Design of a high radiation-hard driver for Mach-Zehnder Modulators based high-speed links for hadron collider applications

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On behalf of the PHOS4BRAIN Collaboration

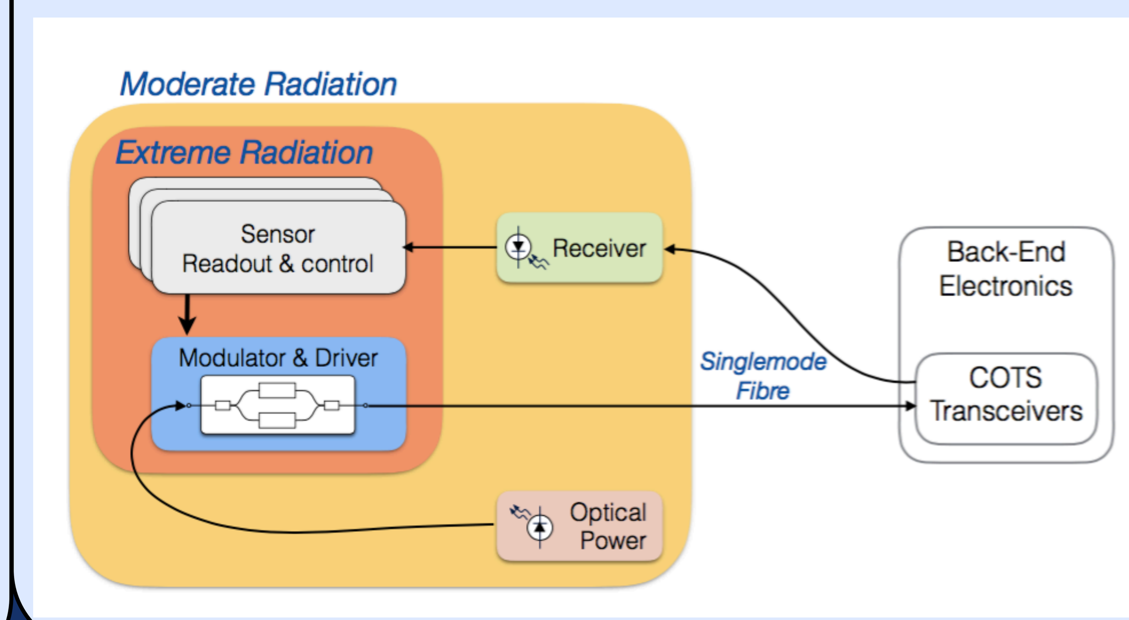
OPTICAL DATA TRANSMISSION IN HEP

Optical Data transmission is a key enabler for present HEP detectors, offering high bandwidths (several Gbps per link), low mass and low power, immunity to EM interference and sufficient radiation hardness. LHC experiments have 50-100k links each

However, the innermost layers of CMS and ATLAS suffer higher fluences and doses, preventing current technologies to be employed. The Future Hadron Colliders will require unprecedented performances [1] (Fluences between 10^{16} and 5 10^{17} n_{eq}/cm^2 and doses between 10 MGy and 400 MGy, for the tracker detectors)

Silicon Mach-Zehnder Modulators (MZM) show good radiation tolerances [2] and emerge as candidates for the next generation optical links: radiation resistance potentially as good as Si-sensors and CMOS electronics, possibility to design circuits in MPW framework and possible co-integration with sensors and electronics

