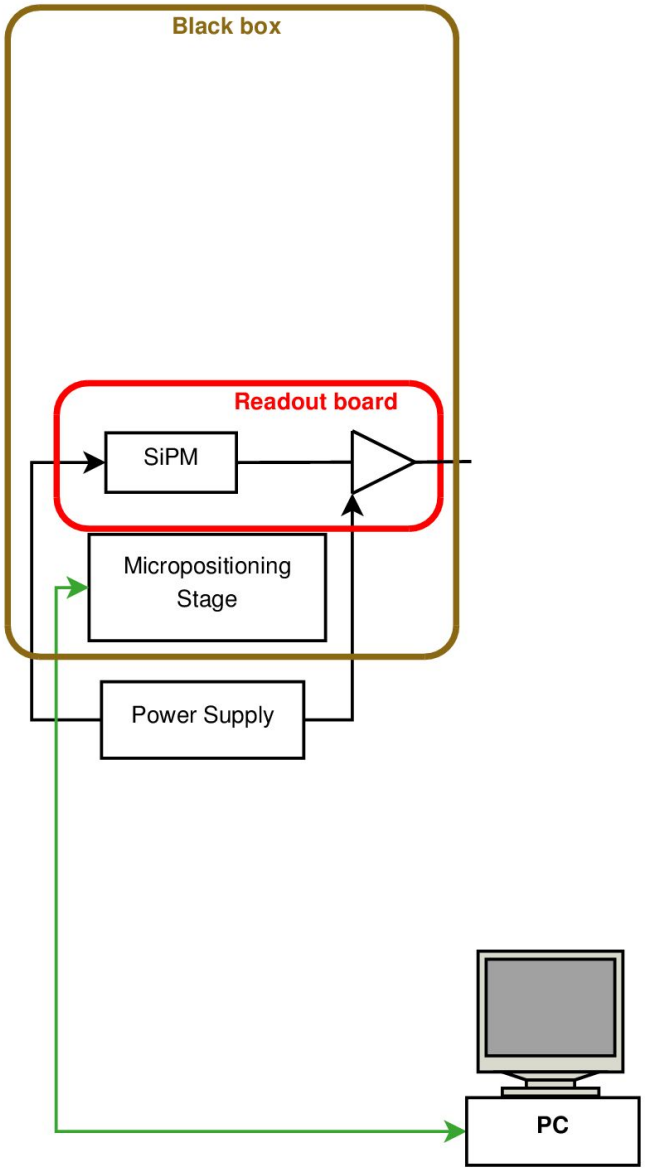

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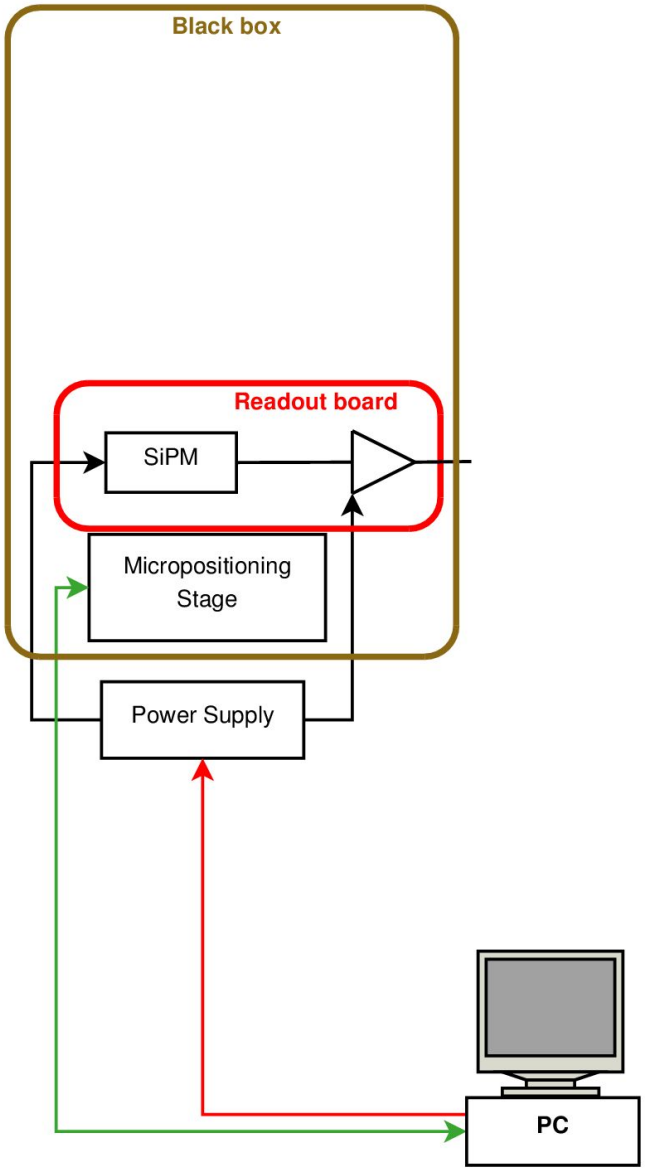

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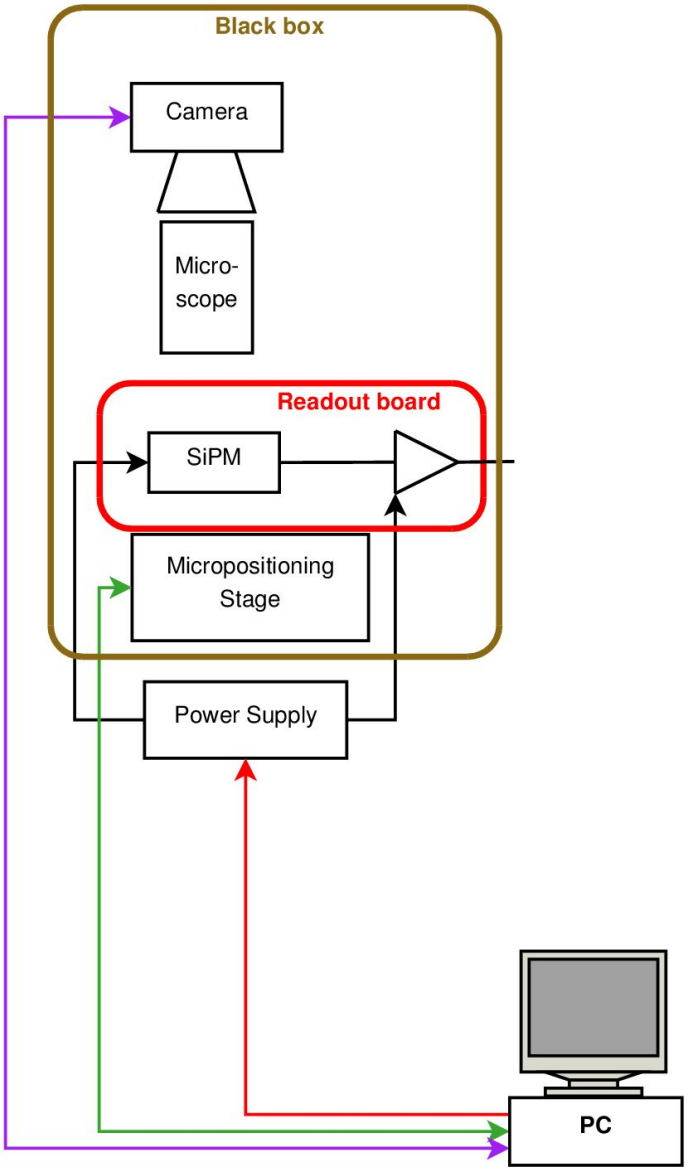

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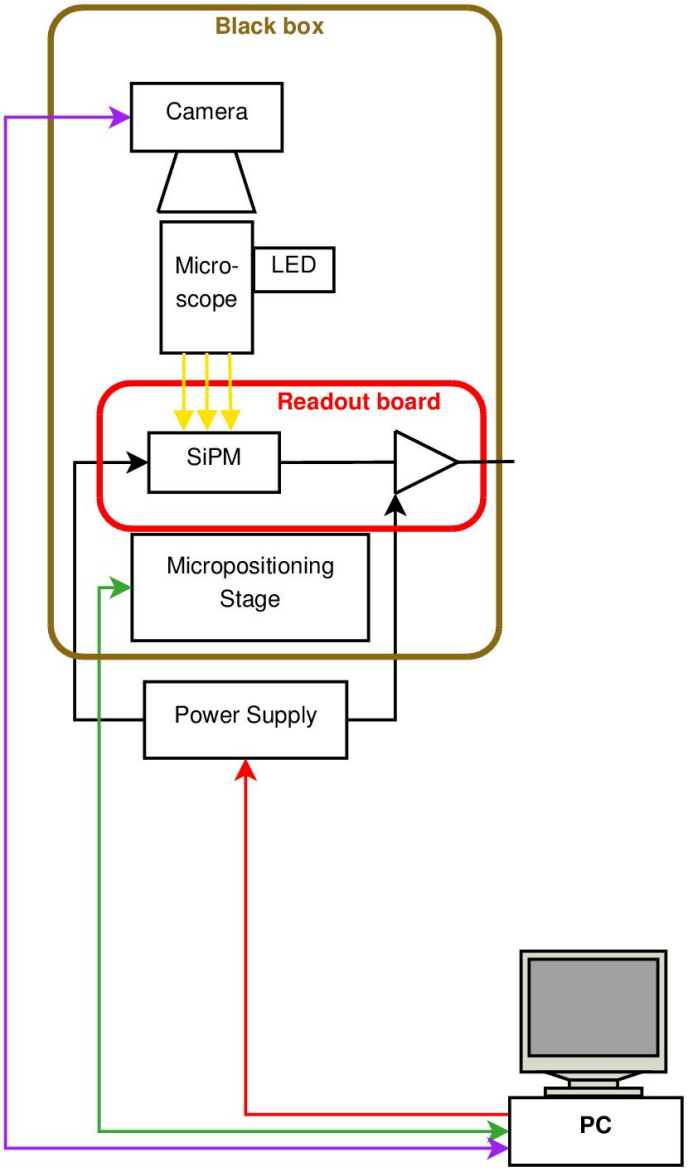

