Designing Electronic Amplifier for FMCW DOFI

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February 11, 2015

STSM Application number: COST-STSM-BM1205-081214-053150

STSM Grantee: Ajit Jha

STSM title: Detection of OFI signal based on laser junction fluctuation

Home Institution: Center for Sensors Instruments and System Developments (CD6), UPC

Host Institution: LAAS-CNRS

STSM period: 11/12/2014 - 19/12/2014

STSM purpose: To detect OFI signal based on laser junction fluctuation and develope a high gain bandwidth electronic amplifier to amplify OFI signal

Description of the work carried out during the STSM: The work carried out during the grant is classified in two categories

1. Developing large gain bandwidth amplifier to process OFI signal
   - Analyzing the frequency spectrum of OFI signal
   - Designing high bandwidth gain product electronic amplifier to amplify OFI signals
2. Laser junction voltage measurement to detect OFI signal

Designing high bandwidth gain product electronic amplifier to amplify OFI signals

1 Preliminary approaches

In this section, the initial circuit design for laser driver, amplifier and their characterization is made. Further the internal photodiode at the rear of DFB laser is characterized to determine its bandwidth. Finally the comparison between the internal and external photodiode is made to get an insight about the bandwidth and responsivity of external photodiode as compared to internal.

1.1 Laser Driver

As a preliminary step, laser driver to drive the laser to MHz range was designed and the schematics is shown in Fig. 1.

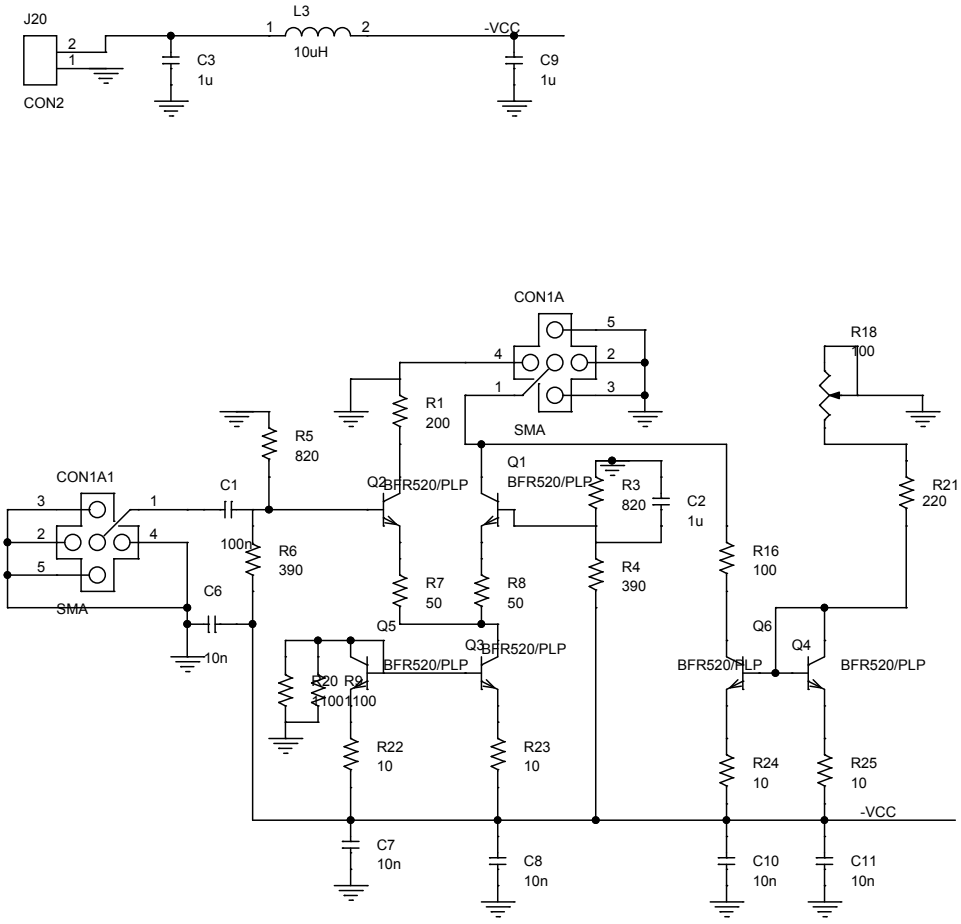

Figure 1: Schematics of laser driver

1.2 Characterizing Laser Driver

To characterize the laser driver, signal generated from signal generator was directly fed to the driver and the voltage output from driver was measured using oscilloscope. Fig. 2 illustrates the experimental setup for characterizing the laser driver. The signal output from oscilloscope was tuned from 30 Hz to 240 MHz and the corresponding output from driver was noted which is shown in Fig. 3. To find the frequency bandwidth and (lower and upper)cutoff frequency of driver, the frequency and voltage measured was converted to decibels using Eq. (1) and (2) respectively. The plot

of frequency (dB) and power (dBm) is shown in Fig. 4.

