Miniaturized multi-channels SiPM read-out electronics for medical imaging application

T. Ait Imando¹, N. Dinu¹, S. Callier¹,², D. Cuisy³, P. Dinaucourt¹, L. Pinot², V. Puill², L. Raux¹,³, R. Sliwa¹, L. Trochet¹, S. Menard²

¹Laboratoire de l’Accélérateur Linéaire, IN2P3-CNRS and Université PARIS-SUD 11, 91898 Orsay, France
²Laboratory of Imaging and Modeling in Neurobiology and Oncology (IMN), IN2P3-CNRS, 91406 Orsay, France
³OMEGA, IN2P3-CNRS, 91898 Orsay, France

Introduction

The SIPMED is a prototype of a very compact intra-operative gamma camera based on arrays of Silicon Photomultiplier (SiPM) coupled to a scintillator and a dedicated read-out electronics to improve the efficiency and the reliability of the image guided surgery of tumors. The SIPMED consists of 2x2 elementary modules covering a field of view of 5x5 cm² having geometrical dimensions adapted for intra-operative interventions (~6 cm width, ~5 cm thickness and weight less than 700 gr). Each elementary module is composed of a very compact stack of three different PCBs. 2x2 monolithic SiPM arrays of 16 channels each are mounted on the first PCB. The 2 readout chips EASIROC of 32 channels are directly bonded on the second PCB. The FPGA and the USB interface are mounted on the third PCB. The SIPMED camera will summarize 256 read-out channels.

Elementary module of the SIPMED gamma camera

Front end electronics

SiPM board:
- 4 layers PCB
- front side: SiPM arrays
- back side: temperature sensor
- passive elements

ASIC board:
- 10 layers PCB
- front side: 2 x EASIROC ASIC
- back side: ADCs, passive elements

FPGA board:
- 10 layers PCB
- front side: FPGA (Cyclone III)
- back side: USB interface

Elementary module stack: photo-detection system composed of three boards stacked together

Monolithic SiPM array

Monolithic Hamamatsu MPPC array in SMD package S11828-3344M
- 16 channels (4x4 ch) monolithic MPPC mounted on a surface-mount package
- Each channel: MPPC, 3x3 mm² total area, 3600 pixels, 50 μm pitch

The EASIROC chip

- 32-channels front-end readout
- Individual 8-bit DAC for SiPM gain adjustment
- Energy measurement from 160 keV to 320 keV (1pe to 2000pe @ SiPM gain = 10⁶)
  - 1 pe/noise ratio ~11
  - Variable gain preamplifier
  - Variable shaping time from 25 to 175ns
  - Common 10-bit DAC for threshold adjustment
  - 2 multiplexed analog outputs (high gain, low gain)
- Trigger output
  - 1 pe/noise ratio ~24
  - Trigger on 1/3 pe (50%)
- 32 Trigger outputs
- Trigger multiplexed output

- Individually addressable calibration capacitance
- Low power: 4.84 mW/Channel, 155 mW/chip

Pedestals dispersion

Work under study and perspectives:
- Electronics: DAC linearity on the 32 channels, charge measurements, signal to noise ratio, linearity tests on analog channels
- SIPMED elementary module: temperature dependence @ 36°C (breakdown voltage, dark count rate), photon detection efficiency, energy resolution