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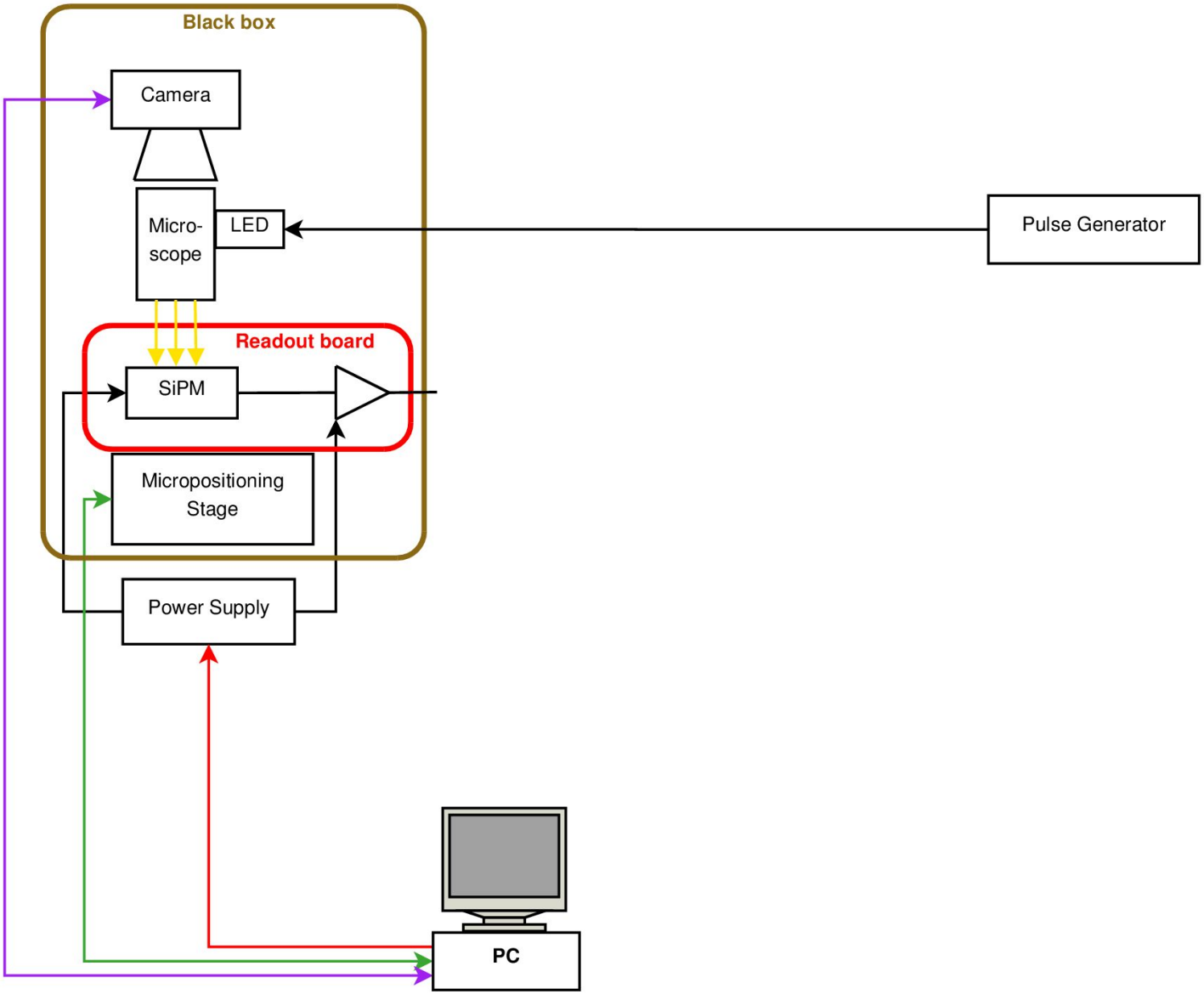

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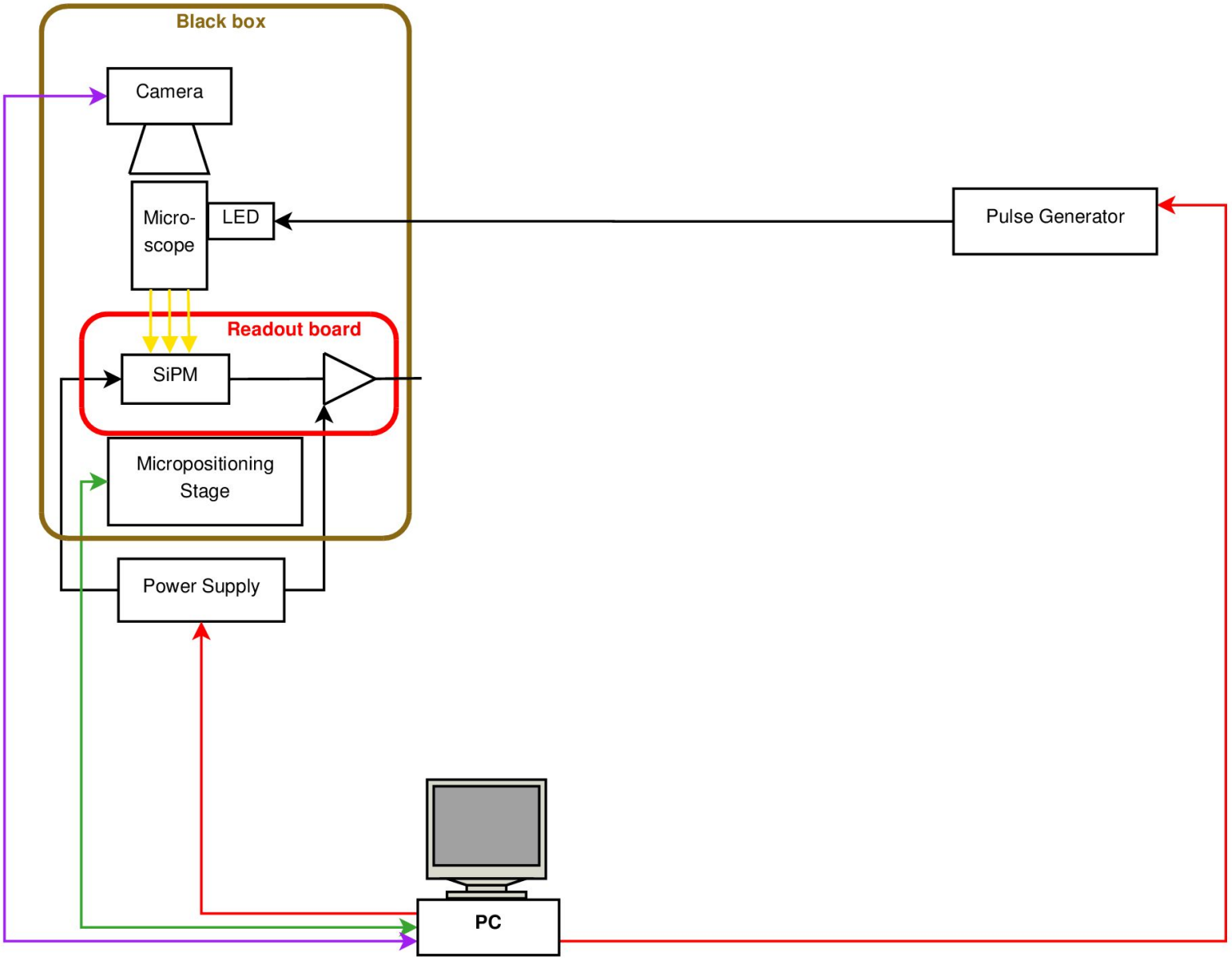

