Ultrafast 1.3 µm Amplifier Based on Praseodymium ZBLAN Fibers

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Fluoride fibers hold immense potential as efficient laser gain media. The low phonon energy of fluoride glass dramatically suppresses non-radiative decay processes, leading to extended upper-state lifetimes. Furthermore, their superior transmission window extending to ∼4 µm, compared to the ∼2.5 µm limit of silica, unlocks access to longer wavelengths. Despite their known fragility, lower heat resistance, and hygroscopic nature, these unique properties make fluoride fibers ideal for specific laser applications.

Our laboratory has been at the forefront of developing ultrafast lasers based on fluoride fibers in the short-wavelength infrared region (1.0-2.5 µm). The inherently low anomalous dispersion of these fibers in this spectral range facilitates the generation of ultrashort pulses. Notably, our thulium-doped ZBLAN (Tm^{3+}:ZBLAN) fiber mode-locked oscillator achieved direct generation of 45 fs pulses, a landmark result that, to our knowledge, remains the shortest pulse ever produced by a 2 µm fiber laser oscillator. Building upon this foundation, we have also engineered several innovative double-clad Tm^{3+}:ZBLAN fiber amplifiers and demonstrated their utility in advanced applications such as multi-photon microscopy. Furthermore, our investigations into the intracavity dispersion dynamics of Tm^{3+}:ZBLAN-based oscillators have yielded valuable insights into optimizing mode-locking performance. Expanding beyond thulium, we have also pioneered a novel laser system employing thulium-doped core and tribium-doped cladding fibers to generate 1.75 µm femtosecond pulses.

In this invited talk, I will focus on our recent groundbreaking advancements in ultrafast lasers based on praseodymium-doped ZBLAN fibers (Pr^{3+}:ZBLAN). While Pr^{3+}:ZBLAN fiber amplifiers have shown promise for O-band optical communication, our work has significantly pushed the boundaries of their power scaling in the ultrafast regime. We have successfully implemented chirped pulse amplification with Pr^{3+}:ZBLAN, achieving an impressive 1.33 W of average power. This result represents a more than five-fold increase over the previously reported maximum average power from continuous-wave Pr^{3+}:ZBLAN amplifiers, opening new avenues for high-power ultrafast laser applications in the O-band.