Conceptual integration of MZM with Silicon module and electronics

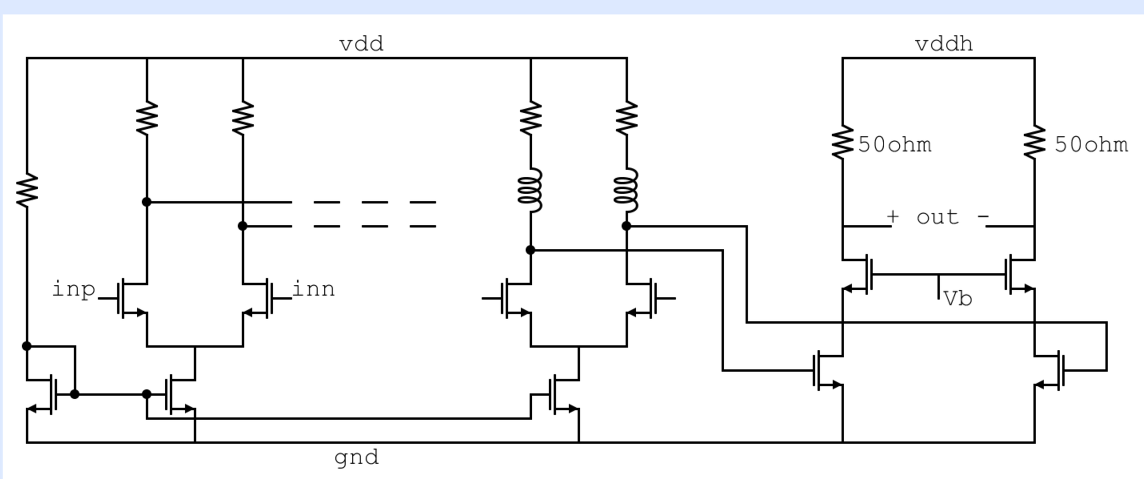


REQUIREMENTS AND DESIGN CHOICES

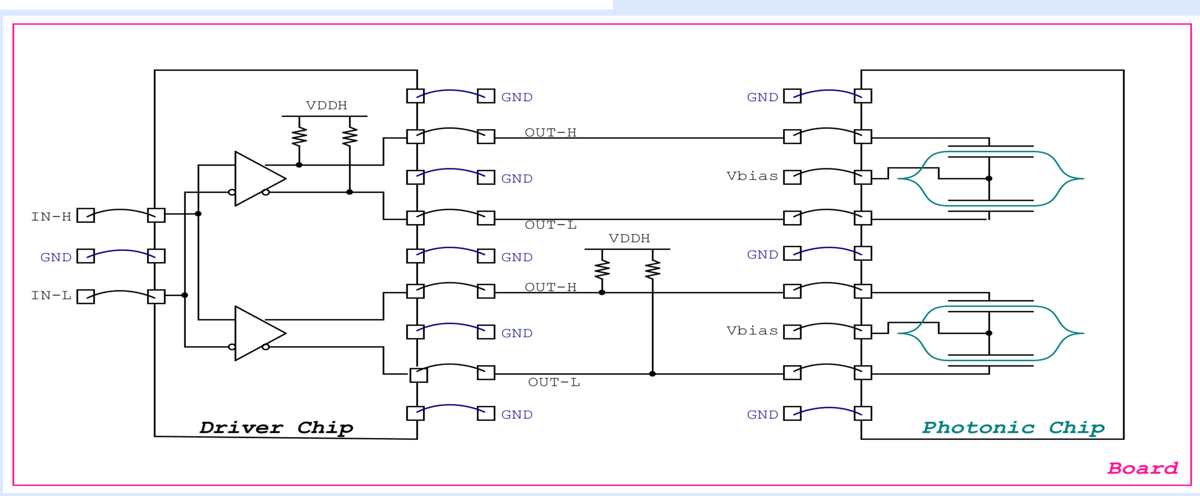
We have chosen 65 nm TSMC technology, which is known to be qualified for radiation doses up to about 5 to 10 MGy [3]

The 65 nm core mosfets can sunstain only 1.2 V. In order to generate 2 V peak-to-peak, as required by the MZM, a cascode architecture is used in the last stage. This allows sharing the "high-voltages" on the two stacked mosfets, preventing their damaging.

The predriver is designed using a chain of four CML buffers with a mosfet's length of 120 nm. The last predriver stage uses an inductive peaking technique to extend the bandwidth.