$$freq(dB) = 10log_{10}(frequency\ value\ in\ Hz) \tag{1}$$
$$power(dBm) = 20log_{10}(signal\ amplitude\ in\ mV) \tag{2}$$

It is seen from Fig. 4 that the lower and upper cutoff frequency of driver is 22.51 and 72.92 dB respectively. Using Eq.(1) they correspond to 178 Hz and 19.5 MHz respectively resulting in 3 dB bandwidth of $\sim$ 19.5 MHz.

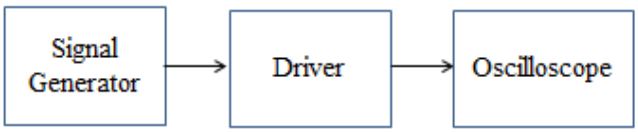

Figure 2: Characterizing laser driver: Experiemntal Setup

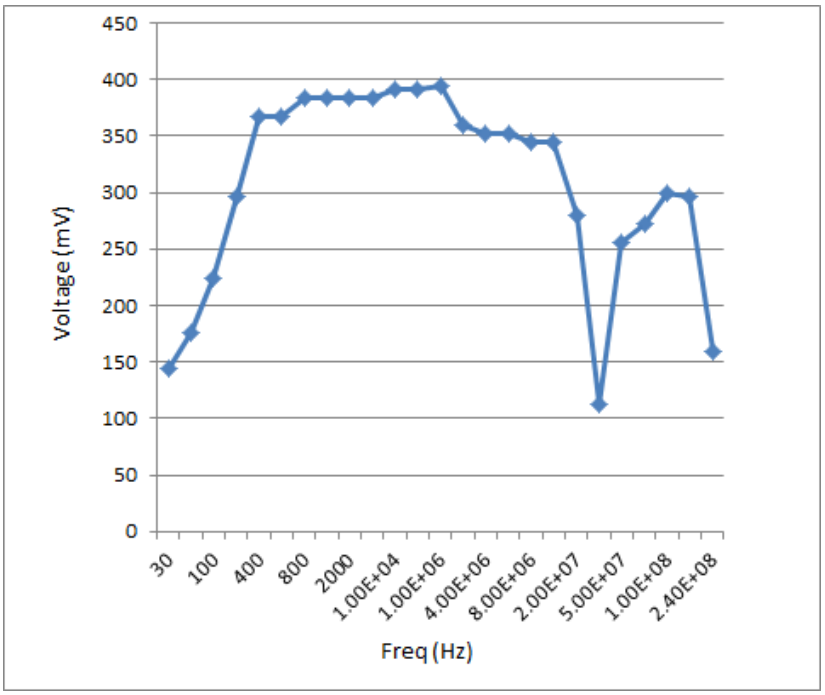

Figure 3: Characterizing laser driver: Variation of voltage output of driver as a function of frequency

