Serrodyne optical frequency shifting using a nonlinear multi-pass cell

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Ultrafast lasers are vital tools for a wide application range including strong-field physics, material processing precision spectroscopy and many more. Available laser platforms supporting femtosecond pulses at high peak and/or average power are primarily Ytterbium- (Yb), Ti:Sapphire- or Thulium-based. The center wavelength of such lasers is thus typically limited to very few operation points in the electromagnetic spectrum. Particularly, Yb-based lasers support femtosecond pulses at kW average powers [1] and, when complemented with suitable post-compression units, ultrashort pulse duration [2]. However, tuning high power femtosecond lasers to wavelength regions outside the amplifier gain bandwidth remains a major challenge, addressed so far at limited power levels using e.g. dispersive wave generation [3], soliton-shifting and Raman-based shifting techniques [4] or parametric frequency conversion.
Here we introduce an efficient and high-power compatible spectral shifting scheme based on a simple but very effective principle, Serrodyne frequency translation, as illustrated in 1(a) [5]. First, phase and optionally amplitude of an ultrashort laser pulse are shaped using a pulse shaper to produce a temporal saw-tooth pulse. In an optional second step, the shaped laser pulse can be amplified. The laser pulse is then spectrally shifted by acquiring linear phase ramp via self-phase-modulation within a dispersion-balanced multi pass cell (MPC). Afterwards, using a spectral filter, the wavelength-shifted spectrum is separated from residual broadband wavelength components.

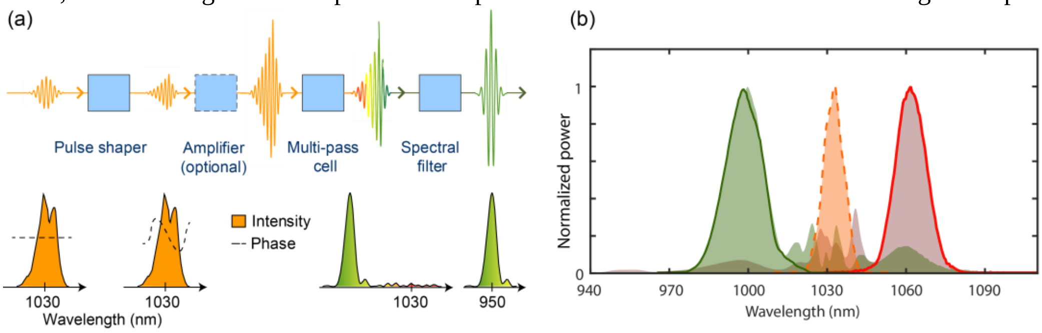

Fig. 1 (a) Schematic of the Serrodyne wavelength shifting scheme based on a dispersion-balanced MPC. (b) Experimental demonstration yielding Yb-laser pulses at high average power cantered around 1000 nm and 1060 nm.

We experimentally verify the principle by shifting the wavelength of an 80 W Yb frequency comb based on chirped-pulse amplification (CPA) delivering pulses with a duration of about 200 fs at 65 MHz repetition rate. Within the CPA chain, the stretched pulses are sent to a programmable phase shaper, followed by a two-stage amplification system and a compressor. The laser output pulses are then mode-matched into an MPC consisting of two concave dielectric mirrors (100 mm radius of curvature, negative mirror dispersion matched to about 10.5 mm fused silica (FS)). The MPC also contains multiple UV FS windows used as Kerr media. The throughput of the MPC is 82%, limited by the performance of the anti-reflection coatings of the windows. A saw-tooth-like pulses shape is applied for spectral shifting. The resulting strongly asymmetrically broadened MPC spectra are shown in 1(b). We use a dielectric dichroic mirror to filter the shifted spectral maxima located at 999 nm and 1062 nm, reaching an efficiency (MPC output to output behind the filter) of 63.1% and 66.7%, respectively.

Our results demonstrate a simple route for efficient spectral shifting of high-average and peak power lasers to wavelength regions not easily accessible by available ultrafast laser platforms, bringing ultrahigh peak and/or average power laser at flexible wavelength into reach.

References

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