Characterisation of the BCM1F Analog Opto Hybrids for the CMS experiment

by

Srinidhi Bheesette

(supervisor: Alan James Bell)

on behalf of the CMS BRM group

August 19, 2013

Introduction

The Fast Beam Condition Monitoring (BCM1F) is one of the subsystems of the CMS detector Beam Condition and Radiation Monitoring (BRM) system. It is designed to monitor the luminosity and also measure any background conditions in real time in the region close to the CMS pixel detector. [1]

It will be based on six sCVD sensors each with dimensions of $5 \times 5 \times 0.5\, mm^3$[3]. It has 2 planes each consisting of 12 diamond sensor arranged around the beam pipe on either side of the CMS interaction point (I.P) at a radial distance of 45mm and at a $|Z|$ distance of 1.8 m. The location of the BCM1F is close to the optimum position in terms of timing separation between ingoing and outgoing particles at 25 ns bunch spacing. It will be installed in 2014 when the LHC will be operated at higher energy and luminosity[2].

Each channel will contain a sCVD (single crystal Chemical Vapour Deposition) sensor, radiation hard front-end pre-amplifier with a 3 ns peaking time and 10 ns FWHM, and an Analog-Opto Hybrid for optical transmission of the signal (See figure 1).

In beam background measurement the BCM1F measures the amount of beam background particles traversing through the CMS detector. This will be achieved by detecting the precise timing of these particles with respect to the proton bunches. Therefore, excellent time resolution is a vital requirement of the BCM1F detector[3]. The BCM1F will be also be used for real-time luminosity measurement. This can be done in two ways, firstly, by counting events and by normalizing to probability and cross section, or secondly by zero counting method which is done by counting channels which are not hit and then by using Poissons distribution to calculate mean value, since the mean is directly proportional to the luminosity.

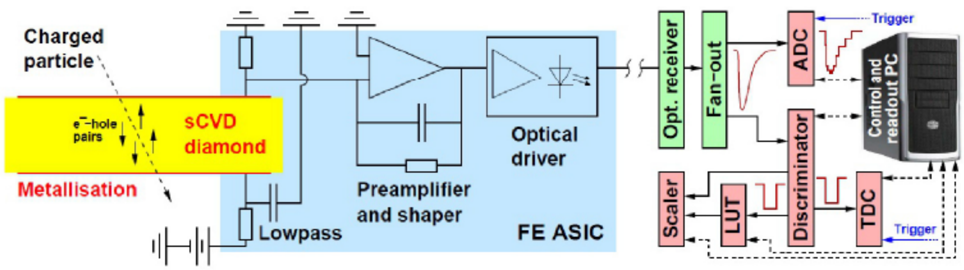

Figure 1: Readout chain of BCM1F A front-end module comprises sensor, pre-amplifier, and optical driver. Test pulses can be injected through a low-pass filter. The back-end employs different devices to process the signals.

Description of Analog-Opto Hybrids

The amplified detector signals are converted to optical by the Analog Opto-hybrid (AOH) which consists of a Linear Laser Driver (LLD) ASIC and three laser diodes (see figure 2).

There are two types of measurement that can be done on the optohybrids; the gain sweep and the bias sweep. In the Gain Sweep the gain of the amplifier can be set by using USB to I2C interface which uses I2C communication to communicate with the AOH board. I2C communication is basically a two wire communication which consists of lines SCL (Serial Clock) and SDA (Serial Data).Four gain levels can be set by the Linear Laser Driver (LLD): Gain 0, 1, 2 and 3. This gain sweep helps to find the best global uniformity of available AOH boards

Secondly the bias sweep sets the laser light output for each laser individually without input signal. Bias must be set so that the whole signal is transmitted, but not so high to cause unnecessary power consumption. The signal from the diamond pre-amp modulates the laser output power. The I2C bus is used to set the register count from 00-7F to obtain the corresponding signal at the output of the laser diode. This will allow better bias tuning of front-end to optimize signals whilst minimizing power consumption.

The measurement of the luminosity is very important for experiments like CMS. The AOH boards are known to be affected by changes in temperature and by radiation damage. As the BCM1F sub-detector will provide one of the real-time luminosity measurements during p-p and heavy ion running, it is vital that these effects are well understood. Additionally it minimizes the power usage to help keep temperatures stable and minimize loading on

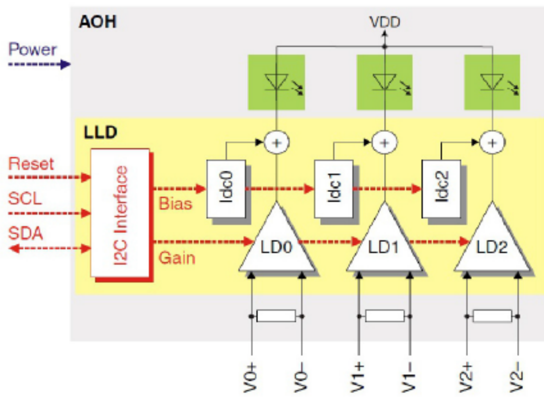

Figure 2: Block diagram of the Analog Optohybrid (AOH) and the Linear Laser Driver (LLD) ASIC contained within[5].

cooling system(which would be provided by C_4F_{16}).

