White Rabbit FMC mezzanine as an interface for the new 10G WR-NIC to remote WR DAQ nodes

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Outline

Intro

The physics case: timing and data acquisition in GW experiments

The White Rabbit project

A well defined technology, highly attractive for the GW community

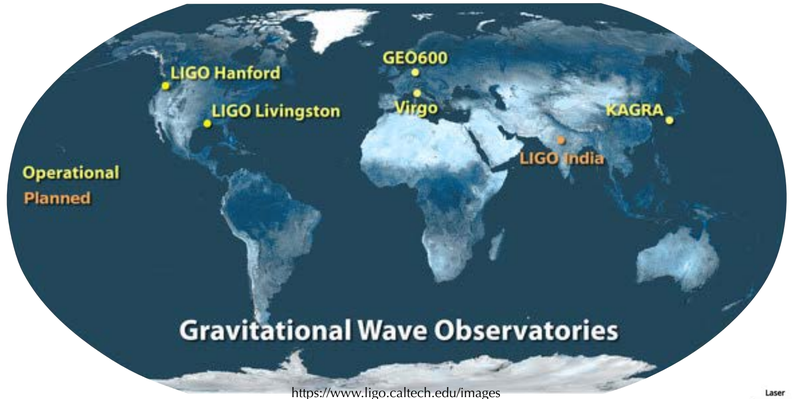
The Air-Plane FMC mezzanine project for the next 10G White Rabbit

