A new micropixel avalanche photon detector with fast response

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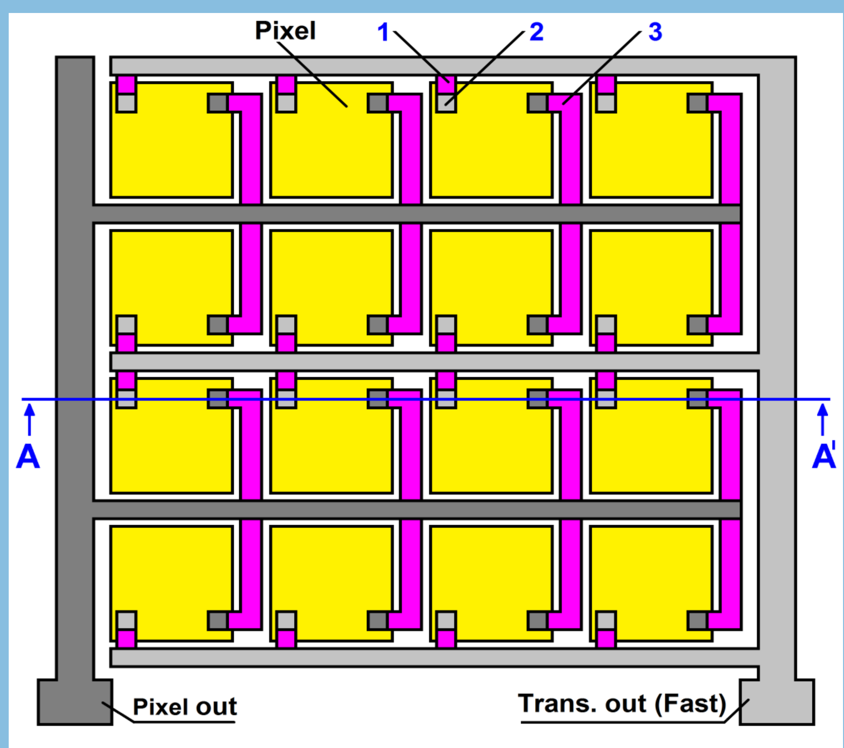
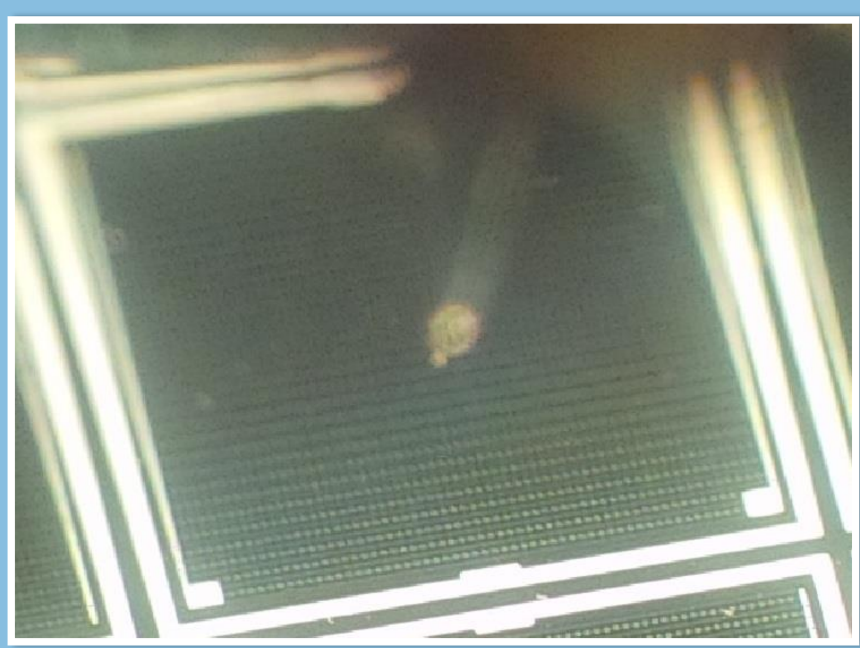
The silicon photomultiplier (SiPM), also named as the micro-pixel avalanche photodiode (MAPD) has widely used in high energy physics experiments. The device comprises an array of small p-n - junctions (pixels) with individual quenching resistors. However, this design has a high specific capacitance (about 30 pF/mm^2), which limits the sensitive area of the MAPD. Here we present a new alterative to the SiPM on basis of a Micro-pixel Avalanche Photo-Transistor (MAPT) structure with low specific capacitance.

