Application of the Carrier Suppressing Interferometry in the MAGO project

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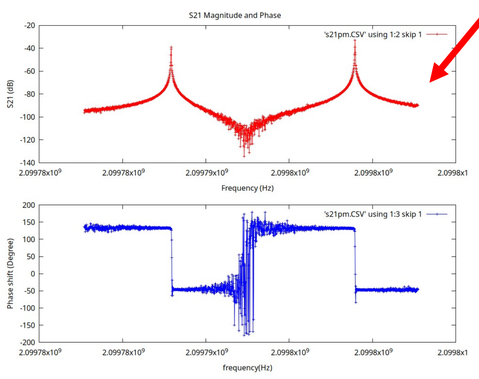
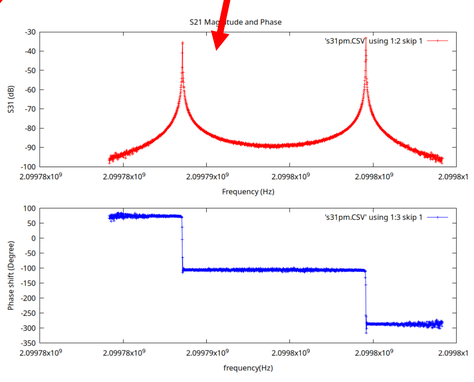
MAGO Project(Microwave Apparatus for Gravitational Waves Observation)

- **Purpose of the MAGO project is detection of the high frequency gravitational waves (GW) with a superconducting RF cavity.**
- **MAGO cavity uses two identical coupled cells and coupling of the cavity produces two close resonant modes(zero and pi mode).**
- **In principle, when the zero mode of the cavity is excited, interactions of the GW with the cavity will cause a power transfer from zero mode to pi mode (heterodyne generation).**
- **GW can couple to the MAGO cavity electromagnetically (Gertsenshtein Effect) also mechanically.**



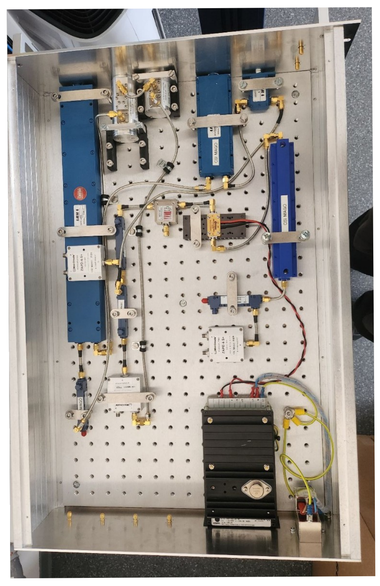
S21 parameter and phase from cell0 antenna

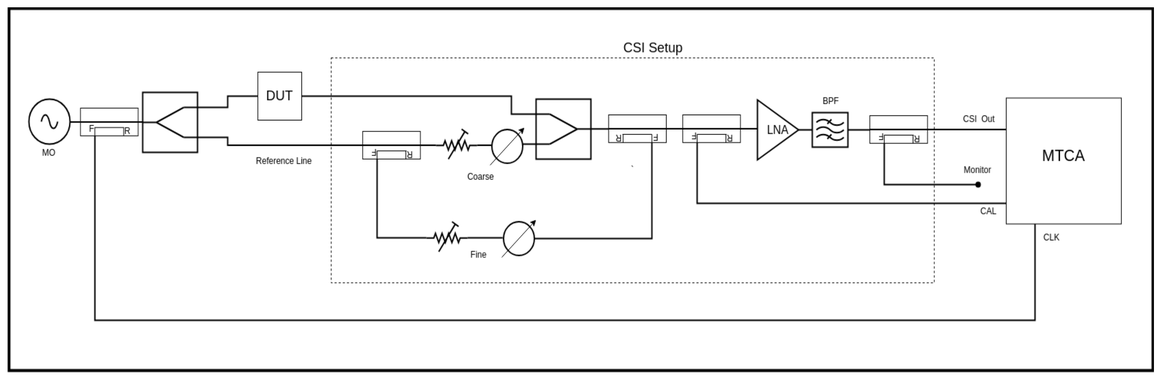


S21 parameter and phase from cell1 antenna

Carrier Suppressing Interferometry (CSI)