Proposal and plan

Summary and conclusion

Current and future GW experiments

A glance at Virgo and Einstein Telescope



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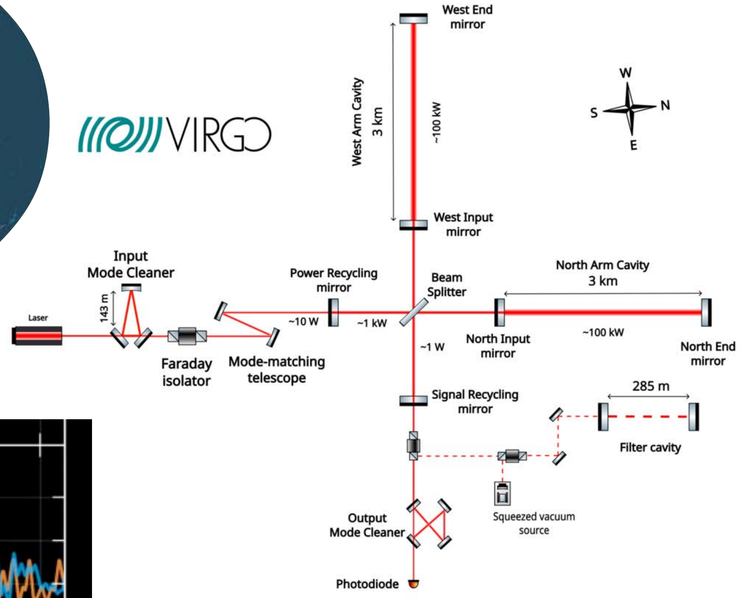
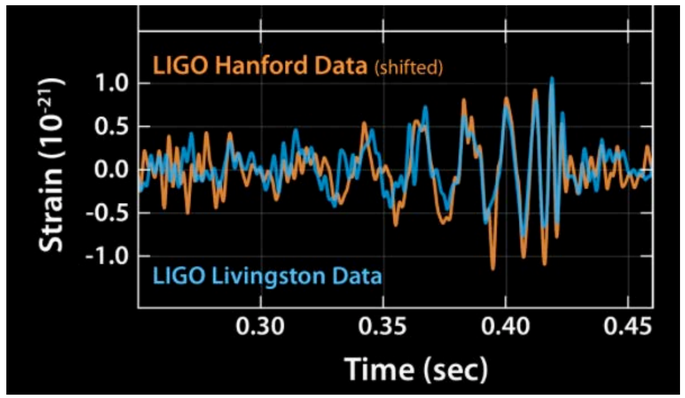
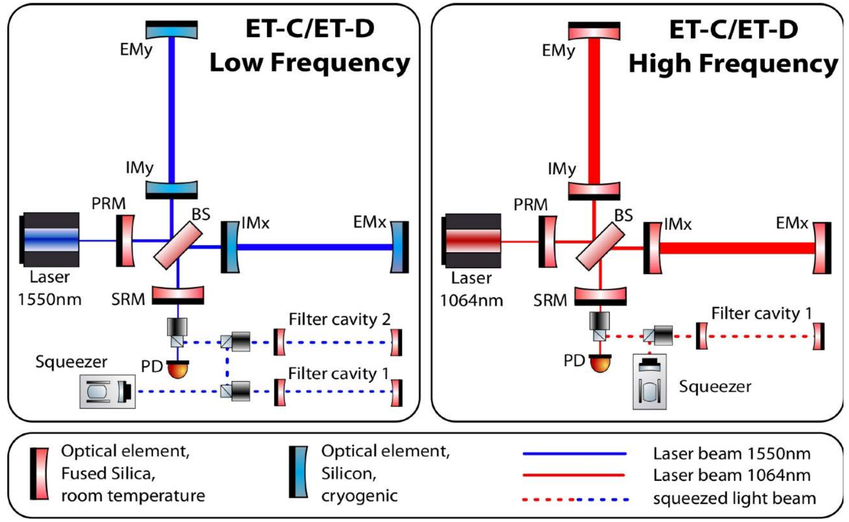
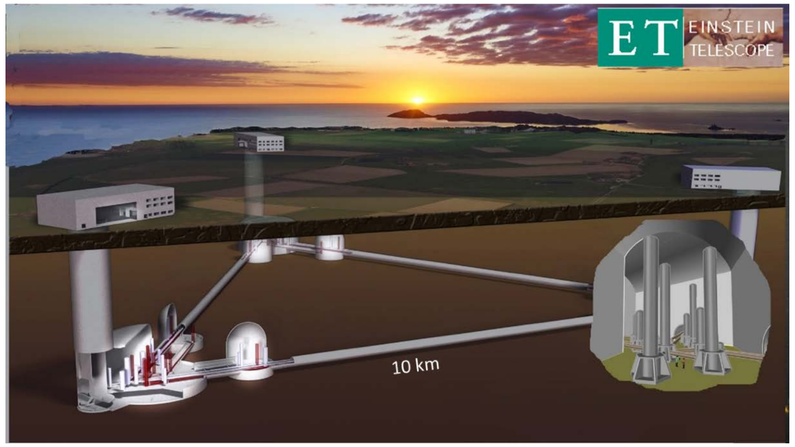






