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Synchronized all-PM-fiber Yb-doped amplifiers for high power fs- and ps-pulse generation

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In life science, a combination of several imaging methods can lead to a more detailed view of cancerous cells. Current laser based microscopes usually acquire the image with only one microscopy technique or need a large, complex and expensive laser system to achieve the necessary laser parameters for multiple imaging approaches. In the CARMEN research project, we aim to develop a compact multimodal laser-based microscope that combines Anti-Stokes Raman Spectroscopy as well as multi-photon and stimulated emission depletion (STED) microscopy. For these microscopy techniques, overlapping of two pulses with durations in the femtosecond (fs) and picosecond (ps) range and tunable wavelengths are desirable. These laser pulses can be generated by two tunable optical parametric oscillators (OPOs) to cover the visible spectral range.

Here we present a two-arm, all-PM-fiber Ytterbium amplifier system with femtosecond and picosecond pulse durations for pumping these OPOs. An overview of the laser system is depicted in Figure 1. To synchronize the amplifiers, they are seeded by a single mode-locked fiber oscillator with a repetition rate of 78.9 MHz at a central wavelength of 1064 nm and a pulse duration of 1.5 ps. Afterwards the seed signal is split towards the two separated amplifier arms.

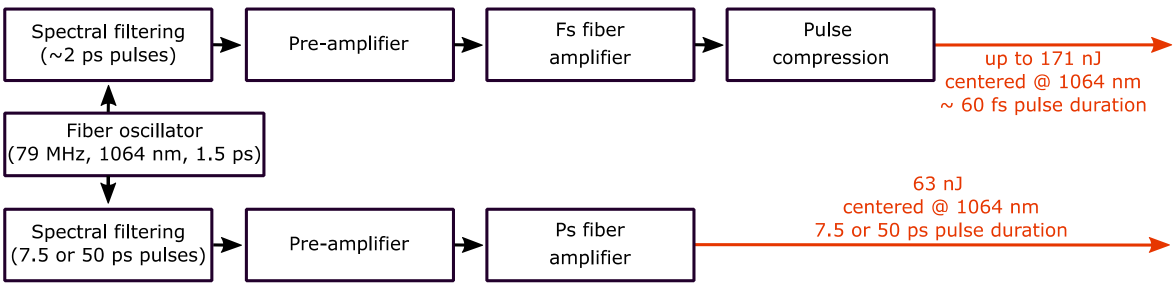

Fig. 1 Schematic overview of the laser system with its two amplifer arms.

In the picosecond arm, the seed pulses are spectrally narrowed by selecting between two fiber Bragg gratings (FBG), controlled by an optical switch. After a pre-amplification stage the pulses are amplified in an Ytterbium-doped large mode area fiber with a 15 µm core to an average power of 5 W (63 nJ pulse energy). Depending on the FBG reflection bandwidth, the Fourier-limited pulse durations are 7.5 ps or 50 ps with corresponding spectral widths of 0.5 nm or 0.05 nm, respectively.

The femtosecond arm is based on nonlinear gain-managed amplification [1]. For improved output pulse characteristics, a band-pass filter and a pre-amplifier ensure a Gaussian shaped spectrum and sufficient seed pulse energies. The main amplification stage consists of a 2 m Ytterbium-doped double-cladding fiber with a 10 µm core. To achieve the desired pulse duration below 100 fs, spectral broadening of the 7 nm wide input spectrum is necessary. This is realized via self-phase modulation in the active fiber, which broadens the spectrum to a width of about 60 nm. The maximum power at the fiber output is 13.5 W, which corresponds to a pulse energy of 171 nJ. The pulses are dechirped by a free space grating compressor to durations below 60 fs.

References

[1] Sidorenko, Pavel, Walter Fu, and Frank Wise. "Nonlinear ultrafast fiber amplifiers beyond the gain-narrowing limit." Optica **6.10** 1328-1333 (2019)