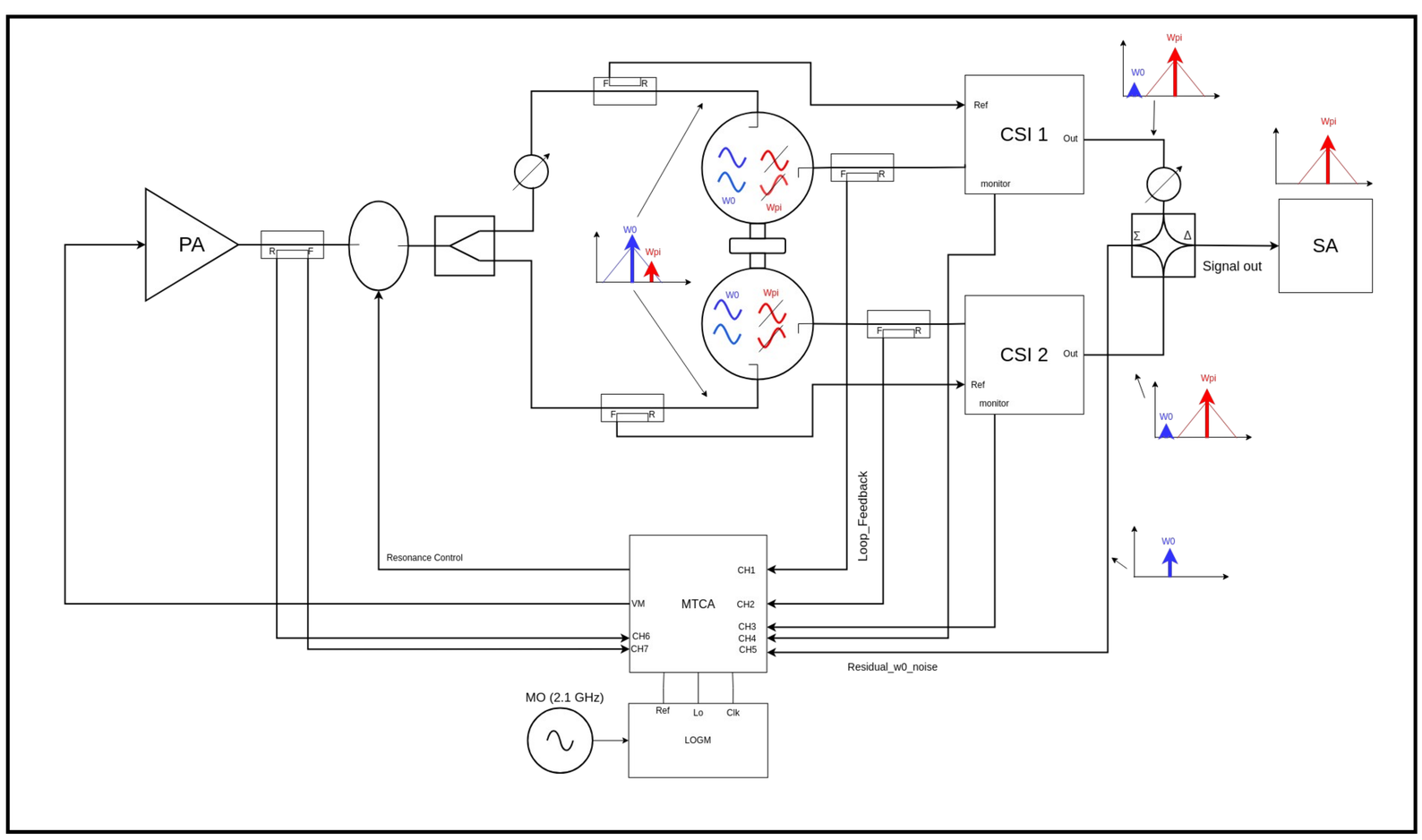
- **Carrier Suppressing Interferometry (CSI) is a setup for measuring extremely low (-205 dBc/Hz) phase noise by suppression of the carrier noise floor.**
- **Working principle of the CSI relies on destructive interference between reference (carrier) signal and the reference signal pass through device under test. Because of the difference between the two signals, resulting signal gives information about devices phase noise characteristics.**
- **CSI is a promising method for the extraction of the GW signal in the MAGO project. Due to extremely low amplitudes of the GW signal.**
- **CSI setup will be used for rejection of the excited mode (zero mode) signal to increase the detection sensitivity of the pi mode signal.**