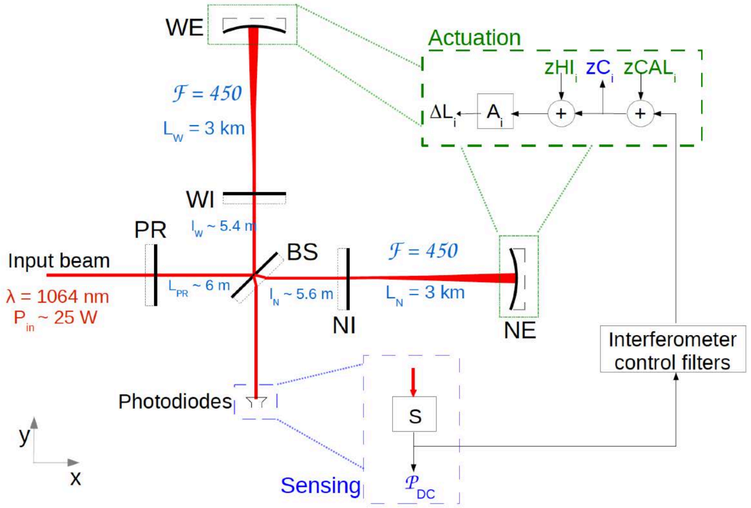


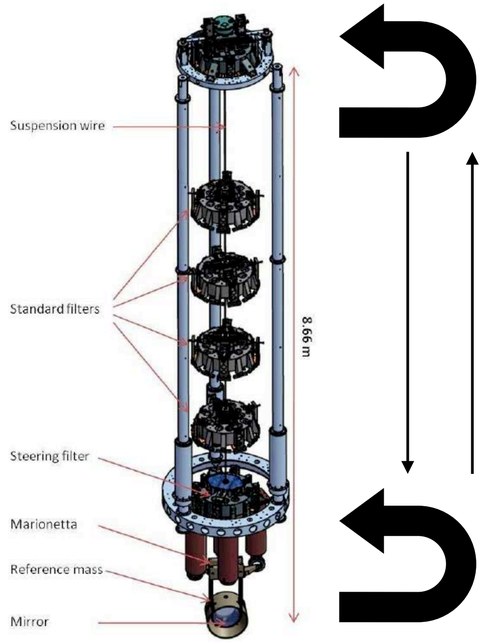
Timing in GW experiments

Absolute, for control loops and for fast sampling

Timing

- Synchronization with others GW observatories (coincidences) and for Multi-messenger analysis require absolute timing of the order of few us
- Control: for Advanced VIRGO the absolute timing precision must be of the order of 0.01 ms or less; ET is expected to be better than 1 us
- Fast sampling: digital demodulation with fast ADCs (~ 500 Msps) with a timing jitter at the level of 1 ps or better





Superattenuator Low-latency fast control loops

Data acquisition in GW experiments

Bandwidth and latency

- Data produced not a big issue

  Virgo: ~1 PB/year - ET: expected ~10x (LHC experiments are ~100x!)

- Bandwidth could be dominated by peak data rate

  Virgo DAQ uses 1.6 Gb/s link - update to 2.5 Gb/s is ongoing

  Virgo Superattenuators Control Cards exchange data @ 2x ~700 Mb/s : will raw data recording be needed or more data to wider loops?

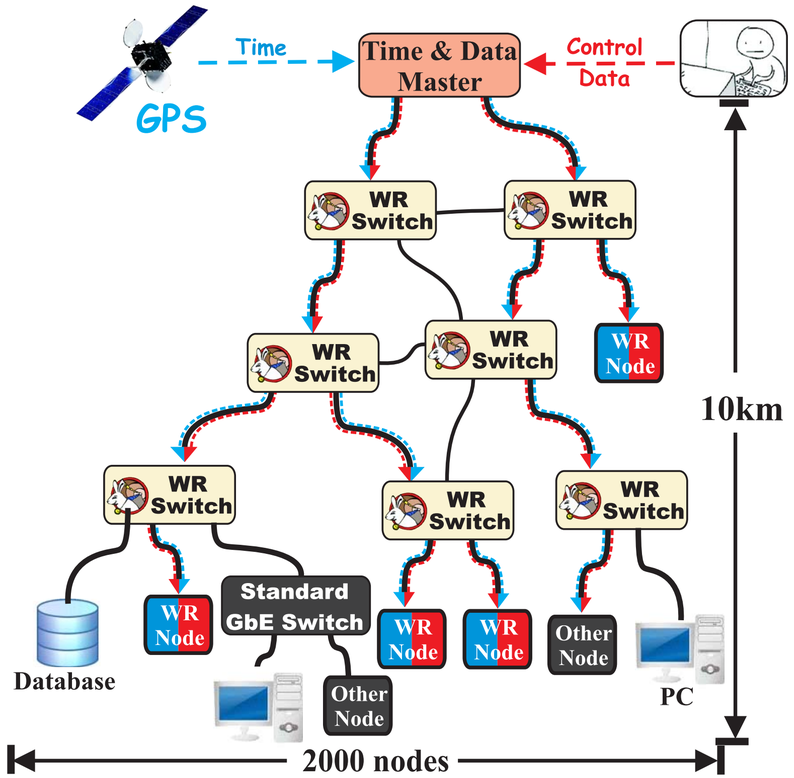
- Latency: ~us

=> ~10 Gb/s links for DAQ

White Rabbit

An open source project

- Initially developed by CERN community; recently the WR Collaboration has been established
- Synchronization with sub-nanosecond accuracy and picoseconds precision
- Typical distances of 10 km between network elements
- Gigabit rate of data transfer (data and synch use the same network)
- A set of open-source basic blocks, WR Switches and WR Nodes interconnected, to create a network.



