Title:
Performances of LIROC with SiPM: a Rad-Hard Front-End ASIC for Space LIDAR

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Thematics:
Space applications for analogue and mixed-signal ICs

Abstract:
LIDAR is a distance and speed measurement device using reflection characteristics of emitted light. In space applications, time-tagging LIDAR allows scanning planet surface before landing missions, formation flights by measuring distances between spacecrafts or atmospheric backscatter measurements. The main requirements for the read-out electronics are trifold: single-photon time-tagging capabilities for long range measurements, timing resolution better than LIDAR system (SiPM intrinsic resolution, laser pulse-width, etc.) and minimized dead time.

LIROC is a 64-channel front-end R&D ASIC designed to read silicon photomultipliers delivering charges in the range 50 fC - 10 pC. The ASIC is composed of a 1 GHz RF preamplifier followed by a fast discriminator and low swing LVDS fast driver with a power consumption of 3 mW per channel. The circuit exhibits also a fast return to baseline thanks to its tunable pole zero cancellation circuit prior to the preamplifier. The ASIC also embeds channel-wise DAC for SiPM overvoltage adjustment. Designed in TSMC 130nm, LIROC can furthermore withstand radiation environments up to multi-MRad radiation levels.[1] LIROC configuration can be programmed using an I2C interface that has been triplicated for SEU tolerance.

LIROC has been extensively characterized: first, a pulser has been used to inject an equivalent charge using a detector-like capacitance connected to the channel under test, second measurements have been performed with multiple SiPM devices using a LASER testbench. The ASIC has a Single Photon Timing Resolution of 17 ps RMS when coupled to a detector-emulated capacitor of 100 pF (with an injected charge of 160 fC obtained with a 200 ps transition time voltage step through a 10 pF capacitance). When coupled to SiPM, LIROC time resolution is therefore limited by SiPM intrinsic performances, as state-of-the-art devices have around 70 ps FWHM time resolution[2] (expressed as FWHM to take into account the tail of the Time-Of-Arrival distribution due to delayed photon conversion). LIROC has also shown excellent double-peak separation with 100% efficiency for double pulses separated above 3 ns, which is consistent with photocounting capability of up to 300 MHz. LIROC allows also time-walk correction and input charge estimation thanks to Time-Over-Threshold/discriminator width measurements. Results from LASER testbench will be detailed and compared with simulation.

LIROC architecture will be described, as well as foreseen spatial LIDAR with CERN PicoTDC enabling sub-centimeter resolution with picosecond TDC precision.

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1. Gonella, L. *et al.* Total Ionizing Dose effects in 130-nm commercial CMOS technologies for HEP experiments. *Nucl. Instruments Methods Phys. Res. Sect. A Accel. Spectrometers, Detect. Assoc. Equip.* **582**, 750–754 (2007).
2. Lecoq, P. & Gundacker, S. SiPM applications in positron emission tomography: toward ultimate PET time-of-flight resolution. *Eur. Phys. J. Plus* **136**, 1–16 (2021).