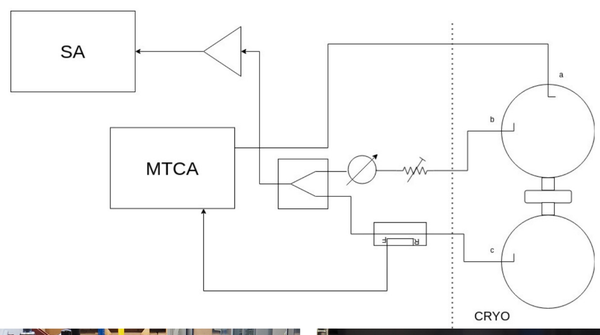
Schematic of the CSI module for the MAGO cavity.

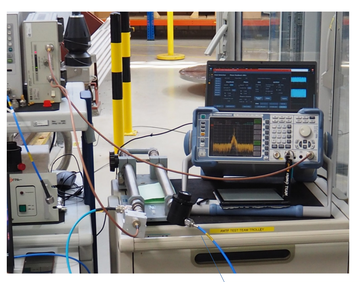
CSI Setup for the MAGO Project



Complete LLRF setup of the MAGO project

- **Zero mode excitation of the cavity is important for the generation of GW signal. So that, detuning of the cavity also should be taken to account.**
- **In the first cold test of the cavity, MTCA based digital self excited loop used as resonance tracker.**
- **Bandwidth of the drive signal should be narrower than the bandwidth of the cavity for the noise free suppression of the output signal of the MAGO cavity. And resonance tracker should not add phase noise to the input signal.**
- **Signal extraction setup consists of three main different stage. First stage prevents excitation of the pi mode, second stage is for suppression of the carrier and last stage is for rejection for the residual noise and amplification of the GW signal.**

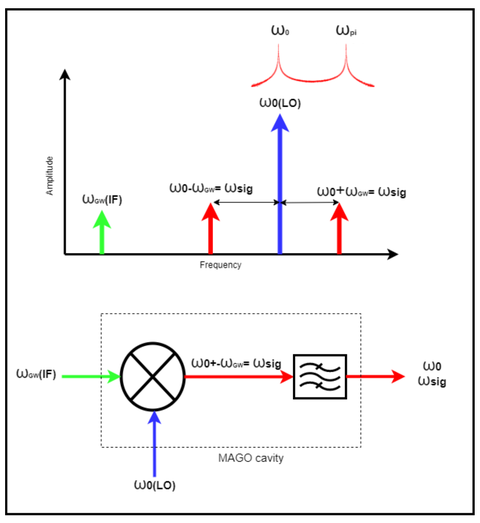




Mode rejection test setup (First 4K test of the cavity)

Principle of the Detection

- **MAGO cavity consists of weak coupling of the two identical spherical cells. Coupling of the two cells causes a split in the resonance frequency. (Zero and pi mode)**
- **Resonant behaviour of the cavity is similar to coupled pendulums.**
- **Since working principle relies on heterodyne detection, MAGO cavity acts like an RF mixer and band pass filter.**
- **When the GW interacts with the cavity, frequency of the GW causes harmonic generation around the zero mode frequency.**
- **Pi mode of the cavity filters out the lower harmonic and only allows the passage of the higher harmonic. GW signal appears on pi mode frequency of the cavity.**
- **Reception frequency can be tuned by changing the coupling between the cells (Coupling changes the band gap between modes) .**



Extraction of the GW Signal

- **To detect the signal on the pi mode, excitation caused by the phase noise of the zero mode signal should be suppressed.**
- **To prevent the accidental excitation of the pi mode cavity should feed from both feed antennas with the same phase. Because of the anti-symmetric phase behaviour between the modes, equal phase feed will cancel out the pi mode excitation.(in ideal case)**
- **CSI suppresses the pump (zero mode) signal and lowers the level of the noise floor. This increases the detection sensitivity of the setup by revealing the actual amplitude of the GW signal.**

Because of the narrow band gap between the resonant modes of the cavity, phase noise of the zero mode signal increases the noise floor of the measurement. This issue also can cause unwanted excitation on pi mode.