Gyrolaser Optical design: STD op.

\[ I_S = I_1 + I_2 + 2 \sqrt{I_1 I_2} \cos[\Psi(t)] \]
3-ways analog cw/ccw signal processing

- Block scheme

<table>
<thead>
<tr>
<th>CW / CCW</th>
<th>Photodiode</th>
<th>+140 dB re V/A</th>
<th>PREAMP</th>
<th>+40 dB</th>
<th>Low pass Bessel 5th order filter 1 KHz</th>
<th>Total signal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low pass Bessel 5th order filter 10 Hz</td>
<td>“DC” signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+40 dB</td>
<td>Band pass Bessel 5th order filter 106 Hz</td>
<td>“AC” signal</td>
</tr>
</tbody>
</table>

Key features:
- Very good matching cw / ccw channels
- Stable gains
- Noise performances over commercial amplifiers
3-ways analog cw/ccw signal processing

- Electrical scheme of the upper branch
3-ways analog cw/ccw signal processing

- Noise performances vs commercial preamp with equivalent gain

Red line: commercial amp preamp (femto LCA-4k-1G)
Blue line: h.m. module (iccw)

Further improvements on noise performances of our modules are still (hopefully) possibles

Simulated noise

An unexpected parasitic capacitance is responsible for the noise peaking

Measured noise

Excess noise zone

Linear Spectral Density (V/sqrt(Hz))

frequency (Hz)
3-ways analog cw/ccw signal processing

- An explanation from circuit theory

\[ e_o = I_p R_1 + I_n R_1 + \frac{1 + j \omega R_1 C_D}{1 + j \omega R_1 C_S} e_n \]

\[ C_s = 10 \text{ pF} \]
\[ C_d = 380 \text{ pF} \]
\[ C_d = 10 \text{ nF} !! \]

Possible cause: parasitic from breadboard
We can try with a PCB board

Simulated noise
An unexpected parasitic capacitance is responsible for the noise peaking

Measured noise
Perimeter lock:
PLL phase and frequency lock

From Gyrolaser

He-Ne-I2 REF laser

Beat signal @ 170 MHz

A/V differential conversion and filter

Ref frequency @ 10 MHz

Frequency divider

Phase/frequency discriminator

LPF and buffer

Error signal

TO PIEZOS

High Voltage amplifier

D/AC

digital elaboration and storage

A/DC

19/20 DECEMBER 2011 – PADOVA – LABORATORI NAZIONALI DI LEGNARO
**Perimeter lock:**
**some considerations on SNR / 1**

- **“Best case”: FEMTO- pre amplifier:**
  
  let 100 uW = power of stabilized laser = \( P_s \)

  1 nW = power of gyrolaser = \( P_g \) (\( P > 1 \text{ nw} \rightarrow \text{multi mode} \))

  power of beat = \( 2 \sqrt{P_s \times P_g} \) (peak value) = 600 nW peak

- After the P.D. and the pre-amplification we get 1,1 mVrms of signal

- **Preamp data sheet:**
  
  - equivalent input noise current @100 MHz = 21 pA/sqrt(Hz)
  
  - Standard deviation of output noise = 300 uV rms

**SNR = 10 dB**

SNR very close to 0 dB even in “ideal” conditions
Perimeter lock: some considerations on SNR / 2

A significantly lower SNR can be expected:

- Many other sources of noise than the input equivalent noise current:
  - Voltage input noise
  - Transimpedance thermal noise
  - Op-amp voltage and current noise noise
  - Shot noise
- The signal is lower
  - Light losses
  - Non-ideal light coupling with the photodiode
  - Non-ideal polarization of incident beams
Perimeter lock: some considerations on SNR / 3

Measurements of SNR on “real” working conditions:

RBW of the real time spectrum analyzer = 100 Khz

- Noise floor -86 dBV (corresponding to 158 nV/sqrt(Hz), near to the data-sheet value of 100 nV/sqrt(Hz))

- Beat from 31 uW + 10 uW He-Ne beams: -36 dBV @126 MHz

- Beat from 31 uW + 10 nW He-Ne beams: -67 dBV @126 MHz

- Beat powers are scaling according to the relation $2 \sqrt{P_1 \cdot P_2}$ but 10 dB (a factors of 10 in power) is missing

- We can take into account those 10 dB considering the non ideal working conditions (for signal and noise) as considered above
  - we measured a loss due to optical coupling of 5dB
  - Beam polarization: work in progress . . .
Automated calibration for:
\[ \beta_{cw}, \beta_{ccw}, \mu_{cw}, \mu_{ccw} \]

Plasma Exc.
and Fluorescence ctrl

+ a dedicated output for observing RDT
Start Calibration

Suspend DAQ, freeze (A_{RF}, V_{pzt})

Plasma OFF
RDT meas

Plasma ON
Calibrate Laser efficiency

Reliable?

False

Restore (A_{RF}, V_{pzt}) Restart DAQ

End Calibration

\( \mu_{cw}, \mu_{ccw} \)

\( \beta_{cw}, \beta_{ccw} \)

Losses estimation (non reciprocal.)

Laser efficiency

Calibration Logic (PC driven)
Effects of wind speed and direction on Sagnac frequency

Orientation of G-Pisa:

- ~ 270 degrees
- ~ 80 degrees
- Same average speed

Further Investigations required

Sagnac frequency
Wind direction
Wind speed