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From frequency to time domain, modeling non-linear effects in gravitational wave interferometers

Next-generation gravitational wave detectors like the Einstein Telescope face new challenges that require advanced simulation tools capable of capturing both linear and non-linear effects. Although frequency-domain models offer valuable insights into linear processes, they fall short when addressing the complex non-linearities inherent in these systems. Given the computational intensity of full time-domain simulations, this work explores alternative methods to model non-linear effects, focusing on the non-linear angle-to-length coupling and cavity power dynamics, by contrasting quasi-static, digital filter, and full time-domain approaches. This analysis clarifies the conditions under which each method is most appropriate and helps lay the groundwork for further exploration of simulation strategies for future detectors.

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