Bachelor/Master's Thesis

The Einstein Telescope (ET) is a proposed underground infrastructure to host a third-generation, gravitational-wave observatory. It will achieve greatly improved sensitivity by increasing the size and implementing new technologies. In line with ET, the ECAP/work group of Stefan Funk takes an active part in developing a conceptual new phase camera, as a tool for monitoring and shaping the laser beam in the interferometer. Via heterodyne detection, the interference of two to each other detuned lasers, the phase camera is able to measure the spatial phase and amplitude of a wavefront for each radio frequency component simultaneously. A novel feature is the introduction of a 2D image sensor in form of a multimode fibre array.

Proposed thesis topics

- Noise hunting in the optical setup
- Development of a scanning configuration for a 1D camera setup
- Higher order mode decomposition with deep-learning

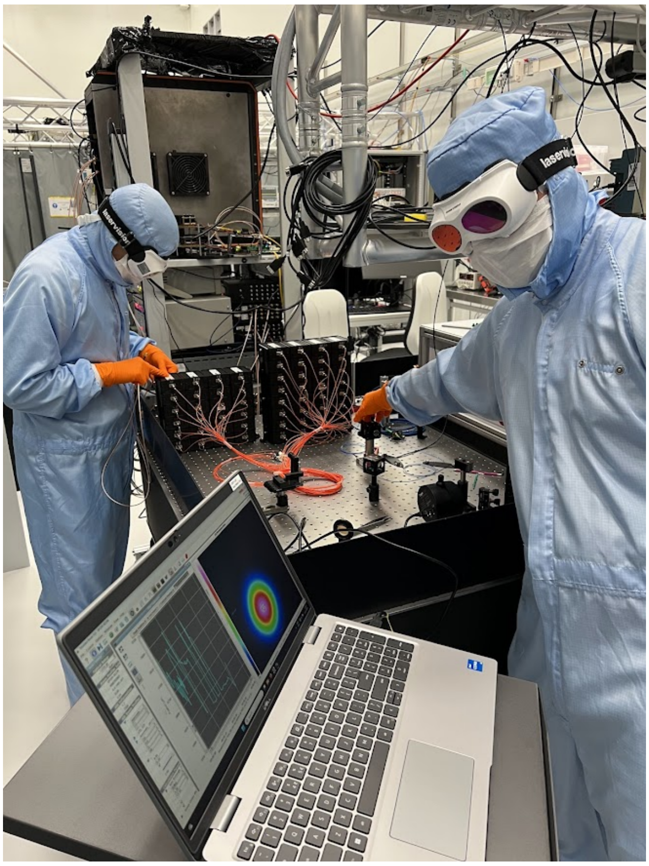

Image taken by Stefan Hild at the ET Pathfinder

Physics topics related to this work

- Gravitational-wave observatories
- Optics
- State-of-the-art electronics

Skills acquired during this work

- Hands-on lab experience
- Statistical analysis of data
- Programming in Python

Interested? Please get in touch!

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Erlangen Centre for Astroparticle Physics

Bachelor/Master's Thesis

Noise hunting in the optical setup

The ECAP fiber based phase camera is a precision instrument capable of detecting phase differences on nanometer scale. It uses a heterodyning technique, comparing the phase of the interferometer wavefront with a reference wavefront. With this precision it also susceptible to all sorts of acoustic, thermal and vibrational noise of the auxiliary optics needed for measurement. This leads to unwanted phase changes unrelated to the interferometer, decreasing the accuracy of the phase images. The goal of the thesis is to find to routines to characterise these noise sources and to eliminate them in the lab as on the ET Pathfinder site.

Development of a scanning configuration for a 1D camera setup

Fast sampling and digitisation (500MSa/s) is expensive. Instead of building a 2D pixel array, we also plan to build an 1D setup which the laser beam scans across, squaring the number of available pixel from 64 to 4096. To then generate a 2D image, one must precisely know the position of the beam at anytime. The goal is to build and test a setup to characterise a suitable Piezo mirror that can handle frequencies up to several kHz and then to synchronise it with the data taking of the camera. Due to the scanning process, image artefacts will be introduced which need to be characterised and tested, if they restrict the phase resolution of the camera.