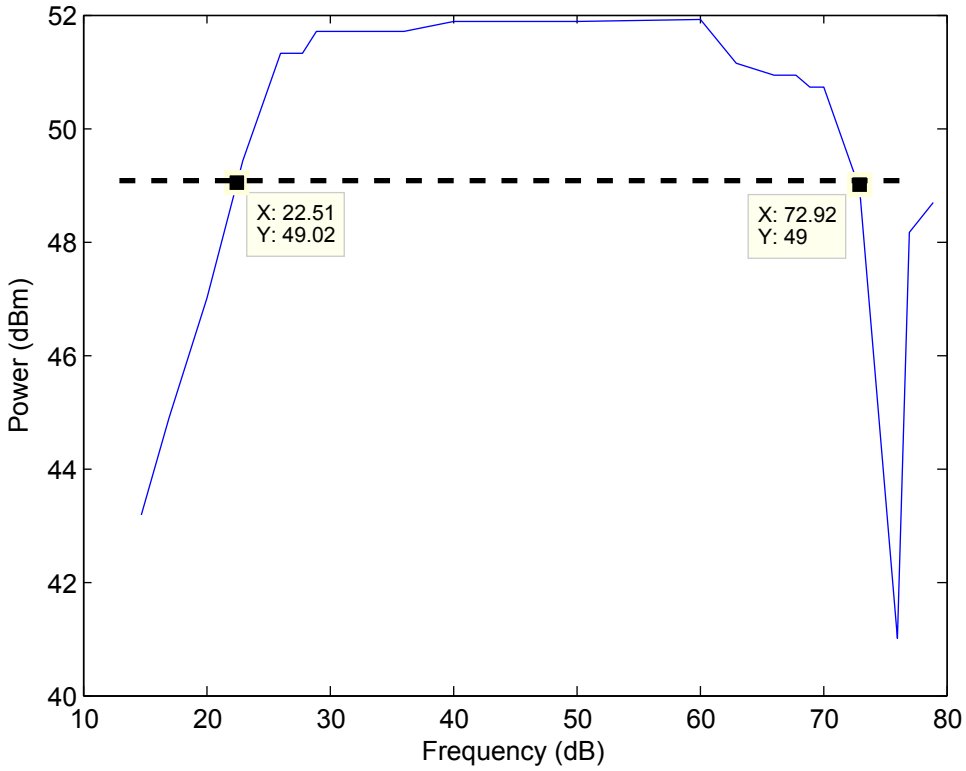

Figure 4: Characterizing laser driver: 3 dB bandwidth estimation of laser driver

1.3 Electronic Amplifier

The schematics of electronic amplifier designed to retrieve self-mixing signal is shown in Fig. 5.

