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MESSAGE/SUBJECT

Salut Agnès,

Je t'envoie comme promis par fait la note sur l'électronique - merci

Gino Richard

Status of the photodiodes front end electronics

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1 Introduction

The purpose of this note is to report about the status of the photodiodes front end electronics prototype built in Annecy.
First, we shall give the results of the measurements performed on the electronic circuit itself and then on the electronics connected to the photodiode illuminated by an adequate laser test beam. For the noise measurements, the photodiode is connected to the electronics, but not illuminated.
The optical power outcoming from the interferometer at the dark fringe port is expected to contain the following informations [1] :

- A D.C. component which is mainly due to the interference of the two sidebands (estimated at 400 mW)
- An A.C. component at the modulation frequency which contains the gravitational wave signal and the information for feedback
  (estimated at 200 mW RMS)
- An A.C. component at twice the modulation frequency also due to the interference of the two sidebands and which does not contain any information.
  (estimated at 800 mW peak to peak)

2 Specifications

- Dynamic range
  The dynamic range is fixed by the ratio between the maximum expected signal at the modulation frequency and the shot noise.
  The simulations [1] give the following numbers for the dark fringe photodiode (D1) : 200 mW peak to peak at the modulation frequency and a shot noise of 400 $pW/\sqrt{Hz}$, i. e. a dynamic range of 1.8 $10^8\sqrt{Hz}$.
  The dark fringe beam is split into sixteen beams due to the limited light power sinkable by one photodiode (100 mW max.). The above numbers thus become : 20 mA D.C., 9 mA peak to peak at the modulation frequency, 40 mA peak to peak at twice the modulation frequency and a shot noise of 75 $pA/\sqrt{Hz}$, i. e. a dynamic range of 4.4 $10^7\sqrt{Hz}$, assuming a quantum efficency of 0.9 for the photodiodes.
- Shot noise
  The detection must be shot noise limited around the modulation frequency.
- D. C. channel
  The D. C. signal must be measured with a bandwith up to 20 kHz.

3 measurements on the electronics

The schematic of an electronic channel for one photodiode is given in figure 1.

