Preamplifier circuit for Direct Photon Detector for luminosity measurement

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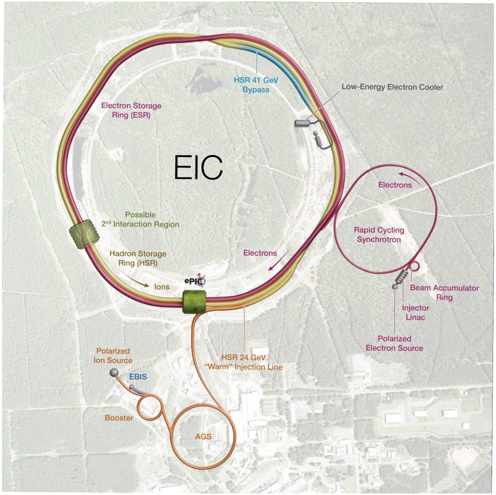
Electron Ion Collider (EIC)

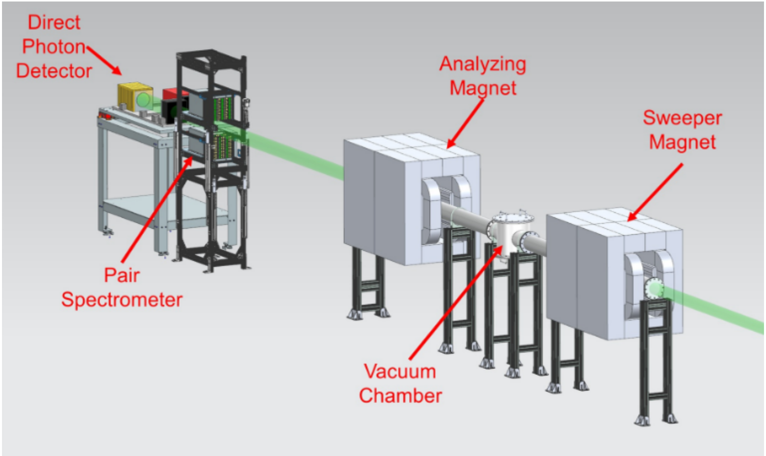


- e + p and e + A collisions
- $\sqrt{s}$ (center of mass energy) range from 20 to 140 GeV
- peak luminosity between 10^{33} cm^{-2}s^{-1} to 10^{34} cm^{-2}s^{-1}
- polarization of beams
- ePIC and a possible second detector
- bunch crossing every 10 ns at nominal luminosity

Luminosity and luminosity measurement

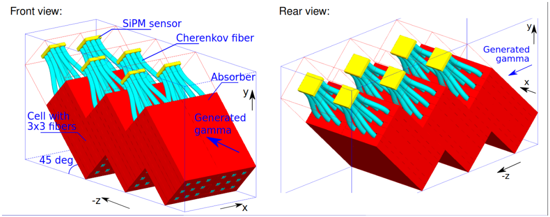
- bremsstrahlung process $\mathrm{e} + \mathrm{p} \longrightarrow \mathrm{e} + \mathrm{p} + \gamma$ is used
  - the cross section is known from theory
  - the final uncertainty is mostly dependent on uncertainties from counting the bremsstrahlung events
- defined by $L = \frac{N_\gamma}{A\sigma}$
  - $N_\gamma =$ amount of detected bremsstrahlung photons
  - $\sigma =$ bremsstrahlung process cross-section
  - $A =$ acceptance
- main methods for luminosity measurement in the Far-Backward area
  - direct detection of photons in a zero degree calorimeter
  - pair spectrometry
  - calibration with electron tagging

Luminosity and luminosity measurement



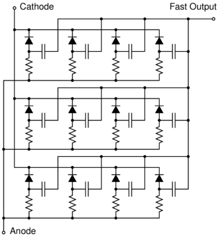
Direct detection of bremsstrahlung photons

- counting of incoming bremsstrahlung photons
- the electromagnetic calorimeter is placed along the photon zero degree line
- uncertainties due to pile up
- short integration time of 10 ns at nominal luminosity (never achieved before)
- one possible design is a Cherenkov spaghetti calorimeter with SiPMs for optical photons readout



Silicon Photomultiplier (SiPM)

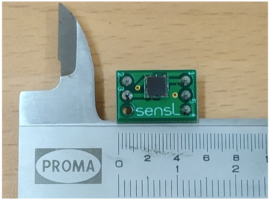
- microcell
  - basic building block of the SiPM
  - consists of a Single Photon Avalanche Diode (SPAD) and its quenching resistor
  - microcell density is usually in the range of 100 to 1000 microcells per mm^2
- the magnitude of initial photon current is proportional to the amount of fired microcells

