T 95: Gravitational waves 1

Time: Thursday 16:00–18:00 Location: Geb. 30.23: 6/1

T 95.1 Thu 16:00 Geb. 30.23: 6/1

A superconducting cavity for the SUPAX experiment — •Tim Schneemann, Kristof Schmieden, and Matthias Schott — Johannes Gutenberg-Universität Mainz

The SUPAX experiment is one of the first RF cavity based haloscope experiments in Germany to search for axions and dark photons as well as high frequency gravitational waves. A proof-of-concept analysis was presented in summer 2023. Our ongoing effort, within the RADES collaboration, is now focused on developing a tuning mechanism of the RF cavity's resonance frequency without the need of tuning rods as well as improving the quality factor Q_0 within a magnetic field of up to 14 T. The quality factor of a resonant system like an RF cavity is a measure of the energy losses, determining the resonance amplification of a signal. Since it mainly depends on the surface resistance of the cavity material superconducting surfaces should yield a boost in Q_0, directly resulting in an increased sensitivity.

Currently superconducting REBCO or YBCO tapes yield the best results. These layered tapes have a very high critical magnetic field, making them suitable for axion searches where the cavity is inside a strong magnetic field. However, they are very sensitive to any kind of curvature in the surface they are applied to. We are presenting a different approach, using a cavity coated with NbN, a superconductor with a high critical magnetic field of $\mathcal{O}(10\ \mathrm{T})$ which does not have any constraints on surface curvature. In this talk the production and coating process, characterization of the coated cavity and expected improvement on sensitivity will be presented.

T 95.2 Thu 16:15 Geb. 30.23: 6/1

Ultra high-frequency Gravitational Waves as Messengers of New Physics — •Lars Fischer[1], Tom Krokotsch[1], Gudrid Moortgat-Pick[1,2], Michel Paulsen[1], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Gravitational wave searches have been strongly motivated for frequencies below $\mathcal{O}(10\ \mathrm{kHz})$. However, Standard Model and beyond Standard Model sources for gravitational waves (GW) could also emit at high (kHz-MHz) and ultra high-frequencies (MHz-GHz). But current state of the art GW detector technologies are not capable of pushing their sensitivities to frequencies above $\mathcal{O}(10\ \mathrm{kHz})$. New detection concepts are thus needed to set upper limits for cosmological models or to find evidence for sources beyond the Standard Model.

Superconducting radio frequency (SRF) cavities as precise quantized electromagnetic systems are well suited to probe interactions between GW and photons in the MHz to GHz regime. Although sources at ultra high-frequencies impose new challenges on this detector concept, observed signals would provide evidence for physics beyond the Standard Model or for a cosmic gravitational microwave background. A search strategy in this regime could aim for exotic compact objects or be optimized for the detection of cosmological GW backgrounds, from e.g. additional scalar fields.

This talk will emphasise the opportunities of GW search at ultra high-frequencies for particle physics and make a connection between GW-photon interactions and SRF cavity detectors.

T 95.3 Thu 16:30 Geb. 30.23: 6/1

Gravitational Wave Detection with SRF-Cavities — •Michel Paulsen[1], Tom Krokotsch[1], Lars Fischer[1], Gudrid Moortgat-Pick[1,2], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Superconducting radio frequency (SRF) cavities, initially developed for particle accelerators, have recently (re-)emerged as some of the most promising tools for high precision measurements. In particular, they can be used to search for axion-like particles but also for gravitational waves (GWs) in previously uncharted frequency ranges.

Even before the first measurements of GWs by VIRGO and LIGO, there were already concepts for measuring GWs with SRF cavities in the so called MAGO project.

In addition to its compactness compared to laser interferometers, this concept is motivated by particularly high sensitivity to GWs in the kHz range up to the GHz range. This could lead to the confirmation of predictions from particle physics and cosmology.

The focus of this talk will be on the concept of 'heterodyne GW detection' with SRF cavities and presenting the work we have done so far on an existing prototype. I will also take a look at the future direction of the project.