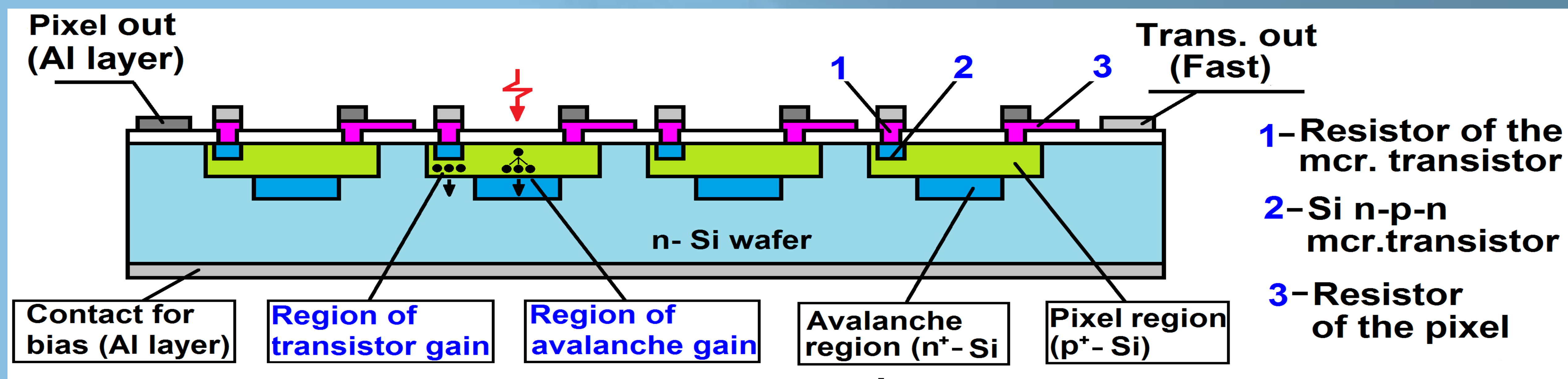


Face view of the MAPT



I. DESIGN OF THE MAPT

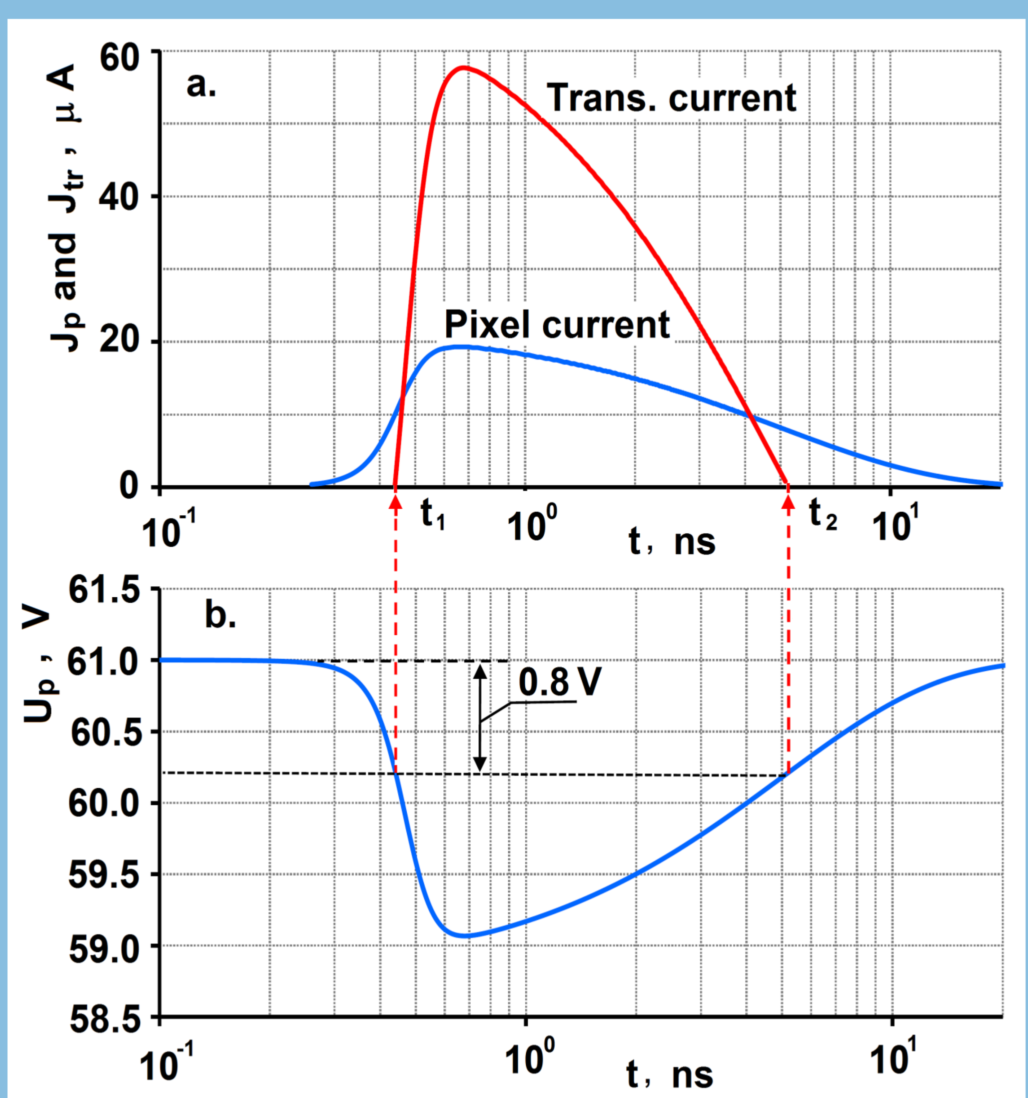
The MAPT comprises an array of micro phototransistors with individual ballast resistors Rt, the base electrodes of which are connected to the pixels with quenching resistors Rp (Z. Sadygov and A. Sadigov. Russian patent №2528107, a priority from 04.16.2013).
Each pixel of the MAPT consists of two parts: an avalanche region and a micro-transistor region . Area of the micro-transistor region is about 3μ×3μ which is about 1÷5% of the pixel area. Therefore, the MAPT device has 30 ÷ 50 times lower capacitance than known SiPMs. (https://www.sciencedirect.com/science/article/pii/S0168900216306441).



