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Synchronous Ultrashort Off-Color Laser for Arbitrary Delay Backlighting of Intense Laser Plasma Interactions

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Spatio-temporally synchronized light sources form the backbone of various laser plasma acceleration (LPA) experimental diagnostic tools including transverse shadowgraphy, schlieren imaging and interferometry. In common practice, electronic pulse picking or physical beam splitting are used to derive sources of synchronized ultrashort probe light from the high-power drive laser. Practical cavity engineering imposes a ~100MHz repetition rate limitation on most solid-state mode-locked oscillators, which require multi-meter delay lines to control the time delay of the probe pulse. These delay lines are prone to temporal jitter and spatial pointing instability. Furthermore, use of on-band or harmonics of the fundamental of the primary drive laser can significantly limit imaging signal-to-noise ratio due to plasma induced light scattering or coupled non-linear processes. In this work, we propose a fiber-based architecture for an off-band femtosecond backlight system with arbitrary delay ranging from ms to fs timescales. Interrogation of intense light matter interactions with off-band but temporally synchronized light is achieved by application of gain managed nonlinearity (GMN) amplification, edge filtering and subsequent nonlinear frequency conversion. In our setup, a 0.977 GHz mode-locked Yb-oscillator will generate the common ultrashort seed pulse for both the high-energy LPA driver and GMN backlighter. Synchronous timing delay down to nanosecond duration will be achieved by electro-optic and acousto-optic pulse picking in tandem with compact free space delay lines that allow for arbitrary delay down to ps and fs timescales. The spectrally broadened GMN output pulse will be electronically picked, and the spectral content that is shifted to longer wavelengths will be isolated with spectral filters and frequency doubled via efficient second harmonic generation. The upconverted backlight signal will be centered at 540 nm, and output pulses are expected to have an energy of 500nJ and sub-100 fs pulse duration. In contrast, the LPA driver will be centered at 1035nm and its second harmonic at 517.5nm. Our GMN architecture avoids the complexity of free space optical parametric systems and necessitates a fraction of the physical footprint of a comparable hollow capillary nonlinear broadening setup. With the exception of the frequency doubling crystal, the entire backlighter system could be fully fiber-integrated.

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