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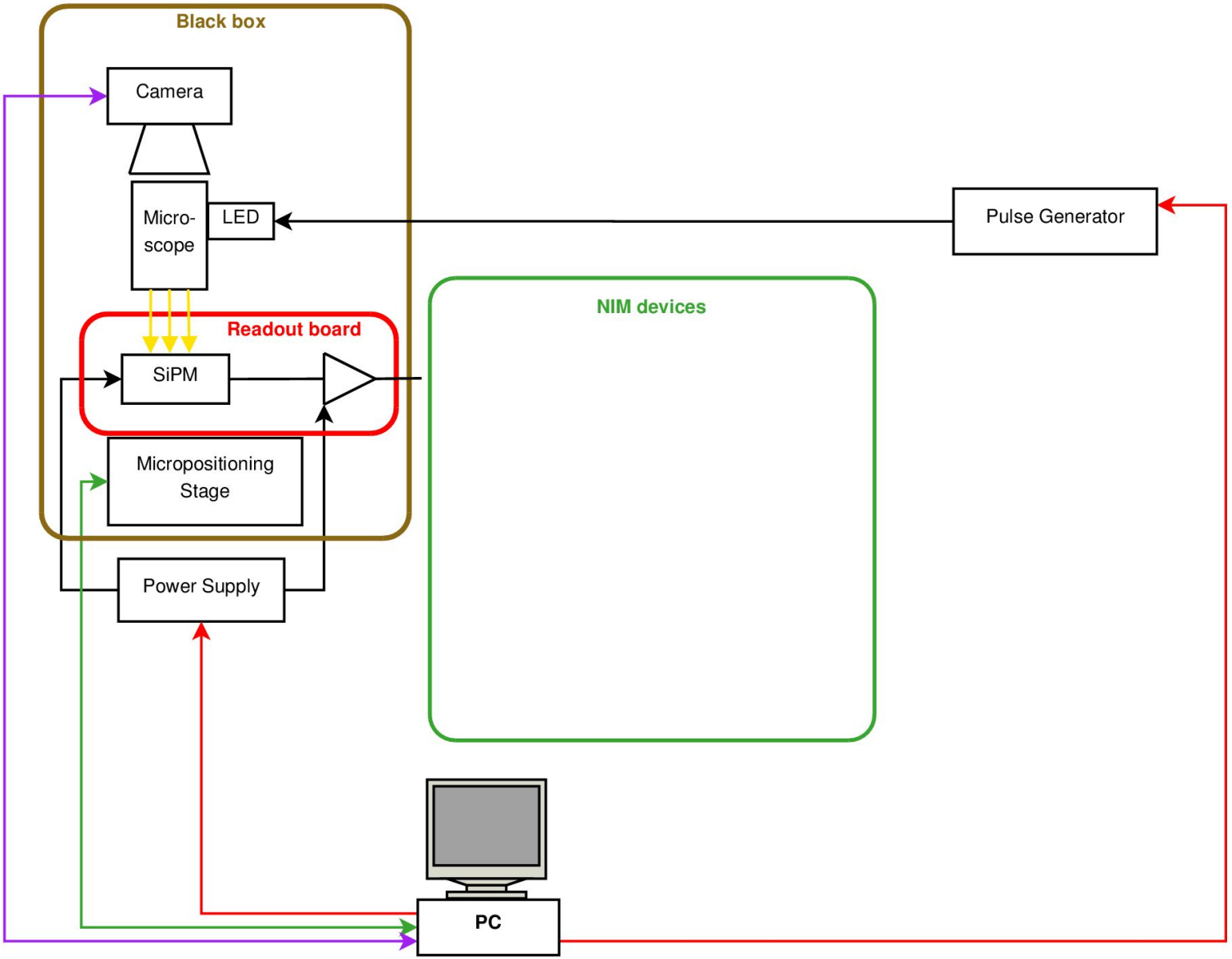

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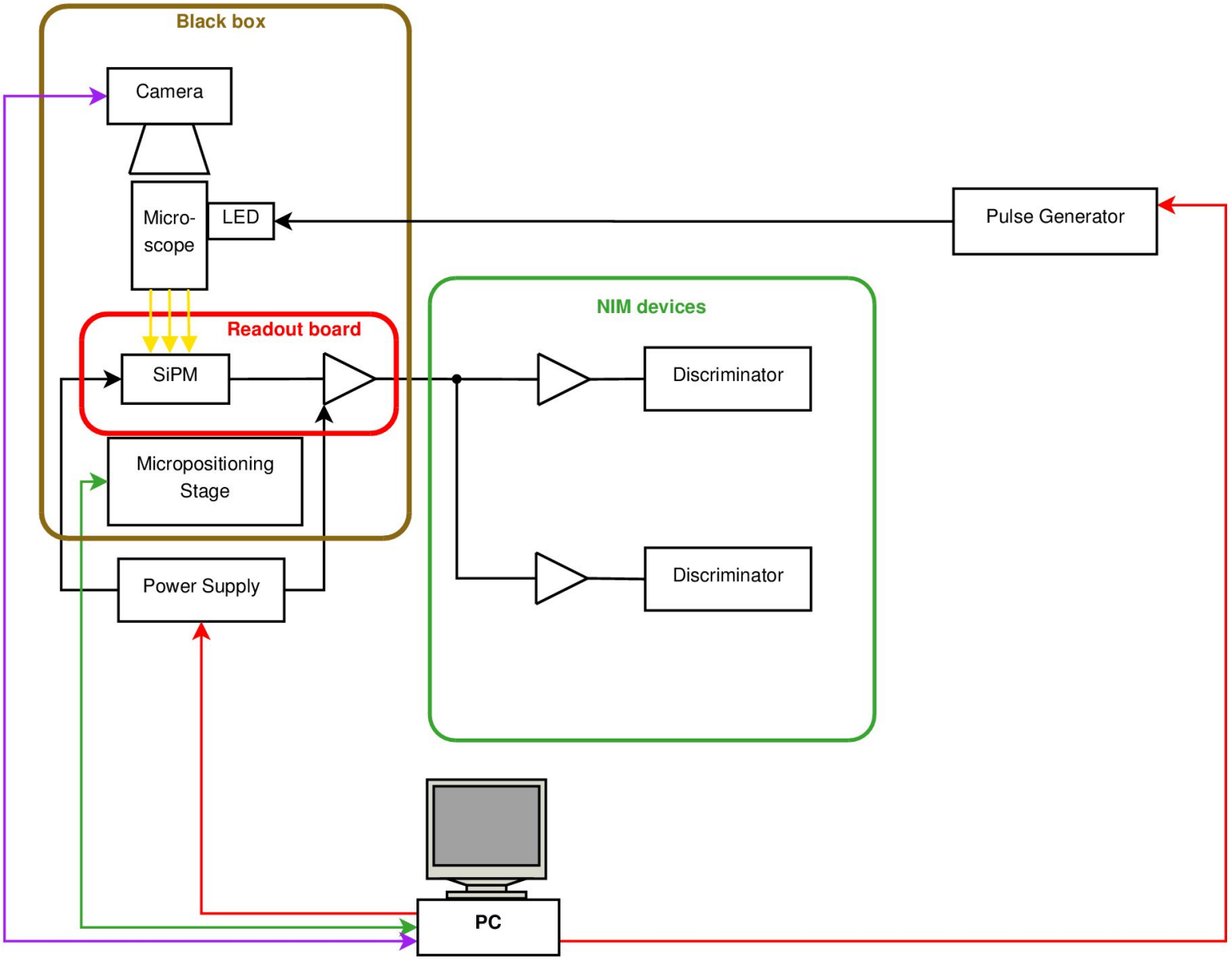