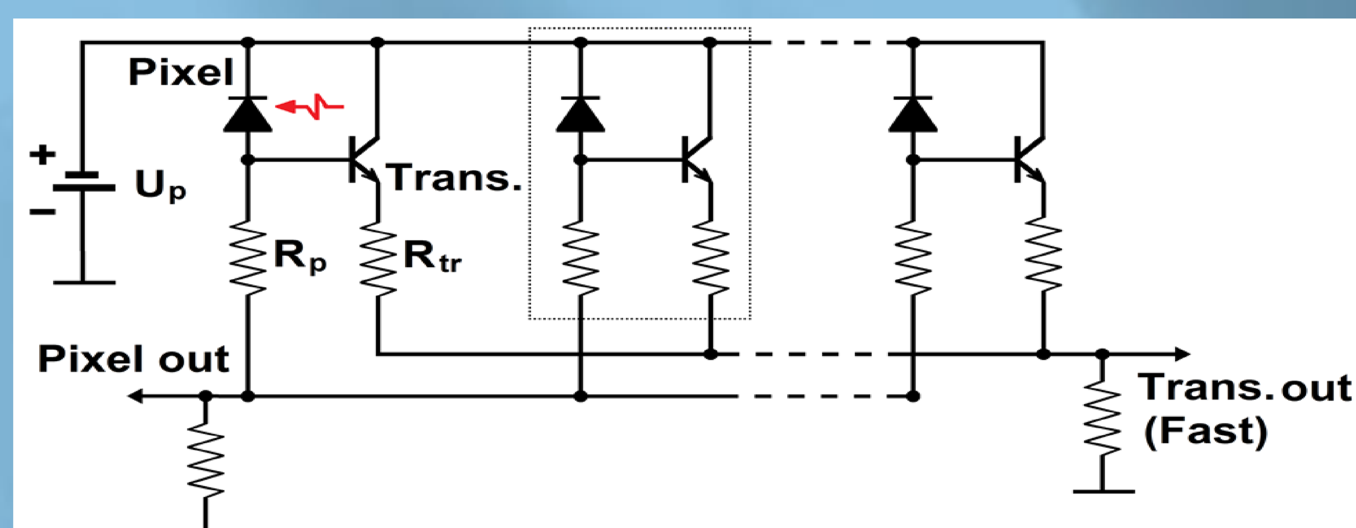
Cross-section A–A'

II. PERFORMANCE OF THE MAPT

It is known that at overvoltage ΔU_p=1V the Geiger mode avalanche discharge results in about 2×ΔU_p=2V voltage drop on the quenching resistor R_p (http://arxiv.org/ftp/arxiv/papers/1410/1410.2619.pdf). When the voltage drop on the base electrode exceeds some characteristic value $U_{c.v}$≈0.8V at t= t_1 the transistor is fully opened, and a large current $J_{tr}=(2\times\Delta U_p-0.8)/R_{tr}$ flows through the resistor R_{tr} . The transistor is closed at t=t_2 when $U_{c.v} \leq 0.8$V.