Method of performing measurements

The bias measurement need to be performed in a stable temperature environment for studying the behavior of each laser attached on the optohybrid. We used Climats Spiral 3 chiller unit to test the AOH boards at temperatures 5°C, 15°C and 25°C as shown in figure 3.

The laser are placed on the AOH board as shown in figure 4 and the necessary connections (I2C lines and power supply) to the test board are made. The chiller unit is then set at a temperature of 25°C and the lasers are left to stabilize to that particular temperature. We developed a code to set the register value from 00-7F using the USB to I2C controller (made by Aadrvark). The lasers turn on at specific turn on values (one register count corresponding to a step of 0.45mA) which differs from laser to laser. The output from the lasers are connected to an optical box[6] which converts the optical signal from the lasers to a voltage signal which can be seen on the oscilloscope which is communicated back to the PC using GPIB (General Purpose Interface Bus IEEE 488)[4]. These measurements are then repeated for 15°C and 5°C.

After we perform the measurements for the three temperatures, we used a laser temperature extrapolation formula to extrapolate the turn on of all lasers in range of (-25°C to +25°C)(see Eqn.1).

Figure 3: The chiller unit with the Oscilloscope, Function generator, Optical Box and Power supply.

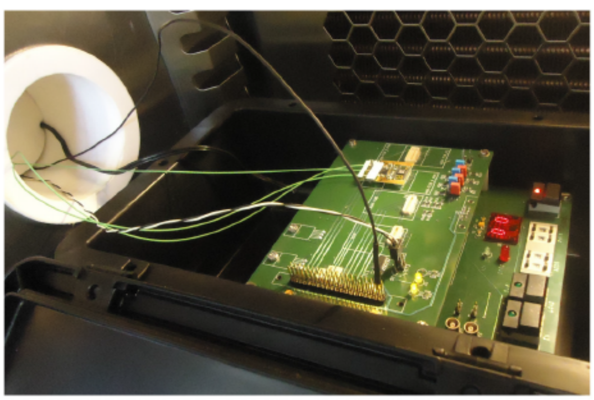

Figure 4: The test board with AOH board, optical lines and I2C lines.

$$T_0 = \frac{(15°C - 25°C)}{ln(I_{15°C}/I_{25°C})} \tag{1}$$

where T_0, is the temperature coefficent.

$I_{15^\circ C}$, is the turn-on current at $T_{15^\circ C}$
$I_{25^\circ C}$, is the turn-on current at $T_{25^\circ C}$
I_T, is the turn-on current at $T^\circ C$

Then, at an extrapolated temperature T, the expected turn on current I_T will be:

$$I_b = I_T e^{\frac{(T-25^\circ C)}{T_0}} \tag{2}$$

Results

We performed the bias measurement for all the lasers. Figure 5 shows an example of the turn-on and extraolation for one laser (id 07250).

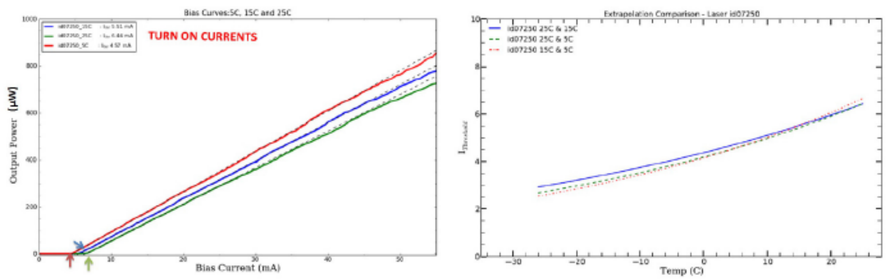

Figure 5: Left: The turn on graph for laser 07250 at 5°C, 15°C and 25°C Right: The extrapolated graph for the laser 07250 from -25°C to +25°C using Eqn.1 and 2.

Similarly we applied this extrapolation to all the laser and the results matched with what we expected.

Conclusions

This work allowed us to choose the best AOH boards available before installation into CMS experiment. This is important as after they are installed they are totally inaccessible. It also helped in minimizing the power consumption as we can choose lasers with early turn on current values than the other which turn on late which consumes more power. This also helps in minimizing the loading on the cooling system (liquid C_4F_{16}).

The temperature stabilization will be provided to the installed AOHs to obtain a stable signal characteristics and stable luminosity $\mathcal{L}$ measurements.

Bibliography

[1] A.J.Bell. Beam and radiation monitoring for cms. In *Proceedings of the 2008 IEEE Nuclear Science Symposium and Medical Imaging Conference*, pages 1597–1600, Oct 2008.

[2] E. Castrol. Application of single crystal diamonds (sCVD) as beam conditions monitors at LHC. 2012.

[3] A.J. Bell et al. Performance of the fast beam conditions monitor. 2010.

[4] HEPHY,Veinna. *The Opto-hybrid tester manual*, 2011.

[5] M.Pernicka M.Friedl. Final results of the industrial production of CMStracker analog optohybrids.

[6] New Focus, Inc. *DC to 3.5-GHz Amplified Photo receivers Models 1592*, 2011.