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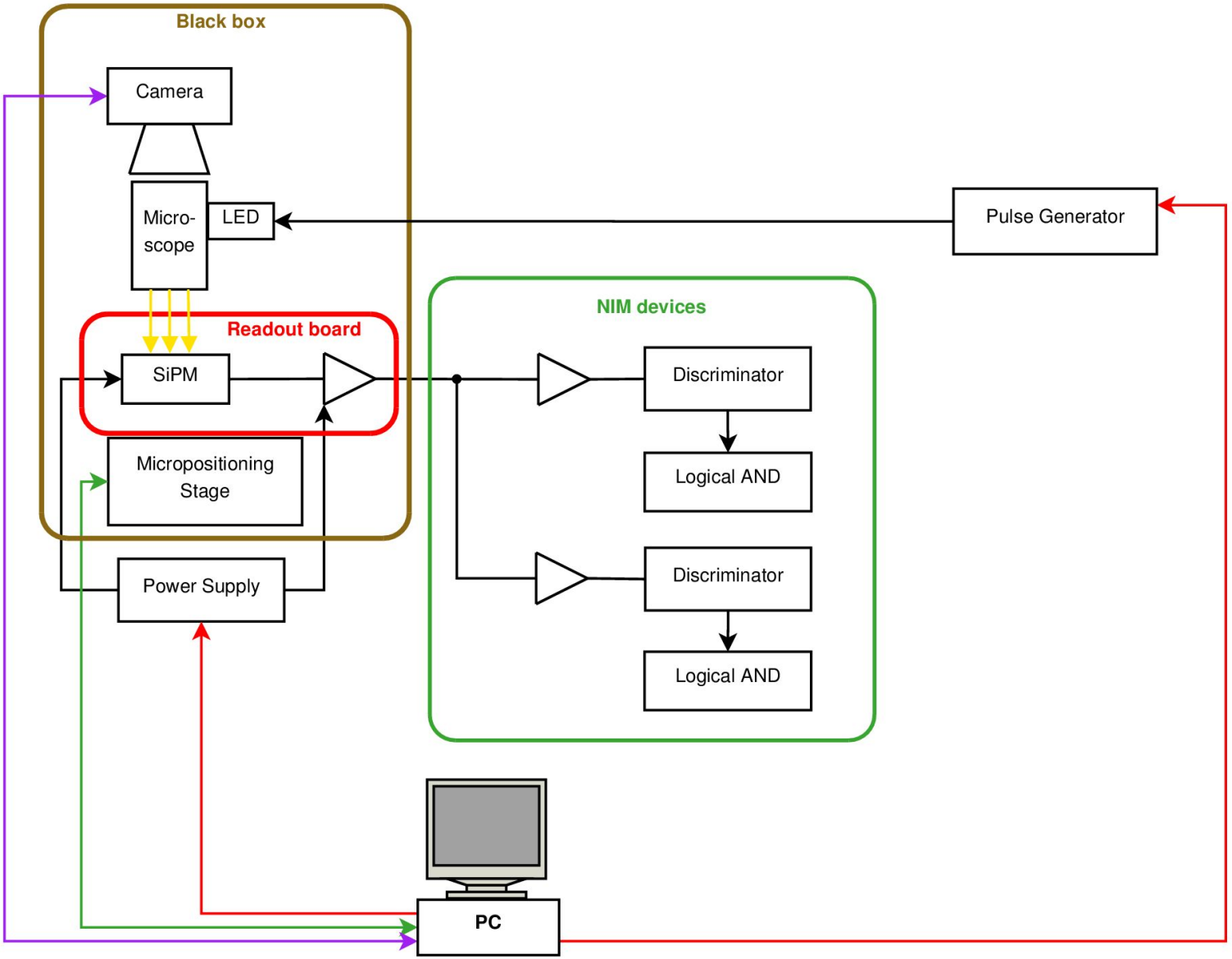

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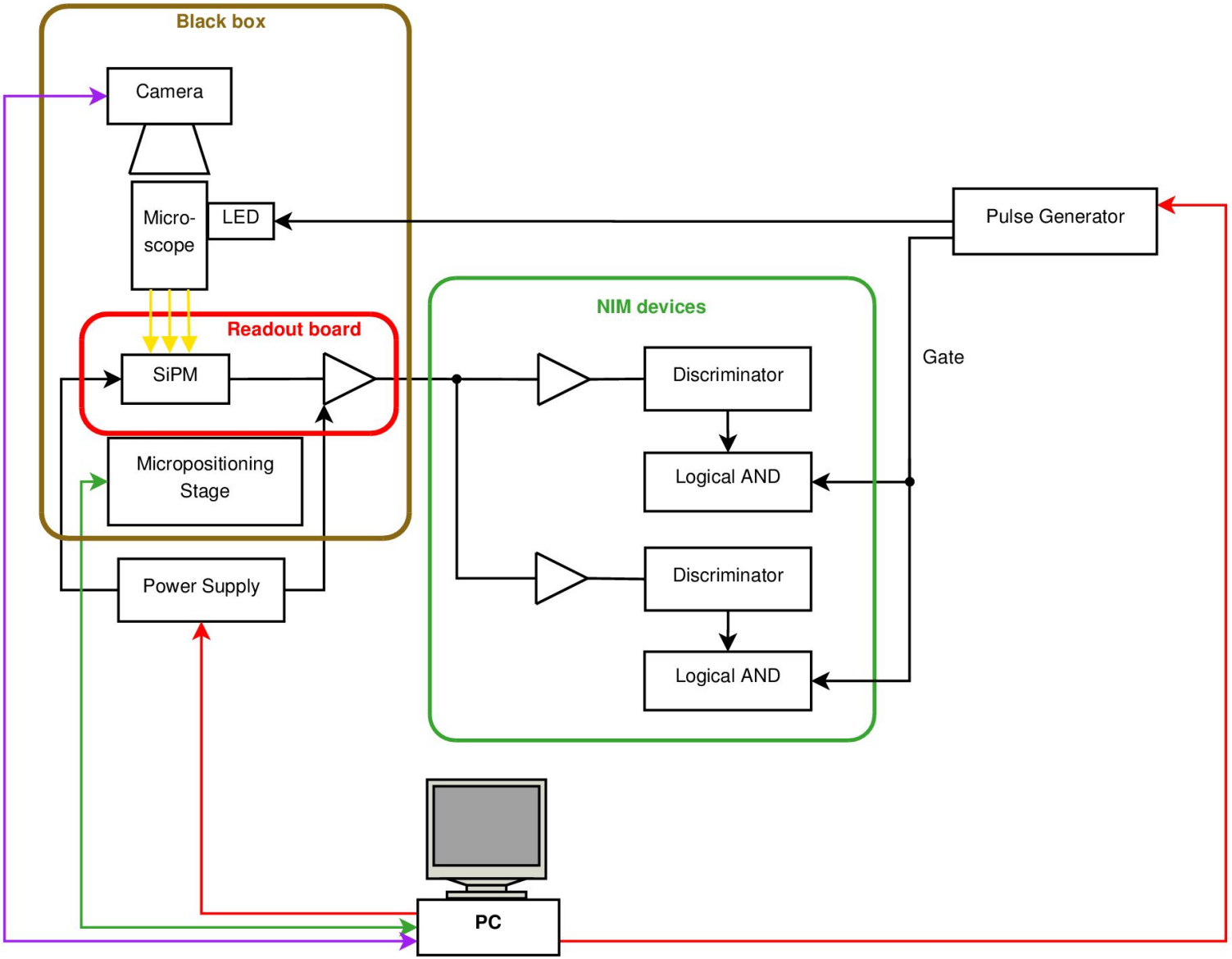

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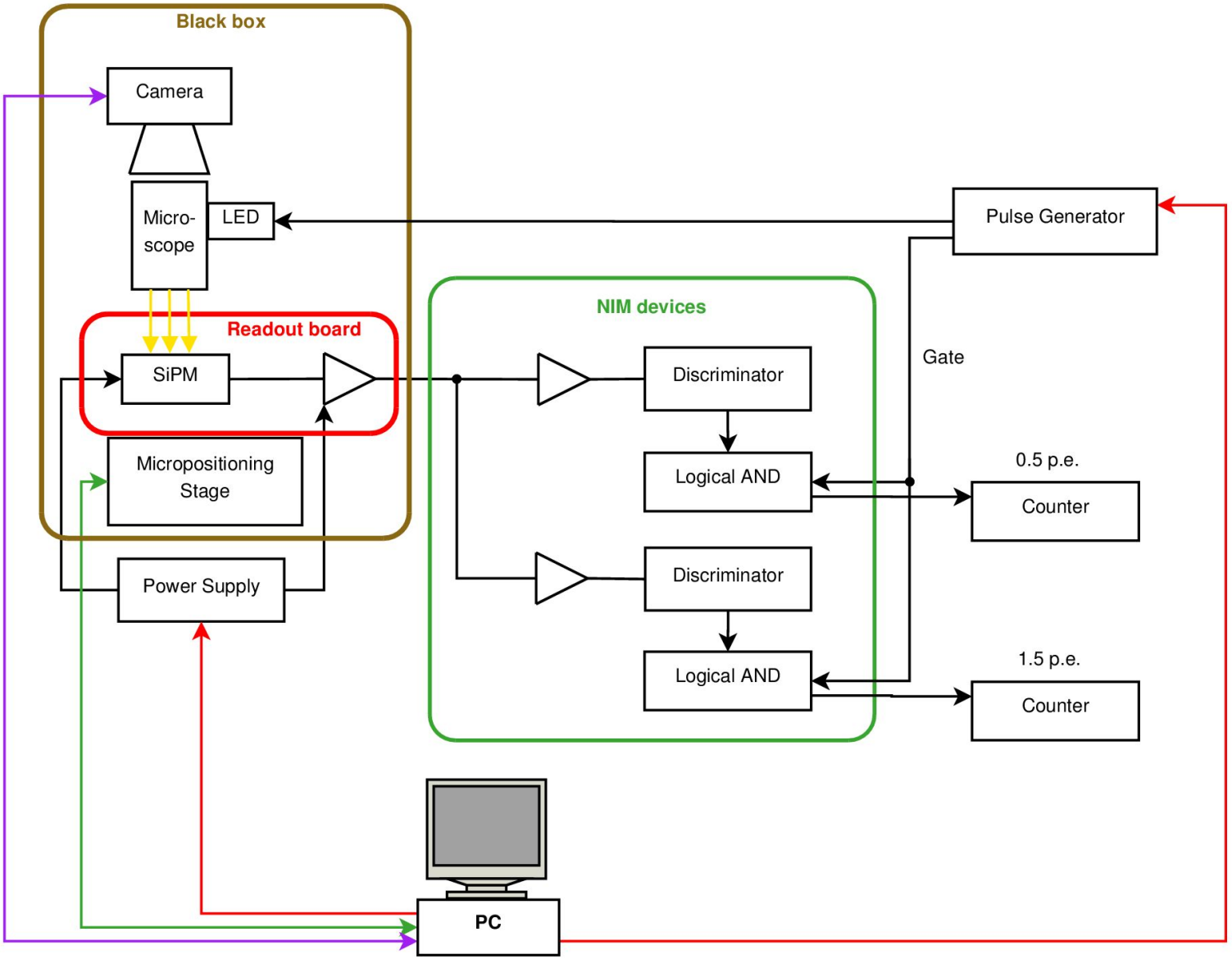