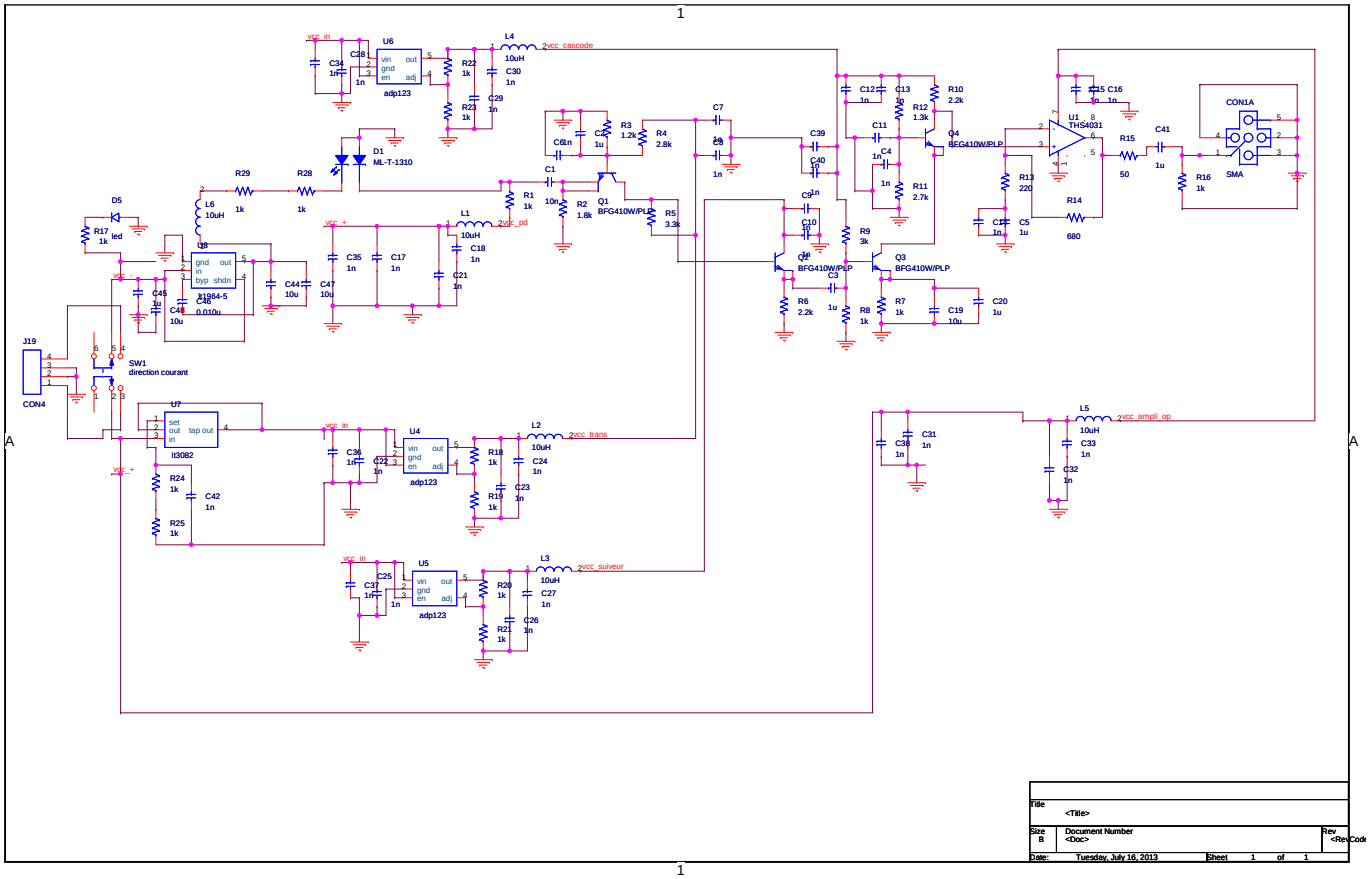

Figure 5: Characterizing amplifier: Variation of voltage output of driver as a function of frequency

1.4 Characterizing Electronic Amplifier

From previous sections we have known that the bandwidth of amplifier is modulation frequency and number of fringes dependent. So determining the bandwidth of amplifier is must. To characterize the laser driver, signal generated from signal generator was directly fed to the driver and the voltage output from driver was fed to electronic amplifier and the output from it was measured using oscilloscope. Fig. 6 illustrates the experimental setup for characterizing the laser driver. The signal output from oscilloscope was tuned from 2 KHz to 100 MHz and the corresponding output from amplifier was noted which is shown in Fig. 7. To find the frequency bandwidth and (lower and upper)cutoff frequency of driver, the frequency and voltage measured was converted to decibels using Eq. (1) and (2) respectively. The plot of frequency (dB) and power (dBm) is shown in Fig. 8. It is seen from Fig. 4 that the lower and upper cutoff frequency of driver is 39.95 and 74.93 dB respectively. Using Eq.(1) they correspond to 9.9 kHz and 31.1 MHz respectively resulting in 3 dB bandwidth of $\sim$ 31.1 MHz.

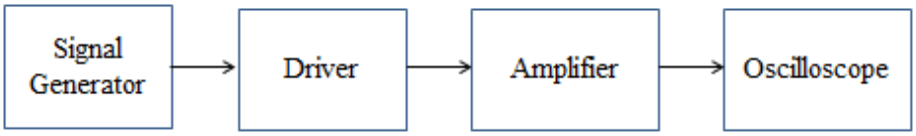

Figure 6: Characterizing amplifier:Experimental setup

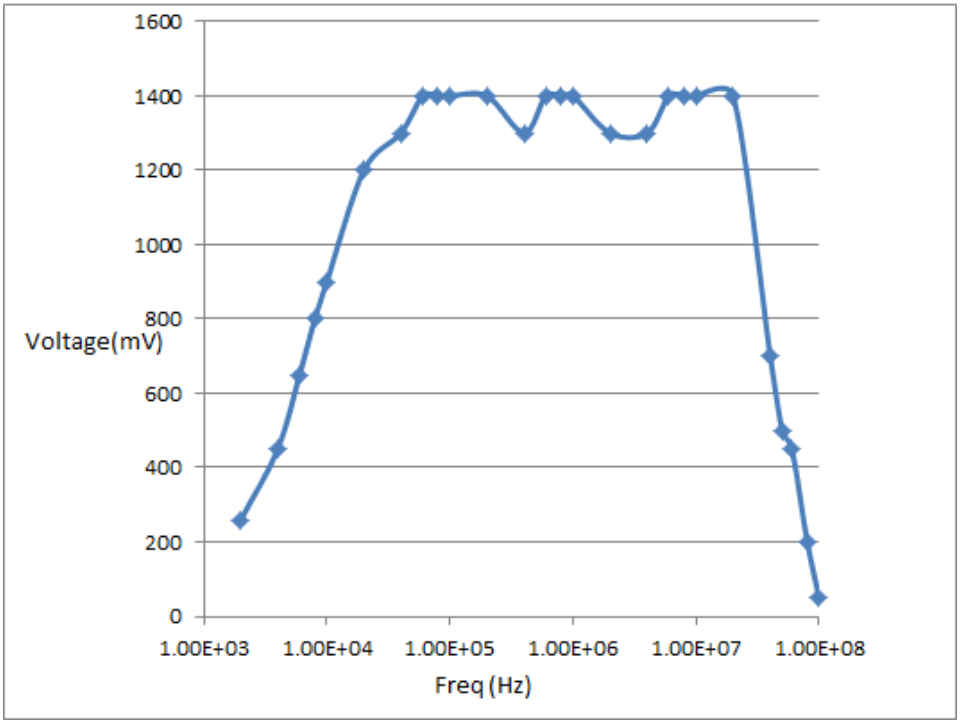

Figure 7: Characterizing amplifier:Variation of voltage output of amplifier as a function of frequency