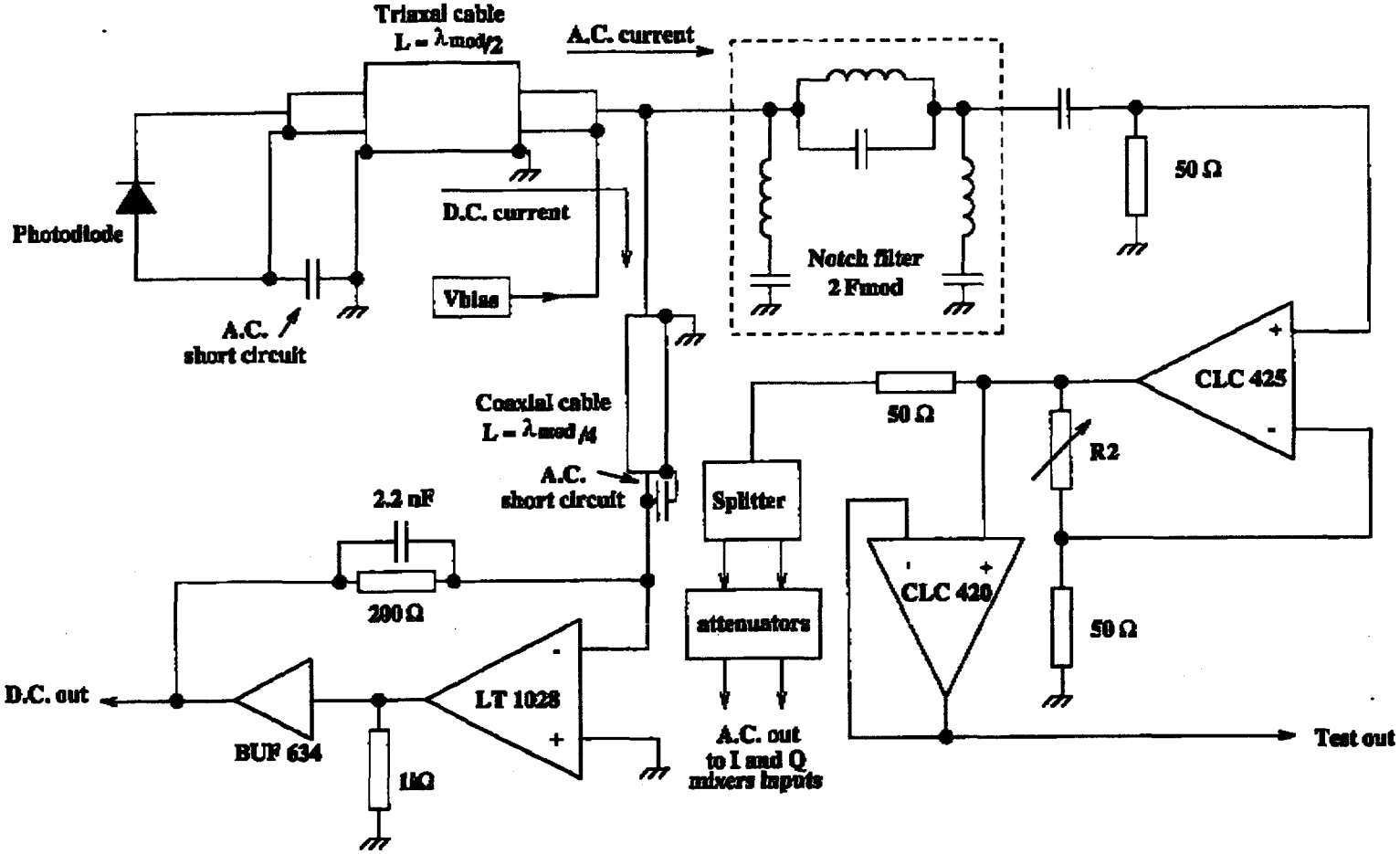

Figure 1: Front end photodiodes electronics

3 measurements on the electronics

The schematic of an electronic channel for one photodiode is given in figure 1.