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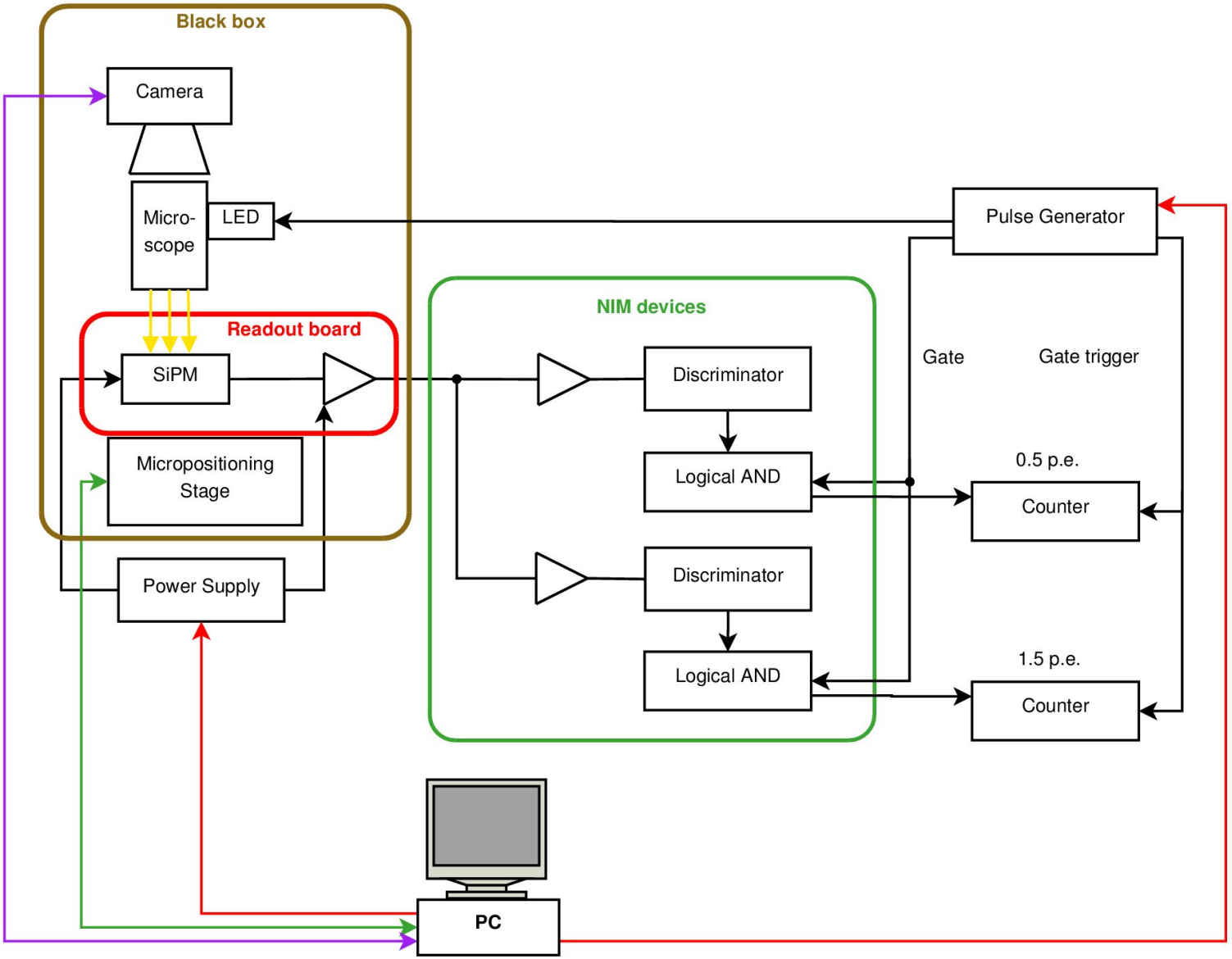

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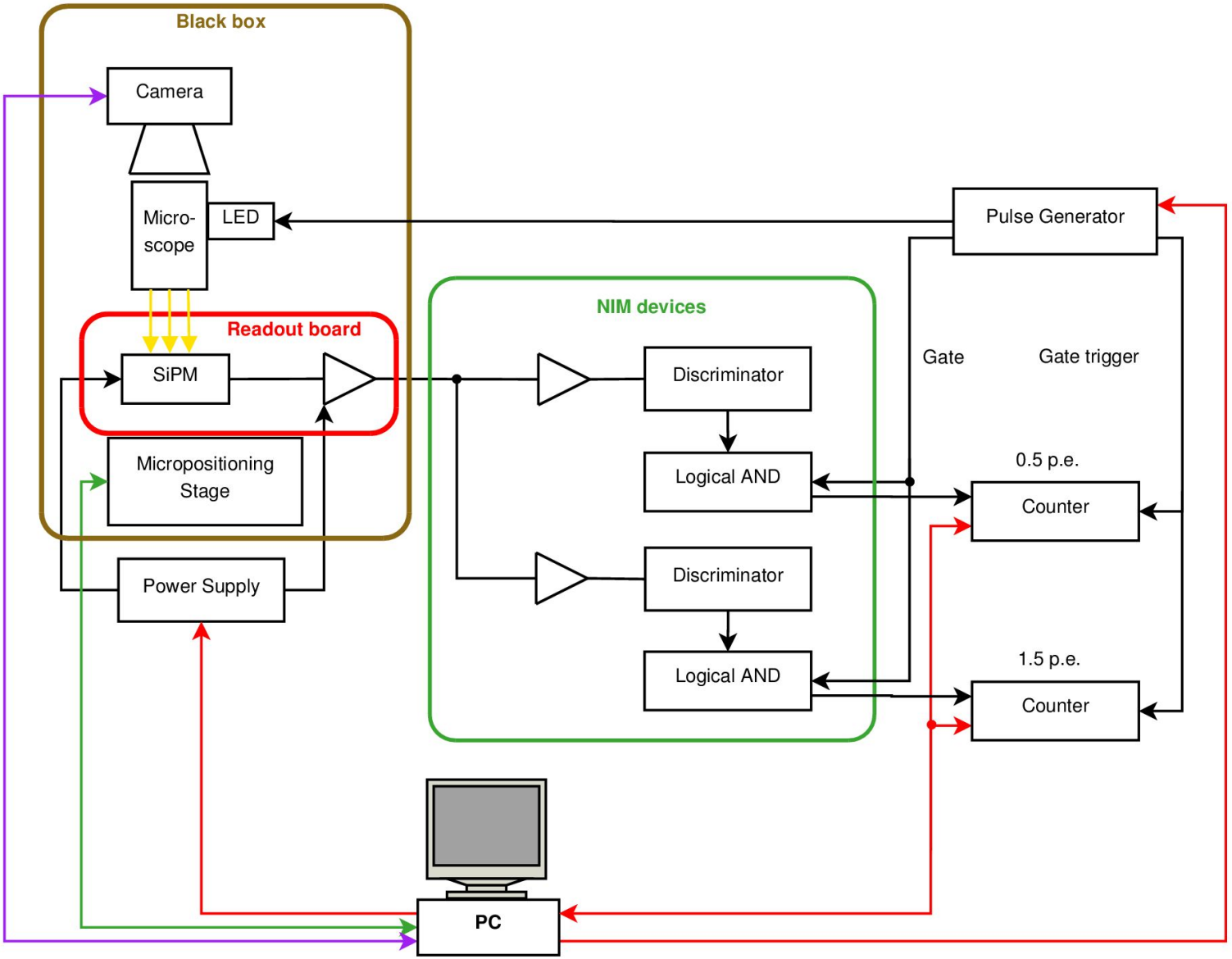

