Non-perturbative nonlinear optics with erbium fiber frequency combs

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Frequency combs have revolutionized measurement science by directly linking optical frequencies to radio frequencies, allowing for precise synthesis and measurement of lightwaves. The applications of these frequency combs span both basic and applied science such as optical timekeeping, low-noise microwave generation, precision metrology, time transfer, astronomical spectrograph calibration, and spectroscopy. An important subset of optical frequency combs made from erbium fiber (Er:fiber) oscillators represent an incredibly robust and low noise platform. They benefit from versatile dispersion-engineered and non-linear fibers, as well as an inexpensive, fiber-integrated off-the-shelf component catalogue aided by the telecommunications industry. The foremost challenge with erbium fiber combs is the low erbium gain limiting the output power hindering and broadband frequency conversion. I show few-cycle MW scale pulses at 100 MHz from a technique of “scalable short pulse generation” by utilizing amplification in a ytterbium/erbium co-doped fiber and subsequent spectral broadening in a normal dispersion highly nonlinear fiber. Broadband frequency conversion with these pulses is not only possible with straight-forward perturbative nonlinear optics, but also with non-perturbative nonlinear optics generating light in the ultraviolet. I will show results on broadband ultraviolet-visible generation from solid state high harmonic generation, as well as a new technique for sensitive measurement of carrier-envelope phase effects in the non-perturbative regime. Finally, I will discuss recent work at FAU exploring Floquet engineering of graphene with an erbium fiber comb. With designer wave-forms composed of the funda-mental and its second harmonic, I show that individual valleys of the graphene band structure can be addressed and used for storing/processing information. The ability to generate and manipulate valley specific observables is a critical degree of freedom for multiplexing ultrafast and quantum information for future lightwave electronics.

Relevant works:

D. M. B. Lesko, H. Timmers, S. Xing, A. Kowligy, A. J. Lind, and S. A. Diddams, “A six-octave optical frequency comb from a scalable few-cycle erbium fibre laser,” Nat. Photonics 15, 281–286 (2021)
D. M. B. Lesko, K. F. Chang, and S. A. Diddams, “High-sensitivity frequency comb carrier-envelope-phase metrology in solid state high harmonic generation” Optica 10, 1156-1162 (2022)
K. F. Chang, D. M. B. Lesko, C. Mashburn, P. Chang, E. Tsao, A. J. Lind, S. A Diddams, “A Multi-Harmonic NIR-UV Dual-Comb Spectrometer” Arxiv, arXiv.2312.08492 (2023)
T. Weitz, D. M. B. Lesko, S. Wittigschlager, and P. Hommelhoff, “Lightwave-Driven Valley Control in Graphene” In Preparation (2024)