Physics topics related to this work

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- Optics
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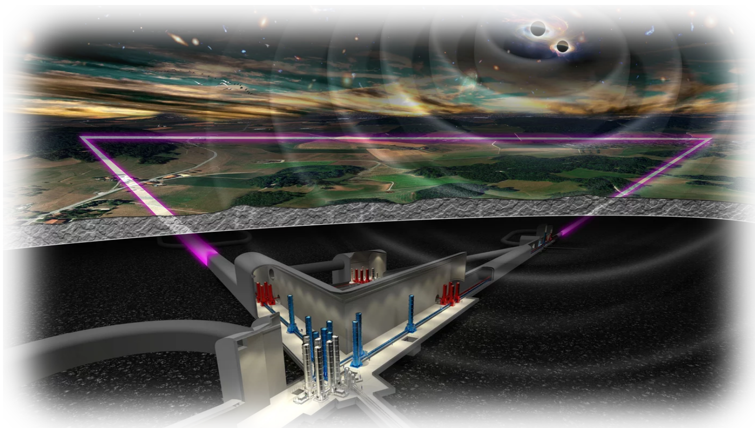

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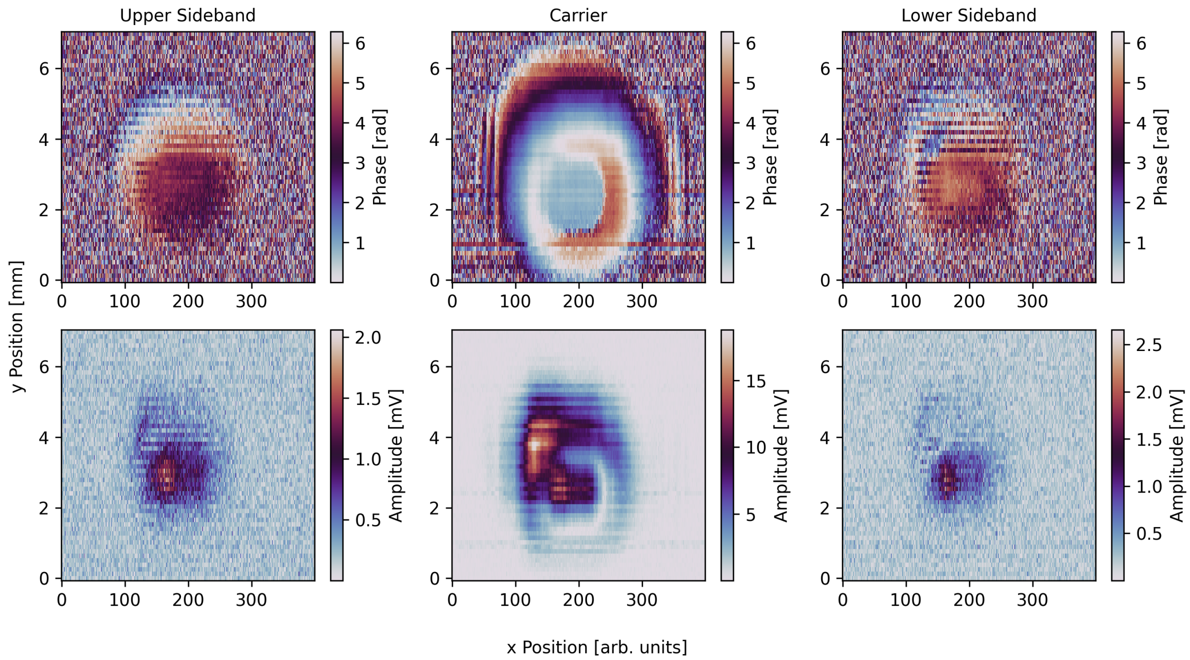
Bachelor/Master's Thesis

Higher order mode decomposition with deep-learning

To explain the detection of gravitational waves with laser interferometers, one always illustrates the beam as perfectly interfered sinewaves. In reality, the beam has a curved 2D wavefront that can be perturbed by thermal lensing, mirror surface roughness, or misalignment for example. These perturbations can best be described by the rise of higher order mode terms and can lead to optical instabilities in the interferometer. The primary goal of the phase camera is to measure the mode content for each sideband individually, to find the source of these perturbations. Traditional methods for mode decomposition as 2D fits are reliably but computational intensive. A proven alternative is the implementation of deep-learning methods, which shall be explored for the case of the phase camera.



Individual phase and amplitude images for each radio frequency component in the laser beam. Only the carrier shows higher mode content

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