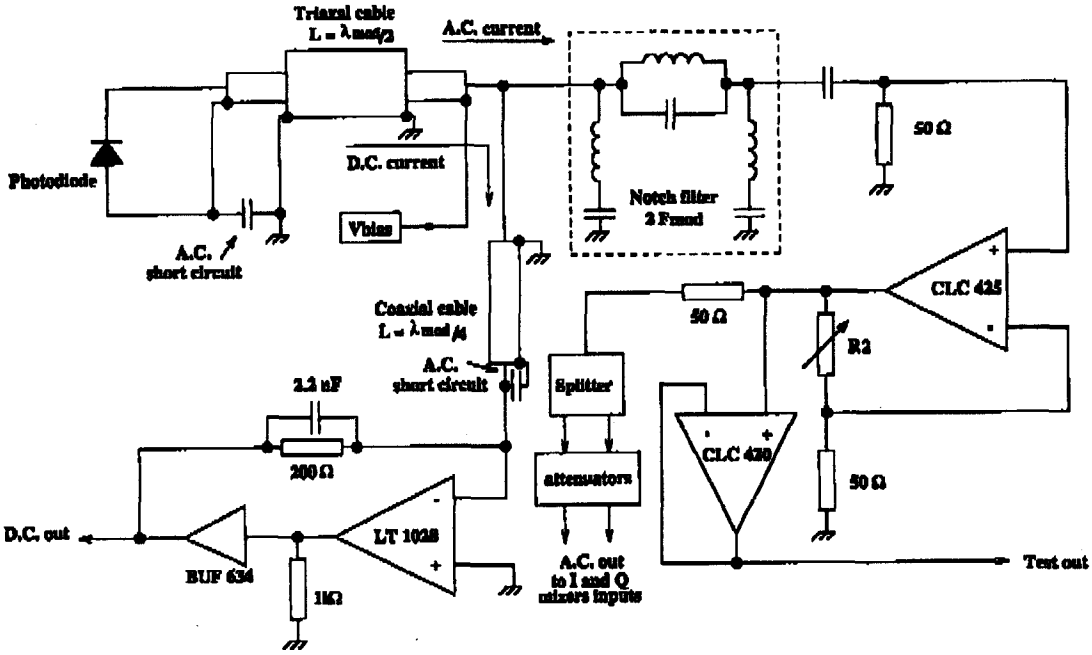

Figure 1: Front end photodiodes electronics

The triaxial cable allows to carry at the same time the signal and the d. c. bias voltage necessary for the photodiode. The role of the $\lambda_{mod}/4$ length coaxial cable is to attenuate the 2 F_{mod} component and to derive the D.C. current towards the D.C. measurement amplifier. An additionnal notch filter is necessary to reduce the 2 F_{mod} component below the useful signal.
The A.C. channel is composed of a very low noise voltage amplifier. The minimum gain allowed for this amplifier is 20 dB, it can be adjusted by the resistor R_2 ($R_2 > 450\Omega$) The output level is adjusted by the attenuators to match the maximum input level of the mixer.

We give the results of our measurements on the prototype in the following sections.

3.1 D.C. channel measurements

- D.C. gain : 200 mV/mA up to 60 mA (figure 2)

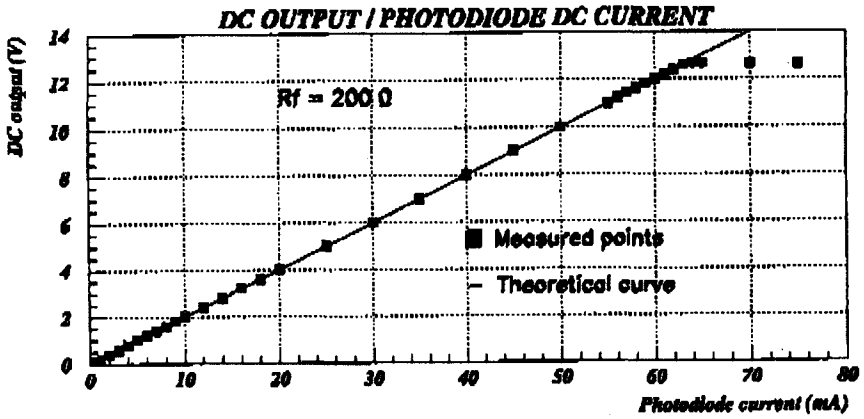

Figure 2: D.C. response

- The transfer function given in figure 3 shows a flat response up to 100 kHz

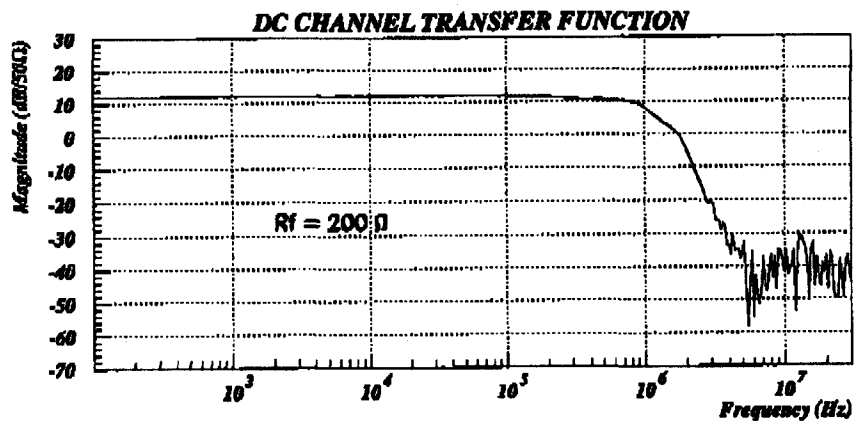

Figure 3: D.C. channel transfer function

- The input reffered noise is below 15 $pA/\sqrt{Hz}$, corresponding to the shot noise of a 0.7 mA DC current.