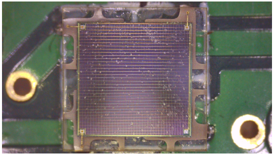


- advantages of SiPMs
  - resistant to magnetic field
  - high gain for relatively low voltage
- disadvantages of SiPMs
  - susceptible to neutron radiation damage
  - small dynamic range

onsemi C-series 30035

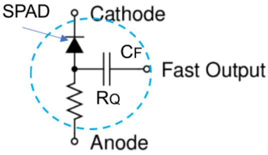
- active zone area - 3 $\times$ 3 mm^2
- microcell size - 35 μm
- P-on-N diodes
- sensitive to shorter wavelengths
- applied voltage 26.8 V
  - breakdown voltage ranging from 24.2 to 24.7 V





Standard and Fast output

- Standard output
  - signal is based on the photocurrent created during Geiger mode
- Fast output
  - derived from the fast switching pulse in the microcell
  - amplitude is proportional to the amount of fired microcells
  - no net charge transfer through fast output
  - lower capacitance than standard output



SiPM signal amplification

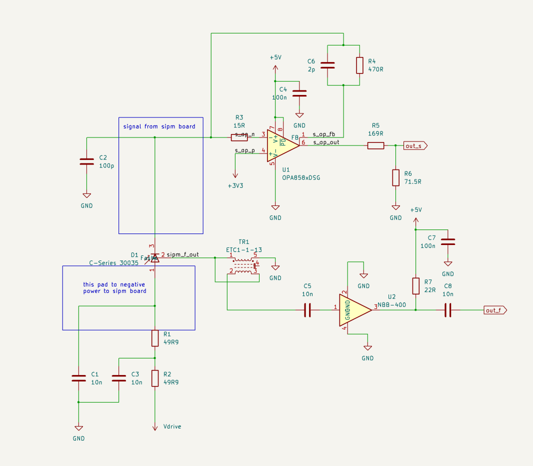


Figure: Schematic of the amplifier circuit.

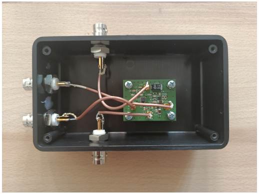
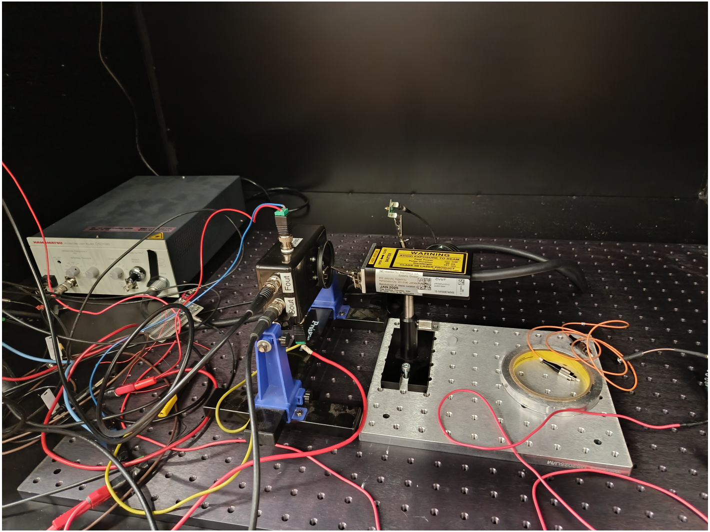


Figure: The amplifier circuit for the SiPM.

SiPM signal amplification



SiPM time characteristics at 1 kHz

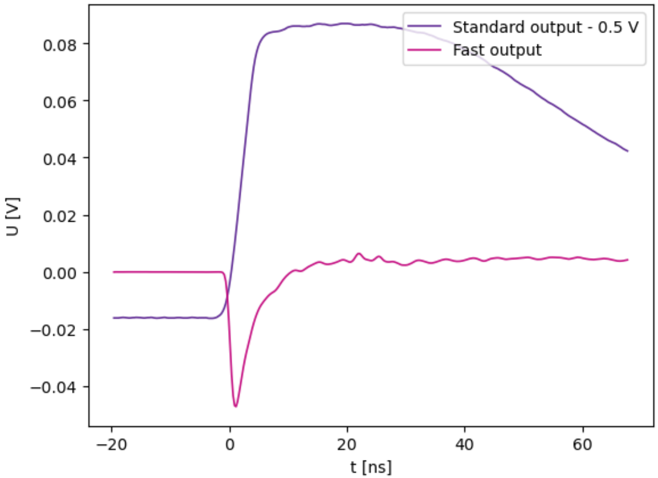


Figure: Output voltage at the standard and fast output of the onsemi C-Series 30035 SiPM with the amplifier circuit for the laser repetition frequency of 1 kHz.

