FLASH-WP4

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WP4

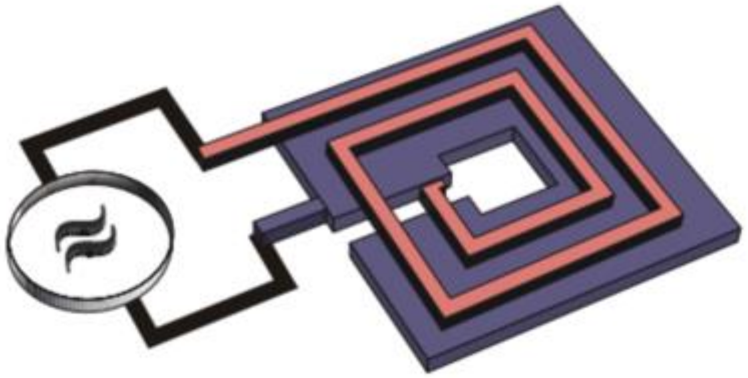
- WP4 “Signal Amplification and acquisition”:
  - The focus is on the development and testing of the system responsible for the acquisition and processing of signals within the experiment. The primary objective is to ensure that FLASH can detect the faint signals generated by the conversion of axions into photons, distinguishing them from background noise.

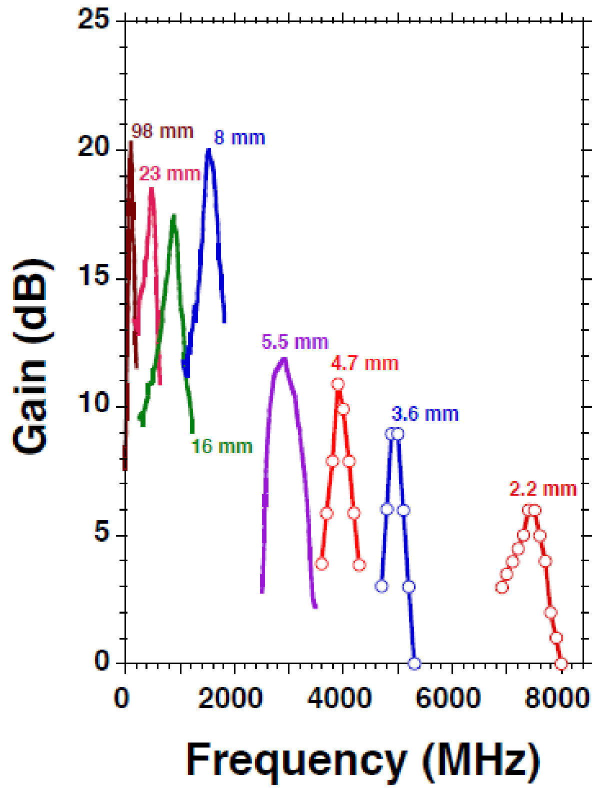
Main tasks of WP4

- **Characterization of MSA Amplifiers**: The MSA (Microstrip SQUID Amplifier) devices, serving as the first amplification stage in FLASH, require thorough characterization in terms of gain, bandwidth, and noise at cryogenic temperatures (down to 300 mK).
- **Validation of MSA Amplifiers Under Operating Conditions**: The performance of MSA amplifiers must be verified under the strong magnetic field of FLASH and with a resonant input load simulating the cavity.
- **Development of a Secondary Amplification Chain**: Following the MSA stage, the signal requires further amplification, both at low temperatures and at room temperature.
- **Design of the Digitization and Data Acquisition System**: To enable analysis, the amplified signal must be digitized and acquired.
- **Definition of the Calibration Procedure**: Developing a calibration procedure is essential to accurately measure system parameters and characterize noise.