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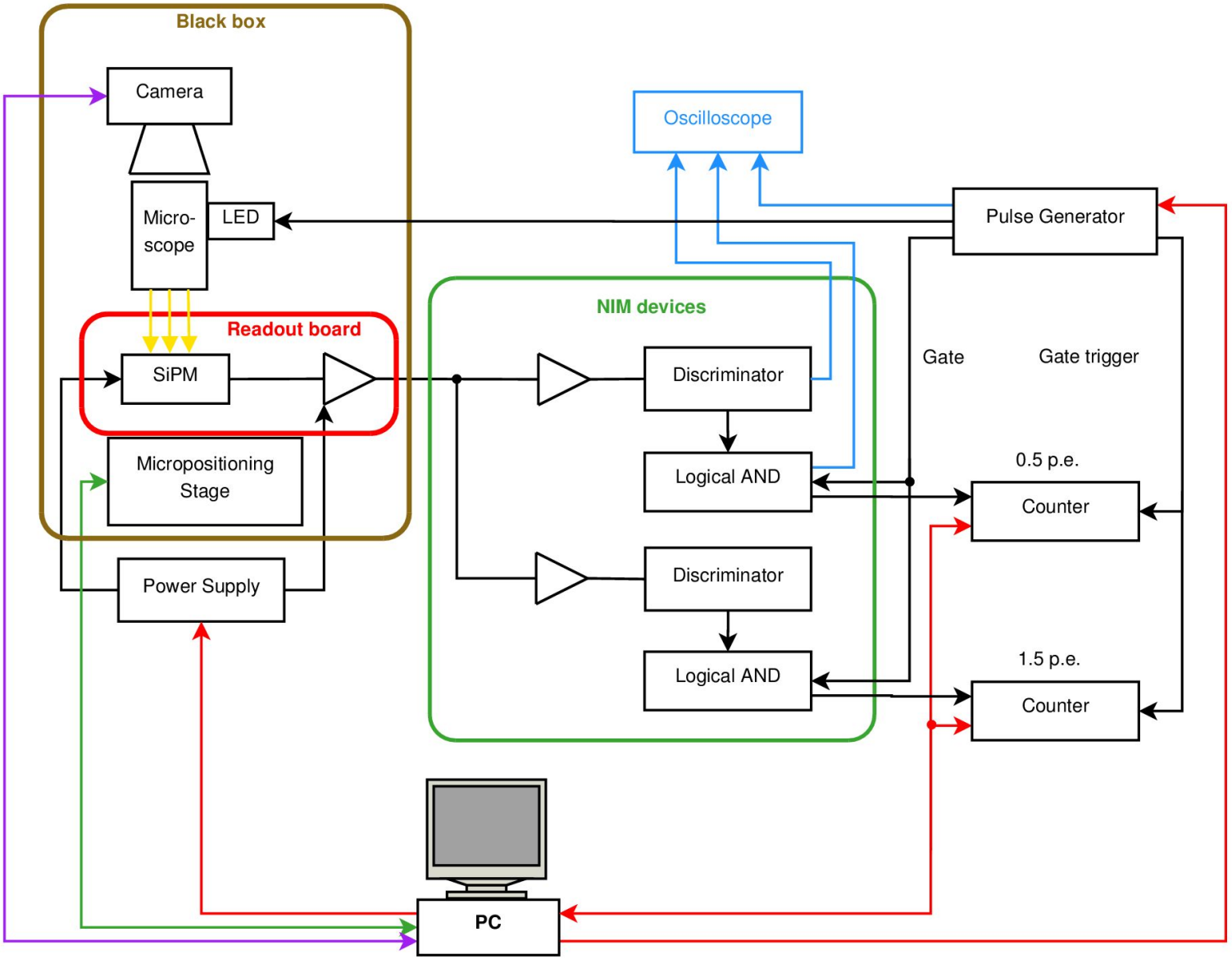
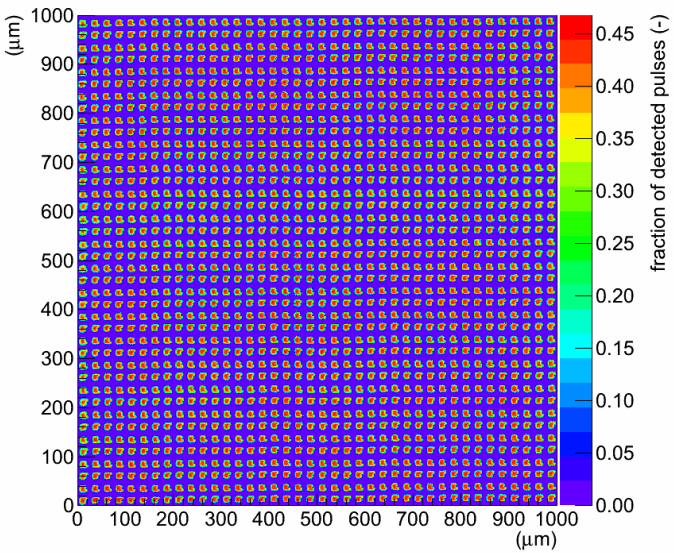
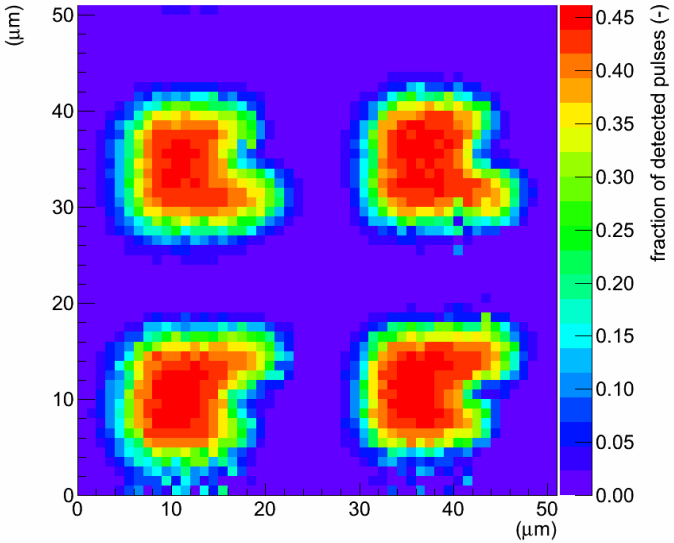


Results: Hamamatsu (MPPC) (25 μm pitch)





sensitive area is obviously significantly reduced by the quenching resistor placed on surface of the device

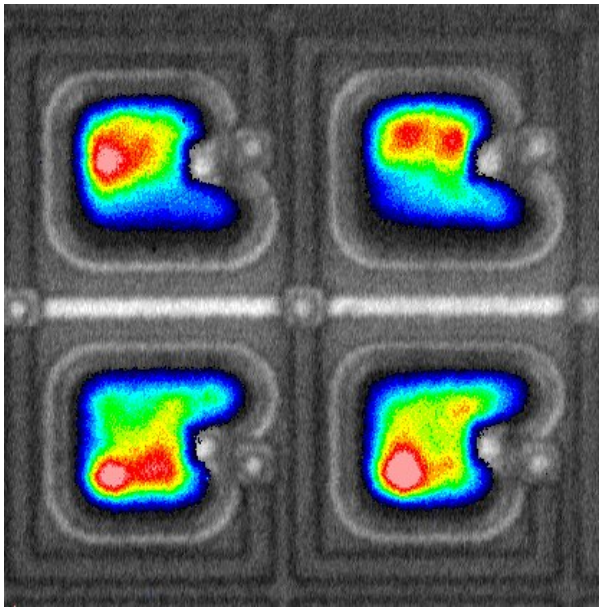
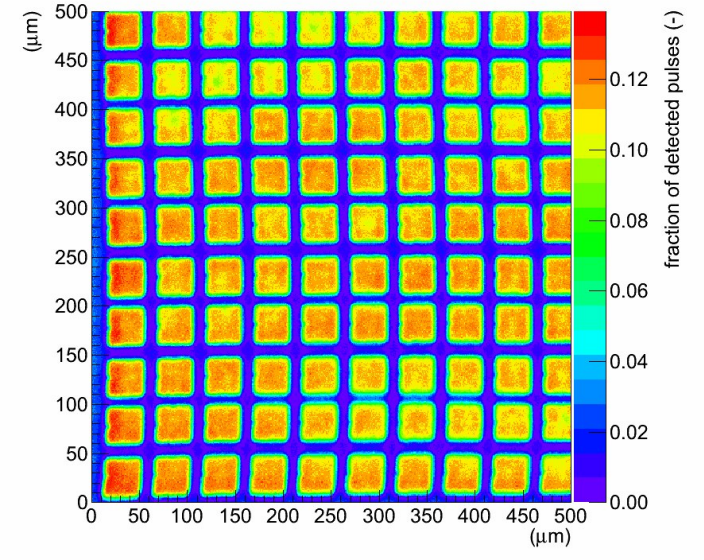
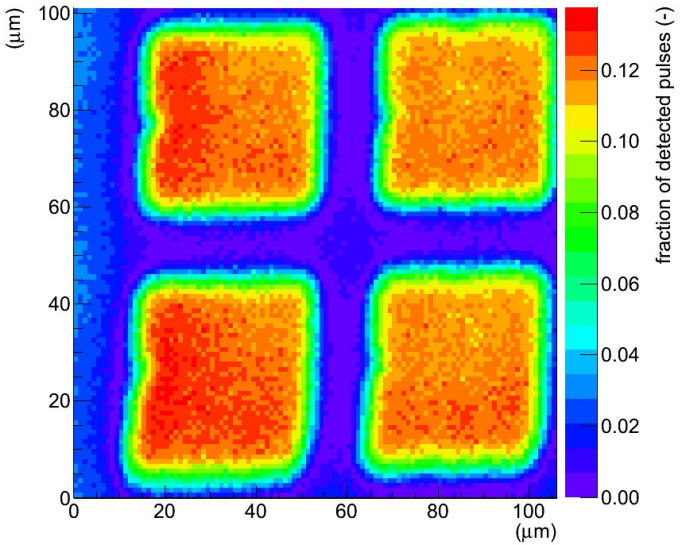