3.2 A.C. channel measurements

The A.C. channel has been designed assuming a modulation frequency (F_{mod}) of 6.27 MHz

- The frequency response (figure 4) shows a gain of 105 mV/mA at F_{mod} and an attenuation greater than 60 dB at 2 F_{mod}

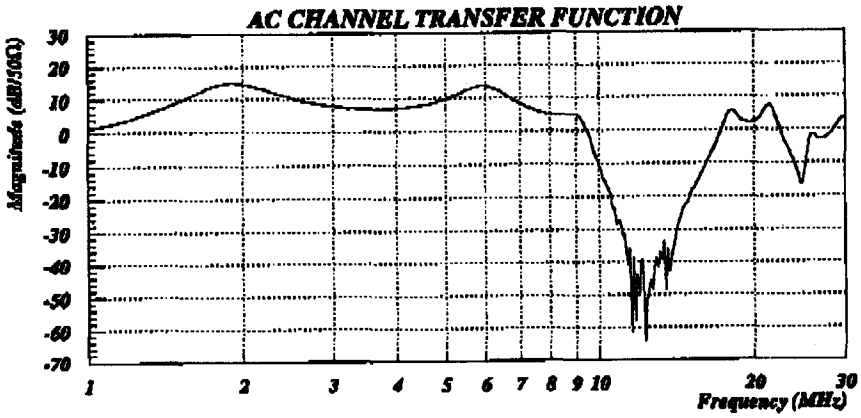

Figure 4: A.C. channel transfer function

- The maximum output level of the low noise amplifier (CLC 425) is 6.2 Vpp at F_{mod}. Its gain is adjusted in order to maximize the dynamic range of the signal at F_{mod}.
- The input reffered noise is 40 $pA/\sqrt{Hz}$ at F_{mod}, corresponding to the shot noise of a 5 mA DC current. (The D.C. current from the photodiode is 20 mA).

The dynamic range of the A.C. channel itself is : 1.5 $10^8\sqrt{Hz}$.

3.3 Mixers

We have chosen a double balanced mixer ($SRA-3MH$) from Mini-Circuits with a L.O. level of +13 dBm. Figure 5 shows the results of the linearity and noise measurements. The input signal is made of a carrier at F_{mod} with a small amplitude and two sidebands at a few hundreds of Hz offset from the carrier. The R.F. input in figure 5 is the R.M.S. value of one sideband.
The linearity curve shows that the output of the mixer is not distorted up to +5 dBm input level, i. e. 0.4 V $R.M.S.$ With a noise level of 10 $nV/\sqrt{Hz}$, the dynamic range of the mixer is : 4 $10^7\sqrt{Hz}$

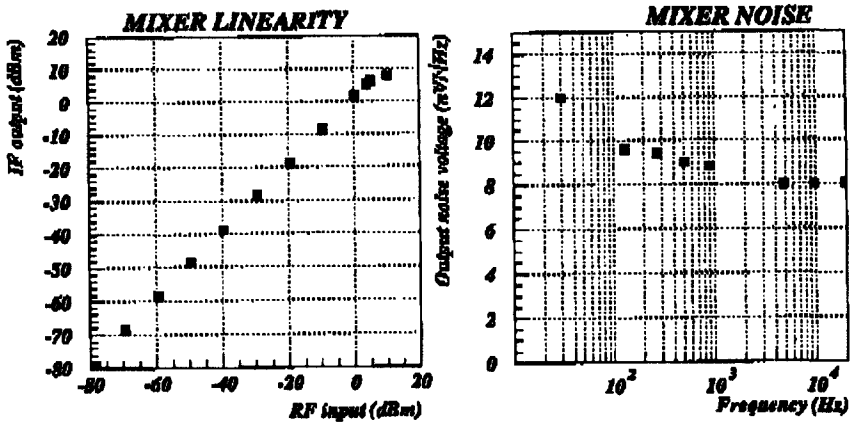

Figure 5: Mixer linearity and noise

3.4 conclusions on the measurements on the electronics

The measurements on the electronics have shown that :

- The detection is shot-noise limited for a D.C. current of 5 mA ; the expected D.C. current in each photodiode is 20 mA
- The dynamic range including the mixer is 4 $10^7\sqrt{Hz}$, which is very near from the specification ($4.4\ 10^7\sqrt{Hz}$). The dynamic range of the electronics from the photodiode to the mixer input is $1.5\ 10^8\sqrt{Hz}$. The weak point of the channel is the mixer.
- The measurement of D.C. signals can be made with a bandwith up to 100 kHz and is shot noise limited at 0.7 mA D.C.

4 measurements with the photodiodes and a test laser beam

References

[1] SIESTA, calculs de Frédérique