MSA

- Microstrip Squid Amplifier
  - Used by ADMX as first amplification stage in the range 812 to 860 MHz
- The gain depends on the operating frequency and the frequency depends on the length of the microstrip resonator
  - About 20 dB@1GHz
- The noise temperature scales linearly with the operation frequency and the bath temperature

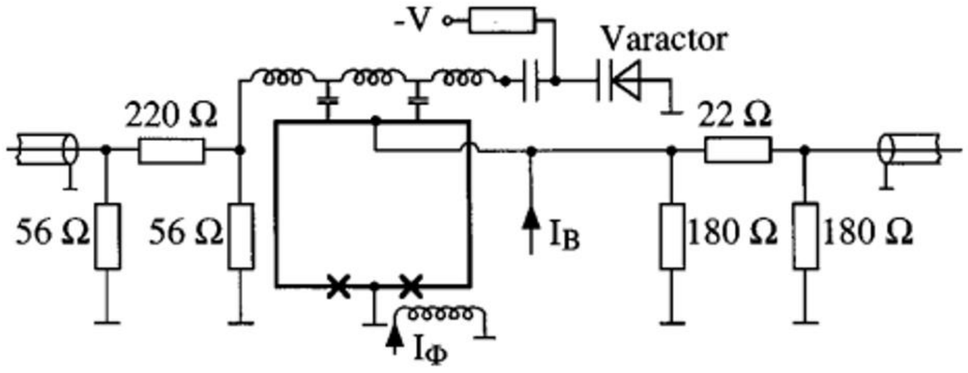


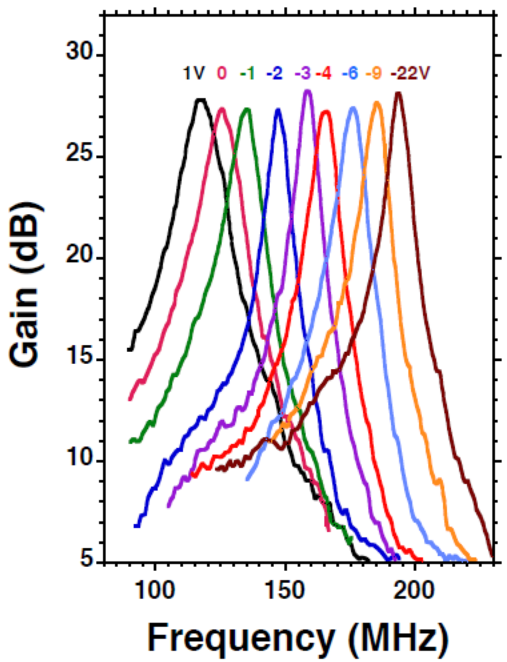


MSA in FLASH wrt ADMX

- Lower and wider frequency range: from 117 to 360 MHz
- Higher temperature (eventually): 4 K or 1.9 K
  - Possibility to use a smaller cryostate to operate the MSA
- Different magnetic field shielding
  - ADMX squid is outside the magnetic filed and Helmotz coils and superconducting shield are used
- Possibility of readout different resonant modes in the cavity (detection of HFGW and BAW readout)
  - Not used in ADMX