Photo + photoemission image

Results: Hamamatsu (MPPC) (50 μm pitch)





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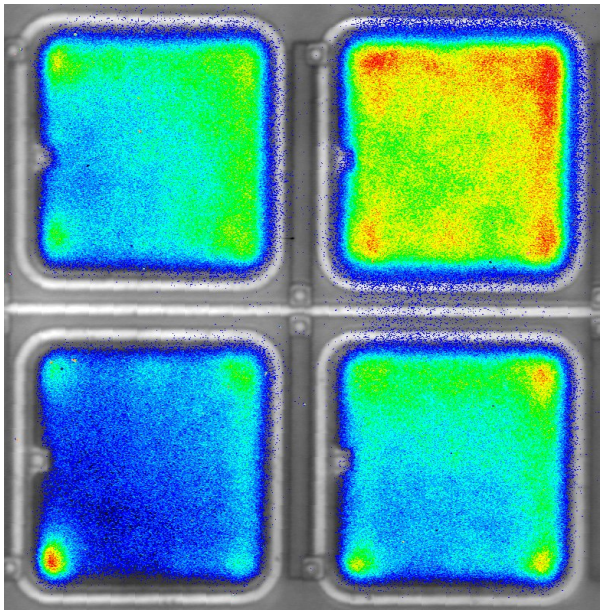
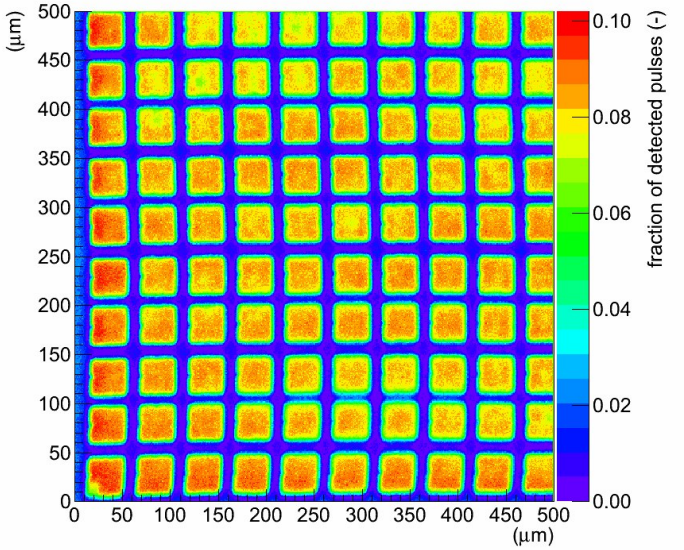
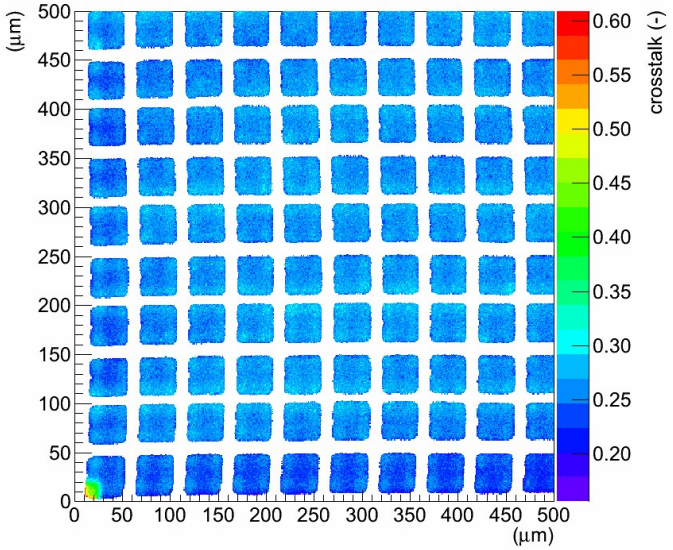


Photo + photoemission image

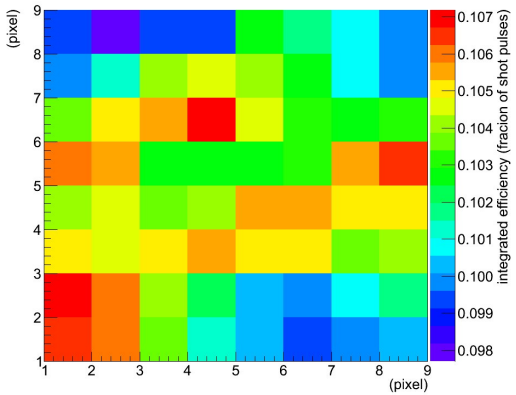
Results: Hamamatsu MPPC (50 μm pixel pitch)



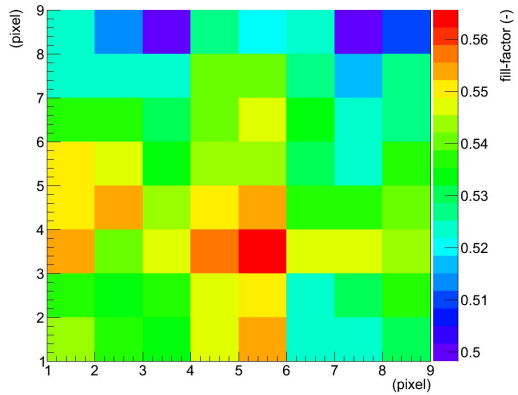
pure 1 p.e. map



crosstalk probability map



integrated efficiency map



fill-factor map

Hamamatsu MPPC 50 μm pitch

study results

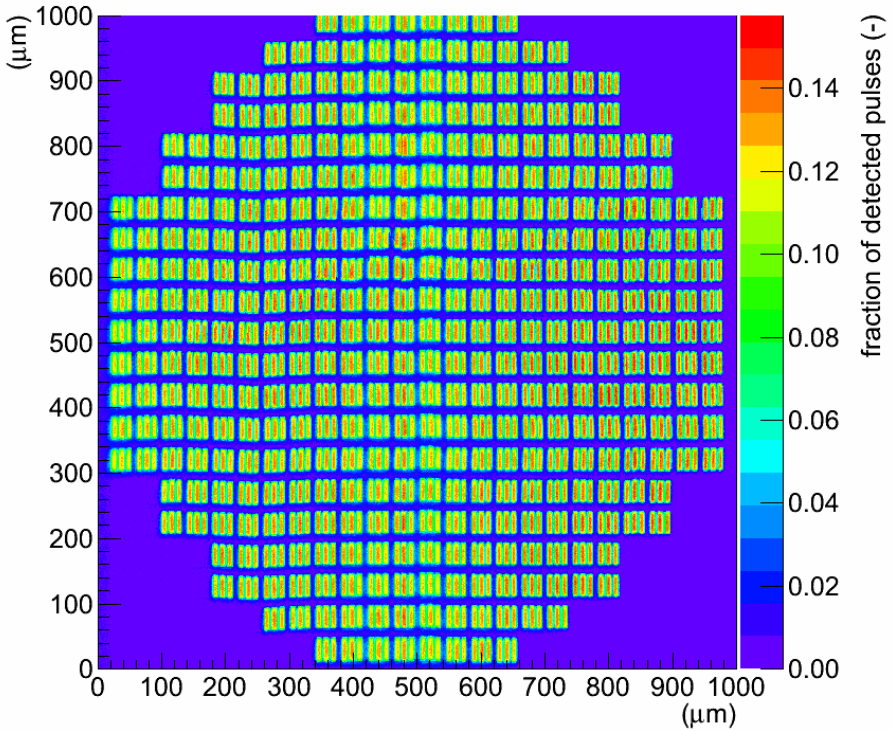
- detection efficiency patterns change with over-bias voltage negligibly
- geometrical fill-factor does not change with over-bias voltage
- edge breakdown observed, disappears with increasing over-bias voltage
- much better homogeneity in comparison with SensL SPMs and MPPC 25 μm pitch

quantity	value
PDE spread	8 %
fill-factor spread	11 %
crosstalk probability	18 %
geometrical fill-factor	55 %

