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GW strain calibration of LIGO detectors with high precision and low latency

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ABSTRACT

The detection of gravitational waves (GW) has opened a new era of astrophysical observation, allowing scientists to view and analyze previously unseen phenomena. This process hinges upon measuring the strain $\Delta L/L$ of space over 4 km long baselines, which change by a differential arm (DARM) length on the order of 10^{-20} meters when a GW passes. From this information-rich time series, a wealth of astrophysical information may be deduced. In order to produce a reliable estimate of the strain, the Laser Interferometer Gravitational Wave Observatory (LIGO) detectors must be precisely calibrated. Furthermore, the calibration pipeline must produce an associated calibration uncertainty estimate with which to characterize the strain. While uncertainty estimates can currently be produced with low latency, it takes months to investigate the sources of error and verify the quality of calibration. Producing a high precision, low latency uncertainty estimate and a diagnostic monitoring software is therefore crucial for LIGO's fourth observing run (O4). It is this task that forms the basis of this research project. The uncertainty estimation and monitoring software are to be produced using pyDARM, a python package which implements the DARM control loop model and is currently under development. The software must reliably output uncertainty estimates and a suite of diagnostic plots on the timescale of an hour. It will actively be of use in O4.