Use of a varactor diode

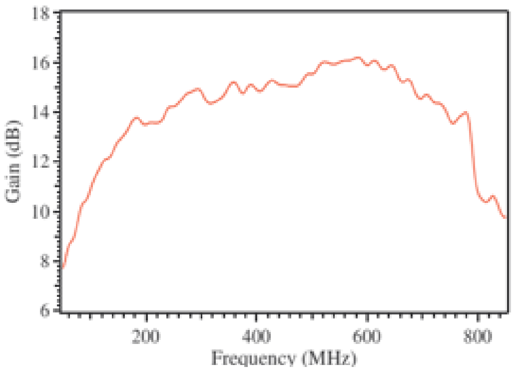




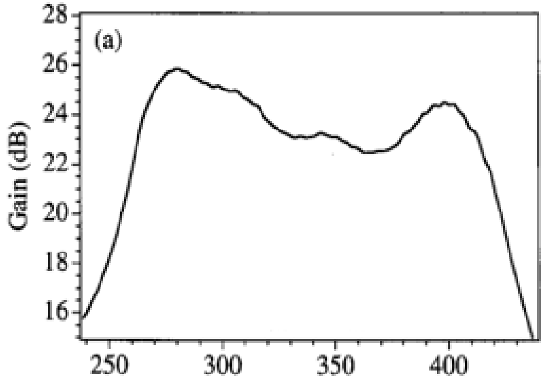
- The capacity of a varactor diode varies with the applied voltage.
- With an MSA, the varactor diode's capacitance affects the resonance frequency of the amplifier.
- By adjusting the bias voltage of the diode, the resonance frequency of the MSA can be tuned, allowing it to cover a broader frequency range.
- The varactor diode introduces additional noise that should be carefully evaluated

Possibility to have a larger bandwidth

- Alternative to the use of the varactor diode (or in addition to the varactor diode)
  - Change the MSA design: lower input inductance, higher microstrip impedance → but we prefere to use commercial MSA
  - Use MSA with lower Q resonator → lower gain, higher bandwidth
  - Use a cascade of MSA tuned at different frequencies: relevant for the multiple frequency acquisition (see HFGW)
  - The possibility to exchange the MSA without warming-up the cryostate will be evaluated (at least for large axions mass scan)



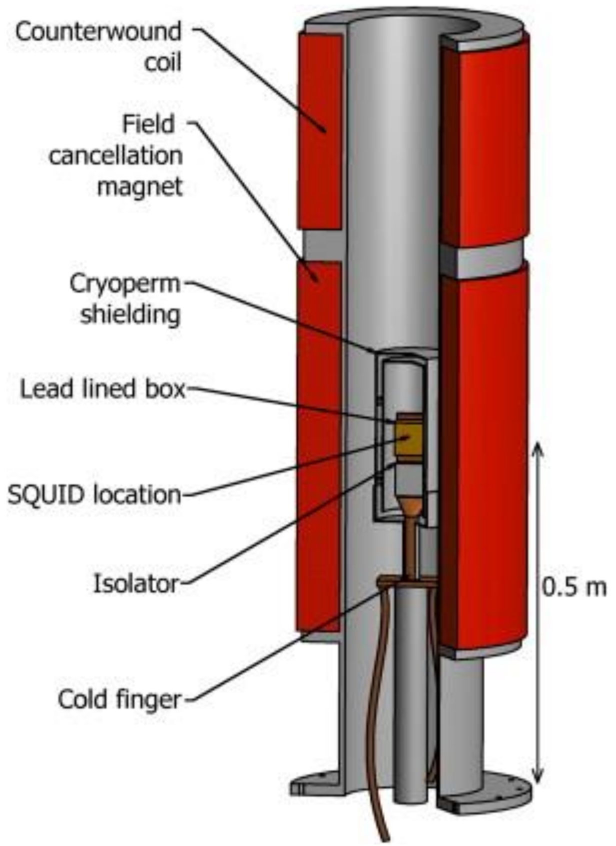
A broad bandwidth can be obtained with a lower quality factor of the resonator but at the expense of a lower gain



A broad bandwidth can be obtained with a second MSA as a postamplifier. Here the resonance frequencies of the first and second amplifiers were about 280 and 400 MHz, respectively.

Magnetic shielding

- Both dc-Squid and MSA are very sensitive to magnetic field
- Passive approach: high-permeability materials (mu metals) and/or superconducting sheets
- Active approach: use a superconducting magnet cooled in a Zero field condition or a normal magnet Helmotz coil
- In FLASH the magnetic field will be 1.1 T, but the effective field in the SQUID region must be << 1 Gauss