SiPM time characteristics at 50 MHz

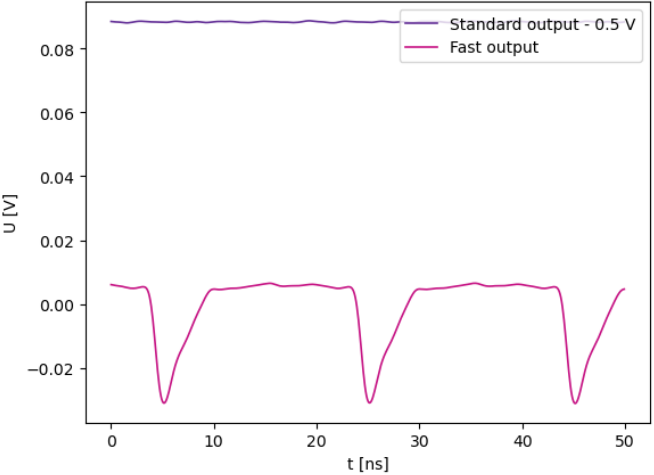
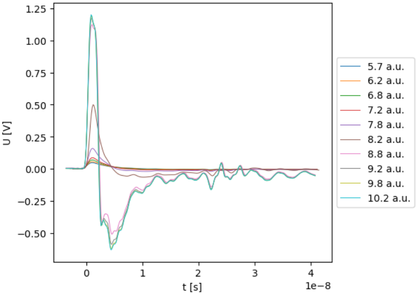


Figure: Output voltage at the standard and fast output of the onsemi C-Series 30035 SiPM with the amplifier circuit for the laser repetition frequency of 50 MHz.

SiPM signal from fast output at various laser intensities



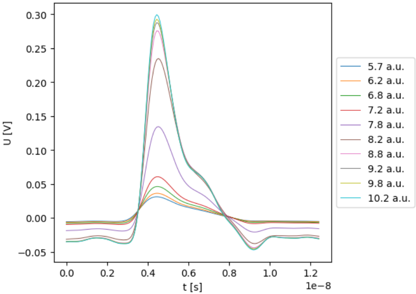


Figure: Fast output signal as a function of time for different values of laser intensity in arbitrary units and laser frequencies 1 kHz and 50 MHz.

Absolute value of fast output signal peak

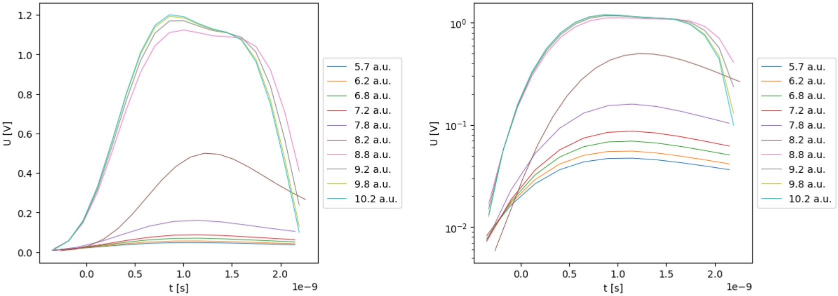


Figure: Absolute values of the main peak of the fast output signal as a function of time for different laser intensities in arbitrary units and laser frequency 1 kHz.

Absolute value of fast output signal peak

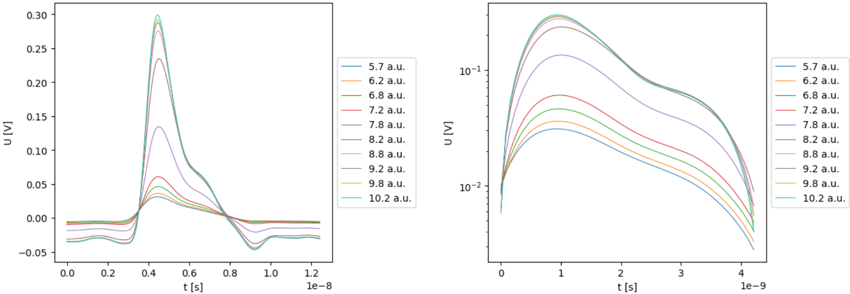


Figure: Absolute values of the main peak of the fast output signal as a function of time for different laser intensities in arbitrary units and laser frequency 50 MHz.

