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Photocathode Laser based on a 3 GHz Electro-Optical Comb Generator for the Ultrafast Electron Diffraction Facility REGAE

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The technique of Ultrafast electron diffraction (UED) combines the excitation of a probe using an optical laser pulse with electron diffraction, allowing the investigation of fast dynamics occurring in matter. It is especially suited for targets with low atomic number, and thus interesting for organic chemistry and biology.

We present recent results on laser system that is going to be used as a photocathode laser at the REGAE UED facility [1] at DESY. One challenge for UED is the so-called space charge, which occurs due to the mutual repulsion of the electrons and which limits the coherence length and the achievable spatial resolution required for biological samples. Our approach to overcome this issue is to distribute the 100 fC charge required to generate sufficient diffraction signal to a burst of about 4500 electron bunches, each containing only about 140 electrons. To still allow a µs time resolution, a very high intra-burst repetition rate is necessary. The currently developed photocathode laser is required to produce 1.5 µs bursts of UV (257 nm), 0.1 nJ picosecond pulses with 3 GHz intra-burst repetition rate and a burst repetition rate of 12 to 50 Hz.

The system is implemented as an electro-optical comb generator, based on polarization maintaining (PM) components. The schematic of our setup is shown in panel (a) of Fig. 1. Light at 1030 nm from a continuous wave (CW) seed laser is spectrally broadened by generating sidebands using three fiber-coupled phase modulators (PM), achieving about 2 nm bandwidth. An additional fiber-coupled intensity modulator (IM) is set to pick the segments with linear chirp, which are compressed to pulses of about 2 ps duration in an integrated spatial light modulator (SLM). The signal afterwards is amplified to the 100 W level using two Ytterbium fiber amplifier stages PA1 and PA2. Frequency conversion to the fourth harmonic at 257 nm is done in two stages, where second harmonic (SHG) is generated in a 15 mm noncritically phase matched LBO, followed by the fourth harmonic generation (FHG) a 5 mm CLBO crystal UV.

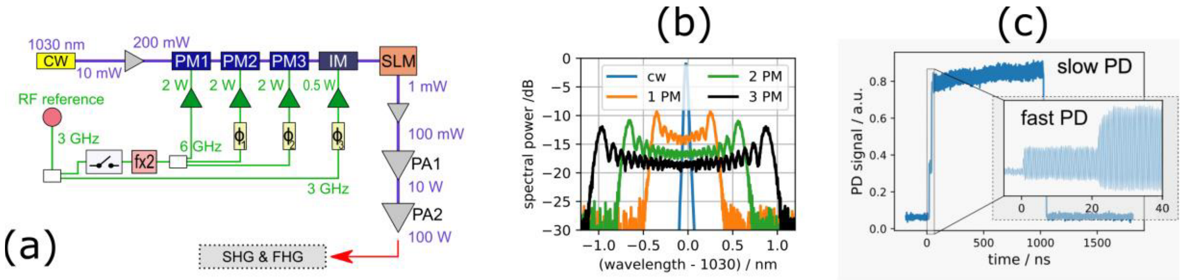

Fig. 1 (a) Schematic of the Photocathode laser system. (b) Optical spectra of the cw laser, and after each of the phase modulator stages. (c) Photo diode trace of a short burst generated by the system at 515 nm. The inset shows a zoom to the rising edge of the burst, resolving the pulse train of 3 GHz repetition rate.

As the radio-frequency (RF) fields driving the modulators are directly derived from the REGAE reference RF, the laser is inherently synchronized to the electron accelerator. To generate the required, µs-long bursts, an RF switch is used rapidly to turn the phase modulators on and off. Within durations of about 20 ns, the system thus can be switched between long pulse (~150 ps pulses) and short pulse (~1 ps) mode. Due to the strong peak-power dependency of the frequency conversion process, the required short and background-free UV bursts can be generated. We are currently in the progress of implementing the frequency conversion stages, reaching about 20 W of green light so far. Panel (c) of Figure 1 shows a photodiode trace of a microsecond long burst of the 515 nm (SHG) light; the inset a zoom to the rising edge of the 3 GHz burst. After completion and characterization of the system, the laser will be integrated in the REGAE facility in Q3 of 2022.

References

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