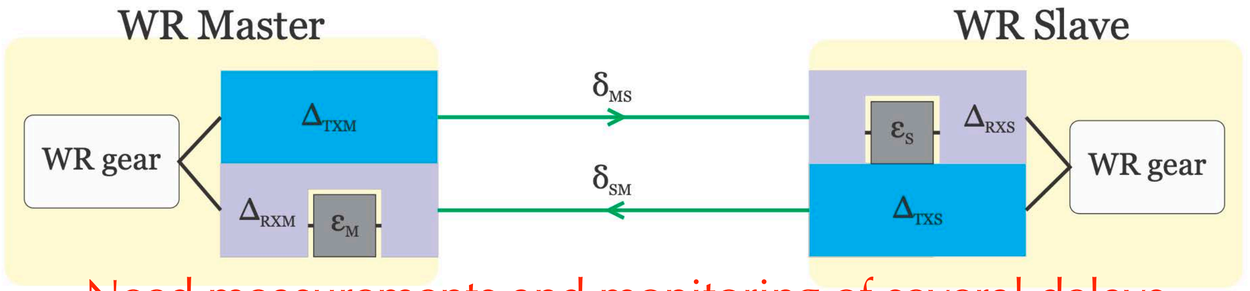
White Rabbit

Current technology (1GbE), next?

Key elements

- Precision Time Protocol (IEEE1588)
- Syntonization (SyncE)
- Phase measurement
- Calibration (link dependent)

Hw-dependent



Need measurements and monitoring of several delays

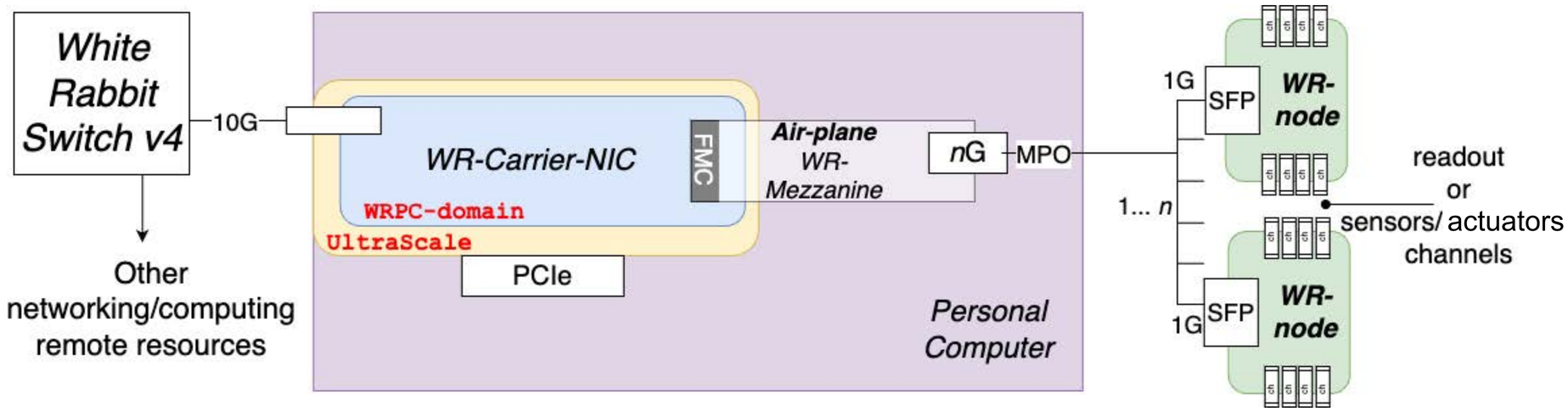
=> moving to 10 GbE requires new hardware, firmware and software!

