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Miniaturized 10 GHz Ultrafast Lasers for Scalable Photonic Systems

Ultrafast lasers and optical frequency combs have become essential tools in modern photonics, enabling applications ranging from optical communications and microwave photonics to quantum technologies, precision timing, sensing, and frequency metrology [1, 2]. While many of these applications increasingly leverage photonic integration, they continue to require compact, low-noise, and environmentally robust laser sources capable of operating outside controlled laboratory environments.

Here, we present a compact 10 GHz mode-locked laser platform operating at 1557 nm, combining high repetition rate operation, ultra-low noise performance, and a scalable architecture suitable for industrial deployment. The laser is based on a quasi-monolithic solid-state cavity with an optical footprint of approximately 1 cm² and delivers more than 50 mW of fiber-coupled average power. The generated pulse train exhibits a fundamental repetition rate of 10 GHz and supports pulse durations of approximately 260 fs. The large comb spacing provides high power per comb line while maintaining direct compatibility with standard telecom infrastructure.

The source combines high repetition rate operation with excellent noise performance. An integrated relative intensity noise of only 0.01% is measured between 1 Hz and 1 MHz, while phase-noise measurements correspond to an integrated timing jitter of 18.2 fs between 1 kHz and 1 MHz. To assess robustness under realistic operating conditions, the complete laser system was subjected to systematic thermal testing. Over a temperature excursion from 20°C to 50°C, the optical output power varied by less than 0.1 dB, while the free-running repetition rate remained within ±2 ppm, demonstrating stable operation well beyond typical laboratory conditions.

The combination of compact size, low noise, and multi-GHz repetition rates makes the platform attractive for a broad range of emerging photonic applications. In particular, the laser can be combined with nonlinear integrated photonic devices to realize compact self-referenced frequency combs through on-chip spectral broadening and f-2f interferometry, enabling fully stabilized frequency-comb and optical-clock systems. The platform is equally well suited for quantum photonic architectures, where integrated waveguide devices are increasingly used for the generation of single photons and entangled photon pairs [3]. Beyond quantum and metrology applications, the laser addresses coherent optical communications, low-noise microwave generation, synchronization, precision timing distribution, and photonic signal processing [4, 5]. By combining the performance of solid-state ultrafast lasers with a highly compact and scalable implementation, the presented platform provides a practical route toward deployable photonic systems in which advanced laser technology and integrated photonic functionality can be co-packaged within future industrial and scientific instruments.

References

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