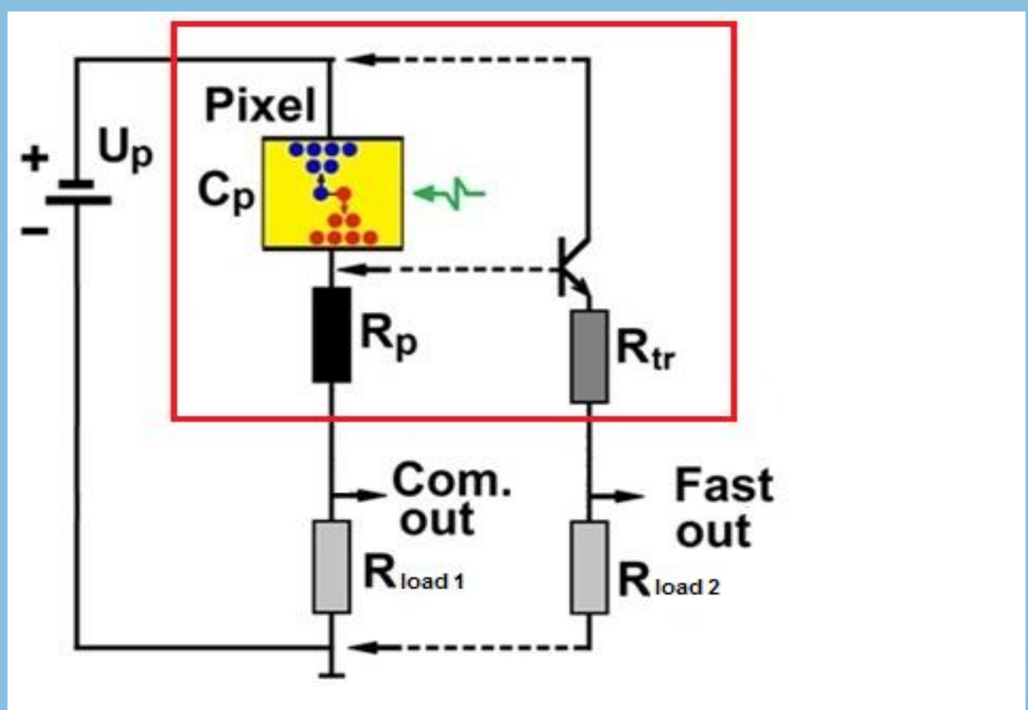


(a.) Photo signals forms, taken from the pixel and a micro-transistor.
(b.) The time dependence of the voltage at the pixel.