The Air-Plain Project

Target and Overview

- Develop a FMC mezzanine to transform the 10 GbE PCIe network interface cards into hubs for WR-based external devices (and no-WR too)

- Remote DAQ low-cost electronics boards (with specific sensors/actuators) can become WR Nodes interfaced with the new 10Gb/s network.



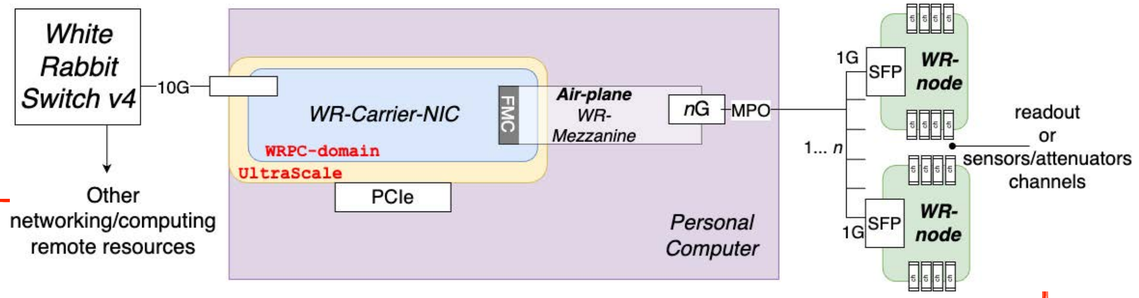
The Air-Plane project

Potential application for Einstein Telescope

- INFN-Bologna and Perugia are going to design a set of low-cost electronic boards for versatile management and readout of the most common sensors or actuators;
  - ➡ Will be WR compliant
  - ➡ Used for standalone test benches (e.g. for R&D on squeezing) as well as in the Italian CAOS infrastructure;
- INFN-Bologna is joining a R&D INFN-Pisa project, proposed as a Real-Time Control System for Superattenuators, to add WR compatibility .

The Air-Plane design roadmap

Proposal



- Define a proper fiber optics layout;
- Scale the number of remote nodes to be connected through 1 GbE;
- Define the electronics requirements and components;
- Define the appropriate firmware/hardware protocol for interfacing a FMC mezzanine with the main processing device (FPGA) of the 10 GbE hosting NIC;

Define design open issues

- Design the FMC mezzanine;
- Design at least 2 different types of WR Node prototypes compliant to specific experiment needs;
- Design a customized firmware version running on the main processing device of the hosting card to read/write/control remote WR Nodes;
- Test the system with at least 5 WR Nodes;
- Verify DAQ functionalities and synchronization between nodes and NIC card.

Prototyping

Summary and Conclusion

Present and future

- White Rabbit technology is of interested for timing and data acquisition for current 2G and future 3G GW experiments
- GW detectors can be interested in the development of White Rabbit 10G technology
- The Air-Plane FMC mezzanine aims to transform the 10 GbE PCIe network interface cards into hubs for WR-based external devices
- The project plan has been defined and funds scouting is ongoing
  - Submitted to the HORIZON-INFRA-2024-TECH-01-01 call
  - Institutional funding is going to be review

Additional Material

KM3NeT: a White Rabbit applications in Astrophysics

- KM3NeT is the next-generation neutrino telescope which is currently under installation phase in the Mediterranean Sea. It is aimed at detecting particles from both galactic and intergalactic sources. The detector will consist of arrays of optical modules aligned in vertical strings, collecting Cherenkov photons.

- A custom WR implementation will be adopted to synchronize the optical detection modules, spread on a ~km3 volume, with a precision of less than one nanosecond. The WR network will consist of custom electronics on the offshore nodes and WR Switches at the onshore stations, organized in layers with different functionality.