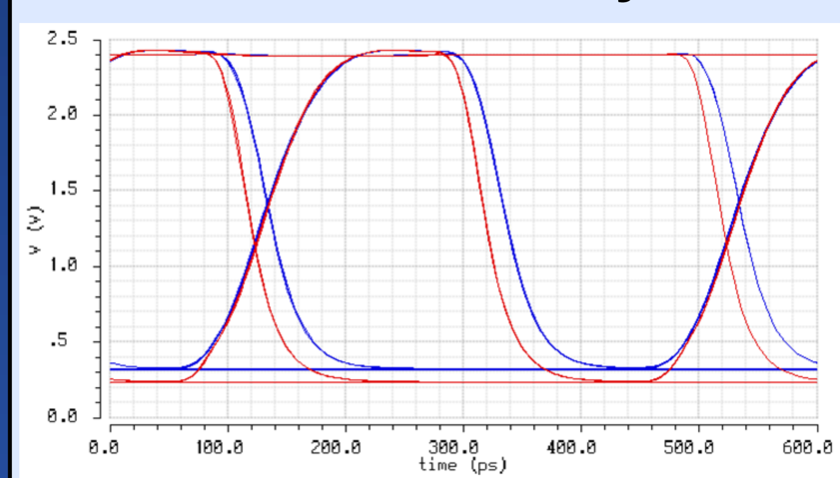


Two designs implemented: with or without the internal pull up resistors

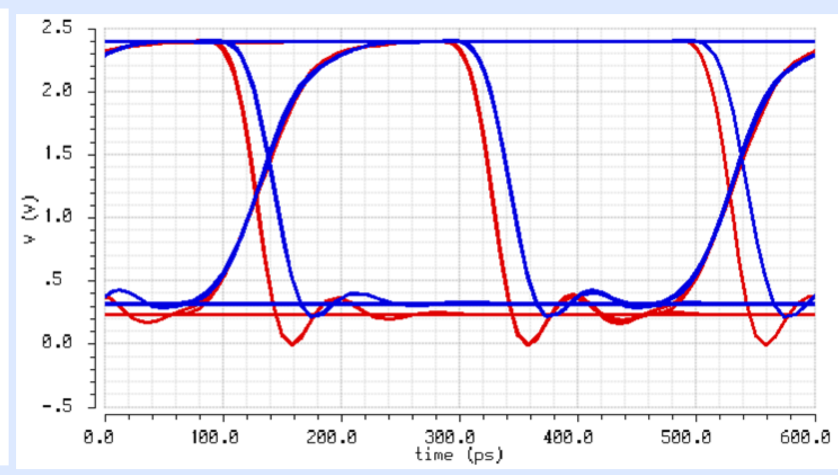


SIMULATION RESULTS

Eye diagram of the 10 Gbps output signals of the TID driver without pull-up resistance. In red the signals waveform in typical condition and in blue the waveform with a TID of 5 MGy.



