A plug-and-play solution for optical frequency comparisons over free-space

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Optical clock networks linked by phase-coherent connections offer tremendous potential for both fundamental physics and practical applications in various scientific fields[1]. Optical frequency transfer over free-space links enables the expansion of fiber-based connection capabilities to access remote locations and, using satellites, span global distances[2].

In this work, we present a transportable rack-integrated configuration designed for optical frequency comparisons over free space. The rack comprises the two-way optical setup and electronics for signal processing. Engineered to be compact and durable, the rack is ideal for field experiments. Moreover, its plug-and-play capability enables seamless interfacing with other systems via a single-mode fiber patch cable, facilitating effortless integration into diverse optical systems.

To assess its performance, we conducted a measurement campaign over a free-space testbed in Jena with two mobile optical terminals separated by a 1.7 km free-space link[3]. Our portable rack was linked to the local optical terminal, utilizing the on-site beam stabilization system. A fiber-optic reflector was located at the remote site, creating a fully folded free-space link of 3.4 km.

Figure 1 shows power spectral density (PSD) over the 3.4 km free-space link. With the stabilization system, a reduction of eight orders of magnitude in phase noise PSD at 1 Hz is observed, decreasing to 3.4×10^{-7} rad^2/Hz. When comparing the measured free-space link data to the calculated link delay noise, the observed nonreciprocity of the free-space link is not limited by the turbulent phase noise, but other potential limitations like amplitude-to-phase modulation (AM-PM). Ongoing data analysis is currently being conducted to identify the limiting factors.

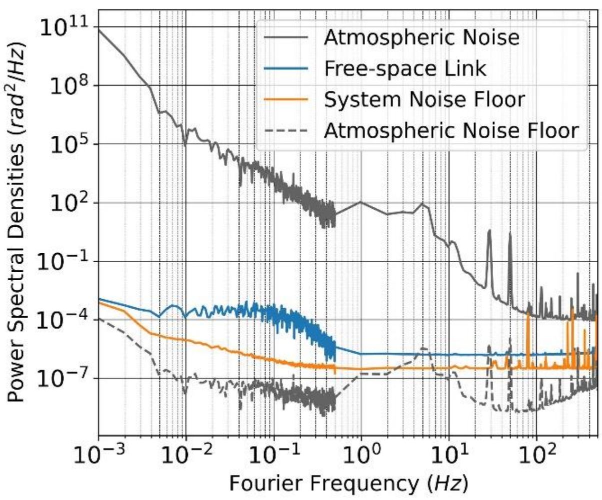

Fig. 1: Power spectral density of phase noise. Blue curve, 3.4 km free-space link; orange curve, noise floor of the setup with short fiber connection; grey curve, free-running phase noise; dashed grey curve: calculated link delay noise, evaluated from solid grey curve.

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