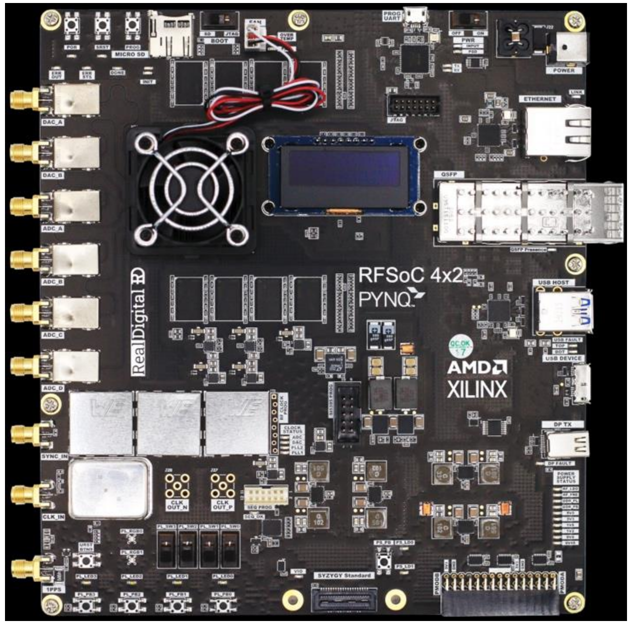
ADMX shield

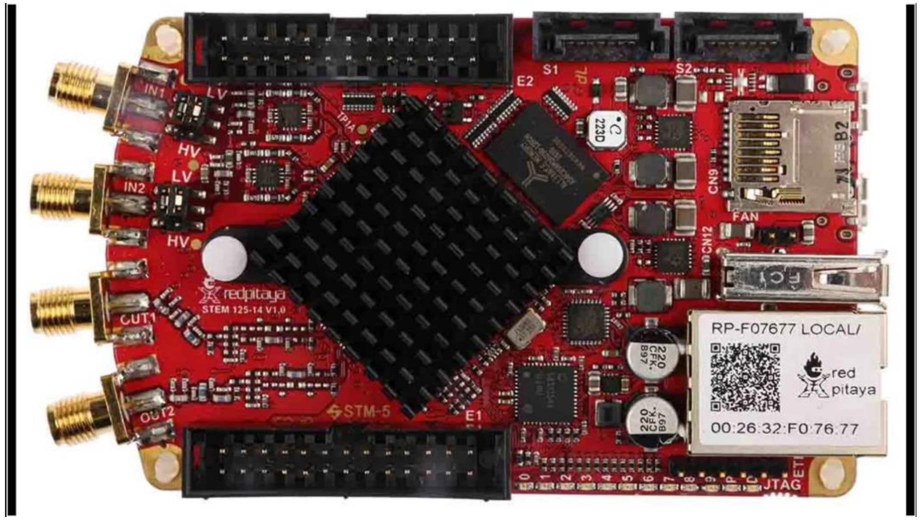
Room temperature amplification and signal acquisition

- In the cold section a further commercial HEMT will be use to have a gain > 35 dB
- Thanks to the low noise in the first stage, the noise in the room temperature section isn't an issue: 150K noise temperature from commercial amplifiers is accettable
- In any case low insertion loss components will be required
- Noise control and acquisition bandwidth considerations will be evaluated for the (eventual) down conversion stage
- A custom multiplexing acquisition system will be designed according to the solution adopted in the previous stage