Fast output signal peak as a function of laser intensity

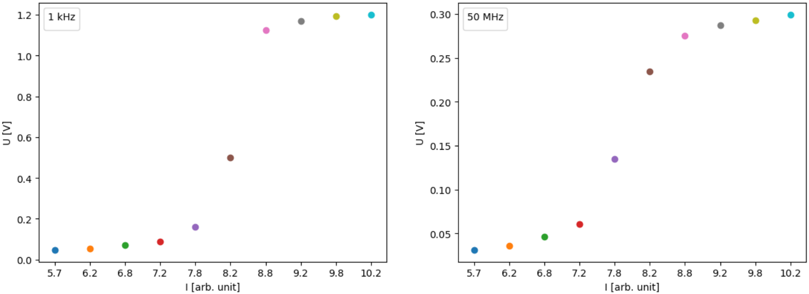


Figure: Peak amplitudes of the fast output signal (from previous slides) as a function of laser intensity for laser frequencies 1 kHz and 50 MHz.

Studying the response of the fast output amplifier

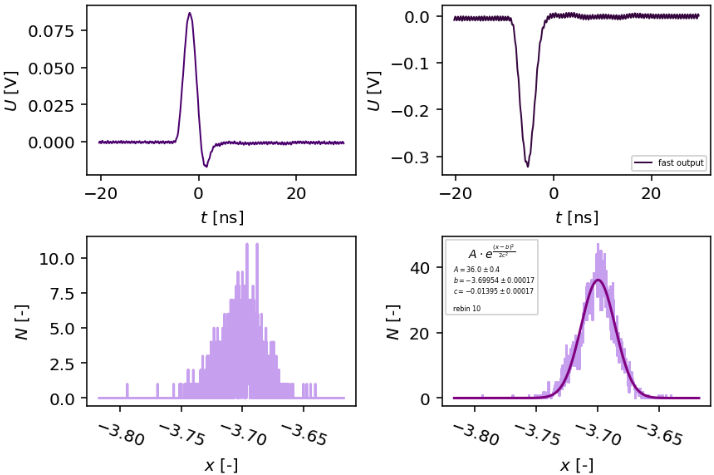
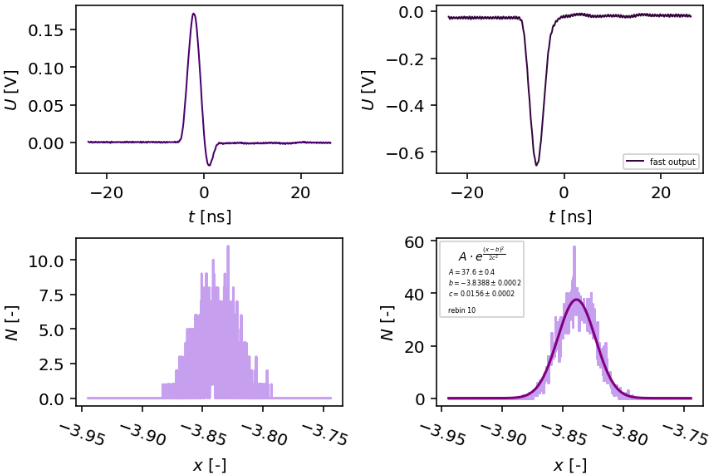


Figure: The original signal from the voltage source, resulting fast output amplifier signal and histogram of ratios of fast output amplifier signal amplitude versus original signal amplitude.

Studying the response of the fast output amplifier



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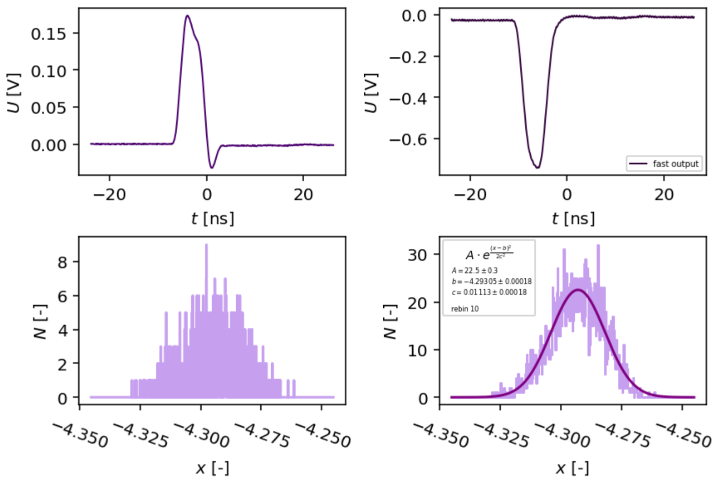

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Summary

- time and amplitude characteristics of an onsemi C-series 30035 SiPM with an amplifier circuit were measured
- above 50 MHz the standard output of the SiPM saturates
- fast output remains responsive for frequency of 50 MHz
- amplitude of fast output signal increases along with increasing laser intensity
- next steps
  - determining the relation between set laser intensity and real provided intensity (seems to be frequency-dependent)
  - modification of the amplifier gain
  - SiPM with smaller microcell size
  - studying the response of the standard output amplifier