Open load

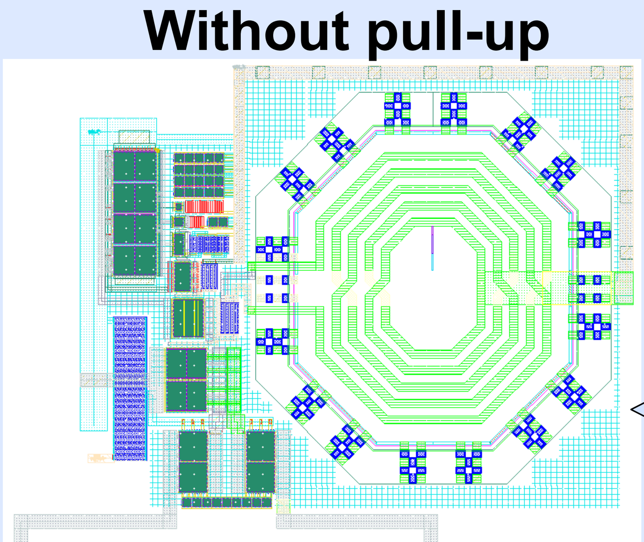


MZM load

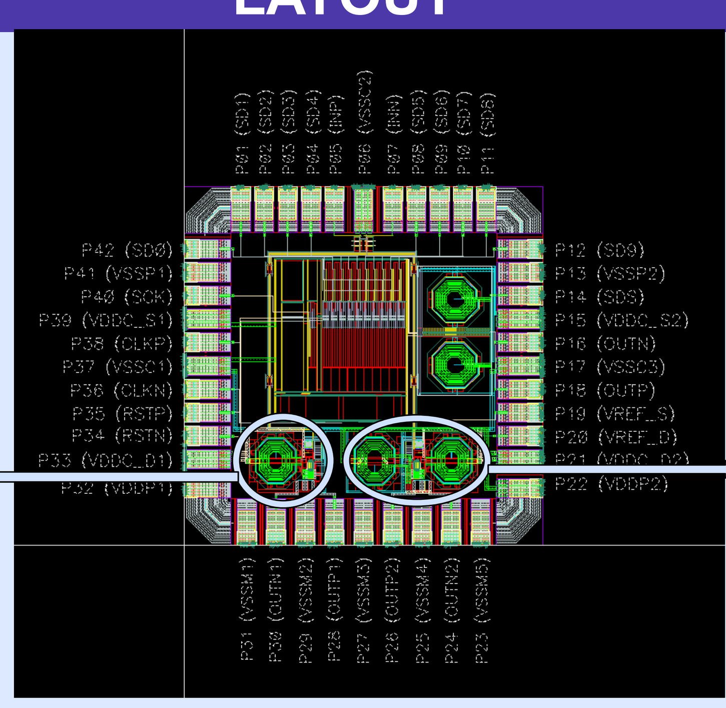
TID conditions	Power (mW) Predriver + cascode
unirradiated	42.65 + 149.35
5 MGy	39.46 + 127.97

LAYOUT

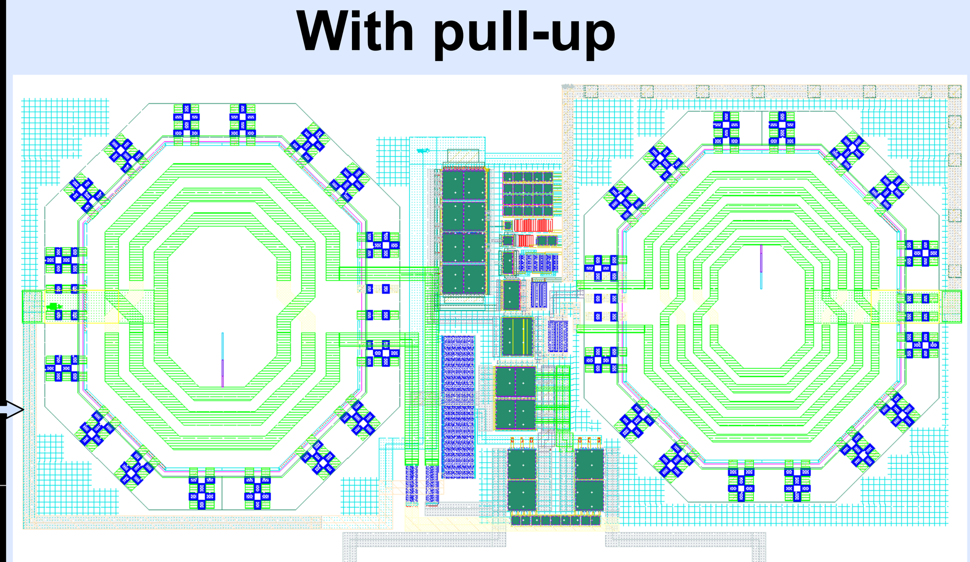
Without pull-up



Area 200 x 180 μm²



With pull-up



Area 347 x 180 μm²

REFERENCES

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2. M. Zeiler *et al*., "Radiation Damage in Silicon Photonic Mach–Zehnder Modulators and Photodiodes," in *IEEE Transactions on Nuclear Science*, vol. 64, no. 11, pp. 2794-2801, Nov. 2017. doi: 10.1109/TNS.2017.2754948
3. L.M. Jara Casas *et al* 2017 *JINST* **12** C02039

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