Multiplexing and digitization

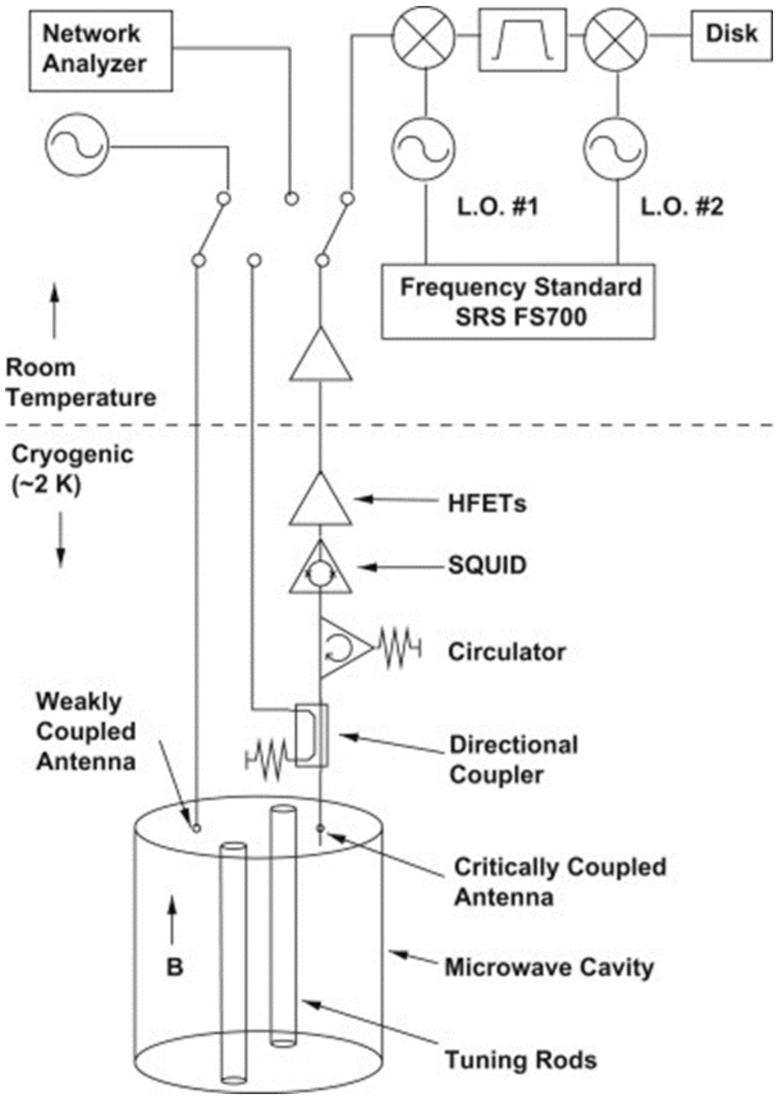
- Both commercial fast FFT solution and RFSoc FPGA with high-end digitizer board will be considered for signal digitization
- Even if more complex the second solution will give us the possibility to implement control algorithms directly on-line to reduce the data bandwidth and the data storage requirements
- In the custom solution the multiplexing stage can be directly integrated in the acquisition board without further levels
- The multiplexing acquisition will be crucial for the HFGW program, for the BAW readout and for the readout of the piezoaxionic crystals





Summary

- WP4 tasks:
  - 4.1: MSA Configuration
  - 4.2: Stability
  - 4.3: Postamplifier
  - 4.4: Magnetic Shielding
  - 4.5: Multiplexing
  - 4.6: Replacement of the MSA
  - 4.7: Secondary amplification and down conversion chain
  - 4.8: Digitization and data acquisition
  - 4.9: Full test of amplification chain with BAW resonator
- Groups involved (in the proposal): TIFPA/Trento, Pisa, Camerino, LNF, Bonn/Mainz



WP4 participant activity

LNF: Evaluating the amplification and acquisition chain in magnetic field with the Camerino group, determining the optimal magnetic field shield, and developing the FPGA firmware for DAQ

University of Camerino: Characterization of the MSA in a 1.1 T magnetic field as in the final experimental setup. The MSA will be appropriately shielded and tested in a cryostat reaching 1.5 K and magnetic field up to 12 T. MSA gain and noise temperature measurements vs operation frequency and temperature

Pisa University and INFN: MSA used in a multiplexed mode, secondary amplification chain, and the DAQ procedure. Same acquisition chain for reading signals from Bulk Acoustic Resonators (BAW) and, potentially, piezo axionic crystals

TIFPA Trento: Characterization in terms of gain, bandwidth and noise down to ultracriogenic temperatures of MSA amplification systems

University of Bonn and University of Mainz: design and construction of prototype cavities, design of DAQ, the subsequent data-analysis and the reinterpretation of the FLASH results in the context of High Frequency Gravitational Waves