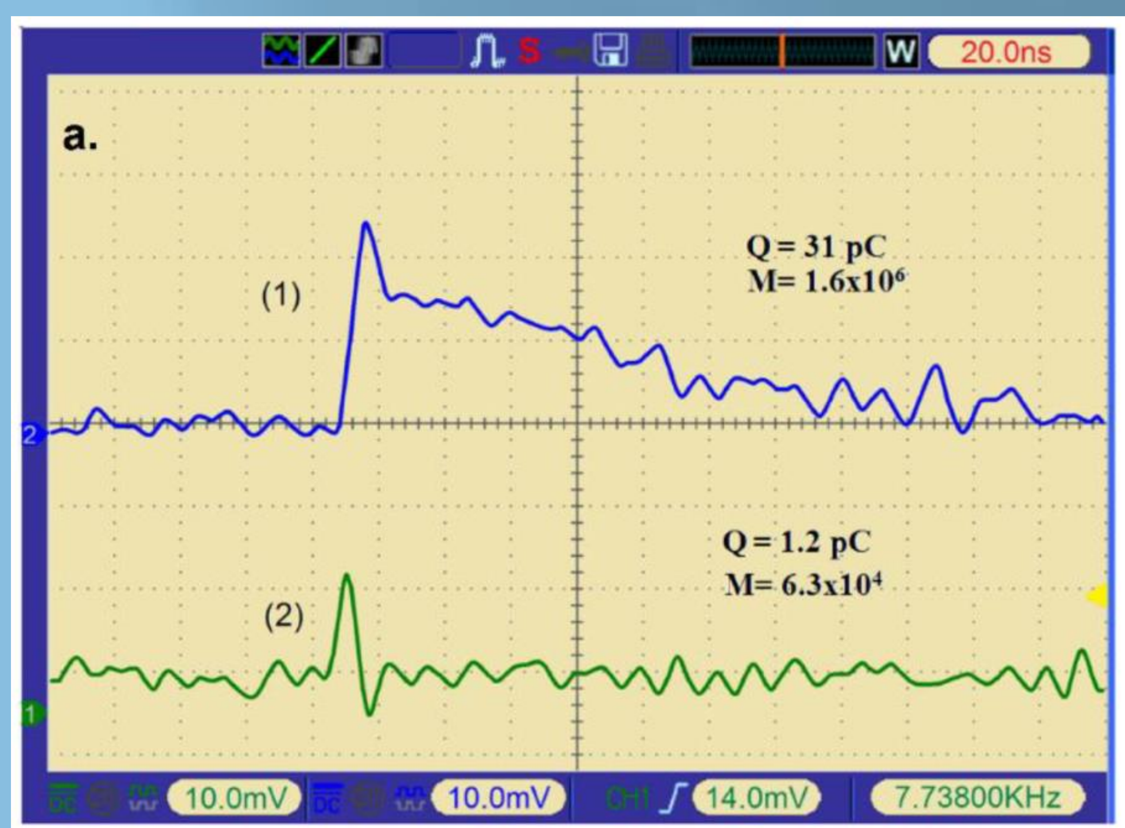


An electric circuit of the MAPT

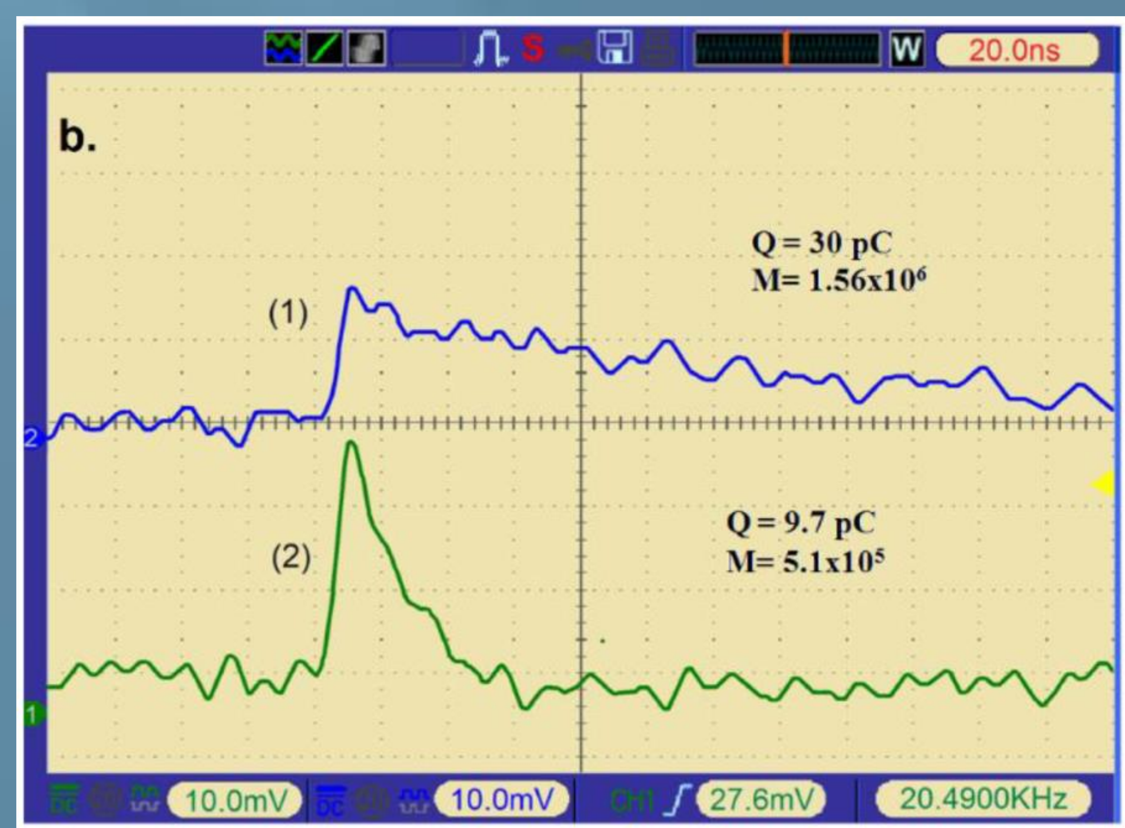
Here the transistor has binary mode performance ("On - Off"), and therefore it is possible to obtain a relatively short signal edges (~ 0.5 ns). The total value of signal gain is $M_p = M_{av} \times M_{tr}$, where M_{av} - avalanche gain, M_{tr} – transistor gain.



Single pixel photo-transistor



Analogue of MAPT from SensL Company



MAPT performance

Main advantages of the new device.

- Low crass talk because of lowering avalanche gain.
- Fast photo response due to individual micro-transistors working in digital mode.
- Very low (about 50 times less) capacitance of devices.
- Capable for use in TOF detectors due to fast photo response.
- Capable for use in astrophysics detectors due to low capacitance.

Collaboration
List of members:
- Joint Institute for Nuclear Research, Dubna, Russia.
- National Nuclear Research Center, Baku Azerbaijan.
- Zecotek Photonics Inc., Canada.

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