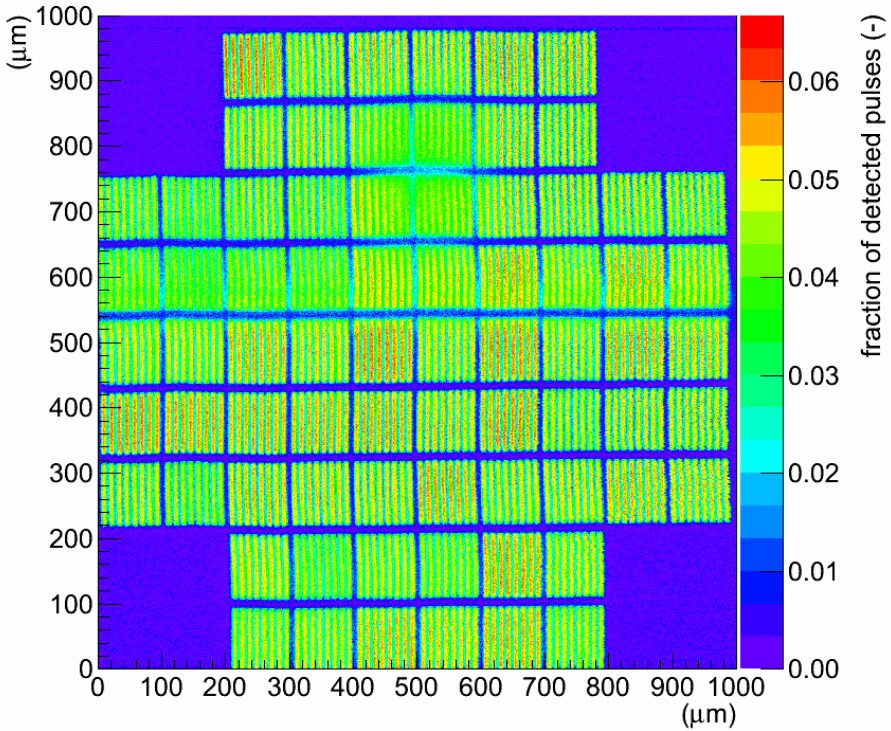
Table: Hamamatsu 50 μm pitch measured characteristics

Results: SensL (SPMMicro)

- SensL SPMs show structured sensitive area
- this leads low fill-factor compared to other sensors
- signs of edge breakdown have been observed



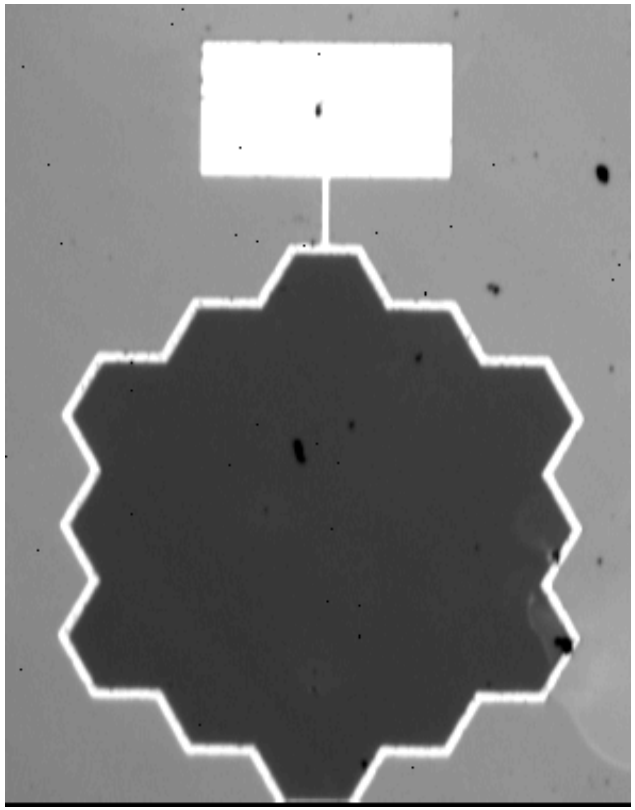
35 μm pitch



100 μm pitch

SiMPI device

- SiMPI - Silicon MultiPixel light detector
- a non-convential concept of a SiPM
- developed and produced MPI Semiconductor Lab
- the SiMPI approach uses a technology of bulk integrated quench resistor

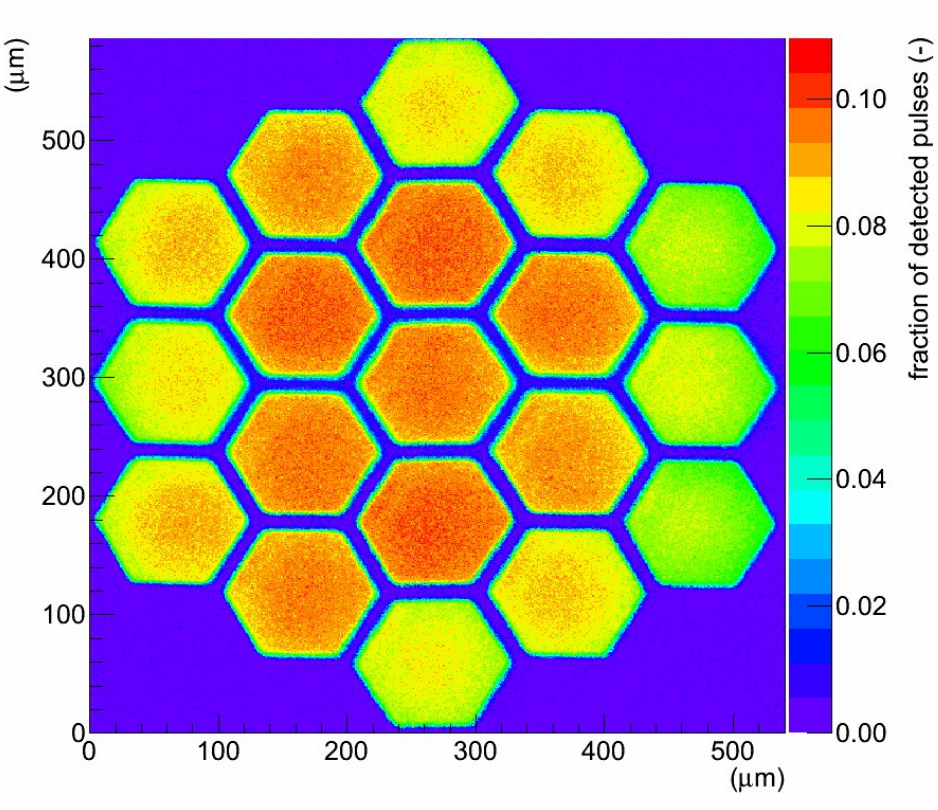


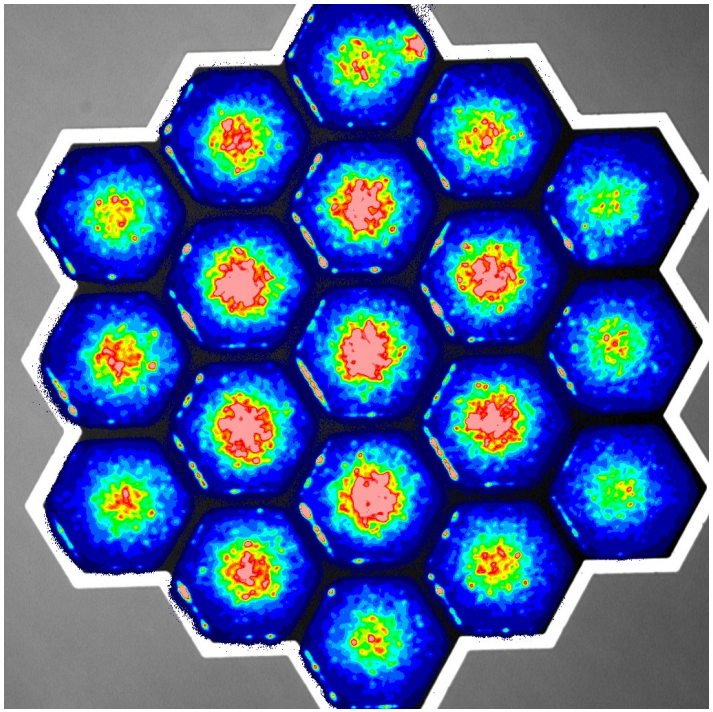
Goal

- simplify production process
- maximize light entrance window

Results: SiMPl (130 μm pitch)

no surface structures inside of a pixel $\Rightarrow$ higher possible geometrical fill-factor





Measurements done at room temperature. Due to high dark count of 2^{nd} iteration series, it would be better to cool the devices down.

Summary

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- setup for uniformity characterization of SiPMs has been developed
- sub-microcell resolution reached
- capability of scanning of arbitrarily oriented sensor surfaces
- successful tests of different devices have been done

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Measurement capabilities:

- relative detection efficiency and crosstalk probability map
- fill-factor and other homogeneity measures
- characterization of single microcells over the whole array
- documentation in progress, expect to submit as an AIDA note in the next months