T 95.4 Thu 16:45 Geb. 30.23: 6/1

Particle Physics Prospects of High Frequency Gravitational Wave Detection — •Tom Krokotsch[1], Lars Fischer[1], Gudrid Moortgat-Pick[1,2], Michel Paulsen[1], Krisztian Peters[2], and Marc Wenskat[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Deutsches Elektronen Synchrotron DESY, Hamburg, Germany

Gravitational wave searches so far have mainly focused on frequencies lower than kHz. However, expanding the search to higher frequencies will open an entirely new window for physics beyond the standard model and dark matter research.

Electromagnetic cavities are particularly sensitive to mechanical deformations caused by gravitational waves in the kHz to MHz regime. A detector based on this concept could search for primordial black holes as dark matter candidates or for novel scalar bosons like axions through the effect of black hole superradiance. Additionally, new exclusion limits could be set on further non-coherent gravitational wave sources.

The aim of this talk is to make a case for high frequency gravitational wave detection with superconducting radio frequency cavities and highlight the opportunities it brings for future particle physics.

T 95.5 Thu 17:00 Geb. 30.23: 6/1

Composite Vacuum Tubes and Distributed Pumping for the Einstein Telescope — •Charlotte Benning[1], Robert Joppe[1], Tim Kuhlbusch[1], Oliver Pooth[1], Purnalingam Revathi[1], Ralf Schleichert[2], and Achim Stahl[1] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Institut für Kernphysik, Forschungszentrum Jülich GmbH

The Einstein Telescope will be the first gravitational wave detector of the third generation. It requires about 120 km of vacuum tubes with a diameter of 1 m to achieve the design sensitivity and reduce scattered light. The pressure inside the tubes needs to be 10^{-11} mbar to minimize the residual gas noise. Stainless steel tubes are currently the standard for ultra-high vacuum applications due to the vacuum requirements and mechanical integrity. Reducing the thickness of stainless steel would reduce vacuum firing costs and also help in logistics and assembly underground. Therefore, the concept of composite tubes with an outer glass fiber-reinforced epoxy shell is explored. The distributed pumping system needed to achieve the design vacuum levels will be a significant cost factor. Integrating getter surfaces into the inside of the tubes promises a cheaper and more homogeneous distribution of pumping power. This talk gives an overview of the development and testing of composite tubes and provides an introduction to distributed pumping.

T 95.6 Thu 17:15 Geb. 30.23: 6/1

Methods to reduce Low-Frequency Noise of Wind Turbines for the Einstein Telescope — Marc Boxberg[2], •Tom Niggemann[1], Niklas Nippe[1], Achim Stahl[1], and Florian Wagner[2] — [1]III. Physikalisches Institut B RWTH Aachen — [2]Geophysical Imaging and Monitoring RWTH Aachen

Seismic vibrations from nearby wind turbines are expected to be a significant noise source in the Einstein Telescope, a future third-generation gravitational wave detector in Europe. Direct and gravitational couplings are a limiting factor for detection of gravitational waves in the low-frequency range. This talk will discuss and evaluate methods to produce less vibrations in the first place and to reduce their coupling to the ground. Measurements of the vibrations from different types of wind turbines will be explicated.

T 95.7 Thu 17:30 Geb. 30.23: 6/1

Characterizing the Seismic Impact of Wind Turbines on the Einstein Telescope — Marc Boxberg[2], Tom Niggemann[1], •Niklas Nippe[1], Achim Stahl[1], and Florian Wagner[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Geophysical Imaging and Monitoring, RWTH Aachen

Knowing the seismic impact of nearby wind turbines is crucial for future gravitational wave detectors like the Einstein Telescope. In the low frequency regime, seismic and gravity gradient noise are the dominant effects impacting the sensitivity. Vibrations of nearby wind turbines are expected to be significant contributions. A deep understanding of these vibrations and the coupling into the ground are necessary to define buffer zones around the detector. I will present measurements of seismic noise at the Einstein Telescope candidate site close to Aachen and their impact on the definition of buffer zones.

T 95.8 Thu 17:45 Geb. 30.23: 6/1

Seismometer Position Optimization for Newtonian Noise Mitigation in the Einstein Telescope — •Patrick Schillings and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise in the detector. To achieve that, an array of seismometers will be installed around the mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonain noise from the seismometer data. In this talk, I will focus on methods for the optimization of such an array.