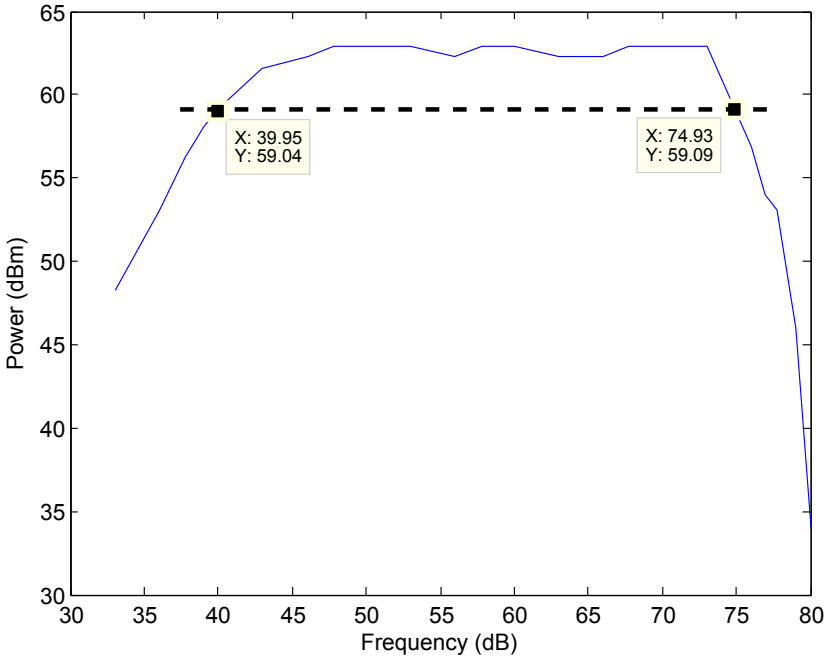

Figure 8: Characterizing amplifier: 3 dB bandwidth estimation of amplifier

1.5 Outcomes and limitations

1.5.1 Outcomes

1. Designed the driver to modulate laser up to 19.5 MHz
2. Designed an amplifier having upper cutoff at 31.5 MHz

1.5.2 Limitations

1. Though the modulation bandwidth of driver is fairly large i.e. 19.5 MHz, but the bandwidth of amplifier is the main limitation. For e.g., with considerably fair number of fringes in one half of modulation period to construct the target vibration (say 9 fringes) and the amplifier with cutoff of 31.5 MHz, we are limited to modulation frequency of 2 MHz and the target vibration of 4 MHz.

Mutual benefits for the home and the host institutions: Both the institutes have been working on OFI and I believe that the proposed methodology will open a common platform in measurements of high frequency vibration as - photo-acoustic pulses, characterizing material to name a few.

Future collaboration with the host institution: Both the institutes have been collaborating in past and will still continue. In fact, the detection of high frequency sub nanometric target vibration using OFI will open doors to many seen / unseen applications and where both the institutes can play their parts. LAAS-CNRS being very strong in electronics and CD6 at signal processing and wide variety of optical and Photonics components and expertise. Further, we will have to collaborate further for detecting OFI signal from laser junction voltage, which is in progress.

Foreseen Journal publications or conference presentations expected to result from the STSM: Spectral features determination of OFI signal and designing high gain bandwidth amplifier is seen to be a publication in near future.

Other comments: I would like to thank COST action BM1205 for providing the funding for my stay at LAAS-CNRS for my research works, experience and opportunity. I would also like to thank Erasmus Mundus to fund my PhD at UPC-CD6 and LAAS-CNRS for their support and vision during the grant.

STSM outcome form

STSM Application Number	Home Institution and Country	Host Institution and Country	BM1205WG	Objective of the collaboration	Results of the Collaboration
COST-STSMBM1205-081214-053150	CD6-UPC, Spain	LAAS-CNRS, France	WG2	Develop high gain bandwidth product amplifier to amplify OFI signal and OFI detection using laser junction fluctuation	Developed laser driver that can modulate upto 19.5 MHz, Developed amplifier having bandwidth of 31.5MHz

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