Prototype Pixel Optohybrid for the CMS phase 1 upgraded Pixel Detector
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ABSTRACT
The CMS Pixel detector phase 1 upgrade calls for an optical readout system operating digitally at or above 320 Mb/s. Since the re-use of the existing link components as is included is excluded, we have designed a new Pixel Optohybrid (POH) for use within this system. We report on the design and choice of components as well as their measured performance. In particular, we have studied the impact upon error-free link operation of the way the data are encoded before being transmitted over the link. We have thus demonstrated the feasibility of operating the new POH within the upgraded readout system.

OPTICAL LINK FOR CMS PIXEL PHASE 1 UPGRADE
The CMS Pixel detector system is to be upgraded in the firstUpgrade Phase 1 UPGRADE. An upgrade is needed to maintain readout efficiencies when the LHC begins to exceed a luminosity of approximately 10^{34} cm^{-2}s^{-1}. Due to the changes to the front-end Readout Chip (ROC) that are necessary to improve the performance of the readout system, it quickly became obvious that the upgraded system should operate using digital readout. The data rates generated by the new system has been calculated to be 320 Mb/s for the 2nd front-end module that houses ROCs. Initially, it was thought that the Analogue Opto-Hybrid (AOH) used in the present Pixel system could simply be re-used as is and used to transmit digital data at the increased rate. A key component of the AOH (its laser diodes) is however no longer manufacturable. It was thus decided to profit from the component selection studies being carried out in the framework of the Versatile Transceiver project that have identiﬁed both functionally-suitable and sufﬁciently radiation-tolerant component candidates that would be suitable for use in the phase 1 Pixel link. Component selection is important as the single-mode optical ﬁbre used in the present system must be re-used for the phase 1 upgrades.

PIXEL OPTOHYBRID
The Pixel Optohybrid (POH) is a PCB design that will be mounted on the mechanical structure of the Pixel detector in the service tube. The POH receives input signals from the detector front-end that will be around 1Mb/s. The final system will require approx. 400 POHs of which one quarter is for the forward end and the remainder for the rear-end detector. With candidate transmitters and Analogue Optical Sub-Assembly (TOSA) component identified by the Versatile Transceiver project, the design of a new Analogue Opto-Hybrid (AOH) has been carried out. The TOSA contains a Fabry–Pérot edge-emitting laser diode operating at 1310 nm that is rather similar to the one currently installed in CMS. Some additional constraints on the POH come from the layout of the service tube in which the POH will be mounted. These constraints have led to a TOSA design featuring a laser diode operating at 40 nm by 25.5 mm. The POH houses the same chipset as the present AOH, consisting of an Analogue Level Translator (ALT) and a Linear Laser Driver (LLD). Each POH needs one LLD, each driving two TOSAs for a total of four readout link transmitters per POH. The footprint of the two in-line connectors was kept compatible with the current AOH to ease system testing. This footprint and/or connector type may change in subsequent iterations of the design. A further iteration of the design to fully match new mechanical constraints may also be required.

TEST BOARD FOR POH EVALUATION
In addition to the POH itself, a test board was designed to be able to supply the necessary signals to the POH in order to be able to test it. Care was taken to ensure that the traces lengths of the power traces on both the POH and the test board. The test board provided power, the POH and the circuit board and it also contains a JTAG interface that allows the interconnects to be programmed.

DATA ENCODING
The initial system design calls for the data to be sent un-coded directly from the readout chips connected to each optical link. The readout chip (the POH detector) can contain many consecutive bits at the same level (one or zero). This is shown in the comparison of the number of consecutive bits at either the one or zero level. This is due to the performance of the POH module 6 as a candidate receiver when sending this raw data compared with standard PRBS7 and a 4/8B encoded data pattern. Except for PRBS7, the patterns have been derived from the data patterns simulated inside the pixel detector and encoded by the readout electronics (ROC and TBM) that will be placed before the optical link. As such they are quite representative of the data that is to be transmitted over the link. For the 4/8B encoded pattern we have tested two line encoding methods: NRZ & NRZI. Non Return To Zero (NRZ) sends the logic level corresponding to the input data for the entire duration of one bit period. In contrast, a Non Return To Zero, Inverted (NRZI) signal has a transition at a clock boundary if the bit data is a logical 1 and maintains a logical 0 transition if the bit being transmitted is a logical 0. As a example of a standardised system, the optical implementation of FDDI uses 48/58 NRZI coding.

CONCLUSIONS
The prototype POH built using the existing radiation-tolerant ALT and LLD chip mounted to the candidate 1310 nm Fabry–Pérot laser TOSA has been shown to operate correctly at both 320 Mb/s and 400 Mb/s in dependence of the data pattern used. The candidate digital optical receiver with 4/8B NRZI encoding successfully received the raw data directly. There is ample margin (4 dB) in the link power budget to guarantee a bit-error rate of 10^-10 if the raw detector data operates at 320 Mb/s are encoded with 4/8B NRZI and transmitted from the TBM at 400 Mb/s. An optical link system based upon our POH prototype containing the current ALT and LLD chipsets matched to the receiver module operates correctly for the Pixel upgrade application.

FULL LINK RESULTS
The eye diagram result is confirmed by full link system BER measurements. We show that there is no additional penalty from operating the link at 400 Mb/s with data encoded with 48/58 NRZ with respect to PRBS7 at 320 Mb/s. There would be an additional power penalty of 2.5 to 3 dB for using NRZ rather than NRZI on the 48/58 encoded data, while for the raw data this penalty is less than 0.5 dB. The receiver sensitivity to 400 Mb/s using 48/58 NRZI encoding was measured to be -18 dBm. Based upon the TOSA specifications and some assumptions regarding the input signal amplitude the minimum transmitted power will be -10 dBm. Operating the link at 400 Mb/s with 48/58 encoded data thus results in a link power budget of 6 dB, which is largely sufficient for a link of 60 m singlemode optical fibre with 2-0 optical connection points.

PRESENTED BY:
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